Build It Yourself from *QST*

Part 1—Thinking about starting to build some of your own gear? Here's how to turn a *QST* project into reality.

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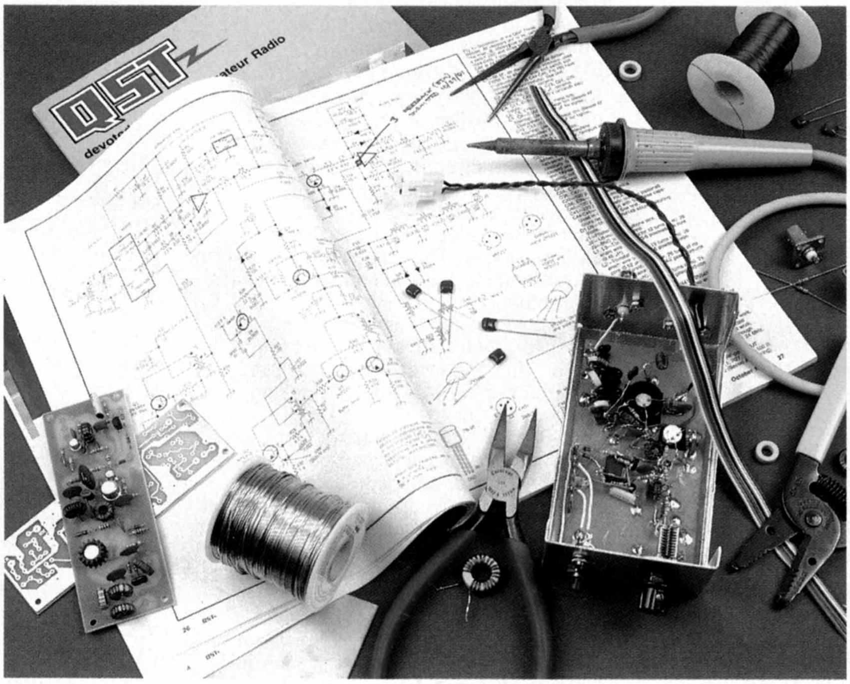
So you've decided you'd like to build that project in the latest *QST*, but you don't know where to start? This series of articles can help. In it, I'll show you how to move a *QST* construction article off the printed page and into your ham shack.

As a sample project for the series, we'll build a 20-meter VXO-controlled QRP transmitter developed from Zack Lau's popular 18, 21 and 24-MHz transceiver design.[1] Fig 1 shows the circuit, and Zack describes its design and performance in the sidebar, "A 20-Meter VXO-Controlled Transmitter."

I'll take you through buying the parts, building the circuit using simple ground-plane construction or by installing its parts on a ready-made PC board, installing it in a box, testing it, and putting it on the air. Fig 2 shows the difference between ground-plane and PC-board construction, in case this sounds mysterious to you.



Although you can buy a ready-made circuit board for this project,[2] I haven't asked anyone to make up complete kits of parts for it. Ordering a kit doesn't take much effort or skill—and every project you'll want to build probably won't be available as a kit. I want you to get the feel of being your own purchasing manager. That means sniffing out parts sources and dealing with them in person, by mail and by telephone to get the parts you need. You won't be able to find all the parts at Radio Shack, so you'll have to order parts by mail. You'll also have to order from more than one mail-order company. (It's almost a corollary to Murphy's Law: No matter how wide a selection you find in one mail-order catalog, you'll always find at least one part you have to buy somewhere else!)

Building a Catalog Library

For starters, you'll need catalogs from part suppliers. Chapter 35 of the *ARRL Handbook* contains an excellent list of mail-order parts dealers. Some of these mail-order companies are listed in Table 1. If you have enough catalogs, you'll be able to find almost any part, so I suggest writing to all the companies in Table 1. Be sure to check *QST* advertisements, too. The part suppliers represented there want to help you build what you read about in *QST*!

Putting Together a Parts List

While you're waiting for your catalogs, let's look at the parts list for the transmitter (see the Fig 1 caption). Hold it—we can't just photocopy this and send it off to a mail-order company with a note that says "please send me these parts." We need to convert the part-placement list into what I call a *part order list* that shows the type and quantity required of each part.

Resistors

We'll start with the resistors. First, check tolerance and power rating. If we needed resistors with different power ratings or tolerances, we'd group them by those parameters before grouping them by value. For this project, all the resistors are specified as ¼-watt, 5%-tolerance parts, so all we need to know is how many of each value to order. If all of the circuit's resistors are already grouped by value on the parts list, we can just count the number of each value. Each time you add parts to the order list, check them off the published parts list. Sometimes the parts list does not include common components like resistors and capacitors. If this is the case, make a copy of the schematic and check off the parts as you build your shopping list.

Capacitors

Next, check the capacitors. There will usually be a number of different capacitor types in an RF circuit, so group these by type first. Put all the common disc-ceramic caps in one column, the metal-film caps in another, and so on. Include any variable capacitors or trimmers. Then count the number of each and add them to the list.

Solid-State Parts: Transistors, Diodes, Integrated Circuits

Count the solid-state parts next. This includes diodes, transistors and integrated circuits (ICs). Make sure you check each part off the published list as you add it to the order list.

[1]Notes appear on page 36.

Coils and Cores

There are a number of coils (inductors) in our project, and each is wound on a toroidal core. Count the number and type of each toroid and add them to the list. The parts list also specifies the gauge of the wire for each coil. This is important—using a different size wire from that specified will give you a different inductance. Add all the different wire sizes to the parts list.

Connectors, Cases and Miscellaneous Stuff

When you're done with the coils and cores, there are a few miscellaneous parts—a switch, some connectors, a box, a piece of circuit board (or a ready-made PC board) and a crystal. You'll also need a heat sink for the final transistor, some heat-sink grease, some solid hookup wire (#22 or #24 insulated wire) and—maybe—a short piece of RG-174 coaxial cable to connect the transmitter to the antenna connector. I used one piece of hookup wire between the circuit's Antenna point and the center terminal of my **ANTENNA** connector. A second piece connects circuit common and chassis near the **ANTENNA**-connector shell. You can use a short piece of coax, shield grounded at both ends, for **ANTENNA**-jack connection in both versions.

Choosing connectors for the antenna, key and power supply is a controversial issue. Some people swear by SO-239 and PL-259 RF ("UHF") connectors, while others will use nothing but BNCs.[3] For my version of this transmitter, I used a BNC connector because it's easier to mount with simple hand tools than an SO-239. (SO-239s require 5/8-inch holes. BNCs need holes no larger than 3/8-inch, depending on whether you get flange- or single-hole mount versions.) I used a 1/8-inch phone jack for the **KEY** jack because my keyer uses a 1/8-inch plug, and I used two-pin polarized Radio Shack connectors (#274-222) for power connectors. You can use a different combination of jacks, but always use different connectors for the antenna, power supply and keyer, if possible. If you use a phono jack for both the antenna and power supply connectors, you'll eventually plug the power supply into the **ANTENNA** jack. In some projects, this may let the smoke out of some components by short-circuiting the supply. (Not in Zack's transmitter, though. Its output terminal has no dc connection to chassis.)

Once the Catalogs Arrive

Now that your catalogs have arrived, let's see who's got the parts we need. You'll be able to get the resistors just about anywhere, including (for common values) Radio Shack. But wait a minute: Most of these mail-order companies will only let you order a multiple of five resistors of one value, and you only need one of some of them. Does this seem like a waste of money? Well, I hope this isn't the only project you'll ever build, and you'll need parts for your next project. If you get more parts than you need now, you can use some of them in the next project. Keep the parts where you can find them, and after you build a few projects you'll be able to reach into your *junk box* (containing all these good parts, not really junk) any time you see an interesting project. If you need fewer than five resistors of one value, order five and save the rest for your next project. They're cheap.

Ordinary disc-ceramic capacitors will be easy to find, but you can't use them everywhere in a circuit. Most disc-ceramic capacitors are rated at a tolerance of ±20%, and some are rated at +80% and −20%. This means that the actual value of the capacitor might be 80% more than the value printed on it! Obviously, this won't do where the value is critical (in a timing, tuned or filter circuit, for example). If the project design specifies metal-film, silver-mica, or some other type of capacitor, *don't* substitute disc-ceramic or other capacitor types! Zack specified silver-mica caps for the filtering circuitry in our transmitter. They're widely available.

Solid-state parts and toroids can sometimes be hard to find, too. Most parts suppliers carry a good stock of digital logic ICs, but don't carry as many linear ICs or RF parts. A number of suppliers specialize in

Fig 1—Schematic diagram for the 20-meter VXO-controlled QRP transmitter. The inset shows how to connect jacks (J1, **KEY**; J2, **RECEIVER**; J3 (**ANTENNA**) and **POWER** binding posts (BP1 and BP2) to the circuit board. You can usually depend on the circuit common foil and mounting hardware to complete ground connections for dc circuits (**KEY, POWER**). Thorough authors will tell you when you shouldn't. For signal connections (**ANTENNA, RECEIVER**) though, use two wires (one for common, one for the *hot* [ungrounded] lead) or coaxial cable. The panel bushings of J1, J2 and J3 usually make sufficient contact with metal box walls to complete the chassis connection shown for them.

BP1, BP2—Plastic binding posts (Radio Shack #274-662) to serve as **POWER** terminals, red for + and black for − This is just a suggestion; you can use your choice of connector as necessary.
C1—0.082-μF ceramic or plastic-film capacitor. Even though this is an uncommon value, don't substitute a different value. This capacitor is important in determining the transmitter's keying characteristics.
C2—0.22-μF ceramic or plastic-film capacitor. Don't substitute a different value. This capacitor is important in determining the transmitter's keying characteristics.
C3—1.8- to 8.7-pF air variable. Johnson 160-104 used, but any panel-mountable air-dielectric variable with a maximum capacitance between 8 and 35 pF should work acceptably. If you're willing to forgo easy frequency adjustment, you can use a PC-board-mountable trimmer capacitor and mount it on the circuit board as shown in Fig 2. (Ceramic- and plastic-dielectric trimmers will also work, but may be a bit less frequency-stable than air-dielectric types.)
C4-C11—General-purpose disc or monolithic ceramic capacitors, values from 0.01 to 0.1-μF suitable. Don't use plastic-film types (Mylar, metallized polyester, etc) here. Such capacitors generally don't work as well as ceramic-dielectric types in radio circuits.
C12—120 pF, silver mica.
C13, C14—390 pF, silver mica.
C15—180 pF, silver mica.
C16—22 pF, silver mica.
D1-D3, D5, D6—1N914, 1N4148 or 1N4152 silicon switching diode.
D4—33-V, 0.5-W Zener diode (1N5257).
J1-J3—**ANTENNA, RECEIVER** and **KEY** connectors of your choice (see text).
L1, L3—15 turns #22 enameled wire on T-37-6 toroid core (0.8 μH).
L2—15 turns #28 enameled wire on T-37-6 toroid core (0.9 μH).
L4—35 turns #30 enameled wire on T-30-2 toroid core (5.9 μH).
Q1, Q2—2N3906 bipolar transistor.
Q3—2N918, MPS918, 2N5179 or MPS5179 bipolar transistor.
Q4—2N2222 or 2N2222A bipolar transistor. Metal- and plastic-cased versions (PN2222, MPS2222) are suitable.
Q5—2N5109 bipolar transistor.
Q6—2N3553 bipolar transistor, with added heat sink. The Fig 2B version uses a Thermalloy 2215B heat sink, but other types are suitable (see text).
R1—22 kΩ. This and all of the other resistors are 5%-tolerance, 1/4-watt carbon-film or carbon-composition units.
R2—100 kΩ.
R3—10 kΩ.
R4, R6—1 kΩ.
R5—270 Ω.
R7, R10—4.7 kΩ.
R8, R13, R14—100 Ω.
R9—47 Ω.
R11—15 kΩ.
R12—470 Ω.
R15—2.2 kΩ.
R16—4.7 Ω.
RFC1—Toroidal RF choke. Use 20 turns of #26 enameled wire on FT-37-67 ferrite toroid (7.7 μH). 6 turns on FT-37-43 should also work.
S1—Normally open, momentary push button (Radio Shack #275-1547 suitable).
T1—Broadband transformer, 5:1 turns ratio. 20 turns of #26 or 28 enameled wire on an FT-37-43 ferrite toroid (primary). Secondary has 4 turns of #24 or 26 enameled wire over primary winding.
T2—Broadband transformer, 3:1 turns ratio. 9 turns of #26 or 28 enameled wire on an FT-37-43 ferrite toroid (primary). Secondary has 3 turns of #24 or 26 enameled wire over primary winding.
Y1—Fundamental crystal, HC-25/U or equivalent holder (International FM-2), parallel resonant, 20-pF load capacitance, room temperature calibration. Specify a frequency 4 kHz lower than the spot frequency (or bottom edge of the frequency range) you want to cover. (Example: For 14060 kHz, the 20-meter QRP calling frequency, specify 14056.000 kHz.) You'll probably be able to hit your spot frequency by adjusting C3, **FREQUENCY**. Frequency swings of 7 to 12 kHz, beginning at 3 or 4 kHz lower than the frequency marked on the crystal holder, are in the ballpark for this circuit.

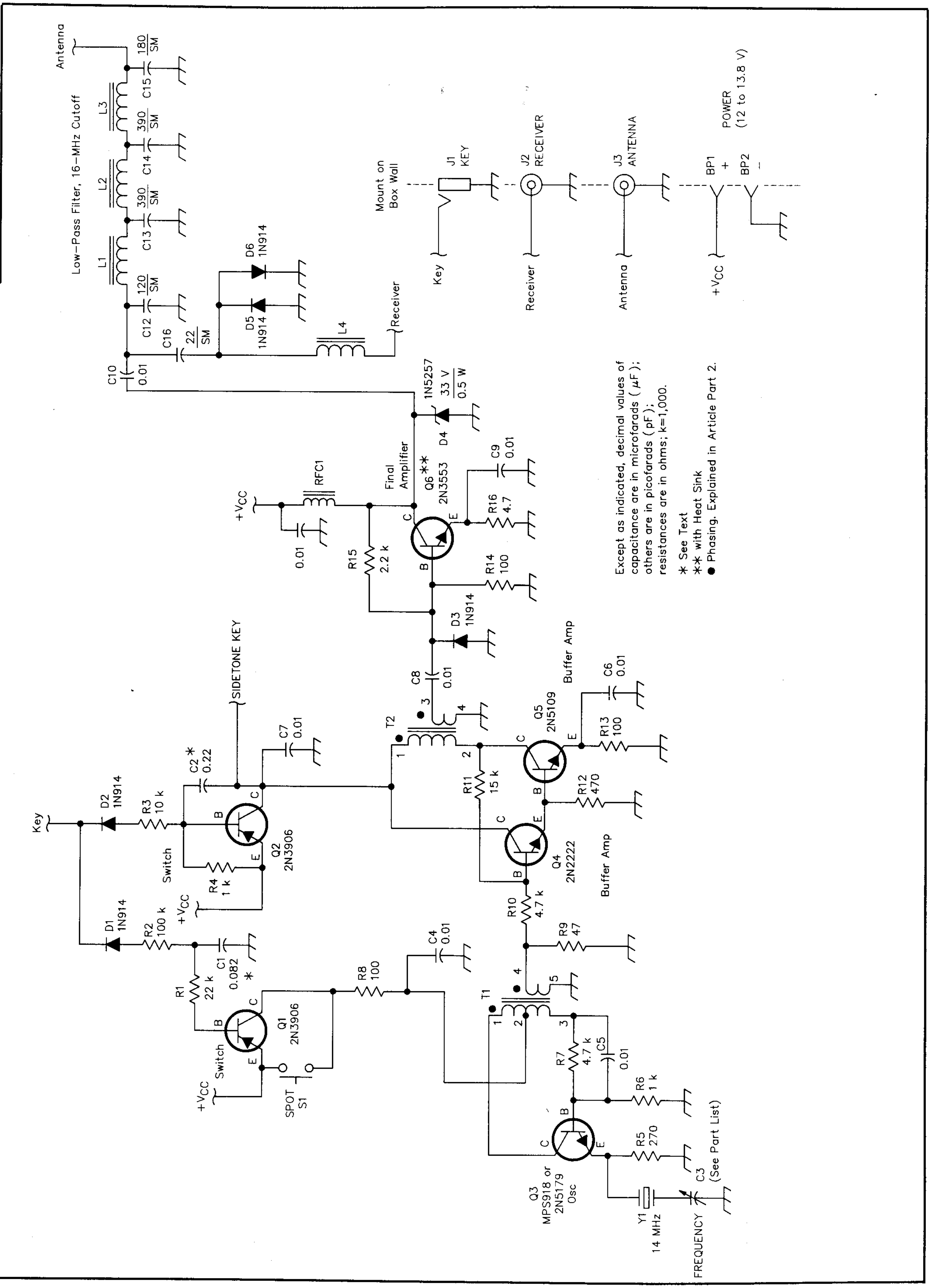

Antenna
Low-Pass Filter, 16-MHz Cutoff
L1
L2
L3
C12 120/SM
C13 390/SM
C14 390/SM
C15 180/SM
C16 22/SM
C10 0.01
D5 1N914
D6 1N914
L4
Receiver
Mount on Box Wall
J1 KEY
J2 RECEIVER
J3 ANTENNA
BP1 +
BP2 −
POWER (12 to 13.8 V)
Key
Receiver
Antenna
+VCC
1N5257 33 V/0.5 W
D4
Final Amplifier
Q6** 2N3553
RFC1
+VCC
0.01
R15 2.2 k
R16 4.7
C9 0.01
R14 100
D3 1N914
SIDETONE KEY
Buffer Amp
C6 0.01
C8 0.01
T2
Q5 2N5109
R13 100
R12 470
R11 15 k
C7 0.01
C2* 0.22
D2 1N914
R3 10 k
Key
Switch
Q2 2N3906
R4 1 k
+VCC
Q4 2N2222
Buffer Amp
R10 4.7 k
R9 47
D1 1N914
R2 100 k
C1 0.082 *
R1 22 k
C4 0.01
R8 100
T1
Q1 2N3906
Switch
+VCC
SPOT S1
R7 4.7 k
C5 0.01
R6 1 k
Q3 MPS918 or 2N5179 Osc
R5 270
Y1 14 MHz
C3 (See Part List)
FREQUENCY
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000.
* See Text
** with Heat Sink
● Phasing. Explained in Article Part 2.

Table 1
Parts Suppliers

All Electronics Corp
PO Box 567
Van Nuys, CA 91408
information/customer service
tel 818-904-0524, fax 818-781-2653
order tel 800-826-5432

Digi-Key Corp
701 Brooks Ave S
PO Box 677
Thief River Falls, MN 56701-0677
tel 800-344-4539, fax 218-681-3380

Easy Tech
2917 Bayview Dr
Fremont, CA 94538
tel 800-582-4044, fax 800-582-1255

International Crystal Manufacturing Co
701 W Sheridan
PO Box 26330
Oklahoma City, OK 73126-0330
fax 800-322-9426

JAN Crystals
2341 Crystal Dr
PO Box 06017
Fort Myers, FL 33906-6017
tel 800-526-9825, fax 813-936-3750

Oak Hills Research
20879 Madison St
Big Rapids, MI 49307
(enclose 50 cents for catalog)
tel 616-796-0920

Ocean State Electronics
PO Box 1458
Westerly, RI 02891
tel 401-596-3080, fax 401-596-3590
order tel 800-866-6626

Because *QST* space is limited, this list is necessarily incomplete. See *QST* advertisements and the 1992 *ARRL Handbook*'s ARRL Parts Suppliers List (Table 42, Chapter 35) for additional suppliers.

Table 2
Transmitter Part Order List

Resistors

Quantity	*Value*
1	4.7 Ω
1	47 Ω
3	100 Ω
1	270 Ω
1	470 Ω
2	1 kΩ
1	2.2 kΩ
2	4.7 kΩ
1	10 kΩ
1	15 kΩ
1	22 kΩ
1	100 kΩ

Capacitors

Quantity	*Value*	*Type*
1	0.082	μF ceramic
1	0.22	μF ceramic
9	0.01	μF ceramic
1	120 pF	silver mica
1	180 pF	silver mica
2	390 pF	silver mica
1	1.8- to 8.7-pF air-dielectric, panel-mountable variable (Johnson 160-104)	

Solid-State Devices

Quantity	*Part*	*(Possible Replacement)*
5	1N914	diode (1N4148, 1N4152)
1	1N5257	Zener diode (1N4752)
2	2N3906	transistor (2N2905, 2N2907)
1	2N2222	transistor (2N2222A, PN2222)
1	2N5109	transistor
1	2N5179	transistor (MPS918, PN5179)
1	2N3553	transistor

Toroidal Cores/Inductors

Quantity	*Part*
2	FT-37-43 ferrite core
1	FT-37-67 ferrite core
3	T-37-6 iron-powder core
1	T-30-2 iron-powder core
¼ pound	#22 enameled magnet wire
¼ pound	#26 enameled magnet wire
¼ pound	#28 enameled magnet wire
¼ pound	#30 enameled magnet wire

(#22, #26 and #30 are currently available at Radio Shack; order #28 from Ocean State)

Miscellaneous (see text for details)

Quantity	*Part*
1	normally open push button
1	project box or other enclosure
1	PC board (optional; see text)
1	antenna connector
1	key jack
1	power connector
1	heat sink
1	small tube of heat-sink grease
1	knob for 1/8-inch shaft
1	20-meter fundamental crystal, 20-pF parallel load capacitance, FM-2 holder (International Crystal part number 434173). For JAN Crystals, specify frequency, HC-25/U holder, 50 ppm tolerance, parallel resonance, 20-pF load capacitance, non-oven.
1	FM-2 or HC-25/U crystal socket (International Crystal part number 035006; JAN Crystals CE-25)
10	feet RG-174 coaxial cable (optional; see text)

22- or 24-gauge insulated solid hookup wire

RF parts, however, and our list includes some of them. All of the solid-state parts (and the variable capacitor) in our project are available from Ocean State Electronics.

Although you'll probably be able to order exactly the right number of each capacitor and transistor for this project, consider buying a few extras for your junk box. It's always good to have a few extra parts on hand—you may break a lead on a part when you're assembling the project, or damage a solid-state component with too much soldering heat or by wiring it in backwards. If you don't have extras, you'll have to order another part. Even if you don't need the extras for this project, they'll always come in handy, and you'll be encouraged to build another project!

Pick up an extra toroid or two as well—Zack used common types that you'll see in other shortwave transmitting and receiving projects.

We need several different sizes of enameled copper wire for the coils. Sometimes called *magnet wire* because of its use in electric-motor windings, it's usually sold by the pound, with a minimum order of ¼ pound. A quarter pound of each size will be more than enough for many RF projects, so we'll have plenty left over for the junk box. You may find a supplier who will sell wire by the foot, but you'll probably pay extra for this convenience. Radio Shack has a magnet-wire package containing three of the sizes we need, and Ocean State Electronics carries all of them. All Electronics has the hookup wire and 10-foot lengths of RG-174 coax.

I ordered my crystal from International Crystal Manufacturing. JAN Crystals is another good source. (Some part dealers list crystals in their catalogs, but I recommend going right to the source.) A variety of crystal holder styles are available that differ in pin spacing and how the can pieces are bonded together. Hams have long known them by their military nomenclature (designators that start with *HC* and end with */U*). The crystal holder we want is generically known by hams as *HC-25/U*. Its pins are 0.040 inch in diameter, 0.25 inch long and spaced 0.192 inch center to center. International Crystals classes HC-25/U-sized holders as *FM-2*. (How the two holder pieces are sealed—solder, cold weld or resistance weld—determines the holder's actual HC designator. For our purposes, this doesn't matter. If you order from International, just specify *FM-2*.) The HC-25/U holder plugs in, so you'll also need to buy a socket to hold it. Crystal manufacturers usually sell sockets in addition to crystals. Table 2 lists particulars for crystals and sockets from International and JAN.

I recommend plug-in crystals because you can easily use them in other projects. You may prefer to solder your crystal in, though. You can order crystals in an HC-25-sized *wire-lead* holder known generically as the HC-18/U. HC-18/U holders solder in and don't fit HC-25/U sockets. If you're after maximum miniaturization, International's solder-in FM-5 holder is the way to go: it's less than 5/16 inch across. You'll see an FM-5 crystal in my transmitter in Part 2 of this series.

A 20-Meter VXO-Controlled Transmitter

The QRP Three-Bander* can be modified for single-band operation at 20 meters by substituting a different receiver-input transformer† and modifying the transmitter. Because the Three-Bander's NE602-based receiver performs marginally under the strong-signal conditions common on this busy band, I decided to develop only a 20-meter *transmitter* from the Three-Bander design and use a separate receiver. The 20-meter transmitter's output circuit is a bit more rugged than the original Three-Bander's MRF237 final.

The main text's Fig 1 shows the circuit. The 20-meter transmitter's VXO and buffer amplifier are almost identical to the Three-Bander's, the major change being the use of a 14-MHz crystal. (By the way, if you're looking for the ultimate in miniaturization, you might consider using FM-5 cased crystals [International Crystal Manufacturing Co order number #434193]. Note, however, that I found the frequency swing available with FM-5 crystals to be about 1 kHz less than that achievable with standard HC-25/U-cased [International FM-2] crystals—14048.5 to 14055.9 kHz with a crystal cut for 14045.00 kHz [parallel resonant, 20-pF load capacitance].) The VXO exhibits some voltage sensitivity: I measured a 50-Hz shift when varying the supply voltage from 11.0 to 13.8—not enough to warrant building in a voltage regulator, in my opinion.

Compared to the original Three-Bander, the final amplifier (Q6 and its associated circuitry) is a bit more complex. I added a bypassed 4.7-Ω emitter resistor (R16) for thermal stability (one MRF237 I tried without an emitter resistor went into thermal runaway). Q6's base clipping diode, D3, is optional, but I recommend including it because it seems to lower Q6's drive requirement about 1 dB. D4, a 33-V Zener diode, protects Q6 when its output (circuitry to the right of C10) is shorted to ground. Short-circuiting the low-pass filter capacitors (C12-C15) in succession caused no apparent damage to Q6, so the circuit seems pretty rugged. (Q6 may oscillate under some conditions of very high SWR, however, so the circuit's stability could be further improved.)

The low-pass filter (L1-L3, C12-C15) may raise a few eyebrows. Yes, all three inductors have the same number of turns, but L2 uses thinner wire (#28) than that used in L1 and L3 (#22), causing L2's inductance (0.9 μH) to be higher than that of L1 and L3 (0.8 μH). (Wind these inductors according to Fig 70B in the 1992 *ARRL Handbook*—with a single layer covering most of the core.) Measured at the RECEIVER point (L4's free end), the filter's insertion loss is only 1 dB throughout the 20-m CW band.†† I measured the worst-case transmit feedthrough to the RECEIVER jack point as −6 dBm (0.25 mW). (Some authors suggest that the RECEIVER tap should be on the ANTENNA jack end of the low-pass filter, but this makes the odd harmonics [3, 5, etc] stronger.)

As to performance: The Fig 2B transmitter's second harmonic is 57 dB below the fundamental carrier; higher-order harmonics are at least 64 dB down. Connecting a receiver to the RECEIVER jack decreases the second harmonic slightly (to −60 dBc) but lowers the circuit's higher-order-harmonic suppression to 50 dB at the third harmonic, 54 dB at the fifth and 60 dB at the seventh. These numbers meet current FCC requirements for signal purity, assuming that your harmonics cause no harmful interference.

As for transmitter output power, you can expect about 1 W with an 11-V supply and 1.8 W at 13.8 V. The transmitter's frequency should be stable. With decent heat sinking at Q6, so should the transmitter's power output. If your transmitter's output power rises when you hold the key down for a long stretch, you're not witnessing miraculous transmitter self-improvement—that's the onset of thermal runaway! If this happens with your transmitter, improve Q6's heat sinking and/or don't hold the key down for so long.—*Zack Lau, KH6CP/1, ARRL Lab Engineer*

*Z. Lau, "The QRP Three-Bander," *QST*, Oct 1989, pp 25-30. See also Feedback, *QST*, Jan 1992, pages 55 and 91. *QRP Classics*, available from The ARRL Bookshelf as #3169, includes the QRP Three-Bander article, but went to press before the Feedback was published in *QST*.

†For 20-meter reception, replace the original Three-Bander's T1 with a transformer wound as follows: Primary, 25 turns of #24 enameled wire on a T-50-6 toroidal, powdered-iron core, ≈80° spacing between winding start and finish; secondary, 2 turns of #24 enameled wire over the RF-ground end of the primary. Use a 14-MHz crystal at Y1 (in the receiver local oscillator).

††Builders who've experienced receive-sensitivity problems in attempting to move the QRP Three-Bander's filter to 20 meters may not have been accurately measuring their filter coils' inductance. Too much inductance can produce a filter that cuts off received signals!

Now's the time to decide whether you're going to build your project ground-plane or with a ready-made PC board. If you need a PC-board, FAR Circuits has them. (It's 5 × 2 inches in size.) If you're going to give ground-plane a go, buy a good-sized piece of single-sided copper-clad board—at least 3 × 5 inches. Get *glass-epoxy* board if you can. *Phenolic* board is distinctly inferior because it's brittle and deteriorates rapidly with soldering heat. You can use either single-sided or double-sided board, and Ocean State has a good selection of sizes. Radio Shack sells a 4-1/2- × 6-3/8-inch piece of double-sided board; I cut this with a hacksaw to 4-1/2 × 2-1/2 inches.

We'll also need a box for the transmitter. This is often overlooked in parts lists for most projects, because different builders like different enclosures. Zack likes die-cast aluminum boxes. They are easy to work with, provide excellent shielding, and can probably protect your project against a pet panda. They're a bit expensive, however. Radio Shack sells two-piece aluminum boxes that are a bit more difficult to work with, but they're cheaper. Boxes of both types, and many more, are available from many mail-order companies as well.

Make sure there's room in the box for the variable capacitor and connectors as well as your ground-plane or PC board. Some people like to cram projects in the smallest possible box, but miniaturization can be extremely frustrating if you're not good at it. (I'm not, but Zack is a master.) I used a Radio Shack P-Box measuring 5-1/4 × 3 × 2-1/8 inches (part #270-238) for both the PC-board and ground-plane versions of the transmitter.

The variable capacitor specified has a 3/16-inch shaft, and it's hard to find a knob that will fit this shaft. You can use a 1/4-inch-shaft knob by building the shaft up to 1/4 inch using plastic or metal shim stock. Another approach is to find knobs to fit 1/8-inch shafts and carefully drill the hole out to 3/16. It's best to do this with a drill press, but you can do it with a hand drill and a vise if you're careful. I don't even have a vise—I did it with a hand drill and held the knob in a pair of pliers. I used a KNB-65 knob from All Electronics, but a KNB-181 might work better. (Get at least one of each; they're cheap and you might need a backup if you make a mistake.)

Several heat sinks in the Ocean State catalog will work in our transmitter (anything that fits a TO-5 or TO-39 transistor will be fine). Ocean State's #HS-05 works well, and it's cheap. You'll need a small tube of heat-sink compound. (You apply a *thin* film of heat-sink compound to the transistor body where it contacts the heat sink. The compound, also known generically as *silicone grease*, greatly improves heat transfer from the transistor to the sink.) You don't need much, so the smallest tube will be plenty for several projects. Both Ocean State and Ra-

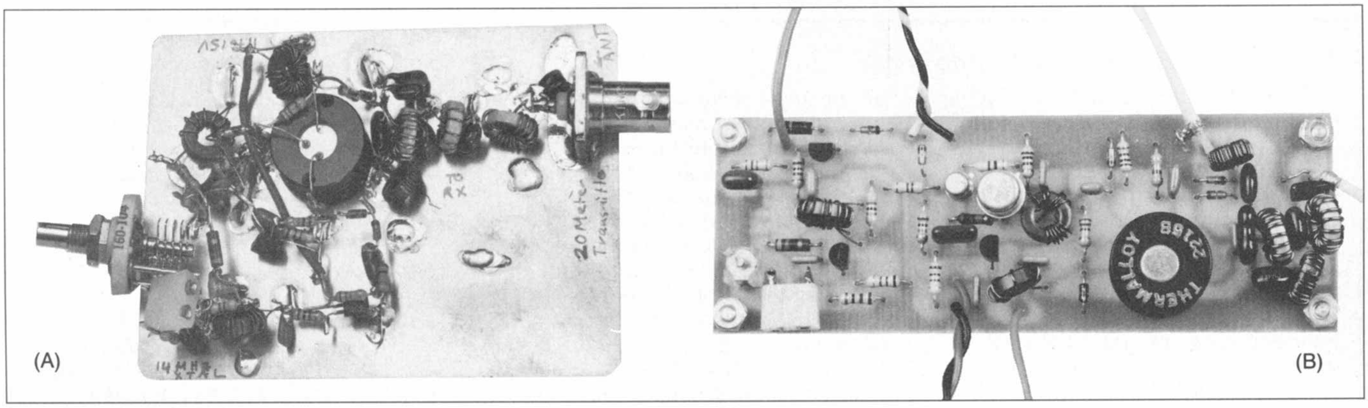


Fig 2—Most audio and MF/HF projects work equally well in ground-plane (A) and PC-board (B) forms. (Where there's a difference, ground-plane construction usually has the edge because of improved grounding.) Most published projects stem from ground-plane prototypes (see Fig 7 in Chapter 35 of the 1992 *ARRL Handbook*, for instance). Hams experienced in ground-plane (sometimes called *dead-bug* or *ugly*) construction can often build a ground-plane prototype faster than its PC-board equivalent! Part 2 of this series describes how to build a 20-meter transmitter using ground-plane techniques. If you prefer to use the PC board available as per Note 2, you'll learn how to install parts on it in Part 3 of this series.

dio Shack have heat-sink grease, and in this case Radio Shack's price is slightly cheaper.

For this project, then, we can buy everything but the crystal and a few of the capacitors from Ocean State Electronics, we can buy the crystal from International or JAN, and we can buy the capacitors from All Electronics. You'll also have to make a trip to Radio Shack for the box, PC board, and screws and nuts to put it all together.

Redistributing the Parts to Reach Minimum Order

Remember I said there would almost always be a few items you can't get from one company? All Electronics has a $10 minimum order, and the capacitors are much less than this, so we need to redistribute the order. If we get the resistors and some of the transistors from All Electronics, we can bring the order up to $10. All Electronics has a minimum purchase of 10 resistors of one value, but they're still cheap. Zack used common values in the transmitter, so you'll be able to use the extra resistors in your next project. Even if you can get something you need from Radio Shack, consider adding it to a mail order if it helps you meet a minimum-order requirement.

Why did I pick these suppliers? Ocean State was easy—they have almost all the parts. I picked All Electronics because they had good prices on the rest of the components, a reasonable selection and low shipping charges. Some companies put out beautiful catalogs, but their minimum order is $25 or they charge $5 for shipping if you place a small order. I've ordered from All Electronics before, and I know they're pretty quick. You can get the parts from other companies, of course. You'll find out which companies you like to deal with and which ones often *back-order* parts or take forever to send anything.

Back-ordering is what many suppliers automatically do if they're out of stock on something you've ordered. They fill your order as fully as they can, ship it to you, and tell you on the invoice when you can expect to receive the out-of-stock parts. Sometimes the delay can be a month or longer! That's back-ordering, and it can be terrifically frustrating because it ties up your money and your project. If the order form includes a box you can check to indicate that you don't want back orders, *check it*. If the order form doesn't give you this vote, write it in in big red letters: *PLEASE DO NOT BACK-ORDER OUT-OF-STOCK PARTS.*

If you're in a huge hurry, most companies will accept telephone credit-card orders. If you order by phone, you can also check at order time to be sure that none of the parts will be back-ordered. Be aware, though, that phone credit-card orders may compromise your credit-card security. So, I don't routinely place credit-card orders by phone.

If you're in a bit less of a hurry but still want your parts quickly, you should pay for your order with a bank check or money order. If you pay with a personal check, some companies will hold your order until your check clears their bank, and this can take up to ten days. Even if you pay with a check, you can still call the company to check on parts availability, but most companies don't like it if you use their 800 order number just for this.

When I've filled out the order forms from the catalogs and the bank checks are ready to go, I like to make a photocopy of the order form and the check before I send it off. I've only had an order lost in the mail once, but it was good to have the photocopy so I could reconstruct the order and send it off again. This also tells you when you ordered the parts, so you know when to start looking for the UPS truck.

Summary, Part 1

For now, get busy with your parts orders. In the next article, we'll look into construction techniques. We'll build the transmitter using ground-plane construction on a piece of copper-clad circuit board. We'll also consider building a power supply if you don't already have one. (Radio Shack carries the parts for this, by the way!) In article three, we'll build a transmitter using a PC board, and think about adding a sidetone oscillator. In the last article of the series, we'll put the transmitter in the box and put it on the air. You really *can* build good radio gear yourself—stay tuned!

Notes

[1]Z. Lau, "The QRP Three-Bander," *QST*, Oct 1989, pp 25-30. See also Feedback, *QST*, Jan 1992, pages 55 and 91.

[2]PC boards are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; price, $4 plus $1.50 shipping and handling. Check or money order only; credit cards are not accepted.

PC-board templates and part overlays for the 20-meter VXO-controlled transmitter featured here are available free of charge from the ARRL Technical Department Secretary. With your request for the HALE 20-M TRANSMITTER PC BOARD TEMPLATE PACKAGE, send a #10 self-addressed envelope with one First-Class stamp.

[3]D. Newkirk, "Connectors for (Almost) All Occasions," *Part 1*, *QST*, Apr 1991, pp 35-38; *Part 2*, *QST*, May 1991, pp 34-40.

Strays

I would like to get in touch with...

☐ Hams who operated club station KJ6DO on Johnston Island. Any information, QSL cards or photographs would be appreciated, as I'd like to track down the history of my call sign. Dr Chuck Bowers, KJ6DO, 837 Ridgeview Ct, Oakdale, CA 95361.

☐ anyone who has a schematic and/or manual for a Black Widow 10-meter transmitter/receiver manufactured by Rogers Electronics, Louisiana. Austin Gutman, W3FOG, 8480 Limekiln Pike, C-401, Wyncote, Pennsylvania.

☐ anyone who has a manual for the following: A Clegg FM-88 2-meter rig, Hitachi V-222 oscilloscope, HP-410B VTVM or an Eico DX-718 receiver. Steve Hammerberg, NI7B, PO Box 822, Thompson Falls, MT 59873.