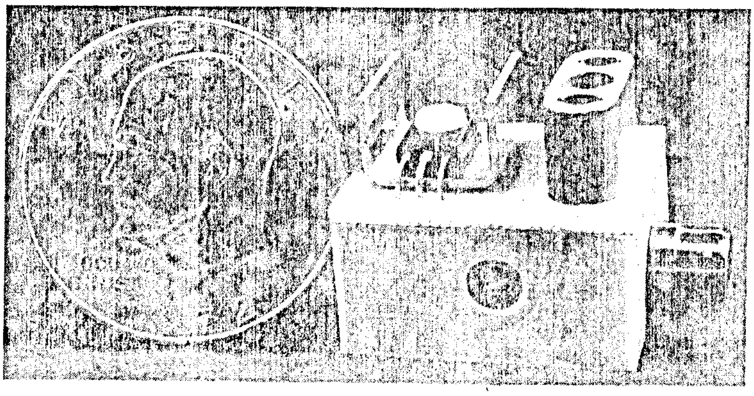
BEGINNER'S BENCH

Build a 40-M Cubic Incher



Just a few hours and a few "bucks" will net you more watts per cubic inch — and fun — than any other rig.

By Dennis Monticelli,* AE6C

Having been afflicted with QRPer's disease[1] for the past 14 years, I found it natural to attempt to build a rig sized in proportion to its power. Of necessity, the circuit had to be simple and emphasize low parts volume as well as low parts count. The design effort was well worth the time because this rig has been more operating fun (per cubic inch or otherwise) than any other rig I have built. Other hams find it hard to believe that 2 watts and a good note can originate from such a tiny box.

Circuit Description

This rig is a crystal-controlled, 1-transistor power oscillator (Fig. 1), designed to generate power efficiently while maintaining a good cw note. A key to achieving the small size is the use of T1, a multifunction transformer. Wound on an iron-powder toroid, T1 passes dc to the transistor, couples power from that device to the tank circuit, forms one half of the resonant tank circuit, and transfers power to the antenna. The primary inductance is chosen deliberately to be unusually high (7.8 μH), so that the unloaded Q (Q_u) will be 140. By designing for such a high Q_u, the tank loss can be minimized. This, in turn, allows the loaded Q (Q_L) to be set high enough (Q_L = 14) to maintain waveform purity without the fear of consuming precious output power in the tank circuit. The impedance across the tank, as reflected by a 50-Ω load, is approximately 5 kΩ, resulting in a healthy 280-V pk-pk swing with a 12 V supply. Tuning is performed by adjusting the small, mica-compression trimmer capacitor, C3.

Normally, feedback for a simple, Pierce-type crystal oscillator is obtained by feeding the entire tank signal back to the base through the crystal. While this method results in quick starting and vigorous oscillation, it also drives the transistor harder into saturation than is necessary. This usually results in a collector current signal rich in harmonics and lower tank Q_L because of transistor input loading. A capacitive impedance transformation provided by C1 and C2 reduces the feedback signal to a more optimum level. The oscillator still starts willingly, and the output waveform is significantly cleaner than that obtained with excessive drive. Saturation still occurs on negative voltage swings, so efficiency is maintained. Start-up resistor R1 delivers about 1 mA to the base of Q1. For a typical β (current gain) of 50, this results in a collector current of 50 mA, which is ample for the circuit to develop the high-frequency voltage gain necessary to initiate oscillation. D1 is optional, but it seems to reduce harmonic output somewhat, perhaps by equalizing the loading on the tank for positive and negative swings. It also serves to protect the base-emitter junction of Q1 from inadvertant, but potentially damaging, reverse breakdown voltage. RFC1 is also optional, but it too reduces harmonics slightly and represents a certain measure of insurance that Q1 won't parasitically oscillate at vhf.

Q1 was chosen carefully, as it is the "heart" of the circuit. Originally designed for service in the Class C output stage of a CB radio, it exhibits good efficiency up to 4-W output at 27 MHz. It also possesses the noteworthy ability to handle infinite SWR when operated at 12 V or less. And although I've found this device to be virtually impossible to destroy in this circuit, that doesn't mean some particularly resourceful ham out there won't find a way to make me eat my words. In any case, the MRF472 is inexpensive, selling for as little as $1 at some outlets (see Fig. 1), and it comes in a tidy TO-126 package.

Construction

The little rig is built in an open-bottomed box constructed from single-sided printed-circuit-board material, and measures (you guessed it!) 1 cu in.[2] The circuit-board foil serves as an effective and convenient solderable ground plane.

*48617 Tonopah Ct., Fremont, CA 94538
[1]Notes appear on page 36.

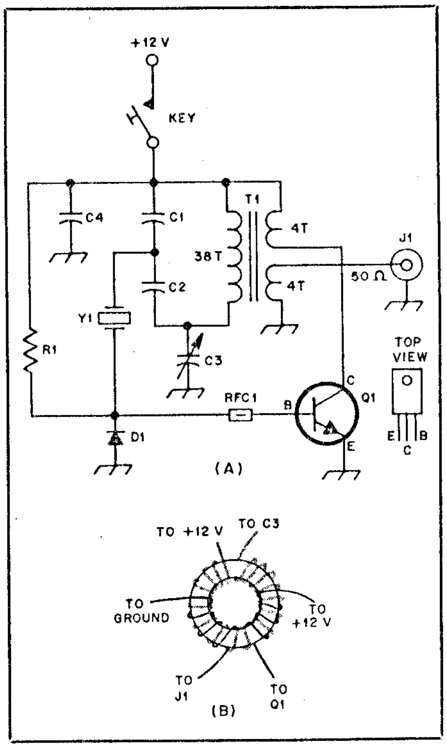


Fig. 1 — Schematic diagram of the 40-Meter Cubic Incher (A), and winding details for T1 (B).

C1 — 430-pF silver mica or disc ceramic (exact value unimportant; 390 or 470 pF will work).
C2 — 51-pF silver mica or disc ceramic.
C3 — 4- to 40-pF miniature mica compression trimmer, 3/8 × 17/32 in., ARCO no. 403[5] or equiv.
C4 — 0.01-μF and 0.001-μF disc ceramics in parallel. The 0.001-μF unit is optional (see text).
D1 — High-speed silicon switching diode, 1N914 or equiv. This diode is optional (see text).
J1 — RCA phono jack.
Q1 — Npn medium-power rf transistor, MRF472[6] or equiv.
R1 — 10-kΩ, 1/4-W carbon type.
RFC1 — Ferrite bead, FB-43-101 or equiv.
T1 — Toroidal transformer wound with no. 26 enameled wire on a T50-2 core,[7] 38 t. primary, 4 t. each secondary.
Y1 — Fundamental-cut crystal in FT-243 or HC-6/U holder.

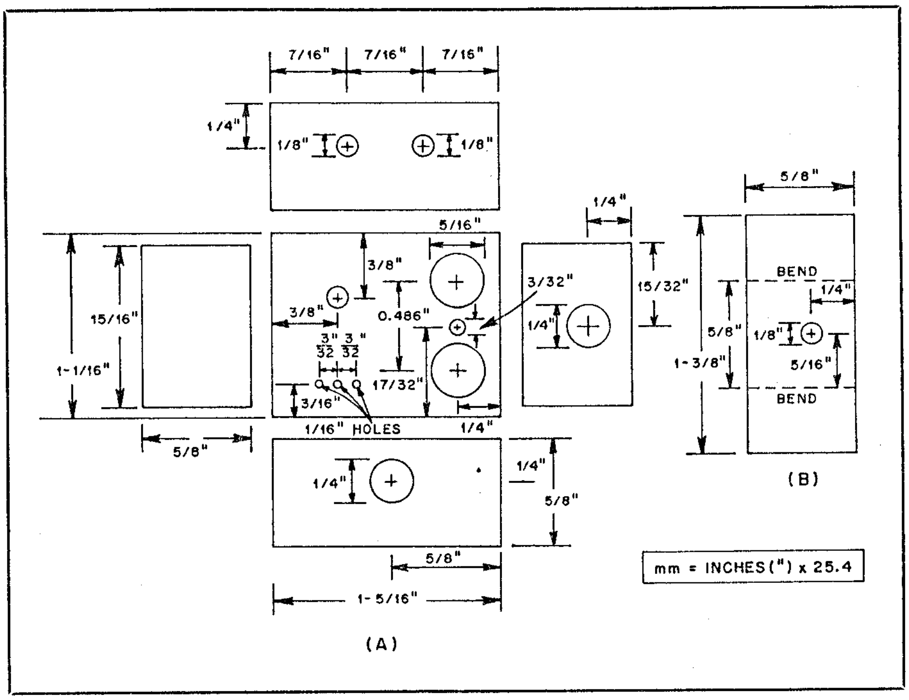


Fig. 2 — The five pieces of circuit-board material used to form the box are cut and drilled as shown in A before the box is assembled. The heat sink, B, is made from 1/16-inch aluminum or brass.

Surprisingly, the parts are not too tightly crammed into the box. Instead, the volumetric needs of each component were carefully considered in planning the layout to ensure efficient use of space. For example, T1, Q1 and the heat sink are all mounted to the box with one nylon bolt. The remaining parts are placed judiciously with regard to the constraints imposed by T1, C3 and the intrusive phono jack, J1 (now you know why I didn't use an SO-239!)

Begin construction by cutting the five pieces shown in Fig. 2 out of 1/16-inch-thick circuit board.[3] Drill all the indicated holes prior to assembly. If some of the parts, such as C3 or the crystal socket, are dimensionally different from mine, you will need to make allowances in your cutting and drilling. Assemble the box by first soldering the long sides to the top member. Next, solder the shorter end pieces to the top. Finally, solder the four corners together. Make it easy on yourself and the circuit board by using only a single blob of solder for each joint. A small box like this one will be plenty strong enough without drowning it in solder and flux and overheating the fiberglass in the process.

Install the two 4-40 bolts that serve as the supply (V+) and ground terminals, taking care to insulate the V+ bolt from the chassis. Scrape away the copper foil from around the immediate area of the V+ hole and use a fiber washer to ensure isolation from ground. Next solder one end of C3 to the underside of the top piece after aligning it carefully with the adjustment hole in the side piece. Cut and bend the heat sink, described in Fig. 2, out of aluminum or brass and drill the mounting hole. Wind T1 as detailed in Fig. 1, paying attention to the phasing direction and placement of the windings. Scrape away the foil from around the holes for the transistor leads as you did for the V+ bolt. Bend the leads of Q1 and install it along with the heat sink and T1 as one unit, using a 3/4-inch nylon bolt. Use nylon or fiber washers to sandwich T1, thus insulating it from the chassis and providing a flat surface for the nut to clamp down on. You may wish to use thermal conducting grease between Q1 and the heat sink, although this is not mandatory because the operating temperature of the device is normally low.

Referring to Fig. 3 for parts placement, first solder in imbedded capacitor C2, and then C1. Plan your routing scheme for the six leads from T1 and solder them in. Drop the ferrite bead over the base lead of Q1 and connect an insulated wire from the base to the crystal socket. The remaining parts, C4, D1 and R1, are all easy to wire in, as they lay near the surface. Note that two capacitors were used for C4 in this model, although one works just fine.

Testing and Tune-up

Apply a current-metered, 12-V power source (I use batteries) capable of supplying at least 300 mA, and connect a 50-Ω noninductive resistor or dummy load to J1. Plug in a crystal known to be active, and adjust C3 until the circuit breaks into oscillation as evidenced by a sudden jump in supply current. By adjusting C3, you can get the supply current to range from roughly 150 mA to 600 mA and still maintain oscillation. At the low current end, leading-edge keying will be soft and efficiency reduced. At the upper end, the power efficiency will be reduced and harmonics increased. It appears that about 300 mA yields the best combination of good keying and efficiency. The particular transistor you use, the crystal activity and your actual antenna impedance will all influence the optimum current value. Determine the optimum value yourself for your particular set-up. Once adjusted, C3 should not have to be changed when you change crystals, unless

40MCI3

they vary widely in activity. Don't expect to find a current dip as you tune; a heavily loaded oscillator like this one will not behave like the 6146 final amplifier in your station rig.

Troubleshooting

Obviously there is very little to go wrong with this rig. Should trouble develop, however, here are a few hints. If the circuit refuses to oscillate and draws no supply current at all, you have a bad connection or a defective transistor. If the circuit pulls roughly 20 to 100 mA, but doesn't oscillate, then your transistor is good but the tank may be out of resonance. Use a grid dip meter to check it, or experiment up and down a bit with the value of C2. It is also possible that insufficient feedback is available to kick the circuit into oscillation. Try reducing the value of C1 by an octave or so to boost this feedback.

80-Meter Operation

I see no reason why this rig shouldn't work on 80 meters with simple modification. Although I haven't tried it, merely scaling up C1, C2 and C3 by two octaves should result in good performance because the primary inductance of T1 is already high at 7.8 μH. I would be pleased to hear from anyone who succeeds in putting a Cubic Incher to work on 80.

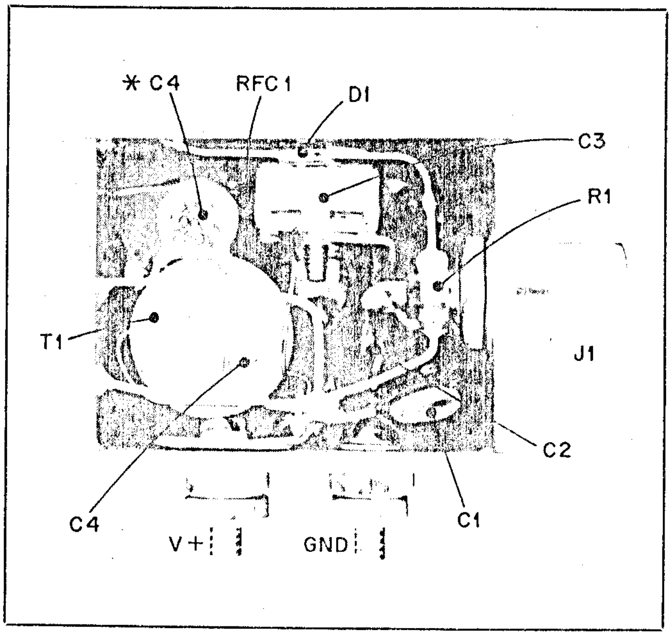
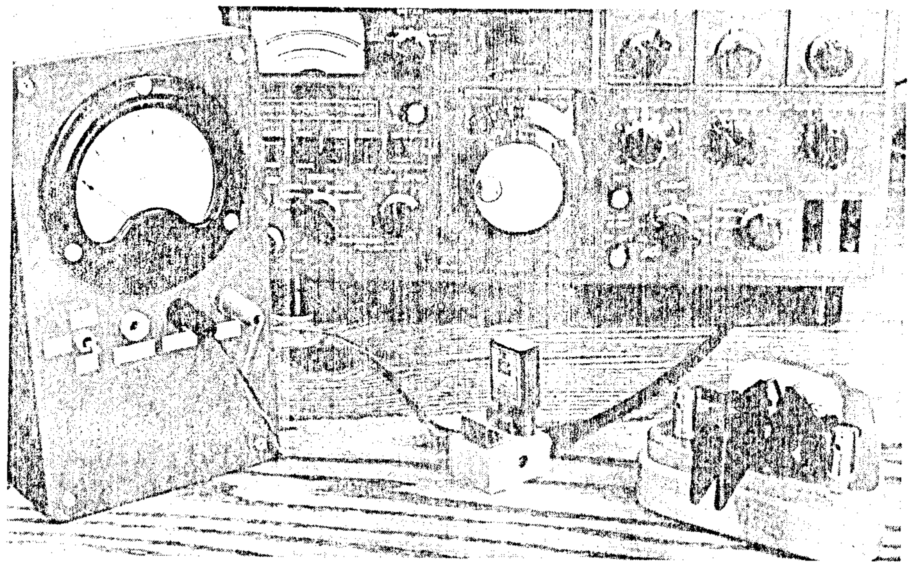


Fig. 3 — This bottom view shows the parts placement used to make the most of the tiny volume.

Performance

For such a simple circuit, the Cubic Incher gives a good account of itself. With a 12-V supply, the transmitter draws 300 mA while producing an output of 2.1 W. That's an efficiency of 58%, relative to total rig power consumption; try that test on your station rig! The Cubic Incher also works well on supplies from 6 to 18 volts, although the power efficiency and ability to withstand infinite SWR is impaired by high supply voltages.

I run the output from my Cubic Incher through the station Transmatch and low-pass filter (always good practice) to a roof-mounted Butternut vertical. This modest arrangement produces plenty of contacts and frequent comments on the nice sounding note. Other hams rarely believe me the first time I tell them the rig measures only 1 cu in. Contacts have been made with stations all over North America, in South America and frequently in Japan.



The QRP apparatus at AE6C. The metered power supply on the left contains two 6-V rechargeable gel cells. A flick of the switch changes the supply, from 12 to 6 volts for an extra QRP challenge.

QRP is a lot of fun for many hams, but others have found it somewhat frustrating. I have some thoughts (certainly not original) on this subject. First of all, it is a misconception that elaborate antennas are needed. All that is required is that your aerial be efficient and mounted up in the clear. If the practices outlined in *The ARRL Antenna Book* are followed, simple dipoles, verticals, Zepps, etc., will work fine. Second, don't call CQ expecting to receive a snappy response. It's much better to listen, select and call the stronger stations on the assumption that either propagation is favorable between the two of you or he has a good antenna. Either way, you stand a better chance of being heard. Third, QRM and especially QRN are your two worst enemies. Choose a clear frequency and avoid operating on days with very high atmospheric noise. Fourth, arm yourself with more than one crystal. Double your crystals and you'll virtually double your opportunity for a QSO. Shop the flea markets for "rocks" or take advantage of the good buys offered by some suppliers.[4]

Some Thoughts

No construction article is complete without mentioning the potential disadvantages of undertaking and completing the suggested project. No doubt about it, this rig is *small!* "How small is it," you ask? It's so small it gets lost on your operating bench. It's so small it dangles on the end of a stiff coaxial cable like some sort of coaxial terminator. It's so small my cat has claimed it as her personal toy, batting it about like a ping-pong ball. Best of all, though, it's so small it puts the thrill back into your QSOs. [QST]

Notes

[1] *Operatus lopowerus*, no know cure.
[2] mm = in. × 25.4; cu mm = cu in. × 16,390.
[3] A complete parts kit, including cut and drilled circuit-board parts, is available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002.
[4] FT-243-style crystals are available from CW Crystals, 570 N. Buffalo St., Marshfield, MO 65706.
[5] Available from Radio Kit, P.O. Box 411, Greenville, NH 03048.
[6] Available from Semiconductor Surplus, 2822 N. 32nd St., No. 1, Phoenix, AZ 85008.
[7] Iron-powder toroids and ferrite beads are available from Amidon Assoc., 12033 Otsego St., N. Hollywood, CA 91607, and from Palomar Engineers, 1925-F W. Mission Rd., Escondido, CA 92025.

Reference

Hayward, W. and DeMaw D. *Solid State Design for the Radio Amateur.* Newington: ARRL, 1977.