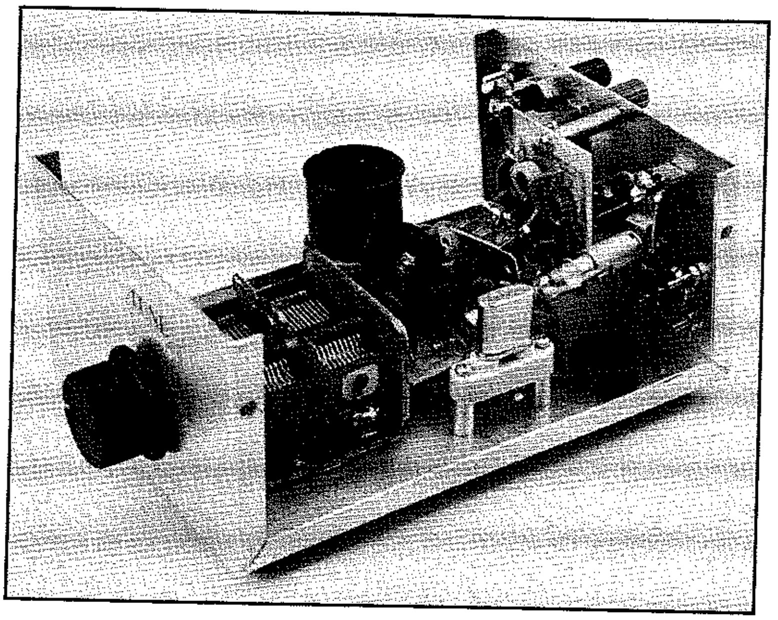
By Charles Kitchin, N1TEV

A Simple CW Transmitter for 80 and 40 Meters

If you've never used a MOSFET-powered transmitter before, give this one a try!



Here's a simple CW transmitter for the 80 and 40 meter bands. It's a modern day equivalent of the classic two-tube MOPA (master oscillator, power amplifier) transmitter used by so many hams for decades—usually their first transmitter and usually homebrewed. Building this equivalent is much simpler and probably less expensive. The two-stage transmitter uses a low-cost, high-speed op amp in the crystal oscillator circuit and a modern HEXFET device (an N-channel, enhancement-mode power MOSFET) for the output amplifier. Unlike some other solid-state designs, this little gem requires few components and can be built by most hams in an evening or two. On 80 meters, it provides a power *output* of 5 to 9 W into a 50 Ω load, depending on Q1's drain voltage (the transmitter's input power is about double the output). ARRL Lab measurements indicate power outputs of 6 W on 80 meters with a 30 V supply, and 1 W on 40 meters using a 25 V supply.

Using a HEXFET (rather than a bipolar transistor) for the output amplifier provides a much higher load impedance for the oscillator. That eliminates the need for a step-down transformer generally required between bipolar transistor stages, and allows the use of simple RC coupling instead. In turn, RC coupling greatly improves circuit stability, making this a simple project to build and get working. With a typical breakdown voltage of 500 V, and built-in Zener diode overvoltage protection, the HEXFET output stage can operate without a load and under conditions of high SWR, *without damage*. Another advantage is that this circuit can use a commonly available 99 cent microprocessor crystal for operation on the 80 meter Novice band.

Oscillator

An Analog Devices AD811AN op amp (U1) is used in the oscillator circuit. This low-cost op amp has a current-output capability of 100 mA, which allows it to drive the typical 350 pF input capacitance of Q1's gate. U1 is biased to mid supply by resistors R1 and R2. Oscillation occurs because of positive feedback applied from U1's output through the crystal (Y1) and R2 and R3 to the positive op amp terminal. By using R3, rather than a direct connection to the positive op amp terminal, the positive feedback level is reduced (as is the crystal current), so that a low-cost microprocessor crystal can be used without noticeable chirp. (Be sure to use 40-meter crystals for operation on 40 meters; doubling in the final using an 80-meter crystal at Y1 isn't efficient.)

Dc stability is maintained by a negative feedback loop using R4 and C2. C2 rolls off the higher frequencies while operating the op amp at a dc gain of one. Note that the transmitter's power supply is directly keyed and that C1, the 33-µF power-supply bypass capacitor, is located *ahead* of the key. If C1 is connected behind the key—to the *circuit side* of the key—the oscillator turns on too slowly and chirps. A 0.01µF capacitor (C3), right at pin 7 of U1, maintains circuit stability and helps smooth out key clicks.

U1's output impedance is about 30 Ω at 3.6 MHz. R5 provides only a dc return for Q1's gate; it is U1's low-impedance output that permits adequate drive levels to Q1 at 3.5 and 7 MHz.

Power Amplifier

Q1's characteristics greatly simplify the transmitter design and provide a high power-output level when using a battery power source. The high impedance input of Q1 makes it much easier to drive than a bipolar transistor. Also, the HEXFET's output impedance is higher than that of a bipolar transistor, so component values for a pi-network output circuit are reasonable.

Q1's drain connects through a 100 µH RF choke to the dc supply. The output signal is capacitively coupled to a pi-network consisting of L1, C7, C8, and C9. L1 is close-wound on a plastic film can, using standard 20 gauge insulated hook-up wire.

The output network is tuned to resonance using C7 (**TUNE**), a 500 pF variable capacitor. S1, **BAND**, switches output inductances for the 40 and 80 meter bands. S3, **LOADING**, selects none (center) or one of two additional output capacitors (C10 or C11) to permit optimum matching to the antenna. The **OPERATE/TUNE** switch (S2) can switch in a #44 lamp during tune-up to provide a visual indi-

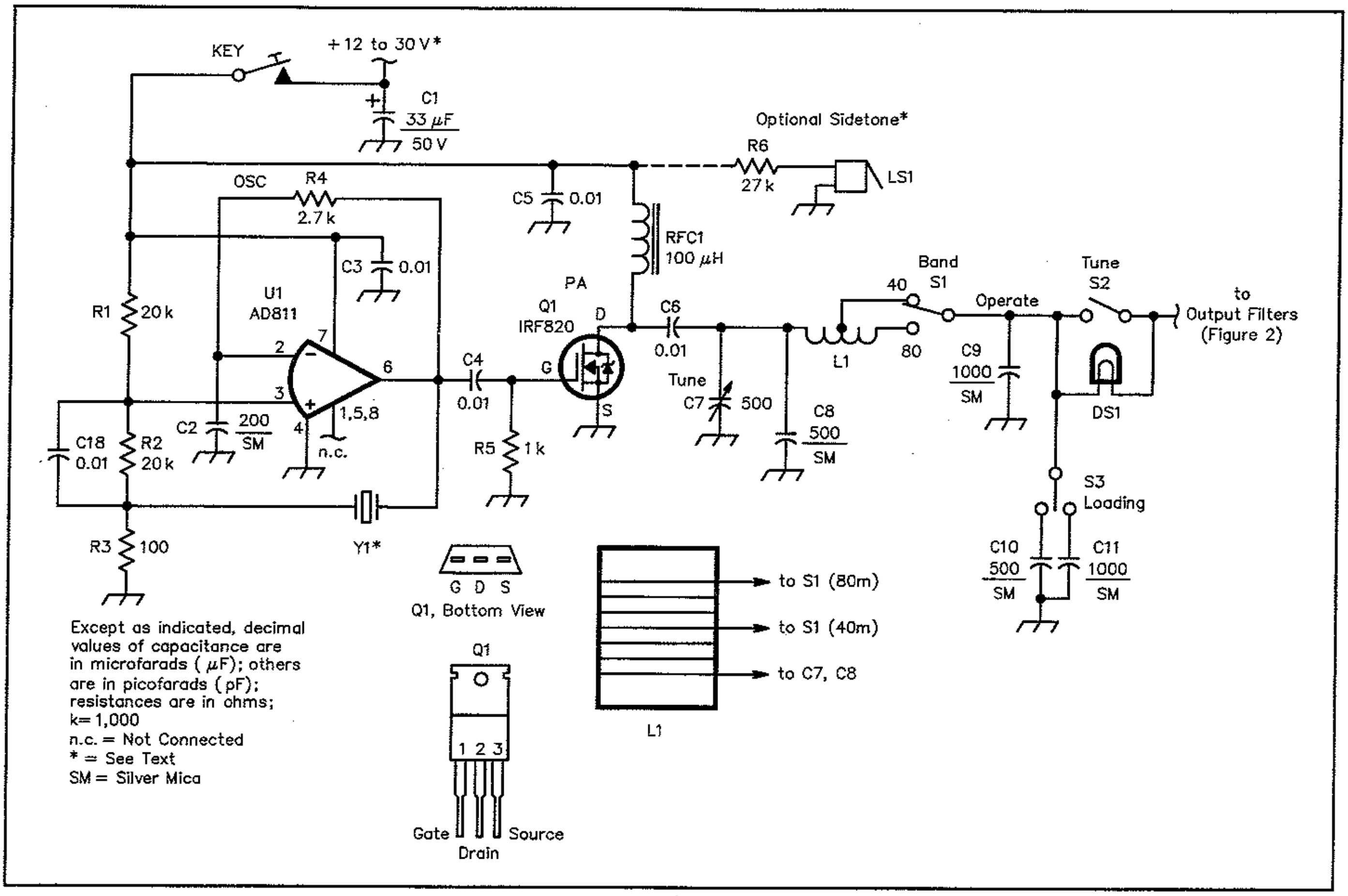


Figure 1—Schematic of the MOSFET transmitter. DK part numbers in parentheses are Digi-Key, RS numbers are Radio Shack; equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition units.

C1—33 µF, 50 V electrolytic or tantalum
C2—200 pF mica capacitor
C3-C6, C18—0.01 µF disc ceramic
C7—500 pF air-dielectric variable capacitor; connect in parallel sections of a discarded AM radio air-dielectric variable capacitor to achieve a total capacitance of about 500 pF; (Fair Radio Sales Co, Inc, 1016 E Eureka St, PO Box 1105, Lima OH 45802, tel 419-223-2196; 419-227-6573; fax 419-227-1313; e-mail **fairadio@alpha.wcoil.com**; **http://alpha.wcoil.com/~fairadio/**. Antique Electronics Supply, 6221 S Maple Ave, PO Box 27468, Tempe AZ 85285-7468, tel 602-820-5411; fax 602,820-4643.)
C8 ,C10—500 pF silver mica
C9, C11—1000 pF silver mica
DS1—#44 lamp (RS 272-1108A; lamp holder RS 272-355)
L1—See text.
LS1—Piezo buzzer (RS 273-060; DK P9914; Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677 tel 800-344-4539, 218-681-6674; fax 218-681-3380 **http://www.digikey.com**)
Q1—International Rectifier IRF820 HEXFET (Digi-Key IRF820, or Active Electronics 26036; Active Electronics [a division of Future Electronics] 811 Cummings Park, Woburn, MA 01801; tel 617-932-0050, fax 617-933-8884)
RFC1—100 µH (RS 273-102C)
S1—SPDT toggle (RS 275-613)
S2—SPST toggle (RS 275-612)
S3—SPDT center-off toggle (RS 275-325)
U1—AD811AN op amp; available from Newark Electronics (check your telephone book for a branch near you). Main office: 4801 N Ravenswood Ave, Chicago, IL 06040-4496; tel 312-784-5100; fax: 312-907-5217, and Allied Electronics, 7410 Pebble Dr, Fort Worth, TX 76118, tel 800-433-5700.
Y1—3.6864 MHz microprocessor crystal; see text (Digi-Key X080; Active Electronics 68010). For conventional 80 and 40 meter crystals, contact Peterson Radio at 2735 Ave A, Council Bluffs, IA, 51501, tel 712-323-7539; closed Fridays.
Misc: Crystal socket, binding posts for battery/power supply connections (RS 274-662); hook-up wire (RS 278-1219), hardware, heat sink, knobs, enclosure, PC boards (see Note 2).

cation of output current to the antenna.

The simple output network is, unfortunately, insufficient to reduce transmitted harmonic levels sufficiently to pass FCC specifications. That obstacle is readily overcome by adding some low-pass filtering to the output of the transmitter (see Figure 2).[1]

Construction

Take steps to avoid static discharges (use a grounded wrist strap) and keep Q1 inside its protective foam as long as possible. Whether you build the transmitter using "dead-bug," perfboard or PC board[2] methods, first wire and test the oscillator circuit, then build and test the output stage. When building the output stage, install all other components first; install Q1 last.

Component layout and lead dress for any HF RF circuit is important. Keep all leads, especially ground wires, as short as possible. Locate power supply bypass capacitor C3 physically as close as possible to U1 pin 7, using a short ground lead. Use noninductive carbon-composition resistors in RF circuits (not wire-wound types). By housing the transmitter in a small metal box, the box will also serve as the groundplane. Alternatively, a $5^1/_2\times8\times^3/_4$-inch piece of wood (poplar or pine are soft) can be used to hold a piece of copper clad PC board screwed (or glued) to it to serve as a groundplane. U1 and Q1 can be wired to a small breadboard mounted above the groundplane using short spacers. All ground leads should be as short as possible and be soldered to the copper groundplane.

L1 is wound on a standard $1^1/_4$-inch OD 35 mm plastic film can or pill bottle coil form. L1 consists of 8 turns of #20 hook-up wire with a tap at the center. Before winding the coil around the form, drill two small holes at the beginning of the winding. Feed one end of the wire into the form through the first

[1]Notes appear on page 42.

Substituting Parts

Being inveterate experimenters (or cheapskates!), some builders might decide to make substitutions for the AD811, U1, and the IRF820 MOSFET, Q1. Don't do so without some forethought! The AD811 was carefully chosen because it has a beefy 100-mA output stage and a very low output impedance at the operating frequencies chosen. Other op amps may work, but they're likely to be expensive ones.

If you're thinking of using a JFET or bipolar transistor oscillator to drive the IRF820, you may have difficulty in getting the oscillator started, or it may not provide enough drive to Q1.

Providing a substitute for the IRF820 is another story. I selected the '820 because it has a fairly low input capacitance of 350 pF. Other HEXFETs, such as the IRF830 and '840 have *very high* input capacitances on the order of 800 to 1500 pF, so you'll never be able to drive them properly without regressing to the use of a step-down transformer between the oscillator and amplifier. Other MOSFETs that do have low values of C_{in} can't handle as much power, have lower break-down voltages and are *not* Zener-diode protected. So, if you're thinking of substituting parts, do so carefully.—*Charles Kitchin, N1TEV*

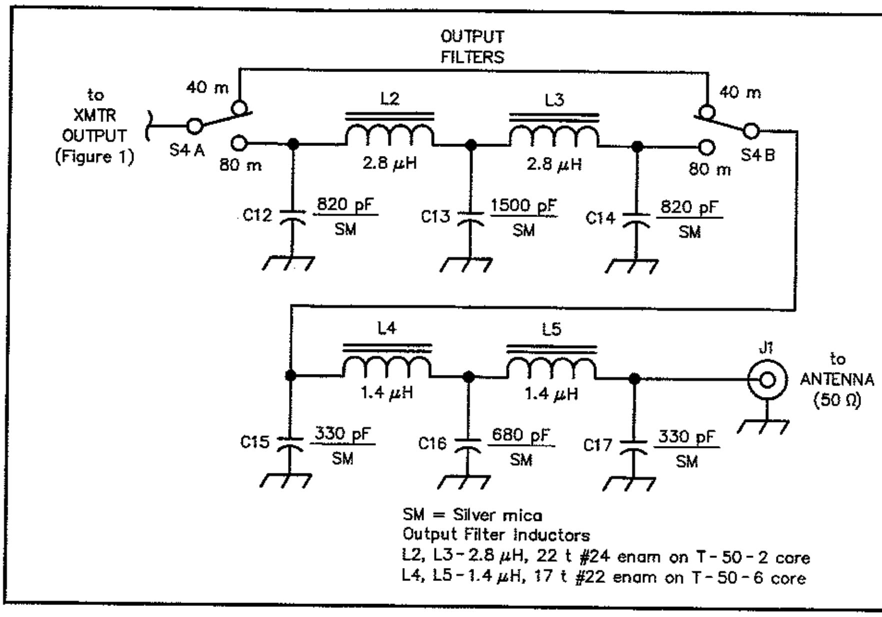


Figure 2—These output filters ensure the transmitter's spectral purity meets FCC requirements. Both filters are in the circuit for 80-meter operation. On 40 meters, the first filter is bypassed. All capacitors are silver mica units.

J1—SO-239 (Digi-Key ARFX1005; RS 278-201)
L2, L3—2.8 µH, 22 turns #24 enameled wire on a T-50-2 powdered-iron toroidal core
L4, L5—1.4 µH, 17 turns #24 enameled wire on a T-50-6 powdered-iron toroidal core
S4—DPDT toggle (RS 275-614)

hole, then out again through the second. Knot the wire where it enters the form—this will hold the wire securely in place. Then wind the wire tightly onto the form so that there are no spaces between the turns. You may need to push the turns together as you wind.

After you have wound four turns, make the tap by removing some insulation from the wire and soldering a short length of wire to that point. When the winding is finished, hold the wire in place while you drill two more holes in the form at the end of the winding. Feed the wire through these holes as before. Tie a knot at the wire end to hold the coil in place and keep it from unwinding.

With a machine screw and nut, attach a one-inch square TO-220 heat sink to Q1. J1 can be a standard SO-239 connector. Connect the key to the circuit using a standard headphone jack, or simply hard-wire it. S1, S2 and S3 are standard subminiature toggle switches. Use short leads between the switches and associated components. You may want to add a crystal socket if you plan to operate on more than one frequency.

Testing and Operation

Series-connected 6-V lantern batteries are ideal for powering this transmitter—they are low cost and deliver many ampere-hours of energy. A 24 V pack of four lantern batteries should deliver 10 to 20 hours transmitting time. Use duct tape to hold the batteries together.

To test the transmitter, attach the batteries (or other power supply—start with a 24 V, or lower, supply), plug in the crystal and place S2 in the **TUNE** position. Connect a 50 Ω resistor or dummy antenna to J1. (You can use four 200 Ω, 1 W resistors connected in parallel.) With S3 in the center position, close the key and adjust C7 for maximum output as indicated by DS1's glow. Then, move S3 first to the left position, then to the right, retuning C7 each time. The correct position is whichever provides the greatest brilliance on the lamp. Using a 24 V supply, the lamp should be lit to near full brilliance on 3.6 MHz and about half that at 7.1 MHz.

To avoid overheating the op amp or Q1, don't keep the key closed any longer than necessary during tune-up. After the best impedance match has been found, move S2 to the **OPERATE** position (to bypass the lamp and provide full power output). Once testing is complete, remove the resistive load, connect the output to a 50 Ω antenna and repeat this procedure.

The optional piezo buzzer shown in Figure 1 provides sidetone for monitoring your keying. It's a good idea to check your keying quality using a nearby receiver with its antenna disconnected.

Summary

Apply no more than 30 V to this transmitter's dc-input line because the AD811 may be destroyed. Battery operation is more forgiving as the batteries' internal resistance reduces the voltage applied to the transmitter. Use of a "hefty" power supply may cause the AD811 to overheat and that can cause "chirp" (a signal-frequency change during keying). If you want more power output, increase the voltage applied to Q1's drain by breaking the connection to Q1's power-supply line and inserting additional series-connected batteries (or a suitable power supply) to increase the supply voltage to Q1 *only*. If you do this, provide Q1 with a larger heat sink to dissipate the additional heat. Some experimentation with the output matching components may also be needed.

Notes

[1]During ARRL Lab tests for spectral purity, we found the transmitter required more filtering than that provided by the existing output network. The second harmonic was only —22 dBc rather than the —32 dBc required by the FCC. All other harmonics were within legal limits.

[2] PC boards for the transmitter and filters are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269, tel 847-836-9148 (voice and fax). Price: $6 plus $1.50 shipping for up to four boards. Visa and MasterCard accepted with a $3 service charge.

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Chuck graduated with an ASET from Wentworth Institute in Boston. Afterwards, he continued studying electrical engineering at the University of Lowell's evening division.

Chuck has been an avid radio builder and shortwave listener since childhood, and a licensed radio amateur (Technician Plus) for three years. His other hobbies include astronomy, brewing beer, and oil painting. You can contact Chuck at Analog Devices, MS 126. 804 Woburn St, Wilmington, MA 01887; tel 781-937-1665; fax 781-937-2019; e-mail **charles.kitchin@analog.com**. QST