An 8-Watt, 2-Meter “Brickette”

Put 20 mW into this little amplifier and get a 26-dB increase in transmitted power! Although the amplifier was designed initially for use with the DSP-10 transceiver, any 20-mW-output 2-meter exciter can enjoy the boost!

The DSP-10 transceiver\(^1\) can be used with UHF/microwave transverters or as a very-QRP all-mode rig on 2-meters. The rig’s 20-mW power output is sufficient for “bare-foot” QSOs with locals, but that’s hardly a big signal at any distance. Adding this little amplifier increases your fun quotient by raising the power level to 8 W, the high end of the QRP plateau. This brickette can also be used to drive an even higher-power, cascaded amplifier. Being a linear amplifier, it’s suitable for use on all modes, including SSB, CW and FM.

The amplifier’s front panel is quite simple, consisting of five monitoring LEDs. Knowing that everything is working correctly justifies the small amount of circuitry needed to operate these lights. The functions monitored include dc power on, transmit/receive status, power output, SWR and dc overvoltage. All amplifier control is done at the transceiver. Two RF cables connect to the transceiver output and receiver input, avoiding the need for an input relay in the amplifier.

This amplifier isn’t limited to use with the DSP-10; any 2-meter transmitter that can deliver an output of 20 mW to drive the amplifier should work fine. In some cases, it might be desirable to use an input TR relay; there is sufficient room in the amplifier for adding one.

Circuitry

At the heart of this amplifier is an integrated power-amplifier module, manufactured by Mitsubishi. Such modules are used in many commercially manufactured transceivers and using one here makes amplifier construction and alignment simple. Within the module are two cascaded linear-amplifier transistors, along with their associated matching networks and biasing circuits for class AB operation. The module has 50-Ω input and output impedances. All we need to do is add a circuit to turn on the bias supply during transmit, install a low-pass filter for harmonic control and include an antenna-switching relay. To monitor amplifier operation, we tack on some simple circuitry.

Refer to the schematic in Figure 1. At the input pin of the RF module, U1, we apply 20 mW of drive. Blocking capacitors for the RF input and output ports are included within the module. Bypass capacitors on the three power leads are external, however. Ferrite beads, L6 to L8, prevent problems that might occur if RF gets on the power leads.

An L network consisting of L1 and C4 improves the impedance match to the module. Adding the network increases the output power by about 0.25 dB. Following the amplifier is a directional coupler (discussed later). Next is a five-pole low-pass filter. For simplicity, it is configured with the same coil and capacitor types as are used in the directional coupler. This filter attenuates the second and higher-order harmonics.

Separate connectors are available on the DSP-10 for the transmitter output and the receiver input. This simplifies adding the antenna relay for the amplifier since no switching is required at the amplifier input. A miniature relay is adequate at the amplifier output. Providing an isolation of about 30 dB, the relay, along with the PIN attenuator that is part of the DSP-10, provides plenty of protection for the receiver.

A lumped-element directional coupler, consisting of L2, L3 and C5 to C10, delivers power samples of the forward and reflected output signals. This directional coupler works quite well, providing a coupling of about −28 dB and a directivity\(^2\) of 20 dB, but only over a narrow (12-MHz) bandwidth. For our application, this is adequate.

Two diode detectors, built around D6 and D7, generate low-level dc signals that indicate the forward and reflected powers. These signals, in turn, are amplified by two sections of op amp U2. The resulting voltages are displayed on two LEDs, green for RF OUT (forward) power and red for HIGH VSWR (reflected) power. The LEDs serve as rough indicators of proper amplifier operation.

\(^1\)Notes appear on page 47.
Figure 1

Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pf); resistances are in ohms; k = 1,000, M = 1,000,000 R27 not used
The OVERVOLTAGE indicator lights when the dc supply voltage exceeds 14.5 V, but the amplifier is not automatically shut down. The idea here is to supply a warning mechanism. When RF is not applied to the amplifier, it is quite resistant to supply overvoltage. As long as the supply overvoltage condition sets an alarm light, an operator will defer applying RF until the voltage is reduced.

Amplifier control is handled by the DSP-10. That transceiver has software-controlled relay sequencing, providing +5 V during transmit. Q2 and Q3 drive the antenna relay from this control. A ferrite bead, L11, and C24 keep RF at the antenna relay from getting back into the control circuits. D10 shunts the inductive kick from the deactuated relay coil. An LED, D2 (XMIT), across the relay displays the amplifier TR status. Q4 provides an output that can control a follow-on amplifier. This output is an open-collector, ground-on-transmit type, compatible with many commercial and homebuilt amplifiers. For added driver-circuit protection, a reverse-voltage shunting diode, D11, is used.

Did the Amplifier Always Look Finished? No, it didn’t. Some people may be able to put a finished amplifier on a PC board and have it work fine. I don’t seem to be able to do that!

My first step in designing the amplifier was to search for suitable RF modules, mostly via the Internet. Once I selected the M57732L as having suitable power, gain and dc operating voltage, I drew a schematic in my notebook. Originally, the circuit had automatic shutdown for high SWR and full voltage regulation to deal with overvoltage. This looked too complex. It was necessary to cut off the drive to the amplifier, and the regulator had to be a low-dropout device. No, it didn’t. Some people may be able to put a finished amplifier on a PC board and have it work fine. I don’t seem to be able to do that!

My first step in designing the amplifier was to search for suitable RF modules, mostly via the Internet. Once I selected the M57732L as having suitable power, gain and dc operating voltage, I drew a schematic in my notebook. Originally, the circuit had automatic shutdown for high SWR and full voltage regulation to deal with overvoltage. This looked too complex. It was necessary to cut off the drive to the amplifier, and the regulator had to be a low-dropout device. No, it didn’t. Some people may be able to put a finished amplifier on a PC board and have it work fine. I don’t seem to be able to do that!
tented directly to the aluminum enclosure. Such construction works very well for RF boards because a low-inductance ground path can be maintained throughout, reducing any interactions between the various circuits. However, this mounting method does not allow component leads to extend beyond the bottom surface of the board. I dealt with this primarily by using surface-mount parts and by carefully bending the component leads so they behave like surface-mount parts.

All of the chip resistors, chip capacitors, diodes, surface-mount ICs and ferrite-bead chips are soldered to their board pads conventionally. Install the amplifier module after the board is mounted in the box. The antenna relay, fuse clips and the variable resistor all have their leads bent away from their host. Avoid making any bends close to the component body; make the bends at a point about 1/16 inch away from the component body. This approach eliminates mechanical stress on the lead attachment. These components end up about 1/16 inch above the board’s top surface after they are soldered in place.

Figure 2 shows the construction of the four toroidal inductors, L2 through L5. Experience shows the inductor values are quite repeatable if the turns are always distributed in the same manner around the core. As the turns are pushed closer together, the inductance increases considerably. The matching-network coil, L1, is noncritical and it should be wound as shown in the part list and Figure 2; it should need little, if any, adjustment.

The LEDs all have long leads and are soldered to the board after bending the lead ends by about 1/8 inch. Be sure to keep track of the LEDs’ longer (anode) leads: Those leads connect to the current-limiting resistors.

Putting the Board in a Box

Once the PC board is assembled, use it as a template for marking the hole locations in the enclosure, a standard Hammond die-cast box. Mount the board flat against the box bottom using #4-40 hardware. Because there will likely be some mold marks and box-identification letters where the board and RF module lie, make the enclosure’s bottom using #4-40 hardware. Bend the leads of the five LEDs to apply a slight forward pressure on the lights as they slide into the holes in the box front. That holds the LEDs in alignment without needing adhesive.

Take care when tightening the PA module mounting screws to be sure that no pressure is applied to the ends of the module cover. The leads from the module need some trimming. They are above the board and need forming to get to the board level for soldering. Don’t apply pressure at the edge of the module cover when doing this. You may need to hold each lead with needle-nose pliers to keep from damaging the case. It should be possible for the leads to reach the board surface within 1/16 inch of the cover.

Three short pieces of 50-Ω coax attach the board to J1, J2 and J3. Solder lugs under the jacks provide for ground connections at one end and PC-board pads take care of the other end of the coax.

Three leads run between connectors J4, J5 and J6 and the PC board. Each of these leads has a bypass capacitor (C28, C6 and C27, respectively) at the connector. Short, low-inductance leads are important on these capacitors. To help keep the RF signals inside the box, a small inductor wound on a ferrite core (L14, L15 and L16) is placed on each wire. Position these inductors close to their connectors. If #22 or #24 stranded hook-up wire with thin insulation is used, it’s possible to wind the coils with the hook-up wire.

Turning on the Amplifier

Now, to see it work! First, connect a 50-Ω noninductive dummy load to the amplifier output. If you have a variable-voltage power supply to use for initial testing, slowly raise the dc supply voltage from 0 V to 13.8 V. Otherwise, you’ll need to rely on the power-supply fuse as protection from any serious construction errors when applying the full 13.8 V. At full voltage, the current drawn by the amplifier during receive should be about 10 mA. Next, set the OVERVOLTAGE alarm. Adjust the voltage at the wiper terminal of R15 to 4.68 V. If you can vary the dc supply voltage, the OVERVOLTAGE LED should light at about 14.5 V.

When making the following adjustments, it is necessary to adjust the turns spacing on the toroidal inductors. For safety, do this only when no RF drive is applied.

Connect the TR control to the DSP-10 and connect J1, the amplifier’s RF input, to the DSP-10 antenna connector. In CW mode, increase the DSP-10’s RF power slowly until the RF OUT LED (D3) glows. Then adjust the turns spacing on L2 and L3 to extinguish the HIGH VSWR light (D4). This indicator is about 10 times more sensitive than the RF OUT LED, but it should be possible to extinguish the HIGH VSWR LED completely. Continue this adjustment process while increas-

Figure 3—Measured power output and dc-supply current as a function of drive power. Notice that the output-power scale is not in decibels. This makes the output appear less compressed than it really is. The 1-dB compression point is at about 4 W.

Figure 4—Measured intermodulation distortion with a PEP output of 8 W. Third-order products are down about 28 dB from peak power, fairly typical of this amplifier type. Perhaps more important is that the fifth and higher-order products continue to drop off as the order increases. These higher-order products are farther from the operating frequency and thus generally more disruptive to nearby stations. The current drawn during this two-tone test was 670 mA.
Pretty outside and pretty inside, the Brickette’s construction reflects a caring hand. At the top-left rear the RF-amplifier module can be seen fastened to the base of the enclosure, which serves as a heat sink for the module. The relay is at the upper-right and a kludge area is visible at the lower right behind the front panel.

Now you’re ready to get on the air with a medium-sized signal. You can increase power even further by cascading another amplifier. Or, use some of the signal processing in the DSP-10 to work deeper into the noise. QRP power levels have pushed the idea of “working smarter instead of harder.”

Concluding Thoughts

Several areas on the PC board have either a ground plane section or pads for mounting transistors, resistors and other components. These areas are available to you to use for modifications or additions to the amplifier (perhaps you have an application that needs an input TR relay or you need a different control circuit).

Notes


The supply voltage of a coupler is the difference, in decibels, between the forward signal and the reflected signal, when the coupler is properly terminated in its designed load, in this case, 50 Ω. Couplers constructed from transmission lines have high directivity over a very wide frequency range. These lumped-element couplers are restricted in the frequency range where their isolation is high, but offer simplicity instead.

Gerber files for making the PC board can be obtained from the author. Alternatively, unpopulated PC boards are available from Marshall Electric, PO Box 5, Eatonville, WA 98328. Price: $20 each in the US, $21 in Canada (air mail) and $22.50 (air mail) elsewhere. These boards have plated through holes, a solder mask on the component side and a silk-screened legend. Check their Web site http://members.aol.com/w7slb/w7slb.htm for details.

See Sam Ulbing, N4UAU, “Surface Mount Technology—You Can Work with It!”, QST—Part 1, Apr 1999, pp 33-39, —Part 2, May 1999, pp 48-50; —Part 3, Jun 1999, pp 34-36; —Part 4, pp 38-41. Additional comments from Avery Davis, WB4RTP, can be found in the QST Technical Correspondence, Feb 2000, p 70. Surface-mount techniques are used for the DSP-10 transceiver. Some people were initially concerned about dealing with the tiny components, but after constructing the board, most builders felt that it went well.

A satisfactory dummy load for 144 MHz can be constructed from four 200-Ω, 3-W metal-oxide resistors. Arrange them in parallel around a coax connector. Short leads are important. Do not use wire-wound resistors.

The OVERVOLTAGE alarm triggers when the dc supply voltage is greater than 14.5 V. If an adjustable dc supply is available, you can set this directly. Alternatively, set the voltage at the wiper of R15 to 0.360 × V — 0.6, where V is the dc supply voltage.

Larry Price, W4RA, and Paul Richards, W4RI, “WARC97, An Amateur Radio Perspective,” QST, Feb 1998, pp 31-34. By these rules, an 8-W 2-meter transmitter must suppress the harmonics by at least 52 dB. Greater amounts of suppression are required for higher power levels.

Bob Larkin, W7PUA, has been active since he was first licensed in 1951 as WN7PUA. Bob holds an MSEE from New York University and is a consulting engineer for communication companies. His interests are primarily VHF/UHF and microwaves; he is active on all bands from 10 to 10368 MHz, with a particular interest in pushing the limits of weak-signal work. You can contact Bob at 2982 NW Acacia Pl, Corvallis, OR 97330; boblark@proaxis.com.

Photos by Joe Bottiglieri, AA1GW.