By Bob Larkin, W7PUA

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 "barefoot" 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-

[1]Notes appear on page 47.

The five LEDs on the Brickette's front panel signal the amplifier's operating status. The power-output (RF OUT) and SWR (HIGH VSWR) LEDs vary in brightness depending on the forward and reflected power levels.

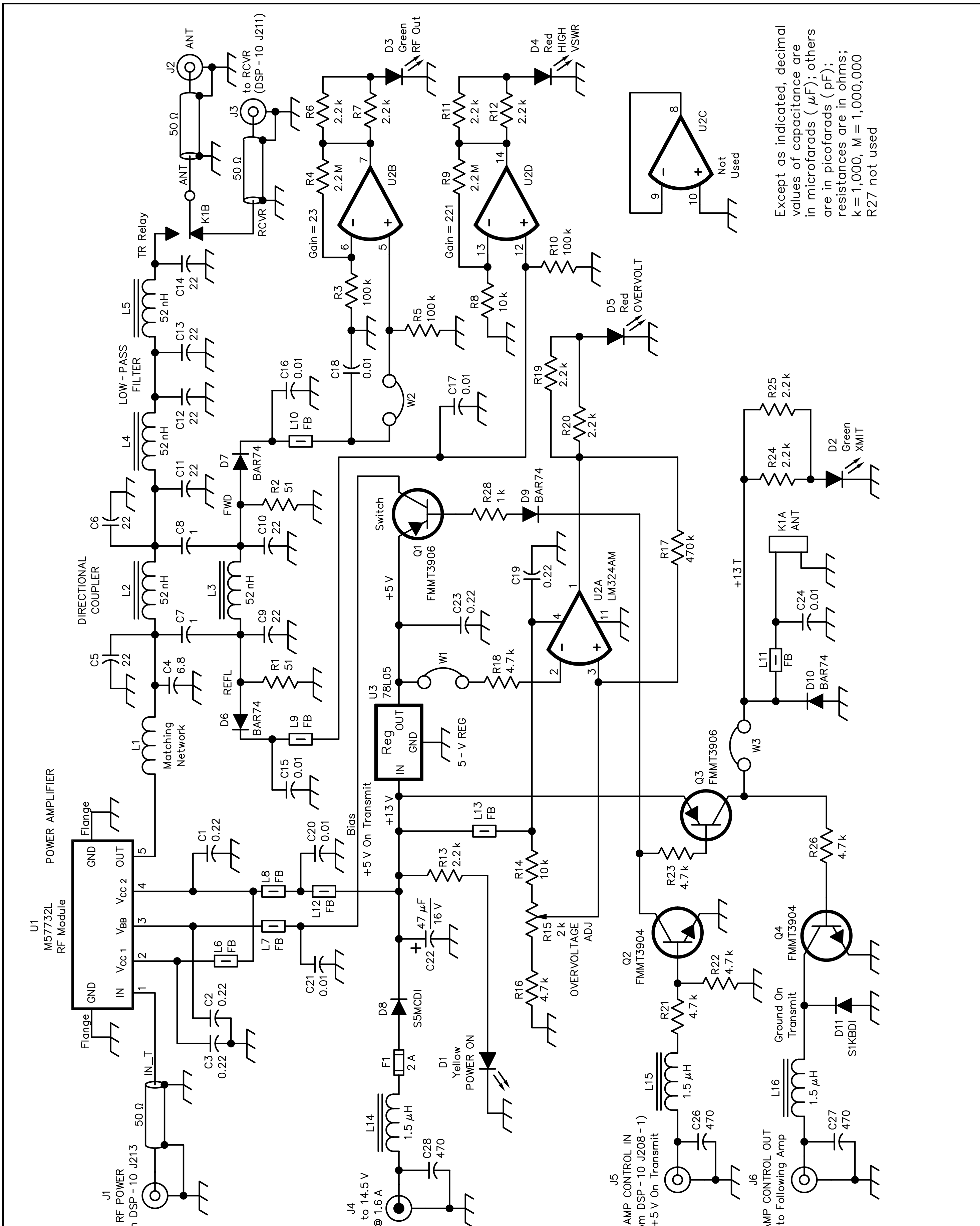
amplifier transistors, along with their associated matching networks and biasing circuits for class AB operation. The module has 50-Ω input and output impedances. All we need to do is add a circuit to turn on the bias supply during transmit, install a low-pass filter for harmonic control and include 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.



J1
RF POWER
from DSP-10 J213
50 Ω
IN_T
U1
M57732L
RF Module
POWER AMPLIFIER
Flange
GND
IN
Vcc 1
VBB
Vcc 2
OUT
C1 0.22
C2 0.22
C3 0.22
L6 FB
L7 FB
L8 FB
L12 FB
C20 0.01
C21 0.01
Bias
+5 V On Transmit
L1
Matching Network
C4 6.8
C5 22
C6 22
C7 1
C8 1
C9 22
C10 22
L2 52 nH
L3 52 nH
DIRECTIONAL COUPLER
R1 51
R2 51
REFL
FWD
D6 BAR74
D7 BAR74
L9 FB
L10 FB
C15 0.01
C16 0.01
C11 22
C12 22
C13 22
C14 22
L4 52 nH
L5 52 nH
LOW-PASS FILTER
TR Relay
K1B
ANT
RCVR
50 Ω
J2 ANT
J3 to RCVR (DSP-10 J211)
C18 0.01
W2
R3 100 k
R4 2.2 M
R5 100 k
R6 2.2 k
R7 2.2 k
Gain = 23
U2B
D3 Green RF Out
C17 0.01
R8 10 k
R9 2.2 M
R10 100 k
R11 2.2 k
R12 2.2 k
Gain = 221
U2D
D4 Red HIGH VSWR
U2C
Not Used
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
J4
+11 to 14.5 V @ 1.6 A
C28 470
L14 1.5 μH
F1 2 A
D8 S5MCDI
C22 47 μF 16 V
R13 2.2 k
D1 Yellow POWER ON
+13 V
L13 FB
U3 78L05
Reg IN OUT GND
5-V REG
W1
R18 4.7 k
+5 V
C23 0.22
Q1 FMMT3906
Switch
R28 1 k
D9 BAR74
C19 0.22
U2A LM324AM
R14 10 k
R15 2 k
OVERVOLTAGE ADJ
R16 4.7 k
R17 470 k
R19 2.2 k
R20 2.2 k
D5 Red OVERVOLT
J5
AMP CONTROL IN (from DSP-10 J208-1) +5 V On Transmit
C26 470
L15 1.5 μH
R21 4.7 k
R22 4.7 k
Q2 FMMT3904
R23 4.7 k
Q3 FMMT3906
W3
+13 T
L11 FB
D10 BAR74
C24 0.01
K1A ANT
R24 2.2 k
R25 2.2 k
D2 Green XMIT
R26 4.7 k
Q4 FMMT3904
Ground On Transmit
D11 S1KBDI
L16 1.5 μH
C27 470
J6
AMP CONTROL OUT to Following Amp

Figure 1

Figure 1—Schematic of the 8-W amplifier. All resistors are 5% 1206 chips. These are available in small quantities from Mouser Electronics (Xicon). Unless otherwise noted all capacitors are either 1206 or 0805 chips (either size fits on the board). Capacitors less than 470 pF are NP0, while values from 470 pF and up are any general-purpose ceramic, such as X7R or Z5U. Component sources listed here are generally only a few of several that manufacture equivalent parts. If the amplifier is built without a pre-made PC board, change the chip components to leaded types. Component designations for the LEDs differ from *QST* style. Parts used in the amplifier are available from one or more of the following sources. Source abbreviations used in the parts list precede the company name: (DK) Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701; tel 800-344-4539, 218-681-6674; http://www.digikey.com; (ME) Mouser Electronics, 958 N Main, Mansfield, TX 76063; tel 800-346-6873, 817-483-4422; http://www.mouser.com; (RS) RadioShack—see your local distributor; http://www.radioshack.com; (RP) RF Parts, 435 South Pacific St, San Marcos, CA 92069; tel 800-737-2787, 760-744-0700; http://www.rfparts.com.

- **C22—47 µF, 16 V surface-mount electrolytic (DK PCE3033CT)**
- **C26, C27, C28—470 pF, 50 V, leaded ceramic (ME 140-50P2-471K)**
- **D1—Yellow T1 LED (DK160-1079)**
- **D2, D3—Green T1 LED (DK 160-1080)**
- **D4, D5—Red T1 LED (DK 160-1078)**
- **D6, D7, D9, D10—BAR74 diode (DK BAR74ZXCT)**
- **D8—5-A, 50-V power rectifier, SMC package (DK S5ACDICT)**
- **D11—1-A, 100-V power rectifier, SMB package (DK S1BBDICT)**
- **K1—SPDT 12-V dc miniature relay, Omron G5V-1-DC12 (DK Z774)**
- **L1—2t, #20 or 22, 1/8-inch ID; see Figure 3.**
- **L2-L5—52 nH; 5 turns, #26 enameled wire on a T-25-17 toroid; see Figure 3.**
- **L6, L7, L9, L10, L11, L13—Ferrite SMT bead, 1206, 600 Ω at 100 MHz, Stewart HZ1206B601R (DK 240-1019-1)**
- **L8, L12—Ferrite SMT bead, 3 A, 1206, 100 Ω at 100 MHz, Stewart HI1206N101R (DK 240-1008-1)**
- **L14-L16—1.5 µH, 5 turns #22 or #24 enameled wire on an FT-23-43 core; see text.**
- **F1—2-A, 5×20-mm fuse (DK F948) with two clips (DK F058)**
- **J1, J5, J6—Phono jacks (RS 274-346)**
- **J2, J3—BNC jack (RS 278-105)**
- **J4—5.5-mm OD, 2.1-mm ID power connector (RS 274-1563)**
- **Q1, Q3—FMMT3906 PNP transistor, SOT23 (DK FMMT3906CT)**
- **Q2, Q4—FMMT3904 NPN transistor, SOT23 (DK FMMT3904CT)**
- **R15—2 kΩ adjustable resistor, Bourns 3329H-1-202 (DK3329H-202)**
- **U1—RF amplifier module, Mitsubishi M57732L, (RP M57732L)**
- **U2—LM324AM dual op-amp (DK LM324AM)**
- **U3—78L05 5-V positive regulator, SO-8 package (DK LM78L05ACM)**
- **Misc: PC board, enclosure 3.7×4.7×1.3 inches, Hammond 1590BB (DK HM152), hardware.**

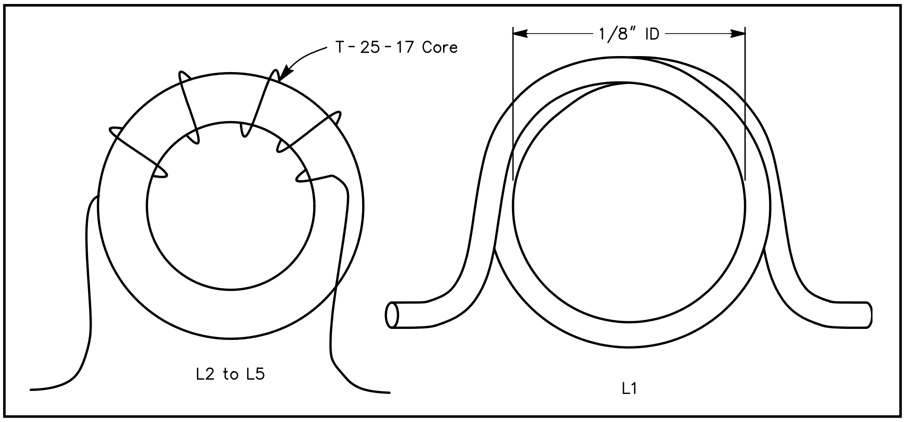


Figure 2—Coil details. Arrange the turns on the four toroids as shown here. L2 and L3 might need to have their turns spacing adjusted during tune-up.

The **OVERVOLTAGE** indicator lights when the dc supply voltage exceeds 14.5 V, but does not automatically shut down the amplifier. 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 observant 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 deactivated 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.

Building the Amplifier

You could build the amplifier on a scrap of PC board. In fact, my first version is built that way (see the sidebar). For many builders, however, a PC board[3] is a more convenient way to assemble the project and that is shown in the photos.

This PC board is double-sided, with plated through holes. The backside is a solid ground plane allowing the board to be fas-

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 type (for these, the difference in voltage between the input and the output need be only a fraction of a volt). I couldn't find an integrated regulator that met my requirements and the thought of building one using op amps and transistors used more parts than I could justify.

I opted for simplification, putting alarm lights on for SWR and overvoltage and turned the automatic part over to the operator! A new schematic resulted, not unlike that of Figure 1. I went to the *ARRL Radio Designer*† and simulated the directional coupler and low-pass filter. A little playing around with the simulation showed that a single inductor value could be used for both subcircuits.

Next, I built the "breadboard" version using scraps of PC board. Testing showed that almost everything worked as expected. The **overvoltage** light did not have snap action, though. That was caused by using a resistor where the ferrite bead, L13, is now. I ran the input voltage temporarily up to 16 V and everything continued to function. Next, I left the amplifier running for an hour and nothing overheated. I checked the intermodulation products and harmonics and found them to be at satisfactory levels.

It was now time to layout the PC board. The experience of putting the breadboard together allowed a smarter final layout. The first version was on two boards and some of the connectors ended up on the front panel. This was all worked out for the final design. *—Bob Larkin, W7PUA*

†ARRL order no. 6796. ARRL publications are available from your local dealer, or directly from the ARRL. See the ARRL Bookcase elsewhere in this issue, or check out the ARRL Web site at: http://www.arrl.org/catalog/.

tened 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[4] 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 inner-bottom surface reasonably flat; you can do this with 60-grit sandpaper. 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 1/8-inch of the cover.

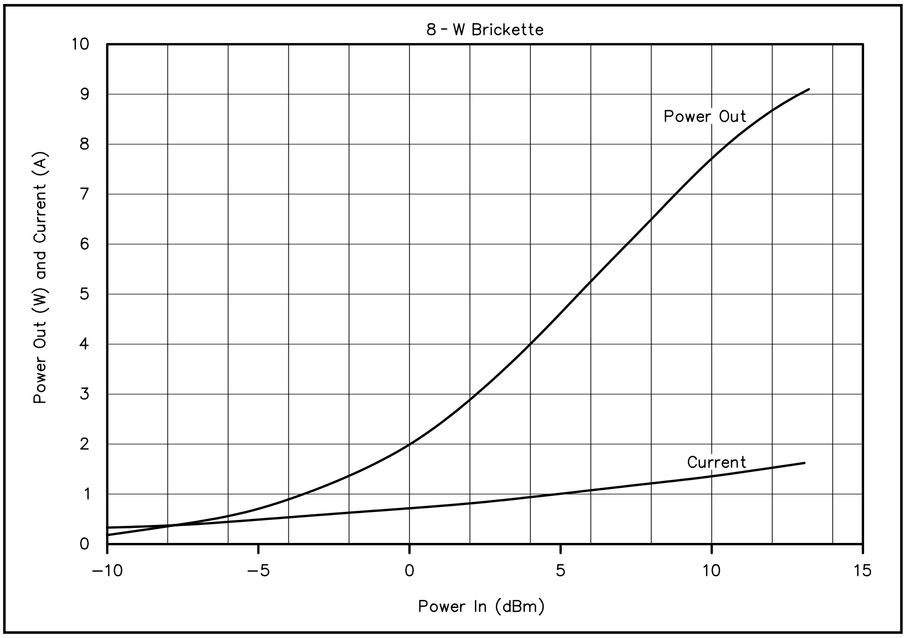


Figure 3—Measured power output and dc-supply current as a function of drive power. Notice that the output-power scale is not in decibels. This makes the output appear less compressed than it really is. The 1-dB compression point is at about 4 W.

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.

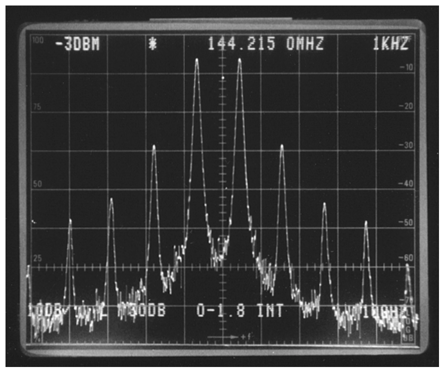


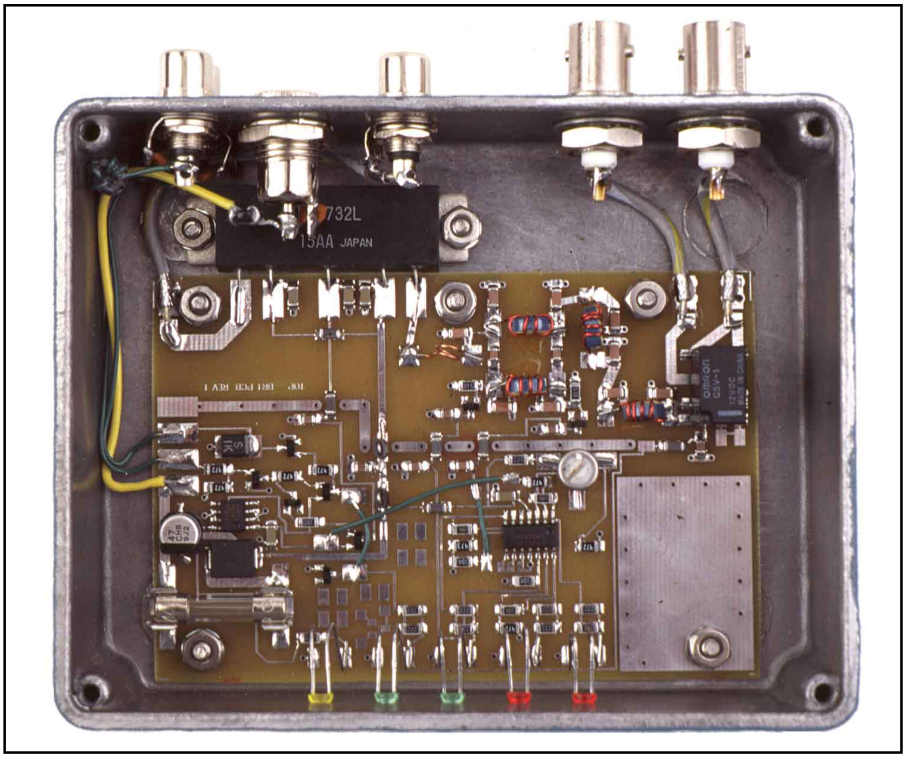
Figure 4—Measured intermodulation distortion with a PEP output of 8 W. Third-order products are down about 28 dB from peak power, fairly typical of this amplifier type. Perhaps more important is that the fifth and higher-order products continue to drop off as the order increases. These higher-order products 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.

Turning on the Amplifier

Now, to see it work! First, connect a 50-Ω noninductive dummy load to the amplifier output.[5] 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.[6] 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-



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.

This rear-panel view of the 8-W Brickette shows compact but uncrowded I/O connectors clearly labeled.

ing the drive power. You can measure the voltage at the output of the SWR op amp (U2 pin 14) and continue to minimize this voltage, although the **VSWR** LED is not lit.

Optimize the amplifier matching by measuring the power output as indicated by the dc voltage at U2 pin 7 and adjusting L1's turn spacing (and perhaps changing the value of C4) for maximum output at high drive. Don't expect major changes with these adjustments as the amplifier is inherently quite well matched.

While in transmit, check that the bias voltage at pin 3 of U1 is about 4.9 V and that the idling current with no RF drive applied is about 140 mA.

Performance

Figure 3 shows the power output and current level for various drive levels. The CW output is over 8 W for the two devices that I tested. When tested with a two-tone input signal and an output of 8 W PEP, the IMD level is down 28 dB for third-order products and 43 dB for fifth-order products (see Figure 4). The strongest harmonic is the second (at about 292 MHz) and this is 65 dB down from peak output, more than enough to meet FCC 2002 requirements.[7]

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).

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."

Notes

[1]Bob Larkin, W7PUA, "The DSP-10: An All-Mode 2-Meter Transceiver Using a DSP IF and PC-Controlled Front Panel," *QST*, —*Part 1*, Sept 1999, pp 33-41, —*Part 2*, Oct 1999, 34-40, —*Part 3*, Nov 1999, pp 42-45. Additional information on that project is available on the author's Web site, **http://www.proaxis.com/~boblark/dsp10.htm**. Any future information about this amplifier project will be placed at this Web site.

[2]The directivity 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.

[3]Gerber files for making the PC board can be obtained from the author. Alternatively, unpopulated PC boards are available from Mashell 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.

[4]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.

[5]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.*

[6]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 $0.360 \times (V - 0.6)$, where V is the dc supply voltage.

[7]Larry Price, W4RA, and Paul Rinaldo, 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.

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Photos by Joe Bottiglieri, AA1GW