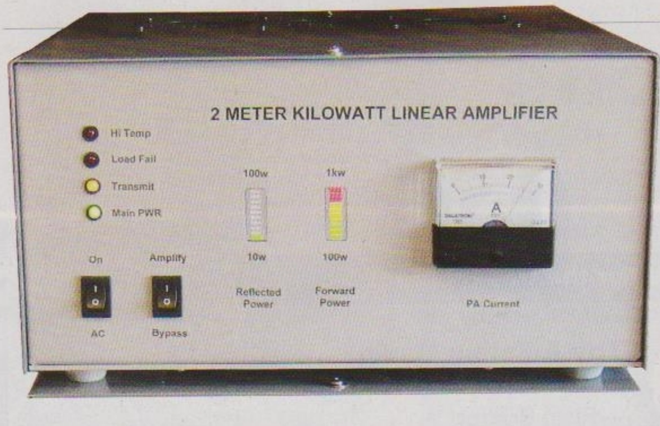


Solid State 1 kW Linear Amplifier for 2 Meters

This high power amplifier does it all with a single RF device.

James Klitzing, W6PQL

Five years ago, if someone had said they could build a kilowatt linear amplifier for 2 meters using a single semiconductor, it would have been tough to convince me. But not only is this possible right now, you can even make the core amplifier assembly as small as 3 × 5 inches, drive it with as little as 2 W, and enjoy efficiencies around 75%. How wonderful is that?

The Secret is in the Device

Freescale Semiconductor makes a wide range of LDMOS (laterally diffused metal oxide semiconductor) transistors, one of which is a new generation 50 V device designed for high mismatch applications such as plasma exciters.

This device is very rugged, touted as able to withstand short duration VSWR mismatches as high as 65:1. Normally they are used in a push-pull configuration (it's a dual device part). The data sheet lists a usable frequency range of 1.8 to 600 MHz (it's not internally matched), lending it to applications over a wide range of amateur bands. The part number is MRFE6VP61K25H, and it currently sells for around $270 in small quantities, making it relatively inexpensive compared to equivalent tube alternatives. It's available from several popular distributors, including Mouser and Digi-Key.[1]

The amplifier described here is very stable, clean and quiet in operation yet it is compact and full-featured. It has over 27 dB gain, and can deliver a little over 1200 W saturated at higher drive levels, but 1 kW is the practical limit for linear operation.

A Design Evolves

The original work on the 2 meter amplifier core was developed and written up in the April 2010 issue of *DUBUS* magazine by Lionel Mongin, F1JRD, and much information can be retrieved with an Internet search on his call sign.[2] As of this writing, a kit containing the more difficult-to-get parts can be purchased for about $130 from RFHAM.[3] Additional information on this is on the F1JRD website.[4] I built the amplifier subassembly (see Figure 1) as documented there with just a few minor changes, and there were no unexpected problems — it worked as published.

Deciding on the Features

Once I had the core amplifier pallet built and tested, I had to decide what features I wanted in a complete amplifier package. The things that seemed important to me were a compact cabinet design (6.5 × 12 × 12 inches), matching other station equipment in shape and color, full VSWR and over-temperature protection and metering for PA current with peak-reading LED bar graph meters for forward and reflected power.

In addition, I wanted automatic TR sequencing, low loss antenna relays and an ALC output available to control the driver. In order to accommodate a wide variety of driving radios, rear panel jumpers are included to select low power drive levels or, for up to 50 W drive, using a built-in 50 W, 10 dB attenuator. I also required low noise, temperature-controlled cooling fans and a front-panel ac POWER switch to control the external power supply.[5]

Lots of Features means Lots of Pieces

This article describes the complete set of features and how to implement them, but you can certainly add or remove anything according to your own requirements (see Figure 2). First, let's take a look at the finished amplifier and see how all of these features are packaged in there.

Removing the cabinet cover and looking down from the top (see Figure 3), the RF pallet can be seen mounted to a large piece of heat sink secured to the cabinet floor at back center. At front center is a surplus Narda dual directional coupler, a 30 dB coupler normally used at 900 MHz. This coupler is quite broadband, and has a coupling factor of about 42 dB at 144 MHz — just right for monitoring forward and

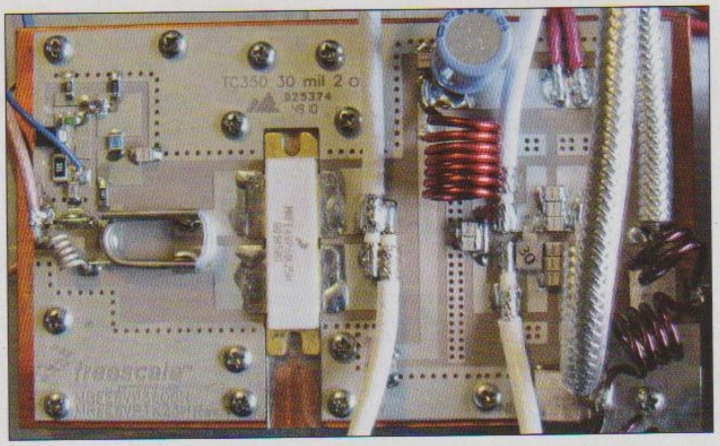


Figure 1 — The single transistor amplifier assembly, based on the F1JRD design, is the heart of the amplifier.

[1]Notes appear on page 36.

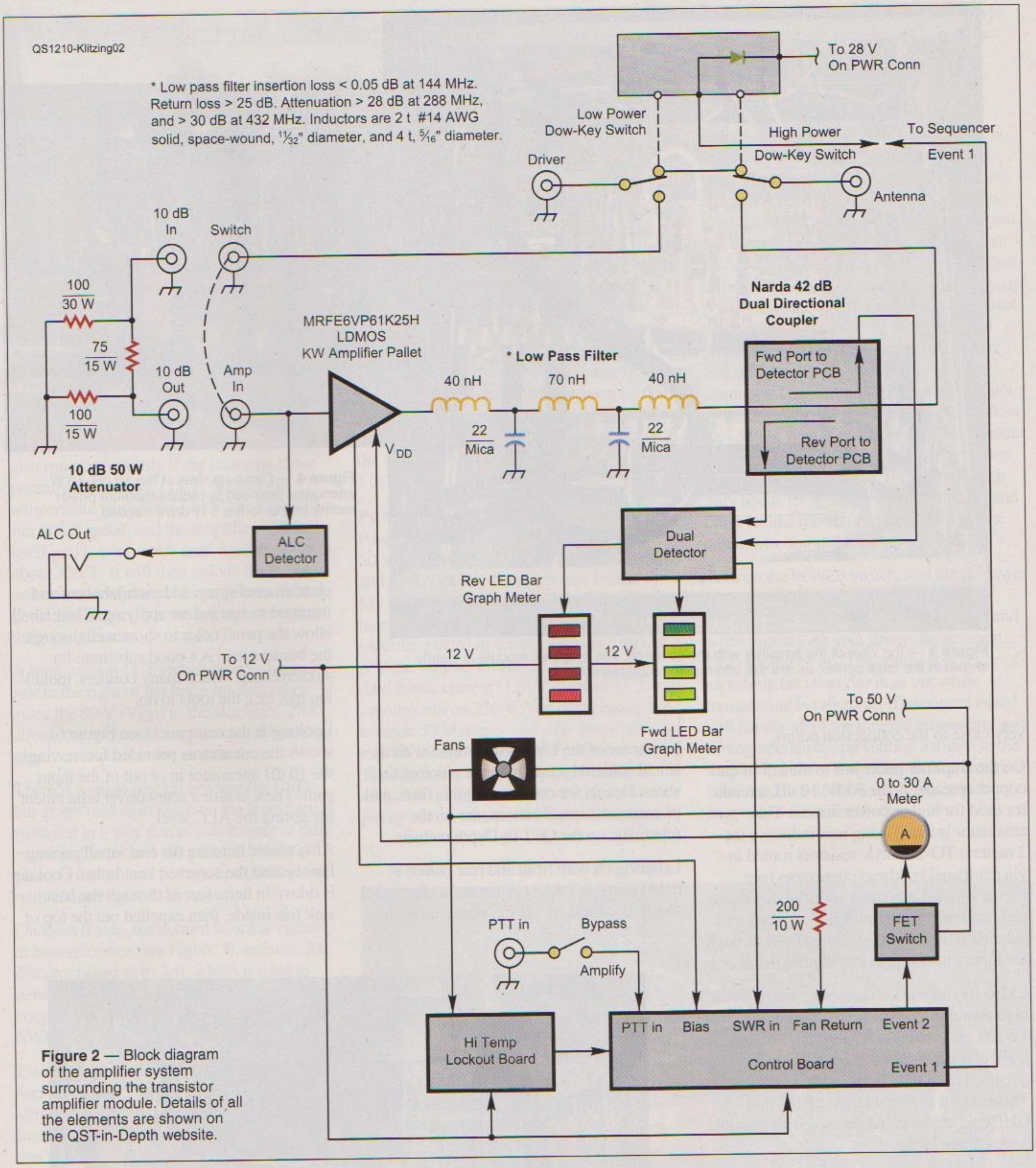


Figure 2 — Block diagram of the amplifier system surrounding the transistor amplifier module. Details of all the elements are shown on the QST-in-Depth website.

reflected power at the 1 kW level.[6] The sampled signals are routed to a detector board shown later. Brackets for holding the directional coupler to the cabinet floor are made from 0.060 inch aluminum sheet and secured with machine screws.

Note the use of ferrite beads and bypass capacitors on the power connector pins and the ALC and PTT connectors. For the POWER connector, a small single-sided PC board was etched with the proper pattern, slotted with a rotary grinding tool, passed over the pins, pressed against the connector body and soldered into place. Detailed subassembly schematics, fabrication drawings and additional photos are on the QST-in-Depth website.[7] The active pins were bypassed using chip capacitors. Since this is for 2 meters, not the microwave bands where I usually use this method, it would have been okay to eliminate the PC board and just use disc ceramic bypass capacitors with very short leads. The ALC and PTT connectors, ammeter and LED meters are fed using this latter method. All these connections have ferrite beads on the wires

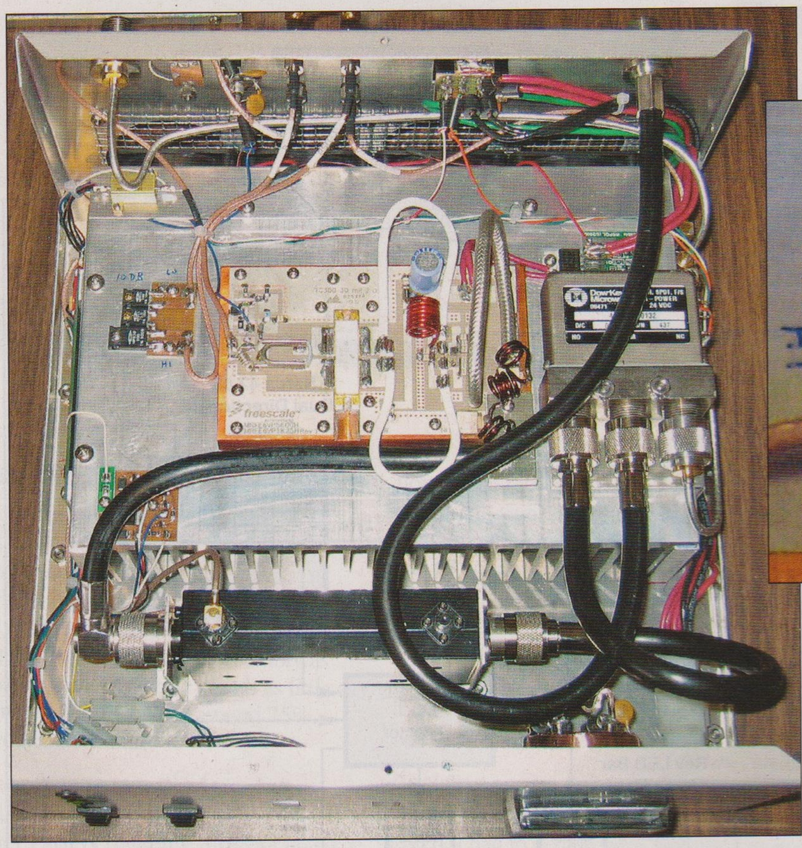


Figure 3 — Top view of the amplifier with the cover off. The amplifier module is clearly shown in the back center, as are the other major subassemblies.

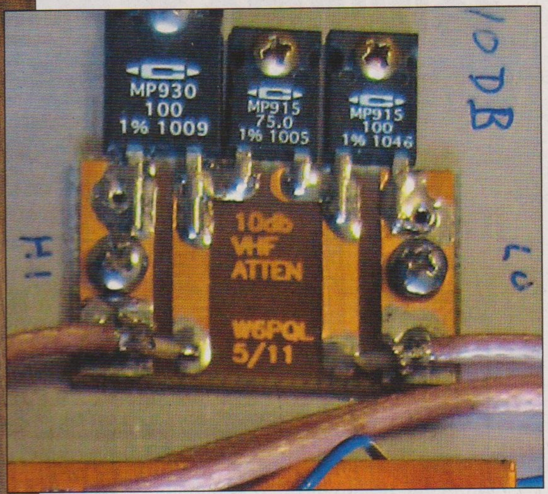


Figure 4 — Close-up view of the 10 dB, 50 W attenuator provided to reduce medium power exciter output to the 3 W drive needed.

very close to the connection points.

On the amplifier pallet just to the left of the copper spreader is the 50 W, 10 dB, attenuator used for higher power drivers. This attenuator is made using non-inductive (at 2 meters) TO-220 style resistors routed in via rear panel bulkhead connectors (see Figure 4). The attenuator is out of the bypass path, and only in circuit following the input antenna switch. It's then routed back through the input jumper quad to the amplifier board.

LMR-400 low loss coax is used for all of the high power jumper connections (good to 1.5 kW continuous at 150 MHz). Though UHF connectors are common at this frequency, I used type N and SMA everywhere. This is just a personal choice. BNC and UHF connectors could be used with minimal issues if you prefer.

The three small coils at the output of the RF pallet next to the output antenna relay (see Figure 5) are part of a low-pass filter built on a small piece of tin sheet and held in place with a couple of the PC board mounting screws. The capacitors are metal-mica types, and are soldered directly to the ground foil of the PC board. They are sturdy enough to support the inductors, which are routed between them. The last one feeds the center conductor of the LMR-400 jumper with its shield soldered securely to the piece of tin sheet. Details for constructing this filter, and its measured specifications, are on the schematic on the QST-in-Depth website.

Lettering on both front and rear panels is made using an inkjet printer and a clear label sheet. The finished label is protected with clear enamel spray, and each label cut and trimmed to size before applying. Clear labels allow the panel color to show well through the borders, and is a good substitute for silkscreening, which many builders, including me, lack the tools to do.

Looking at the rear panel (see Figure 6) shows the connectors provided for moving the 10 dB attenuator in or out of the input path. There is also a screwdriver adjustment for setting the ALC level.

Also visible here are the four small cooling fans behind the screened vent holes. Cool air is drawn in here, forced through the heat sink fins inside, then expelled out the top of

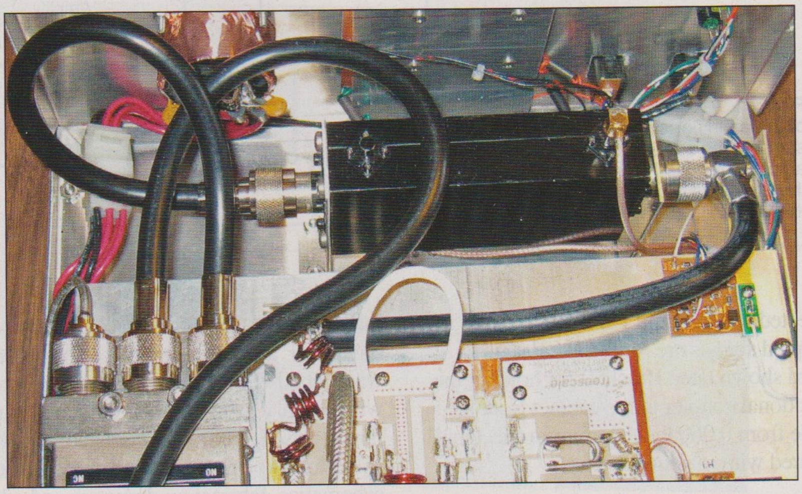


Figure 5 — The three small coils on the left end of the amplifier module are part of a low-pass filter built on a small piece of tin sheet and held in place with a couple of the PC board mounting screws.

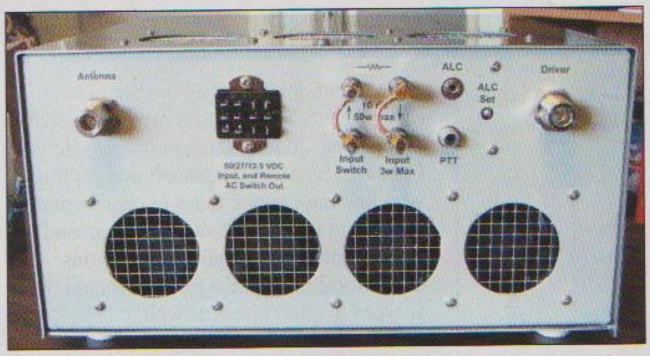


Figure 6 — View of the rear panel showing the connectors provided for moving the 10 dB attenuator in or out of the input path. There is also a screwdriver adjustment for setting the ALC level.

the cabinet through additional screened vents (just visible here in the cabinet cover). These fans run at reduced speed (to keep them quieter) during the transmit cycle, and will also run continuously if the heat sink temperature rises above 115°F. Should the temperature rise above 130°F, the fans will run at full speed, and the amplifier will lock itself into bypass mode until it cools down to about 120°F. It will then unlock itself again and operate normally. I haven't been able to get it that hot yet, but the extra protection is there just in case.

A high-current FET switch board, shown just to the right of the large antenna relay, gates the 50 V (V_{DD}) to the amplifier. This allows the sequencer on the control board to turn it on and off at the correct times.

There is a small bracket holding the LED bar graph meters in place on the front panel, mounted in a way that avoids having to drill mounting holes into the panel. It's held in place to the top and bottom lips of the panel with counter sunk 2-56 screws.

On the left side, the control board is visible at bottom center (see Figure 7), as is the RF detector board to its left, which is used to detect the signals from the directional coupler and drive the power meters and SWR lockout switch on the control board.

Even though the LDMOS transistor will handle 65 to 1 VSWR without failing (it's very tough), many of the other components, including the antenna switches and coax, can't survive the extreme voltages this would place on the transmission lines. Thus, I set the SWR lockout adjustment at 100 W reflected power, or about 2:1 VSWR at 1 kW out. When tripped, this feature will lock the amplifier in bypass mode until it is manually reset. The main power must be turned off for several seconds to reset it.

I'm sure glad I put that SWR lockout in there. While doing some offline testing, I forgot to hook up the output coax. I really didn't intend to test the amplifier at 1 kW without a load, but it happened, and it locked out the amplifier just like it was supposed to do. No damage, even after I managed to do it again about an hour later.

The small PC board on the heat sink above and to the right of the control board is the HIGH-TEMP LOCKOUT switch. There is also a smaller (green) board there, fastened by one of the lockout board mounting screws; this is the fan sensor (a thermistor), used to signal the control board to force the fan on at 115°F.

Power Requirements

Power requirements for this amplifier are 50 V at up to 30 A, 28 V at less than ½ A, and 13.5 V at less than ½ A (see Figure 8). My personal power supply was constructed using four 12.5 V, 30 A switching PSU modules placed in series, and thus it has all of these outputs available. It runs on standard house current (120 V at about 15 A) or can also run on 230 V. You could easily use a single 50 V supply and step-down regulators for the 28 V and 13.5 V requirements. The regulators could be located in the amplifier on the main heat sink, since there's plenty of room in there. Other builders are making use of surplus 48 V computer-type "blade" switching supplies, although these run only on 230 V.

Operating the Amplifier

If constructed with all of the features described, set the rear panel input jumpers according to the drive power that will be used. For drive levels up to 5 W, the input attenuator need not be used (ALC will be used for overdrive control). However, if you use a driver capable of 15 W or more, it is probably capable of a reduced power output setting. Be certain to check the initial key-up power, as some of the older radios will emit a burst at full power when keyed up, and then drop back to your reduced setting. If this is the case with yours, use the input attenuator and an input relay capable of hot switching drive levels of 50 W or so (a Dow Key SPDT type 402 or four port 412 transfer switch will do this). The input relay shown in this amplifier (type 401) can hot-switch only about 15 W. Hook up the PTT line, and don't be like me and forget to hook up the antenna or dummy load.

Turn on the POWER switch, and the dc power LED should be on. Place the AMPLIFY/BYPASS switch in the AMPLIFY position, and when you key on your driver, the transmit LED should be on. The common practice of switching the amplifier in or out while transmitting is safe to do. The control board will handle all of the internal sequencing and timing operations, preventing damage to the amplifier and the antenna switches. Here is a brief rundown of the sequencing, which happens at 50 ms intervals:

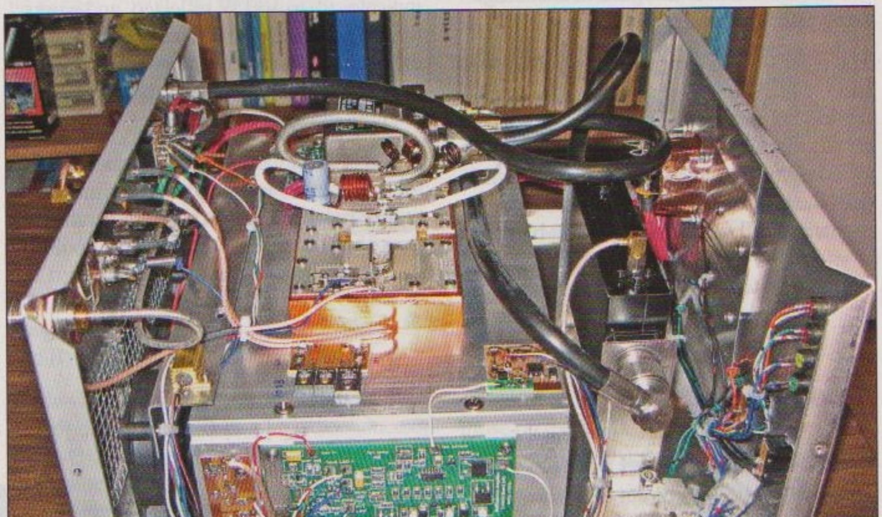
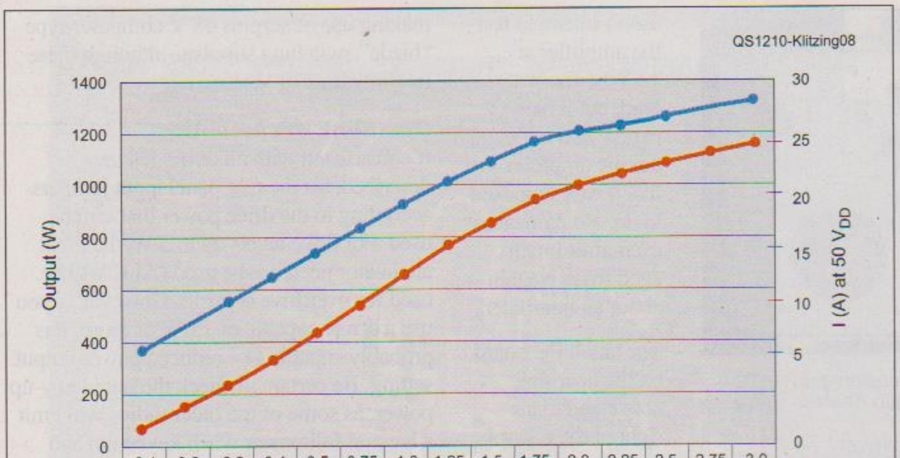


Figure 7 — The left side of the amplifier. The control board is at the bottom center, as is the RF detector on its left.



Input (W)	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0
Pout	70	150	230	330	435	550	660	775	860	950	1000	1050	1090	1125	1165
I (A)	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	23.5	25.2	26.0	26.5	27.2	28.0	28.5

Figure 8 — Power output and current drain versus drive level.

Event 1 — Antenna relays switch over and fans come on.

Event 2 — 50 V (V_{DD}) and bias are turned on.

These events are repeated in reverse order when the driver is unkeyed, spaced apart briefly in time.

A snow load or other antenna problem that causes the SWR to reach unacceptable levels will cause the LOAD FAIL LED to come on, and the control board to sequence the amplifier into bypass mode and lock it there. To reset, you'll have to shut down the main POWER switch for a few seconds; this persistent lockout is designed to encourage an investigation of the problem.

The other trouble indicator is the HIGH TEMP LED, which comes on if you get the amplifier too hot for safe operation, or for your comfort level (above 130°F for me). This switches the unit into bypass mode just as does the LOAD FAIL function, runs the cooling fans at full speed and will reset by itself when the temperature drops about 10°. You cannot do a manual reset on this one.

Under normal operation, the amplifier will draw about 27 A at 1 kW out. On SSB, as with any other class AB linear amplifier, a good rule of thumb is to adjust drive levels for about half of that (13-15 A) on voice peaks. An even better indicator is the forward power LED bar graph display, which will illuminate all segments at 1 kW output. This meter is peak reading, so you can adjust voice peaks until the last segment just illuminates while speaking into the microphone.

The REVERSE POWER bar graph display indicates up to 100 W reflected, and works the same way, giving a relative indication of the health of the load. If your SWR is high enough to illuminate the last segment, the load fail function will engage.

You'll hear the fans running whenever in transmit mode, and they will also run continuously when the heat sink temperature rises above 115°F; as the heat sink cools to 110°F or less, they will again run only in transmit mode.

This amplifier has met all my operational requirements as well as all my objectives for monitoring, control and equipment safety. I believe it is an excellent solution for those who find high power tubes expensive and difficult to find and want an efficient and linear high power amplifier. While this unit is for 2 meters, the platform could be adapted to other bands as well.

Notes

[1]www.mouser.com, www.digikey.com

[2]www.dubus.org

[3]www.rfham.com

[4]www.qsl.net/f1jrd

[5]The author's station power supply for all-solid-state amplifiers is multioutput and universal, and can be remotely located and switched on from the front panel of a given amplifier.

[6]The surplus Narda model 31119 coupler was purchased on an Internet auction site. As of this writing, there are lots of them available for around $35.

[7]www.arrl.org/qst-in-depth

ARRL member and Advanced class licensee James Klitzing, W6PQL, was first licensed in 1964 as WB6MYC. He has been a meteorologist for both the US Air Force and Hewlett-Packard Company. He is currently manager of engineering services at Agilent Laboratories in Palo Alto, California.

Jim has always enjoyed building his own equipment including a kW SSB/CW transceiver as well as VHF through microwave transverters and antennas.

You can reach him at 38105 Paseo Padre Ct, Fremont, CA 94536-5207 or at **jim@w6pql.com**. Jim's website, **www.w6pql.com**, has any updates to the project and versions for other bands.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.

New Products

Bonito 1102S RadioJet Software Defined Receiver

The Bonito 1102S RadioJet SDR shortwave receiver covers 40 kHz to 30 MHz. Modes include LSB, USB, CW, AM, FM and stereo DRM. The supplied software and features include an integrated frequency database, IF/AF spectrum analyzer and oscilloscopes, variable filters, audio and IF recording and playback, a calibrated S meter and online updates. Price: $784. The Bonito 1102S is available from Computer International and select dealers. For more information, visit **www.computer-int.com**.