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The FARA Project

An economical, easy-to-build, 25 watt 2 meter amplifier.

by James R. Valdes WA1GPO

The Falmouth (Massachusetts) Amateur Radio Association (FARA) is well-known on Cape Cod for its hospitality to newcomers. It is also one of the more active groups in Southeastern Massachusetts supporting two repeaters and a digital Node/LAN. One subgroup of the association is the HACKERS, a group of amateurs who enjoy designing and building their own equipment. When the HACKERS noted that a majority of the new members joining FARA were using 2 meter HTs, we recognized that we might entice some of these new hams into joining this select group of builders by helping them construct a power amplifier for 2 meters. We did this as a group project: Those with tools drilled the holes and those without cleaned and prepped the circuit boards for fabrication or wound the inductors. Those who had experience building gear Elmered those who didn't. All of the participants contributed to the success of this project.

This article describes a 2 meter amplifier capable of running 25-30 watts output. More than 35 amplifiers have been procured at a cost of less than $50 each in these quantities.

Photo A shows the final version of the circuit board; the completed amplifier is shown in Photo B. It is designed around one of the newer bipolar RF devices from Motorola, an MRF1946A (Q1). This device compares favorably with many of the RF FETs available as the MRF1946 is capable of developing 10 dB gain at 146 MHz, while the older bipolar devices (the 2N6080 series) produce only about 5.7 dB gain. RF FETs are generally rated at 13 dB gain at 28 volts; in the 12-14 volt range they also yield about 10 dB. The design presented here is unconditionally stable, while FET amplifiers require a bias supply and careful tuning at the higher voltages to maintain stability. The cost of the MRF1946A is only about two-thirds that of the FETs, yielding the most "Bang for the Buck!"

Circuit Description

Motorola produced an application note (RF Device Data, Application AN955) for a 150 mW to 30 watt land mobile VHF amplifier in the 160 MHz range, based on the MRF1946. This was the starting point for this design.

The schematic diagram is shown in Figure 1. DC voltage into the amplifier is decoupled by C2, C3, L1, C4, C5, and L2. D2 is the reverse polarity protection diode—if the voltage is inadvertently reversed, D2 will limit the reverse voltage to 0.7 volts and fuse F1 will open, protecting the amplifier. The output stripline (Z1) described in the application note was lengthened for operation at 146 MHz and the output capacitor (C10) was empirically adjusted to yield an efficiency in the 70% range, just about what one would expect of a Class-C amplifier. The input circuit was derived from the formulas given in the *RSGB VHF/UHF Manual*. This manual is highly recommended for those interested in VHF/UHF construction. Similar examples of impedance calculations can be found in several editions of *The Radio Amateur's Handbook*. This approach was intended to demonstrate the microstrip vs. lumped constant techniques for impedance matching as one of the more subtle objectives of the HACKERS group is to provide some informal education on radio construction and

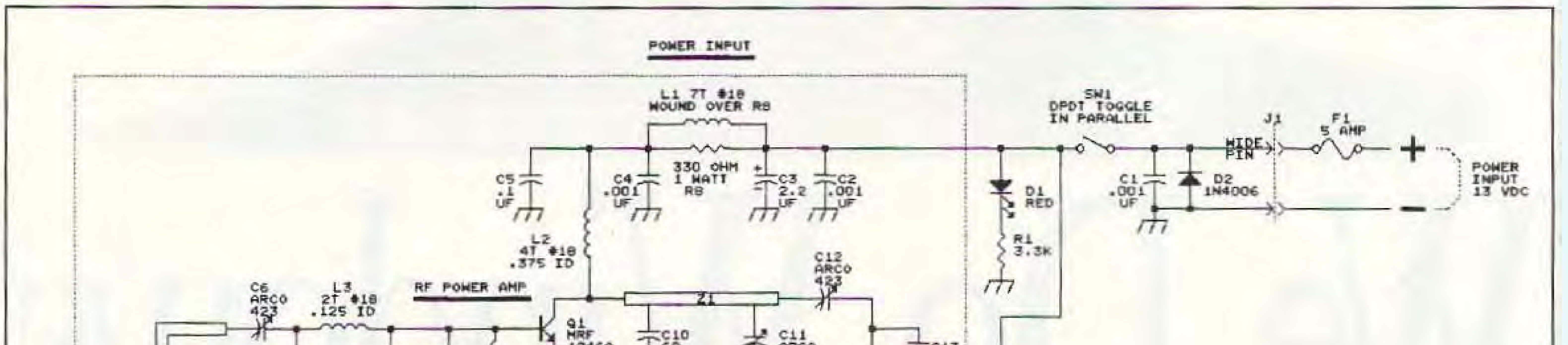

Figure 1. Schematic diagram.

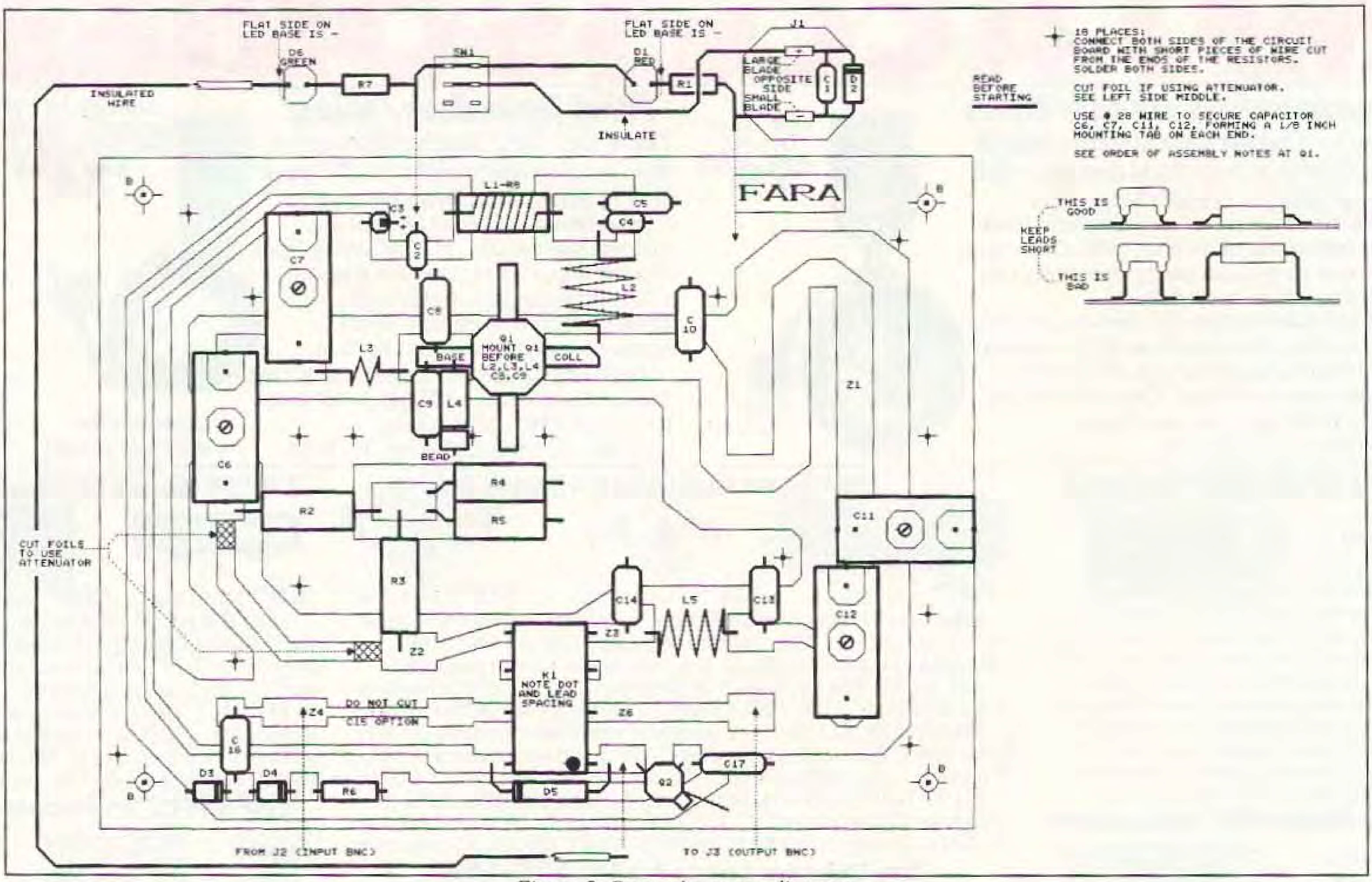

Figure 2. Parts placement diagram.

design practices. A low-pass filter network (C13,C14,L5) is in series with the output to enhance harmonic rejection.

Incorporated into the design is a resistive input attenuator network (R2,R3,R4,R5). The RF power transistor (Q1) is intended to be driven with 2 to 3 watts input; higher drive levels will not increase the output substantially. Most of the older HTs can drive the amplifier directly, but the new breed of high power, 4 to 7 watt HTs will require the input attenuator. When the attenuator is used, the 50 ohm microstrip must be isolated at the 10 ohm resistors. Cut the circuit foil at the locations noted on the parts placement diagram, Figure 2. The attenuator represents a nominal 3 dB loss; that is, half of the power is dissipated in the network. In addition to limiting the drive power to a safe level, the attenuator also enhances the stability of the amplifier by isolating the amplifier from the driver. It also presents a nominal 50 ohm resistive load to both units. If the attenuator is not required, the network consisting of resistors R2,R3,R4,R5 should be omitted.

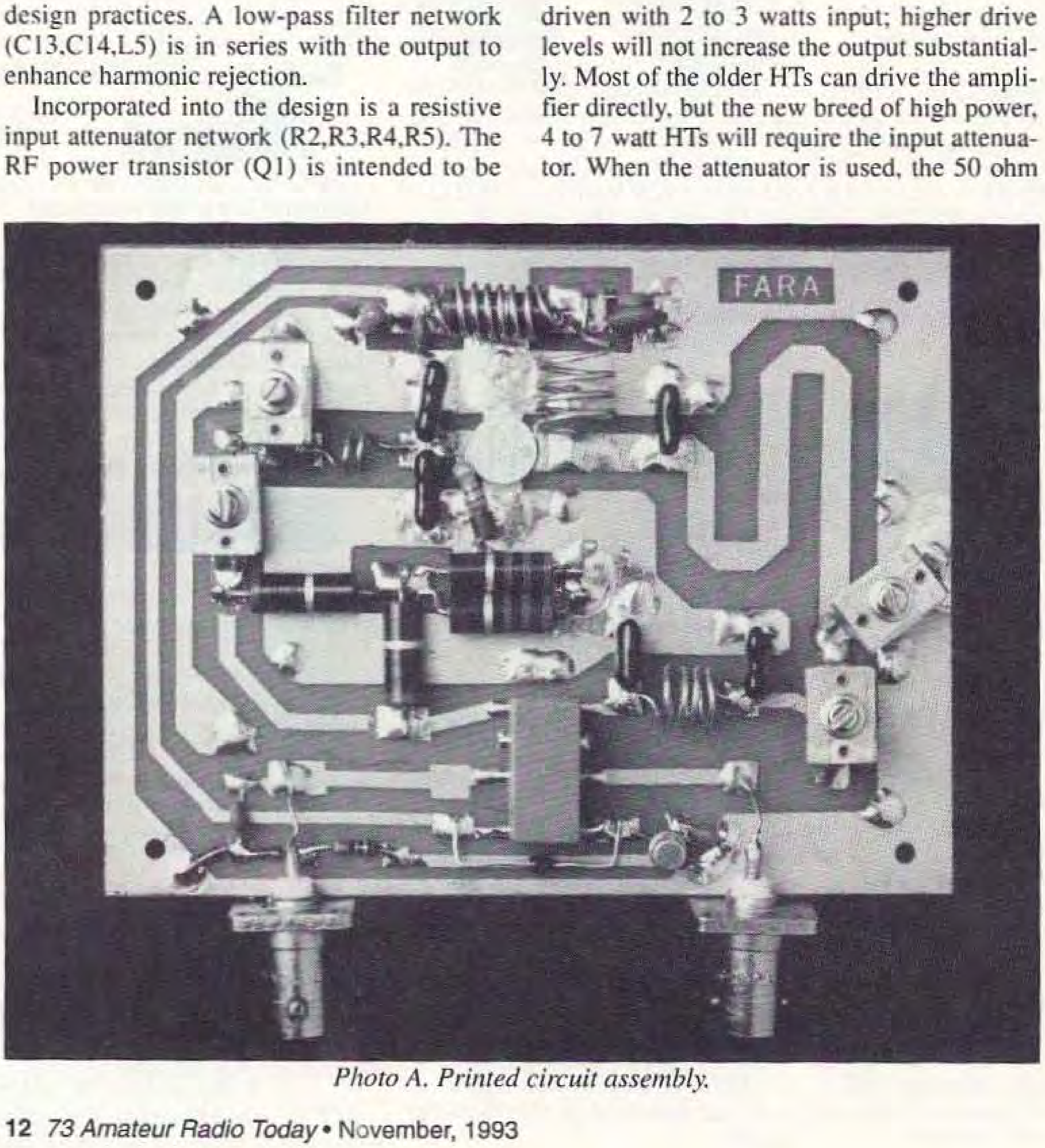

Photo A. Printed circuit assembly.

An RF-actuated T/R relay (K1) has been incorporated into the amplifier. RF on the input is sampled by C16, rectified and limited by D3, D4, R6, and C17 to turn on Q2, which pulls in the relay. We considered using solid-state T/R switching. However, relay switching has the advantage that the amplifier can be turned off when it is not required. Conversely, diode-switched amplifiers must be powered at all times. This is in keeping with the spirit of the FCC regulations that require radio amateurs to use "the minimum power necessary to carry out the desired communications." Relay switching also results in a more compact, easier-to-duplicate amplifier. The relay specified in the Parts List is a small, open-frame style. Its performance is adequate for 2 meters.

Should you be a "purist," you can compensate for the inductance of the relay by installing a variable capacitor (C15) in series with the input to the relay, as noted on the parts placement diagram. This capacitor was

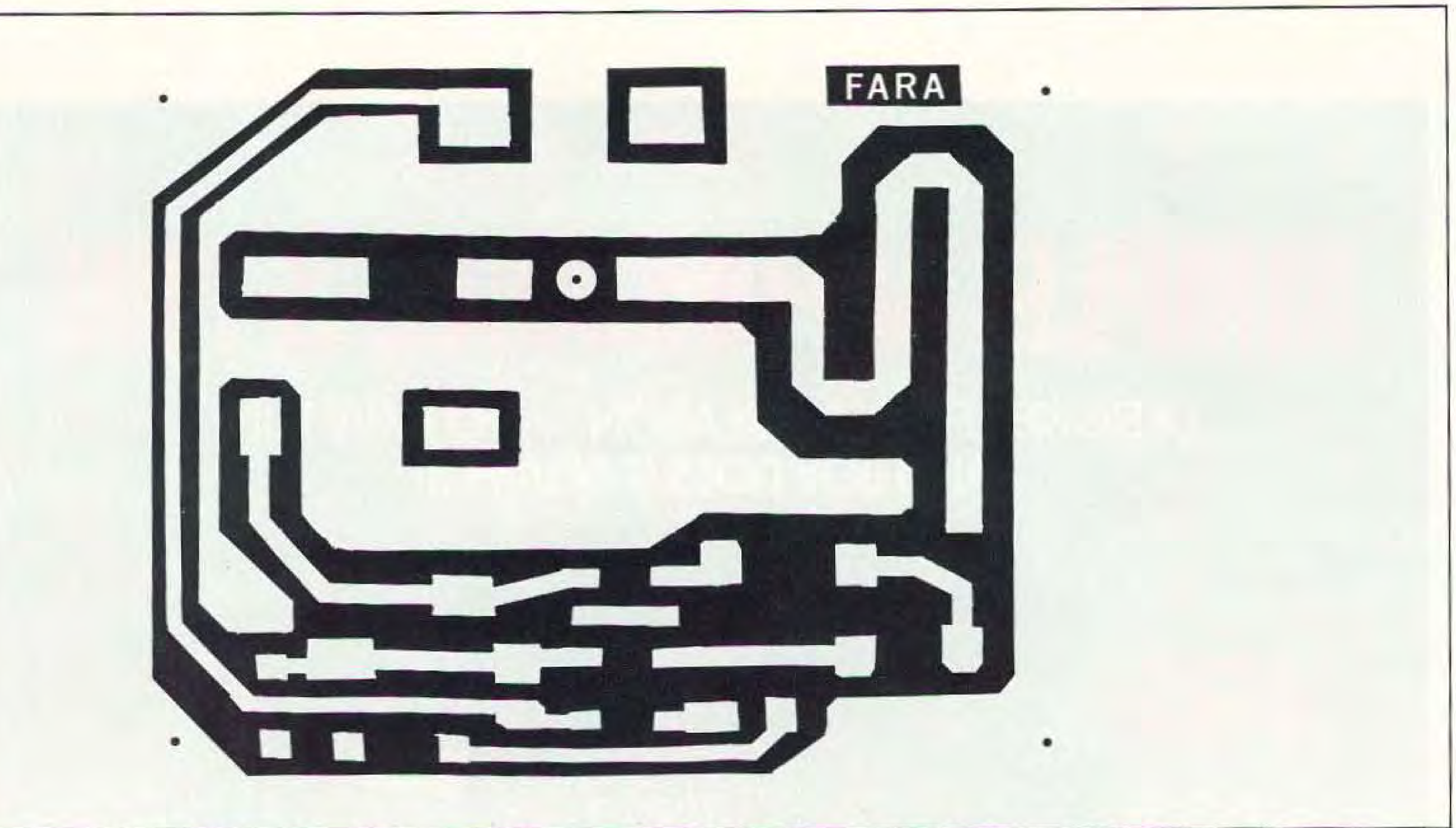

Figure 3. Printed circuit foil pattern (component side). Metal is shown in white, black areas are the etched surfaces.

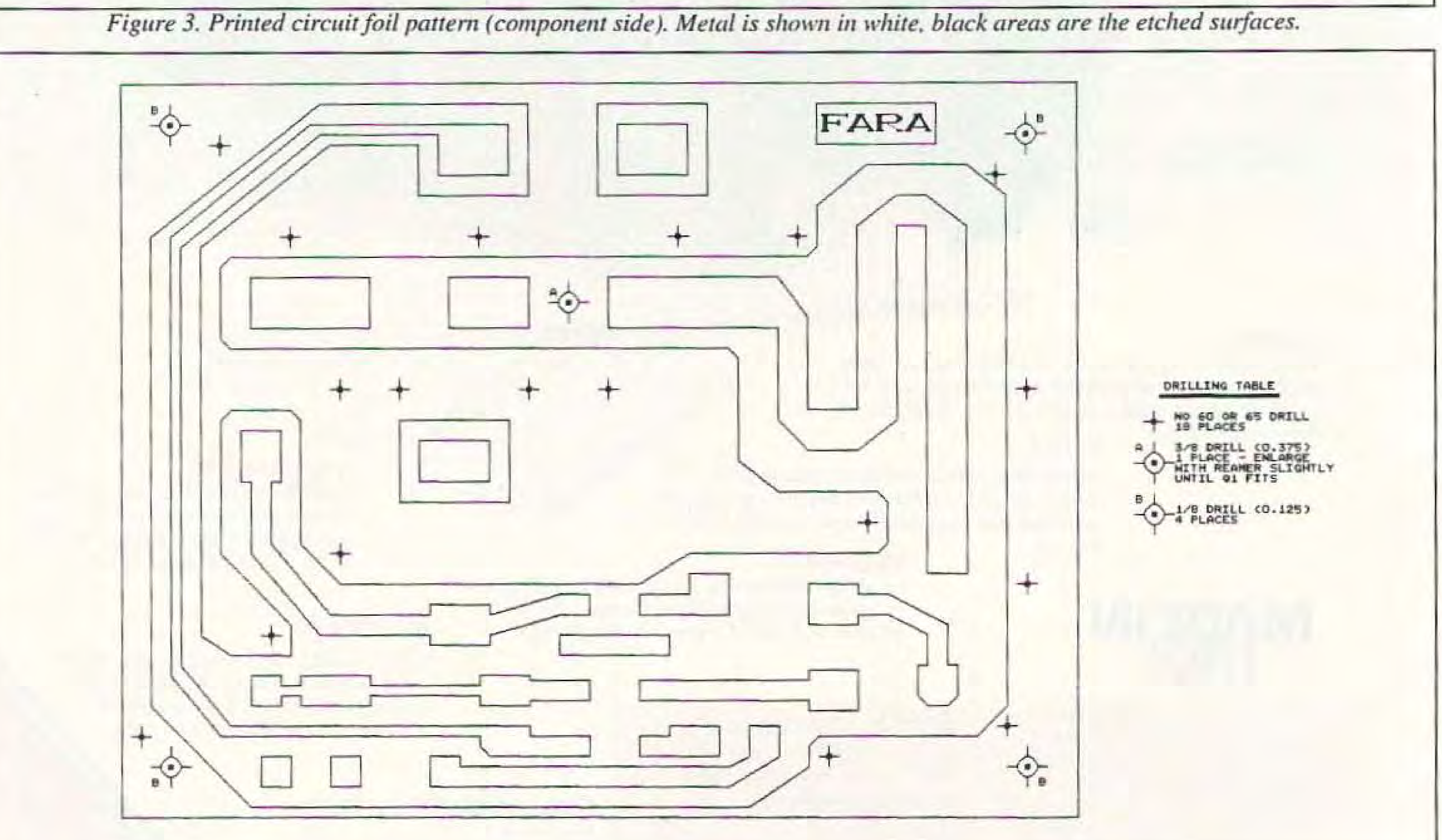

Figure 4. Drilling template.

not used on our production run. All of the input and output foil runs are constructed of 50 ohm microstrip (Z2-Z6) etched into the circuit board. The circuit can be modified for solid-state T/R switching. A PIN Diode T/R switch may be a better choice for packet operations, which require high speed switching. Several articles (including "A 2 Meter FET Amplifier for Your Handheld" by John Cunningham AA4AW, *73 Amateur Radio Today*, Oct. 1992, p.20) and the ARRL handbooks contain examples of diode switching.

A word of caution concerning the circuit board. It must be constructed of 1/16", double-sided, G-10 glass-epoxy board with 2 or 3 oz. copper. A full-size negative for the circuit board is provided (see Figure 3). The side of the board opposite the stripline remains a solid copper ground plane as it is not etched. Failure to reproduce the board exactly as shown, with the materials specified, will dramatically affect the performance of the amplifier because the dimensions for the striplines are critical.

Low impedance grounds are crucial to the operation of the amplifier. A number of holes (18) must be drilled through the board (see Figure 4). No. 20 wire is inserted through these holes and soldered to electrically tie both sides of the circuit board together at the

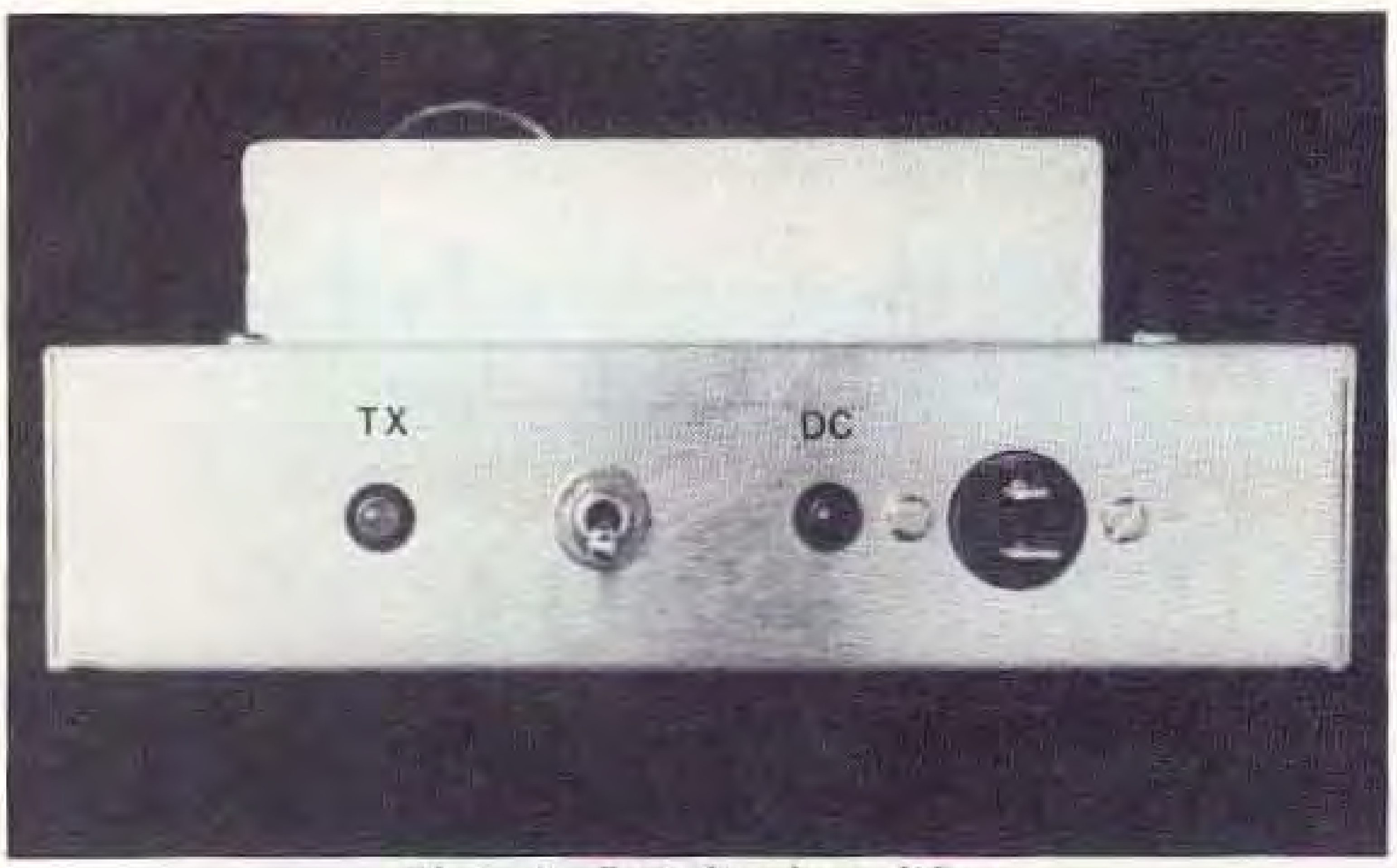

Photo B. Completed amplifier.

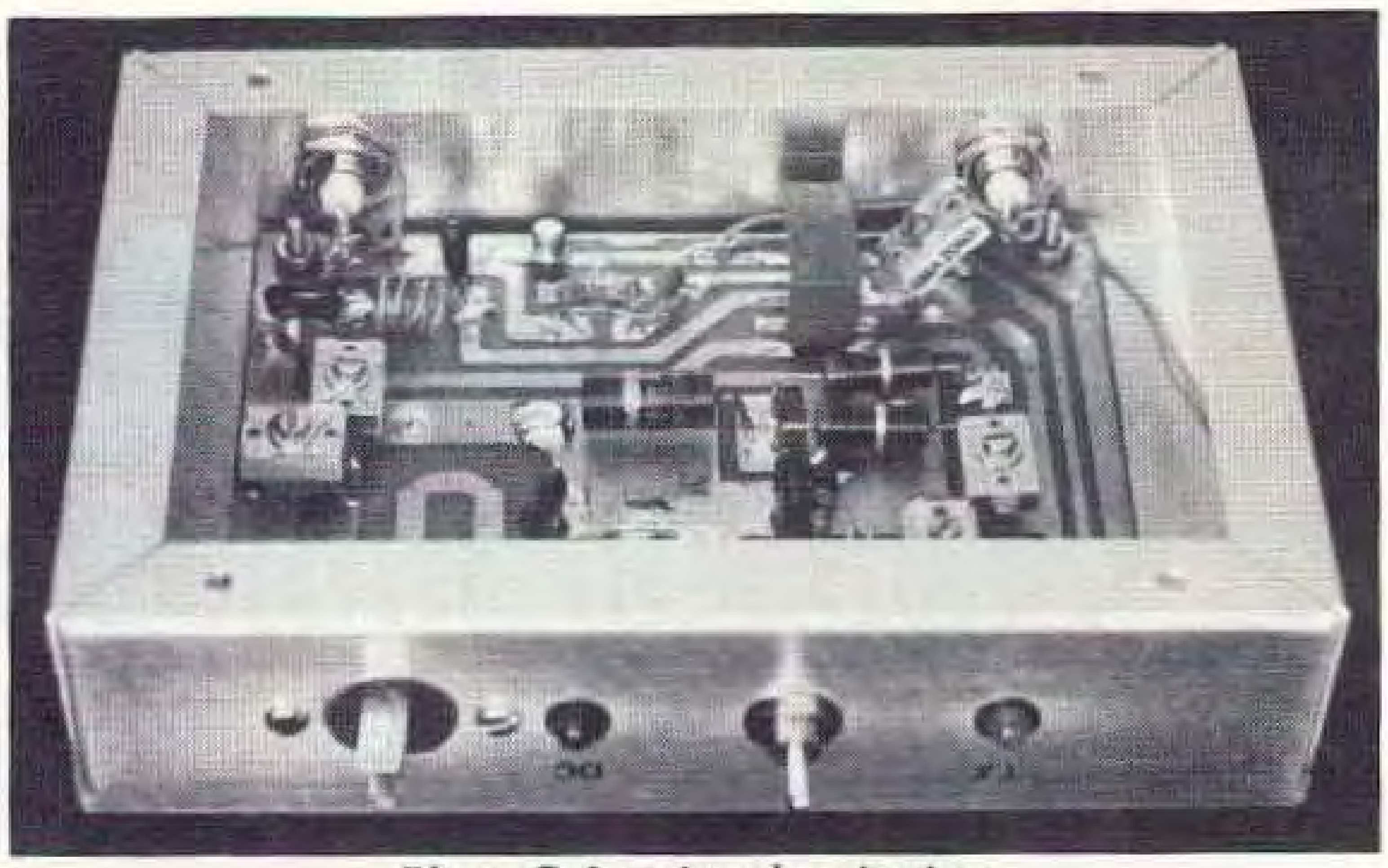

Photo C. Interior chassis view.

points indicated. Some flux may enhance the solderability on the ground plane side of the circuit board. Be sure to use only rosin core-solder!

Construction

Photo C is a view of the amplifier mounted in the suggested enclosure; it should be noted that the circuit board shown in this view is one of the earlier prototypes. It's a good idea to use the circuit board as a template to mark the case for the mounting holes before soldering the components to the board.

The MRF1946A utilizes an 8-32 stud for the heat sink and mounts with a single hole through the circuit board. Take care when mounting the device to insure that no strain is placed on the transistor's leads when it is soldered. It must fit flush on the circuit board. A little thermal heat-sink compound on the flange of the transistor mounting stud is recommended to maximize heat transfer. Careful—don't get this stuff on your clothes because you'll never get it off! The circuit board mounts to the case with 4-40 hardware. Use 4-40 nuts under the circuit board corners to space the transistor mounting stud correctly. The heat sink (aluminum channel stock) and the chassis details are given in Figure 5. I prefer BNC connectors for the RF connections as they mount with a single hole and perform better that UHF connectors at the frequencies of interest. The LEDs, switches, and reverse polarity protection diode are wired from the case-mounted components to the circuit board. Don't forget to install the fuse in series with the DC power plug.

Attention should be paid to standard VHF construction practices. Some pitfalls to be aware of when constructing the amplifier are:

•Components should be mounted flush to the board; i.e., the fixed capacitors should be mounted as close to the foil as possible. Bend the leads perpendicular to the body after removing any enamel from the leads, then solder the components to the board with the minimum lead length possible.

•The wires through the board should be bent into a "Z" shape after insertion through the board prior to soldering.

•Periodically, the flux should be removed from the board during the construction process. Pay particular attention to the striplines

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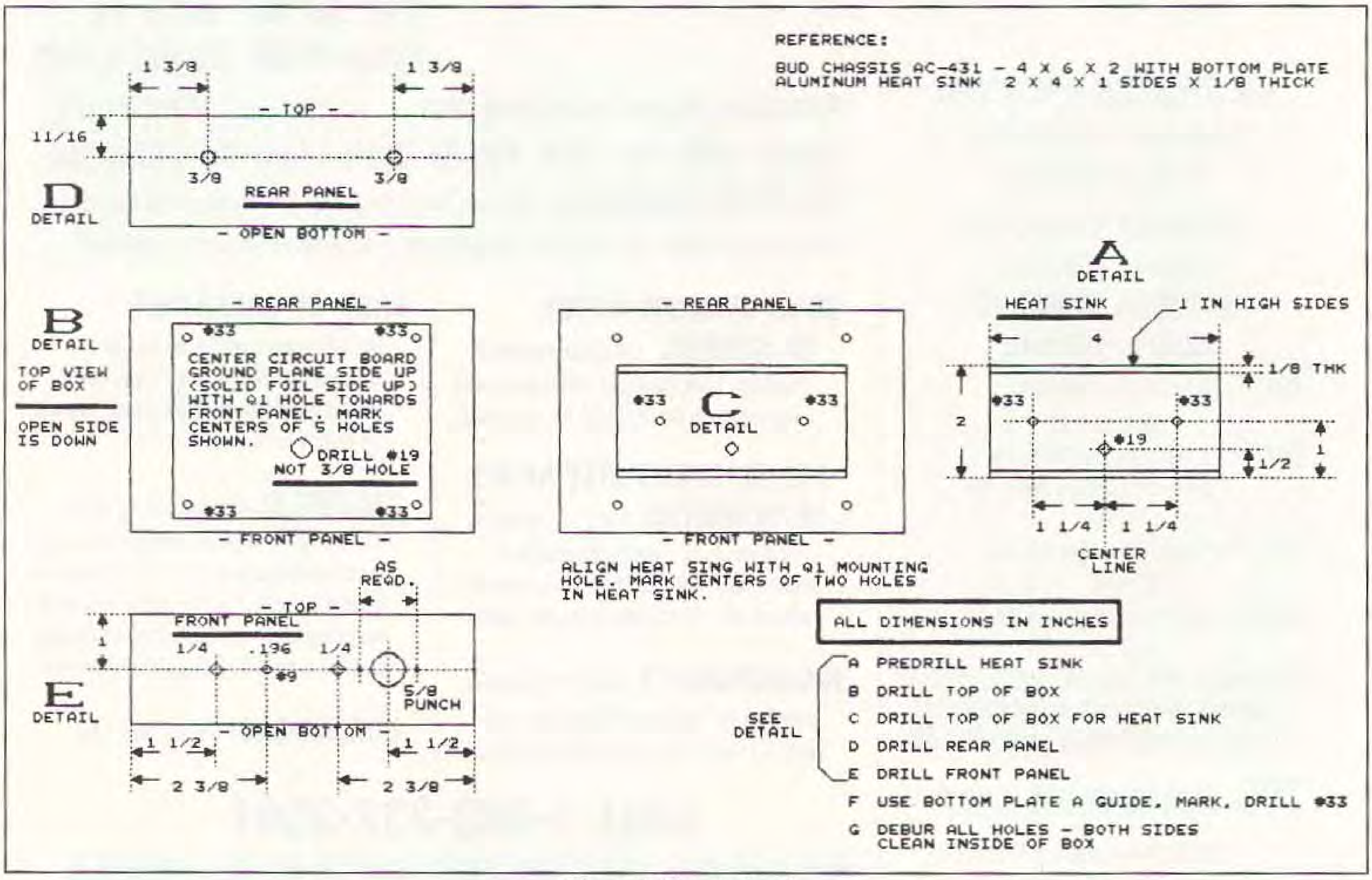

Figure 5. Chassis details.

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and the transistor mounting tabs. These areas must be *clean*. If not, you may have some difficulties when tuning the amplifier.

Parts List

Component	Type	No. Required	Source
C1,C2,C4	0.001 µF	3	
C5,C17	0.1 µF	2	
C8,C9	120 pF	2	
C10	68 pF	1	
C13,C14	22 pF	2	
C16	3 pF	1	
C3	2.2 µF	1	
C6,C7,C11,C12	ARCO 423	4	CS/RF
C15	ARCO 424	1	CS/RF
R1,R7	3.3k, 1/4W	2	
R2,R3	10 ohm, 1W	2	
R4,R5,R8	330 ohm, 1W	3	
R6	2.2k, 1/4W	1	
Q1	MRF 1946 A	1	RF
Q2	2N2222	1	
D1	LED—red	1	
D6	LED—green	1	
D2,D5	1N4006	2	
D3,D4	1N914	2	
L1	7T, #18 wound over R8		
L2	4T, #18 3/8" i.d.		
L3	2T, #18 1/8" i.d.		
L5	4T, #18 1/4" i.d.		
L4	0.22 µH w/ferrite bead		CS
K1	Relay, P/N ME431-ORV-SH-212L		M
J1	2-pin, Jones/TRW/Cinch		
J2,J3	BNC chasis receptacle, UG1094/U		
CH1	Bud chasis AC-431, 4" x 6" x 2"		
BP1	Bud bottom plate, 4" x 6" inches		
HS1	Heat sink, 2 x 1 x 4 channel stock		
Misc. #4 hardware			

M: Mouser Electronics, Tel. 1-800-346-6873
CS: Circuit Specialists, Inc., Tel. 1-800-528-1417

•With the large ground plane of the circuit board you must be careful that there are no cold solder joints. The joints should be shiny and should puddle well after soldering; they should not look crystalline or like a blob. Good soldering techniques are crucial to the performance of the amplifier.

Tune Up

The amplifier is quite easy to tune: Only a DC ammeter (5A full-scale), a 12-14 volt 5A power supply, a suitable RF power meter (50 watts full-scale), and dummy load are required. Initially the amplifier should be tuned at 12 volts with an input power of no more than 1 watt. Until the amplifier is completely tuned, RF should be applied to the input for no more than three to five seconds at any one time. Prior to mounting the amplifier in the enclosure you should rough-tune the amplifier. Be sure the transistor is mounted to the heat sink when tuning.

Tune the amplifier as follows:

1. Apply 12 volts, with the ammeter in series with the positive lead. There should be no current indicated on the meter. Set the power switch to OFF, then peak the relay compensating capacitor (C15), if installed, for maximum output in the bypass mode.
2. Turn the power switch ON and apply 1 watt (as noted). The relay should pull in. Tune all capacitors (C6,C7,C11,C12) for maximum output. Do not tune the relay compensating capacitor (C15) at this time.
3. Set the power supply voltage to 14 volts and increase the drive to the maximum 2 to 3 watts input at the transistor, 4 to 7 watts *maximum* at the input of the amplifier, provided the attenuator is in place.
4. Again, tune the capacitors for maximum output.

Pay attention to the current being drawn. You will notice a substantial increase in current when the series output capacitor (C12) is off resonance. Tune the amplifier for the best efficiency; that is, tune for the highest power output consistent with the minimum current being drawn. Nominal values are about 3.5 amperes at 28 watts output.

Results

To date, the 30 amplifiers we have built have been a great success! The primary goal of the Hackers Group—that of introducing new hams to the construction side of the hobby—was met. They were able to construct a useful piece of equipment at a nominal cost and they enjoyed doing it.

This was a group project and everyone who participated contributed to its success. I would personally like to acknowledge the support of four individuals: Don N1JCT, who helped coordinate the project and who prodded me into designing the unit; Bob W1HWU, whose expertise in circuit board fabrication was crucial to the success of the project; Harry W2RKB, who helped with the circuit boards and tune-up; and, last but not least, John N1ILO, who provided the CAD drawings.