Number 5 on your Feedback card

An *Almost* Everything Amplifier

Change from 7 MHz to 225 MHz with no bandswitching or tuning!

by John Cunningham AA4AW

There are times when you need more power to get into a repeater or to be heard across the country. People who operate handhelds or QRP sometimes find that they have a hard time communicating with such limited power at their disposal. However, buying an amplifier for 10 meters, another for 6 meters, another for 2 meters, and still another for 1.25 meters can get expensive. Wouldn't it be nice to have an amplifier that took care of all these bands?

The amplifier described here meets these requirements. It is broadbanded from 7 to 225 MHz—the range of 10 amateur bands (40, 30, 20, 17, 15, 12, 10, 6, 2, and 1.25 meters). It will operate on CW, SSB, AM, and FM—or any other mode that is used on these frequencies. It can be fed with an input of 1/10 to 24 watts (though there is not much gain above 12 watts input) and can deliver an output of more than 200 watts. It can be operated over a voltage range of 12 to 28 volts.

Field-effect transistors are more immune to damage from high SWR and thermal runaway than bipolar transistors. They also have higher gain, greater efficiency, and lower noise. They can be operated over a greater voltage and power range than bipolar transistors.

The MRF175GV is a Gemini twin which means it is two balanced transistors in one package. The amplifier designed here will not work unless the transistors are balanced.

Field-effect transistors have a few drawbacks. They are more prone to static damage, and care must be exercised during handling until they are soldered onto the board. They easily go into oscillation, owing to their high gain. Be careful not to drive them too hard and destroy the gates. If there is a chance of this happening a limiting circuit should be installed at the input of the amplifier.

Collecting the Parts

The MRF175GV field-effect transistor can be ordered from RF Parts (telephone: 1-800-737-2787 or 619-744-0700). The transformers, chip caps, and copper heat spreader are available from Communication Concepts, Inc. (hereafter referred to as CCI) at 508 Millstone Drive, Xenia, Ohio 45385 (telephone: 513-426-8600). Experimenters who plan to use a similar design in future projects should purchase the coax needed to make the transformers instead of buying them fully assembled. CCI will not send less than five feet of the coax in any one shipment. Five feet is enough to build five output transformers and almost 10 input transformers. However, once you go this route you must also buy the ferrite beads that accompany the transformers.

The total cost of this project is about $362, but that doesn't seem so high when you consider that many of the parts must be ordered in more quantity than is necessary for this project, and the excess can be used on future ventures. The copper heat spreader, for instance, can be cut into three pieces and used in two other projects. Also remember that a high percentage of the cost is in the transistor at $154. If this sounds expensive, consider that to get 200 watts from commercially-built amplifiers you usually pay more than $200, and most of these amplifiers are single-band! Multiply $200 by the 10 amateur bands that this amplifier covers and you get a whopping $2,000—far more than the cost of this amplifier. Maybe you will not work all 10 of the amateur bands which this amplifier will handle, but if you are an experimenter you probably will.

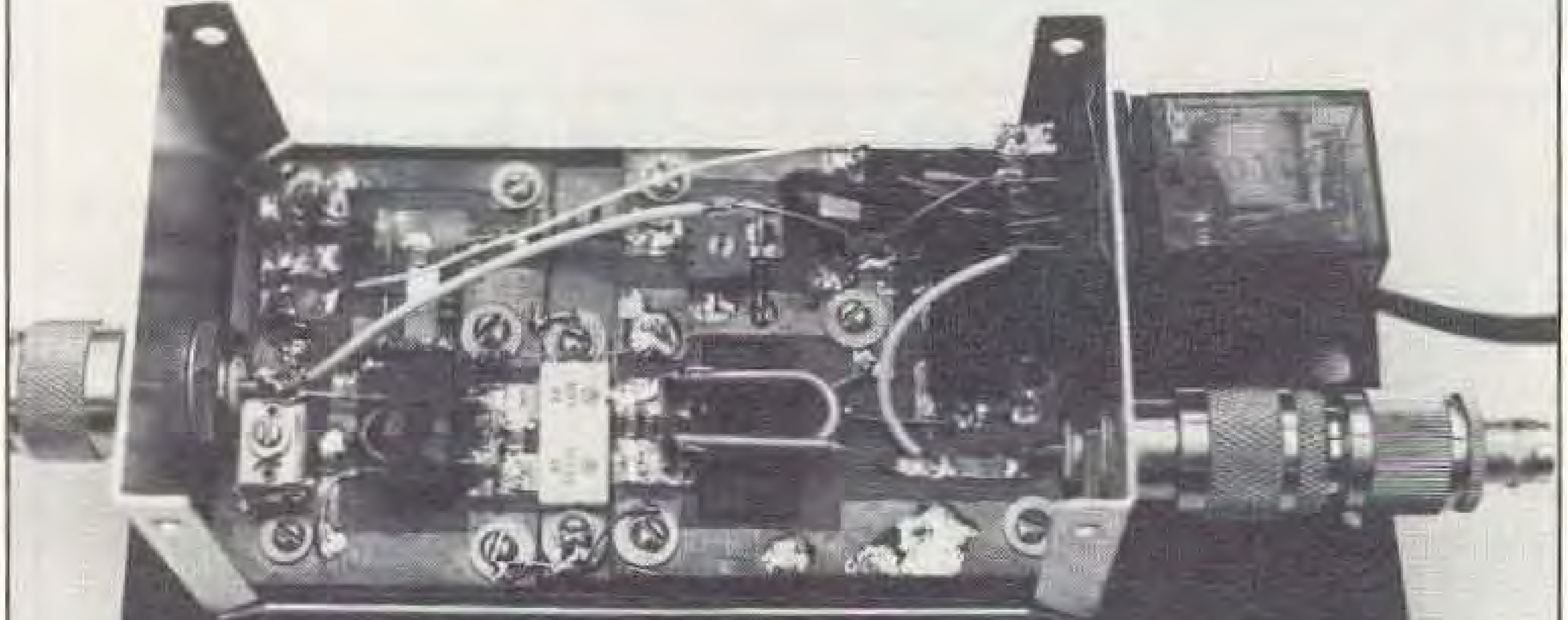

Photo A. The multi-octave amplifier. Photo by John Cunningham AA4AW.

Construction

I used a Radio Shack 276-1499 circuit board and cut it to the proper size. A single Radio Shack card will build two of these amplifiers. This design consists of two separate cards: one for the input and one for the output. The cards are cut to a size that will enable them to fit into a Radio Shack aluminum box (no. 270-238) 5-1/4" x 3" x 2-1/8". The output card should be cut to 2-3/4" x 2-11/16". The size of the input card should be 2-11/16" x 1-3/4". (Custom pre-etched circuit boards for this project are available for $7 a set plus $1.50 S & H from FAR Circuits, 18N640 Field Court, Dundee IL 60118.)

A copper heat spreader is cut to a size that will allow it to fit into the box and enable the lid of the box to fit over it: 5-1/16" x 2-11/16" will make the proper fit.

You will need to drill holes into the boards, box, heat spreader, and heat sink to mount the hardware that holds these devices together. These holes must be lined up with the holes drilled for the circuit board, except that the rectangular holes will not be made in the heat spreader, box, or heat sink. You will also need to drill holes for the bolts that hold the transistor in place. See Figures 2 and 6.

In addition, you will need to make inserts in the circuit boards and the heat spreader (See Figures 2, and 6). I used a grindstone to make the inserts. Without the inserts, the connectors will not fit on the sides of the box.

Holes should be drilled on the output board to bond the ground on the component side of the board. (See Figure 2.) Once the holes are drilled, a lead from a resistor or other component can be placed in the holes and soldered to both sides of the board.

I used Radio Shack 276-1435 etchant, according to the instructions printed on the etchant bottle. Only one side of the board will be etched, except for a little on the lower side of the output board where the power transistor will be. See Figure 2. I drew the pattern with a felt pencil which left the copper to be etched exposed. The unetched copper was further protected by duct tape. All components are located and soldered on one side of the board, similar to a ground-plane configuration—the difference being that some etching is done. This design makes for improved grounding and ease of troubleshooting, repair, and modification.

Once the circuit boards are etched, components can be soldered in place. The component layout is not critical, except that capacitors C5 and C6 must be soldered before transformers T1 and T2 are put on the boards. I recommend that you don't place these transformers on the boards until the boards are bolted inside the box and the ferrite beads are put in place. Otherwise, the parts placement is according to Figure 3. I recommend using only chip caps because the leads from other types of capacitors may pick up stray RF and make the amplifier inoperable.

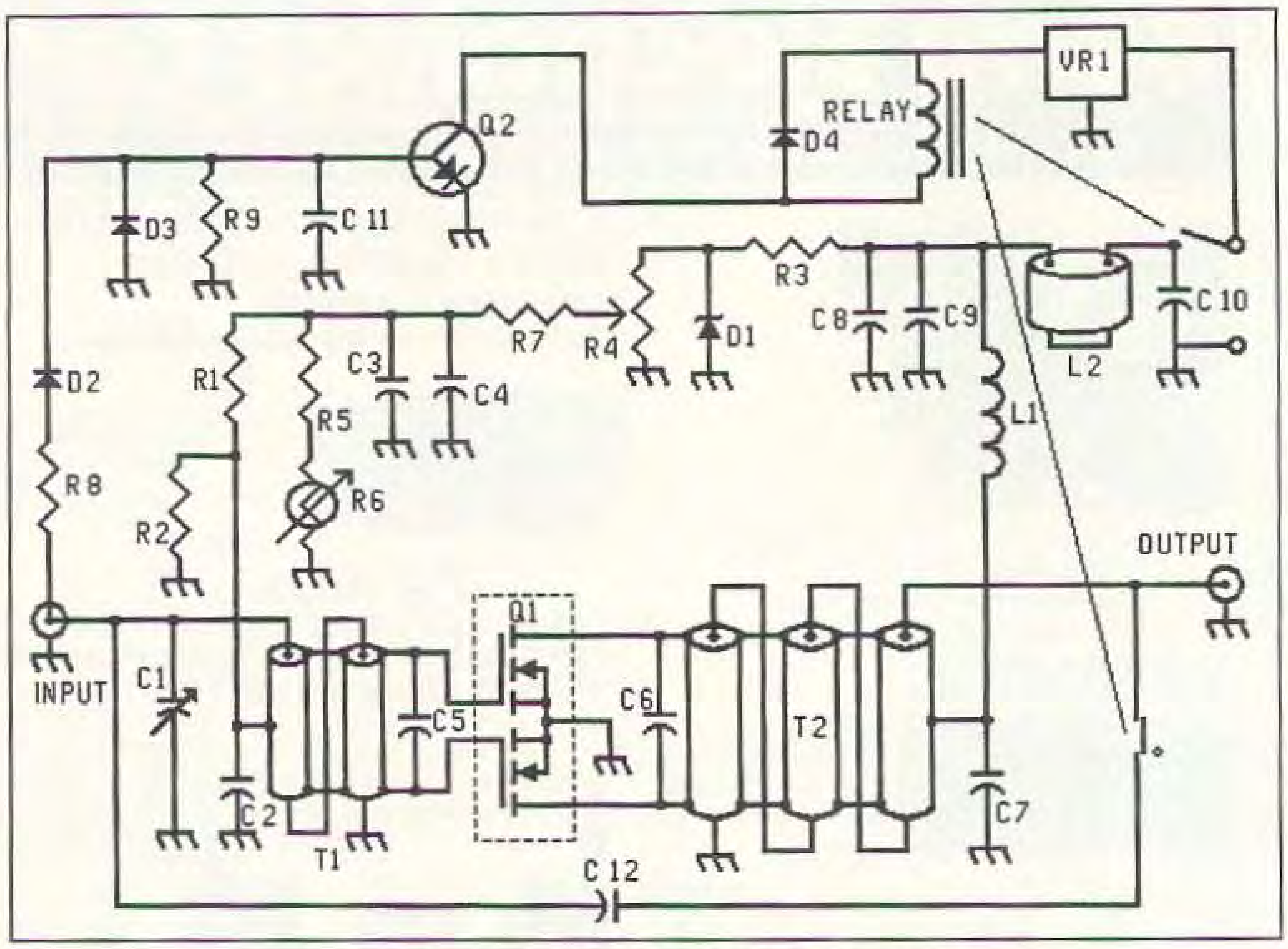

Figure 1. Schematic for the MRF175GV amplifier.

The most difficult part is assembling the transformers. If you order from CCI specify that you want a low-impedance input transformer and a high-impedance output transformer with a 1:9 ratio. CCI does not sell low-impedance input transformers with a 4:1 ratio as called for in this design, but you can order a 9:1 impedance input transformer and convert it to a 4:1 transformer by removing one of the windings. Otherwise, assemble the transformers according to Figures 3 and 4. If you order the coax to build the transformers yourself, specify that you want both input and output coax; they are not the same.

For use at frequencies below 100 MHz, ferrite beads must be put on the input and output transformers to control parasitic oscillations, thereby increasing stability. See Photo A and Figure 4. These oscillations can get so bad that they destroy the transistor in-

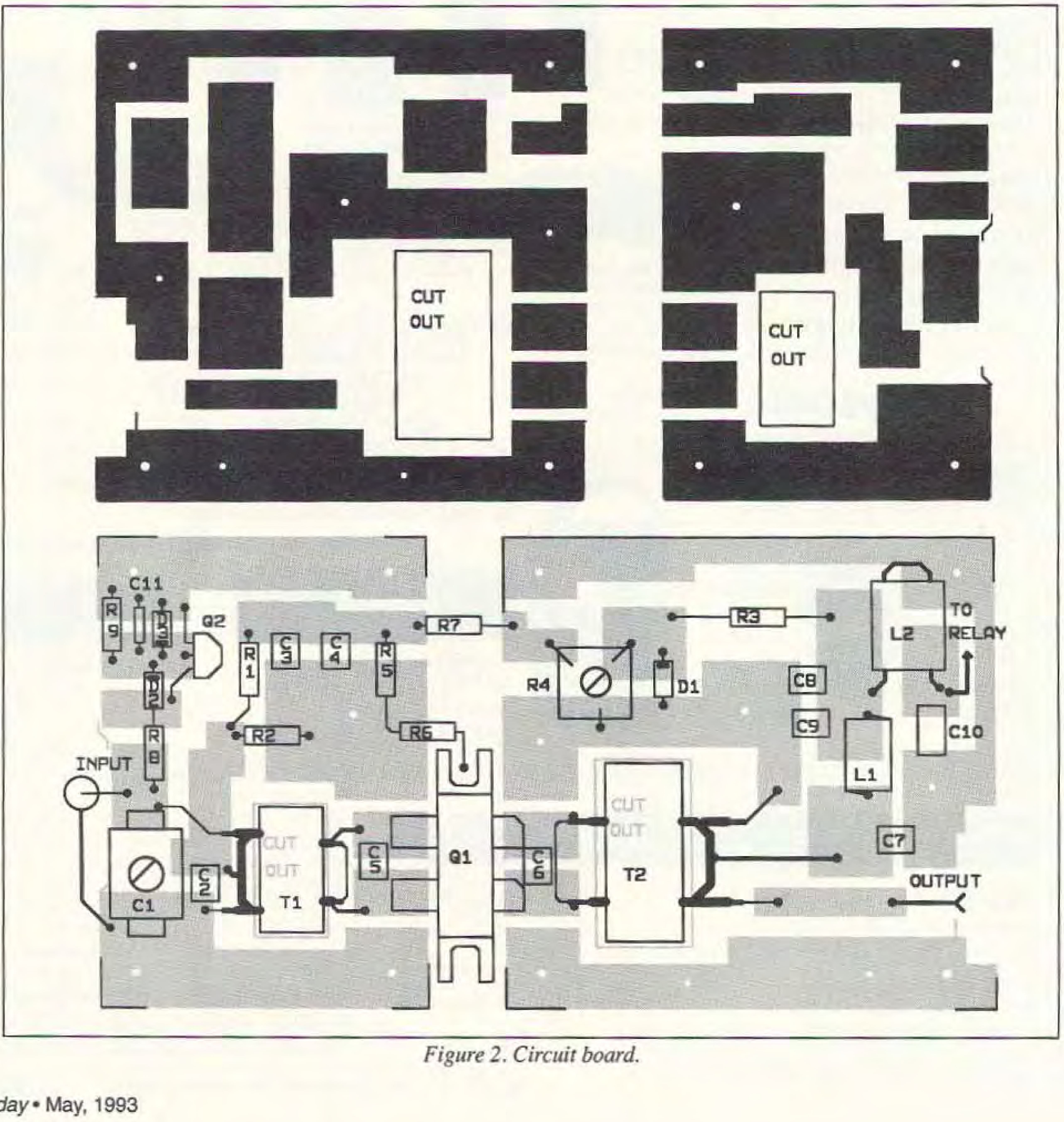

Figure 2. Circuit board.

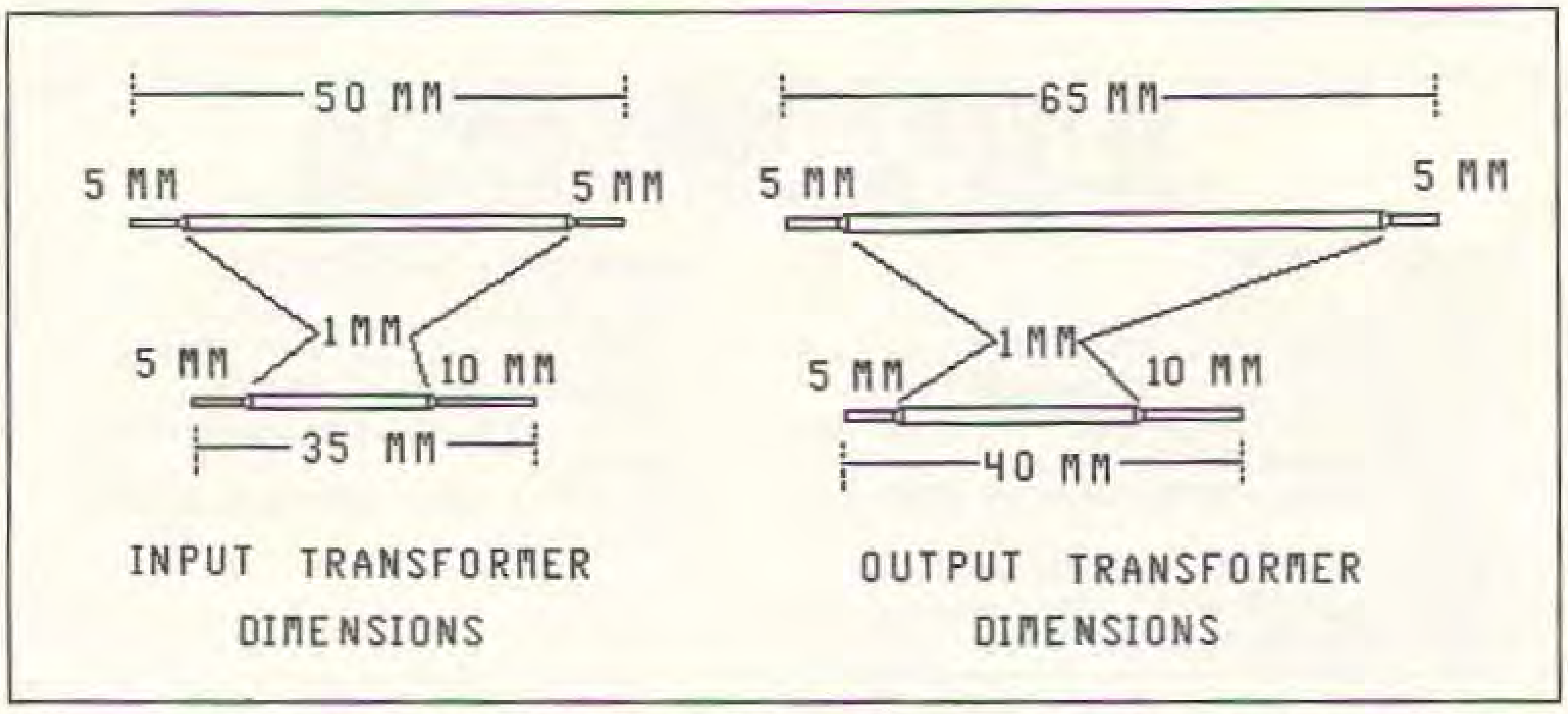

Figure 3. Preparation of the transformer coax. Cut the transformers to the lengths shown, and strip the outer conductors. The inner leads that are to be 5mm should have their outer conductors stripped 6mm and the leads that are to be 10 mm should be stripped 11mm. Then strip the insulator that goes between the inner and outer conductors, leaving 1mm of insulator as shown, which will leave the inner conductors bare at the proper lengths.

stantly—especially when operated with more than 20 volts on the drain. If you intend to use the amplifier exclusively above 100 MHz, the beads can be left off the output transformer to get greater efficiency. In addition to stabilizing the amplifier, these beads can also aid in heat dissipation—something that is critical if the amplifier is to be operated at its maximum power. As for putting beads at the input transformer for use above 100 MHz, they should be installed if the amplifier will be operated at more than 20 volts. For operation below 20 volts, generally more power is obtained from the amplifier if they are left off—especially at frequencies above 200 MHz. However, the amplifier is more broadband if the input beads are left on.

Instructions for installing the beads are included if you order them from CCI. I used only a weak kind of glue, such as a little dab of silicone rubber, to hold the E ferrite beads to the I beads because I anticipated taking them off. The input E bead ordered from CCI fits the 9:1 transformer they sell but is a bit large for a 4:1 transformer. Therefore, I filed down the E bead until it made a tight fit. The I beads need to be glued to the heat spreader after the circuit boards are installed, but before the transformers are soldered to the circuit boards.

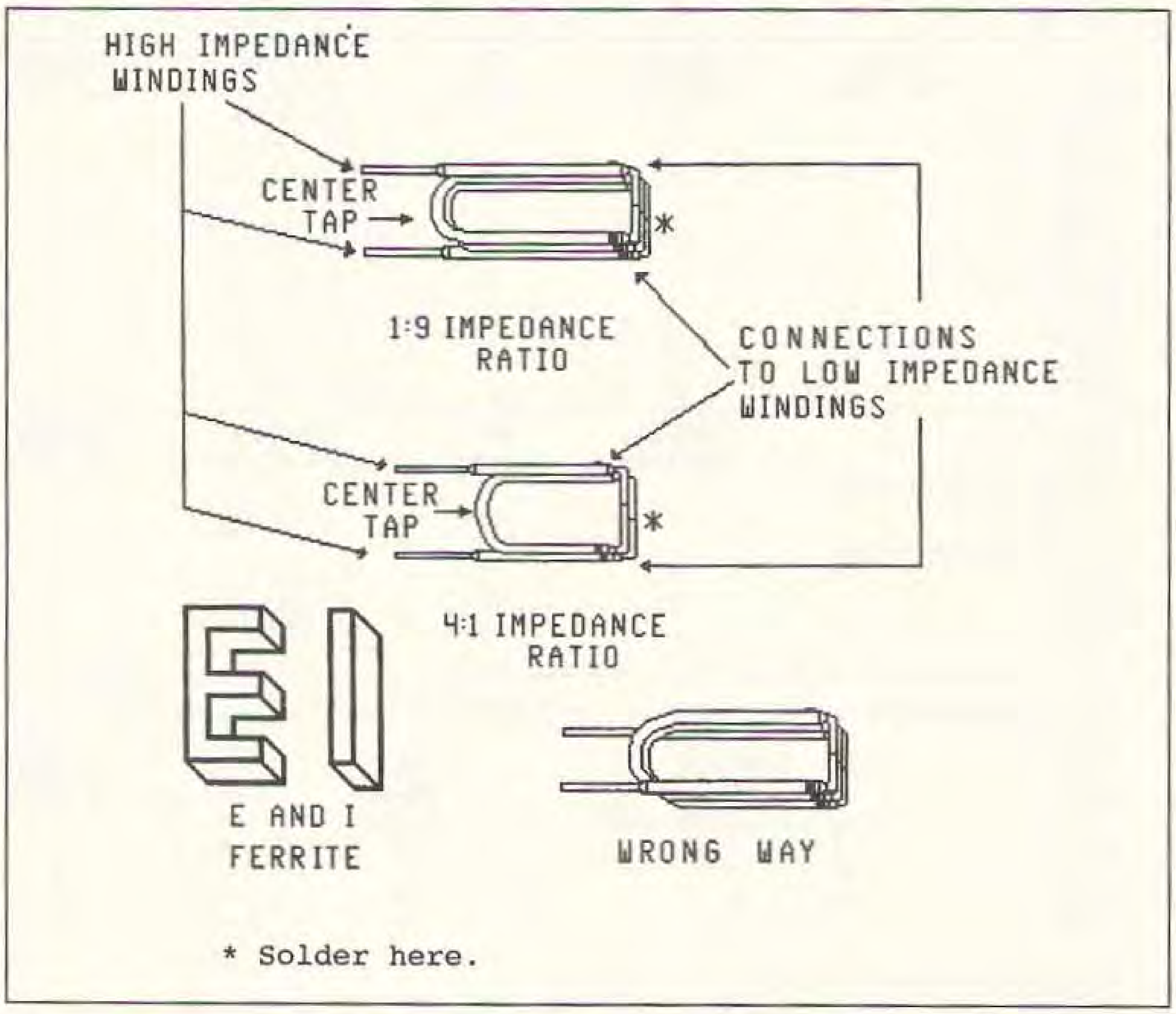

Figure 4. Preparation of the transformers. The leads between the transformer windings should be as short as possible. Bend the coax and bend the leads till they touch tip to tip, and solder the tips together. When properly assembled, an ohmmeter check will show a closed circuit between the two ends of the transformer leads and an open circuit between the inner and outer conductors. The mistake made on the bottom right drawing is easily made by persons assembling the transformers themselves. Nothing feels worse than getting the transformer assembled and having to redo it.

A rectangular hole needs to be made in the output side of the box for the relay. If you do not have the tools to cut a square hole you can drill several small holes inside the area of the opening. Then use a hacksaw to further cut the area into straight sides. I deliberately made the cutout smaller than the dimensions shown because I did not want the relay socket to fit too loosely. In order to have a tight fit, I used a file to gradually increase the opening to the dimensions necessary for the relay socket. See Figure 5 for the positioning of the relay and the input and output connections.

When the box and circuit board have been properly prepared you are ready to assemble the amplifier. The heat sink, box, and heat spreader fit flush together; they should be sanded to eliminate burrs. Thermal heat sink compound should be applied between these parts as they are placed together. I used Radio Shack 276-1372 compound for this project. However, no thermal compound should be put on the circuit boards, which are raised above the heat spreader by means of washers (see Figure 6). The leads of the power transistor will need to be bent sharply upward—especially the output (drain) leads. Separating the boards from the heat spreader reduces heat on the components on the boards. It also makes the transformers fit flat on the boards when ferrite coils are used, instead of being elevated above the boards as they would be if the circuit boards were not elevated from the heat spreader.

The heat sink, box, heat spreader, and circuit boards are bolted together, using five bolts for each board. See Figures 2 and 6. I recommend that you don't tighten the bolts holding the boards in place until the transistor is bolted securely.

The power transistor should be placed on the board next. Use care in handling a field-effect transistor as these devices are subject to being destroyed by static buildup. When handling FETs, pick them up only by their sources. It is a good idea to wear a grounded wrist strap and to work on a static-free table using a grounded soldering iron. Once the device is soldered in place the danger from static buildup is minimized.

The transistor is mounted between the two circuit boards on the copper heat spreader. Thermal heat sink compound must be used when mounting the transistor. Be careful not to mount the transistor backwards—that's easy to do. The two flanges that have one of their corners cut are the drains; the other two are the gates. The leads on the output side of the transistor are bent sharply upward, but be careful not to break them. Also, there is a chance of the output leads shorting to the unused side of the board. One way to prevent this is to etch away a small part of the output board near the transistor. See Figures 2 and 6.

Once the transistor and circuit boards are mounted and their bolts tightened, solder the flanges to the transistors. The transformers can be positioned now and soldered, completing the installation of the circuit boards. Then the last of the components can be soldered in place—VR1 and C12—as well as the connective wires for the receive circuit and the wire that provides the power for Q2. See Figure 5.

Before applying voltage, it is a good idea to do a few continuity checks. See if there is zero resistance from the voltage input to the drain of the transistor. Then check for shorts between the drain and ground and between the gate and ground. If you find shorts, do not proceed until the trouble is corrected. Both the input and output, however, should have a short to ground.

Checking It Out

When the resistance checks are made, you are ready to test the amplifier. Connect the input to a handie-talkie or other low-power transmitter and the output to a dummy load that has some kind of power indicator. If you have a spectrum analyzer, so much the better. A dummy load wattmeter will do—so will a dummy load with an SWR and relative power indicator placed between the amplifier and the dummy load. Be sure the dummy load is capable of handling more than 200 watts.

When applying voltage, put no more than 12 volts to the amplifier at first. Once voltage is applied, quickly check the voltage on the gates. This voltage will vary, depending on the adjustment of R3. For now, adjust R3 until the gate voltage reads approximately 2 volts. The gate voltage should not exceed 6 volts.

If you wish, you can check out the amplifier portion of the project before you check out the receive portion. To do this, do not connect one side of R10. However, once the amplifier is tested and R10 is reinstalled, it will have to be realigned.

Once the voltage on the gate is 2 volts, apply a 0.5 or 1 watt RF signal to the input of the amplifier. The relay should click on. If it does not, adjust C1 until it does. If the relay still does not come on, there is either a component breakdown or an error in construction. Once the relay has engaged, see if there is any output indication. Adjust capacitor C1 and R3 for maximum output. One good feature of this amplifier is that there are only two adjustments to be made: C1 and R3.

All this sounds simple, and it usually is. However, these amplifiers have a tendency to go into oscillation. Turn off the exciter, and see if you still get a power indication on the wattmeter. If so, the amplifier is oscillating. Back off from R3 until the oscillation stops. C1 may also be adjusted. The trick is to get the maximum power out of the amplifier without it going into oscillation and remaining in that state after the drive has stopped.

When properly adjusted, the amplifier should give out more than 30 watts at 12 volts with 1 watt drive. At this point, you can increase the power of the amplifier by gradually applying more voltage to the drains. Never exceed 28 volts on the drains, and never let the voltage on the gates exceed 6 volts—if even that much.

If you are content to use only 14 volts (the power available in most automobile electrical systems), the amplifier can be used for continuous duty operation on all modes. At this voltage the transistor can withstand infinite SWR and any other conceivable abuse (except overdriving) and should easily outlast its owner. Notice that the amplifier gets warm after only a few minutes—even at this power level.

A word of caution: Some late-model automobiles are equipped with computers that will break down if a transmitter putting out more than 10 watts is used. This can stop the engine and lead to a thousand-dollar repair bill. Check your automobile owner's manual.

Once the transmitter is functioning, you are ready to test the receive circuits. Since the receive circuit consists of nothing more than a relay and capacitor C12, there should

Parts List

C1	Arco 404 mica trimmer, 8-60 pF or equivalent	Available from CCI.
C2, C3, C7, C8	1000 pF chip	CCI no. C1210C NPO 200V
C4, C9	0.1 mF chip	CCI no. C1813 BX 100V
C5	200 pF chip	ATC 100B 300V
C6	In parallel:	
	100 pF chip	CCI no.C1210C NPO 50V
	130 pF chip	ATC 100B 500V
C10	.47 mF chip	CCI no. C2225 BX 100V
C11, C12	.001 mF PC mount capacitor	Radio Shack 272-126 (or equivalent)
D1	8.2 volt zener	1N5923A or 1N756A, available from CCI.
D2, D3, D4	1N4148 high-speed switching diodes or equivalent	Radio Shack 276-1112 (for 10 diodes) or 276-1620 (for 50 diodes)
L1	10 turns AWG # 16 enamel wire, close wound, 1/4" i.d.	
L2	CCI VK 20/4B RF choke or ferrite beads of suitable material for 1.5—2 mH total inductance.	
Q1	Motorola MRF175GV	
Q2	2N4401 NPN transistor or equivalent	
R1	1k 1/2 watt	
R2	10k 1/2 watt	
R3	330 ohm 2 watt	
R4	1k variable trim resistor	CCI 3386P-102 or equivalent
R5	6.8K 1/4 watt	
R6	10k (25C)-2.5K (75C) thermistor	
R7	2k 1/2 watt	
R8	100 ohm 2 watt	
R9	10k 1/4 watt	
Relay	12 volt DPDT, 15 amp contacts	Radio Shack 275-218 and 275-220 relay socket.
T1	4:1 impedance ratio RF transformer. Can be made of 25 ohm semirigid coax, 47-52 millimeters outside diameter.	
T2	1:9 impedance ratio RF transformer. Can be made of 15-18 ohm semirigid coax, 62-90 millimeters outside diameter.	

NOTE: Both T1 and T2 are available from CCI. If you don't buy the transformers fully assembled you will need magnetic cores for the transformers. For T1 use Fair-Rite Products Corp. #9461012002/9361021002 E (or type 75-26 E and I Micrometals powdered iron core). For T2 use type 100-8 E and I Micrometals powdered iron core). See text.

VR1	12 volt regulator	Radio Shack 276-1771
Connectors	Type N chassis mount female	Radio Shack 278-152 (or equivalent)
Optional	Radio Shack auto cigarette lighter power cord	#276-021

Circuit boards for this project are available for $7 plus $1.50 S & H from FAR Circuits, 18N640 Field Court, Dundee IL 60118.

Figure 5. The front and back sides of the box, showing the relay mounting and relay connections. The hole near the relay which allows DC into the box should be approximately 1/4" diameter. The rectangular opening for the relay should be 1" by 7/8". The holes for the "n" connectors should be 9/16".

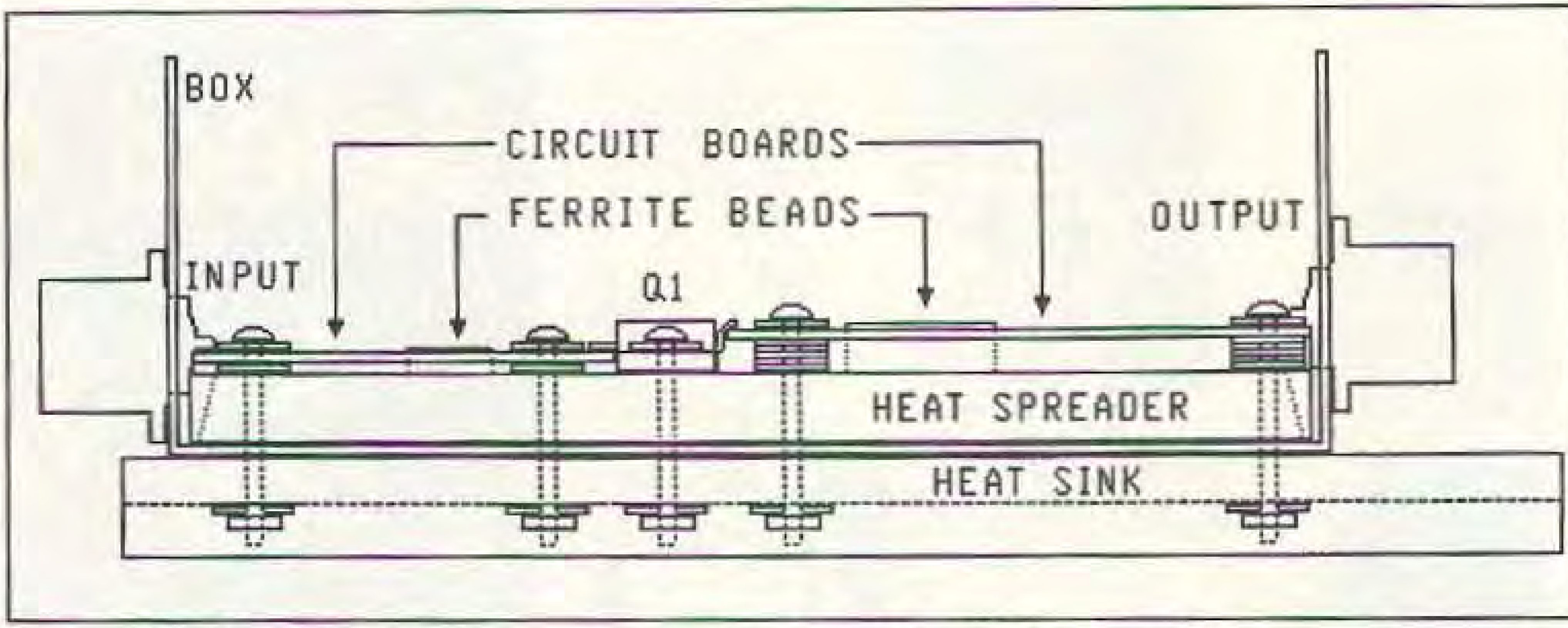

Figure 6. Bolting the amplifier parts together. Note that the flanges of the output of the power transistor have to be bent upward. The output of the transistor can short to the bottom of the circuit board unless a small part of the bottom of the board is etched. See Figure 2.

Be careful to make the input and output connectors touch on the circuit board, or the amplifier may not work at 225 MHz. Solder the inputs and outputs directly to the foil of the board without using lead lengths. A BNC connector could be used in place of the type N connector used in this experiment.

be no problem if everything was installed correctly.

How It Works

When an RF signal is put into the amplifier, a small portion of it flows through R12 and D2 (see Figure 1), which turns on Q2. This action causes the relay to engage, thereby disconnecting the receive circuit and allowing voltage from the power supply to enter the amplifier.

Resistors R1 through R7 supply the proper bias voltage to the gates of Q1. The power supply voltage goes to the drains through the T2 center tap.

The transformers are wound in such a way that they match the 50 ohm impedances of the input and output over a range of several octaves. The transformers' ratios are the ratios of the square of their turns. For instance, one turn would give a 1:1 ratio, two turns a 1:4 ratio, three turns a 1:9 ratio, and four turns a 1:16 ratio.

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An Everything Amplifier

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Results

At 223 MHz the amplifier will put out more power than is legal for Novice operators. However, this power can be backed up to the legal 25 watts by adjusting R3. I tested this amplifier with my 1.25 meter handie-talkie, 2 meter handie-talkie, 6 meter transceiver, 10 meter mobile rig, a 10 MHz home-brew transmitter, and an HF rig at 3.5, 7, 10, 14, 17, 21, 24, and 28 MHz. The amp does not work well at 3.5 MHz, but it does at the other frequencies tested. At HF frequencies with only 13 volts from the power supply, 1 watt input gives a little more than 30 watts out. One point cannot be emphasized enough: Do not put more than 25 watts into this amplifier—so be careful if you test this amplifier with a transmitter that is capable of putting out more power than that.

If the amp is used for SSB, the relay may not want to stay engaged. It may be necessary to manually key the relay if you're going to use the amp on SSB or to design a circuit that will delay the relay from opening once it closes.

As the power supply voltage is changed, the bias will sometimes have to be adjusted. Furthermore, bias sometimes has to be changed if you go from one band to one of a much different frequency. The power gain of a broadband amplifier will go up at the lower frequencies, and if you switch to a lower frequency with no adjustment, the amp may go into oscillation.

Receive sensitivity is slightly reduced—especially at the higher frequencies. If you want to get the receive sensitivity back up to the level it would be without the amplifier, consider installing a broadband preamp.

Remember that FCC regulations, common courtesy, and good operating practice require the use of minimum power when operating on the airwaves. Also remember that experimentation is one of the main reasons for our hobby.

My thanks to the XYL, Carolyn KC4NBE, who encouraged me in the project and proofread the manuscript. Also thanks to Will Payne N4YWK, who worked with me on the project and gave me tips that enabled the amplifier to work. 73

Bibliography: Motorola Semiconductor Products, Inc., *RF Device Data*, Vols. 1 and 2, 1990.

Approximate Metric to English Conversions

	List:65mm 2-19/32"
50mm	1-63/64"
40mm	1-19/32"
35mm	1-25/64"
11mm	7/32"
6mm	15/64"
5mm	13/64"
1mm	Less than 3/64" or more than 1/32"