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Satellite Supremacy

Sometimes 15 Watts just doesn't cut it with OSCAR 10. The solution? Use W2GEF's 60-Watt uplink amp—stripline construction makes building it a snap!

Many hams who have followed the homebuilt transverter route for OSCAR 10 have wound up in the 10–25-Watt output range and feel a little underpowered. You can build an effective, low-cost amplifier to get a good solid signal into the satellite without feeling guilty about robbing transponder power from the other guy. With 60 Watts and a net gain of 10 dB (antenna gain less feedline loss), the effective radiated power will be 600 Watts. This level will result in a received signal which is about the same strength as the 145.810-MHz beacon.

Design

The amplifier uses a Motorola Semiconductor MRF-648 rf power transistor characterized as a 60-Watt device (power output) at 470 MHz. This power level is reached, typically, with an input of 19 Watts and a 12.5-volt collector supply voltage. Power gain is slightly higher at 13.6 volts.

Design of the amplifier began with an examination of the MRF-648 test circuit in the *Motorola R.F. Data Manual*. This circuit closely resembles the designs of several commercial units and was considered a pretty safe way to do the job. Unfortunately, it uses rather expensive and hard-to-get capacitors and has four tuning adjustments.

In the interest of low cost, ease of construction, and simple adjustment, an amplifier was designed using an approach which features a single input- and a single output-tuning adjustment and a minimum number of fixed capacitors. Low-power linearity is improved by a simple bias circuit which stabilizes against thermal runaway and idles the amplifier at 150 mA collector current.

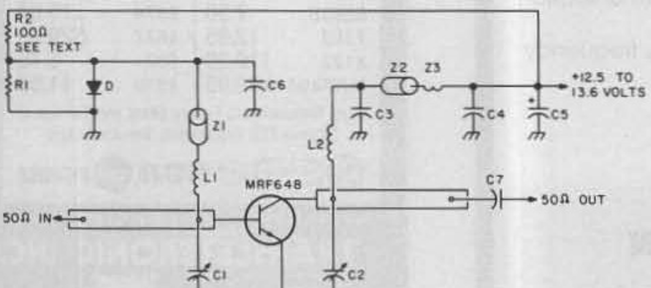

Fig. 1. Schematic.

The MRF-648, at a power output of 60 Watts and a collector supply voltage of 12.5 volts, has a series-equivalent input impedance of 0.82 + j3.3 Ohms and requires a series-equivalent load impedance of 1.07 + j2.7 Ohms (this is the conjugate of the load impedance into which the device operates). So input and output matching networks are required to perform a transformation from a 50-Ohm resistive source and load (the amplifier's input and output impedance) to these impedances.

One way of doing this is to use quarter-wave transmission lines with variable capacitors in series to cancel the inductive components of the input and output impedances. This requires input and output transmission-line characteristic impedances in the six-to-seven-Ohm region. These lines are too wide to fit the base and collector tabs of the transistor without removing material to avoid shorts and also results in high currents in the variable capacitors. A better scheme is to represent the input and output impedances by their parallel-equivalent values, then cancel the reactances with an appropriate parallel variable capacitor. Line widths fit the transistors nicely, capacitor currents are reduced, and layout is considerably simplified.

The input circuit consists of a quarter-wave transmission-line transformer which transforms the 50-Ohm input to match the low (.81-Ohm series-equivalent) value of the real part of the transistor input impedance. The parallel equivalent of the input resistance is 13.9 Ohms, so a transmission line Z_0 of about 26 Ohms is needed, and a parallel capacity of about 100 pF cancels the equivalent parallel inductive reactance of the transistor input impedance. A similar scheme in the output calls for a shunt-tuning capacitor of about 120 pF and a quarter-wave transmission line of 19 Ohms. The dimensions, using glass-epoxy board, are reasonable (3.4-inch length for the input line and output lines). Dielectric losses are small at the low impedances involved and no attempt was made to use more expensive, hard-to-get materials.

The input- and output-tuning capacitors are garden

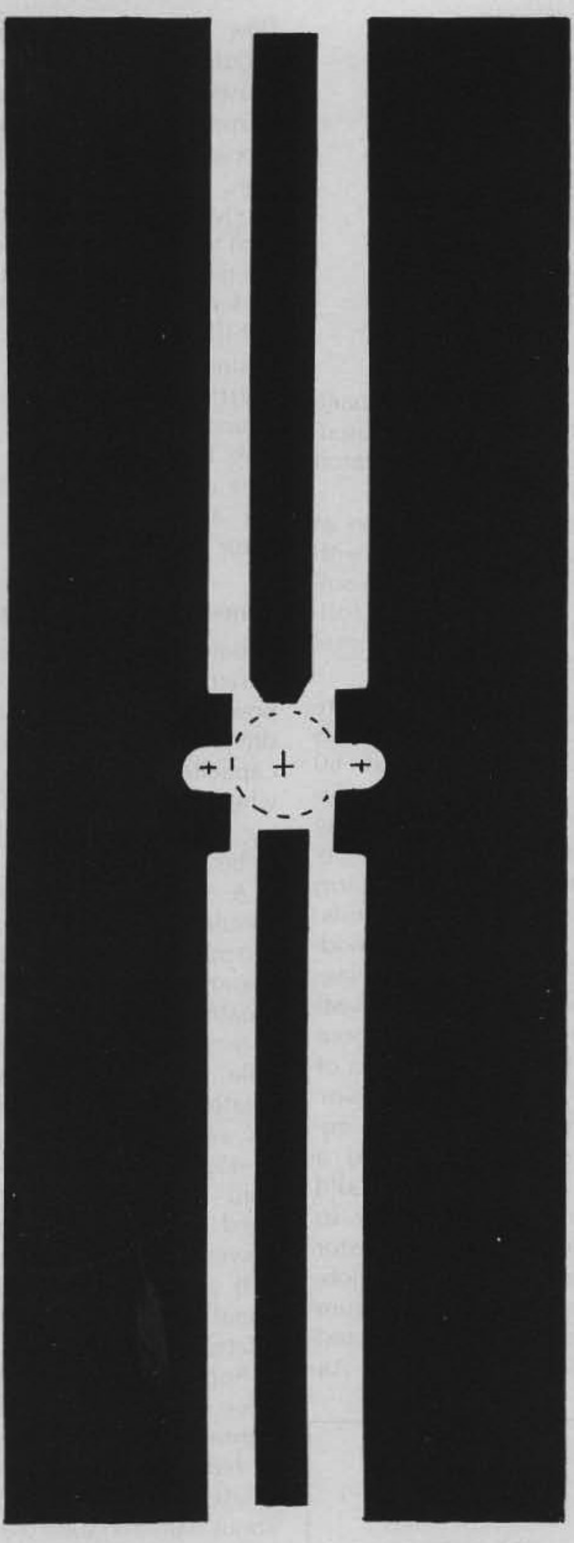

Fig. 2. PC-board pattern.

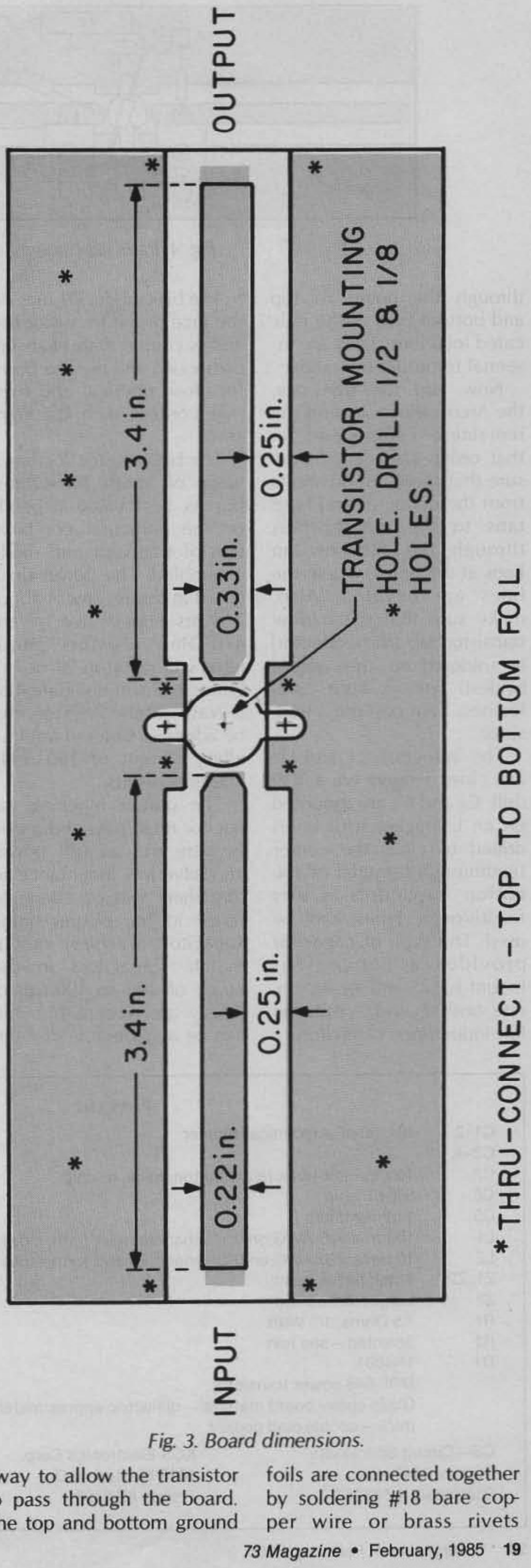

Fig. 3. Board dimensions.

variety Arco mica compression trimmers which handle the required current without any problem.

Construction

Since the board layout consists of a few straight lines, I used tape as a resist and cut and peeled the areas to be etched.

Next, the body of the MRF-648 must be recessed into the board to make connection to the PC board. A center mark for drilling a half-inch hole should be placed midway between the inner ends of the input and output transmission lines and on the transmission line center lines. Next, 1/8" hole centers, 0.73" apart, are drilled above and below the center of the half-inch hole and the board webs are filed away to allow the transistor to pass through the board. The top and bottom ground foils are connected together by soldering #18 bare copper wire or brass rivets

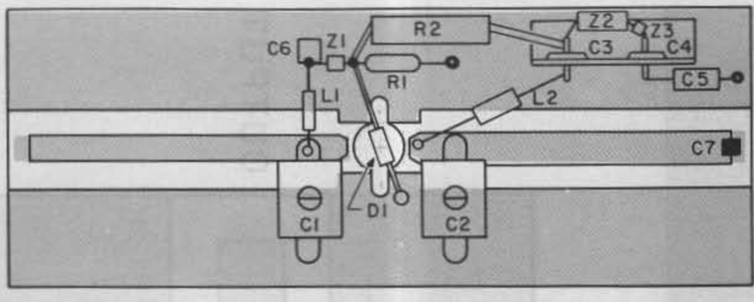

Fig. 4. Parts placement.

through the board to top and bottom foils at the indicated locations. They are essential to proper operation.

Now add the transistor, the Arco capacitors, and the remaining components in that order. Use care to ensure that there are no shorts from the collector and base tabs to the emitter tabs through the transmission lines at the points where the lines are beveled. Also, make sure that the narrow transistor tab (the collector) is soldered to the output (widest) line. A little carelessness here cost me a transistor.

The inductors, L_1 and L_2, are close wound on a #39 drill; C_3 and C_4 are mounted on an L bracket with holes drilled to clear the center feedthrough terminal of the button capacitors. Other feedthrough types can be used. This type of capacitor provides a convenient mount for Z_2 and Z_3. At any rate, both C_2 and C_3 must be low-inductance capacitors.

The bias diode, D1, lies on the face of the transistor top and is coated with heat-sink compound and pressed down for close physical and thermal contact with the transistor.

The bias resistor, R_2, has a value of about 100 Ohms, but its best value depends on the particular combination of transistor and diode assembled. The power dissipated in the resistor is about 2 Watts. Four or five 1-Watt, 470-Ohm resistors paralleled will result in 94 or 117 Ohms and will dissipate 4 to 5 Watts safely. Resistors can be added or deleted until an idling current of 150 milliamperes results.

The output blocking capacitor must pass about one Ampere rms at full power and have low inductance so that there will be adequate range in the output-tuning capacitor to achieve output match. Capacitors in the range of 100 to 1000 picofarads are acceptable and can be a solderable disc (no leads) or chip (ATC) capacitor. If a mica trimmer is used, keep leads short and watch out for heating.

I used BNC connectors at the input and output with brass shim stock mounts soldered to the lower foil. (Note the through-connects at input and output.)

Heat-sinking for the amplifier is a matter of serious concern since about 60 Watts of heat must be disposed of without causing the transistor to exceed its short-term and long-term upper temperature limits. First, choose a black anodized (or black air-drying-enamel sprayed finish) heat sink; it will require about one-fifth the surface area of bright (polished) aluminum. Surface area is of prime importance so try to find a finned sink. The fins should be on one surface only so that the board and transistor can mount on a flat unobstructed side. The aluminum thickness is important and should be at least 1/8". Air flow along the fin grooves should be ensured. The sink I used is 1/4" thick at the transistor, has fin grooves along the long (9") dimension, and is 6" wide. The grooves (fins) are 2" deep. Don't be afraid to use an oversize sink. If you must go undersize, use forced air.

Filled heat-sink compound provides the best thermal conductivity between the transistor and sink, but make sure air bubbles are excluded by pressing and rotating the transistor as it is mounted.

Parts List

C1-2	16-150-pF Arco mica trimmer	CS #424
C3-4, C7	1000-pF low-inductance button, mica, or chip	KCS #21CC510
C6	500-pF chip	KCS #21CR650
C5	1-uF tantalum	
L1	10 turns #26 AWG on 0.1" inner diameter form, close wound	
L2	10 turns #20 AWG on 0.1" inner diameter form, close wound	
Z1, Z2	Small ferrite bead	KCS #FB43-226 DP
Z3	Large ferrite bead	KCS #FB43-287 DP
R1	7.5 Ohms, 1/2 Watt	
R2	Selected—see text	
D1	1N4001	
	MRF-648 power transistor.	R.F. Parts Co.
	Glass-epoxy board material—dielectric approximately .050" thick—double-clad copper	

CS—Circuit Specialists PO Box 3047 Scottsdale AZ 85257	KCS Electronics Corp. 1043 N. Stadem Dr. Tempe AZ 85281	R.F. Parts Co. 1320 Grand San Marcos CA 92069

Tune-Up and Operation

Before connecting the amplifier to a source of drive power, make sure that the driver has a series blocking capacitor. In the rare cases where there is no dc blocking capacitor, one will have to be added.

A 50-Ohm dummy load should be connected to the output connector. Most dummy loads available to amateurs are not purely resistive and some are not usable at 70 cm. The new Heath "Cantenna" advertises an swr of less than 1.5:1 at 450 MHz. A lightly coupled diode probe can be used to indicate relative power.

If you have a VHF directional coupler, use it for a relative power indicator.

Apply about 10 Watts of drive and peak the input trimmer for maximum power, reduce drive to cut the indicated power reading by about half, and tune the output trimmer for maximum. Further reduce the drive and re-peak the input. Touch up the output at full drive and you are ready to connect to the antenna. For maximum stability and safest operation of this amplifier, the antenna and feedline combination should present a load close to 50 Ohms resistive, which means an swr close to 1. Make antenna adjustments at reduced power and operate with an swr of less than 1.5. ■