NOTE: The theory in this application note is still applicable, but some of the products referenced may be discontinued.

AN955

A Cost Effective VHF Amplifier for Land Mobile Radios

Prepared by: Ken Dufour
Motorola Power Products Division

INTRODUCTION

This application note describes a two stage, 30 watt VHF amplifier featuring high-gain, broad bandwidth and outstanding ruggedness to load mismatch, achieved by use of the new MRF1946A power transistor. It uses a die geometry intended for RF power devices operating in the UHF region. The emitter periphery (EP) to base area (BA) ratio of this die is 4.9, up from the normal EP/BA range of 1.5 to 3.5 for VHF devices. Power sharing and current sharing in the chip are controlled with diffused emitter resistors. The end result is a VHF transistor with very high power gain (10 + dB), sufficient so that processing steps can be taken to provide tolerance to load mismatch while still maintaining excellent performance. By mounting this die in the 0.380 flange or stud package and providing characterization data that spans 136 to 220 MHz, Motorola has provided a very versatile component for the RF designer.

CIRCUIT DESCRIPTION

Smith chart techniques were used to develop the two stage amplifier shown pictorially in Figure 1 and schematically in Figure 2. The end result is an amplifier that can produce 20 dB overall gain in the specified band (150 to 175 MHz), with a midband efficiency of 50 percent. The Motorola MRF237 was selected for the driver stage. This common emitter (TO-39) RF power transistor produces

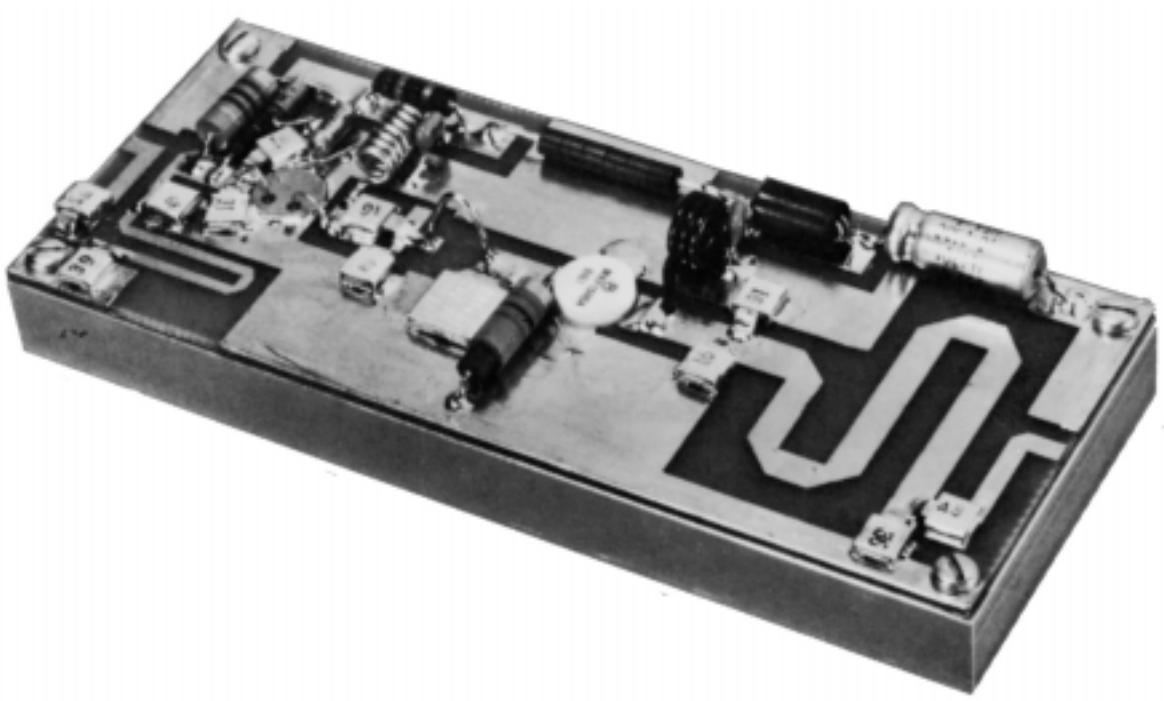
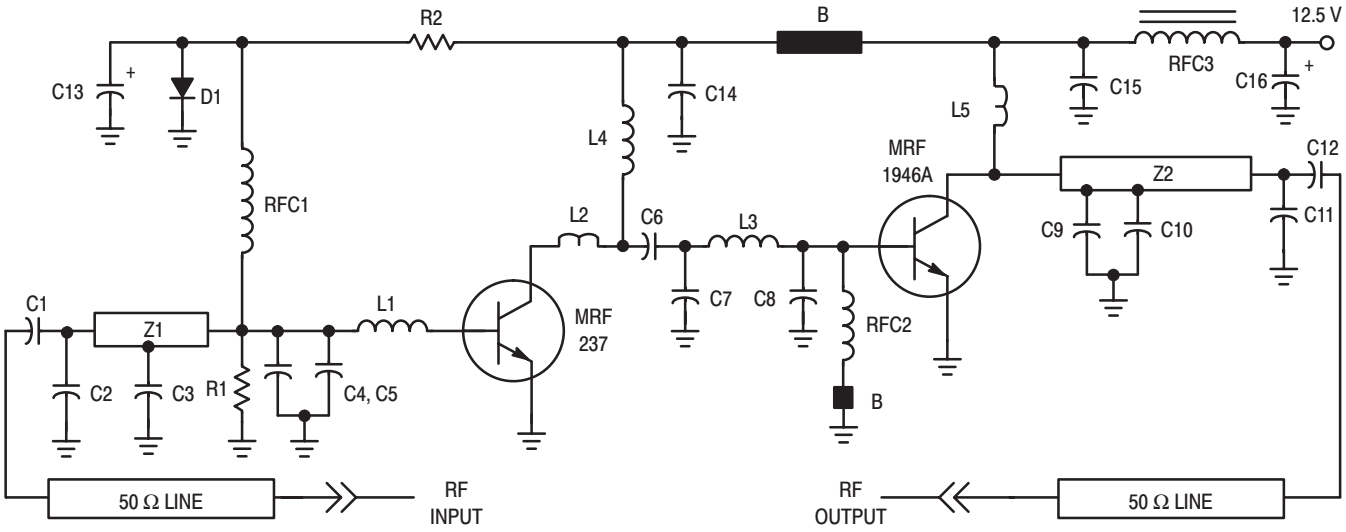


Figure 1. Engineering Model of MRF1946A Wideband Amplifier

high-gain, is easy to mount and is cost effective. In this design, the MRF237 is inserted into a hole in the circuit board and soldered to the ground plane for heat sinking, as shown in Figures 1 and 3. This method of attachment also provides a very effective emitter ground connection. By introducing a small amount of forward bias (5–15 mA) to the MRF237, it will track low drive levels and help maintain stability in the input stage. The amplifier is constructed on 1/16″, double sided G-10 board with 2 ounce copper cladding. A photomaster of the printed circuit board is shown in Figure 4. The top and bottom ground planes of the board are connected by wrapping the board edges with thin copper foil (0.002″) and then soldering it in place. Figures 1 and 3 illustrate how and where the board edges are wrapped in the prototype amplifier. No eyelets or plated-through-holes are required to achieve the level of performance noted here. Printed lines are used to match the devices' input and output impedance to 50 ohms, and an inductor and two capacitors form the interstage match. This allows some flexibility in shaping the overall frequency response and helps conserve board area. The MRF1946A stage is operated in Class C and is mounted to the heatsink using conventional methods, i.e.; an 8–32 stud inserted into an appropriately prepared heatsink. An alternate packaging arrangement, the 0.380 flange, allows one to attach the transistor to the topside of the heatsink with two screws. A Motorola Application Note on mounting techniques for various semiconductors is available and provides detailed information on installing either of these package styles (see reference 1). Additional information on thermal considerations can be found in reference 2. Performance of the amplifier is illustrated in Figures 5, 6 and 7. Figure 5 is a plot of P_{out} versus P_{in} at 160 MHz, 12.5 volts; Figure 6 shows output power, input VSWR and collector efficiency as functions of frequency; while Figure 7 demonstrates harmonic content for 30 watts output power.



C1 = 56 pF Dura Mica
C2 = 39 pF Mini-Unelco
C3, C7 = 68 pF Mini-Unelco
C4, C5, C6, C9, C10 = 91 pF Mini-Unelco
C8 = 250 pF Unelco J101
C11 = 36 pF Mini-Unelco
C12 = 43 pF Mini-Unelco
C13 = 1 μF, 25 V Tantalum
C14, C15 = 0.1 μF Mono-Block
C16 = 10 μF 25 V Electrolytic

D1 = Diode, 1N4933 or Equivalent
L1 = Base Lead Cut to 0.4″, Formed Into Loop
L2 = Collector Lead Cut to 0.35″, Formed Into Loop
L3 = 0.7" #18 AWG Into Loop
L4 = 7 Turns #18 AWG, 1/8″ ID
L5 = 3 Turns #16 Enam, 3/16″ ID
R1 = 10 Ω, 1/4 W Carbon

R2 = 1500 Ω, 1/2 W (Select For Most Appropriate ICQ)
RFC1 = 10 μH Molded Choke
RFC2 = 0.15 μH Molded Choke
RFC3 = VK200 – 4B Choke
Z1, Z2 = Printed Line
Z3 = 50 Ohm Printed Line
B = Ferroxcube Ferrite Bead 56-590-65-3B

Figure 2. Schematic Diagram of MRF1946A Wideband Amplifier

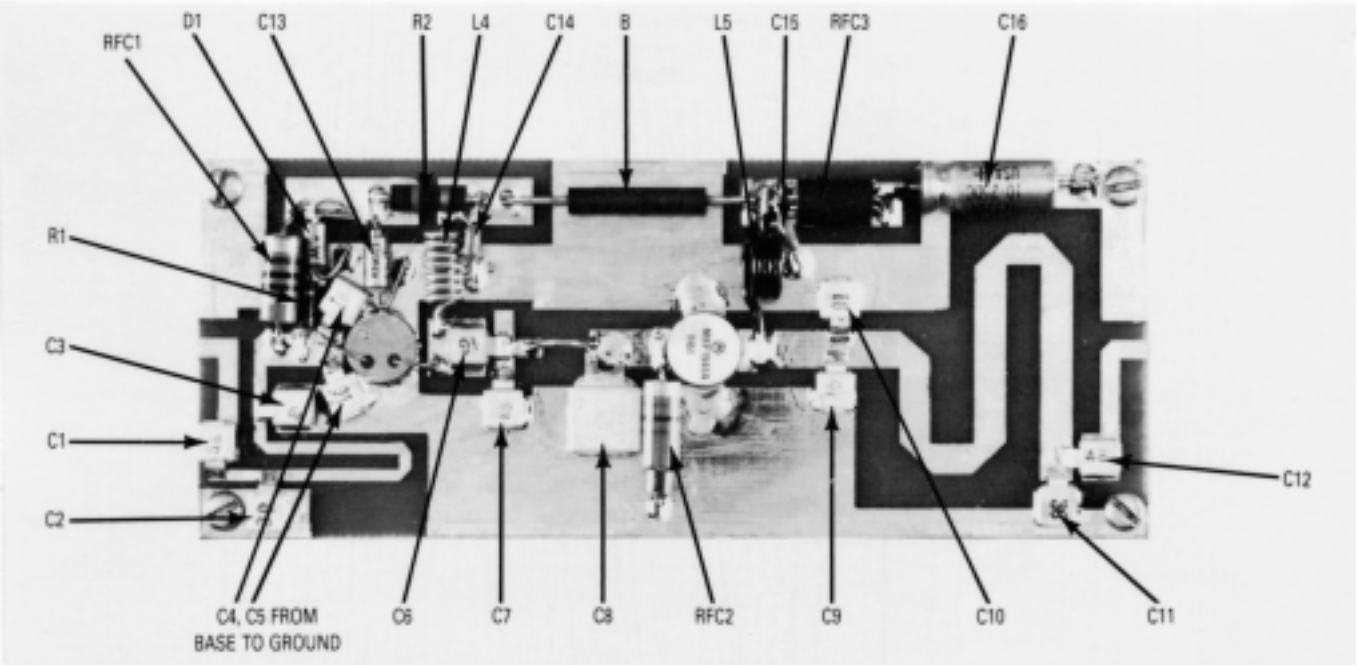
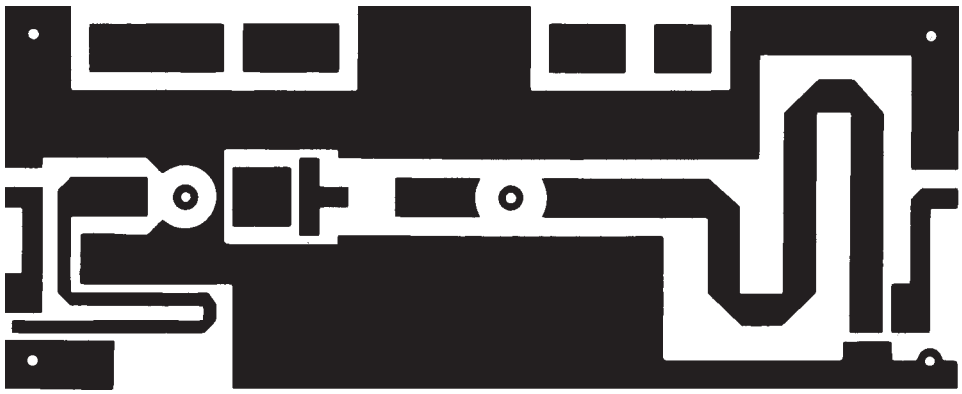


Figure 3. Parts Placement



NOTE: Not to scale.

Figure 4. PCB Photomaster

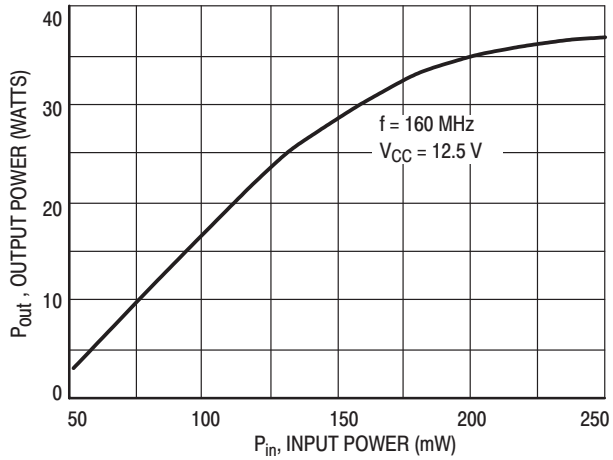


Figure 5. Output Power versus Input Power

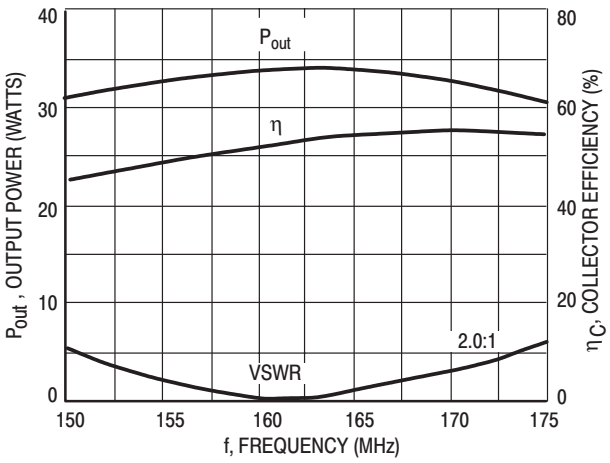


Figure 6. Output Power, Efficiency, and Input VSWR versus Frequency

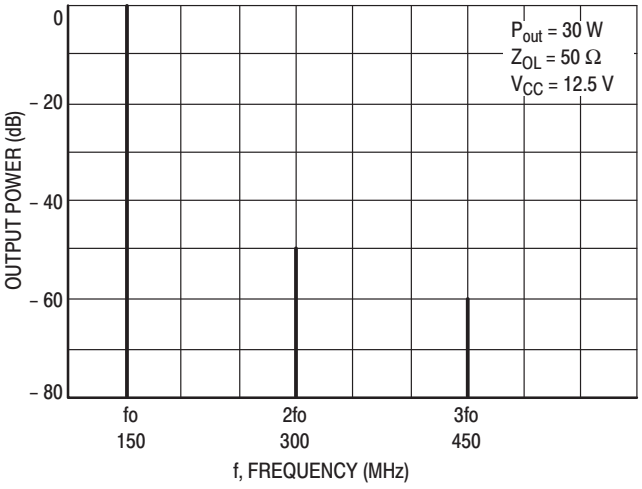


Figure 7. Output Spectrum

CONCLUSIONS

The two-stage amplifier described produces greater than 20 dB gain with 30 watts of output power over the frequency range of 150 to 175 MHz. Ruggedness and stability are achieved by use of the new MRF1946/A power transistor. The amplifier illustrates that relatively unsophisticated construction techniques properly implemented with the appropriate high gain devices can provide a cost effective 30 watt VHF amplifier for land mobile applications.

REFERENCES

1. Roehr, Bill: Mounting Techniques for Power Semiconductors, AN778. Motorola Semiconductor Products, Inc.
2. Johnsen, Robert J.: Thermal Rating of RF Power Transistors, AN790. Motorola Semiconductor Products, Inc.

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