

# The RF MOSFET Line

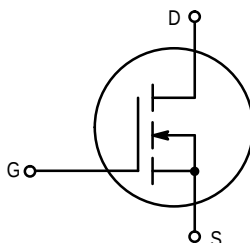
## RF Power

## Field-Effect Transistors

## N-Channel Enhancement-Mode MOSFET

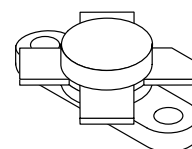
Designed for wideband large-signal amplifier and oscillator applications up to 400 MHz range, in single ended configuration.

- Guaranteed 28 Volt, 150 MHz Performance  
Output Power = 15 Watts  
Narrowband Gain = 16 dB (Typ)  
Efficiency = 60% (Typical)
- Small-Signal and Large-Signal Characterization
- 100% Tested For Load Mismatch At All Phase Angles With 30:1 VSWR
- Excellent Thermal Stability, Ideally Suited For Class A Operation
- Facilitates Manual Gain Control, ALC and Modulation Techniques



**MRF136**

15 W, to 400 MHz  
N-CHANNEL  
MOS BROADBAND  
RF POWER FET



CASE 211-07, STYLE 2

### MAXIMUM RATINGS

| Rating                                                                                 | Symbol    | Value       | Unit                         |
|----------------------------------------------------------------------------------------|-----------|-------------|------------------------------|
| Drain-Source Voltage                                                                   | $V_{DSS}$ | 65          | Vdc                          |
| Drain-Gate Voltage ( $R_{GS} = 1.0 \text{ M}\Omega$ )                                  | $V_{DGR}$ | 65          | Vdc                          |
| Gate-Source Voltage                                                                    | $V_{GS}$  | $\pm 40$    | Vdc                          |
| Drain Current — Continuous                                                             | $I_D$     | 2.5         | Adc                          |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$     | 55<br>0.314 | Watts<br>W/ $^\circ\text{C}$ |
| Storage Temperature Range                                                              | $T_{stg}$ | -65 to +150 | $^\circ\text{C}$             |
| Operating Junction Temperature                                                         | $T_J$     | 200         | $^\circ\text{C}$             |

### THERMAL CHARACTERISTICS

| Characteristic                       | Symbol          | Max | Unit               |
|--------------------------------------|-----------------|-----|--------------------|
| Thermal Resistance, Junction to Case | $R_{\theta JC}$ | 3.2 | $^\circ\text{C/W}$ |

NOTE – **CAUTION** – MOS devices are susceptible to damage from electrostatic charge. Reasonable precautions in handling and packaging MOS devices should be observed.

**ELECTRICAL CHARACTERISTICS** ( $T_C = 25^\circ\text{C}$  unless otherwise noted.)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**OFF CHARACTERISTICS (1)**

|                                                                      |               |    |   |     |                 |
|----------------------------------------------------------------------|---------------|----|---|-----|-----------------|
| Drain–Source Breakdown Voltage<br>( $V_{GS} = 0$ , $I_D = 5.0$ mA)   | $V_{(BR)DSS}$ | 65 | — | —   | Vdc             |
| Zero–Gate Voltage Drain Current<br>( $V_{DS} = 28$ V, $V_{GS} = 0$ ) | $I_{DSS}$     | —  | — | 2.0 | mAdc            |
| Gate–Source Leakage Current<br>( $V_{GS} = 40$ V, $V_{DS} = 0$ )     | $I_{GSS}$     | —  | — | 1.0 | $\mu\text{Adc}$ |

**ON CHARACTERISTICS (1)**

|                                                                |              |     |     |     |       |
|----------------------------------------------------------------|--------------|-----|-----|-----|-------|
| Gate Threshold Voltage<br>( $V_{DS} = 10$ V, $I_D = 25$ mA)    | $V_{GS(th)}$ | 1.0 | 3.0 | 6.0 | Vdc   |
| Forward Transconductance<br>( $V_{DS} = 10$ V, $I_D = 250$ mA) | $g_{fs}$     | 250 | 400 | —   | mmhos |

**DYNAMIC CHARACTERISTICS (1)**

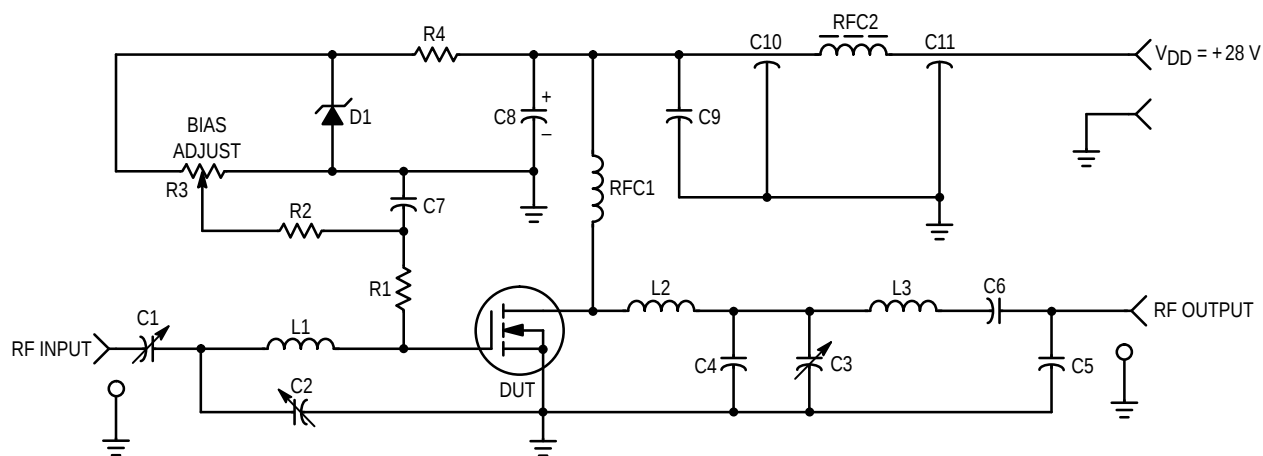
|                                                                                  |           |   |     |   |    |
|----------------------------------------------------------------------------------|-----------|---|-----|---|----|
| Input Capacitance<br>( $V_{DS} = 28$ V, $V_{GS} = 0$ , $f = 1.0$ MHz)            | $C_{iss}$ | — | 24  | — | pF |
| Output Capacitance<br>( $V_{DS} = 28$ V, $V_{GS} = 0$ , $f = 1.0$ MHz)           | $C_{oss}$ | — | 27  | — | pF |
| Reverse Transfer Capacitance<br>( $V_{DS} = 28$ V, $V_{GS} = 0$ , $f = 1.0$ MHz) | $C_{rss}$ | — | 5.5 | — | pF |

**FUNCTIONAL CHARACTERISTICS**

|                                                                                                                                            |          |                                |     |   |    |
|--------------------------------------------------------------------------------------------------------------------------------------------|----------|--------------------------------|-----|---|----|
| Noise Figure<br>( $V_{DS} = 28$ Vdc, $I_D = 500$ mA, $f = 150$ MHz)                                                                        | NF       | —                              | 1.0 | — | dB |
| Common Source Power Gain (Figure 1)<br>( $V_{DD} = 28$ Vdc, $P_{out} = 15$ W, $f = 150$ MHz, $I_{DQ} = 25$ mA)                             | $G_{ps}$ | 13                             | 16  | — | dB |
| Drain Efficiency (Figure 1)<br>( $V_{DD} = 28$ Vdc, $P_{out} = 15$ W, $f = 150$ MHz, $I_{DQ} = 25$ mA)                                     | $\eta$   | 50                             | 60  | — | %  |
| Electrical Ruggedness (Figure 1)<br>( $V_{DD} = 28$ Vdc, $P_{out} = 15$ W, $f = 150$ MHz, $I_{DQ} = 25$ mA, VSWR 30:1 at all Phase Angles) | $\psi$   | No Degradation in Output Power |     |   |    |

## NOTES:

- Each side measured separately.



C1, C2 — Arco 406, 15–115 pF or Equivalent  
 C3 — Arco 404, 8–60 pF or Equivalent  
 C4 — 43 pF Mini-Unelco or Equivalent  
 C5 — 24 pF Mini-Unelco or Equivalent  
 C6 — 680 pF, 100 Mils Chip  
 C7 — 0.01  $\mu$ F Ceramic  
 C8 — 100  $\mu$ F, 40 V  
 C9 — 0.1  $\mu$ F Ceramic  
 C10, C11 — 680 pF Feedthru  
 D1 — 1N5925A Motorola Zener

L1 — 2 Turns, 0.29" ID, #18 AWG, 0.10" Long  
 L2 — 2 Turns, 0.23" ID, #18 AWG, 0.10" Long  
 L3 — 2–1/4 Turns, 0.29" ID, #18 AWG, 0.125" Long  
 RFC1 — 20 Turns, 0.30" ID, #20 AWG Enamel Closewound  
 RFC2 — Ferroxcube VK-200 — 19/4B  
 R1 — 27  $\Omega$ , 1 W Thin Film  
 R2 — 10 k $\Omega$ , 1/4 W  
 R3 — 10 Turns, 10 k $\Omega$   
 R4 — 1.8 k $\Omega$ , 1/2 W  
 Board Material — 0.062" G10, 1 oz. Cu Clad, Double Sided

**Figure 1. 150 MHz Test Circuit**

## TYPICAL CHARACTERISTICS

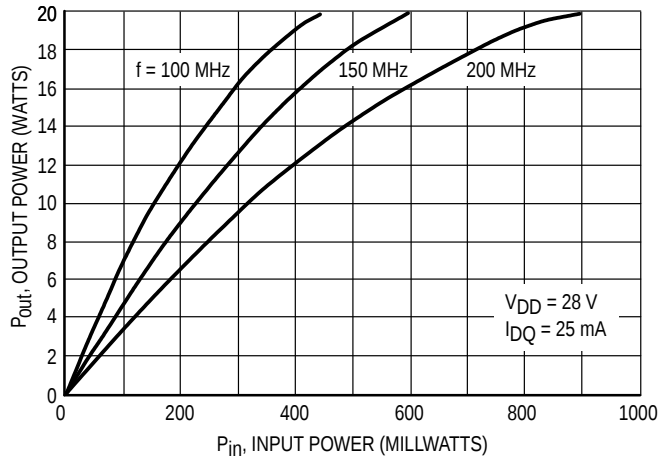


Figure 2. Output Power versus Input Power

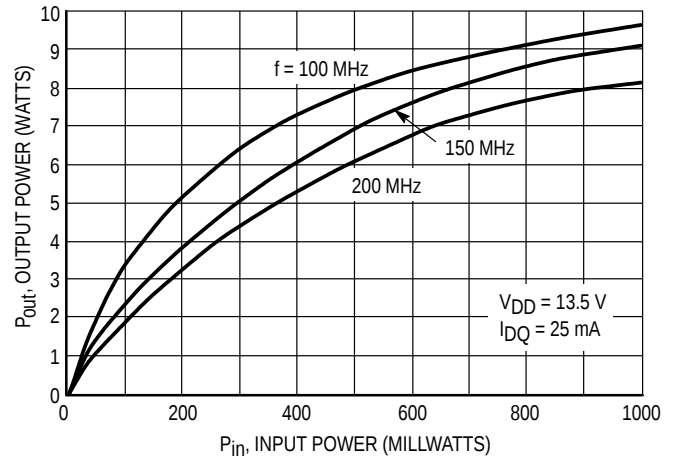


Figure 3. Output Power versus Input Power

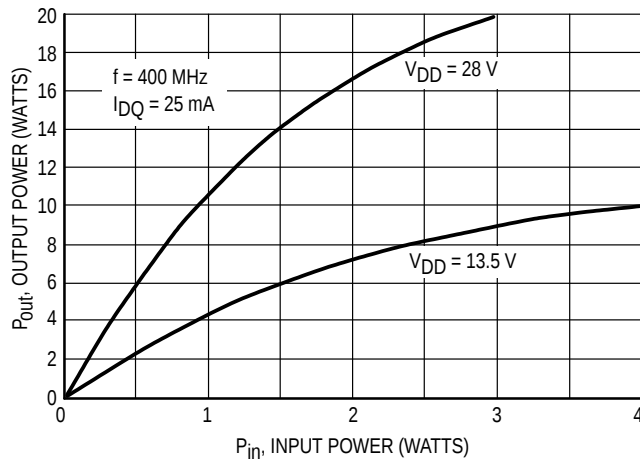


Figure 4. Output Power versus Input Power

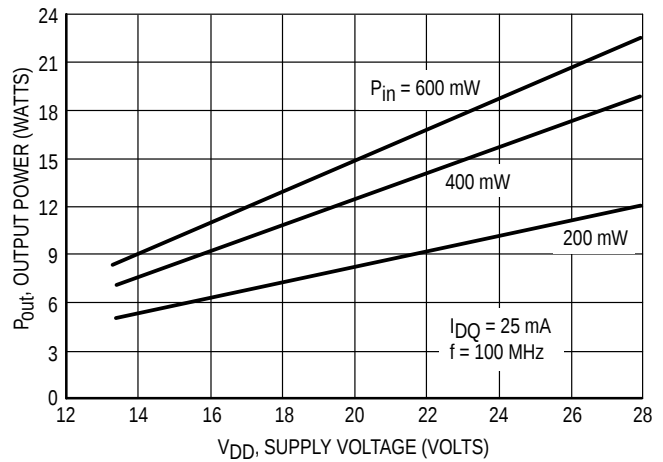


Figure 5. Output Power versus Supply Voltage

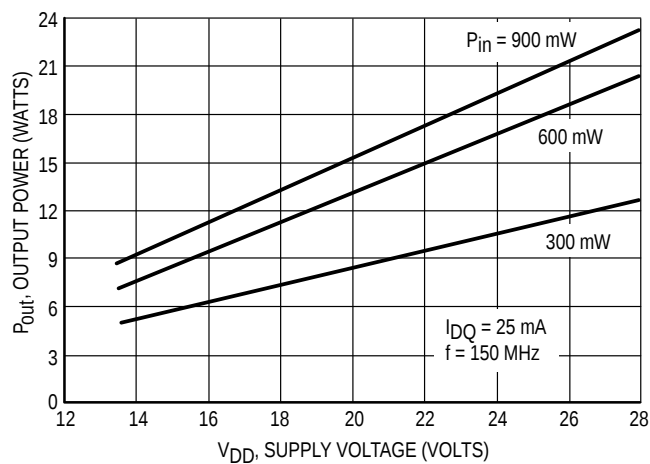


Figure 6. Output Power versus Supply Voltage

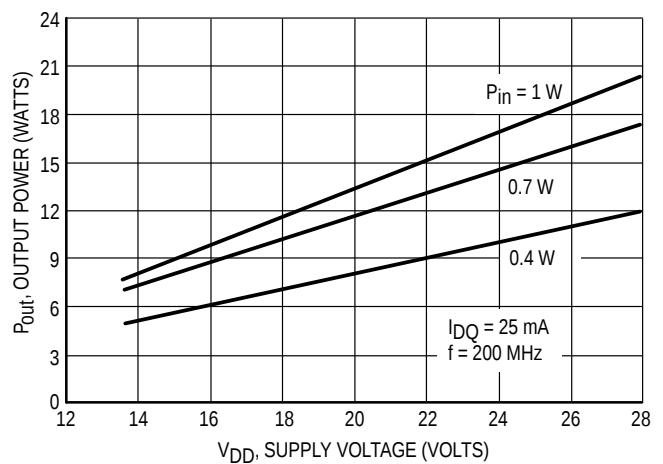


Figure 7. Output Power versus Supply Voltage

## TYPICAL CHARACTERISTICS

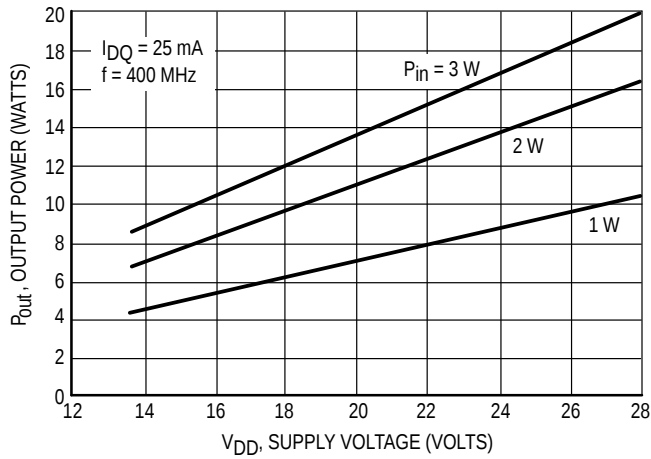


Figure 8. Output Power versus Supply Voltage

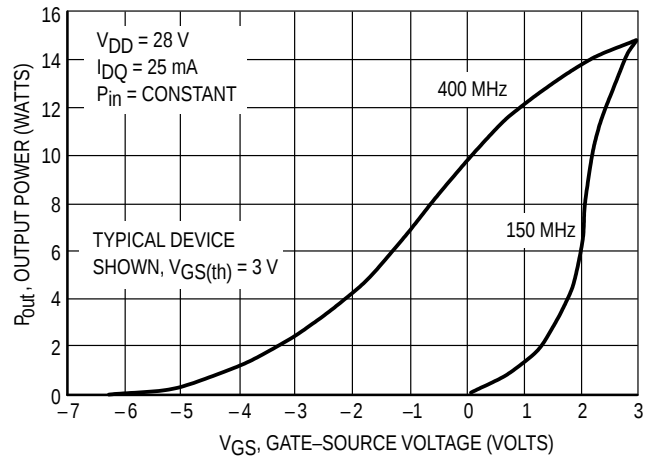


Figure 9. Output Power versus Gate Voltage

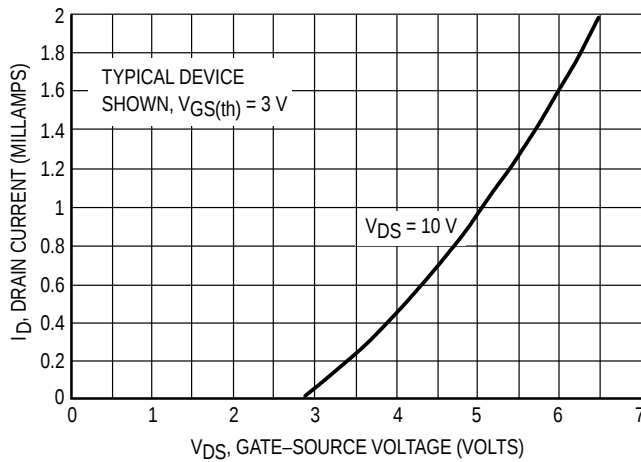


Figure 10. Drain Current versus Gate Voltage (Transfer Characteristics)

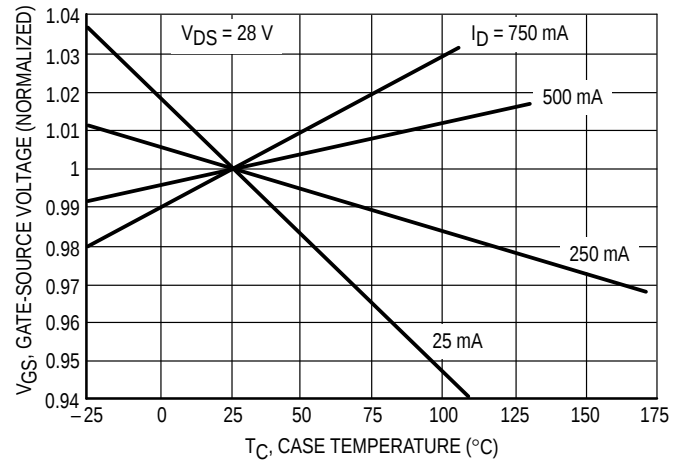


Figure 11. Gate-Source Voltage versus Case Temperature

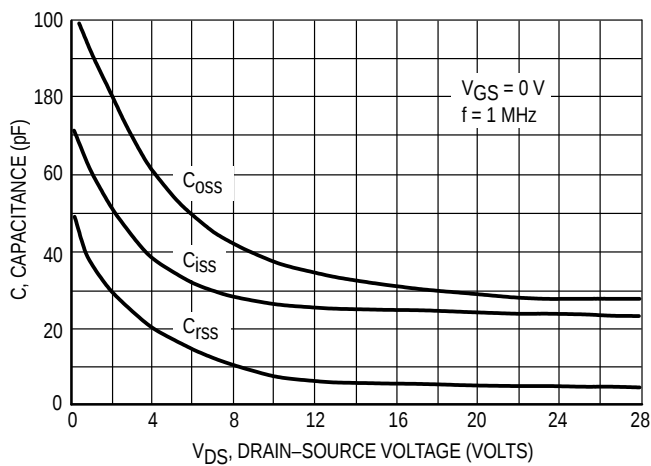


Figure 12. Capacitance versus Drain-Source Voltage

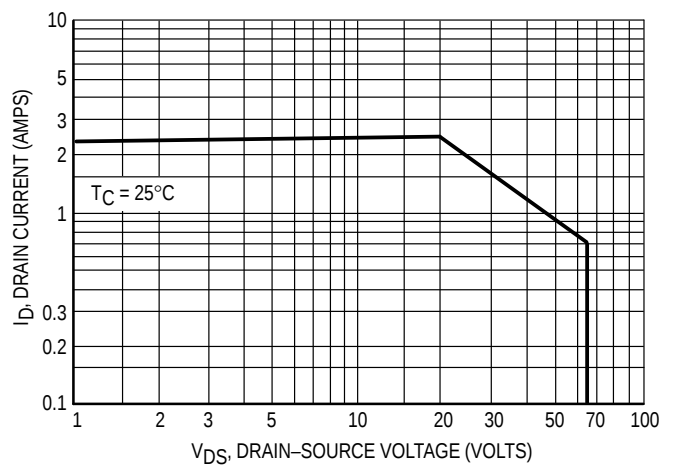


Figure 13. DC Safe Operating Area

## TYPICAL CHARACTERISTICS

### TYPICAL 400 MHz PERFORMANCE

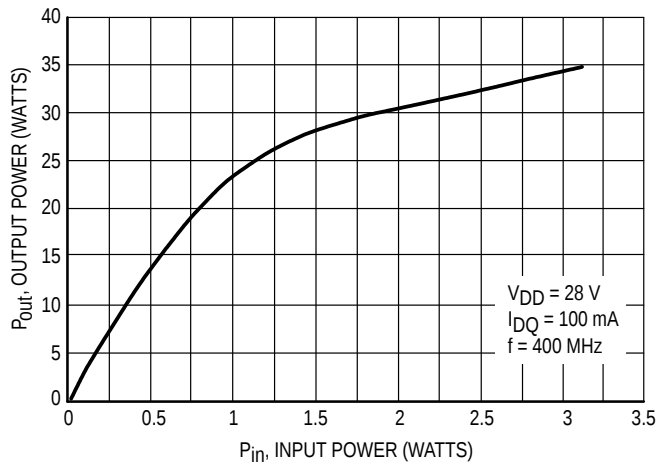


Figure 14. Output Power versus Input Power

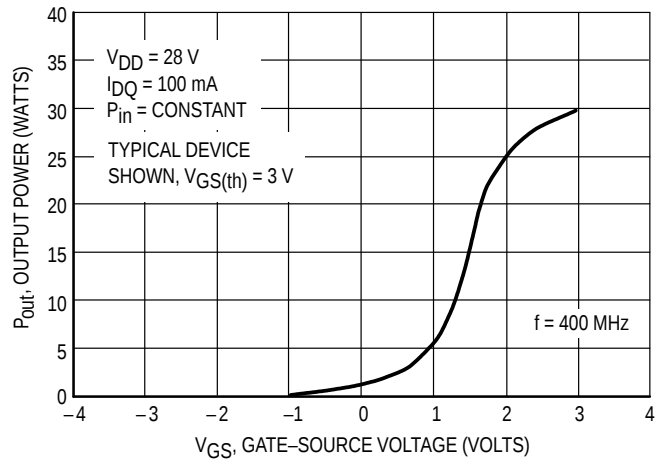


Figure 15. Output Power versus Gate Voltage

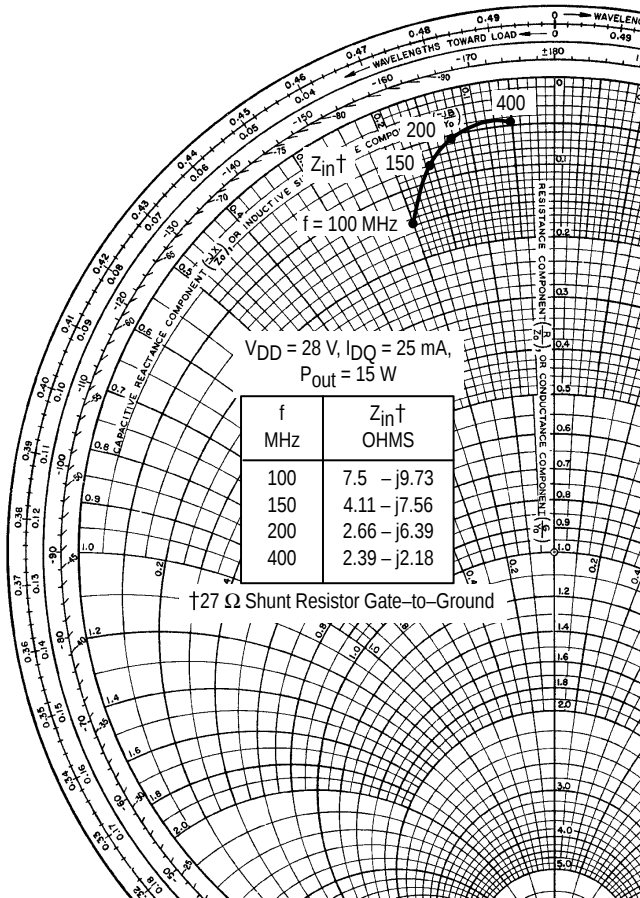


Figure 16. Large-Signal Series Equivalent Input Impedance,  $Z_{in}^{\dagger}$

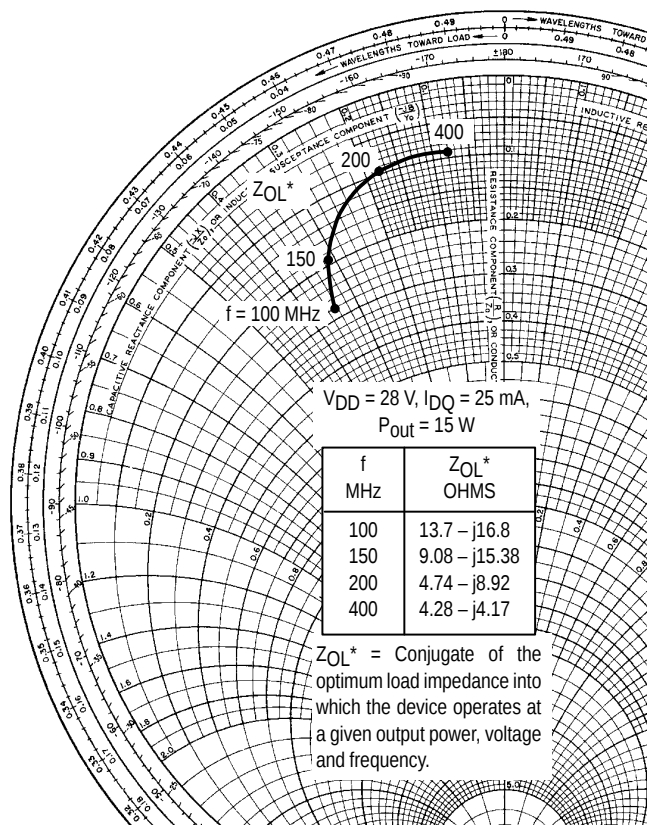


Figure 17. Large-Signal Series Equivalent Output Impedance,  $Z_{OL}^*$

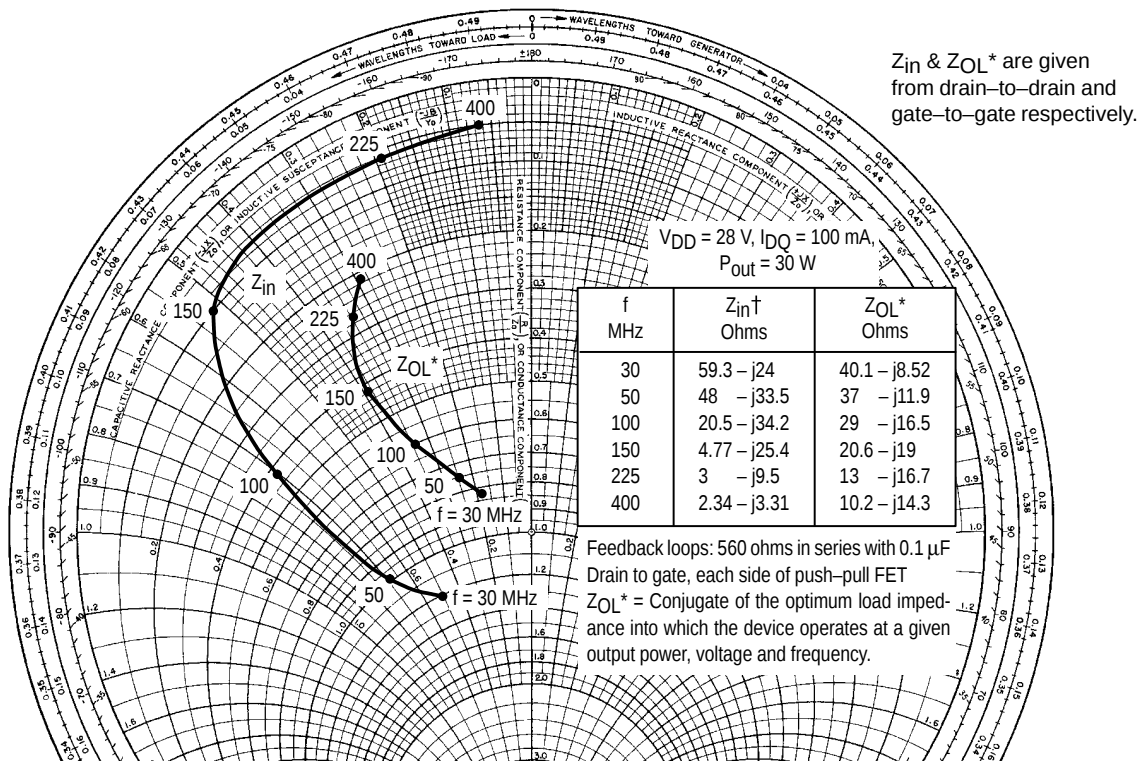
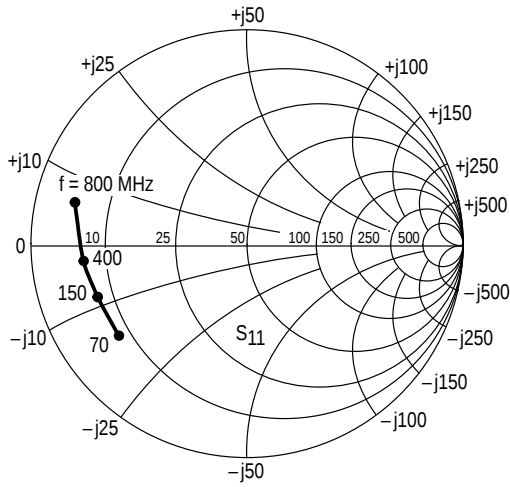


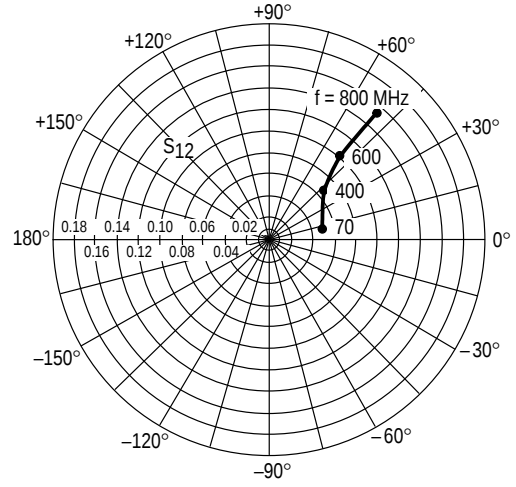
Figure 18. Input and Outut Impedance

| f<br>(MHz) | S <sub>11</sub> |      | S <sub>21</sub> |     | S <sub>12</sub> |    | S <sub>22</sub> |      |
|------------|-----------------|------|-----------------|-----|-----------------|----|-----------------|------|
|            | S <sub>11</sub> | φ    | S <sub>21</sub> | φ   | S <sub>12</sub> | φ  | S <sub>22</sub> | φ    |
| 2.0        | 0.988           | -11  | 41.19           | 173 | 0.006           | 67 | 0.729           | -12  |
| 5.0        | 0.970           | -27  | 40.07           | 164 | 0.014           | 62 | 0.720           | -31  |
| 10         | 0.923           | -52  | 35.94           | 149 | 0.026           | 54 | 0.714           | -58  |
| 20         | 0.837           | -88  | 27.23           | 129 | 0.040           | 36 | 0.690           | -96  |
| 30         | 0.784           | -111 | 20.75           | 117 | 0.046           | 27 | 0.684           | -118 |
| 40         | 0.751           | -125 | 16.49           | 108 | 0.048           | 22 | 0.680           | -131 |
| 50         | 0.733           | -135 | 13.41           | 103 | 0.050           | 19 | 0.679           | -139 |
| 60         | 0.720           | -142 | 11.43           | 99  | 0.050           | 16 | 0.678           | -145 |
| 70         | 0.709           | -147 | 9.871           | 96  | 0.050           | 14 | 0.679           | -149 |
| 80         | 0.707           | -152 | 8.663           | 93  | 0.051           | 13 | 0.683           | -153 |
| 90         | 0.706           | -155 | 7.784           | 91  | 0.051           | 13 | 0.682           | -155 |
| 100        | 0.708           | -157 | 7.008           | 88  | 0.051           | 13 | 0.680           | -157 |
| 110        | 0.711           | -159 | 6.435           | 86  | 0.051           | 14 | 0.681           | -158 |
| 120        | 0.714           | -161 | 5.899           | 85  | 0.051           | 15 | 0.682           | -159 |
| 130        | 0.717           | -163 | 5.439           | 82  | 0.052           | 16 | 0.684           | -160 |
| 140        | 0.720           | -164 | 5.068           | 80  | 0.052           | 17 | 0.684           | -161 |
| 150        | 0.723           | -165 | 4.709           | 80  | 0.052           | 18 | 0.686           | -161 |
| 160        | 0.727           | -166 | 4.455           | 78  | 0.052           | 18 | 0.690           | -161 |
| 170        | 0.732           | -167 | 4.200           | 77  | 0.052           | 18 | 0.694           | -162 |
| 180        | 0.735           | -168 | 3.967           | 75  | 0.052           | 19 | 0.699           | -162 |
| 190        | 0.738           | -169 | 3.756           | 74  | 0.052           | 19 | 0.703           | -163 |
| 200        | 0.740           | -170 | 3.545           | 73  | 0.052           | 20 | 0.706           | -163 |
| 225        | 0.746           | -171 | 3.140           | 69  | 0.053           | 22 | 0.717           | -163 |
| 250        | 0.742           | -172 | 2.783           | 67  | 0.053           | 25 | 0.724           | -163 |
| 275        | 0.744           | -173 | 2.540           | 64  | 0.054           | 27 | 0.724           | -163 |
| 300        | 0.751           | -174 | 2.323           | 60  | 0.055           | 29 | 0.736           | -163 |
| 325        | 0.757           | -175 | 2.140           | 58  | 0.058           | 32 | 0.749           | -163 |
| 350        | 0.760           | -176 | 1.963           | 54  | 0.059           | 35 | 0.758           | -163 |
| 375        | 0.762           | -177 | 1.838           | 52  | 0.062           | 38 | 0.768           | -163 |
| 400        | 0.774           | -179 | 1.696           | 50  | 0.065           | 41 | 0.783           | -163 |
| 425        | 0.775           | -179 | 1.590           | 48  | 0.068           | 43 | 0.793           | -163 |
| 450        | 0.781           | +179 | 1.493           | 46  | 0.071           | 46 | 0.805           | -163 |
| 475        | 0.787           | +177 | 1.415           | 43  | 0.074           | 47 | 0.813           | -164 |
| 500        | 0.792           | +176 | 1.332           | 40  | 0.079           | 48 | 0.825           | -164 |
| 525        | 0.797           | +175 | 1.259           | 38  | 0.083           | 50 | 0.831           | -164 |
| 550        | 0.801           | +175 | 1.185           | 37  | 0.088           | 51 | 0.843           | -164 |
| 575        | 0.810           | +174 | 1.145           | 36  | 0.094           | 52 | 0.855           | -164 |
| 600        | 0.816           | +173 | 1.091           | 34  | 0.101           | 52 | 0.869           | -165 |
| 625        | 0.818           | +171 | 1.041           | 32  | 0.106           | 53 | 0.871           | -165 |
| 650        | 0.825           | +170 | 0.994           | 30  | 0.112           | 53 | 0.884           | -165 |
| 675        | 0.834           | +169 | 0.962           | 29  | 0.119           | 53 | 0.890           | -165 |
| 700        | 0.837           | +168 | 0.922           | 27  | 0.127           | 53 | 0.906           | -166 |
| 725        | 0.836           | +167 | 0.879           | 25  | 0.133           | 52 | 0.909           | -167 |
| 750        | 0.841           | +166 | 0.838           | 25  | 0.140           | 53 | 0.917           | -167 |
| 775        | 0.844           | +165 | 0.824           | 24  | 0.148           | 52 | 0.933           | -167 |
| 800        | 0.846           | +163 | 0.785           | 21  | 0.154           | 50 | 0.941           | -168 |

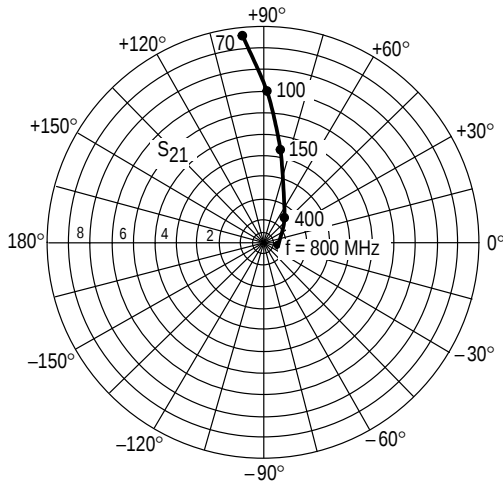
Table 1. Common Source Scattering Parameters  
V<sub>DS</sub> = 28 V, I<sub>D</sub> = 0.5 A



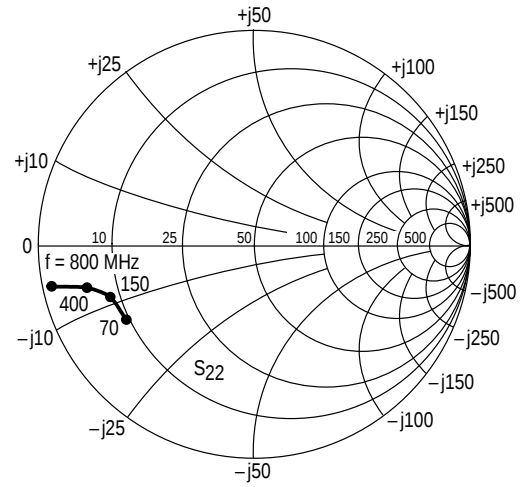
**Figure 19.  $S_{11}$ , Input Reflection Coefficient versus Frequency**  
 $V_{DS} = 28\text{ V}$   $I_D = 0.5\text{ A}$



**Figure 20.  $S_{12}$ , Reverse Transmission Coefficient versus Frequency**  
 $V_{DS} = 28\text{ V}$   $I_D = 0.5\text{ A}$



**Figure 21.  $S_{21}$ , Forward Transmission Coefficient versus Frequency**  
 $V_{DS} = 28\text{ V}$   $I_D = 0.5\text{ A}$



**Figure 22.  $S_{22}$ , Output Reflection Coefficient versus Frequency**  
 $V_{DS} = 28\text{ V}$   $I_D = 0.5\text{ A}$

## DESIGN CONSIDERATIONS

The MRF136 is an RF power N-Channel enhancement mode field-effect transistor (FET) designed especially for HF and VHF power amplifier applications. M/A-COM RF MOS FETs feature planar design for optimum manufacturability.

M/A-COM Application Note AN211A, FETs in Theory and Practice, is suggested reading for those not familiar with the construction and characteristics of FETs.

The major advantages of RF power FETs include high gain, low noise, simple bias systems, relative immunity from thermal runaway, and the ability to withstand severely mismatched loads without suffering damage. Power output can be varied over a wide range with a low power dc control signal, thus facilitating manual gain control, ALC and modulation.

## DC BIAS

The MRF136 is an enhancement mode FET and, therefore, does not conduct when drain voltage is applied without gate bias. A positive gate voltage causes drain current to flow (see Figure 10). RF power FETs require forward bias for optimum gain and power output. A Class AB condition with quiescent drain current ( $I_{DQ}$ ) in the 25–100 mA range is sufficient for many applications. For special requirements such as linear amplification,  $I_{DQ}$  may have to be adjusted to optimize the critical parameters.

The MOS gate is a dc open circuit. Since the gate bias circuit does not have to deliver any current to the FET, a simple resistive divider arrangement may sometimes suffice for this function. Special applications may require more elaborate gate bias systems.

## GAIN CONTROL

Power output of the MRF136 may be controlled from rated values down to the milliwatt region (>20 dB reduction in power output with constant input power) by varying the dc gate

voltage. This feature, not available in bipolar RF power devices, facilitates the incorporation of manual gain control, AGC/ALC and modulation schemes into system designs. A full range of power output control may require dc gate voltage excursions into the negative region.

## AMPLIFIER DESIGN

Impedance matching networks similar to those used with bipolar transistors are suitable for MRF136. See M/A-COM Application Note AN721, Impedance Matching Networks Applied to RF Power Transistors. Both small signal scattering parameters and large signal impedance parameters are provided. Large signal impedances should be used for network designs wherever possible. While the s parameters will not produce an exact design solution for high power operation, they do yield a good first approximation. This is particularly useful at frequencies outside those presented in the large signal impedance plots.

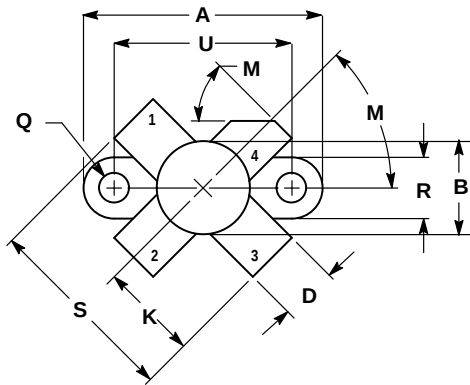
RF power FETs are triode devices and are therefore not unilateral. This, coupled with the very high gain, yields a device capable of self oscillation. Stability may be achieved using techniques such as drain loading, input shunt resistive loading, or feedback. S parameter stability analysis can provide useful information in the selection of loading and/or feedback to insure stable operation. The MRF136 was characterized with a 27 ohm input shunt loading resistor.

For further discussion of RF amplifier stability and the use of two port parameters in RF amplifier design, see M/A-COM Application Note AN215A.

## LOW NOISE OPERATION

Input resistive loading will degrade noise performance, and noise figure may vary significantly with gate driving impedance. A low loss input matching network with its gate impedance optimized for lowest noise is recommended.

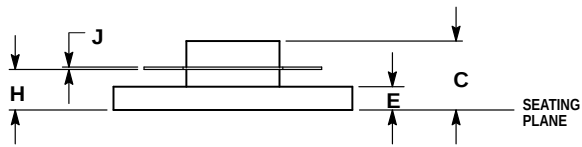
## PACKAGE DIMENSIONS



- NOTES:  
 1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.  
 2. CONTROLLING DIMENSION: INCH.

| DIM | INCHES |       | MILLIMETERS |       |
|-----|--------|-------|-------------|-------|
|     | MIN    | MAX   | MIN         | MAX   |
| A   | 0.960  | 0.990 | 24.39       | 25.14 |
| B   | 0.370  | 0.390 | 9.40        | 9.90  |
| C   | 0.229  | 0.281 | 5.82        | 7.13  |
| D   | 0.215  | 0.235 | 5.47        | 5.96  |
| E   | 0.085  | 0.105 | 2.16        | 2.66  |
| H   | 0.150  | 0.108 | 3.81        | 4.57  |
| J   | 0.004  | 0.006 | 0.11        | 0.15  |
| K   | 0.395  | 0.405 | 10.04       | 10.28 |
| M   | 40°    | 50°   | 40°         | 50°   |
| Q   | 0.113  | 0.130 | 2.88        | 3.30  |
| R   | 0.245  | 0.255 | 6.23        | 6.47  |
| S   | 0.790  | 0.810 | 20.07       | 20.57 |
| U   | 0.720  | 0.730 | 18.29       | 18.54 |

- STYLE 2:  
 PIN 1. SOURCE  
 2. GATE  
 3. SOURCE  
 4. DRAIN



**CASE 211-07  
 ISSUE N**

*Specifications subject to change without notice.*

- **North America:** Tel. (800) 366-2266, Fax (800) 618-8883
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- **Europe:** Tel. +44 (1344) 869 595, Fax+44 (1344) 300 020

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