

# RF Power Field Effect Transistors

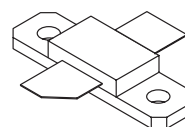
## N-Channel Enhancement-Mode Lateral MOSFETs

Designed for broadband commercial and industrial applications with frequencies up to 1000 MHz. The high gain and broadband performance of these devices make them ideal for large-signal, common-source amplifier applications in 26 volt base station equipment.

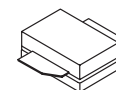
- Typical Two-Tone Performance at 945 MHz, 26 Volts
  - Output Power — 60 Watts PEP
  - Power Gain — 17 dB
  - Efficiency — 40%
  - IMD — -31 dBc
- Integrated ESD Protection
- Designed for Maximum Gain and Insertion Phase Flatness
- Capable of Handling 10:1 VSWR, @ 26 Vdc, 945 MHz, 60 Watts CW Output Power
- Excellent Thermal Stability
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- In Tape and Reel. R1 Suffix = 500 Units per 32 mm, 13 inch Reel.
- Low Gold Plating Thickness on Leads. L Suffix Indicates 40μ" Nominal.

**MRF9060LR1**  
**MRF9060LSR1**

**945 MHz, 60 W, 26 V**  
**LATERAL N-CHANNEL**  
**BROADBAND**  
**RF POWER MOSFETs**



**CASE 360B-05, STYLE 1**  
**NI-360**  
**MRF9060LR1**



**CASE 360C-05, STYLE 1**  
**NI-360S**  
**MRF9060LSR1**

**Table 1. Maximum Ratings**

| Rating                                                                | Symbol           | Value                      | Unit                   |
|-----------------------------------------------------------------------|------------------|----------------------------|------------------------|
| Drain-Source Voltage                                                  | V <sub>DSS</sub> | -0.5, +65                  | Vdc                    |
| Gate-Source Voltage                                                   | V <sub>GS</sub>  | -0.5, +15                  | Vdc                    |
| Total Device Dissipation @ T <sub>C</sub> = 25°C<br>Derate above 25°C | P <sub>D</sub>   | 159<br>0.91<br>219<br>1.25 | W<br>W/°C<br>W<br>W/°C |
| Storage Temperature Range                                             | T <sub>stg</sub> | -65 to +150                | °C                     |
| Operating Junction Temperature                                        | T <sub>J</sub>   | 200                        | °C                     |

**Table 2. Thermal Characteristics**

| Characteristic                       | Symbol           | Value      | Unit |
|--------------------------------------|------------------|------------|------|
| Thermal Resistance, Junction to Case | R <sub>θJC</sub> | 1.1<br>0.8 | °C/W |

**Table 3. ESD Protection Characteristics**

| Test Conditions  | Class        |
|------------------|--------------|
| Human Body Model | 1 (Minimum)  |
| Machine Model    | M1 (Minimum) |

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

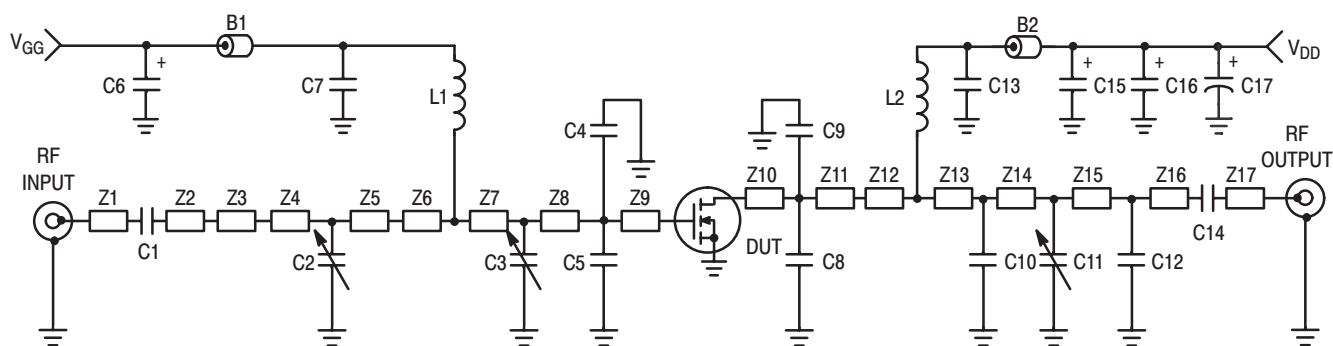
**Table 4. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

| Characteristic                                                                                                        | Symbol       | Min | Typ  | Max | Unit            |
|-----------------------------------------------------------------------------------------------------------------------|--------------|-----|------|-----|-----------------|
| <b>Off Characteristics</b>                                                                                            |              |     |      |     |                 |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 65\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )                     | $I_{DSS}$    | —   | —    | 10  | $\mu\text{Adc}$ |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 26\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )                     | $I_{DSS}$    | —   | —    | 1   | $\mu\text{Adc}$ |
| Gate–Source Leakage Current<br>( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )                                  | $I_{GSS}$    | —   | —    | 1   | $\mu\text{Adc}$ |
| <b>On Characteristics</b>                                                                                             |              |     |      |     |                 |
| Gate Threshold Voltage<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 200\text{ }\mu\text{Adc}$ )                             | $V_{GS(th)}$ | 2   | 2.9  | 4   | Vdc             |
| Gate Quiescent Voltage<br>( $V_{DS} = 26\text{ Vdc}$ , $I_D = 450\text{ mAdc}$ )                                      | $V_{GS(Q)}$  | —   | 3.7  | —   | Vdc             |
| Drain–Source On–Voltage<br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 1.3\text{ Adc}$ )                                      | $V_{DS(on)}$ | —   | 0.17 | 0.4 | Vdc             |
| Forward Transconductance<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 4\text{ Adc}$ )                                       | $g_{fs}$     | —   | 5.3  | —   | S               |
| <b>Dynamic Characteristics</b>                                                                                        |              |     |      |     |                 |
| Input Capacitance<br>( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )            | $C_{iss}$    | —   | 98   | —   | pF              |
| Output Capacitance<br>( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )           | $C_{oss}$    | —   | 50   | —   | pF              |
| Reverse Transfer Capacitance<br>( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$    | —   | 2    | —   | pF              |

(continued)

**Table 4. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted) (continued)

| Characteristic                                                                                                                                                                                                                                           | Symbol    | Min                            | Typ | Max | Unit |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------|-----|-----|------|
| <b>Functional Tests</b> (In Freescale Test Fixture, 50 ohm system)                                                                                                                                                                                       |           |                                |     |     |      |
| Two-Tone Common-Source Amplifier Power Gain<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                            | $G_{ps}$  | 16                             | 17  | —   | dB   |
| Two-Tone Drain Efficiency<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                              | $\eta$    | 36                             | 40  | —   | %    |
| 3rd Order Intermodulation Distortion<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                   | IMD       | —                              | -31 | -28 | dBc  |
| Input Return Loss<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                                      | IRL       | —                              | -16 | -9  | dB   |
| Two-Tone Common-Source Amplifier Power Gain<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ ) | $G_{ps}$  | —                              | 17  | —   | dB   |
| Two-Tone Drain Efficiency<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ )                   | $\eta$    | —                              | 39  | —   | %    |
| 3rd Order Intermodulation Distortion<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ )        | IMD       | —                              | -31 | —   | dBc  |
| Input Return Loss<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ )                           | IRL       | —                              | -16 | —   | dB   |
| Power Output, 1 dB Compression Point<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                               | $P_{1dB}$ | —                              | 70  | —   | W    |
| Common-Source Amplifier Power Gain<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                                 | $G_{ps}$  | —                              | 17  | —   | dB   |
| Drain Efficiency<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                                                   | $\eta$    | —                              | 51  | —   | %    |
| Output Mismatch Stress<br>( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ ,<br>$f = 945.0\text{ MHz}$ , VSWR = 10:1, All Phase Angles at Frequency<br>of Tests)                                                       | $\Psi$    | No Degradation In Output Power |     |     |      |

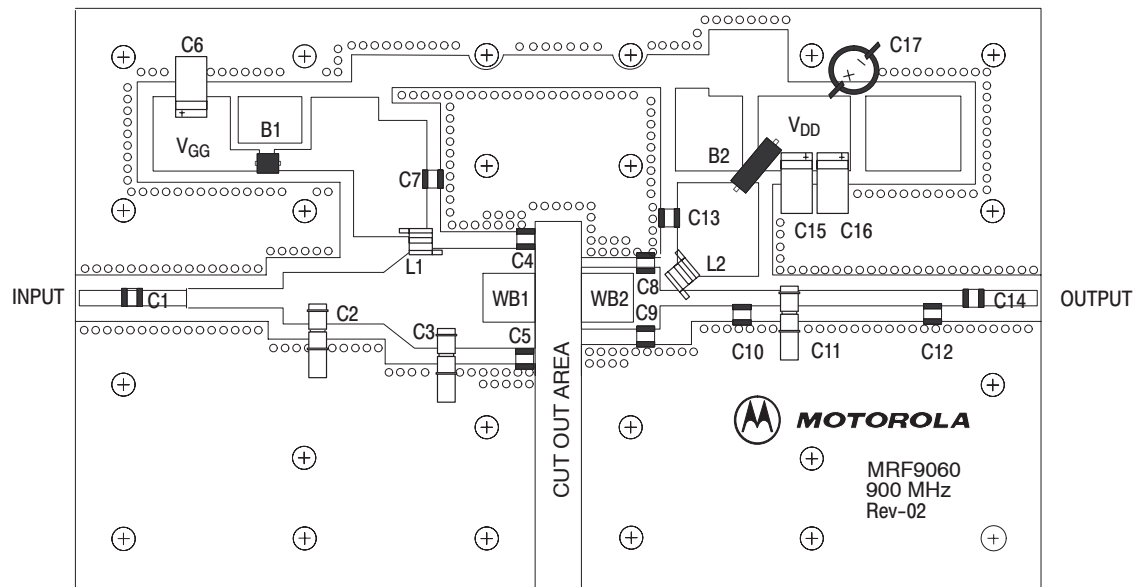


|    |                               |     |                                                 |
|----|-------------------------------|-----|-------------------------------------------------|
| Z1 | 0.240" x 0.060" Microstrip    | Z10 | 0.360" x 0.270" Microstrip                      |
| Z2 | 0.240" x 0.060" Microstrip    | Z11 | 0.060" x 0.270" Microstrip                      |
| Z3 | 0.500" x 0.100" Microstrip    | Z12 | 0.110" x 0.060" Microstrip                      |
| Z4 | 0.180" x 0.270" Microstrip    | Z13 | 0.330" x 0.060" Microstrip                      |
| Z5 | 0.350" x 0.270" Microstrip    | Z14 | 0.230" x 0.060" Microstrip                      |
| Z6 | 0.270" x 0.520 x 0.140" Taper | Z15 | 0.740" x 0.060" Microstrip                      |
| Z7 | 0.170" x 0.520" Microstrip    | Z16 | 0.130" x 0.060" Microstrip                      |
| Z8 | 0.410" x 0.520" Microstrip    | Z17 | 0.340" x 0.060" Microstrip                      |
| Z9 | 0.060" x 0.520" Microstrip    | PCB | Taconic RF-35-0300, 30 mil, $\epsilon_r = 3.55$ |

**Figure 1. 945 MHz Broadband Test Circuit Schematic**

**Table 5. 945 MHz Broadband Test Circuit Component Designations and Values**

| Part             | Description                                                         | Part Number                      | Manufacturer |
|------------------|---------------------------------------------------------------------|----------------------------------|--------------|
| B1               | Short Ferrite Bead                                                  | 95F786                           | Newark       |
| B2               | Long Ferrite Bead                                                   | 95F787                           | Newark       |
| C1, C7, C13, C14 | 47 pF Chip Capacitors                                               | 100B470JP 500X                   | ATC          |
| C2, C3, C11      | 0.8–8.0 Gigatrim Variable Capacitors                                | 44F3360                          | Newark       |
| C4, C5, C8, C9   | 10 pF Chip Capacitors                                               | 100B100JP 500X                   | ATC          |
| C6, C15, C16     | 10 $\mu$ F, 35 V Tantalum Chip Capacitor                            | 93F2975                          | Newark       |
| C10              | 3.0 pF Chip Capacitor                                               | 100B3R0JP 500X                   | ATC          |
| C12              | 0.5 pF Chip Capacitor (MRF9060)<br>0.7 pF Chip Capacitor (MRF9060S) | 100B0R5BP 500X<br>100B0R7BP 500X | ATC<br>ATC   |
| C17              | 220 $\mu$ F Electrolytic Chip Capacitor                             | 14F185                           | Newark       |
| L1, L2           | 12.5 nH Inductors                                                   | A04T-5                           | Coilcraft    |
| N1, N2           | N-Type Panel Mount, Stripline                                       | 3052-1648-10                     | Avnet        |
| WB1, WB2         | 10 mil Brass Wear Blocks                                            |                                  |              |



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**Figure 2. 930 – 960 MHz Broadband Test Circuit Component Layout**

## TYPICAL CHARACTERISTICS

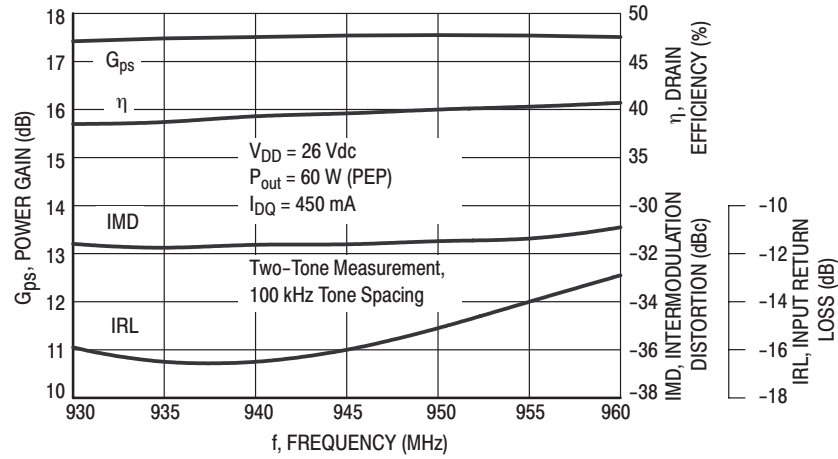


Figure 3. Class AB Broadband Circuit Performance

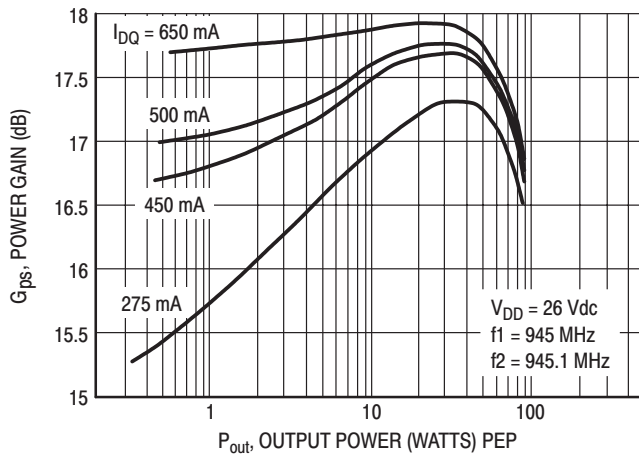


Figure 4. Power Gain versus Output Power

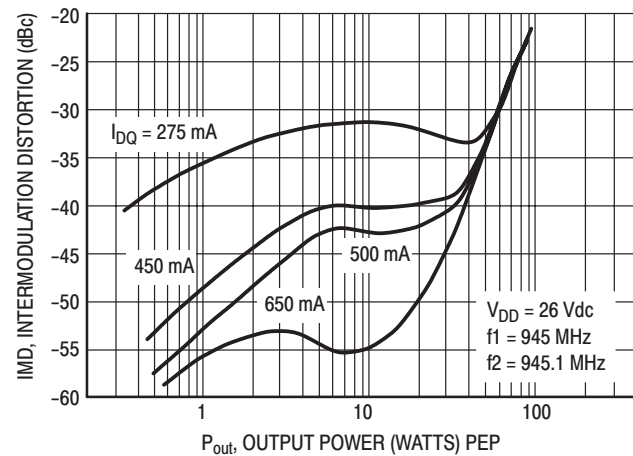


Figure 5. Intermodulation Distortion versus Output Power

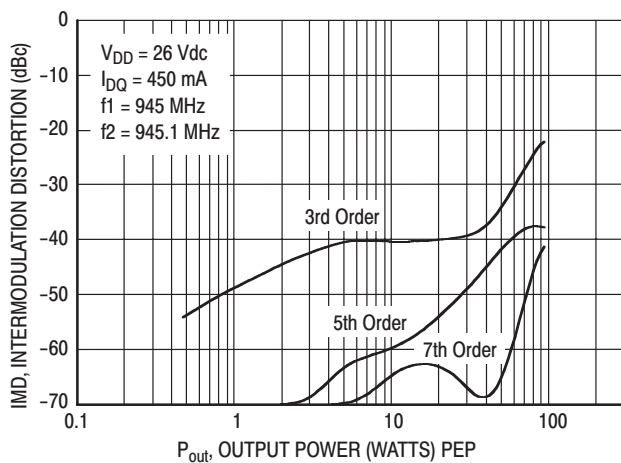


Figure 6. Intermodulation Distortion Products versus Output Power

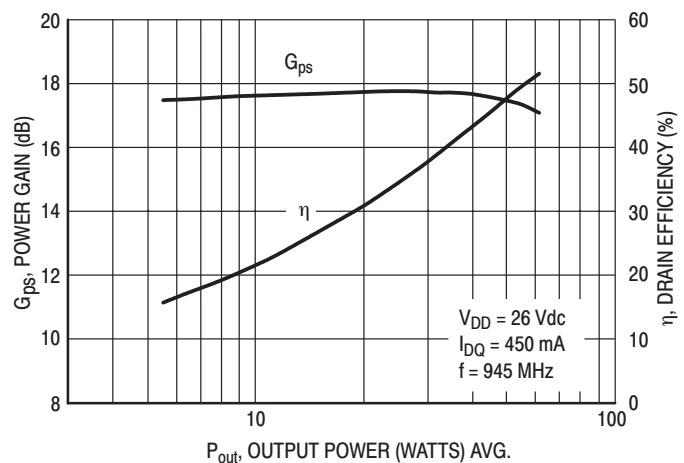
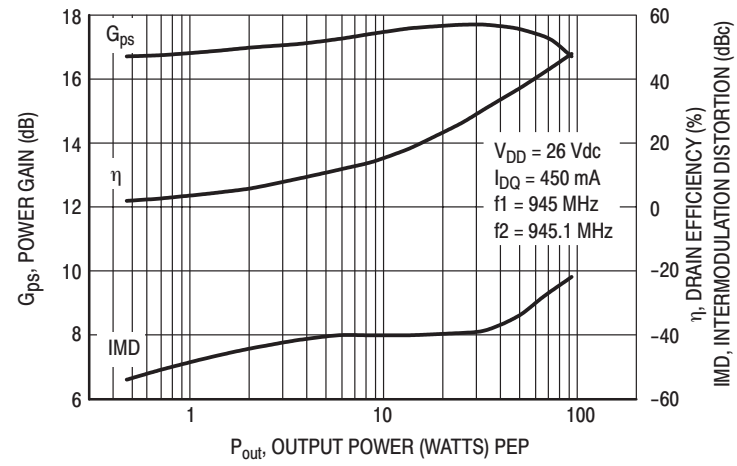
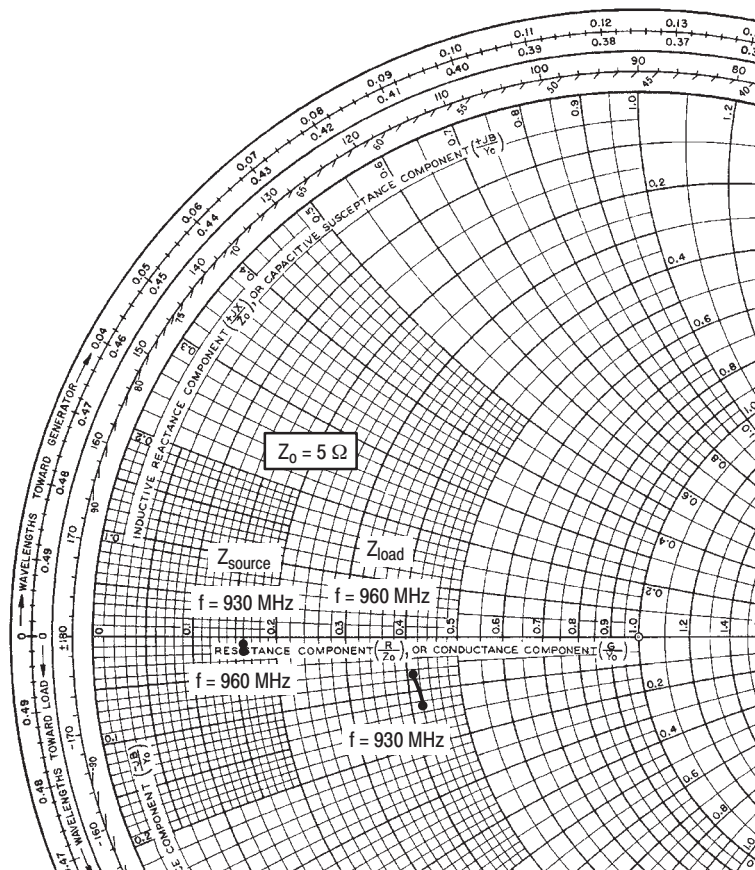


Figure 7. Power Gain and Efficiency versus Output Power

## TYPICAL CHARACTERISTICS



**Figure 8. Power Gain, Efficiency, and IMD versus Output Power**



$V_{DD} = 26\text{ V}$ ,  $I_{DQ} = 450\text{ mA}$ ,  $P_{out} = 60\text{ W PEP}$

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 930      | $0.80 - j0.10$           | $2.08 - j0.65$         |
| 945      | $0.80 - j0.05$           | $2.07 - j0.38$         |
| 960      | $0.81 - j0.10$           | $2.04 - j0.37$         |

$Z_{source}$  = Test circuit impedance as measured from gate to ground.

$Z_{load}$  = Test circuit impedance as measured from drain to ground.

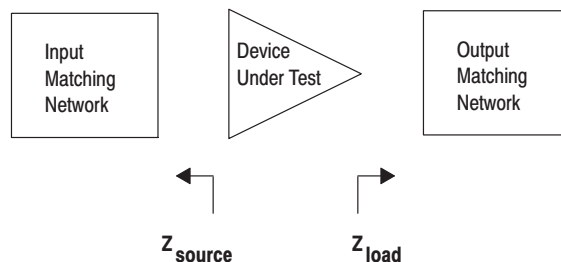


Figure 9. Series Equivalent Source and Load Impedance



## NOTES



## NOTES



- |     | INCHES    |       | MILLIMETERS |       |
|-----|-----------|-------|-------------|-------|
| DIM | MIN       | MAX   | MIN         | MAX   |
| A   | 0.795     | 0.805 | 20.19       | 20.45 |
| B   | 0.225     | 0.235 | 5.72        | 5.97  |
| C   | 0.125     | 0.175 | 3.18        | 4.45  |
| D   | 0.210     | 0.220 | 5.33        | 5.59  |
| E   | 0.055     | 0.065 | 1.40        | 1.65  |
| F   | 0.004     | 0.006 | 0.10        | 0.15  |
| G   | 0.562 BSC |       | 14.28 BSC   |       |
| H   | 0.077     | 0.087 | 1.96        | 2.21  |
| K   | 0.220     | 0.250 | 5.59        | 6.35  |
| M   | 0.355     | 0.365 | 9.02        | 9.27  |
| N   | 0.357     | 0.363 | 9.07        | 9.22  |
| Q   | 0.125     | 0.135 | 3.18        | 3.43  |
| R   | 0.227     | 0.233 | 5.77        | 5.92  |
| S   | 0.225     | 0.235 | 5.72        | 5.97  |
| aaa | 0.005 REF |       | 0.13 REF    |       |
| bbb | 0.010 REF |       | 0.25 REF    |       |
| ccc | 0.015 REF |       | 0.38 REF    |       |

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



- | DIM | INCHES    |       | MILLIMETERS |      |
|-----|-----------|-------|-------------|------|
|     | MIN       | MAX   | MIN         | MAX  |
| A   | 0.375     | 0.385 | 9.53        | 9.78 |
| B   | 0.225     | 0.235 | 5.72        | 5.97 |
| C   | 0.105     | 0.155 | 2.67        | 3.94 |
| D   | 0.210     | 0.220 | 5.33        | 5.59 |
| E   | 0.035     | 0.045 | 0.89        | 1.14 |
| F   | 0.004     | 0.006 | 0.10        | 0.15 |
| H   | 0.057     | 0.067 | 1.45        | 1.70 |
| K   | 0.085     | 0.115 | 2.16        | 2.92 |
| M   | 0.355     | 0.365 | 9.02        | 9.27 |
| N   | 0.357     | 0.363 | 9.07        | 9.22 |
| R   | 0.227     | 0.23  | 5.77        | 5.92 |
| S   | 0.225     | 0.235 | 5.72        | 5.97 |
| aaa | 0.005 REF |       | 0.13 REF    |      |
| bbb | 0.010 REF |       | 0.25 REF    |      |
| ccc | 0.015 REF |       | 0.38 REF    |      |

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

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