

# 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 28 volt base station equipment.

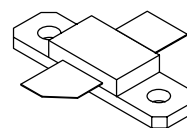
- Typical Two-Tone Performance at 945 MHz, 28 Volts  
Output Power — 45 Watts PEP  
Power Gain — 18.8 dB  
Efficiency — 42%  
IMD — -32 dBc
- Capable of Handling 10:1 VSWR, @ 28 Vdc, 945 MHz, 45 Watts CW Output Power

### Features

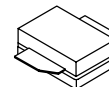
- Integrated ESD Protection
- Designed for Maximum Gain and Insertion Phase Flatness
- Excellent Thermal Stability
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Low Gold Plating Thickness on Leads. L Suffix Indicates 40μ" Nominal.
- RoHS Compliant
- In Tape and Reel. R1 Suffix = 500 Units per 32 mm, 13 inch Reel.

**MRF9045LR1**  
**MRF9045LSR1**

**945 MHz, 45 W, 28 V**  
**LATERAL N-CHANNEL**  
**BROADBAND**  
**RF POWER MOSFETs**



**CASE 360B-05, STYLE 1**  
**NI-360**  
**MRF9045LR1**



**CASE 360C-05, STYLE 1**  
**NI-360S**  
**MRF9045LSR1**

**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>   | 125<br>0.71<br>175<br>1 | W<br>W/°C |
| Storage Temperature Range                                             | T <sub>stg</sub> | - 65 to +150            | °C        |
| Case Operating Temperature                                            | T <sub>C</sub>   | 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> | 1.4<br>1.0 | °C/W |

**Table 3. ESD Protection Characteristics**

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

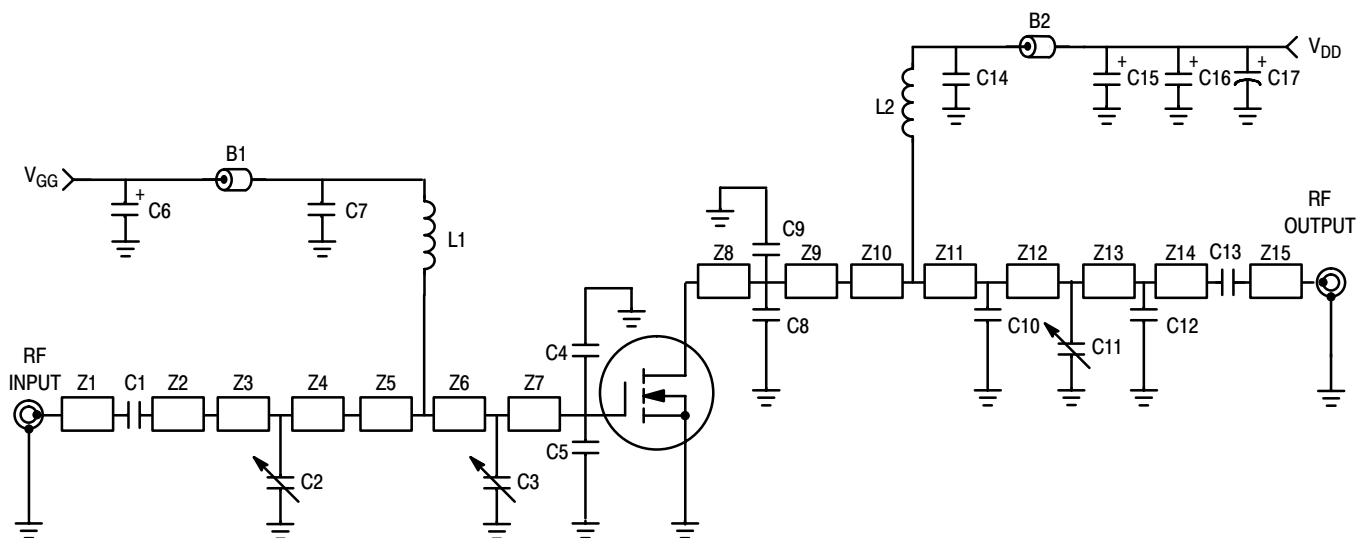
**Table 4. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

| 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>( $V_{DS} = 28\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )                     | $I_{DSS}$    | —   | —    | 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>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 150\text{ }\mu\text{Adc}$ )                             | $V_{GS(th)}$ | 2   | 3    | 4   | Vdc             |
| Gate Quiescent Voltage<br>( $V_{DS} = 28\text{ Vdc}$ , $I_D = 350\text{ mAdc}$ )                                      | $V_{GS(Q)}$  | —   | 3.7  | —   | Vdc             |
| Drain-Source On-Voltage<br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 1\text{ Adc}$ )                                        | $V_{DS(on)}$ | —   | 0.19 | 0.4 | Vdc             |
| Forward Transconductance<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 3\text{ Adc}$ )                                       | $g_{fs}$     | —   | 4    | —   | S               |
| <b>Dynamic Characteristics</b>                                                                                        |              |     |      |     |                 |
| Input Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )            | $C_{iss}$    | —   | 69   | —   | pF              |
| Output Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )           | $C_{oss}$    | —   | 37   | —   | pF              |
| Reverse Transfer Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$    | —   | 1.5  | —   | pF              |

(continued)

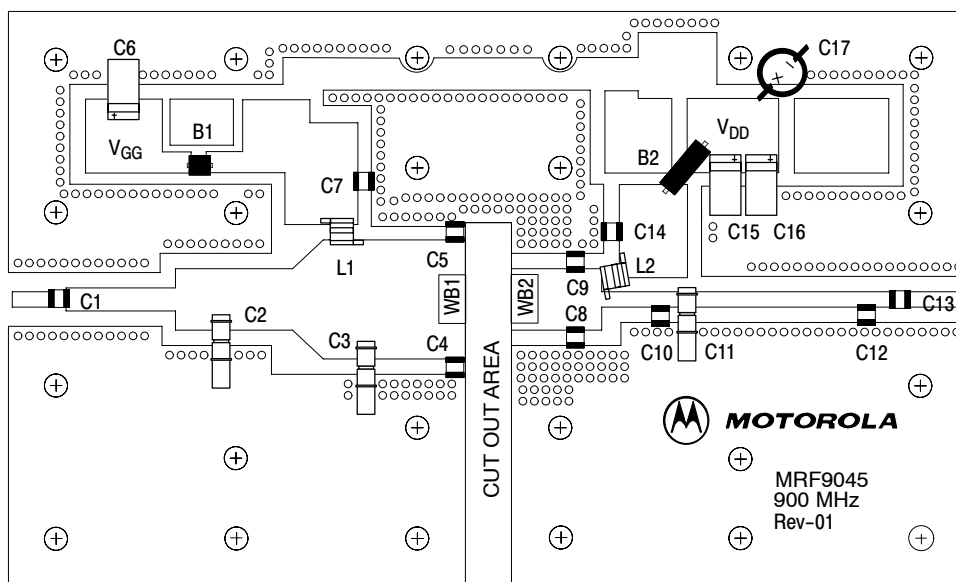
**Table 4. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted) (continued)

| 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>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                            | $G_{ps}$  | 17  | 18.8 | —   | dB   |
| Two-Tone Drain Efficiency<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                              | $\eta$    | 38  | 42   | —   | %    |
| 3rd Order Intermodulation Distortion<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                   | IMD       | —   | -32  | -28 | dBc  |
| Input Return Loss<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )                                                                                      | IRL       | —   | -14  | -9  | dB   |
| Two-Tone Common-Source Amplifier Power Gain<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ ) | $G_{ps}$  | —   | 18.5 | —   | dB   |
| Two-Tone Drain Efficiency<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ ,<br>$f_2 = 960.1\text{ MHz}$ )                   | $\eta$    | —   | 41   | —   | %    |
| 3rd Order Intermodulation Distortion<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<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       | —   | -33  | —   | dBc  |
| Input Return Loss<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W PEP}$ , $I_{DQ} = 350\text{ mA}$ ,<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       | —   | 13   | —   | dB   |
| Power Output, 1 dB Compression Point<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W CW}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                               | $P_{1dB}$ | —   | 55   | —   | W    |
| Common-Source Amplifier Power Gain<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W CW}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                                 | $G_{ps}$  | —   | 18   | —   | dB   |
| Drain Efficiency<br>( $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 45\text{ W CW}$ , $I_{DQ} = 350\text{ mA}$ ,<br>$f_1 = 945.0\text{ MHz}$ )                                                                                                                   | $\eta$    | —   | 60   | —   | %    |



|                  |                                                         |     |                                                 |
|------------------|---------------------------------------------------------|-----|-------------------------------------------------|
| B1               | Short Ferrite Bead Surface Mount                        | Z4  | 0.360" x 0.320" Microstrip                      |
| B2               | Long Ferrite Bead Surface Mount                         | Z5  | 0.240" x 0.320" x 0.620", Taper                 |
| C1, C7, C13, C14 | 47 pF Chip Capacitors                                   | Z6  | 0.140" x 0.620" Microstrip                      |
| C2, C3, C11      | 0.8-8.0 pF Gigatrim Variable Trim Capacitors            | Z7  | 0.510" x 0.620" Microstrip                      |
| C4, C5, C8, C9   | 10 pF Chip Capacitors                                   | Z8  | 0.330" x 0.320" Microstrip                      |
| C6, C15, C16     | 10 $\mu$ F, 35 V Tantalum Surface Mount Chip Capacitors | Z9  | 0.140" x 0.320" Microstrip                      |
| C10              | 2.2 pF Chip Capacitor                                   | Z10 | 0.070" x 0.080" Microstrip                      |
| C12              | 0.7 pF Chip Capacitor - MRF9045LS                       | Z11 | 0.240" x 0.080" Microstrip                      |
| C17              | 220 $\mu$ F, 50 V Electrolytic Capacitor                | Z12 | 0.140" x 0.080" Microstrip                      |
| L1, L2           | 12.5 nH Surface Mount Inductors, Coilcraft              | Z13 | 0.930" x 0.080" Microstrip                      |
| Z1               | 0.260" x 0.080" Microstrip                              | Z14 | 0.180" x 0.080" Microstrip                      |
| Z2               | 0.610" x 0.120" Microstrip                              | Z15 | 0.350" x 0.080" Microstrip                      |
| Z3               | 0.260" x 0.320" Microstrip                              | PCB | Arlon GX-0300-55-22, 0.03", $\epsilon_r = 2.55$ |

Figure 1. 930 - 960 MHz Broadband Test Circuit Schematic



Freescall has begun the transition of marking Printed Circuit Boards (PCBs) with the Freescall Semiconductor signature/logo. PCBs may have either Motorola or Freescall markings during the transition period. These changes will have no impact on form, fit or function of the current product.

Figure 2. 930 - 960 MHz Broadband Test Circuit Component Layout

# TYPICAL CHARACTERISTICS

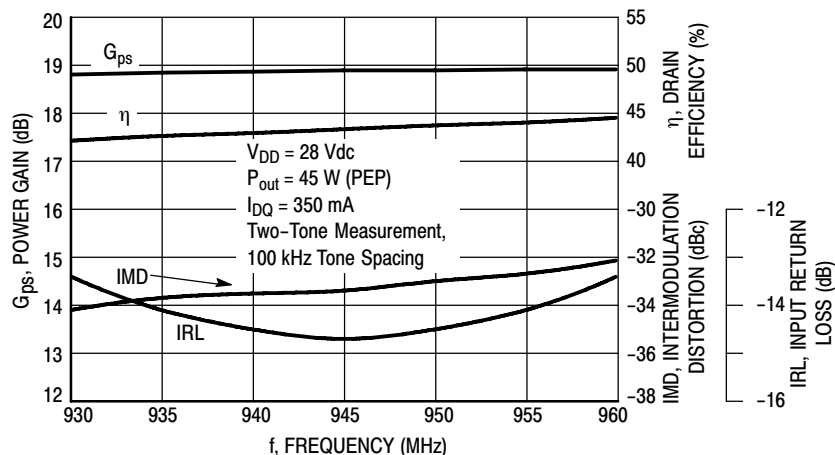


Figure 3. Class AB Broadband Circuit Performance

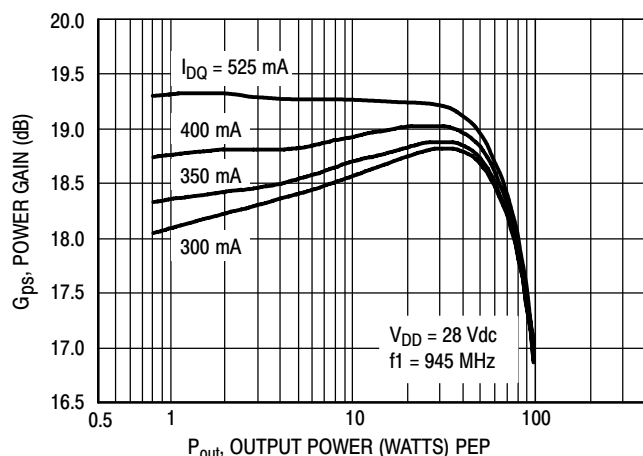


Figure 4. Power Gain versus Output Power

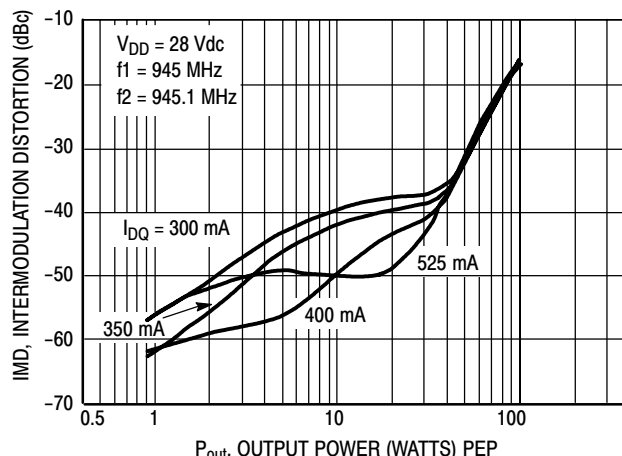


Figure 5. Intermodulation Distortion versus Output Power

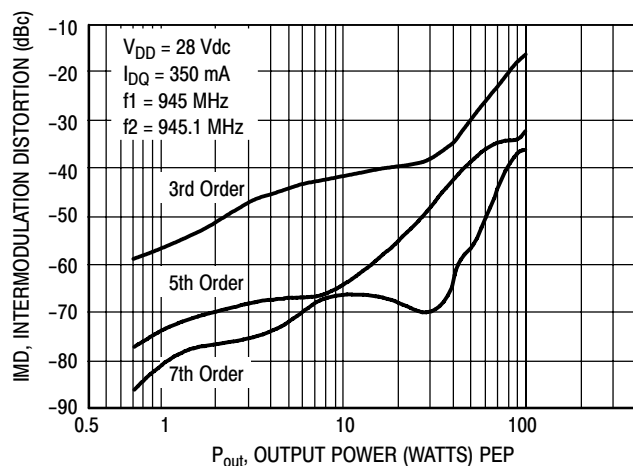


Figure 6. Intermodulation Distortion Products versus Output Power

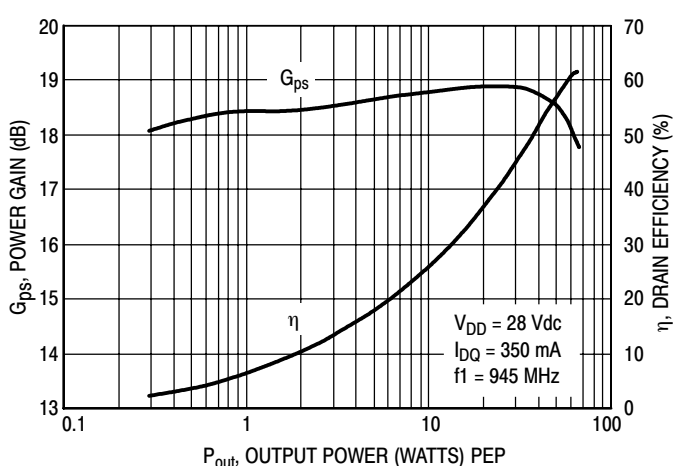
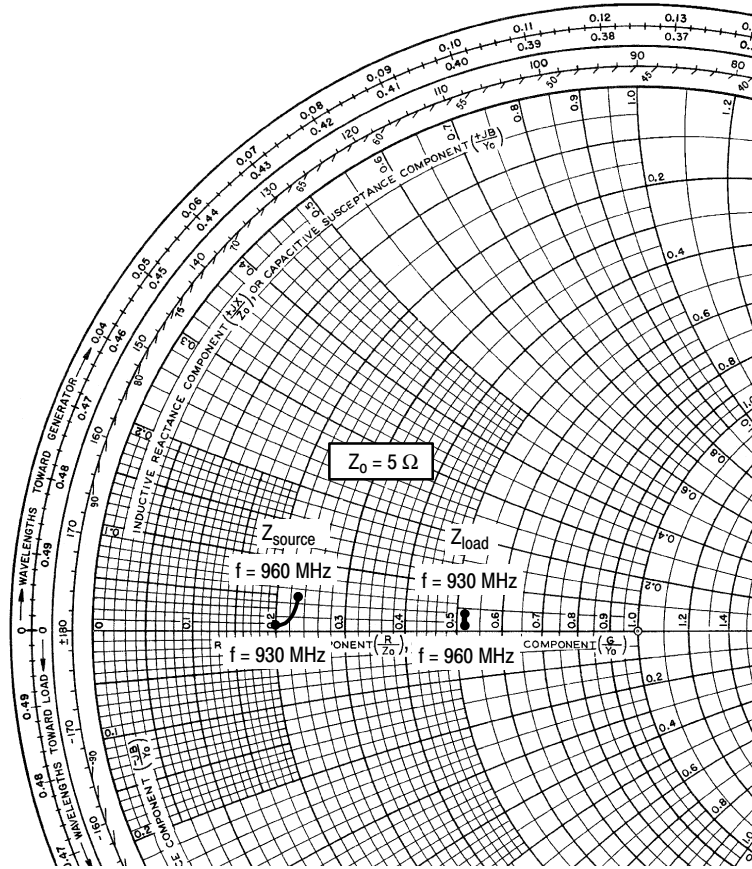


Figure 7. Power Gain, Efficiency versus Output Power



$V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 350\text{ mA}$ ,  $P_{out} = 45\text{ W PEP}$

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 930      | $1.02 + j0.06$           | $2.6 + j0.20$          |
| 945      | $1.10 + j0.11$           | $2.6 + j0.16$          |
| 960      | $1.15 + j0.25$           | $2.6 + j0.10$          |

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

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

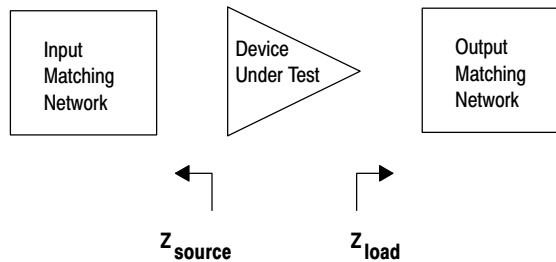
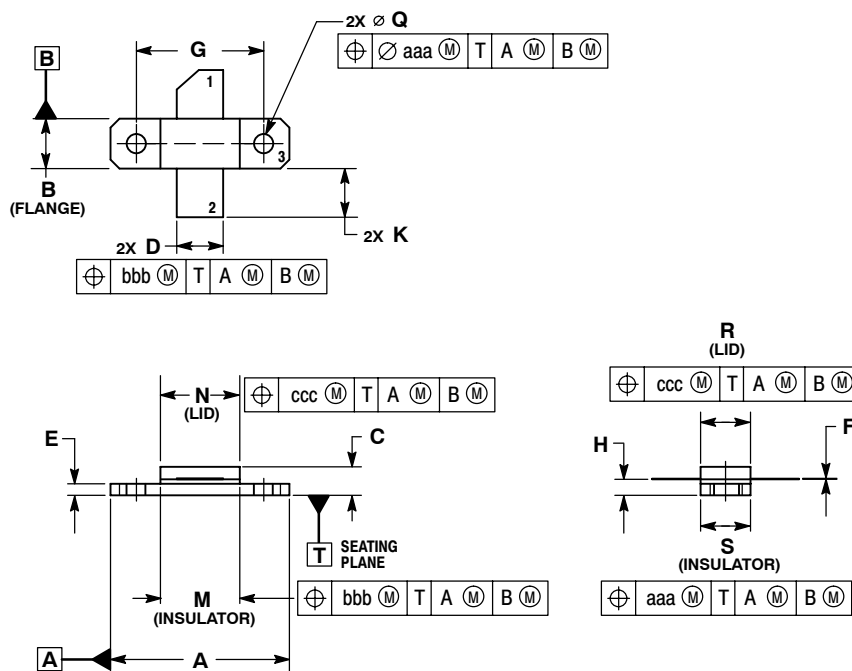


Figure 8. Series Equivalent Source and Load Impedance

# PACKAGE DIMENSIONS

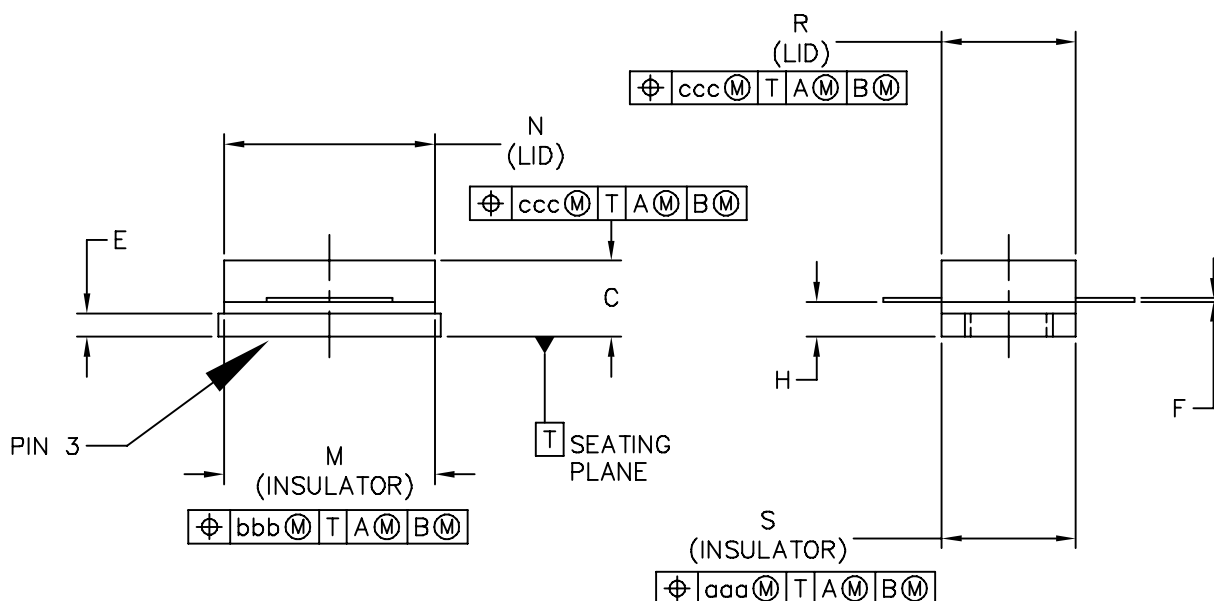
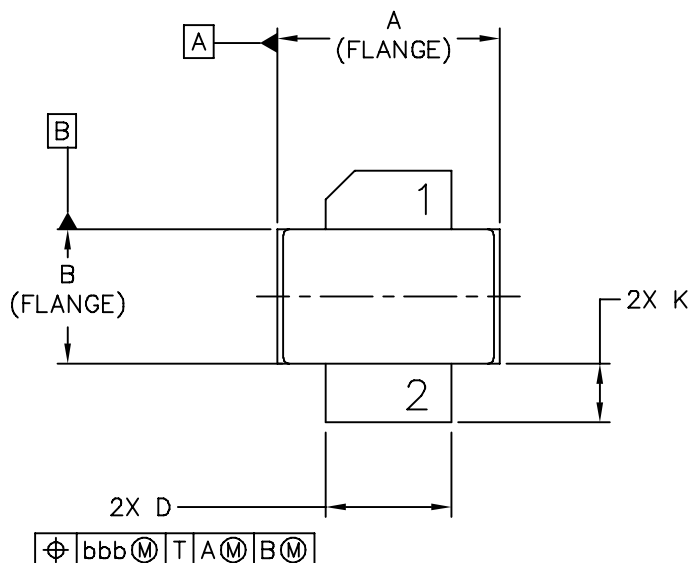


- NOTES:
1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
  2. CONTROLLING DIMENSION: INCH.
  3. DIMENSION H IS MEASURED 0.030 (0.762) AWAY FROM PACKAGE BODY.

| DIM | INCHES    |       | MILLIMETERS |       |
|-----|-----------|-------|-------------|-------|
|     | 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

CASE 360B-05  
ISSUE G  
NI-360  
MRF9045LR1



|                                                         |  |                          |  |                            |  |
|---------------------------------------------------------|--|--------------------------|--|----------------------------|--|
| © FREESCALE SEMICONDUCTOR, INC.<br>ALL RIGHTS RESERVED. |  | MECHANICAL OUTLINE       |  | PRINT VERSION NOT TO SCALE |  |
| TITLE:<br><br>NI-360S<br>SURFACE MOUNT                  |  | DOCUMENT NO: 98ASB14516C |  | REV: F                     |  |
|                                                         |  | CASE NUMBER: 360C-05     |  | 10 MAR 2006                |  |
|                                                         |  | STANDARD: NON-JEDEC      |  |                            |  |

NOTES:

1. INTERPRET DIMENSIONS AND TOLERANCES  
PER ASME Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH
3. DIMENSION H IS MEASURED .030 (0.762)  
AWAY FROM PACKAGE BODY

STYLE 1:

- PIN 1 - DRAIN  
2 - GATE  
3 - SOURCE

| INCH                                                    |      |      | MILLIMETER         |      | INCH                     |                            |      | MILLIMETER  |      |
|---------------------------------------------------------|------|------|--------------------|------|--------------------------|----------------------------|------|-------------|------|
| DIM                                                     | MIN  | MAX  | MIN                | MAX  | DIM                      | MIN                        | MAX  | MIN         | MAX  |
| A                                                       | .375 | .385 | 9.53               | 9.78 | N                        | .357                       | .363 | 9.07        | 9.22 |
| B                                                       | .225 | .235 | 5.72               | 5.97 | R                        | .227                       | .233 | 5.77        | 5.92 |
| C                                                       | .105 | .155 | 2.67               | 3.94 | S                        | .225                       | .235 | 5.72        | 5.97 |
| D                                                       | .210 | .220 | 5.33               | 5.59 |                          |                            |      |             |      |
| E                                                       | .035 | .045 | 0.89               | 1.14 | aaa                      | .005                       |      | 0.13        |      |
| F                                                       | .004 | .006 | 0.1                | 0.15 | bbb                      | .010                       |      | 0.25        |      |
| H                                                       | .057 | .067 | 1.45               | 1.7  | ccc                      | .015                       |      | 0.38        |      |
| K                                                       | .085 | .115 | 2.16               | 2.92 |                          |                            |      |             |      |
| M                                                       | .355 | .365 | 9.02               | 9.27 |                          |                            |      |             |      |
| © FREESCALE SEMICONDUCTOR, INC.<br>ALL RIGHTS RESERVED. |      |      | MECHANICAL OUTLINE |      |                          | PRINT VERSION NOT TO SCALE |      |             |      |
| TITLE:<br><br>NI-360S<br>SURFACE MOUNT                  |      |      |                    |      | DOCUMENT NO: 98ASB14516C |                            |      | REV: F      |      |
|                                                         |      |      |                    |      | CASE NUMBER: 360C-05     |                            |      | 10 MAR 2006 |      |
|                                                         |      |      |                    |      | STANDARD: NON-JEDEC      |                            |      |             |      |

## PRODUCT DOCUMENTATION

Refer to the following documents to aid your design process.

### Engineering Bulletins

- EB212: Using Data Sheet Impedances for RF LDMOS Devices

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date       | Description                                                                                                                                                                      |
|----------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11       | Sept. 2008 | <ul style="list-style-type: none"><li>• Replaced Case Outline 360C-05, Issue E with Issue F, p. 8-9.</li><li>• Added Product Documentation and Revision History, p. 10</li></ul> |

**How to Reach Us:****Home Page:**

[www.freescale.com](http://www.freescale.com)

**Web Support:**

<http://www.freescale.com/support>

**USA/Europe or Locations Not Listed:**

Freescale Semiconductor, Inc.  
Technical Information Center, EL516  
2100 East Elliot Road  
Tempe, Arizona 85284  
1-800-521-6274 or +1-480-768-2130  
[www.freescale.com/support](http://www.freescale.com/support)

**Europe, Middle East, and Africa:**

Freescale Halbleiter Deutschland GmbH  
Technical Information Center  
Schatzbogen 7  
81829 Muenchen, Germany  
+44 1296 380 456 (English)  
+46 8 52200080 (English)  
+49 89 92103 559 (German)  
+33 1 69 35 48 48 (French)  
[www.freescale.com/support](http://www.freescale.com/support)

**Japan:**

Freescale Semiconductor Japan Ltd.  
Headquarters  
ARCO Tower 15F  
1-8-1, Shimo-Meguro, Meguro-ku,  
Tokyo 153-0064  
Japan  
0120 191014 or +81 3 5437 9125  
[support.japan@freescale.com](mailto:support.japan@freescale.com)

**Asia/Pacific:**

Freescale Semiconductor China Ltd.  
Exchange Building 23F  
No. 118 Jianguo Road  
Chaoyang District  
Beijing 100022  
China  
+86 10 5879 8000  
[support.asia@freescale.com](mailto:support.asia@freescale.com)

**For Literature Requests Only:**

Freescale Semiconductor Literature Distribution Center  
P.O. Box 5405  
Denver, Colorado 80217  
1-800-441-2447 or +1-303-675-2140  
Fax: +1-303-675-2150  
[LDCForFreescaleSemiconductor@hibbertgroup.com](mailto:LDCForFreescaleSemiconductor@hibbertgroup.com)

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductor products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© Freescale Semiconductor, Inc. 2008. All rights reserved.

