

# 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.

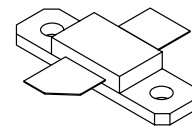
- Typical Two-Tone Performance at 945 MHz, 26 Volts  
Output Power — 60 Watts PEP  
Power Gain — 17 dB  
Efficiency — 40%  
IMD — -31 dBc
- Capable of Handling 10:1 VSWR, @ 26 Vdc, 945 MHz, 60 Watts CW  
Output Power

### Features

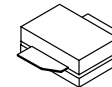
- Integrated ESD Protection
- Designed for Maximum Gain and Insertion Phase Flatness
- Excellent Thermal Stability
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Low Gold Plating Thickness on Leads. L Suffix Indicates 40μ" Nominal.
- RoHS Compliant
- In Tape and Reel. R1 Suffix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

**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 Derate above 25°C	MRF9060LR1 P <sub>D</sub> MRF9060LSR1	159 0.91 219 1.25	W W/°C W 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 (1)	Unit
Thermal Resistance, Junction to Case	MRF9060LR1 R <sub>θJC</sub> MRF9060LSR1	1.1 0.8	°C/W

**Table 3. ESD Protection Characteristics**

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

1. MTTF calculator available at <http://www.freescale.com/rf>. Select Tools/Software/Application Software/Calculators to access the MTTF calculators by product.

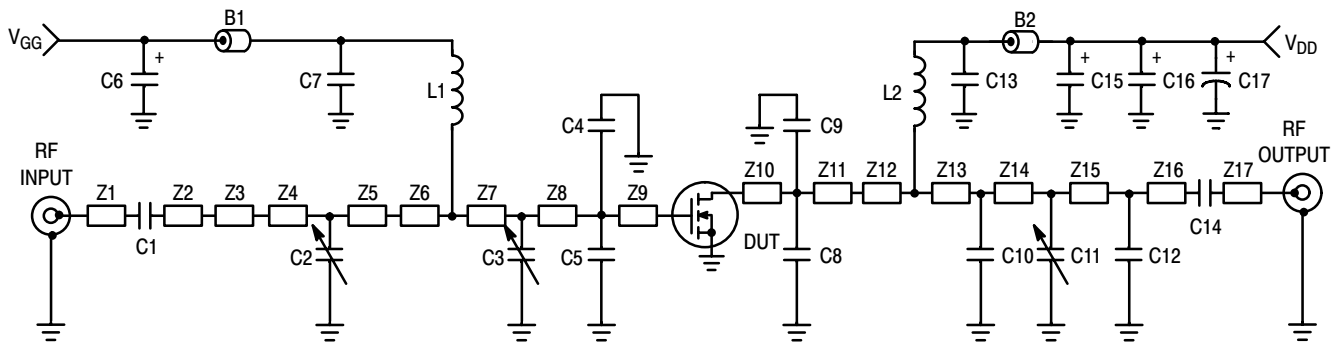
**Table 4. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>Off Characteristics</b>					
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 65\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	10	$\mu\text{Adc}$
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 26\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	1	$\mu\text{Adc}$
Gate-Source Leakage Current ( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )	$I_{GSS}$	—	—	1	$\mu\text{Adc}$
<b>On Characteristics</b>					
Gate Threshold Voltage ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 200\ \mu\text{Adc}$ )	$V_{GS(th)}$	2	2.9	4	Vdc
Gate Quiescent Voltage ( $V_{DS} = 26\text{ Vdc}$ , $I_D = 450\text{ mAdc}$ )	$V_{GS(Q)}$	—	3.7	—	Vdc
Drain-Source On-Voltage ( $V_{GS} = 10\text{ Vdc}$ , $I_D = 1.3\text{ Adc}$ )	$V_{DS(on)}$	—	0.17	0.4	Vdc
Forward Transconductance ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 4\text{ Adc}$ )	$g_{fs}$	—	5.3	—	S
<b>Dynamic Characteristics</b>					
Input Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{iss}$	—	98	—	pF
Output Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{oss}$	—	50	—	pF
Reverse Transfer Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 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 ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	$G_{ps}$	16	17	—	dB
Two-Tone Drain Efficiency ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	$\eta$	36	40	—	%
3rd Order Intermodulation Distortion ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	IMD	—	-31	-28	dBc
Input Return Loss ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	IRL	—	-16	-9	dB
Two-Tone Common-Source Amplifier Power Gain ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	$G_{ps}$	—	17	—	dB
Two-Tone Drain Efficiency ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	$\eta$	—	39	—	%
3rd Order Intermodulation Distortion ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	IMD	—	-31	—	dBc
Input Return Loss ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 930.0\text{ MHz}$ , $f_2 = 930.1\text{ MHz}$ and $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	IRL	—	-16	—	dB
Power Output, 1 dB Compression Point ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ )	$P_{1dB}$	—	70	—	W
Common-Source Amplifier Power Gain ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ )	$G_{ps}$	—	17	—	dB
Drain Efficiency ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W CW}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ )	$\eta$	—	51	—	%

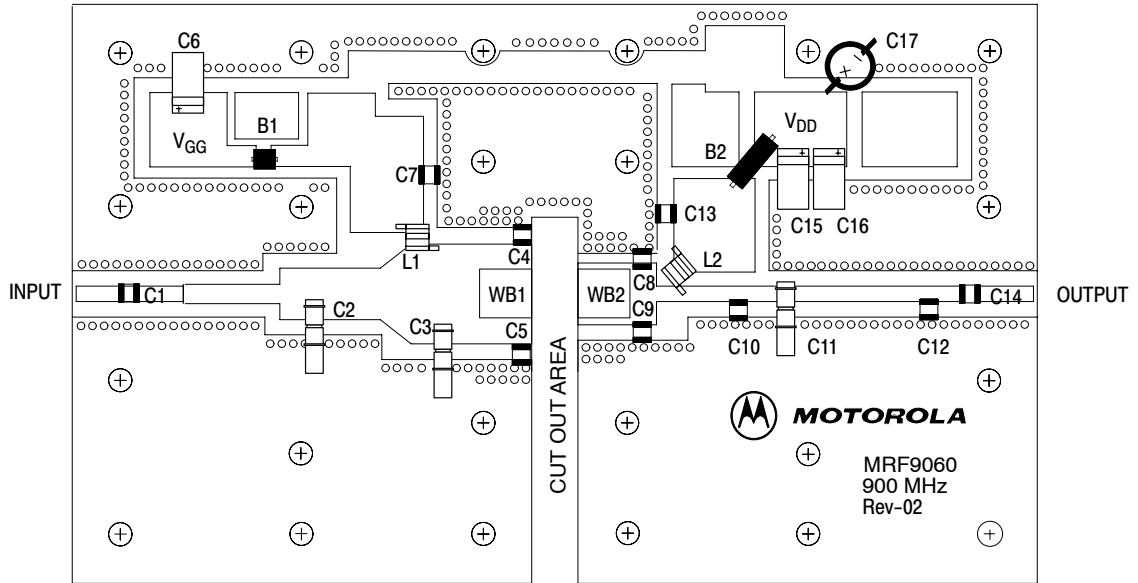


Z1	0.240" x 0.060" Microstrip	Z10	0.360" x 0.270" Microstrip
Z2	0.240" x 0.060" Microstrip	Z11	0.060" x 0.270" Microstrip
Z3	0.500" x 0.100" Microstrip	Z12	0.110" x 0.060" Microstrip
Z4	0.180" x 0.270" Microstrip	Z13	0.330" x 0.060" Microstrip
Z5	0.350" x 0.270" Microstrip	Z14	0.230" x 0.060" Microstrip
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) 0.7 pF Chip Capacitor (MRF9060S)	100B0R5BP 500X 100B0R7BP 500X	ATC 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

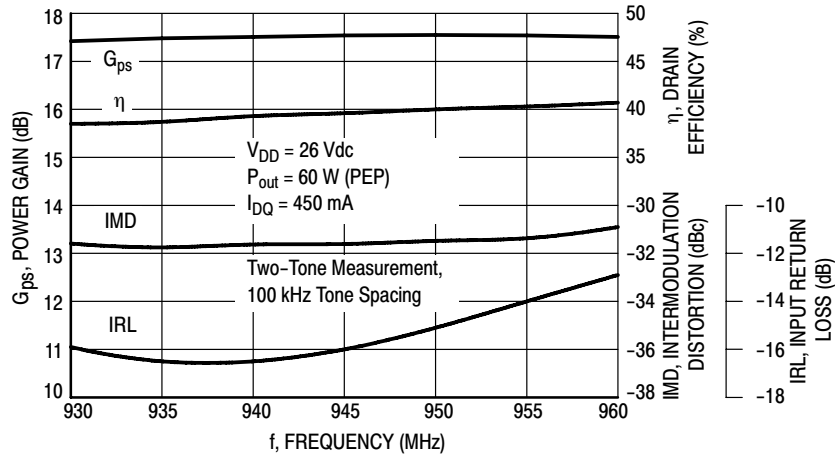


Figure 3. Class AB Broadband Circuit Performance

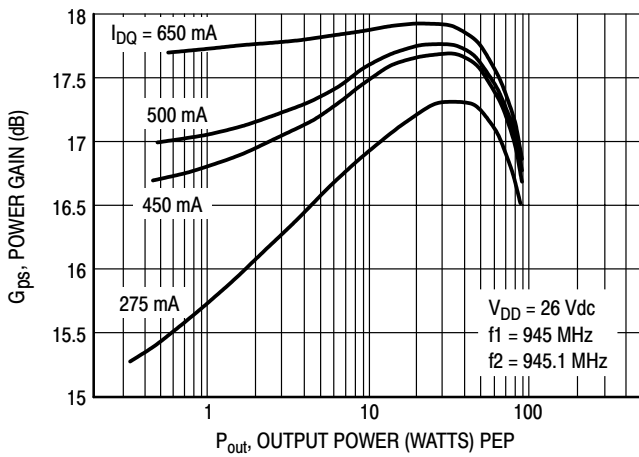


Figure 4. Power Gain versus Output Power

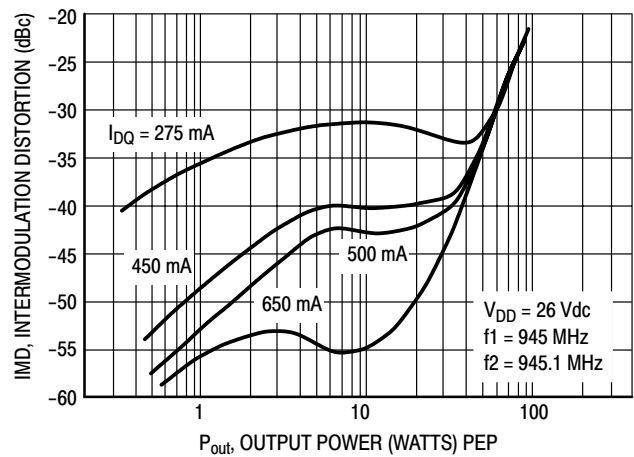


Figure 5. Intermodulation Distortion versus Output Power

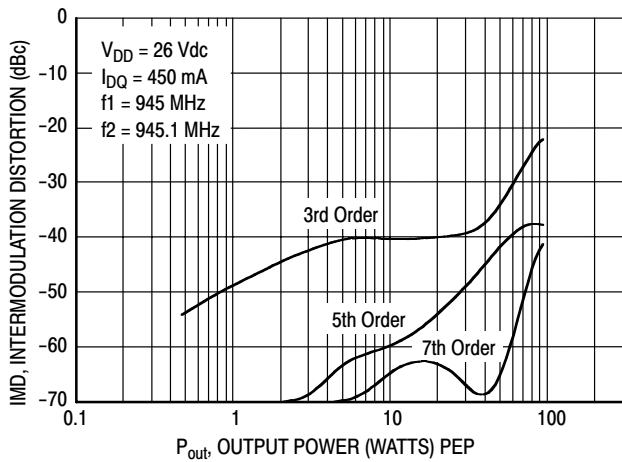


Figure 6. Intermodulation Distortion Products versus Output Power

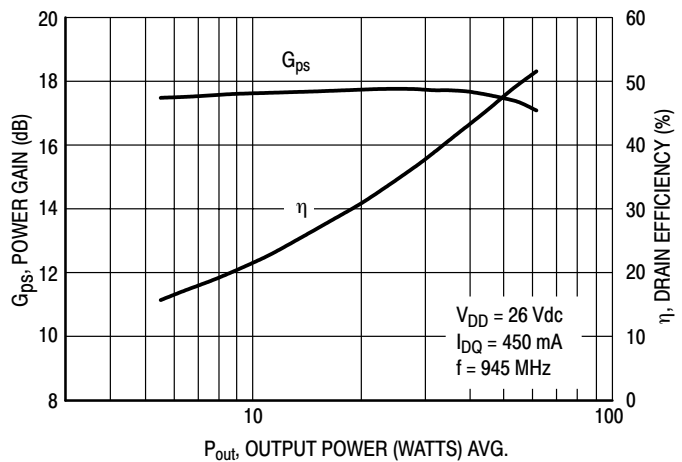


Figure 7. Power Gain and Efficiency versus Output Power

TYPICAL CHARACTERISTICS

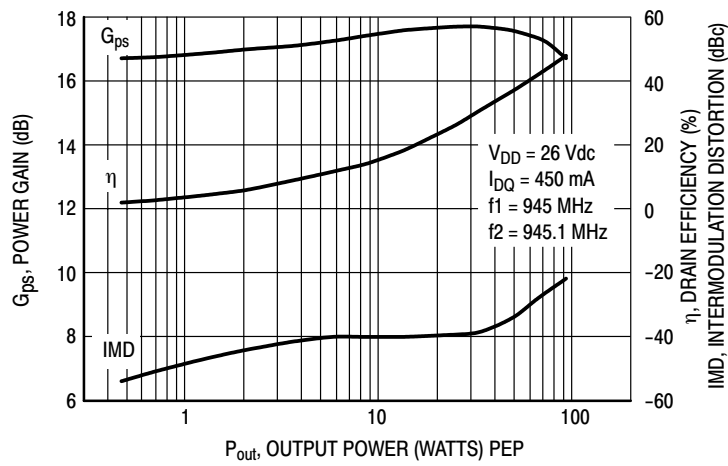
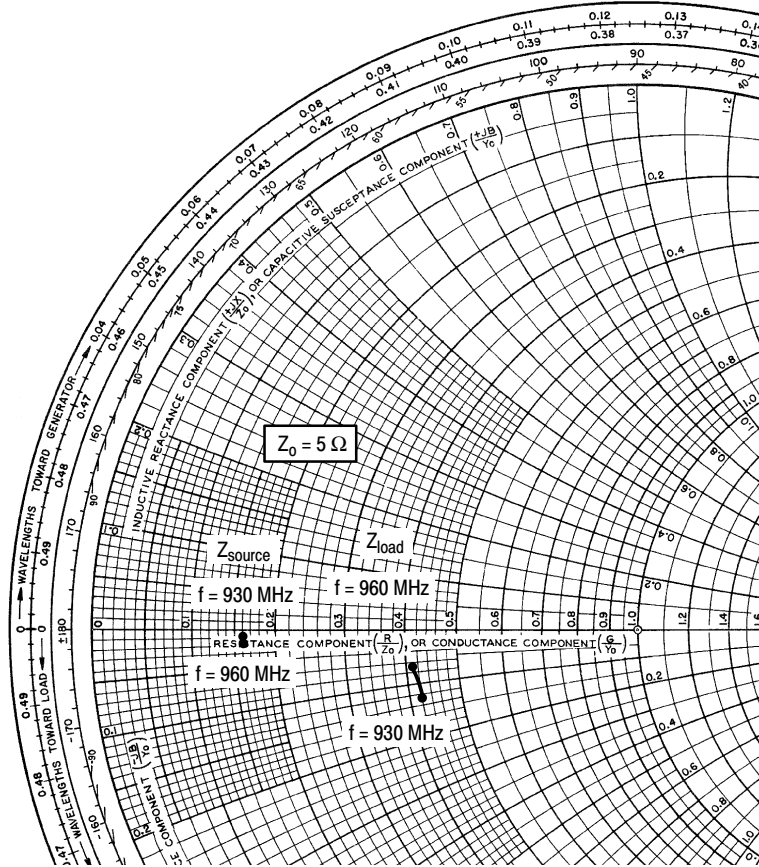


Figure 8. Power Gain, Efficiency, and IMD versus Output Power



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

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
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.

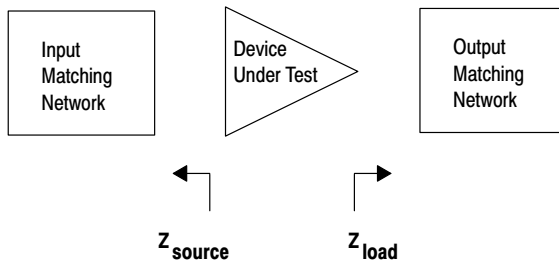


Figure 9. Series Equivalent Source and Load Impedance



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# NOTES

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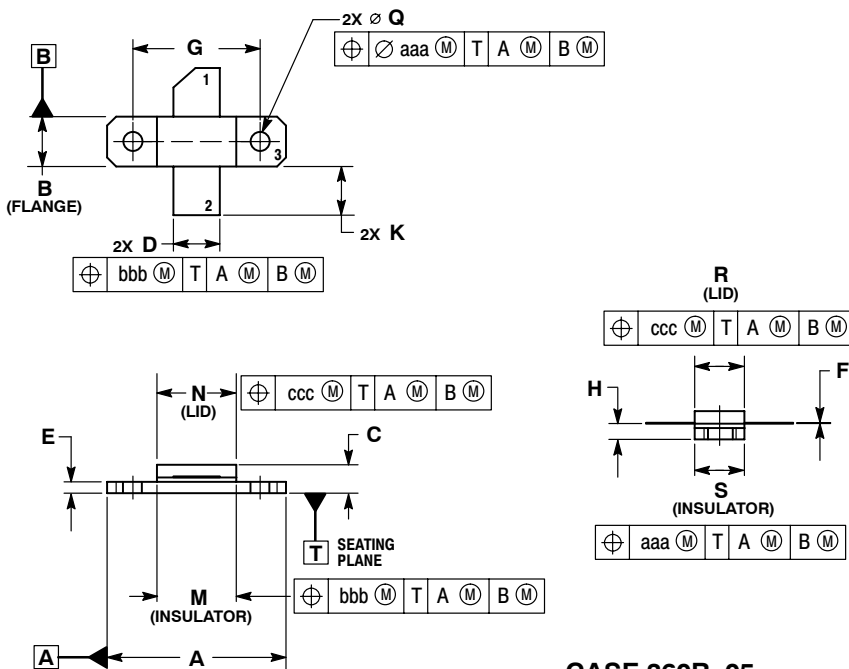
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# NOTES

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## PACKAGE DIMENSIONS

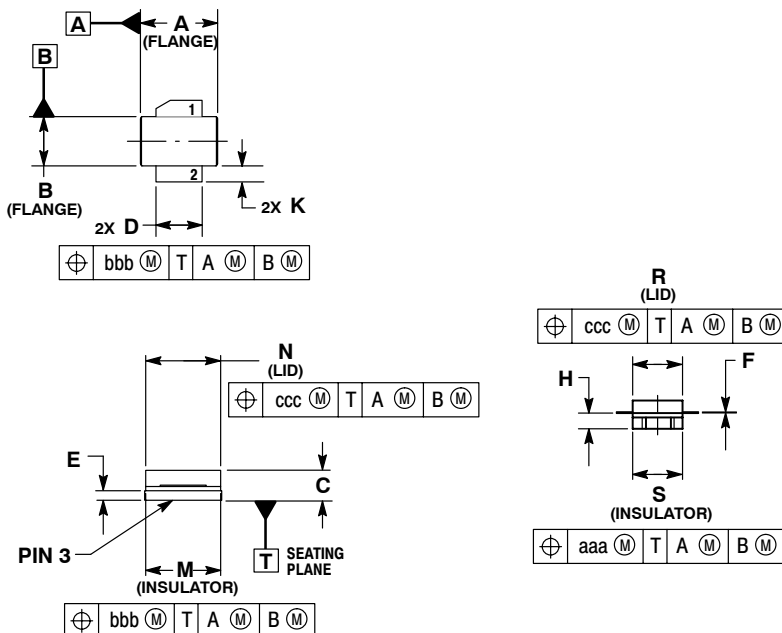


- NOTES:
1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
  2. CONTROLLING DIMENSION: INCH.
  3. DIMENSION H IS MEASURED 0.030 (0.762) AWAY FROM PACKAGE BODY.

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  
 MRF9060LR1**



- NOTES:
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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

**CASE 360C-05  
 ISSUE E  
 NI-360S  
 MRF9060LSR1**

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