

**Freescale Semiconductor**  
Technical Data

MRF9060M  
Rev. 8, 3/2005

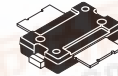
**RF Power Field Effect Transistors**  
N-Channel Enhancement-Mode Lateral MOSFETs

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.

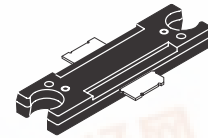
- Typical Performance at 945 MHz, 26 Volts  
Output Power — 60 Watts PEP  
Power Gain — 18.0 dB  
Efficiency — 40% (Two Tones)  
IMD — -31.5 dBc
- Integrated ESD Protection
- Capable of Handling 5:1 VSWR, @ 26 Vdc, 945 MHz, 60 Watts CW Output Power
- Excellent Thermal Stability
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- N Suffix Indicates Lead-Free Terminations
- 200°C Capable Plastic Package
- TO-270 Dual Lead Available in Tape and Reel. R1 Suffix = 500 Units per 24 mm, 13 inch Reel.
- TO-272 Dual Lead Available in Tape and Reel. R1 Suffix = 500 Units per 44 mm, 13 inch Reel.

**MRF9060NR1**  
**MRF9060NBR1**  
**MRF9060MR1**  
**MRF9060MBR1**

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



**CASE 1265-08, STYLE 1**  
**TO-270 DUAL LEAD**  
**PLASTIC**  
**MRF9060NR1(MR1)**



**CASE 1337-03, STYLE 1**  
**TO-272 DUAL LEAD**  
**PLASTIC**  
**MRF9060NBR1(MBR1)**

**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	P <sub>D</sub>	223 1.79	W 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>	0.56	°C/W

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

**Table 3. ESD Protection Characteristics**

Test Conditions	Class
Human Body Model	1 (Minimum)
Machine Model	M2 (Minimum)
Charge Device Model	C6 (Minimum) C5 (Minimum)

**Table 4. Moisture Sensitivity Level**

Test Methodology	Rating	Package Peak Temperature	Unit
Per JESD 22-A113, IPC/JEDEC J-STD-020			°C
MRF9060NR1 (MR1)	1	260	
MRF9060NBR1 (MBR1)	3	260	

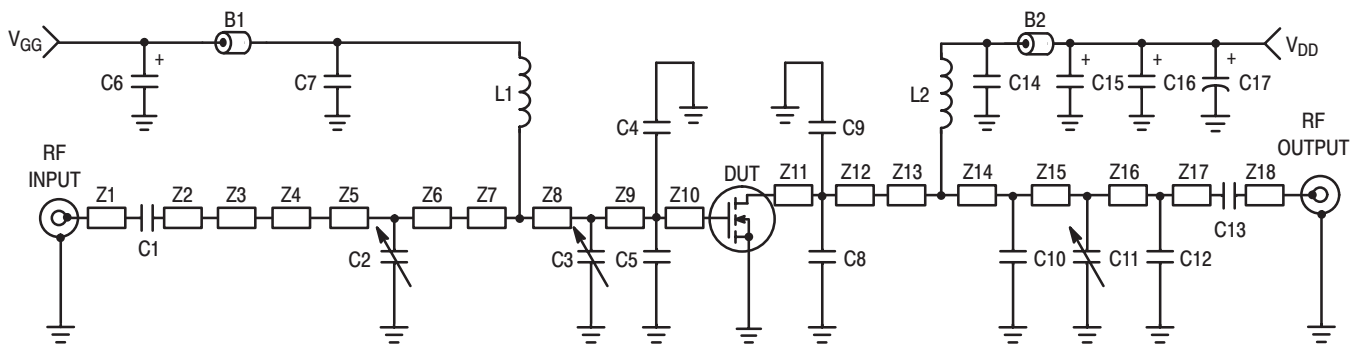
**Table 5. Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

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	2.8	4	Vdc
Gate Quiescent Voltage ( $V_{DS} = 26\text{ Vdc}$ , $I_D = 450\text{ mAdc}$ )	$V_{GS(Q)}$	3	3.7	5	Vdc
Drain-Source On-Voltage ( $V_{GS} = 10\text{ Vdc}$ , $I_D = 1.3\text{ Adc}$ )	$V_{DS(on)}$	—	0.21	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, $V_{GS} = 0\text{ Vdc}$ )	$C_{iss}$	—	101	—	pF
Output Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{oss}$	—	53	—	pF
Reverse Transfer Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{rss}$	—	2.5	—	pF

(continued)

**Table 5. 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 ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	$G_{ps}$	17	18	—	dB
Two-Tone Drain Efficiency ( $V_{DD} = 26\text{ Vdc}$ , $P_{out} = 60\text{ W PEP}$ , $I_{DQ} = 450\text{ mA}$ , $f_1 = 945.0\text{ MHz}$ , $f_2 = 945.1\text{ MHz}$ )	$\eta$	37	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	—	-31.5	-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	—	-14.5	-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 $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	$G_{ps}$	—	18	—	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 $f_1 = 960.0\text{ MHz}$ , $f_2 = 960.1\text{ MHz}$ )	$\eta$	—	40	—	%
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	—	-12.5	—	dB

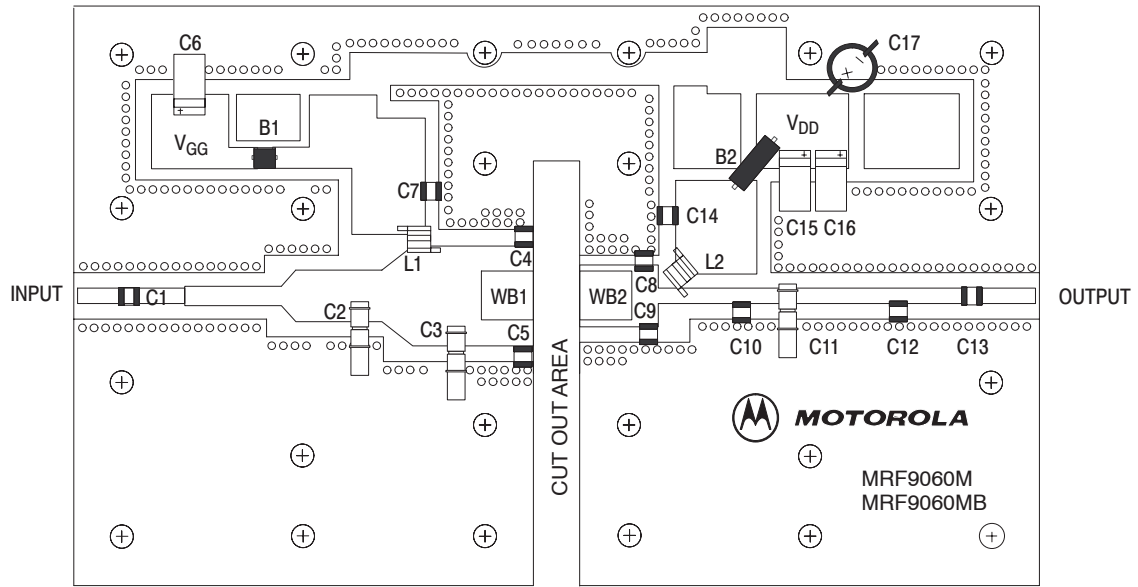


Z1	0.240" x 0.060" Microstrip	Z10	0.060" x 0.520" Microstrip
Z2	0.240" x 0.060" Microstrip	Z11	0.360" x 0.270" Microstrip
Z3	0.500" x 0.100" Microstrip	Z12	0.060" x 0.270" Microstrip
Z4	0.100" x 0.270" x 0.080", Taper	Z13	0.130" x 0.060" Microstrip
Z5	0.330" x 0.270" Microstrip	Z14	0.300" x 0.060" Microstrip
Z6	0.120" x 0.270" Microstrip	Z15	0.210" x 0.060" Microstrip
Z7	0.270" x 0.520" x 0.140", Taper	Z16	0.600" x 0.060" Microstrip
Z8	0.240" x 0.520" Microstrip	Z17	0.290" x 0.060" Microstrip
Z9	0.340" x 0.520" Microstrip	Z18	0.340" x 0.060" Microstrip

Figure 1. 930–960 MHz Broadband Test Circuit Schematic

Table 6. 930–960 MHz Broadband Test Circuit Component Designations and Values

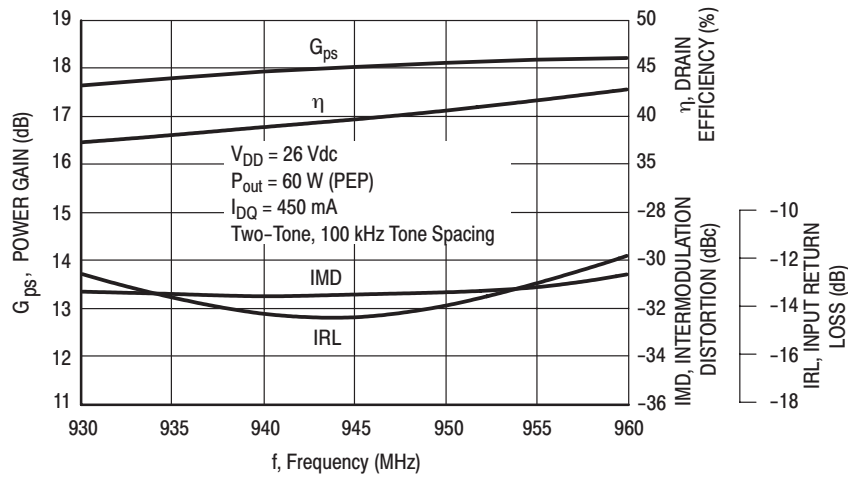
Part	Description	Part Number	Manufacturer
B1	Short Ferrite Bead	95F786	Newark
B2	Long Ferrite Bead	95F787	Newark
C1, C7, C13, C14	47 pF Chip Capacitors	100B470JP 500X	ATC
C2, C3, C11	0.8–8.0 Gigatrim Variable Capacitors	44F3360	Newark
C4, C5	11 pF Chip Capacitors (MRF9060NR1/MR1) 10 pF Chip Capacitors (MRF9060NBR1/MBR1)	100B110JP 500X 100B100JP 500X	ATC
C6, C15, C16	10 μF, 35 V Tantalum Chip Capacitors	93F2975	Newark
C8, C9	10 pF Chip Capacitors	100B100JP 500X	Newark
C10	3.9 pF Chip Capacitor	100B3R9CP 500X	ATC
C12	1.7 pF Chip Capacitor	100B1R7BP 500X	ATC
C17	220 μF 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	15 mil Brass Wear Blocks		
Board Material	30 mil Glass Teflon <sup>®</sup> , ε <sub>r</sub> = 2.55 Copper Clad, 2 oz Cu	RF–35–0300	Taconic
PCB	Etched Circuit Board	TO–270/TO–272 Surface/Bolt	DSelectronics



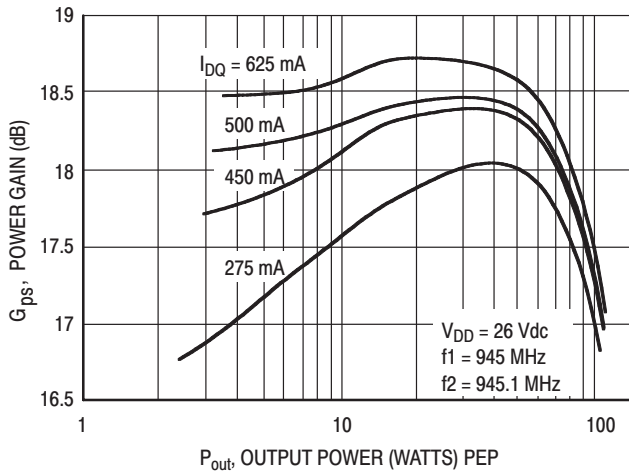
Freescal has begun the transition of marking Printed Circuit Boards (PCBs) with the Freescal Semiconductor signature/logo. PCBs may have either Motorola or Freescal markings during the transition period. These changes will have no impact on form, fit or function of the current product.

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

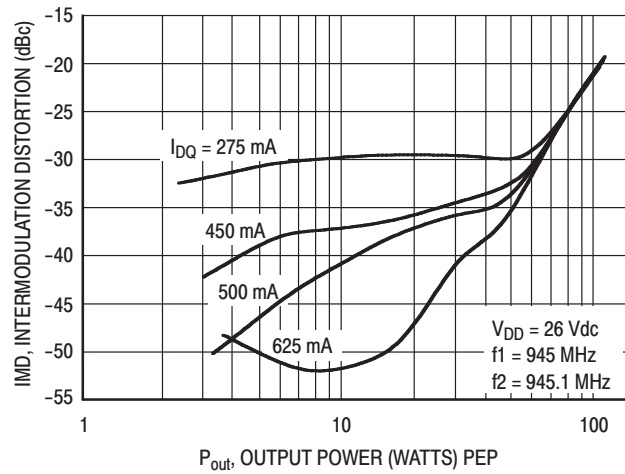
## TYPICAL CHARACTERISTICS



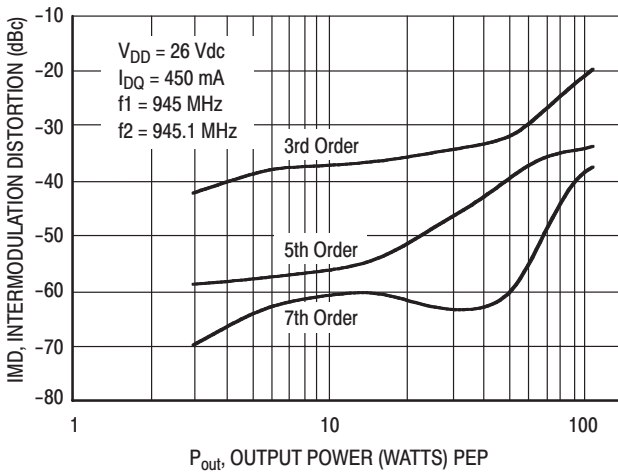
**Figure 3. Class AB Broadband Circuit Performance**



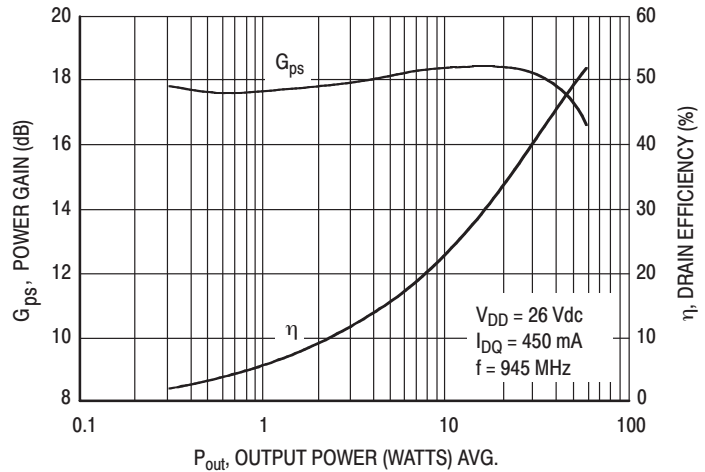
**Figure 4. Power Gain versus Output Power**



**Figure 5. Intermodulation Distortion versus Output Power**



**Figure 6. Intermodulation Distortion Products versus Output Power**



**Figure 7. Power Gain and Efficiency versus Output Power**

### TYPICAL CHARACTERISTICS

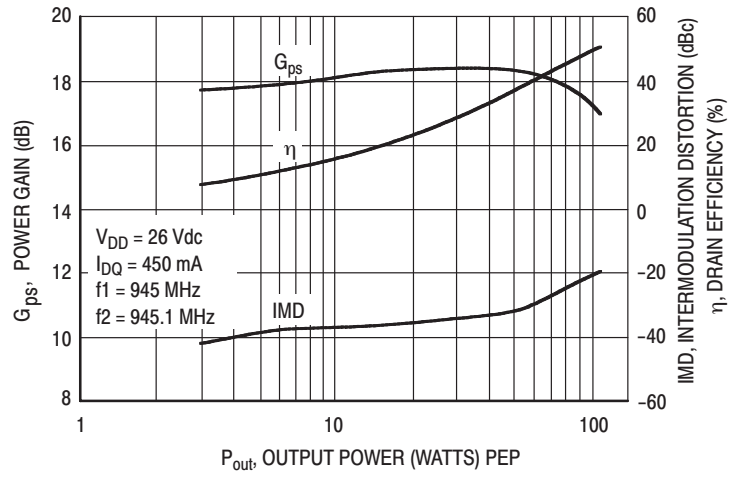
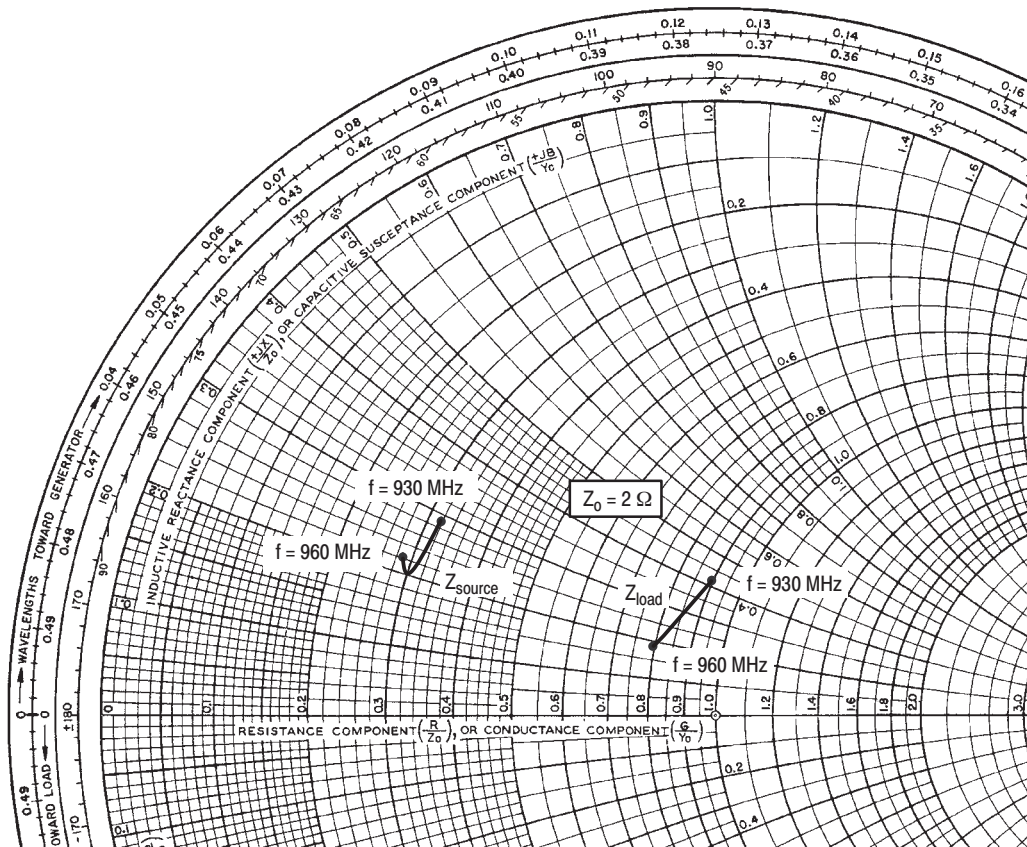


Figure 8. Power Gain, Efficiency, and IMD versus Output Power



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

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
930	$0.63 + j0.57$	$1.8 + j0.84$
945	$0.60 + j0.41$	$1.7 + j0.55$
960	$0.57 + j0.45$	$1.6 + j0.36$

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

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

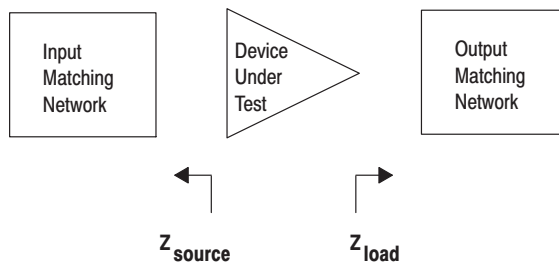


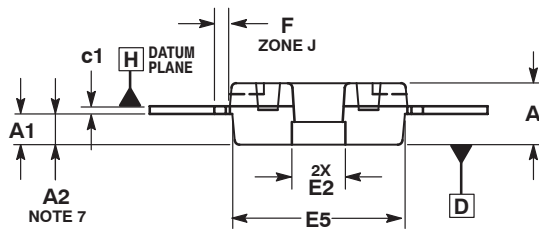
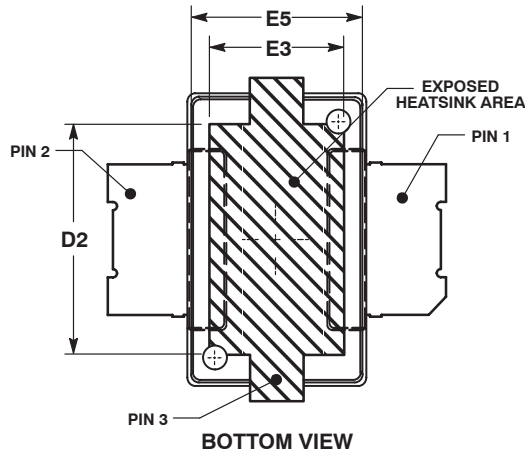
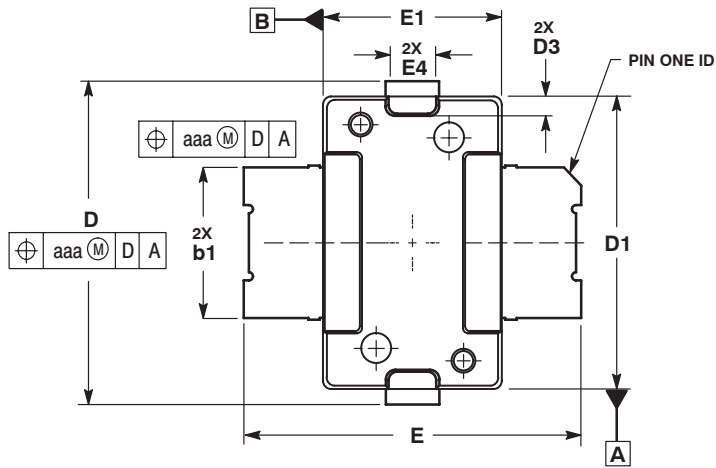
Figure 9. Series Equivalent Source and Load Impedance





## NOTES

## PACKAGE DIMENSIONS



**NOTES:**

1. CONTROLLING DIMENSION: INCH.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DATUM PLANE -H- IS LOCATED AT TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D1" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .006 PER SIDE. DIMENSIONS "D1" AND "E1" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -H-.
5. DIMENSION b1 DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 TOTAL IN EXCESS OF THE b1 DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUMS -A- AND -B- TO BE DETERMINED AT DATUM PLANE -H-.
7. DIMENSION A2 APPLIES WITHIN ZONE "J" ONLY.
8. DIMENSIONS "D" AND "E2" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .003 PER SIDE. DIMENSIONS "D" AND "E2" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -D-.

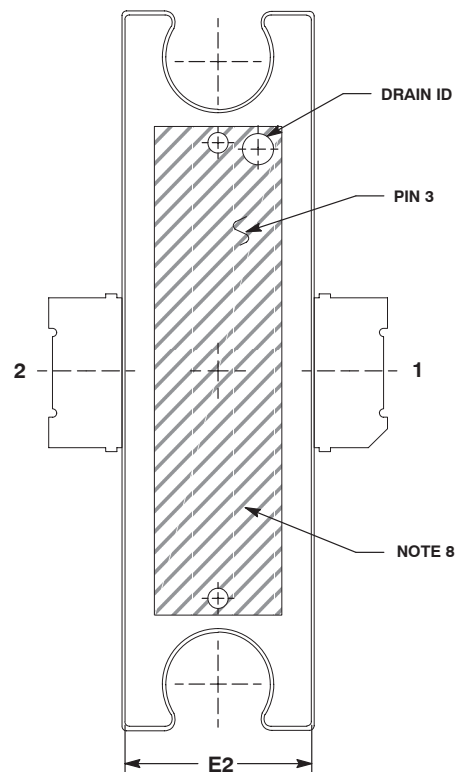
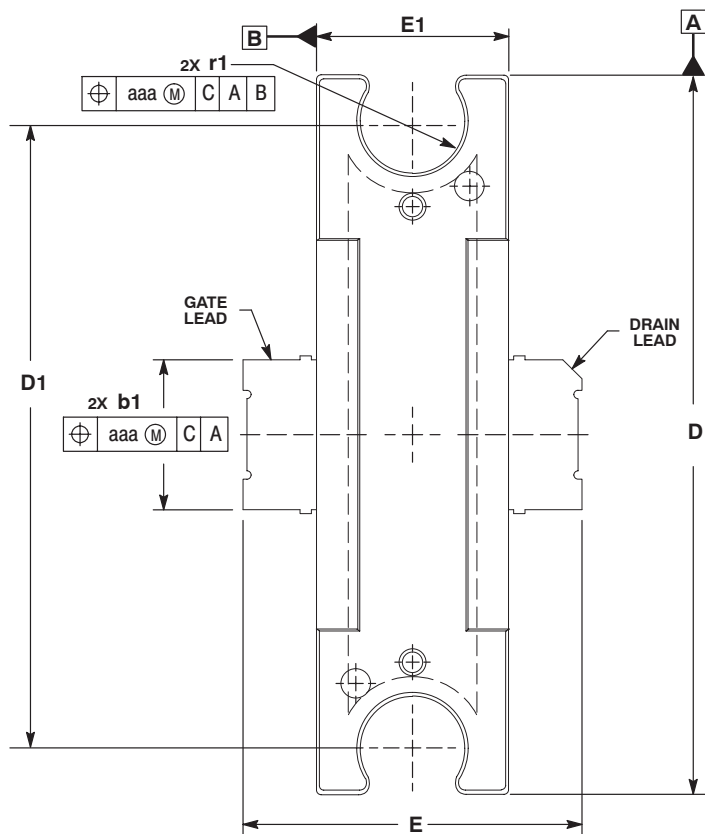
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.078	.082	1.98	2.08
A1	.039	.043	0.99	1.09
A2	.040	.042	1.02	1.07
D	.416	.424	10.57	10.77
D1	.378	.382	9.60	9.70
D2	.290	.320	7.37	8.13
D3	.016	.024	0.41	0.61
E	.436	.444	11.07	11.28
E1	.238	.242	6.04	6.15
E2	.066	.074	1.68	1.88
E3	.150	.180	3.81	4.57
E4	.058	.066	1.47	1.68
E5	.231	.235	5.87	5.97
F	.025 BSC		0.64 BSC	
b1	.193	.199	4.90	5.06
c1	.007	.011	0.18	0.28
aaa	.004		0.10	

**STYLE 1:**

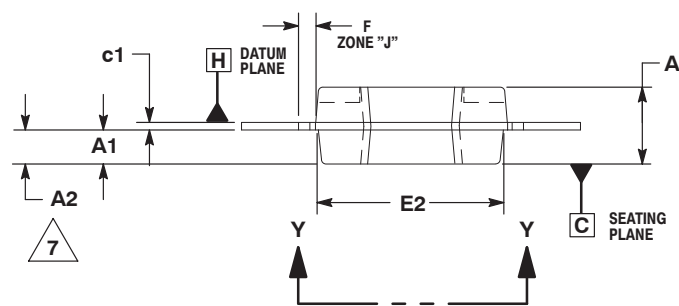
- PIN 1. DRAIN
2. GATE
3. SOURCE

**CASE 1265-08  
ISSUE G  
TO-270 DUAL LEAD  
PLASTIC  
MRF9060NR1(MR1)**

## PACKAGE DIMENSIONS



VIEW Y-Y



**NOTES:**

1. CONTROLLING DIMENSION: INCH.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DATUM PLANE -H- IS LOCATED AT THE TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .006 PER SIDE. DIMENSIONS "D" AND "E1" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -H-.
5. DIMENSION "b1" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 TOTAL IN EXCESS OF THE "b1" DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUMS -A- AND -B- TO BE DETERMINED AT DATUM PLANE -H-.
7. DIMENSION A2 APPLIES WITHIN ZONE "J" ONLY.
8. CROSSHATCHING REPRESENTS THE EXPOSED AREA OF THE HEAT SLUG.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.100	.104	2.54	2.64
A1	.039	.043	0.99	1.09
A2	.040	.042	1.02	1.07
D	.928	.932	23.57	23.67
D1	.810 BSC		20.57 BSC	
E	.438	.442	11.12	11.23
E1	.248	.252	6.30	6.40
E2	.241	.245	6.12	6.22
F	.025 BSC		0.64 BSC	
b1	.193	.199	4.90	5.05
c1	.007	.011	.18	.28
r1	.063	.068	1.60	1.73
aaa	.004		.10	

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

**CASE 1337-03  
 ISSUE B  
 TO-272 DUAL LEAD  
 PLASTIC  
 MRF9060NBR1(MBR1)**

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