



# 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.

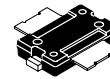
- Typical Performance at 945 MHz, 26 Volts  
 Output Power — 60 Watts PEP  
 Power Gain — 18.0 dB  
 Efficiency — 40% (Two Tones)  
 IMD — -31.5 dBc
- Capable of Handling 5:1 VSWR, @ 26 Vdc, 945 MHz, 60 Watts CW  
 Output Power

### Features

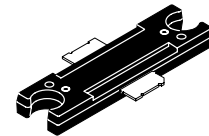
- Excellent Thermal Stability
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Integrated ESD Protection
- 200°C Capable Plastic Package
- N Suffix Indicates Lead-Free Terminations. RoHS Compliant.
- TO-270-2 Available in Tape and Reel. R1 Suffix = 500 Units per 24 mm, 13 inch Reel.
- TO-272-2 Available in Tape and Reel. R1 Suffix = 500 Units per 44 mm, 13 inch Reel.

**MRF9060NR1**  
**MRF9060NBR1**

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



**CASE 1265-08, STYLE 1**  
**TO-270-2**  
**PLASTIC**  
**MRF9060NR1**



**CASE 1337-03, STYLE 1**  
**TO-272-2**  
**PLASTIC**  
**MRF9060NBR1**

**Table 1. Maximum Ratings**

Rating	Symbol	Value	Unit
Drain-Source Voltage	$V_{DSS}$	- 0.5, +65	Vdc
Gate-Source Voltage	$V_{GS}$	- 0.5, +15	Vdc
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	$P_D$	223 1.79	W W/°C
Storage Temperature Range	$T_{stg}$	- 65 to +150	°C
Operating Junction Temperature	$T_J$	200	°C

**Table 2. Thermal Characteristics**

Characteristic	Symbol	Value (1)	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	0.56	°C/W

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

**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	1	260	
MRF9060NBR1	3	260	

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

Characteristic	Symbol	Min	Typ	Max	Unit
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**Off Characteristics**

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	$\mu\text{Adc}$

**On Characteristics**

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

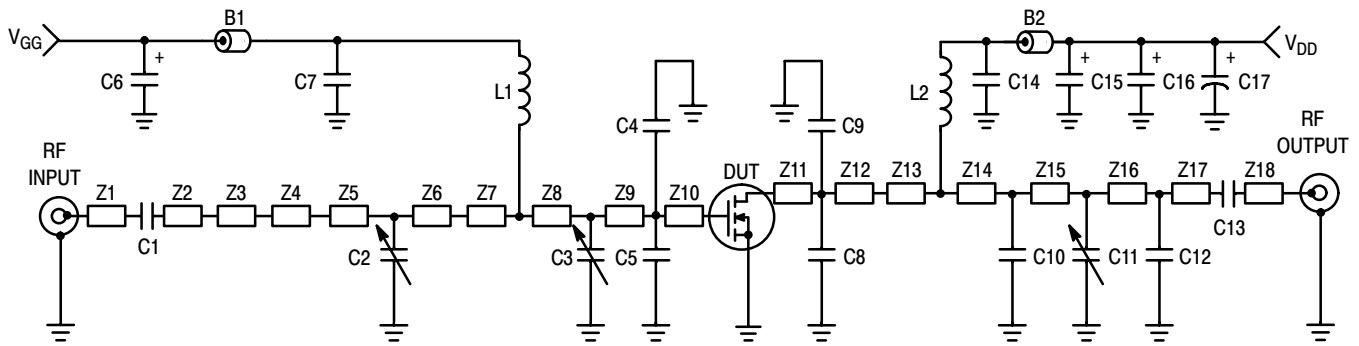
**Dynamic Characteristics**

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

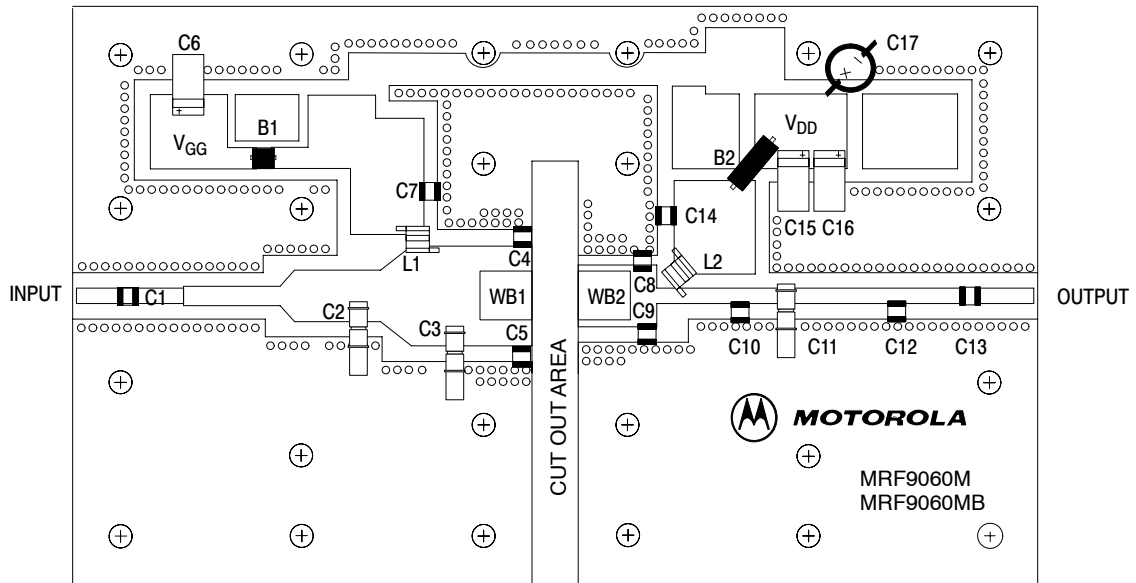


Z1	0.240" x 0.060" Microstrip	Z10	0.060" x 0.520" Microstrip
Z2	0.240" x 0.060" Microstrip	Z11	0.360" x 0.270" Microstrip
Z3	0.500" x 0.100" Microstrip	Z12	0.060" x 0.270" Microstrip
Z4	0.100" x 0.270" x 0.080", Taper	Z13	0.130" x 0.060" Microstrip
Z5	0.330" x 0.270" Microstrip	Z14	0.300" x 0.060" Microstrip
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**

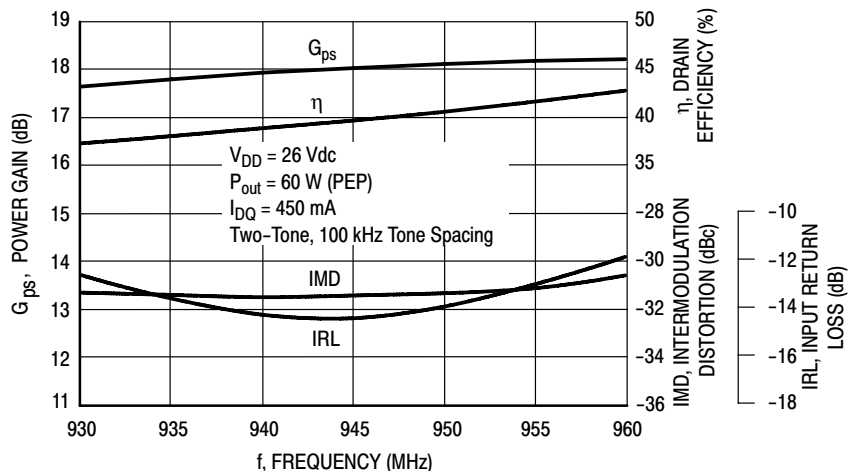
Part	Description	Part Number	Manufacturer
B1	Short Ferrite Bead	95F786	Newark
B2	Long Ferrite Bead	95F787	Newark
C1, C7, C13, C14	47 pF Chip Capacitors	100B470JP 500X	ATC
C2, C3, C11	0.8-8.0 Gigatrim Variable Capacitors	44F3360	Newark
C4, C5	11 pF Chip Capacitors (MRF9060NR1) 10 pF Chip Capacitors (MRF9060NBR1)	100B110JP 500X 100B100JP 500X	ATC
C6, C15, C16	10 $\mu$ F, 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 $\mu$ 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	15 mil Brass Wear Blocks		
Board Material	30 mil Glass Teflon <sup>®</sup> , $\epsilon_r = 2.55$ Copper Clad, 2 oz Cu	RF-35-0300	Taconic
PCB	Etched Circuit Board	TO-270/TO-272 Surface/Bolt	DSelectronics



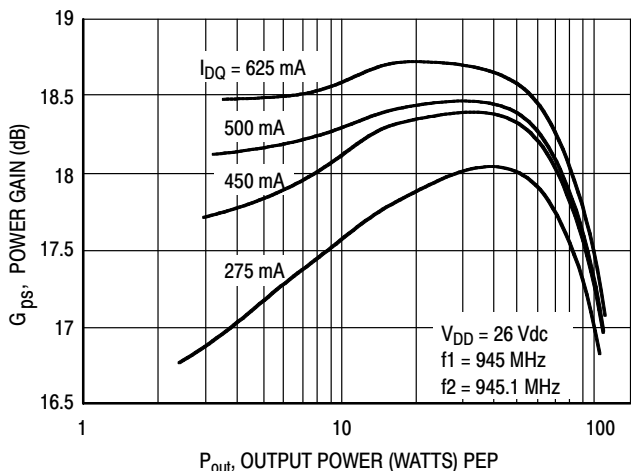
Freescale has begun the transition of marking Printed Circuit Boards (PCBs) with the Freescale Semiconductor signature/logo. PCBs may have either Motorola or Freescale markings during the transition period. These changes will have no impact on form, fit or function of the current product.

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

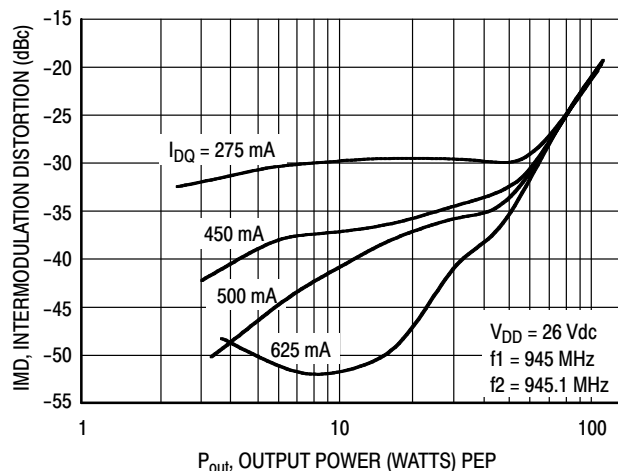
## TYPICAL CHARACTERISTICS



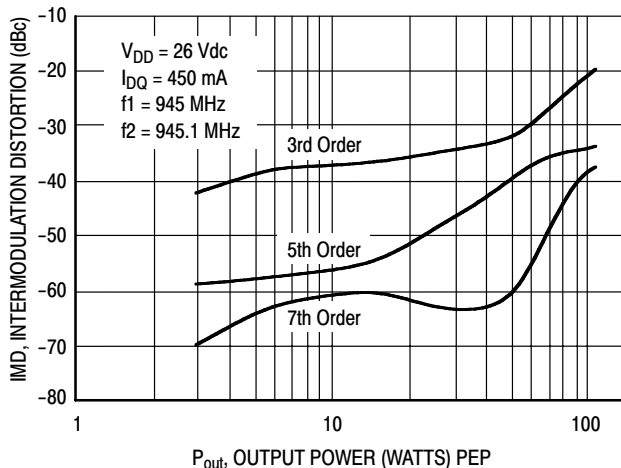
**Figure 3. Class AB Broadband Circuit Performance**



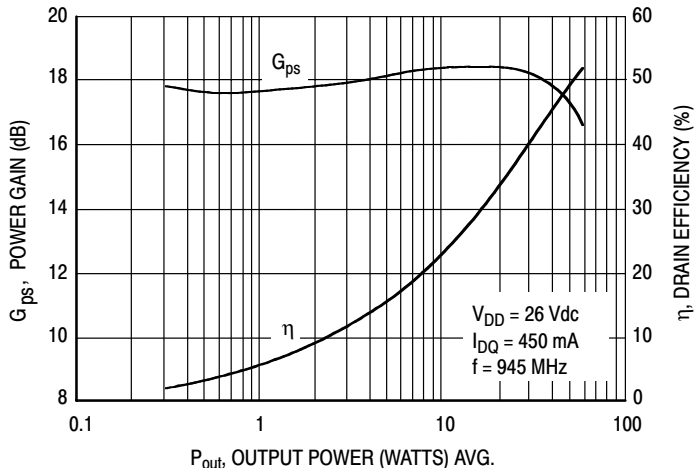
**Figure 4. Power Gain versus Output Power**



**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

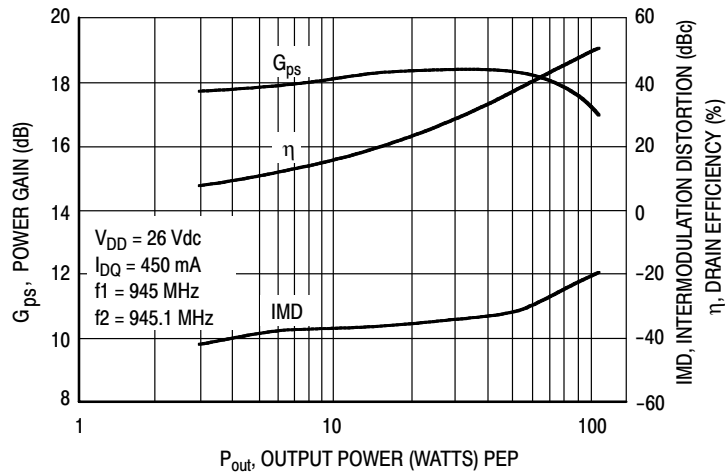
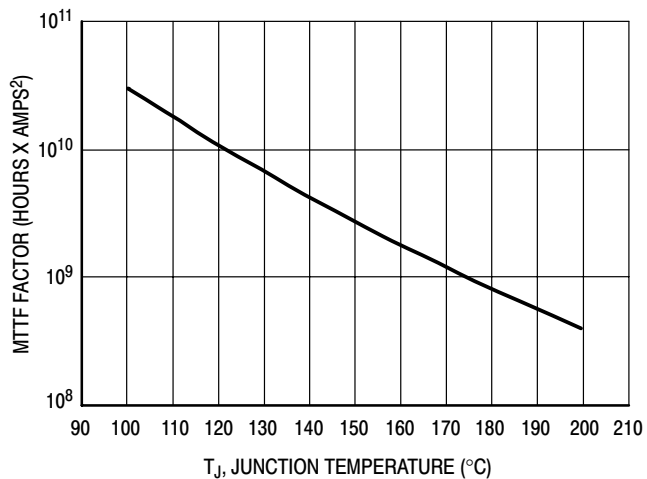
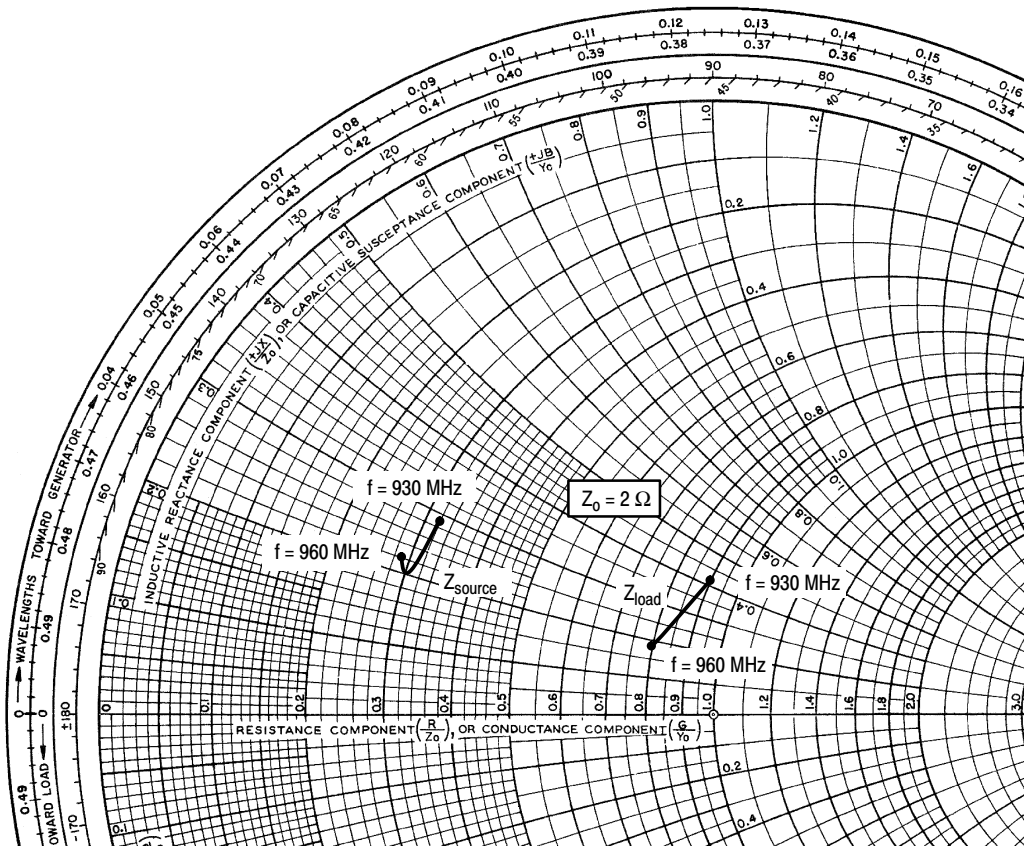


Figure 8. Power Gain, Efficiency, and IMD versus Output Power



This above graph displays calculated MTTF in hours x ampere<sup>2</sup> drain current. Life tests at elevated temperatures have correlated to better than  $\pm 10\%$  of the theoretical prediction for metal failure. Divide MTTF factor by  $I_D^2$  for MTTF in a particular application.

Figure 9. MTTF Factor versus Junction Temperature



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

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.

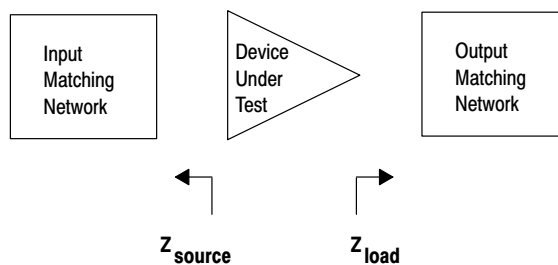


Figure 10. Series Equivalent Source and Load Impedance

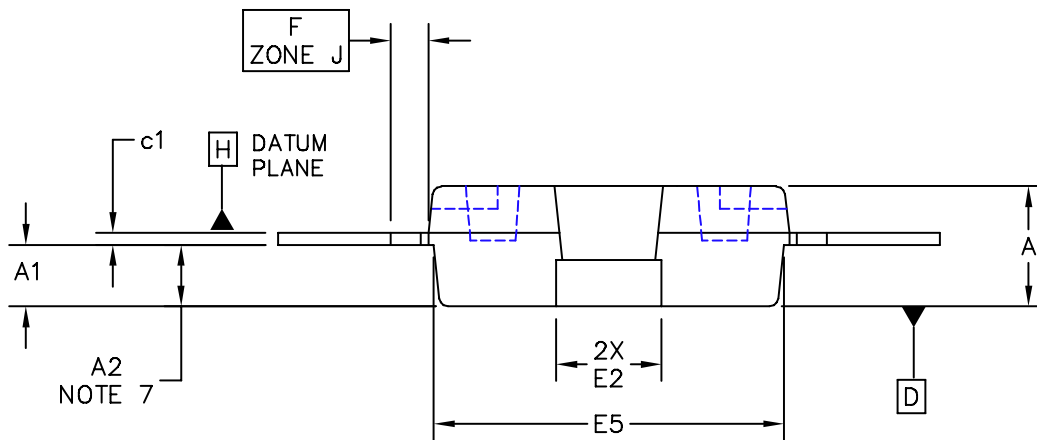
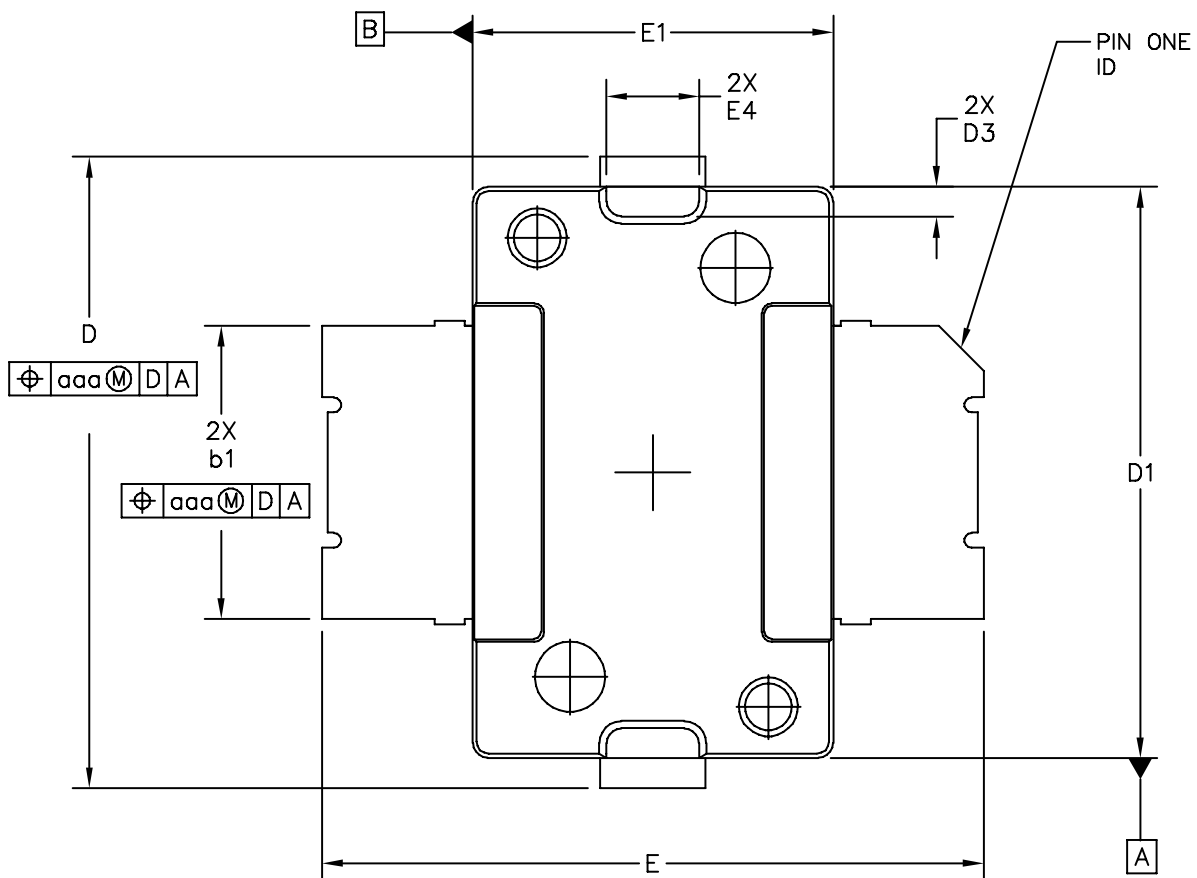


# NOTES

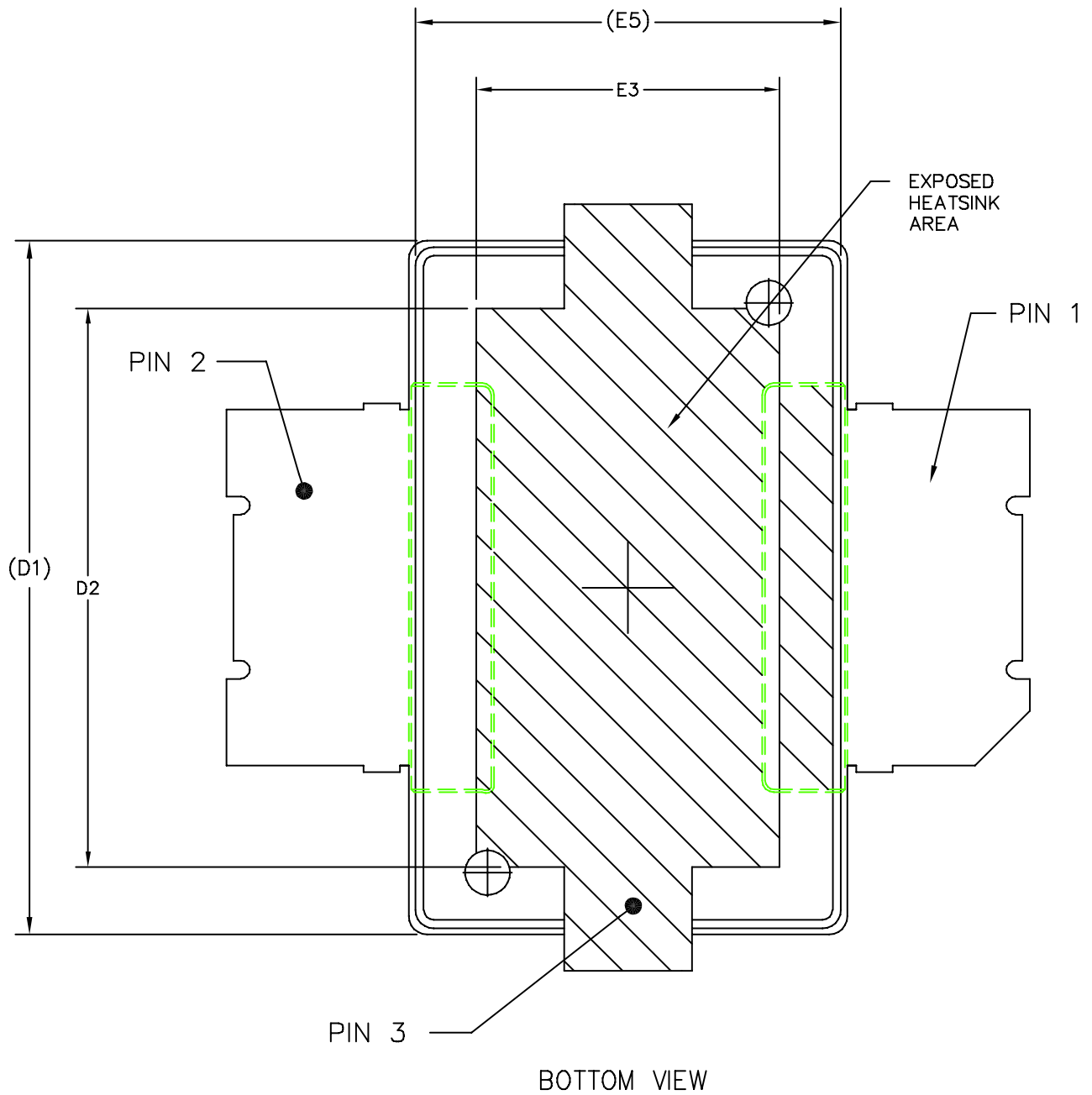
# NOTES

# NOTES

**PACKAGE DIMENSIONS**



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TITLE: TO-270 SURFACE MOUNT	DOCUMENT NO: 98ASH98117A	REV: J
	CASE NUMBER: 1265-08	01 APR 2005
	STANDARD: NON-JEDEC	



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TITLE: <div style="text-align: center;"> <p>TO-270 SURFACE MOUNT</p> </div>	DOCUMENT NO: 98ASH98117A	REV: J	
	CASE NUMBER: 1265-08	01 APR 2005	
	STANDARD: NON-JEDEC		

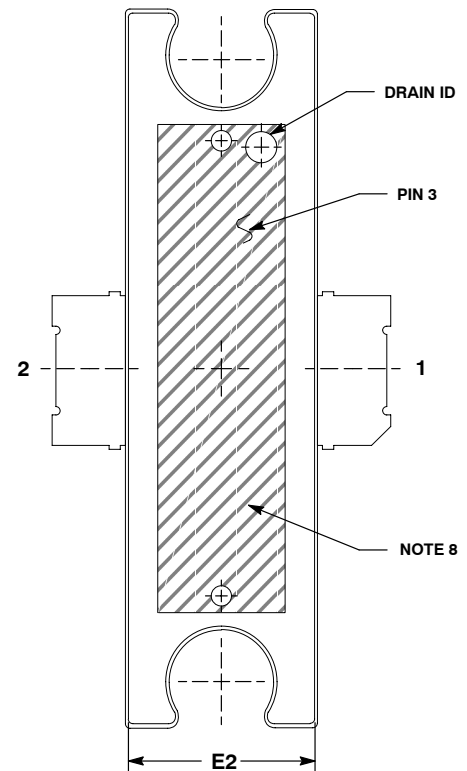
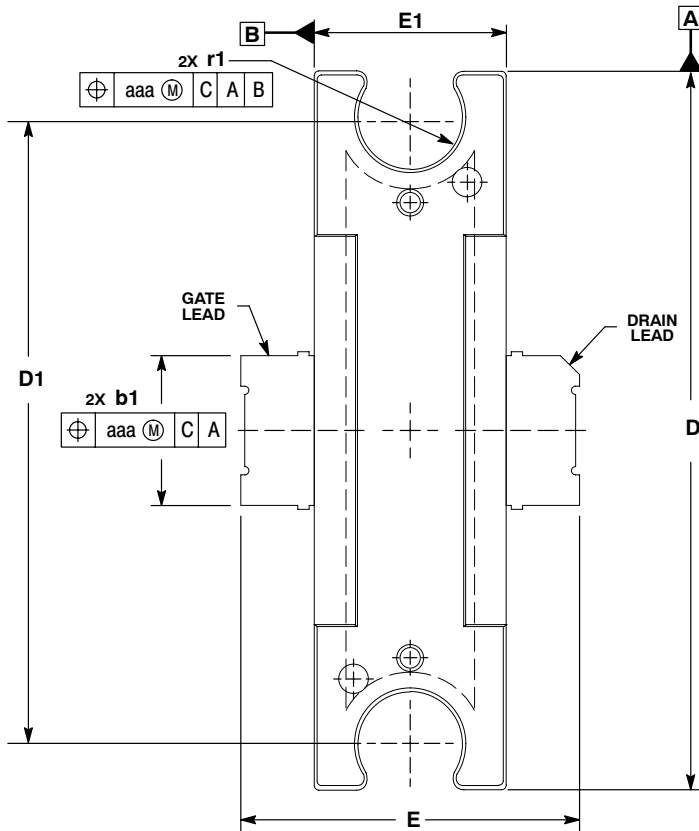
MRF9060NR1 MRF9060NBR1

NOTES:

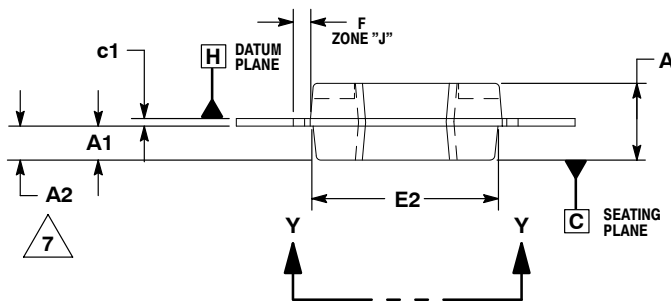
1. CONTROLLING DIMENSION: INCH
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DATUM PLANE -H- IS LOCATED AT TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D1" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE 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. OVERALL LENGTH INCLUDING MOLD PROTRUSION SHOULD NOT EXCEED 0.430 INCH FOR DIMENSION "D" AND 0.080 INCH FOR DIMENSION "E2". DIMENSIONS "D" AND "E2" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -D-.

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

DIM	INCH		MILLIMETER		DIM	INCH		MILLIMETER	
	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	.078	.082	1.98	2.08	F	.025 BSC		0.64 BSC	
A1	.039	.043	0.99	1.09	b1	.193	.199	4.90	5.06
A2	.040	.042	1.02	1.07	c1	.007	.011	0.18	0.28
D	.416	.424	10.57	10.77	aaa	.004		0.10	
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					
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TITLE:  TO-270 SURFACE MOUNT					DOCUMENT NO: 98ASH98117A			REV: J	
					CASE NUMBER: 1265-08			01 APR 2005	
					STANDARD: NON-JEDEC				



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.

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

**CASE 1337-03  
 ISSUE C  
 TO-272-2  
 PLASTIC  
 MRF9060NBR1**

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	

MRF9060NR1 MRF9060NBR1

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