



# RF Power Field Effect Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

Designed for GSM and GSM EDGE base station applications with frequencies from 1800 to 2000 MHz. Suitable for TDMA, CDMA, and multicarrier amplifier applications.

### GSM Application

- Typical GSM Performance:  $V_{DD} = 26$  Vdc,  $I_{DQ} = 600$  mA,  $P_{out} = 60$  Watts CW,  $f = 1990$  MHz  
 Power Gain — 15 dB  
 Drain Efficiency - 50%

### GSM EDGE Application

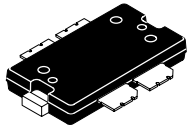
- Typical GSM EDGE Performance:  $V_{DD} = 26$  Volts,  $I_{DQ} = 450$  mA,  $P_{out} = 25$  Watts Avg., Full Frequency Band (1805-1880 MHz or 1930-1990 MHz)  
 Power Gain — 15.5 dB  
 Spectral Regrowth @ 400 kHz Offset = -62 dBc  
 Spectral Regrowth @ 600 kHz Offset = -76 dBc  
 EVM — 2% rms
- Capable of Handling 5:1 VSWR, @ 26 Vdc, 1990 MHz, 60 Watts CW Output Power

### Features

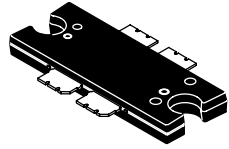
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Matched for Ease of Use
- Qualified Up to a Maximum of 32  $V_{DD}$  Operation
- Integrated ESD Protection
- 225°C Capable Plastic Package
- N Suffix Indicates Lead-Free Terminations. RoHS Compliant.
- In Tape and Reel. R1 Suffix = 500 Units per 44 mm, 13 inch Reel.

**MRF6S18060NR1**  
**MRF6S18060NBR1**

**1800-2000 MHz, 60 W, 26 V**  
**GSM/GSM EDGE**  
**LATERAL N-CHANNEL**  
**RF POWER MOSFETs**



**CASE 1486-03, STYLE 1**  
**TO-270 WB-4**  
**PLASTIC**  
**MRF6S18060NR1**



**CASE 1484-04, STYLE 1**  
**TO-272 WB-4**  
**PLASTIC**  
**MRF6S18060NBR1**

**Table 1. Maximum Ratings**

Rating	Symbol	Value	Unit
Drain-Source Voltage	$V_{DSS}$	-0.5, +68	Vdc
Gate-Source Voltage	$V_{GS}$	-0.5, +12	Vdc
Storage Temperature Range	$T_{stg}$	- 65 to +150	°C
Case Operating Temperature	$T_C$	150	°C
Operating Junction Temperature (1,2)	$T_J$	225	°C

**Table 2. Thermal Characteristics**

Characteristic	Symbol	Value (2,3)	Unit
Thermal Resistance, Junction to Case Case Temperature 80°C, 60 W CW Case Temperature 77°C, 25 W CW	$R_{\theta JC}$	0.81 0.95	°C/W

1. Continuous use at maximum temperature will affect MTTF.
2. MTTF calculator available at <http://www.freescale.com/rf>. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.
3. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf>. Select Documentation/Application Notes - AN1955.

**Table 3. ESD Protection Characteristics**

Test Methodology	Class
Human Body Model (per JESD22-A114)	1B (Minimum)
Machine Model (per EIA/JESD22-A115)	A (Minimum)
Charge Device Model (per JESD22-C101)	III (Minimum)

**Table 4. Moisture Sensitivity Level**

Test Methodology	Rating	Package Peak Temperature	Unit
Per JESD 22-A113, IPC/JEDEC J-STD-020	3	260	°C

**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 ( $V_{DS} = 68\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	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 ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 200\ \mu\text{Adc}$ )	$V_{GS(th)}$	1	2	3	Vdc
Gate Quiescent Voltage ( $V_{DD} = 26\text{ Vdc}$ , $I_D = 600\ \text{mA}$ , Measured in Functional Test)	$V_{GS(Q)}$	2	2.8	4	Vdc
Drain-Source On-Voltage ( $V_{GS} = 10\text{ Vdc}$ , $I_D = 2\ \text{Adc}$ )	$V_{DS(on)}$	—	0.24	—	Vdc

**Dynamic Characteristics**

Reverse Transfer Capacitance (1) ( $V_{DS} = 26\text{ Vdc} \pm 30\ \text{mV(rms)}$ ac @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{rss}$	—	1.5	—	pF
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**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 26\text{ Vdc}$ ,  $I_{DQ} = 600\ \text{mA}$ ,  $P_{out} = 60\ \text{W CW}$ ,  $f = 1990\ \text{MHz}$ 

Power Gain	$G_{ps}$	14	15	17	dB
Drain Efficiency	$\eta_D$	48	50	—	%
Input Return Loss	IRL	—	-12	-9	dB
$P_{out}$ @ 1 dB Compression Point	P1dB	60	65	—	W

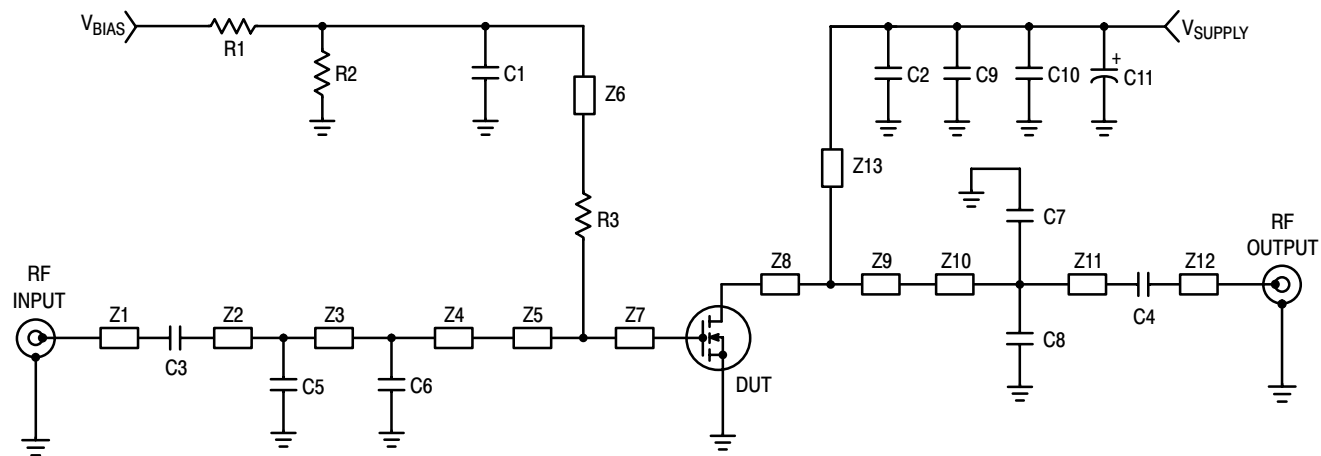
**Typical GSM EDGE Performances** (In Freescale Broadband Test Fixture, 50 ohm system)  $V_{DD} = 26\text{ Vdc}$ ,  $I_{DQ} = 450\ \text{mA}$ ,  $P_{out} = 25\ \text{W Avg.}$ , 1805-1880 MHz or 1930-1990 MHz, EDGE Modulation

Power Gain	$G_{ps}$	—	15.5	—	dB
Drain Efficiency	$\eta_D$	—	32	—	%
Error Vector Magnitude	EVM	—	2	—	% rms
Spectral Regrowth at 400 kHz Offset	SR1	—	-62	—	dBc
Spectral Regrowth at 600 kHz Offset	SR2	—	-76	—	dBc

**Typical CW Performances** (In Freescale Broadband Test Fixture, 50 ohm system)  $V_{DD} = 26\text{ Vdc}$ ,  $I_{DQ} = 600\ \text{mA}$ ,  $P_{out} = 60\ \text{W}$ , 1805-1880 MHz or 1930-1990 MHz

Power Gain	$G_{ps}$	—	15	—	dB
Drain Efficiency	$\eta_D$	—	50	—	%
Input Return Loss	IRL	—	-12	—	dB
$P_{out}$ @ 1 dB Compression Point, CW	P1dB	—	65	—	W

1. Part is internally matched both on input and output.



- |        |                            |      |  |
|--------|----------------------------|------|--|
| Z1     | 0.250" x 0.083" Microstrip | Z9   | 0.485" x 1.000" Microstrip                     |
| Z2*    | 0.950" x 0.083" Microstrip | Z10* | 0.500" x 0.083" Microstrip                     |
| Z3*    | 0.250" x 0.083" Microstrip | Z11* | 0.895" x 0.083" Microstrip                     |
| Z4*    | 0.315" x 0.083" Microstrip | Z12  | 0.250" x 0.083" Microstrip                     |
| Z5     | 0.365" x 1.000" Microstrip | Z13  | 0.200" x 0.080" Microstrip                     |
| Z6     | 0.680" x 0.080" Microstrip | PCB  | Taconic TLX8-0300, 0.030", $\epsilon_r = 2.55$ |
| Z7, Z8 | 0.115" x 1.000" Microstrip |      |  |
- \* Variable for tuning

Figure 1. MRF6S18060NR1(NBR1) Test Circuit Schematic — 1900 MHz

Table 6. MRF6S18060NR1(NBR1) Test Circuit Component Designations and Values — 1900 MHz

Part	Description	Part Number	Manufacturer
C1, C2, C3, C4	6.8 pF Chip Capacitors	ATC100B6R8CT500XT	ATC
C5	1.5 pF Chip Capacitor	ATC100B1R5BT500XT	ATC
C6	1.8 pF Chip Capacitor	ATC100B1R8BT500XT	ATC
C7, C8	1 pF Chip Capacitors	ATC100B1R0BT500XT	ATC
C9, C10	10 $\mu$ F Chip Capacitors	C5750X5R1H106MT	TDK
C11	220 $\mu$ F, 63 V Electrolytic Capacitor, Radial	2222 - 136 - 68221	Vishay
R1, R2	10 k $\Omega$ , 1/4 W Chip Resistors	CRCW12061002FKEA	Vishay
R3	10 $\Omega$ , 1/4 W Chip Resistor	CRCW120610R0FKEA	Vishay

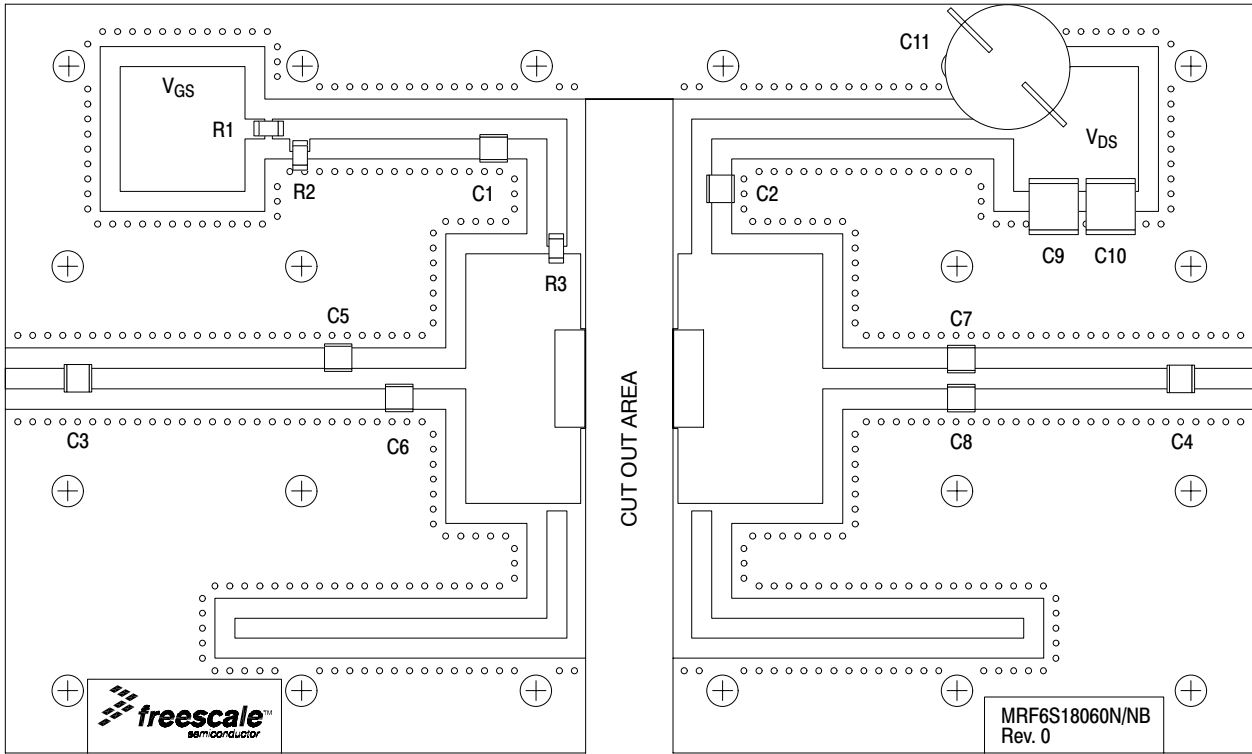


Figure 2. MRF6S18060NR1(NBR1) Test Circuit Component Layout — 1900 MHz

TYPICAL CHARACTERISTICS — 1900 MHz

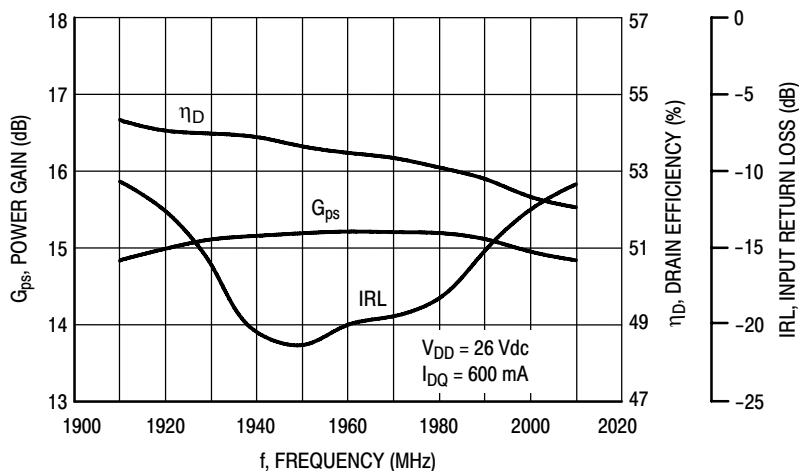


Figure 3. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @ P<sub>out</sub> = 60 Watts

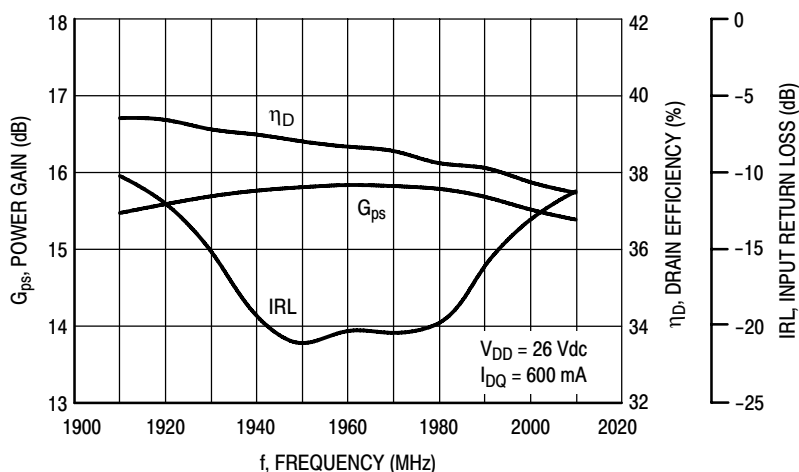


Figure 4. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @ P<sub>out</sub> = 30 Watts

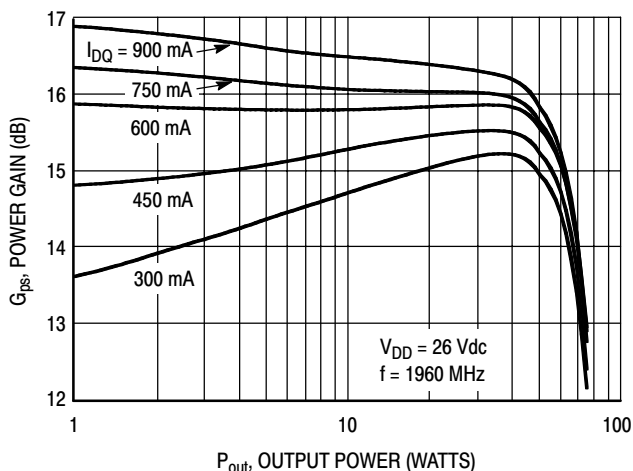


Figure 5. Power Gain versus Output Power

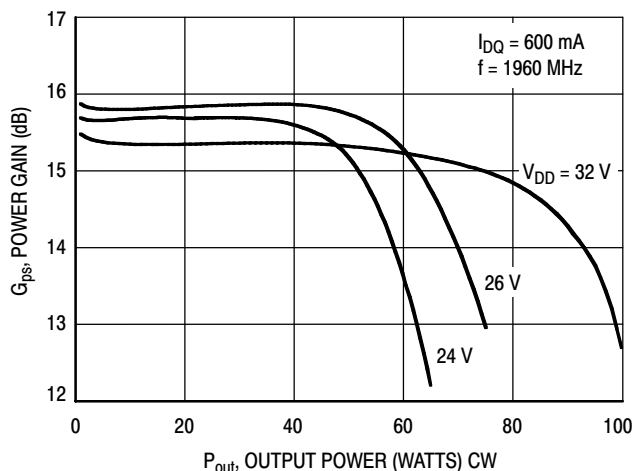
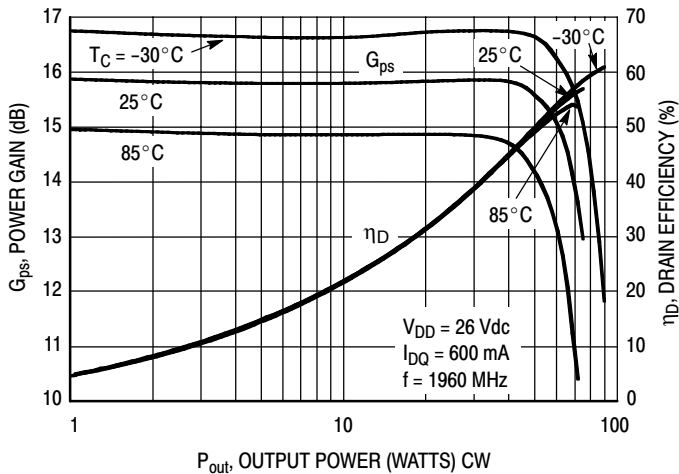
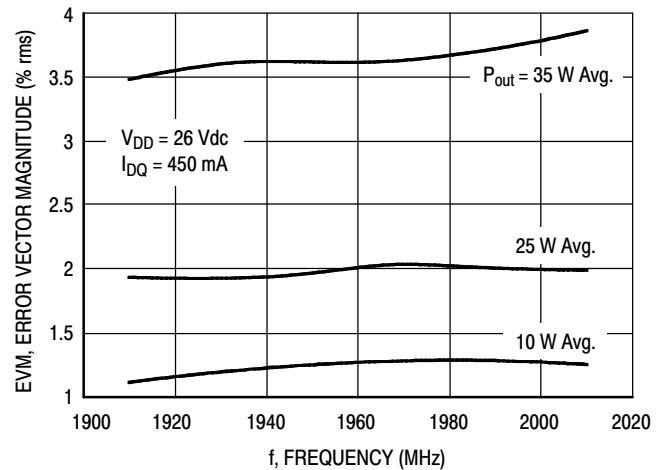


Figure 6. Power Gain versus Output Power

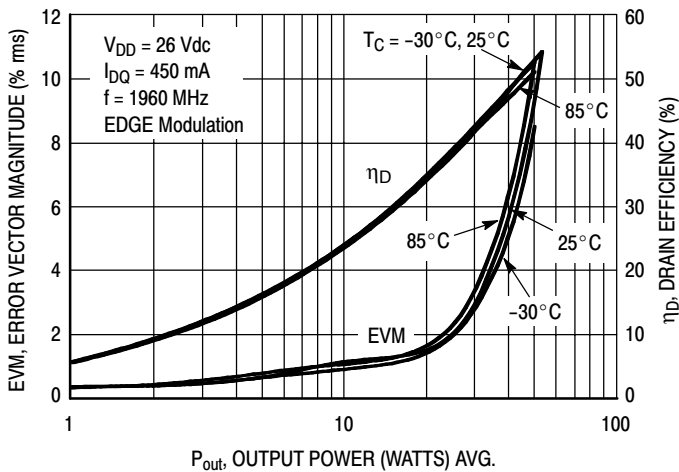
## TYPICAL CHARACTERISTICS — 1900 MHz



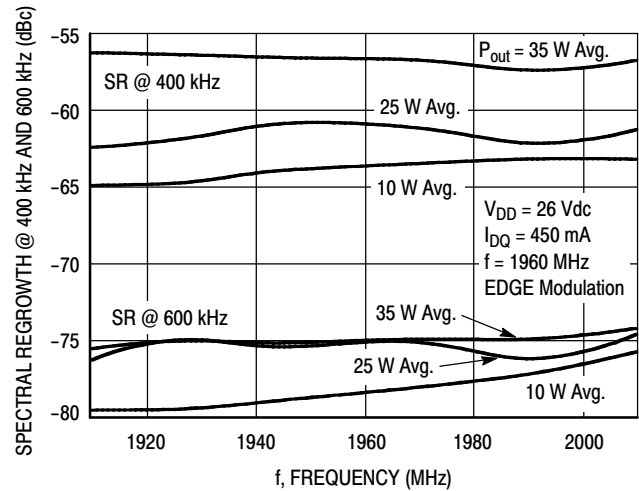
**Figure 7. Power Gain and Drain Efficiency versus CW Output Power**



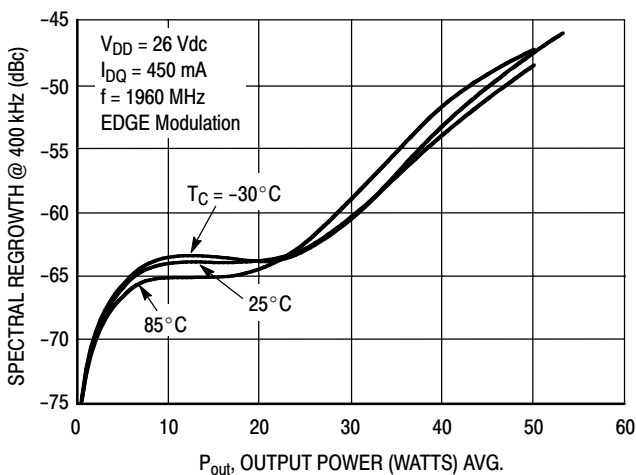
**Figure 8. EVM versus Frequency**



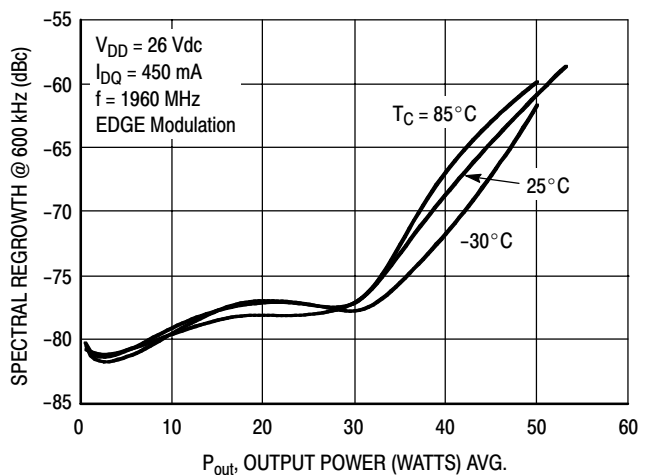
**Figure 9. EVM and Drain Efficiency versus Output Power**



**Figure 10. Spectral Regrowth at 400 kHz and 600 kHz versus Frequency**

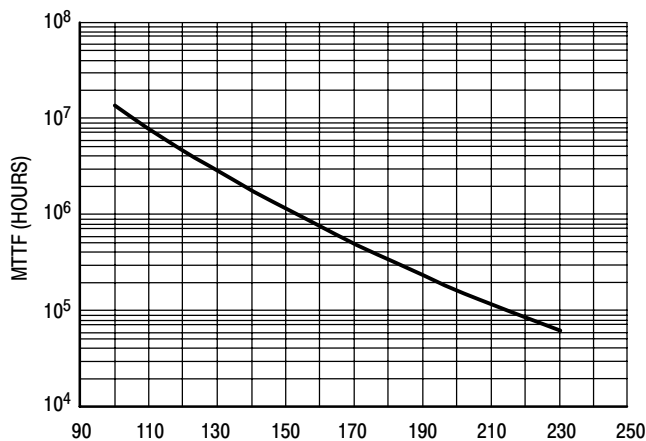


**Figure 11. Spectral Regrowth at 400 kHz versus Output Power**



**Figure 12. Spectral Regrowth at 600 kHz versus Output Power**

## TYPICAL CHARACTERISTICS

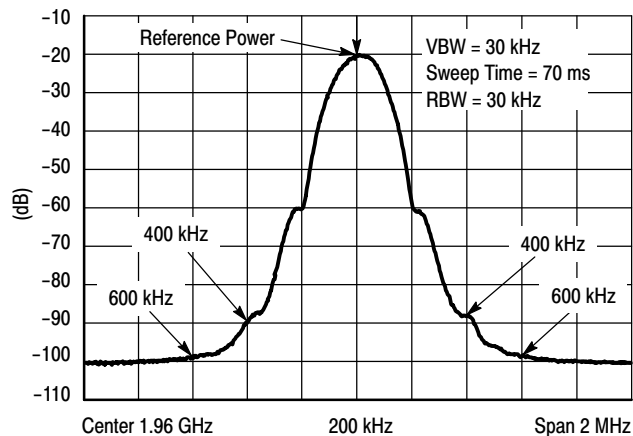


This above graph displays calculated MTTF in hours when the device is operated at  $V_{DD} = 28$  Vdc,  $P_{out} = 60$  W CW, and  $\eta_D = 50\%$ .

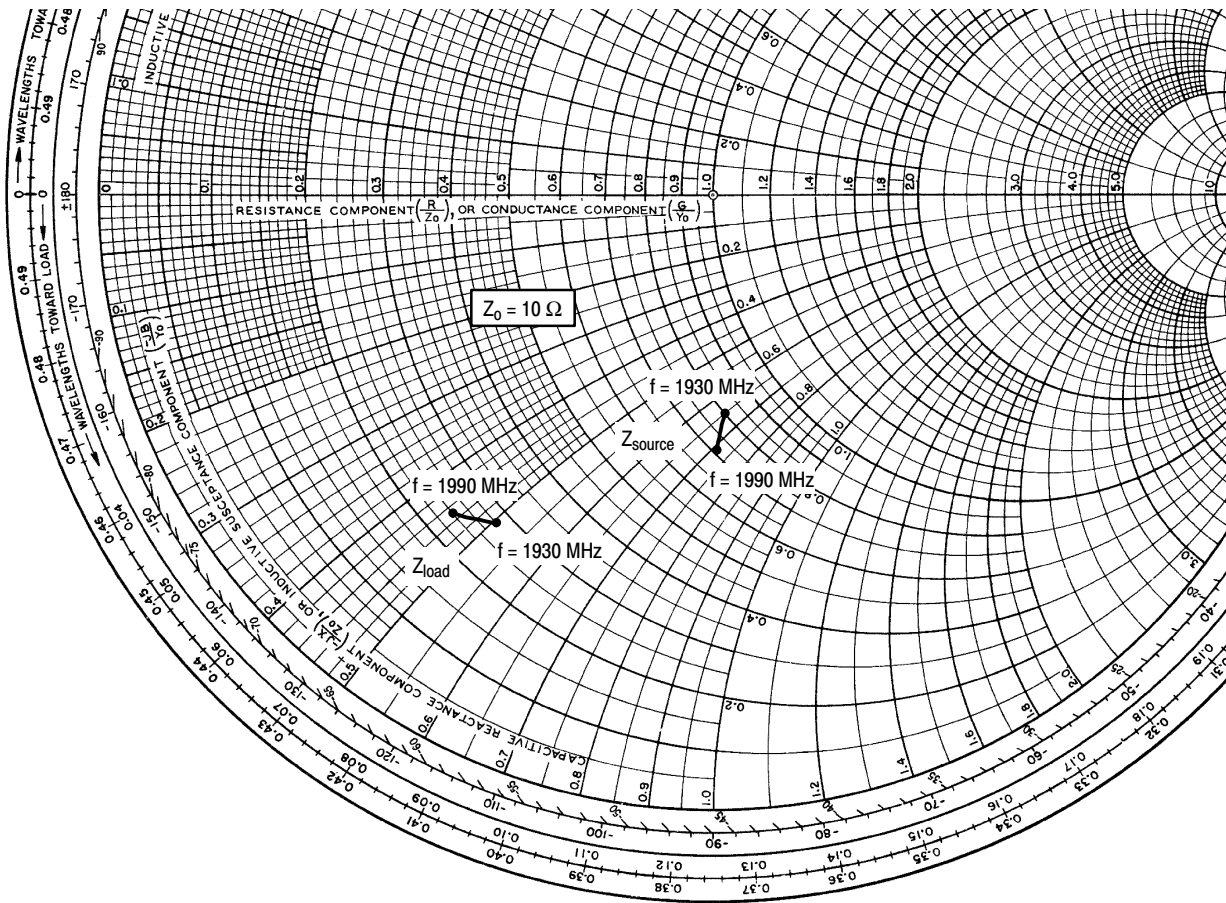
MTTF calculator available at <http://www.freescale.com/rf>. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.

**Figure 13. MTTF Factor versus Junction Temperature**

## GSM TEST SIGNAL



**Figure 14. EDGE Spectrum**



$V_{DD} = 26 \text{ Vdc}$ ,  $I_{DQ} = 600 \text{ mA}$ ,  $P_{out} = 60 \text{ W CW}$

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
1930	8.00 - j6.48	2.83 - j5.13
1960	7.57 - j6.82	2.63 - j4.84
1990	7.06 - j7.06	2.44 - j4.54

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

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

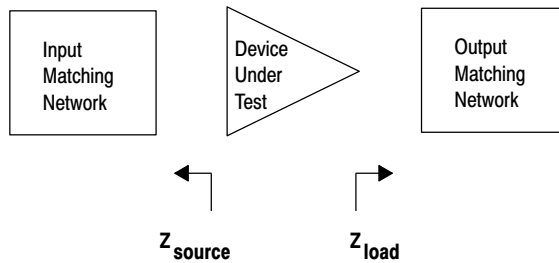
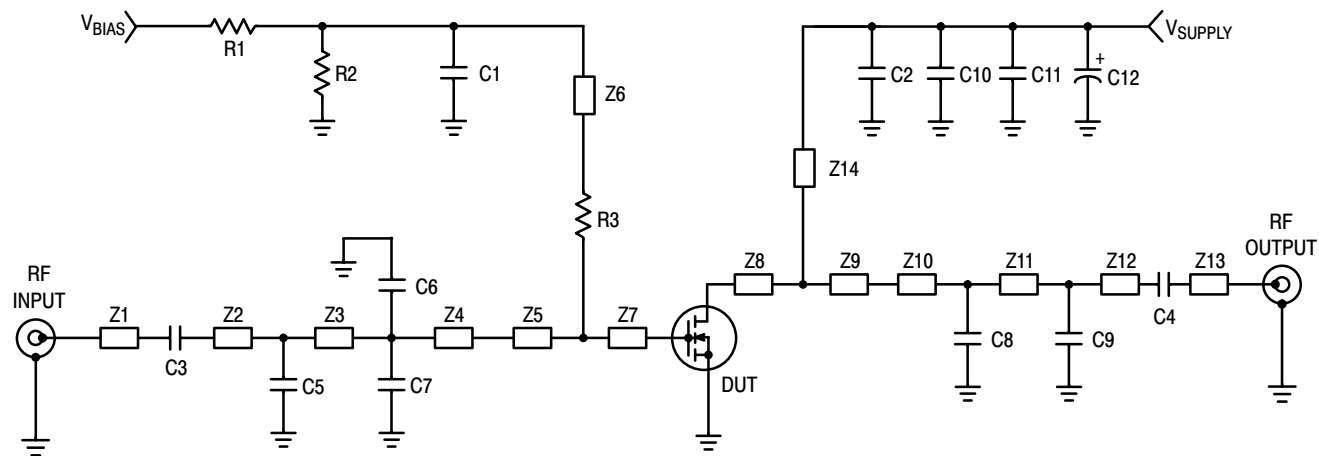


Figure 15. Series Equivalent Source and Load Impedance — 1900 MHz





Z1            0.250" x 0.083" Microstrip  
 Z2\*          0.320" x 0.083" Microstrip  
 Z3\*          0.660" x 0.083" Microstrip  
 Z4\*          0.535" x 0.083" Microstrip  
 Z5            0.365" x 1.000" Microstrip  
 Z6            0.860" x 0.080" Microstrip  
 Z7, Z8       0.115" x 1.000" Microstrip

Z9            0.485" x 1.000" Microstrip  
 Z10\*        0.420" x 0.083" Microstrip  
 Z11\*        0.230" x 0.083" Microstrip  
 Z12\*        0.745" x 0.083" Microstrip  
 Z13          0.250" x 0.083" Microstrip  
 Z14          0.640" x 0.080" Microstrip  
 PCB         Taconic TLX8-0300, 0.030",  $\epsilon_r = 2.55$

\* Variable for tuning

Figure 16. MRF6S18060NR1(NBR1) Test Circuit Schematic — 1800 MHz

Table 7. MRF6S18060NR1(NBR1) Test Circuit Component Designations and Values — 1800 MHz

Part	Description	Part Number	Manufacturer
C1, C2, C3, C4	6.8 pF Chip Capacitors	ATC100B6R8CT500XT	ATC
C5	0.8 pF Chip Capacitor	ATC100B0R8BT500XT	ATC
C6, C9	0.5 pF Chip Capacitors	ATC100B0R5BT500XT	ATC
C7	2.2 pF Chip Capacitor	ATC100B2R2BT500XT	ATC
C8	1.5 pF Chip Capacitor	ATC100B1R5BT500XT	ATC
C10, C11	10 $\mu$ F Chip Capacitors	C5750X5R1H106MT	TDK
C12	220 $\mu$ F, 63 V Electrolytic Capacitor, Radial	2222-136-68221	Vishay
R1, R2	10 k $\Omega$ , 1/4 W Chip Resistors	CRCW12061002FKEA	Vishay
R3	10 $\Omega$ , 1/4 W Chip Resistor	CRCW120610R0FKEA	Vishay

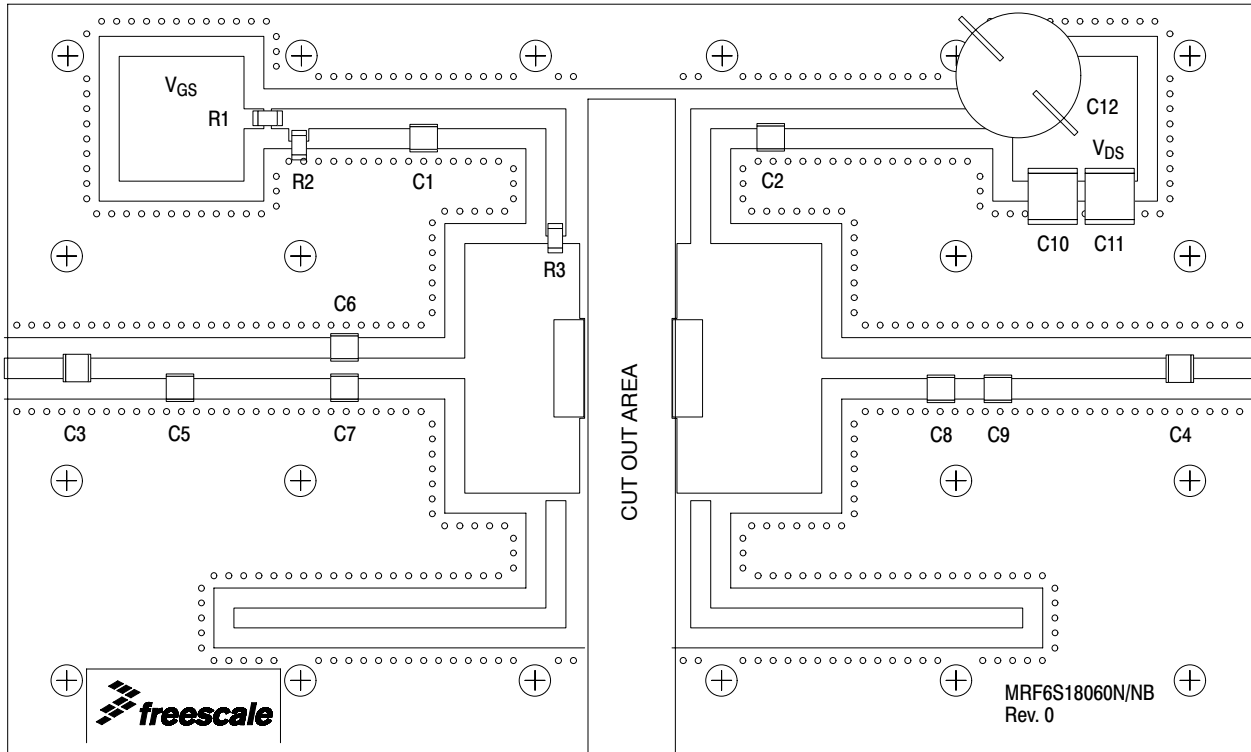


Figure 17. MRF6S18060NR1(NBR1) Test Circuit Component Layout — 1800 MHz

## TYPICAL CHARACTERISTICS — 1800 MHz

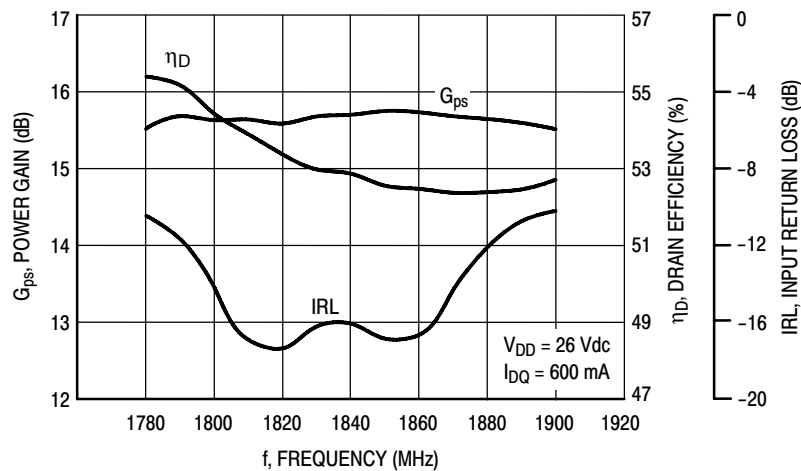


Figure 18. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 60$  Watts

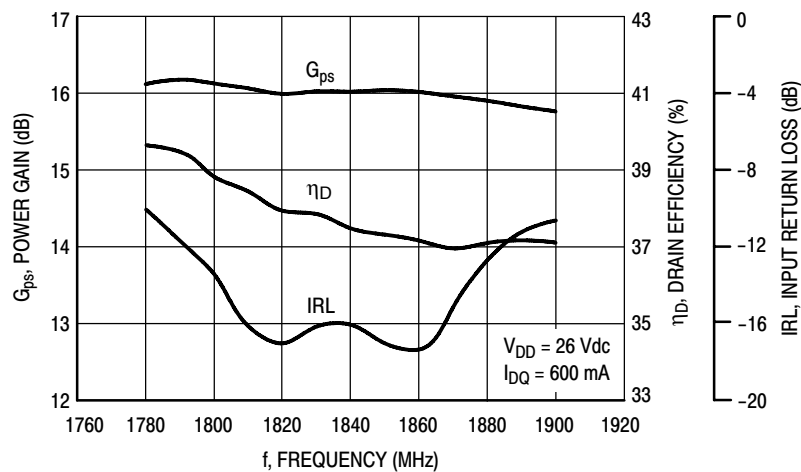


Figure 19. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 30$  Watts

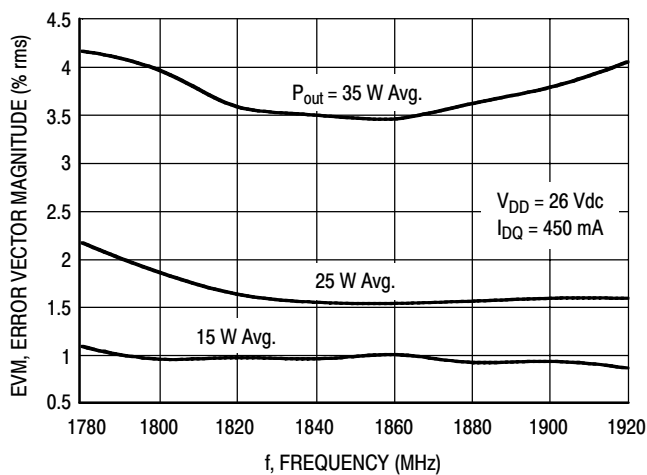


Figure 20. EVM versus Frequency

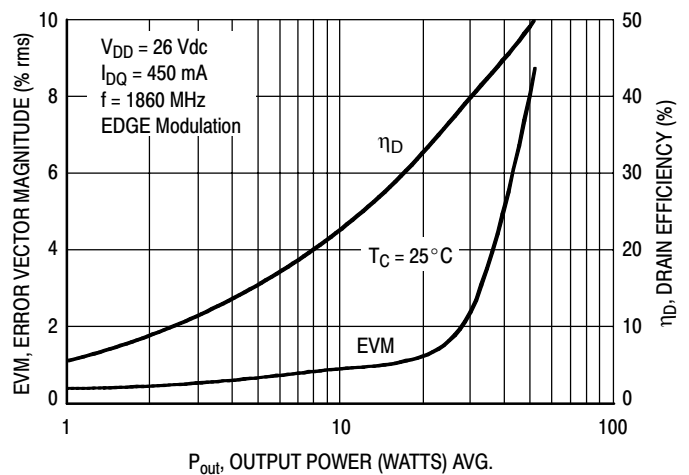
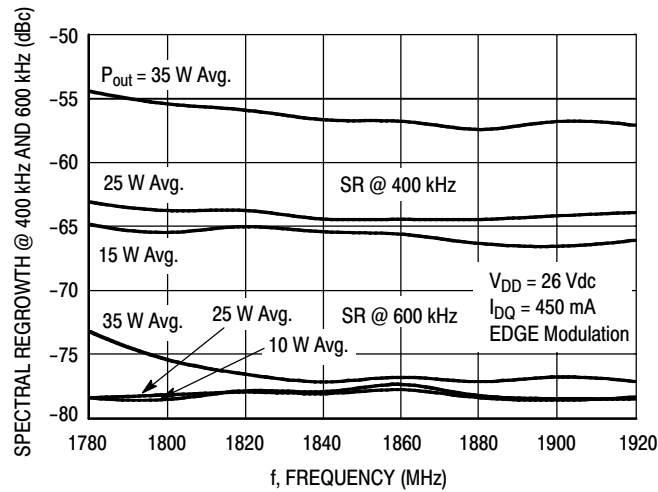


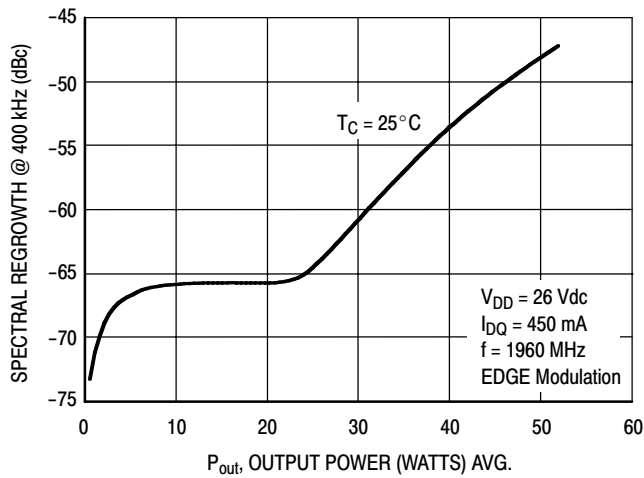
Figure 21. EVM and Drain Efficiency versus Output Power

MRF6S18060NR1 MRF6S18060NBR1

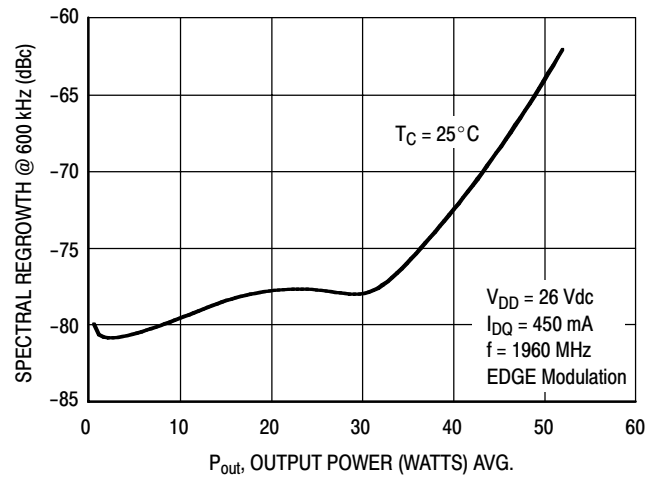
## TYPICAL CHARACTERISTICS — 1800 MHz



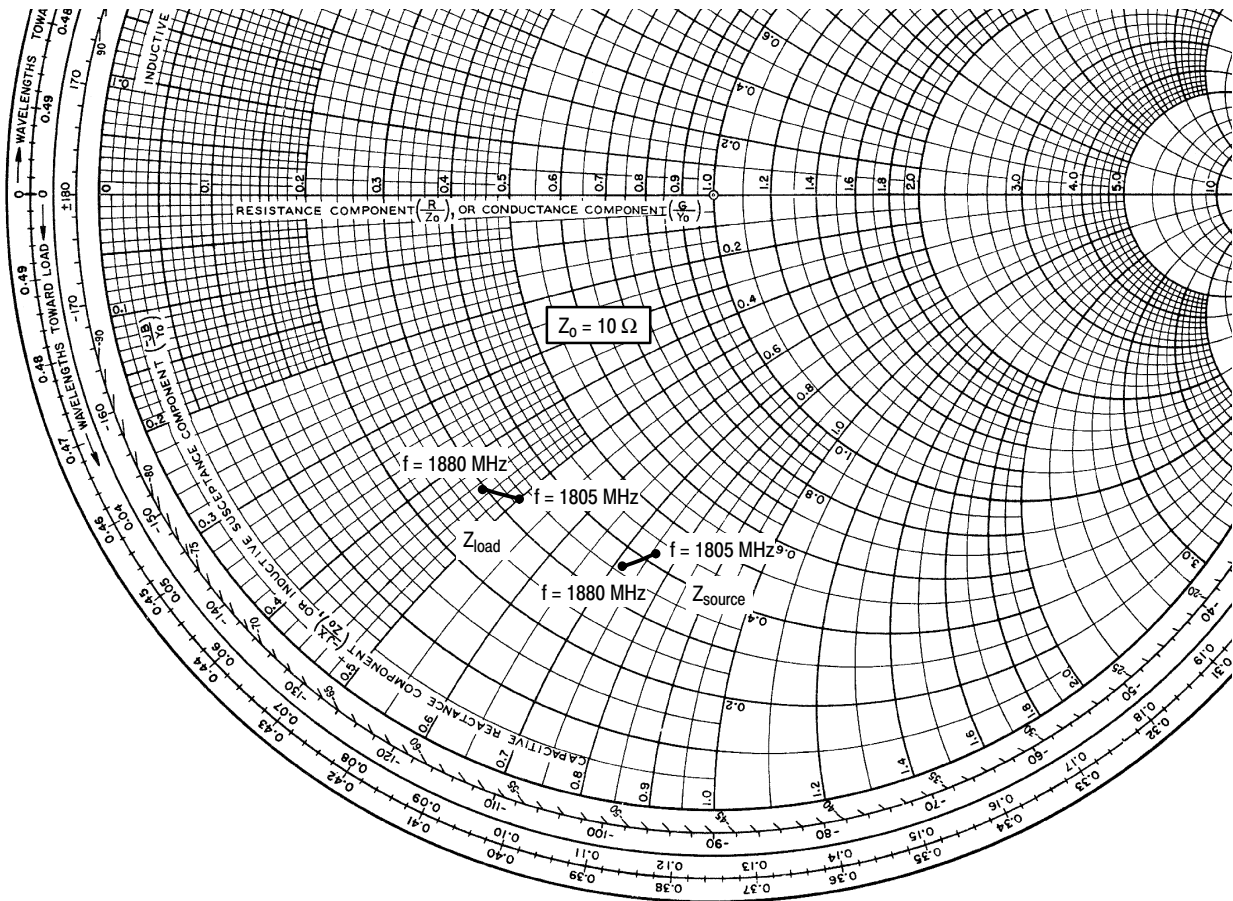
**Figure 22. Spectral Regrowth at 400 kHz and 600 kHz versus Frequency**



**Figure 23. Spectral Regrowth at 400 kHz versus Output Power**



**Figure 24. Spectral Regrowth at 600 kHz versus Output Power**



$V_{DD} = 26 \text{ Vdc}$ ,  $I_{DQ} = 600 \text{ mA}$ ,  $P_{out} = 65 \text{ W CW}$

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
1805	$4.16 - j7.56$	$3.29 - j4.91$
1840	$3.89 - j7.40$	$3.10 - j4.69$
1880	$3.56 - j7.21$	$2.88 - j4.45$

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

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

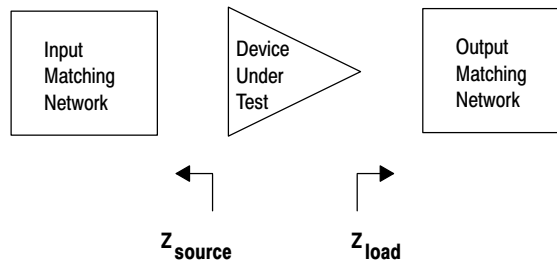
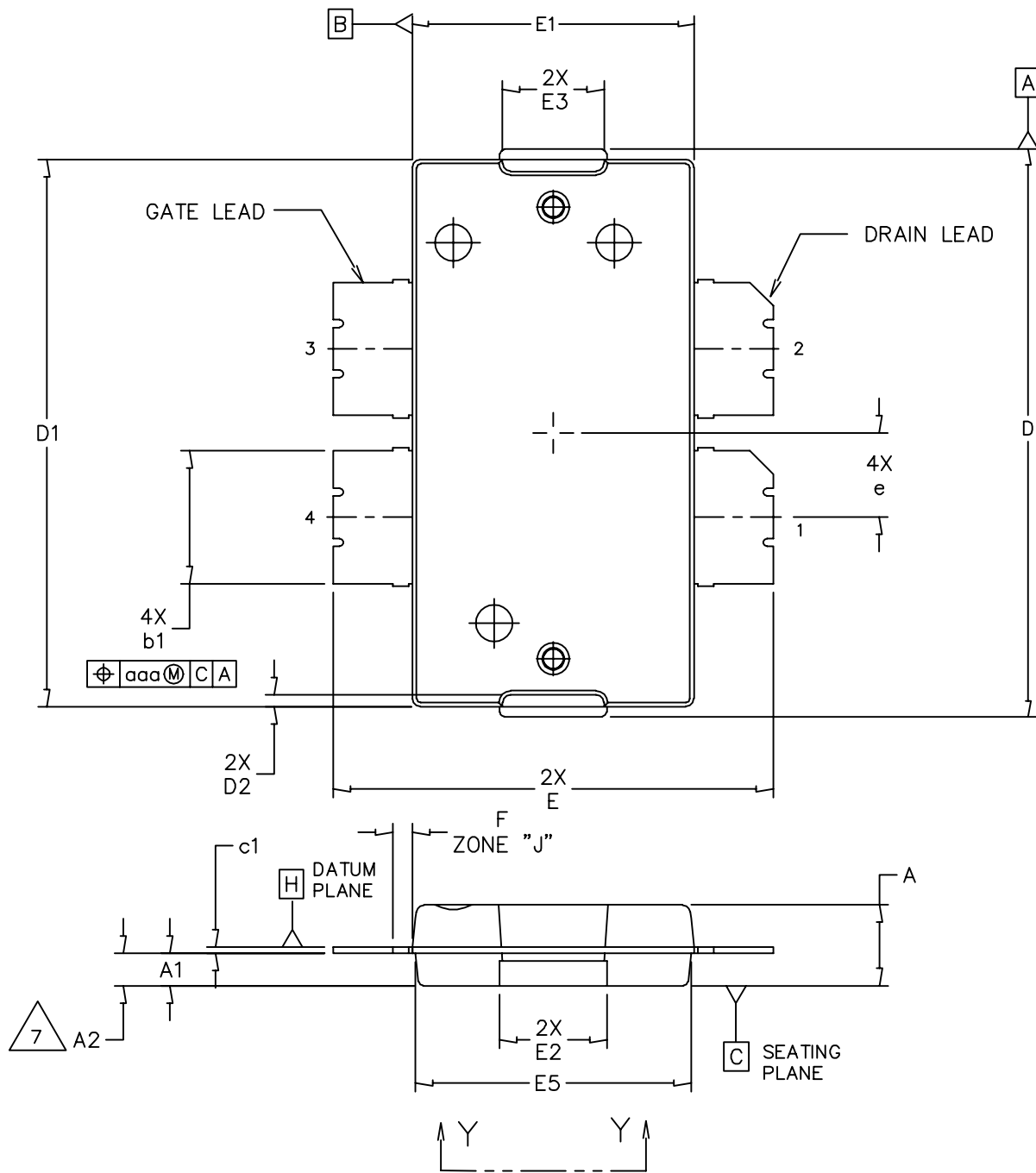
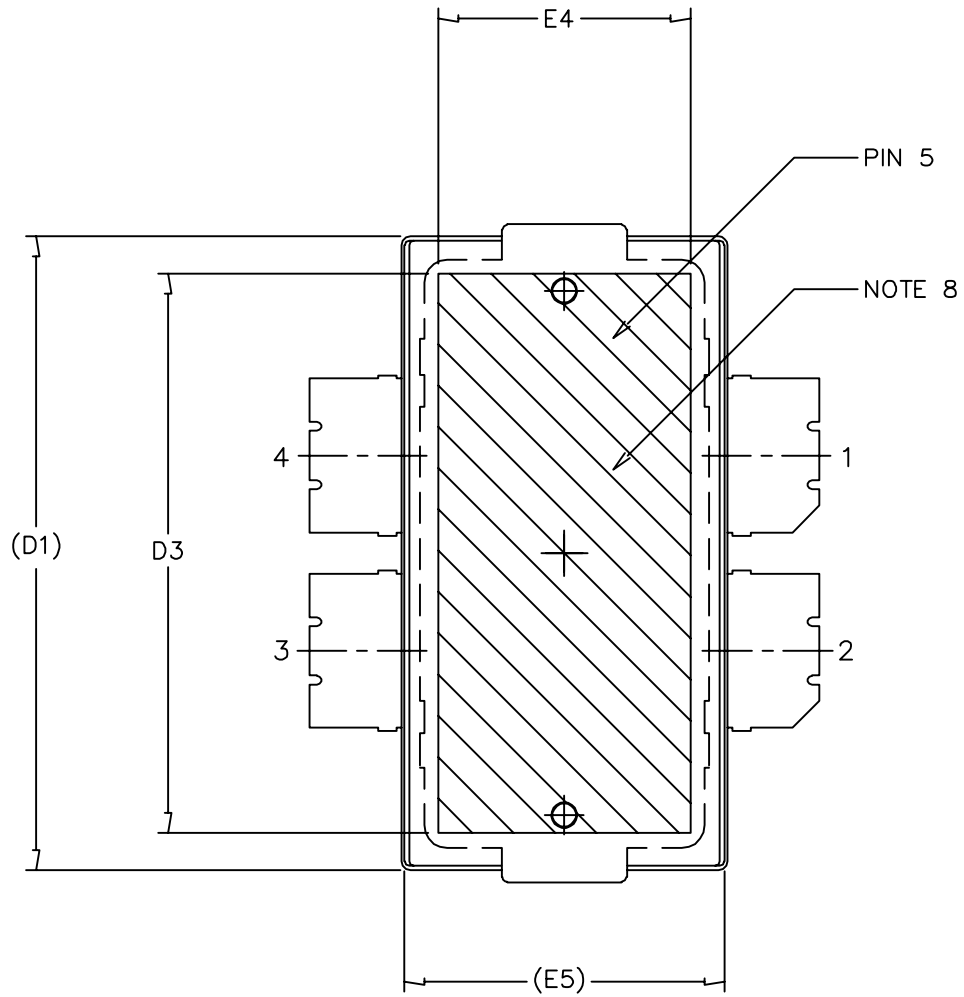


Figure 25. Series Equivalent Source and Load Impedance — 1800 MHz

### PACKAGE DIMENSIONS



© FREESCALE SEMICONDUCTOR, INC. ALL RIGHTS RESERVED.		MECHANICAL OUTLINE		PRINT VERSION NOT TO SCALE	
TITLE: TO-270 4 LEAD, WIDE BODY		DOCUMENT NO: 98ASA10577D		REV: D	
		CASE NUMBER: 1486-03		13 AUG 2007	
		STANDARD: NON-JEDEC			



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TITLE: TO-270 4 LEAD, WIDE BODY		DOCUMENT NO: 98ASA10577D	REV: D
		CASE NUMBER: 1486-03	13 AUG 2007
		STANDARD: NON-JEDEC	

MRF6S18060NR1 MRF6S18060NBR1

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. DIMENSIONS "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. HATCHING REPRESENTS THE EXPOSED AREA OF THE HEAT SLUG.

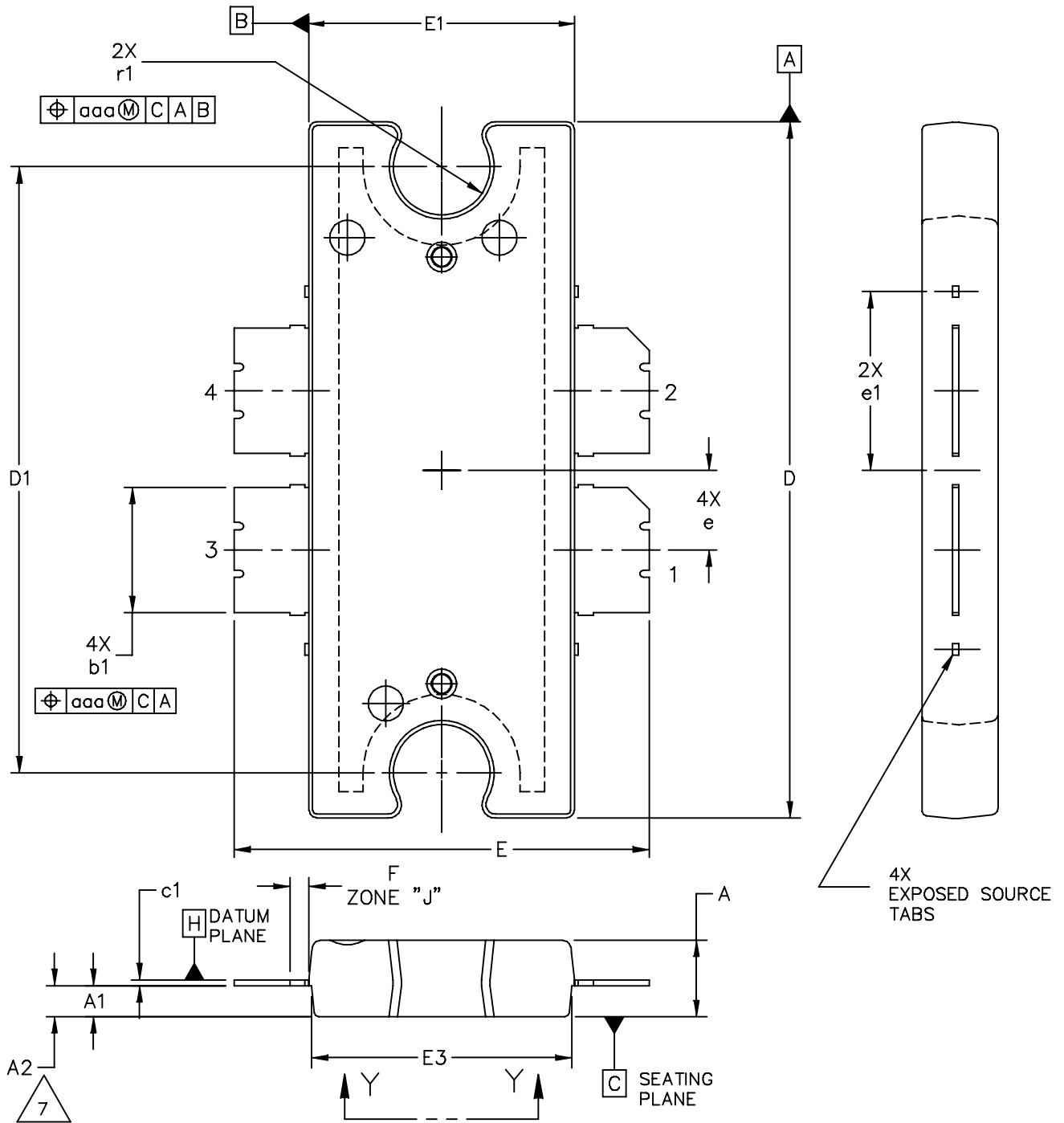
STYLE 1:

PIN 1 - DRAIN      PIN 2 - DRAIN  
 PIN 3 - GATE      PIN 4 - GATE  
 PIN 5 - SOURCE

DIM	INCH		MILLIMETER		DIM	INCH		MILLIMETER	
	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	.100	.104	2.54	2.64	F	.025 BSC		0.64 BSC	
A1	.039	.043	0.99	1.09	b1	.164	.170	4.17	4.32
A2	.040	.042	1.02	1.07	c1	.007	.011	.18	.28
D	.712	.720	18.08	18.29	e	.106 BSC		2.69 BSC	
D1	.688	.692	17.48	17.58	aaa	.004		.10	
D2	.011	.019	0.28	0.48					
D3	.600	---	15.24	---					
E	.551	.559	14	14.2					
E1	.353	.357	8.97	9.07					
E2	.132	.140	3.35	3.56					
E3	.124	.132	3.15	3.35					
E4	.270	---	6.86	---					
E5	.346	.350	8.79	8.89					

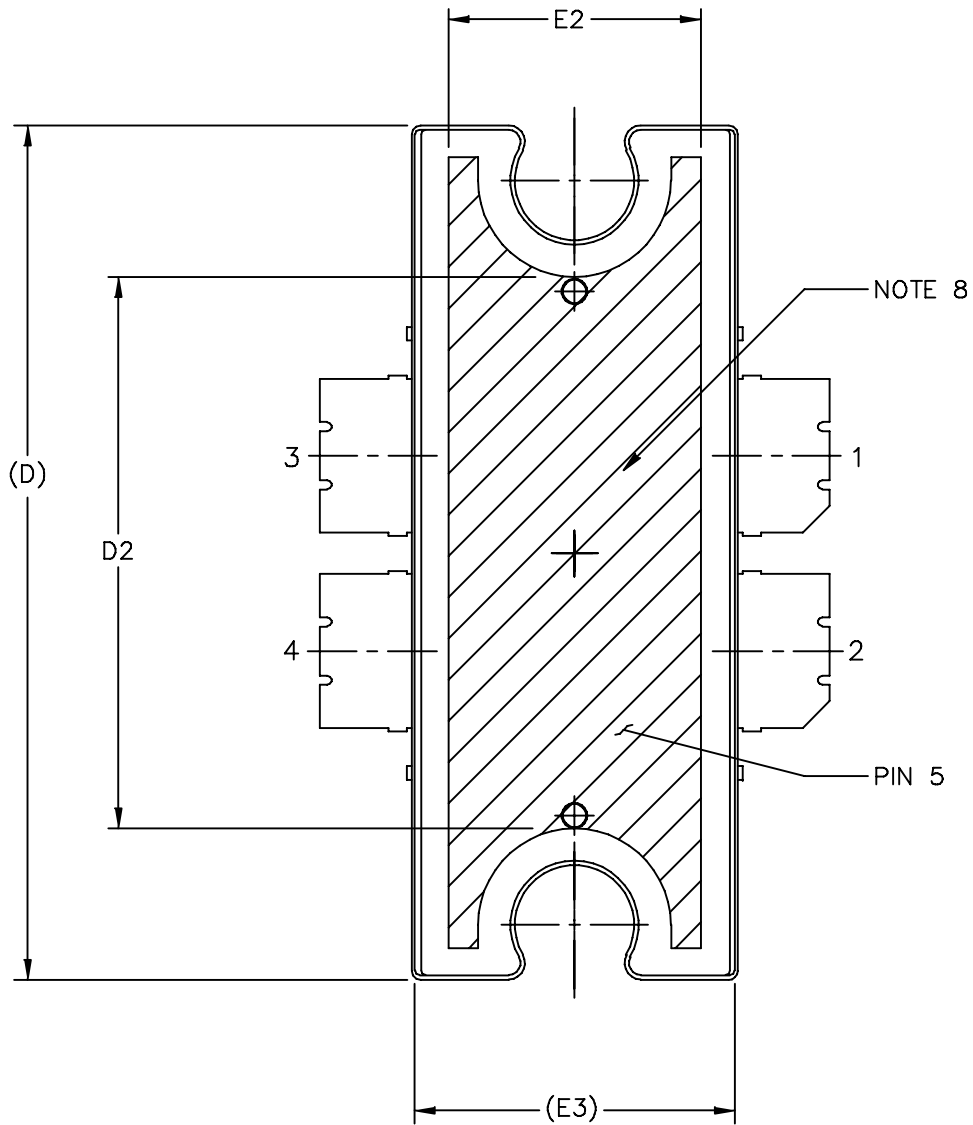
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TITLE:  TO-270 4 LEAD WIDE BODY		DOCUMENT NO: 98ASA10577D		REV: D	
		CASE NUMBER: 1486-03		13 AUG 2007	
		STANDARD: NON-JEDEC			





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TITLE: TO-272 4 LEAD, WIDE BODY	DOCUMENT NO: 98ASA10575D	REV: E
	CASE NUMBER: 1484-04	31 AUG 2007
	STANDARD: NON-JEDEC	

MRF6S18060NR1 MRF6S18060NBR1



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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. DIMENSIONS "b1" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 TOTAL IN EXCESS OF THE "b1" DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUM A AND B TO BE DETERMINED AT DATUM PLANE H.
7. DIMENSION A2 APPLIES WITHIN ZONE "J" ONLY.
8. HATCHING REPRESENTS EXPOSED AREA OF THE HEAT SLUG. HATCHED AREA SHOWN IS ON THE SAME PLANE.

STYLE 1:

PIN 1 - DRAIN      PIN 2 - DRAIN  
 PIN 3 - GATE      PIN 4 - GATE  
 PIN 5 - SOURCE

DIM	INCH		MILLIMETER		DIM	INCH		MILLIMETER	
	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	.100	.104	2.54	2.64	b1	.164	.170	4.17	4.32
A1	.039	.043	0.99	1.09	c1	.007	.011	.18	.28
A2	.040	.042	1.02	1.07	r1	.063	.068	1.60	1.73
D	.928	.932	23.57	23.67	e	.106 BSC		2.69 BSC	
D1	.810 BSC		20.57 BSC		e1	.239 INFO ONLY		6.07 INFO ONLY	
D2	.600	---	15.24	---	aaa	.004		.10	
E	.551	.559	14	14.2					
E1	.353	.357	8.97	9.07					
E2	.270	---	6.86	---					
E3	.346	.350	8.79	8.89					
F	.025 BSC		0.64 BSC						

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## PRODUCT DOCUMENTATION

Refer to the following documents to aid your design process.

### Application Notes

- AN1907: Solder Reflow Attach Method for High Power RF Devices in Plastic Packages
- AN1955: Thermal Measurement Methodology of RF Power Amplifiers
- AN3263: Bolt Down Mounting Method for High Power RF Transistors and RFICs in Over-Molded Plastic Packages

### Engineering Bulletins

- EB212: Using Data Sheet Impedances for RF LDMOS Devices

## REVISION HISTORY

The following table summarizes revisions to this document.

Revision	Date	Description
4	Dec. 2008	<ul style="list-style-type: none"><li>• Modified data sheet to reflect RF Test Reduction described in Product and Process Change Notification number, PCN13232, p. 1, 2</li><li>• Removed Total Device Dissipation from Max Ratings table as data was redundant (information already provided in Thermal Characteristics table), p. 1</li><li>• Changed Storage Temperature Range in Max Ratings table from -65 to +175 to -65 to +150 for standardization across products, p. 1</li><li>• Added Case Operating Temperature limit to the Maximum Ratings table and set limit to 150°C, p. 1</li><li>• Operating Junction Temperature increased from 200°C to 225°C in Maximum Ratings table, related “Continuous use at maximum temperature will affect MTTF” footnote added and changed 200°C to 225°C in Capable Plastic Package bullet, p. 1</li><li>• Corrected <math>V_{DS}</math> to <math>V_{DD}</math> in the RF test condition voltage callout for <math>V_{GS(Q)}</math>, and added “Measured in Functional Test”, On Characteristics table, p. 2</li><li>• Removed Forward Transconductance from On Characteristics table as it no longer provided usable information, p. 2</li><li>• Updated Part Numbers in Tables 6, 7, Component Designations and Values, to latest RoHS compliant part numbers, p. 3, 9</li><li>• Removed lower voltage tests from Fig. 6, Power Gain versus Output Power, due to fixed tuned fixture limitations, p. 5</li><li>• Replaced Fig. 13, MTTF versus Junction Temperature with updated graph. Removed Amps<sup>2</sup> and listed operating characteristics and location of MTTF calculator for device, p. 7</li><li>• Replaced Case Outline 1486-03, Issue C, with 1486-03, Issue D, p. 14-16. Added pin numbers 1 through 4 on Sheet 1.</li><li>• Replaced Case Outline 1484-04, Issue D, with 1484-04, Issue E, p. 17-19. Added pin numbers 1 through 4 on Sheet 1, replacing Gate and Drain notations with Pin 1 and Pin 2 designations.</li><li>• Added Product Documentation and Revision History, p. 20</li></ul>

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