

**Freescale Semiconductor**  
Technical Data

Document Number: MRF5S9101  
Rev. 2, 7/2005

# RF Power Field Effect Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

Designed for GSM and GSM EDGE base station applications with frequencies from 869 to 960 MHz. Suitable for multicarrier amplifier applications.

**GSM Application**

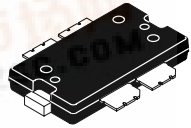
- Typical GSM Performance:  $V_{DD} = 26$  Volts,  $I_{DQ} = 700$  mA,  $P_{out} = 100$  Watts CW, Full Frequency Band (869-894 MHz and 921-960 MHz)  
Power Gain - 17.5 dB  
Drain Efficiency - 60%

**GSM EDGE Application**

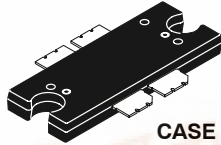
- Typical GSM EDGE Performance:  $V_{DD} = 28$  Volts,  $I_{DQ} = 650$  mA,  $P_{out} = 50$  Watts Avg., Full Frequency Band (869-894 MHz and 921-960 MHz)  
Power Gain — 18 dB  
Spectral Regrowth @ 400 kHz Offset = -63 dBc  
Spectral Regrowth @ 600 kHz Offset = -78 dBc  
EVM — 2.3% rms
- Capable of Handling 10:1 VSWR, @ 26 Vdc, @ 100 W CW Output Power, @  $f = 960$  MHz
- 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
- N Suffix Indicates Lead-Free Terminations
- 200°C Capable Plastic Package
- In Tape and Reel. R1 Suffix = 500 Units per 44 mm, 13 inch Reel.

**MRF5S9101NR1**  
**MRF5S9101NBR1**  
**MRF5S9101MR1**  
**MRF5S9101MBR1**

**869-960 MHz, 100 W, 26 V**  
**GSM/GSM EDGE**  
**LATERAL N-CHANNEL**  
**RF POWER MOSFETs**



**CASE 1486-03, STYLE 1**  
**TO-270 WB-4**  
**PLASTIC**  
**MRF5S9101NR1(MR1)**



**CASE 1484-02, STYLE 1**  
**TO-272 WB-4**  
**PLASTIC**  
**MRF5S9101NBR1(MBR1)**

**Table 1. Maximum Ratings**

Rating	Symbol	Value	Unit
Drain-Source Voltage	$V_{DSS}$	- 0.5, +68	Vdc
Gate-Source Voltage	$V_{GS}$	- 0.5, +15	Vdc
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	$P_D$	427 2.44	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 (1,2)	Unit
Thermal Resistance, Junction to Case Case Temperature 80°C, 100 W CW Case Temperature 80°C, 50 W CW	$R_{\theta JC}$	0.41 0.47	°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.
2. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf>. Select Documentation/Application Notes - AN1955.

**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 Methodology	Class
Human Body Model (per JESD22-A114)	1C (Minimum)
Machine Model (per EIA/JESD22-A115)	A (Minimum)
Charge Device Model (per JESD22-C101)	IV (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
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 68\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	10	$\mu\text{A}$
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 26\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	1	$\mu\text{A}$
Gate-Source Leakage Current ( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )	$I_{GSS}$	—	—	1	$\mu\text{A}$

**On Characteristics**

Gate Threshold Voltage ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 400\ \mu\text{A}$ )	$V_{GS(th)}$	2	2.8	3.5	Vdc
Gate Quiescent Voltage ( $V_{DS} = 26\text{ Vdc}$ , $I_D = 700\text{ mA}$ )	$V_{GS(Q)}$	—	3.7	—	Vdc
Drain-Source On-Voltage ( $V_{GS} = 10\text{ Vdc}$ , $I_D = 2\text{ A}$ )	$V_{DS(on)}$	—	0.21	0.3	Vdc
Forward Transconductance ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 6\text{ A}$ )	$g_{fs}$	—	7	—	S

**Dynamic Characteristics** (1)

Output Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)}$ ac @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{oss}$	—	70	—	pF
Reverse Transfer Capacitance ( $V_{DS} = 26\text{ Vdc} \pm 30\text{ mV(rms)}$ ac @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{rss}$	—	2.2	—	pF

**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 26\text{ Vdc}$ ,  $P_{out} = 100\text{ W}$ ,  $I_{DQ} = 700\text{ mA}$ ,  $f = 960\text{ MHz}$ 

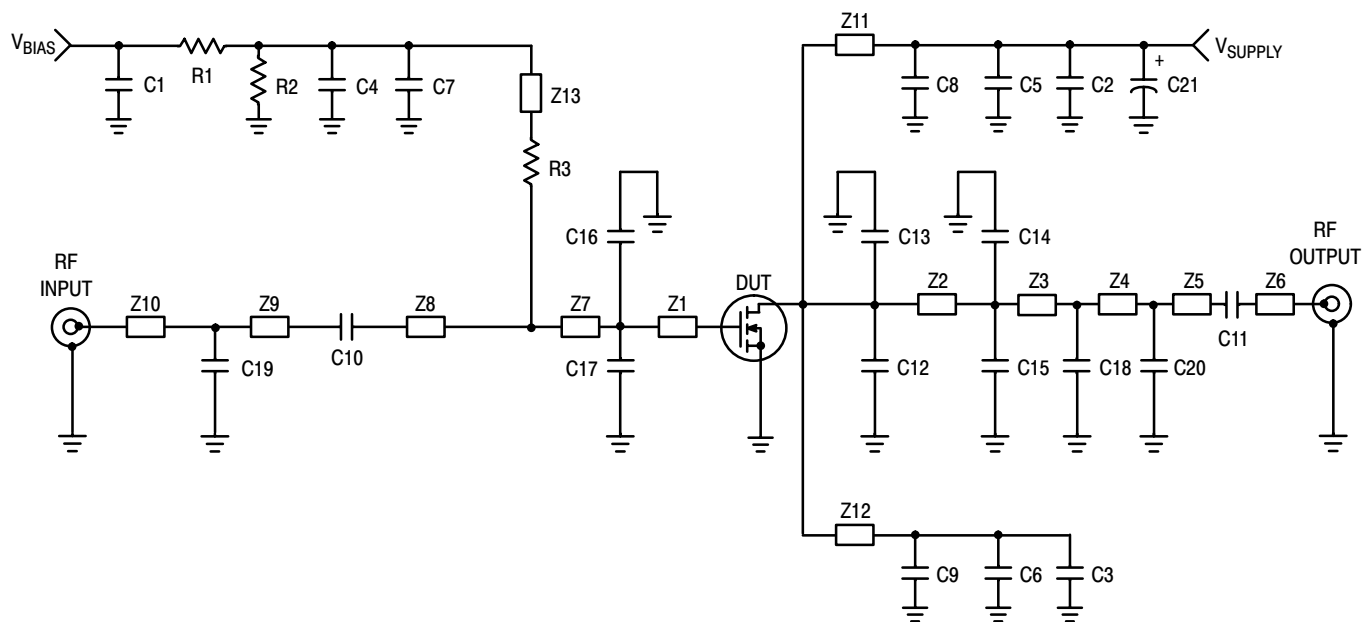
Power Gain	$G_{ps}$	16	17.5	19	dB
Drain Efficiency	$\eta_D$	56	60	—	%
Input Return Loss	IRL	—	-15	-9	dB
$P_{out}$ @ 1 dB Compression Point, CW	P1dB	100	110	—	W

1. Part is internally input matched.

(continued)

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

Characteristic	Symbol	Min	Typ	Max	Unit
<b>Typical GSM EDGE Performances</b> (In Freescale GSM EDGE Test Fixture, 50 ohm system) $V_{DD} = 28\text{ Vdc}$ , $P_{out} = 50\text{ W Avg.}$ , $I_{DQ} = 650\text{ mA}$ , $869\text{ MHz} < \text{Frequency} < 894\text{ MHz}$ , $920\text{ MHz} < \text{Frequency} < 960\text{ MHz}$					
Power Gain	$G_{ps}$	—	18	—	dB
Drain Efficiency	$\eta_D$	—	42	—	%
Error Vector Magnitude	EVM	—	2.3	—	% rms
Spectral Regrowth at 400 kHz Offset	SR1	—	-63	—	dBc
Spectral Regrowth at 600 kHz Offset	SR2	—	-78	—	dBc



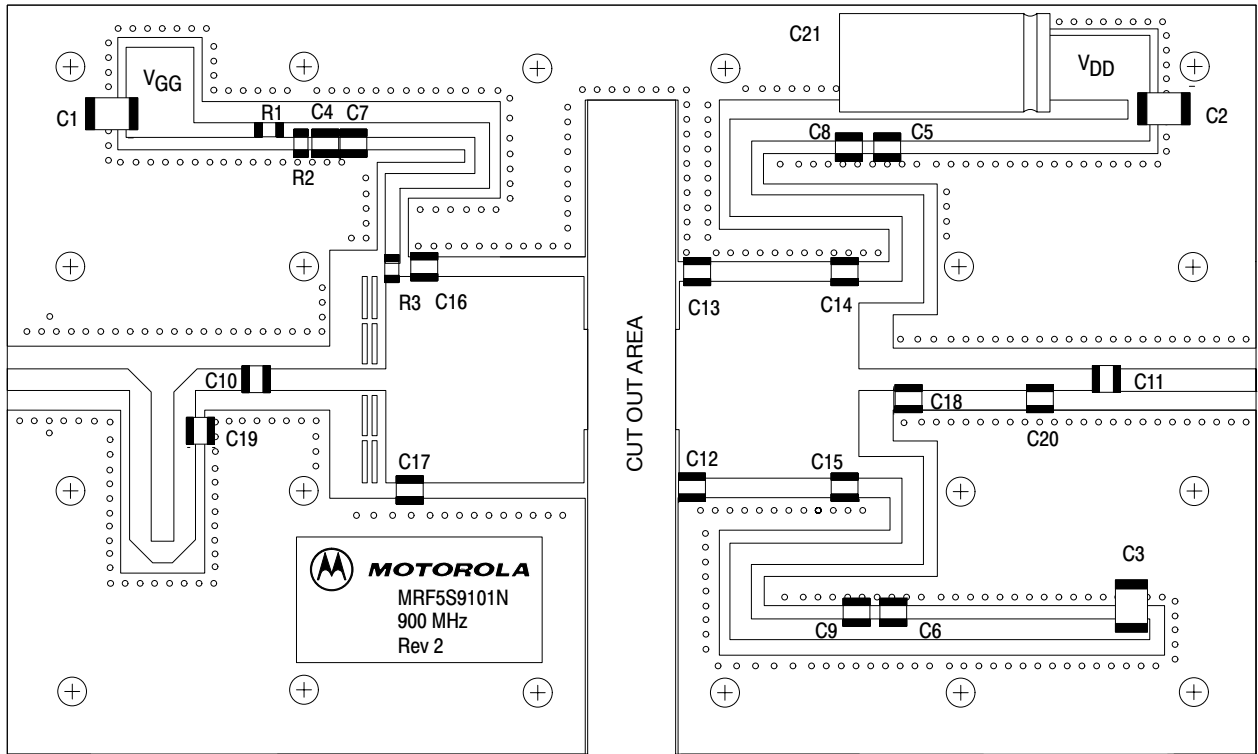
Z1	0.698" x 0.827" Microstrip	Z10	1.491" x 0.087" Microstrip
Z2	0.720" x 0.788" Microstrip	Z11, Z12*	1.6" x 0.089" Microstrip (quarter wave length for supply purpose)
Z3	0.195" x 0.087" Microstrip	Z13*	1.2" x 0.059" Microstrip (quarter wave length for bias purpose)
Z4	0.524" x 0.087" Microstrip	PCB	Taconic TLX8-0300, 0.030", $\epsilon_r = 2.55$
Z5	0.233" x 0.087" Microstrip		
Z6	0.560" x 0.087" Microstrip		
Z7	0.095" x 0.827" Microstrip		
Z8	0.472" x 0.087" Microstrip		
Z9	0.384" x 0.087" Microstrip		

\*Variable for tuning

Figure 1. MRF5S9101NR1(NBR1)/MR1(MBR1) 900 MHz Test Circuit Schematic

Table 6. MRF5S9101NR1(NBR1)/MR1(MBR1) 900 MHz Test Circuit Component Designations and Values

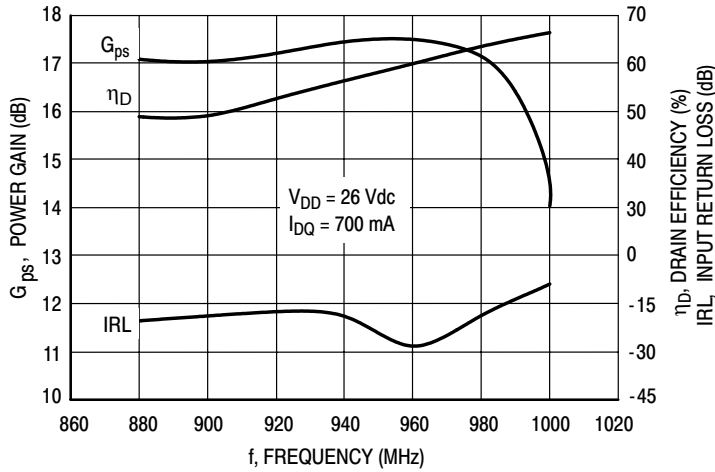
Part	Description	Part Number	Manufacturer
C1, C2, C3	4.7 $\mu$ F Chip Capacitors (2220)	GRM55ER7H475KA01	Murata
C4, C5, C6	10 nF 200B Chip Capacitors	200B103MW	ATC
C7, C8, C9	33 pF 100B Chip Capacitors	100B330JW	ATC
C10, C11	22 pF 100B Chip Capacitors	100B220GW	ATC
C12, C13	10 pF 100B Chip Capacitors	100B100GW	ATC
C14, C15, C16, C17	8.2 pF 100B Chip Capacitors	100B8R2CW	ATC
C18	5.6 pF 100B Chip Capacitor	100B5R6CW	ATC
C19	4.7 pF 100B Chip Capacitor	100B4R7BW	ATC
C20	3.9 pF 100B Chip Capacitor	100B3R9BW	ATC
C21	220 $\mu$ F, 50 V Electrolytic Capacitor, Axial	516D227M050NP7B	Sprague
R1, R2	10 k $\Omega$ , 1/4 W Chip Resistors (1206)		
R3	10 $\Omega$ , 1/4 W Chip Resistor (1206)		



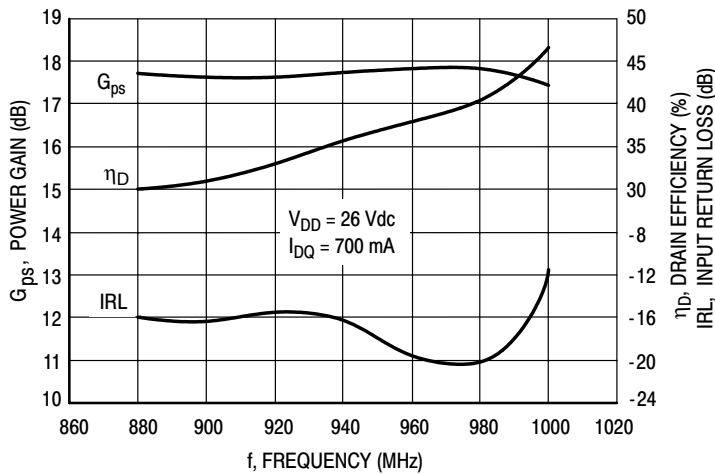
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**Figure 2. MRF5S9101NR1(NBR1)/MR1(MBR1) 900 MHz Test Circuit Component Layout**

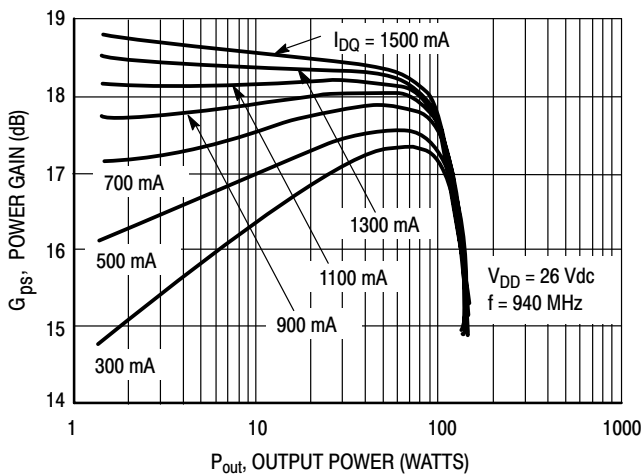
### TYPICAL CHARACTERISTICS - 900 MHz



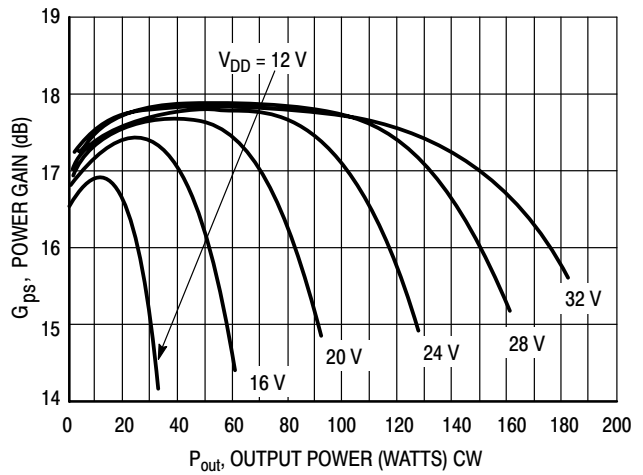
**Figure 3. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 100$  Watts CW**



**Figure 4. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 40$  Watts CW**

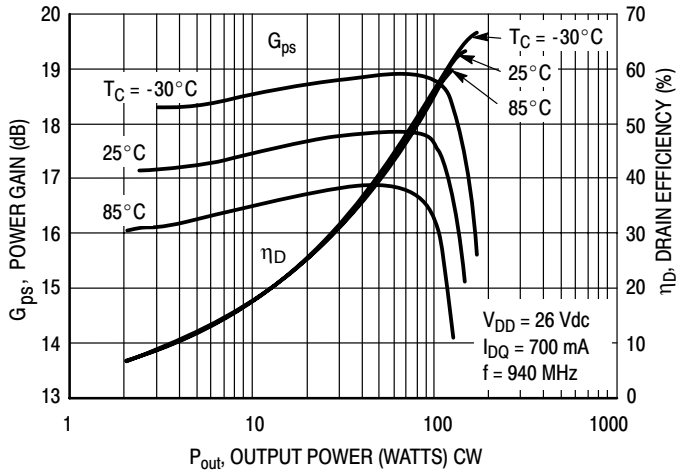


**Figure 5. Power Gain versus Output Power**

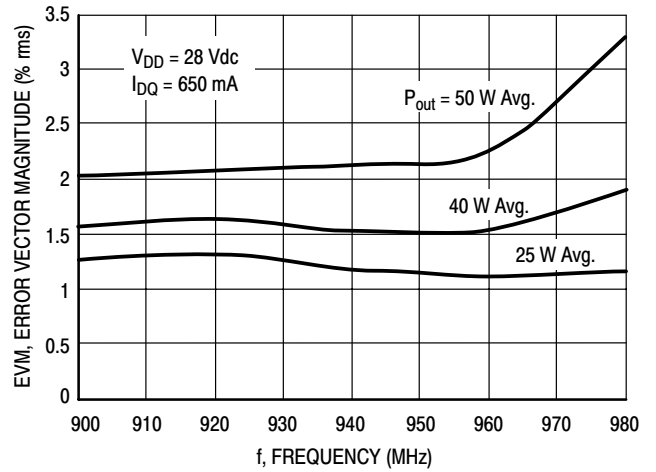


**Figure 6. Power Gain versus Output Power**

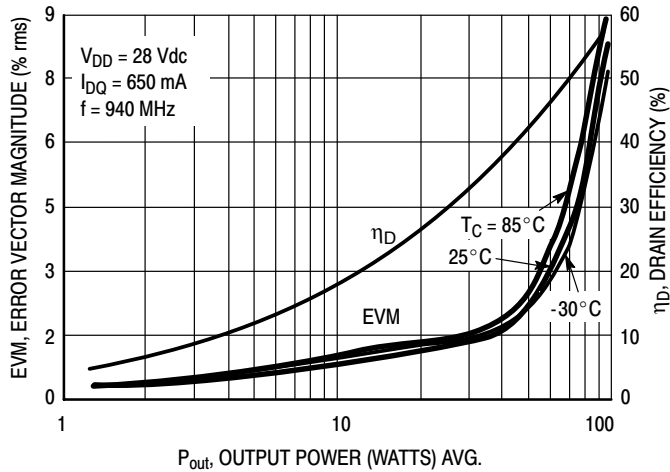
## TYPICAL CHARACTERISTICS - 900 MHz



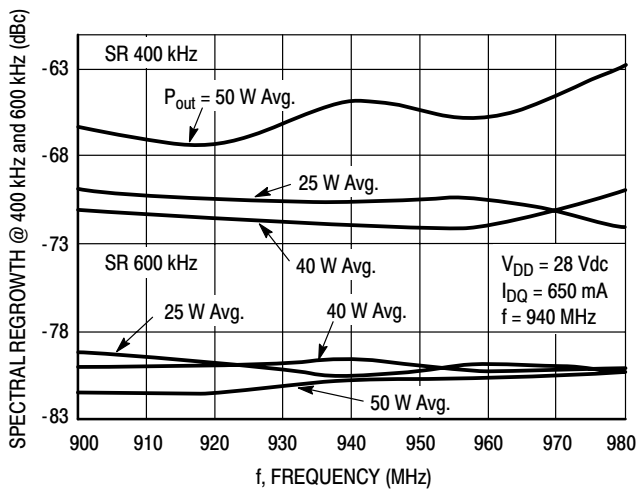
**Figure 7. Power Gain and Drain Efficiency versus CW Output Power**



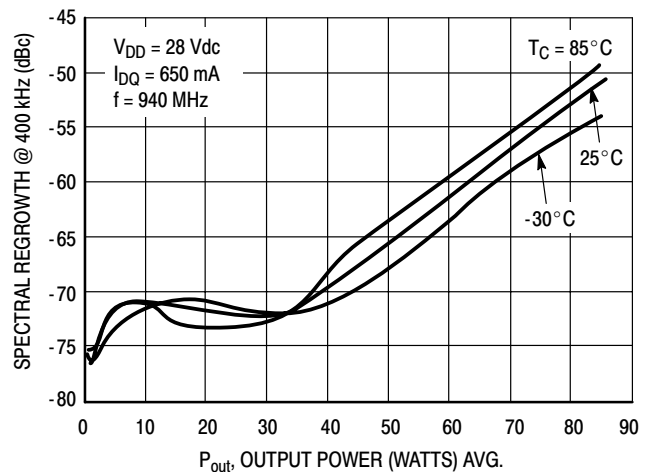
**Figure 8. Error Vector Magnitude versus Frequency**



**Figure 9. Error Vector Magnitude and Drain Efficiency versus Output Power**

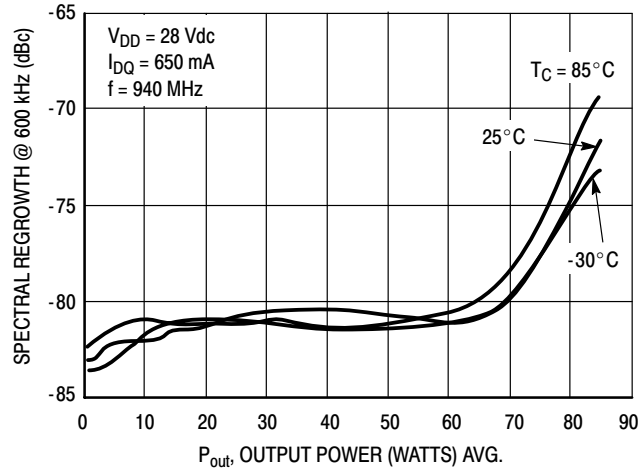


**Figure 10. Spectral Regrowth at 400 kHz and 600 kHz versus Frequency**

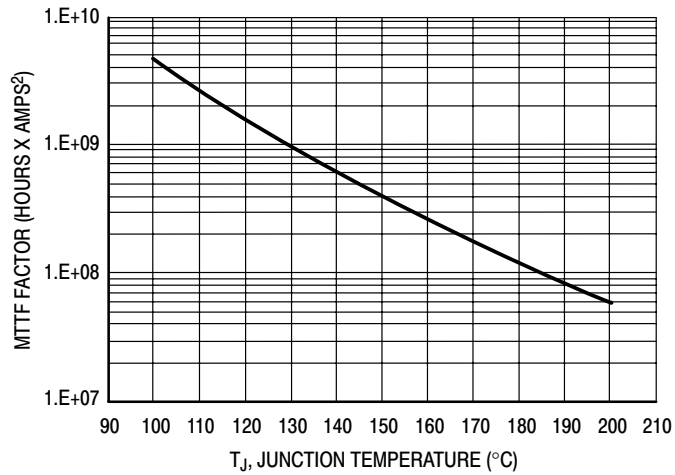


**Figure 11. Spectral Regrowth at 400 kHz versus Output Power**

### TYPICAL CHARACTERISTICS - 900 MHz



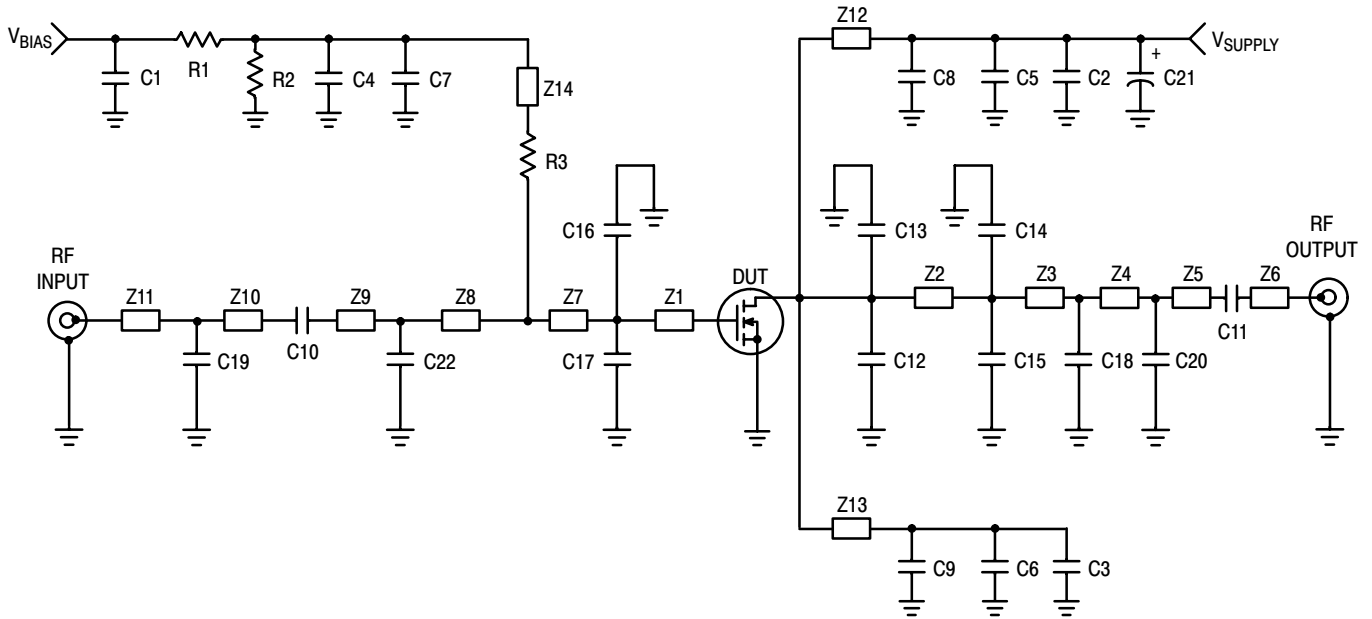
**Figure 12. Spectral Regrowth @ 600 kHz versus Output Power**



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 13. MTTF Factor versus Junction Temperature**



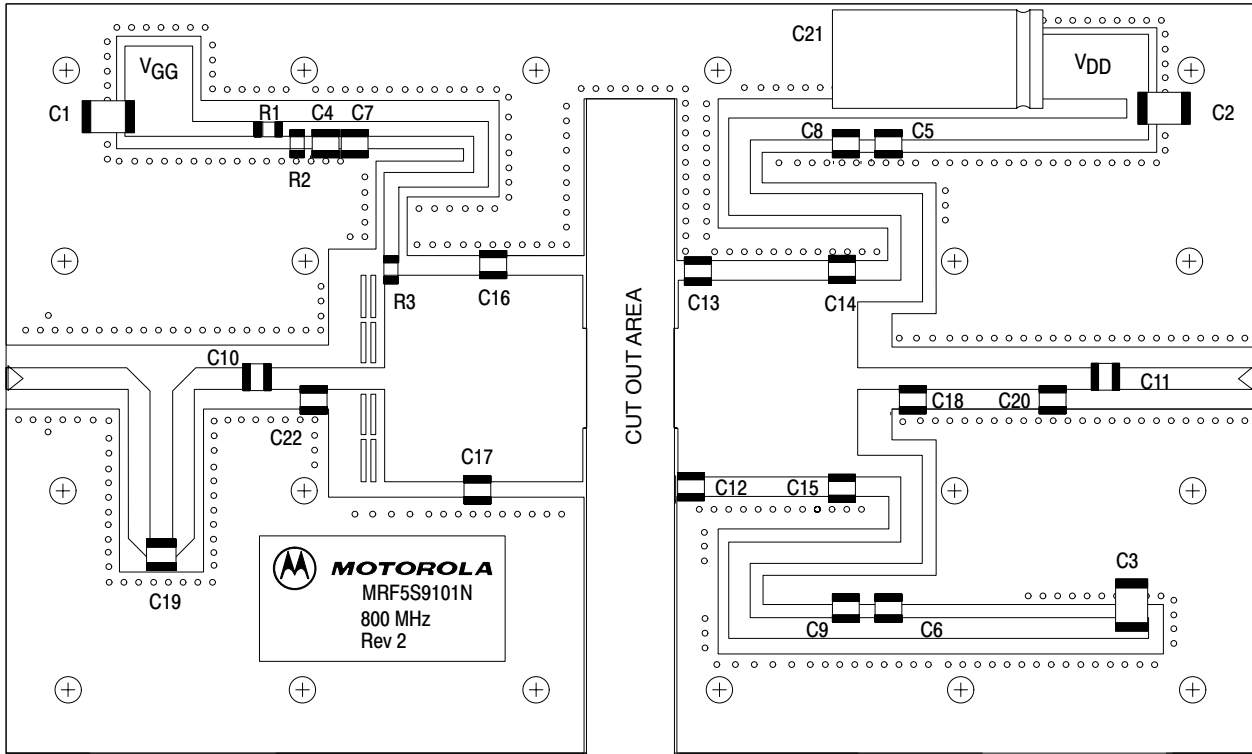


Z1	0.432" x 0.827" Microstrip	Z10	0.897" x 0.087" Microstrip
Z2	0.720" x 0.788" Microstrip	Z11	1.161" x 0.087" Microstrip
Z3	0.195" x 0.087" Microstrip	Z12, Z13*	1.6" x 0.089" Microstrip (quarter wave length for supply purpose)
Z4	0.584" x 0.087" Microstrip	Z14*	1.2" x 0.059" Microstrip (quarter wave length for bias purpose)
Z5	0.173" x 0.087" Microstrip	PCB	Taconic TLX8-0300, 0.030", $\epsilon_r = 2.55$
Z6	0.560" x 0.087" Microstrip		
Z7	0.378" x 0.827" Microstrip		
Z8	0.279" x 0.087" Microstrip		
Z9	0.193" x 0.087" Microstrip		
			*Variable for tuning

**Figure 14. MRF5S9101NR1(NBR1)/MR1(MBR1) 800 MHz Test Circuit Schematic**

**Table 7. MRF5S9101NR1(NBR1)/MR1(MBR1) 800 MHz Test Circuit Component Designations and Values**

Part	Description	Part Number	Manufacturer
C1, C2, C3	4.7 $\mu$ F Chip Capacitors (2220)	GRM55ER7H475KA01	Murata
C4, C5, C6	10 nF 200B Chip Capacitors	200B103MW	ATC
C7, C8, C9	33 pF 100B Chip Capacitors	100B330JW	ATC
C10, C11	22 pF 100B Chip Capacitors	100B220GW	ATC
C12, C13, C17	10 pF 100B Chip Capacitors	100B100GW	ATC
C14, C15	8.2 pF 100B Chip Capacitors	100B8R2CW	ATC
C16, C22	6.8 pF 100B Chip Capacitors	100B6R8CW	ATC
C18	5.6 pF 100B Chip Capacitor	100B5R6CW	ATC
C19, C20	2.7 pF 100B Chip Capacitors	100B2R7BW	ATC
C21	220 $\mu$ F, 50 V Electrolytic Capacitor, Axial	516D227M050NP7B	Sprague
R1, R2	10 k $\Omega$ , 1/4 W Chip Resistors (1206)		
R3	10 $\Omega$ , 1/4 W Chip Resistor (1206)		



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**Figure 15. MRF5S9101NR1(NBR1)/MR1(MBR1) 800 MHz Test Circuit Component Layout**

### TYPICAL CHARACTERISTICS - 800 MHz

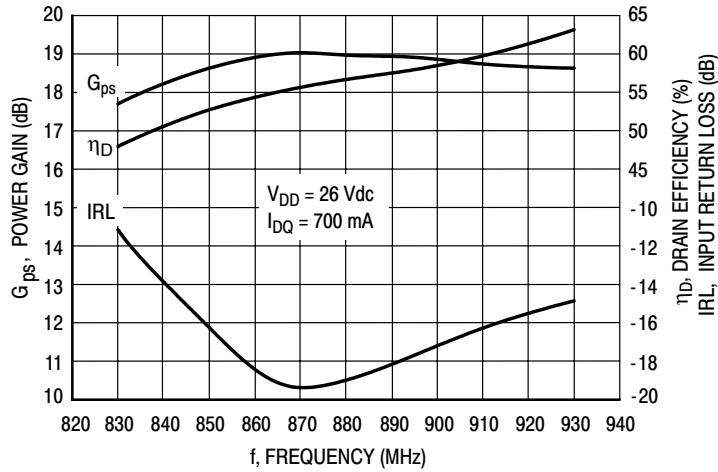


Figure 16. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 100$  W CW

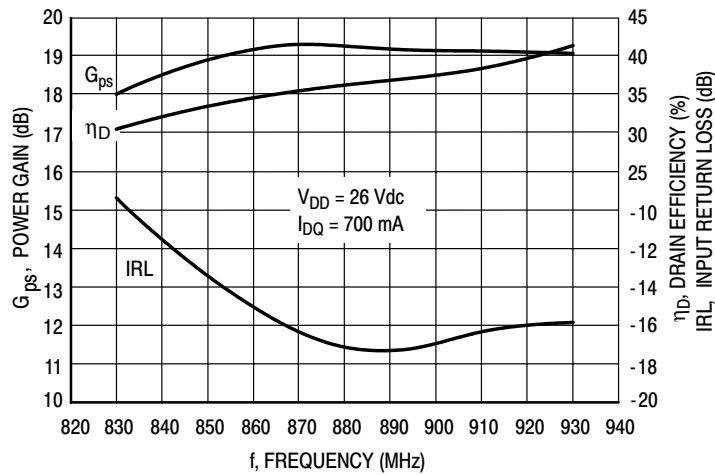


Figure 17. Power Gain, Input Return Loss and Drain Efficiency versus Frequency @  $P_{out} = 40$  W CW

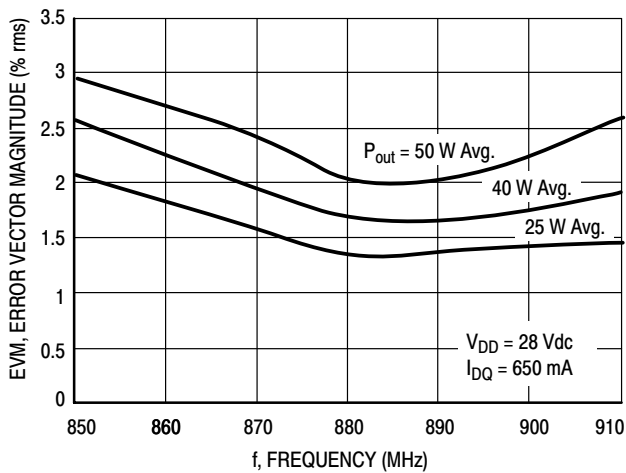


Figure 18. Error Vector Magnitude versus Frequency

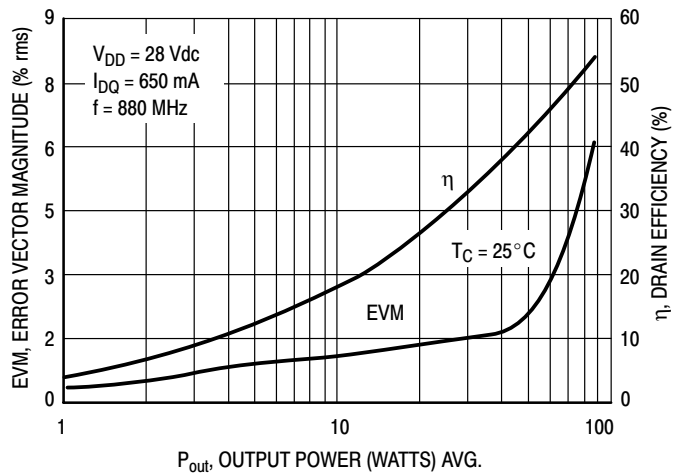


Figure 19. Error Vector Magnitude and Drain Efficiency versus Output Power

## TYPICAL CHARACTERISTICS - 800 MHz

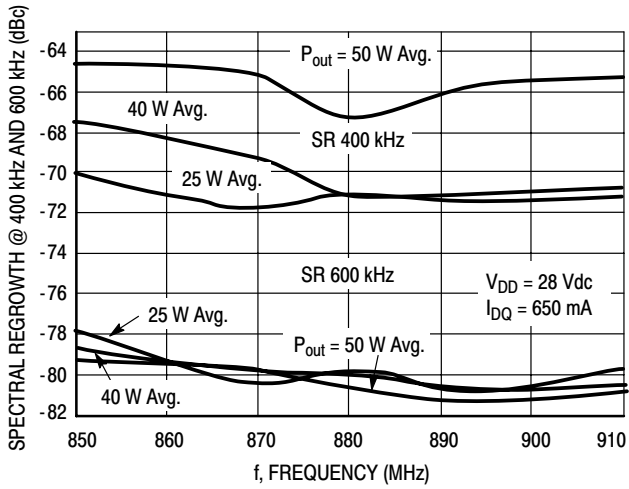


Figure 20. Spectral Regrowth at 400 kHz and 600 kHz versus Frequency

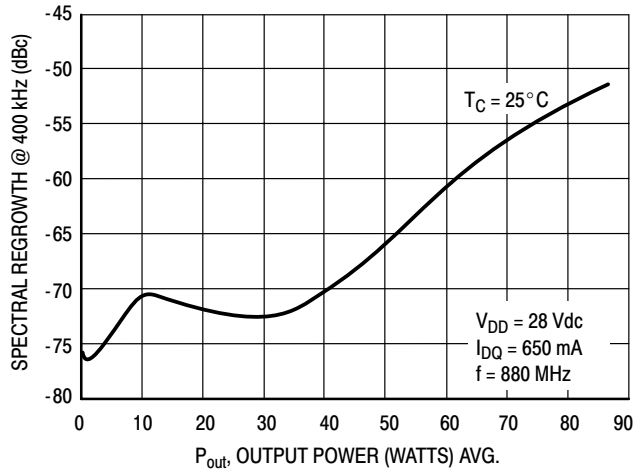


Figure 21. Spectral Regrowth at 400 kHz versus Output Power

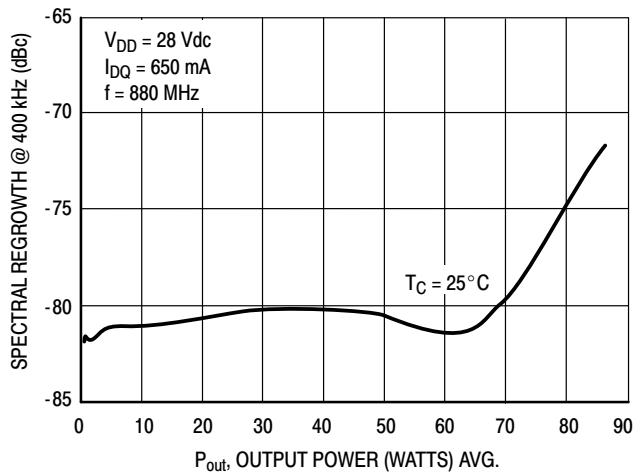
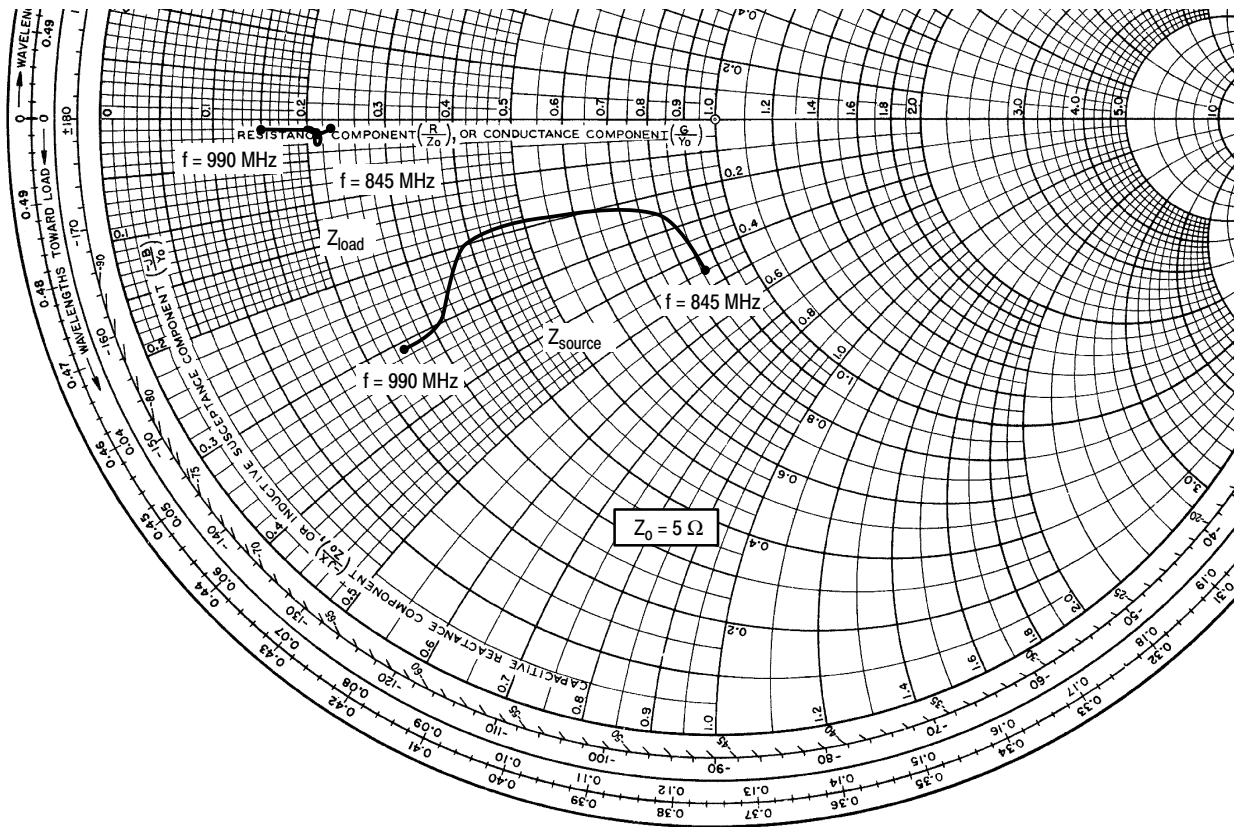


Figure 22. Spectral Regrowth at 600 kHz versus Output Power



$V_{DD} = 26 \text{ Vdc}$ ,  $I_{DQ} = 700 \text{ mA}$ ,  $P_{out} = 100 \text{ W CW}$

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
845	$4.29 - j2.23$	$1.15 - j0.04$
865	$3.94 - j1.24$	$1.05 - j0.10$
890	$2.72 - j0.96$	$1.02 - j0.07$
920	$1.96 - j1.02$	$1.03 - j0.15$
960	$1.58 - j1.43$	$1.03 - j0.05$
990	$1.27 - j1.54$	$0.73 - j0.07$

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

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

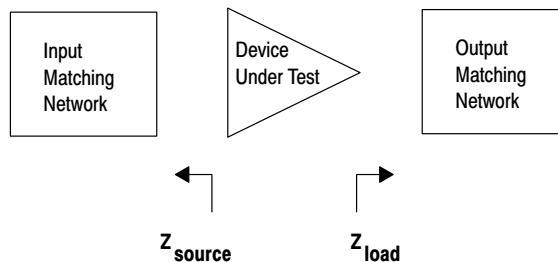
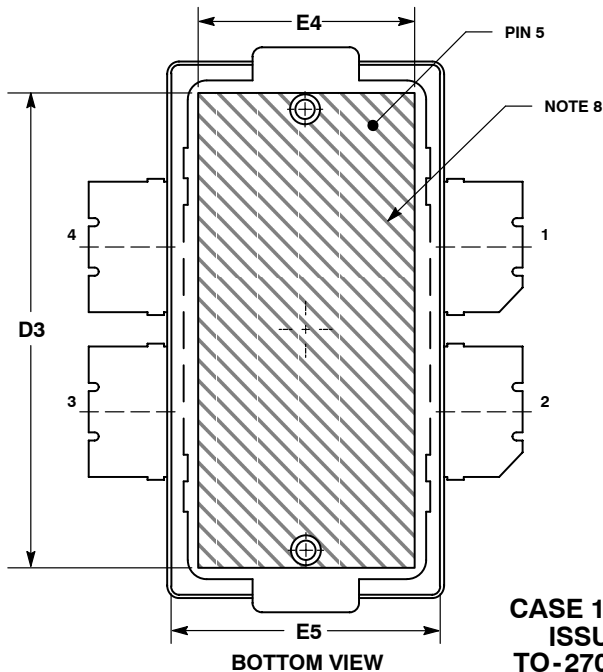
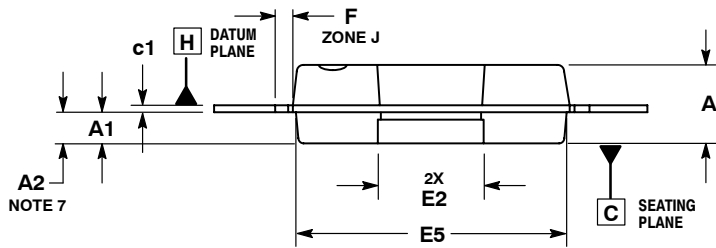
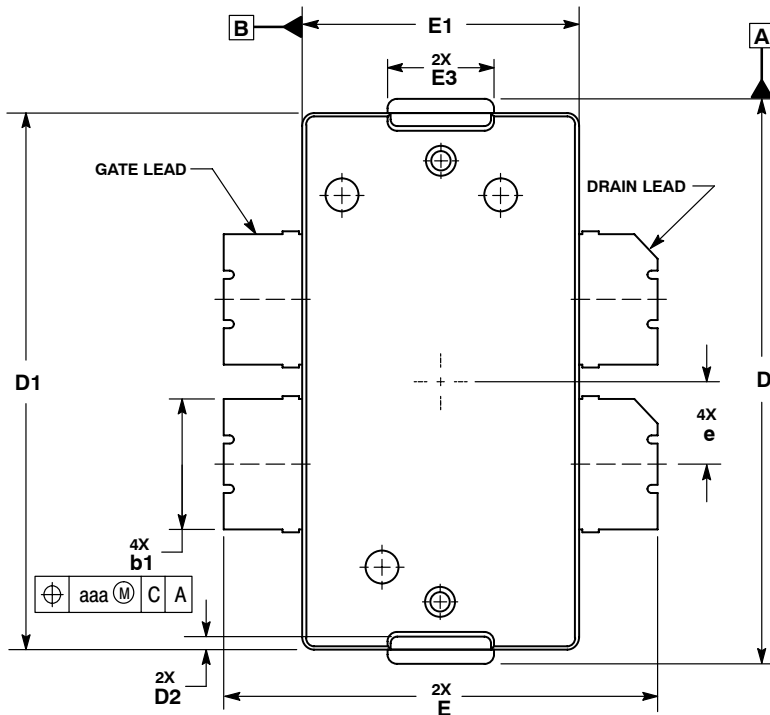


Figure 23. Series Equivalent Source and Load Impedance

## PACKAGE DIMENSIONS



### NOTES:

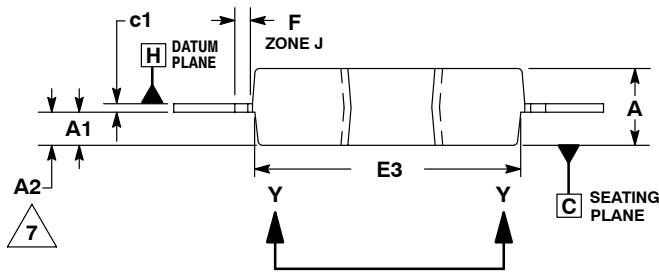
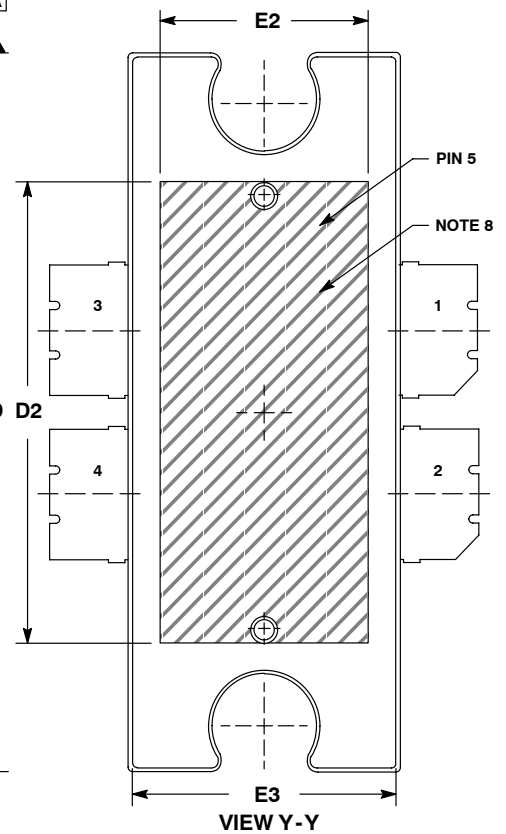
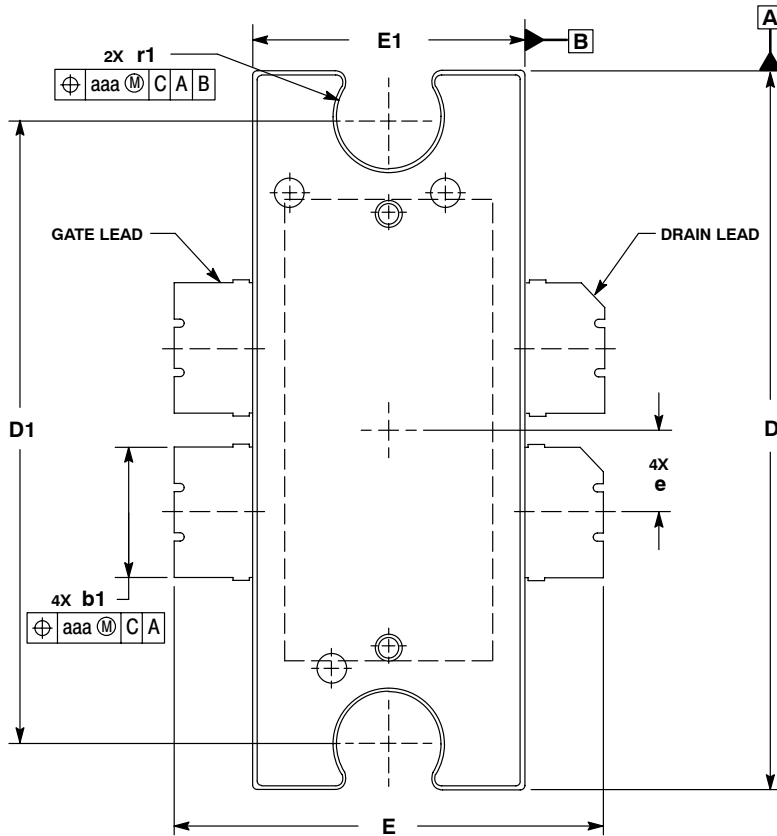
1. CONTROLLING DIMENSION: INCH.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M - 1994.
3. DATUM PLANE - H - IS LOCATED AT THE TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. 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. HATCHING 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	.712	.720	18.08	18.29
D1	.688	.692	17.48	17.58
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
F	.025 BSC		0.64 BSC	
b1	.164	.170	4.17	4.32
c1	.007	.011	0.18	0.28
e	.106 BSC		2.69 BSC	
aaa	.004		0.10	

### STYLE 1:

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

**CASE 1486-03  
ISSUE C  
TO-270 WB-4  
PLASTIC  
MRF5S9101NR1(MR1)**



NOTES:

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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 "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. HATCHING 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	
D2	.600	---	15.24	---
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	
b1	.164	.170	4.17	4.32
c1	.007	.011	.18	.28
r1	.063	.068	1.60	1.73
e	.106 BSC		2.69 BSC	
aaa	.004		.10	

- STYLE 1:  
 PIN 1. DRAIN  
 2. DRAIN  
 3. GATE  
 4. GATE  
 5. SOURCE

CASE 1484-02  
 ISSUE B  
 TO-272 WB-4  
 PLASTIC  
 MRF5S9101NBR1(MBR1)

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