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# RF Power LDMOS Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

These high ruggedness devices are designed for use in high VSWR military, industrial (including laser and plasma excitors), broadcast (analog and digital), and radio/land mobile applications. They are unmatched input and output designs allowing wide frequency range utilization between 1.8 and 600 MHz.

- Typical Performance:  $V_{DD} = 50$  Vdc,  $I_{DQ} = 100$  mA

Signal Type	$P_{out}$ (W)	f (MHz)	$G_{ps}$ (dB)	$\eta_D$ (%)	IRL (dB)
Pulse (100 $\mu$ sec, 20% Duty Cycle)	300 Peak	230	26.5	74.0	-16
CW	300 Avg.	130	25.0	80.0	-15

- Capable of Handling a Load Mismatch of 65:1 VSWR @ 50 Vdc, 230 MHz, at all Phase Angles
  - 300 W CW Output Power
  - 300 W Pulse Peak Power, 20% Duty Cycle, 100  $\mu$ sec
- Capable of 300 W CW Operation

### Features

- Unmatched Input and Output Allowing Wide Frequency Range Utilization
- Device can be used Single-Ended or in a Push-Pull Configuration
- Qualified Up to a Maximum of 50 V<sub>DD</sub> Operation
- Characterized from 30 V to 50 V for Extended Power Range
- Suitable for Linear Application with Appropriate Biasing
- Integrated ESD Protection
- Greater Negative Gate-Source Voltage Range for Improved Class C Operation
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- NI-780H-4L in Tape and Reel. R5 Suffix = 50 Units, 56 mm Tape Width, 13-inch Reel.
- NI-780S-4L in Tape and Reel. R5 Suffix = 50 Units, 32 mm Tape Width, 13-inch Reel.

**Table 1. Maximum Ratings**

Rating	Symbol	Value	Unit
Drain-Source Voltage	$V_{DSS}$	-0.5, +133	Vdc
Gate-Source Voltage	$V_{GS}$	-6.0, +10	Vdc
Storage Temperature Range	$T_{stg}$	-65 to +150	°C
Case Operating Temperature	$T_C$	150	°C
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$	$P_D$	1050 5.26	W W/°C
Operating Junction Temperature (1,2)	$T_J$	225	°C

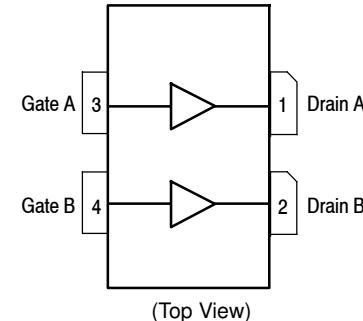
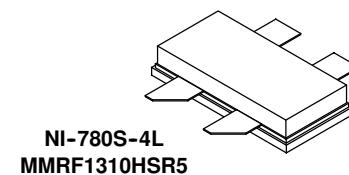
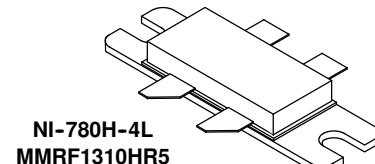
**Table 2. Thermal Characteristics**

Characteristic	Symbol	Value (2,3)	Unit
Thermal Resistance, Junction to Case (4) Pulse: Case Temperature 75°C, 300 W Peak, 100 $\mu$ sec Pulse Width, 20% Duty Cycle, 50 Vdc, $I_{DQ} = 100$ mA, 230 MHz CW: Case Temperature 87°C, 300 W CW, 50 Vdc, $I_{DQ} = 1100$ mA, 230 MHz	$Z_{\theta JC}$ $R_{\theta JC}$	0.05 0.19	°C/W

- Continuous use at maximum temperature will affect MTTF.
- MTTF calculator available at <http://www.freescale.com/rf>. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.
- Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf>. Select Documentation/Application Notes - AN1955.
- Same test circuit is used for both pulsed and CW.

## MMRF1310HR5 MMRF1310HSR5

1.8-600 MHz, 300 W CW, 50 V  
BROADBAND  
RF POWER MOSFETs



Note: The backside of the package is the source terminal for the transistors.

**Figure 1. Pin Connections**

**Table 3. ESD Protection Characteristics**

Test Methodology	Class
Human Body Model (per JESD22-A114)	2
Machine Model (per EIA/JESD22-A115)	B
Charge Device Model (per JESD22-C101)	IV

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

Characteristic	Symbol	Min	Typ	Max	Unit
<b>Off Characteristics (1)</b>					
Gate-Source Leakage Current ( $V_{GS} = 5 \text{ Vdc}$ , $V_{DS} = 0 \text{ Vdc}$ )	$I_{GSS}$	—	—	1	$\mu\text{Adc}$
Drain-Source Breakdown Voltage ( $V_{GS} = 0 \text{ Vdc}$ , $I_D = 50 \text{ mA}$ )	$V_{(BR)DSS}$	133	—	—	$\text{Vdc}$
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 50 \text{ Vdc}$ , $V_{GS} = 0 \text{ Vdc}$ )	$I_{DSS}$	—	—	5	$\mu\text{Adc}$
Zero Gate Voltage Drain Leakage Current ( $V_{DS} = 100 \text{ Vdc}$ , $V_{GS} = 0 \text{ Vdc}$ )	$I_{DSS}$	—	—	10	$\mu\text{Adc}$

**On Characteristics**

Gate Threshold Voltage (1) ( $V_{DS} = 10 \text{ Vdc}$ , $I_D = 480 \mu\text{Adc}$ )	$V_{GS(\text{th})}$	1.7	2.2	2.7	$\text{Vdc}$
Gate Quiescent Voltage ( $V_{DD} = 50 \text{ Vdc}$ , $I_D = 100 \text{ mA}$ , Measured in Functional Test)	$V_{GS(Q)}$	2.0	2.5	3.0	$\text{Vdc}$
Drain-Source On-Voltage (1) ( $V_{GS} = 10 \text{ Vdc}$ , $I_D = 1 \text{ Adc}$ )	$V_{DS(\text{on})}$	—	0.25	—	$\text{Vdc}$

**Dynamic Characteristics (1)**

Reverse Transfer Capacitance ( $V_{DS} = 50 \text{ Vdc} \pm 30 \text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0 \text{ Vdc}$ )	$C_{rss}$	—	0.8	—	$\text{pF}$
Output Capacitance ( $V_{DS} = 50 \text{ Vdc} \pm 30 \text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0 \text{ Vdc}$ )	$C_{oss}$	—	76	—	$\text{pF}$
Input Capacitance ( $V_{DS} = 50 \text{ Vdc}$ , $V_{GS} = 0 \text{ Vdc} \pm 30 \text{ mV(rms)ac}$ @ 1 MHz)	$C_{iss}$	—	188	—	$\text{pF}$

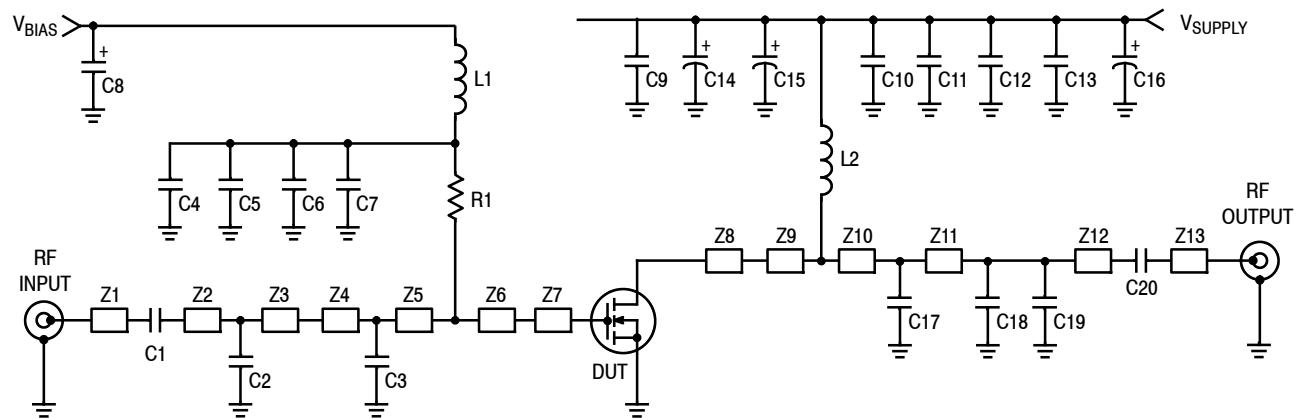
**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 100 \text{ mA}$ ,  $P_{\text{out}} = 300 \text{ W Peak}$  (60 W Avg.),  $f = 230 \text{ MHz}$ , 100  $\mu\text{sec}$  Pulse Width, 20% Duty Cycle

Power Gain	$G_{ps}$	25.0	26.5	28.0	$\text{dB}$
Drain Efficiency	$\eta_D$	72.0	74.0	—	%
Input Return Loss	$IRL$	—	-16	-9	$\text{dB}$

**Load Mismatch** (In Freescale Application Test Fixture, 50 ohm system)  $V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 100 \text{ mA}$

VSWR 65:1 at all Phase Angles Pulse: $P_{\text{out}} = 300 \text{ W Peak}$ (60 W Avg.), $f = 230 \text{ MHz}$ , 100 $\mu\text{sec}$ Pulse Width, 20% Duty Cycle CW: $P_{\text{out}} = 300 \text{ W Avg.}$ , $f = 130 \text{ MHz}$	$\Psi$	No Degradation in Output Power
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1. Each side of device measured separately.



Z1      0.352" x 0.080" Microstrip  
 Z2\*     1.780" x 0.080" Microstrip  
 Z3\*     0.576" x 0.080" Microstrip  
 Z4      0.220" x 0.220" Microstrip  
 Z5      0.322" x 0.220" Microstrip  
 Z6      0.168" x 0.220" Microstrip  
 Z7, Z8   0.282" x 0.630" Microstrip

Z9      0.192" x 0.170" Microstrip  
 Z10\*    0.366" x 0.170" Microstrip  
 Z11\*    2.195" x 0.170" Microstrip  
 Z12\*    0.614" x 0.170" Microstrip  
 Z13    0.243" x 0.080" Microstrip

\* Line length includes microstrip bends

Note: Same test circuit is used for both pulsed and CW.

**Figure 2. MMRF1310HR5(HSR5) Test Circuit Schematic**

**Table 5. MMRF1310HR5(HSR5) Test Circuit Component Designations and Values**

Part	Description	Part Number	Manufacturer
C1, C20	15 pF Chip Capacitors	ATC100B150JT500XT	ATC
C2	82 pF Chip Capacitor	ATC100B820JT500XT	ATC
C3, C17	91 pF Chip Capacitors	ATC100B910JT500XT	ATC
C4, C10	1000 pF Chip Capacitors	ATC100B102JT50XT	ATC
C5, C11	10K pF Chip Capacitors	ATC200B103KT50XT	ATC
C6	0.1 $\mu$ F, 50 V Chip Capacitor	CDR33BX104AKWS	AVX
C7	2.2 $\mu$ F, 100 V Chip Capacitor	HMK432B7225KM-T	Taiyo Yuden
C8	10 $\mu$ F, 35 V Tantalum Capacitor	T491D106K035AT	Kemet
C9	2.2 $\mu$ F, 100 V Chip Capacitor	G2225X7R225KT3AB	ATC
C12	0.1 $\mu$ F, 100 V Chip Capacitor	C1812F104K1RAC	Kemet
C13	0.01 $\mu$ F, 100 V Chip Capacitor	C1825C103K1GAC	Kemet
C14, C15, C16	220 $\mu$ F, 100 V Electrolytic Capacitors	MCGPR100V227M16X26-RH	Multicomp
C18, C19	18 pF Chip Capacitors	ATC100B180JT500XT	ATC
L1	120 nH Inductor	1812SMS-R12JLC	Coilcraft
L2	17.5 nH Inductor	GA3095-ALC	Coilcraft
R1	1000 $\Omega$ , 1/2 W Chip Resistor	CRCW20101K00FKEF	Vishay
PCB	0.030", $\epsilon_r = 2.55$	AD255A	Arlon

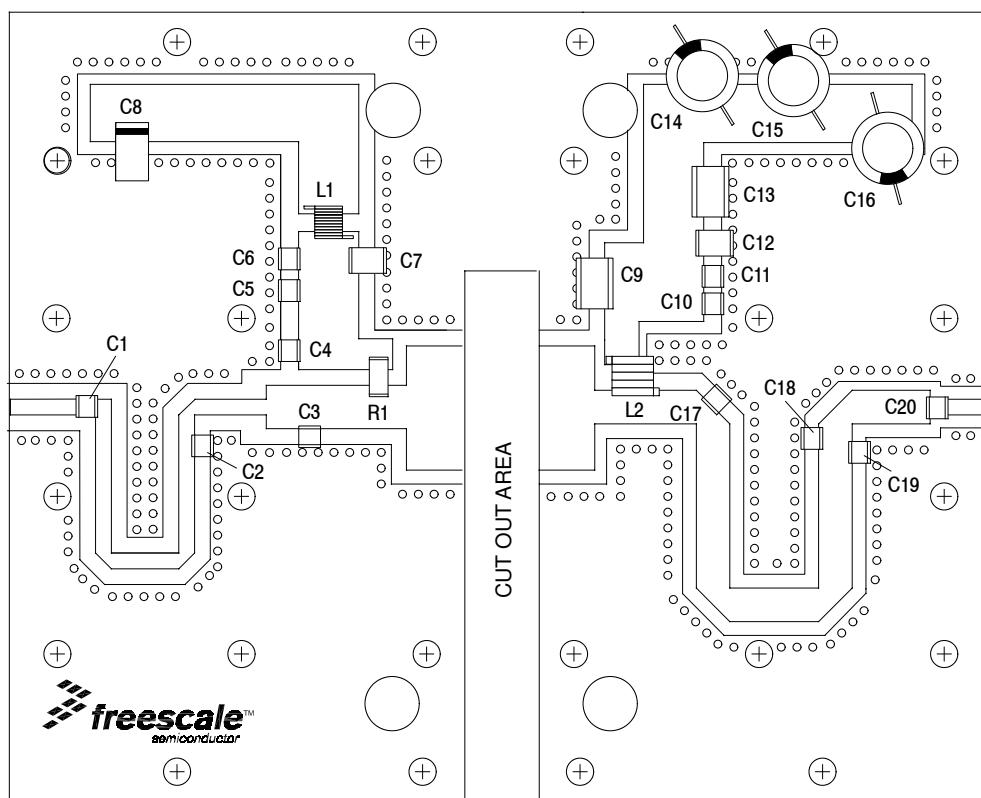
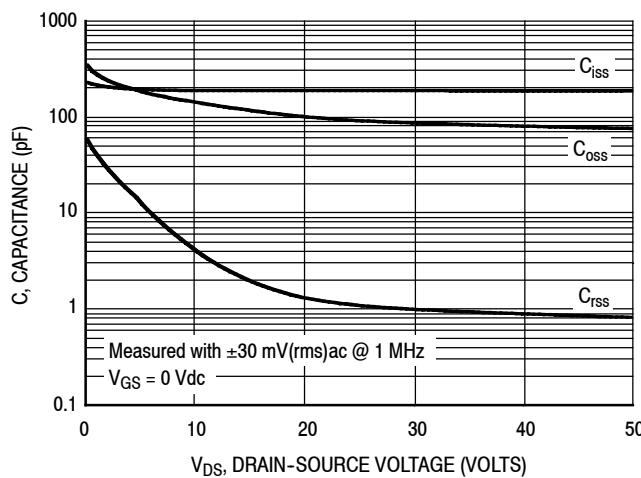


Figure 3. MMRF1310HR5(HSR5) Test Circuit Component Layout

## TYPICAL CHARACTERISTICS — PULSED



Note: Each side of device measured separately.

Figure 4. Capacitance versus Drain-Source Voltage

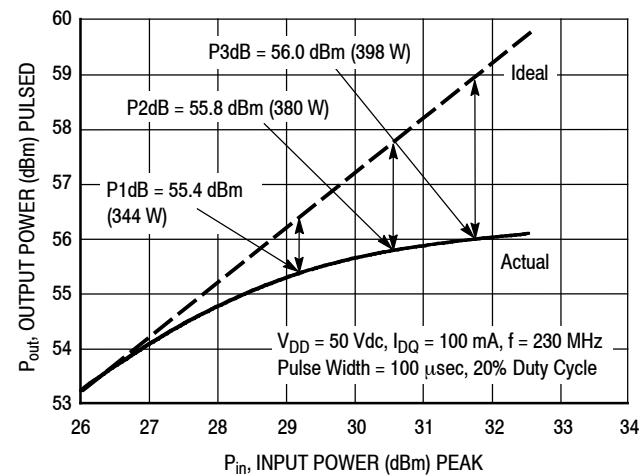


Figure 5. Output Power versus Input Power

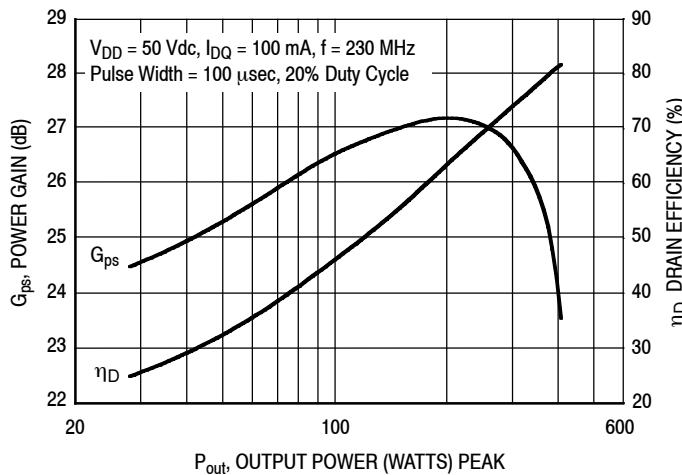


Figure 6. Power Gain and Drain Efficiency versus Output Power

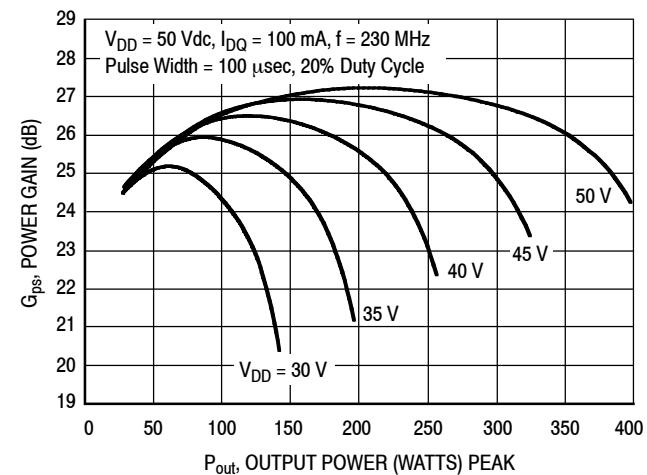


Figure 7. Power Gain versus Output Power

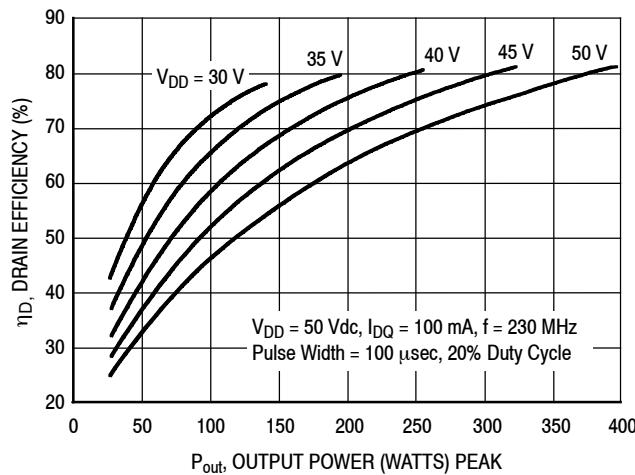


Figure 8. Drain Efficiency versus Output Power

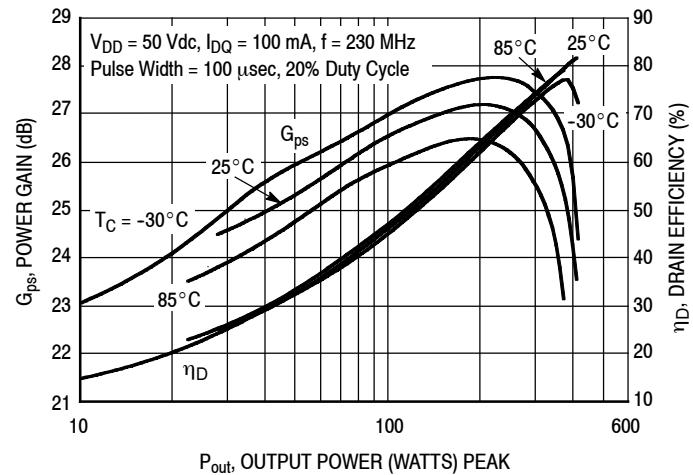
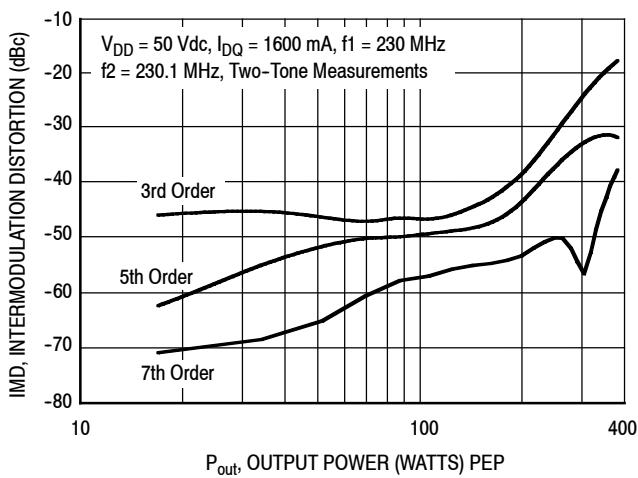
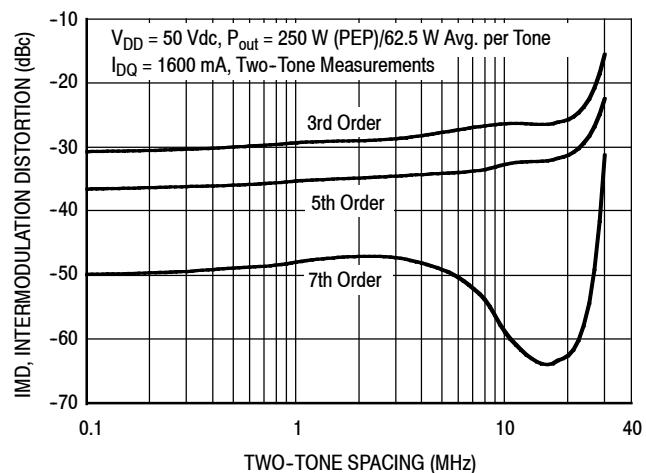


Figure 9. Power Gain and Drain Efficiency versus Output Power

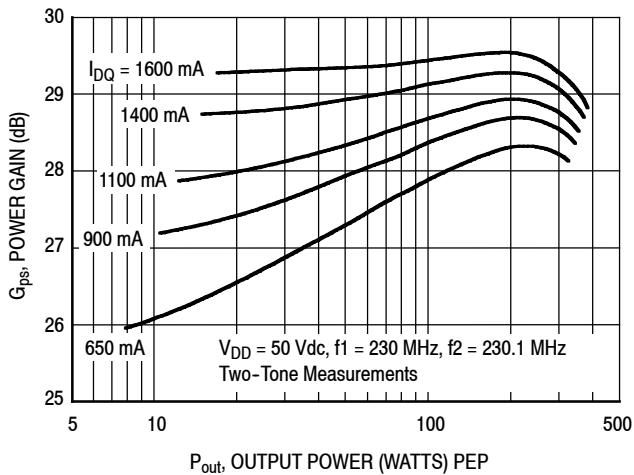
## TYPICAL CHARACTERISTICS — TWO-TONE (1)



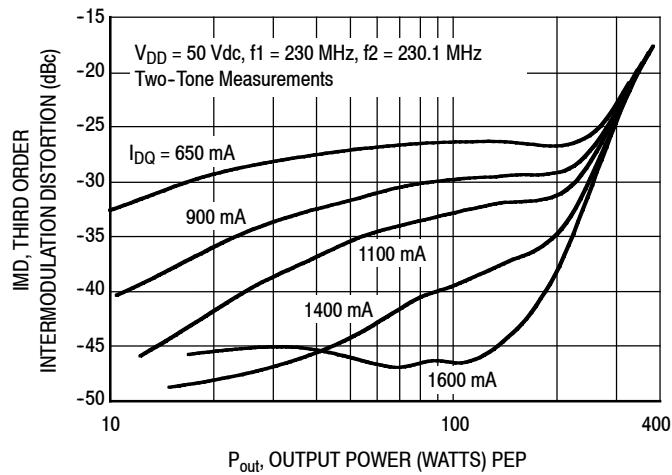
**Figure 10. Intermodulation Distortion Products versus Output Power**



**Figure 11. Intermodulation Distortion Products versus Two-Tone Spacing**



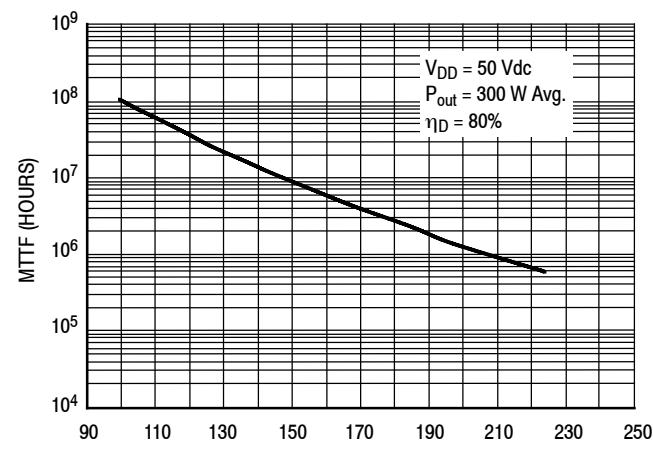
**Figure 12. Two-Tone Power Gain versus Output Power**



**Figure 13. Third Order Intermodulation Distortion versus Output Power**

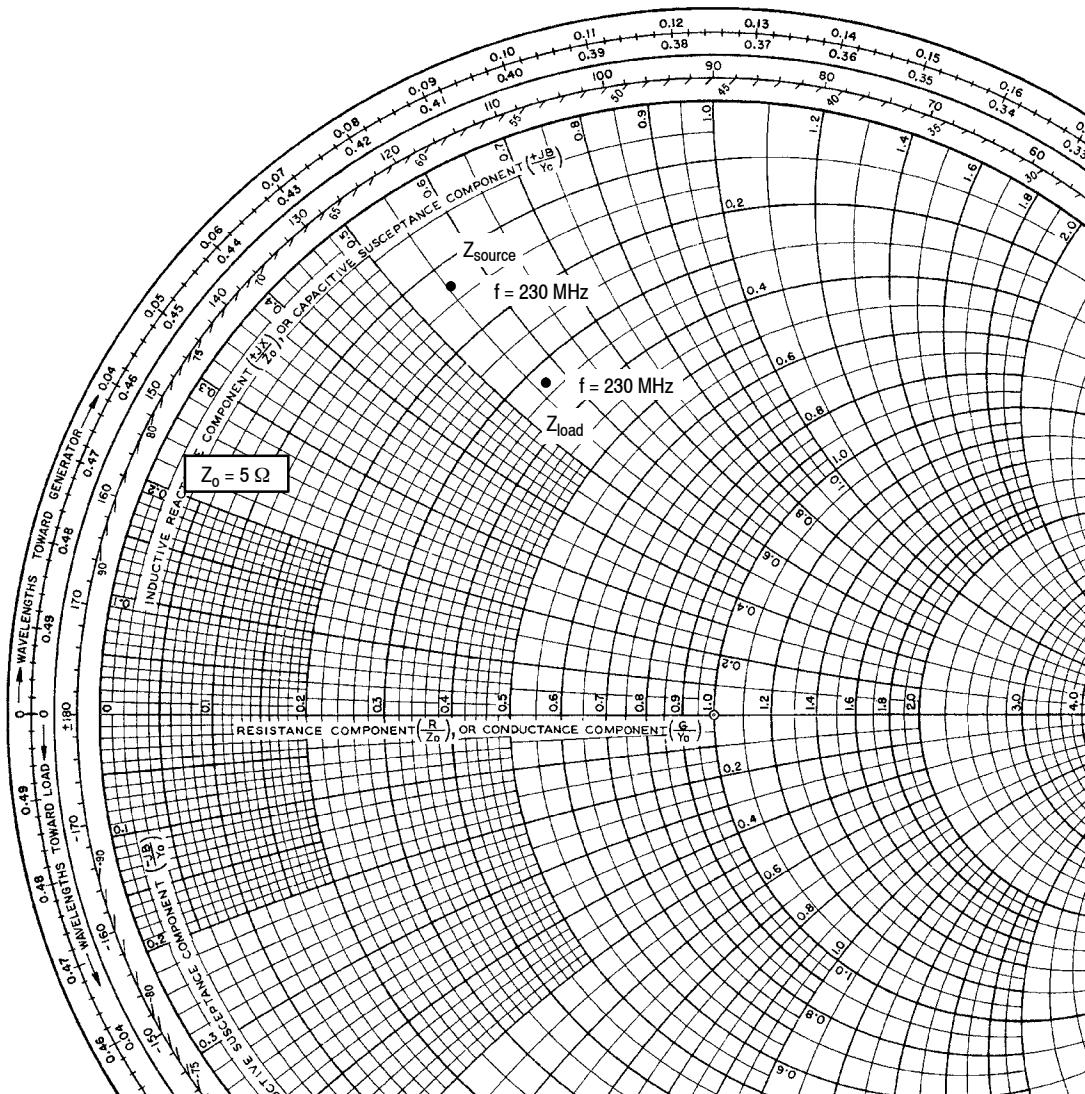
1. The distortion products are referenced to one of the two tones and the peak envelope power (PEP) is 6 dB above the power in a single tone.

## TYPICAL CHARACTERISTICS



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

Figure 14. MTTF versus Junction Temperature — CW



$$V_{DD} = 50 \text{ Vdc}, I_{DQ} = 100 \text{ mA}, P_{out} = 300 \text{ W Peak}$$

f MHz	Z <sub>source</sub> Ω	Z <sub>load</sub> Ω
230	0.65 + j2.79	1.64 + j2.85

Z<sub>source</sub> = Test circuit impedance as measured from gate to ground.

Z<sub>load</sub> = Test circuit impedance as measured from drain to ground.

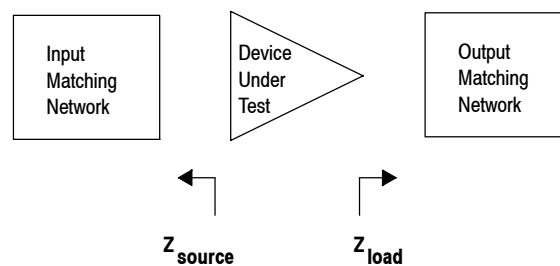


Figure 15. Series Equivalent Source and Load Impedance

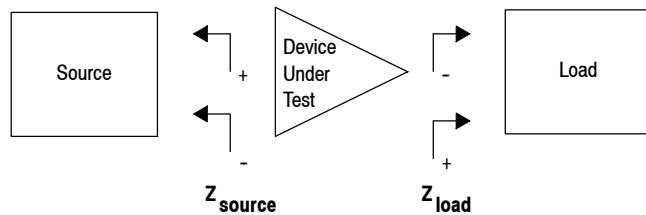
$V_{DD} = 50$  Vdc,  $I_{DQ} = 100$  mA

$f$ MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
10	$36.0 + j128$	$12.0 + j8.80$
25	$20.0 + j64.0$	$12.4 + j6.40$
50	$16.0 + j41.6$	$11.6 + j14.4$
100	$8.00 + j24.8$	$9.00 + j9.80$
200	$3.00 + j12.8$	$7.20 + j6.40$
300	$1.52 + j7.92$	$6.00 + j5.00$
400	$1.08 + j5.04$	$4.20 + j4.00$
500	$1.04 + j3.16$	$3.32 + j2.72$
600	$0.88 + j1.76$	$2.72 + j1.68$

1. Simulated performance at 1 dB gain compression.

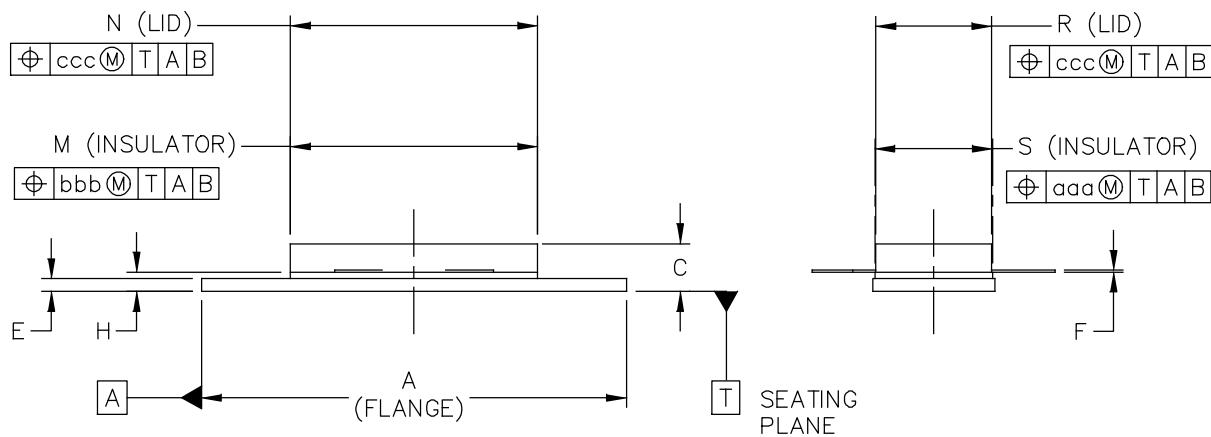
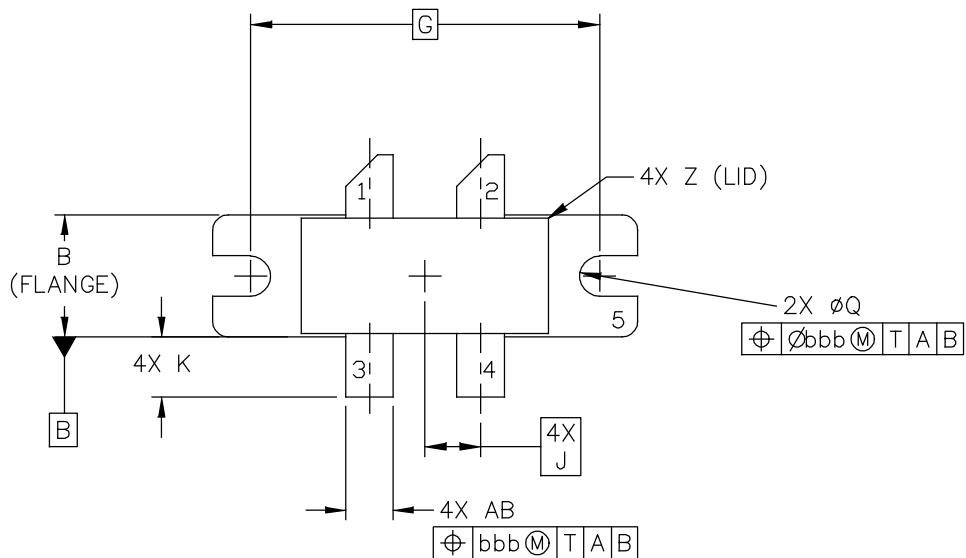
$Z_{source}$  = Source impedance presented from gate to gate.

$Z_{load}$  = Load impedance presented from drain to drain.



**Figure 16. Simulated Source and Load Impedances Optimized for IRL, Output Power and Drain Efficiency — Push-Pull**

## PACKAGE DIMENSIONS



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## NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION H IS MEASURED .030 (0.762) AWAY FROM PACKAGE BODY.

## STYLE 1:

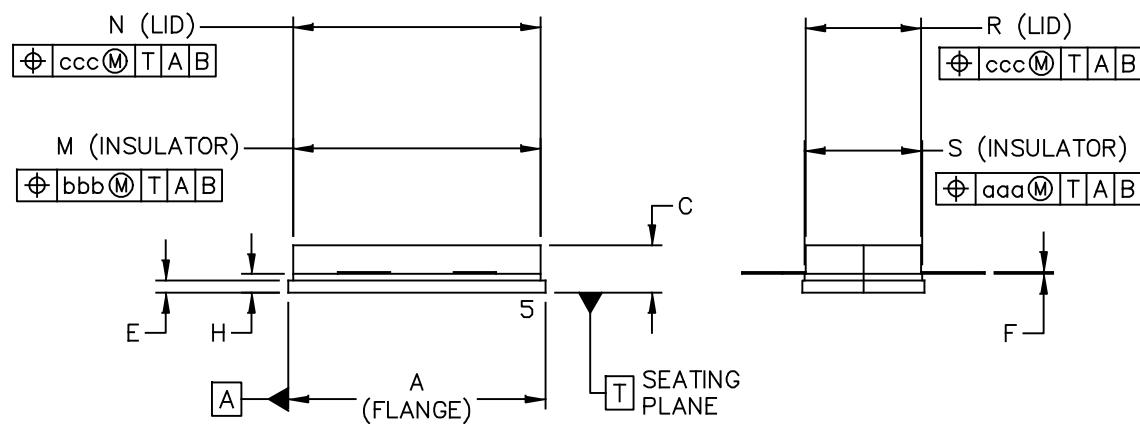
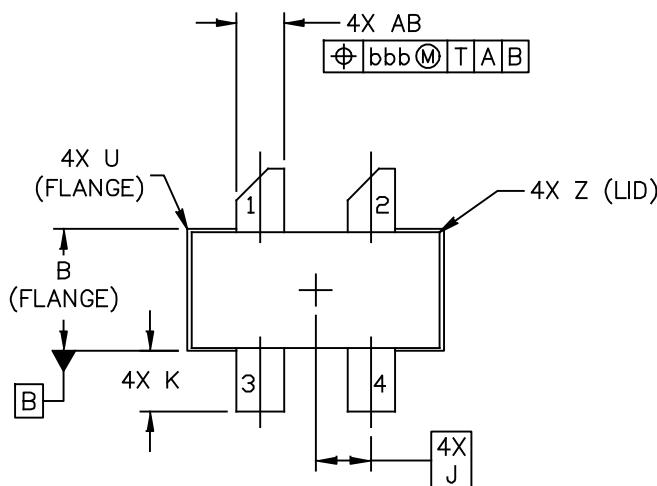
- PIN 1. DRAIN  
 2. DRAIN  
 3. GATE  
 4. GATE  
 5. SOURCE

DIM	INCH		MILLIMETER		DIM	INCH		MILLIMETER	
	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	1.335	1.345	33.91	34.16	R	.365	.375	9.27	9.53
B	.380	.390	9.65	9.91	S	.365	.375	9.27	9.52
C	.125	.170	3.18	4.32	U		.040		1.02
E	.035	.045	0.89	1.14	Z		.030		0.76
F	.003	.006	0.08	0.15	AB	.145	.155	3.68	3.94
G	1.100 BSC		27.94 BSC						
H	.057	.067	1.45	1.7	aaa		.005		0.127
J	.175 BSC		4.44 BSC		bbb		.010		0.254
K	.170	.210	4.32	5.33	ccc		.015		0.381
M	.774	.786	19.61	20.02					
N	.772	.788	19.61	20.02					
Q	ø.118	ø.138	ø3	ø3.51					

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MMRF1310HR5 MMRF1310HSR5



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3. DELETED
4. DIMENSION H IS MEASURED .030 (0.762) AWAY FROM PACKAGE BODY.

## STYLE 1:

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

DIM	INCH		MILLIMETER		DIM	INCH		MILLIMETER	
	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	.805	.815	20.45	20.7	U		.040		1.02
B	.380	.390	9.65	9.91	Z		.030		0.76
C	.125	.170	3.18	4.32	AB	.145	.155	3.68	- 3.94
E	.035	.045	0.89	1.14					
F	.003	.006	0.08	0.15	aaa		.005		0.127
H	.057	.067	1.45	1.7	bbb		.010		0.254
J	.175	BSC	4.44	BSC	ccc		.015		0.381
K	.170	.210	4.32	5.33					
M	.774	.786	19.61	20.02					
N	.772	.788	19.61	20.02					
R	.365	.375	9.27	9.53					
S	.365	.375	9.27	9.52					

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TITLE:  NI 780S-4	DOCUMENT NO: 98ASA10718D  CASE NUMBER: 465H-02  STANDARD: NON-JEDEC	REV: A  27 MAR 2007

MMRF1310HR5 MMRF1310HSR5

## PRODUCT DOCUMENTATION AND SOFTWARE

Refer to the following resources to aid your design process.

### Application Notes

- AN1955: Thermal Measurement Methodology of RF Power Amplifiers

### Engineering Bulletins

- EB212: Using Data Sheet Impedances for RF LDMOS Devices

### Software

- Electromigration MTTF Calculator

For Software, do a Part Number search at <http://www.freescale.com>, and select the “Part Number” link. Go to the Software & Tools tab on the part’s Product Summary page to download the respective tool.

## REVISION HISTORY

The following table summarizes revisions to this document.

Revision	Date	Description
0	July 2014	• Initial Release of Data Sheet

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