

# RF Power Field Effect Transistor

## N-Channel Enhancement-Mode Lateral MOSFET

Designed for Class A or Class AB base station applications with frequencies up to 2000 MHz. Suitable for analog and digital modulation and multicarrier amplifier applications.

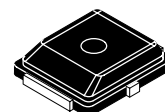
- Typical Two-Tone Performance @ 1960 MHz, 28 Volts,  $I_{DQ} = 50$  mA,  
 $P_{out} = 4$  Watts PEP  
 Power Gain — 18 dB  
 Drain Efficiency — 33%  
 IMD — -34 dBc
- Typical Two-Tone Performance @ 900 MHz, 28 Volts,  $I_{DQ} = 50$  mA,  
 $P_{out} = 4$  Watts PEP  
 Power Gain — 19 dB  
 Drain Efficiency — 33%  
 IMD — -39 dBc
- Capable of Handling 5:1 VSWR, @ 28 Vdc, 1960 MHz, 4 Watts CW Output Power

### Features

- Characterized with Series Equivalent Large-Signal Impedance Parameters
- On-Chip RF Feedback for Broadband Stability
- Integrated ESD Protection
- RoHS Compliant
- In Tape and Reel. T1 Suffix = 1000 Units per 12 mm, 7 inch Reel.

**MW6S004NT1**

**1-2000 MHz, 4 W, 28 V  
LATERAL N-CHANNEL  
RF POWER MOSFET**



**CASE 466-03, STYLE 1  
PLD 1.5  
PLASTIC**

**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
Operating Junction Temperature	$T_J$	150	°C

**Table 2. Thermal Characteristics**

Characteristic	Symbol	Value (1,2)	Unit
Thermal Resistance, Junction to Case Case Temperature 76°C, 4 W PEP, Two-Tone Case Temperature 79°C, 4 W CW	$R_{\theta JC}$	8.8 8.5	°C/W

**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)

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

**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** ( $T_A = 25^\circ\text{C}$  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 ( $V_{DS} = 28\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )	$I_{DSS}$	—	—	10	$\mu\text{Adc}$
Gate-Source Leakage Current ( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )	$I_{GSS}$	—	—	500	$\text{nAdc}$

**On Characteristics**

Gate Threshold Voltage ( $V_{DS} = 10\text{ Vdc}$ , $I_D = 50\text{ mAdc}$ )	$V_{GS(th)}$	1.2	2	2.7	Vdc
Gate Quiescent Voltage ( $V_{DS} = 28\text{ Vdc}$ , $I_D = 50\text{ mAdc}$ )	$V_{GS(Q)}$	—	2.7	—	Vdc
Fixture Gate Quiescent Voltage <sup>(1)</sup> ( $V_{DD} = 28\text{ Vdc}$ , $I_D = 50\text{ mAdc}$ , Measured in Functional Test)	$V_{GG(Q)}$	2.2	3	4.2	Vdc
Drain-Source On-Voltage ( $V_{GS} = 10\text{ Vdc}$ , $I_D = 50\text{ mAdc}$ )	$V_{DS(on)}$	—	0.27	0.37	Vdc

**Dynamic Characteristics**

Reverse Transfer Capacitance ( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{rss}$	—	21	—	pF
Output Capacitance ( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )	$C_{oss}$	—	25	—	pF
Input Capacitance ( $V_{DS} = 28\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz)	$C_{iss}$	—	30	—	pF

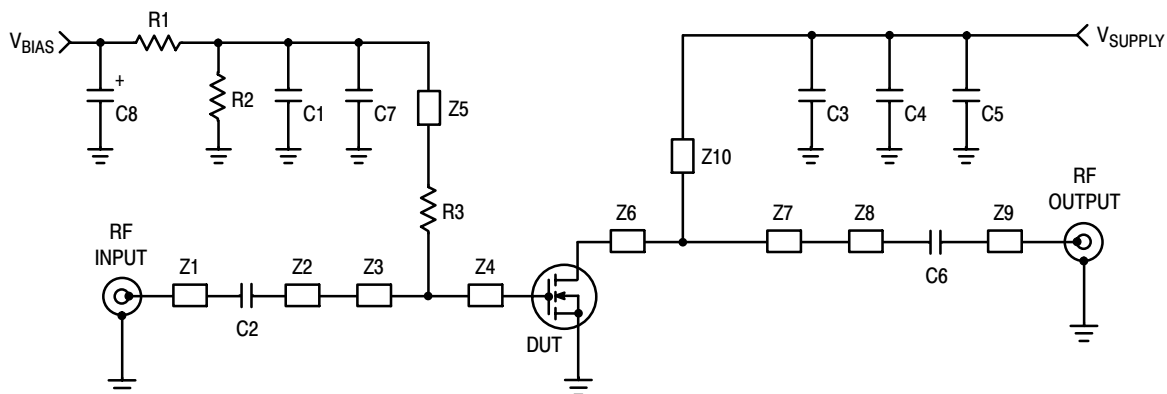
**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 50\text{ mA}$ ,  $P_{out} = 4\text{ W PEP}$ ,  $f_1 = 1960\text{ MHz}$ ,  $f_2 = 1960.1\text{ MHz}$ , Two-Tone Test

Power Gain	$G_{ps}$	16.5	18	20	dB
Drain Efficiency	$\eta_D$	28	33	—	%
Intermodulation Distortion	IMD	—	-34	-28	dBc
Input Return Loss	IRL	—	-12	-10	dB

**Typical Performance** (In Freescale 900 MHz Demo Board, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 50\text{ mA}$ ,  $P_{out} = 4\text{ W PEP}$ ,  $f = 900\text{ MHz}$ , Two-Tone Test, 100 kHz Tone Spacing

Power Gain	$G_{ps}$	—	19	—	dB
Drain Efficiency	$\eta_D$	—	33	—	%
Intermodulation Distortion	IMD	—	-39	—	dBc
Input Return Loss	IRL	—	-12	—	dB

1.  $V_{GG} = \frac{11}{10} \times V_{GS(Q)}$ . Parameter measured on Freescale Test Fixture, due to resistive divider network on the board. Refer to Test Circuit Schematic.



Z1	0.054" x 0.430" Microstrip	Z7	0.210" x 1.220" Microstrip
Z2	0.054" x 0.137" Microstrip	Z8	0.054" x 0.680" Microstrip
Z3	0.580" x 0.420" Microstrip	Z9	0.054" x 0.260" Microstrip
Z4	0.580" x 0.100" Microstrip	Z10	0.025" x 0.930" Microstrip
Z5	0.025" x 0.680" Microstrip	PCB	Arlon CuClad 250GX-0300-55-22, 0.020", $\epsilon_r = 2.5$
Z6	0.210" x 0.100" Microstrip		

**Figure 1. MW6S004NT1 Test Circuit Schematic**

**Table 6. MW6S004NT1 Test Circuit Component Designations and Values**

Part	Description	Part Number	Manufacturer
C1	100 nF Chip Capacitor	CDR33BX104AKYS	Kemet
C2, C3, C6, C7	9.1 pF Chip Capacitors	ATC100B9R1CT500XT	ATC
C4, C5	10 $\mu$ F, 50 V Chip Capacitors	GRM55DR61H106KA88B	Murata
C8	10 $\mu$ F, 35 V Tantalum Chip Capacitor	T490D106K035AT	Kemet
R1	1 k $\Omega$ , 1/4 W Chip Resistor	CRCW12061001FKEA	Vishay
R2	10 k $\Omega$ , 1/4 W Chip Resistor	CRCW12061002FKEA	Vishay
R3	10 $\Omega$ , 1/4 W Chip Resistor	CRCW120610R0FKEA	Vishay

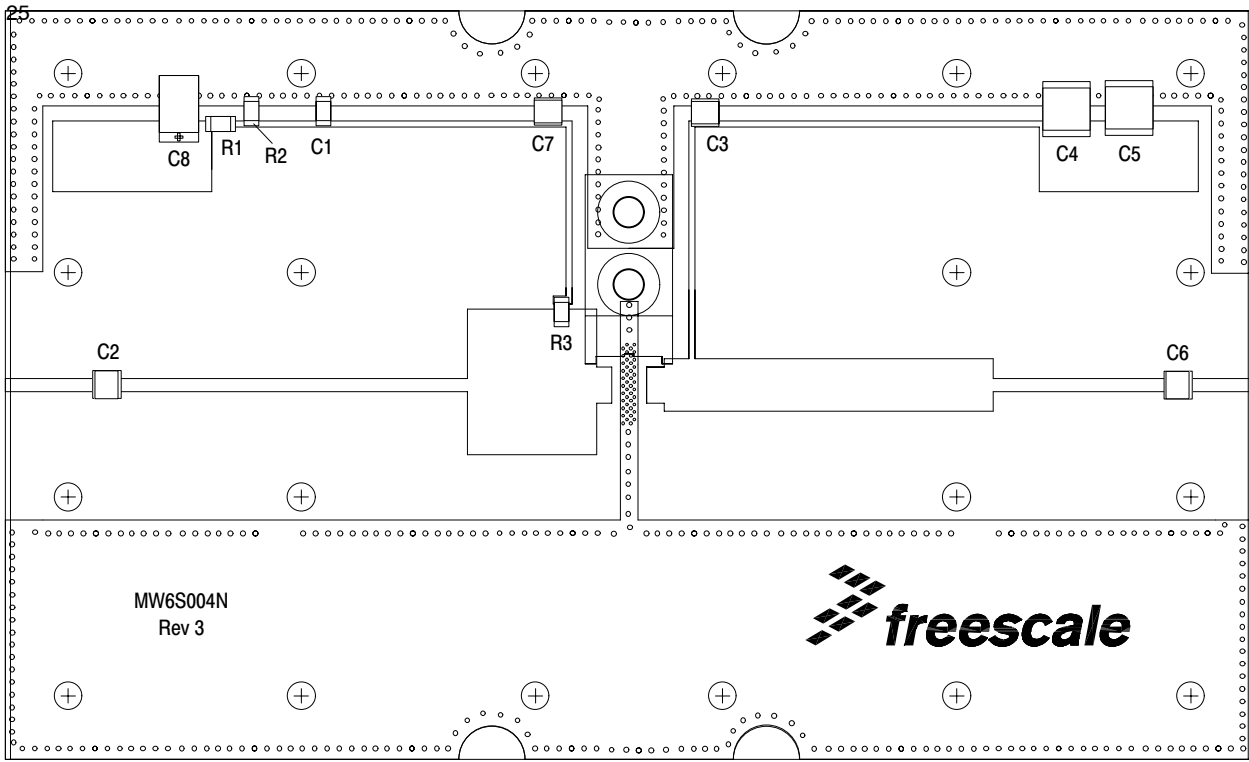
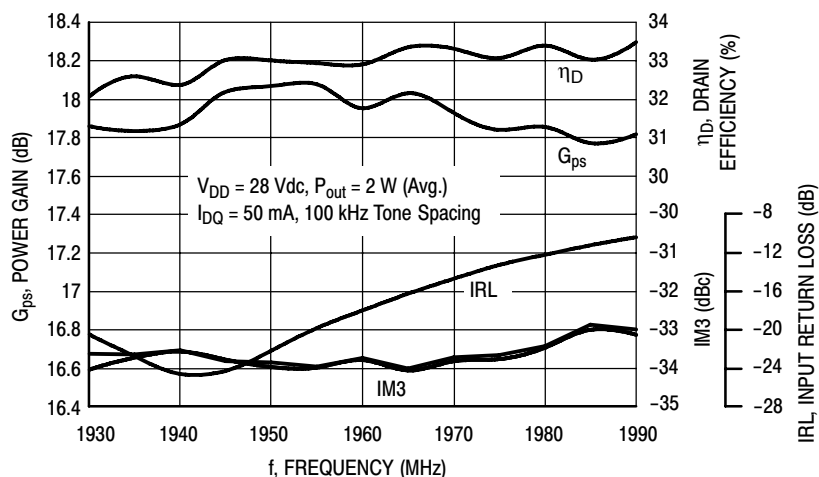
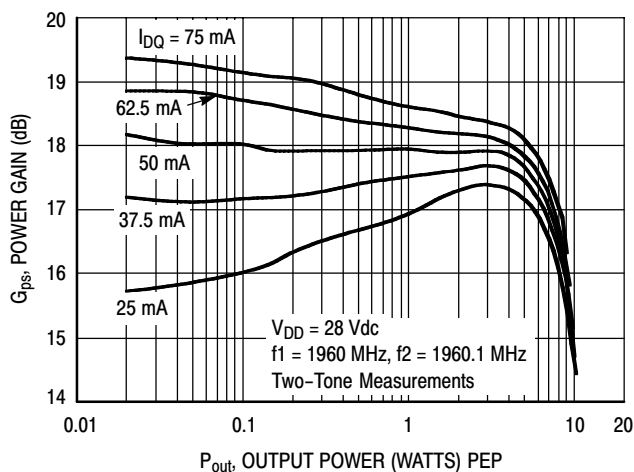


Figure 2. MW6S004NT1 Test Circuit Component Layout

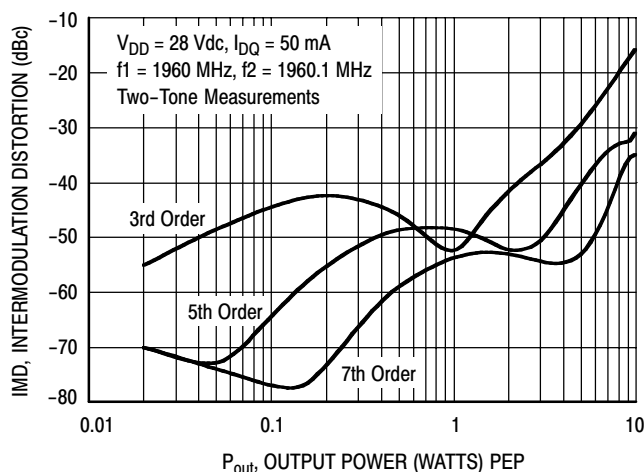
### TYPICAL CHARACTERISTICS



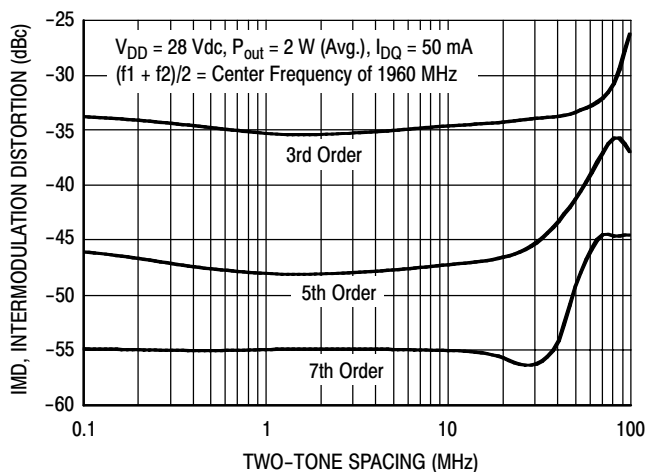
**Figure 3. Two-Tone Wideband Performance @ P<sub>out</sub> = 2 Watts Avg.**



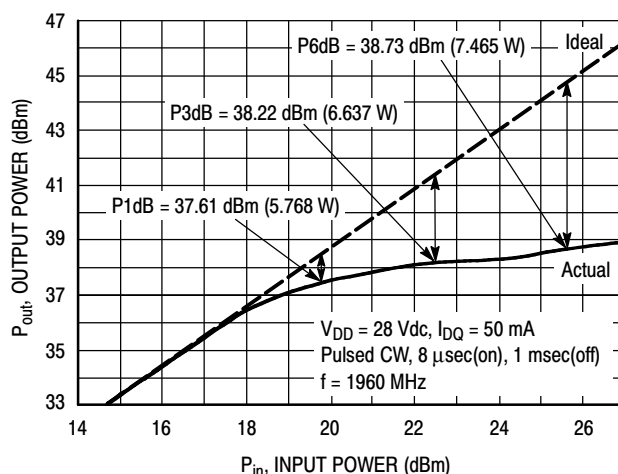
**Figure 4. Two-Tone Power Gain versus Output Power**



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

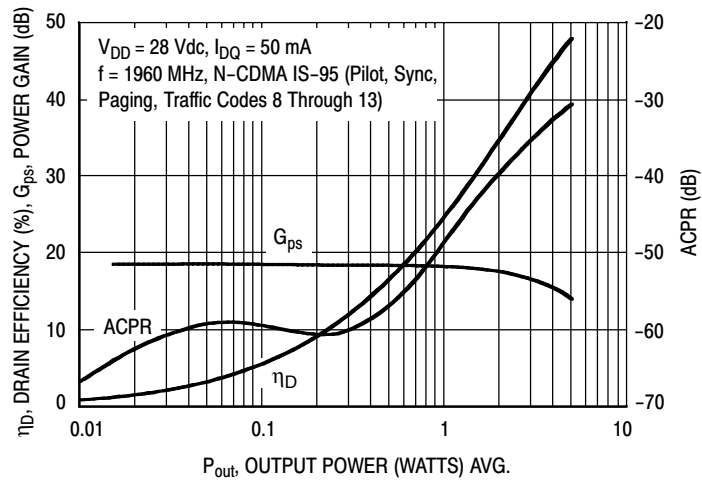


**Figure 6. Intermodulation Distortion Products versus Tone Spacing**

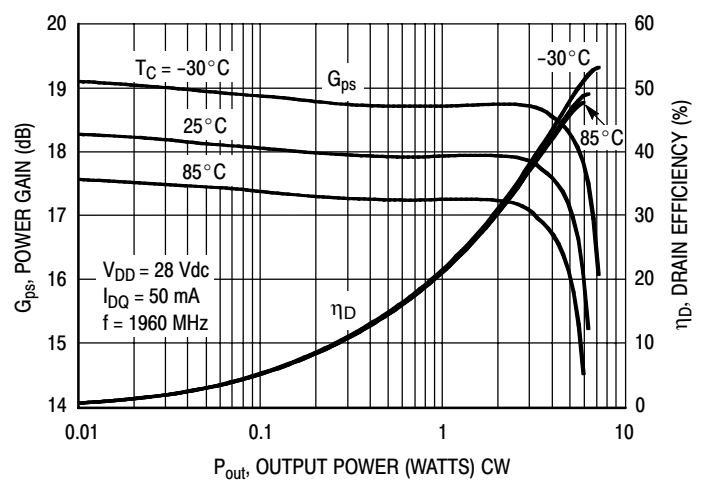


**Figure 7. Pulsed CW Output Power versus Input Power**

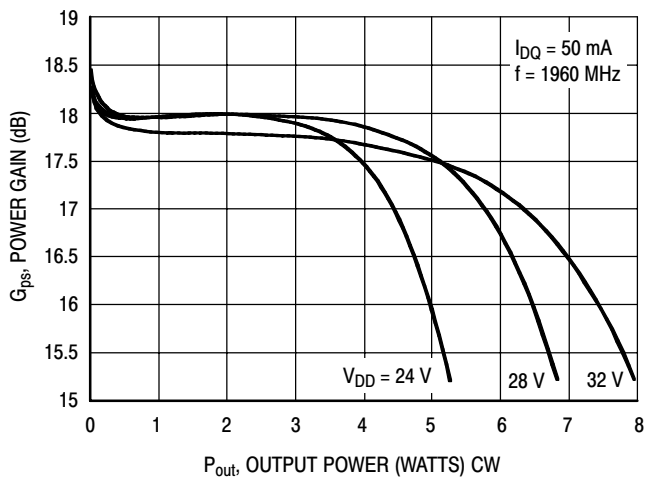
### TYPICAL CHARACTERISTICS



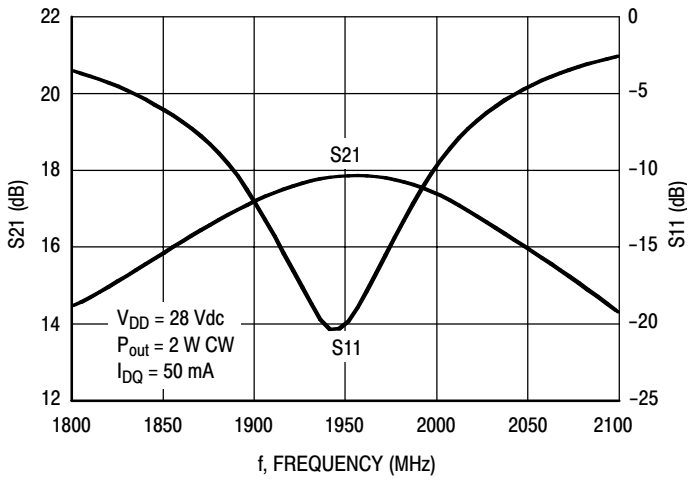
**Figure 8. Single-Carrier CDMA ACPR, Power Gain and Drain Efficiency versus Output Power**



**Figure 9. Power Gain and Drain Efficiency versus CW Output Power**

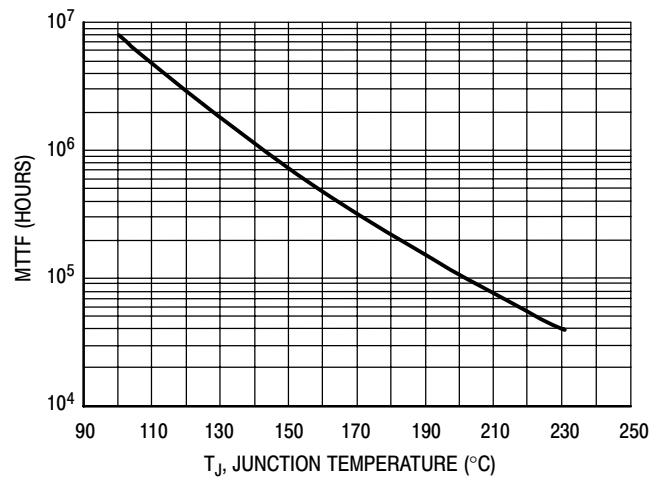


**Figure 10. Power Gain versus Output Power**



**Figure 11. Broadband Frequency Response**

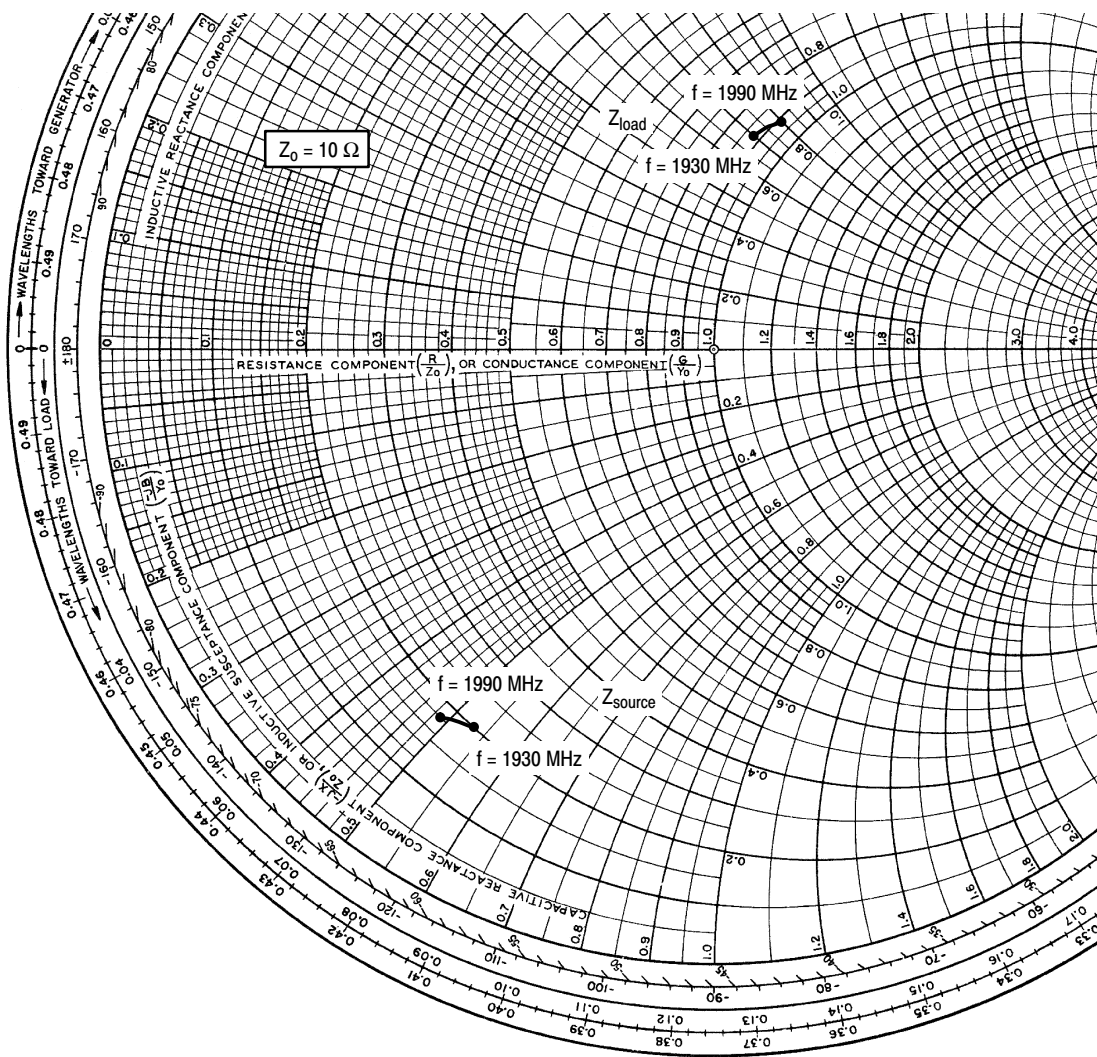
## TYPICAL CHARACTERISTICS



This above graph displays calculated MTTF in hours when the device is operated at  $V_{DD} = 28$  Vdc,  $P_{out} = 4$  W PEP, and  $\eta_D = 33\%$ .

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

**Figure 12. MTTF versus Junction Temperature**



$V_{DD} = 28 \text{ Vdc}$ ,  $I_{DQ} = 50 \text{ mA}$ ,  $P_{out} = 4 \text{ W PEP}$

f MHz	$Z_{source}$ $\Omega$	$Z_{load}$ $\Omega$
1930	$1.96 - j5.34$	$8.78 + j6.96$
1960	$1.89 - j5.10$	$8.93 + j7.46$
1990	$1.82 - j4.85$	$9.11 + j7.97$

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

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

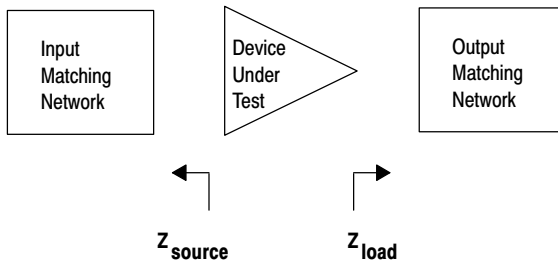


Figure 13. Series Equivalent Source and Load Impedance



**Table 7. Common Source Scattering Parameters ( $V_{DD} = 28\text{ V}$ , 50 ohm system)**

$I_{DQ} = 50\text{ mA}$

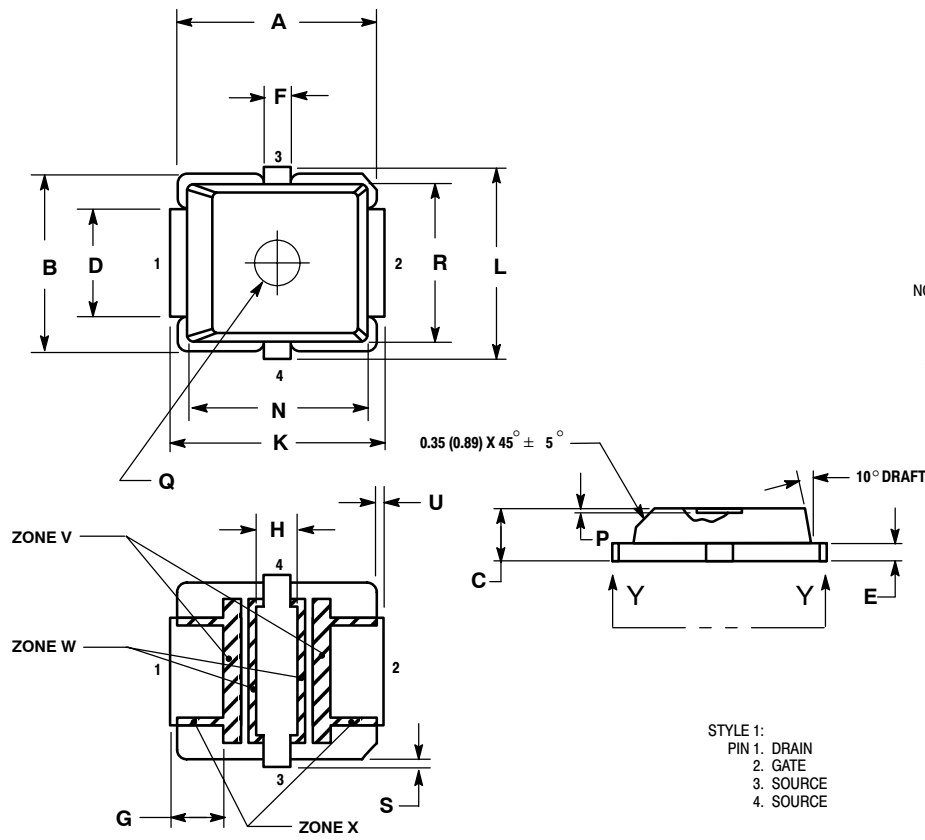
f MHz	S <sub>11</sub>		S <sub>21</sub>		S <sub>12</sub>		S <sub>22</sub>	
	S <sub>11</sub>	∠ φ	S <sub>21</sub>	∠ φ	S <sub>12</sub>	∠ φ	S <sub>22</sub>	∠ φ
500	0.649	-116.340	7.902	105.420	0.056	-73.750	0.548	-33.570
550	0.695	-121.680	7.502	98.790	0.053	-80.570	0.593	-41.480
600	0.733	-126.560	7.111	92.380	0.049	-87.010	0.632	-48.890
650	0.770	-131.340	6.699	86.290	0.045	-93.280	0.669	-56.000
700	0.800	-135.740	6.302	80.450	0.041	-99.120	0.701	-62.810
750	0.827	-140.030	5.922	74.850	0.038	-104.850	0.727	-69.290
800	0.848	-143.950	5.552	69.630	0.035	-110.110	0.750	-75.350
850	0.866	-147.690	5.220	64.580	0.032	-115.220	0.770	-81.130
900	0.882	-151.140	4.891	59.970	0.029	-119.960	0.786	-86.570
950	0.895	-154.560	4.597	55.490	0.026	-124.790	0.800	-91.730
1000	0.907	-157.590	4.315	51.240	0.024	-129.090	0.813	-96.660
1050	0.916	-160.540	4.060	47.170	0.022	-133.370	0.824	-101.340
1100	0.923	-163.310	3.819	43.340	0.020	-137.460	0.833	-105.790
1150	0.929	-165.930	3.601	39.650	0.018	-141.440	0.840	-110.050
1200	0.935	-168.430	3.398	36.110	0.017	-145.330	0.847	-114.170
1250	0.938	-170.770	3.210	32.740	0.015	-149.540	0.851	-118.060
1300	0.942	-173.030	3.036	29.490	0.014	-153.430	0.856	-121.880
1350	0.945	-175.140	2.875	26.360	0.013	-157.460	0.859	-125.520
1400	0.948	-177.170	2.728	23.330	0.012	-161.910	0.863	-129.020
1450	0.951	-179.090	2.590	20.440	0.011	-166.180	0.866	-132.390
1500	0.953	179.030	2.464	17.640	0.010	-170.630	0.869	-135.650
1550	0.954	177.270	2.347	14.920	0.009	-174.890	0.872	-138.760
1600	0.955	175.570	2.240	12.320	0.008	179.950	0.875	-141.750
1650	0.956	173.980	2.139	9.740	0.008	173.920	0.877	-144.650
1700	0.957	172.350	2.047	7.250	0.007	167.710	0.880	-147.480
1750	0.957	170.800	1.958	4.810	0.007	161.810	0.882	-150.180
1800	0.958	169.340	1.879	2.440	0.006	155.370	0.884	-152.760
1850	0.959	167.920	1.806	0.260	0.006	148.940	0.886	-155.230
1900	0.959	166.510	1.736	-1.980	0.005	142.630	0.887	-157.580
1950	0.960	165.200	1.668	-4.310	0.005	136.740	0.888	-160.050
2000	0.959	163.800	1.611	-6.240	0.005	129.910	0.890	-162.070
2050	0.959	162.420	1.555	-8.290	0.005	123.810	0.891	-164.190
2100	0.958	161.170	1.504	-10.270	0.005	118.200	0.892	-166.140
2150	0.958	159.840	1.456	-12.210	0.005	112.740	0.893	-168.060
2200	0.957	158.560	1.412	-14.130	0.005	108.460	0.894	-169.840
2250	0.957	157.160	1.372	-16.010	0.005	103.840	0.896	-171.610
2300	0.955	155.870	1.334	-17.870	0.005	99.310	0.896	-173.260
2350	0.954	154.510	1.300	-19.700	0.005	95.360	0.897	-174.830
2400	0.953	153.120	1.268	-21.510	0.005	91.030	0.898	-176.390
2450	0.953	151.730	1.238	-23.250	0.005	87.460	0.899	-177.840

**Table 7. Common Source Scattering Parameters ( $V_{DD} = 28\text{ V}$ , 50 ohm system) (continued)**

$I_{DQ} = 50\text{ mA}$

f MHz	S <sub>11</sub>		S <sub>21</sub>		S <sub>12</sub>		S <sub>22</sub>	
	S <sub>11</sub>	∠ φ	S <sub>21</sub>	∠ φ	S <sub>12</sub>	∠ φ	S <sub>22</sub>	∠ φ
2500	0.952	150.340	1.211	-25.120	0.006	84.160	0.899	-179.270
2550	0.950	149.010	1.187	-26.920	0.006	80.780	0.897	179.420
2600	0.949	147.380	1.166	-28.650	0.006	77.880	0.897	178.120
2650	0.948	145.920	1.144	-30.420	0.007	74.670	0.898	176.840
2700	0.944	144.200	1.121	-32.310	0.007	71.360	0.896	175.480
2750	0.944	142.790	1.105	-34.230	0.007	67.980	0.897	174.060
2800	0.943	141.020	1.088	-36.000	0.007	63.950	0.897	172.930
2850	0.941	139.410	1.073	-37.870	0.007	61.230	0.896	171.630
2900	0.940	137.640	1.058	-39.760	0.008	59.810	0.896	170.330
2950	0.938	135.900	1.045	-41.680	0.008	58.280	0.896	169.040
3000	0.937	133.860	1.032	-43.610	0.008	56.740	0.895	167.510

# PACKAGE DIMENSIONS



- NOTES:
1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1984.
  2. CONTROLLING DIMENSION: INCH
  3. RESIN BLEED/FLASH ALLOWABLE IN ZONE V, W, AND X.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.255	0.265	6.48	6.73
B	0.225	0.235	5.72	5.97
C	0.065	0.072	1.65	1.83
D	0.130	0.150	3.30	3.81
E	0.021	0.026	0.53	0.66
F	0.026	0.044	0.66	1.12
G	0.050	0.070	1.27	1.78
H	0.045	0.063	1.14	1.60
J	0.160	0.180	4.06	4.57
K	0.273	0.285	6.93	7.24
L	0.245	0.255	6.22	6.48
N	0.230	0.240	5.84	6.10
P	0.000	0.008	0.00	0.20
Q	0.055	0.063	1.40	1.60
R	0.200	0.210	5.08	5.33
S	0.006	0.012	0.15	0.31
U	0.006	0.012	0.15	0.31
ZONE V	0.000	0.021	0.00	0.53
ZONE W	0.000	0.010	0.00	0.25
ZONE X	0.000	0.010	0.00	0.25

**CASE 466-03**  
**ISSUE D**  
**PLD 1.5**  
**PLASTIC**

Refer to the following documents 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
- RF High Power Model

For Software and Tools, 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
2	Feb. 2007	<ul style="list-style-type: none"> <li>• Corrected MSL Rating from 3 to 1 in Table 4, Moisture Sensitivity Level, p. 2</li> <li>• Updated <math>V_{GS(th)}</math> and <math>V_{GS(Q)}</math> to reflect tighter HV6 windows and added Fixture Gate Quiescent <math>V_{GG(Q)}</math> to On Characteristics table to account for test fixture resistor divider network, p. 2</li> <li>• Updated Part Numbers in Table 6, Component Designations and Values, to RoHS compliant part numbers, p. 3</li> <li>• Removed lower voltage tests from Fig. 10, Power Gain versus Output Power, due to fixed tuned fixture limitations, p. 6</li> <li>• Replaced Figure 12, 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>• Added Product Documentation and Revision History section, p. 12</li> </ul>
3	Apr. 2009	<ul style="list-style-type: none"> <li>• Corrected ESD structures to reflect current testing results. Changed HBM from 1A to 1C and CDM from III to IV, p. 1</li> <li>• Corrected <math>C_{iss}</math> test condition to indicate AC stimulus on the <math>V_{GS}</math> connection versus the <math>V_{DS}</math> connection, Dynamic Characteristics table, p. 2</li> <li>• Updated PCB information to show more specific material details, Fig. 1, Test Circuit Schematic, p. 3</li> <li>• Updated Part Numbers in Table 6, Component Designations and Values, to latest RoHS compliant part numbers, p. 3</li> </ul>
4	June 2009	<ul style="list-style-type: none"> <li>• Modified data sheet to reflect MSL rating change from 1 to 3 as a result of the standardization of packing process as described in Product and Process Change Notification number, PCN13516, p. 2</li> <li>• Added Electromigration MTTF Calculator and RF High Power Model availability to Product Documentation, Tools and Software, p. 12</li> </ul>

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