

# RF Power Field Effect Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

Designed for W-CDMA base station applications with frequencies from 2110 to 2170 MHz. Suitable for TDMA, CDMA and multicarrier amplifier applications. To be used in Class AB for PCN-PCS/cellular radio and WLL applications.

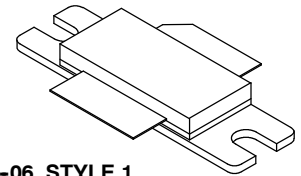
- Typical 2-carrier W-CDMA Performance:  $V_{DD} = 28$  Volts,  $I_{DQ} = 850$  mA,  $P_{out} = 19$  Watts Avg.,  $f = 2112.5$  MHz, Channel Bandwidth = 3.84 MHz, PAR = 8.5 dB @ 0.01% Probability on CCDF.  
Power Gain — 14.5 dB  
Drain Efficiency — 26%  
IM3 @ 10 MHz Offset — -37.5 dBc in 3.84 MHz Channel Bandwidth  
ACPR @ 5 MHz Offset — -40.5 dBc in 3.84 MHz Channel Bandwidth
- Capable of Handling 10:1 VSWR, @ 28 Vdc, 2140 MHz, 90 Watts CW Output Power

### Features

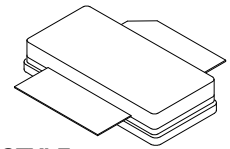
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Matched for Ease of Use
- Qualified Up to a Maximum of 32  $V_{DD}$  Operation
- Integrated ESD Protection
- Lower Thermal Resistance Package
- Low Gold Plating Thickness on Leads, 40 $\mu$ " Nominal.
- RoHS Compliant
- In Tape and Reel. R3 Suffix = 250 Units per 56 mm, 13 inch Reel.

**MRF5S21090HR3**  
**MRF5S21090HSR3**

**2110-2170 MHz, 19 W AVG., 28 V**  
**2 x W-CDMA**  
**LATERAL N-CHANNEL**  
**RF POWER MOSFETs**



**CASE 465-06, STYLE 1**  
**NI-780**  
**MRF5S21090HR3**



**CASE 465A-06, STYLE 1**  
**NI-780S**  
**MRF5S21090HSR3**

**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 @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$     | 269<br>1.5  | W<br>W/ $^\circ\text{C}$ |
| Storage Temperature Range                                                              | $T_{stg}$ | -65 to +150 | $^\circ\text{C}$         |
| Case Operating Temperature                                                             | $T_C$     | 150         | $^\circ\text{C}$         |
| Operating Junction Temperature                                                         | $T_J$     | 200         | $^\circ\text{C}$         |

**Table 2. Thermal Characteristics**

| Characteristic                                                                                                                         | Symbol          | Value (1,2)  | Unit               |
|----------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------------|--------------------|
| Thermal Resistance, Junction to Case<br>Case Temperature $80^\circ\text{C}$ , 90 W CW<br>Case Temperature $76^\circ\text{C}$ , 19 W CW | $R_{\theta JC}$ | 0.65<br>0.69 | $^\circ\text{C/W}$ |

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 3. ESD Protection Characteristics**

| Test Conditions     | Class        |
|---------------------|--------------|
| Human Body Model    | 1 (Minimum)  |
| Machine Model       | M3 (Minimum) |
| Charge Device Model | C7 (Minimum) |

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**Off Characteristics**

|                                                                                                   |           |   |   |    |                 |
|---------------------------------------------------------------------------------------------------|-----------|---|---|----|-----------------|
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 65\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$ | — | — | 10 | $\mu\text{Adc}$ |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 28\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$ | — | — | 1  | $\mu\text{Adc}$ |
| Gate-Source Leakage Current<br>( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )              | $I_{GSS}$ | — | — | 1  | $\mu\text{Adc}$ |

**On Characteristics (DC)**

|                                                                                           |              |     |      |     |     |
|-------------------------------------------------------------------------------------------|--------------|-----|------|-----|-----|
| Gate Threshold Voltage<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 200\text{ }\mu\text{Adc}$ ) | $V_{GS(th)}$ | 2.5 | 2.9  | 3.5 | Vdc |
| Gate Quiescent Voltage<br>( $V_{DS} = 28\text{ Vdc}$ , $I_D = 850\text{ mAdc}$ )          | $V_{GS(Q)}$  | —   | 3.9  | —   | Vdc |
| Drain-Source On-Voltage<br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 2\text{ Adc}$ )            | $V_{DS(on)}$ | —   | 0.25 | —   | Vdc |
| Forward Transconductance<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 2\text{ Adc}$ )           | $g_{fs}$     | —   | 5    | —   | S   |

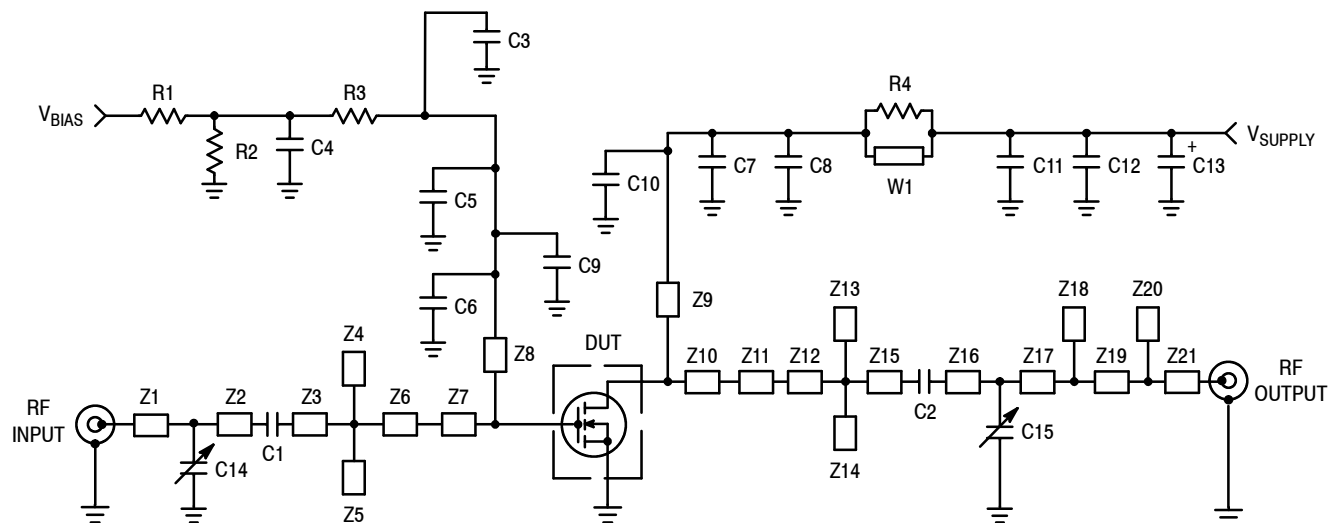
**Dynamic Characteristics <sup>(1)</sup>**

|                                                                                                                       |           |   |     |   |    |
|-----------------------------------------------------------------------------------------------------------------------|-----------|---|-----|---|----|
| Reverse Transfer Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$ | — | 1.7 | — | pF |
|-----------------------------------------------------------------------------------------------------------------------|-----------|---|-----|---|----|

**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 850\text{ mA}$ ,  $P_{out} = 19\text{ W Avg.}$ ,  $f = 2112.5\text{ MHz}$ , 2-carrier W-CDMA, 3.84 MHz Channel Bandwidth Carriers. ACPR measured in 3.84 MHz Channel Bandwidth @  $\pm 5\text{ MHz}$  Offset. IM3 measured in 3.84 MHz Bandwidth @  $\pm 10\text{ MHz}$  Offset. PAR = 8.5 dB @ 0.01% Probability on CCDF.

|                              |          |      |       |     |     |
|------------------------------|----------|------|-------|-----|-----|
| Power Gain                   | $G_{ps}$ | 12.5 | 14.5  | —   | dB  |
| Drain Efficiency             | $\eta_D$ | 24   | 26    | —   | %   |
| Intermodulation Distortion   | IM3      | —    | -37.5 | -35 | dBc |
| Adjacent Channel Power Ratio | ACPR     | —    | -40.5 | -38 | dBc |
| Input Return Loss            | IRL      | —    | -15   | -9  | dB  |

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

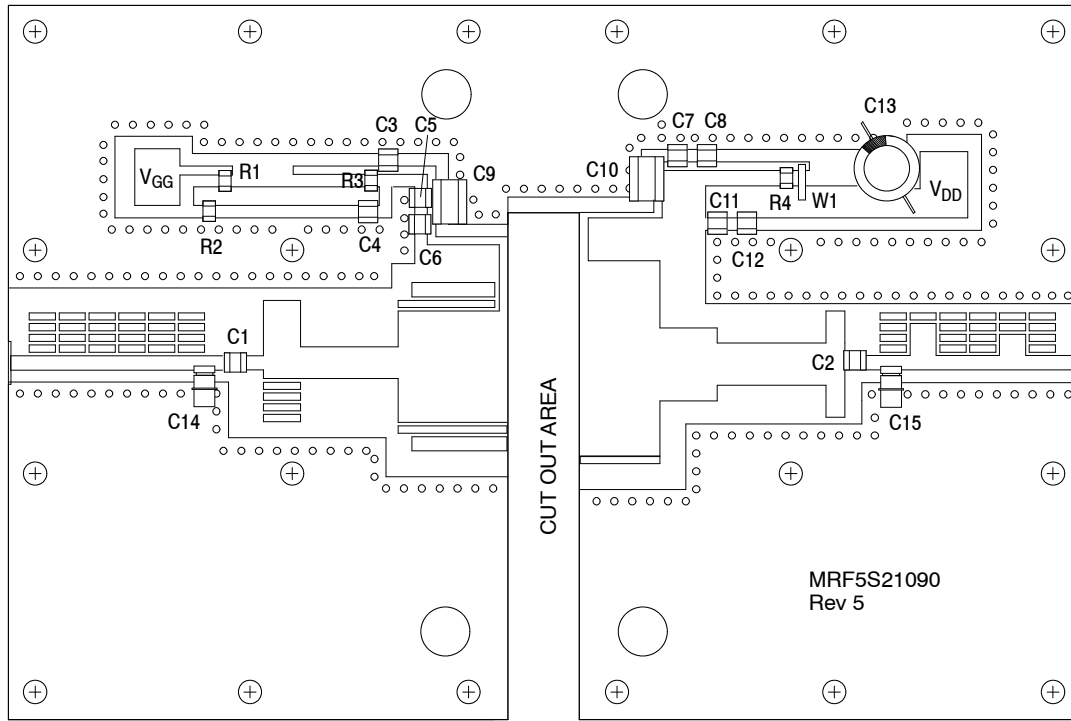


|     |                             |     |                                                |
|-----|-----------------------------|-----|------------------------------------------------|
| Z1  | 1.0856" x 0.080" Microstrip | Z12 | 0.609" x 0.220" Microstrip                     |
| Z2  | 0.130" x 0.080" Microstrip  | Z13 | 0.290" x 0.106" Microstrip                     |
| Z3  | 0.230" x 0.080" Microstrip  | Z14 | 0.290" x 0.106" Microstrip                     |
| Z4  | 0.347" x 0.208" Microstrip  | Z15 | 0.080" x 0.025" Microstrip                     |
| Z5  | 0.090" x 0.208" Microstrip  | Z16 | 1.080" x 0.160" Microstrip                     |
| Z6  | 0.650" x 0.176" Taper       | Z17 | 0.180" x 0.080" Microstrip                     |
| Z7  | 0.623" x 0.610" Microstrip  | Z18 | 0.260" x 0.147" Microstrip                     |
| Z8  | 0.044" x 0.881" Microstrip  | Z19 | 0.500" x 0.080" Microstrip                     |
| Z9  | 0.044" x 0.869" Microstrip  | Z20 | 0.199" x 0.147" Microstrip                     |
| Z10 | 1.076" x 0.446" Microstrip  | Z21 | 0.365" x 0.080" Microstrip                     |
| Z11 | 0.320" x 0.393" Microstrip  | PCB | Arlon GX0300-55-22, 0.03", $\epsilon_r = 2.55$ |

Figure 1. MRF5S21090HR3(HSR3) Test Circuit Schematic

Table 5. MRF5S21090HR3(HSR3) Test Circuit Component Designations and Values

| Part     | Description                              | Part Number        | Manufacturer     |
|----------|------------------------------------------|--------------------|------------------|
| C1       | 9.1 pF Chip Capacitor                    | ATC100B9R1CT500XT  | ATC              |
| C2       | 8.2 pF Chip Capacitor                    | ATC100B8R2CT500XT  | ATC              |
| C3       | 2.0 pF Chip Capacitor                    | ATC100B2R0BT500XT  | ATC              |
| C4, C12  | 0.1 $\mu$ F Chip Capacitors              | CDR33BX104AKYS     | Kemet            |
| C5       | 5.6 pF Chip Capacitor                    | ATC100B5R6CT500XT  | ATC              |
| C6       | 5.1 pF Chip Capacitor                    | ATC100B5R1CT500XT  | ATC              |
| C7       | 7.5 pF Chip Capacitor                    | ATC100B7R5JT500XT  | ATC              |
| C8       | 1.2 pF Chip Capacitor                    | ATC100B1R2BT500XT  | ATC              |
| C9, C10  | 0.56 $\mu$ F Chip Capacitors             | 700A561MT150XT     | ATC              |
| C11      | 1000 pF Chip Capacitor                   | ATC100B102JT500XT  | ATC              |
| C13      | 470 $\mu$ F, 35 V Electrolytic Capacitor | EKME630ELL471MK25S | Nippon Chemi-Con |
| C14, C15 | 0.4 – 2.5 Variable Capacitors, Gigatrim  | 27281SL            | Johanson         |
| R1       | 1 k $\Omega$ , 1/4 W Chip Resistor       | CRCW12061001FKEA   | Vishay           |
| R2       | 560 k $\Omega$ , 1/4 W Chip Resistor     | CRCW12065600FKEA   | Vishay           |
| R3, R4   | 12 $\Omega$ , 1/4 W Chip Resistors       | CRCW120612R0FKEA   | Vishay           |
| W1       | Wire Strap                               |                    |                  |



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

**Figure 2. MRF5S21090HR3(HSR3) Test Circuit Component Layout**

## TYPICAL CHARACTERISTICS

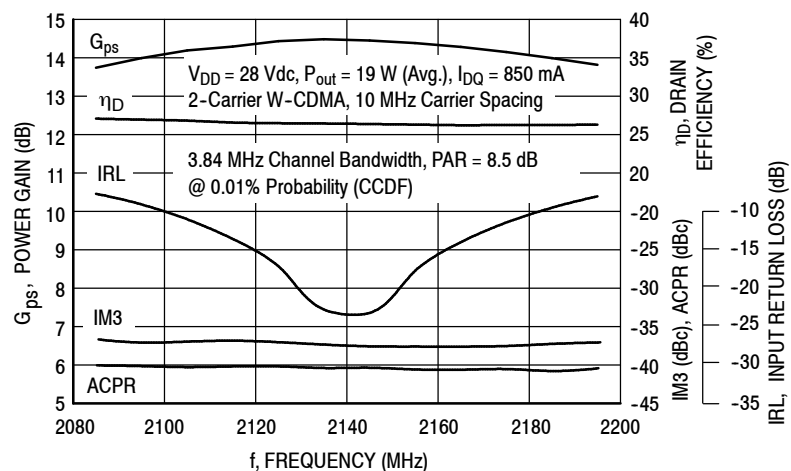


Figure 3. 2-Carrier W-CDMA Broadband Performance

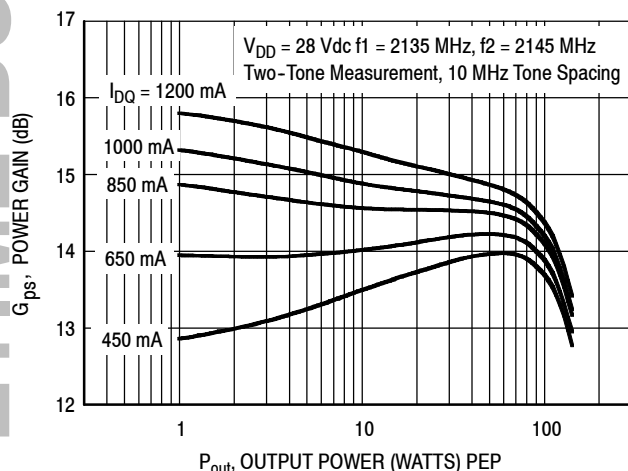


Figure 4. Two-Tone Power Gain versus Output Power

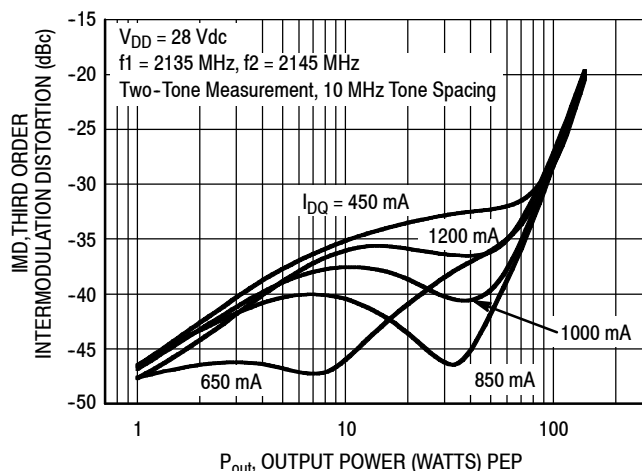


Figure 5. 3rd Order Intermodulation Distortion versus Output Power

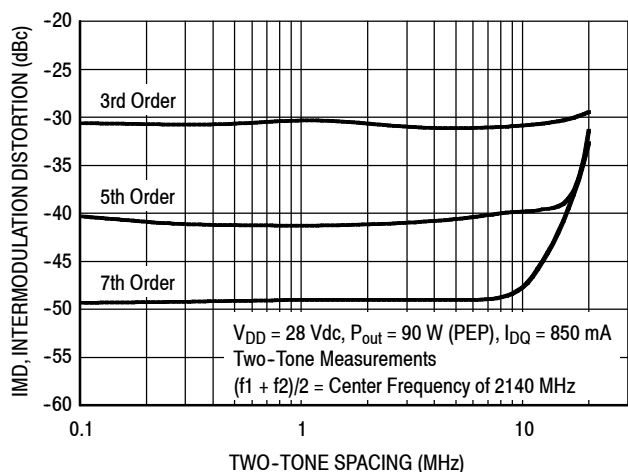


Figure 6. Intermodulation Distortion Products versus Tone Spacing

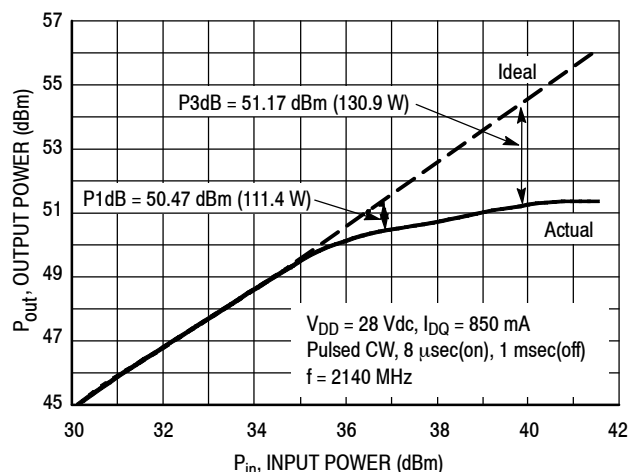
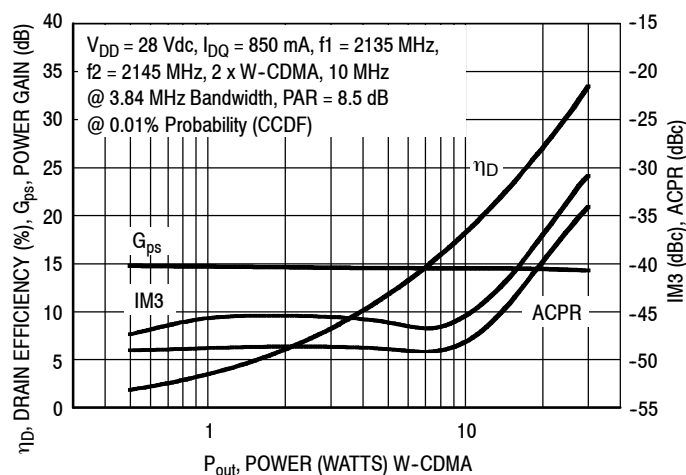


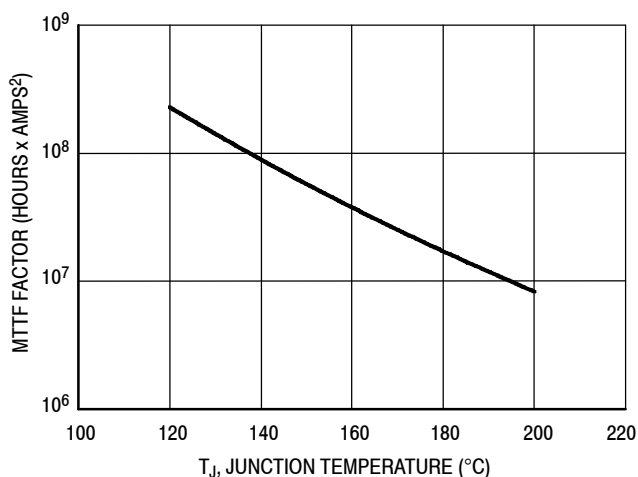
Figure 7. Pulse CW Output Power versus Input Power

MRF5S21090HR3 MRF5S21090HSR3

## TYPICAL CHARACTERISTICS



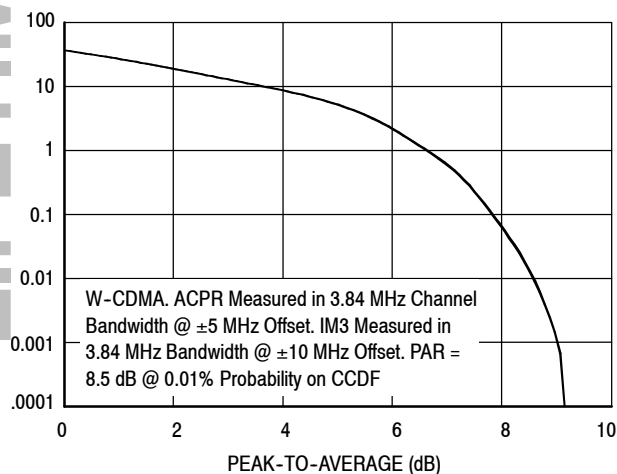
**Figure 8. 2-Carrier W-CDMA ACPR, IM3, Power Gain and Drain Efficiency versus Output Power**



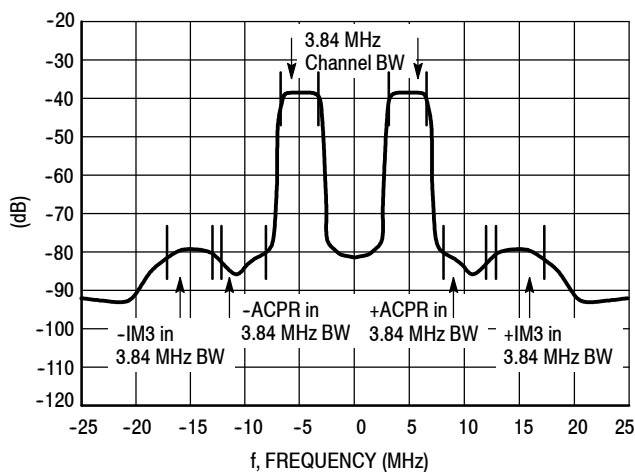
This above graph displays calculated MTTF in hours x ampere<sup>2</sup> drain current. Life tests at elevated temperatures have correlated to better than  $\pm 10\%$  of the theoretical prediction for metal failure. Divide MTTF factor by  $I_D^2$  for MTTF in a particular application.

**Figure 9. MTTF Factor versus Junction Temperature**

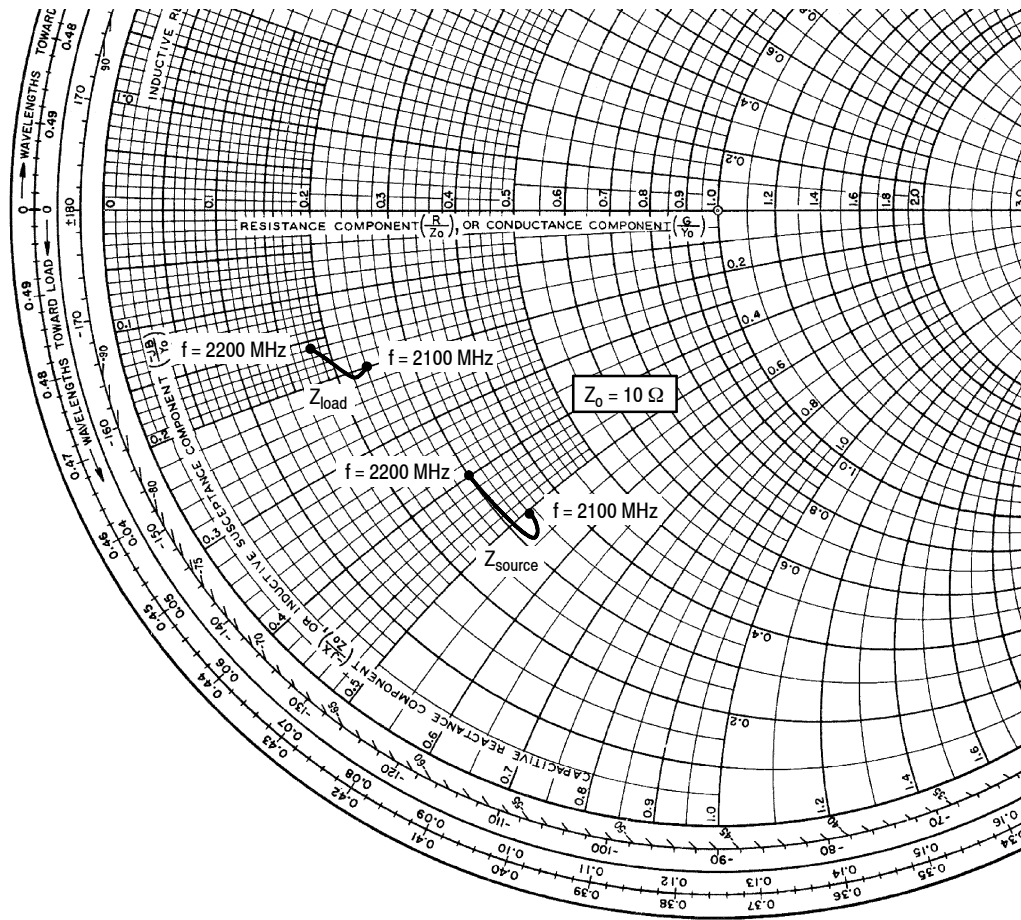
## W-CDMA TEST SIGNAL



**Figure 10. CCDF W-CDMA 3GPP, Test Model 1, 64 DPCH, 67% Clipping, Single Carrier Test Signal**



**Figure 11. 2-Carrier W-CDMA Spectrum**



$V_{DD} = 28 \text{ Vdc}$ ,  $I_{DQ} = 850 \text{ mA}$ ,  $P_{out} = 19 \text{ W Avg.}$

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 2100     | $3.4 - j5.1$             | $2.4 - j2.0$           |
| 2120     | $3.2 - j5.4$             | $2.2 - j2.1$           |
| 2160     | $3.0 - j4.4$             | $2.1 - j1.9$           |
| 2200     | $3.0 - j4.0$             | $1.8 - j1.6$           |

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

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

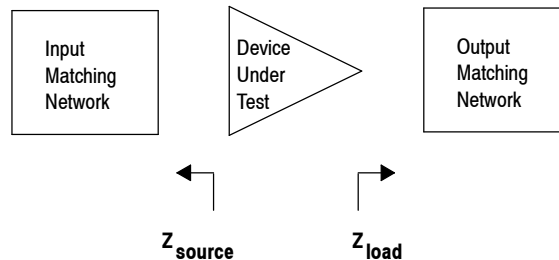
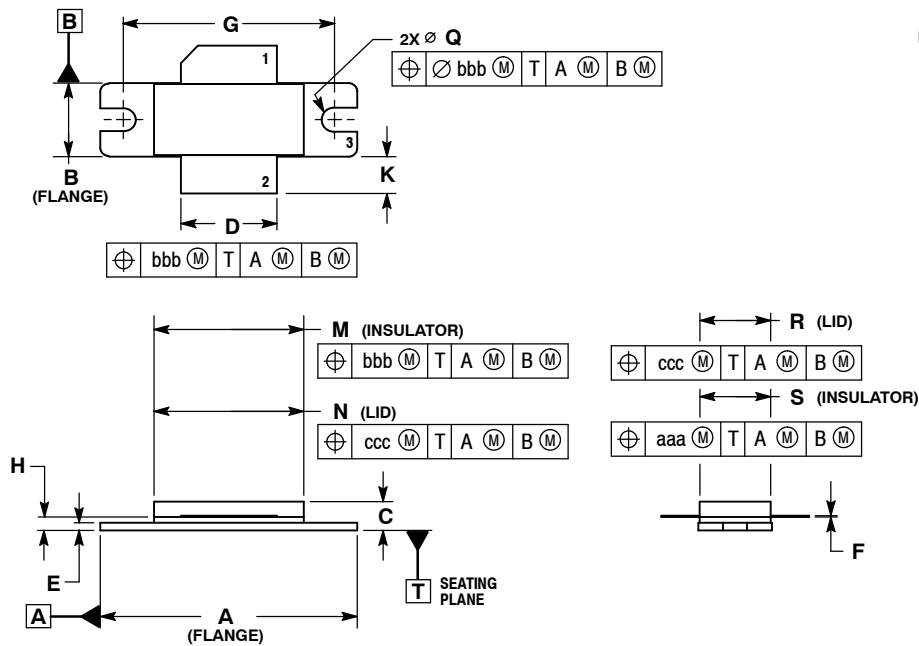


Figure 12. Series Equivalent Source and Load Impedance

MRF5S21090HR3 MRF5S21090HSR3

## PACKAGE DIMENSIONS



### NOTES:

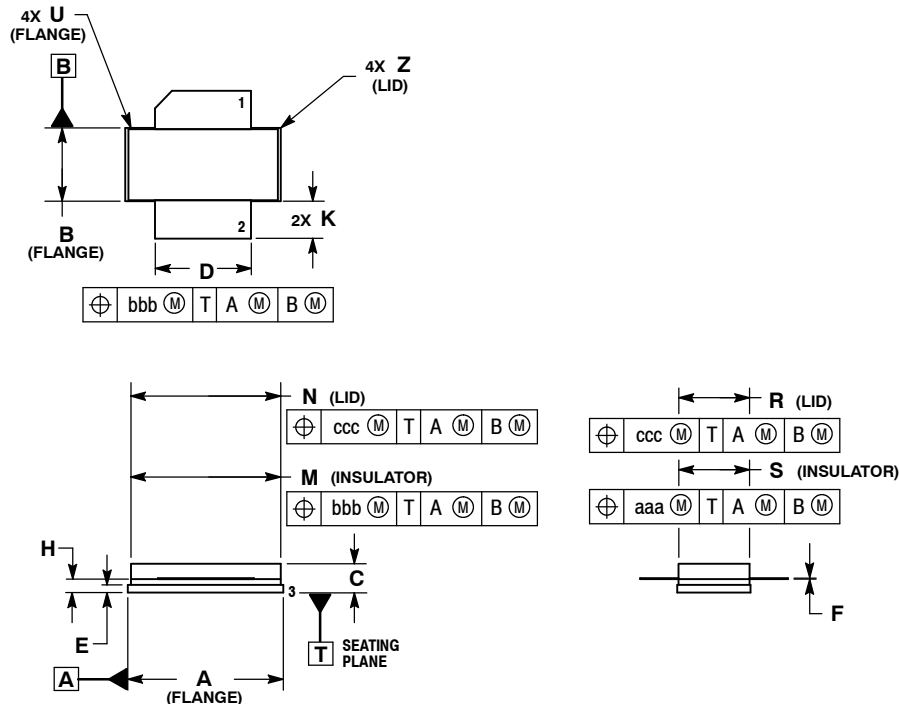
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DELETED
4. DIMENSION H IS MEASURED 0.030 (0.762) AWAY FROM PACKAGE BODY.

| DIM | INCHES |        | MILLIMETERS |        |
|-----|--------|--------|-------------|--------|
|     | MIN    | MAX    | MIN         | MAX    |
| A   | 1.335  | 1.345  | 33.91       | 34.16  |
| B   | 0.380  | 0.390  | 9.65        | 9.91   |
| C   | 0.125  | 0.170  | 3.18        | 4.32   |
| D   | 0.495  | 0.505  | 12.57       | 12.83  |
| E   | 0.035  | 0.045  | 0.89        | 1.14   |
| F   | 0.003  | 0.006  | 0.08        | 0.15   |
| G   | 1.100  | BSC    | 27.94       | BSC    |
| H   | 0.057  | 0.067  | 1.45        | 1.70   |
| K   | 0.170  | 0.210  | 4.32        | 5.33   |
| M   | 0.774  | 0.786  | 19.66       | 19.96  |
| N   | 0.772  | 0.788  | 19.60       | 20.00  |
| Q   | Ø 1.18 | Ø 1.38 | Ø 3.00      | Ø 3.51 |
| R   | 0.365  | 0.375  | 9.27        | 9.53   |
| S   | 0.365  | 0.375  | 9.27        | 9.52   |
| aaa | 0.005  | REF    | 0.127       | REF    |
| bbb | 0.010  | REF    | 0.254       | REF    |
| ccc | 0.015  | REF    | 0.381       | REF    |

### STYLE 1:

- PIN 1. DRAIN
- GATE
- SOURCE

### CASE 465-06 ISSUE G NI-780 MRF5S21090HR3



### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DELETED
4. DIMENSION H IS MEASURED 0.030 (0.762) AWAY FROM PACKAGE BODY.

| DIM | INCHES |       | MILLIMETERS |       |
|-----|--------|-------|-------------|-------|
|     | MIN    | MAX   | MIN         | MAX   |
| A   | 0.805  | 0.815 | 20.45       | 20.70 |
| B   | 0.380  | 0.390 | 9.65        | 9.91  |
| C   | 0.125  | 0.170 | 3.18        | 4.32  |
| D   | 0.495  | 0.505 | 12.57       | 12.83 |
| E   | 0.035  | 0.045 | 0.89        | 1.14  |
| F   | 0.003  | 0.006 | 0.08        | 0.15  |
| H   | 0.057  | 0.067 | 1.45        | 1.70  |
| K   | 0.170  | 0.210 | 4.32        | 5.33  |
| M   | 0.774  | 0.786 | 19.61       | 20.02 |
| N   | 0.772  | 0.788 | 19.61       | 20.02 |
| R   | 0.365  | 0.375 | 9.27        | 9.53  |
| S   | 0.365  | 0.375 | 9.27        | 9.52  |
| U   | ---    | 0.040 | ---         | 1.02  |
| Z   | ---    | 0.030 | ---         | 0.76  |
| aaa | 0.005  | REF   | 0.127       | REF   |
| bbb | 0.010  | REF   | 0.254       | REF   |
| ccc | 0.015  | REF   | 0.381       | REF   |

### STYLE 1:

- PIN 1. DRAIN
- GATE
- SOURCE

### CASE 465A-06 ISSUE H NI-780S MRF5S21090HSR3

MRF5S21090HR3 MRF5S21090HSR3

RF Device Data  
Freescale Semiconductor

## PRODUCT DOCUMENTATION

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

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date      | Description                                                                                                                                                                                                                                                                                                                                                           |
|----------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3        | Oct. 2008 | <ul style="list-style-type: none"><li>• Modified data sheet to reflect RF Test Reduction described in Product and Process Change Notification number, PCN12779, p. 1, 2</li><li>• Updated Part Numbers in Table 5, Component Designations and Values, to RoHS compliant part numbers, p. 3</li><li>• Added Product Documentation and Revision History, p. 9</li></ul> |

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