

## Freescal Semiconductor

### Technical Data

Document Number: MRF6S9160H  
Rev. 0, 10/2005

# RF Power Field Effect Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

Designed for N-CDMA, GSM and GSM EDGE base station applications with frequencies from 865 to 960 MHz. Suitable for multicarrier amplifier applications.

- Typical Single-Carrier N-CDMA Performance @ 880 MHz:  $V_{DD} = 28$  Volts,  $I_{DQ} = 1200$  mA,  $P_{out} = 35$  Watts Avg., IS-95 CDMA (Pilot, Sync, Paging, Traffic Codes 8 Through 13) Channel Bandwidth = 1.2288 MHz. PAR = 9.8 dB @ 0.01% Probability on CCDF.  
Power Gain — 20.9 dB  
Drain Efficiency — 30.5%  
ACPR @ 750 kHz Offset — -46.8 dBc @ 30 kHz Bandwidth

### GSM EDGE Application

- Typical GSM EDGE Performance:  $V_{DD} = 28$  Volts,  $I_{DQ} = 1200$  mA,  $P_{out} = 76$  Watts Avg., Full Frequency Band (865-895 MHz)  
Power Gain — 20 dB  
Drain Efficiency — 45%  
Spectral Regrowth @ 400 kHz Offset = -66 dBc  
Spectral Regrowth @ 600 kHz Offset = -75 dBc  
EVM — 2% rms

### GSM Application

- Typical GSM Performance:  $V_{DD} = 28$  Volts,  $I_{DQ} = 1200$  mA,  $P_{out} = 160$  Watts, Full Frequency Band (921-960 MHz)  
Power Gain — 20 dB  
Drain Efficiency — 58%
- Capable of Handling 10:1 VSWR, @ 28 Vdc, 880 MHz, 160 Watts CW Output Power
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Input 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 $\mu$ m Nominal.
- Pb-Free and RoHS Compliant
- In Tape and Reel. R3 Suffix = 250 Units per 56 mm, 13 inch Reel.

**MRF6S9160HR3**  
**MRF6S9160HSR3**

**880 MHz, 35 W AVG., 28 V**  
**SINGLE N-CDMA**  
**LATERAL N-CHANNEL**  
**RF POWER MOSFETs**

**CASE 465-06, STYLE 1**  
**NI-780**  
**MRF6S9160HR3**

**CASE 465A-06, STYLE 1**  
**NI-780S**  
**MRF6S9160HSR3**

**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                      |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$     | 565<br>3.2  | W<br>W/ $^\circ\text{C}$ |
| Storage Temperature Range                                                              | $T_{stg}$ | -65 to +150 | $^\circ\text{C}$         |
| Operating Junction Temperature                                                         | $T_J$     | 200         | $^\circ\text{C}$         |
| CW Operation                                                                           | CW        | 160         | W                        |

NOTE - **CAUTION** - MOS devices are susceptible to damage from electrostatic charge. Reasonable precautions in handling and packaging MOS devices should be observed.



**Table 2. Thermal Characteristics**

| Characteristic                                                                                            | Symbol          | Value (1,2)  | Unit |
|-----------------------------------------------------------------------------------------------------------|-----------------|--------------|------|
| Thermal Resistance, Junction to Case<br>Case Temperature 81°C, 160 W CW<br>Case Temperature 73°C, 35 W CW | $R_{\theta JC}$ | 0.31<br>0.33 | °C/W |

**Table 3. ESD Protection Characteristics**

| Test Methodology                      | Class        |
|---------------------------------------|--------------|
| Human Body Model (per JESD22-A114)    | 1A (Minimum) |
| Machine Model (per EIA/JESD22-A115)   | A (Minimum)  |
| Charge Device Model (per JESD22-C101) | IV (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>( $V_{DS} = 68\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$ | — | — | 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**

|                                                                                                                |              |     |     |     |     |
|----------------------------------------------------------------------------------------------------------------|--------------|-----|-----|-----|-----|
| Gate Threshold Voltage<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 525\text{ }\mu\text{Adc}$ )                      | $V_{GS(th)}$ | 1   | 2   | 3   | Vdc |
| Gate Quiescent Voltage<br>( $V_{DS} = 28\text{ Vdc}$ , $I_D = 1200\text{ mAdc}$ , Measured in Functional Test) | $V_{GS(Q)}$  | 2   | 3   | 4   | Vdc |
| Drain-Source On-Voltage<br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 3.6\text{ Adc}$ )                               | $V_{DS(on)}$ | 0.1 | 0.2 | 0.3 | Vdc |
| Forward Transconductance<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 8\text{ Adc}$ )                                | $g_{fs}$     | —   | 9.7 | —   | S   |

**Dynamic Characteristics<sup>(3)</sup>**

|                                                                                                                       |           |   |      |   |    |
|-----------------------------------------------------------------------------------------------------------------------|-----------|---|------|---|----|
| Output Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )           | $C_{OSS}$ | — | 80.2 | — | pF |
| Reverse Transfer Capacitance<br>( $V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$ | — | 2.2  | — | pF |

**Functional Tests** (In Freescale Test Fixture, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 1200\text{ mA}$ ,  $P_{out} = 35\text{ W Avg.}$  N-CDMA,  $f = 880\text{ MHz}$ , Single-Carrier N-CDMA, 1.2288 MHz Channel Bandwidth Carrier. ACPR measured in 30 kHz Channel Bandwidth @  $\pm 750\text{ kHz}$  Offset. PAR = 9.8 dB @ 0.01% Probability on CCDF

|                              |          |    |       |     |     |
|------------------------------|----------|----|-------|-----|-----|
| Power Gain                   | $G_{ps}$ | 20 | 20.9  | 23  | dB  |
| Drain Efficiency             | $\eta_D$ | 29 | 30.5  | —   | %   |
| Adjacent Channel Power Ratio | ACPR     | —  | -46.8 | -45 | dBc |
| Input Return Loss            | IRL      | —  | -17   | -9  | dB  |

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.
3. Part is internally matched on input.

(continued)

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

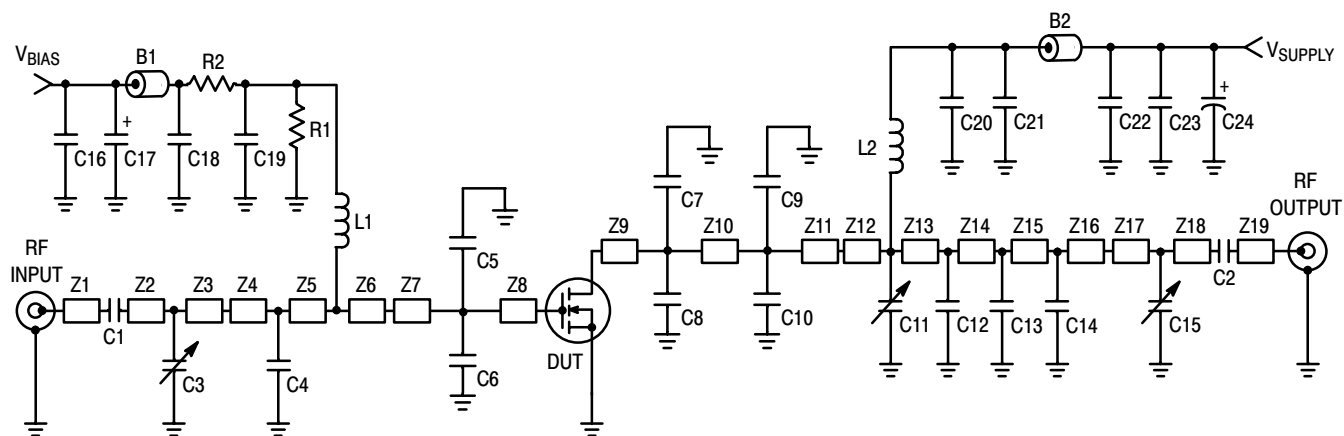
| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**Typical GSM EDGE Performances** (In Freescale GSM EDGE Test Fixture, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 1200\text{ mA}$ ,  
 $P_{out} = 76\text{ W Avg.}$ ,  $865\text{ MHz} < \text{Frequency} < 895\text{ MHz}$

|                                     |          |   |     |   |       |
|-------------------------------------|----------|---|-----|---|-------|
| Power Gain                          | $G_{ps}$ | — | 20  | — | dB    |
| Drain Efficiency                    | $\eta_D$ | — | 45  | — | %     |
| Error Vector Magnitude              | EVM      | — | 2   | — | % rms |
| Spectral Regrowth at 400 kHz Offset | SR1      | — | -66 | — | dBc   |
| Spectral Regrowth at 600 kHz Offset | SR2      | — | -75 | — | dBc   |

**Typical CW Performances** (In Freescale GSM Test Fixture, 50 ohm system)  $V_{DD} = 28\text{ Vdc}$ ,  $I_{DQ} = 1200\text{ mA}$ ,  $P_{out} = 160\text{ W}$ ,  
 $921\text{ MHz} < \text{Frequency} < 960\text{ MHz}$

|                                                                    |          |   |     |   |    |
|--------------------------------------------------------------------|----------|---|-----|---|----|
| Power Gain                                                         | $G_{ps}$ | — | 20  | — | dB |
| Drain Efficiency                                                   | $\eta_D$ | — | 58  | — | %  |
| Input Return Loss                                                  | IRL      | — | -12 | — | dB |
| $P_{out}$ @ 1 dB Compression Point, CW<br>( $f = 940\text{ MHz}$ ) | P1dB     | — | 160 | — | W  |



|     |                                |     |                                                  |
|-----|--------------------------------|-----|--------------------------------------------------|
| Z1  | 0.426" x 0.080" Microstrip     | Z11 | 0.066" x 0.630" Microstrip                       |
| Z2  | 0.813" x 0.080" Microstrip     | Z12 | 0.630" x 0.425" x 0.220" Taper                   |
| Z3  | 0.471" x 0.080" Microstrip     | Z13 | 0.120" x 0.220" Microstrip                       |
| Z4  | 0.319" x 0.220" Microstrip     | Z14 | 0.292" x 0.220" Microstrip                       |
| Z5  | 0.171" x 0.220" Microstrip     | Z15 | 0.023" x 0.220" Microstrip                       |
| Z6  | 0.200" x 0.425" x 0.630" Taper | Z16 | 0.030" x 0.220" Microstrip                       |
| Z7  | 0.742" x 0.630" Microstrip     | Z17 | 0.846" x 0.080" Microstrip                       |
| Z8  | 0.233" x 0.630" Microstrip     | Z18 | 0.440" x 0.080" Microstrip                       |
| Z9  | 0.128" x 0.630" Microstrip     | Z19 | 0.434" x 0.080" Microstrip                       |
| Z10 | 0.134" x 0.630" Microstrip     | PCB | Arlon GX-0300-55-22, 0.030", $\epsilon_r = 2.55$ |

**Figure 1. MRF6S9160HR3(SR3) Test Circuit Schematic**

**Table 5. MRF6S9160HR3(SR3) Test Circuit Component Designations and Values**

| Part          | Description                              | Part Number        | Manufacturer     |
|---------------|------------------------------------------|--------------------|------------------|
| B1, B2        | Ferrite Beads, Small                     | 2743019447         | Fair Rite        |
| C1, C2, C19   | 47 pF Chip Capacitors                    | 100B470JP500X      | ATC              |
| C3, C11       | 0.8-8.0 pF Variable Capacitors, Gigatrim | 27291SL            | Johanson         |
| C4            | 2.7 pF Chip Capacitor                    | 100B2R7JP500X      | ATC              |
| C5, C6        | 15 pF Chip Capacitors                    | 100B150JP500X      | ATC              |
| C7, C8        | 12 pF Chip Capacitors                    | 100B120JP500X      | ATC              |
| C9, C10       | 4.3 pF Chip Capacitors                   | 100B4R3JP500X      | ATC              |
| C12           | 8.2 pF Chip Capacitor                    | 100B8R2JP500X      | ATC              |
| C13, C14      | 3.9 pF Chip Capacitors                   | 100B3R9JP500X      | ATC              |
| C15           | 0.6-4.5 pF Variable Capacitor, Gigatrim  | 27271SL            | Johanson         |
| C16           | 22 pF Chip Capacitor                     | 100B220JP500X      | ATC              |
| C17           | 1 $\mu$ F, 50 V Tantalum Capacitor       | T491C105K0J0AS     | Kemit            |
| C18           | 20K pF Chip Capacitor                    | CDR353P203AK0S     | Kemit            |
| C20           | 180 pF Chip Capacitor                    | 100B181JP500X      | ATC              |
| C21, C22, C23 | 10 $\mu$ F, 50 V Chip Capacitors (2220)  | GRM55DR61H106KA88B | Murata           |
| C24           | 470 $\mu$ F, 63 V Electrolytic Capacitor | KME63VB471M12x25LL | United Chemi-Con |
| L1, L2        | 10 nH Inductors                          | 0603HC             | Coilcraft        |
| R1            | 180 $\Omega$ Chip Resistor               |                    |                  |
| R2            | 10 $\Omega$ Chip Resistor                |                    |                  |

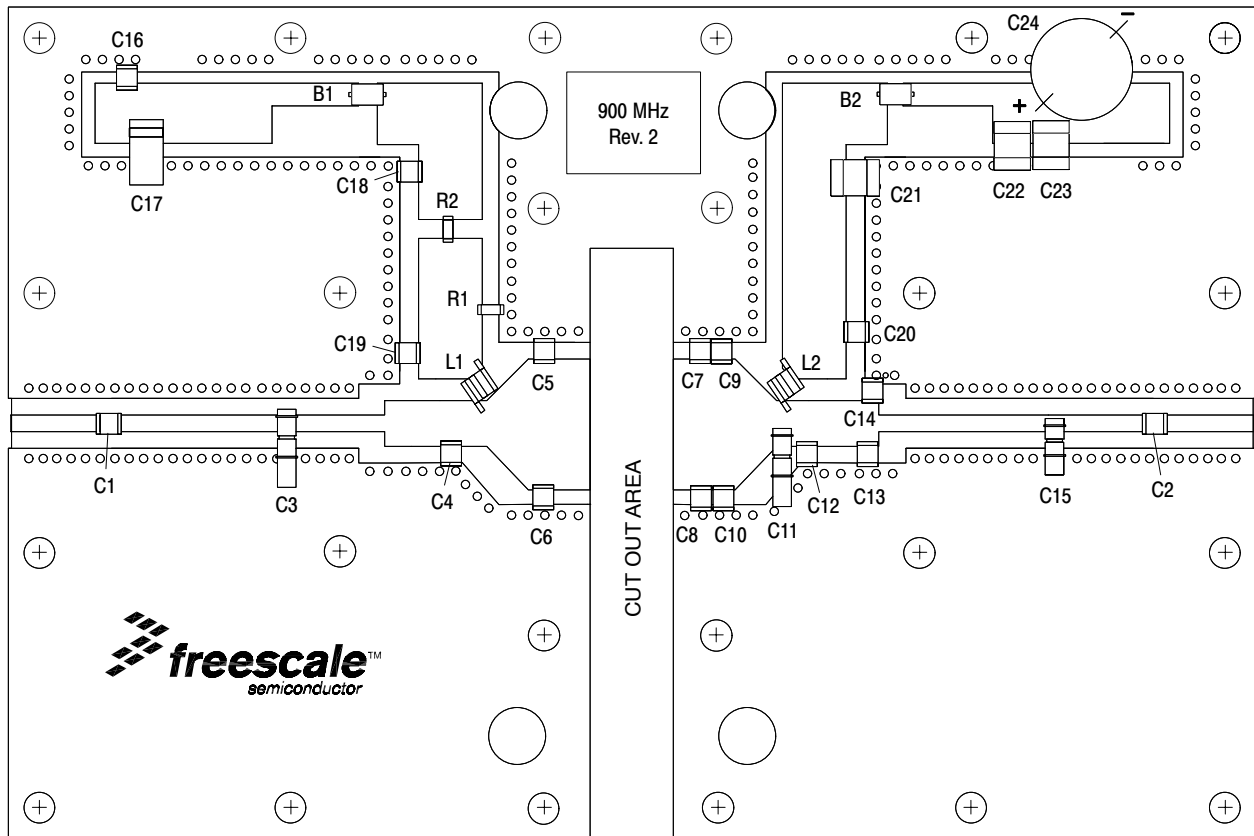
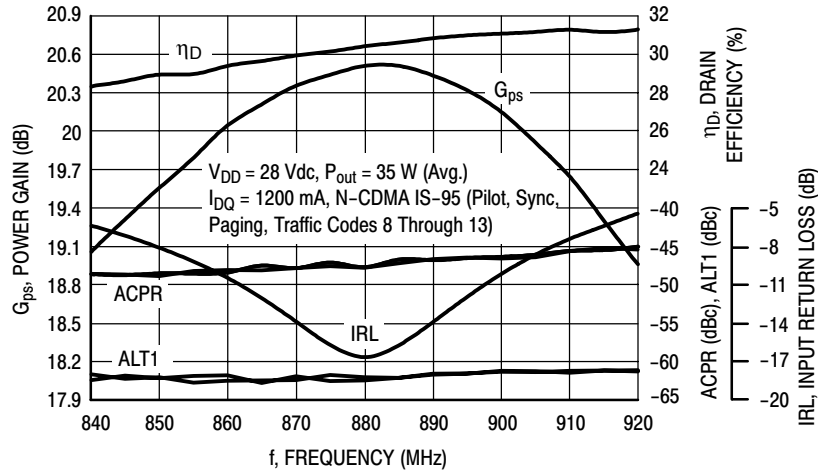
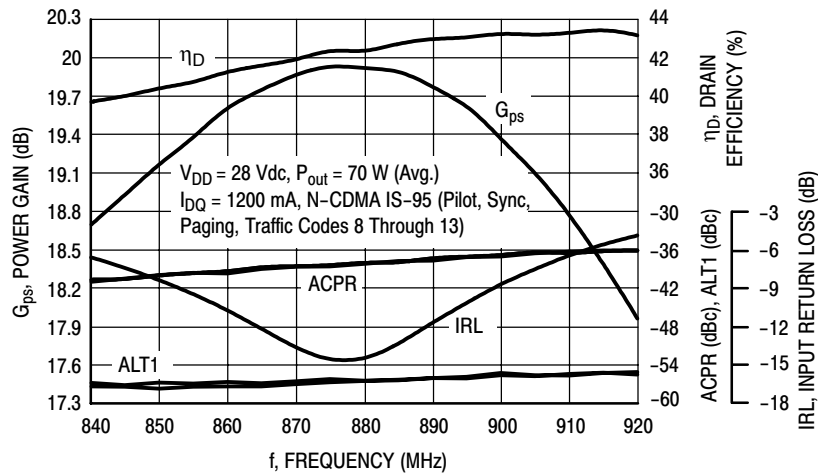


Figure 2. MRF6S9160HR3(SR3) Test Circuit Component Layout

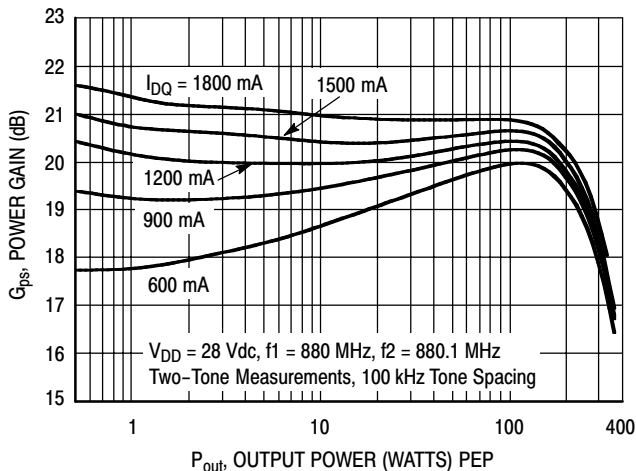
## TYPICAL CHARACTERISTICS



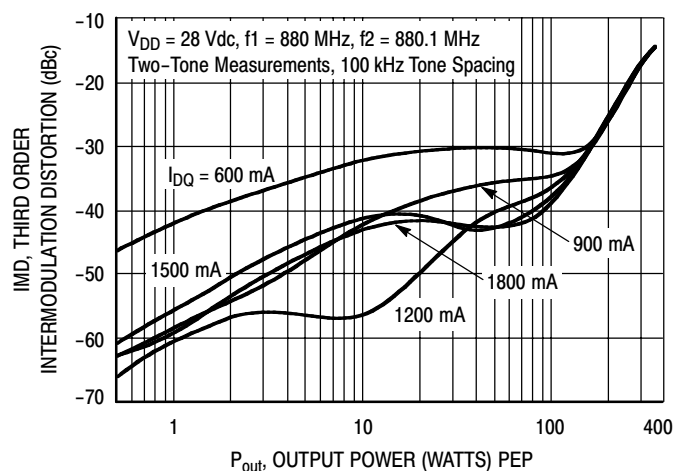
**Figure 3. Single-Carrier N-CDMA Broadband Performance  
@  $P_{out} = 35$  Watts Avg.**



**Figure 4. Single-Carrier N-CDMA Broadband Performance  
@  $P_{out} = 70$  Watts Avg.**



**Figure 5. Two-Tone Power Gain versus  
Output Power**



**Figure 6. Third Order Intermodulation Distortion  
versus Output Power**

## TYPICAL CHARACTERISTICS

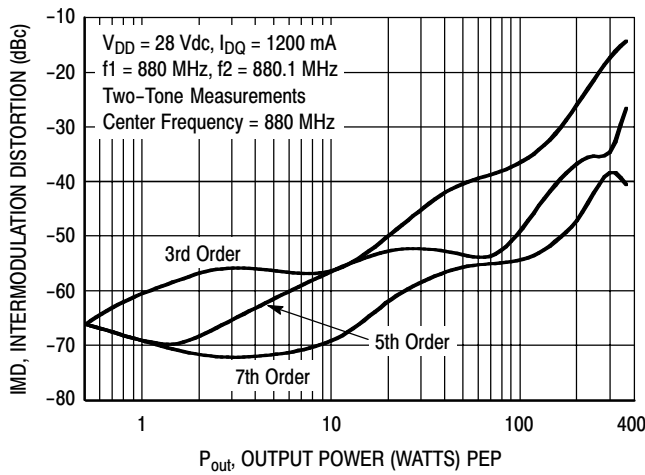


Figure 7. Intermodulation Distortion Products versus Output Power

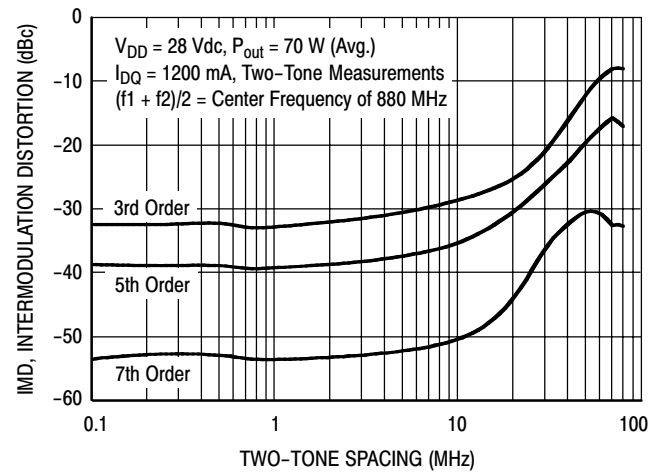


Figure 8. Intermodulation Distortion Products versus Tone Spacing

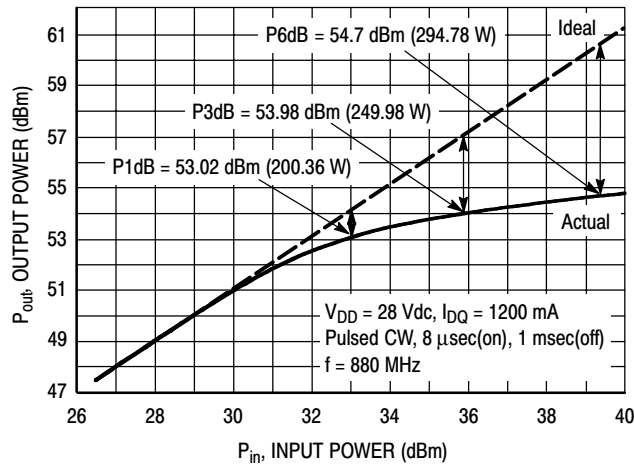


Figure 9. Pulse CW Output Power versus Input Power

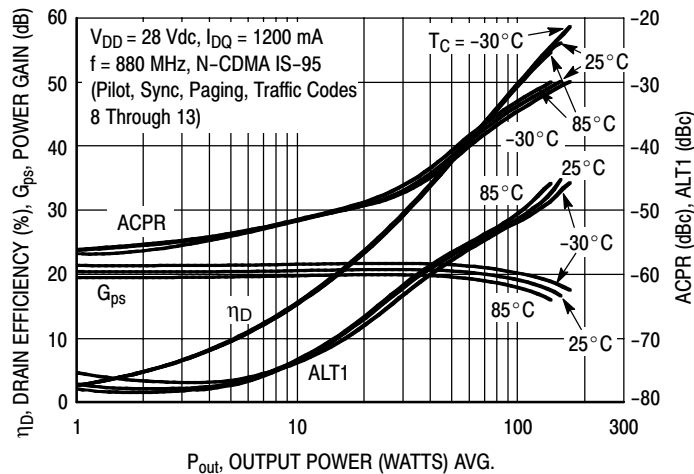
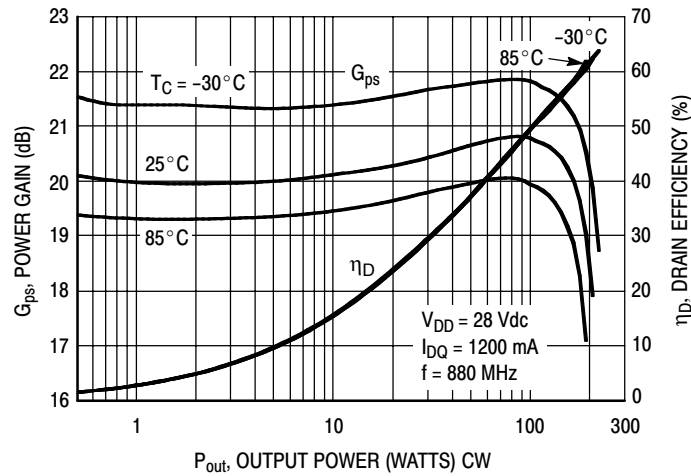
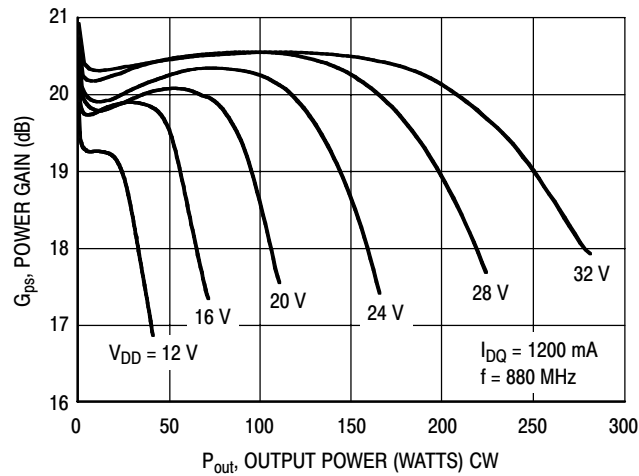


Figure 10. Single-Carrier N-CDMA ACPR, ALT1, Power Gain and Drain Efficiency versus Output Power

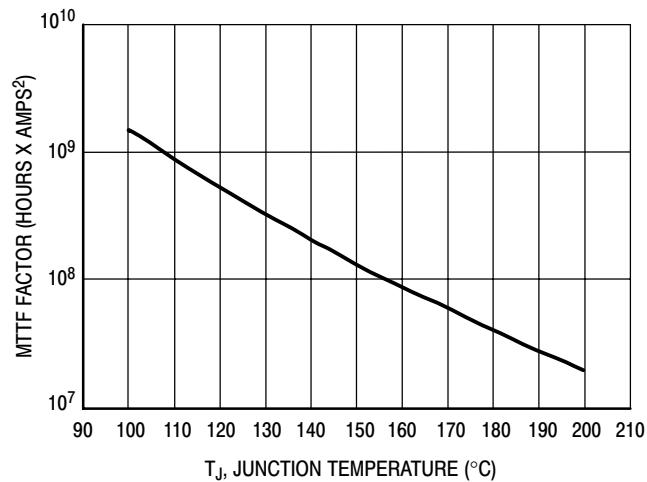
## TYPICAL CHARACTERISTICS



**Figure 11. Power Gain and Drain Efficiency versus CW Output Power**



**Figure 12. Power Gain versus Output Power**

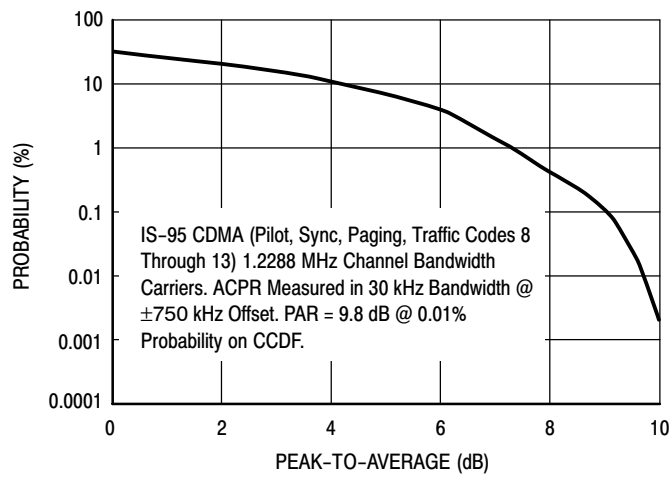


This above graph displays calculated MTTF in hours x ampere<sup>2</sup> drain current. Life tests at elevated temperatures have correlated to better than  $\pm 10\%$  of the theoretical prediction for metal failure. Divide MTTF factor by  $I_D^2$  for MTTF in a particular application.

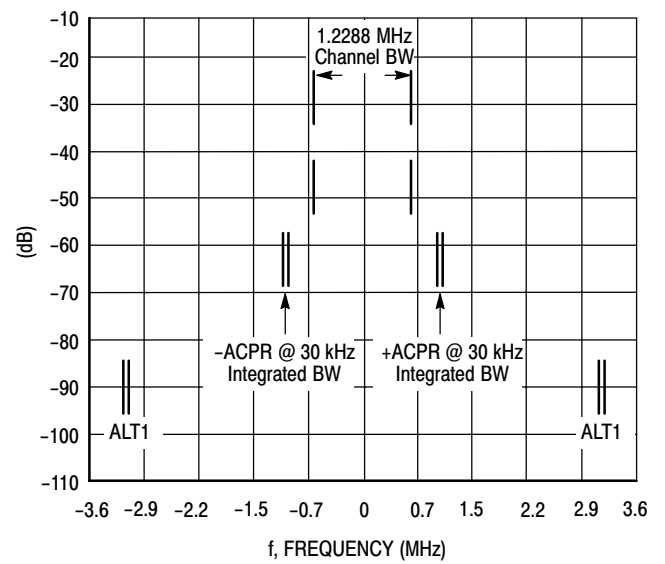
**Figure 13. MTTF Factor versus Junction Temperature**



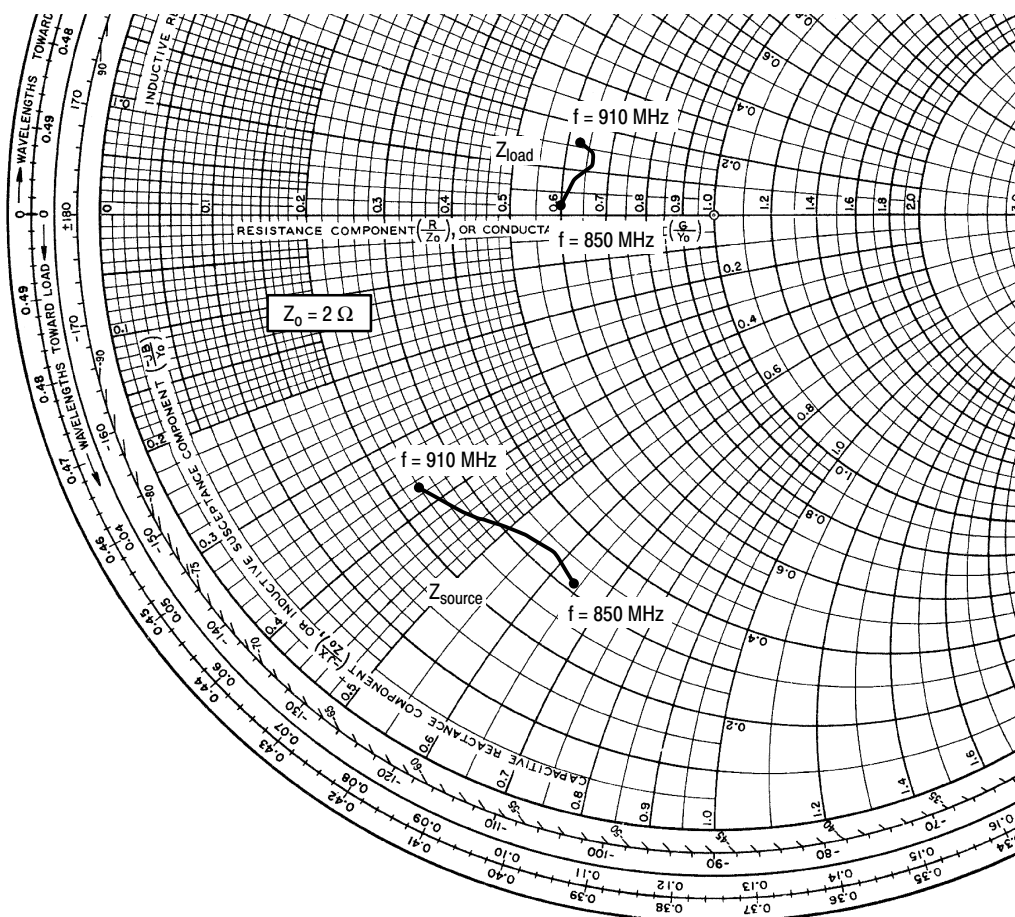
## N-CDMA TEST SIGNAL



**Figure 14. Single-Carrier CCDF N-CDMA**



**Figure 15. Single-Carrier N-CDMA Spectrum**



$V_{DD} = 28 \text{ Vdc}$ ,  $I_{DQ} = 1200 \text{ mA}$ ,  $P_{out} = 35 \text{ W Avg.}$

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 850      | $0.61 - j1.27$           | $1.20 + j0.03$         |
| 865      | $0.66 - j1.15$           | $1.26 + j0.15$         |
| 880      | $0.64 - j1.05$           | $1.31 + j0.22$         |
| 895      | $0.55 - j0.90$           | $1.32 + j0.28$         |
| 910      | $0.48 - j0.74$           | $1.26 + j0.32$         |

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

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

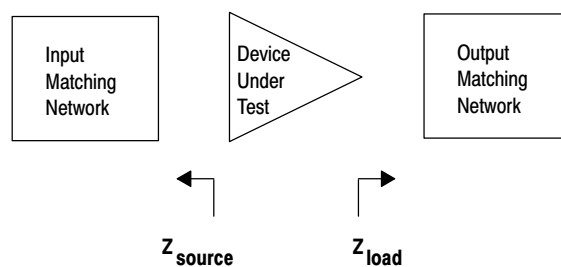
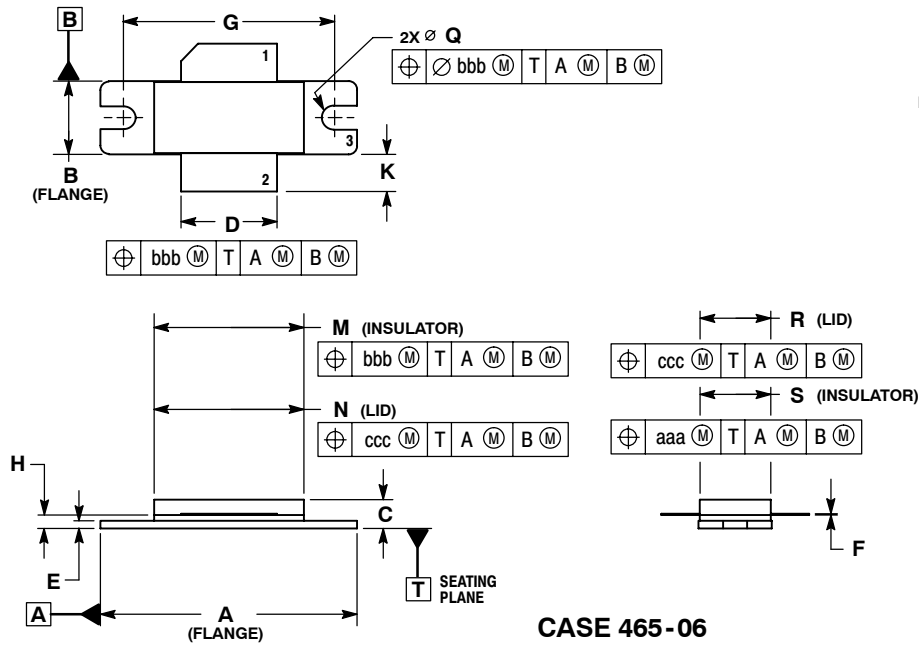


Figure 16. Series Equivalent Source and Load Impedance

## PACKAGE DIMENSIONS



**CASE 465-06  
ISSUE G  
NI-780  
MRF6S9160HR3**

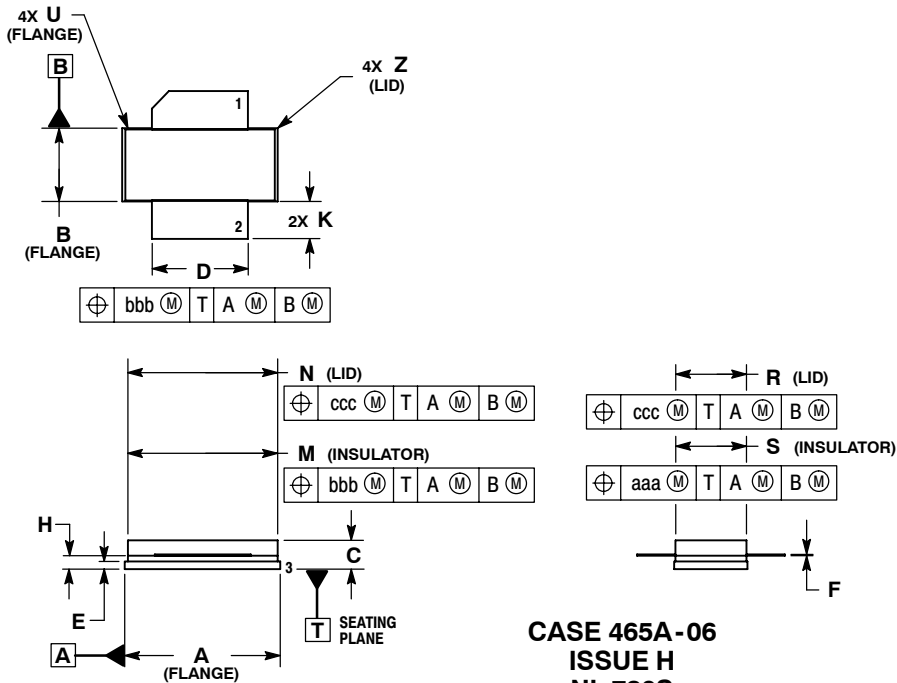
### NOTES:

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 118     | Ø 138 | 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:

1. DRAIN
2. GATE
3. SOURCE



**CASE 465A-06  
ISSUE H  
NI-780S  
MRF6S9160HSR3**

### 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:

1. DRAIN
2. GATE
5. SOURCE

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