

RF Power Field Effect Transistors

N-Channel Enhancement-Mode Lateral MOSFETs

Designed for broadband commercial and industrial applications with frequencies up to 1000 MHz. The high gain and broadband performance of these devices make them ideal for large-signal, common-source amplifier applications in 28 volt base station equipment.

- Typical Single-Carrier N-CDMA Performance @ 880 MHz, $V_{DD} = 28$ Volts, $I_{DQ} = 450$ mA, $P_{out} = 14$ 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 — 21.4 dB
 - Drain Efficiency — 32.1%
 - ACPR @ 750 kHz Offset — -47.6 dBc @ 30 kHz Bandwidth

GSM EDGE Application

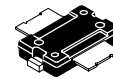
- Typical GSM EDGE Performance: $V_{DD} = 28$ Volts, $I_{DQ} = 500$ mA, $P_{out} = 21$ Watts Avg., Full Frequency Band (921-960 MHz)
 - Power Gain — 20 dB
 - Drain Efficiency — 46%
 - Spectral Regrowth @ 400 kHz Offset = -62 dBc
 - Spectral Regrowth @ 600 kHz Offset = -78 dBc
 - EVM — 1.5% rms

GSM Application

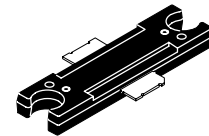
- Typical GSM Performance: $V_{DD} = 28$ Volts, $I_{DQ} = 500$ mA, $P_{out} = 60$ Watts, Full Frequency Band (921-960 MHz)
 - Power Gain — 20 dB
 - Drain Efficiency — 63%
- Capable of Handling 10:1 VSWR, @ 28 Vdc, 880 MHz, 60 Watts CW Output Power
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Integrated ESD Protection
- N Suffix Indicates Lead-Free Terminations
- 200°C Capable Plastic Package
- TO-270-2 in Tape and Reel. R1 Suffix = 500 Units per 24 mm, 13 inch Reel.
- TO-272-2 in Tape and Reel. R1 Suffix = 500 Units per 44 mm, 13 inch Reel.

MRF6S9060NR1
MRF6S9060NBR1
MRF6S9060MR1
MRF6S9060MBR1

880 MHz, 14 W AVG., 28 V
SINGLE N-CDMA
LATERAL N-CHANNEL
BROADBAND RF POWER MOSFETs



CASE 1265-08, STYLE 1
TO-270-2
PLASTIC
MRF6S9060NR1(MR1)



CASE 1337-03, STYLE 1
TO-272-2
PLASTIC
MRF6S9060NBR1(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, +12 | Vdc |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C | P_D | 227 1.3 | W W/°C |
| Storage Temperature Range | T_{stg} | - 65 to +150 | °C |
| Operating Junction Temperature | T_J | 200 | °C |

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 Case Temperature 80°C, 60 W CW Case Temperature 80°C, 14 W CW | $R_{\theta JC}$ | 0.77 0.88 | °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. 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 |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

Off Characteristics

| | | | | | |
|---|-----------|---|---|----|-----------------|
| Zero Gate Voltage Drain Leakage Current ($V_{DS} = 68\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$) | I_{DSS} | — | — | 10 | μAdc |
| Zero Gate Voltage Drain Leakage Current ($V_{DS} = 28\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$) | I_{DSS} | — | — | 1 | μAdc |
| Gate-Source Leakage Current ($V_{GS} = 5\text{ Vdc}$, $V_{DS} = 0\text{ Vdc}$) | I_{GSS} | — | — | 1 | μAdc |

On Characteristics

| | | | | | |
|---|--------------|---|------|-----|-----|
| Gate Threshold Voltage ($V_{DS} = 10\text{ Vdc}$, $I_D = 200\ \mu\text{A}$) | $V_{GS(th)}$ | 1 | 2 | 3 | Vdc |
| Gate Quiescent Voltage ($V_{DS} = 28\text{ Vdc}$, $I_D = 450\text{ mAdc}$) | $V_{GS(Q)}$ | — | 2.9 | — | Vdc |
| Drain-Source On-Voltage ($V_{GS} = 10\text{ Vdc}$, $I_D = 1.5\text{ Adc}$) | $V_{DS(on)}$ | — | 0.18 | 0.4 | Vdc |
| Forward Transconductance ($V_{DS} = 10\text{ Vdc}$, $I_D = 3\text{ Adc}$) | g_{fs} | — | 4.2 | — | S |

Dynamic Characteristics

| | | | | | |
|---|-----------|---|-----|---|----|
| Input Capacitance ($V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$) | C_{iss} | — | 106 | — | pF |
| Output Capacitance ($V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$) | C_{oss} | — | 33 | — | pF |
| Reverse Transfer Capacitance ($V_{DS} = 28\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$) | C_{rss} | — | 1.4 | — | pF |

Functional Tests (In Freescale Test Fixture, 50 ohm system) $V_{DD} = 28\text{ Vdc}$, $I_{DQ} = 450\text{ mA}$, $P_{out} = 14\text{ W Avg.}$, $f = 880\text{ MHz}$, 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} | 20.5 | 21.4 | 23.5 | dB |
| Drain Efficiency | η_D | 30.5 | 32.1 | — | % |
| Adjacent Channel Power Ratio | ACPR | — | -47.6 | -45 | dBc |
| Input Return Loss | IRL | — | -15.3 | -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.

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

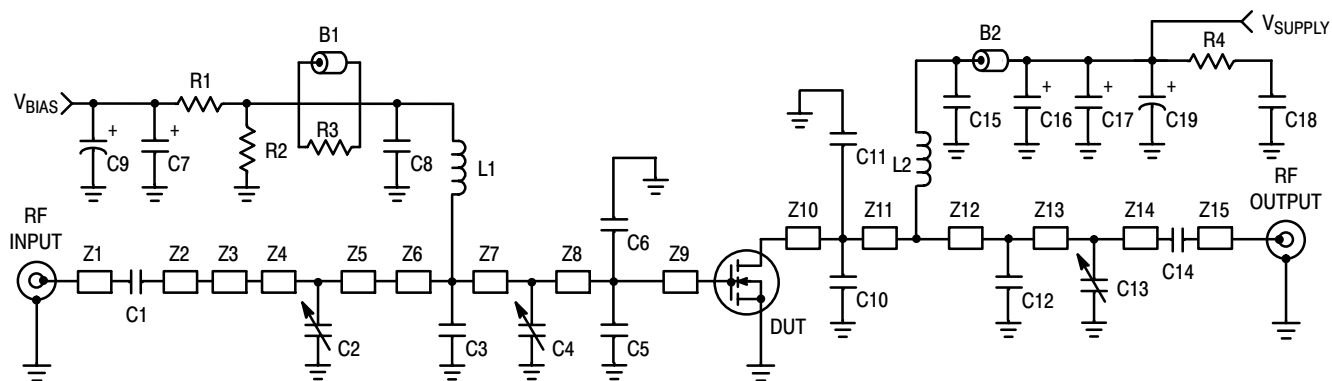
| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

Typical GSM EDGE Performances (In Freescale GSM EDGE Test Fixture Optimized for 921-960 MHz, 50 ohm system) $V_{DD} = 28\text{ Vdc}$, $I_{DQ} = 500\text{ mA}$, $P_{out} = 21\text{ W Avg.}$, $f = 921\text{-}960\text{ MHz}$, GSM EDGE Signal

| | | | | | |
|-------------------------------------|----------|---|-----|---|-----|
| Power Gain | G_{ps} | — | 20 | — | dB |
| Drain Efficiency | η_D | — | 46 | — | % |
| Error Vector Magnitude | EVM | — | 1.5 | — | % |
| Spectral Regrowth at 400 kHz Offset | SR1 | — | -62 | — | dBc |
| Spectral Regrowth at 600 kHz Offset | SR2 | — | -78 | — | dBc |

Typical CW Performances (In Freescale GSM Test Fixture Optimized for 921-960 MHz, 50 ohm system) $V_{DD} = 28\text{ Vdc}$, $I_{DQ} = 500\text{ mA}$, $P_{out} = 60\text{ W}$, $f = 921\text{-}960\text{ MHz}$

| | | | | | |
|--|----------|---|-----|---|----|
| Power Gain | G_{ps} | — | 20 | — | dB |
| Drain Efficiency | η_D | — | 63 | — | % |
| Input Return Loss | IRL | — | -12 | — | dB |
| P_{out} @ 1 dB Compression Point ($f = 940\text{ MHz}$) | P1dB | — | 67 | — | W |



| | | | |
|----|--------------------------------|-----|--|
| Z1 | 0.215" x 0.065" Microstrip | Z9 | 0.057" x 0.525" Microstrip |
| Z2 | 0.221" x 0.065" Microstrip | Z10 | 0.360" x 0.270" Microstrip |
| Z3 | 0.500" x 0.100" Microstrip | Z11 | 0.063" x 0.270" Microstrip |
| Z4 | 0.460" x 0.270" Microstrip | Z12 | 0.360" x 0.065" Microstrip |
| Z5 | 0.040" x 0.270" Microstrip | Z13 | 0.170" x 0.065" Microstrip |
| Z6 | 0.280" x 0.270" x 0.530" Taper | Z14 | 0.880" x 0.065" Microstrip |
| Z7 | 0.087" x 0.525" Microstrip | Z15 | 0.260" x 0.065" Microstrip |
| Z8 | 0.435" x 0.525" Microstrip | PCB | Taconic RF-35 0.030", $\epsilon_r = 3.5$ |

Figure 1. MRF6S9060NR1(NBR1)/MR1(MBR1) Test Circuit Schematic

Table 6. MRF6S9060NR1(NBR1)/MR1(MBR1) Test Circuit Component Designations and Values

| Part | Description | Part Number | Manufacturer |
|------------------|--|---------------|--------------|
| B1 | Ferrite Bead | 95F786 | Newark |
| B2 | Ferrite Bead | 95F787 | Newark |
| C1, C8, C14, C15 | 47 pF Chip Capacitors | 100B470JP500X | Newark |
| C2, C4, C13 | 0.8 - 8.0 pF Variable Capacitors, Gigatrim | 44F3360 | Newark |
| C3 | 3.0 pF Chip Capacitor | 100B3R0JP500X | Newark |
| C5, C6 | 15 pF Chip Capacitors | 100B150JP500X | Newark |
| C7, C16, C17 | 10 μ F, 35 V Tantalum Capacitors | 93F2975 | Newark |
| C9 | 100 μ F, 50 V Electrolytic Capacitor | 51F2913 | Newark |
| C10, C11 | 13 pF Chip Capacitors | 100B130JP500X | Newark |
| C12 | 3.9 pF Chip Capacitor | 100B3R9JP500X | Newark |
| C18 | 0.56 μ F Chip Capacitor | 700A561MP150X | Newark |
| C19 | 470 μ F, 63 V Electrolytic Capacitor | 95F4579 | Newark |
| L1, L2 | 12.5 nH Inductor | A04T-5 | Coilcraft |
| R1 | 1 k Ω Chip Resistor | 05F1545 | Newark |
| R2 | 560 k Ω Chip Resistor | 84N2435 | Newark |
| R3 | 12 Ω Chip Resistor | 97C9103 | Newark |
| R4 | 27 Ω Chip Resistor | 04H7058 | Newark |

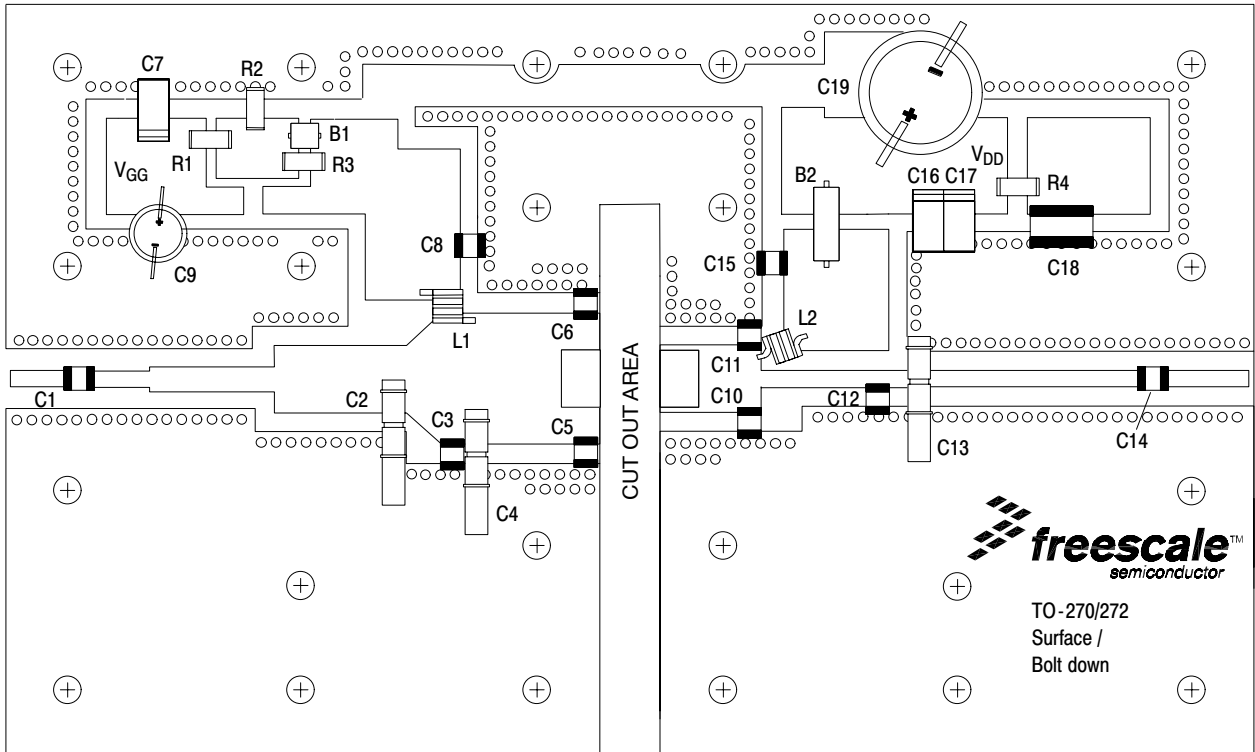


Figure 2. MRF6S9060NR1(NBR1)/MR1(MBR1) Test Circuit Component Layout

TYPICAL CHARACTERISTICS

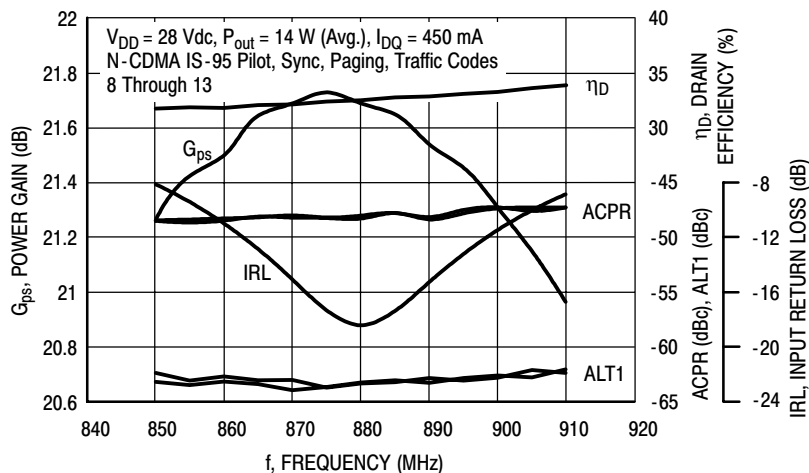


Figure 3. Single-Carrier N-CDMA Broadband Performance @ $P_{out} = 14$ Watts Avg.

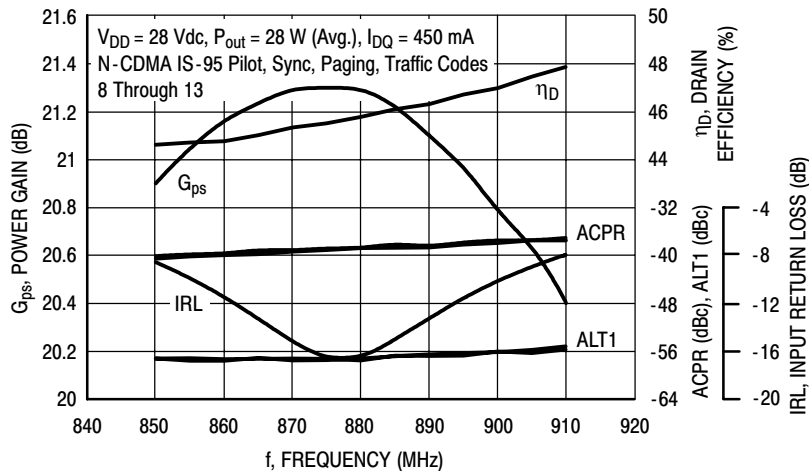


Figure 4. Single-Carrier N-CDMA Broadband Performance @ $P_{out} = 28$ Watts Avg.

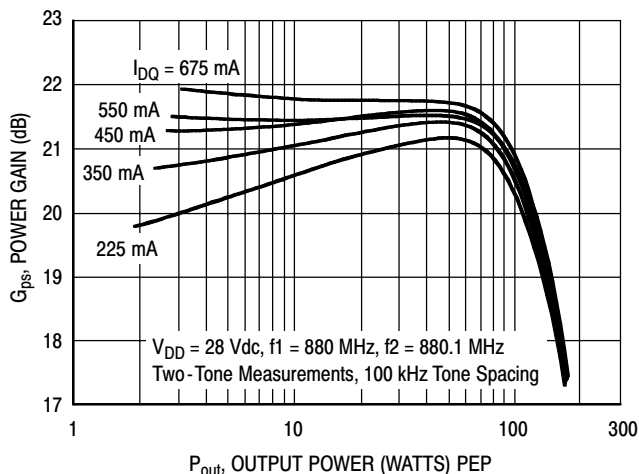


Figure 5. Two-Tone Power Gain versus Output Power

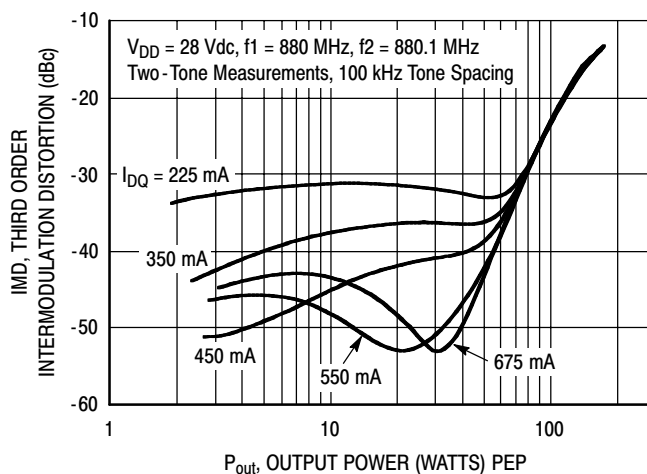


Figure 6. Third Order Intermodulation Distortion versus Output Power

TYPICAL CHARACTERISTICS

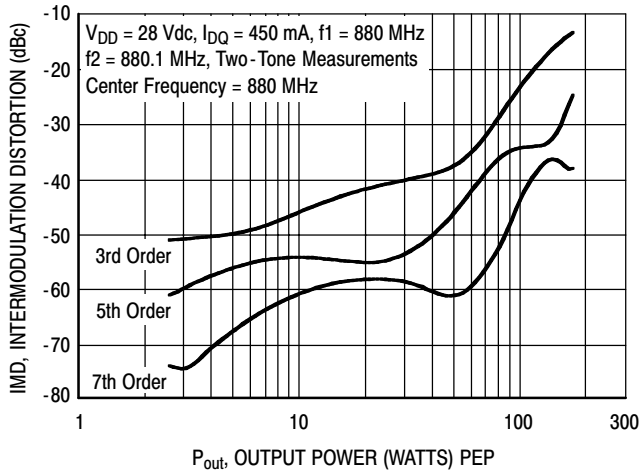


Figure 7. Intermodulation Distortion Products versus Output Power

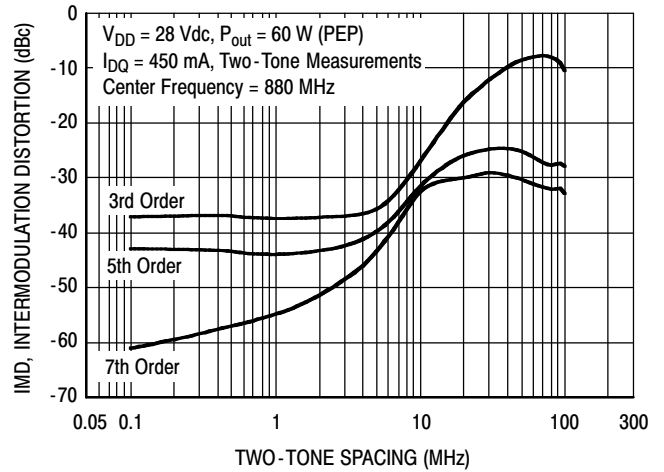


Figure 8. Intermodulation Distortion Products versus Tone Spacing

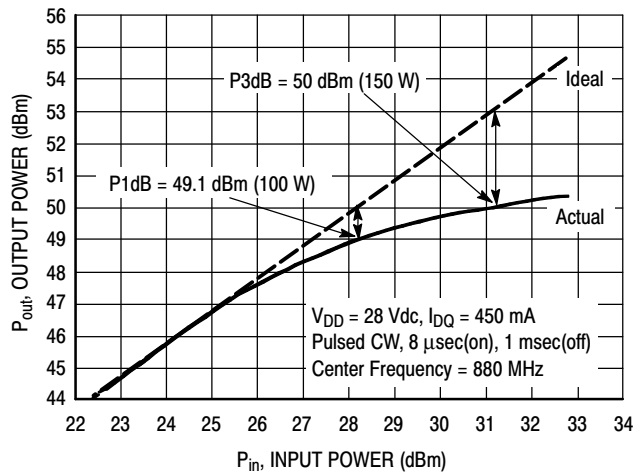


Figure 9. Pulse CW Output Power versus Input Power

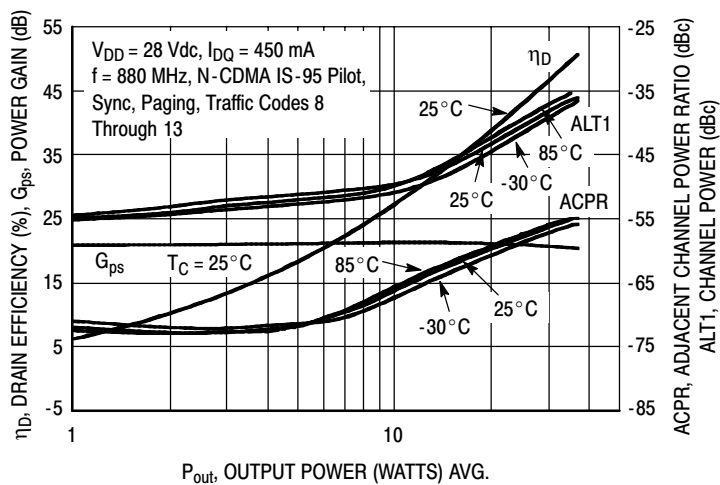


Figure 10. Single-Carrier N-CDMA ACPR, ALT1, Power Gain and Drain Efficiency versus Output Power

MRF6S9060NR1 MRF6S9060NBR1 MRF6S9060MR1 MRF6S9060MBR1

TYPICAL CHARACTERISTICS

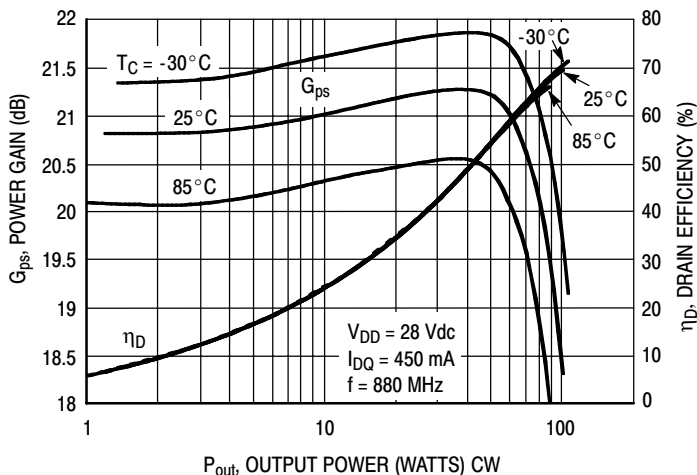


Figure 11. Power Gain and Drain Efficiency versus CW Output Power

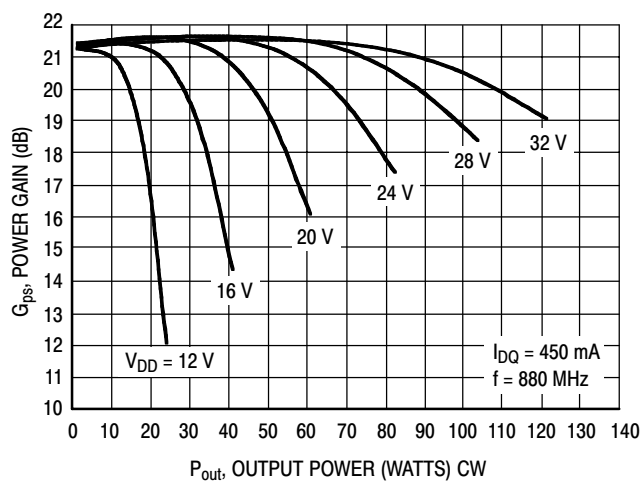
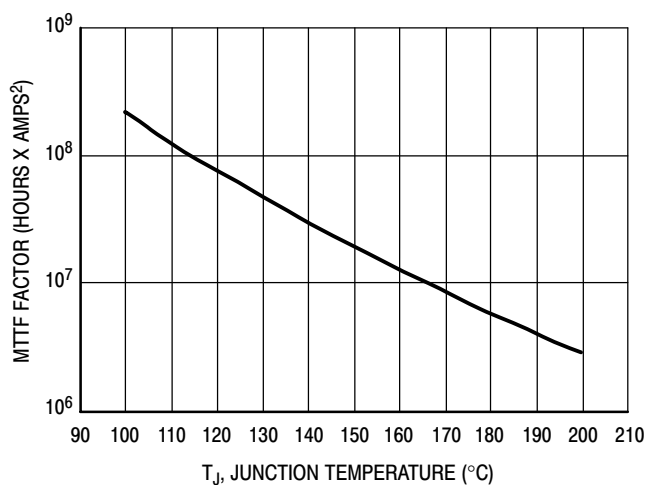


Figure 12. Power Gain versus Output Power



This above graph displays calculated MTTF in hours x ampere² 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

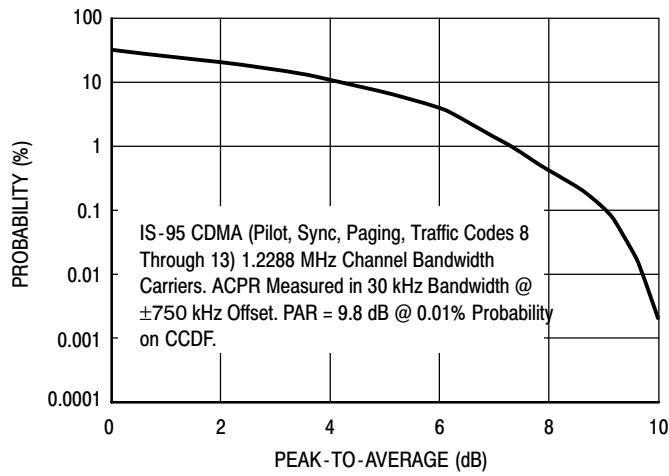


Figure 14. Single-Carrier CCDF N-CDMA

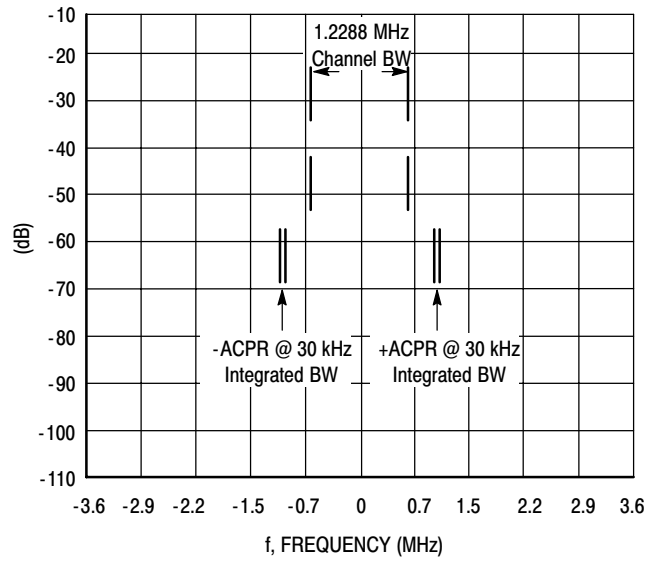
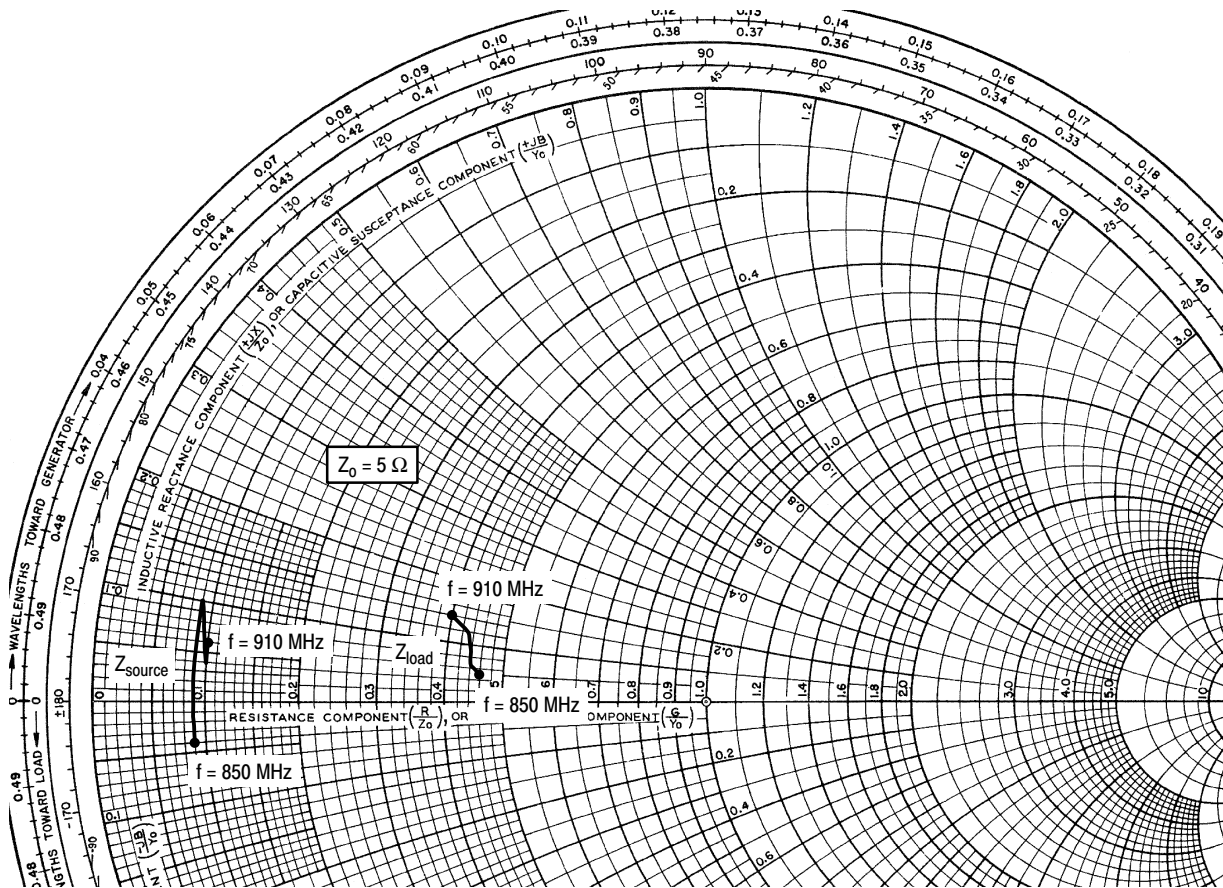


Figure 15. Single-Carrier N-CDMA Spectrum



$V_{DD} = 28 \text{ Vdc}$, $I_{DQ} = 450 \text{ mA}$, $P_{out} = 14 \text{ W Avg.}$

| f MHz | Z_{source} Ω | Z_{load} Ω |
|----------|--------------------------|------------------------|
| 850 | $0.44 - j0.20$ | $2.28 + j0.23$ |
| 865 | $0.44 - j0.07$ | $2.18 + j0.33$ |
| 880 | $0.45 + j0.50$ | $2.20 + j0.47$ |
| 895 | $0.48 + j0.18$ | $2.15 + j0.61$ |
| 910 | $0.52 + j0.29$ | $2.00 + j0.68$ |

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

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

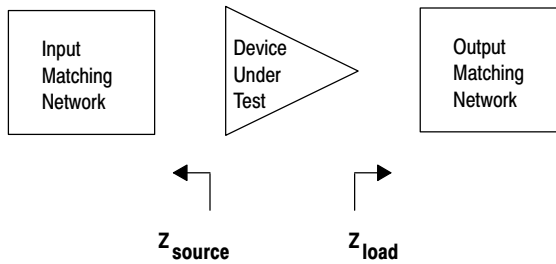


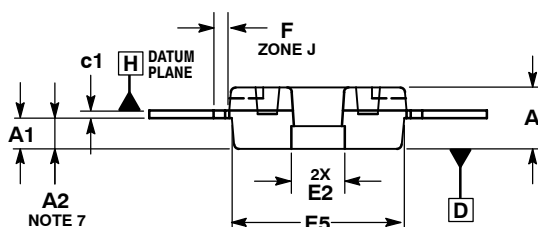
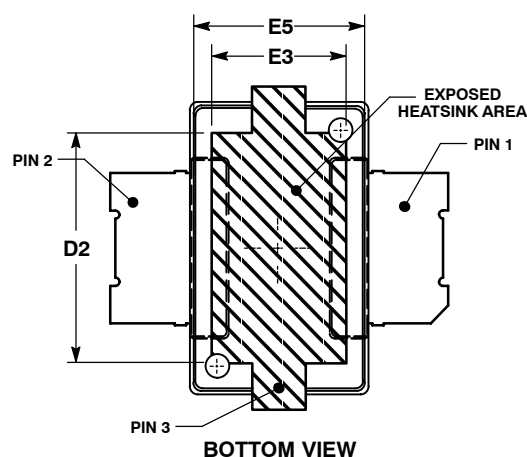
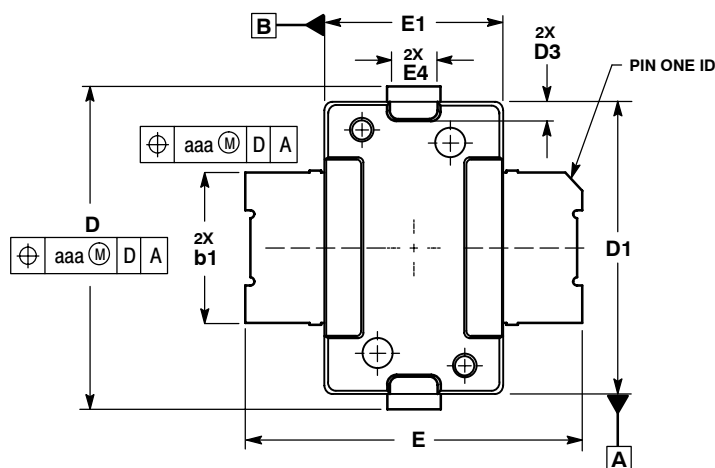
Figure 16. Series Equivalent Source and Load Impedance

NOTES

NOTES

NOTES

PACKAGE DIMENSIONS



NOTES:

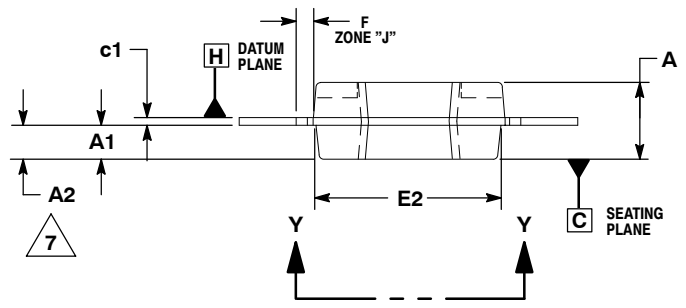
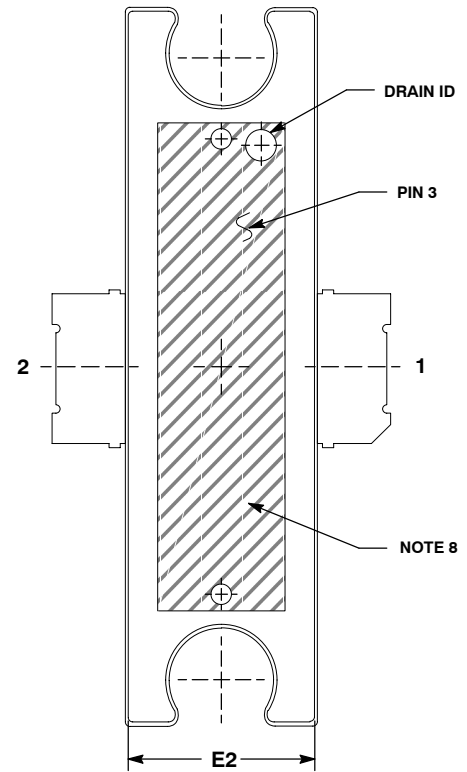
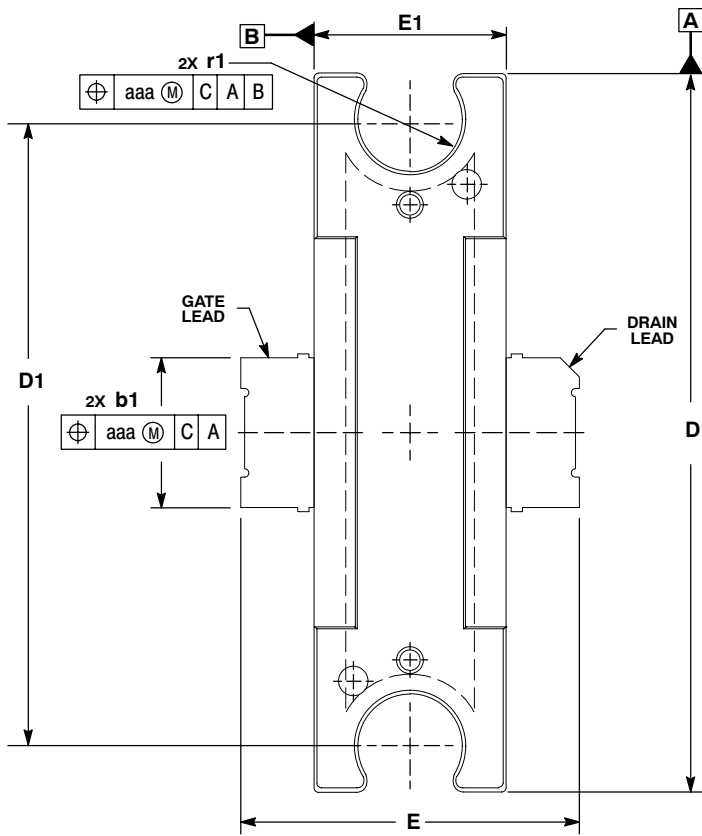
1. CONTROLLING DIMENSION: INCH.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DATUM PLANE -H- IS LOCATED AT TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D1" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .006 PER SIDE. DIMENSIONS "D1" 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. DIMENSIONS "D" AND "E2" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .003 PER SIDE. DIMENSIONS "D" AND "E2" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -D-.

| DIM | INCHES | | MILLIMETERS | |
|-----|----------|------|-------------|-------|
| | MIN | MAX | MIN | MAX |
| A | .078 | .082 | 1.98 | 2.08 |
| A1 | .039 | .043 | 0.99 | 1.09 |
| A2 | .040 | .042 | 1.02 | 1.07 |
| D | .416 | .424 | 10.57 | 10.77 |
| D1 | .378 | .382 | 9.60 | 9.70 |
| D2 | .290 | .320 | 7.37 | 8.13 |
| D3 | .016 | .024 | 0.41 | 0.61 |
| E | .436 | .444 | 11.07 | 11.28 |
| E1 | .238 | .242 | 6.04 | 6.15 |
| E2 | .066 | .074 | 1.68 | 1.88 |
| E3 | .150 | .180 | 3.81 | 4.57 |
| E4 | .058 | .066 | 1.47 | 1.68 |
| E5 | .231 | .235 | 5.87 | 5.97 |
| F | .025 BSC | | 0.64 BSC | |
| b1 | .193 | .199 | 4.90 | 5.06 |
| c1 | .007 | .011 | 0.18 | 0.28 |
| aaa | .004 | | 0.10 | |

STYLE 1:

1. DRAIN
2. GATE
3. SOURCE

CASE 1265-08
 ISSUE H
 TO-270-2
 PLASTIC
 MRF6S9060NR1(MR1)



- 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. CROSSHATCHING 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 | |
| E | .438 | .442 | 11.12 | 11.23 |
| E1 | .248 | .252 | 6.30 | 6.40 |
| E2 | .241 | .245 | 6.12 | 6.22 |
| F | .025 BSC | | 0.64 BSC | |
| b1 | .193 | .199 | 4.90 | 5.05 |
| c1 | .007 | .011 | .18 | .28 |
| r1 | .063 | .068 | 1.60 | 1.73 |
| aaa | .004 | | .10 | |

STYLE 1:
 PIN 1. DRAIN
 2. GATE
 3. SOURCE

**CASE 1337-03
 ISSUE C
 TO-272-2
 PLASTIC
 MRF6S9060NBR1(MBR1)**

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