

RF Power Field Effect Transistors

N-Channel Enhancement-Mode Lateral MOSFETs

Designed for CDMA base station applications with frequencies from 1800 to 2200 MHz. Can be used in Class AB and Class C for all typical cellular base station modulation formats.

- Typical Doherty Single-Carrier W-CDMA Performance: $V_{DD} = 32$ Volts, $I_{DQA} = 150$ mA, $V_{GSB} = 1.5$ Vdc, $P_{out} = 10$ Watts Avg., IQ Magnitude Clipping, Channel Bandwidth = 3.84 MHz, Input Signal PAR = 9.9 dB @ 0.01% Probability on CCDF.

| Frequency | G_{ps} (dB) | η_D (%) | Output PAR (dB) | ACPR (dBc) |
|-----------|---------------|--------------|-----------------|------------|
| 2025 MHz | 18.2 | 42.6 | 7.3 | -34.8 |

- Capable of Handling 5:1 VSWR, @ 32 Vdc, 2017.5 MHz, 50 Watts CW (1) Output Power (3 dB Input Overdrive from Rated P_{out})
- Typical P_{out} @ 3 dB Compression Point \approx 50 Watts CW (1)

Features

- Production Tested in a Symmetrical Doherty Configuration
- 100% PAR Tested for Guaranteed Output Power Capability
- Characterized with Series Equivalent Large-Signal Impedance Parameters and Common Source S-Parameters
- Internally Matched for Ease of Use
- Integrated ESD Protection
- Greater Negative Gate-Source Voltage Range for Improved Class C Operation
- Designed for Digital Predistortion Error Correction Systems
- RoHS Compliant
- In Tape and Reel. R3 Suffix = 250 Units, 56 mm Tape Width, 13 inch Reel. For R5 Tape and Reel option, see p. 15.

Table 1. Maximum Ratings

| Rating | Symbol | Value | Unit |
|---|-----------|--------------|---------------------|
| Drain-Source Voltage | V_{DSS} | -0.5, +65 | Vdc |
| Gate-Source Voltage | V_{GS} | -6.0, +10 | Vdc |
| Operating Voltage | V_{DD} | 32, +0 | Vdc |
| Storage Temperature Range | T_{stg} | -65 to +150 | $^{\circ}C$ |
| Case Operating Temperature | T_C | 150 | $^{\circ}C$ |
| Operating Junction Temperature (2,3) | T_J | 225 | $^{\circ}C$ |
| CW Operation @ $T_C = 25^{\circ}C$ Derate above 25 $^{\circ}C$ | CW | 42.4 0.17 | W W/ $^{\circ}C$ |

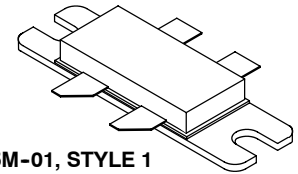
Table 2. Thermal Characteristics

| Characteristic | Symbol | Value (3,4) | Unit |
|---|-----------------|--------------|---------------|
| Thermal Resistance, Junction to Case Case Temperature 78 $^{\circ}C$, 10 W CW, 32 Vdc, $I_{DQA} = 150$ mA, $V_{GSB} = 1.5$ Vdc, 2017.5 MHz Case Temperature 82 $^{\circ}C$, 40 W CW(1), 32 Vdc, $I_{DQA} = 150$ mA, $V_{GSB} = 1.5$ Vdc, 2017.5 MHz | $R_{\theta JC}$ | 2.11 1.50 | $^{\circ}C/W$ |

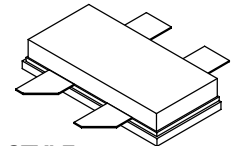
- Exceeds recommended operating conditions. See CW operation data in Maximum Ratings table.
- Continuous use at maximum temperature will affect MTTF.
- MTTF calculator available at <http://www.freescale.com/rf>. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.
- Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf>. Select Documentation/-Application Notes - AN1955.

MRF7P20040HR3
MRF7P20040HSR3

2010-2025 MHz, 10 W AVG., 32 V
SINGLE W-CDMA
LATERAL N-CHANNEL
RF POWER MOSFETs



CASE 465M-01, STYLE 1
NI-780-4
MRF7P20040HR3



CASE 465H-02, STYLE 1
NI-780S-4
MRF7P20040HSR3

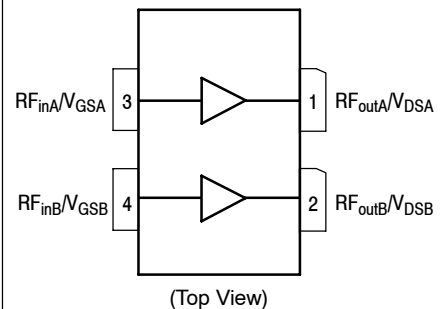


Figure 1. Pin Connections

Table 3. ESD Protection Characteristics

| Test Methodology | Class |
|---------------------------------------|--------------|
| Human Body Model (per JESD22-A114) | 1A (Minimum) |
| Machine Model (per EIA/JESD22-A115) | B (Minimum) |
| Charge Device Model (per JESD22-C101) | IV (Minimum) |

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|-----------|-----|-----|-----|-----------------|
| Off Characteristics (1) | | | | | |
| Zero Gate Voltage Drain Leakage Current ($V_{DS} = 65\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$) | I_{DSS} | — | — | 10 | μAdc |
| Zero Gate Voltage Drain Leakage Current ($V_{DS} = 32\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$) | I_{DSS} | — | — | 1 | μAdc |
| Gate-Source Leakage Current ($V_{GS} = 5\text{ Vdc}$, $V_{DS} = 0\text{ Vdc}$) | I_{GSS} | — | — | 1 | μAdc |

On Characteristics (1)

| | | | | | |
|--|--------------|-----|------|-----|-----|
| Gate Threshold Voltage ($V_{DS} = 10\text{ Vdc}$, $I_D = 33.5\ \mu\text{Adc}$) | $V_{GS(th)}$ | 1.2 | 2 | 2.7 | Vdc |
| Gate Quiescent Voltage ($V_{DD} = 32\text{ Vdc}$, $I_{DA} = 150\text{ mAdc}$, Measured in Functional Test) | $V_{GS(Q)}$ | 2 | 2.7 | 3.5 | Vdc |
| Drain-Source On-Voltage ($V_{GS} = 10\text{ Vdc}$, $I_D = 0.325\text{ Adc}$) | $V_{DS(on)}$ | 0.1 | 0.24 | 0.3 | Vdc |

Functional Tests (2,3) (In Freescale Doherty Test Fixture, 50 ohm system) $V_{DD} = 32\text{ Vdc}$, $I_{DQA} = 150\text{ mA}$, $V_{GSB} = 1.5\text{ Vdc}$, $P_{out} = 10\text{ W Avg.}$, $f = 2025\text{ MHz}$, Single-Carrier W-CDMA, IQ Magnitude Clipping, Input Signal PAR = 9.9 dB @ 0.01% Probability on CCDF. ACPR measured in 3.84 MHz Channel Bandwidth @ $\pm 5\text{ MHz}$ Offset.

| | | | | | |
|--|----------|-----|-------|-----|-----|
| Power Gain | G_{ps} | 16 | 18.2 | 21 | dB |
| Drain Efficiency | η_D | 39 | 42.6 | — | % |
| Output Peak-to-Average Ratio @ 0.01% Probability on CCDF | PAR | 6.9 | 7.3 | — | dB |
| Adjacent Channel Power Ratio | ACPR | — | -34.8 | -30 | dBc |
| Input Return Loss | IRL | — | -17.8 | -10 | dB |

Typical Performance (3) (In Freescale Doherty Test Fixture, 50 ohm system) $V_{DD} = 32\text{ Vdc}$, $I_{DQA} = 150\text{ mA}$, $V_{GSB} = 1.5\text{ Vdc}$, 2010–2025 MHz Bandwidth

| | | | | | |
|--|------------------|---|-------|---|----------------------|
| P_{out} @ 1 dB Compression Point, CW | P_{1dB} | — | 35 | — | W |
| P_{out} @ 3 dB Compression Point, CW (4) | P_{3dB} | — | 50 | — | W |
| IMD Symmetry @ 15 W PEP, P_{out} where IMD Third Order Intermodulation $\cong 30\text{ dBc}$ (Delta IMD Third Order Intermodulation between Upper and Lower Sidebands > 2 dB) | IMD_{sym} | — | 8 | — | MHz |
| VBW Resonance Point (IMD Third Order Intermodulation Inflection Point) | VBW_{res} | — | 70 | — | MHz |
| Gain Flatness in 15 MHz Bandwidth @ $P_{out} = 10\text{ W Avg.}$ | G_F | — | 0.04 | — | dB |
| Gain Variation over Temperature (-30°C to $+85^\circ\text{C}$) | ΔG | — | 0.013 | — | dB/ $^\circ\text{C}$ |
| Output Power Variation over Temperature (-30°C to $+85^\circ\text{C}$) (4) | ΔP_{1dB} | — | 0.006 | — | dB/ $^\circ\text{C}$ |

- Each side of device measured separately.
- Part internally matched both on input and output.
- Measurement made with device in a Symmetrical Doherty configuration.
- Exceeds recommended operating conditions. See CW operation data in Maximum Ratings table.

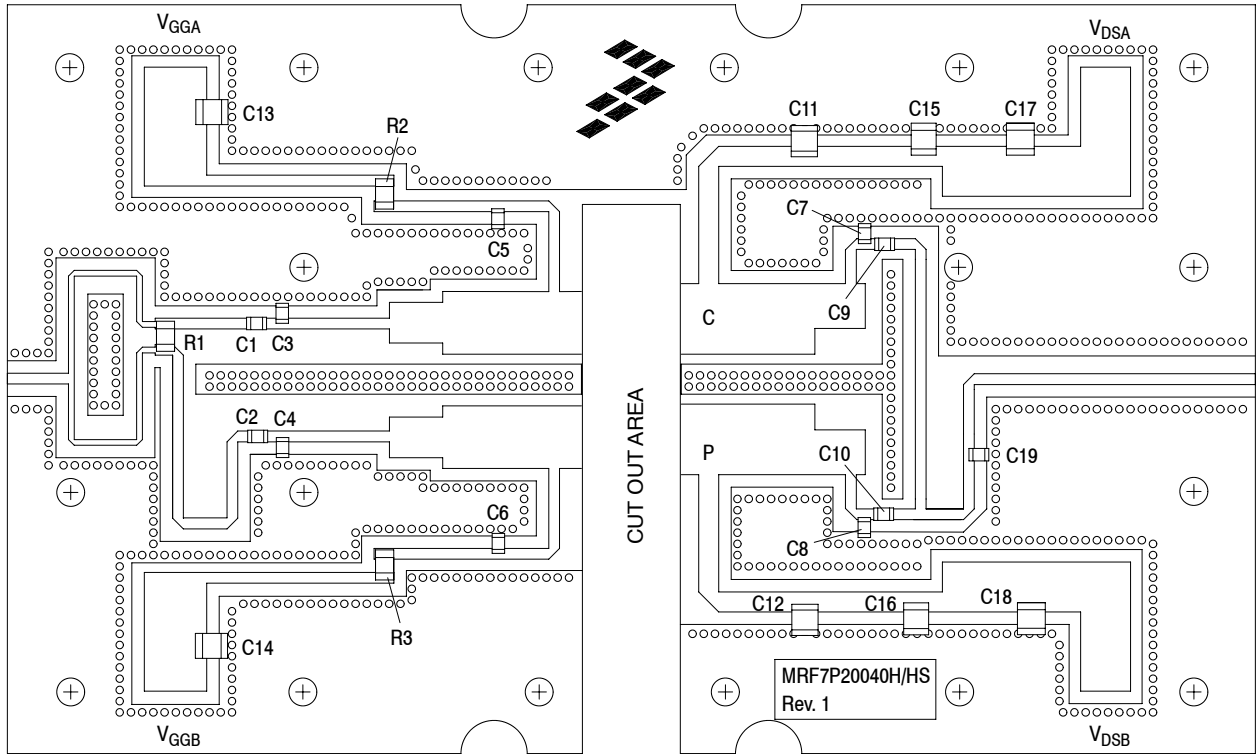


Figure 2. MRF7P20040HR3(HSR3) Test Circuit Component Layout

Table 5. MRF7P20040HR3(HSR3) Test Circuit Component Designations and Values

| Part | Description | Part Number | Manufacturer |
|-----------------|------------------------------------|--------------------|--------------|
| C1, C2, C9, C10 | 12 pF Chip Capacitors | ATC600F120FT250XT | ATC |
| C3, C4 | 2.4 pF Chip Capacitors | ATC600F2R4AT250XT | ATC |
| C5, C6 | 27 pF Chip Capacitors | ATC600F270FT250XT | ATC |
| C7, C8 | 1.1 pF Chip Capacitors | ATC600F1R1AT250XT | ATC |
| C11, C12 | 12 pF Chip Capacitors | ATC100B120FT1500XT | ATC |
| C13, C14 | 2.2 μ F, 50 V Chip Capacitors | C3225X7R1H225KT | TDK |
| C15, C16 | 4.7 μ F, 50 V Chip Capacitors | GRM43ER61H475MA88L | Murata |
| C17, C18 | 10 μ F, 50 V Chip Capacitors | GRM55DR61H106KA88L | Murata |
| C19 | 0.8 pF Chip Capacitor | ATC600F0R8AT250XT | ATC |
| R1 | 100 Ω , 1/4 W Chip Resistor | CRCW12061000FKEA | Vishay |
| R2, R3 | 12 Ω , 1/4 W Chip Resistors | CRCW120612R0FKEA | Vishay |
| PCB | 0.020", $\epsilon_r = 3.5$ | RO4350B | Rogers |

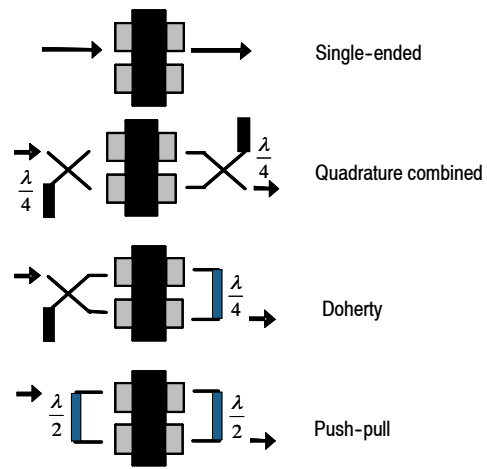


Figure 3. Possible Circuit Topologies

TYPICAL CHARACTERISTICS

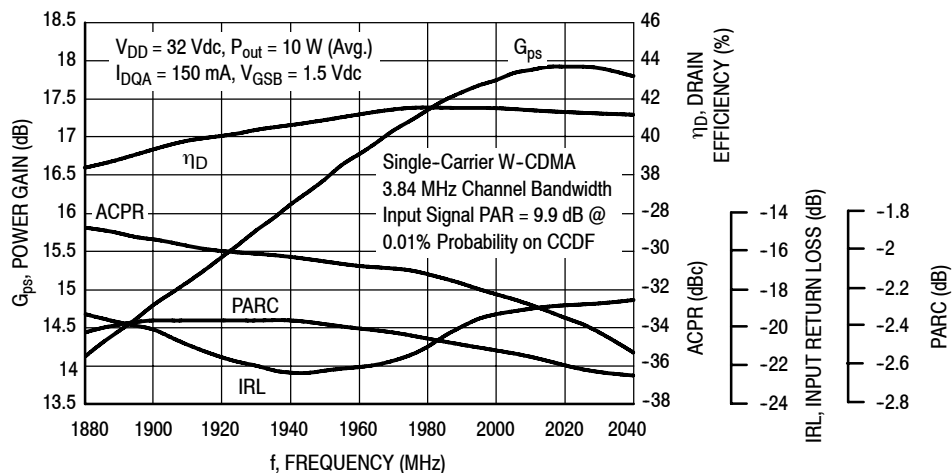


Figure 4. Output Peak-to-Average Ratio Compression (PARC) Broadband Performance @ $P_{out} = 10$ Watts Avg.

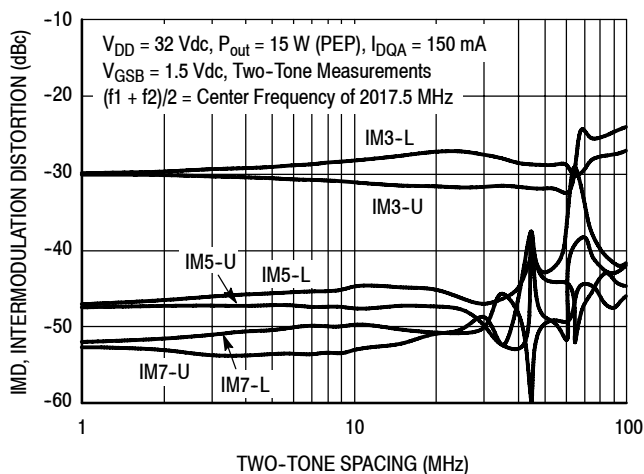


Figure 5. Intermodulation Distortion Products versus Two-Tone Spacing

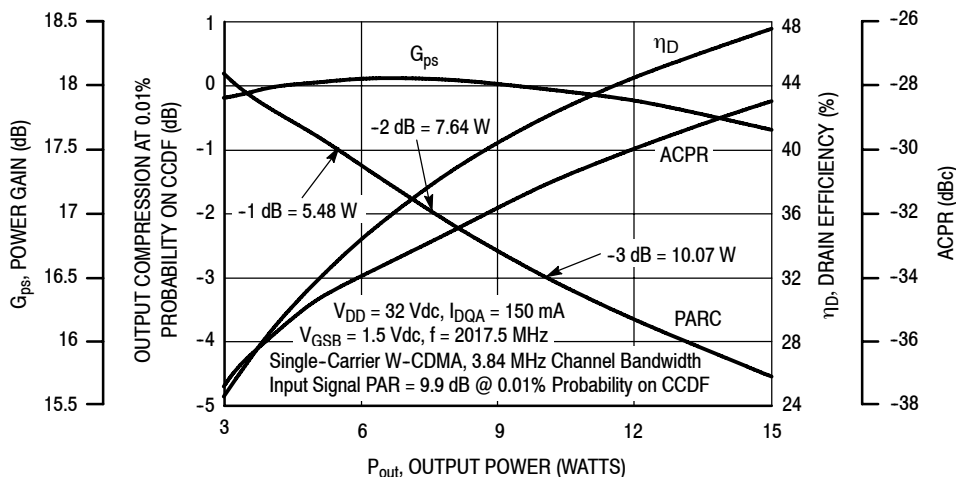


Figure 6. Output Peak-to-Average Ratio Compression (PARC) versus Output Power

TYPICAL CHARACTERISTICS

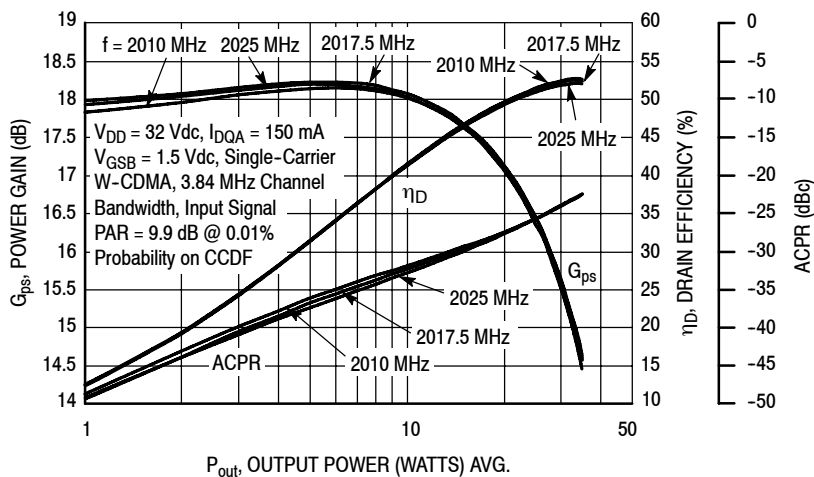


Figure 7. Single-Carrier W-CDMA Power Gain, Drain Efficiency and ACPR versus Output Power

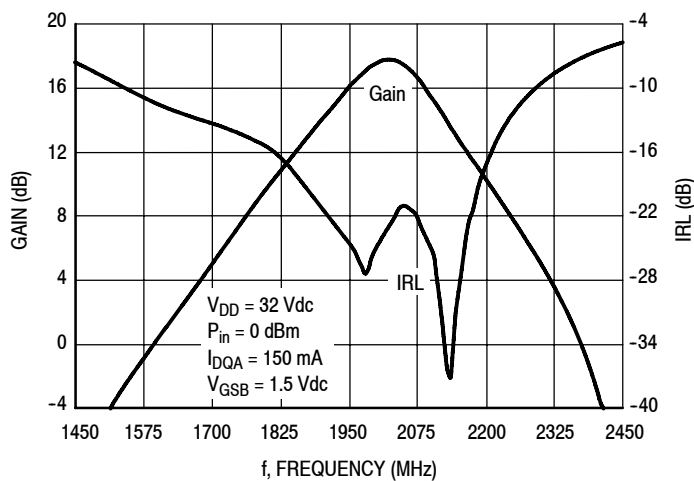


Figure 8. Broadband Frequency Response

W-CDMA TEST SIGNAL

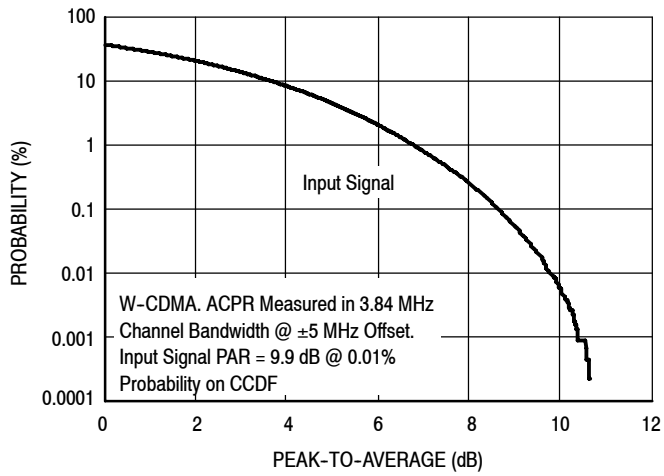


Figure 9. CCDF W-CDMA IQ Magnitude Clipping, Single-Carrier Test Signal

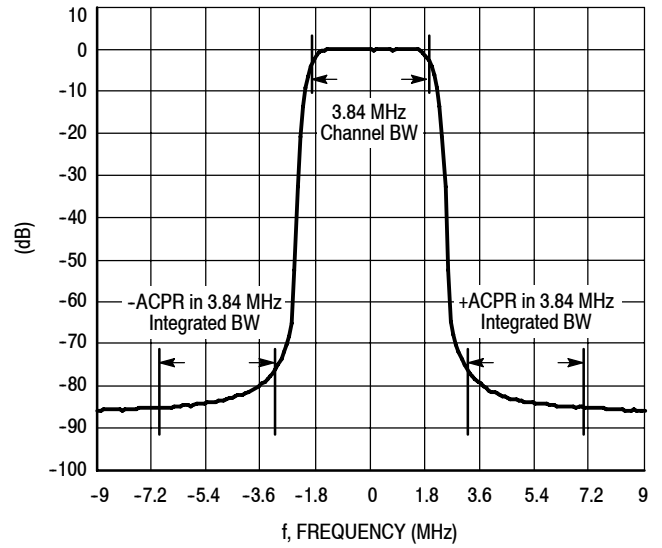


Figure 10. Single-Carrier W-CDMA Spectrum

$V_{DD} = 32 \text{ Vdc}$, $I_{DQA} = 150 \text{ mA}$, $V_{GSB} = 1.5 \text{ Vdc}$, $P_{out} = 10 \text{ W Avg.}$

| f MHz | Z_{source} Ω | Z_{load} Ω |
|----------|--------------------------|------------------------|
| 1995 | 6.80 - j13.11 | 14.67 + j4.09 |
| 2000 | 6.66 - j13.03 | 14.87 + j3.82 |
| 2005 | 6.52 - j12.93 | 15.08 + j3.58 |
| 2010 | 6.37 - j12.85 | 15.27 + j3.29 |
| 2015 | 6.22 - j12.78 | 15.45 + j3.00 |
| 2020 | 6.08 - j12.69 | 15.62 + j2.77 |
| 2025 | 5.94 - j12.60 | 15.80 + j2.44 |
| 2030 | 5.80 - j12.49 | 15.95 + j2.14 |
| 2035 | 5.65 - j12.40 | 16.08 + j1.82 |

Note: Measured with Peaking side open.

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

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

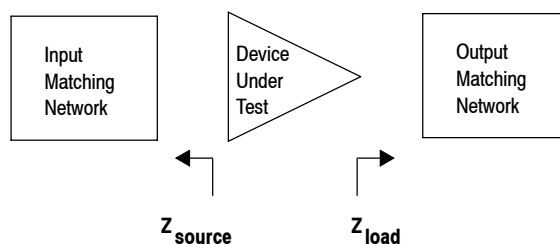


Figure 11. Series Equivalent Source and Load Impedance — Carrier Side

$V_{DD} = 32 \text{ Vdc}$, $I_{DQA} = 150 \text{ mA}$, $V_{GSB} = 1.5 \text{ Vdc}$, $P_{out} = 10 \text{ W Avg.}$

| f MHz | Z_{source} Ω | Z_{load} Ω |
|----------|--------------------------|------------------------|
| 1995 | 8.45 - j12.85 | 5.83 - j10.09 |
| 2000 | 8.28 - j12.79 | 5.57 - j10.11 |
| 2005 | 8.11 - j12.70 | 5.32 - j10.08 |
| 2010 | 7.95 - j12.63 | 5.06 - j10.07 |
| 2015 | 7.79 - j12.56 | 4.80 - j10.06 |
| 2020 | 7.63 - j12.48 | 4.55 - j10.01 |
| 2025 | 7.50 - j12.40 | 4.32 - j9.96 |
| 2030 | 7.34 - j12.32 | 4.06 - j9.88 |
| 2035 | 7.19 - j12.24 | 3.82 - j9.81 |

Note: Measured with Carrier side open.

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

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

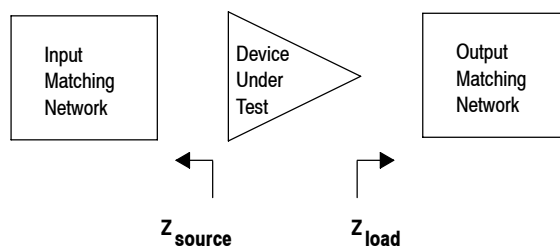
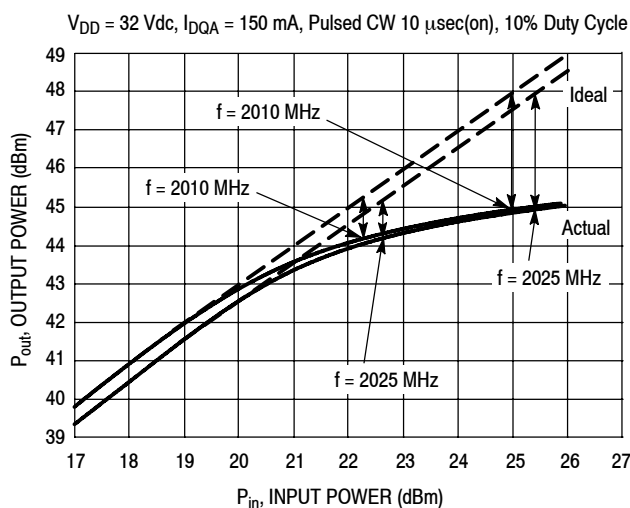


Figure 12. Series Equivalent Source and Load Impedance — Peaking Side

ALTERNATIVE PEAK TUNE LOAD PULL CHARACTERISTICS



Load Pull Test Fixture Tuned for Peak P1dB Output Power @ 32 V

| f (MHz) | P1dB | | P3dB | |
|------------|-------|------|-------|------|
| | Watts | dBm | Watts | dBm |
| 2010 | 26 | 44.1 | 31 | 44.9 |
| 2025 | 26 | 44.2 | 31 | 44.9 |

Test Impedances per Compression Level

| f (MHz) | | Z_{source} Ω | Z_{load} Ω |
|------------|------|--------------------------|------------------------|
| 2010 | P1dB | 2.49 - j18.56 | 15.82 - j0.28 |
| 2025 | P1dB | 2.66 - j19.78 | 15.78 + j0.52 |

Figure 13. Pulsed CW Output Power versus Input Power @ 32 V

NOTE: Measurement made on the Class AB, carrier side of the device.

$V_{DD} = 28 \text{ Vdc}$, $I_{DQA} = 150 \text{ mA}$

| f MHz | Max P_{out} ⁽¹⁾ | | Z_{source} Ω | Z_{load} Ω |
|----------|------------------------------|------|--------------------------|------------------------|
| | Watts | dBm | | |
| 1805 | 35 | 45.4 | 2.2 - j9.3 | 17.1 - j7.9 |
| 1880 | 35 | 45.5 | 2.3 - j11.3 | 14.0 - j4.2 |
| 1930 | 35 | 45.5 | 2.4 - j13.0 | 14.7 - j5.9 |
| 2025 | 35 | 45.5 | 3.5 - j17.3 | 15.5 - j8.0 |
| 2110 | 34 | 45.3 | 3.8 - j20.6 | 15.4 - j9.3 |
| 2200 | 35 | 45.5 | 5.6 - j25.8 | 14.4 - j9.4 |

(1) Maximum output power measurement reflects pulsed 3 dB gain compression.

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

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

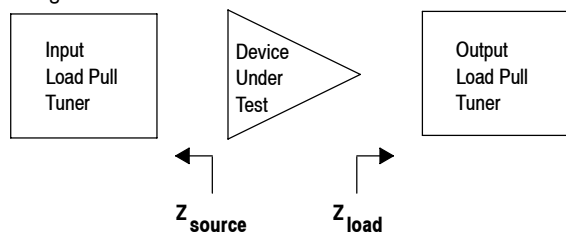


Figure 14. Carrier Side Load Pull Performance — Maximum P3dB Tuning

$V_{DD} = 28 \text{ Vdc}$, $I_{DQA} = 150 \text{ mA}$

| f MHz | Max Eff. ⁽¹⁾ % | Z_{source} Ω | Z_{load} Ω |
|----------|------------------------------|--------------------------|------------------------|
| | | | |
| 1805 | 66.6 | 2.2 - j9.3 | 17.6 + j9.5 |
| 1880 | 70.1 | 2.3 - j11.3 | 16.1 + j9.8 |
| 1930 | 69.8 | 2.4 - j13.0 | 14.2 + j8.9 |
| 2025 | 67.7 | 3.5 - j17.3 | 13.8 + j6.2 |
| 2110 | 67.9 | 3.8 - j20.6 | 11.5 + j3.9 |
| 2200 | 70.3 | 5.6 - j25.8 | 9.6 - j0.6 |

(1) Maximum efficiency measurement reflects pulsed 3 dB gain compression.

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

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

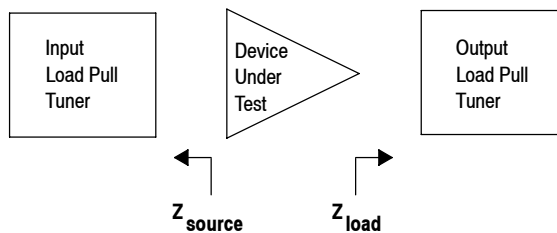
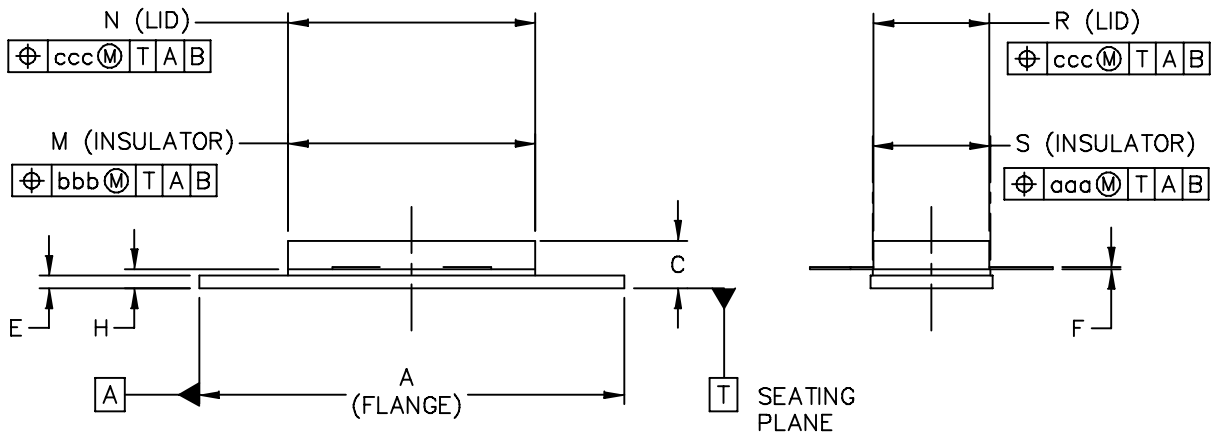
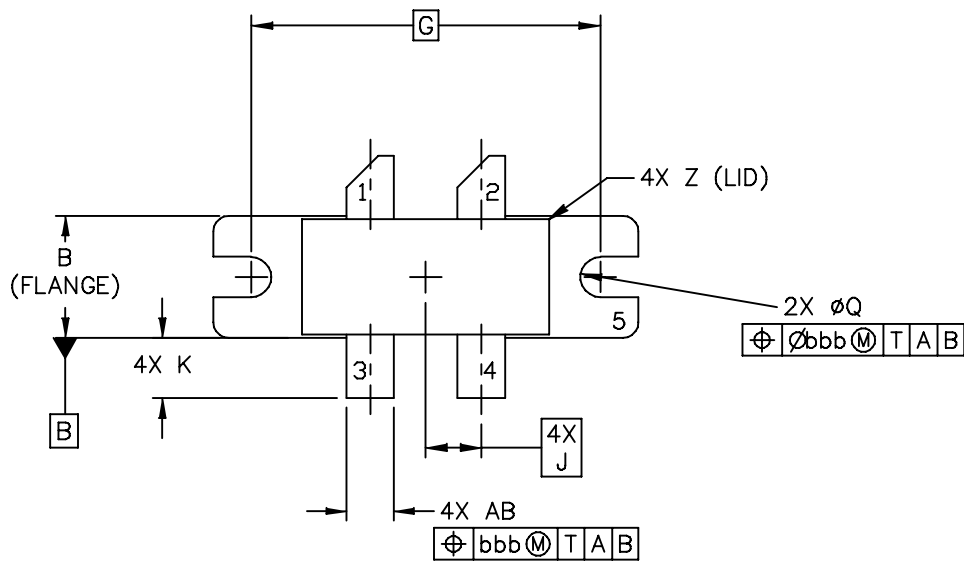


Figure 15. Carrier Side Load Pull Performance — Maximum Efficiency Tuning

PACKAGE DIMENSIONS



| | | | |
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| | CASE NUMBER: 465M-01 | | 27 MAR 2007 |
| | STANDARD: NON-JEDEC | | |

MRF7P20040HR3 MRF7P20040HSR3

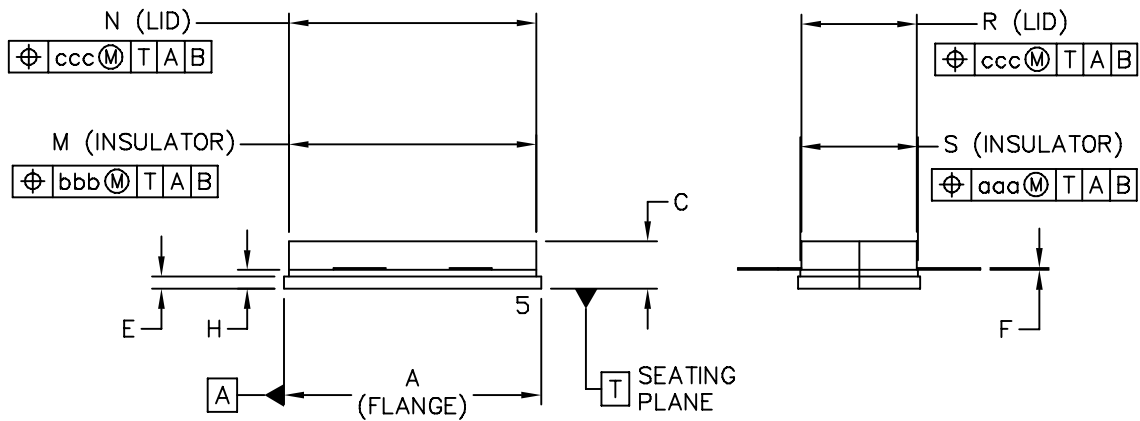
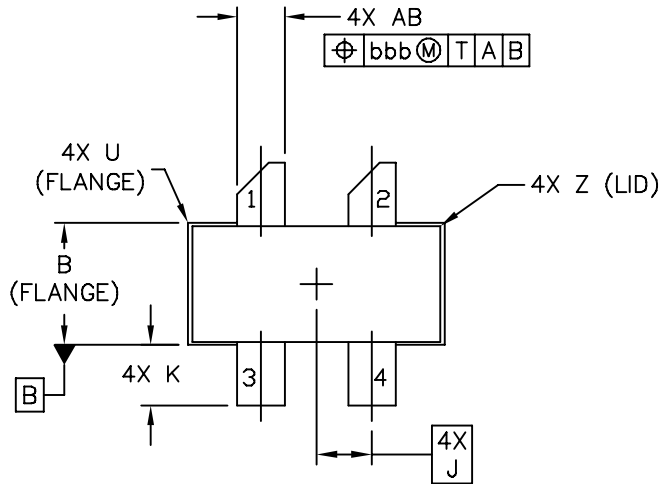
NOTES:

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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| | CASE NUMBER: 465H-02 | 27 MAR 2007 | |
| | STANDARD: NON-JEDEC | | |

NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
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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| | | | | | CASE NUMBER: 465H-02 | | | 27 MAR 2007 | |
| | | | | | STANDARD: NON-JEDEC | | | | |

PRODUCT DOCUMENTATION, TOOLS AND SOFTWARE

Refer to the following documents, tools and software 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
- .s2p File

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.

R5 TAPE AND REEL OPTION

R5 Suffix = 50 Units, 56 mm Tape Width, 13 inch Reel.

The R5 tape and reel option for MRF7P20040H and MRF7P20040HS parts will be available for 2 years after release of MRF7P20040H and MRF7P20040HS. Freescale Semiconductor, Inc. reserves the right to limit the quantities that will be delivered in the R5 tape and reel option. At the end of the 2 year period customers who have purchased these devices in the R5 tape and reel option will be offered MRF7P20040H and MRF7P20040HS in the R3 tape and reel option.

REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date | Description |
|----------|-----------|---|
| 0 | June 2009 | <ul style="list-style-type: none">• Initial Release of Data Sheet |
| 1 | Aug. 2009 | <ul style="list-style-type: none">• Removed IQ Magnitude Clipping from Typical Performance bullet, p. 1 and Functional Test header, p. 2• Electrical Characteristics, DC tests: updated footnote to indicate each side of device measured separately, p. 2 |
| 2 | Dec. 2010 | <ul style="list-style-type: none">• Updated frequency in overview paragraph from “2010 to 2025 MHz” to “1800 to 2200 MHz” per expanded load pull characterization shown in Fig. 14, Carrier Side Load Pull Performance — Maximum P3dB Tuning and Fig. 15, Carrier Side Load Pull Performance — Maximum Efficiency Tuning, p. 1• Added CW Operation information to Maximum Ratings table, p. 1• In Table 2, Thermal Characteristics, $P_{out} = 10$ W CW thermal resistance values changed from $I_{DQA} 2.5/V_{GSB} 2.9$ to 2.11 °C/W and $P_{out} = 40$ W CW thermal resistance value changed from 2.3 to 1.50 °C/W. Thermal values now reflect the use of the combined dissipated power from the carrier amplifier and peaking amplifier, p. 1• Added Fig. 14, Carrier Side Load Pull Performance — Maximum P3dB Tuning and Fig. 15, Carrier Side Load Pull Performance — Maximum Efficiency Tuning to show load pull data for expanded frequency range presented in p. 1 overview paragraph, p. 10 |

MRF7P20040HR3 MRF7P20040HSR3

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