

# RF Power GaN on SiC Transistor

## Depletion Mode HEMT

This 125 W CW RF power GaN transistor is optimized for wideband operation up to 2700 MHz and includes input matching for extended bandwidth performance. With its high gain and high ruggedness, this device is ideally suited for CW, pulse and wideband RF applications.

This part is characterized and performance is guaranteed for applications operating in the 1–2700 MHz band. There is no guarantee of performance when this part is used in applications designed outside of these frequencies.

**Typical Narrowband Performance:**  $V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 350 \text{ mA}$ ,  $T_A = 25^\circ\text{C}$

| Frequency (MHz) | Signal Type                                        | $P_{out}$ (W) | $G_{ps}$ (dB) | $\eta_D$ (%) |
|-----------------|----------------------------------------------------|---------------|---------------|--------------|
| 2500 (1)        | CW                                                 | 125 CW        | 16.0          | 64.2         |
| 2500 (1)        | Pulse<br>(100 $\mu\text{sec}$ ,<br>20% Duty Cycle) | 125 Peak      | 16.6          | 68.0         |

**Typical Wideband Performance:**  $V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 300 \text{ mA}$ ,  $T_A = 25^\circ\text{C}$

| Frequency (MHz) | Signal Type                                        | $P_{out}$ (W) | $G_{ps}$ (dB) | $\eta_D$ (%) |
|-----------------|----------------------------------------------------|---------------|---------------|--------------|
| 200–2500 (2)    | Pulse<br>(100 $\mu\text{sec}$ ,<br>50% Duty Cycle) | 100 Peak      | 12.0          | 40.0         |

### Load Mismatch/Ruggedness

| Frequency (MHz) | Signal Type                                        | VSWR                             | $P_{in}$ (W)                    | Test Voltage | Result                   |
|-----------------|----------------------------------------------------|----------------------------------|---------------------------------|--------------|--------------------------|
| 2500 (1)        | Pulse<br>(100 $\mu\text{sec}$ ,<br>20% Duty Cycle) | > 20:1 at<br>All Phase<br>Angles | 8.0 Peak<br>(3 dB<br>Overdrive) | 50           | No Device<br>Degradation |

1. Measured in 2500 MHz narrowband test circuit.

2. Measured in 200–2500 MHz broadband reference circuit.

### Features

- Decade bandwidth performance
- Plastic package enables improved thermal resistance
- Advanced GaN on SiC, offering high power density
- Input matched for extended wideband performance
- High ruggedness: > 20:1 VSWR

### Applications

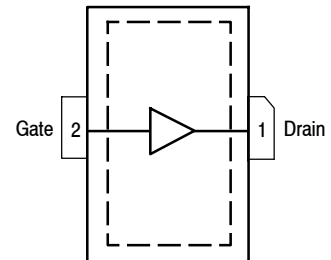
- Ideal for military end-use applications, including the following:
  - Narrowband and multi-octave wideband amplifiers
  - Radar
  - Jammers
  - EMC testing
- Also suitable for commercial applications, including the following:
  - Public mobile radios, including emergency service radios
  - Industrial, scientific and medical
  - Wideband laboratory amplifiers
  - Wireless cellular infrastructure

**MMRF5015N**

**1–2700 MHz, 125 W CW, 50 V  
WIDEBAND  
RF POWER GaN ON SiC  
TRANSISTOR**



**OM-270-2  
PLASTIC**



(Top View)

**Note:** Exposed backside of the package is the source terminal for the transistor.

**Figure 1. Pin Connections**

**Table 1. Maximum Ratings**

| Rating                                                                     | Symbol    | Value       | Unit      |
|----------------------------------------------------------------------------|-----------|-------------|-----------|
| Drain–Source Voltage                                                       | $V_{DS}$  | 125         | Vdc       |
| Gate–Source Voltage                                                        | $V_{GS}$  | –8, 0       | Vdc       |
| Operating Voltage                                                          | $V_{DD}$  | 0 to +50    | Vdc       |
| Storage Temperature Range                                                  | $T_{stg}$ | –65 to +150 | °C        |
| Case Operating Temperature Range                                           | $T_C$     | –55 to +150 | °C        |
| Operating Junction Temperature Range <sup>(1)</sup>                        | $T_J$     | –55 to +225 | °C        |
| Total Device Dissipation @ $T_C = 25^{\circ}\text{C}$<br>Derate above 25°C | $P_D$     | 303<br>1.52 | W<br>W/°C |

**Table 2. Thermal Characteristics**

| Characteristic                                                                                                                                                | Symbol          | Value <sup>(2)</sup> | Unit |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------|------|
| Thermal Resistance, Junction to Case<br>CW: Case Temperature 80°C, 125 W CW, 50 Vdc, $I_{DQ} = 350$ mA, 2500 MHz                                              | $R_{\theta JC}$ | 0.66                 | °C/W |
| Thermal Impedance, Junction to Case<br>Pulse: Case Temperature 56°C, 125 W Peak, 100 µsec Pulse Width,<br>20% Duty Cycle, 50 Vdc, $I_{DQ} = 350$ mA, 2500 MHz | $Z_{\theta JC}$ | 0.16                 | °C/W |

**Table 3. ESD Protection Characteristics**

| Test Methodology                      | Class             |
|---------------------------------------|-------------------|
| Human Body Model (per JESD22-A114)    | 1B, passes 500 V  |
| Machine Model (per EIA/JESD22-A115)   | A, passes 100 V   |
| Charge Device Model (per JESD22-C101) | IV, passes 2000 V |

**Table 4. Moisture Sensitivity Level**

| Test Methodology                     | Rating | Package Peak Temperature | Unit |
|--------------------------------------|--------|--------------------------|------|
| Per JESD22-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 |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**Off Characteristics**

|                                                                         |               |     |   |   |      |
|-------------------------------------------------------------------------|---------------|-----|---|---|------|
| Drain Leakage Current<br>( $V_{GS} = -8$ Vdc, $V_{DS} = 10$ Vdc)        | $I_{DSS}$     | —   | — | 5 | mAdc |
| Drain–Source Breakdown Voltage<br>( $V_{GS} = -8$ Vdc, $I_D = 25$ mAdc) | $V_{(BR)DSS}$ | 150 | — | — | Vdc  |

**On Characteristics**

|                                                                                               |              |      |      |      |     |
|-----------------------------------------------------------------------------------------------|--------------|------|------|------|-----|
| Gate Threshold Voltage<br>( $V_{DS} = 10$ Vdc, $I_D = 25$ mAdc)                               | $V_{GS(th)}$ | –3.8 | –2.9 | –2.3 | Vdc |
| Gate Quiescent Voltage<br>( $V_{DS} = 50$ Vdc, $I_D = 350$ mAdc, Measured in Functional Test) | $V_{GS(Q)}$  | –3.3 | –2.7 | –2.3 | Vdc |

**Dynamic Characteristics**

|                                                                                                        |           |   |      |   |    |
|--------------------------------------------------------------------------------------------------------|-----------|---|------|---|----|
| Reverse Transfer Capacitance<br>( $V_{DS} = 50$ Vdc $\pm$ 30 mV(rms)ac @ 1 MHz, $V_{GS} = -4$ Vdc)     | $C_{rss}$ | — | 1.0  | — | pF |
| Output Capacitance<br>( $V_{DS} = 50$ Vdc $\pm$ 30 mV(rms)ac @ 1 MHz, $V_{GS} = -4$ Vdc)               | $C_{oss}$ | — | 8.7  | — | pF |
| Input Capacitance <sup>(3)</sup><br>( $V_{DS} = 50$ Vdc, $V_{GS} = -4$ Vdc $\pm$ 30 mV(rms)ac @ 1 MHz) | $C_{iss}$ | — | 52.0 | — | pF |

1. Continuous use at maximum temperature will affect MTTF.

2. Refer to [AN1955](#), *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf> and search for AN1955.

3. Part internally input matched.

(continued)

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

| Characteristic                                                                                                                                                                                                                                                                       | Symbol   | Min | Typ  | Max | Unit |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----|------|-----|------|
| <b>Functional Tests</b> (In Freescale Test Fixture, 50 ohm system) $V_{DD} = 50\text{ Vdc}$ , $I_{DQ} = 350\text{ mA}$ , $P_{out} = 125\text{ W Peak}$ (25 W Avg.), $f = 2500\text{ MHz}$ , 100 $\mu\text{sec}$ Pulse Width, 20% Duty Cycle. [See note on correct biasing sequence.] |          |     |      |     |      |
| Power Gain                                                                                                                                                                                                                                                                           | $G_{ps}$ | —   | 16.6 | —   | dB   |
| Drain Efficiency                                                                                                                                                                                                                                                                     | $\eta_D$ | —   | 68.0 | —   | %    |
| Input Return Loss                                                                                                                                                                                                                                                                    | IRL      | —   | -12  | -9  | dB   |

**Load Mismatch/Ruggedness** (In Freescale Test Fixture, 50 ohm system)  $I_{DQ} = 350\text{ mA}$ 

| Frequency (MHz) | Signal Type                                  | VSWR                       | $P_{in}$ (W)              | Test Voltage, $V_{DD}$ | Result                |
|-----------------|----------------------------------------------|----------------------------|---------------------------|------------------------|-----------------------|
| 2500            | Pulse (100 $\mu\text{sec}$ , 20% Duty Cycle) | > 20:1 at All Phase Angles | 8.0 Peak (3 dB Overdrive) | 50                     | No Device Degradation |

**Table 6. Ordering Information**

| Device      | Tape and Reel Information                           | Package  |
|-------------|-----------------------------------------------------|----------|
| MMRF5015NR5 | R5 Suffix = 50 Units, 24 mm Tape Width, 7-inch Reel | OM-270-2 |

**NOTE: Correct Biasing Sequence for GaN Depletion Mode Transistors**
**Turning the device ON**

1. Set  $V_{GS}$  to the pinch-off ( $V_P$ ) voltage, typically -5 V
2. Turn on  $V_{DS}$  to nominal supply voltage (50 V)
3. Increase  $V_{GS}$  until  $I_{DS}$  current is attained
4. Apply RF input power to desired level

**Turning the device OFF**

1. Turn RF power off
2. Reduce  $V_{GS}$  down to  $V_P$ , typically -5 V
3. Reduce  $V_{DS}$  down to 0 V (Adequate time must be allowed for  $V_{DS}$  to reduce to 0 V to prevent severe damage to device.)
4. Turn off  $V_{GS}$

## 200–2500 MHz WIDEBAND REFERENCE CIRCUIT

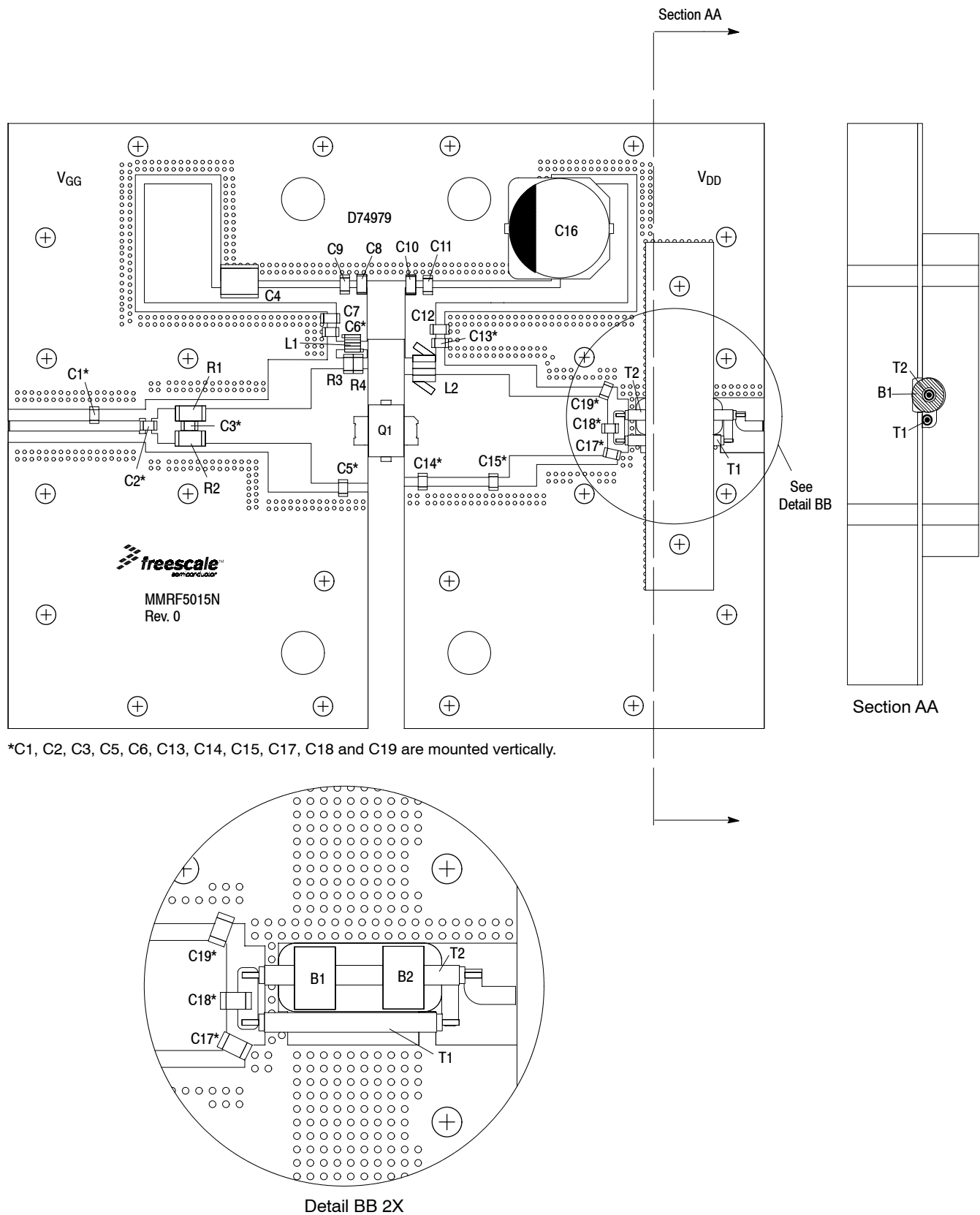
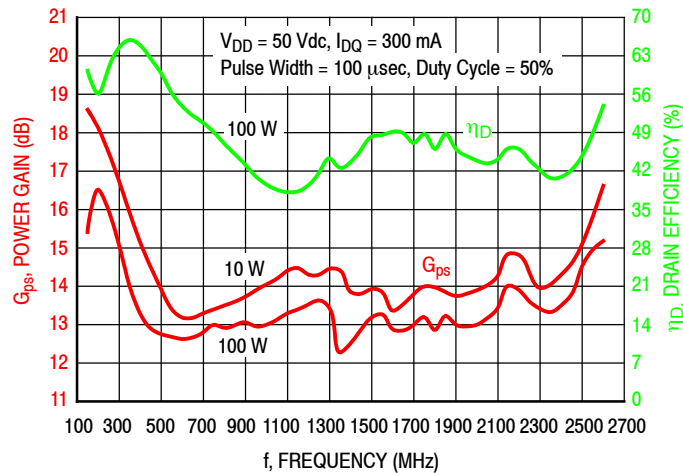


Figure 2. MMRF5015N Wideband Reference Circuit Component Layout — 200–2500 MHz

**Table 7. MMRF5015N Wideband Reference Circuit Component Designations and Values — 200–2500 MHz**

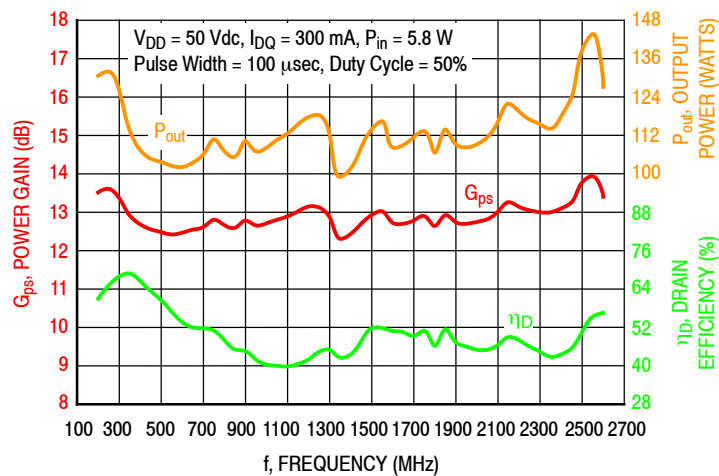
| Part             | Description                                       | Part Number         | Manufacturer  |
|------------------|---------------------------------------------------|---------------------|---------------|
| B1, B2           | Ferrite Beads                                     | T22-6               | Micro Metals  |
| C1               | 0.3 pF Chip Capacitor                             | ATC800B0R3BT500XT   | ATC           |
| C2               | 75 pF Chip Capacitor                              | ATC800B750JT500XT   | ATC           |
| C3               | 24 pF Chip Capacitor                              | ATC800B240JT500XT   | ATC           |
| C4               | 6.8 $\mu$ F Chip Capacitor                        | C4532X7R1H685K250KB | TDK           |
| C5               | 0.5 pF Chip Capacitor                             | ATC800B0R5BT500XT   | ATC           |
| C6, C13          | 5.6 pF Chip Capacitors                            | ATC800B5R6BT500XT   | ATC           |
| C7, C8, C10, C12 | 0.015 $\mu$ F Chip Capacitors                     | GRM319R72A153KA01D  | Murata        |
| C9, C11          | 1 $\mu$ F Chip Capacitors                         | GRM31CR72A105KAO1L  | Murata        |
| C14, C15         | 1.0 pF Chip Capacitors                            | ATC800B1R0BT500XT   | ATC           |
| C16              | 220 $\mu$ F, 100 V Electrolytic Capacitor         | EEV-FK2A221M        | Panasonic-ECG |
| C17              | 0.8 pF Chip Capacitor                             | ATC800B0R8BT500XT   | ATC           |
| C18              | 56 pF Chip Capacitor                              | ATC800B560JT500XT   | ATC           |
| C19              | 1.2 pF Chip Capacitor                             | ATC800B1R2BT500XT   | ATC           |
| L1               | 12.5 nH Inductor                                  | A04TJLC             | Coilcraft     |
| L2               | 22 nH Inductor                                    | 1812SMS-22NJLC      | Coilcraft     |
| Q1               | RF Power GaN Transistor                           | MMRF5015NR5         | Freescale     |
| R1, R2           | 100 $\Omega$ , 1/2 W Chip Resistors               | CRCW2010100RFKEF    | Vishay        |
| R3, R4           | 39 $\Omega$ , 1/4 W Chip Resistors                | CRCW120639R0FKEA    | Vishay        |
| T1               | 25 $\Omega$ Semi Rigid Coax, 0.770" Shield Length | UT-070-25           | Micro-Coax    |
| T2               | 25 $\Omega$ Semi Rigid Coax, 0.850" Shield Length | UT-070-25           | Micro-Coax    |
| PCB              | Rogers RO4350B, 0.030", $\epsilon_r = 3.66$       | D74979              | MTL           |

## TYPICAL CHARACTERISTICS — 200–2500 MHz WIDEBAND REFERENCE CIRCUIT



**Note:** Pulse performance achieved with device clamped into the reference circuit; similar CW performance can be achieved by soldering the device to the heatsink.

**Figure 3. 200–2500 MHz Wideband Circuit Performance**

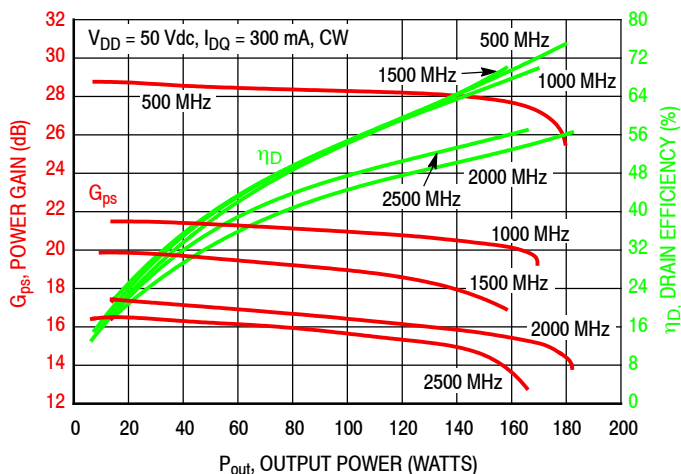


**Figure 4. Power Gain, Output Power and Drain Efficiency versus Frequency at a Constant Input Power**

## TYPICAL CHARACTERISTICS — OPTIMIZED NARROWBAND PERFORMANCE

### Narrowband Performance and Impedance Information ( $T_C = 25^\circ\text{C}$ )

The measured input and output impedances are presented to the input of the device at the package reference plane. Measurements are performed in Freescale narrowband fixture tuned at 500, 1000, 1500, 2000 and 2500 MHz.

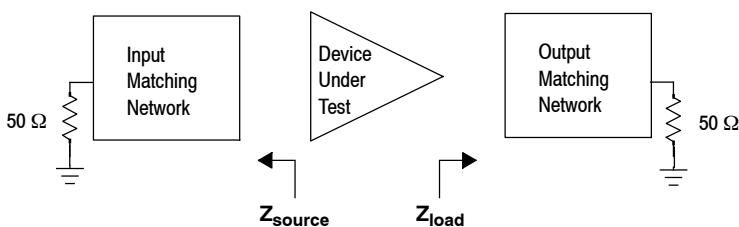


**Figure 5. Power Gain and Drain Efficiency versus Output Power**

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 500      | $0.7 + j2.9$             | $6.0 + j3.3$           |
| 1000     | $1.1 - j0.03$            | $5.6 + j2.3$           |
| 1500     | $0.9 - j1.2$             | $3.3 + j3.0$           |
| 2000     | $1.3 - j1.8$             | $3.8 + j0.9$           |
| 2500     | $3.5 - j4.0$             | $3.1 + j0.3$           |

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

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



**Figure 6. Narrowband Fixtures: Series Equivalent Source and Load Impedances**

## 2500 MHz NARROWBAND PRODUCTION TEST FIXTURE

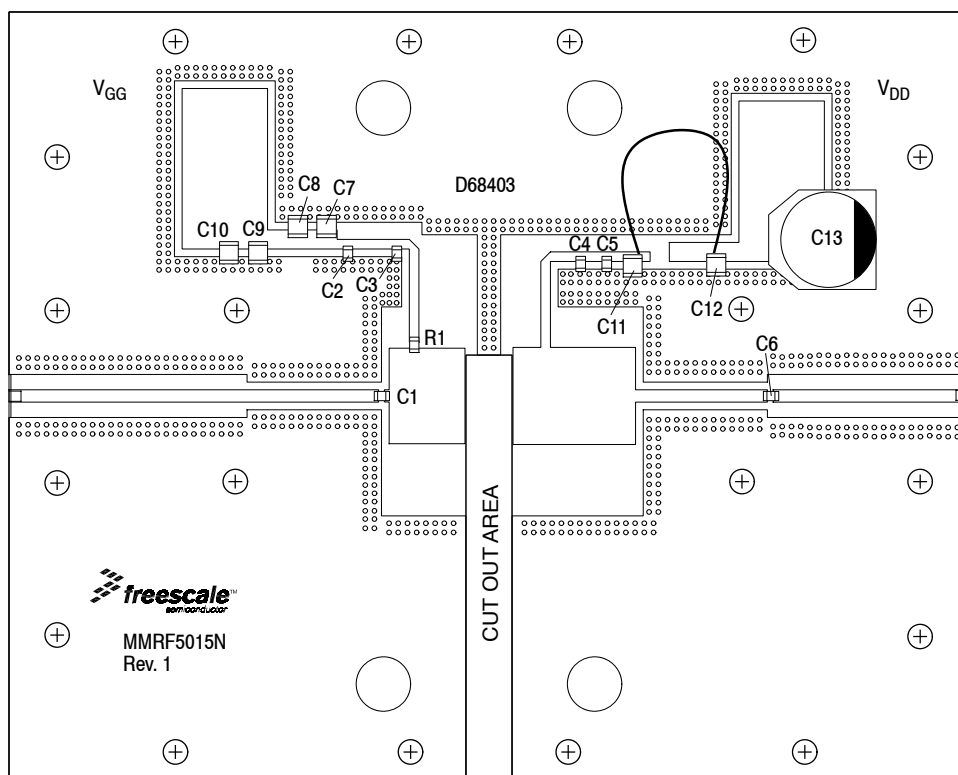
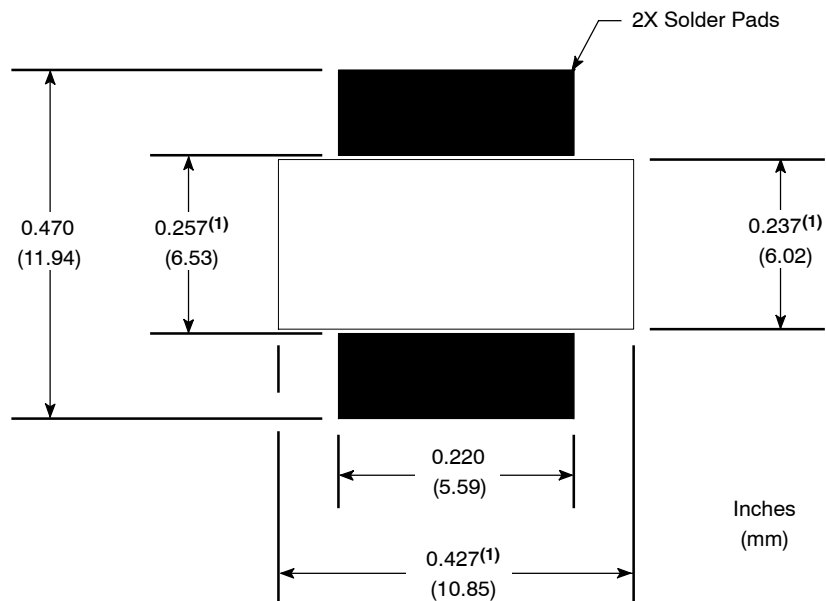


Figure 7. MMRF5015N Narrowband Test Circuit Component Layout — 2500 MHz

Table 8. MMRF5015N Narrowband Test Circuit Component Designations and Values — 2500 MHz

| Part               | Description                                           | Part Number        | Manufacturer  |
|--------------------|-------------------------------------------------------|--------------------|---------------|
| C1                 | 3.0 pF Chip Capacitor                                 | ATC600F3R0BT250XT  | ATC           |
| C2, C3, C4, C5, C6 | 12 pF Chip Capacitors                                 | ATC600F120JT250XT  | ATC           |
| C7, C11            | 1000 pF Chip Capacitors                               | ATC800B102JT50XT   | ATC           |
| C8                 | 0.1 $\mu$ F Chip Capacitor                            | GRM319R72A104KA01D | Murata        |
| C9, C10            | 4.7 $\mu$ F Chip Capacitors                           | GRM32ER71H475KA88B | Murata        |
| C12                | 1.0 $\mu$ F Chip Capacitor                            | GRM32CR72A105KA35L | Murata        |
| C13                | 220 $\mu$ F, 100 V Electrolytic Capacitor             | EEV-FK2A221M       | Panasonic-ECG |
| R1                 | 51 $\Omega$ , 1/8 W Chip Resistor                     | SG732ATTD51R0F     | KOA Speer     |
| —                  | 18 AWG Teflon Wire, Total Wire Length = 4.0"/101.6 mm | —                  | —             |
| PCB                | Rogers RO4350B, 0.030", $\epsilon_r = 3.66$           | D68403             | MTL           |

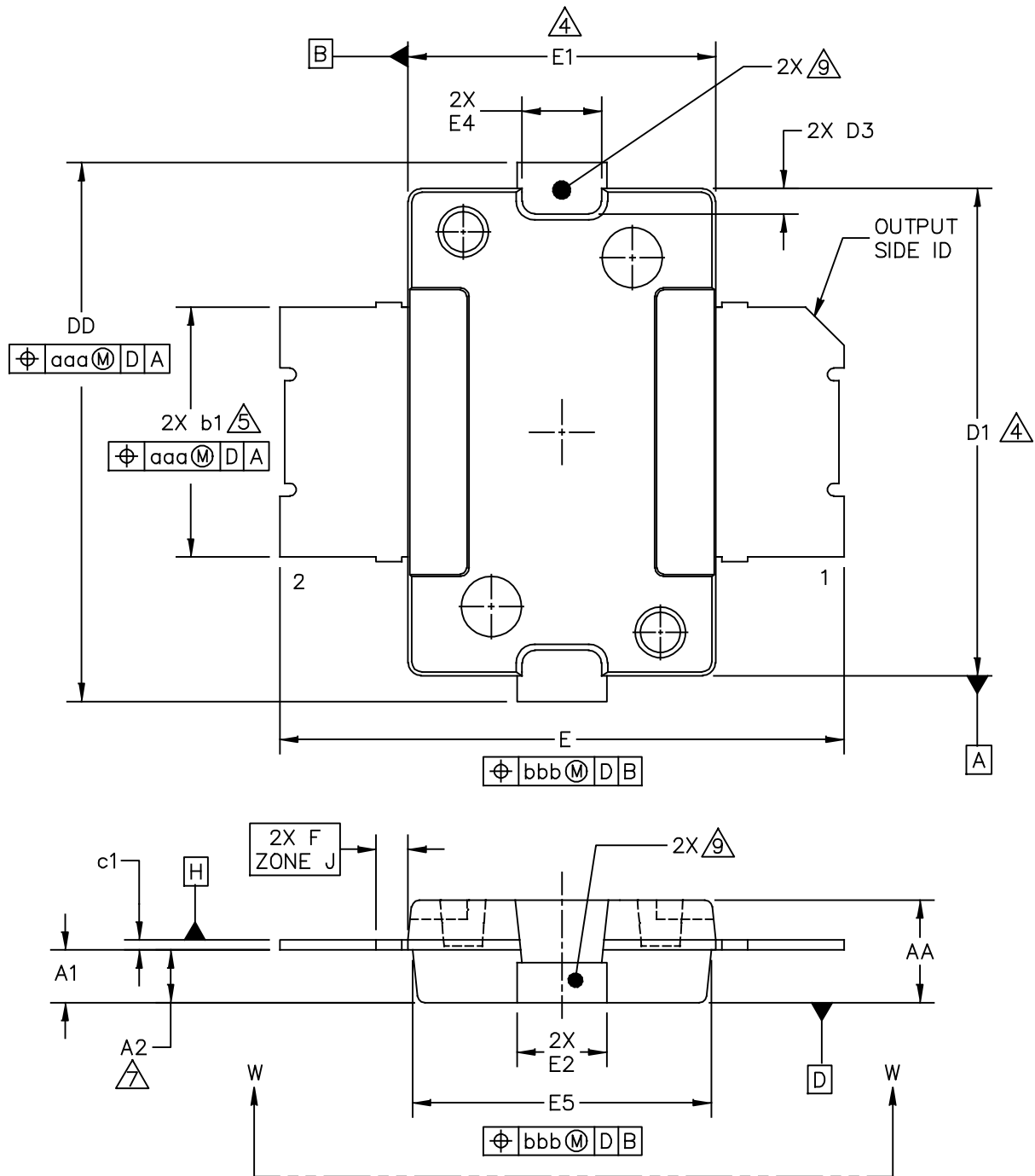


**Figure 8. PCB Pad Layout for OM-270-2**

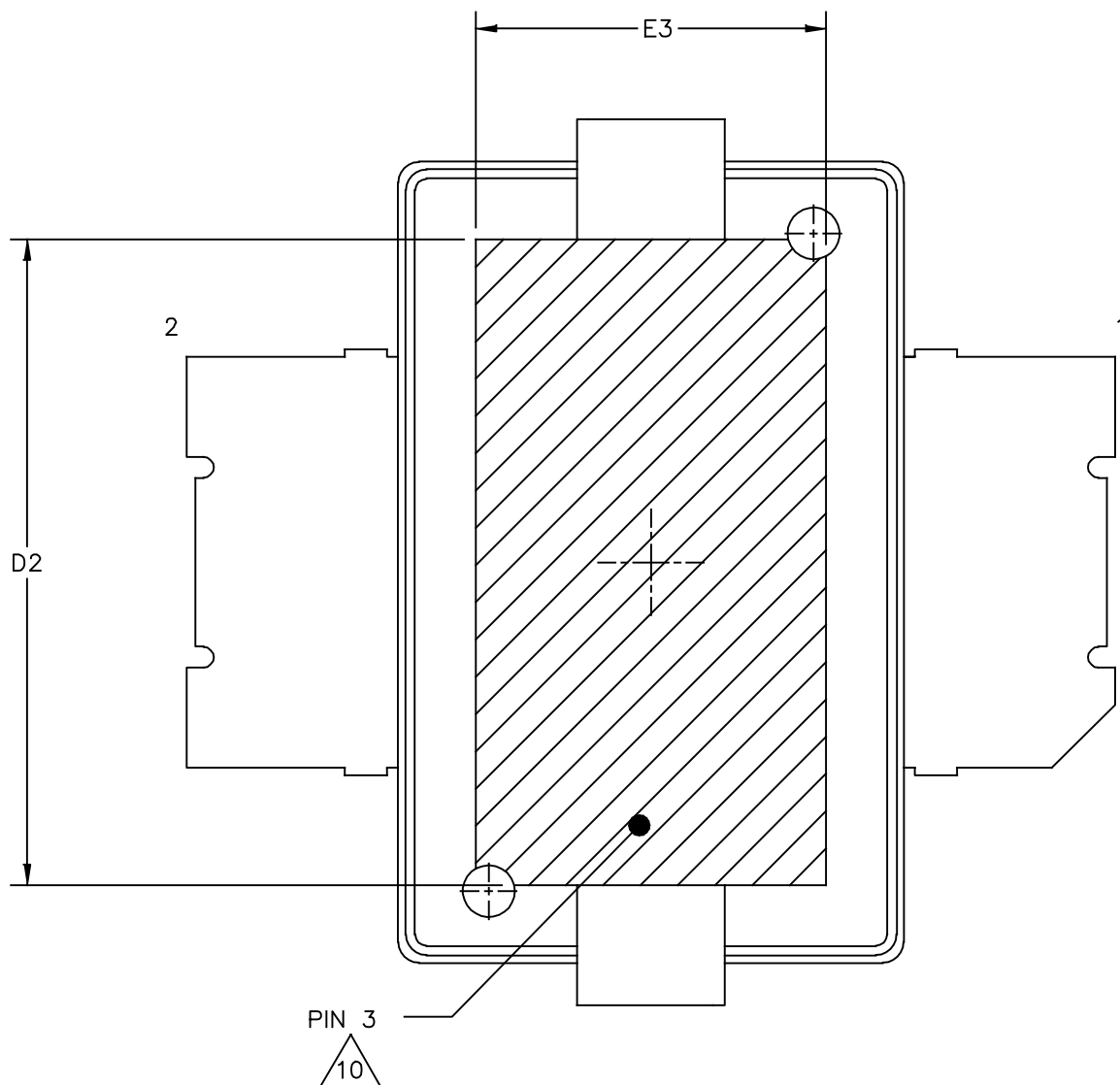


**Figure 9. Product Marking**

# PACKAGE DIMENSIONS



|                                                         |                                 |                            |
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| TITLE:<br><br>OM-270-2                                  | DOCUMENT NO: 98ASA00814D REV: 0 |                            |
|                                                         | STANDARD: JEDEC TO-270 AA       |                            |
|                                                         | 26 NOV 2014                     |                            |



VIEW W-W  
BOTTOM VIEW

|                                                         |  |                                      |                            |
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|                                                         |  | STANDARD: JEDEC TO-270 AA            |                            |
|                                                         |  | 26 NOV 2014                          |                            |

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 INCH (0.15 MM) 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 INCH (0.13 MM) 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 DD AND E2 DO NOT INCLUDE MOLD PROTRUSION. OVERALL LENGTH INCLUDING MOLD PROTRUSION SHOULD NOT EXCEED 0.430 INCH (10.92 MM) FOR DIMENSION DD AND 0.080 INCH (2.03 MM) FOR DIMENSION E2. DIMENSIONS DD AND E2 DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE D.
9. THESE SURFACES OF THE HEAT SLUG ARE NOT PART OF THE SOLDERABLE SURFACES AND MAY REMAIN UNPLATED.
10. HATCHING REPRESENTS THE EXPOSED AREA OF THE HEAT SLUG. DIMENSIONS D2 AND E3 REPRESENT THE VALUES BETWEEN THE TWO OPPOSITE POINTS ALONG THE EDGES OF EXPOSED AREA OF THE HEAT SLUG.

| INCH                                                    |      |      | MILLIMETER         |       | INCH                                                 |                            |      | MILLIMETER |      |
|---------------------------------------------------------|------|------|--------------------|-------|------------------------------------------------------|----------------------------|------|------------|------|
| DIM                                                     | MIN  | MAX  | MIN                | MAX   | DIM                                                  | MIN                        | MAX  | MIN        | MAX  |
| AA                                                      | .078 | .082 | 1.98               | 2.08  | E4                                                   | .058                       | .066 | 1.47       | 1.68 |
| A1                                                      | .039 | .043 | 0.99               | 1.09  | E5                                                   | .231                       | .235 | 5.87       | 5.97 |
| A2                                                      | .040 | .042 | 1.02               | 1.07  | F                                                    | .025 BSC                   |      | 0.64 BSC   |      |
| DD                                                      | .416 | .424 | 10.57              | 10.77 | b1                                                   | .193                       | .199 | 4.90       | 5.06 |
| D1                                                      | .378 | .382 | 9.60               | 9.70  | c1                                                   | .007                       | .011 | 0.18       | 0.28 |
| D2                                                      | .290 | ---- | 7.37               | ----  | aaa                                                  | .004                       |      | 0.10       |      |
| D3                                                      | .016 | .024 | 0.41               | 0.61  | bbb                                                  | .008                       |      | 0.20       |      |
| E                                                       | .436 | .444 | 11.07              | 11.28 |                                                      |                            |      |            |      |
| E1                                                      | .238 | .242 | 6.04               | 6.15  |                                                      |                            |      |            |      |
| E2                                                      | .066 | .074 | 1.68               | 1.88  |                                                      |                            |      |            |      |
| E3                                                      | .150 | ---- | 3.81               | ----  |                                                      |                            |      |            |      |
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|                                                         |      |      |                    |       | STANDARD: JEDEC TO-270 AA                            |                            |      |            |      |
|                                                         |      |      |                    |       | 26 NOV 2014                                          |                            |      |            |      |

## PRODUCT DOCUMENTATION AND TOOLS

Refer to the following resources to aid your design process.

### Application Notes

- AN1955: Thermal Measurement Methodology of RF Power Amplifiers

### Development Tools

- Printed Circuit Boards

### To Download Resources Specific to a Given Part Number:

1. Go to <http://www.freescale.com/rf>
2. Search by part number
3. Click part number link
4. Choose the desired resource from the drop down menu

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date       | Description                                                                       |
|----------|------------|-----------------------------------------------------------------------------------|
| 0        | Sept. 2015 | <ul style="list-style-type: none"> <li>• Initial Release of Data Sheet</li> </ul> |

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