

# RF Power LDMOS Transistors

## High Ruggedness N-Channel Enhancement-Mode Lateral MOSFETs

These high ruggedness devices are designed for use in high VSWR CW or pulse applications, such as HF, VHF, and low-band UHF radar and high power radio communications. They are unmatched input and output designs allowing wide frequency utilization from 1.8 to 600 MHz.

- Typical Performance:  $V_{DD} = 50$  Vdc,  $I_{DQ} = 100$  mA

| Signal Type                              | $P_{out}$<br>(W) | f<br>(MHz) | $G_{ps}$<br>(dB) | $\eta_D$<br>(%) |
|------------------------------------------|------------------|------------|------------------|-----------------|
| Pulse<br>(100 $\mu$ sec, 20% Duty Cycle) | 1250 Peak        | 230        | 24.0             | 74.0            |
| CW                                       | 1250 CW          | 230        | 22.9             | 74.6            |

### Application Circuits <sup>(1)</sup> — Typical Performance

| Frequency<br>(MHz) | Signal Type                                 | $P_{out}$<br>(W) | $G_{ps}$<br>(dB) | $\eta_D$<br>(%) |
|--------------------|---------------------------------------------|------------------|------------------|-----------------|
| 27                 | CW                                          | 1300             | 27               | 81              |
| 40                 | CW                                          | 1300             | 26               | 85              |
| 81.36              | CW                                          | 1250             | 27               | 84              |
| 87.5–108           | CW                                          | 1100             | 24               | 80              |
| 144–148            | CW                                          | 1250             | 26               | 78              |
| 170–230            | DVB-T                                       | 225              | 25               | 30              |
| 352                | Pulse<br>(200 $\mu$ sec,<br>20% Duty Cycle) | 1250             | 21.5             | 66              |
| 352                | CW                                          | 1150             | 20.5             | 68              |
| 500                | CW                                          | 1000             | 18               | 58              |

- Contact your local Freescale sales office for additional information on specific circuit designs.

### Load Mismatch/Ruggedness

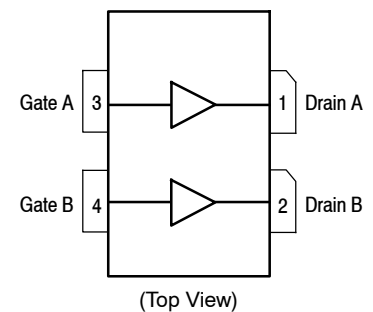
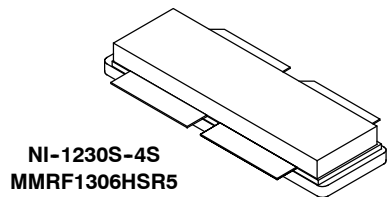
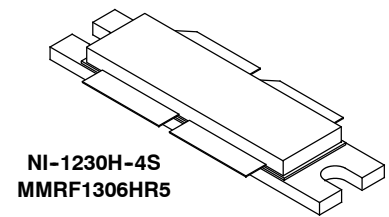
| Frequency<br>(MHz) | Signal Type                                 | VSWR                         | $P_{out}$<br>(W)                 | Test<br>Voltage | Result                   |
|--------------------|---------------------------------------------|------------------------------|----------------------------------|-----------------|--------------------------|
| 230                | Pulse<br>(100 $\mu$ sec, 20%<br>Duty Cycle) | >65:1 at all<br>Phase Angles | 1500 Peak<br>(3 dB<br>Overdrive) | 50              | No Device<br>Degradation |

### Features

- Unmatched Input and Output Allowing Wide Frequency Range Utilization
- Device can be used Single-Ended or in a Push-Pull Configuration
- Qualified Up to a Maximum of 50  $V_{DD}$  Operation
- Characterized from 30 V to 50 V for Extended Power Range
- Suitable for Linear Application with Appropriate Biasing
- Integrated ESD Protection with Greater Negative Gate-Source Voltage Range for Improved Class C Operation
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- In Tape and Reel. R5 Suffix = 50 Units, 56 mm Tape Width, 13-inch Reel.

## MMRF1306HR5 MMRF1306HSR5

1.8–600 MHz, 1250 W CW, 50 V  
WIDEBAND  
RF POWER LDMOS TRANSISTORS



Note: The backside of the package is the source terminal for the transistors.

Figure 1. Pin Connections

**Table 1. Maximum Ratings**

| Rating                                                                                 | Symbol    | Value        | Unit      |
|----------------------------------------------------------------------------------------|-----------|--------------|-----------|
| Drain-Source Voltage                                                                   | $V_{DS}$  | -0.5, +133   | Vdc       |
| Gate-Source Voltage                                                                    | $V_{GS}$  | -6.0, +10    | Vdc       |
| Storage Temperature Range                                                              | $T_{stg}$ | -65 to +150  | °C        |
| Case Operating Temperature                                                             | $T_C$     | 150          | °C        |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$     | 1333<br>6.67 | W<br>W/°C |
| Operating Junction Temperature <sup>(1)</sup>                                          | $T_J$     | 225          | °C        |

**Table 2. Thermal Characteristics**

| Characteristic                                                                                                                                                                           | Symbol          | Value <sup>(2)</sup> | Unit |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------|------|
| Thermal Resistance, Junction to Case<br>CW: Case Temperature $63^\circ\text{C}$ , 1250 W CW, $I_{DQ} = 100\text{ mA}$ , 230 MHz                                                          | $R_{\theta JC}$ | 0.15                 | °C/W |
| Thermal Impedance, Junction to Case<br>Pulse: Case Temperature $66^\circ\text{C}$ , 1250 W Pulse, 100 $\mu\text{sec}$ Pulse Width, 20% Duty Cycle,<br>$I_{DQ} = 100\text{ mA}$ , 230 MHz | $Z_{\theta JC}$ | 0.027                | °C/W |

**Table 3. ESD Protection Characteristics**

| Test Methodology                      | Class             |
|---------------------------------------|-------------------|
| Human Body Model (per JESD22-A114)    | 2, passes 3500 V  |
| Machine Model (per EIA/JESD22-A115)   | B, passes 250 V   |
| Charge Device Model (per JESD22-C101) | IV, passes 4000 V |

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

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

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

|                                                                                                    |               |     |   |    |                 |
|----------------------------------------------------------------------------------------------------|---------------|-----|---|----|-----------------|
| Gate-Source Leakage Current<br>( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )               | $I_{GSS}$     | —   | — | 1  | $\mu\text{Adc}$ |
| Drain-Source Breakdown Voltage<br>( $V_{GS} = 0\text{ Vdc}$ , $I_D = 100\text{ mA}$ )              | $V_{(BR)DSS}$ | 133 | — | —  | Vdc             |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 50\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ )  | $I_{DSS}$     | —   | — | 10 | $\mu\text{Adc}$ |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 100\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$     | —   | — | 20 | $\mu\text{Adc}$ |

**On Characteristics**

|                                                                                                               |              |     |      |     |     |
|---------------------------------------------------------------------------------------------------------------|--------------|-----|------|-----|-----|
| Gate Threshold Voltage <sup>(3)</sup><br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 1776\text{ }\mu\text{Adc}$ )     | $V_{GS(th)}$ | 1.7 | 2.2  | 2.7 | Vdc |
| Gate Quiescent Voltage<br>( $V_{DD} = 50\text{ Vdc}$ , $I_D = 100\text{ mAdc}$ , Measured in Functional Test) | $V_{GS(Q)}$  | 1.9 | 2.2  | 2.9 | Vdc |
| Drain-Source On-Voltage <sup>(3)</sup><br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 2\text{ Adc}$ )                 | $V_{DS(on)}$ | —   | 0.15 | —   | Vdc |
| Forward Transconductance<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 30\text{ Adc}$ )                              | $g_{fs}$     | —   | 28.0 | —   | S   |

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

|                                                                                                                       |           |   |     |   |    |
|-----------------------------------------------------------------------------------------------------------------------|-----------|---|-----|---|----|
| Reverse Transfer Capacitance<br>( $V_{DS} = 50\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$ | — | 2.8 | — | pF |
| Output Capacitance<br>( $V_{DS} = 50\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )           | $C_{oss}$ | — | 185 | — | pF |
| Input Capacitance<br>( $V_{DS} = 50\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz)            | $C_{iss}$ | — | 562 | — | 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>.  
Select Documentation/Application Notes - AN1955.

3. Each side of device measured separately.

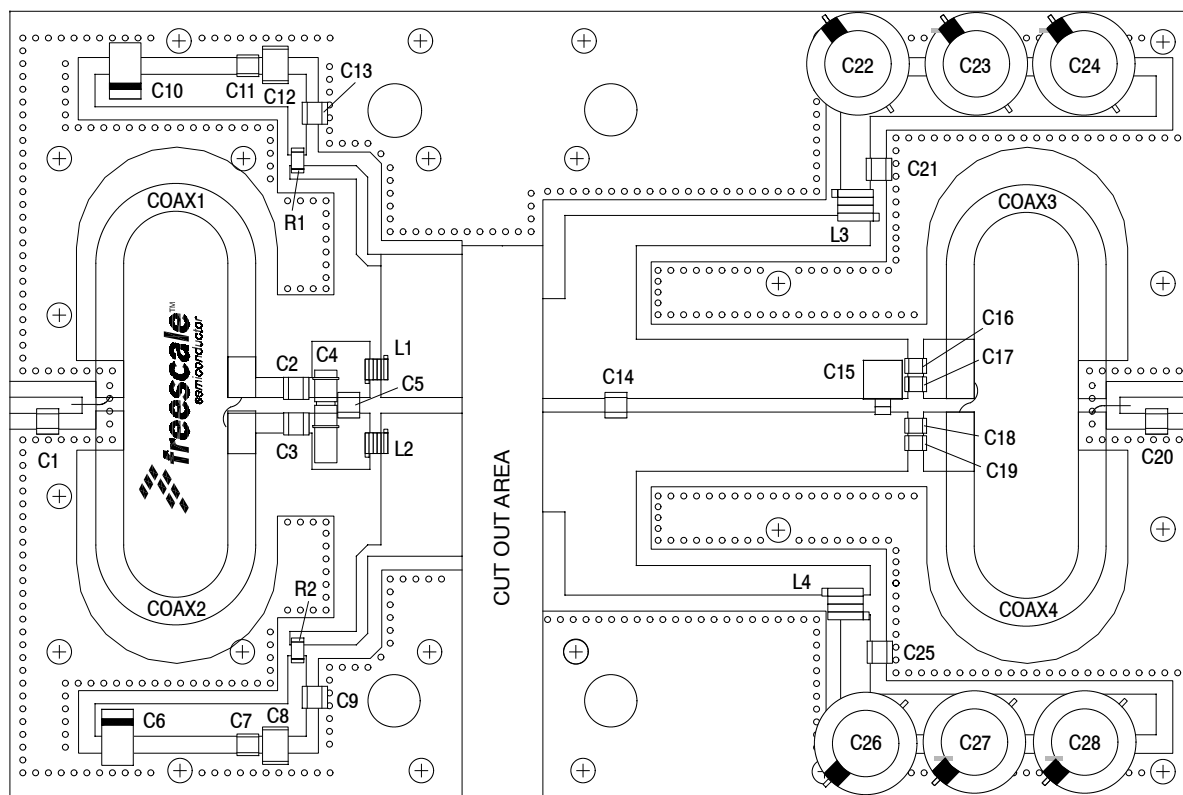
(continued)

**Table 4. 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) $V_{DD} = 50\text{ Vdc}$ , $I_{DQ} = 100\text{ mA}$ , $P_{out} = 1250\text{ W Peak}$ (250 W Avg.), $f = 230\text{ MHz}$ , 100 $\mu\text{sec}$ Pulse Width, 20% Duty Cycle |          |      |      |      |      |
| Power Gain                                                                                                                                                                                                                                   | $G_{ps}$ | 23.0 | 24.0 | 26.0 | dB   |
| Drain Efficiency                                                                                                                                                                                                                             | $\eta_D$ | 72.5 | 74.0 | —    | %    |
| Input Return Loss                                                                                                                                                                                                                            | IRL      | —    | -14  | -10  | dB   |

**Table 5. Load Mismatch/Ruggedness** (In Freescale Test Fixture, 50 ohm system)  $I_{DQ} = 100\text{ mA}$ 

| Frequency (MHz) | Signal Type                                     | VSWR                         | $P_{out}$ (W)                 | Test Voltage, $V_{DD}$ | Result                |
|-----------------|-------------------------------------------------|------------------------------|-------------------------------|------------------------|-----------------------|
| 230             | Pulse<br>(100 $\mu\text{sec}$ , 20% Duty Cycle) | >65:1 at all<br>Phase Angles | 1500 Peak<br>(3 dB Overdrive) | 50                     | No Device Degradation |



**Figure 2. MMRF1306HR5(HSR5) 230 MHz Production Test Circuit Component Layout — Pulse**

**Table 6. MMRF1306HR5(HSR5) 230 MHz Production Test Circuit Component Designations and Values — Pulse**

| Part                         | Description                                     | Part Number          | Manufacturer |
|------------------------------|-------------------------------------------------|----------------------|--------------|
| C1                           | 20 pF Chip Capacitor                            | ATC100B200JT500XT    | ATC          |
| C2, C3, C5                   | 27 pF Chip Capacitors                           | ATC100B270JT500XT    | ATC          |
| C4                           | 0.8–8.0 pF Variable Capacitor, Gigatrim         | 27291SL              | Johanson     |
| C6, C10                      | 22 $\mu$ F, 35 V Tantalum Capacitors            | T491X226K035AT       | Kemet        |
| C7, C11                      | 0.1 $\mu$ F Chip Capacitors                     | CDR33BX104AKYS       | AVX          |
| C8, C12                      | 220 nF Chip Capacitors                          | C1812C224K5RACTU     | Kemet        |
| C9, C13, C21, C25            | 1000 pF Chip Capacitors                         | ATC100B102JT50XT     | ATC          |
| C14                          | 43 pF Chip Capacitor                            | ATC100B430JT500XT    | ATC          |
| C15                          | 75 pF Metal Mica                                | MIN02-002EC750J-F    | CDE          |
| C16, C17, C18, C19           | 240 pF Chip Capacitors                          | ATC100B241JT200XT    | ATC          |
| C20                          | 6.2 pF Chip Capacitor                           | ATC100B6R2BT500XT    | ATC          |
| C22, C23, C24, C26, C27, C28 | 470 $\mu$ F, 63 V Electrolytic Capacitors       | MCGPR63V477M13X26-RH | Multicomp    |
| Coax1, 2, 3, 4               | 25 $\Omega$ Semi Rigid Coax, 2.2" Shield Length | UT-141C-25           | Micro-Coax   |
| L1, L2                       | 5 nH Inductors                                  | A02TKLC              | Coilcraft    |
| L3, L4                       | 6.6 nH Inductors                                | GA3093-ALC           | Coilcraft    |
| R1, R2                       | 10 $\Omega$ Chip Resistors                      | CRCW120610R0JNEA     | Vishay       |
| PCB                          | 0.030", $\epsilon_r = 2.55$                     | AD255A               | Arlon        |

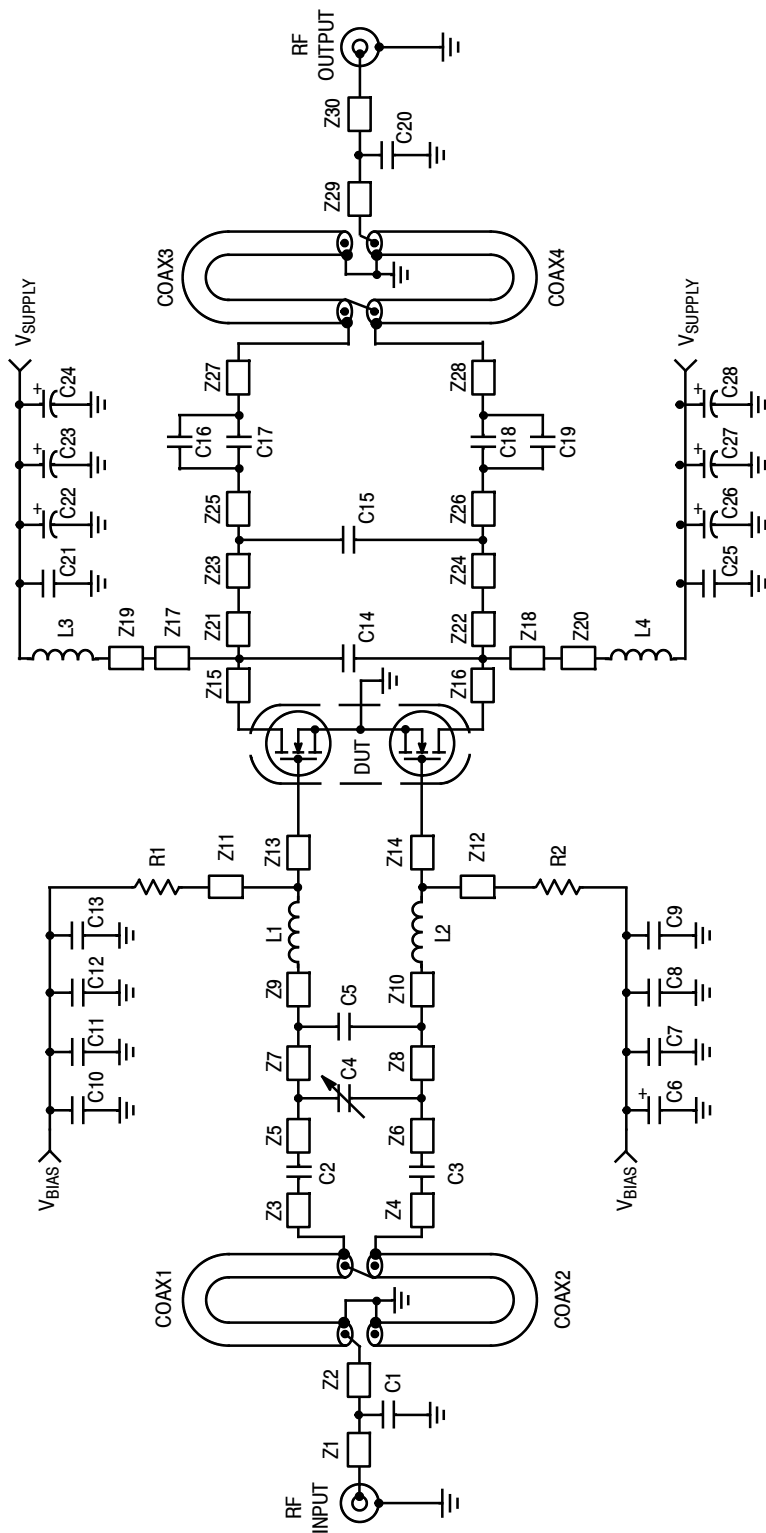


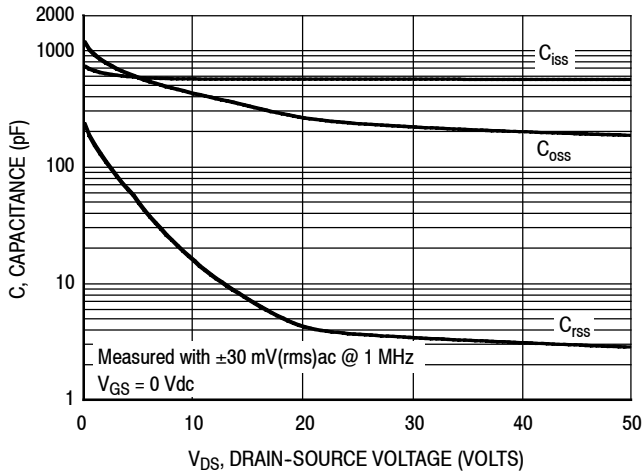
Figure 3. MMRF1306HR5(HSR5) 230 MHz Production Test Circuit Schematic — Pulse

Table 7. MMRF1306HR5(HSR5) 230 MHz Production Test Circuit Microstrips — Pulse

| Microstrip | Description                | Microstrip | Description                |
|------------|----------------------------|------------|----------------------------|
| Z1         | 0.192" × 0.082" Microstrip | Z11*, Z12* | 0.872" × 0.058" Microstrip |
| Z2         | 0.175" × 0.082" Microstrip | Z13, Z14   | 0.412" × 0.726" Microstrip |
| Z3, Z4     | 0.170" × 0.100" Microstrip | Z15, Z16   | 0.371" × 0.507" Microstrip |
| Z5, Z6     | 0.116" × 0.285" Microstrip | Z17*, Z18* | 0.466" × 0.363" Microstrip |
| Z7, Z8     | 0.116" × 0.285" Microstrip | Z19*, Z20* | 0.187" × 0.154" Microstrip |
| Z9, Z10    | 0.108" × 0.285" Microstrip | Z21, Z22   | 0.104" × 0.507" Microstrip |
|            |                            | Z23, Z24   | 1.251" × 0.300" Microstrip |
|            |                            | Z25, Z26   | 0.127" × 0.300" Microstrip |
|            |                            | Z27, Z28   | 0.116" × 0.300" Microstrip |
|            |                            | Z29        | 0.186" × 0.082" Microstrip |
|            |                            | Z30        | 0.179" × 0.082" Microstrip |

\* Line length includes microstrip bends

## TYPICAL CHARACTERISTICS



Note: Each side of device measured separately.

Figure 4. Capacitance versus Drain-Source Voltage

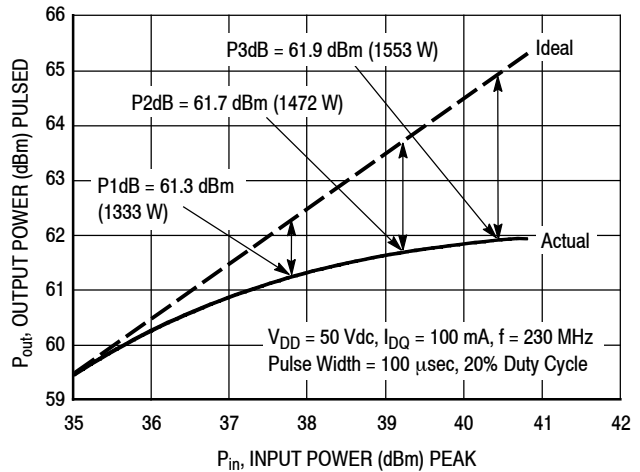


Figure 5. Output Power versus Input Power

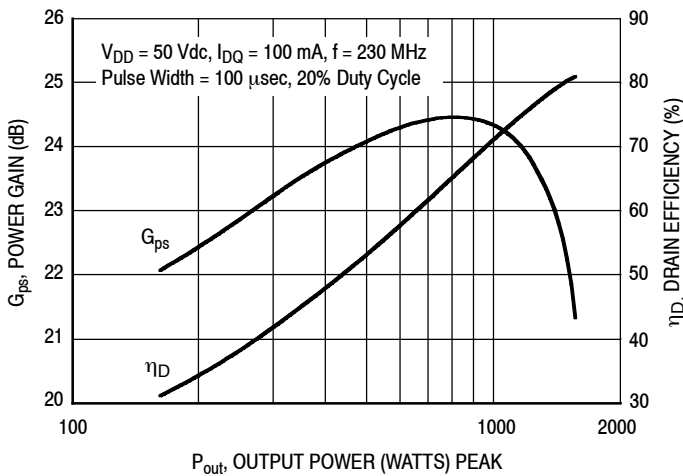


Figure 6. Power Gain and Drain Efficiency versus Output Power

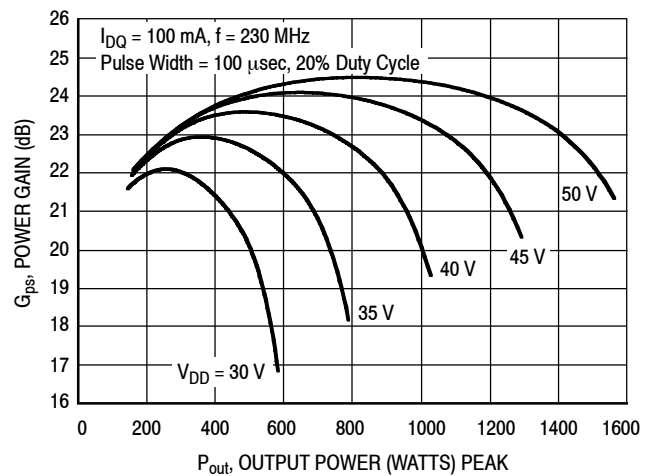


Figure 7. Power Gain versus Output Power

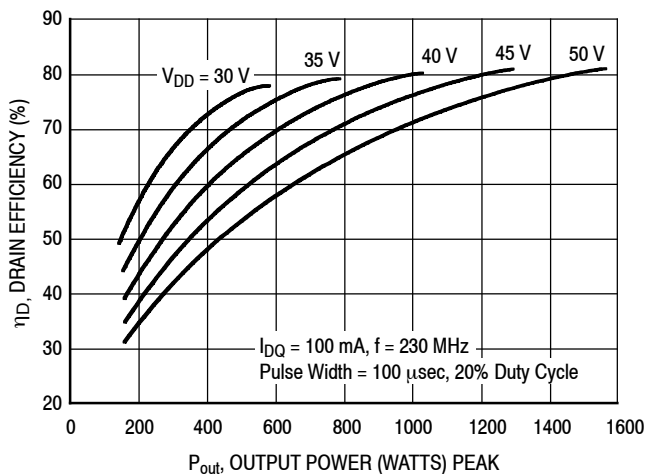


Figure 8. Drain Efficiency versus Output Power

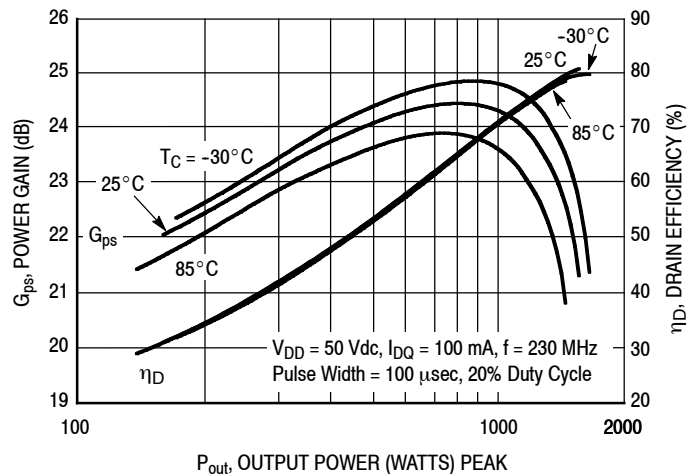
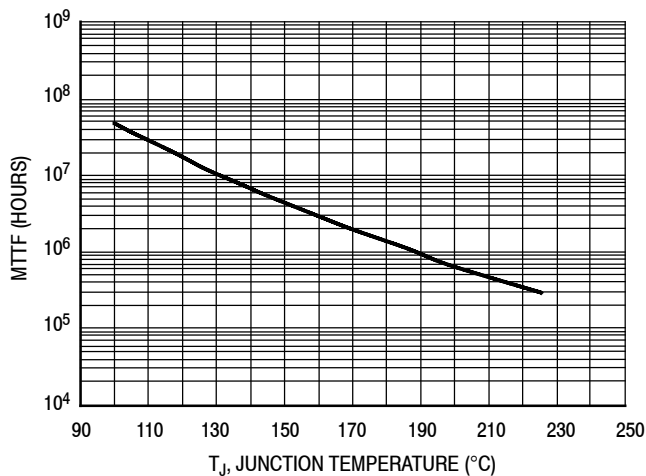


Figure 9. Power Gain and Drain Efficiency versus Output Power

## TYPICAL CHARACTERISTICS



This above graph displays calculated MTTF in hours when the device is operated at  $V_{DD} = 50$  Vdc,  $P_{out} = 1250$  W CW, and  $\eta_D = 74.6\%$ .

MTTF calculator available at <http://www.freescale.com/rf>. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.

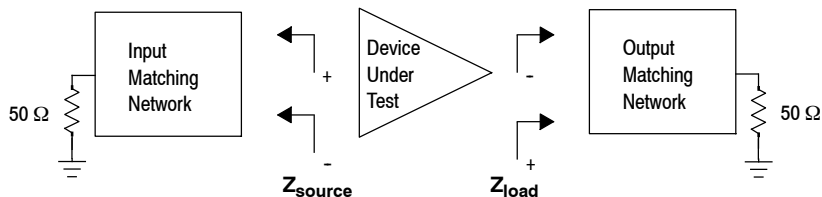
**Figure 10. MTTF versus Junction Temperature — CW**

$V_{DD} = 50$  Vdc,  $I_{DQ} = 100$  mA,  $P_{out} = 1250$  W Peak

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 230      | $1.29 + j3.54$           | $2.12 + j2.68$         |

$Z_{source}$  = Test circuit impedance as measured from gate to gate, balanced configuration.

$Z_{load}$  = Test circuit impedance as measured from drain to drain, balanced configuration.



**Figure 11. Series Equivalent Test Circuit Source and Load Impedance — 230 MHz Pulse**

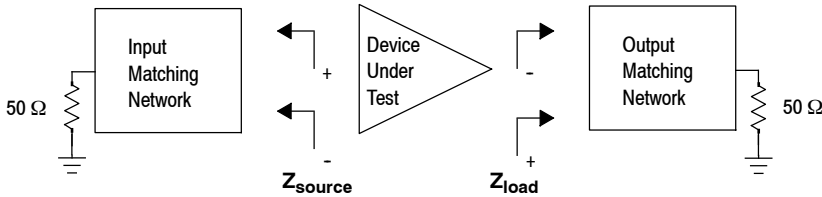
$V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 100 \text{ mA}$

| f<br>(MHz) | $Z_{\text{source}}$<br>( $\Omega$ ) | $Z_{\text{load}}$<br>( $\Omega$ ) |
|------------|-------------------------------------|-----------------------------------|
| 1.8 (1)    | $34.4 + j192.0$ (1)                 | $5.00 - j4.00$ (1)                |
| 27         | $12.5 + j7.00$                      | $7.00 + j0.70$                    |
| 40         | $5.75 + j5.06$                      | $5.39 + j2.62$                    |
| 81.36      | $4.04 + j5.93$                      | $4.89 + j2.95$                    |
| 88         | $2.20 + j6.70$                      | $4.90 + j2.90$                    |
| 98         | $2.30 + j6.90$                      | $4.10 + j2.50$                    |
| 108        | $2.30 + j7.00$                      | $4.40 + j3.60$                    |
| 144        | $1.60 + j5.00$                      | $3.90 + j1.50$                    |
| 175        | $1.33 + j3.90$                      | $3.50 + j2.50$                    |
| 230        | $1.29 + j3.54$                      | $2.12 + j2.68$                    |
| 352        | $0.98 + j1.45$                      | $1.82 + j2.05$                    |
| 500        | $0.29 + j1.47$                      | $1.79 + j1.80$                    |

1. Simulated data.

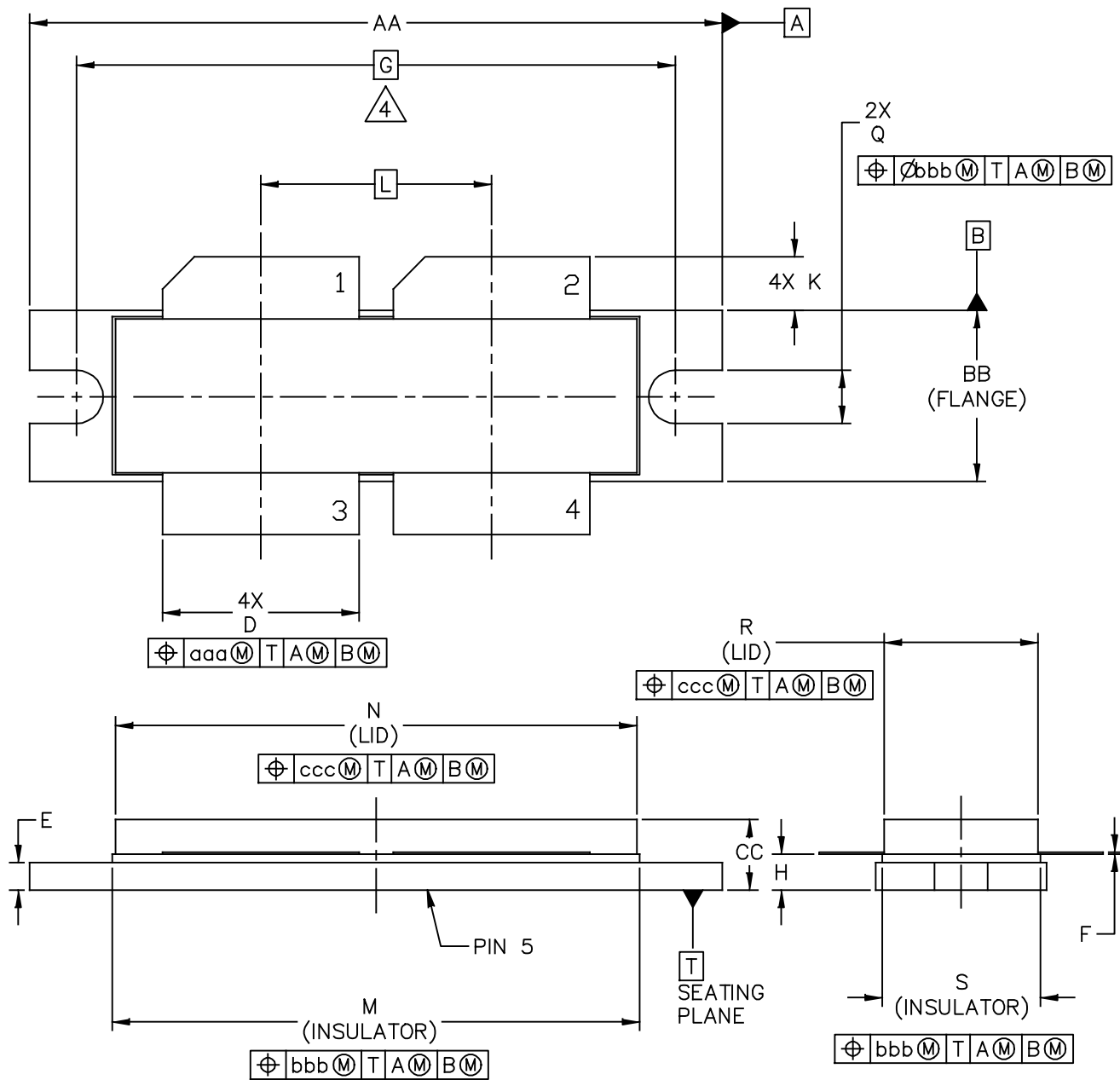
$Z_{\text{source}}$  = Test circuit impedance as measured from gate to gate, balanced configuration.

$Z_{\text{load}}$  = Test circuit impedance as measured from drain to drain, balanced configuration.



**Figure 12. Source and Load Impedances Optimized for IRL, Power and Efficiency — Push-Pull**

# PACKAGE DIMENSIONS



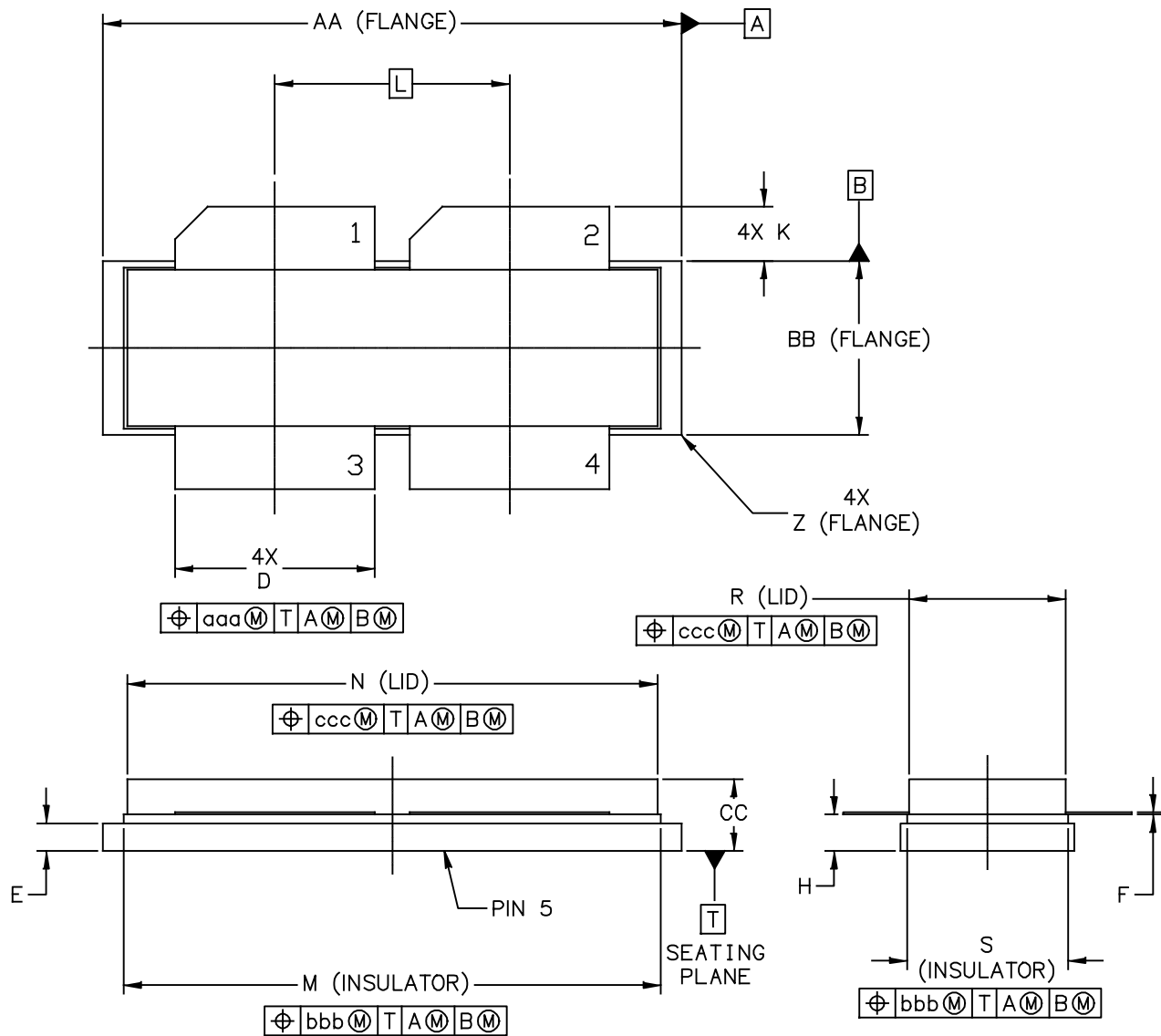
|                                                         |                          |                            |
|---------------------------------------------------------|--------------------------|----------------------------|
| © FREESCALE SEMICONDUCTOR, INC.<br>ALL RIGHTS RESERVED. | MECHANICAL OUTLINE       | PRINT VERSION NOT TO SCALE |
| TITLE:<br><br>NI-1230-4H                                | DOCUMENT NO: 98ASB16977C | REV: F                     |
|                                                         | STANDARD: NON-JEDEC      |                            |
|                                                         |                          | 28 FEB 2013                |

# NOTES:

1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH
3. DIMENSION H IS MEASURED .030 INCH (0.762 MM) AWAY FROM PACKAGE BODY.

4.  RECOMMENDED BOLT CENTER DIMENSION OF 1.52 INCH (38.61 MM) BASED ON M3 SCREW.

| INCH                                                    |           |       | MILLIMETER         |       | DIM                                                  | INCH                       |       | MILLIMETER |       |
|---------------------------------------------------------|-----------|-------|--------------------|-------|------------------------------------------------------|----------------------------|-------|------------|-------|
| DIM                                                     | MIN       | MAX   | MIN                | MAX   |                                                      | MIN                        | MAX   | MIN        | MAX   |
| AA                                                      | 1.615     | 1.625 | 41.02              | 41.28 | N                                                    | 1.218                      | 1.242 | 30.94      | 31.55 |
| BB                                                      | .395      | .405  | 10.03              | 10.29 | Q                                                    | .120                       | .130  | 3.05       | 3.30  |
| CC                                                      | .170      | .190  | 4.32               | 4.83  | R                                                    | .355                       | .365  | 9.02       | 9.27  |
| D                                                       | .455      | .465  | 11.56              | 11.81 | S                                                    | .365                       | .375  | 9.27       | 9.53  |
| E                                                       | .062      | .066  | 1.57               | 1.68  |                                                      |                            |       |            |       |
| F                                                       | .004      | .007  | 0.10               | 0.18  |                                                      |                            |       |            |       |
| G                                                       | 1.400 BSC |       | 35.56 BSC          |       | aaa                                                  | .013                       |       | 0.33       |       |
| H                                                       | .082      | .090  | 2.08               | 2.29  | bbb                                                  | .010                       |       | 0.25       |       |
| K                                                       | .117      | .137  | 2.97               | 3.48  | ccc                                                  | .020                       |       | 0.51       |       |
| L                                                       | .540 BSC  |       | 13.72 BSC          |       |                                                      |                            |       |            |       |
| M                                                       | 1.219     | 1.241 | 30.96              | 31.52 |                                                      |                            |       |            |       |
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| TITLE:<br><br>NI-1230-4H                                |           |       |                    |       | DOCUMENT NO: 98ASB16977C                      REV: F |                            |       |            |       |
|                                                         |           |       |                    |       | STANDARD: NON-JEDEC                                  |                            |       |            |       |
|                                                         |           |       |                    |       | 28 FEB 2013                                          |                            |       |            |       |



|                                                         |                          |                            |
|---------------------------------------------------------|--------------------------|----------------------------|
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| TITLE:<br><br>NI-1230-4S                                | DOCUMENT NO: 98ARB18247C | REV: G                     |
|                                                         | STANDARD: NON-JEDEC      |                            |
|                                                         | 01 MAR 2013              |                            |

NOTES:

1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M—1994.
2. CONTROLLING DIMENSION: INCH
3. DIMENSION H IS MEASURED .030 INCH (0.762 MM) AWAY FROM PACKAGE BODY

| DIM                                                     | INCHES   |       | MILLIMETERS        |       | DIM | INCHES                               |       | MILLIMETERS |       |
|---------------------------------------------------------|----------|-------|--------------------|-------|-----|--------------------------------------|-------|-------------|-------|
|                                                         | MIN      | MAX   | MIN                | MAX   |     | MIN                                  | MAX   | MIN         | MAX   |
| AA                                                      | 1.265    | 1.275 | 32.13              | 32.39 | R   | .355                                 | .365  | 9.02        | 9.27  |
| BB                                                      | .395     | .405  | 10.03              | 10.29 | S   | .365                                 | .375  | 9.27        | 9.53  |
| CC                                                      | .170     | .190  | 4.32               | 4.83  | Z   | R.000                                | R.040 | R0.00       | R1.02 |
| D                                                       | .455     | .465  | 11.56              | 11.81 |     |                                      |       |             |       |
| E                                                       | .062     | .066  | 1.57               | 1.68  | aaa | .013                                 |       | 0.33        |       |
| F                                                       | .004     | .007  | 0.10               | 0.18  | bbb | .010                                 |       | 0.25        |       |
| H                                                       | .082     | .090  | 2.08               | 2.29  | ccc | .020                                 |       | 0.51        |       |
| K                                                       | .117     | .137  | 2.97               | 3.48  |     |                                      |       |             |       |
| L                                                       | .540 BSC |       | 13.72 BSC          |       |     |                                      |       |             |       |
| M                                                       | 1.219    | 1.241 | 30.96              | 31.52 |     |                                      |       |             |       |
| N                                                       | 1.218    | 1.242 | 30.94              | 31.55 |     |                                      |       |             |       |
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|                                                         |          |       |                    |       |     | STANDARD: NON-JEDEC                  |       |             |       |
|                                                         |          |       |                    |       |     | 01 MAR 2013                          |       |             |       |

## 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                                                                                                           |
|----------|-----------|-----------------------------------------------------------------------------------------------------------------------|
| 0        | Dec. 2013 | • Initial Release of Data Sheet                                                                                       |
| 1        | Aug. 2014 | • Application circuit table added and band of operation updated to 1.8–600 MHz to reflect performance of device, p. 1 |

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