**Freescale Semiconductor**
Technical Data

Document Number: MML25231HT1
Rev. 0, 4/2016

# Enhancement Mode pHEMT Technology (E-pHEMT)

## Low Noise Amplifier

**MML25231HT1**

**1000–4000 MHz, 15.2 dB**
**23 dBm, 0.36 NF**
**E-pHEMT LNA**



**DFN 2 × 2**

The MML25231H is a single-stage low noise amplifier (LNA) with active bias and high isolation for use in cellular infrastructure applications. It is designed for a range of low noise, high linearity applications such as picocell, femtocell, tower mounted amplifiers (TMA) and receiver front-end circuits. It operates from a single voltage supply and is suitable for applications with frequencies from 1000 to 4000 MHz such as CDMA, W-CDMA and LTE.

### Features

- Ultra Low Noise Figure: 0.39 dB @ 1900 MHz, 0.54 dB @ 2500 MHz
- High Linearity: 34.7 dBm OIP3 @ 1900 MHz, 35.2 dBm @ 2500 MHz
- Frequency: 1000–4000 MHz
- Unconditionally Stable Over Temperature
- P1dB: 22.6 dBm @ 1900 MHz, 22.5 dBm @ 2500 MHz
- Small-Signal Gain: 17.2 dB @ 1900 MHz, 15.2 dB @ 2500 MHz
- Single 5 V Supply
- Power-down Pin
- Supply Current: 60 mA (adjustable externally)
- 50 Ohm Operation (some external matching required)
- Cost-effective 8-pin, 2 mm DFN Surface Mount Plastic Package

**Table 1. Typical Performance (1)**

| Characteristic | Symbol | 1750 MHz | 1920 MHz | 2350 MHz | 2600 MHz | 3600 MHz | Unit |
|---|---|---|---|---|---|---|---|
| Noise Figure | NF | 0.38 | 0.39 | 0.50 | 0.57 | 0.98 | dB |
| Input Return Loss (S11) | IRL | –12.0 | –12.8 | –15.1 | –15.9 | –10.7 | dB |
| Output Return Loss (S22) | ORL | –14.4 | –14.4 | –14.8 | –15.3 | –20.7 | dB |
| Small-Signal Gain (S21) | GP | 17.8 | 17.2 | 15.6 | 14.8 | 11.7 | dB |
| Power Output @ 1dB Compression | P1dB | 22.9 | 22.6 | 22.6 | 22.5 | 22.8 | dBm |
| Third Order Input Intercept Point | IIP3 | 16.5 | 17.5 | 19.3 | 20.7 | 25.1 | dBm |
| Third Order Output Intercept Point | OIP3 | 34.4 | 34.7 | 35.0 | 35.7 | 37.0 | dBm |

1. $V_{DD}$ = 5 Vdc, $T_A$ = 25°C, 50 ohm system, application circuit tuned for specified frequency.

**Table 2. Maximum Ratings**

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{DD}$ | 6 | V |
| Supply Current | $I_{DD}$ | 150 | mA |
| RF Input Power | $P_{in}$ | 20 | dBm |
| Storage Temperature Range | $T_{stg}$ | –65 to +150 | °C |
| Junction Temperature | $T_J$ | 175 | °C |

**Table 3. Thermal Characteristics**

| Characteristic | Symbol | Value (3) | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Case<br>Case Temperature 87°C, 5 Vdc, 65 mA, no RF applied | $R_{\theta JC}$ | 134 | °C/W |

1. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers.* Go to http://www.nxp.com/RF and search for AN1955.

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**Table 4. Electrical Characteristics** ($V_{DD}$ = 5 Vdc, 2600 MHz, $T_A$ = 25°C, 50 ohm system, in Freescale Application Circuit)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Small–Signal Gain (S21) | $G_p$ | 14.2 | 14.8 | — | dB |
| Input Return Loss (S11) | IRL | — | –16.0 | — | dB |
| Output Return Loss (S22) | ORL | — | –15.3 | — | dB |
| Power Output @ 1dB Compression | P1dB | — | 22.5 | — | dBm |
| Third Order Input Intercept Point | IIP3 | — | 20.7 | — | dBm |
| Reverse Isolation (S12) | \|S12\| | — | –20.9 | — | dB |
| Noise Figure | NF | — | 0.56 | — | dB |
| Supply Current (1) | $I_{DD}$ | 55 | 60 | 65 | mA |
| Supply Voltage | $V_{DD}$ | — | 5 | — | V |
| Supply Current in Power Down Mode | $I_{PD}$ | — | 2.8 | — | mA |
| Logic Voltage for Power Down (2)<br>Input High Voltage<br>Input Low Voltage | $V_{PD}$ | <br>1.8<br>0 | <br>—<br>— | <br>$V_{DD}$<br>0.4 | V |

**Table 5. ESD Protection Characteristics**

| Test Methodology | Class |
|---|---|
| Human Body Model (per JESD 22–A114) | 1C |
| Machine Model (per EIA/JESD 22–A115) | A |
| Charge Device Model (per JESD 22–C101) | IV |

**Table 6. Moisture Sensitivity Level**

| Test Methodology | Rating | Package Peak Temperature | Unit |
|---|---|---|---|
| Per JESD22–A113, IPC/JEDEC J–STD–020 | 1 | 260 | °C |

**Table 7. Ordering Information**

| Device | Tape and Reel Information | Package |
|---|---|---|
| MML25231HT1 | T1 Suffix = 1,000 Units, 12 mm Tape Width, 7–inch Reel | DFN 2 × 2 |

1. DC current measured with no RF signal applied.
2. Limits derived from device characterization.

**Table 8. Functional Pin Description**

| Pin Number | Pin Function |
|---|---|
| 1 | $V_{BIAS}$ |
| 2 | $RF_{in}$ |
| 3 | No Connection |
| 4 | No Connection |
| 5 | No Connection |
| 6 | No Connection |
| 7 | $RF_{out}$/Supply Voltage |
| 8 | Power Down (Active High) |

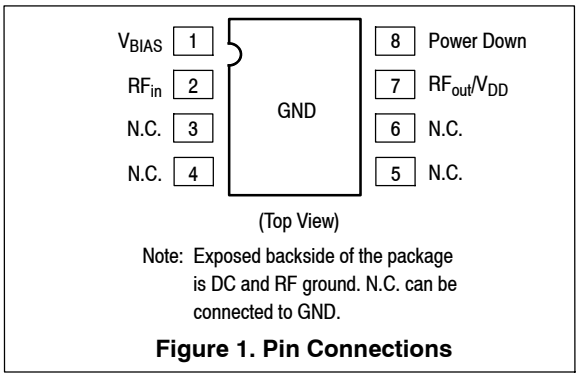



**Figure 1. Pin Connections**

## 50 OHM APPLICATION CIRCUIT: 2500 MHz

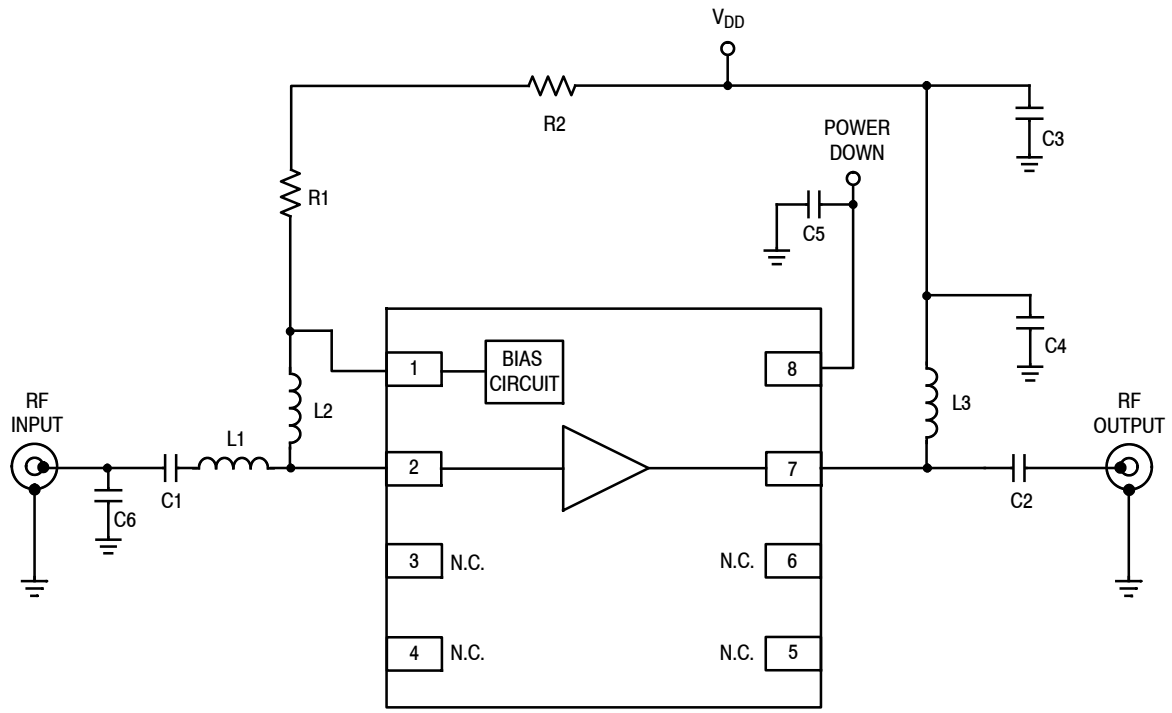
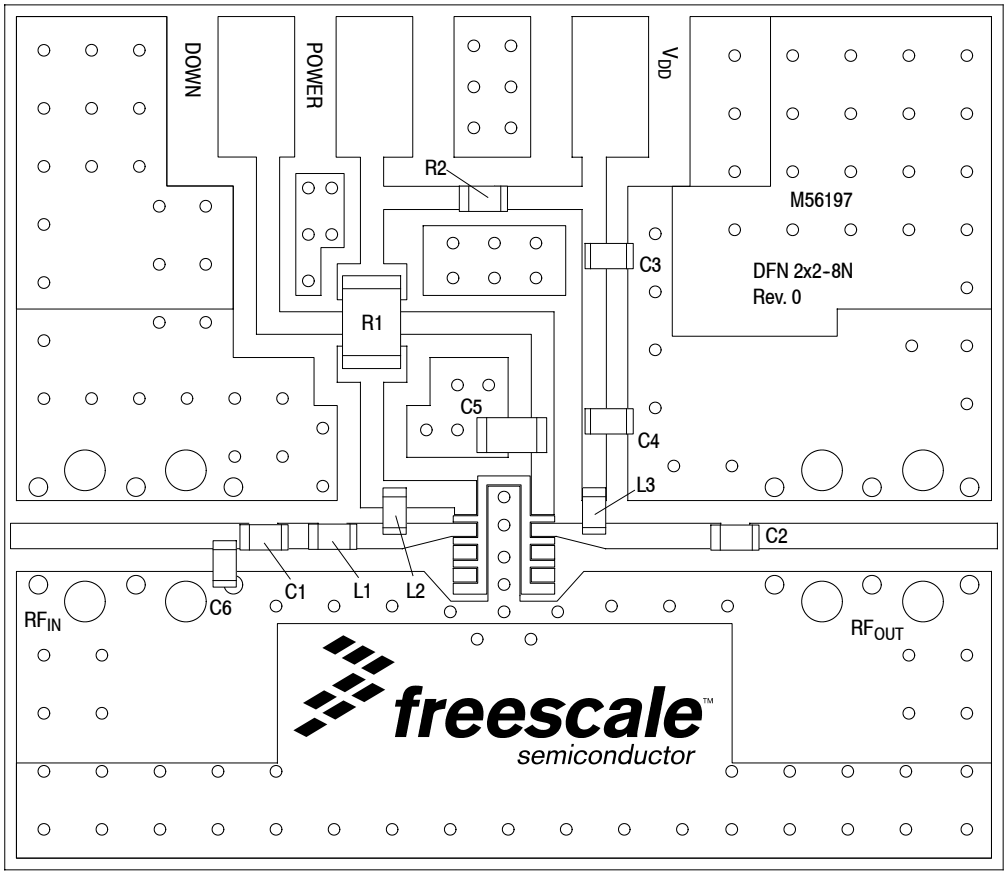



**Figure 2. MML25231HT1 Test Circuit Schematic**

**Table 9. MML25231HT1 Test Circuit Component Designations and Values**

| Part | Description | Part Number | Manufacturer |
|---|---|---|---|
| C1 | 82 pF Chip Capacitor | GRM1555C1H820JA01 | Murata |
| C2 | 9 pF Chip Capacitor | GJM1555C1H9R0CB01 | Murata |
| C3 | 10 pF Chip Capacitor | GJM1555C1H100JB01 | Murata |
| C4 | 0.01 μF Chip Capacitor | GRM155R71E103KA01 | Murata |
| C5 | 1000 pF Chip Capacitor | GRM155R71H102KA01 | Murata |
| C6 | 0.4 pF Chip Capacitor | 04023U0R4BBW | AVX |
| L1 | 1.0 nH Chip Inductor | 0402CS-1N0XJLW | Coilcraft |
| L2 | 68 nH Chip Inductor | 0402HPH-68NXGL | Coilcraft |
| L3 | 40 nH Chip Inductor | 0402HP-40NXGL | Coilcraft |
| R1 | 1800 Ω, 1/4 W Chip Resistor | RK73B2ATTD182J | KOA |
| R2 | 0 Ω, 1.5 A Chip Resistor | CR0402-J/-000GLFCT-ND | Bourns |
| PCB | Rogers RO4350B, 0.010″, $\varepsilon_r$ = 3.66 | M56197 | MTL |

## 50 OHM APPLICATION CIRCUIT: 2500 MHz




PCB actual size: 0.75″ × 0.86″.

NOTE: To achieve optimal noise performance, it is critical that proper biasing, input matching, supply decoupling and grounding are employed.

**Figure 3. MML25231HT1 Test Circuit Component Layout**

**Table 9. MML25231HT1 Test Circuit Component Designations and Values**

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| C3 | 10 pF Chip Capacitor | GJM1555C1H100JB01 | Murata |
| C4 | 0.01 μF Chip Capacitor | GRM155R71E103KA01 | Murata |
| C5 | 1000 pF Chip Capacitor | GRM155R71H102KA01 | Murata |
| C6 | 0.4 pF Chip Capacitor | 04023U0R4BBW | AVX |
| L1 | 1.0 nH Chip Inductor | 0402CS-1N0XJLW | Coilcraft |
| L2 | 68 nH Chip Inductor | 0402HPH-68NXGL | Coilcraft |
| L3 | 40 nH Chip Inductor | 0402HP-40NXGL | Coilcraft |
| R1 | 1800 Ω, 1/4 W Chip Resistor | RK73B2ATTD182J | KOA |
| R2 | 0 Ω, 1.5 A Chip Resistor | CR0402-J/-000GLFCT-ND | Bourns |
| PCB | Rogers RO4350B, 0.010″, $\varepsilon_r$ = 3.66 | M56197 | MTL |

(Test Circuit Component Designations and Values repeated for reference.)

## 50 OHM TYPICAL CHARACTERISTICS: 2500 MHz

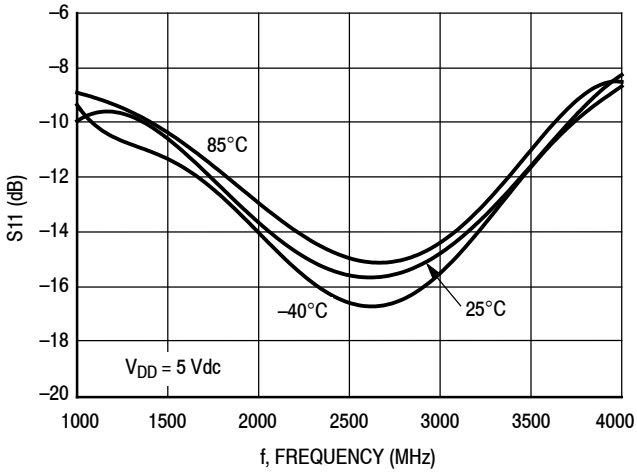



**Figure 4. S11 versus Frequency and Temperature**

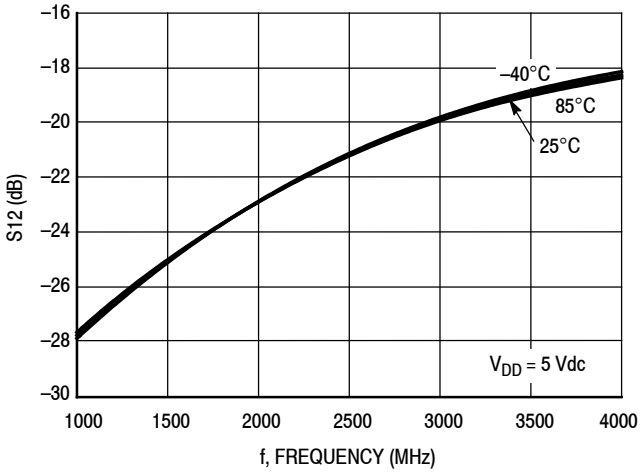



**Figure 5. S12 versus Frequency and Temperature**

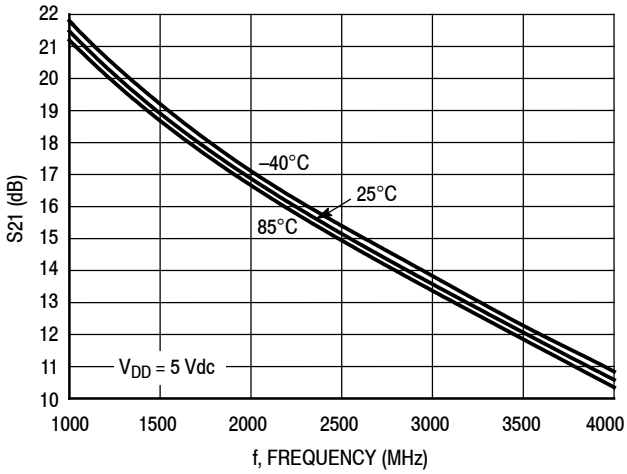



**Figure 6. S21 versus Frequency and Temperature**

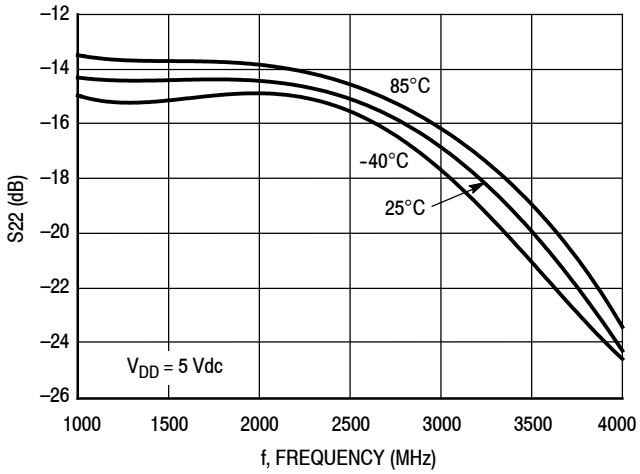



**Figure 7. S22 versus Frequency and Temperature**

## 50 OHM TYPICAL CHARACTERISTICS: 2500 MHz

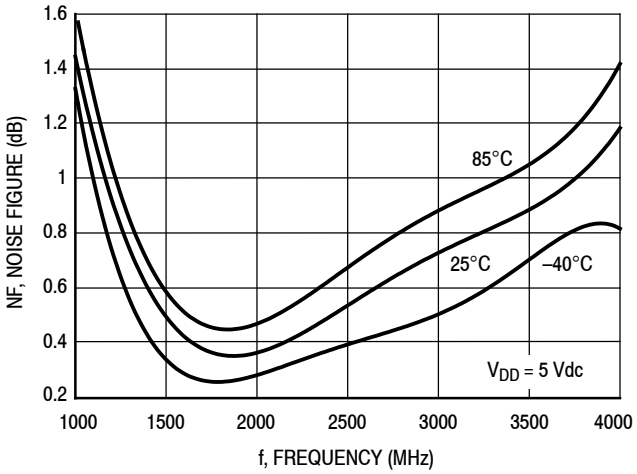



**Figure 8. Noise Figure versus Frequency and Temperature**

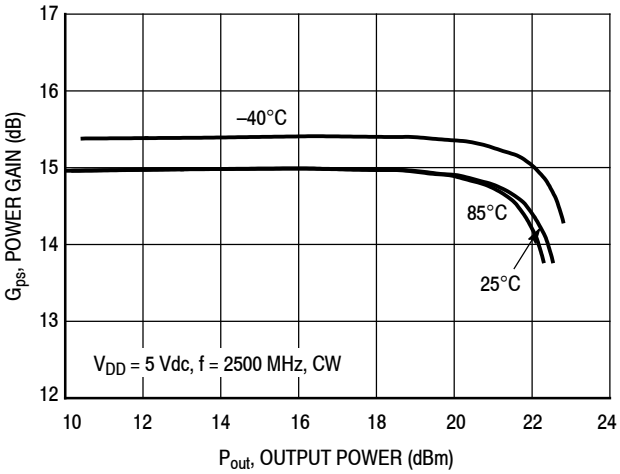



**Figure 9. Power Gain versus Output Power and Temperature**

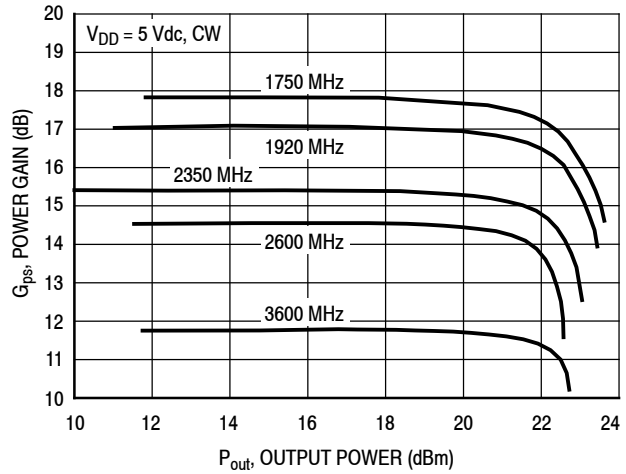



**Figure 10. Power Gain versus Output Power and Frequency**

**Power Gain versus Temperature**

| f (MHz) | Temperature (°) | Gain (dB) | P1dB (dBm) |
|---|---|---|---|
| 1750 | 25 | 17.86 | 22.9 |
| 1750 | –40 | 18.09 | 23 |
| 1750 | 85 | 17.68 | 22.2 |
| 1920 | 25 | 17.16 | 22.6 |
| 1920 | –40 | 17.37 | 23 |
| 1920 | 85 | 16.98 | 22.25 |
| 2350 | 25 | 15.64 | 22.6 |
| 2350 | –40 | 15.84 | 22.9 |
| 2350 | 85 | 15.47 | 22.2 |
| 2500 | 25 | 15.13 | 22.5 |
| 2500 | –40 | 15.38 | 22.75 |
| 2500 | 85 | 14.96 | 22.18 |
| 2600 | 25 | 14.89 | 22.45 |
| 2600 | –40 | 15.11 | 22.75 |
| 2600 | 85 | 14.74 | 22.3 |
| 3600 | 25 | 11.83 | 22.8 |
| 3600 | –40 | 12 | 23 |
| 3600 | 85 | 11.67 | 22.4 |

## 50 OHM TYPICAL CHARACTERISTICS: 2500 MHz

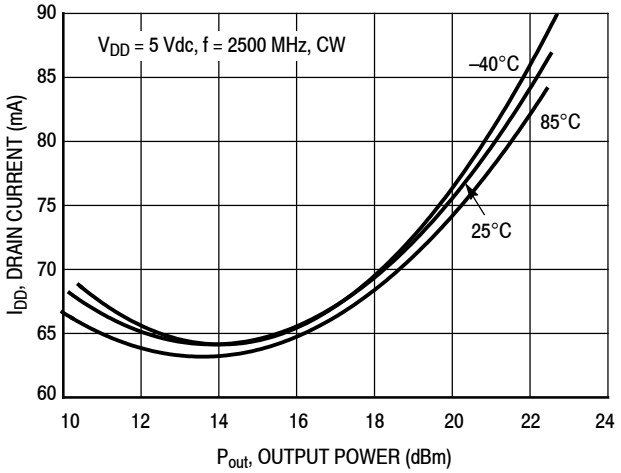



**Figure 11. Drain Current versus Output Power and Temperature**

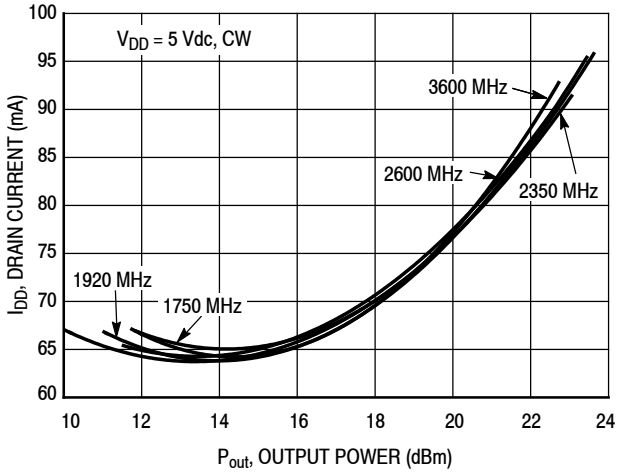



**Figure 12. Drain Current versus Output Power and Frequency**

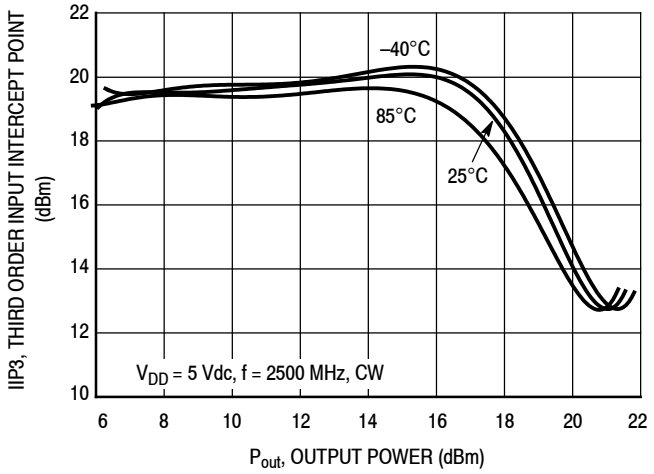



**Figure 13. Third Order Input Intercept Point versus Output Power and Temperature**

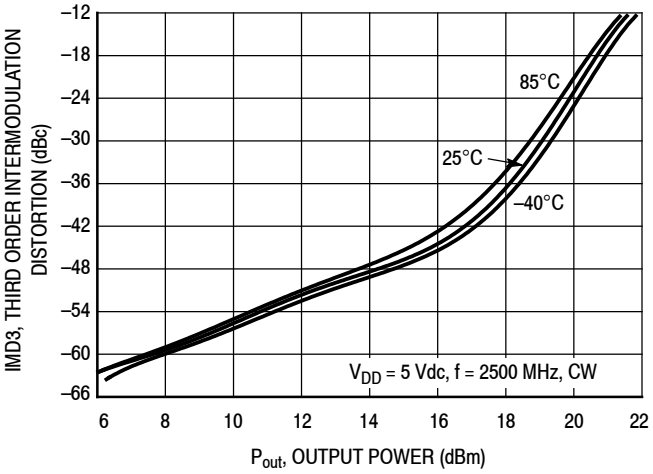



**Figure 14. Third Order Intermodulation Distortion versus Output Power and Temperature**

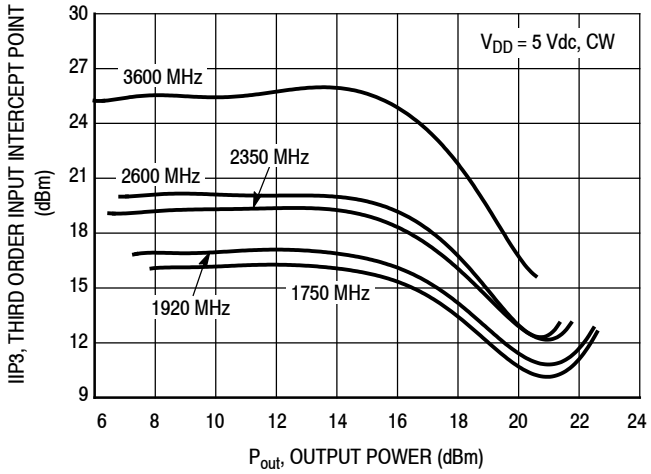



**Figure 15. Third Order Input Intercept Point versus Output Power and Frequency**

## 50 OHM TYPICAL CHARACTERISTICS: 2500 MHz

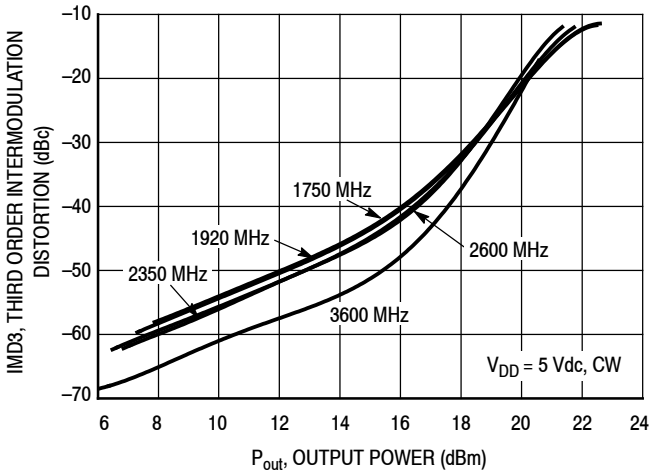



**Figure 16. Third Order Intermodulation Distortion versus Output Power**

**IMD3 and IIP3 versus Temperature**

| f (GHz) | Temperature (°) | $P_{out}$ (dBm) | Gain (dB) | IIP3 (dBm) | IMD3 (dBc) |
|---|---|---|---|---|---|
| 1750 | 25 | 13.9 | 17.9 | 16.5 | –47.0 |
| 1750 | –40 | 14.1 | 18.1 | 16.7 | –47.4 |
| 1750 | 85 | 13.7 | 17.7 | 16.0 | –46.0 |
| 1920 | 25 | 14.2 | 17.2 | 17.6 | –47.1 |
| 1920 | –40 | 14.4 | 17.4 | 17.7 | –47.4 |
| 1920 | 85 | 14.0 | 17.0 | 17.0 | –47.9 |
| 2350 | 25 | 13.7 | 15.7 | 19.3 | –48.7 |
| 2350 | –40 | 13.9 | 15.9 | 19.6 | –49.1 |
| 2350 | 85 | 13.5 | 15.5 | 19.2 | –47.3 |
| 2500 | 25 | 14.2 | 15.2 | 20.0 | –48.1 |
| 2500 | –40 | 14.4 | 15.4 | 20.2 | –48.5 |
| 2500 | 85 | 14.0 | 15.0 | 19.7 | –47.3 |
| 2600 | 25 | 13.9 | 14.9 | 20.7 | –49.5 |
| 2600 | –40 | 14.2 | 15.2 | 20.9 | –49.9 |
| 2600 | 85 | 13.8 | 14.8 | 20.4 | –48.7 |
| 3600 | 25 | 13.9 | 11.9 | 25.1 | –52.3 |
| 3600 | –40 | 14.1 | 12.1 | 25.4 | –52.9 |
| 3600 | 85 | 13.7 | 11.7 | 25.0 | –52.0 |

## 50 OHM APPLICATION CIRCUIT: 2000 MHz

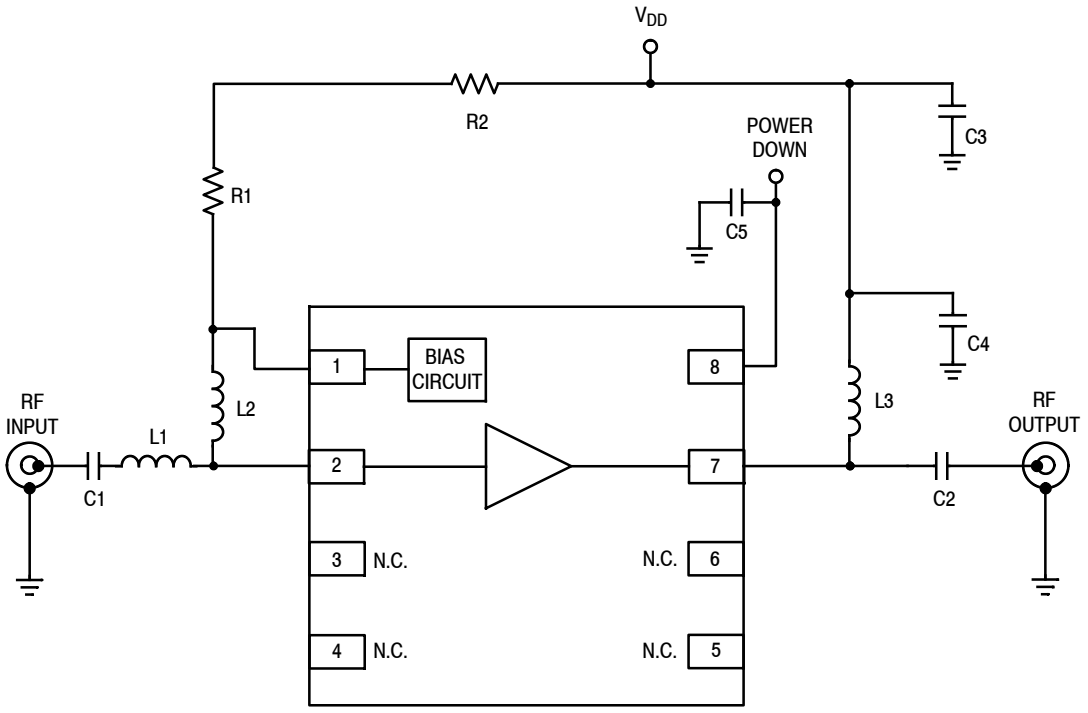
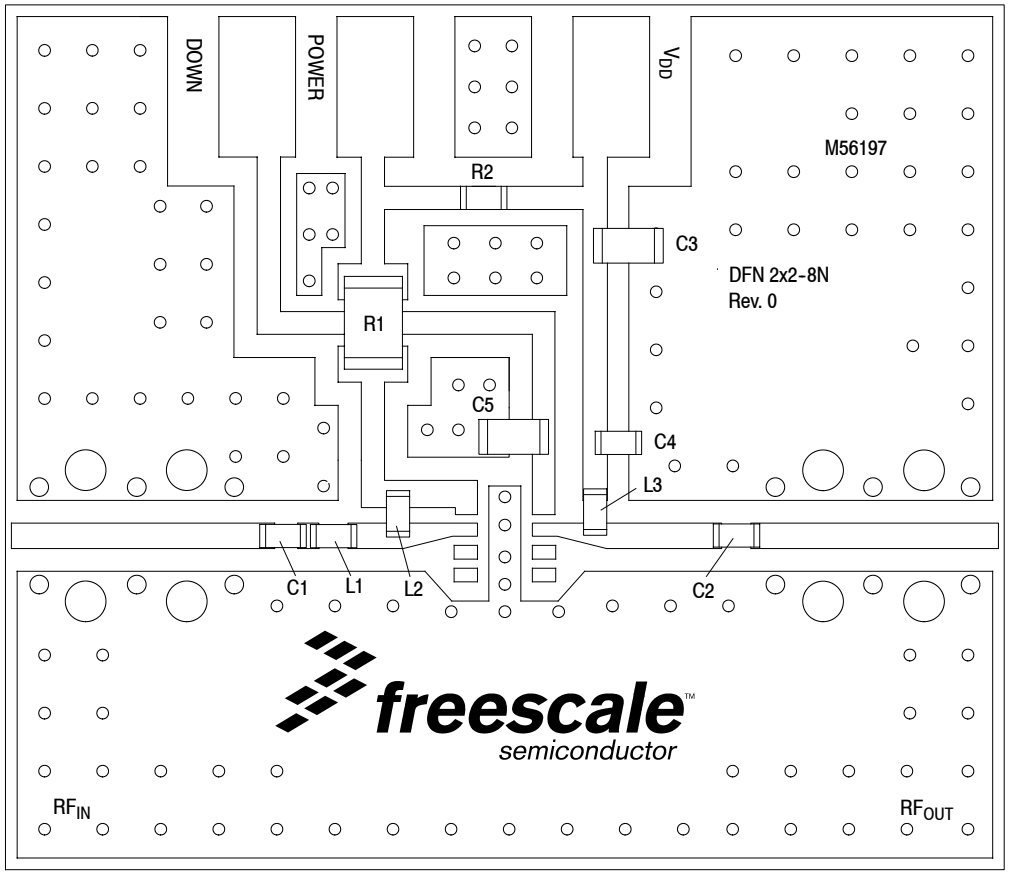



**Figure 17. MML25231HT1 Test Circuit Schematic**

**Table 10. MML25231HT1 Test Circuit Component Designations and Values**

| Part | Description | Part Number | Manufacturer |
|---|---|---|---|
| C1 | 82 pF Chip Capacitor | GRM1555C1H820JA01 | Murata |
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| C4 | 0.01 μF Chip Capacitor | GRM155R71E103KA01 | Murata |
| C5 | 1000 pF Chip Capacitor | GRM155R71H102KA01 | Murata |
| L1 | 1.0 nH Chip Inductor | 0402CS-1N0XJLW | Coilcraft |
| L2 | 68 nH Chip Inductor | 0402HPH-68NXGL | Coilcraft |
| L3 | 40 nH Chip Inductor | 0402HP-40NXGL | Coilcraft |
| R1 | 1800 Ω, 1/4 W Chip Resistor | RK73B2ATTD182J | KOA |
| R2 | 0 Ω, 1.5 A Chip Resistor | CR0402-J/-000GLFCT-ND | Bourns |
| PCB | Rogers RO4350B, 0.010″, $\varepsilon_r$ = 3.66 | M56197 | MTL |

## 50 OHM APPLICATION CIRCUIT: 2000 MHz




PCB actual size: 0.75″ × 0.86″.

NOTE: To achieve optimal noise performance, it is critical that proper biasing, input matching, supply decoupling and grounding are employed.

**Figure 18. MML25231HT1 Test Circuit Component Layout**

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(Test Circuit Component Designations and Values repeated for reference.)

## 50 OHM TYPICAL CHARACTERISTICS: 2000 MHz

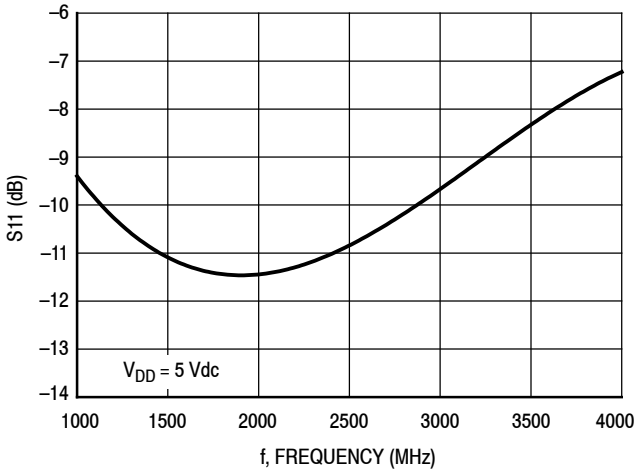



**Figure 19. S11 versus Frequency**

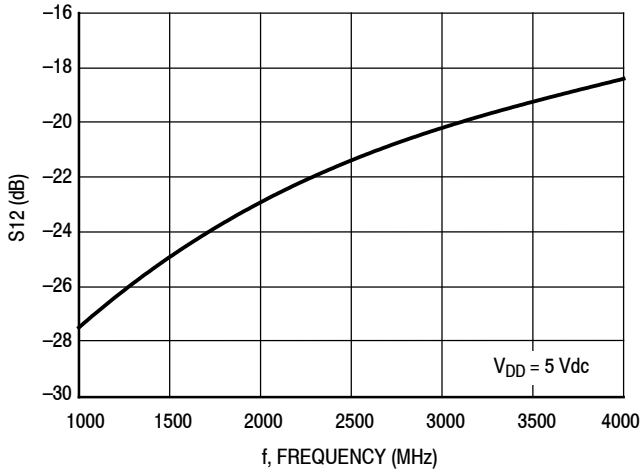



**Figure 20. S12 versus Frequency**

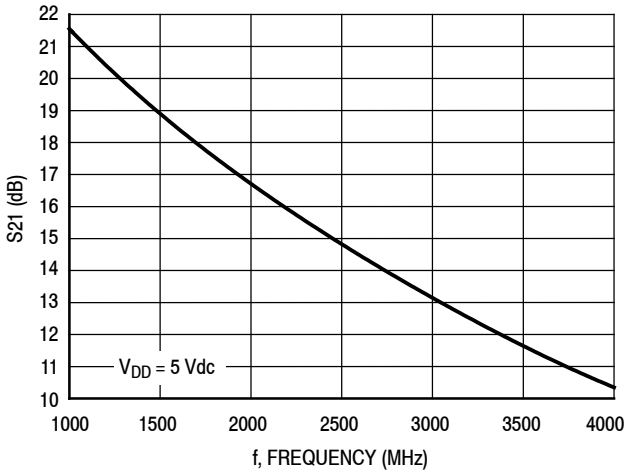



**Figure 21. S21 versus Frequency**

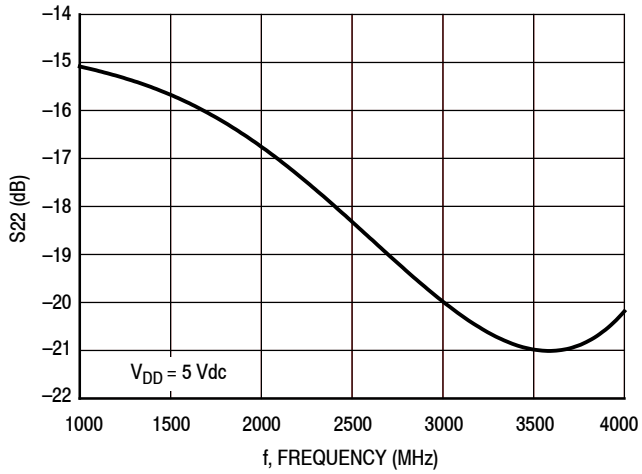



**Figure 22. S22 versus Frequency**

## 50 OHM TYPICAL CHARACTERISTICS: 2000 MHz

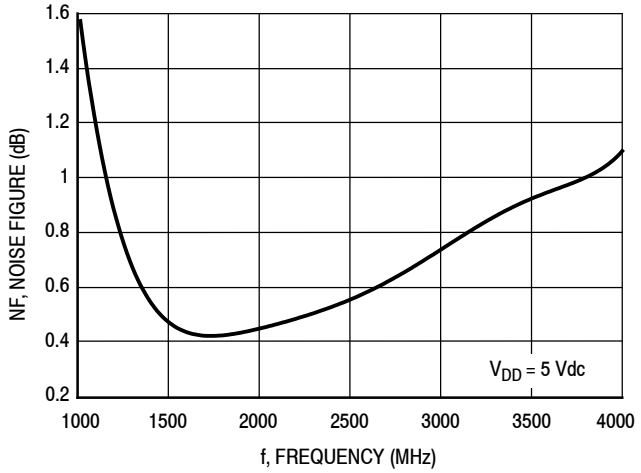



**Figure 23. Noise Figure versus Frequency**

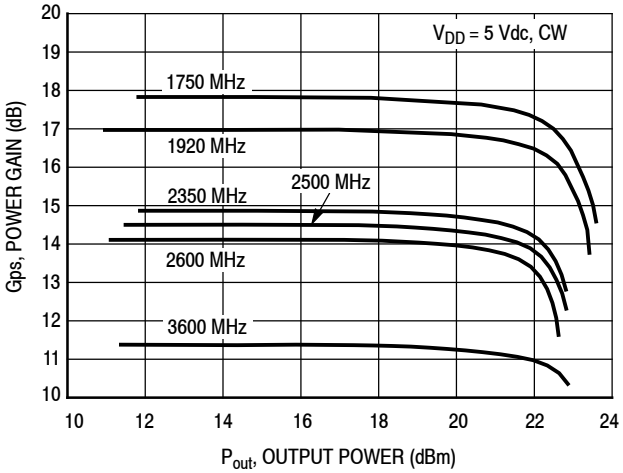



**Figure 24. Power Gain versus Output Power and Frequency**

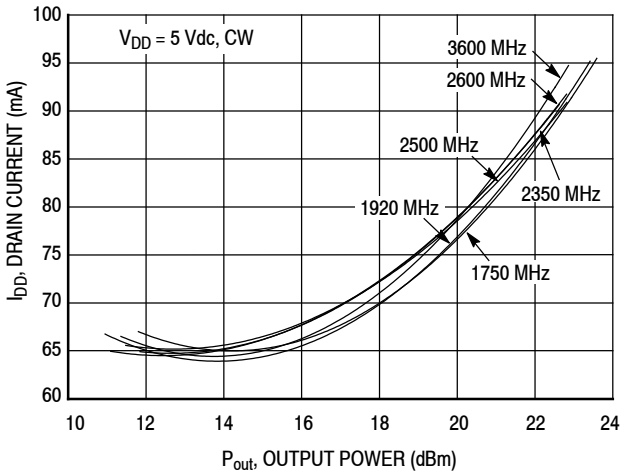



**Figure 25. Drain Current versus Output Power and Frequency**

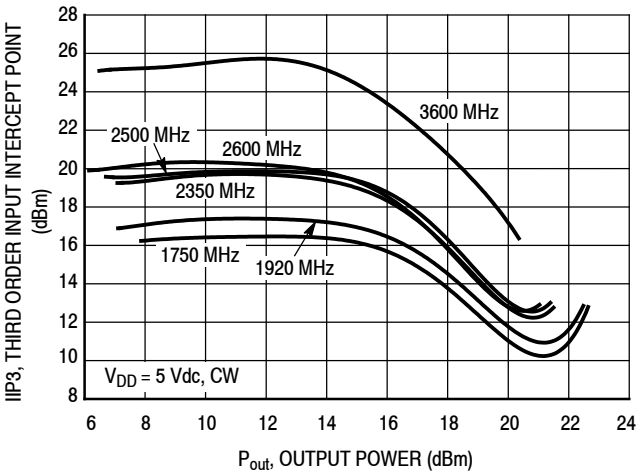



**Figure 26. Third Order Input Intercept Point versus Output Power and Frequency**

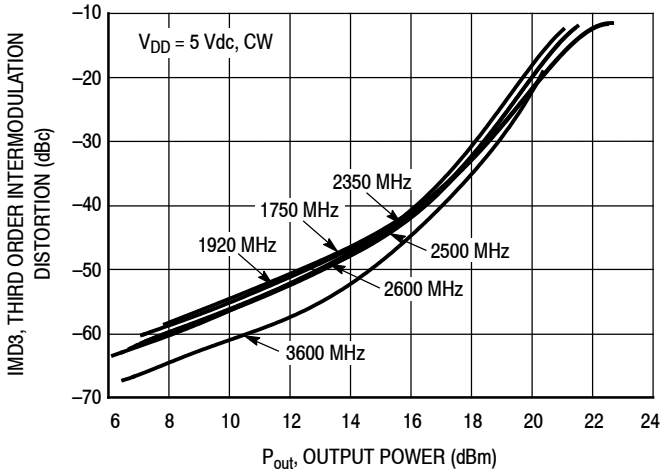



**Figure 27. Third Order Intermodulation Distortion versus Output Power and Frequency**

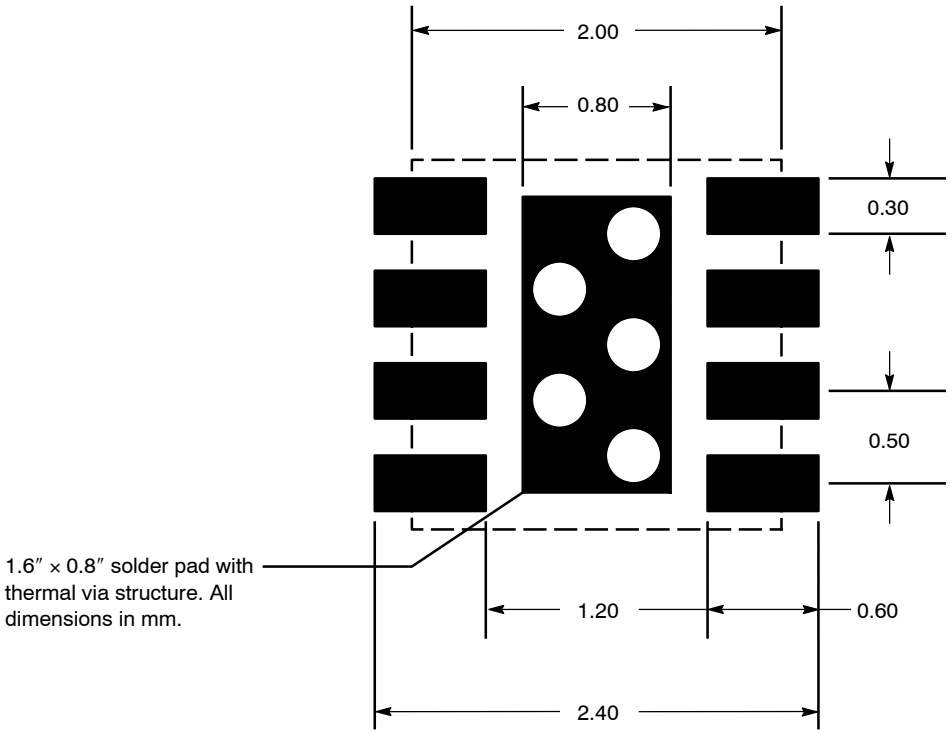



**Figure 28. PCB Pad Layout for DFN 2 × 2**

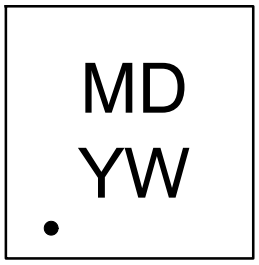
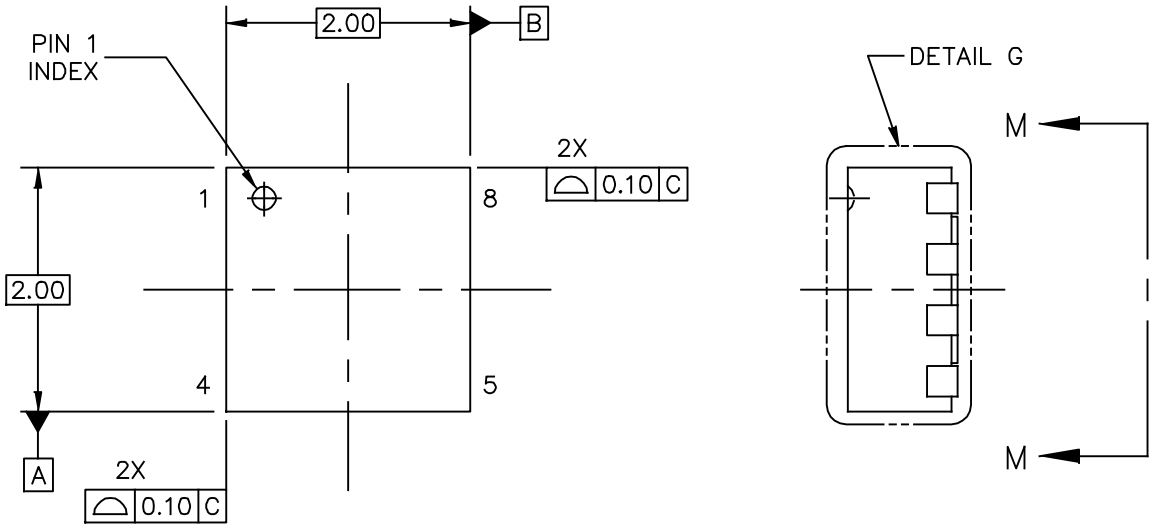
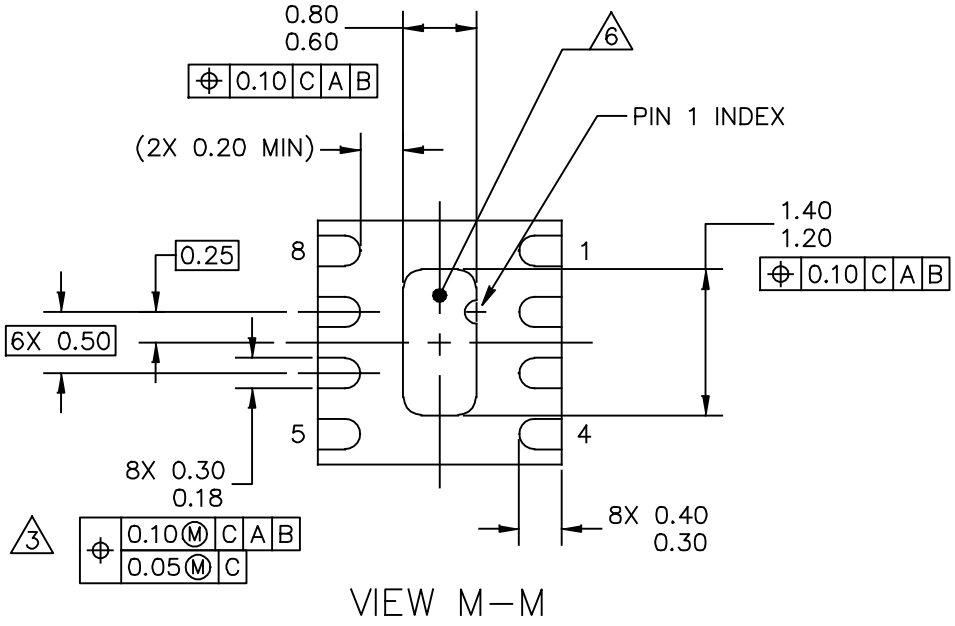



**Figure 29. Product Marking**

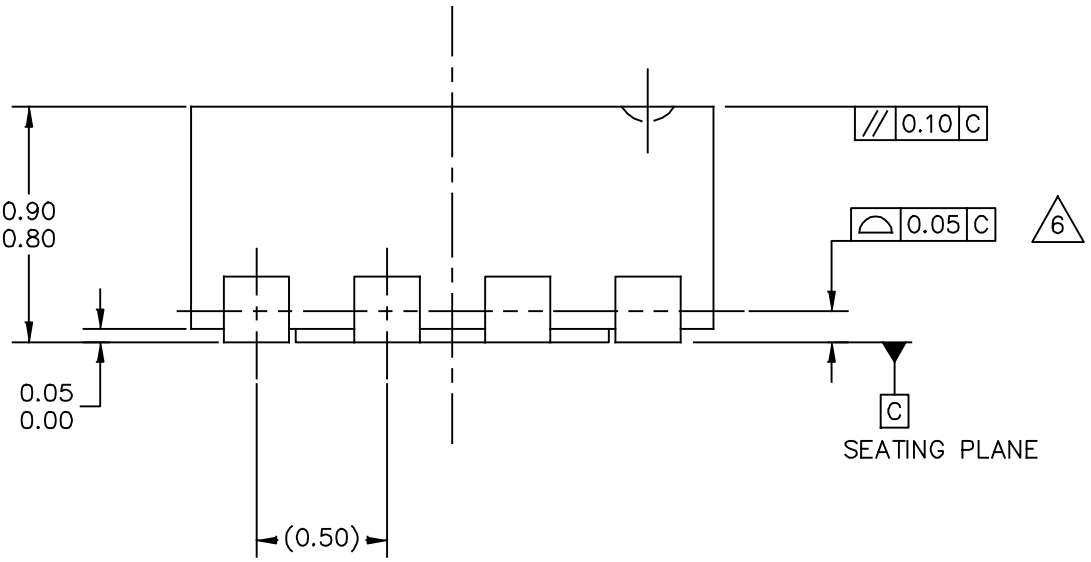
## PACKAGE DIMENSIONS




VIEW M–M

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|---|---|---|
| TITLE: THERMALLY ENHANCED DUAL FLAT NON–LEADED PACKAGE (DFN) 8 TERMINAL, 0.5 PITCH (2 X 2 X 0.85) | DOCUMENT NO: 98ASA00228D | REV: A |
| | STANDARD: NON–JEDEC | |
| | SOT908–4 | 06 JAN 2016 |




DETAIL G
VIEW ROTATED 90° CW

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NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5 – 2009

2. ALL DIMENSIONS ARE IN MILLIMETERS.

3. THIS DIMENSION APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL TIP. IF THE TERMIMAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THIS DIMENSION SHOULD NOT BE MEASURED IN THAT RADIUS AREA.

4. MAX. PACKAGE WARPAGE IS 0.05 mm.

5. MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.

6. BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.

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| | STANDARD: NON–JEDEC | |
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## PRODUCT DOCUMENTATION, SOFTWARE AND TOOLS

Refer to the following resources to aid your design process.

**Application Notes**

- AN1955: Thermal Measurement Methodology of RF Power Amplifiers
- AN3100: General Purpose Amplifier and MMIC Biasing

**Software**

- .s2p File

**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

## FAILURE ANALYSIS

At this time, because of the physical characteristics of the part, failure analysis is limited to electrical signature analysis. In cases where Freescale is contractually obligated to perform failure analysis (FA) services, full FA may be performed by third party vendors with moderate success. For updates contact your local Freescale Sales Office.

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date | Description |
|---|---|---|
| 0 | Apr. 2016 | • Initial Release of Data Sheet |

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