Document Number: AFT23S170–13S
Rev. 0, 6/2013

# RF Power LDMOS Transistor

## N–Channel Enhancement–Mode Lateral MOSFET

This 45 watt RF power LDMOS transistor is designed for cellular base station applications covering the frequency range of 2300 to 2400 MHz.

- Typical Single–Carrier W–CDMA Performance: $V_{DD}$ = 28 Volts, $I_{DQ}$ = 1100 mA, $P_{out}$ = 45 Watts Avg., Input Signal PAR = 9.9 dB @ 0.01% Probability on CCDF.

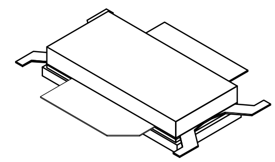
| Frequency | $G_{ps}$ (dB) | $\eta_D$ (%) | Output PAR (dB) | ACPR (dBc) | IRL (dB) |
|---|---|---|---|---|---|
| 2300 MHz | 18.3 | 33.8 | 6.9 | −34.4 | −13 |
| 2350 MHz | 18.6 | 33.8 | 6.9 | −34.3 | −16 |
| 2400 MHz | 18.8 | 33.9 | 6.8 | −33.9 | −13 |

### Features

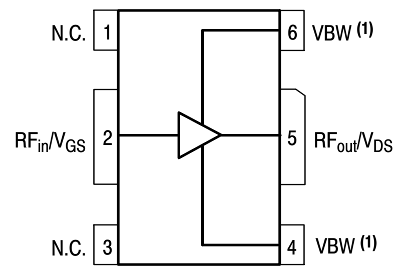
- Greater Negative Gate–Source Voltage Range for Improved Class C Operation
- Designed for Digital Predistortion Error Correction Systems
- Optimized for Doherty Applications
- In Tape and Reel. R3 Suffix = 250 Units, 44 mm Tape Width, 13–inch Reel.

**AFT23S170–13SR3**

**2300–2400 MHz, 45 W AVG., 28 V**



**NI–780S–2L4S**




(Top View)

**Figure 1. Pin Connections**

1. Device can operate with the $V_{DD}$ current supplied through pin 4 and pin 6 at a reduced RF output power level. Refer to CW operation data in the Maximum Ratings table.

**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 | °C |
| Case Operating Temperature Range | $T_C$ | −40 to +150 | °C |
| Operating Junction Temperature Range (1,2) | $T_J$ | −40 to +225 | °C |
| CW Operation @ $T_C$ = 25°C when DC current is fed through pin 4 and pin 6<br>Derate above 25°C | CW | 94<br>0.44 | W<br>W/°C |

**Table 2. Thermal Characteristics**

| Characteristic | Symbol | Value (2,3) | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Case<br>Case Temperature 78°C, 45 W CW, 28 Vdc, $I_{DQ}$ = 1100 mA, 2350 MHz | $R_{\theta JC}$ | 0.42 | °C/W |

**Table 3. ESD Protection Characteristics**

| Test Methodology | Class |
|---|---|
| Human Body Model (per JESD22−A114) | 2 |
| Machine Model (per EIA/JESD22−A115) | B |
| Charge Device Model (per JESD22−C101) | IV |

**Table 4. Electrical Characteristics** ($T_A$ = 25°C unless otherwise noted)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **Off Characteristics** | | | | | |
| Zero Gate Voltage Drain Leakage Current<br>($V_{DS}$ = 65 Vdc, $V_{GS}$ = 0 Vdc) | $I_{DSS}$ | — | — | 10 | µAdc |
| Zero Gate Voltage Drain Leakage Current<br>($V_{DS}$ = 28 Vdc, $V_{GS}$ = 0 Vdc) | $I_{DSS}$ | — | — | 1 | µAdc |
| Gate−Source Leakage Current<br>($V_{GS}$ = 5 Vdc, $V_{DS}$ = 0 Vdc) | $I_{GSS}$ | — | — | 1 | µAdc |
| **On Characteristics** | | | | | |
| Gate Threshold Voltage<br>($V_{DS}$ = 10 Vdc, $I_D$ = 219 µAdc) | $V_{GS(th)}$ | 0.9 | 1.3 | 1.7 | Vdc |
| Gate Quiescent Voltage<br>($V_{DD}$ = 28 Vdc, $I_D$ = 1100 mAdc, Measured in Functional Test) | $V_{GS(Q)}$ | 1.4 | 1.8 | 2.2 | Vdc |
| Drain−Source On−Voltage<br>($V_{GS}$ = 6 Vdc, $I_D$ = 2.19 Adc) | $V_{DS(on)}$ | 0.1 | 0.2 | 0.3 | Vdc |

**Functional Tests** (4) (In Freescale Test Fixture, 50 ohm system) $V_{DD}$ = 28 Vdc, $I_{DQ}$ = 1100 mA, $P_{out}$ = 45 W Avg., f = 2400 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 @ ±5 MHz Offset.

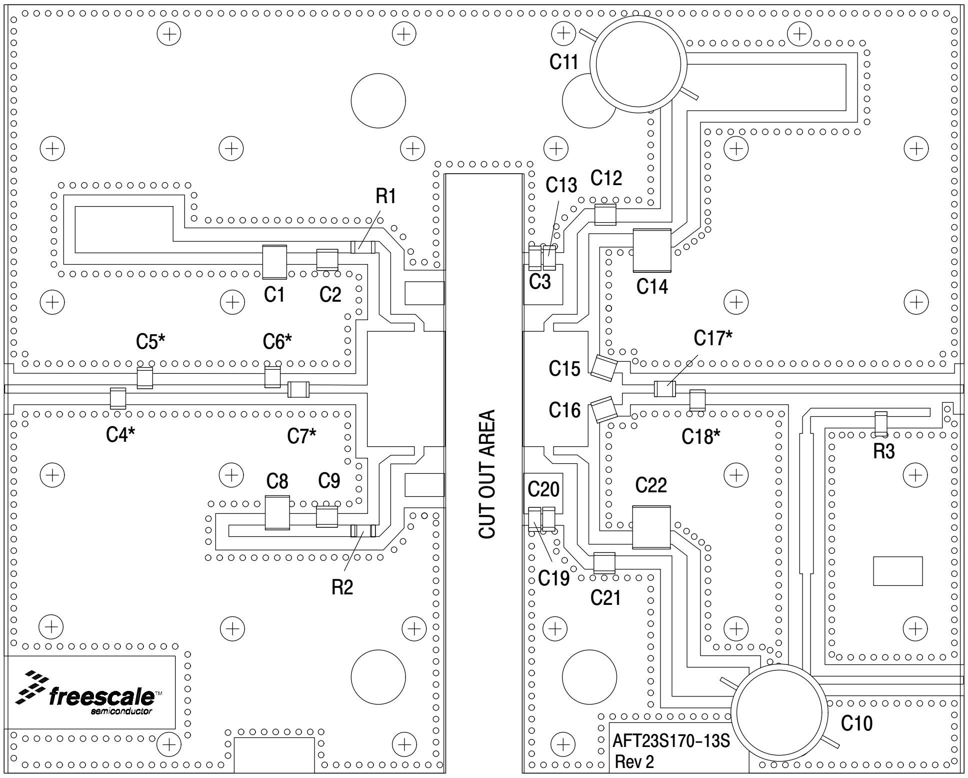
| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Power Gain | $G_{ps}$ | 17.5 | 18.8 | 20.0 | dB |
| Drain Efficiency | $\eta_D$ | 32.0 | 33.9 | — | % |
| Output Peak−to−Average Ratio @ 0.01% Probability on CCDF | PAR | 6.3 | 6.8 | — | dB |
| Adjacent Channel Power Ratio | ACPR | — | −33.9 | −32.0 | dBc |
| Input Return Loss | IRL | — | −13 | −9 | dB |

1. Continuous use at maximum temperature will affect MTTF.
2. MTTF calculator available at http://www.freescale.com/rf. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.
3. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers.* Go to http://www.freescale.com/rf. Select Documentation/Application Notes − AN1955.
4. Part internally matched both on input and output.

(continued)

**Table 4. Electrical Characteristics** ($T_A$ = 25°C unless otherwise noted) **(continued)**

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **Load Mismatch** (In Freescale Test Fixture, 50 ohm system) $I_{DQ}$ = 1100 mA, f = 2350 MHz | | | | | |
| VSWR 10:1 at 32 Vdc, 230 W CW Output Power (3 dB Input Overdrive from 178 W CW Rated Power) | No Device Degradation | | | | |
| **Typical Performance** (In Freescale Test Fixture, 50 ohm system) $V_{DD}$ = 28 Vdc, $I_{DQ}$ = 1100 mA, 2300−2400 MHz Bandwidth | | | | | |
| $P_{out}$ @ 1 dB Compression Point, CW | P1dB | — | 147 | — | W |
| AM/PM (Maximum value measured at the P3dB compression point across the 2300−2400 MHz bandwidth) | Φ | — | –14.3 | — | ° |
| VBW Resonance Point (IMD Third Order Intermodulation Inflection Point) | $VBW_{res}$ | — | 95 | — | MHz |
| Gain Flatness in 100 MHz Bandwidth @ $P_{out}$ = 45 W Avg. | $G_F$ | — | 0.5 | — | dB |
| Gain Variation over Temperature (−30°C to +85°C) | ΔG | — | 0.015 | — | dB/°C |
| Output Power Variation over Temperature (−30°C to +85°C) | ΔP1dB | — | 0.006 | — | dB/°C |




*C4, C5, C6, C7, C17 and C18 are mounted vertically.

**Figure 2. AFT23S170−13SR3 Test Circuit Component Layout**

**Table 5. AFT23S170−13SR3 Test Circuit Component Designations and Values**

| Part | Description | Part Number | Manufacturer |
|---|---|---|---|
| C1, C8 | 2.2 μF, 100 V Chip Capacitors | C3225X7R1H225KT | TDK |
| C2, C7, C9, C12, C17, C21 | 4.7 pF Chip Capacitors | ATC100B4R7BT500XT | ATC |
| C3, C13, C19, C20 | 1000 nF Chip Capacitors | 12065G105AT2A | AVX |
| C4, C5, C18 | 0.3 pF Chip Capacitors | ATC100B0R3BT500XT | ATC |
| C6 | 1.0 pF Chip Capacitor | ATC100B1R0BT500XT | ATC |
| C10, C11 | 470 μF Electrolytic Capacitors | B41858C8477M000 | EPCOS |
| C14, C22 | 10 μF, 100 V Chip Capacitors | C5750X7S2A106KT | TDK |
| C15, C16 | 0.2 pF Chip Capacitors | ATC100B0R2BT500XT | ATC |
| R1, R2 | 4.7 Ω, 1/4 W Chip Resistors | WCR1206-4R7FI | Welwyn |
| R3 | 0 Ω, 2 A Chip Resistor | WCR1206-R005J | Welwyn |
| PCB | 0.020″, $\varepsilon_r$ = 3.5 | RO4350B | Rogers |

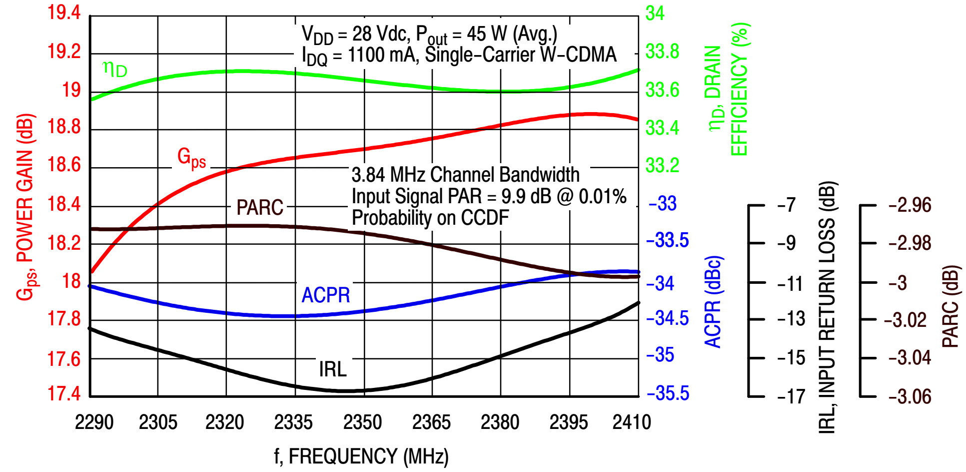



**Figure 3. Single−Carrier Output Peak−to−Average Ratio Compression (PARC) Broadband Performance @ $P_{out}$ = 45 Watts Avg.**

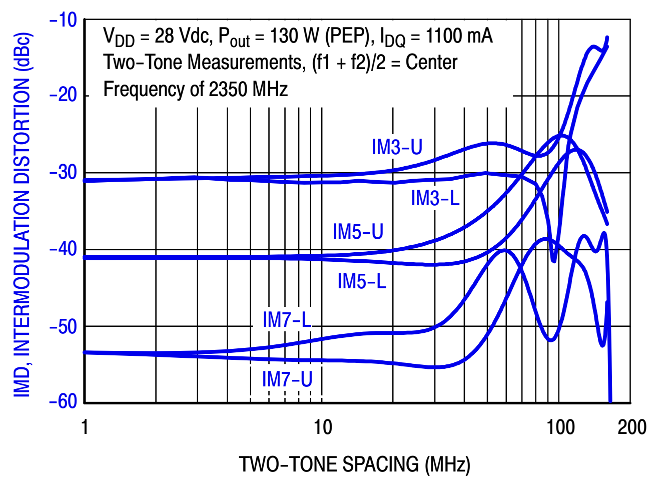



**Figure 4. Intermodulation Distortion Products versus Two−Tone Spacing**

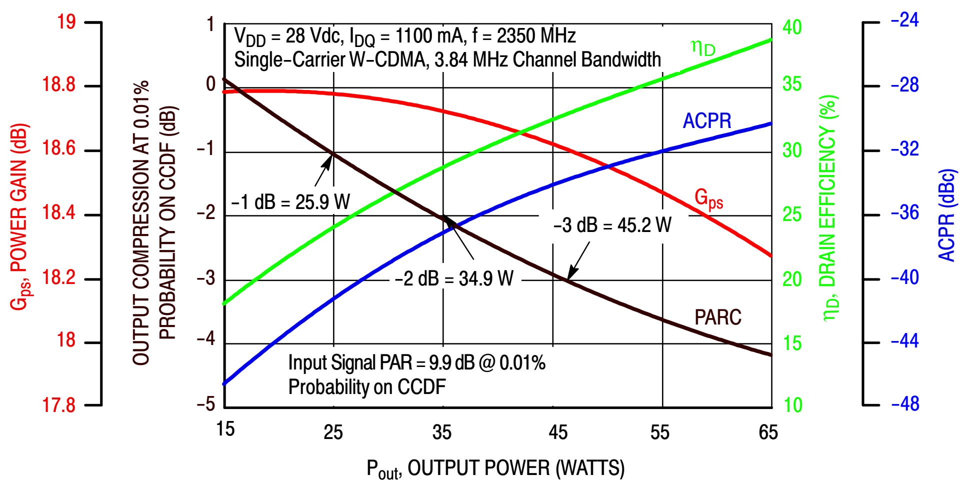



**Figure 5. Output Peak−to−Average Ratio Compression (PARC) versus Output Power**

## TYPICAL CHARACTERISTICS

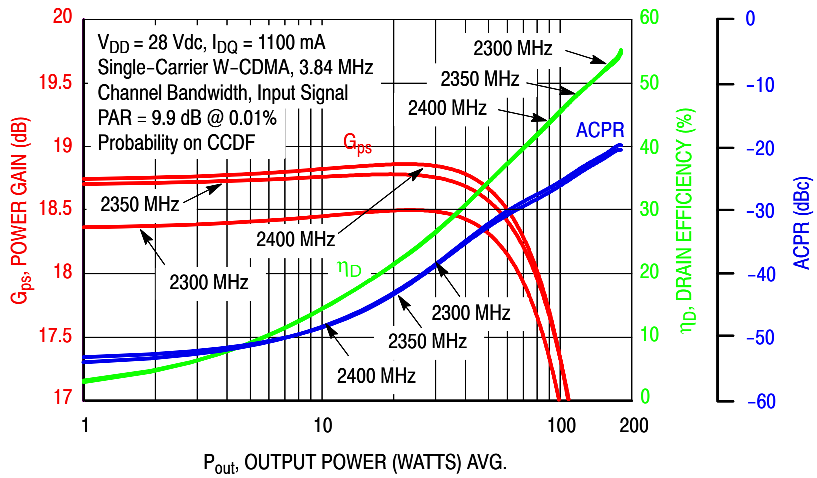



**Figure 6. Single−Carrier W−CDMA Power Gain, Drain Efficiency and ACPR versus Output Power**

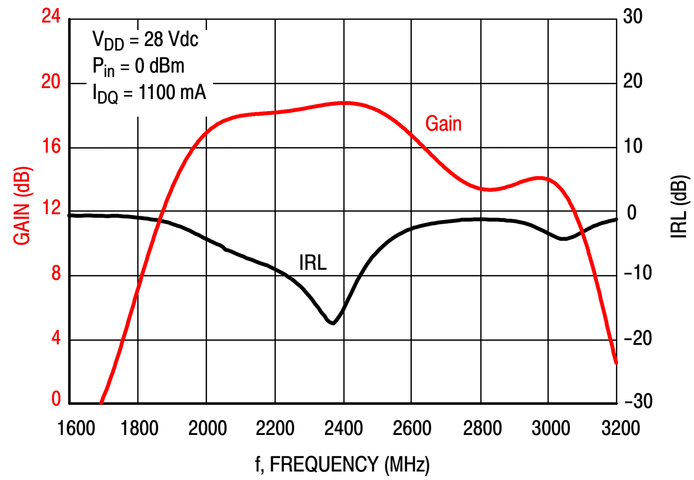



**Figure 7. Broadband Frequency Response**

$V_{DD}$ = 28 Vdc, $I_{DQ}$ = 1161 mA, Pulsed CW, 10 μsec(on), 10% Duty Cycle

| f (MHz) | $Z_{source}$ (Ω) | $Z_{in}$ (Ω) | Max Output Power P1dB | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $Z_{load}$ (1) (Ω) | Gain (dB) | (dBm) | (W) | $\eta_D$ (%) | AM/PM (°) |
| 2300 | 3.46 – j9.07 | 3.45 + j8.51 | 2.09 – j4.35 | 18.2 | 53.2 | 210 | 51.5 | –11 |
| 2350 | 5.27 – j10.0 | 4.90 + j8.90 | 2.11 – j4.50 | 18.0 | 53.3 | 213 | 51.8 | –11 |
| 2400 | 8.84 – j10.7 | 7.40 + j10.2 | 2.06 – j4.47 | 18.5 | 53.2 | 211 | 52.4 | –12 |

| f (MHz) | $Z_{source}$ (Ω) | $Z_{in}$ (Ω) | Max Output Power P3dB | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $Z_{load}$ (2) (Ω) | Gain (dB) | (dBm) | (W) | $\eta_D$ (%) | AM/PM (°) |
| 2300 | 3.46 – j9.07 | 3.53 + j8.93 | 2.09 – j4.54 | 16.0 | 54.2 | 260 | 54.3 | –16 |
| 2350 | 5.27 – j10.0 | 5.22 + j9.48 | 2.15 – j4.69 | 15.9 | 54.2 | 260 | 54.3 | –17 |
| 2400 | 8.84 – j10.7 | 8.20 + j10.7 | 2.18 – j4.77 | 16.3 | 54.1 | 258 | 54.7 | –17 |

(1) Load impedance for optimum P1dB power.
(2) Load impedance for optimum P3dB power.
$Z_{source}$ = Measured impedance presented to the input of the device at the package reference plane.
$Z_{in}$ = Impedance as measured from gate contact to ground.
$Z_{load}$ = Measured impedance presented to the output of the device at the package reference plane.

**Figure 8. Load Pull Performance — Maximum Power Tuning**

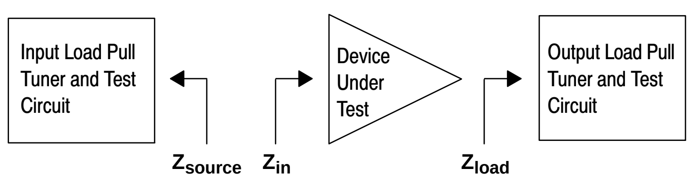
$V_{DD}$ = 28 Vdc, $I_{DQ}$ = 1161 mA, Pulsed CW, 10 μsec(on), 10% Duty Cycle

| f (MHz) | $Z_{source}$ (Ω) | $Z_{in}$ (Ω) | Max Drain Efficiency P1dB | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $Z_{load}$ (1) (Ω) | Gain (dB) | (dBm) | (W) | $\eta_D$ (%) | AM/PM (°) |
| 2300 | 3.46 – j9.07 | 3.56 + j8.75 | 3.81 – j2.63 | 20.3 | 51.8 | 152 | 60.4 | –14 |
| 2350 | 5.27 – j10.0 | 5.04 + j9.29 | 3.29 – j2.43 | 20.2 | 51.8 | 152 | 61.1 | –16 |
| 2400 | 8.84 – j10.7 | 7.80 + j10.4 | 2.95 – j2.60 | 20.5 | 51.9 | 154 | 61.5 | –16 |

| f (MHz) | $Z_{source}$ (Ω) | $Z_{in}$ (Ω) | Max Drain Efficiency P3dB | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $Z_{load}$ (2) (Ω) | Gain (dB) | (dBm) | (W) | $\eta_D$ (%) | AM/PM (°) |
| 2300 | 3.46 – j9.07 | 3.59 + j9.10 | 3.67 – j2.84 | 18.1 | 52.9 | 193 | 62.7 | –20 |
| 2350 | 5.27 – j10.0 | 5.26 + j9.74 | 3.29 – j2.76 | 18.0 | 52.9 | 193 | 63.0 | –22 |
| 2400 | 8.84 – j10.7 | 8.48 + j10.9 | 3.06 – j2.82 | 18.4 | 52.8 | 192 | 63.0 | –23 |

(1) Load impedance for optimum P1dB efficiency.
(2) Load impedance for optimum P3dB efficiency.
$Z_{source}$ = Measured impedance presented to the input of the device at the package reference plane.
$Z_{in}$ = Impedance as measured from gate contact to ground.
$Z_{load}$ = Measured impedance presented to the output of the device at the package reference plane.

**Figure 9. Load Pull Performance — Maximum Drain Efficiency Tuning**



## P1dB – TYPICAL LOAD PULL CONTOURS — 2350 MHz

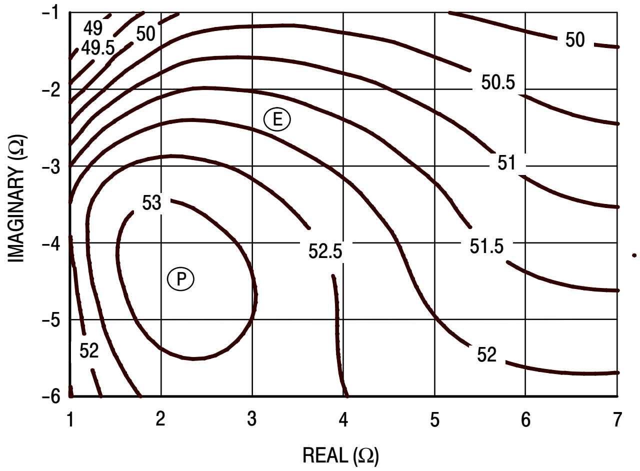



Figure 10. P1dB Load Pull Output Power Contours (dBm)

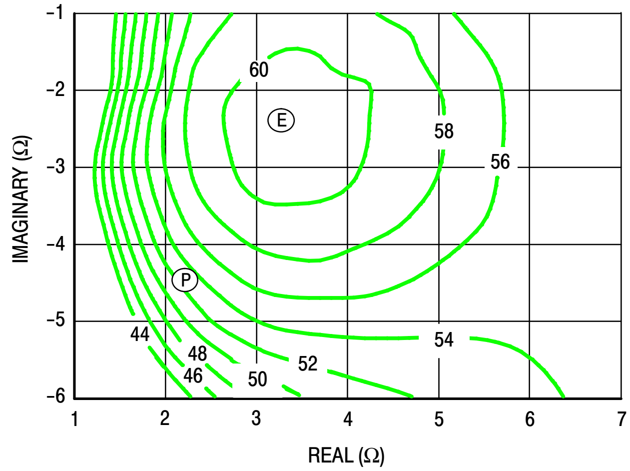



Figure 11. P1dB Load Pull Efficiency Contours (%)

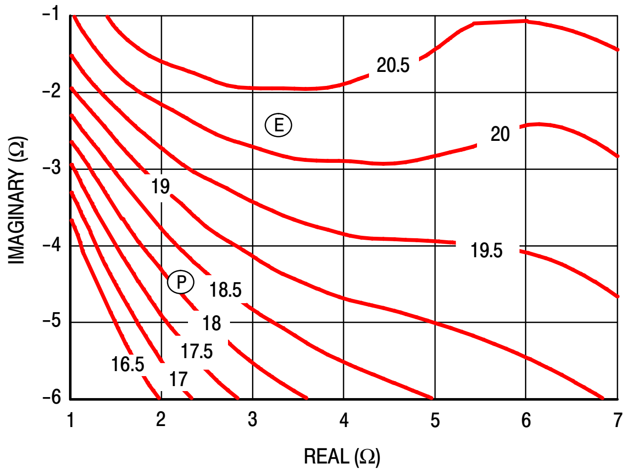



Figure 12. P1dB Load Pull Gain Contours (dB)

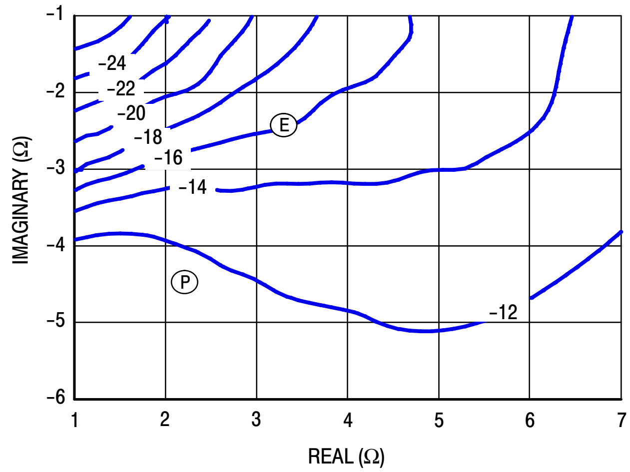



Figure 13. P1dB Load Pull AM/PM Contours (°)

**NOTE:** Ⓟ = Maximum Output Power

Ⓔ = Maximum Drain Efficiency

Power Gain
Drain Efficiency
Linearity
Output Power

## P3dB – TYPICAL LOAD PULL CONTOURS — 2350 MHz

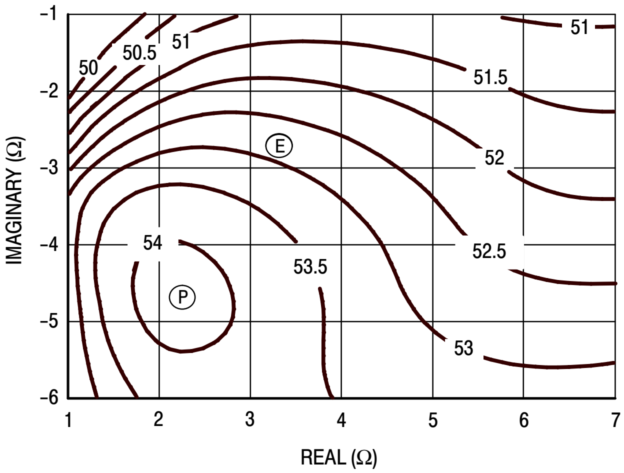



**Figure 14. P3dB Load Pull Output Power Contours (dBm)**

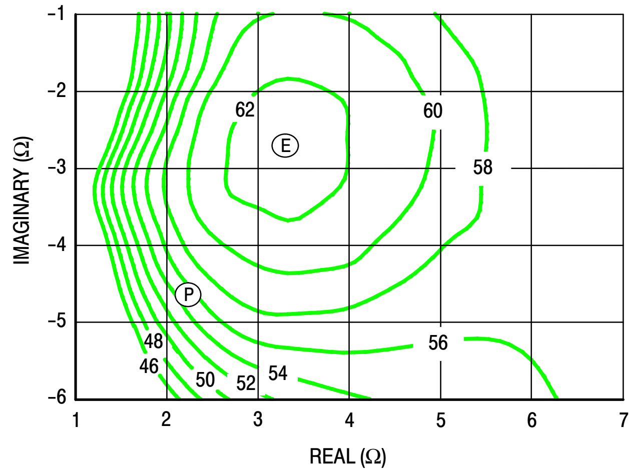



**Figure 15. P3dB Load Pull Efficiency Contours (%)**

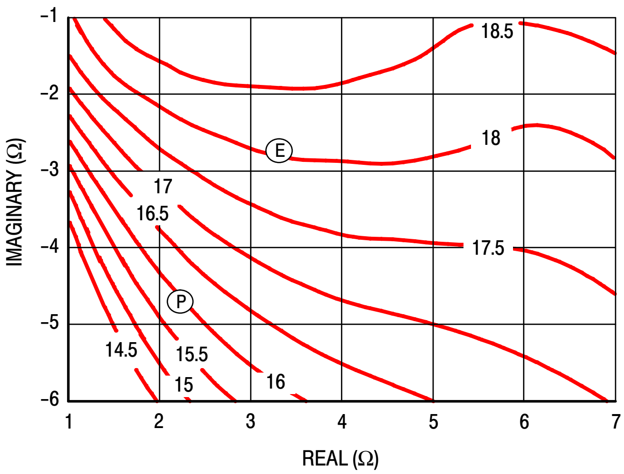



**Figure 16. P3dB Load Pull Gain Contours (dB)**

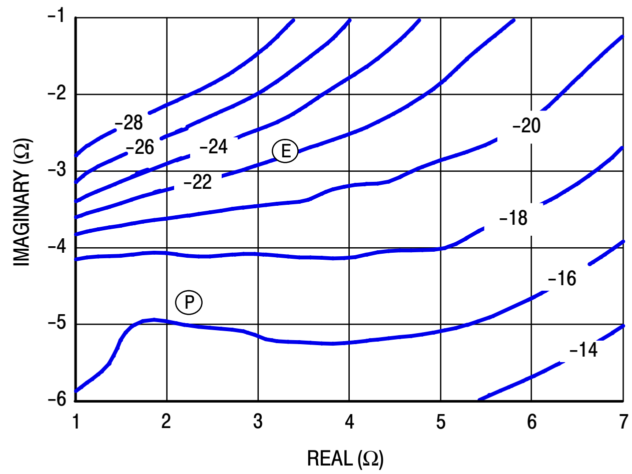
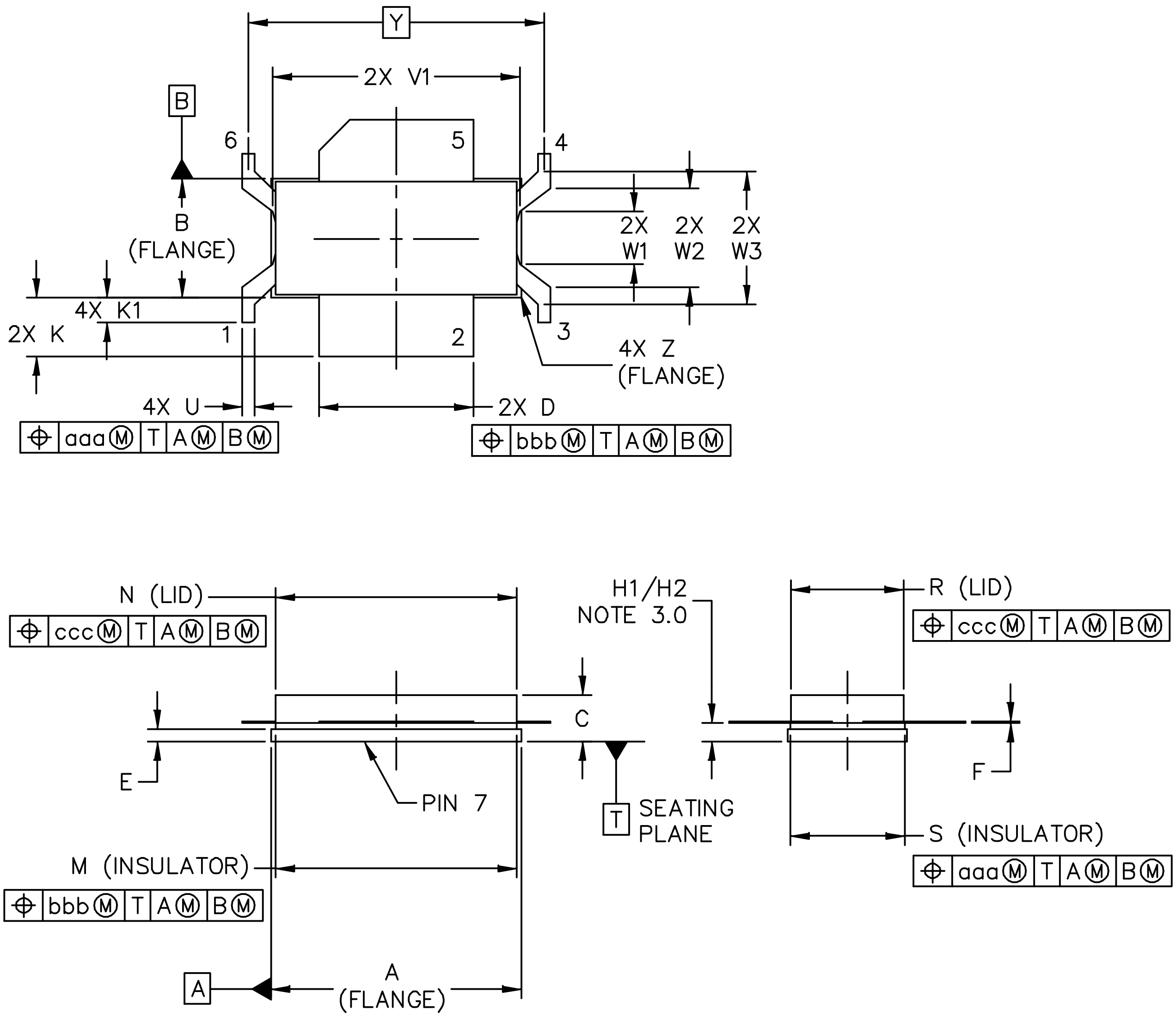



**Figure 17. P3dB Load Pull AM/PM Contours (°)**

**NOTE:** Ⓔ = Maximum Output Power
Ⓟ = Maximum Drain Efficiency

- Power Gain
- Drain Efficiency
- Linearity
- Output Power

## PACKAGE DIMENSIONS




| | | |
|---|---|---|
|  | MECHANICAL OUTLINE | PRINT VERSION NOT TO SCALE |
| TITLE: NI−780S−6 | DOCUMENT NO: 98ASA00443D | REV: A |
| | CASE NUMBER: 2268−02 | 24 MAY 2012 |
| | STANDARD: NON−JEDEC | |

NOTES:

1.0 CONTROLLING DIMENSION: INCH.

2.0 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.

3.0 DIMENSIONS H1 AND H2 ARE MEASURED .030 INCH (0.762 MM) AWAY FROM FLANGE PARALLEL TO DATUM B. H1 APPLIES TO PINS 2 & 5. H2 APPLIES TO PINS 1, 3, 4 & 6.

| DIM | INCH MIN | INCH MAX | MILLIMETER MIN | MILLIMETER MAX | DIM | INCH MIN | INCH MAX | MILLIMETER MIN | MILLIMETER MAX |
|---|---|---|---|---|---|---|---|---|---|
| A | .805 | .815 | 20.45 | 20.70 | R | .365 | .375 | 9.27 | 9.53 |
| B | .380 | .390 | 9.65 | 9.91 | S | .365 | .375 | 9.27 | 9.53 |
| C | .125 | .170 | 3.18 | 4.32 | U | .035 | .045 | 0.89 | 1.14 |
| D | .495 | .505 | 12.57 | 12.83 | V1 | .795 | .805 | 20.19 | 20.45 |
| E | .035 | .045 | 0.89 | 1.14 | W1 | .165 | .175 | 4.19 | 4.45 |
| F | .004 | .007 | 0.10 | 0.18 | W2 | .315 | .325 | 8.00 | 8.26 |
| H1 | .057 | .067 | 1.45 | 1.70 | W3 | .425 | .435 | 10.80 | 11.05 |
| H2 | .054 | .070 | 1.37 | 1.78 | Y | .956 BSC | | 24.28 BSC | |
| K | .170 | .210 | 4.32 | 5.33 | Z | R.000 | R.040 | R.00 | R1.02 |
| K1 | .070 | .090 | 1.78 | 2.29 | aaa | – | .005 | – | 0.127 |
| M | .774 | .786 | 19.66 | 19.96 | bbb | – | .010 | – | 0.254 |
| N | .772 | .788 | 19.61 | 20.02 | ccc | – | .015 | – | 0.381 |



| | | |
|---|---|---|
| MECHANICAL OUTLINE | PRINT VERSION NOT TO SCALE | |
| TITLE: NI-780S-6 | DOCUMENT NO: 98ASA00443D | REV: A |
| | CASE NUMBER: 2268-02 | 24 MAY 2012 |
| | STANDARD: NON-JEDEC | |

## PRODUCT DOCUMENTATION, SOFTWARE AND TOOLS

Refer to the following documents, software and tools to aid your design process.

**Application Notes**

- AN1955: Thermal Measurement Methodology of RF Power Amplifiers

**Software**

- Electromigration MTTF Calculator
- RF High Power Model
- .s2p File

**Development Tools**

- Printed Circuit Boards

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.

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date | Description |
|---|---|---|
| 0 | June 2013 | • Initial Release of Data Sheet |

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Rev. 0, 6/2013