

# GaN on Silicon General Purpose Amplifier

## DC - 2 GHz, 48 V, 100 W



NPT2022

Rev. V3

### Features

- GaN on Si HEMT D-Mode Amplifier
- Suitable for Linear & Saturated Applications
- Tunable from DC - 2 GHz
- 48 V Operation
- 20 dB Gain @ 900 MHz
- 60% Drain Efficiency @ 900 MHz
- 100% RF Tested
- TO-272 Package
- RoHS\* Compliant and 260°C Reflow Compatible



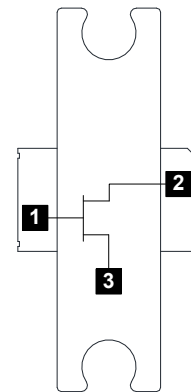
### Description

The NPT2022 GaN on silicon HEMT D-Mode amplifier optimized for DC - 2 GHz operation. This device supports CW, pulsed, and linear operation with output power levels to 100 W in an industry standard plastic package with bolt down flange.

The NPT2022 is ideally suited for defense communications, land mobile radio, avionics, wireless infrastructure, ISM applications and VHF/UHF/L/S-band radar.

Built using the SIGANTIC® process - a proprietary GaN-on-Silicon technology.

### Functional Schematic



### Ordering Information

| Part Number    | Package       |
|----------------|---------------|
| NPT2022        | Bulk Quantity |
| NPT2022-SMB1   | Sample Board  |
| NPT2022-TR0250 | Tape & Reel   |

### Pin Configuration

| Pin # | Pin Name                           | Function          |
|-------|------------------------------------|-------------------|
| 1     | RF <sub>IN</sub> / V <sub>G</sub>  | RF Input / Gate   |
| 2     | RF <sub>OUT</sub> / V <sub>D</sub> | RF Output / Drain |
| 3     | Pad <sup>1</sup>                   | Ground / Source   |

1. The exposed pad centered on the package bottom must be connected to RF and DC ground. This path must also provide a low thermal resistance heat path.

\* Restrictions on Hazardous Substances, compliant to current RoHS EU directive.

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### RF Electrical Specifications: $T_C = 25^\circ\text{C}$ , $V_{DS} = 48\text{ V}$ , $I_{DQ} = 600\text{ mA}$

| Parameter                      | Test Conditions                   | Symbol       | Min.                          | Typ. | Max. | Units |
|--------------------------------|-----------------------------------|--------------|-------------------------------|------|------|-------|
| Small Signal Gain              | CW, 900 MHz                       | $G_{SS}$     | -                             | 21   | -    | dB    |
| Saturated Output Power         | CW, 900 MHz                       | $P_{SAT}$    | -                             | 50.5 | -    | dBm   |
| Drain Efficiency at Saturation | CW, 900 MHz                       | $\eta_{SAT}$ | -                             | 62   | -    | %     |
| Power Gain                     | 900 MHz, $P_{OUT} = 100\text{ W}$ | $G_P$        | 19                            | 20   | -    | dB    |
| Drain Efficiency               | 900 MHz, $P_{OUT} = 100\text{ W}$ | $\eta$       | 56                            | 58   | -    | %     |
| Ruggedness: Output Mismatch    | All phase angles                  | $\Psi$       | VSWR = 10:1, No Device Damage |      |      |       |

### DC Electrical Characteristics: $T_C = 25^\circ\text{C}$

| Parameter                    | Test Conditions   | Symbol      | Min. | Typ. | Max. | Units |
|------------------------------|---|-------------|------|------|------|-------|
| Drain-Source Leakage Current | $V_{GS} = -8\text{ V}$ , $V_{DS} = 160\text{ V}$            | $I_{DLK}$   | -    | -    | 24   | mA    |
| Gate-Source Leakage Current  | $V_{GS} = -8\text{ V}$ , $V_{DS} = 0\text{ V}$              | $I_{GLK}$   | -    | -    | 12   | mA    |
| Gate Threshold Voltage       | $V_{DS} = 48\text{ V}$ , $I_D = 24\text{ mA}$               | $V_T$       | -2.5 | -1.6 | -0.5 | V     |
| Gate Quiescent Voltage       | $V_{DS} = 48\text{ V}$ , $I_D = 600\text{ mA}$              | $V_{GSQ}$   | -2.1 | -1.4 | -0.3 | V     |
| On Resistance                | $V_{DS} = 2\text{ V}$ , $I_D = 180\text{ mA}$               | $R_{ON}$    | -    | 0.2  | -    | W     |
| Maximum Drain Current        | $V_{DS} = 7\text{ V}$ pulsed, pulse width 300 $\mu\text{s}$ | $I_{D,MAX}$ | -    | 14   | -    | A     |

**Absolute Maximum Ratings<sup>2,3,4</sup>**

| Parameter                      | Absolute Maximum |
|--------------------------------|------------------|
| Drain Source Voltage, $V_{DS}$ | 160 V            |
| Gate Source Voltage, $V_{GS}$  | -10 to 3 V       |
| Gate Current, $I_G$            | 48 mA            |
| Junction Temperature, $T_J$    | +200°C           |
| Operating Temperature          | -40°C to +85°C   |
| Storage Temperature            | -65°C to +150°C  |

2. Exceeding any one or combination of these limits may cause permanent damage to this device.
3. MACOM does not recommend sustained operation near these survivability limits.
4. Operating at nominal conditions with  $T_J \leq 200^\circ\text{C}$  will ensure  $\text{MTTF} > 1 \times 10^6$  hours.

**Thermal Characteristics<sup>5</sup>**

| Parameter          | Test Conditions                                  | Symbol          | Typical | Units |
|--------------------|--|-----------------|---------|-------|
| Thermal Resistance | $V_{DS} = 48 \text{ V}, T_J = 200^\circ\text{C}$ | $R_{\theta JC}$ | 1.3     | °C/W  |

5. Junction temperature ( $T_J$ ) measured using IR Microscopy. Case temperature measured using thermocouple embedded in heat-sink.

**Handling Procedures**

Please observe the following precautions to avoid damage:

**Static Sensitivity**

Gallium Nitride Circuits are sensitive to electrostatic discharge (ESD) and can be damaged by static electricity. Proper ESD control techniques should be used when handling these HBM Class 1B devices.

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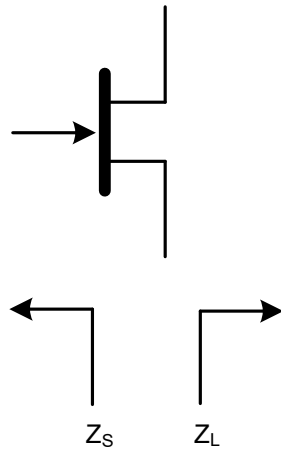
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**Load-Pull Performance:  $V_{DS} = 48\text{ V}$ ,  $I_{DQ} = 600\text{ mA}$ ,  $T_C = 25^\circ\text{C}$**

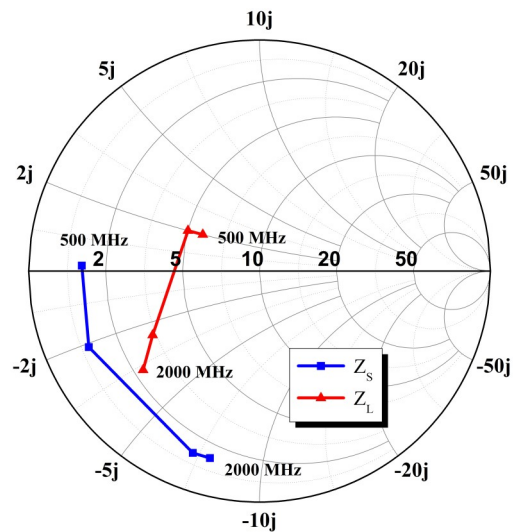
**Reference Plane at Device Leads, CW Drain Efficiency and Output Power Tradeoff Impedance**

| Frequency (MHz) | $Z_S$ (W)    | $Z_L$ (W)    | $P_{SAT}$ (W) | $G_{SS}$ (dB) | Drain Efficiency @ $P_{SAT}$ (%) |
|-----------------|--------------|--------------|---------------|---------------|----------------------------------|
| 500             | $1.3 + j0.8$ | $5.8 + j2.5$ | 152           | 26            | 71                               |
| 900             | $1.1 - j1.3$ | $5.0 + j2.8$ | 139           | 22            | 70                               |
| 1800            | $1.3 - j5.7$ | $3.2 - j1.4$ | 133           | 17            | 66                               |
| 2000            | $1.4 - j6.3$ | $2.3 - j2.3$ | 119           | 16            | 66                               |

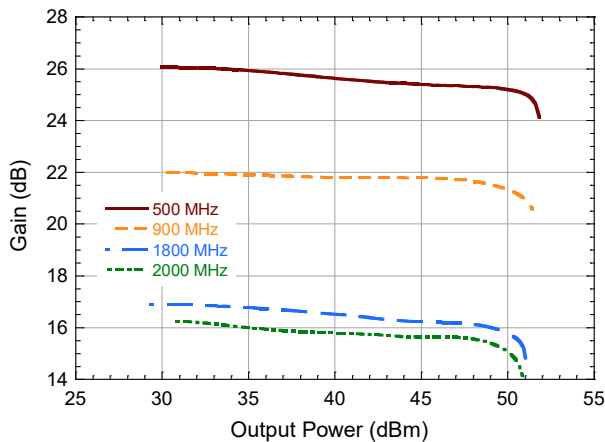
### Impedance Reference



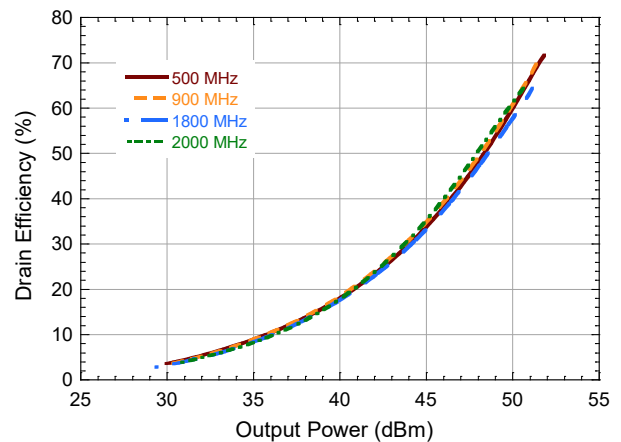
### $Z_S$ and $Z_L$ vs. Frequency



### Gain vs. Output Power

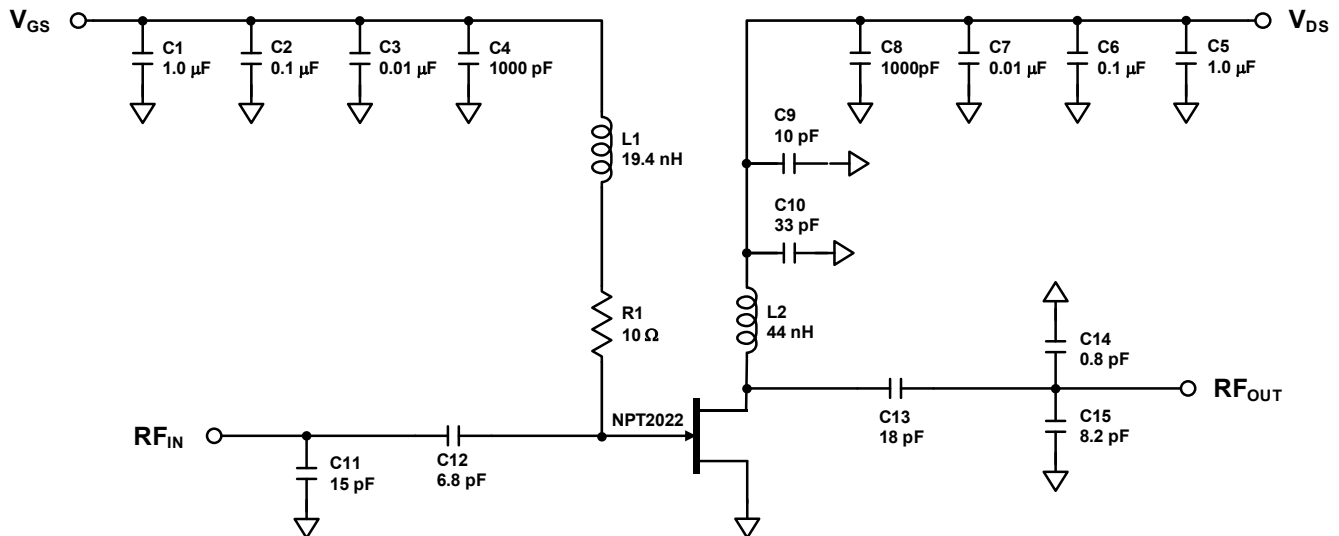


### Drain Efficiency vs. Output Power



## Evaluation Board and Recommended Tuning Solution

### 900 MHz Narrowband Circuit



### Description

Parts measured on evaluation board (30-mil thick RO4350). The PCB's electrical and thermal ground is provided using a standard-plated densely packed via hole array (see recommended via pattern).

Matching is provided using a combination of lumped elements and transmission lines as shown in the simplified schematic above. Recommended tuning solution component placement, transmission lines, and details are shown on the next page.

### Bias Sequencing

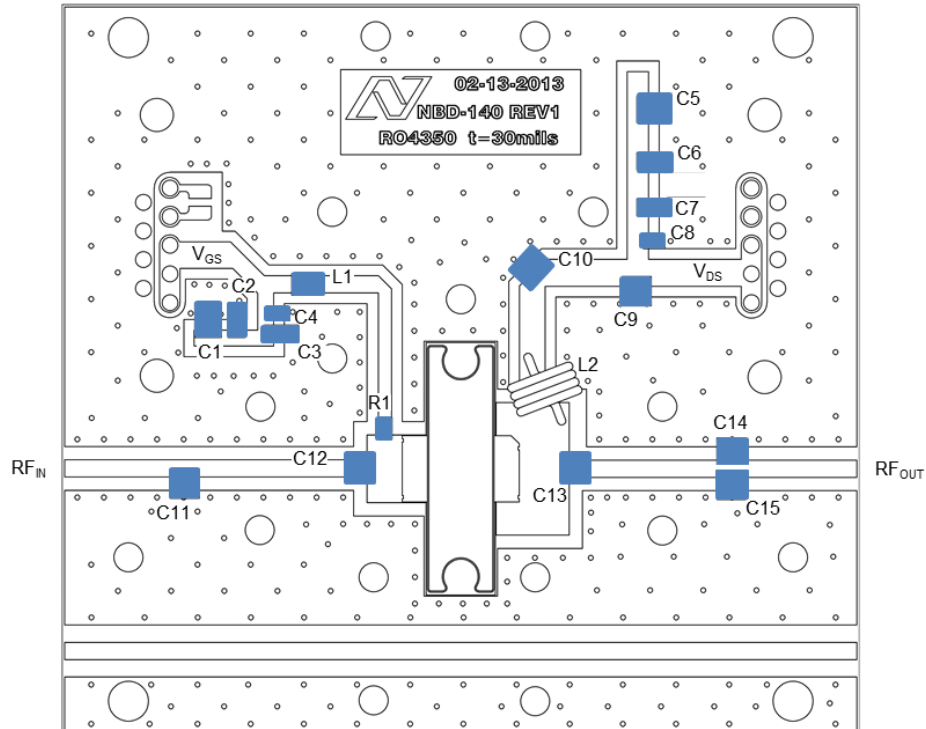
#### Turning the device ON

1. Set  $V_{GS}$  to the pinch-off ( $V_P$ ), typically -5 V.
2. Turn on  $V_{DS}$  to nominal voltage (48 V).
3. Increase  $V_{GS}$  until the  $I_{DS}$  current is reached.
4. Apply RF power to desired level.

#### Turning the device OFF

1. Turn the RF power off.
2. Decrease  $V_{GS}$  down to  $V_P$ .
3. Decrease  $V_{DS}$  down to 0 V.
4. Turn off  $V_{GS}$ .

**Evaluation Board and Recommended Tuning Solution**  
**900 MHz Narrowband Circuit**



**Parts list**

| Reference | Value                                    | Tolerance | Manufacturer   | Part Number      |
|-----------|--|-----------|----------------|------------------|
| C1, C5    | 1.0 $\mu$ F                              | 10%       | AVX            | 12101C105KAT2A   |
| C2, C6    | 0.1 $\mu$ F                              | 10%       | Kemet          | C1206C104K1RACTU |
| C3, C7    | 0.01 $\mu$ F                             | 10%       | AVX            | 12061C103KAT2A   |
| C4, C8    | 1000 pF                                  | 10%       | Kemet          | C0805C102K1RACTU |
| C9        | 10 pF                                    | 5%        | ATC            | ATC800B100J      |
| C10       | 33 pF                                    | 10%       | ATC            | ATC800B330K      |
| C11       | 15 pF                                    | 10%       | ATC            | ATC800B150K      |
| C12       | 6.8 pF                                   | 0.1 pF    | ATC            | ATC800B6R8B      |
| C13       | 18 pF                                    | 10%       | ATC            | ATC800B180K      |
| C14       | 0.8 pF                                   | 0.1 pF    | ATC            | ATC800B0R8B      |
| C15       | 8.2 pF                                   | 0.1 pF    | ATC            | ATC800B8R2B      |
| R1        | 10 $\Omega$                              | 1%        | Panasonic      | ERJ-2RKF10R0X    |
| L1        | 19.4 nH                                  | 5%        | Coilcraft      | 0806SQ-19NJLB    |
| L2        | ~44 nH                                   | 10%       | 20 AWG Cu Wire | 4 turn, 5mm ID   |
| PCB       | Rogers RO4350, $\epsilon_r=3.5$ , 30 mil |           |                |                  |

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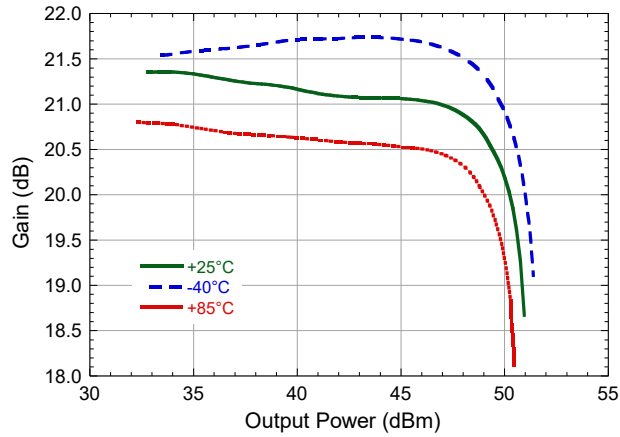


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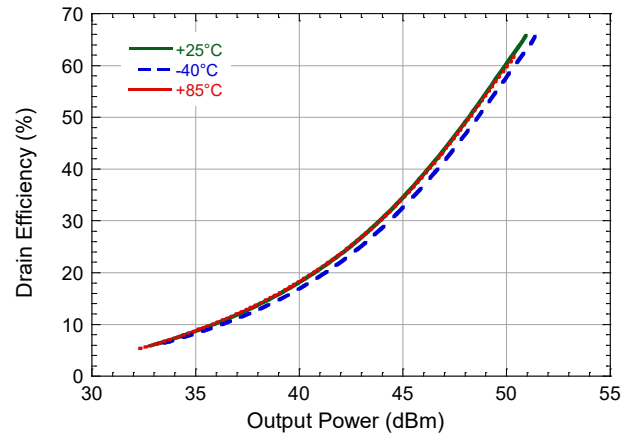
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Typical performance as measured in the 900 MHz evaluation board:  
 CW,  $V_{DS} = 48\text{ V}$ ,  $I_{DQ} = 600\text{ mA}$  (unless noted)

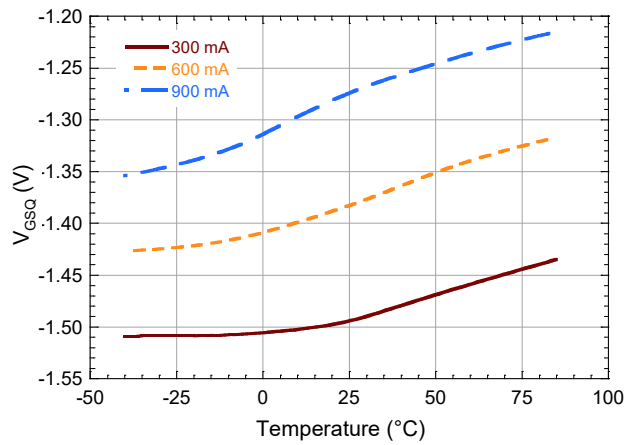
Gain vs. Output Power over Temperature



Drain Efficiency vs. Output Power over Temperature

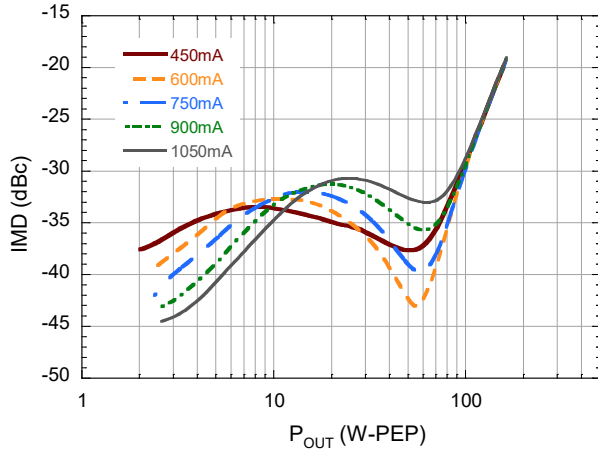


Quiescent  $V_{GS}$  vs. Temperature

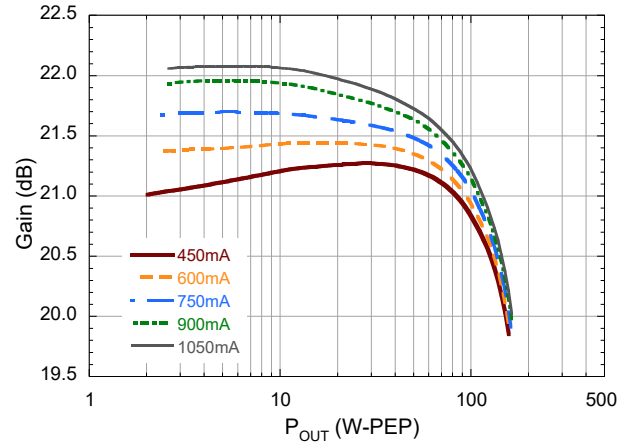


**Typical 2-Tone performance as measured in the 900 MHz evaluation board:**  
**1 MHz Tone Spacing,  $V_{DS} = 48\text{ V}$ ,  $I_{DQ} = 600\text{ mA}$ ,  $T_C = 25^\circ\text{C}$  (unless noted)**

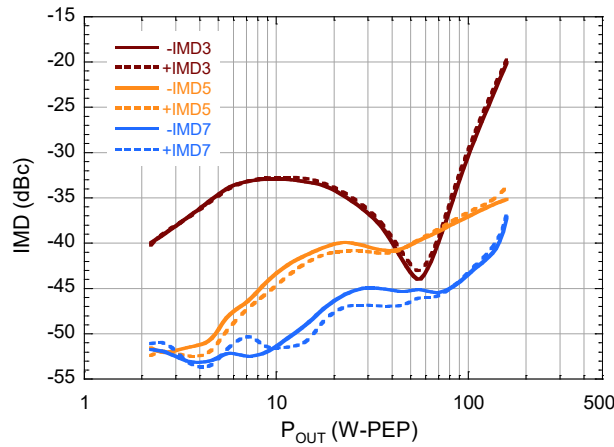
**2-Tone IMD3 vs. Output Power vs. Quiescent Current**



**2-Tone Gain vs. Output Power vs. Quiescent Current**



**2-Tone IMD vs. Output Power**





# GaN on Silicon General Purpose Amplifier

## DC - 2 GHz, 48 V, 100 W

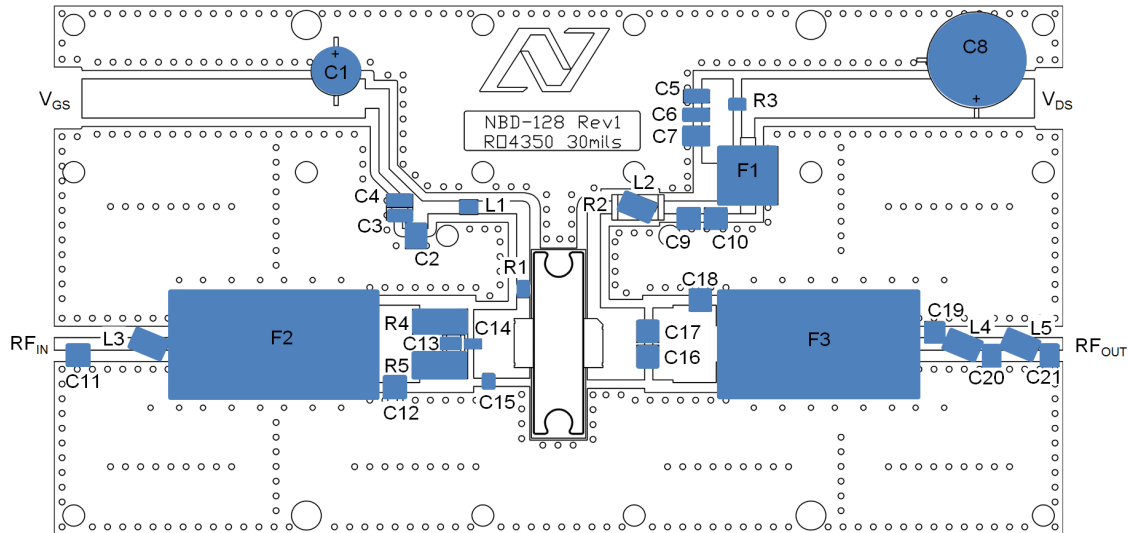


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### Evaluation Board and Recommended Tuning Solution

#### 130 - 940 MHz Broadband Circuit



#### Parts list

| Reference | Value                                    | Tolerance | Manufacturer     | Part Number         |
|-----------|--|-----------|------------------|---------------------|
| C1        | 150 $\mu$ F                              | 20%       | Nichicon         | UPW1C151MED         |
| C2, C7    | 1.0 $\mu$ F                              | 10%       | AVX              | 1210C105KAT2A       |
| C3, C6    | 0.1 $\mu$ F                              | 10%       | Kemet            | C1206C104K1RACTU    |
| C4, C5    | 0.01 $\mu$ F                             | 10%       | AVX              | 12061C103KAT2A      |
| C8        | 270 $\mu$ F                              | 20%       | United Chemi-Con | ELXY 630ELL271MK25S |
| C9        | 18 pF                                    | 5%        | ATC              | ATC100B180J         |
| C10       | 1000 pF                                  | 5%        | ATC              | ATC100B102J         |
| C11       | 1.5 pF                                   | 0.1 pF    | ATC              | ATC100B1R5B         |
| C12       | 5.6 pF                                   | 0.1 pF    | ATC              | ATC100B5R6B         |
| C13       | 15 pF                                    | 5%        | ATC              | ATC100B150J         |
| C14       | 220 pF                                   | 5%        | ATC              | ATC600F221J         |
| C15       | 12 pF                                    | 2%        | ATC              | ATC600F120F         |
| C16, C17  | 82 pF                                    | 10%       | ATC              | ATC100B820K         |
| C18       | 4.7 pF                                   | 0.1 pF    | ATC              | ATC100B4R7B         |
| C19       | 2.4 pF                                   | 0.1 pF    | ATC              | ATC100B2R4B         |
| C20       | 3.9 pF                                   | 0.1 pF    | ATC              | ATC100B3R9B         |
| C21       | 1.0 pF                                   | 0.1 pF    | ATC              | ATC100B1R0B         |
| R1        | 49.9 $\Omega$                            | 1%        | Panasonic        | ERJ-6ENF49R9V       |
| R2        | 470 $\Omega$                             | 1%        | Panasonic        | ERJ-1TNF4700U       |
| R3        | 0.33 $\Omega$                            | 1%        | Panasonic        | ERJ-6RQFR33V        |
| R4, R5    | 24.9 $\Omega$                            | 1%        | Panasonic        | ERJ-1TNF24R9U       |
| F1        | Material 73                              | -         | Fair-Rite        | 2673000801          |
| F2, F3    | 4:1 Transformer                          | -         | Anaren           | XMT031B5012         |
| L1        | 25 nH                                    | 5%        | Coilcraft        | 0908SQ-25NJL        |
| L2, L4    | 8.0 nH                                   | 5%        | Coilcraft        | A03TJL              |
| L3, L5    | 5.0 nH                                   | 5%        | Coilcraft        | A02TJL              |
| PCB       | Rogers RO4350, $\epsilon_r=3.5$ , 30 mil |           |                  |                     |

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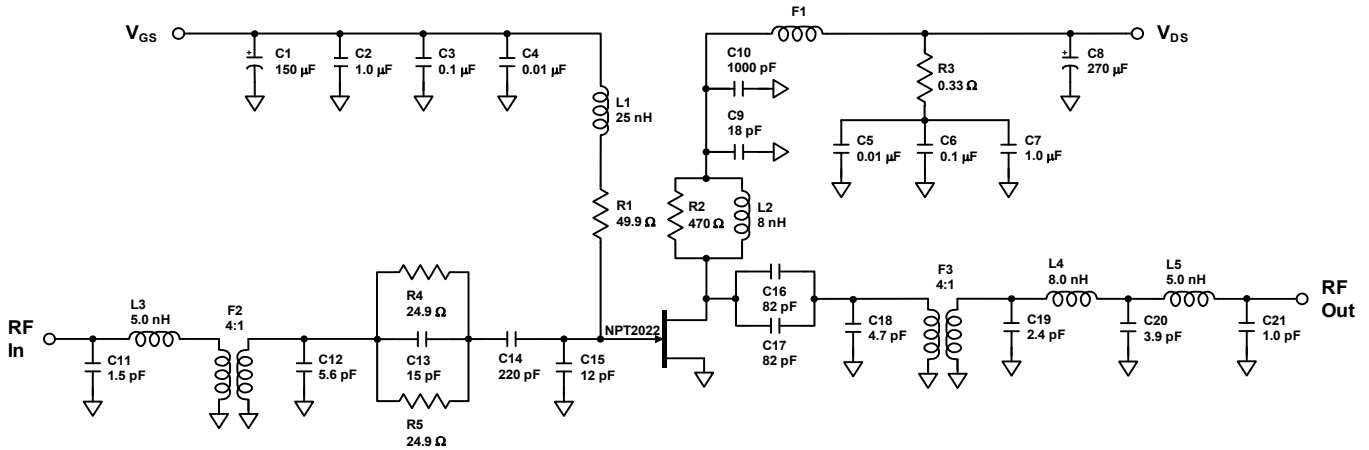
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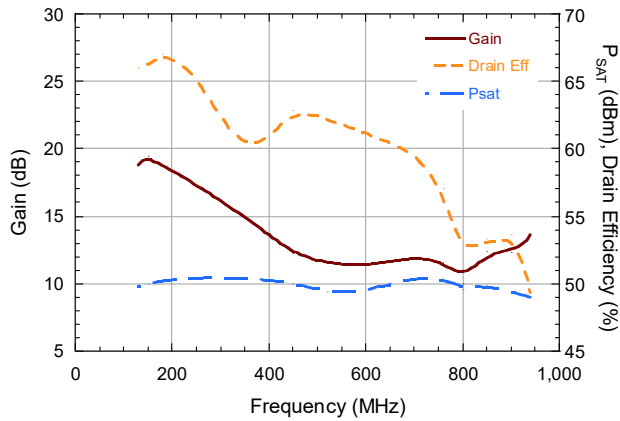
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### Evaluation Board and Recommended Tuning Solution

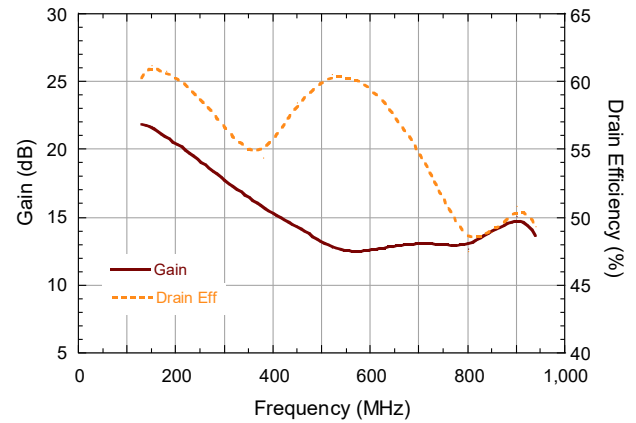
#### 130 - 940 MHz Broadband Circuit



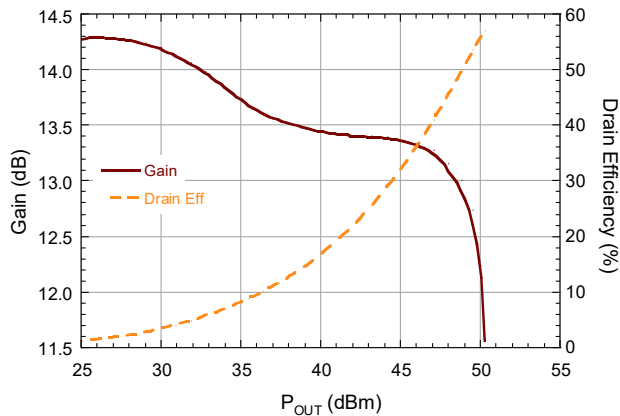
Performance vs. Frequency at  $P_{OUT} = P_{SAT}$



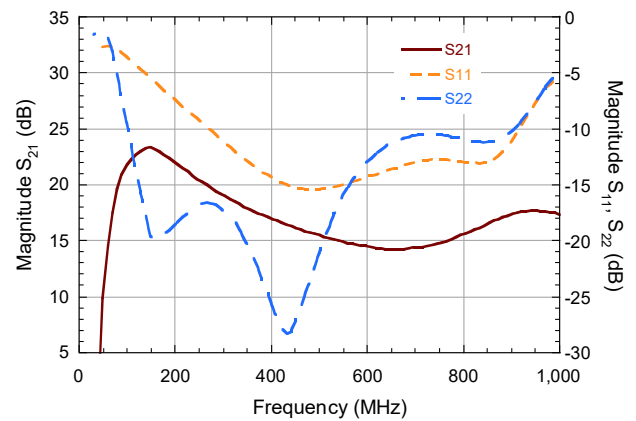
Performance vs. Frequency at  $P_{OUT} = 49 \text{ dBm}$



Performance vs. Output Power ( $f = 760 \text{ MHz}$ )



Small Signal s-parameters vs. Frequency



# GaN on Silicon General Purpose Amplifier

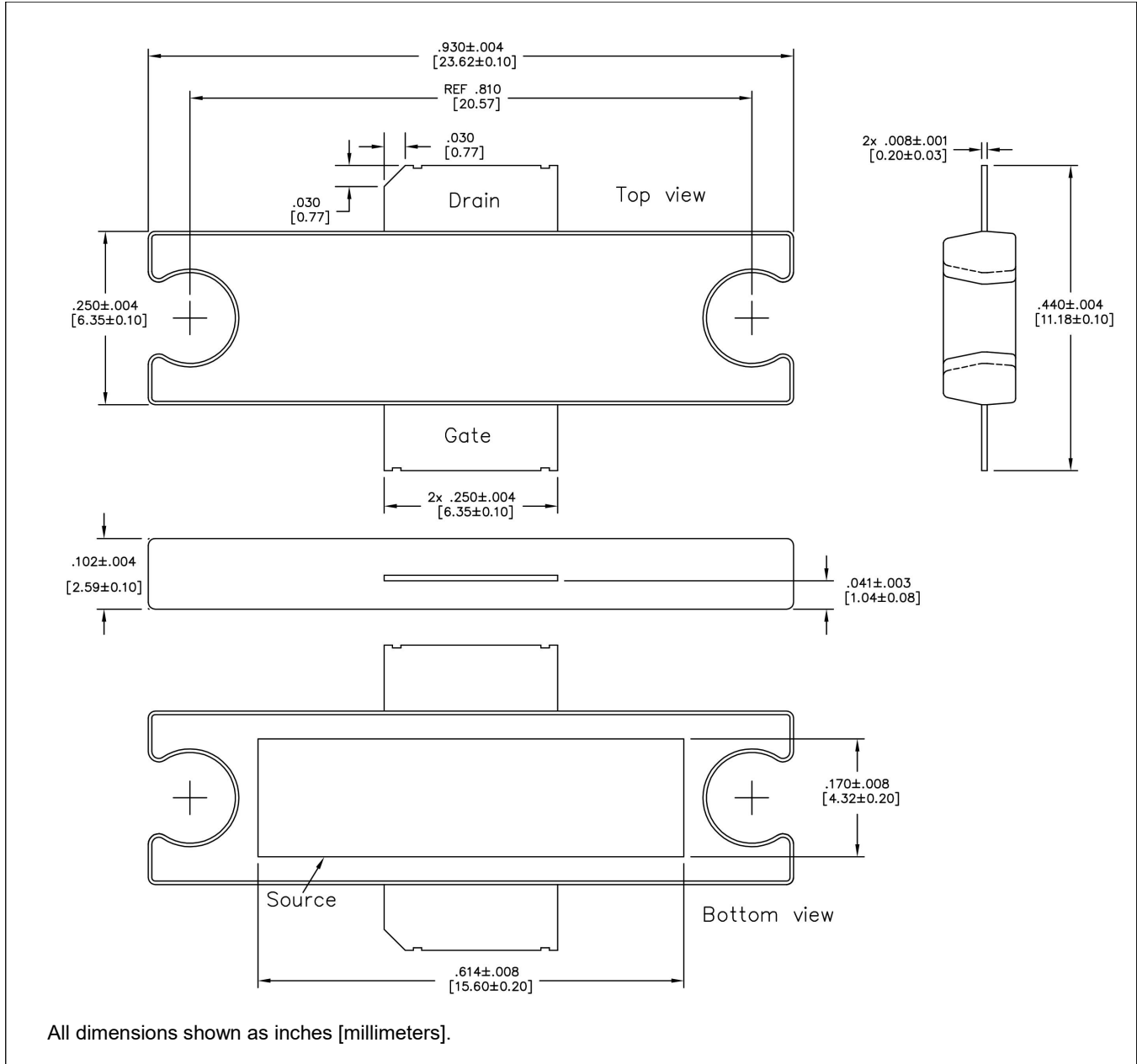
## DC - 2 GHz, 48 V, 100 W



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### TO-272-2 Plastic Package<sup>†</sup>



<sup>†</sup> Meets JEDEC moisture sensitivity level 3 requirements.  
Plating is Matte Sn.

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