

GRF5604

High Efficiency 6 Watt Power Amplifier 100 to 600 MHz

RELEASE Ø DATA SHEET

FEATURES

- Excellent OP1dB/PSAT
- 190 mA Native Mode Quiescent Current Consumption
- 5 V Supply Voltage
- 50 Ω Single-Ended Input/Output Impedances
- Digital Shutdown
- -40 to 85 °C Operating Temperature Range
- Compact 3 x 3 mm QFN-16 Package
- Process: InGaP HBT

Reference: 5 V / 247 mA IccQ / 460 MHz

- Gain: 37.5 dB
- OP1dB: 38 dBm
- Evaluation Board Noise Figure: 3.5 dB

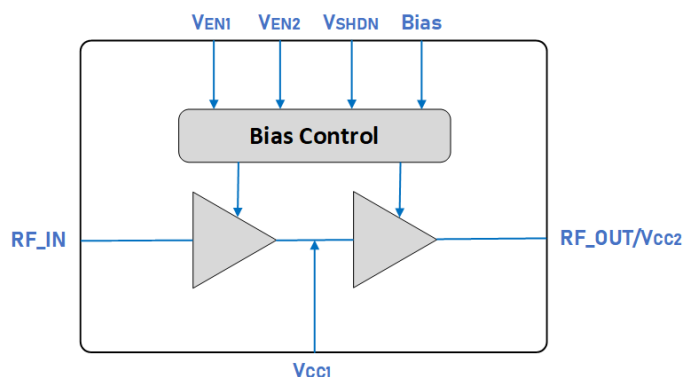
DESCRIPTION

The GRF5604 is a high efficiency PA that delivers up to 6 Watts P_{SAT} with V_{CC} at 5 volts and 3 Watts P_{SAT} with V_{CC} at 3.6 Volts. PAE at P_{SAT} is roughly 60%. The device can be externally matched over a range of frequencies from 100 to 600 MHz with typical fractional bandwidths of 5-10%.

Please consult with the GRF applications engineering team for custom tuning/evaluation board data.

Additional tunes can be found on the GRF5604 "Custom Tunes" product page: [GRF5604 Custom Tunes](#)

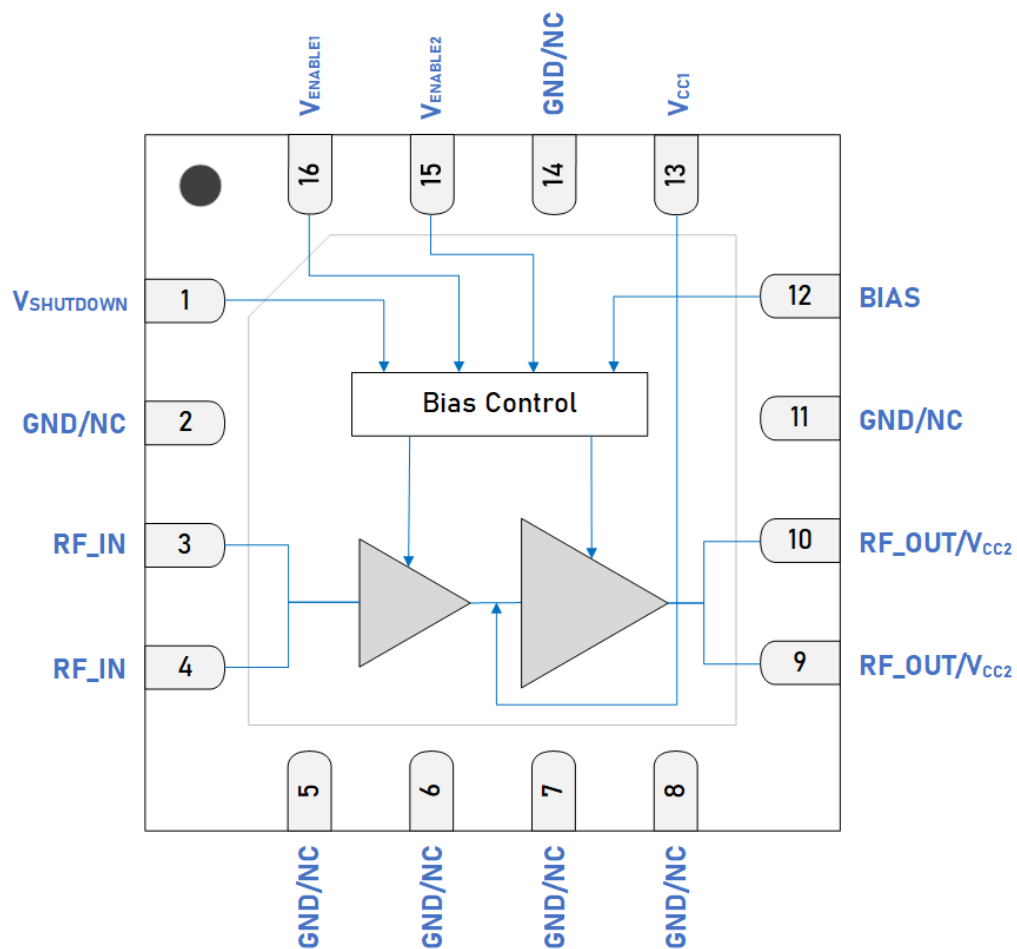
BLOCK DIAGRAM



APPLICATIONS

- Automatic Meter Reader
- VHF/UHF
- IOT

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Pin Assignments

| Pin | Name | Description | Note |
|-----------------------|-------------------------|------------------------|---|
| 1 | V _{SHUTDOWN} | Digital Shutdown Pin | V _{SHDN} ≥ 1.8 volts (logic HIGH) disables device. V _{SHDN} ≤ 0.8 volts (logic LOW) enables device. |
| 2, 5, 6, 7, 8, 11, 14 | GND/NC | Ground or No Connect | No internal connection to die. These pins can be left disconnected or be connected to ground (recommended). Use a via as close to the pin as possible if grounded. |
| 3, 4 | RF_IN | RF Input | Pins 3 & 4 tied together on system board. An external DC blocking capacitor must be used. |
| 9, 10 | RF_OUT/V _{CC2} | PA Output/Bias Voltage | Pins 9 & 10 tied together on system board. V _{CC2} must be applied to this pin via an RF choke. |
| 12 | Bias | Bias Circuit Supply | Connect to V _{CC2} through an external resistor. |
| 13 | V _{CC1} | Bias Voltage | Connect V _{CC1} through an external inductor and capacitive termination (see application schematic). |
| 15 | V _{ENABLE2} | Enable2 Voltage Input | V _{EN2} and series resistor set I _{CCQ} for the output stage. V _{EN2} ≤ 0.2 volts disables stage 2. |
| 16 | V _{ENABLE1} | Enable1 Voltage Input | V _{EN1} and series resistor set I _{CCQ} for the input stage. V _{EN1} ≤ 0.2 volts disables stage 1. Connecting an external de-coupling capacitor to ground is required for optimal NF performance. |
| PKG Base | GND | Ground | Provides DC and RF ground for the amplifier, as well as thermal heat sink. Recommend multiple 8 mil vias beneath the package for optimal RF and thermal performance. Refer to evaluation board top layer graphic on schematic page. |

Absolute Ratings

| Parameter | Symbol | Min. | Max. | Unit |
|---|--------------------------------------|------|--------|------|
| Supply Voltage | V_{CC} | 3 | 5.25 | V |
| RF Input Power: 50 Ω , V_{CC} = 5 V, CW Tone, 100% Duty Cycle, $T_{PKG\ BASE}$ = 25 °C. | $P_{IN\ MAX} - 1:1$ | | 20 | dBm |
| RF Input Power: Load VSWR \leq 3.5:1, all phase angles, V_{CC} = 5 V, CW Tone, 100% Duty Cycle, $T_{PKG\ BASE}$ = -40 to 85 °C (\leq 5.2:1 for 25 to 85 °C). | $P_{IN\ MAX} - 3.5:1$ (5.21 @ 25 °C) | | 15 | dBm |
| Operating Temperature (Package Base). | $T_{PKG\ BASE}$ | -40 | 85 | °C |
| Maximum Junction Temperature (MTTF > 10 ⁶ Hours). | $T_J\ MAX$ | | 190 | °C |
| Maximum Dissipated Power: Stage 1, DC only (no RF applied). | $P_{DISS\ MAX}$ | | 750 | mW |
| Maximum Dissipated Power: Stage 2, DC only (no RF applied). | $P_{DISS\ MAX}$ | | 2250 | mW |
| Shutdown Voltage | V_{SHDN} | 0 | **5.25 | V |

** V_{SHDN} = 5.25 V yields I_{SHDN} = 512 μ A. I_{SHDN} decreases linearly vs. V_{SHDN} to 64 μ A with V_{SHDN} = 1.8 V. This linear relationship can be used to place series bias R in line with V_{SHDN} voltage: use pin condition V_{SHDN}/I_{SHDN} = 2.4 V/137 μ A.

Calculate bias R for 5V/137 μ A: Bias R = (5-2.4)/(0.000137) = 19 k Ω .

Absolute Ratings (continued)

Electrostatic Discharge

| Parameter | Symbol | Min. | Max. | Unit |
|----------------------|--------|------|------|------|
| Charged Device Model | CDM | 750 | | V |
| Human Body Model | HBM | 500 | | V |

Storage

| | | | | |
|----------------------------|------------------|-----|-----|----|
| Storage Temperature | T _{STG} | -65 | 150 | °C |
| Moisture Sensitivity Level | MSL | | 1 | -- |



Caution! ESD Sensitive Device.

Exceeding Absolute Maximum Rating conditions may cause permanent damage.

Note: For additional information, please refer to [Manufacturing Note MN-001 - Packaging and Manufacturing Information](#).



All Guerrilla RF products are provided in RoHS compliant lead (Pb)-free packaging. For additional information, please refer to the [Certificate of RoHS Compliance](#).

Recommended Operating Conditions

| Parameter | Symbol | Specification | | | Unit | Condition |
|---|-----------------|---------------|------|------|----------|---|
| | | Min. | Typ. | Max. | | |
| Supply Voltage | V_{CC} | 3 | 5 | 5.25 | V | |
| Operating Temperature (Package Base) | $T_{PKG\ BASE}$ | -40 | | 85 | °C | |
| RF Frequency Range | FRF | 100 | 450 | 600 | MHz | Typical application schematic using the 450 to 470 MHz tuning set (note 1 & 2) . |
| RF_IN Port Impedance | Z_{RFIN} | | 50 | | Ω | Single-Ended with 3 element match. |
| RF_OUT Port Impedance | Z_{RFOUT} | | 50 | | Ω | Single-Ended with 5 element match. |

Note 1: Operation outside of this range is supported by using different custom tunes. Examples of other optimized tunes can be found here: [GRF5604 Custom Tunes](#)

Note 2: Contact the Guerrilla RF Applications team for guidance on optimizing the tuning of the device for alternative bands.

Nominal Operating Parameters - General

| Parameter | Symbol | Specification | | | Unit | Condition |
|---|----------------|---------------|------|----------|---------|---|
| | | Min. | Typ. | Max. | | |
| Supply Quiescent Current | I_{CCQ} | | 247 | | mA | $I_{CCQ1} + I_{CCQ2}$. No RF applied. |
| Supply Quiescent Current with RF applied. | I_{CC} | | 2050 | | mA | $I_{CC1} + I_{CC2}$. RF applied, $P_{OUT} = 38$ dBm. |
| Enable Current 1 | I_{EN1} | | 2.1 | | mA | $V_{CC} = 5$ V. $T_{PKG BASE} = 25$ °C. |
| Enable Current 2 | I_{EN2} | | 0.4 | | mA | $V_{CC} = 5$ V. $T_{PKG BASE} = 25$ °C. |
| Operating Temperature Range | $T_{PKG BASE}$ | -40 | | 85 | °C | Measured on Package Base. |
| Logic Input Low | V_{IL} | 0 | | 0.8 | | Applies to V_{SHDN} Input. |
| Logic Input High | V_{IH} | 1.8 | | V_{CC} | | Applies to V_{SHDN} Input. |
| Logic Current Low | I_{IL} | | 1.3 | | nA | Applies to V_{SHDN} Input. $V_{IL} = 0.8$ V. |
| Logic Current High | I_{IH} | | 64 | | μA | Applies to V_{SHDN} Input. $V_{IH} = 1.8$ V. |
| | | | 248 | | | Applies to V_{SHDN} Input. $V_{IH} = 3.3$ V. |
| Switching Rise Time | T_{RISE} | | 200 | | ns | Applies to V_{SHDN} Input. |
| Switching Fall Time | T_{FALL} | | 2200 | | ns | Applies to V_{SHDN} Input. |

Disabled Mode

| | | | | | | |
|--------------------------|------------------|--|-----|--|---------|---|
| Supply Quiescent Current | $I_{CCQ - SHDN}$ | | 12 | | μA | $V_{CC} = 5$ V, $V_{SHDN}/V_{EN1}/V_{EN2} = HIGH$. |
| Enable Current 1 | $I_{EN1 - SHDN}$ | | 2.4 | | mA | $V_{CC} = 5$ V, $V_{SHDN}/V_{EN1}/V_{EN2} = HIGH$. |
| Enable Current 2 | $I_{EN2 - SHDN}$ | | 0.8 | | mA | $V_{CC} = 5$ V, $V_{SHDN}/V_{EN1}/V_{EN2} = HIGH$. |

Nominal Operating Parameters - General (continued)

Thermal Data (Stage 1 and Stage 2)

| | | | | | | |
|---|---------------|--|----|--|-----------------------------|---|
| Stage 1: Thermal Resistance (Infrared Scan). DC only (no RF applied). | Θ_{JC} | | 80 | | $^{\circ}\text{C}/\text{W}$ | On standard evaluation board (note 3) . |
| Stage 2: Thermal Resistance (Infrared Scan). DC only (no RF applied). | Θ_{JC} | | 20 | | $^{\circ}\text{C}/\text{W}$ | On standard evaluation board (note 3) . |
| Thermal Data Stage 1 & 2: see plot of junction temp vs. output power. | T_J | | | | $^{\circ}\text{C}$ | $V_{CC} = V_{EN1} = V_{EN2} = 5\text{ V}$. On standard evaluation board (note 3) . |

Note 3: MTTF > 10^6 hours for $T_J \leq 190\text{ }^{\circ}\text{C}$

Nominal Operating Parameters - RF

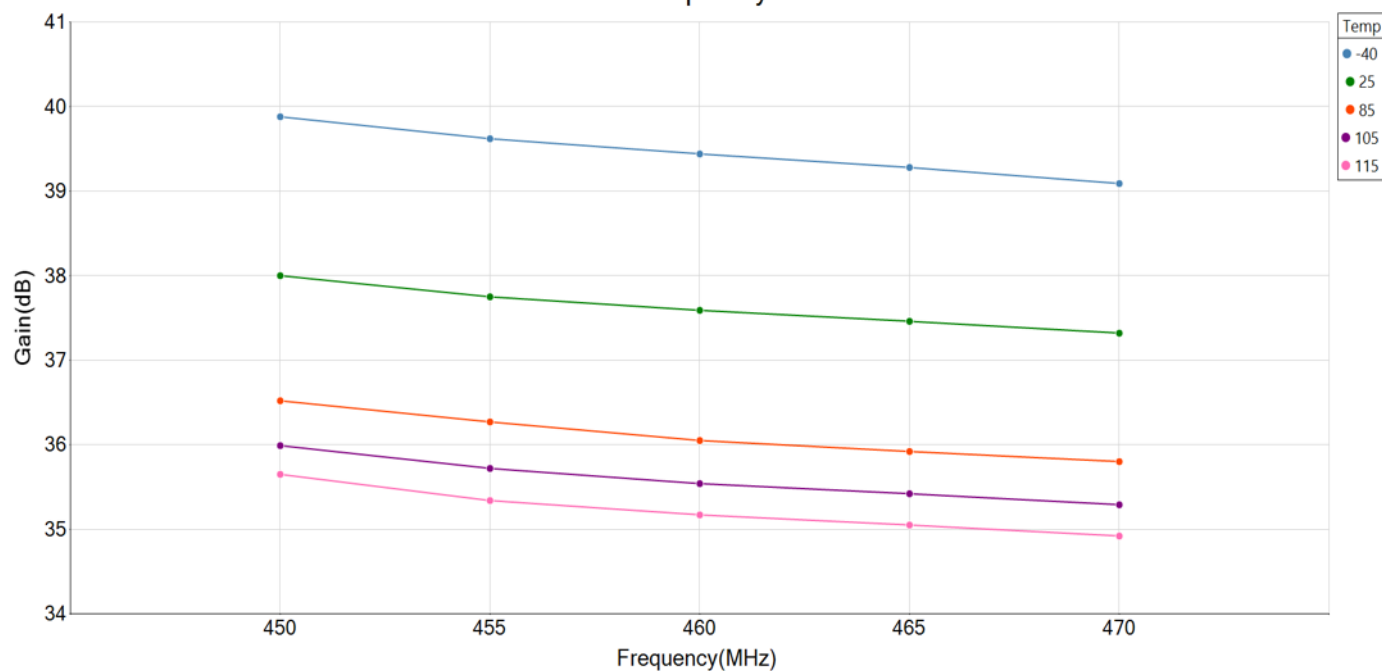
The following conditions apply unless noted otherwise; Typical application schematic using the 450 to 470 MHz Tuning set, $F_{TEST} = 460$ MHz, $M1 = 1.96$ k Ω , $M5 = 6.04$ k Ω , $V_{CC} = 5$ V, $V_{SHDN} = LOW$, $I_{CCQ} = 247$ mA, 50 Ω system impedance, $T_{PKG\ BASE} = 25$ °C. Evaluation board losses are included within the specifications.

| Parameter | Symbol | Specification | | | Unit | Condition |
|-------------------------------|---------------------|---------------|--------|------|------|--|
| | | Min. | Typ. | Max. | | |
| Small Signal Gain | S21 | | 37.5 | | dB | $V_{CC} = 5$ V, $P_{IN} = -25$ dBm. |
| Standby Mode Gain | S21 _{STBY} | | -50 | | dB | Disabled Mode, $V_{SHDN}/V_{EN1}/V_{EN2} = HIGH$, $P_{IN} = 0$ dBm. |
| Input Return Loss | S11 | | < -8.5 | | dB | $F_{RF} = 450$ to 470 MHz. |
| Output Return Loss | S22 | | < -8.5 | | dB | $F_{RF} = 450$ to 470 MHz. |
| Reverse Isolation | S12 | | < -50 | | dB | $F_{RF} = 450$ to 470 MHz. |
| Output 1 dB Compression Power | OP1dB | | 38 | | dBm | $V_{CC} = 5$ V, Sinewave input. |
| Noise Figure | NF | | 3.5 | | dB | On standard evaluation board. |

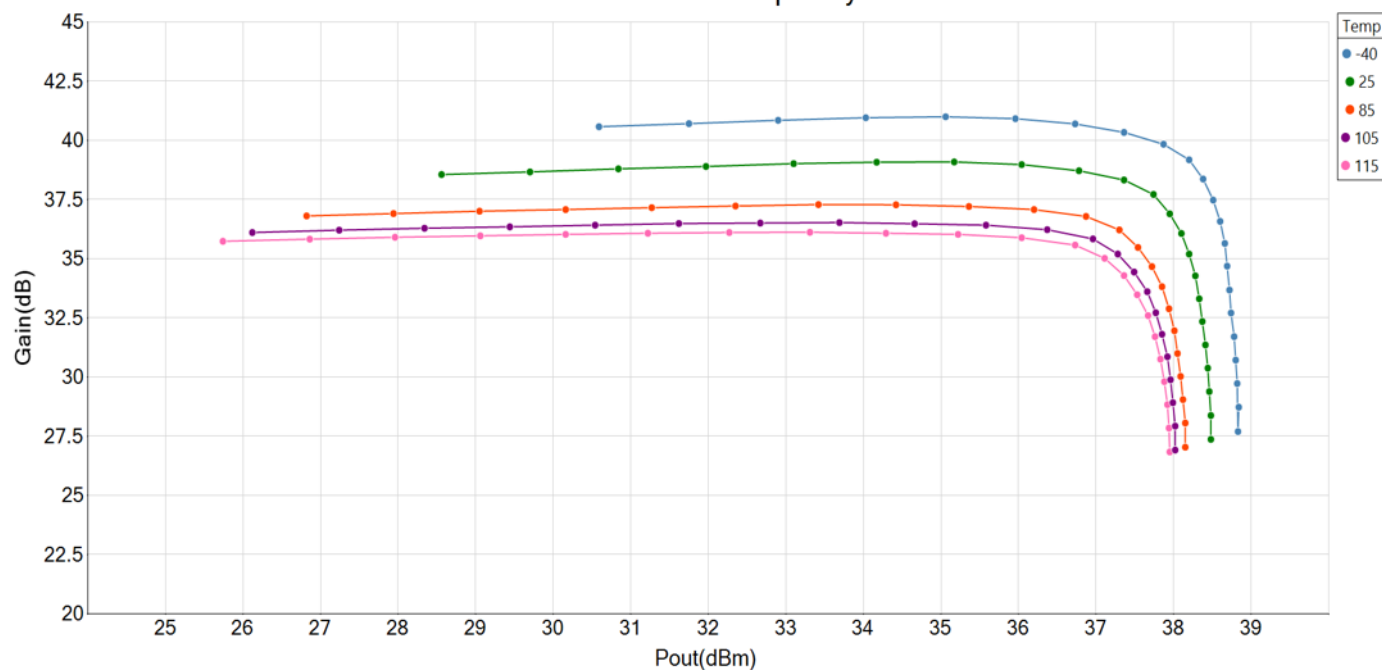
Note 4: MIN/MAX limits defined using *modeled estimates* that account for part-to-part variations and expected process spreads. As additional production lots are fabricated, accumulated test data will be used to refine MIN/MAX limits.

GRF5604 Typical Operating Curves: 450 to 470 MHz Tune

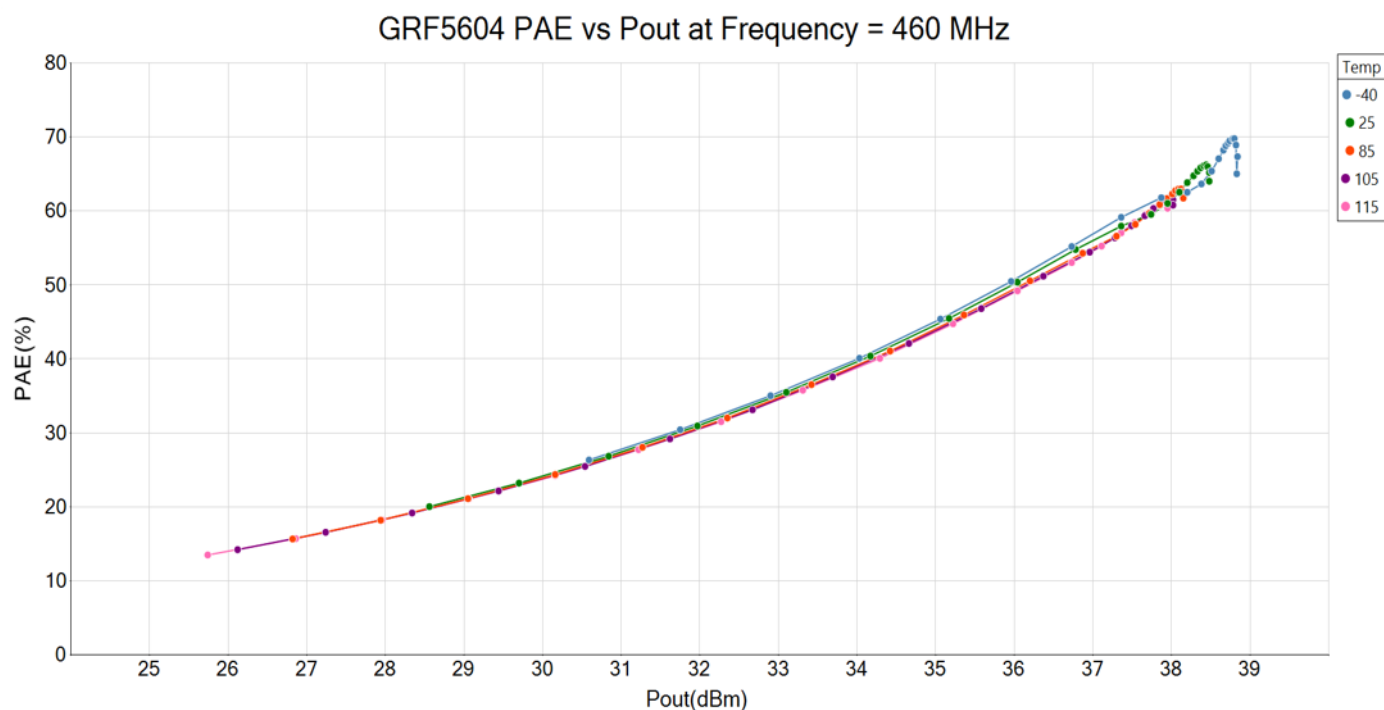
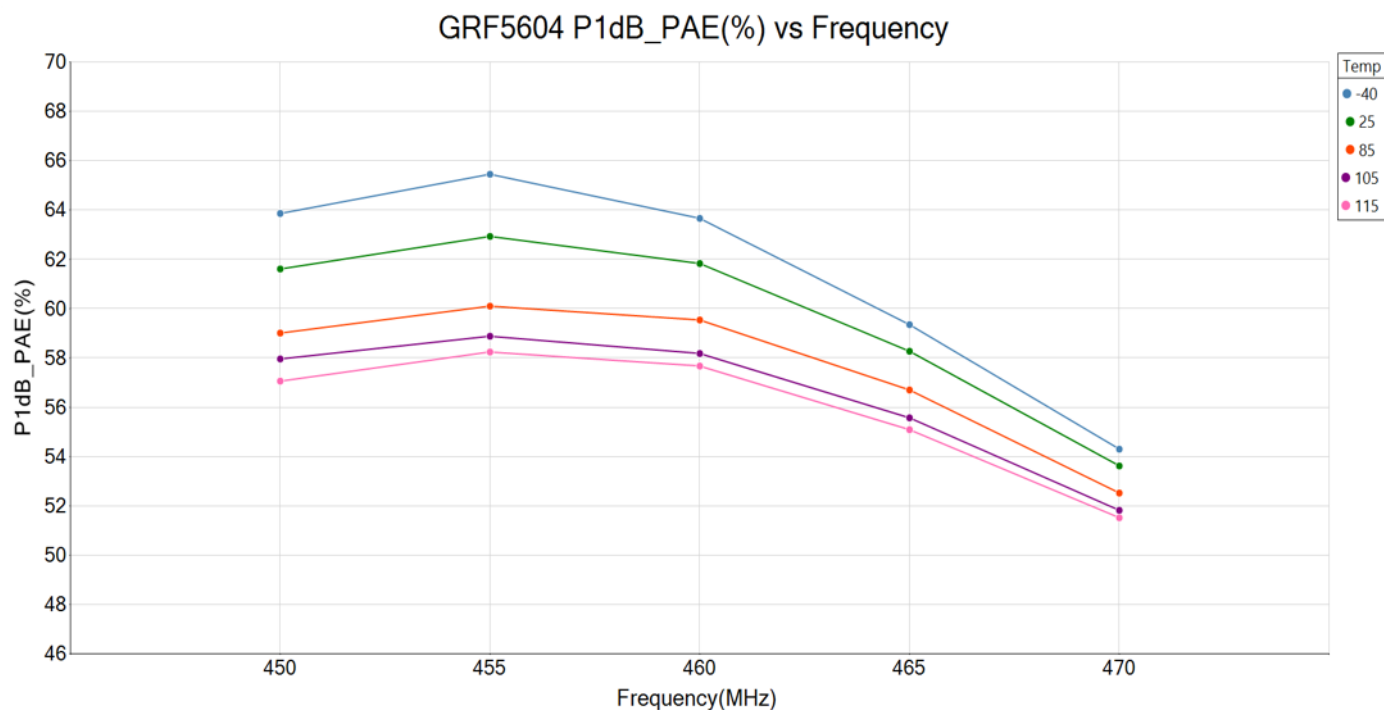
GRF5604 Gain vs Frequency at Pin = -25 dBm



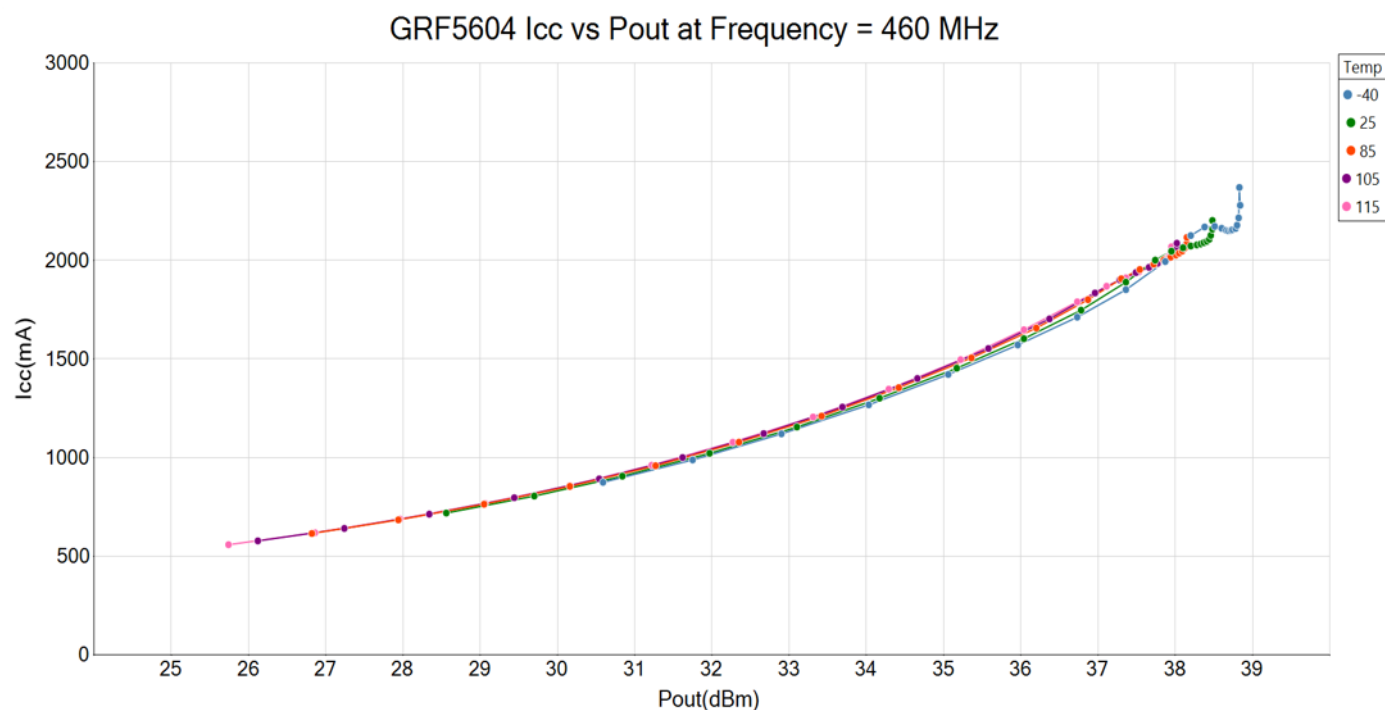
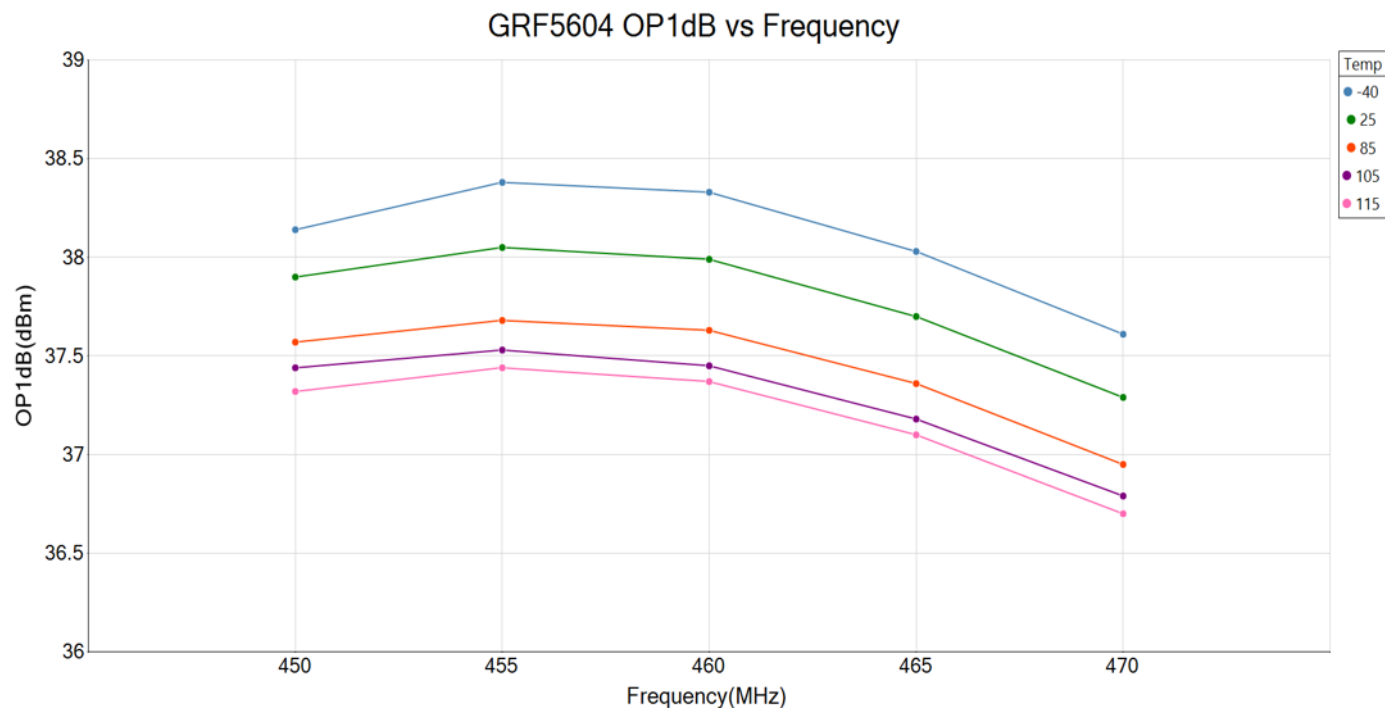
GRF5604 Gain vs Pout at Frequency = 460 MHz



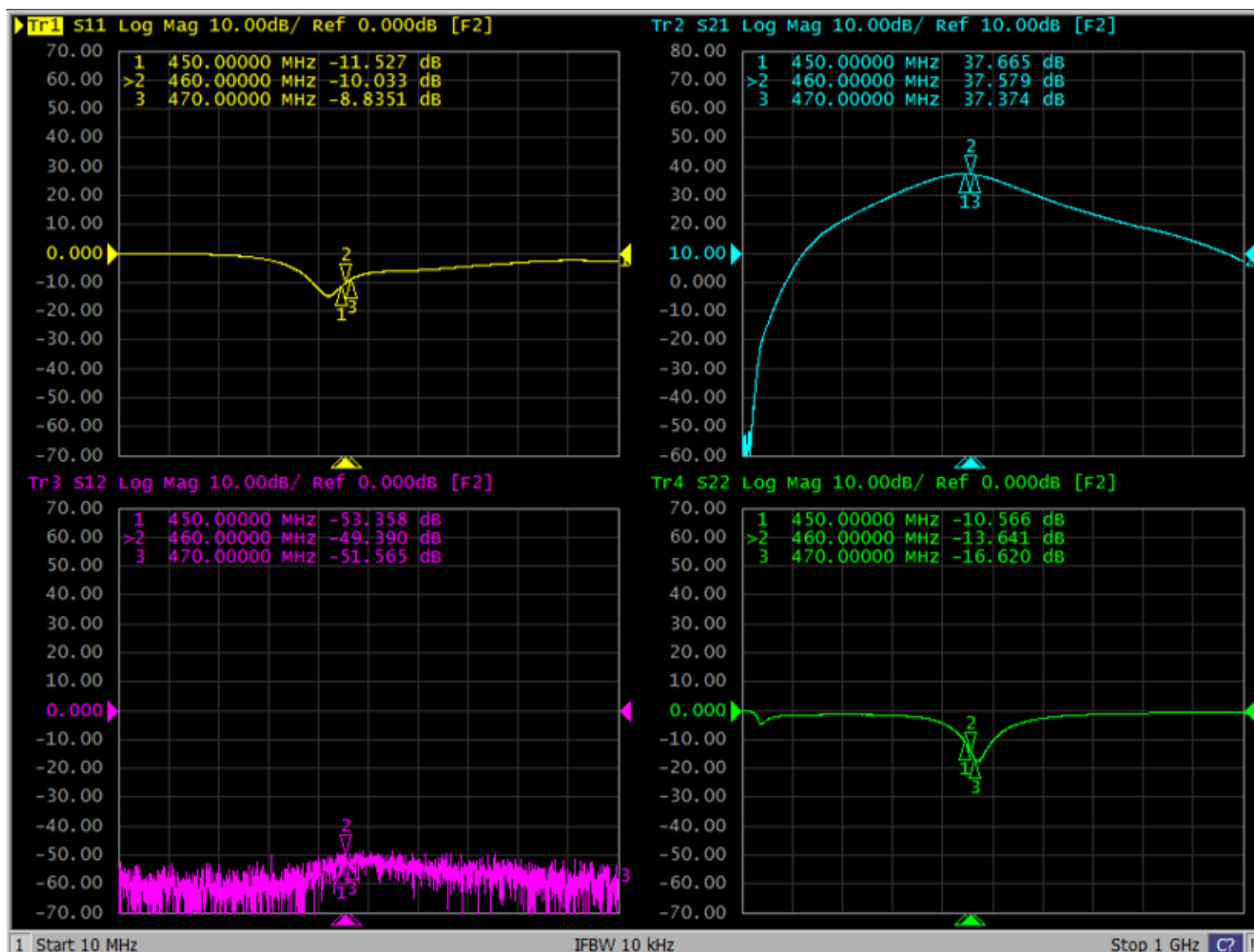
GRF5604 Typical Operating Curves: 450 to 470 MHz Tune



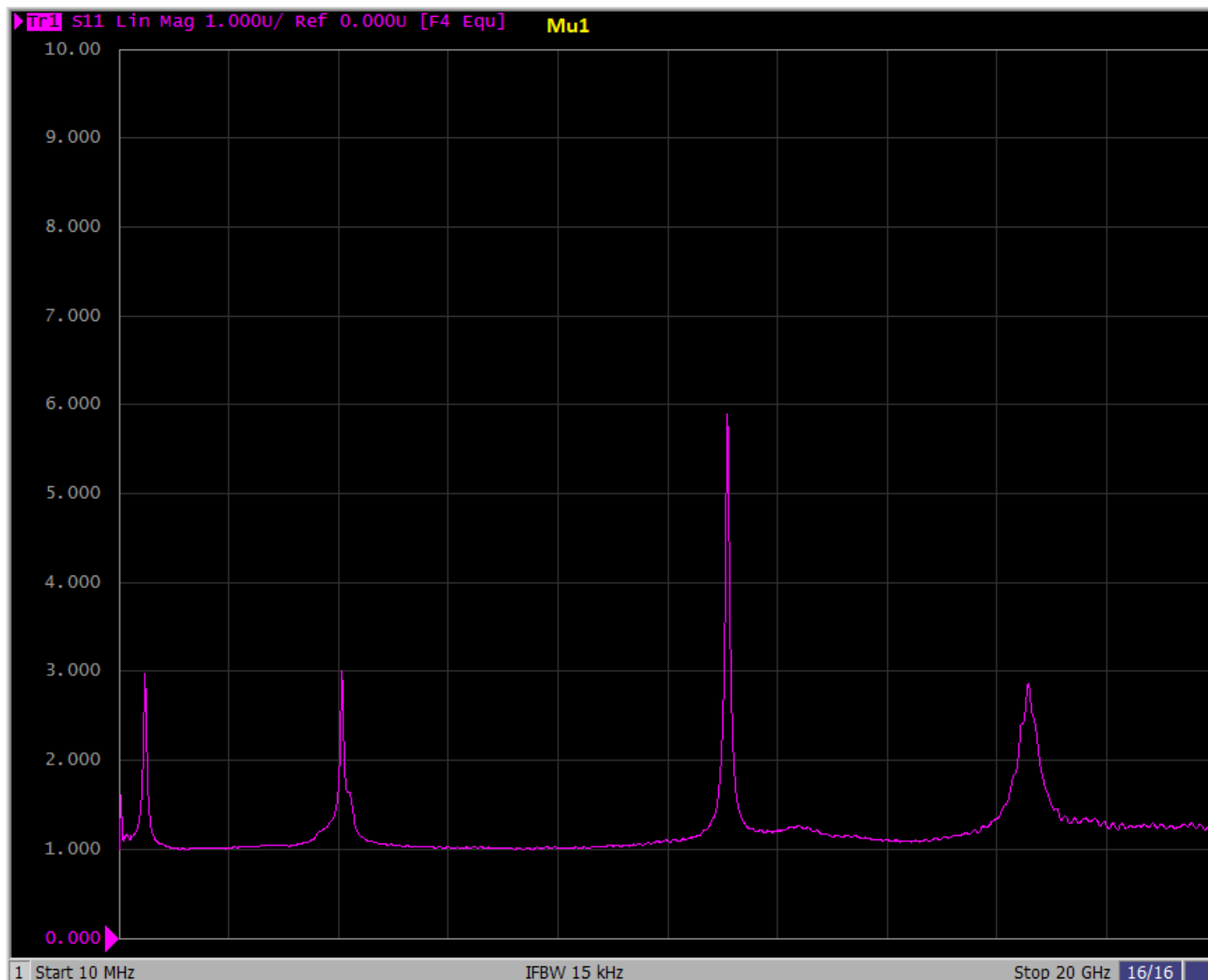
GRF5604 Typical Operating Curves: 450 to 470 MHz Tune



GRF5604 Typical Operating Curves: Small Signal S-Parameters (450 to 470 MHz Tune)



GRF5604 Typical Operating Curves: Stability Mu (10 MHz to 20 GHz Tune)

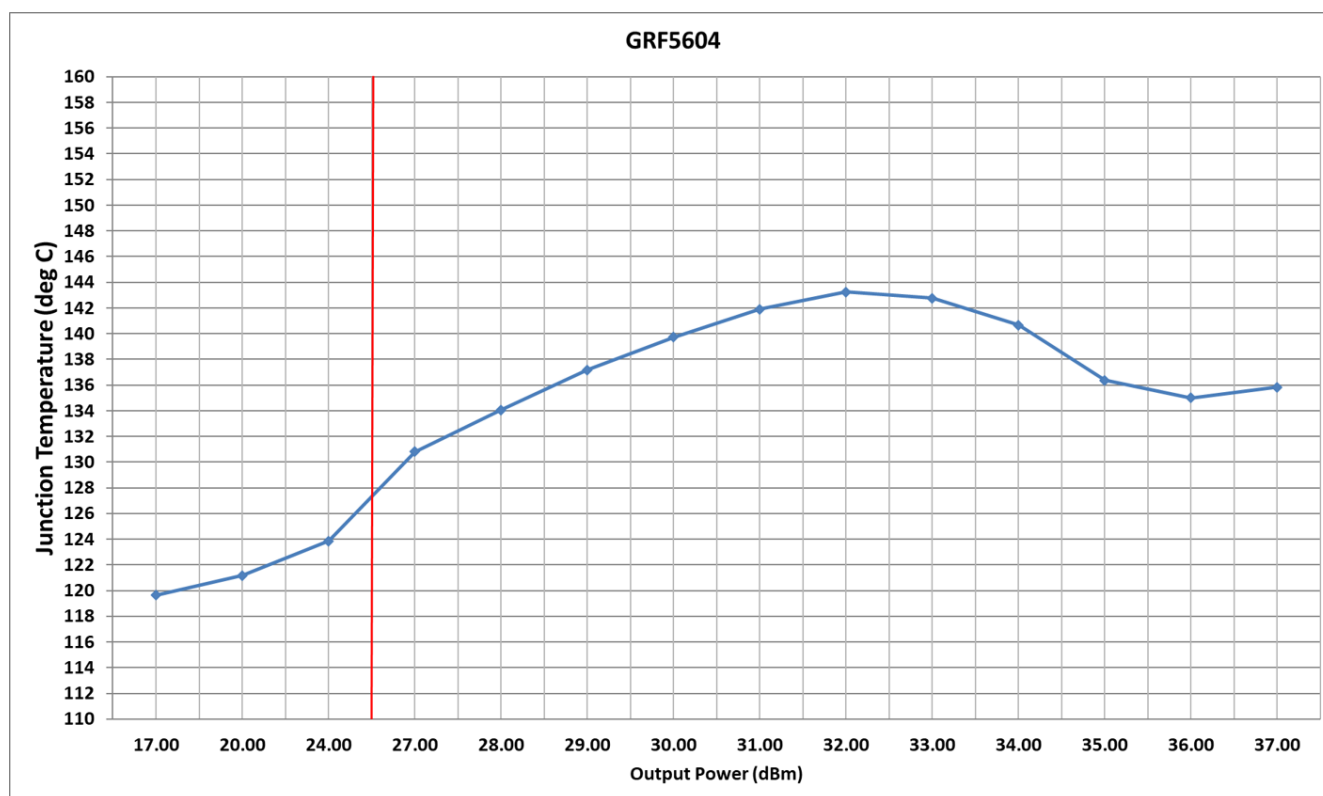


Note: Mu factor ≥ 1.0 implies unconditional stability (small signal).

GRF5604 Typical Operating Curves: Junction Temperature (per application schematic @ 85 °C)

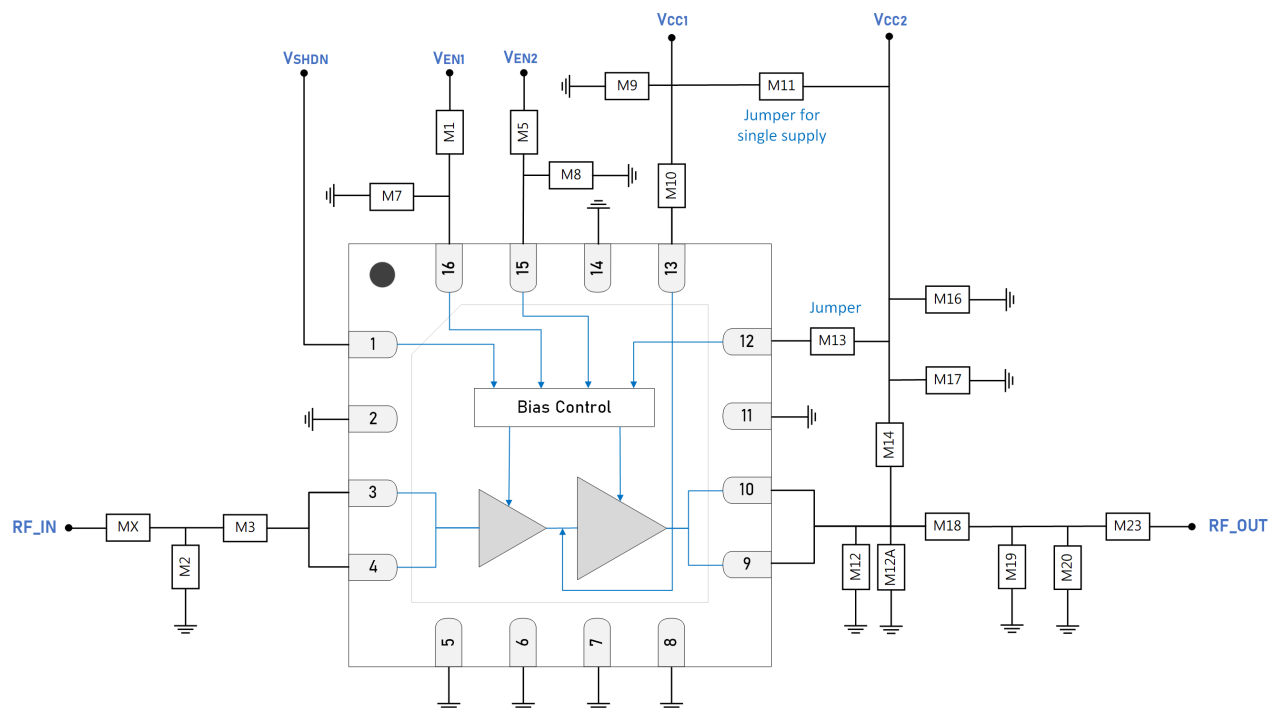
GRF5604, being a 2-stage device, sees one of the stages governing junction temperature over power sweep. Red line = 25.5 dBm shows where T_J is equivalent in both stages. At left of red line, stage 1 governs T_J (Q1 T_J is higher). To the right of red line, stage 2 governs T_J (Q2 T_J is higher).

Setting bias resistor M1 and M5 per application schematic ensures best linearity and yields thermal performance shown in the plot. If the application does not require high IMD3/ACLR linearity, bias resistor can be adjusted higher. This will lower bias point(s) and junction temperature will be contained within/below that shown in the plot.

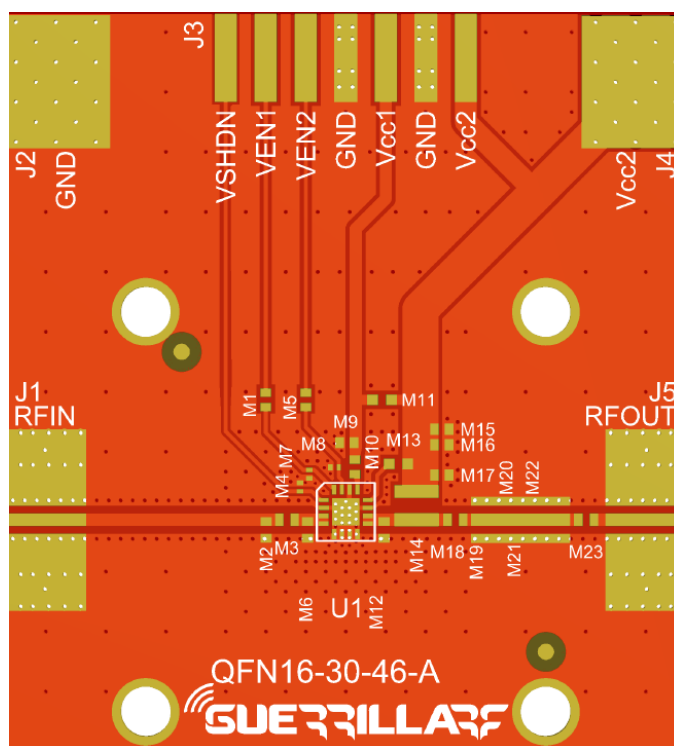


Truth Table

| Pin | Logic | Condition |
|-------------------|-------|-----------------------|
| V_{SHDN} | LOW | Full Operation |
| | HIGH | All Amplifiers OFF |
| V_{EN1} | LOW | Stage 1 Amplifier OFF |
| | HIGH | Stage 1 Amplifier ON |
| V_{EN2} | LOW | Stage 2 Amplifier OFF |
| | HIGH | Stage 2 Amplifier ON |



GRF5604 Standard Evaluation Board Schematic



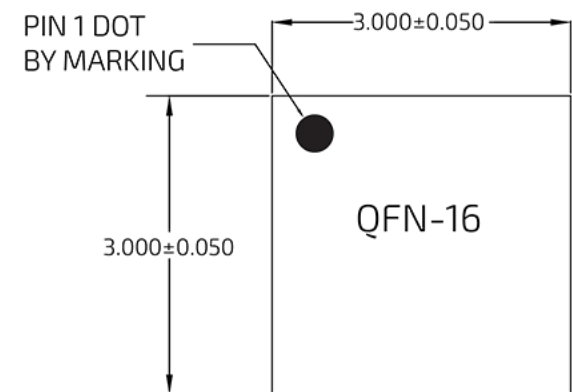
GRF5604 Evaluation Board Assembly Diagram

GRF5604 Evaluation Board Assembly Diagram Reference: 450 to 470 MHz Tune

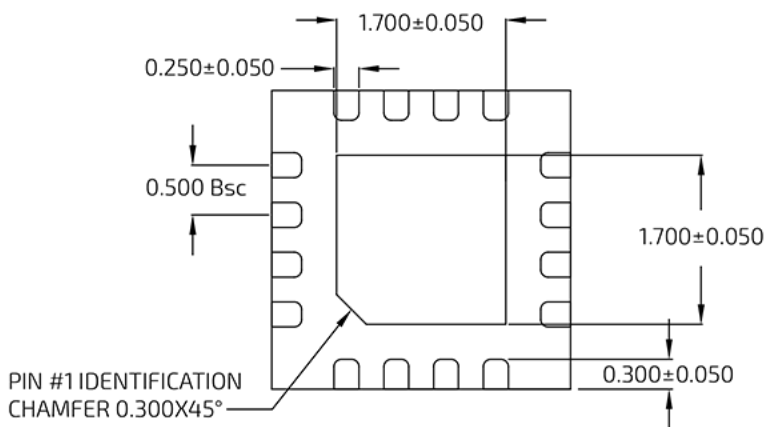
| Component | Type | Manufacturer | Family | Value | Package Size | Substitution |
|------------------|-------------------|--------------|------------|---------------|--------------|--------------|
| M1 | Resistor | Various | 1% | 1960 Ω | 0402 | ok |
| M2 | Inductor | Murata | LQG | 10 nH | 0402 | ok |
| M3 | Capacitor | Murata | GJM | 33 pF | 0402 | ok |
| MX | Capacitor | Murata | GJM | 10 pF | 0402 | ok |
| M5 | Resistor | Various | 1% | 6040 Ω | 0402 | ok |
| M7 | Capacitor | Murata | GRM | 1000 pF | 0402 | ok |
| M8 | Capacitor | Murata | GRM | 1000 pF | 0402 | ok |
| M9 | Capacitor | Murata | GRM | 0.1 μ F | 0402 | ok |
| M10 | Inductor | Coilcraft | 0402HP | 20 nH | 0402 | ok |
| M11 | Resistor (jumper) | Various | 1% | 0 Ω | 0402 | ok |
| M12 | Capacitor | Murata | GJM | 33 pF | 0402 | ok |
| M12A | Capacitor | Murata | GJM | 2.0 pF | 0402 | ok |
| M13 | Resistor (jumper) | Various | 1% | 0 Ω | 0402 | ok |
| M14 | Inductor | Coilcraft | 0908SQ | 23 nH | 0908 | ok |
| M16 | Capacitor | Murata | GRM | **10 μ F | 0402 | ok |
| M17 | Capacitor | Murata | GRM | 1000 pF | 0402 | ok |
| M18 | Inductor | Murata | LQW18AN 80 | 2.2 nH | 0603 | ok |
| M19 | Capacitor | Murata | GJM | 27 pF | 0402 | ok |
| M20 | Capacitor | Murata | GJM | 1.8 pF | 0402 | ok |
| M23 | Capacitor | Murata | GRM | 100 pF | 0402 | ok |
| Evaluation Board | QFN16-30-46-A | | | | | |

Notes: Standard evaluation board bias: $V_{CC} = 5\text{ V}$, $V_{ENABLE} = 5\text{ V}$.

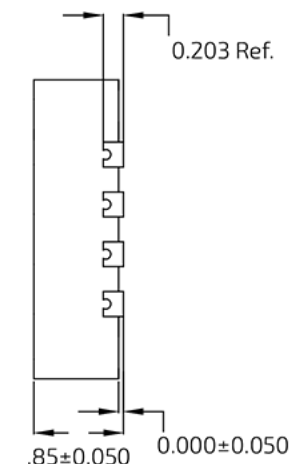
**10 μ F must be rated for > 5 V at maximum ambient temperature. Manufacturer Part Number in this case = GRM155C80J106ME11D.



TOP VIEW

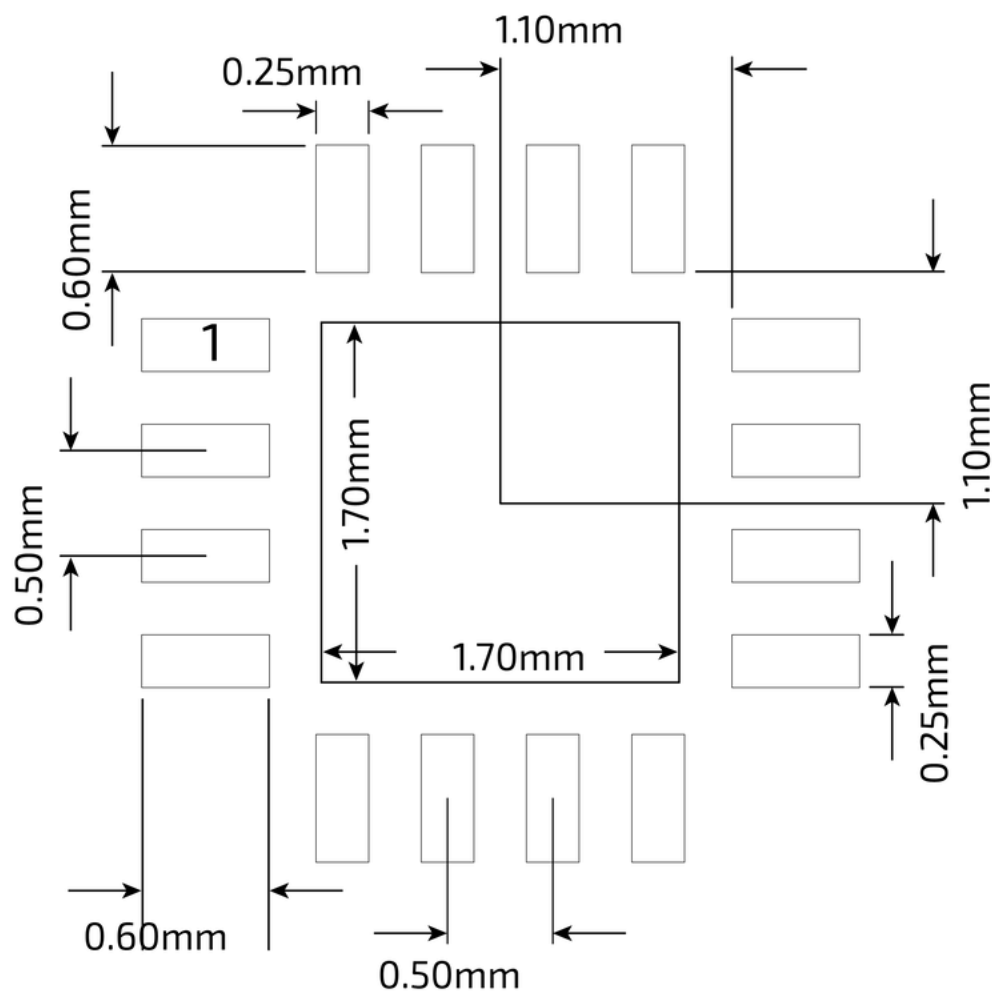


BOTTOM VIEW



SIDE VIEW

QFN 16 3x3mm Package Dimensions



QFN 16 3x3mm Suggested PCB Footprint (Top View)

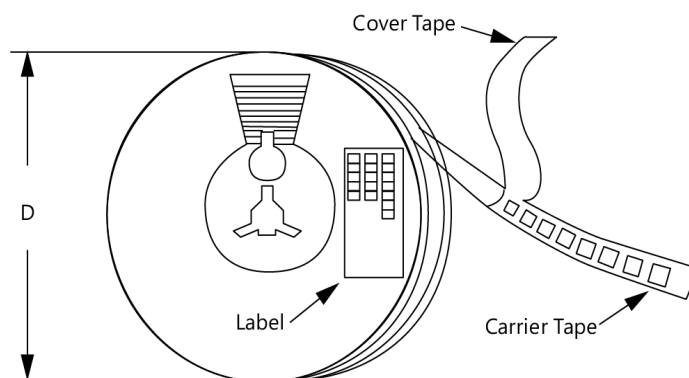
Package Marking Diagram



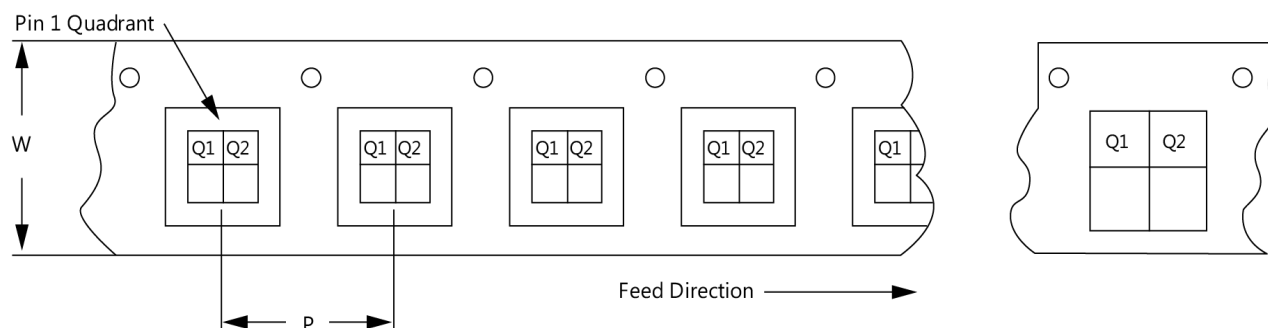
Line 1: "YY" = Year. "WW" = WORK WEEK the Device was assembled.
 Line 2: "GRF" = Guerrilla RF
 Line 3: "XXXX" = Device Part Number.

Tape and Reel Information

Guerrilla RF's tape and reel specification complies with Electronics Industries Association (EIA) standards for "Embossed Carrier Tape of Surface Mount Components for Automatic Handling" (reference EIA-481). Devices are loaded with pins down into the carrier pocket with protective cover tape and reeled onto a plastic reel. Each reel is packaged in a cardboard box. There are product labels on the reel, the protective ESD bag, and the outside surface of the box. For the latest reel specifications and package information (including units/reel), please visit [Package Manufacturing Information](#) | [Guerrilla RF](#) (guerrilla-rf.com).



Tape and Reel Packaging with Reel Diameter Noted (D)



Carrier Tape Width (W), Pitch (P), Feed Direction and Pin 1 Quadrant Information



Revision History

| Revision Date | Description of Change |
|-------------------|-------------------------|
| August 15, 2023 | Advance Data Sheet. |
| February 26, 2024 | Preliminary Data Sheet. |
| November 22, 2024 | Release Ø Data Sheet. |



Data Sheet Classifications

| Data Sheet Status | Notes |
|-------------------|--|
| Advance | S-parameter and NF data based on EM simulations for the fully packaged device using foundry-supplied transistor S-parameters. Linearity estimates based on device size, bias condition and experience with related devices. |
| Preliminary | All data based on evaluation board measurements taken within the Guerrilla RF Applications Lab. Any MIN/MAX limits represented within the data sheet are based solely on <i>estimated</i> part-to-part variations and process spreads. All parametric values are subject to change pending the collection of additional data. |
| Release Ø | All data based on measurements taken with <i>production-released</i> material. TYP values are based on a combination of ATE and bench-level measurements, with MIN/MAX limits defined using <i>modelled estimates</i> that account for part-to-part variations and expected process spreads. Although unlikely, future refinements to the TYP/MIN/MAX values may be in order as multiple lots are processed through the factory. |
| Release A-Z | All data based on measurements taken with production-released material <i>derived from multiple lots which have been fabricated over an extended period of time</i> . MIN/MAX limits may be refined over previous releases as more statistically significant data is collected to account for process spreads. |

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