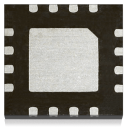
DATA SHEET



GRF5604

High Efficiency 6 Watt Power Amplifier 100 to 600 MHz

RELEASE Ø DATA SHEET

FEATURES

- Excellent OP1dB/P_{SAT}
- 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 I_{CCQ} / 460 MHz

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

APPLICATIONS

- Automatic Meter Reader
- VHF/UHF
- IOT

ORDERING INFORMATION

Buy it Now

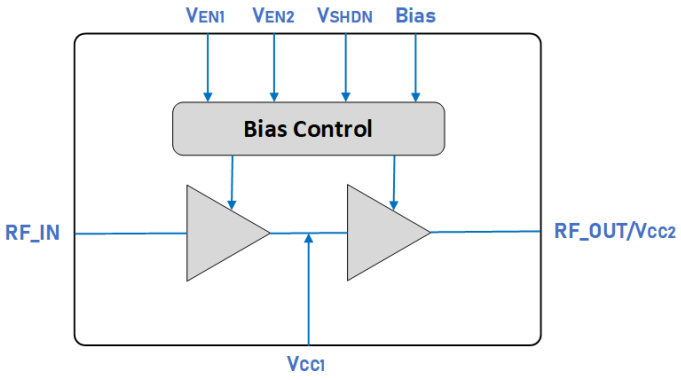
DESCRIPTION

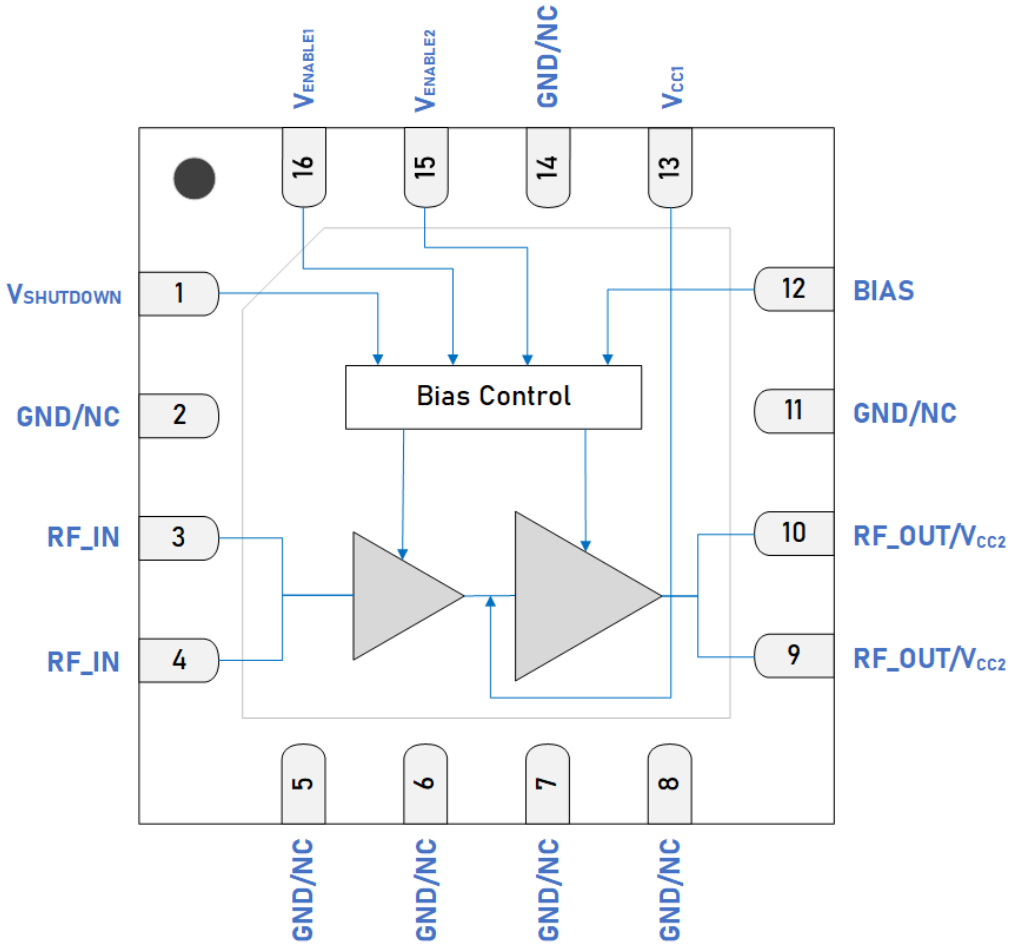
The GRF5604 is a high efficiency PA that delivers up to 6 Watts P_{SAT} with V_{CC} at 5 volts and 3 Watts P_{SAT} with V_{CC} at 3.6 Volts. PAE at P_{SAT} is roughly 60%. The device can be externally matched over a range of frequencies from 100 to 600 MHz with typical fractional bandwidths of 5-10%.

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





Pin Out (Top View)

Pin Assignments

Pin	Name	Description	Note
1	$V_{SHUTDOWN}$	Digital Shutdown Pin	$V_{SHDN} \geq 1.8$ volts (logic HIGH) disables device. $V_{SHDN} \leq 0.8$ 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. $V_{EN2} \leq 0.2$ volts disables stage 2.
16	$V_{ENABLE1}$	Enable1 Voltage Input	V_{EN1} and series resistor set I_{CCQ} for the input stage. $V_{EN1} \leq 0.2$ 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 ≤ 3.5:1, all phase angles, V_{CC} = 5 V, CW Tone, 100% Duty Cycle, $T_{PKG\ BASE}$ = -40 to 85 °C (≤ 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 µA. I_{SHDN} decreases linearly vs. V_{SHDN} to 64 µA 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/137µA.

Calculate bias R for 5V/137µA: Bias R = (5-2.4)/(0.000137) = 19 kΩ.

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.

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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	F_{RF}	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}= 5V, V_{SHDN}/V_{EN1}/V_{EN2} = HIGH.
Enable Current 1	I_{EN1} - SHDN		2.4		mA	V_{CC}= 5V, V_{SHDN}/V_{EN1}/V_{EN2} = HIGH.
Enable Current 2	I_{EN2} - SHDN		0.8		mA	V_{CC}= 5V, 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		°C/W	On standard evaluation board **(note 3)**.
Stage 2: Thermal Resistance (Infrared Scan). DC only (no RF applied).	Θ_{JC}		20		°C/W	On standard evaluation board **(note 3)**.
Thermal Data Stage 1 & 2: see plot of junction temp vs. output power.	T_J				°C	V_{CC} = V_{EN1} = V_{EN2} = 5 V. On standard evaluation board **(note 3)**.

Note 3: MTTF > 10^6 hours for $T_j \leq 190$ °C

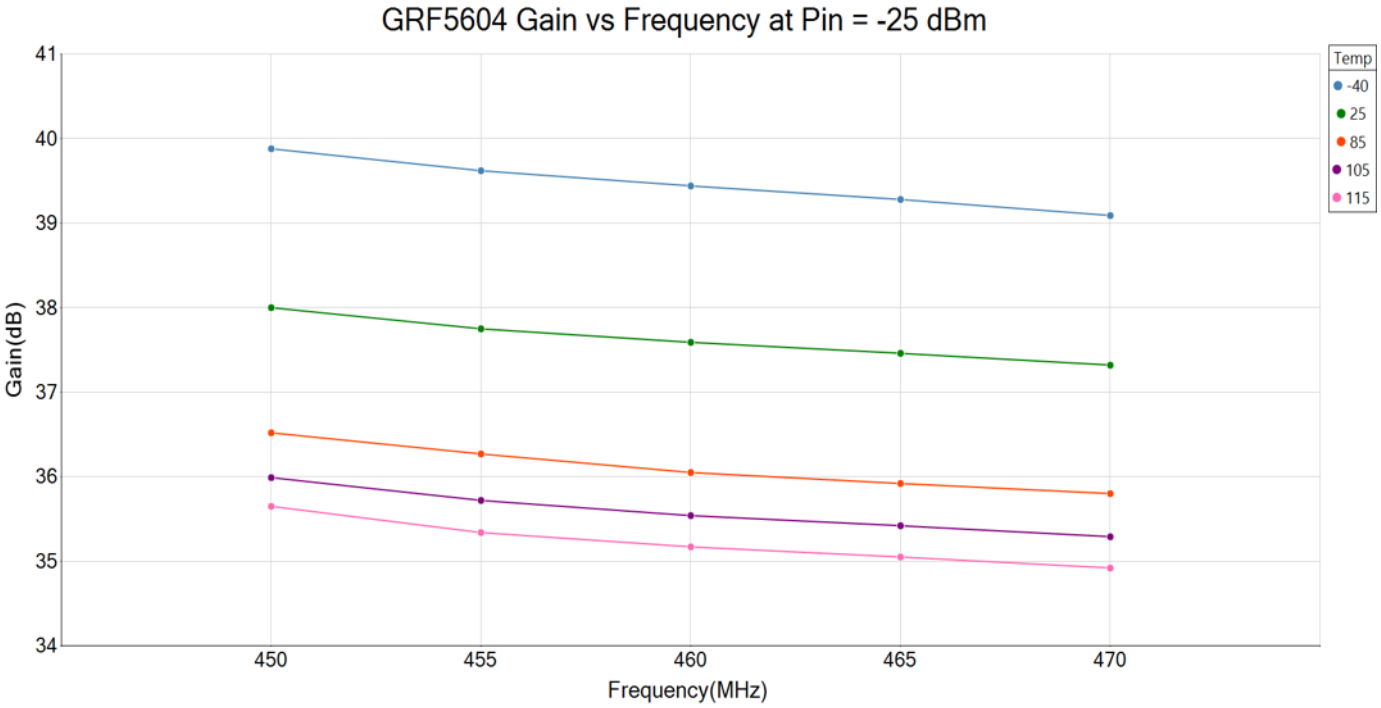
Nominal Operating Parameters - RF

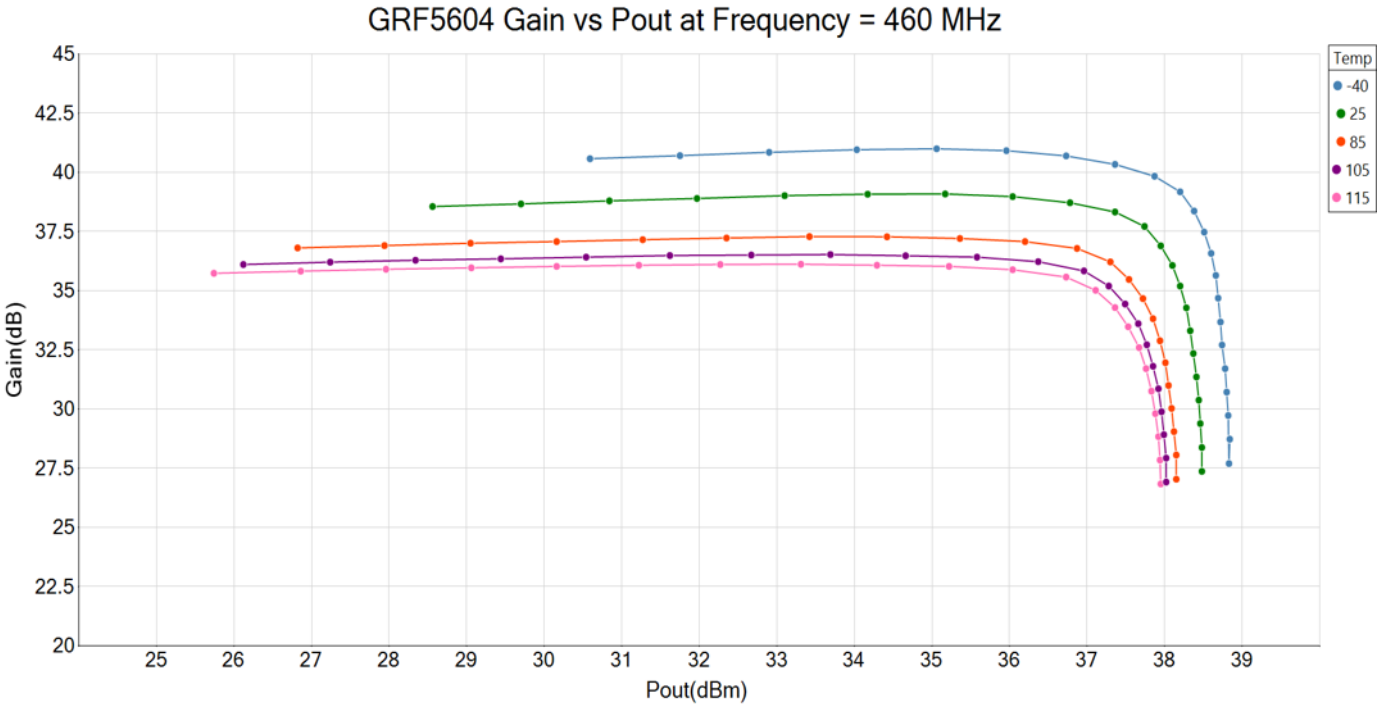
The following conditions apply unless noted otherwise; Typical application schematic using the 450 to 470 MHz Tuning set, F_{TEST} = 460 MHz, M1 = 1.96 kΩ, M5 = 6.04 kΩ, V_{CC} = 5 V, V_{SHDN} = LOW, I_{CCQ} = 247 mA, 50 Ω system impedance, $T_{PKG\ BASE}$ = 25 °C. Evaluation board losses are included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

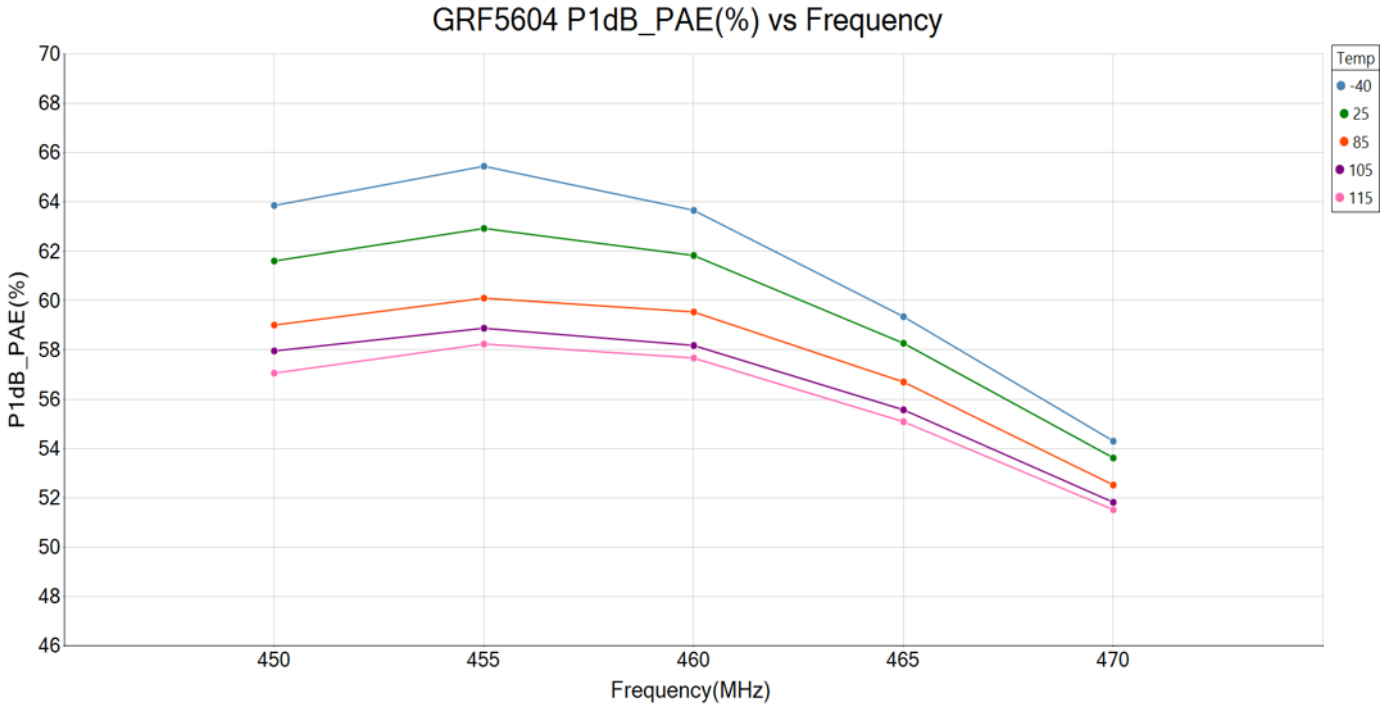
Note 4: MIN/MAX limits defined using *modeled estimates* that account for part-to-part variations and expected process spreads. As additional production lots are fabricated, accumulated test data will be used to refine MIN/MAX limits.

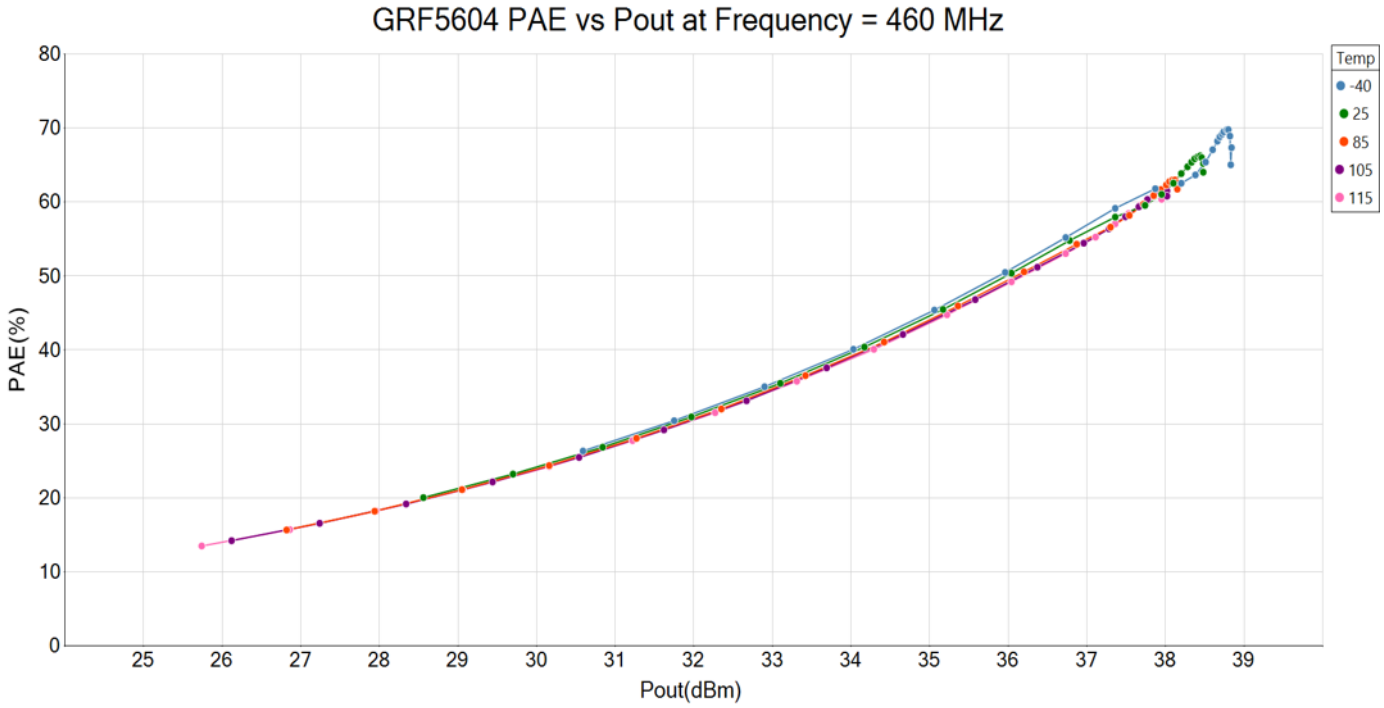
GRF5604 Typical Operating Curves: 450 to 470 MHz Tune



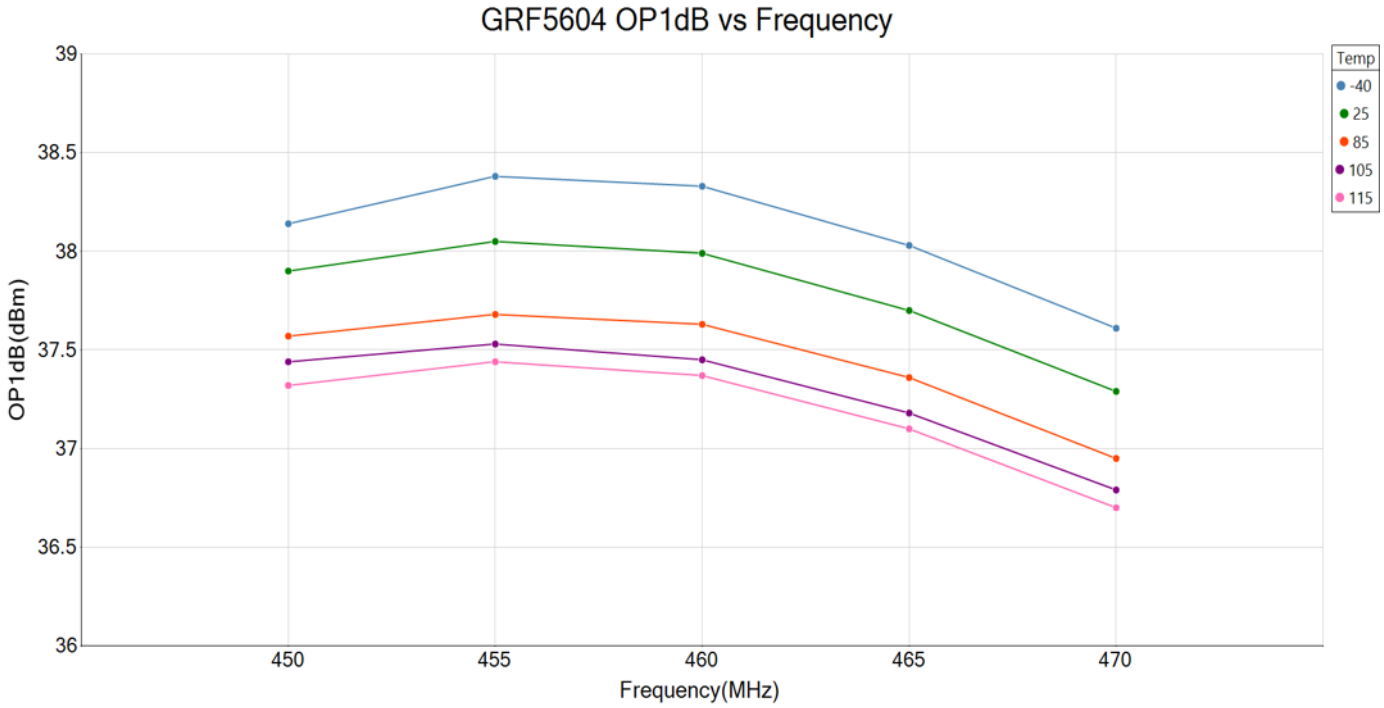


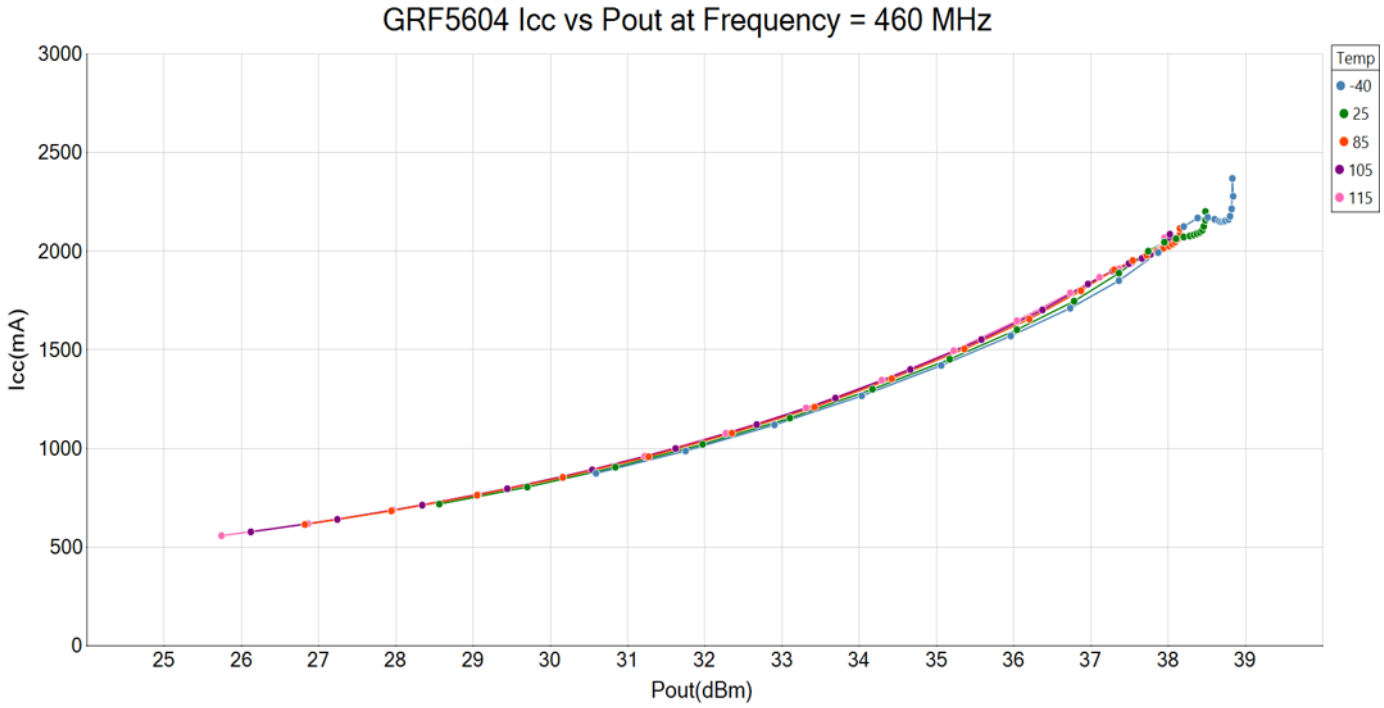
GRF5604 Typical Operating Curves: 450 to 470 MHz Tune



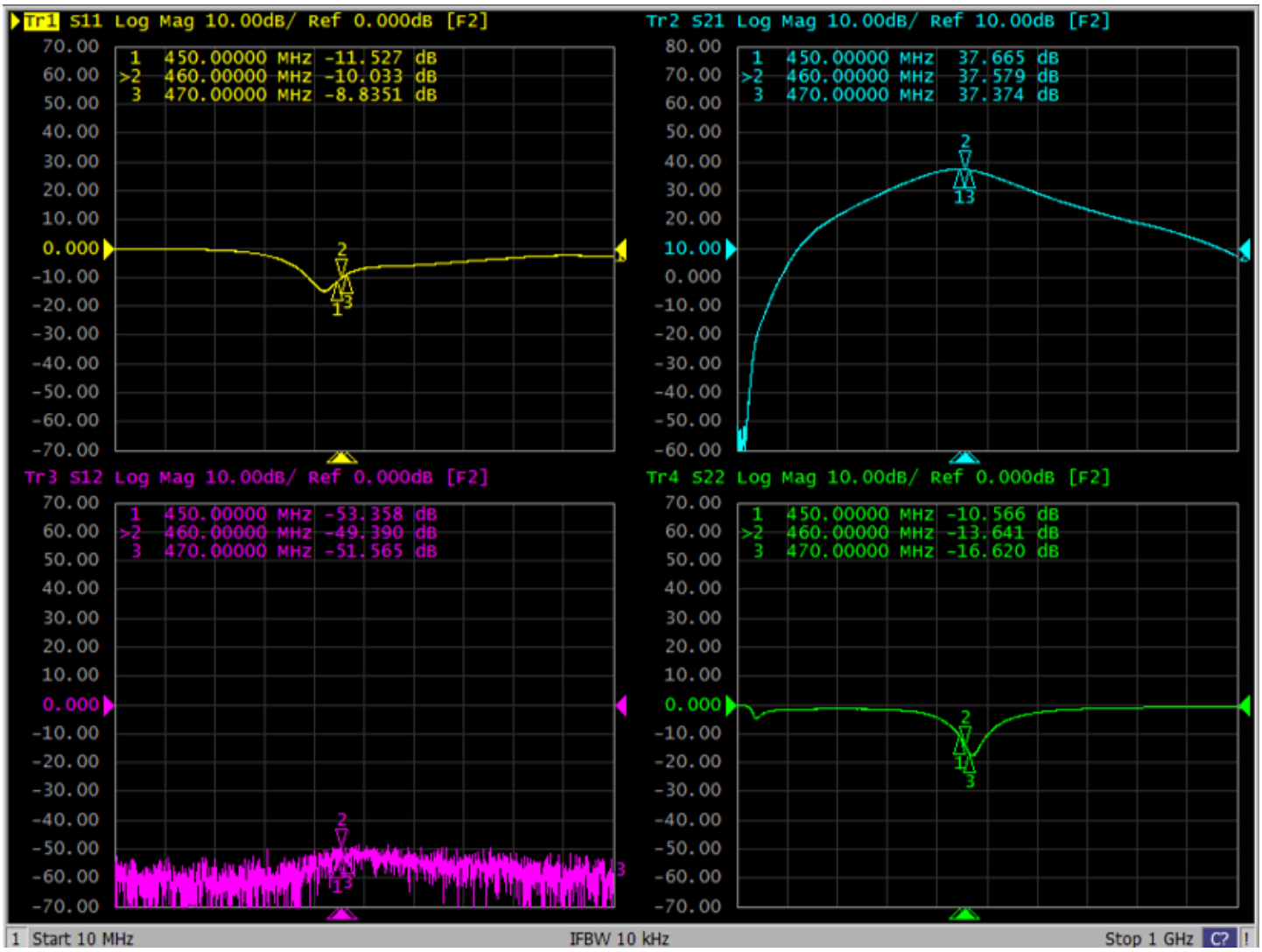


GRF5604 Typical Operating Curves: 450 to 470 MHz Tune

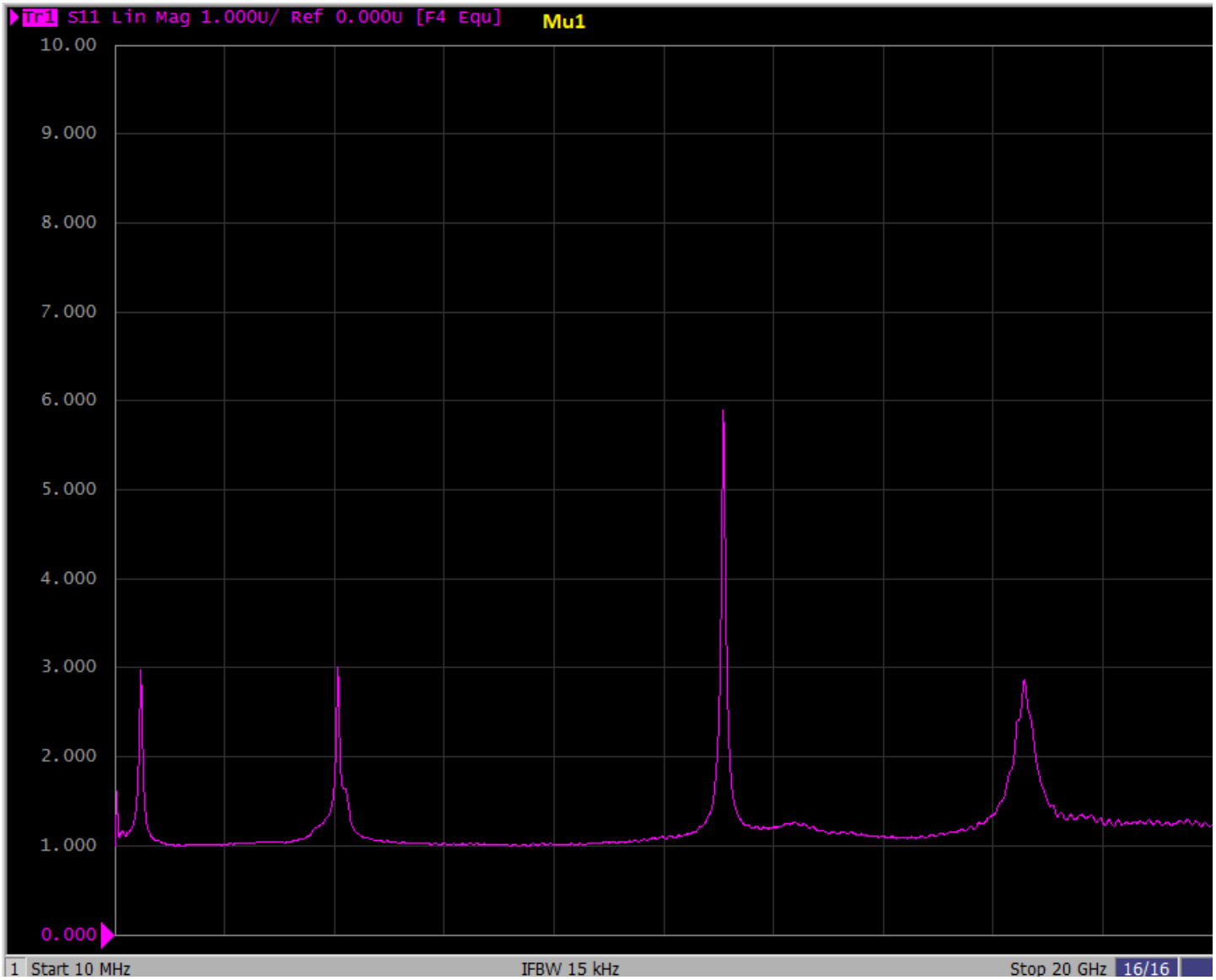




GRF5604 Typical Operating Curves: Small Signal S-Parameters (450 to 470 MHz Tune)



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

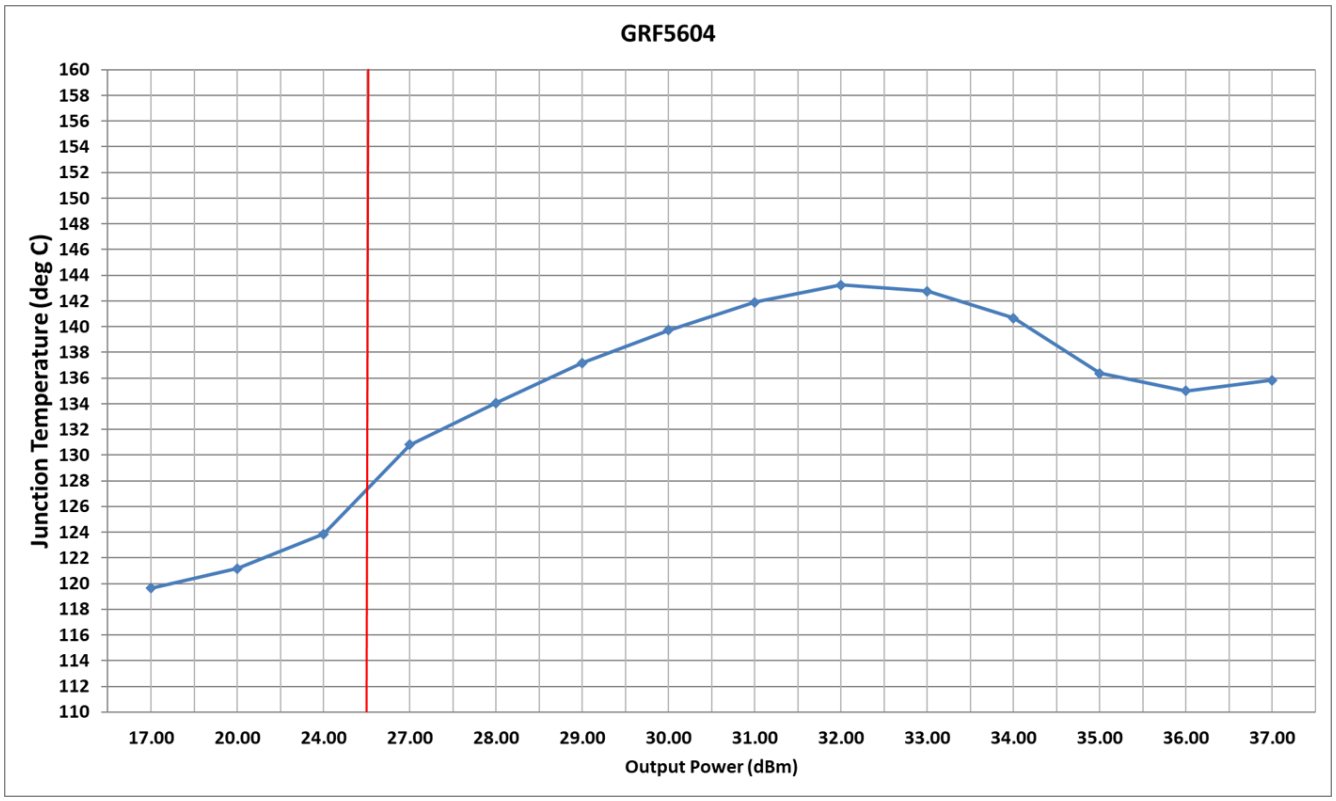


Note: Mu factor ≥ 1.0 implies unconditional stability (small signal).

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

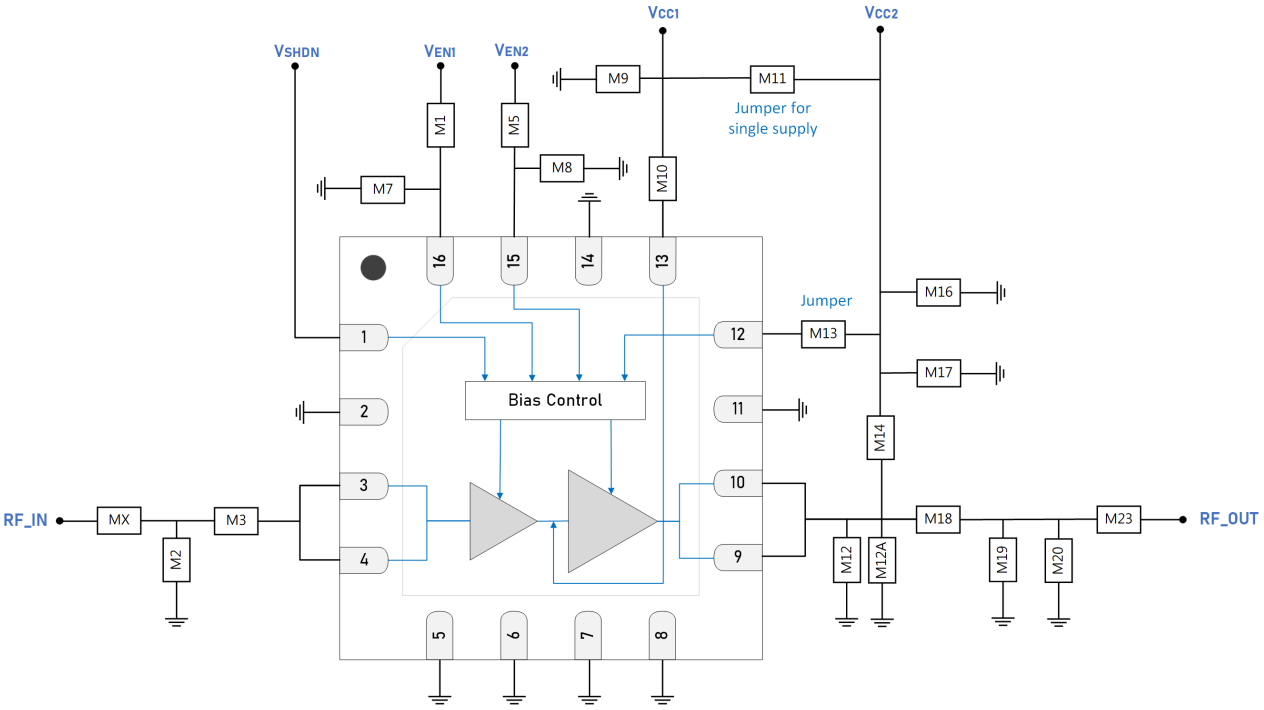
GRF5604, being a 2-stage device, sees one of the stages governing junction temperature over power sweep. Red line = 25.5 dBm shows where T_J is equivalent in both stages. At left of red line, stage 1 governs T_J (Q1 T_J is higher). To the right of red line, stage 2 governs T_J (Q2 T_J is higher).

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.

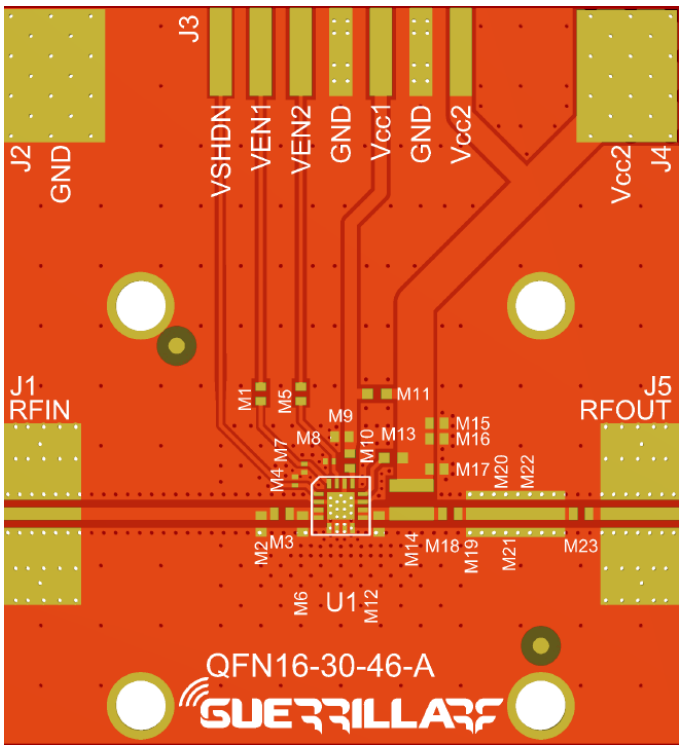


Truth Table

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



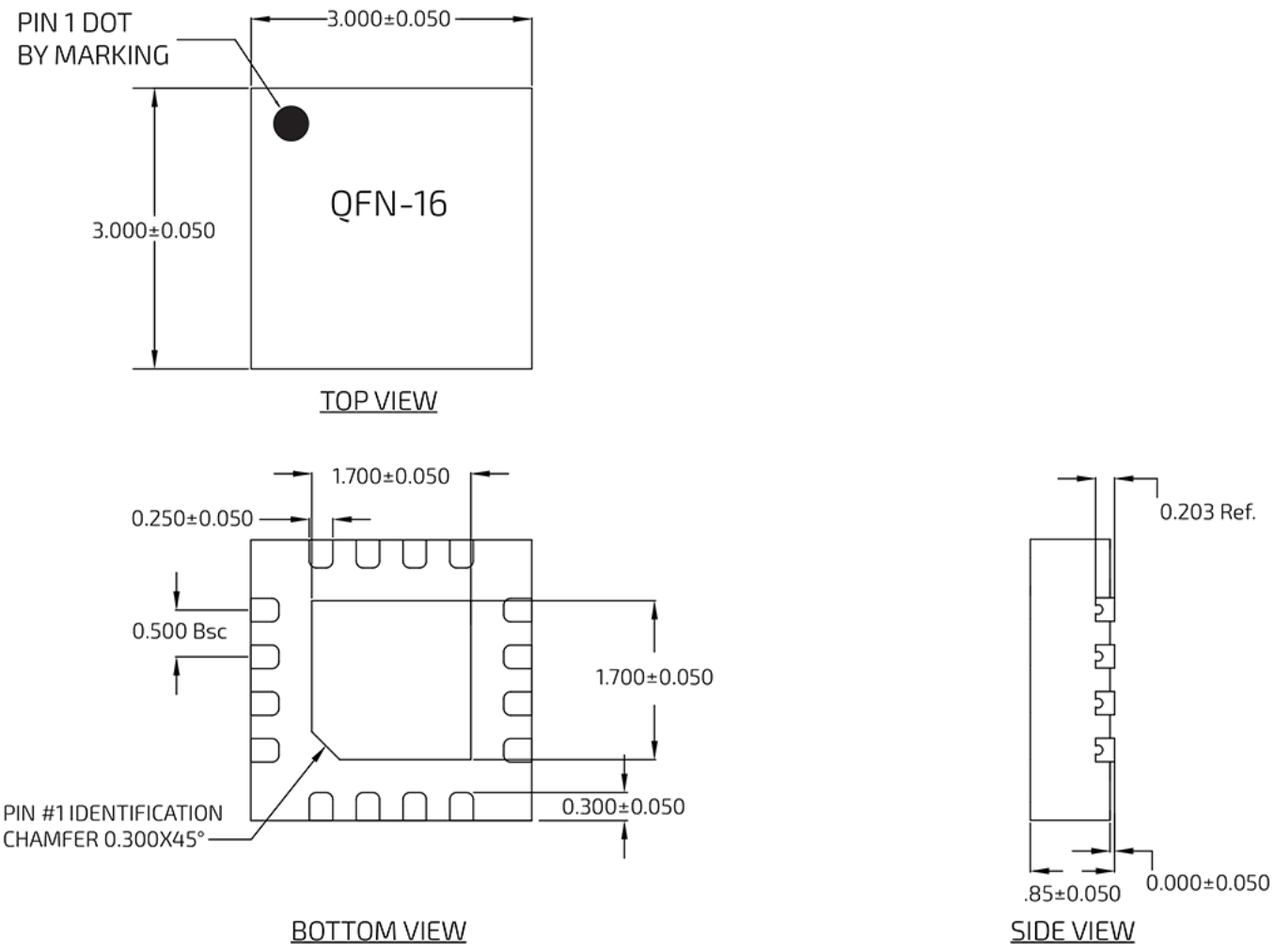
GRF5604 Evaluation Board Assembly Diagram

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

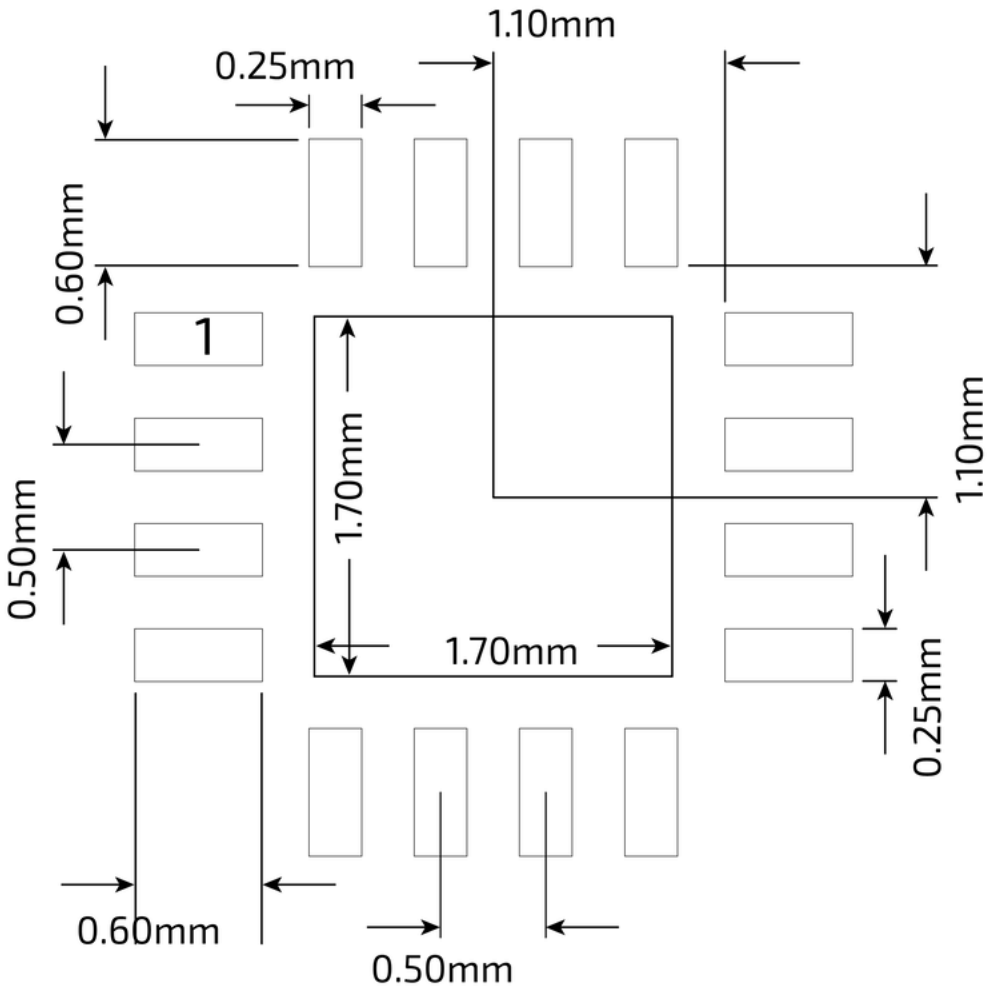
Component	Type	Manufacturer	Family	Value	Package Size	Substitution
M1	Resistor	Various	1%	1960 Ω	0402	ok
M2	Inductor	Murata	LQG	10 nH	0402	ok
M3	Capacitor	Murata	GJM	33 pF	0402	ok
MX	Capacitor	Murata	GJM	10 pF	0402	ok
M5	Resistor	Various	1%	6040 Ω	0402	ok
M7	Capacitor	Murata	GRM	1000 pF	0402	ok
M8	Capacitor	Murata	GRM	1000 pF	0402	ok
M9	Capacitor	Murata	GRM	0.1 µF	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 µF	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 V, V_{ENABLE} = 5 V.

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



QFN 16 3x3mm Package Dimensions



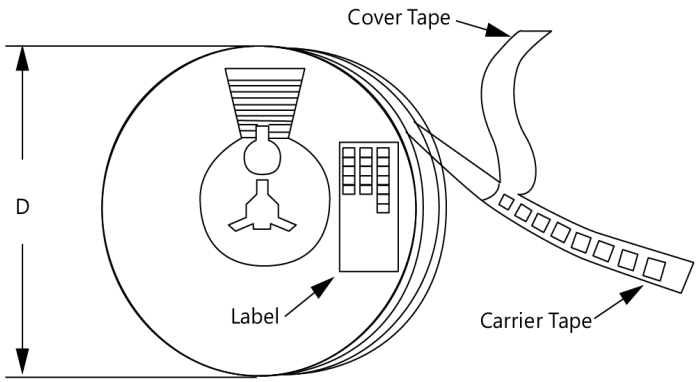
QFN 16 3x3mm Suggested PCB Footprint (Top View)

Package Marking Diagram

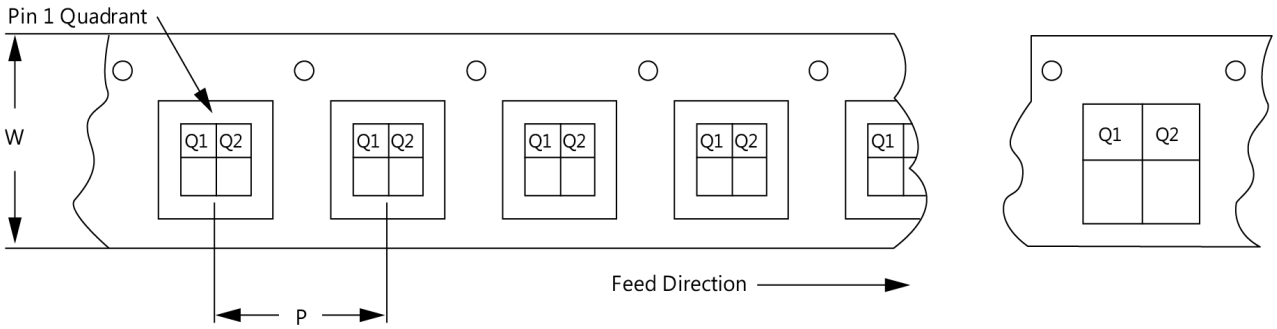
Line 1: “YY” = Year. “WW” = WORK WEEK the Device was assembled.
Line 2: “GRF” = Guerrilla RF
Line 3: “XXXX” = Device Part Number.

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 *estimated* 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 *production-released* material. TYP values are based on a combination of ATE and bench-level measurements, with MIN/MAX limits defined using *modelled estimates* 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 *derived from multiple lots which have been fabricated over an extended period of time*. 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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