AN11453

BGU7258 802.11 a/n/ac Low Noise Amplifier 5-6 GHz WiFi LNA MMIC with Bypass

Rev. 2 — 16 March 2016 Application note

Document information

Info	Content
Keywords	BGU7258, 5-6GHz LNA, 5 GHz ISM, WiFi (WLAN)
Abstract	This document provides circuit schematic, layout, BOM and typical evaluation board performance for a 5-6 GHz WiFi (WLAN) LNA with bypass

Revision history

Rev	Date	Description
2	20160316	Chapter 5 “Thermal info” added
1	20141003	First publication

Contact information

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1. Introduction

The BGU7258 is a fully integrated MMIC Low Noise Amplifier (LNA) for wireless receiver applications in the 5 GHz to 6 GHz ISM band. Manufactured in NXP's high performance SiGe:C technology, the BGU7258 couples best-in-class gain, noise figure, linearity and efficiency with the process stability and ruggedness that are the hallmarks of SiGe technology. The BGU7258 features a robust temperature-compensated internal bias network and an integral bypass / shutdown feature that stabilizes the DC operating point over temperature and enables operation in the presence of high input signals, while minimizing current consumption in bypass (standby) mode. The 1.6 mm x 1.6 mm footprint coupled with only two external components, makes the circuit board implementation of the BGU7258 LNA the smallest IEEE 802.11ac LNA with bypass solution on the market, ideal for space sensitive applications.

Key Benefits:

- Fully integrated, high performance LNA with built-in bypass
- Exceptional 1.6 dB noise figure with 13 mA current consumption
- Extremely low bypass current (2 μA)
- Single supply 3.0 V to 3.6 V operation
- Integrated concurrent 2.4 GHz notch filter and temperature stabilized bias network
- High IIP3 and low EVM
- High ESD protection of 2 kV (HBM) on all pins
- Small 0.5 mm pitch, 1.6 x 1.6 x 0.5 mm QFN-style package, MSL 1 at 260ºC
- Compliant to Directive 2002/95/EC, regarding Restriction of Hazardous Substances (RoHS) following NXP's RHF-2006 indicator D (dark green)

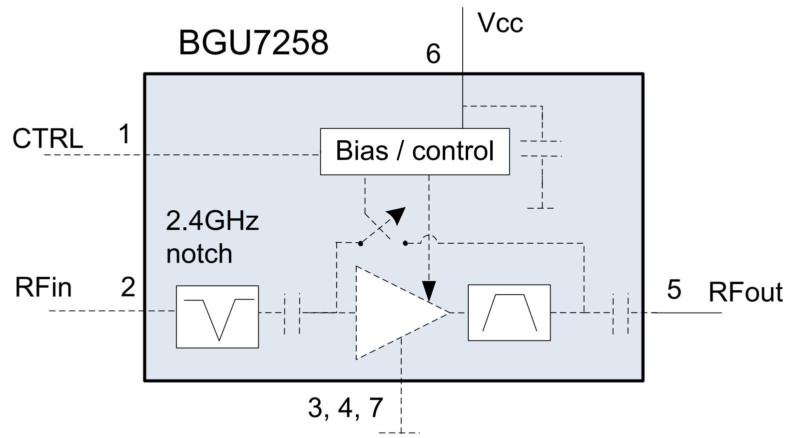


Fig 1. BGU7258 Block Diagram

2. Design and Application

The overall intent of this application note is to demonstrate the performance of the BGU7258 in a 5 GHz LNA application e.g. 802.11a/n/ac “MIMO” WiFi (WLAN). Key requirements for this type of WLAN application are gain, noise figure, linearity, input and output return loss, and turn on/off time.

The BGU7258 itself is a fully integrated MMIC consisting of an RF Gain block, internal temperature compensated bias network, bypass mode functionality, 2.4 GHz notch filter to suppress jammers from 2.4 GHz ISM Band, ESD protection, internal RF matching, and internal DC blocking. Only two external components, a 4.7 nF DC-decoupling capacitor on the power supply line and an optional shunt 0.3 pF capacitor for matching at RF input is necessary.

On NXP’s Application Board, the BGU7258 can be also used without the matching capacitor at the RF_IN, but in this case, the gain will decrease by ~0.5 dB and the noise figure increases by ~ 0.1 dB at 5.8 GHz.

The 5 GHz WiFi LNA evaluation board simplifies the evaluation of the BGU7258 application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BGU7258 MMIC, and includes the 4.7 nF DC-decoupling capacitor and the 0.3 pF input matching capacitor. The board is also supplied with two SMA connectors for input and output connection to RF test equipment.

A 50 ohm “through line” is provided at the top of the evaluation board in case the user wishes to verify RF connector and grounded coplanar wave guide losses for de-embedding purposes.

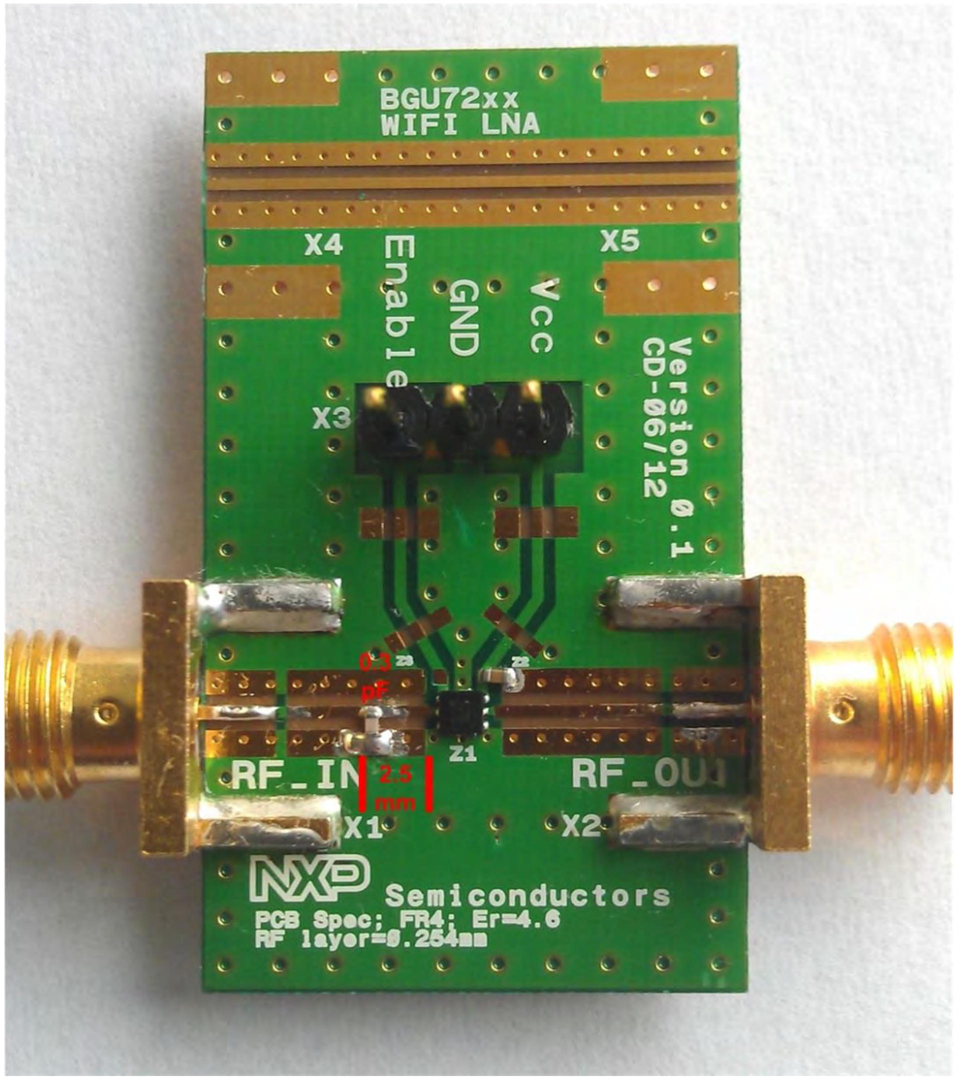


Fig 2. BGU7258 Evaluation Board 5-6 GHz WiFi LNA EVB

2.1 Application Circuit Schematic

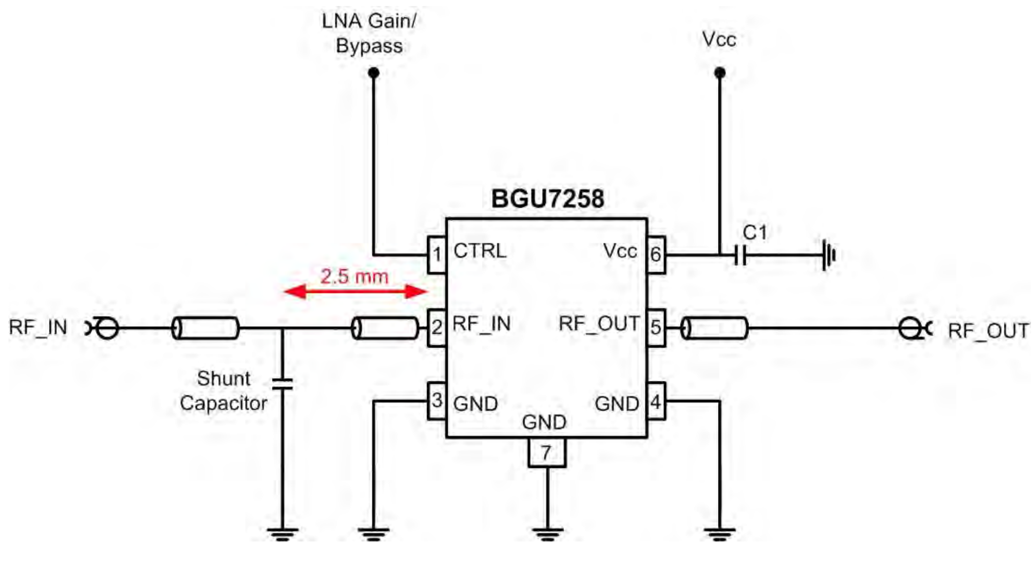


Fig 3. BGU7258 Evaluation Board: Schematic

Note: Figure 3 is the schematic for BGU7258 evaluation board with only two external components (Matching shunt capacitor on RF_IN and DC-decoupling capacitor, placed near the V_{CC} pin).

The BGU7258 can be also used without the matching capacitor at the RF_IN, but then the gain will be ~0.5 dB less and the noise figure increases ~0.1 dB at 5.8 GHz!

2.2 PCB Layout

- Use controlled impedance lines (50 Ω) for RF_in & RF_out
- Place the decoupling capacitor as close as possible to the device pin 6 (Vcc)
- Proper grounding of the RF GND especially pin 7 (ground pad) is essential for good RF-performance. Connect the GND pins direct to ground plane and use through vias on ground pad (size and amount depends on the technology used)

2.3 Board Layout

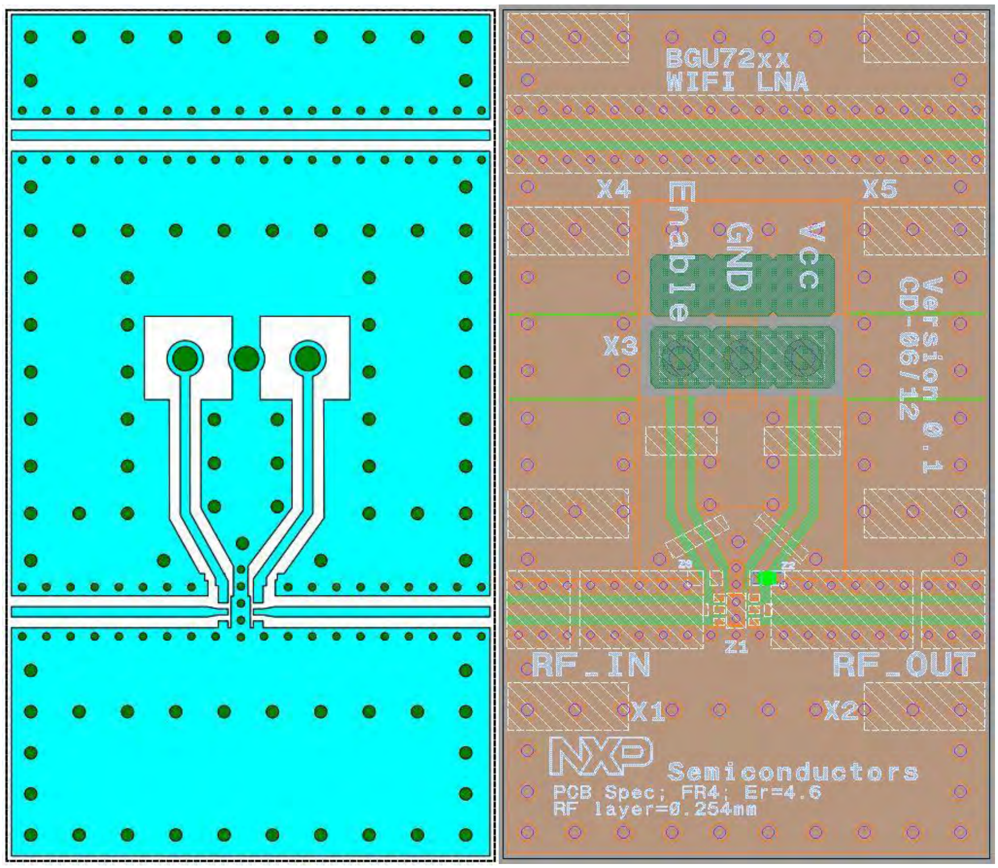


Fig 4. BGU7258 Evaluation Board

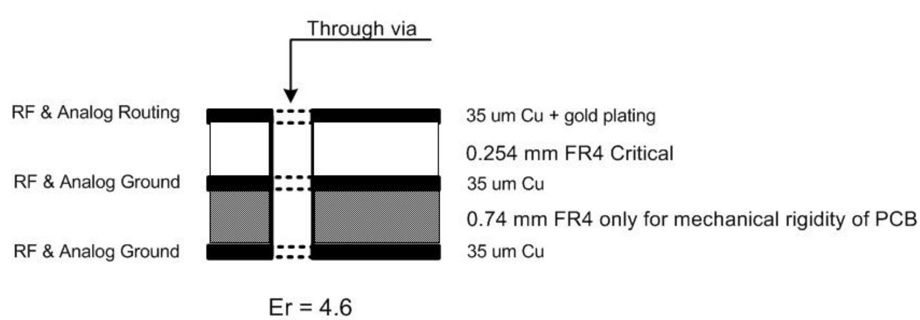


Fig 5. BGU7258 Stack of the PCB material

2.4 Application Board Bill-Of-Material

Table 1. BGU7258 5-6 GHz WiFi LNA Part List

Customer can choose their preferred vendor but should be aware that the performance could be affected. “0402” case size passives are used on NXP’s evaluation board.

Item	Position on Layout	Reference (Fig 2)	Type	Vendor	Value
1	Z1	BGU7258	BGU7258	NXP SEMICONDUCTORS	BGU7258
2	Z2	C1	GRM155	Murata	4.7 nF
3	RF_IN	Shunt Capacitor	GJM155	Murata	0.3 pF
4	X1, X2	RF_IN, RF_OUT		Emerson Network Power	CON-SMA-1
5	X3	Vcc/LNA gain/bypass		Molex	CON-3PIN

3. Typical Application Board Test Result

This section presents the results of a typical BGU7258 as used in NXP's Application Circuit. Unless otherwise noted, all measurement references are at the SMA connectors on the evaluation board.

3.1.1 S-Parameters

Figures 6 and 7 below show the broadband (10 MHz – 10 GHz) and narrowband s-parameters for the BGU7258 respectively. Figure 8 shows the measured stability factor from 1 GHz – 20 GHz.

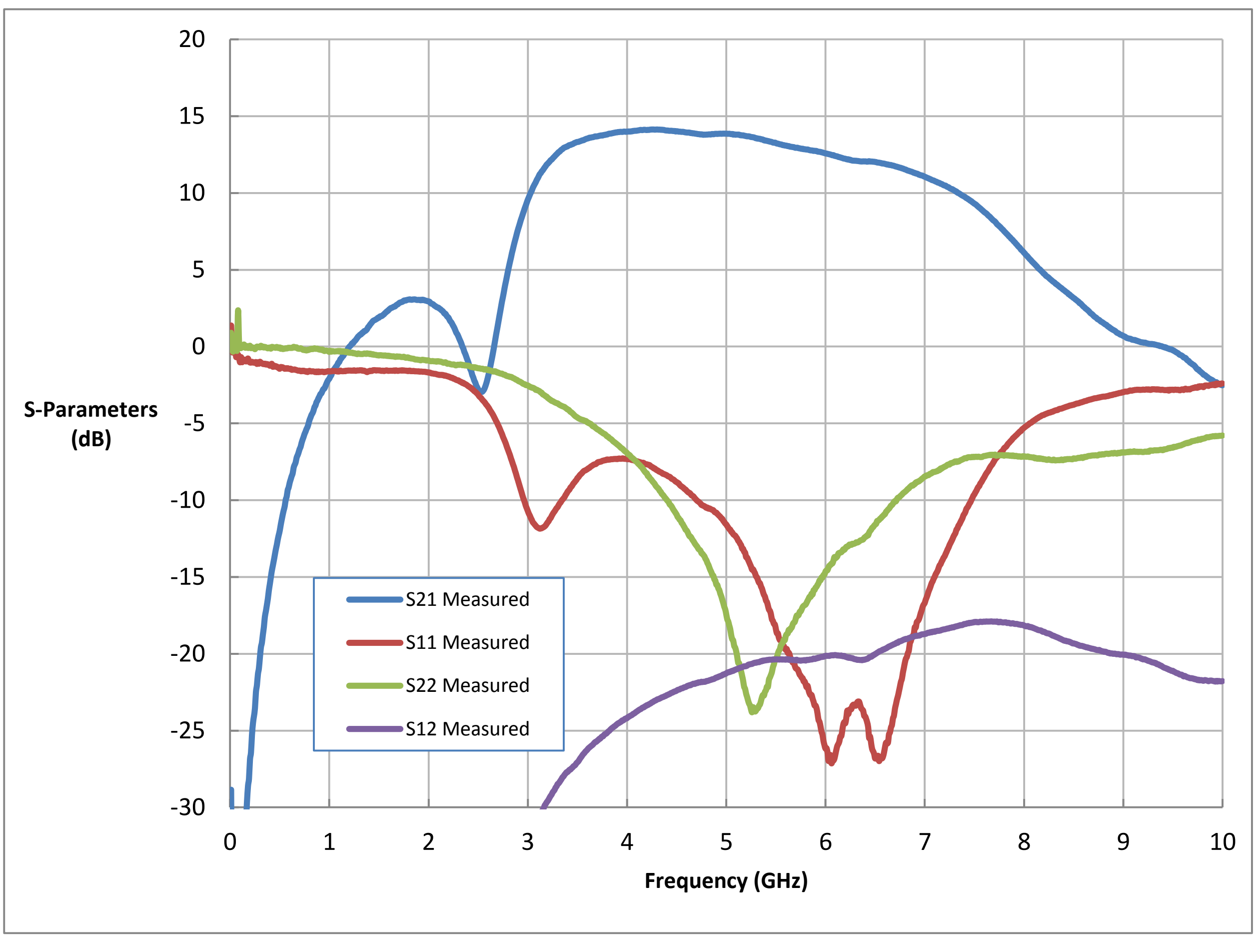


Fig 6. BGU7258 Broadband S-Parameters V_{CC} = 3.3V 25°C ambient

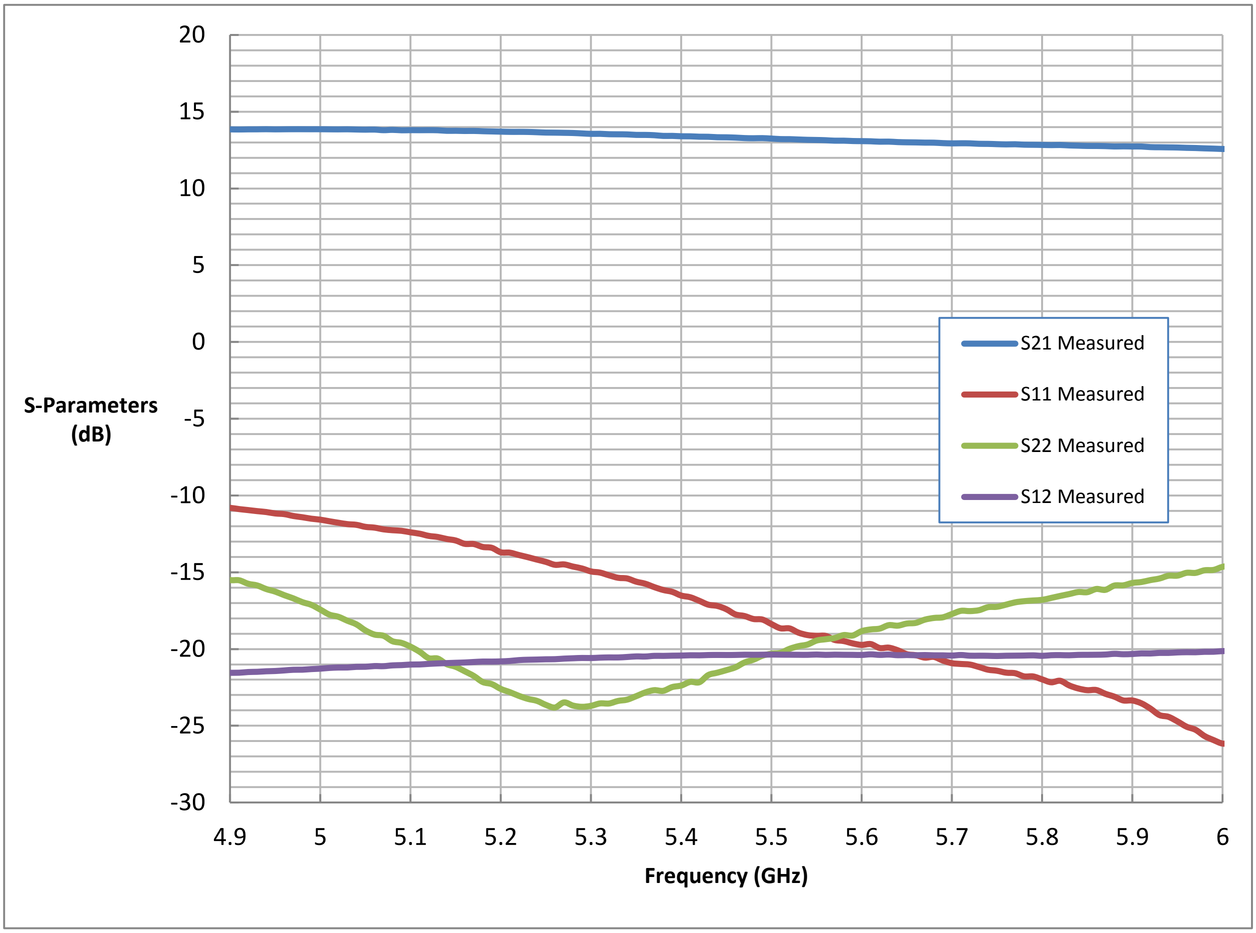


Fig 7. BGU7258 Narrowband S-Parameters V_{CC} = 3.3V 25°C ambient

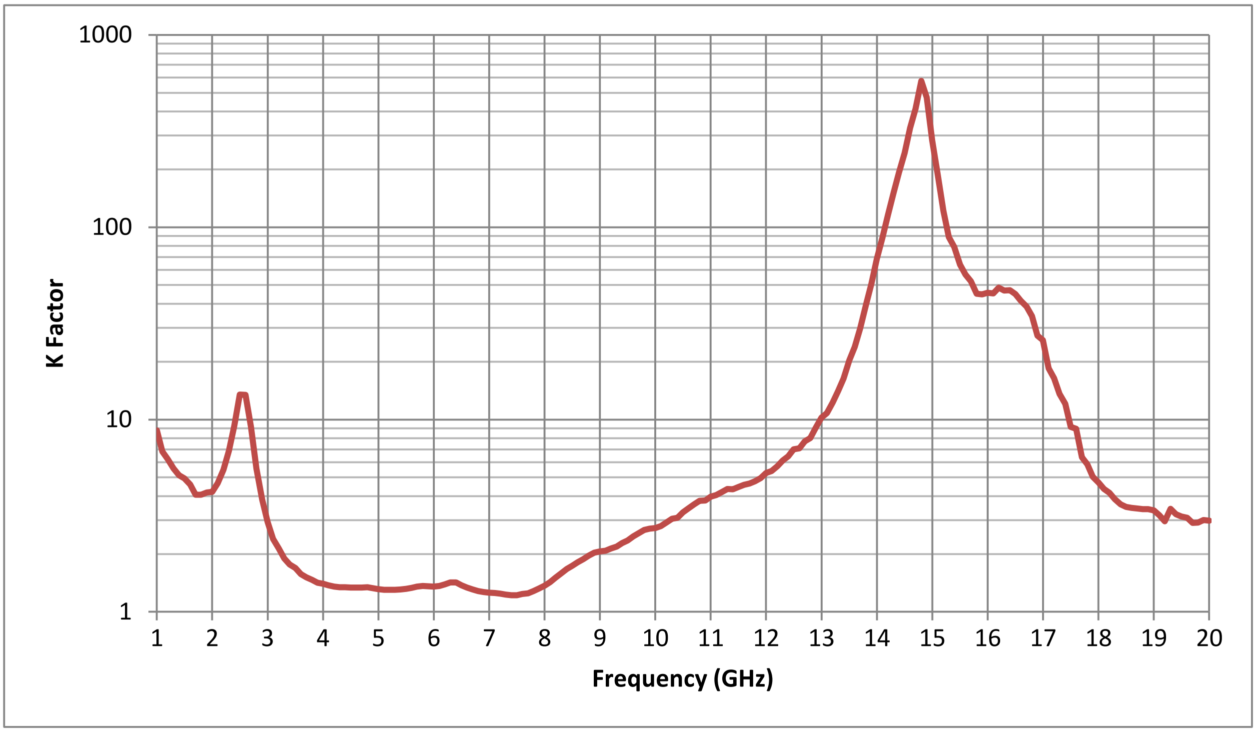


Fig 8. BGU7258 Broadband K Factor (Rollett Stability Factor) V_{CC} = 3.3V 25°C ambient

3.1.2 S-Parameters in Bypass mode

Figure 9 and 10 below shows the gain, input return loss, and output return loss of the BGU7258 in bypass mode.

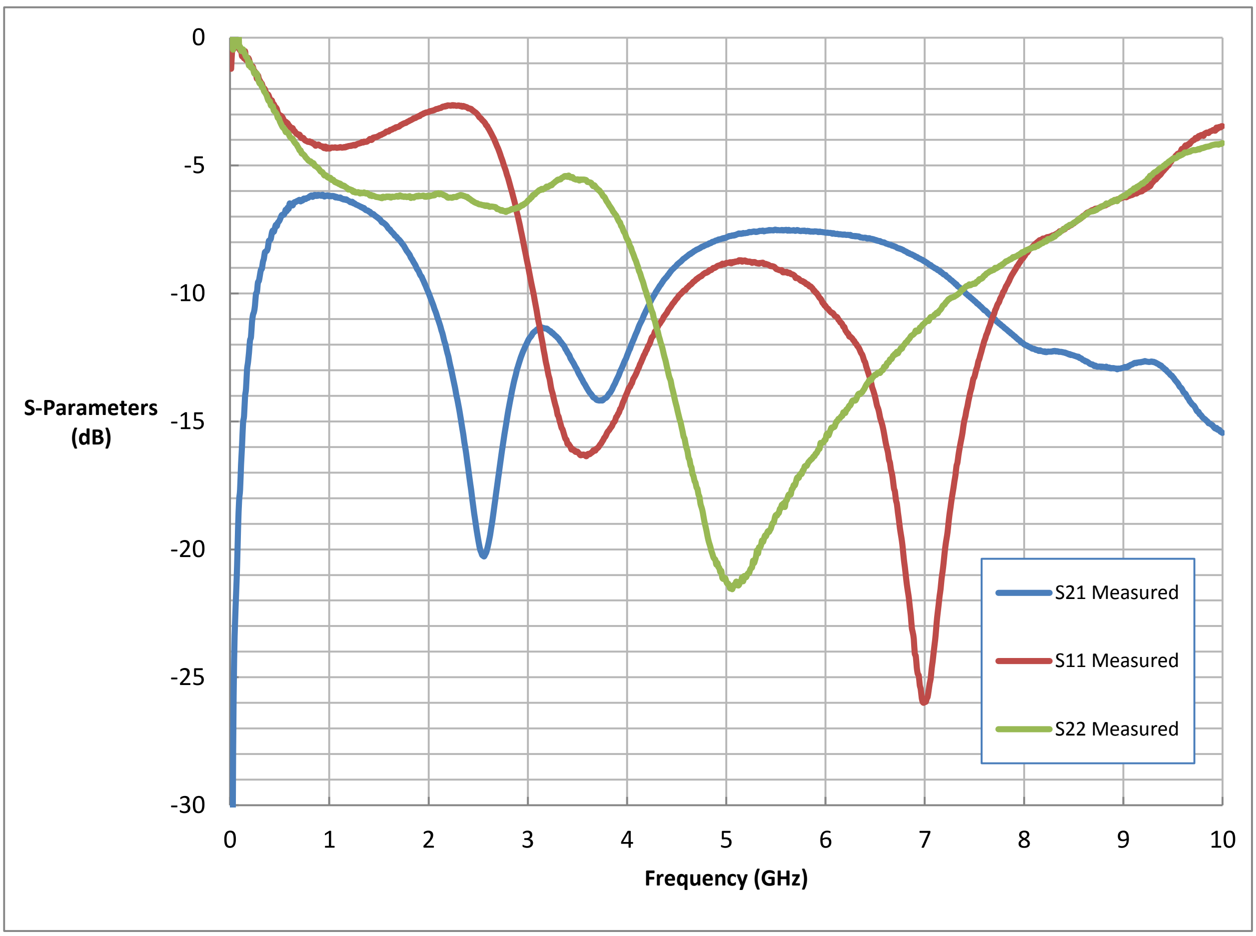


Fig 9. BGU7258 Broadband S-Parameters Bypass Mode Vcc = 3.3V 25°C ambient

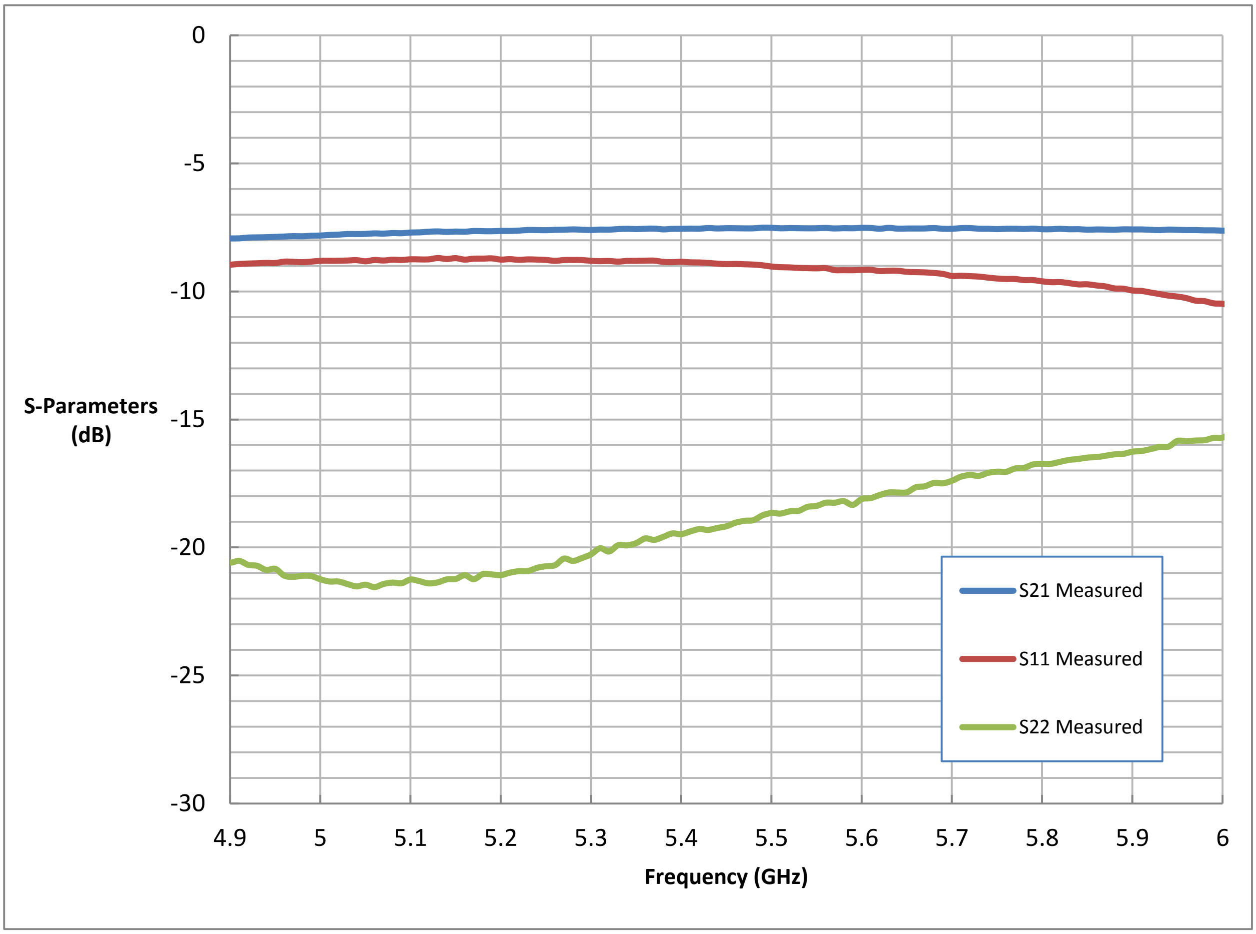


Fig 10. BGU7258 Narrowband S-Parameters Bypass Mode Vcc = 3.3V 25°C ambient

3.1.3 Noise Figure in Gain mode

The noise figure is physically measured at the SMA connectors of the evaluation board. The total loss of the connectors and the printed circuit board are 0.5dB at 5.5 GHz (RF_IN to RF_OUT). After de-embedding the input portion of connector and PCB losses (0.25dB at 5.5 GHz) to the device pins, the noise figure is around 1.6dB at 5.5 GHz. Figure 11 below shows both the noise figure at the EVB level and the de-embedded noise figure.

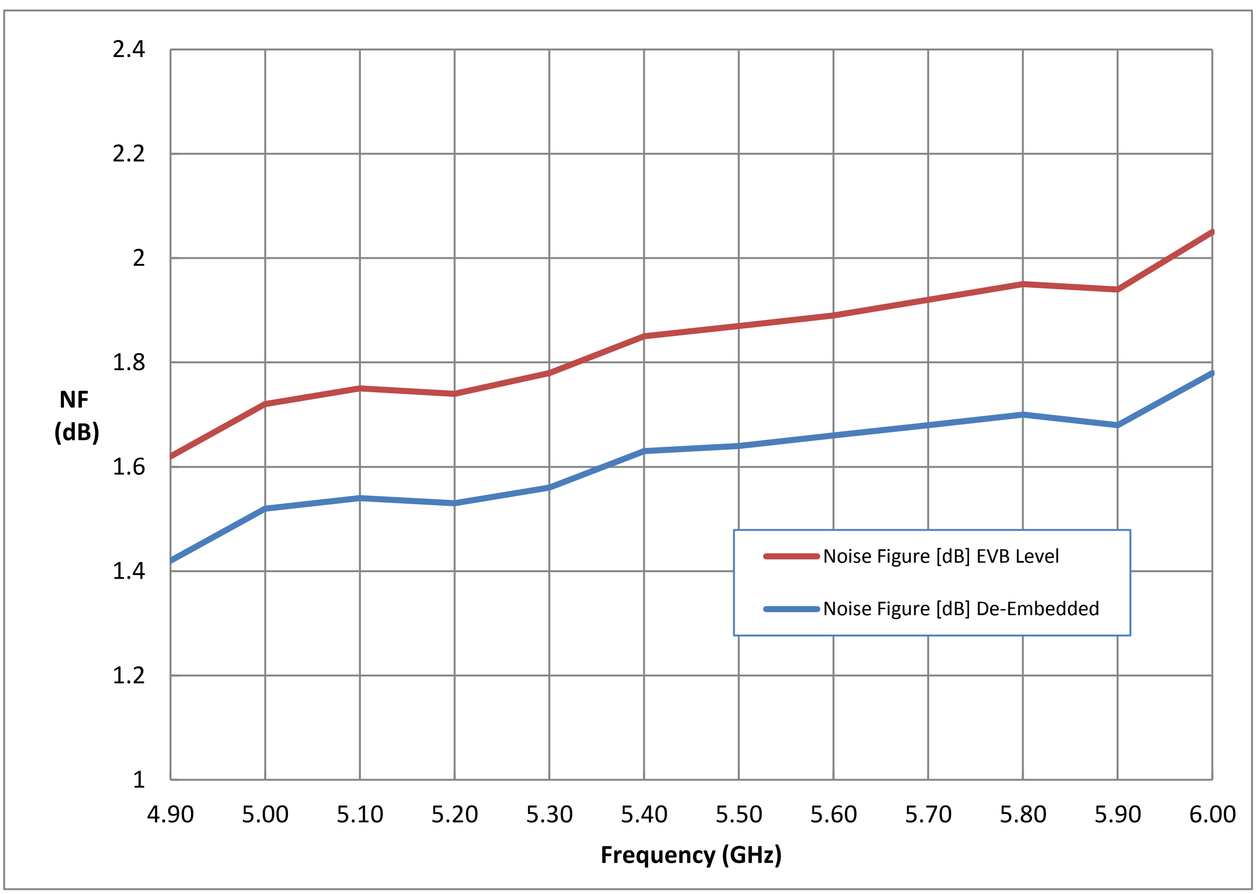


Fig 11. BGU7258 Noise Figure V_{CC} = 3.3V 25°C ambient

3.1.4 Small Signal Linearity in Gain mode

Figure 12 shows the input-referred IP3 level for the BGU7258, measured with 5 MHz tone spacing, -25 dBm input power per tone, and a swept center frequency from 5 GHz to 6 GHz.

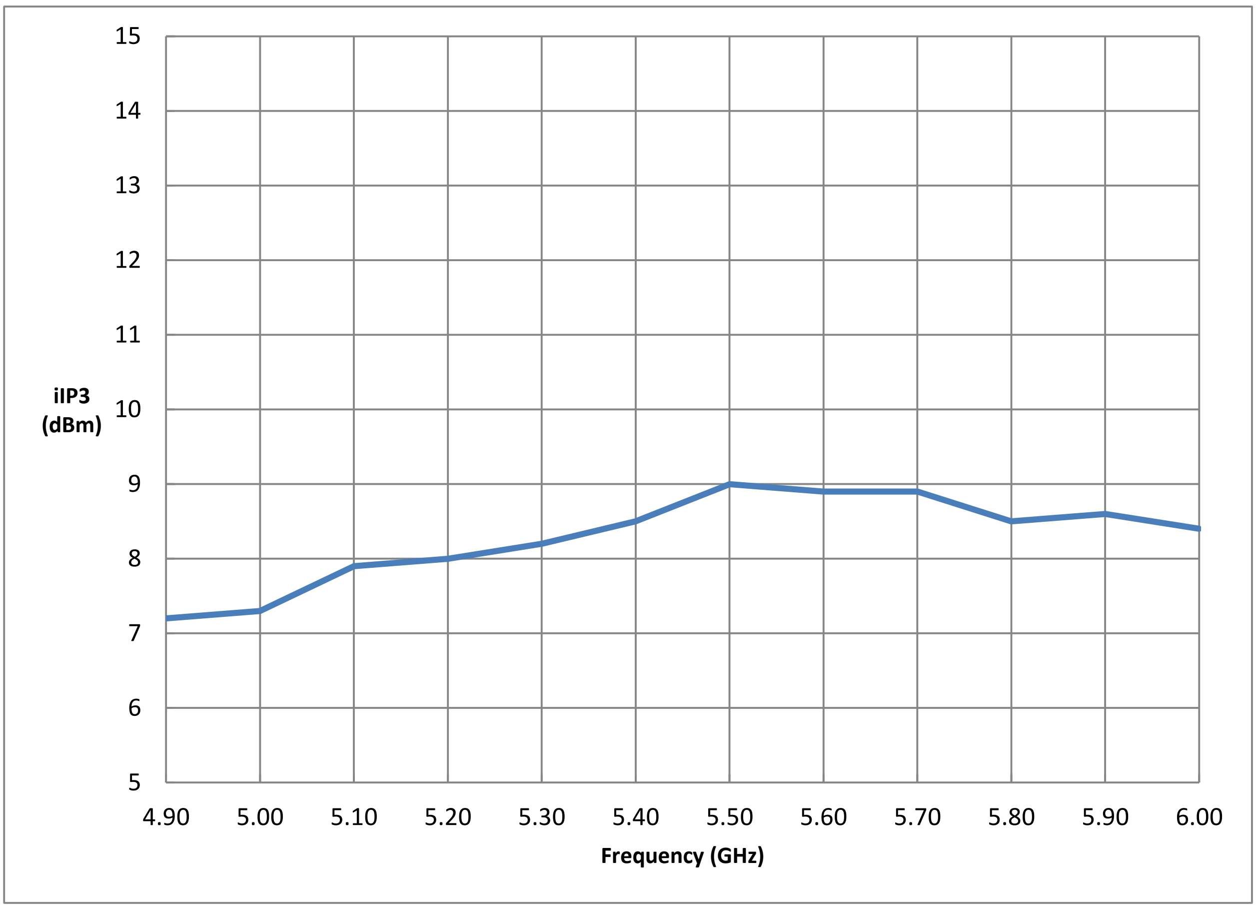


Fig 12. BGU7258 Swept input-IP3 5MHz Tone Spacing Pin=-25dBm/Tone V_{CC} = 3.3V 25°C ambient

3.1.5 Large Signal Linearity in Gain mode

Figure 13 shows the input referred P1dB level from 5 GHz to 6 GHz.

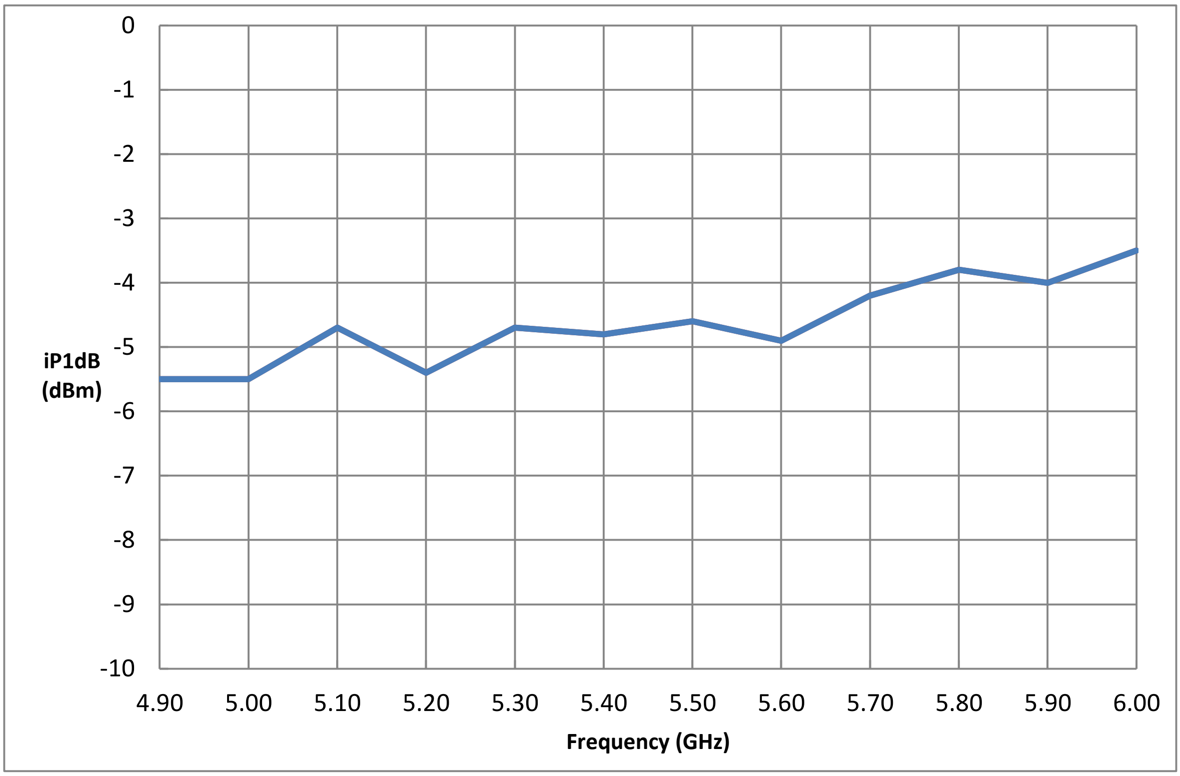


Fig 13. BGU7258 input-P1dB vs. frequency V_{CC} = 3.3V 25°C ambient

Figure 14 shows Error Vector Magnitude (EVM) as a function of output power, with BGU7258 in Gain mode. Specifically, these data are captured using a 256 QAM OFDM waveform MSC9-VHT40. Note that the output power is the average power over the burst.

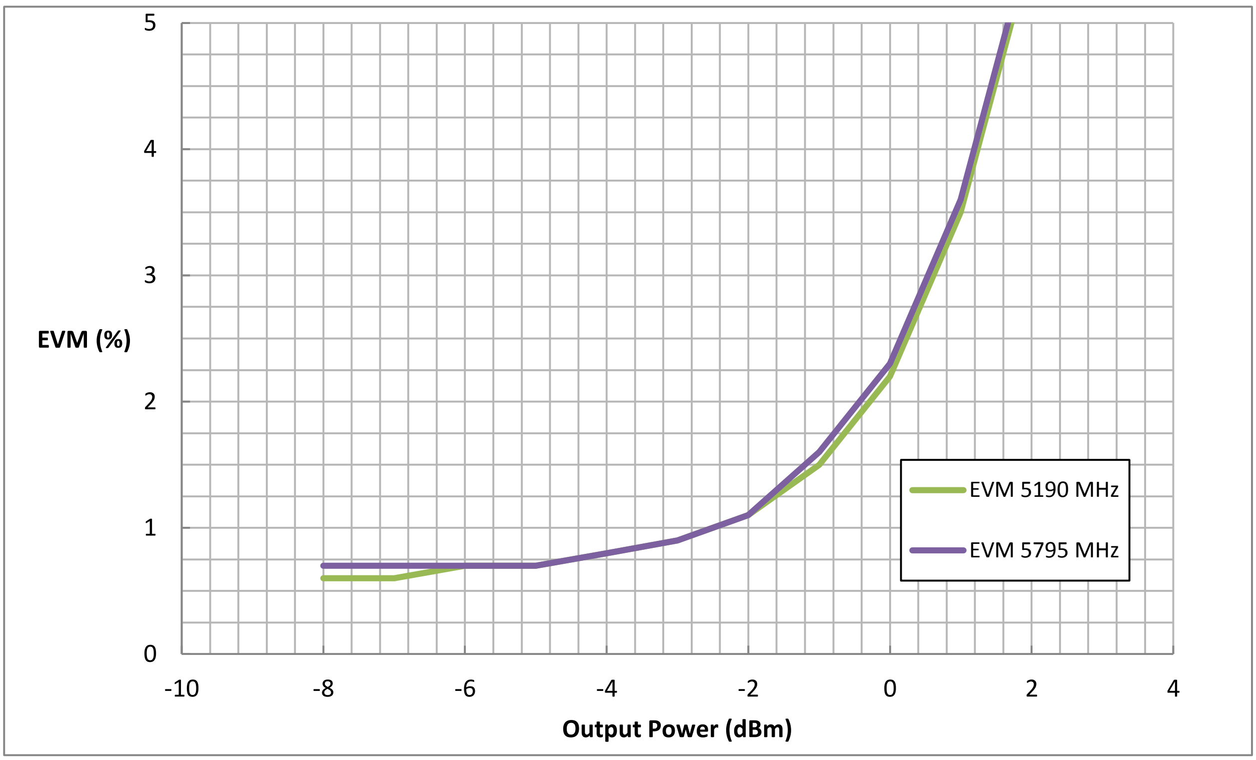


Fig 14. BGU7258 EVM vs. burst average output power MCS9-VHT40 256 QAM V_{CC} = 3.3V 25°C ambient

3.1.6 Out-of-band spurious

In order to characterize the BGU7258 under potential jamming conditions, a 5.180 GHz signal is applied to the evaluation board at an RF input power level of -30 dBm. A second tone is applied at 2.462 GHz and swept over a range of input power levels. The 2.462 GHz "leakage" and the second harmonic at 4.924 GHz are measured. The measurement set-up is shown in Figure 15. As a function of the 2.462 GHz jammer input level, Figure 16 reports the 2.462 GHz jammer output level, the 4.924 GHz second harmonics output level, and the 5.180 GHz Gain.

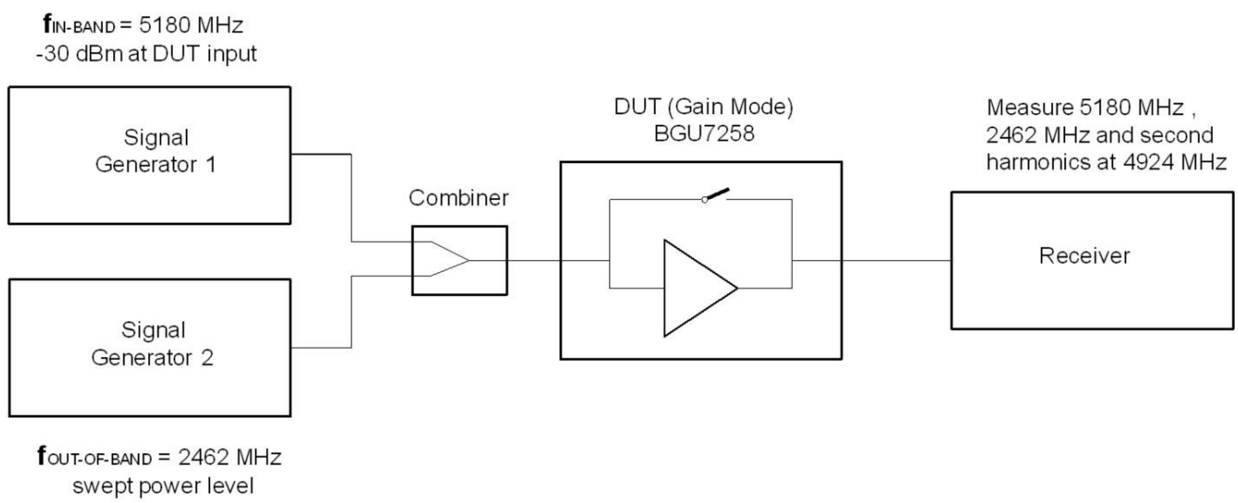


Fig 15. Out-of-band suppression test setup (if necessary use additional low pass filter at signal generator 2 output)

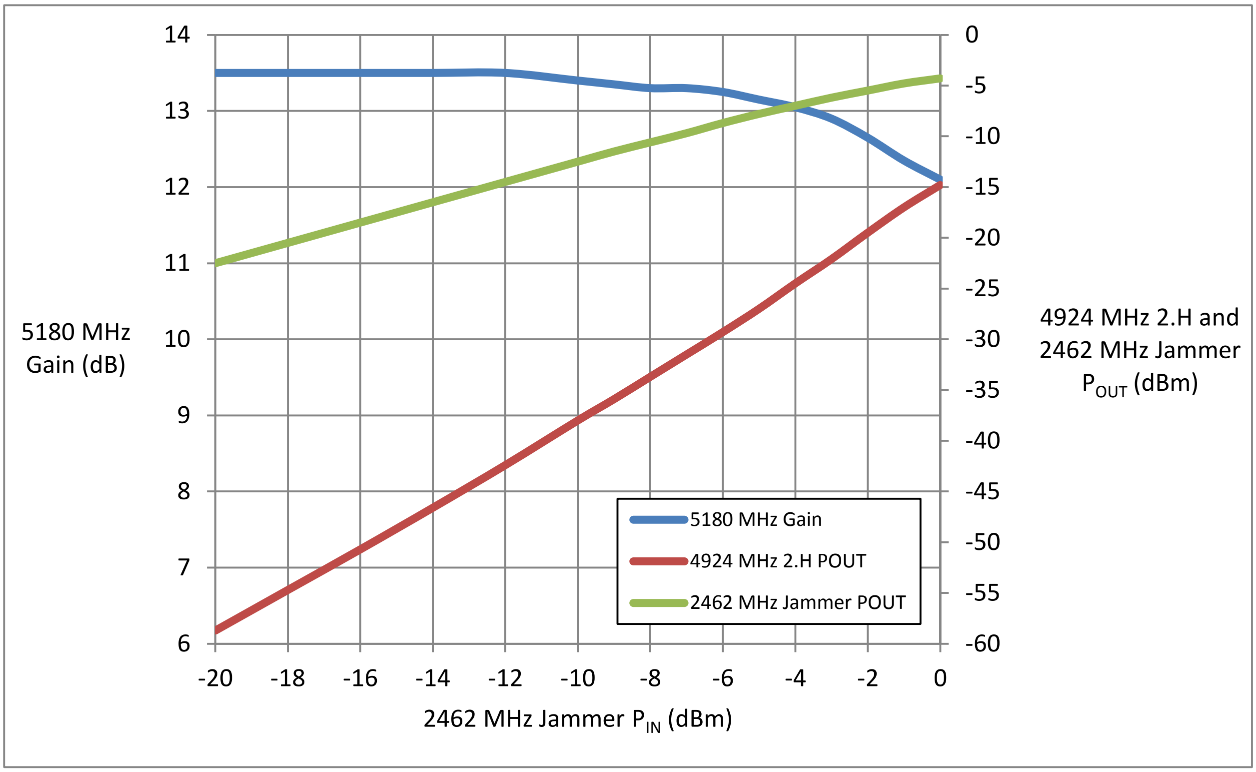


Fig 16. BGU7258 2462 MHz Jammer Level at Output, 4924 MHz second harmonics and 5180 MHz Gain vs. Jammer Input Power V_{CC} = 3.3V 25°C ambient 5180 MHz input at -30 dBm

3.1.7 Harmonics

By applying large RF signals at the input during bypass mode (OFF mode) operation, harmonics can be created by the LNA and then emanate from its RF input. In a real operating environment, these harmonic signals can be re-emitted by the antenna. The measurement set up used for characterizing the harmonics generated by the BGU7258 in bypass mode is shown in Figure 17. A 5.500 GHz signal is used for the measurement results shown in Figure 18.

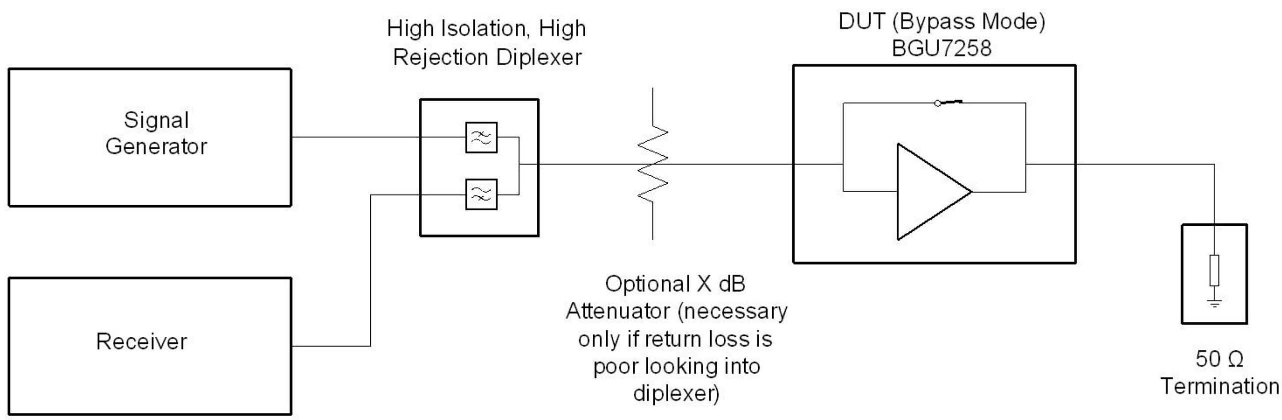
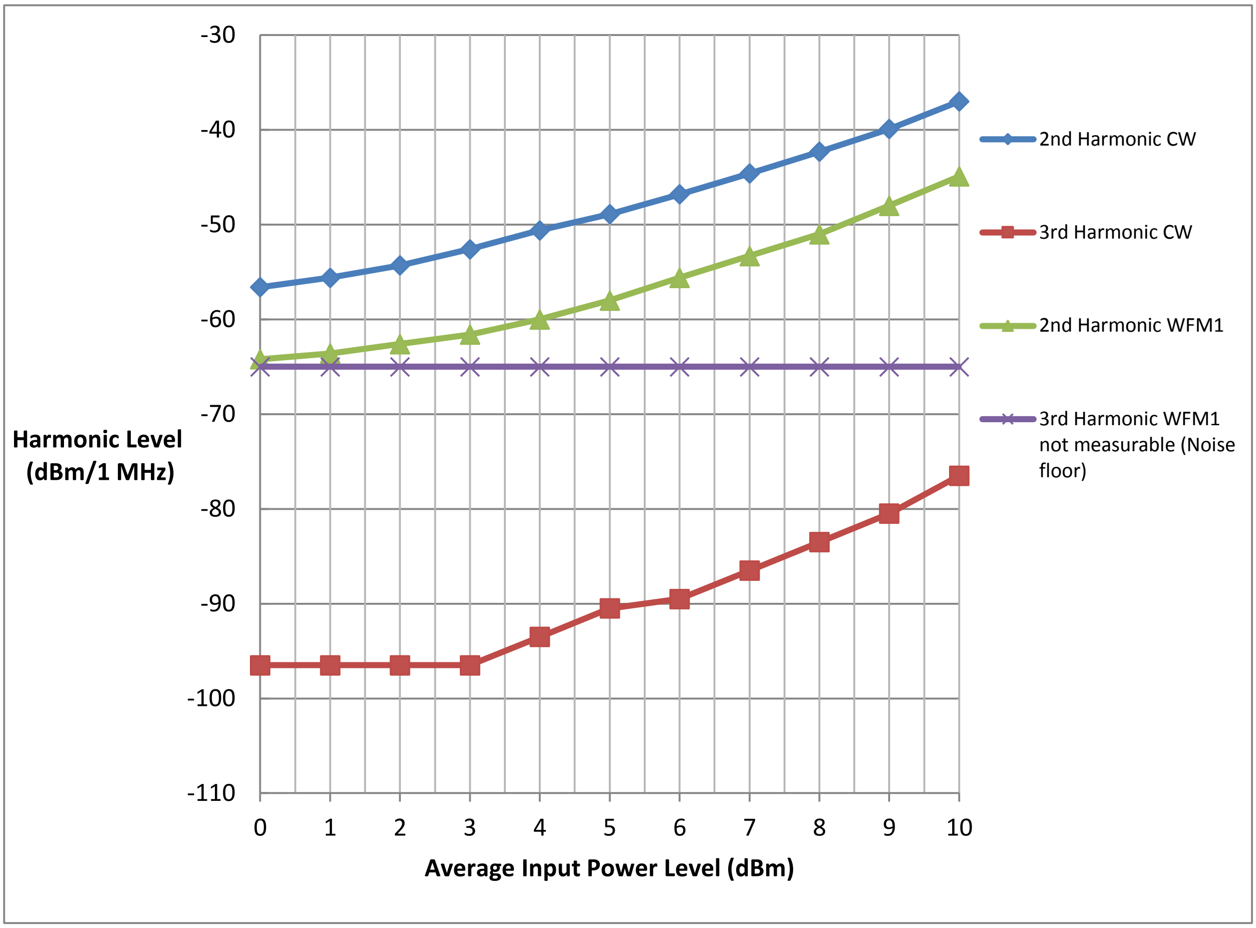


Fig 17. Harmonic test setup



(1) CW – Continuous Wave (only for test / comparison)

(2) WFM1 - 802.11a 6 Mbps (BPSK) 90% duty cycle (worst case signal)

Fig 18. BGU7258 (Bypass Mode) 2nd and 3rd Reflected Harmonic Levels 5.5 GHz Fundamental

3.1.8 LNA Turn ON-OFF Time

The following diagram shows the setup to test LNA Turn ON and Turn OFF time.

The waveform generator is set to square wave mode and the output amplitude at 3.3V peak with 50Ω output impedance. The RF signal generator output level is -20dBm at 5.5 GHz. It is very important to minimize or compensate for the time delay skew between the trigger signal and the detector signal. Also note that the scope input impedances are set to 50Ω on both channels.

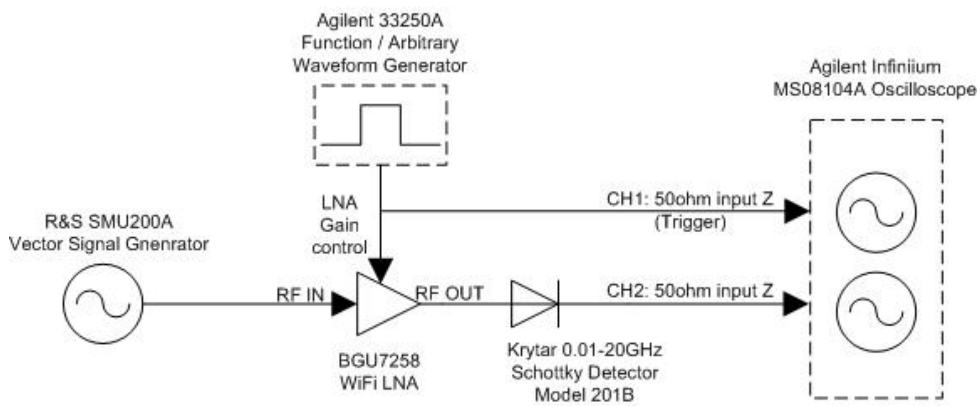
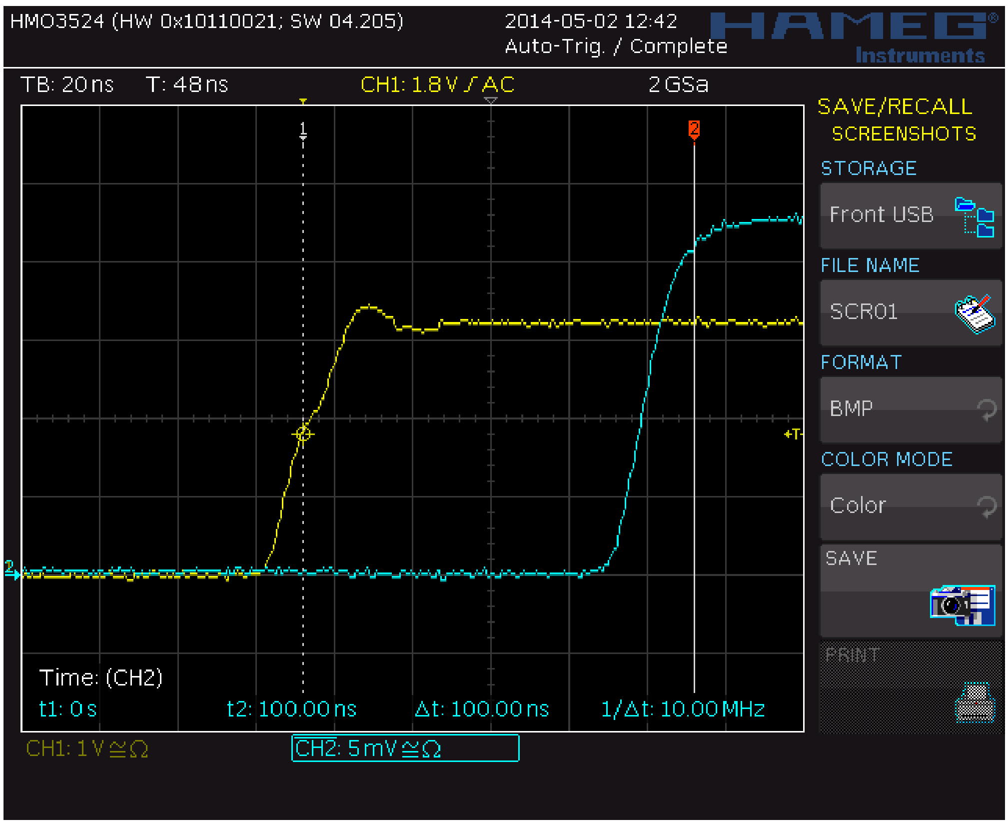


Fig 19. LNA Turn On and Turn Off time test setup

3.1.8.1 LNA Turn ON Time

Figure 20 below shows a screen capture from an oscilloscope used to record the turn on time of the BGU7258.

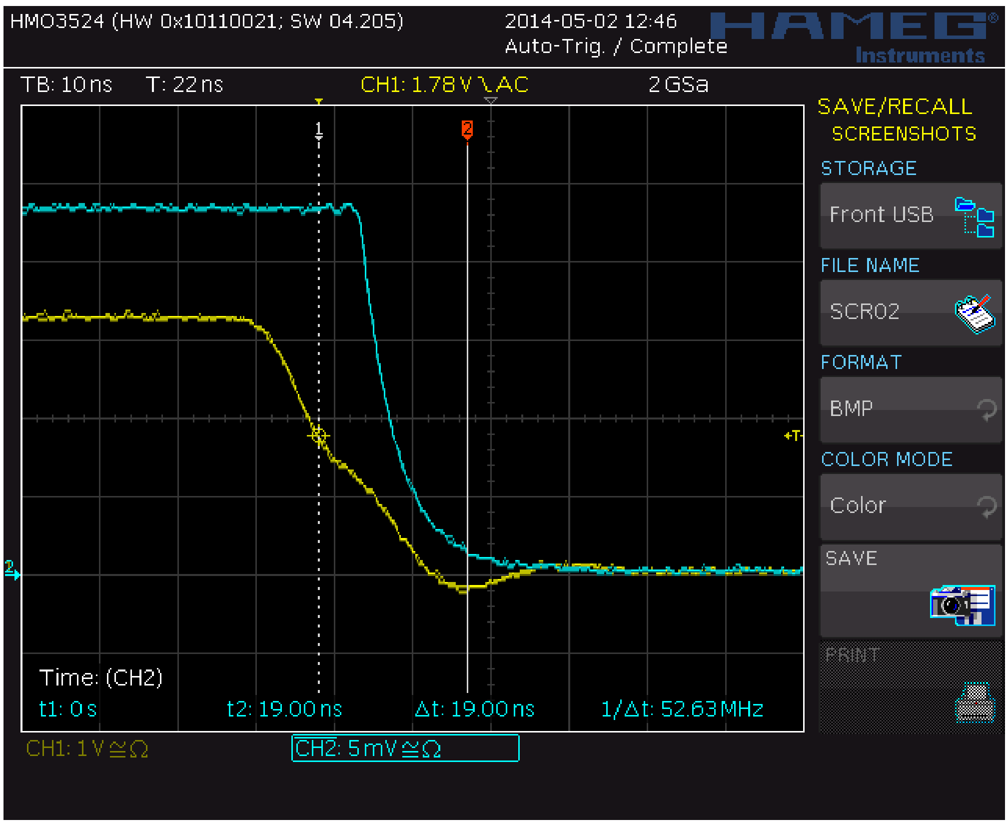


100Hz 0/3.3V Square Wave, applied on V_{enable} pin, measured from 50% of input pulse to 90% of maximum output power

Fig 20. BGU7258 Turn On Time

3.1.8.2 LNA Turn OFF Time

Figure 21 below shows an oscilloscope screen capture with the turn off time for the BGU7258.



100Hz 0/3.3V Square Wave, applied on V$_{enable}$ pin, measured from 50% of input pulse to 10% of maximum output power

Fig 21. BGU7258 Turn Off Time

4. Summary of the Typical Evaluation Board Test Result

Table 2. Typical results measured on the BGU7258 5-6 GHz WiFi LNA Evaluation Board with 0.3 pF matching capacitor at the RF_IN

Operating frequency 4.9-5.925 GHz, testing at 5.1 GHz and 5.9 GHz in Gain mode unless otherwise specified, Temp = 25°C. ***Unless noted, all measurements are done with SMA-connectors as reference plane.***

Parameter		Symbol	Value	Unit
Supply Voltage		V_{CC}	3.3	V
Supply Current		I_{CC}	12.5	mA
ByPass Current		I_{bypass}	1.0	µA
Noise Figure [1]	@ 5.1 GHz	NF	1.6	dB
	@ 5.9 GHz	NF	1.7	dB
Power Gain	@ 5.1 GHz	Gp	13.8	dB
	@ 5.9 GHz	Gp	12.7	dB
Input Return Loss	@ 5.1 GHz	IRL	12.5	dB
	@ 5.9 GHz	IRL	23.0	dB
Output Return Loss	@ 5.1 GHz	ORL	20.0	dB
	@ 5.9 GHz	ORL	16.0	dB
Reverse Isolation	@ 5.1 GHz	ISLrev	-21.0	dB
	@ 5.9 GHz	ISLrev	-20.0	dB
Power Gain (bypass mode)	@ 5.1 GHz	Gp	-7.7	dB
	@ 5.9 GHz	Gp	-7.6	dB
Input Return Loss (bypass mode)	@ 5.1 GHz	IRL	9.0	dB
	@ 5.9 GHz	IRL	10.0	dB
Output Return Loss (bypass mode)	@ 5.1 GHz	ORL	21.0	dB
	@ 5.9 GHz	ORL	16.0	dB
Input Third Order Intercept Point Two Tones: 5 MHz Tone Spacing Power: -5 dBm/tone (bypass mode)	@ 5.1 GHz	IIP3	26.7	dBm
	@ 5.9 GHz	IIP3	28.1	dBm
Output Third Order Intercept Point Two Tones: 5 MHz Tone Spacing Power: -5 dBm/tone (bypass mode)	@ 5.1 GHz	OIP3	19.0	dBm
	@ 5.9 GHz	OIP3	20.5	dBm
Input 1dB Gain Compression Point	@ 5.1 GHz	iP1dB	-4.7	dBm
	@ 5.9 GHz	iP1dB	-4.0	dBm
Output 1dB Gain Compression Point	@ 5.1 GHz	oP1dB	8.1	dBm
	@ 5.9 GHz	oP1dB	7.7	dBm
Error Vector Magnitude	@ 5.1 GHz	EVM	2.2	%

Parameter		Symbol	Value	Unit
Pout = 0dBm (256 QAM, MSC9-VHT-40)	@ 5.9 GHz	EVM	2.3	%
Input Third Order Intercept Point Two Tones: 5 MHz Tone Spacing power: -25 dBm/tone	@ 5.1 GHz	IIP3	7.9	dBm
	@ 5.9 GHz	IIP3	8.6	dBm
Output Third Order Intercept Point Two Tones: 5 MHz Tone Spacing power: -25 dBm/tone	@ 5.1 GHz	OIP3	21.5	dBm
	@ 5.9 GHz	OIP3	21.2	dBm
1 dB input/output cross-compression with jammer	@ 5180 MHz with 2462 MHz Jammer		-1.0	dBm
Harmonics generated at RF input Pin = 4 **dBm (5.5 GHz)**	2.H. @ 11.0 GHz	H2	-50	dBm
CW signal input (bypass mode)	3.H. @ 16.5 GHz	H3	<-90	dBm
Stability (1 - 20 GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	100	nS
		Toff	19	nS

[1] PCB and connector losses excluded.

5. Thermal info

The following temperature simulations are done based on the BGU7258 soldered onto the NXP evaluation board (see Fig. 22) in still air and 85 °C ambient temperature.

Part number	θ_{JCbot} [1]	θ_{JB} [2]	Ψ_{JC} [3]	Maximum Junction Temperature	T_a
BGU7258	250 K/W	250 K/W	204 K/W	101 °C	85 °C

[1] Thermal resistance from junction to exposed diepad

[2] Thermal resistance from junction to board

[3] Thermal characterization parameter junction to package top

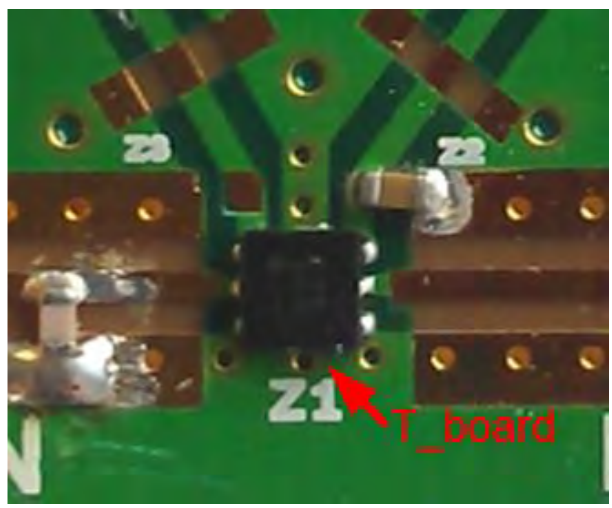


Fig 22. BGU7258 reference position board temperature

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