BGA123N6 as low-current GNSS LNA (1559 MHz to 1610 MHz) with LTE B13/B14 rejection

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA123N6 as a low noise amplifier (LNA) for GNSS applications in the range 1559 MHz to 1610 MHz with a rejection filter for LTE band 13/band 14 (787 MHz to 788 MHz) implemented at LNA input side.

The BGA123N6 is an ultra-low-current silicon-germanium (SiGe) LNA supporting 1550 to 1615 MHz.

1. The target application of this circuit is GPS L1/Galileo E1/GLONASS L1/BeiDou B1/QZSS L1 bands in the range of 1559 MHz to 1610 MHz.

2. In this application note, the performance of BGA123N6 is investigated on a FR4 board. This device is matched with 0201 size high Q-factor LQP03T inductors. Two circuit options are presented, with option A optimized for noise figure and option B optimized for rejection level in LTE B13/B14.

3. Key performance parameters at 1.8 V, 1575 MHz:
   Option A:
   Insertion gain = 18.3 dB
   Rejection at 787 MHz = 26 dB
   Noise figure = 1.05 dB
   Input return loss = 11 dB
   Output return loss = 16 dB
   Out-of-band IP3 = -8 dBm

   Option B:
   Insertion gain = 17.4 dB
   Rejection at 787 MHz = 37 dB
   Noise figure = 1.3 dB
   Input return loss = 11 dB
   Output return loss = 18 dB
   Out-of-band IP3 = -6 dBm

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1) The graphs were generated with the simulation program AWR Microwave Office®.

List of tables

1 Introduction and product overview

1.1 Global Navigation Satellite Systems

Global Navigation Satellite Systems (GNSSs) are among the mostly commonly used services in the electronics industry. Today, the following GNSSs are in operation: GPS, GLONASS, BeiDou, Galileo, QZSS, and IRNSS or NavIC. Main market segments include GNSS-enabled cell phones, personal navigation devices (PNDs) and GNSS-enabled wearable devices.

Traditionally, the upper L band in the range of 1560 MHz to 1610 MHz has been the main band for global navigation services, however, the lower L band in the range of 1160 MHz to 1300 MHz offers the facilitating navigation signal for safety-of-life purposes. The figure below includes an overview of the GNSS frequency allocation.

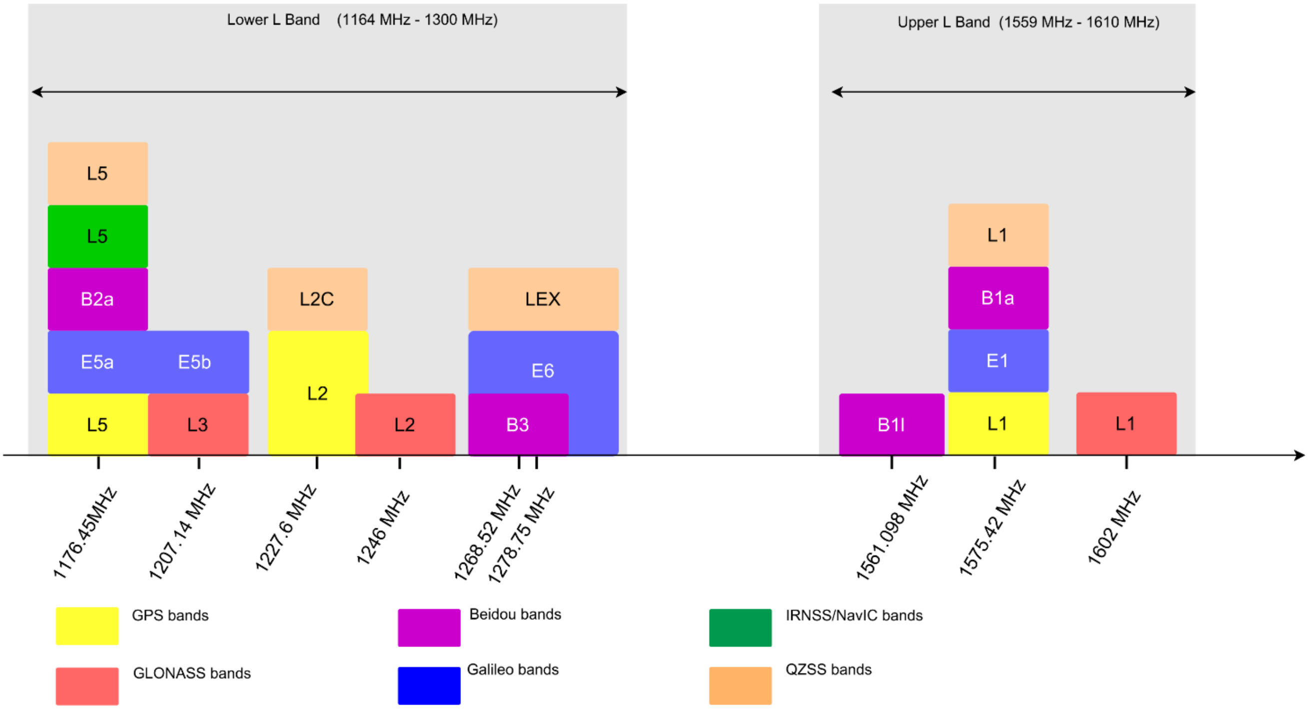


Figure 1 Frequency allocation for GNSSs, upper L band and lower L band

1.2 Key challenges for modern GNSS reception

This section summarizes the main technical challenges for GNSS-enabled mobile devices.

1.2.1 Receiver sensitivity in the presence of a weak incoming signal

The GNSS satellite signal transmits at an extremely low power level of about -130 dBm. High-power jammer signals may leak into the GNSS receiver and affect the receiver's sensitivity by overdriving the receiver's LNA. This presents a major challenge to RF front-end designers – to maintain the receiver's sensitivity to weak incoming GNSS signals.

1.2.2 Out-of-band (OoB) interference and high-power jammer signal

In a cell phone, GNSS and other wireless functions coexist in a compact area. Coupling from other wireless transceivers to the GNSS receive path results in intermixing of high-frequency signals into the GNSS RF front end, such as intermodulation between LTE band 2 and band 3 signals, and between the 5G NR band N77 and LTE band 3 signals, etc. Such intermodulation products introduce strong jammer signals to the GNSS receiver.

1.3 BGA123N6 overview

- Operation frequencies: 1550 MHz to 1615 MHz
- Ultra-low current consumption: 1.3 mA
- Wide supply voltage range: 1.1 V to 3.3 V
- High insertion power gain: 19.0 dB
- Low noise figure: 0.75 dB
- 2 kV HBM ESD protection (including AI-pin)
- Only one external matching component needed
- Ultra-small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm^2)
- RF output internally matched to 50 Ω
- RoHS/WEEE-compliant package

RoHS Halogen-Free Lead-Free Green

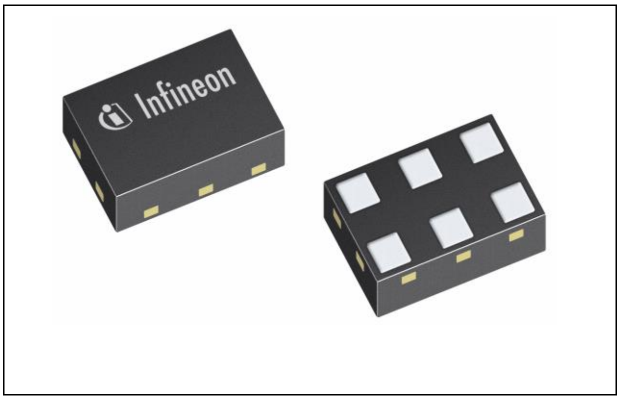


Figure 3 BGA123N6 in TSNP-6-2

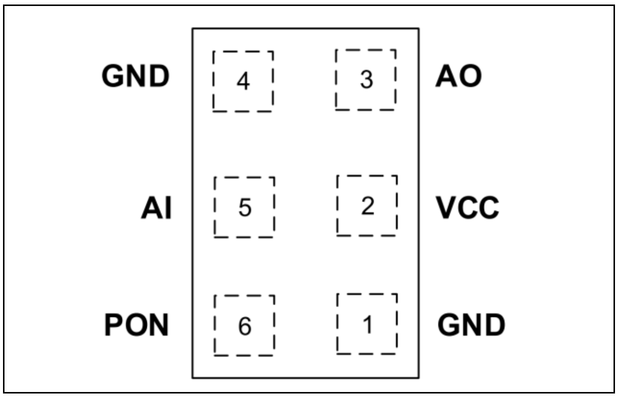


Figure 2 BGA123N6 pin configuration (transparent top view)

Table 1 Pin assignment

Pin no.	Symbol	Function
1	GND	Ground
2	V_{CC}	DC supply
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	PON	Power on/off control

2 Application circuit and performance overview

In this chapter the performance of the application circuit, the schematic and bill of materials (BOM) are presented.

Device: BGA123N6

Application: Low-current GNSS LNA from 1559 MHz to 1610 MHz with LTE B13 rejection

PCB marking: M110705

EVB order no.: EVAL BGA123N6 (AN628)

2.1 Summary of measurement results

The circuit performance is summarized in the following tables.

Table 2 Electrical characteristics, option A (room temperature)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1559 - 1610			MHz	Measured @ 1575 MHz
DC voltage	V_{CC}	1.2	1.8	2.8	V	
DC current	I_{CC}	1.30	1.35	1.40	mA	Measured with random sample
Gain	G	18.0	18.3	18.5	dB	
Gain @ LTE B13	G_B13	-26	-26	-26	dB	Measured @ 787.7 MHz
Noise figure	NF	1.10	1.05	1.05	dB	LQP03T inductor for matching, loss of SMA and input line of 0.1 dB de-embedded
Input return loss	RL_{IN}	10	11	11	dB	
Output return loss	RL_{OUT}	20	16	17	dB	
Reverse isolation	I_{REV}	44	44	44	dB	
Input P1dB	IP1dB	-19	-15.5	-12	dBm	Measured @ 1575 MHz
Stability factor	k	>1				Up to 10 GHz
LTE B13 second harmonic input referred	LTE B13 IHD2	-65	-66	-66	dBm	Power @ input: -25 dBm f = 787.7 MHz Measured @ 1575.4 MHz
LTE B13 second harmonic output referred	LTE B13 OHD2	-49	-49	-49	dBm	
Out-of-band input IP2	Oob_IIP2	11	10	10	dBm	Power @ input: -20 dBm f1 = 1950 MHz, f2 = 3525 MHz Measured @ 1575 MHz
Out-of-band output IM2	Oob_OIM2	-32	-31	-31	dBm	

Table 2 Electrical characteristics, option A (room temperature)

Parameter	Symbol	Value			Unit	Comment/test condition
Input IP3	IIP3	-16	-15	-14	dBm	Power @ input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Out-of-band input IP3	Oob_IIP3	-9	-8	-7	dBm	Power @ input: -20 dBm f1 = 1712.7 MHz, f2 = 1850 MHz, measured @ 1575.4 MHz
Out-of-band output IM3	Oob_OIM3	-24	-26	-28	dBm	
Switching time OFF-to-ON	t_{OFF-ON}	9[a)]/2[b)]	7[a)]/1[b)]	7[a)]/1[b)]	µs	Power up settling time: LNA gain changed to 90% of final gain value (in dB) a) C1 = 1000 pF b) C1 = 100 pF
Switching time ON-to-OFF	t_{ON-OFF}	0.5[a)]/0.5[b)]	0.5[a)]/0.5[b)]	0.5[a)]/0.5[b)]	µs	LNA gain dropped to 10% of final gain value (in dB) a) C1 = 1000 pF b) C1 = 100 pF

Table 3 Electrical characteristics, option B (room temperature)

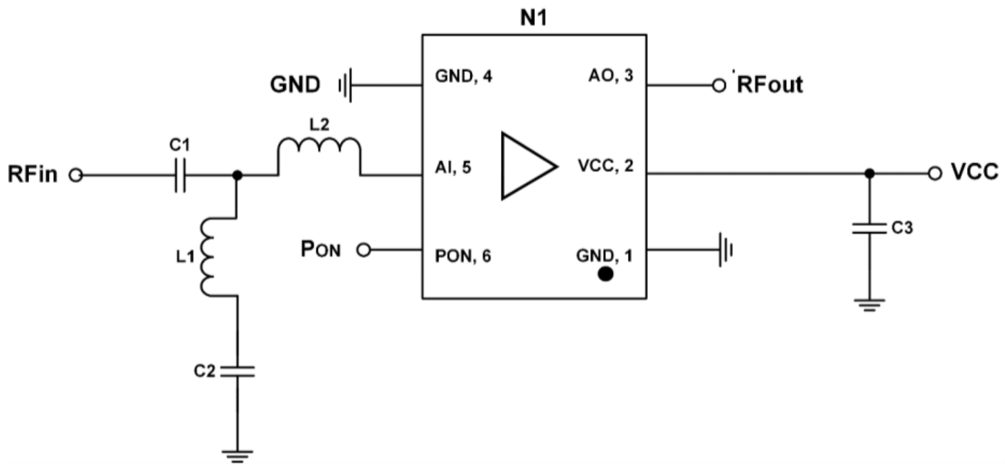
Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1559 – 1610			MHz	Measured @ 1575 MHz
DC voltage	V_{CC}	1.2	1.8	2.8	V	
DC current	I_{CC}	1.30	1.35	1.40	mA	Measured with random sample
Gain	G	17.1	17.4	17.6	dB	
Gain @ LTE B13	G_B13	-37	-37	-37	dB	Measured @ 787.7 MHz
Noise Figure	NF	1.30	1.30	1.30	dB	LQP03T inductor for matching, loss of SMA and input line of 0.1dB deembedded
Input return loss	RL_{IN}	11	11	11	dB	
Output return loss	RL_{OUT}	20	18	17	dB	
Reverse isolation	I_{REV}	44	44	44	dB	
Input P1dB	IP1dB	-19	-15	-11	dBm	Measured @ 1575 MHz
Stability factor	k	>1				Up to 10 GHz

Table 3 Electrical characteristics, option B (room temperature)

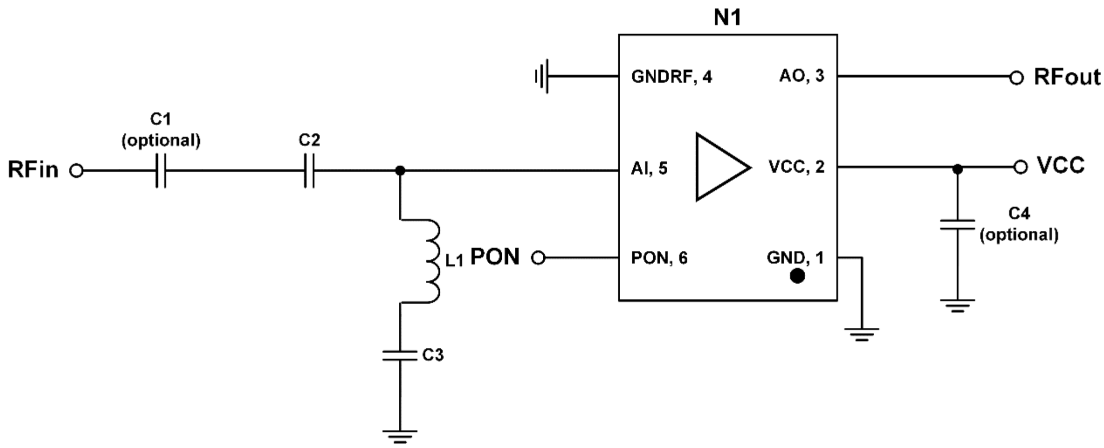
Parameter	Symbol	Value			Unit	Comment/test condition
LTE B13 second harmonic input referred	LTE B13 IHD2	-68	-68	-68	dBm	Power @ input: -25 dBm f = 787.7 MHz Measured @ 1575.4 MHz
LTE B13 second harmonic output referred	LTE B13 OHD2	-49	-49	-49	dBm	
Out-of-band input IP2	Oob_IIP2	1	0	0	dBm	Power @ input: -20 dBm f1 = 1950 MHz, f2 = 3525 MHz Measured @ 1575 MHz
Out-of-band output IM2	Oob_OIM2	-22	-21	-21	dBm	
Input IP3	IIP3	-13	-13	-13	dBm	Power @ input: -30 dBm f1 = 1575 MHz, f2= 1576 MHz
Out-of-band input IP3	Oob_IIP3	-8	-6	-5	dBm	Power @ input: -20 dBm f1 = 1712.7 MHz, f2 = 1850 MHz, measured @ 1575.4 MHz
Out-of-band output IM3	Oob_OIM3	-26	-29	-32	dBm	
Switching time OFF-to-ON	t_{OFF-ON}	9[a)]/2[b)]	7[a)]/1[b)]	7[a)]/1[b)]	µs	Power up settling time: LNA gain changed to 90% of final gain value (in dB) a) C1 = 1000 pF b) C1 = 100 pF
Switching time ON-to-OFF	t_{ON-OFF}	0.5[a)]/0.5[b)]	0.5[a)]/0.5[b)]	0.5[a)]/0.5[b)]	µs	LNA gain dropped to 10% of final gain value (in dB) a) C1 = 1000 pF b) C1 = 100 pF

2.2 Schematic and bill of materials

The schematic is presented in Figure 4 and its BOM is shown in Table 4.



(option A)



(option B)

Figure 4 Schematic of the BGA123N6 application circuit

Table 4 Bill of materials

Symbol	Value	Unit	Size	Manufacturer	Comment
Option A					
C1	1000/100[1)]	pF	0201	Various	DC block[1)]
C2	3.3	pF	0201	Various	Notch filter and input matching
C3	≥ 1	nF	0201	Various	RF bypass[2)]
L1	12	nH	0201	Murata LQP03T	Notch filter and input matching

Table 4 Bill of materials

Symbol	Value	Unit	Size	Manufacturer	Comment
L2	9.1	nH	0201	Murata LQP03T	Input matching
N1	BGA123N6		TSNP-6-2	Infineon Technologies	SiGe LNA
Option B					
C1	1000/100[1)]	pF	0201	Various	DC block
C2	1.3	pF	0201	Various	Input matching
C3	6.8	pF	0201	Various	Notch filter and input matching
C4	≥ 1	nF	0201	Various	RF bypass[2)]
L1	6.2	nH	0201	Murata LQP03T	Notch filter and input matching
N1	BGA123N6		TSNP-6-2	Infineon Technologies	SiGe LNA

Note:

1) DC block function is NOT integrated at the input pin. DC block capacitor C1 is not necessary if the DC block function on the RF input line can be ensured by the previous stage.For reducing switching time, lower DC block cap value is recommended. C1 = 100 pF enables less than 3 µS switching time.
2) The RF bypass capacitor at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor is not necessary if a clean and stable DC supply can be ensured.

3 Measurement graphs

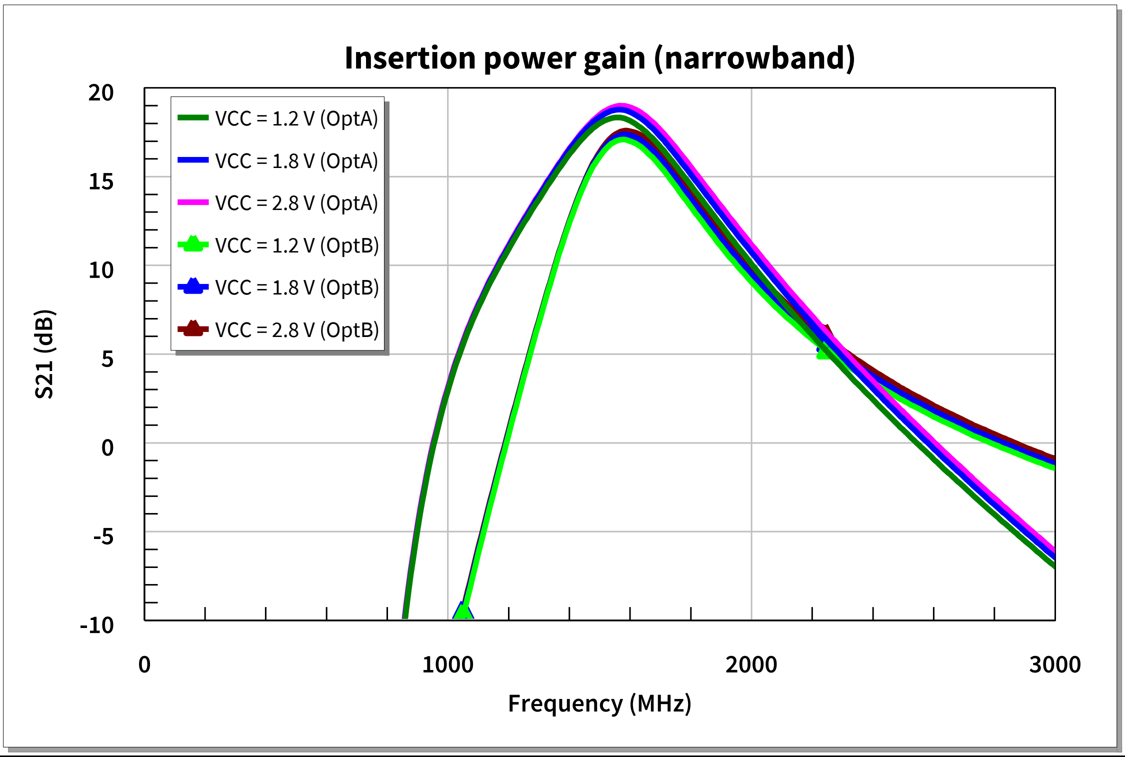


Figure 5 Insertion power gain (narrowband)

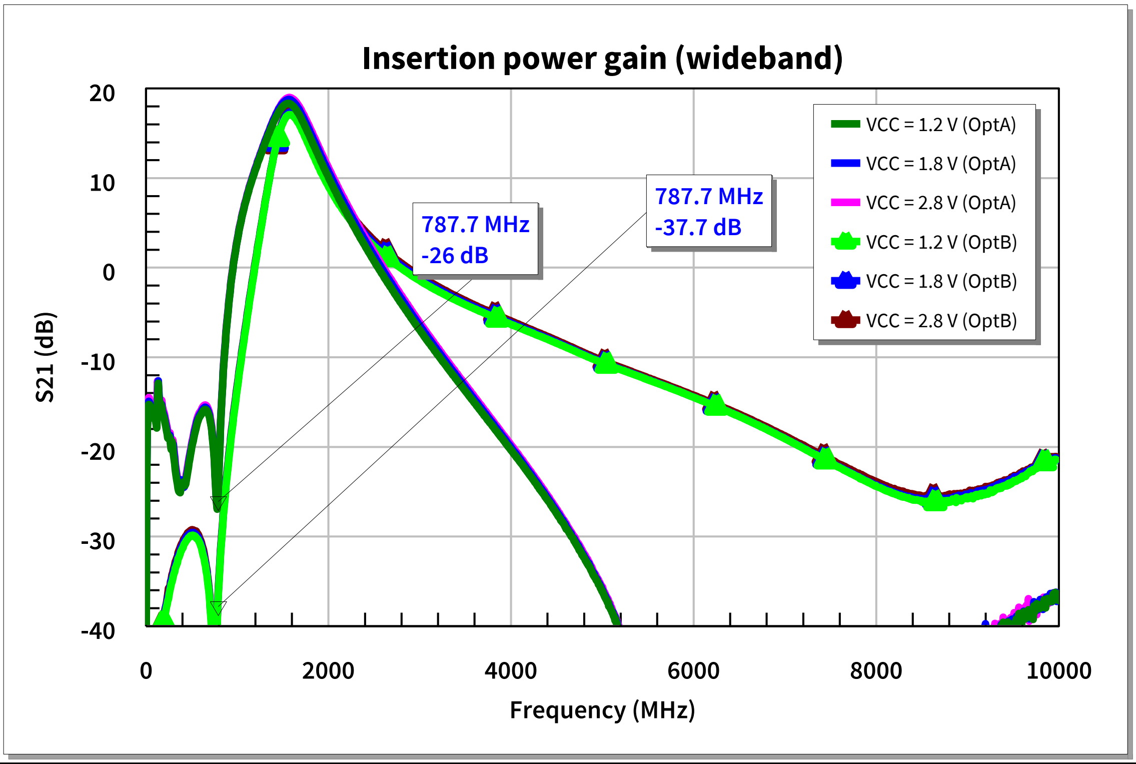


Figure 6 Insertion power gain (wideband)

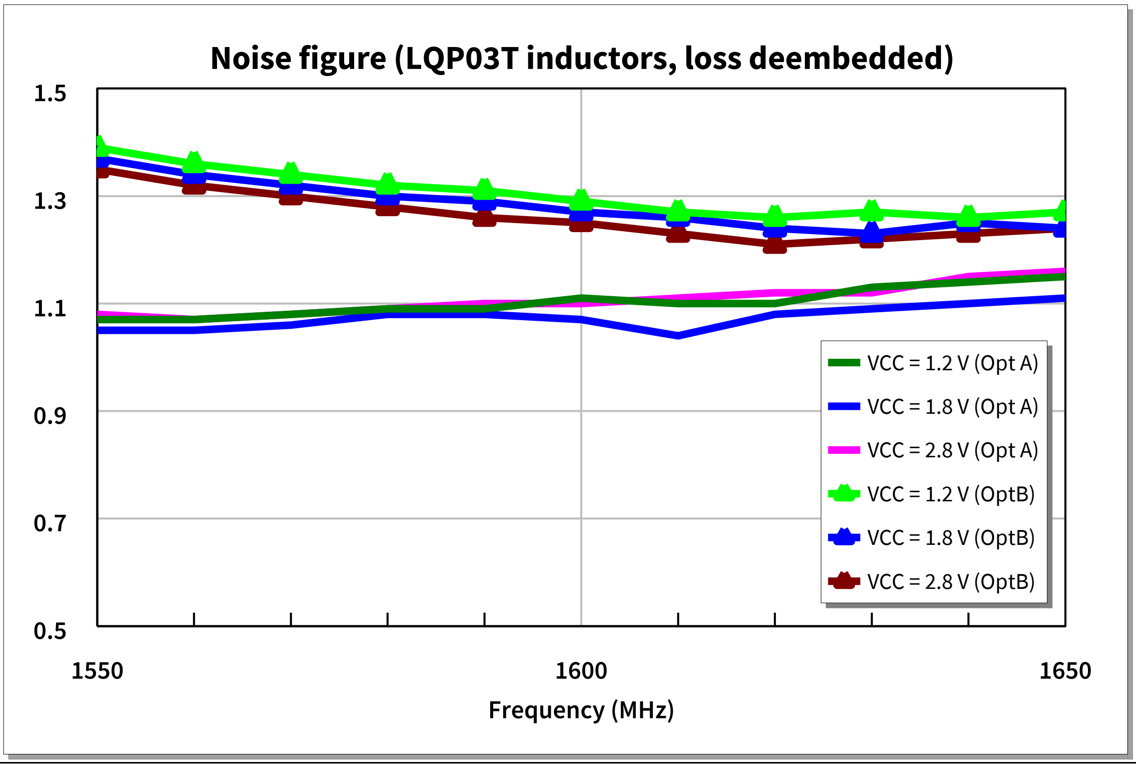


Figure 7 Noise figure (SMA and connector losses de-embedded, LQP03T inductors for matching)

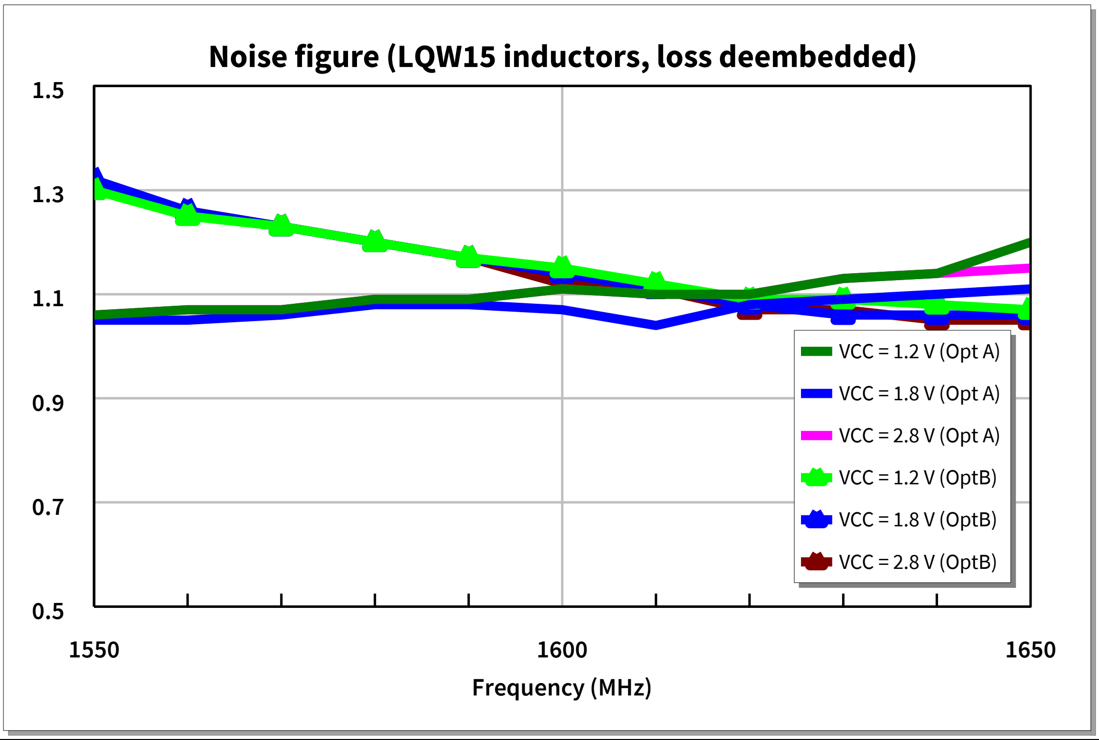


Figure 8 Noise figure (SMA and connector losses de-embedded, LQW15 inductors for matching)

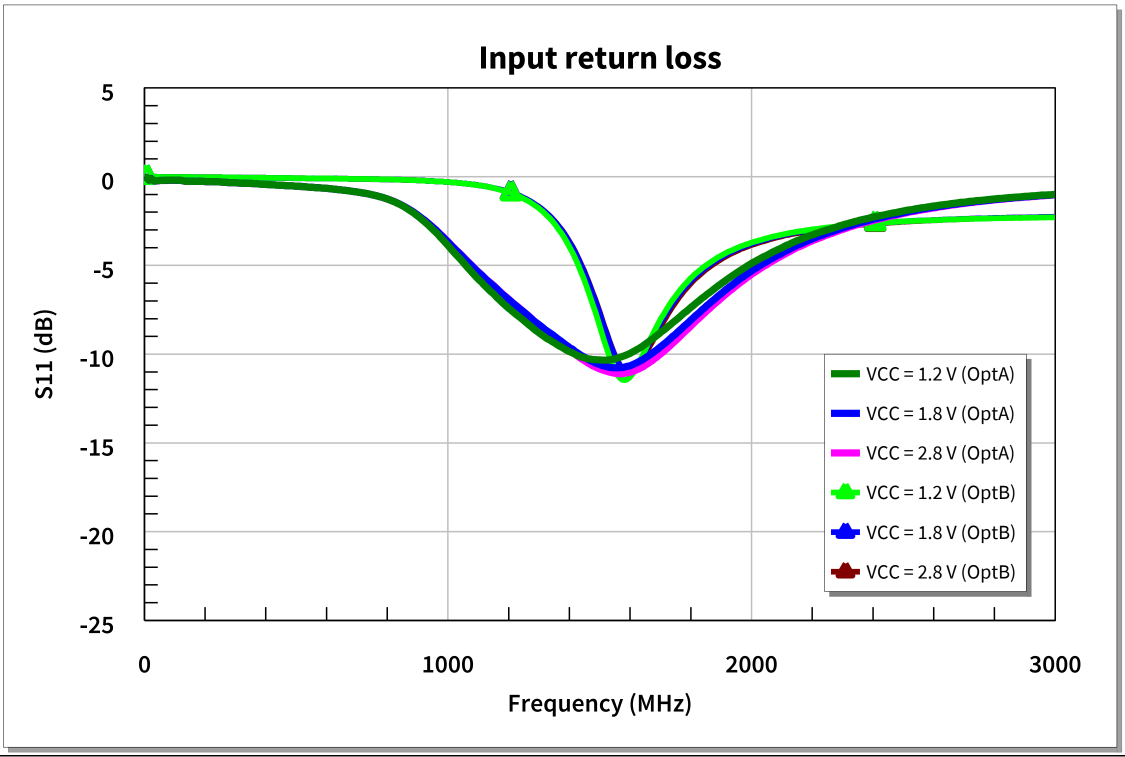


Figure 9 Input return loss

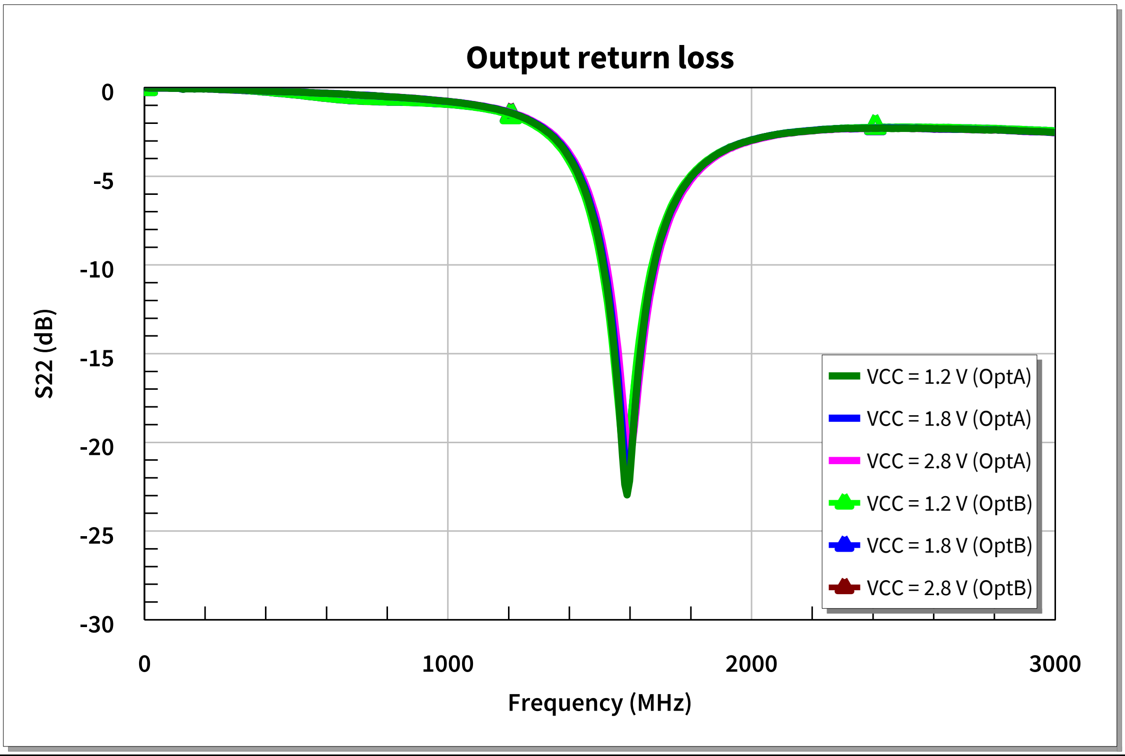


Figure 10 Output return loss

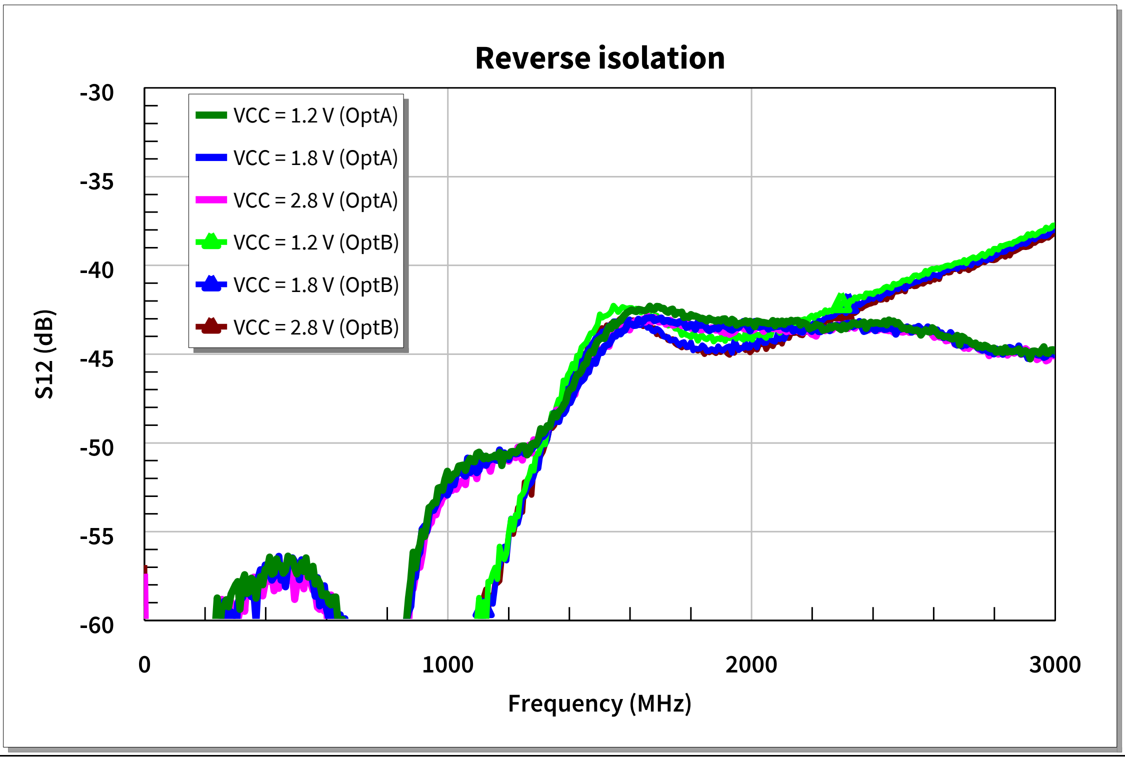


Figure 11 Reverse isolation

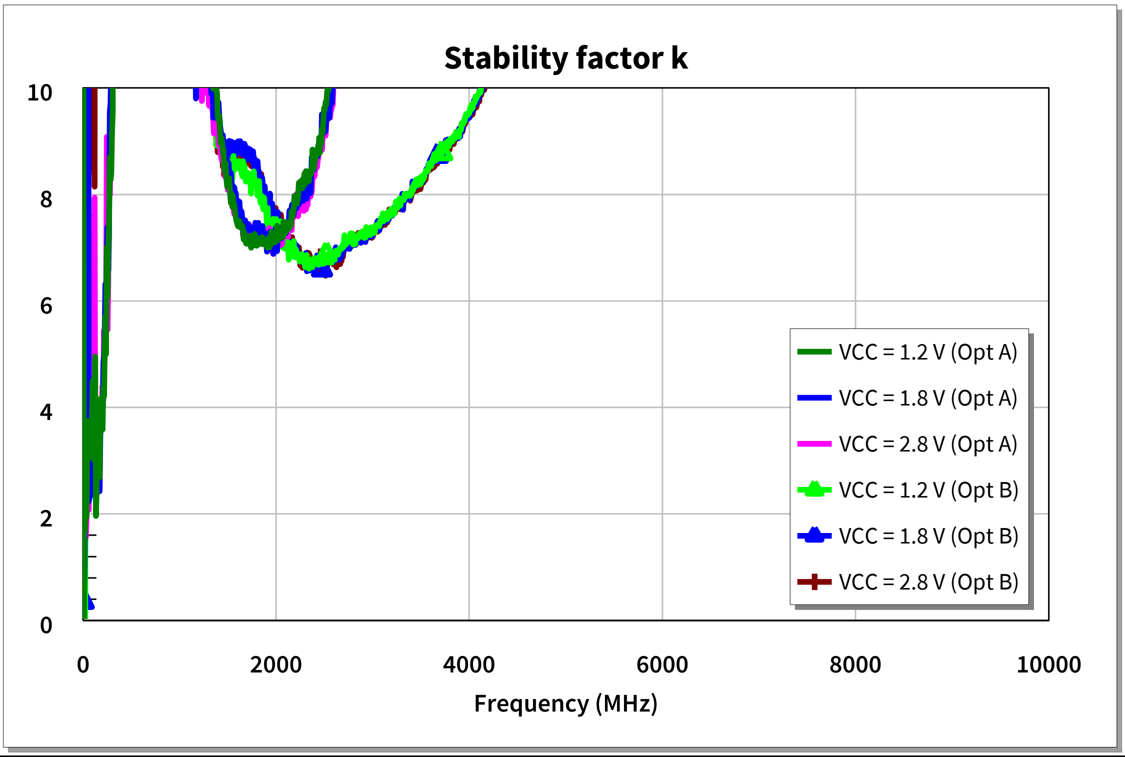


Figure 12 Stability k-factor

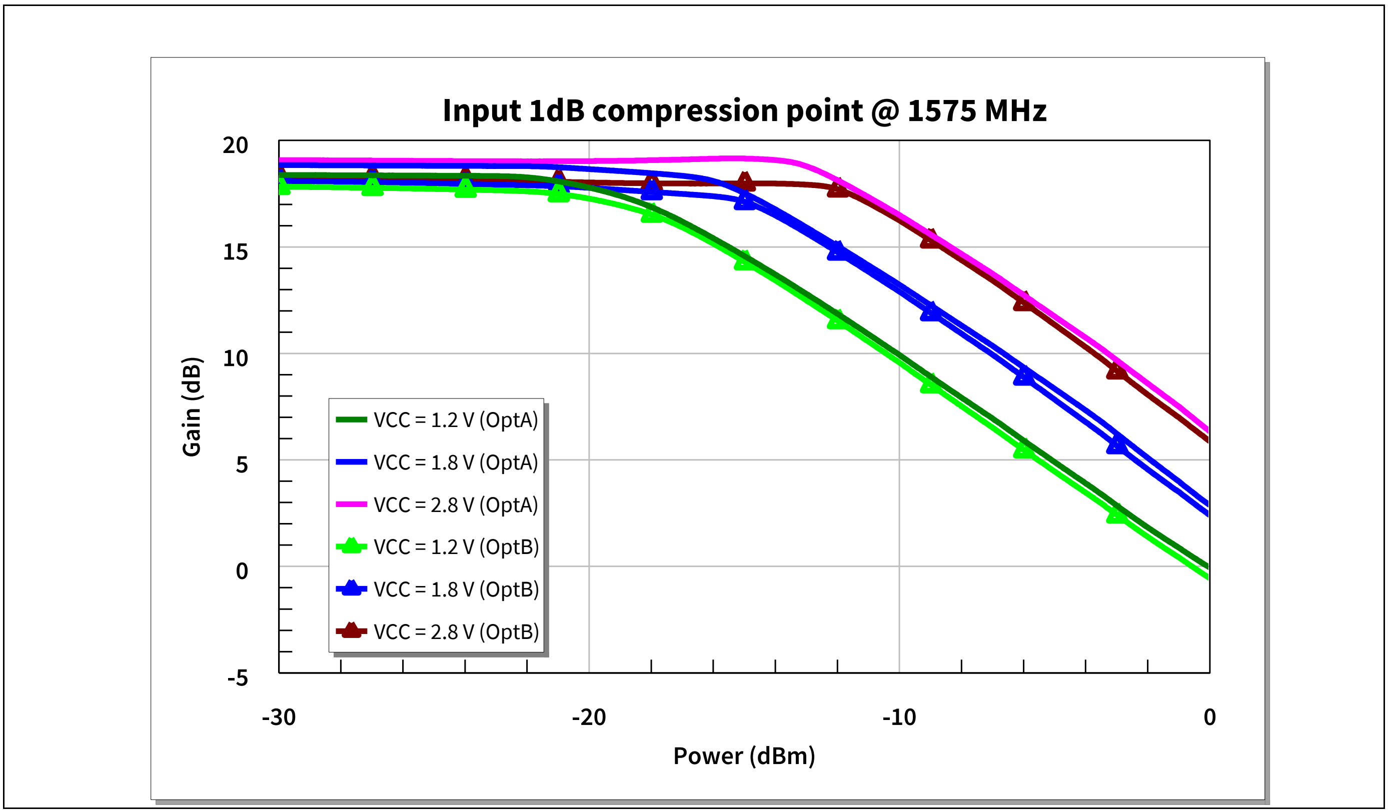


Figure 13 Input 1 dB compression point

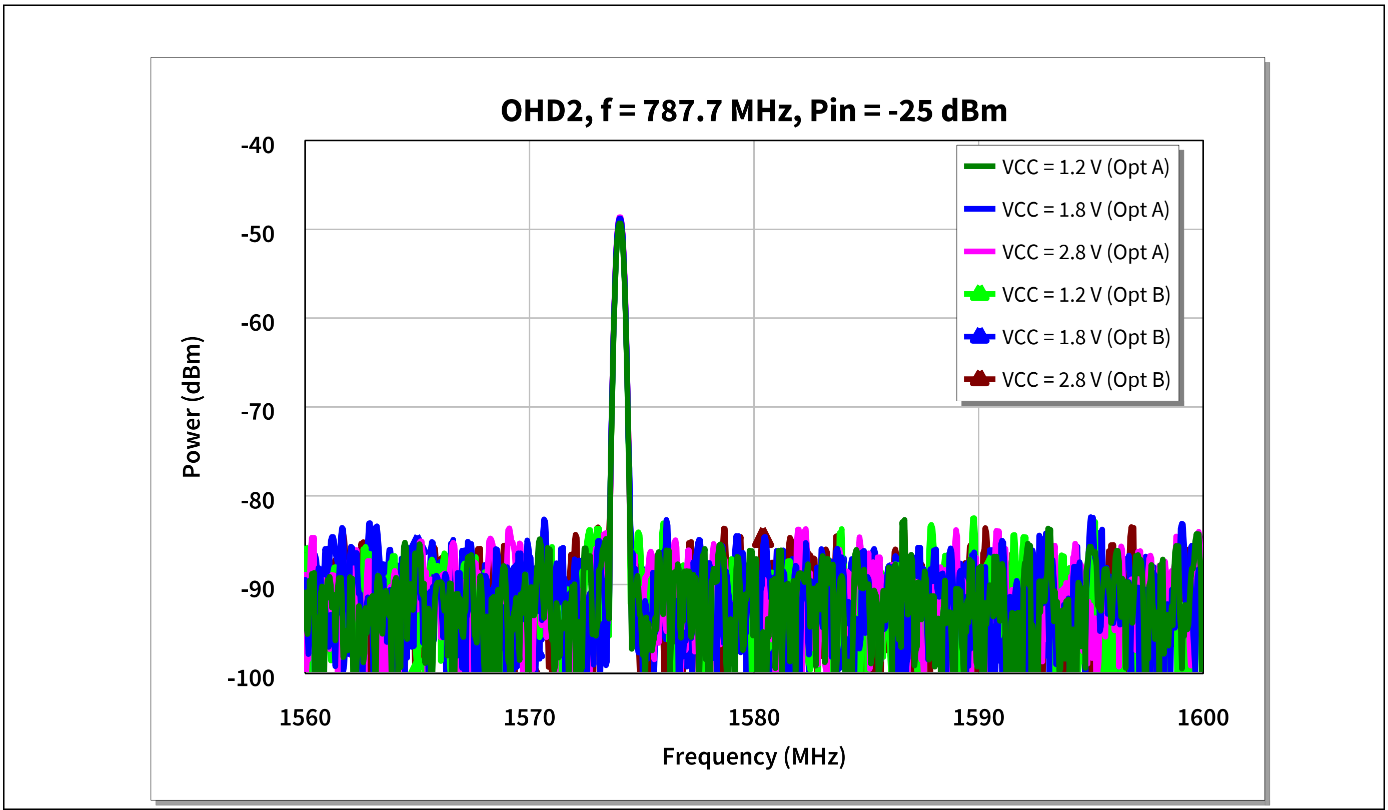


Figure 14 Second-order harmonics LTE band 13/band 14 (output referred)

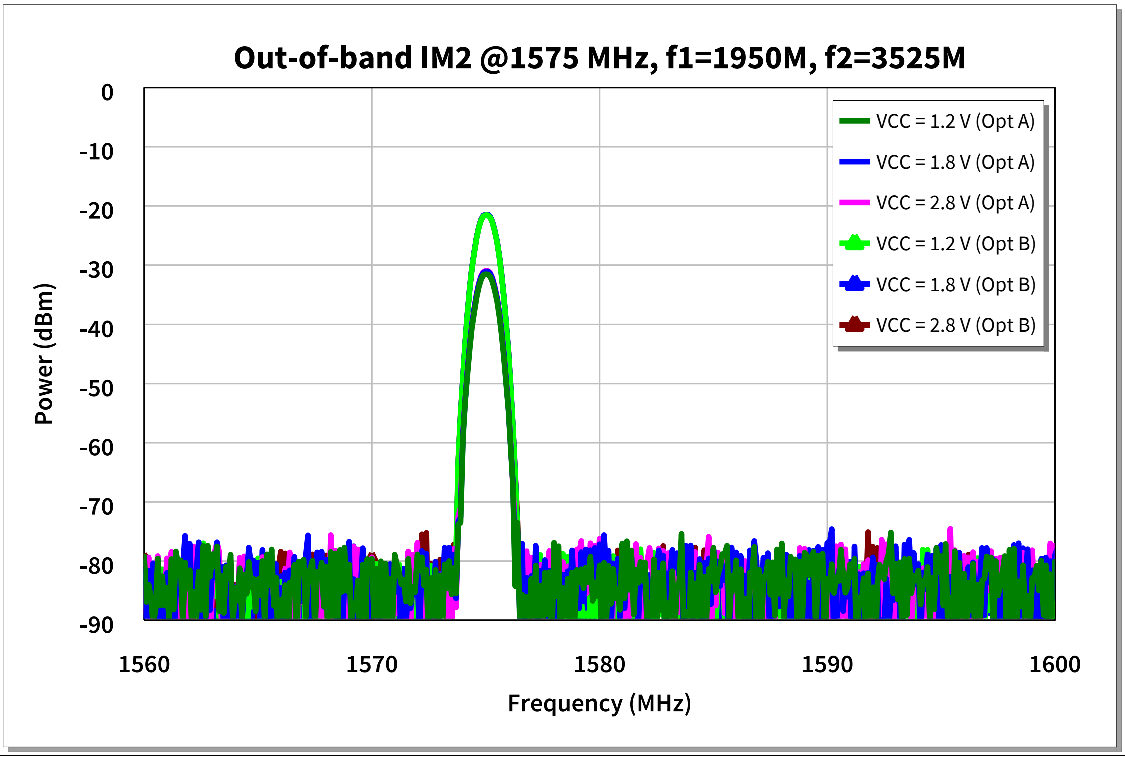


Figure 15 Second-order out-of-band intermodulation (f1 = 1950 MHz, f2 = 3525 MHz, output referred)

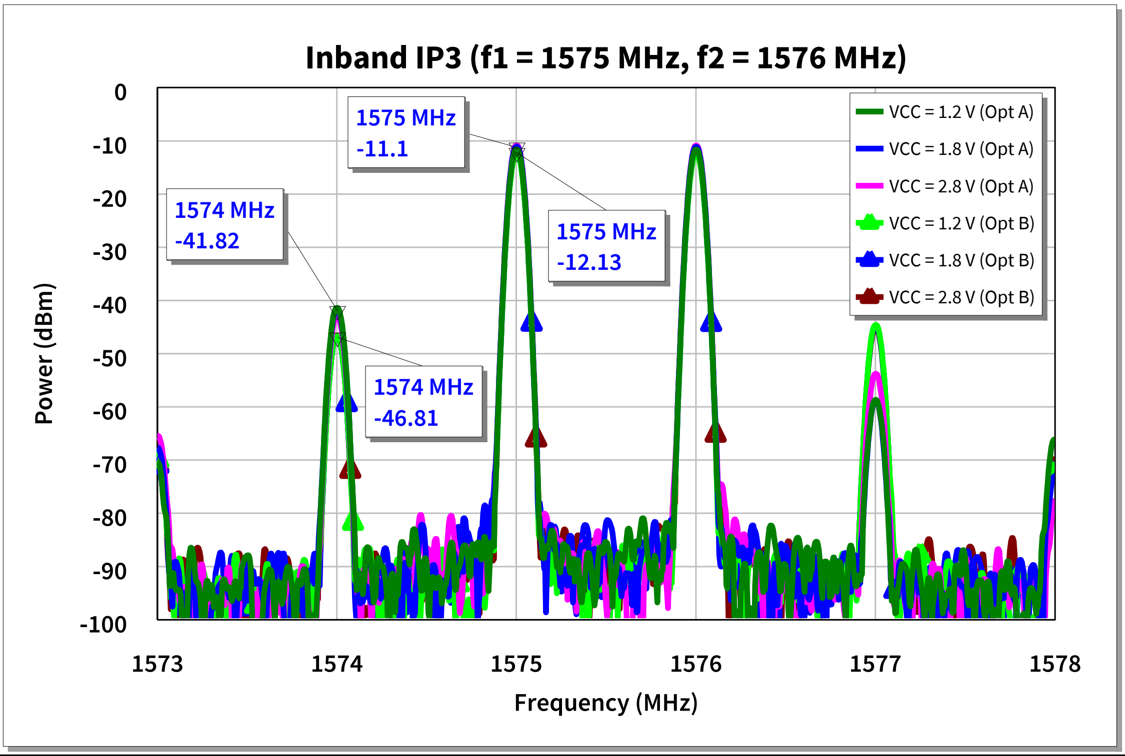


Figure 16 Inband third-order intermodulation point (f1 = 1575 MHz, f2 = 1576 MHz, output referred)

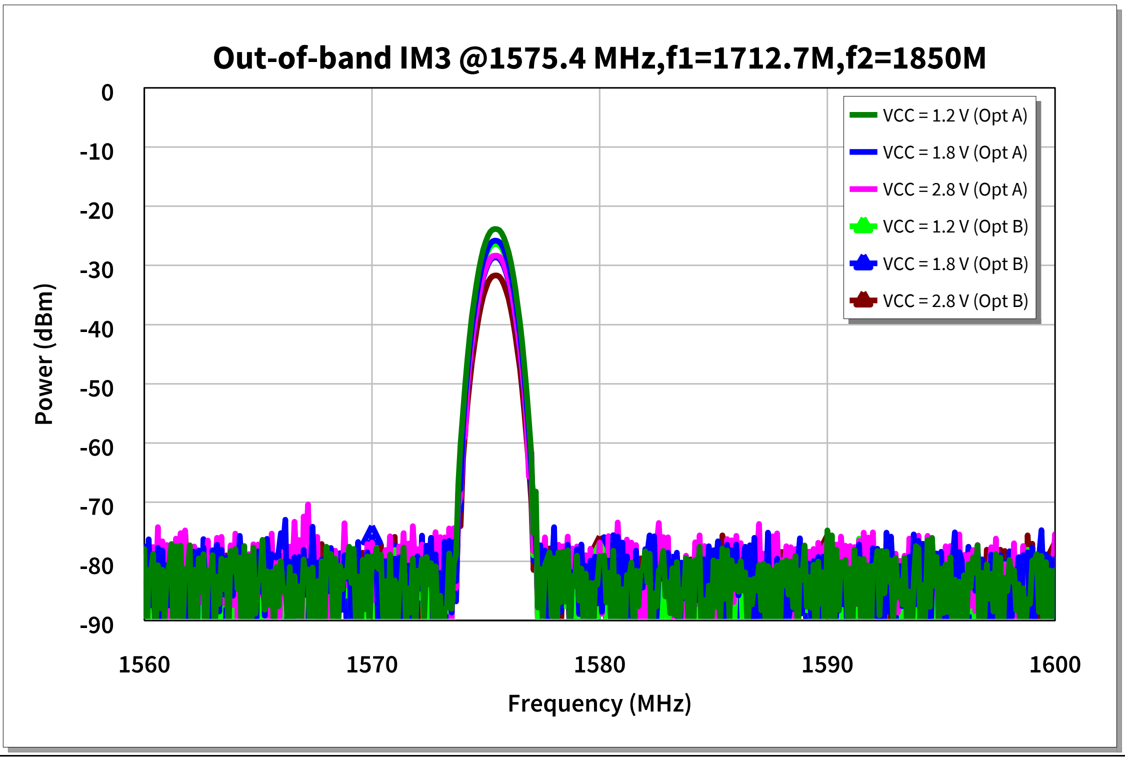


Figure 17 Out-of-band third-order intermodulation point (f1 = 1712.7 MHz, f2 = 1850 MHz, output referred)

4 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: **M110705**

PCB material: **FR4**

ε_r of PCB material: **4.3**

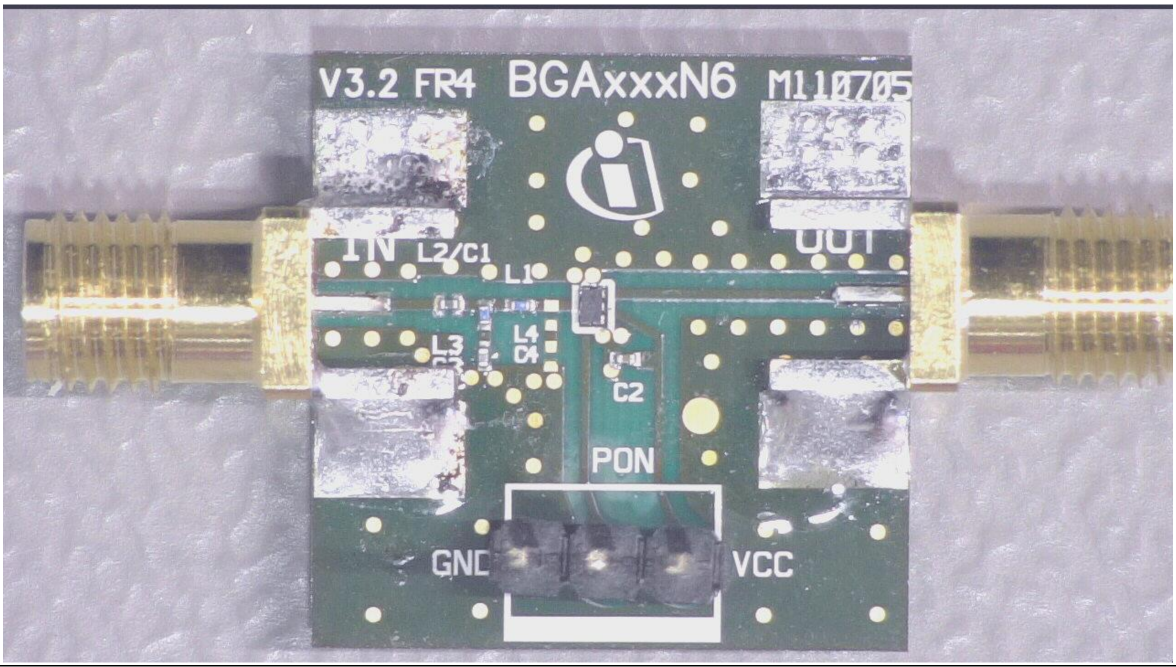


Figure 18 Evaluation board (option A)

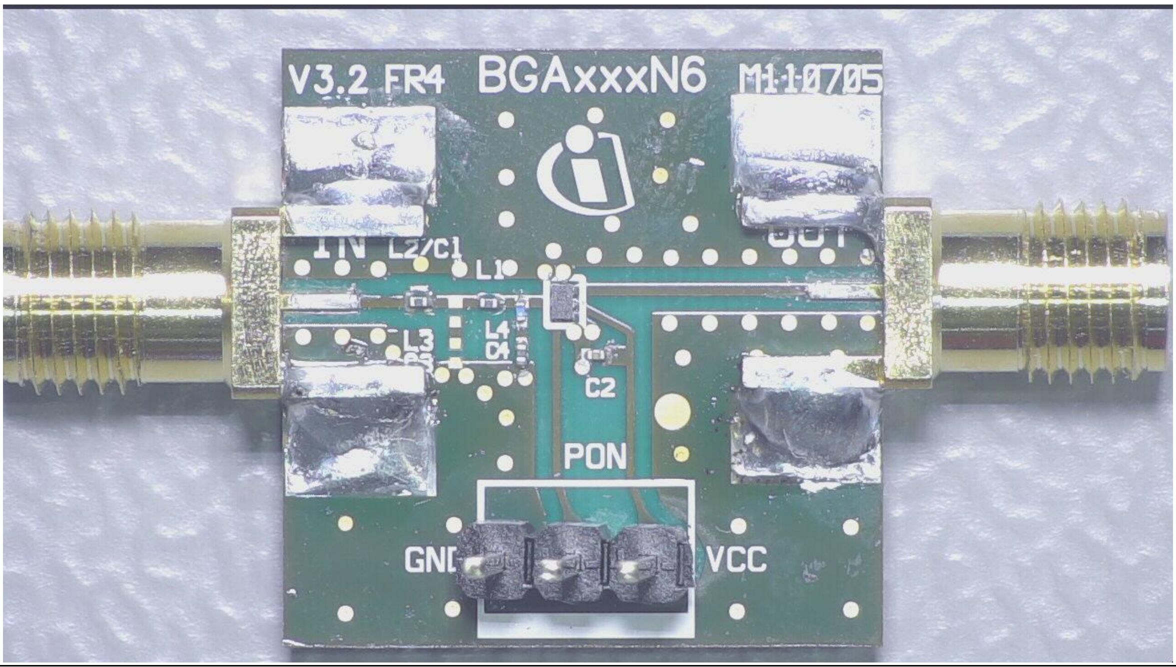


Figure 19 Evaluation board (option B)

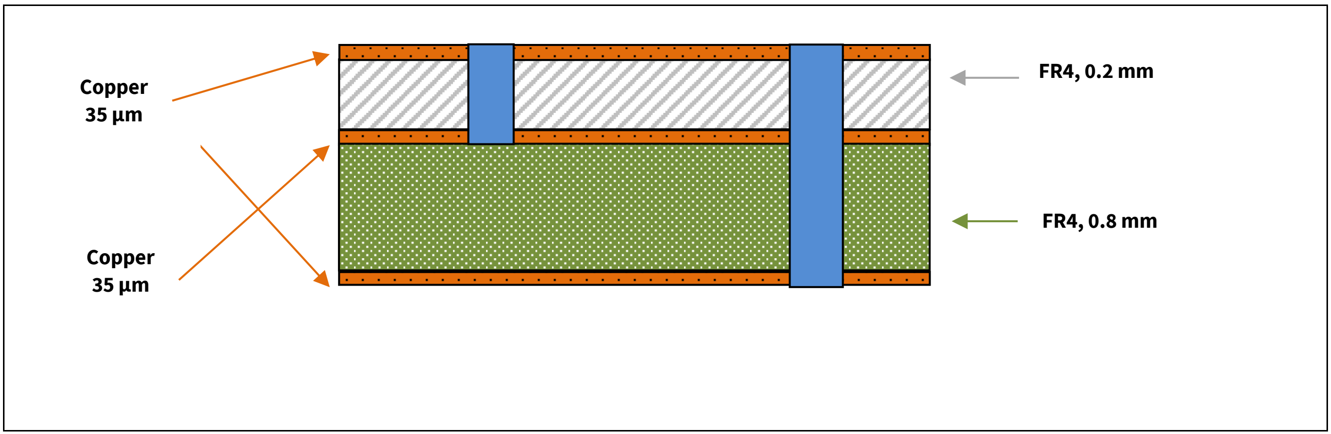


Figure 20 PCB layer information

5 Authors

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Revision history

Major changes since the last revision

Page or reference	Description of change

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