BGA123N6 as low-current LNA for GNSS applications from 1550 MHz to 1615 MHz

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 frequency range of 1550 MHz to 1615 MHz.

The BGA123N6 is an ultra-low-current silicon germanium (SiGe) LNA supporting 1550 MHz 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 report, the performance of BGA123N6 is investigated on a Megtron 6 board. This device is matched with 0402 size high Q-factor LQW15 inductors. Two circuit options are investigated: Option A according to the datasheet and option B with reduced current. Performance difference, when matched with 0201 size high Q factor LQP03TN inductors, is also presented.

3. Key performance parameters at 1.8 V, 1575 MHz, LQW15 inductors for matching:

Option A	Option B
I_{CC} = 1.35 mA	I_{CC} = 1.20 mA
Insertion gain = 18.6 dB	Insertion gain = 18.1 dB
Noise figure = 0.80 dB	Noise figure = 0.85 dB
Input return loss = 12 dB	Input return loss = 11 dB
Output return loss = 18 dB	Output return loss = 18 dB
Out-of-band IP3 = -8 dBm	Out-of-band IP3 = -7 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 most commonly used services in the electronics industry. Today, the following GNSS systems are in operation: GPS, GLONASS, BDS, 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 1560MHz 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 facilitates the navigation signal for safety-of-life purposes. The figure below includes an overview of the GNSS frequency allocation.

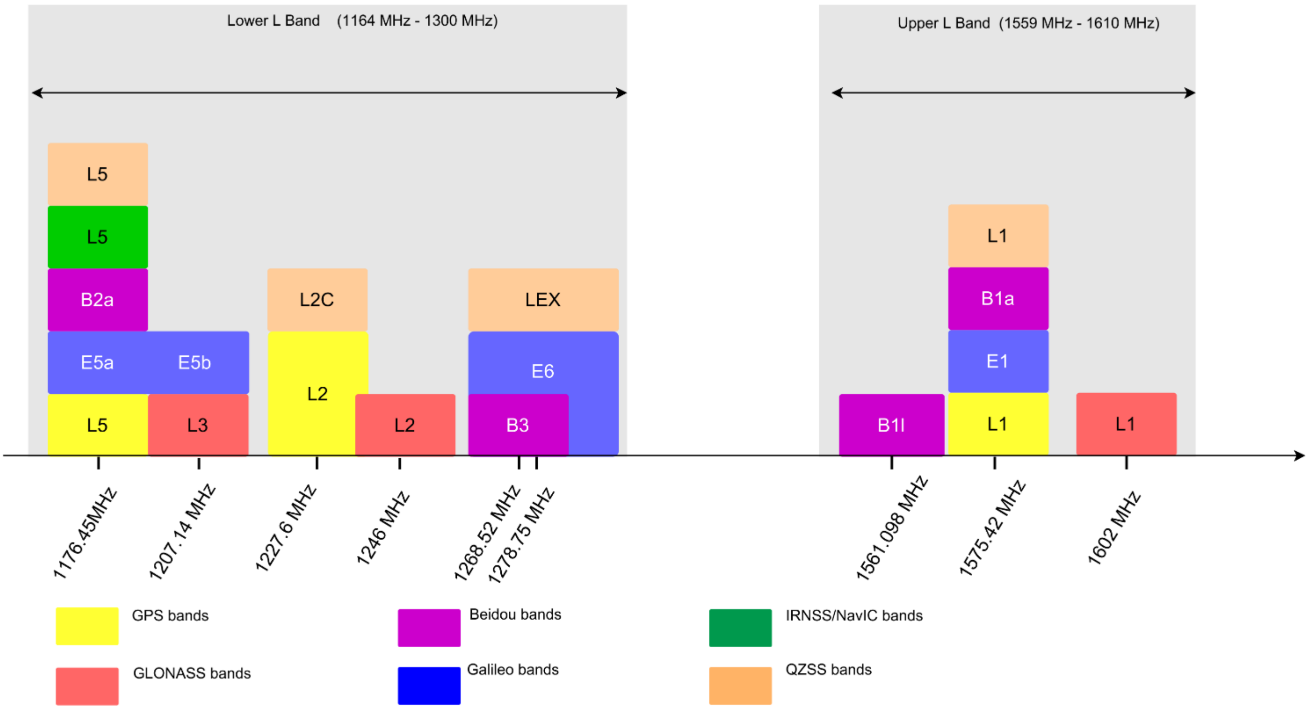

Figure 1 Frequency allocation for GNSSs, upper L band and lower L band

1.2 Key challenges for modern GNSS reception

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

1.2.1 Noise figure degradation due to weak incoming signal and high-power jammer signal

The GNSS satellite signal transmits at an extremely low power level of about -130 dBm. High-power jammer signals can 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

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 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)
- RF output internally matched to 50 Ω
- RoHS/WEEE-compliant package

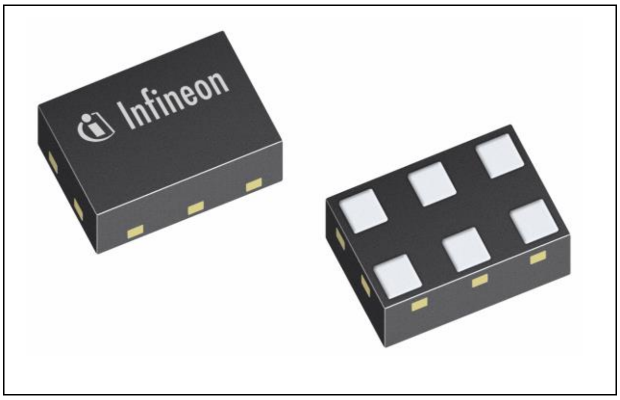

Figure 3 BGA123N6 in TSNP-6-2

RoHS Halogen-Free Lead-Free Green

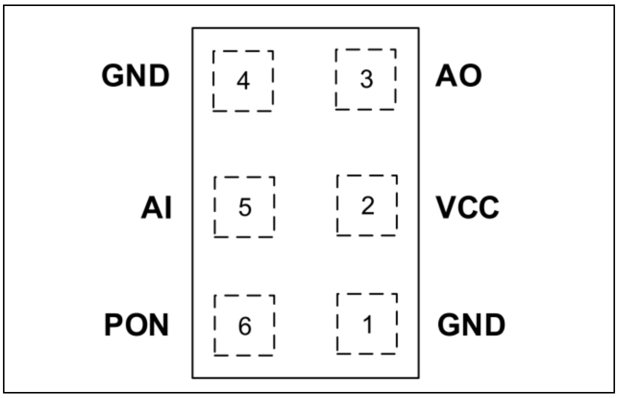

Figure 2 BGA123N6 pin configuration (transparent top view)

Table 1 Pin assignment

Pin no.	Symbol	Function
1	GND	Ground
2	VCC	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 are presented.

Device: BGA123N6

Application: Low-current LNA for GNSS applications from 1550 MHz to 1615 MHz

PCB marking: 080920

EVB order no.: EVAL BGA123N6 (AN626)

2.1 Summary of measurement results

The performance of BGA123N6 for GNSS upper L band applications is summarized in the following tables.

Table 2 Electrical characteristics at T_A = 25 °C (Option A)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1550 - 1615			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	
Gain	G	18.2	18.6	18.8	dB	
Noise figure	NF	0.85	0.80	0.80	dB	LQW15 inductor for matching, loss of input line of 0.04 dB is de-embedded
Noise figure	NF_LQP	1.05	1.00	1.00	dB	LQP03TN inductor for matching, loss of input line of 0.04 dB is de-embedded
Input return loss	RL_{IN}	12	12	13	dB	
Output return loss	RL_{OUT}	18	18	17	dB	
Reverse isolation	I_{REV}	35	35	35	dB	
Input P1dB	IP1dB	-19	-15	-12	dBm	Measured @ 1575 MHz
LTE band 13 second harmonic input referred	LTE B13 IHD2	-42	-42	-42	dBm	Power @ Input: -25 dBm f = 787.7 MHz Measured @ 1575.52 MHz
LTE band 13 second harmonic output referred	LTE B13 OHD2	-23	-24	-24	dBm	
Out-of-band input IP2	Oob_IIP2	5	6	6	dBm	Power @ Input: -20 dBm f1 = 1950 MHz, f2 = 3525 MHz Measured @ 1575 MHz
Out-of-band output IM2	Oob_OIM2	-27	-27	-27	dBm	
Input IP3	IIP3	-14	-13	-14	dBm	Power @ Input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Out-of-band Input IP3	Oob_IIP3	-9	-8	-6	dBm	Power @ Input: -20 dBm

Table 2 Electrical characteristics at T_A = 25 °C (Option A)

Parameter	Symbol	Value			Unit	Comment/test condition
Out-of-band Output IM3	Oob_OIM 3	-24	-26	-29	dBm	f1 = 1712.7 MHz, f2 = 1850 MHz, measured @ 1575.4 MHz
Stability	k	>1				Measured up to 10 GHz
Switching time ON-to-OFF	$t_{ON\text{-}OFF}$	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
Switching time OFF-to-ON	$t_{OFF\text{-}ON}$	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 = 1 nF b) C1 = 100 pF

Table 3 Electrical characteristics at T_A = 25°C (Option B)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1550 - 1615			MHz	Measured @ 1575 MHz
DC voltage	V_{CC}	1.2	1.8	2.8	V	
DC current	I_{CC}	1.10	1.20	1.25	mA	
Gain	G	17.6	18.1	18.3	dB	
Noise figure	NF	0.90	0.85	0.85	dB	LQW15 inductor for matching, loss of input line of 0.04 dB is de-embedded
Noise figure	NF_LQP	1. 05	1.05	1.05	dB	LQP03TN inductor for matching, loss of input line of 0.04 dB is de-embedded
Input return loss	RL_{IN}	10	11	12	dB	
Output return loss	RL_{OUT}	18	18	17	dB	
Reverse isolation	I_{REV}	-34	-34	-34	dB	
Input P1dB	IP1dB	-17	-14	-10	dBm	Measured @ 1575 MHz
LTE band 13 second harmonic input referred	LTE B13 IHD2	-40	-41	-41	dBm	Power @ Input: -25 dBm f = 787.7 MHz Measured @ 1575.4 MHz
LTE band 13 second harmonic output referred	LTE B13 OHD2	-23	-23	-23	dBm	
Out-of-band input IP2	Oob_IIP2	6	7	7	dBm	Power @ Input: -20 dBm f1 = 1950 MHz, f2 = 3525 MHz Measured @ 1575 MHz
Out-of-band Output IM2	Oob_OIM 2	-29	-29	-29	dBm	

Table 3 Electrical characteristics at T_A = 25°C (Option B)

Parameter	Symbol	Value			Unit	Comment/test condition
Input IP3	IIP3	-14	-13	-13	dBm	Power @ Input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Out-of-band input IP3	Oob_IIP3	-8	-7	-7	dBm	Power @ Input: -20 dBm. f1 = 1712.7 MHz, f2 = 1850 MHz, measured @ 1575.4 MHz
Out-of-band output IM3	Oob_OIM3	-27	-29	-28	dBm	
Stability	k	>1				Measured up to 10 GHz
Switching time ON-to-OFF	$t_{ON\text{-}OFF}$	0.4 a)/ 0.4 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 = 1 nF b) C1 = 100 pF
Switching time OFF-to-ON	$t_{OFF\text{-}ON}$	22 a) /3b)	17 a) / 2b)	14 a) / 2b)	µs	Power up settling time: LNA gain changed to 90% of final gain value (in dB) a) C1 = 1 nF b) C1 = 100 pF

2.2 Schematics and bill of materials

The schematic of Option A is presented in Figure 4, and its BOM is shown in Table 4.

The schematic of Option B is presented in Figure 5, and its BOM is shown in Table 5.

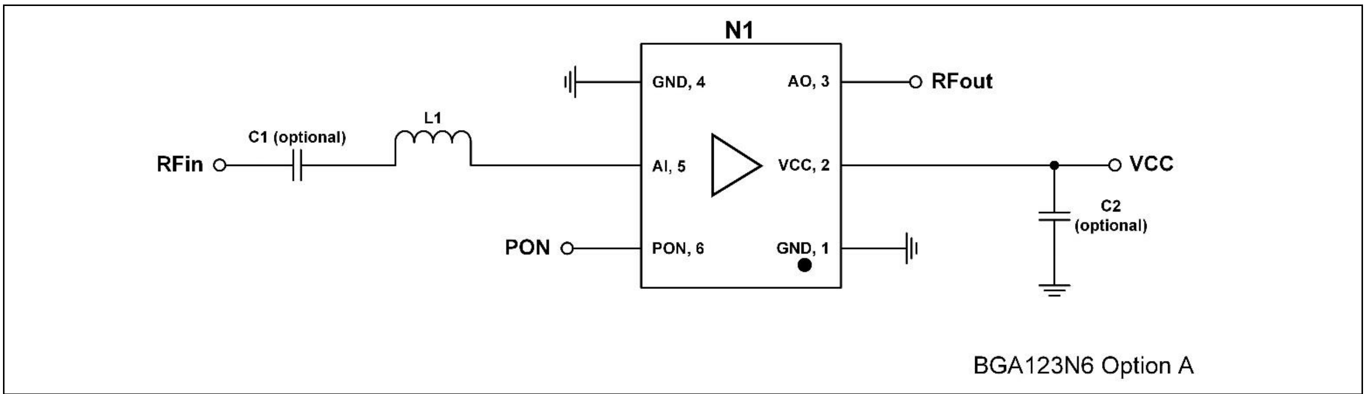

Figure 4 Schematic of the BGA123N6 application circuit (Option A)

Table 4 Bill of materials (Option A)

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0402	Various	DC block[1) 3)]
C2	≥ 1	nF	0402	Various	RF bypass[2)]
L1	10	nH	0402	Murata LQW15	Input matching
N1	BGA123N6		TSNP-6-2	Infineon Technologies	SiGe LNA

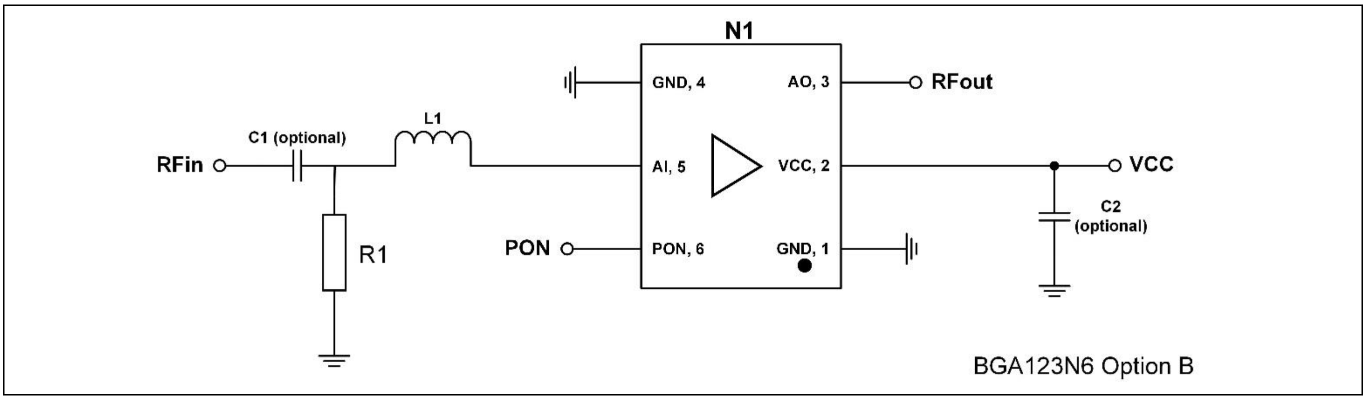

Figure 5 **Schematic of the BGA123N6 application circuit (Option B)**

Table 5 Bill of materials (Option B)

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0402	Various	DC block[1) 3)]
C2	≥ 1	nF	0402	Various	RF bypass[2)]
L1	11	nH	0402	Murata LQW15	Input matching
R1	220	kΩ	0402	Various	I_{CC} reduction
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 C2 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor C2 is not necessary if a clean and stable DC supply can be ensured.

3 Measurement graphs

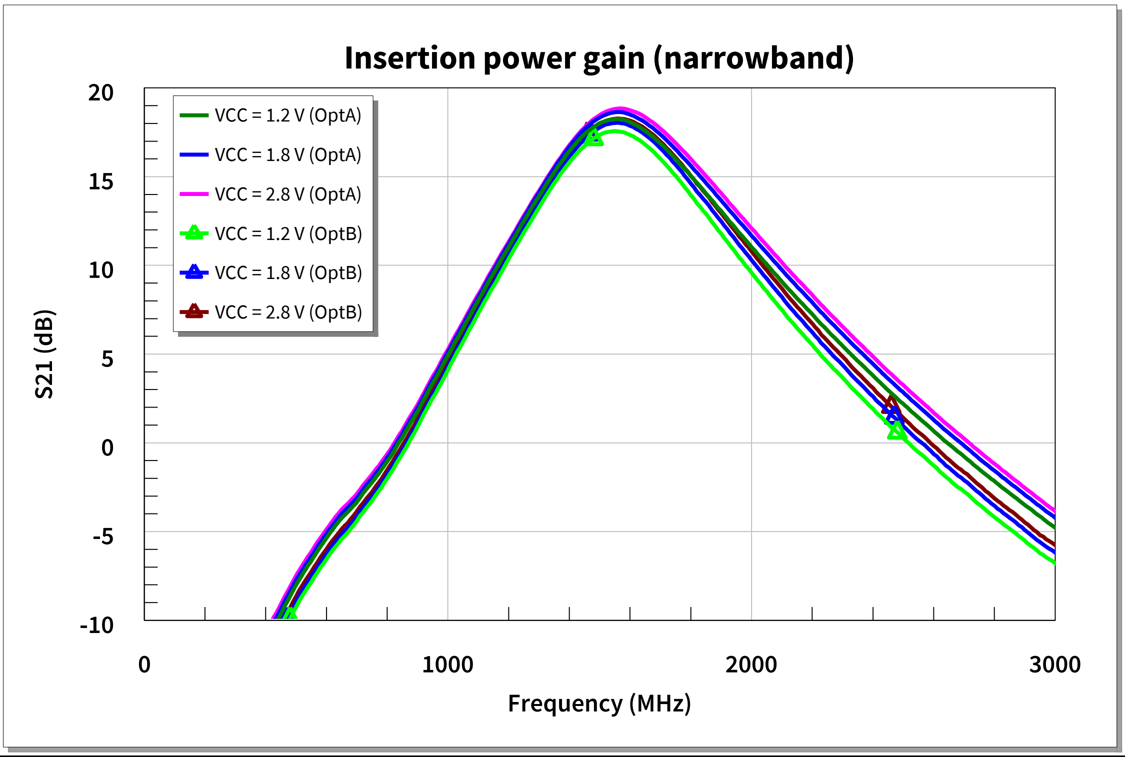

Figure 6 Insertion power gain (narrowband)

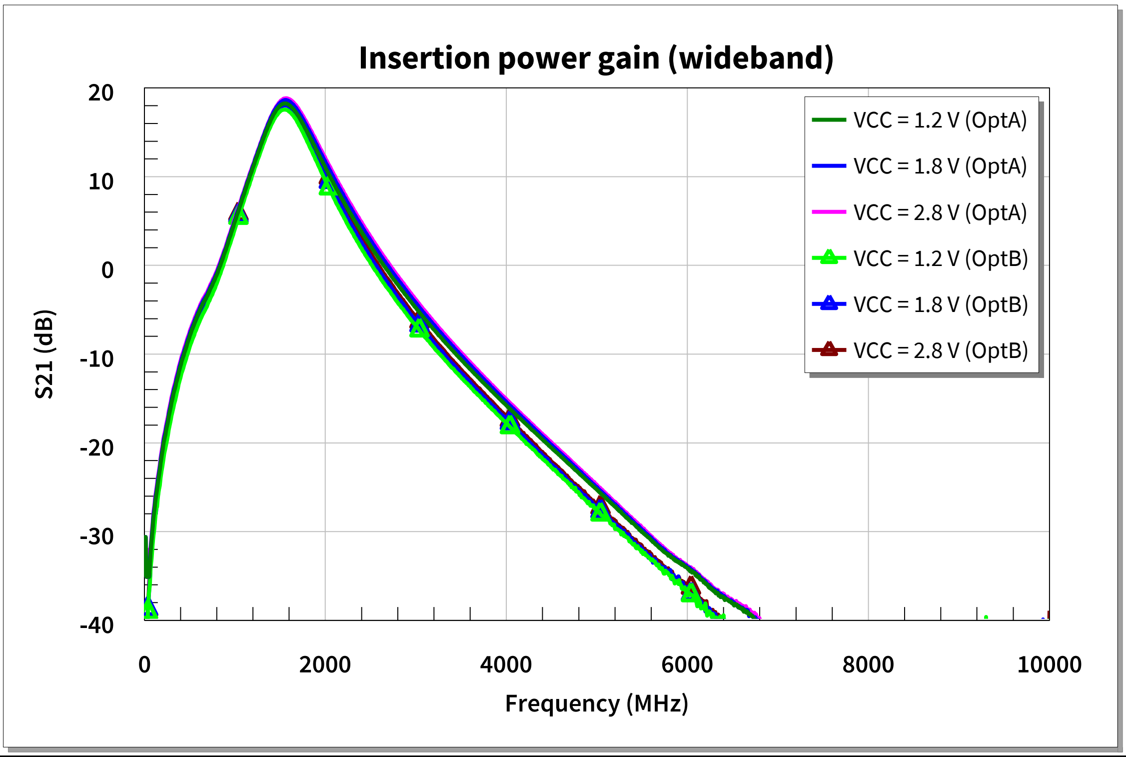

Figure 7 Insertion power gain (wideband)

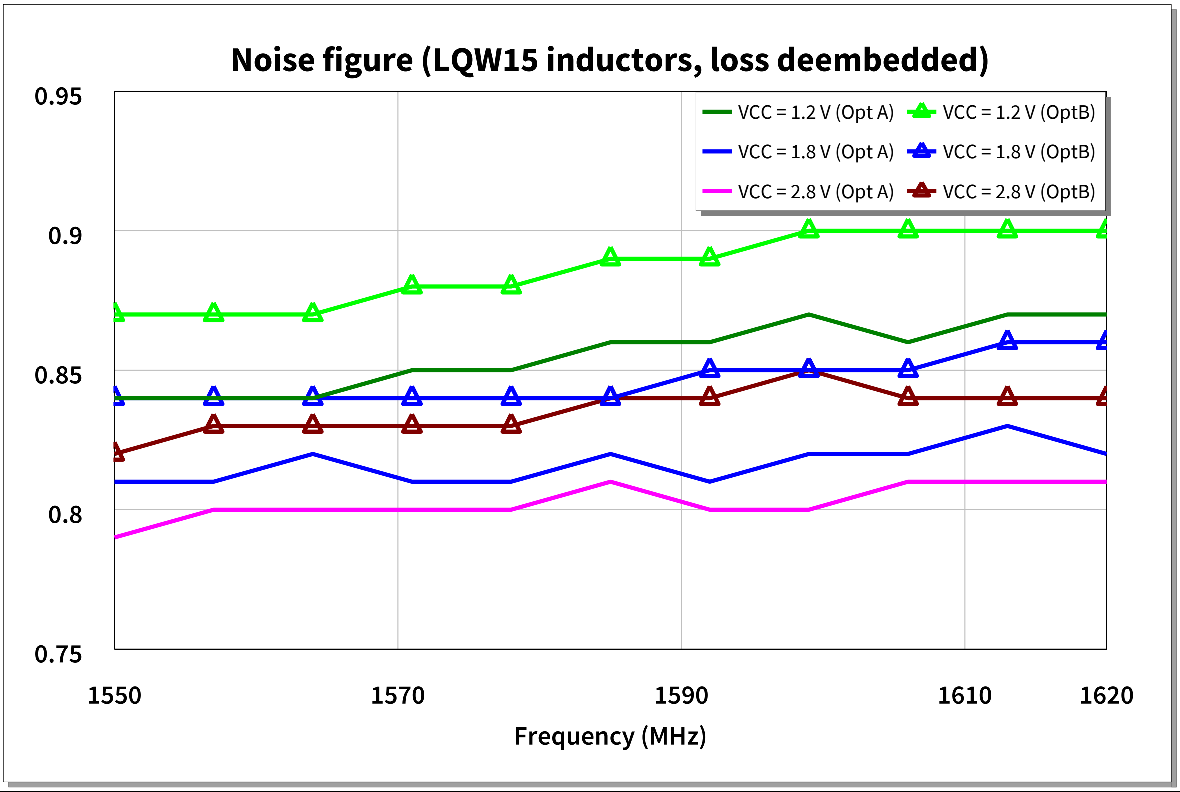

Figure 8 **Noise figure (SMA and connector losses de-embedded, LQW15 inductors for matching)**

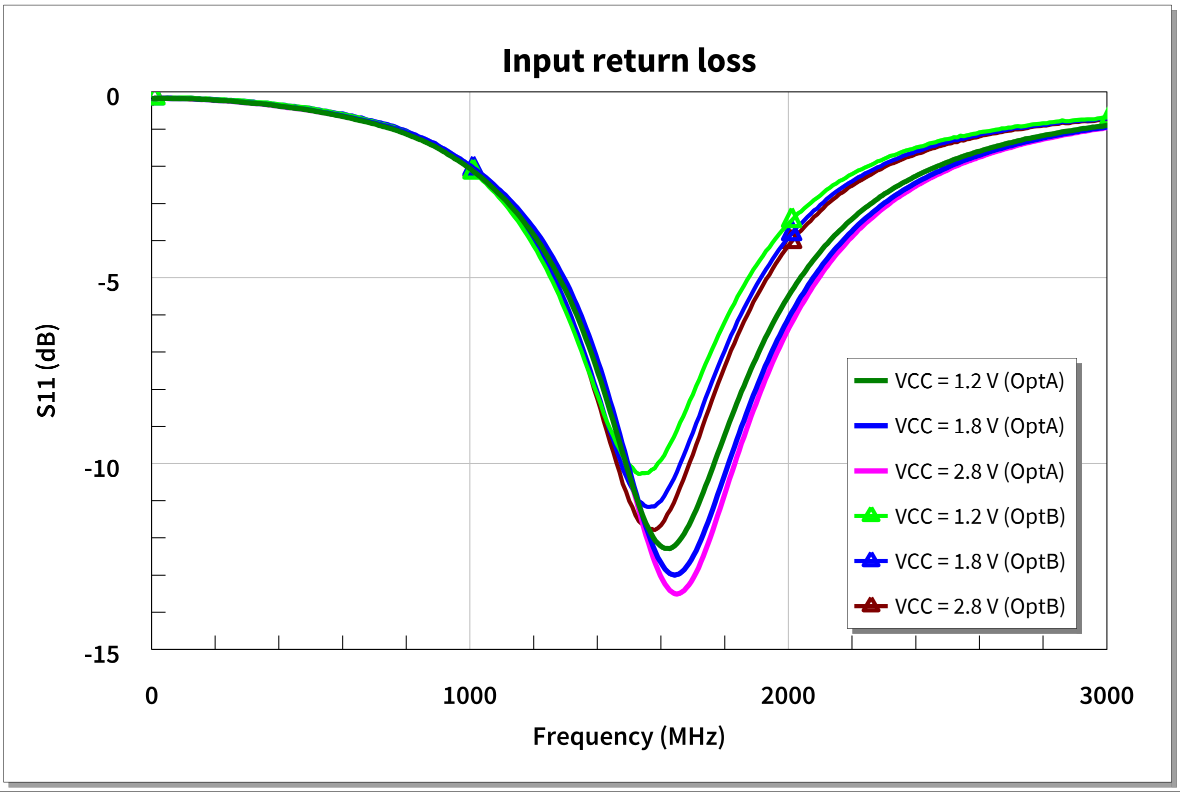

Figure 9 **Input return loss**

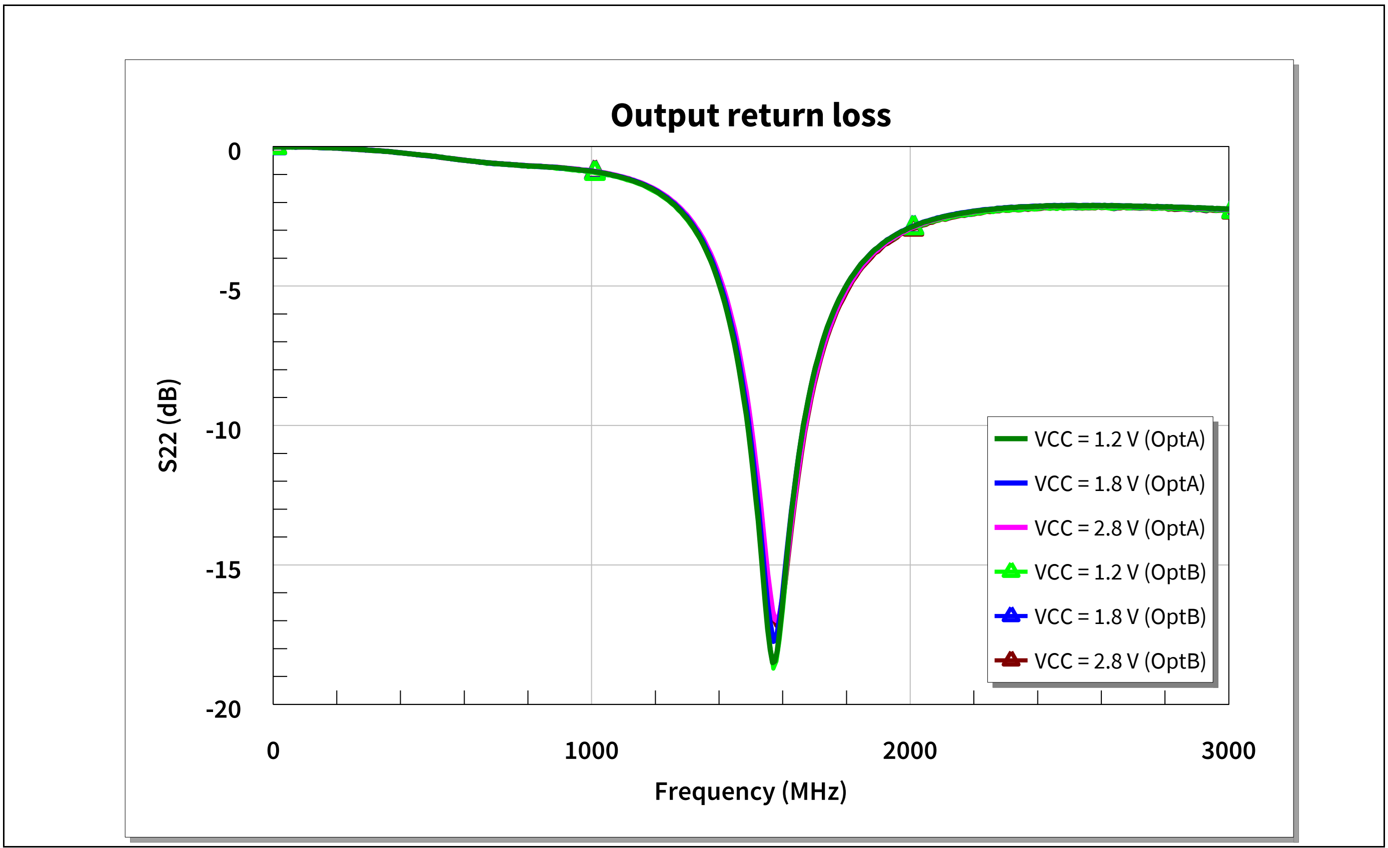

Figure 10 Output return loss

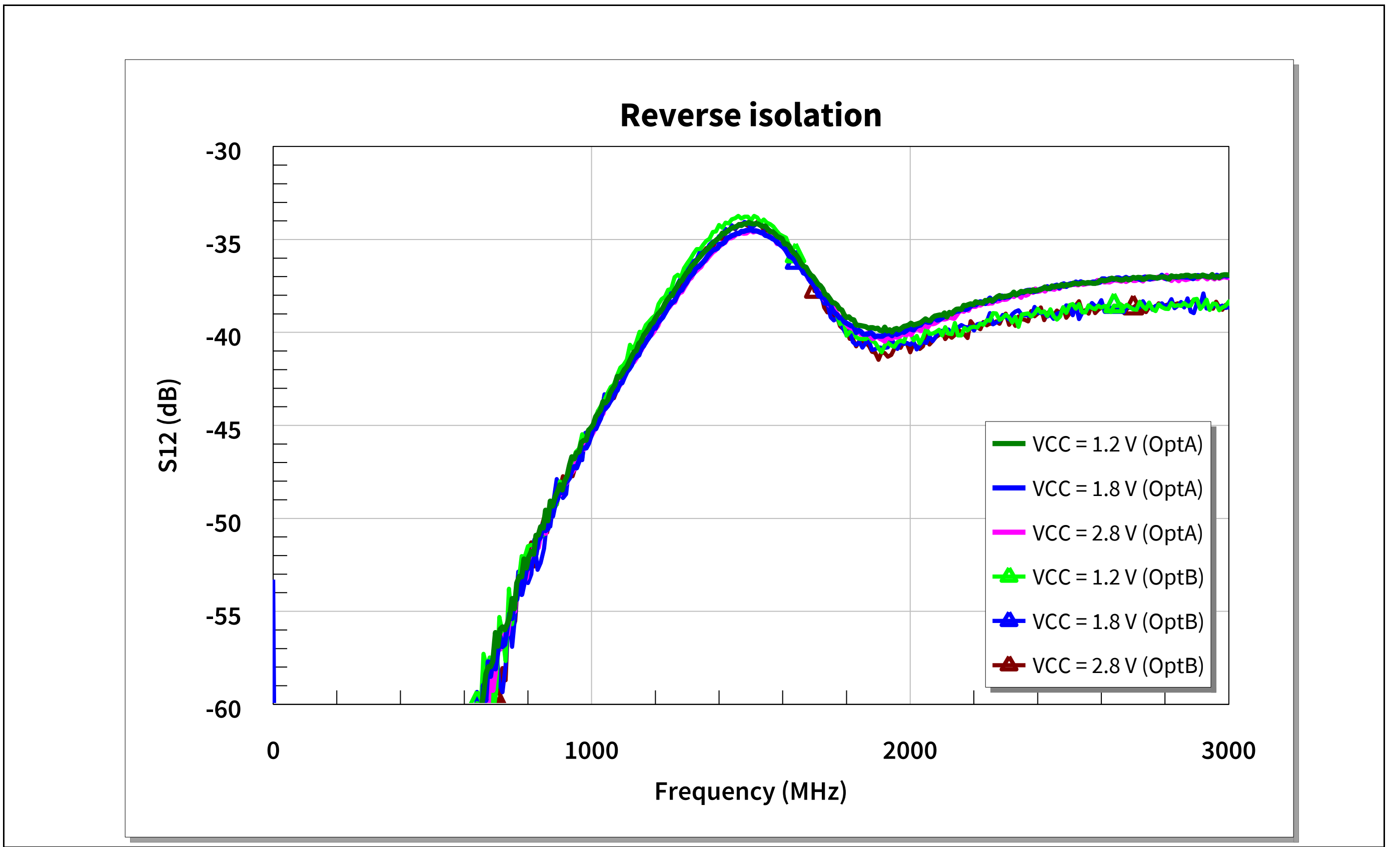

Figure 11 Reverse isolation

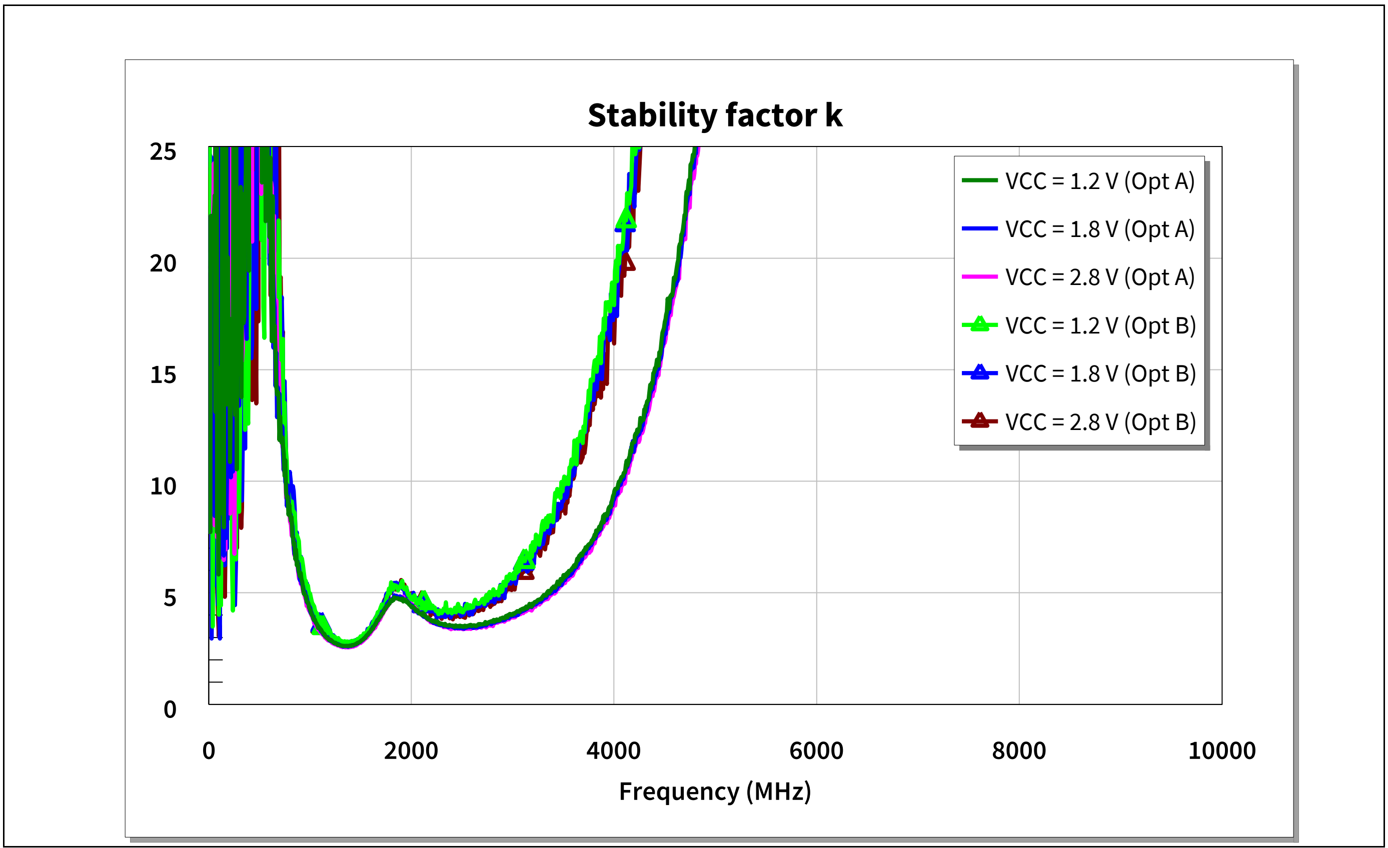

Figure 12 Stability k-factor

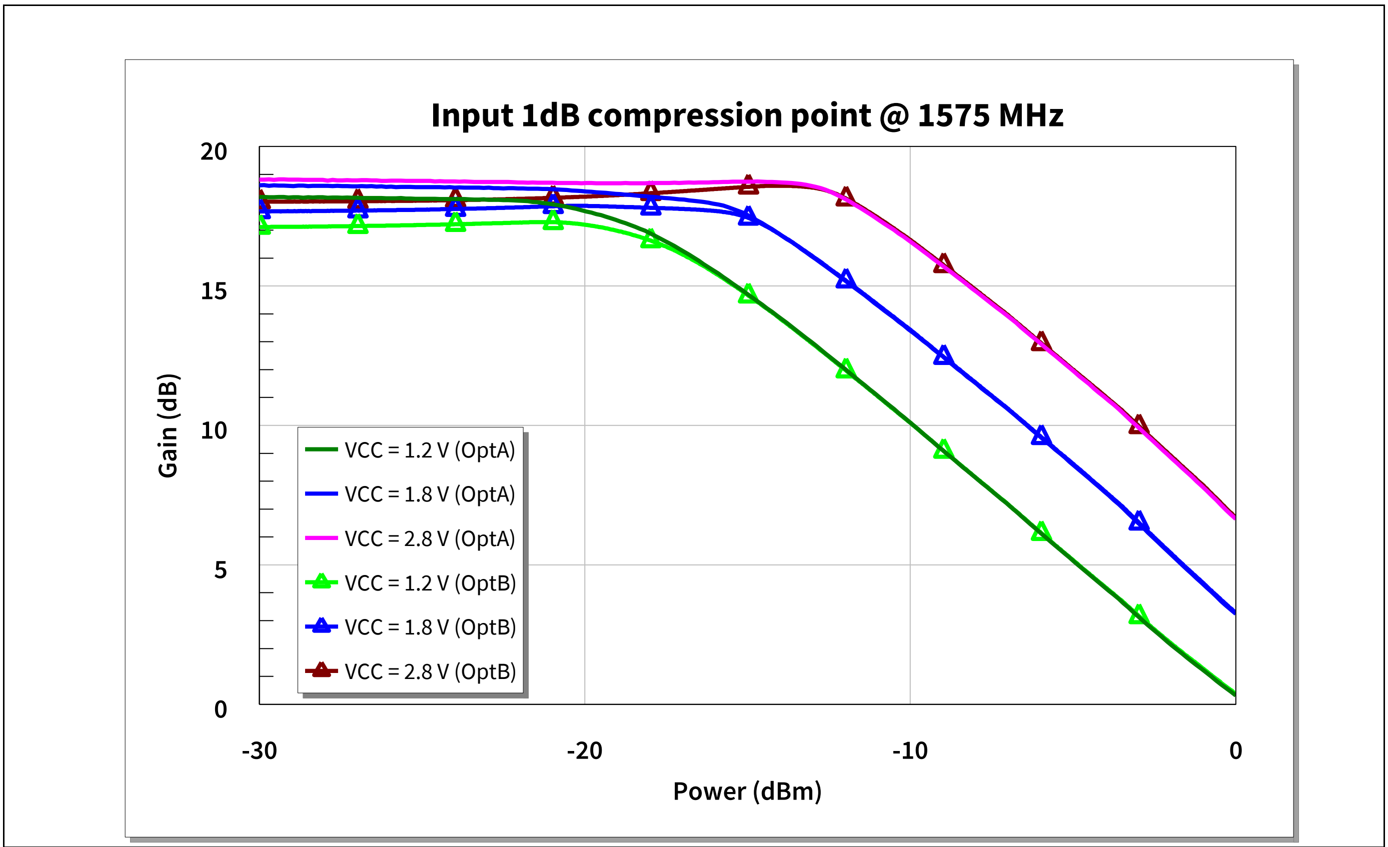

Figure 13 Input 1 dB compression point @ 1575 MHz

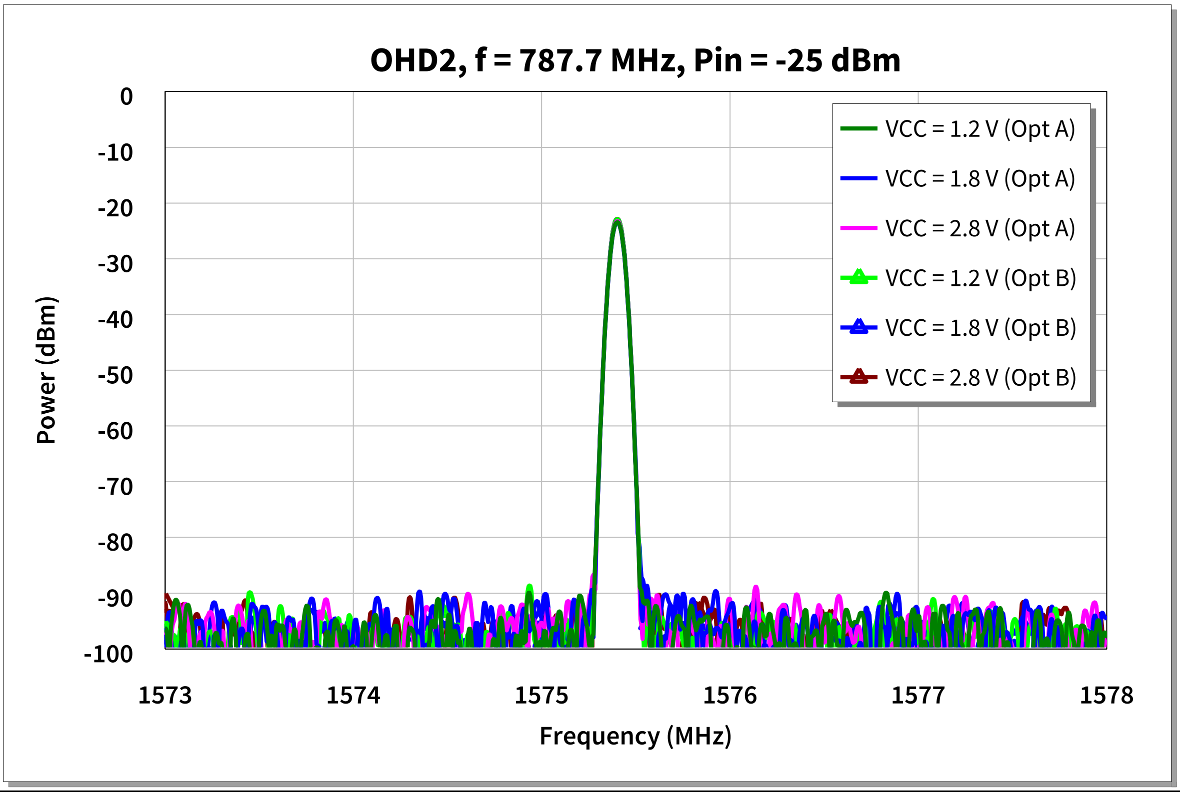

Figure 14 LTE band 13 second harmonic output referred

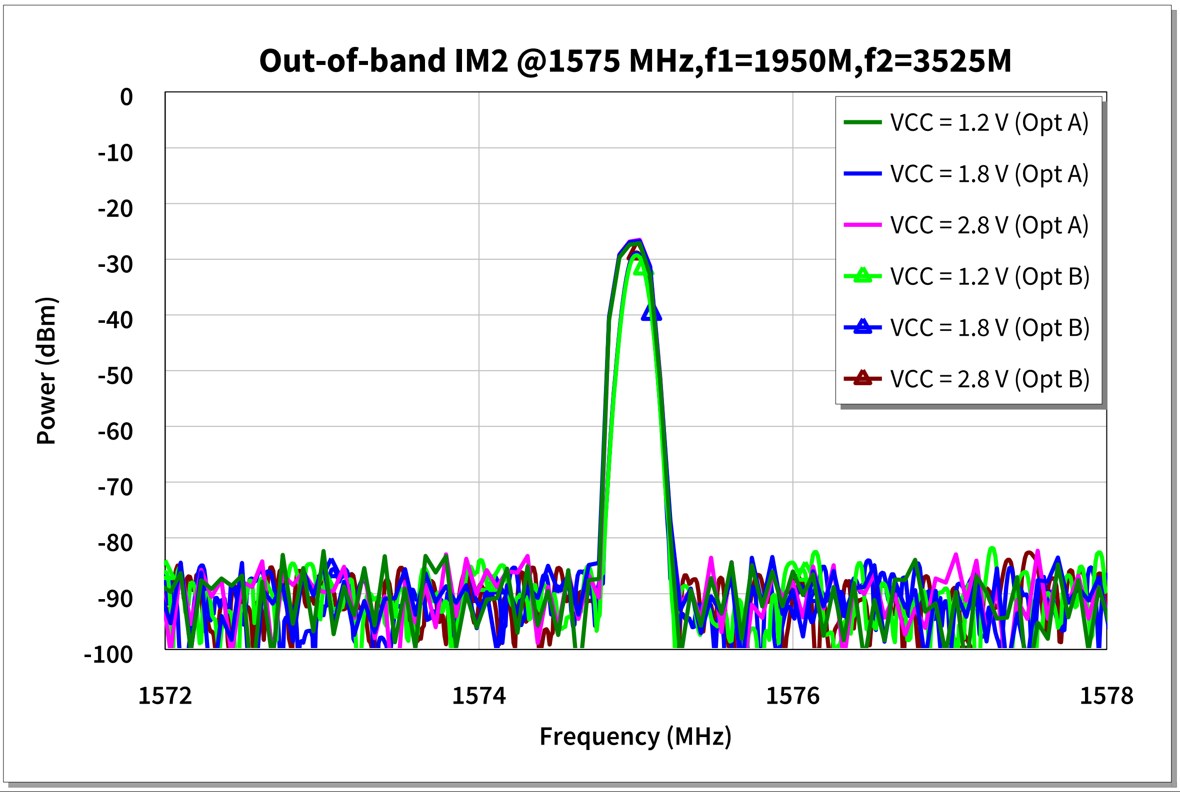

Figure 15 OoB second-order intermodulation point (f1 = 1950 MHz, f2 = 3525 MHz, output referred)

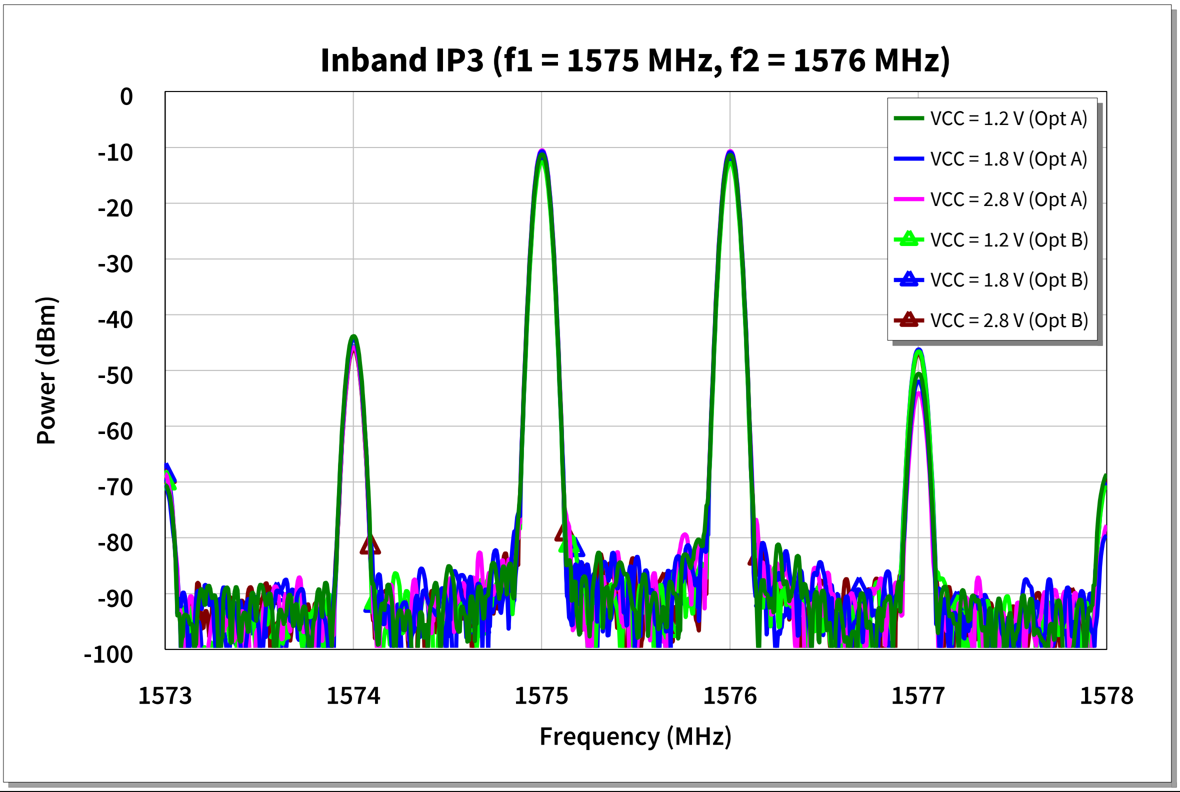

Figure 16 Inband third-order intermodulation point (f1 = 1575 MHz, f2 = 1576 MHz, output referred)

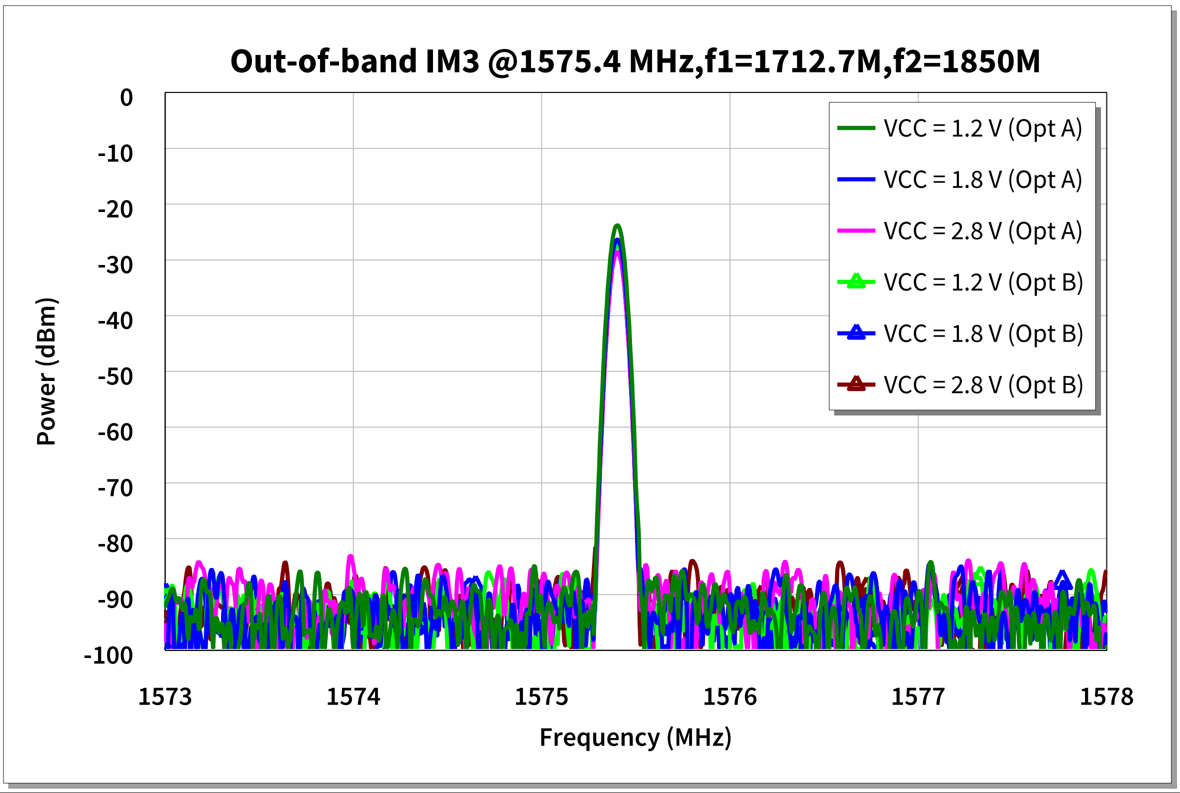

Figure 17 OoB third-order intermodulation point (f1 = 1712.7 MHz, f2 = 1850 MHz, L1 band, output referred)

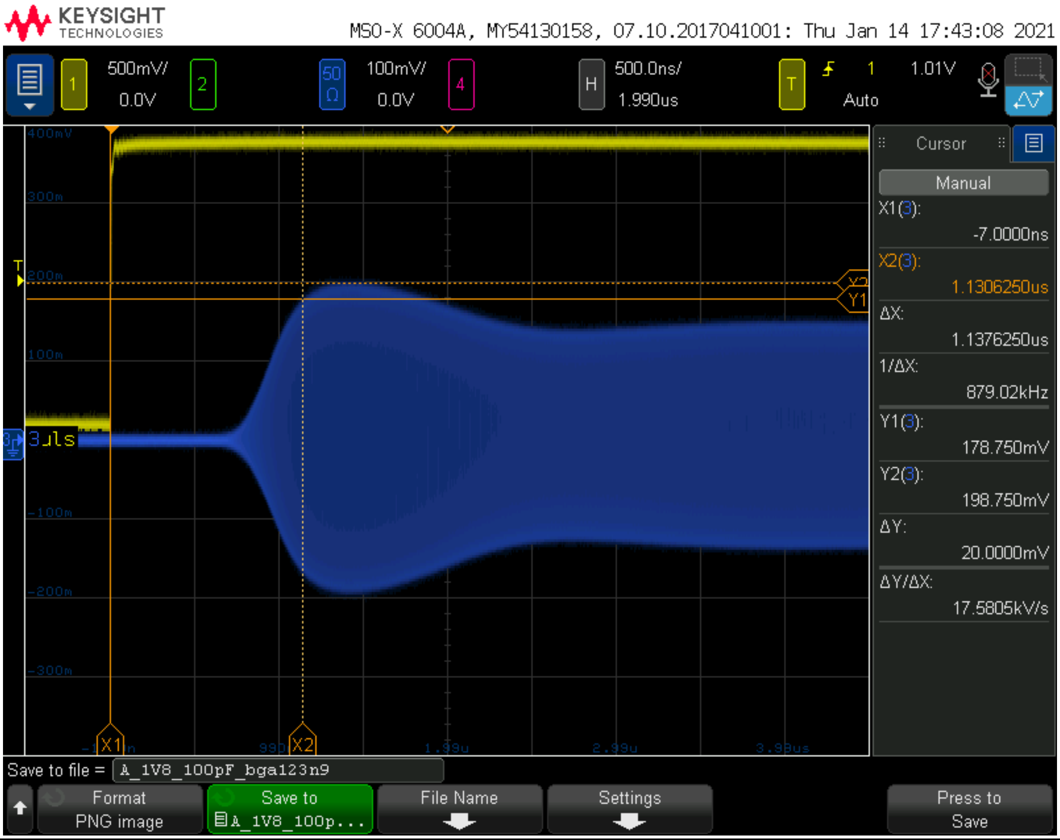

Figure 18 Switching time OFF-to-ON t_{OFF-ON} (Option A, C1 = 100 pF, V_{CC} = 1.8 V)

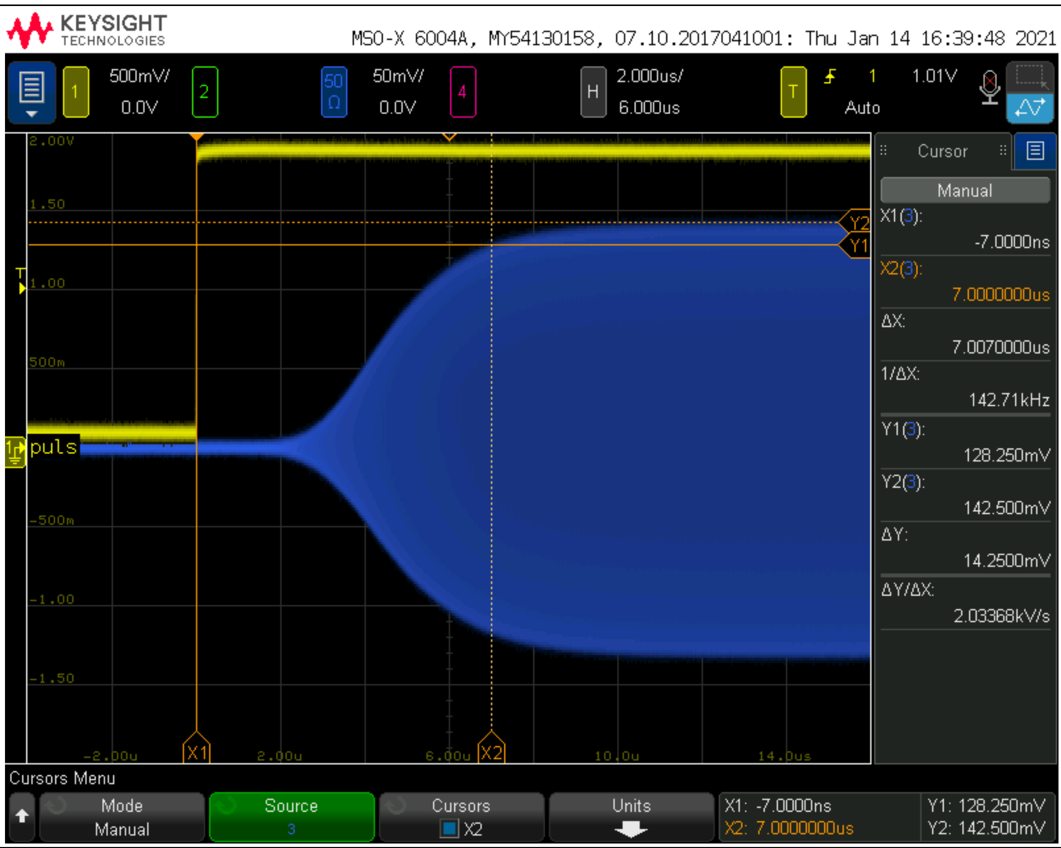

Figure 19 Switching time OFF-to-ON t_{OFF-ON} (Option A, C1 = 1 nF, V_{CC} = 1.8 V)

Figure 20 Switching time OFF-to-ON $t_{OFF\text{-}ON}$ (Option B, C1 = 100 pF, V_{CC} = 1.8 V)

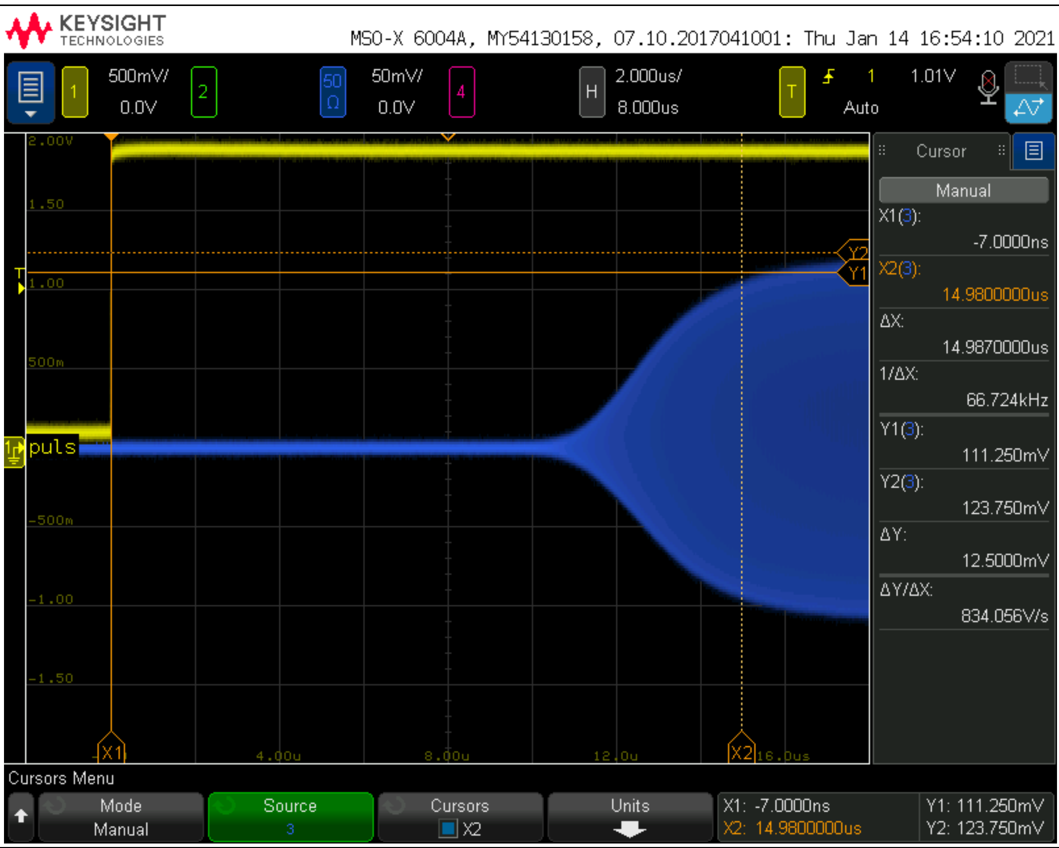

Figure 21 Switching time OFF-to-ON $t_{OFF\text{-}ON}$ (Option B, C1 = 1 nF, V_{CC} = 1.8 V)

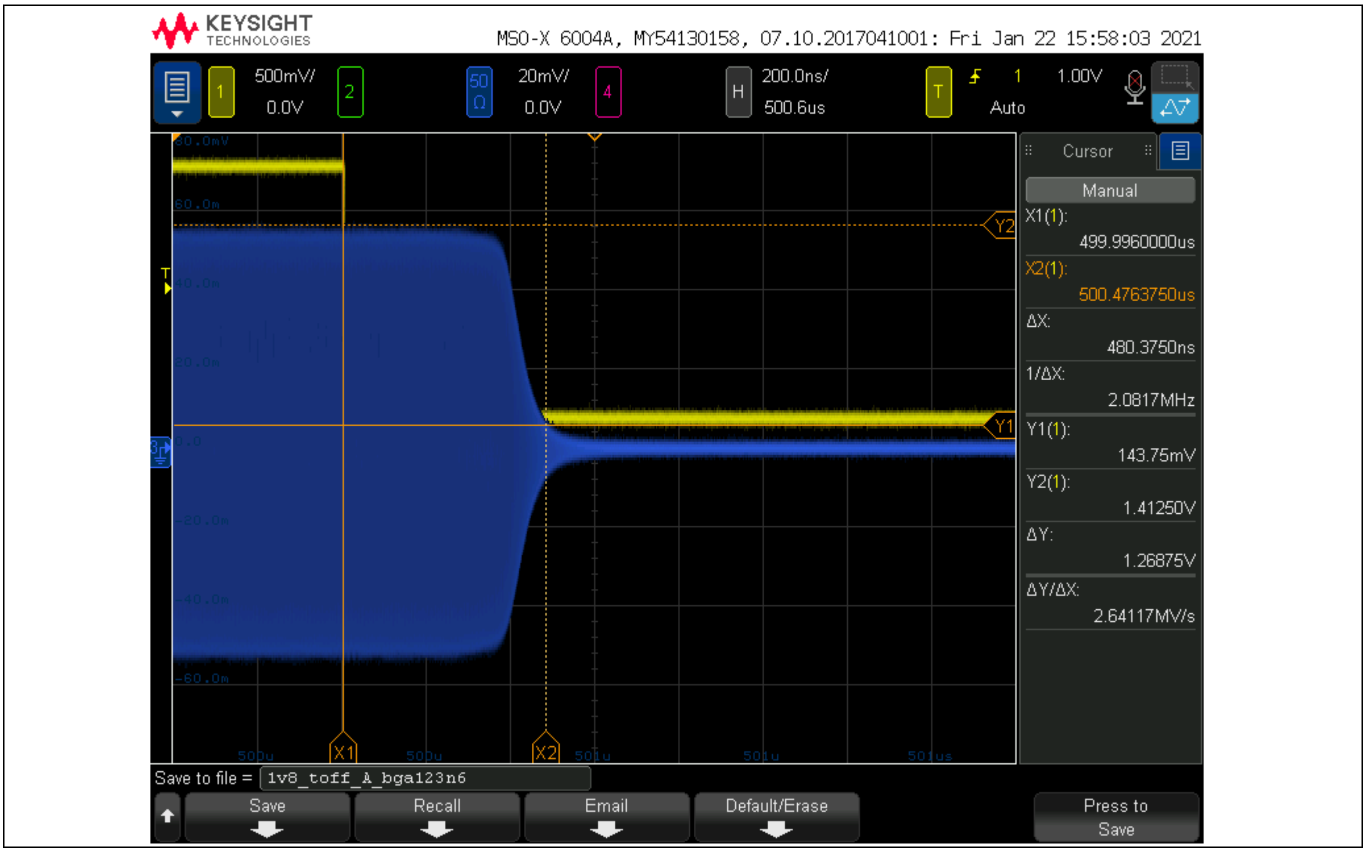

Figure 22 Switching time ON-to-OFF $t_{ON\text{-}OFF}$ (Option A)

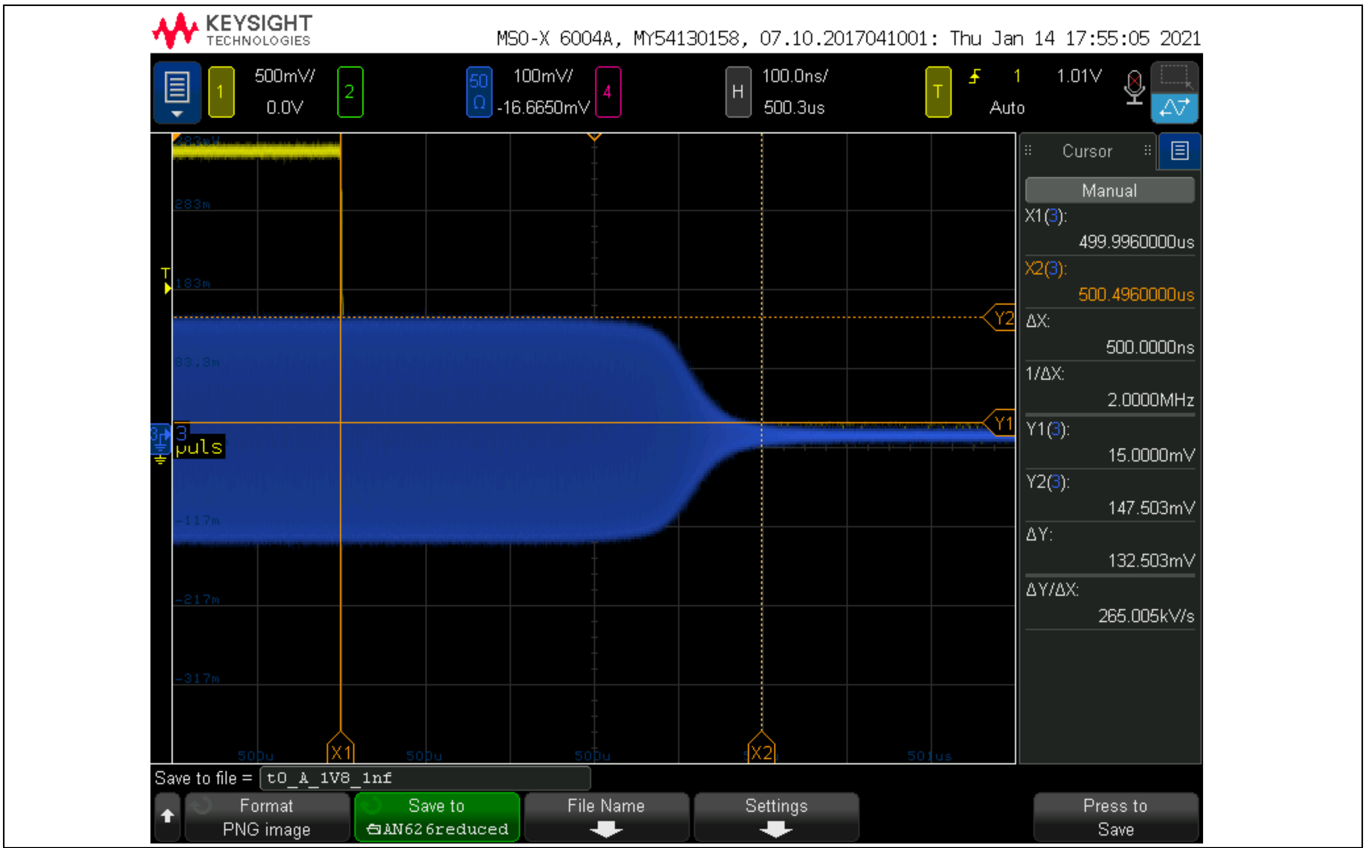

Figure 23 Switching time ON-to-OFF $t_{ON\text{-}OFF}$ (Option B)

4 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: **080920**

PCB material: **Megtron 6**

ε_r of PCB material: **3.7**

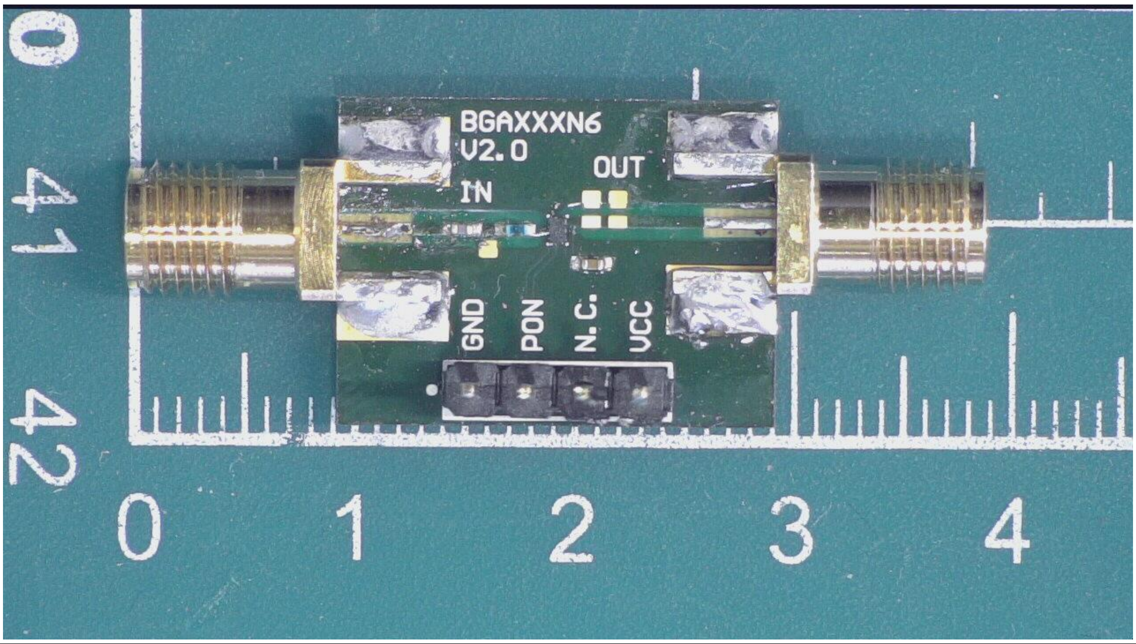

Figure 24 Evaluation board Option A (overview)

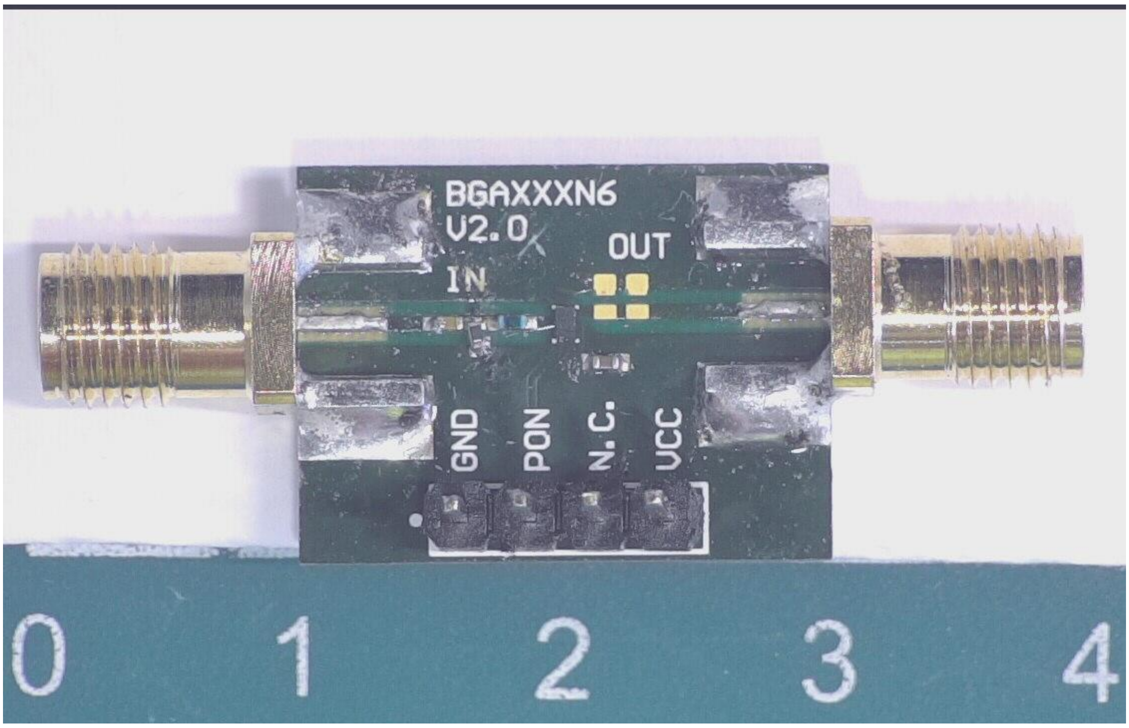

Figure 25 Evaluation board Option B (overview)

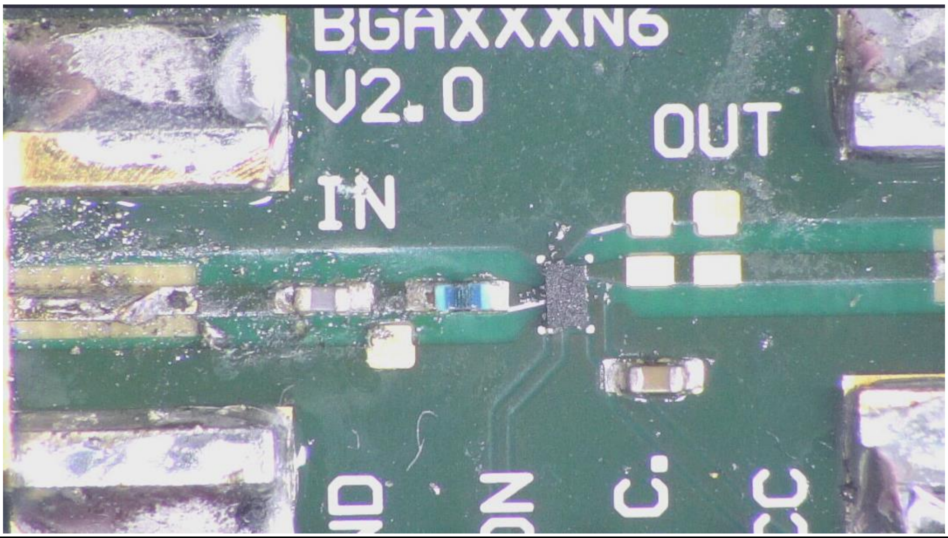

Figure 26 Evaluation board Option A (detailed view)

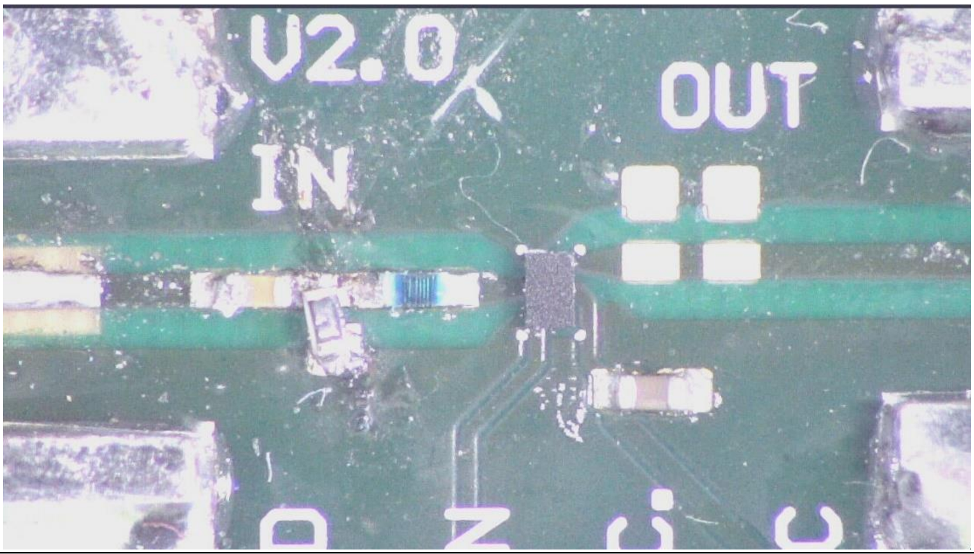

Figure 27 Evaluation board Option B (detailed view)

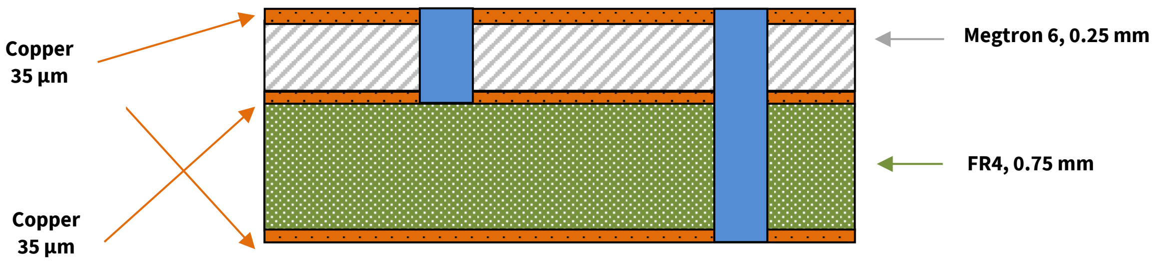

Figure 28 PCB layer information

5 Authors

Xiang Li, Staff Application Engineer of Business Unit "Radio Frequency and Sensors"

Ardit Shulemaja, Working Student of Business Unit "Radio Frequency and Sensors"

Revision history

Major changes since the last revision

Page or reference	Description of change

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