BGA123N6 as low-current LNA for GNSS applications from 1164 to 1214 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 1164 to 1214 MHz.

The BGA123N6 is an ultra-low-current silicon germanium (SiGe) LNA supporting 1550 to 1610 MHz.

1. The target application of this circuit is to retune the BGA123N6 to GPS L5/Galileo E5/GLONASS L3/BeiDou B2/IRNSS L5 bands in the range of 1164 to 1214 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. Change in noise figure (NF) values, when matched with 0201 size high Q-factor LQP03T inductors, is also presented.

3. Key performance parameters at 1.8 V, 1176 MHz, LQW15 inductors for matching:
   Insertion gain = 17.0 dB
   NF = 0.85 dB
   Input return loss = 11 dB
   Output return loss = 13 dB
   Out-of-band (OoB) IP3 = 3 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 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 1560 to 1610 MHz has been the main band for global navigation services; however, the lower L band in the range of 1160 to 1300 MHz facilitates the navigation signal for safety-of-life purposes. The figure below includes an overview of the GNSS frequency allocation.

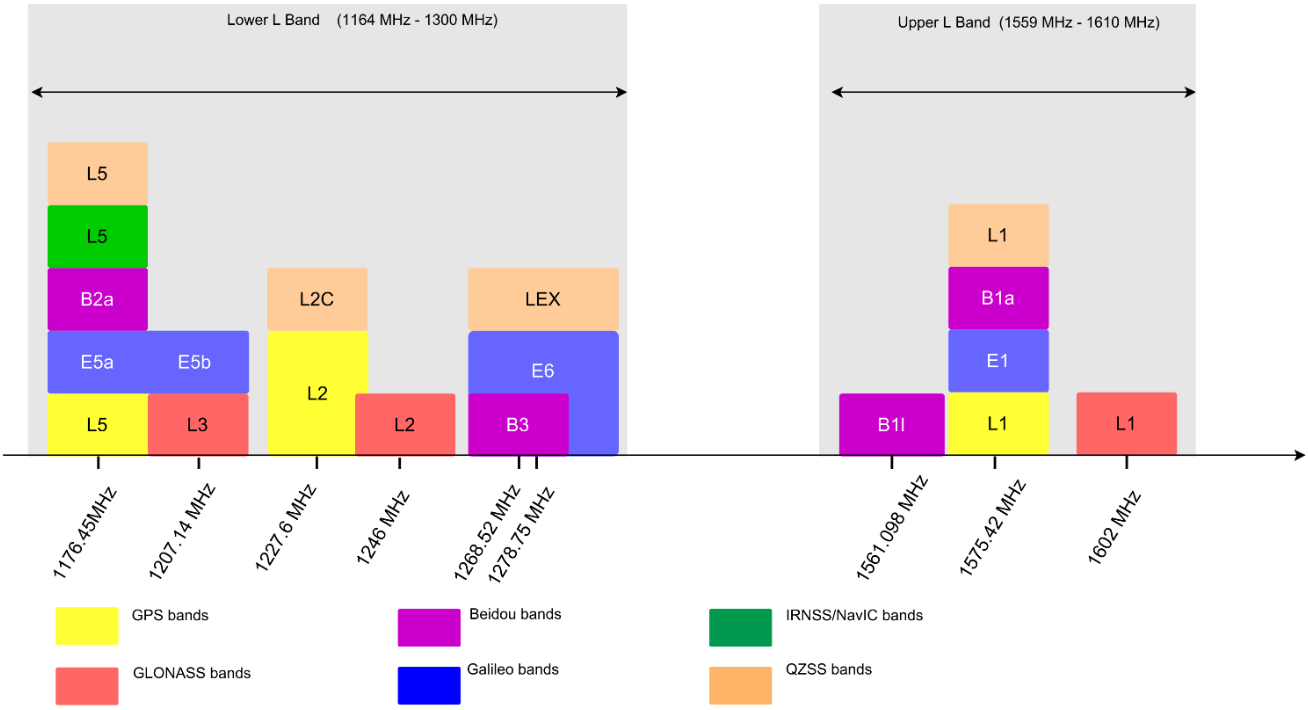

Figure 1 Frequency allocation for GNSS systems, upper L band and lower L band

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 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 FE designers to maintain the receiver’s sensitivity to weak incoming GNSS signals.

1.2.2 Out-of-band 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 FE, 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

- Operating frequencies: 1550 to 1615 MHz
- Ultra-low current consumption: 1.3 mA
- Wide supply voltage range: 1.1 to 3.3 V
- High insertion power gain: 19.0 dB
- Low NF: 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

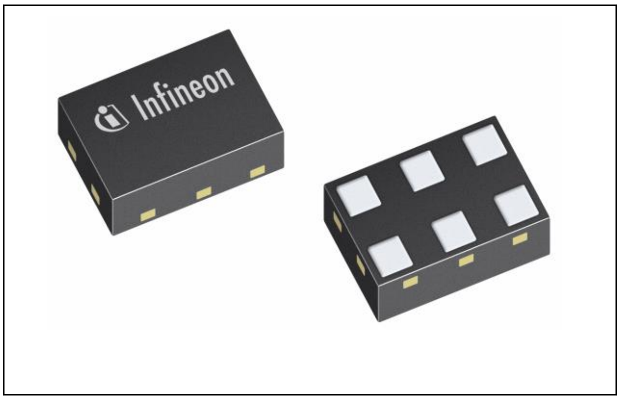

Figure 2 BGA123N6 in TSNP-6-2

RoHS Halogen-Free Lead-Free Green

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 (BOM) are presented.

Device:	BGA123N6
Application:	Low-current LNA retuned for GNSS applications from 1164 to 1214 MHz
PCB marking:	080920
EVB order no.:	EVAL BGA123N6 (AN629)

2.1 Summary of measurement results

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

Table 2 Electrical characteristics at T_A = 25°C

<table>
<tr><th>Parameter</th><th>Symbol</th><th colspan="3">Value</th><th>Unit</th><th>Comment/test condition</th></tr>
<tr><td>Frequency</td><td>Freq</td><td colspan="3">1164 - 1214</td><td>MHz</td><td>Measured at 1176 MHz</td></tr>
<tr><td>DC voltage</td><td>V_{CC}</td><td>1.2</td><td>1.8</td><td>2.8</td><td>V</td><td></td></tr>
<tr><td>DC current</td><td>I_{CC}</td><td>1.25</td><td>1.35</td><td>1.4</td><td>mA</td><td></td></tr>
<tr><td>Gain</td><td>G</td><td>16.7</td><td>17.0</td><td>17.1</td><td>dB</td><td></td></tr>
<tr><td>Noise figure</td><td>NF</td><td>0.85</td><td>0.85</td><td>0.85</td><td>dB</td><td>LQW15 inductor for matching, loss of input line of 0.04 dB is de-embedded</td></tr>
<tr><td>Noise figure</td><td>NF</td><td>1.05</td><td>1.05</td><td>1.05</td><td>dB</td><td>LQP03T inductor (15 nH) for matching, loss of input line of 0.04 dB is de-embedded</td></tr>
<tr><td>Input return loss</td><td>RL_{IN}</td><td>12</td><td>11</td><td>11</td><td>dB</td><td></td></tr>
<tr><td>Output return loss</td><td>RL_{OUT}</td><td>13</td><td>13</td><td>13</td><td>dB</td><td></td></tr>
<tr><td>Reverse isolation</td><td>I_{REV}</td><td>35</td><td>35</td><td>35</td><td>dB</td><td></td></tr>
<tr><td>Input P1dB</td><td>IP1dB</td><td>-16</td><td>-14</td><td>-14</td><td>dBm</td><td>Measured at 1575 MHz</td></tr>
<tr><td>OoB IP2</td><td>Oob_IIP2</td><td>24</td><td>23</td><td>23</td><td>dBm</td><td rowspan="2">Power at input: -20 dBm
f1 = 2550 MHz, f2 = 3726 MHz
Measured at 1176 MHz</td></tr>
<tr><td>OoB output IM2</td><td>Oob_OIM2</td><td>-48</td><td>-47</td><td>-47</td><td>dBm</td></tr>
<tr><td>Input IP3</td><td>IIP3</td><td>-15</td><td>-14</td><td>-14</td><td>dBm</td><td>Power at input: -30 dBm
f1 = 1176 MHz, f2 = 1177 MHz</td></tr>
<tr><td>OoB input IP3</td><td>Oob_IIP3</td><td>3</td><td>3</td><td>3</td><td>dBm</td><td rowspan="2">Power at input: -20 dBm
f1 = 1785 MHz, f2 = 2401 MHz, measured at 1169 MHz</td></tr>
<tr><td>OoB output IM3</td><td>Oob_OIM3</td><td>-48</td><td>-48</td><td>-48</td><td>dBm</td></tr>
<tr><td>Stability</td><td>k</td><td colspan="3">> 1</td><td>–</td><td>Measured up to 10 GHz</td></tr>
</table>

Table 2 Electrical characteristics at T_A = 25°C

Parameter	Symbol	Value			Unit	Comment/test condition
Switching time off to on	t_S	9[a)]/2[b)]	7[a)]/1[b)]	7[a)]/1[b)]	µs	Power-up settling time: LNA gain changed to 90 percent of final gain value a) C1 = 1 nF b) C1 = 100 pF
Switching time on to off	t_{OFF}	0.5/0.5	0.5/0.5	0.5/0.5	µs	LNA gain dropped to 10 percent of final gain value C1 = 1 nF/100 pF

2.2 Schematic and bill of materials

The schematic is presented in Figure 3 and its BOM is shown in Table 3.

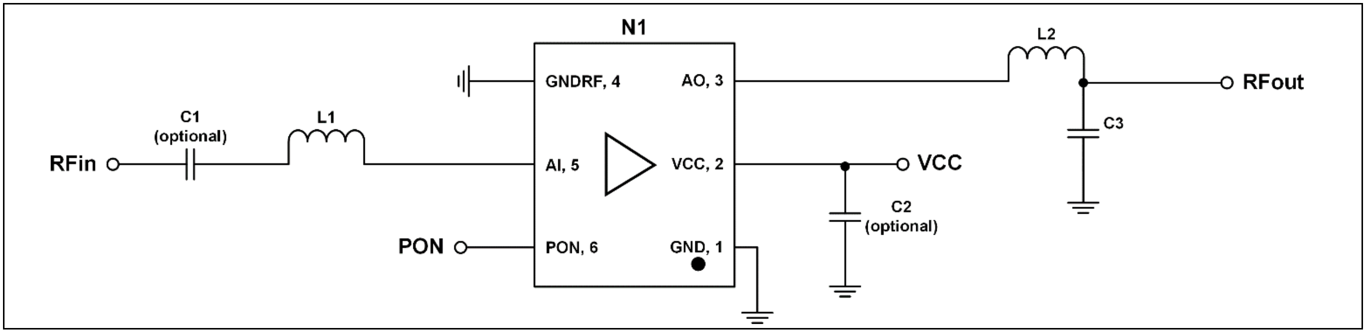

Figure 3 Schematic of the BGA123N6 application circuit

Table 3 BOM

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1000/100	pF	0402	Various	DC block[1)]
C2	>= 1	nF	0402	Various	RF bypass[2)]
C3	4.3	pF	0402	Various	Output matching
L1	16	nH	0402	Murata LQW15	Input matching
L2	8.2	nH	0402	Murata LQW15	Output matching
N1	BGA123N6		TSNP-6-2	Infineon Technologies	SiGe LNA

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

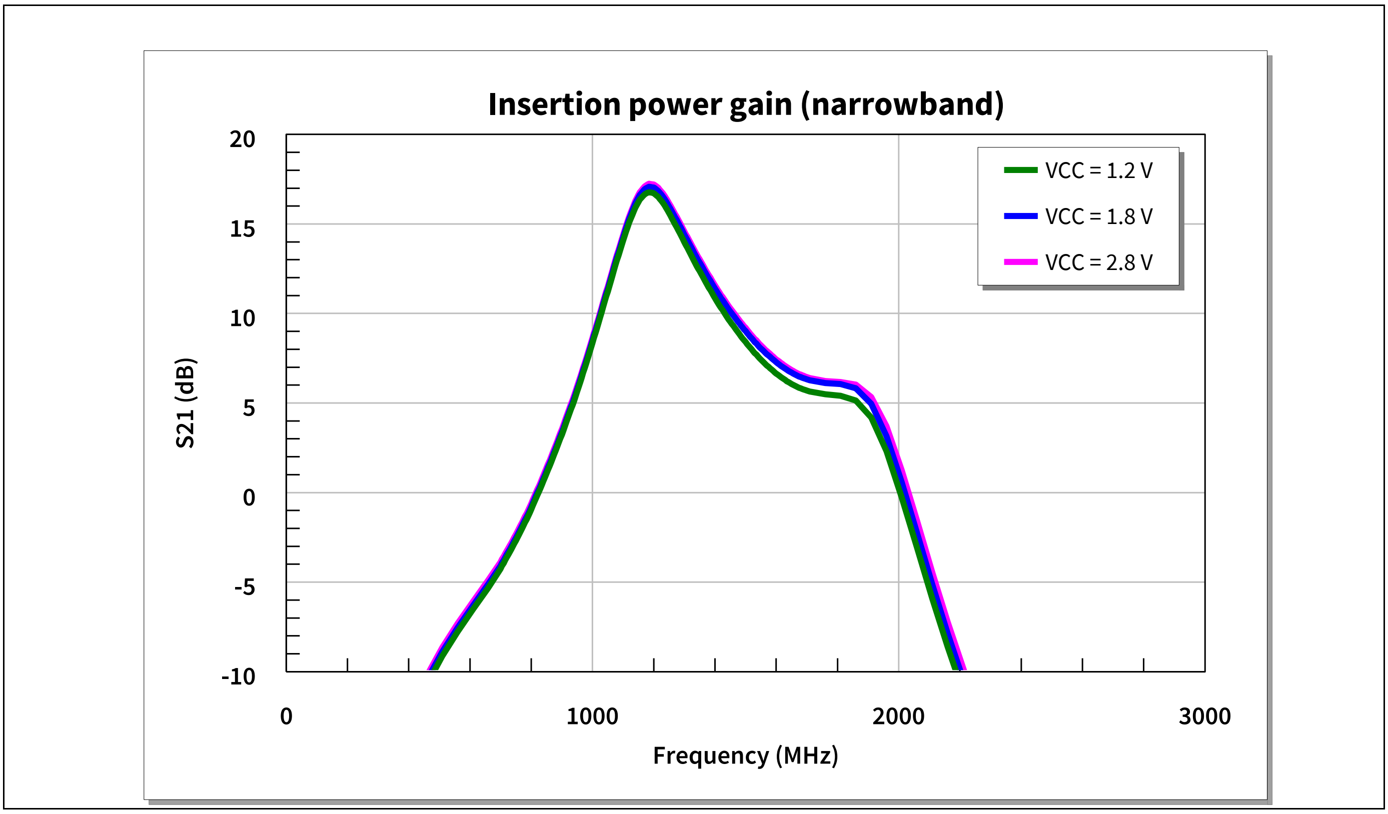

Figure 4 Insertion power gain (narrowband)

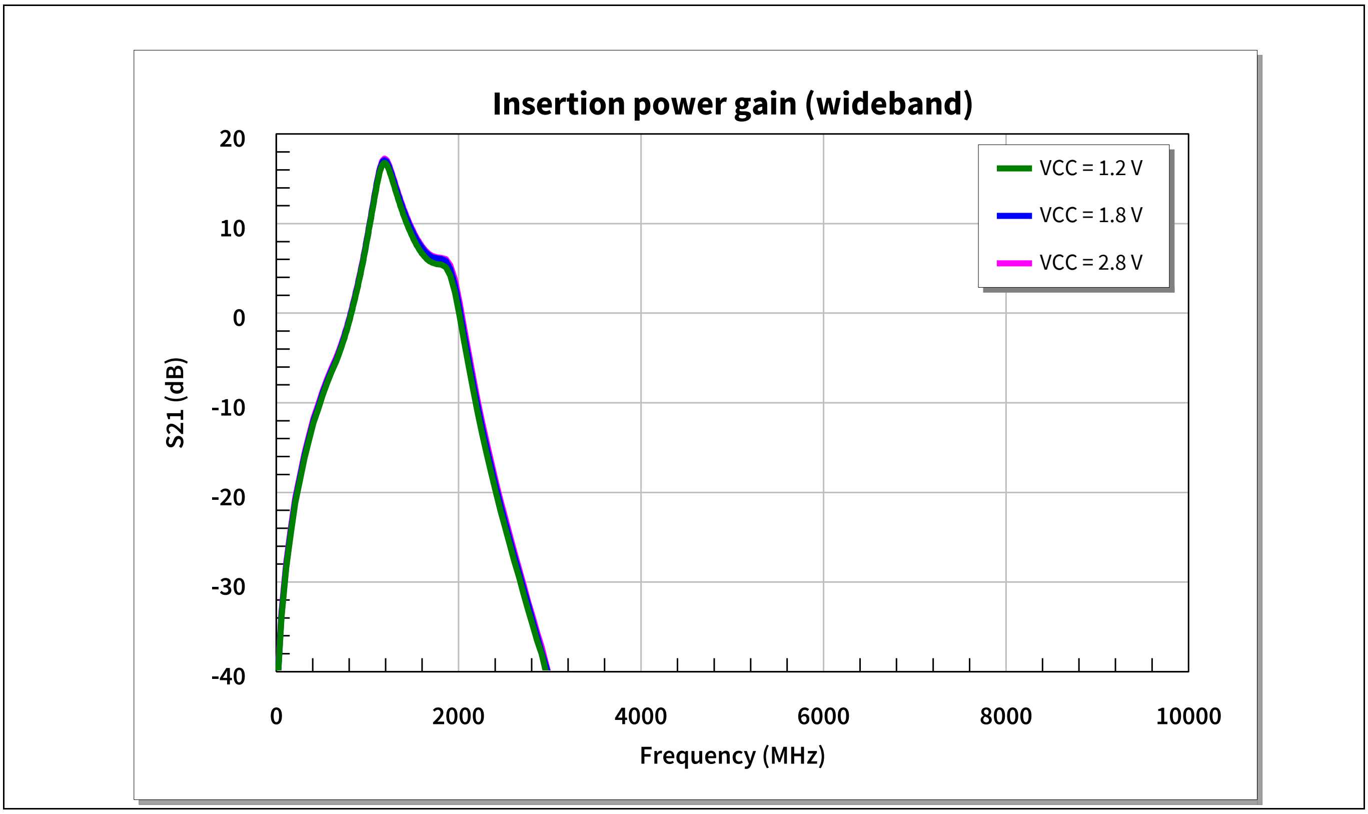

Figure 5 Insertion power gain (wideband)

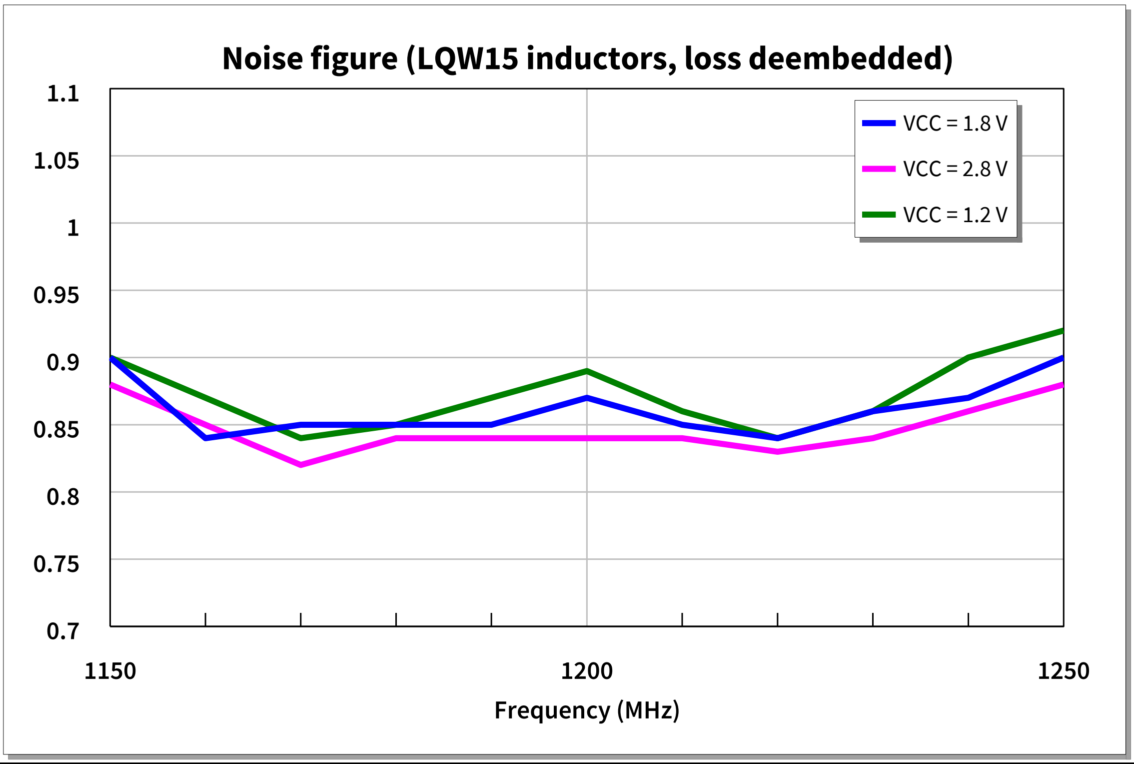

Figure 6 NF (SMA and connector losses de-embedded, LQW15 inductors for matching)

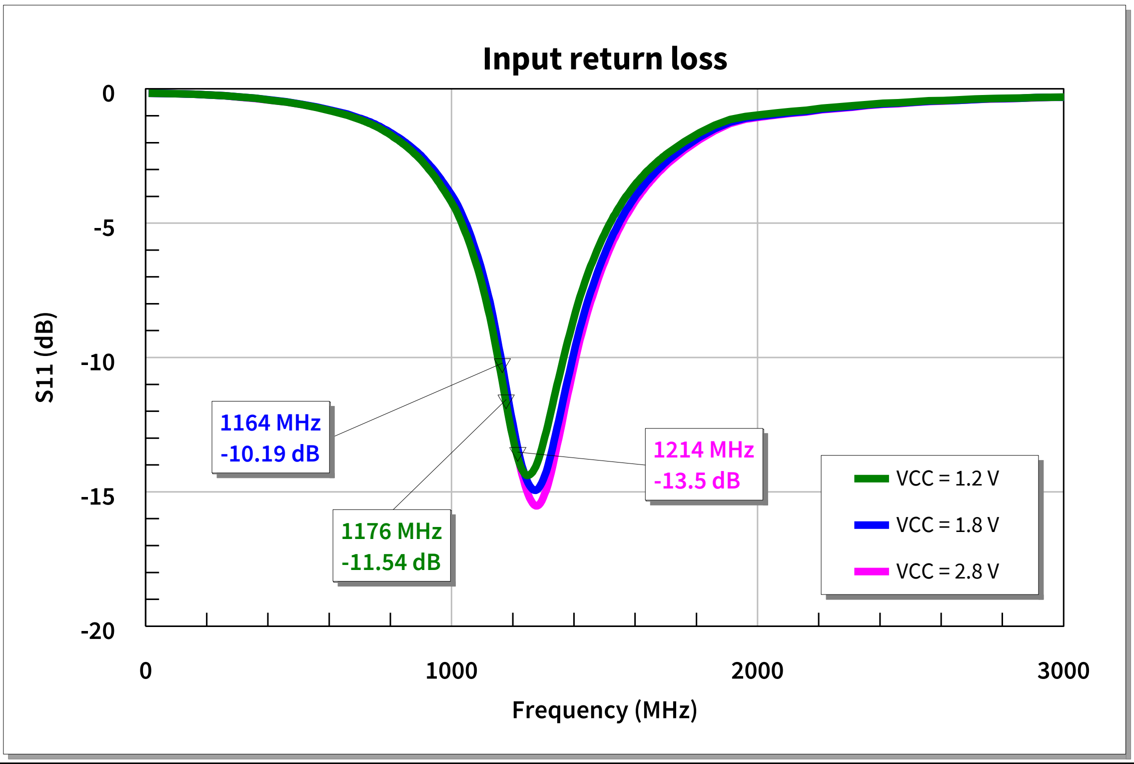

Figure 7 Input return loss

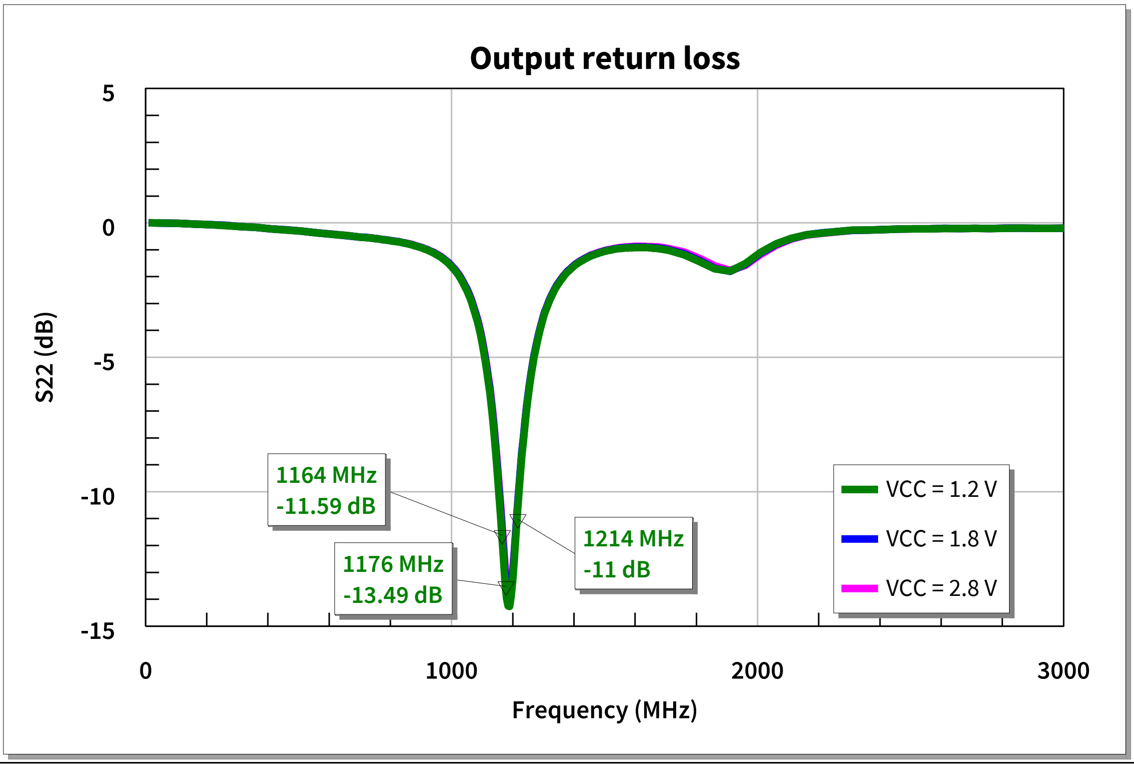

Figure 8 Output return loss

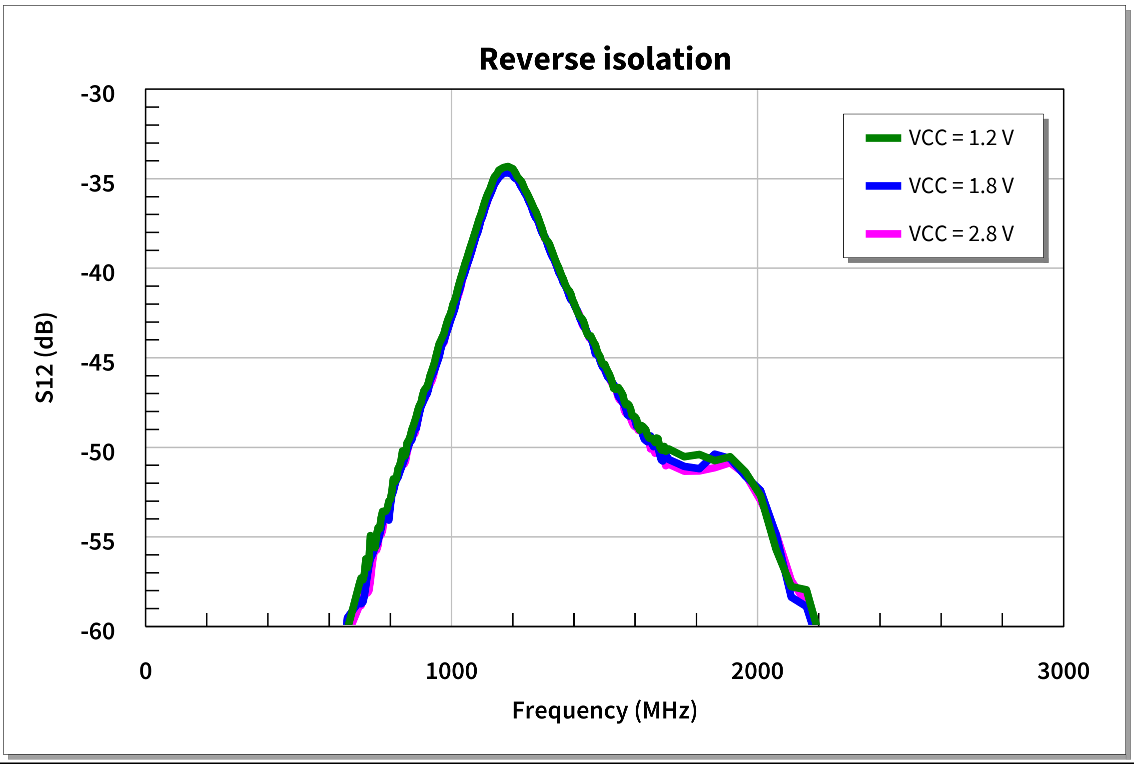

Figure 9 Reverse isolation

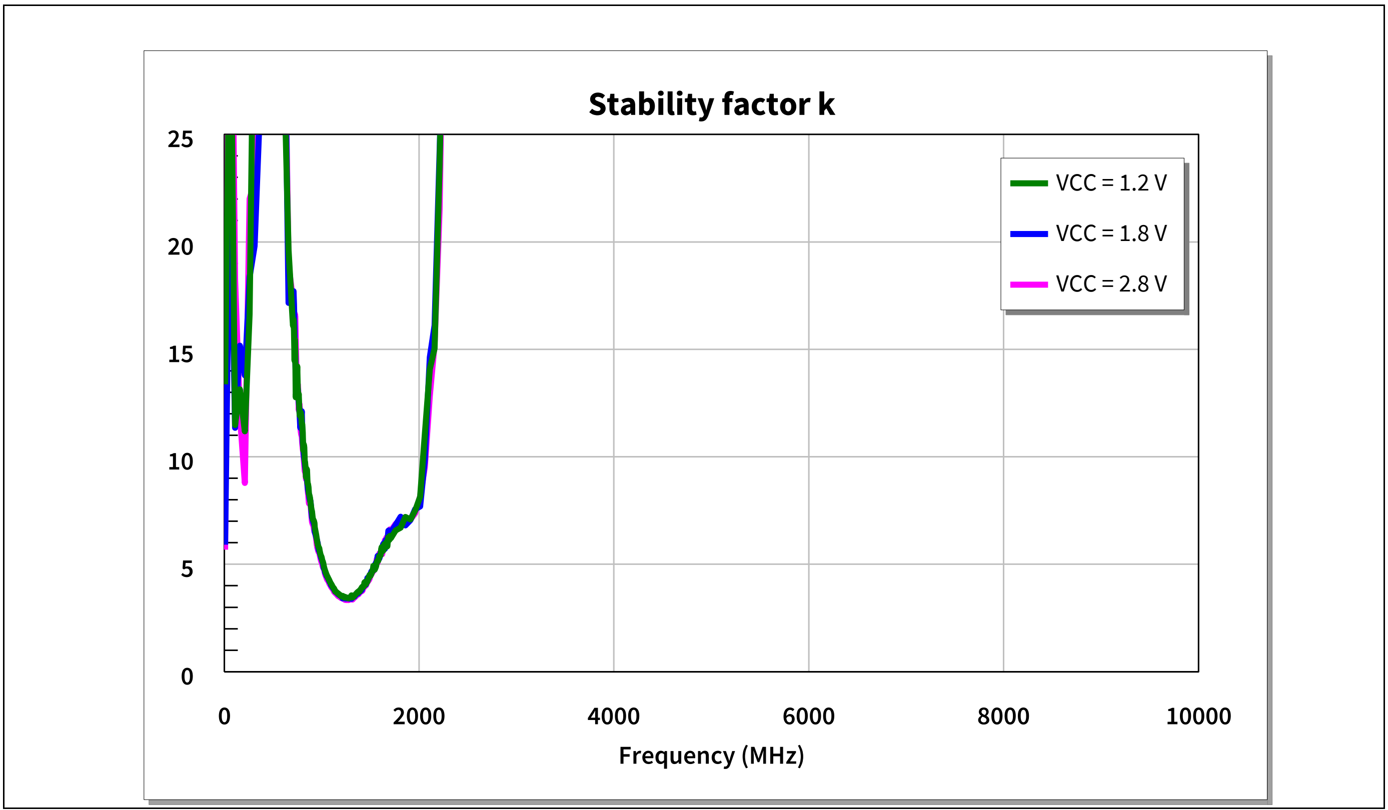

Figure 10 Stability k-factor

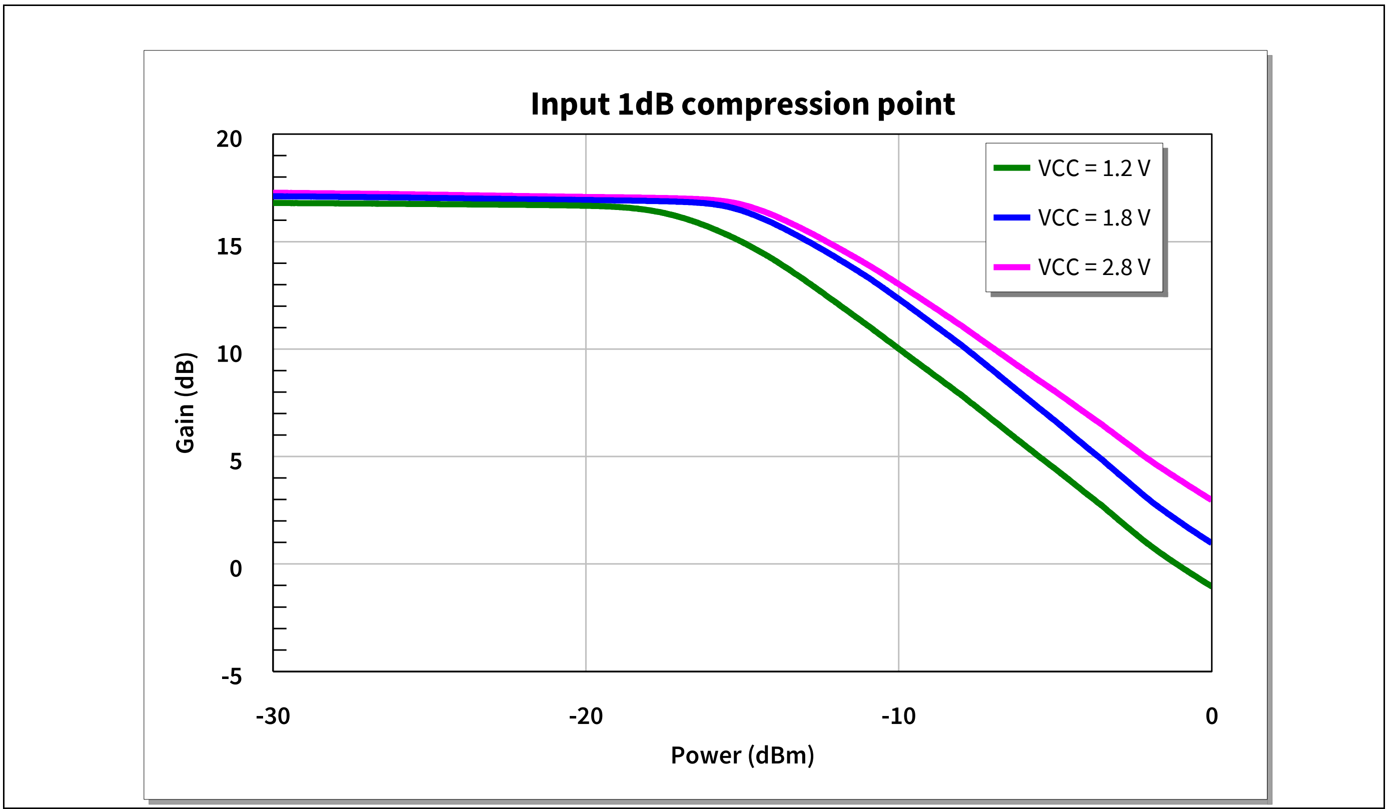

Figure 11 Input 1 dB compression point (1176 MHz)

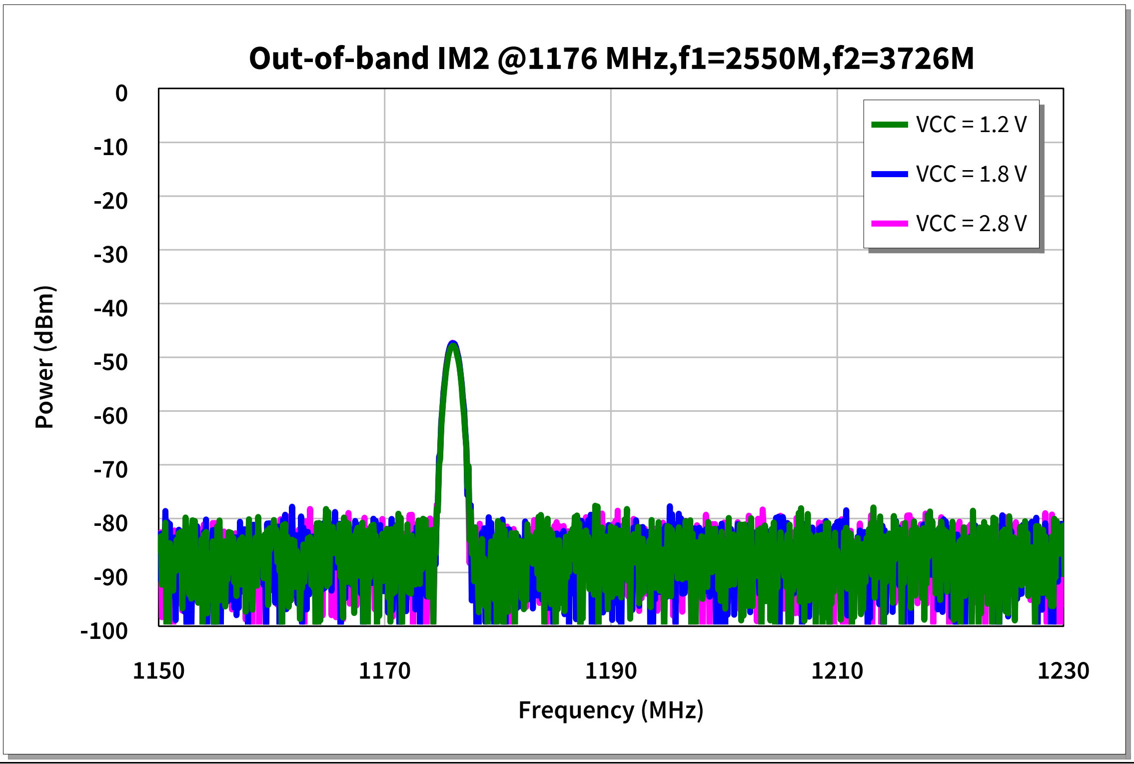

Figure 12 OoB second intermodulation point (f1 = 2550 MHz, f2 = 3726 MHz, output referred)

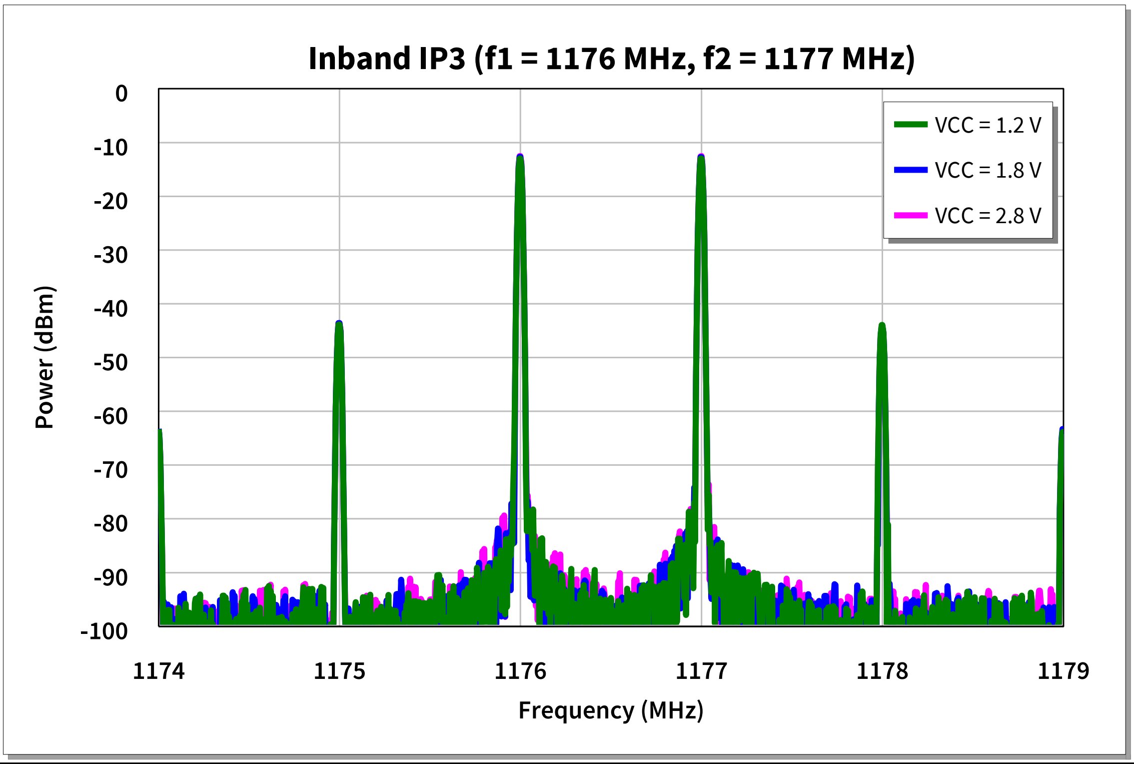

Figure 13 Inband third-order intermodulation point (f1 = 1176 MHz, f2 = 1177 MHz, output referred)

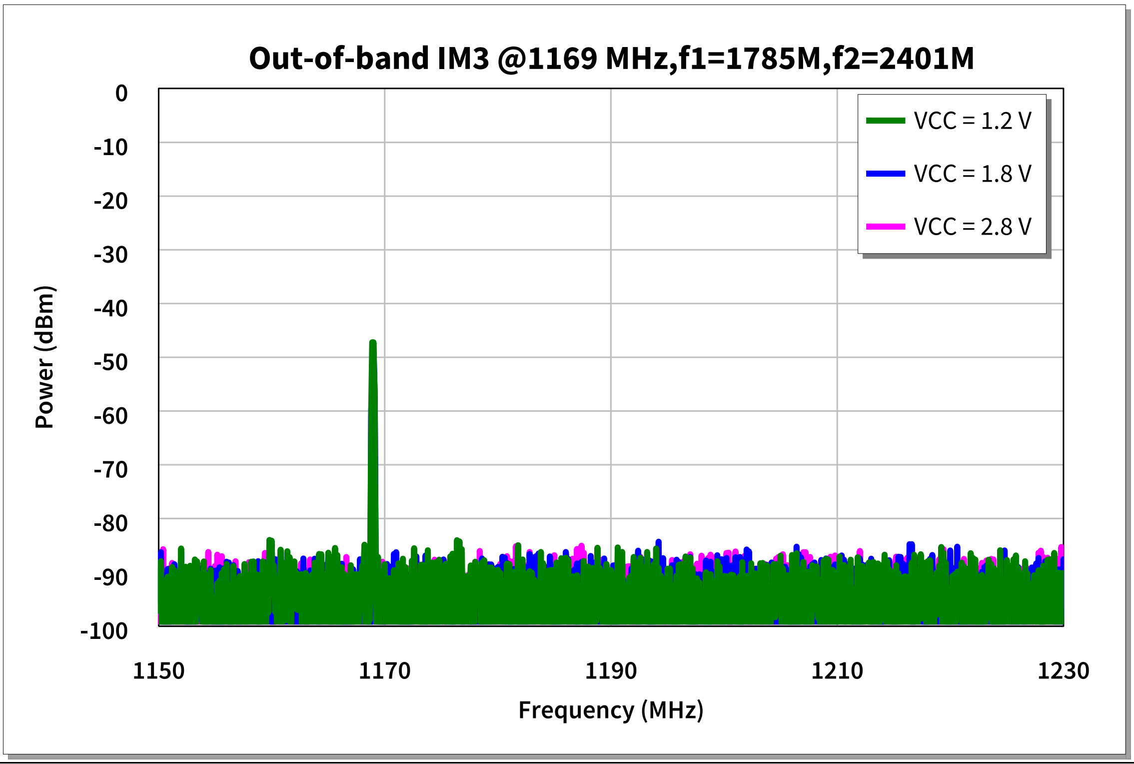

Figure 14 **Out-of-band third-order intermodulation point (f1 = 1712.7 MHz, f2 = 1850 MHz, L1 band, output referred)**

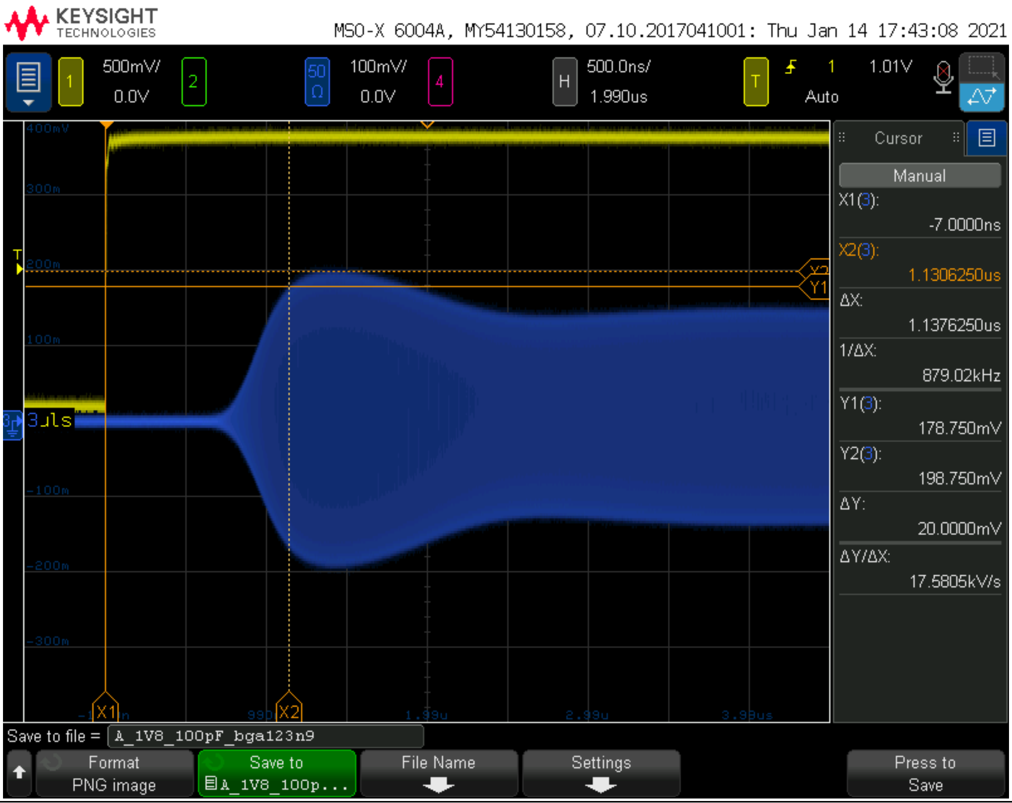

Figure 15 **Switching time off to on t_S of BGA123N6 for GNSS applications (C1 = 100 pF, V_{CC} = 1.8 V)**

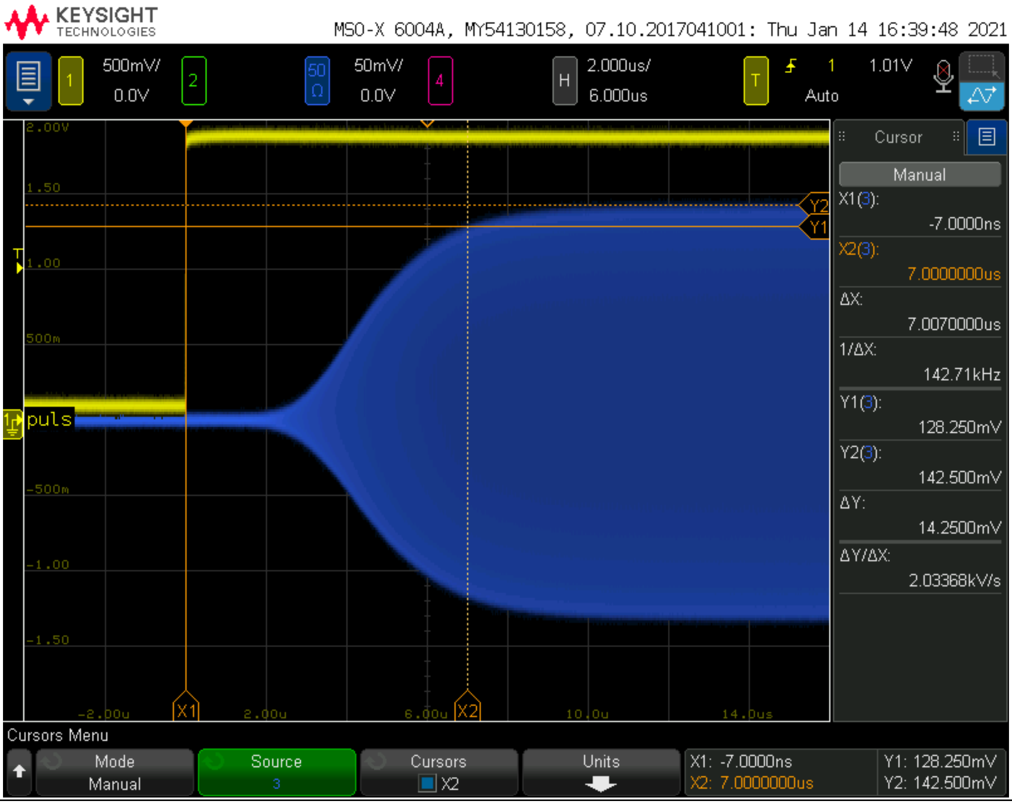

Figure 16 Switching time off to on t_S of BGA123N6 for GNSS applications (C1 = 1 nF, V_{CC} = 1.8 V)

Figure 17 Switching time on to off t_S of BGA123N6 for GNSS applications (C1 = 1 nF/100 pF, V_{CC} = 1.8 V)

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**

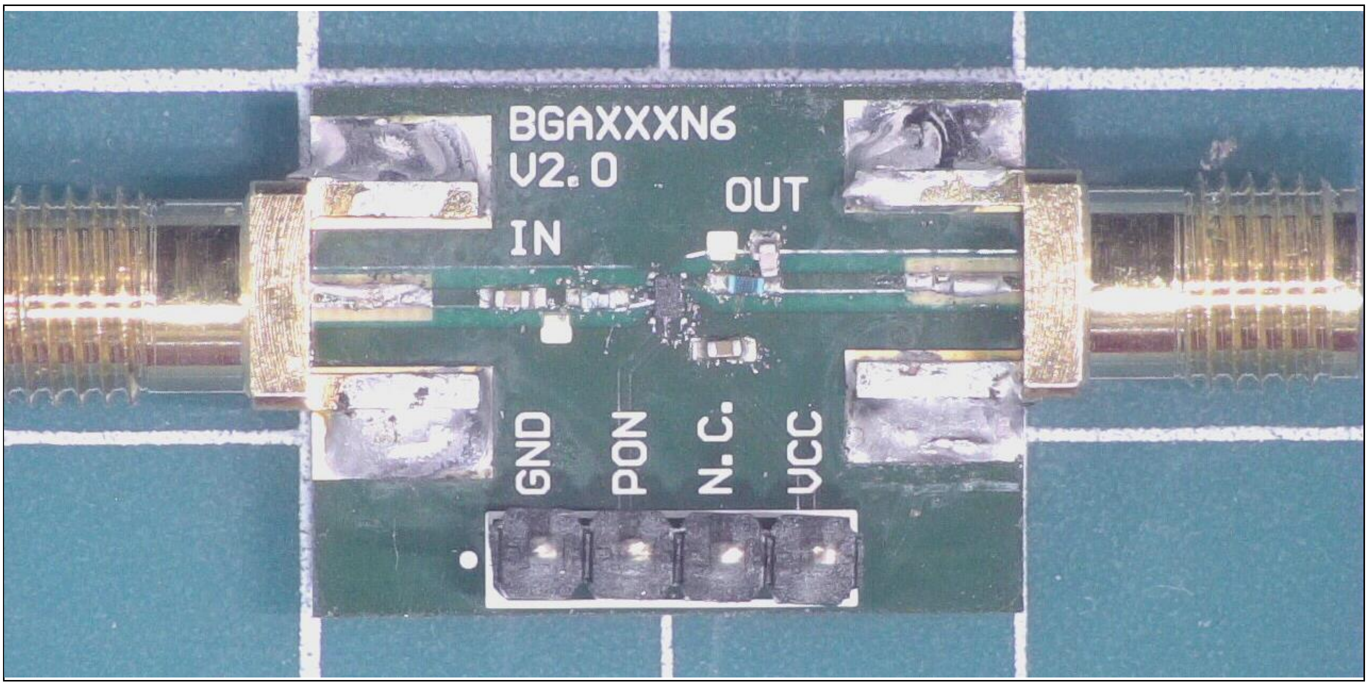

Figure 18 Evaluation board (overview)

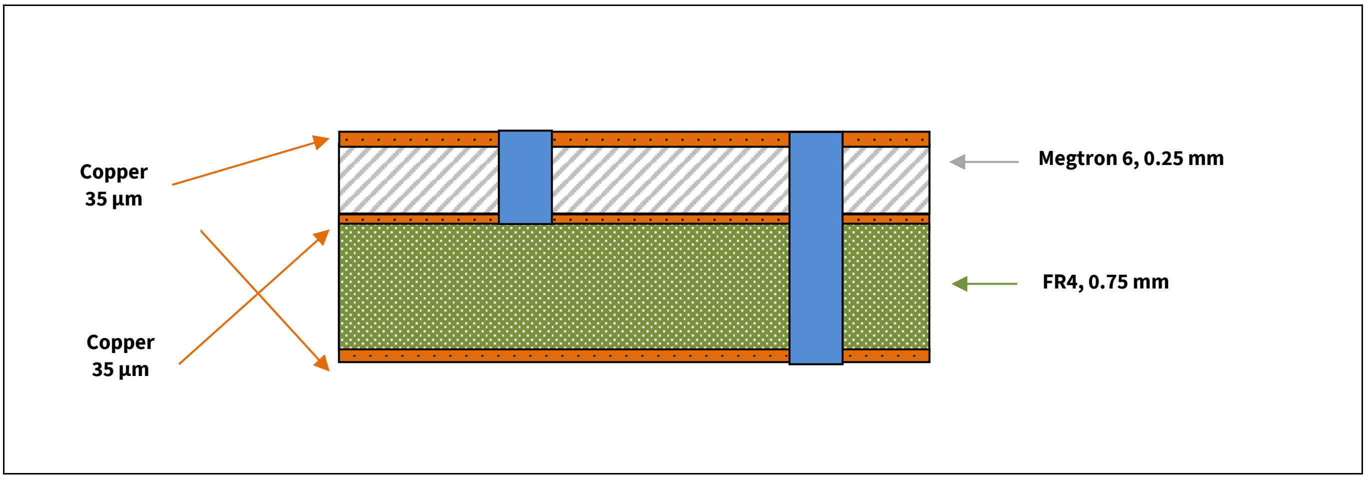

Figure 19 PCB layer information

5 Author

Xiang Li, Staff Application Engineer 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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