BGA125N6 as low-current LNA for GNSS applications from 1164 MHz to 1254 MHz

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA125N6 as a low-noise amplifier (LNA) for GNSS applications in the frequency range of 1164 MHz to 1254 MHz.

The BGA125N6 is an ultra-low-current silicon germanium (SiGe) LNA supporting 1164 MHz to 1300 MHz.

1. The target applications of this circuit are GPS L5/Galileo E5/GLONASS L3/BeiDou B2/QZSS L5/NavIC L5 bands, GPS L2/QZSS L2C in the range of 1164 MHz to 1254 MHz.

2. In this report, the performance of BGA125N6 is investigated on a Megtron 6 board. This device is matched with 0402 size high Q-factor LQW15 inductors. Two circuit options are implemented: Option A according to the datasheet, and Option B with reduced current consumption.

3. Key performance parameters at 1.8 V, 1176 MHz, LQW15 inductors for matching:

Option A	Option B
I_{CC} = 1.35 mA	I_{CC} = 1.2 mA
Insertion gain = 19.9 dB	Insertion gain = 19.0 dB
Noise figure = 0.80 dB	Noise figure = 0.85 dB
Input return loss = 13 dB	Input return loss = 13 dB
Output return loss = 14 dB	Output return loss = 13 dB
Out-of-band IP3 = 4 dBm	Out-of-band IP3 = 2 dBm

4. Key performance parameters at 1.8 V, 1227 MHz, LQW15 inductors for matching:

Option A	Option B
I_{CC} = 1.35 mA	I_{CC} = 1.2 mA
Insertion gain = 19.4 dB	Insertion gain = 18.7 dB
Noise figure = 0.80 dB	Noise figure = 0.85 dB
Input return loss = 12 dB	Input return loss = 11 dB
Output return loss = 14 dB	Output return loss = 13 dB
Out-of-band IP3 = 5 dBm	Out-of-band IP3 = 4 dBm

Table of contents

List of figures

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 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 facilitates the navigation signal for safety-of-life purposes. The figure below includes an overview of the GNSS frequency allocation.

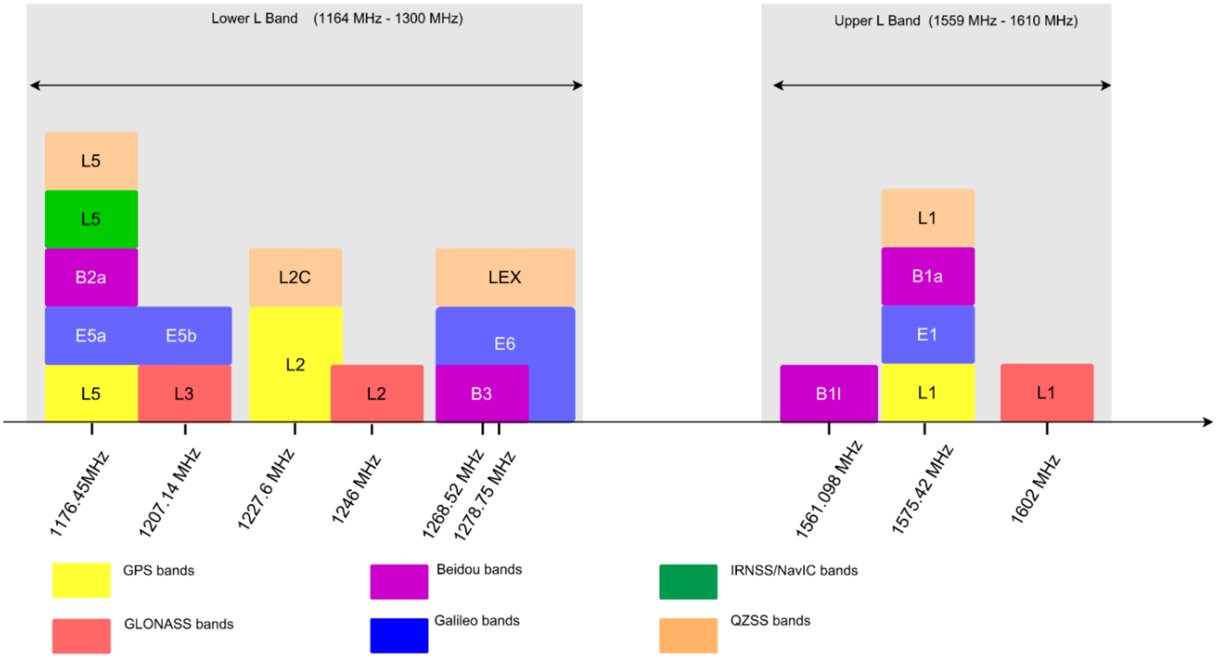

Figure 1 Frequency allocation for GNSSs, upper L band and lower L band

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 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 BGA125N6 overview

- Operation frequencies: 1164 MHz to 1300 MHz
- Ultra-low current consumption: 1.3 mA
- Wide supply voltage range: 1.1 V to 3.3 V
- High insertion power gain: 20.0 dB
- Low noise figure: 0.80 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

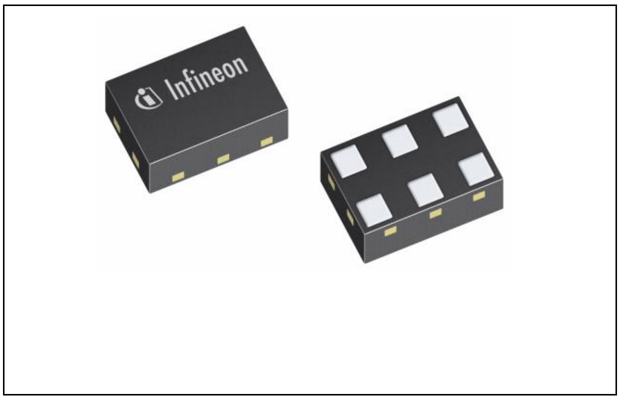

Figure 3 BGA125N6 in TSNP-6-2

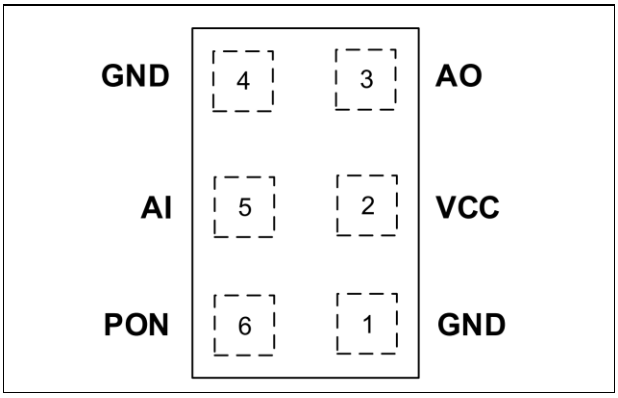

Figure 2 BGA125N6 pin configuration (transparent top view)

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 schematics and bill of materials (BOM) are presented.

Device:	BGA125N6
Application:	Ultra-low-current LNA for GNSS applications from 1164 MHz to 1254 MHz
PCB marking:	080920
EVB order no.:	EVAL BGA125N6 (AN629)

2.1 Summary of measurement results

The performance of BGA125N6 for GNSS lower L band applications is summarized in the following tables.

Table 2 Electrical characteristics at T_A = 25°C, f = 1176 MHz (Option A)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1176			MHz	
DC voltage	V_{CC}	1.2	1.8	2.8	V	
DC current	I_{CC}	1.30	1.35	1.45	mA	
Gain	G	19.5	19.9	20.2	dB	
Noise figure	NF	0.85[1]	0.80[1]	0.80[1]	dB	LQW15 inductor[1] / LQP03TN inductor[2] for matching, loss of input line of 0.04 dB is de-embedded
	NF_LQP	1.05[2]	1.00[2]	1.00[2]		
Input return loss	RL_{IN}	12	13	13	dB	
Output return loss	RL_{OUT}	14	14	14	dB	
Reverse isolation	I_{REV}	36	36	36	dB	
Input P1dB	IP1dB	-18	-16	-12	dBm	Measured @ 1176 MHz
Input IP3	IIP3	-15	-14	-14	dBm	Power @ input: -30 dBm f1 = 1176 MHz, f2 = 1177 MHz
Out-of-band input IP3	Oob_IIP3	4	4	5	dBm	Power @ input: -20 dBm f1 = 1785 MHz, f2 = 2401 MHz, Oob_IM3 measured @ 1169 MHz
Out-of-band output IM3	Oob_OIM3	-49	-49	-49	dBm	
Out-of-band input IP2	Oob_IIP2	28	28	28	dBm	Power @ input: -20 dBm f1 = 3726 MHz, f2 = 2550 MHz, Oob_IM2 measured @ 1176 MHz
Out-of-band Output IM2	Oob_OIM2	-48	-48	-48	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Table 2 Electrical characteristics at T_A = 25°C, f = 1176 MHz (Option A)

Parameter	Symbol	Value			Unit	Comment/test condition
Switching time OFF-to-ON	t_{OFF-ON}	9 a) / 2 b)	6 a)/ 1 b)	6 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
Switching time ON-to-OFF	t_{ON-OFF}	0.5	0.5	0.5	µs	LNA gain dropped to 10% of final gain value (in dB)

Table 3 Electrical characteristics at T_A = 25 °C, f = 1176 MHz (Option B)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1176			MHz	
DC voltage	V_{CC}	1.2	1.8	2.8	V	
DC current	I_{CC}	1.13	1.22	1.28	mA	
Gain	G	18.6	19.0	19.2	dB	
Noise figure	NF	0.85[1]	0.85[1]	0.85[1]	dB	LQW15 inductor[1] / LQP03TN inductor[2] for matching, loss of input line of 0.04 dB is de-embedded
	NF_LQP	1.05[2]	1.05[2]	1.05[2]	dB	
Input return loss	RL_{IN}	12	13	13	dB	
Output return loss	RL_{OUT}	14	13	12	dB	
Reverse isolation	I_{REV}	35	36	37	dB	
Input P1dB	IP1dB	-17	-14	-11	dBm	Measured @ 1176 MHz
Input IP3	IIP3	-13	-13	-14	dBm	Power @ input: -30 dBm f1 = 1176 MHz, f2 = 1177 MHz
Out-of-band Input IP3	Oob_IIP3	2	2	2	dBm	Power @ input: -20 dBm f1 =1785 MHz, f2= 2401 MHz, Oob_IM3 measured @ 1169 MHz
Out-of-band Output IM3	Oob_OIM3	-45	-46	-45	dBm	
Out-of-band input IP2	Oob_IIP2	27	26	26	dBm	Power @ input: -20 dBm a) f1 = 3726 MHz, f2 = 2550 MHz, Oob_IM2 measured @ 1176 MHz
Out-of-band Output IM2	Oob_OIM2	-48	-48	-47	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Table 3 Electrical characteristics at T_A = 25 °C, f = 1176 MHz (Option B)

Parameter	Symbol	Value			Unit	Comment/test condition
Switching time OFF-to-ON	t_{OFF-ON}	23 [a] / 3 [b]	18 [a] / 2 [b]	17 [a] / 2 [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
Switching time ON-to-OFF	t_{ON-OFF}	0.5[a]/0.5[b]	0.5[a]/0.5[b]	0.6[a]/0.6[b]	µs	LNA gain dropped to 10% of final gain value (in dB) a) C1 = 1000 pF b) C1 = 100 pF

Table 4 Electrical characteristics at T_A = 25 °C, f = 1227 MHz (Option A)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1227			MHz	
DC voltage	V_{CC}	1.2	1.8	2.8	V	
Gain	G	18.8	19.4	19.7	dB	
Noise figure	NF	0.85[1]	0.80[1]	0.80[1]	dB	LQW15 inductor[1] / LQP03TN inductor[2] for matching, loss of input line of 0.04 dB is de-embedded
	NF_LQP	1.05[2]	1.00[2]	1.00[2]	dB	
Input return loss	RL_{IN}	10	12	12	dB	
Output return loss	RL_{OUT}	14	14	14	dB	
Reverse isolation	I_{REV}	36	37	37	dB	
Input P1dB	IP1dB	-17	-14	-11	dBm	Measured @ 1227 MHz
Input IP3	IIP3	-14	-14	-13	dBm	Power @ input: -30 dBm f1 = 1226 MHz, f2 = 1227 MHz
Out-of-band Input IP3	Oob_IIP3	5	5	6	dBm	Power @ input: -20 dBm f1 =1856 MHz, f2= 2485 MHz, Oob_IM3 measured @ 1227 MHz
Out-of-band Output IM3	Oob_OIM3	-52	-52	-52	dBm	
Stability	k	>1				Measured up to 10 GHz

Note: for switching time ts, please refer to the results at table 2.

Table 5 Electrical characteristics at T_A = 25 °C, f = 1227 MHz (Option B)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency	Freq	1227			MHz	
DC voltage	V_{CC}	1.2	1.8	2.8	V	
Gain	G	18.2	18.7	19.0	dB	
Noise figure	NF	0.90[1]	0.85[1]	0.85[1]	dB	LQW15 inductor[1] / LQP03TN inductor[2] for matching, loss of input line of 0.04 dB is de-embedded
	NF_LQP	1.10[2]	1.05[2]	1.05[2]	dB	
Input return loss	RL_{IN}	10	11	11	dB	
Output return loss	RL_{OUT}	14	13	13	dB	
Reverse isolation	I_{REV}	36	37	37	dB	
Input P1dB	IP1dB	-16	-13	-10	dBm	Measured @ 1227 MHz
Input IP3	IIP3	-14	-13	-14	dBm	Power @ input: -30 dBm f1 = 1226 MHz, f2 = 1227 MHz
Out-of-band Input IP3	Oob_IIP3	4	4	5	dBm	Power @ input: -20 dBm f1 =1856 MHz, f2= 2485 MHz, Oob_IM3 measured @ 1227 MHz
Out-of-band Output IM3	Oob_OIM3	-50	-50	-50	dBm	
Stability	k	>1				Measured up to 10 GHz

Note: for switching time ts, please refer to the results at table 3.

2.2 Schematics and bill of materials

The schematic of Option A is shown in Figure 4 and its BOM is shown in Table 6.

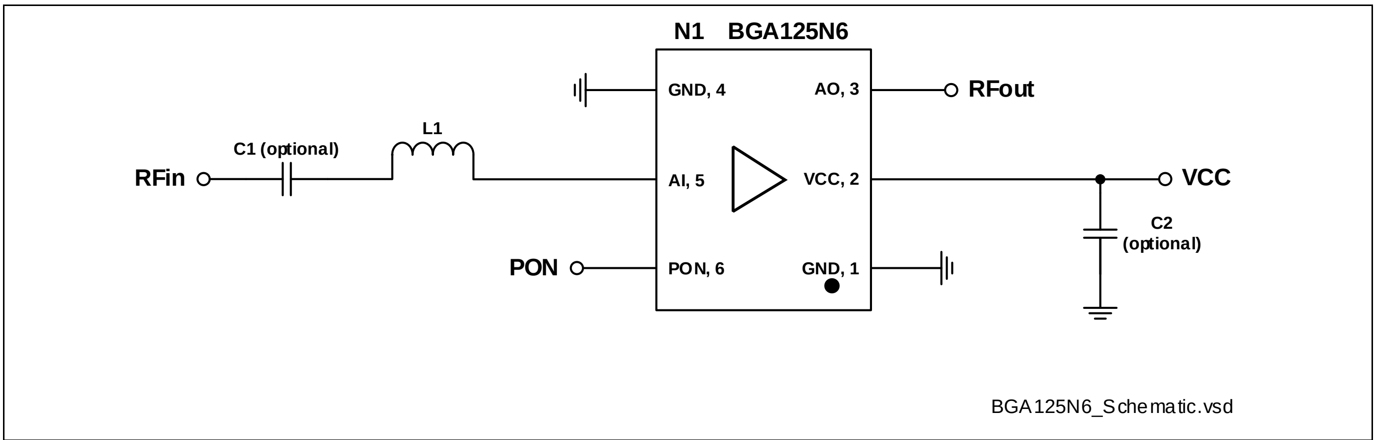

Figure 4 Schematic of the BGA125N6 application circuit (Option A)

Table 6 BOM (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	16	nH	0402	Murata LQW15	Input matching
N1	BGA125N6		TSNP-6-2	Infineon Technologies	SiGe LNA

The schematic of Option B is shown in Figure 5 and its BOM is shown in Table 7.

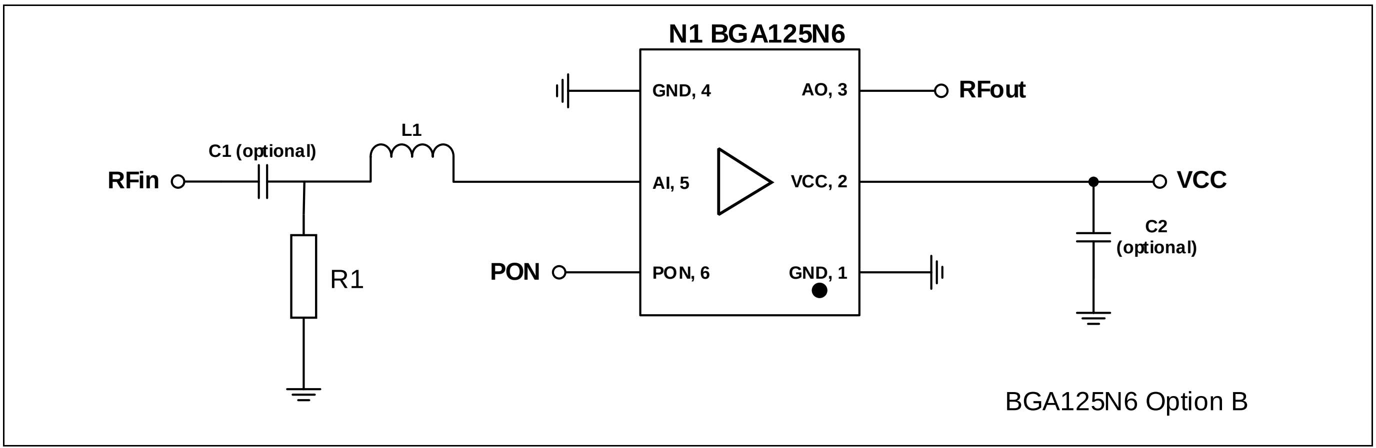

Figure 5 Schematic of the BGA125N6 application circuit (Option B)

Table 7 BOM (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	18	nH	0402	Murata LQW15	Input matching
R1	220	kΩ	0402	Various	Current reduction
N1	BGA125N6		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) The value of C1 may be changed to 100 pF resulting in a faster switching time OFF-to-ON.

3 Measurement graphs

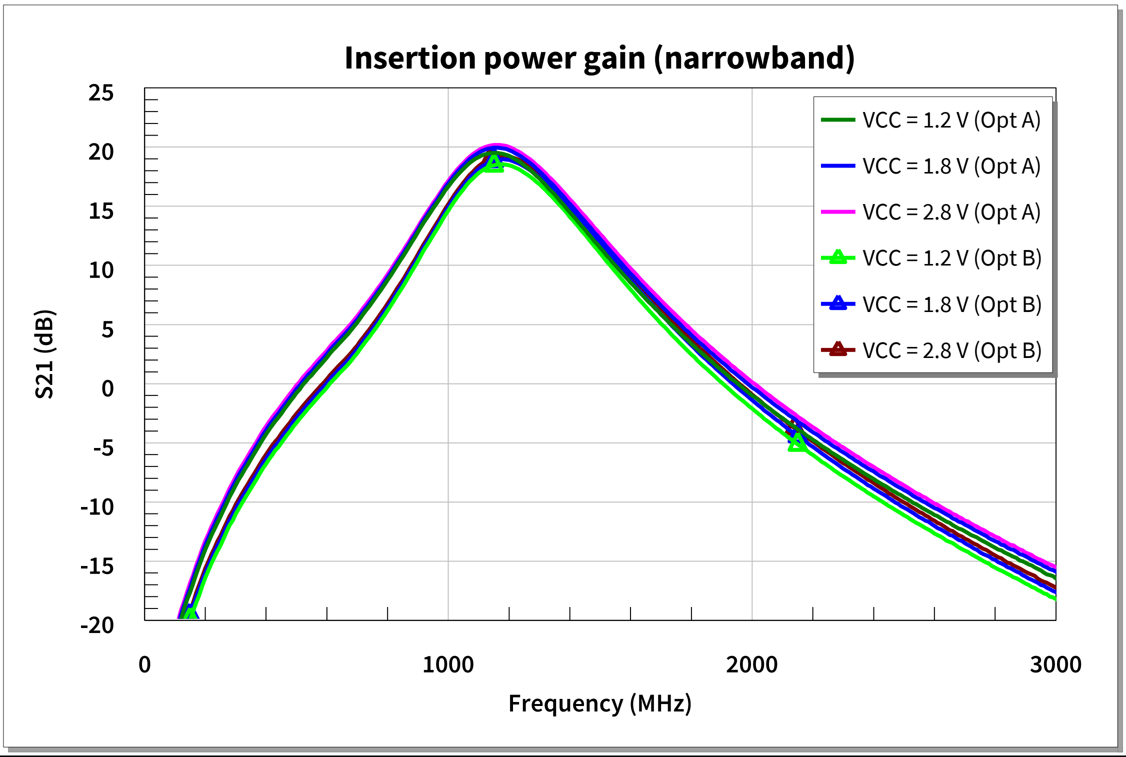

Figure 6 Insertion power gain (narrowband)

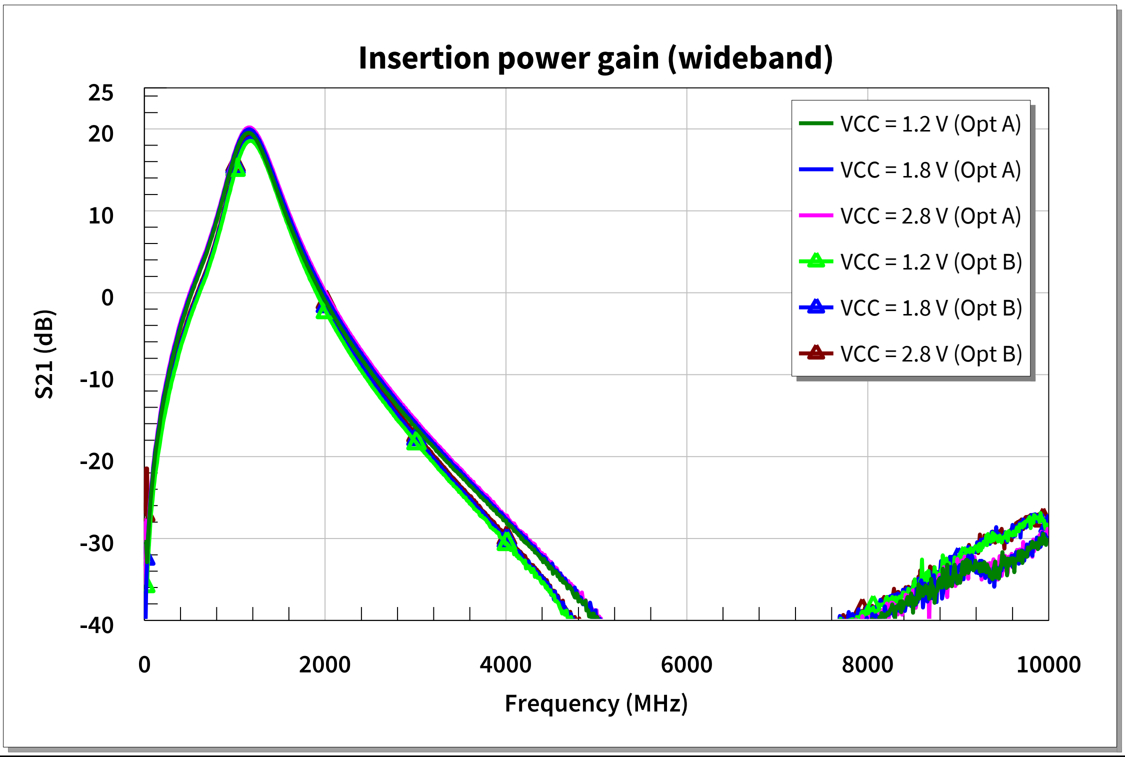

Figure 7 Insertion power gain (wideband)

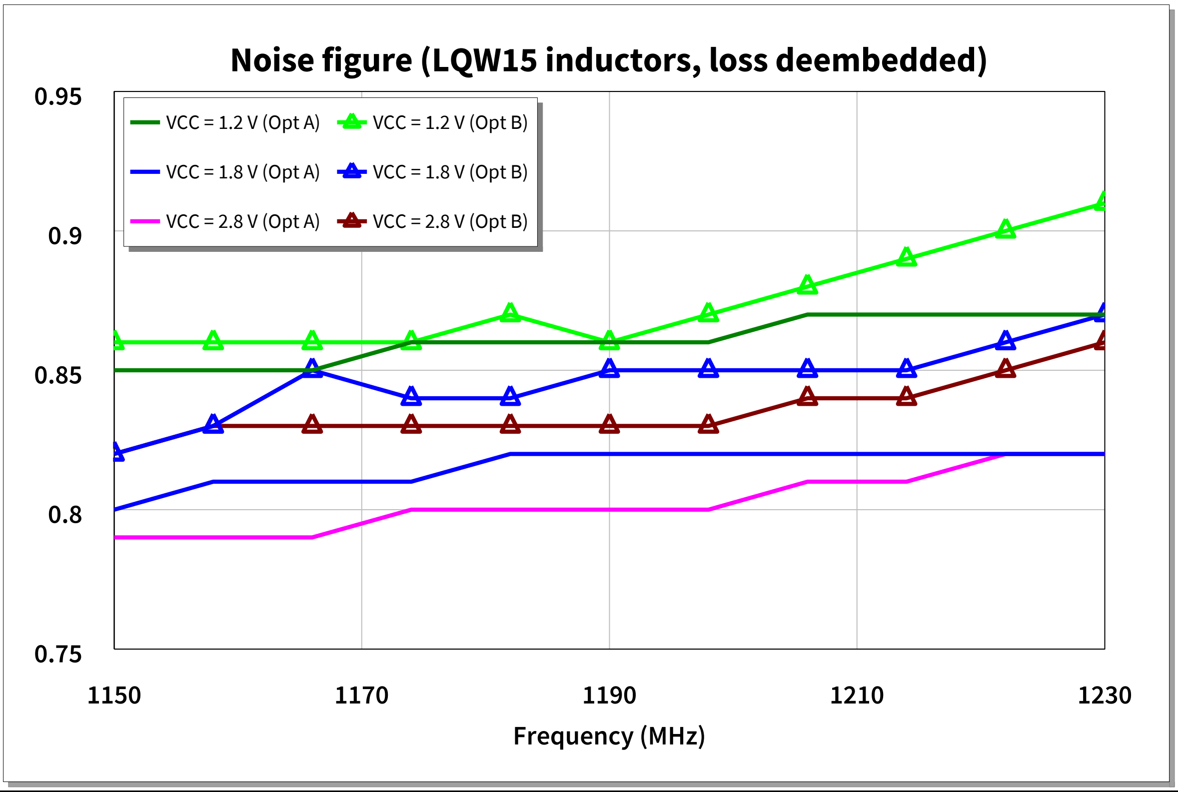

Figure 8 Noise figure (SMA and connector losses deembedded, LQW15 inductors for matching)

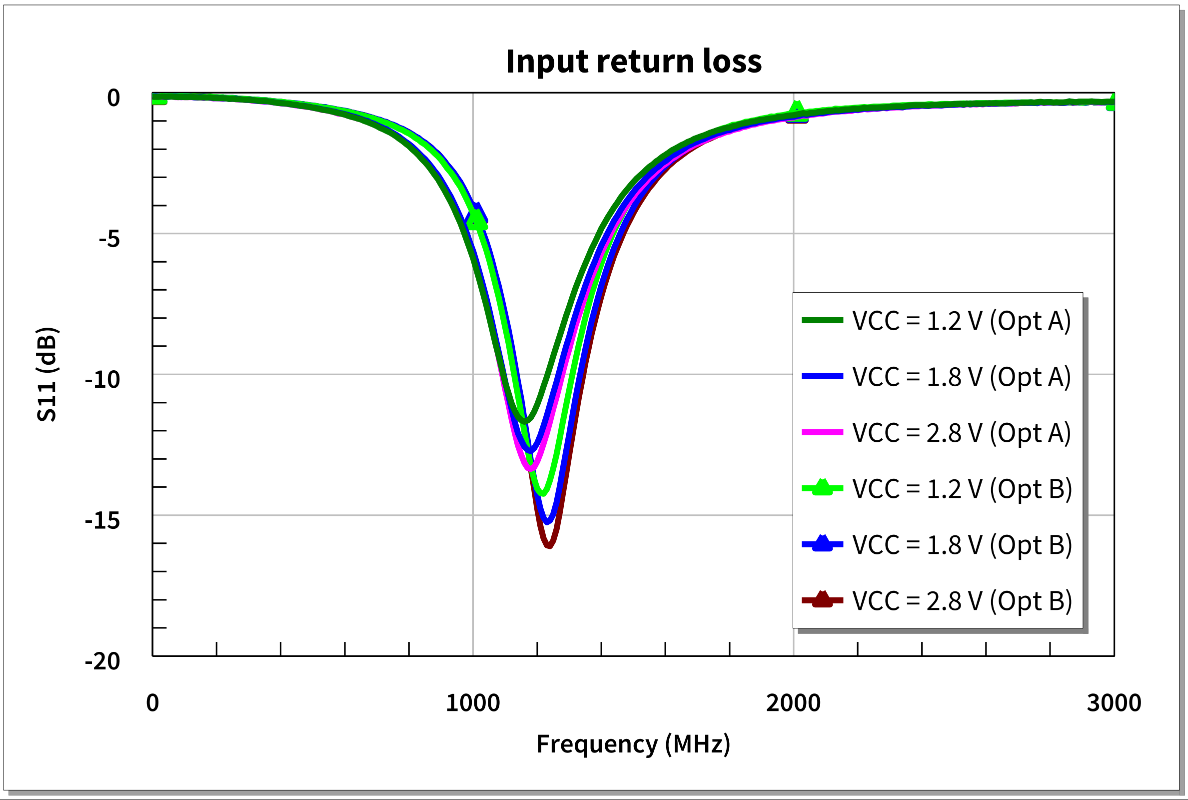

Figure 9 Input return loss

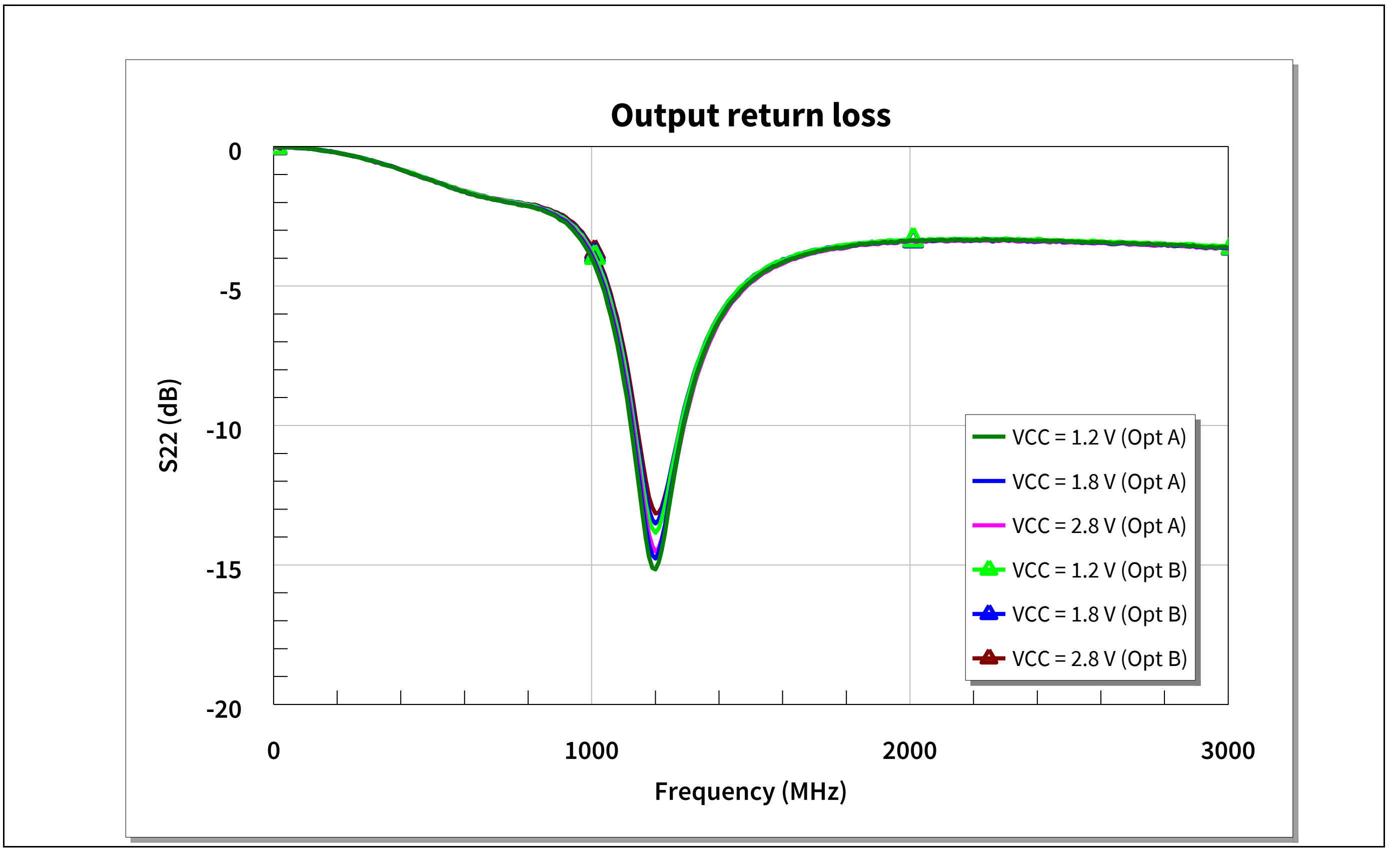

Figure 10 Output return loss

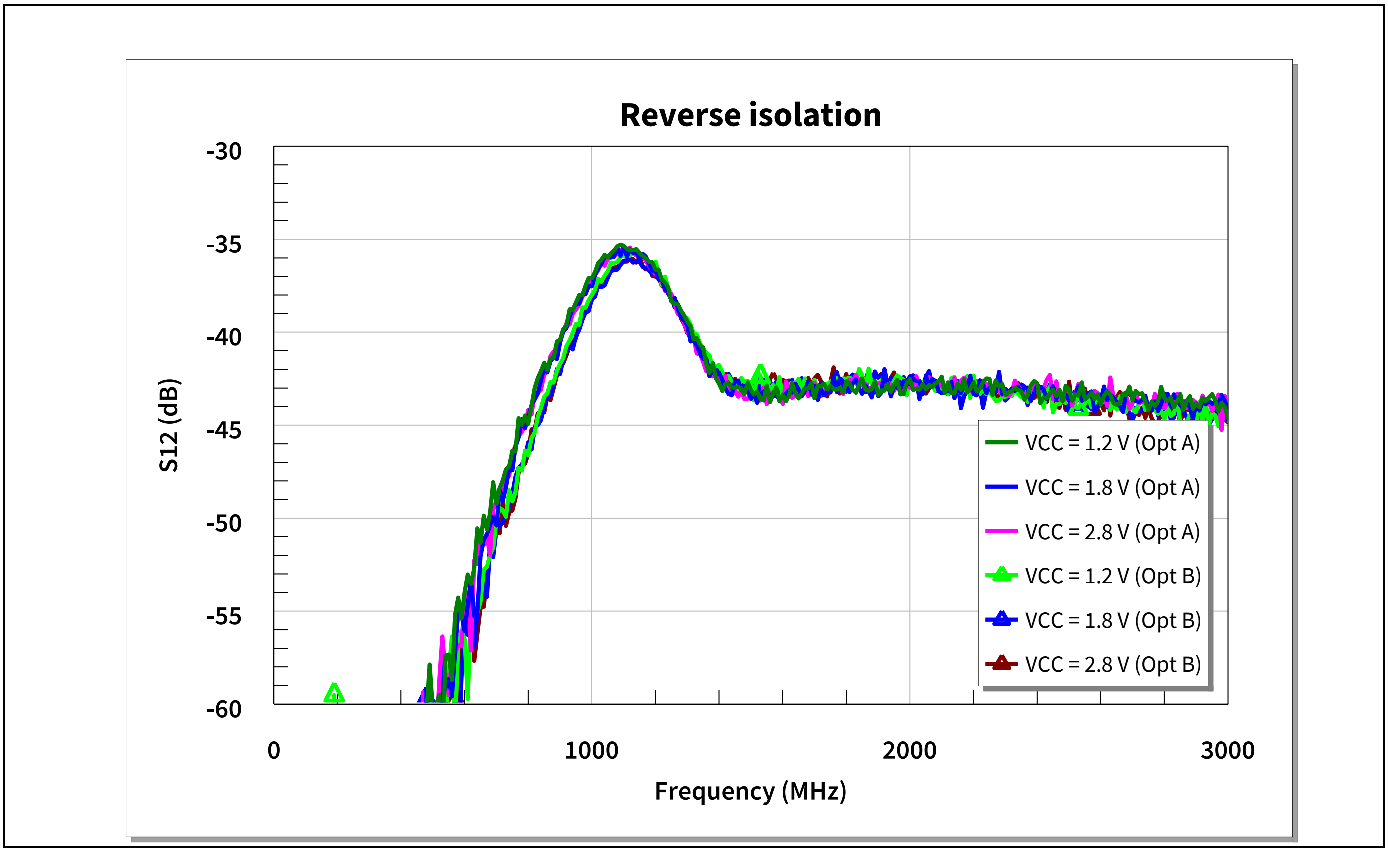

Figure 11 Reverse isolation

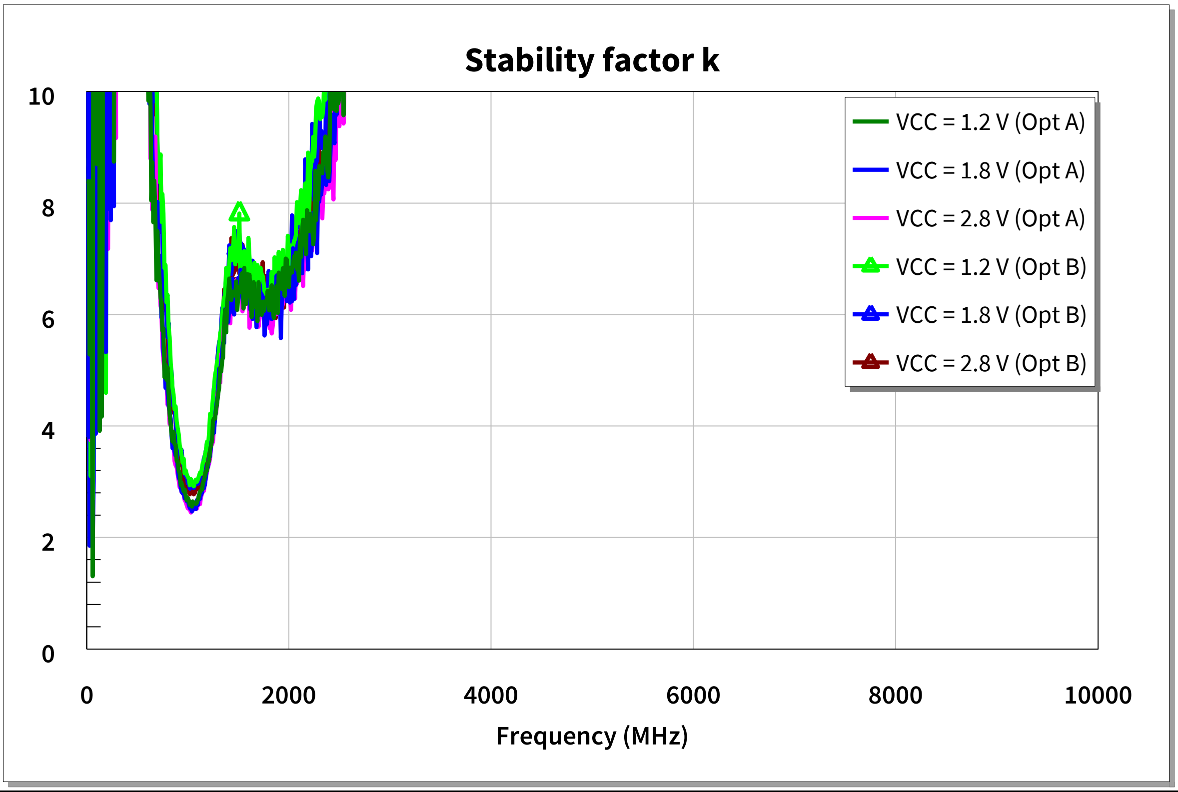

Figure 12 Stability k-factor

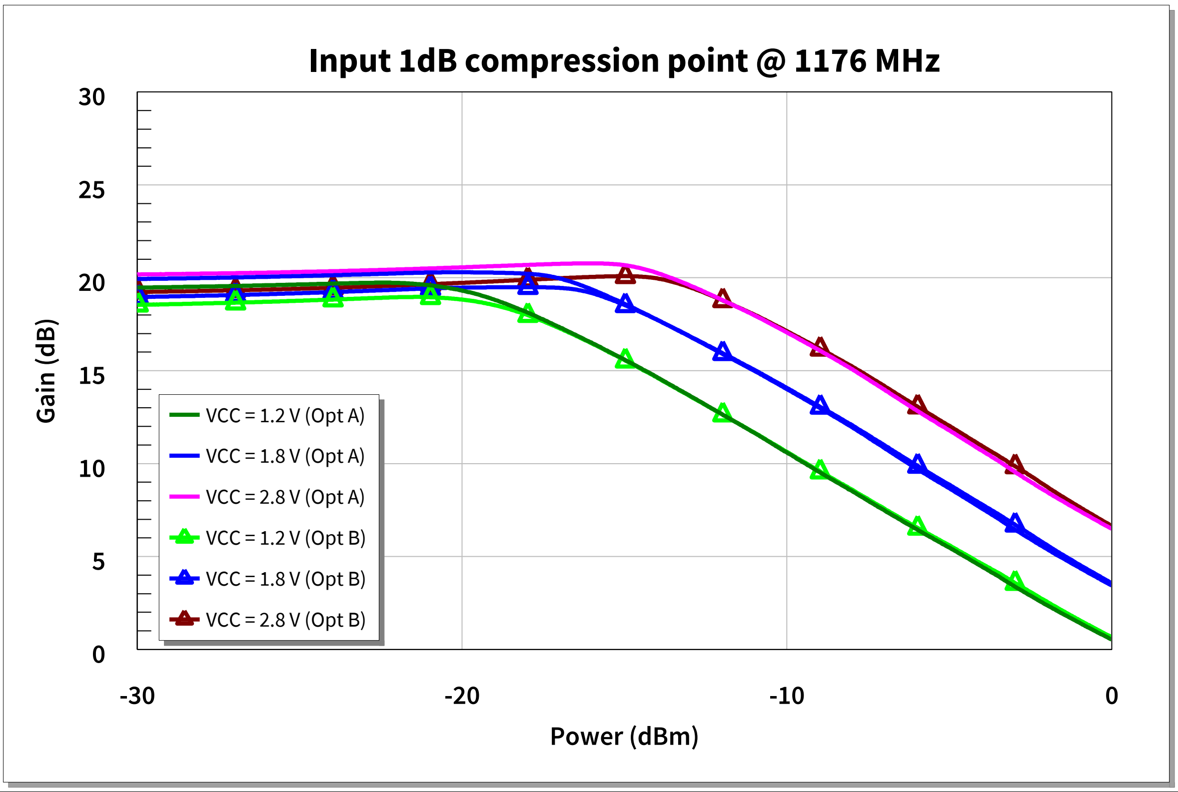

Figure 13 Input 1 dB compression point at 1176 MHz

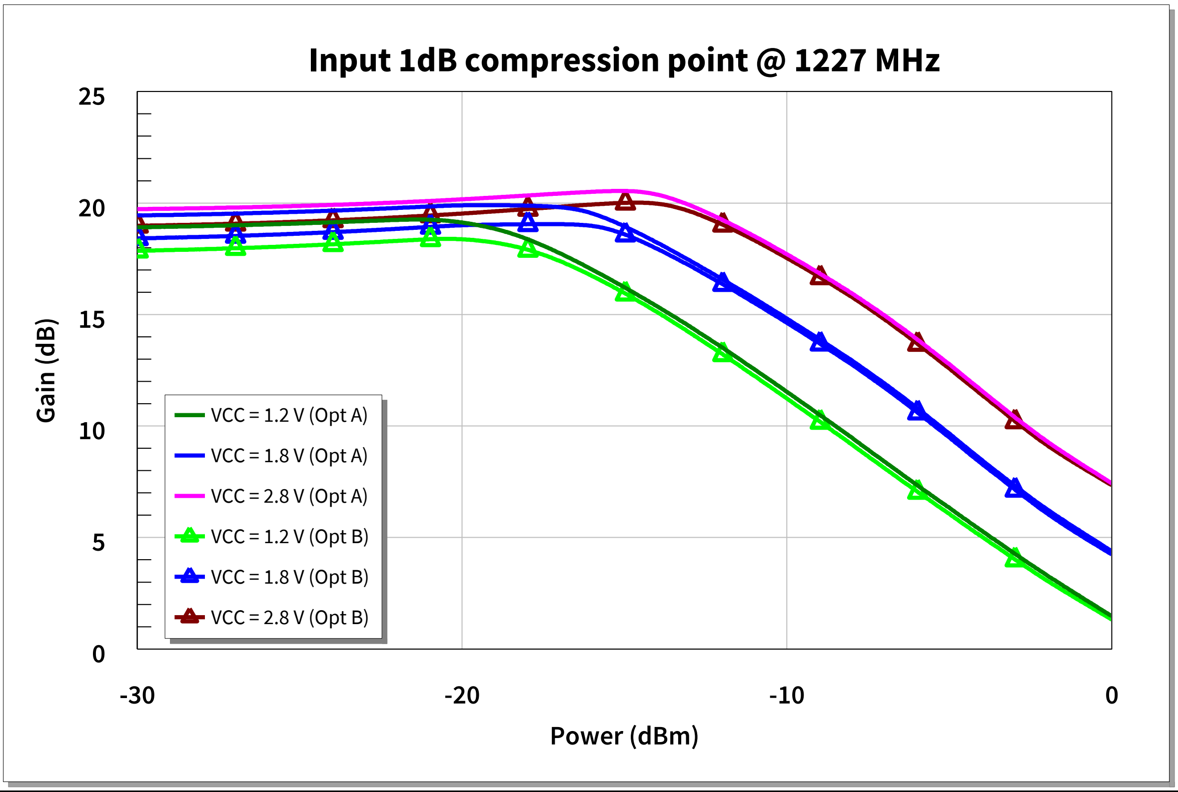

Figure 14 Input 1dB compression point at 1227 MHz

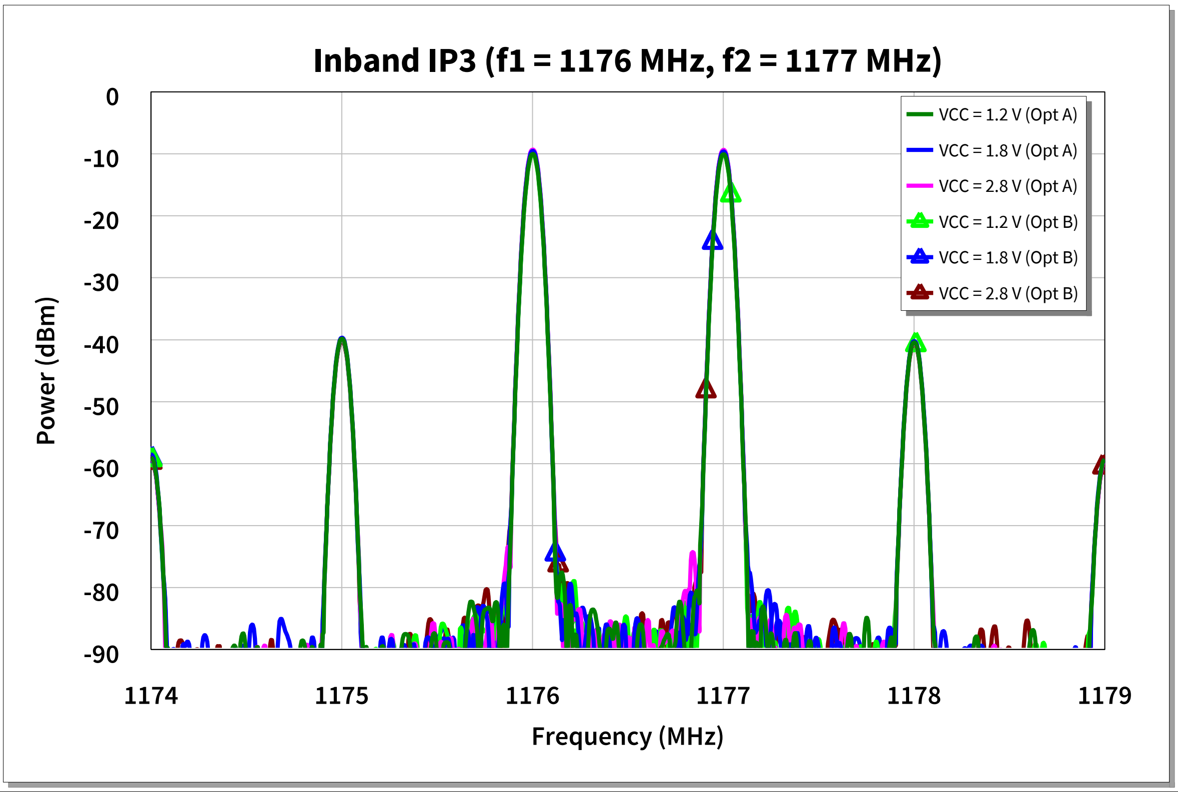

Figure 15 Inband third-order intermodulation point (1176 MHz, output referred)

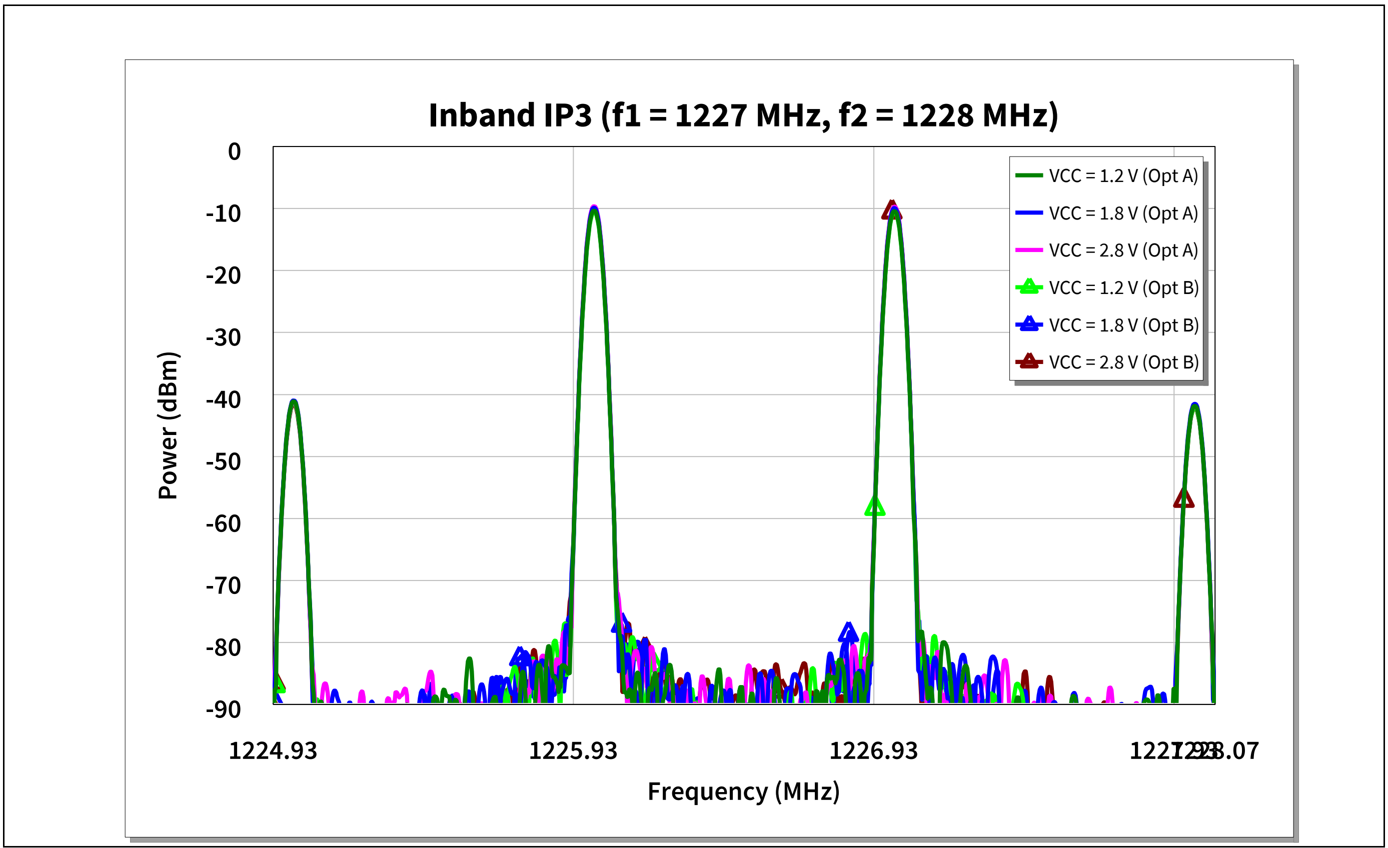

Figure 16 Inband third-order intermodulation point (1227 MHz, output referred)

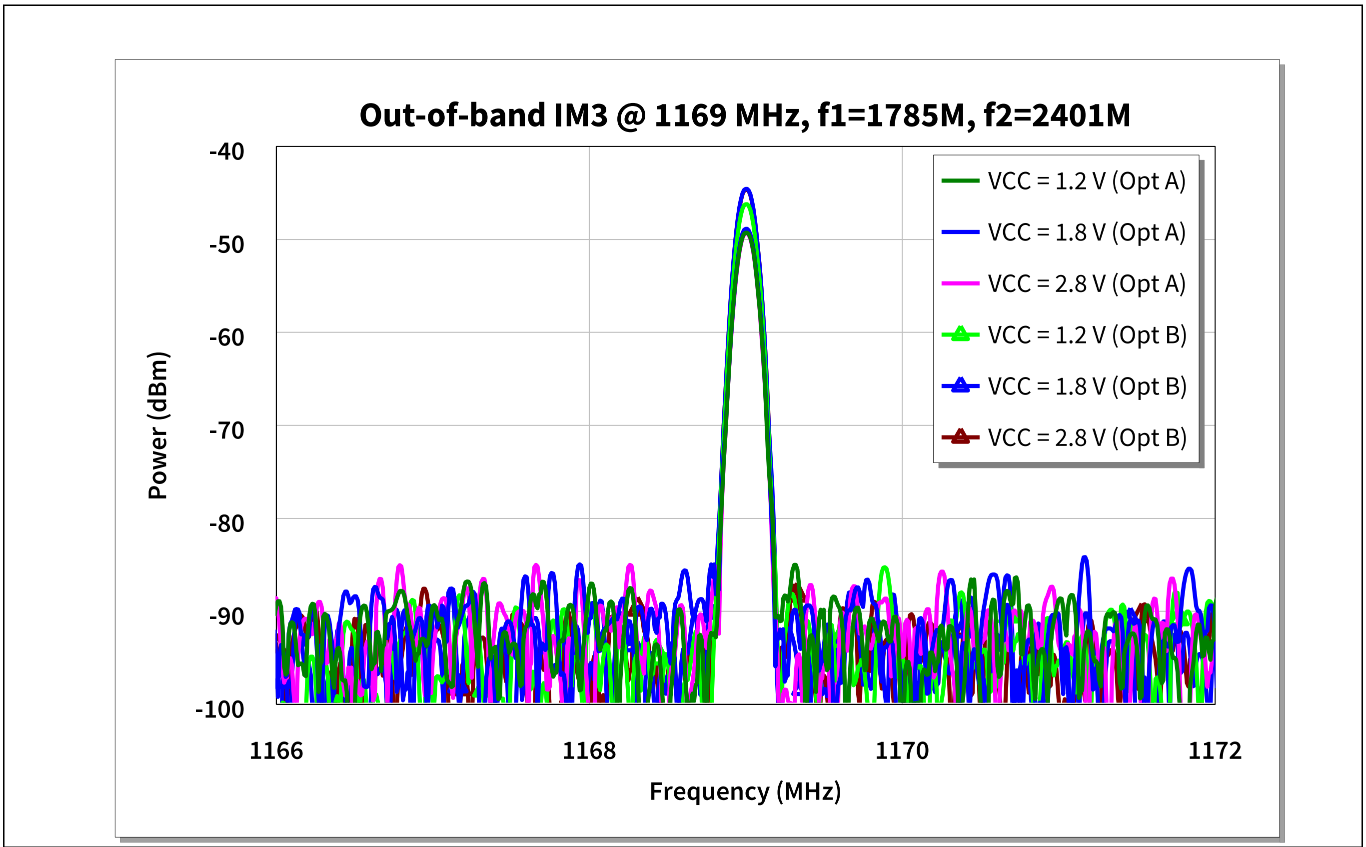

Figure 17 OoB third-order intermodulation point (f1 = 1785 MHz, f2 = 2401 MHz, L5 band, output referred)

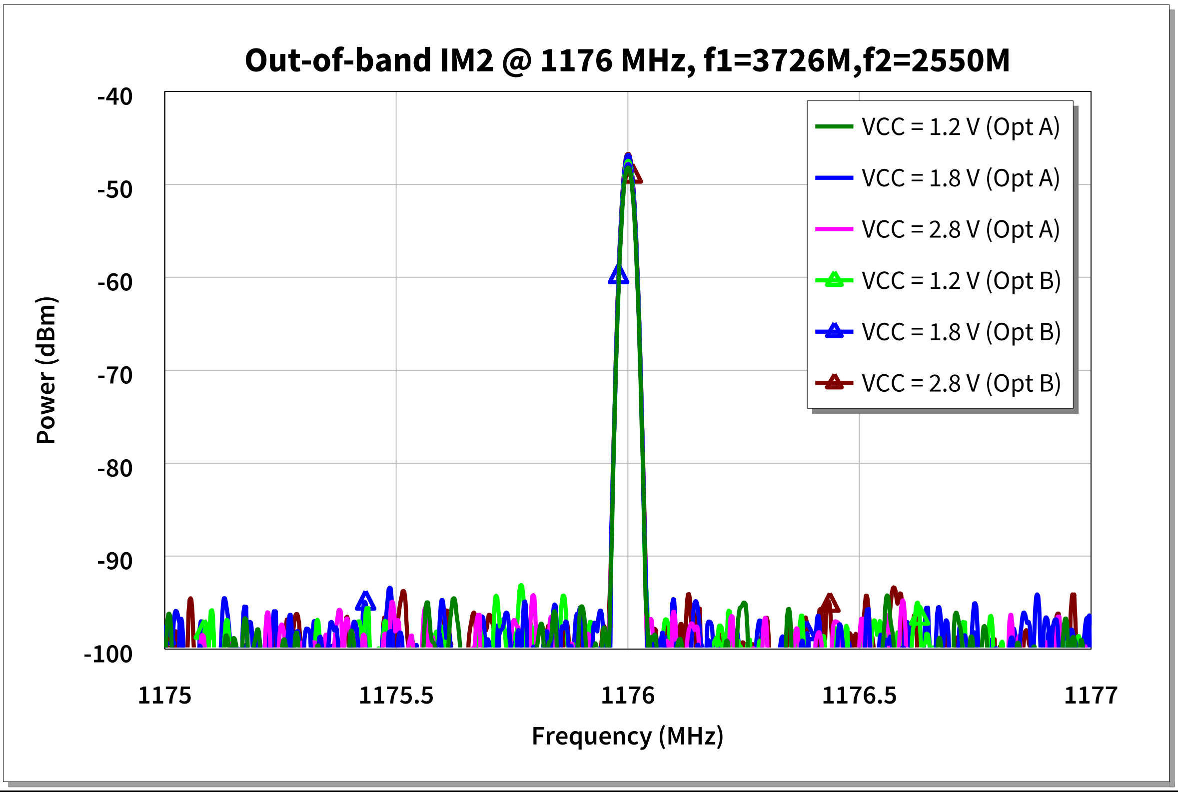

Figure 18 OoB second-order intermodulation point (f1 = 3726 MHz, f2 = 2550 MHz, output referred)

Figure 19 OoB third-order intermodulation point (f1 = 1856 MHz, f2 = 2485 MHz, output referred)

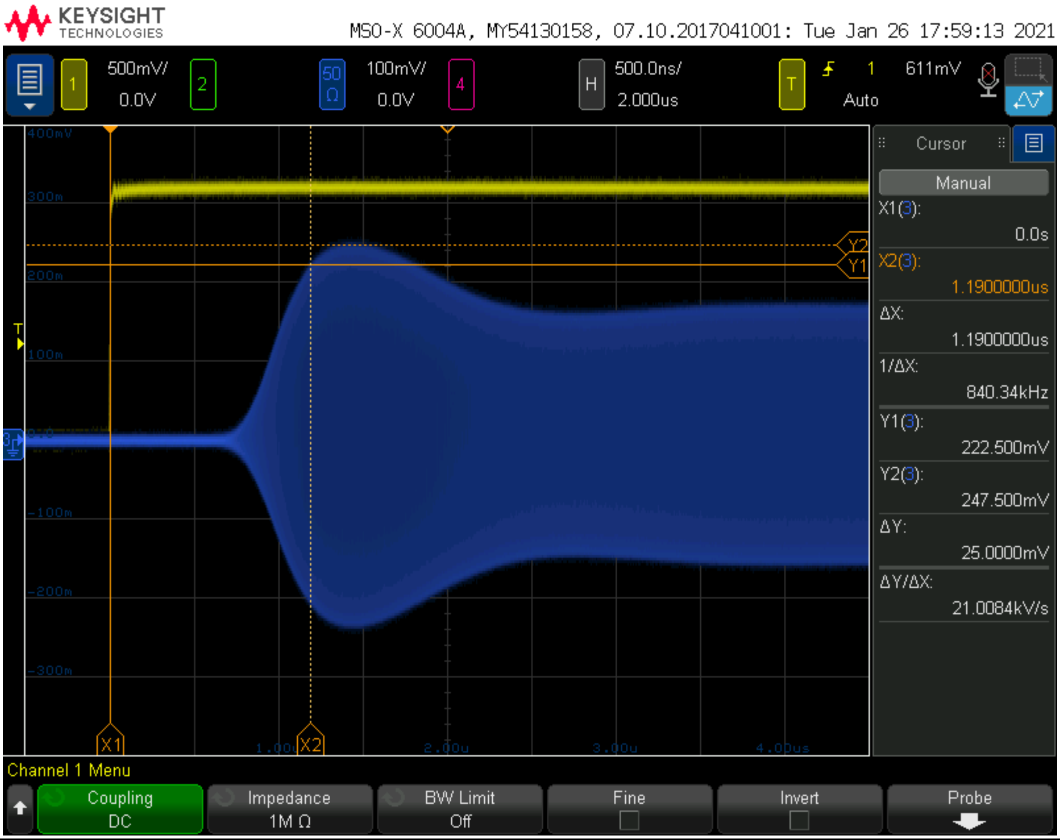

Figure 20 **Switching time OFF-ON $t_{OFF\text{-}ON}$ (Option A, C1 = 100 pF, V_{CC} = 1.8 V)**

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

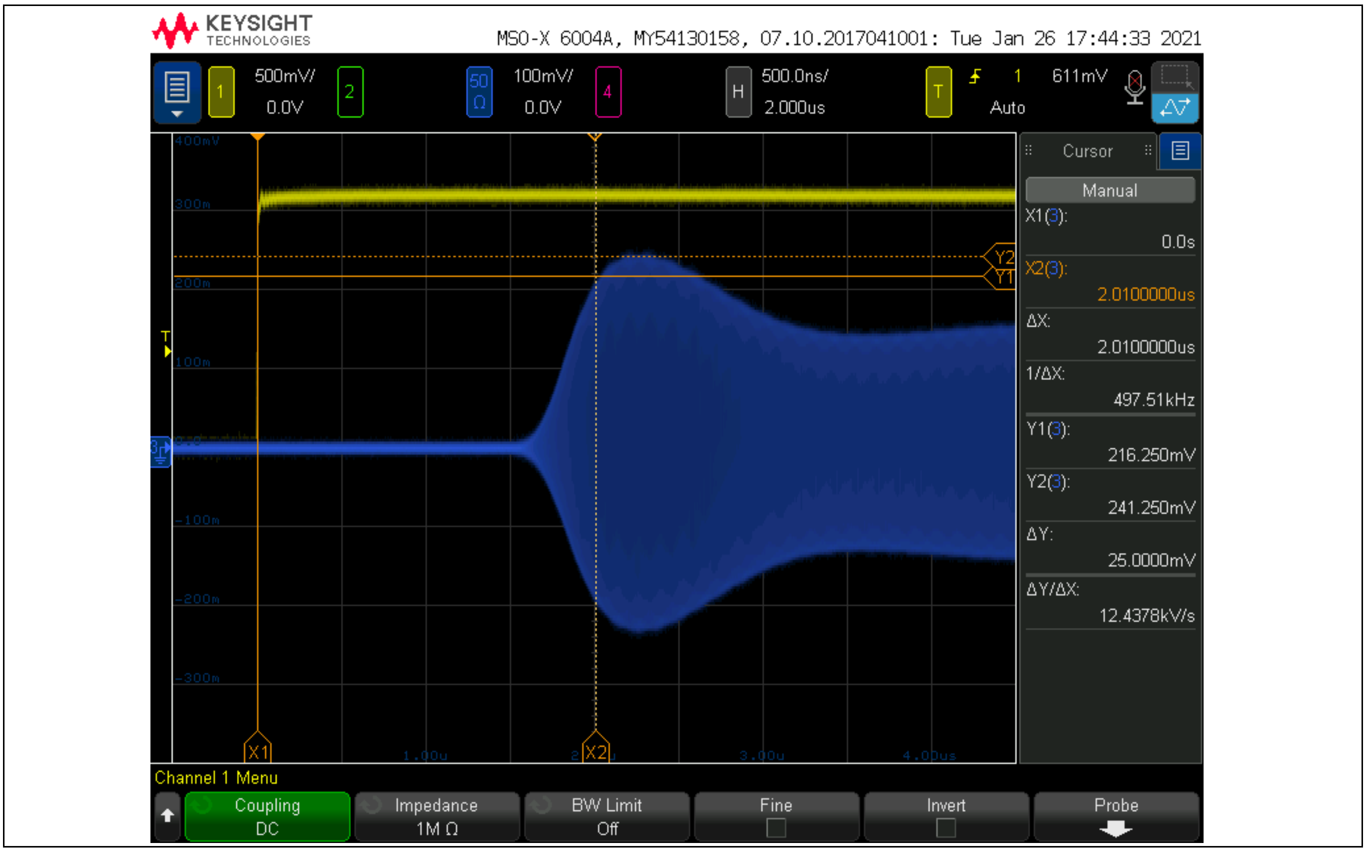

Figure 22 Switching time OFF-ON $t_{OFF\text{-}ON}$ (Option B, C1 = 100 pF, V_{CC} = 1.8 V)

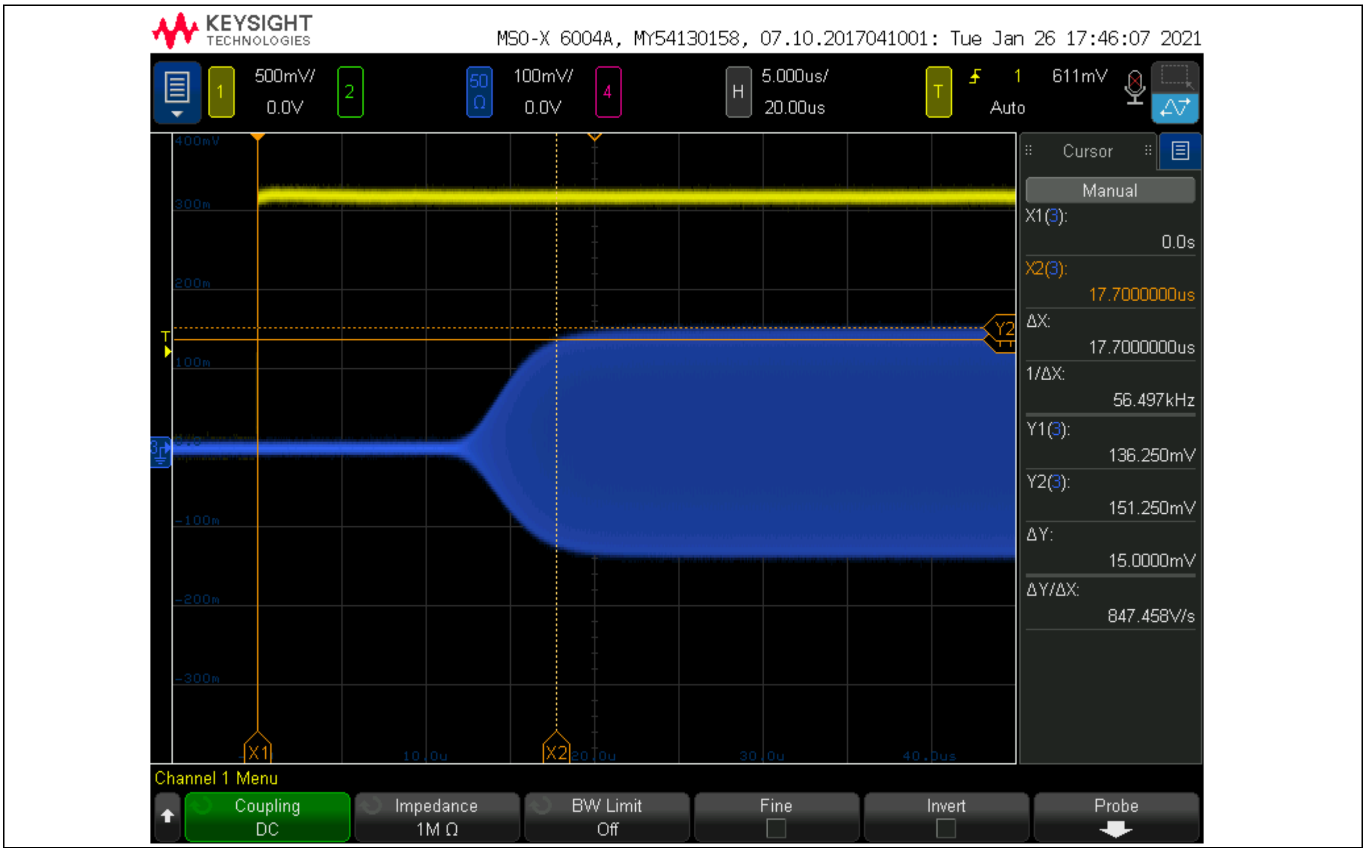

Figure 23 Switching time OFF-ON $t_{OFF\text{-}ON}$ (Option B, C1 = 1 nF, V_{CC} = 1.8 V)

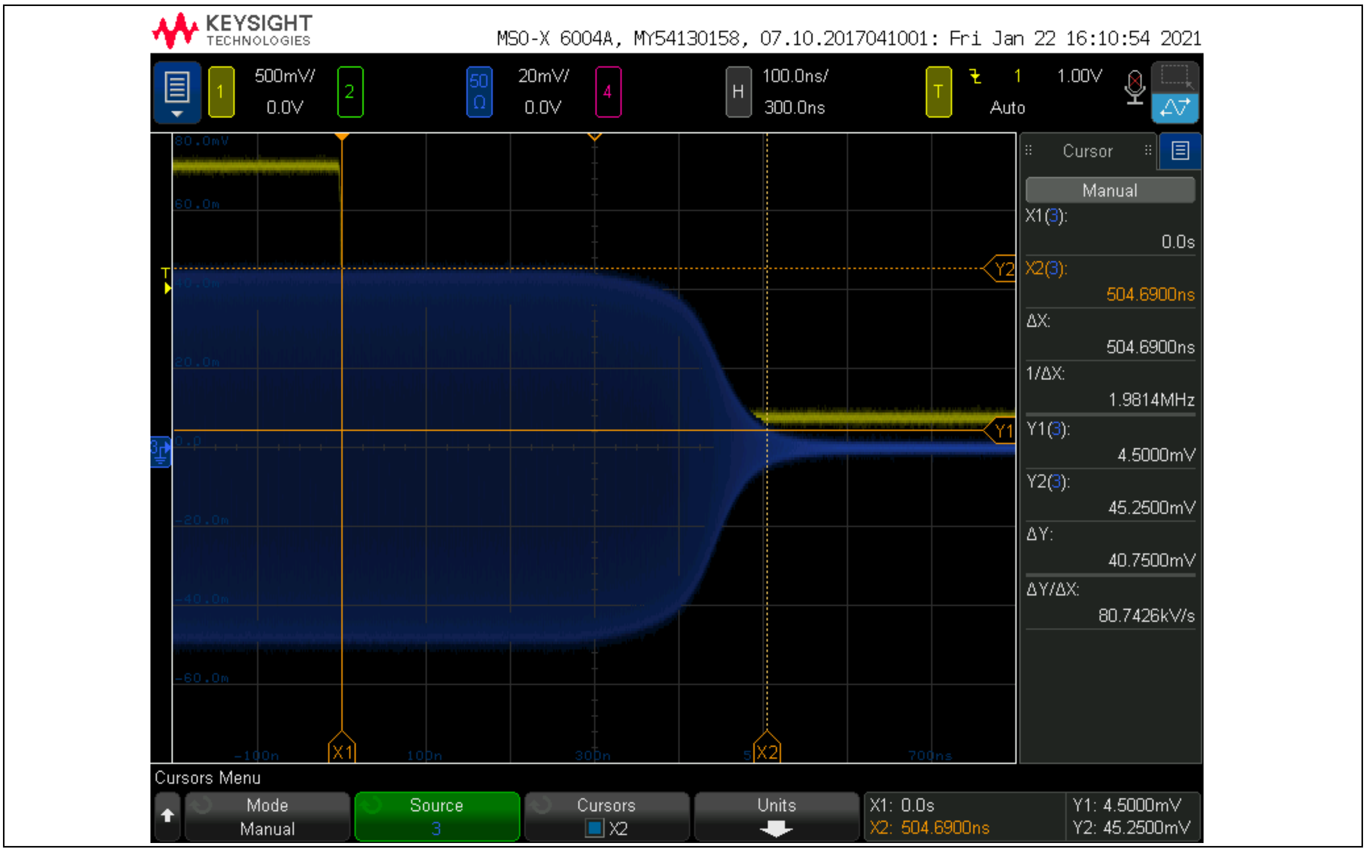

Figure 24 Switching time ON-OFF $t_{ON\text{-}OFF}$ (Option A)

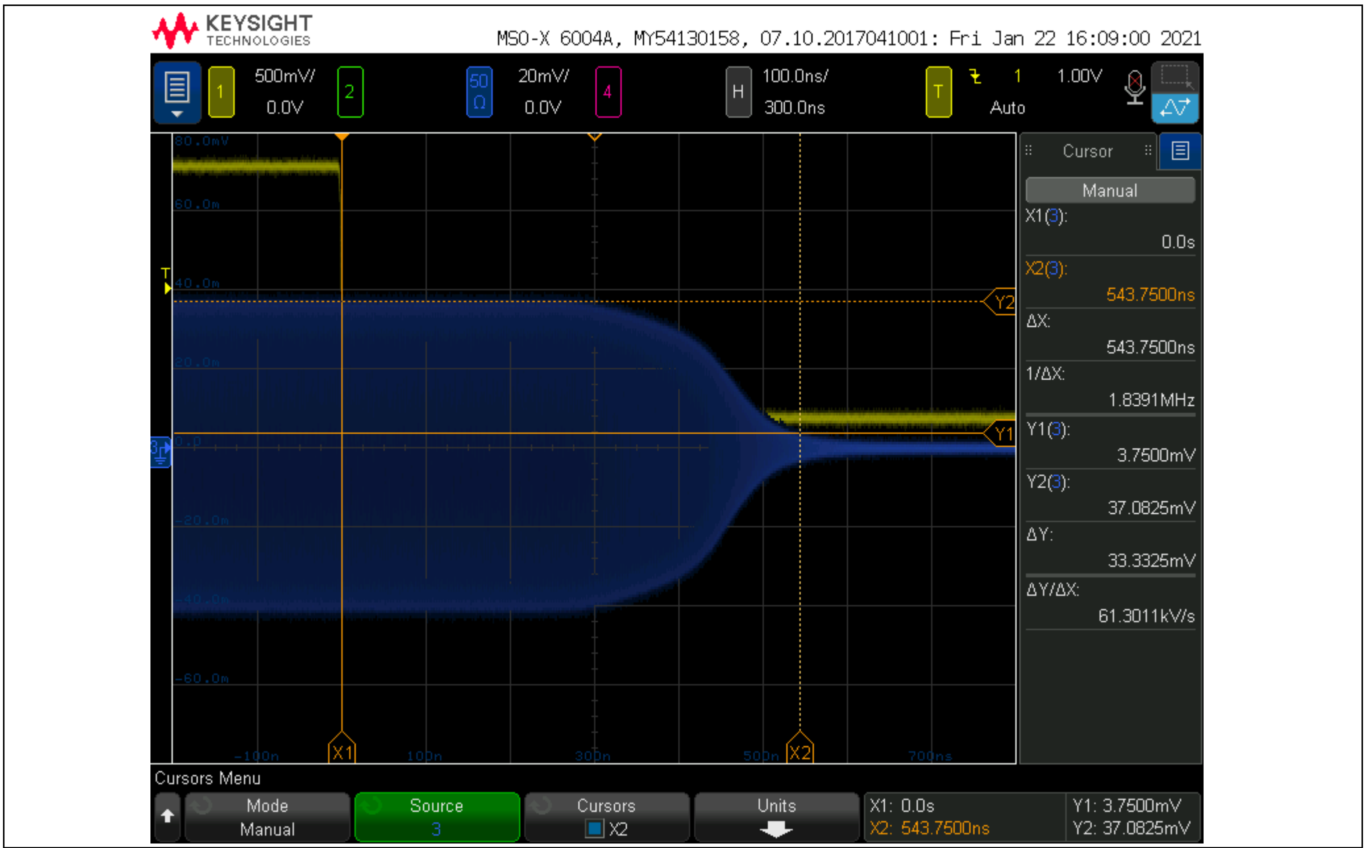

Figure 25 Switching time ON-OFF $t_{ON\text{-}OFF}$ (Option B)

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**

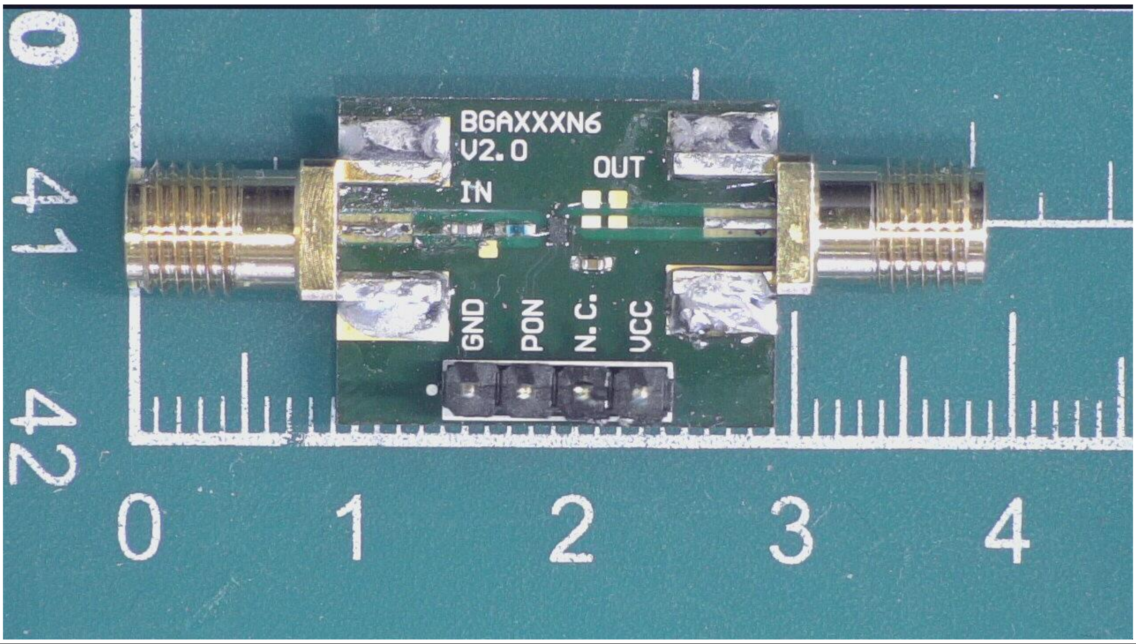

Figure 26 Evaluation board Option A (overview)

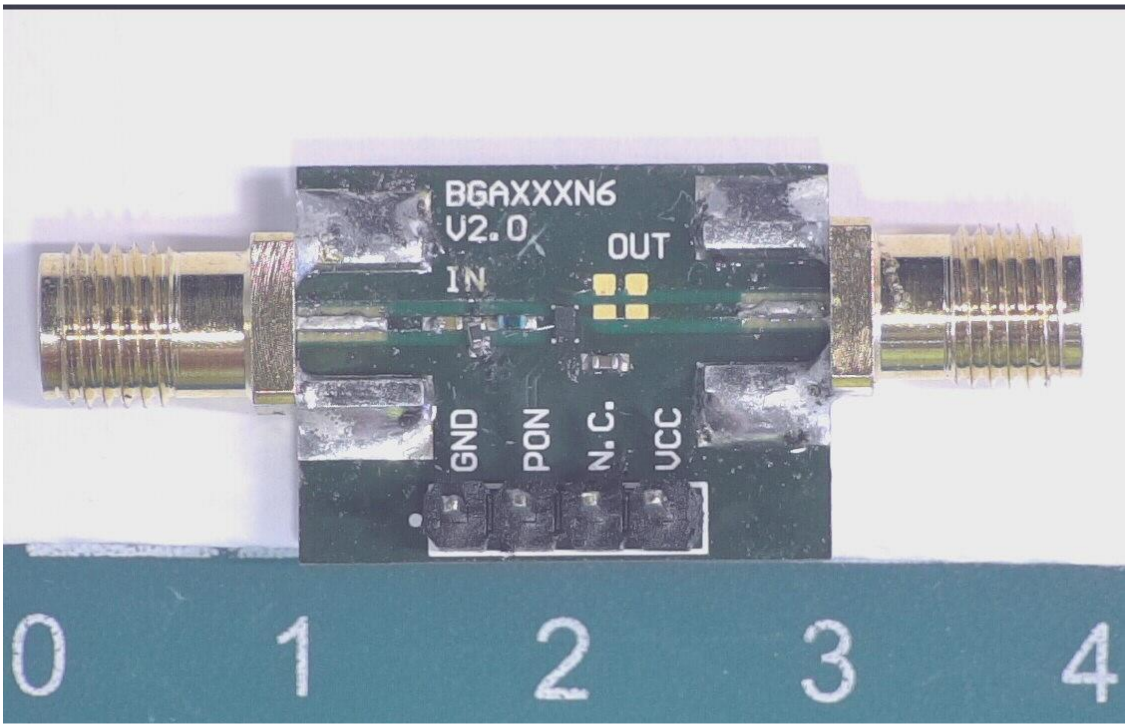

Figure 27 Evaluation board Option B (overview)

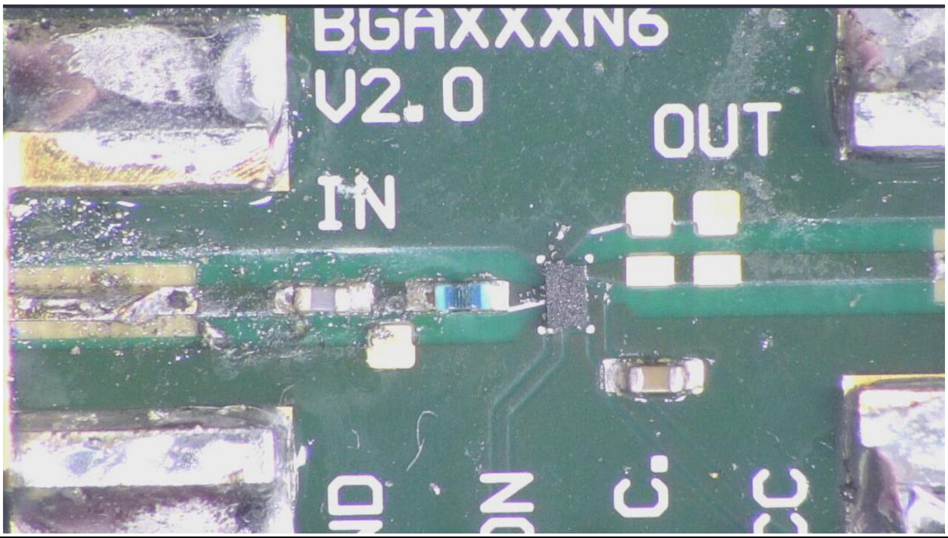

Figure 28 Evaluation board Option A (detailed view)

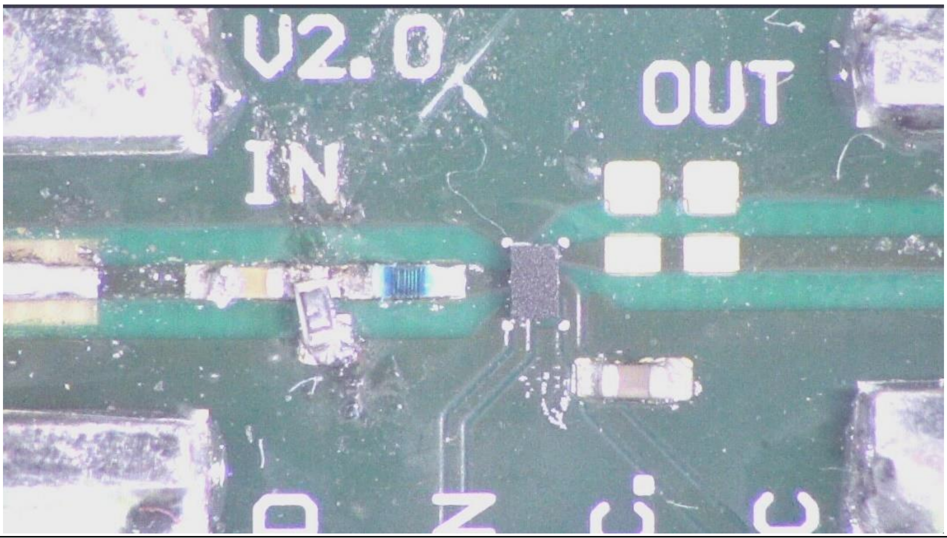

Figure 29 Evaluation board Option B (detailed view)

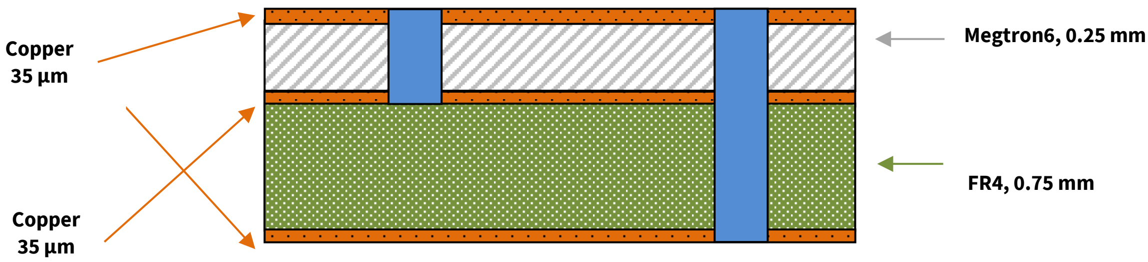

Figure 30 PCB layer information

5 Authors

Horson Hao, Staff Application Engineer of Business Unit “Radio Frequency and Sensors”

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

Trademarks of Infineon Technologies AG

µHVIC™, µIPM™, µPFC™, AU-ConvertIR™, AURIX™, C166™, CanPAK™, CIPOS™, CIPURSE™, CoolDP™, CoolGaN™, COOLiR™, CoolMOS™, CoolSET™, CoolSiC™, DAVE™, DI-POL™, DirectFET™, DrBlade™, EasyPIM™, EconoBRIDGE™, EconoDUAL™, EconoPACK™, EconoPIM™, EiceDRIVER™, eupec™, FCOS™, GaNpowIR™, HEXFET™, HITFET™, HybridPACK™, iMOTION™, IRAM™, ISOFACE™, IsoPACK™, LEDrivIR™, LITIX™, MIPAQ™, ModSTACK™, my-d™, NovalithIC™, OPTIGA™, OptiMOS™, ORIGA™, PowIRaudio™, PowIRStage™, PrimePACK™, PrimeSTACK™, PROFET™, PRO-SIL™, RASIC™, REAL3™, SmartLEWIS™, SOLID FLASH™, SPOC™, StrongIRFET™, SupIRBuck™, TEMPFET™, TRENCHSTOP™, TriCore™, UHVIC™, XHP™, XMC™

Trademarks updated November 2015

Other Trademarks

All referenced product or service names and trademarks are the property of their respective owners.

Edition 2021-02-09

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN2011_PL55_2012_082141