Ease-to-use broadband LNA BGA729N6 for sub 1GHz ISM applications

About this document

Scope and purpose

This application note describes Infineon's General Purpose MMIC: BGA729N6 as a low-noise amplifier (LNA) for ISM applications in the frequency range of 70 to 1000 MHz.

1. The BGA729N6 is a silicon germanium (SiGe) broadband LNA.
2. The target applications of this circuit are ISM applications in the range of 70 to 1000 MHz, and there are various types of applications in this range, such as LoRaWAN, NB-IoT, Zigbee, Wi-Fi HaLow, etc. Existing application notes AN441 covers other wireless broadcasting applications such as FM, DAB, DVB, etc.
3. In this application note, the performance of BGA729N6 is presented at 1.8 V and 2.8 V on a FR4 board. The circuit requires no external components for matching.
4. Key performance parameters at 2.8 V:

433 MHz

a) High-gain mode:
Noise figure (NF) = 1.05 dB
Insertion gain = 16.6 dB
Input return loss = 10 dB
Output return loss = 18 dB
Input P1dB = -16 dBm

b) Bypass mode:
NF = 5 dB
Insertion loss = 4 dB
Input return loss = 16 dB
Output return loss = 14 dB
Input P1dB = 6 dBm

866 MHz

a) High-gain mode:
NF = 1.05 dB
Insertion gain = 15.8 dB
Input return loss = 10 dB
Output return loss = 15 dB
Input P1dB = -15 dBm

b) Bypass mode:
NF = 5 dB
Insertion loss = 4 dB
Input return loss = 14 dB
Output return loss = 12 dB
Input P1dB = 6 dBm

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1 Introduction and product overview

1.1 Sub-1 GHz ISM applications

Sub-1 GHz includes various frequency bands allocated to a rich range of applications. We can classify them according to basic target functions into sub-groups: public safety systems, low-power wide-area network (LPWAN) systems closely linked to Internet of Things (IoT) operation, as well as wireless connectivity standards for short-range and long-range connections.

The graph in Figure 1 summarizes the various systems below 1 GHz.

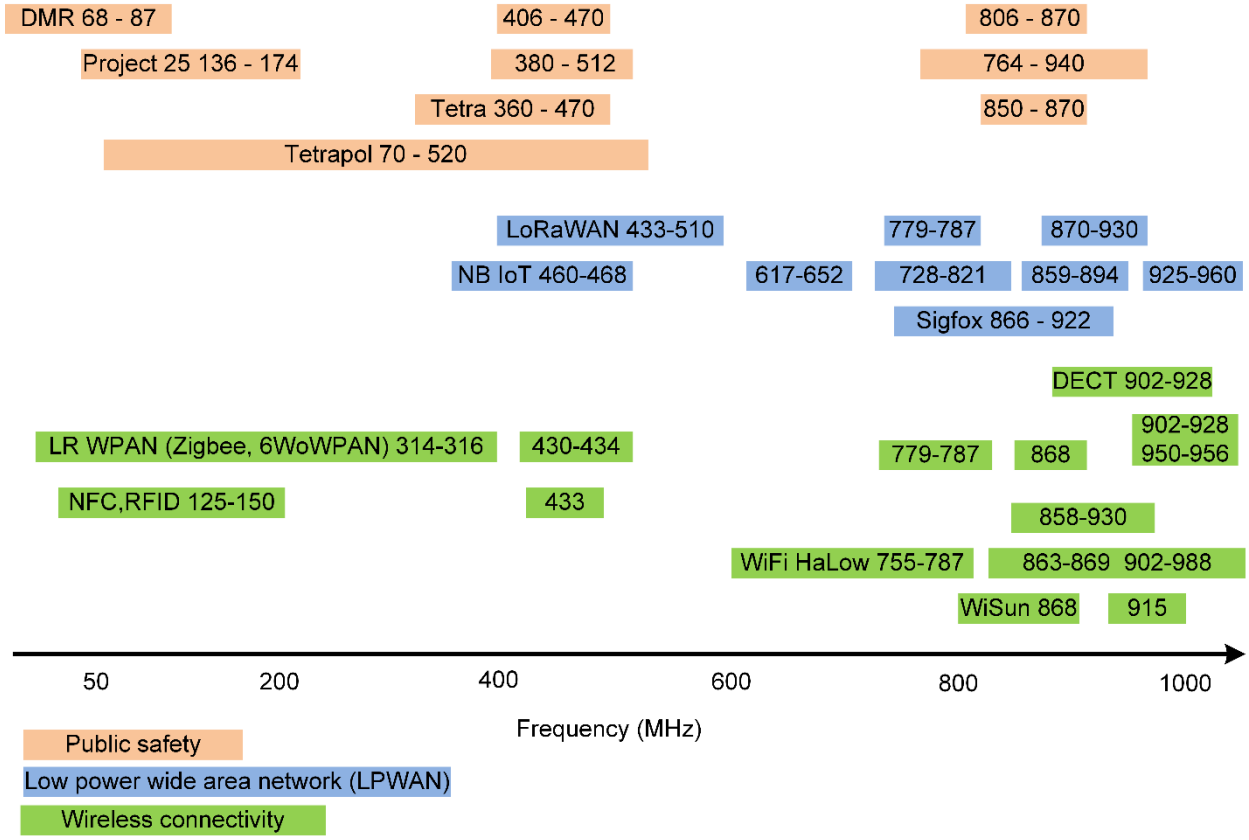


Figure 1 Frequency allocation for various RF systems sub-1 GHz

This application note focuses on target functions not related to multimedia wireless broadcasting. For a performance overview of BGA729N6 targeting wireless broadcasting applications such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB), please refer to application notes AN441 that is available on the BGA729N6 product pages.

1.2 RF front end of ISM applications sub-1 GHz

Generally, the receiver front end of a sub-1 GHz radio frequency (RF) system consists of a LNA to improve the sensitivity at weak RF signal conditions, and/or filters to suppress out-of-band interference before the main chipset. On the transmitter side, a power amplifier may be added to enhance the output level of the transmitted signal. Figure 2 shows a typical block diagram of a sub-1 GHz RF front end.

Infineon offers various components for sub-1 GHz ISM RF front ends. Integrated LNAs and RF switches are easy to use and require less design effort and shorter design cycle time. Discrete components such as RF transistors and diodes allow tailoring of the circuit performance according to specific needs. The electrostatic discharge (ESD) protection diodes protect the different types of ports and interfaces from electrical overstress. All related devices and datasheets are available online at https://www.infineon.com/cms/de/product/rf/.

This application note describes the performance of BGA729N6. It is an excellent broadband LNA featuring flat gain, low NF, a very low external part count and bypass/high-linearity mode.

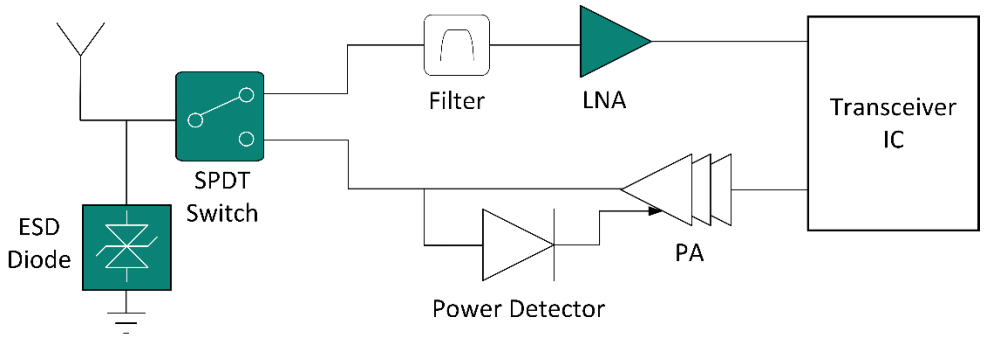


Figure 2 General block diagram – front end of a sub-1 GHz RF system

1.3 BGA729N6 overview

- Insertion power gain: 16.3 dB
- Insertion loss in bypass mode: -4.2 dB
- Low NF: 1.05 dB/4.3 dB in High gain/Bypass mode
- Low current consumption: 6.3 mA
- Power-off function
- Operating frequency: 70 to 1000 MHz
- Three-state control: Off, Bypass and High gain mode
- No external matching inductor required
- RF input and output internally matched to 50 Ω
- 2 kV HBM ESD protection (including AI pin)
- Pb-free (RoHS compliant) package

RoHS Halogen-Free Lead-Free Green

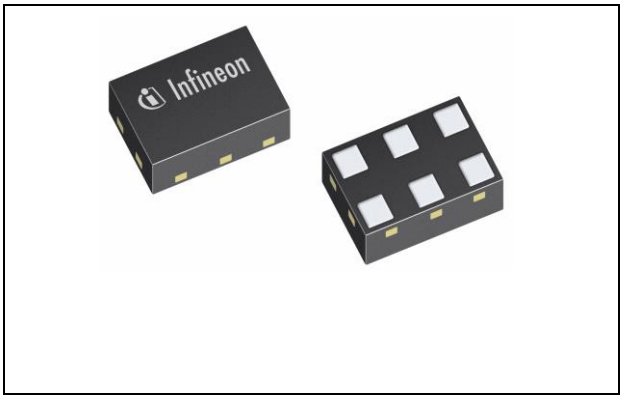


Figure 3 BGA729N6 in TSNP-6-2

Table 1 Pin assignment

Pin no.	Symbol	Function
1	GS	High gain/bypass control
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 circuit performance, schematics and bill of materials (BOM) are presented.

Device: BGA729N6

Application: BGA729N6 as broadband LNA for sub-1 GHz ISM applications

EVB order no.: EVAL BGA729N6 (AN671)

2.1 Summary of measurement results

Table 2 Electrical characteristics at T_A = 25°C, 2.8 V, f < 500 MHz

Parameter	Symbol	Value					Unit	Comment/test condition
Target applications		Tetrapol	Project 25, Tetrapol	Tetrapol	Tetra, Tetrapol	LoRaWAN, Tetra, Tetrapol		
Frequency	Freq.	88	170	230	360	433	MHz	
DC voltage	V_{CC}	2.8					V	
DC current	I_{CC}	6.6/0.55					mA	HG/BP mode
High-gain mode V_{PON} = 2.8 V, V_{BP} = 0 V								
Gain	G	17.2	17.0	16.9	16.7	16.6	dB	
Noise figure	NF	0.95	0.95	1.00	1.05	1.05	dB	
Input return loss	RL_{IN}	9	10	10	10	10	dB	
Output return loss	RL_{OUT}	20	20	20	19	18	dB	
Reverse isolation	I_{REV}	27	27	27	27	27	dB	
Input P1dB	IP1dB	-18	-17	-16	-16	-16	dBm	
Input IP3	IIP3	-4	-4	-4	-3	-3	dBm	P_{IN} = -30 dBm, Δf = 1 MHz
Bypass mode V_{PON} = 2.8 V, V_{BP} = 2.8 V								
Gain	G	-7	-6	-5	-4	-4	dB	
Noise figure	NF	8.0	6.0	5.0	5.0	5.0	dB	
Input return loss	RL_{IN}	5	9	11	15	16	dB	
Output return loss	RL_{OUT}	11	12	13	14	14	dB	
Reverse isolation	I_{REV}	7	6	5	5	5	dB	
Input P1dB	IP1dB	6	6	6	6	6	dBm	
Input IP3	IIP3	22	22	21	21	21	dBm	P_{IN} = -10 dBm, Δf = 1 MHz

Table 2 Electrical characteristics at T_A = 25°C, 2.8 V, f < 500 MHz

Parameter	Symbol	Value	Unit	Comment/test condition
Stability	K	> 1		All modes, less than or equal to 10 GHz

Table 3 Electrical characteristics at T_A = 25°C, 1.8 V, f < 500 MHz

Parameter	Symbol	Value					Unit	Comment/test condition
Target applications		Tetrapol	Project 25, Tetrapol	Tetrapol	Tetra, Tetrapol	LoRaWAN, Tetra, Tetrapol		
Frequency	Freq.	88	170	230	360	433	MHz	
DC voltage	V_{CC}	1.8					V	
DC current	I_{CC}	6.3/0.3					mA	HG/BP mode
High-gain mode V_{PON} = 1.8 V, V_{BP} = 0 V								
Gain	G	17.0	16.9	16.8	16.6	16.5	dB	
Noise figure	NF	0.95	0.95	1.00	1.05	1.05	dB	
Input return loss	RL_{IN}	9	10	10	10	10	dB	
Output return loss	RL_{OUT}	20	20	20	19	18	dB	
Reverse isolation	I_{REV}	27	27	27	27	27	dB	
Input P1dB	IP1dB	-18	-17	-16	-16	-16	dBm	
Input IP3	IIP3	-4	-4	-4	-4	-4	dBm	P_{IN} = -30 dBm, Δf = 1 MHz
Bypass mode V_{PON} = 1.8 V, V_{BP} = 1.8 V								
Gain	G	-7	-6	-5	-5	-5	dB	
Noise figure	NF	8.0	6.0	5.0	5.0	5.0	dB	
Input return loss	RL_{IN}	5	9	11	15	16	dB	
Output return loss	RL_{OUT}	11	12	13	14	14	dB	
Reverse isolation	I_{REV}	7	6	5	5	5	dB	
Input P1dB	IP1dB	4	4	4	4	3	dBm	
Input IP3	IIP3	17	17	16	16	16	dBm	P_{IN} = -10 dBm, Δf = 1 MHz
Stability	K	> 1						All modes, less than or equal to 10 GHz

Table 4 Electrical characteristics at T_A = 25°C, 2.8 V, f >= 500 MHz

Parameter	Symbol	Value					Unit	Comment/test condition
Target applications		Project 25 Tetrapol	NB-IoT	LRWPAN Wi-Fi HaLow	LoRaWAN/NFC/ RFID/ Zigbee/ Tetra/ Wi-SUN	LR-WPAN/ Wi-Fi HaLow/ Wi-SUN		
Frequency	Freq.	510	630	760	866	950	MHz	
DC voltage	V_{CC}	2.8					V	
DC current	I_{CC}	6.6/0.55					mA	HG/BP mode
High-gain mode V_{PON} = 2.8 V, V_{BP} = 0 V								
Gain	G	16.4	16.2	15.9	15.8	15.8	dB	
Noise figure	NF	1.05	1.05	1.05	1.05	1.05	dB	
Input return loss	RL_{IN}	10	10	10	10	9	dB	
Output return loss	RL_{OUT}	18	17	16	15	14	dB	
Reverse isolation	I_{REV}	27	27	27	27	27	dB	
Input P1dB	IP1dB	-16	-15	-15	-15	-15	dBm	
Input IP3	IIP3	-3	-3	-3	-3	-2	dBm	P_{IN} = -30 dBm, Δf = 1 MHz
Bypass mode V_{PON} = 2.8 V, V_{BP} = 2.8 V								
Gain	G	-7	-6	-5	-4	-4	dB	
Noise figure	NF	8.0	6.0	5.0	5.0	5.0	dB	
Input return loss	RL_{IN}	17	16	15	14	13	dB	
Output return loss	RL_{OUT}	13	13	12	12	12	dB	
Reverse isolation	I_{REV}	4	4	4	5	5	dB	
Input P1dB	IP1dB	6	6	6	6	6	dBm	
Input IP3	IIP3	22	23	24	24	25	dBm	P_{IN} = -10 dBm, Δf = 1 MHz
Stability	K	> 1						All modes, less than or equal to 10 GHz

Table 5 Electrical characteristics at T_A = 25°C, 1.8 V, f >= 500 MHz

Parameter	Symbol	Value					Unit	Comment/test condition
Target applications		Project 25 Tetrapol	NB-IoT	LR-WPAN Wi-Fi HaLow	LoRaWAN/NFC/ RFID/ Zigbee/Tetra/ Wi-SUN	LR-WPAN/ Wi-Fi HaLow/ Wi-SUN		
Frequency	Freq.	510	630	760	866	950	MHz	
DC voltage	V_{CC}	1.8					V	
DC current	I_{CC}	6.3/0.3					mA	HG/BP mode
High-gain mode V_{PON} = 1.8 V, V_{BP} = 0 V								
Gain	G	16.4	16.0	15.8	15.7	15.7	dB	
Noise figure	NF	1.05	1.05	1.05	1.05	1.10	dB	
Input return loss	RL_{IN}	10	10	10	10	9	dB	
Output return loss	RL_{OUT}	18	17	15	14	13	dB	
Reverse isolation	I_{REV}	27	27	27	27	27	dB	
Input P1dB	IP1dB	-16	-16	-15	-15	-15	dBm	
Input IP3	IIP3	-5	-5	-5	-4	-3	dBm	P_{IN} = -30 dBm, Δf = 1 MHz
Bypass mode V_{PON} = 1.8 V, V_{BP} = 1.8 V								
Gain	G	-7	-6	-5	-5	-5	dB	
Noise figure	NF	8.0	6.0	5.0	5.0	5.0	dB	
Input return loss	RL_{IN}	16	15	14	13	12	dB	
Output return loss	RL_{OUT}	14	13	12	12	12	dB	
Reverse isolation	I_{REV}	5	6	5	5	5	dB	
Input P1dB	IP1dB	3	4	5	5	6	dBm	
Input IP3	IIP3	16	17	18	19	20	dBm	P_{IN} = -10 dBm, Δf = 1 MHz
Stability	K	> 1						All modes, less than or equal to 10 GHz

2.2 Schematic and bill of materials

The schematic is shown in Figure 4, and its bill of materials is shown in Table 6.

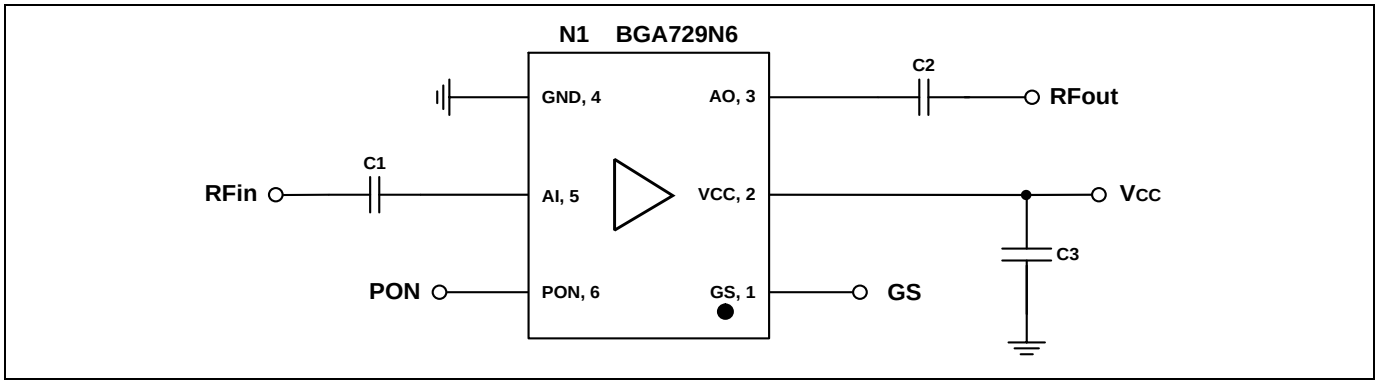


Figure 4 Schematic of the BGA729N6 application circuit

Table 6 Bill of Materials (BOM)

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0201	Various	DC block LNA input[1) 3)]
C2	1	nF	0201	Various	DC block LNA output[1)]
C3	1	nF	0201	Various	RF bypass[2)]
N1	BGA729N6		TSNP-6-2	Infineon Technologies	SiGe LNA

1) DC-block function is NOT integrated at the input pin and output pin. DC-block capacitor is not necessary if the DC-block function on the RF input or output line can be ensured by the previous or subsequent stage.
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) The value of C1 may be changed to 100 pF resulting in a faster off-to-on switching time. For reducing switching time, lower DC-block cap value is recommended. C1 = 100 pF enables less than 3 µS switching time.

Table 7 Mode selection table

Control pins	V_{PON}	V_{BP}	Operation mode	Comment
Status	High	Low	High gain	
	High	High	Bypass	
	Low	Low	Off	

3 Measurement graphs

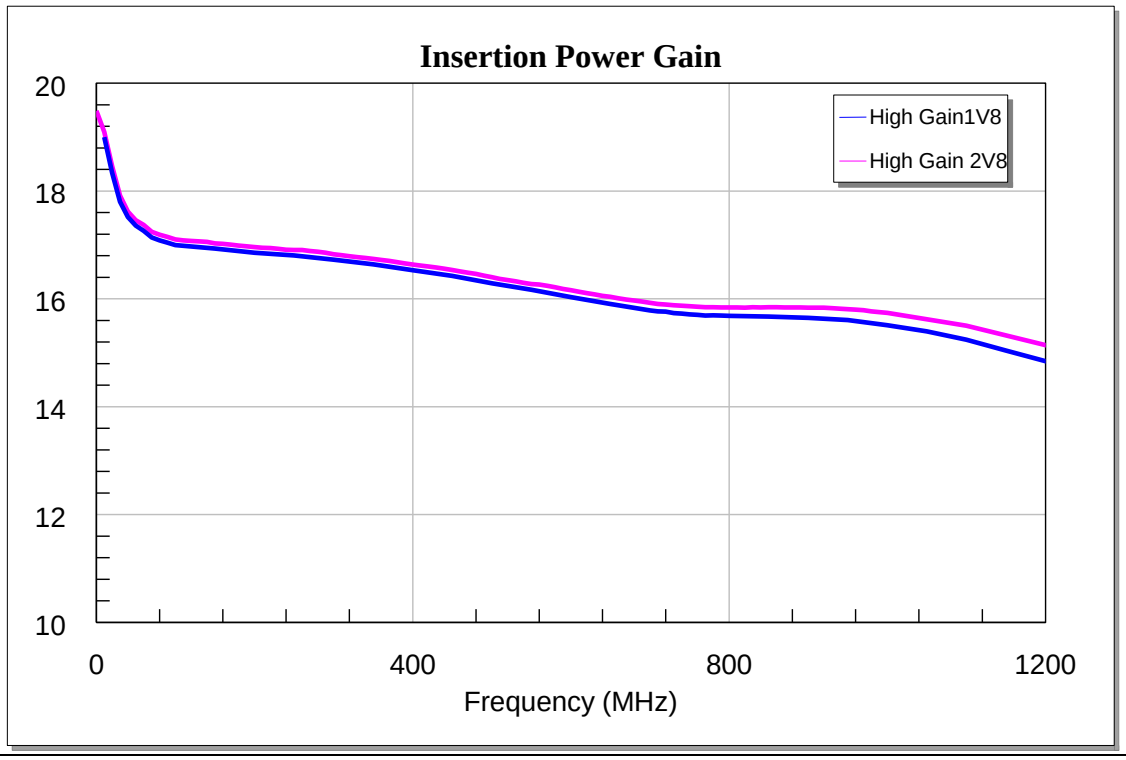


Figure 5 Insertion power gain (high-gain mode, narrowband)

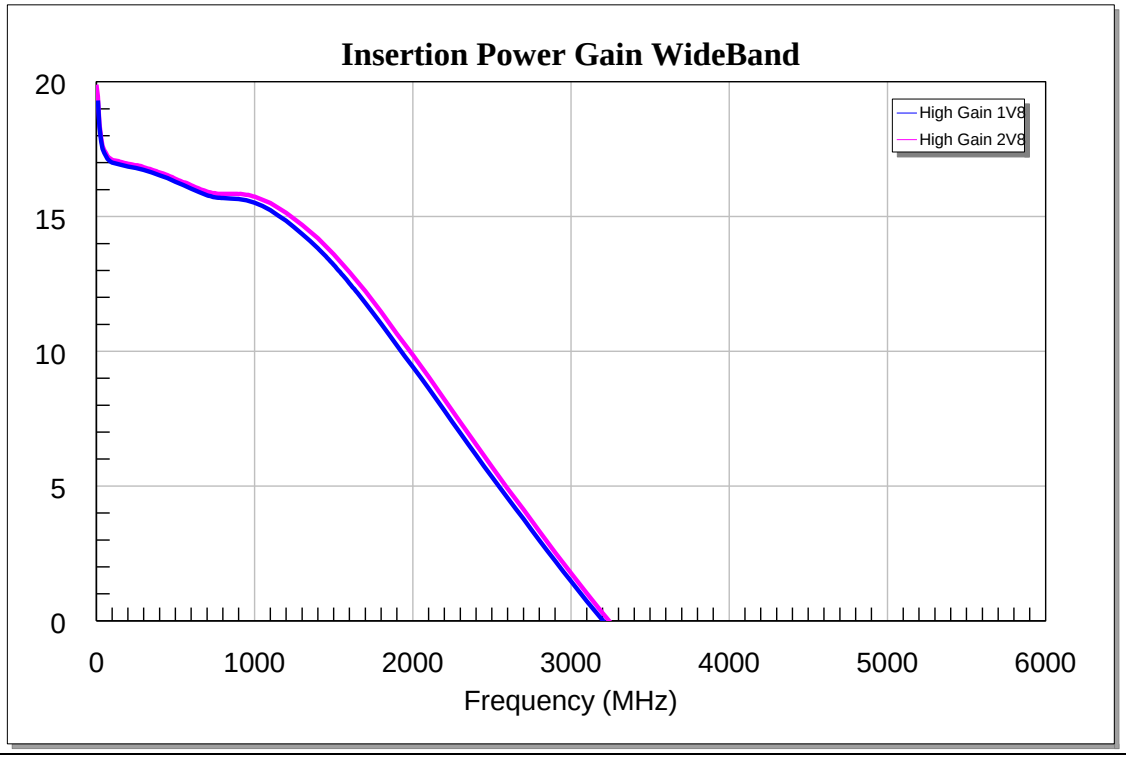


Figure 6 Insertion power gain (high-gain mode, wideband)

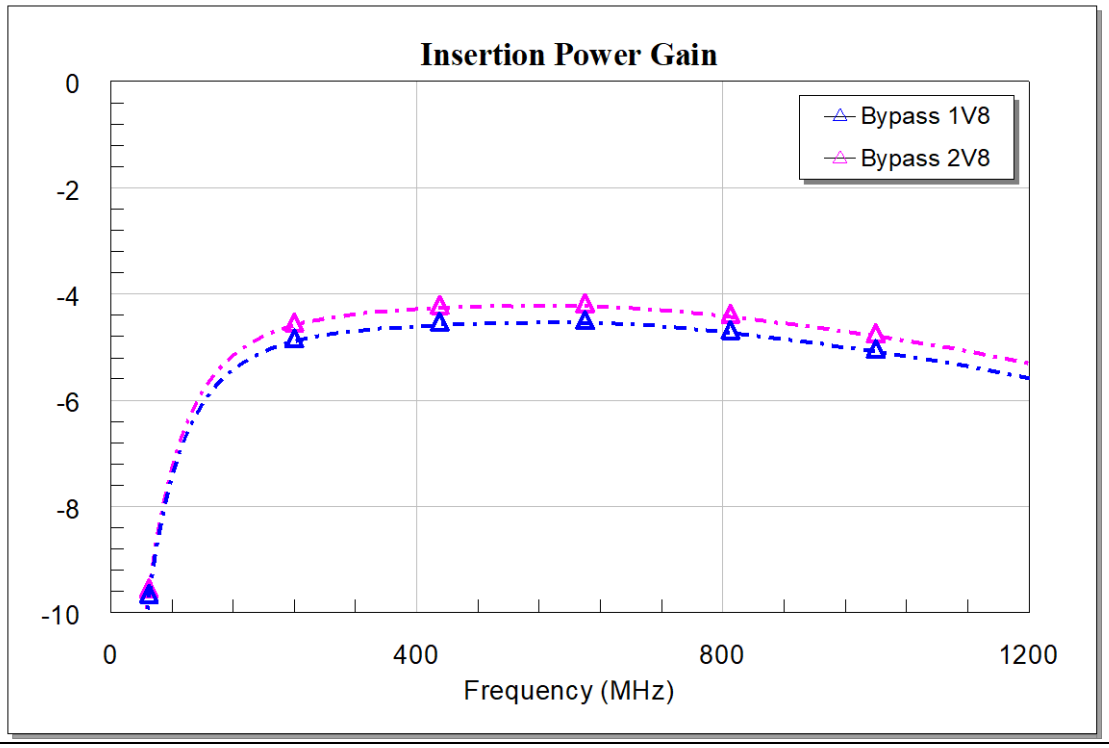


Figure 7 Insertion power gain (bypass mode, narrowband)

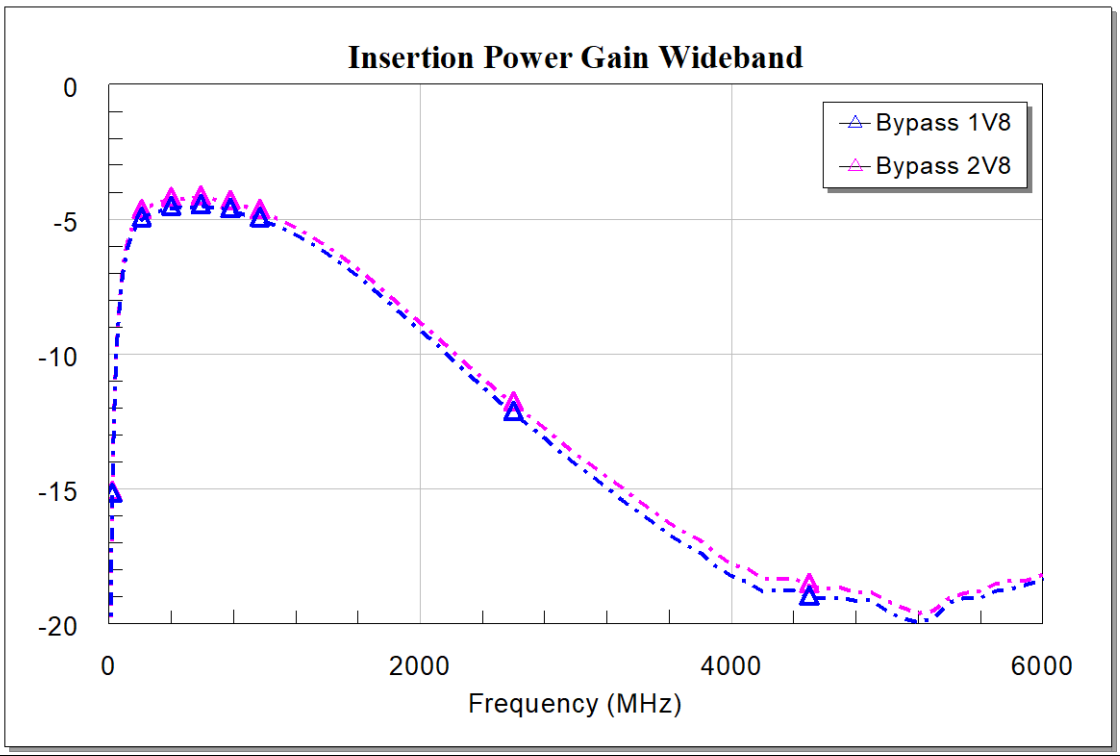


Figure 8 Insertion power gain (bypass mode, wideband)

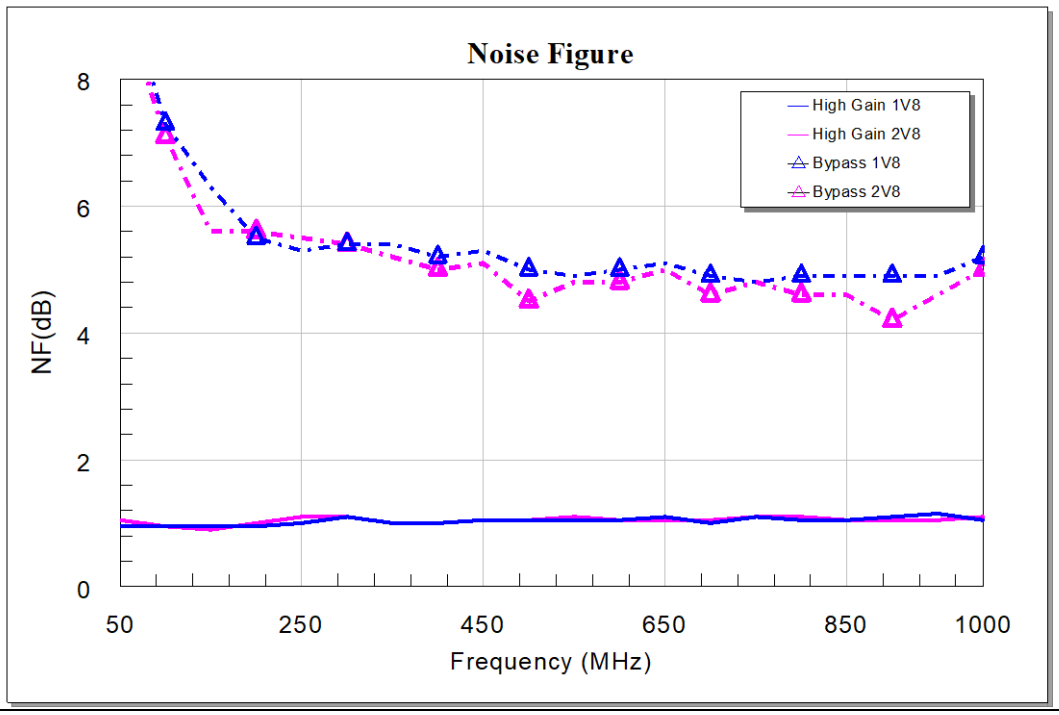


Figure 9 NF (SMA and connector losses de-embedded)

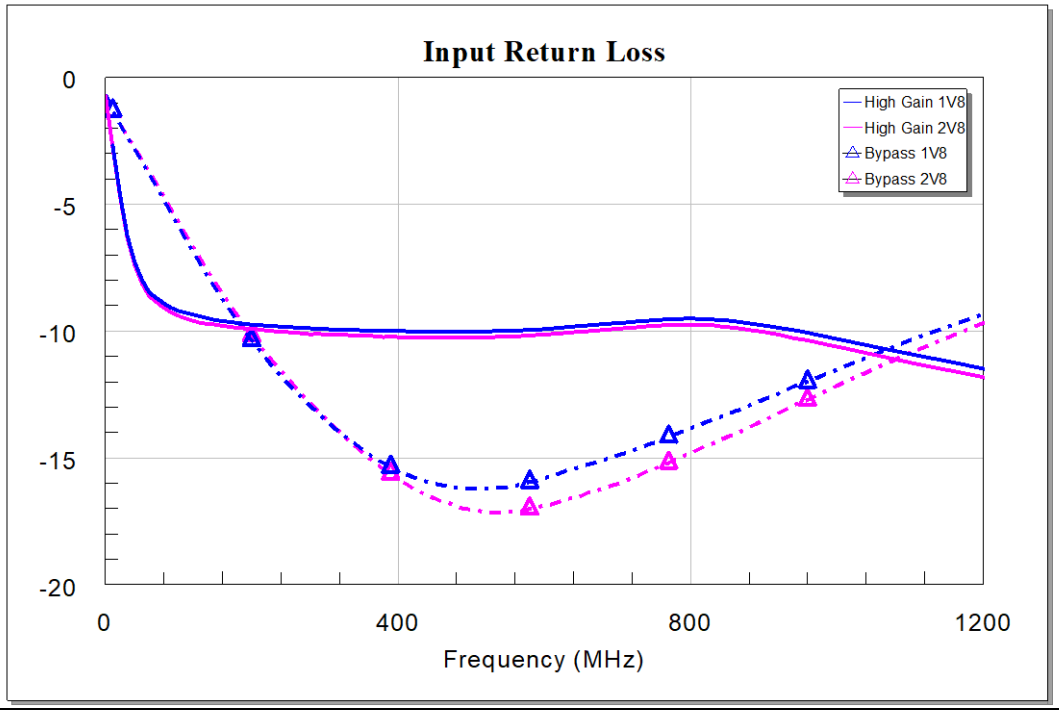


Figure 10 Input return loss

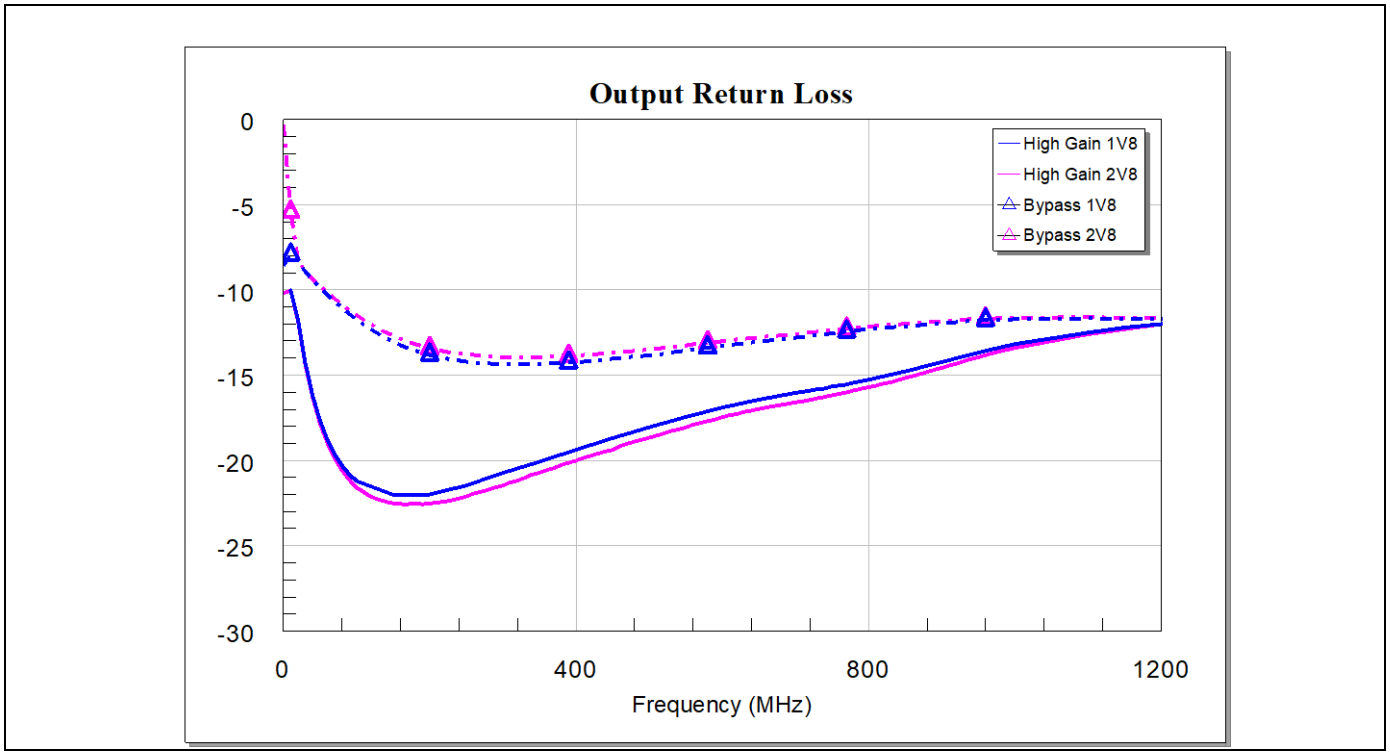


Figure 11 Output return loss

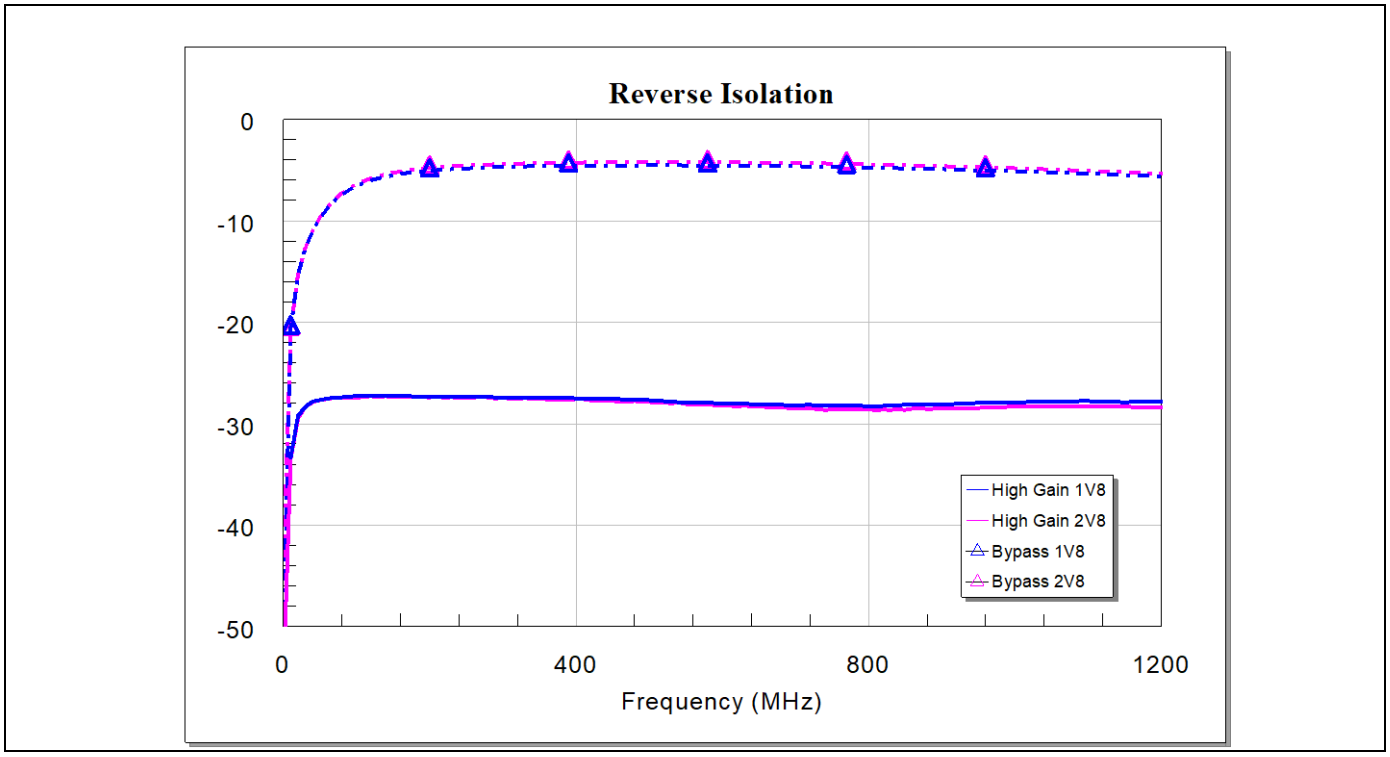


Figure 12 Reverse isolation

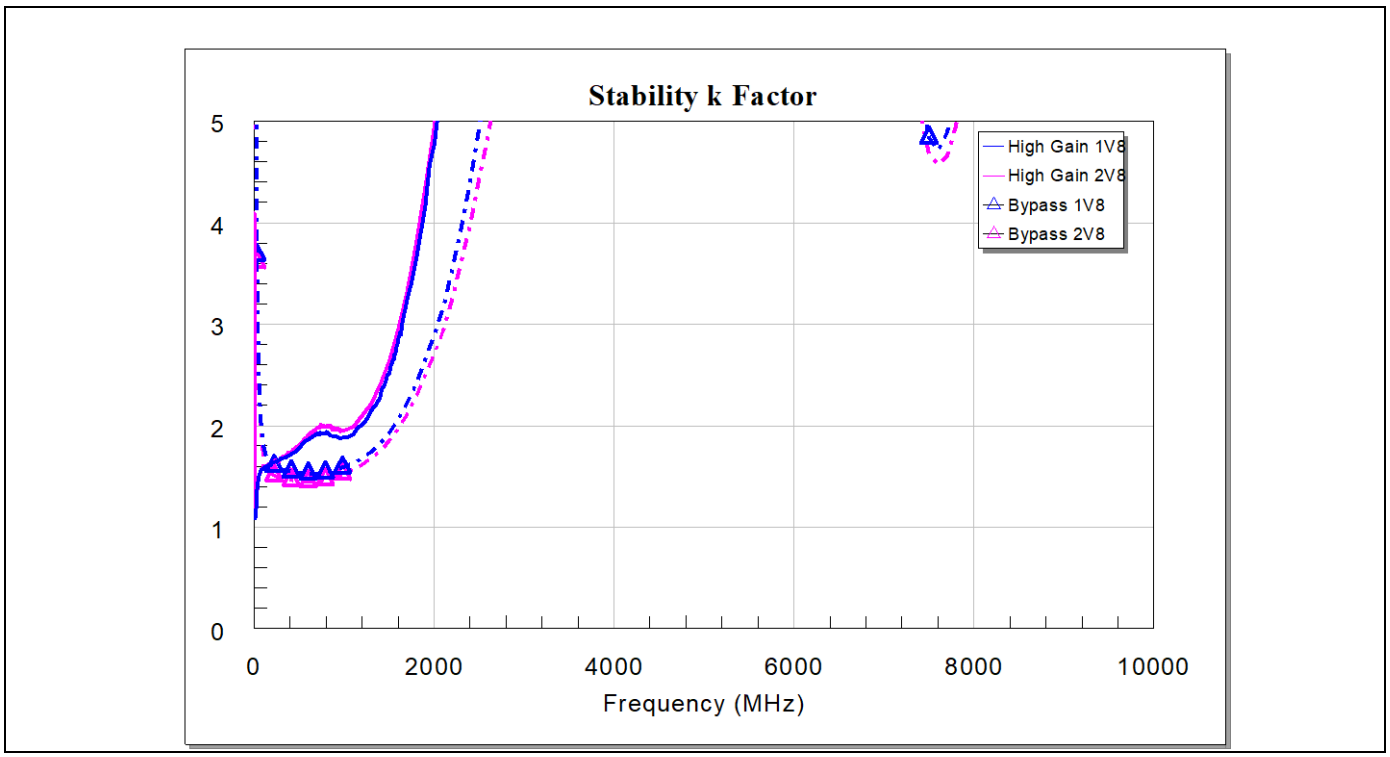


Figure 13 Stability k-factor

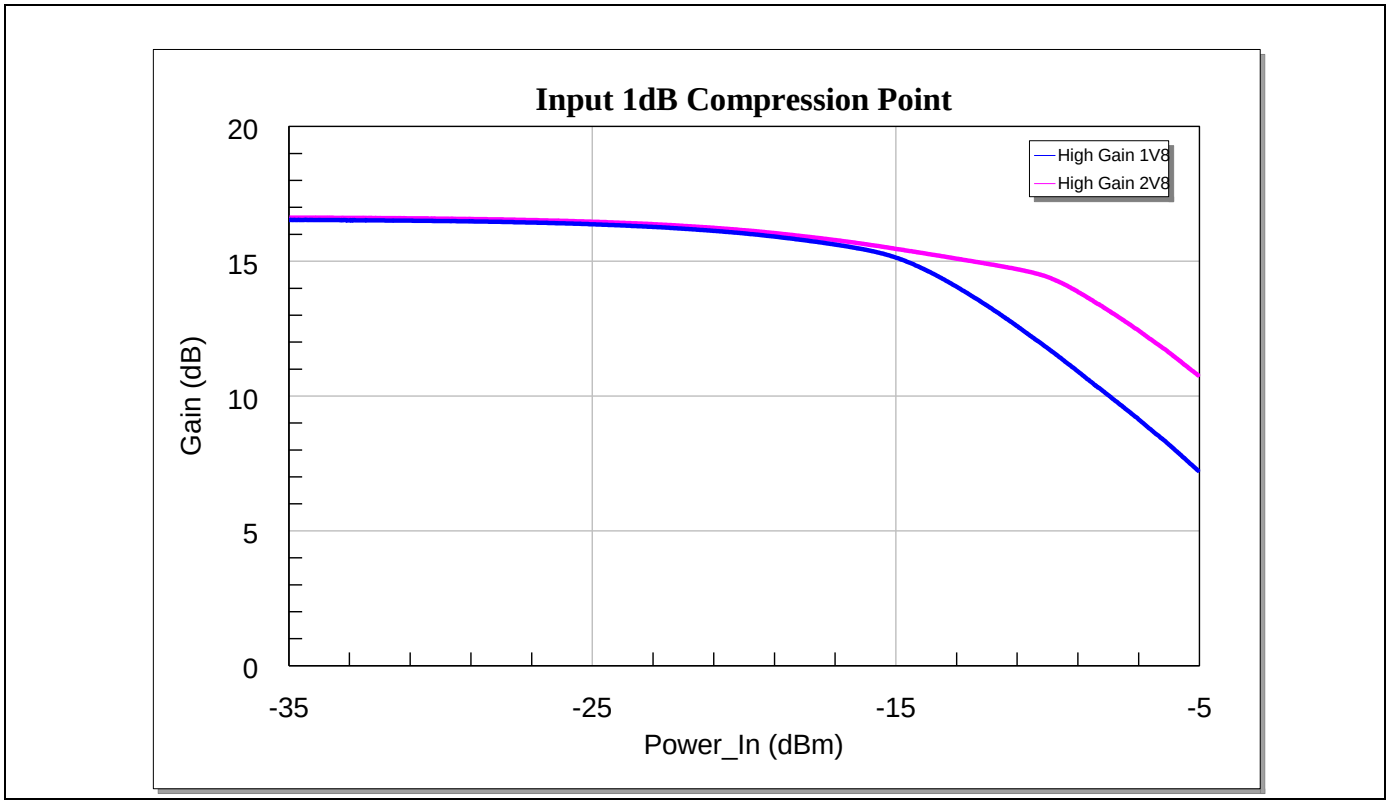


Figure 14 Input 1 dB compression point 433 MHz (high-gain mode)

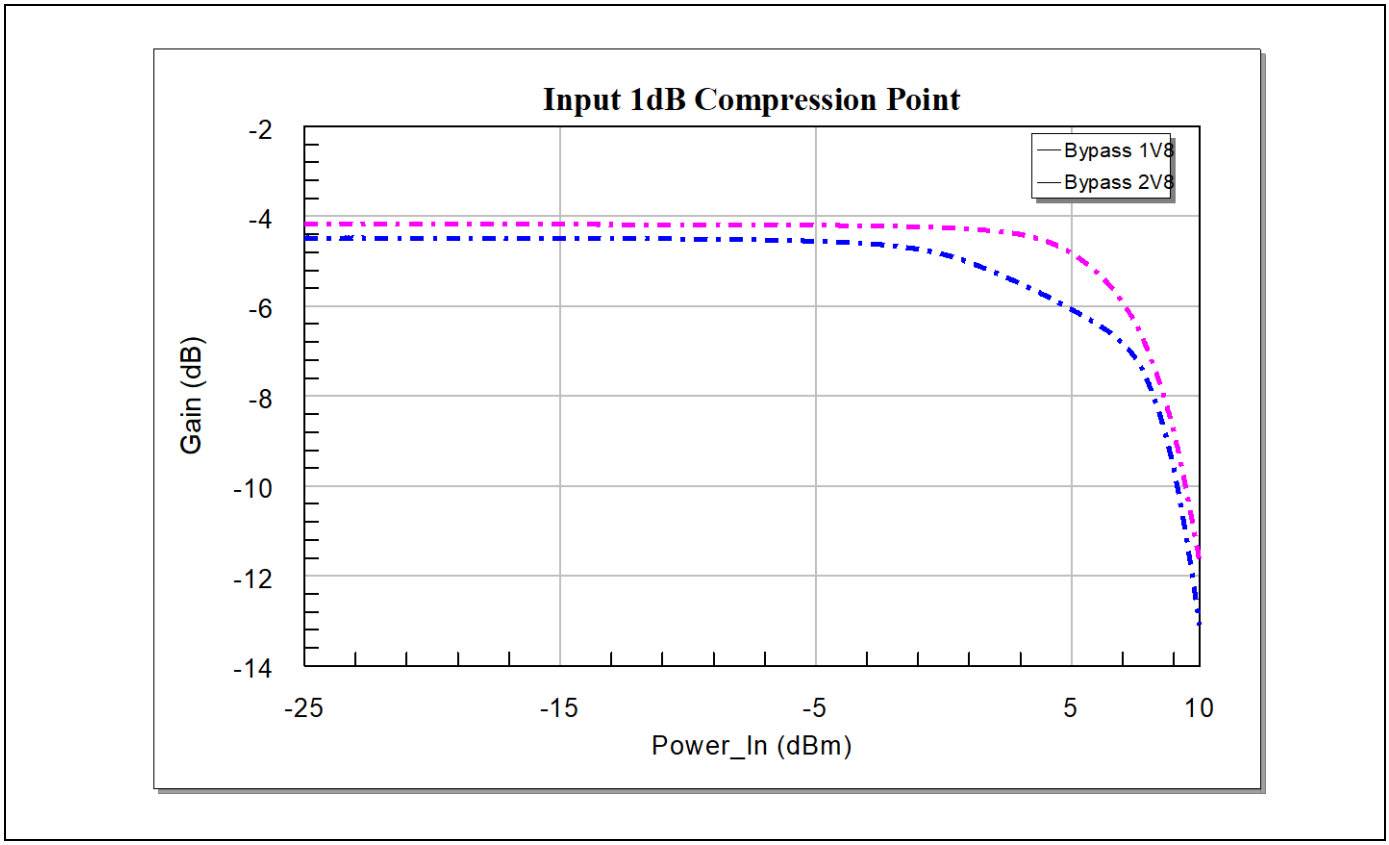


Figure 15 Input 1 dB compression point 433 MHz (bypass mode)

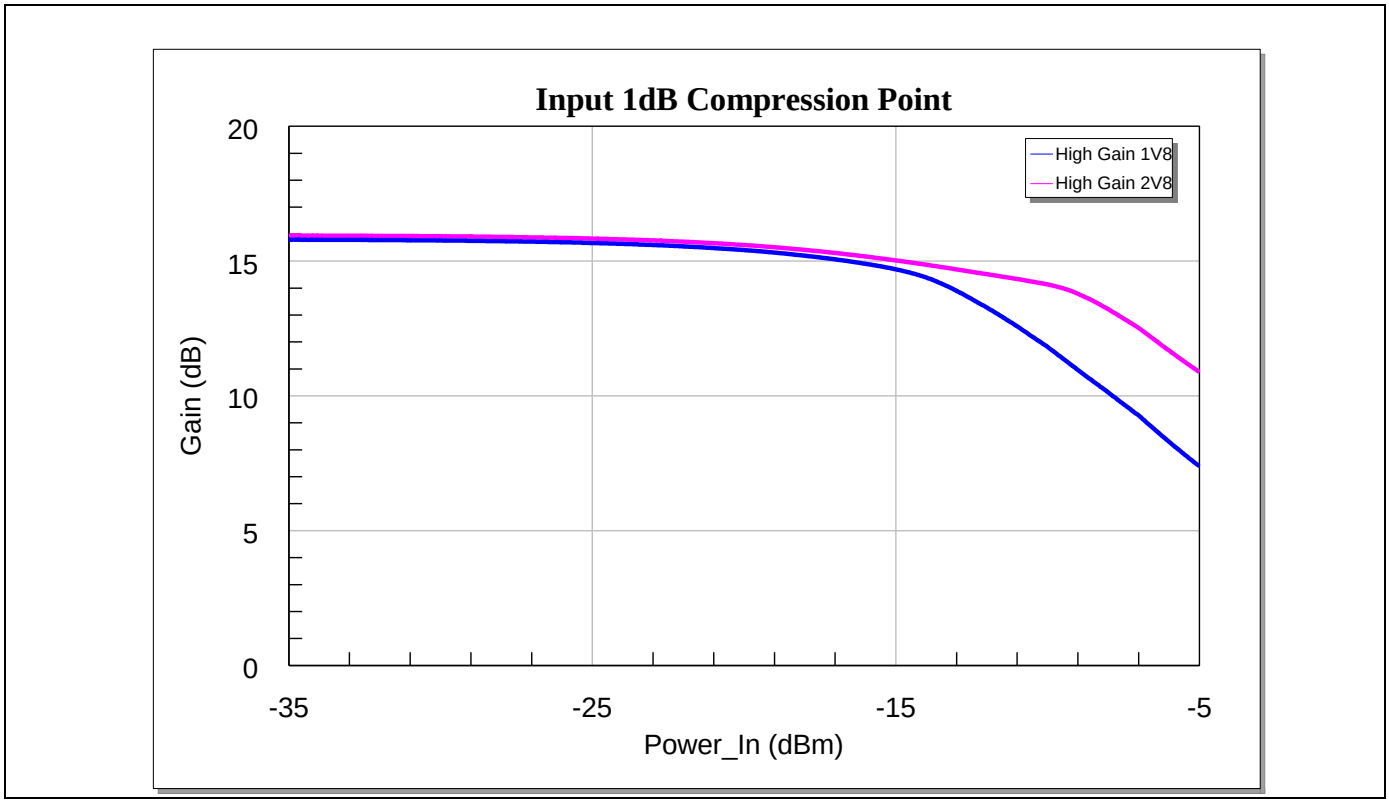


Figure 16 Input 1 dB compression point 866 MHz (high-gain mode)

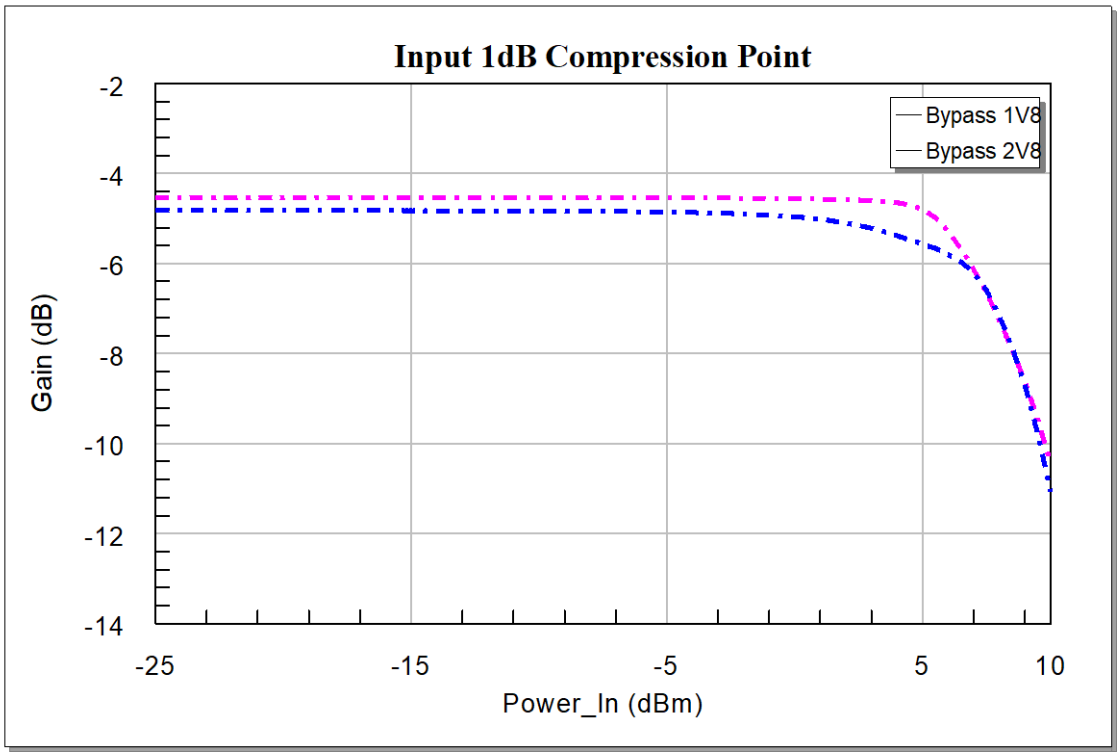


Figure 17 Input 1 dB compression point 866 MHz (bypass mode)

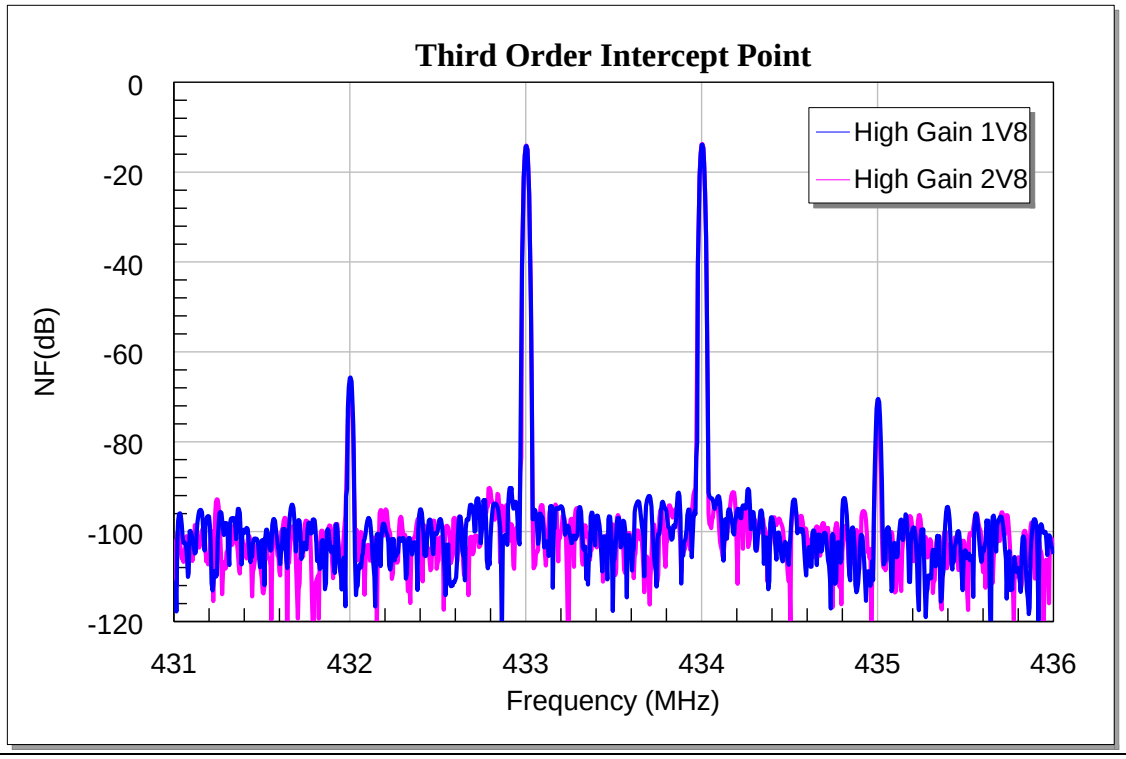


Figure 18 Inband third-order intermodulation point (high-gain mode, 433 MHz)

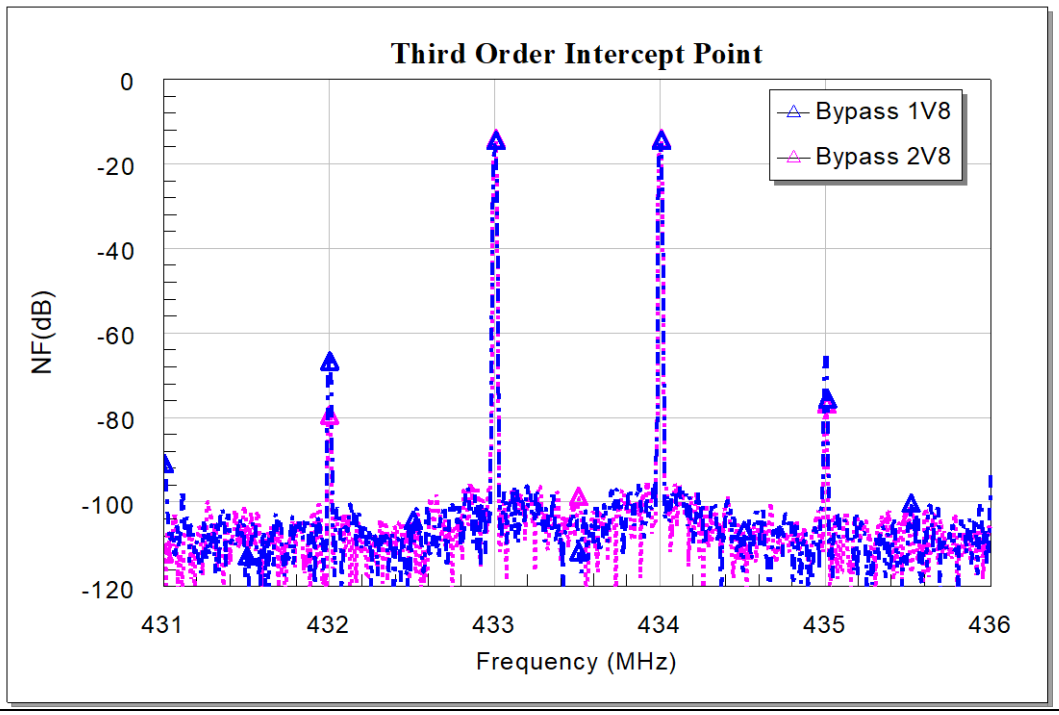


Figure 19 Inband third-order intermodulation point (bypass mode, 433 MHz)

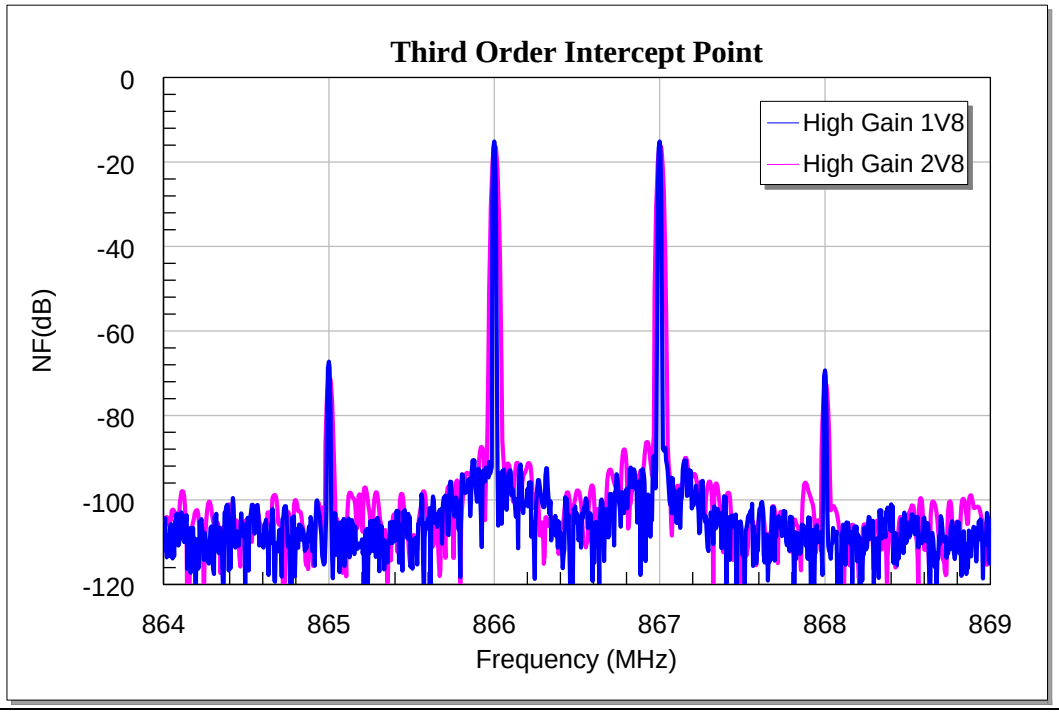


Figure 20 Inband third-order intermodulation point (high-gain mode, 866 MHz)

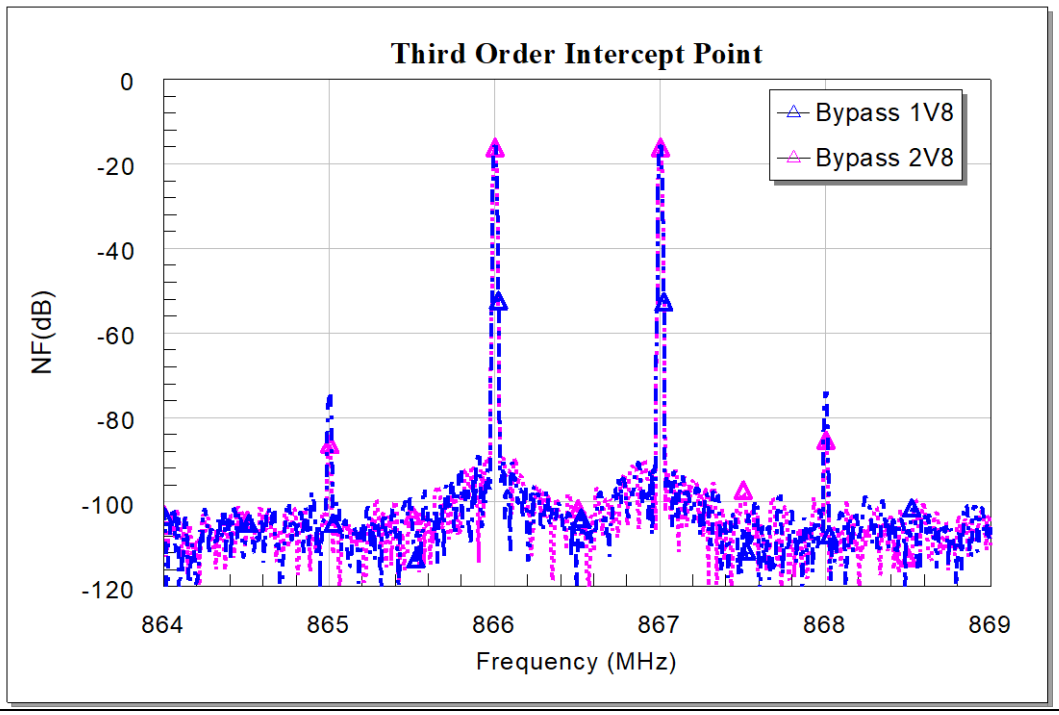


Figure 21 Inband third-order intermodulation point (bypass mode, 866 MHz)

4 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: **M150901**

PCB material: **FR4**

ε_r of PCB material: **4.4**

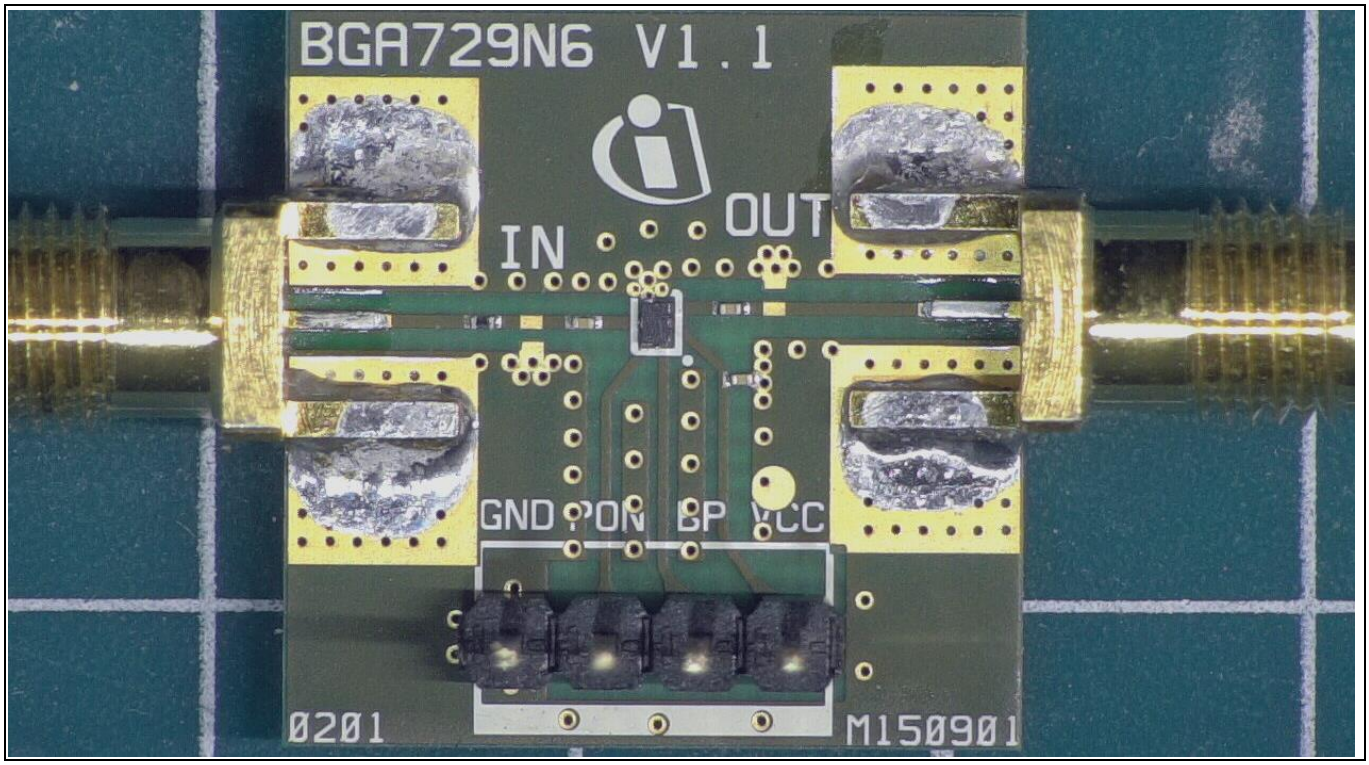


Figure 22 Evaluation board (overview)

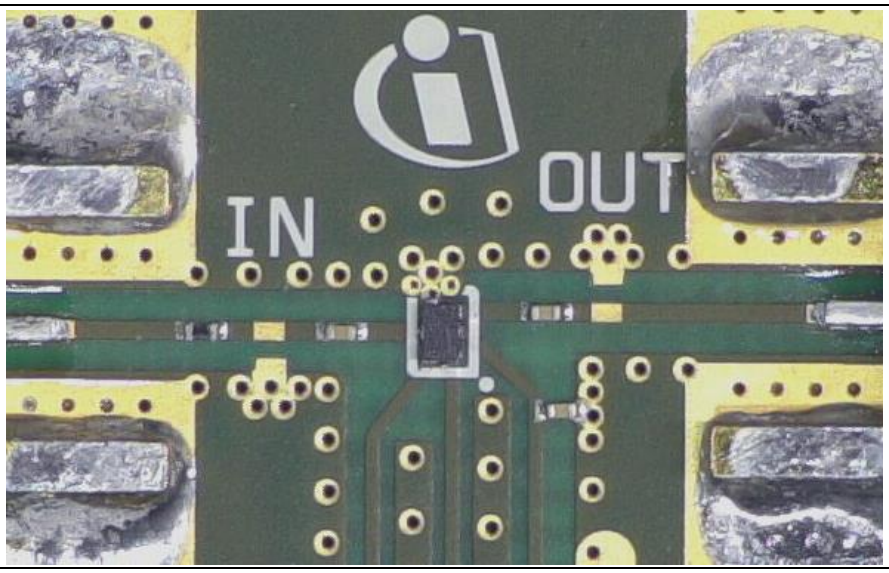


Figure 23 Evaluation board (detailed view)

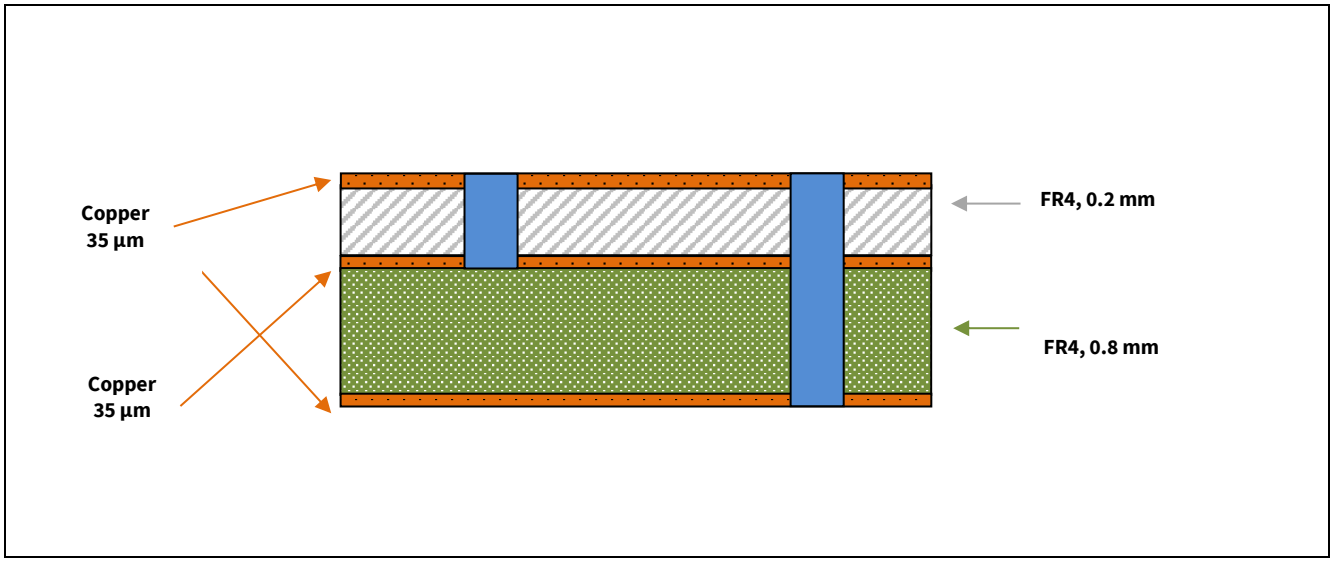


Figure 24 PCB layer information

5 Authors

Xiang Li, Senior Staff Application Engineer of Business Unit “Radio Frequency and Sensors”

Stefan Mueller, Working Student of Business Unit “Radio Frequency and Sensors”

6 References

1. LPWAN https://en.wikipedia.org/wiki/Low-power_wide-area_network
2. LR-WPAN https://en.wikipedia.org/wiki/IEEE_802.15.4, https://ieeexplore.ieee.org/document/6012487
3. LoRaWAN https://lora-alliance.org/
4. NB-IoT https://en.wikipedia.org/wiki/Narrowband_IoT
5. Sigfox https://en.wikipedia.org/wiki/Sigfox
6. Wi-Fi HaLow https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-halow
7. Wi-SUN https://wi-sun.org/

Revision history

Major changes since the last revision

Page or reference	Description of change

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Edition 2023-07-31

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference
AN_2307_PL55_2308_154726

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