Broadband MMIC : BGA729N6

Low Noise Amplifier for Portable and Mobile TV Applications and FM Radio Application

Application Note AN441

About this document

Scope and purpose

This application note describes Infineon's BGA729N6 for portable and mobile apppliations and FM radio application in the range of 70 – 1000 MHz.

1. The BGA729N6 is a Silicon Germanium broadband Low Noise Amplifier (LNA).
2. It supports the portable and mobile TV applications and the FM radio application.
3. In this application note, the performance of BGA729N6 is presented. The circuit requires no external components for matching. The performance is measured on a FR4 board.
4. Key performance parameters at 2.8V, 470 MHz
   a) High Gain Mode:
   Noise Figure = 1.05 dB
   Insertion Gain = 16.5 dB
   Input return loss = 9.7 dB
   Output return loss = 17.7 dB
   Input P1dB = -15.8 dBm

   b) Bypass Mode:
   Noise figure = 5.0 dB
   Insertion Loss = 4.2 dB
   Input return loss = 15.5 dB
   Output return loss = 12.9 dB
   Input P1dB = 5.9 dBm

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

1 Introduction of Mobile TV and FM Radio Applications

1.1 Mobile TV application overview

Mobile phones today are all-in-one devices. They have not only wireless functions for voice and data but also entertainment features. Mobile TV is one of the most fascinating features. It brings live news and entertainment programs onto the phone display and enables people not to miss their favorite programs.

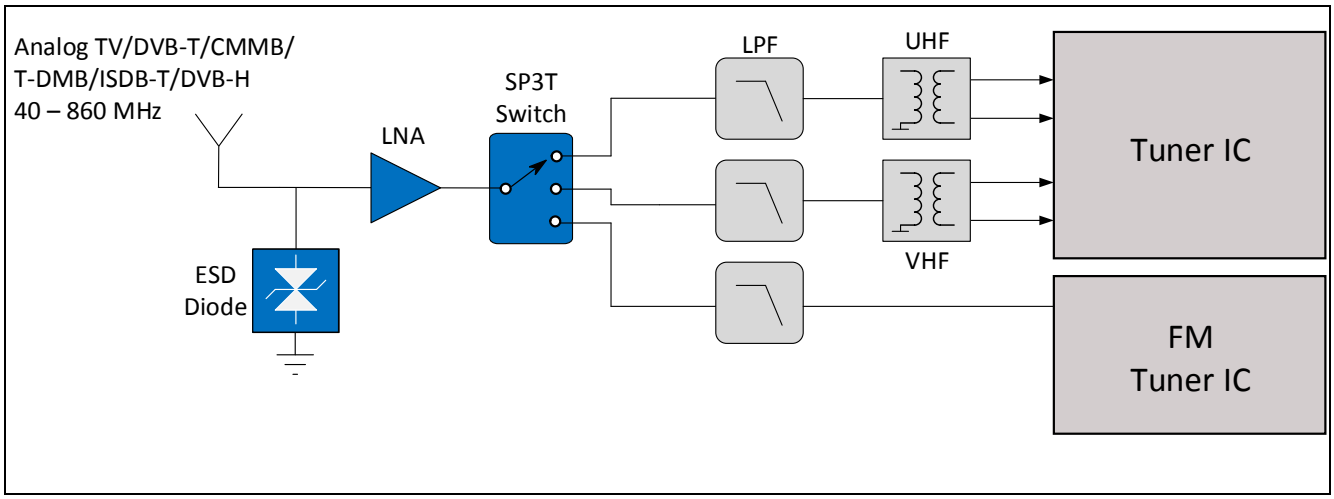


Figure 1 Application Diagram: Mobile TV and FM Reception in Mobile Phones with Band Selection Switch

1.2 Infineon's devices for the Mobile TV application

Infineon's mobile TV LNA BGA729N6 is especially designed for the mobile TV reception with 50-Ohm interfaces, while our RF transistors offer cost-effective solutions to improve the signal-to-noise ratio and therefore the quality of the TV reception. Those LNAs together with Infineon's ESD protection diode from the ESD108-B1-CSP0201 and ESD103-B1-02EL/02ELS series improve systems' ESD performance up to 8 kV contact discharge (IEC61000-4-2) at the antenna input. The parasitic capacitance is only 0.2 pF.

Infineon's SP3T switch series can be used to switch between the mobile TV tuner IC and the FM tuner IC.

1.3 Requirement of the Mobile TV application on the Low Noise Amplifier

Low Noise Figure & High Gain

An external LNA or LNA module boosts the sensitivity of the system by reducing the overall NF. In addition due to the size constraint, the modem antenna and the receiver FE cannot always be placed close to the transceiver Integrated Circuit (IC). The path loss in front of the integrated LNA on the transceiver IC increases the system NF significantly. An external LNA physically close to the antenna can help to eliminate

the path loss and reduce the system NF. The sensitivity can be improved by several dB, which means a significant increase in the connectivity range

High Linearity (1-dB compression point P1dB and 3rd-order intercept point IP3): An increased number of bands at the receiver input create strong interference, leading to high requirements in linearity characteristics such as high input 1-dB compression point, 2nd intermodulation (IMD2) products and input IP3 performance.

Stable Gain:

The portable and mobile TV application ranges from 170 MHz to 960 MHz, a stable gain over this broad frequency range is a key requirement to the mobile TV LNA.

1.4 FM Radio application overview

Frequency Modulation (FM) radio has a long history, starting from its development in 1933. Today, FM radio is an integral part of almost all mobile phones. The headset cable can serve as an antenna for FM reception. Its size (~75 cm) is ideal to have good reception. Nevertheless, no FM reception is possible when the headset is not available.

There is a clear market trend to be able to use FM radio without the headset cable, meaning that the antenna has to be integrated inside the phone. However, there are space constraints on the antenna design. Shrinking the size of the antenna introduces a high loss in the system which reduces the receiver's sensitivity.

1.5 BGA729N6 as Low Noise Amplifier for the FM Radio application

The BGA729N6 also covers the FM radio frequencies, and is a potential solution as low noise amfplifier for FM radio application. The LNA is prematched as a 50 Ohm solution, it solves the problem of the short FM antenna in mobile phones through better impedance match between the FM antenna and the FM receiver. Therefore, it can keep the sytem signal-to-noise ratio as good as with a headset.

2 BGA729N6 Overview

2.1 Features

- Insertion power gain: 16.3 dB
- Insertion Loss in bypass mode: -4.2 dB
- Low noise figure: 1.05 dB / 4.3 dB in high gain / bypass mode
- Low current consumption: 6.3 mA
- Power off function
- Operating frequency: 70 -1000 MHz
- Three-state control: OFF-, Bypass- and High gain-Mode
- Supply voltage: 1.5 V to 3.3 V
- Ultra small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm2)
- B7HF Silicon Germanium technology
- No external matching inductor required
- RF input and output internally matched to 50Ω
- Only 2 external SMD components necessary
- 2kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package



Figure 2 BGA729N6 in TSNP-6-2

2.2 Key Applications of BGA729N6

The BGA729N6 is a broadband low power low noise amplifier (LNA) MMIC for portable and mobile TV applications and FM radio application.

2.3 Description

The BGA729N6 is a broadband low power low noise amplifier (LNA) MMIC for portable and mobile TV applications and FM radio application which covers a wide frequency range from 70 MHz to 1000 MHz. The LNA provides 16.3 dB gain and 1.05 dB noise figure at a current consumption of 6.3 mA in the application configuration described in Chapter 3. In bypass mode, the LNA provides an insertion loss of -4.2 dB. The bypass mode with much higher linearity enables this LNA to work with much lower current consumption than commonly used TV LNAs. The BGA729N6 is based upon Infineon Technologies‘s B7HF Silicon Germanium technology. It operates from 1.5 V to 3.3 V supply voltage.

Please visit the product page of **BGA729N6** for more information.

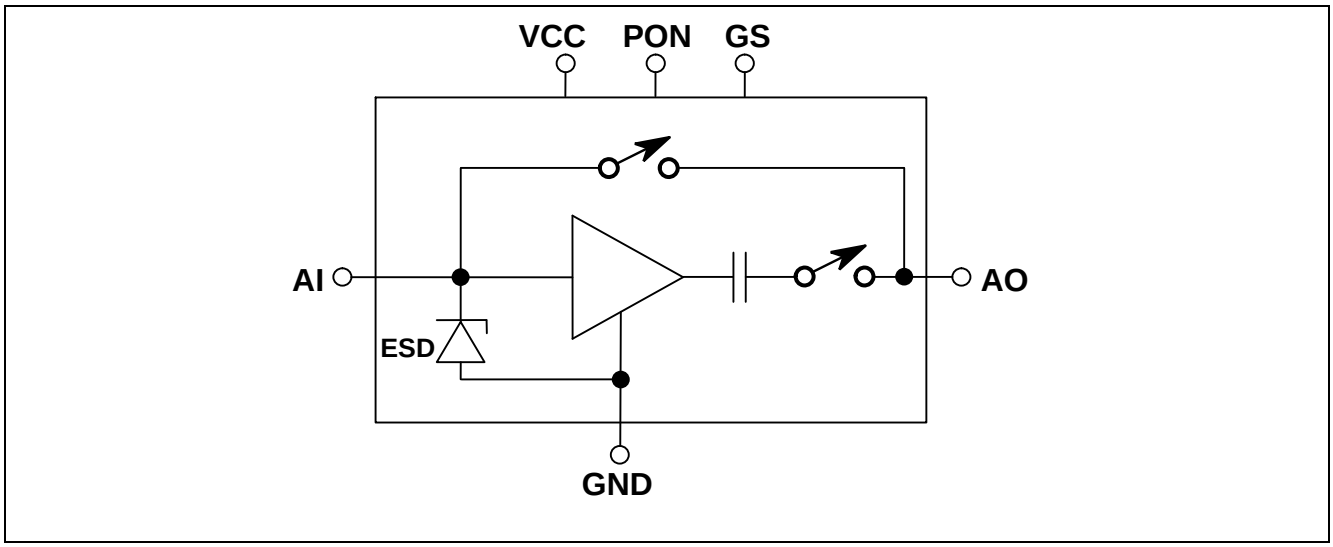


Figure 3 Equivalent Circuit of BGA729N6

Product Name	Marking	Code
BGA729N6	M	TSNP-6-2

Table 1 Pin Assignment of BGA729N6

Pin No.	Symbol	Function
1	GS	High gain / bypass control
2	VCC	DC supply
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	PON	Power on / off control

Table 2 Gain Mode Selection Truth Table

Control Voltage V_{PON}	Control Voltage V_{GS}	Gain Mode
High	Low	High Gain
High	High	Bypass
Low	High	Bypass
Low	Low	Off

3 Application Circuit and Performance Overview

In this chapter the performance of the application circuit, the schematic and bill-on-materials are presented.

Device: **BGA729N6**
Application: **Broadband LNA for Mobile TV and FM Radio Applications**
PCB Marking: **M150831**
EVB Order No.: **AN441**

3.1 Summary of Measurement Results

Ther performance of BGA729N6 for Mobile TV and FM Radio Applications is summarized in the following table.

Table 3 Electrical Characteristics (at room temperature) at 2.8 V for High Gain Mode

V_{PON} = 2.8V , V_{BP} = 0 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
Application System	Sys	FM Radio	MobileTV UHF	MobileTV UHF	MHz	
DC Voltage	Vcc	2.8			V	
DC Current	Icc	6.4			mA	
Frequency Range	Freq	88[1)]	470	860	MHz	
Insertion Power Gain	G	17.2	16.5	15.8	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are included
Noise Figure	NF	1.00	1.05	1.05	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are deembedded
Input Return Loss	RLin	9.1	9.7	8.8	dB	
Output Return Loss	RLout	21.3	17.7	13.6	dB	
Reverse Isolation	IRev	27.5	28.0	28.8	dB	
Input P1dB	IP1dB	-18.2	-15.8	-14.8	dBm	
Output P1dB	OP1dB	-2.0	-0.3	0	dBm	
Input IP3	IIP3	-5.1	-4.5	-3.3	dBm	f1 = 88, 470, 860 MHz respectively, f2 = f1 + 1 MHz -30 dBm per tone
Output IP3	OIP3	11.8	11.7	12.5	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Note: 1) Globally the FM radio frequencies are allocated between 66 – 108 MHz.

2) To view the performance in VHF III band (174 MHz -230 MHz), please refer to application note AN505.

Table 4 Electrical Characteristics (at room temperature) at 2.8 V for Bypass Mode

V_{PON} = 2.8V , V_{BP} = 2.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
Application System	Sys	FM Radio	MobileTV UHF	MobileTV UHF	MHz	
DC Voltage	Vcc	2.8			V	
DC Current	Icc	0.6			mA	
Frequency Range	Freq	88[1)]	470	860	MHz	
Gain	G	-6.7	-4.2	-4.9	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are included
Noise Figure	NF	7.9	5.0	4.2	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are deembedded
Input Return Loss	RLin	5.2	15.5	13.0	dB	
Output Return Loss	RLout	11.1	12.9	11.4	dB	
Reverse Isolation	IRev	6.8	4.2	4.5	dB	
Input P1dB	IP1dB	6.1	5.9	6.3	dBm	
Output P1dB	OP1dB	-1.6	0.7	0.4	dBm	
Input IP3	IIP3	21.1	21.2	23.7	dBm	f1 = 88, 470, 860 MHz respectively, f2 = f1 + 1 MHz -10 dBm per tone
Output IP3	OIP3	14.2	17.0	18.8	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Note: 1) Globally the FM radio frequencies are allocated between 66 – 108 MHz.

2) To view the performance in VHF III band (174 MHz -230 MHz), please refer to application note AN505.

Table 5 Electrical Characteristics (at room temperature) at 1.8 V for High Gain Mode

V_{PON} = 1.8V , V_{BP} = 0 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
Application System	Sys	FM Radio	MobileTV UHF	MobileTV UHF	MHz	
DC Voltage	Vcc	1.8			V	
DC Current	Icc	6.3			mA	
Frequency Range	Freq	88[1)]	470	860	MHz	[1)]Measured @ 98 MHz
Insertion Power Gain	G	17.1	16.4	15.7	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are included
Noise Figure	NF	0.95	1.05	1.05	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are deembedded
Input Return Loss	RLin	8.9	9.5	8.6	dB	
Output Return Loss	RLout	21.0	17.3	13.5	dB	
Reverse Isolation	IRev	27.4	27.8	28.3	dB	
Input P1dB	IP1dB	-18.1	-16.3	-15.5	dBm	
Output P1dB	OP1dB	-2.0	-0.9	-0.8	dBm	
Input IP3	IIP3	-4.7	-4.0	-4.5	dBm	f1 = 88, 470, 860 MHz respectively, f2 = f1 + 1 MHz -30 dBm per tone
Output IP3	OIP3	11.9	12.0	11.2	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Note: 1) Globally the FM radio frequencies are allocated between 66 – 108 MHz.

2) To view the performance in VHF III band (174 MHz -230 MHz), please refer to application note AN505.

Table 6 Electrical Characteristics (at room temperature) at 1.8 V for Bypass Mode

V_{PON} = 1.8V , V_{BP} = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
Application System	Sys	FM Radio	MobileTV UHF	MobileTV UHF	MHz	
DC Voltage	Vcc	1.8			V	
DC Current	Icc	0.3			mA	
Frequency Range	Freq	88[1)]	470	860	MHz	[1)]Measured @ 98 MHz
Insertion Power Gain	G	-6.9	-4.5	-4.8	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are included
Noise Figure	NF	7.9	5.0	4.4	dB	Loss of input/output line of 0.01 dB@ 88MHz, 0.03 dB @ 470MHz, 0.05 dB @860 MHz are deembedded
Input Return Loss	RLin	5.1	15.1	12.3	dB	
Output Return Loss	RLout	11.3	13.1	11.5	dB	
Reverse Isolation	IRev	6.9	4.5	4.8	dB	
Input P1dB	IP1dB	3.5	3.0	6.0	dBm	
Output P1dB	OP1dB	-4.4	-2.5	0.2	dBm	
Input IP3	IIP3	15.5	15.6	17.9	dBm	f1 = 88, 470, 860 MHz respectively, f2 = f1 + 1 MHz -10 dBm per tone
Output IP3	OIP3	8.5	11.1	13.1	dBm	
Stability	k	>1			--	Measured up to 10 GHz

Note: 1) Globally the FM radio frequencies are allocated between 66 – 108 MHz.

2) To view the performance in VHF III band (174 MHz -230 MHz), please refer to application note AN505.

3.2 BGA729N6 as 70 MHz – 1000 MHz Low Noise Amplifier for Mobile TV and FM Radio Applications

The BGA729N6 is a Silicon Germanium Low Noise Amplifier for mobile TV applications and FM radio application in the range from 70 MHz – 1000 MHz. In this application note, the performance of BGA729N6 for mobile TV and FM radio applications is investigated at 1.8 V and 2.8 V supply voltages. The circuit targets to use as few components as possible.

At 2.8V, 88 MHz, in the high gain mode the BGA729N6 achieves a noise figure of 1.0 dB and a gain of 17.2 dB. The input return loss is 9.1 dB and output return loss is 21.3 dB. It obtains the input 1dB Compression Point (IP1dB) at -18.2 dBm. Using two tones of –30 dBm spacing 1 MHz, the circuit achieves an input Third-order Intercept Point (IIP3) of -5.1 dBm.

At 2.8 V, 88 MHz, in the bypass mode the BGA729N6 achieves a noise figure of >3.0 dB and an insertion loss of 6.7 dB. The input return loss is 5.2 dB and output return loss is 11.1 dB. It obtains the input 1dB Compression Point (IP1dB) at 3.5 dBm. Using two tones of –10 dBm spacing 1 MHz, the circuit achieves an input Third-order Intercept Point (IIP3) of 15.5 dBm.

At 2.8V, 470 MHz, in the high gain mode the BGA729N6 achieves a noise figure of 1.2 dB and a gain of 16.5 dB. The input return loss is 9.7 dB and output return loss is 17.7 dB. It obtains the input 1dB Compression Point (IP1dB) at -15.8 dBm. Using two tones of –30 dBm spacing 1 MHz, the circuit achieves an input Third-order Intercept Point (IIP3) of -4.5 dBm.

At 2.8 V, 470 MHz, in the bypass mode the BGA729N6 achieves a noise figure of >3.0 dB and an insertion loss of 4.2 dB. The input return loss is 15.5 dB and output return loss is 12.9 dB. It obtains the input 1dB Compression Point (IP1dB) at 5.9 dBm. Using two tones of –10 dBm spacing 1 MHz, the circuit achieves an input Third-order Intercept Point (IIP3) of 21.2 dBm.

The circuit is unconditionally stable up to 10 GHz.

3.3 Schematics and Bill-of-Materials

Ther schematic of BGA729N6 for mobile TV and FM radio applications is presented in **Figure 4** and its bill-of-materials is shown in **Table 7**.

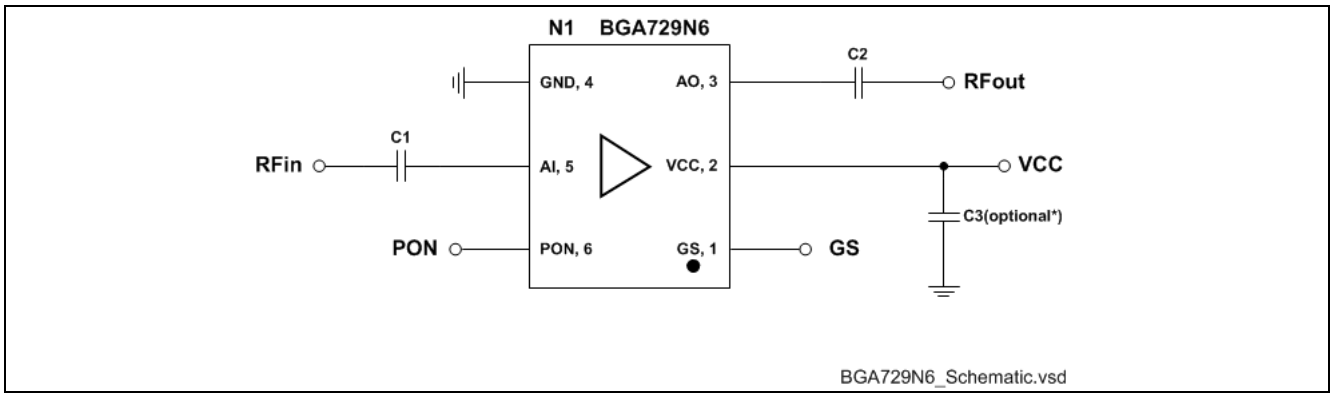


Figure 4 Schematics of the BGA729N6 Application Circuit

Table 7 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0402	Various	DC block [1)]
C2	1	nF	0402	Various	DC block [1)]
C3	>=1	nF	0402	Various	RF bypass[2)]. Necessary in FM application, optional in mobile TV application
N1	BGA729N6		TSNP-6-2	Infineon	SiGe LNA

Note:1) DC block might be necessary due to internal LNA bias voltage @ AI (LNA Analog Input pin). The DC block can be realized pre-filter (e.g. SAW)

2) The RF bypass capacitor C3 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor C3 is not necessary if a clean and stable DC supply can be ensured.

4 Measurement Graphs

The performance of the application circuit is presented with the following graphs.

4.1 High Gain Mode (Selected Graphs)

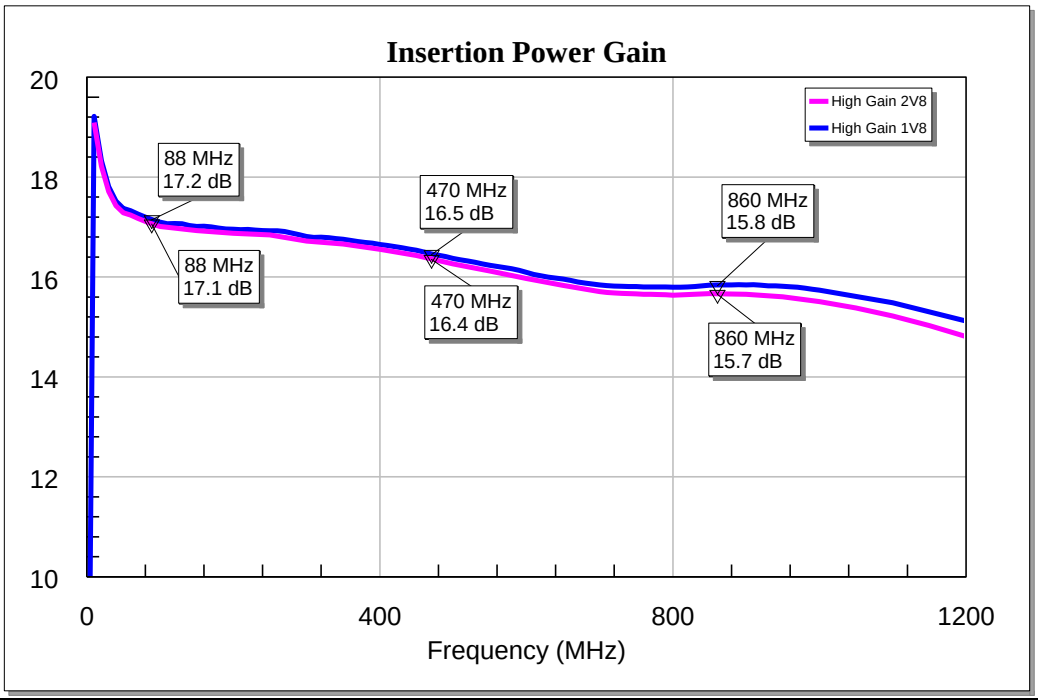


Figure 5 Insertion Gain (Narrowband) of the BGA729N6 for Mobile TV and FM Radio Applications

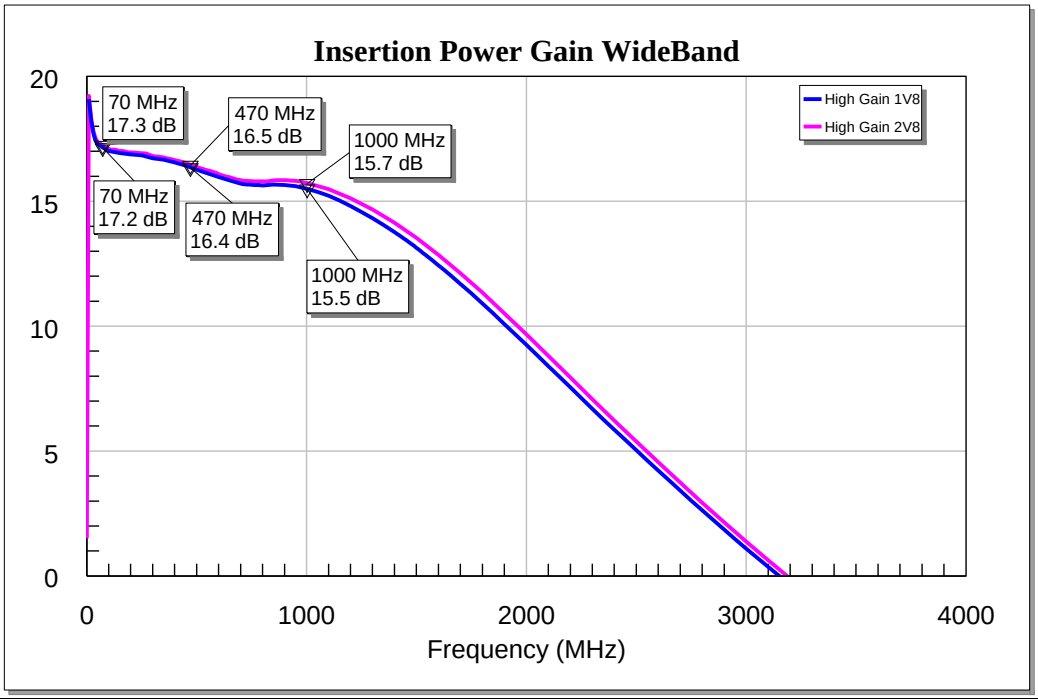


Figure 6 Insertion Gain (Wideband) of the BGA729N6 for Mobile TV and FM Radio Applications

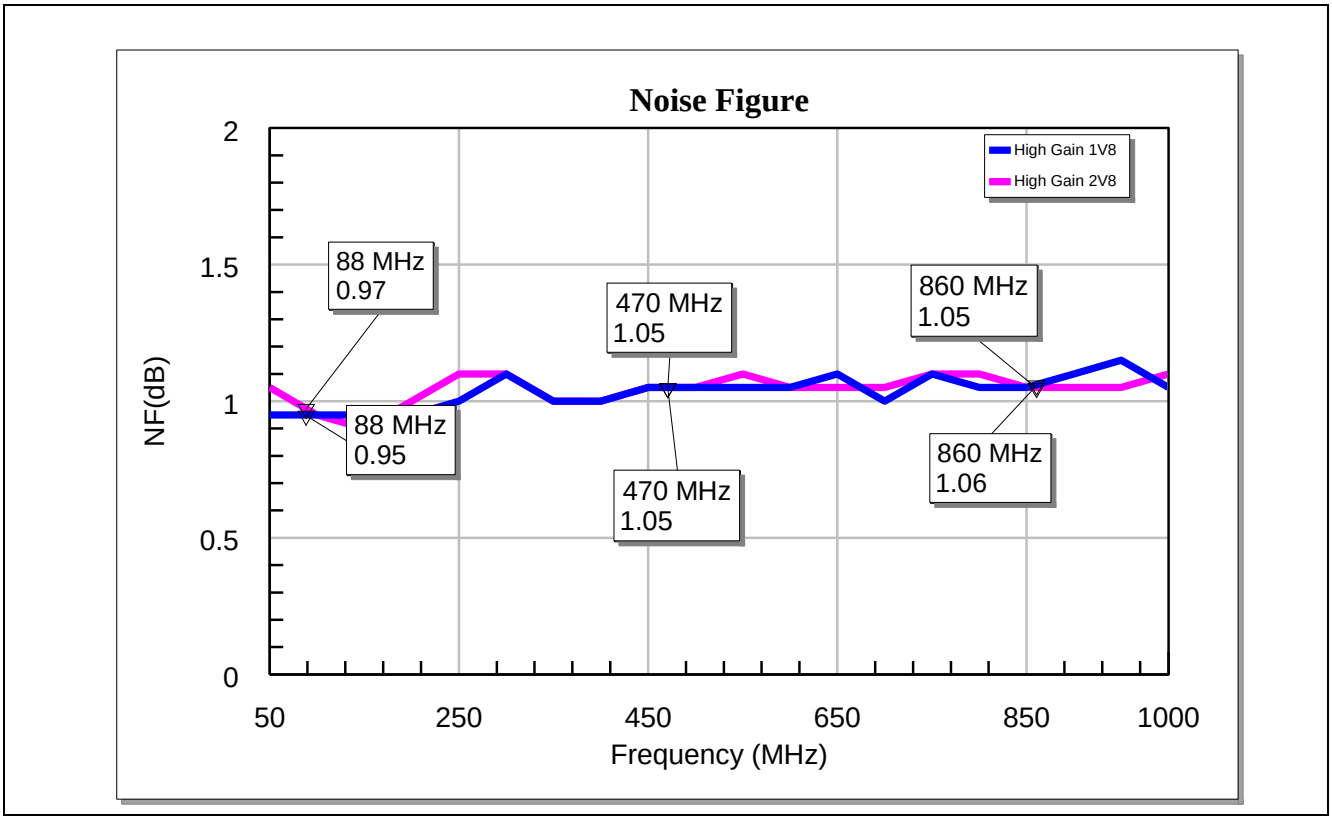


Figure 7 Noise Figure (SMA and connector loss deembedded) of the BGA729N6 for Mobile TV and FM Radio Applications

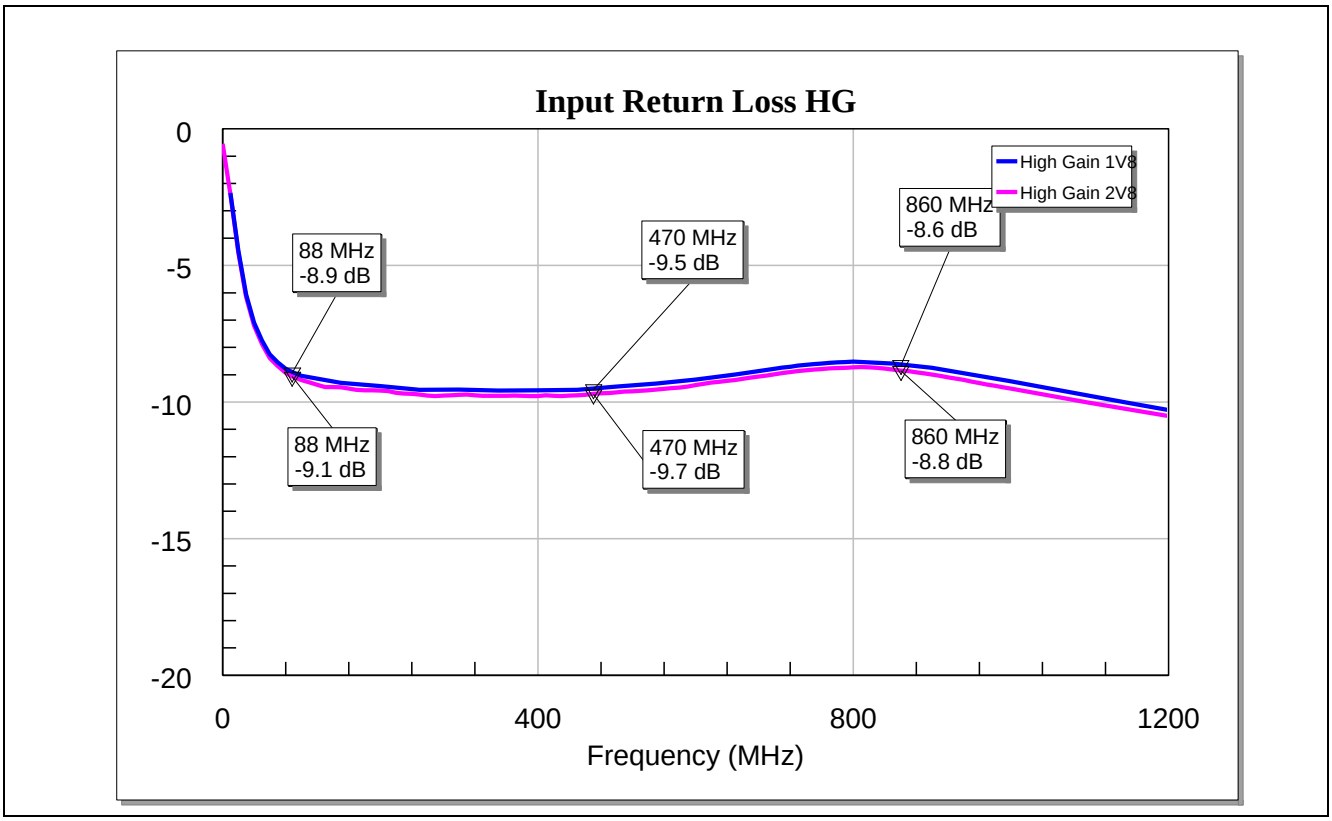


Figure 8 Input Return Loss of the BGA729N6 for Mobile TV and FM Radio Applications

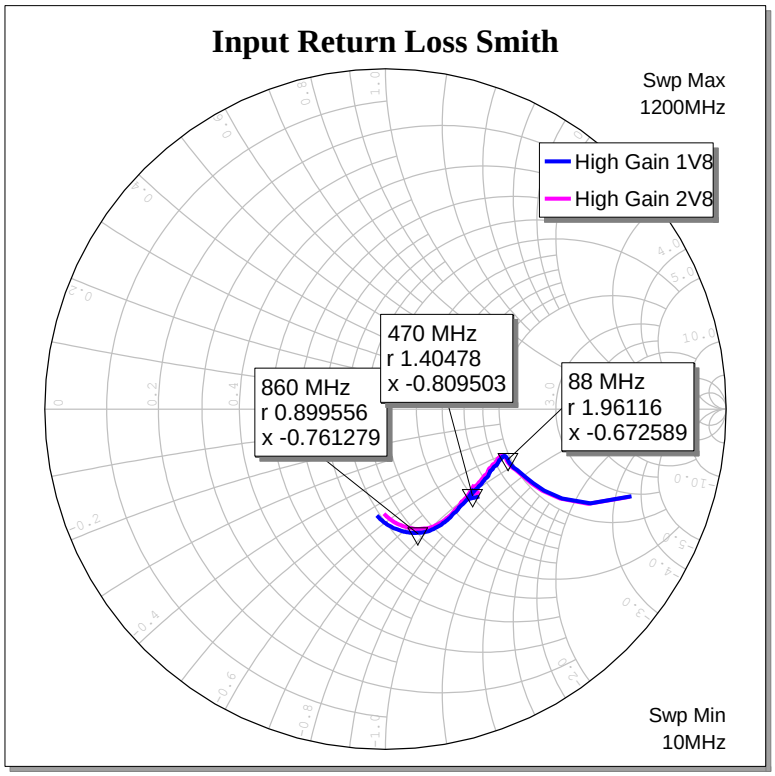


Figure 9 Input Return Loss (Smith Chart) of the BGA729N6 for Mobile TV and FM Radio Applications

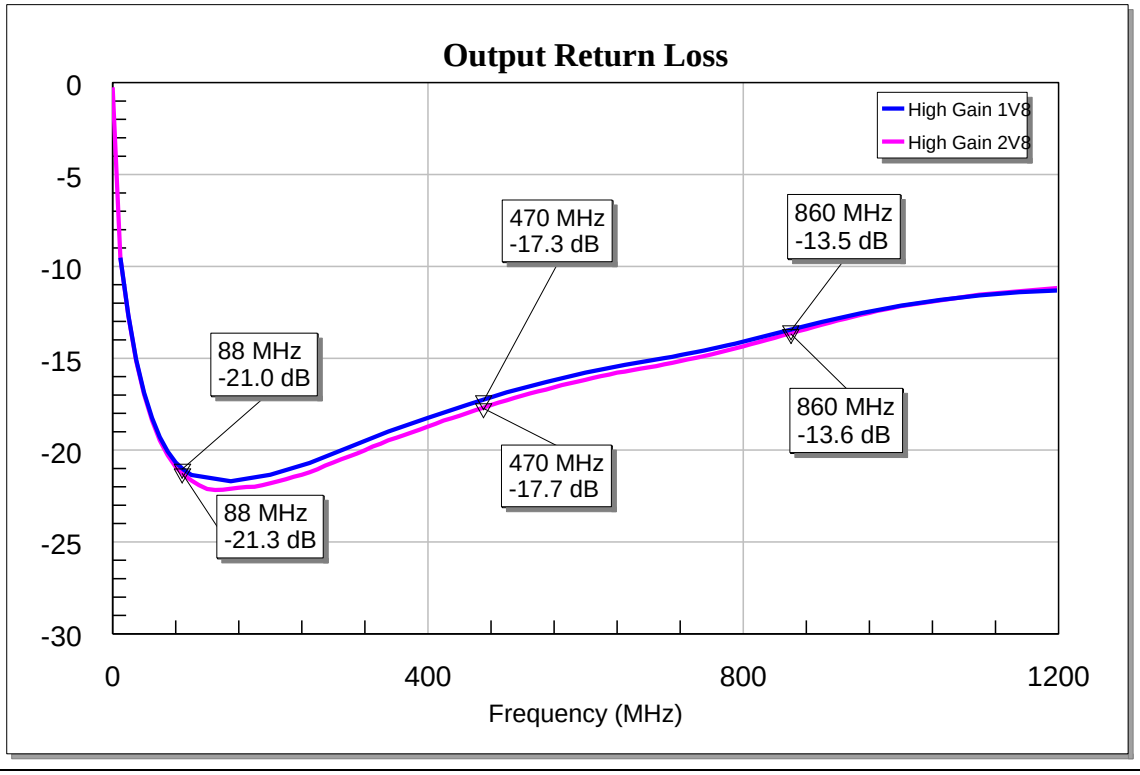


Figure 10 Output Return Loss of the BGA729N6 for Mobile TV and FM Radio Applications

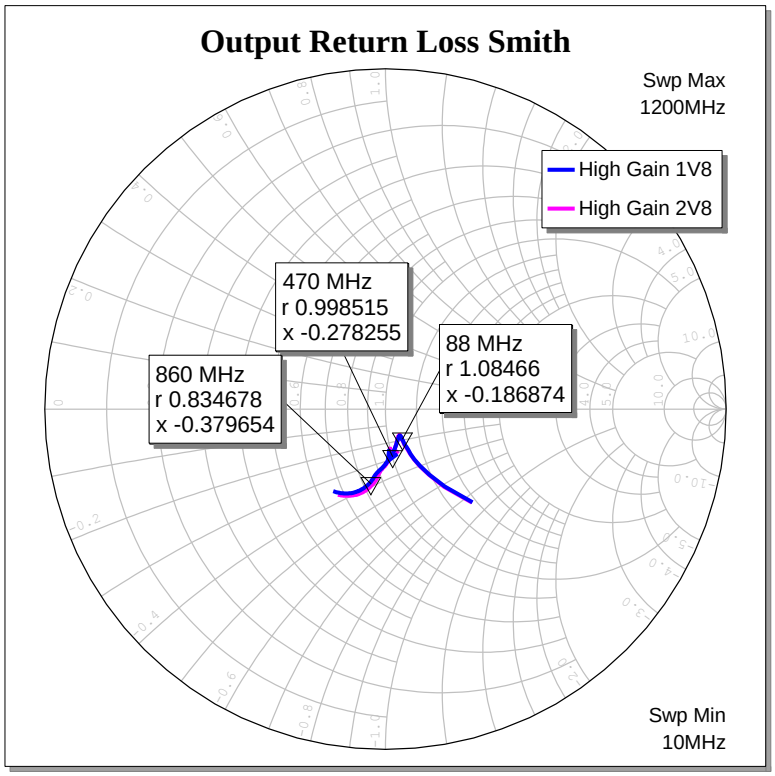


Figure 11 Output Return Loss (Smith Chart) of the BGA729N6 for Mobile TV and FM Radio Applications

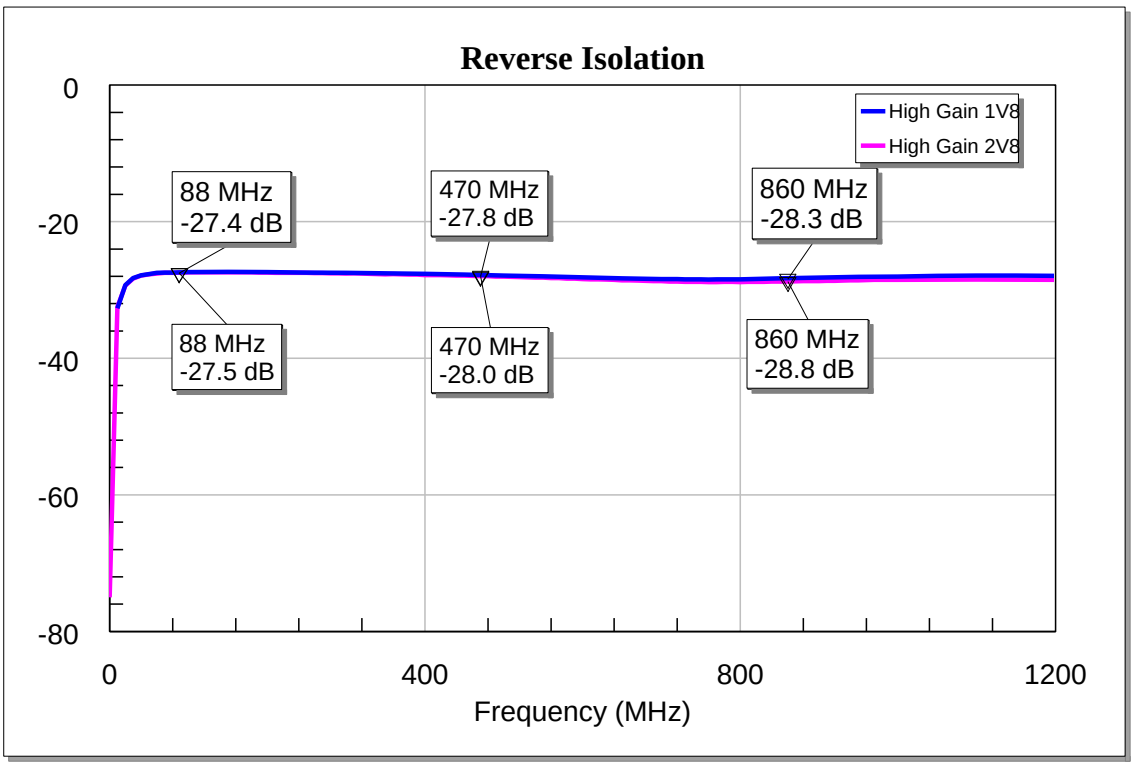


Figure 12 Reverse Isolation of the BGA729N6 for Mobile TV and FM Radio Applications

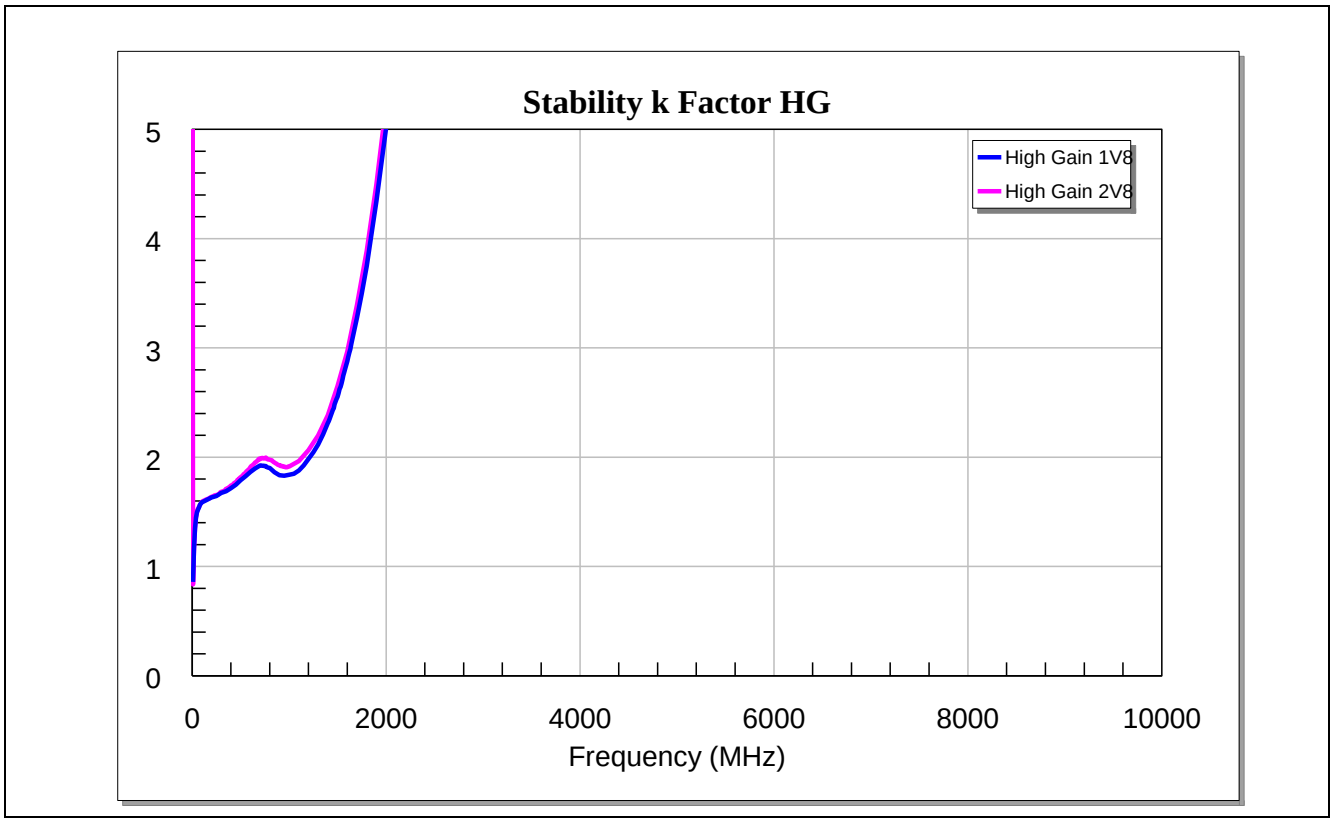


Figure 13 Stability Factor k of the BGA729N6 for Mobile TV and FM Radio Applications

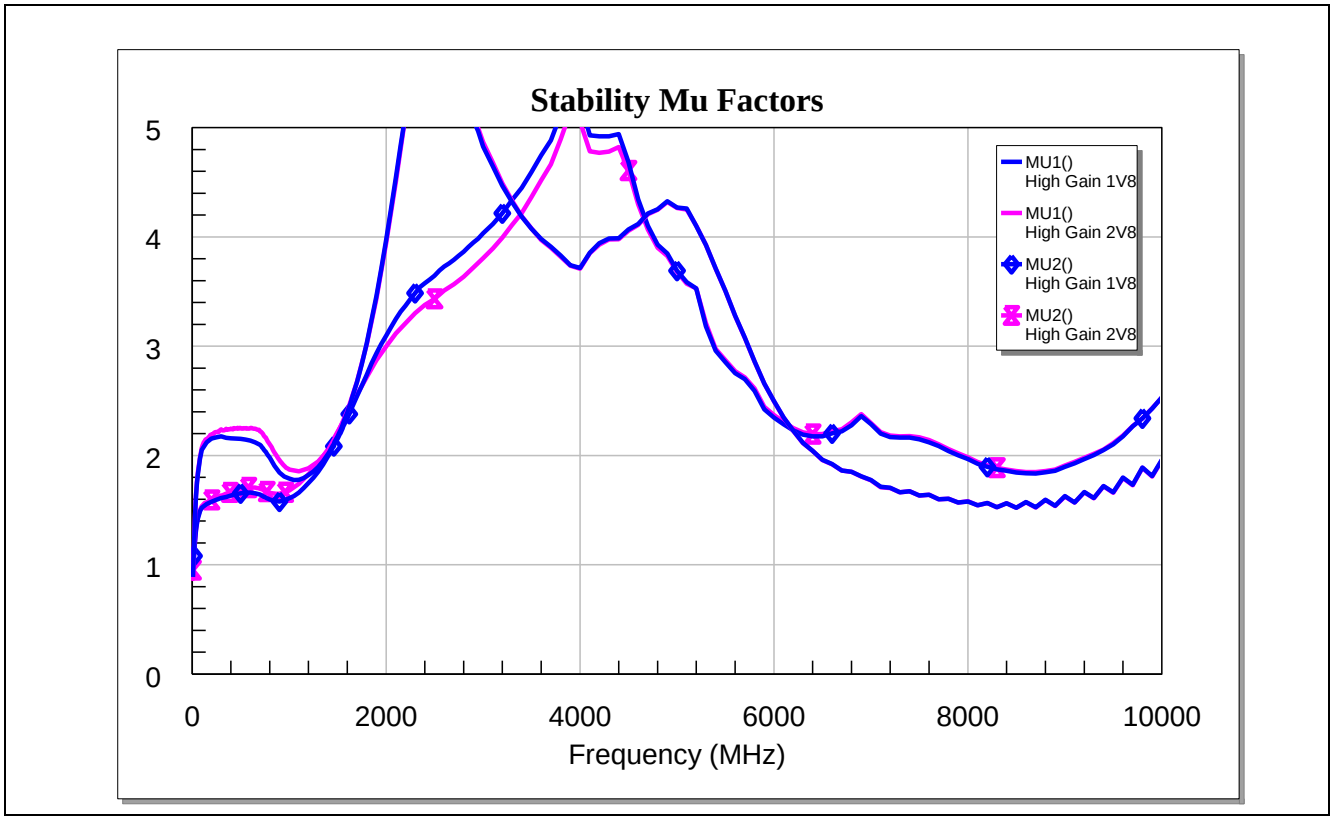


Figure 14 Stability Factor µ1, µ2 of the BGA729N6 for Mobile TV and FM Radio Applications

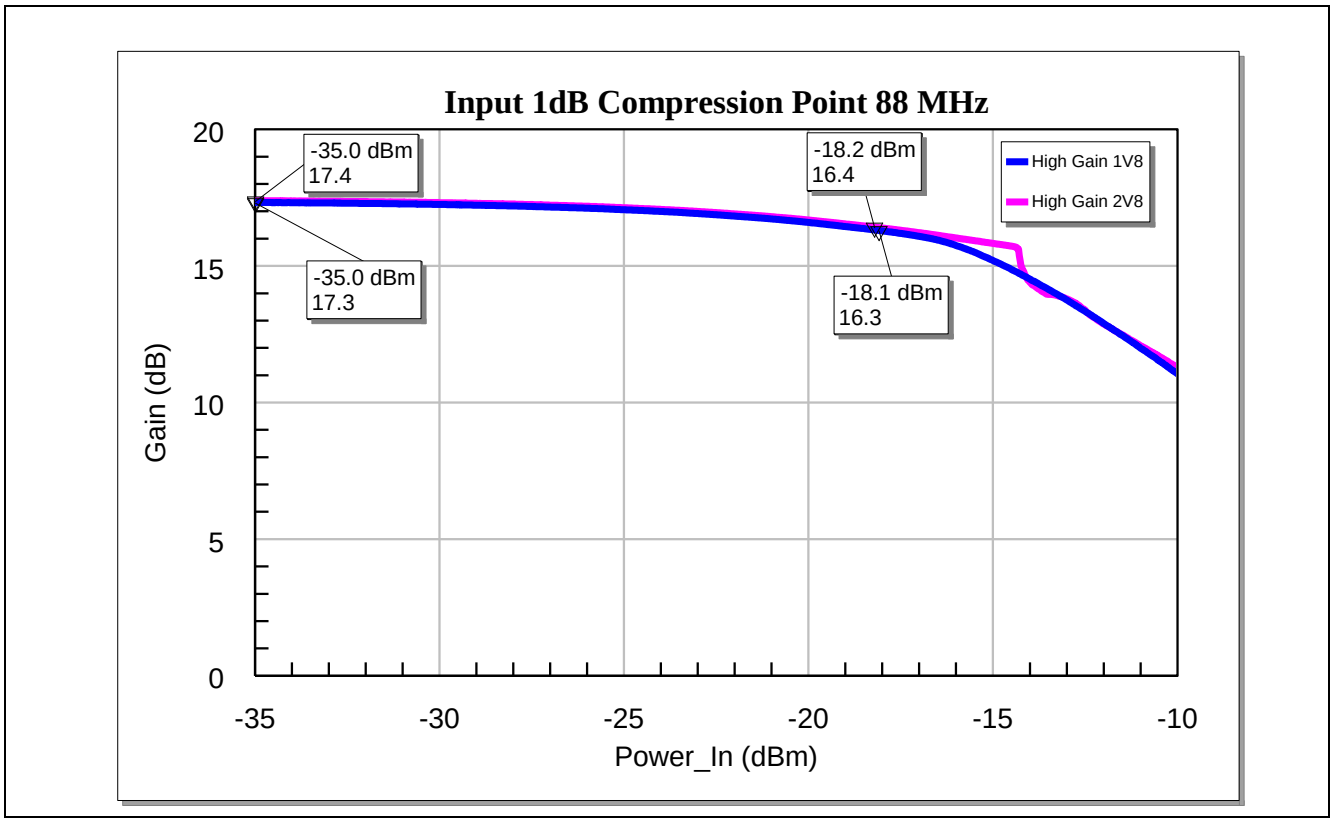


Figure 15 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (88 MHz)

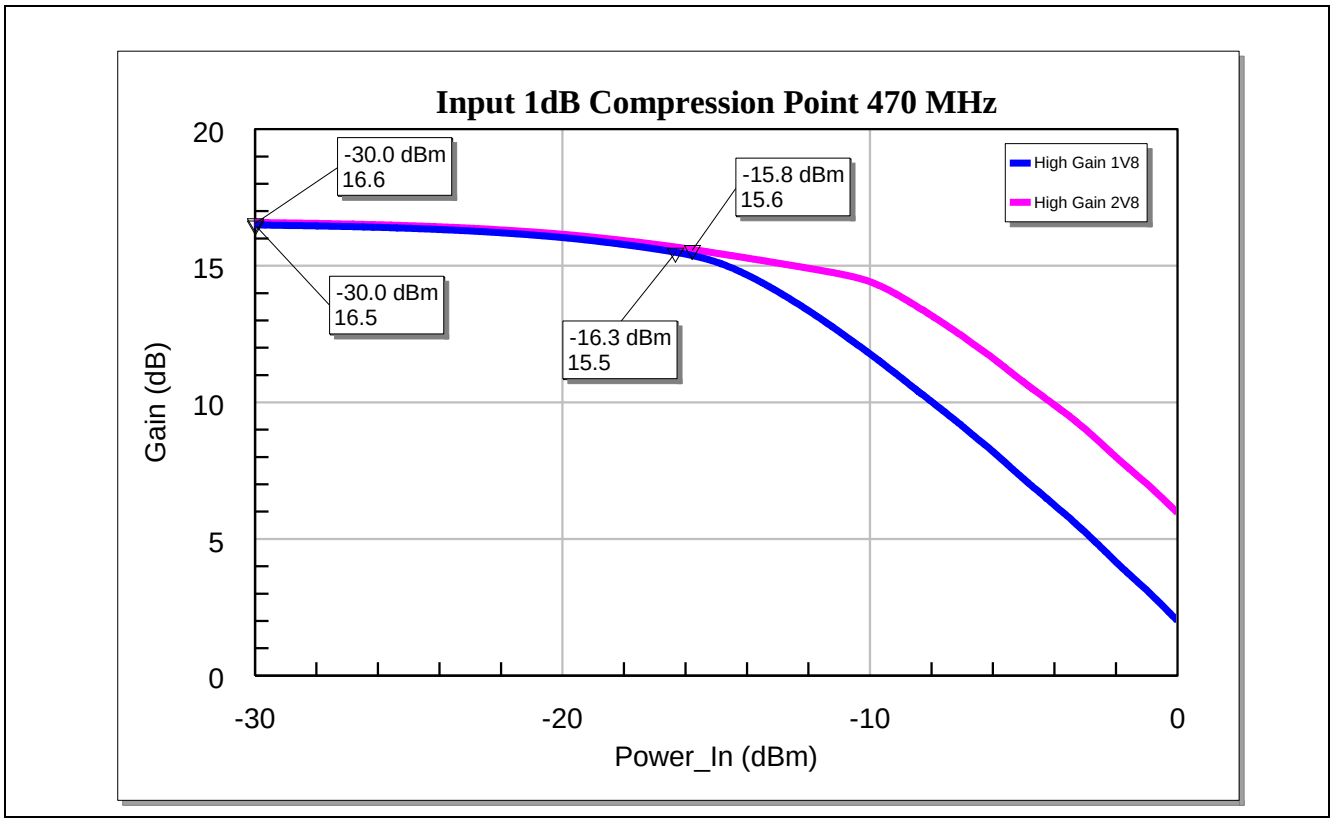


Figure 16 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (470 MHz)

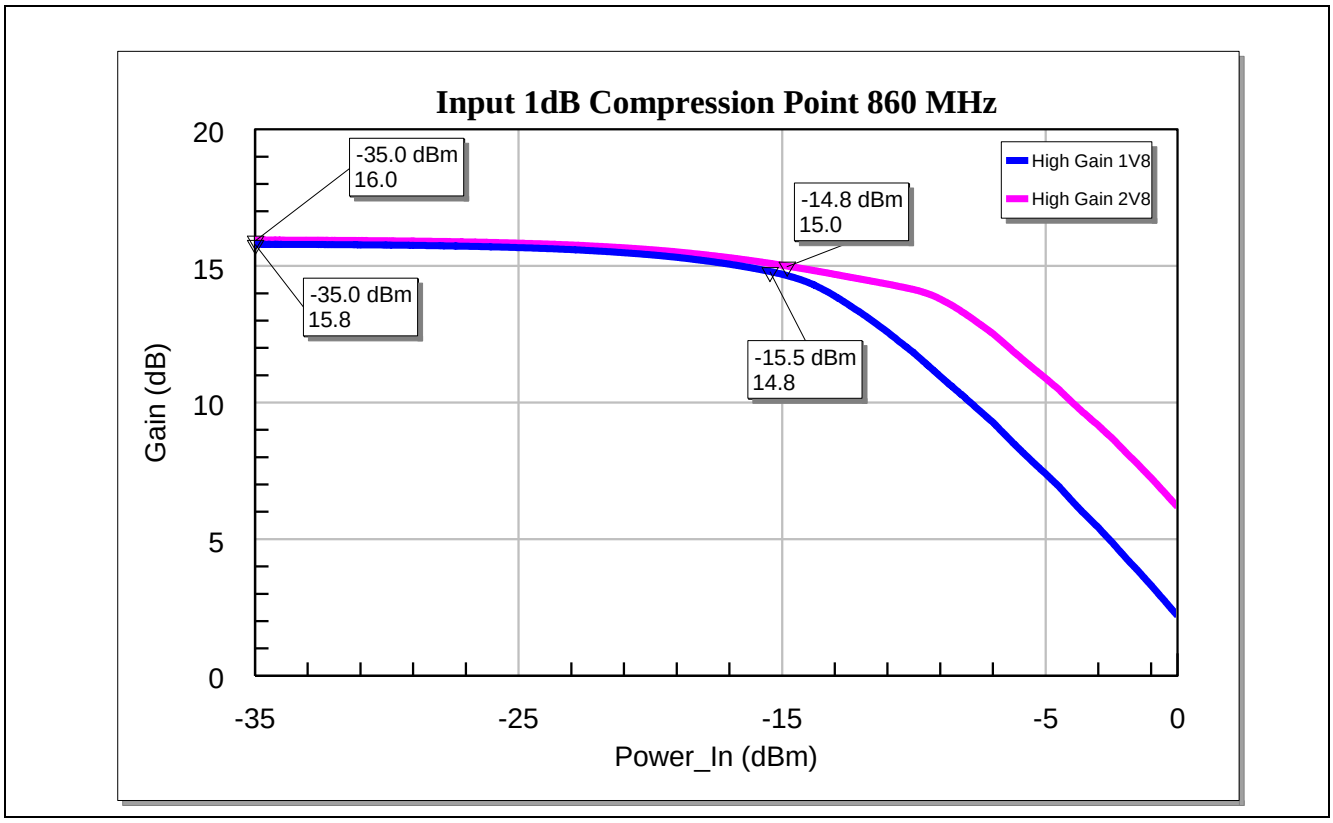


Figure 17 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (860 MHz)

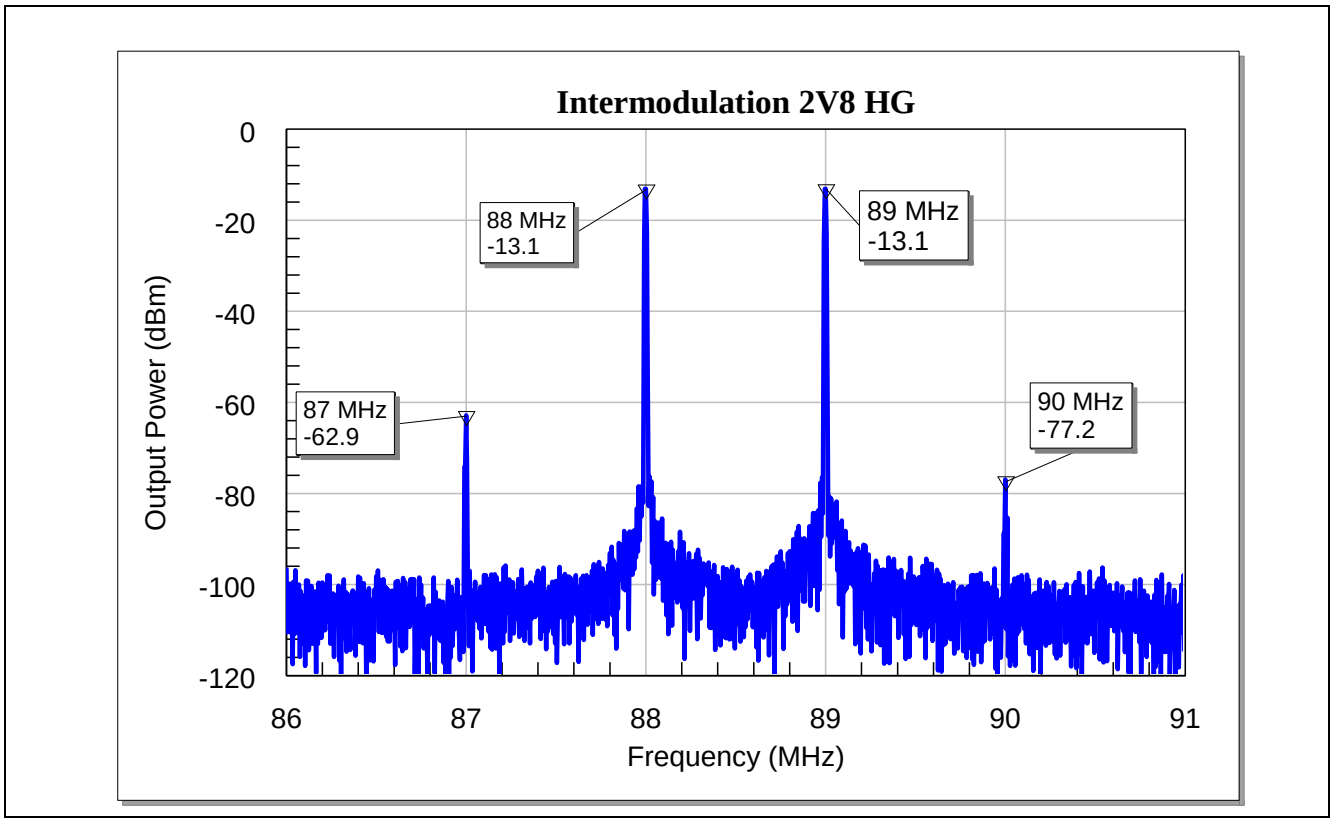


Figure 18 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 88 MHz)

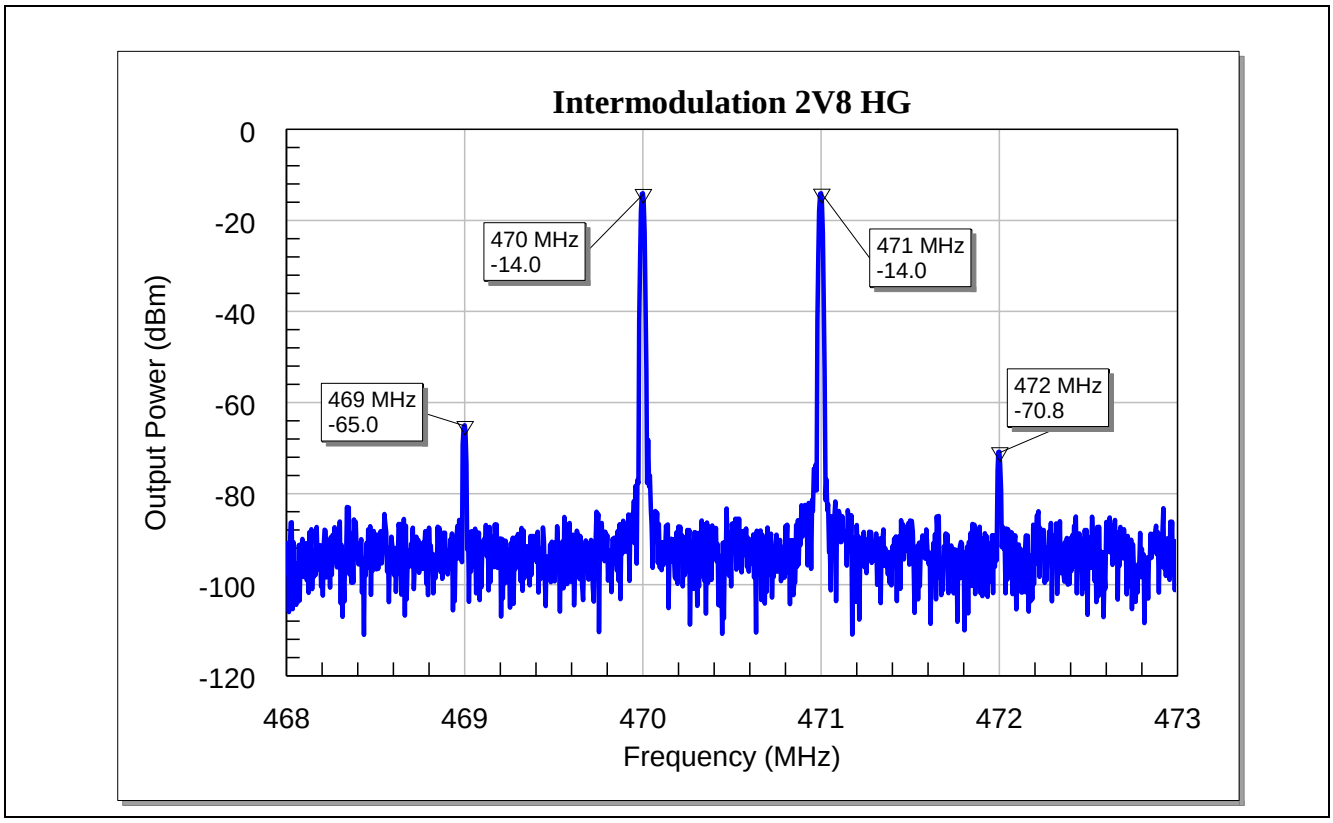


Figure 19 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 470 MHz)

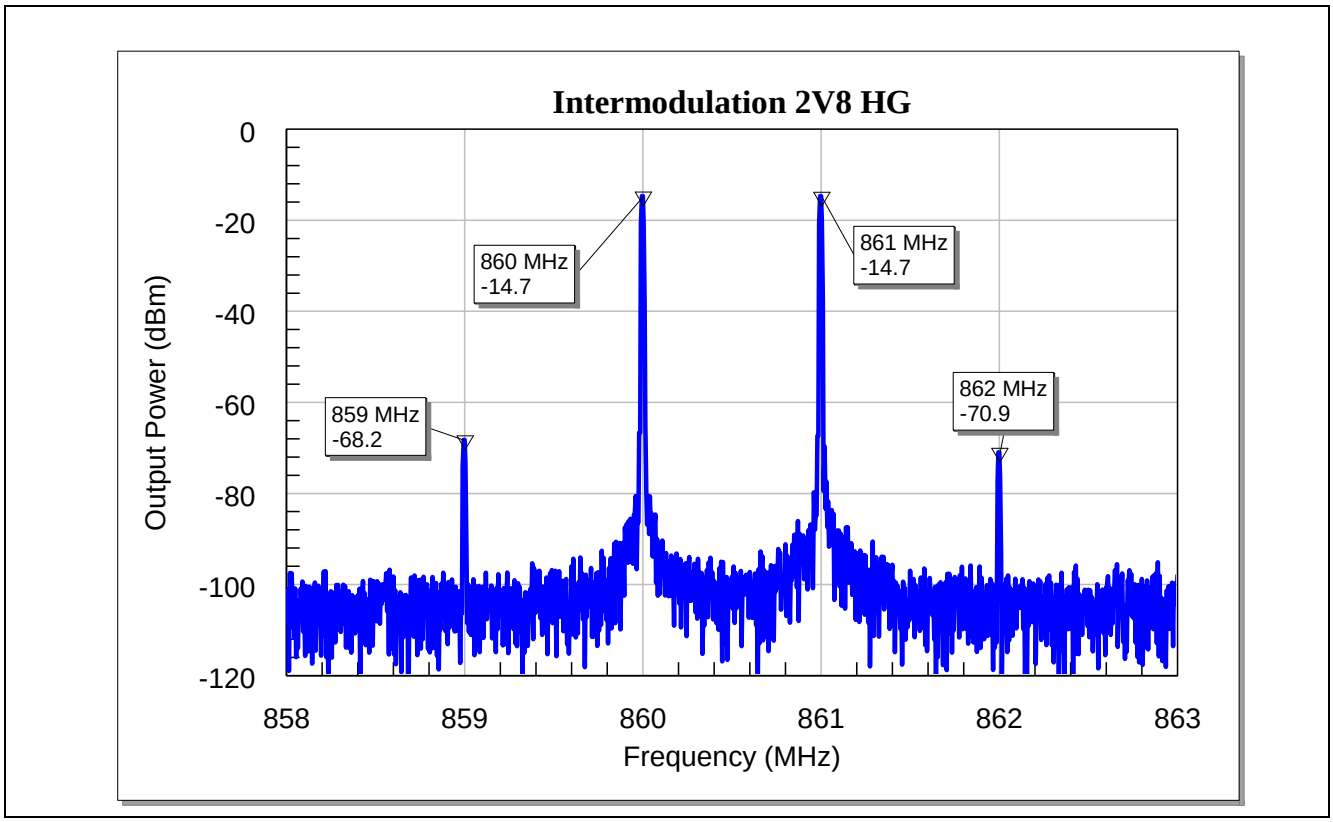


Figure 20 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 860 MHz)

4.2 Bypass Mode (Selected Graphs)

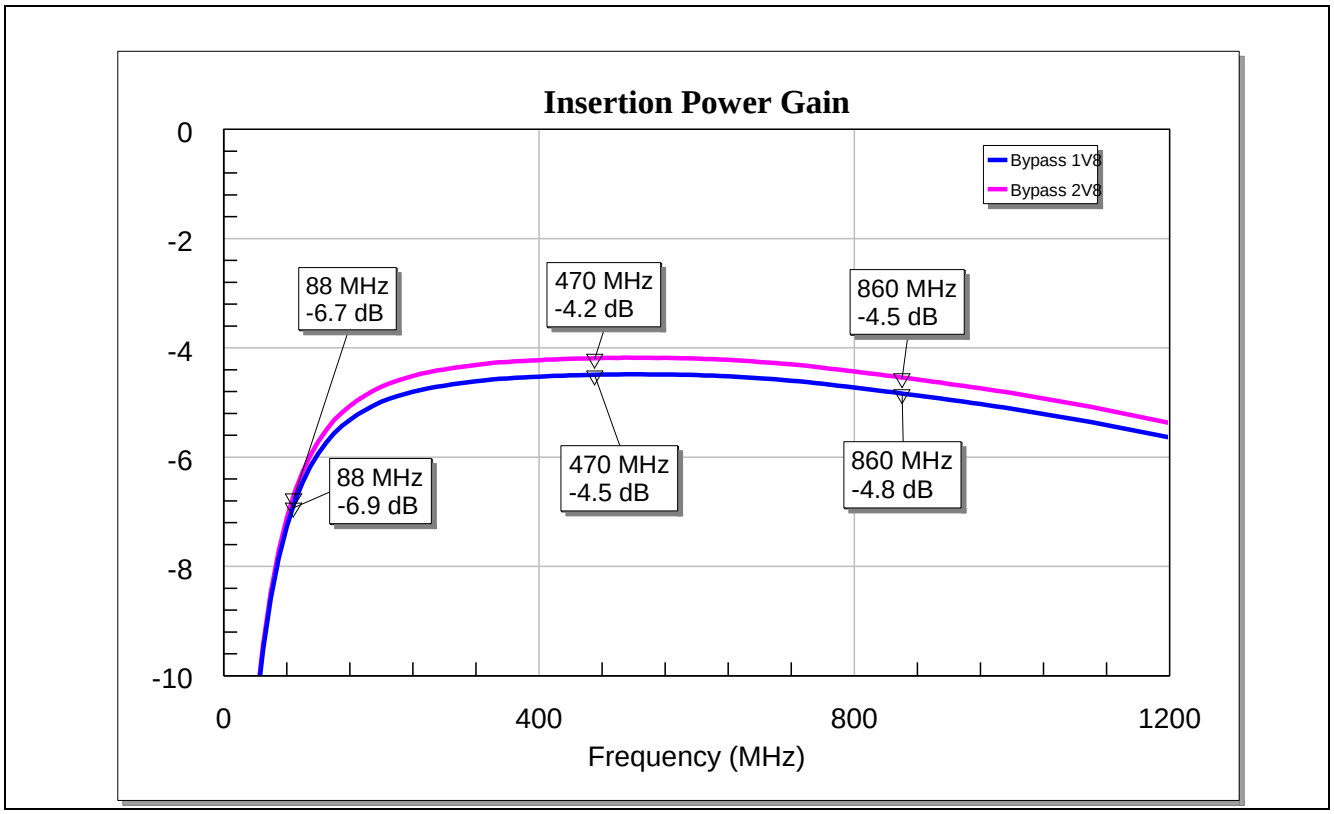


Figure 21 Insertion Gain (Wideband) of the BGA729N6 for Mobile TV and FM Radio Applications

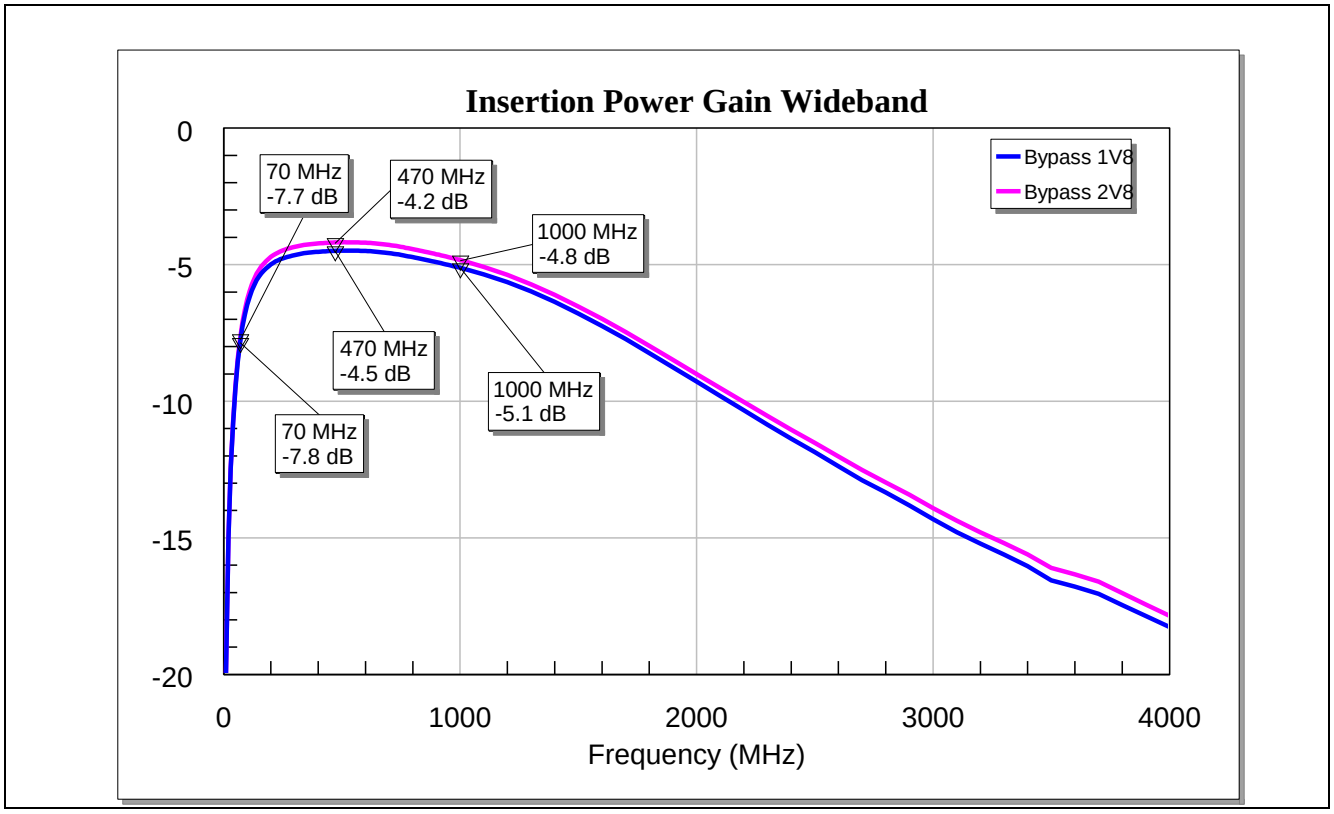


Figure 22 Insertion Gain (Wideband) of the BGA729N6 for Mobile TV and FM Radio Applications

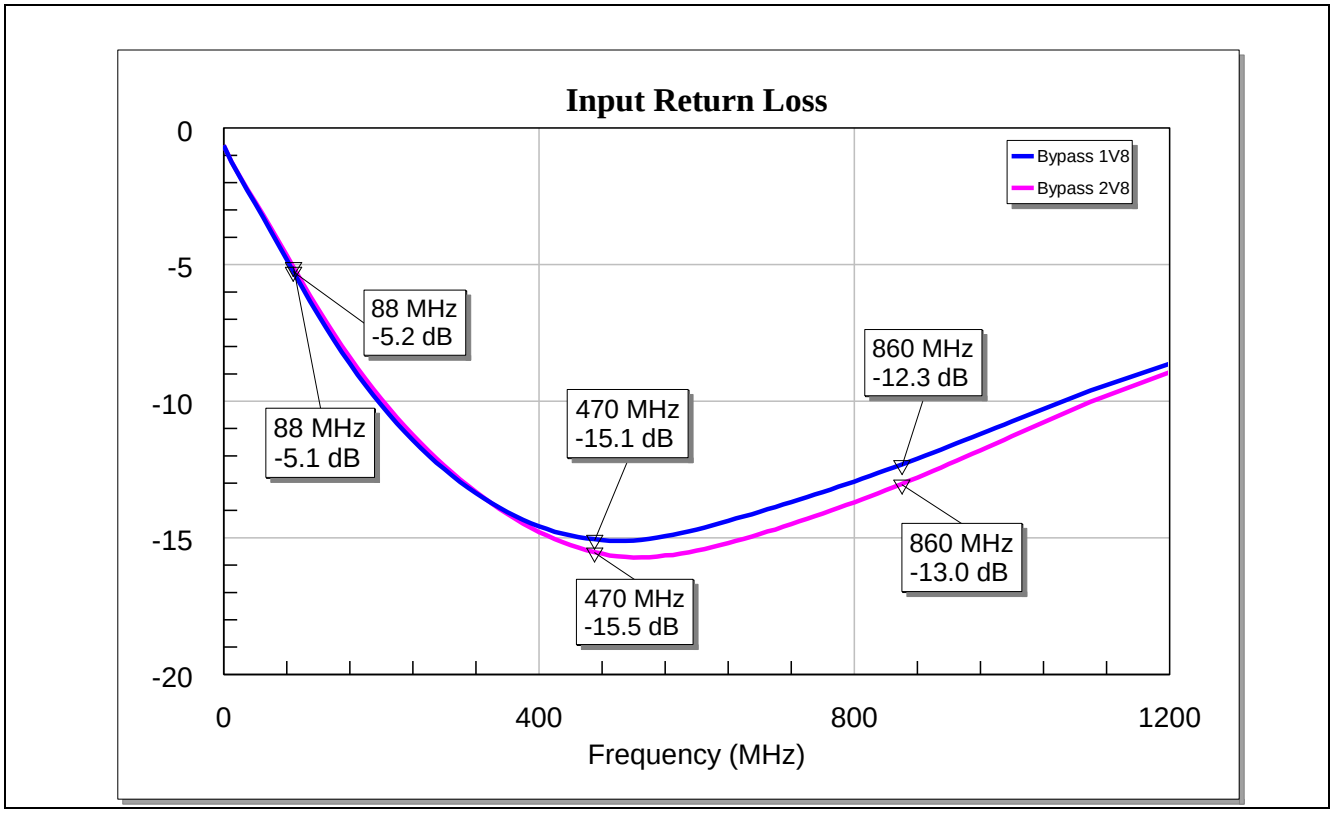


Figure 23 Input Return Loss of the BGA729N6 for Mobile TV and FM Radio Applications

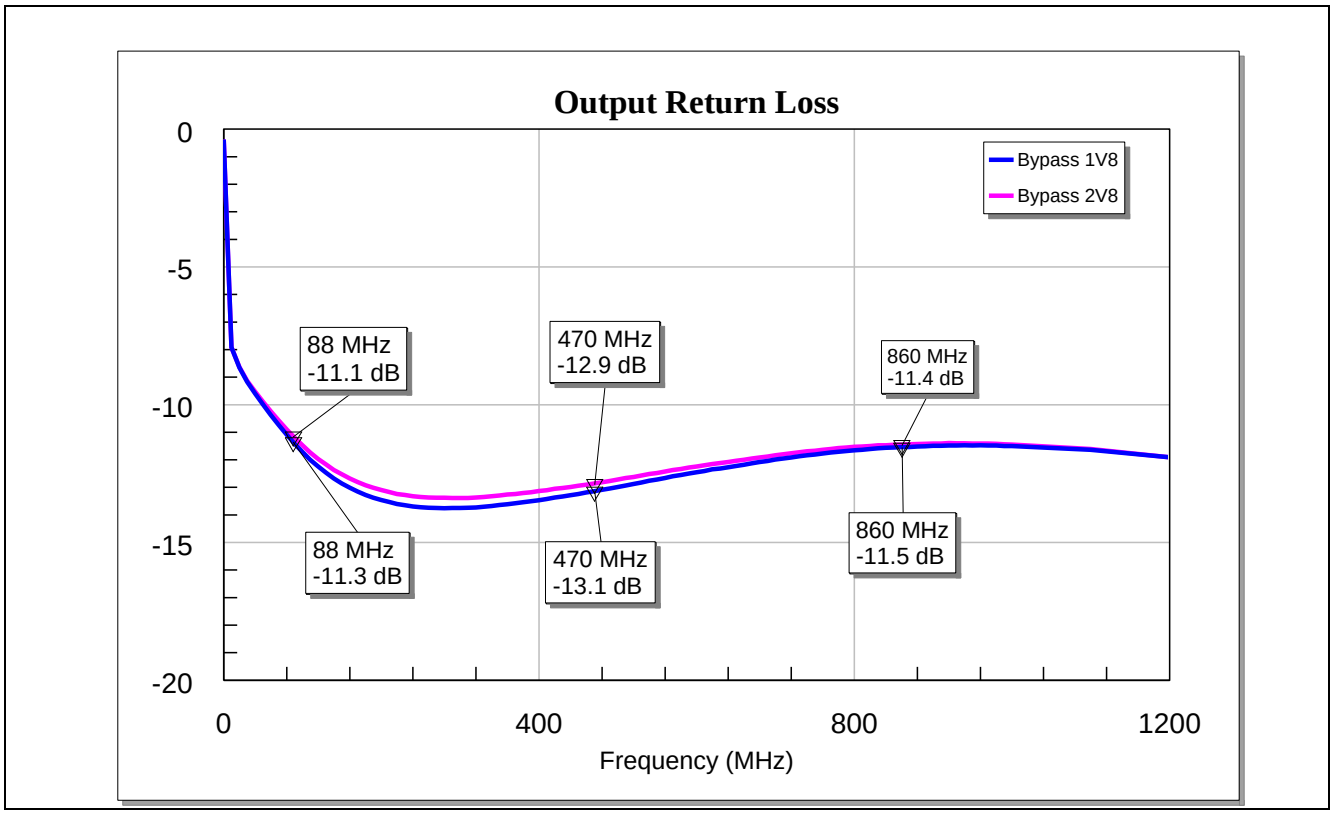


Figure 24 Output Return Loss of the BGA729N6 for Mobile TV and FM Radio Applications

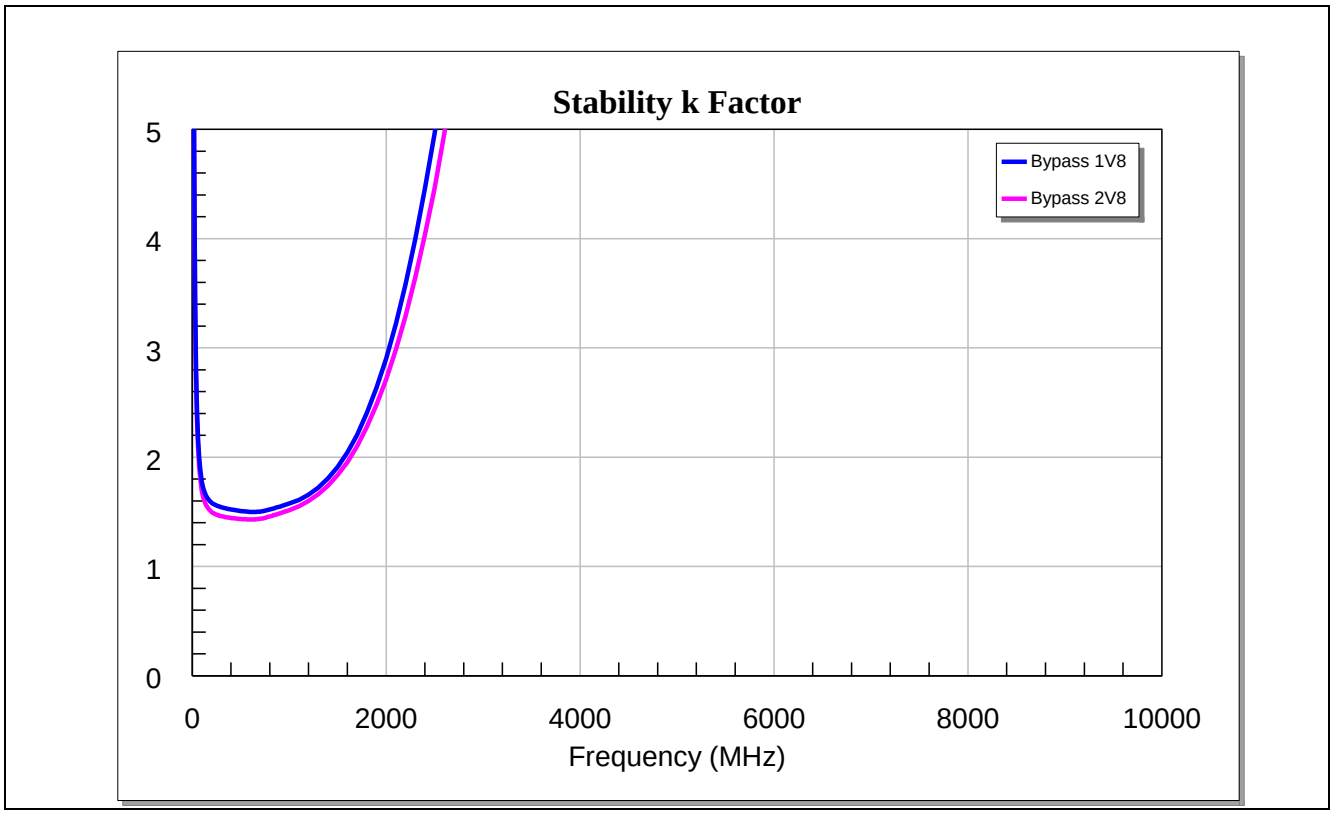


Figure 25 Stability Factor k of the BGA729N6 for Mobile TV and FM Radio Applications

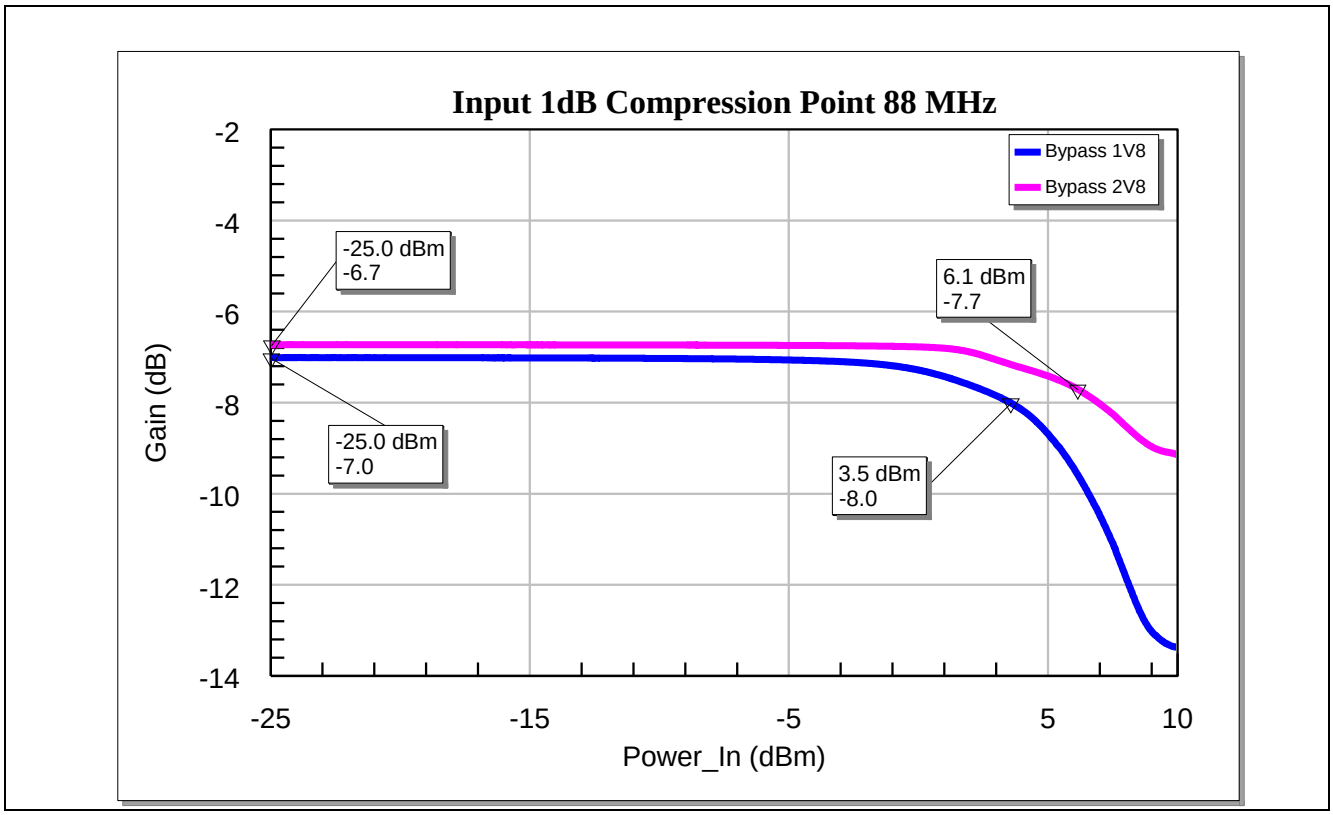


Figure 26 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (88 MHz)

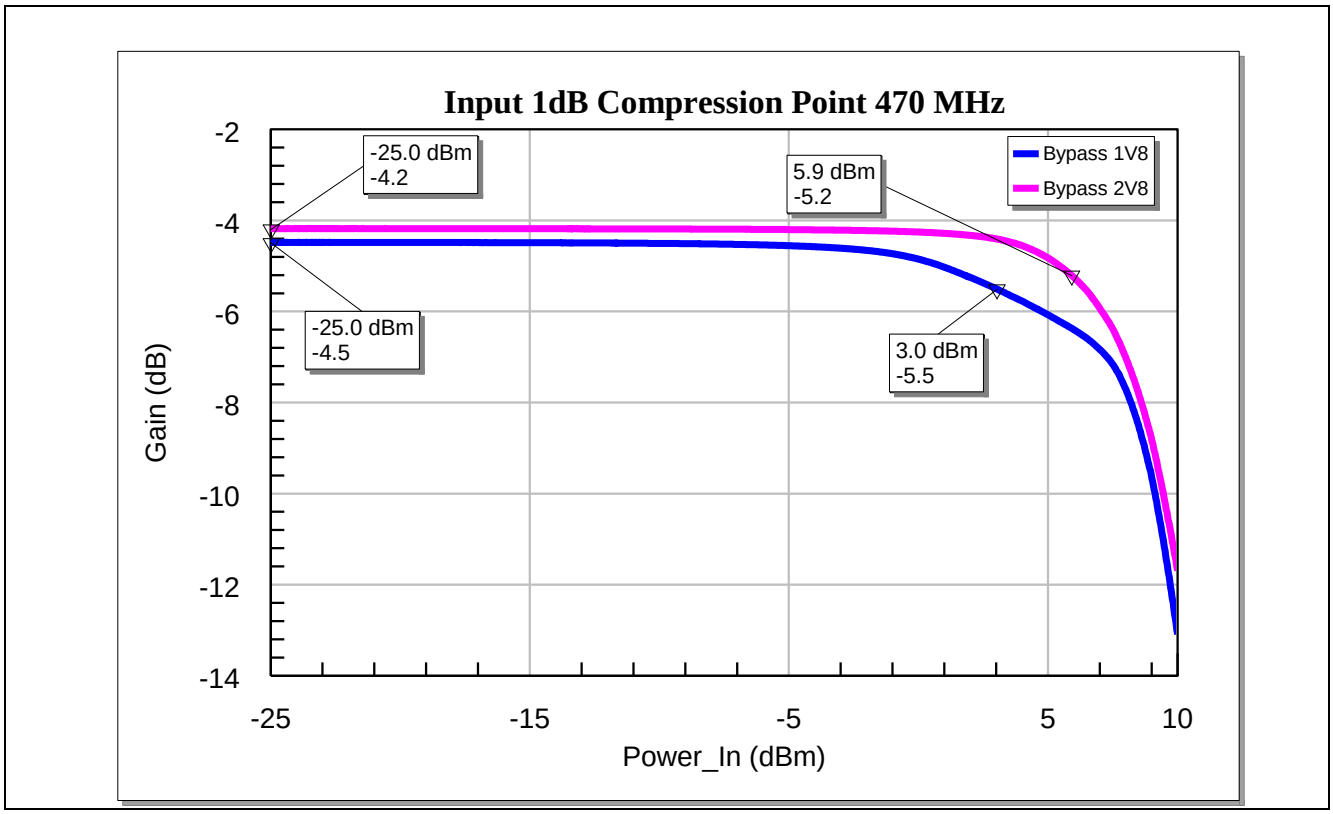


Figure 27 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (470 MHz)

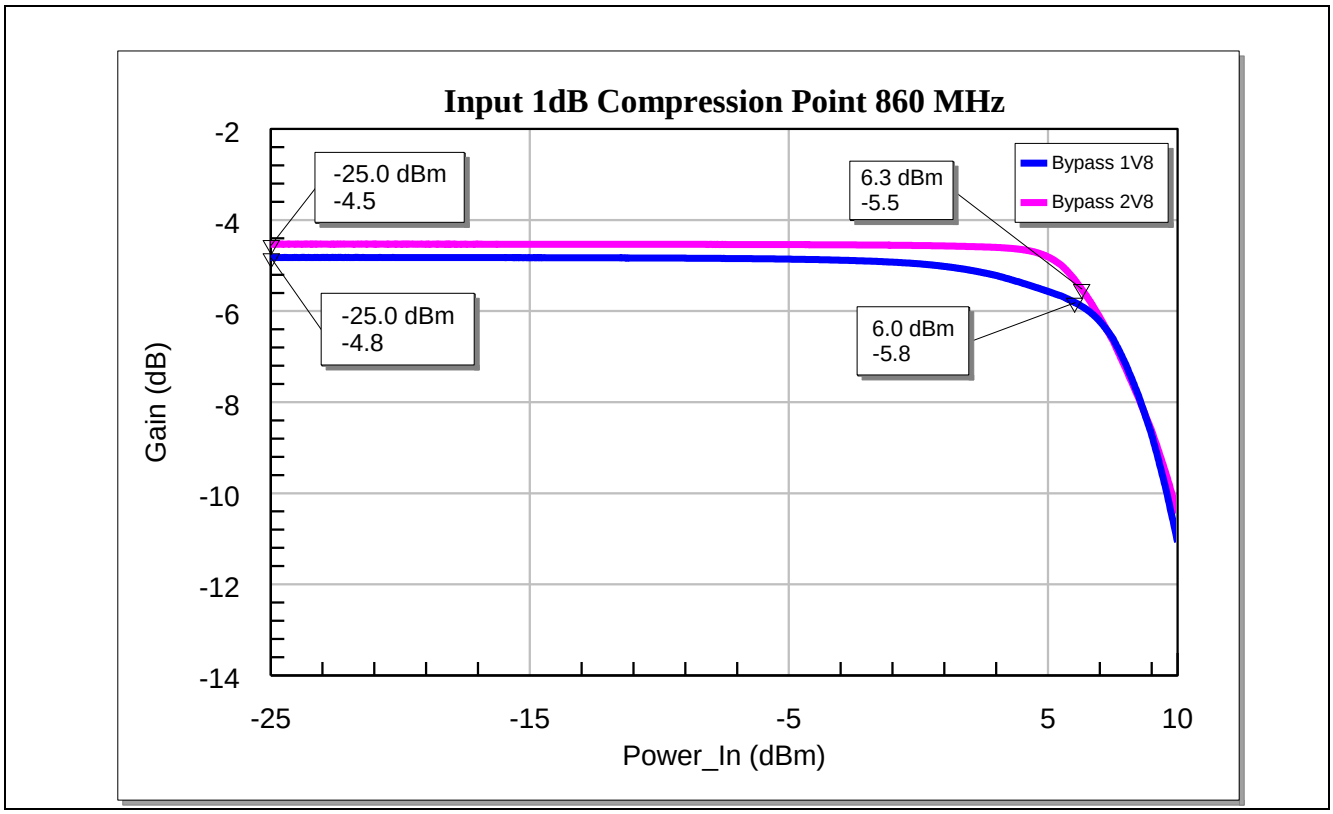


Figure 28 1 dB Compression Point of the BGA729N6 for Mobile TV and FM Radio Applications (860 MHz)

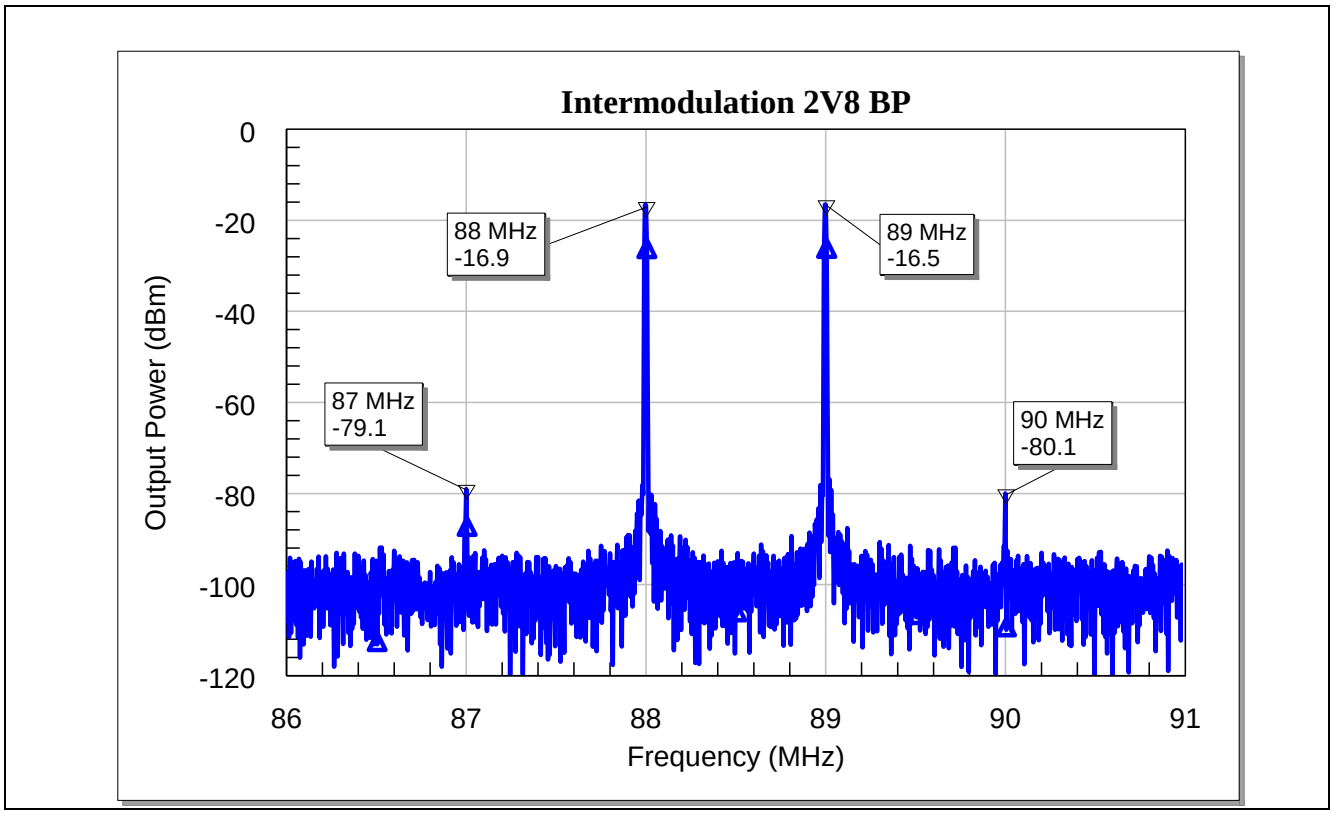


Figure 29 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 88 MHz)

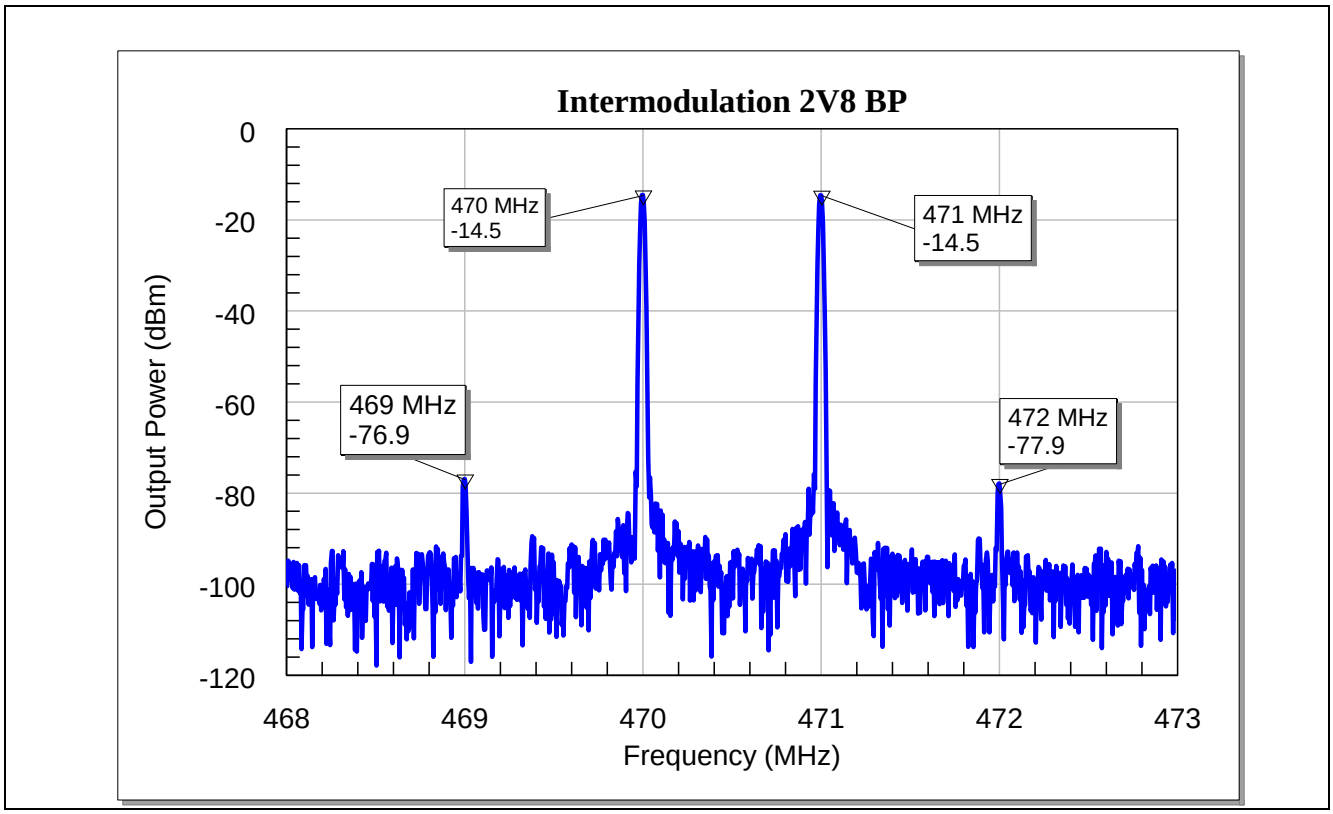


Figure 30 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 470 MHz)

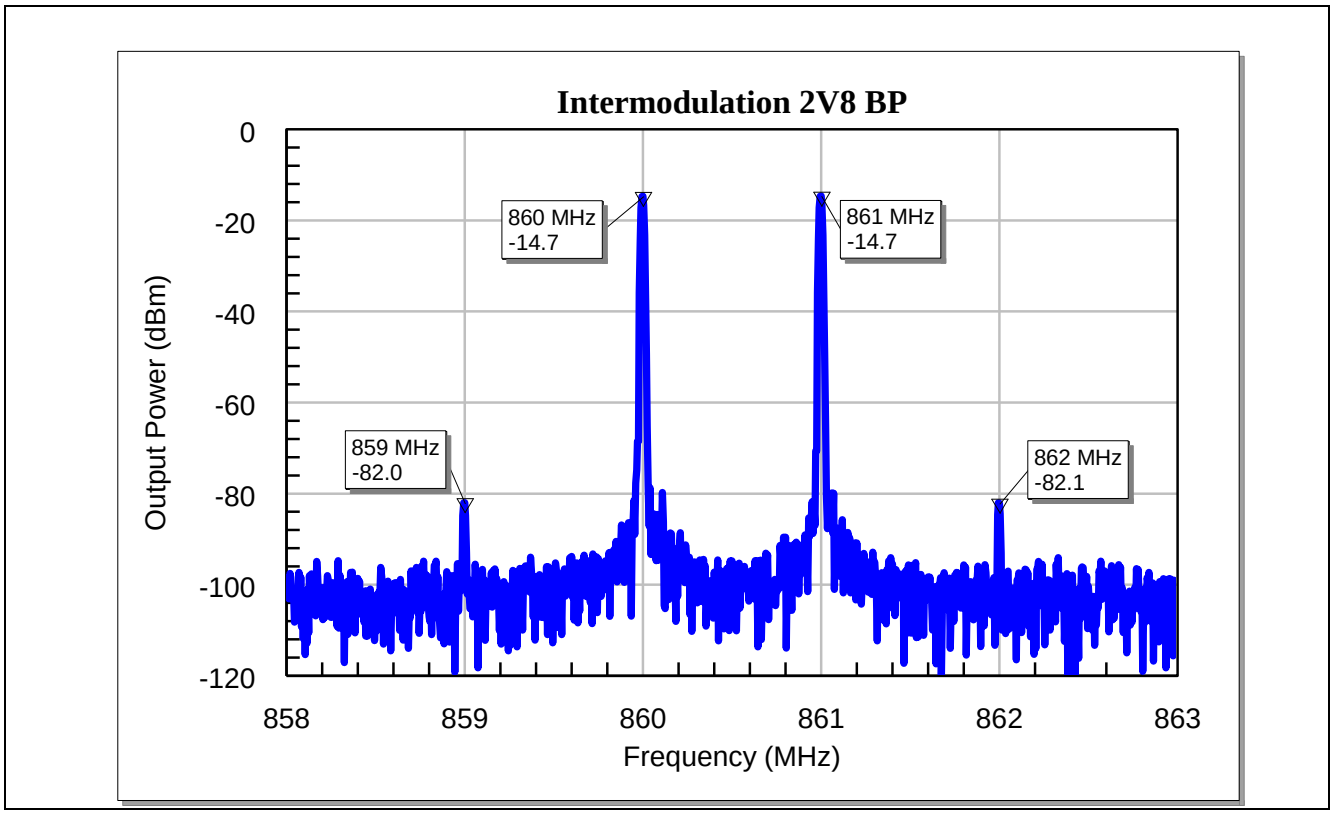


Figure 31 Third-Order Intercept Point of the BGA729N6 for Mobile TV and FM Radio Applications (2.8V, 860 MHz)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M150831**

PCB material: **<FR4 >**

ε_r of PCB material: **<4.8>**

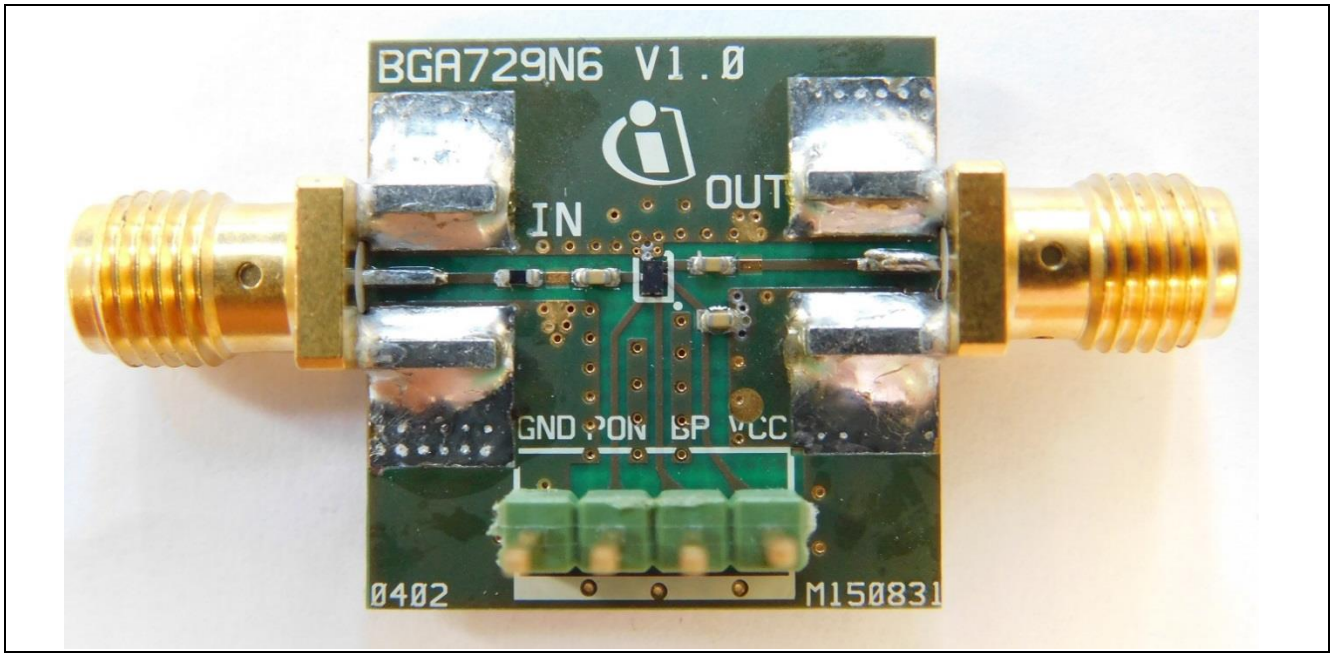


Figure 32 Photo Picture of Evaluation Board (overview) <PCB Marking M150831 Rev.1.0>

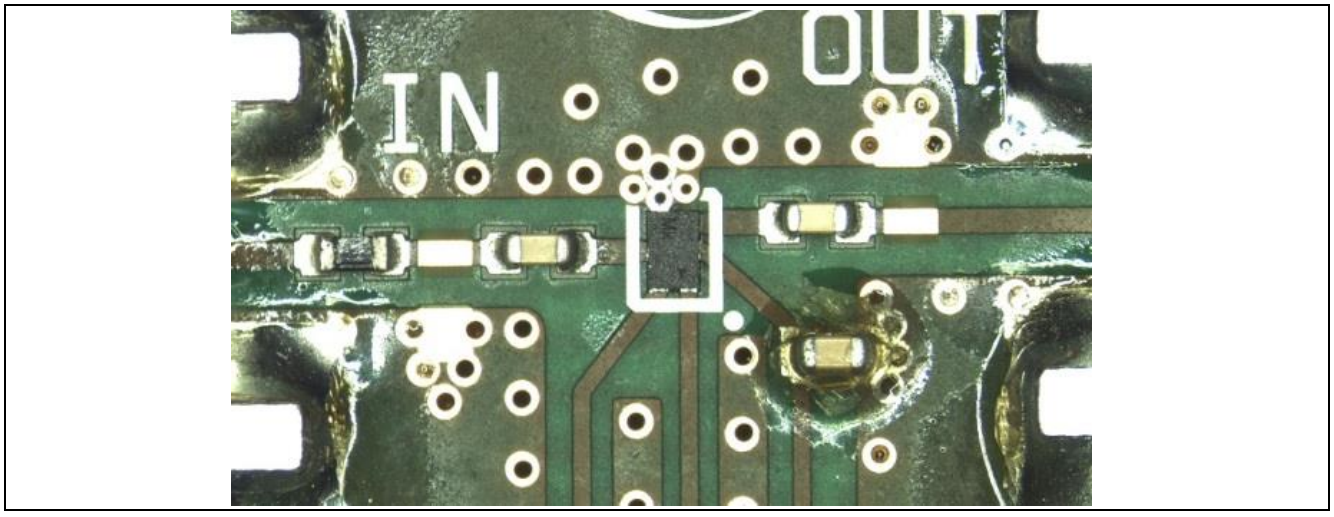


Figure 33 Photo Picture of Evaluation Board (detailed view)

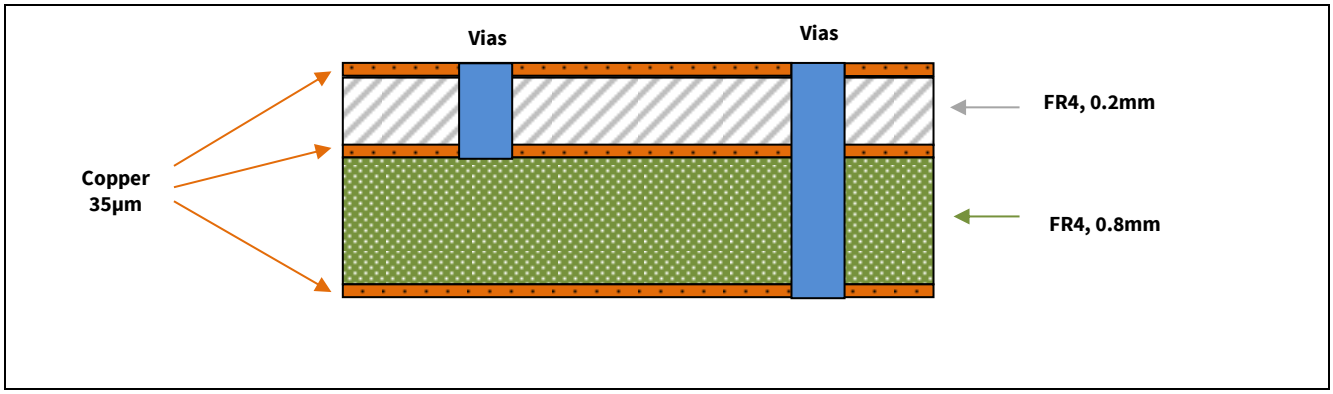


Figure 34 PCB Layer Information

6 Authors

Xiang Li, Application Engineer of Business Unit “RF and Sensor Devices”

7 Reference

[1] Application Guide for Mobile Communications 2015, Infineon Technologies, Business Unit RF and Sensors

[2] https://en.wikipedia.org/wiki/FM_broadcasting

[3] FM broadcasting frequencies: most of the countries transmit FM signals between 87.5 MHz – 108 MHz; a few other countries transmit FM signals at 66 MHz – 74 MHz and 76 MHz – 90 MHz. http://www.itu.int/dms_pubrec/itu-r/rec/bs/R-REC-BS.450-3-200111-I!!PDF-E.pdf

Revision History

Major changes since the last revision

Page or Reference	Description of change
8 - 28	Removed the 1000 MHz measurement point, added the measurement point 860 MHz for mobile TV application, updated measurement results
7- 28	Measurement results updated with results from final samples

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Edition 2016-09-01

Published by

Infineon Technologies AG

81726 Munich, Germany

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AN_201509_PL32_002

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