

# **BGA725L6**

High-Gain Low Noise Amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz Applications using 0201 components

**Application Note AN280** 

Revision: Rev. 1.0 2012-06-08

Edition 2012-06-15
Published by
Infineon Technologies AG
81726 Munich, Germany
© 2012 Infineon Technologies AG
All Rights Reserved.

#### **LEGAL DISCLAIMER**

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

#### Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (www.infineon.com).

#### Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office.

Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.



# BGA725L6 High-Gain LNA for GPS/GLONASS/Galileo/COMPASS

Application	Note AN280					
<b>Revision Hi</b>	story: 2012-06-08					
Previous R	Previous Revision: None					
Page	Subjects (major changes since last revision)					

#### Trademarks of Infineon Technologies AG

AURIX<sup>™</sup>, C166<sup>™</sup>, CanPAK<sup>™</sup>, CIPOS<sup>™</sup>, CIPURSE<sup>™</sup>, EconoPACK<sup>™</sup>, CoolMOS<sup>™</sup>, CoolSET<sup>™</sup>, CORECONTROL<sup>™</sup>, CROSSAVE<sup>™</sup>, DAVE<sup>™</sup>, DI-POL<sup>™</sup>, EasyPIM<sup>™</sup>, EconoBRIDGE<sup>™</sup>, EconoDUAL<sup>™</sup>, EconoPIM<sup>™</sup>, EconoPACK<sup>™</sup>, EiceDRIVER<sup>™</sup>, eupec<sup>™</sup>, FCOS<sup>™</sup>, HITFET<sup>™</sup>, HybridPACK<sup>™</sup>, I²RF<sup>™</sup>, ISOFACE<sup>™</sup>, IsoPACK<sup>™</sup>, MIPAQ<sup>™</sup>, ModSTACK<sup>™</sup>, my-d<sup>™</sup>, NovalithIC<sup>™</sup>, OptiMOS<sup>™</sup>, ORIGA<sup>™</sup>, POWERCODE<sup>™</sup>, PRIMARION<sup>™</sup>, PrimePACK<sup>™</sup>, PrimeSTACK<sup>™</sup>, PRO-SIL<sup>™</sup>, PROFET<sup>™</sup>, RASIC<sup>™</sup>, ReverSave<sup>™</sup>, SatRIC<sup>™</sup>, SIEGET<sup>™</sup>, SINDRION<sup>™</sup>, SIPMOS<sup>™</sup>, SmartLEWIS<sup>™</sup>, SOLID FLASH<sup>™</sup>, TEMPFET<sup>™</sup>, thinQ!<sup>™</sup>, TRENCHSTOP<sup>™</sup>, TriCore<sup>™</sup>.

#### Other Trademarks

Advance Design System™ (ADS) of Agilent Technologies, AMBA™, ARM™, MULTI-ICE™, KEIL™, PRIMECELL™, REALVIEW™, THUMB™, µVision™ of ARM Limited, UK. AUTOSAR™ is licensed by AUTOSAR development partnership. Bluetooth™ of Bluetooth SIG Inc. CAT-iq™ of DECT Forum. COLOSSUS™, FirstGPS™ of Trimble Navigation Ltd. EMV™ of EMVCo, LLC (Visa Holdings Inc.). EPCOS™ of Epcos AG. FLEXGO™ of Microsoft Corporation. FlexRay™ is licensed by FlexRay Consortium. HYPERTERMINAL™ of Hilgraeve Incorporated. IEC™ of Commission Electrotechnique Internationale. IrDA™ of Infrared Data Association Corporation. ISO™ of INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. MATLAB™ of MathWorks, Inc. MAXIM™ of Maxim Integrated Products, Inc. MICROTEC™, NUCLEUS™ of Mentor Graphics Corporation. MIPI™ of MIPI Alliance, Inc. MIPS™ of MIPS Technologies, Inc., USA. muRata™ of MURATA MANUFACTURING CO., MICROWAVE OFFICE™ (MWO) of Applied Wave Research Inc., OmniVision™ of OmniVision Technologies, Inc. Openwave™ Openwave Systems Inc. RED HAT™ Red Hat, Inc. RFMD™ RF Micro Devices, Inc. SIRIUS™ of Sirius Satellite Radio Inc. SOLARIS™ of Sun Microsystems, Inc. SPANSION™ of Spansion LLC Ltd. Symbian™ of Symbian Software Limited. TAIYO YUDEN™ of Taiyo Yuden Co. TEAKLITE™ of CEVA, Inc. TEKTRONIX™ of Tektronix Inc. TOKO™ of TOKO KABUSHIKI KAISHA TA. UNIX™ of X/Open Company Limited. VERILOG™, PALLADIUM™ of Cadence Design Systems, Inc. VLYNQ™ of Texas Instruments Incorporated. VXWORKS™, WIND RIVER™ of WIND RIVER SYSTEMS, INC. ZETEX™ of Diodes Zetex Limited.

Last Trademarks Update 2011-11-11



## BGA725L6 High-Gain LNA for GPS/GLONASS/Galileo/COMPASS

Table of Content, List of Figures and Tables

# **Table of Content**

1	SiGe Low Noise Amplifier for Global Navigation Satellite Systems (GNSS)	6
2	Introduction	7
3	Application Circuit	11
4	Typical Measurement Results	12
5	Measured Graphs for COMPASS/Galileo, GPS and GLONASS bands	14
6	Miscellaneous Measured Graphs	20
7	Evaluation Board	23
8	Authors	24



### BGA725L6 High-Gain LNA for GPS/GLONASS/Galileo/COMPASS

## Table of Content, List of Figures and Tables

# **List of Figures**

Figure 1	BGA725L6 in TSLP-6-2 Package (0.70mm x 1.1mm x 0.40mm)	6
Figure 2	BGA725L6 package size in comparison with 0402 and 0201 components	
Figure 3	Block diagram of the BGA725L6 for GNSS band 1559-1615MHz applications	10
Figure 4	BGA725L6 application circuit	
Figure 5	Power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	14
Figure 6	Narrowband power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	14
Figure 7	Input matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	15
Figure 8	Output matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	15
Figure 9	Reverse isolation of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	16
Figure 10	Noise figure of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands	16
Figure 11	Input 1 dB compression point of BGA725L6 at supply voltage of 1.8V for COMPASS, Galileo, and GLONASS bands	17
Figure 12	Input 1 dB compression point of BGA725L6 at supply voltage of 2.8V for COMPASS, Galileo, and GLONASS bands	
Figure 13	Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=1.8V	18
Figure 14	Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=2.8V	
Figure 15	Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=1.8V	
Figure 16	Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=2.8V	
Figure 17	Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=1.8V	20
Figure 18	Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=2.8V	20
Figure 19	Stability factor µ1 of BGA725L6 upto 10GHz	
Figure 20	Stability factor µ2 of BGA725L6 upto 10GHz	
Figure 21	Stability factor k of BGA725L6 upto 10GHz	
Figure 22	Populated PCB picture of BGA725L6	
Figure 23	PCB layer stack	23
List of	Tables	
Table 1	Pin Definition	
Table 2	Switching Mode	
Table 3	Bill-of-Materials	
Table 4	Electrical Characteristics (at room temperature), Vcc = Vpon = 1.8 V	
Table 5	Electrical Characteristics (at room temperature), Vcc = Vpon = 2.8 V	13



SiGe Low Noise Amplifier for Global Navigation Satellite Systems (GNSS)

# 1 SiGe Low Noise Amplifier for Global Navigation Satellite Systems (GNSS)

#### 1.1 Features

- High insertion power gain: 20.0 dB
- Out-of-band input 3<sup>rd</sup>-order intercept point: -2 dBm
- Input 1dB compression point: -15 dBm
- Low noise figure: 0.65 dB
- Low current consumption: 3.6 mA
- Operating frequency: 1550 1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Ultra small TSLP-6-2 leadless package (footprint: 0.7 x 1.1 mm<sup>2</sup>)
- B7HF Silicon Germanium technology
- RF output internally matched to 50  $\Omega$
- Only one external SMD component necessary
- 2 kV HBM ESD protection (including Al-pin)
- Pb-free (RoHS compliant) package



Figure 1 BGA725L6 in TSLP-6-2 Package (0.70mm x 1.1mm x 0.40mm)

#### 1.2 Applications

- GPS (Global Positioning System) working in the L1 band at 1575.42 MHz
- GLONASS (Russian GNSS) working in the L1 band from 1598.06 MHz to 1605.38 MHz
- Galileo (European GNSS) working in the E2-L1-E1 band from 1559 MHz to 1592 MHz
- COMPASS (Chinese Beidou Navigation System) working in E2 band at 1561.10 MHz and E1 band at 1589.74 MHz



#### 2 Introduction

The BGA725L6 is a front-end Low Noise Amplifier (LNA) for Global Navigation Satellite Systems (GNSS) application. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe) technology, enabling a cost-effective solution in a ultra small TSLP-6-2 package with ultra low noise figure, high gain, high linearity and low current consumption over a wide range of supply voltages from 3.6 V down to 1.5 V. All these features make BGA725L6 an excellent choice for GNSS LNA as it improves sensitivity, provide greater immunity against out-of-band jammer signals, reduces filtering requirement and hence the overall cost of the GNSS receiver.

The GNSS satellites are at an orbit altitude of more than 20,000 km away from earth's surface and transmit power in the range of +47 dBm. After taking losses (atmospheric, antenna etc.) into account, the received signal strength at the GNSS device input is very low in the range of -130 dBm. The ability of the GNSS device to receive such a low signal strength and provide meaningful information to the end-user depends strongly on the noise figure of the GNSS receive chain. This ability which is called receiver sensitivity can be improved by using a low-noise amplifier with low noise figure and high gain at the input of the receiver chain. The improved sensitivity results in a shorter Time-To-First-Fix (TTFF), which is the time required for a GNSS receiver to acquire satellite signals and navigation data, and calculate a position. Noise figure of the LNA defines the overall noise figure of the GNSS receiver system. This is where BGA725L6 excels by providing noise figure as low as 0.65 dB and high gain of 20.0 dB, thereby improving the receiver sensitivity significantly.

The ever growing demand to integrate more and more functionality into one device leads to many challenges when transmitter/receiver has to work simultaneously without degrading the performance of each other. In today's smart-phones a GNSS receiver simultaneously coexists with transceivers in the GSM/EDGE/UMTS/LTE bands. These 3G/4G transceivers transmit high power in the range of +24 dBm which due to insufficient isolation couple to the GNSS receiver. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band. For example, GSM 1712.7 MHz mixes with UMTS 1850 MHz to produce third-order-product exactly at GPS. To quantify the effect, BGA725L6 shows

out-of-band input IP3 at GPS of +2.9 dBm as a result of frequency mixing between GSM 1712.7 MHz and UMTS 1850 MHz with power levels of -20 dBm. BGA725L6 has a high out-of-band input 3<sup>rd</sup> order intercept point (IIP3) of +2.9 dBm, so that it is especially suitable for the GPS function in mobile phones.

BGA725L6 also offers sufficient rejection at 787.76MHz, which is band-13 of upcoming LTE and whose 2<sup>nd</sup> harmonic is at GPS frequency, to meet specifications of 2<sup>nd</sup> harmonic of band-13 without any additional circuitry. BGA725L6 has input referred band-13 second harmonic level of -44.7 dBm when the input signal of 787.76 MHz at -25 dBm is applied.

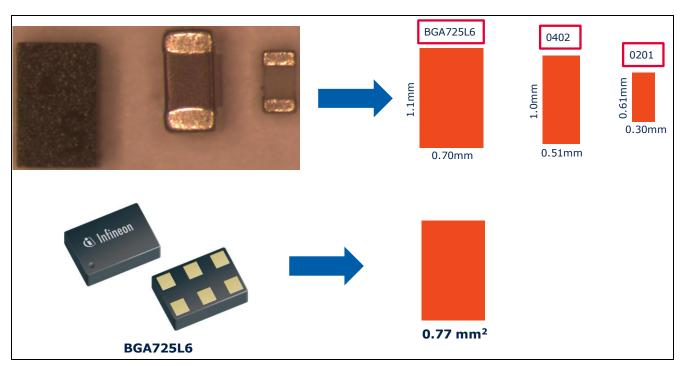


Figure 2 BGA725L6 package size in comparison with 0402 and 0201 components

As the industry inclines toward assembly miniaturization and also surface mount technology matures, there is a desire to have smaller and thinner components. This is especially the case with portable electronics where higher circuit density allows device design flexibility and also optimum use of the limited space available. BGA725L6 has ultra small package with dimensions of 0.70mm x 1.1mm x 0.40mm and it requires only two components at its input, the capacitor at the input has to be used if a DC block is required and the inductor provides input matching. The DC block at input is optional as it is usually provided by the pre-filter before the LNA in many GPS applications. All the device manufacturers implement very good



power supply filtering on their boards so that the RF bypass capacitor mentioned in this application circuit may not be needed in the end. The minimal number of external SMD components reduces the application bill of materials and the PCB area thus making it an ideal solution for compact and cost-effective GNSS LNA. The output of the BGA725L6 is internally matched to 50  $\Omega$ , and a DC blocking capacitor is integrated on-chip, thus no external component is required at the output.

The device also integrates an on-chip ESD protection which can resist until 2 kV (referenced to Human Body Model). The integrated power on/off feature provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (3.6 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

The Internal circuit diagram of the BGA725L6 is presented in Figure 3. Table 1 show the pin assignment of BGA725L6. Table 2 shows the truth table to turn on/off BGA725L6 by applying different voltage to the PON pin.

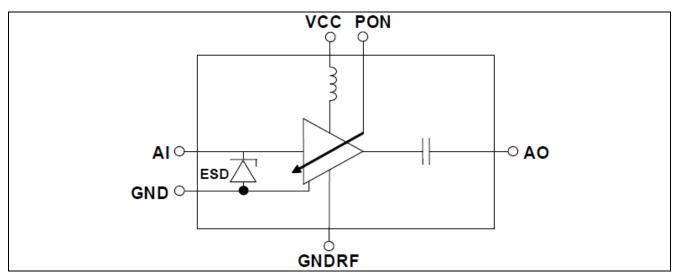


Figure 3 Block diagram of the BGA725L6 for GNSS band 1559-1615MHz applications

Pin	Symbol	Comment
1	GND	General ground
2	VCC	DC supply
3	AO	LNA output
4	GNDRF	LNA RF ground
5	Al	LNA input
6	PON	Power on control

Table 2 Switching Mode

LNA	Symbol	ON/OFF Control Voltage at PON pin			
Mode		Min	Max		
ON	PON, on	1.0 V	VCC		
OFF	PON, off	0 V	0.4 V		



# 3 Application Circuit

## 3.1 Schematic Diagram

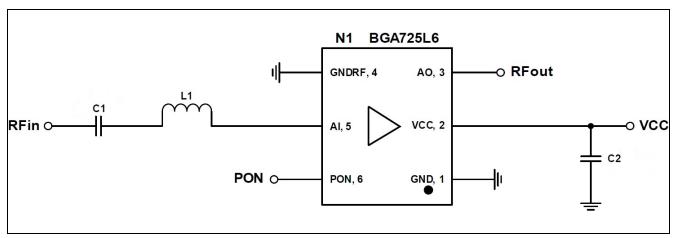


Figure 4 BGA725L6 application circuit

Table 3 Bill-of-Materials

Symbol	Value	Unit	Package	Manufacturer	Comment
C1	1	nF	0201	Various	DC block
C2	10	nF	0201	Various	RF bypass
L1	6.8	nH	0201	Murata LQP series	Input matching
N1	BGA725L6		TSLP-6-2	Infineon	SiGe:C LNA
PCB substrate	FR4				

**Typical Measurement Results** 

# 4 Typical Measurement Results

Table 4 and Table 5 show typical measurement results of the application circuit shown in Figure 4. The values given in this table include losses of the board and the SMA connectors if not otherwise stated.

Table 4 Electrical Characteristics (at room temperature), Vcc = Vpon = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8				
DC Current	Icc	3.8			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	19.9	19.9	19.8	dB	
Noise Figure	NF	0.71	0.71	0.71	dB	PCB and SMA losses of 0.07dB substracted
Input Return Loss	RLin	13.9	14.5	15.6	dB	
Output Return Loss	RLout	26.6	35.0	18.6	dB	
Reverse Isolation	IRev	35.2	35.4	36.0	dB	
Input P1dB	IP1dB	-15.4	-15.5	-15.8	dBm	$f_{galileo}$ = 1559 MHz $f_{gps}$ = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	3.5	3.4	3.0	dBm	
Input IP3 In-band	IIP3	-6.9	-6.9	-7.0	dBm	
Output IP3 In-band	OIP3	13.0	13.0	12.8	dBm	$\begin{aligned} f_{1gal/gps} &= 1575 \text{ MHz} \\ f_{2gal/gps} &= 1576 \text{MHz} \\ f_{1GLONASS} &= 1602 \text{ MHz} \\ f_{2GLONASS} &= 1603 \text{ MHz} \\ \text{Input power= -30dBm} \end{aligned}$
LTE band-13 2 <sup>nd</sup> Harmonic	H2 – input referred	-44.7				$f_{IN} = 787.76 \text{ MHz}$ $P_{IN} = -25 \text{ dBm}$ $f_{H2} = 1575.52 \text{ MHz}$
Input IP3 out-of-band	IIP3 <sub>OOB</sub>	-0.5			dBm	$f_1 = 1712.7 \text{ MHz}$ $f_2 = 1850 \text{ MHz}$ Input power = -20dBm $f_{\text{IIP3}} = 1575.4 \text{ MHz}$
Stability	k		>1			Unconditionnally Stable from 0 to 10GHz



Table 5 Electrical Characteristics (at room temperature), Vcc = Vpon = 2.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc		3.9		mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	19.9	19.9	19.9	dB	
Noise Figure	NF	0.72	0.70	0.73	dB	PCB and SMA losses of 0.07dB substracted
Input Return Loss	RLin	13.7	14.3	15.5	dB	
Output Return Loss	RLout	21.9	33.4	21.7	dB	
Reverse Isolation	IRev	35.2	35.3	35.7	dB	
Input P1dB	IP1dB	-14.8	-14.7	-14.6	dBm	$f_{galileo}$ = 1559 MHz $f_{gps}$ = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	4.1	4.2	4.3	dBm	
Input IP3 In-band	IIP3	-5.8	-5.8	-5.9	dBm	
Output IP3 In-band	OIP3	14.1	14.1	14.0	dBm	$f_{1gal/gps} = 1575 \text{ MHz}$ $f_{2gal/gps} = 1576 \text{MHz}$ $f_{1GLONASS} = 1602 \text{ MHz}$ $f_{2GLONASS} = 1603 \text{ MHz}$ Input power= -30dBm
LTE band-13 2 <sup>nd</sup> Harmonic	H2 – input referred		-44.7		dBm	$f_{IN} = 787.76 \text{ MHz}$ $P_{IN} = -25 \text{ dBm}$ $f_{H2} = 1575.52 \text{ MHz}$
Input IP3 out-of-band	IIP3 <sub>OOB</sub>		2.9		dBm	$f_1 = 1712.7 \text{ MHz}$ $f_2 = 1850 \text{ MHz}$ Input power = -20dBm $f_{IIP3} = 1575.4 \text{ MHz}$
Stability	k	>1				Unconditionnally Stable from 0 to 10GHz

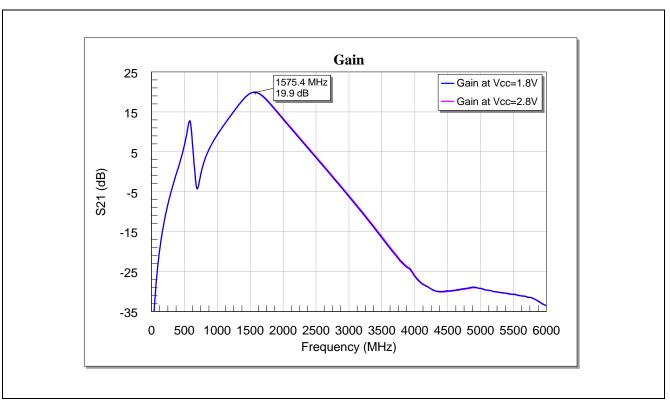


Figure 5 Power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

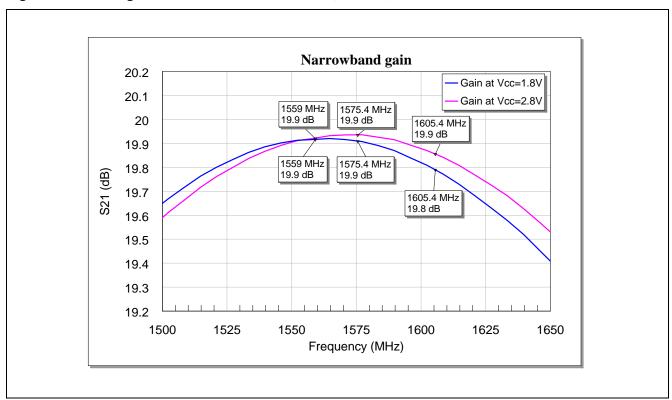


Figure 6 Narrowband power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands



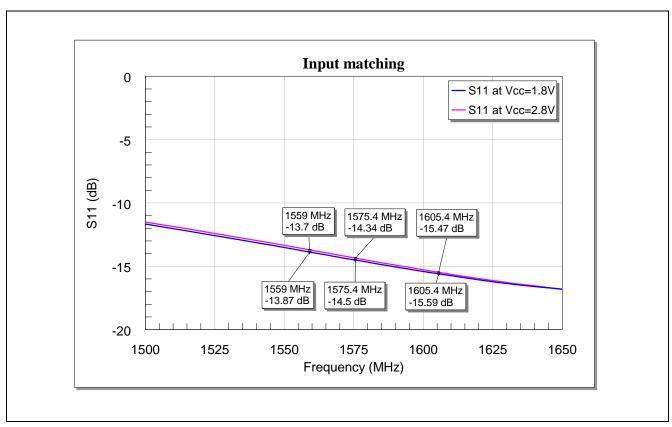


Figure 7 Input matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

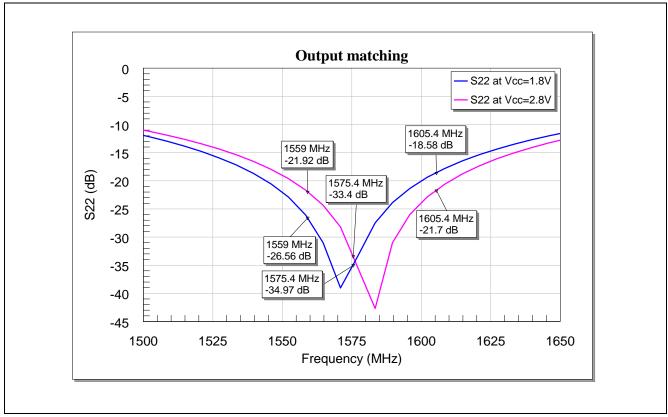


Figure 8 Output matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

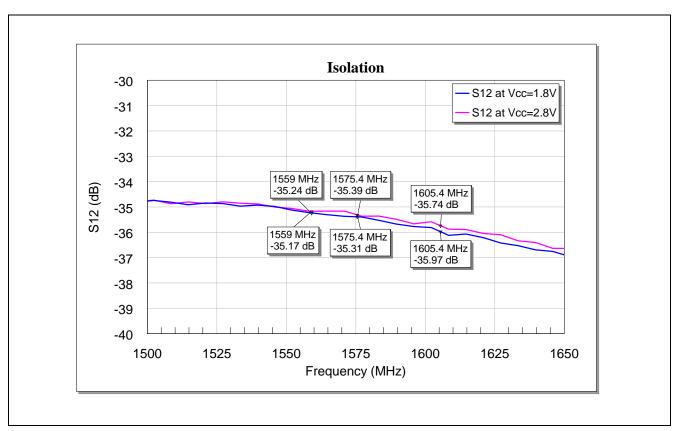


Figure 9 Reverse isolation of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

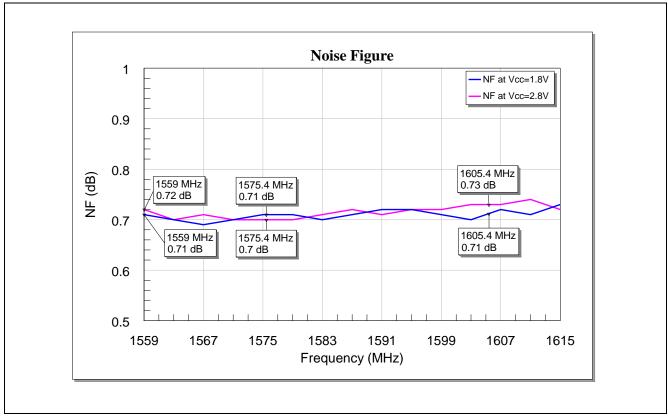


Figure 10 Noise figure of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

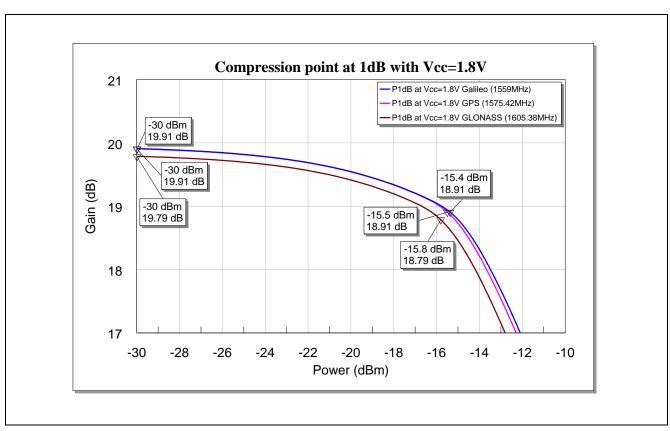


Figure 11 Input 1 dB compression point of BGA725L6 at supply voltage of 1.8V for COMPASS, Galileo, GPS and GLONASS bands

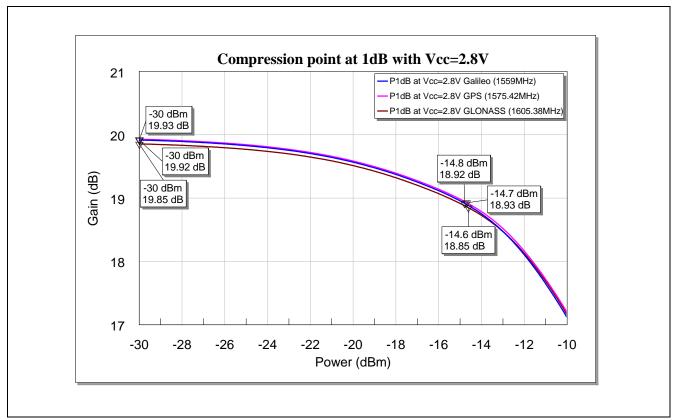


Figure 12 Input 1 dB compression point of BGA725L6 at supply voltage of 2.8V for COMPASS, Galileo, GPS and GLONASS bands



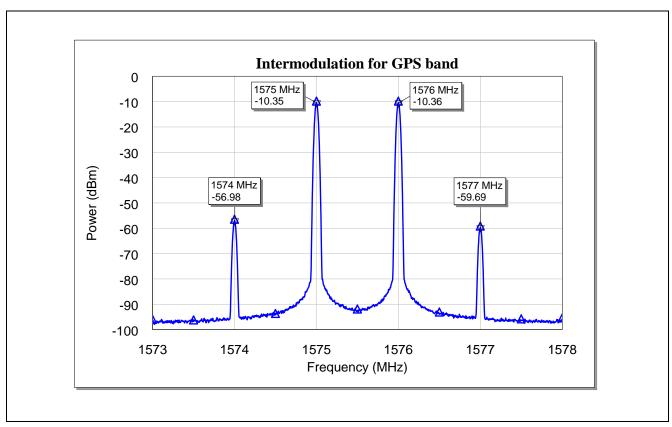


Figure 13 Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=1.8V

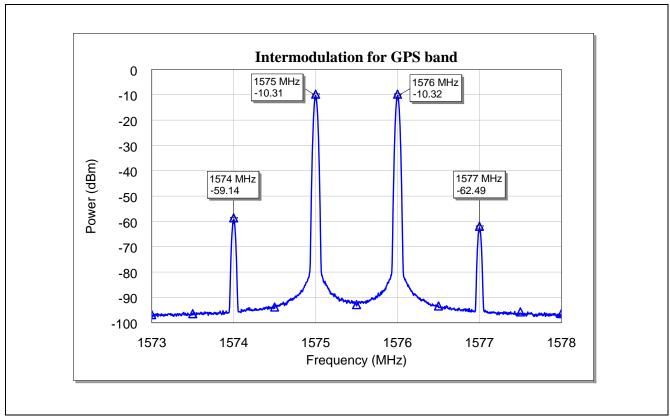


Figure 14 Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=2.8V

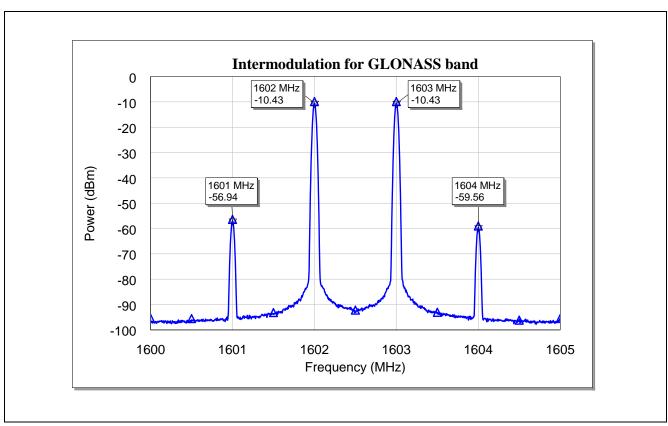


Figure 15 Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=1.8V

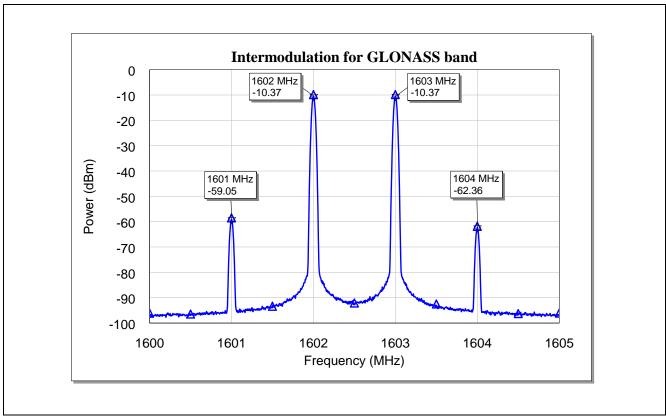


Figure 16 Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=2.8V

Miscellaneous Measured Graphs

## 6 Miscellaneous Measured Graphs

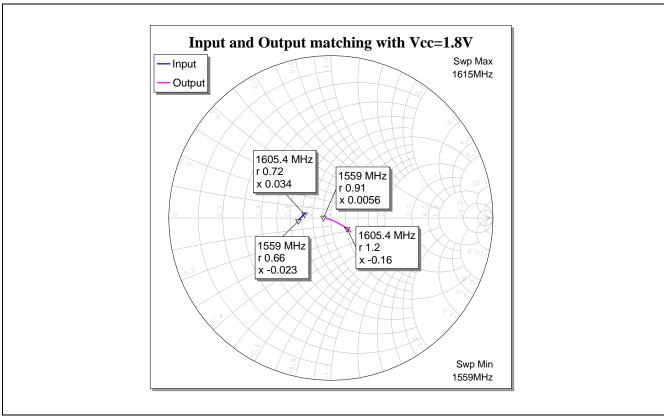


Figure 17 Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=1.8V

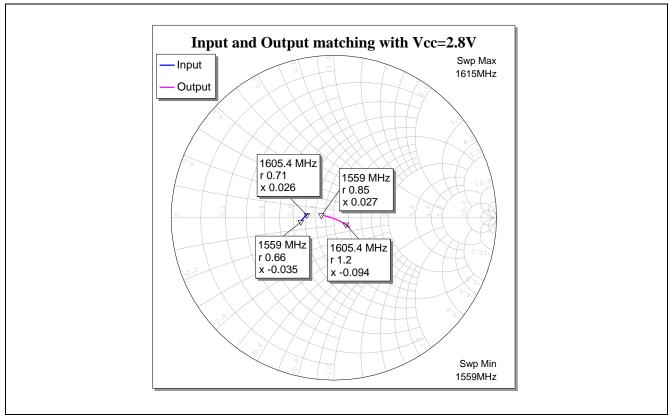


Figure 18 Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=2.8V

Miscellaneous Measured Graphs

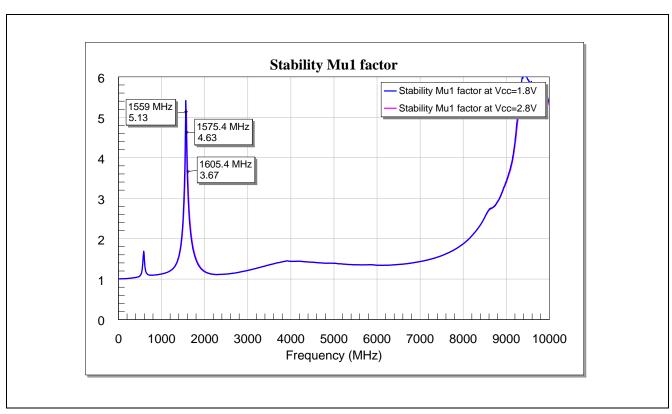


Figure 19 Stability factor μ1 of BGA725L6 upto 10GHz

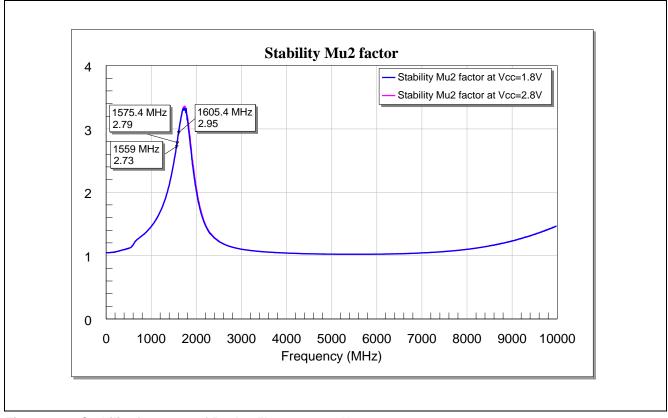


Figure 20 Stability factor µ2 of BGA725L6 upto 10GHz

**Miscellaneous Measured Graphs** 

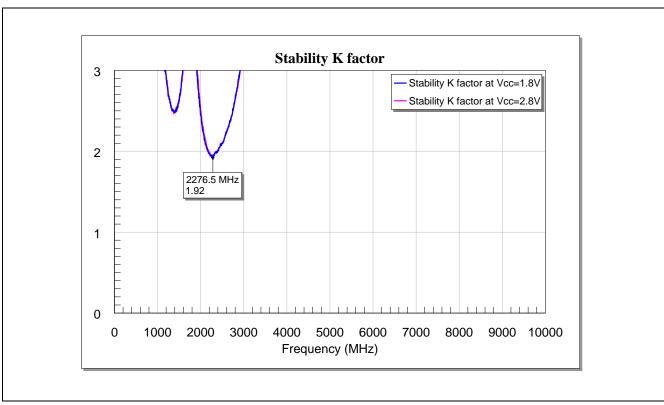


Figure 21 Stability factor k of BGA725L6 upto 10GHz

**Evaluation Board** 

### 7 Evaluation Board

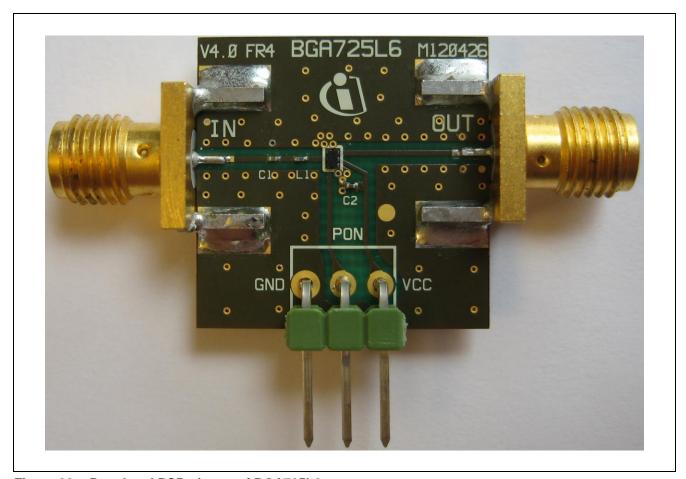


Figure 22 Populated PCB picture of BGA725L6

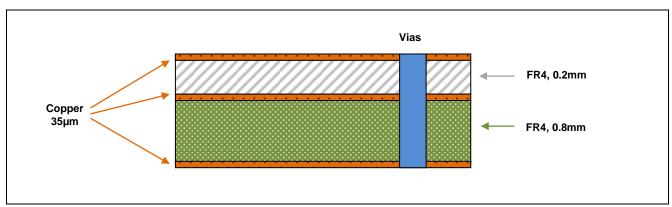


Figure 23 PCB layer stack



Authors

## 8 Authors

Jagjit Singh Bal, Senior Application Engineer of Business Unit "RF and Protection Devices". Dr. Chih-I Lin, Senior Staff Engineer of Business Unit "RF and Protection Devices".

www.infineon.com