AN11140

Low Noise Fast Turn ON/OFF 5-5.9GHz WiFi LNA with BFU730F

Rev. 1 — 15 October 2012 Application note

Document information

Info	Content
Keywords	BFU730F, 5-5.9GHz LNA, WiFi (WLAN)
Abstract	This document provides circuit simulation, schematic, layout, BOM and typical EVB performance for a 5-5.9GHz WiFi (WLAN) LNA

Revision history

Rev	Date	Description
v.1	15 October 2012	First publication

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1. Introduction

The BFU730F is a discrete HBT that is produced using NXP Semiconductors' advanced 110 GHz fT SiGe:C BiCmos process. SiGe:C is a normal silicon germanium process with the addition of Carbon in the base layer of the NPN transistor. The presence of carbon in the base layer suppresses the boron diffusion during wafer processing. This allows a steeper and narrower SiGe HBT base and a heavier doped base. As a result, lower base resistance, lower noise and higher cut off frequency can be achieved.

The BFU730F is one of a series of transistors made in SiGe:C.

BFU710F, BFU760F and BFU790F are the other types. BFU710F is intended for ultra low current applications. The BFU760F and BFU790F are high current types and are intended for application where linearity is key.

New 6th & 7th Generation Wideband transistors from NXP offer best RF noise figure / gain tradeoff at 12GHz drawing lowest current which means best signal reception at low power, enabling products to be more sensitive in noisy environments and friendlier to the environment.

Key Benefits:

- Application up to 18 GHz and higher
- Broad choice of parts for the perfect fit in the application
- Lowest current consumption meaning greener products
- SOT343F package for high performance and easy manufacturing

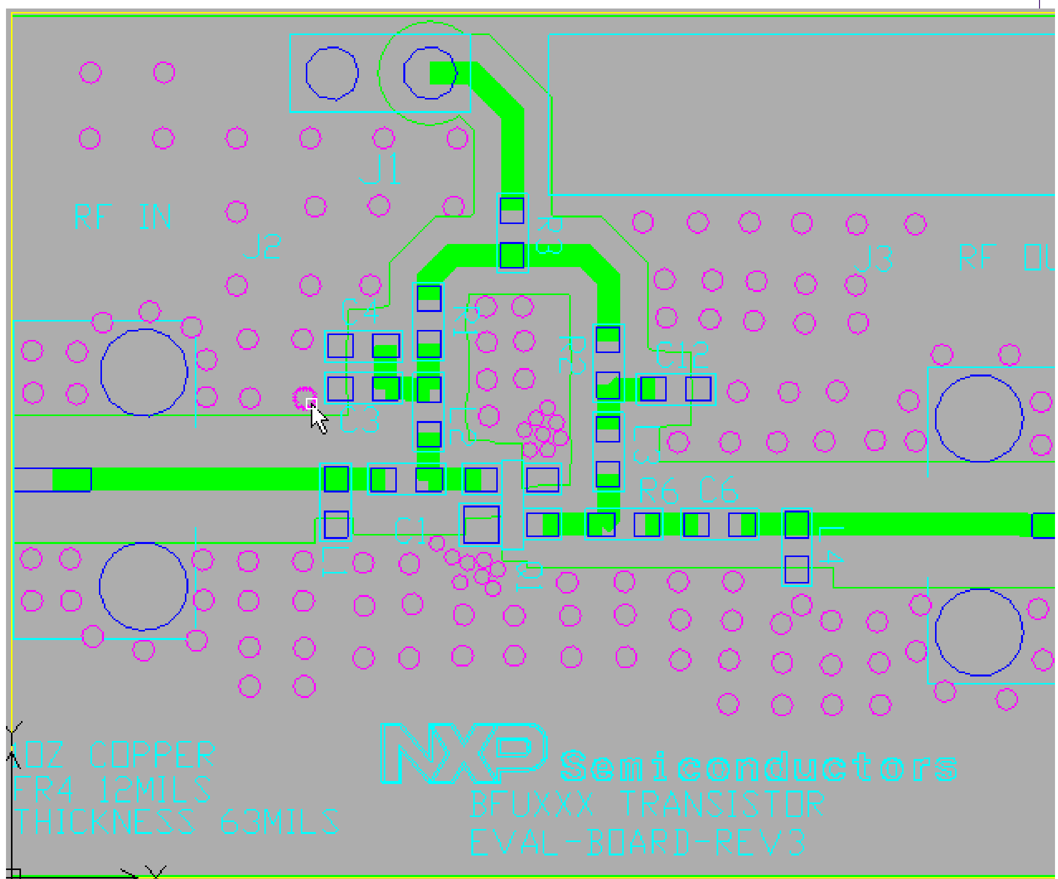


Fig 1. BFUXXX Universal Demo Board/BFU730F 5-5.9GHz WiFi LNA EVB Demo Board

2. Requirements and design of the 5-5.9GHz WiFi LNA

The circuit shown in this application note is intended to demonstrate the performance of the BFU730F in a 5-5.9 GHz LNA for e.g. 802.11a/b/g & 802.11n “MIMO” WiFi (WLAN) applications.

Key requirements for this application are:

- Frequency Band 5 – 5.9GHz
- Gain
- Input/output Match
- Linearity
- NF
- Turn ON/OFF Time

Table 1. 5-5.9GHz WiFi LNA Design Target Spec
Target specification for 5– 5.9GHz WiFi LNA

VCC	Icc	NF	Gain	IP1dB	IIP3	ORL	IRL	Turn ON/OFF Time
3.0	10	<2	>10	>-8	>2	>10	>10	<500
V	mA	dB	dB	dBm	dBm	dB	dB	nS

3. Design and Simulation

The 5-5.9 GHz WiFi LNA consists of one stage BFU730F amplifier. For this amplifier the minimum number of external components is used for low cost purpose:

- 1 multilayer chip inductor, lower cost comparing to wirewound type
- 3 resistors
- 4 capacitors

The design has been simulated using Agilent's Advanced Design System (ADS), and the simulation results are given in the following figures.

The LNA shows excellent match at input/output with greater than 10dB return loss and gain of 14dB @5.9GHz with superior Noise Figure of 1.1dB.

With only 10.8mA it also shows a high input P1 dB compression of –6.5dBm@5.9GHz, as well as high input IP3 of +5.7dBm.

The LNA Turn ON and OFF time are 300nS and 18nS respectively.

The designed LNA is unconditionally stable at 10 MHz-20 GHz.

3.1 BFU730F 5-5.9GHz WiFi LNA Simulation

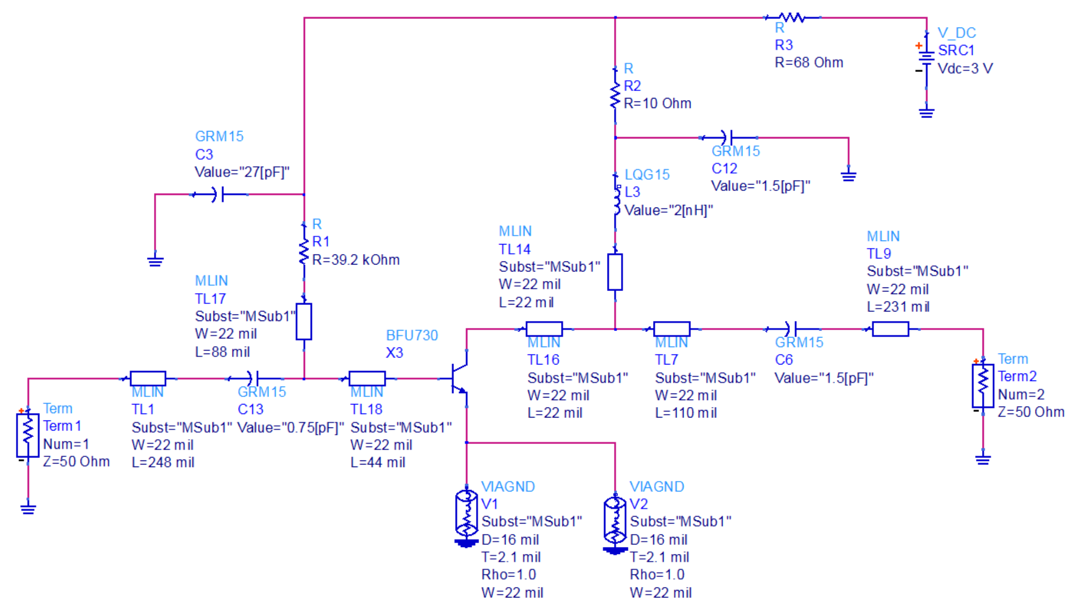


Fig 2. BFU730F 5-5.9GHz WiFi LNA Simulation: Circuit

3.2 BFU730 5-5.9GHz WiFi LNA Simulation Result

3.2.1 Gain and Match in 5-5.9GHz Band

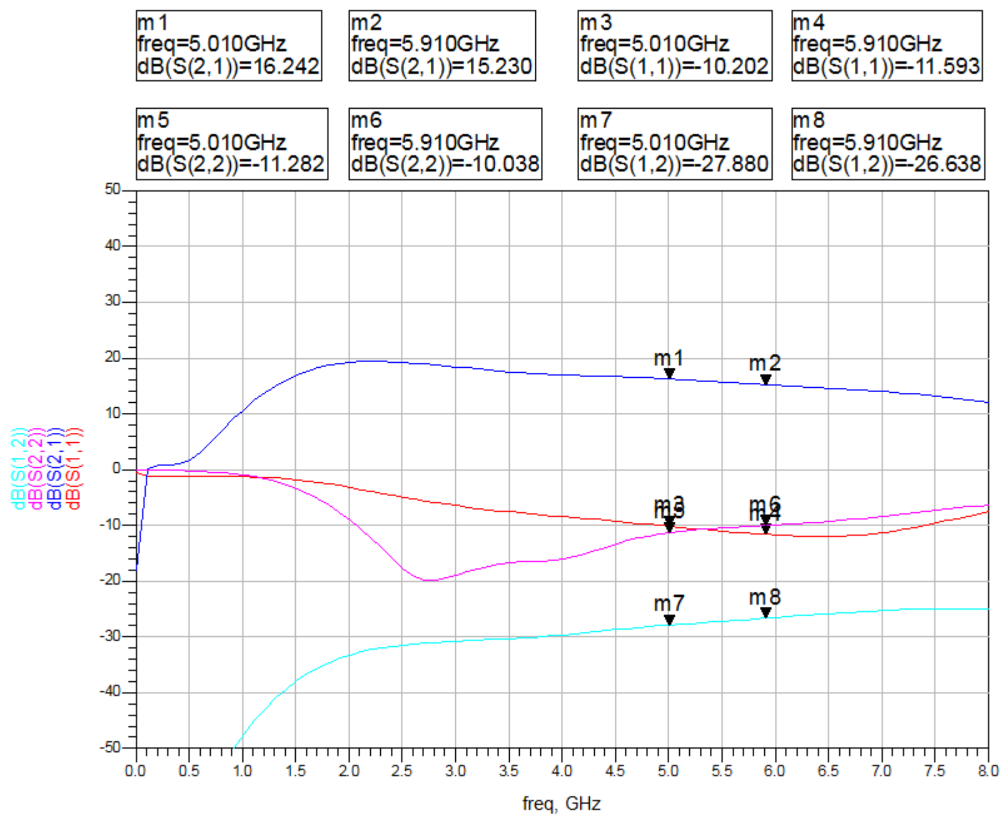
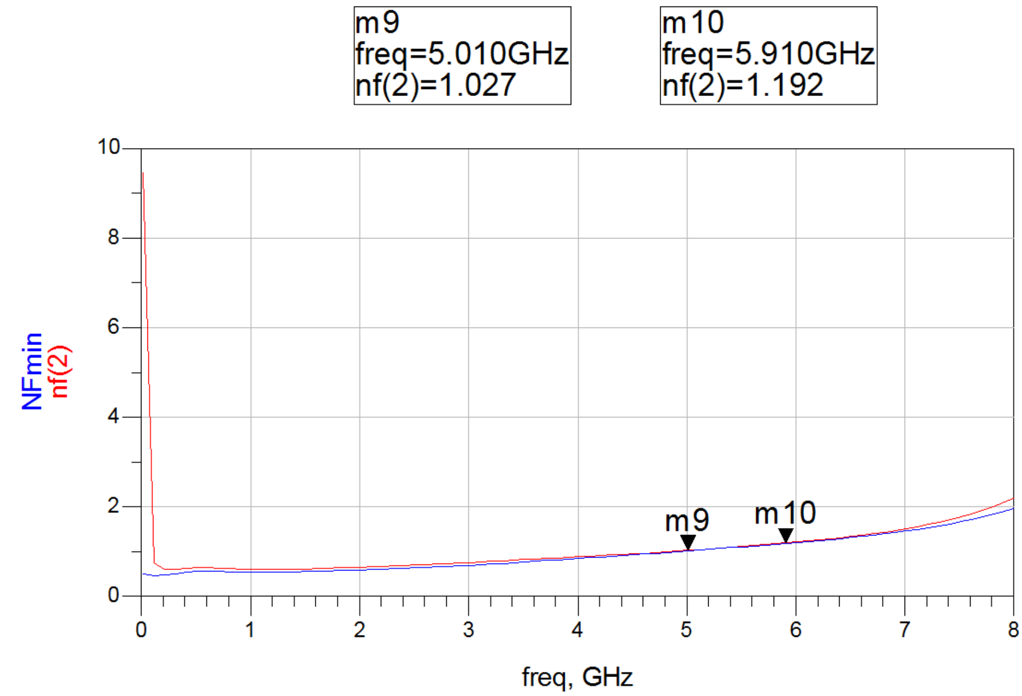


Fig 3. BFU730F 5-5.9GHz WiFi LNA Simulation: Gain and Match

3.2.2 Noise Figure in 5-5.9GHz Band



Note: the simulated NF includes the loss at input and output(no de-embedding)

Fig 4. BFU730F 5-5.9GHz WiFi LNA Simulation: Noise Figure

3.2.3 Stability

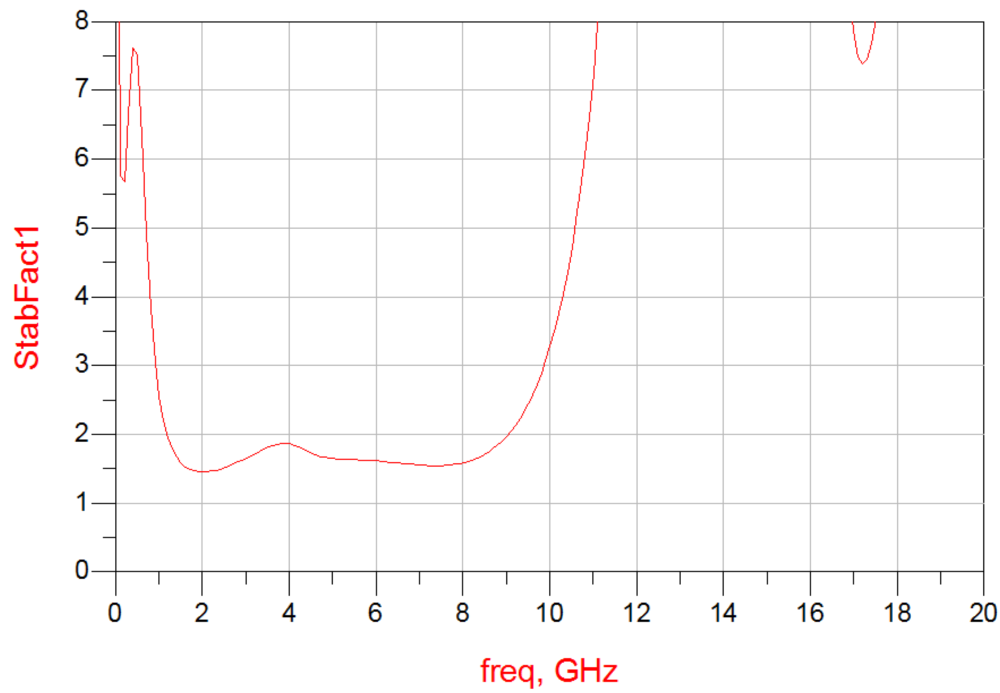


Fig 5. BFU730F 5-5.9GHz WiFi LNA Simulation: Stability

4. Application Board

The 5-5.9GHz WiFi LNA evaluation board simplifies the evaluation of the BFU730F application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BFU730F transistor, including input and output matching components, to optimize performance.

The board is supplied with two SMA connectors for input and output connection to RF test equipment.

4.1 Application Circuit Schematic

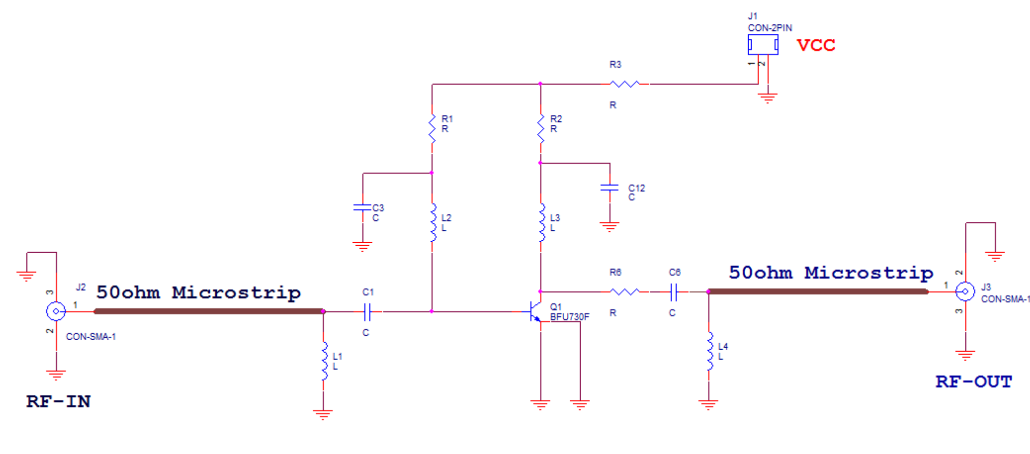


Fig 6. BFUXXX Universal Demo Board: Schamatic

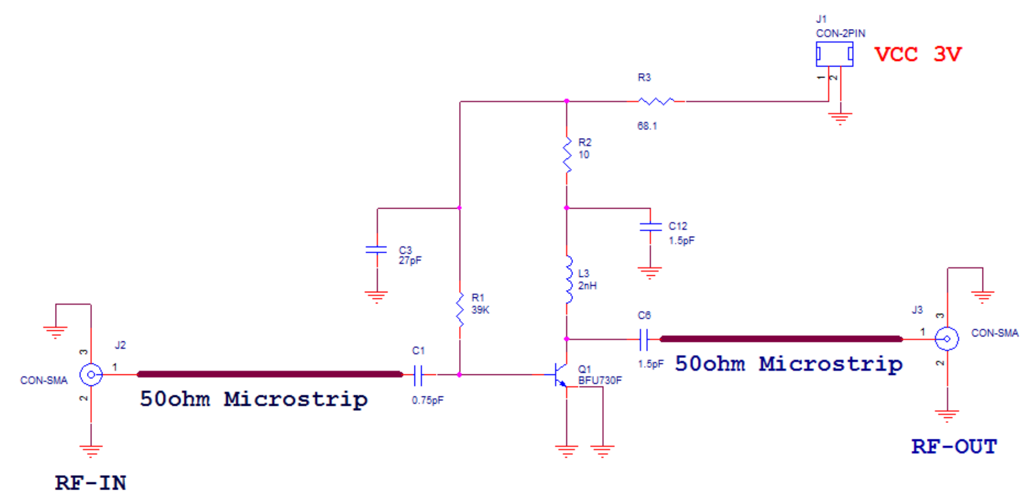


Fig 7. BFU730F 5-5.9GHz WiFi LNA: Schematic

Note: Figure 6 is the schematic for BFUXXX universal demo board, some assembly changes are made to accommodate this simplified low cost design, the revised schematic is shown in figure 7, and the changes are as following:

1. L1, L2, L4, C4, R6: not populated
2. Move R1 (39K) to L2 location, short two solder pads of R1 or put a 0 ohm jumper
3. Short two solder pads of R6 or put a 0 ohm jumper

4.2 Application Board Bill-Of-Material

Table 2. BFU730F 5-5.9GHz WiFi LNA Part List
Customer can choose their preferred vendor but should be aware that the performance could be affected.

Item	Quantity	Reference	Part Number	Vendor	Value
1	1	C1	GRM1555C1HR75CZ01D	Murata	0.75pF
2	1	C3	GRM1555C1H270JZ01D	Murata	27pF
3	2	C6,C12	GRM1555C1H1R5CZ01D	Murata	1.5pF
4	1	J1	90120-0762	Molex	CON-2PIN
5	2	J2,J3	901-10110	Amphenol	CON-SMA-1
6	1	L3	LQG15HN2N0S02D	Murata	2nH
7	1	Q1	BFU730F	NXP SEMICONDUCTORS	BFU730F
8	1	R2	ERJ-2RKF10R0X	Panasonic - ECG	10
9	1	R3	ERJ-2RKF68R1X	Panasonic - ECG	68.1
10	1	R1	ERJ-2GEJ393X	Panasonic - ECG	39K

4.3 Typical Application Board Test Result

4.3.1 S-Parameter – Gain and Match

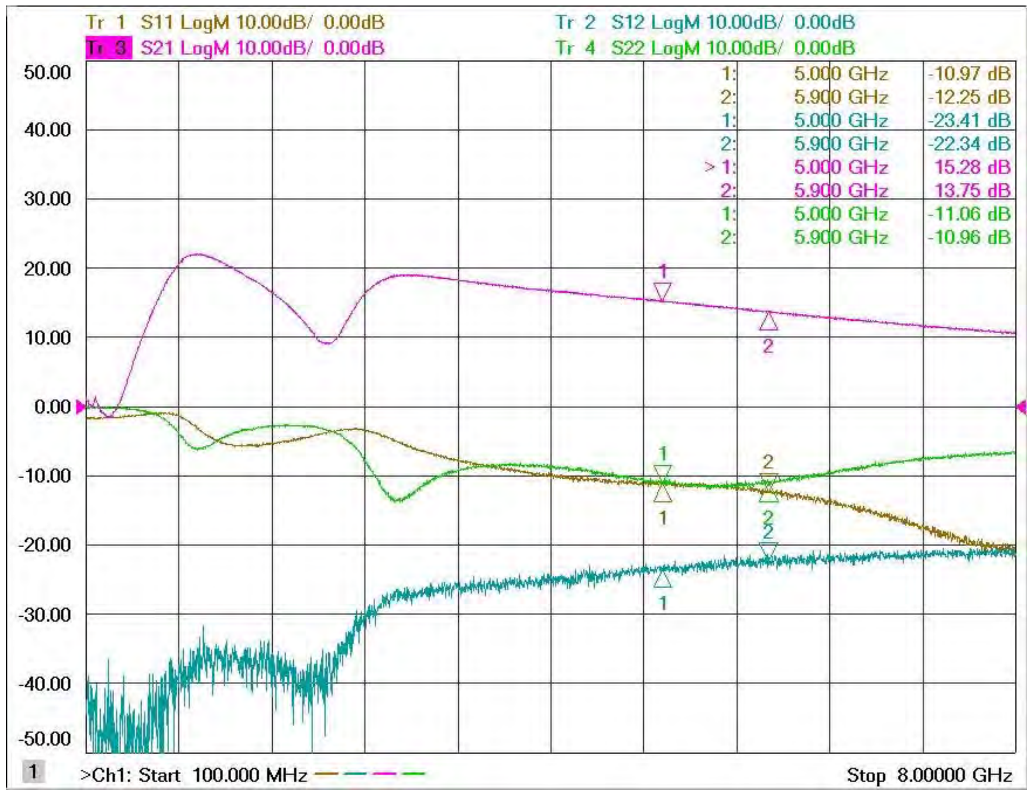


Fig 8. BFU730F 5-5.9GHz WiFi LNA: S-Parameter

4.3.2 P1dB

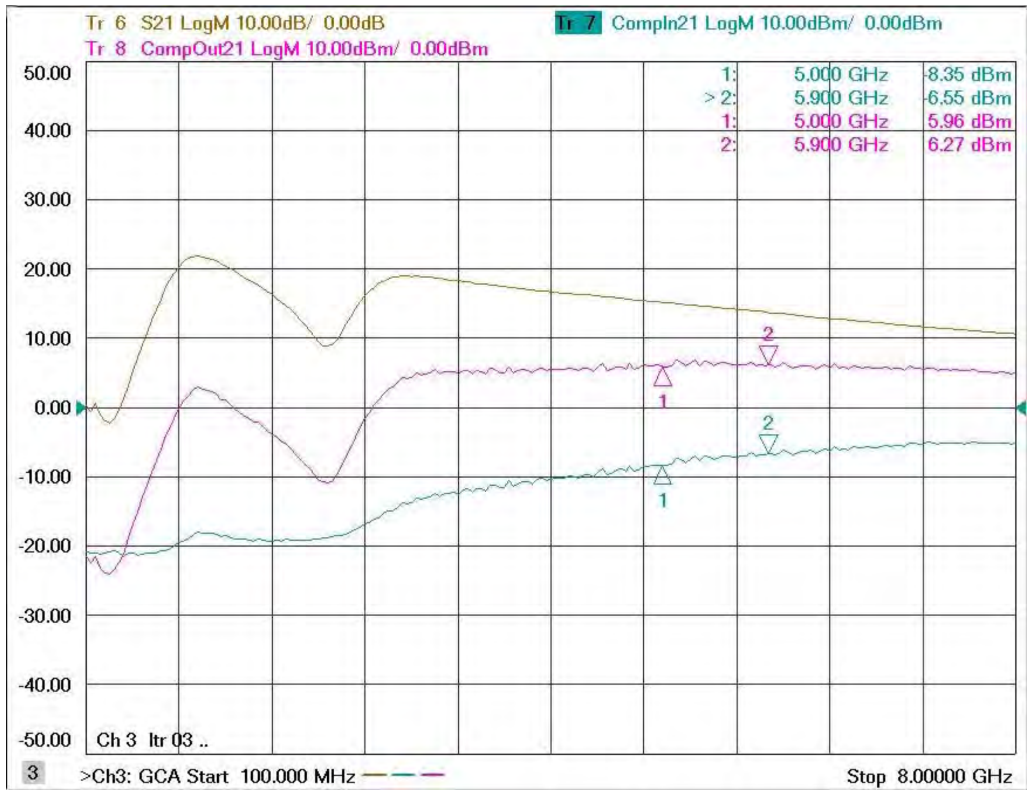
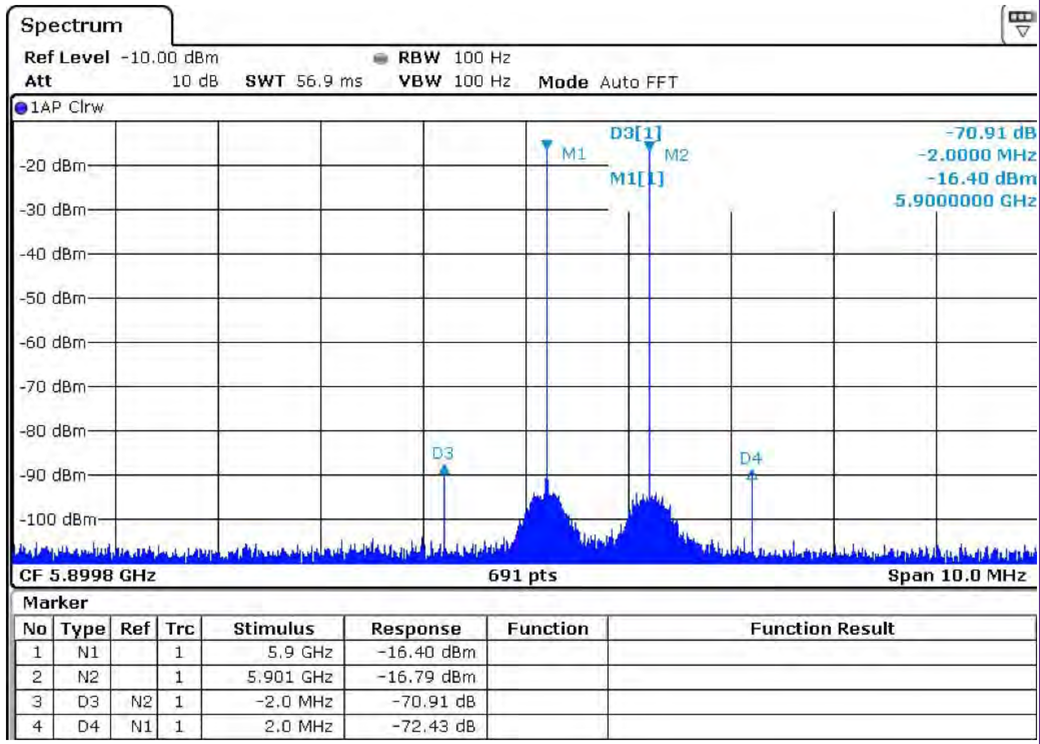


Fig 9. BFU730F 5-5.9GHz WiFi LNA: P1dB

4.3.3 Linearity/IP3



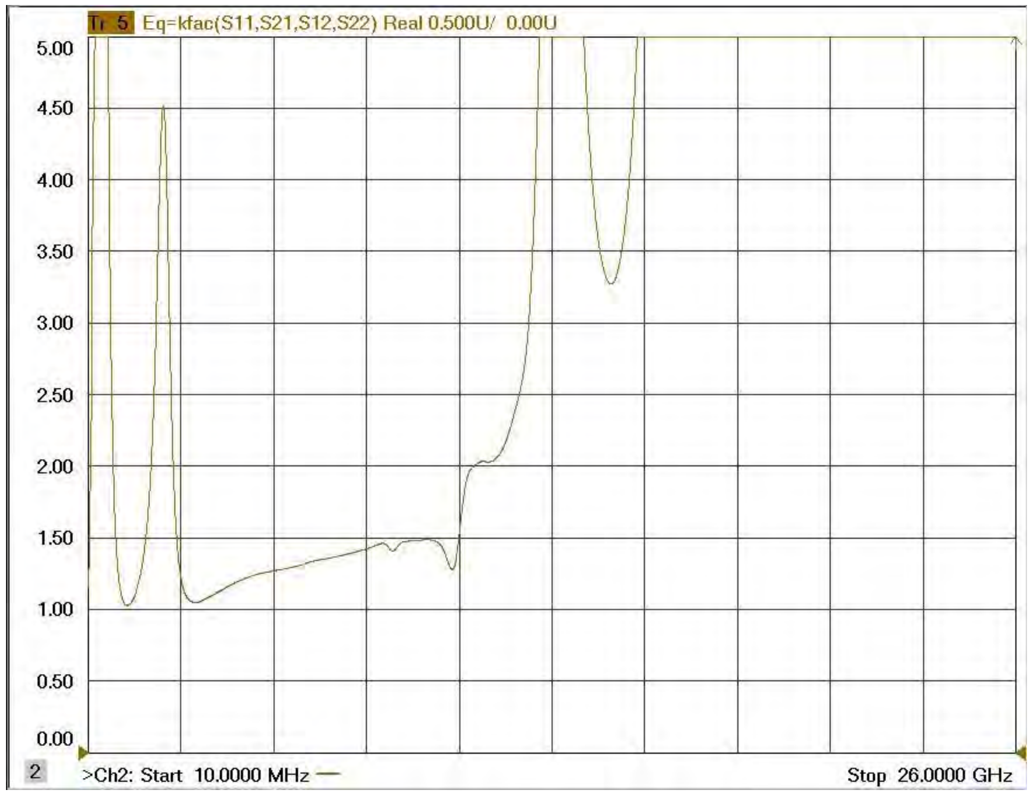
Two tones: f1: 5.9GHz, f2: 5.901GHz, -25dBm each tone, tone spacing: 1MHz

OIP3 = 72/2 + (-16.5) = 19.5dBm

IIP3 = OIP3- Gain = 19.5-13.8 = 5.7dBm

Fig 10. BFU730F 5-5.9GHz WiFi LNA: IP3

4.3.4 Stability



K Factor

Fig 11. BFU730F 5-5.9GHz WiFi LNA: Stability

4.3.5 Noise Figure Measurement

A network analyzer is used to measure the loss between the connector input to the first matching component of the device. The measured return loss is approximately 0.4dB across the band, therefore a 0.2dB input loss must be de-embedded to get device noise figure.

The Noise figure data in the graphic below is the noise figure after de-embedding the connector and input loss.

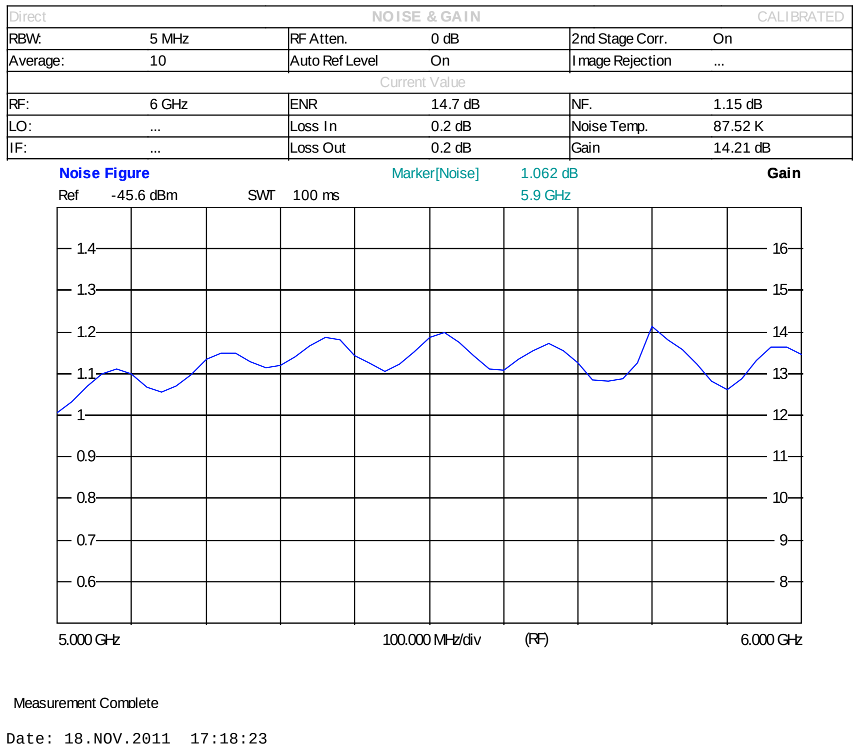


Fig 12. BFU730F 5-5.9GHz WiFi LNA: Noise Figure

4.3.6 LNA Turn ON-OFF Time

The following diagram shows the setup to test LNA Turn ON and Turn OFF time. The LNA Turn ON and Turn OFF time are mainly determined by the R-C time constant of the biasing circuitries: on the Base bias path the $\tau 1 = R3*C3$ and on the Collector bias path $\tau 2 = (R2+R3)*C12$.

Set the waveform generator to square mode and the output amplitude at 3Vrms with high output impedance. The waveform generator has adequate output current to drive the LNA therefore no extra DC power supply is required which simplifies the test setup.

Set the RF signal generator output level to -25dBm at 5.9GHz and increase its level until the output DC on the oscilloscope is at 5mV on 1mV/division, the signal generator RF output level is approximately -18dBm.

It is very important to keep the cables as short as possible at input and output of the LNA so the propagation delay difference on cables between the two channels is minimized.

It is also critical to set the oscilloscope input impedance to 50ohm on channel 2 so the diode detector can discharge quickly to avoid a false result on the Turn OFF time testing.

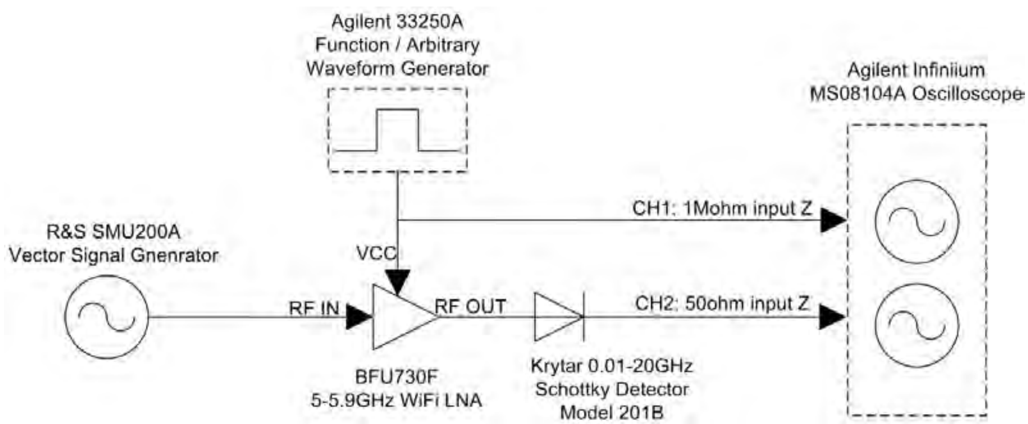
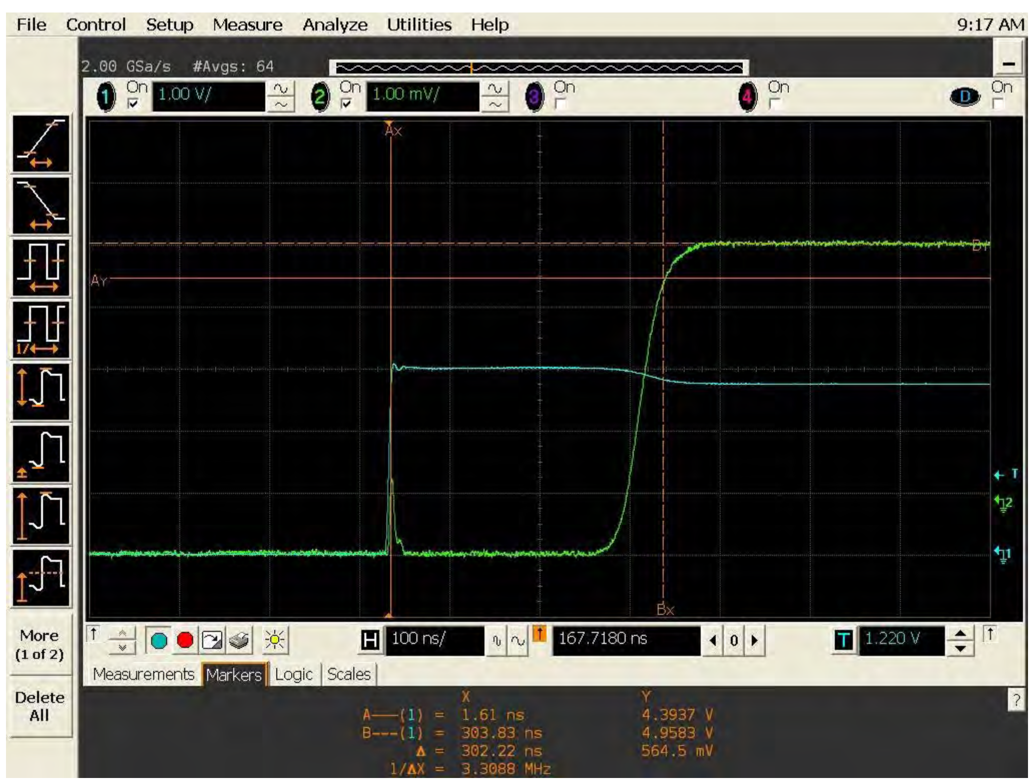


Fig 13. LNA Turn ON and Turn OFF time test setup

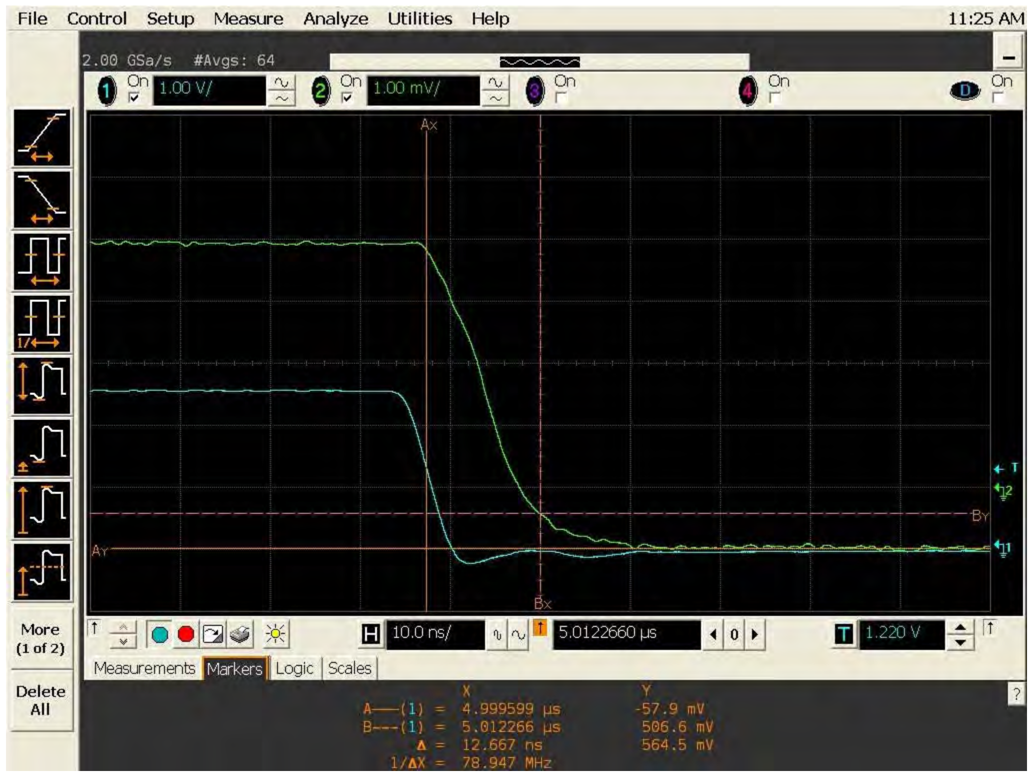
4.3.6.1 LNA Turn ON Time



3.0Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 90% of max. output power

Fig 14. BFU730F 5-5.9GHz WiFi LNA: Turn ON time

4.3.6.2 LNA Turn OFF Time



3.0Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 10% of max. output power

Fig 15. BFU730F 5-5.9GHz WiFi LNA: Turn OFF time

4.3.7 Summary Of the Typical Evaluation Board Test Result

Table 3. Typical results measured on the BFU730F 5-5.9GHz WiFi LNA Evaluation Board

Operating frequency 5-5.9GHz, testing at 5GHz and 5.9GHz unless otherwise specified, Temp = 25°C.

Parameter		Symbol	Value	Unit
Supply Voltage		Vcc	3.0	V
Supply Current		Icc	10.8	mA
Noise Figure	@5GHz	NF	1	dB
	@5.9GHz	NF	1.15	dB
Power Gain	@5GHz	Gp	15.3	dB
	@5.9GHz	Gp	13.8	dB
Input Return Loss	@5GHz	IRL	11	dB
	@5.9GHz	IRL	12.3	dB
Output Return Loss	@5GHz	ORL	11	dB
	@5.9GHz	ORL	11	dB

Parameter		Symbol	Value	Unit
Reverse Isolation	@5GHz	ISLrev	23.4	dB
	@5.9GHz	ISLrev	22.3	dB
Input 1dB Gain Compression Point	@5GHz	Pi1dB	-8.4	dBm
	@5.9GHz	Pi1dB	-6.6	dBm
Output 1dB Gain Compression Point	@5GHz	PL1dB	6	dBm
	@5.9GHz	PL1dB	6.3	dBm
Input Third Order Intercept Point Two Tones: f1: 5.9GHz, f2: 5.901GHz, power: -25dBm	@5.9GHz	IIP3	5.6dBm	dBm
Output Third Order Intercept Point Two Tones: f1: 5.9GHz, f2: 5.901GHz, power: -25dBm	@5.9GHz	OIP3	19.5	dBm
Stability (0- 26GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	302	nS
		Toff	12	nS

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