AN11006

Single stage 2.3_2.7GHz LNA with BFU730F

Rev. 4.0 — 21 June 2016

Application note

Info	Content
Keywords	BFU730F, LNA, 2.3-2.7 GHz, WiMAX, WLAN, ISM, LTE, High linearity.
Abstract	The document provides circuit, layout, BOM and performance information on 2.3-2.7 GHz LNA equipped with NXP’s BFU730F wide band transistor. This Application note is related to evaluation board OM7690/BFU730F,598 12nc 934065627598

Revision history

Rev	Date	Description
1.0	20110106	Initial document
2.0	20110710	Schematic updated
3.0	20121120	Chapter added about switching time
4.0	20160621	Small updates

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1. Introduction

The BFU730F is a discrete HBT that is produced using NXP Semiconductors' advanced 110 GHz f_T 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 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, BFU760 and BFU790 are the other types, BFU710 is intended for ultra low current applications. The BFU760F and BFU790F are high current types and are intended for application where linearity is key.

The BFU7XXF are ideal in all kind of applications where cost matters. It also gives design flexibility.

2. Requirements and design of the 2.3-2.7GHz LNA

The BFU730 2.3-2.7GHz LNA EVB simplifies the evaluation of the BFU730 wideband transistor, for this frequency range, in which e.g. WLAN, Bluetooth, WiMax, LTE etc systems are present. The EVB enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with BFU730, including input- and output matching, to optimize the performance. The input match is a compromise between best noise figure and good Input return loss. The board is supplied with two SMA connectors for input and output connection to RF test equipment.

Table 1. Target spec.
Target specification of the 2.3-2.7 GHz LNA.

Vcc	Icc	NF	Gain	IRL	ORL
3	10	<1dB	>18	>10	>10
V	mA	dB	dB	dB	dB

3. Design

The 2.3_2.7 GHz LNA consists of one stage grounded emitter BFU730F amplifier. For this amplifier 11 external components are used, for matching, biasing and decoupling.

The design has been conducted using Agilent's Advanced Design System (ADS). The 2D EM Momentum tool has been used to co-simulate the PCB. Results are given in paragraph 4.5. The LNA shows a gain of 20 dB, NF of 0.8 dB, input P1dB of –16.5 dBm and an input IP3 of 1.5 dBm

The LNA shown in this application note is unconditional stable 10 MHz-20 GHz.

3.1 BFU730F 2.3-2.7 GHz LNA-ADS Simulation circuit

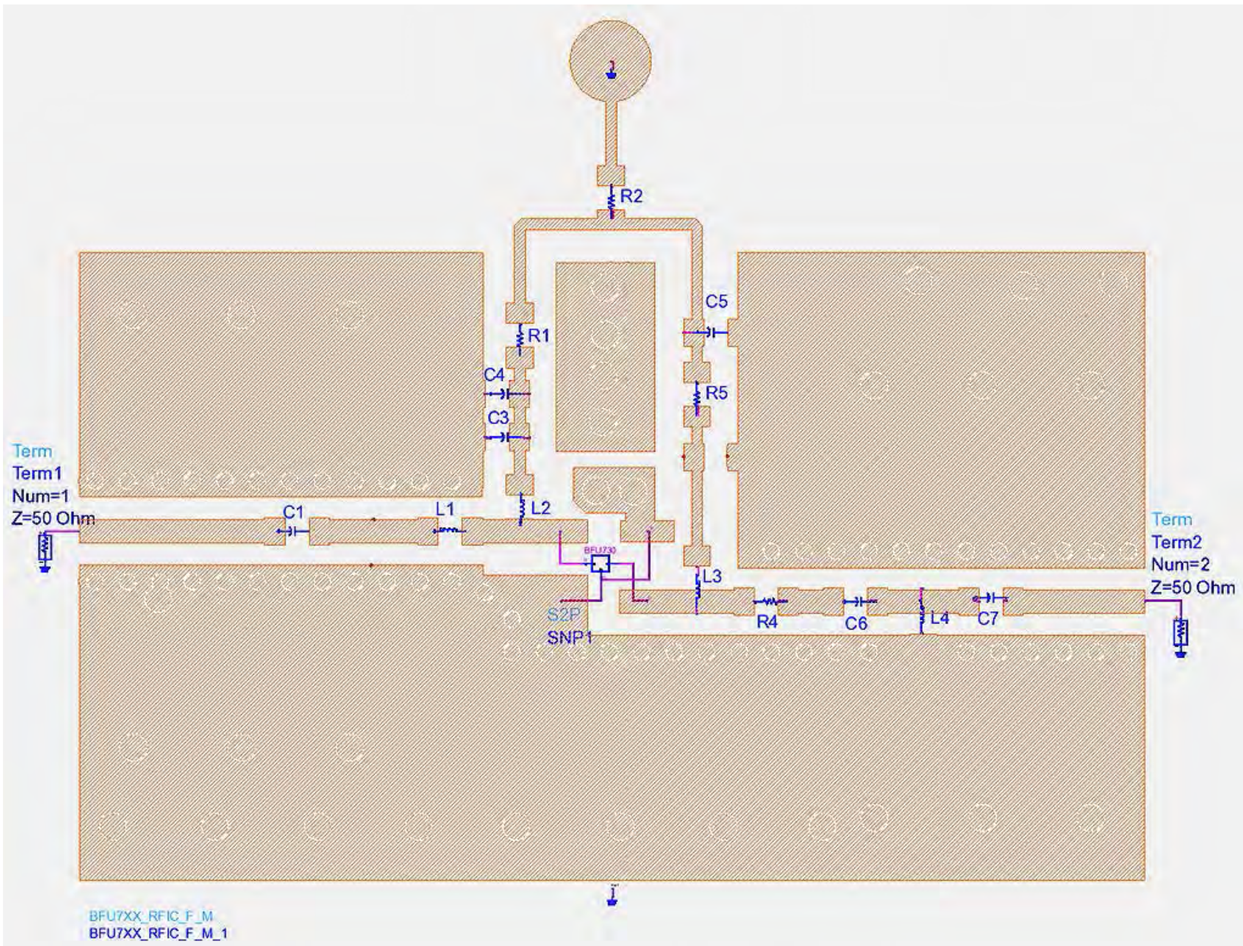


Fig 1. ADS simulation circuit for 2.3-2.7 GHz LNA

3.2 BFU730F 2.3-2.7 GHz LNA - ADS Gain and match simulation results

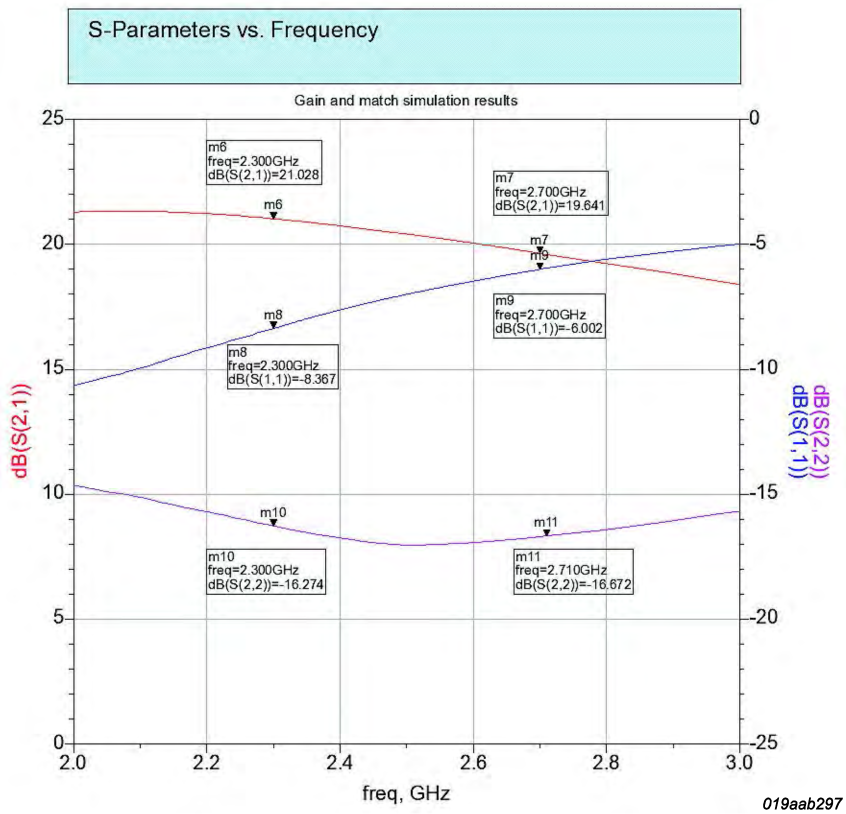


Fig 2. ADS Gain and match simulation results for 2.3-2.7 GHz LNA

3.3 BFU730F 2.3-2.7 GHz LNA - ADS NF simulation results

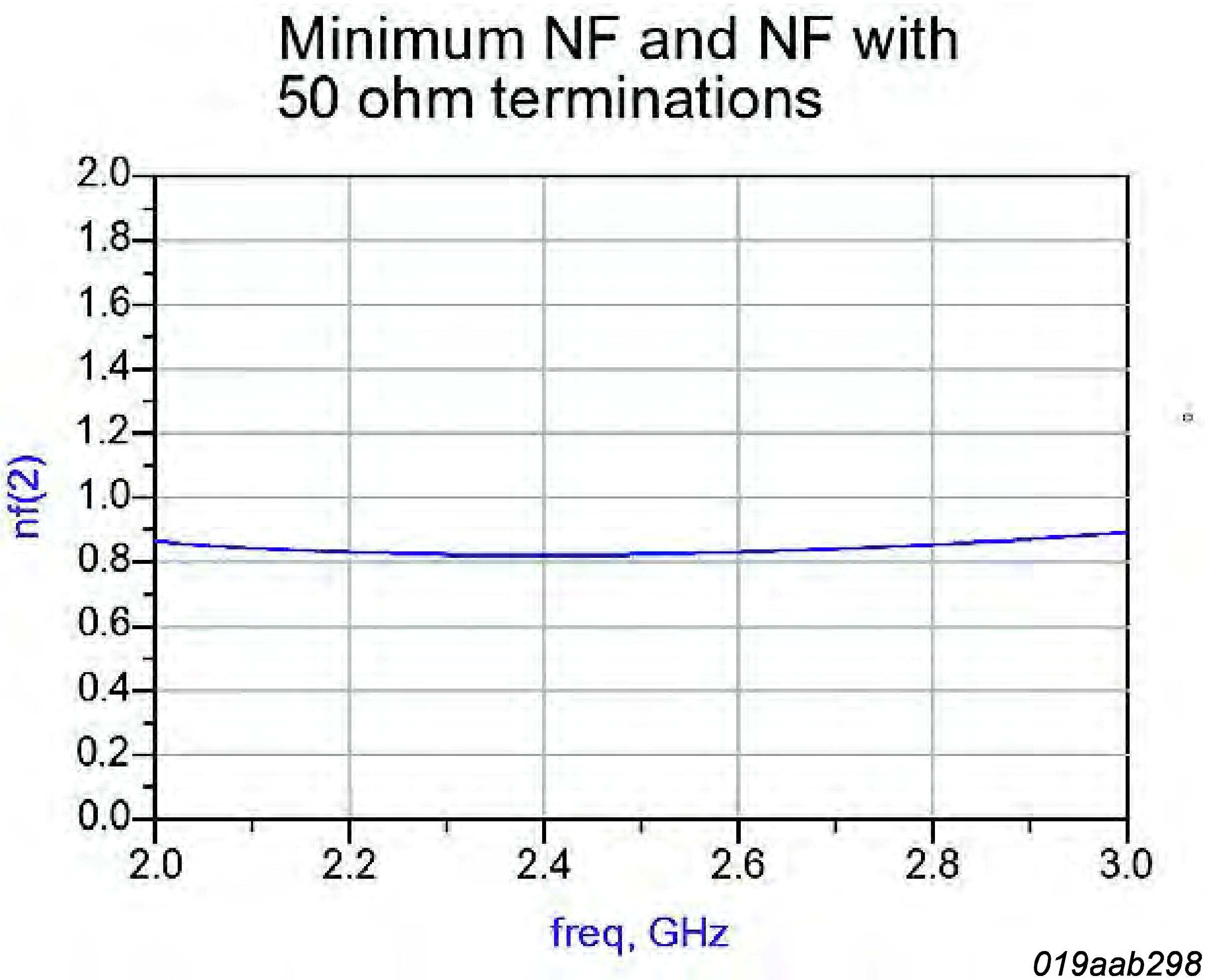
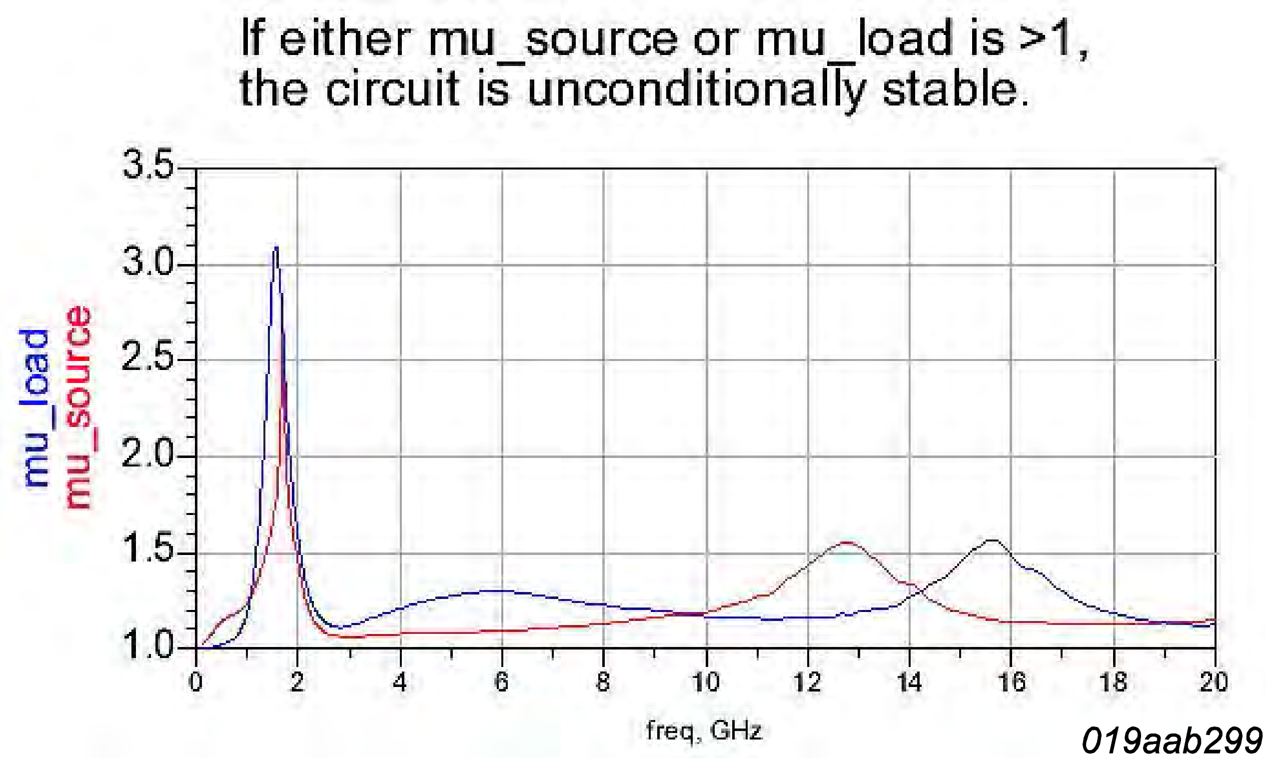


Fig 3. ADS Noise Figure simulation results for 2.3-2.7 GHz LNA

3.4 BFU730F 2.3-2.7 GHz LNA - ADS Stability simulation results



(1) As K≥1 and Mu≥1, the LNA is unconditionally stable for the whole frequency band

Fig 4. ADS stability simulation results for 2.3-2.7 GHz LNA

4. Implementation

4.1 Schematic

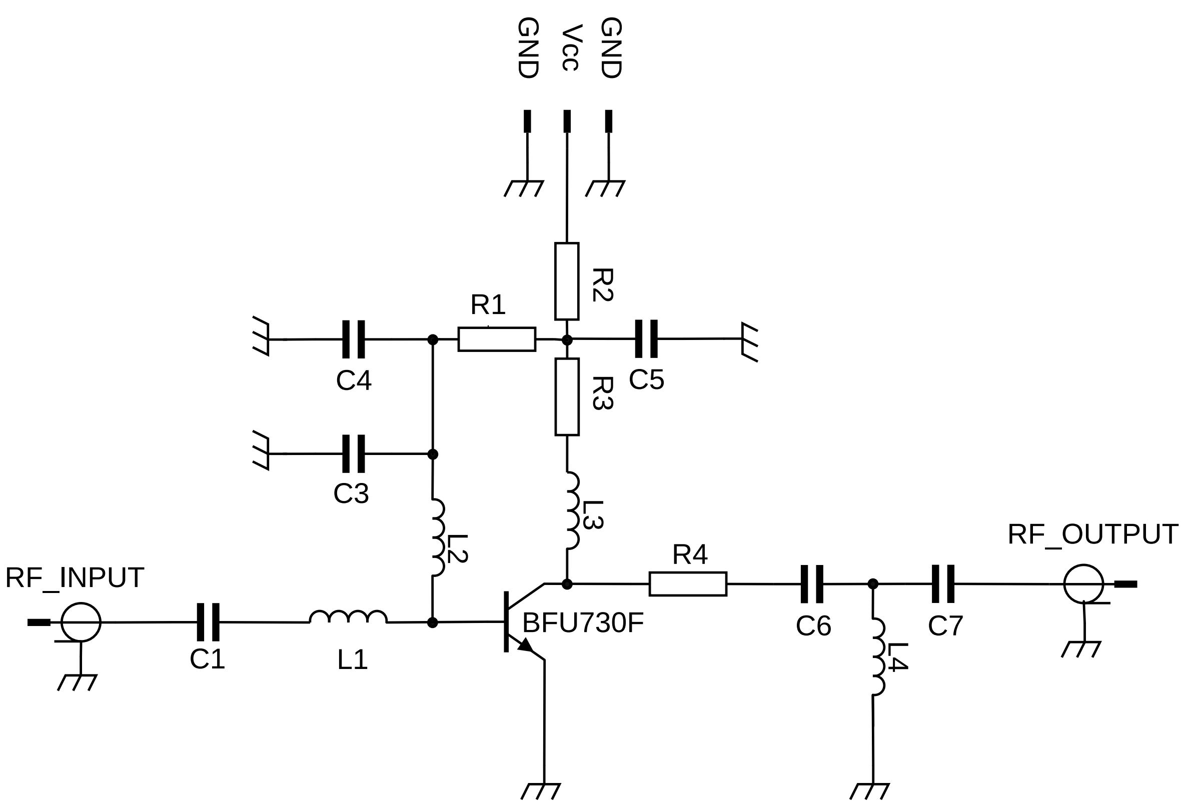


Fig 5. BFU730F 2.3-2.7 GHz LNA schematic

4.2 Layout and assembly

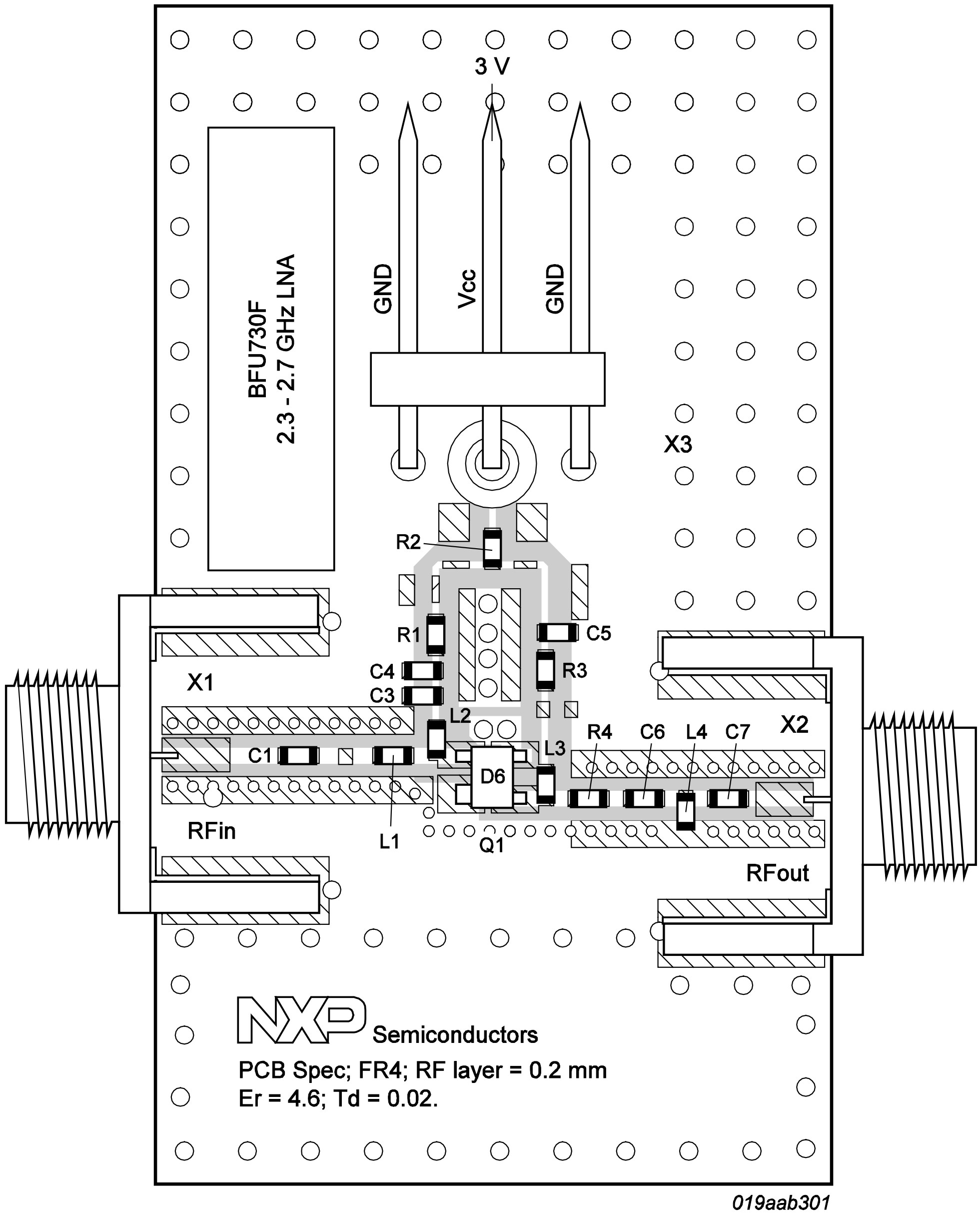


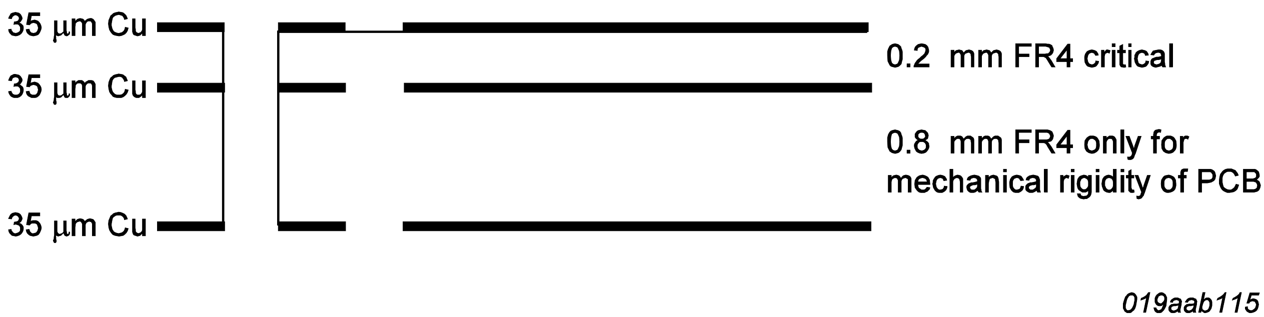
Fig 6. Layout and assembly information for BFU730F 2.3-2.7 GHz LNA EVB

Table 2. Bill of materials

Designator	Description	Size	Value	Type	Note
Q1	BFU730F	2X2mm		NXP Semiconductors	HBT
PCB		20X35mm			
C1	Capacitor	0402	100 pF	MurataGRM1555	DC block
C3	Capacitor	0402	68 nF	MurataGRM1555	Bias Decoupling
C4	Capacitor	0402	6.8 pF	MurataGRM1555	Bias Decoupling
C5	Capacitor	0402	1 pF	MurataGRM1555	Bias Decoupling
C6	Capacitor	0402	3.3 pF	MurataGRM1555	output match
C7	Capacitor	0402	4.7 pF	MurataGRM1555	output match
L1	Inductor	0402	1.5 nH	Murata LQW15	input match
L2	Inductor	0402	8.7 nH	Murata LQW15	input match
L3	Inductor	0402	4.7 nH	Murata LQW15	output match
L4	Inductor	0402	3.6 nH	Murata LQP15	output match
R1	Resistor	0402	37 K		Bias Setting
R2	Resistor	0402	100 R		Bias Setting Hfe and Temp spread cancellation
R3	Resistor	0402	10 Ohm		Stability
R4	Resistor	0402	0 R		NA
X1,X2	SMA RF connector	-		Johnson, End launch SMA 142-0701-841	RF input/ RF output
X3	DC header	-		Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector

4.3 PCB layout

A good PCB Layout is an essential part of an RF circuit design. The EVB of the BFU730 can serve as a guideline for laying out a board using either the BFU730 or one of the other SiGe.C HBTs in the SOT343F package. Use controlled impedance lines for all high frequency inputs and outputs. Bypass V_{CC} with decoupling capacitors, preferable located as close as possible to the device. For long bias lines it may be necessary to add decoupling capacitors along the line further away from the device. Proper grounding the emitters is also essential for the performance. Either connect the emitters directly to the ground plane ore through vias, or do both. The material that has been used for the EVB is FR4 using the stack shown in Fig 7



(1) Material supplier is Isola Duraver; Er=4.6-4.9 Tδ=0.02

Fig 7. PCB material stack

4.4 LNA View

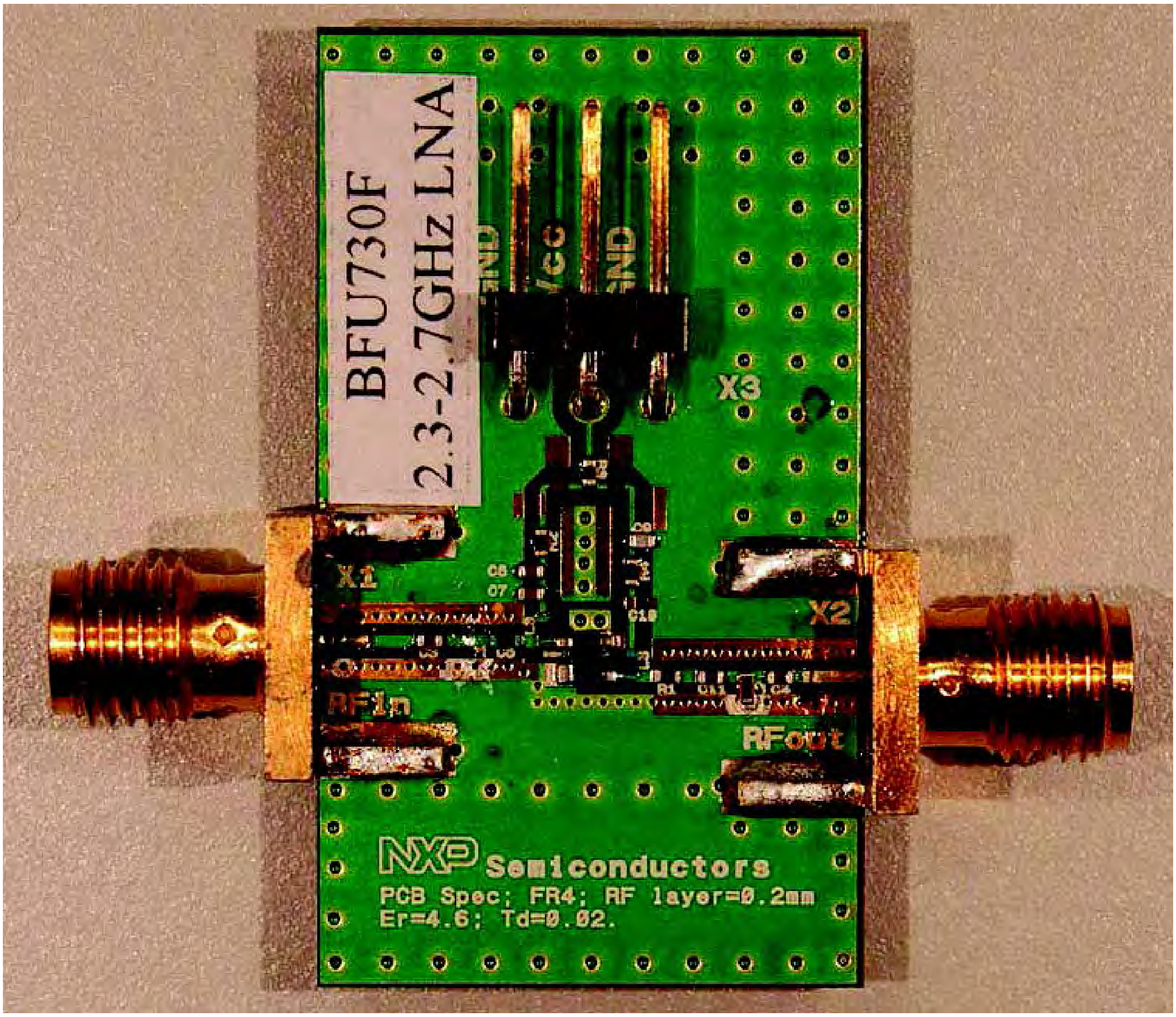


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Fig 8. 2.3_2.7 GHz LNA

4.5 Measurement results

Table 3. Typical measurement results measured on the evaluation board.
Temp=25 ℃, frequency is 2.5GHz unless otherwise specified.

Parameter		Symbol	Value	Unit	Remarks
Supply Voltage		V_{cc}	3	V	
Supply Current		I_{cc}	10	mA	
Noise Figure		NF[1]	0.8	dB	
Power Gain	2.3 GHz	G_P	21.2	dB	
	2.5 GHz		21	dB	
	2.7 GHz		20.5	dB	
Input return Loss		IRL	7.9	dB	
Output return Loss		ORL	17.5	dB	
Input 1dB Gain compression Point		P_i1dB	-16.5	dBm	
Output 1dB Gain compression Point		P_o1dB	+3.7	dBm	
Input third order intercept point		$IP3_i$	+1.5	dBm	
Output third order intercept point		$IP3_o$	+22.5	dBm	
Power settling time		Ton	430	us	
		Toff	24	ns	

[1] The NF and gain figures are being measured at the SMA connectors of the evaluation board, so losses of the connectors and the PCB of approximately 0.1 dB are not substracted

4.5.1 Faster Switching time <1 μs

If no switching speed is required in the application, the recommendation is to keep the BOM as is presented in this application note. However if the LNA is applied in e.g. a WLAN application where power settling time is required to be <1 μs, the value of C1 an C3 should be changed to 27pF. This will result in a Ton power settling time of 860ns and the Toff power settling time stays 24ns. However this change in capacitor values will result in about 5-10dB of degradation of the IP3 figures reported in Table 3

4.5.2 Gain and match - typical values

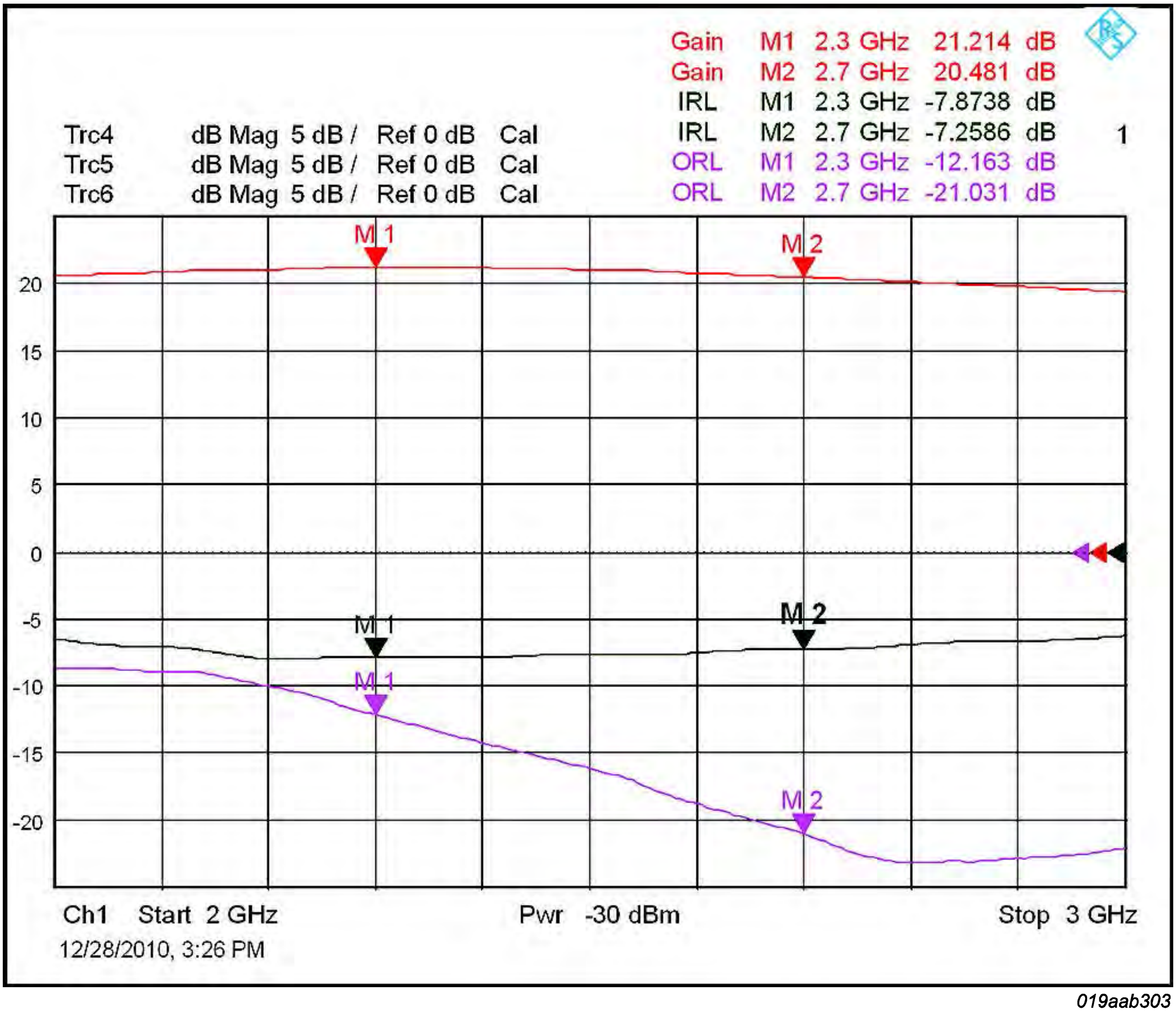
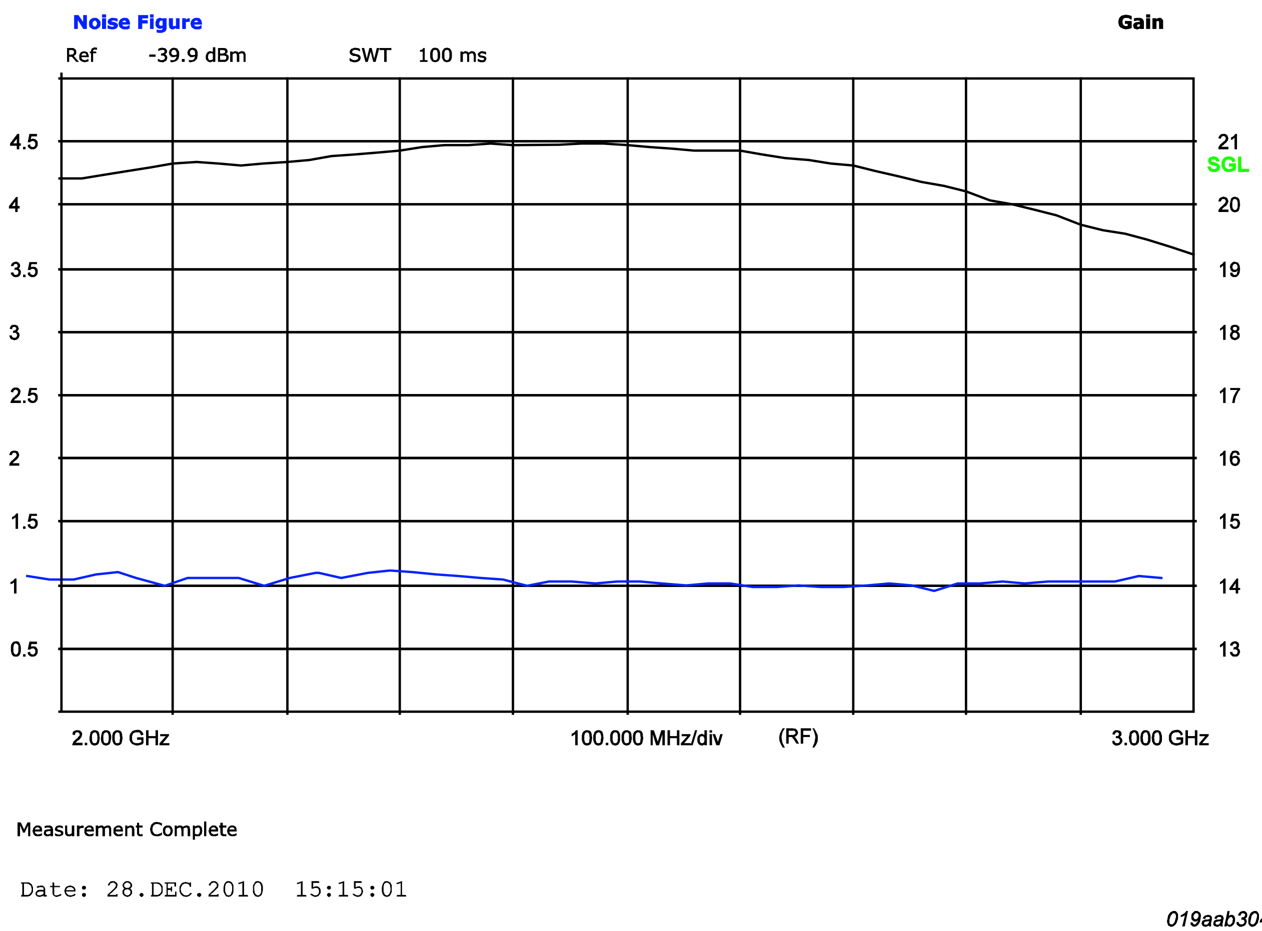


Fig 9. Typical Gain and match measured values

4.5.3 NF and Gain- typical values



(1) NF and Gain measurements correction applied see § 5 for values

Fig 10. Typical NF curve

4.5.4 Stability

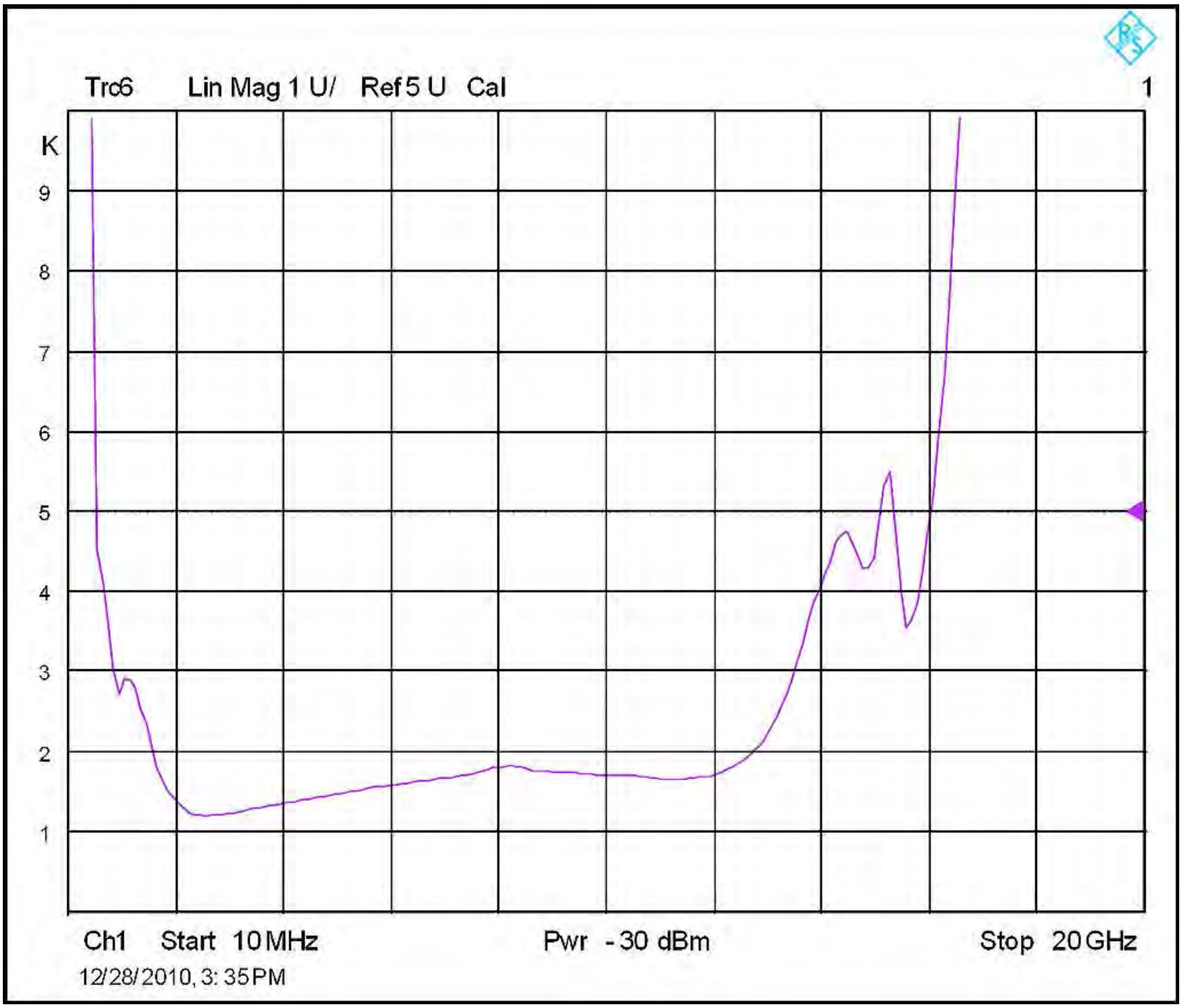


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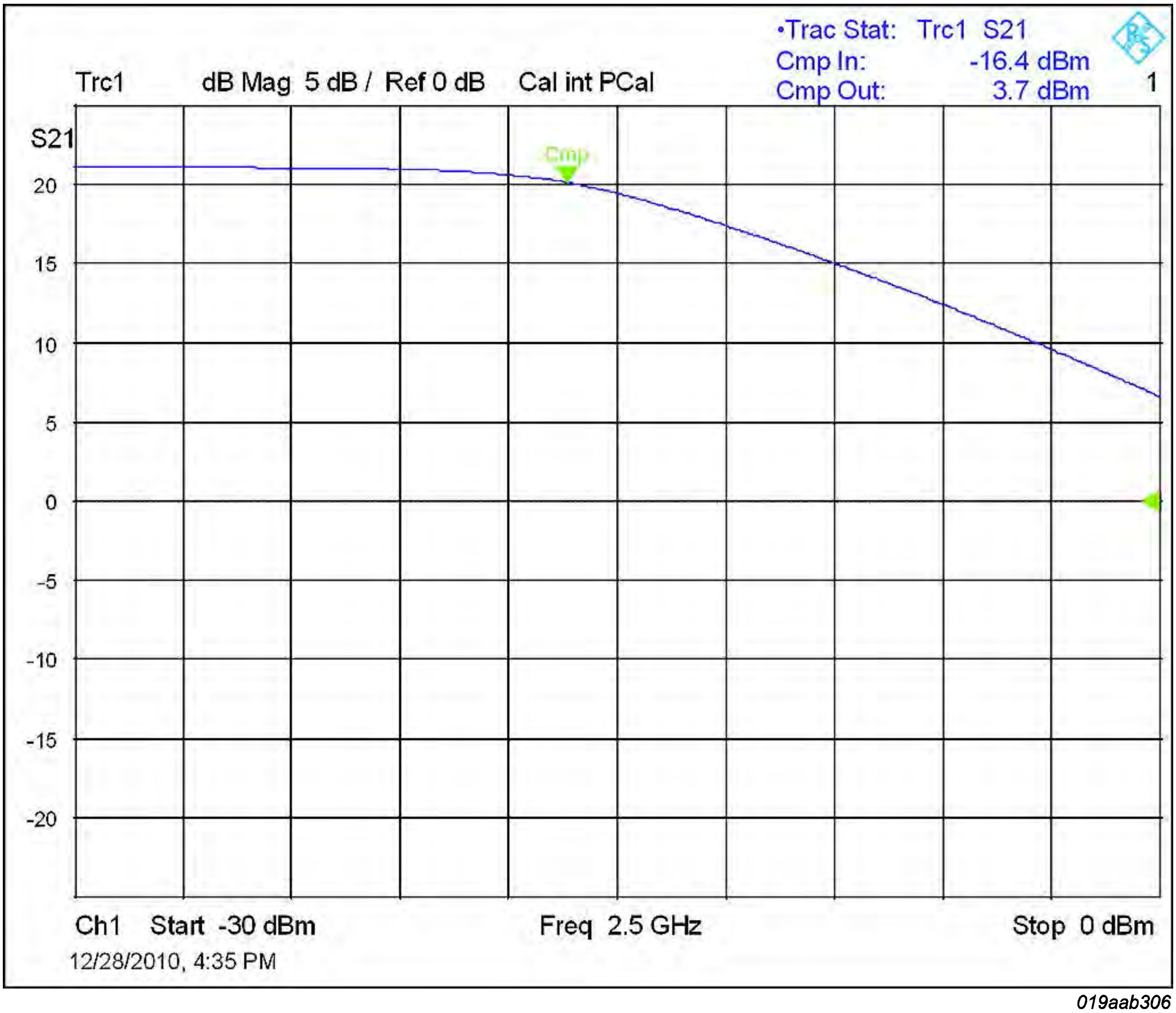
Fig 11. Stability typical measurement results

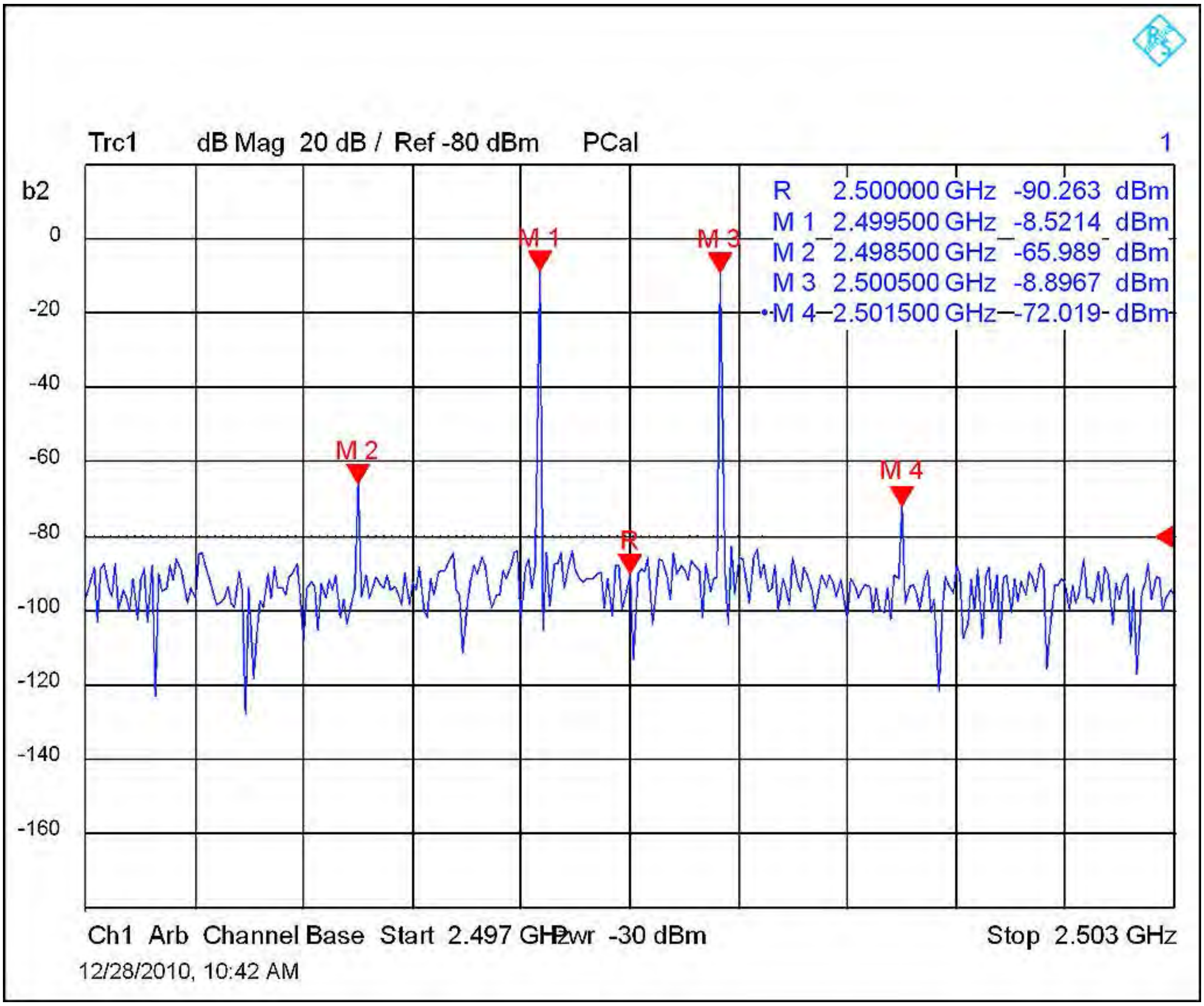
4.5.5 1dB compression point typical values.



(1) P_i1dB=-16.4 dBm P_o1dB=3.7 dBm

Fig 12. Typical 1 dB compression point curve.

4.5.6 Linearity IP3 – typical values



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(1) $IP3_o$=-8.9+((72-8.9)/2)=+22.65 dBm; $IP3_i$= -30 dBm+63.1/2=-30+31.55=+1.55 dBm

Fig 13. IM3 - typical values

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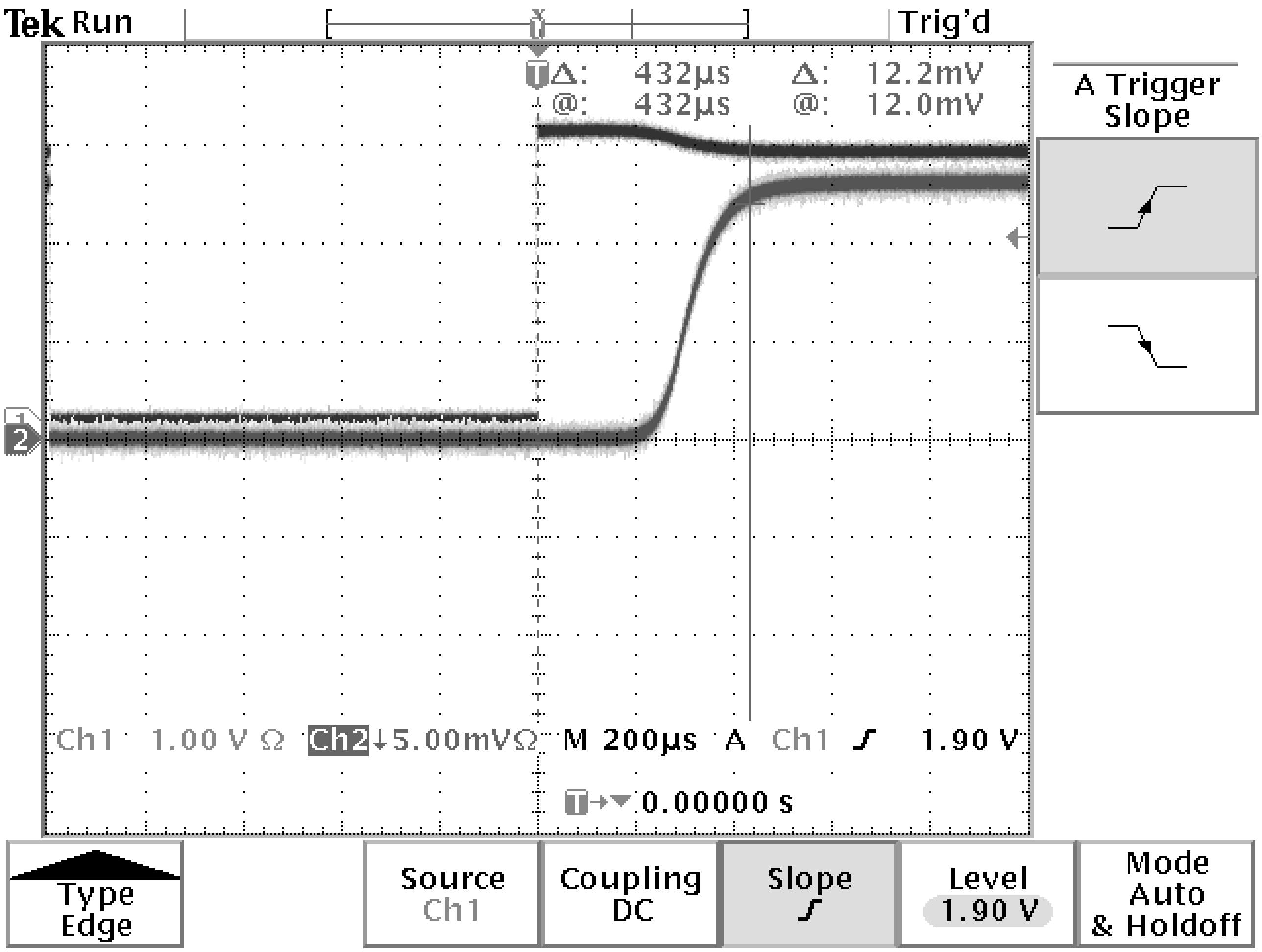
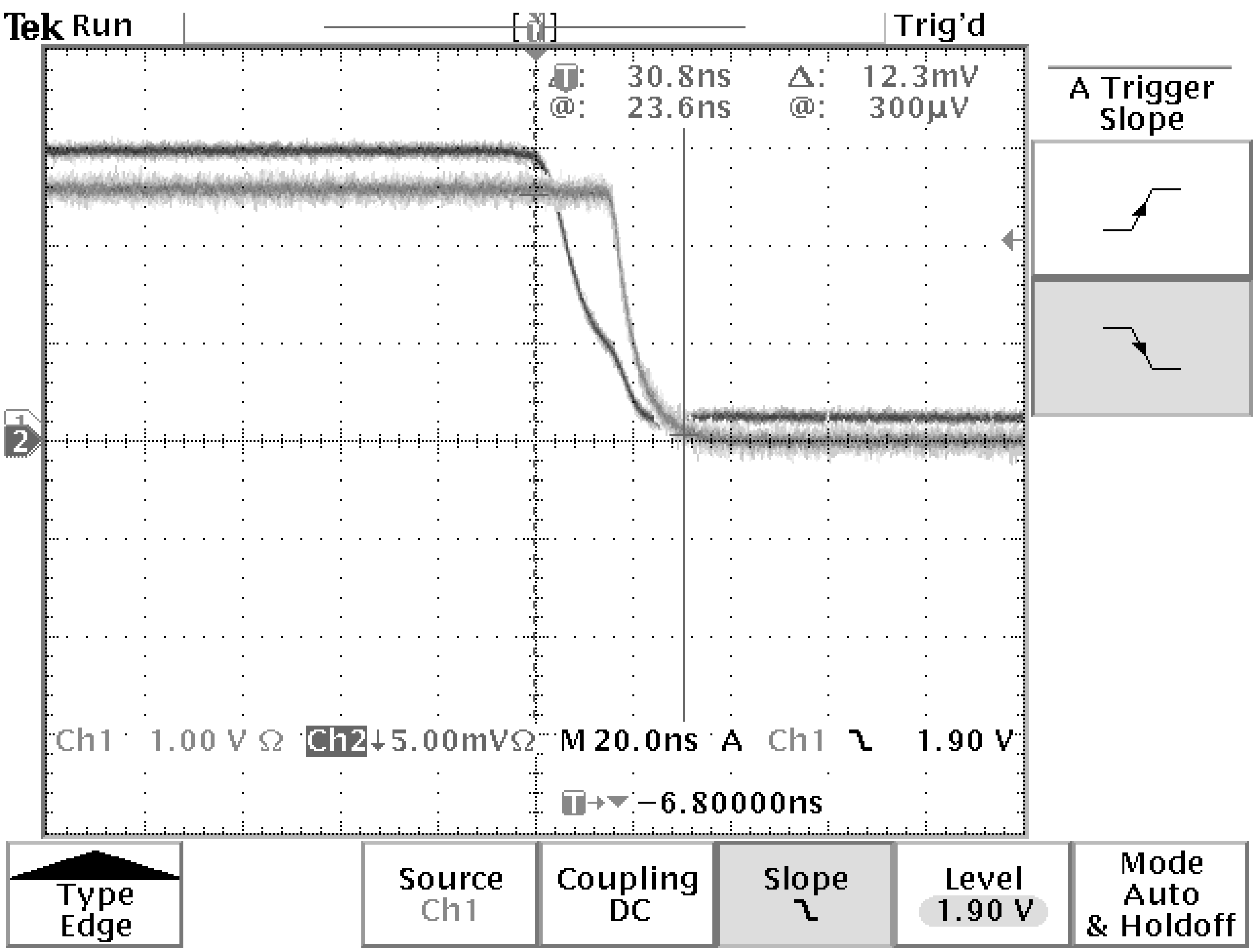
4.5.7 Power settling time



(1) curve1 is power supply; curve 2 is de output of the detection diode.

Fig 14. t_{on} Power settling time



(1) curve1 is power supply; curve 2 is de output of the detection diode.

Fig 15. t_{off} **Power settling time**

5. NF measurement corrections

There are two types of errors and losses that have been taken into account to correct the NF measurement results: (1) Own system error for NF measurement and (2) insertion losses accounted to RF IN and RF OUT connectors, microstrip feed lines used at the input of the LNA in NF measurements.

5.1 NF measurement system error

A Miteq professional amplifier, rated as NF=0.41 dB, Gain=30 dB, has been used as reference for NF measurement system correction. Its manufacturer data is in Fig 16

MITEQ

MITEQ, INC.
100 Davids Drive
Hauppauge, New York 11788-2086
Tel. : (631) 436-7400
FAX : (631) 436-7430

Project : M00150794
Int. Transfer : N/A
Customer P/N : N/A
Customer P. O. : I608051
Model Number : AMF-2F-02000400-05-10P
Serial Number : 1228 664

NOTE - This unit can safely handle a maximum input power of +10.0 dBm, CW.

TEST DATA at + 25 °C

Frequency (GHz)	Noise Figure (dB)	P_{out} @ 1 dB Comp (dBm)	Output IP3 (dBm)
2.00	0.41	+ 14.5	N/A
3.00	0.42	+ 14.9	|
4.00	0.42	+ 15.3	N/A

Maximum Input VSWR	Maximum Output VSWR
1.50:1	1.63:1

SPECIFICATIONS

Frequency (GHz)	2.00 - 4.00 GHZ
Gain (dB)	28.0 DB MIN
Gain Flatness (dB)	+/- 2.00 DB MAX
Δ Gain vs. Temp (dB)	N/A
VSWR: Input / Output	2.00:1 MAX
Noise Figure (dB)	0.50 DB MAX
P_{OUT} @ 1 dB Comp (dBm)	+10.0 DBM MIN
Output IP3 (dBm)	N/A
Voltage (VDC)	+15.0 VDC
Current (mA)	100 MA NOM
Operating Temp (°C)	+25.0 °C
Outline Drawing	131580

Measured Current : 95 mA

Tested By : TOM ANDERSEN

Date : 10-04-06

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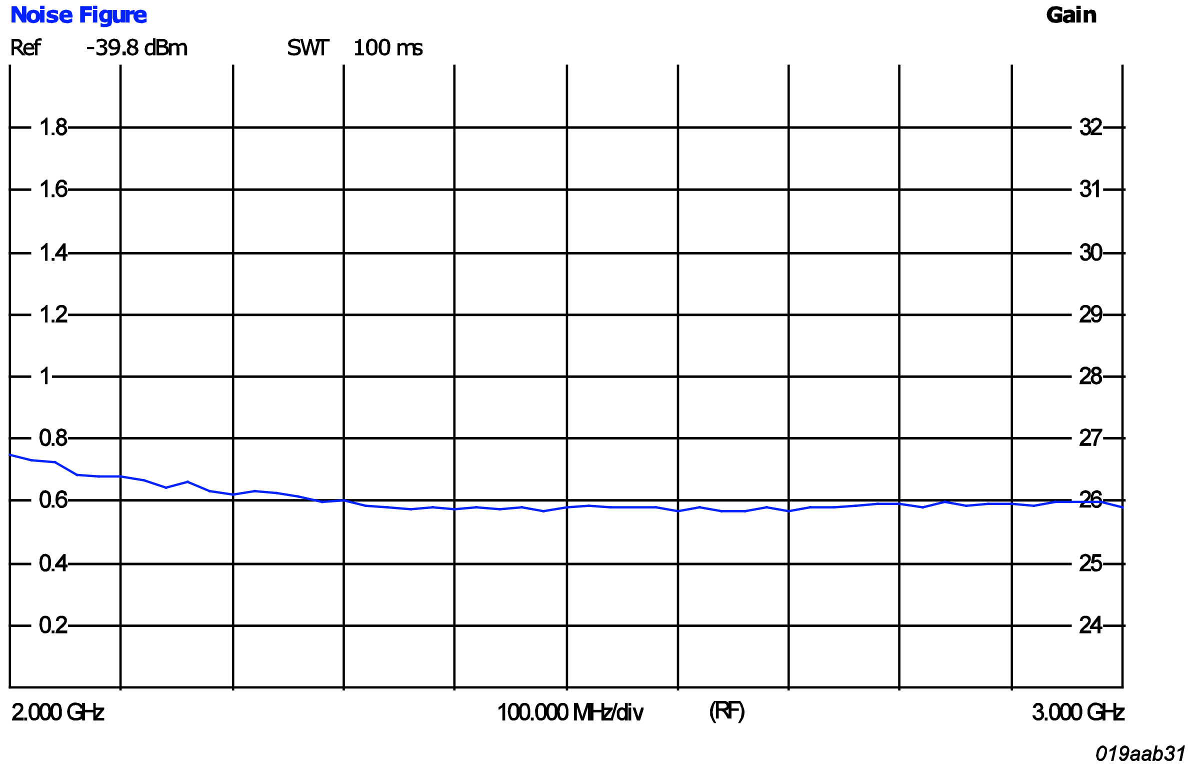
Fig 16. Miteq amp 1228664

Miteq 1228664 amplifier measured with the NF setup used to qualify the BFU730F 2.3-2.7GHz LNA has the NF performances listed in Fig 17. The system correction factor, NFsys, is the difference between the NF measured and the 0.42 dB value from the catalog. At 2GHz this difference is about 0.3 dB and at 3 GHz around 0.15 dB.



(2) **NFsys**= (NF in Fig 17 – NF in Fig 16) represents the NF system correction factor: average value = 0.2 dB

Fig 17. Miteq 1228664 amplifier NF and Gain

5.2 Insertion losses.

Insertion losses have not been taken in to account so measurements are referenced to the SMA connectors.

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