PHILIPS

High IP3 MMIC LNA at 1.8-2.4 GHz

Application note for the BGA2012

The BGA2012 is a MMIC 50 Ω LNA block for cellular applications at 1.8 GHz to 2.4 GHz that require low noise, high gain and good linearity.
Possible applications:

- 1.8 GHz - **DECT** - gain 15 dB, low noise 1.7 dB, supply curent 4 mA
- 1.9 GHz - **CDMA** - high IIP3 +10 dBm, gain 12 dB, NF 2.2 dB, supply current 7 mA
- 2.4 GHz - **Blue Tooth** - gain 11.5 dB, NF 2.3 dB, supply current 6 mA

The MMIC is produced in the single metal DPO Philips process and is packaged in the small 6 pins SOT363. The circuit is equipped with a control pin that can set the amplifier to low current-low noise mode or to high current-high linearity mode and/or disable (off) mode.
A simple solution requires only input/output decoupling capacitors.
This report describes an application in which the LNA can be tuned for gain and input IP3. At 1900 Mhz, the input IP3 is adjustable between 5 dBm at 16 dB gain and 10 dBm at 12 dB gain.

Circuit description

The LNA is a one stage amplifier. The RF transistor is biased with the controlled bias circuit that can set the collector current of RF transistor to the desired value. With the control voltage from 0 to 3 Volt it is posssible to set the collector current from 0 to 7 mA (enable/disable

function as well). The best performance on gain, noise and linearity is achieved in the range of 4 to 7 mA.
Low noise and high gain is obtained by the current source that biases the RF transistor and by the layout of RF transistor.
The device works directly without the external components except input/output decoupling capacitors. However, to get even higher gain and linearity (IIP3), a few more external components are necessary.
The next four examples show some possible applications:

- version 1 : simple solution with only 2 decoupling capacitors; acceptable gain and low noise
- version 2: high gain through output shunt coil ⇒ one component more than version 1
- version 3: **high IIP3** and high gain with input filter ⇒ three components more than version1
- version 4: **super high IIP3** ⇒ like version 3 with ustripline to ground

Measured results

General conditions: Vsupply= 3V, temp=25 deg

Quick overview of all four versions:

frequency=1.9 GHz

Parameter	Unit	**Version1** **simple**	**Version 2** **high gain**	**Version 3** **high IIP3, gain**	**Version 4** **high IIP3**	Conditions Isupply [mA]
Gain $\|S21\|^2$	dB	13.7 14.0	14.9 15.5	15.4 15.8	12.0 12.3	4 7
NF	dB	**1.7** **1.7**	1.8 1.8	2.0 2.1	2.1 2.3	4 7
IIP3	dBm	-9 -7	-9 -7	0 **5**	7 **10**	4 7

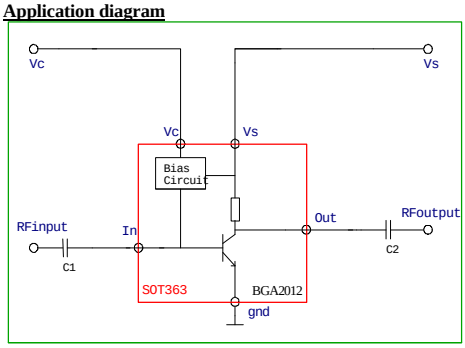
note:
IIP3 - input IP3 measured with Δf=100 kHz and Pin -25 dBm
Isupply - is a total supply current from 3 Volt supply source
Control current from a control voltage does not exceed **120 uA**. (@max Vc=3V)

The next tabels and figures show more data for each version.

Version 1

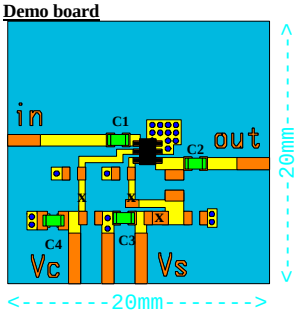
		Frequency				Conditions	
Parameter	Unit	1.8 GHz	1.9 GHz	2.1 GHz	2.4 GHz	Isupply [mA]	Vcontrol [V]
0Gain |S21|²	dB	13.6	13.2	12.5	11.5	3.5	2.0
		14.3	13.9	13.1	12.1	5.3	2.6
		14.4	14	13.2	12.2	7	3.0
NF	dB	1.7	1.7	1.8	2.3	3.5	2.0
		1.7	1.7	1.8	2.3	5.3	2.6
		1.7	1.7	1.8	2.3	7	3.0
Return Loss input	dB		9			3.5	2.0
			11			5.3	2.6
		10	11	11	12	7	3.0
Return Loss output	dB		8			3.5	2.0
			9			5.3	2.6
		9	9	9	10	7	3.0
IIP3	dBm		-9			3.5	2.0
			-7			5.3	2.6
Δf=100kHz			-7			7	3.0

Application diagram



notes:
1. There are 4 types of demo board layouts available: no stripline (marked L0), 0.5 mm, 1.0 mm and 1.5 mm stripline. The L0 PCB should be used for application version 1.
2. The metal under pin 5 and 6 is filled with vias to the ground plane to reduce inductance.
3. The standard demo board also needs three 0 Ù SMD's (0603) at the spots marked with an X. Additional components to adjust the biasing can be placed at these spots.

Demo board



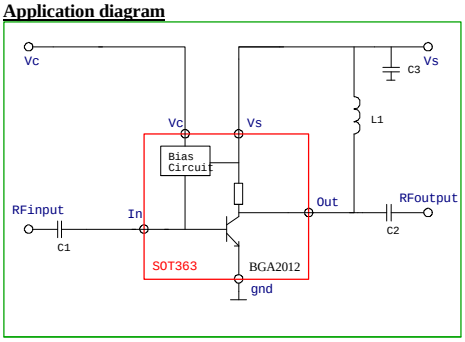
Component	Value	Typ
C1	100 pF	Philips 0603
C2	100 pF	Philips 0603
C3	22 nF	Philips 0603
C4	22 nF	Philips 0603

Component	*Function*
C1, C2	DC decoupling capacitors
C3, C4	LF filter of dc supply source

Version 2

		Frequency				Conditions	
Parameter	Unit	1.8 GHz	1.9 GHz	2.1 GHz	2.4 GHz	Isupply [mA]	Vcontrol [V]
Gain $\|S21\|^2$	dB	14.8	14.5	13.0	11.0	3.5	1.8
		15.6	15.2	13.8	11.4	5.3	2.5
		16.0	15.5	14.0	11.5	7.5	3.0
NF	dB	1.7	1.7	1.8	2.2	3.5	1.8
		1.7	1.7	1.9	2.3	5.3	2.5
		1.8	1.8	1.9	2.3	7.5	3.0
Return Loss input	dB		8			3.5	1.8
			10			5.3	2.5
		10	10	11	12	7.5	3.0
Return Loss output	dB		9			3.5	1.8
			9			5.3	2.5
		9	10	10	10	7.5	3.0
IIP3	dBm		-9			3.5	1.8
			-7			5.3	2.5
Δf=100kHz			-7			7.5	3.0

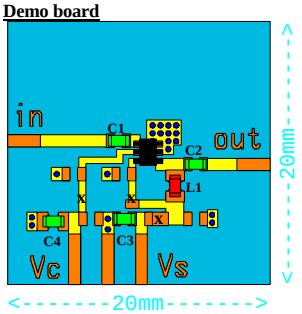
Application diagram



notes:

1. There are 4 types of demo board layouts available: no stripline (marked L0), 0.5 mm, 1.0 mm and 1.5 mm stripline. The L0 PCB should be used for application version 2.
2. The metal under pin 5 and 6 is filled with vias to the ground plane to reduce inductance.
3. The standard demo board also needs three 0 Ù SMD's (0603) at the spots marked with an X. Additional components to adjust the biasing can be placed at these spots.

Demo board



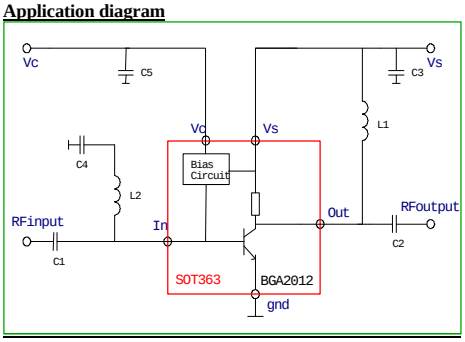
Component	Value	Typ
C1	100 pF	Philips 0603
C2	100 pF	Philips 0603
C3	22 nF	Philips 0603
C4	22 nF	Philips 0603
L1	10 nH	TDK 0603

Component	*Function*
C1, C2	DC decoupling capacitors
C3, C4	LF filter of dc supply source
L1	Output schunt coil, higher Vce

Version 3

		Frequency				Conditions	
Parameter	Unit	1.8 GHz	1.9 GHz	2.1 GHz	2.4 GHz	Isupply [mA]	Vcontrol [V]
Gain $\|S21\|^2$	dB	15.3	15.0	13.5	10.9	3.5	1.8
		16.1	15.7	14.0	11.4	5.3	2.5
		16.2	15.8	14.1	11.4	7.5	3.0
NF	dB	2.0	2.0	2.1	2.4	3.5	1.8
		2.0	2.1	2.3	2.5	5.3	2.5
		2.1	2.2	2.3	2.6	7.5	3.0
Return Loss input	dB		18			3.5	1.8
			22			5.3	2.5
		23	23	18	14	7.5	3.0
Return Loss output	dB		9			3.5	1.8
			10			5.3	2.5
		10	10	12	13	7.5	3.0
IIP3	dBm		-1			3.5	1.8
			3			5.3	2.5
Δf=100kHz			5			7.5	3.0

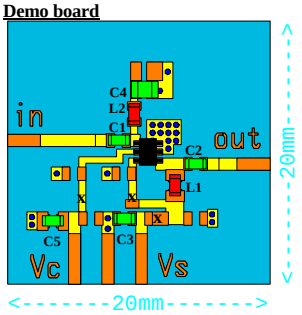
Application diagram



notes:

1. There are 4 types of demo board layouts available: no stripline (marked L0), 0.5 mm, 1.0 mm and 1.5 mm stripline. The L0 PCB should be used for application version 3.
2. The metal under pin 5 and 6 is filled with vias to the ground plane to reduce inductance.
3. The standard demo board also needs three 0 Ù SMD's (0603) at the spots marked with an X. Additional components to adjust the biasing can be placed at these spots.

Demo board



Component	Value	Typ
C1	100 pF	Philips 0603
C2	100 pF	Philips 0603
C3	22 nF	Philips 0603
C4	100 nF	Philips 0805
C5	22 nH	Philips 0603
L1	3.9 nH	TDK 0603
L2	3.9 nH	TDK0603

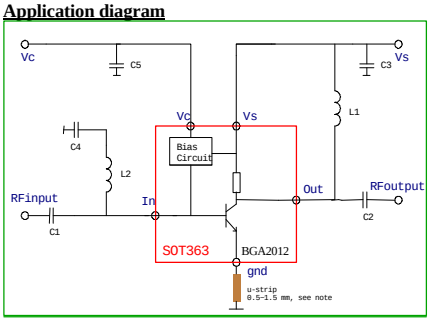
Component	*Function*
C1, C2	DC decoupling capacitors
C3, C5	LF filter of dc supply source
L1	Output schunt coil, higher Vce
L2, C4	Input LP filter to increase IP3

Version 4 with 0.5 mm stripline

		Frequency				Conditions	
Parameter	Unit	1.8 GHz	1.9 GHz	2.1 GHz	2.4 GHz	Isupply [mA]	Vcontrol [V]
Gain $\|S21\|^2$	dB	14.0	13.3	12.5	9.9	3.5	1.8
		14.4	13.9	12.9	10.3	5.3	2.5
		14.5	14.0	13.0	10.3	7.5	3.0
NF	dB	2.0	2.1	2.2	2.5	3.5	1.8
		2.2	2.2	2.3	2.7	5.3	2.5
		2.2	2.3	2.4	2.7	7.5	3.0
Return Loss input	dB		13			3.5	1.8
			14			5.3	2.5
		11	14	16	16	7.5	3.0
Return Loss output	dB		8			3.5	1.8
			8			5.3	2.5
		8	8	8	10	7.5	3.0
IIP3	dBm		1			3.5	1.8
			6			5.3	2.5
Δf=100kHz			7*			7.5	3.0

* with 1.5 mm stripline, the IIP3 improves to 10 dBm at 12.2 dB gain

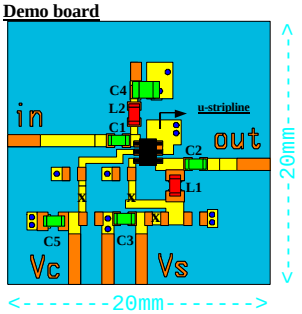
Application diagram



notes:

1. There are 4 types of demo board layouts available: no stripline, 0.5 mm, 1.0 mm and 1.5 mm stripline; marked L0, L05, L10, L15.
2. The u-stripline to ground is optimized for each length. For no stripline, the metal under pin 5 and 6 is filled with vias to the ground plane to reduce inductance. For the stripline versions, the stripline ends in 2 vias.
3. The standard demo board also needs three 0 Ù SMD's (0603) at the spots marked with an X. Additional components to adjust the biasing can be placed at these spots.

Demo board



Component	Value	Typ
C1	100 pF	Philips 0603
C2	100 pF	Philips 0603
C3	22 nF	Philips 0603
C4	100 nF	Philips 0805
C5	22 nH	Philips 0603
L1	3.9 nH	TDK 0603
L2	3.9 nH	TDK0603

Component	*Function*
	like in version 3