

## 1GHz LNA and mixer

## NE/SA600

## DESCRIPTION

The NE/SA600 is a combined low noise amplifier (LNA) and mixer designed for high-performance low-power communication systems from 800-1200MHz. The low-noise preamplifier has a 2dB noise figure at 900MHz with 16dB gain and an  $IM_3$  intercept of -10dBm at the input. Input and output impedances are  $50\Omega$  and the gain is stabilized by on-chip compensation to vary less than  $\pm 0.5$ dB over the -40 to +85°C temperature range. The wide-dynamic-range mixer has a 14dB noise figure and  $IM_3$  intercept of +6dBm at the input at 900MHz. Mixer input impedance is  $50\Omega$  with an open-collector output. The chip incorporates an option so the LNA can be disabled and replaced by a through connection. The amplifier  $IM_3$  intercept increases to +26dBm in this mode; thus, large signals can be handled. The nominal current drawn from a single 5V supply is 13mA and 4.2mA in the LNA thru mode.

## FEATURES

- Low current consumption: 13mA nominal, 4.2mA in the LNA thru mode
- Excellent noise figure: 2dB for the amplifier and 14dB for the mixer at 900MHz
- Excellent gain stability versus temperature
- Switchable overload capability
- Amplifier matched to  $50\Omega$
- Mixer input matched to  $50\Omega$
- Oscillator input matched to  $50\Omega$

## ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
14-Pin Plastic Small Outline (SO) package (Surface-mount)	0 to +70°C	NE600D	SOT108-1
14-Pin Plastic Small Outline (SO) package (Surface-mount)	-40 to +85°C	SA600D	SOT108-1

## BLOCK DIAGRAM

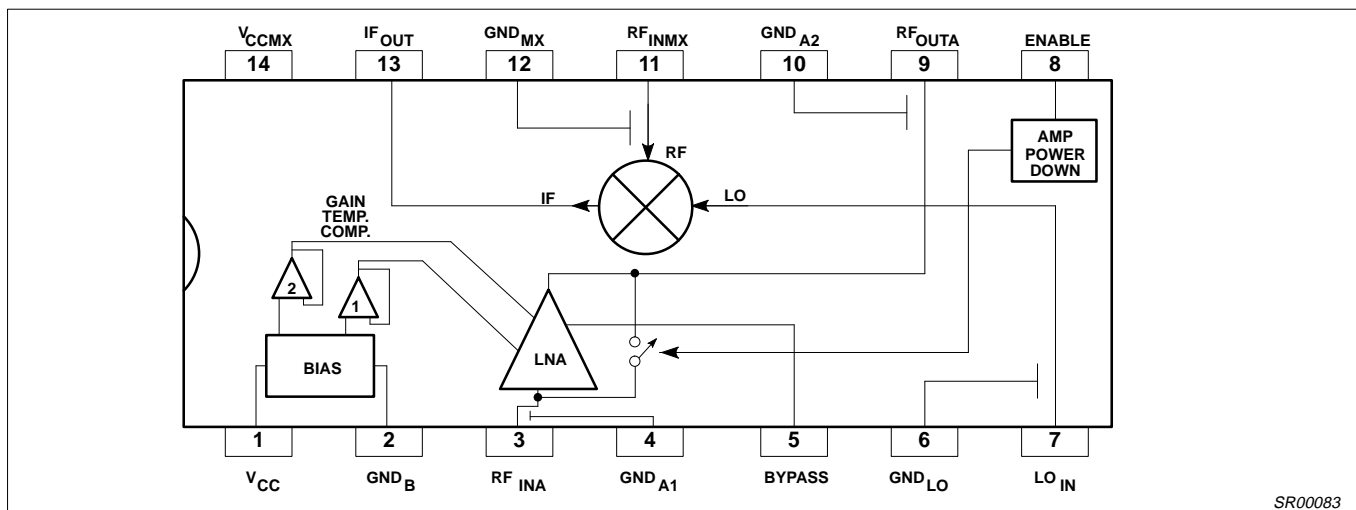


Figure 2. Block Diagram

## PIN CONFIGURATION

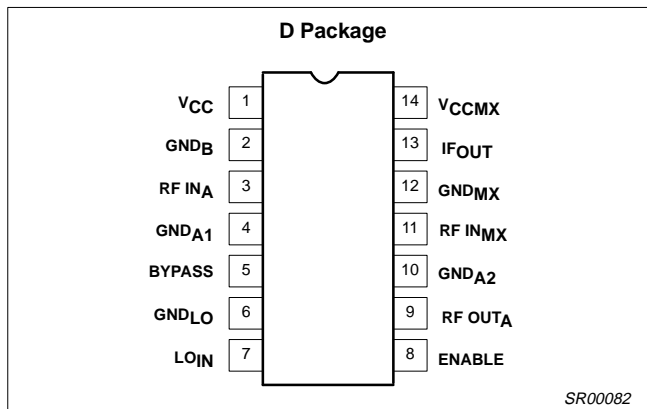


Figure 1. Pin Configuration

## APPLICATIONS

- 900MHz front end for GSM/AMPS/TACS/ hand-held units
- RF data links
- UHF frequency conversion
- Portable radio
- Spread spectrum receivers
- 900MHz cordless phones

## 1GHz LNA and mixer

NE/SA600

## ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNITS
$V_{CC}, V_{CCMX}$	Supply voltage <sup>1</sup>	-0.3 to +6.0	V
$V_{IN}$	Voltage applied to any other pin	-0.3 to ( $V_{CC}+0.3$ )	V
$\Delta V$	$V_{CC}$ to $V_{CCMX}$	-0.3 to +0.3	V
$\Delta G$	Any GND pin to any other GND pin	-0.3 to +0.3	V
$P_D$	Power dissipation, $T_A = 25^\circ\text{C}$ (still air) <sup>2</sup> 14-Pin Plastic SO	980	mW
$T_{JMAX}$	Maximum operating junction temperature	150	$^\circ\text{C}$
$P_{MAX}$	Maximum power input/output	+20	dBm
$T_{STG}$	Storage temperature range	-65 to +150	$^\circ\text{C}$

## NOTE:

- Transients exceeding 9V on  $V_{CC}$  pin may damage product.
- Maximum dissipation is determined by the operating ambient temperature and the thermal resistance,  $\theta_{JA}$ :  
14-Pin SO:  $\theta_{JA} = 125^\circ\text{C/W}$
- CAUTION: The NE/SA600 is built on a BiCMOS process and is sensitive to electrostatic discharge.

## RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	RATING	UNITS
$V_{CC}, V_{CCMX}$	Supply voltage	4.5 to 5.5	V
$T_A$	Operating ambient temperature range NE Grade SA Grade	0 to +70 -40 to +85	$^\circ\text{C}$ $^\circ\text{C}$
$T_J$	Operating junction temperature NE Grade SA Grade	0 to +90 -40 to +105	$^\circ\text{C}$ $^\circ\text{C}$

DC ELECTRICAL CHARACTERISTICS<sup>1,2</sup>

$V_{CC} = V_{CCMX} = +5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ; Test Figure 1, unless otherwise stated.

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS					UNITS
			MIN	-3 $\sigma$	TYP	+3 $\sigma$	MAX	
$I_{CC}$	Supply current (Pin 1, 13, 14)	Enable input high	10	11	13.0	15	16	mA
		Enable input low	3.2	3.6	4.2	4.8	5.2	
$V_T$	Enable logic threshold voltage		1.12	1.17	1.27	1.37	1.42	V
$V_{IH}$	Logic 1 level: LNA gain mode		2.0				$V_{CC}$	V
$V_{IL}$	Logic 0 level: LNA thru mode		-0.3				0.8	V
$I_{IL}$	Enable input current	Enable = 0.4V	-1		0		1	$\mu\text{A}$
$I_{IH}$	Enable input current	Enable = 2.4V	-1		0		1	$\mu\text{A}$
$V_{LNA-IN}$	LNA input bias voltage	Enable input high			0.78			V
$V_{LNA-OUT}$	LNA output bias voltage	Enable input high			1.27			V
$V_{BY}$	LNA bypass bias voltage	Enable input high			1.05			V
$V_{MX-IN}$	Mixer RF input bias voltage				1.43			V
$V_{LO-IN}$	Mixer LO input bias voltage				3.35			V

## NOTE:

- The ENABLE input must be connected to a valid logic level for proper operation of the NE/SA600.
- Standard deviations are estimated from design simulations to represent manufacturing variations over the life of the product.

## 1GHz LNA and mixer

## NE/SA600

AC ELECTRICAL CHARACTERISTICS<sup>1,2</sup>

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNITS
			-3 $\sigma$	TYP	+3 $\sigma$	
<b>LNA</b> ( $V_{CC} = V_{CCMX} = +5V$ , $T_A = 25^\circ C$ ; Enable = Hi, Test Figure 1, unless otherwise stated.)						
$S_{21}$	Amplifier gain	900MHz	14.9	16	17.1	dB
$S_{21}$	Amplifier gain in thru mode	Enable = LO, 900MHz	-9.0	-7.5	-6.0	dB
$\Delta S_{21}/\Delta T$	Gain temperature sensitivity enabled	900MHz		-0.008		dB/ $^\circ C$
$\Delta S_{21}/\Delta T$	Gain temperature sensitivity in thru mode	Enable = LO, 900MHz		-0.014		dB/ $^\circ C$
$\Delta S_{21}/\Delta f$	Gain frequency variation	800MHz - 1.2GHz		-0.014		dB/MHz
$S_{12}$	Amplifier reverse isolation	900MHz	-47	-42	-37	dB
$S_{11}$	Amplifier input match <sup>3</sup>	900MHz	-11	-10	-9	dB
$S_{22}$	Amplifier output match	900MHz	-16.8	-15	-13.2	dB
$P_{-1dB}$	Amplifier input 1dB gain compression	900MHz	-21.2	-20	-18.8	dBm
$IP_3$	Amp input 3rd-order intercept	Test Fig. 2, 900MHz	-11.6	-10	-8.6	dBm
	Amp input 3rd-order intercept (thru mode)	Test Fig. 2, 900MHz, Enable = LO		+26		dBm
NF	Amplifier noise figure	900MHz	1.9	2.2	2.5	dB
	Amp noise figure w/shunt 15nH inductor at input	900MHz	1.7	2.0	2.3	dB
$t_{ON}$	Amplifier turn-on time	Enable Lo $\rightarrow$ Hi	Coupling = 100pF	30		$\mu s$
			Coupling = 0.01 $\mu F$	3		ms
$t_{OFF}$	Amplifier turn-off time	Enable Hi $\rightarrow$ Lo	Coupling = 100pF	10		$\mu s$
			Coupling = 0.01 $\mu F$	1		ms
<b>Mixer</b> ( $V_{CC} = V_{CCMX} = +5V$ , $T_A = 25^\circ C$ , Enable = Hi, $f_{LO} = 1GHz @ 0dBm$ , $f_{RF} = 900MHz$ , $f_{IF} = 100MHz$ , Test Fig. 1, unless otherwise stated)						
$VG_C$	Mixer voltage conversion gain	$R_{L1} = R_{L2} = 1k\Omega$	9.5	10.4	11.3	dB
$PG_C$	Mixer power conversion gain	$R_{L1} = R_{L2} = 1k\Omega$	-3.05	-2.6	-2.15	dB
$S_{11RF}$	Mixer input match	900MHz	-23	-20	-17	dB
$NF_M$	Mixer SSB noise figure	Test Fig. 3, 900MHz, $f_{IF} = 80MHz$	12.2	14	15.8	dB
$P_{-1dB}$	Mixer input 1dB gain compression	900MHz	-5.3	-4	-2.7	dBm
$IP_{3INT}$	Mixer input third order intercept	900MHz	+5	+6	+7	dBm
$IP_{2INT}$	Mixer input second order intercept	900MHz	+18	+20	+22	dBm
$GR_{FM-IF}$	Mixer RF feedthrough	900MHz, $C_{IF} = 3pF$		-7		dB
$G_{LO-IF}$	Mixer LO feedthrough	900MHz, $C_{IF} = 3pF$		-10		dB
$G_{LO-RFM}$	Local oscillator to mixer input feedthrough	900MHz		-33		dB
$S_{11LO}$	LO input match	900MHz	-24	-20	-16	dB
$G_{LO-RF}$	Local oscillator to RF input feedthrough	900MHz		-46		dB
$GR_{FO-RFM}$	Filter feedthrough	900MHz		-39		dB
<b>LNA + Mixer</b> ( $V_{CC} = V_{CCMX} = +5V$ , $T_A = 25^\circ C$ , Enable = Hi, $f_{LO} = 1GHz @ 0dBm$ , $f_{RF} = 900MHz$ , $f_{IF} = 100MHz$ , Test Fig. 1, unless otherwise stated)						
$PG_C$	Overall power conversion gain			13.4		dB
NF	Overall noise figure			3.5		dB
$IP_3$	Overall input 3rd-order intercept			-13		dBm

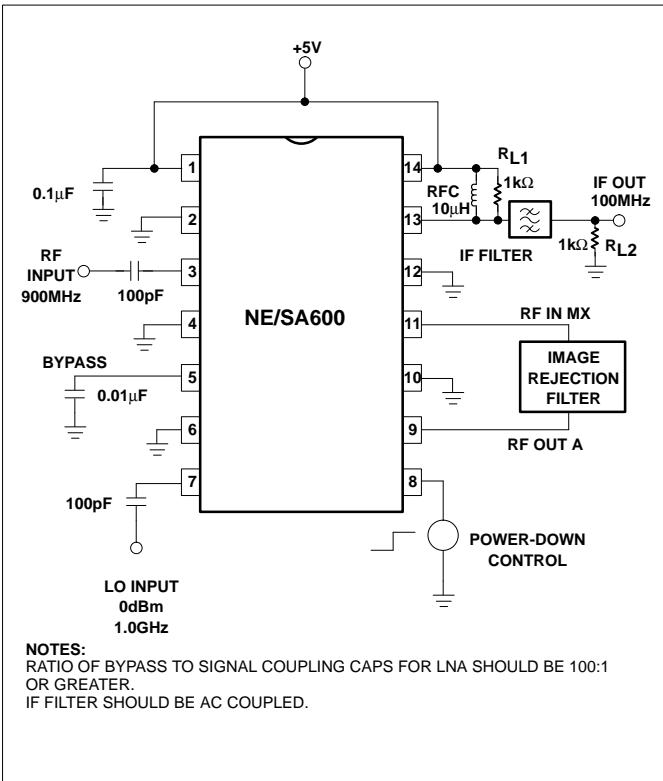
## NOTE:

- All measurements include the effects of the NE/SA600 Evaluation Board (see Figure ) unless otherwise noted. Measurement system impedance is 50 $\Omega$ .
- Standard deviations are estimated from design simulations to represent manufacturing variations over the life of the product.
- With a shunt 15nH inductor at the input of the LNA, the value of  $S_{11}$  is typically -15dB.

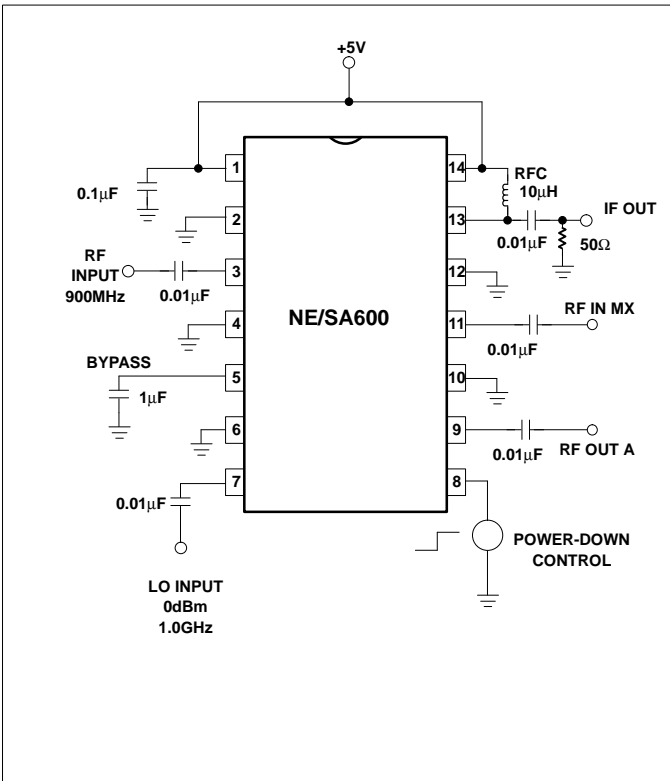
# 1GHz LNA and mixer

# NE/SA600

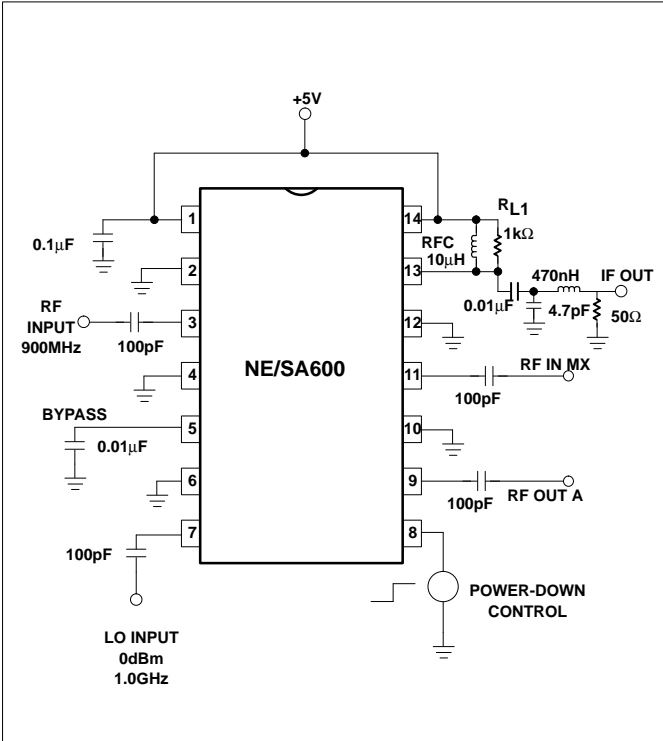
## TYPICAL APPLICATION



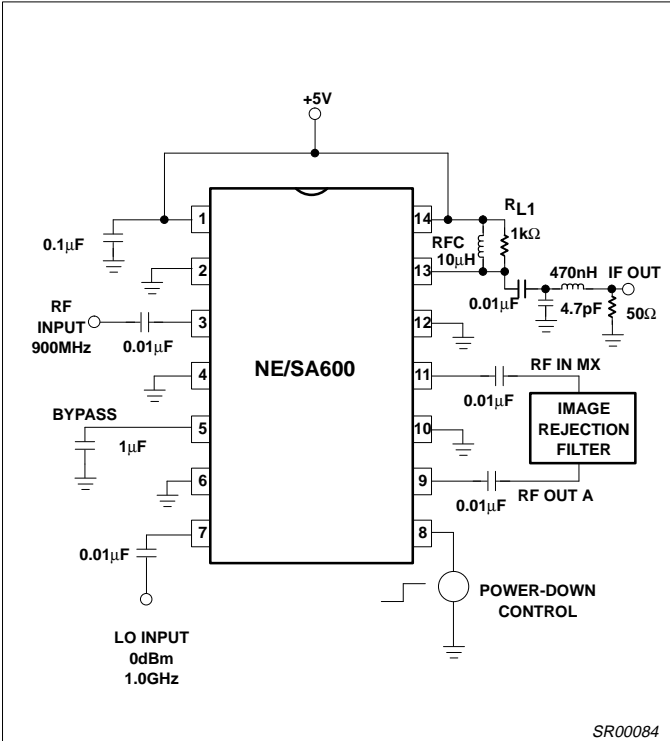
## TEST FIGURE 1



## TEST FIGURE 2



## TEST FIGURE 3



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Figure 3. Test Application and Test Figures 1, 2 and 3

# 1GHz LNA and mixer

# NE/SA600

NOTE: All performance curves include the effects of the NE/SA600 evaluation board.

## LNA S21 CHARACTERISTICS $4.5V \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Figure 1, unless otherwise specified.

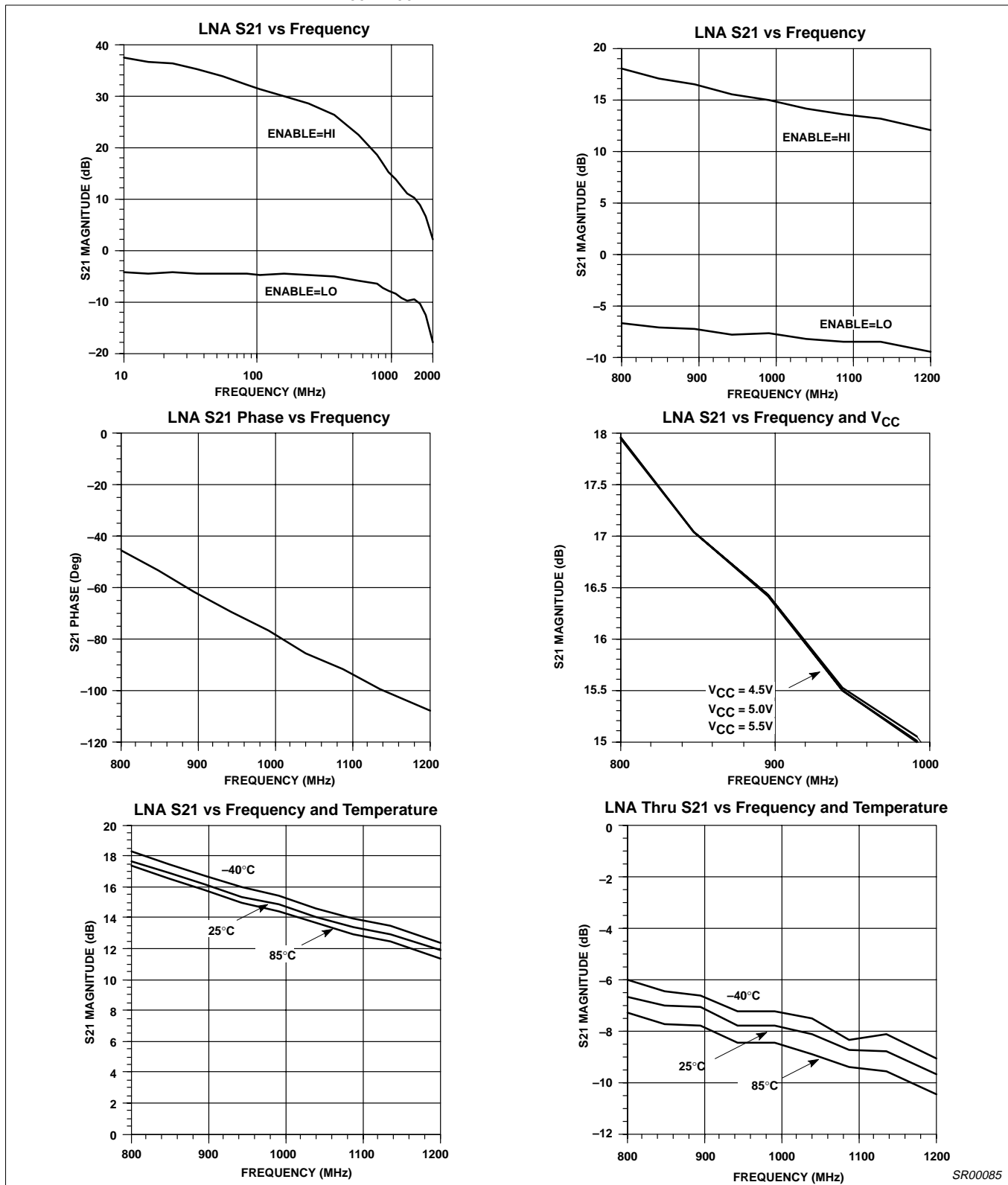


Figure 4. LNA S21 Performance Characteristics

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# 1GHz LNA and mixer

# NE/SA600

**LNA S11/S12/S22 CHARACTERISTICS**  $4.5V \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Figure 1, unless otherwise specified.

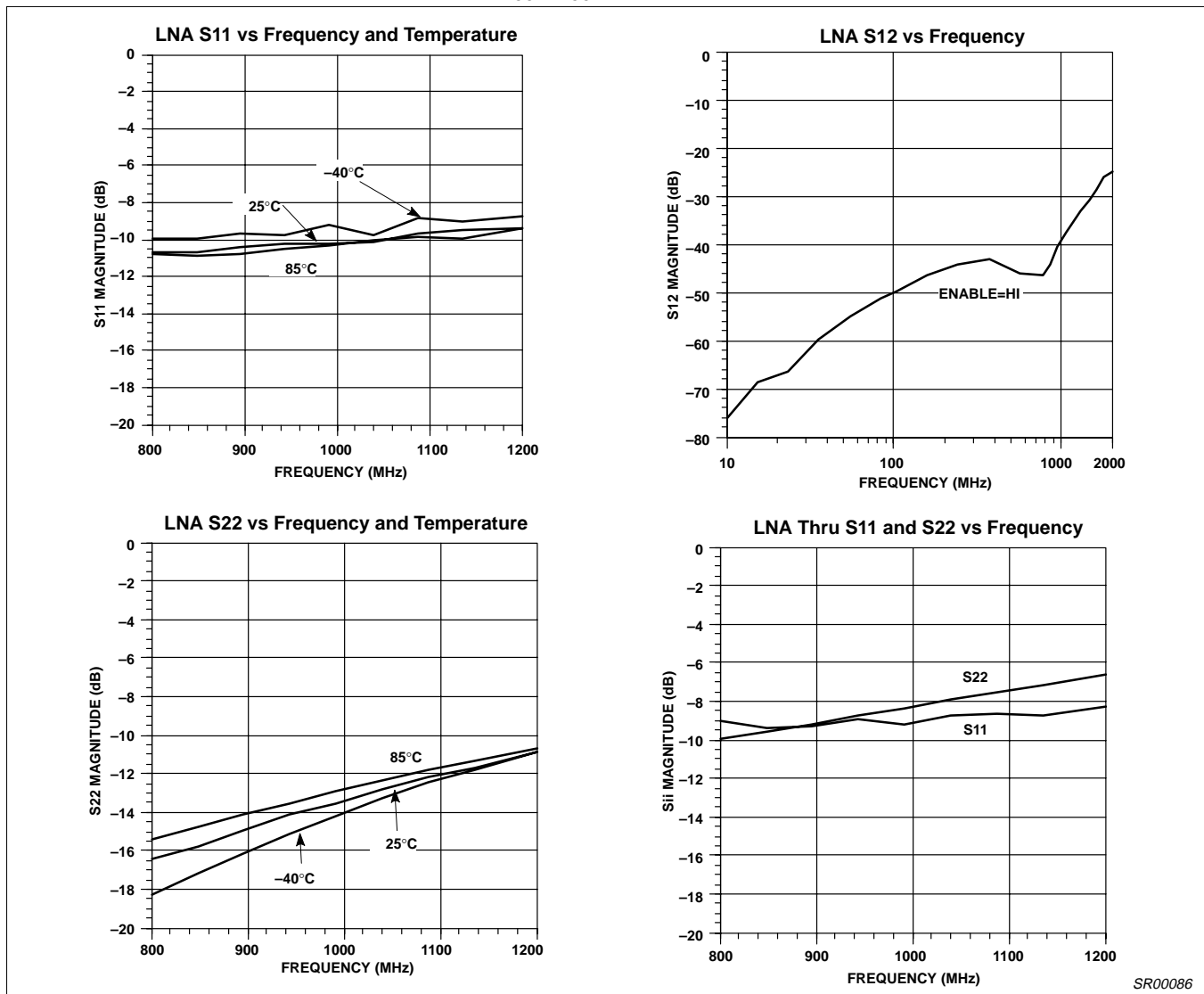


Figure 5. LNA S11/S12/S22 Performance Characteristics

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Table 1. S-Parameters

Freq. MHz	S <sub>11</sub>		S <sub>12</sub>		S <sub>21</sub>		S <sub>22</sub>	
	dB	∠	dB	∠	dB	∠	dB	∠
800	-9.5	-160	-46	8	17.9	125	-18.0	151
900	-9.5	-172	-43	19	16.4	105	-15.8	122
1000	-9.4	-173	-40	17	15.1	88	-14.0	98
1100	-9.1	-200	-37	12	13.8	70	-12.4	77
1200	-8.9	-216	-35	1	12.9	55	-11.1	58

# 1GHz LNA and mixer

# NE/SA600

## LNA OVERLOAD/NOISE/DISTORTION CHARACTERISTICS

$4.5V \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Fig. 1, unless otherwise specified.

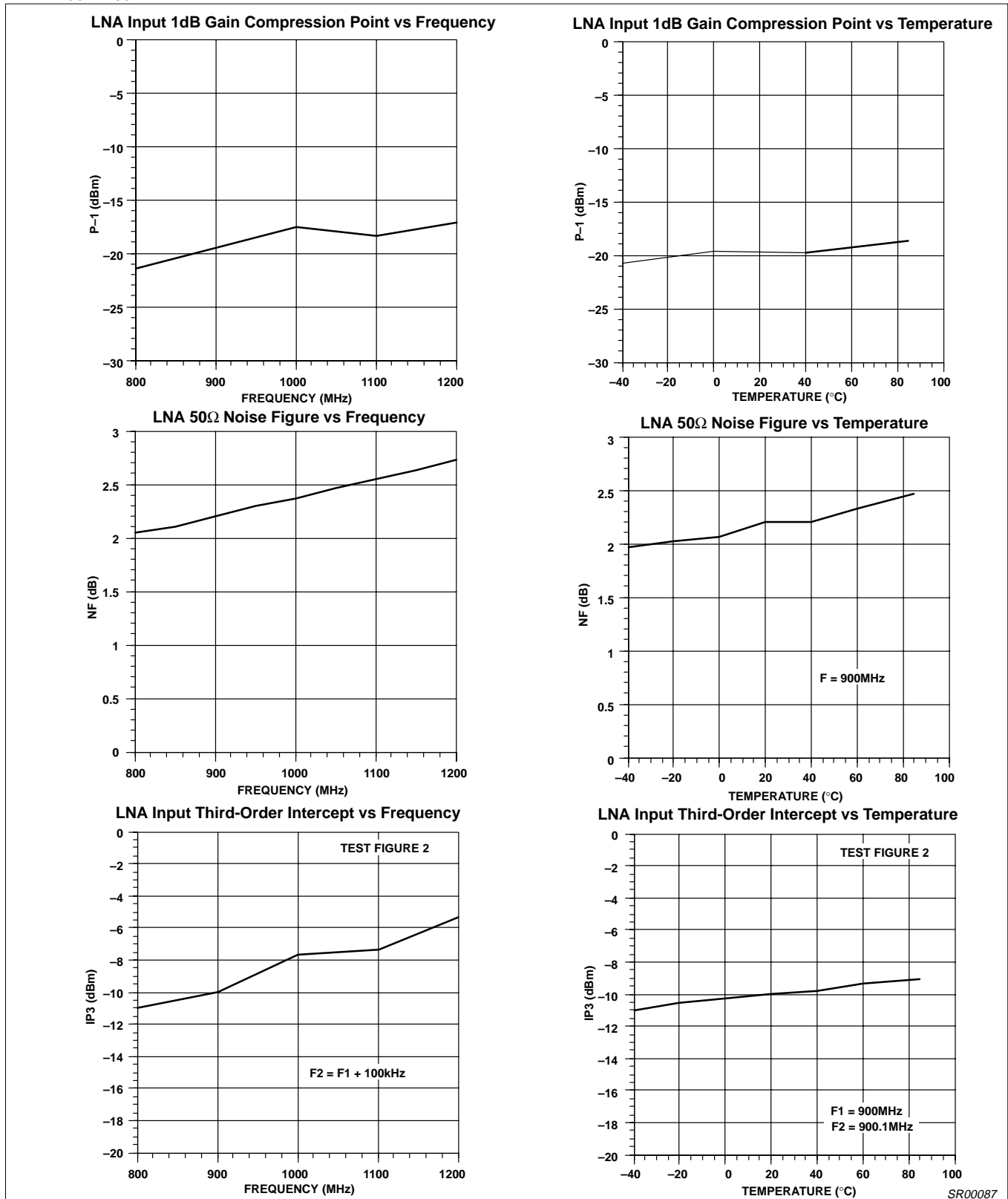


Figure 6. LNA Overload/Noise/Distortion Performance Characteristics

SR00087

# 1GHz LNA and mixer

# NE/SA600

**MIXER GAIN/NOISE CHARACTERISTICS**  $4.5V \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Figure 1, unless otherwise specified.

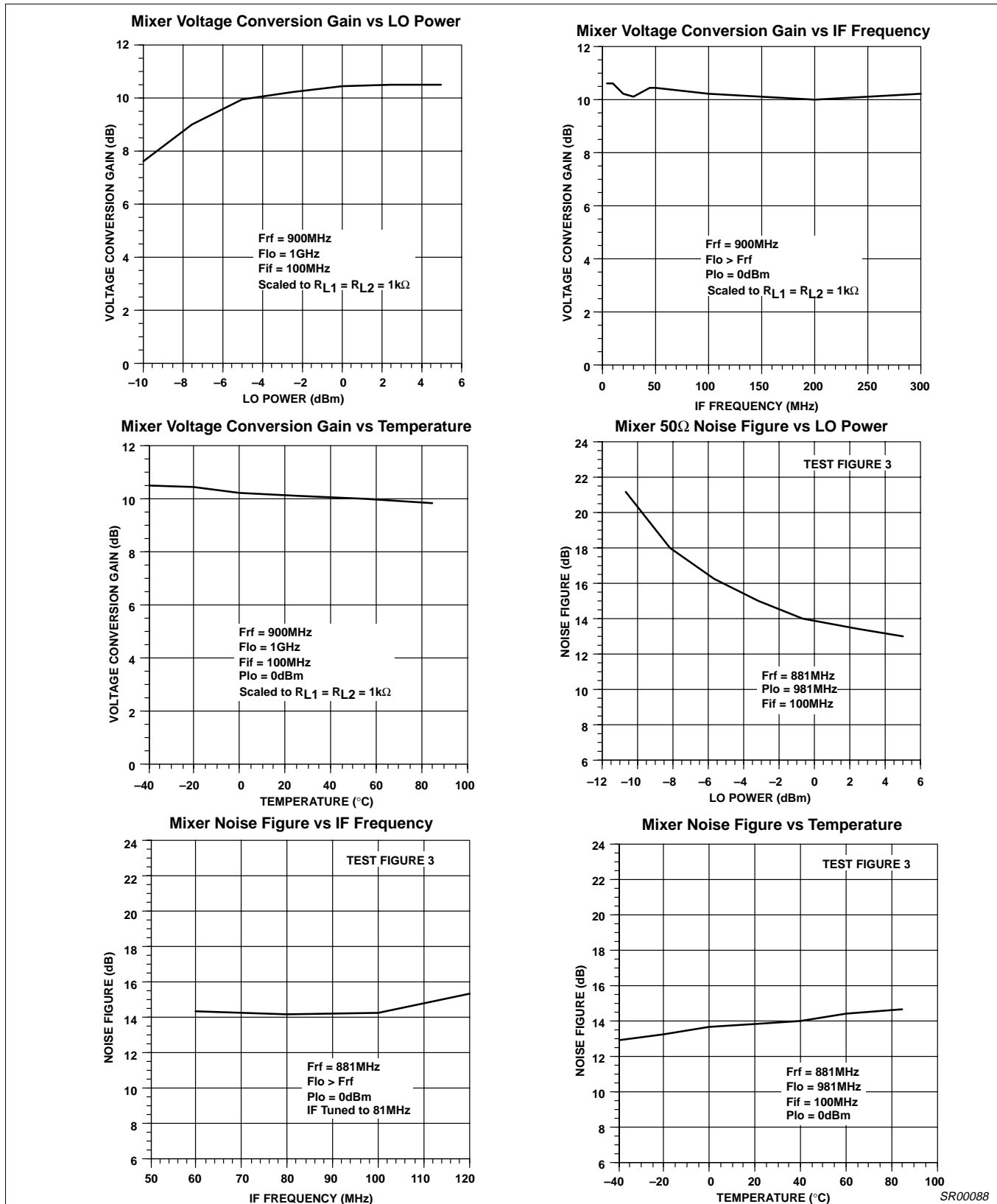


Figure 7. Mixer Gain/Noise Performance Characteristics

SR00088



# 1GHz LNA and mixer

# NE/SA600

## MIXER OVERLOAD/DISTORTION CHARACTERISTICS $4.5 \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Fig. 1, unless otherwise specified

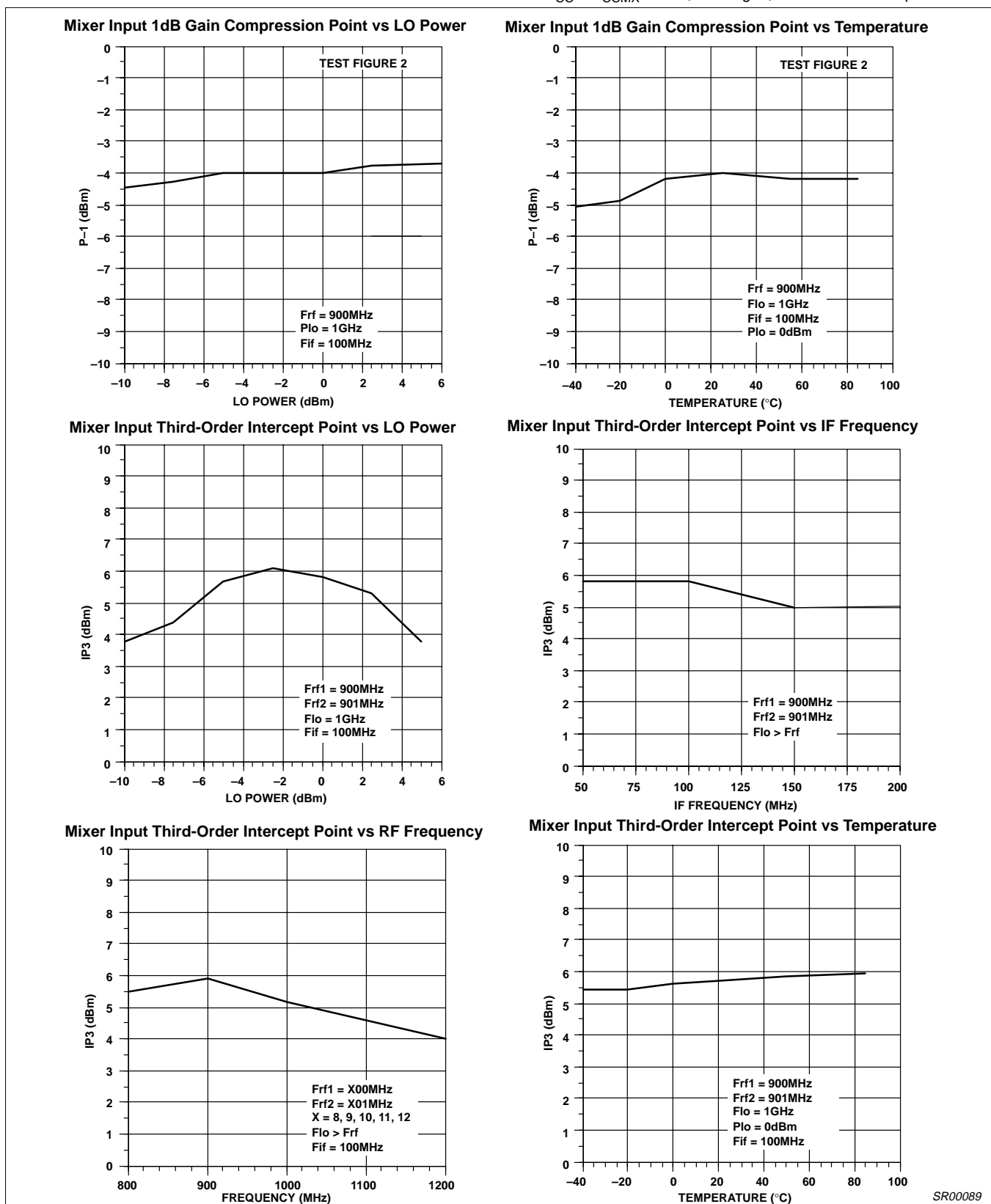


Figure 8. Mixer Overload/Distortion Characteristics

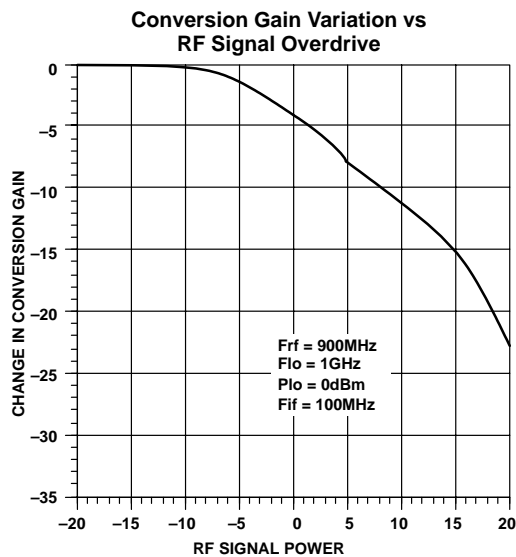
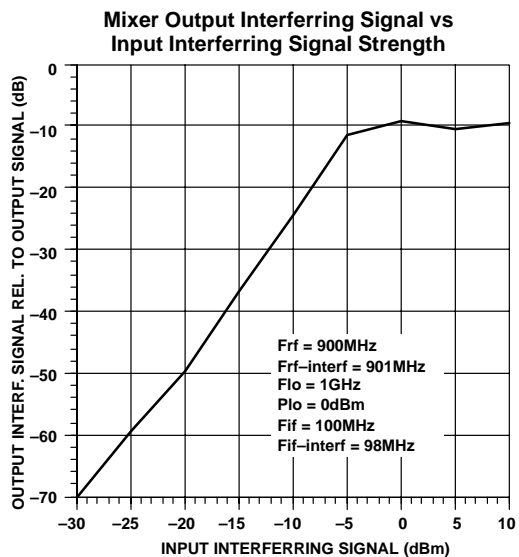
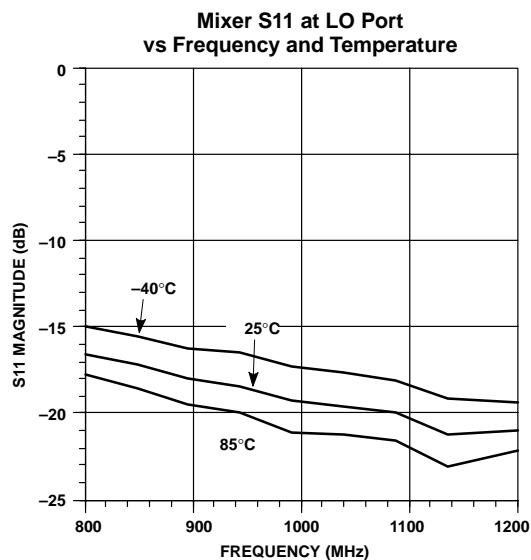
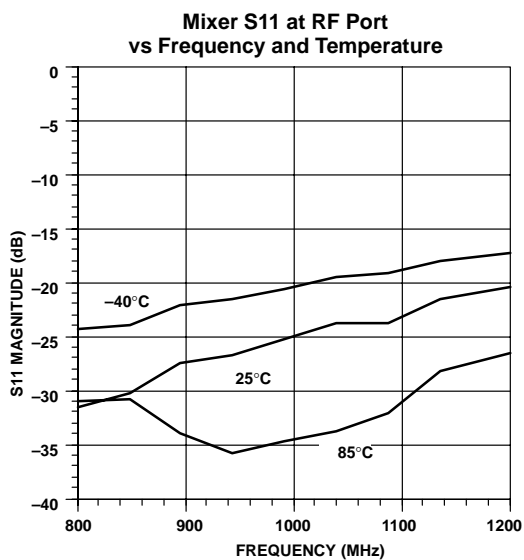
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# 1GHz LNA and mixer

# NE/SA600

## MIXER S11/ISOLATION/INTERFERENCE CHARACTERISTICS

$4.5 \leq V_{CC} = V_{CCMX} \leq 5.5V$ , Test Fig. 1, unless otherwise specified



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Figure 9. Mixer S11/Isolation/Interference Characteristics

# 1GHz LNA and mixer

NE/SA600

## OVERALL PERFORMANCE: ISOLATION CHARACTERISTICS

4.5 ≤ V<sub>CC</sub> = V<sub>CCMX</sub> ≤ 5.5V, Test Fig. 1, unless otherwise specified

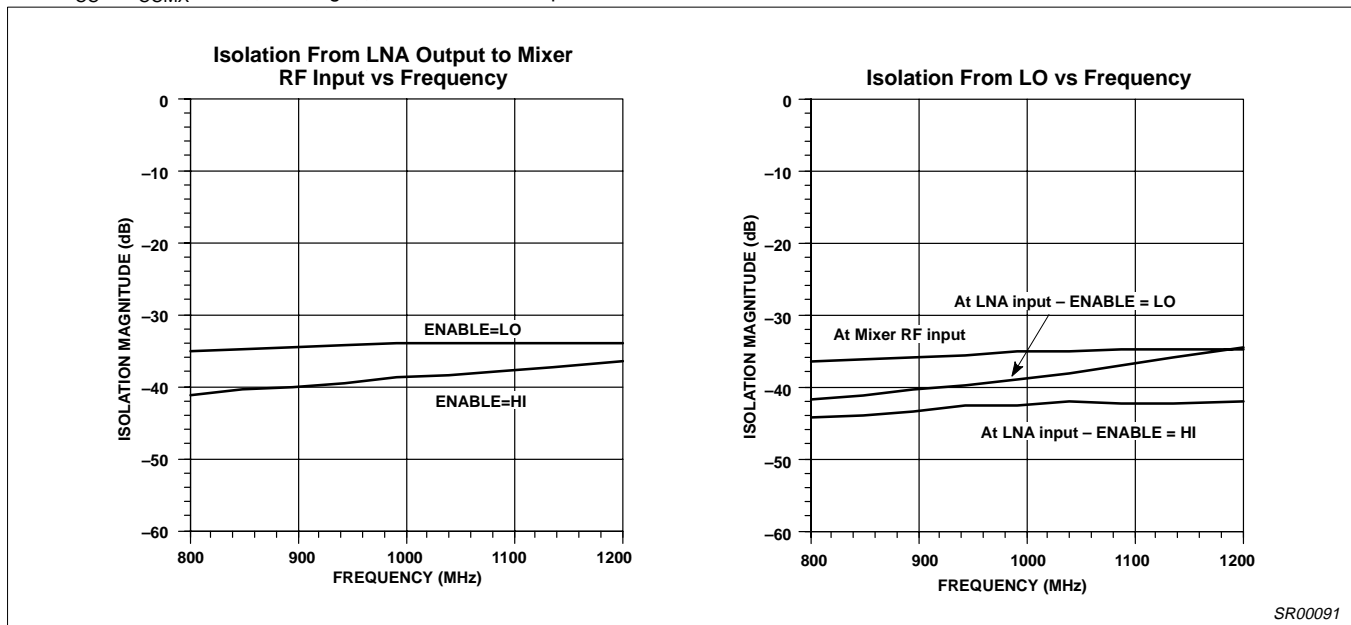


Figure 10. Overall Performance: Isolation Characteristics

## SPECIFICATIONS

The goal of the Specifications section of the datasheet is to provide information on the NE/SA600 in such a way that the designer can estimate statistical variations, and can reproduce the measurements. To this end the high frequency measurements are specified with a particular PC board layout. Variations in board layout will cause parameter variations (sensitive parameters are discussed in the sections on the LNA and mixer below). For many RF parameters the ±3 sigma limits are specified. Statistically only 0.26% of the units will be outside these limits.

The LNA + mixer conversion gain is measured with an incident 900MHz signal and a 83MHz SAW filter at the IF output. This measurement along with a gain measurement of the LNA ensure the correct operation of the chip and also allows a calculation of mixer conversion gain.

## PIN DESCRIPTIONS AND OPERATIONAL LIMITS

### RF<sub>INA</sub>

Input of LNA, AC coupling required, DC = 0.78V, frequency range from DC to 2GHz, gain at low frequencies is 40dB — so be careful of overload, impedance below 50Ω, shunt 15-18nH inductor helps input match and noise figure.

### RF<sub>OUTA</sub>

Output of LNA, AC coupling required, DC = 1.27V, frequency range from DC to 2GHz, impedance above 50Ω.

### BYPASS

Bypass capacitor should be 100 times larger than the largest signal coupling capacitor for the LNA, DC = 1.05V.

### RF<sub>INMX</sub>

Mixer RF port, AC coupling required, DC = 1.43V, frequency range from 100MHz to 2.5GHz, impedance close to 50Ω resistive.

### LO<sub>IN</sub>

Mixer LO port, AC coupling required, DC=3.35V, frequency range from 100MHz to 2.5GHz, impedance close to 50Ω resistive.

### IF<sub>OUT</sub>

Mixer IF port, open-collector output with 1.6mA DC, frequency range DC to 1GHz, impedance approximately 1pF capacitive.

### Enable

TTL/CMOS compatible input. Bias current approximately zero.

## CONVERSION GAIN DEFINITIONS

Referring to the figure above, we define the ratio of V<sub>A</sub> (at the IF frequency) to V<sub>I</sub> (at the RF frequency) to be the Available Voltage Conversion Gain, or more simply Voltage Conversion Gain,

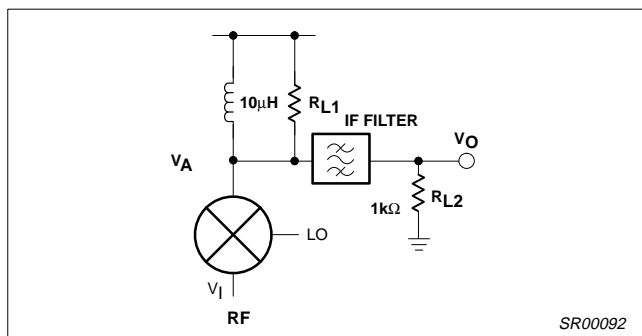


Figure 11.

$$VG_C = 20 \log \left( \frac{V_A}{V_I} \right)$$

where V<sub>A</sub> and V<sub>I</sub> are expressed in similar voltage units (such as peak-to-peak). The voltage output V<sub>A</sub> is decreased by the IF Filter

# 1GHz LNA and mixer

# NE/SA600

loss (and any other matching required). Typically,  $V_{GC}$  is 10.4dB for the NE/SA600 mixer with the net IF impedance equal to 500Ω.

It is more common to express the conversion gain in terms of power, so we have the Power Conversion Gain,

$$PG_C = 10 \log \left( \frac{P_A}{P_I} \right) - 3 \text{dB}$$

where  $P_A = V_A^2 / R_{IF}$  and  $P_I = V_I^2 / R_{RF}$ .  $R_{IF}$  is the net resistance at the IF frequency at the IF port, and  $R_{RF}$  is the input impedance at the mixer RF port. With a 500Ω IF impedance and a 50Ω RF input impedance, the conversion gain works out to -2.6dB typically. The power delivered to the load is down 3dB with respect to the available power because of loss in  $R_{L1}$ .

## THEORY OF OPERATION

The NE/SA600 is fabricated on the Philips Semiconductors advanced QUBiC technology that features 1μm channel length MOSFETs and 13GHz FT bipolar transistors.

### LNA

The Low Noise Amplifier (LNA) is a two stage design incorporating feedback to stabilize the amplifier. An external bypass capacitor of (typically) 0.01μF is used. The inputs and outputs are matched to 50Ω. The amplifier has two gain states: when the ENABLE pin is taken high, the amplifier draws 9mA of current and has 16dB of gain at 900MHz. When the ENABLE pin is low, the amplifier current goes to zero, and the amplifier is replaced by a thru. Typical loss for the thru is 7dB. This dual-gain state approach can be used in bang-bang control systems to achieve a low gain, high overload front-end as well as the more usual high gain, low overload front-end.

The amplifier has gain to frequencies past 2GHz, but a practical upper end is 1.6-1.7GHz. Both the input match and the noise figure (NF) can be improved with a shunt 15-18nH inductor at the input. Typically, the gain increases 0.4dB, the match improves to 13-16dB, and the noise figure drops to 1.95-2dB. Variations of any of the RF parameters with  $V_{CC}$  is negligible, and variation with temperature is minimal.

### Mixer

The mixer is a single-balanced topology designed to draw very low current, typically 4mA, and provide a very high input third-order intermodulation intercept point, typically  $IP3=+6\text{dBm}$ . The RF and LO ports impedances are nearly 50Ω resistive, and the IF output is an open collector. The open-collector output allows direct interfacing with high impedance IF filters, such as surface acoustic wave (SAW) filters without the need for external step-up transformers (which are needed for 50Ω output mixers).

The basic mixer is functional from DC to well over 2.5GHz, but RF and LO return losses degrade below 100MHz. The IF output can be used from DC to 500MHz or more, although typically the intermediate frequency is in the range 45-120MHz in many 900MHz receivers. To achieve the lowest noise, the LO drive level should be increased as high as possible, consistent with power dissipation limitations.

## POWER SUPPLY ISSUES

$V_{CC}$  bypassing is important, but not extremely critical because of the internal supply regulation of the NE/SA600. The Pin 1  $V_{CC}$  supplies the LNA and powers overhead circuitry. Typical current

draw is 9.8mA while enable is high (1mA powered down). The Pin 14  $V_{CCMX}$  powers the mixer and typically has 3.2mA of current (assuming an inductor biasing the IFout back to  $V_{CCMX}$ ). Care must be taken to avoid bringing any IC pin above  $V_{CC}$  by more than 0.3V, or below any ground by more than 0.3V. For example, this can occur if the enable pin is fed from a microcontroller that is powered up quicker than the NE/SA600. In this condition the internal electrostatic discharge (ESD) protection network may turn-on, possibly causing a part malfunction. Generally this condition is reversible, so long as the source creating the overstress is current limited to less than 100mA. To avoid the problem, make sure both  $V_{CC}$  pins are tied together near the IC, and install a 1kΩ resistor in series with the enable pin if it is likely to go above  $V_{CC}$ .

## BOARD LAYOUT CONSIDERATIONS

The LNA is sensitive to mutual inductance from the input to ground. Therefore long narrow input traces will degrade the input match. Ideally, a top side ground-plane should be employed to maximize LNA gain and minimize stray coupling (such as LO to antenna). To avoid amplifier peaking, the output and input grounds should not be run together. Attach both grounds to a solid ground plane. A solid ground plane beneath the package will maximize gain. Top side to back side ground through holes are highly recommended.

The mixer is relatively insensitive to grounding. Care should be taken to minimize the capacitance on the RF port (Pin 11) for best noise figure. Also, the capacitance on the IFout pin must be kept small to avoid conversion gain rolloff when using high IF frequencies. The purpose of the inductor from IFout to  $V_{CC}$  is to set the midpoint of the IF swing to be  $V_{CC}$ . Without this inductor the part is sensitive to output overload under low  $V_{CC}$  ( $V_{CC} = 4.5\text{V}$ ) and hot temperature conditions. The  $V_{CCMX}$  pin must be kept at the same potential as the  $V_{CC}$  pin.

## APPLICATIONS INFORMATION

The NE/SA600 is a high performance, wide-band, low power, low noise amplifier (LNA) and mixer circuit integrated in a BiCMOS technology. It is ideally suited for RF receiver front-ends for both analog and digital communications systems.

There are several advantages to using the NE/SA600 as a high frequency front-end block instead of a discrete implementation. First is the simplicity of use. The NE/SA600 does not need any external biasing components. Due to the higher level of integration and small footprint (SO14) package it occupies less space on the printed circuit board and reduces the manufacturing cost of the system. Also the higher level of integration improves the reliability of the LNA and mixer over a discrete implementation with several components.

The LNA thru mode in NE/SA600 helps reduce power consumption in applications where the amplifiers can be disabled due to higher received signal strength (RSSI). Other advantages of this feature are described later in this section.

The mixer is an active mixer with excellent conversion gain at low LO input levels, so LO levels as low as -5dBm to -10dBm can be used depending on the applications requirement for mixer gain, mixer noise figure and mixer third order intercept point. This reduces the LO drive requirements from the VCO buffer, thus reducing its current consumption. Also, due to lower LO levels, the shielding requirements can be minimized or eliminated, resulting in substantial cost savings and weight and space reduction.

# 1GHz LNA and mixer

NE/SA600

And last but not least, is the impedance matching at LNA inputs and outputs and mixer RF and LO input ports. Only those who have toiled through discrete transistor implementations for 50 $\Omega$  input and output impedance matching can truly appreciate the elegance and simplicity of the NE/SA600 input and output impedance matching to 50 $\Omega$ . Also, the mixer output impedance is high, so matching to a crystal or SAW IF filter becomes extremely easy without the need for additional IF impedance transformers (tapped-C networks with inductors or baluns).

The NE/SA600 applications and demo board features standard low cost 62mil FR-4 board. A top-side ground plane is used and 50 $\Omega$  coplanar transmission lines are used. LO and RF<sub>INA</sub> traces are perpendicular. Provisions for the image reject filter between RF<sub>OUTA</sub> and RF<sub>INMX</sub> are provided. A simple LC match for 80MHz IF is used so that 50 $\Omega$  measurements can be made on the demo board.

The NE/SA600 applications evaluation board schematic is shown in Figure 1. The V<sub>CC</sub> (Pin 1) and V<sub>CCMX</sub> (Pin 14) are tied together and the power supply is bypassed with capacitors C5 and C6. These capacitors should be placed as close to the device as practically possible.

C1 is the DC blocking capacitor to the input of the LNA. L1 provides additional input matching to the LNA for an improved return loss (S11). This inductor can be a surface-mount component or can be easily drawn on the printed circuit board (small spiral or serpentine). This additional match improves the gain of the LNA by 0.4dB and lowers the noise figure to 2dB or less. If the typical gain of the LNA of 16dB is acceptable with 2.2dB of noise figure, then L1 can be eliminated. If the LNA input is fed from a duplexer or selectivity filter after the antenna, C1 can also be eliminated since the filter will also provide DC blocking. The LNA bypass capacitor C3 should be at least 100 times C1 or C9 for low frequency stability. Switch S1 toggles the LNA gain/through function. R1 is used only to limit the maximum current into the enable pin and only necessary if enable may power up before the V<sub>CC</sub>.

C4 is a DC blocking capacitor for the LO input pin and may not be needed in actual applications if the VCO output is isolated and will not upset the internal DC biasing of the mixer. The image reject filter goes between the output of the LNA and the RF input to the mixer. Since the LO input, RF output and mixer input are all 50 $\Omega$  matched impedances internally, there is no need for any external components. C8 and C9 are DC blocking capacitors to the connectors and will not be needed in an actual application.

R2 and L2 are the load to the mixer output which is typical of the IF crystal or SAW filters. C2 and L3 provide a match from the high impedance mixer output to a 50 $\Omega$  test set-up (spectrum analyzer, etc.) and C7 is a DC blocking capacitor for the mixer output.

The printed circuit board layout for the schematic of Figure 1 is shown in Figure 14. It is a very simple printed circuit board layout with all the components on a single side. The layout also accommodates a two pole image reject filter between the LNA output and mixer input. All the input and output traces to the LNA and mixer should be 50 $\Omega$  tracks with the exception of mixer output, which can be very narrow due to the higher impedances of the filter.

The NE/SA600 internal supply is very well regulated. This is seen from Figure 15 which shows the I<sub>CC</sub> vs. V<sub>CC</sub> for the NE/SA600. Table NO TAG shows the S11, S21, S22 and S21 for the LNA from 800-1200MHz. Typical measurements at 900MHz for the critical parameters such as gain, noise figure, IP<sub>3</sub>, 1dB compression point, etc. as measured on an applications evaluation board are as follows :

LNA gain = 16.5dB  
 LNA through = -7dB  
 Mixer gain = -3dB (into a 50 $\Omega$  load)  
 LNA noise figure = 2dB  
 Mixer noise figure = 14dB  
 LNA IP<sub>3</sub> = -10dBm (in gain mode)  
 LNA IP<sub>3</sub> = +26dBm (in through mode)  
 LNA 1dB compression point = -20dBm  
 Mixer 1dB compression point = -4dBm

The shunt inductor L1 for input match is optional. Figure 16 shows the effect of the inductor value from 8.2nH to 15nH on gain, noise figure and input match.

The total power gain for the LNA and mixer (excluding the image reject filter) in a system where the output of the mixer is loaded with 50 $\Omega$  is about 14dB. In an actual system the output impedance of the mixer is usually much higher than 50 $\Omega$  (more like 1k $\Omega$  or higher) and so it is more important to consider the voltage gain from the input at the LNA to the mixer output. The voltage gain in this case will be about 29.85V/V. The total noise figure for the LNA and mixer combination is about 3.27dB. The input third order intercept point for the LNA and mixer is about -11dBm. In the LNA through mode, the intercept point for the combination is higher than +19dBm. This LNA through feature provides an additional boost to the total dynamic range of the system.

The NE/SA600 finds applications in many areas of RF communications. It is an ideal down converter block for high performance, low cost, low power RF communications transceivers. The front-end of a typical AMPS/TACS/NMT/TDMA/CDMA cellular phone is shown in Figure 13. This could also be the front-end of a VHF/UHF handheld transceiver, UHF cordless telephone or a spread spectrum system.

The antenna is connected to the duplexer input. The receiver output of the duplexer is connected to the RF input of the LNA. If the additional improvement in noise figure and gain are not needed to meet the system specifications then L1 and C1 can be eliminated. In TDMA systems, the NE/SA600 can be totally powered down by Q1 and the two resistors. In this mode the current consumption will be zero mA. Care should be taken in the software of the system to insure that the enable pin on NE/SA600 tied to the LNA gain control port is held low while the device is in total power down mode. L2 and C2 can be tuned to the IF frequency and to match to the IF filter impedance.

A complete analysis of the front-end shows that the total voltage gain from the antenna input to the mixer output is about 9.5V/V. This value includes a 3.2dB loss for the duplexer and a 1.8dB loss for the bandpass filter. The noise figure as referred to the antenna is 7dB and the input third order intercept point is about -7.5dBm. In LNA through mode the input third order intercept point increases to about +24dBm.

During normal operation of a handheld RF receiver the received signal strength (RSSI) is nominally greater than -100dBm. The signal only drops below this level due to severe multipath fading, shadow effect or when the receiver is at extreme fringes of cell coverage. The LNA through mode can be used here as a two step gain control such that when RSSI is below a certain threshold level (e.g. -90dBm), the LNA has a -7dB loss and the total current consumption of the NE/SA600 is only 4.3mA. The sensitivity of the system will not suffer because the received RF signal is much higher than the noise floor of the system. When the RSSI falls below a certain threshold (e.g. -95dBm) the LNA is enabled to give the full

# 1GHz LNA and mixer

# NE/SA600

16.5dB of gain with 2dB of noise figure. In this mode the current consumption is increased to 13mA. But for hand-held equipment, the average current consumption will be closer to 5-6mA. The other advantage of the LNA through mode besides power savings is the input overload characteristics. Due to the much higher input third order intercept point of the LNA (+26dBm), the receiver is immune to strong adjacent channel interference. Implementing this feature with an FM/IF device such as the NE625/7 with fast RSSI response and a window comparator toggling the LNA mode of NE/SA600, a fast two-step AGC with response time less than 10µs can be achieved.

This is a very useful feature to equalize multipath fading effects in a mobile radio system.

In conclusion, the NE/SA600 offers higher level of integration, higher reliability, higher level of performance, ease of use, simpler system design at a cost lower than the discrete multi-transistor implementations. In addition, the NE/SA600 provides unique features to enhance receiver performance which are almost unattainable with discrete implementations.

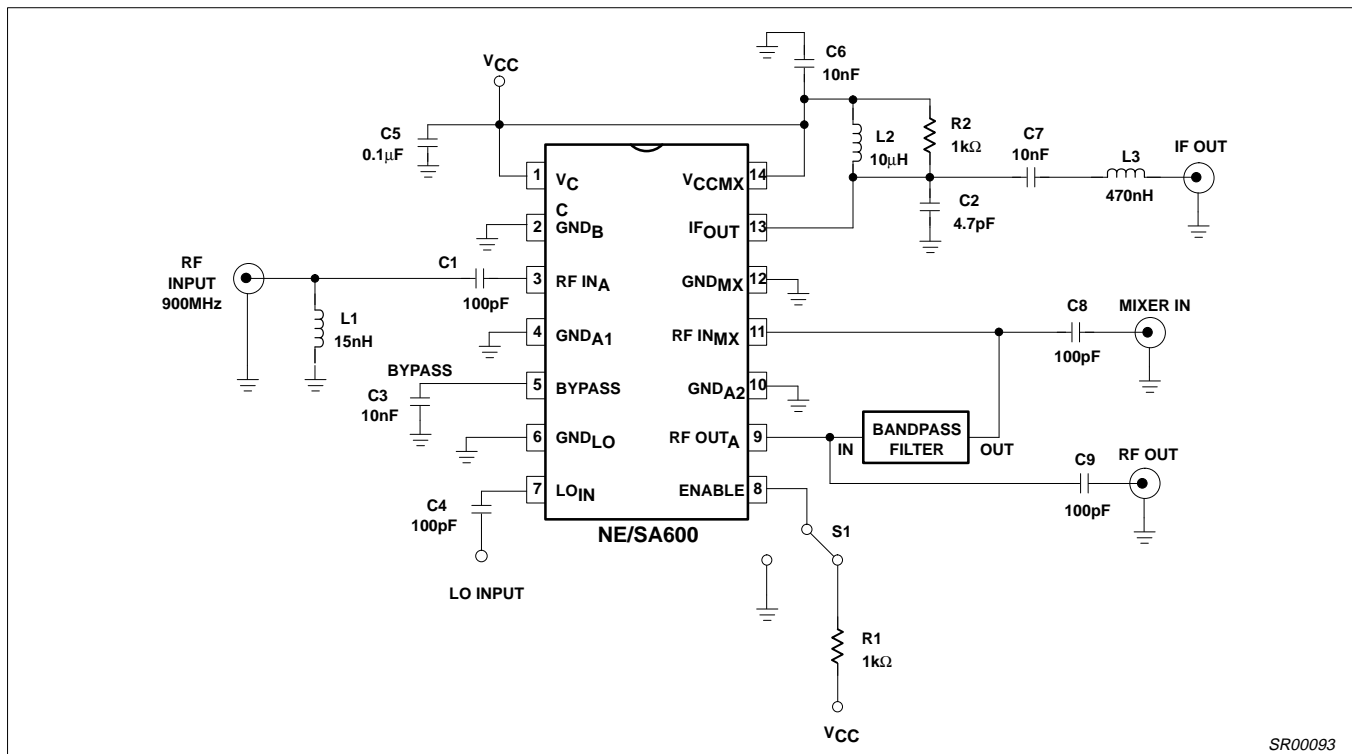


Figure 12.

SR00093

# 1GHz LNA and mixer

# NE/SA600

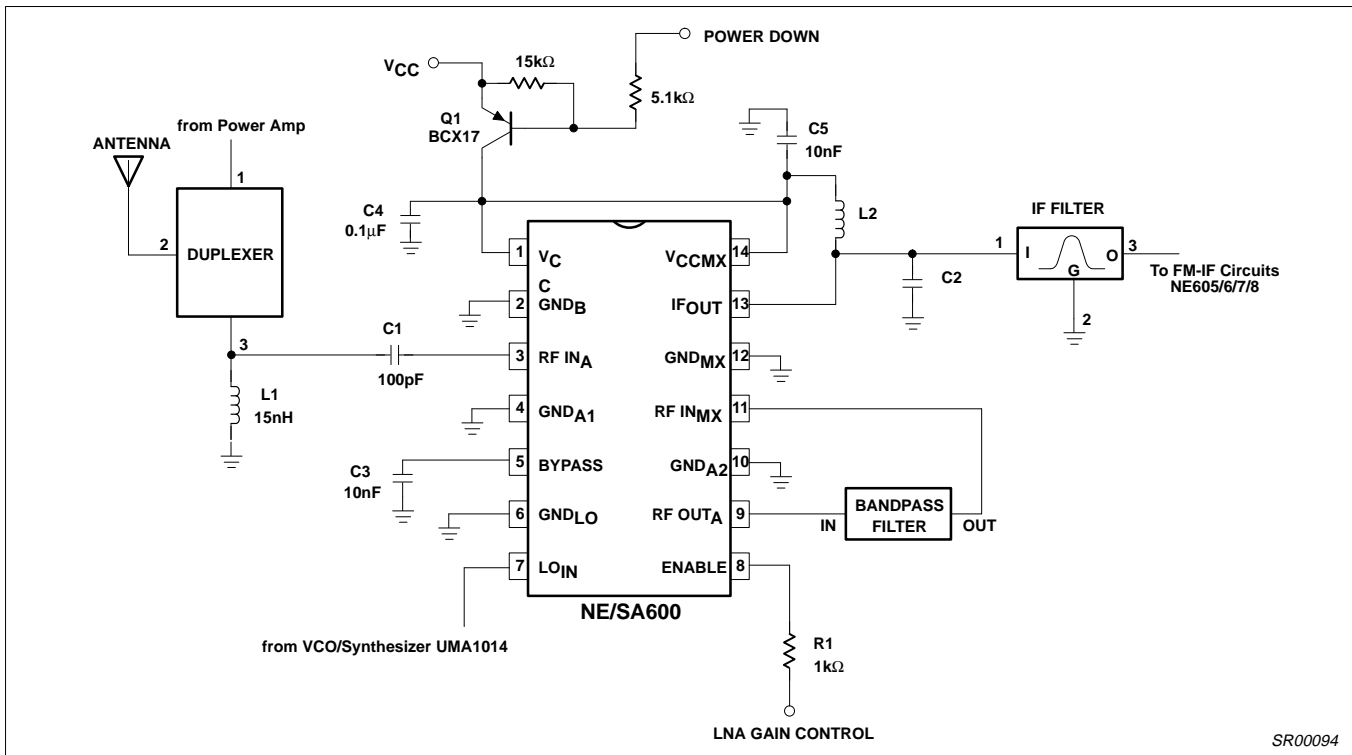


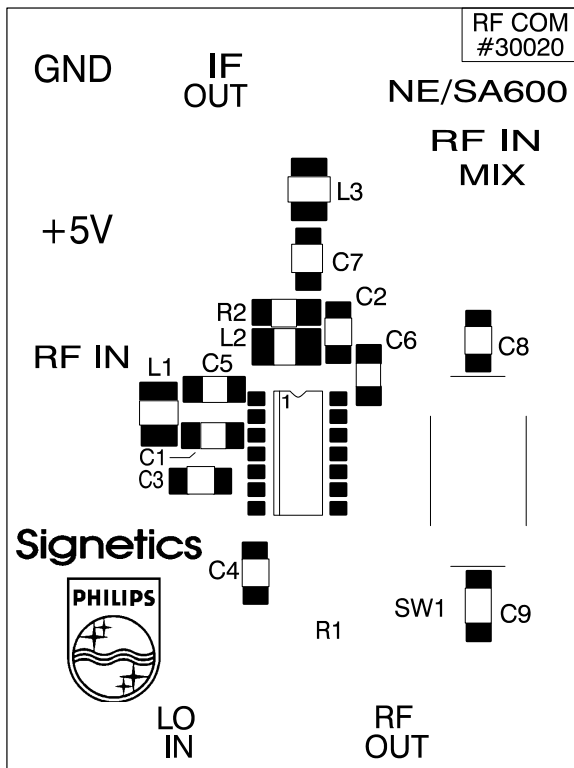
Figure 13.

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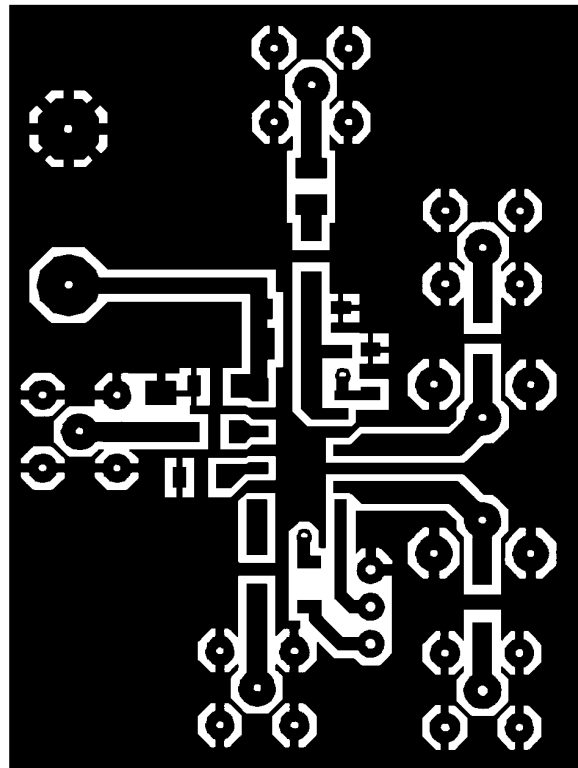
# 1GHz LNA and mixer

# NE/SA600

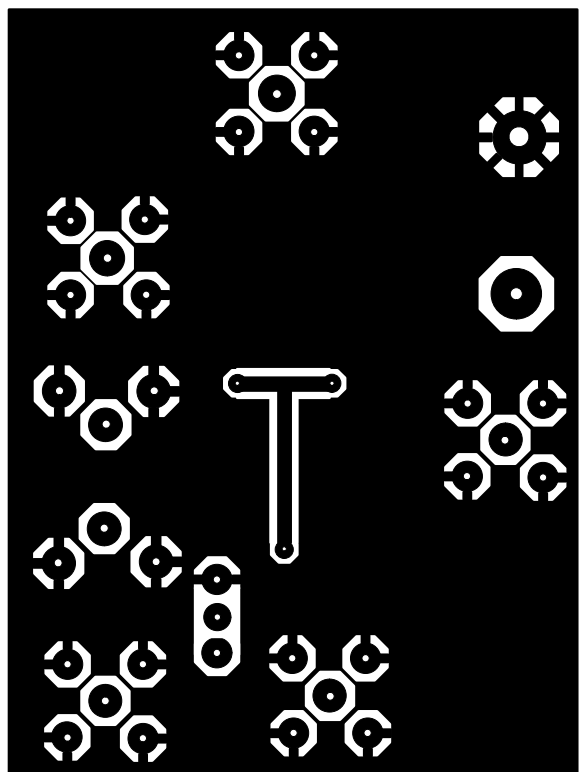
SILKSCREEN



TOP



BOTTOM



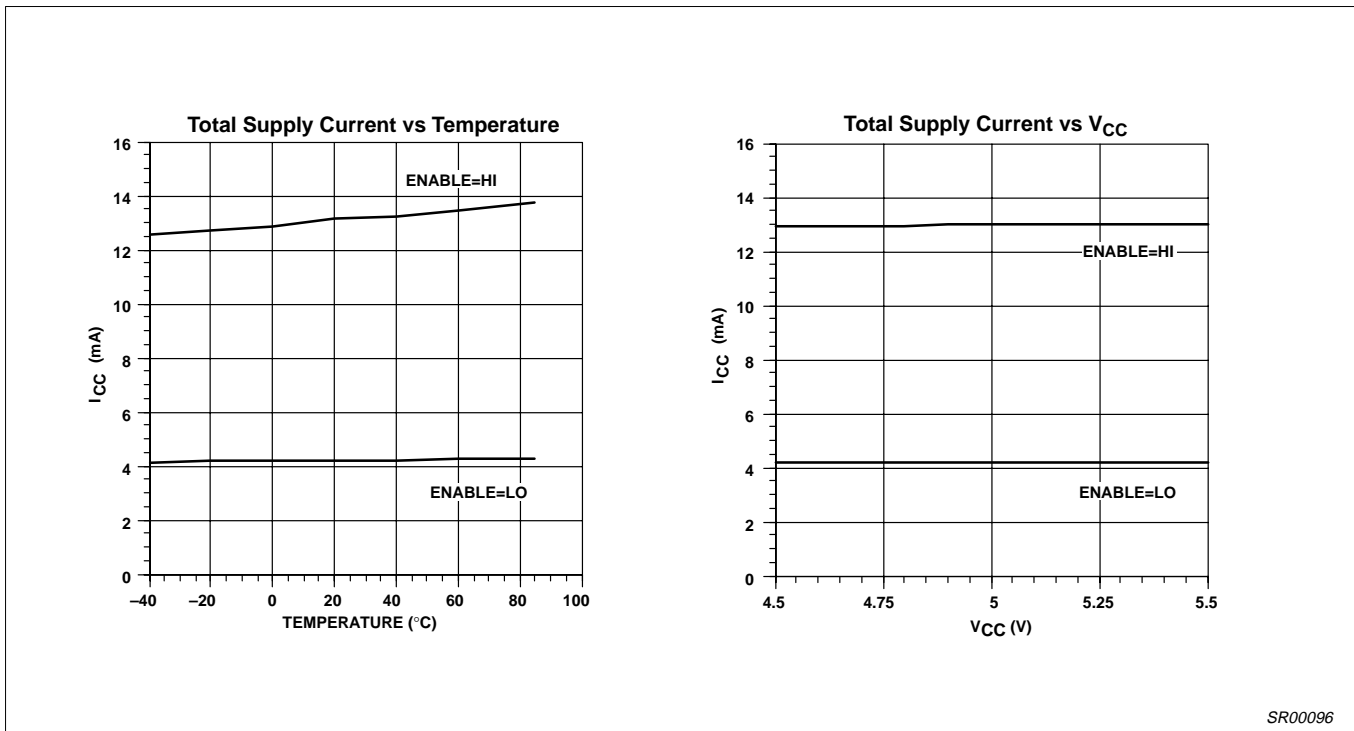
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Figure 14. PC Board Layout



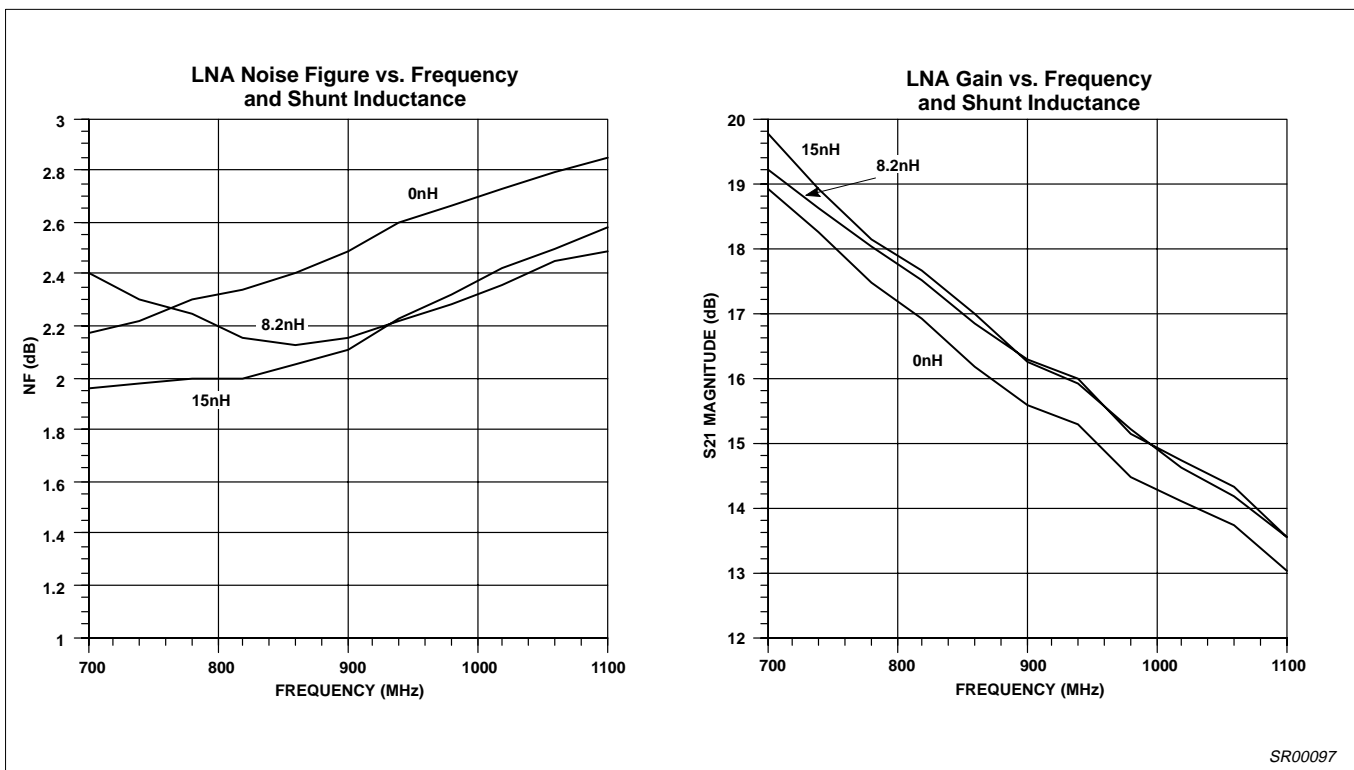
# 1GHz LNA and mixer

# NE/SA600



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Figure 15.



SR00097

Figure 16.