Low-Noise Amplifier Stability—Concept to Practical Considerations, Part 1

Part one of a three-part series. Presents a brief overview of transmission lines and power gain definitions. Provides the basic background needed to design amplifiers for stability.

- Part 1
- Part 2
- Part 3

The design of small-signal, low-noise RF amplifiers is a step-by-step logical procedure with an exact solution for each problem. To aid the designer, many books offer complete schematics with component values "adaptable to the needs of a given application." But such circuits are designed for a specific set of operating conditions that may not correspond to your requirements. The absence of design procedures in these texts can leave readers helpless when attempting to adapt their circuit to a particular set of operating conditions.

This article takes the opposite approach. It presents a design process in which detailed, step-by-step procedures allow you to choose the LNA you want and operate it under any realistic operating conditions. You no longer have to adapt someone else's schematic to your specifications. Instead, you can create your own RF low-noise amplifiers and optimize them for a targeted application.

This article (Part 1) begins the discussion with a brief overview of transmission lines and a reminder on RF power gain definitions.

In Part 2, we jump into the RF aspect of low-noise amplifiers by examining stability (the tendency for oscillation), impedance matching, and general amplifier design, using the scattering parameters (s-parameters) as design tools.

Part 3 completes the series by presenting application examples. The first shows how to match an LNA in the maximum available gain condition. The second deals with an LNA matched in the constant desired gain condition. The third exercise stresses the importance of matching a potentially unstable LNA in its stable area.

Transmission-Line Background (Reflection and Transmission)

Voltage, current, or power emanating from a source impedance Z_s and delivered to a load Z_L can be regarded as the sum of incident and reflected waves traveling in opposite directions along a transmission line of characteristic impedance Z_o. If Z_L equals Z_o exactly, the incident wave is totally absorbed in the load and produces no reflected wave.

If Z_L differs from Z_o, some of the incident wave is not absorbed in the load, but is reflected back toward the source. If the source impedance Z_s equals Z_o, the reflected wave from the load is absorbed in the source and no further reflection occurs. For Z_s not equal to Z_o, a portion of the reflected wave from the load is re-reflected from the source back toward the load. For a lossless transmission line, this process repeats indefinitely.

The degree of mismatch between Z_o and Z_L (or Z_s) determines the amount of incident wave reflected. The ratio of reflected wave to incident wave is known as the reflection coefficient, and is simply a measure of the quality of the match between the transmission line and the terminating impedance. The reflection coefficient Γ is a complex quantity expressed in polar form as a magnitude and an angle:

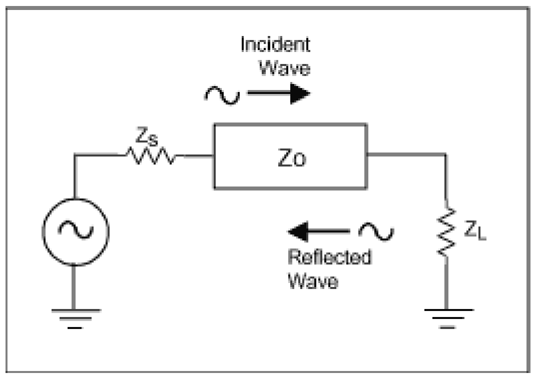


Figure 1.

$$\Gamma = \frac{\text{WAVEreflected}}{\text{WAVEincident}} = \rho/\theta \qquad \text{Eq. 1-1}$$

As matching between the characteristic impedance of the transmission line and the terminating impedance improves, the reflected wave becomes smaller. As a result, the reflection coefficient (Γ) decreases. When the match is perfect there is no reflected wave, and equals zero. If the load impedance is an open or short circuit, no incident power can be absorbed in the load, and all must be reflected back toward the source. In that case, Γ is 1. The normal range of magnitude for Γ is between zero and one.

For reflection coefficients greater than one, the magnitude of the wave reflected from the load impedance should be greater than that of the incident wave to that load. It follows, therefore, that the load in question must be a source of power. This concept is useful in designing an oscillator, but at the input network of an amplifier it represents bad news. Reflection coefficients can be expressed in terms of the impedances under consideration. For example, the reflection coefficient at the load can be expressed as:

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \text{ or with } z_L = \frac{Z_L}{Z_0} \text{ in a normalized form } \Gamma = \frac{z_L - 1}{z_L + 1} \qquad \text{Eq. 1-2}$$

For impedance matching in microwave and RF networks, the source and load impedances are often expressed in terms of the source reflection coefficient (Γ_s) and load reflection coefficient (Γ_L). Incident and reflected waves are represented by wave flow graphs. Flow graphs let you build a graphic based on linear relations among different variables in the network, and they help in rapidly constructing a transfer function between two points in the network.

Each variable is represented by a node in the graph, and the different nodes are linked together by directive paths that give the relations between related and unrelated variables. Paths are directed from the node representing the independent variable to those representing the dependant variables, and to each path is assigned a gain related to the reflection coefficient linking the two variables.

Microwave load and power source:

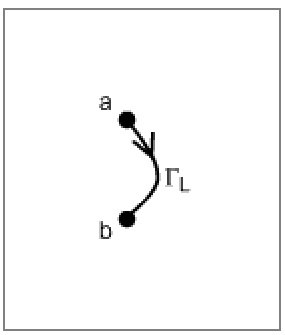


Figure 1-2a. Load flow graph

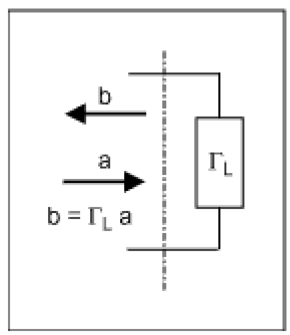


Figure 1-2b. Load reflection coefficient

Variables a and b are complex values associated with the incident and reflected waves. The presence of variable b (reflected wave) depends on the presence of variable a (incident wave).

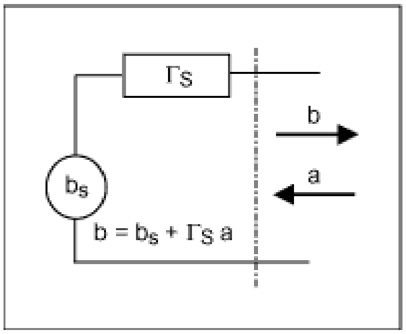


Figure 1-3a. Power source reflection coefficient

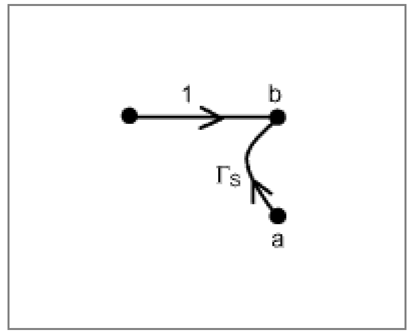


Figure 1-3b. Power source flow graph

$\Gamma_s = b/a$ is the reflection coefficient related to the power source when $b_s = 0$.
$b_s = b$ is the incident wave from the power source when it supplies a 100% matched load.

S-Parameters and the Two-Port Network

By inserting a two-port network between source and load in the circuit of Figure 1-3a, we produce the circuit of Figure 2-1. The following may be said for any traveling wave that originates at the source:

- A portion of the wave that originates at the source and is incident on the two-port device (a1) will be reflected (b1), and another portion will be transmitted through the two-port device.
- A fraction of the transmitted signal is then reflected from the load and becomes incident on the output port of the two-port device (a2).
- A portion of the signal (a2) is then reflected from the output port back toward the load (b2), while a fraction is transmitted through the two-port device to the source.

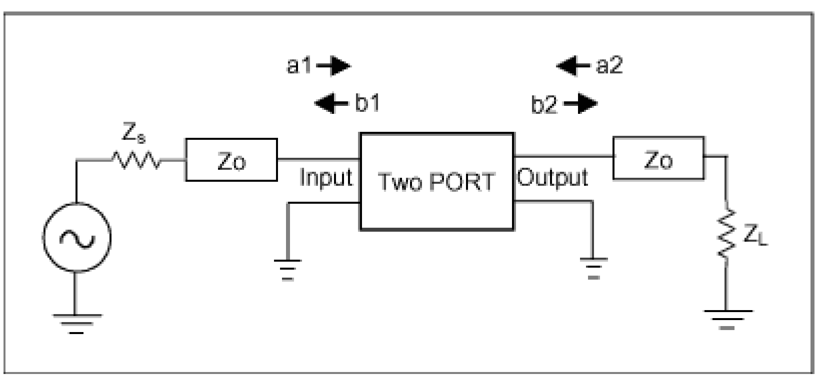


Figure 2-1.

It is obvious from the above discussion that any traveling wave present in the circuit is composed of two components. For instance, the traveling wave components flowing from the output of the two-port device to the load consist of the portion of a2 reflected from the output of the two-port device, and the portion of a1 transmitted through the two-port device. Similarly, the traveling wave flowing from the input of the two-port device back toward the source consists of the portion of a1 reflected from the input and the fraction of a2 transmitted through the two-port device. If we set these observations in equation form we get the following:

$$b_1 = S_{11}a_1 + S_{12}a_2$$
$$b_2 = S_{21}a_1 + S_{22}a_2.$$

Where:

S_{11} = the input reflection coefficient
S_{12} = the reverse transmission coefficient
S_{21} = the forward transmission coefficient
S_{22} = the output reflection coefficient with $\Delta S = (S_{11}S_{22} - S_{21} S_{12})$

If we set a_2 equal to zero, then $S_{11} = b_1/a_1 \mid a_2 = 0$.
If we set a_1 equal to zero, then $S_{22} = b_2/a_2 \mid a_1 = 0$.

By definition, a reflected wave divided by an incident wave is equal to the reflection coefficient, as noted above for the input and output of a two-port network. A two-port network (LNA) can be characterized completely by its scattering parameters (S-parameters). With these parameters, you can calculate potential instabilities (tendency to oscillate), maximum available gain, input and output impedances, and transducer gain. You can also calculate the optimum source and load impedances, either for simultaneous conjugate matching, or simply to help choose specific source and load impedances for a specified transducer gain.

Figure 2-2a shows a two-port network connection for available gain definition. Γin is the two-port input reflection coefficient, and the output is terminated in Γ_L. Γout is the two-port output reflection coefficient, as long as the input is terminated with Γ_s.

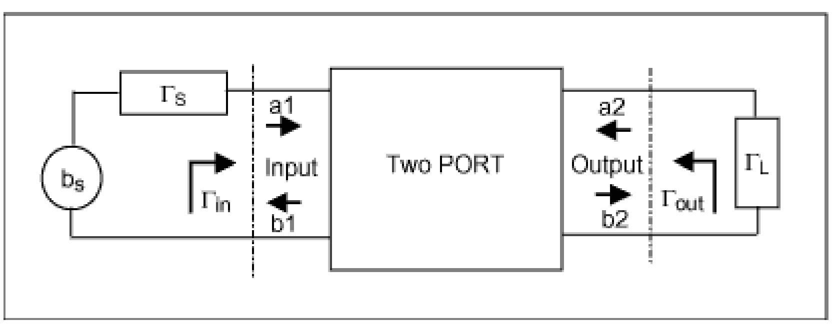


Figure 2-2a.

The flow graph for a loaded two-port network (Figure 2-2b) shows a closed loop that allows starting from one node and returning to that node without going through it twice. The precise physical significance of these loops is illustrated by our two-port network (an LNA for example), whose output is closed on a load Γ_L (Figure 2-3).

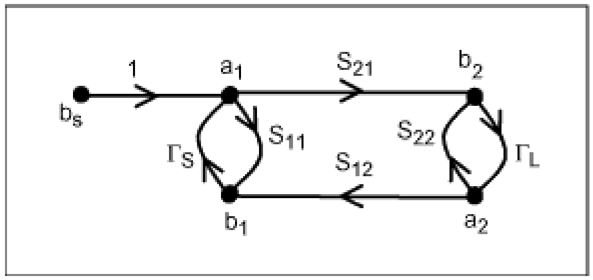


Figure 2-2b.

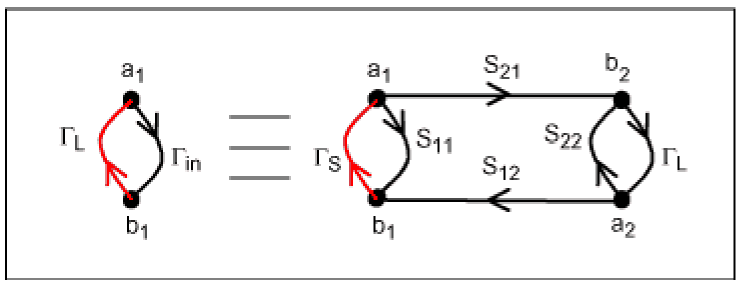


Figure 2-3.

To define the wave b_1 reflected back to the input, we just follow the different paths leading from a_1 to b_1. Possible paths are the following:

S_{11}, $S_{21}\Gamma_L S_{12}$, $S_{21}\Gamma_L S_{22}\Gamma_L S_{12}$, $S_{21}\Gamma_L S_{22}\Gamma_L S_{22}\Gamma_L S_{12}$, ...

It appears that the loop $S_{22}\Gamma_2$ represents a multiple reflection due to the two-port network reflection coefficient between the output and the mismatched load.

$$b_1 = S_{11}a_1 + S_{21}\Gamma_L S_{12} a_1 \underbrace{\{1 + S_{22}\Gamma_L + ... + (S_{22}\Gamma_L)^n + ...\}}_{\frac{1}{1 - S_{22}\Gamma_L}}$$

The network input reflection coefficient for the two ports is:

$$\Gamma_{IN} = \frac{b_1}{a_1} = S_{11} + \frac{S_{21}\Gamma_L S_{12}}{1 - S_{22}\Gamma_L} \qquad \text{Eq. 2-1}$$

When we close the two-port network input on a source impedance, the reflection coefficient seen from the output is (Figure 2-4):

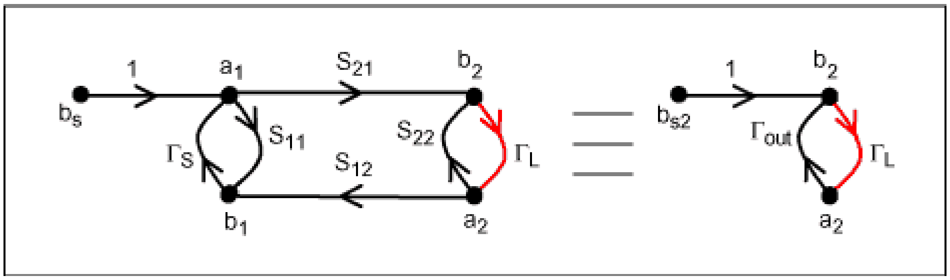


Figure 2-4.

$$\Gamma_{OUT} = \frac{b_2}{a_2} = S_{22} + \frac{S_{21}\Gamma_S S_{12}}{1 - S_{11}\Gamma_S} \qquad \text{Eq. 2-2}$$

Gain for Two-Port Networks

Waves a and b are directly related to the concept of power. Unlike the low-frequency domain in which current and voltage gain are of primary interest, in the RF and microwave domains only power gain is considered. The different gains used by two-port devices are defined below, but first consider some facts regarding electrical power.

Maximum Available Power

The amount of power delivered to a load is easily determined, as shown by the connection of a source b_s, Γ_s to a load termination Γ_L (Figure 3-1). The power delivered by a source to a matched load is defined as the maximum available power (maximum power transferred) from the source when $\Gamma_s = \Gamma_L^*$. For these conditions, half the power is dissipated in the source and half is dissipated (transmitted) into the load. Figure 3-1 includes a flow graph.

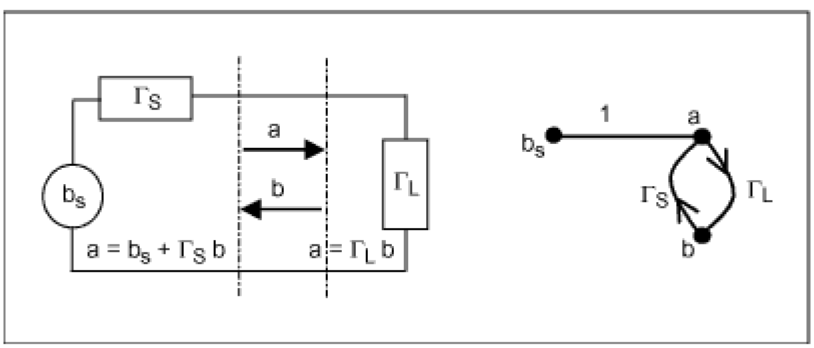


Figure 3-1.

The reflection seen from the source is:

$$a = b_S + b_S\Gamma_L\Gamma_S + \ldots\ldots + b_S(\Gamma_L\Gamma_S)^n \longrightarrow \frac{a}{b_S} = \frac{1}{1 - \Gamma_L\Gamma_S} \qquad \text{Eq. 3-1}$$

Power transmitted to the load can be expressed as

$$P_2 = \frac{1}{2}(\ |a|^2 - |b|^2\ ) = \frac{1}{2}|a|^2(1 - |\Gamma_L|^2) \qquad \text{Eq. 3-2}$$

$$P_2 = \frac{1}{2}|b_S|^2 \frac{1 - |\Gamma_L|^2}{(1 - \Gamma_L \Gamma_S)^2} \qquad \text{Eq. 3-3}$$

When $\Gamma_L = \Gamma_s*$, the source can provide

$$P_{1AV} = \frac{|b_S|^2}{2(1 - |\Gamma_L|^2)} \qquad \text{Eq. 3-4}$$

The asterisk indicates the complex conjugate, in which magnitude is the same but the angle has the opposite sign.

Two-Port Network Power Gain

Also defined as the operating gain or desired gain, it is the specific gain we want from a two-port network (LNA) for a particular application:

$$G = \frac{P_2}{P_1} \qquad \text{Eq. 3-5}$$

Where P_2 is power dissipated in the two-port output's load:

$$P_2 = \frac{1}{2}(|b_2|^2 - |a_2|^2) = \frac{1}{2}|b_2|^2(1 - |\Gamma_L|^2) \qquad \text{Eq. 3-6}$$

Where P_1 is the power absorbed by the two-port input

$$P_1 = \frac{1}{2}(|b_1|^2 - |a_1|^2) = \frac{1}{2}|a_1|^2(1 - |\Gamma_{IN}|^2)$$

From the Figure 2-4 flow chart, we can easily extrapolate how b_2 is related to a_1:

$$b_S = S_{21}a_1\{1 + S_{22}\Gamma_L + \ldots\ldots + (S_{22}\Gamma_L)^n + \ldots\ldots\} \longrightarrow \frac{b_2}{a_1} = \frac{S_{21}}{1 - S_{22}\Gamma_L} \qquad \text{Eq. 3-7}$$

$$G = \frac{P_2}{P_1} = \frac{|b_2|^2(1 - |\Gamma_L|^2)}{|a_1|^2(1 - |\Gamma_{IN}|^2)} = \frac{|S_{21}|^2(1 - |\Gamma_L|^2)}{(1 - S_{22}\Gamma_L)^2(1 - |\Gamma_{IN}|^2)} \qquad \text{Eq. 3-8}$$

With

$$\Gamma_{IN} = \frac{b_1}{a_1} = S_{11} + \frac{S_{21}\Gamma_L S_{12}}{1 - S_{22}\Gamma_L} \qquad \text{Eq. 2-1}$$

Two-port network power gain (operating or desired) is:

$$G = \frac{P_2}{P_1} = \frac{|S_{21}|^2(1 - |\Gamma_L|^2)}{(1 - S_{22}\Gamma_L)^2(1 - \left|S_{11} + \frac{S_{21}\Gamma_L S_{12}}{(1 - S_{22}\Gamma_L)}\right|^2)} \quad \text{Eq. 3-9}$$

$$G = \frac{|S_{21}|^2(1 - |\Gamma_L|^2)}{(1 - S_{22}\Gamma_L)^2 \, |S_{11} - \Delta_S\Gamma_L|^2}$$

Maximum Available Gain for Two-Port Network

The maximum gain available from a two-port network is a particular case of the transducer gain obtained when $\Gamma_L^* = \Gamma_{OUT}$. For a two-port network, the maximum available gain G_{AV} is defined as the ratio of power available at the output to power available from the source, mathematically expressed as $G_{AV} = P_{2AV}/P_{1AV}$. P_{2AV} is the available output power, and P_{1AV} is the power available from the source. Because maximum available gain can indicate whether an LNA has enough gain for the task, the calculation of this parameter is useful as a preliminary screening criteria for LNAs.

The initial wave b_{s2} seen from the two-port network output (Figure 2-4) is expressed as:

$$b_{S2} = \frac{b_S S_{21}}{(1 - S_{11}\Gamma_L)} \quad \text{Eq. 4-1}$$

At the two-port input, the source is able to supply (Figure 2-2b and Figure 2-3):

$$P_{1AV} = \frac{1}{2}|b_S|^2 \, \frac{(1 - |\Gamma_{IN}|^2)}{(1 - \Gamma_{IN}\Gamma_S)^2} \quad \text{Eq. 4-2}$$

$$P_{1AV} = \frac{|b_S|^2}{2(1 - |\Gamma_S|^2)} \text{ When } \Gamma_{IN} = \Gamma_S^* \quad \text{Eq. 4-3}$$

Power available at the two-port output is:

$$P_{2AV} = \frac{|b_{S2}|^2}{2(1 - |\Gamma_{OUT}|^2)} \text{ When } \Gamma_{OUT} = \Gamma_L^* \quad \text{Eq. 4-4}$$

Expressed as a function of the two-port network's input source,

$$P_{2AV} = \frac{|b_S S_{21}|^2}{2(1 - |\Gamma_{OUT}|^2)(1 - S_{11}\Gamma_S)^2} \quad \text{Eq. 4-5}$$

$$G_{AV} = \frac{P_{2AV}}{P_{1AV}} = \frac{|S_{21}|^2(1 - |\Gamma_S|^2)}{(1 - |\Gamma_{OUT}|^2)(1 - S_{11}\Gamma_S)^2} \quad \text{Eq. 4-6}$$

As shown by Eq. (4-7):

$\Gamma_{OUT} = S_{22} + (S_{21}\Gamma_S S_{12} / 1 - S_{11}\Gamma_S$

the maximum available gain factor depends on the source termination Γ_s and the two-port s-parameters. Maximum available gain depends on the two-port output being conjugately matched to Γ_L. Thus, $\Gamma_L = \Gamma_{out}$*. As shown in Eq. 2-2, Γ_{out} is a function of Γ_S and the two-port parameters:

$$G_{AV} = \frac{P_{2AV}}{P_{1AV}} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)}{(1-|\Gamma_{OUT}|^2)(1-S_{11}\Gamma_S)^2}$$

$$G_{AV} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)}{(1-\left|S_{22}+\frac{S_{21}\Gamma_S S_{12}}{(1-S_{11}\Gamma_S)}\right|^2)(1-S_{11}\Gamma_S)^2} \qquad \text{Eq. 4-7}$$

The power available at the two-port output load is a function of power delivered to the two-port input, and power delivered to the two-port input depends on the mismatch between Γ_s and Γ_{in}. To determine power available from the source, you must terminate the source with a complex-conjugate load.

Transducer Gain

Transducer gain (the gain term most often referenced in RF-amplifier design) is defined as the output power P_2 delivered to a load by a source, divided by the maximum power available from the source. Transducer gain includes the effects of impedance matching at the input and output, as well as the contribution made by the LNA to the overall gain of the amplifier stage. Transducer gain neglects resistive losses in the components.

$$P_2 = 1/2|b_2|^2(1-|\Gamma_L|^2) \quad \text{and } P_{1AV} = \frac{|bs|^2}{2(1-|\Gamma_S|^2)} \text{ When } \Gamma_{IN} = \Gamma_S{}^* \qquad \text{Eq. 5-1}$$

$$G_T = \frac{P_2}{P_{1AV}} = \frac{|b_2|^2}{|b_S|^2}(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)$$

To complete the transducer gain equation, define b_s (the source initial wave) as a function of b_{s2}, the initial wave seen from the two-port output (Figure 2-4), and b_2 as the wave fed back from the load Γ_L to the two-port network output.

$$b_2 = b_{S2} + b_{S2}\Gamma_{OUT}\Gamma_L + \ldots\ldots + b_{S2}(\Gamma_{OUT}\Gamma_L)^n \longrightarrow b_2 = \frac{b_{S2}}{1-\Gamma_{OUT}\Gamma_L} \qquad \text{Eq. 5-2}$$

$$b_{S2} = \frac{b_S S_{21}}{(1-S_{11}\Gamma_S)} \longrightarrow b_2 = \frac{b_S S_{21}}{(1-S_{11}\Gamma_S)(1-\Gamma_{OUT}\Gamma_L)} \qquad \text{Eq. 5-3}$$

As shown in Eq. 2-2, Γ_{OUT} is a function of Γ_s and the two-port parameters:

$$\Gamma_{OUT} = S_{22} + \frac{S_{21}\Gamma_S S_{12}}{1 - S_{11}\Gamma_S} \quad b_2 = \frac{b_S S_{21}}{(1-S_{11}\Gamma_S)(1-(S_{22}+\frac{S_{21}\Gamma_S S_{12}}{1-S_{11}\Gamma_S})\Gamma_L)} \qquad \text{Eq. 5-4}$$

Stability and maximum available gain (MAG) are two of the more important considerations in choosing a two-port network (LNA) for use in amplifier design. As used here, stability measures the tendency of an LNA to oscillate. Maximum available gain is a figure of merit for the LNA, which indicates the maximum theoretical power gain you can expect from the device when it is conjugately matched to its source and load impedances.

Transducer gain for a two-port network is:

$$G_T = \frac{P_2}{P_{1AV}} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-S_{11}\Gamma_S)(1-\Gamma_{OUT}\Gamma_L)|^2}$$

$$G_T = \frac{P_2}{P_{1AV}} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-S_{11}\Gamma_S)|(1-S_{22}\Gamma_L)-S_{12}S_{21}\Gamma_S\Gamma_L|^2} \quad \text{Eq. 5-5}$$

Reference

Bowick, Chris. *RF Circuit Designs*. Howard W. Sams & Co. Inc., a publishing subsidiary of ITT.

A similar version of this article appeared in the October 2001 issue of *Microwaves and RF* magazine.

MORE INFORMATION

MAX2320: QuickView -- Full (PDF) Data Sheet (536k) -- Free Sample

MAX2720: QuickView -- Full (PDF) Data Sheet (328k) -- Free Sample

MAX2721: QuickView -- Full (PDF) Data Sheet (328k) -- Free Sample

19-1535; Rev 1; 6/00

EVALUATION KIT MANUAL
FOLLOWS DATA SHEET

Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

MAX2320/21/22/24/26/27

General Description

The MAX2320/MAX2321/MAX2322/MAX2324/MAX2326/MAX2327 high-performance silicon germanium (SiGe) receiver front-end ICs set a new industry standard for low noise and high linearity at a low supply current. This family integrates a variety of unique features such as an LO frequency doubler and divider, dual low-noise amplifier (LNA) gain settings, and a low-current paging mode that extends the handset standby time.

The MAX2320 family includes six ICs: four operate at both cellular and PCS frequencies, one operates at cellular frequencies, and one at PCS frequencies (see *Selector Guide*). Each part includes an LNA with a high input third-order intercept point (IIP3) to minimize intermodulation and cross-modulation in the presence of large interfering signals. In low-gain mode, the LNA is bypassed to provide higher cascaded IIP3 at a lower current. For paging, a low-current, high-gain mode is provided.

The CDMA mixers in cellular and PCS bands have high linearity, low noise, and differential IF outputs. The FM mixer is designed for lower current and a single-ended output.

All devices come in a 20-pin TSSOP-EP package with exposed paddle (EP) and are specified for the extended temperature range (-40°C to +85°C).

Applications

CDMA/TDMA/PDC/WCDMA/GSM Cellular Phones

Single/Dual/Triple-Mode Phones

Wireless Local Loop (WLL)

Selector Guide

PART	DESCRIPTION
MAX2320	Dual-band, dual VCO inputs, and dual IF outputs
MAX2321	MAX2320 with LO doubler
MAX2322	PCS band, single mode with optional frequency doubler
MAX2324	Cellular band, dual IF outputs
MAX2326	MAX2320 with LO divider
MAX2327	Dual-band, dual VCO inputs, and separately controlled VCO buffers

Typical Application Circuits appear at end of data sheet.

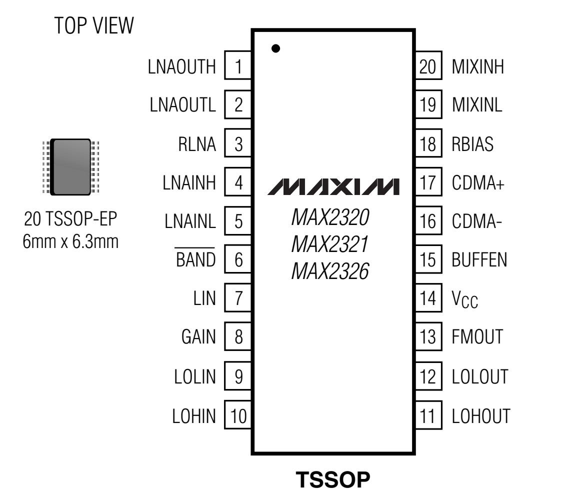
Features

- ♦ **Ultra-High Linearity at Ultra-Low Current and Noise**
- ♦ **+2.7V to +3.6V Operation**
- ♦ **Pin-Selectable Low-Gain Mode Reduces Gain by 17dB and Current by 3mA**
- ♦ **Pin-Selectable Paging Mode Reduces Current Draw by 6mA when Transmitter Is Not in Use**
- ♦ **LO Output Buffers**
- ♦ **LO Frequency Doubler (MAX2321)**
- ♦ **LO Frequency Divider (MAX2326)**
- ♦ **0.1µA Shutdown Current**
- ♦ **20-Pin TSSOP-EP Package**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX2320EUP	-40°C to +85°C	20 TSSOP-EP
MAX2321EUP	-40°C to +85°C	20 TSSOP-EP
MAX2322EUP	-40°C to +85°C	20 TSSOP-EP
MAX2324EUP	-40°C to +85°C	20 TSSOP-EP
MAX2326EUP	-40°C to +85°C	20 TSSOP-EP
MAX2327EUP	-40°C to +85°C	20 TSSOP-EP

Pin Configurations



Pin Configurations continued at end of data sheet.

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ABSOLUTE MAXIMUM RATINGS

V_{CC} to GND ....-0.3V to +4.3V
Digital Input Voltage to GND ....-0.3V to (V_{CC} + 0.3V)
RF Input Signals ....1.0V peak
Continuous Power Dissipation (T_A = +70°C)
  20-Pin TSSOP-EP (derate 80mW/°C above +70°C)........6.4W
Operating Temperature Range ....-40°C to +85°C
Junction Temperature ....+150°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS—MAX2320/MAX2321/MAX2326

(V_{CC} = +2.7V to +3.6V, R_{RBIAS} = R_{RLNA} = 20kΩ, no RF signals applied, BUFFEN = low, LO buffer outputs connected to V_{CC} through 50Ω resistors, all other RF and IF outputs connected to V_{CC}, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{CC} = +2.75V and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}				+2.7		+3.6	V
Operating Supply Current (Note 1)	I_{CC}	High-gain, high-linearity modes	PCS band	MAX2320/6		20	25.3	mA
				MAX2321		24	30.8	
			Cellular band	MAX2320/1		20	25.3	
				MAX2326		21	25.5	
		High-gain, low-linearity paging modes	PCS band	MAX2320/6		15	19.5	
				MAX2321		19	25	
			Cellular band	MAX2320/1		15	19.5	
				MAX2326		15.5	20	
		Low-gain, high-linearity modes	PCS band	MAX2320/6		17	21.5	
				MAX2321		21	26	
			Cellular band	MAX2320/1		17	21.5	
				MAX2326		17.5	21.5	
		FM mode				14	18.5	
LO Buffer Supply Current	I_{LOBUF}	Additional current for BUFFEN = high	Cellular band MAX2320/1			5	7.5	mA
			Cellular band MAX2326			5.5	8.5	
			PCS band MAX2320/1/6			5	7.5	
Shutdown Supply Current	I_{SHDN}	(Note 1)				0.1	20	µA
Digital Input Logic High	V_{IH}				2.0			V
Digital Input Logic Low	V_{IL}						0.6	V
Digital Input Current High	I_{IH}						5	µA
Digital Input Current Low	I_{IL}				-35			µA

DC ELECTRICAL CHARACTERISTICS—MAX2322/MAX2324

(V_{CC} = +2.7V to +3.6V, R_{RBIAS} = R_{RLNA} = 20kΩ, no RF signals applied, BUFFEN = low, LO buffer outputs connected to V_{CC} through 50Ω resistors, all other RF and IF outputs connected to V_{CC}, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{CC} = +2.75V and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}				+2.7		+3.6	V
Operating Supply Current (Note 1)	I_{CC}	High-gain, high-linearity modes	PCS band (MAX2322)	LOX2 = low		20	25.3	mA
				LOX2 = high		24	30.8	
			Cellular band (MAX2324)			20	25.3	
		High-gain, low-linearity paging modes	PCS band (MAX2322)	LOX2 = low		15	19.5	
				LOX2 = high		19	25	
			Cellular band (MAX2324)			15	19.5	
		Low-gain, high-linearity modes	PCS band (MAX2322)	LOX2 = low		17	21.5	
				LOX2 = high		21	26	
			Cellular band (MAX2324)			17	21.5	
		FM mode (MAX2324 only)				14.5	18.5	
LO Buffer Supply Current	I_{LOBUF}	Additional current for BUFFEN = high				5	7.5	mA
Shutdown Supply Current	I_{SHDN}	(Note 1)				0.1	20	µA
Digital Input Logic High	V_{IH}				2.0			V
Digital Input Logic Low	V_{IL}						0.6	V
Digital Input Current High	I_{IH}						5	µA
Digital Input Current Low	I_{IL}				-35			µA
Digital Output Logic High	V_{OH}	MAX2324 only			1.7			V
Digital Output Logic Low	V_{OL}	MAX2324 only					0.4	V
Digital Output Current High	I_{OH}	MAX2324 only			30			µA
Digital Output Current Low	I_{OL}	MAX2324 only, $V_{MODEOUT}$ = 2.4V					-100	µA

DC ELECTRICAL CHARACTERISTICS—MAX2327

(V_{CC} = +2.7V to +3.6V, R_{RBIAS} = R_{RLNA} = 20kΩ, no RF signals applied, BUFFEN = low, LO buffer outputs connected to V_{CC} through 50Ω resistors, all other RF and IF outputs connected to V_{CC}, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{CC} = +2.75V and T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}			+2.7		+3.6	V
Operating Supply Current (Note 1)	I_{CC}	High-gain mode	PCS band		15	19.5	mA
			Cellular band		15	19.5	
		FM mode			14.5	18.5	
LO Buffer Supply Current	I_{LOBUF}	Additional current for BUFFEN = high			5	7.5	mA
Shutdown Supply Current	I_{SHDN}	(Note 1)			0.1	20	µA
Digital Input Logic High	V_{IH}			2.0			V
Digital Input Logic Low	V_{IL}					0.6	V
Digital Input Current High	I_{IH}					5	µA
Digital Input Current Low	I_{IL}			-35			µA

Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

AC ELECTRICAL CHARACTERISTICS—MAX2320/MAX2321/MAX2326

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOLIN} = 1091MHz (digital mode), f_{LOLIN} = 991MHz (FM mode), f_{LOHIN} = 1750MHz (MAX2320, MAX2322 with LOX2 = low, MAX2326 with $\overline{BAND}$ = low, MAX2327), f_{LLOHIN} = 1085MHz (MAX2321 with $\overline{BAND}$ = low, MAX2322 with LOX2 = high), f_{LOHIN} = 1091MHz (MAX2321 with $\overline{BAND}$ = high), f_{LOHIN} = 2182MHz (MAX2326 with $\overline{BAND}$ = high), LO input power = -7dBm (MAX2320/MAX2326), 50Ω system, T_A = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	-3σ	TYP	+3σ	MAX	UNITS
Low-Band RF Frequency Range (Note 3)				800				1000	MHz
High-Band RF Frequency Range (Note 3)				1800				2500	MHz
Low-Band LO Frequency Range (Note 3)				700				1150	MHz
High-Band LO Frequency Range (Note 3)				1600				2300	MHz
IF Frequency Range (Note 3)				50				400	MHz
LNA PERFORMANCE									
HIGH-GAIN, HIGH-LINEARITY MODES (Note 1)									
Gain (Note 4)	G	T_A = +25°C	PCS		13	14.5	16		dB
			Cellular		14	15	16		
		T_A = -40°C to +85°C	PCS	11.5		14.5		17	
			Cellular	13		15		16.5	
Gain Variation Over Temperature Relative to +25°C		T_A = -40°C to +85°C	PCS			±0.5			dB
			Cellular			±0.5			
Noise Figure (Note 5)	NF	PCS				1.8	2	2.1	dB
		Cellular				1.3	1.4	1.5	
Input Third-Order Intercept (Notes 5, 6)	IIP3	T_A = T_{MIN} to T_{MAX}	PCS		7	+8			dBm
			Cellular		6	+8			
Input 1dB Compression	P_{OUT} 1dB	T_A = T_{MIN} to T_{MAX}	PCS	-11	-10				dBm
			Cellular	-11	-10				
HIGH-GAIN, LOW-LINEARITY PAGING MODES AND FM MODE (Note 1)									
Gain (Note 4)	G	PCS				13.5			dB
		Cellular				14.5			
Gain Variation Over Temperature Relative to +25°C		T_A = -40°C to +85°C	PCS			±0.5			dB
			Cellular			±0.5			
Noise Figure (Note 5)		PCS				1.9	2.1	2.2	dB
		Cellular				1.4	1.5	1.6	

AC ELECTRICAL CHARACTERISTICS (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOLIN} = 1091MHz (digital mode), f_{LOLIN} = 991MHz (FM mode), f_{LOHIN} = 1750MHz (MAX2320, MAX2322 with LOX2 = low, MAX2326 with $\overline{BAND}$ = low, MAX2327), f_{LLOHIN} = 1085MHz (MAX2321 with $\overline{BAND}$ = low, MAX2322 with LOX2 = high), f_{LOHIN} = 1091MHz (MAX2321 with $\overline{BAND}$ = high), f_{LOHIN} = 2182MHz (MAX2326 with $\overline{BAND}$ = high), LO input power = -7dBm (MAX2320/MAX2326), 50Ω system, T_A = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	-3σ	TYP	+3σ	MAX	UNITS
Input Third-Order Intercept (Notes 5, 6)		PCS				+6.5			dBm
		Cellular				+6			
LOW-GAIN, HIGH-LINEARITY MODES (Note 1)									
Gain (Note 4)	G	PCS				-2			dB
		Cellular				-1.5			
Gain Variation Over Temperature Relative to +25°C		T_A = -40°C to +85°C	PCS			0.5			dB
			Cellular			0.5			
Noise Figure (Note 5)	NF	PCS				5	5.5	6	dB
		Cellular				4	4.25	4.5	
Input Third-Order Intercept (Notes 5, 6)	IIP3	PCS			+10.5	+11.5	+12.5		dBm
		Cellular			+11.5	+12.5	+13.5		
MIXER PERFORMANCE									
HIGH-GAIN, HIGH-LINEARITY, AND LOW-GAIN MODES (Note 1)									
Gain (Note 4)	G	T_A = +25°C, PCS	Without doubler	11	11.8	12.5	13.2	14	dB
			With doubler	10.5	11.1	12	12.9	13.5	
		T_A = -40°C to +85°C, PCS	Without doubler	10	10.8	12.5	14.3	15.3	
			With doubler	9.6	10.4	12	13.1	14.3	
		T_A = +25°C, cellular		12	127	13.4	14.0	14.7	
		T_A = -40°C to +85°C, cellular		11.3	11.9	13.4	15.5	16.5	
Gain Variation Over Temperature Relative to +25°C (Note 5)		T_A = -40°C to +85°C	PCS			±1			dB
			Cellular			±1			
Noise Figure	NF	PCS	Without doubler			7.5	7.8	8	dB
			With doubler			11	12.3	13.5	
		Cellular	Without divider			7.5	8.1	8.5	
			With divider			7.8	8.4	8.8	
Input Third-Order Intercept (Notes 5, 6)	IIP3	PCS, T_A = T_{MIN} to T_{MAX}	Without doubler	1.8	2.4	+4			dBm
			With doubler	1.4	2.8	+4.7			
		Cellular, T_A = T_{MIN} to T_{MAX}		1	1.8	3.2			
Input dB Compression		PCS	T_A = T_{MIN} to T_{MAX}	-11	-10				dBm
		Cellular		-12	-10.7				

AC ELECTRICAL CHARACTERISTICS (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOLIN} = 1091MHz (digital mode), f_{LOLIN} = 991MHz (FM mode), f_{LOHIN} = 1750MHz (MAX2320, MAX2322 with LOX2 = low, MAX2326 with $\overline{\text{BAND}}$ = low, MAX2327), f_{LLOHIN} = 1085MHz (MAX2321 with $\overline{\text{BAND}}$ = low, MAX2322 with LOX2 = high), f_{LOHIN} = 1091MHz (MAX2321 with $\overline{\text{BAND}}$ = high), f_{LOHIN} = 2182MHz (MAX2326 with $\overline{\text{BAND}}$ = high), LO input power = -7dBm (MAX2320/MAX2326), 50Ω system, T_A = +25°C, unless otherwise noted.) (Note 2)

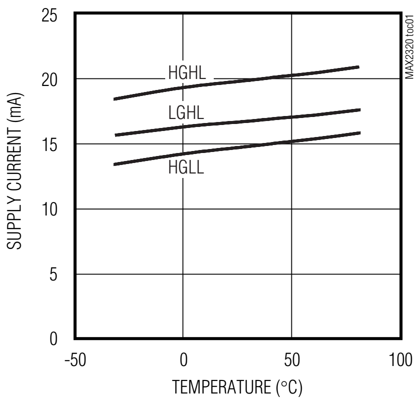
PARAMETER	SYMBOL	CONDITIONS		MIN	-3σ	TYP	+3σ	MAX	UNITS
HIGH-GAIN, LOW-LINEARITY, AND LOW-GAIN MODES (Note 1)									
Gain (Note 4)	G	PCS	Without doubler	10.6	11.3	12	12.1	12.8	dB
			With doubler	10.2	10.8	11.5	12.4	13.1	
		Cellular Band		11.2	12.1	13	13.8	14.7	
Gain Variation Over Temperature Relative to +25°C		T_A = -40°C to +85°C	PCS			±1		±1	dB
			Cellular			±1		±1	
Noise Figure	NF	PCS	Without doubler			7.2	7.5	7.6	dB
			With doubler (Note 7)			10.5	12	13.4	
		Cellular	Without divider			7	7.2	7.6	
			With divider			7.5	7.7	8.1	
Input Third-Order Intercept	IIP3	PCS	Without doubler			+1			dBm
			With doubler			+2.2			
		Cellular				+1.0			
FM MODE (Note 1)									
Gain (Note 4)	G	T_A = +25°C		9.7	10.4	11.2	11.9	12.7	dB
		T_A = -40°C to +85°C		7.8	9.0	11.2	14.0	15.4	
Noise Figure	NF					10.6	11.1	11.5	dB
Input Third-Order Intercept (Notes 5, 6)	IIP3	T_A = -40°C to +85°C		2.3	3.2	4.9			dBm
LO BUFFER PERFORMANCE (BUFFEN = HIGH)									
LO Output Level		Load = 100Ω pullup resistor				-12			dBm
		BUFFEN = GND				-44			
LO_OUT Even Harmonic Distortion						-31			dBc
LO Emissions at LNA Input Port		Interstage filter rejection = 20dB				-50			dBm

Note 1: See Tables 1–5 for operational mode selection.
Note 2: A total of 36 devices from 3 different wafer lots are used to determine the standard deviation. The lots were selected to represent worst-case process conditions.
Note 3: Operation is characterized for the frequencies specified in the conditions; for other frequencies in the band, see Tables 8–12 for LNA and mixer S parameters.
Note 4: Guaranteed by design, characterization, and production functional test.
Note 5: Guaranteed by design and characterization.
Note 6: For cellular band, RF inputs are -25dBm each tone at 881MHz and 882MHz, f_{LO} = 1091MHz. For PCS band, RF inputs are -25dBm each tone at 1960MHz and 1961MHz, f_{LO} = 2170MHz. For IIP3 vs. I_{CC} trade-off, see *Typical Operating Characteristics*.

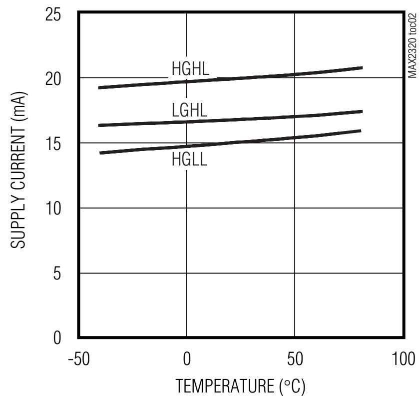
Typical Operating Characteristics

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

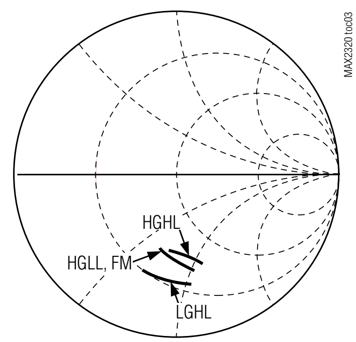
PCS-BAND SUPPLY CURRENT vs. TEMPERATURE



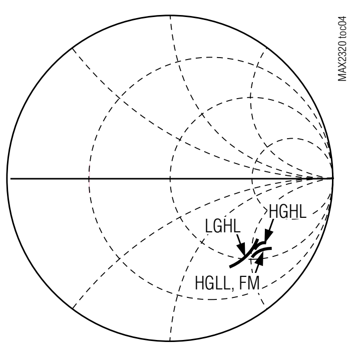
CELLULAR-BAND SUPPLY CURRENT vs. TEMPERATURE



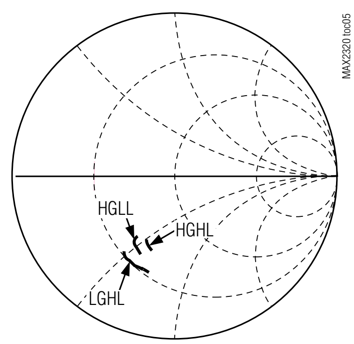
CELLULAR-BAND LNA S11



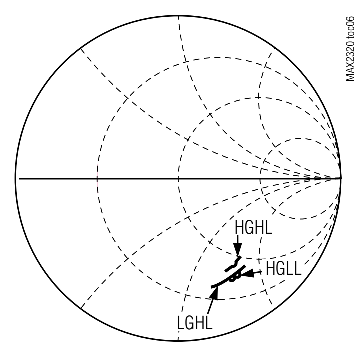
CELLULAR-BAND LNA S22



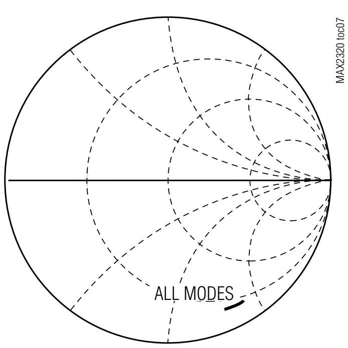
PCS-BAND LNA S11



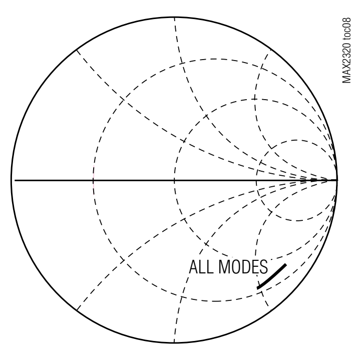
PCS-BAND LNA S22



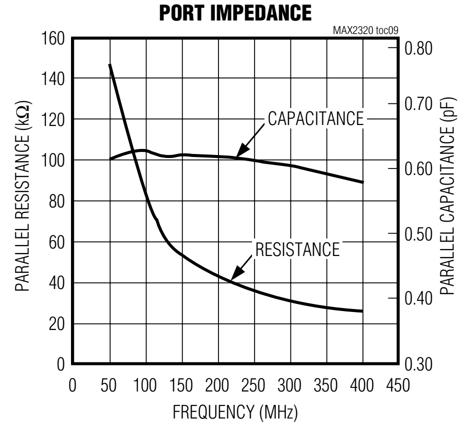
PCS-BAND MIXER S11



CELLULAR-BAND MIXER S11



DIGITAL MIXER DIFFERENTIAL IF PORT IMPEDANCE

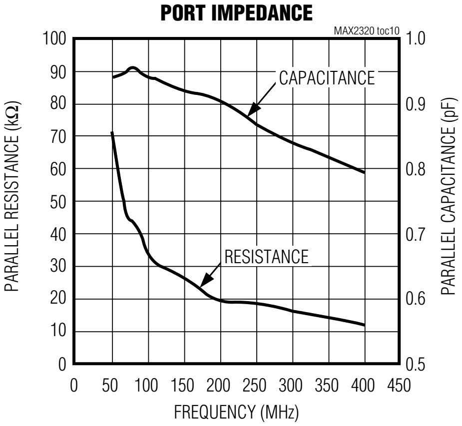


Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

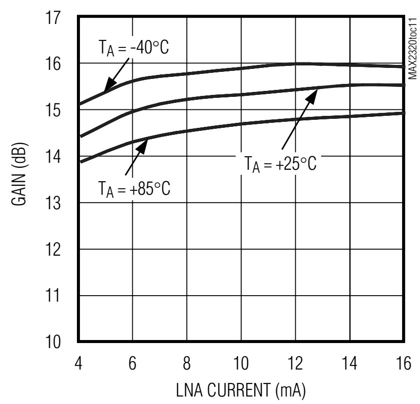
Typical Operating Characteristics (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

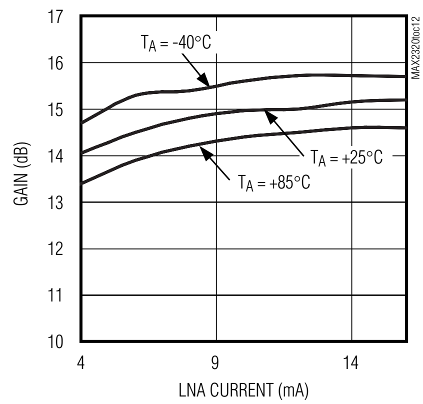
FM MIXER IF PORT IMPEDANCE



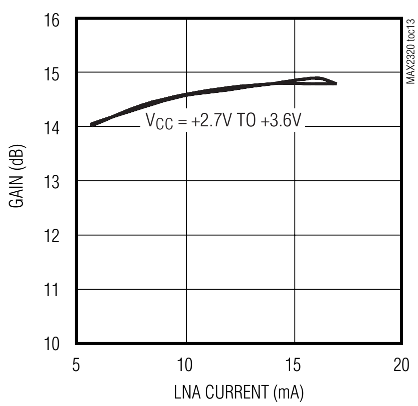
CELLULAR-BAND HGHL LNA GAIN vs. CURRENT



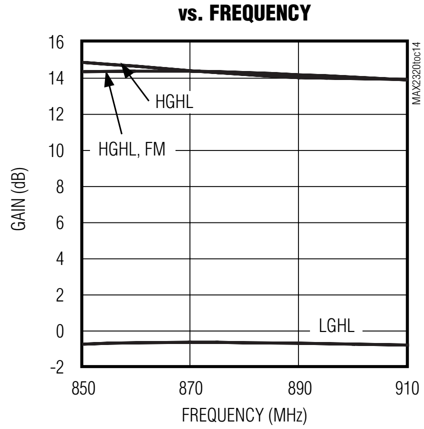
PCS-BAND HGHL LNA GAIN vs. CURRENT



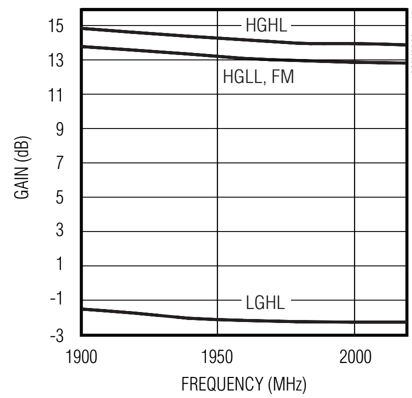
PCS-BAND HGHL LNA GAIN vs. CURRENT



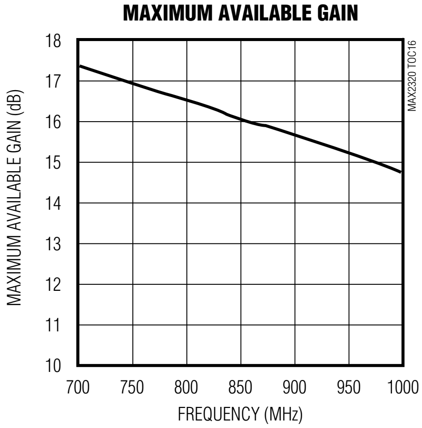
CELLULAR-BAND LNA GAIN vs. FREQUENCY



PCS-BAND LNA GAIN vs. FREQUENCY

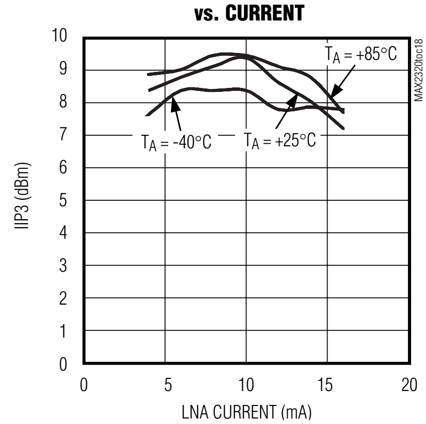


CELLULAR-BAND HGHL LNA MAXIMUM AVAILABLE GAIN



PCS-BAND HGHL LNA MAXIMUM AVAILABLE GAIN

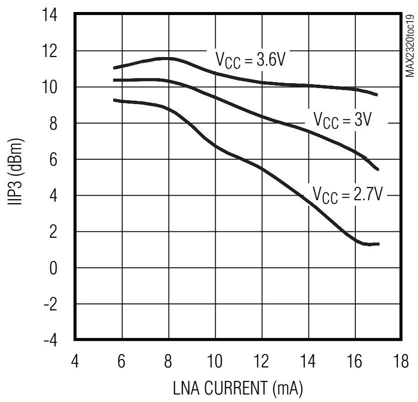
CELLULAR-BAND HGHL LNA IIP3 vs. CURRENT



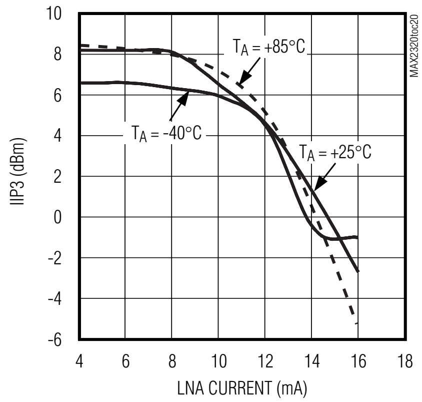
Typical Operating Characteristics (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

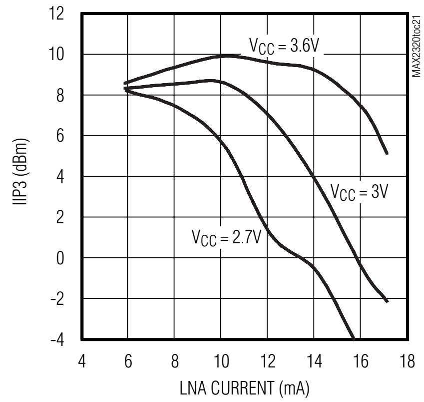
CELLULAR-BAND HGHL LNA IIP3 vs. CURRENT



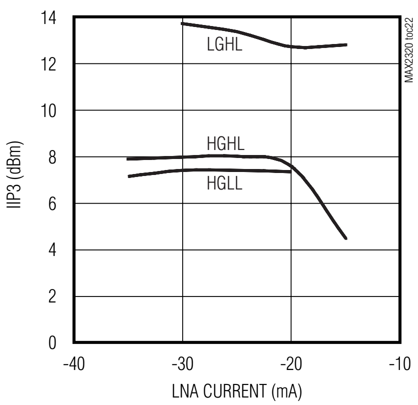
PCS-BAND HGHL LNA IIP3 vs. CURRENT



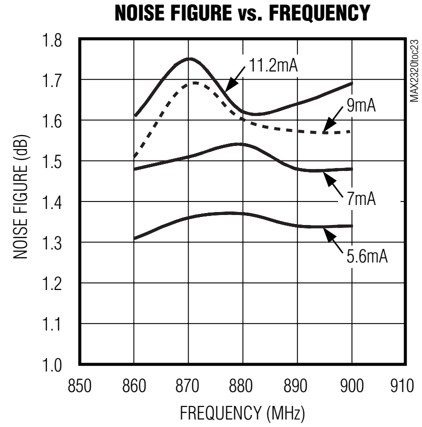
PCS-BAND HGHL LNA IIP3 vs. CURRENT



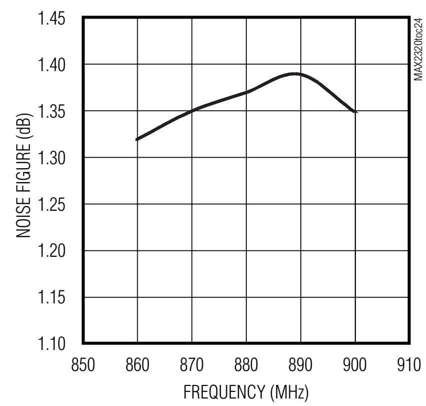
PCS-BAND HGHL LNA IIP3 vs. CURRENT



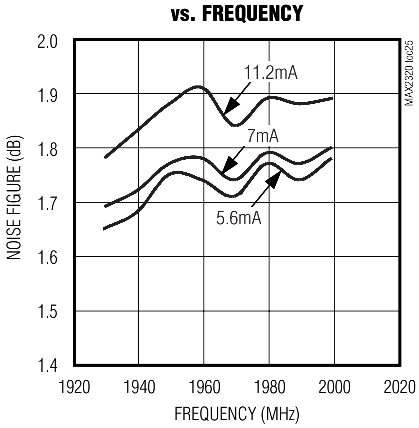
CELLULAR-BAND HGHL LNA NOISE FIGURE vs. FREQUENCY



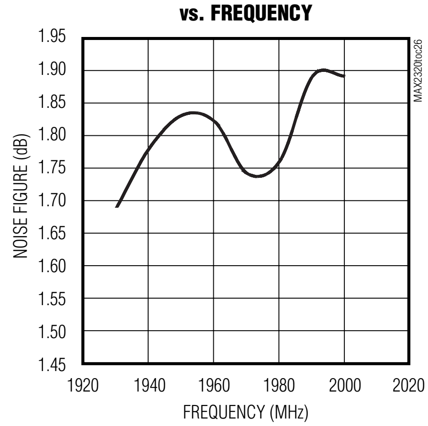
CELLULAR-BAND HGLL LNA NOISE FIGURE vs. FREQUENCY



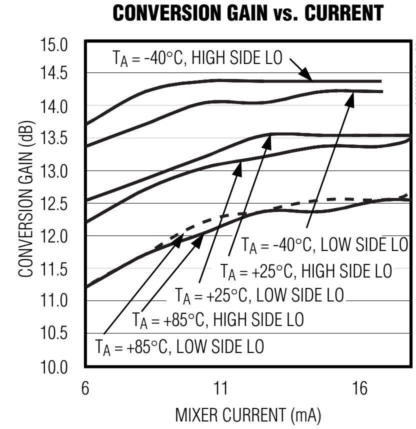
PCS-BAND HGHL NOISE FIGURE vs. FREQUENCY



PCS-BAND HGLL LNA NOISE FIGURE vs. FREQUENCY



CELLULAR-BAND HGHL MIXER CONVERSION GAIN vs. CURRENT

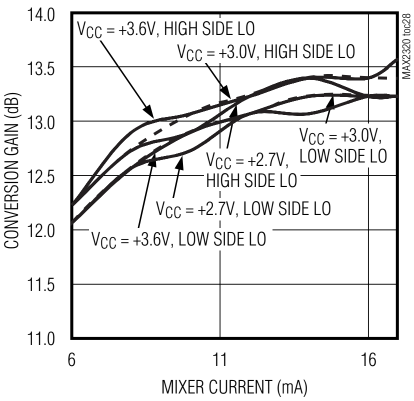


Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

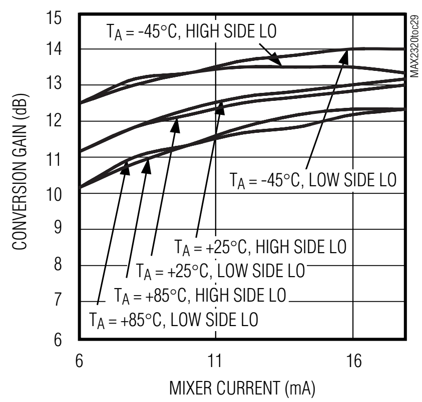
Typical Operating Characteristics (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

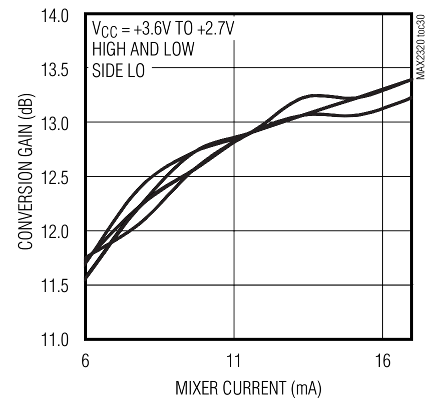
CELLULAR-BAND HGHL MIXER CONVERSION GAIN vs. CURRENT



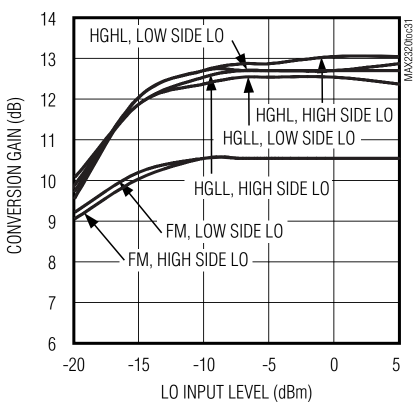
PCS-BAND HGHL MIXER CONVERSION GAIN vs. CURRENT



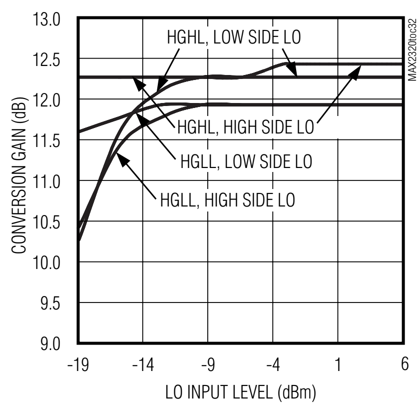
PCS-BAND HGHL MIXER CONVERSION GAIN vs. CURRENT



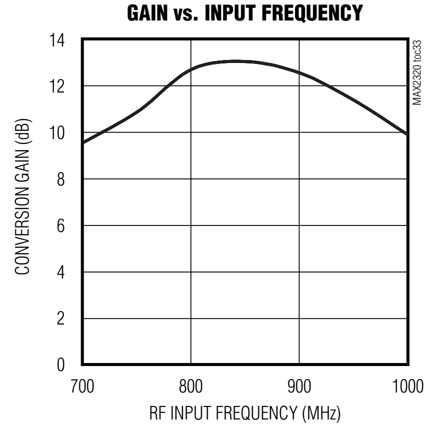
CELLULAR-BAND MIXER CONVERSION GAIN vs. LO INPUT LEVEL



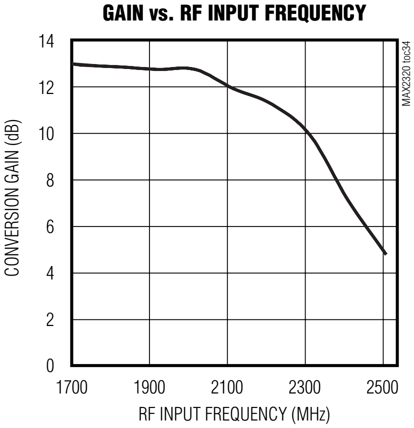
PCS-BAND HGHL MIXER CONVERSION GAIN vs. LO INPUT LEVEL



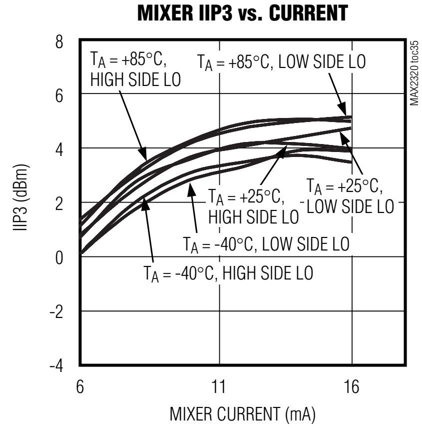
CELLULAR-BAND HGHL MIXER CONVERSION GAIN vs. INPUT FREQUENCY



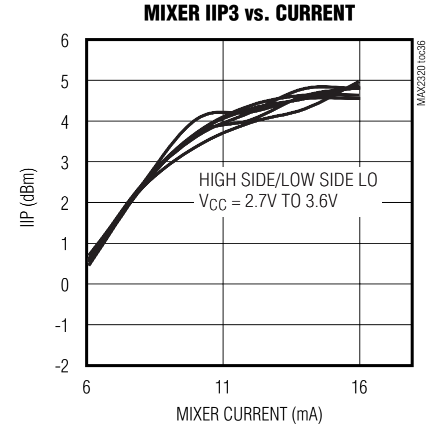
PCS-BAND HGHL MIXER CONVERSION GAIN vs. RF INPUT FREQUENCY



CELLULAR-BAND HGHL MIXER IIP3 vs. CURRENT



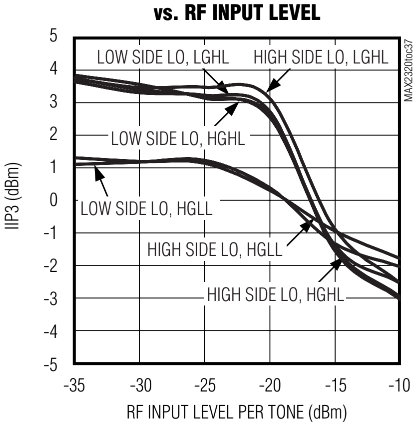
CELLULAR-BAND HGHL MIXER IIP3 vs. CURRENT



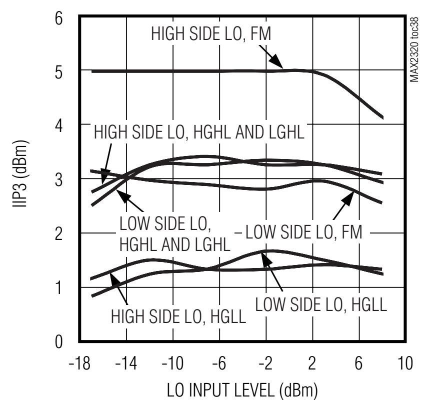
Typical Operating Characteristics (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

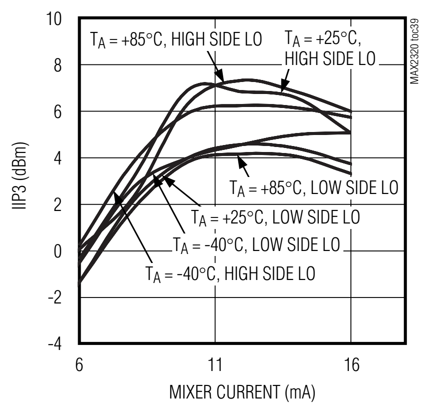
CELLULAR-BAND MIXER IIP3 vs. RF INPUT LEVEL



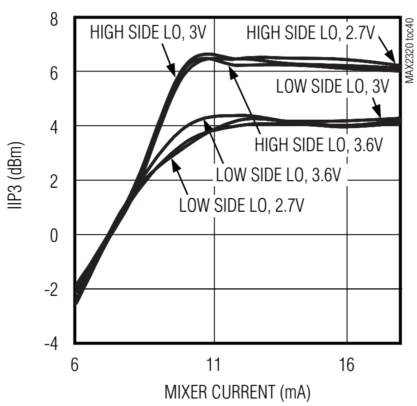
CELLULAR-BAND MIXER IIP3 vs. LO INPUT LEVEL



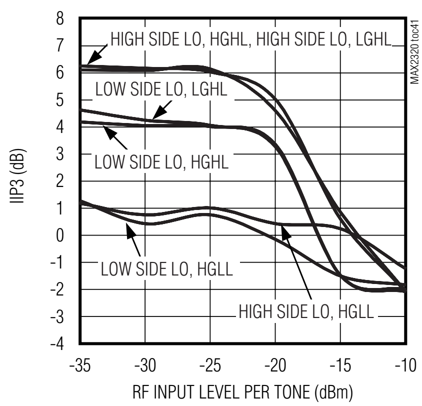
PCS-BAND HGHL MIXER IIP3 vs. CURRENT



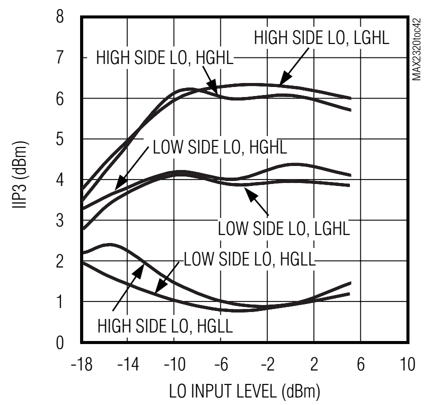
PCS-BAND HGHL MIXER IIP3 vs. CURRENT



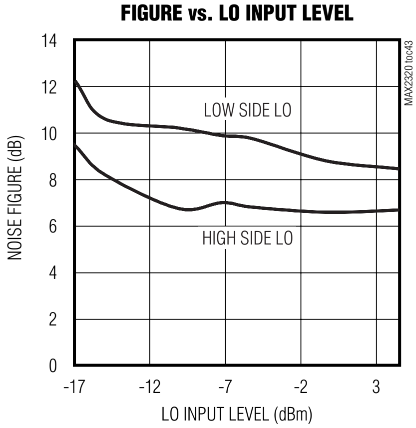
PCS-BAND MIXER IIP3 vs. RF INPUT LEVEL



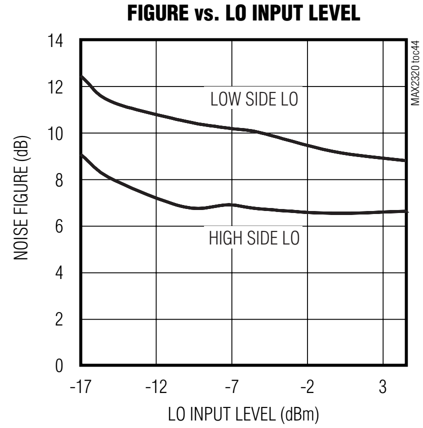
PCS-BAND MIXER IIP3 vs. LO INPUT LEVEL



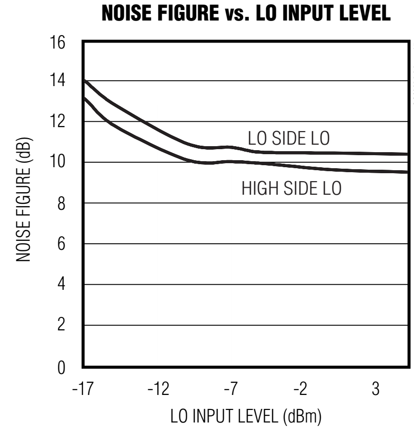
CELLULAR-BAND HGHL MIXER NOISE FIGURE vs. LO INPUT LEVEL



CELLULAR-BAND HGLL MIXER NOISE FIGURE vs. LO INPUT LEVEL



CELLULAR-BAND FM MIXER NOISE FIGURE vs. LO INPUT LEVEL

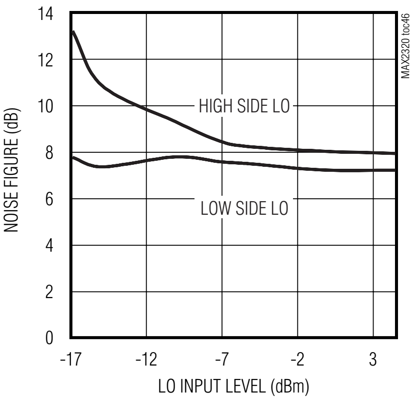


Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

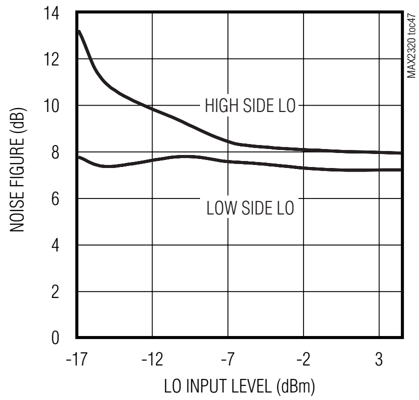
Typical Operating Characteristics (continued)

(MAX232_ EV kit, V_{CC} = +2.75V, f_{LNAINH} = f_{MIXINH} = 1960MHz, f_{LNAINL} = f_{MIXINL} = 881MHz, f_{LOHIN} = 1750MHz, f_{LOLIN} = 1091MHz (digital modes), f_{LOLIN} = 991MHz (FM mode), LO input power = -7dBm, 50Ω system, all measurements include matching component losses but not connector and trace losses, T_A = +25°C, unless otherwise noted.)

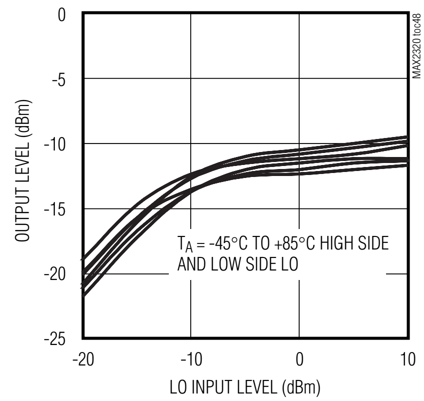
PCS-BAND HGHL MIXER NOISE FIGURE vs. LO INPUT LEVEL



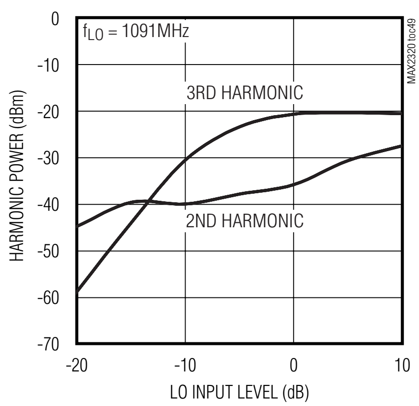
PCS-BAND HGLL MIXER NOISE FIGURE vs. LO INPUT LEVEL



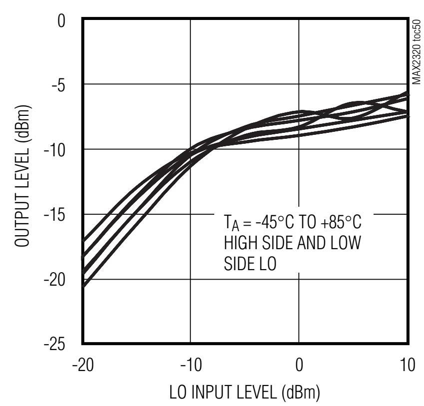
CELLULAR-BAND LO BUFFER OUTPUT LEVEL vs. INPUT LEVEL



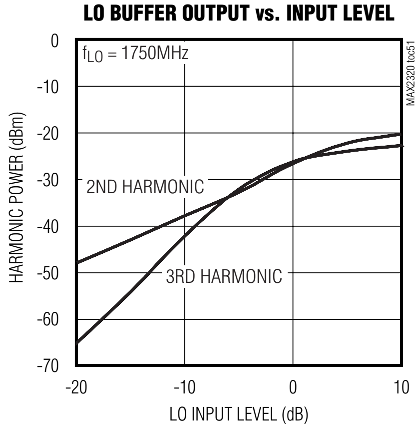
CELLULAR-BAND 2ND AND 3RD HARMONICS vs. LO INPUT POWER



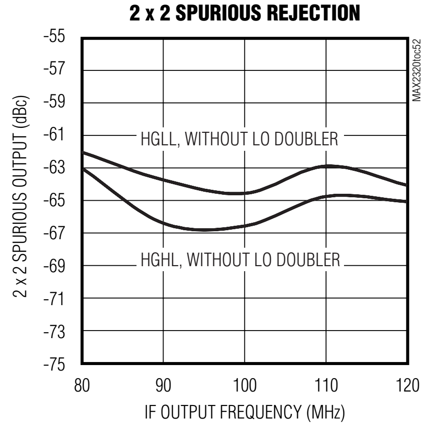
PCS-BAND LO BUFFER OUTPUT LEVEL vs. INPUT LEVEL



PCS-BAND 2ND AND 3RD HARMONICS LO BUFFER OUTPUT vs. INPUT LEVEL



PCS-BAND MIXER 2 x 2 SPURIOUS REJECTION



Pin Description

PIN				NAME	FUNCTION
MAX2320 MAX2321 MAX2326	MAX2322	MAX2324	MAX2327		
1	1	—	1	LNAOUTH	High-Band LNA Output. Connect a pull-up inductor to V_{CC} and an external series capacitor as part of the matching network.
2	—	2	2	LNAOUTL	Low-Band LNA Output. Connect a pull-up inductor to V_{CC} and an external series capacitor as part of the matching network.
3	3	3	—	RLNA	LNA Bias-Setting Resistor Connection. For nominal bias, connect a 20kΩ resistor to ground. The resistor value controls the LNA's linearity in high-gain, high-linearity modes.
4	4	—	4	LNAINH	High-Band RF Input. Requires a blocking capacitor and a matching network. The capacitor may be used as part of the matching network.
—	—	4	—	MODEOUT	Logic Output. Indicates mode of operation. $V_{MODEOUT}$ = high in FM mode.
5	—	5	5	LNAINL	Low-Band RF Input. Requires a blocking capacitor and a matching network. The capacitor may be used as part of the matching network.
—	6	6	7	$\overline{SHDN}$	Shutdown Logic Input. See *Detailed Description* for control modes.
6	—	—	6	$\overline{BAND}$	Band-Select Logic Input. See *Detailed Description* for control modes.
7	7	7	—	LIN	Linearity-Select Logic Input. See *Detailed Description* for control modes.
8	8	8	—	GAIN	Gain-Select Logic Input. See *Detailed Description* for control modes.
—	—	—	8	MODE	Cellular-Band Mode Select Logic Input. See *Detailed Description* for control modes.
9	—	9	9	LOLIN	Low-Frequency LO Input. Used in FM mode on all parts and in cellular digital mode for MAX2320/MAX2324.
10	10	—	10	LOHIN	High-Frequency LO Input. For MAX2321, used in cellular digital mode and in PCS mode with the doubler active. For MAX2320/MAX2327, used in PCS mode without the doubler. For MAX2322, used with or without the doubler. For MAX2326, used in PCS mode and cellular digital mode with the divide-by-two.

Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

Pin Description (continued)

PIN				NAME	FUNCTION
MAX2320 MAX2321 MAX2326	MAX2322	MAX2324	MAX2327		
11	11	—	11	LOHOUT	High-Frequency LO Buffer Output. Open-collector output requires pull-up inductor or pull-up resistor of 100Ω or less. Reactive match to the load delivers maximum power.
12	—	12	12	LOLOUT	Low-Frequency LO Buffer Output. Open-collector output requires pull-up inductor or pull-up resistor of 100Ω or less. Reactive match to the load delivers maximum power.
13	—	13	13	FMOUT	FM Mixer Output. Requires a pull-up inductor to V_{CC} and a series capacitor as part of the matching network.
—	13	—	—	LOX2	LO Doubler Logic Input. Drive LOX2 high to enable the LO doubler.
14	14	14	14	V_{CC}	Power Supply. Bypass with a 1000pF capacitor as close to the pin as possible.
15	15	15	15	BUFFEN	LO Output Buffer Enable. The LO buffers are controlled separately from the rest of the IC. Drive BUFFEN high to power up the LO output buffer associated with the selected LO input port.
16, 17	16, 17	16, 17	—	CDMA-, CDMA+	CDMA Mixer Differential Outputs. Require pull-up inductors and series capacitors as part of the matching network.
—	—	—	16, 17	IFOUT+, IFOUT-	Mixer Differential Outputs. Require pull-up inductors and series capacitors as part of the matching network.
18	18	18	18	RBIAS	Bias-Setting Resistor Connection. For nominal bias, connect 20kΩ resistor to ground. The resistor value controls the digital LNA's linearity in low-gain, digital, or FM mode, and controls the mixers in all modes.
19	—	19	19	MIXINL	Low-Band Mixer Input. Requires a blocking capacitor and a matching network. The capacitor may be used as part of the matching network.
20	20	—	20	MIXINH	High-Band Mixer Input. Requires a blocking capacitor and a matching network. The capacitor may be used as part of the matching network.
—	2, 5, 9, 12, 19	1, 10, 11, 20	3	N.C.	No Connection. Do not make any connection to these pins.
Slug	Slug	Slug	Slug	GND	Ground Reference for RF, DC, and Logic Inputs. Solder the slug evenly to the board ground plane.

Detailed Description

Low-Noise Amplifier

Within its operating bands, each device in the MAX2320 family (except the MAX2327) has three modes of LNA operation: high gain, high linearity (HGHL); high gain, low linearity (HGLL); and low gain, high linearity (LGHL). The logic inputs control the LNA mode as described in the *AC Electrical Characteristics*. Use HGHL mode when extra-high LNA linearity is required for cross-modulation suppression. Use HGLL mode when the transmitter is off and cross-modulation is not a concern. When the LNA changes modes, the input VSWR change is minimal. Use LGHL mode for receiving large signals and when high sensitivity is not required. The MAX2327 LNA has only an HGLL mode. Adjust the HGHL mode LNA linearity by changing R_{RLNA}, and adjust linearity of the other modes by changing R_{RBIAS}.

Downconverter

The downconverters in these devices are double-balanced mixers. The PCS-band mixer and digital cellular-band mixer share the same IF output ports. The cellular band FM mixer has its own IF output to feed a different filter. Adjust the downconverter linearity and current by changing R_{RBIAS} (see *Typical Operating Characteristics*). When the linearity requirement is high, the mode control inputs increase the current in the downconverter. When the linearity requirement is not high, the current is lower.

LO Output Buffers

The BUFFEN logic input turns the open-collector LO output buffers on and off. This feature saves current if the buffers are not required.

Operational Modes

Each device has logic input pins that control the different operational modes listed in Tables 1–5.

MAX2320/MAX2321/MAX2326 Operation

The MAX2320/MAX2321/MAX2326 are dual-band, triple-mode receivers that amplify and downconvert cellular- and PCS-band signals. They consist of cellular and PCS LNAs; cellular digital, cellular FM, and PCS digital mixers; and cellular and PCS LO buffers. The MAX2321 has an LO frequency doubler on-chip, so a single cellular-band VCO can be used for both the cellular- and PCS-band mixers. Selecting the PCS path activates the LO frequency doubler. The MAX2326 has an LO divide-by-two circuit, so a single PCS-band VCO can be used for both the cellular and PCS mixers. Selecting the cellular path activates the LO divide-by-two circuit. Three logic input pins—$\overline{\text{BAND}}$, GAIN, and LIN—control eight operational modes of the LNAs and mixers. The modes are summarized in Table 1.

Table 1. MAX2320/MAX2321/MAX2326 Operational Modes

DESCRIPTION	$\overline{\text{BAND}}$	GAIN	LIN
Shutdown. The entire part is shut down except for the LO buffer, which is controlled by BUFFEN.	L	L	L
Low-Gain, High-Linearity (LGHL) PCS Mode. The PCS LNA and mixer are in LGHL mode.	L	L	H
High-Gain, Low-Linearity (HGLL) PCS Mode. The LNA and mixer are in HGLL mode.	L	H	L
High-Gain, High-Linearity (HGHL) PCS Mode. The LNA and mixer are in HGHL mode.	L	H	H
High-Gain, Low-Linearity (HGLL) Cellular FM Mode. The cellular LNA is in HGLL mode. The FM mixer and associated LO buffer are selected.	H	L	L
Low-Gain, High-Linearity (LGHL) Cellular Digital Mode. The cellular LNA and mixer are in LGHL mode.	H	L	H
High-Gain, Low-Linearity (HGLL) Cellular Digital Mode. The cellular LNA and mixer are in HGLL mode.	H	H	L
High-Gain, High-Linearity (HGHL) Cellular Digital Mode. The cellular LNA and mixer are in HGHL mode.	H	H	H

Note: *L = Logic Low; H = Logic High*

MAX2322 Operation

The MAX2322 is a lower-cost PCS-only version that can be installed as a drop-in replacement for the dual-band versions. It consists of a PCS LNA, PCS mixer, pin-selectable LO frequency doubler, and LO buffer. Logic input $\overline{SHDN}$ = V_{CC} / GND turns on/off the entire IC except the LO buffer. The LOX2 logic input controls the LO frequency doubler. LOX2 = GND disables the doubler when using a PCS band VCO, and LOX2 = V_{CC} activates the doubler when using a cellular-band VCO. GAIN and LIN logic inputs control the MAX2322's three operational modes, as summarized in Table 2.

MAX2324 Operation

The MAX2324 is a lower-cost cellular-only version that can be installed as a drop-in replacement for the dual-band versions. It consists of a cellular LNA, cellular digital mixer, cellular FM mixer, and LO buffer. A $\overline{SHDN}$ logic input turns on/off the entire IC except the LO buffer. GAIN and LIN logic inputs control the MAX2324's three operational modes, as summarized in Table 3.

MAX2327 Operation

The MAX2327 is similar to the MAX2320 except it only features an HGLL mode, and either LO output buffer is selectable during shutdown. It consists of PCS and cellular LNAs; PCS, cellular digital, and cellular FM mixers; and PCS and cellular LO buffers. A $\overline{SHDN}$ logic input turns on/off the entire IC except the LO buffer. $\overline{BAND}$ and MODE logic inputs control the MAX2327's three operational modes, as summarized in Table 4.

Applications Information

Cascaded LNA/Mixer Performance

The LNA and mixer design aims at optimizing cascaded performance in all gain and linearity modes. In high-gain, high-linearity mode, both the LNA and mixer have a low noise figure, high gain, and high linearity. The LNA has high gain to minimize the noise contribution of the mixer, thus increasing the receiver's sensitivity and extra-high linearity for superior cross-modulation suppression. The HGLL mode is used when the transmitter is off and cross-modulation is not a concern. In low-gain, high-linearity mode, the received signal is strong enough that linearity is the primary concern. The LNA gain is reduced for higher system linearity. Tables 5 and 6 summarize the cascaded performance.

S Parameters

The S parameters are listed in Tables 7–11. An electronic copy is also available at www.maxim-ic.com /MAX2320/S_table/.

Table 2. MAX2322 Operational Modes

OPERATIONAL MODE	GAIN	LIN
Not used.	L	L
Low-Gain, High-Linearity (LGHL) PCS Mode. The LNA and mixer are in LGHL mode.	L	H
High-Gain, Low-Linearity (HGLL) PCS Mode. The LNA and mixer are in HGLL mode.	H	L
High-Gain, High-Linearity (HGHL) PCS Mode. The LNA and mixer are in HGHL mode.	H	H

Note: *L = Logic Low; H = Logic High*

Table 3. MAX2324 Operational Modes

OPERATIONAL MODE	GAIN	LIN
FM Mode. The LNA is in HGLL mode. The FM mixer and the associated LO buffer are selected.	L	L
Low-Gain, High-Linearity (LGHL) Cellular Mode. The LNA and digital mixer are in LGHL mode.	L	H
High-Gain, Low-Linearity (HGLL) Cellular Mode. The LNA and digital mixer are in HGLL mode.	H	L
High-Gain, High-Linearity (HGHL) Cellular Mode. The LNA and digital mixer are in HGHL mode.	H	H

Note: *L = Logic Low; H = Logic High*

Table 4. MAX2327 Operational Modes

OPERATIONAL MODE	$\overline{BAND}$	MODE
Not used.	L	L
Digital PCS Mode. The LNA and mixer are in HGLL mode.	L	H
FM Mode. The cellular FM mixer is selected.	H	L
Digital Cellular Mode. The cellular digital mixer is selected.	H	H

Note: *L = Logic Low; H = Logic High*

Layout Considerations

Keep RF signal lines as short as possible to minimize losses and radiation. Use high-Q components for the LNA input matching circuit to achieve the lowest possible noise figure. At the digital mixer outputs, keep the differential signal lines together and of equal length to ensure signal balance. For best gain and noise performance, solder the slug evenly to the board ground plane.

Table 5. Typical Cascaded Performance of Cellular-Band Receiver with 3dB Interstage Filter Loss

PARAMETER	HIGH GAIN, HIGH LINEARITY	HIGH GAIN, LOW LINEARITY	LOW GAIN, HIGH LINEARITY	FM
Conversion Power Gain	25.4dB	24.5dB	8.9dB	22.7dB
Noise Figure	2.1dB	2.3dB	11.8dB	3.3dB
Third-Order Input Intercept	-8.9dBm	-10.6dBm	-6.8dBm	-6.8dBm

Table 6. Typical Cascaded Performance of PCS-Band Receiver with 3dB Interstage Filter Loss

PARAMETER	HIGH GAIN, HIGH LINEARITY	HIGH GAIN, LOW LINEARITY	LOW GAIN
Conversion Power Gain	24dB	22.5dB	7.5dB
Noise Figure	2.6dB	3.0dB	12.4dB
Third-Order Input Intercept	-7.6dBm	-9.3dBm	7.1dBm

Table 7. Cellular LNA S Parameters in High-Gain, High-Linearity Mode

FREQUENCY (MHz)	S11 (mag)	S11 (phase)	S21 (mag)	S21 (phase)	S12 (mag)	S12 (phase)	S22 (mag)	S22 (phase)
700	0.579	-74.8	4.63	92.1	0.085	60.9	0.714	-34.7
750	0.548	-78.4	4.39	87.9	0.089	60.6	0.696	-35.9
800	0.534	-81.2	4.13	84.4	0.0908	60	0.689	-36.6
850	0.52	-83.7	3.88	81.9	0.096	60.1	0.683	-37.6
900	0.51	-86.1	3.7	79.4	0.099	58.8	0.677	-38.3
950	0.503	-88.5	3.5	76.6	0.104	58.3	0.674	-39.3
1000	0.496	-90.6	3.3	74.9	0.109	59.1	0.669	-40.8

Table 8. PCS LNA S Parameters in High-Gain, High-Linearity Mode

FREQUENCY (MHz)	S11 (mag)	S11 (phase)	S21 (mag)	S21 (phase)	S12 (mag)	S12 (phase)	S22 (mag)	S22 (phase)
1700	0.46	-112	4.22	86	0.077	77	0.64	-51
1750	0.446	-113	4.07	88	0.082	77	0.64	-52
1800	0.44	-113	4.18	88	0.086	76	0.643	-52
1850	0.439	-113	4.23	84	0.09	77	0.657	-53
1900	0.434	-114	3.9	82	0.093	72	0.68	-55
1950	0.43	-115	3.82	84	0.09	75	0.673	-57
2000	0.423	-116	3.85	83	0.094	76	0.681	-58
2050	0.407	-115	3.82	83	0.098	76	0.69	-59
2100	0.391	-112	3.82	81	0.103	74	0.7	-61
2150	0.405	-106	3.68	79	0.101	71	0.695	-63
2200	0.467	-104	3.56	81	0.093	73	0.677	-64
2250	0.503	-107	3.67	82	0.094	79	0.683	-63
2300	0.525	-110	3.83	81	0.099	82	0.705	-64
2350	0.54	-112	3.88	78	0.1	86	0.727	-66
2400	0.55	-113	3.9	75	0.106	93	0.739	-67
2450	0.571	-113	3.79	73	0.126	99	0.754	-69
2500	0.614	-113	3.78	74	0.158	100	0.769	-71

Table 9. Cellular Mixer S11 in High-Gain, High-Linearity Mode

FREQUENCY (MHz)	S11 (mag)	S11 (phase)
700	0.853	-35.8
750	0.849	-38
800	0.846	-40.2
850	0.844	-42.2
900	0.843	-44.1
950	0.842	-46.3
1000	0.842	-48.5

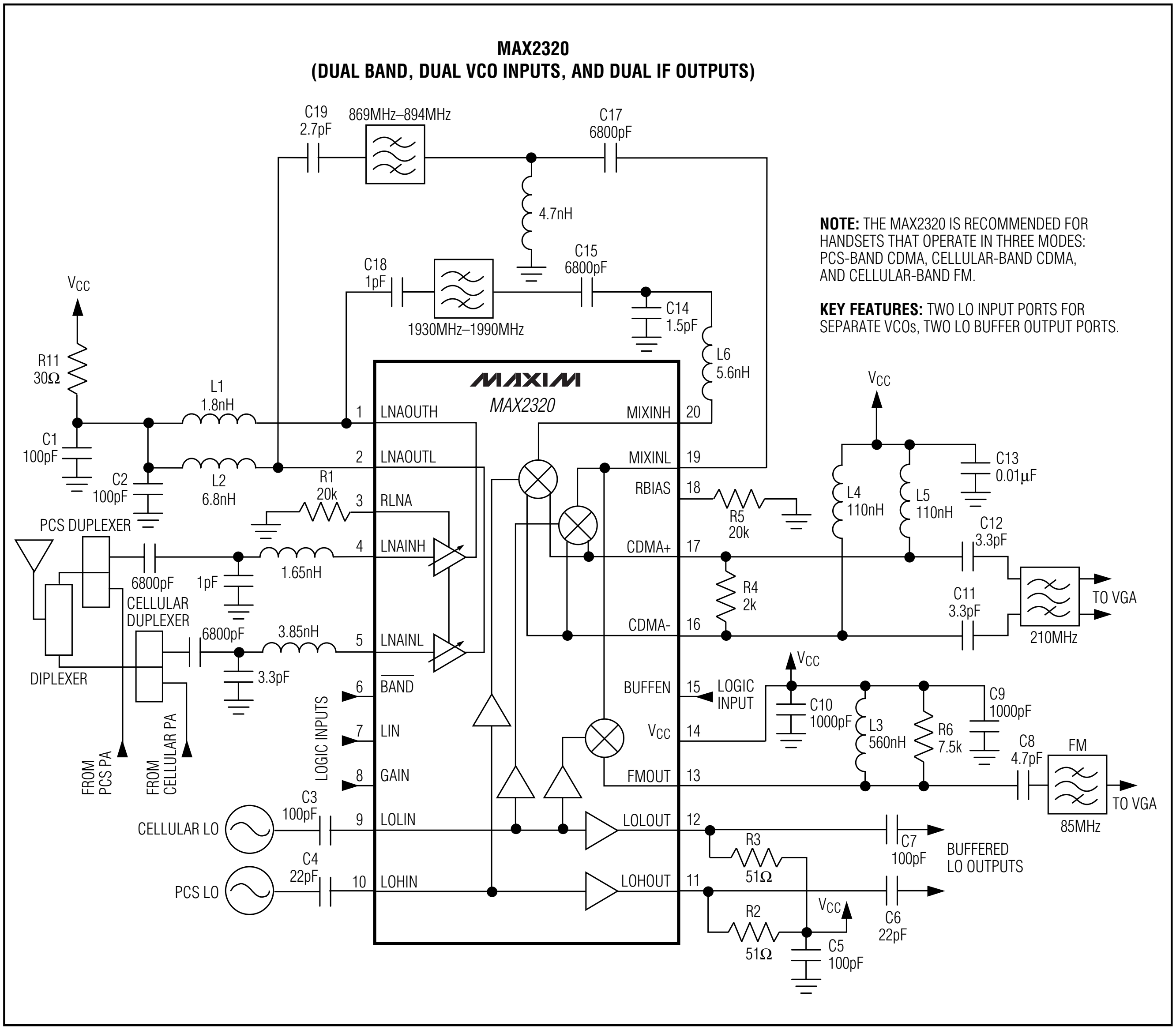
Table 10. PCS Mixer S11 in High-Gain High-Linearity Mode

FREQUENCY (MHz)	S11 (mag)	S11 (phase)
1700	0.865	-62
1750	0.864	-63
1800	0.865	-64
1850	0.867	-64
1900	0.863	-65
1950	0.862	-65
2000	0.861	-66
2050	0.879	-67
2100	0.86	-68
2150	0.858	-68
2200	0.854	-69
2250	0.85	-71
2300	0.845	-72
2350	0.838	-74
2400	0.83	-76
2450	0.825	-78
2500	0.805	-82

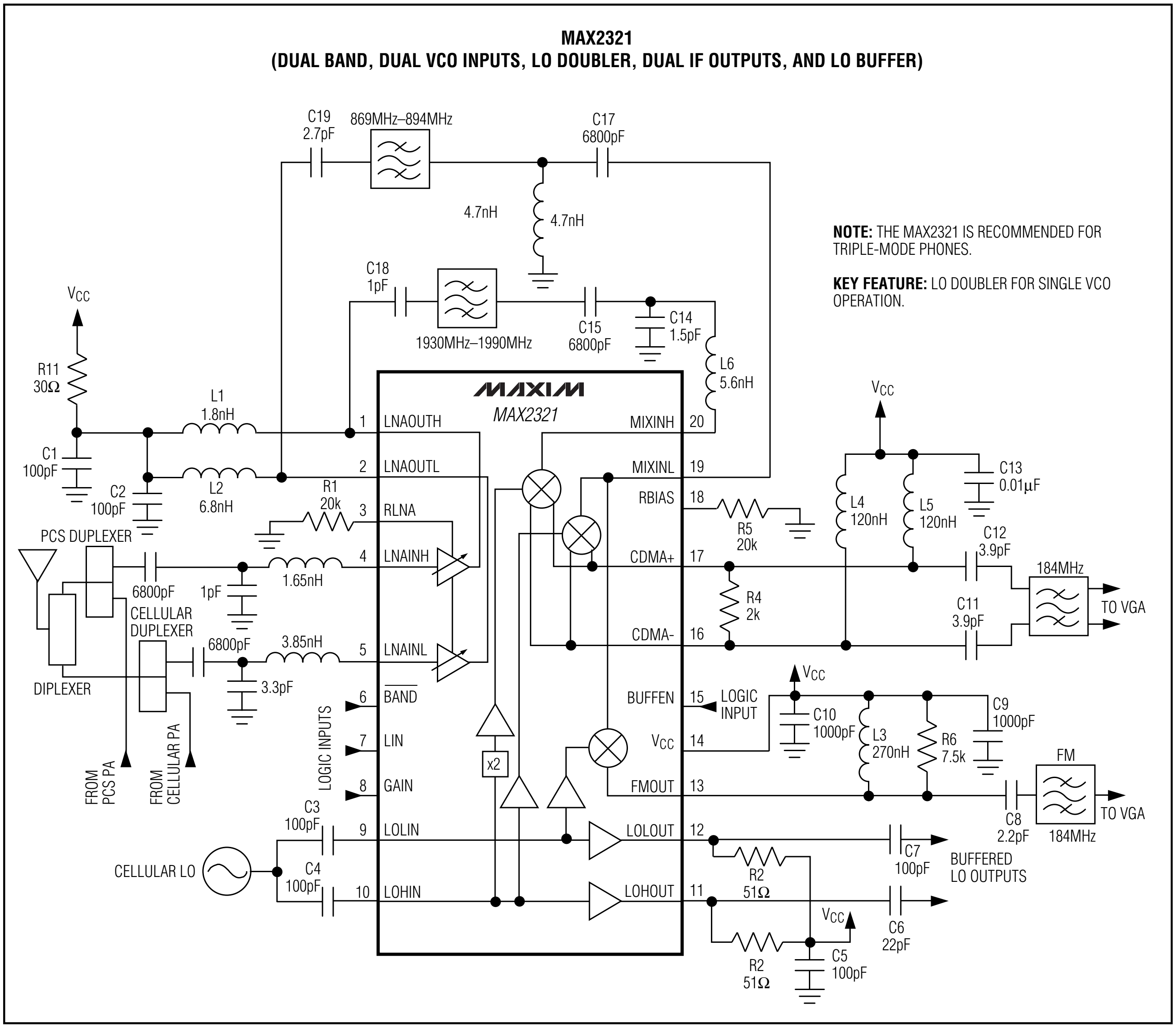
Table 11. Mixer IF Port S22

FREQUENCY (MHz)	DIGITAL MIXER		FREQUENCY (MHz)	FM MIXER	
	S22 (mag)	S22 (phase)		S22 (mag)	S22 (phase)
50	0.999	-1.10	50	0.999	-1.69
100	0.999	-2.26	70	0.998	-2.38
110	0.999	-2.46	85	0.998	-2.92
130	0.998	-2.89	100	0.997	-3.38
150	0.998	-3.35	110	0.997	-3.71
200	0.998	-4.45	150	0.996	-4.97
210	0.998	-4.67	200	0.995	-6.49
250	0.997	-5.48	250	0.995	-7.82
300	0.997	-6.48	300	0.994	-9.06
350	0.996	-7.47	350	0.993	-10.28
400	0.996	-8.36	400	0.992	-11.40

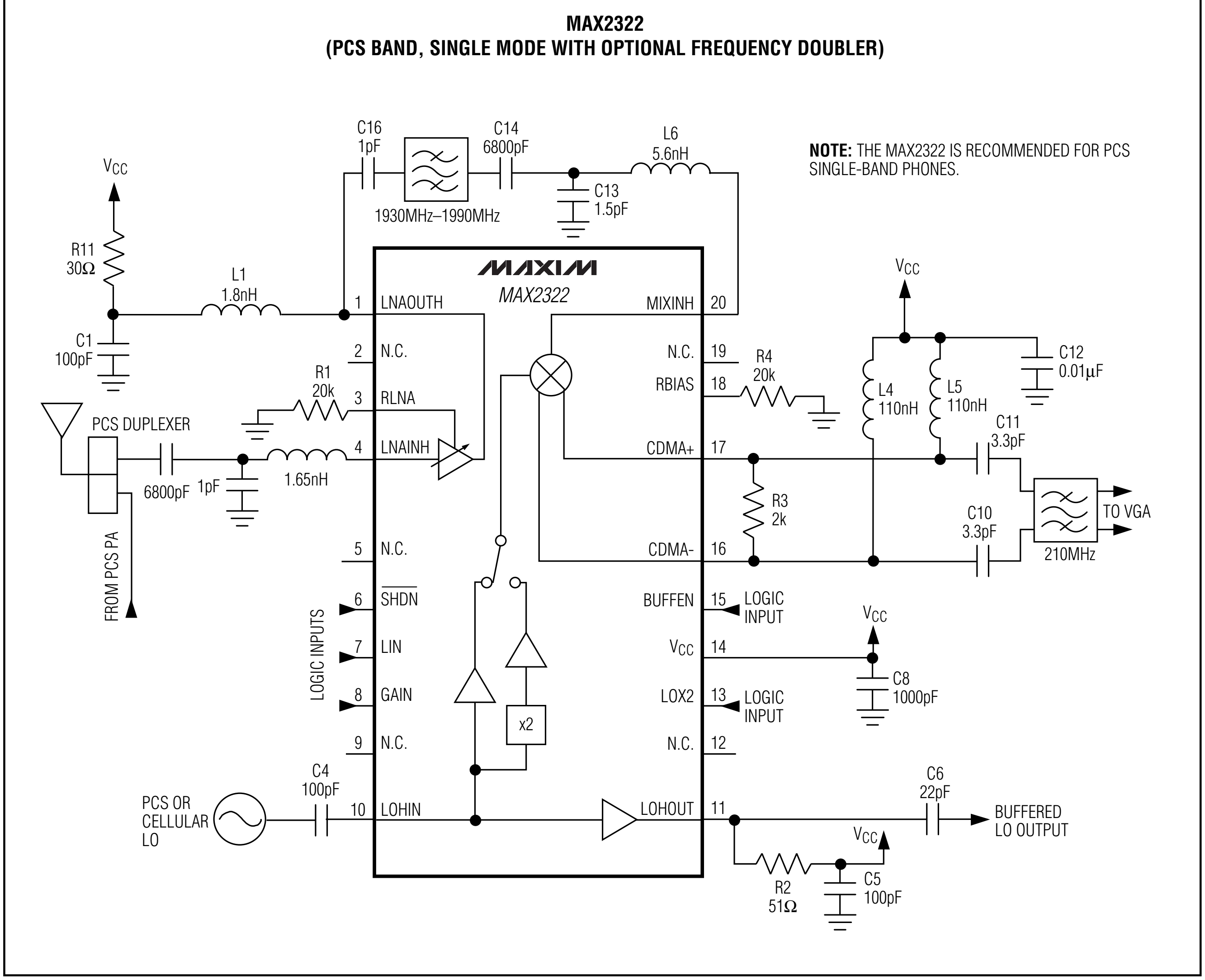
Typical Application Circuits



Typical Application Circuits (continued)

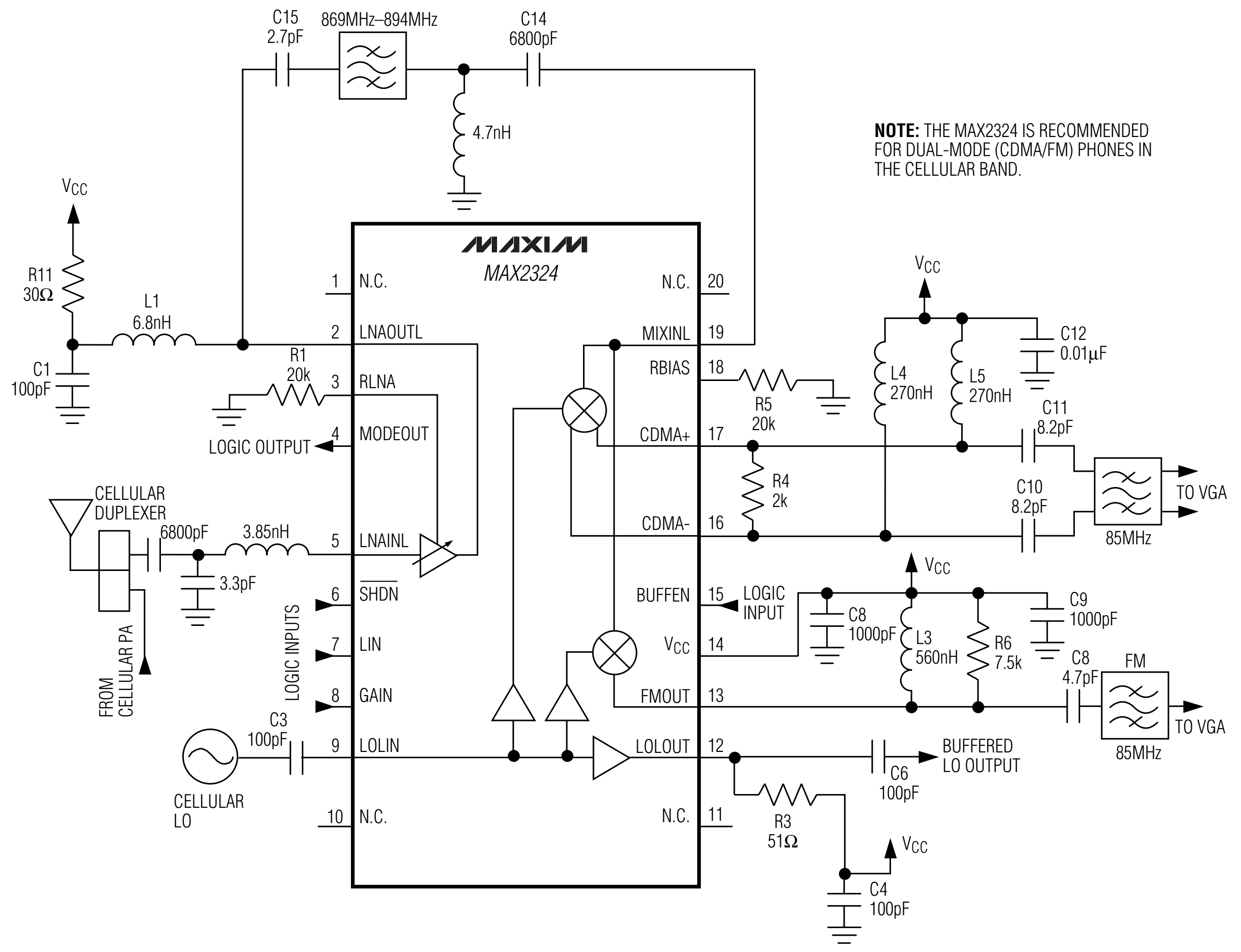


Typical Application Circuits (continued)



Typical Application Circuits (continued)

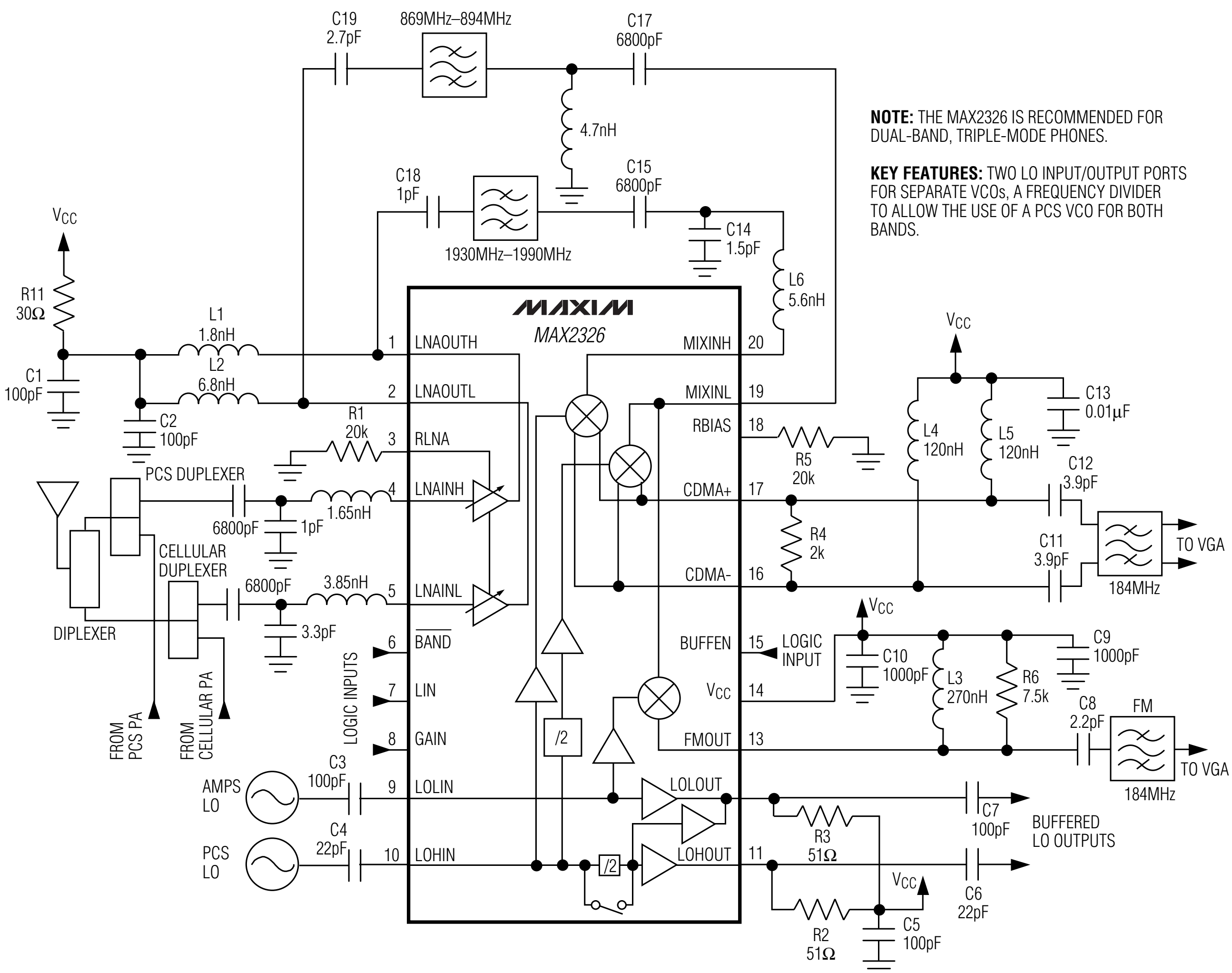
MAX2324
(CELLULAR BAND, DUAL IF OUTPUTS)



Adjustable, High-Linearity, SiGe Dual-Band LNA/Mixer ICs

Typical Application Circuits (continued)

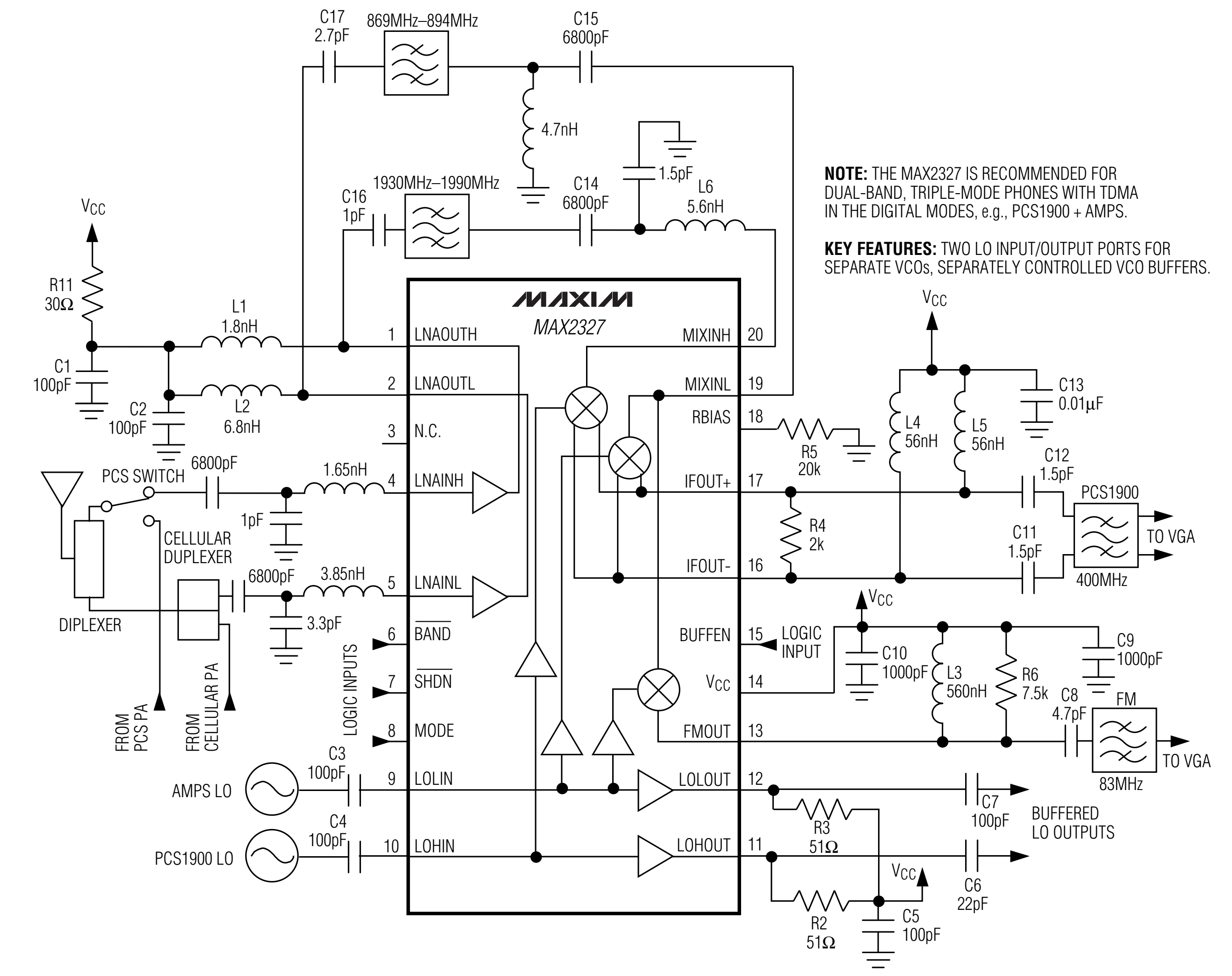
MAX2326
(DUAL BAND, DUAL VCO INPUTS, AND DUAL IF OUTPUTS WITH LO DIVIDER)



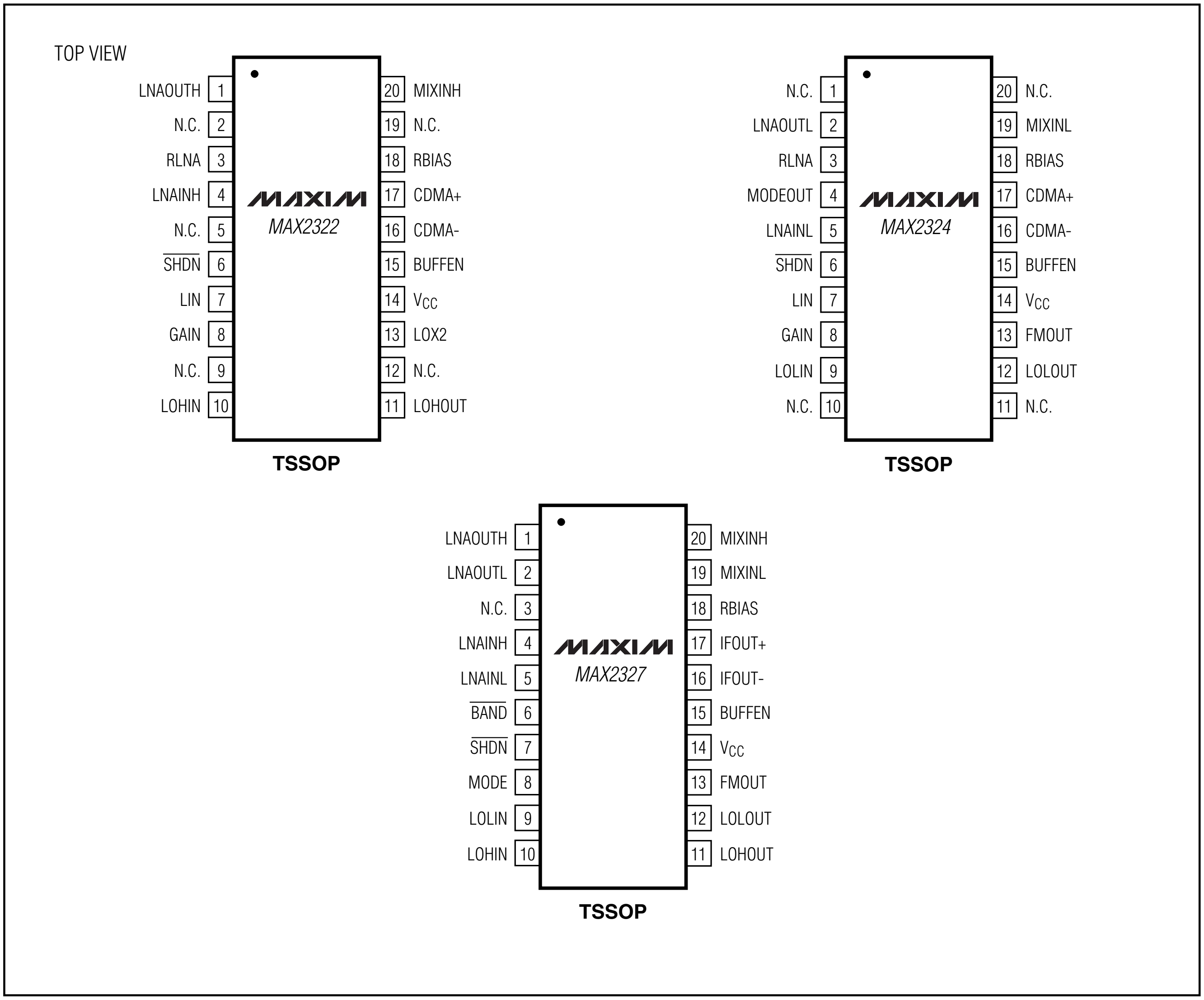
Typical Application Circuits (continued)

MAX2327

(DUAL BAND, DUAL VCO INPUTS, AND SEPARATELY CONTROLLED VCO BUFFERS)



Pin Configurations (continued)

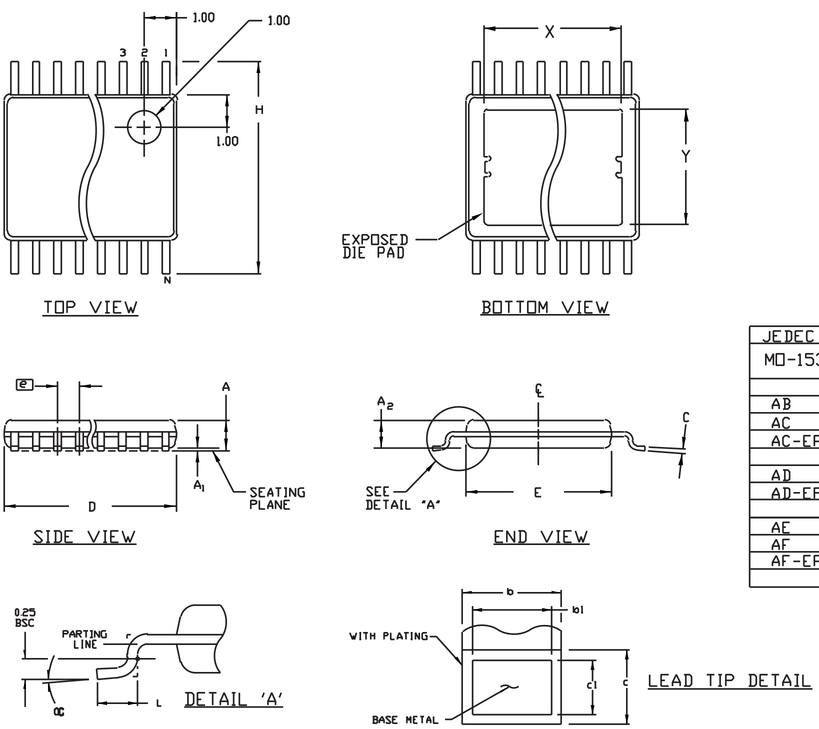


Chip Information

TRANSISTOR COUNT: 1315

Package Information

TSSOP.EPS



SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	—	1.10		.043
A_1	0.05	0.15	.002	.006
A_2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b1	0.19	0.25	.007	.010
c	0.090	0.20	.0035	.008
c1	0.090	0.135	.0035	.0053
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.50	.246	.256
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
Y	2.85	3.15	.112	.124
α	0°	8°	0°	8°

JEDEC			VARIATIONS			
MO-153	N		MILLIMETERS		INCHES	
			MIN.	MAX.	MIN.	MAX.
AB	14	D	4.90	5.10	.193	.201
AC	16	D	4.90	5.10	.193	.201
AC-EP	16	D	4.90	5.10	.193	.201
		X	2.85	3.15	.112	.124
AD	20	D	6.40	6.60	.252	.260
AD-EP	20	D	6.40	6.60	.252	.260
		X	4.00	4.34	.157	.171
AE	24	D	7.70	7.90	.303	.311
AF	28	D	9.60	9.80	.378	.386
AF-EP		D	9.60	9.80	.378	.386
		X	5.35	5.65	.211	.222

NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15 mm PER SIDE.
3. CONTROLLING DIMENSION: MILLIMETER.
4. MEETS JEDEC OUTLINE MO-153 VARIATIONS AB, AC, AD, AE, AF.
5. DIMENSIONS X AND Y APPLY TO EXPOSED PAD (EP) VERSIONS ONLY.
6. EXPOSED PAD FLUSH WITH BOTTOM OF PACKAGE WITHIN .002".

MAXIM
PROPRIETARY INFORMATION
TITLE:
PACKAGE OUTLINE, TSSOP, 4.40mm BODY, 0.65mm PITCH

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0066	C	1/1

NOTES