LMX2216

LMX2216 0.1 GHz to 2.0 GHz Low Noise Amplifier/Mixer for RF Personal Communications

Literature Number: SNOS689A

National Semiconductor

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0.1 GHz to 2.0 GHz Low Noise Amplifier/Mixer for RF Personal Communications

General Description

The LMX2216 is a monolithic, integrated low noise amplifier (LNA) and mixer suitable as a first stage amplifier and down-converter for RF receiver applications. The wideband operating capabilities of the LMX2216 allow it to function over frequencies from 0.1 GHz to 2.0 GHz. It is fabricated using National Semiconductor's ABiC IV BiCMOS process.

All input and output ports of the LMX2216 are single-ended. The LNA input and output ports are designed to interface to a 50Ω system. The Mixer input ports are matched to 50Ω. The output port is matched to 200Ω. The only external components required are DC blocking capacitors. The balanced architecture of the LMX2216 maintains consistent operating parameters from unit to unit, since it is implemented in a monolithic device. This consistency provides manufacturers a significant advantage since tuning procedures—often needed with discrete designs—can be reduced or eliminated.

The low noise amplifier produces very flat gain over the entire operating range. The doubly-balanced, Gilbert-cell mixer provides good LO-RF isolation and cancellation of second-order distortion products. A power down feature is implemented on the LMX2216 that is especially useful for stand-by operation common in Time Division Multiple Access (TDMA) and Time Division Duplex (TDD) systems.

The LMX2216 is available in a narrow-body 16-pin surface mount plastic package.

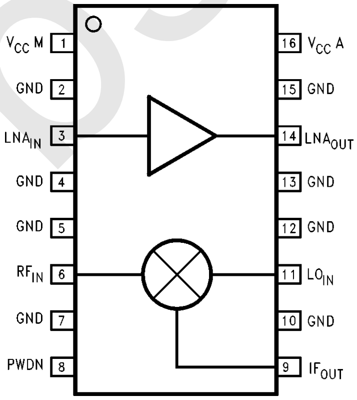
Features

- Wideband RF operation from 0.1 GHz to 2.0 GHz
- No external biasing components necessary
- 3V operation
- LNA input and output ports matched to 50Ω
- Mixer input ports matched to 50Ω, output port matched to 200Ω.
- Doubly balanced Gilbert cell mixer (single ended input and output)
- Low power consumption
- Power down feature
- Small outline, plastic surface mount package

Applications

- Digital European Cordless Telecommunications (DECT)
- Portable wireless communications (PCS/PCN, cordless)
- Wireless local area networks (WLANs)
- Digital cellular telephone systems
- Other wireless communications systems

Functional Block/Pin Diagram



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Order Number LMX2216M
See NS Package Number M16A

RRD-B30M115/Printed in U. S. A.

Pin Description

Pin No.	Pin Name	I/O	Description
1	V_{CC} M	I	Voltage supply for the mixer. The input voltage level to this pin should be a DC Voltage ranging from 2.85V to 3.15V.
2	GND		Ground
3	LNA_{IN}	I	RF input signal to the LNA. External DC blocking capacitor is required.
4	GND		Ground
5	GND		Ground
6	RF_{IN}	I	RF input to the mixer. The RF signal to be down converted is connected to this pin. External DC blocking capacitor is required.
7	GND		Ground
8	PWDN	I	Power down signal pin. Both the LNA and mixer are powered down when a HIGH level is applied to this pin (V_{IH}).
9	IF_{OUT}	O	IF output signal of the mixer. External DC blocking capacitor is required.
10	GND		Ground
11	LO_{IN}	I	Local oscillator input signal to the mixer. External DC blocking capacitor is required.
12	GND		Ground
13	GND		Ground
14	LNA_{OUT}	O	Output of the LNA. This pin outputs the amplified RF signal. External DC blocking capacitor is required.
15	GND		Ground
16	V_{CC} A	I	LNA supply Voltage. DC Voltage ranging from 2.85V to 3.15V.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (V_{CC})	6.5V
Storage Temperature (T_S)	−65°C to +150°C
Operating Temperature (T_O)	−40°C to +85°C

Recommended Operating Conditions

Supply Voltage (V_{CC})	2.85V−3.15V
Operating Temperature (T_A)	−10°C to +70°C
RF_{IN}	0.1 GHz to 2.0 GHz
LO_{IN}	0.1 GHz to 2.0 GHz

Electrical Characteristics: LNA

(V_{CC} = +3.0V ±5%, T_A = 25°C, Z_o = 50Ω and f_{IN} = 2.0 GHz @ −30 dBm unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{CC}	Supply Current	In Operation		6.5	8.0	mA
$I_{CC\text{-}PWDN}$	Supply Current	In Power Down Mode			10	μA
G	Gain		9	10		dB
P_{1dB}	Output 1 dB Compression Point		−5.0	−3.0		dBm
OIP3	Output 3rd Order Intercept Point		5.0	7.0		dBm
NF	Single Side Band Noise Figure			4.8	6.0	dB
RL_{IN}	Input Return Loss		10	15		dB
RL_{OUT}	Output Return Loss		10	11		dB

Electrical Characteristics: Mixer

(V_{CC} = +3.0V ±5%, T_A = 25°C, Z_o = 50Ω, f_{RF} = 2.0 GHz @ −30 dBm, f_{LO} = 1.89 GHz @ 0 dBm; f_{IF} = 110 MHz unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{CC}	Supply Current	In Operation		9.0	12.0	mA
$I_{CC\text{-}PWDN}$	Supply Current	In Power Down Mode			10	μA
G_C	Conversion Gain (Single Side Band)		4.0	6.0		dB
P_{1dB}	Output 1 dB Compression Point		−13.0	−9.0		dBm
OIP3	Output Third Order Intercept Point		−3.0	0.0		dBm
SSB NF	Single Side Band Noise Figure			17	18	dB
DSB NF	Double Side Band Noise Figure			14	15	dB
LO-RF	LO to RF Isolation		20	30		dB
LO-IF	LO to IF Isolation		20	30		dB
RF RL	RF Return Loss		10	15		dB
LO RL	LO Return Loss		10	15		dB
IF RL	IF Return Loss			15		dB
Z_{IF}	IF Port Impedance			200		Ω

Electrical Characteristics: Power Down

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IH}	High Level Input Voltage		V_{CC} − 0.8			V
V_{IL}	Low Level Input Voltage				0.8	V
I_{IH}	High Level Input Current	$V_{IH} = V_{CC}$	−10.0		10.0	μA
I_{IL}	Low Level Input Current	V_{IL} = GND	−10.0		10.0	μA

Typical Application Block Diagram

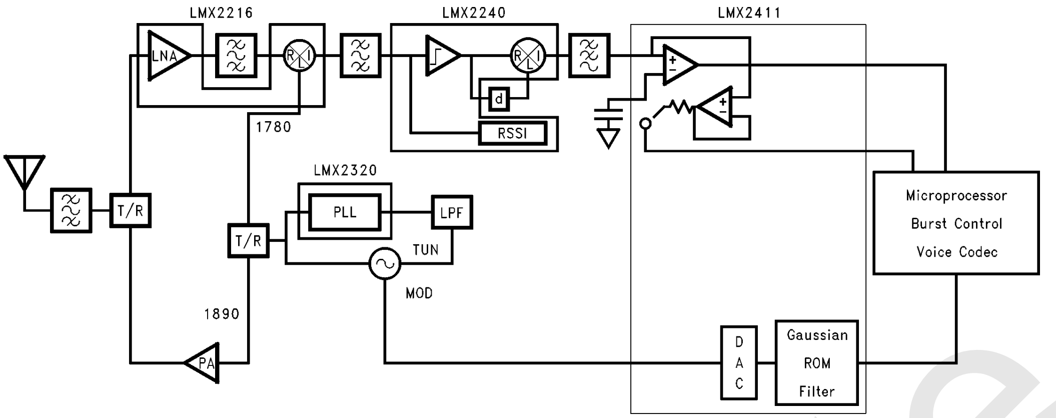

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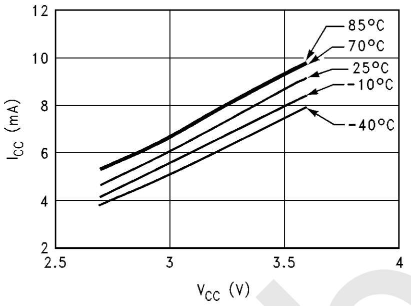
FIGURE 2

Typical Characteristics

LNA



LNA Current Composition vs Supply Voltage with Temperature as a Parameter

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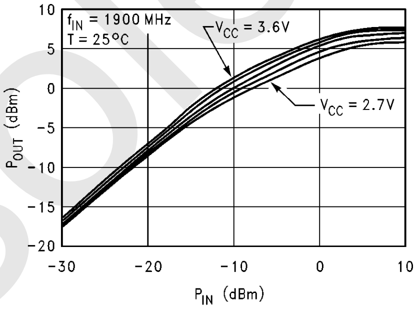

LNA P_{OUT} vs P_{IN} with Supply Voltage as a Parameter

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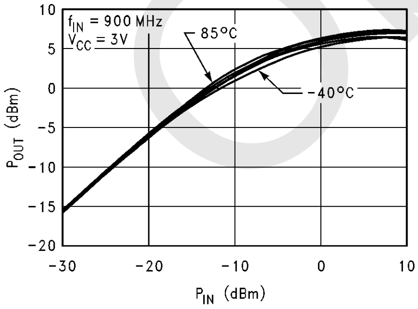

LNA P_{OUT} vs P_{IN} with Temperature as a Parameter

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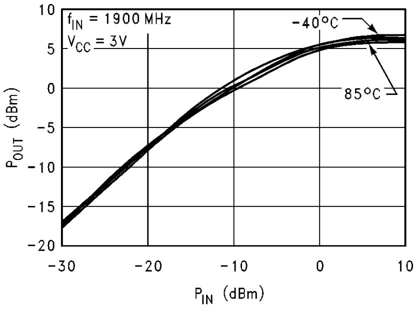

LNA P_{OUT} vs P_{IN} with Temperature as a Parameter

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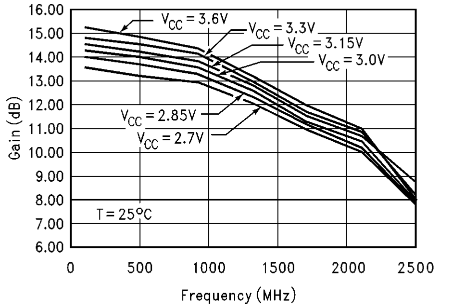
Typical Characteristics (Continued)

LNA (Continued)

LNA Gain vs Frequency with Supply Voltage as a Parameter



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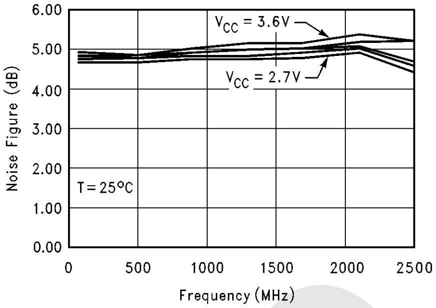
LNA Noise Figure vs Frequency with Supply Voltage as a Parameter



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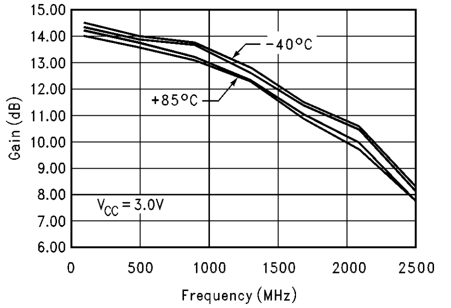
LNA Gain vs Frequency with Temperature as a Parameter



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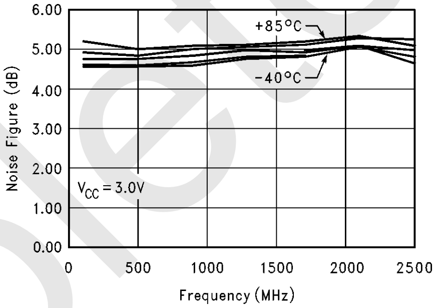
LNA Noise Figure vs Frequency with Temperature as a Parameter



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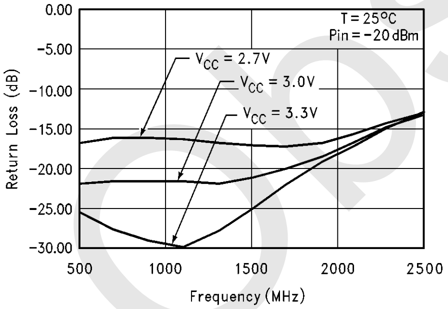
LNA Input Return Loss vs Frequency with Voltage as a Parameter



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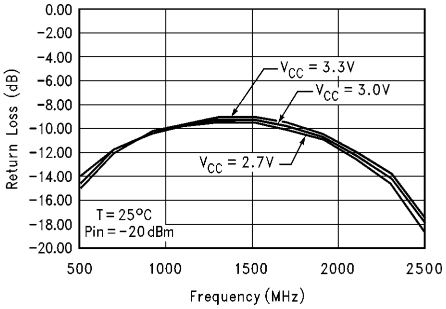
LNA Output Return Loss vs Frequency with Voltage as a Parameter



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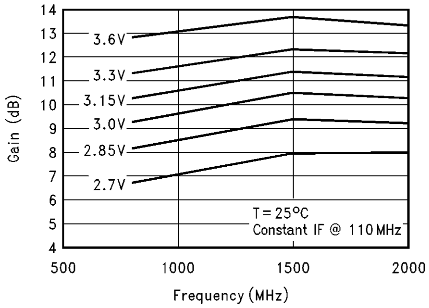
Typical Characteristics (Continued)

MIXER

Mixer Gain (Double Sideband) vs Frequency with Supply Voltage as a Parameter



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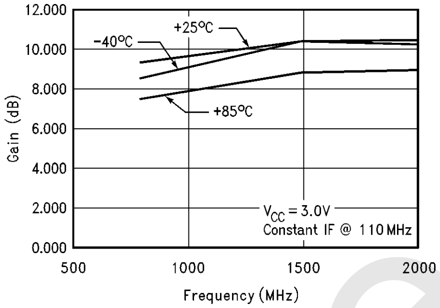
Mixer Gain (Double Sideband) vs Frequency with Temperature as a Parameter



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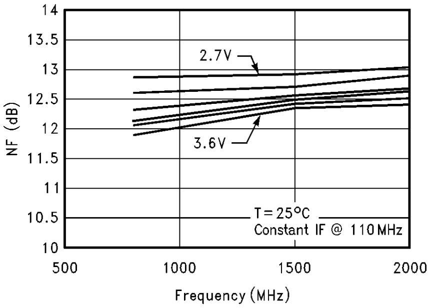
Mixer Noise Figure (Double Sideband) vs Frequency with Supply Voltage as a Parameter



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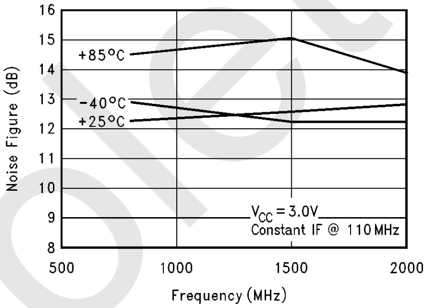
Mixer Noise Figure (Double Sideband) vs Frequency with Temperature as a Parameter



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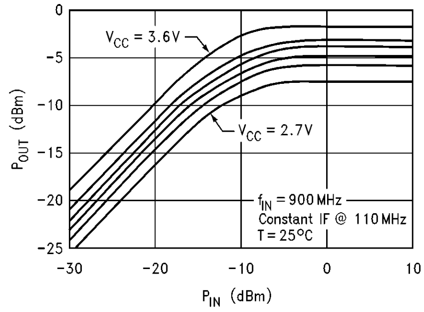
Typical Characteristics (Continued)

MIXER (Continued)

Mixer P_{OUT} vs P_{IN} with Supply Voltage as a Parameter



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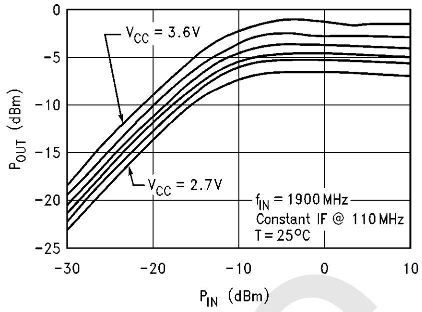
Mixer P_{OUT} vs P_{IN} with Supply Voltage as a Parameter



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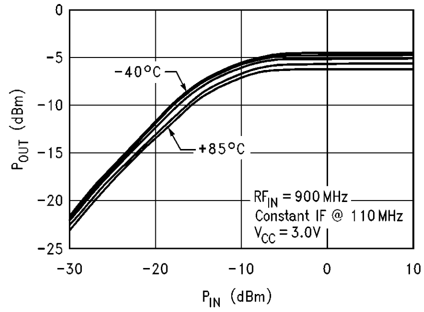
Mixer P_{OUT} vs P_{IN} with Temperature as a Parameter



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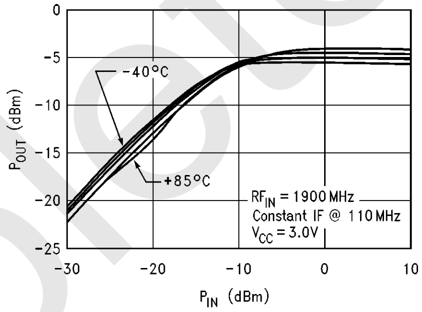
Mixer P_{OUT} vs P_{IN} with Temperature as a Parameter



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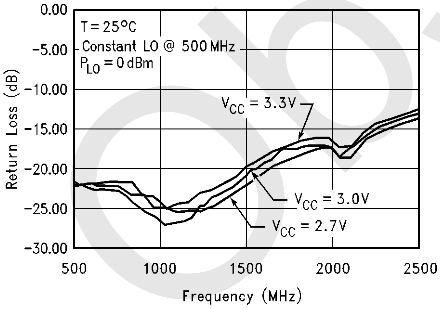
Mixer RF_{IN} Return Loss vs Frequency with Supply Voltage as a Parameter



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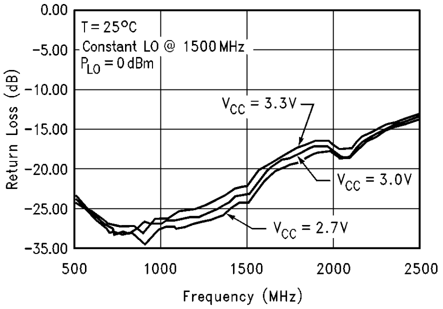
Mixer RF_{IN} Return Loss vs Frequency with Supply Voltage as a Parameter



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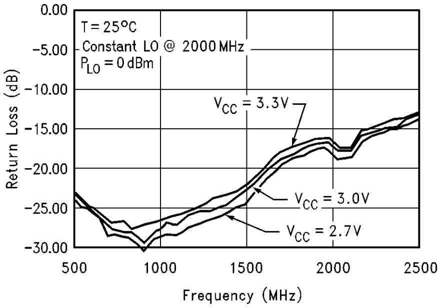
Typical Characteristics (Continued)

MIXER (Continued)

Mixer RF_{IN} Return Loss vs Frequency with Supply Voltage as a Parameter



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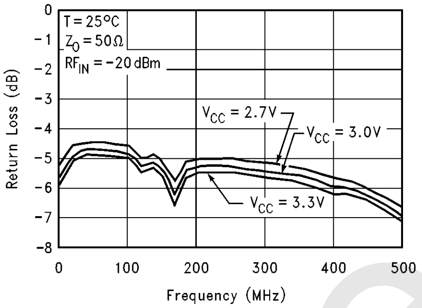
Mixer IF_{OUT} Return Loss vs Frequency with Supply Voltage as a Parameter



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Functional Description

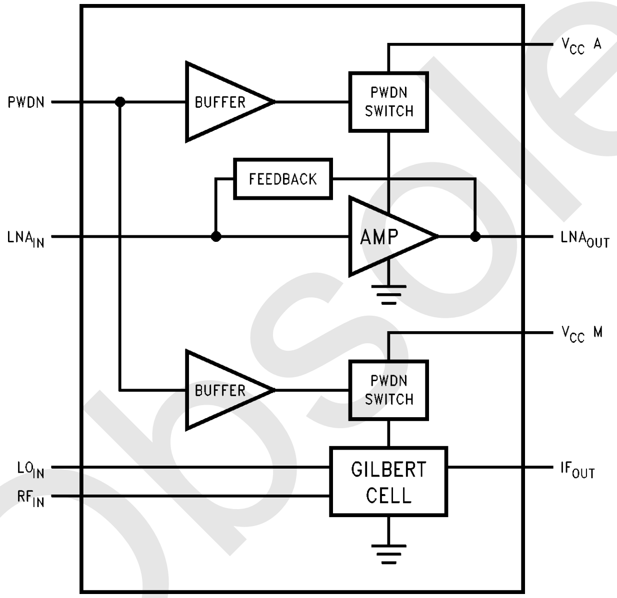

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FIGURE 3. Block Diagram of the LMX2216

Functional Description (Continued)

THE LNA

The LNA is a common emitter stage with active feedback. This feedback network allows for wide bandwidth operation while providing the necessary optimal input impedance for low noise performance. The power down feature is implemented using a CMOS buffer and a power-down switch. The power down switch is implemented with CMOS devices. During power down, the switch is open and only leakage currents are drawn from the supply.

THE MIXER

The mixer is a Gilbert cell architecture, with the RF input signal modulating the LO signal and single ended output taken from the collector of one of the upper four transistors. The power down circuitry of the mixer is similar to that of the LNA. The power down switch is used to provide or cut off bias to the Gilbert cell.

Typical Low Noise Amplifier

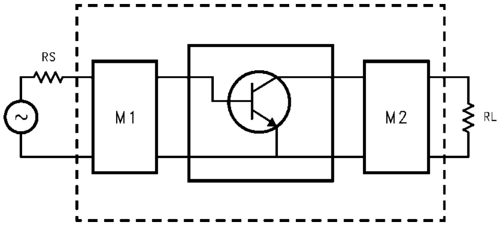

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FIGURE 4. Typical LNA Structure

A typical low noise amplifier consists of an active amplifying element and input and output matching networks. The input matching network is usually optimized for noise performance, and the output matching network for gain. The active element is chosen such that it has the lowest optimal noise figure, F_{MIN}, an intrinsic property of the device. The noise figure of a linear two-port is a function of the source admittance and can be expressed by

$$F = F_{MIN} + \frac{R_n}{G_G}\left[(G_{ON} - G_G)^2 + (B_{ON} - B_G)^2\right]$$

where $G_G + jB_G$ = generator admittance presented to the input of the two port,

$G_{ON} + jB_{ON}$ = generator admittance at which optimum noise figure occurs,

R_n = empirical constant relating the sensitivity of the noise figure to generator admittance.

Typical Gilbert Cell

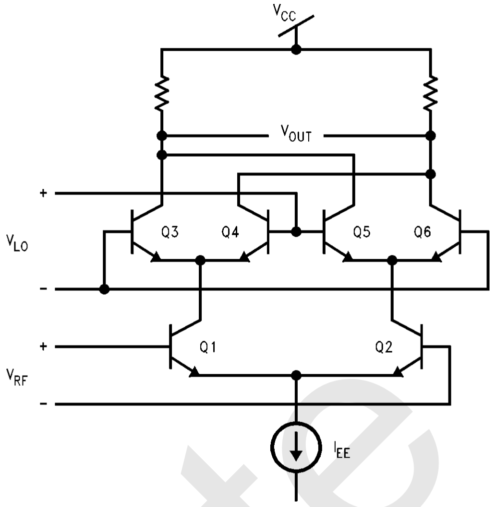

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FIGURE 5. Typical Gilbert Cell Circuit Diagram

The Gilbert cell shown above is a circuit which multiplies two input signals, RF and LO. The input RF voltage differentially modulates the currents on the collectors of the transistors Q1 and Q2, which in turn modulate the LO voltage by varying the bias currents of the transistors Q3, Q4, Q5, and Q6. Assuming that the two signals are small, the result is a product of the two signals, producing at the output a sum and difference of the frequencies of the two input signals. If either of these two signals are much larger than the threshold voltage V_T, the output will contain other mixing products and higher order terms which are undesirable and may need to be attenuated or filtered out.

Analysis of the Gilbert cell shows that the output, which is the difference of the collector currents of Q3 and Q6, is related to the two inputs by the equation:

$$\Delta I = I_{C3} - I_{C6} = I_{EE}\left[\tanh\left(\frac{V_{RF}}{2V_T}\right)\right]\left[\tanh\left(\frac{V_{LO}}{2V_T}\right)\right]$$

and the hyperbolic tangent function can be expressed as a Taylor series

$$\tanh(x) = x - \frac{x^3}{3} + \frac{x^5}{5} - \ldots$$

Assuming that the RF and LO signals are sinusoids.

$$V_{RF} = A\cos(\omega_{RF}t + \phi_{RF})$$
$$V_{LO} = B\cos(\omega_{LO}t + \phi_{LO})$$

then

$$\Delta I = I_{EE}\left[A\cos(\omega_{RF}t + \phi_{RF}) - \frac{A^3}{3}\cos^3(\omega_{RF}t + \phi_{RF}) + \ldots\right]$$
$$\bullet \left[B\cos(\omega_{LO}t + \phi_{LO}) - \frac{B^3}{3}\cos^3(\omega_{LO}t + \phi_{LO}) + \ldots\right]$$

The lowest order term is a product of two sinusoids, yielding a sum of two sinusoids,

$$I_{EE}\frac{AB}{2}\left[\begin{array}{l}\cos((\omega_{RF} + \omega_{LO})t + \phi_{RF} + \phi_{LO}) \\ + \cos((\omega_{RF} - \omega_{LO})t + \phi_{RF} - \phi_{LO})\end{array}\right]$$

one of which is the desired intermediate frequency signal.

Figures of Merit

GAIN (G)

Many different types of gain are specified in RF engineering. The type referred to here is called transducer gain and is defined as the ratio of the power delivered to the load to the available power from the source,

$$G = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT}^2/R_L}{V_{IN}^2/R_S} = 4\,\frac{R_S\,V_{OUT}^2}{R_L\,V_{IN}^2}$$

where V_{OUT} is the voltage across the load R_L and V_{IN} is the generator voltage with internal resistance R_S. In terms of scattering parameters, transducer gain is defined as

$$G = 20 \log (|S_{21}|)$$

where S_{21} is the forward transmission parameter, which can be measured using a network analyzer.

1 dB COMPRESSION POINT (P_{1dB})

A measure of amplitude linearity, 1 dB compression point is the point at which the actual gain is 1dB below the ideal linear gain. For a memoryless two-port with weak nonlinearity, the output can be represented by a power series of the input as

$$v_o = k_1\,v_i + k_2\,v_i^2 + k_3\,v_i^3 + \ \ldots$$

For a sinusoidal input,

$$v_i = A\cos \omega_1 t$$

the output is

$$v_o = \frac{1}{2}\,k_2\,A^2 + \left(k_1\,A + \frac{3}{4}\,k_3\,A^3\right)\cos \omega_1\,t + \frac{1}{2}\,k_2\,A^2 \cos 2\omega_1\,t + \frac{1}{4}\,k_3\,A^3 \cos 3\omega_1\,t$$

assuming that all of the fourth and higher order terms are negligible. For an amplifier, the fundamental component is the desired output, and it can be rewritten as

$$k_1\,A\left[1 + \frac{3}{4}\,(k_3/k_1)\,A^2\right].$$

This fundamental component is larger than k_1 A (the ideally linear gain) if $k_3 > 0$ and smaller if $k_3 < 0$. For most practical devices, $k_3 < 0$, and the gain compresses as the amplitude A of the input signal gets larger. The 1 dB compression point can be expressed in terms of either the input power or the output power. Measurement of P_{1dB} can be made by increasing the input power while observing the output power until the gain is compressed by 1 dB.

THIRD ORDER INTERCEPT (OIP_3)

Third order intercept is another figure of merit used to characterize the linearity of a two-port. It is defined as the point at which the third order intermodulation product equals the ideal linear, uncompressed, output. Unlike the P_{1dB}, OIP_3 involves two input signals. However, it can be shown mathematically (similar derivation as above) that the two are closely related and $OIP_3 \approx P_{1dB} + 10$ dB. Theses two figures of merit are illustrated in *Figure 6*.

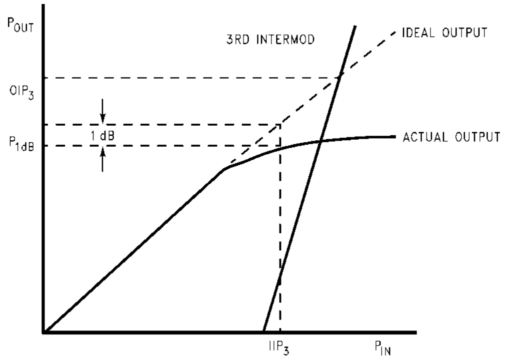

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FIGURE 6. Typical P_{OUT}–P_{IN} Characteristics

NOISE FIGURE (NF)

Noise figure is defined as the input signal to noise ratio divided by the output signal to noise ratio. For an amplifier, it can also be interpreted as the amount of noise introduced by the amplifier itself seen at the output. Mathematically,

$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i/N_i}{G_a\,S_i/(N_a + G_a\,N_i)} = \frac{N_a + G_a\,N_i}{G_a\,N_i}$$

$$NF = 10 \log (F)$$

where S_i and N_i represent the signal and noise power levels available at the input to the amplifier, S_o and N_o the signal and noise power levels available at the output, G_a the available gain, and Na the noise added by the amplifier. Noise figure is an important figure of merit used to characterize the performance of not only a single component but also the entire system. It is one of the factors which determine the system sensitivity.

IMAGE FREQUENCY, DSB/SSB NF

Image frequency refers to that frequency which is also down-converted by the mixer, along with the desired RF component, to the intermediate frequency. This image frequency is located at the same distance away from the LO, but on the opposite side of the RF. For most mixers, it must be filtered out before the signal is down-converted; otherwise, an image-reject mixer must be used. *Figure 7* illustrates the concept.

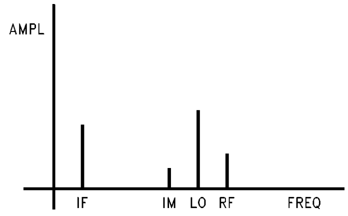

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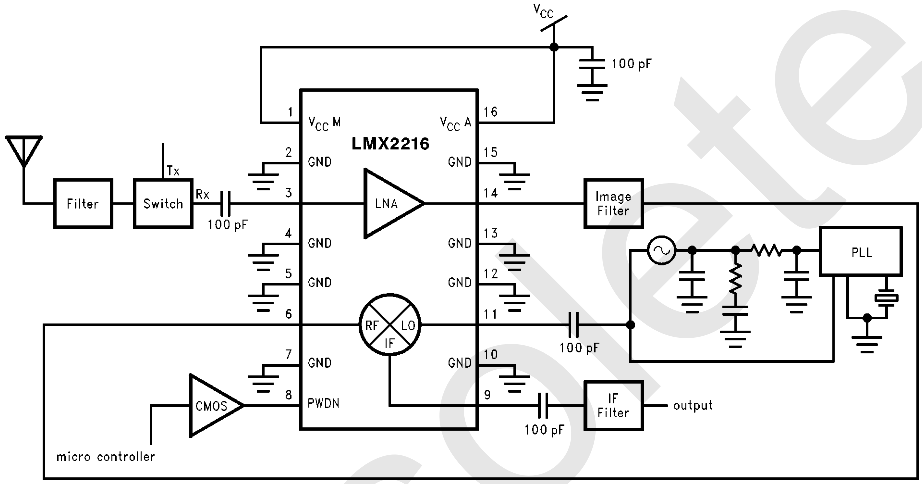
FIGURE 7. Input and Output Spectrum of Mixers

Figures of Merit (Continued)

Due to the presence of image frequencies and the method in which noise figure is defined, noise figures can be measured and specified in two ways: double side band (DSB) or single side band (SSB). In DSB measurements, the image frequency component of the input noise source is not filtered and contributes to the total output noise at the intermediate frequency. In SSB measurements. the image frequency is filtered and the output noise is not caused by this frequency component. In most mixer applications where only one side band is wanted, SSB noise figure is 3 dB *higher* than DSB noise figure.

In this application, the LMX2216 is used in a radio receiver front end, where it amplifies the signal from the antenna and then down converts it to an intermediate frequency. The image filter placed between the LNA and the mixer attenuates the image frequency. The mixer is shown to use an LO signal generated by a PLL synthesizer, but, depending on the type of application, the LO signal could be generated by a device as simple as a free-running oscillator. The IF output is then typically filtered by a channel-select filter following the mixer, and this signal can then be demodulated or go through another down conversion, depending upon the intermediate frequency and system requirements. This external filter rejects adjacent channels and also attenuates any LO feed through. Figure 9 shows a cascade analysis of a typical RF front-end subsystem in which the LMX2216 is used. It includes the bandpass filter and the switch through which the input RF signal goes in a radio system before reaching the LNA. Typical values are used for the insertion loss of the various filters in this example.



TL/W/11814–18

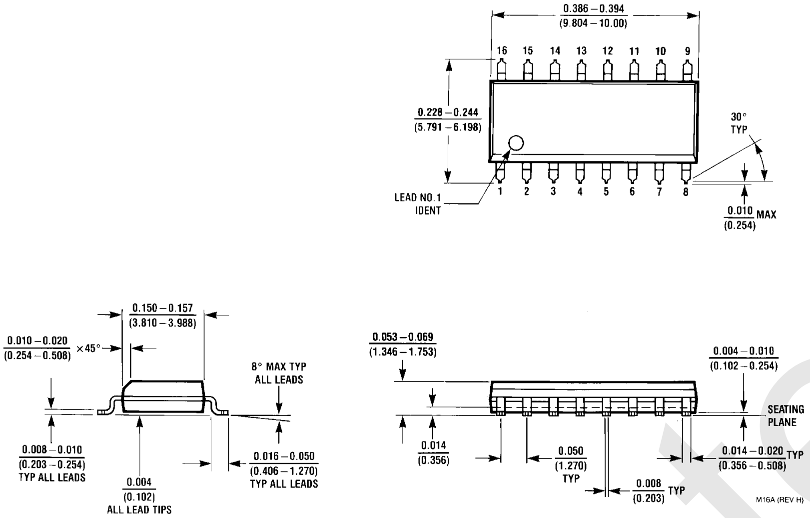
FIGURE 8. Typical Applications Circuit of the LMX2216

	Data per Stage					Cumulative Data			
#	Comp	Gain	N Fig	OIP3	#	Gain	N Fig	IIP3	OIP3
1	Filter	−2.0	2.0	100.0	1	−2.0	2.0	97.9	95.9
2	Switch	−0.6	0.6	100.0	2	−2.6	2.6	96.6	94.0
3	LNA	12.3	3.7	6.0	3	9.7	6.3	−3.7	6.0
4	Filter	−3.0	3.0	100.0	4	6.7	6.4	−3.7	3.0
5	Mixer	5.8	13.7	3.0	5	12.5	9.6	−10.5	2.0
6	Filter	−3.0	3.0	100.0	6	9.5	9.7	−10.5	−1.0

System Cumulative Values		
	Gain	9.5 dB
	N Fig	9.7 dB
	IIP_3	−10.5 dBm
	OIP_3	−1.0 dBm

FIGURE 9. Cascade Analysis Example

Physical Dimensions inches (millimeters)



JEDEC 16-Lead (0.150″ Wide) Small Outline Molded Package (M)
Order Number LMX2216M
For Tape and Reel Order Number LMX2216MX
NS Package Number M16A

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