Polyphase
MICROWAVE
A Technology Service Corporation Company

AD60100B
QUADRATURE DEMODULATOR
6 - 10 GHz

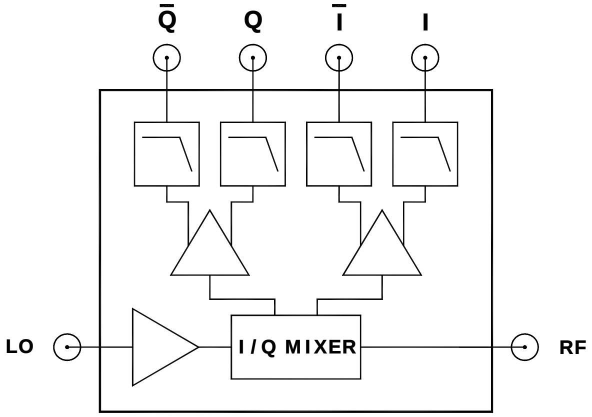
FEATURES

LO/RF Frequency:	6 – 10 GHz
I/Q Bandwidth:	275 MHz
Input IP3:	+22 dBm
Input P1dB:	+12 dBm
Amplitude Imbalance:	±0.1 dB
Phase Error:	- 2 Degrees
LO Power:	+5 dBm
DC Supplies:	+5V @ 110 mA, -5V @ 40 mA

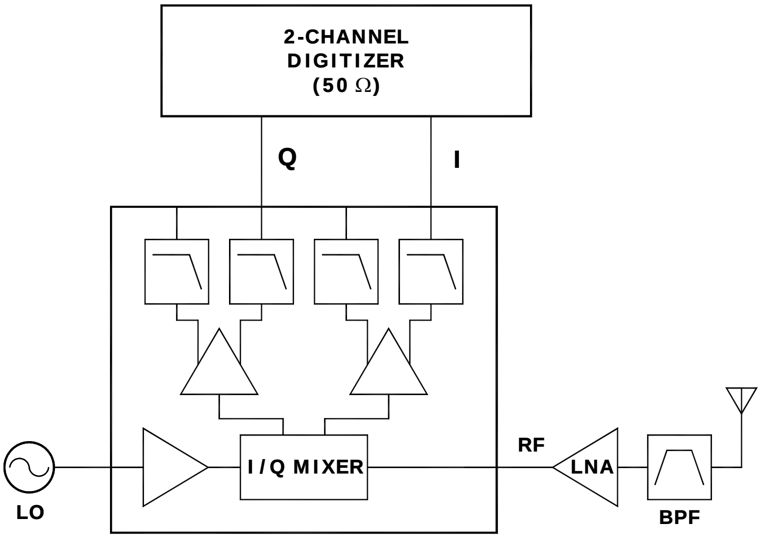
DESCRIPTION

When a LO signal is applied, the AD60100B converts the RF input signal centered at the LO frequency directly to baseband I and Q outputs. Integral low pass filters provide I and Q anti-alias filtering. The AD60100B's differential I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD60100B can be easily interfaced with differential high-speed analog-to-digital converters (ADCs). For more information, please refer to the **APPLICATIONS** section of this datasheet.



TYPICAL APPLICATION: DIRECT CONVERSION RECEIVER



ELECTRICAL SPECIFICATIONS

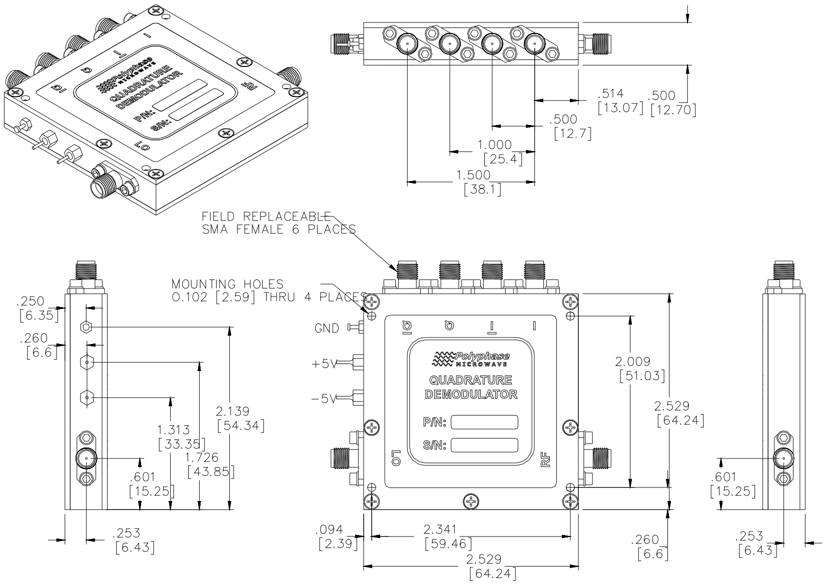
Test Conditions: +25°C, LO = +5 dBm, RF input = +0 dBm @ LO+100 kHz unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
LO/RF Frequency Range[1]		6.0		10.0	GHz
+5V DC Supply Range		+4.9	+5.0	+5.2	V
-5V DC Supply Range		-5.2	-5.0	-4.9	V
+5V DC Supply Current			110		mA
-5V DC Supply Current			40		mA
LO Power		+3	+5	+7	dBm
LO VSWR			1.5:1		Ratio
RF VSWR			2.5:1		Ratio
I/Q Baseband Filter Bandwidth[2]	<1 dB Flatness	DC		275	MHz
I/Q Baseband Filter Stop Band[2]	>25 dB Rejection	450		7000	MHz
I/Q Differential Output Impedance			100		Ω
I/Q DC Offset		-8	±4	+8	mV
Conversion Loss			7	10	dB
Noise Figure			7.5		dB
Input IP3	2-Tone, Δf = 1 MHz		+22		dBm
Input P1dB			+12		dBm
LO-RF Isolation	No RF input drive		45		dB
LO-I/Q Isolation	No RF input drive		60		dB
Amplitude Imbalance		-0.3	±0.1	+0.3	dB
Quadrature Phase Error		-6.0	-2.0	+2.5	Degree
Operating Temperature Range		-40		+85	°C
LO/RF Input Power w/o Damage				+15	dBm

Notes:

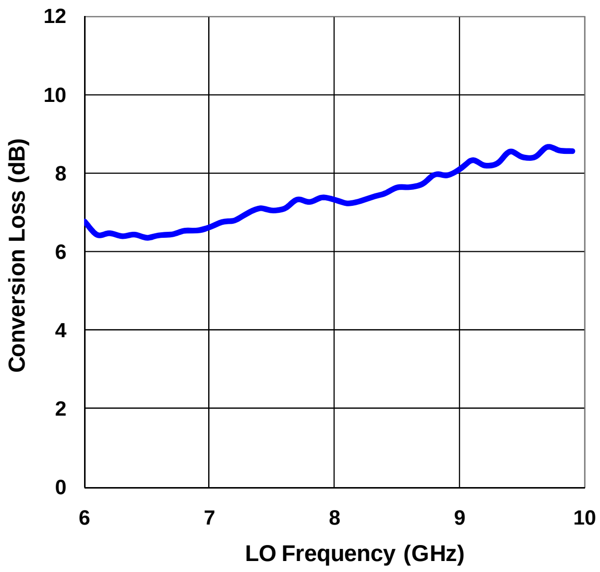
1. When RF > LO frequency: $I = \cos(), \quad Q = \sin()$
2. Standard low pass filters. Contact factory for other options.

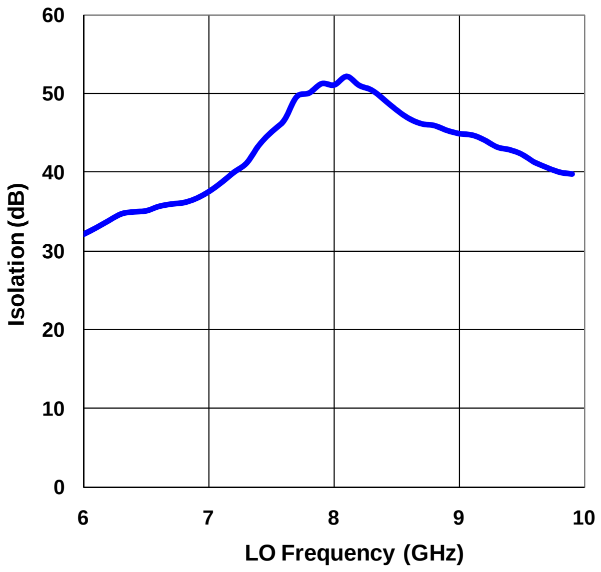
DIMENSION DRAWING

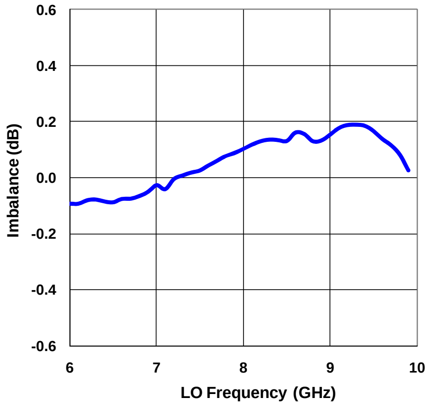


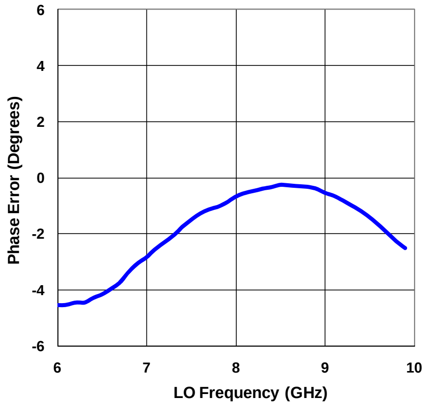
TYPICAL PERFORMANCE CHARACTERISTICS

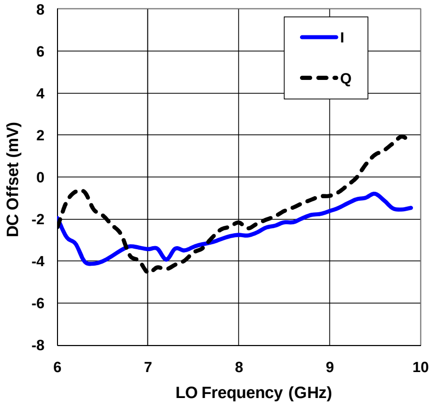
Standard Test Conditions: +25°C, LO = +5 dBm, RF = +0 dBm @ LO+100 kHz.


Conversion Loss


LO-RF Isolation


Amplitude Imbalance


Quadrature Phase Error


DC Offsets

APPLICATIONS

LO Input Drive Requirements

The AD60100B requires an LO signal be applied at +5 dBm nominal to demodulate the RF input. If the LO is pulsed, the I and Q outputs will be valid approximately 15 ns after the LO pulse is applied.

Interfacing with Differential ADCs

The AD60100B's differential I and Q outputs can be interfaced with differential high-speed analog-to-digital converters (ADCs). The AD60100B's I and Q outputs are DC-coupled with a common-mode voltage of 0 V (ground). Most ADCs have a positive input common-mode voltage requirement between 0.8 V and 2.5 V.

Series DC blocking capacitors can be used to float the I and Q signals to the ADC's common-mode voltage. Figure 1 shows the AD60100B interfaced to a dual ADC with differential inputs.

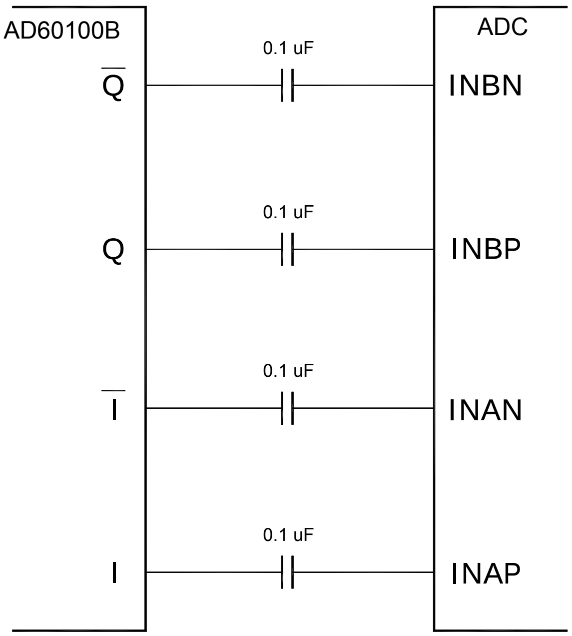


Figure 1. Differential ADC Interface

I/Q DEMODULATION

The AD60100B converts an RF signal centered at the LO frequency into I and Q baseband outputs. To understand the process of I/Q demodulation, first consider the case of an ideal demodulator. The original RF signal is defined using the complex envelope representation:

$$\mathrm{z}(t) = \mathbf{R}\left[A(t)e^{j(2\pi f_c t + \phi(t))}\right] \tag{1}$$

$\mathrm{z}(t)$ is the real time-domain signal present at the RF port of the demodulator centered at frequency f_c. $\mathrm{z}(t)$ has amplitude $A(t)$ in volts and phase $\phi(t)$ in radians. Both $A(t)$ and $\phi(t)$ are time-dependent. $\mathbf{R}[\;]$ denotes taking only the real part of the expression.

$\mathrm{z}(t)$ can be written in terms of two orthogonal signals, $I(t)$ and $Q(t)$:

$$\mathrm{z}(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t) \tag{2}$$

where

$$A(t) = \sqrt{I^2(t) + Q^2(t)} \tag{3}$$

and

$$\phi(t) = \arctan(Q(t), I(t)) \tag{4}$$

An ideal quadrature demodulator extracts the $I(t)$ and $Q(t)$ signals defined in (2). A real demodulator introduces several linear distortions including conversion loss, amplitude imbalance, quadrature phase error, I-axis phase rotation, and I/Q DC offsets. After applying these linear distortions, the real measured I and Q output signals are obtained:

$$\hat{I}(t) = C_I(\cos\theta_R I(t) - \sin\theta_R Q(t)) + B_I \tag{5}$$

$$\hat{Q}(t) = C_Q(\cos\theta_R \cos\theta_E Q(t) - \sin\theta_E I(t) + \sin\theta_R I(t)) + B_Q \tag{6}$$

C_I is the I channel conversion loss factor, C_Q is the Q channel conversion loss factor, θ_R is the I-axis phase rotation in radians, B_I is the I channel DC offset in volts, B_Q is the Q channel DC offset in volts, and θ_E is the quadrature phase error in radians.

When the LO and RF frequencies are not equal, θ_R can be set to 0 to simplify (5) and (6):

$$\hat{I}(t) = C_I I(t) + B_I \tag{7}$$

$$\hat{Q}(t) = C_Q(\cos\theta_E Q(t) - \sin\theta_E I(t)) + B_Q \tag{8}$$

θ_R is only important in applications when the phase difference between the RF and LO signals must be known (i.e. phase detector).

Example: Apply a 6 GHz CW LO signal at +5 dBm and a 6.001 GHz CW RF signal at -2 dBm. To estimate the AD60100B's $\hat{I}(t)$ and $\hat{Q}(t)$ signals, start by determining all the parameters in (7) and (8).

C_I and C_Q are determined by the conversion loss and amplitude imbalance of the AD60100B. From the datasheet's typical performance plots at 6 GHz, use 7.3 dB conversion loss and 0.1 dB amplitude imbalance to find C_I and C_Q :

$$\frac{C_I + C_Q}{2} = 10^{\left(-7.5/20\right)} = 0.4315 \tag{9}$$

$$20\log\left(\frac{C_Q}{C_I}\right) = 0.1 \tag{10}$$

$$C_I = 0.429 \qquad C_Q = 0.434 \tag{11), (12}$$

Quadrature phase error and DC offsets are also obtained from the typical performance plots at 6 GHz:

$$\theta_E = -0.5 Deg. = -0.0087 Radians \tag{13}$$

$$B_I = -0.0025V \qquad B_Q = -0.002V \tag{14), (15}$$

The next step in estimating $\hat{I}(t)$ and $\hat{Q}(t)$ is to calculate the ideal $I(t)$ and $Q(t)$ from the RF input signal. Given that the RF signal frequency is 1 kHz greater than the LO frequency, $I(t)$ and $Q(t)$ define an upper sideband tone of 1 kHz having a constant amplitude of:

$$\frac{A^2}{0.1} = 10^{\left(-2.0/10\right)} \tag{16}$$

$$A = 0.2512V \tag{17}$$

From (3) and (17) we know:

$$I(t) = 0.1776\cos(2\pi 1000t) \tag{18}$$

and

$$Q(t) = 0.1776\sin(2\pi 1000t) \tag{19}$$

The final step in estimating $\hat{I}(t)$ and $\hat{Q}(t)$, the demodulator's real I and Q outputs signals, is to insert (11), (12), (13), (14), (15), (18), and (19) into (7) and (8) giving the final result:

$$\hat{I}(t) = 0.0762\cos(2\pi 1000t) - 0.0025$$

$$\hat{Q}(t) = 0.077\sin(2\pi 1000t - 0.0087) - 0.002$$