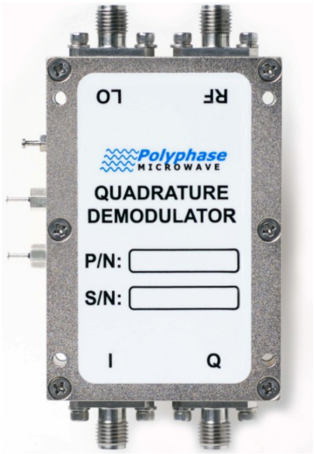
AD0540B
QUADRATURE DEMODULATOR
500 – 4000 MHz

FEATURES

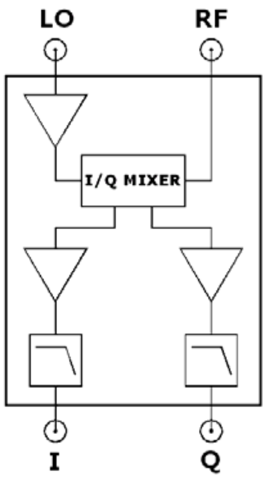
LO/RF Frequency:	500 – 4000 MHz
I/Q Bandwidth:	275 MHz
Input IP3:	+30 dBm
Input P1dB:	+12 dBm
Amplitude Imbalance:	±0.05 dB
Phase Error:	±0.5 Degree
LO Power:	+0 dBm
DC Supplies:	+5V @ 290 mA, -5V @ 50 mA



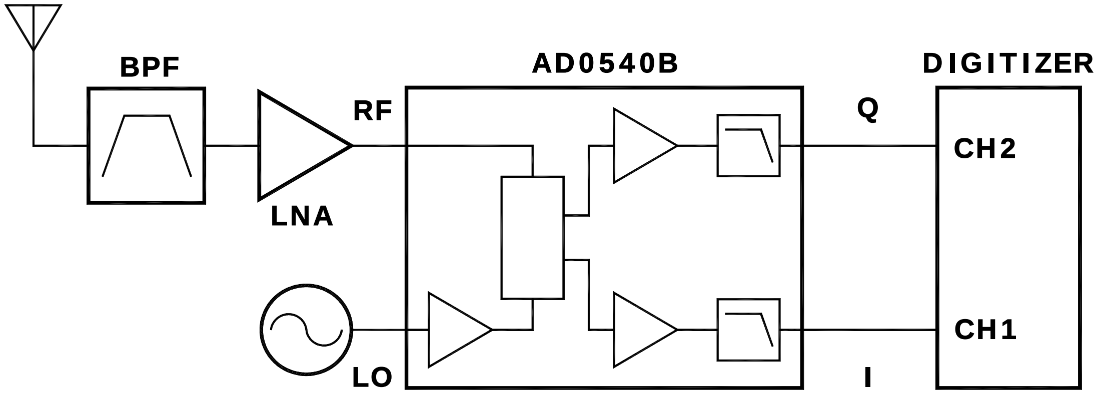
DESCRIPTION

When a LO signal is applied, the AD0540B 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 AD0540B's single-ended I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD0540B 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



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ELECTRICAL SPECIFICATIONS

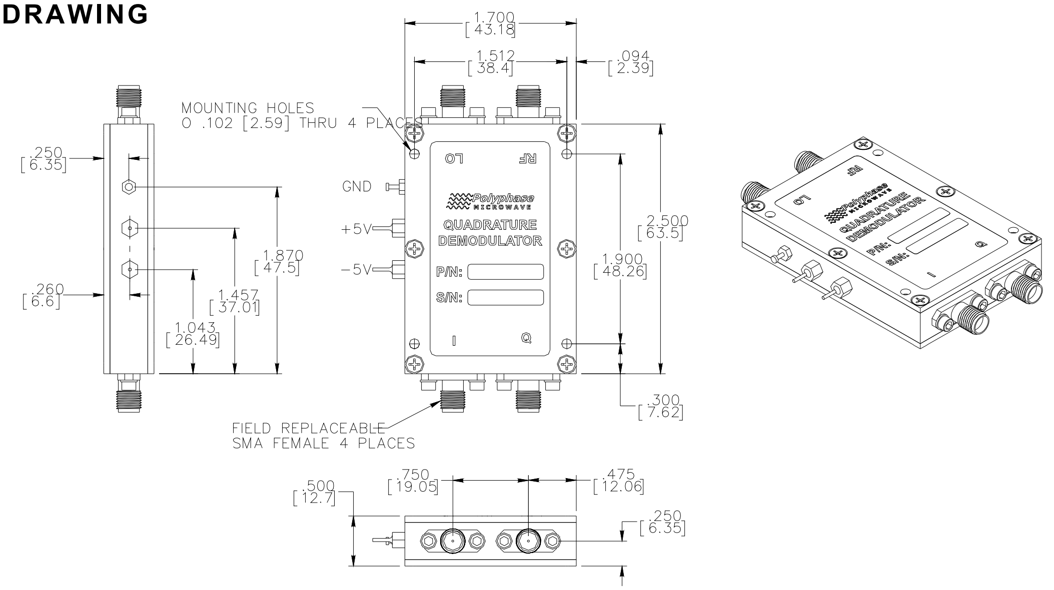
Test Conditions: +25°C, LO = +0 dBm, RF input = +0 dBm @ LO+100 kHz unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
LO/RF Frequency Range[1]		500		4000	MHz
+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			290		mA
-5V DC Supply Current			50		mA
LO Power		-3	+0	+3	dBm
LO/RF VSWR			1.5:1		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 Output Impedance			50		Ω
I/Q DC Offset		-5	±1	+5	mV
Conversion Loss			0	4	dB
Noise Figure			12		dB
Input IP2			+68		dBm
Input IP3	2-Tone, Δf = 1 MHz		+30		dBm
Input P1dB			+12		dBm
LO-RF Isolation	No RF input drive		50		dB
LO-I/Q Isolation	No RF input drive		60		dB
Amplitude Imbalance		-0.2	±0.05	+0.2	dB
Quadrature Phase Error		-2	±0.5	+2	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



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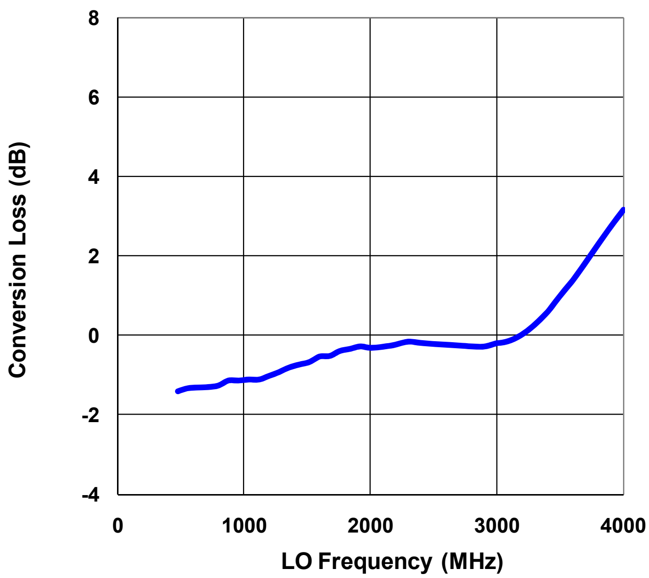
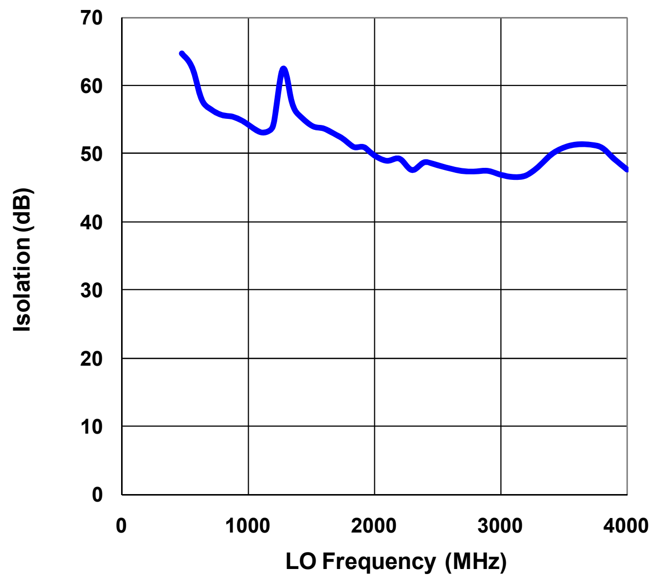
TYPICAL PERFORMANCE CHARACTERISTICS

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

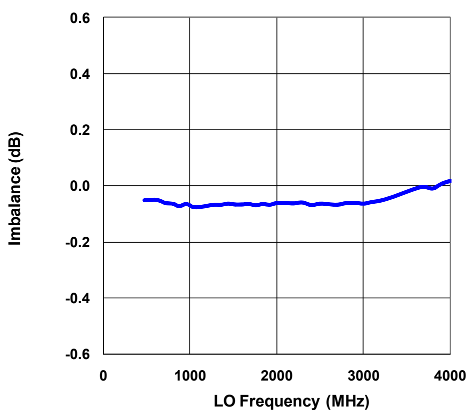
Conversion Loss



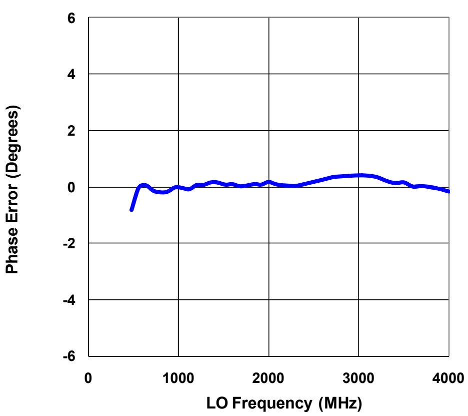
LO-RF Isolation



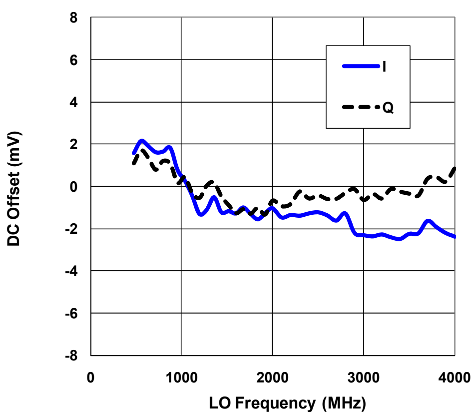
Amplitude Imbalance



Quadrature Phase Error



DC Offsets



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APPLICATIONS

LO Input Drive Requirements

The AD0540B requires an LO signal be applied at +0 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 AD0540B's single-ended I and Q outputs can be interfaced with differential high-speed analog-to-digital converters (ADCs). Figure 1 shows a single-ended to differential amplifier circuit based on the ADA4927 from Analog Devices.

The differential amplifiers in Figure 1 are DC-coupled and have a -3 dB frequency bandwidth greater than 100 MHz. The V_{OCM} inputs should be connected to the common-mode voltage required by the ADC. The ADA4927s are configured for a voltage gain of 2, an input impedance of 50 Ω (single-ended), and an output impedance of 100 Ω (differential).

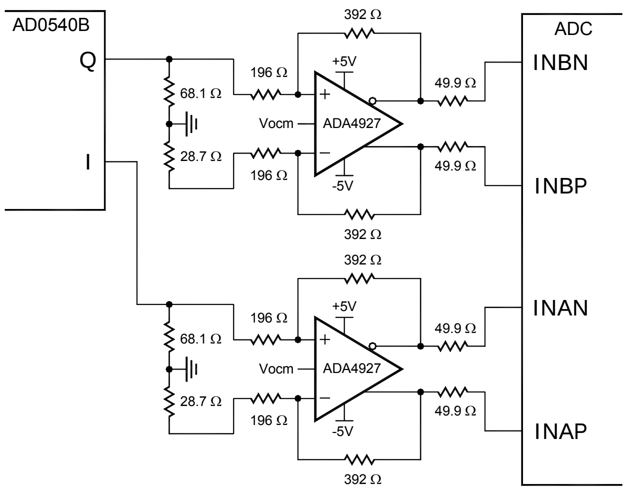

Figure 1. Differential ADC Interface

I/Q DEMODULATION

The AD0540B 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:

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

$\mathrm{z}(t)$ 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 $Q(t)$:

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

where

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

and

$$\phi(t) = \arctan(Q(t), I(t)) \quad (4)$$

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:

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

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

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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 1000 MHz CW LO signal at +0 dBm and a 1000.001 MHz CW RF signal at -2 dBm. To estimate the AD0540B'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 AD0540B. From the datasheet's typical performance plots at 1000 MHz, use -1.2 dB conversion loss and -0.07 dB amplitude imbalance to find C_I and C_Q :

$$\frac{C_I + C_Q}{2} = 10^{(1.2/20)} = 1.148 \tag{9}$$

$$20\log\left(\frac{C_Q}{C_I}\right) = -0.07 \tag{10}$$

$$C_I = 1.153 \qquad C_Q = 1.143 \qquad (11), (12)$$

Quadrature phase error and DC offsets are also obtained from the typical performance plots at 1000 MHz:

$$\theta_E = -0.1 Deg. = -0.002 Radians \tag{13}$$

$$B_I = 0.0003V \qquad B_Q = 0.0001V \qquad (14), (15)$$

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:

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

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

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:

$$\hat{I}(t) = 0.205\cos(2\pi 1000t) + .0003$$

$$\hat{Q}(t) = 0.203\sin(2\pi 1000t - 0.002) + 0.0001$$