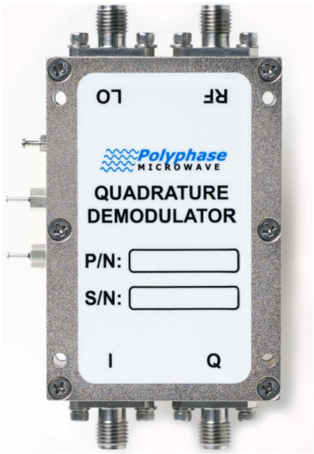
AD0105B
QUADRATURE DEMODULATOR
100 – 500 MHz

FEATURES

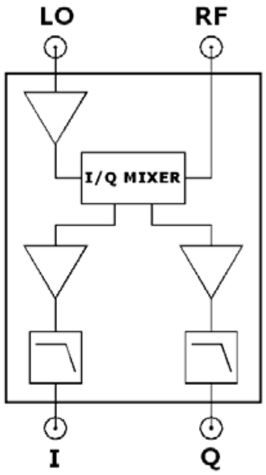
LO/RF Frequency:	100 – 500 MHz
I/Q Bandwidth:	100 MHz
Input IP3:	+30 dBm
Input P1dB:	+15 dBm
Amplitude Imbalance:	±0.1 dB
Phase Error:	±1.5 Degree
LO Power:	+5 dBm
DC Power:	+5V @ 100 mA, -5V @ 50 mA



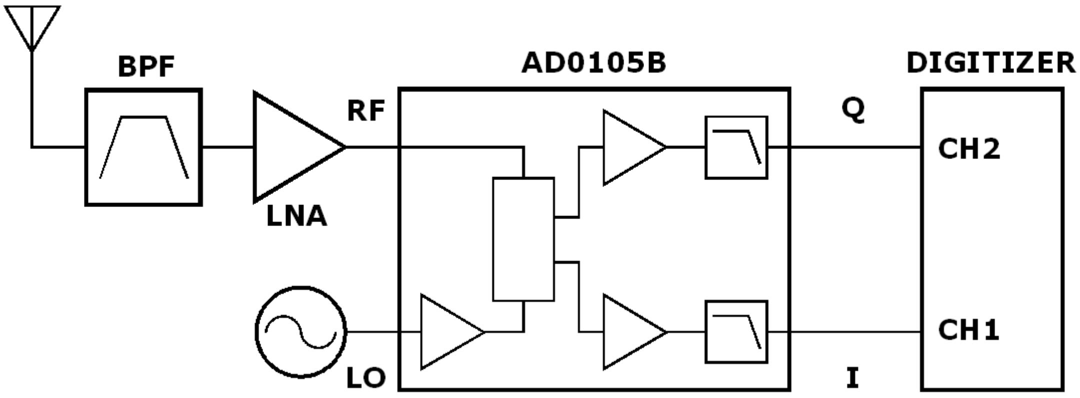
DESCRIPTION

When a LO signal is applied, the AD0105B 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 AD0105B's single-ended I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD0105B 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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AD0105B

ELECTRICAL SPECIFICATIONS

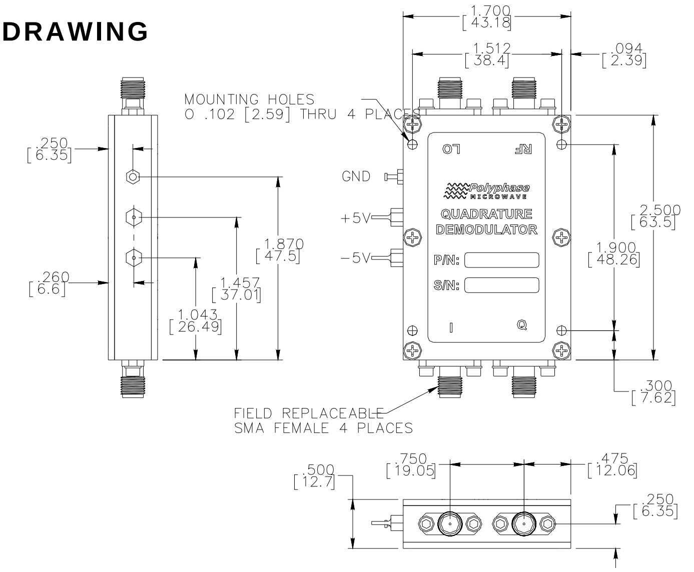
Test Conditions: +25°C, LO = +5 dBm, RF input = 0 dBm @ LO+100 kHz unless otherwise noted.

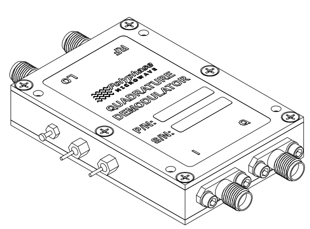
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
LO/RF Frequency Range[1]		100		500	MHz
+5V DC Supply Range		+4.9	+5.0	+5.2	V
-5V DC Supply Range		-5.2	-5.0	-4.9	V
+5V DC Supply Current			100		mA
-5V DC Supply Current			50		mA
LO Power		+3	+5	+6	dBm
LO/RF VSWR			1.5:1		Ratio
I/Q Baseband Filter Bandwidth[2]	<1 dB Flatness	DC		100	MHz
I/Q Baseband Filter Stop Band[2]	>25 dB Rejection	250		7000	MHz
I/Q Output Impedance			50		Ω
I/Q DC Offset		-5	±2	+5	mV
Conversion Loss			7.5	9.0	dB
Noise Figure			16		dB
Input IP2			+67		dBm
Input IP3	2-Tone, Δf = 1 MHz		+30		dBm
Input P1dB			+15		dBm
LO-RF Isolation	No RF input drive		60		dB
LO-I/Q Isolation	No RF input drive		60		dB
Amplitude Imbalance		-0.2	±0.1	+0.2	dB
Quadrature Phase Error		-6	±1.5	+3	Degree
Operating Temperature Range		-40		+85	°C
LO Input Power w/o Damage				+10	dBm
RF Input Power w/o Damage				+20	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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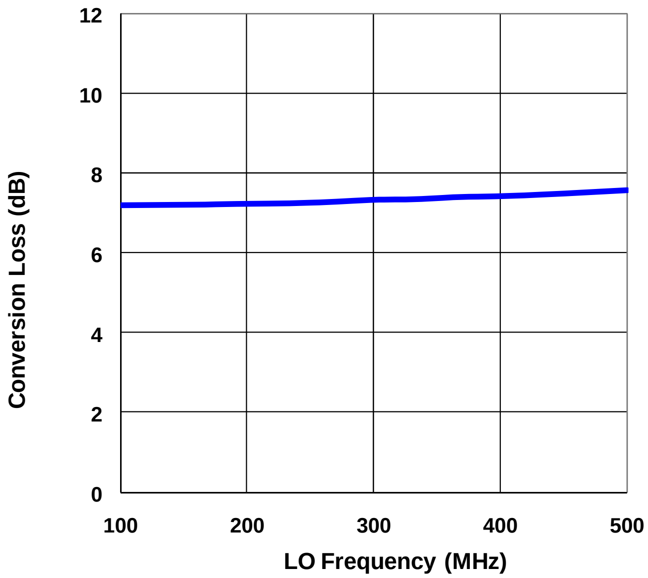
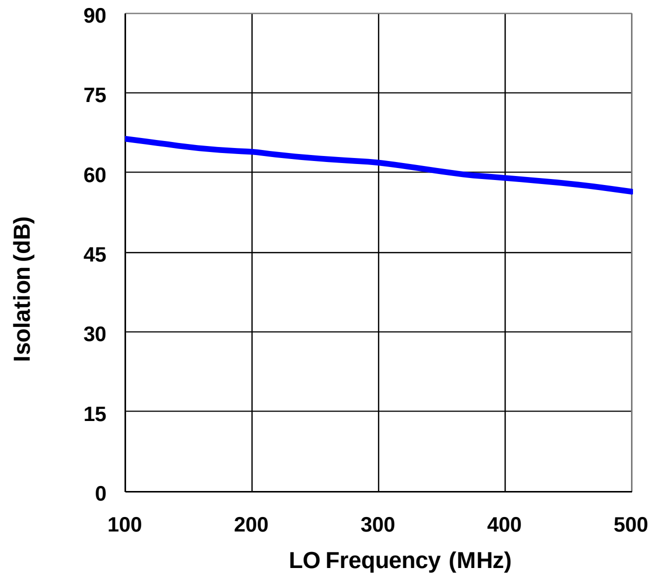
TYPICAL PERFORMANCE CHARACTERISTICS

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

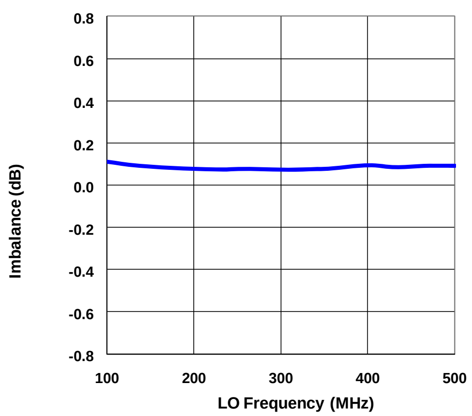
Conversion Loss



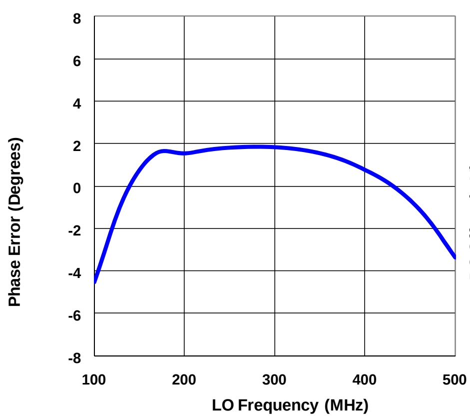
LO-RF Isolation



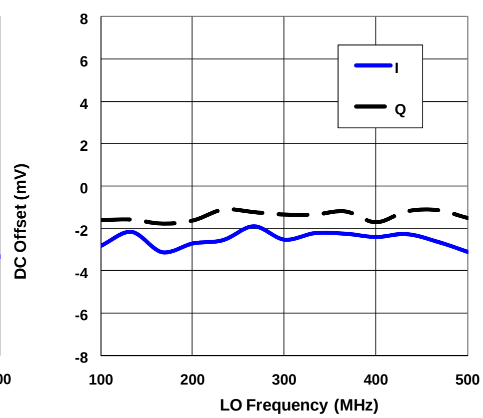
Amplitude Imbalance



Quadrature Phase Error



DC Offsets



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APPLICATIONS

LO Input Drive Requirements

The AD0105B 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 AD0105B'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).

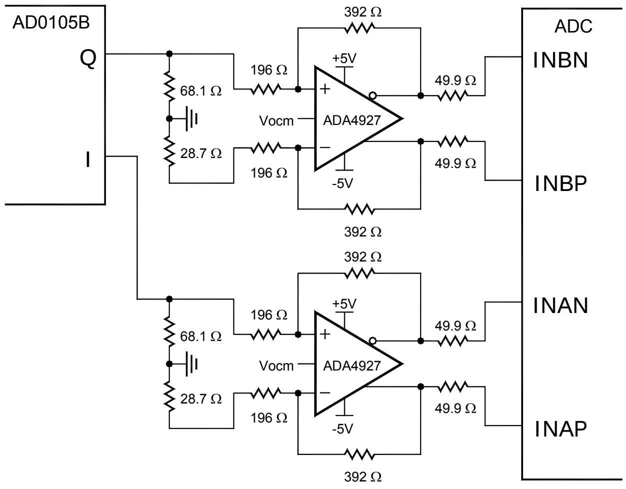

Figure 1. Differential ADC Interface

I/Q DEMODULATION

The AD0105B 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:

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

$z(t)$ is the real time-domain signal present at the RF port of the demodulator centered at frequency f_c. $z(t)$ 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.

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

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

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:

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

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

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):

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

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

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 300 MHz CW LO signal at +5 dBm and a 300.001 MHz CW RF signal at -2 dBm. To estimate the AD0105B'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 AD0105B. From the datasheet's typical performance plots at 300 MHz, use 7.5 dB conversion loss and 0.08 dB amplitude imbalance to find C_I and C_Q :

$$\frac{C_I + C_Q}{2} = 10^{(-7.5/20)} = 10.4217 \quad (9)$$

$$20\log(\frac{C_Q}{C_I}) = 0.08 \quad (10)$$

$$C_I = 0.4198 \qquad C_Q = 0.4236 \quad (11), (12)$$

Quadrature phase error and DC offsets are also obtained from the typical performance plots at 300 MHz:

$$\theta_E = 1.9 Deg. = 0.033 Radians \quad (13)$$

$$B_I = -0.0024V \qquad B_Q = -0.0015V \quad (14), (15)$$

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:

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

$$A = 0.2512V \quad (17)$$

From (3) and (17) we know:

$$I(t) = 0.1776\cos(2\pi 1000t) \quad (18)$$

and

$$Q(t) = 0.1776\sin(2\pi 1000t) \quad (19)$$

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:

$$\hat{I}(t) = 0.0746\cos(2\pi 1000t) - .0024$$

$$\hat{Q}(t) = 0.0752\sin(2\pi 1000t + 0.033) - 0.0015$$

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