

AD0460B
QUADRATURE DEMODULATOR
400 – 6000 MHz

FEATURES

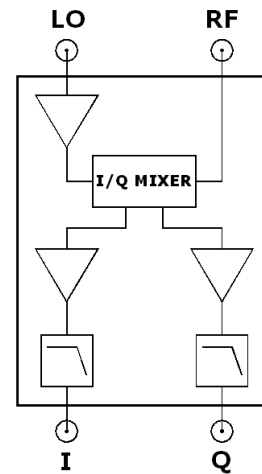
| | |
|----------------------|---------------------------|
| LO/RF Frequency: | 400 – 6000 MHz |
| I/Q Bandwidth: | 275 MHz |
| Input P1dB: | +12 dBm |
| Amplitude Imbalance: | ±0.05 dB |
| Phase Error: | ±0.5 Degree |
| LO Power: | +0 dBm |
| DC Supplies: | +5V @ 290 mA, -5V @ 50 mA |



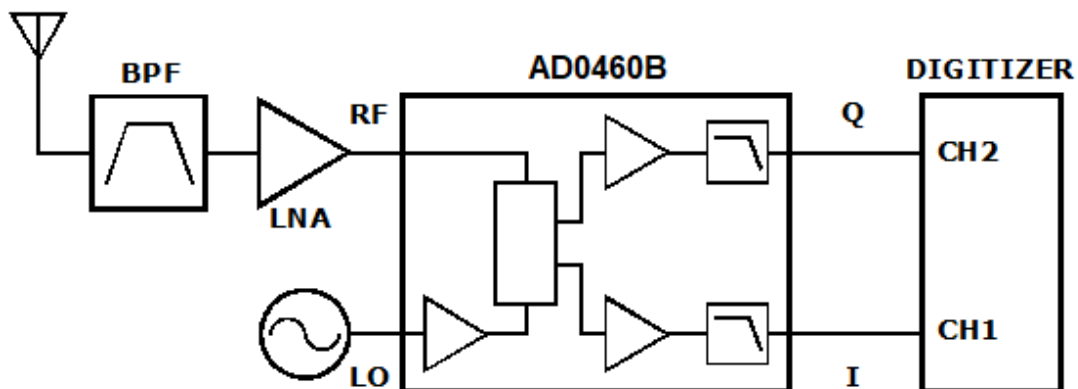
DESCRIPTION

When a LO signal is applied, the AD0460B 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 AD0460B's single-ended I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD0460B 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

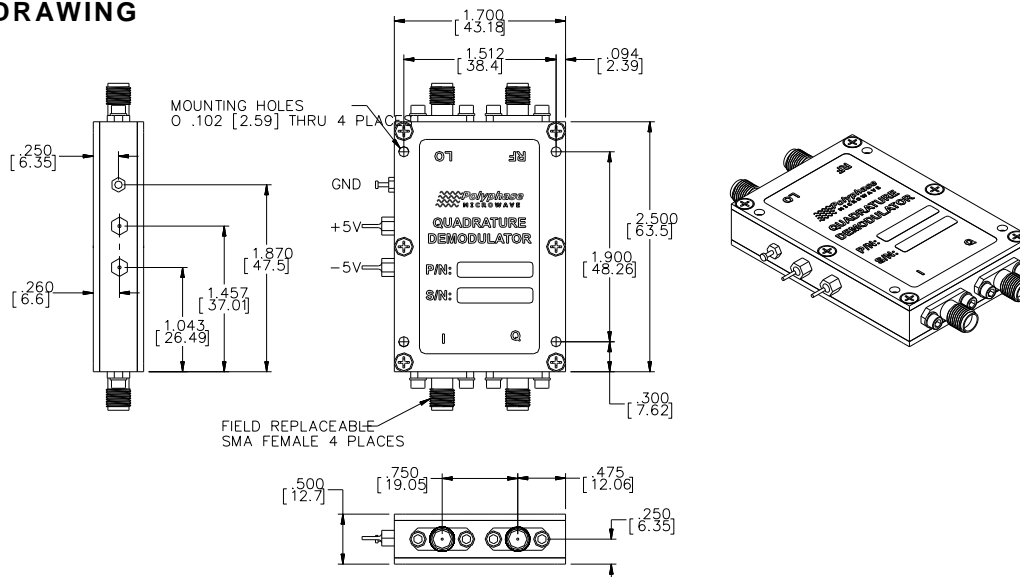
Test Conditions: +25°C, LO = +0 dBm, RF input = +0 dBm @ LO+100 kHz unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|--|-------------------|------|-------|------|--------|
| LO/RF Frequency Range ¹ | | 400 | | 6000 | 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 | | | 0.5 | 6 | dB |
| 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:

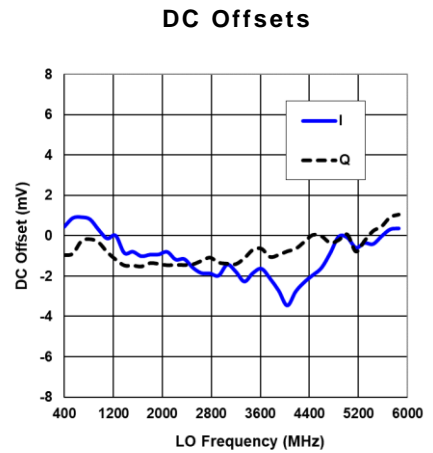
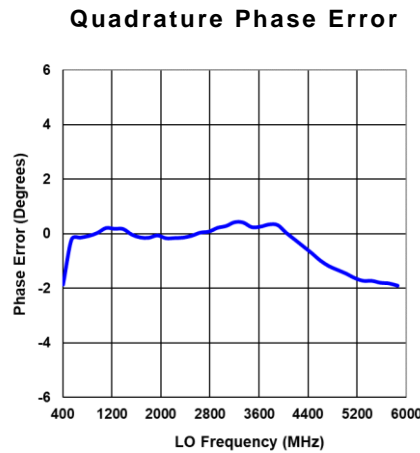
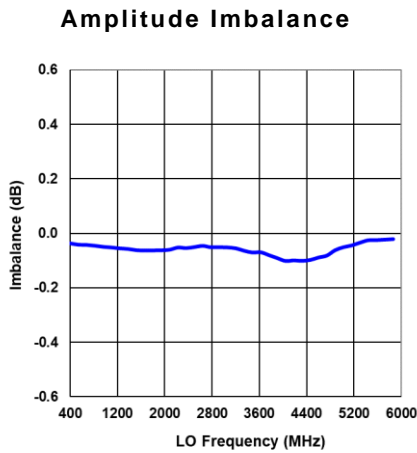
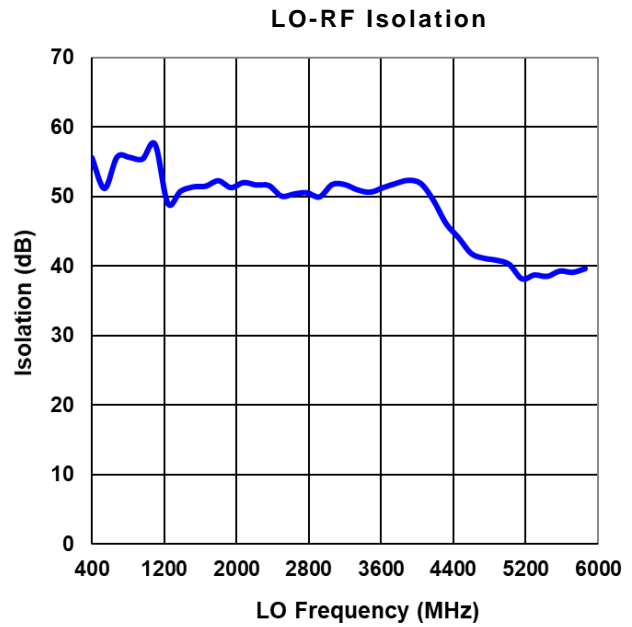
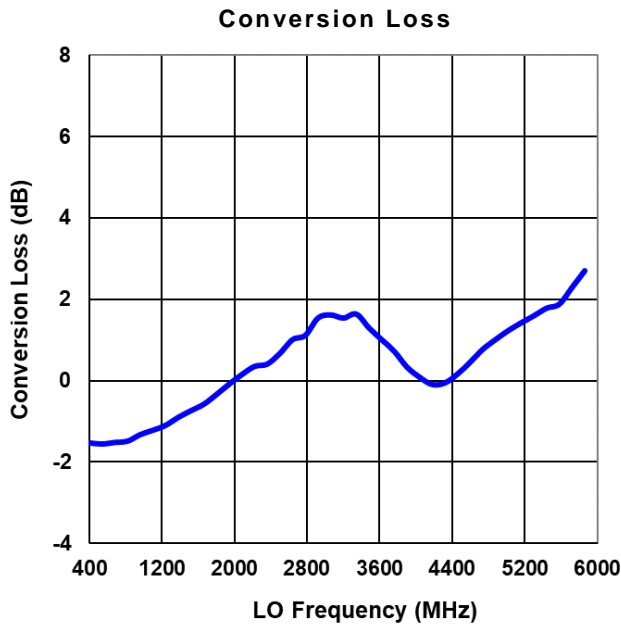
1. When RF > LO frequency: I = cos(), Q = sin()
2. Standard low pass filters. Contact factory for other options.

DIMENSION DRAWING



TYPICAL PERFORMANCE CHARACTERISTICS

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



APPLICATIONS

LO Input Drive Requirements

The AD0460B 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 AD0460B'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 50Ω (single-ended), and an output impedance of 100Ω (differential).

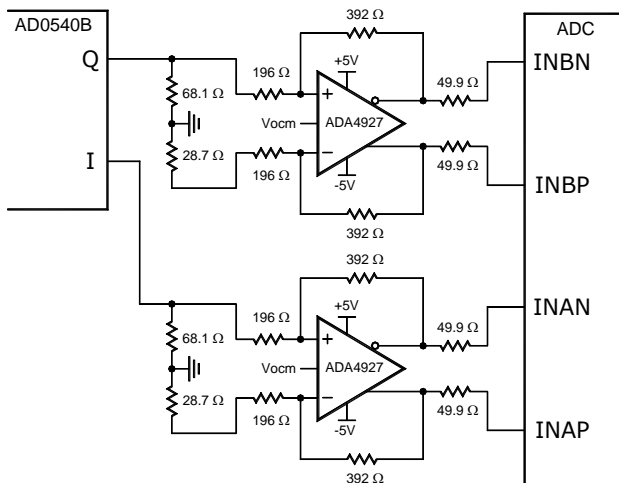


Figure 1. Differential ADC Interface

I/Q DEMODULATION

The AD0460B 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 $Q(t)$:

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

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:

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

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

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 1000 MHz CW LO signal at +0 dBm and a 1000.001 MHz CW RF signal at -2 dBm. To estimate the AD0460B'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 AD0460B. 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 :

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

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

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

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

$$\theta_E = -0.1 \text{ Deg.} = -0.002 \text{ Radians} \quad (13)$$

$$B_I = 0.0003 \text{ V} \quad B_Q = 0.0001 \text{ V} \quad (14), (15)$$

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:

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

$$A = 0.2512 \text{ V} \quad (17)$$

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:

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

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