FEATURES
LO/RF Frequency: 11 – 14 GHz
I/Q Bandwidth: 275 MHz
Input IP3: +20 dBm
Input P1dB: +12 dBm
Amplitude Imbalance: ±0.2 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 AD110140B 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 AD110140B’s differential I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD110140B 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.

<table>
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<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
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<tr>
<td>LO/RF Frequency Range</td>
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<td>11.0</td>
<td>14.0</td>
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<td>GHz</td>
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<td>+5V DC Supply Range</td>
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<td>+4.9</td>
<td>+5.0</td>
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<tr>
<td>+5V DC Supply Current</td>
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<td>LO Power</td>
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<td>+5</td>
<td>+7</td>
<td>dBm</td>
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<td>LO VSWR</td>
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<td>1.5:1</td>
<td>Ratio</td>
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<td>RF VSWR</td>
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<td>2.5:1</td>
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<td>I/Q Baseband Filter Bandwidth&lt;1 dB Flatness</td>
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<td>2-Tone, Δf = 1 MHz</td>
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<td></td>
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<tr>
<td>Input P1dB</td>
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<td>+12</td>
<td></td>
<td></td>
<td>dBm</td>
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<td>+3.0</td>
<td>Degree</td>
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<td>Operating Temperature Range</td>
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<td>dBm</td>
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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 = +5 dBm, RF = +0 dBm @ LO+100 kHz.
APPLICATIONS

LO Input Drive Requirements
The AD110140B 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 AD110140B’s differential I and Q outputs can be interfaced with differential high-speed analog-to-digital converters (ADCs). The AD110140B’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 AD110140B interfaced to a dual ADC with differential inputs.

I/Q DEMODULATION
The AD110140B 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:

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

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

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

\[ z(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t) \]  

where:

\[ A(t) = \sqrt{I^2(t) + Q^2(t)} \]  

and

\[ \phi(t) = \arctan(Q(t), I(t)) \]

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:

\[ \hat{I}(t) = C_I (\cos \theta_R I(t) - \sin \theta_R Q(t)) + B_I \]  

\[ \hat{Q}(t) = C_Q (\cos \theta_R \cos \theta_E Q(t) - \sin \theta_E I(t) + \sin \theta_R I(t)) + B_Q \]

Figure 1. Differential ADC Interface
$C_I$ is the I channel conversion loss factor, $C_Q$ is the Q channel conversion loss factor, $\theta_R$ 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 $\theta_E$ is the quadrature phase error in radians.

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

$$\hat{I}(t) = C_I I(t) + B_I \quad (7)$$
$$\hat{Q}(t) = C_Q (\cos \theta_E Q(t) - \sin \theta_E I(t)) + B_Q \quad (8)$$

$\theta_R$ 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 12 GHz CW LO signal at +5 dBm and a 12.001 GHz CW RF signal at -2 dBm. To estimate the AD110140B’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 AD110140B. From the datasheet’s typical performance plots at 12 GHz, use 8.8 dB conversion loss and -0.21 dB amplitude imbalance to find $C_I$ and $C_Q$:

$$\frac{C_I + C_Q}{2} = 10^{(-8.8/20)} = 0.3631 \quad (9)$$
$$20 \log \left(\frac{C_Q}{C_I}\right) = -0.21 \quad (10)$$

$C_I = 0.3675 \quad C_Q = 0.3587 \quad (11), (12)$

Quadrature phase error and DC offsets are also obtained from the typical performance plots at 12 GHz:

$$\theta_E = -1.5 \text{Deg.} = -0.026 \text{Radians} \quad (13)$$
$$B_I = -0.005 V \quad B_Q = -0.004 V \quad (14), (15)$$

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:

$$A^2 = 10^{(-2.9/10)} \quad (16)$$
$$A = 0.2512 V \quad (17)$$

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:

$$\hat{I}(t) = 0.065 \cos(2\pi 1000t) - 0.005$$
$$\hat{Q}(t) = 0.064 \sin(2\pi 1000t - 0.026) - 0.004$$