FEATURES

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO/RF Frequency</td>
<td>4.0 – 8.0 GHz</td>
</tr>
<tr>
<td>I/Q Bandwidth</td>
<td>275 MHz</td>
</tr>
<tr>
<td>Input IP3</td>
<td>+23 dBm</td>
</tr>
<tr>
<td>Input P1dB</td>
<td>+14 dBm</td>
</tr>
<tr>
<td>Amplitude Imbalance</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>Phase Error</td>
<td>±2 Degrees</td>
</tr>
<tr>
<td>LO Power</td>
<td>+4 dBm</td>
</tr>
<tr>
<td>DC Supplies</td>
<td>+5V @ 110 mA, -5V @ 40 mA</td>
</tr>
</tbody>
</table>

DESCRIPTION

When a LO signal is applied, the AD4080B 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 AD4080B’s differential I and Q outputs can be directly connected to 50 Ω digitizers or instrumentation.

The AD4080B 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>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO/RF Frequency Range¹</td>
<td></td>
<td>4.0</td>
<td>8.0</td>
<td></td>
<td>GHz</td>
</tr>
<tr>
<td>+5V DC Supply Range</td>
<td></td>
<td>+4.9</td>
<td>5.0</td>
<td>+5.2</td>
<td>V</td>
</tr>
<tr>
<td>-5V DC Supply Range</td>
<td></td>
<td>-5.2</td>
<td>-5.0</td>
<td>-4.9</td>
<td>V</td>
</tr>
<tr>
<td>+5V DC Supply Current</td>
<td></td>
<td>110</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>-5V DC Supply Current</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>LO Power</td>
<td></td>
<td>+2</td>
<td>+4</td>
<td>+6</td>
<td>dBm</td>
</tr>
<tr>
<td>LO VSWR</td>
<td></td>
<td>1.5:1</td>
<td></td>
<td></td>
<td>Ratio</td>
</tr>
<tr>
<td>RF VSWR</td>
<td></td>
<td>2.5:1</td>
<td></td>
<td></td>
<td>Ratio</td>
</tr>
<tr>
<td>I/Q Baseband Filter Bandwidth²</td>
<td></td>
<td>&lt;1 dB Flatness</td>
<td>DC</td>
<td>275</td>
<td>MHz</td>
</tr>
<tr>
<td>I/Q Baseband Filter Stop Band²</td>
<td></td>
<td>&gt;25 dB Rejection</td>
<td>450</td>
<td>7000</td>
<td>MHz</td>
</tr>
<tr>
<td>I/Q Differential Output Impedance</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>I/Q DC Offset</td>
<td></td>
<td>-10</td>
<td>±3</td>
<td>+10</td>
<td>mV</td>
</tr>
<tr>
<td>Conversion Loss</td>
<td></td>
<td>8</td>
<td>10</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Noise Figure</td>
<td></td>
<td>8.5</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Input IP3</td>
<td>2-Tone, Δf = 1 MHz</td>
<td>23</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>Input P1dB</td>
<td></td>
<td>14</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
<tr>
<td>LO-RF Isolation</td>
<td>No RF input drive</td>
<td>40</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>LO-I/Q Isolation</td>
<td>No RF input drive</td>
<td>60</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Amplitude Imbalance</td>
<td></td>
<td>-0.3</td>
<td>±0.1</td>
<td>+0.3</td>
<td>dB</td>
</tr>
<tr>
<td>Quadrature Phase Error</td>
<td></td>
<td>-4.0</td>
<td>±2</td>
<td>+4.0</td>
<td>Degree</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td></td>
<td>-40</td>
<td></td>
<td>+85</td>
<td>°C</td>
</tr>
<tr>
<td>LO/RF Input Power w/o Damage</td>
<td></td>
<td>+15</td>
<td></td>
<td></td>
<td>dBm</td>
</tr>
</tbody>
</table>

Notes:

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

### DIMENSION DRAWING

[Diagram of the AD4080B component dimensions]
TYPICAL PERFORMANCE CHARACTERISTICS
Standard Test Conditions: +25°C, LO = +4 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 AD4080B requires an LO signal be applied at +4 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 AD4080B’s differential I and Q outputs can be interfaced with differential high-speed analog-to-digital converters (ADCs). The AD4080B’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 AD4080B interfaced to a dual ADC with differential inputs.

I/Q DEMODULATION
The AD4080B 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:

\[ z(t) = R[A(t)e^{j(2\pi f_c t + \phi(t))}] \] (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. \( R[ ] \) denotes taking only the real part of the expression.

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

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

where

\[ A(t) = \sqrt{I^2(t) + Q^2(t)} \] (3)

and

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

\[ \hat{I}(t) = C_I(\cos\theta_R I(t) + \sin\theta_R Q(t)) + B_I \] (5)

\[ \hat{Q}(t) = C_Q(\cos\theta_R \cos\theta_E Q(t) - \sin\theta_E I(t) + \sin\theta_R I(t)) + B_Q \] (6)
\( C_I \) is the I channel conversion loss factor, \( C_Q \) is the Q channel conversion loss factor, \( \theta_k \) 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, \( \theta_k \) can be set to 0 to simplify (5) and (6):

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

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

\( \theta_k \) 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 5 GHz CW LO signal at +4 dBm and a 5.001 GHz CW RF signal at -2 dBm. To estimate the AD4080B’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 AD4080B. From the datasheet’s typical performance plots at 5 GHz, use 7 dB conversion loss and -0.1 dB amplitude imbalance to find \( C_I \) and \( C_Q \):

\[
\frac{C_I + C_Q}{2} = 10^{-7/20} = 0.4467 \quad (9)
\]

\[
20 \log \left( \frac{C_Q}{C_I} \right) = -0.1 \quad (10)
\]

\( C_I = 0.4493 \quad C_Q = 0.4441 \quad (11), (12) \)

Quadrature phase error and DC offsets are also obtained from the typical performance plots at 5 GHz:

\[
\theta_E = -2.1 \text{ Deg.} = -0.037 \text{ Radians} \quad (13)
\]

\[
B_I = -0.0015V \quad B_Q = -0.003V \quad (14), (15)
\]

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:

\[
A^2 = 10^{(-2.9/10)}
\]

\[
A = 0.2512V
\]

From (3) and (17) we know:

\[
I(t) = 0.1776 \cos(2\pi 1000t)
\]

and

\[
Q(t) = 0.1776 \sin(2\pi 1000t)
\]

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:

\[
\hat{I}(t) = 0.080 \cos(2\pi 1000t) - 0.0015
\]

\[
\hat{Q}(t) = 0.079 \sin(2\pi 1000t - 0.037) - 0.003
\]