

Wideband LO PLL Synthesizer with Simple Interface to Quadrature Demodulators

CIRCUIT FUNCTION AND BENEFITS

The circuit, shown in Figure 1, highlights the ease of interfacing the ADF4350 wideband synthesizer with integrated VCO with the ADL5380 and ADL5387 wideband I/Q demodulators. In this circuit, the ADF4350 provides the high frequency, low phase noise local oscillator (LO) signal to the wideband I/Q demodulator.

This circuit configuration offers quite a few benefits that make it an attractive solution in applications requiring quadrature mixing down to baseband or to an intermediate frequency. The ADF4350 offers RF differential outputs and, likewise, the ADL5380/ADL5387 accept differential inputs. This interface offers both ease of use and performance advantages. The differential signal configuration provides common-mode noise reduction and even order cancellation of the LO harmonics, which maintains the quadrature accuracy of the I/Q demodulators. Additionally, the output power level of the ADF4350 matches the input power requirements of the quadrature demodulators very well. As a result, an LO buffer is not necessary.

The ADF4350 outputs cover a wide frequency range from 137.5 MHz to 4400 MHz. The ADL5387 frequency range spans from 50 MHz to 2 GHz, and the ADL5380 covers the higher frequency range from 400 MHz to 6 GHz. Between the ADL5380 and ADL5387 the RF input range can span from 50 MHz to 6 GHz. Therefore, the two chip circuit configuration as shown in Figure 1 offers coverage of a wide frequency range from 50 MHz to 4400 GHz.



Figure 1. Simple Interface Between the ADF4350 PLL Synthesizer and the ADL5380 or ADL5387 Quadrature Demodulator (Simplified Schematic: All Connections and Decoupling Not Shown)

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REVISION HISTORY

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Deleted Evaluation and Design Support Section	1
Changes to Circuit Functions and Benefits Section	1
Deleted Circuit Evaluation and Test Section, Equipment Needed Section, Test Section, Figure 9, Learn	
More Section, and Data Sheets and Evaluation Boards Section	3

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CIRCUIT DESCRIPTION

The ADF4350 is a wideband fractional-N and integer-N phaselocked loop frequency synthesizer covering the frequency range of 137.5 MHz to 4400 MHz. The ADF4350 has an integrated voltage controlled oscillator (VCO) with a fundamental frequency range of 2200 MHz to 4400 MHz. The ADF4350 offers high quality synthesizer performance. However, depending on the demodulator architecture, LO filtering may be required to minimize the effects of harmonics from the PLL on the quadrature accuracy of the I/Q demodulator.

Analog Devices offers quadrature demodulators that cover a wide frequency range. The ADL5387 frequency range spans from 50 MHz to 2 GHz, and the ADL5380 covers the higher frequency range from 400 MHz to 6 GHz. The ADL5387 and ADL5380 utilize two different architectures to generate the 90° phase shift between the I and Q paths. The ADL5387 utilizes a 2 × LO architecture where the local oscillator is at twice the RF frequency, while the ADL5380 uses a polyphase filter-based phase splitter. The polyphase architecture has a narrower fractional bandwidth (i.e., operates across less octaves) and is more sensitive to PLL harmonics compared to a 2 × LO-based phase splitter. As a result, the ADL5380 requires harmonic filtering of the LO to maintain the quadrature accuracy of the I/Q demodulator, while filtering is only required for the 2 × LO-based ADL5387 at the top end of its frequency range.

Figure 2 shows a simplified 2 × LO phase splitter as implemented in the ADL5387. The 90° phase split of the LO path is achieved via digital circuitry that uses D-type flip-flops and an inverter. This architecture requires an external LO operating at twice the frequency of the desired LO.



Figure 2. Simplified 2 × LO-Based Phase Splitter

Figure 3 shows a simplified first order polyphase circuit, as implemented in the ADL5380. The polyphase circuit consists of complementary RC subcircuits that create a low-pass transfer function from input to one output, and a high-pass transfer function to the other output. If the R and C values of the two polyphased paths are matched, then both paths have the same corner frequency and, more importantly, the phase of one output tracks the other with a 90° phase shift.



Figure 3. Simplified First Order Polyphase Filter

INTERFACING THE ADF4350 PLL WITH THE ADL5387 I/Q DEMODULATOR

The ADL5387 and ADL5380 I/Q demodulators utilize different architectures to achieve the ultimate goal of generating precise quadrature signals. When interfacing with an LO synthesizer like the ADF4350, it is important to consider how the architectures respond to the LO signal and its harmonics. This will determine the requirement for LO filtering. Figure 4 shows the basic interface between the ADF4350 and ADL5387. Depending on the frequency of operation, an LO harmonic filter may or may not be required between the ADF4350 and ADL5387.



Figure 4. ADF4350 PLL Interface to the 2 × LO-Based Phase Splitter of the ADL5387 Demodulator

In a 2 × LO-based phase splitter, the quadrature accuracy is dependent on the duty cycle accuracy of the incoming LO.

The matching of the internal divider flip-flops also affects quadrature accuracy but to a much lesser extent. So a 50% duty cycle of the externally applied LO is critical for minimizing quadrature errors. Additionally, any imbalance in the rise and fall times causes even order harmonics to appear. When driving the demodulator LO inputs differentially, even order cancellation of the harmonics is achieved and results in improved overall quadrature generation.

With a target image suppression of -40 dBc, Figure 5 shows the performance of the ADL5387 with the ADF4350 providing the differential LO source with and without filtering. The blue signal trace representing the "Signal Generator" is the ideal case where the LO is generated using a Rhode & Schwarz signal generator with a sinusoidal output and much lower harmonic levels compared to the ADF4350. This is the ideal case and the target comparison point. From Figure 5, it can be seen that filtering is not required at frequencies below 1 GHz. However, above 1 GHz small errors due to harmonics of the LO become a larger percentage of the input period. In this case, filtering should be used to further attenuate the even order harmonics of the LO and so that the I/Q demodulator's specified quadrature accuracy can be achieved.



Figure 5. ADL5387 Image Rejection vs. RF Frequency

INTERFACING THE ADF4350 PLL WITH THE ADL5380 QUADRATURE DEMODULATOR

Unlike the ADL5387, the polyphase architecture of the ADL5380's phase splitter requires filtering of the ADF4350 outputs, as shown in Figure 6. Filtering is required to attenuate the odd order harmonics of the LO to minimize errors in the quadrature generation block of the ADL5380. The odd order harmonics contribute more than even order harmonics to quadrature errors.



Figure 6. ADF4350 Interface to the Polyphase Filter Architecture of the ADL5380 Demodulator

Figure 7 shows the measurement results when the ADF4350 outputs are filtered before they are applied to the differential LO inputs of the ADL5380. After filtering, the resulting image rejection is comparable to what is achievable from a low harmonic signal generator.

Table 1. ADF4350 R	F Output Filter	Component Value	(DNI = Do Not Insert)
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Figure 7. ADFL5380 Image Rejection vs. Frequency

FILTERING REQUIREMENTS

In summary, LO filtering the ADF4350 outputs to suppress the harmonics of the fundamental helps to maintain the phase accuracy of the quadrature signals of the demodulator. In the case of the ADL5380, which uses a polyphase architecture, filtering is a requirement. The ADL5387 architecture consists of digital circuitry which is more immune to the harmonics of the LO signal. Therefore filtering may not be required, depending on the frequency of operation.

In the case where filtering is necessary, Figure 8, shows an example LO output filter schematic, and Table 1, summarizes the filter component values. This circuit is flexible and provides four different filter options to cover four different bands The filters were designed for a 100 Ω differential input and 50 Ω differential output to match the LO input requirements of the demodulator. A Chebyshev response was used for optimal filter roll-off at the expense of increased pass-band ripple.

Frequency Range (MHz)	Z _{BIAS}	L1 (nH)	L2 (nH)	C1a (pF)	C1c (pF)	C2a (pF)	C2c (pF)	C3a (pF)	C3c (pF)
a. 500–1300	27 nH 50 Ω	3.9	3.9	DNI	4.7	DNI	5.6	DNI	3.3
b. 850–2450	19 nH (100 Ω in position C1c)	2.7	2.7	3.3	100 Ω	4.7	DNI	3.3	DNI
c. 1250–2800	50 Ω	0 Ω	3.6	DNI	DNI	2.2	DNI	1.5	DNI
d. 2800–4400	3.9 nH	0 Ω	0 Ω	DNI	DNI	DNI	DNI	DNI	DNI



Figure 8. ADF4350 RF Output Filter Schematic

COMMON VARIATIONS

The interface discussed above is applicable to any PLL with differential LO outputs and to any 1 × LO or 2 × LO-based I/Q demodulator. The ADL5382 is a 1 × LO-based I/Q demodulator that operates from 700 MHz to 2700 MHz and provides slightly higher IP3 than the ADL5380. The AD8347 (1 × LO) and AD8348 (2 × LO) are lower power I/Q demodulators that integrate front-end variable gain amplifiers and fixed-gain baseband amplifiers.

