ANALOG DEVICES

Circuit Note
CN-0144

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Devices Connected/Referenced	
ADF4350	Fractional-N PLL IC with Integrated VCO
ADL5385	Wideband Transmit Modulator
ADP150	Low Noise 3.3 V LDO
ADP3334	Low Noise Adjustable LDO

Broadband Low Error Vector Magnitude (EVM) Direct Conversion Transmitter Using LO Divide-by-2 Modulator

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

ADF4350 Evaluation Board (EVAL-ADF4350-EB1Z)

ADL5385 Evaluation Board (ADL5385-EVALZ)

Design and Integration Files

Schematics, Layout Files, Bill of Materials

CIRCUIT FUNCTION AND BENEFITS

This circuit is a complete implementation of the analog portion of a broadband direct conversion transmitter (analog baseband in, RF out). RF frequencies from 68.75 MHz to 2.2 GHz are supported through the use of a PLL with a broadband integrated voltage controlled oscillator (VCO). Unlike modulators that use a divide-by-1 LO stage (as described in CN-0134), harmonic filtering of the LO is not required.

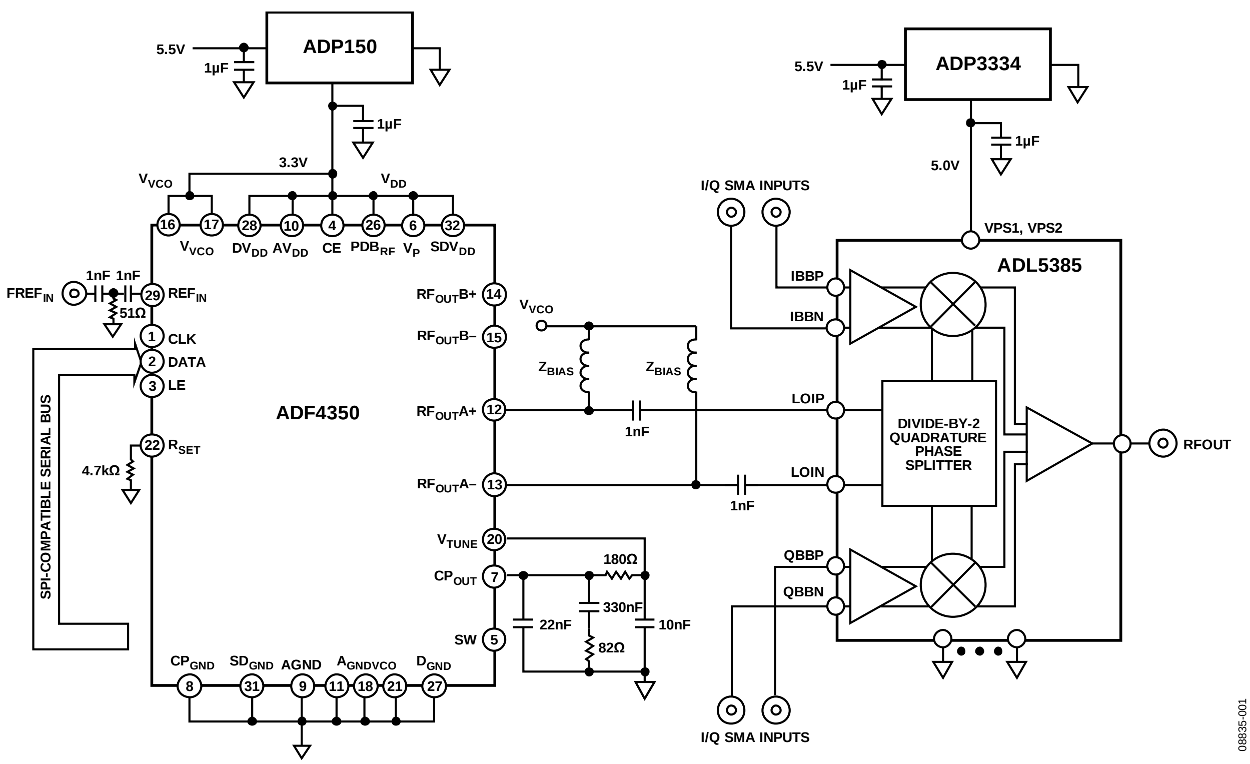

Figure 1. Direct Conversion Transmitter (Simplified Schematic: All Connections and Decoupling Not Shown)

Rev. C

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To achieve optimum performance, the only requirement is that the LO inputs of the modulator be driven differentially. The ADF4350 provides differential RF outputs and is, therefore, an excellent match. This PLL-to-modulator interface is applicable to all I/Q modulators and I/Q demodulators that contain a 2XLO-based phase splitter. Low noise LDOs ensure that the power management scheme has no adverse impact on phase noise and error vector magnitude (EVM). This combination of components represents industry-leading direct conversion transmitter performance over a frequency range of 68.75 MHz to 2.2 GHz. For frequencies above 2.2 GHz, it is recommended to use a divide-by-1 modulator, as described in CN-0134.

CIRCUIT DESCRIPTION

The circuit shown in Figure 1 utilizes the ADF4350, a fully integrated fractional-N PLL IC, and the ADL5385 wideband transmit modulator. The ADF4350 provides the local oscillator (the LO is twice the modulator RF output frequency) signal for the ADL5385 transmit quadrature modulator, which upconverts analog I/Q signals to RF. Taken together, the two devices provide a wideband baseband I/Q-to-RF transmit solution.

The ADF4350 is powered off the ultralow noise 3.3 V ADP150 regulator for optimal LO phase noise performance. The ADL5385 is powered off a 5 V ADP3334 LDO. The ADP150 LDO has an output voltage noise of only 9 μV rms, integrated from 10 Hz to 100 kHz, and helps to optimize VCO phase noise and reduce the impact of VCO pushing (equivalent to power supply rejection). See CN-0147 for more details on powering the ADF4350 with the ADP150 LDO.

The ADL5385 uses a divide-by-2 block to generate the quadrature LO signals. The quadrature accuracy is, thus, dependent on the duty cycle accuracy of the incoming LO signal (as well as the matching of the internal divider flip-flops). Any imbalance in the rise and fall times causes even order harmonics to appear, as evident on the ADF4350 RF outputs. When driving the modulator LO inputs differentially, even-order cancellation of harmonics is achieved, improving the overall quadrature generation. (See "Wideband A/D Converter Front-End Design Considerations: When to Use a Double Transformer Configuration." Rob Reeder and Ramya Ramachandran. *Analog Dialogue*, 40-07.)

Because sideband suppression performance is dependent on the modulator quadrature accuracy, better sideband suppression is achievable when driving the LO input ports differentially vs. single-ended. The ADF4350 has differential RF outputs compared to a single-ended output available on most competitor PLL devices with integrated VCO.

The ADF4350 output match consists of the Z_{BIAS} pull-up and, to a lesser extent, the decoupling capacitors on the supply node. To get a broadband match, it is recommended to use either a resistive load (Z_{BIAS} = 50 Ω) or a resistive in parallel with a reactive load for Z_{BIAS}. The latter gives slightly higher output power, depending on the inductor chosen. Use an inductor value of 19 nH or greater for LO operation below 1 GHz. The measured results in this circuit were performed using Z_{BIAS} = 50 Ω and an output power setting of 5 dBm. When using the 50 Ω resistor, this setting gives approximately 0 dBm on each output across the full band, or 3 dBm differentially. The ADL5385 LO input drive level specification is −10 dBm to +5 dBm; therefore, it should be possible to reduce the ADF4350 output power to save current.

A sweep of sideband suppression versus RF output frequency is shown in Figure 2. In this sweep, the test conditions were as follows: baseband I/Q amplitude = 1.4 V p-p differential sine waves in quadrature with a 500 mV dc bias; baseband I/Q frequency (f_{BB}) = 1 MHz; LO = 2 × RFOUT. A simplified diagram of the test setup is shown in Figure 3. A modified ADL5385 evaluation board was used because the standard ADL5385 board does not allow a differential LO input drive.

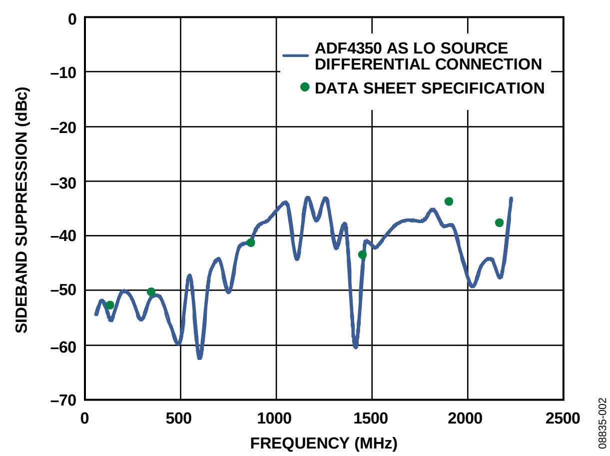

Figure 2. Sideband Suppression, RFOUT Swept from 68.75 MHz to 2200 MHz

This circuit achieves comparable or improved sideband suppression performance when compared to driving the ADL5385 with a low noise RF signal generator, as used in the data sheet measurement. Using the differential RF outputs of the ADF4350 provides even-order harmonic cancellation and improves modulator quadrature accuracy. This impacts sideband suppression performance and EVM (error vector magnitude). A single carrier W-CDMA composite EVM of better than 2% was measured with the circuit shown in Figure 1. The solution thus provides a low EVM broadband solution for frequencies from 68.75 MHz to 2.2 GHz. For frequencies above 2.2 GHz, a divide-by-1 modulator block should be used, as described in CN-0134.

A complete design support package for this circuit note can be found at http://www.analog.com/CN0144-DesignSupport.

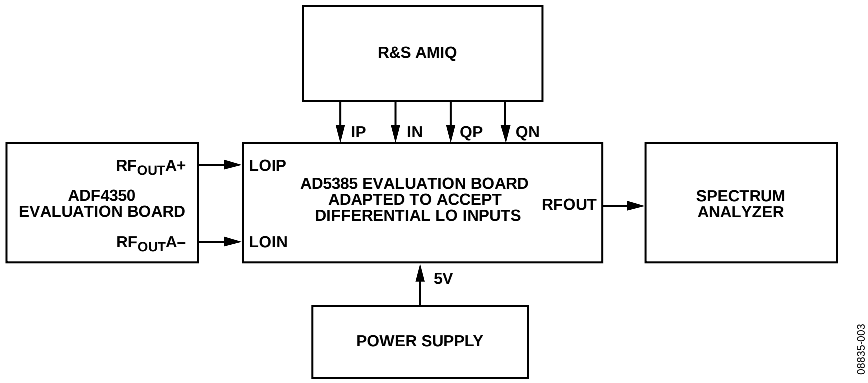

Figure 3. Sideband Suppression Measurement Test Setup (Simplified Diagram)

COMMON VARIATIONS

The PLL-to-modulator interface described in this circuit note is applicable to all I/Q modulators that contain a 2XLO-based phase splitter. It is also applicable to 2XLO-based I/Q demodulators such as the ADL5387.

CIRCUIT EVALUATION AND TEST

The CN-0144 uses the EVAL-ADF4350EB1Z and the ADL5385-EVALZ boards for evaluation of the described circuit, allowing for quick setup and evaluation. The EVAL-ADF4350EB1Z board uses the standard ADF4350 programming software, contained on the CD that accompanies the evaluation board.

Equipment Needed

Windows® XP, Windows Vista (32-bit), or Windows 7 (32-bit) PC with USB Port, the EVAL-ADF4350EB1Z, and the ADL5385-EVALZ circuit evaluation boards, the ADF4350 programming software, power supplies, I-Q signal source, such as a Rhode & Schwarz AMIQ, and a spectrum analyzer. See the CN-0144 and the UG-109 user guide for evaluation board EVAL-ADF4350EB1Z and the ADF4350 and ADL5385 data sheets.

Getting Started

This circuit note contains a description of the circuit, the schematic, and a block diagram of the test setup. The user guide UG-109 details the installation and use of the EVAL-ADF4350 evaluation software. The UG-109 also contains board setup instructions and the board schematic, layout, and bill of materials. The ADL5385-EVALZ board schematic, block diagram, bill of materials, layout, and assembly information is included in the ADL5385 data sheet. See the ADF4350 and ADL5385 data sheet for device information.

Functional Block Diagram

The CN-0144 contains the function block diagram of the described test setup in Figure 3.

Setup and Test

After setting up the equipment, use standard RF test methods to measure the sideband suppression of the circuit.

FURTHER IMPROVEMENTS WITH FILTERING

The sideband suppression of this circuit can be further improved by filtering the LO signal before the LOIP and LOIN pins of the ADL5385. Filtering attenuates harmonic levels so as to minimize errors in the quadrature generation block of the ADL5385. At some frequencies, this can result in improvements over 10 dB. However, using a filter will limit the bandwidth of the circuit. See Figure 4 for narrowband results.

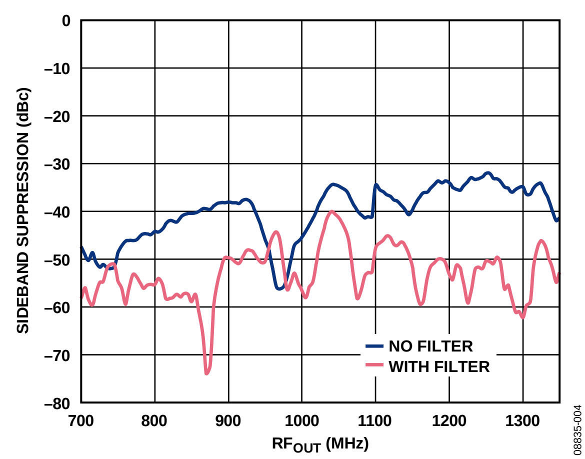

Figure 4. Sideband Suppression Comparison With and Without a Harmonic Filter

The LO signal was passed through a low-pass filter with a 3 dB point at approximately 2600 MHz. This results in a usable output frequency up to approximately 1300 MHz.

LEARN MORE

CN0144 Design Support Package:
http://www.analog.com/CN0144-DesignSupport

ADIsimPLL Design Tool

ADIsimPower Design Tool

ADIsimRF Design Tool

Brandon, David, David Crook, and Ken Gentile. AN-0996 Application Note, *The Advantages of Using a Quadrature Digital Upconverter (QDUC) in Point-to-Point Microwave Transmit Systems.* Analog Devices.

CN-0134, *Broadband Low EVM Direct Conversion Transmitter.* Analog Devices.

CN-0147, *Using the ADP150 LDO Regulators to Power the ADF4350 PLL and VCO.* Analog Devices.

Nash, Eamon. AN-1039 Application Note, *Correcting Imperfections in IQ Modulators to Improve RF Signal Fidelity.* Analog Devices.

Reeder, Rob, and Ramya Ramachandran. "Wideband A/D Converter Front-End Design Considerations: When to Use a Double Transformer Configuration." *Analog Dialogue*, 40-07.

Data Sheets and Evaluation Boards

ADF4350 Data Sheet

ADF4350 Evaluation Board

ADL5385 Data Sheet

ADL5385 Evaluation Board

ADP150 Data Sheet

ADP3334 Data Sheet

REVISION HISTORY

10/12—Rev. B to Rev. C

Added Further Improvements with Filtering Section 3

11/10—Rev. A to Rev. B

Changes to Circuit Note Title 1
Added Evaluation and Design Support Section 1
Changes to Figure 3 3
Added Circuit Evaluation and Test Section 3

8/10—Rev. 0 to Rev. A

Changes to Circuit Function and Benefits Section 1
Changes to Circuit Description Section 2
Added Common Variations Section 3

3/10—Revision 0: Initial Version