ANALOG DEVICES

Circuit Note
CN-0311

Devices Connected/Referenced	
ADF4351	Fractional-N PLL IC with Integrated VCO
ADL5385	Wideband Transmit Modulator
ADP150	Low Noise 3.3 V LDO
ADP3334	Low Noise Adjustable LDO

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

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

ADF4351 Evaluation Board (EVAL-ADF4351EB1Z)

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 30 MHz to 2.2 GHz are supported by using a phase-locked loop (PLL) with a broadband integrated voltage controlled oscillator (VCO). Unlike modulators that use a divide-by-1 local oscillator (LO) stage (as described in CN-0285), harmonic filtering of the LO is not required.

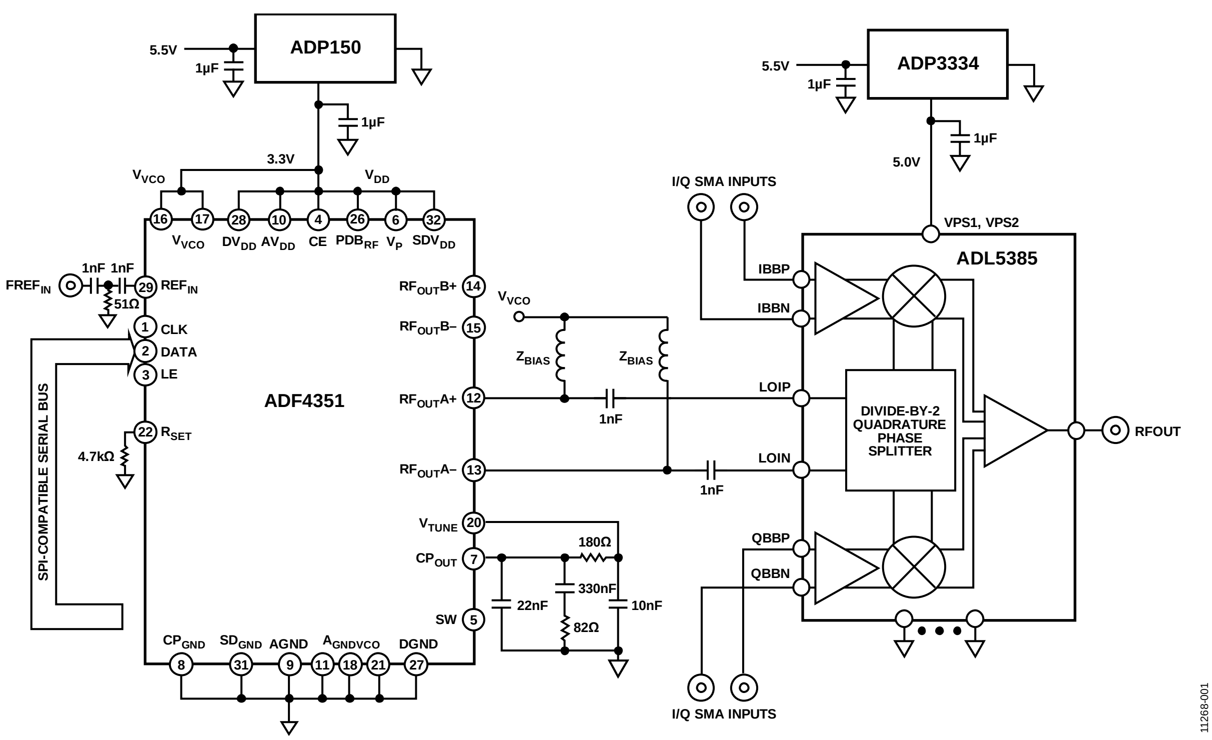

Figure 1. Direct Conversion Transmitter (Simplified Schematic: All Connections and Decoupling Not Shown)

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To achieve optimum performance, the only requirement is that the LO inputs of the modulator be driven differentially. The ADF4351 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 an industry-leading direct conversion transmitter performance over a frequency range of 30 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-0285.

CIRCUIT DESCRIPTION

The circuit shown in Figure 1 uses the ADF4351, a fully integrated fractional-N PLL IC, and the ADL5385 wideband transmit modulator. The ADF4351 provides the local oscillator (the LO is twice the modulator RF output frequency) signal for the ADL5385 transmit quadrature modulator, which upconverts the analog I/Q signals to RF. Taken together, the two devices provide a wideband, baseband I/Q-to-RF transmit solution.

The ADF4351 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 ADF4351 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 ADF4351 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 ADF4351 has differential RF outputs compared to the single-ended output available on most of the competitor's PLL devices with integrated VCOs.

The ADF4351 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 is possible to reduce the ADF4351 output power to save current.

A sweep of sideband suppression vs. 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 × RF_{OUT}

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.

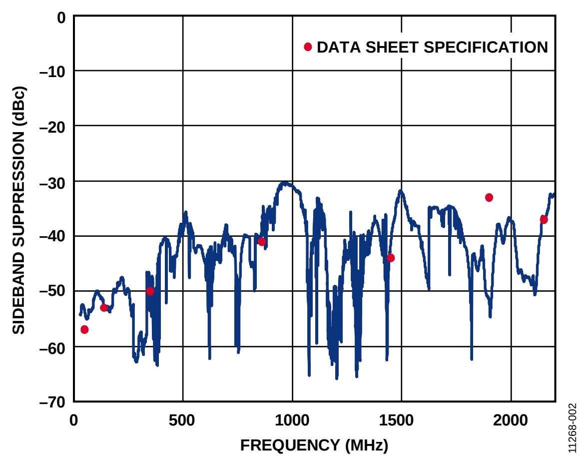

Figure 2. Sideband Suppression, RFOUT Swept from 30 MHz to 2200 MHz

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 ADF4351 provides even-order harmonic cancellation and improves modulator quadrature accuracy. This affects sideband suppression performance and EVM. 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 30 MHz to 2.2 GHz. For frequencies above 2.2 GHz, use a divide-by-1 modulator block, as described in CN-0285.

The complete design support package can be found at http://www.analog.com/CN0311-DesignSupport.

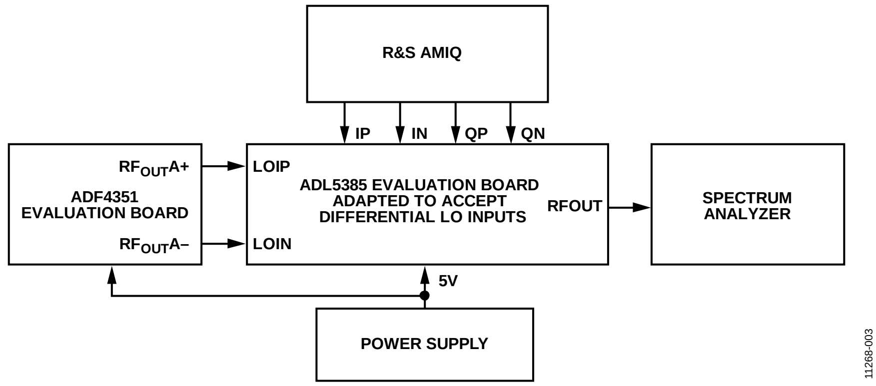

Figure 3. Sideband Suppression Measurement Test Setup (Simplified Diagram)

COMMON VARIATIONS

The PLL-to-modulator interface described 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-0311 uses the EVAL-ADF4351EB1Z and the ADL5385-EVALZ for the evaluation of the described circuit, allowing for quick setup and evaluation. The EVAL-ADF4351EB1Z uses the standard ADF4351 programming software contained on the CD that accompanies the evaluation board.

Equipment Needed

The following equipment is needed:

- A PC with a USB port that contains Windows® XP, Vista, or Windows 7
- The EVAL-ADF4351EB1Z evaluation board
- The ADL5385-EVALZ evaluation board,
- ADF4351 programming software
- Power supplies (5 V, 500 mA)
- An I-Q signal source, such as a Rohde & Schwarz AMIQ
- A spectrum analyzer

Also, see the UG-435 User Guide for the EVAL-ADF4351EB1Z evaluation board, the ADF4351 data sheet, and the ADL5385 data sheet.

Getting Started

A description of the circuit, the schematic, and a block diagram of the test setup is detailed within the CN-0311 (see Figure 1 and Figure 3). The UG-435 user guide details the installation and use of the EVAL-ADF4351EB1Z evaluation software. The UG-435 also contains the 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 ADF4351 data sheet and ADL5385 data sheet for device information.

Functional Block Diagram

The functional block diagram of the described test setup is shown in Figure 3.

Setup and Test

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

LEARN MORE

CN0311 Design Support Package:
http://www.analog.com/CN0311-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

ADF4351 Data Sheet

ADF4351 Evaluation Board

ADL5385 Data Sheet

ADL5385 Evaluation Board

ADP150 Data Sheet

ADP3334 Data Sheet

REVISION HISTORY

12/12—Revision 0: Initial Version