TI High Speed Designs
Wideband Dual Transmit Solution With Integrated Local Oscillator

TEXAS INSTRUMENTS

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Design Resources

TIDA-00409	Tool Folder Containing Design Files
TSW38J84	Product Folder
DAC38J84	Product Folder
TRF3722	Product Folder
TRF3705	Product Folder

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Circuit Description

The TIDA-00409 reference design provides a platform to demonstrate a wideband dual transmit solution that incorporates an integrated local oscillator (LO). The reference design uses the 2.5-GSPS DAC38J84 device with the high-performance modulators TRF3722 (including an integrated PLL/VCO) and TRF3705. The TRF3722 and TRF3705 can be combined to form a dual transmit solution with the TRF3722 generating the LO for both modulators. The interface between the DAC38J84 and the modulators is discussed as well as measurements showing the combined performance of the DAC and modulators. The measurements illustrate the bandwidth performance, output third-order intercept performance, harmonic distortion, and sideband suppression (SBS) performance.

Featured Applications

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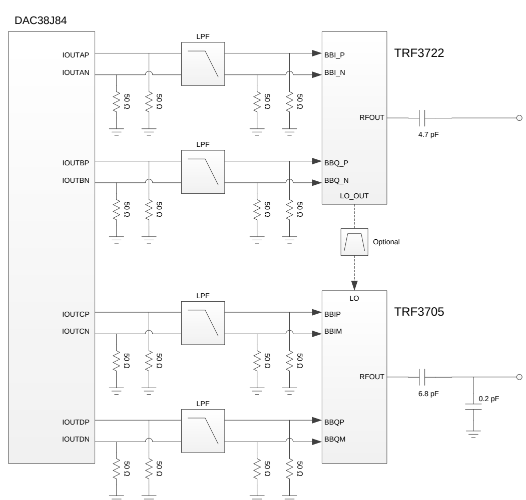

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1 System Description

The TIDA-00409 reference design demonstrates a high-performance dual radio frequency (RF) transmitter. The reference design includes the 2.5-GSPS Quad DAC38J84, which is a JESD204B compliant digital-to-analog converter (DAC). The quad DAC supports two separate I/Q channels to drive two modulators. One I/Q pair interfaces to the TRF3722 modulator with an integrated PLL/VCO. The other pair interfaces with the TRF3705 modulator. The output frequency of the TRF3722 and TRF3705 is up to 4 GHz, and the solution can output up to 1 GHz of bandwidth.

2 Block Diagram

Figure 1 shows a simplified representation of the TSW38J84 evaluation module (EVM).

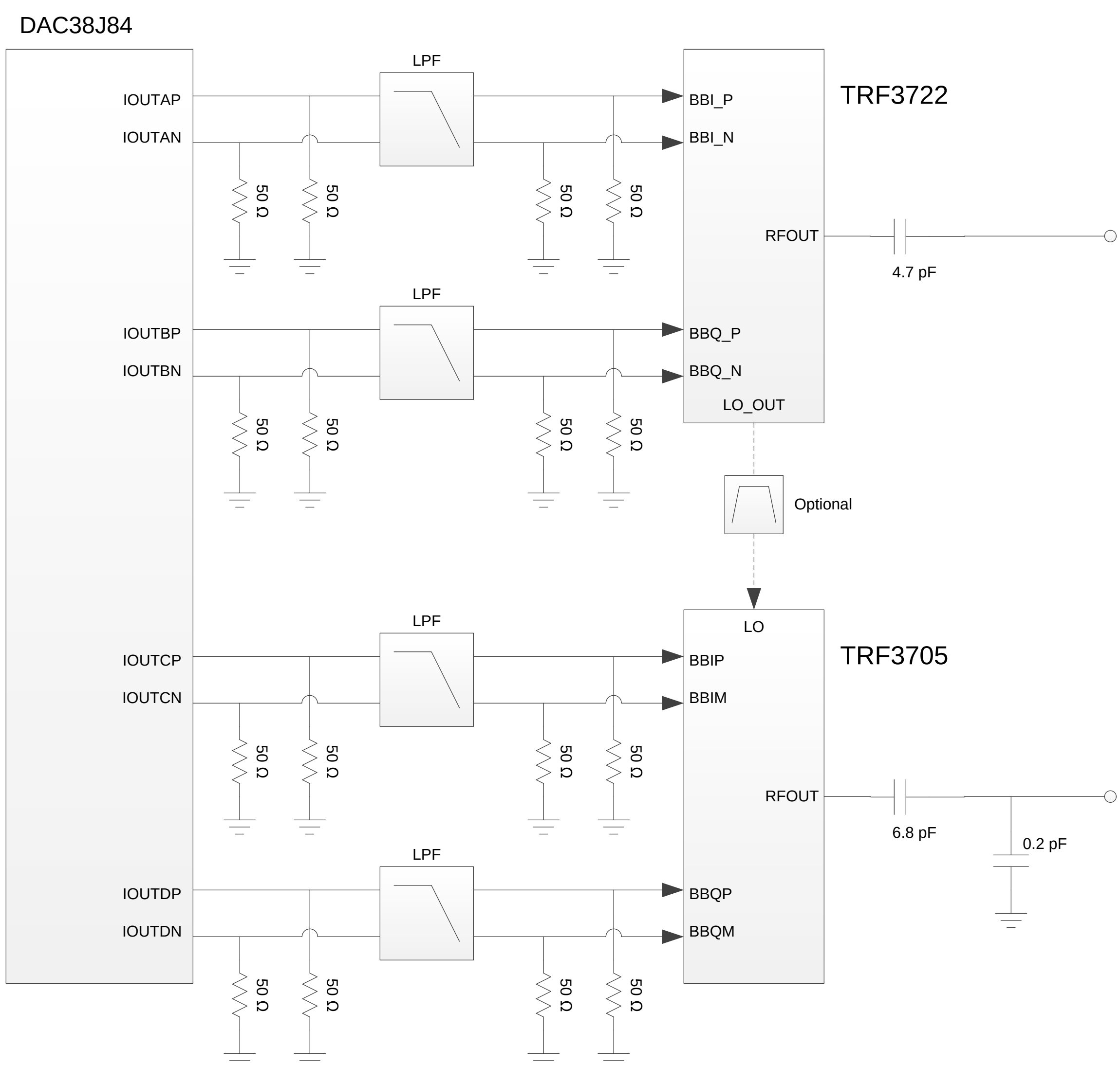

Figure 1. TSW38J84 Block Diagram

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2.1 Analog Output

The DAC38J84 is a current sourcing, high-speed DAC with an adjustable full-scale current of up to 30 mA. The full-scale output current from the DAC38J84 can be calculated by Equation 1. V_{EXTIO} is 0.9 V and typically R_{BIAS} is set to 1.9 kΩ and coarse_dac is set to 10, which sets the full-scale current at 20 mA. Note that there is an additional constant bias current of 2.5 mA for each IOUT pin, so the typical range of the output current for a 20-mA full-scale current is from 2.5 to 22.5 mA.

$$IOUT_{FS} = \frac{(coarse\_dac + 1)}{16} \times \frac{V_{EXTIO}}{R_{BIAS}} \times 64 \quad (1)$$

To calculate the common mode voltage, first calculate the mid code current given by Equation 2 for $IOUT_{BIAS}$ and the total DC impedance to ground. When the DAC drives two parallel 50-Ω resistors to ground for a total DC resistance of 25 Ω, this drive translates into a common-mode voltage at IOUT of:

$$IOUT_{BIAS} = \frac{IOUT_{FS}}{2} + 2.5\text{ mA} \quad (2)$$

$$V_{CM} = IOUT_{BIAS} \times 25\ \Omega$$

$$V_{CM} = 312.5\text{ mV} \quad (3)$$

The single-ended voltage swing at each IOUT pin can be calculated by multiplying the full-scale current by the total AC impedance seen by each DAC output pin. For Figure 1, the total AC impedance per leg is also 25 Ω.

$$V_{SE} = IOUT_{FS} \times 25\ \Omega \quad (4)$$

So the single-ended voltage range with a 20-mA full scale and the diagram shown in Figure 1 is 62.5 to 562.5 mV, which is within the output compliance voltage of the DAC38J84. The differential voltage swing between terminals IOUTP and IOUTN is:

$$V_{DIFF} = 2 \times V_{SE} = 1\ V_{PP} \quad (5)$$

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2.2 Low-Pass Filter

The zero-order hold output of the DAC will produce images at multiples of the sampling rate plus and minus the DAC output frequency. A low-pass filter is typically used to filter out these images before the modulator to prevent unwanted signals from showing up at the RF output. The corner frequency and order of the filter is dependent on the required filtering of the images and other undesired signals, such as the second-order distortion (HD2) and third-order distortion (HD3). Because the DAC38J84 is capable of such high sampling rates, a low-pass filter can typically be used to eliminate HD2 and HD3 from the output spectrum. Using a low-pass filter also allows for correction of the LO feedthrough using the digital offset feature of the DAC38J84.

The low-pass filter on the TSW38J84 is a filter module designed by Soshin Electronic Company for approximately 650 MHz of bandwidth. A filter module will typically provide better filter matching between the I and Q paths, which will improve the SBS performance while also creating a smaller overall solution that would be achieved with an LC filter. The TSW38J84 EVM does contain placeholders for an LC filter so that the user can design a filter to meet their system requirements.

2.3 LO Interface

The TRF3722 LO output can be used to drive the TRF3705 LO input while maintaining high performance. Note that harmonics of the LO will cause poor SBS, so filtering must be used between the LO ports of the TRF3705 and TRF3722. For more details, see the application report *LO Harmonic Effects on I/Q Balance and Sideband Suppression in Complex I/Q Modulators*.[1]

2.4 RF Matching Network

The RF output is AC-coupled and is designed for a 50-Ω environment. The output matching network shown in Figure 1 is designed to be a broadband matching network and provides good performance across the frequency range of the device. However, for narrow bandwidths, modify the output matching to optimize performance within a selected band. The RF output s-parameters are available on the ti.com product pages for the TRF3722 and TRF3705 for RF simulation programs. These files can be used to design a proper matching network for the desired RF band.

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3 Measured Performance

For the measurements presented in Figure 2, the input data rate is 614.4 MSPS with four times the interpolation. This data rate sets the DAC output rate at 2457.6 MSPS, which is near its maximum sampling rate. This configuration can be replicated by configuring the TSW38J84 GUI as shown in Figure 2.

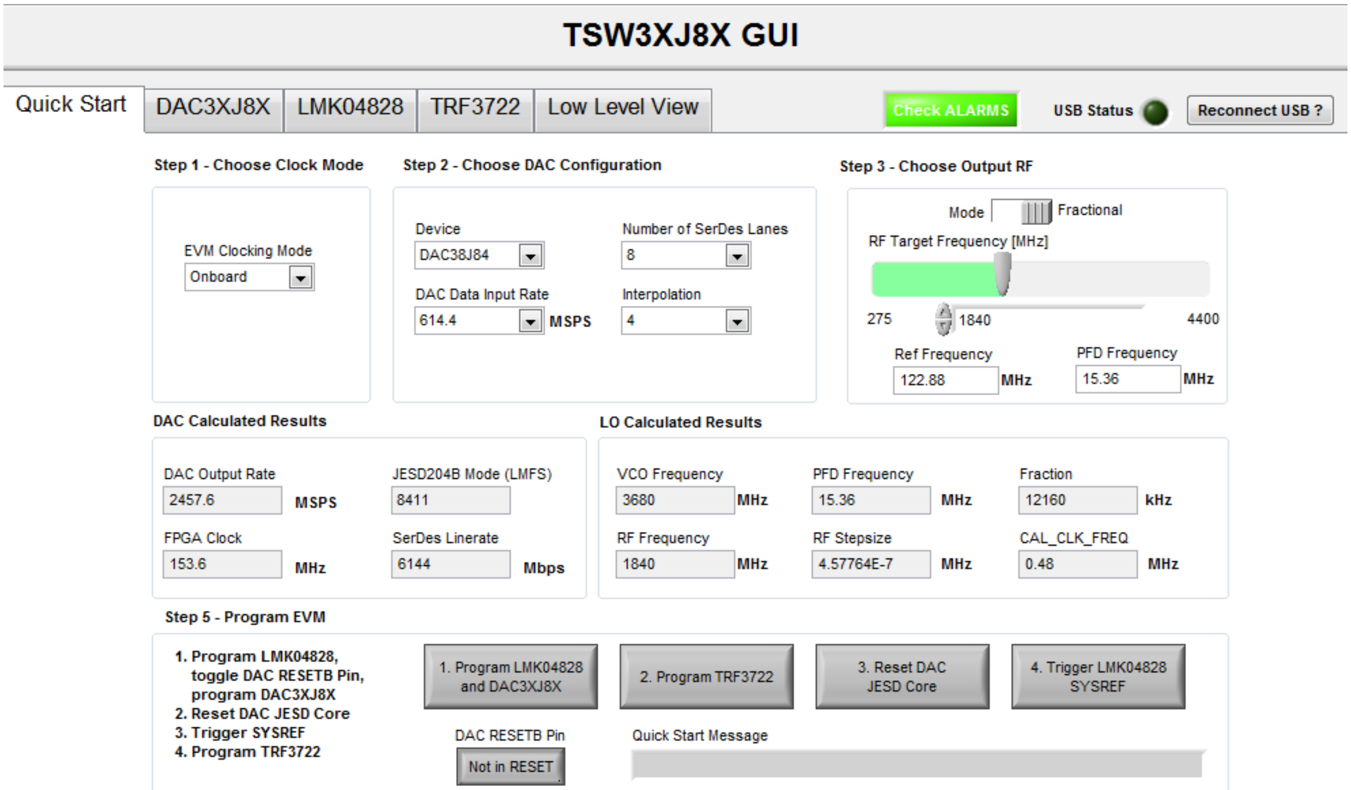

Figure 2. TSW38J84 GUI Configuration

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3.1 Output Power versus LO Frequency

The output power is measured using a single tone out of the DAC at 5 MHz and then varying the LO frequency. Figure 3 shows the POUT response by varying the RF from 400 to 4000 MHz. The matching network shown in Section 2 will affect the output flatness. For lower frequencies, use a larger DC blocking capacitor.

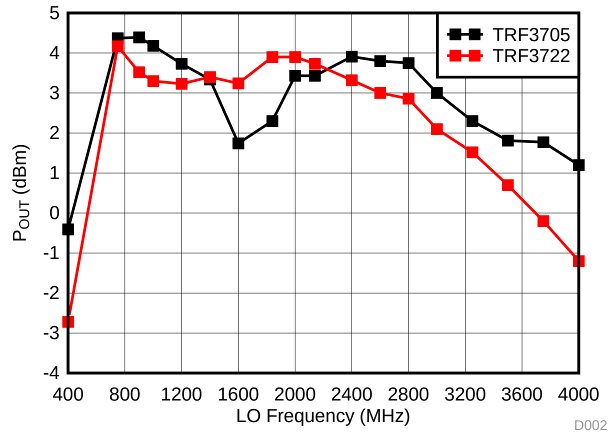

Figure 3. Output Power versus LO Frequency

3.2 Baseband Bandwidth Response

The baseband bandwidth is measured by sweeping the DAC output frequency and while keeping the TRF3722 and TRF3705 LO frequency constant. An external LO is used for the TRF3705 with an LO power of 0 dBm. The baseband 3-dB gain bandwidth response is just under 700 MHz and the 1-dB corner is roughly around 550 MHz. The baseband bandwidth is typically limited by the filter used between the DAC and the modulator.

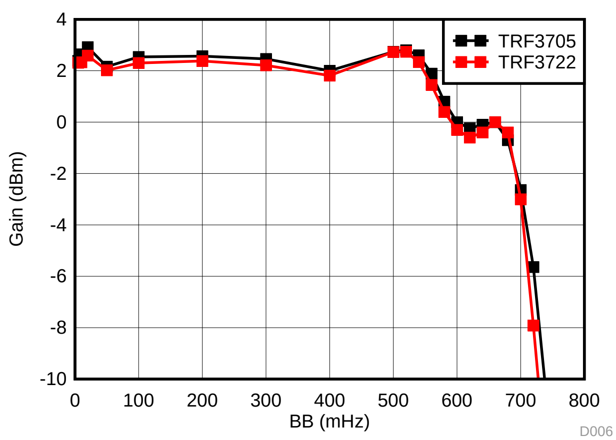

Figure 4. Output Power versus Baseband Frequency

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3.3 Unadjusted LO Feedthrough versus LO Frequency

The unadjusted LO feedthrough is measured using a single tone out of the DAC at 5 MHz and then sweeping the LO frequency for each modulator. Correct the LO feedthrough by using the digital offset correction feature of the DAC38J84.

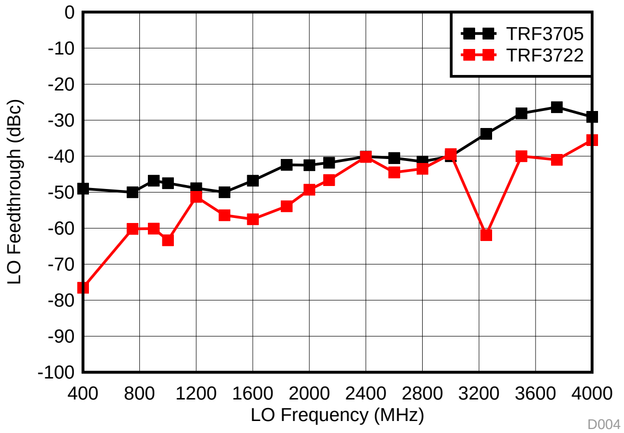

Figure 5. Unadjusted LO Feedthrough versus LO Frequency

3.4 HD2 and HD3 versus LO Frequency

The baseband harmonic distortion is measured using a single tone out of the DAC at 5 MHz and then sweeping the LO frequency for each modulator.

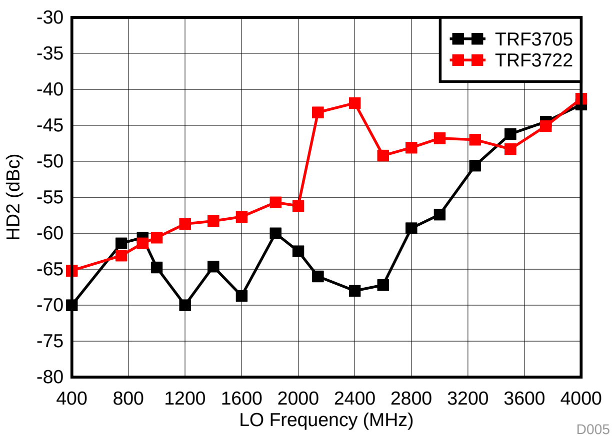

Figure 6. HD2 versus LO Frequency

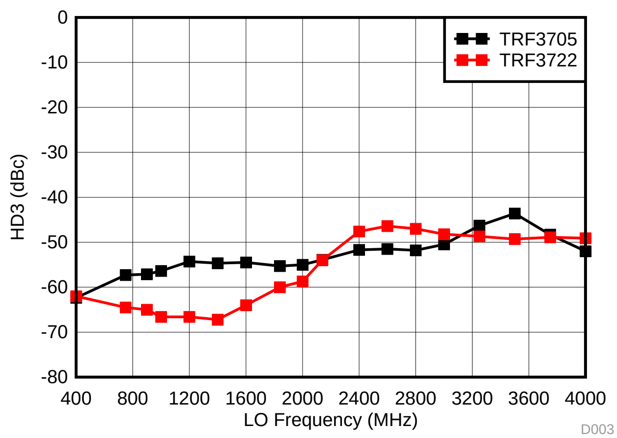

Figure 7. HD3 versus LO Frequency

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3.5 Unadjusted SBS versus LO Frequency

The SBS performance is measured using a single tone out of the DAC at 5 MHz while sweeping the LO frequency.

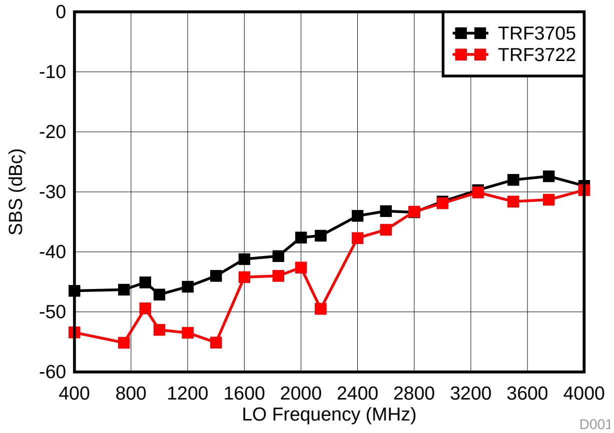

Figure 8. Unadjusted SBS versus LO Frequency

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3.6 Adjusted SBS

One key concern for complex transmitters is the SBS performance. For an intermediate frequency (IF) transmitter (for example, DAC output center frequency ≠ 0 Hz) the SBS performance will have a strong impact on the RF filtering requirements. For a zero-IF (ZIF) transmitter (for example, DAC output center frequency = 0 Hz) the SBS performance will have a large impact on the error vector magnitude performance. The DAC38J84 includes some digital features to correct the sideband at the modulator output. These features include the quadrature modulation correction (QMC) block and a correction block for the digital group delay correction block. The combination of both blocks can be used to correct the SBS over a large bandwidth. In Figure 9, a 340-MHz wide signal is output from the DAC and mixed up to 1.84 GHz using the TRF3722. The yellow signal is the unadjusted SBS, the blue signal is the performance with just the QMC block on, and the red signal is with both QMC and group delay correction enabled. The unadjusted SBS performance is approximately 40 dBc down and matches the performance shown in Figure 8. The QMC was used to correct for the phase and gain mismatch between the complex signals. The group delay correction was then used to correct the remaining higher frequency sideband. For an IF transmitter, the filtering requirements are relaxed by eliminating the need to filter the sideband close to the LO frequency, where the correction improved the performance by approximately 15 dB. For ZIF transmitters, the adjusted sideband shows 10 dB of improvement over 500 MHz of bandwidth.

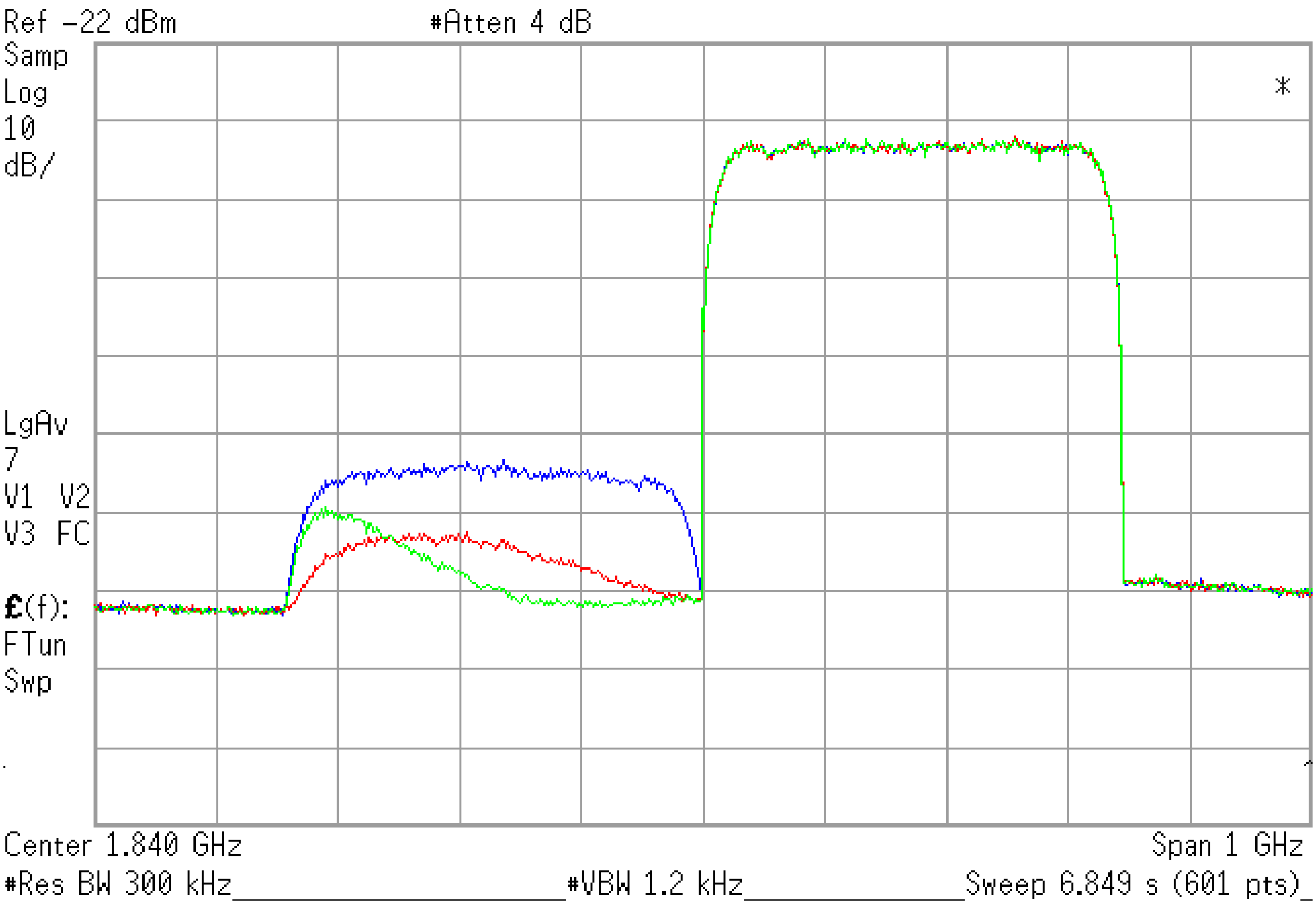

Figure 9. Adjusted SBS

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3.7 OIP3 versus LO Frequency

The output third-order intercept point (OIP3) performance versus the LO frequency is measured with two tones coming from the DAC at 4.5 MHz and 5.5 MHz. Note that the matching network used at the RF output of each modulator affects the OIP3 performance. The performance at high frequencies can be improved by designing a better matching network for the desired frequency.

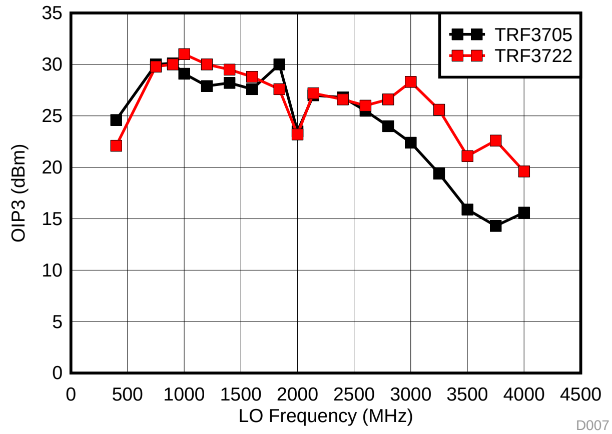

Figure 10. OIP3 versus LO Frequency

3.8 OIP3 versus Baseband Frequency

The OIP3 performance versus baseband frequency is measured by shifting the baseband frequency from 5 to 700 MHz. The LO frequency is fixed at 2140 MHz and the two tones have 1-MHz spacing.

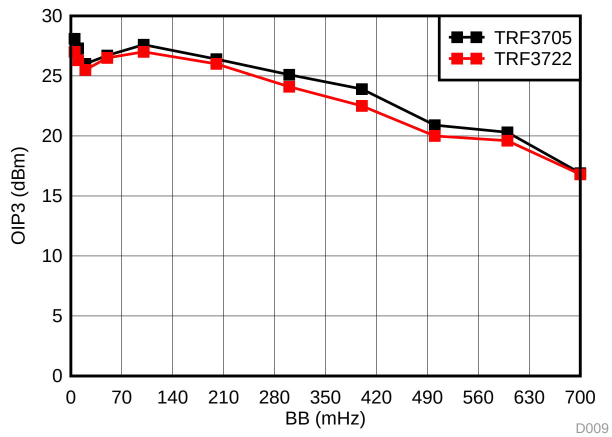

Figure 11. OIP3 versus Baseband Frequency

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3.9 OIP3 versus Tone Spacing

The OIP3 performance versus tone spacing is measured by changing the spacing between the two tones from 1 to 200 MHz with the DAC output center frequency fixed at 150 MHz. The LO frequency is fixed at 1 GHz, so the RF is at 1150 MHz.

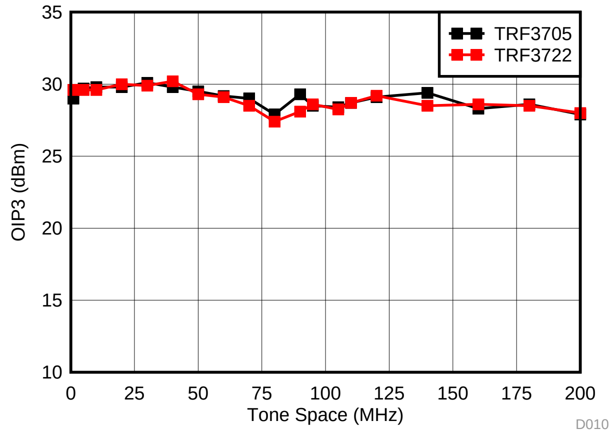

Figure 12. OIP3 versus Tone Spacing

3.10 OIP2 versus LO Frequency

The OIP2 performance is measured using a fixed DAC output frequency of 5 MHz and then sweeping the LO frequency for each modulator.

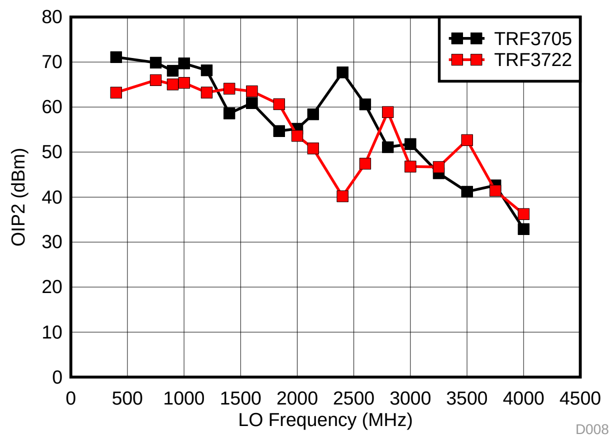

Figure 13. OIP2 versus LO Frequency

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4 Conclusion

The DAC38J84 in conjunction with the TRF3722 and TRF3705 is a suitable platform across the operating ranges of each device. Together, these devices create a small, high-performance, high-bandwidth, dual transmit solution for modern communication, military, and test and measurement systems. Alternatively, using two TRF3722 modulators enables transmission at two different RFs. The solution supports RF signal bandwidths of up to 1 GHz. Note that the performance for a specified RF band can be improved by modifying the output matching network for a selected band.

5 References

1. Texas Instruments, *LO Harmonic Effects on I/Q Balance and Sideband Suppression in Complex I/Q Modulators*, Application Report (SLWA059)

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