AFE76xx Evaluation Module

Contents

1 Introduction 2
2 Test Setup 4
2.1 Software Requirements 4
2.2 Hardware Requirements 4
2.3 Software Configuration 6

List of Figures

1 AFE76xx 4TX and 4RX Transceiver Setup 2
2 Overall Hardware Setup 4
3 HSDC Pro GUI Connecting TSW14J56EVM 6
4 HSDC Pro GUI Selecting DAC JESD204B Format 7
5 HSDC Pro DAC Tone Setup 8
6 HSDC Pro Load Custom Waveform 9
7 HSDC PRO SERDES Rate Calculation 9
8 AFE76xx GUI Setup 10
9 AFE76xx GUI RX Setup 11
10 AFE76xx GUI TX Setup 12
11 AFE76xx GUI Execution 13
12 TXDAC Output Spectrum 14
13 TXDAC NCO Setup 15
14 TXDAC Summing of TXDUC Paths 16
15 TXDSA Setup 16
16 JESD204B DAC Resync Process 17
17 JESD204B DAC Re-Equalization and Resync Process 18
18 HSDC Pro Setup For RXADC Capture 19
19 HSDC Pro Setup for RXADC Down-Conversion Calculation 20
20 RXADC Output FFT Spectrum 21
21 RXADC NCO Setup 22
22 RXDSA Setup 22
23 RXADC JESD204B Resync Process 23

List of Tables

1 Terminology 2
2 JESD204B Frame Format for DACs: L-M-F-S-Hd = 44210 (2 TX) 3
3 JESD204B Frame Format for ADCs: L-M-F-S-Hd = 44210 (2 RX, Complex Mode) 3

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1 Introduction

The intention of this guide is to help users set up the AFE76xxEVM and the TSW14J56EVM devices correctly. Users can then customize the AFE76xx configuration per the system requirements in their end equipment.

Table 1. Terminology

Abbreviation	Definition
TXDAC	RF sampling digital-to-analog converter (DAC)
TXDUC	TXDAC digital signal processing and upsampling converter
RXADC	RF sampling analog-to-digital converter (ADC)
RXDDC	RXADC digital signal processing and downsampling converter
TX	RF analog transmitter
RX	RF analog receiver
JESD204B RX for DAC	JESD204B standard receiver for serialized data stream of the TXDAC digital data
JESD204B TX for ADC	JESD204B standard transmitter for serialized data stream of the RXADC digital data
Interpolation	Process of upsampling from a slower data rate to faster digital-to-analog sampling rate
Decimation	Process of downsampling from a faster analog-to-digital sampling rate to slower data rate

The setup in this EVM manual specifically configures the AFE76xx device into a 4T-4R RF sampling transceiver (shown in Figure 1). For the two sets of 2TX paths, both TXAp/m and TXBp/m are used within TXTOP0, and both TXCp/m and TXDp/m are used within TXTOP1. The goal is to evaluate both DAC cores independently, and possibly combine both TXAp/m and TXBp/m paths into a single DAC core output at TXAp/m, for dual-band evaluation (and the same for the TXCp/m and TXDp/m paths).

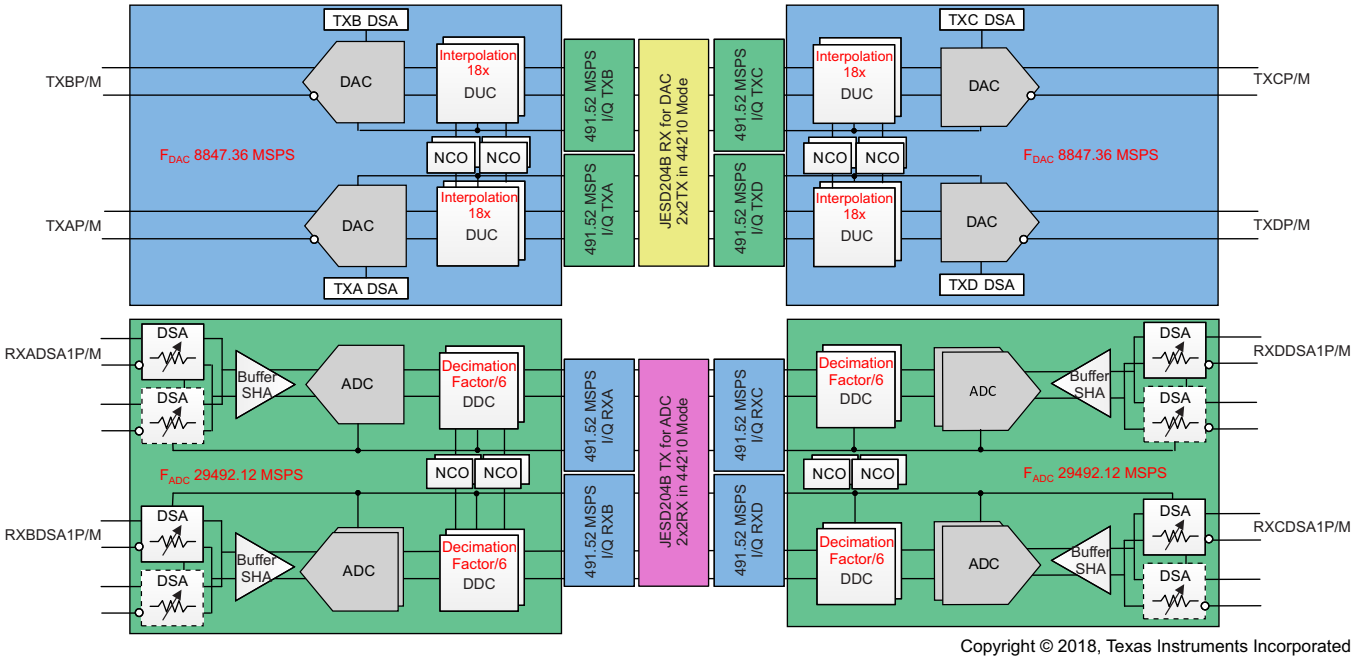

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Figure 1. AFE76xx 4TX and 4RX Transceiver Setup

The TX DUC is set up as 18x interpolation, with a 491.52-MSPS input data rate. The DAC is sampling at 8847.36 MSPS, with the on-chip PLL providing the sampling clock. The 18x interpolation filter interpolates the sample rate from the baseband to the DAC output.

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The JESD204B RX mode for the TXDACs is 2x2TX in 44210 mode (see Table 2). Each TX is configured as 22210 mode, with 2 SERDES lanes to receive a single I/Q channel. A total of eight lanes are available to support the 4TX mode.

Table 2. JESD204B Frame Format for DACs: L-M-F-S-Hd = 44210 (2 TX)

OCTET	1	2
Lane SRX0	TXA_i0[15:0]	
Lane SRX1	TXA_q0[15:0]	
Lane SRX2	TXB_i0[15:0]	
Lane SRX3	TXB_q0[15:0]	

For the two sets of the 2RX paths, both RXA-DSA1p/m and RXB-DSA1p/m are used within RXTOP0, and both RXC-DSA1p/m and RXD-DSA1p/m are used within RXTOP1.

The same on-chip PLL that provides the 8847.36-MHz DAC clock also provides a divide-by-3 clock for ADC sampling at 2949.12 MSPS. The RX DDC is set up for 6x decimation at 491.52 MSPS. The ADC raw data at 2949.12 MSPS is decimated by six times to a baseband rate of 491.52 MSPS.

The JESD204B TX mode for the RXADCs is 2x2RX in 44210 mode (see Table 3). Each RX is configured as 22210 mode, with 2 SERDES lanes to transmit a single I/Q channel. A total of eight lanes are available to support the 4RX mode.

Table 3. JESD204B Frame Format for ADCs: L-M-F-S-Hd = 44210 (2 RX, Complex Mode)

OCTET	1	2
Lane STX0	RXA_i0[15:0]	
Lane STX1	RXA_q0[15:0]	
Lane STX2	RXB_i0[15:0]	
Lane STX3	RXB_q0[15:0]	

Other system parameters follow:

- Input the reference clock to the AFE76xx device (CLKINp/CLKINm pins): 368.64 MHz.

NOTE: The on-chip PLL/VCO circuit converts the 368.64-MHz reference clock through a 24x multiplier to the final PLL/VCO frequency of 8847.32 MHz.

- TXDAC A/B and C/D cores:
  - DAC sample rate: 8847.36 MSPS
  - Interpolation factor: 18
  - JESD204B RX for DAC mode: 44210 complex
- RXADC A/B and C/D cores:
  - ADC sample rate: 2949.12 MSPS
  - Decimation factor: 6
  - JESD204B TX for ADC mode: 44210 complex
- JESD204B SYNCb communication:
  - Syncinp0/Syncinm0 for JESD204B TX for ADCs in single-link fashion
  - Syncoutp0/Syncoutm0 for JESD204B RX for DACs in single-link fashion
- JESD204B SERDES rate: 9.8304 Gbps

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2 Test Setup

The following sections list the test setup.

2.1 Software Requirements

This section lists the software requirements.

1. Install HSDC Pro Version 4.8 or later.
2. Install AFE76xx GUI v1.84 RC5 or later.

NOTE: To maintain a back-up of previously working HSDC Pro versions, go to C:\Program Files (x86)\Texas Instruments, and rename the existing HSDC Pro folders another name before the HSDC Pro v4.8 (or later) installation.

To maintain a back-up of previously working AFE76xx GUI versions, go to C:\Program Files (x86)\Texas Instruments, and rename the existing AFE76xx folders another name before the AFE76xx GUI installation.

2.2 Hardware Requirements

Figure 2 shows the hardware setup.

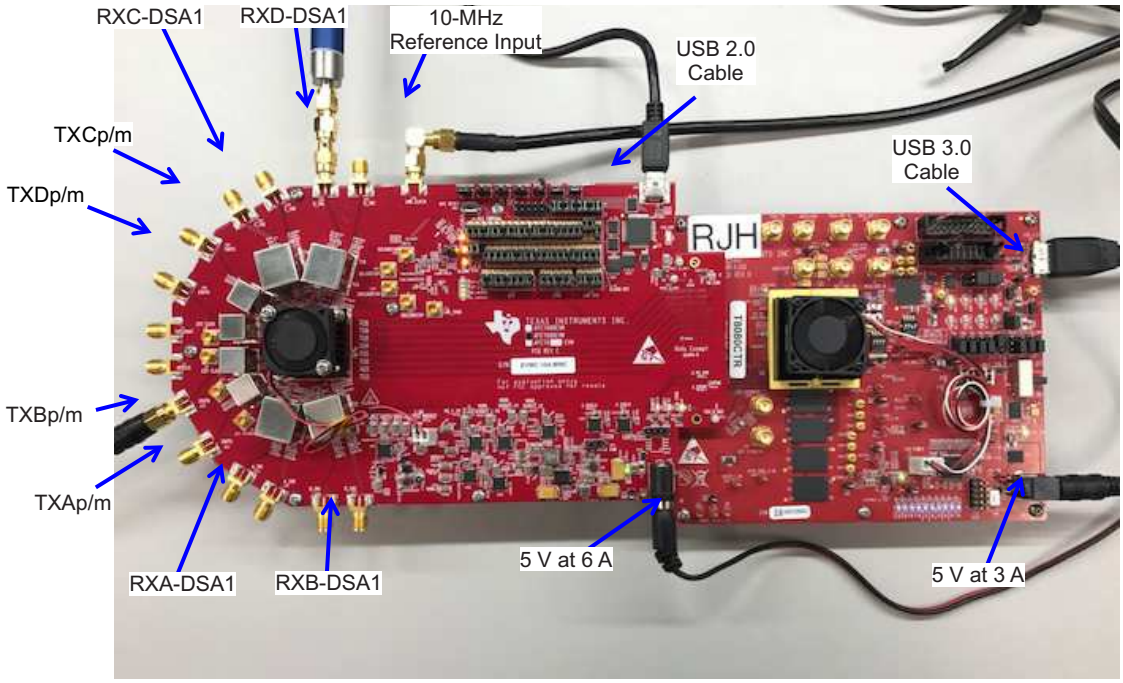

Figure 2. Overall Hardware Setup

NOTE: For 5-V power supplies, adjust the power supply voltage to compensate for cable loss.

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Follow these instructions to set up the hardware.

AFE76xxEVM and TSW14J56EVM devices:

1. Connect the AFE76xx EVM Revision C J32 FMC male connector to the TSW14J56 Revision D J2 FMC female connector.

AFE76xxEVM device only:

1. Connect the USB 2.0 Type A connector to the Type Mini-B connector, from the PC to the AFE76xx EVM.
2. Connect the 10-MHz reference clock (from the signal generator 10-MHz reference, CMOS level is supported) to the J26 connector. This step is necessary only for coherent capture of RX signals.
3. Connect the signal generator output (RF input) to either the A_IN1 (J14), BIN1 (J16), C_IN1 (J18), or D_IN1 (J20) connector. Limit the input power to –8 dBm with the 0-dB RXDSA enabled. The default power-on RXDSA level is 4-dB attenuation. Turn off the signal generator power at this point to ensure successful RX-signal chain calibration during the AFE76xx device start-up.
4. Connect the IOUTA (J22), IOUTB (J23), IOUTC (J24), and IOUTD (J25) TX DAC output to the spectrum analyzer. The maximum power of the DAC output is expected to be 7 dBm. Adjust the spectrum analyzer level to prevent damage to the signal chain devices.
5. Provide 5 V at 6-A power supply to the AFE76xx EVM at connector J35. Do not power up the board at this point.

NOTE: With the high current consumption of the AFE76xx EVM, users must be aware of the voltage drop, due to the power cable loss. Further adjustments of the power supply voltage may be needed, to compensate for the cable loss.

TSW14J56EVM device only:

1. Provide 5 V at 3-A power supply to the TSW14J56EVM at connector J16. The power can be enabled at this point.
2. Connect the USB 3.0 cable from the PC to the TSW14J56EVM.
3. Power-up the TSW14J56 EVM by switching the SW6 switch from the OFF to the ON position.

AFE76xxEVM device only:

1. Turn on the 5-V power supply to enable the AFE76xxEVM.

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2.3 Software Configuration

2.3.1 DAC Setup

This section lists the software configuration and start up with the DAC setup.

1. Start HSDC Pro V4.8.
2. Connect to the TSW14J56EVM through the USB ID (see Figure 3).

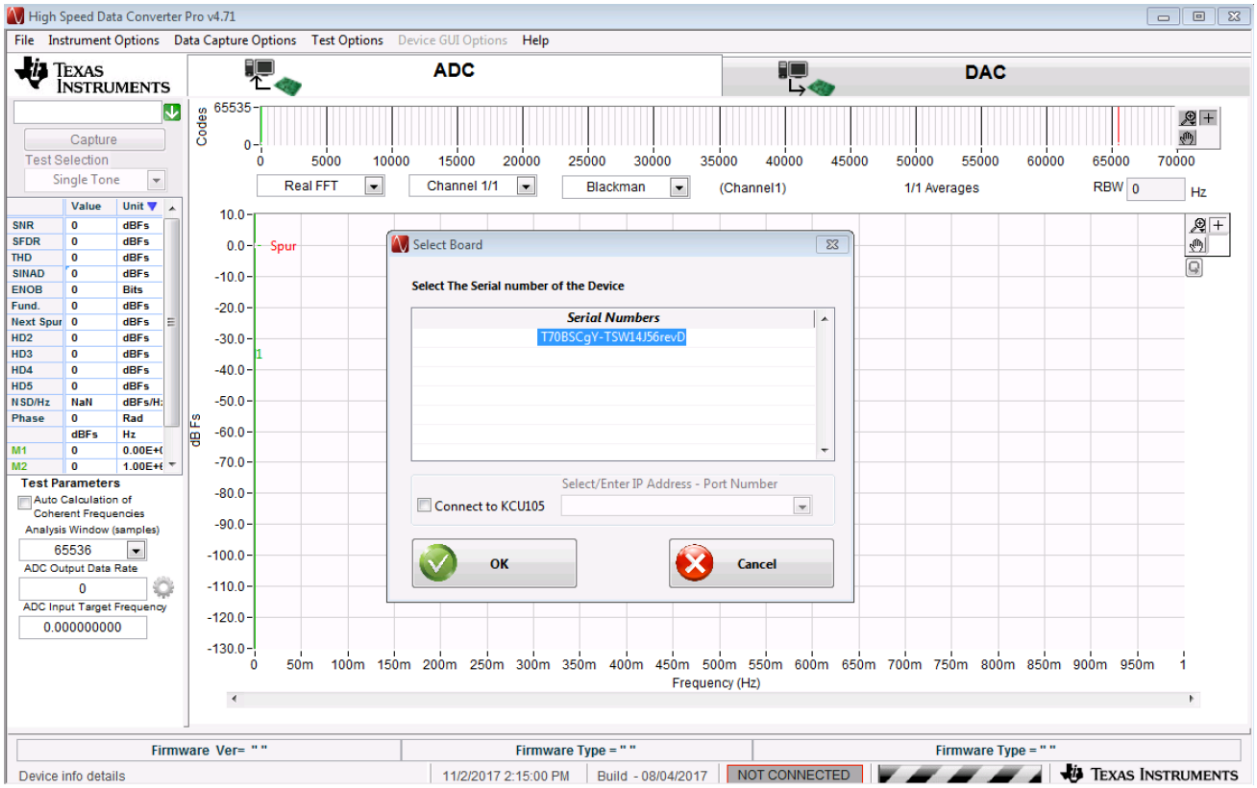

Figure 3. HSDC Pro GUI Connecting TSW14J56EVM

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3. When the USB ID is selected, and the GUI is connected to the board, go to the DAC tab.
4. Select the ini file from the drop down menu and then select the AFE76xx_2x2TX_44210 file (see Figure 4).

Figure 4. HSDC Pro GUI Selecting DAC JESD204B Format

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5. Set up HSDC Pro as follows to generate the two tone signal (see Figure 5). Any waveform file accepted by HSDC Pro can be loaded at this point. Enter the proper scaling factor (1x), data rate (SPS), and DAC option in the main DAC tab to ensure a proper baseband processing setup. Enter the Tone BW, #, Tone Center, and Tone Selection in the I/Q Multitone Generator for proper tone generation.
   1. Click on the Create Tones button.

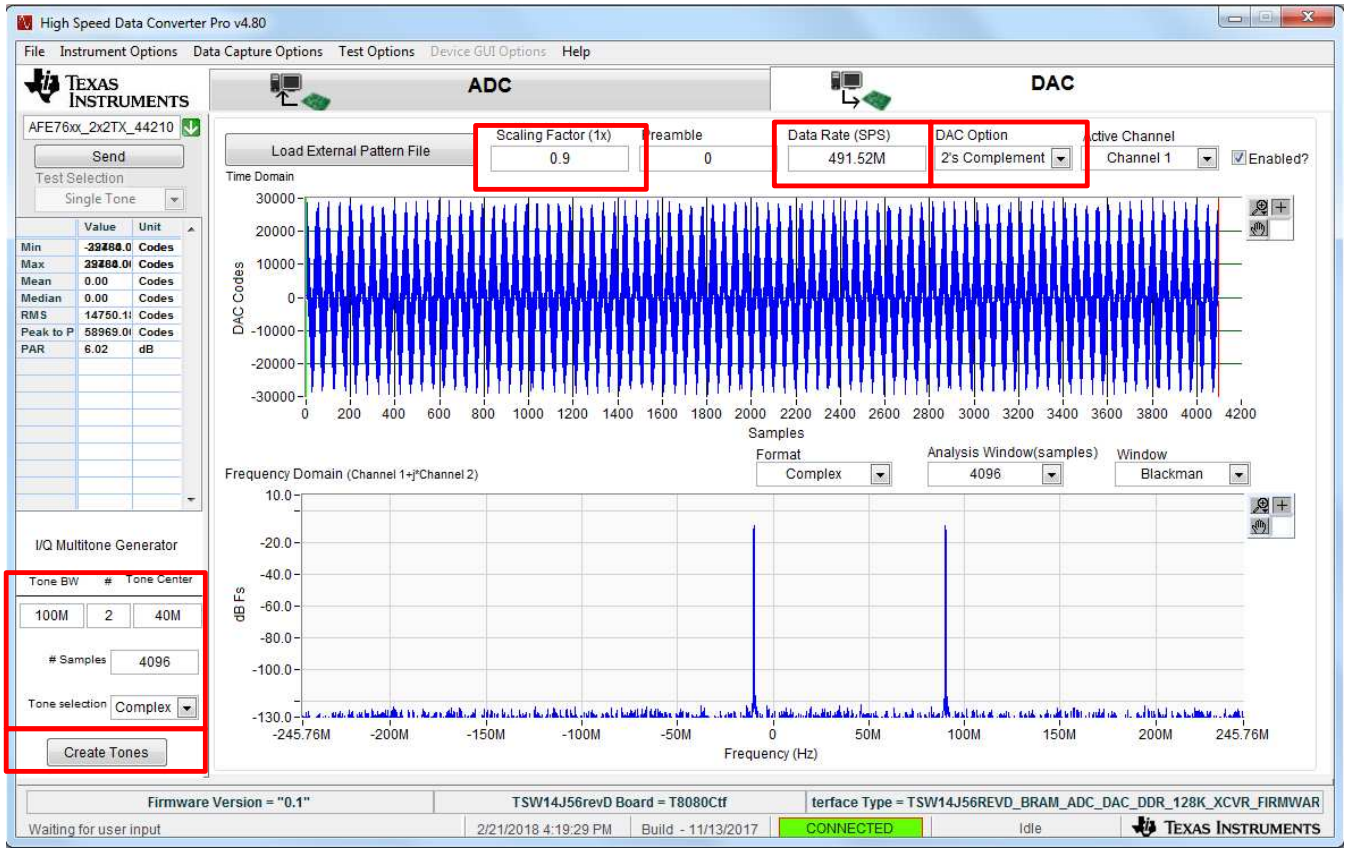

Figure 5. HSDC Pro DAC Tone Setup

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2. Or, load the custom waveform provided by the customer (see Figure 6).

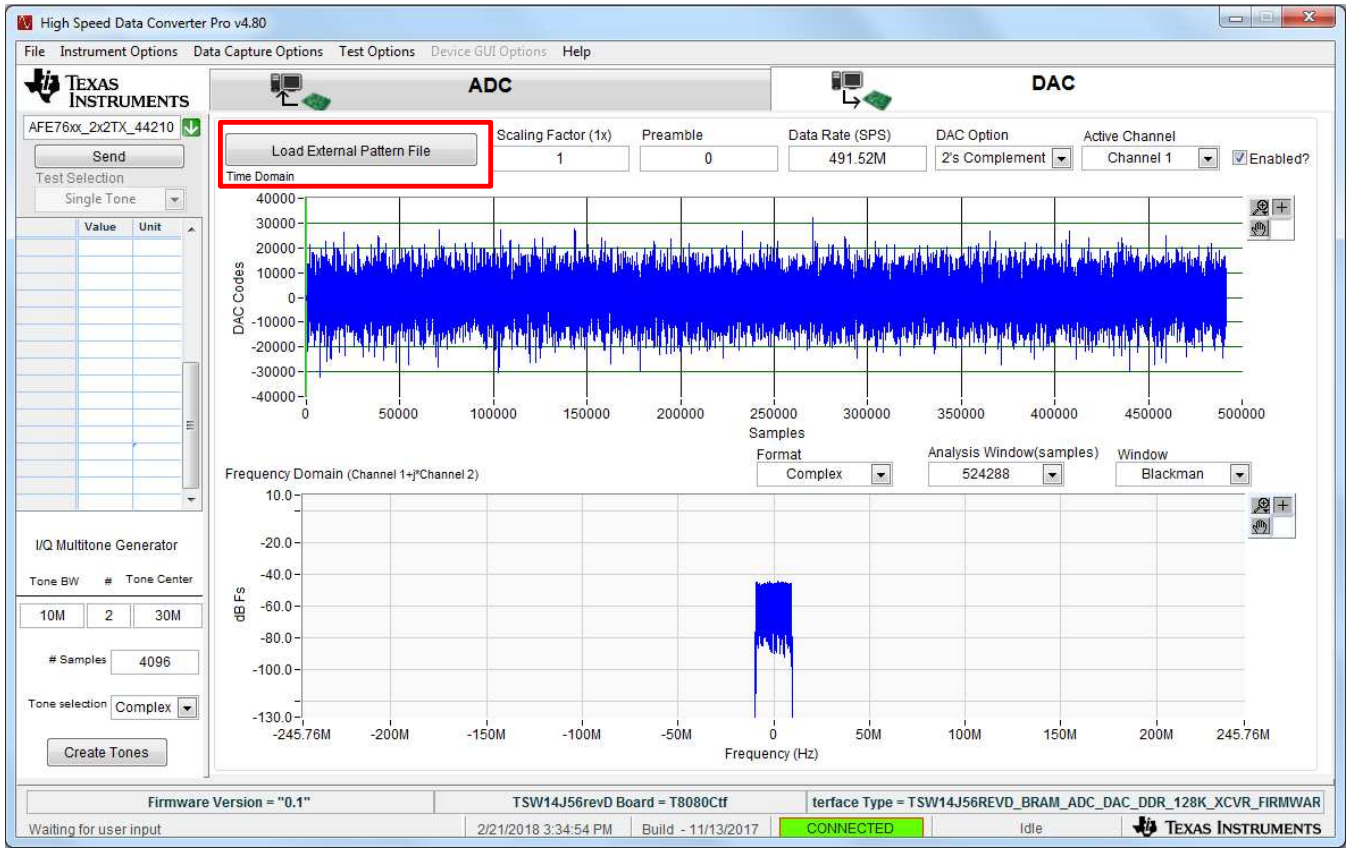

Figure 6. HSDC Pro Load Custom Waveform

3. Click on the Send button.
4. Click the OK button when the message in Figure 7 appears.

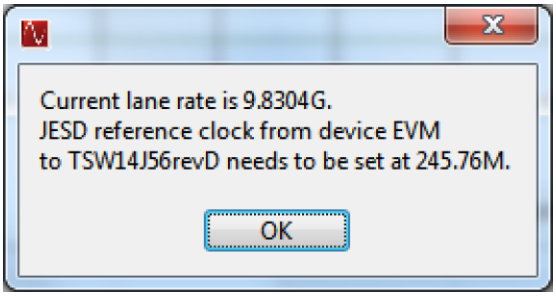

Figure 7. HSDC PRO SERDES Rate Calculation

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6. Open the AFE76xx GUI. The screen in Figure 8 should appear.
7. Press the Init Script button, and wait.

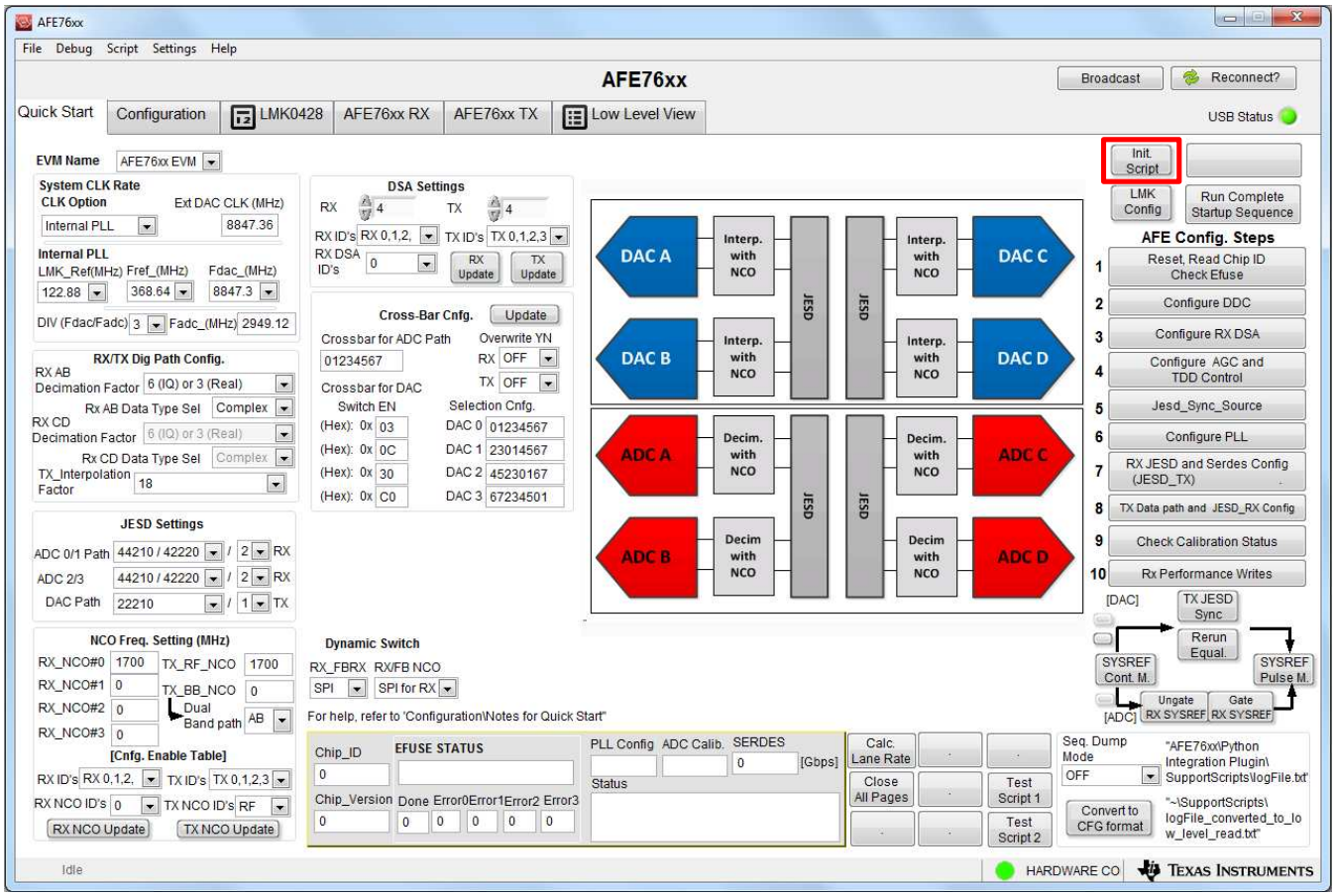

Figure 8. AFE76xx GUI Setup

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8. Go to the AFE76xx RX Tab (see Figure 9).
    1. Set up the modes for the different RX channels to allow each channel to be active in RX mode, FB mode, or both RX and FB mode. This example has all four channels in only RX mode with no FB enabled.
    2. Update the operating Nyquist zone for the input frequency. Select the first Nyquist for DC to 1500-MHz operation, select the second Nyquist for 1500-MHz to 3000-MHz operation, and then select the third Nyquist for 3000-MHz to 4500-MHz operation. This example uses the second Nyquist zone of operation with input of 1710 MHz.
    3. Click the update button when finished.

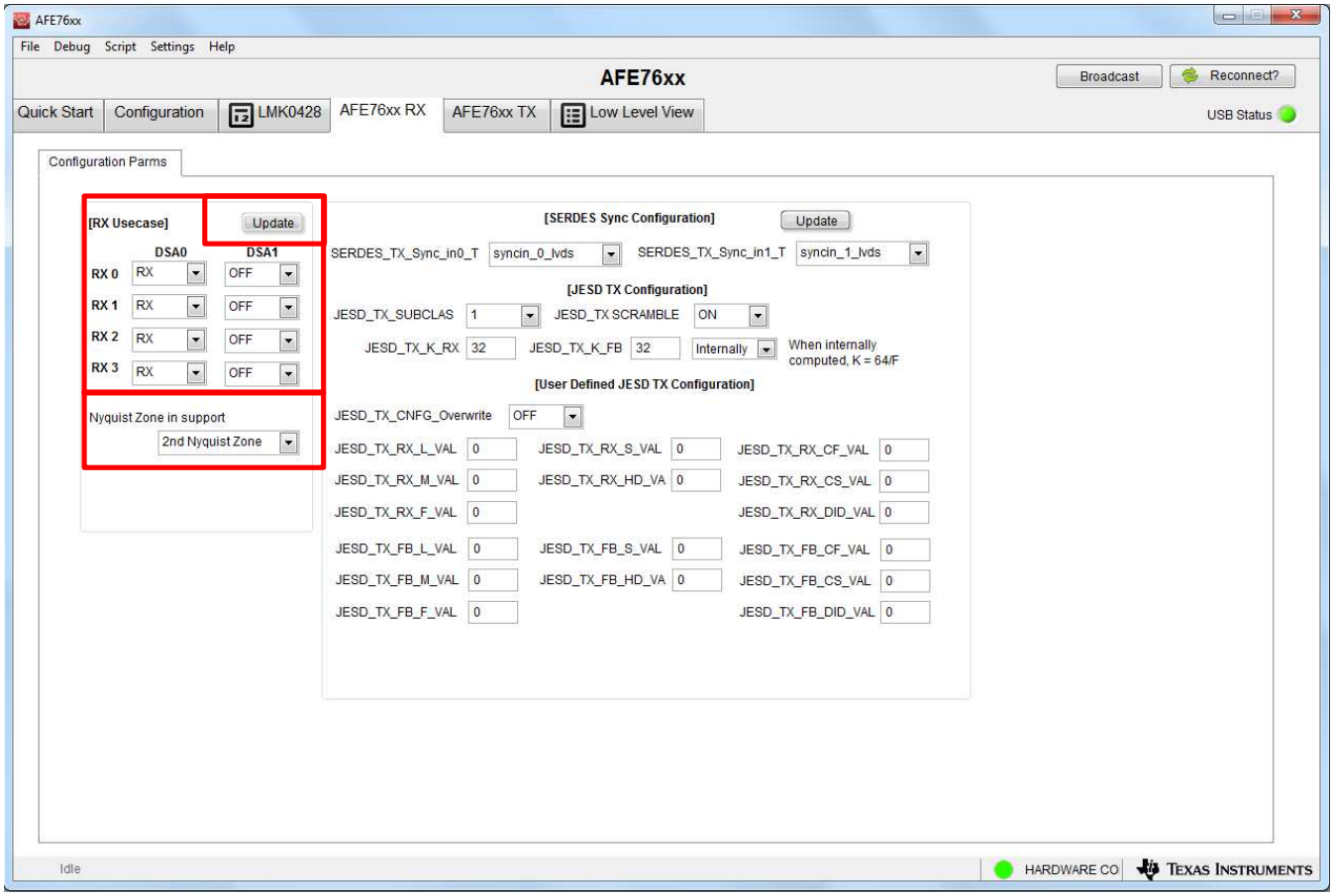

Figure 9. AFE76xx GUI RX Setup

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9. Go to the AFE76xx TX tab (see Figure 10).
    1. Enable or disable each TX path. This example has all four TX path enabled.
    2. Select NCO synchronization method. This example has NCOs synchronized by SPI register.
    3. Click update when finished.

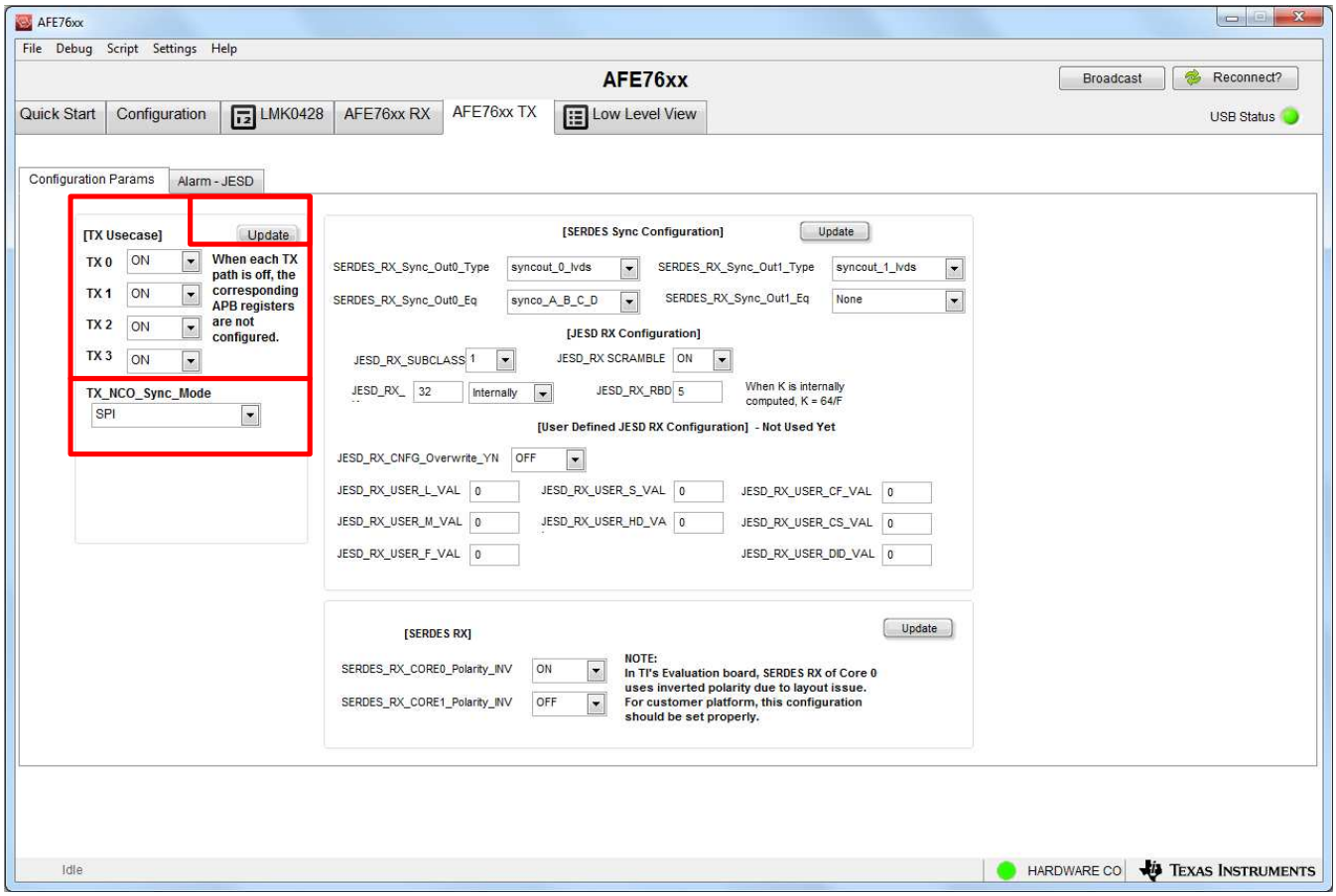

Figure 10. AFE76xx GUI TX Setup

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10. Go to the Main tab (see Figure 11).
    1. Fill the sections highlighted in Figure 11, including the proper decimation and interpolation mode, JESD setting, and NCO frequencies.
    2. Press the LMK Config button, and wait.
    3. Press the Run Complete Start-up Sequence button, and wait.

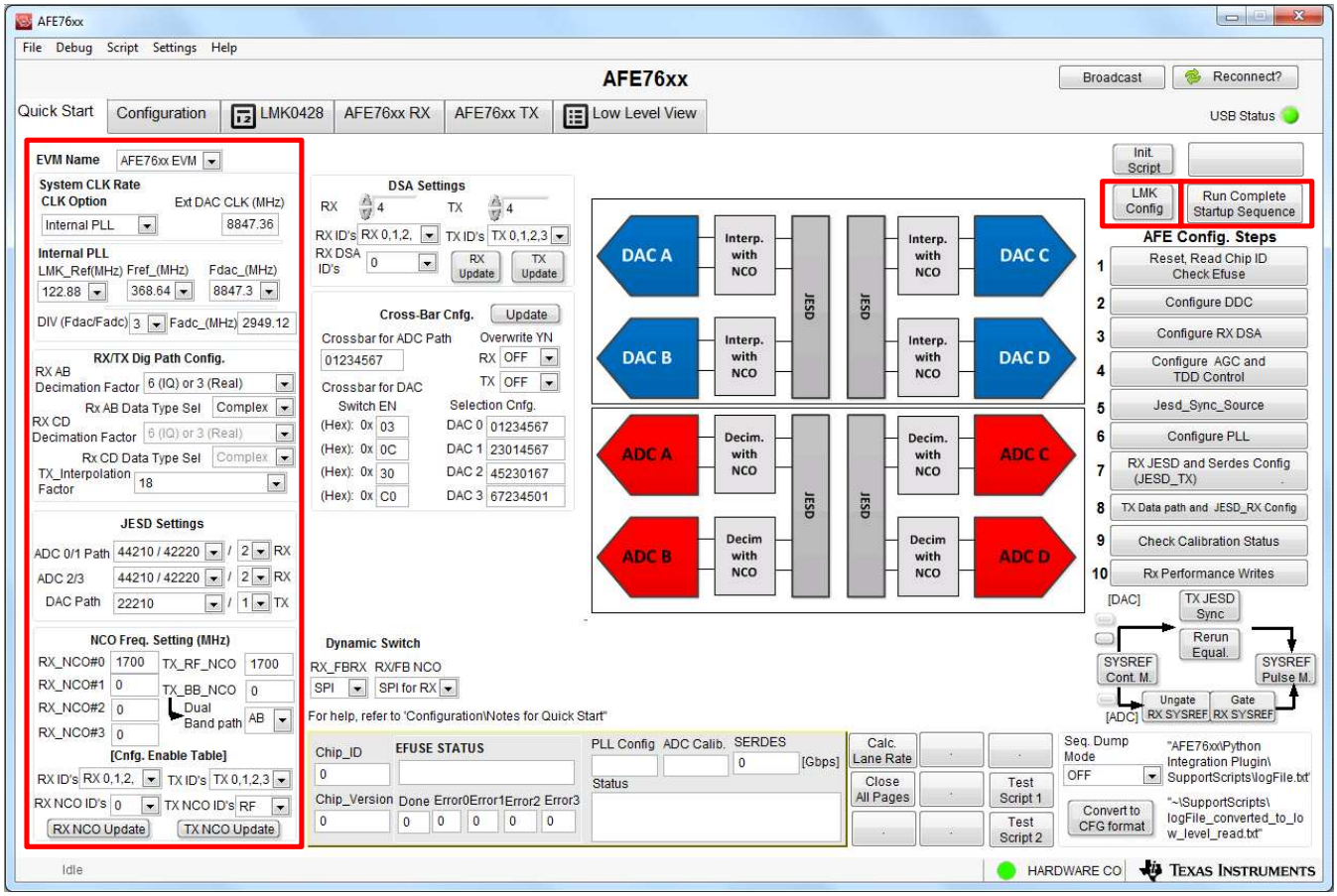

Figure 11. AFE76xx GUI Execution

11. When the GUI finishes loading, the current consumption of the AFE EVM is around 4.5 to 5 A.

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12. The user can see IOUTA (J32), IOUTB (J23), IOUTC (J24), and IOUTD (J25) outputting two, 100-MHz separation tones centered at 1740-MHz RF frequency (see Figure 12).

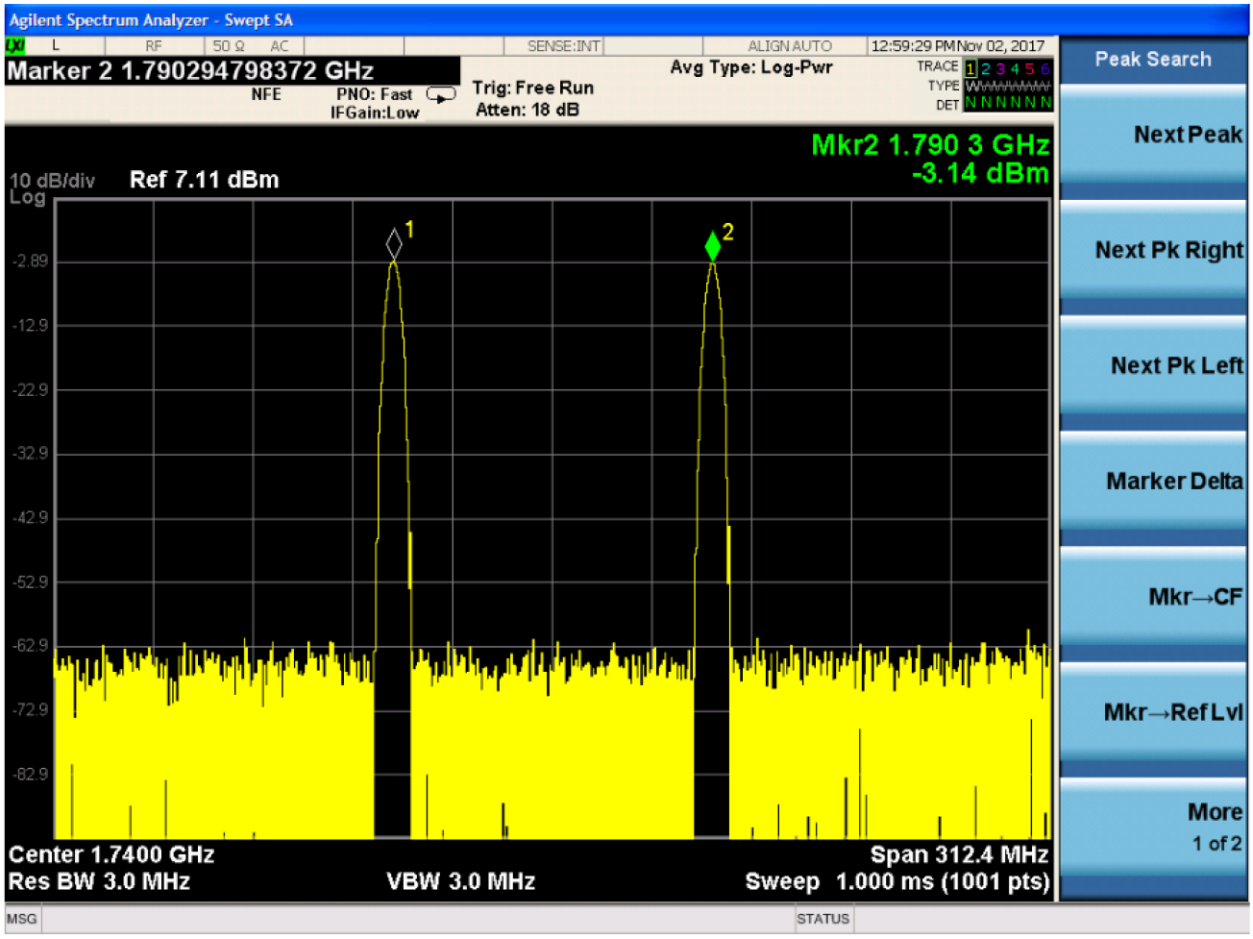

Figure 12. TXDAC Output Spectrum

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2.3.2 Check Point 1

1. At this point, the TX NCO can be adjusted on the start-up page. Enter a number in the TX_RF_NCO box and click on TX NCO Update. The RF frequency should be moved now. TX_BB_NCO is not used here, because the front mixers are not enabled. This configuration only enables the back mixer (see Figure 13).

NOTE: TX_BB_NCO is only available in dual-band configuration. In single-band configuration, the ID of TXNCO must only be RF. In dual-band configuration, the ID of TXNCO can be both, for both the RF and BB.

2. Use TX ID to adjust the individual TX channels. In this configuration, only TX0 and TX1 are available (see Figure 13).

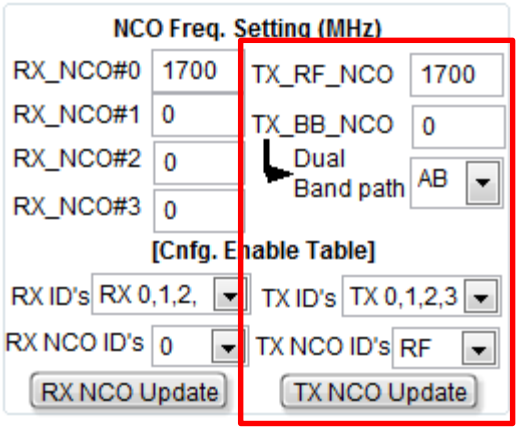

Figure 13. TXDAC NCO Setup

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3. Use the digital summer to add the TX0 and TX1 data onto the TXA channel output. To do so, adjust the TX0 and TX1 RF frequency, so that they do not overlap. Then, make the following selection on the overview GUI (see Figure 14).

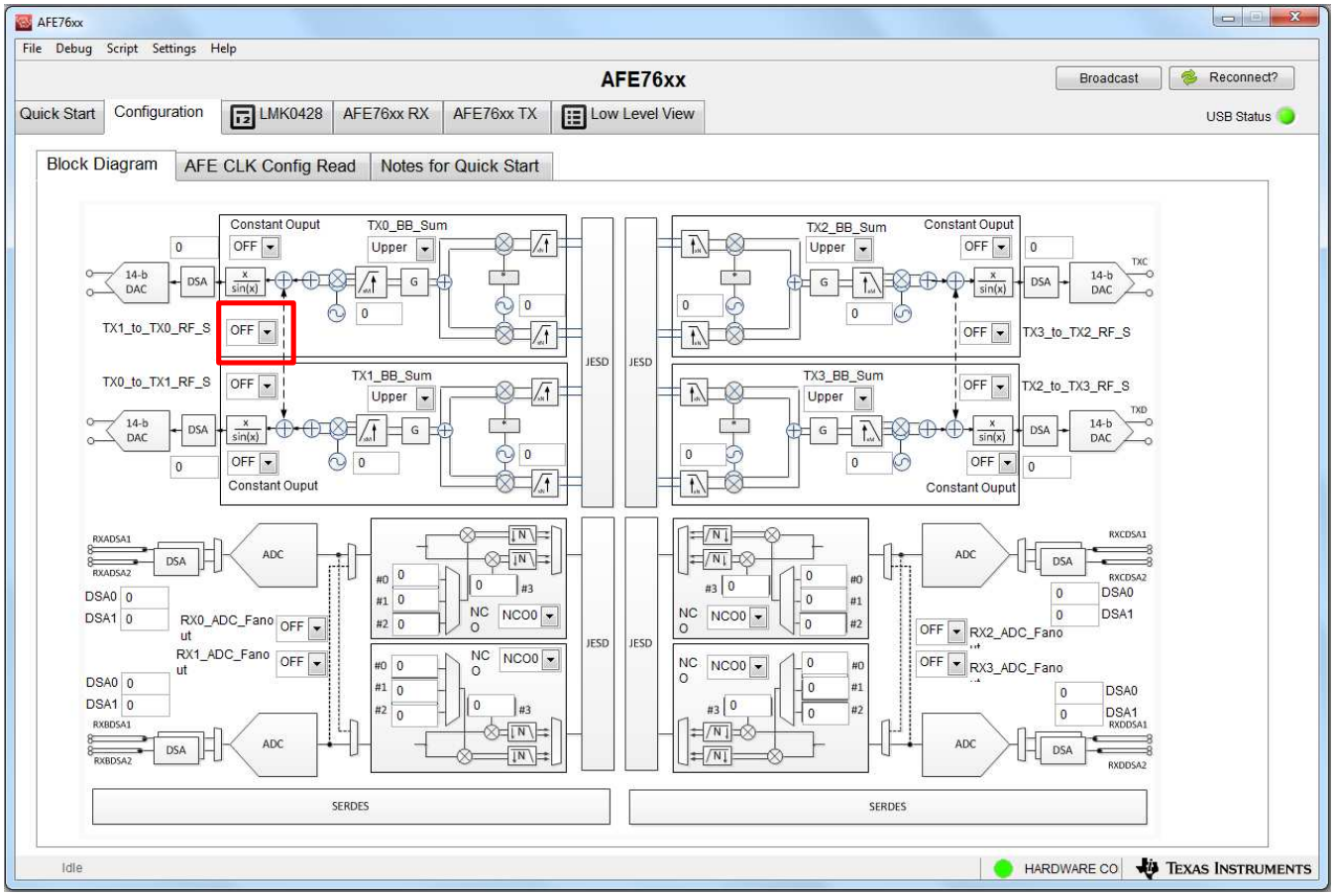

Figure 14. TXDAC Summing of TXDUC Paths

The TXA (IOUTA) output should now output two spectrums from TX0 and TX1. The same can be applied to the TXC and TXD pair.

4. At this point, TXDSA can be adjusted on the start-up page. Enter a number in the TX DSA box and click on the TX Update button. The TX power should drop accordingly. The TX DSA has a range of 0 dB to 45 dB in 1 dB steps each. The number entered is in a dB scale (see Figure 15).

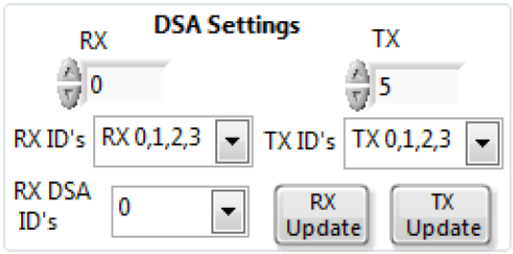

Figure 15. TXDSA Setup

NOTE: Double check that JP7 (DSASW) on the AFE76xxEVM is disconnected from the board. Double check that JP4 (TXTDD1/TXTDD2) on the AFE76xxEVM is connected to the board. This ensures proper operation of the TXDSA setting.

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2.3.3 Check Point 2

AFE76XXEVM device:

Green LEDs D6 and D7 should be lit at this point. D6 indicates that PLL loop 1 of the LMK04828 is locked. D7 indicates that PLL loop 2 of the LMK04828 is locked. The EVM is still functional without PLL loop 1 running, but PLL loop 2 is necessary for successful bring-up.

- If PLL loop 1 is not running, check the 10-MHz reference. This is needed to achieve signal coherency with the signal generators and spectrum analyzer.
- If PLL loop 2 is not locked, contact TI applications for additional support.

TSW14J56EVM device:

The LEDs D1 and D4 should not be lit, D3 should be lit, and D2 should be flashing. These are necessary requirements for the JESD204B RX link for the DAC.

- If D1 is lit and D2 is not flashing, go to the main start-up page of the AFE76xx GUI, and click on the TX JESD Sync button (see Figure 16). This manually resets the DAC JESD204B logic to force a re-handshake of the JESD204B link.

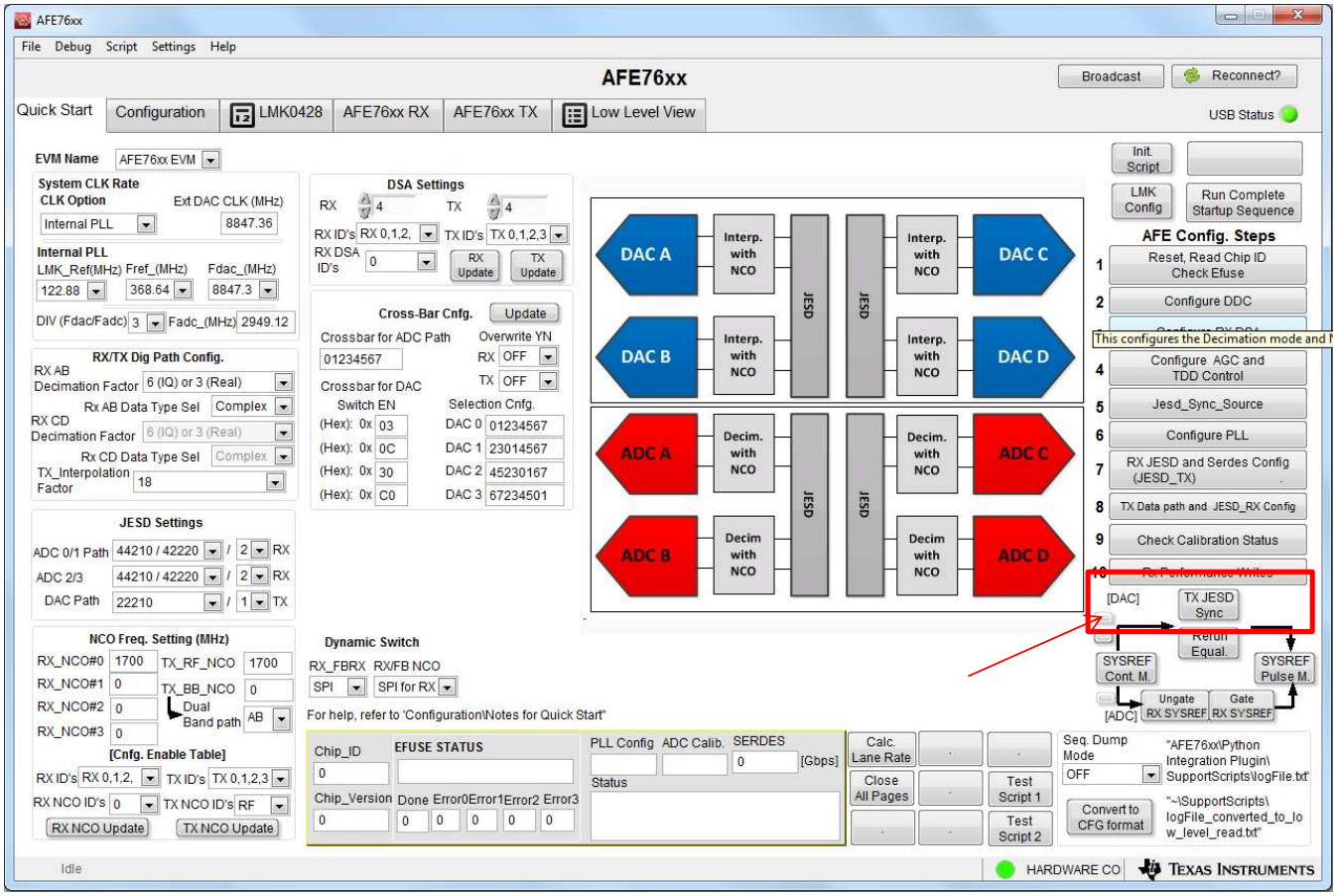

Figure 16. JESD204B DAC Resync Process

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- If the previous step still does not work, click on the Rerun Equal button, (see Figure 17). This manually readapts the SERDES receiver, manually resets the JESD204B core, and forces the re-handshake of the JESD204B link.

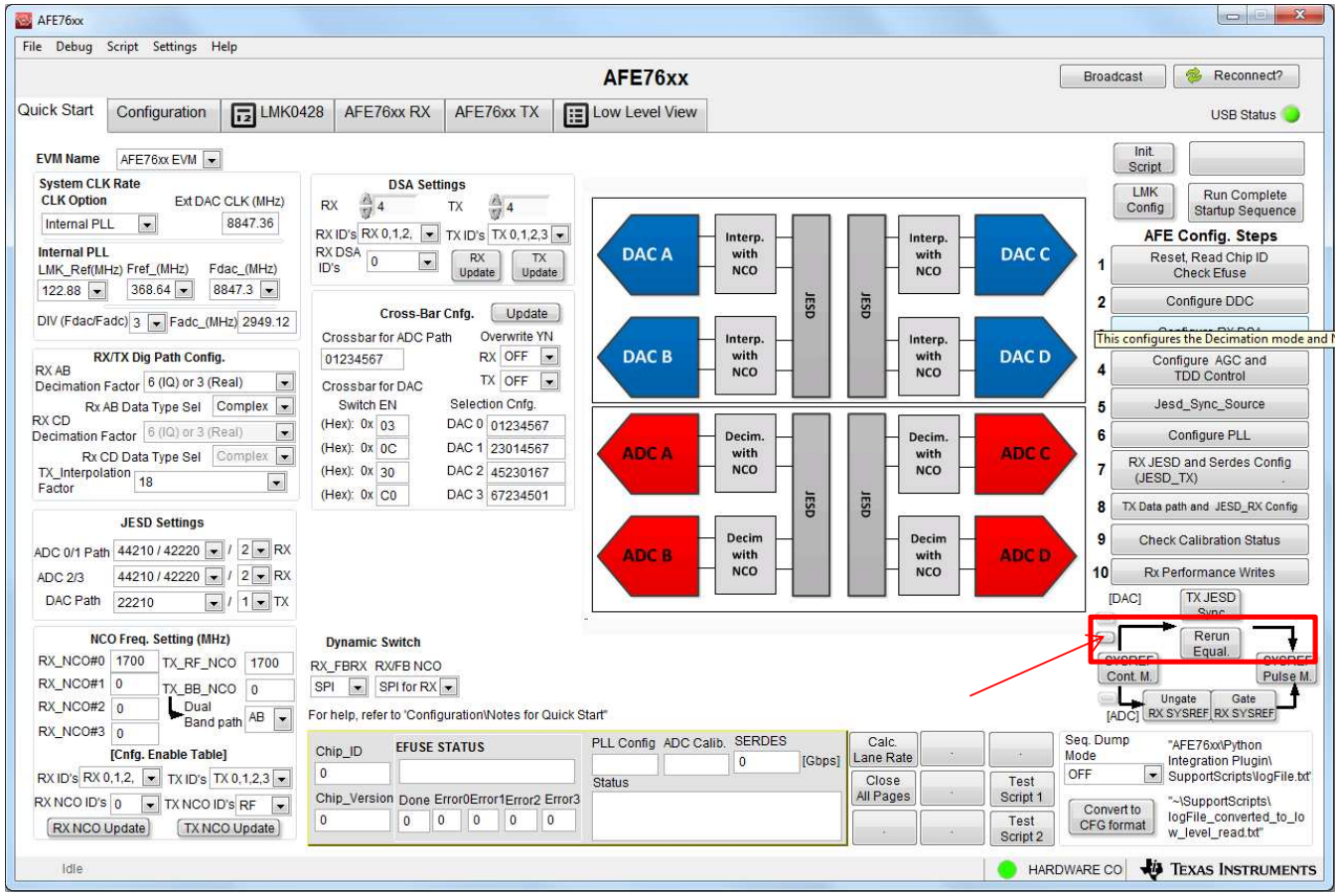

Figure 17. JESD204B DAC Re-Equalization and Resync Process

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2.3.4 ADC Setup

For the RX output out of the ADC, do the following.

1. Go to the ADC tab in the HSDC Pro GUI and select AFE76xx_2x2RX_44210 mode, then set up the number of samples per channel and the averaging feature (see Figure 18).

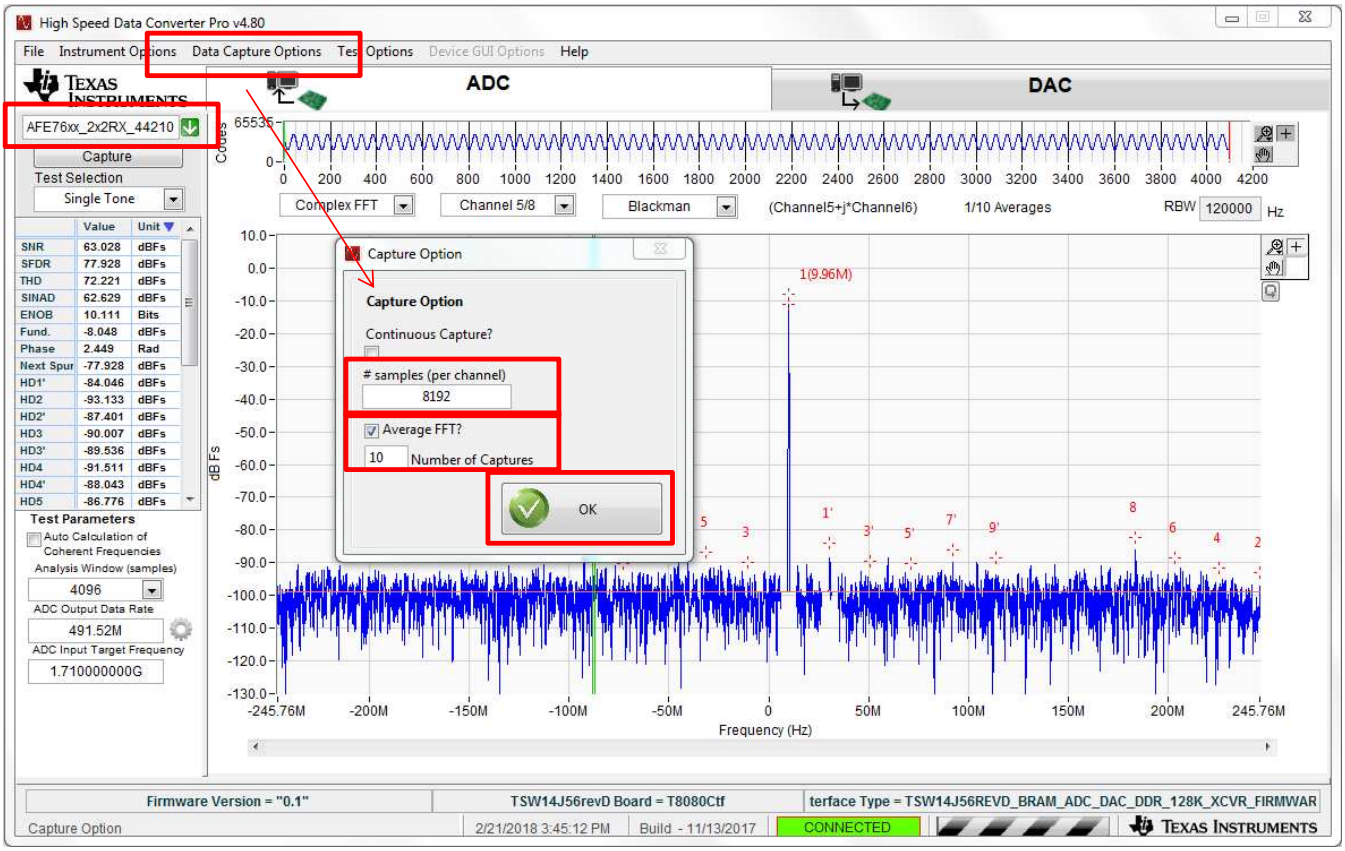

Figure 18. HSDC Pro Setup For RXADC Capture

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2. Press the down-conversion setup button (Tool Box Icon) to start the down-conversion processing feature. The raw sample rate of the ADC is 2949.12 MSPS, with a decimation-by-6 feature. The down-conversion mixer is set to be –1700 MHz. The RF input is 1710 MHz, see Figure 19).

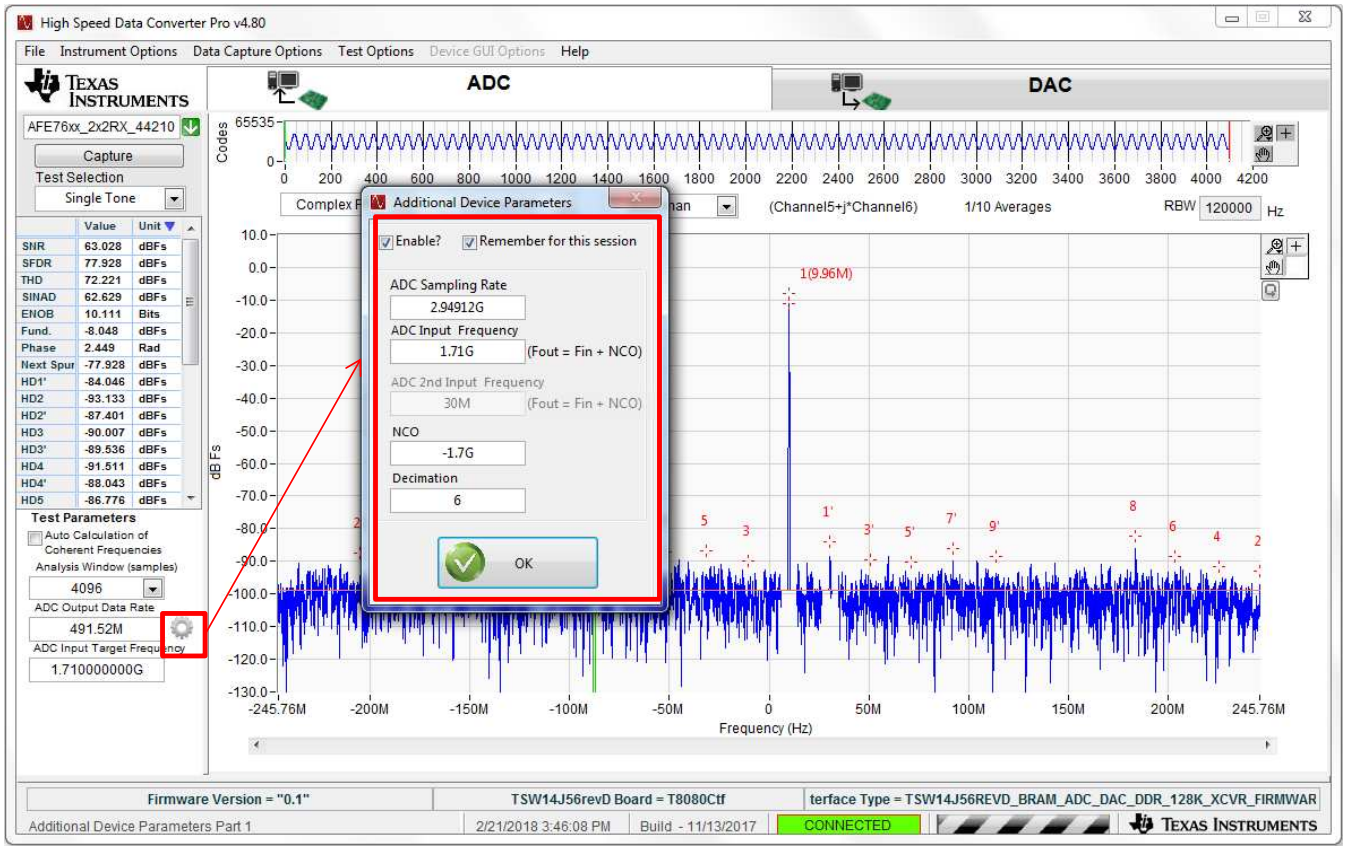

Figure 19. HSDC Pro Setup for RXADC Down-Conversion Calculation

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3. Press the Capture button to capture the ADC data (see Figure 20).

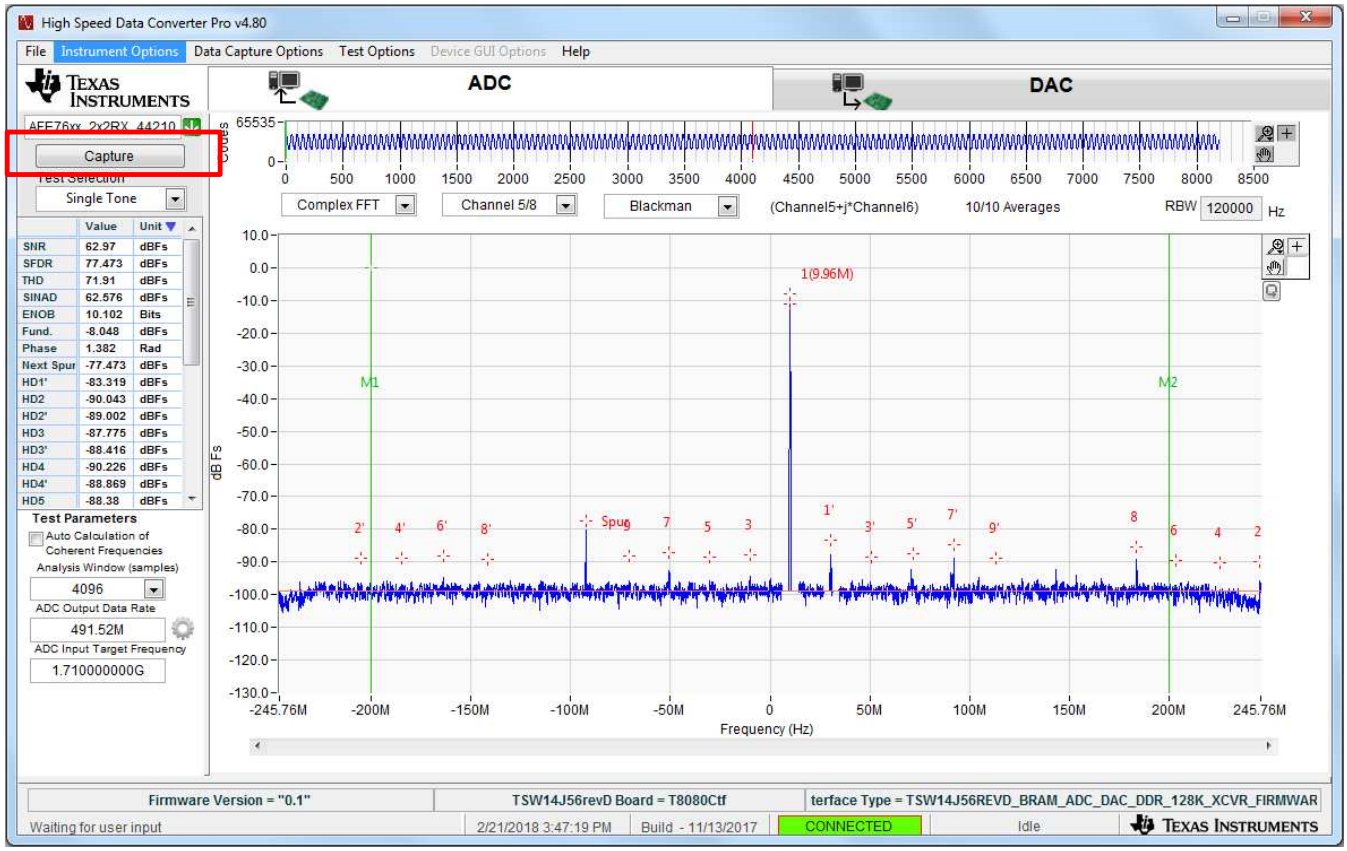

Figure 20. RXADC Output FFT Spectrum

In this case, RX_NCO = 1700 MHz and RF input = 1710 MHz.

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2.3.5 Check Point 3

1. At this point, RX NCO can be adjusted at the start-up page. Enter a number in the RX_RF_NCO box and click on the RX NCO Update button (see Figure 21). The RF frequency should be moved now.

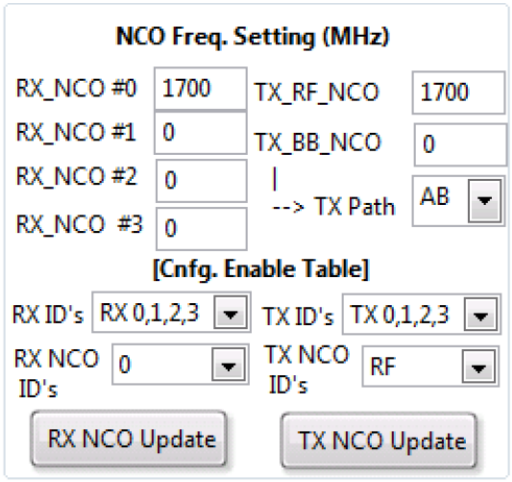

Figure 21. RXADC NCO Setup

2. At this point, RXDSA can be adjusted on the start-up page. Enter a number at the RX DSA box and click on the RX Update button (see Figure 22). The RX power should drop accordingly. The RX DSA has a range of 0 dB to 28 dB in 1 dB steps each. The number entered is in a dB scale.

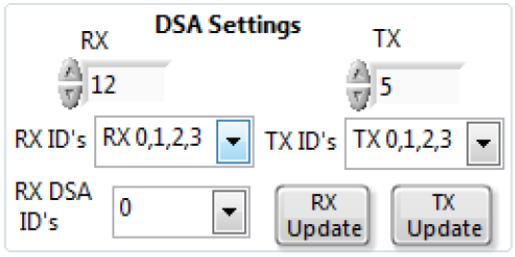

Figure 22. RXDSA Setup

NOTE: Double check that JP7 (DSASW) on the AFE76xxEVM is disconnected from the board. This ensures proper operation of the TXDSA setting.

2.3.6 Check Point 4

TSW14J56EVM – D1 and D3 should not be lit. D2 and D4 should be flashing. These are necessary requirements for the JESD204B transceiver mode to work.

AFE76xxEVM – Data transmission on the DAC and data capture on the ADC should be enabled at this point.

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2.3.7 Check Point 5

If the ADC capture is not working, use the ADC resync process and capture the pattern again, see Figure 23.

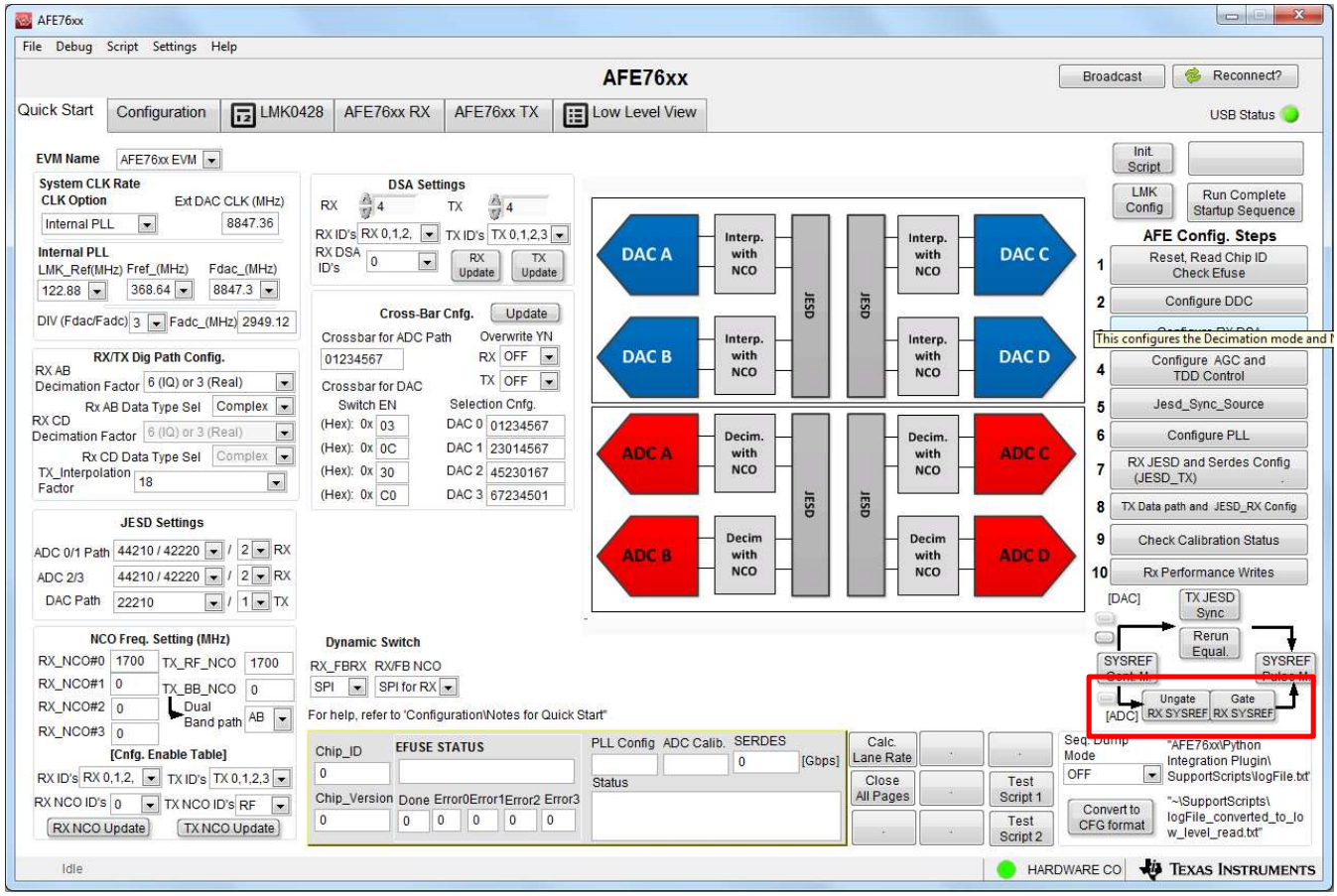

Figure 23. RXADC JESD204B Resync Process

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STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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西新宿三井ビル

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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