January 2014
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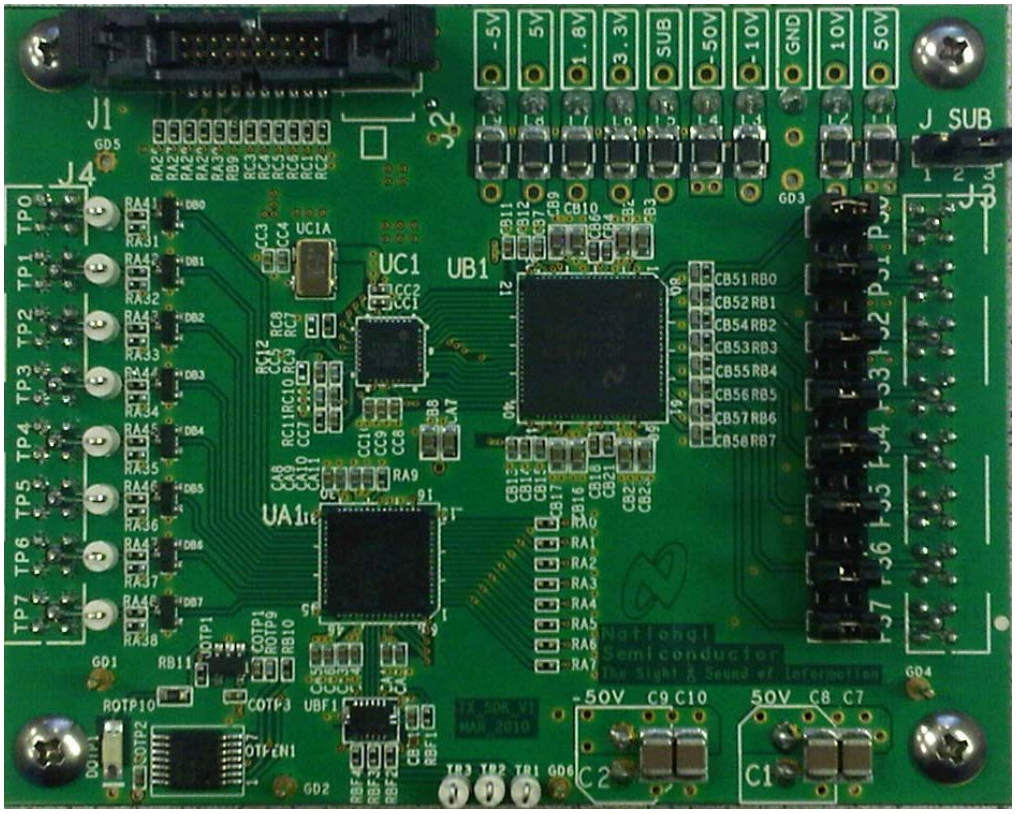
Ultrasound Tx Evaluation Kit (TX_SDK_V1) User's Guide



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1.0 Overview

Texas Instruments' Ultrasound Transmit Solution Evaluation Board demonstrates a comprehensive transmit-side signal path featuring:

- LM96530 Octal T/R Switch
- LM96551 Octal High Voltage Pulser
- LM96570 Octal Digital Beamformer

The digital beamformer serves as the onboard signal generator by outputting programmable digital pulse patterns (an external 40MHz VCXO is included to drive the internal PLL of the beamformer). These output pulse patterns then drive the inputs of the high voltage pulser. The pulser outputs drive both the inputs of the T/R switch, as well as SMA connectors for measuring the high voltage pulsers' performance. The outputs of the T/R switches also drive SMA connector output ports for measuring their performance, such as cross-talk. The board can also be configured for individual device evaluation of the LM96530 T/R Switch and LM96551 Pulser as shown in **Figure 1** and **Figure 2**.

The LM96530 T/R Switch LM96551 Pulser and LM96570 Digital Beamformer are controlled by a PC driven software GUI using an Opal Kelly FPGA module.

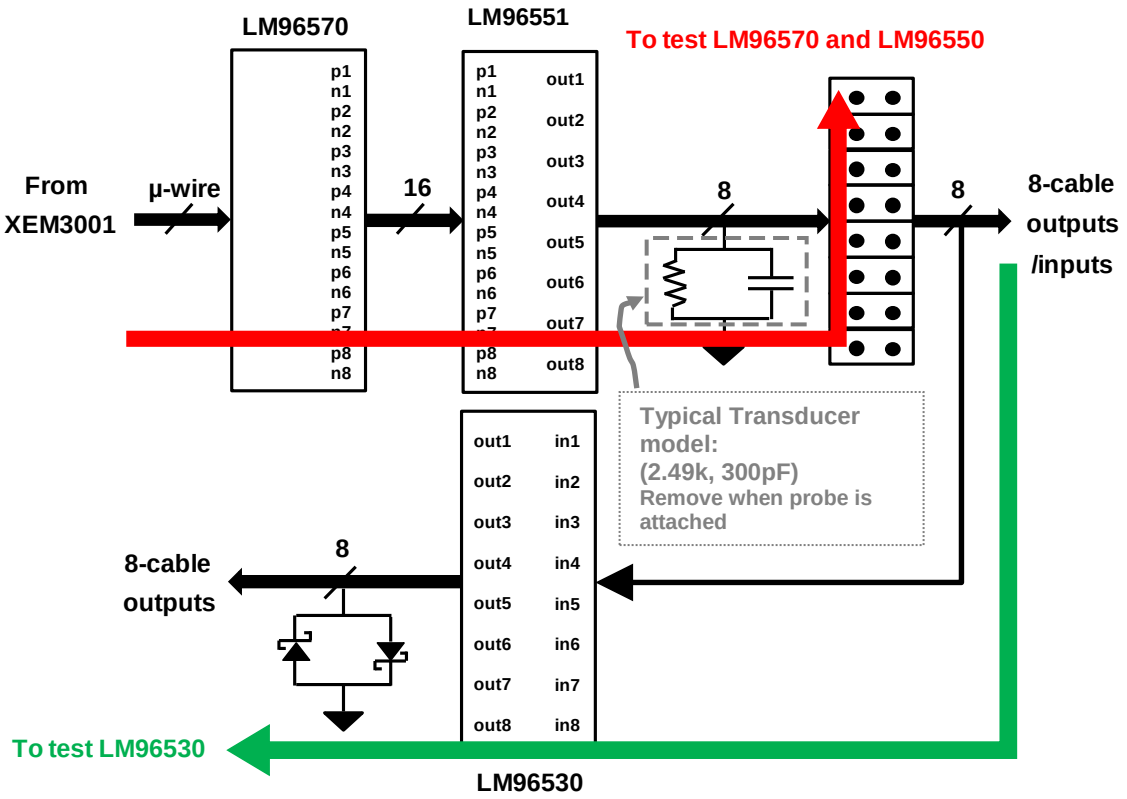


Figure 1: Simplified Schematic of Tx Eval Board for Individual Device Evaluation

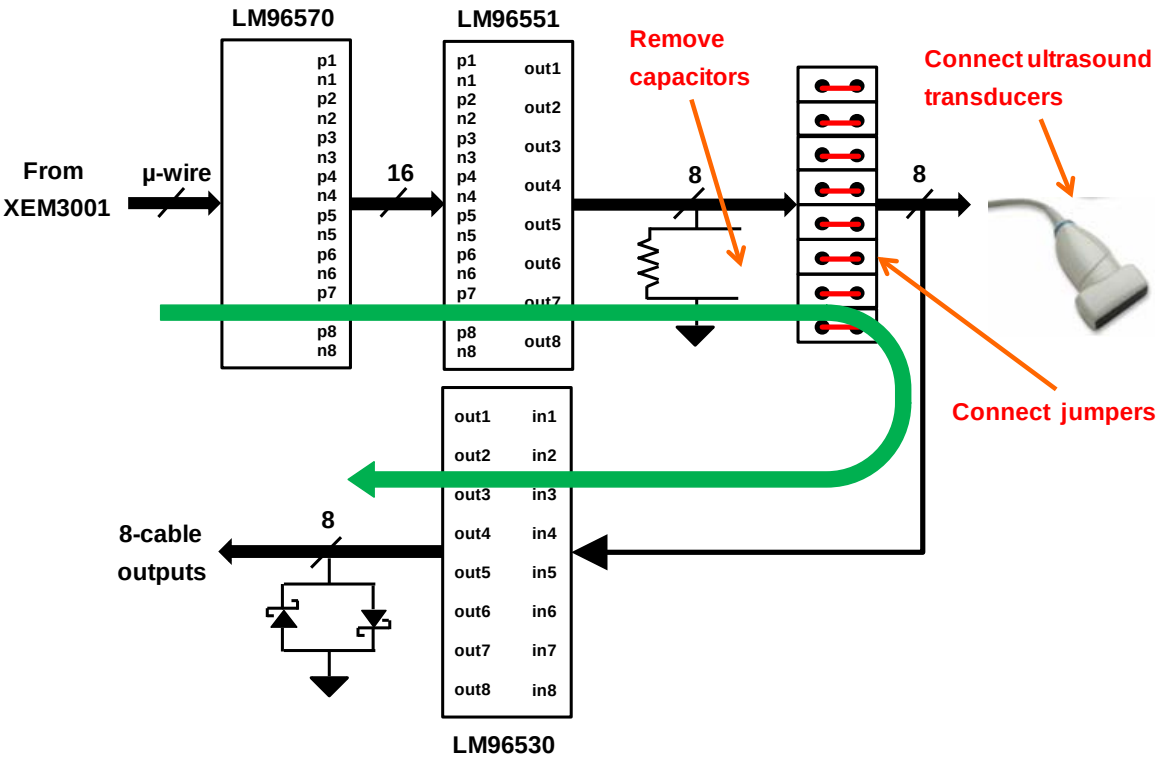


Figure 2: Simplified Schematic of Tx Eval Board for Loop Tests

1.1 Features

- Demonstrates the LM96530 T/R Switch, LM96551 HV Pulser, and LM96570 Digital Beamformer's key dynamic specifications
- 8 RF connector output ports for:
  - measuring the outputs of the LM96551 HV Pulser
  - directly driving an ultrasound transducer probe
  - driving the inputs of the LM96530 T/R Switch
- 8 RF connector output ports for:
  - measuring the outputs of the LM96530 T/R Switch
  - directly driving an ultrasound Rx analog front end
- Graphical user interface (GUI) software provided to control the LM96570 Digital Beamformer and LM96530 T/R Switch.

1.2 Packing List

The TI Ultrasound Tx Evaluation Kit consists of the following components:

- 1 Ultrasound Transmit Solution Evaluation Board
- 1 Set of 8 SAMTEC RF Connector-to-SMA bulkhead cables
- 1 Supply Voltage Cable with Phoenix Connector and labeled Banana Plugs for:
    - +1.8V
    - +3.3V
    - ±5V
    - ±10V
    - ±50V
    - VSUB
- 1 Opal Kelly XEM3001 FPGA Module
- 1 Opal Kelly-to-Evaluation Board Adapter & Ribbon Cable
- 1 USB Cable

1.3 Board Schematic and Orientation

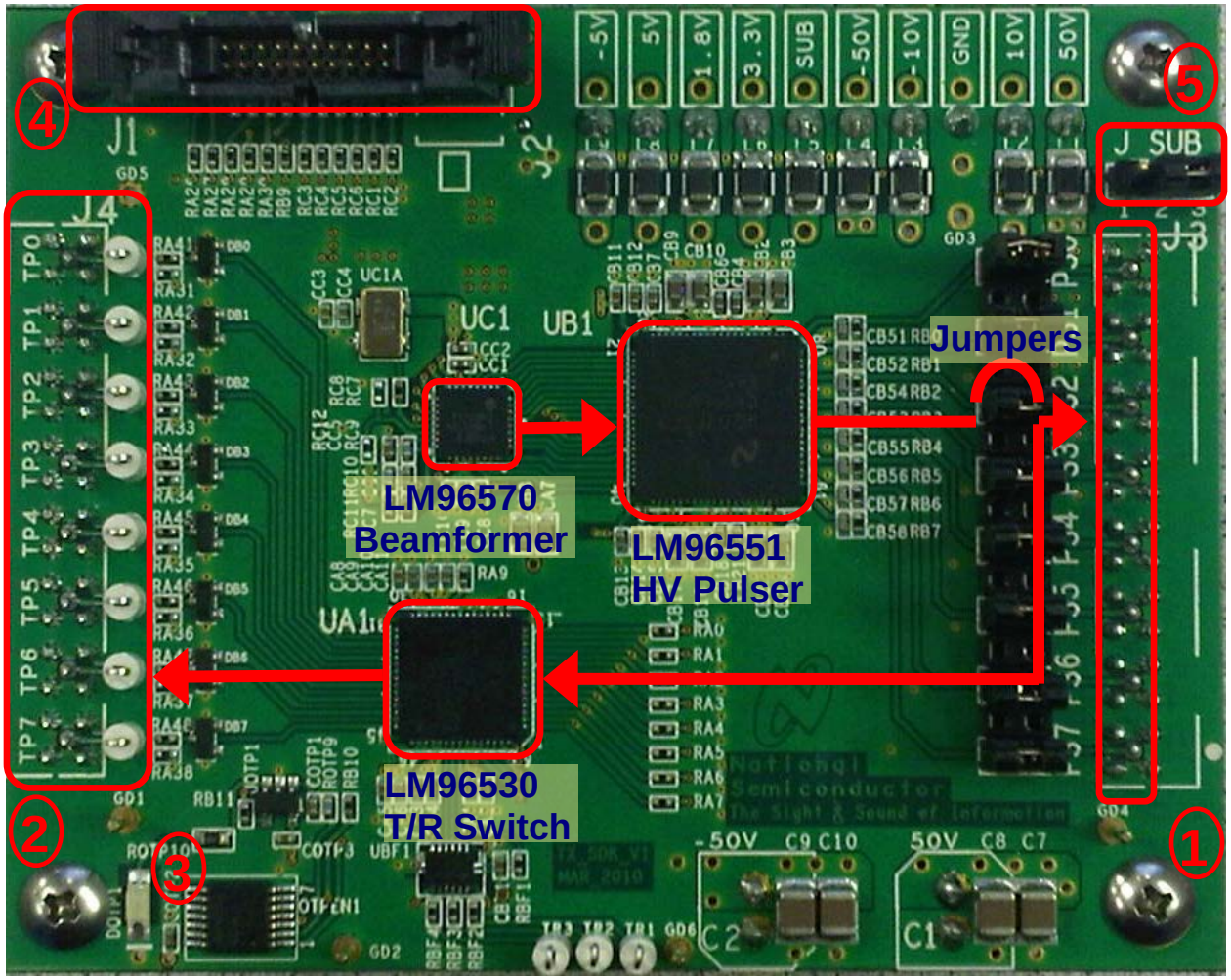


Figure 3: TI Ultrasound Tx Eval Board Orientation

1. **J3**. These 8 RF connectors allow the user to measure the Pulser outputs. When jumpers, **PS0-PS7** are uninstalled, the J3 RF connectors can also be used to drive the inputs of the T/R switch with an external test signal source. See Schematic and ***Section 6.0 Individual Device Evaluation*** for more details.
    a. The RF connectors at **J3** can also directly drive a transducer probe. To do this, 330pF capacitors **CB51-CB58**, must be removed.
    b. **PS0-PS7** can also be used to monitor the Pulser output waveforms with a high impedance oscilloscope probe.
2. **J4**. These 8 RF connectors allow the user to measure the T/R Switch outputs. Test Points **TP0** to **TP7** are also provided for convenient waveform monitoring.
3. **DOTP1**. This LED indicates the status of the OTP flag on the HV Pulser. If the LED is ON, the OTP status is OK. If the LED is OFF, the OTP flag is active, and thus the Pulser Enable pin will be held low. *See Schematic for details*.
4. **J1**. This connector mates with the Ribbon cable, which connects to the Opal Kelly Adapter board.

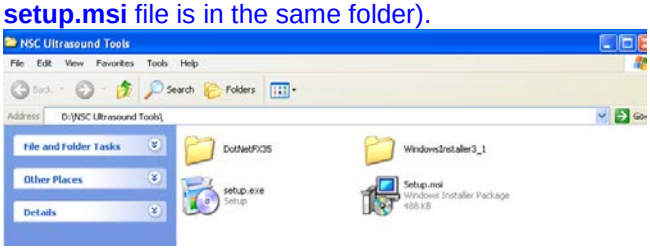
5. **J_SUB**. This header separates or ties the VSUB and -50V supply voltages on the board. It is recommended to separate these two voltages by configuring J_SUB in the “2-3” position.

2.0 Quick Start-Up Procedure

This section will describe the basic start-up procedure for (1) installing the GUI software, (2) powering up the Eval Board, and (3) exercising control and functionality of the board.

2.1 TI Ultrasound TX Control Software Installation

1. Double click on the file, “**setup.exe**” in the “**TX-SDK-V1**” folder (web download. Please Make sure the **setup.msi** file is in the same folder).



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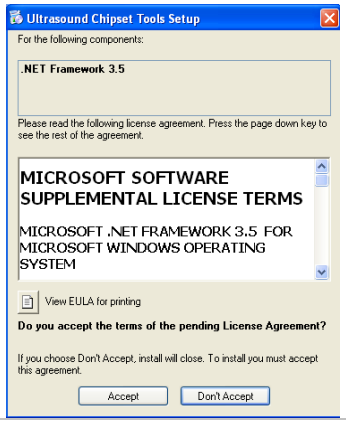

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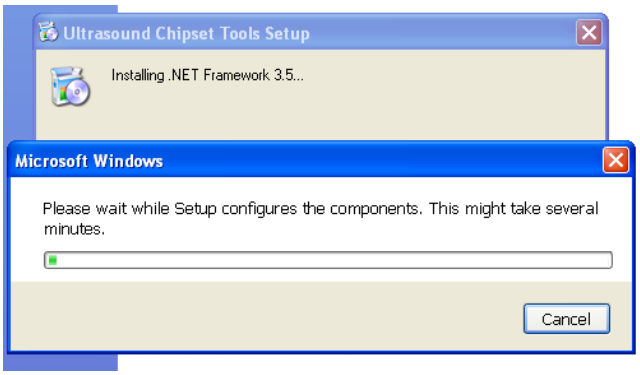

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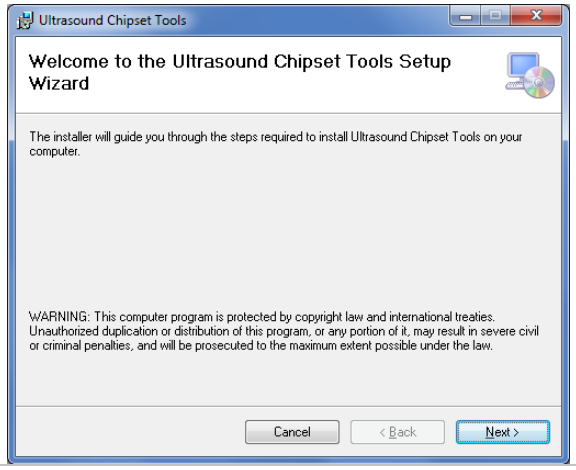

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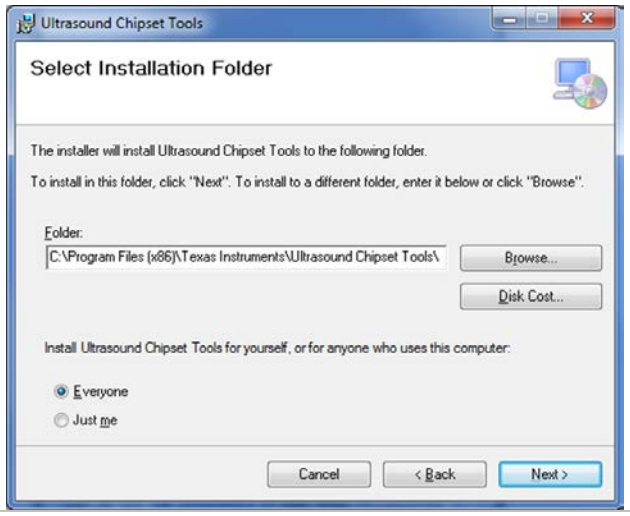

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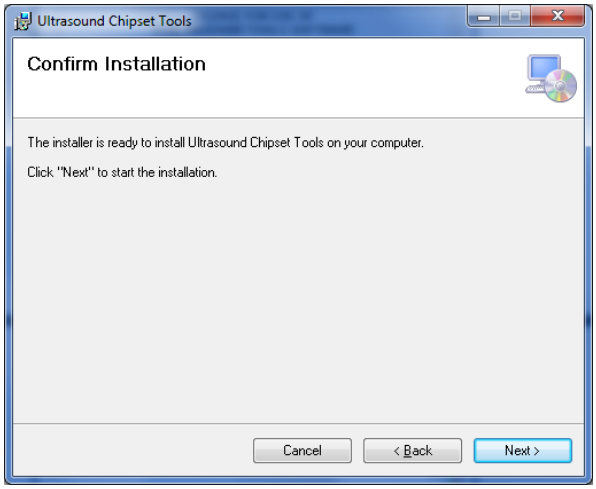

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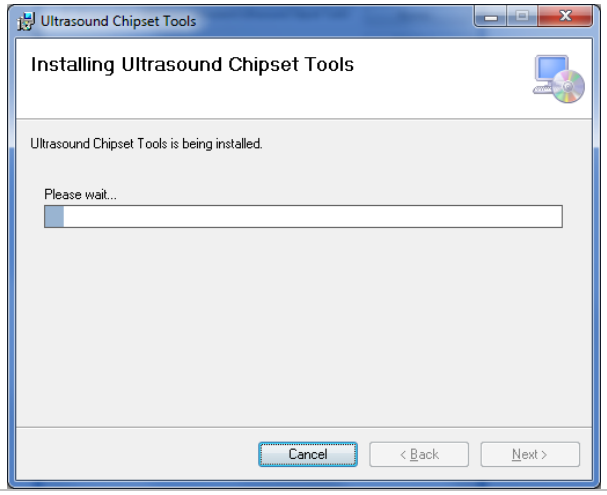

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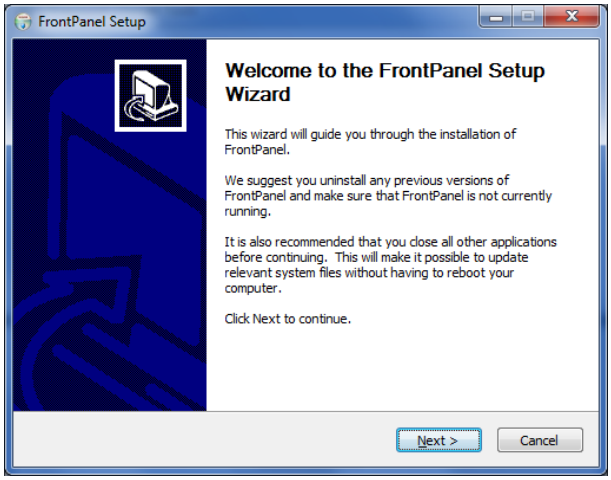
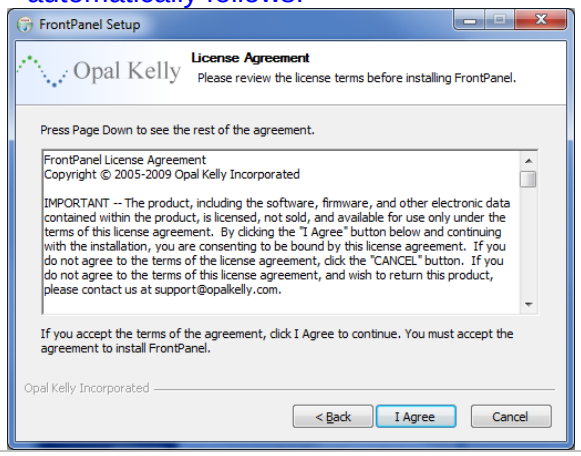


10. Installation for the Opal Kelly module automatically follows.



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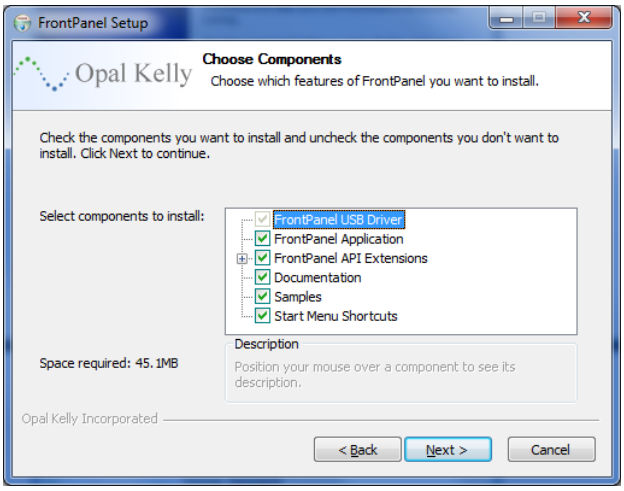
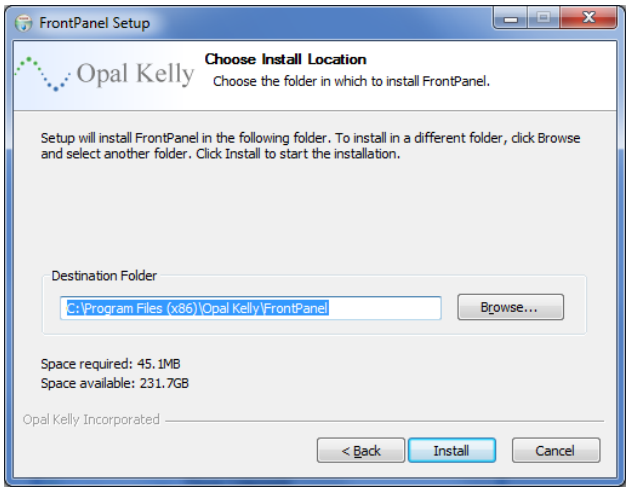
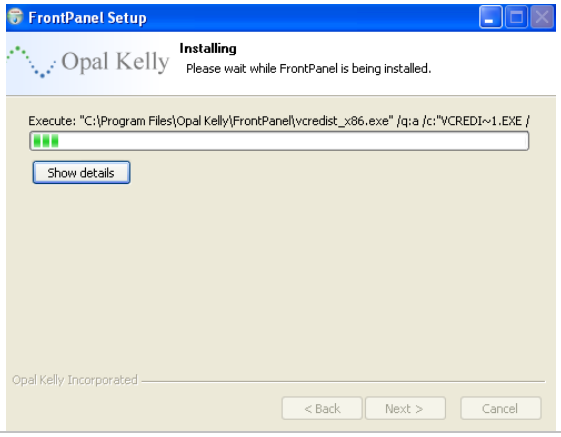

FrontPanel Setup
Opal Kelly
Choose Components
Choose which features of FrontPanel you want to install.
Check the components you want to install and uncheck the components you don't want to install. Click Next to continue.
Select components to install:
FrontPanel USB Driver
FrontPanel Application
FrontPanel API Extensions
Documentation
Samples
Start Menu Shortcuts
Space required: 45.1MB
Description
Position your mouse over a component to see its description.
Opal Kelly Incorporated
< Back
Next >
Cancel

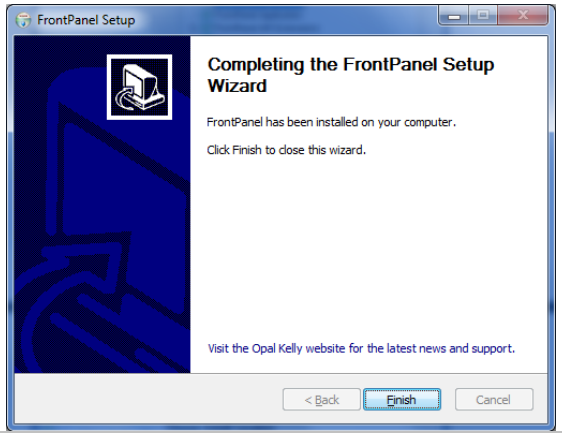
12.


FrontPanel Setup
Opal Kelly
Choose Install Location
Choose the folder in which to install FrontPanel.
Setup will install FrontPanel in the following folder. To install in a different folder, click Browse and select another folder. Click Install to start the installation.
Destination Folder
C:\Program Files (x86)\Opal Kelly\FrontPanel
Browse...
Space required: 45.1MB
Space available: 231.7GB
Opal Kelly Incorporated
< Back
Install
Cancel

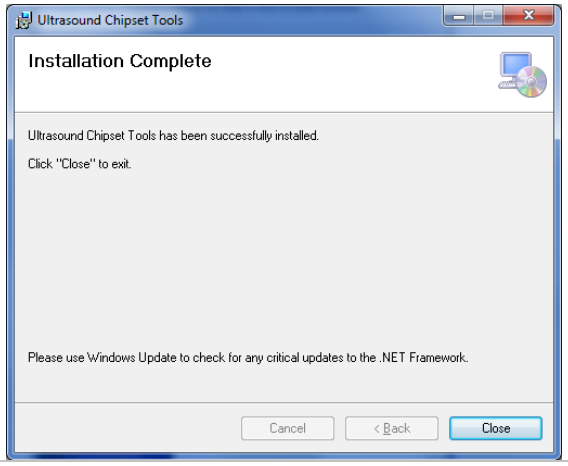
13.


FrontPanel Setup
Opal Kelly
Installing
Please wait while FrontPanel is being installed.
Execute: "C:\Program Files\Opal Kelly\FrontPanel\vcredist_x86.exe" /q:a /c:"VCREDI~1.EXE /
Show details
Opal Kelly Incorporated
< Back
Next >
Cancel

14.


FrontPanel Setup
Completing the FrontPanel Setup Wizard
FrontPanel has been installed on your computer.
Click Finish to close this wizard.
Visit the Opal Kelly website for the latest news and support.
< Back
Finish
Cancel

15.


Ultrasound Chipset Tools
Installation Complete
Ultrasound Chipset Tools has been successfully installed.
Click "Close" to exit.
Please use Windows Update to check for any critical updates to the .NET Framework.
Cancel
< Back
Close

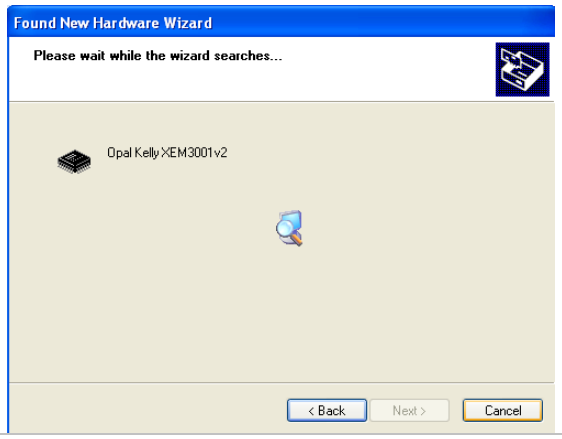
2.2 Opal Kelly Module USB Driver Installation

1. Connect the board to the PC with the USB cable.

2.

3.

4.



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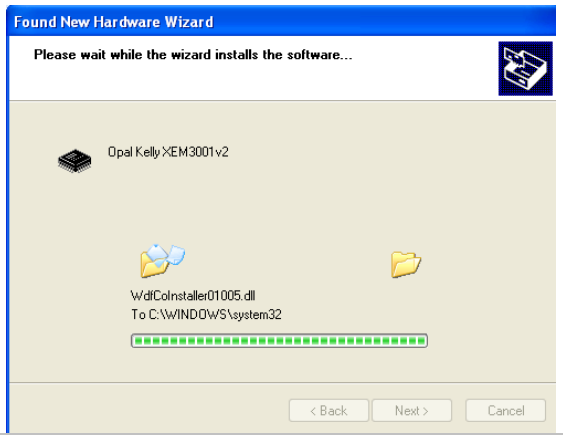

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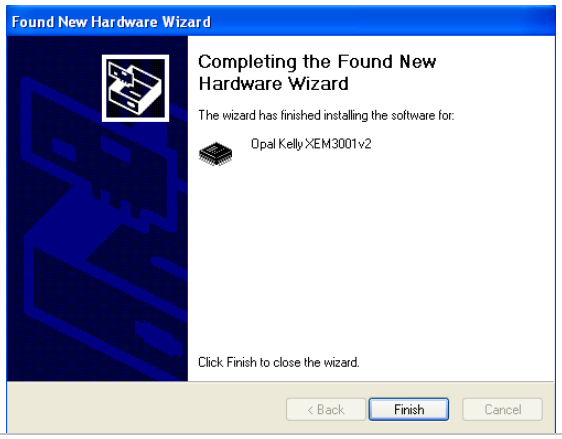

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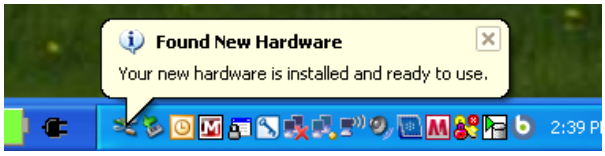
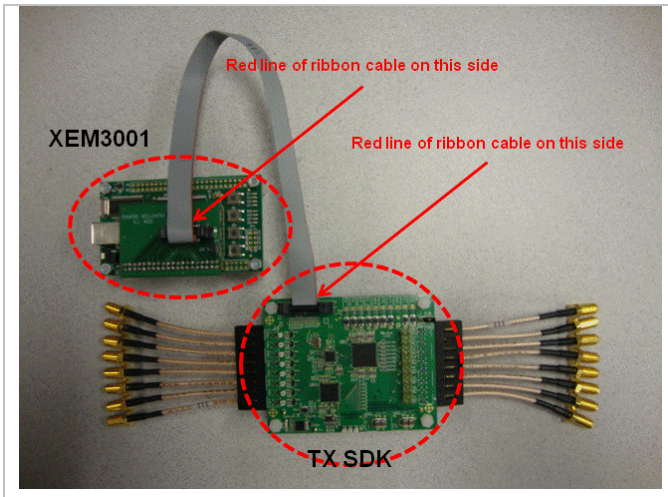


8. Plug the Adapter board into JP3 of the Opal Kelly board.

	**9. Please be sure the red line of ribbon cable at the right sides of Tx Eval board and XEM3001**

2.3 Eval Board Power Cable Connections

The Eval Board requires a total of 9 power supply voltages:

- VSUB (the most negative supply voltage, **greater than or at least equal to -50V**)
- ±50V for the LM96551's VPP and VNN
- ±10V for the LM96551's VPN and VDN
- ±5V for the LM96530's VDD and VSS
- +3.3 for the LM96530, LM96551, and LM96570's Digital IO Supply
- +1.8V for the LM96570's VDDA and VDDC

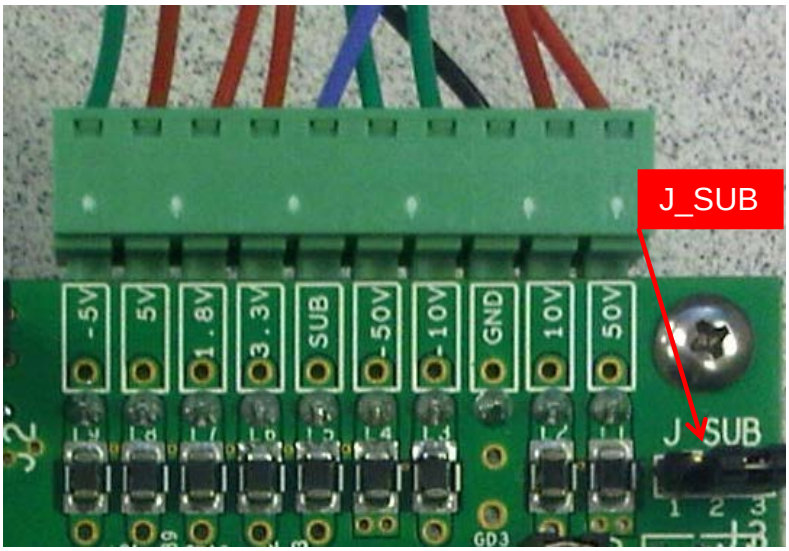


Figure 4: Board Power Cable Connector

☑ Connect the GREEN Supply Voltage Phoenix connector to the Tx Eval board at J2 the board as shown in **Figure 4**.

☑ Connect the other ends of the banana cables to the appropriate bench power supplies. Tracking power supplies are recommended for the ±10V and ±5V pairs.

2.4 Eval Board Power-Up Sequence

Refer to Figure 5 for the block diagram of the external power supplied to be used:

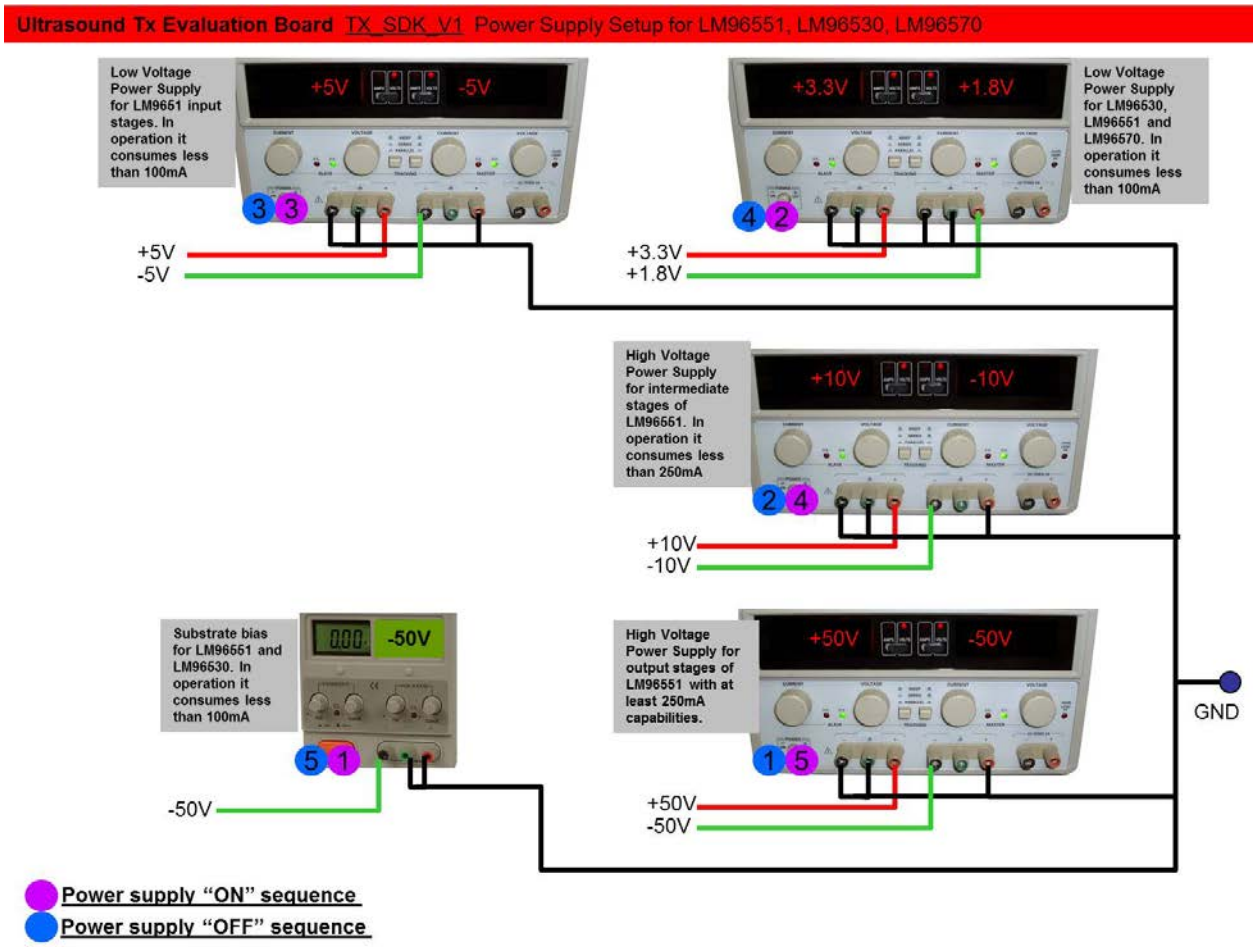


Figure 5: Power Supply Connection View

Note: Power Supply current limits are for board protection only! These do not represent the actual current consumption and should not be used for that purpose!

The typically recommended power-up and power-down sequence for the Tx chipset is:

1	**VSUB**	**Turn ON the Substrate Voltage (VSUB, which, must be the most negative voltage in the system, greater than or at least equal to -50V)**
2	**+3.3V**	**Turn ON all digital IO voltage supplies**
3	**+1.8V**	**Turn ON the LM96570 Beamformer**
4	**±5V**	**Turn ON the LM96530 T/R Switch**
5*	**±10V** **±50V**	**Turn ON the LM96551 HV Pulser last.**

To Power-down, follow this sequence in the exact reverse order.

*** Note that VSUB and VNN (negative HV supply of the LM96551) may be tied together and powered by the same -50V to minimize the number of bench power supplies. To do this, jumper J_SUB (see Figure 4) must be configured in the "1-2" position. However, it is recommended to configure jumper J_SUB in the default "2-3" position such that VSUB and VNN are separated.**

*** A Power Module Reference design schematic is provided in the web download to eliminate the need for external power supplies and to ensure proper power-up, power-down sequence for protection.**

<u>The following procedure should be followed each time the Eval Board is powered up:</u>

☑ **Power up VSUB first.**

- ⚠ ***To prevent fatal device damage, the VSUB MUST ALWAYS be the most negative voltage applied to the Eval Board at all times! VSUB must be greater than or at least equal to -50V. Thus, VSUB MUST ALWAYS be turned ON FIRST and turned OFF LAST.***

☑ **Power up +3.3V Digital IO Voltage supply for all of the devices.**

☑ **Power up +1.8V for the Beamformer.**

☑ **Power up ±5V for the T/R Switch.**

- At this point, the LM96530 (with Rref = 50Kohm) should be drawing about ~20mA of current (I_{DD} & I_{SS}) from the ±5V Analog Voltage supplies.

☑ **Power up ±10V for the Pulser's Level Shifter Voltages.**

☑ **Power up ±50V for the Pulser.**

- At this point, the LM96551 should be drawing about ~1mA from the VSUB, ~4mA of current from the +50V supply, ~3mA from the -50V supply, ~12mA from the +10V supply, and ~8mA from the -10V supply.

☑ **Launch and Initialize the Control Software**

1. **Double-click on the "TI Ultrasound Tools" icon on the Desktop to launch the Beamformer Control Software.**

Figure 6: TI Ultrasound Tools Desktop Icon

2. **Click on the "<u>T/R Switch</u>" tab to display the T/R Switch GUI controls. Choose the right configuration which users want to test.**

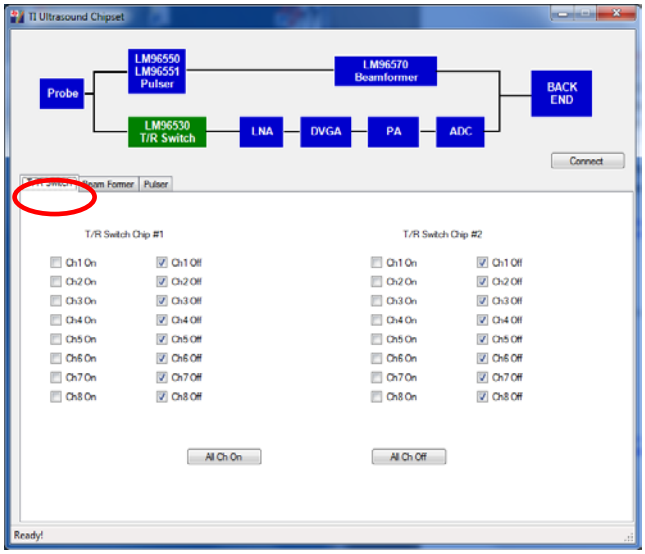


Figure 7: TI Ultrasound Tools GUI Start-up Screen – T/R Switch Controls

3. **Click on the Pulser tab to display the pulser GUI. Uncheck Enable High Voltage Pulser and Max Current Mode.**

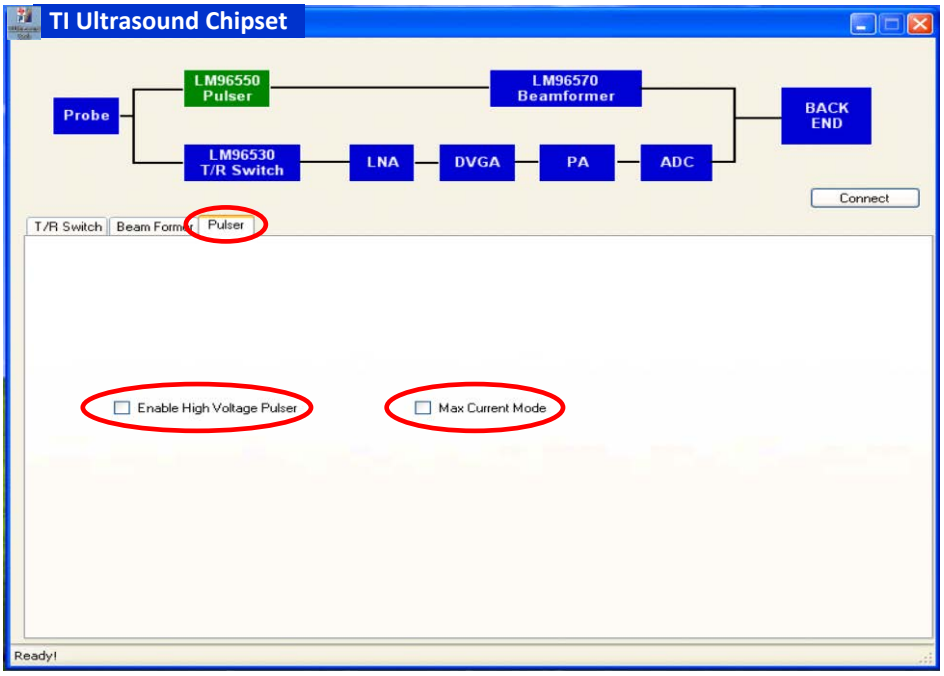


Figure 8: Pulser Controls

4. **Every time when powering up Tx Eval board, beamformer registers are suggested to reset.**
   - **Make sure the status of five red circles matched in Figure 9**
   - **Click on Connect button.**
   - **Enable and then Disable RESET.**

- **Disable and then Enable PLL_EN.**
- **Click on Disconnect button.**

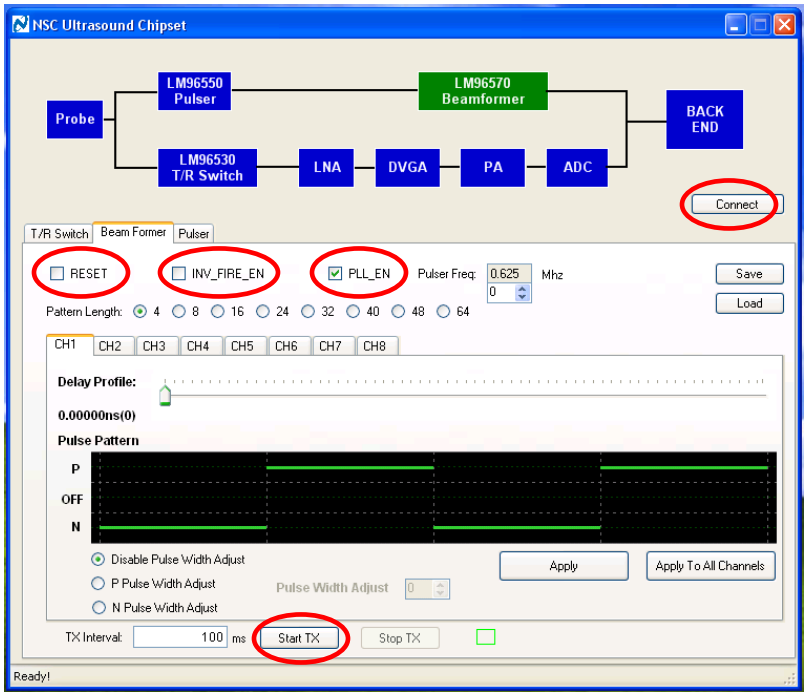
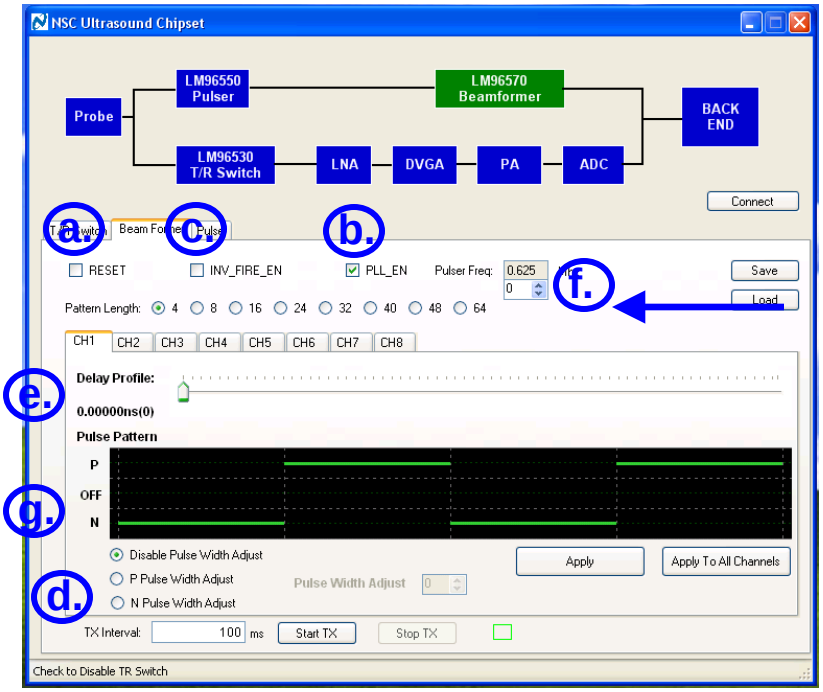


Figure 9: Beam Former Controls

5. **Some initial settings that are suitable for powering up the Beamformer and Pulser the first time are as follows: (*See section 3.1 for more details*)**

   a. **RESET Disabled**
   b. **PLL_EN Enabled**
   c. **Invert Fire Mode Disabled**
   d. **Pulse Width Adjust Mode Disabled**
   e. **Pulse Fire Delay = 0µs**
   f. **Pulse Pattern Frequency = 5MHz**
   g. **Pulse Pattern = 4-Pulse "0101" P Pattern**



Type in "16" as the Pulse Freq. Divider value and PRESS ENTER (Pulser Freq changes to 5MHz)

Figure 10: TI Ultrasound Tools GUI

6. **Click on the "Pulser" tab to display the Pulser GUI controls. Click on the "Enable High Voltage Pulser" check box to enable the Pulser. (*See Section 5.0 for more details*)**

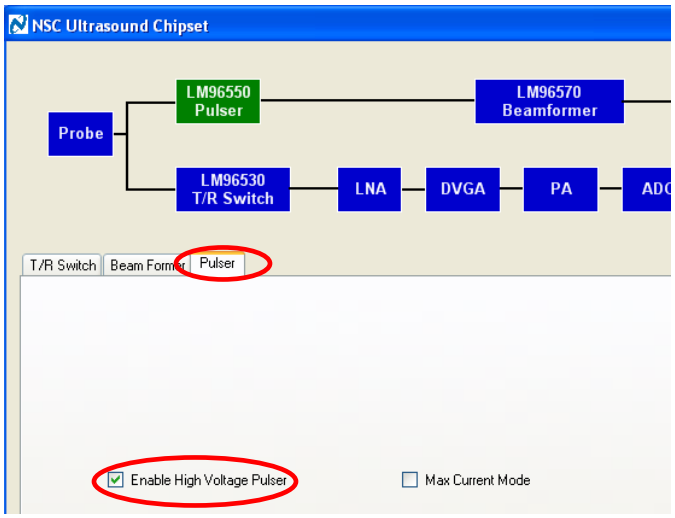


Figure 11: TI Ultrasound Tools GUI – Pulser Controls

7. **Once all parameters in step 5 are set:**
   a. **Click on the "Connect" button to establish connectivity between the Opal Kelly Module and the PC.**
   b. **Click on the "Start TX" button to send a periodic "TX_EN" / Fire signal to the beamformer.**

Upon clicking on the "Connect" button", the status message on the bottom left of the screen will read "Connected!" and upon clicking on the "Start TX"

button, the "LED box" will begin BLINKING red to indicate that the Opal Kelly Module is actively outputting a "TX_EN" / Fire signal.

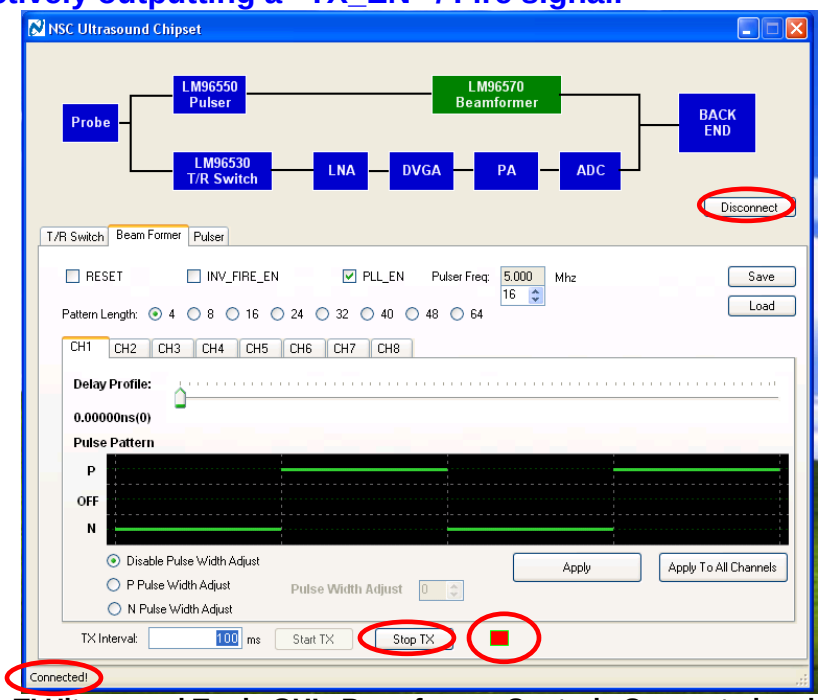


Figure 12: TI Ultrasound Tools GUI –Beamformer Controls Connected and Active

8. Probe Test Point PS0 to verify the Pulser's Channel 1 output

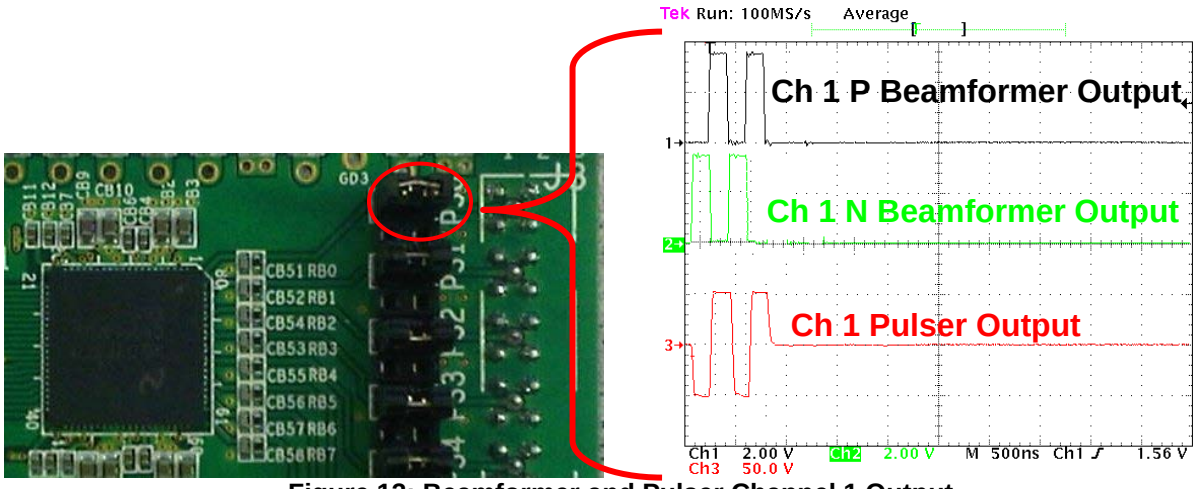


Figure 13: Beamformer and Pulser Channel 1 Output

☑ **To power down, follow the sequence in exact reverse order by turning OFF:**

1	±50V
2	±10V
3	±5V
4	+1.8V
5	+3.3V

6	**VSUB**

3.0 Beamformer GUI Controls

3.1 Global Beamformer Parameters

Figure 14: Beamformer Global Parameter Controls

- **RESET**: Checking the RESET box will pull the RESET pin HIGH on the LM96570 to reset all SPI registers back to their default values. If the TX_EN signal is firing when the RESET box is checked, the software will automatically STOP firing. The user should uncheck (pull RESET pin LOW) the RESET box after resetting the registers to resume normal operation.
- **INV_FIRE_EN**: Checking the INV_FIRE_EN box will enable the Invert Firing Mode, which is used for harmonic imaging. In this mode, each TX transmission consists of two firings. First, the programmed pulse pattern will be fired directly (non-inverted). Second, after RX is completed, the pulse pattern will be inverted and fired again.
- **PLL_EN**: Checking this box will enable the LM96570's on-chip PLL. This box should always remain checked to maintain PLL lock.
- **Pulser Freq**: This parameter determines the frequency of the P and N output pulses. Either click on the UP and DOWN arrows or type in a decimal value and press ENTER to set the desired frequency. The decimal value corresponds to the EVEN Division Factor by which the LM96570's internal 160MHz clock is divided. For example, when the desired output frequency is 160MHz / 2 = 80MHz, then the factor = 2 and the decimal value = 1. If the desired output frequency is 160MHz / 254 = 0.63MHz, then the factor = 254 and the decimal value 127. If the desired output frequency is 160MHz / 256 = 0.625MHz, then factor = 256, which is the Maximum, and decimal value 0.

Figure 15: Beamformer Tx Fire Control

- Clicking on the "Start TX" button will have the Opal Kelly Module apply a periodic TX_EN signal to the LM96570. Once this button is clicked, the GREEN box on the right will begin to blink RED as a status indicator that the TX_EN / fire signal is active.
- The time interval of the periodic TX_EN signal from the Opal Kelly Module can be adjusted by typing in a different value in the "TX Interval" box. The range of adjustment for this value is limited by the PC and is typically <u>between 10 and 100 milliseconds</u>.
- NOTE that in this Evaluation Kit, the TX_EN / fire signal from the Opal Kelly Module is not synchronized in any way with the LM96570 PLL. In a real application or system, this signal would be synchronized. **JP1** on the Adapter board provides access to the signal so that TX_EN may be externally synchronized.

3.2 Pulse Pattern Control

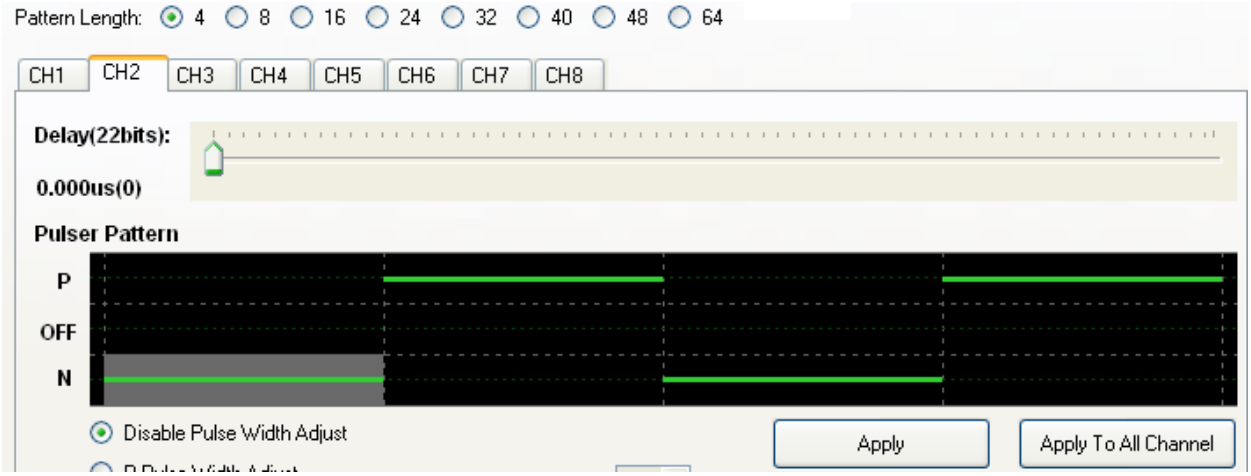
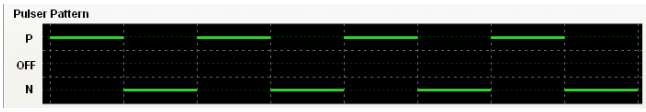
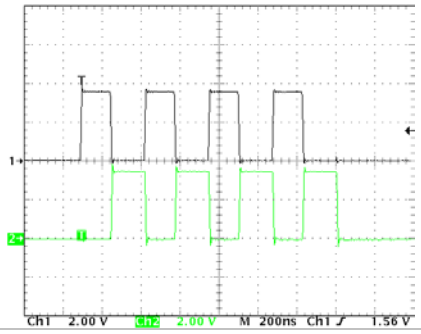
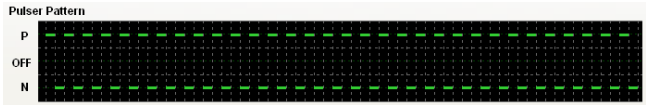
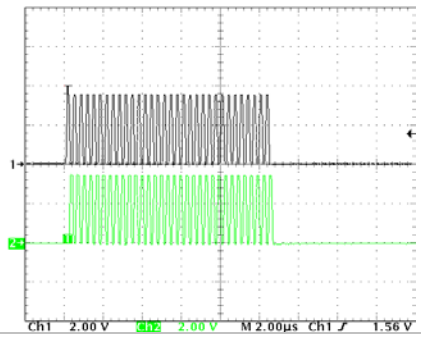
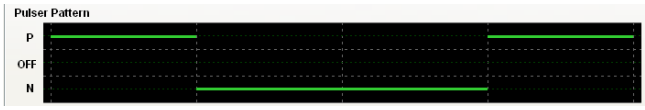


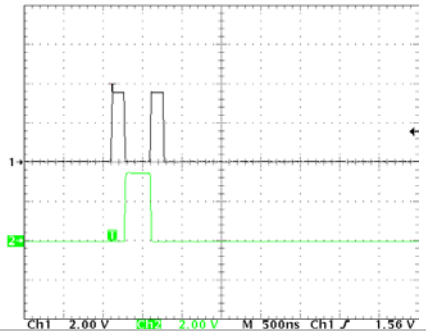
Figure 16: Beamformer Pulse Pattern Control

- Clicking on the **Channel Tabs** will display the pulse pattern of the desired channel.
- Clicking on the **Pattern Length** radio buttons will select the desired pattern length.
- The **Pulse Pattern** window displays the current pulse pattern and allows the user to design or modify the P and N outputs to any desired pulse pattern by simply clicking on each of the three levels (P, OFF, or N). See some examples by illustration below:

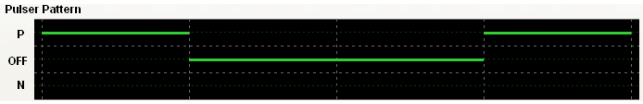
Pattern Length = 8 P Pattern = 10101010 N Pattern = 01010101  	
Pattern Length = 64 P Pattern = 1010 . . . 10 N Pattern = 0101 . . . 01  	

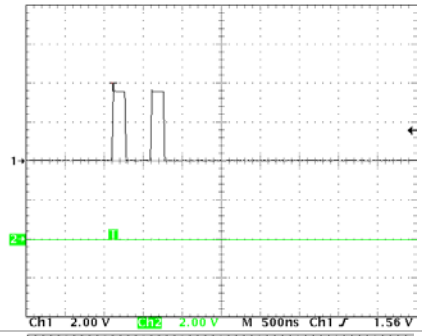
Pattern Length = 4
P Pattern = 1001
N Pattern = 0110



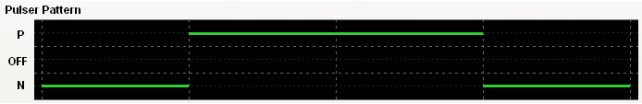


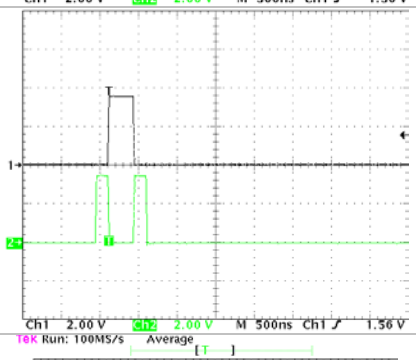
Pattern Length = 4
P Pattern = 1--1
N Pattern = 0--0



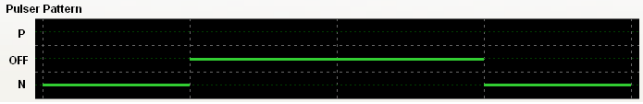


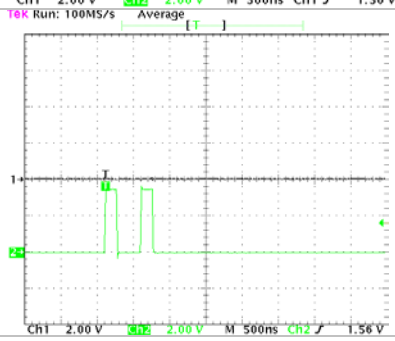
Pattern Length = 4
P Pattern = 0110
N Pattern = 1001



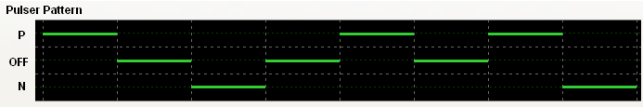


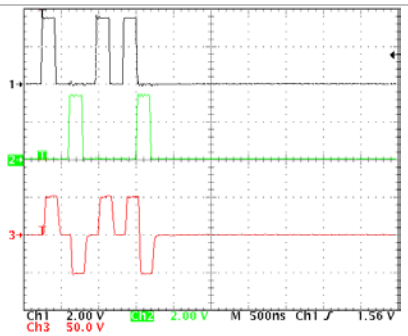
Pattern Length = 4
P Pattern = 0--0
N Pattern = 1—1



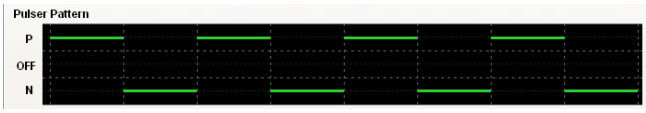


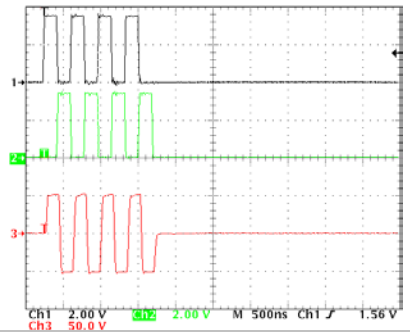
Pattern Length = 8
P Pattern = 1-0-1-10
N Pattern = 0-1-0-01





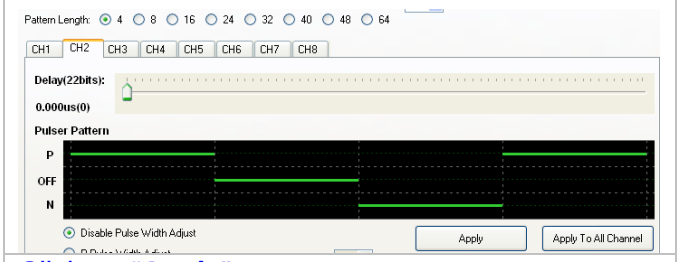
Pattern Length = 8
P Pattern = 10101010
N Pattern = 01010101



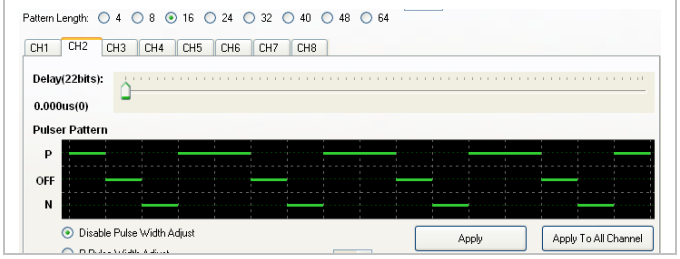


- A convenient way of designing long repetitive pulse patterns is to begin designing with a short pulse pattern length, and then selecting a longer pulse pattern, as shown below.

Pattern Length = 4
P Pattern = 1-01
N Pattern = 0-10



Click on "**Apply**"
Select Pattern Length = 16
P Pattern = 1-011-011-011-01
N Pattern = 0-100-100-100-10



- Once the desired pulse pattern has been designed, click on either the **Apply** button to apply the pattern to only the specific channel or the **Apply To All Channel** button to apply the pattern to all 8 channels.

3.3 Saving and Loading Custom / Preset Pulse Patterns

- Custom designed pulse patterns can be saved for use at a later time. To save a pattern, click on the **Save** button, as shown below in **Figure 17.**

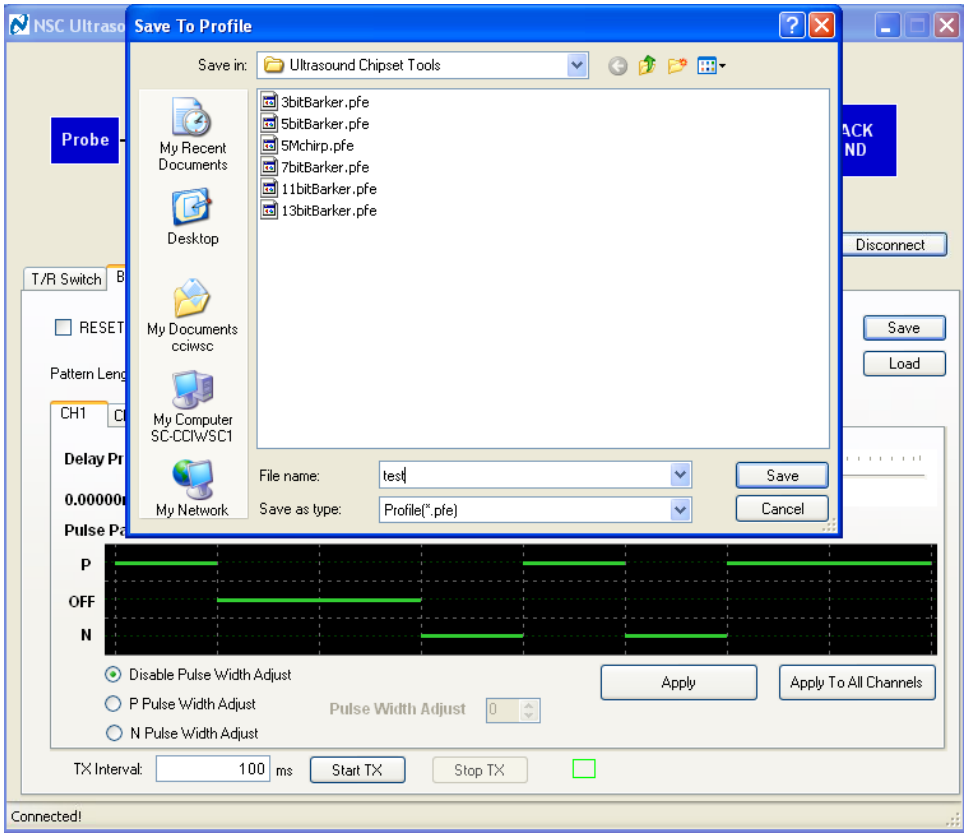


Figure 17: Saving a Custom Pulse Pattern

- To load saved pulse patterns, click on the **Load** button and select the desired pulse pattern file, as shown below in. **Figure 18.**
- A few commonly used pulse patterns are already saved, such as “5M Chirp” and “7 Bit Barker,” etc.

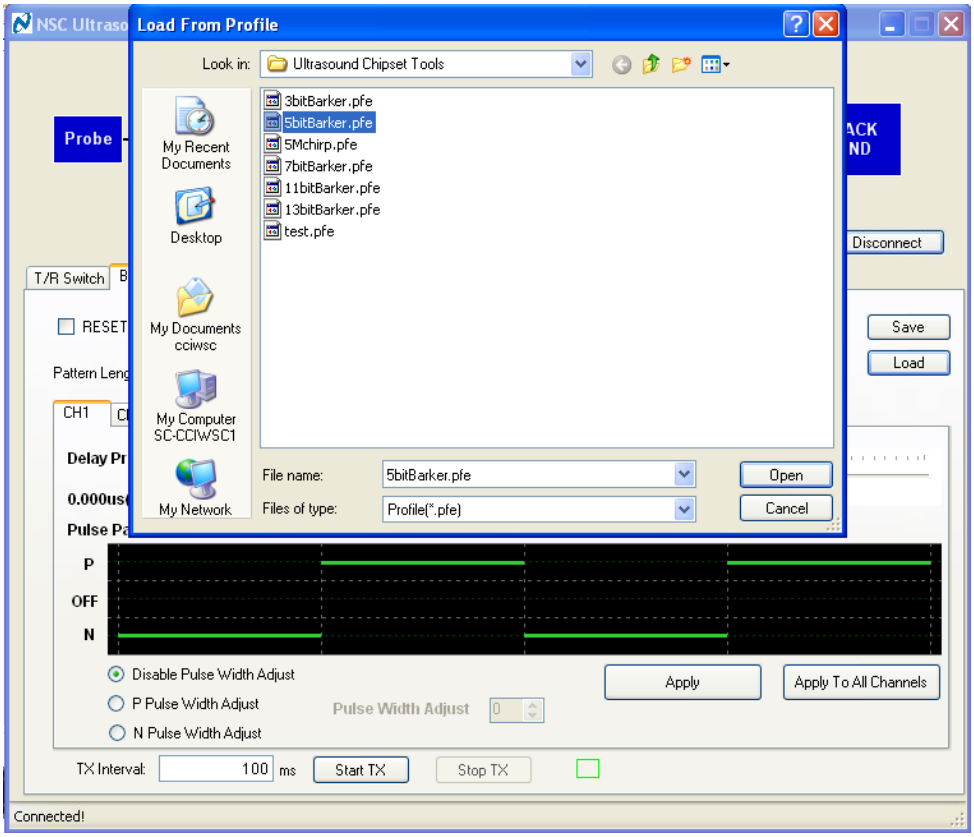


Figure 18: Loading a Preset Pulse Pattern

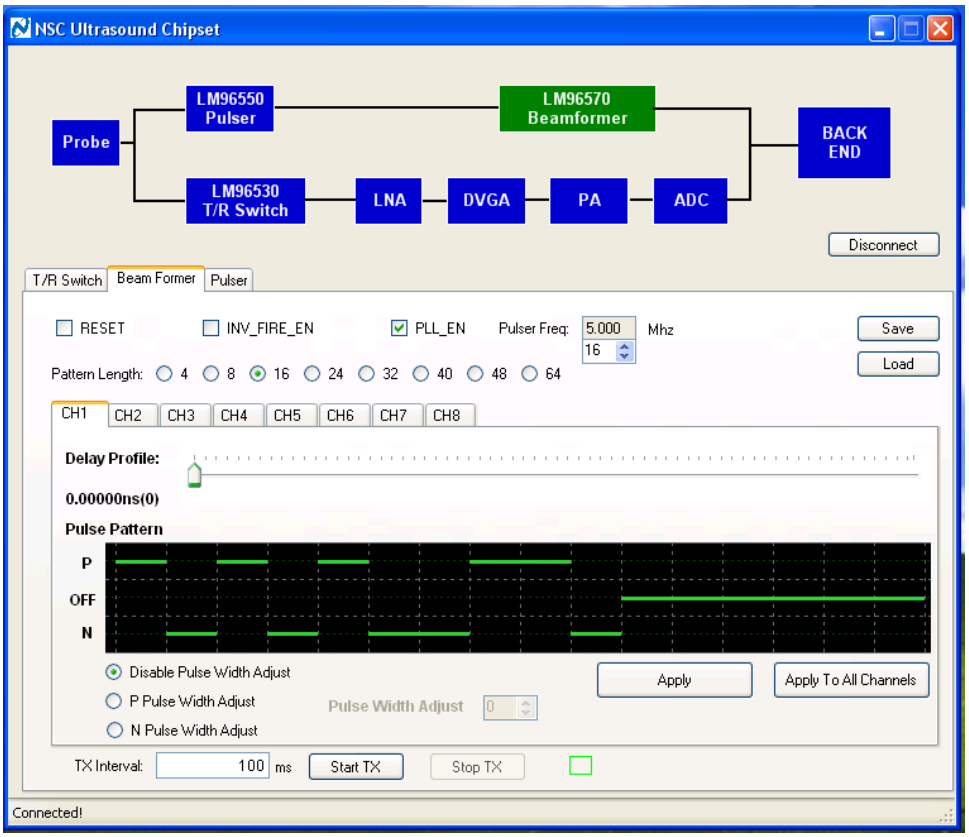
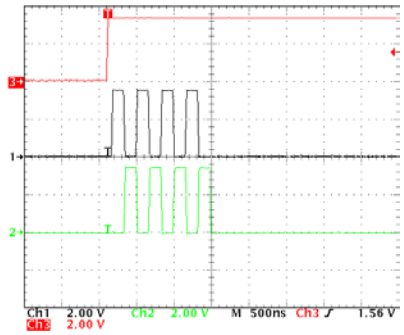


Figure 19: "5 Bit Barker" Pattern

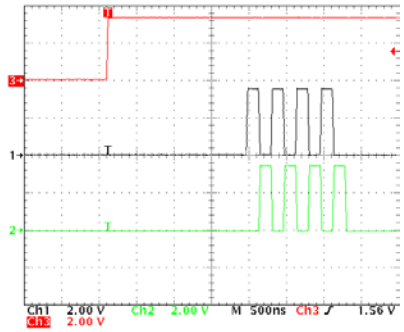
3.4 Fire Delay

- The **<u>Delay Profile</u>** "slider" controls the P & N output pulse delay relative to the TX_EN / fire signal. NOTE that since the TX_EN signal from the Opal Kelly Module is not synchronized with the LM96570's PLL, the absolute actual delay may not be precise in this Eval Kit.

Pattern Length = 8
P Pattern = 10101010
N Pattern = 01010101
No Delay



Pattern Length = 8
P Pattern = 10101010
N Pattern = 01010101
Delay



3.5 Copying & Pasting Delay Profiles and Pulse Patterns

- Both delay profiles and pulse patterns may be copied from one channel and pasted into another channel. To copy a delay profile and/or pulse pattern, point to the respective area and right mouse-click to copy, as shown in **Figure 20.** <u>NOTE: Both parameters can be copied one right after the other, rather than copying one, pasting, and then back to copying the other and pasting.</u>

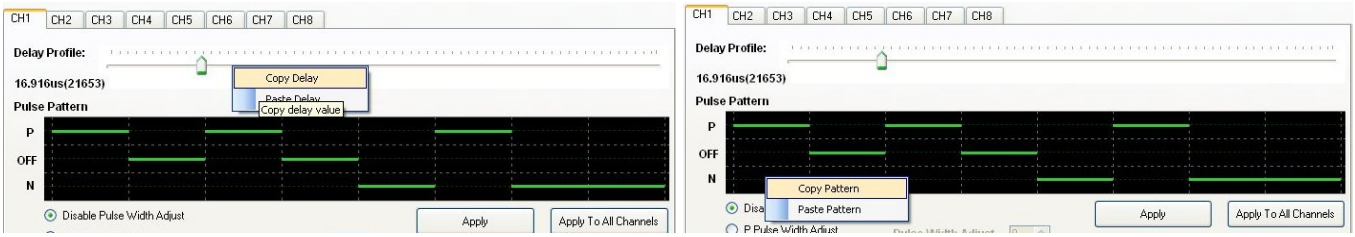


Figure 20: Copying Delay Profile and Pulse Pattern

- To paste a delay profile and/or pulse pattern into another channel, click on the desired channel tab, and then point to the respective area to right mouse-click, as shown in **Figure 21**.

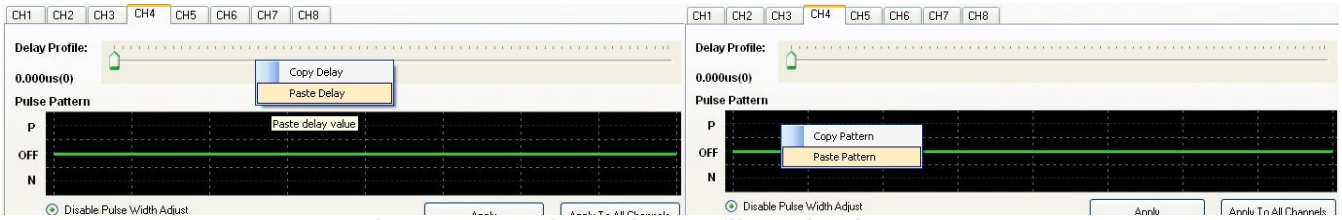


Figure 21: Pasting Delay Profile and Pulse Pattern

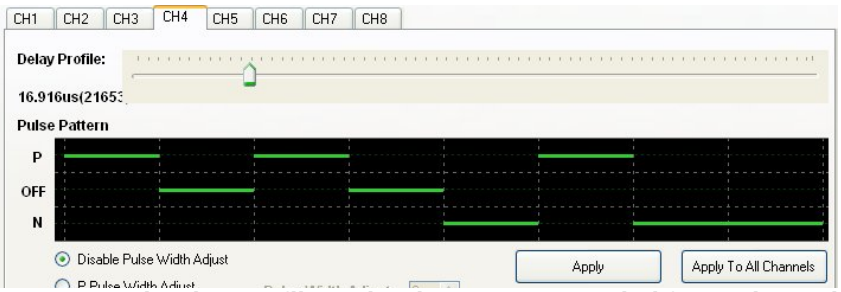


Figure 22: Pasted Delay Profile and Pulse Pattern; Copied from Channel 1

3.6 Pulse Width Adjustment

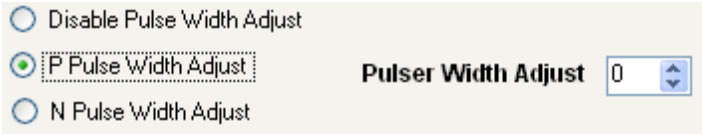


Figure 23: Pulse Width Adjust

- The LM96570 offers Pulse Width Adjustment to the user indirectly by exploiting the fact that the P and N pulses can never overlap and by manipulating the phase delays of P and N relative to each other. For example, delaying P relative to N will reduce the pulse width of P and increase the pulse width of N. Similarly, delaying N relative to P will reduce the pulse width of N and increase the pulse width of P.
- Clicking on the **P Pulse Width Adjust** radio button enables adjustment of the P Pulse delay relative to the N pulse, and clicking on the **N Pulse Width Adjust** radio button enables adjustment of the N Pulse delay relative to the P Pulse.
- The **Pulse Width Adjust** field determines the amount of P to N relative pulse delay, and thus the amount of pulse width adjustment, as the user enters a value between 0 and 7, where 1 is the Minimum and 0 is the Maximum.

4.0 T/R Switch GUI Controls

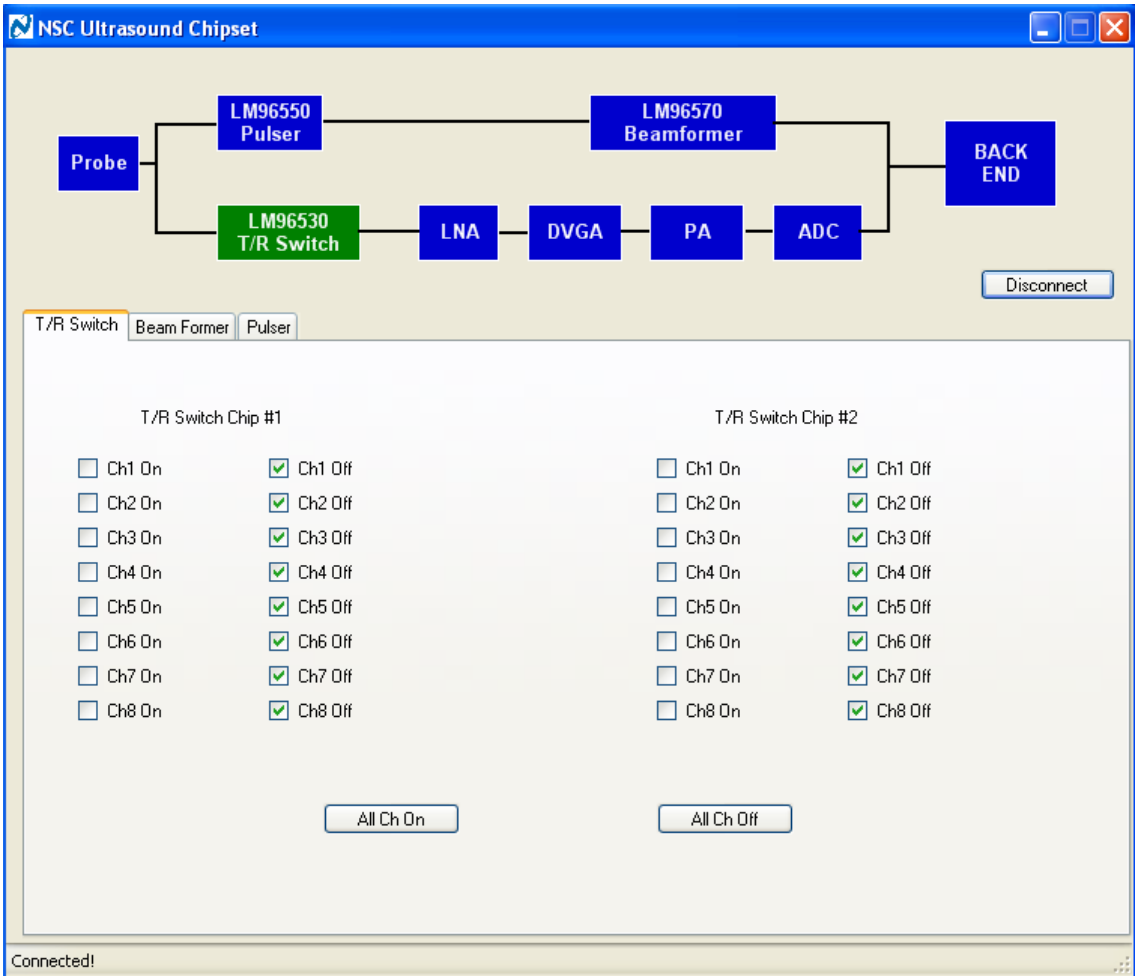


Figure 24: TI Ultrasound Tools GUI –T/R Switch Controls

- The T/R Switch GUI allows the user to control up to 2 SPI bus-daisy-chained T/R Switch chips. (The current Eval Kit is shipped with only one T/R Switch chip installed.)
- To turn ON or turn OFF individual channels, check on the appropriate boxes shown in **Figure 24.**
- To turn ON or turn OFF ALL channels, check on the appropriate boxes shown in **Figure 24**.

5.0 Pulser GUI Controls

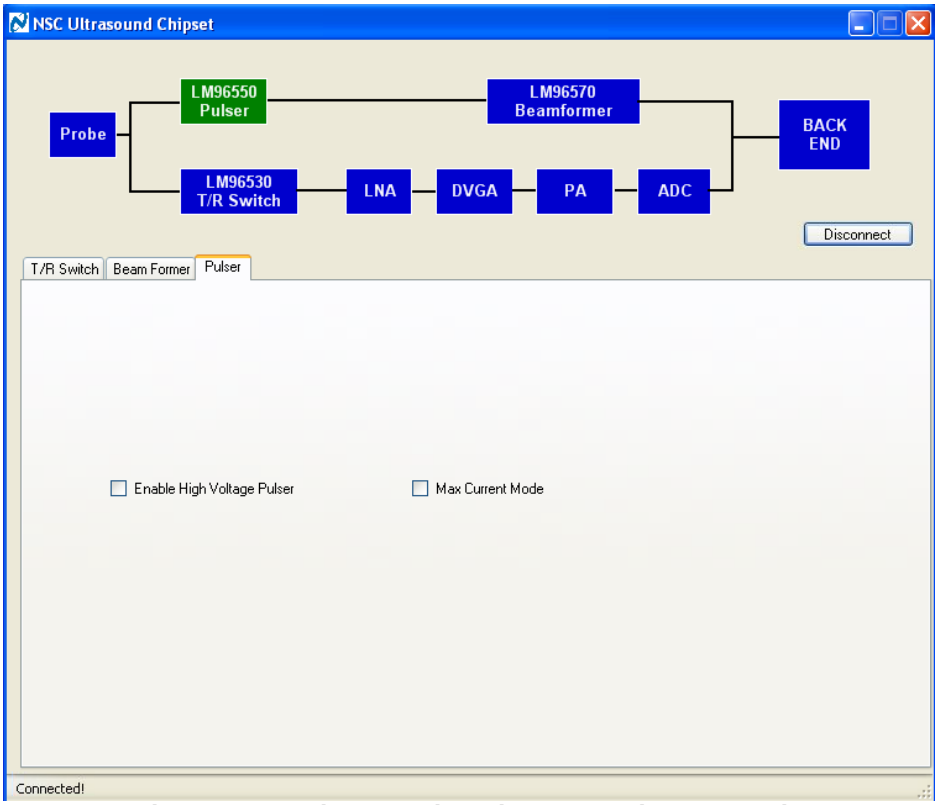


Figure 25: TI Ultrasound Tools GUI – Pulser Controls

- The Pulser GUI allows the user to control the Enable pin on the Pulser. With an AND gate, the Enable pin is also controlled by the OTP status flag output of the LM96551. See board schematic for more details.
- The Pulser GUI also allows the user to control the Current Mode pin on the Pulser. By default, the Current Mode is set LOW for maximum current in B-Mode operation.

5.1 External Tx Interval Adjustment

In order to adjust the transmit interval beyond software limitation, the following connection as it described on Figure 26 with external pulse generator can allow higher speed Tx interval frequency. In order to synchronize properly, during serial interface programming, this Tx_En external pulse generator should be held at logic low.

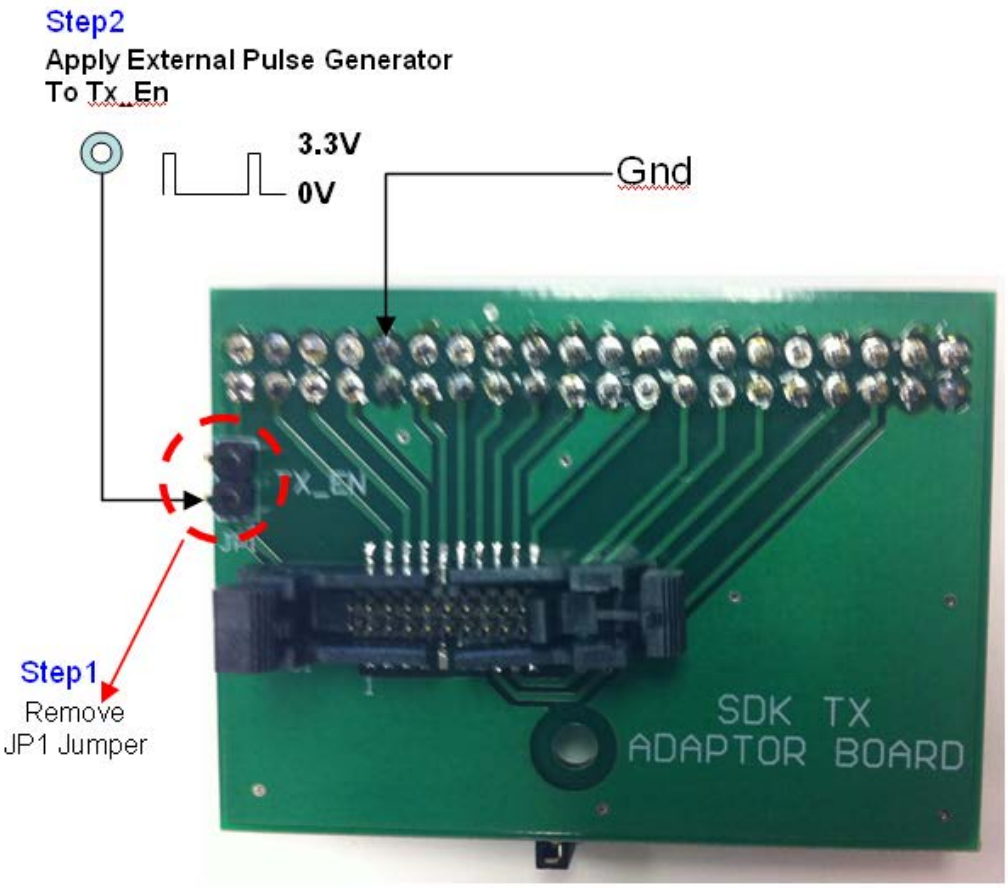


Figure 26: External Tx Interval Adjustment

6.0 Individual Device Evaluation

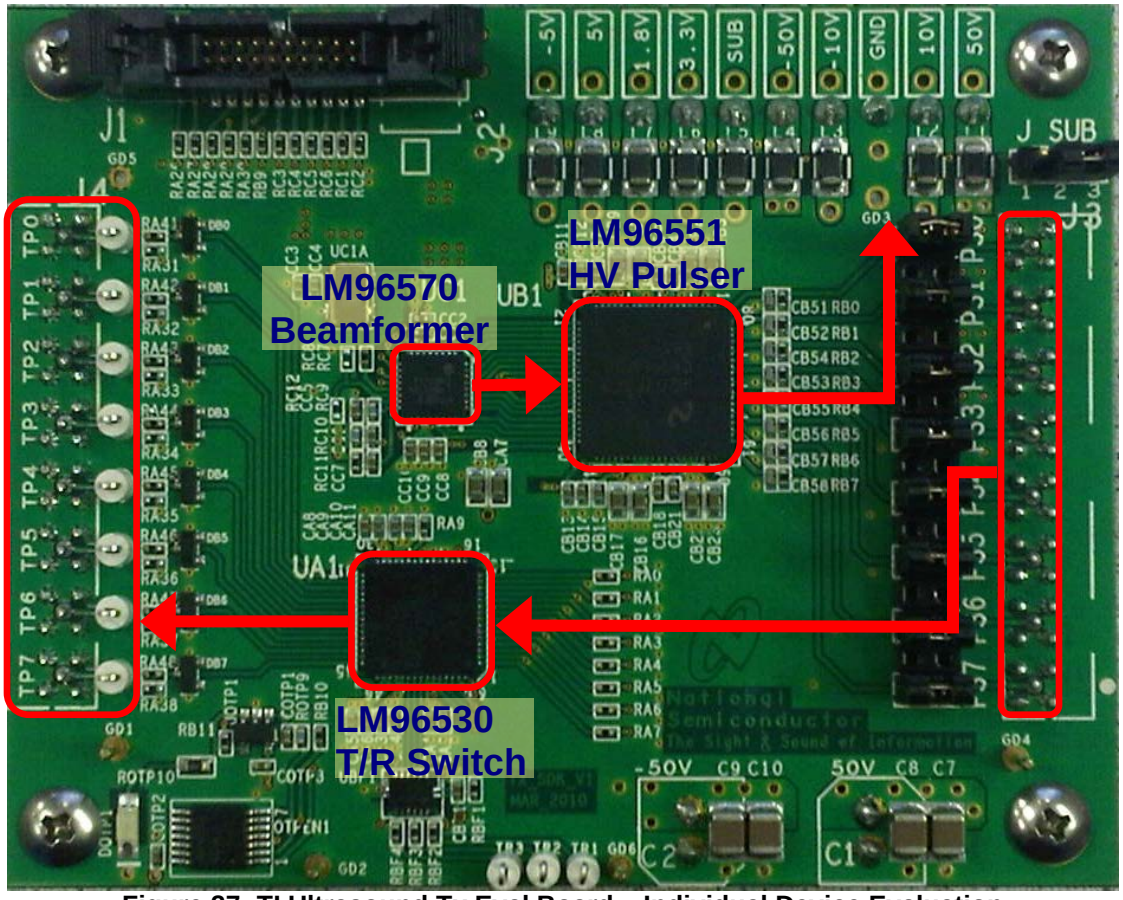


Figure 27: TI Ultrasound Tx Eval Board – Individual Device Evaluation

<u>LM96570 Beamformer</u>

- The outputs of the Beamformer cannot be readily probed. However, the results of programming the Beamformer may be monitored at the LM96551 Pulser outputs.

<u>LM96551 Pulser</u>

- The LM96551 Pulser inputs are supplied by the programmable LM96570 Beamformer.
- The output waveforms of the Pulser can be monitored with high impedance oscilloscope probes at **PS0** to **PS7** or the outputs can be measured at the 8 RF connectors at **J3**. These 8 Pulser outputs have load components: **CB51** to **CB58** = 330pF & **RB0** to **RB8** = 2.49kΩ.
- The 8 RF connectors at **J3** can also directly drive an ultrasound transducer probe. In this case, **CB51** to **CB58** must be removed.

<u>LM96530 T/R Switch</u>

- The LM96530 T/R Switch inputs can be supplied by either the LM96551 Pulser outputs or by an external signal source.
  - To drive the T/R switch with the Pulser outputs, install jumpers **PS0** to **PS7**.
  - To drive the T/R switch with an external signal source, uninstall jumpers **PS0** to **PS7** and connect external signal to the RF connectors at **J3**.

- The output waveforms of the T/R Switch can be monitored with high impedance (or 50 ohm terminated) oscilloscope probes at **TP0** to **TP7** or the outputs can be measured at the 8 RF connectors at **J4.**

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