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# ***IGLOO2 FPGA Adaptive FIR Filter***

***Demo Guide***

Superseded

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June 2014

## Revision History

Date	Revision	Change
11 June 2014	2	Second release
7 January 2014	1	First release

## Confidentiality Status

This is a non-confidential document.

Superseded

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## Preface

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### About this document

This demo is for IGLOO<sup>®</sup>2 field programmable gate array (FPGA) devices. It provides instructions on how to use the corresponding reference design.

### Intended Audience

The following designers using the IGLOO2 devices:

- FPGA designers
- System-level designers

### References

#### Microsemi Publications

- IGLOO2 FPGA Programming User Guide
- IGLOO2 FPGA System Controller User Guide
- IGLOO2 FPGA High Performance Memory Subsystem User Guide
- Configuring Serial Terminal Emulation Programs Tutorial

See the following web page for a complete and up-to-date listing of IGLOO2 device documentation:  
<http://www.microsemi.com/products/fpga-soc/fpga/igloo2-fpga>

# IGLOO2 FPGA Adaptive FIR Filter Demo

## Introduction

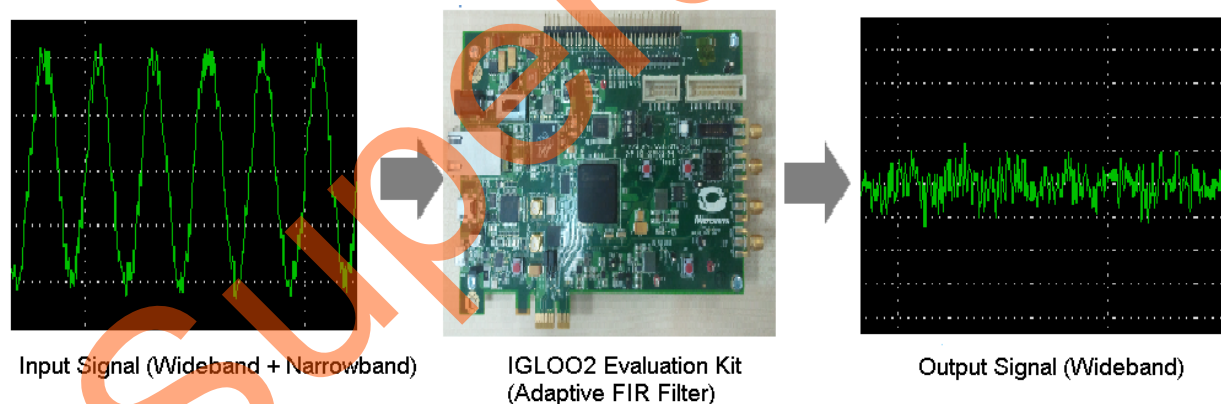
The IGLOO2 FPGA devices integrate a fourth generation flash-based FPGA fabric architecture, which includes embedded mathblocks optimized specifically for digital signal processing (DSP) applications such as, finite impulse response (FIR) filters, infinite impulse response (IIR) filters, and fast Fourier transform (FFT) functions.

An adaptive filter is a filter that automatically adjusts the filter coefficients according to the underlying adaptive algorithm and the input signal characteristics. Due to its self adjustment of transfer function of an unknown system and computational requirements, adaptive filters are widely used in different areas of DSP application such as communication, biomedical instrumentation, audio processing, and video processing.

The least mean square (LMS) is the basic adaptive algorithm used in adaptive filters to update the filter coefficients. The LMS algorithm has advantages over other algorithms because of its simplicity, less computations and best performance in terms of the number of iterations required for convergence.

In this demo an adaptive FIR filter application, the suppression of a narrow band signal interference on a wide band signal is implemented using an IGLOO2 device. Refer to [Figure 1](#).

The LMS algorithm is implemented in the FPGA fabric to adjust the filter coefficients based on the mean square error (MSE) approach. CoreFIR IP is used to perform the filtering operation and CoreFFT IP is used to generate the output spectrum to observe that the narrow band interfering signal component is suppressed. The host interface is implemented in FPGA fabric using CoreUART IP to communicate with the Host PC. A user friendly `IGL2_Adaptive_FIR_Filter.exe` generates input signals (narrow band signal and wide band signal), and also plots the input/output waveforms and the required spectrum.



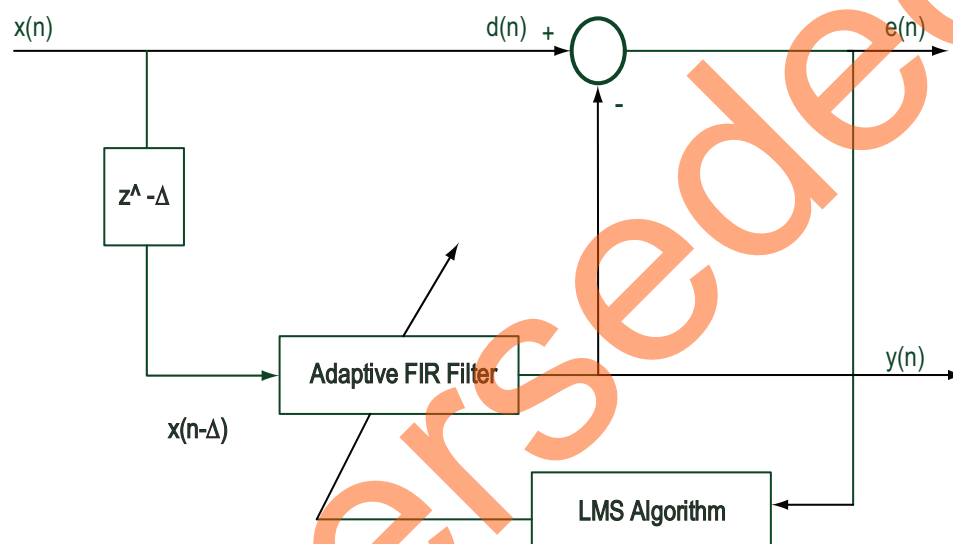
**Figure 1 • Narrowband Interference Cancellation**

## Theory of Operation

Adaptive filters are mainly categorized into four basic architectures:

- System identification
- Noise cancellation
- Linear prediction
- Inverse modeling

In this demo, linear prediction architecture is used to implement adaptive filter. The LMS algorithm uses a gradient search technique to determine the filter coefficients that minimize the mean square prediction error. The estimate of the gradient is based on the sample values of the tap-input vector and the error signal. The algorithm iterates over each coefficient in the filter, moving it in the direction of the approximated gradient. After reaching the optimal filter coefficients, the error signal  $e(n)$  consists of the Wideband signal. Figure 2 shows the linear prediction based adaptive filter architecture.



**Figure 2 • Linear Prediction Adaptive Filter Architecture**

The input signal  $x(n)$  consists of wideband signals along with the narrow band signals that are not required, refer to Figure 3 on page 8. In a linear prediction architecture, the desired signal  $d(n)$  is same as the input signal  $x(n)$  and a delayed input  $x(n-\Delta)$  is fed to the adaptive filter as shown in Figure 2. The delay factor  $\Delta$  (delta) de-correlates the wide band component and correlates the narrow band component of the desired signal  $d(n)$  with the delayed input signal  $x(n-\Delta)$ .

The adaptive filter tries to estimate the narrow-band component  $y(n)$ , and forms an equivalent transfer function, which is similar to that of narrow-band filters centered at the frequencies of the narrow-band components of the input signal. At the summing junction, the filtered input signal subtracting with delayed input signal produces an error signal. The error signal is used by the LMS algorithm to adjust the filter coefficients. After some iterations, the Error signal converges to a wide band component. The following equations describe computing the coefficients using the LMS algorithm.

$$y(n) = \sum_{k=0}^{l-1} h(n) \times x(n-\Delta-k)$$

EQ 1

where,

According to EQ 1, narrow-band component  $y(n)$ , is the adaptive filter output

$h(n)$  is the filter coefficients

$x(n-\Delta)$  is the input signal to the adaptive filter

$l$  is the length of the filter (number of taps)

$k$  is the index variable

The error is computed using the following equation:

$$e(n) = d(n) - y(n)$$

EQ 2

where,

$e(n)$  is the error signal

$d(n)$  is desired signal

The filter coefficients are updated using the following equation:

$$h(n+1) = h(n) + \mu \cdot e(n) \cdot x(n-\Delta)$$

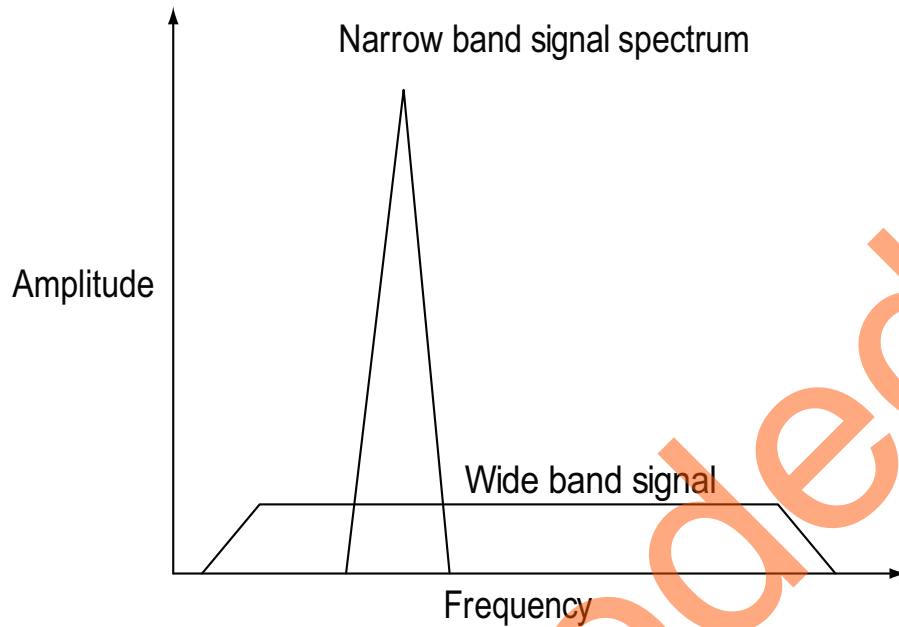
EQ 3

where,

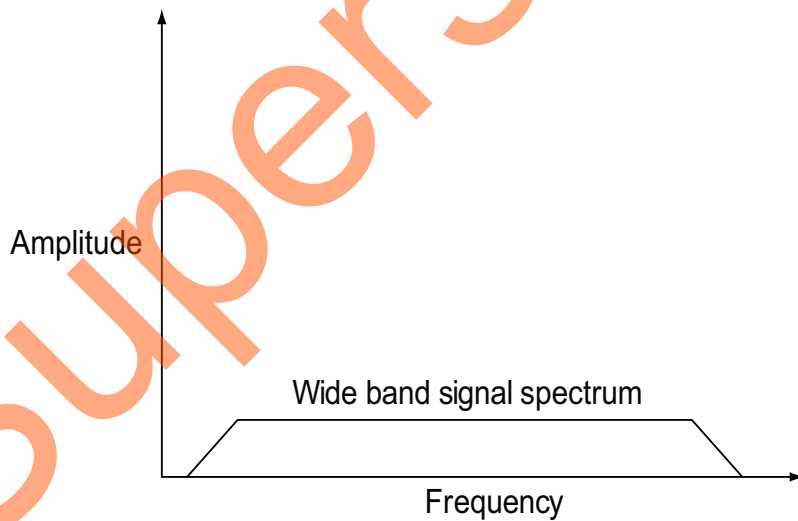
$h(n+1)$  is the estimated filter coefficients

$h(n)$  is present filter coefficients

$\mu$  is the step size factor



**Figure 3 • Input Spectrum of Narrow Band Signal + Wide Band Signal**



**Figure 4 • Output Spectrum of Wide Band Signal**



## Design Requirements

**Table 1 • Design Requirements**

Design Requirements	Description
<b>Hardware Requirements</b>	
IGLOO2 Evaluation Kit <ul style="list-style-type: none"> <li>FlashPro4 programmer</li> <li>USB A to Mini-B cable</li> </ul>	Rev C or later
Host PC or Laptop	Windows 7 64-bit Operating System
<b>Software Requirements</b>	
Libero® System-on-Chip (SoC)	11.3
FlashPro Programming Software	11.3
Host PC Drivers	<a href="#">USB to UART drivers</a>
Framework	<a href="#">Microsoft .NET Framework 4 Client</a> for launching demo GUI

## Demo Design

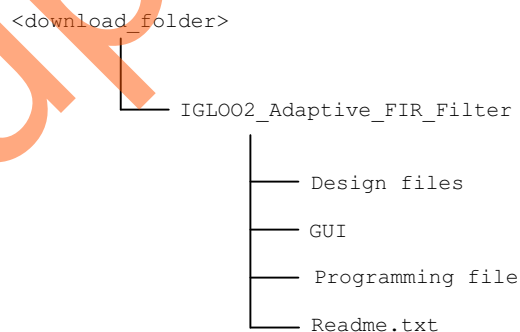
### Introduction

The design files for this demo can be downloaded from the Microsemi website:  
[http://soc.microsemi.com/download/rsc/?f=IGLOO2\\_Adaptive\\_FIR\\_Filter\\_DF](http://soc.microsemi.com/download/rsc/?f=IGLOO2_Adaptive_FIR_Filter_DF)

Design files include:

1. Libero SoC project
2. Programming files
3. GUI executable
4. Readme file

Figure 5 shows the top-level structure of the design files. For further details, refer to the `Readme.txt` file.

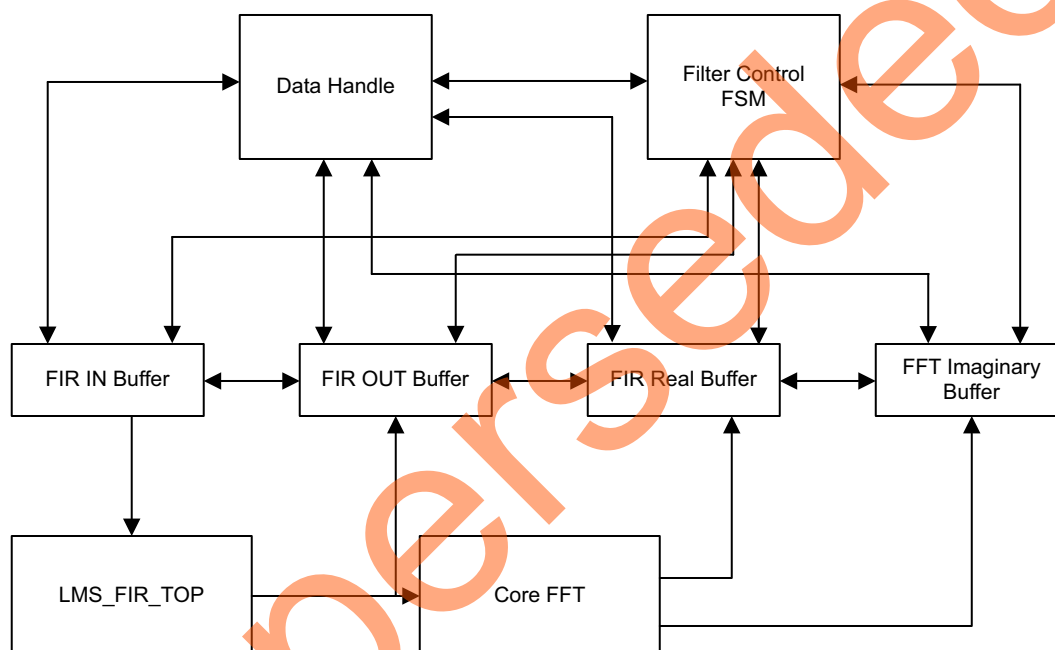


**Figure 5 • Demo Design Files Top-Level Structure**

## Demo Design Description

This demo design uses the following blocks:

- "Data Handle Block" (SmartDesign)
- "Filter Control" (user RTL)
- "LMS\_FIR\_TOP" (Smart Design)
- "TPSRAM IP" (IPcore)
- "CoreFFT" (IPcore)
- "SYSRESET"(IPcore)
- "OSC" (IPcore)
- "CCC" (IPcore)
- "CoreUART" (IP Core)



**Figure 6 • Adaptive FIR Filter Demo Design Block Diagram**

### Data Handle Block

The Data handle block consists of a CoreUART IP and UART interface finite state machine to handle the controls and operations between the Host PC (GUI interface) and fabric logic. It controls loading filter input data to the corresponding input data buffer and then send and receive data from the Host PC.

### Filter Control

Controls the FIR filter and FFT operations. It loads the filtered data to the corresponding output buffer and moves the FFT output data to the corresponding output data buffer.

### LMS\_FIR\_TOP

This is a SmartDesign block implemented in the fabric. It consists of the following blocks:

- **LMS\_CONTROL\_FSM:** This finite-state machine (FSM) is implemented in the RTL to provide the control signals to the LMS\_ALGO block.
- **LMS\_ALGO:** This LMS algorithm is implemented in RTL to compute the error signal, correction factor, filter coefficients, and to send the filter coefficients to the Core FIR filter.

- **CoreFIR:** CoreFIR IP is used in the Reloadable Coefficient mode to configure its coefficients on the fly. CoreFIR IP configuration is as follows:
  - Version: 8.5.104
  - Filter Type: Single rate fully enumerated
  - No of taps: 8
  - Coefficients type: Reloadable
  - Coefficients bit width: 16 (signed)
  - Data bit width: 16 (signed)
  - Filter structure: Transposed with no symmetry

### TPSRAM IP

TPSRAM IP uses the following configurations:

- Input signal data buffer
- Output signal buffer
- Output signal FFT real data buffer
- Output signal FFT imaginary data buffer

**Table 2 • TPSRAM Configuration for Data Buffers**

Buffer	Write Port		Read Port	
	Depth	Width	Depth	Width
FIR Input Signal	2048	8	1024	16
FIR Output Signal	1024	16	1024	16
FFT Output Real Signal	1024	16	1024	16
FFT Output Imaginary Signal	1024	16	1024	16

### CoreFFT

CoreFFT IP is used to generate the frequency spectrum of the filtered data. CoreFFT IP configuration is as follows:

- Version: 6.3.102
- FFT Architecture: In place
- FFT type: Forward
- FFT Scaling: Conditional
- FFT Transform Size: 256
- Width: 16

### SYSRESET

SYSRESET IP provides the power-on reset signal.

### OSC

OSC IP is configured as an RC oscillator to provide the 50 MHz signal to the CCC (clock conditioning circuit), narrowband component y(n).

### CCC

CCC IP is configured to provide a 100 MHz clock signal

For detailed SmartDesign implementation and resource usage summary, refer to ["Appendix 1: SmartDesign Implementation" on page 32.](#)

## CoreUART

The CoreUART IP is used to transfer the data between the Host PC (GUI) and the IGLOO2 device. The CoreUART Configuration is as follows:

- Version: 5.2.2
- TxFIFO: Disable
- RxFIFO: Disable
- RxLegacyMode: Disable
- Baud rate: 115200
- Number of bits: 8
- Stop bits: 1
- Parity: None

## Setting Up the Demo Design

The following steps describe how to setup the hardware demo:

1. Connect the jumpers on the IGLOO2 Evaluation Kit board as shown in [Table 3](#).

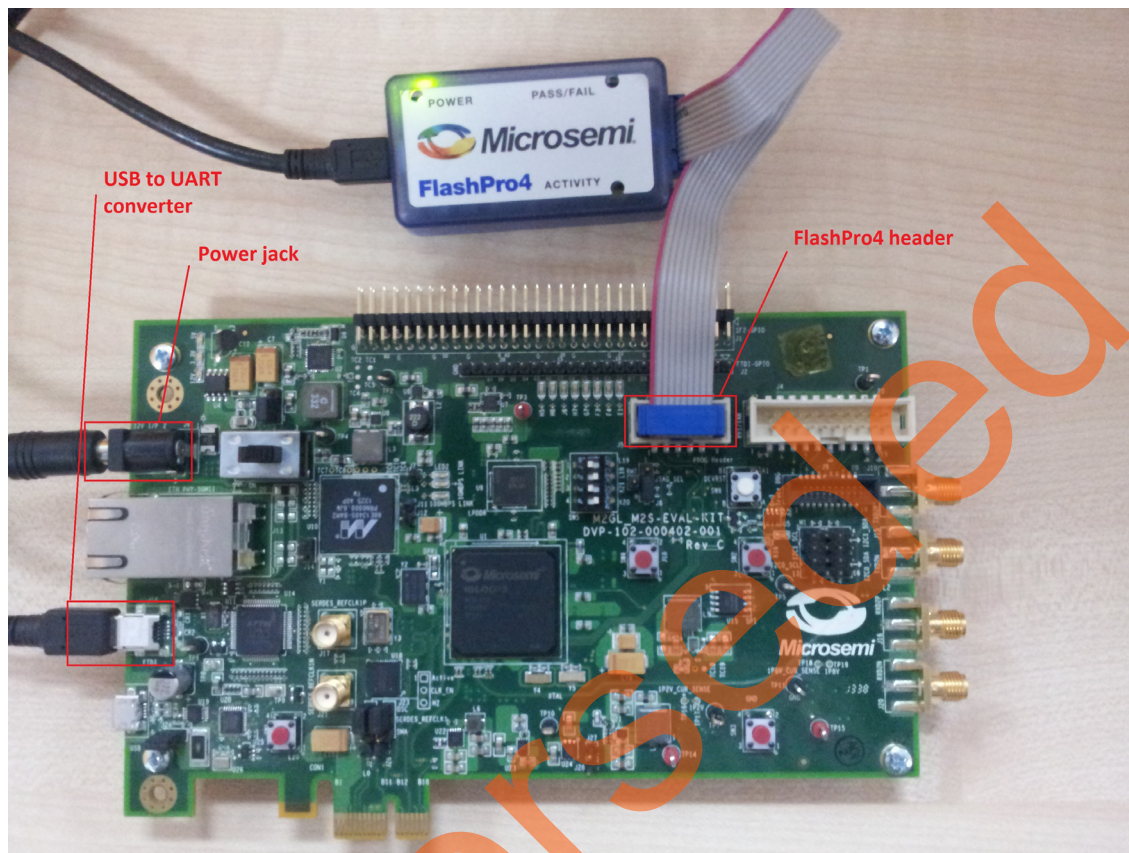
**Table 3 • IGLOO2 FPGA Evaluation Kit Jumper Settings**

Jumper	Pin (From)	Pin (To)	Comments
J22	1	2	Default
J23	1	2	Default
J24	1	2	Default
J8	1	2	Default
J3	1	2	Default

**CAUTION:** While making the jumper connections, the power supply switch **SW7** must be switched off.

2. Connect the Power supply to the J6 connector, switch on the power supply switch, **SW7**.
3. Connect the FlashPro4 programmer to the J5 connector of the IGLOO2 Evaluation Kit board.
4. Connect the Host PC USB port to the J18 USB connector on the IGLOO2 Evaluation Kit board using the USB mini-B cable.

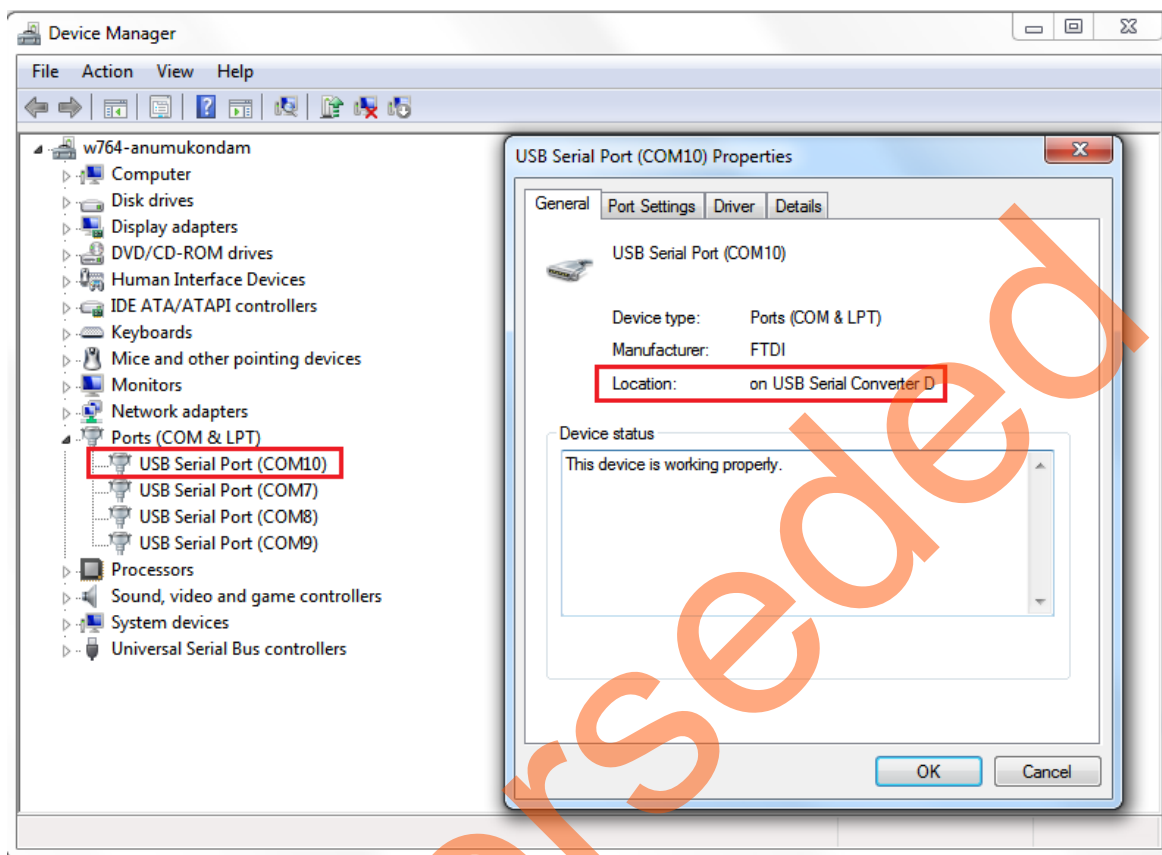
Figure 7 shows the board setup for running the Adaptive FIR Filter Demo on the IGLOO2 Evaluation Kit.



**Figure 7 • IGLOO2 FPGA Evaluation Kit Adaptive FIR Filter Demo Setup**

5. Ensure that the USB to UART bridge drivers are automatically detected. This can be verified in the Device Manager of the Host PC. The FTDI USB to UART converter enumerates four COM ports. For USB 2.0, note down the USB Serial Converter D COM port number to use it in the IGL2\_Adaptive\_FIR\_Filter.exe.

Figure 8 shows the USB 2.0 Serial port properties and the connected COM10 and USB Serial Converter D.



**Figure 8 • USB to UART Bridge Drivers**

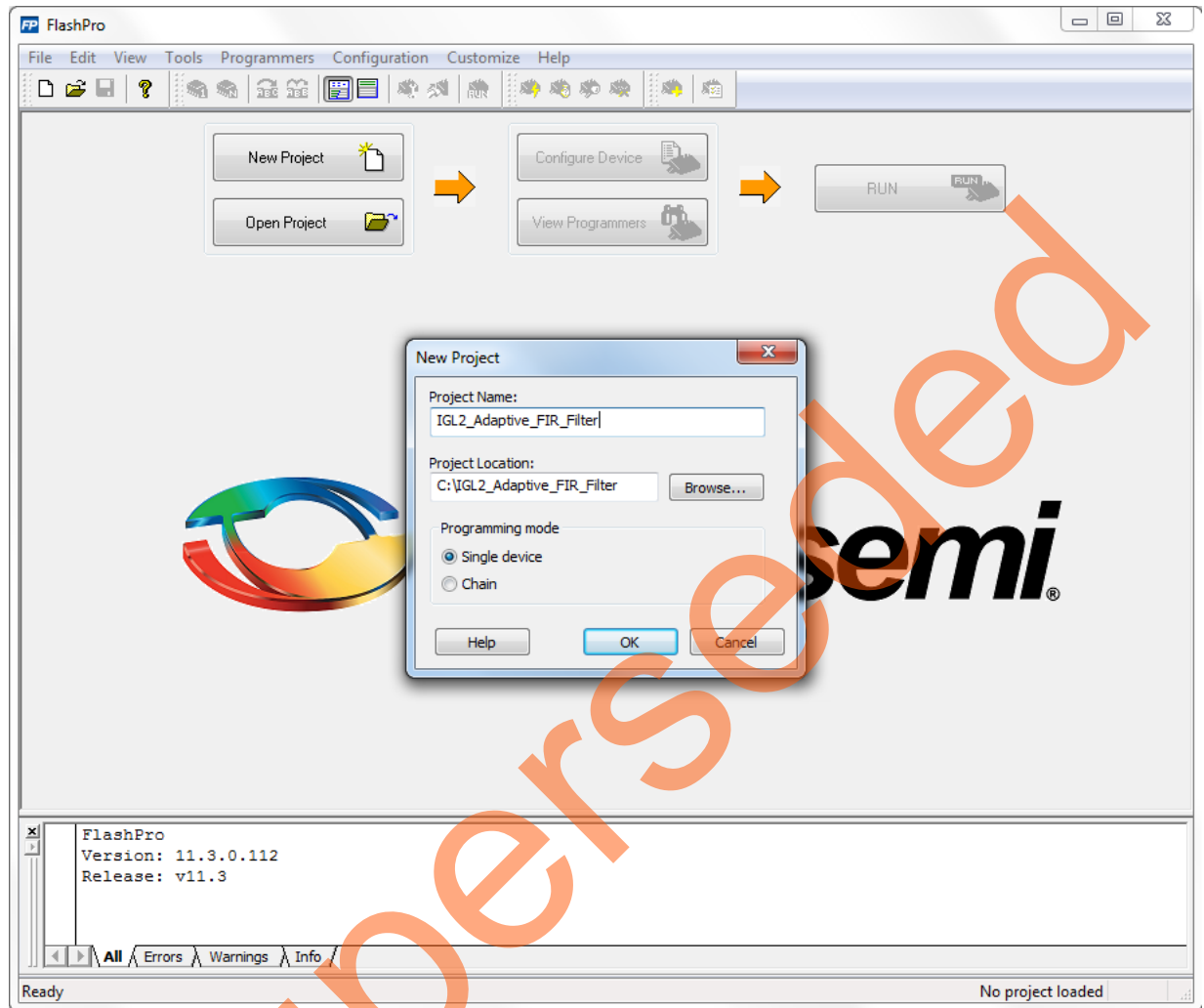
6. If the USB to UART bridge drivers are not installed, download and install the drivers from [www.microsemi.com/soc/documents/CDM\\_2.08.24\\_WHQL\\_Certified.zip](http://www.microsemi.com/soc/documents/CDM_2.08.24_WHQL_Certified.zip).

## Programming the Demo Design

The following steps describe how to program the demo design:

1. Download the demo design from:  
[http://soc.microsemi.com/download/rsc/?f=IGLOO2\\_Adaptive\\_FIR\\_Filter\\_DF](http://soc.microsemi.com/download/rsc/?f=IGLOO2_Adaptive_FIR_Filter_DF)
2. Launch the FlashPro software.
3. Click **New Project**.

4. In the **New Project** window, type the project name as IGL2\_Adaptive\_FIR\_Filter.



**Figure 9 • FlashPro - New Project**

5. Click **Browse** and navigate to the location where you want to save the project.
6. Select **Single device** as the **Programming mode**.
7. Click **OK** to save the project.

## Setting Up the Device

The following steps describe how to configure the device:

1. Click **Configure Device** on the FlashPro GUI.
2. Click **Browse** and navigate to the location where the IGL2\_Adaptive\_FIR\_Filter.stp file is located and select the file. The default location is:  
<download\_folder>\IGLOO2\_Adaptive\_FIR\_Filter\Programmingfile\IGL2\_Adaptive\_FIR\_Filter.stp.
3. Click **Open**. The required programming file is selected and is ready to be programmed in the device.

## Programming the Device

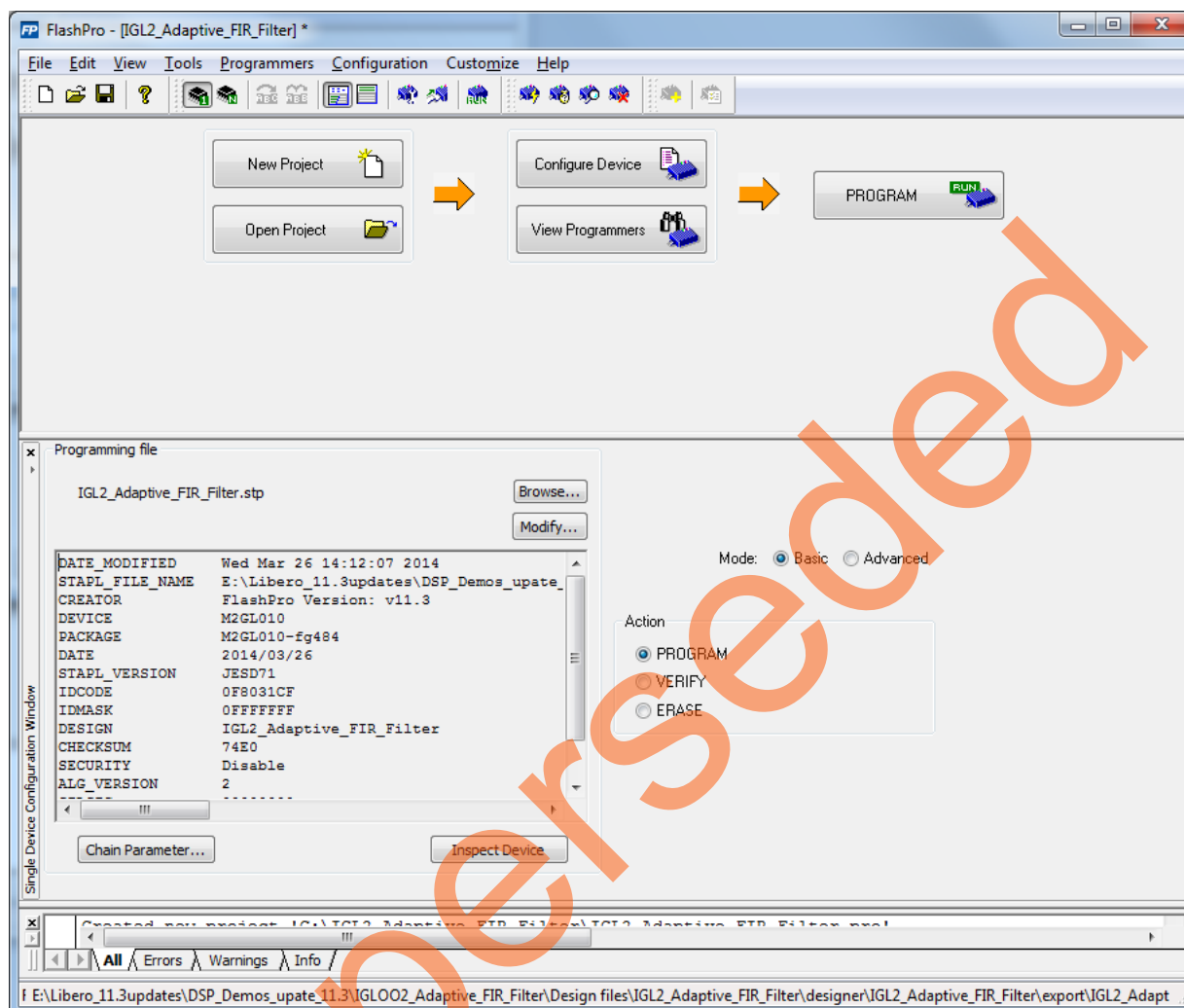


Figure 10 • FlashPro Project Configured



The following steps describe how to program the device:

Click **PROGRAM** to start programming the device. Wait until you get a message indicating that the **RUN PASSED**.

### Adaptive FIR Filter Demo GUI

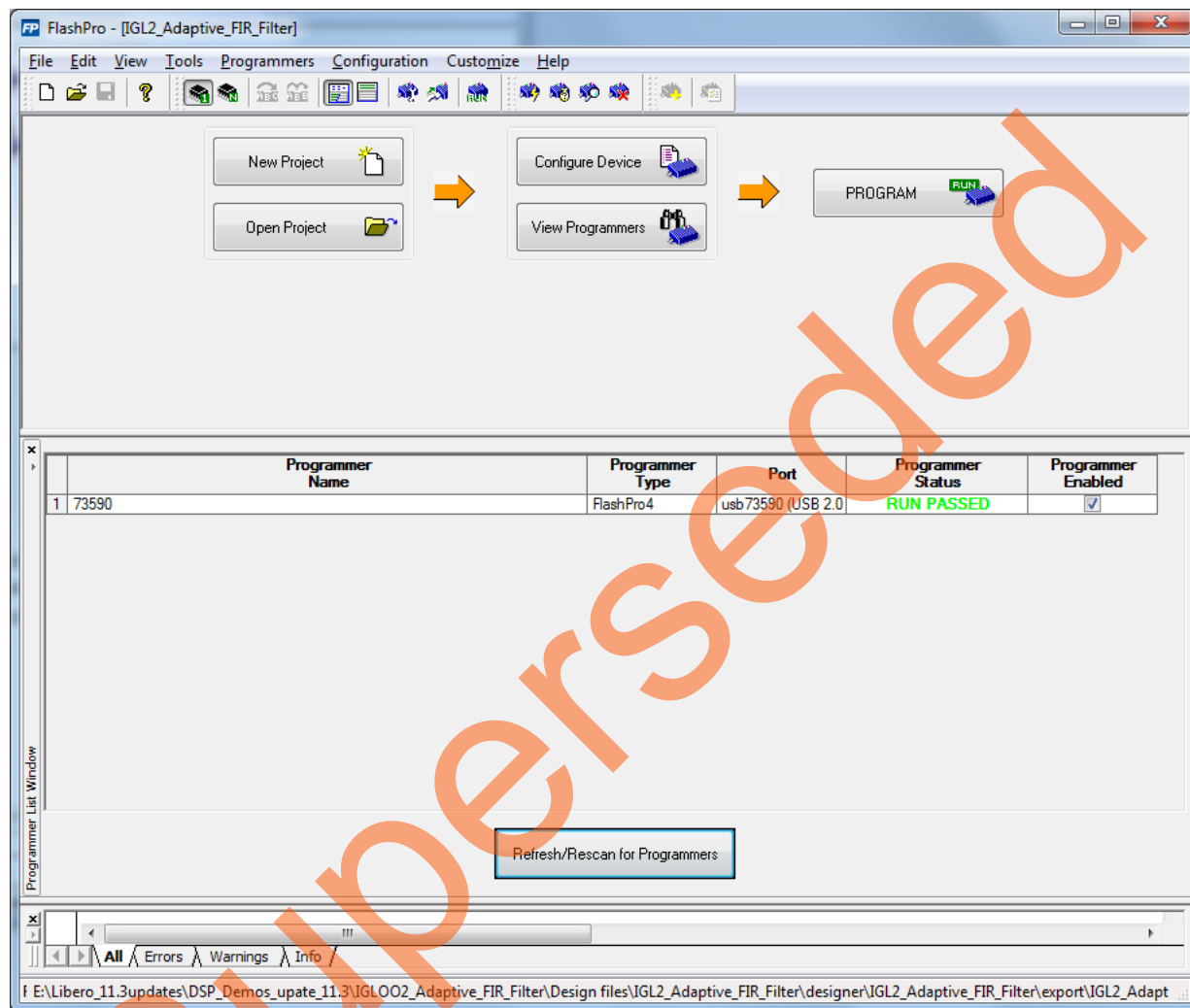
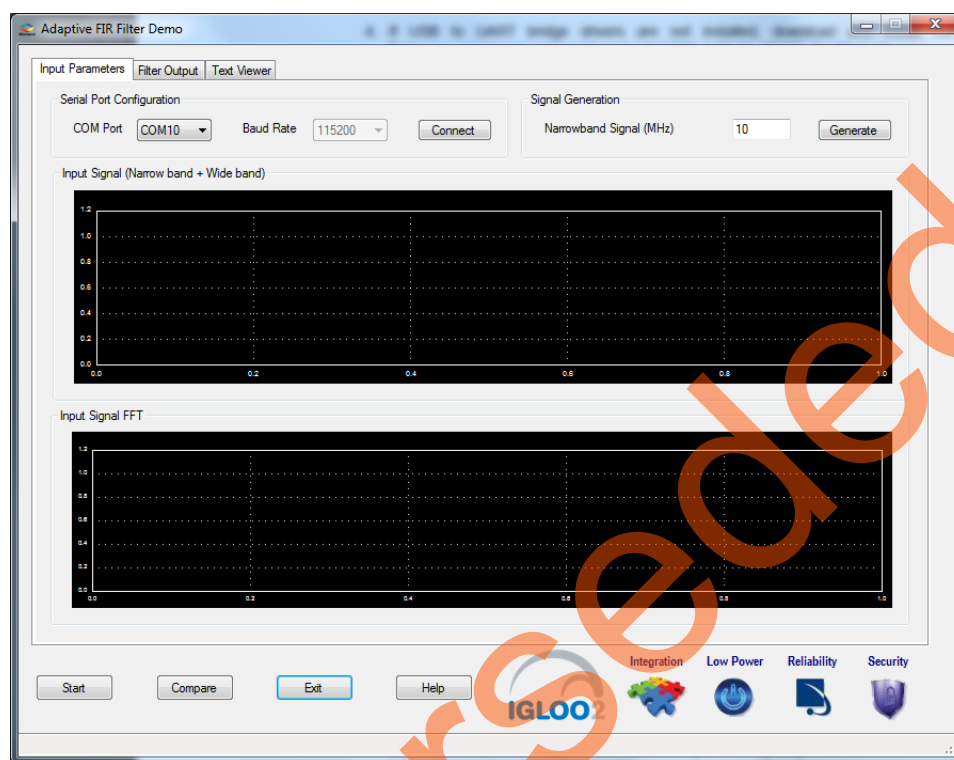


Figure 11 • FlashPro Project RUN Passed

The adaptive FIR filter demo is provided with a user friendly GUI that runs on the Host PC and communicates with the IGLOO2 Evaluation Kit. UART is used as the communication protocol between the Host PC and the IGLOO2 Evaluation Kit.



**Figure 12 • Adaptive FIR Filter Demo Window**

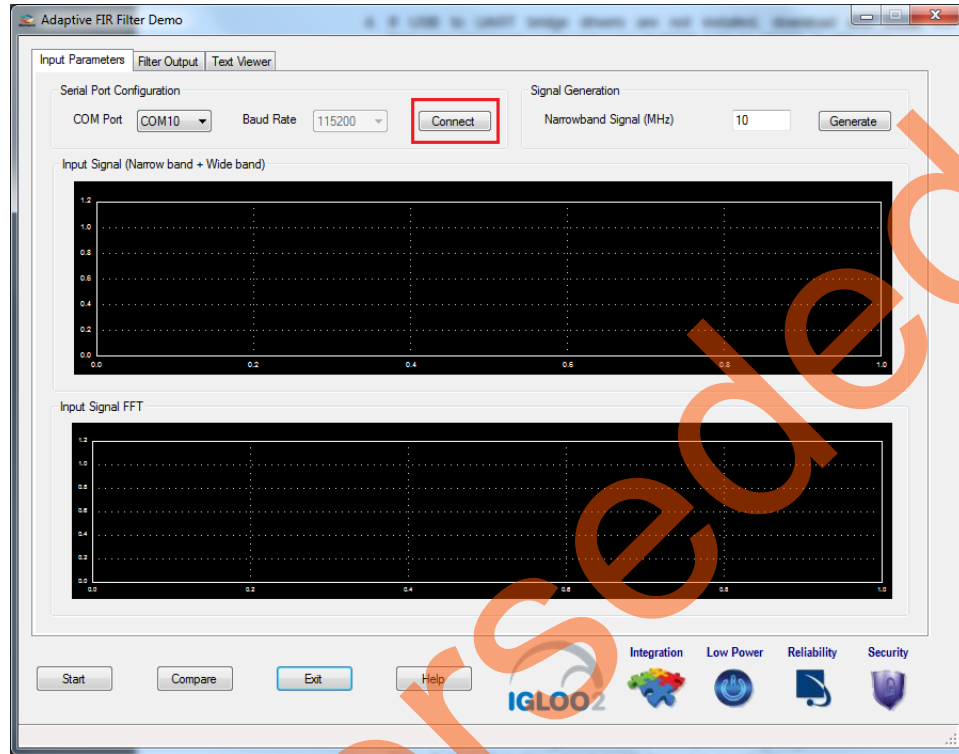
The Adaptive FIR Filter Demo window consists of the following tabs:

- **Input Parameters:** Configures the serial COM port and signal generation.
- **Filter Output:** Plots Error signal and its frequency spectrum.
- **Text viewer:** Shows Input signal, Error signal data values.

Click **Help** for more information on the GUI.

## Running the Demo Design

1. Launch the adaptive FIR filter demo GUI, install and invoke the executable file provided with the design files. (\\IGLOO2\_Adaptive\_FIR\_Filter\\GUI\\GL2\_Adaptive\_FIR\_Filter.exe). The Adaptive FIR Filter Demo window is displayed, refer to [Figure 13](#).



**Figure 13 • Serial Port Configuration**

2. **Serial Port Configuration:** The COM port number is automatically detected and baud rate is fixed at 115200. Press **Connect**. Refer to [Figure 13](#).

3. **Signal Generation:** Enter the narrow band signal frequency as 2 MHz (supported range is 1 MHz and 20 MHz), and click **Generate**. Refer to Figure 14.

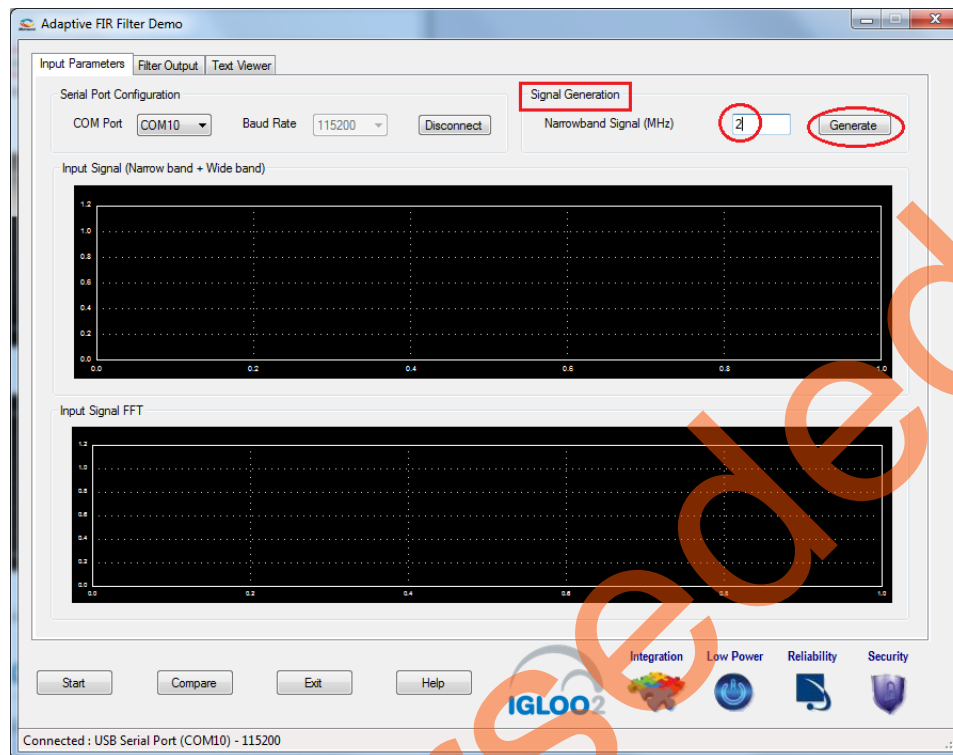
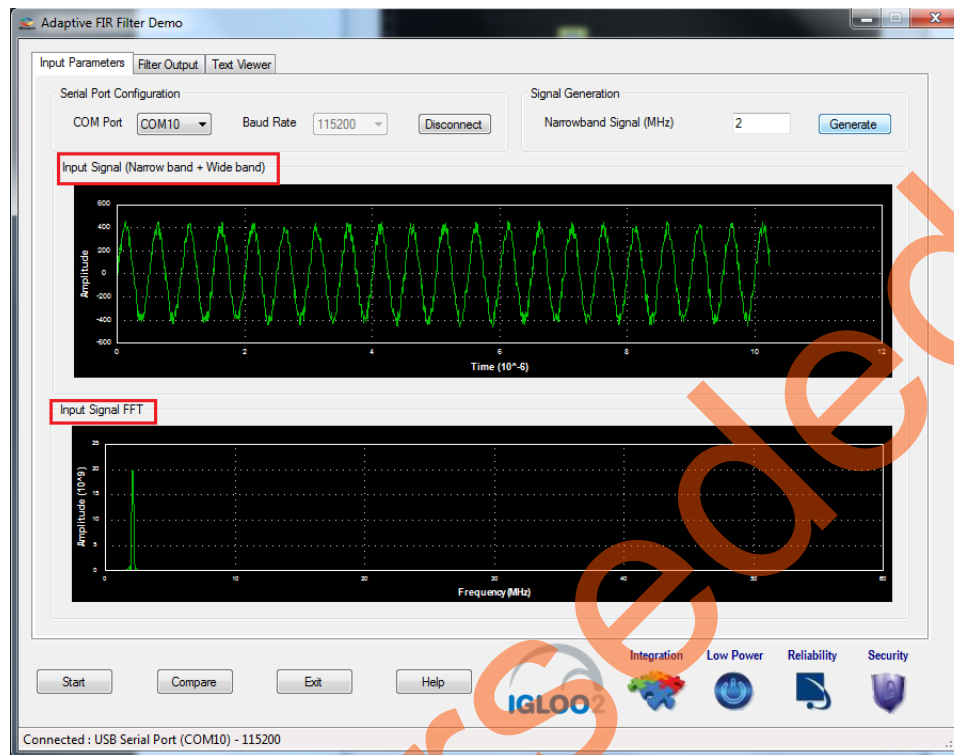


Figure 14 • Signal Generation

Adaptive FIR Filter Demo adds the wide band signal (generated inside the Adaptive FIR Filter Demo window) to the narrow band signal component and plots the combined signal (Narrow band and Wide band), FFT spectrum. Refer to [Figure 15](#).



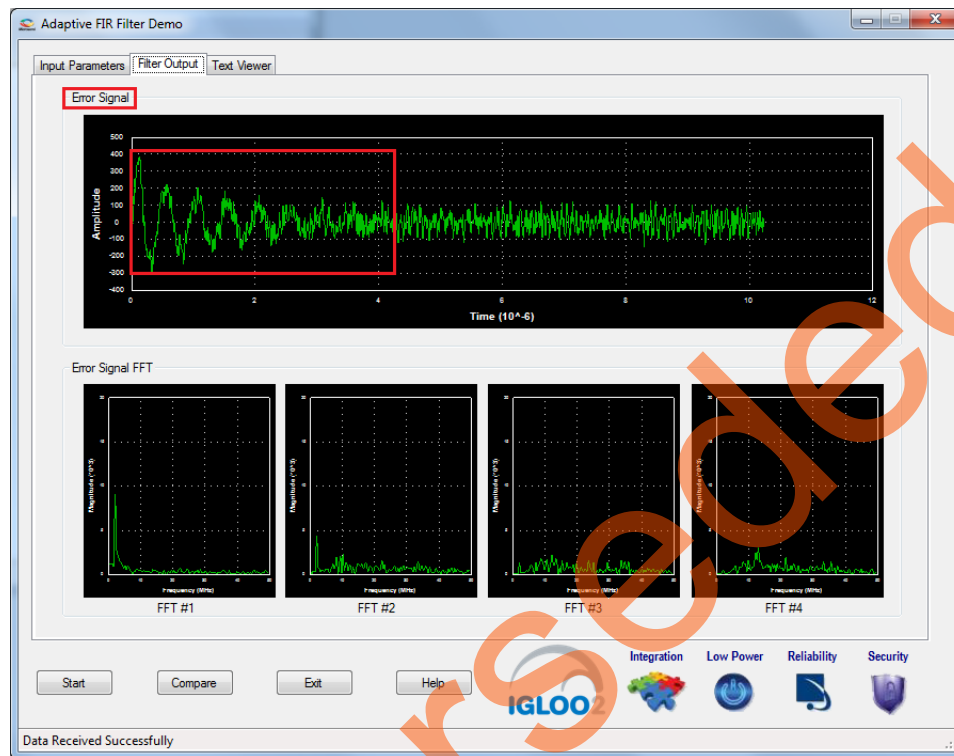
**Figure 15 • Signal Generation**

4. Click **Start**, to load the input data (1k samples) to the IGLOO2 device for processing the filtering operation, refer to [Figure 16](#).



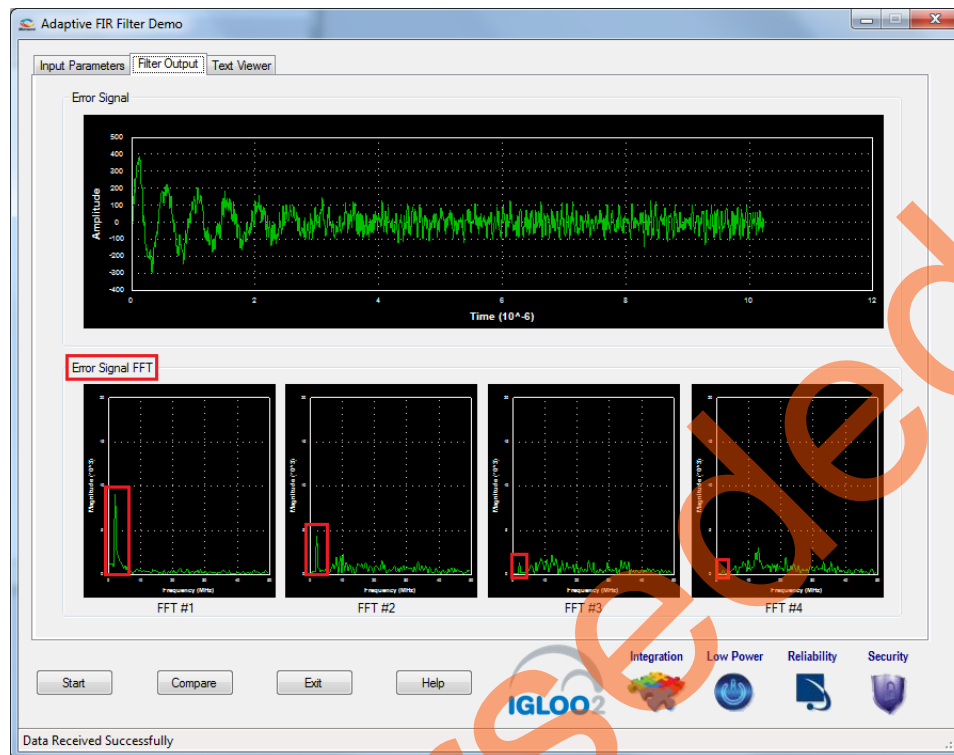
Figure 16 • Adaptive FIR Filter Demo Start

5. After completing the filter operation, the GUI displays the error data and its FFT data from the IGLOO2 device and plots as shown in [Figure 17](#). The error signal plot shows the suppression of narrow band component from the signal and outputting wide band signals only after the required number of iterations.



**Figure 17 • Error Signal: Time and Frequency Plot**

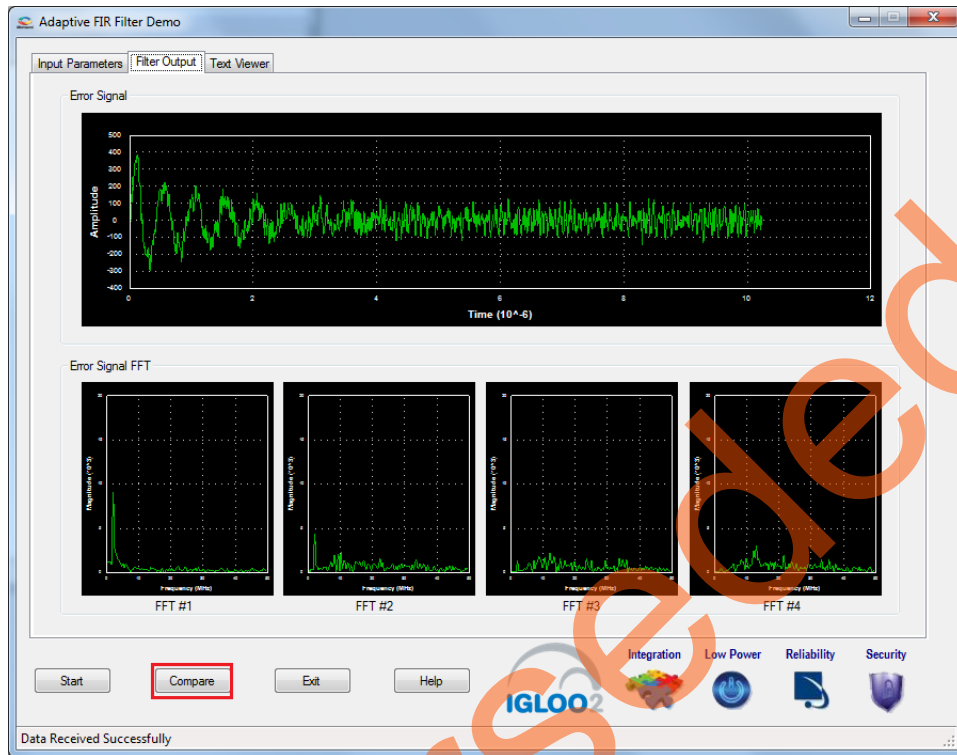
The narrow band signal component is suppressed gradually in the Error signal frequency spectrum. This can be observed in the Error signal FFT plot as shown in [Figure 18](#).



**Figure 18 • Error Signal FFT: Time and Frequency Plot**

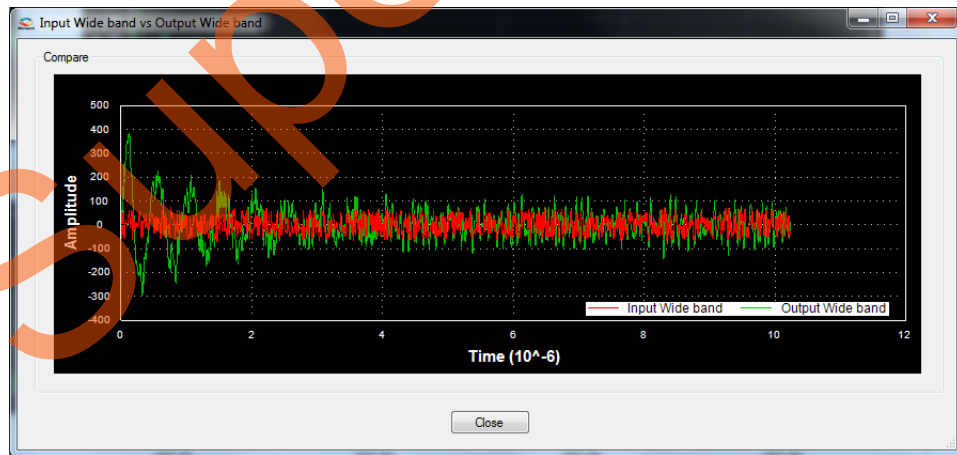


6. You can compare the input wide band and the output wide band signals. Click **Compare** to analyze the Input wide band data with the Output wide band data.



**Figure 19 • Compare Error Signal: Time and Frequency Plot**

7. A window displaying the comparison between the Input wide band and Output wide band is displayed, refer to [Figure 20](#).



**Figure 20 • Comparison of Input Wide Band and Output Wide Band**

8. The plot can be zoomed in for comparison, refer to [Figure 21](#).



**Figure 21 • Input Wide Band vs Output Wide Band - Zoomed In**

9. Compare the Error signal (output wide band signal) with the input wide band signal, refer to [Figure 22](#). You can see that the narrow band interfering component is eliminated and the wide band signal is preserved in Error signal.



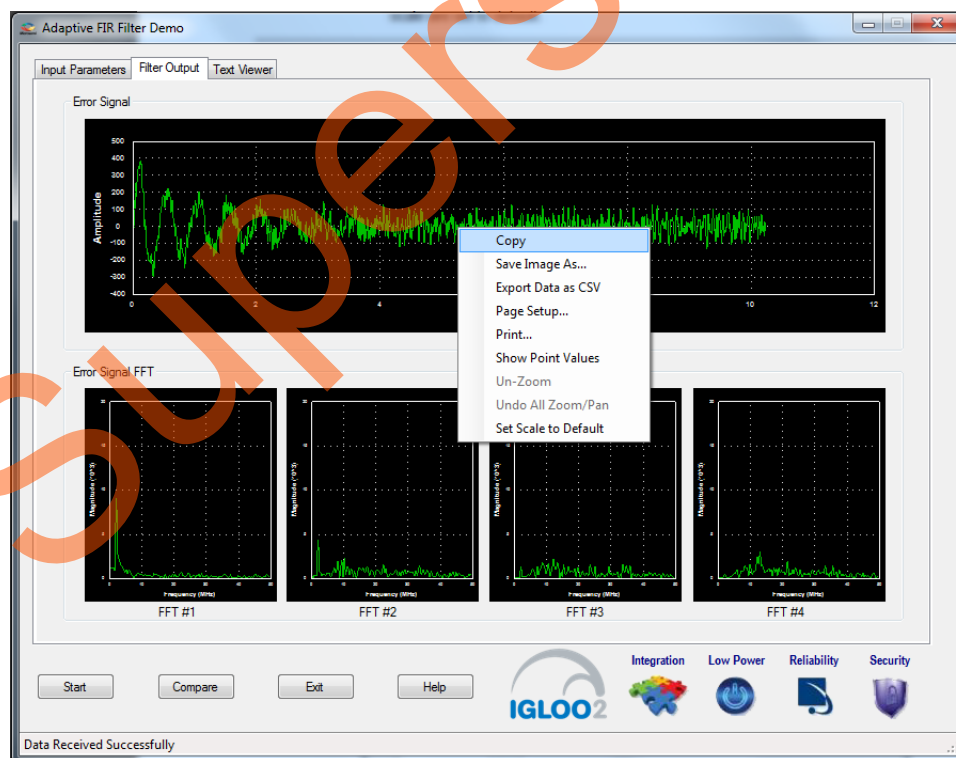
**Figure 22 • Comparison of Input Wide Band and Output Wide Band**

10. Click **Close**, refer to Figure 23.



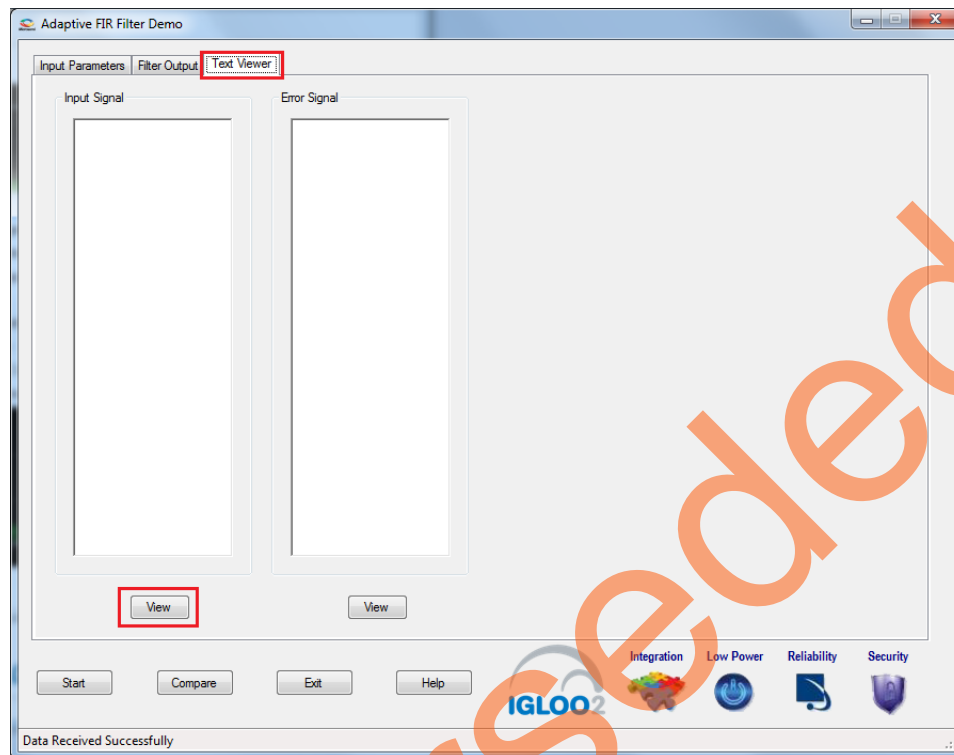
**Figure 23 • Closing Input Wide Band vs Output Wide Band Window**

11. You can copy, save, export and customize page and configure print setup the Error Signal plot. Right click on the **Error Signal** plot.
12. From the context sensitive pop up select the required option.
13. It shows the different options as shown in Figure 24. The data can be copied, saved, and exported to CSV plot for analysis purpose. Page setup, print, show point values, Zoom, and set scale are set to default.



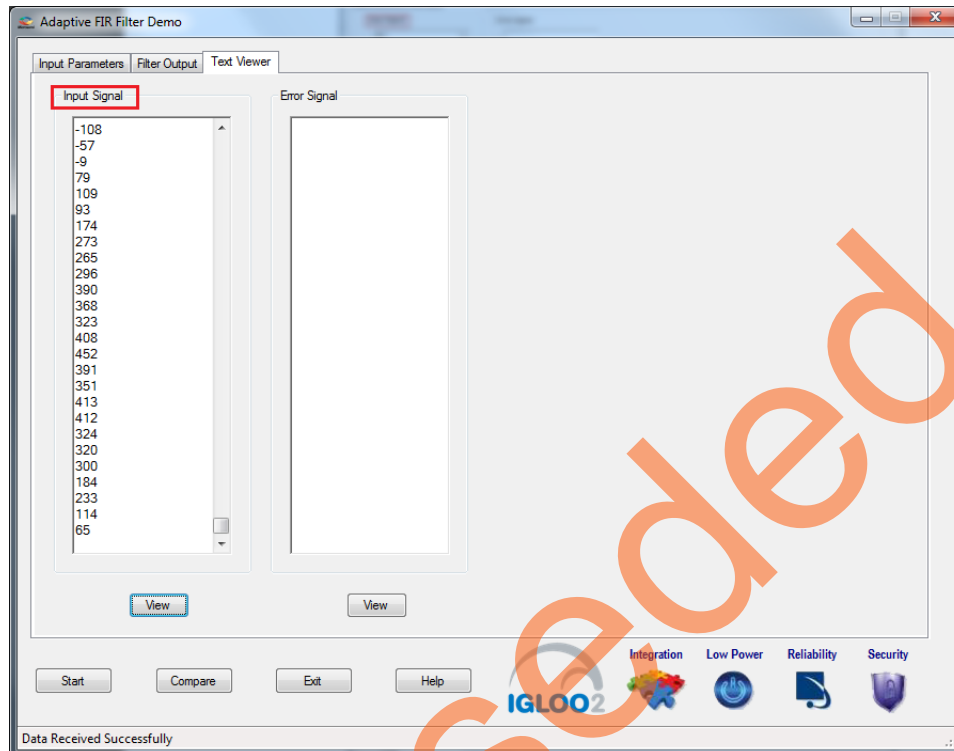
**Figure 24 • Error Signal - GUI Options**

14. The input signal and error signal values can be viewed in the **Text Viewer** tab. Click on the **Text Viewer** tab and then click on the corresponding **View** shown in Figure 25.



**Figure 25 • Text Viewer**

Figure 26 shows the **Text Viewer** tab showing the **Input Signal** values.



**Figure 26 • Text Viewer: Input Signal Values**

15. To save the Input Signal as a text file, right-click on the Input Signal window. The Input Signal window displays different options as shown in Figure 27 on page 30.

16. Click **Save**. Select **OK** to save the text file.

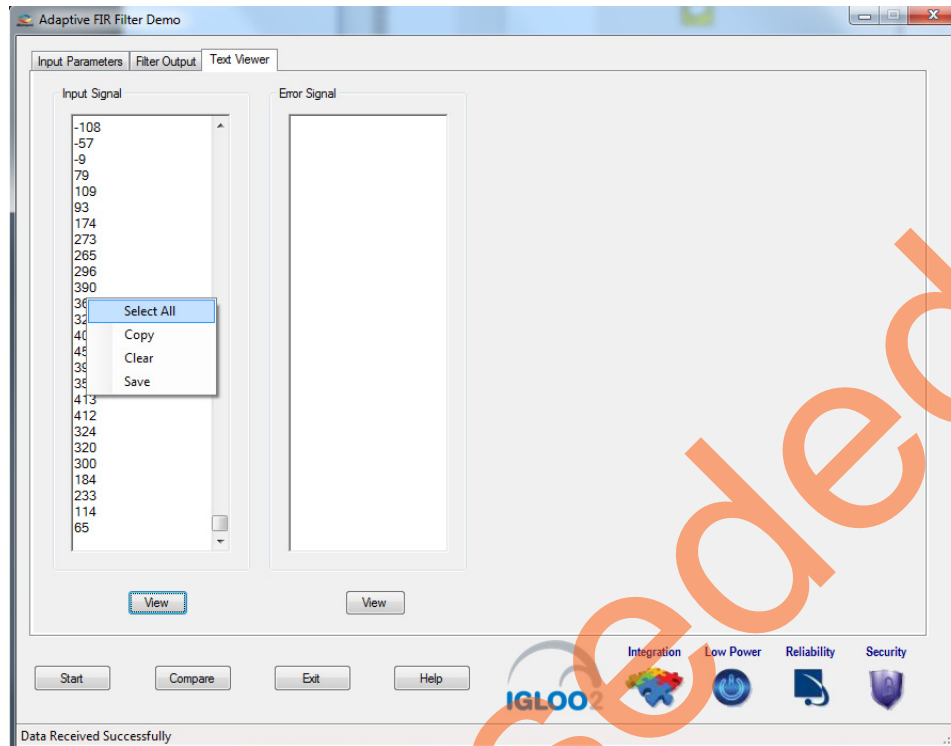
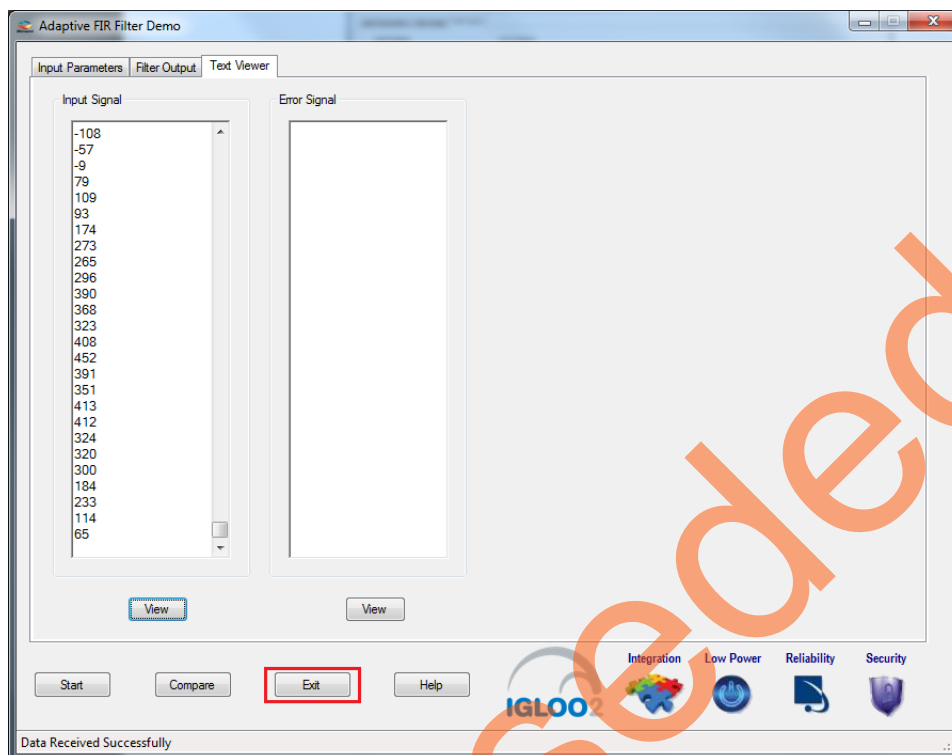


Figure 27 • Text Viewer - Input Signal Save Option

17. Click **Exit** to stop the demo, refer to Figure 28.



**Figure 28 • Exit Demo**

## Conclusion

This demo provides information about the features of the IGLOO2 device including mathblocks and how to use Microsemi IPs (CoreFIR and CoreFFT) for narrow band interference cancellation application using Adaptive filters. This Adaptive FIR Filter based demo is easy to use and provides many options to understand and implement DSP filters on the IGLOO2 device.

## Appendix 1: SmartDesign Implementation

Adaptive FIR filter SmartDesign is shown in Figure 1.

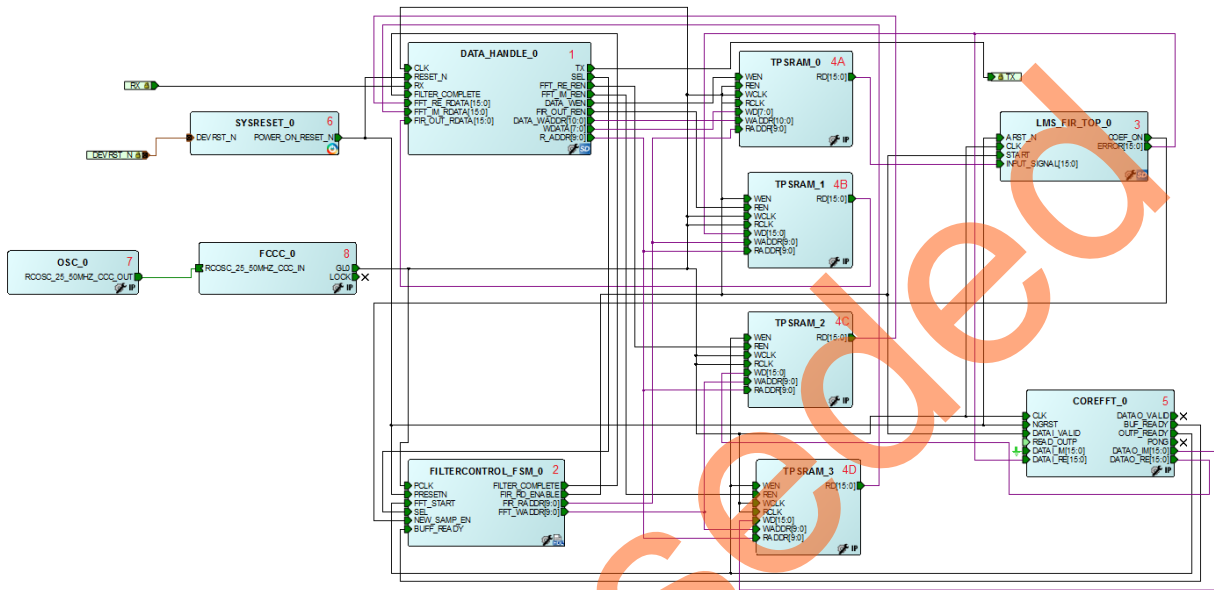


Figure 1 • Adaptive FIR Filter SmartDesign

SmartDesign LMS\_FIR\_TOP is shown in Figure 2.

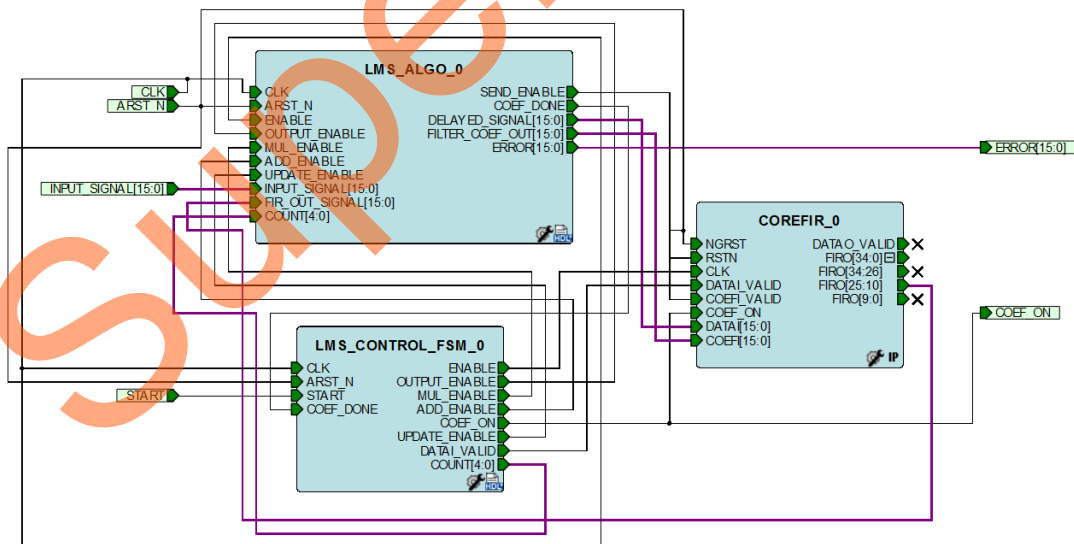


Figure 2 • SmartDesign LMS\_FIR\_TOP



Table 1 describes SmartDesign blocks in Adaptive FIR Filter.

**Table 1 • Adaptive FIR Filter Demo SmartDesign Blocks and Description**

S.No	Block Name	Description
1	DATAHANDLE_0	Handles communication between the Host PC and IGLOO2 Evaluation Kit board.
2	FILTERCONTROL_FSM_0	Control logic to generate the control signals for FIR and FFT operations.
3	LMS_FIR_TOP	SmartDesign.
4	INPUT_Buffer	FIR input signal data buffer.
	OUTPUT_Buffer	FIR output signal buffer.
	FFT_Im_Buffer	FFT output imaginary data buffer.
	FFT_Re_Buffer	FFT output real data buffer.
5	COREFFT_0	COREFFT IP.
6	SYSRESET_0	Reset IP.
7	OSC_0	Oscillator IP.
8	FCCC_0	Clock conditioning circuit IP.

Table 2 describes SmartDesign blocks in LMS\_FIR\_TOP.

**Table 2 • LMS\_FIR\_TOP SmartDesign Blocks and Description**

S.No	Block Name	Description
1	LMS_ALGO	LMS algorithm implemented in the RTL to compute error, correction factor, and filter coefficients.
2	LMS_CONTROL_FSM	FSM implemented in the RTL to control LMS_ALGO block.
3	COREFIR	COREFIR IP.

## Appendix 2: Resource Usage Summary

Table 1 shows adaptive FIR filter demo resource usage summary.

**Device:** IGLOO2 device

**Die:** M2GL010

**Package:** 484 FBGA

**Table 1 • Adaptive FIR Filter Demo Resource Usage Summary**

Type	Used	Total	Used vs Total in Percentage (%)
COMB	2978	12084	24.64
SEQ	2903	12084	24.02
RAM1Kx18	11	21	52.38
MACC	13	22	59.09

Table 2 shows MACC blocks usage summary.

**Table 2 • MACC Blocks Usage Summary**

CoreFIR	CoreFFT	LMS_ALGO	Total
8	04	1	13

Table 3 shows RAM1Kx18 blocks usage summary.

**Table 3 • RAM1Kx18 Blocks Usage Summary**

CoreFIR	CoreFFT	Fabric Buffers	Total
0	7	4	11

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## A – List of Changes

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The following table lists critical changes that were made in each revision of the chapter in the demo guide.

Date	Changes	Page
Revision 2 (June 2014)	Updated the document for Libero v11.3 software release (SAR 56264).	NA
	The "Theory of Operation" section updated (SAR 56264).	6
	Figure 6 updated (SAR 56264).	10
Revision 1 (January 2014)	Initial Release	NA

Superseded

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## B – Product Support

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Microsemi SoC Products Group backs its products with various support services, including Customer Service, Customer Technical Support Center, a website, electronic mail, and worldwide sales offices. This appendix contains information about contacting Microsemi SoC Products Group and using these support services.

### Customer Service

Contact Customer Service for non-technical product support, such as product pricing, product upgrades, update information, order status, and authorization.

From North America, call 800.262.1060

From the rest of the world, call 650.318.4460

Fax, from anywhere in the world, 408.643.6913

### Customer Technical Support Center

Microsemi SoC Products Group staffs its Customer Technical Support Center with highly skilled engineers who can help answer your hardware, software, and design questions about Microsemi SoC Products. The Customer Technical Support Center spends a great deal of time creating application notes, answers to common design cycle questions, documentation of known issues, and various FAQs. So, before you contact us, please visit our online resources. It is very likely we have already answered your questions.

### Technical Support

Visit the Customer Support website ([www.microsemi.com/soc/support/search/default.aspx](http://www.microsemi.com/soc/support/search/default.aspx)) for more information and support. Many answers available on the searchable web resource include diagrams, illustrations, and links to other resources on the website.

### Website

You can browse a variety of technical and non-technical information on the SoC home page, at [www.microsemi.com/soc](http://www.microsemi.com/soc).

### Contacting the Customer Technical Support Center

Highly skilled engineers staff the Technical Support Center. The Technical Support Center can be contacted by email or through the Microsemi SoC Products Group website.

#### Email

You can communicate your technical questions to our email address and receive answers back by email, fax, or phone. Also, if you have design problems, you can email your design files to receive assistance. We constantly monitor the email account throughout the day. When sending your request to us, please be sure to include your full name, company name, and your contact information for efficient processing of your request.

The technical support email address is [soc\\_tech@microsemi.com](mailto:soc_tech@microsemi.com).

## My Cases

Microsemi SoC Products Group customers may submit and track technical cases online by going to [My Cases](#).

## Outside the U.S.

Customers needing assistance outside the US time zones can either contact technical support via email ([soc\\_tech@microsemi.com](mailto:soc_tech@microsemi.com)) or contact a local sales office. [Sales office listings](#) can be found at [www.microsemi.com/soc/company/contact/default.aspx](http://www.microsemi.com/soc/company/contact/default.aspx).

## ITAR Technical Support

For technical support on RH and RT FPGAs that are regulated by International Traffic in Arms Regulations (ITAR), contact us via [soc\\_tech\\_itar@microsemi.com](mailto:soc_tech_itar@microsemi.com). Alternatively, within [My Cases](#), select **Yes** in the ITAR drop-down list. For a complete list of ITAR-regulated Microsemi FPGAs, visit the [ITAR](#) web page.

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Microsemi Corporation (Nasdaq: MSCC) offers a comprehensive portfolio of semiconductor and system solutions for communications, defense and security, aerospace, and industrial markets. Products include high-performance and radiation-hardened analog mixed-signal integrated circuits, FPGAs, SoCs, and ASICs; power management products; timing and synchronization devices and precise time solutions, setting the world's standard for time; voice processing devices; RF solutions; discrete components; security technologies and scalable anti-tamper products; Power-over-Ethernet ICs and midspans; as well as custom design capabilities and services. Microsemi is headquartered in Aliso Viejo, Calif. and has approximately 3,400 employees globally. Learn more at [www.microsemi.com](http://www.microsemi.com).

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