



Gowin NLMS Adaptive Filter User Guide

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Revision History

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1 About This Guide

1.1 Purpose

Gowin NLMS Adaptive Filter IP User Guide provides an introduction of the function, signal, port, timing, configuration call, and reference design, etc. The guide helps users to quickly learn the feature and usage of Gowin NLMS Adaptive Filter IP.

1.2 Supported Products

The information presented in this guide applies to the following products:

1. GW1N series of FPGA products: GW1N-2, GW1N-2B, GW1N-4, GW1N-4B, GW1N-6, GW1N-9
2. GW1NR series of FPGA Products
3. GW2A series of FPGA Products
4. GW2AR series of FPGA Products
5. GW1NS series of FPGA products:GW1NS-4, GW1NS-4C
6. GW1NRF series of FPGA products: GW1NRF-4B

1.3 Related Documents

The user guides are available on the GOWINSEMI Website. You can find the related documents at www.gowinsemi.com:

1. DS100, GW1N series of FPGA Products Data Sheet
2. DS117, GW1NR series of FPGA Products Data Sheet
3. DS102, GW2A series of FPGA Products Data Sheet
4. DS226, GW2AR series of FPGA Products Data Sheet
5. DS821, GW1NS series of FPGA products Data Sheet
6. DS891, GW1NRF series of FPGA products Data Sheet
7. SUG100, Gowin YunYuan Software User Guide

1.4 Terminology and Abbreviations

The terminology and abbreviations used in this manual are as shown in the below Table 1-1.

Table 1-1 Abbreviations and Terminologies

Terminology and Abbreviations	Full Name
FPGA	Field Programmable Gate Array
NLMS	Normalized Least Mean Square
IP	Intellectual Property
DSP	Digital Signal Processing
SRAM	Static Random Access Memory

1.5 Support and Feedback

Gowin Semiconductor provides customers with comprehensive technical support. If you have any questions, comments, or suggestions, please feel free to contact us directly by the following ways.

Website: www.gowinsemi.com

E-mail: support@gowinsemi.com

2Overview

2.1 NLMS Adaptive Filter IP Introduction

Gowin NLMS Adaptive Filter IP is based on NLMS (Normalized Least Mean Square) algorithm, and rational utilization of DSP resources can achieve relatively accurate calculation results. It supports 16-1024 tapsize and adaptive step size can be configured. It can be applied to echo cancellation in voice communication system.

Table 2-1 NLMS Adaptive Filter IP

NLMS Adaptive Filter IP	
IP Core Application	
Supported Devices	● GW1N Series: GW1N-2, GW1N-2B, GW1N-4, GW1N-4B, GW1N-6, GW1N-9 ● GW1NR Series ● GW2A Series ● GW2A Series
Logic Resource	Please refer to Table 2-2.
Delivered Doc.	
Design Files	Verilog (encrypted)
Reference Design	Verilog
TestBench	Verilog
Test and Design Flow	
Synthesis Software	Synplify_Pro
Application Software	GoWinYunYuan

2.2 Key Features

1. Data bit width supports 8-18 bits.
2. Adaptive step size can be configured.
3. It supports 16-1024 tapsize.

2.3 Max. Frequency

The maximum frequency of NLMS Adaptive Filter IP is mainly determined by the speed grade of the devices, and it can reach 100M.

2.4 Resource Utilization

NLMS Adaptive Filter is implemented by Verilog language. Due to different IP configuration, its resource utilization varies greatly accordingly. In addition, its performance and resource utilization may vary when the design is employed in different devices, or at different density, speed, or grade.

Take gw2a-55 with the input data bit width of 18bits as an example, and select some situations of resource utilization under configuration as shown in Table 2-2

Table 2-2 NLMS Adaptive Filter Resource Utilization

Device	Speed Grade	mu	tapsize	LOGI CS	REGS	DSP Macros	BSRAMS
GW2A-55	C8/I7	3	32	1007	1047	5	2
			1024	1014	1080	5	5

Note!

The actual resource utilization is also related to the YunYuan software version, and the actual comprehensive result shall prevail.

3Port Description

For the I/O port details, I/O port diagram is shown in Figure 3-1, and I/O port list is shown in Table 3-1;

Figure 3-1 NLMS Adaptive Filter Interface Diagram

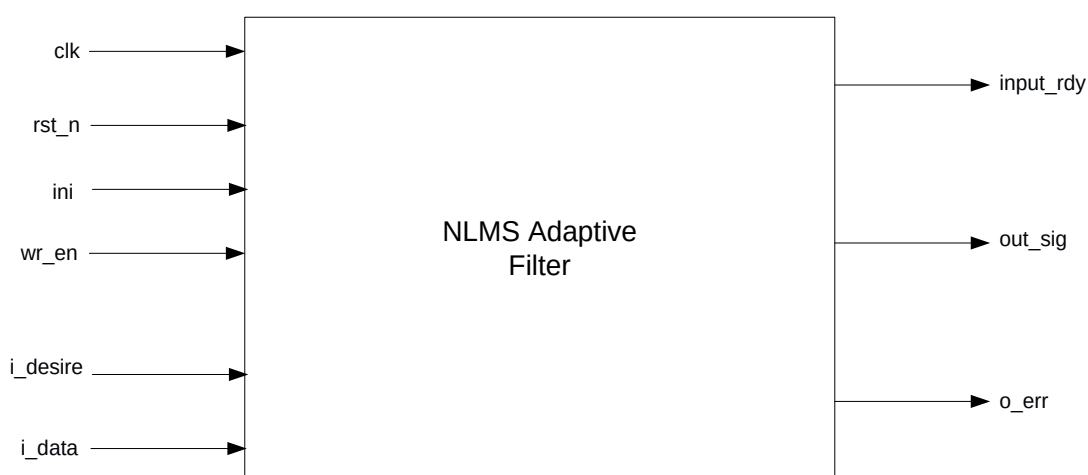


Table 3-1 Gowin FD Adaptive Filter IP I/O Port List

Signal	I/O	Data Width	Description
rst_n	I	1	Reset signal, active - low
clk	I	1	Clock signal
ini	I	1	Initialization signal for zeroing coefficients and data storage registers
wr_en	I	1	Read enable signal
i_data	I	8-18	Input signal
i_desire	I	8-18	Desired signal input;
o_err	O	8-18	The output error signal is the signal after the echo is filtered
out_sig	O	1	High level, output indication signal means the filter is completed, and the output is effective.

Signal	I/O	Data Width	Description
input_rdy	O	1	Indicate that one calculation cycle is completed and data can be input again

4GUI Parameters

4.1 Overview

Gowin NLMS Adaptive Filter provides relevant parameters for users to configure according to their actual requirements, as shown in Table 4-1.

4.2 Gowin NLMS Adaptive Filter Parameter

Table 4-1 Gowin NLMS Adaptive Filter Parameter

No.	Name	Options	Description
1	Number of Taps	16-1024	Tapsize
2	Adaption Step Size	3/4/5	Adaptive step size (3, 4 and 5 represent 2^{-3} , 2^{-4} , 2^{-5} respectively)
3	Data bit Width	8-18	idata、idesire and o_err width, signed

Note!

If the input bit width is too narrow or the input data is too small, the calculation accuracy may be insufficient.

5 Principle

5.1 Algorithm Introduction

Normalized Least Mean Square (NLMS) Adaptive Filter is based on the Normalized Least Mean Square algorithm, the calculation formula of which is as follows:

$$y(n) = \mathbf{w}^T(n-1)\mathbf{u}(n)$$

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

$$\mathbf{w}(n) = \mathbf{w}(n-1) + f(\mathbf{u}(n), e(n), \mu)$$

Among them:

$$f(\mathbf{u}(n), e(n), \mu) = \mu e(n) \frac{\mathbf{u}^*(n)}{\mathbf{u}^H(n)\mathbf{u}(n)}$$

The variable values in the formula are as follows.

Table 5-1 Variable Values

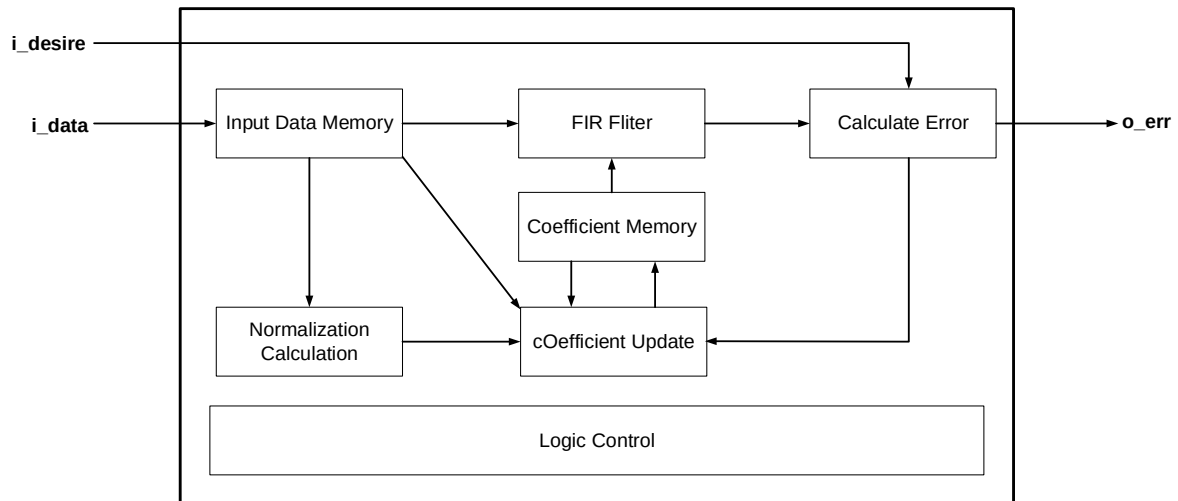
Variable	Description
n	The current time index
$\mathbf{u}(n)$	The vector of buffered input samples at step n
$\mathbf{u}^*(n)$	The complex conjugate of the vector of buffered input samples at step n
$\mathbf{w}(n)$	The vector of filter weight estimates at step n
$y(n)$	The filtered output at step n
$e(n)$	The estimation error at step n
$d(n)$	The desired response at step n
μ	The adaptation step size

Gowin NLMS Adaptive Filter IP implements the algorithm with $\mathbf{u}(n)$ as

the input signal i_data , $d(n)$ as the input desired signal i_desire , and $e(n)$ as the output error signal o_err .

5.2 Gowin NLMS Adaptive Filter IP Implementation

Figure5-1 Gowin NLMS Adaptive Filter IP Implementation Diagram



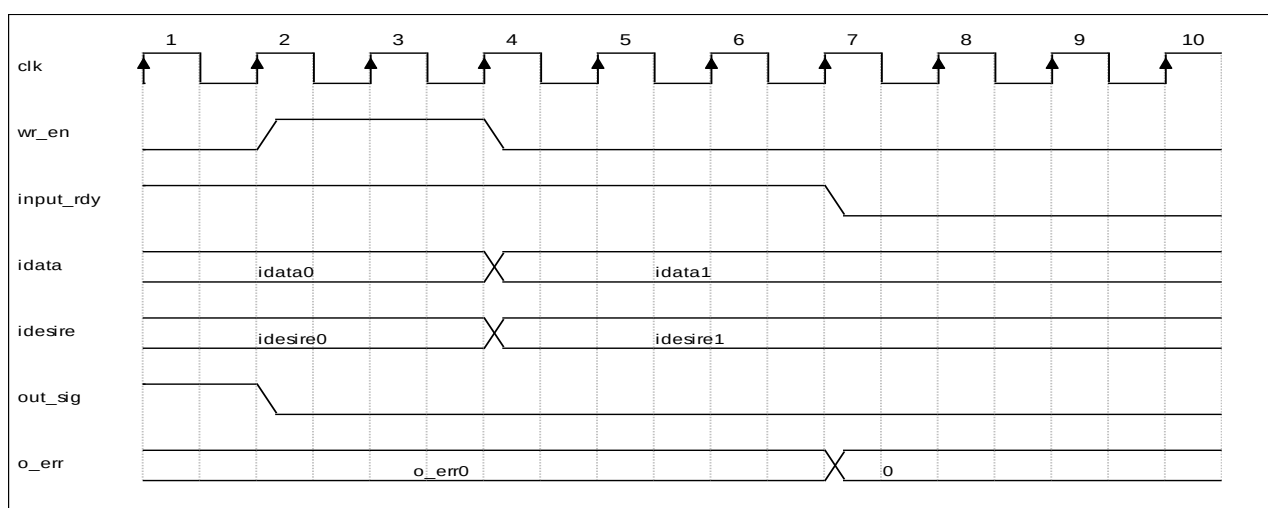
NLMS Adaptive Filter IP implementation diagram is shown in Figure5-1 above. After the input data is sent to IP, it is stored in the input data memory. The output error signal is obtained by subtracting the filtered result by FIR filter from the desired input signal. Then the stored data is read again for normalization calculation. Finally, the normalized calculation results, error values, coefficients and the stored data are used to update the coefficients. After the update, the coefficients are stored in the coefficient memory again, thus finishing a complete calculation process.

6Timing Description

This section aims to introduce the timing of Gowin NLMS Adaptive Filter IP.

6.1 Input Signal Timing

Figure6-1 NLMS Adaptive Filter Input Signal Timing

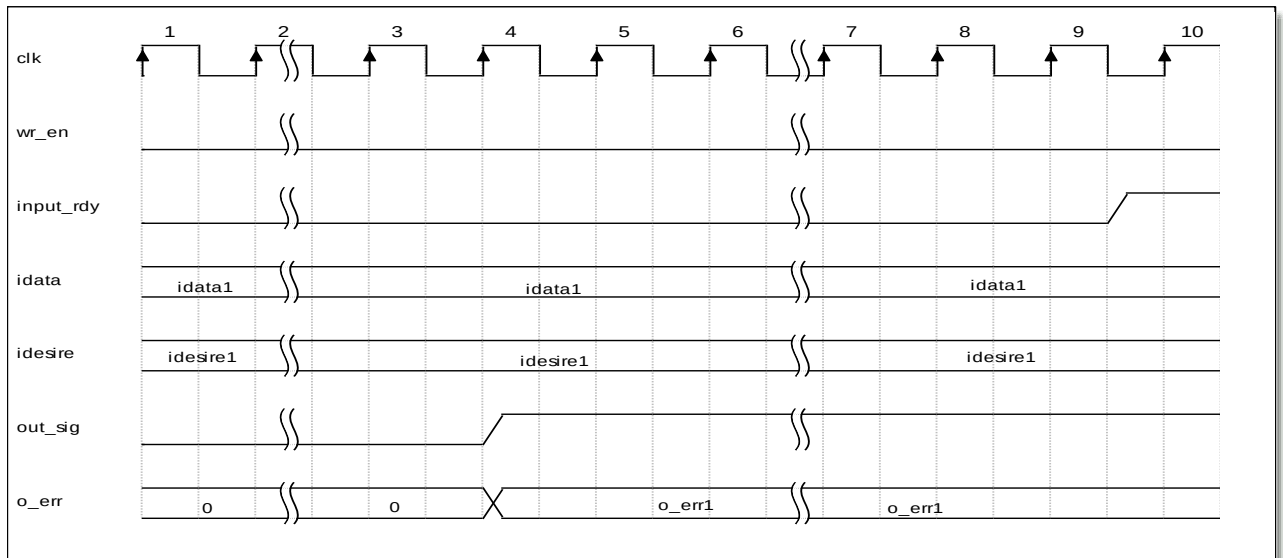


NLMS Adaptive Filter input signal timing is shown in Figure6-1.

In the diagram, when **wr_en** is high, **out_sig** is set to zero; When **wr_en** becomes low, NLMS Adaptive Filter will input the current **idata** and **idesire** for calculation (as shown in the figure, **idata0** and **idesire0** are used for calculation). After three clock cycles of delay, **input_rdy** will be set to zero, indicating that **wr_en** can no longer be set to high level. Meanwhile, **o_err** is also set to zero, and the output data of the previous calculation cycle is cleared.

6.2 Signal Output Timing

Figure6-2 NLMS Adaptive Filter Signal Output Timing



NLMS Adaptive Filter output signal timing is shown in Figure6-2.

After the data is input, NLMS Adaptive Filter IP completes the calculation of the output error signal, and the out_sig signal is pulled up, indicating that the output is effective, while the o_err outputs results. After calculation, coefficients update finished, the input_rdy signal is pulled up, indicating that the input signal can be received again.

6.3 Input Interval

Because the Adaptive Filter of NLMS involves a lot of mathematical calculation, the calculation process takes much time. If a calculation is not completed (input_rdy signal is not pulled up) and the input data is written, the output will be wrong. In the use process, new data can be input after input_rdy is pulled up or at a fixed rate. The following provides a simple algorithm for data input interval as a reference.

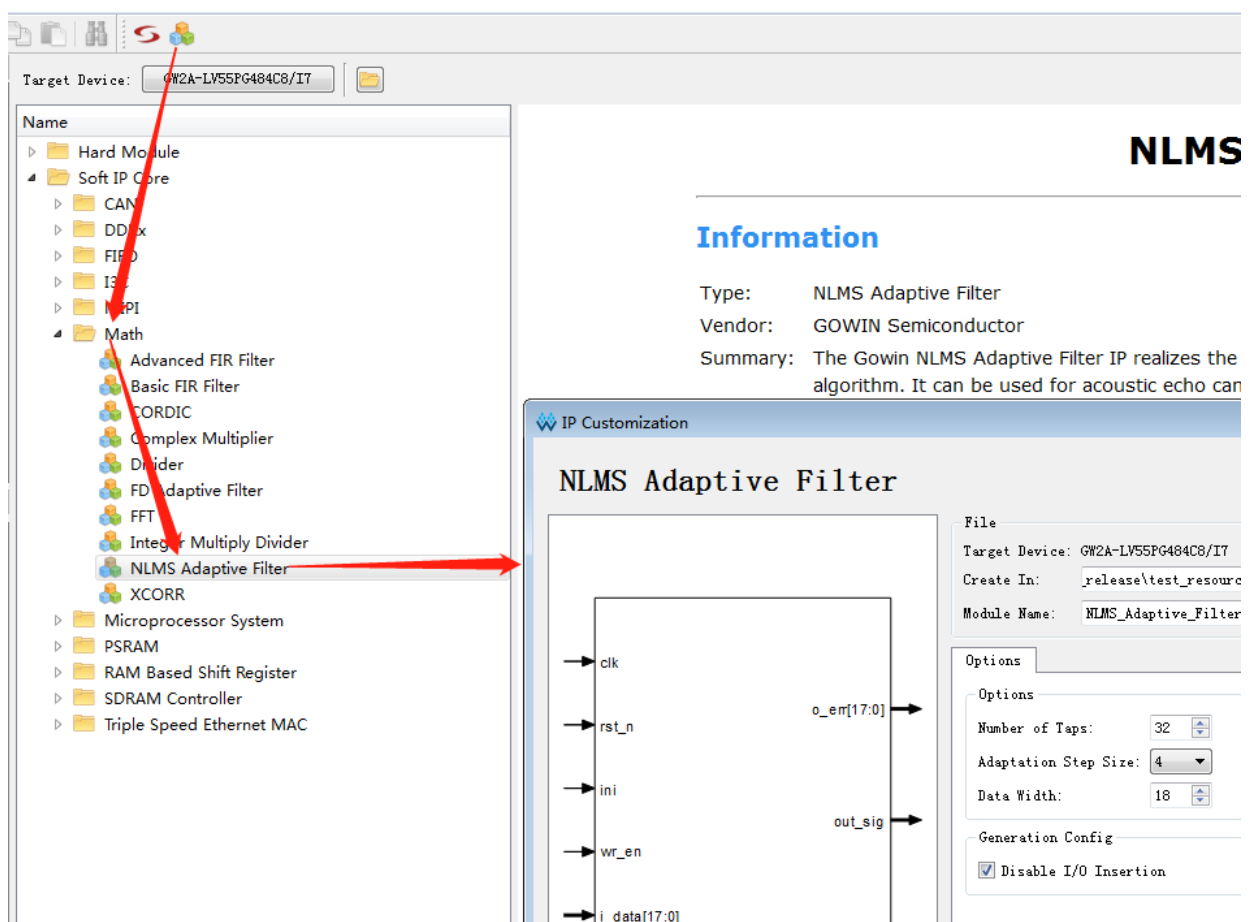
Assuming that the input clk frequency is f_c HZ, and the tap size is n , and $f_{w\max}$ means the maximum frequency of input data, then:

$$f_{w\max} = \frac{f_c}{2n+300}$$

7 Configuration and Call

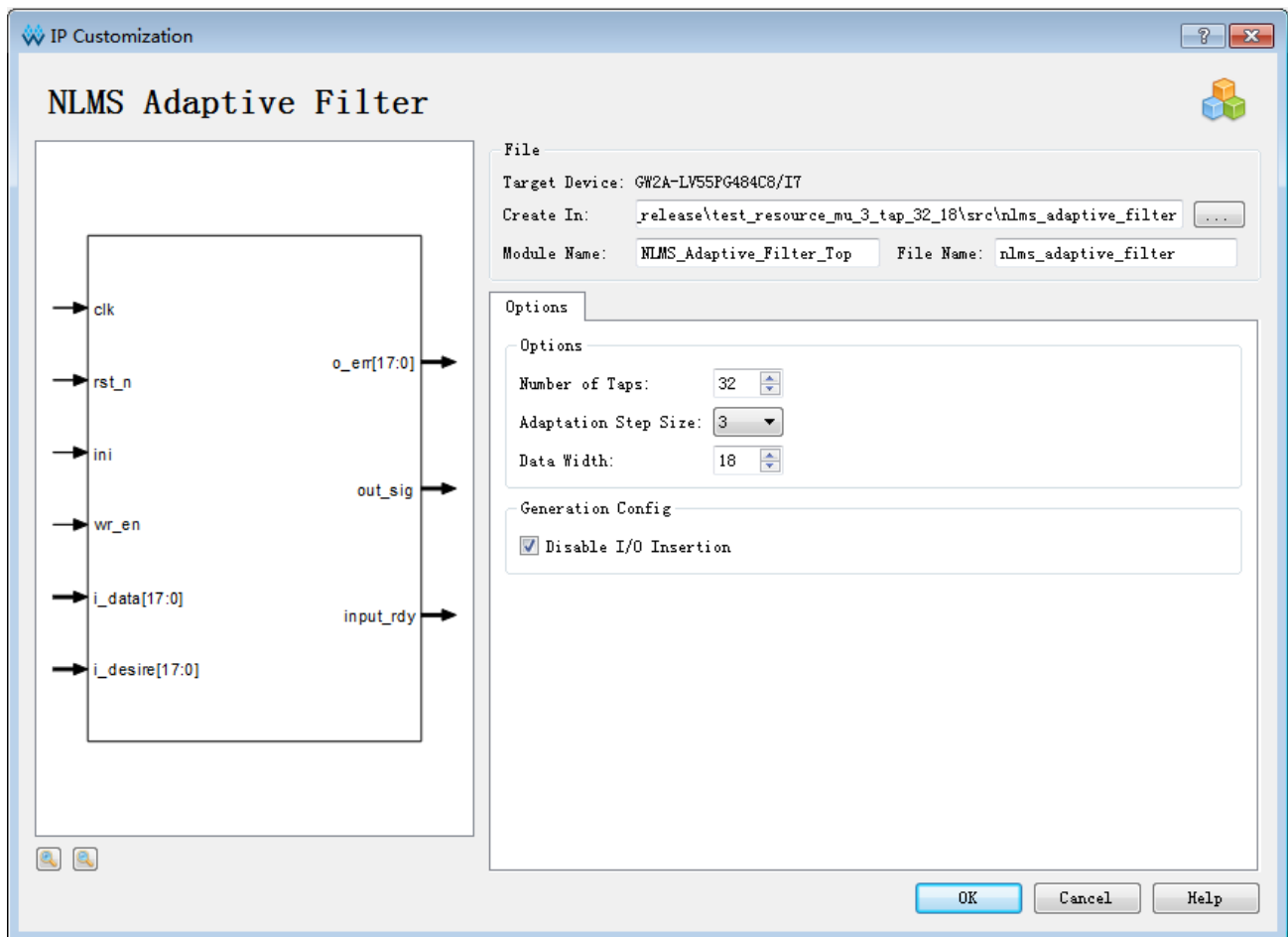
Start "IP Core Generator" from the "Tools" menu in the Gowin YunYuan software, then complete the call and configure NLMS Adaptive Filter in Math. Toolbar icon is also available as shown in Figure 7-1.

Figure7-1 Toolbar Icon Opens the IP Configuration Interface



NLMS Adaptive Filter configuration interface is shown in the figure 7-2.

Figure7-2 NLMS Adaptive Filter Configuration Interface



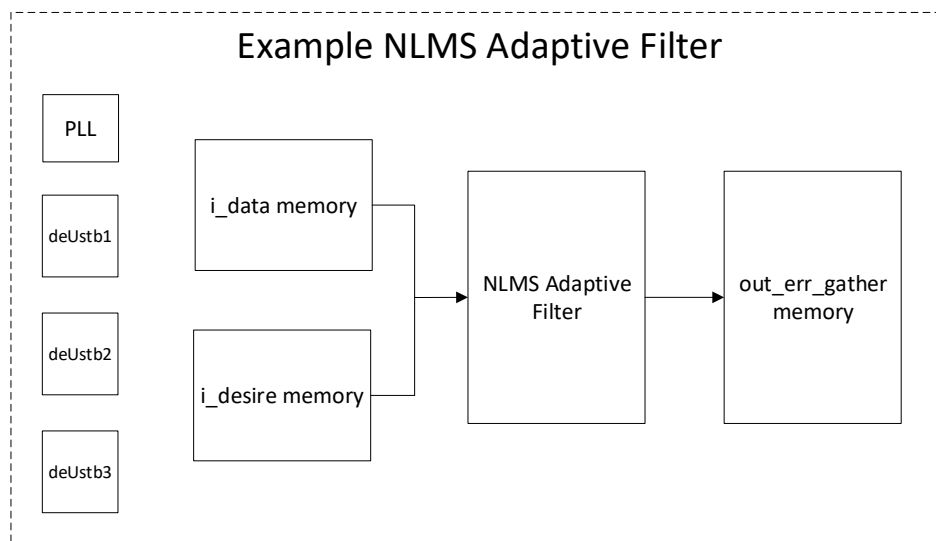
1. NLMS Adaptive Filter can be configured to generate the file name by modifying the File Name.
2. The generated NLMS Adaptive Filter top-level Module Name can be configured by modifying the Module Name.

8Reference Design

This section briefly introduces the Adaptive Filter Adaptive NLMS reference design instance structure and its operation steps.

The design instance structure of the Adaptive Filter NLMS is shown in Figure8-1. It is composed of PLL key, deUstb1, deUstb2 and deUstb3, i_data memory, i_desire memory, NLMS Adaptive Filter and out_err_gather memory.

Figure8-1 NLMS Adaptive Filter Reference Design Instance Structure



In this design instance, the input data and input desired signal have been stored in the corresponding memory, and the user only needs to reset, initialize and "start" by pressing the button to start the operation. The user can capture the signal through simulation or GAO. Please refer to the NLMS Adaptive Filter RefDesign for specific details.

