



Gowin IIR Filter IP

User Guide

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Revision History

Date	Version	Description
01/06/2021	1.0E	Initial version published.
04/16/2021	1.1E	Read and write timing description updated.

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1 About This Guide

1.1 Purpose

The purpose of Gowin IIR Filter IP User Guide is to help users learn the features and usage of this product by providing the descriptions of functions, ports, timing, call and configuration, and reference design.

1.2 Related Documents

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

- [DS100, GW1N series FPGA Products Data Sheet](#)
- [DS117, GW1NR series FPGA Products Data Sheet](#)
- [DS102, GW2A series of FPGA Products Data Sheet](#)
- [DS226, GW2AR series of FPGA Products Data Sheet](#)
- [DS961, GW2ANR series of FPGA Products Data Sheet](#)
- [SUG100, Gowin Software User Guide](#)

1.3 Terminology and Abbreviations

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

Table 1-1 Terminology and Abbreviations

Terminology and Abbreviations	Meaning
FPGA	Field Programmable Gate Array
IIR	Infinite Impulse Response
IP	Intellectual Property
DSP	Digital Signal Processing
SRAM	Static Random Access Memory
BSRAM	Block Static Random Access Memory

1.4 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

2 Overview

2.1 Introduction to Gowin IIR Filter IP

Gowin IIR Filter IP is used for high data throughput filtering that requires high cutoff, and IIR filters require less hardware and respond faster than FIR filters. Gowin IIR Filter IP supports multi-channel and multiplexer time division multiplexing, and supports reloading coefficients during operation, so it is convenient and flexible to use.

Table 2-1 Gowin IIR Filter IP

IIR Filter IP	
IP Core Application	
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	Gowin Software

2.2 Features

- Input data bit width supports 2-36 bits.
- Coefficient bit width supports 2-36 bits.
- Output data bit width supports 2-36 bits.
- The number of tap size supports 2-64 (depending on chip resource).
- The number of channels supports 1-32 (depending on chip resource).
- The number of multipliers supports 1-48 (depending on chip resource).
- The coefficients can be reloaded.

2.3 Max. Frequency

The maximum frequency of Gowin IIR Filter IP is primarily determined by the device used and the speed grade of the devices. Take GW2A-18 series of FPGA for an instance. It can be up to 90M.

2.4 Resource Utilization

Gowin IIR Filter IP resource utilization mainly depends on the tapsize and configuration. The resource utilization may be different with different devices. Taking GW2A-18 series of FPGA as an example, Gowin IIR Filter IP resource utilization in different configurations is shown in Table 2-2.

Table 2-2 Resource Utilization (GW2A-18 C8/I7)

Device Series	Speed Grade	Order Size	Channels	Multipliers	LOGICS	REGS	DSP Macros	BSRAMS
GW2A-18	C8/I7	12	1	4	1577	1298	4	2

3 Functional Description

3.1 Introduction to Algorithm

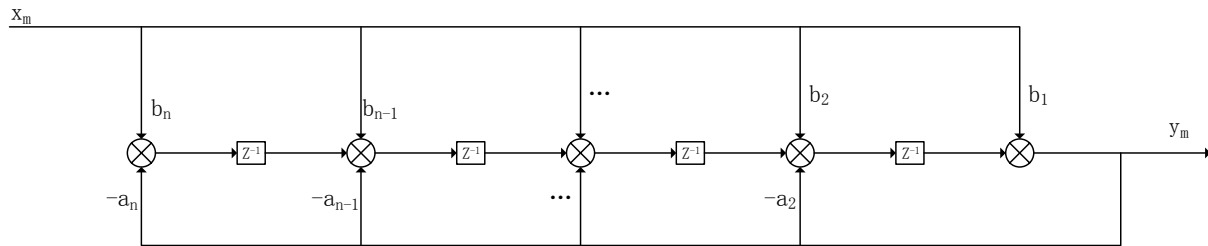
The formulas for IIR Filter calculation are as follows:

$$a_1 y_n = b_1 x_n + b_2 x_{n-1} + \cdots + b_{n_b+1} x_{n-n_b} - a_2 y_{n-1} - \cdots - a_{n_a+1} y_{n-n_a}$$

3.2 Structure and Function

In Gowin FIR Filter IP, data input and output is processed by pipeline, which can get results quickly. It is suitable for the design with large data width and coefficient but relatively small order. Its basic structure is shown in Figure 3-1.

Figure 3-1 Gowin FIR Filter IP Structure



3.3 Initialization Coefficient File

Gowin IIR Filter IP supports coefficient initialization function. When calling Gowin IIR Filter IP, two initialization coefficient files must be specified, that is, feedforward coefficient file and feedback coefficient file. If the filter is as follows:

$$a_1 y_n = b_1 x_n + b_2 x_{n-1} + \cdots + b_{n_b+1} x_{n-n_b} - a_2 y_{n-1} - \cdots - a_{n_a+1} y_{n-n_a}$$

Then in the feedback coefficient file, the data should be placed in the following position:

$$a_1$$

a_2
 ...
 a_n

and the in the feedforward coefficient file, the data should be placed in the following position:

b_1
 b_2
 ...
 b_n

And the data is decimal plain text. The size of the initialization coefficient should be within the range of the selected coefficient bit width, otherwise the GUI interface will pop up data error.

In the case of multi-channel configuration, the data in the coefficient file should be placed:

0 of channel 0 (Coeff 0 0)

1 of channel 0 (Coeff 0 1)

...

n-1 of channel 0 (Coeff 0 n-1)

0 of Channel 1 (Coeff 1 0)

1of Channel 1 (Coeff 1 1)

...

n-1 of channel 1 (Coeff 1 n-1)

...

0 of channel M-1 (Coeff M-1 0)

1 of channel M-1 (Coeff M-1 1)

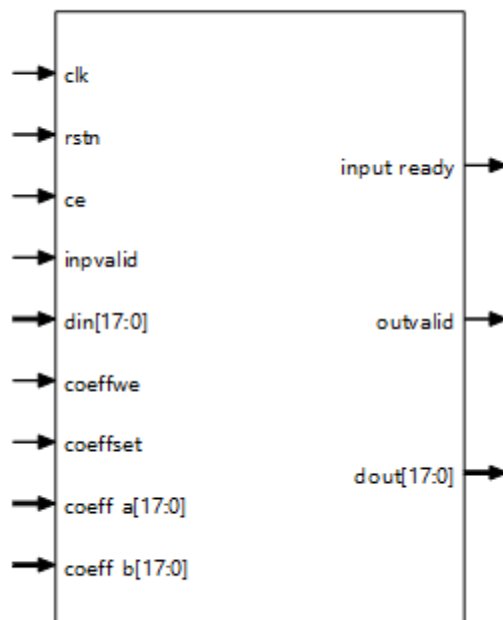
...

n-1 of channel M-1 (Coeff M-1 n-1)

4 Port Description

The details of Gowin IIR Filter IP I/O ports are shown in Figure 4-1.

Figure 4-1 Gowin IIR Filter IP Ports Diagram



For the detailed IO ports description of Gowin IIR Filter IP, please refer to Table 4-1.

Table 4-1 Ports List

Signal	I/O	Data Width	Description
clk	input	1	Input clock signal
rstn	input	1	Reset signal, active-low.
ce	input	1	Module enable signal
coeffwe	input	1	Reload coefficient at high level
coeffset	input	1	After the completion of coefficient reloading, the next clock cycle is set to high level, indicating the completion of coefficient reloading.

Signal	I/O	Data Width	Description
coeff_a	input	2-18	Feedback input coefficient
coeff_b	input	2-18	Feedforward input coefficient
ininvalid	input	1	High level means the input data is valid at this time.
ibstart	input	1	Set to high level each time the first channel data is input (The signal only exists in multiple channels).
din	input	2-18	Input signal
input_ready	output	1	High level means that the data can be input.
outvalid	output	1	Output valid signal, active-high.
obstart	output	1	Set to high level each time the first channel data is input (The signal only exists in multiple channels).
dout	output	2-36	The output signal

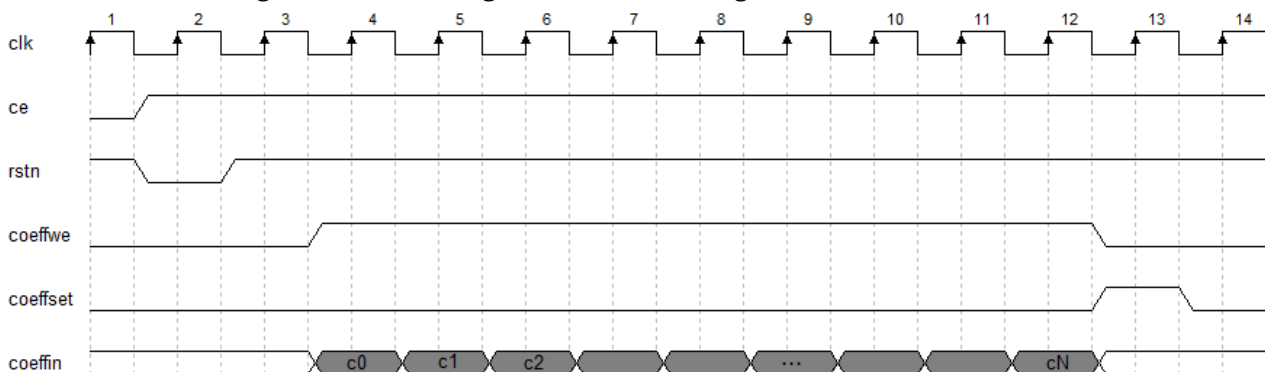
5 Timing Description

This chapter mainly introduces the timing of Gowin IIR Filter IP.

5.1 Reloading Coefficient Timing Description

Reloading coefficient timing description is shown in Figure 5-1.

Figure 5-1 Reloading Coefficient Timing

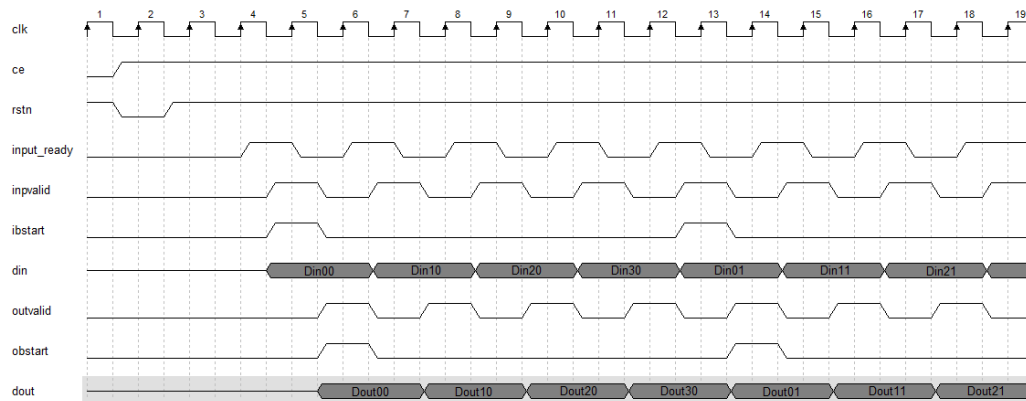


In reloading coefficient, the COEFFWE signal is set to high level and a coefficient is written per clock period. The number of written coefficients shall be consistent with the number of tapsize configured. (The number of written coefficients is the product of the number of tap size and channel in multiple channels) The COEFFSET signal should be set to high level in the next clock cycle after reloading coefficient operation.

When write coefficient, coeff_a and coeff_b need to be written synchronously. The sequence of coefficients for multi-channel is the same as the one in initialization file.

5.2 Read and Write Timing of Gowin IIR Filter IP

Figure 5-2 Read and Write Timing of Gowin IIR Filter IP



The read and write timing of Gowin IIR Filter IP is as shown in Figure 5-2. When `input_ready` is high, it means Gowin IIR Filter IP is ready to receive input data. When the data is input, the `inval` signal should be pulled up to make it valid. When `inval` is high, a data is input to calculate for every clock period. If it is multi-channel, it is from channel 0 data to the last channel data. After several clock periods of latency, the output signal `dout` can be obtained. At the same time, the `outvalid` signal will also become high, indicating that the output is valid at this time.

In the case of multi-channel configuration, the data in the coefficient file should be placed:

0 of channel 0 (Data 0 0)

0 of channel 1 (Data 1 0)

...

0 of channel M-1 (Data M-1 0)

1 of channel 0 (Data 0 1)

1 of channel 1 (Data 1 1)

...

1 of channel M-1 (Data M-1 1)

...

n-1 of channel 0 (Data 0 n-1)

n-1 of channel 1 (Data 1 n-1)

...

n-1 of channel M-1 (Data M-1 n-1)

For the IIR coefficient format conversion, you can see the following MATLAB example.

Figure 5-3 MATLAB Example

```
% generate coefficient
[coeff_b,coeff_a] = butter(n,Wn,options);

% Convert to fixed point
scale_a_length=Feedback_Coefficient_Scale_Length;
scale_b_length=user_define;
% note :
%      DOUT_WIDTH=DIN_WIDTH+scale_b_length-scale_a_length;
coeff_a_fi=round(coeff_a*2^(scale_a_length-1));
coeff_b_fi=round(coeff_b*2^(scale_b_length-1));

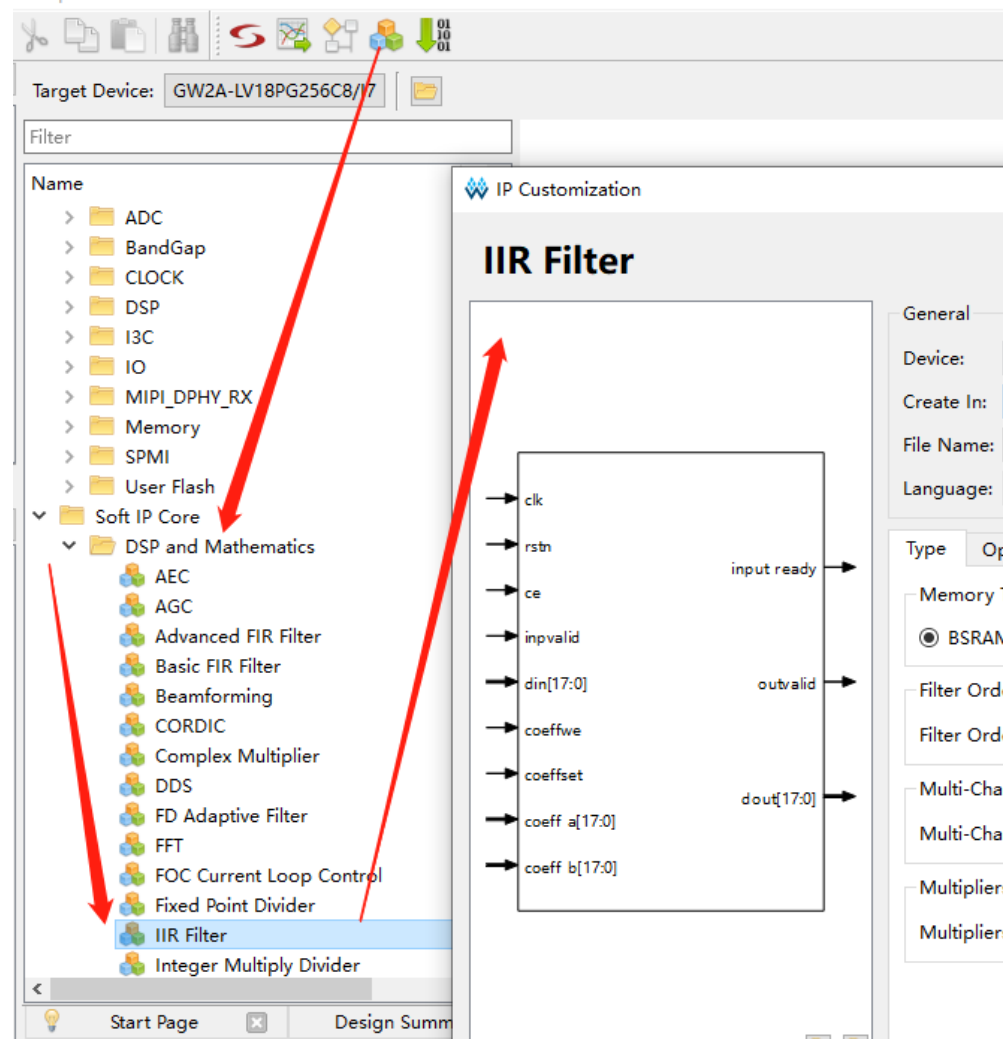
% tofile
coeff_a_file = "./data/coeff_a.dat";
coeff_b_file = "./data/coeff_b.dat";
save(coeff_a_file, coeff_a_fi);
save(coeff_b_file, coeff_b_fi);
```

The DIN_WIDTH, DOUT_WIDTH, and Feedback_Coefficient_Scale_Length can be configured via the Input Data Width, Output Data Width, and Feedback Coefficient Scale Length options in the IP generation interface.

6 Call and Configuration

Start "IP Core Generator" from the "Tools" menu in the Gowin software, then you can call and configure IIR Filter in DSP & Mathematic. Toolbar icon is also available as shown in Figure 6-1.

Figure 6-1 Open GUI Via Icon



IIR Filter IP configuration interface is as shown in Figure 6-2 and Figure 6-3.

Figure 6-2 Gowin IIR Filter IP Configuration Interface

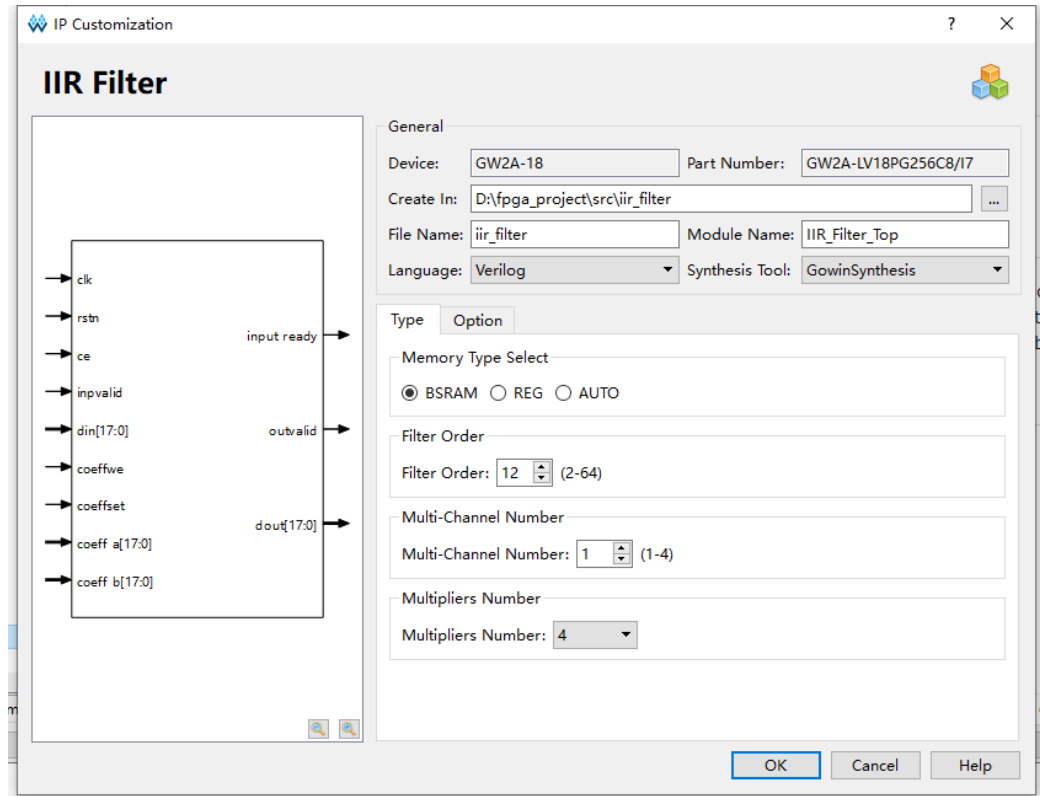
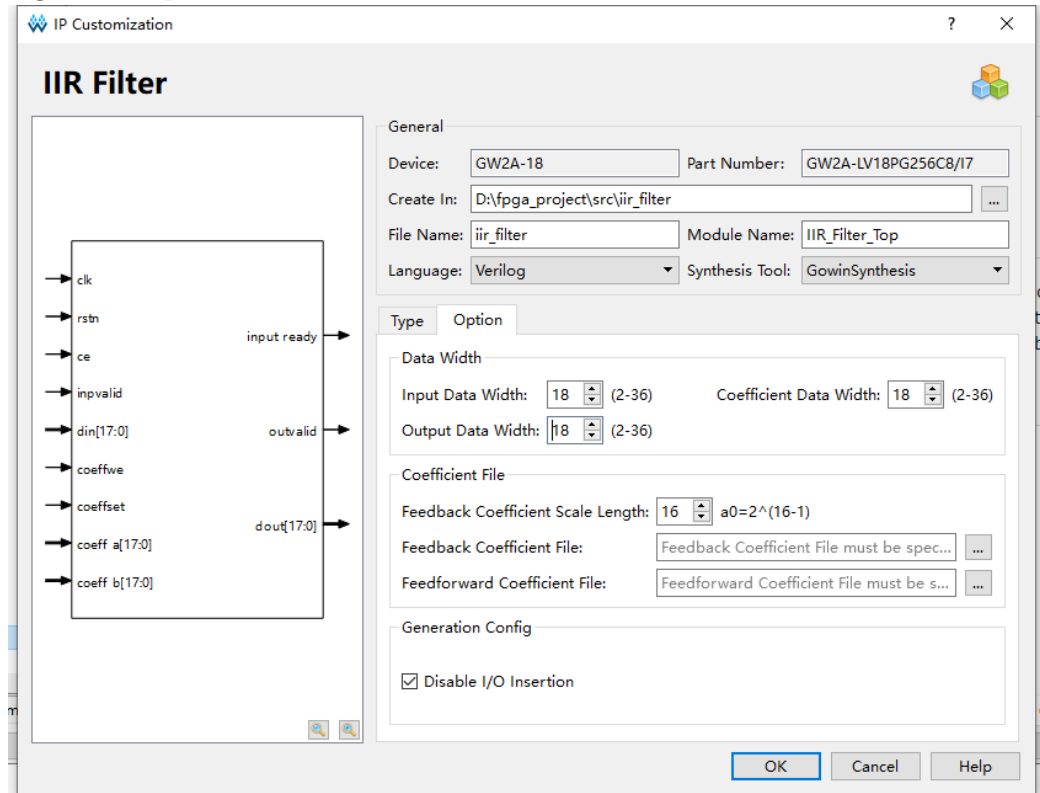


Figure 6-3 Options



- You can configure the generated file name by modifying the File Name.

- You can configure the module name by modifying the Module Name.
- You can configure IP mode by Type.
- You can configure IP other options by Options.

The configuration options are shown in Table 6-1.

Table 6-1 Configuration Options

Options	Description
Type	
Memory Type Select	Select memory type
Filter Order	2-64 configurable
Channel Number	1-4 configurable
Multipliers Number	2-48 configurable
Option	
Input Data Width	2-18 bits configurable
Coefficient Data Width	2-18 bits configurable
Output Data Width	2-36 bits configurable
Feedback Coefficient Scale Length	1-17 configurable
Coefficient File	You must specify initialization coefficient file.

7 Reference Design

Please refer to the related test cases in [RefDesign](#).

8 File Delivery

The delivery file for Gowin IIR Filter IP includes documents and reference design.

8.1 Documents

The documents folder contains the user guide in PDF version.

Table 8-1 Documents List

Name	Description
IPUG758, Gowin IIR Filter IP User Guide	Gowin IP User Guide, namely this one

8.2 Reference Design

The Ref. Design folder contains netlist file, reference design, constraint file, the top module file, the project folder, etc.

Table 8-2 Ref. Design Folder

Name	Description
exp_iir.v	Top module and excitation generation module of reference design
iir_filter.vo	Gowin IIR Filter IP netlist file
default.cst	IIR Filter physical constraints file
fpga_project.gao	Capture output data of IIR Filter
iir_filter	IIR Filter IP project folder

