Course Name:	Digital Signal & Image Processing Laboratory	Semester:	VI
Date of Performance:	20 / 03 / 2025	Batch No.:	B - 2
Faculty Name:	Dr. Om Goswami	Roll No.:	16014022050
Faculty Sign & Date:		Grade/Marks:	___ / 20

Experiment No: 5

Title: Implementation of FIR/IIR filters

Objective:
To design and implement a Finite Impulse Response (FIR) and Infinite Impulse Response filters

COs to be achieved:
CO2: Design different filters in digital domain.

Materials Required: Python/MATLAB software
Books/ Journals/ Websites referred:

1. A. Nagoor Kani "Digital Signal Processing", 2nd Edition, TMH Education.
2. Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing."
3. MATLAB Documentation: https://www.mathworks.com/help/matlab/

Theory:

A Finite Impulse Response (FIR) filter is a type of digital filter where the impulse response is of finite duration because it settles to zero in a finite number of sample intervals. The output of an FIR filter is given by the convolution of the input signal with the filter coefficients (impulse response).

Mathematical Representation:
FIR Filters: For an input sequence x[n], the output sequence y[n] of an FIR filter with coefficients h[k] is:

$$y(n) = \sum_{k=0}^{N} b_k x(n-k)$$

Where:

y(n) is the output signal,
x(n) is the input signal,
b_k are the filter coefficients (impulse response),
N is the filter order (determines how many past inputs are used).

Properties of FIR Filters

- Linear phase response (if coefficients are symmetric or anti-symmetric).
- Always stable (since there are no feedback elements).
- Can be designed to have an exact linear-phase response.

Infinite Impulse Response (IIR) filters are a class of digital filters used in signal processing. Unlike Finite Impulse Response (FIR) filters, IIR filters have feedback, which allows them to have an infinite duration response to an impulse input.

Characteristics of IIR Filters:

1. **Recursive Structure:** IIR filters use both past and present input values as well as past output values to compute the current output.
2. **Infinite Impulse Response:** Since the filter has feedback, the impulse response theoretically extends indefinitely.
3. **Efficient Implementation:** Compared to FIR filters, IIR filters typically require fewer coefficients to achieve a given frequency response, making them computationally efficient.
4. **Potential for Stability Issues:** Due to feedback, an improperly designed IIR filter can become unstable if the poles of its transfer function lie outside the unit circle in the Z-domain.

Mathematical Representation:

An IIR filter is described by the difference equation:

$$H(z) = \frac{\sum_{k=0}^{N} b_k z^{-k}}{1 + \sum_{k=1}^{M} a_k z^{-k}}$$

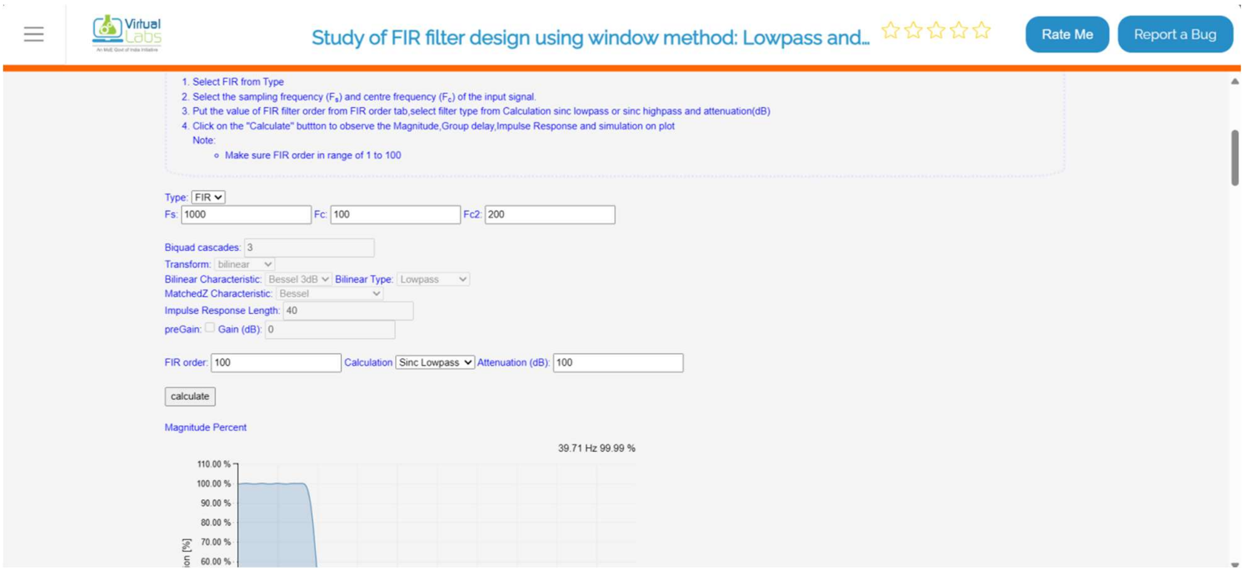
where:

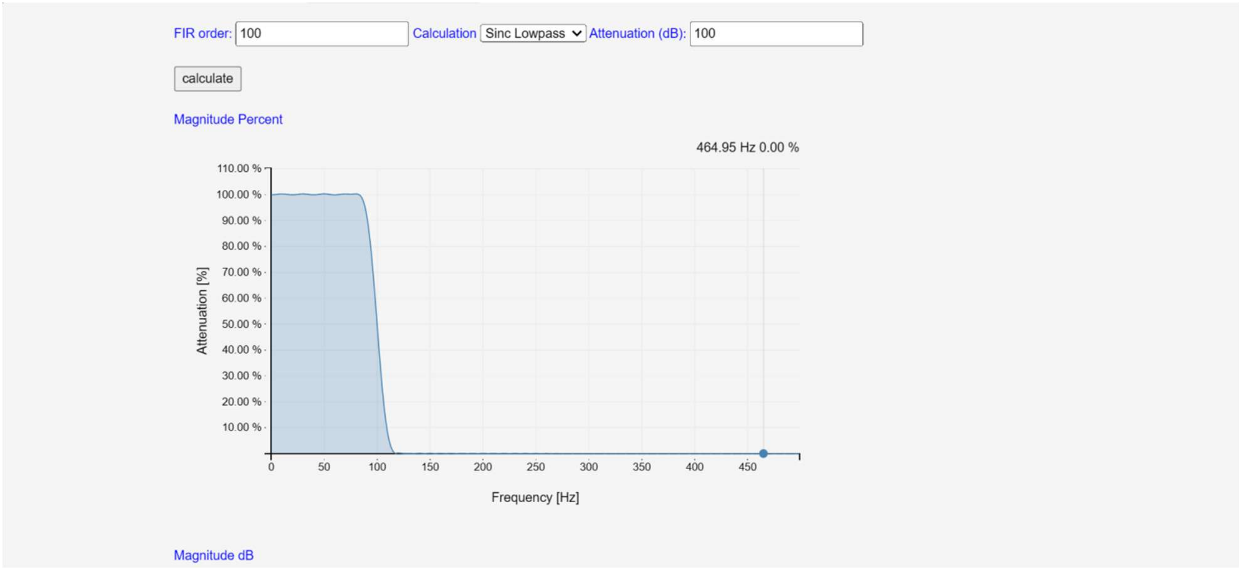
y(n) is the output signal,
x(n) is the input signal,
a_k and bk are filter coefficients,
M and N are the number of feedback and feedforward coefficients, respectively.

Stepwise-Procedure:

FIR Filters: https://dsp-iitkgp.vlabs.ac.in/exp/fir-lowpass-highpass/

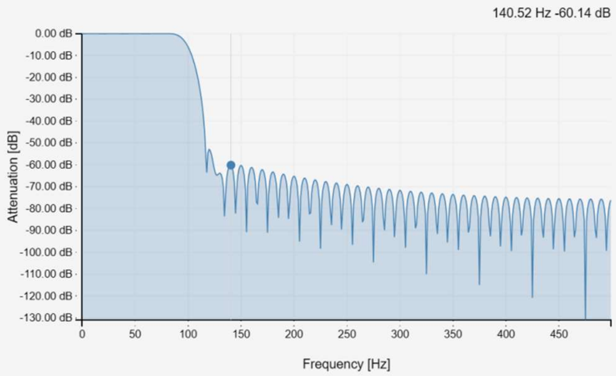
Screenshots:



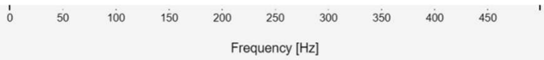


Frequency [Hz]

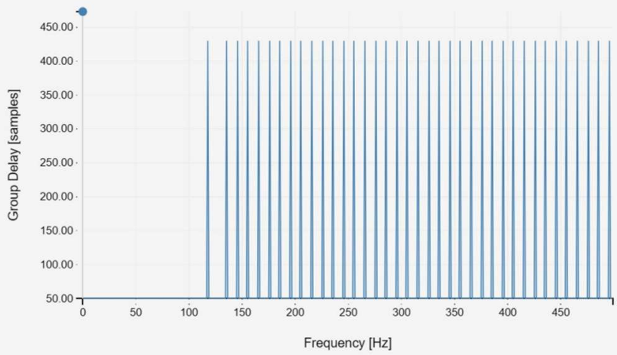
Magnitude dB



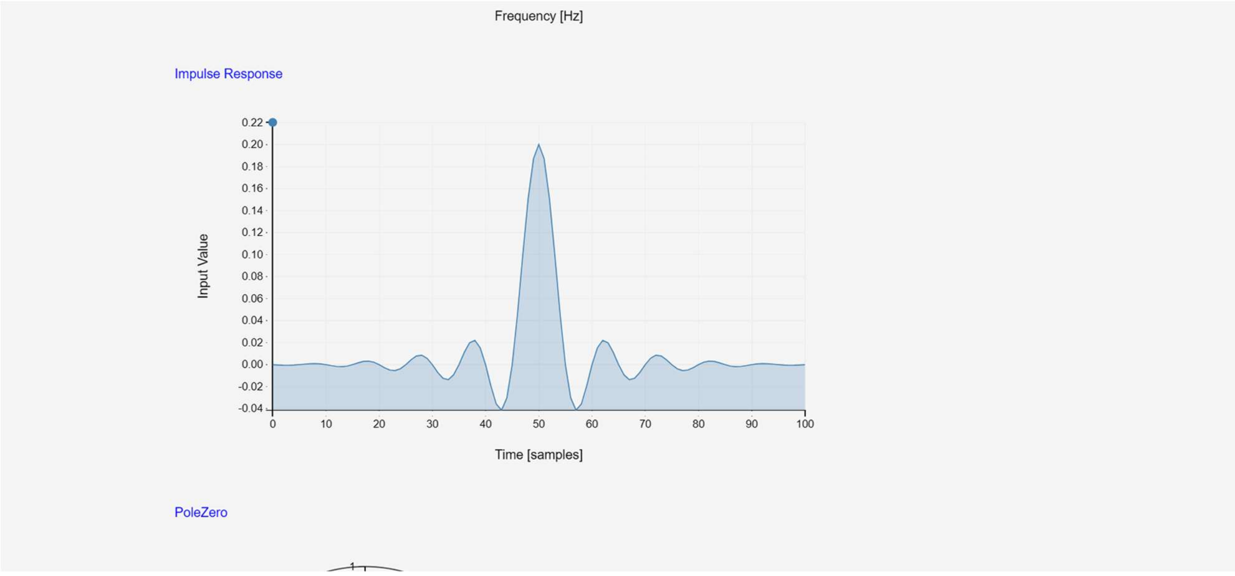
Group Delay

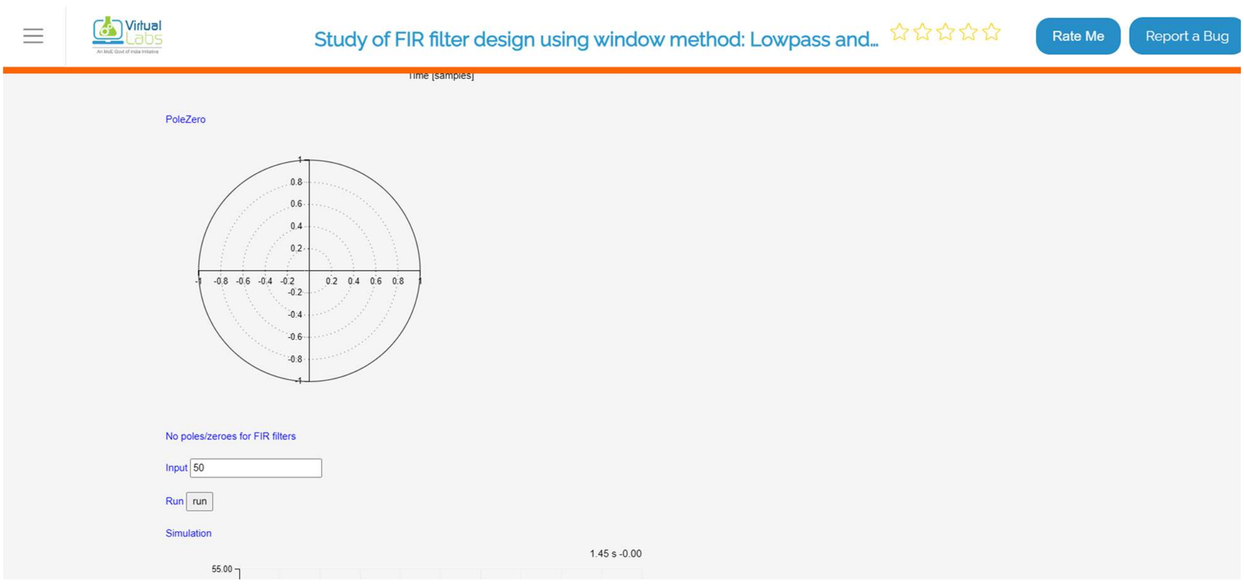


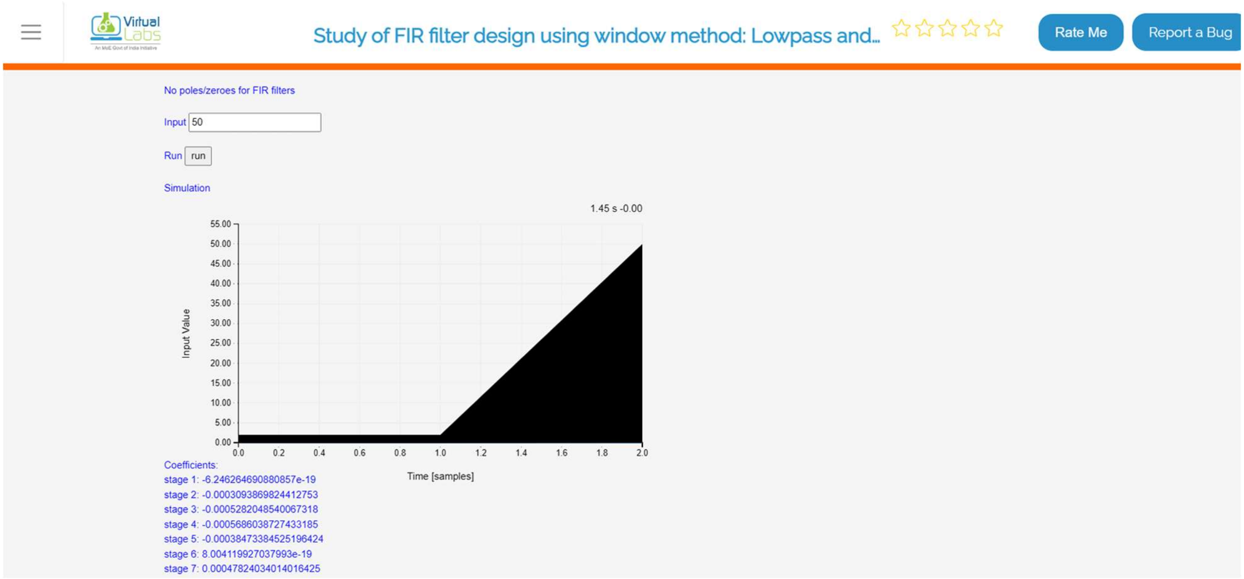
Group Delay



Impulse Response

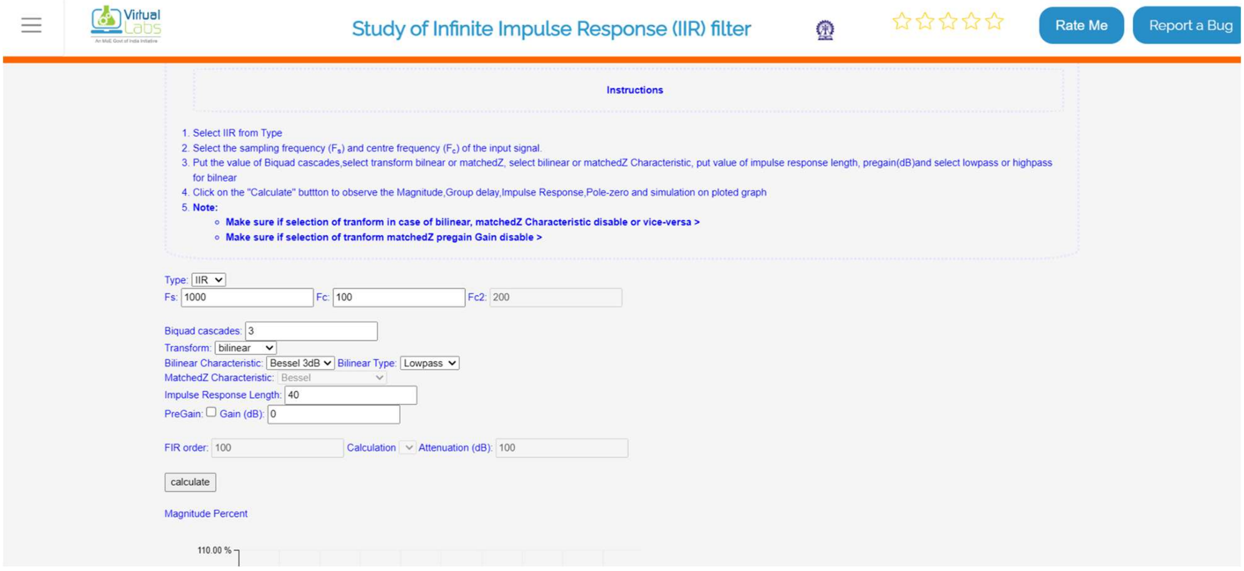

Frequency [Hz]
Impulse Response
Input Value
Time [samples]
PoleZero

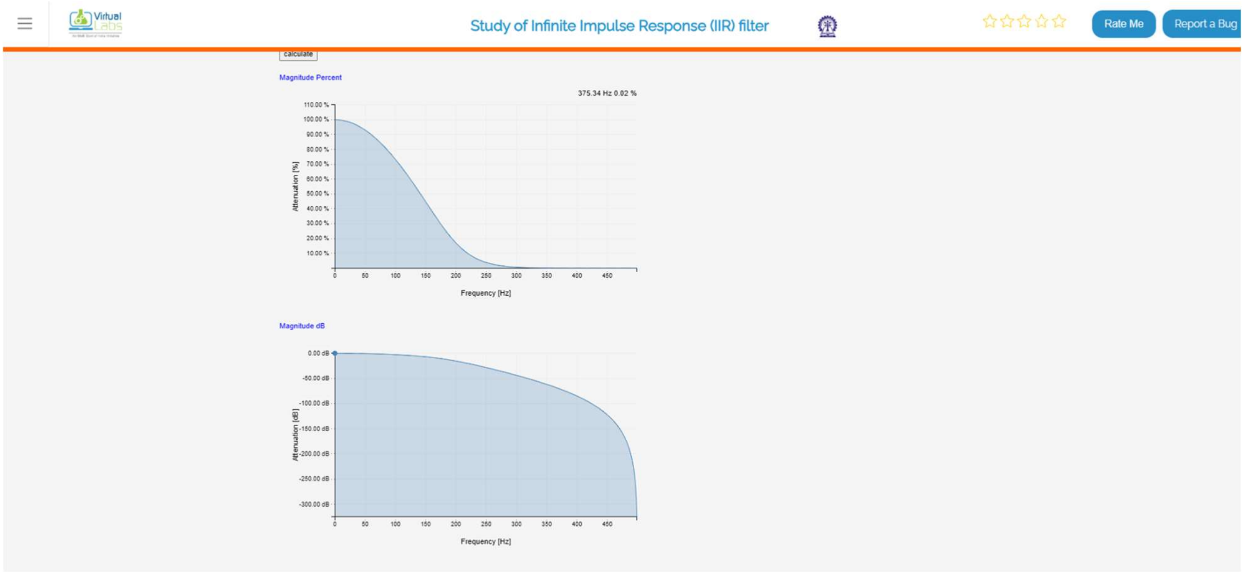

Virtual Labs
Study of FIR filter design using window method: Lowpass and...
Rate Me
Report a Bug
PoleZero
No poles/zeroes for FIR filters
Input 50
Run run
Simulation
1.45 s -0.00
55.00

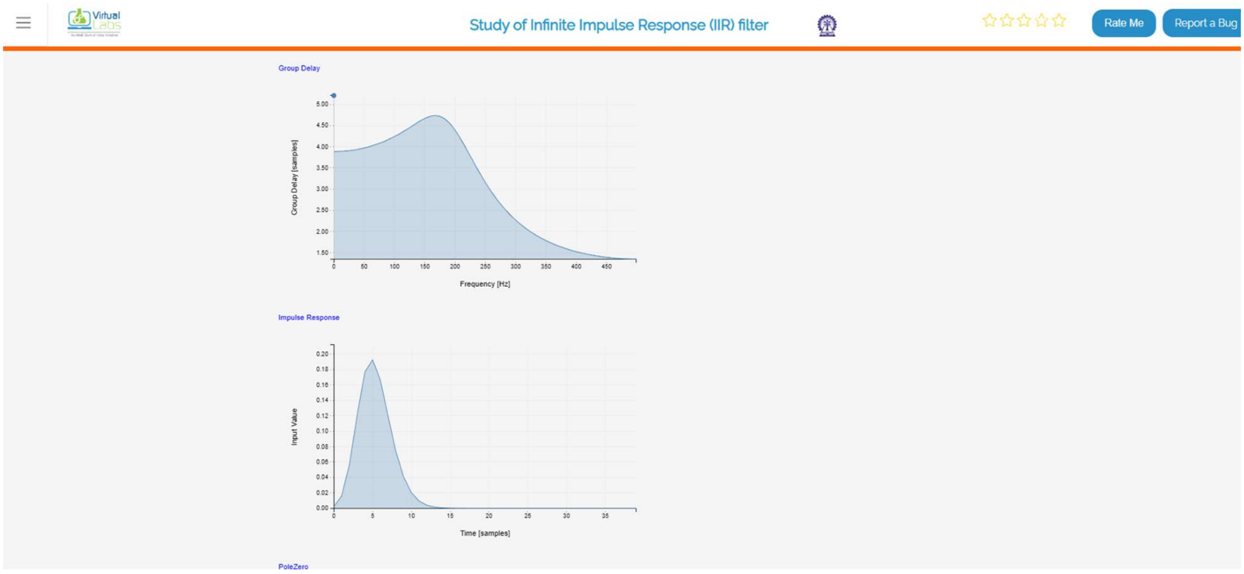


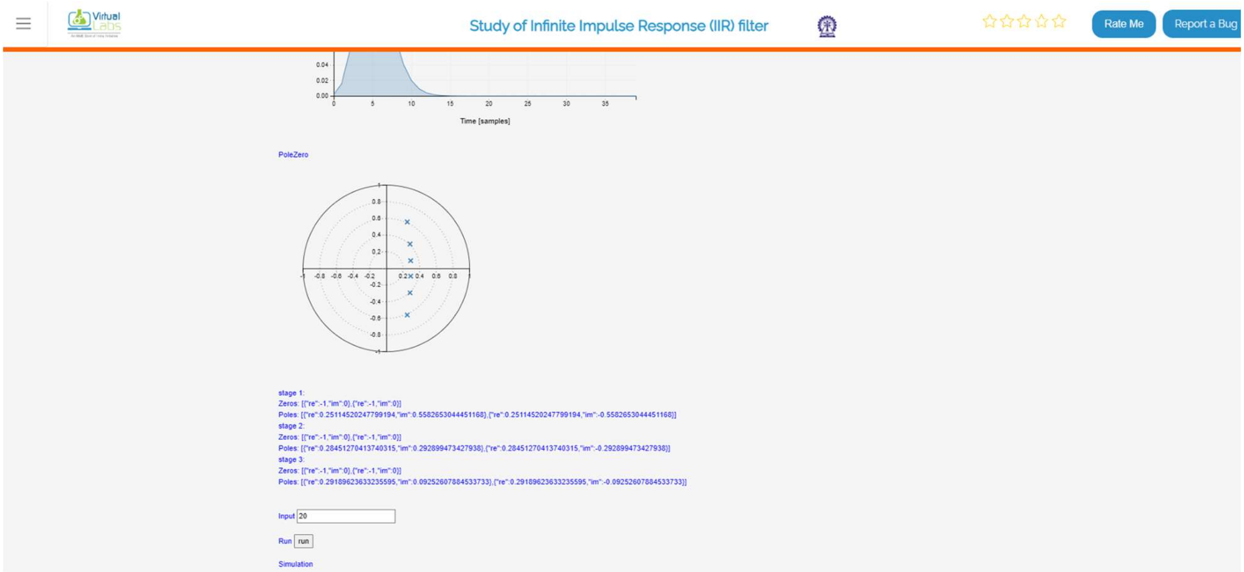
IIR Filters: https://dsp-iitkgp.vlabs.ac.in/exp/infinite-impulse-response/

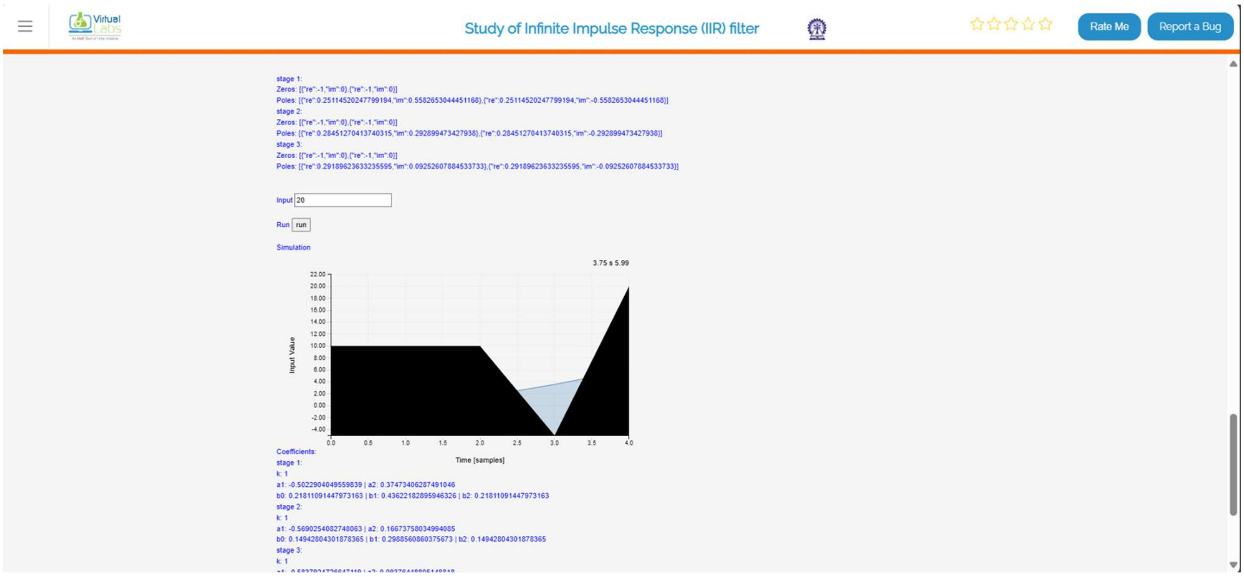
Screenshots:




Study of Infinite Impulse Response (IIR) filter
Rate Me
Report a Bug
calculate
Magnitude Percent
375.34 Hz 0.02 %
Attenuation [%]
Frequency [Hz]
Magnitude dB
Attenuation [dB]
Frequency [Hz]


Study of Infinite Impulse Response (IIR) filter
Rate Me
Report a Bug
Group Delay
Group Delay [samples]
Frequency [Hz]
Impulse Response
Input Value
Time [samples]
PoleZero


Study of Infinite Impulse Response (IIR) filter
Rate Me
Report a Bug
Time [samples]
PoleZero
stage 1:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.25114520247799194,"im":0.5582653044451168},{"re":0.25114520247799194,"im":-0.5582653044451168}]
stage 2:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.28451270413740315,"im":0.292899473427938},{"re":0.28451270413740315,"im":-0.292899473427938}]
stage 3:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.29189623633235595,"im":0.09252607884533733},{"re":0.29189623633235595,"im":-0.09252607884533733}]
Input 20
Run run
Simulation


Study of Infinite Impulse Response (IIR) filter
Rate Me
Report a Bug
stage 1:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.25114520247799194,"im":0.5582653044451168},{"re":0.25114520247799194,"im":-0.5582653044451168}]
stage 2:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.28451270413740315,"im":0.292899473427938},{"re":0.28451270413740315,"im":-0.292899473427938}]
stage 3:
Zeros: [{"re":-1,"im":0},{"re":-1,"im":0}]
Poles: [{"re":0.29189623633235595,"im":0.09252607884533733},{"re":0.29189623633235595,"im":-0.09252607884533733}]
Input 20
Run run
Simulation
Input Value
Time [samples]
Coefficients:
stage 1:
k: 1
a1: -0.5022904049559839 | a2: 0.37473406287491046
b0: 0.21811091447973163 | b1: 0.43622182895946326 | b2: 0.21811091447973163
stage 2:
k: 1
a1: -0.5690254082748063 | a2: 0.16673758034994085
b0: 0.14942804301878365 | b1: 0.2988560860375673 | b2: 0.14942804301878365
stage 3:
k: 1

Conclusion:
In this experiment, we designed and implemented FIR and IIR filters using the virtual lab. It helped us understand the filtering process and the difference between FIR and IIR filters in signal processing.

Post Lab Question:

1. **What is the role of the window function in FIR filter design?**
   The window function is used in FIR filter design to control the frequency response of the filter. When designing an FIR filter using the Fourier series method, truncation of the impulse response can introduce unwanted ripples in both the passband and stopband. The window function smooths the transition and reduces these ripples by tapering the impulse response at the edges, thereby improving the filter's performance. Different window functions (e.g., Hamming, Hanning, Blackman) offer trade-offs between main lobe width and side lobe attenuation.

2. **How does the filter order affect the filter's performance?**
   The filter order determines the number of coefficients in the FIR filter and directly affects its performance:
   - Higher Order: Improves frequency selectivity, reduces transition bandwidth, and achieves better attenuation in the stopband. However, it increases computational complexity.
   - Lower Order: Reduces computational cost but results in a wider transition band and poorer stopband attenuation.

   In general, a higher-order filter provides better performance but at the expense of increased processing time and hardware complexity.

3. **Why are FIR filters always stable?**
   FIR filters are always stable because they do not use feedback in their implementation. Their impulse response is finite, meaning they only rely on present and past input values without recursive elements. As a result, there is no possibility of an unstable oscillatory response, making FIR filters inherently stable under all conditions.

4. **What is the difference between FIR and IIR filters?**
   The main difference between FIR (Finite Impulse Response) and IIR (Infinite Impulse Response) filters lies in their impulse response and structure.
   - FIR filters have a finite duration impulse response because they depend only on the current and past input values. They are always stable and have linear phase characteristics, making them ideal for applications where phase accuracy is important.
   - IIR filters have an impulse response that lasts indefinitely because they use both past input and past output values (feedback). They can achieve a desired filter response with a lower order than FIR filters but may become unstable if not designed

carefully. IIR filters typically have a non-linear phase response.

Signature of faculty in-charge with Date: