

Design of Digital Lock-in Amplifier on System Generator and LabVIEW

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Abstract—Today’s digital world demands a technological solution for the detection of weak signals. The phase locked Amplifying technology is an extensively used solution for the detection of weak signal as it meets the requirement of accuracy and fast speed. The ‘LabVIEW’ helps in giving more information about the signal at any moment. This Project is divided into 2 parts: the first one is the execution of a digital Lock-in Amplifier (DLIA) found on system Generator and the second is the use of LabVIEW. The System generator helped in making the design easy and efficient. The Right angled vector type DLIA has been introduced. Simulation was done to check the feasibility of the design. The “LabVIEW” work is divided into 2 parts in which the first one is done by simulating the input signal and reference signal and the second one by capturing signals externally to make it more realistic.

Keywords—low signal, amplifier, System generator, LabVIEW, Phase sensitive Detectors, simulation.

I. INTRODUCTION

In today’s world of digitalization, the transmission of signals for various communication is on the peak level and it is well known to us that the presence of sound or noise can be found everywhere around us. Technically, noise can be defined as the irregular fluctuations that goes along an electrically transmitted signal. The recovery of the most appropriate signal under noisy environment is a significant problem that the latest research focuses on. The traditional amplifier designs do not dispense acceptable results in a highly deteriorated noise scenarios as they layout very low signal power levels.

A Lock-in Amplifier (LIA) is a tool efficient in measuring low signals with a investigated carrier wave from an extremely boisterous background [1] and is used for its high speed and high Accuracy. The phase sensitive detector is one of the important feature of the LIA. It can also be operated to get the phase as well as amplitude. The next part of this research is based on the LabVIEW which can be done afterwards the completion of the previous part. However, both the parts have been explained simultaneously to get a better ease in understanding the difference.

The LabVIEW is part is divided into two program in which the concept of two phase lock-in amplifier is used. The first one works on simulation where we have to select some variable of the input signal and the signal of reference and the second one works on seizing both signal

from an outer source. However, the second program has created many troubles during the advancement of the project. Also there is a portion where an example is given based on the simulated programme, similarly thorough which we can change the input phase for a better understanding of the significance of LPF and the foremost constant time .

II. CONSTRUCTION AND CONCEPT

A. LOCK-IN AMPLIFICATION

The signal channel, reference channel, phase sensitive detector (PSD) and the low-pass filter (LPF) are the basic composition of a LIA. A basic LIA block diagram is shown in fig.-1. In this LIA, a input signal is send through an AC amplifier in the signal channel for the PSD. The reference signal is amplified for the PSD to an appropriate level. The reference channel helps in shifting the phase of the reference signal in order to get the appropriate result for the input signal with a different phase. The next part is the PSD, also termed as mixer [2] where the input signal $X(t)$ and the reference signal $r(t)$ are multiplied. The input signal gets shifted through this multiplication. At last, the output of the mixture is passed through a LPF, removing any unwanted signal .

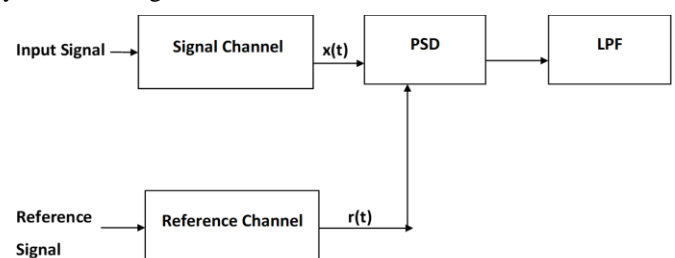


Fig.1:Basic LIA Block Diagram

B. Right angled Vector Lock-in Amplification

The right angled vector LIA constitutes two phase sensitive detector with the like input signal and two signals of reference with a difference in phase of 90 degree. The references of the two channels are sinusoidal signal and cosine signal as shown in Fig.2. They are commonly known as in-phase component (I) and quadrature component (Q) [3] respectively.

The signal to be measured is given as :

$$S(t) = A \sin(\omega t + \alpha) + n(t)$$

where A is the amplitude, α is initial phase and $n(t)$ is the signal of noise.

The two reference signals are:

$$R_x(t) = B \cos(\omega t + \beta)$$

$$R_y(t) = B \sin(\omega t + \beta)$$

The output of two separate channels are :

$$X(t) = S(t) \times R_x(t) =$$

$$AB/2 \sin(\alpha - \beta) + AB/2 \sin(2\omega t + \alpha + \beta) + n(t)B \cos(\omega t + \beta)$$

$$Y(t) = S(t) \times R_y(t) =$$

$$AB/2 \sin(\alpha - \beta) - AB/2 \cos(2\omega t + \alpha + \beta) + n(t)B \sin(\omega t + \beta)$$

The outputs of the LPF are:

$$I = AB/2 \cos(\alpha - \beta)$$

$$Q = AB/2 \sin(\alpha - \beta)$$

The amplitude and phase of the signal measured is given as:

$$\text{Amplitude} = \frac{2}{B} \sqrt{I^2 + Q^2}$$

$$\text{Phase} = \beta + \arctan\left(\frac{Q}{I}\right)$$

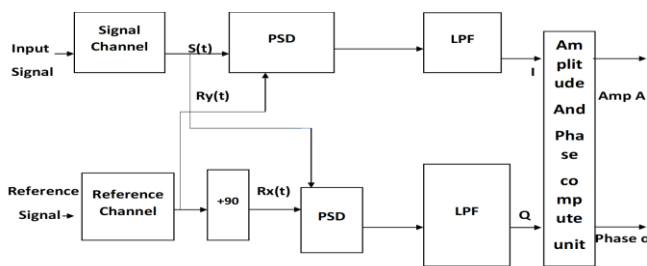


Fig :2: Right angled vector LIA Block Diagram

C.Two-Phase lock in Amplifier based on LabVIEW

The Lock-in amplifier can be distinguished in to two parts depending on how the reference signal is used. The single phase LIA consists of single PSD [4], whereas the two phase LIA consists of two PSDs.

Hence, the input signal is of the form :

$$V_i(t) = V_i \sin(\omega_i t + \psi_i)$$

Where ω_i is the angular frequency, ψ_i is the initial phase angle of the input signal and v_i is the input amplitude .

The amplifier needs a reference signal which must have the same frequency as the input signal. Another reference signal is also needed which is obtained by shifting the phase of the refence signal. So the two signal are of the following form :

$$V_{R1}(t) = V_{R1} \sin(\omega_R + \psi_R)$$

$$V_{R2}(t) = V_{R2} \sin(\omega_R - \psi_R + \pi/2)$$

Now the amplifier does the multiplication using the PSD, giving the output of the PSD.

The first signal reference is :

$$V_{out1}(t) = V_i(t) \cdot V_{R1}(t) = V_i \sin(\omega_i(t) + \psi_i) \cdot V_{R1} \sin(\omega_R + \psi_R)$$

The output signal from PSD using the basic trigonometrical function is of the form :

$$V_{out1}(t) = V_i V_{R1} [\cos([\omega_i - \omega_R]t + \psi_i - \psi_R) - \cos([\omega_i + \omega_R]t + \psi_i + \psi_R)]$$

The output is an AC signal. Assuming $\omega = \omega_i = \omega_R$ as stated earlier , the output signal has a DC component. By using a Low-pass filter the out signal will contain only a DC component as the AC component will be filtered.

The output signal is obtained as :

$$V_{out1} = \frac{1}{2} V_i V_{R1} \cos \psi \approx V_i \cos \psi = X$$

Where $\psi = \psi_i - \psi_R$

The second output signal obtained by repeating the same step with the shifted reference signal is :

$$V_{out2} = \frac{1}{2} V_i V_{R2} \sin \psi \approx V_i \sin \psi = Y$$

The two outputs have been obtained and the amplitude of the signal can be calculated using these outputs.

The phase shift is given by,

$$V_i = \sqrt{X^2 + Y^2}$$

$$W = \tan^{-1}\left(\frac{Y}{X}\right)$$

Therefore the result can be summarized in the block diagram as :

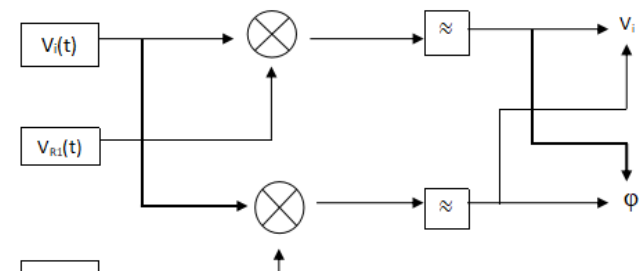


Fig. 3: Schematic diagram of a two-phase lock-in amplifier

III. DESIGN OF DIGITAL LOCK-IN AMPLIFIER

(I) WORKING ON SYSTEM GENERATOR

The design is done using the System Generator. It is a modeling tool of Xilinx .Inc [5].

A.Initiation to System Generator

It is a designing tool of Xilinx for the DSP advancement. Xilinx Blockset is embedded into Simulink library to complete the simulation of hardware ,implementation and confirmation .

B.Reference signal Generation

A pair of right angled Signals are the reference signals in this case. Direct Digital Synthesis(DDS) technique is adopted by the signal generator for creating waveforms randomly [6].The implemented DDS model (figure 4) comprises of the DDS complier 6.0 listed in Xilinx Blockset of DSP library .

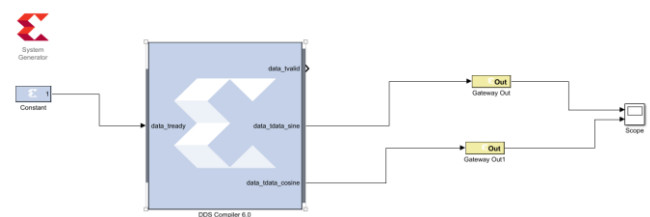
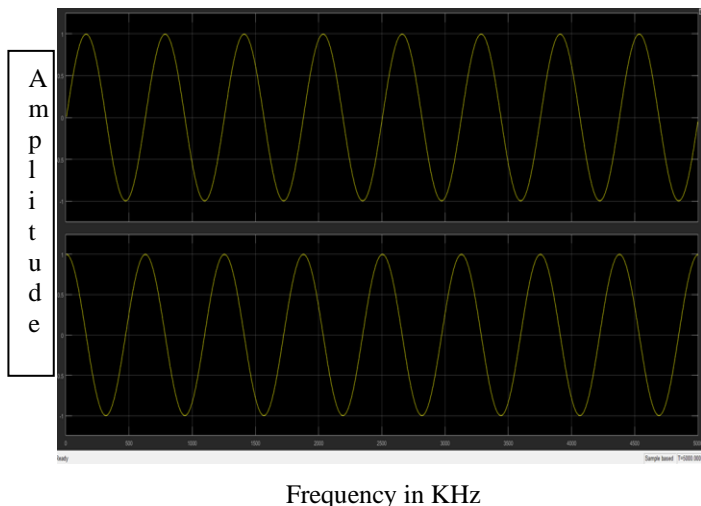


Figure 4 : DDS model

The simulated right angled signals are:



Frequency in KHz

Figure 5. Right angled signals

C. Mixing of signals

The multiplier lies at the heart of LIA which is composed of the Mult block Xilinx Block set. The result of the multiplied model is shown (figure 6) .

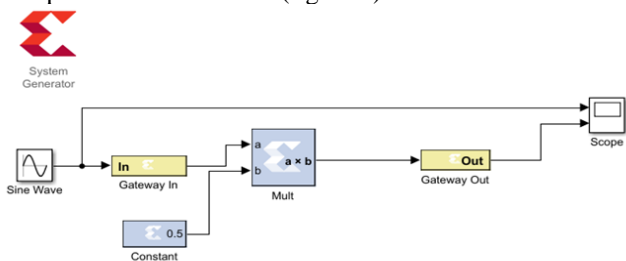
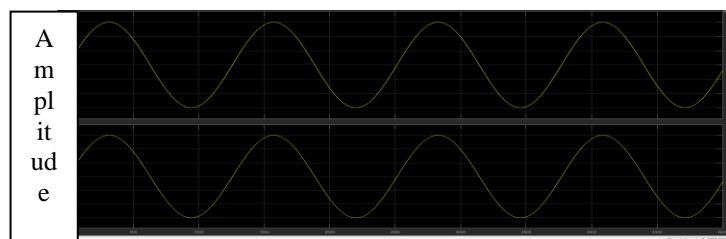


Figure 6: Multiplier Model



Frequency in KHz

Figure 7: Simulation of multiplier model

D. Low pass filter

The implementation of the low pass filter stage was done by using a low pass FIR filter . A 16 order FIR filter is used.

The FIR module and FDA tools is used to design the FIR filter. FDA tool module is used to make the types , the order and the co-efficient of the FIR filter [7] .

The Low-pass filter has been designed with a sampling frequency of 48KHz and cut-off frequency of 5KHz The figure (8) shows the design interface of the FDA tools.

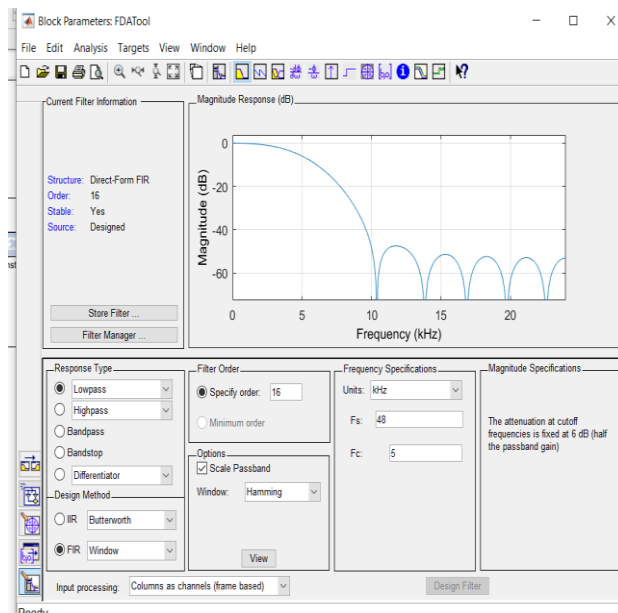


Figure 8. Design interface of the FDA Tool

In the figure (9),in the low pass filter model the two input signal are of the frequency 5 KHz and 10 KHz respectively and a same amplitude of 10.

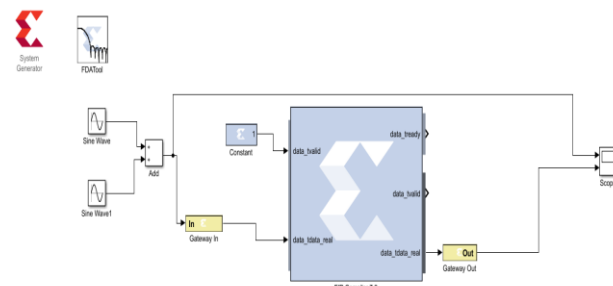
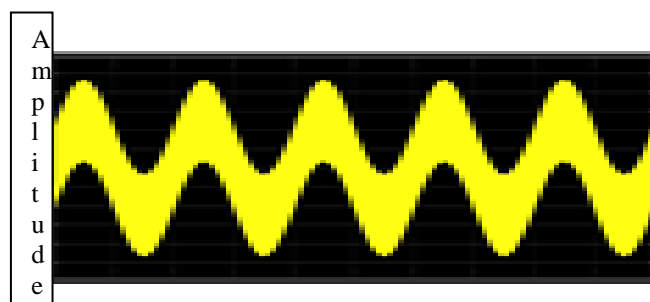
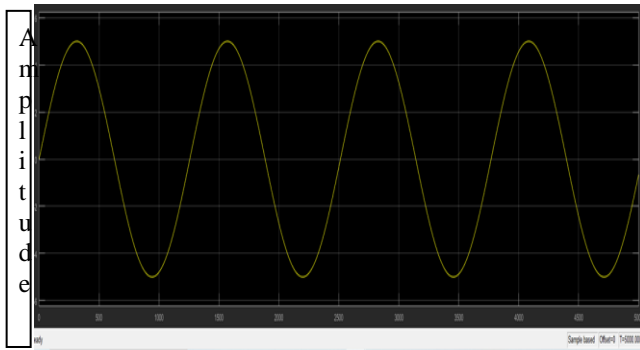


Figure 9: Low-pass FIR Filter Model

In figure (10), it can be seen that the two signals are the placement of the two input signal and output signal. From the output it is clear that the signal of 10KHz is efficiently removed.



Frequency in KHz



Frequency in KHz

Figure 10. low-pass FIR filter result

E. Digital Lock-in Amplifier simulation.

The simulation model of Right angled vector DLIA is shown in figure(11).

The frequency of desired signal and reference signal are set to 100Hz in order to test the feasibility of the system. The amplitude of the desired and reference signals are also set to 1. The figure(12) shows the signal to be measured and the figure(13) shows the signal to be calculated polluted by noise signal.

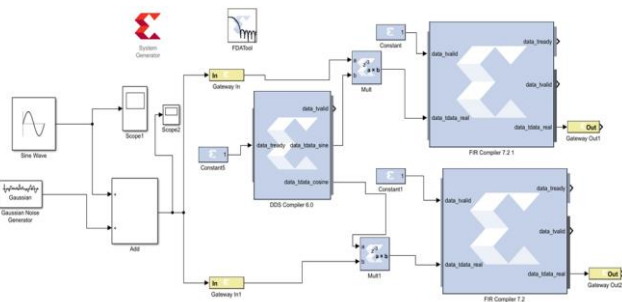
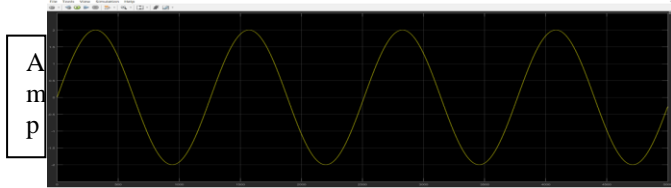
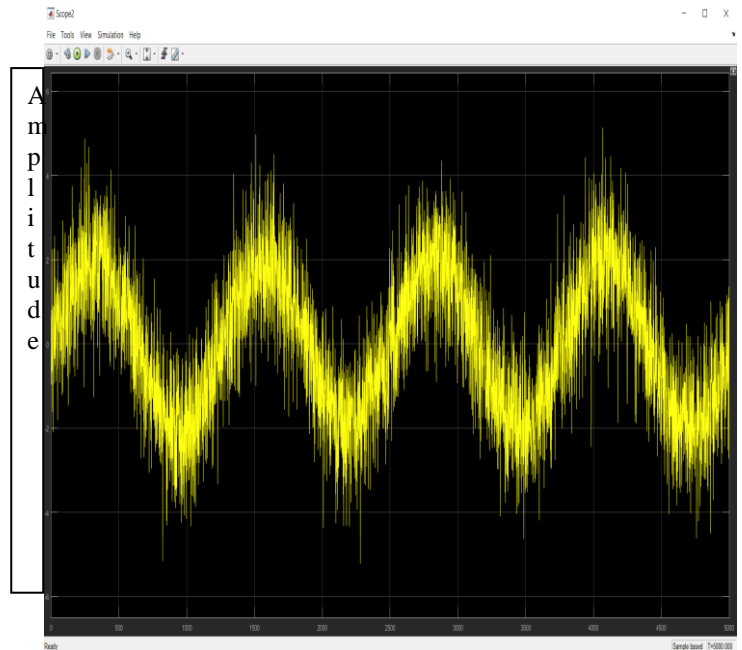


Figure 11. Simulation model of the right angled vector digital lock-in amplifier



Frequency in KHz

Figure 12: Signal to be calculated



Frequency in KHz

Figure 13: Signal to be calculated polluted by Noise signal

(II) WORKING OF LABVIEW PROGRAM

Taking in consideration of the previous section, a digital two phase Lock-in amplifier has been made. The program has been divided in to two parts, the first one is simulated [8] and the second one is more real. LabVIEW has two windows i.e. the front panel window which is a user oriented window where the program runs and shows its result and the second one is the block diagram where the user can add codes using graphical representation in order to control the front panel object.

A. Simulated Program

We have to make a program that produces the signal by itself. In the front panel, the necessary parameters of input section are needed to be set at first, such as the frequency, the form, the amplitude, the phase and also the noise. The time constant variable of the LPF needs to be modified after the selectin of the characteristics of both signal. The figure of the simulated program has been shown in the fig. below.

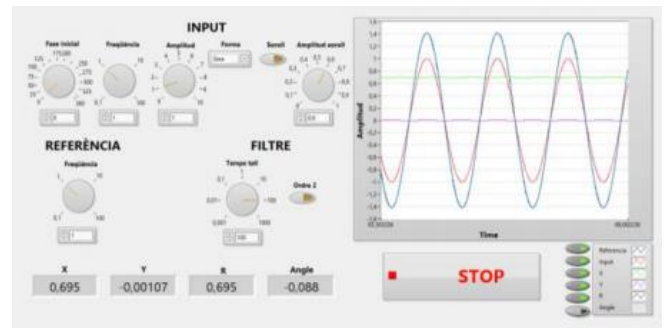


Figure 14: Simulated program from the front panel

Three express functions are used to simulate each signal. After that the multiplication function is used for the signal to get multiplied and then passed through a LPF (Butter Worth Filter). All the signals are represented graphically.

At last, stop button is used to stop the while loop and consequently the programs.

B. Programme with Signal from outer Sources

This is slightly different from the first one as both signals are caught by outer sources as generated or circuits. All the parameters have not been chosen before in this case. The time constant of the Low-Pass filter and which graphic can be used to represent the result can be chosen before. The front panel is tried to make like the previous one but the determined parameters have been deleted. For opening the signals, some extra blocks need to be added so that we can update them during the processing. However, in this program we have got some difficulties and various situation has interrupted the progress. The synchronization of both signals can not be done properly. A PLL will be required to synchronize the reference signal with the input one.

IV. EXPERIMENTAL RESULT

A triangle signal is used with an initial phase of 90 degree. It can also be done with different forms such as square and sine.

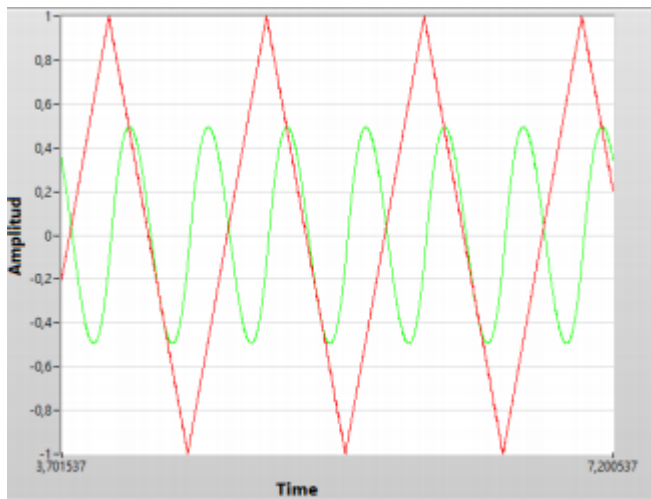


Figure 15: The front panel which shows V(t) for a phase of 90 degree. Red is input signal and green is output signal

Now in the low pass filter, the time constant will be varied to understand the working of the filter. The front panel which shows V(t) for a constant time of 1 has been shown in figure 16.

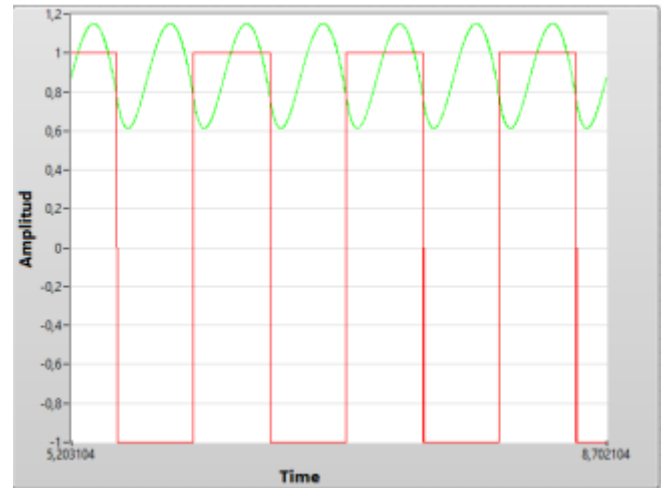


Figure 16: The front panel which shows V(t) for a constant time of 1.

Now we can check whether the lock-in amplifier is working well or not by comparing the input noise signal with the input signal which has no noise.

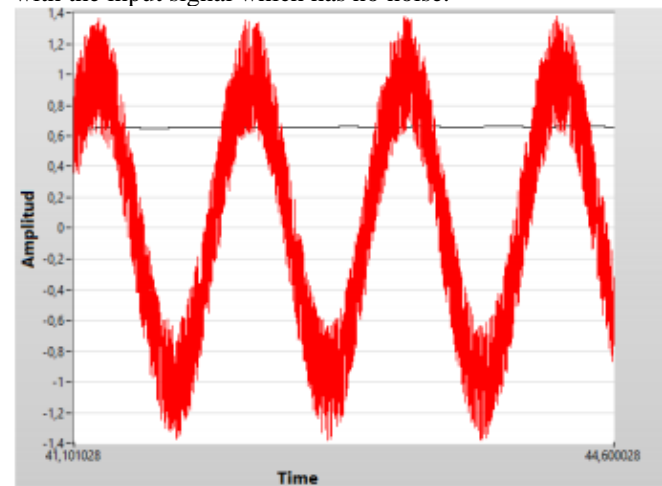


Figure 17: The front panel which shows input signal with noise, 0.36 standard deviation, and value of R for 0 degree phase shift

Now to study the dependence of the output signal two tests can be done. So the results are:

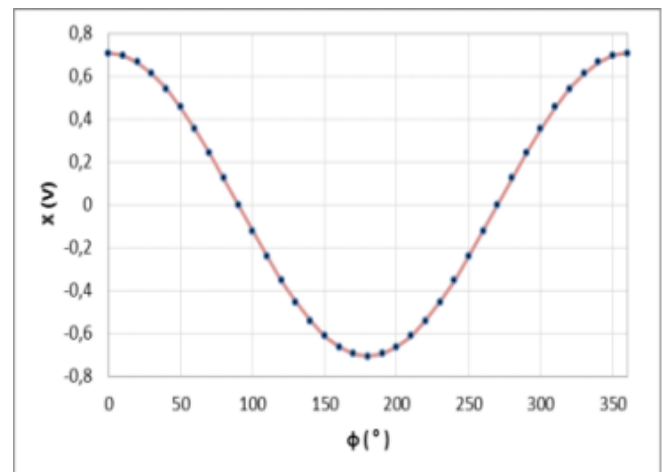


Figure 18: Output voltage versus phase shift

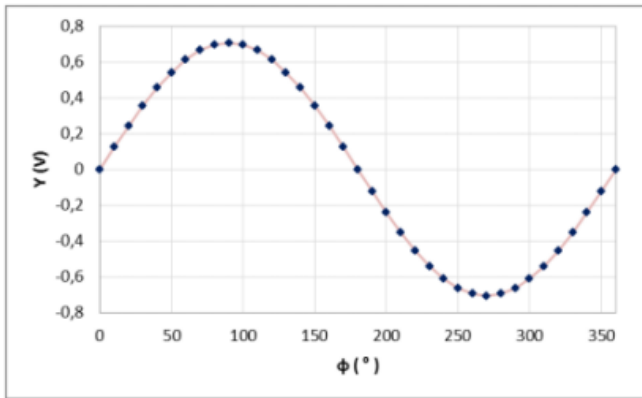


Figure 19: Output voltage versus phase shift

V. CONCLUSION

The Lock-In amplifier can be used for the recovery of extremely weak signal present in the background noise. The execution of a digital Lock-In amplifier with the system generator can be done successfully. The system generated tool improved the design of the Lock-in amplifier effectively to a great extent. The result shows that the design can suppress noise very effectively with detection accuracy. The implemented design is feasible. The implementation of two phase Lock-in amplifier based on LabVIEW has been done successfully and the result give more information about the signals. It is very helpful to evaluate or check the signals at every moment to see how it is working. It can be used as a very helpful teaching tool. In future the response time of the program, PLL and the other difficulties faced can be improved.

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