

Review on Control System Design and Simulation basics using LabVIEW

Shirish Adam¹

¹Assistant Professor, Instrumentation Engineering Department, Government College of Engineering Jalgaon, India

Abstract: “The Transfer Function fully describes a control system. The Order, Type and Frequency response can all be taken from this specific function. Nyquist and Bode plots can be drawn from the open loop Transfer Function. These plots show the stability of the system when the loop is closed. Using the denominator of the transfer function, called the characteristic equation, roots of the system can be derived. For all these reasons and more, the Transfer function is an important aspect of classical control systems.”

To understand the basic concepts a simulation platform with graphical display is very useful. In Control System and Simulation course various plots like state response, frequency response, Nyquist plot, bode plot are useful for analysis. The first step is to create a transfer function in LabVIEW. LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. The graphical language is named “G”. Originally released for the Apple Macintosh in 1986, LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various flavours of Linux, and Mac OS X.[1]

Keywords: Control System, Simulation, LabVIEW,

1. INTRODUCTION

Control design is a process that involves developing mathematical models that describe a physical system, analyzing the models to learn about their dynamic characteristics, and creating a controller to achieve certain dynamic characteristics. [1]

LabVIEW has several additional modules and Toolkits for Control and Simulation purposes, e.g., “LabVIEW Control Design and Simulation Module”, “LabVIEW PID and Fuzzy Logic Toolkit”, “LabVIEW System Identification Toolkit” and “LabVIEW Simulation Interface Toolkit”.

Simulation is a process that involves using software to recreate and analyze the behavior of dynamic systems. Simulation provides insight into the behavior of dynamic system.[1]

1.1 Transfer Function

“A Transfer Function is the ratio of the output of a system to the input of a system, in the Laplace domain considering its initial conditions and equilibrium point to be zero. If input function is X(s) and output function

is Y(s) then the transfer function $H(s) = \frac{Y(s)}{X(s)}$.” Transfer function block in LabVIEW implements a system model in transfer function form. User defines the system model by specifying the Numerator and Denominator of the transfer function equation. In LabVIEW all VIs related to this are placed in Control and Simulation toolkit. Using Model Construction toolbox in Control Design toolkit, CD Construct Transfer Function Model creates a transfer function representation of a system using the Sampling Time (s), Numerator, Denominator, and Delay. This VI also produces a transfer function model which specifies the data in symbolic form. CD draw transfer function displays the transfer function equation of the model. Fig.1 shows the transfer function block diagram and front panel using different tools in LabVIEW to generate the equation.

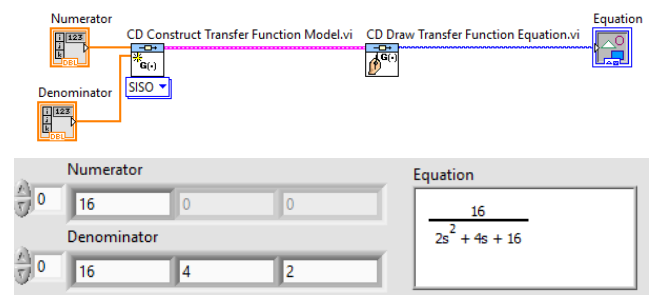


Fig -1: Transfer Function block diagram and Front Panel in LabView [4]

1.2 Impulse response

For comparison, the time-domain equivalent to the input/output relationship will be considered. In the time domain, generally input to a system is denoted as x(t), and the output of the system as y(t). The relationship between the input and the output is denoted as the impulse response, $h(t) = \frac{Y(t)}{X(t)}$. CD

Impulse response VI calculates the output of the system when an impulse excites it. Fig.2 shows the block diagram to generate impulse response graph using a CD impulse response VI.

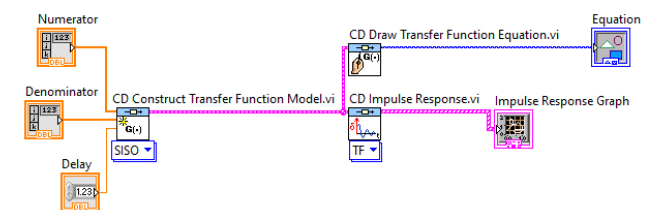


Fig -2: Impulse Response VI block diagram

After running the above block diagram with delay set to 1 second and numerator=16, denominator=16,4,2 impulse response is generated as shown in fig. 3. Impulse response starts at 1 second. Students can change the values and view the responses graphically on the Graph as shown in fig. 4.

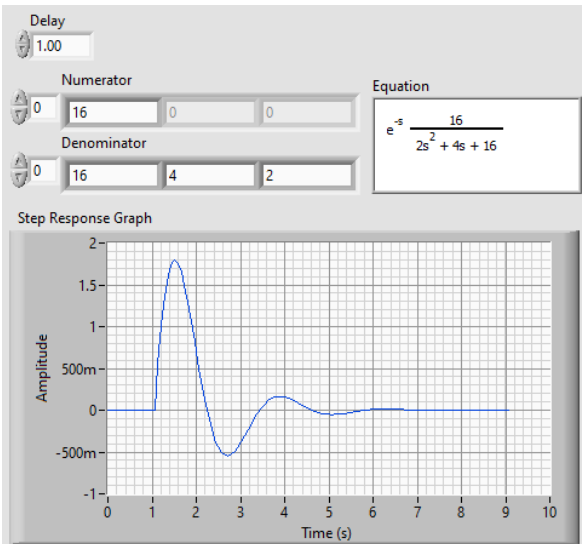


Fig -3: Impulse Response of transfer function with delay 1 s[4]

Impulse response is meant to evaluate the response of the system for all frequency elements with the same magnitude. The only signal which contains all single-frequency elements with unit magnitude is Impulse. Laplace transform of impulse is 1 which means all frequencies have same contribution. So, by having the impulse response of a system, actually the overall behavior of that system is available, which is very important. In control theory the impulse response is the response of a system to a Dirac delta input. This proves useful in the analysis of dynamic systems; the Laplace transform of the delta function is 1, so the impulse response is equivalent to the inverse Laplace transform of the system's transfer function.

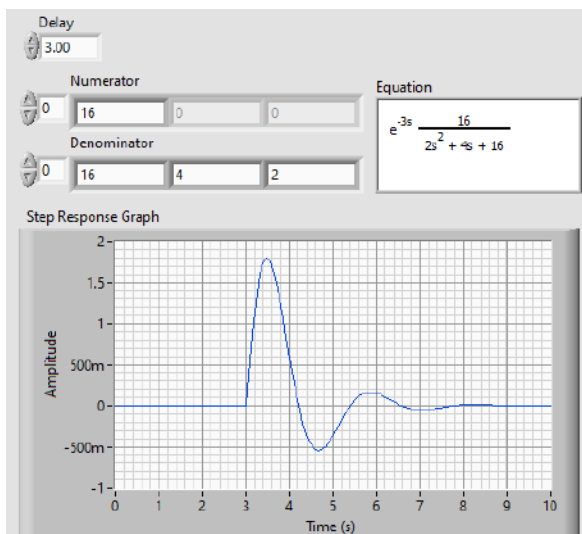


Fig -4: Impulse Response of transfer function with delay 3 s [4]

1.3 Step response

Similar to the impulse response, the step response of a system is the output of the system when a unit step function is used as the input. The step response is a common analysis tool used to determine certain metrics about a system. Typically, when a new system is designed, the step response of the system is the first characteristic of the system to be analysed. CD Step response VI calculates the output of the system when a step input excites it. This VI assumes the initial states of the system to be zero. Fig.5 shows the step response VI block diagram.

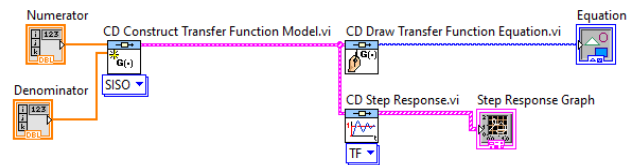


Fig -5: Step Response VI block diagram

From a practical standpoint, knowing how the system responds to a sudden input is important because large and possibly fast deviations from the long-term steady state may have extreme effects on the component itself and on other portions of the overall system dependent on this component. In addition, the overall system cannot act until the component's output settles down to some vicinity of its final state, delaying the overall system response.[3]

Fig. 6,7,8 and 9 are the step responses for different denominator values. This simulation helps for comparing and understanding basic concepts related to step response.

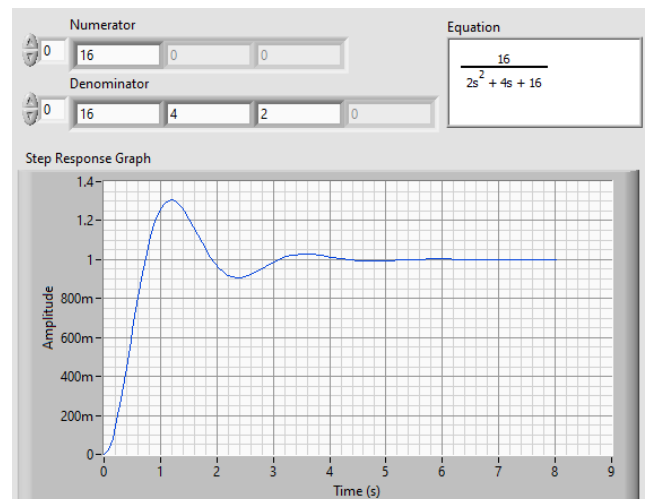


Fig -6: Step Response of transfer function of fig.1 [4]

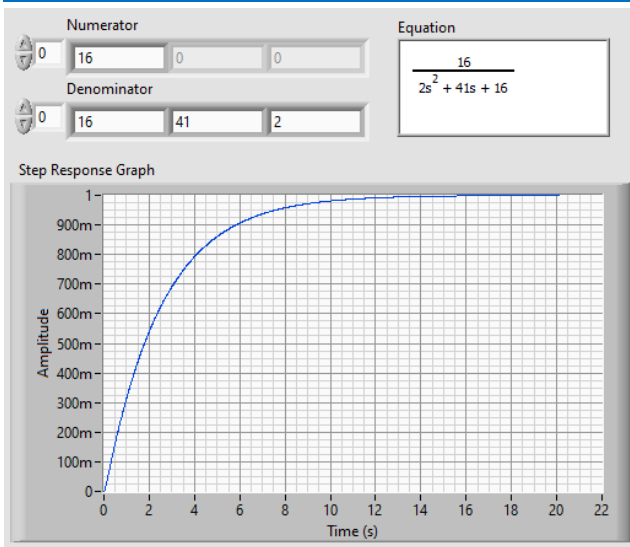


Fig -7: Step Response of transfer function [4]

A typical step response for a second order and third order systems, illustrating overshoot, followed by ringing, all subsiding within a settling time.

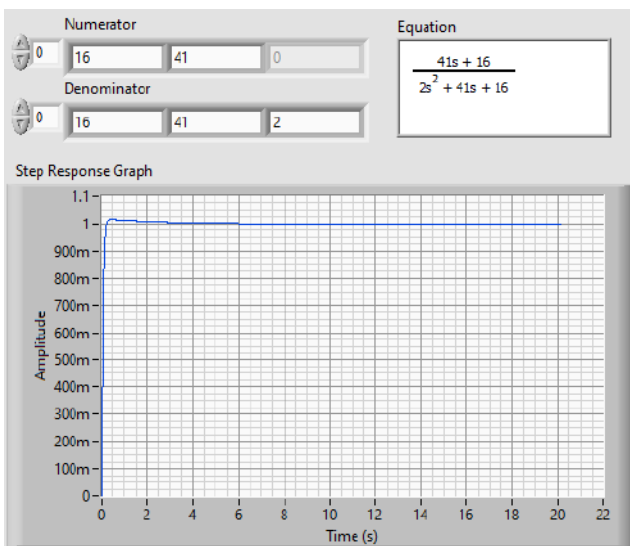


Fig -8: Step Response of transfer function [4]

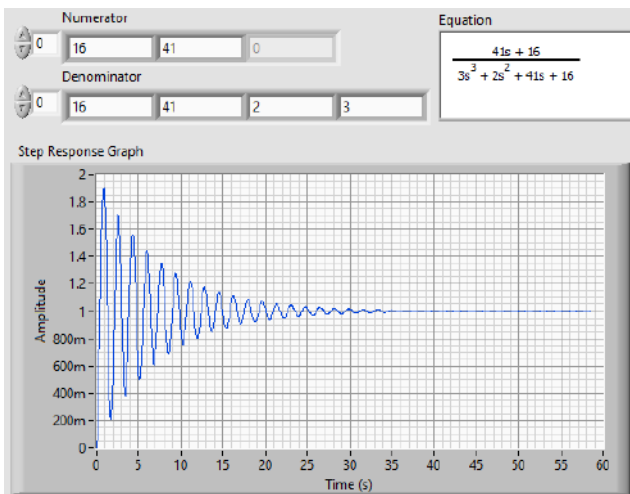


Fig -9: Step Response of transfer function [4]

2. FREQUENCY PLOTS

The frequency response is a representation of the system's response to sinusoidal inputs at varying frequencies. The output of a linear system to a sinusoidal input is a sinusoid of the same frequency but with a different magnitude and phase. The frequency response is defined as the magnitude and phase differences between the input and output sinusoids. Open-loop frequency response of a system can be used to predict its behavior in closed-loop. [5]

2.1 Bode and Nyquist plot

To plot the frequency response, a vector of frequencies is created (varying between zero or "DC" and infinity) and values of the plant transfer function at those frequencies are computed using LabVIEW toolkit. "If $G(s)$ is the open loop transfer function of a system and w is the frequency vector, then plot $G(j*w)$ versus w . Since $G(j*w)$ is a complex number, the plot showing both its magnitude and phase called the Bode plot and its position in the complex plane called the Nyquist plot." [5][6] Fig. 10 shows the use of CD Bode VI, located in the Frequency Response section of the Control Design palette in LabVIEW.

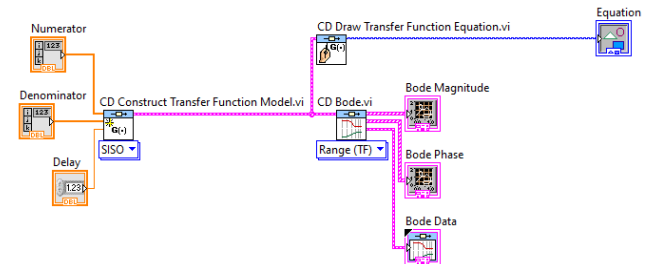


Fig -10: Bode Plot VI block diagram

Figure 11 and 12 shows the front panel of the VI that was built in Figure 10 for different terms in numerator and denominator.

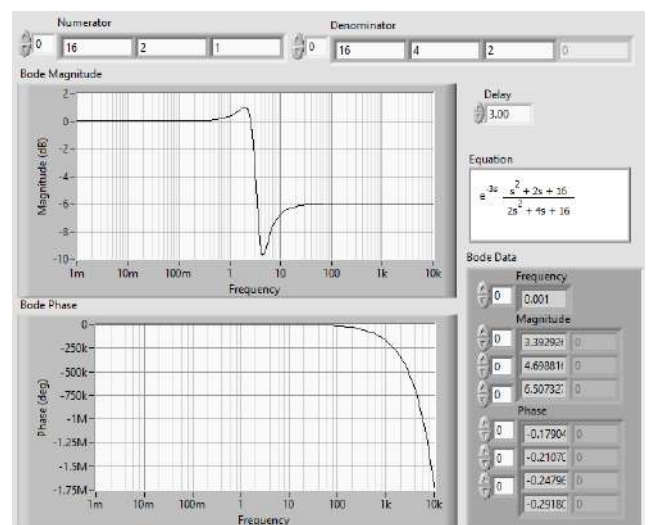


Fig -11: Bode Magnitude and Phase plots [4]

Note the axes of the plots in Figure. The frequency is on a logarithmic scale, the phase is given in degrees, and the magnitude is given as the gain in decibels. A decibel is defined as $20 \cdot \log_{10} (|G(j\omega)|)$.

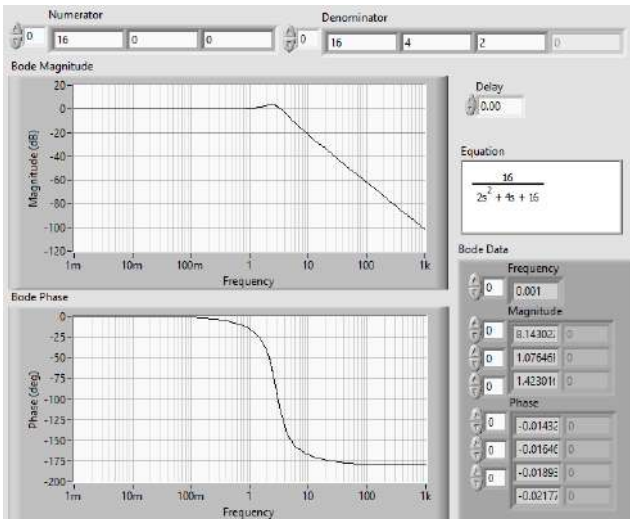


Fig -12: Bode Magnitude and Phase plots [4]

Fig. 13 shows the use of CD Nyquist VI, located in the Frequency Response section of the Control Design palette in LabVIEW and Fig. 14 and 15 shows the front panel of the same for different values.

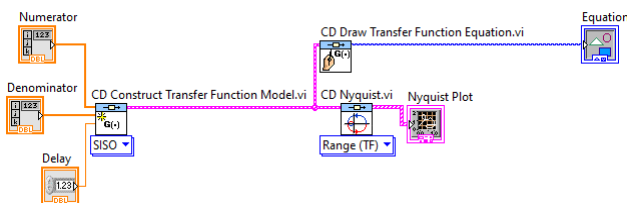


Fig -13: Nyquist Plot VI block diagram

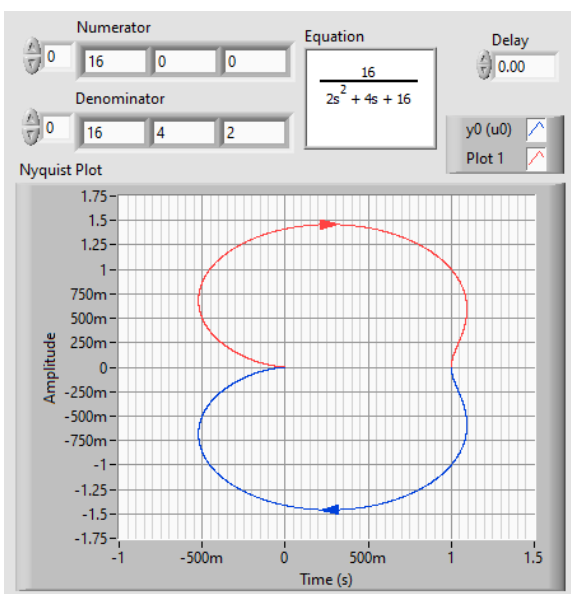


Fig -14: Nyquist Plot [4]

A Nyquist plot is a parametric plot of a frequency response used in automatic control and signal

processing. The most common use of Nyquist plots is for assessing the stability of a system with feedback.

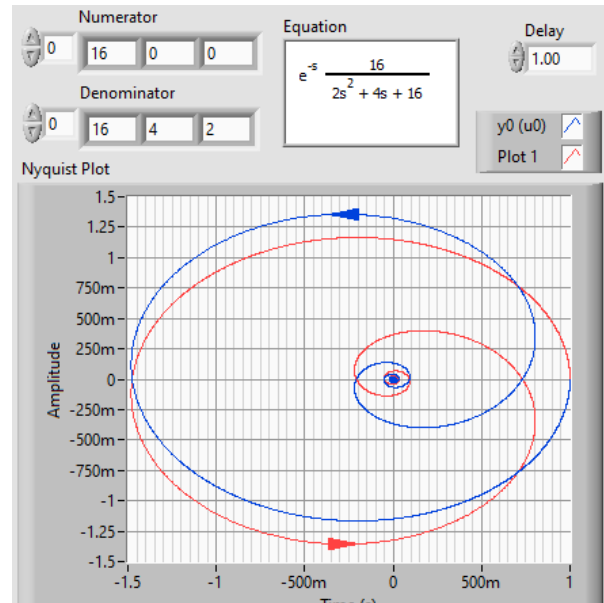


Fig -15: Nyquist Plot [4]

2.2 Root Locus

The root locus of an open-loop transfer function $H(s)$ is a plot of the locations (locus) of all possible closed loop poles with proportional gain k and unity feedback. Since the root locus is actually the locations of all possible closed loop poles, from the root locus a gain can be selected such that the closed-loop system needs to perform. If any of the selected poles are on the right half plane, the closed-loop system will be unstable. The poles that are closest to the imaginary axis have the greatest influence on the closed-loop response, so even though the system has three or four poles, it may still act like a second or even first order system depending on the location(s) of the dominant pole(s). [6]

Fig. 16 shows the use of CD Root Locus VI, located in the Frequency Response section of the Control Design palette in LabVIEW and Fig. 17 and 18 shows the front panel of the same for different values.

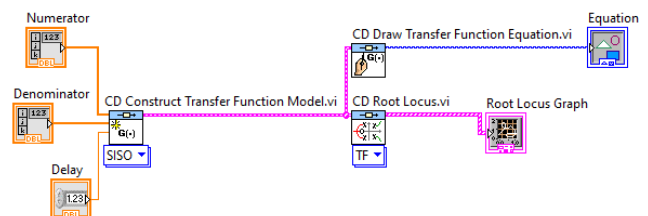


Fig -16: Root Locus VI block diagram

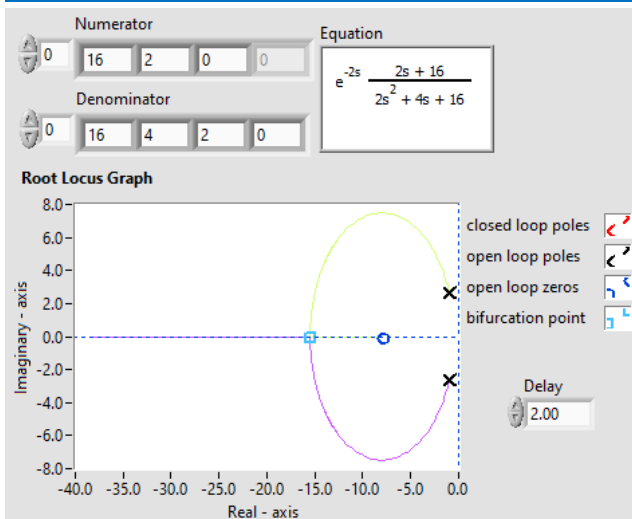


Fig -17: Root Locus Plot [4]

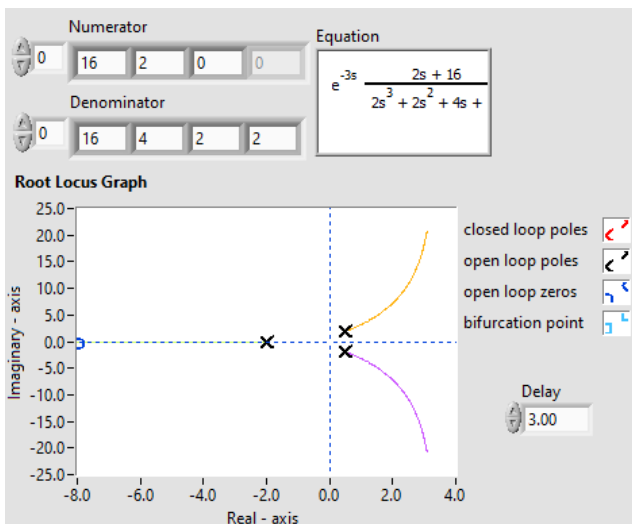


Fig -18: Root Locus Plot [4]

3. CONCLUSIONS

The Control Design and Simulation (CDSim) module for LabVIEW can be used to simulate dynamic systems. With the help of these plots and simulation in LabVIEW, basic concepts related to transfer function and various plots can easily be understood by students. To facilitate model definition, CDSim adds functions to

the LabVIEW environment that resemble those found in SIMULINK. There is also the ability to use m-file syntax directly in LabVIEW through the new MathScript node. [7]

ACKNOWLEDGEMENT

The authors acknowledge Nitesh Pradhan, Coordinator of NI Innovation Center, ITS Engineering College Greater Noida for conducting Online Summer Internship Program.

REFERENCES

- [1] Hans Peter Halvorsen, *Control and Simulation in LabVIEW*, 2017.
- [2] Lütkepohl, Helmut "Impulse response function". The New Palgrave Dictionary, 2nd ed., 2008.
- [3] Benjamin C Kuo & Golnaraghi F. Automatic control systems, Eighth ed., New York: Wiley. ISBN 0-471-13476-7, 2003
- [4] Nitesh Pradhan, *Let US LabVIEW Part 1: Collection of more than 1000 programs*, April 2020.
- [5] <http://www.ni.com/tutorial/6450/en/>
- [6] <https://www.ni.com/tutorial/6446/en/>
- [7] Seborg, Edgar, Mellichamp, *Process Dynamics and Control* 2nd edition, by, Wiley 2004
- [8] en.m.wikibooks.org
- [9] ftp.ni.com

Authors' Biography



Shirish Adam received his B.E from North Maharashtra University, (2000) and MTech (BME) from Indian Institute of Technology Bombay, Mumbai (2011). He joined Government College of Engineering Chandrapur in 2002. His research interests are pedagogy, biosensor, and Neuroplasticity. He is currently with Government College of Engineering, Jalgaon.