STUDY AND ANALYSIS OF OTRA AND ITS APPLICATIONS

A dissertation submitted in partial fulfilment of the requirement for the degree of

MASTER OF TECHNOLOGY
IN
CONTROL AND INSTRUMENTATION

by

HARDEV MEENA
(Roll No. **2K12/C&I/31**)

Under the guidance of
MR. RAM BHAGAT
Assistant Professor

DEPARTMENT OF ELECTRICAL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
DELHI – 110042
MAY 2015

CERTIFICATE

This is certified that the thesis work contained in this dissertation entitled "STUDY AND ANALYSIS OF OTRA AND ITS APPLICATIONS," by **Hardev Meena (2K12/C&I/31)** has been carried out under my supervision for award of the degree of **"MASTER OF TECHNOLOGY"** in **Control and Instrumentation** of Delhi Technological University, Delhi

(Sh. Ram Bhagat)
Assistant Professor
Project Guide

ACKNOWLEDGEMENT

I feel honored in expressing sense of gratitude and indebtedness to my respected guide Mr. Ram Bhagat, Assistant Professor, Electrical Engineering Department, Delhi Technological University for their guidance, meticulous efforts, constructive criticism, inspiring encouragement and invaluable co-operation which enabled me to work on thesis entitled “STUDY AND ANALYSIS OF OTRA AND ITS APPLICATIONS.

I would like to extend my gratefulness to Prof. Madushudhan, Head of Electrical Engineering Department, Delhi Technological University, and Delhi for his perpetual encouragement, generous help and inspiring guidance.
I am thankful to Dr. Bharat Bhusan and Dr. D. Joshi to enhance my awareness about Mat lab and faculty and staff members Department of Electrical Engineering for their direct or indirect cooperation.

I humbly extend my grateful appreciation to my friends Mr. Ashok Kumawat and Mr.Robin they are help me to know Pspice using Orcad. I thankful to Mr. Karam veer singh and Mr.Rakesh gaushwami for their time to time suggestions and cooperation without which I would not have been able to complete my work.

I would like to thanks, Directorate of Training and Technical Education, Pitampura, Delhi, Principal and I/C (Electrical Engg. Deptt.), Pusa Institute of Technology, where I got full Cooperation and guidance to complete my thesis. And greatest thanks to my family and my classmates who bestowed ability and strength in me to complete this work.

Hardev Meena
(2K12/C&I/31)

ABSTRACT

The major goal of this thesis is to know about Operational Transresistance Amplifier (OTRA), its applications, performance and practical implementation of OTRA two CFOA AD844 ICs.

Study and realization of Operational Transresistance Amplifier is presented. The development and use of operational Transresistance Amplifier model is very important in control and instrumentation engineering. This analysis taking the effect of Transresistance gain. The characteristics of OTRA circuit demonstrated through Proteus and Pspice simulation.

The study and analysis of RC sine wave oscillator based on OTRA. Proposed oscillator consists of two CFOA AD844 ICs for implementing the OTRA and few passive components. The proposed OTRA based sine wave oscillator exhibit low sensitivity and good frequency stability.

Operational Transresistance Amplifier (OTRA) based second order low pass filter is presented. The proposed LPF is depending on RC parameters. It’s insensitive to parasitic capacitances. It also insensitive to input resistance due to internally grounded input terminals of OTRA.

Conventional controller such as proportional, integral and derivative individual and combined developed using operational Transresistance amplifier. These OTRA based conventional controllers are study and their characteristics analysis through Proteus simulation and results are verified in Mat lab.

Operational Transresistance Amplifier and its application such as filter, oscillator and controllers are design and simulated with help of Proteus ISIS Professional simulation software. Their transient, frequency, phase and noise responses derived using Proteus.

Some electronic part analysis using Orcad capture, Pspice A/D.

The performance of controllers evaluated using Mat lab simulink.

Hardware implementation of OTRA may be possible due to AD844AN current feedback amplifier.

The Chapters focuses on the software tools, particular control problem and results.

CONTENTS

LIST OF FIGURES

Figures No. And Description	**Page No.**

LIST OF TABLES

CHAPTER - 1

INTRODUCTION

This thesis is serves as study and analysis about Operational Transresistance Amplifier (OTRA) and its various instrumental applications like oscillator, filter and conventional controllers (Proportional, Integral and Derivative). This work done is analysis with Electrical and Electronic simulator Proteus ISIS Professional, Electronic simulator Orcad Pspice capture and Mat – lab. Implementation of OTRA is based on AD844AN (CFOA).

1.1 INTRODUCTION TO OTRA

The OTRA is a high gain current input voltage output three terminal device. Both input and output terminals of the OTRA are characterized by very low impedance resulting in circuits that are insensitive to stray capacitance making OTRA appropriate for high frequency application. To maintain compatibility with voltage processing circuits, it is necessary to convert the input and output signals of current mode circuits to voltage, using Transresistance. This is the disadvantages of increasing both the power dissipation and chip area. OTRA as the active element benefits from the current processing capabilities at the input terminals and can directly drive the existing voltage mode signal processing circuits eliminating the requirement of additional circuitry and associated power consumption at the output.

1.1.1 OVERVEIW OF FILTER

OTRA based second order filter could be design with help of AD844AP (CFOA), and its performance can be analysis using Proteus ISIS Professional simulation software and result can be verified practically.

1.1.2 OVERVEIW OF OSCILLATOR

Generating signals carrier for test signals, clock pulses for control and time. These signals have various shapes such as sinusoidal, triangle etc. Wave generated by signal generator describe by shape, amplitude, frequency and duty cycle. In continuation we will learn about sinusoidal oscillator using single OTRA.

1.1.3 OVERVEIW OF CONTROLLERS

Controller action depends on error, the difference between measured output variables and set point, it called error. Controller tries to minimize the error value by adjusting the process control inputs.

1.2 AD844

The AD844 is fabricated using the analog device. It is high speed monolithic operational amplifier [31]. Its current feedback results are better. AD844 is free from slew rate limitation. AD844 operated from ±4.5V to ±18V biasing supply. AD844 have low noise, low distortion, and low drift with wide band width [31].

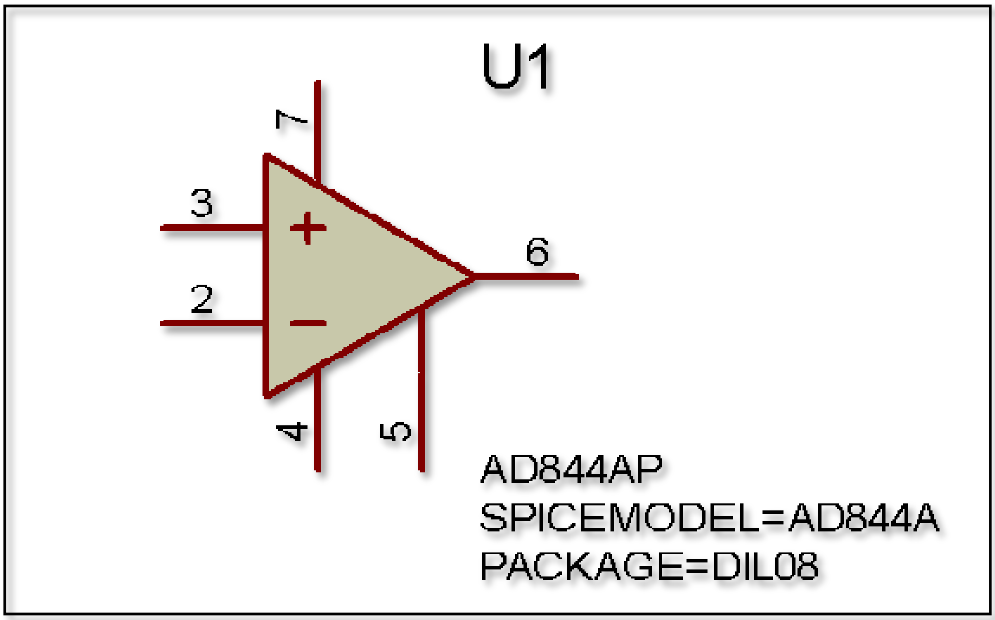


Figure 1.1 Model of AD844A [31]

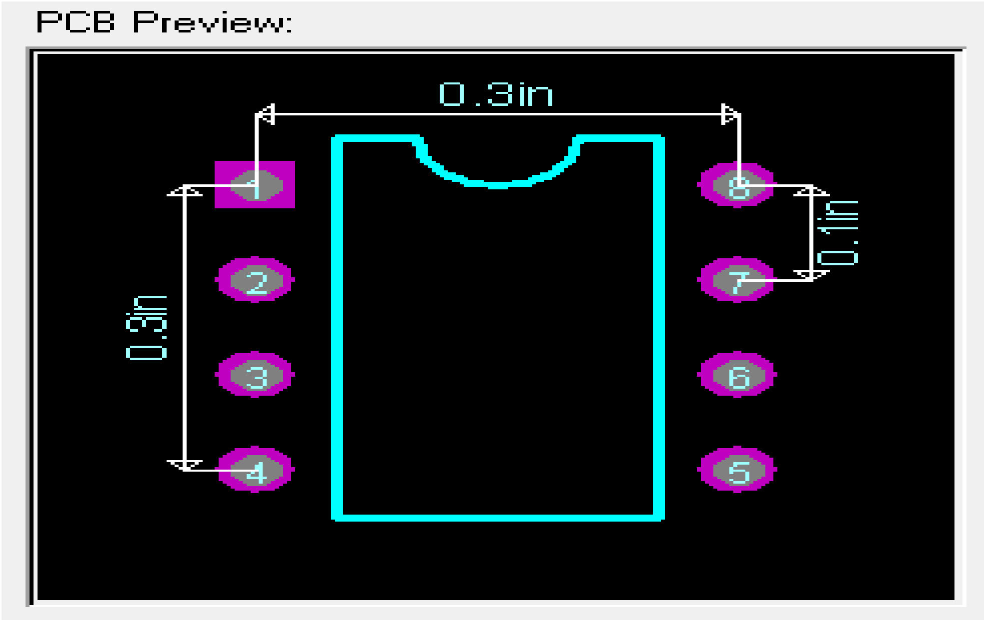


Figure1.2 AD844AN PCB preview

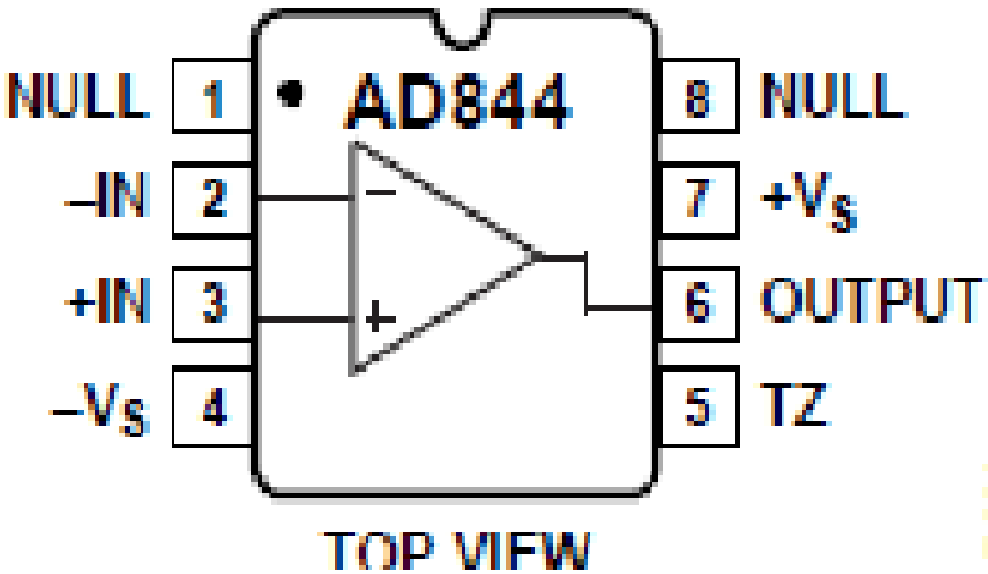


Figure1.3 Pin diagram of AD844 [31]

The AD844AN is available in three packages and four grade

a. 16 – lead SOIC (RW) Package, the AD844, it is specified for commercial temp. Range of 0degree centigrade to 70 degree centigrade.
b. The AD844AN and AD844B used for temperature range -40 degree centigrade to +85 degree centigrade.

c. The AD844S used over the military temperature range -55 degree centigrade to +125 degree centigrade.

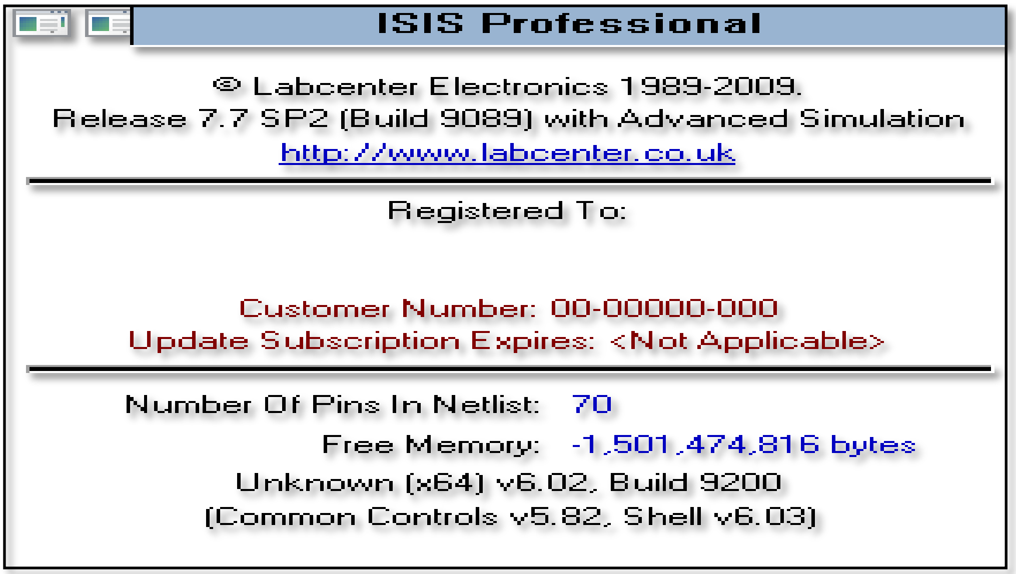
The AD844AN is available in an 8 – lead PDIP (N).

HIGHLIGHTS

- It is provides excellent performance combination of AC and DC.
- Rise and fall time independent of output level and it is free from slew rate limitations.
- It can be operated from ±4.5 to ±18 biasing supply.
- It is capable driving load down to 50Ω.
- It is support to variety of video application with bandwidth up to 60MHz.

1.3 PROTEUS ISIS PROFESSIONAL SIMULATION SOFTWARE

This is the software by using this we can design and simulate the electrical and electronic circuit, and analysis concern result as Orcad Pspice.



Proteus 7.0 is use to circuit simulation, microprocessor model, animated component and microcontroller based design. Proteus 7.0 is a product that use a SPICE analogue simulator kernel combined with an event driven digital simulator that allow user to utilize the any SPICE MODEL.

Proteus Virtual System Modelling (VSM) has following features prior to design of hardware

- Variable display
- Debugging feature

- Including break point
- Single stepping

Proteus has single integrated application with 3D Viewer modules, ISIS and ARES appearing as tabbed modules. Design explore in real time, Proteus stored the common data base design (DSN), LAYOUT (LYT) in a single project file (PDSPRJ).

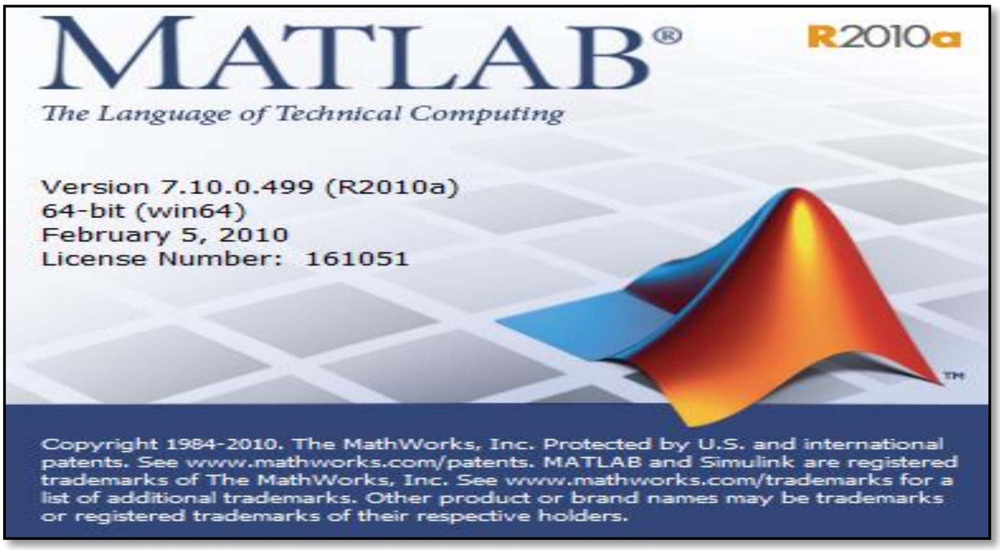
1.4 MAT – LAB

MATrix LABoratory (MATLAB), It is a computer program which is used for optimized performance of engineering and scientific calculations. It programmed for matrix mathematics, but over the years it is capable to solve technical problem.

MATLAB is set of huge software and variety of functions. It is includes more than 1000 functions.

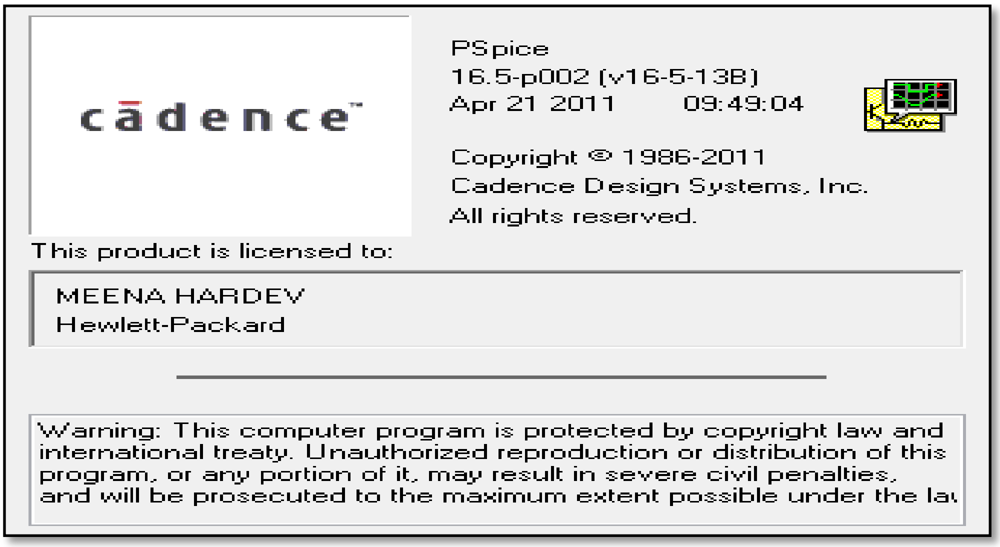
MATLAB has so many advantages as compare to other computer languages for analysis the technical problems. Such as

a. Easy to use
b. Platform independence
c. Predefine function
d. Graphical user interface
e. MATLAB Compiler



A MATLAB user get help using help, it is provide function related and other help to solve any problem.

1.5 ORCAD PSPICE



Computer aided circuit could not be analysis and examine with laboratory prototype measurements. Computer aided analysis are

a. Evaluate the effect of variation in elements, transistors, transformer and resistor etc.
b. Performance assessment
c. Analysis effect of noise and signal distortion.
d. Optimization of required circuit parameters.

Pspice can perform so many analyses of electrical and electronic circuits such as time domain response, transient response, operating point. The Pspice stand for simulation program with integrated circuits. Spice software supports program for Linux, DOS, Windows and UNIX. The following three platforms are used for Pspice

a. OrCAD Pspice A/D
b. Pspice Schematics
c. OrCAD Capture

1.6 OUTLINE OF THESIS

Chapter 2: An introduction to Operational Transresistance Amplifier and study and characteristics analysis of OTRA. Implementation of OTRA using CFOA TWO AD844A ICs.

Chapter 3: focuses on the behavior of OTRA based oscillator.

Chapter 4: The development and use of operational Transresistance Amplifier model is very important in control and instrumentation engineering. According to application of OTRA we develop a second order low pass filter.

Chapter 5: Conventional controller such as proportional, integral and derivative individual and combined developed using operational Transresistance amplifier.

CHAPTER - 2
LITERATURE SURVEY

Srinivasulu Avireni, Chandra Shaker Pittala [1] have describe the operational transresistance amplifier based five sinusoidal oscillator controlled by ground resistance and capacitance, it is important for integration point of view, performance of said circuit is examined with pspice models. K.N. Salama, A.M. soliman [2] have introduced the operational transresistance amplifier (OTRA) based novel active RC oscillators, which is generated minimum component oscillator, two OTRA based four new oscillator are reported. Hung – Chun Chein [3] have study and proposed operational transresistance amplifier based three new sinusoidal oscillators, said OTRA based sinusoidal oscillator use to minimum RC oscillator and discuss nonideal effect, sensitivity and frequency stability of said circuit. Rajeshwari Pandy, Neeta Pandy, Sajal K. Paul [4] have describe electronic tunable circuit OTRA based applications and design of Transimpedance instrument amplifier. Rajeshwari Pandy, Saurabh Chitransi, Neeta Pandy, Chander Shekhar [5] describe the design of OTRA based analog controller proportional (P), proportional – integral and derivate (PID) controller with control application of operational transresistace amplifier. Mayank Bothra, Rajeshwari Pandey, Neeta Pandey, Sajal Paul [6] have present operational transresistance amplifier based flexible and modular wave active filter structure, to overcome the effect of parasitic capacitor they have suggested the doubly terminated butterworth filter. V.Zeman, K. Vebra [7] are shown the solution design high order synthetic elemens with the type D admittance and maximum possible use of elements in higher order filter. Ashish Ranjan, Vivek Bhatt and Manoj Joshi [8] have present single – input single – output (SISO) butterworth, Chebyshev and Bessel operational transresistance amplifier based voltage mode low pass filters. Khaled N. Salama, Ahmed M. Soliman [9] have introduced Operational Transresistance Amplifier new CMOS realization, OTRA properties are shown be for VLSI application , imploying MOS transistors operating in the ohmic resign, proposed circuits are present with both passive compensation and self compensation. Rajeshwari pandey, Neeta Pandey, Mayank Bhotra, Sajal K. Paul [10] are utilized operational transresistance amplifier for multipurpose sinusoidal amplifier as the active element, described circuits are simple to realize. Cevat Erdal [11] have implemented a PID controller using commercial available active component AD844, this is based on current feedback amplifier (CFOA), by use of parameter sensitivity optimized the PID controller circuit parameters. Vijaylaxmi Kalyani, Aayushi Arya [12] have introduced CFA by considering the advantages high slew rate due to architecture of current feedback, in this paper they present the comparison of maximum frequency range of differentiator and integrator for both CFA and VFA. A Budak[13],A.M. Soliman, M.H. Al-Shamaa, M. Dakalbab[14], A.M. Soliman[15], in the literature sinusoidal oscillator proposed using operational amplifier, bandwidth and slew rate are limitation of operational amplifier, these conditions affect the frequency of oscillator. C.M.Chang[15], A. Srinivasulu[16], A.M. Soliman[17], D.R. Bhaskar[19] are study to overcome these said drawback many oscillator based on current feedback amplifier (CFOA) and current conveyor are used as active element in above literature, these oscillators are known to for their wider bandwidth, large frequency range, M.T. Abuelma Atti and M. A. Al-Qahtani[20]MSOs based on current conveyor II (CC II) are presented. Thiers drawback is that they require a JFET and three additional current conveyor for each phase in order to achieve electronic tunability , C. Lloecharataramdee, W. Kiranon, W. Sangpisit, and W. Yadum[21] the structure proposed in[20,21], W. Tangsrirat and W. Tanjaroen[22] are based on current differencing Transcondctance amplifier, W. Tangsrirat and W. Tanjaroen, and T. Pukkalanun[23], D. S. Wa, S. I. Liu, Y. S. Hwang, and Y. P. Wu[24] are not very accurate in producing the desire phase shift the structure produce in using current feedback operational amplifier as a good output voltage swing and capable of producing high frequency signals , A. S. Sedra and K. C. Smith[25] there are a number of techniques available for controlling amplitude of oscillations for voltage mode op-amps, C. Toumazon, F. J. Lidgey and D. J. Haigh[26], J. Chen, H. Tsao and C. Chen[27], Y. K. Lo, H.C. Chein, and H. G. Chiu[28] nonideality Attribute to Realization of OTRA using commercially available AD844, Rajeshwari Pandey , Neeta Pandey, Rajendra Kumar and Garima Solanki [29], Rajeshwari Pandey, Neeta Pandey and Sajal K. Paul [30], are introduced the signal generator and find wide application in communication, instrumentation and measurement and control system, Generating signals carriers for clock pulses for timing and control and information transformation.

CHAPTER - 3

OTRA IMPLEMENTATION AND ANALYSIS

3.1 INTRODUCTION

The OTRA is three terminal current mode analog devices with two low impedance input terminals and one low impedance output terminal. The input terminal of OTRA is virtually grounded [28].

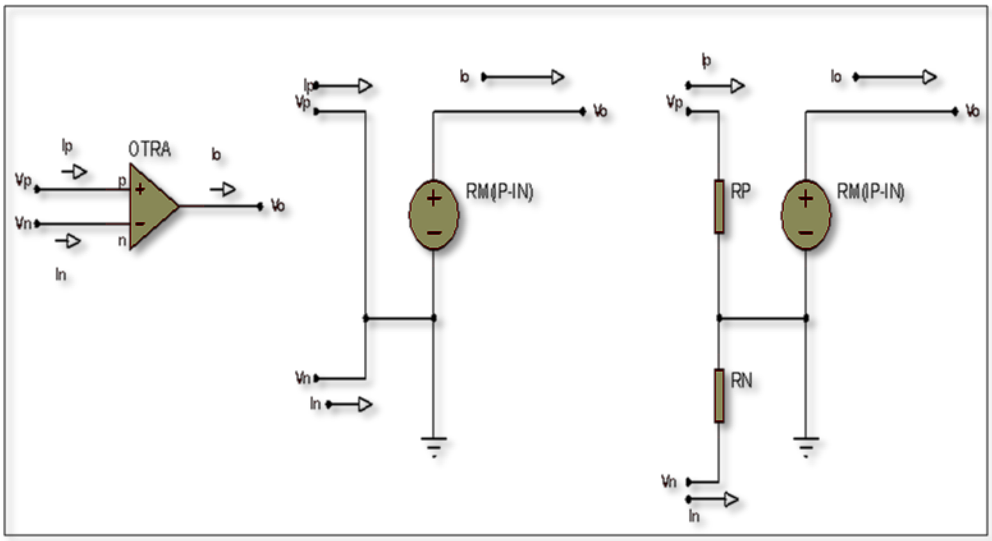


Figure 3.1 OTRA Symbol and equal anent circuit [28]

The OTRA is a high gain current input voltage output device. Both input and output terminals of the OTRA are characterized by low impedance resulting in circuits that are insensitive to stray capacitance making OTRA appropriate for high frequency application. To maintain compatibility with existing voltage processing circuits, it is necessary to convert the input and output signals of current mode circuits to voltage, using Transresistance. This has the disadvantages of increasing both the chip area and power dissipation. OTRA as the active elements benefit from the current processing capabilities at the input terminals and can directly drive the existing voltage mode signal processing circuits eliminating the requirement of additional circuitry and associated power consumption at the output.

An ideal OTRA senses the difference of the currents at its two input terminals, namely ‘p’ and ‘n’, amplifies it and provides a resulting voltage at the output terminal Fig. 3.1. For ideal operation the input terminal voltages should be zero.

The output voltage should be independent of the current that may be drawn from the output terminal by the load impedance. Where R_m is Transresistance gain of OTRA. For ideal operations the Rm approaches infinity and force the input current to be equal.

$$\begin{bmatrix} V_p \\ V_n \\ V_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ R_m & -R_m & 0 \end{bmatrix} \begin{bmatrix} i_p \\ i_n \\ io \end{bmatrix} \qquad (1)$$

OTRA can be used in an open loop configuration. Its gain being infinity the output voltage saturates either at $+v_e$ or $-v_e$ saturation level.

Thus OTRA must be used in a negative feedback configuration where the output is not driven into saturation and the circuit behaves linearly. The OTRA is a current input and voltage output, a shunt- shunt feedback is used which places the feedback network and amplifier in parallel. A parallel configuration is suitable for low voltage operations as it minimizes stacking of transistors thereby providing more head room for signal swing. OTRA bandwidth independent of closed loop gain by using current feedback.

3.2 OTRA IMPLEMENTATION

The OTRA implementation based on the following

1. Using commercially available AD844AN (current feedback operational amplifier).
2. Using integrating circuit implementation

Current feedback operational amplifiers commercially available as IC AD844AN. Here in thesis OTRA realize by using AD844 Figure 3.2 [28] shows the implementation of OTRA using two AD844 ICs [28].

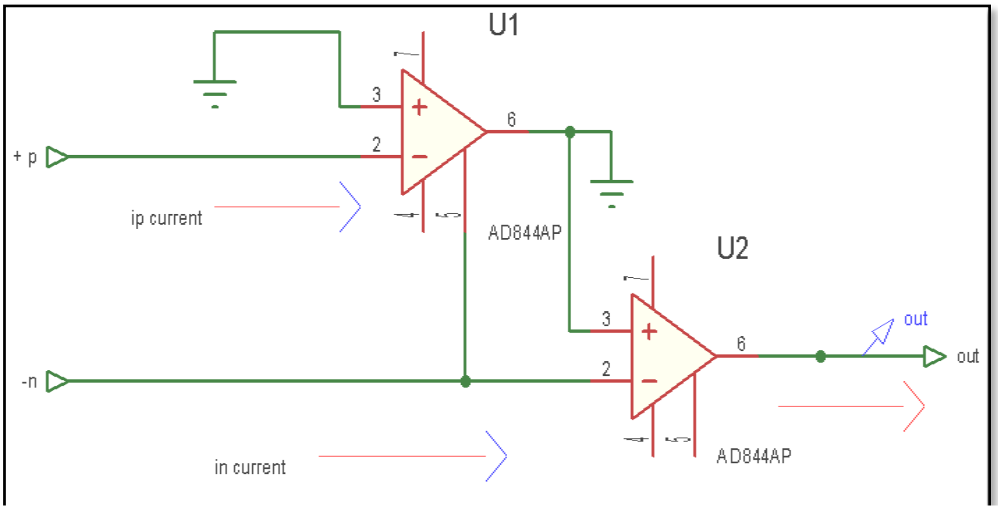


Figure 3.2 OTRA implementation using of two AD844AP (CFOA) [28]

Current calculated according to given circuit diagram in figure 3.2

$$i_{z1} = i_p \qquad (2)$$

$$i_{x2} = i_n - i_{z1} \qquad (3)$$

$$i_{z2} = i_{x2} \qquad (4)$$

The current through Z_2 terminal can be computed as

$$i_{z2} = i_n - i_p \qquad (5)$$

The voltage at various ports may be written as

$$V_p = V_1 -= V_1 += 0 \qquad (6)$$

$$V_n = V_2 -= V_2 += 0 \qquad (7)$$

$$V_o = V_{z2} = -i_{z2}R_{z2} = (i_p - i_n)R_{z2} \qquad (8)$$

$$V_o = (i_p - i_n)R_{z2} \qquad (9)$$

Where R_{z2} is Transresistance gain of the OTRA.

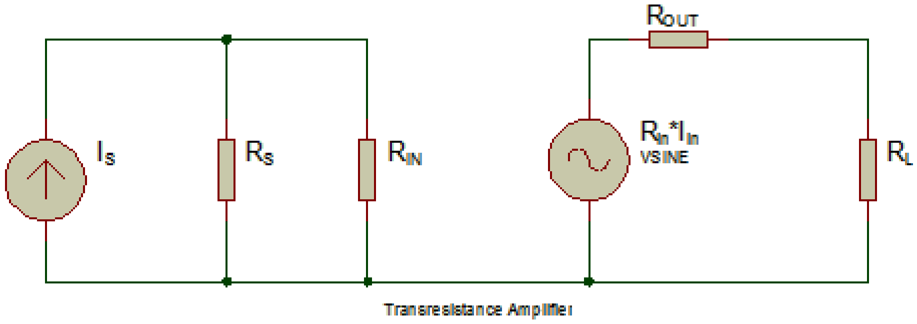


Figure 3.3 Transresistance Amplifier internal circuits

If Rin << Rs then $I_{in} = I_s$

If Rout << R_L than $V_{out} = R_{in}*I_{in} = R_{in}*I_s$

An ideal Transresistance amplifier should have input and output resistance zero.

3.3 SIMULATION AND HARDWARE RESULTS

Figure 2.4 shows the simulation circuit of OTRA using AD844 and hardware circuit design by following active and passive components mentions in table 2.1.

Quantity	Part – Name	Value
 2 1	Resistance R1, R2 R3	 10KΩ 3MΩ
2	Integrated Circuits U1,U2	AD844AP
2	Miscellaneous B1,B2	15V
1	Function Generator	0 – 1MHz
1	CRO	

Table 2.1List of component used for OTRA implementation

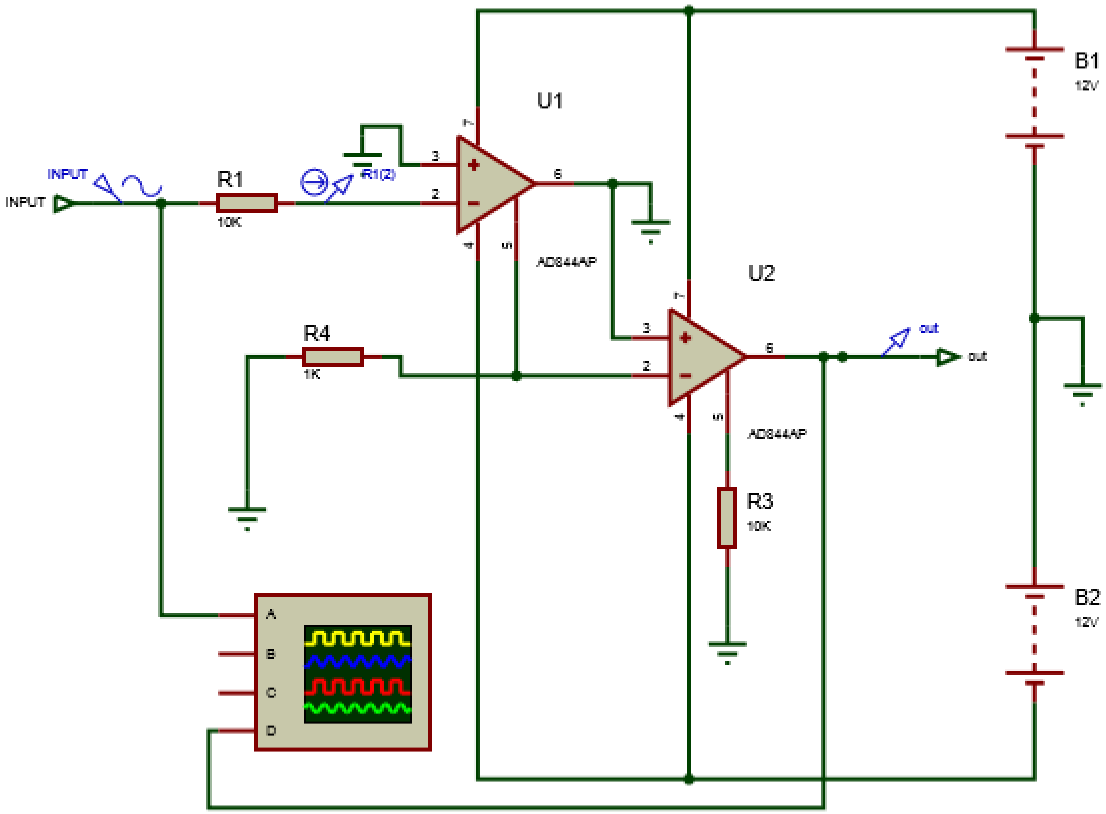


Figure 3.4 Simulation circuit of OTRA using AD844

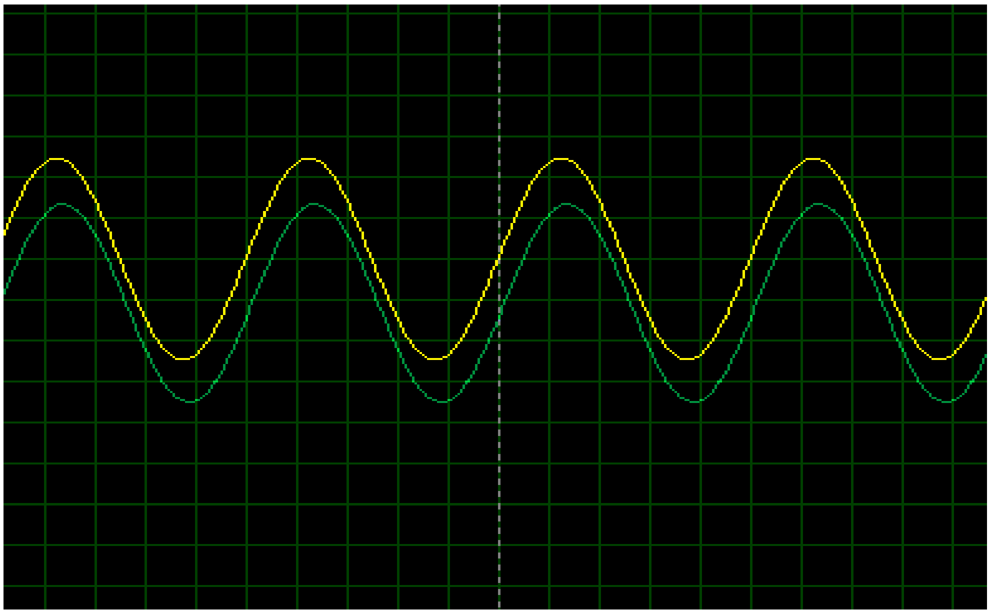


Figure 3.5 Simulated Input – Output response

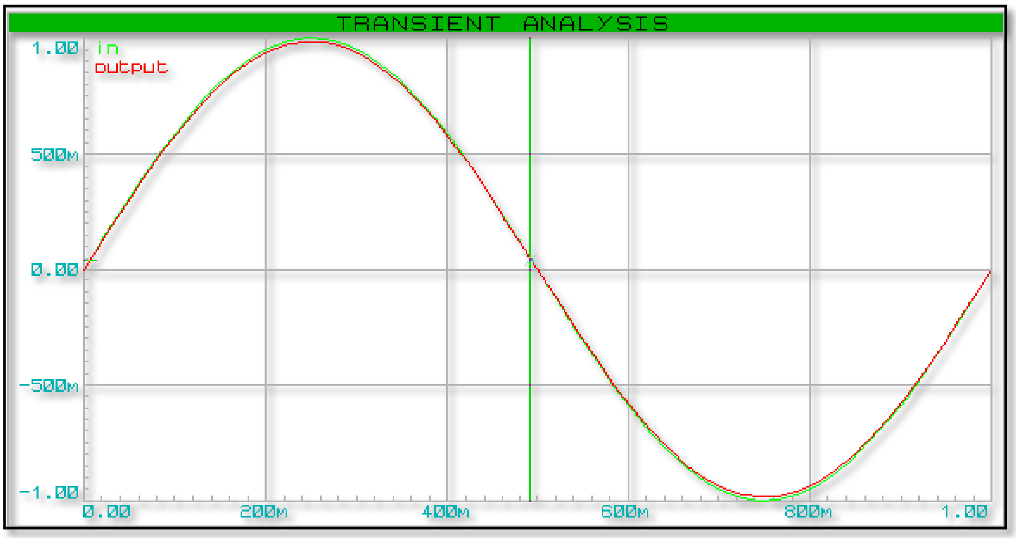


Figure 3.6 Time domain Input – Output response

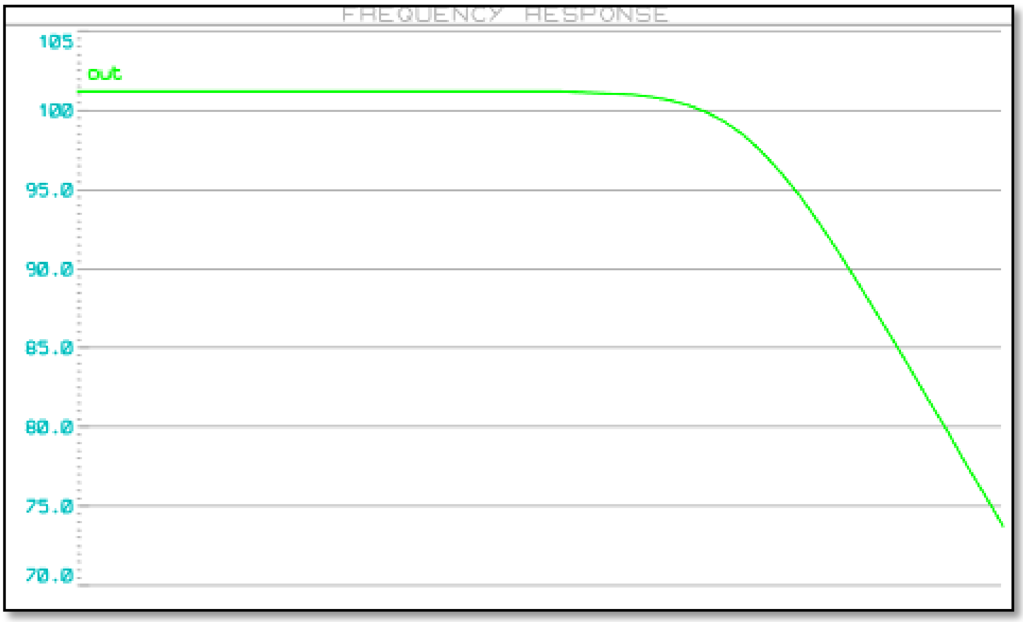


Figure 3.7 Open loop Transresistance gain frequency response

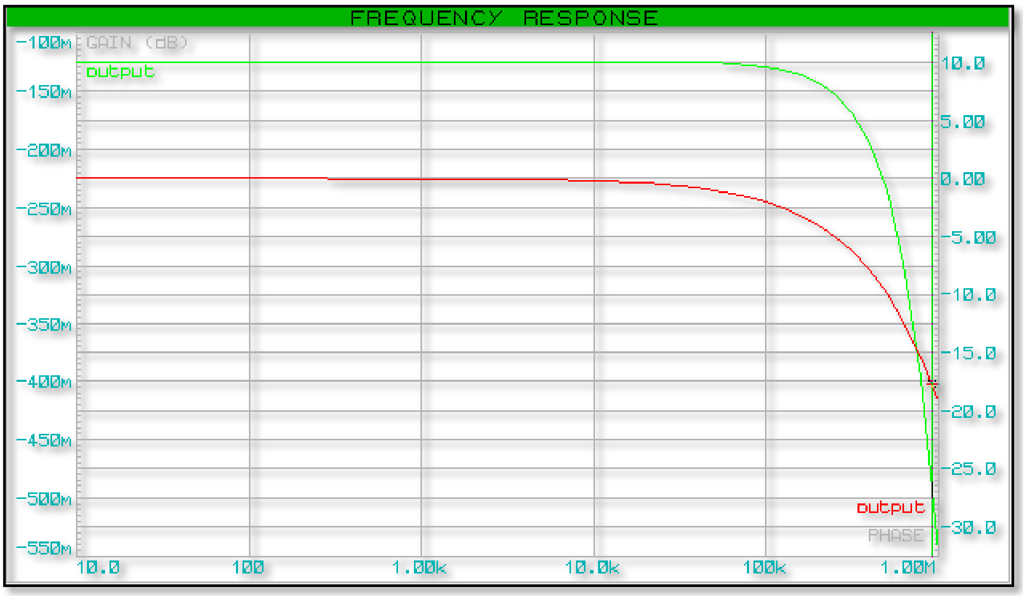


Figure 3.8 Frequency and Phase response of OTRA

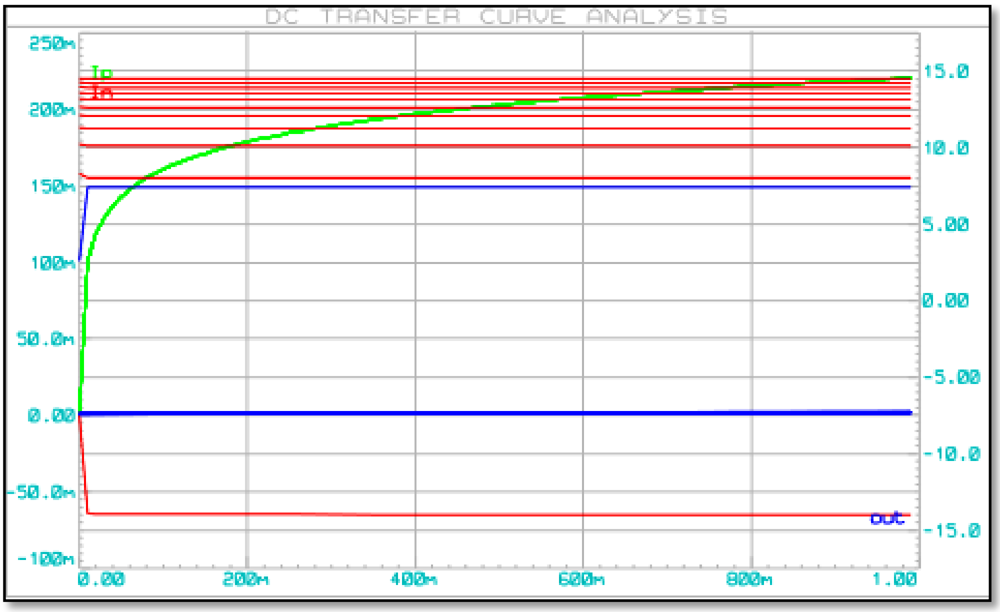


Figure 3.9 DC Transfer curve response

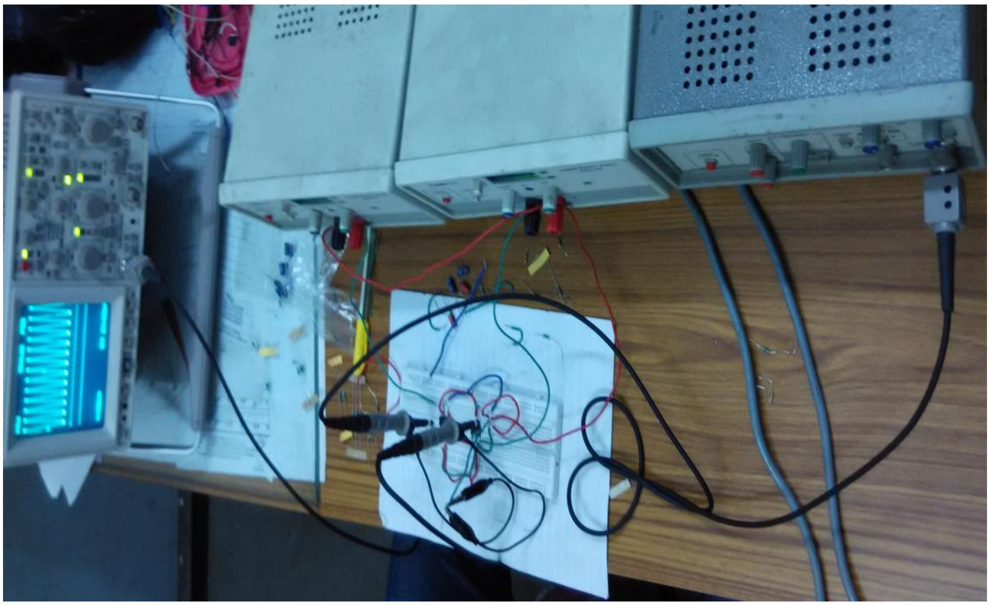


Figure 3.10 Experimental setup of OTRA implementation

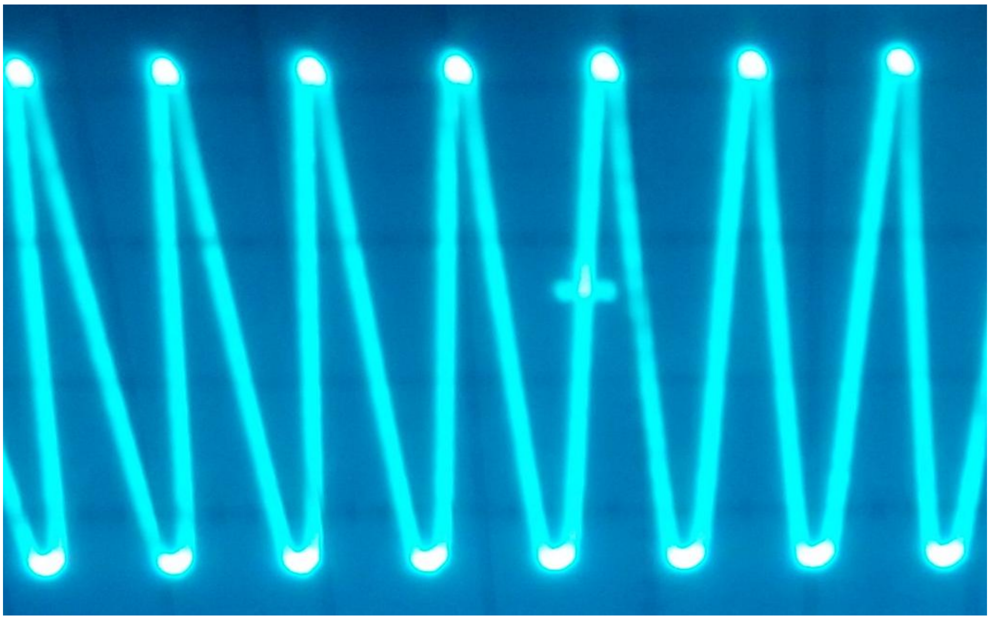


Figure 3.11 Experimental output of OTRA

Parameters	Results
Input current dynamic range	-50.0μA to 50.0μA
Input resistances R_p, R_n	13Ω
DC open loop Transresistance	98.0 dBΩ
Gain Bandwidth product	30 GHzΩ
Transresistance gain B.W.	416KHz

Table 3.2 Simulated results of circuit shown in figure 2.4

Simulated results are summarised in table 3.2.

CHAPTER - 4

OTRA BASED SINE WAVE RC OSCILLATOR

4.1 INTRODUCTION

In communication, instrumentation, control system and measurement application signal generators have an important role. Generating signals carrier for test signals, clock pulses for control and time. These signals have various shapes such as sinusoidal, triangle etc. Wave generated by signal generator describe by shape, amplitude, frequency and duty cycle. In continuation we will learn about sinusoidal oscillator using single OTRA.

Other waveform can be explained as a Fourier combination of sine waves. Sinusoidal waveform can be generated by shaping of triangular wave, or consisting positive feedback loop of an amplifier shown in figure 4.1 [29, 30].

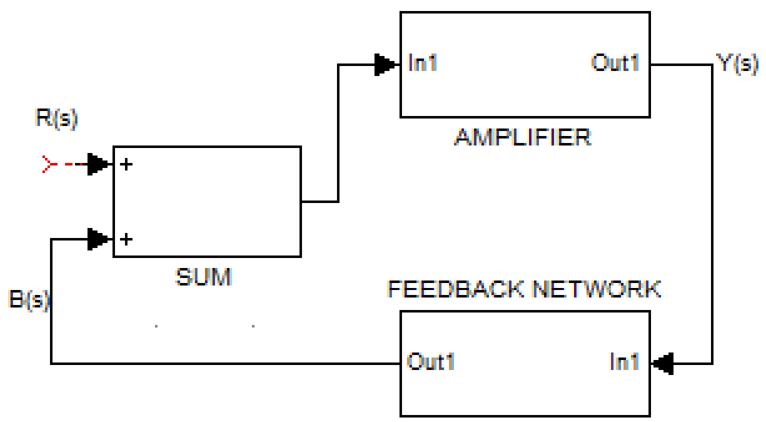


Figure 4.1 Functional block of a sinusoidal oscillator [29, 30]

All the circuits utilize the positive feedback approach and Barkhuasen criterion; it is satisfied for a single frequency only.

4.2 GENERALIZED CIRCUIT OF OTRA BASED OSCIILLATOR

Single OTRA based generalized configuration shown in figure 4.2 [1].

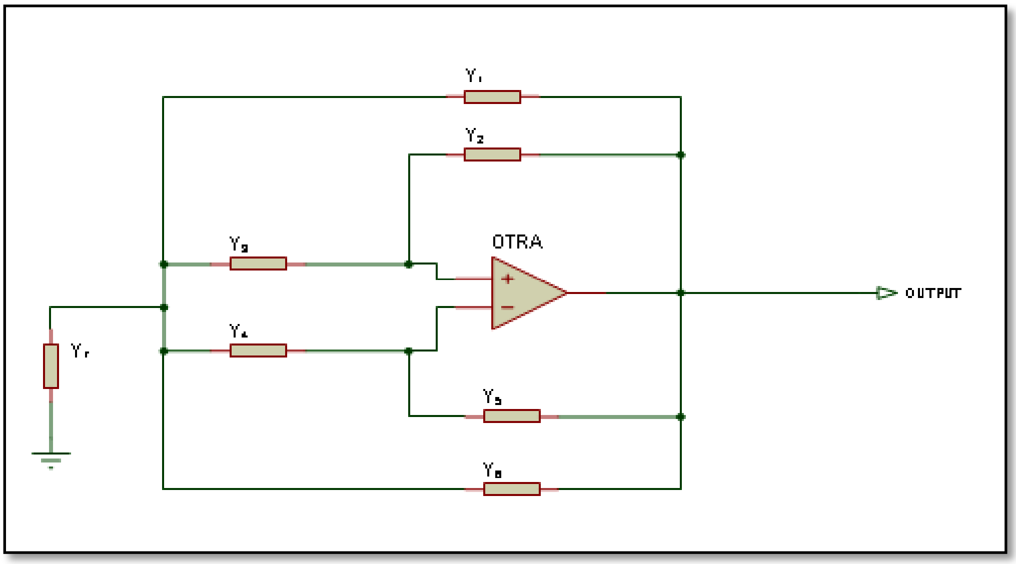


Figure 4.2 Generalize circuit of OTRA base Oscillator [1]

Generalised characteristics equation of single OTRA based oscillator can be expressed as

$$i_p = VY_3 + V_oY_2 \qquad (1)$$

$$i_n = VY_4 + V_oY_5 \qquad (2)$$

$$VY_1 + VY_3 + VY_4 + VY_6 + VY_7 = 0 \qquad (3)$$

Let's assuming that in ideal condition of OTRA, the amplifier voltage gain can by calculate by equating the current of positive (p) and negative (n) terminal, that is

$$i_p = i_n \qquad (4)$$

$$VY_3 + V_oY_2 = VY_4 + V_oY_5 \qquad (5)$$

$$VY_3 + V_oY_2 - VY_4 - V_oY_5 = 0 \qquad (6)$$

By comparing equations (5) and (6) we get

$$\frac{Y_1 + Y_3 + Y_4 + Y_6 + Y_7}{Y_1 + Y_6} = \frac{Y_3 - Y_4}{Y_5 - Y_2} \qquad (7)$$

$$Y_1Y_2 + Y_2Y_3 + Y_2Y_4 + Y_2Y_6 + Y_2Y_7 + Y_1Y_3 + Y_3Y_6 - Y_1Y_4 - Y_1Y_5$$
$$-Y_4Y_6 - Y_3Y_5 - Y_4Y_5 - Y_5Y_6 - Y_5Y_7 = 0 \qquad (8)\ [1]$$

Equation (8) [1] is general characteristics equation of OTRA based oscillator. There Y_1 to Y_7 are the admittance of the passive elements.

The various conditions of frequency and oscillation given table 4.1 [1]. The proposed single OTRA based oscillator could be controlled by a grounded resistor said circuit could be controlled if resistor replaced by grounded capacitor.

Design	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
A	0	sC_2	G_3	sC_4	G_5	0	G_7
B	sC_1	0	G_3	sC_4	G_5	0	sC_7
C	G_1	0	G_3	0	sC_5	sC_6	G_7
D	0	G_2	G_3	sC_4	G_5	sC_6	G_7
E	0	G_2	sC_3	G_4	0	sC_6	G_7

Table 4.1 Condition of oscillation frequency generation

4.3 SIMULATION AND HARDWARE SESULT

A second order sinusoidal oscillator can be design with help of characteristics equation (8) is shown in figure 4.3.

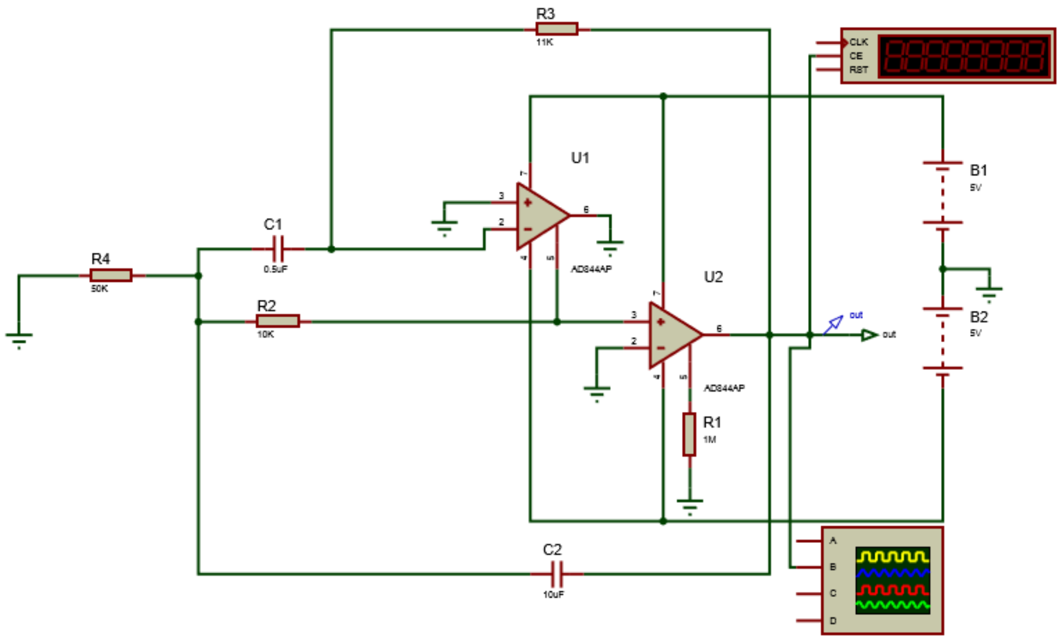


Figure 4.3 Simulation circuit of second order OTRA based Oscillator

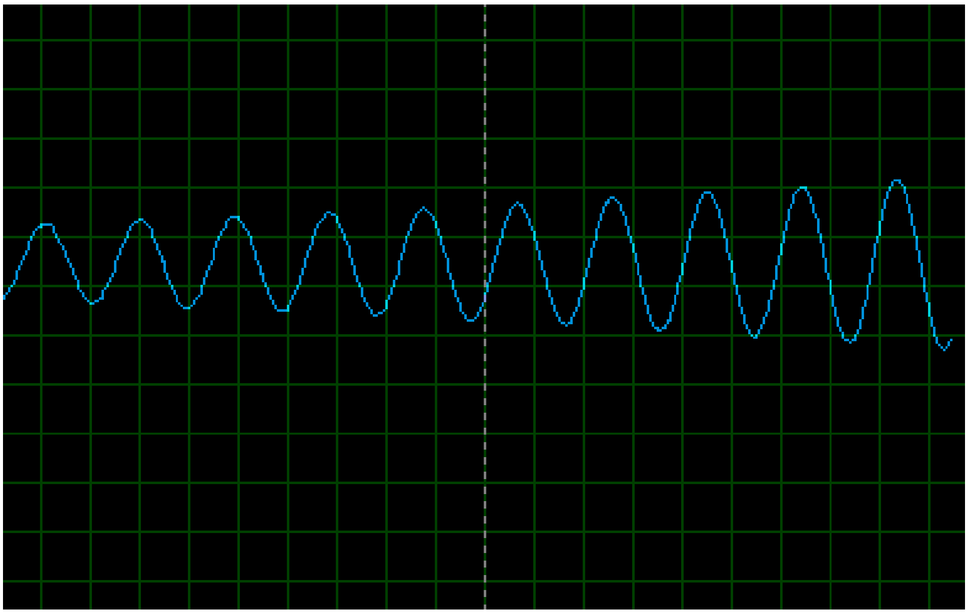


Figure 4.4 Simulated Output response of oscillator

Characteristics equation of figure 4.3 according to equation (8) expressed as

$$s^2C_1C_2 + s\left(G_3C_2 + G_3C_1 - G_2C_2\right) + G_2G_3 + G_3G_4 = 0 \qquad (9),$$

Where $G_i = \frac{1}{Ri}$

From characteristics equation (9) we find

1. The condition of oscillation (CO)

$$G_3C_2 + G_3C_1 = G_2C_2$$

2. The frequency of oscillation (FO)

$$\omega o = \sqrt{\frac{G_3(G_2+G_4)}{C_1C_2}} = 10.045\text{KHz}$$

It is observed that CO can be controlled through R_2 independently and FO can controlled by R_4.

Figure 3.3 and hardware components used in analysis of second order oscillator are stored in table 4.1.

Quantity	Part – Name	Value
	Resistance	
1	R1	15KΩ
1	R2	100Ω
1	R3	1KΩ
1	R4	10KΩ
	Capacitor	
1	C1	0.01uF
1	C2	10Uf
	Integrated Circuits	
2	U1,U2	AD844AP
	Miscellaneous	
2	B1,B2	5V
1	Function Generator	0 – 1MHz
1	CRO	

Table 4.2 List of used components used in design of OTRA based oscillator

Figure 4.5 Experimental result of OTRA based oscillator

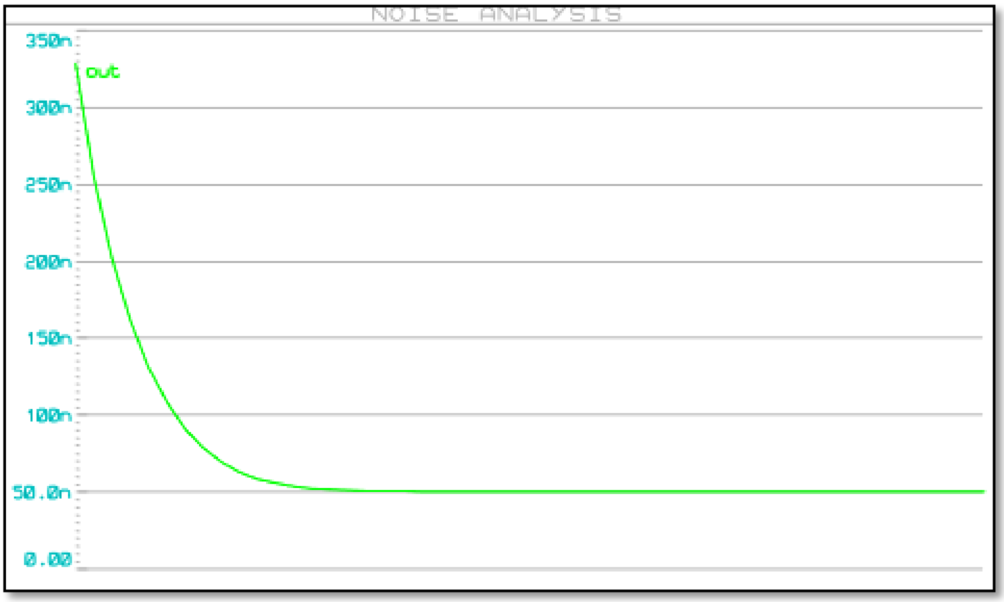


Figure 4.6 Output noise in OTRA based oscillator

To verified the theoretically known sinusoidal oscillator design for simulation using Proteous simulator shown in figure 4.3 The computed value of passive components for design circuit are shown in table 4.2. Simulated output of circuit are shown in figure 4.4

Design circuit verified experimentally using commercial available CFOA IC AD844AN to implement the OTRA.

CHAPTER - 5

OTRA BASED SECOND ORDER LOW PASS FILTER

5.1 INTRODUCTION

Analog designer got new boost in form of Operational Transresistance Amplifier because it is replace the current mode analog building block. Parasitic capacitance eliminated which are internally generated at input terminals. High slew rate and bandwidth are major strength of OTRA. In this chapter we will introduce single OTRA based analog filter.

5.2 Generalized circuit of OTRA based filter

Generalized structure of filter using admittance term shown in figure 4.1 [8]

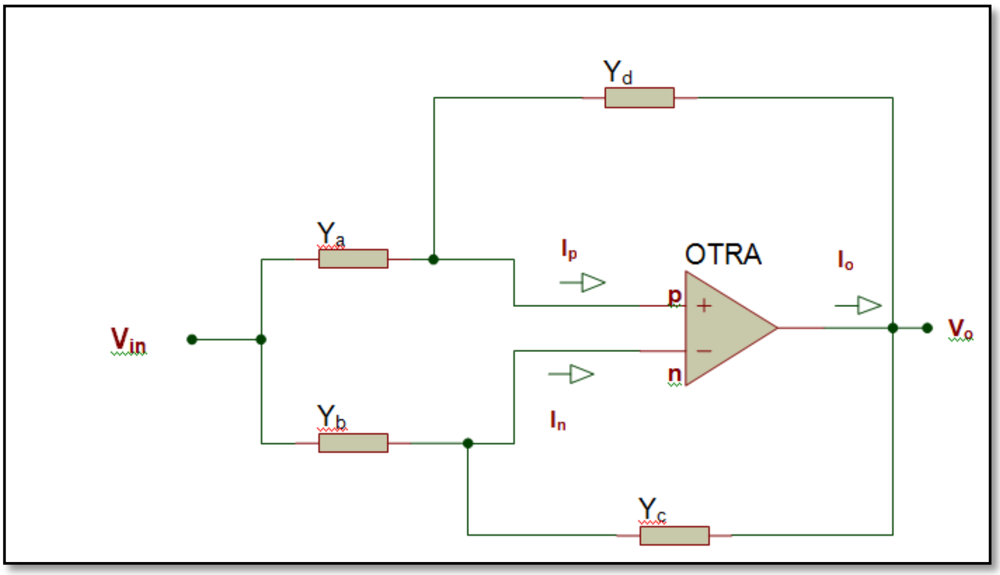


Figure 5.1 Generalized circuit of OTRA based filter [8]

Transfer function of proposed circuit is derived as

Current at positive terminal ip calculated with help of figure 5.1 as

$$i_p = V_{in} Y_a + V_o Y_d \qquad (1)$$

Current at negative terminal in calculated with help of figure 4.1 as

$$i_n = V_{in} Y_b + V_o Y_c \qquad (2)$$

Let's assuming that in ideal condition of OTRA, the amplifier voltage gain can by calculate by equating the current of positive (p) and negative (n) terminal, that is

$$i_p = i_n \tag{3}$$

$$V_{in} Y_a + V_o Y_d = V_{in} Y_b + V_o Y_c \tag{4}$$

Transfer function of OTRA based filter given by

$$T(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{Y_a - Y_b}{Y_c - Y_d} \tag{5}$$

There is Y_a, Y_b, Y_c and Y_d are admittance function of passive elements.

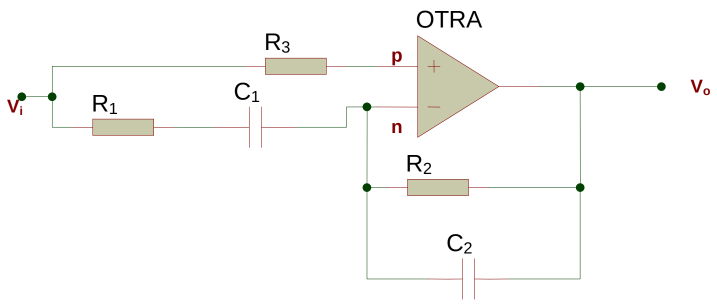


Figure 5.2 Single OTRA based low pass filter [5]

By using equation (5) we derived transfer function of circuit given in figure 5.2

$$Y_a = \frac{1}{R_3} \tag{6}$$

$$Y_b = \frac{sC_1}{1 + sR_1C_1} \tag{7}$$

$$Y_c = \frac{1 + sR_2C_2}{R_2} \tag{8}$$

$$Y_d = 0 \tag{9}$$

$$T(s) = \frac{1 + sR_1R_2C_1 - sR_2R_3C_1}{s^2R_1R_2C_1C_2 + s(R_1R_3C_1 + R_2R_3C_2) + R_3} \tag{9}$$

Rearranged equation after putting $R_1=R_2=R_3=R$ and $C_1=C_2=C$

$$T(s) = \frac{\frac{1}{R^2C^2}}{s^2 + \frac{2s}{CR} + \frac{1}{R^2C^2}} \tag{10}$$

5.3 SIMULATION AND HARDWARE RESULTS

OTRA based second order filter could be design with help of AD844AP (CFOA), and its performance can be analysis using Proteus ISIS Professional simulation software. Simulation verified by practically also. Details of used component for hardware and simulation implementation given in table 5.1.

Quantity	Part – Name	Value
 3 1	Resistance R_1 - R_3 R_4	 1KΩ 25KΩ
 2	Capacitor C_1, C_2	 0.001uF
 2	Integrated Circuits U_1,U_2	 AD844AP
 2	Miscellaneous B_1,B_2	 15V
1	Function Generator	0 – 1MHz
1	CRO	

Table 5.1 List of used component for OTRA based filter designing

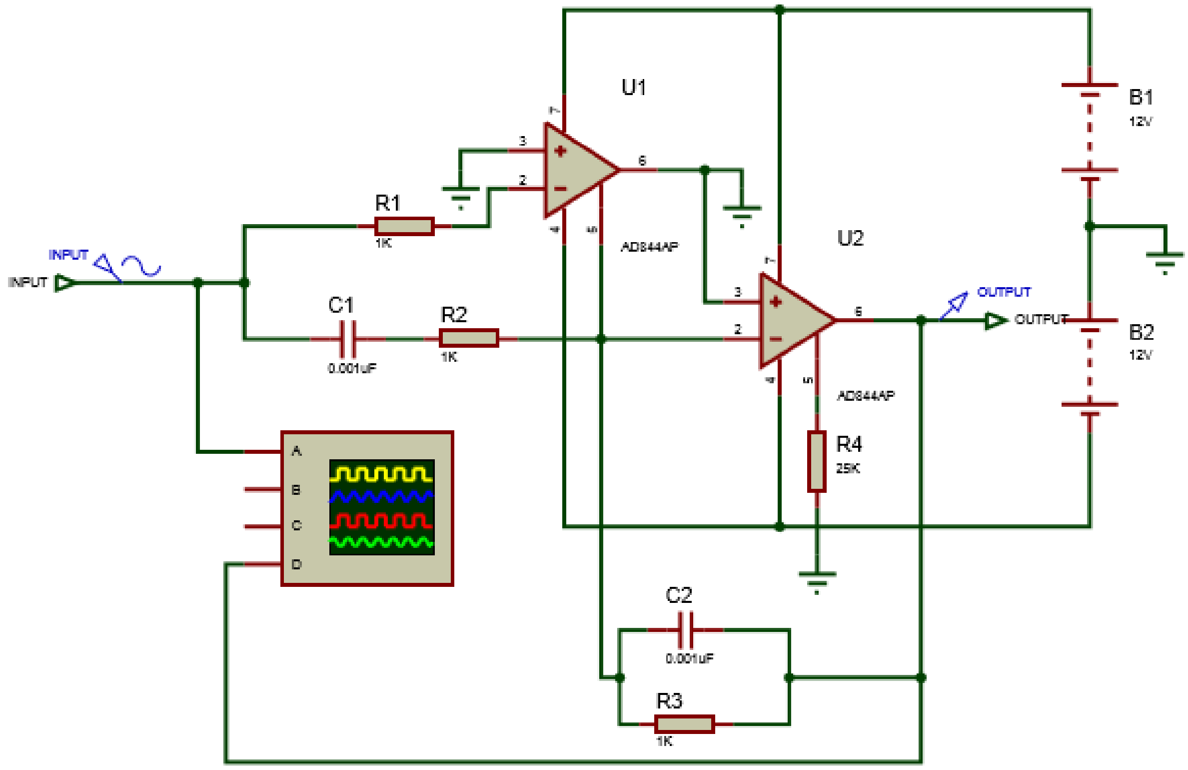


Figure 5.3 Simulation circuit of OTRA based second order filter

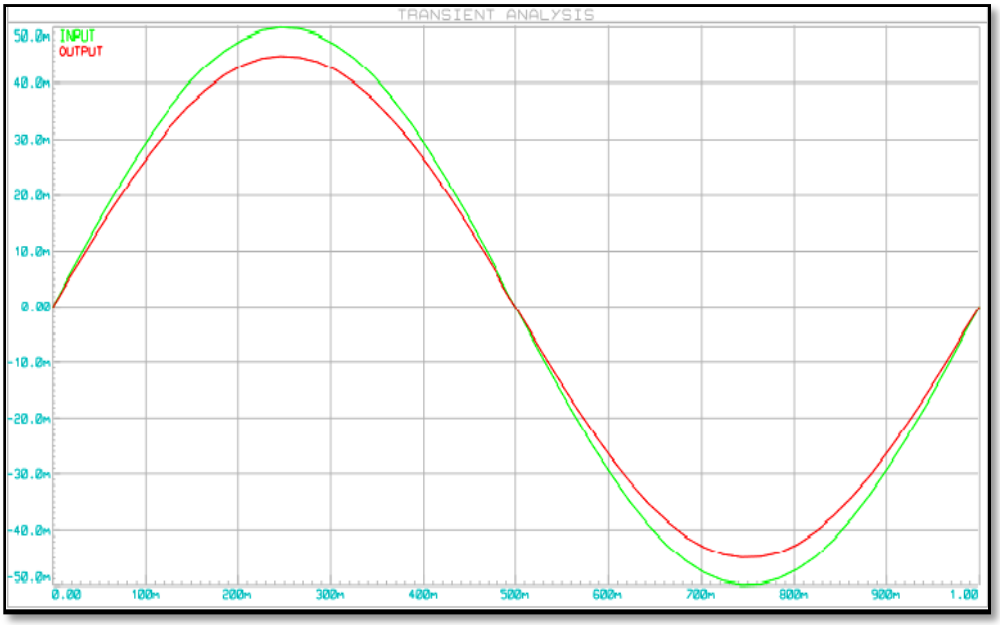


Figure 5.4 Time domain Input – Output response of OTRA based LPF

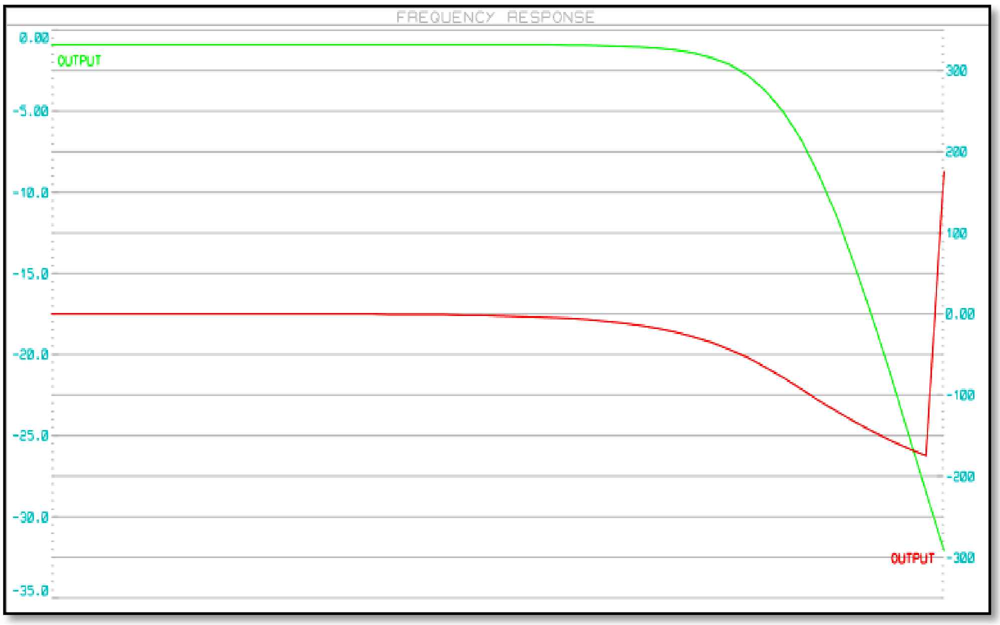


Figure 5.5 Frequency and Phase response of OTRA based LPF

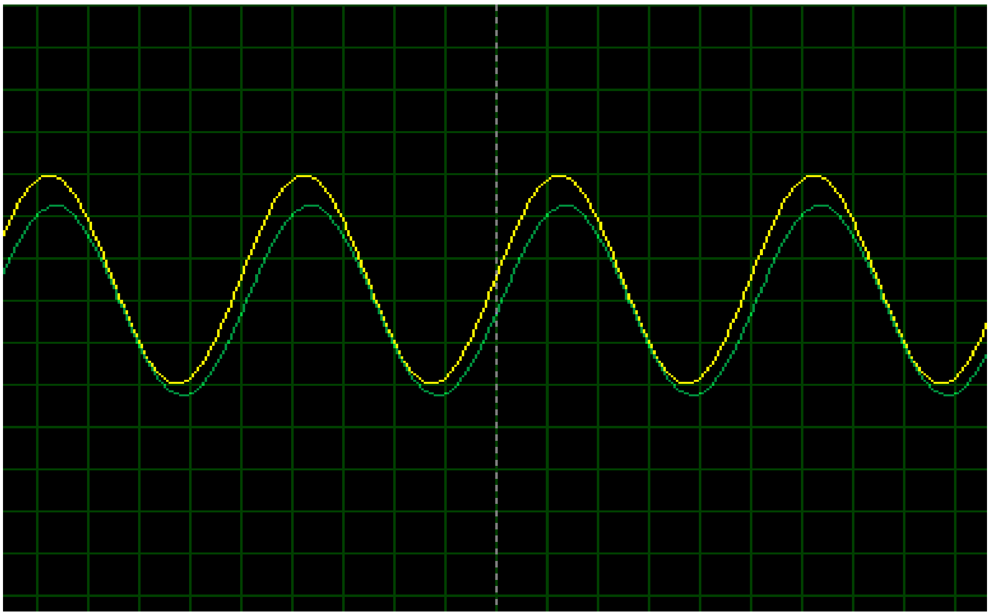


Figure 5.6 Simulated Input – Output response

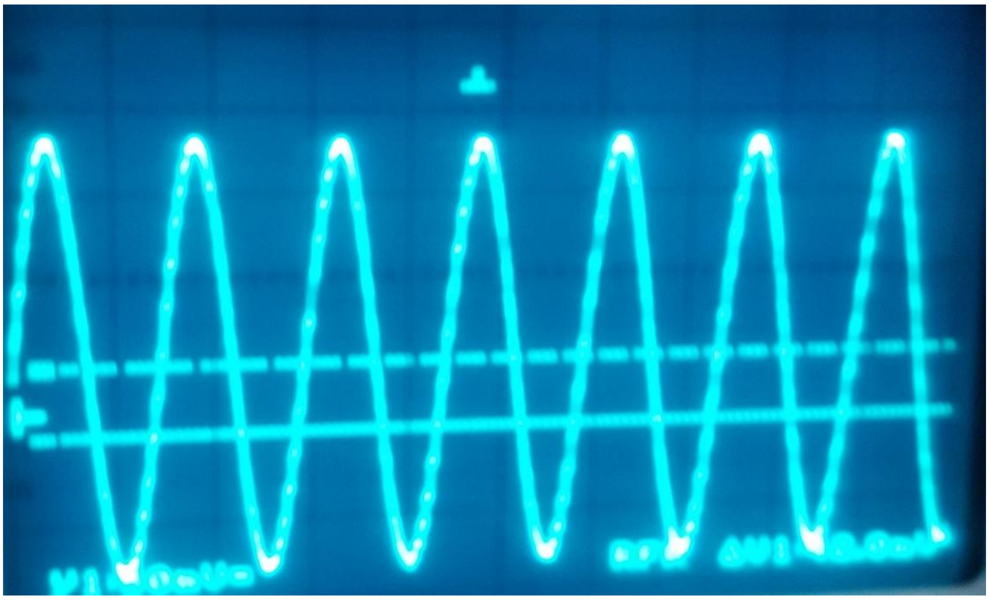


Figure 5.7 experimental result

The second order LPF can be design and make electronically tuneable by implementing commercial available CFOA IC AD844AN for OTRA. The LPF of figure 5.2. May be design by

$$\omega_n = \frac{1}{RC}, \text{ב} = 1$$

And

$$\frac{\omega_n}{Q} = \frac{2}{CR}$$

Where Q = is Q factor of LPF.

The LPF is design for $\omega_n = 1MHz \; and \; \text{ב} = 1$, with reference of this the passive component values computed for capacitance as $C_1 = C_2 = 0.001uF$ and resistances are computed as $R_1=R_2=R_3 = 1K\Omega$.

The frequency /phase response is shown in figure 5.5. For the time domain transient analysis shown in figure 5.4.

CHAPTER – 6

OTRA BASED CONVENTIONAL CONTROLLERS

6.1 INTRODUCTION

The operational condition of any system and dynamical system could observe and rectify by using a controller. Operational condition of any system related to as measured output variables and can be change by adjusting certain input variables. Controller action depends on the difference between measured output variables and set point, it called error. Controller tries to minimize the error value by adjusting the process control inputs.

Controller classified as:-

1. Conventional controller
   Example of conventional controller are Proportional (P), Proportional derivative (PD), Proportional integral (PI), Proportional derivative and integral(PID) controllers.
2. Non conventional controller
   Example of Non conventional controller are Neuro, Fuzzy controllers.

The conventional controllers are mostly used in the process industries. PID controller algorithm are popularly used, proper tuning of controller parameters. The proportional, derivative and integral of the error signal E(s) are summed up to calculate the output actuating signal U(s) of the controller.

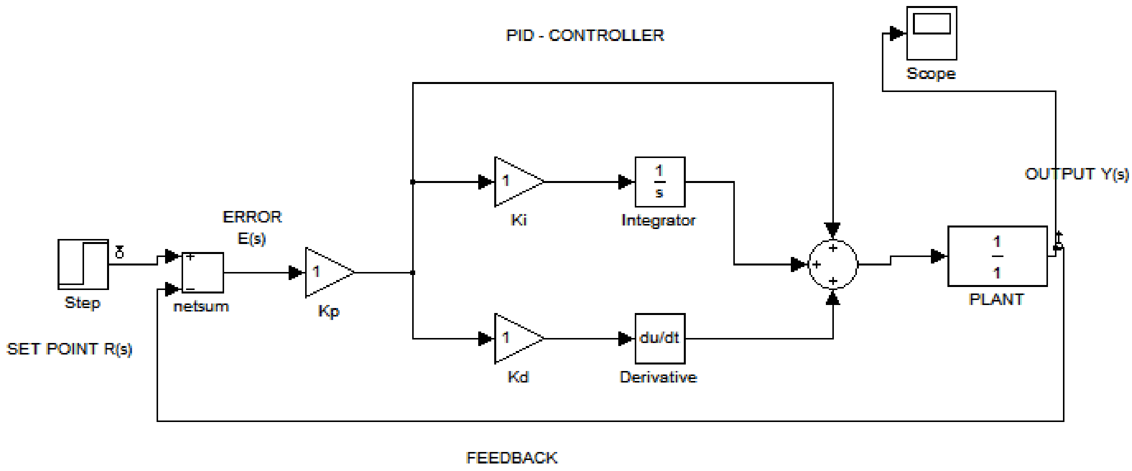


Figure 6.1 Basic architecture of PID - Controller

The transfer function of PID controller can be written as

$$G_{pid}(s) = \frac{U(s)}{E(s)} = K_p + \frac{K_i}{s} + K_d s$$

Where

K_p, K_d, and K_i are the proportional, derivative and integral constants respectively.

Case-1

The transfer function of proportional controller given by

$$G_p(s) = \frac{U(s)}{E(s)} = K_p$$

The transfer function of proportional controller in control system given by

$$T_p(s) = \frac{K_p \omega_n^2}{s^2 + 2\xi\omega_n s + K_p \omega_n^2}$$

Case- II

$G_{pi}(s)$ transfer function of the PI controller given by

$$G_{pi}(s) = \frac{U(s)}{E(s)} = K_p + \frac{K_i}{s}$$

Closed loop transfer given by

$$Tp(s) = \frac{\left(K_i + sK_p\right)\omega_n^2}{s^3 + 2\xi\omega_n s^2 + (K_i + sK_p)\omega_n^2}$$

Case – III

$G_{pd}(s)$ transfer function of the PD controller in control system given by

$$G_{pd}(s) = \frac{U(s)}{E(s)} = K_p + sK_d$$

Closed loop transfer given by

$$T_{pd}(s) = \frac{\left(K_p + sK_d\right)\omega_n^2}{s^2 + (2\xi\omega_n + K_d\omega_n^2)s^1 + K_p\omega_n^2}$$

6.2 OTRA BASED PROPORTIONAL CONTOLLER

The OTRA based (using TWO CFOA ICs AD844AN) P-Controller is shown in Figure 6.2 [4, 5].Its transfer function derived as

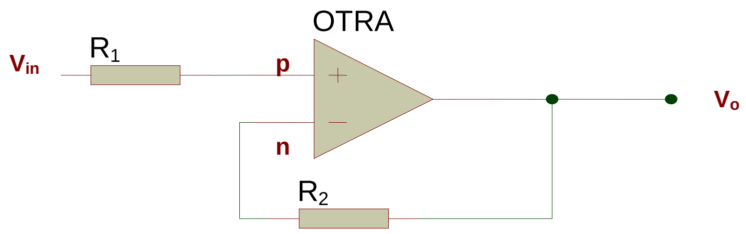


Figure 6.2 OTRA based P – Controller [4, 5]

The current at positive terminal (p) derived as

$$i_p = \frac{V_{in}}{R_1} \qquad (1)$$

The current at negative terminal (n) derived as

$$i_n = \frac{V_o}{R_2} \qquad (2)$$

Let's assuming that in ideal condition of OTRA, the amplifier voltage gain can by calculate by equating the current of positive (p) and negative (n) terminal, that is

$$i_p = i_n \qquad (3)$$

$$\frac{V_{in}}{R_1} = \frac{V_o}{R_2} \qquad (4)$$

$$\frac{V_o}{V_{in}} = \frac{R_2}{R_1} = \text{constant} = K_p \qquad (5)$$

Transfer function of OTRA based P controller is

$$G_p(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{R_2}{R_1} \qquad (6)$$

The controller parameter K_p can be tuned by changing either R_1 or R_2 or both.

6.2.1 SIMULATION RESULTS

The proposed P – Controller shown in figure 6.2 [4, 5]. Simulation circuit of OTRA based P – controller design with reference of table 6.1. The simulation of P –Controller shown in figure 6.3, by choose value of passive component as R_1=10KΩ and R_2 = 20KΩ. For resulting parameter of P - Controller Kp=2.

Quantity	Part – Name	Value
 1 1	Resistance R_2 R_3	 10KΩ 3MΩ
1	Variable resistor R_{VP}	100K
2	Integrated Circuits U_1,U_2	AD844AP
2	Miscellaneous B_1,B_2	15V
1	Function Generator	0 – 1MHz
1	CRO	

Table 6.1 List of computed passive component used to design OTRA based P - Controller

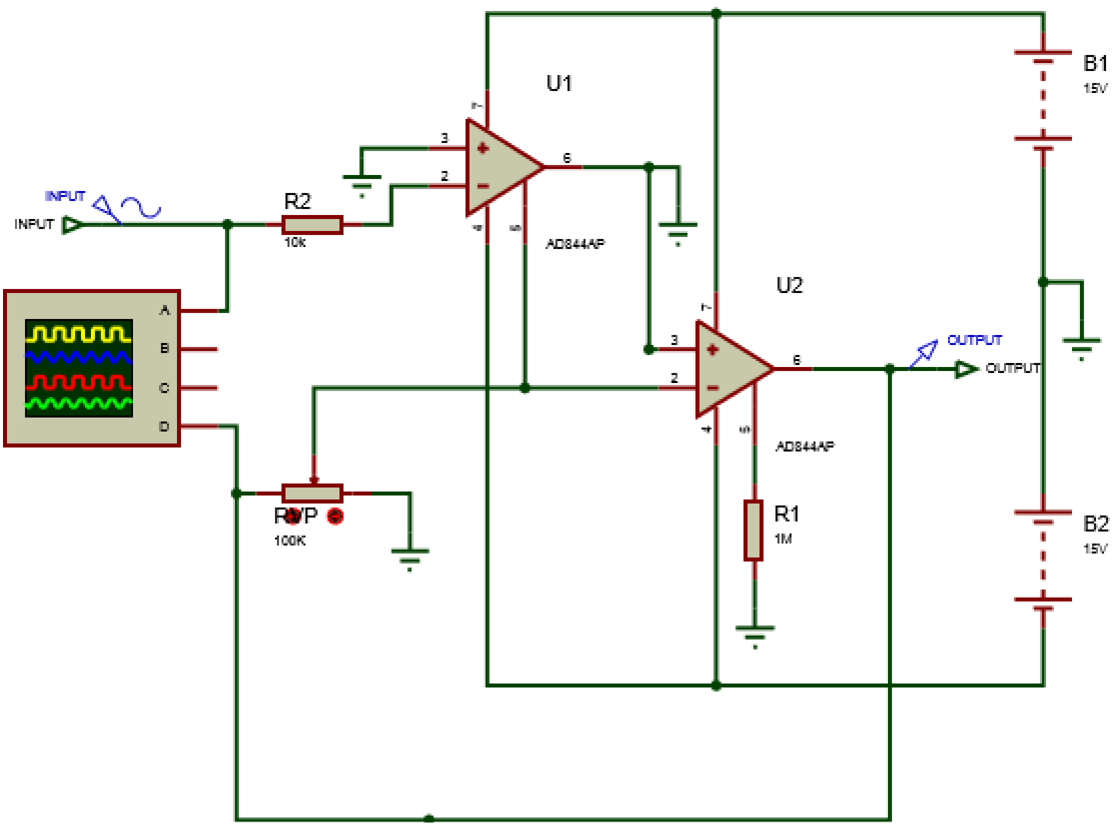


Figure 6.3 Simulation circuit of OTRA based P – Controller

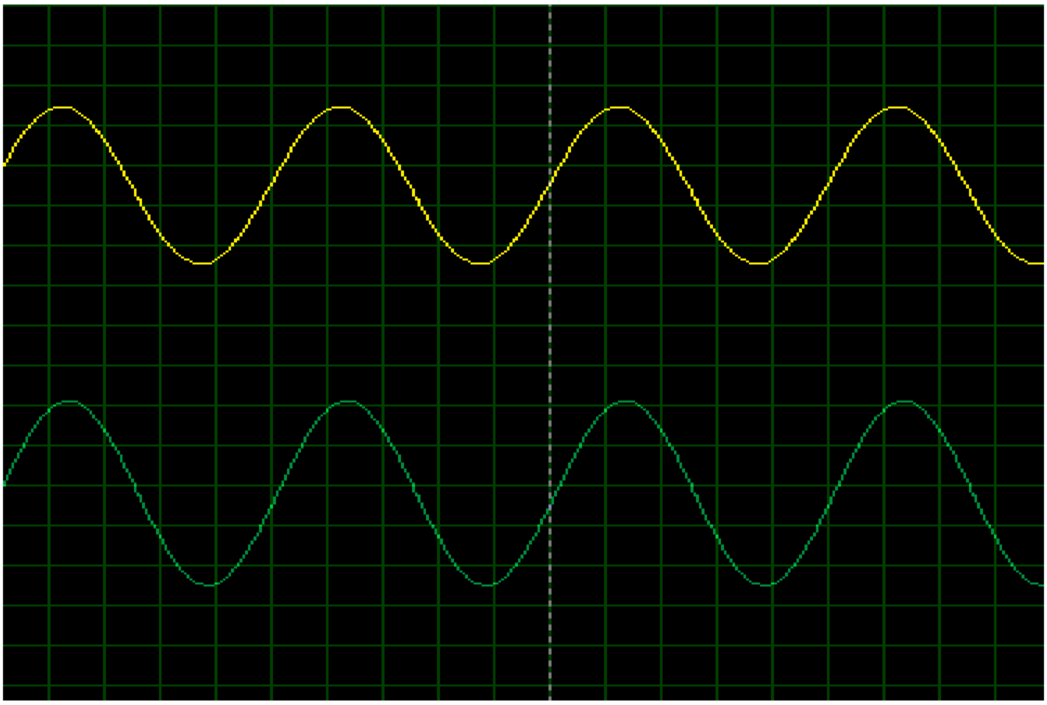


Figure 6.4 Simulated Input – Output response

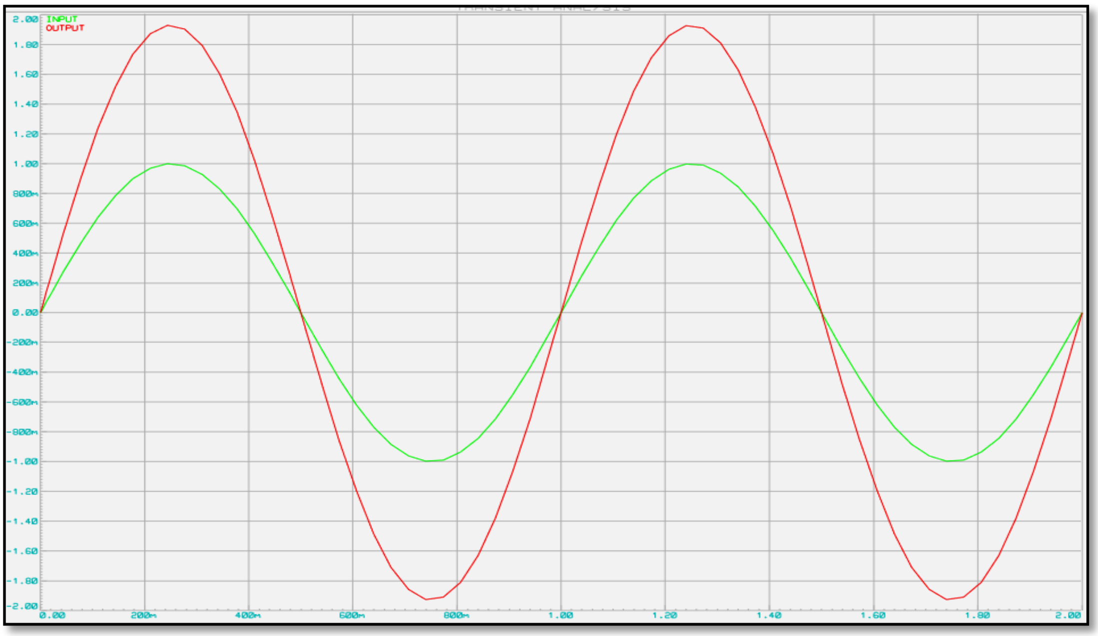


Figure 6.5 Transient response of P - Controller

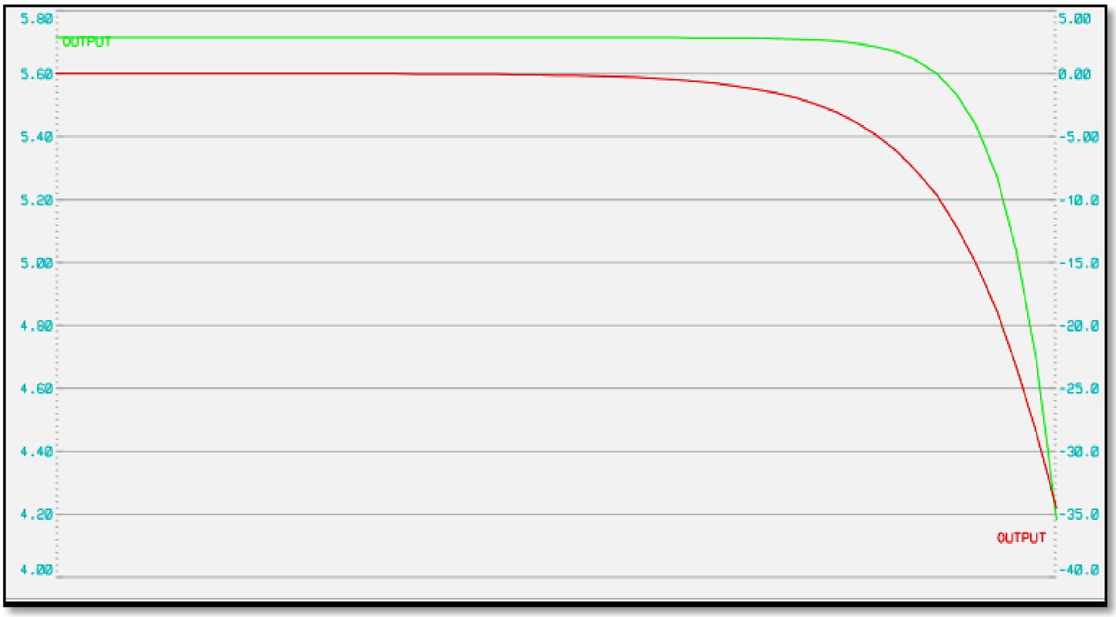


Figure 6.6 Frequency and Phase response of P – Controller

The OTRA based P – Controller simulated time domain and frequency domain responses shown in figures 6.5 and 6.6 respectively.

For electronic tunability feature we get transfer characteristics by keeping R_1 constant and R_2 varied.

6.3 OTRA BASED PROPORTIONAL, INTEGRAL CONTROLLER

The OTRA based (using TWO CFOA ICs AD844AN) PI-Controller is shown in Figure 6.7 [4, 5].Its transfer function derived as

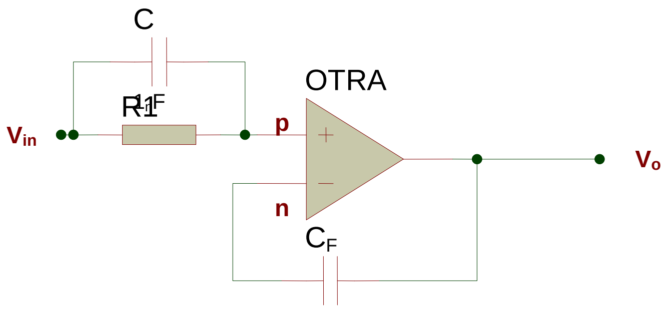


Figure 6.7 OTRA based PI – Controller [4, 5]

The current at positive terminal (p) derived as

$$i_p = \frac{V_{in}}{R_1} \ (1 + R_1 Cs) \qquad (7)$$

The current at positive terminal (p) derived as

$$i_n = V_o C_f s \qquad (8)$$

Let's assuming that in ideal condition of OTRA, the amplifier voltage gain can by calculate by equating the current of positive (p) and negative (n) terminal, that is

$$i_p = i_n \qquad (9)$$

$$\frac{V_{in}}{R_1} \ (1 + R_1 Cs) = V_o C_f s \qquad (10)$$

$$\frac{V_o}{V_{in}} = \frac{1 + R_1 Cs}{R_1 C_f s} = \frac{C}{C_f} + \frac{1}{R_1 C_f s} \qquad (11)$$

Derived transfer function of OTRA based PI – controller is given by

$$G_{pi}(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{1 + R_1 Cs}{R_1 C_f s} = \frac{C}{C_f} + \frac{1}{R_1 C_f s} \qquad (12)$$

There is

$$K_p = \frac{C}{C_f}, \qquad K_i = \frac{1}{R_1 C_f}$$

K_p and K_i values may adjusted independently by varying C and R_1 respectively.

5.4.1 SIMULATION RESULTS

The passive component values for simulation of proposed PI – Controller shown in figure 6.8 computed as R_1=10K – 1MΩ, R_2 = 50KΩ, R_4 = 50KΩ, C_1=10uF and C_3 = 5uF to compute the parameter K_p and K_i.

Quantity	Part – Name	Value
	Resistance	
1	R_3	20KΩ
	Variable Resistor	
1	R_{V1}	100K
1	R_{V2}	1K
	Capacitor	
1	C_1	0.1uF
1	C_2	0.5uF
	Integrated Circuits	
2	U_1,U_2	AD844AP
	Miscellaneous	
2	B_1,B_2	15V
1	Function Generator	0 – 1MHz
1	CRO	

Table 6.2 List of required apparatus and components for OTRA based PI - Controller

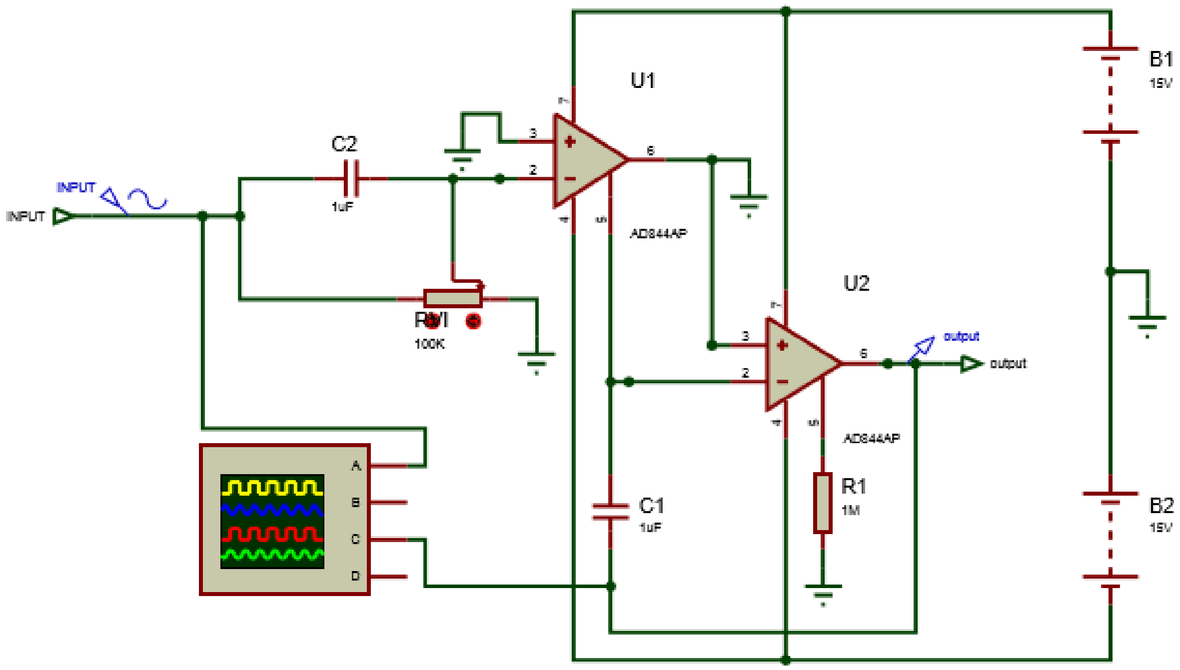


Figure 6.8 Simulation circuit of PI – Controller

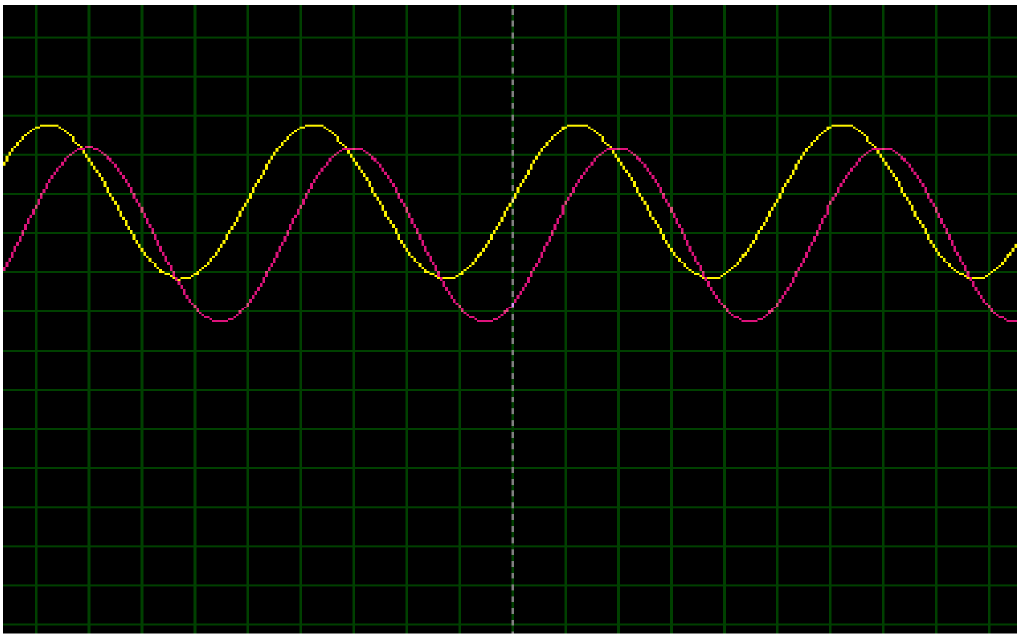


Figure 6.9 Simulated Input – Output response of PI - Controller

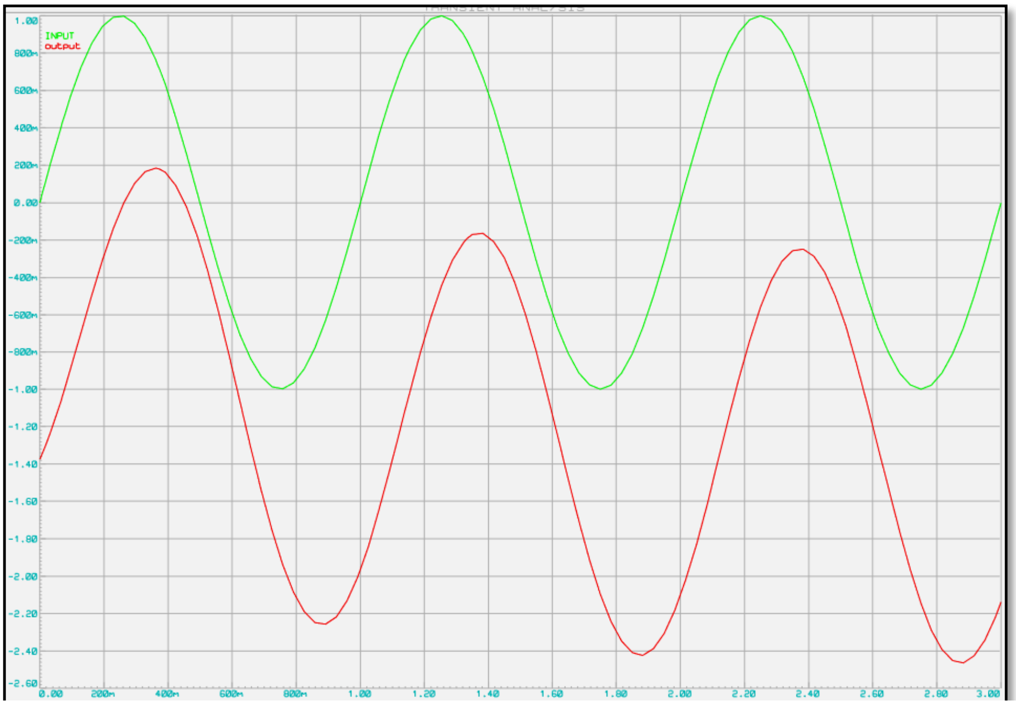


Figure 6.10 Time domain response of PI - Controller

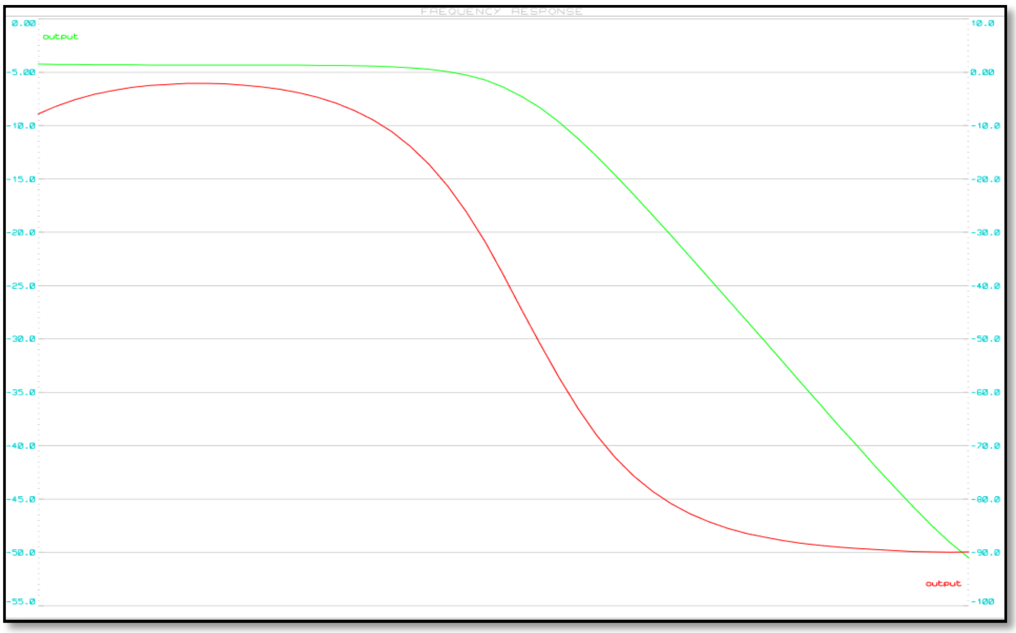


Figure 6.11 Frequency and Phase response PI - Controller

The simulated frequency response shown in figure 6.11 and transient response depicted in figure 6.10.

6.4 OTRA BASED PROPORTIONAL, DERIVATIVE CONTROLLER

The OTRA based (using Two CFOA ICs AD844AN) PD-Controller circuit diagram is shown in Figure 6.12 [4, 5]. Transfer function of given circuit is derived as

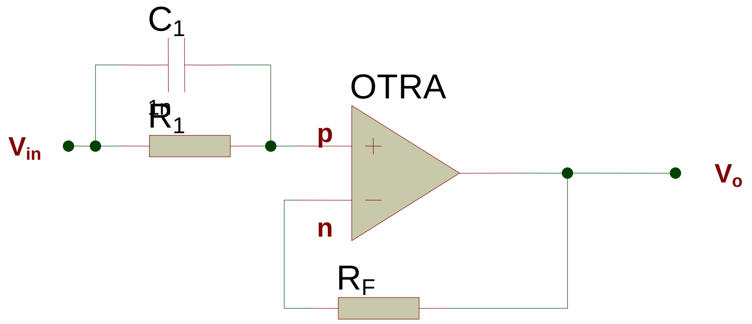


Figure 6.12 OTRA based PD – Controller [4, 5]

The current at positive terminal (p) derived as

$$i_p = \frac{V_{in}}{R_1}\ (1 + R_1 Cs) \qquad (13)$$

The current at negative terminal (n) derived as

$$i_n = \frac{V_o}{R_f} \qquad (14)$$

Let’s assuming that in ideal condition of OTRA, the amplifier voltage gain can by calculate by equating the current of positive (p) and negative (n) terminal, that is

$$i_p = i_n \qquad (15)$$

$$\frac{V_{in}}{R_1}\ (1 + R_1 Cs) = \frac{V_o}{R_f} \qquad (16)$$

$$R_f \frac{(1 + R_1 Cs)}{R_1} = \frac{V_o}{V_{in}} \qquad (17)$$

$$\frac{V_o}{V_{in}} = \frac{R_f}{R_1} + R_f Cs \qquad (18)$$

Derived transfer function of OTRA based PI – controller is given by

$$G_{pd}(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{Rf}{R1} + RfCs \qquad (19)$$

There is

$$K_p = \frac{R_f}{R_1}, \qquad K_d = CR_f$$

By varying values of R_1 and R_f, parameter K_p and K_d are tuned respectively.

6.4.1 SIMULATION RESULTS

Passive component values and requirement to design simulated circuit of PID – Controller are stored in table 6.3.

Quantity	Part – Name	Value
 1 1	Variable Resistance RVP RVD	 100KΩ 100KΩ
1	Capacitor C1	0.05uf
2	Integrated Circuits U1,U2	AD844AP
2	Miscellaneous B1,B2	12V
1	Function Generator	0 – 1MHz
1	CRO	

Table 6.3 List of required apparatus and component to design OTRA based PD - Controller

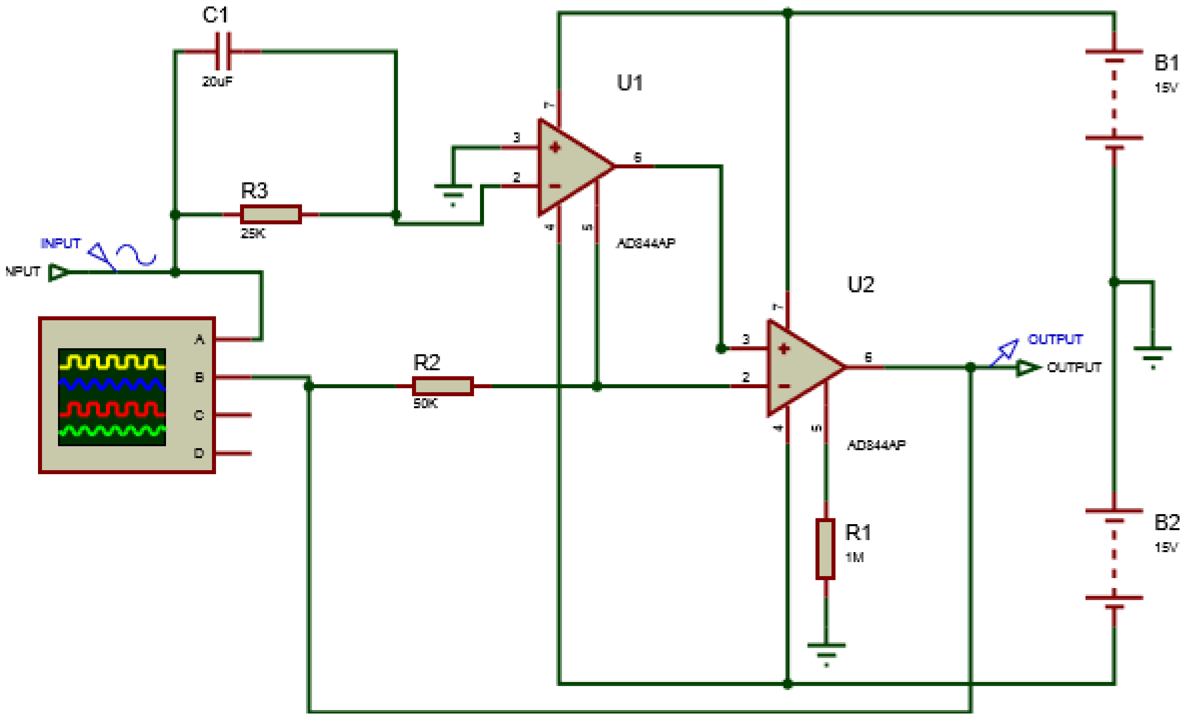


Figure 6.13 Simulation circuit of PD - Controller

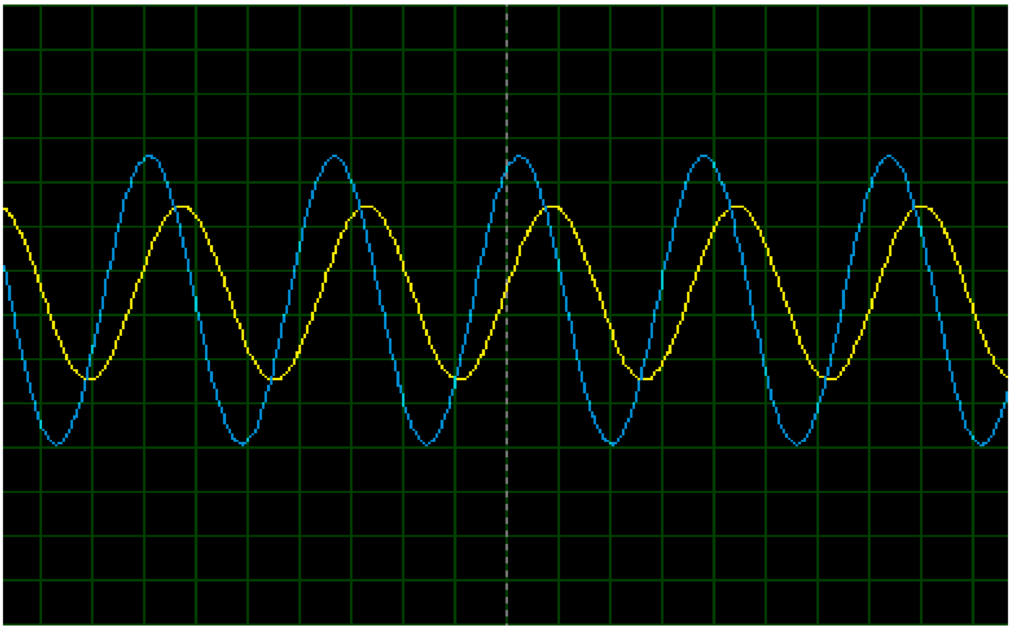


Figure 6.14 Simulated Input – Output response of PD - Controller

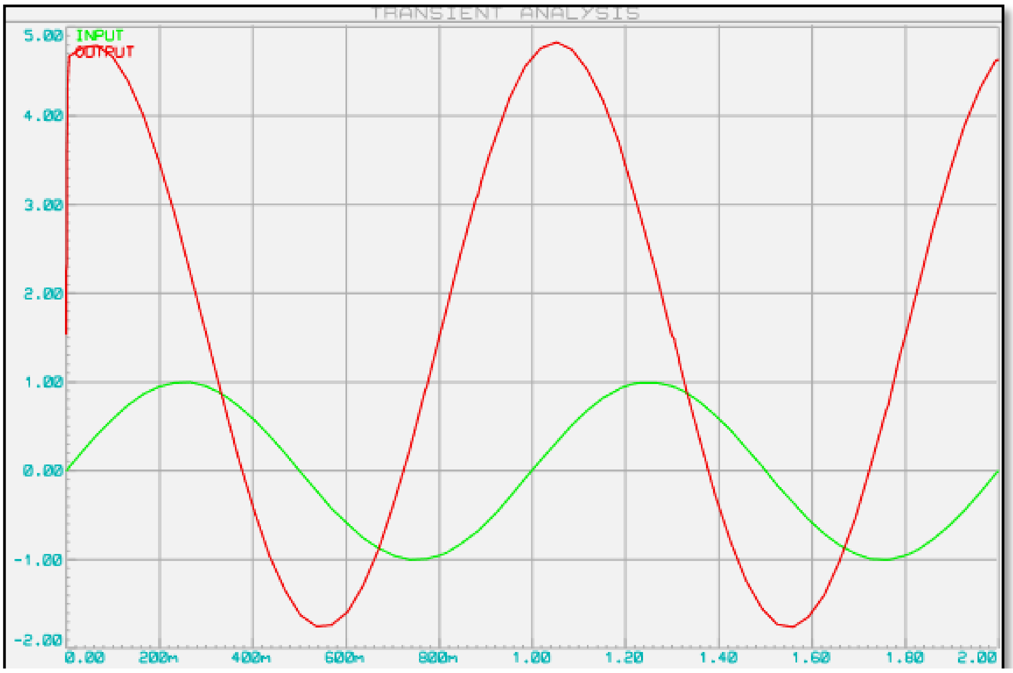


Figure 6.15 Transient response of PD - Controller

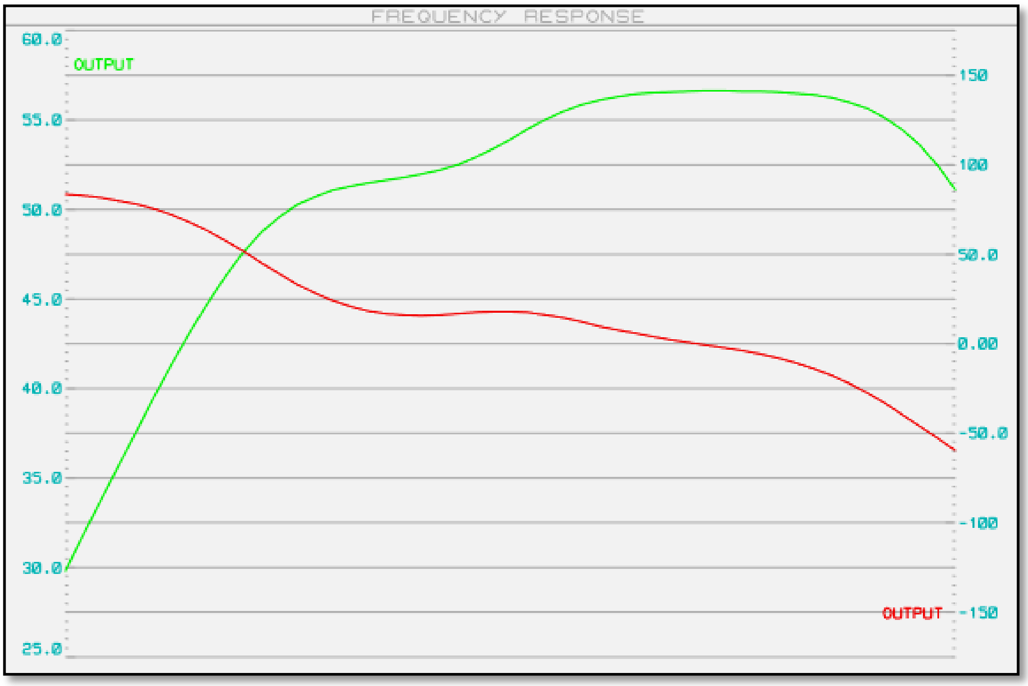


Figure 6.16 Frequency and Phase response of PD – Controller

The values of passive component used for proposed PD – Controller are computed as R_1=1KΩ, R_f = 10KΩ and C= 0.06uF, according to required parameters K_p = 10 and K_d =6 The transient and frequency response of PD – Controller depicted in figure 5.15 and 5.16 respectively.

6.5 OTRA BASED PROPORTIONAL INTEGRAL AND DERIVATIVE CONTROLLER (PID – Controller)

Figure 6.17 [4, 5] shown the circuit diagram of OTRA based PID – Controller. Transfer function of said circuit diagram expressed as

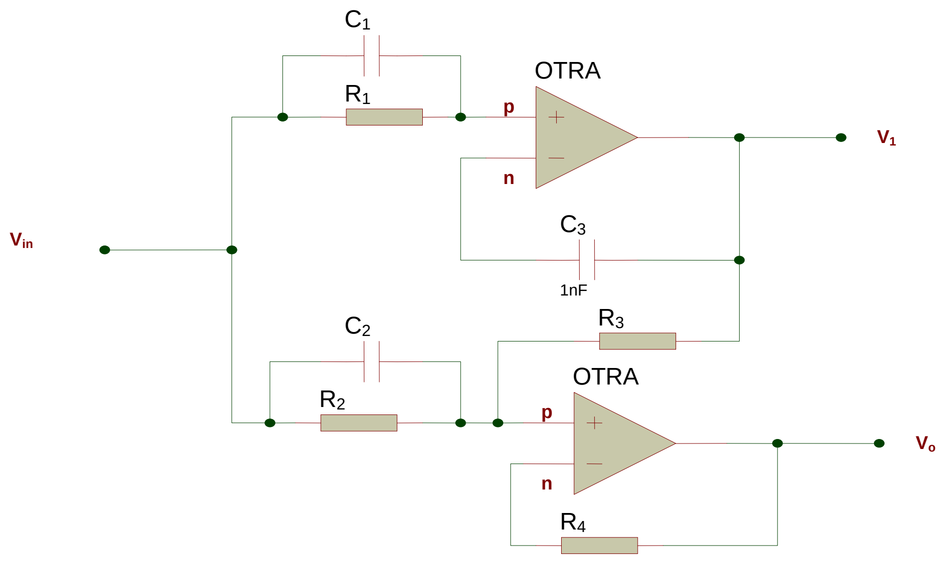


Figure 6.17 OTRA based PID – Controller [4, 5]

The current at positive terminal (p_1) at Figure 6.17

$$i_{p1} = \frac{V_{in}}{R_1}\ (1 + R_1C_1s) \qquad (20)$$

The current at negative terminal (n_1) at Figure 6.17

$$i_{n1} = V_1 C_3 s \qquad (21)$$

The current at positive terminal (p_2) at Figure 6.17

$$i_{p2} = i_2 - i_{10} \qquad (22)$$

$$i_{p2} = \frac{V_{in}}{R_2}\ (1 + R_2 C_2 s) + \frac{V_1}{R_3} \qquad (23)$$

The current at negative terminal (n_2) at Figure 6.17

$$i_{n2} = \frac{V_o}{R_4} \qquad (24)$$

In ideal case of OTRA, we find voltage gain of amplifier by equating the i_p=i_n

$$i_{p1} = i_{n1} \qquad (25)$$

$$\frac{V_{in}}{R_1}\ (1 + sR_1 C_1)\ = sV_1 C_3 \qquad (26)$$

$$V_1 = \frac{V_{in}}{R_1 C_3 s}\ (1 + sR_1 C_1) \qquad (27)$$

And

$$\frac{V_{in}}{R_2}\ (1 + R_2 C_2 s) + \frac{V_1}{R_3}\ = \frac{V_o}{R_4} \qquad (28)$$

$$\frac{V_1}{R_3} = \frac{V_o}{R_4}\ - \frac{V_{in}}{R_2}\ (1 + R_2 C_2 s) \qquad (29)$$

$$V_1 = \frac{V_o}{R_4}\ R_3\ - \frac{V_{in}}{R_2}\ R_3\ (1 + R_2 C_2 s) \qquad (30)$$

By using equation (27) and (30) we find

$$\frac{V_{in}}{R_1 C_3 s}\ (1 + sR_1C_1)\ = V_1 = \frac{V_o}{R_4}\ R_3\ - \frac{V_{in}}{R_2}\ R_3\ (1 + R_2C_2s) \qquad (31)$$

Transfer function of PID – Controller is

$$G_{pid}\,(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{R_4}{R_2} + \frac{R_4C_1}{R_3C_3} + \frac{R_4}{sR_1R_3C_3} + sR_4C_2 \qquad (32)$$

There is

$$K_p = \frac{R_4}{R_2} + \frac{R_4C_1}{R_3C_3}$$

$$K_i = \frac{R_4}{sR_1R_3C_3}$$

$$K_d = sR_4C_2$$

Proposed controllers	K_P	K_I	K_D
P	$\frac{R_2}{R_1}$		
PI	$\frac{C}{C_F}$	$\frac{1}{R_1C_F}$	
PD	$\frac{R_F}{R_1}$		R_FC
PID	$\frac{R_4}{R_2} + \frac{R_4C_1}{R_3C_3}$	$\frac{R_4}{R_1R_3C_3}$	R_4C_2

Table 6.4 List of computed parameter of conventional controller indicator shows variable for tuning

6.1 SIMULATION RESULTS

Quantity	Part – Name	Value
	Resistance	
1	R1	50KΩ
1	R2	625Ω
1	R3	5K
1	R4	1.8M
1	R5	1M
1	R6	3M
	Variable Resistor	
1	RV1	1K
1	RVI	1M
1	RVP	100K
1	RVD	1M
	Capacitor	
1	C1	0.1Uf
1	C2	1uF
1	C3	0.5uF
	Integrated Circuits	
2	U1,U2	AD844AP
	Miscellaneous	
2	B1,B2	12V
1	Function Generator	0 – 1MHz
1	CRO	
1	Switch	SW – SPDT

Table 6.5 List of used element in design of OTRA based PID - Controller

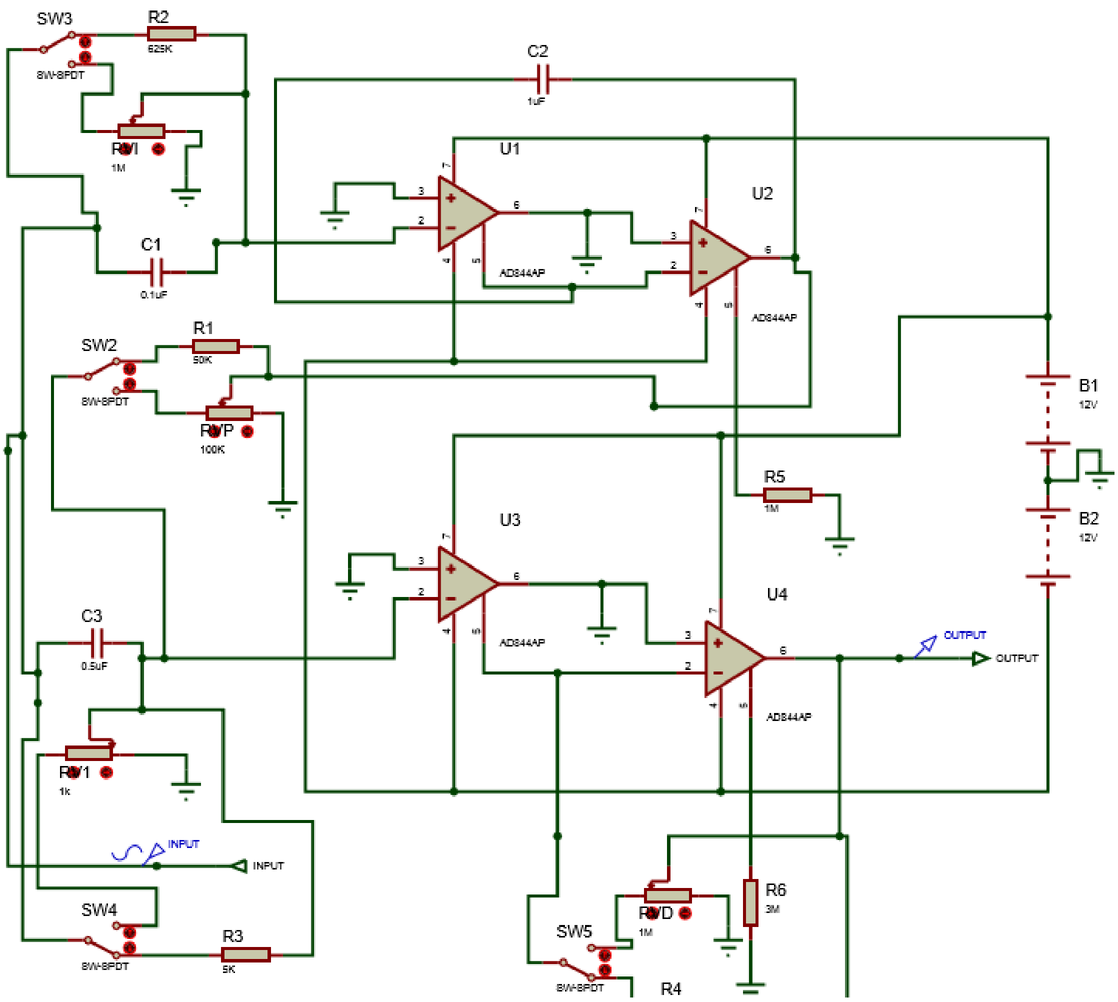


Figure 6.18 Simulation circuit of PID - Controller

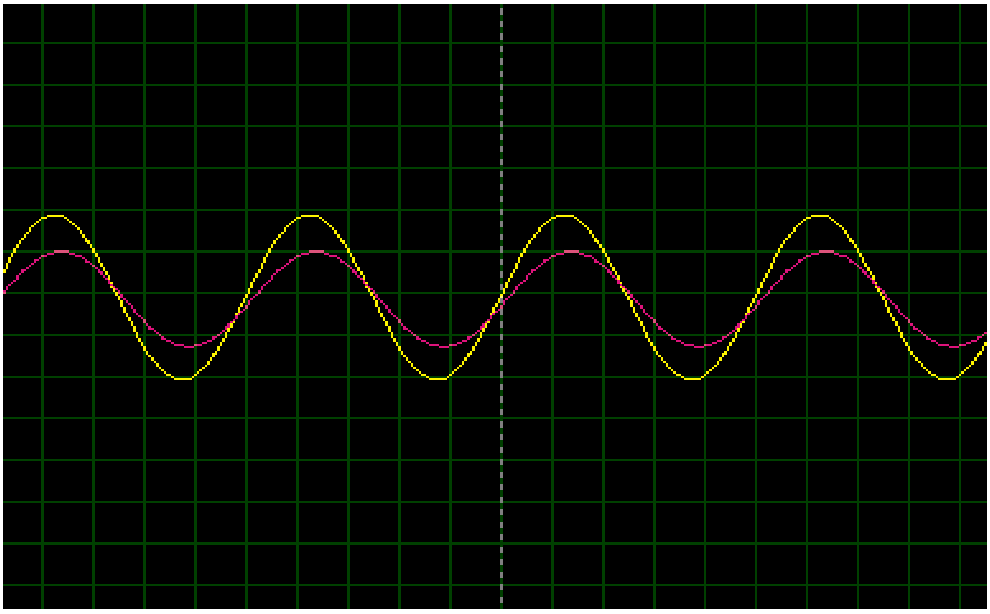


Figure 6.19 Simulated Input – Output response of PID - Controller

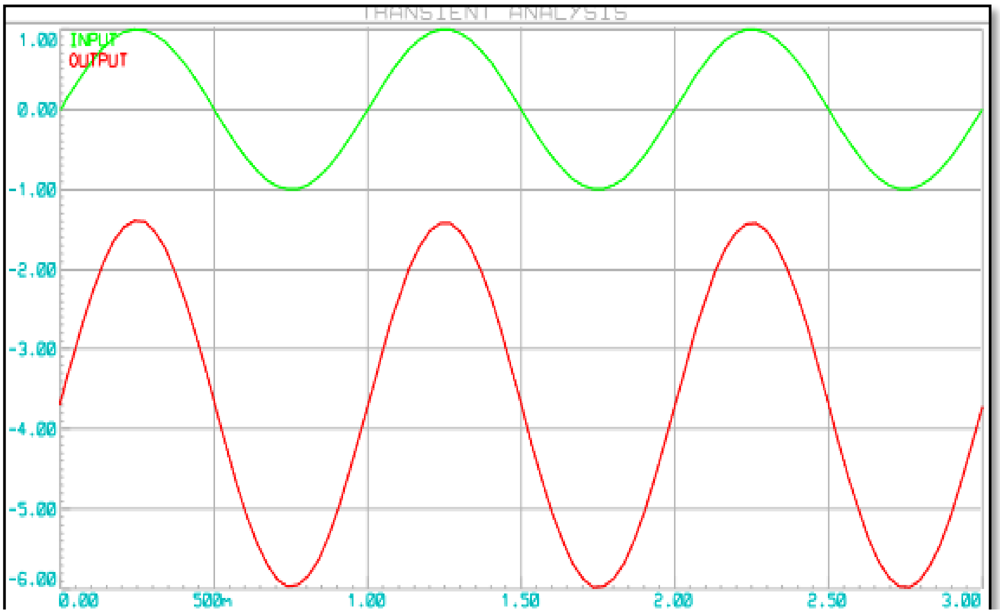


Figure 6.20 Time domain response PID - Controller

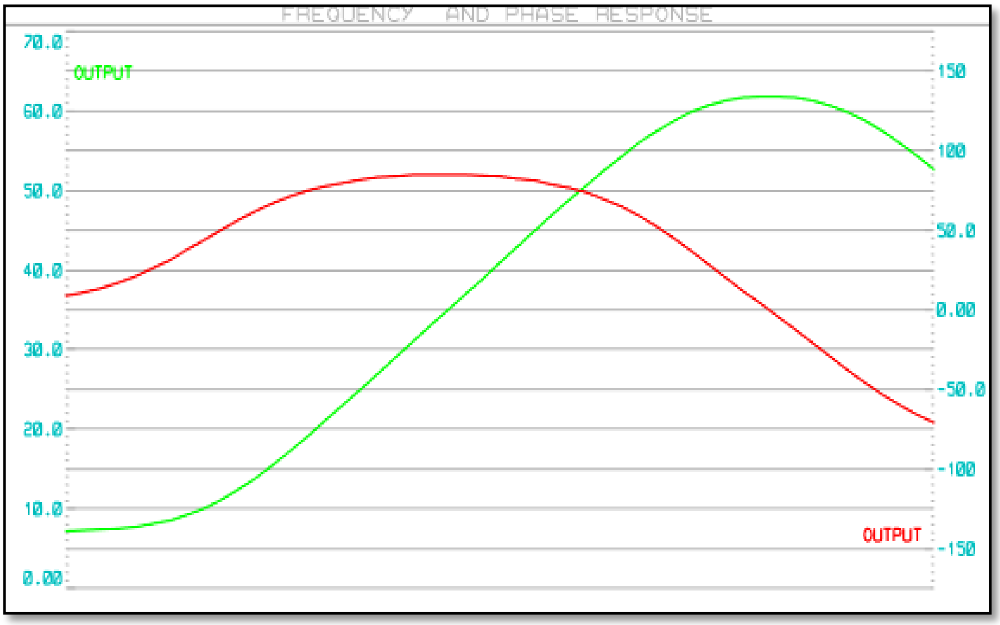


Figure 6.21 Frequency and Phase response of PID - Controller

6.16 PERFORMANCE EVALUATION OF OTRA BASED CONTROLLERS

The performance of controllers and their effect on third order plant (turbine) is analyzed by using closed loop system. The transfer function of the turbine is given by

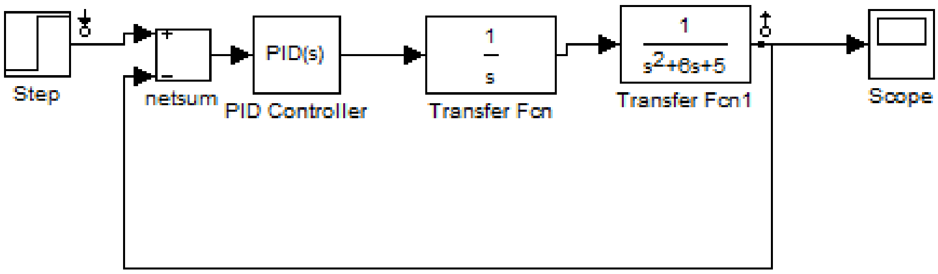


Figure 6.22 Closed – loop system

$$Gp(s) = \frac{1}{s(s+1)(s+5)}$$

The step response of the open loop third order system study and calculate the effect of various controller by realising thea closed loop system figure 6.22.

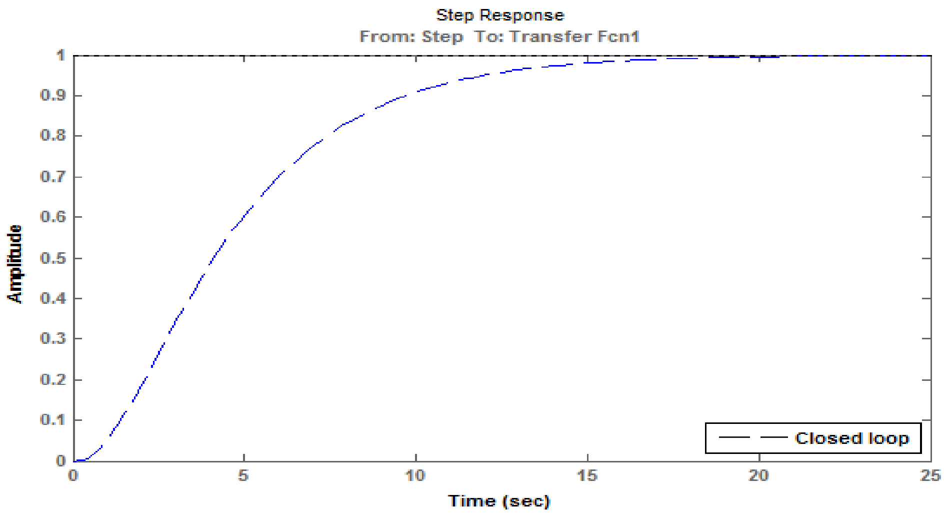


Figure 6.23 Closed loop response of system

For time domain analysis a step signal and simulate the response shown in figure 6.23.

To evaluate the performance of P – controller with third order system. Step response of the system, choosing K_p =10 of the closed loop system shown in figure 6.24.

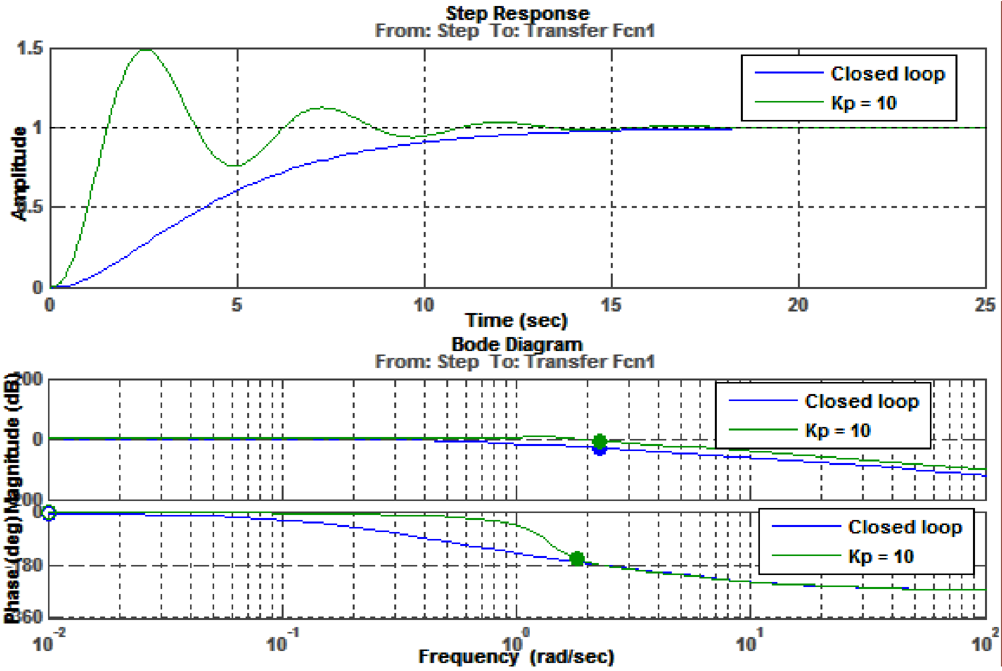


Figure 6.24 Step response of third order closed loop system with P – Controller at K_p = 10

To study the performance of P – controller, the concern values of overshoot, peak response, settling time and rise time recorded in table 6.6.

SYS NAME	OVERSHOOT	PEAK O/P	RISE TIME (Sec.)	SETTLING TIME(Sec.)
CLOSED LOOP SYS	0	0.999	8.33	15
SYS WITH P-CONTROLLER	48.5%	1.49	0.943	12.7

Table 6.6 Performance comparison of closed loop system with P – Controller (K_p = 10)

The step response of PD – controller with closed loop with K_p =10 and K_d=6 depicted in figure 6.25.

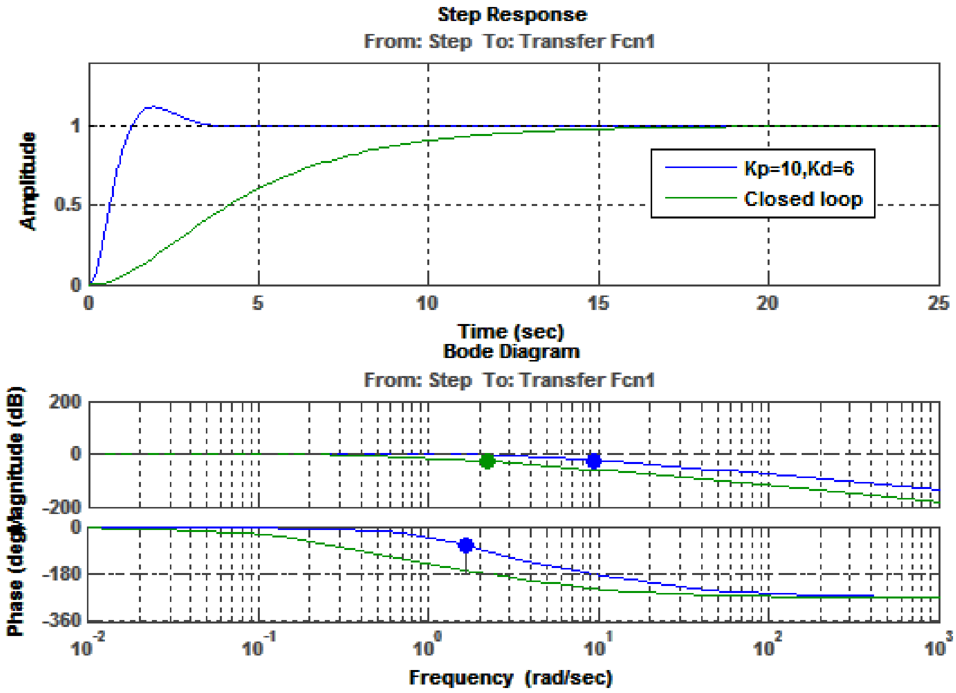


Figure 6.25 Closed loop step response of system with PD – Controller and Frequency and Phase response

Effect of parameter of PD – controller observed by system parameter improvement, this effect is recorded in table 6.7.

SYS NAME	OVERSHOOT	PEAK O/P	RISE TIME(Sec.)	SETTLING TIME(Sec.)
CLOSED LOOP SYS	0	0.999	8.33	15
SYS WITH P-CONTROLLER	11.9%	1.12	0.838	3.25

Table 6.7 Performance comparison of closed loop system with PD – Controller (Kp=10, Kd=6)

Observed that the PD – controller improve the parameter in terms of rise time ,maximuim overshoot and settling time are increased.

Step response for varying values of parameters K_i = 1 while keeping K_p = 10 constant recorded in figure 6.26.

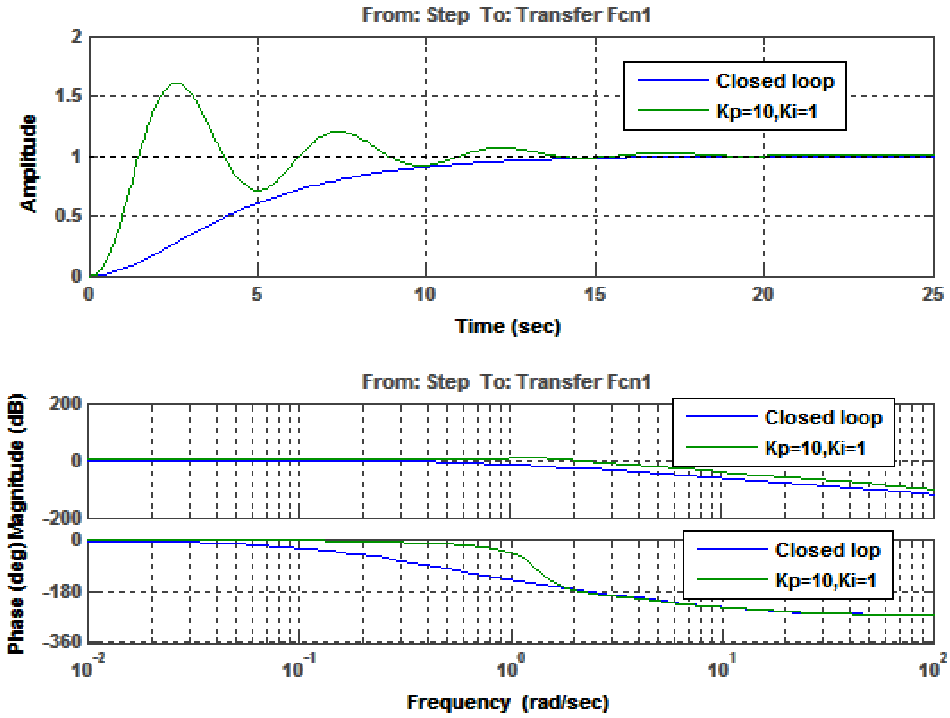


Figure 6.26 Step response of system with PI – Controller (K_p =10, K_i = 1)

The performance of parameters of PI – controller recorded in table 6.8.

SYS NAME	OVERSHOOT	PEAK O/P	RISE TIME(Sec.)	SETTLING TIME(Sec.)
CLOSED LOOP SYS	0	0.999	8.33	15
SYS WITH P-CONTROLLER	60.6	1.61	0.906	17.7

Table 6.8 Performance comparison of closed loop system with P I- Controller(K_p=10,K_i=1)

Observed that the PI – controller improve the performance in terms of rise time.

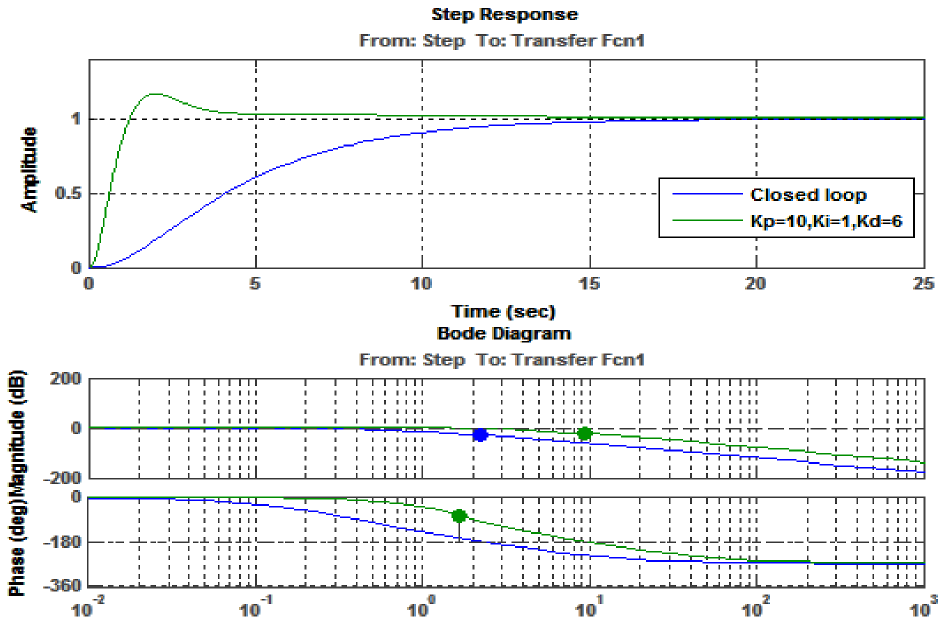


Figure 6.27 Closed loop response with PID – Controller

The step response of the closed loop system with PID – controller for K_p = 10, K_i =1 and K_d =6 shown figure 6.27.The performance of parameters are recorded in table 6.9.

SYS NAME	OVERSHOOT	PEAK O/P	RISE TIME(Sec.)	SETTLING TIME(Sec.)
CLOSED LOOP SYS	0	0.999	8.33	15
SYS WITH P-CONTROLLER	16.7%	1.17	0.816	10.2

Table 6.9 Performance comparison of system with PID – Controller (K_p=10,K_i=1,K_d=6)

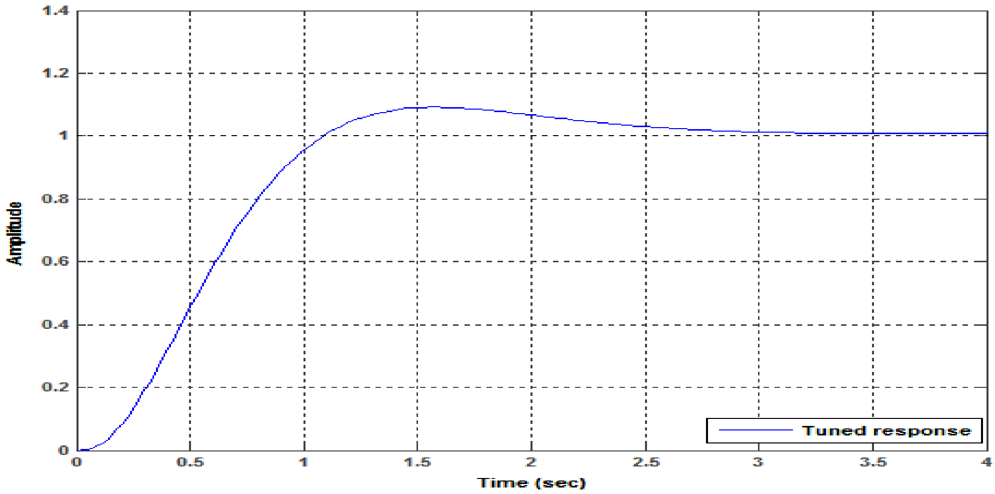


Figure 6.28 Tune response of PID – Controller

Parameters	Turbine	With P - Controller	With PI - Controller	With PD - Controller	With PID - controller	With PID - Tunning
Overshoot(%)	0	48.5	60.6	11.9	9.16	9.16
Peak o/p(sec.)	0.999	1.49	1.61	1.12	1.09	1.09
Rise time(sec.)	8.33	0.943	0.906	0.838	0.699	0.699
Settling time	15	12.7	17.7	3.25	2.72	2.72

Table 6.10 Performance comparison of closed loop system with and without controllers

Performance of all conventional controller analysis and study so far are summarized in table 6.10.This observation shows that PD – controller improve the overshoot and PI – Controller influences the settling time. PID – Controller includes best feature of all controller.

CHAPTER - 7

CONCLUDING THESIS REMARK AND FUTURE SCOPE OF OTRA

7.1 CONCLUSION

Realization, terminal characteristics and practical realised of OTRA taken into consideration to evaluation of OTRA and OTRA based circuit. By using OTRA we make circuits fully integrable and electronically tuneable. The OTRA implementing by using two CFOA AD844 ICs.

Sine wave oscillator design with single OTRA and few passive components for different frequencies. The results are independent on parasitic capacitance.

An operational Transresistance amplifier voltage mode, single input single output based second order low pass filters theoretical practical and simulation based result verified.

Conventional controllers are presented and their performance has verified.

7.2 SCOPE FOR FUTURE WORK

The OTRA provides virtually independent of the gain constant bandwidth. OTRA has ability to implement different analog circuits without using resistor. Application of OTRA in realizing voltage amplifier, multiplier, integrators, continuous time filter and oscillators. The basic building block of OTRA is simpler to realize and also provides low impedance voltage output.