Remote Laboratory for Conducting Various Experiments on Operational Amplifier

Trupti Kadam[1], Vidhyadhar Dharmadhikari[2]

[1] Student, M.Tech in Electronics Engineering, Walchand College of Engineering, Sangli, Maharashtra, India
[2]Professor, Walchand College of Engineering, Sangli, Maharashtra, India.

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Abstract - *This paper presents the project of the remote laboratory development in Walchand College of Engineering, Sangli of subject Electronics Circuits and Devices. The different circuits using Operational Amplifier are implemented on single broad using combination of relays, buffers, BC547 Transistors, DAC 0808, IC741, Raspberry Pi, Arduino Uno. Different circuits of Operational Amplifier are implemented and each circuit has its own variety of components like resistors and capacitors. Various Input voltage combinations are available for greater understanding of circuits. The Raspberry Pi is accessed and controlled from internet. Also, web cam interface to Raspberry Pi allows the live monitoring of experiment by understanding the circuit and verifying the output at different points on the circuit. Different measuring instruments like multimeter and digital signal oscilloscope are connected, to observe the output and electrical parameters at different test points.*

Key Words—Remote Laboratory, Operational Amplifier, Raspberry Pi, Camera Interface, on-line learning

1.INTRODUCTION

Laboratory and experimentation of various theoretical concepts is an important part of Engineering education. As engineering is a stream of science where practical knowledge is important than mugging the theory, laboratory plays an important role in life of engineer in gaining deep knowledge about the subject. Today practical knowledge is boon for development of Engineer. Laboratories play an important role to understand theoretical concepts and implement what we have learned in theory in actual practical setup. Laboratory works also give practical approach among students to solve various engineering problems. Laboratory helps to visualize and observe various phenomenon and theories related to different branches of Engineering. Excelling in laboratory courses indicates the practical knowledge and understanding of subject by student. It also shows the problem-solving capacity of student. In laboratory actual parameters and real time data is taken in consideration so the theoretical calculation and actual test calculation may vary, this helps student to take into consideration various real time parameters and try to maintain ideal condition while performing practical. Students get a hands-on experience of tackling different problems while performing practical. Some issues can only observe while doing practical in laboratories and not by simulation and virtual circuit software's. [1]

Electronics Engineering is the branch of engineering where many concepts could be only understood only if we perform the experiments in laboratory. The components in electronics labs are costly and buying them for each and every student is not feasible. The devices used for measurement of different parameters are also very costly. Therefore, overall setup of laboratory is very costly for electronics engineering. Administration of these laboratories should be done by person having good knowledge of this equipment and instruments. [5] Some colleges in remote areas or new colleges are not able to set up laboratories due to costly implementation or non-availability of professionals to handle the laboratory. Sometimes the laboratories are not easily accessed by handicapped students and many students face a problem in accessing the lab. As limited time is allocated to each student and students performing the experiments in group, each and every concept is not understood by every student. Due to group performance the actual hands-on experience is not acquired by each student and student may deviate from understanding. Due to limited time of laboratories each concept is not covered and students can miss some important practical part in the course. Due to limited availability of resources, there is competition among the students to acquire the resources. The maintenance and repairing cost of these laboratories is also very high. The solution to this problem is "REMOTE LABORATORIES".

According to Wikipedia Remote laboratory (also known as online laboratory, remote workbench) is the use of telecommunications to remotely conduct real (as opposed to virtual) experiments, at the physical location of the operating technology, whilst the scientist is utilizing technology from a separate geographical location. Remote laboratory is used to conduct the experiments from a distant place's by actually varying parameters from actual kit or experimental setup. The experimental setup is monitored, controlled and studied by sending the data through internet. Remote labs can be accessible from any place connected to internet and at any time in a day. The remote laboratories are classified according to:

1) Type of interaction between user and experiment.

2) Nature of the experiment to be performed.

3) Interaction type between user and experiment.

Remote laboratories can be implemented using 1) Actual instrumental setup and experiments based on actual circuits implemented.

2) Conduction of experiments through virtual machines and virtual reality instrumentation.

The type of remote laboratory implemented depends on the type of experiment being performed and complexity and functionality of experiment. [1]

Operational Amplifier (Op-Amp) is a DC coupled high-gain electronic voltage amplifier with a differential Input and single-ended output. [2] Op-Amp is an important device used by Electronics and Electrical engineers. Many applications in these fields require Op-Amp as their main component. There are many different circuits of Op-Amp to be studied by students. Understanding of different basic circuits of Op-Amp is crucial for understanding different complex circuits and analysis of such complex circuits. Different circuits perform different operations and can be used as adder, subtracter, Inverting Amplifier, Noninverting Amplifier, Differentiator, Integrator, Instrumentation Amplifier etc.

The given paper gives the demonstration of remote laboratory implemented for different applications of OpAmp. The basic applications of Op-Amp are crucial for understanding various other complex circuits and are very important to understand due to their wide scope and use to

Electronics engineer.

The VIRTUAL LABS implemented by initiative of IITs and NITs and several institutes are only providing the simulations of practical and we cannot understand the actual implementation of circuits. [7] The VLabs are just simulations which can be used to know the output of the various circuits but does not give the implementation and real time details in the experiment. The technologies used are flash player, Java script and jQuery so this does not give the real time data from live server. Students get the standard result and cannot see the actual setup of practical. Actual problems while doing practical like voltage drop at various nodes, saturation in Op-Amp etc. cannot be seen by students. The components used during experiments are considered as ideal so output is also ideal which is not in real time scenario. The complete understanding of circuit by analyzing current and voltages in every node is not possible. [6]

Currently implemented MIT's iLab or the VISIR system [3][4] use expensive due to proprietary software packages like LabView and MATLAB and their implementation is also very costly.

The remote laboratory for Op-Amp circuits not only gives the student access at any time but also it gives freedom for students to study experiments using different combinations of components like resistors, capacitors and observe output

for range of input voltages. By making own selection of components and input voltages students actual can get insight about the circuit and interpret the result. The facility to see the live video or real time images and indication by LEDs of selected components actually helps student to understand circuit in deep.

This laboratory does not require proprietary software like LabView, MATLAB and can be implemented and replicated in very low cost. The programming is done using C language so it can be modified and replicated as many times as possible. Camera and internet interface are done by using Raspberry Pi; this causes reduction in size and cost project. The Op-Amp board is also controlled by Raspberry Pi so we do not need another microcontroller setup to be control the board. Almost all applications of Op-Amp are implemented in single board so students can easily access the experiment, he wants to study without actually going to lab. The review of the basic concepts regarding the experiment is possible by adding the theoretical study matter before beginning of each experiment. After selecting experiment and setting basic configurations, the LEDs are illuminated to indicate each selected component combination so that students find it very easy to visualize the output. The pre-set voltage and current indicators and measuring devices at various test points in the circuit and output help students to take readings of given experiments. Digital signal oscilloscope is used to see input and output waveforms. Students may also check variations in output at each point by changing input from their remote PC. This use of live visual experimentation enhances the understanding of student. Suggestions and guidelines given by software while performing experiments acts as tutor for students.

Disadvantage of such kind of laboratory is that students will not get actually to mount the components on breadboard and set actual parameters. Students may procrastinate to do experiments and may skip critical steps due to absence of teacher.

1.1 Implementation of Operational Amplifier Circuit

The given remote laboratory is used to implement the following circuits of Op-Amp

1) Inverting Amplifier

2) Non-inverting Amplifier

3) Unity Gain Amplifier

4) Summing Amplifier

Variable Voltage Source for Input

The variable supply is used as an input to the Op-Amp circuit so that students can visualize the applications using various combinations of input. The input can be varied while performing practical to observe changes in output. This

combination of inputs is provided by using DAC 0808. The input to the DAC is from the port pins of Raspberry Pi. The output of DAC is used as variable supply. The output of 8-bit DAC is given by formula

$$V0 = V_{ref}\left(\frac{A1}{2} + \frac{A2}{4} + \frac{A3}{8} + \ldots + \frac{A8}{256}\right)$$

where V0 = Variable Voltage Output Voltage

V_{ref} = reference voltage provided

A1...A8 = The value at port pins of Raspberry Pi (can be 0 or 1 according to state of pin)

The theoretical output is calculated according to given formula. A probe of multimeter is connected to the output of DAC 0808 to know the practical output while performing experiment. Students can verify the theoretical and actual output of DAC by observing output on multimeter. The block diagram of variable voltage source is shown along with its interfacing with Raspberry Pi.

Proteus simulation of variable power supply is shown in the diagram below:
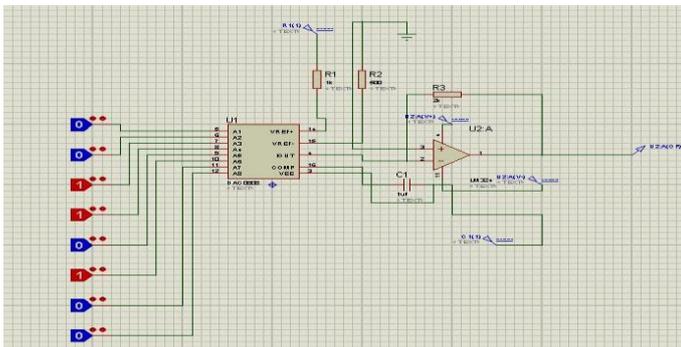
Fig -1: Variable power supply

1.2 Main Circuit

1.2.1 Rpi Controlling

This circuit consists of implementation of Op-Amp circuits on a one single board. All the applications are selected using relay switching. The different combinations of relay help student to select the experiments from experiments list. The user can select different combinations of relays and we can change the input voltage also by changing the input levels of the logic circuit which is connected to the voltage divider network. The number and type of components available depends on the application selected by the user. The select lines of relays are connected to port pins of Raspberry Pi. When the user selects the particular application and components the corresponding relay is selected by software, at the back end, by varying state of the pins connected to select lines of relay or Doubly changing the state of pins of Raspberry Pi the combination of applications as mentioned

above are selected. The program is written for selecting the required application and required combination of component to get the required output. The program runs on the back end on Raspberry Pi which selects input value of voltage according to user requirement. Main circuit is interfaced to raspberry pi for remote controlling which is discussed in next sessions. This board is observed on web-cam. The output of the circuit is observed and changes according to the selected configurations by the user. User is able to observe the voltages and current at different points on multimeter and also view input and output waveforms on oscilloscope which is set in" AUTO" mode. By using auto mode in digital oscilloscope there is no need of always adjusting the oscilloscope and output can be viewed with the required measurements of oscilloscope. Block diagram of the main Op-Amp circuit is shown in the figure below.
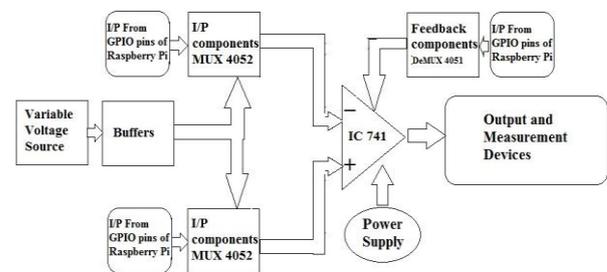

Fig -2: Block diagram of main circuit

1.2.2   Circuit diagram of main Op amp circuit
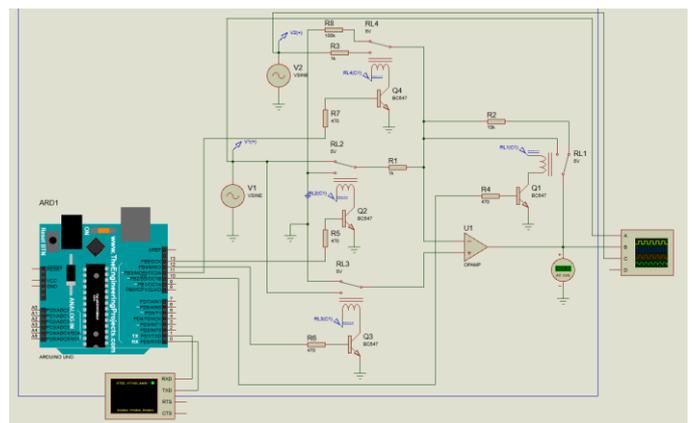

Fig -3: Simulation circuit of Main circuit

Main purpose of remote laboratory is to provide a platform for students so that they can perform experiment 24/7 from any place having good network connection. Based on the idea it is inconvenient to provide many experiments sets differently so we integrated all circuits in one. Every Experiments in the circuit are connected to each other relay. To control every experiment, we have to

control relay. Relay works in two mode naturally open and naturally close mode. And in our project, we are going to use relay in naturally open mode.

Normally open relay

Normally open relays default in the open position, meaning that when they're not in use, there is no contact between the circuits. When power is introduced, an electro- magnet pulls the first circuit into contact with the second, thereby closing the circuit and allowing power to flow through. When the electricity turns off, the circuit opens up again to stop the flow.

Normally closed relay

Normally closed relays default in the closed position, meaning that the circuit is closed unless otherwise specified. Introducing too much power draws the first circuit away from the second circuit to turn it off.

Here, we are controlling relay through Arduino will give a command to Arduino which will trigger the experiment regarding with that comment. In proteus simulation, we are giving command to Arduino through virtual window. The command will make particular pins of Arduino high or low to give proper connections to the relays to perform experiments. The actual working of relays is totally based on Arduino code.

In Arduino code we declared many variables to assign digital in of Arduino as out-put pins because we are going to give input to Arduino through serial communication.

1.2.3   Output of the Simulation Circuit

1.2.3.1 Inverting amplifier
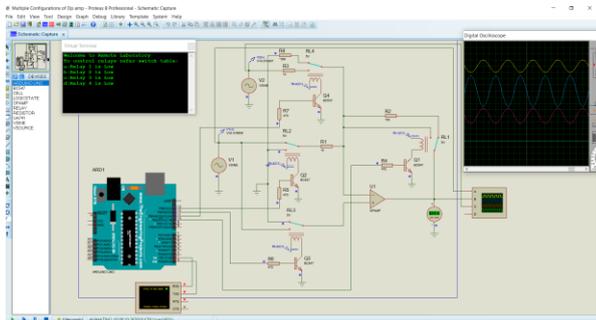
Fig -4: Simulation of Inverting Amplifier

Inverting amplifier is a simple circuit in which the output is 180-degree phase shift with respect to input. Operational amplifier has two inputs, one is Inverting and other is Non-Inverting terminal. When input supply is given to inverting terminal, it is referred as Inverting Amplifier. The output generated after performing the operation this signal is

again fed back to the input terminal. The feedback is provided to minimize the noise and distortions in the circuit.

Like the inverting amplifier we have done the simulation for remaining three circuits also.

Table -1: Switching conditions of relays

Relays →	Relay 1	Relay 2	Relay 3	Relay 4
Circuits ↓				
Inverting Amplifier	LOW	LOW	LOW	LOW
Non-Inverting Amplifier	LOW	HIGH	HOGH	HIGH
Unity Gain Amplifier	HIGH	HIGH	HIGH	LOW
Summing Amplifier	LOW	LOW	LOW	HIGH

1.3   Common Generic architecture designed for Remote lab
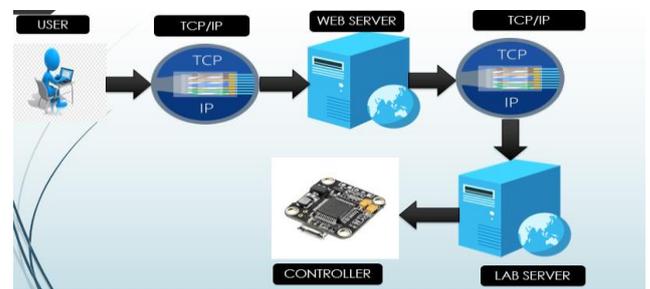
Fig -5: Generic architecture of remote lab

The diagram above shows the generic architectural implementation remote lab. The user gives the IP address of the lab server and connect the lab server via Internet. The IP address of Lab is public IP address so it can be formed outside the network.

1.3.1   Raspberry pi

Fig -6: Raspberry pi 3 b

The Raspberry Pi is a small single-board computer developed in the UK by the Raspberry Pi Foundation. The original Raspberry Pi is based on the Broad- com BCM2835 system on a chip (SoC), which includes an ARM1176JZF-700 MHz processor. Video Core IVGPU, 512Mb of RAM. The Foundation provides Debian and Arch Linux ARM distributions for downloads. Apache is a popular web server application that can be installed on the R-pi which provides web services for client We need to forward a port in order to make a computer accessible to internet this is done by R-pi. FTP (File Transfer Protocol) can be used to transfer files between R-pi and another computer.

1.3.2   Arduino UNO
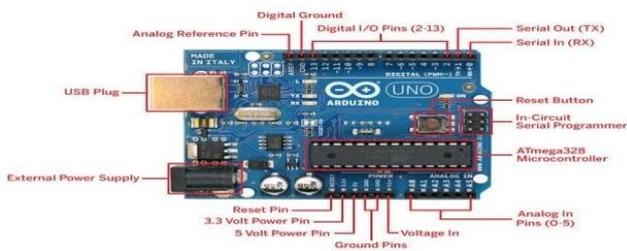
Fig -7: Arduino uno

Arduino UNO is an open source microcontroller based on Microchip ATmega328P microcontroller and developed Arduino. Arduino UNO provides 14 digital pins that can be used as output/input.it has 6 analog inputs pins, A USB connection, a power jack and a reset button.it used Single Cycle and Low Power for execution. it has Efficient C Language Code Density and On-chip in-system programmable memories. We have used 4 Pins of Arduino for switching the relays.

1.4   Website of the Remote Lab

1.4.1 Flowchart of the site
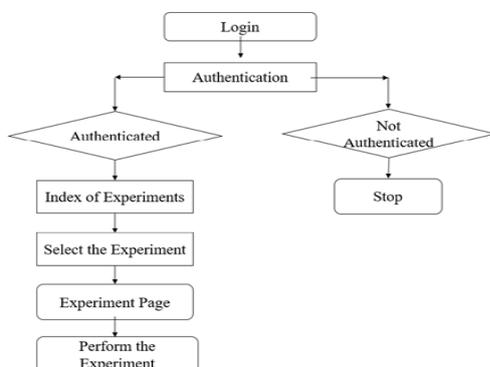
1.4.2   Procedure for performing experiments using site

The First page of the site is welcoming page. Then user have to login with their login credential. If

account is not found then it shows invalid login and it redirected to registration .If account found then user have to go through the experiment list then after they have to choose the experiment which they want to perform. A f t e r choosing experiment it redirect to experiment page where we have provided all the essential data which is required for performing experiment like aim, apparatus. theory, procedure, observation table, conclusion etc. Here we have pro-vided one button 'perform experiment' after clicking on this button user can easily perform the experiment from anywhere. Apart from that we have provided video guide for performing the experiment.

1.4.3 Proposed site of the System

#### 1.4.3.1 Home page

1.4.3.2 Login page

1.4.3.3 Index Page

1.4.3.4 Experiment page

Experiment No. 1

Inverting Amplifier

Aim:
To implement an Inverting Amplifier using Op-Amp IC 741.

Apparatus:
CRO, Function Generator, Bread Board, 741 IC, ±12V supply, Resistors 1KΩ, 10KΩ

Theory:
An Inverting Amplifier using opamp is a type of amplifier where the output waveform will be phase opposite to the input waveform. The input waveform will be amplifier by the factor Av (voltage gain of the amplifier) in magnitude and its phase will be inverted. In the inverting amplifier circuit the signal to be amplified is applied to the inverting input of the opamp through the input resistance Rl. Rf is the feedback resistor. Rf and Rin together determine the gain of the amplifier. Inverting operational amplifier gain can be expressed using the equation Av = - Rf/R1. Negative sign implies that the output signal is negated.

Circuit Diagram:
The circuit diagram of a basic Inverting amplifier using opamp is shown below.

Circuit Diagram :
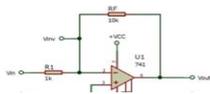
Here we provided video guide for performing experiments.
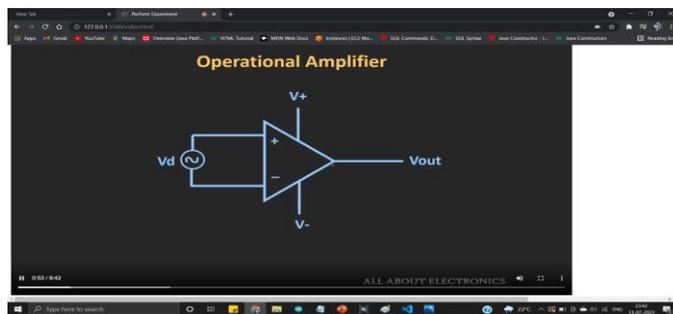
### 1.4.3.5 Image of the experimental setup captured by Web Camera
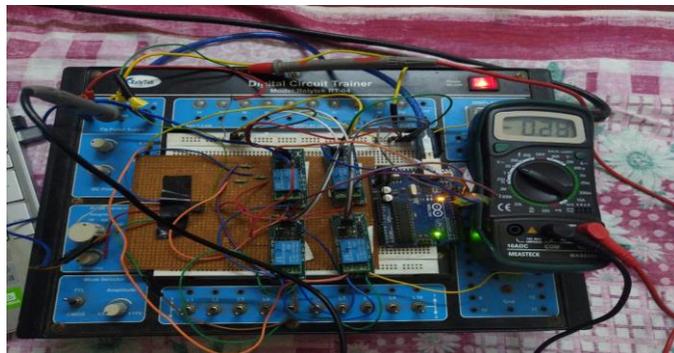
Fig -8: Hardware of the System.

1.5 FUTURE EXPANSION

This project can be further extended for many applications related to Op-Amp. Designs of filters and different circuits of Op-Amp can be built. By using SMD packages of ICs and components like resistors and capacitors many different combinations of input and feedback components will be made available.

Further to grow number of users one PCB board can be designed for one application. Many users can be connected to that PCB and each user many try to perform that experiment with different combinations of input voltages and feedback components. As all users cannot perform experiment simultaneously, the users will be asked questions generated by system so that they waiting time will

not be wasted. The questions will create a brainstorming among students and each student will understand each experiment thoroughly. The waiting time will be less as delay is only due to transmitting and reception of data between the servers and executions of commands.

This approach can be further be increased to different subjects of different disciplines of engineering. Creation of such remote laboratories for different subjects of different branches will make the learning easy and cost efficient.

1.6 CONCLUSIONS

The given paper shows the need and demonstration of remote laboratory for conducting experiments on OpAmp. The given paper provides state of art remote laboratory for implementing Electronic Circuits and Design practical's for students. This paper also shows the implementation of such remote laboratories in economical ways and also encourage the students to work on future development of such laboratories.

This project will be very helpful for students to understand the each and every circuit properly and in depth understanding of each property of each circuit. The given project will be accessed by student at any time and also it will create interest among students. Students will enjoy learning as the live results of the experiments performed by them will be visualized.

1.7 ACKNOWLEDGEMENT

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