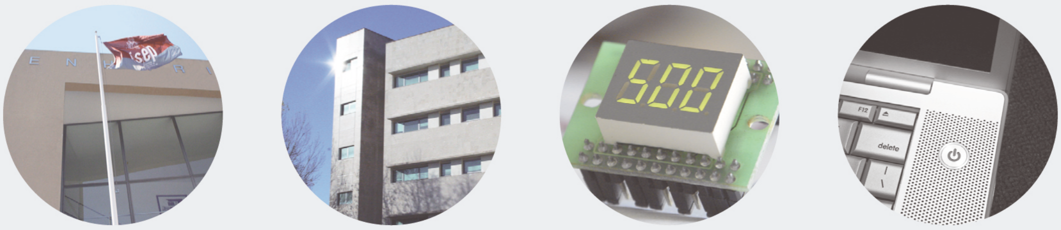
INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO
MESTRADO EM ENGENHARIA ELECTROTÉCNICA E DE COMPUTADORES



# REMOTE LABORATORY TO SUPPORT CONTROL THEORY

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# REMOTE LABORATORY TO SUPPORT CONTROL THEORY

Master in Electrical and Computer Engineering

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# Abstract

The *Control Systems* plays a vital role in the industry, which is the most essential application of the Electrical Engineering. The control concepts are present in most of the automation systems.

The *Control Systems* theory is the key concept to achieve the automation and makes world faster. But, in reality the study of control engineering is decreased in the recent years, because of the difficulty in learning the concepts of the control theory. Most of the students feel difficult to understand theoretical concepts of control systems. The traditional teaching methodology is one way of teaching control systems concepts.

Even though books are proper way of teaching control systems in a systematic way, we need additional tool to create interaction between the subject and the students. The teaching platform is worth to analyse the possibility to add or complement the way of standing with means able to add Real evidences. In another way, it is important that the provided lab experiment should be affordable.

The teaching platform to support control theory has been introduced with set of experiments to create Real evidences, and manuals to carry out those experiments, slides to have a guidance and Graphical User Interface (GUI) to have an interaction with the control system is provided.

### Keywords

Automation, Teaching, Graphical User Interface and Control Theory.

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# Glossary

| Abbreviations | Description |
|---|---|
| AC | *Alternative Current* |
| DC | *Direct Current* |
| ESD | *Education for Sustainable Development* |
| GER | *Gross Enrollment Ratio* |
| GUI | *Graphical User Interface* |
| ICSP | *In-Circuit Serial Programming* |
| IIT | *Indian Institute of Technology* |
| IoT | *Internet of Things* |
| LabVIEW | *Laboratory Virtual Instrument Engineering Workbench* |
| LLL | *Life Long Learning* |
| MATLAB | *Matrix laboratory* |
| NIT | *National Institute of Technology* |
| OECD | *Organization for Economic Co-operation and Development* |
| PBL | *Problem Based Learning* |
| PjBL | *Project Based Learning* |
| PID | *Proportional Integral Derivative* |
| PISA | *Program for International Student Assessment* |
| PWM | *Pulse Width Modulation* |
| RPM | *Rotation Per Minute* |
| SISO | *Single Input Single Output* |
| SSD | *Sustainability and Sustainable Development* |
| VISA | *Virtual Instrument Software Architecture* |

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I am deeply indebted to my respected teachers and other members of the Electrical engineering department at ISEP for their valuable help to access the laboratories during weekends.

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Last but not least, I humbly extend my thanks to all concerned persons who co-operated with me in this regard.

# Chapter 1

# Introduction

## 1.1 Context

This project is developed within the scope of the master's degree of the Electrical and Computer Engineering at *Instituto Superior de Engenharia de Porto* (ISEP) as a master thesis.

The project is developed at *Centro de Inovação em Engenharia e Tecnologia Industrial* (CIETI), a research development group . This Center for Innovation in Engineering and Industrial Technology has its own equipment for remote laboratory.

The project was intended to develop and demonstrate a better solution to support control theory using a simple integrated circuits with the microcontroller, where student can test and learn the basics of control systems. The platform developed come across a series of experiments, slides , manuals and control system that has to interacted with PC to visualize and observe the real time experience with the control system. The developed platform can be used by students autonomously to have the versatility, by opening hands for various control system techniques.

## 1.2 Objectives

The objective of the project is to mainly develop a simple affordable means to have a control system with Graphical User Interface (GUI) that any student can interact with that system to learn control system theory. Keeping in mind all the developed tools to support this teaching of control theory in an easier way , where they can re-create or re-use for future purpose multiplying the given platform into a usable way, by adding and exploring other features.

These are the following objectives for developing this thesis, such as:

- To develop a simple and handy platform which is portable and affordable.
- To develop a Graphical User Interface (GUI), where the user can visualize and have simple control system, where he/she doesn't need or require to learn the software in initial stage, but later on provided with means to learn and develop on their own.
- To develop a manual to use the developed platform.
- Slides, to make a short attempt to have a gist of process in an easier way of learning the creation of the GUI.
- Need to have guidelines for flashing of the firmware, which has to communicate with the hardware.
- later on provisions are made to learn those concepts through well defined manuals.

## 1.3 Text organization

This text follows the structure outlined to meet the objectives proposed in the thesis. In the first instance, a brief introduction to the project proposal is made, a brief contextualization of the project, as well as the objectives that are intended to be obtained in the end.

In Chapter 2, a study about the current trends and scenario in electrical engineering education.

In Chapter 3 speaks about the fundamental concepts of the electronic and tuning of the control parameters.

In Chapter 4, is about the comparison of Remote Labs with the traditional laboratory.

In Chapter 5, Analyzing the possibilities and discussion of the requirements for the development of the efficient platform.

In Chapter 6, discuss the implementation and it outcomes through validation of the project.

In Chapter 7, discuss about the conclusion and future implementation.

## Chapter 2

# Literature Review

## 2.1 Sustainable Development

Sustainable Development is to make better place without compromising resources of the future people. In other words, the term sustainable development is referred as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. After various summits being held by Brundtland Commission called for an international conference to be convened to review the progress made by nations with regards to the Sustainable Development in their respective countries [1].

At Rio, a global plan of action, title Agenda 21 was developed focusing on climate change, loss of biodiversity, management of the earth's forests. In fact, it was Chapter 36 on Education, Awareness and Training of Agenda 21 that laid the foundation of Education for Sustainable Development (ESD) [2].

It stated that, Education, including formal education, public awareness and training should be recognized as a process by which human beings and societies. Both formal and non-formal educations are indispensable to changing people's attitudes so that they have the capacity to assess and address their sustainable development concerns.

Education for Sustainable Development (ESD) therefore is an important pedagogical tool as it is based on the fundamental principle of making an individual see and recognize the interdependence between human beings and each unit of ecology. A few may ask what the purpose is of introducing sustainability in control system. What is the relation between control system engineering and sustainability? There comes the fact that Education for Sustainability is defined as a transformative learning process that equips students, teachers and school systems with the new concept and innovative thinking, which drives the student to acquire knowledge where they don't have future discussion, if they have taught those concepts with evidence.

### 2.1.1 Sustainability on education

Several courses exist on the university regarding various fields of engineering. However, the overall relationship between engineering and the Sustainability and Social Commitment (SSC), on how to include this skill in only particular subjects or in a curriculum in a bachelor or a master thesis. Some of the common questions raised when discussing this skill are: What is sustainability? What is its relationship with electronics? How students should learn? And how the student should be evaluated in the perspective of the teachers? Universities must always be prepared to meet the new challenges and adopt roles that focus on selling current or preventing the future social crises on energy, ecology, food and finance. Hence, universities should prepare the course curriculum that makes or equips students to take part an active role in the society so that they will be able to participate and to resolve any challenge posed by local or the international level. Now once after implementing the course in the curriculum is not at all enough.

The Figure 2.1 represents the sustainability on education and its principles to be included. The schools and colleges should be actively involved in the

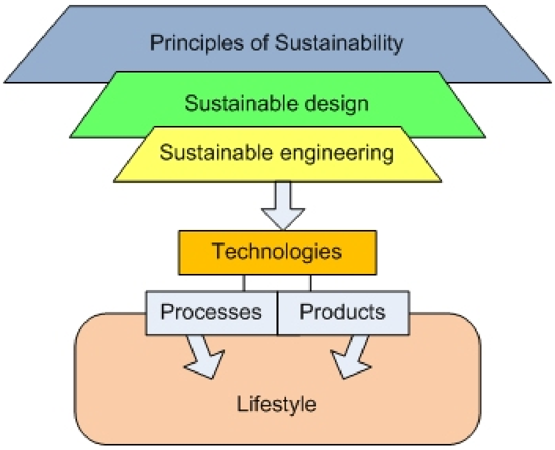


Figure 2.1: Sustainability on education

other steps to promote the students how the education for sustainability concepts must be taught. Learning sustainability requires a new way of thinking and innovative teaching. Intellectual development, critical thinking and a systematic way of approach are necessary in order to implement sustainability on education. It is better to adopt few methods that are useful and more closely related with the concept of sustainability, like Service Learning, a method of learning that integrates meaningful community service with instruction and reflection to enrich the learning experience.

### 2.1.2 Sustainability on engineering

There is always a question behind implementing or introducing the sustainability concepts on the engineering background. Hence adapting these roles on engineering makes what the future purpose. All the questions lead to the final answer of the solution which focus on solving the current social issues and crises on energy and the future resources. Though the (European Union) EU has set very well-defined targets in what concerns on (Sustainability and Sustainable Development) SSD. Through the politics and the lines of the action of the established in the 2020 program, education for the sustainable development in higher education is gradually gaining its importance. Thus, sustainability is the key issue that must be kept in mind in any of the engineering degree that constitutes an important factor in an engineer's education.

SSD must be perceived as a fundamental concept in engineer's training and is still regarded as a skill that each and every engineer should possess. The rapid growth of cellphones, laptops and other electronic devices made connectivity easier. On the same way it has formed a narrow bridge between the digital divide between develop and developing countries [3]. As the population increases in the country, there is a steep increase in the demand proportional to the population and there is no end in the demands of the people. A recent nation-wide survey conducted by researchers at UT-Austin CMU and Arizona State University on sustainable engineering education finds that only 27% of the electrical and computer engineering curricula includes courses which focuses on sustainability issues and 40% of them have some sustainability content integrated into existing courses [3]. The emerging problem which is unsolved in the recent years is that E-waste, which is recognized as a complex global problem. Therefore, it is beneficial to use and implement recycling methods and the focus on "how to reuse the e-waste in new and productive means.

## 2.2 Modern teaching and its issues

The enrollment for the education towards electrical engineering is enormous. The universities and the enrollment rate are increasing in at a higher rate. Hence, universities play an important role for the outcoming of the engineering graduates. One of the major teaching approaches is the concept-based learning. This type of approach where the knowledge is transmitted from teachers to students. Such type of knowledge transformation of students can be revealed in series of assessments. In the beginning of the course the student might have no idea they have to start everything from the scratch. While undergoing the process of transmission the student first undergoes all the theoretical concepts with the help of the faculty during class hours dedicated for the course. Then periodical practical sessions make them involved in designing the electronic circuits with what they have learnt during the theoretical approach.

The concepts of the electrical engineering are kind of difficult for the students to understand. One important fact is that they cannot skip the fundamental and can go for the other. It's like when you are pointed out and asking which eyes do you want? Obviously, you will say need both, likewise it's difficult to jump off and landing on the course where you don't have the basic knowledge behind the course. The goal is to make the concepts clear, where the teaching of engineering courses with student interest and some initiative. Not everyone is born with engineering skills or electronics. They will get practiced only when they are involved in kind of practical work experience on the project or practical assessment and by doing mistakes. Thus, the control engineering is one of the subjects or the courses which needs labs with some sophisticated instruments to teach those concepts. When students are engaged with the practical works with the problems, they will learn in depth how the concepts work.

## 2.3 Student's perception on mathematics

The control engineering and electronics is always interconnected with mathematics. The one big drawback set behind this teaching issues of Control Engineering is that students don't want to involve in performing the complex calculation. Sometimes, they get feared on doing this, which will result in the answer what they are not expecting. [4] Mathematics is a very important area in the formation of all individuals in society, since mathematical operations are part of daily human life. Hence, math is one of the key things, which cannot be omitted or cannot be skipped by any of the person. On taking a survey of the Brazilian institution where to get the adequate results of their learning progress in Math from the university Inep/MEC[1] . They learnt of a proper math problem-solving skill in the $5^{th}$ year in public school was only 35% and in the secondary school this percentage is even worse, representing only 11% of students, about one in ten students [4].

In addition to this, Brazil remains in the last positions in The Program for International Student Assessment (PISA) general ranking occupying the $58^{th}$ place. Mathematics in Brazil obtained the $58^{th}$ ranking out of 391 among the members of The Organization for Economic Co-operation and Development (OECD). This reality is connected many times to the motivation of these students, a mainly caused by the form of transmission of the knowledge in the

[1] National Institute for Educational Studies and Research

classroom. The motivation is major problem in the Brazilian schools nowadays, and it results in having poor performance in studies, math classes usually follow the procedures and repetition exercises, training without commitment to demonstrate the real sense of the numbering system and its rules of operations.

From the Figure 2.2 it depicts some of the facts that the students why they hate mathematics.

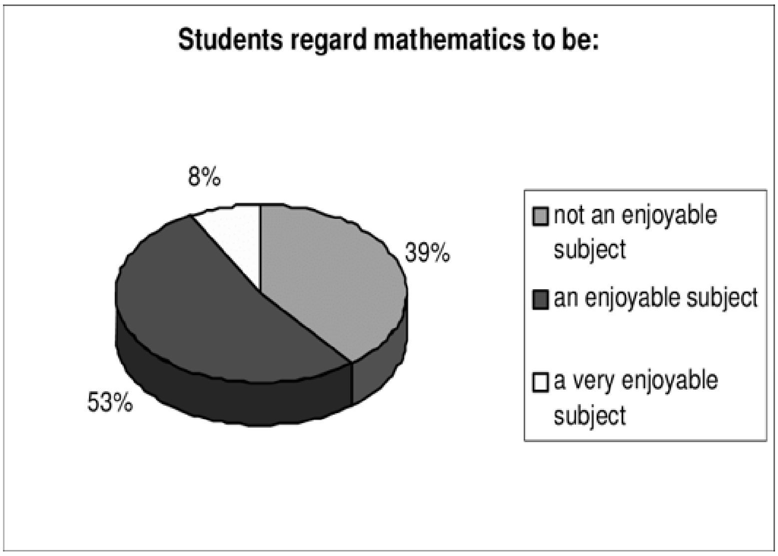


Figure 2.2: Student's acceptance on mathematics

They usually undergo easy mathematical calculations like addition, subtraction like arithmetic problems. As the student grows the topics and newer topics involved, which making there it seems to be difficult for the student. Sometimes they felt confused in trying mathematics, those who don't like mathematics they tend to go out of engineering.

From the Figure 2.3 , the different levels of mathematics, the acceptance and their response shows some of the graduates think that math is harder and boring subjects involving lot of equations and derivations where they lose the marks.

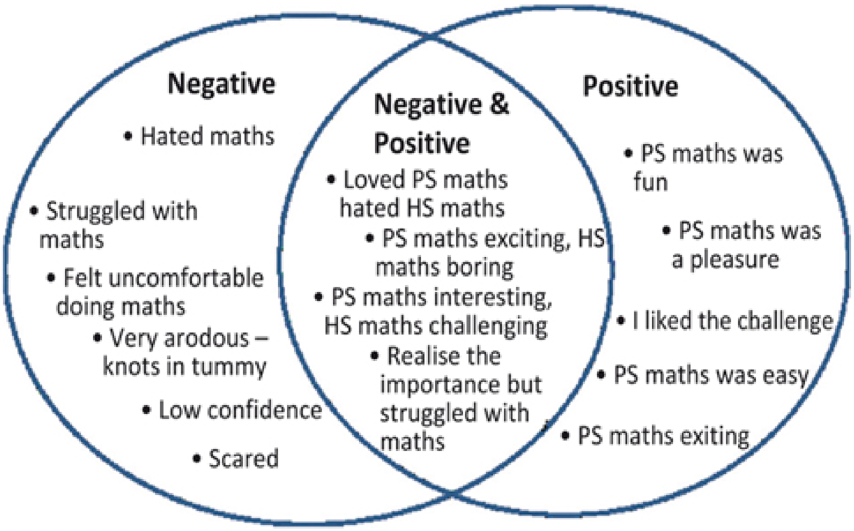


Figure 2.3: Level of mathematics

Some of the high school math are challenging, and there is nothing bad in trying. As we know practice makes a man perfect. It is better as per the proverb mentioned, that each and every student should try various methods and they should analyze the outcomes as well as the results. As well as time is one of the important criteria, they should focus not only on mathematics they should give equal importance for the other courses also. But, math is the foundation for the other courses, without skipping this course, they cannot land on other, which has the basics or foundation of the mathematics.

## 2.4 Importance of mathematics in electrical engineering

There is a very big relation between the mathematics and electrical engineering course. There is a common saying or question about in our mind rolling about,Why is mathematics important to engineers? And which part in mathematics is correlated with Electrical engineering? The purpose of including mathematics for electrical engineering or any field of engineering related to the electronics field forms a greatest part. At least the students might have basic knowledge on algebra, trigonometry from the elementary schools. During their high school they might have come across the advanced versions of trigonometry and application of calculus in their high schools [5].

Following key reasons states that why engineering mathematics is important for engineers:

- The laws of nature (e.g., Maxwell's equations for electromagnetics, Kirchhoff's Rules for circuit analysis) are mathematical expressions.
- Mathematics is a tool to solve complex block diagrams into a simple equation in the form of matrices. All the control systems courses have a foundation of mathematics in the form of state space models and the integral calculus.
- Problems involving logarithmic conversions are useful in terms of reducing an exponential component.
- Learning derivations is an intellectual skill, where further they will have to deduce or reduce a much larger equation into simpler one.

## 2.5 Problems faced by technical schools students

On a note the number of students who enroll for the engineering is increasing dramatically. And the number of candidates registered for the Electrical Engineering course because of the excellent future of the industrial exposure, people tends to choose electronics as their future career [6]. The purpose of the research was to take an appropriate action on the difficulties faced by the technical students and the Engineering graduates and the barriers they face during their coursework.

On taking a survey from the technical schools and the polytechnic institutes the electrical and electronic subject is one of the courses and the control system in one of the courses, that student has to undergo which is a mandatory one. Based on the examination results, the course outcome seems to be terrible, that most of the students who fail to do the exam properly gave a review on the electrical course is one of the toughest and they couldn't go beyond certain level leads to discontinuation in the course. There could be some of the candidates who can be excellent on their background of the electronics, sometimes they would be able to give proper answer for the questions or the topic discussion during the class hours. But, the pupil who consider themselves as less capacity to understand the electronics may have this complex situation involving difficult mathematics solving tasks, which may end up in distress and sorrow. When the problem is really hard, or less hard they often abstain to work on the specific unknown topic. Actually, this lack of interest makes them not to try more just give up.

The electronics course is one of the subjects which involves a complex calculation most of the time, where it is under pressure for the students to learn the complex calculation, but they don't pursue this kind of subjects or the courses because of this long-lasting works. But, the university has fixed something for the proper education of the electronic course and the student cannot skip the fundamental and whatever calamity comes, they must undergo these courses. On the other hand, the students in statistics says that the courses have conceptions that tend to focus on mastery of material, tools and process, rather than critical thinking, and they also reported a low willingness to learn and surface approach to learning.

The lack of effectiveness of the elective courses appears to be unrelated to discipline or profession. The worst consequences are the they are so lost in much of the abstraction of concepts that even the simpler ideas are becoming difficult to comprehend and this often leads to discouragement, high stress, burn out and as a result, high failure rate. Some of the universities faced the difficulties after undertaking the course for a year, and the students or the graduates terminate or dropped out because of the learning capability and their expectation towards the standards of the education are the possible reasons which makes them to move out of the course.

## 2.6 Student perception on electronics

General electronics is one of the main courses in electronics that students have in many engineering syllabi, i.e., the first impression for the student about idea on electronics. It is the one of the main factors that it is university's duty to allocate or to put in the industrial area an appropriate number of electronic engineers, hence it is important to give a glance about the electronics [7]. The perception of the subject is depending on the teaching methodology. The electronic course is compulsory for the all the students enrolled during electrical engineering course, although it is the first electronic course they undergo with previous background of basic electronic course related with electric circuits theory and elementary electric rules. Students those who studied during their high school, they may not have a continuation in terms of electronics, they need to refresh their basics. Then, keeping these basics, students have to come across lot of milestones in electric and electronic circuits and machines.

In the previous pre-Bologna program, settles in 1998, the situation was very similar, and only one course on electronic systems was taught to the students to their third year of the degree, just before choosing the specialization. During this period of choosing their electives and the other similar courses, because of the term and fancy words, students started choosing the other fields of Engineering like the Telecommunication and Industrial Engineering, rather than the Electronic Engineering. It was commonly accepted by the teachers that the main reason was the lack of interest of students with the term electronics [7]. This lack of interest discourages them to continue an electronic engineering specialization. As per the Figure 2.4, there is some of the probable reasons, one of that could be the curriculum which is full of the unit standards of the study and the workload was too high.

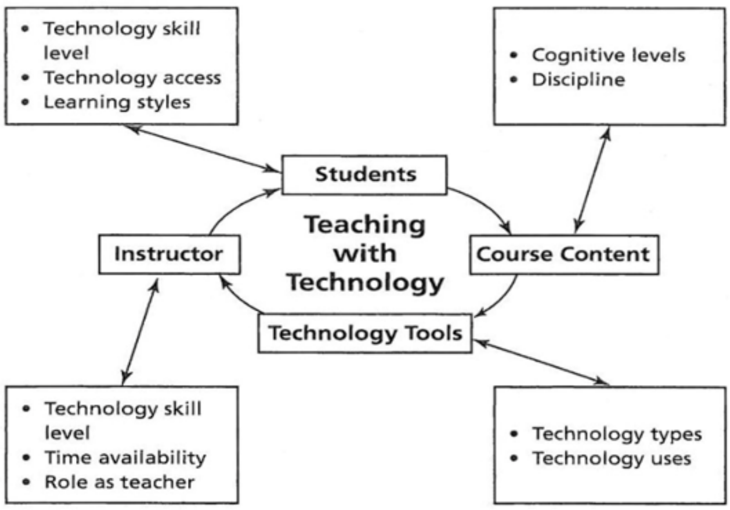


Figure 2.4: Teaching technologies

In fact, one large unit of study covering principles of electrical engineering; from basics of circuit debugging and circuit analysis to the power electronics, from electromechanical energy conversion of analogue to digital electronics and the power signals. These kind of fundamental concepts and theoretical studies are generally learnt by the electrical engineering students through various courses. This kind of pressurized situation with compressed of courses, where the size of the course curriculum is the critical issue. This critical issue can be a criterion for the mismatch between teachers and students, and students may encounter this inability to process this information wisely, where altogether damped all at once. The final most reason, is the attendance of the lectures which is given by the faculties. It is often noticed that, as low as 20% of the attendance where it is coming to a great conclusion that they often regret the classes where they didn't give value to the lectures. At the end of the course, while conducting a group discussion, many students didn't recognize the relevancy in the course taken.

## 2.7 Freshman's perceptions in electrical/electronics

Engineering courses correspond to a significant percentage of students' preferences when applying to higher education systems. On taking this case study, they attended a common first-year engineering program regardless of the major. The responses were used to assess the students' feedback concerning the material and software used in the course, the experiences in working on a multidisciplinary team improving the technical communication skills and their perception towards the time and mere effort spent on the course. The authors concluded that students' view on the first-year program improved from 2001 to 2004 by analysis [8]. The students in Chemical and Electrical and Computer Engineering showed the most positive change.

The transition from the high school to university, especially to engineering courses, can be a challenging one. The students' regret to learn the course are also quite varied and the response may differ from one another. Many students had only limited interest in the "Non-major" courses like electrical engineering. The background of the students in the non-major area varied greatly and was frequently reported as weak some students have already acquired relevant knowledge from their high school and others have none. This presented a challenging environment in terms of providing clear and attainable learning outcomes of the course.

During every academic year of the admission student's curiosity in choosing the electrical engineering will be in peak because of the fascinating nomenclature of the course. But once the year passes, the people or the graduates who land onto the particular theoretical course, it can be seen that electrical engineering is often considered as a boring subject for the students who pursue electrical engineering during the master's or as well as their Bachelor's degree[9].

As the research from the investigation of the students who are pursuing the electrical engineering course. It clearly seems that they possess lack of interest when deeply teaching for the electrical circuits, control system and digital signal processing. Most often the lack of interest is based on the reduction of the complex block diagrams and pure mathematical concepts of control engineering. While doing or interpreting complex circuit diagrams and may lose concentration keeping all the concepts in the mind. On coming across the survey mentioned in [9], it says that analysis which they made has a multi-institutional survey where it indicates the level of motivation for the students of different engineering majors may vary depending upon the person to person.

## 2.8 Teaching methodologies adopted

By coming across lot of difficulties faced by the students in learning of the electronics and the control Systems. The teachers and the faculty members have some decision committee and board of members to improve the methodology of teaching and on coming with the conclusion from the survey taken, they are bored with the old teaching methodology and in-depth knowledge of electronics leads to imagination, where they couldn't see how the electronics in real time, for example the movement of electron cannot be visualized. The presence of the current in the circuit, can only be verified by placing or connecting the appropriate terminals with the multimeter to measure the voltage across the terminals and the passage of the current through the circuit. Here, the students are the customers who become the future background and backbone of the country's economic background. Hence, the engineering colleges should provide effective teaching methodology and innovative methods for learning. In an educational environment, feedback can occur in many forms, with the student feedback being a unique example.

## 2.9 Teaching Tool

Engineers are a driving force in the fast-moving global economy. The need of engineers and the requirement of engineers are increasing day by day to assist the modern science and technology. They need better engineers in the field. Across the board many upcoming engineers and the freshers lack the hands-on experience when they arrive at the college as well as landing into a well reputed industry. This lack of hands-on experience gap must be fixed which is one of the most important one. The application of the theory studied must be implemented on a real time. University education is responsible for the student to provide enough stuffs where applying physics, math and electronics and theory behind it. Providing enough means of significant design and hands-on experiences they are ready to drive the technology jobs in the $21^{st}$ century.

Basic requirements to undergo a technical education like electronics and control engineering, one must finish foundation courses like calculus, physics and basics of electronics and little bit of math. These foundation courses must be finished and there be an excellent knowledge of the solving engineering problems in their majors. Sometimes when students taking classes during the first year of course, they might be feeling like drowning in the pure theoretical concept and this makes them kind of uneasy and lose sight of why they chose engineering in the first place. They might lose interest in the program, often leading to drop out of the course. Students need an interesting, fun and challenging hands on projects during their graduation course work in order to not make them deviate from the control engineering courses and make them more interactive during the sessions. Student from more affluent backgrounds often have significant exposure to programming and electronics during their higher studies. The gap between the hands-on experience didn't meet their expectation, then they will widen, and students may further and further behind. It is therefore critical to give students better ideas and concepts through hands-on experience and interactive tools to support learning or teaching of electronics. The Figure 2.5 shows students carrying out a simple experiment with their experimentation on electronics.

Figure 2.5: hands on experience with electronics

Always there will be a glitch while installation or setting up of an engineering laboratory which are cost and logical barriers. Engineering colleges and universities often face this challenge of setup of a laboratory, it is always costlier and are expensive to run and maintain. An engineering lab with initial apparatus requirements and essential needs will costs between 50k euros to 100k. what is the next step? Setting up an initial laboratory is done, but it is not enough, next is the persons or the lab-in-charge and specific persons and authorities must be assigned to take care and for the maintenance of the laboratory. Due to the large number of the intake of the students every year, the schedule for the laboratory is very less and the time allotted for the course work and the course must be completed within the stipulated time. Most of the students for a specific course get merely 3 hours of practice in the laboratory due to the time constraints. And at the same time once a student completes a project, he cannot land at the same project on more time.

A simple small and tiny project or a tiny kit with electronics like shown in the Figure 2.6, with almost of all capabilities of the standard electronics test bench, makes student to take their own time and concentrate and they feel free to do the experiments without time limits. These types of tiny kit include a micropro-


Figure 2.6: On the go tool kit

cessor and an electronic kit [10], and they just need a computer to use the kit, and it is handy that students can take anywhere. This flexibility allows student to come up with their own solution to a problem rather than following a certain principles or procedures. We cannot judge or access student on their understanding capacity, each and every one is unique, depends upon the time of the project or theoretical concept he/she understands. Hence, they need to install an inexpensive and scalable ways to get the hands-on experience to be available and this is most important because on doing so they will work on time, innovate, experiment and create.

### 2.9.1 Simulation for learning

The control engineering discipline is one which student encounter difficulties in assimilating the theoretical concepts undergoing lectures. Mainly, this is due to the fact that before teaching the elementary control design, it is necessary to explain fundamental mathematical concepts. These concepts correspond to the first lessons on system analysis. In this tough scenario, it is better to introduce a simulation tool that makes students to practice themselves the solved problems during their theoretical classes. As we know one of the mostly used tools for control engineering is MATLAB [11]. It has wide range of options for analyzing and designing feedback control systems. Due to its high usability, it is adopted in many engineering schools as the simulation platform to motivate students to learn the control engineering easily. The Figure 2.7 shows some of the simulations available with electronics and other supported softwares related to control systems.

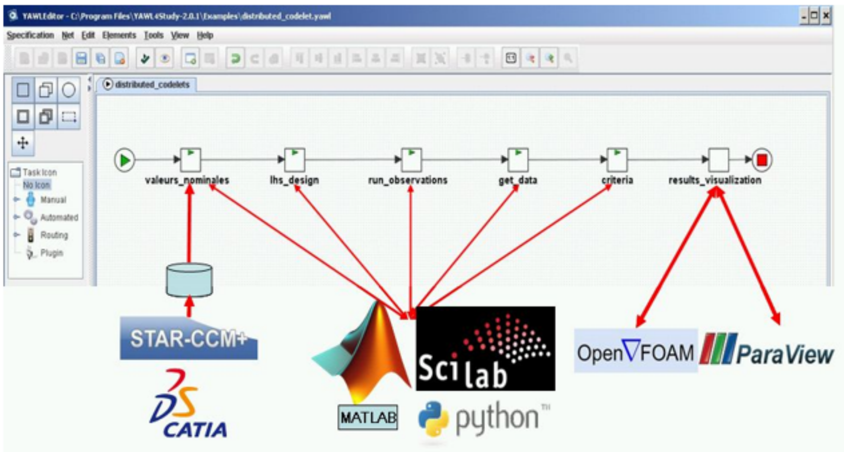


Figure 2.7: Mathematical software packages

There are similar other software packages supports control engineering such as follows;

- VISSIM
- MATHCAD
- MatrixX
- SCILAB

These are frequently used in engineering colleges and schools. Some of them prefer to work with free software like OCTAVE along with Octave Control System Toolbox [11]. All of the software packages, both with commercial and free purpose are good for numerical computation tools and in particular have many control functions. One type of teaching tool is based on a real time system or real electronic components are interfaced with internet. The other case could be on simulation. Some of them used Java-based modules are implemented to show some didactic learning [11]. It is a well-known fact that the simulation contributes to one of the basic points in control engineering teaching and learning. Since the simulation tool does not require any external equipment, where everything is available in front your screen, students can directly pick and place and give connections and simulate it.

### 2.9.2 Control web simulation tools

Control-web is a visual tool implemented by means of web pages and Java applets that is an open source and can be accessible for the users. The web interface is designed to be simple and easy to use and with a user-friendly interface. The Figure 2.8 shows the Control web-platform which allows the user to analyze the linear Single-Input and Single-Output (SISO) plants, determine the stability of the SISO systems and to simulate it using different types of input signals. Not only the control web can perform the SISO systems but also it can simulate other closed-loop simulation using different controllers [11].

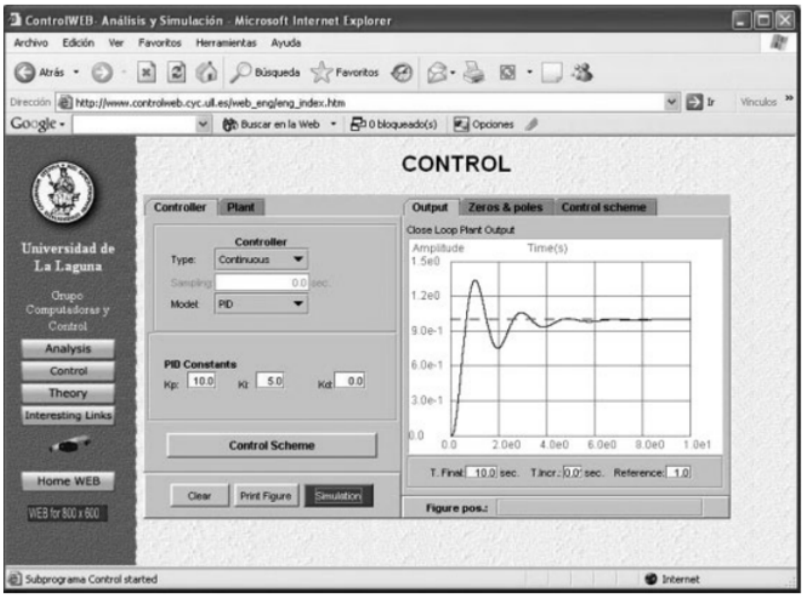


Figure 2.8: Control web

This user-friendly interface helps to reduce the time of access or the platform is easier and doesn't take much time to run the experiments.

The control web simulation tool introduced by Universidad de La Laguna covers some of the important topics of control engineering courses with different approaches to teach the students. It consists of two blocks; the first block has the introduction of the system theory and the following topics are covered:

- System Representation: For transfer function and State space
- Time-response analysis
- Frequency response: Bode plot, Nyquist plot and other similar representation.
- Stability: absolute and relative stability.

The second block belong to the Analysis Section, in this section, there is an introduction part for the design features of the control engineering. In this section the following topics are covered:

- PID control
- Compensation
- Basic state-feedback design.

## 2.10 Project based learning

By definition we can say that Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate, analyze, troubleshoot and respond to an authentic, complex question problem or challenge. As per the Figure 2.9 Project Based Learning (PBL) prepares students for academic, personal and career success and makes ready the young graduates to rise the upcoming challenges arisen and will be efficient to fight against the challenge. "Science is about knowing; engineering is about doing." - Henry Petroski

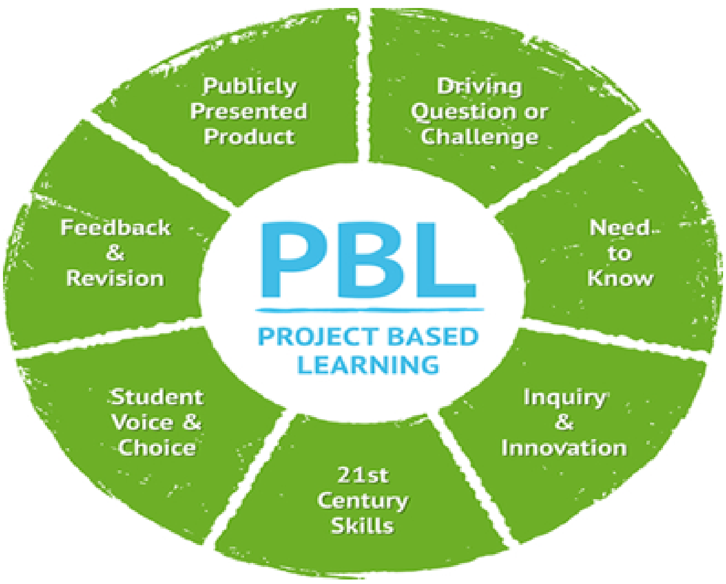


Figure 2.9: Purpose of PBL

According to the above quotes of Henry Petroski, PBL can be transformative for students. By presenting students with a mixed choice and responsibility cognitive concepts and practical activities, within an environment of real-world authenticity, projects engage students in learning that is deep and long-lasting. Since engineering education is under pressure to change.

From Figure 2.10 a possible outcomes of a Project Based Learning (PBL), where it is a student-centred pedagogy that involves a dynamic classroom approach in which it is believed that the students acquire a deeper knowledge through active exploration of real-world challenges and the problems.


Figure 2.10: Outcomes of PBL

By doing so, the students can learn about a subject, particularly when it comes to an engineering subject working on the elements of core curriculum, helps on providing a better result of acquiring knowledge [12].

More effort should be taken to motivate and attract students and to engage them in their studies and as well as in the learning process. As the topic is mostly spoken before regarding the traditional methods for teaching engineering such as lectures are most often considered bored, exercises that they feel tougher to do or to solve the problems and lab-work have been criticized because they do not prepare engineering students to collaborate and to learn active learning. As per the comparison provided in the Table 2.1 that the traditional teaching method has an approach of lecture method where professor recites the content of the context based on the academic content which has lower learning retention rates. In the last few decades, they are changing the trends of the teaching and learning method which has an attractive approach to enrich engineering education.

Table 2.1: Comparison between Traditional methods and Interactive methods

| TRADITIONAL METHODS | INTERACTIVE METHODS |
|---|---|
| Magistral lectures | Introducing workshops |
| Knowledge transmission | Knowledge building |
| Analytical syllabi | Defining objectives |
| Theory and fundamentals | Problems |
| Knowledge acquisition | Motivation to learn |
| Deductive thinking | Inductive thinking |

The Table 2.2 speaks the contrasts between the traditional learning and active learning. The goal of introducing is to attain some generic skills by solving those problems and strategical method to teach students and educates students how to learn rather than teaching them specific skills and focus more explicitly on contemporary skills including problem solving , communication , team work and leadership skills [13],[14] and [15].

In comparison with the situation of a traditional learning in which the professors expose or read the lectures and students are passive listeners. In active learning many strategies are proposed like individual activities, peer activities, group working. The role of teacher/tutor is essential in establishing the type of strategy- depending on the number of students taking part and the space allocation.

Table 2.2: Comparison between Traditional learning and Active learning

| **Traditional Learning** | **Active Learning** |
|---|---|
| Lectures | Work based on Tutorial |
| Knowledge is transferred | Foundation laid |
| Focusing on syllabus | Defining Innovative Tasks |
| Theoretical Concepts | Working on Problems / Scenarios |
| Memorizing Lectures | Finding useful information |
| Individual work | Group works and discussion |
| Exams | Self-assessment |

## 2.11 Project based learning on control engineering

The modified demands of the industrial needs and their demanding needs for the technological progress and development require a renewal of engineering education. One fact is the future engineering must be well trained to work with complex technical problems irrespective of the time pressure. And skills like basic mathematical knowledge, physics and Life Long Learning (LLL) competencies have to be renewed continuously. However, the complexity of new technology requires the engineering graduates to work with complex mathematical problems and control systems. But, still there is a question in their mind that "Can PBL train them to involve effectively in control systems engineering?" The project based on PBL with exercise solving project with robotics speaks about the importance of control engineering. And they have efficiently introduced the needs to robots to enhance the study of robotics and control systems. Since, most of the Bachelor programs in electrical engineering in almost all countries include control theory [14],[16] and [15]. The content may differ little bit depending on their curriculum from university to university. Basically, it comprises of the following:

- Introduction to control systems
- Differential equations by Laplace transformations.
- Modelling in the frequency domain.

- Time response
- Stability
- Steady state errors.
- Frequency response techniques
- Digital control systems

The case study of their introduced work challenges the students to find individual solutions to engineering problems with robot project. During that project students design and implement an autonomous mobile robot, executing a compulsory task and an optional task chosen by the students. The students are organized as teams. The formation of the groups is done during the first week of the beginning of the semester. They are allotted a specific task of using robot's movement, and in order to avoid plagiarism some of the instructions has been changed. The use of microcontroller and high speed and accuracy achievements are goal of the project [15].

## 2.12 PBL on embedded systems design

The PBL on embedded systems design focusses in supporting the course for digital electronic system design with the study of basic concepts of microprocessor and microcontroller and all of its development tools are introduced. Some students may have learnt or might have basic knowledge of C programming, analog and digital electronics. This course was offered in the name of Advanced Digital Electronic Systems for the UG degree students in Telecommunications Engineering at the University of Alcalá [17]. This is a 15-week course with 60 credit hours. The part of the time is structured as theory classes and other half is spent for doing the project and a total of 90hours of personal work has to be done. The course is designed in such a way that the entire course is focused on developing a project of intermediate complexity that deals with the design of an embedded system based on a micro-controller [17]. The specifications required for the project and microcontroller study is made on LPC1768 and a development tool with professional version of KEIL is used [17]. Some of the possible outcomes by implementing this project as follows:

- Description of the different technologies that can be integrated into the design of a digital electronic system created for a specific application.
- Use of the peripheral devices integrated on a micro-controller such as A/D and D/A converters, times, communication devices, etc. and to integrated

them with external peripheral devices like memory devices, microphones and sensors and actuators.

- Some of the commonly used techniques for the design of the embedded systems of intermediate complexity, “state chart”, task planning and execution analysis.
- Design of an embedded system with intermediate complexity from the view of hardware and software, including the corresponding technical documents.
- Adequate use of manuals, data sheets, specifications and regulations related with electrical devices used in the embedded design.

### 2.12.1 Visually guided object tracking system

The visually guided object tracking system was introduced by University of Alcalá for the embedded system on PBL for teaching the telecommunication students enrolled on the Advanced Digital Electronic Systems course [17]. The Figure 2.11 on visually guided tracking system shows the block diagram about the interface of the peripherals.

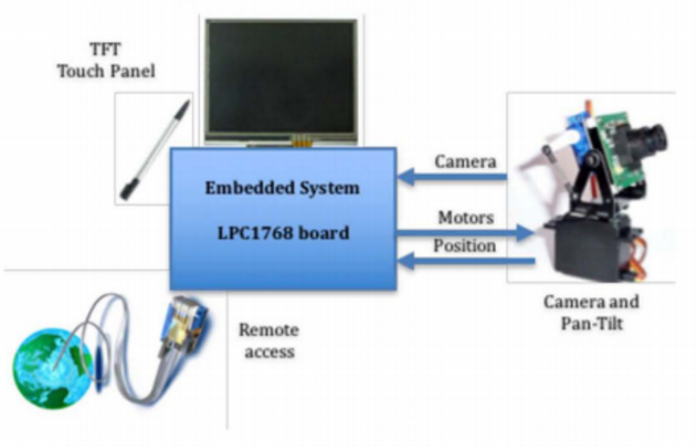


Figure 2.11: Visually guided object tracking system

The embedded system of LPC1768 is interfaced with camera with pan-tilt option, motor and position sensor. Along with these peripherals it has a remote access. This project consists of a visually guided system with possibility of remote communication enabled via TCP/IP. Apart from the remote access, the system has given an additional feature of monitoring and enabling control using local media access through a TFT monitor with touch screen. The OV7670 is used as an image sensor for the project. Then the two-servo motor is used to move or control the position of the camera and the movement of the camera is also assisted with the pan and tilt option of the camera.

### 2.12.2 Ultrasonic obstacle detection system

The ultrasonic obstacle detection system introduced for the PBL in the University of Alcalá for the embedded system course. The motive of the project is to design an embedded system with the ability to detect the approaching objects. The platform used for doing this project is LPC1786 (Cortex.M3) microcontroller.

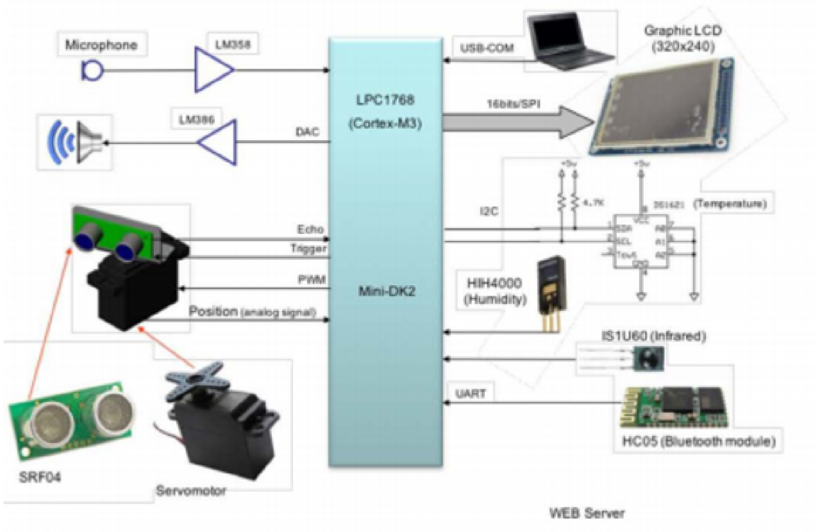


Figure 2.12: Ultrasonic obstacle detection system

The Figure 2.12 shows the functional block diagram of the ultrasonic obstacle detection system [17]. The system has a motor that is integrated with an ultrasonic sensor to measure the distance of the approaching objects or the obstacle is approaching towards the system. The ultrasonic distance sensor can be controlled by a Webpage, a Bluetooth connection or by an infrared remote control. To calculate the distance precisely they have additional installed temperature and humidity sensor.

## 2.13 Engineering education in India

According to the census results in India, the population of India states to be 1.2 billion, out of that 672 million people are in the age group of 15 to 64 years. The youth population of India needs to be equipped with relevant knowledge and skills, for their development, so as to contribute effectively for the development of the nation as well as the global economy [18]. Present criteria regarding

India, is that dragging the attention from the global inverter as the economy is growing. Obviously, the growth of industry depends on the skilled labor. But the industry has been facing major problem in skilled labor in India for some years. On other side of the scenario, the growth of engineering colleges and technical schools have grown up across India. Every year more than 2.5 lakh fresh graduates are getting passed out of various engineering branches. Even there is a sufficient number of graduates for the industry as a technical graduate trainee, still the industry is facing a major problem of hiring a skilled labor.

Growth of engineering colleges let's say is increasing more than 3000 of the counts. Establishing a number of colleges is an easy task, but the colleges fail to have a proper engineering curriculum that meets the industry requirements. From Fig.19, it can be noticed that the present engineering curriculum not all or never meets the requirement of the industrial requirements. Next coming to the labs and the installation of the labs, even though construction of the engineering college has to keep in mind that providing a practical laboratory for each course will make the pass out candidates a skilled one. But, engineering colleges, nowadays lack of infrastructure with improper lab facilities, where students won't have the clear idea of the image of an industrial process.

### 2.13.1 Lack of industrial exposure

India secures the third largest system of the education but still facing problems in access, equity and quality. Gross enrollment ratio (GER) at higher and technical education is only 22% and there is a scope for further expansion of technical education. During the last two decades, there has been tremendous increase in the number of technical institutions. At present, there are 81 centrally funded institutions; and 8562-degree level institutions and 3524 diploma level approved technical institutions. Out of these very few prestigious institutions have a strong tie-up with industries.

As the competition in the market is increasing day by day, the taste of industry is also changing. Old scenario is company used to hire a freshly graduated candidates, but modern society needs a well-equipped candidate for placing right candidates on the right place. According to the quotes mentioned in the Fig.19, the industry and company is looking for a readymade product from the institution for their demand to be fulfilled. Maximum of the institutions including Indian Institute of Technology's (IIT's) and National Institute of Technology (NIT) are facing the main problem of a well-trained faculty. Since the lack of industrial exposure of the faculty members, they still follow the old methodology of the book and chalk. Although they used to teach the classes with smart rooms, the exact amount of education is not supplied properly. This lack of industrial exposure like making students to be involved in the requirement of the industry or allowing the students for internships. And research is also one of the contributing factors where it corresponds to the personal growth and they fail to encourage.

In order to fill the gap, there are various factors are considered for improving the quality of education [19]. For example, some of the companies they took initiative in offering electives to students. Some of the notable companies like Infosys offered courses in Business Intelligence and Enterprise Resource Planning. The Sona College of Technology offered courses on Mobile applications like Mobile Application Development. This kind of arrangement helps engineering graduates to gain the knowledge in specific course curriculum.

### 2.13.2 Control engineering education in India

The contribution to control engineering from India is a greatest part, where lot of education institution offers UG (Undergraduate Courses) in an around 45 major engineering disciplines [20]. UG level course B. E (Bachelor of Engineering)/ B. Tech (Bachelor of Technology) is a four-year duration course with almost 25 laboratory courses with final year project. The (PG)Post-graduation course M. E (Master of Engineering) / M. Tech (Master of Technology) is a two-year duration consisting of four semesters having 10 theoretical courses with final semester fully dedicated for the carrying out their master thesis in their preferred area. Students have to defend their thesis before the jury members with special jury from other institution. Apart from this some premium institutions in India offers candidate a Post-doctoral research on Control Engineering to solve the industry-based research as per the interest of the candidate.

Control engineering as branch at undergraduate level is not offered by any Indian technical institute but it is offered as Instrumentation & Control Engineering by some technical institutions across India. At the post graduate level, it is offer under the specialization Instrumentation & Control, Control & Automation, Control System Engineering, Control & Computing, and Systems & Control by electrical engineering department in major technical institutions. Theoretical topics studied under it which include linear control theory, optimal control, fuzzy systems, stochastic control, adaptive control, nonlinear control, modelling & simulation etc. Beside these, students opt some optional courses from mathematical departments & electronics department that are useful in their final semester dissertation which includes abstract algebra, topology, numerical techniques, digital signal processing, power electronics etc.

At doctoral level, students do theoretical analysis for their thesis. Some few research projects funded by funding agency may form a part in their research work. Generally doctoral level research in control engineering is conducted in all standard areas in which majors are nonlinear control, robotics, path-planning, embedded control, coordination of autonomous vehicles, multi-agent systems, game theory, information theory, combinatorics, sliding mode control and applications, fractional-order modelling and control, optimization and optimization-based control, process control, identification, behavioral theory, matrix computation, automotive control, stochastic processes etc. Post-doctoral level research is more focused on the industry base issues [20].

# Chapter 3

# Fundamentals

## 3.1 General scenario on control systems

The control engineering is one of the foundation or the basics of automation. It contributes a large part to the development of modern industrial society. In the automation systems of modern days, control engineering remains one of the core functions.

The engineering course at the university level has lot of courses involve large number of mathematical and physical knowledge and its applications. Students most often find such math included courses difficult to understand which involves complex calculation part and average student feel it is less interesting. However, these courses are a fundamental requirement which is preferred by an industry for a professional engineer. Under such circumstances, there is a general lack of interests, when they were asked to do a work where they don't have interest. Since, they are stepping into one of the most important courses, they don't have the real time working experience in an industrial area.

Students find it difficult in learning the control systems, sometimes difficult to relate their studies underwent during the course work may be different from the industrial scenario. The acute problem lies in the course curriculum of the control systems. The time constrains is also one of the factors that leads to the shortage of tutorials in the theoretical classes as well as the course must be completed due to pressurized circumstances.

## 3.2 Need of control systems in modern life

In day to day life we see many control systems that takes place automatic action. For example, the air conditioner, refrigerator and microwave oven. The industry now is moving on to a different era. The built-in components of the industry are connected on to a tablet, smartphone and laptop, where internet is enabled, and the control can be sent wirelessly, and the effect can be monitored. From the Fig. 20 you can see , How important is automatic control in our day to day life? Perhaps to understand and appreciate its importance first of all we need to imagine in case what we will do if we don't have automatic control! We know for example that electric power is important in everyday life. We really appreciate electricity's importance when there is an electric power interruption, in case of periodical shutdown, that moment we can image how we are annoyed in the absence of electricity.


Figure 3.1: Control systems with wi-fi and remote monitoring

But let's now focus on the control applications in engineering systems are so important. If there is no automatic control, there is no heating or air-conditioning the way we got practiced where our body temperature and humidity are maintained. Any safety device is a control device. The electric power grids, which is supplying power for the entire city maintains precise control of frequency of the AC voltage, and if that fails shutdown occurs.

The truth of automatic control lies behind the fact that feedback control acts as an important entity. The output variable which is measured when there is a disturbance is used with the comparator to find out the error, then this error is responsible to maintain the desired setpoint. For, example let's take a simple example when we set 25° C by using the remote control of the air conditioner, primarily the air conditioner measures the room temperature, then takes a proper action of increasing or decreasing the temperature based on the information obtained from the room temperature.

The purpose of the speed control of dc motor is to maintain the optimum speed in terms of revolutions per minute(rpm). Hence, due to external disturbances like load, the speed of the dc motor gets decreased, where the control signal in the form of voltage manages the desired speed.

## 3.3 Control systems

The Control Theory deals with the study of an interdisciplinary branch of engineering and mathematics. This Control Theory deals with the behavior of the dynamic input systems and which helps in verifying the resulting behavior of the output of the system. The Control systems enable us to operate out processes in a safe and profitable manner. The use of the control system is to measure the dynamically varying process variables such as temperature, pressure, and the flow. These dynamically process variables are controlled by using controller which sends the control signal to actuate process such as opening of valves, reducing the pressure in pumps and to maintain the temperature of the water in case of Aquarium. To achieve this kind of process, the process variable must be measured and compared with the reference which throws an error. This error is called controller error which is given to the controller to take a necessary action to overcome the error.

The control systems work like a central processing unit of the computer, it takes a proper action when desired signal is received. The control system is used to enhance the production, efficiency and safety in the field of quality control, environmental control, sugar refining plants and Nuclear power plants. The purpose of using the control system is to attain or achieve two criteria one is the stability and the other is the desired output.

The representation of the system can be in various ways such as descriptive, schematic and mathematical model. Most of the electronic systems are schematically represented as a series of interconnected signals and blocks.

## 3.4 Sensors

Sensor is a device, module or a subsystem which serves the purpose of detecting events or changes and send the information to the other modules or the electronics present in it, it could be a microprocessor. In other words, it can be said that a device which measures a physical quantity and converts it into a 'signal' which can be read by using a micro-controller or micro-processor. A sensor is always used with other electronics, whether as simple as a light or as a complex as a computer. Sensors are used in everyday objects such as touch-sensitive elevator and lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware. There are various types of sensors available in the market.

## 3.5 PWM signals

Pulse Width Modulation (PWM) is used to describe the binary or discrete signal that was created through a modulation technique. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photo-voltaic solar battery chargers, other being maximum power point tracking. The average value of the voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

PWM switching frequency has to be much higher than what would affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible. The frequency at which the power supply must switch can vary greatly depending upon the load.

The 3.2 shows the various duty cycle depending upon the quantity required to be supplied. The term duty cycle describes the proportion of 'ON' time to the regular interval or 'period' of time; a low duty cycle corresponds to the low power applied, because the power is 'OFF' for most of the time. Duty cycle is often expressed in percentage, for example 100% is fully ON. When a digital signal is on half of the time and off the other half of the time, the digital signal has a duty cycle of 50% and resembles a square wave. The duty cycle can be varied according to the needs of the system depending upon the user.

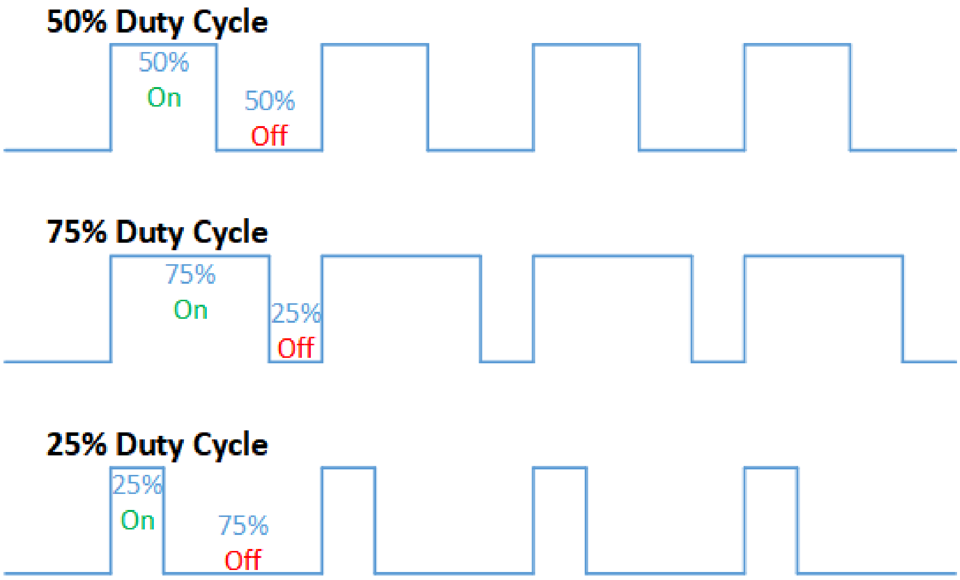


Figure 3.2: PWM signals

## 3.6 Open loop systems

The open loop system is referred as to a non-feedback system, where it lacks a feedback controller to maintain the process in automatic mode. In general, it has an input, controller and a process. In an open loop control system, the output is neither measured nor it has been feedback for the comparison to measure the error. Therefore, the open loop system follows bluntly the input set by an operator, you can neither decrease the output nor increase the output based on the environment. In other words, it can be said that the control action from the controller is independent of the process variable.

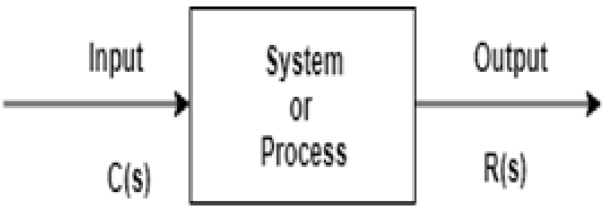


Figure 3.3: open loop control system

From the 3.3 an open loop control system consists of an input, a process and an output. The electronic systems can be represented by using interconnected block diagrams where the lines between each block. The block diagrams need not represent a simple single system but can represent very complex systems made from many interconnected subsystems. These subsystems can be connected in series, parallel or combinations of both depending upon the flow of signals.

## 3.7 Closed loop systems

The closed loop system is referred as to a feedback system, where it has a feedback controller to maintain the process in automatic mode. In general, it has an input, controller, feedback and a process. From the 3.4, the closed loop consists of a forward path but has with a feedback. This feedback is a part of the output is feedback to the reference to make some comparison and take necessary action. The motive of the closed loop system is performed automatic actions and to maintain the output with desired level. The comparison of the part of the output with the reference signal throws an error, this error signal is responsible for the controller to generate a desired control signal to overcome this error. In other words, the closed loop system can be said as a fully automatic control system in which its control action being dependent on the output.

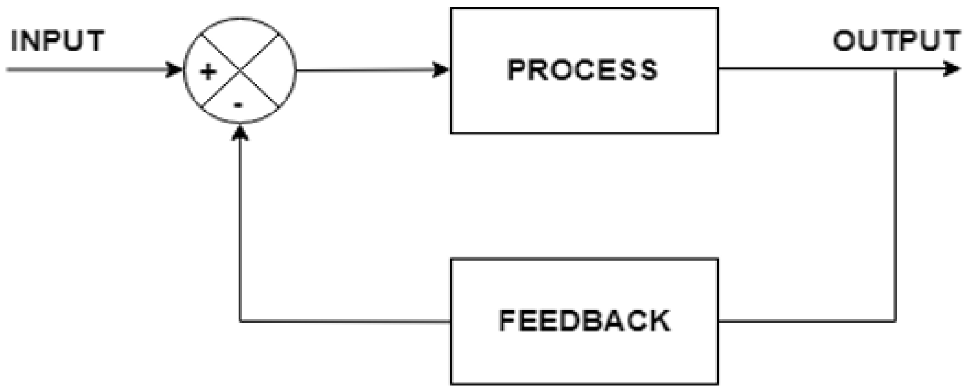


Figure 3.4: Closed loop control system

**Characteristics**

- To improve the stability of the system
- To increase or reduce the system sensitivity.
- To reduce errors by adjusting automatically the system input.

**Advantages**

- Improved dynamic response

- Greater accuracy with fine control of speed
- Stabilized operation without any major deviations.

**Disadvantages**

- They are relatively more complex in construction.
- The cose of establishment is higher compared to open loop.
- Due to the presence of feedback,the overall gain of the system gets reduced .

## 3.8 Controller

The PID control [21] is the most common way of using feedback in natural and man-made systems. PID controllers are commonly used in small scale as well as large scale industries which exists in their instruments and their laboratory equipment. In the engineering applications the controllers appear in many different forms, as a stand-alone controller, as a part of hierarchical, as distributed control systems, or in the form of embedded components. Most controllers do not use derivative action.

The ideal version of the PID controller is given by the equation 3.1,

$$u(t) = K_p e(t) + K_i \int_0^{\tau} e(\tau) d(\tau) + K_d \frac{d(e)}{d(t)} \tag{3.1}$$

From the equation (1), where u(t) is the control signal and the e(t) is the control error (e(t)=r(t)-y(t)). The reference value, r(t) is also called as the setpoint. The control signal is finally the sum of the three terms: proportional term that is proportional to the error, an integral term that is proportional to the integral of the error, and a derivative term that is proportional to the derivative of the error.

The controller parameters are proportional gain $K_p$, integral-gain $K_e$ and the derivative-gain $K_d$.

The controller can also be parameterized as mentioned in the equation 3.2,

$$u(t) = K_p \quad (e(t) + \frac{1}{T_i} \int_0^{\tau} e(\tau) d(\tau) + T_d \frac{d(e)}{d(t)}) \tag{3.2}$$

From the equation (2), where $T_i$ is the integral time constant and $T_d$ is the derivative time constant. The proportional gain or the proportional controller works on the present error or the current error. The integral part represents the average of the summation of the past errors. The derivative can be interpreted as a prediction of future error.

### 3.8.1 Proportional controller

The proportional controller is one of the simplest and more sophisticated and potentially precise approach is proportional control. This control output is set to be proportional to the error between the desired setpoint and observed error. On depending upon the error is large, more is allowed, if the error is small, less is allowed. It steps towards precise maintenance of the observed variable or the error close to the desired setpoint with minimized error, even upsets or collapse of the system occurs in the form of unstable system where it overshoots.

The term P is proportional to the current value of the difference between the setpoint and the measured value i.e. (SP-PV) =e(t).

$$P_{out}(t) = K_p e(t) \tag{3.3}$$

Where $P_{out}$ in the equation 3.3 is the output proportional to the systems, $K_p$ is the proportional gain and e(t) is the error value. In case the error is large and positive, the control output will be proportionally large and positive. This controller requires biasing or manual reset when used alone. This is because it never reaches the steady state condition. It provides stable operation but always maintains the steady state error. Speed of the response is increased when the proportional constant $K_p$ increases. Hence it is better to add or include the integral controller and the derivative controller to reduce the overshoot and to attain or reach the setpoint and enhanced performance.

#### Advantages

- Proportional controller helps in reducing the steady state error, thus making the system more stable.
- Slow response of the over damped system can be made faster with the help of these controllers.

#### Disadvantages

The controller has some of the following drawbacks as follows:

- Higher values of the gain of the proportional controller sometimes lead to the overshoot and instability of the system.
- Due to the proportional controllers there is always offsets in the system.

### 3.8.2 Integral controller

The integral part of the PID system is proportional to both the magnitude of the error and the integral term which accelerates the process of the stability of the system with reference of our system and eliminates the residual error that occur. The limitation of the Proportional controller always exists an offset between the process variable and setpoint, hence Integral controller is employed to eliminate the steady state error. This integrates the error over a period until error value gets minimized. It holds the value to the final control element at which error becomes zero. The integral control decreases its output when negative error takes place. It limits the speed of response and affects stability of the system. The speed of response is increased by decreasing integral gain $K_i$.

In the Figure 3.5, as the gain of the I- controller decreases, steady state error also goes on decreasing. In most of the cases, PI controller is used particularly where high-speed response is not required.

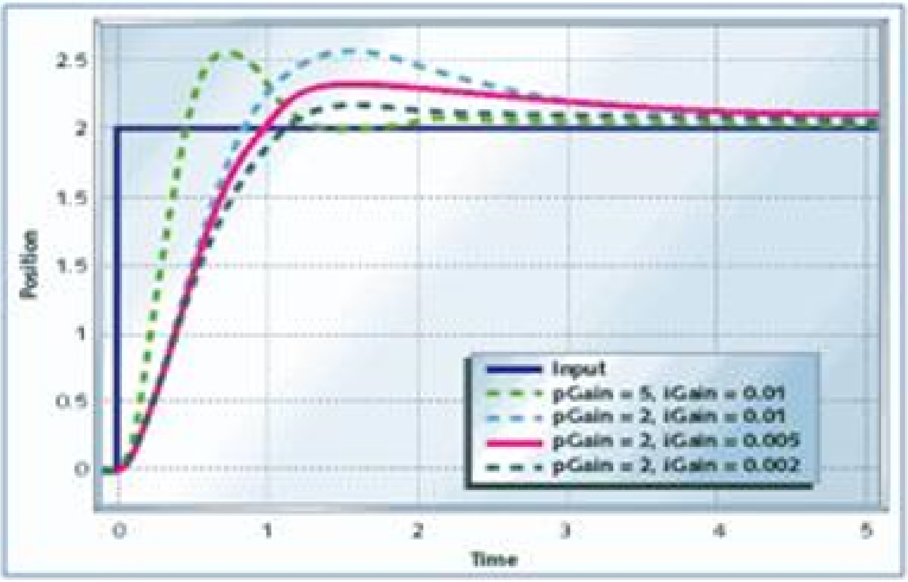


Figure 3.5: Response of the system with Integral controller

### 3.8.3 Derivative controller

In the derivative part of our process the error is calculated the slope of the error over the time and multiplying this value by the derivative gain of the system $K_d$. This part of the controller predicts the behavior of the system by improving the response time and stability of the system around the stability of the response. I-controller doesn't have the capability to predict the future behavior of error. So, it reacts normally once the set point is changed. The specialty of the D-Controller overcomes this problem by anticipating future behavior of the error. Its output depends on the rate of change of error with respect to the time, multiplied by derivative constant. It gives the kick start for the output thereby increasing system response.

The PID tuning is usually based on the Ziegler-Nichols (ZN) heuristics open loop and closed loop and the Cohen-coon are the commonly available tuning methods. These methods can be applied with or without mathematical model of the process. If the model is known, then one can process to the designing techniques, if the model is not known it is necessary to resort to the methods to draw the closest model. The parameters taken from these techniques are always a first adjustment and must be tuned to meet the intended specifications. Since the PID controller has very few parameters for tuning, they have several special empirical methods. A simplest form of tuning is to connect the controller, increase the gain until the system starts to oscillate, and then reduce the gains by an appropriate factor. Another is to measure some features in the open loop and to determine the controller parameters which will be in Ziegler method of tuning.

## 3.9 Rules of open loop method

The Ziegler-Nichols' open loop method is based on the process of step response. The PID parameters are calculated from the response in the process measurement after a step with height in the control variable. The term process here means all blocks in the control except the controller. The step response experiment is executed on the uncontrolled process, so the control loop is open. The step response is recorded with a delay.

The Figure3.6 shows the step response of the reaction, where y(t) is the output and u(t) is the input.

The mathematical equation that describes this system is in equation 3.4, where K is the Permanent gain, $\tau_D$ is the process delay time, and $\tau$ is the process time

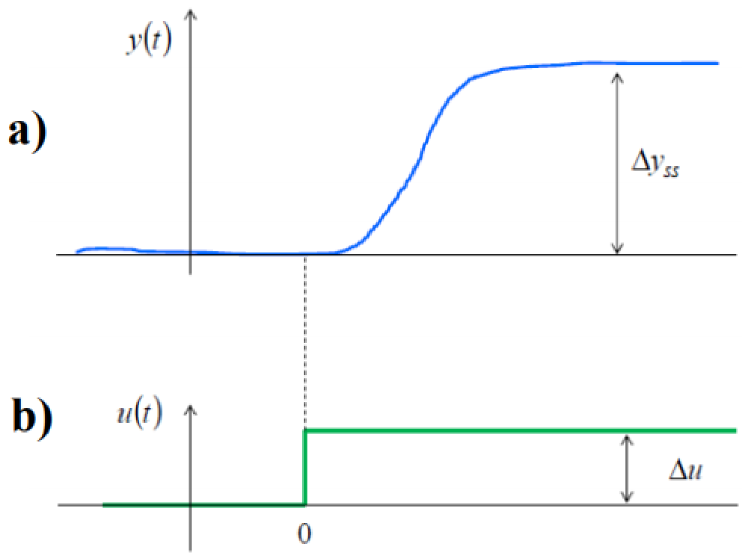


Figure 3.6: Step response

constant.

$$\frac{Y(s)}{U(s)} = G(s) = \frac{K.e^{(-\tau_D s)}}{\tau s + 1} \tag{3.4}$$

To calculate the gain K is found out by the ratio of the steady state error and the unit step response, which is shown in the equation 3.5.

$$K = \frac{\triangle y_{ss}}{\triangle u} \tag{3.5}$$

The parameters $\tau_D$ and $\tau$ are obtained by the following three different methods as follows:

### Tangent method

A tangent line is drawn the concavity point of the system response. The time values are removed for the positions where the line intercepts the reference values and Zero, this value corresponds to $\tau.\tau_D$ the time between the system which is powered and the line of intersection of the tangent line with zero. The Figure3.7 it is possible to observe the graph represents the tangent line method.

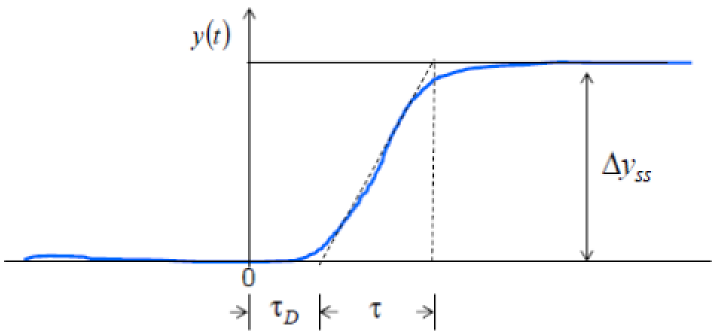


Figure 3.7: Tangent method

### One-point method

This method is used to obtain $\tau$ using the tangent line and a point corresponding to the position in the time where the system response curve reaches the value 0.632 (it is the 63% of the value). The $\tau_D$ is calculated in the same way as the previous method. It is presented with the representation of this method. The value of the time constant of the process is usually smaller than the previous process and the model is generally more approximate.

The Figure 3.8 shows the tangent with one point method.

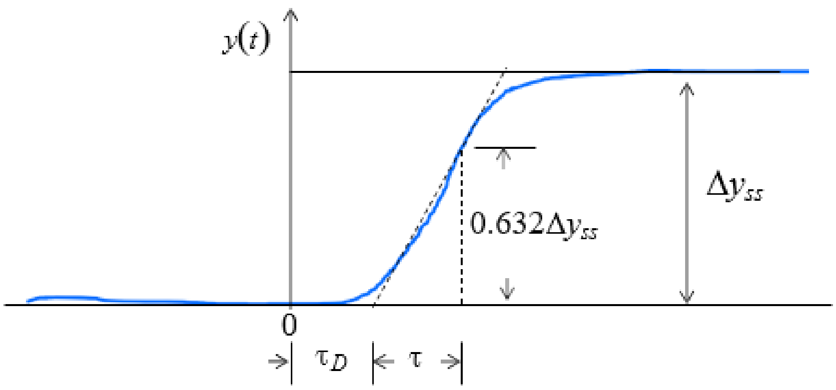


Figure 3.8: One-point method

### Two-point method

In this method, $\tau_1$ and $\tau_2$ are obtained through equations 3.6 and 3.7 respectively. Obtaining two points t2 and t1 correspond to the time instant where the system response curve reaches curve reaches the value of 63 and 28%, respectively, the value of the permanent system. The Figure 3.9 shows the graph with the illustration of the application with tangent and two-point method.

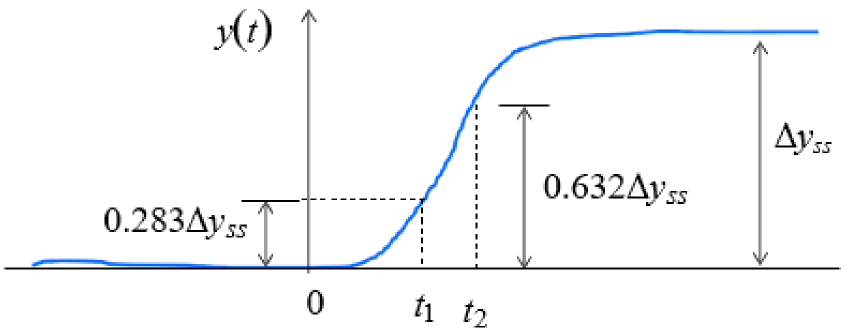


Figure 3.9: Two-point method

$$\tau = \frac{3}{2} \times (t_2 - t_1) \tag{3.6}$$

$$\tau_D = t_2 - \tau \tag{3.7}$$

## 3.10 Effects of controller

In many of the applications we will not use all the three controllers together. There is no necessity of applying all the controllers. Some of the systems get saturated with PI Controller and some do the dynamic systems get saturated only with PID Controller, it depends on the dynamic of the system. There could be a possible reason that due to some extreme vibrations systems may lead to out of control.

Most of the controller include, P Controller, which is the primary one, which produces almost mere output of the input supplied and it is one of the simplest controllers. Next question arises in our mind, which one we should neglect like adding I or D Controller. As we have mentioned it earlier that the combination of P and I controller eliminate the offset in proportional control. The disadvantages of PI are that it gives rise to higher maximum deviation, a longer response time and a longer period of oscillation than with proportional action alone. This type of control action is therefore used where the above can be tolerated and offset is undesirable.

Table 3.1: Tuning parameters

| **Parameter** | **Rise time** | **Overshoot** | **Settling time** | **Steady-state error** | **Stability** |
|---|---|---|---|---|---|
| $\mathbf{K_p}$ | Decrease | Increase | Small change | Decrease | Degrade |
| $\mathbf{K_i}$ | Decrease | Increase | Increase | Eliminate | Degrade |
| $\mathbf{K_d}$ | Minor change | Decrease | Decrease | No effect in theory | Improve if $\mathbf{K_d}$ small |

Derivative control is usually found in combination with proportional control, to form so called PD control. By adding the derivative action, lead is added to the controller and to compensate for lag around the loop, and so PD can eliminate excessive oscillations. A disadvantage is that it cannot eliminate the offset although somehow it makes it smaller.

## Chapter 4

# Remote Laboratory

This Chapter discusses the important concepts that speaks about the remote laboratory. The contrasting effects of remote and virtual laboratory. The remote laboratories contribution to the e-learning and E-laboratories and the important components of the learning environment. How far the implementation of the simulated labs and hands on experience gave a better opportunity for teaching the electronics and analyze the signals. As it is important to establish a remote laboratory, the educators in the engineering disciplines procure technical skills and knowledge needed to create a technology-enriched laboratory.

## 4.1 Introduction

Today laboratories are one of the important tools for the students to gain the experimental skills and knowledge they can acquire what they have underwent during their theoretical studies. The laboratory courses play a crucial role in the event of electrical engineering education. One excellent feature let's say automation is changing the future of these laboratories. This introduction of remote laboratories in education, provides a hands-on experience for designing skills as well as the lab focuses on conceptual understanding.

The Remote laboratory is also known as online laboratory or remote workbench which also the use of simulating the electrical and electronic circuits remotely as well as monitor the real time situation remotely by the use of computer and with the help of internet connections. The purpose of introducing the remote laboratories is to provide the students the same kind of facilities what they can experience in the local laboratory [22]. The remote laboratories in other words can be said that the physical apparatus is connected to a computer system and interfaced with micro-controllers to acquire the relevant data of the digital and analog signals.

On a note, *learning by doing* is the efficient practice in any engineering profession. The profession or the task of the engineer is to design, analyze and build their own inventions and focus was clearly on practice the skills of the fundamental concepts. The local laboratory refers to the physical space where the students enrolled during the course, use those physical spaces to directly manipulate the instruments apparatus carrying out various experiments. The labs need to be specific in terms of accessibility and to implement the desire activity, where it is dedicated for the teaching of electronics. Hence, in terms of build quality of the hardware and equipment setup for the experiment.

## 4.2 Purpose of Introducing Remote Labs

The use of remote laboratories made a significant role in teaching for undergraduate or for post graduate studies in support tool for teaching fundamental concepts. The laboratory classes for any field is important while students undergo graduate or technical courses. It is a good motive of introducing a laboratory-based teaching class room than the classes being taught with the old traditional way by a chalk and black board. Here, students acquire some of the technical knowledge regarding the content of the subject. By doing this laboratory-based teaching will not remove the importance of the lecturers. But, by adapting the new concepts of the technology will give raise to a new platform-based teaching, where the students get more enthusiastic in learning. Moreover, during this teaching methodology, the teachers or the tutors will have to prepare some additional efforts with computer based pedagogical teaching, where it will create a clear-cut idea for the students about the fundamental concepts.

## 4.3 VISIR System

VISIR (Virtual Instruments System in Reality) is a remote laboratory for performing and wiring experiments with electrical and electronic circuits [23]. It is a replication of a laboratory workbench equipped with a digital multimeter, a triple DC power supply, a two-channel oscilloscope, a signal generator and a solderless breadboard. This sort of workbench is similar in all engineering schools and faculties, for experimenting electrical and electronic circuits. VISIR system is based on PXI instruments. This enables interaction of a simulation of real equipment and real instruments at a distance, VISIR creates a real electronic laboratory environment to the student. VISIR gives access to the students at a distance as well as it can be accessed at any time and from anywhere just one

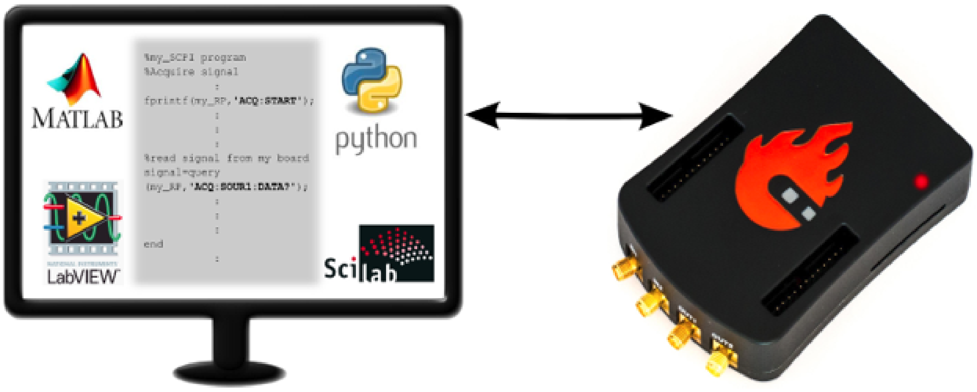


Figure 4.1: Remote Lab featured softwares

essential thing that student must have connected with PC and internet. With such environment, students interact with real electric and electronic components. They can make some adjustment with the wiring; the lab sends back the measured values to the student screen.

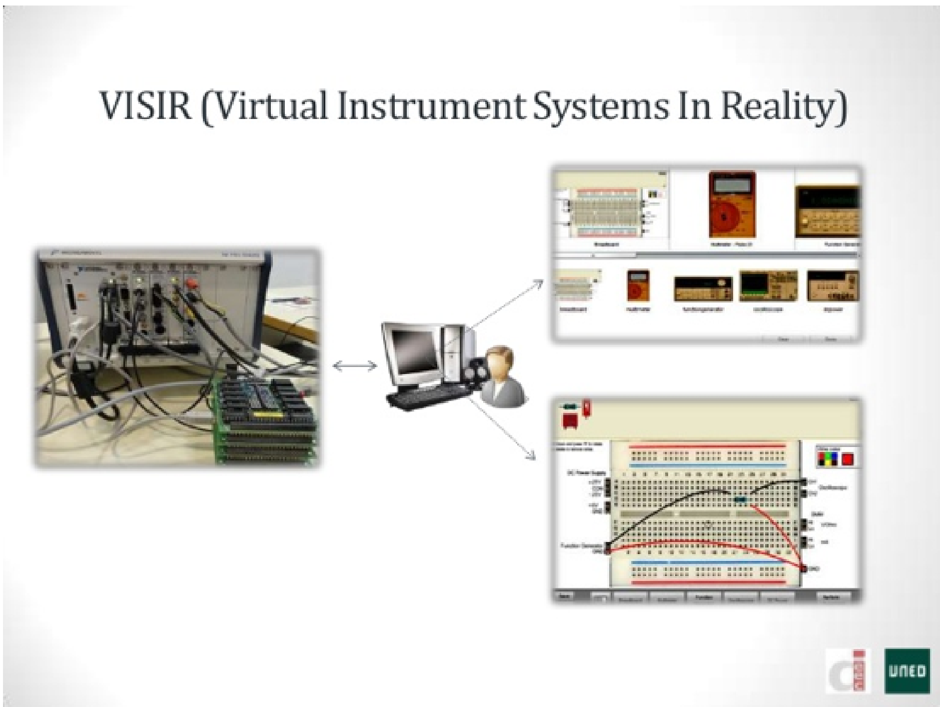


Figure 4.2: VISIR

Figure 4.2 VISIR has its own web interface in which the contents of the laboratory are arranged for accessible. It contains administration features such as:

registration, login, booking, account types. The availability of the laboratory contents depends on the user account type. Each user has their own account type, limit and features. Now, some of the universities have integrated VISIR into their own Learning Management System (LMS), and their own Remote Lab Management System (RLMS), allowing the use of the provided LMS services the laboratory work to create a completely online educational platform. So, VISIR is considered as a remote workbench for electrical and electronic circuits. At the same time hands-on laboratory for conducting experiments with the electric and electronic circuits.

# Chapter 5

# Proposed solution

This chapter discuss about the proposed solutions and requirements of the means or the tools to support control theory. The requirements for the creation and various purpose of creating those files and which would be most suitable for the students. what are the most adequate and appropriate that the created platform could be useful to them in what aspect.

Secondly, we are going to analyze various kinds of hardware platforms which is available in the market. Each of those has its uniqueness and their uses and its features and its integrations depend solely on the software which they use to integrate.

Next, once after analyzing the platforms available, we are analysing the software required to create a Graphical User Interface which is one of the requirement to have easier user interaction which doesn't require much difficult programming and it is user friendly.

## 5.1 Requirements

This section discuss about the importance of specific requirements for which an essential teaching platform or learning platform to support control theory. Some of the essential needs are discussed as follows:

- This product should be obviously with the help of a small microcontroller which is cheaper and should be able to afford by the students of the electrical and electronic engineering and this kit will be always stays with them because they can perform n number of the simple experiments to gain lots of conceptual knowledge of the control system topics by simple, cheaper and easiest way to control it.

- This microcontroller should easily communicate with the electronics that has been developed in the system to acquire data signals properly and to communicate with the software developed. Hence it has to perform front and back motion.
- The experiment or the demonstration of the learning tool should be able to be used by both students and the professors, they should be able to handle the electronic kit easily without any troubles and the developed means should be a simpler one. The Graphical user interface in the computer system is available to control all the aspects that communicates with the electronic components easily through digital communication.
- To control and process all these signals which has to be both converted analog to digital and digital to analog signals, which has to be further sent and processed by computer easily.
- The system should be simple, to be used and understandable by all the students.
- To have a built-in feature to control real-world electronics using this GUI.
- It should have an on/off Condition either remote or local control using the Graphical User Interface.
- Visualization of the Voltage acquired using analog ports and measured digital outputs of the Control signals.
- To measure and provide instantaneous results of the inputs and outputs.
- On the go control (this feature, has the capability to change the values or controls without stopping the running process).
- Command to change the parameters like sp, kp, ki and kd
- A graph to analyse should have the following parameters
    1. Set-Point
    2. Feedback
    3. Control signal
- The control system window or the Graphical User Interface which has developed should have the following parameter,
    1. The PID control, is to be able to perform, each individual operation. It should have the support to measure the error signal, control signal and the feedback signal.

2. Each parameter should be visible so that the teaching professional can able to teach the parametric control to the students and students once visualize all those things it is a never deleting process from the students mind this kind of concept.

- Once, the Graphical User Interface(GUI) is developed, a step by step procedure to use the GUI must be provided for students in the form of Student's Manual to check the basic working of the GUI.
- Along with the student's manual, a technical manual has to be provided in order to support the creation of GUI which interacts with the real world control system and gives access to the create their own GUI file and allows to learn the basics of LabVIEW.
- Slides or presentation has to be provided which sometimes, helps to user not to deviate from the principal part of creation of the GUI and helps to create in a shortcut manner.
- A LabVIEW file of set of experiments has to be created to have the real world control system as well as to support the learning of control theory in an easier way.

## 5.2 Possibilities

This sub-section discusses the needs or the possibilities to create an efficient system or the supporting tool for teaching control system.

- GUI should have the following features:
  1. Measure voltage signals
  2. Acquires potentiometer values
  3. Sends the control signal
  4. Measure the light intensity
  5. Panel for the set point
  6. Panel for controlling parameters
- Hardware to process should have the following features:
  1. Efficiently communicates between the hardware and software
  2. Acquires the signal from the Real world and send the information about the real world to the software or the GUI.
  3. Again, acquires the control signal or the process signal to the Real world.

- Real world hardware should perform these functions:
  1. To process the analog signals
  2. To Convert the Digital signals to analog
  3. To convert the analog signals into digital

In order to have all the things in compact to provide a complete set of teaching means, which satisfying all our requirements. The Figure 5.1 provides the efficient control system with required blocks.


Figure 5.1: Basic entities for a control system

### 5.2.1 Graphical User Interface

GUI stands for Graphical User Interface; it usually refers to a layout on a computer screen where it has icons displayed or which has direct interaction with electronic devices. Graphical User Interface is the GUI where all the controls and indicators such as the COM port, serial baud rate of the microcontroller which you are using. The GUI can be created in various ways. The GUI is to mainly show the measurements of the instruments or the equipment which we are using for the demonstration of the control system teaching means. This can be created by means of PYTHON, C# using Visual studio and the LabVIEW.

## Python

Python is a powerful programming language and an open source. It is easily understandable programming language. You can define your own commands, unless and unlike the other programming language, you no need to stick to some specific syntax, here you create your own object-oriented programming language. You have lot of libraries that can interact with microcontrollers. Where are Tkinter is the main package, which is related for the creation of the GUI and serial port is the common means of communication between the PC and microcontroller as well as the electronics or the real world is interacted or interfaced with the microcontroller. Tkinter is the standard graphical user interface package that comes with Python. While other Python GUI frameworks exist, like wxPython, PyQt and Kivy of this Tkinter is easy to learn, comes along with Python and shares the same open source license as Python. We recommend starting with Tkinter as a place to learn about GUI development (or for quickly prototyping your own dashboard!) and then moving on to another package if you feel you need something prettier or more powerful. So, lot of packages which facilitates the programming with electronics and creation of the GUI, and GUI acquires the digital and analog values and it displays in the gauge which is available.

Essential components required to communicate Arduino with python and to create a GUI, as follows:

- Tkinter
- Pyserial
- Arduino IDE.

Since there are lot of programming languages available as a free source or free versions, why do we need to use python. Because, Python is a versatile, easy to learn, saves time in implementation and easy to use scripting language. Its power and huge library of user-created modules makes it an ideal language for a wide variety of computer side tasks. You could easy parse network and make an Arduino visualizer. And there are several ways to approach Arduino USB communication, but in this case, we will be using Python on the computer side to send and receive information


Figure 5.2: PySerial package

One you have the basic knowledge of working with python its data type and conversion, then this pySerial library package, allows python to work with Arduino as the brain or the CPU for controlling and receiving information through the Serial Monitor.

### Advantages:

- Easy to learn
- Its an open source.
- You have lot of tutorial.
- Easy to program.

### Disadvantages:

- Takes a lot of time in programming.
- Requires a prior knowledge in programming with Arduino.
- Requires an excellent knowledge in programming of Arduino.
- Doesn't have proper integration between the Arduino and python.
- Tkinter is missing some widgets to analyze graphical solutions.
- Unable to measure some specific output.

### C sharp

C# is a general object-oriented programming (OOP) language for networking and web development. It is general-purpose language designed for developing apps on the Microsoft platform and requires the .NET framework on windows to work. The Figure 5.3 shows the integration or working of serial communication of Arduino Uno with C sharp.

C# improved features such as:

- C# has a strict Boolean data variable type, such as bool, whereas c++ bool variable types may be returned as integers or pointers to avoid common programming errors.
- C# automatically manges inaccesible obejct emenory usign a garbage collector, which eleminated developer concerns and memory leaks.
- C# type is safer than c++ and has safe default conversions, which are implemented during compilations or runtime.


Figure 5.3: Csharp with arduino

### Advantages:

- C# is easy to learn but complex
- C# has many features that make it easy to learn. It's a high level language relatively easy to read, with many of the most complex tasks abstracted away, so the programmer doesn't have to worry about them. Memory management, for example, is removed form the users responsibility and handled by .NET's garbage collection scheme.
- It's also a statically-typed language, so the code is checked before it is turned into an application. This makes it easier to find errors, something which can be particularly useful for beginners.
- C# is an In-Demand Skill

### LabVIEW

The LabVIEW is the acronym for the Laboratory Virtual Instrument Engineering Workbench is a logical programming language graphic originally from National Instruments. The main fields of application of LabVIEW are the realization of the measurements and automation. Programming is done according to the data flow model, which offers this language advantages for data acquisition and manipulation. The programs in LabVIEW are called virtual instruments, or simply IVs. They are composed of the front panel, which contains the interface, and the block diagram, which contains the program's graphic code. The program is not processed by an interpreter but compiled. In this way its performance is comparable to the exhibited by high level programming languages. The LabVIEW graphical language is called "G".

I/O channels sold in the last 10 years, National Instruments is a global market leader in PC-based data acquisition, with a complete family of data acquisition products for desktop, portable, industrial, and embedded applications. You can use NI-DAQmx driver software to integrate more than 200 data acquisition devices in LabVIEW on a variety of major buses and form factors, including USB, PCI, PCI Express, PXI, PXI Express, wireless, and Ethernet.

In addition to data acquisition hardware, NI also offers other specialty test, measurement, and control hardware. Modular instruments synchronize measurements, signal generation, radio frequency (RF), and switching components for automated test systems. NI programmable automation controllers combine the ruggedness of a PLC and the performance of a PC for industrial measurement and control applications. Vision devices also offer unique capabilities not found in many traditional sensors, such as verifying component positioning, counting physical elements, and reading bar codes.

Each hardware type includes its own driver software for easy integration into LabVIEW. Examples include:

- Digital Multimeters
- High-Speed Digitizers (Oscilloscopes)
- RF Signal Analyzers
- RF Signal Generators
- Signal Generators
- High-Speed Digital I/O
- Switches
- Programmable Power Supplies
- Reconfigurable FPGA I/O
- Motion Controllers
- Vision Systems

After analyzing the various methods of implementation for the creation of the GUI. The below table 5.1 shows the overall comparison and discuss about the choosing of which platform could be suitable and more easier for the learning and understanding.

Table 5.1: Properties comparison

| PROPERTIES | PYTHON | C# | LABVIEW |
|---|---|---|---|
| Free ware | Yes | Yes | Free for students |
| Features | Easily programmable | Little bit complex | Completely graphical programming |
| Feasibility | More feasible | Portable | It supports wide range of products |
| Product support | Microcontrollers | Microcontrollers | Micrcontroller, FPGA, ARM processors, Raspberry pi and Mydaq |
| Reusable | Moderate efficiency | Little bit difficult | Easier modification in the code |
| Remote control | No | No | Yes |

### 5.2.2 Hardware

A micro-controller is a small computer on a single integrated circuit. A micro-controller contains CPU's(Central Processing Units) along with the memory and programmable input and output peripherals. A small memory for processing possibly RAM could be included on chip. Micro-controllers are designed for the embedded applications, which are used in automatically controlled products and devices, such as automobile engine control systems, medical devices, remote controls, and power tools. For most of the IoT (Internet of things) applications, micro-controllers are an economical solutions and helps in data collections, sensing and actuating the physical world as and edge devices.

#### Arduino UNO

The Arduino Uno is a prototyping platform it is designed with a microcontroller Atmel AVR with support input / output built a programming language standard, which originates from wiring and is essentially C/ C++. The Arduino Uno is an excellent hardware which is affordable, inexpensive, flexible and easy to use by beginners and professionals. The Arduino Uno gives supports for the most of the hobbyists and the professionals to start with projects in an affordable price. An Arduino Uno is usually interfaced with the host PC(Personnel Computer) using serial interface or USB interface to interface with the host, which is used to perform and interact with the real world.

The Arduino Uno pin-out consists of 14 digital pins, 6 analog inputs, a power jack, USB connection and ICSP header. The versatility of the pinout provides many different options such as driving motors, LED's, reading sensors and more.


Figure 5.4: Arduino Uno

### Software

The Arduino IDE is a cross-platform application written in Java. It is schematized to introduce programming with software development. It includes a code editor with syntax capabilities, corresponding parentheses and auto indentation, being able to compile and load programs to the card with a single click. There is no need to edit or run programs in command line.

Supported Platforms:

- Windows
- Mac OS X
- Linux

### Importance

- When you deal with electronics, yo usually deal with low voltages, typically 5 volts or below. These voltages are considered safe. So touching these electronics with your hands is safe.
- Controls real world hardware through easier programming code.
- It allows you to reuse your existing knowledge and experience and extend it to a new platform.

### Raspberry pi

Raspberry pi is a series of small single-board computers developed in the united kingdom by the Raspberry pi foundation to promote teaching of basic in schools and in developing countries. The original model became far more popular than anticipated and it mostly attracted towards the people who are more interested in robotics. It Raspberry pi is a microcomputer which has modest features as a computer and is heavily used by hobbyists, students and developers all around the world. It was aimed at encouraging students into computing and developing because of it's affordability.

Figure 5.5: Raspberry Pi

### Application in home automation

There are huge number of developers and applications that are leveraging the Raspberry pi for home automation. These programmers are constantly implementing their efforts on modifying the Raspberry Pi into a cost-affordable solution in energy monitoring and power consumption. Because of the relatively low cost product, Raspberry pi has become a popular and economical alternative to the more expensive commercial solution.

### Application in education

As of January 2012, enquiries states the education board in the United Kingdom have been received from schools impose both the state and private sectors, with around five times as much interest from the latter [24]. It is hoped that businesses will sponsor purchases for less advantaged schools. The CEO of Premier Farnell said that the government of a country in the Middle East has expressed interest in providing a board to every schoolgirl, to enhance her employment prospects. In 2014, the Raspberry Pi Foundation hired a number of its community members including ex-teachers and software developers to launch a set of free learning resources for its website. The foundation also started a teacher training course called Picademy with the aim of providing full support to provide means to prepare and teach electronics in their class room session.

Features:

- CPU: Broadcom BCM2836 900MHz quad-core ARM Cortex-A7 processor
- RAM: 1 GB SDRAM
- USB Ports: 4 USB 2.0 ports (same as Raspberry Pi B+)
- Network: 10/100 Mbit/s Ethernet (same as Raspberry Pi B+)

- Power Ratings: 600 mA (3.0 W) (same as Raspberry Pi B+)
- Power Source: 5V Micro USB (same as previous models)
- Size: 85.60$mm \times$ 56.5$mm$ (same as Raspberry Pi B+)
- Weight: 45 g (same as Raspberry Pi B+)

### MyDAQ

The NI myDAQ is a data acquisition device designed mainly for students. As a tool for introducing engineering concepts and problem-solving, it allows hands-on experimentation. As it is a portable device, it allows for analyzing and measuring live signals in the classroom or wherever you may be. The myDAQ combines easy-to-use software-defined instruments and hardware that you can use as a function generator, digital multimeter, oscilloscope and much more. Pairing myDAQ with LabVIEW and Multisim expands it ability to create prototype systems and more.

It is a low-cost portable data acquisition (DAQ) device that uses NI LabVIEW-based software instruments, allowing students to measure and analyze real-world signals [25]. NI myDAQ is ideal for exploring electronics and taking sensor measurements.

Combined with the NI LabVIEW on the PC, students can analyze and process acquired signals and control simple processes at anytime,anywhere. NI myDAQ is a clearly a powerful tool in its own right. However, combining it with different programs and accessories expands its capabilities even further. There are so many possibilities, but especially designed accessories and mini-systems for myDAQ create even more possibilities and opportunities for interlinking.

Another system designed to work with your myDAQ is the mySTEM Project Board. Its focus is on creating solutions to unique design problems. It is an affordable solution to create a programmable action controller. This is an excellent tool for introducing control systems.

### Learning Objectives

These are the following objectives to use NI-myDAQ:

- Students will learn the fundamentals of data acquisition and processing through use of a variety of sensors.
- Students will relate the skills they learn through projects to real-world engineering applications.
- Students will gain proficiency in using a myDAQ, DAQ Express, and common circuit components.

### Requirements

- NI-ELVISmx – driver that provides access for your myDAQ.
- NI-DAQmx – driver that programmatically allows control or automate measurements with your myDAQ.
- Analog inputs
- Stereo inputs
- DMM all channels that are physically available for analog input task.

### Applications of NI myDAQ

- Circuits and Electronics
- Mechanical Measurements
- Signals and systems

After coming across various comparison about the discussed platforms which could be helpful for the students, based on their affordability and on seeing this Table 5.2 gives us to choose further which could be suitable for the beginners in terms of the hardware.

Table 5.2: Platform comparison

| PROPERTIES | ARDUINO UNO | RASPBERRY PI | MYDAQ |
|---|---|---|---|
| Affordable | Yes | Yes | Costlier |
| Features | Can perform various operations with limited efficiency of processing | Has capability of including more GPIO pins for future purposes. | Included Oscilloscope, Multimeter, Audio in and out frequency measurement |
| Easy to access | Yes , | Little bit complicated | |
| Software support | Completely free and it supports all platform | Yes it a free ware | Supports all platforms like windows and Mac osx, and limited ubuntu versions of the software operating systems |
| Powerful | | Comparitively powerful the Arduino but less powerfull the mydaq. | Morepowerfull of all |
| Remote control | Yes | Yes | Yes |

# Chapter 6

# Implementation

This chapter discuss about the ways of choosing the adequate solution for the problems and the requirements which were discussed earlier in the previous chapter. The justification of the solution is discussed in detail after careful consideration and reviews why this stands as the better solution of the discussed possible ways of teaching methodologies.

The right platform chosen could be helpful for the student in an intuitive way could be having a GUI with which provides a control panel where we can visualize, analyze and measure the quantity of signals applied. Once, after the creation of the GUI file, set of experiments were created with step by step clear guidelines or Manuals to re-use the platform developed for teaching of the control systems. The flashing of firmware guidance is explained.

The validation part is later discussed and their valuable suggestions and pedagogical survey shows the way of acceptance level of the implementation part by the students.

## 6.1 Justification of the proposed solution

This section discuss about the history of selecting possible solution. As per the block diagram mentioned in the Figure 6.1, nowadays student use PC or their Laptop for the study purposes, which they used to carry with them most of the time. As we know that Laptops support as one of education tool which they used to have with them most of the time, it could be useful however, the developed GUI could be installed in their PC and they can perform experiment carried out anywhere they want. Thus, PC could be the user friendly solution where you will get all the features, using a front end to control the electronics or the real-world hardware. The LabVIEW (Laboratory Virtual Instrument Engineering Workbench) which is free for students and provides the control panel to have the overall control of the real-world hardware and the communication between the hardware and the Arduino is made easy.


Figure 6.1: Essential element for the proposed solution

### Arduino uno

The Arduino Uno is one of the great and simple micro-controller unit, where it is an all in one package. Nowadays hobbyists are more fascinated towards the word electronics and Arduino gives a big support to begin with it. Easier interface for acquisition of the Analog inputs and digital outputs. Internal simple 12 bit ADC conversion helps to integrate for electronics and analog devices which works on 5V. Its easier library integration with various hardware and integrated sensors makes this device versatile one. It is recommended for everyone who is beginner to electronics or for understanding the concepts easier where it doesn't costs you much.

Some of the following factors to choose Arduino Uno as a micro-controller as follows:

- Simpler to use and can be promoted for educational purposes.
- Supports majority of operating systems.
- Has support with LabVIEW.
- Gives hand to communicate between the control signals from the PC and sends proper message to the Real world electronics and communicates it back to the PC I mean the user the proper information sent and received.
- It supports majority of sensor modules which are essential for implementing a closed loop system.
- Easier integration with Real world electronic modules.

### LabVIEW

LabVIEW is an excellent software from National Instruments. It is a powerful graphical programming software. LabVIEW can be used to perform a huge number of mathematical and logic functions, including but certainly no limited to basic arithmetic, if/then/elseif conditional statements, case statements, filtering, PID control loops,etc. There are huge libraries of functions to pull form. You can also interface to code developed in other programming languages, through DLLs. .NET assemblies, and run-time interpreters like MATLAB for example. All these things can be experienced by the students for free to work with this software.

### Graphical Programming

LabVIEW is different from most of the other commonly available programming languages in the market, First, G programming is performed by wiring together graphical icons on a diagram, which is then compiled directly to a machine code so the computer processors can execute it. While represented graphically instead of text, G contains the same programming concepts found inmost traditional languages [26]. For example, G includes all the standard constructors, such as data types, loops, event handling, variables, recursion, and object-oriented programming.

These are the following features of the graphical programming:

- Most people, engineers and scientists learn by seeing and processing images. Many engineers and scientists can also be characterized as visual thinkers, meaning that they are especially adept at using visual processing to organize information. In other words, they think best in pictures. This is often reinforced in colleges and universities, where students are encouraed to model solutions to problems as process diagrams.
- Reduces time in implementing the loop concepts than mapping with the original context takes more time.
- LabVIEW helps in reducing the time of creation of such conditional statements then the original statements, with simple and intuitive integration.
- LabVIEW is a system design platform and development environment for graphical language programming. It is a visual programming language from National Instruments (NI).
- LabVIEW programs or virtual instruments (VIs) have front panels and block diagrams. The front panel is the user interface (UI), and the block diagram contains the graphical source code, which is the programming behind the User Interface (UI).

- After building the front panel, the code is added to the block diagram using graphical representations of functions to control front-panel objects. The code on the block diagram is graphical code, also known as G code or block diagram code.
- The front panel is built using controls (inputs) and indicators (outputs). Controls supply information to the VI, and indicators indicate or display the results based on the inputs given to the VI.
- LabVIEW is commonly used for data acquisition, instrument control and industrial automation on different operating systems. Graphical programming helps to build programs just by dragging and dropping virtual representations of lab equipment.
- LabVIEW programming environment makes it easy to create small applications. For a complex code, it is important to have extensive knowledge of the special LabVIEW syntax and topology of its memory management.

### Characteristics

These are the following features which describes better that why LabVIEW stands as the proper solution of all programming languages and Front end software:

- LabVIEW is powerful software that it provides cross platform integration.
- Calibration of sensors with defined units is easier to measure and analyze in LabVIEW than any other software.
- On the go features like changes the important parameters, but the program will execute continuously, you don't need to stop the program and to continue. Instead of that , the program will automatically execute and it will automatically gets input from the User.
- If there is kind of error, it can be reprogrammed easily, unless other programming languages you need to start from the scratch.
- Measurement of the Values at certain specific inputs and outputs can be done then and there.
- Graphical analysis of PID outputs and the corresponding inputs required for the actuator can be measured graphically with ease.
- Not only for teaching the basic concepts of control system, apart from this many basic concepts of digital electronics and analogue electronics can be done with LabVIEW.

### Real World Electronics

This electronic part is the third design of the proposed solution. The electronics and its associated modules are easier to buy in the market. This electronics are easier to buy which are affordable by students and it is safer to use. You can explain the concepts using some kind of simulation, but explaining the concepts in terms of simulation is not a good idea. Students should learn something and the work being provided should be intuitive and they should work in real world. Working on real-time and real-world electronics gives them better idea and learn and work with true concepts and it is not an imaginary one. We use real-world electronics to support the teaching of control systems in an easier way, where the students can visualize what is happening? We can use simulation tools to teach,but providing some kind of simple electronic kits make students to involve themselves by providing how to interact with electronics. These electronic components are simple, affordable and safer to use.

## 6.2 Implementation

The implementation part briefly explains about the step by step procedures and creating a structured procedure to implement a PID control using a simple electronic circuit which is cost efficient and portable along with the microcontroller unit for processing and communicating the useful information of the conversion of the analog to digital conversion and digital to analog conversion. This platform creates a *learning by doing* implementation and gives an intuition for learning in an easier way.

Provided set of experiments which were created as a means to support control theory, as well as to increase the complexity at each stage and it is the strategy lies behind to implement these experiments. The implementation includes as follows:

- Student Manual
- Technical Manual
- Slides
- VIs

A *Student Manual* is the one which has been prepared for giving basic ideas of students who will start with the experiments. The *Technical Manual* is the one which is prepared to support the creation of GUI which the students have used and it helps to create their own file in a step by step procedure. Slides gives the crisp ideas of the Technical Manual to cut short the time of creation of GUI.

The VI is the Virtual Instrument file, which is especially designed and to work with LabVIEW, where you have the complete package of the GUI to interact, visualize and measure the signals virtually.

### Student Manual

There are provided a set of experiments, creation of experiments is not enough, we need to provide some supporting guides to use the LabVIEW files in the VI format. Each experiments has provided a VI file, which has to be executed with real world electronics as well as it has to undergo some electronic circuit connections and that has to be connected to the PC, where the LabVIEW is installed with all supporting drivers to communicate with Arduino UNO. We need to have some kind of tool like guide or manuals which provides the information then and there which helps to facilitate the electronic kit to be controlled using a personal computer and carry out the experiments autonomously. They can rewind those experiments how many times they want to do. They can utilize their free time to carryout these simple experiments.

The features of Student Manual are as follows:

- Each student manual explains basic construction of the electronic circuit and its uses.
- Helps you to install drivers using the manual for flashing the hardware.
- Each experiment created is to provide a way of creating an interest among the students using the plug and play methodology for the control systems. All these means help to create a PID control system.
- Student manual provides a basic schematic of electronic circuit. Student is intended to make connection with breadboard a simple electronic circuit with the Arduino board, as like the schematic provided in the student manual.
- Then next step is to connect the USB cable with the PC and the Arduino. Where the PC is installed with LabVIEW and another driver software required to run the VI program with the Arduino UNO.
- Then before starting the program, he has to flash the firmware, once the flashing of the Linx firmware with the Arduino Uno, it opens the communication port with the LabVIEW.
- After the successful flashing of the software is done, they can open the ZIP file where the LabVIEW files are provided then they can start plug and playing with the Software as well as they can observe the Real-world electronics reaction with the Remote control from the LabVIEW.

- The Student Manual is provided with a flashing of firmware software that which creates a door to open the serial port communication and flashing the total Arduino memory into the LabVIEW, where the controls provided in the LabVIEW directly connected or let's say programmatically the physical pins gets access via the VISA architecture, which pays the way for the Virtual Instruments Software Architecture.

### Technical Manual

The student will get some basic ideas, how to plug and play with the Student Manual, and the purpose of introducing each experiment and its final observation. Now, the student wants to create his own VI, that he/she wants to create his own LabVIEW file for the *Control System*. To do so, the Technical Manual is organized in a step by step manner, how to create the LabVIEW file in each instance but same as the LabVIEW file which they have used to do the experiments. The Technical Manual gives them a basic idea of LabVIEW as well as create the experiments using LabVIEW VI file, that which they tested or used for carrying out the experiments using a Student Manual. The Student Manual just provides the instructions to plug and play, Whereas the Technical Manual works as behind the scene, which means it helps to create a replica of the VI file which they have used for carrying out the experiment. Through this set of experiment students, they will get trained how to create their own VI file by using the Technical Manual as well as how to use the options for creating their own VI in the future.

The features of the Technical Manual as follows:

- Helps to create a blank VI file.
- Teaches you the basic structure of LabVIEW.
- Guides you how to create and organize blocks with front and block diagram.
- Gives you the importance of the Front panel, and what it should contain.
- It helps to how to create a program in the block diagram.
- Shows the importance of the controls and indicators.
- Guides you how to create a well-structured program in the block diagram.
- Provides you some tips then and there the proper usage of the LabVIEW blocks.

### Slides

Slides helps the student to give a shortcut way of creating those VI files by reducing their time in concentrating the Technical Manual. It is obvious that Technical Manual is the complete guide for the creation of the GUI, while coming to the time constraints providing these kind of means helps them to create GUI in an easier way.

The features of the *slides* as follows:

- Slides explain briefly the motive of each experiment.
- It helps to create a LabVIEW file which is same as that of the *VI file* of the Experiment from each modules.
- This guides step by step procedure, how to create a VI file exactly same as the VI file that the student has used for carrying out each experiment.
- This guidance helps the student not only to create the VI file exactly same as the parent file, but this creates a platform for them to implement their own ideas with different hardware platforms and to learn and gain knowledge in the field of electronics control system.
- These slides guides student in a precise manner of the technical manual, but it saves time.
- These slides cut shorts the time for creation of VI than using a technical manual, in fact the technical manual is well scripted, but when it comes in terms of shortage of time. The student can use the slides to create rapidly than using technical manual.
- It precisely involves the steps and procedures to be followed for the creation of the LabVIEW front panel and block diagram file.
- It helps to pass information to the students about the important elements and parameters to be included in the *Front Panel* and *Block Diagram* of the LabVIEW file.

### Graphical User Interface using LabVIEW

VI file is the Graphical User Interface (GUI) which is designed to control , visualize the signals virtually and measure the analog input values and digital outputs.

These are the following reasons to provide the VI files, such as:

- There may be some odd case, where student can end up with failures in creating the VI file (the GUI created using LabVIEW), exactly same as depicted in their specific manuals provided to them.
- Student should not give up their try, when they face failures. They should try until they succeed it. But in case, it is better to give them a solution.
- While doing those experiments or creation of the Graphical User Interface using the Technical Manual, if the fail to follow a step in between they might end up in error. It is better to provide the VI file, which they have to create so that they can analyze "what was the mistake ?".
- "What are the possible errors they are encountering while they program in LabVIEW?" At which creation of the segment they have errors, they can rectify it and verify it on their own if they will be provided with a original file where the GUI is present.
- This VI file helps them to verify their files which they have created to learn the support and teaching of the control system.
- And this makes them, not only to stick in this single file creation, they might get some new ideas, in the future, they can implement their own ideas of creating the VI file.

## EXPERIMENTS

To implement PID control, it is not an easy way for the students to implement directly without knowing the basics of LabVIEW. They need to have some starter kit for basic plug and play operations then they have certain specific step by step manuals which assists them to implement a digital control system on their own using documents provided. Hence, we have provided set of six experiments lets say rating from simpler to complexity of the experiments, with passing through some medium difficulty of the project.

## EXPERIMENT 1

This is to provide a simple on/off control via remote interface, where there is no physical contact with the Lamp. And the lamp is controlled remotely via PC. Before teaching LabVIEW through electronics to teach control system. It is better to provide some basic idea of why and what is the purpose of using each and every experiment. By starting with this simple experiment, the student at the end of the tutorial will have some idea of how simple on/off works, which is achieved through simple graphical user interface, which is friendly. Doesn't requires a huge thinking. It hardly takes 5-10 mins to take a look and start and doing.

The LabVIEW is installed in the PC, which sends the signal to the microcontroller, where the LabVIEW is communicating through the VISA driver where the LabVIEW sends signal to the Microcontroller using this Architecture. By using the VISA driver, LabVIEW has full access to the pins in the Arduino Uno like digital and Analog pins, we can measure, read and write signals. As you can notice in the block diagram shown in the Figure 6.2, once student knows that he wants to basically constructs an open loop but, the open loop doesn't have any measurement included in the system. The LabVIEW sends the digital on/off signal from the LabVIEW to the Arduino UNO PWM pin, but we are sending the digital high and low signals, whereas output of the Arduino Uno is not sufficient to drive the lamp. Hence, the driver is connected between the lamp and the Arduino Uno PWM output. In order to avoid confusion for the beginners, it is recommended to use the same pin as mentioned in the schematic, until the end of the $6^{th}$ experiment.

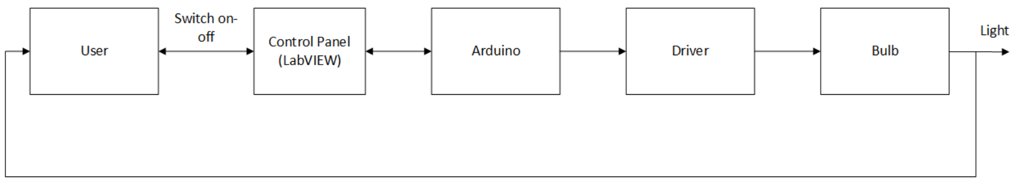


Figure 6.2: Block diagram for on-off control

The schematic of the experiment is given as shows in the Figure 6.3, this simple experiment gives you a detailed explanation of simple on / off concept.

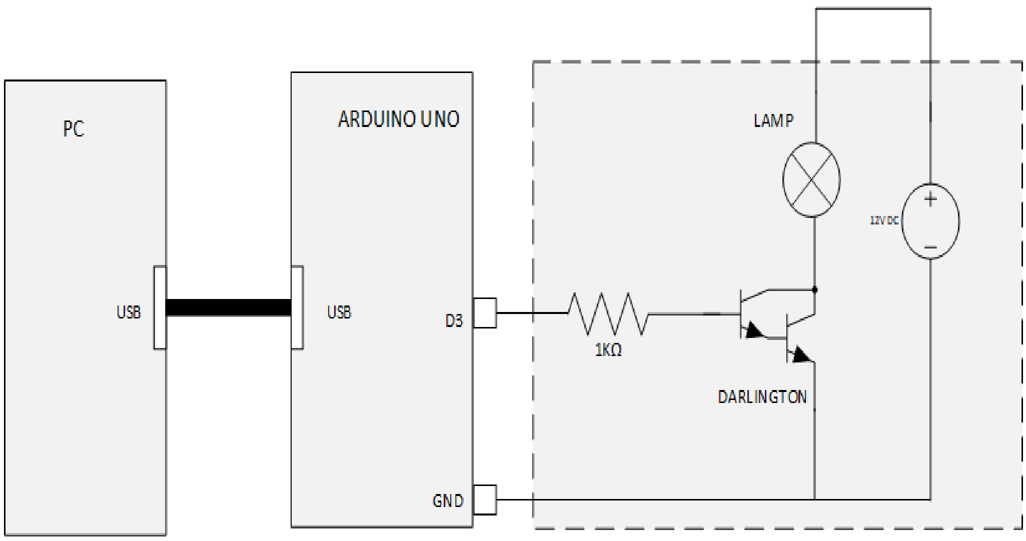


Figure 6.3: Simple on-off control

The Figure 6.4 is the GUI developed for the Simple on-off Control. The operating range of the Arduino Uno during this digital on/off is 0-5V, but whereas we are converting this scale of 0-5V to 0-12V, which is 0-100% operating range of the lamp.

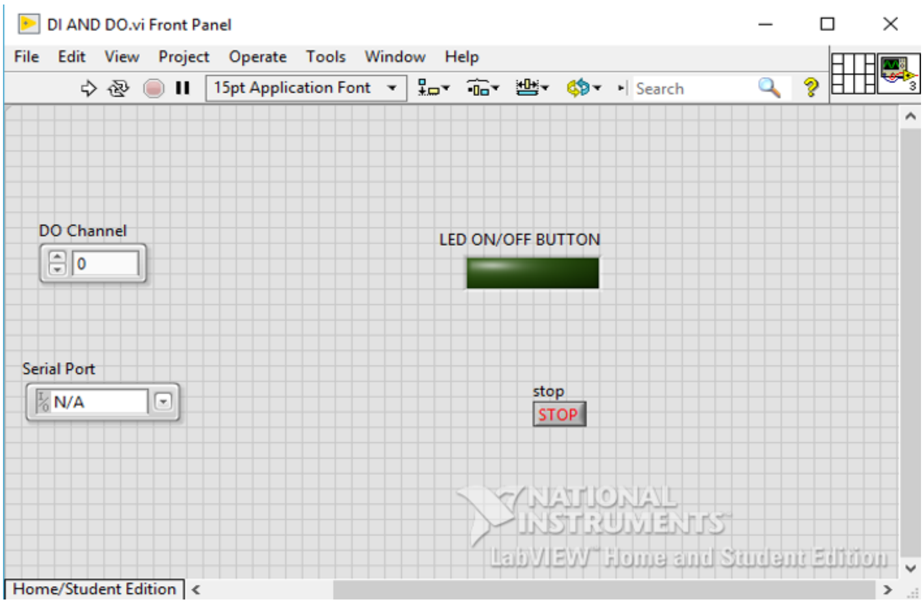


Figure 6.4: Simple on-off control GUI

That is, we have the VI which can be extracted from the zip folder provided. The first module has the LabVIEW file. Once, they upon opening the LabVIEW file, the student, first have to make the circuit connections (see Figure 6.3). Once, it has been done, we have now the experimental part been ready. Next, we have to upload the firmware to the Hardware.

## Preliminary steps to be followed to use LabVIEW with Arduino Uno

- Important Note: Please ensure that you have already installed LINX package for the Arduino support to the LabVIEW.

- Or else, Open VI package manager. In the search bar type Arduino, it shows various options It will display few options like shown in the Figure 6.5.

- Please follow the steps below to flash or upload the firmware to the Arduino.

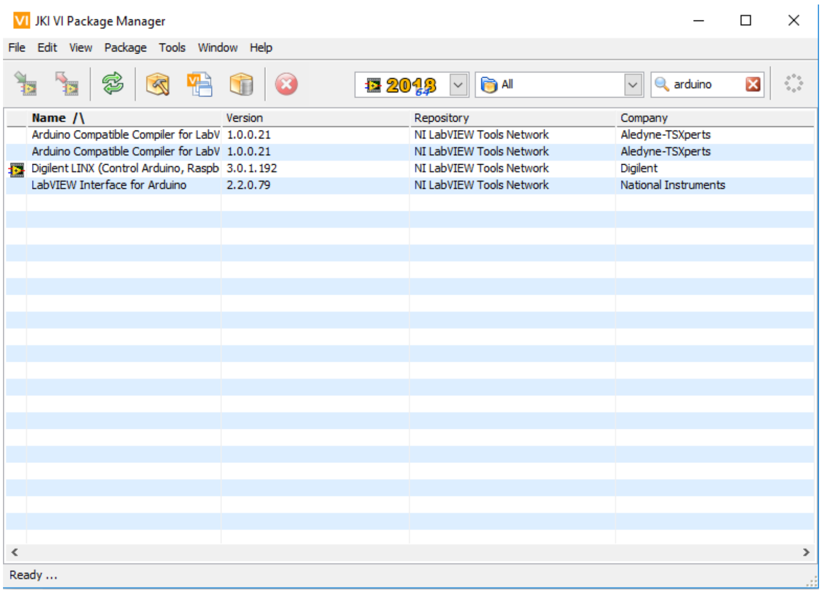


Figure 6.5: VI package manager

- Before flashing please keep in mind that, make all the necessary circuit connections as provided in each module. Once you verify that all the circuit connections are correct. Please connect your USB Type B to the Arduino Uno and the USB Type A to the Personal Computer (PC) or the Laptop where you have installed LabVIEW and all other supporting files and drivers.

- Now open the LabVIEW file of the modules provided. Please select one VI module at a time. Once you open the VI file go to->tools.

- Go to Tools-> Maker Hub->LINX-> and select Linx Firmware wizard as shown in the Figure 6.6 .

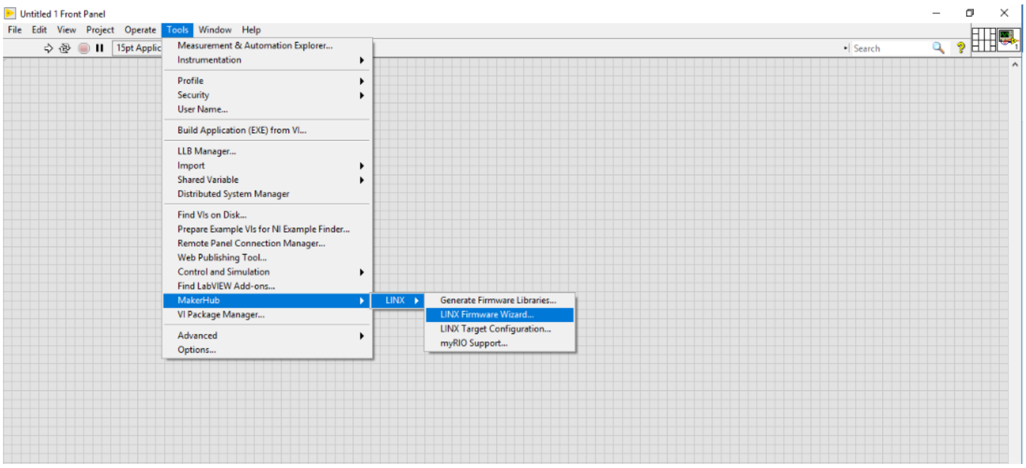


Figure 6.6: Firmware wizard

- Once you select the desired COM port, it will navigate to the next page of the Linx Firmware wizard appears like Figure 6.7.
- In that dialog box, select Arduino under the device family.
- Next, select the Device Type as Arduino Uno from the drop-down menu.
- Now, select the Serial/USB in the Firmware Upload Method. Click on the Next option.

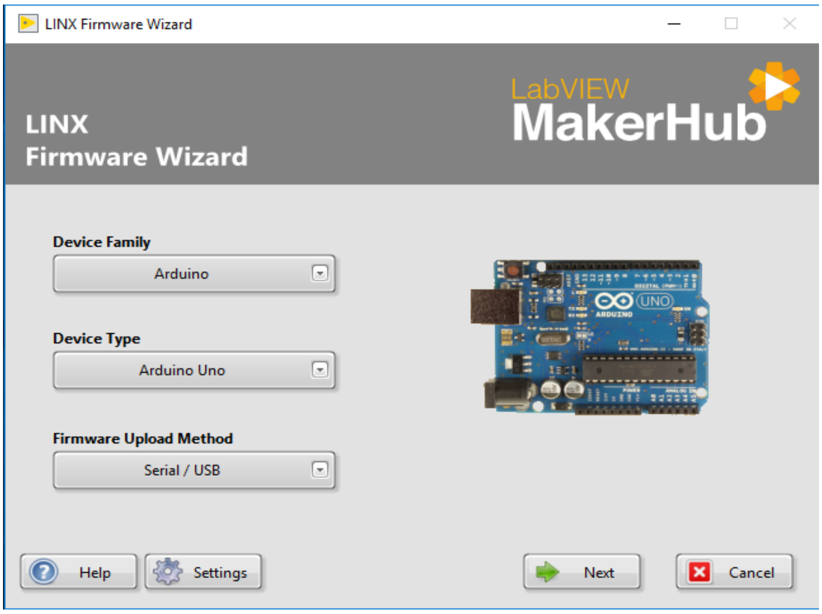


Figure 6.7: Selection of device family, type and upload method

- Make sure, which COM port, the Arduino Uno from the device manager and use the mentioned COM port before uploading the firmware of LINX into the Arduino Uno. Please see in the Figure 6.8, once you find out the correct or exact COM port to which the Arduino Uno is connected, then select the COM port from the combo box in the (See Figure 6.8 mentioned above, once you select please click on the Next option.

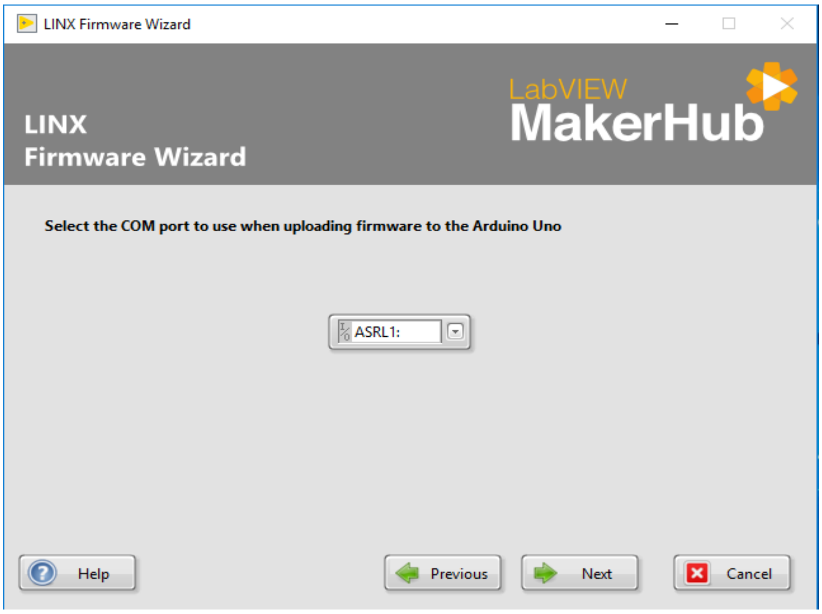


Figure 6.8: COM port selection

- In the next page, the default option for the Firmware Version is LINX-Serial/USB and the upload type select the Pre-Built Firmware from the drop-down menu and Click on the Next option in the dialog box shown in the Figure 6.9.

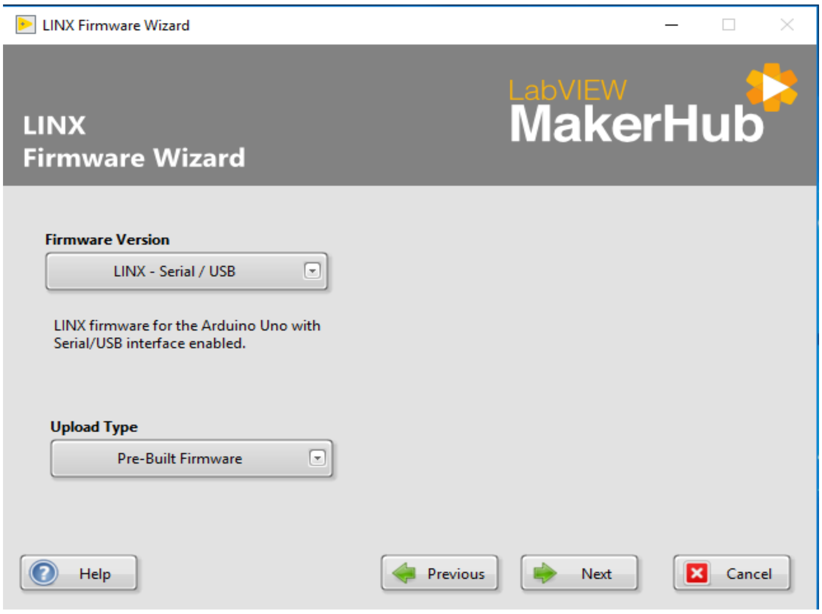


Figure 6.9: Selection of Firmware version and upload type

- Once the Building of the firmware is successful it shows the Figure 6.10 and displays a message with two option, one is Launch example and the other is to Finish. It is better to go with the Finish and follow the instructions of the manuals either the student's manual or the Technical Manual.
- Note for Student's Manual: For student's Manual you will directly make circuit connections connect it to the Arduino. Then follow the instructions.
- Note for Technical Manual: For the technical manual you will have the same circuit connections, please follow the guidelines to create your own VI file, then upload the firmware or flash the firmware using this guide.

The next step is to run the VI experiment and observe the results. In fact, purpose of the project to give some basic concepts of digital on/off. Where the students can learn digital high and digital low. Using this VI hence, digital to real world experiment is done.

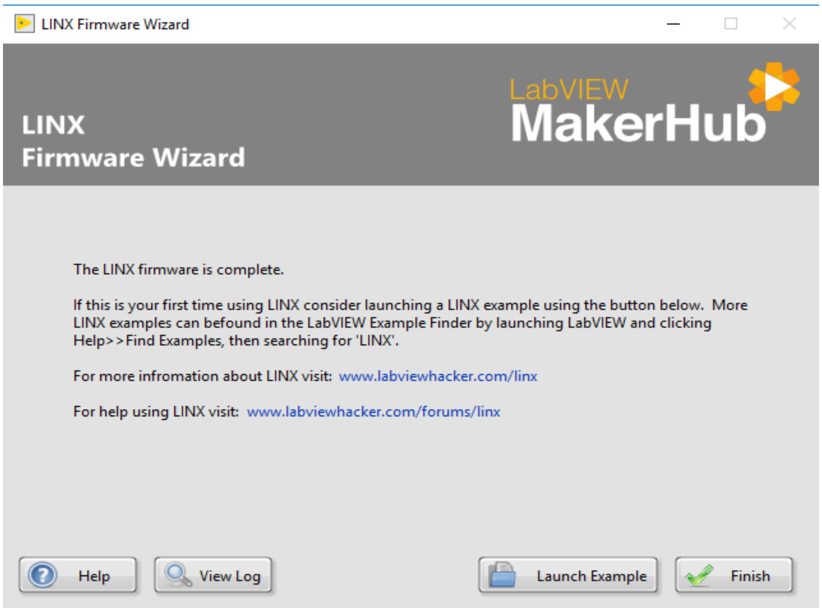


Figure 6.10: Completion of flashing firmware

## EXPERIMENT 2

This experiment teaches you how to control the brightness of the light intensity virtually using the control panel. The purpose of introducing this experiment is that, to give basic idea of controlling the light intensity remotely. We need to control the light intensity, because we are going to use light as one of the important elements to demonstrate the support of teaching control system.

According to the open-loop control system, this is the first phase of introduction of the reference and the output. Here, the user will learn, working of system in the open loop condition by varying reference in the range of 0-5v in the virtual potentiometer as shown in the Figure 6.12). By using a transistor or a driver to couple the output voltage from the Arduino to the Lamp so that this 0-5v corresponds to the scale of 0-12v of the lamp. Hence, the open loop condition is verified experimentally. Where the output is not reflected back to the input. As well as the output is not measured in this condition. But we are manually controlling the intensity of the light using a virtual potentiometer.

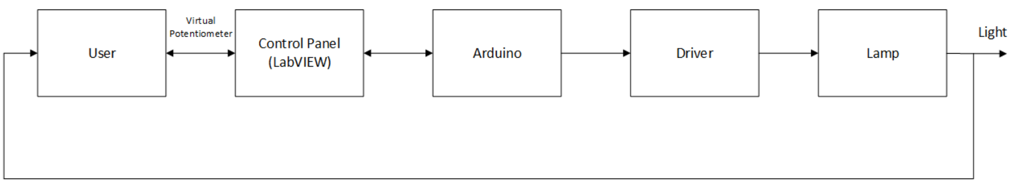


Figure 6.11: Block diagram of light intensity variation using GUI

The Graphical User Interface in the Figure 6.12 has a virtual potentiometer, this feature helps to control remotely the light intensity, when we don't have physical contact. This virtual potentiometer works same as like that of the analog potentiometer.

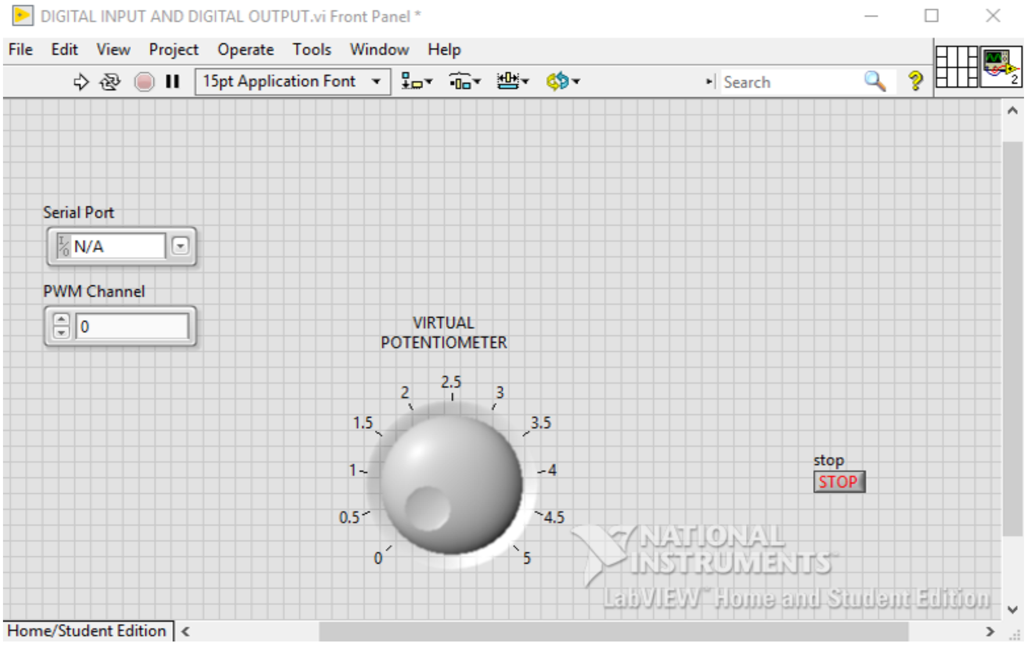


Figure 6.12: Light intensity variation using GUI

As mentioned in the block diagram ,shown in the Figure 6.11, the LabVIEW sends the control of variable potentiometer, which is available on the GUI. Once when you hit run button, let's say you are increasing the intensity of the light by 25% of the PWM duty cycle, which is equivalent to the 1.25V and which is converted into the corresponding brightness of the lamp using a driver. Again, by the second instance you are varying the PWM duty cycle to 50% and so on, thus increasing PWM duty cycle increases the intensity of the lamp, as well as decreasing the PWM duty cycle will reduce the intensity of the light. This variation of the light intensity helps to make understand the concept of the Pulse Width Modulation (PWM). For this experiment you no need to change the schematic, you can use the same schematic of the previous experiment as mentioned in the Figure 6.3.

## EXPERIMENT 3

This simple experiment is to give the basic idea of local control with electronics. This control has same thing in LabVIEW, only difference between the local control and virtual control is that we are going to replace the virtual potentiometer into an analog potentiometer. This experiment teaches you how to control the brightness of the light intensity in real time scenario. The block diagram shown in the Figure 6.13, shows that an user has the control over potentiometer to control the variation of the light intensity then can be read from the LabVIEW those digital values, as well as LabVIEW sends the corresponding signal to the Arduino Digital pin to which the PWM output is connected to the lamp through the driver.

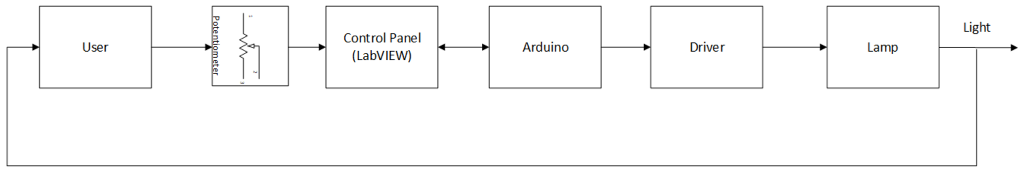


Figure 6.13: Block diagram of light intensity variation

The Figure 6.14 shows the schematic of this experiment.

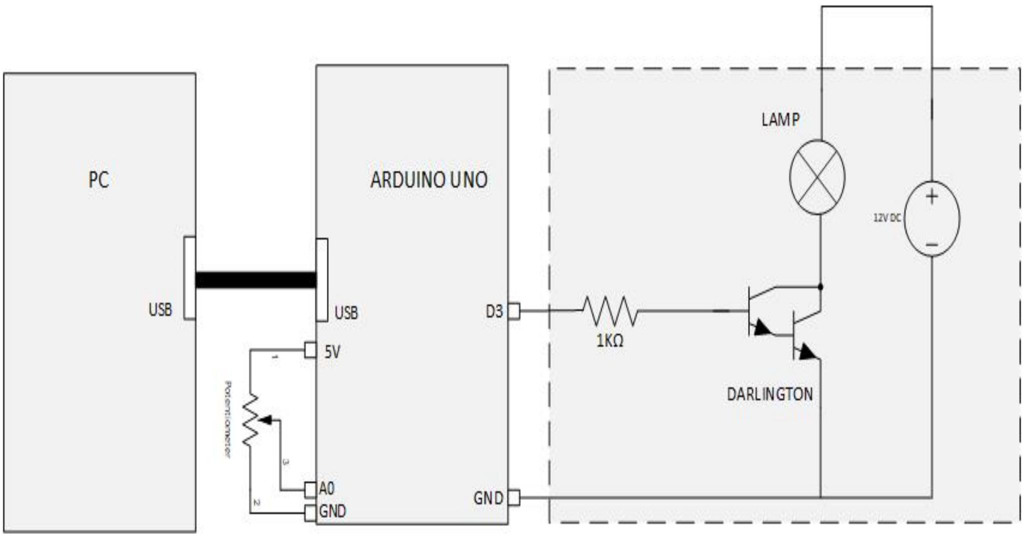


Figure 6.14: Schematics to integrate analog potentiometer with Arduino

This create platform (Figure 6.15) to read the analog input from the Potentiometer using a meter gauge, here the scale of the potentiometer is from 0-5v whereas in terms of the bits it is in the range of 0-1023. Hence varying the potentiometer will produce an analog output, which is provided as the digital input to the PWM where the analog input of 0-1023 in terms bits is converted as 0-100% of the PWM duty cycle and corresponding output can be seen as the varying the light intensity vice versa.

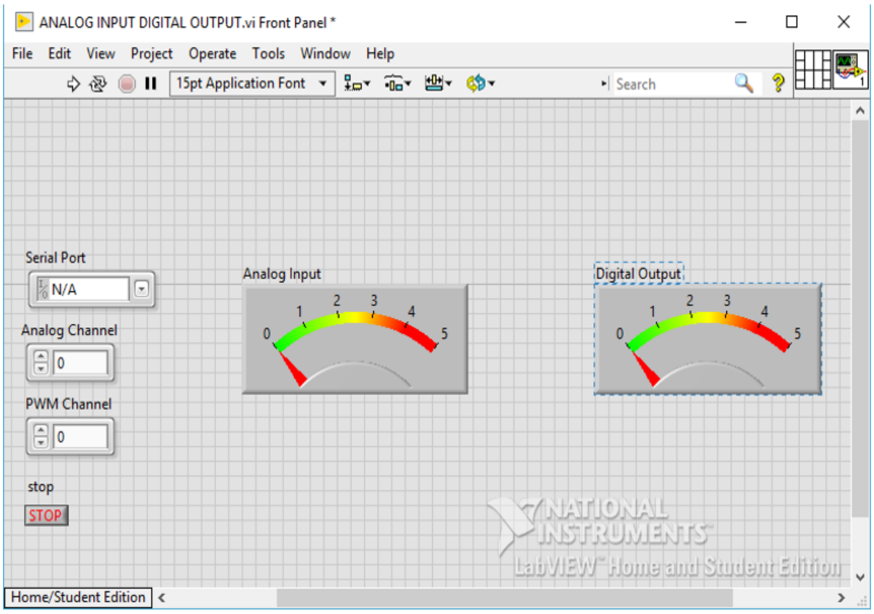


Figure 6.15: Analog potentiometer using GUI

## EXPERIMENT 4

Already you have seen two concepts, local control and virtual control, and to control the intensity of light. This experiment shows the importance of the feedback loop, but the feedback doesn't have any effect. This is just to have a measurement quantity. This is useful for implementing the automatic light intensity control. It is important that the student should know the operating range of the sensor and importance of using sensor in the feedback loop. Based on this value, the output can be controlled using a feedback loop. Then the results can be analysed visually using a virtual oscilloscope. It is very simple we need an LDR to measure the light intensity. As LDR is simple, when you have maximum brightness it shows the minimum resistance where the voltage increases, vice versa when there is increase in resistance there is minimum brightness. It is analogic one, and it is affordable, and one more important thing it can be easily connected with Arduino to acquire sensor signals. The user access the control panel to measure the light intensity and its corresponding block diagram is shown in the Figure 6.16.

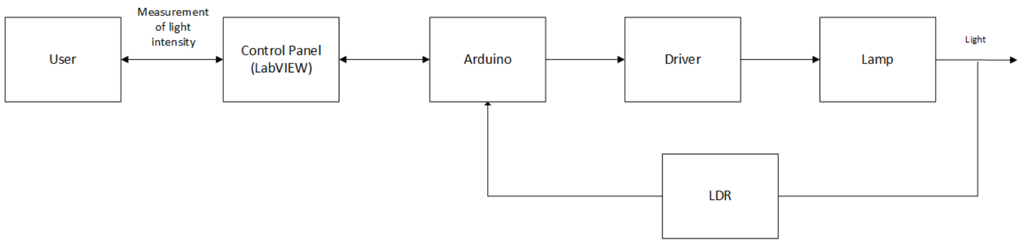


Figure 6.16: Block diagram for measurement of light intensity

The important part of the measurement of the light intensity is done like the schematic shown in the Figure 6.17.

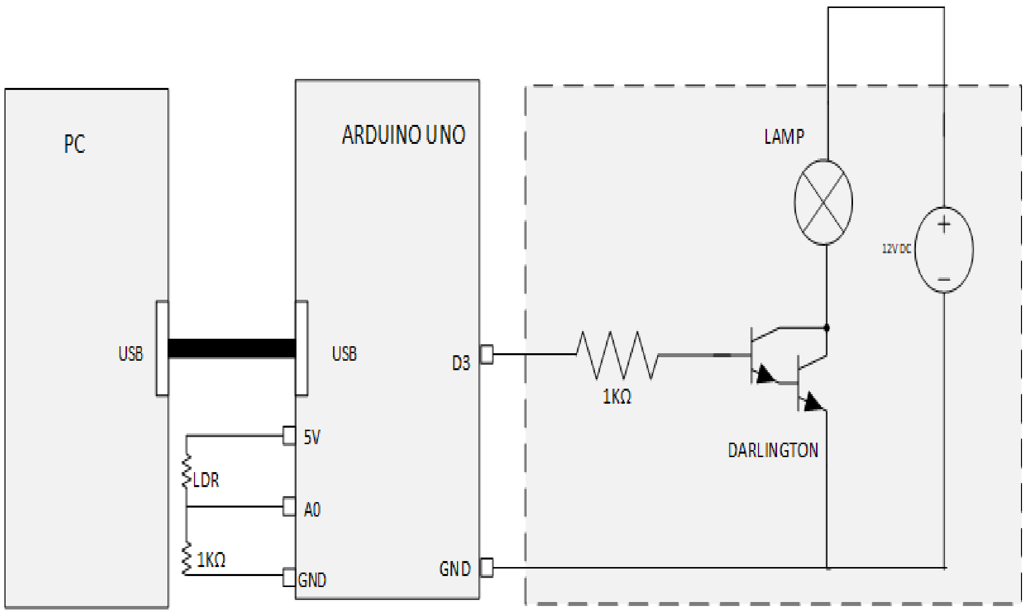


Figure 6.17: Light intensity measurement

When the LDR (Light Dependent Resistor) which is connected to an analog input of the analog 0th pin in the Arduino Uno. Here, the measurement range is 0-1023 which is 0-5v where it represents the 0-100% of the brightness or intensity of the lamp, when you control the intensity of the lamp either with virtual potentiometer.

When it is measured with the no light condition minimum brightness measured is 10% which corresponds to 0.5V which is again then corresponds to 102 bits of analog input. And the maximum brightness of the lamp when measured is 4.0V which is almost 80% of the intensity measured by the light sensor, then the maximum operating range of the sensor is between 10% to 80% which is then again 0.5V to 4V. This is the control variable or the process variable to the PID parameters of the LabVIEW. Measurement of light intensity of the lamp using

LDR can be done by using the GUI created, which is shown in the Figure 6.18

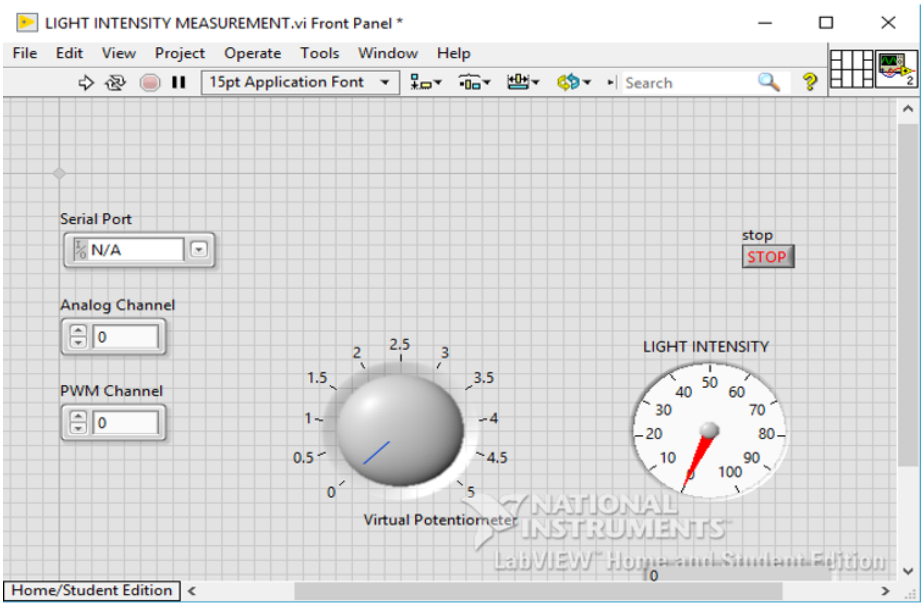


Figure 6.18: Light intensity measurement using GUI

## EXPERIMENT 5

In the previous experiment, we know how to measure the light intensity. We know that feedback loop is important for a closed loop control system. But in the last experiment, we have just measured the light intensity using the LDR (Light Dependent Resistor), where it is placed from certain distance from the lamp.

Now, we have a measured quantity of the light intensity. In this experiment we are not going to change any schematic, it is going to be the same schematic, but it is a different VI file.

Now, in the open loop system, we have the reference from the Virtual potentiometer which is present in the Personal Computer, an Arduino Uno microcontroller for processing the signals that are acquired from the PC for the Reference of the light intensity, and a lamp with driver. In the feedback loop, we have the LDR (Light Dependent Resistor) which is a sensor for measuring the light intensity. The schematic for the implementation of the Simple P control is shown in the Figure 6.19.

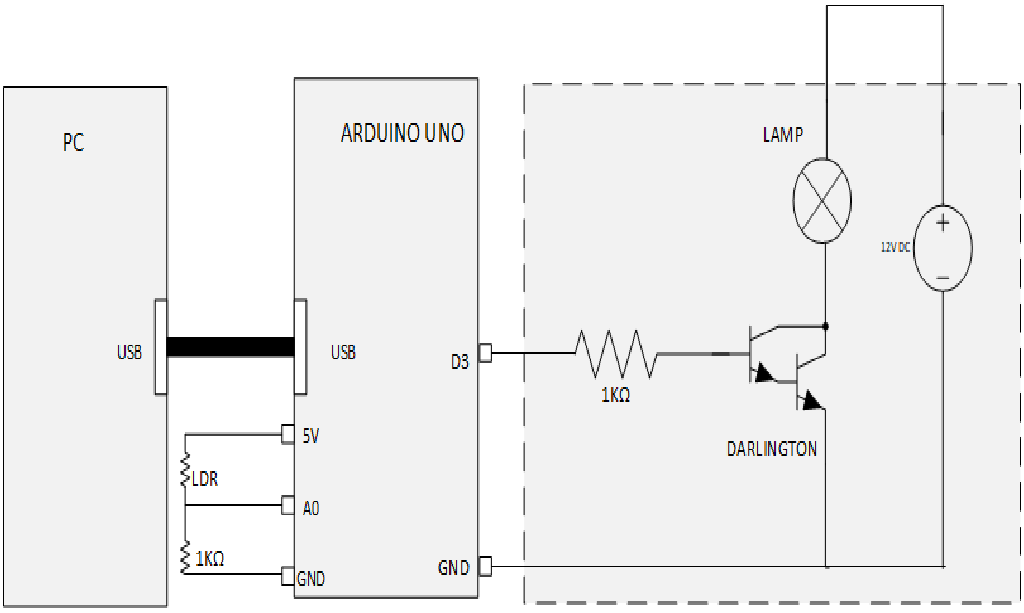


Figure 6.19: Schematic for inverse logic

In this experiment, we can observe how the intervention of the external light changes the actual light intensity present. As we know that according to the schematic diagram, the lamp is connected to the PWM output of the Arduino Uno through a driver. And the LDR is connected to the analog 0th pin of the analog port of the Arduino Uno.

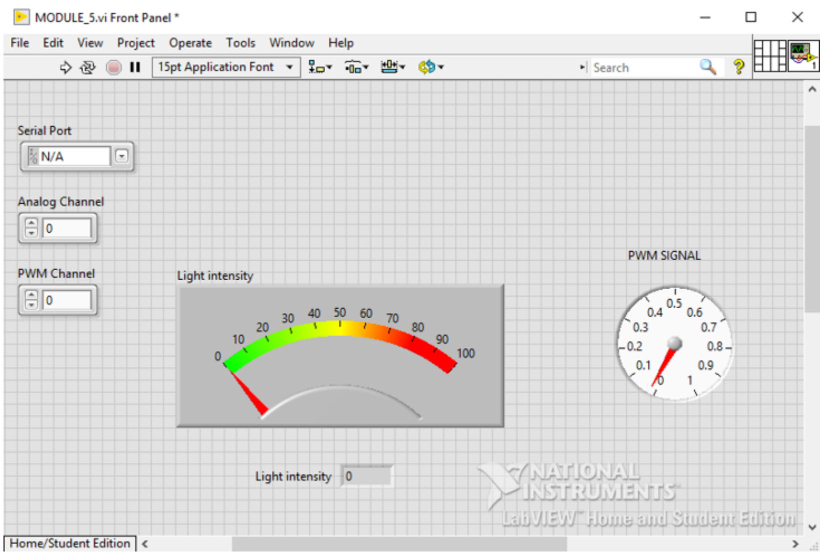


Figure 6.20: Simple P control GUI

Now when you increase the light intensity from the external source, it decreases the light intensity of the lamp, PWM is actually responsible for the decrease of the light intensity of the lamp. When the LDR measures maximum intensity from the external light source, the light intensity of the lamp connected to the PWM output decreases its intensity to save the source of energy for the future purpose in a sustainable way. Now coming to the other case, when you have minimum light intensity from the ambience or from the external light source, the actual light intensity of the lamp connected to the PWM output of the Arduino Uno will increase in this condition. This kind of increasing and decreasing of light intensity can be used to save the light energy or we can use the amount of light energy for the desired level or according to the available source in order to save energy in a sustainable way for the future purpose.

## EXPERIMENT 6

In the first experiment the student might get some idea about the on-off control. In the second experiment, he will get some idea about control the brightness or light intensity using PWM signals. On the fourth experiment he/she will get an idea about measurement of light intensity. In fact, the measurement of the light intensity is one of the important factors in implementing a PID control system, where the light intensity measurement is the sensor feedback part. This feedback values of the measured values are useful to find out the errors that is the difference between the reference and the feedback, based on the error values, the PID system, will generate the control signals to achieve the reference or the setpoint value specified by the user. So far, the student can able to control the light intensity manually and measure the light intensity.

The operating range of the sensor is 30-80%, which is equivalent to 1.5V to 4V in terms of the Arduino analog input measurement, where the 0-1023 bits is converted to 0-5V. Now, we know the sensor operating range, we have to create a closed-loop control system, with the reference which is operating between the 1.5V to 4V thus we are providing the threshold to operate above the rise time or the overshoot and below the overshoot , it goes until zero. All these features can be accessed in the control panel by the student or the user, as shown in the block diagram 6.21

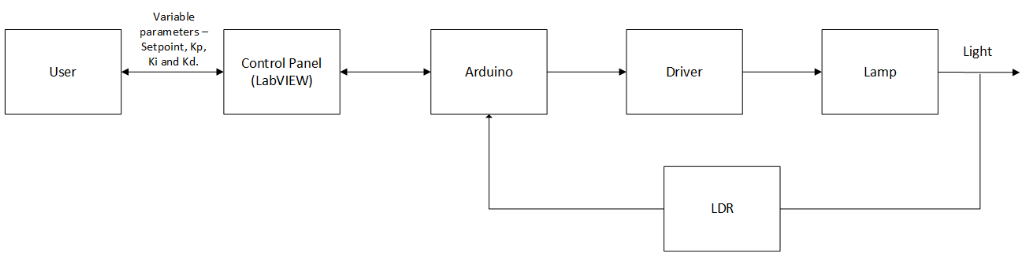


Figure 6.21: Block diagram of PID control

Now, the second thing is the measured variable is given to the PID control loop, which efficiently measures the value of the PID output, based on the PID output values generated, the output is supplied to the PWM pin of the Arduino, which is responsible for driving the current of the Lamp or the voltage across the lamp. The voltage output of the system is proportional to the Intensity of the light. But, when the system, reaches beyond the setpoint, it should decrease its intensity automatically. Vice versa, it should increase the intensity, when the output goes below the measured light intensity. The schematic for this experiment is shown in the Figure 6.22

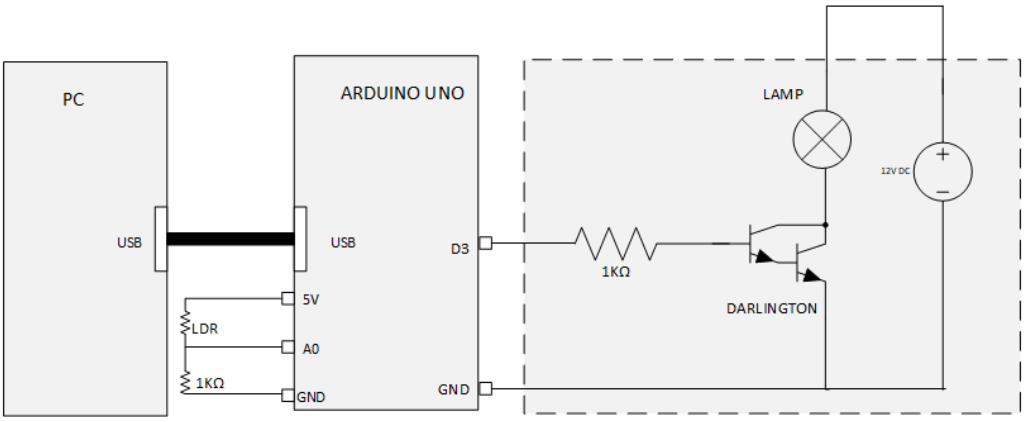


Figure 6.22: Schematic for PID control

The GUI for this experiment is given in the Figure 6.23

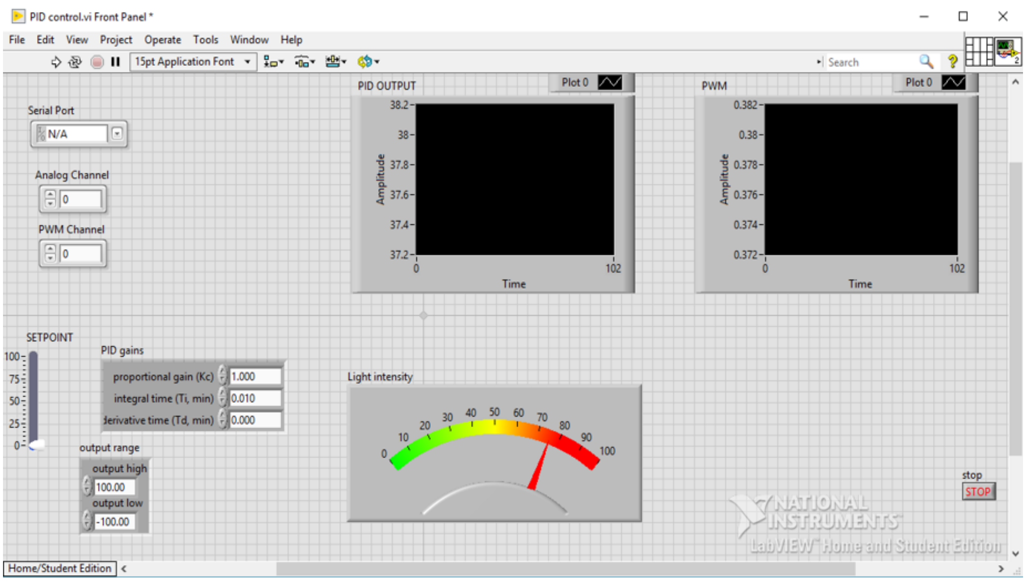


Figure 6.23: PID control using GUI

These are the following features present in the PID control using GUI, you can notice that in the Figure 6.23:

- Set-point of the lamp in terms of intensity.
- Sensor feedback from the LDR.
- PWM signal which is the input to the light, where it is output from the PID, it is scaled from -100 to 100.
- Process variable is the sensor feedback.
- We need to specify the operating range.
- This operating range works based on the sensor value.
- This operating range is between -100 to +100 which is scaled to 0-100
- Control parameters, KP, KI AND KD
- Conversion factor, that is we need to convert the output of PID in the range of 0-1 in the PWM duty cycle scale.
- To monitor the PID OUTPUT VALUES USING THE GRAPH.
- To monitor the values of the PWM output, which is the input to the lamp.
- To create a meter gauge to measure the light intensity of the lamp.

These are the following steps required to implement a PID control with all the above specified features as follows:

- Open LabVIEW.
- Figure 6.24 appears once you click on the LabVIEW icon.
- Now go to File->New VI, to create a New VI file.
- Both Block diagram and Front panel appears in front of you in a cascaded view.
- Maximize Block diagram and right click on the mouse, Functions menu appears then you can set of options as per the requirements.

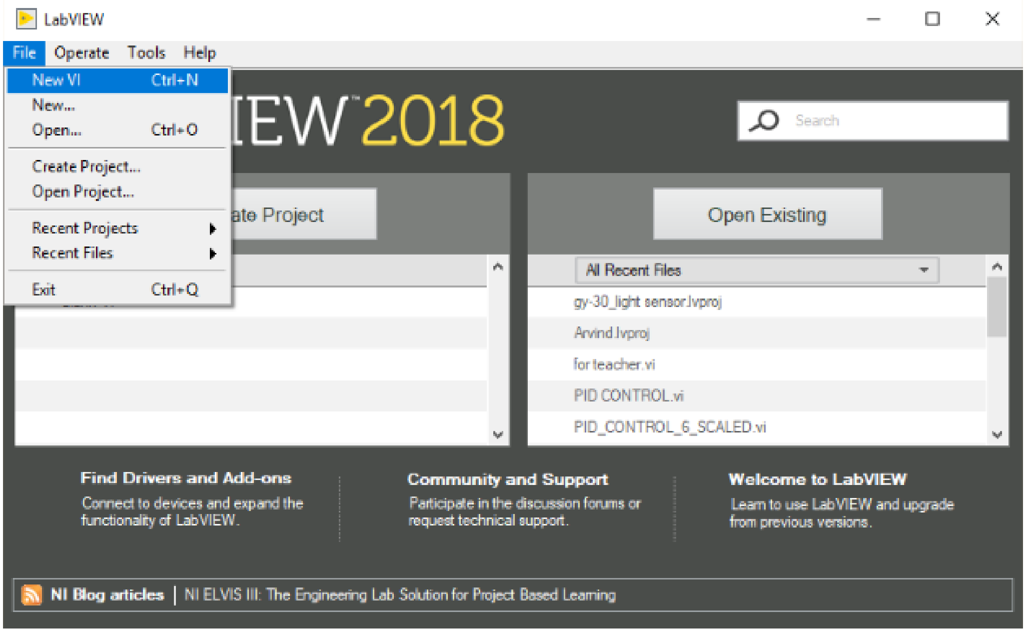


Figure 6.24: To create a New VI file

- In that Functions menu, scroll down and go to Maker Hub -> LINX -> Click on "open" icon and place it in the Block Diagram.
- Now, to read the analog channel, we need to open an analog port using LINX, Hence, in Maker Hub->LINX->Sensors ->Misc->select Photocell and place it in the Block Diagram.
- Now, we need to create a PWM channel for the lamp, which is connected to the PWM channel, hence go to Maker Hub->LINX->Peripherals->PWM-> select Duty cycle place it in the Block Diagram.
- If you open the serial port, you need to close it.
- Once again, press right click and the Functions menu appears, scroll down and go to Maker Hub -> LINX -> Click on "close" icon and drop it in the block diagram. Once you place all the icons in the block diagram, you can notice the appearance of the icons as mentioned below Figure 6.25.


Figure 6.25: Appearance of the preliminary steps

Second, step is to make wiring connections.

- Now, connect to the LINX resource wire from the open port to close port connecting in between icons, like connect the error, wire which is responsible for detecting errors and it will show while running the VI.
- Once, the connections are done, it looks similar like this Figure 6.26.

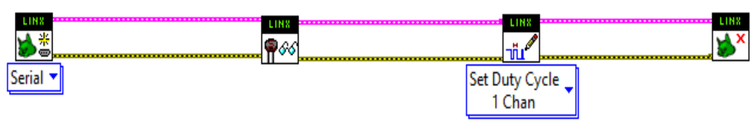


Figure 6.26: Linking the Resource wire and Error wire

- Now, apply control on indicators for the serial, Photocell and PWM channels.
- As you might have noticed that when you are pointing your mouse near the serial icon in the block diagram, a serial pop-up appear, do the same and right click a drop-down menu appears, go to create -> control, to create a control for the serial port.
- Repeat the same for the Photocell and the PWM Channel. On doing so, you can create controls for the specific channels.

- Now once you arrange the channels in the same side, to avoid readability problems. It appears like shown in the Figure 6.27.

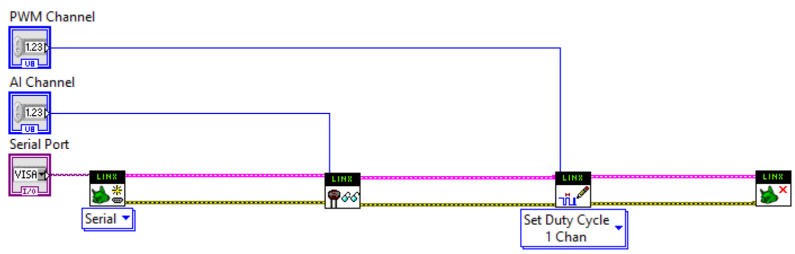


Figure 6.27: Rearranging of icons

- Once, after rearranging the icons for readability purpose (see Figure 6.27), now we need to select the PID icon from the control systems.

- To create a PID Manual tuning from the LabVIEW using a block diagram, please right click on your block diagram, once the Functions menu appears, navigate to Control  Simulation Then go to PID icon, in that you have various PID control options for Autotuning and semi auto control, but for manual tuning by default we will use the first option by neglecting the other PID control options and place it in the block diagram as shown in the Figure 6.28.

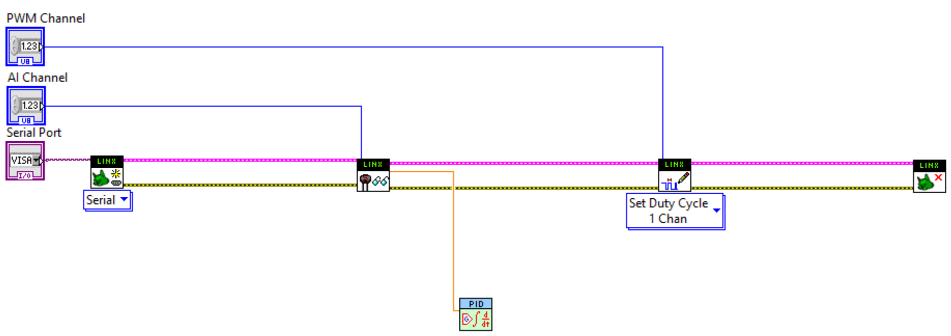


Figure 6.28: Creation of the PID icon from Functions Menu

- After creation of the PID manual tuning, we need a math for the conversion of the output range, in order to satisfy the PWM range of 0-1 duty cycle, so that output of the lamp will be varied in the range of 0-12V which is 0-100% of the operating range of the lamp.
- Once the operating conversion scale is done, next we are creating control for the PID gains and output range so as to appear in the front panel or GUI for the control purpose.
- Now, we need to improve the visualization of the front panel, so to improve visualization and for the better understanding of the concept, we are going to measure certain outputs in the front panel. Like creating outputs for the following:
    1. intensity of the sensor,
    2. measuring the output of the PID in graph for analyzing
    3. measuring the input of the PWM signal.
- Once, after placing all the icons join the icons to the specific places, so that the joined icons, looks like as shown in the Figure 6.29

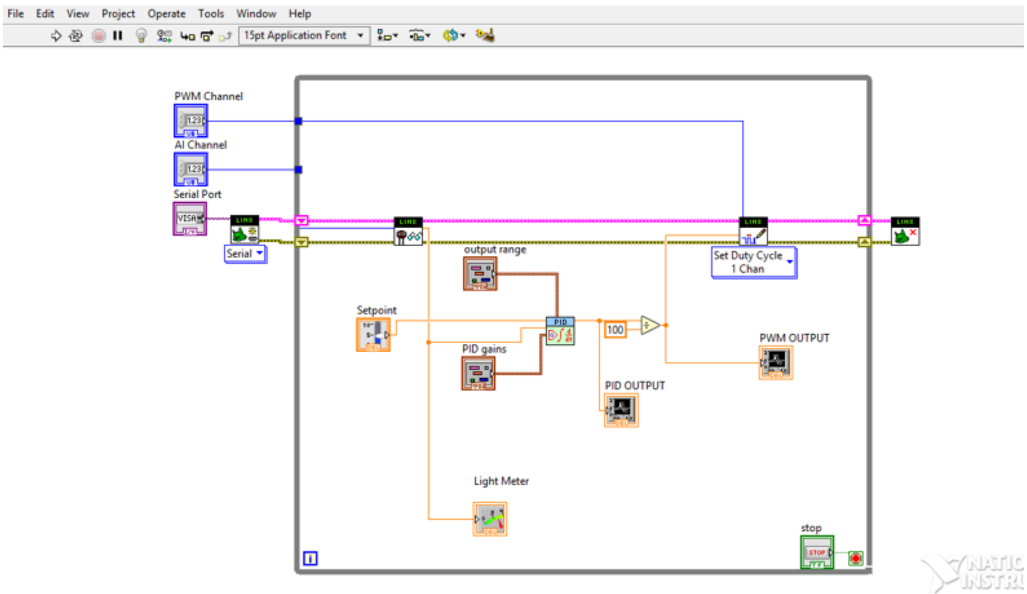


Figure 6.29: Creation of graphs and control knobs

- As you can notice in the above mentioned image, (see Figure 6.29), the labels has been changed to the PID output and the PWM output that has to be given to the duty cycly port and the Setpoint or the Reference, all the icons created in the *front panel*, appears in the block diagram. This image is the final appearance of the block diagram, where everything is connected and the communication wires are given in the proper place.
- The final appearance of the creation of GUI for the PID control of the light intensity is available in the (see Figure 6.23).

### Deliverables

The below shown Table 6.1, gives the details about the number of documents in terms of Student Manual, Technical Manual and the Slides to support the creation of the files for the development of the GUI using LabVIEW and finally total set of experiments in terms of the VI files of the LabVIEW.

Table 6.1: Deliverables

| **Experiment** | **Student Manual (pages)** | **Technical Manual (pages)** | **VI – LabVIEW file** | **Slides (No. of slides)** |
|---|---|---|---|---|
| Experiment 1 | 5 | 14 | 1 | 19 |
| Experiment 2 | 5 | 14 | 1 | 21 |
| Experiment 3 | 6 | 14 | 1 | 19 |
| Experiment 4 | 6 | 15 | 1 | 21 |
| Experiment 5 | 5 | 14 | 1 | 21 |
| Experiment 6 | 6 | 19 | 1 | 17 |
| Total | 33 | 90 | 7 | 118 |

## 6.3 Validation of the project

This sub section describes about the validation of the project. We have conducted a session with some students. During the session, they carryout the experiments with student manual and technical manual provided to them. And the Graphical User Interface (GUI) created in the LabVIEW. At the end of the session, a set of questionnaire has been passed to them to collect about the reviews and a survey. The below Table 6.2 and Table 6.3 shows the response collected from individual students. Each one of them gave specific suggestions to improve the way of implementation and where they felt difficulty. How can we improve better to support the teaching method.

The Table 6.2 shows the students suggestions to improve the implementation part, difficulties faced and the importance to included this in their course curriculum.

Table 6.2: Pedagogical survey-1

| **Question** | **Improvements** |
| --- | --- |
| Answer 1 | Need a complement with a video, with step by step procedure. |
| Answer 2 | Used methodology for explaining is more useful, but a video could be provided |
| Answer 3 | I agree the manual is complete to carry out the experiments. |
| **Question** | **Faced difficulties** |
| Answer 1 | N. A |
| Answer 2 | In the beginning stage, for starting of the LabVIEW is harder but as it goes on it is easier to understand. |
| Answer 3 | Installation of the LabVIEW is difficult. |
| **Question** | **Importance in the course** |
| Answer 1 | It is better that a course introduced with Arduino and LabVIEW, it could be easier to learn electronics. |
| Answer 2 | Learning of the LabVIEW is important in the subject of electronics, its usage in the future can be motivating for the students to learn electronics with LabVIEW, which is easier understanding languages with Graphics. |
| Answer 3 | It is versatile and easier to create circuits in easier and quicker way. |

The Table 6.3 shows the students general review and their valuable suggestions to the future implements.

Table 6.3: Pedagogical survey - 2

| **Question** | **General review** |
|---|---|
| Answer 2 | Experience to learn electronics with LabVIEW, where learning makes more practical. |
| Answer 3 | Modules created is useful for students in the other countries, because manual is easy to understand. |
| **Question** | **Suggestions for future implements** |
| Answer 1 | Creation of the LabVIEW with Arduino shields to open a big platform for learning. |
| Answer 2 | Creation of the LabVIEW tutorial helps to work autonomously. |
| Answer 3 | If it has the video tutorials creating the circuits and simulation, it will be more attractive. |

### Discussions

The Table 6.2 and 6.3 shows the survey collected from students when the validation of the project is done. They expressed their reviews and suggestions based on each experiment they carried out.

Some of the suggestions as follows:

- Most of the student accepted using Arduino with LabVIEW to teach electronics in an intuitive way.
- They save a lot of time while doing the experiment than listening to traditional teaching method.
- The manual provided with intuitive connection with the schematic picture helps them to create the circuit in an easier way.

- They suggest providing videos in place of amnuals, to redce the time of implementation and videos sometimes help to pause and resume the work, in case they got stuck in the middle of the creation of the GUI.
- The created platform, while explaining the concepts of digital electronics they understood their importance of including LabVIEW in their course curriculum.
- One thing, is that they can use the same platform for different experiments, which is provided other than manuals, if they want to create and learn something.
- One suggestion was to integrate Arduino Shield with LabVIEW and explore its features.

# Chapter 7

# Conclusion

This chapter discuss about the general conclusion and the future implementation that can be included which helps to give the better results.

## 7.1 General conclusion

This project was developed with the preference of teaching of PID control and its digital implementation. Along with the implementation, it discusses about the simulation techniques. The use of Arduino Uno micro-controller helps in easier test and verification of the results.

The verification of the P, PI and PID controller and its results are discussed and PID controller seems to maintain the desired setpoint with maximum efficiency and the maximum reduction of the steady state error. This type of system developed with PID is compatible with speed control of DC motor, where the light sensor in this case can be replaced with the encoder to measure the speed of the DC motor in terms of the encoder ticks or else use of the external counter to measure the speed of the rpm is also another way of measuring the speed of the dc motor later on includes PID control is useful to show the disturbance or by applying the load and its corresponding PWM can be shown in order to show the characteristics and also used for teaching its uses. This model developed in Arduino is a versatile one. The hardware of the system is simple to use and be able to be used by students as a trial and error method. Using this type of the model to learn, students can implement the same kind of the PID in different system with the same approach.

## 7.2 Future implementation

The students start creating and learning of microcontroller basics from Arduino Uno. This platform is useful for the easier integration with sensor modules where the analog inputs are used to read the sensor data. Since, Arduino is a used for robotics it gives an insight learning and creates interest among students. Interfacing Arduino Uno with ethernet shield is helpful further for monitoring of the sensor data from any part of the world. The development of the specific servers like IoT server it is possible both monitoring and controlling from the IoT server from any part of the world.

Some of the features where the developed platform can be reused in different ways of integration as follows:

- MyDAQ can be used in place of Arduino UNO for the development purpose and more featured options can be implemented.
- Platform developed doesn't have the limitation to use only with the Arduino, whereas it can be replaced by using Raspberry Pi, and Ni myDAQ.
- Since, the board was developed with a purpose of cost effectiveness to be affordable by all the students. May be in a later on purpose, a PCB with all the products can be designed so that you no need to unplug and plug it every time. Once it is fixed you can use it for different purpose.

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