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DESIGN AND IMPLEMENTATION OF A PID-BASED LUMINANCE CONTROL AND LIGHT SENSING USING SMOOTHING AVERAGING TECHNIQUE

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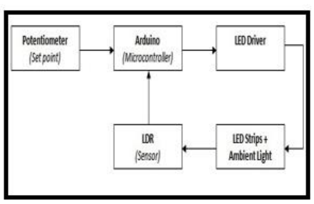
Graphical abstract



Abstract

Nowadays, lighting shares a large part in the global energy consumption, lighting consumption can be easily reduced with the use of efficient light sources. The most commonly used light source is the incandescent light bulb. As time passed by, Compact Fluorescent Lamp and Light Emitting Diode use became prevalent because of their advantages over the incandescent light. The researchers were able to develop and implement a PID controlled lighting system using Light Emitting Diode utilizing the smoothing-averaging technique in its sensors. Tests were done with the system with and without smoothing technique to identify the effect of the technique used. The system automatically varies its light intensity output depending on the light stimuli maintaining the luminance level of the laboratory based on standards.

Keywords: Compact Fluorescent Lamp (CFL); Light Emitting Diode (LED)

1.0 INTRODUCTION

1.1 System Overview

Lighting shares a large part in the global energy consumption. Lighting consumption can be easily reduced with the use of efficient light sources. Incandescent light bulbs are one of the light sources which are widely used in household, schools, commercial lighting, portable lighting, decorative and advertisement lighting [1]. As time passed by, incandescent lights are being replaced by many other types of electric light such as Compact Fluorescent Lamps (CFL) and Light Emitting Diode (LED) – two of the most efficient light sources than incandescent lamp [2].

The Vice President for government relations at National Electrical Manufacturers Association, Kyle Pistor, explains, "CFLs are 75 percent more efficient and LED's are 85 percent more efficient an incandescent light bulbs. Lighting in residential homes is about 12 to 15 percent of an average home electrical bill, so the electricity savings to consumers are not trivial." CFL and LED have become popular alternative to incandescent bulbs for it has lower power consumption, "Where incandescent light last an average of 1000hrs, whereas CFLs last 10000hrs and LEDs last between 25000 to 100000 hours" stated by Joe Rey-Barreau, University of Kentucky lighting design professor and American lighting Association consultant [3].

CFLs are simply smaller versions of full-sized fluorescent lighting. The only difference is the quality of light is much better than it is used to be some time ago. According to furniture.about.com, CFLs are more up to four times more efficient than incandescent bulbs. But unfortunately CFLs has disadvantage, the mercury content of its light bulb and this mercury is toxic and very hard to dispose [4].

LED lighting is the cleanest and the most eco-friendly way of illumination. It has an outstanding operational life time expectation of up to 100,000 hours. The long operational life time acts as a multiplicator and helps achieve even more energy efficiency especially in large scale and other infrastructure projects [5].

LEDs are different to standard lighting. They don't really burn out and stop working like a standard light. When dimming LED lamps, their power consumption is also reduced, producing further running cost savings. A dimmed LED lamp also produces less heat which will help increase their operation life and protects the investment an end-user has made into their LED lamps. It makes a big leap in technology that can be seen much as an upgrade from analog to digital. LED is digital light, and the advantages versus conventional analog lighting are so huge and of major benefit to both users of this technology of digital light as well as to our planet. That's why people believe to have plenty of good reasons for being passionate about LED illumination [6].

Experimental work is the key to both a solid understanding of scientific concepts and for motivating an interest in the subject. Our laboratories have been designed to ensure that a wide range of experiments can be conducted at the full age range of our students and across all science and engineering subjects. This includes the integration of the latest technologies available for use in practical situations, such as digital data logging equipment, digital microscopes and software modeling.

1.2 Statement of the Problem

Lighting is important in life. It provides and helps us see visual tasks. The importance of good lighting is absolute as lighting provides essential service to people in all places. Academic institutions follow lighting standard based on Illuminating Engineering Society (IES) recommendations for laboratories where students and faculty perform experiments and other related activities that require sufficient lighting. With the vast evolutions of technology, the automation concept in lighting classrooms or laboratories is now a trend using light bulbs. However, all light bulbs have nominal or rated operating life. It depends on how many times they are turned on and off.

LPU-Laguna currently uses fluorescent lamp tubes as light sources in their classrooms, laboratories, offices and other places. Some classroom and laboratories of LPU-Laguna have glass windows which ambient light enters through it. When the flourescent lamp tube is on and ambient light enters the glass window, it will give more light. With that, there is a need of a system that will automatically balance the illuminance of the LEDs and ambient light coming from outside of the ECE Laboratory of LPU-Laguna specifically in every work station. Instead of turning on and off the lights manually, there is a need of a system that automatically give the right amount of brightness to the LEDs base on the level set by the user and ambient light coming from the sun to lighten up the work station. There is also a need for a system that maintains the illuminace level based on the set point from standard requirement.

1.3 Objectives of the Study

The study generally aims at developing an arduino-based lighting system prototype that will automatically control the illuminance of the LEDs in a work station at ECE Laboratory of LPU-L using the smoothing averaging technique in light sensing and drive the light source using PID control Algorithm.

The specific objectives of the study are the following:

- Control the brightness of the light source using PID control algorithm implemented in Arduino.
- To identify the PID gains i.e. Proportional gain, Integral gain and differential gain that will yield zero percent steady state error of the output and produce the fastest response under the identified range of the gains.
- To identify the light sensor suitable for the averaging technique that will give faster response.
- To identify "the averaging Technique for the feedback input".
- To identify light reflector design to maximize the illuminance of the LED's brightness.

2.0 METHODOLOGY

This chapter discusses the methodology that is used in this study. The first section describes how the research study was conducted, follows by the data gathering procedure. Block diagram, conceptual framework and circuit design were also presented in this chapter.

Luminance control is accomplished through the system block diagram shown in Figure 2. First input parameter is the potentiometer. It serves as set point for the desired light level of brightness that will be fed to the Arduino. Next input is the luminance or light level sense by the sensor that comes from the LEDs brightness. The process starts at the microcontroller; it will compare the data between set point and light level. It reads the set point where the luminance sense by sensor will be compared and then drive the LED driver to produce exact amount of power to light the LED. It is a loop where the driver will not stop giving power to the LED until it reaches the desired level of luminance.

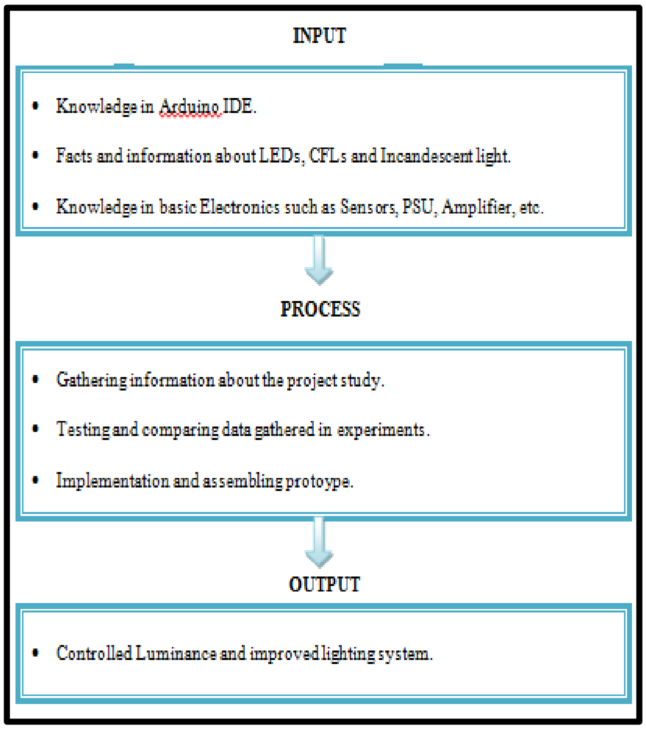


Figure 1 Design Process (IPO Chart)

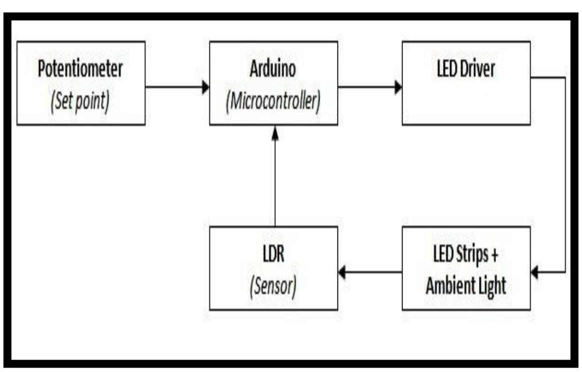


Figure 2 System block diagram

3.0 DESIGN CONSIDERATION

The tables will be simulated and held up with data measured at the ECE Laboratory in Lyceum of the Philippines – University using lux meter.

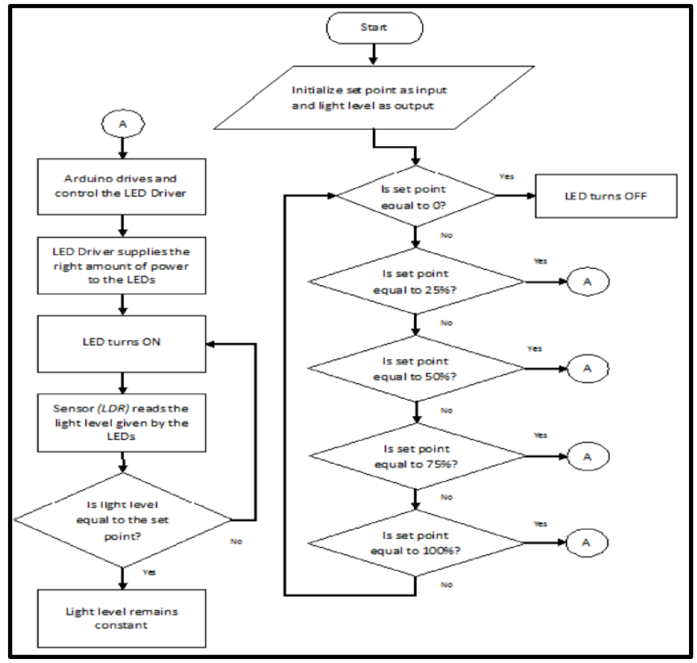


Figure 3 Flow chart of the program

3.1 The Prototype

The project is composed of Light Dependent Resistor (LDR), Light Emitting Diode (LED), Reflector, Electronic Display, Arduino Microcontroller, and LED Driver.

The work station has seven photo sensors which are Light Dependent Resistor (LDR). LDRs are embedded on the table of the work station. The six sensors will sense the ambient light that comes from light sources and the other sensor will determine if it is dim, light, bright, and very bright. User will use the set point knob to place the level of the light. The set point level will display on Electronic display.

Reflector is used to focus the light on the work station. LED is used as the light source of the system. The emission of LED will depend on the gathered luminance of the sensors. Electronic display is installed for the user to determine the percentage given by the natural light and LED, and it displays the level of light, if it is dark, dim, light, bright, and very bright. The power supply module supplies a DC 5V to power up the Arduino Microcontroller. Arduino Microcontroller will give also an output voltage of 0-5VDC that will control the TIP – 120 transistor. The internal component of the device (TIP – 120) is connected to the LED driver, which gives an output voltage of 12VDC to light the LEDs.

Figure 4(a) Actual Prototype

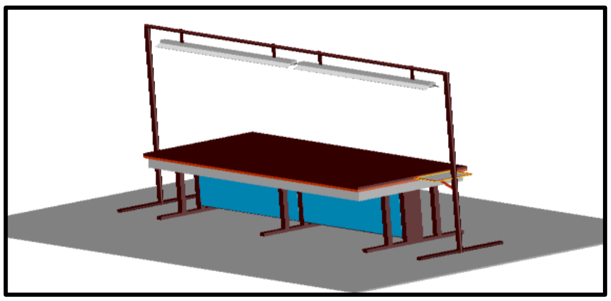


Figure 4 (b) AutoCAD Layout of the Prototype

3.2 Project Capabilities

The proposed system is designed to give users a convenient way in using the ECE laboratory when doing their experiments and projects. It is installed with components which can be easily distinguished by users.

The system is capable of controlling the light luminance in a work station. It is also capable of giving the standard luminance that a laboratory should have.

The system will based its light output depending on the light sensed by the sensors. The proponents used LDR as their sensor because it gives good response than Photodiode and Phototransistor based on the experiment conducted.

3.3 Design Consideration and Dimension

• Sensor and LED

Only the LED and natural light are taken into account in this analysis. It is decided to conduct different experiments to prove the effectiveness of the system.

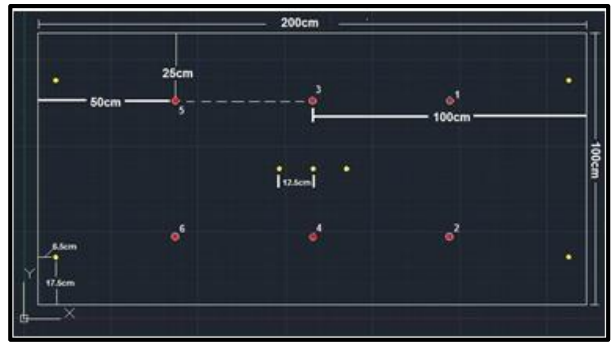


Figure 5(a) Top view of table with sensors and lux meter spots

The points measured have been marked in Figure 5a. The distance from the LEDs to the surface of the table is 1.1 meter. Figure 5b shows the top view of the LEDs along the table

The yellow dots are the representation of the sensors in the table while the red dots are the spots where the lux meter is placed.

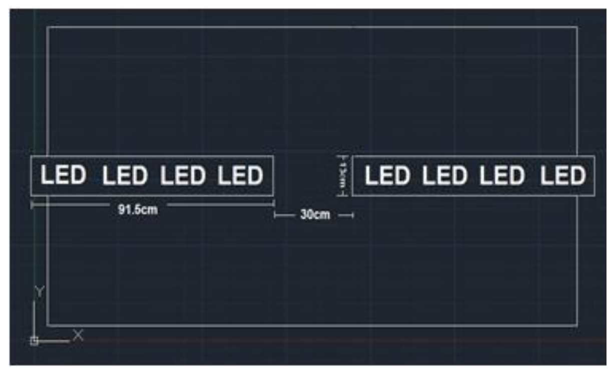


Figure 5(b) Top view of LEDs

4.0 RESULTS AND DISCUSSION

The following experimentation will determine if what sensor and algorithm will be used in the project.

4.1 Sensor

LDR, photo-diode, and phototransistor are the three sensors that are commonly used in light sensing. In this project the proponents conducted experiments involving these three sensors to determine what is suitable to the system. Each sensor will be tested with the same trial. 50%, 75%, and 100% are the set-points that will be used for all sensor in the duration of 20seconds. Serial monitor of the Arduino will display the value each sensor.

- Photo-Diode

Photo diode			
Time (Second)	Set-point = 50%	Set-point = 75%	Set-point = 100%
1	276	267	254
2	101	263	247
3	111	234	245
4	50	254	243
5	241	257	242
6	0	256	242
7	276	256	241
8	276	228	240
9	1	4	239
10	276	262	238
11	2	28	237
12	4	39	237
13	273	261	237
14	5	191	237
15	249	258	236
16	0	252	235
17	275	256	236
18	0	267	236
19	276	255	235
20	2	3	236
Average	135	205	240

Figure 5(a) Using photo-diode

- Photo-Transistor

Phototransistor			
Time (Second)	Set-point = 50%	Set-point = 75%	Set-point = 100%
1	283	282	282
2	51	280	247
3	1	283	282
4	1	283	282
5	250	282	282
6	3	27	282
7	282	282	282
8	282	282	140
9	16	26	282
10	282	282	227
11	55	41	244
12	1	65	282
13	4	283	244
14	266	65	282
15	3	252	282
16	281	283	282
17	282	282	131
18	15	34	282
19	17	282	244
20	15	50	241
Average	120	197	255

Figure 5(b) Using photo-transistor as photo sensor

- Photo-Resistor or Light Dependent Resistor

LDR			
Time (Second)	Set-point = 50%	Set-point = 75%	Set-point = 100%
1	122	186	245
2	131	193	255
3	124	184	249
4	123	186	251
5	130	198	258
6	121	188	250
7	131	166	257
8	132	202	257
9	125	189	251
10	123	187	256
11	125	192	254
12	128	194	255
13	127	186	254
14	130	198	256
15	122	186	253
16	124	187	252
17	133	195	257
18	123	186	250
19	131	199	258
20	126	202	257
Average	127	190	254

Figure 5(c) Using photo-resistor as photo sensor

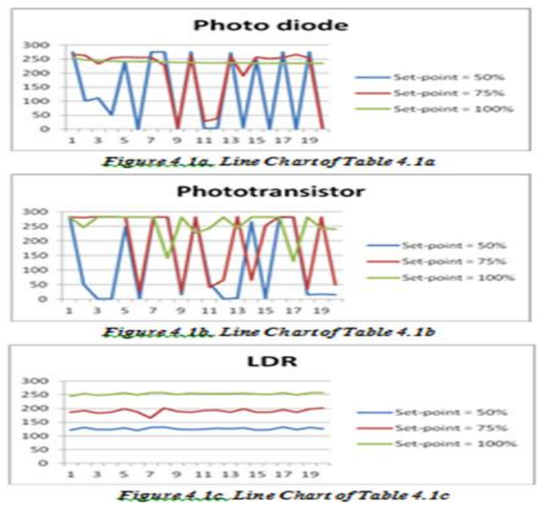


Figure 6 Line Chart each for figure 5

All sensors are tested without any algorithm. The graph clearly states that the LRD has the best response among the three. Therfore, the proponents choose LDR as their light sensor.

4.2 Algorithm

- LDR without Smoothing

LDR without smoothing			
Time (Second)	Set-point = 50%	Set-point = 75%	Set-point = 100%
1	122	186	245
2	131	193	255
3	124	184	249
4	123	186	251
5	130	198	258
6	121	188	250
7	131	166	257
8	132	202	257
9	125	189	251
10	123	187	256
11	125	192	254
12	128	194	255
13	127	186	254
14	130	198	256
15	122	186	253
16	124	187	252
17	133	195	257
18	123	186	250
19	131	199	258
20	126	202	257
Average	127	190	254

Figure 7 LDR without smoothing technique

- LDR with Smoothing

LDR with smoothing			
Time (Second)	Set-point = 50%	Set-point = 75%	Set-point = 100%
1	124	191	242
2	122	193	240
3	126	192	241
4	123	192	242
5	126	193	241
6	130	193	240
7	132	193	242
8	127	193	240
9	129	192	242
10	124	192	240
11	121	192	242
12	127	192	242
13	124	193	242
14	124	191	241
15	121	191	241
16	127	192	242
17	124	192	241
18	122	193	241
19	127	193	240
20	122	192	240
Average	125	192	241.10

Figure 8 LDR with smoothing technique

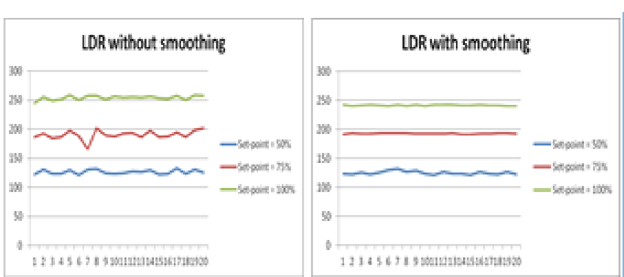


Figure 9 Line chart for Figure 7 and 8

Based on the previous experiment LDR without any algorithm gives a stable value but using LDR with smoothing algorithm gives a more stable value to the microcontroller.

4.3 Proportional-Integral-Derivative (PID)

PID is another algorithm used in the system to control the illuminance of the work station. It is an algorithm used to control the output of a certain system that uses feedback control.

Time (Second)	PID	PID with Smoothing
1	129	131
2	131	133
3	132	133
4	133	133
5	136	131
6	131	133
7	129	131
8	134	131
9	129	132
10	127	133
11	133	133
12	129	132
13	128	131
14	135	132
15	134	131
16	128	132
17	132	133
18	134	132
19	130	132
20	135	133
Average	131	132

Figure 10 LDR in PID w/&w/o smoothing averaging technique

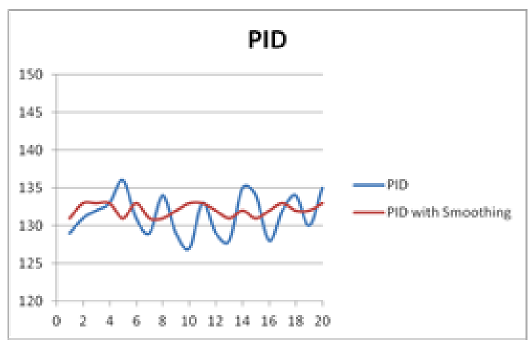


Figure 11 Line chart for figure 10

Based on the experiment and data on figure 10, using smoothing algorithm in light sensing and PID in controlling light level gives a constant output to the LED.

5.0 CONCLUSION

Using Pulse Width Modulation (PWM) and Analog dimming technique at the same time, controlled by Arduino, the light intensity of the LEDs were varied. Through PWM mechanism, the intensity of the LEDs was changed based on the set-point (switch) by adjusting the duty cycle of the LEDs using the adjustable switch. The adjustable switch varies the set-point. The use of analog dimming technique is for the LEDs to vary its intensity automatically depending on what the sensor is sensing.

Photo-diode, photo-transistor, and LDR are the sensor tested and based from the actual experimentation LDR has the best sensitivity. The same sensors are used in simulation using the serial readings in the Arduino software. Two algorithms were used to give the best and fastest response for the LEDs. By using the Proportional Integral Differential (PID) control algorithm the system is able to minimize the error value between the process variable and the desired set-point. Another algorithm is used in the system which is the Smoothing Averaging technique algorithm. The purpose of using this algorithm is for the multiple sensors. The data coming from different sensor is being average by the algorithm which gives a better output. The two separated LEDs gives the same intensity depending on what is calculated in the averaging algorithm. By measuring the lux in different spot on the table, the data shows that the LEDs can produce the standard level of illumination in a certain work station which ranges from 250-500 lux based from the standard of illumination.

Future researcher may use other algorithms aside from PID control and Smoothing averaging technique. Choosing the proper averaging technique may improve the response of the LED. Additional sensors and placing it in a good spot in the table would contribute to the overall sensitivity of the LDR. Drawing Laboratory of LPU-L would be a better area for the future workers to conduct experiments since the standard level of illumination for drawing room is higher than the ECE Laboratory. The standard level of illumination for drawing room is 500-1000 lux. The proponents also recommend using data logger for to get the Data and Result to formulate the transfer function of the system. The proponents suggests to the future researcher to add additional LED lights to give more accurate results for the other work stations.

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