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ENERGY SAVER LIGHTING CONTROL SYSTEM

PRESENTED BY

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DECLARATION OF ORIGINALITY

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DEDICATION

This project is dedicated to my Dad for the moral and financial support and all those who have guided and inspired me throughout my journey of education

ACKNOWLEDGEMENT

I am grateful to Almighty God for His unconditional love and provision in the course of the project.

Secondly, I am grateful to my supervisor Professor. H. A. Ouma for his enormous input and for the useful comments and suggestions which have led to the improvement of this project and for his guidance during the project period.

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ABSTRACT

Lighting in specified spaces is often not controlled and this leads to energy wastage and also impacts on the final cost of the electricity. The lighting intensity given by the lighting devices is usually steady regardless of the current conditions of the area they illuminate. Due to this, a power saving lighting system is vital in order to control light intensity of a given space according to occupancy and the prevailing lighting condition of that space.

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CHAPTER ONE

1.1 Introduction

It has been reported that around 30-40 percent of the total building electricity energy used in many commercial buildings is consumed by the lighting systems. The effective use of lighting energy has not been properly implemented efficiently. This is attributed to factors such as poor daylight use and that maybe it is not integrated with the artificial lighting system, or in cases where integration exists, energy-efficient lighting technology has not been explored well.

Therefore, it is desired to automatically provide the appropriate illuminance to an arbitrary location, or to allow other lighting to compensate illuminance in response to the prevailing light conditions when an occupant is present in that location and also to flexibly respond when lighting conditions are compromised.

1.2 Main objective

To design and implement an energy saver lighting control system that controls lighting intensity of a defined place based on occupancy and illumination criterion.

1.3 Specific objectives

- a. Review of the existing lighting control methods.
- b. Design logic for lighting control circuit and its peripherals.
- c. Design circuit for lighting control.
- d. Write algorithm controlling the sensors and other microcontroller peripherals
- e. Implement and Test system operation.

1.4 Justification of the project

If proper technology in lighting including the use of daylighting controls and energy efficient lighting, then, there will be a good definite possibility of reducing energy consumption in residential, commercial and industrial buildings.

Also, lighting control help conserve energy and make a lighting system more flexible.

1.4 Scope of the project

A single room will be used to test the practically of the system.

CHAPTER TWO: LITERATURE REVIEW

2.1 introduction

Lighting controls help conserve energy and make a lighting system more flexible. The most common light control is the on/off switch, Manual dimming, Photo sensors, Occupancy sensors, Clock switches or timers and Centralized controls.

Manual dimming controls allow occupants of a space to adjust the light output or illuminance. This can result in energy savings through reductions in input power, as well as reductions in peak power demand, and enhanced lighting flexibility. This type of technology is well suited for retrofit projects, where it is useful to minimize rewiring. Photo sensors automatically adjust the light output of a lighting system based on detected illuminance.

Occupancy sensors turn lights on and off based on their detection of motion within a space. Some sensors can also be used in conjunction with dimming controls to keep the lights from turning completely off when a space is unoccupied. These sensors can also be used to enhance the efficiency of centralized controls by switching off lights in unoccupied areas during normal working hours as well as afterhours

2.2 control systems

Lighting controls can be grouped into two general categories:

- i) centralized controls and
- ii) local controls.

2.2.1 Centralized control system

Centralized control systems are used in buildings where it is desirable to control large areas of the building on the same schedule.

2.2.2 Localized control systems

Localized control systems are designed to affect only specific areas.

2.3 Ways of controlling lighting system

There are various ways to control the lighting system for energy saving purpose.

The most common lighting control methods include;

- i. On-Off switch
- ii. The use of timers
- iii. Use of manual dimmers
- iv. Use of automatic dimmer devices

2.3.1 On-Off switch

Is the simplest and the most widely used form of controlling a lighting installation. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required-

2.3.2 Timer control

A timer control is used to set the time which the light will be on and off. Mostly, during day time, lights are set to be off when natural light is presumed to be enough for illumination and timer switch switches on light when needed especially at night.

2.3.3 Manual controllers

These can be used to manually dim light when natural light is available or to achieve certain illumination.

2.3.4 Automatic controllers

The lighting control can be obtained by using logic units located in the ceiling, which can take pre-programmer commands and activate specified lighting circuits. Advanced lighting control system uses.

- i) Movement or occupancy detectors
- ii) Lighting sensors,
- iii) dimmers
- iv) Controllers
- v) Lighting fixtures

Whenever the orientation of a building permits, daylighting can be used in combination with electric lighting. This should not introduce glare or a severe imbalance of brightness in visual environment. Additionally, sensor technology influences how well it detects occupants. Some sensors use infrared technology, some use ultrasonic technology, while others use a combination. Daylight sensors or photo sensors automatically dim the lights when there's sufficient daylight coming into a room. Having that perfect balance of electric light and daylight also makes a room more inviting.

These sensors work in conjunction with dimmers or switches.

An occupancy sensor turns lights on automatically when you walk into a room and turns them off when you leave a room.

2.4 Photo Sensors

Photosensors are light sensitive transducers that change their behavior according to the amount of light falling on them.

Types of Optical Sensors

- i. Photoresistor
- ii. Photo emitter
- iii. Photovoltaic & Photodiodes
- iv. Optical Fibre
- v. Sensors with negligible sensor dynamics

2.4.1 Light Dependent Resistors(LDR)

Also known as Photo resistor.

An LDR or a photo resistor has a resistance which changes based on the amount of visible light that falls on it.

The light falls on the zigzag lines on the sensor (usually made of Cadmium Sulphide), causes the resistance of the device to fall.

2.4.2 Photo emitters

Photo emissive cells are the dominant type of sensors used in sound tracking of films.

It is a vacuum device - with Cesium as cathode, Nickel as anode.

Current flow between the electrodes is proportional to the energy carried by the light.

It has a limited range of response where UV is easy to sense, Infrared mostly difficult to sense.

2.4.3 Photovoltaic Cells

The original and still the most common semiconducting material used in PV cells is single crystal silicon.

It is the most efficient type of PV cells with conversion up to 23%.

Alternatives to single crystal silicon cells include polycrystalline silicon cells, a variety of "thin film" PV cells, and concentrating collectors.

Poly- crystalline silicon cells are less expensive to manufacture because they do not require the growth of large crystals. Unfortunately, they are less efficient than single crystal cells (15- 17%).

Amorphous silicon thin film PV cells are widely used in commercial electronics, powering watches and calculators. The problem with these cells is that they are not very efficient and they degrade with time.

2.4.4 Photoelectric Sensing System

Photoelectric sensing requires an emitter (to generate light) and a receiver (which "sees" the light from the emitter).

Most photoelectric sensors use LEDs (Light Emitting Diodes) as a light source, a solid state semiconductor, similar electrically to a diode, except that it emits a small amount of light when current flows through it in the forward direction.

LEDs can be built to emit green, blue, blue-green, yellow, red, or infrared light. The LED colors most commonly used in sensing are visible red and infrared.

In applications which sense color contrasts, the choice of LED color can be important. Because LEDs are solid-state, they will last for the entire useful life of a sensor.

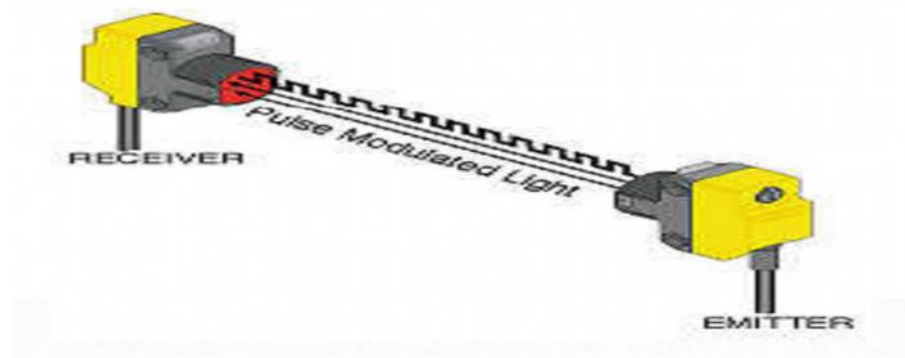


Figure 1: Illustration of Photoelectric Sensing System

The figure above is showing how a photo emitter and receiver combination could be used for sensing an object. This is a very common sensor used in automated plants.

Photoelectric receivers typically use one of three light-sensitive electronic elements.

The phototransistor is the most widely used receiver opto-element in industrial photoelectric sensor design, because they offer the best tradeoff between light sensitivity and response speed.

2.4.5 Optical Fibre Sensing mechanism

When an optical Fibre is subjected to perturbations of different kinds, it experiences geometrical (size, shape) and optical (refractive index, mode conversion) changes depending upon the nature and the magnitude of the perturbation.

In Fibre optic sensing, this response to external influence is magnified so that the resulting change in optical radiation can be used as a measure of the external perturbation.

The optical Fibre serves as a transducer and converts parameters like temperature, stress, strain, rotation or electric and magnetic currents into a corresponding change in the optical radiation.

Since light is characterized by intensity, phase, frequency and polarization, any one or many of these parameters may undergo a change during the motion of a dynamic system.

2.4.6 Photo Junction Devices

These photo sensors are made from silicon pn-junctions which are sensitive to light and can detect both visible and infrared light levels. They include photo diode and the phototransistor.

2.4.6.1 photodiode

The junction responds to light particularly longer wavelengths such as red and infrared rather than visible light.

When the photodiode is forward biased, there is an exponential increase in the current, same as for normal diode. When a reverse bias is applied, a small reverse saturation current appears which causes an increase of the depletion region, which is the sensitive part of the junction. The current mode is very linear over a wide range.

The photodiode construction and bias characteristics is as shown below.

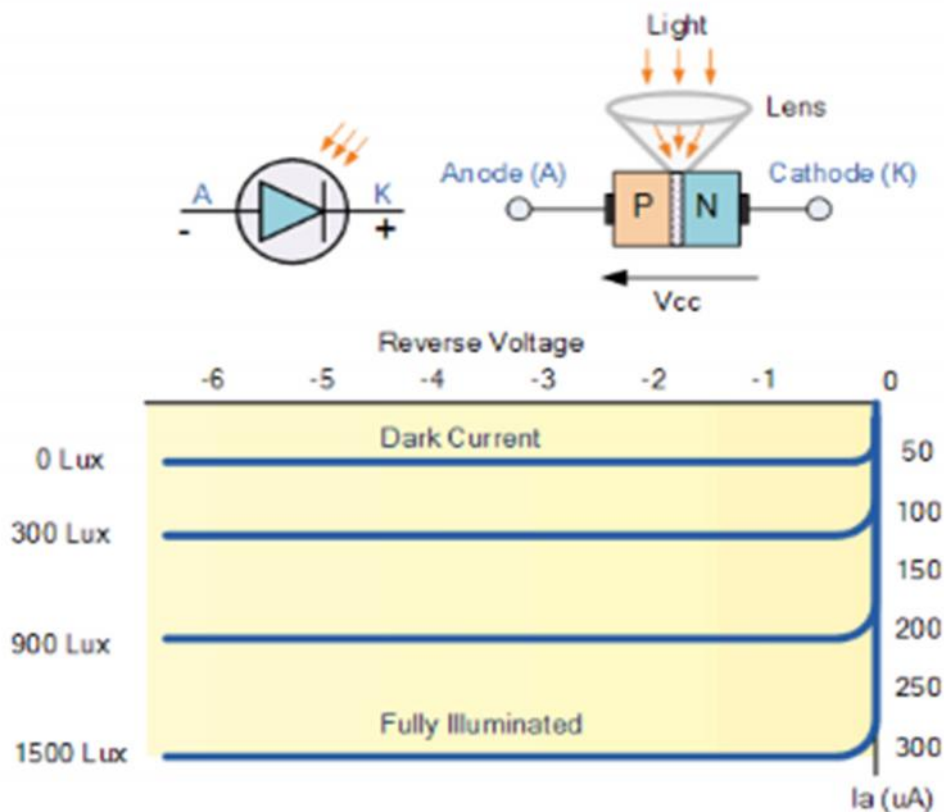


Figure 2: Photodiode V-I characteristics

When light falls upon the junction more holes/ electrons pairs are formed and the leakage current increases. This leakage current increases as the illumination of the junction decreases.

Thus, the photodiodes current is directly proportional to light intensity falling onto the junction.

One main advantage of the photodiodes when used as light sensors is their fast response to changes in the light levels, but the drawback is that the relatively small current flow even when fully lit.

2.4.6.2 phototransistor

This is basically a photodiode with amplification.

They operate same as the photodiode except that they can provide current gain and are much more sensitive than the photodiode with currents 50 to 100 times greater than the standard photodiode and any normal transistor can be easily converted into a phototransistor light sensor by connecting a photodiode between the collector and base.

Phototransistor construction and connection is as below,

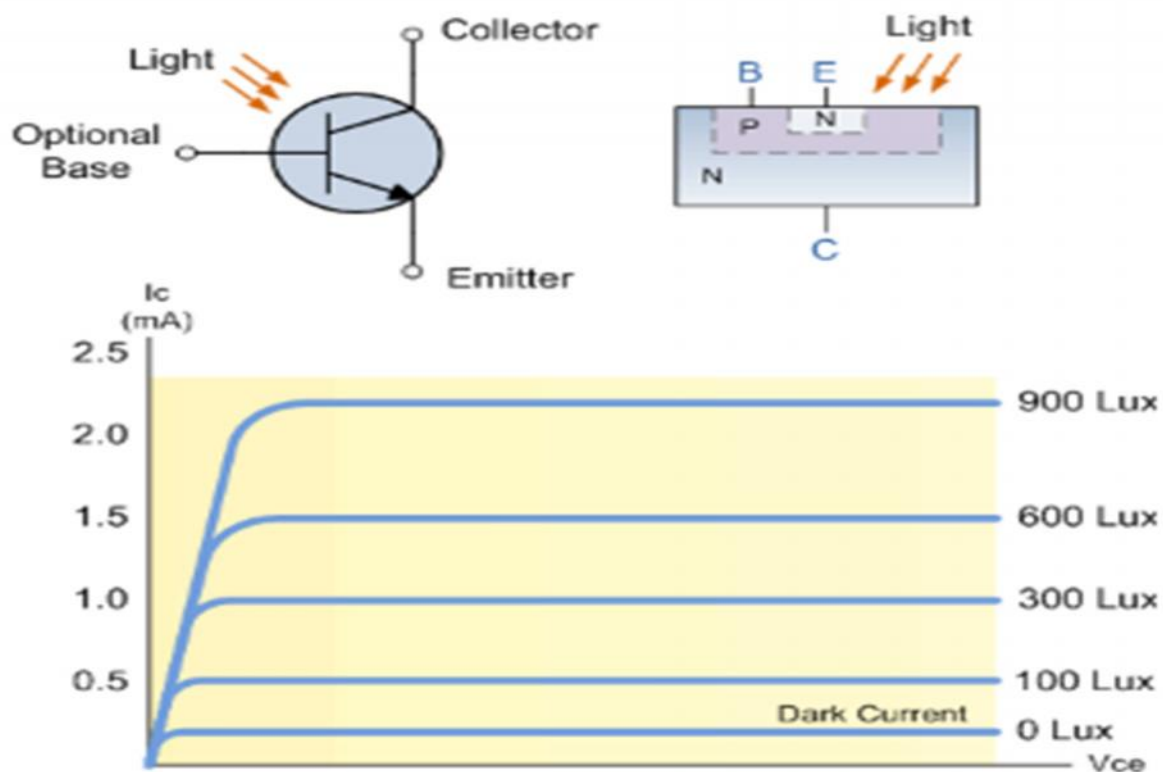


Figure 3: phototransistor V-I characteristics

2.5 Occupancy Sensors

An occupancy sensor is a lighting control device that detects occupancy of a space by people and turns the lights on or off automatically, using infrared, ultrasonic or microwave technology.

Occupancy sensors are typically used to save energy, provide automatic control. Three basic types of occupancy sensors are as follows.

2.5.1 Passive infrared sensor

A PIR detector is a motion detector that senses the heat emitted by a living body.

The sensor is passive because, instead of emitting a beam of light or microwave energy that must be interrupted by a passing person in order to “sense” that person, the PIR is simply sensitive to the infrared energy emitted by every living thing. When an intruder walks into the detector’s field of vision, the detector “sees” a sharp increase in infrared energy.

A moving person exhibits a sudden change in infrared energy, but a slower change is emitted by a motionless body.

Passive infrared sensor measures infrared light radiating from objects in its field of view. PIRs are often used in the construction of PIR-based motion detectors. Apparent motion is detected when an infrared source with one temperature, such as a human, passes in front of an infrared source with another temperature, such as a wall.

Infrared radiation enters through the front of the sensor, known as the sensor face. Inside of device is a pyroelectric sensor calibrated to detect infrared radiation radiated by human body movement.

2.5.1.1 Operation of PIR sensor

A few mechanisms have been used to focus the distant infrared energy onto the sensor surface. The window may have Fresnel lenses molded into it. Alternatively, sometimes PIR sensors are used with plastic segmented parabolic mirrors to focus the infrared energy; when mirrors are used, the plastic window cover has no Fresnel lenses molded into it. A filtering window (or lens) may be used to limit the wavelengths to 8-14 micrometers, which is most sensitive to human infrared radiation (9.4 micrometers being the strongest).

The PIR device can be thought of as a kind of infrared ‘camera’, which remembers the amount of infrared energy focused on its surface.

A person entering the monitored area is detected when the infrared energy emitted from the intruder's body is focused by a Fresnel lens or a mirror segment and overlaps a section on the

chip, which had previously been looking at some much cooler part of the protected area. That portion of the chip is now much warmer than when the intruder wasn't there. As the intruder moves, so does the hot spot on the surface of the chip-

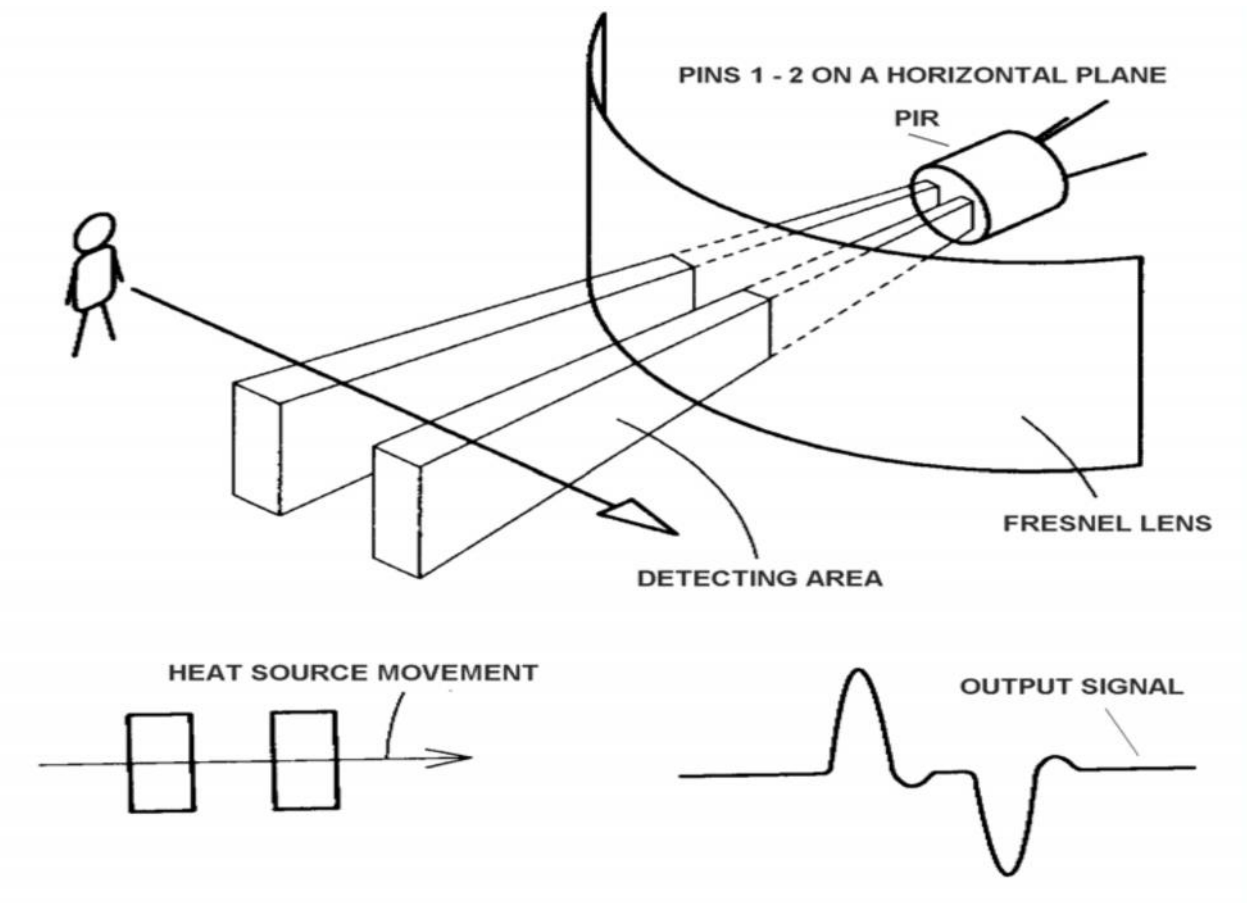


Figure 4: Diagram showing PIR working mechanism

At the heart of the sensor is the pyro-electric material. This material generates energy when exposed to radiation. Whenever a body emitting infrared passes across the sensor, the intensity of the incoming radiation with respect to the background increases. As a result, the energy generated by the sensor also increases. Suitable signal conditioning circuits convert the energy generated by the sensor to a suitable voltage output.

2.5.2 Ultrasonic sensor

It is similar to radar. It works on the Doppler shift principle. An ultrasonic sensor will send high frequency sound waves in area and will check for their reflected patterns. If the reflected pattern

is changing continuously then it assumes that there is occupancy. If the reflected pattern is the same for a preset time, then the sensor assumes there is no occupancy.

2.5.3 Microwave sensor

Similar to the ultrasonic sensor, a microwave sensor also works on the Doppler shift principle. A microwave sensor will send high frequency microwaves in an area and will check for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy. If the reflected pattern is the same for a preset time, then the sensor assumes there is no occupancy. A microwave sensor has high sensitivity as well as detection range compared to other types of sensors.

2.6 Dimmers

The most commonly used dimmers are as listed below:

- i) Using Pulse Width Modulation.
- ii) Relays
- iii) Triacs
- iv) Potentiometers

2.6.1 Relays

The Relay is a device that acts upon the same fundamental principle as the solenoid. The difference between a relay and a solenoid is that a relay does not have a movable core (plunger) while the solenoid does. Where multipole relays are used, several circuits may be controlled at once.

Relays are electrically operated control switches, and are classified according to their use as power relays or control relays. Power relays are called contactors; control relays are usually known simply as relays.

The function of a contactor is to use a relatively small amount of electrical power to control the switching of a large amount of power. The contactor permits you to control power at other locations in the equipment, and the heavy power cables need be run only through the power relay contacts.

Only lightweight control wires are connected from the control switches to the relay coil. Safety is also an important reason for using power relays, since high power circuits can be switched remotely without danger to the operator.

Control relays, as their name implies, are frequently used in the control of low power circuits or

other relays, although they also have many other uses. In automatic relay circuits, a small electric signal may set off a chain reaction of successively acting relays, which then perform various functions.

2.6.2 Pulse width Modulation(PMW)

Pulse-width modulation (PWM) is a modulation technique used to encode a message into a pulsing signal. 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.

The average value of voltage (and current) 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.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there being practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero.

PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform.

Light dimmers for home use employ a specific type of PWM control. Home-use light dimmers typically include electronic circuitry which suppresses current flow during defined portions of each cycle of the AC line voltage.

Adjusting the brightness of light emitted by a light source is then merely a matter of setting at what voltage (or phase) in the AC half-cycle the dimmer begins to provide electric current to the light source (e.g. by using an electronic switch such as a triac). In this case the PWM duty cycle is the ratio of the conduction time to the duration of the half AC cycle defined by the frequency of the AC line voltage.

2.6.3 Triacs

TRIAC, from triode for alternating current, is a generic trademark for a three terminal electronic component that conducts current in either direction when triggered. Its formal name is bidirectional triode thyristor or bilateral triode thyristor. A thyristor is analogous to a relay in that

a small voltage and current can control a much larger voltage and current. The illustration below shows the circuit symbol for a TRIAC where A1 is Anode 1, A2 is Anode 2, and G is Gate. Anode 1 and Anode 2 are normally termed Main Terminal 1 (MT1) and Main Terminal 2 (MT2) respectively.

Triac is most commonly used as a switching device and for controlling power of ac systems. The Triac can be switched on by either a positive and a negative gate pulse, regardless of the polarity of the ac supply at that time. This makes Triacs ideal for controlling ac loads with very basic driving circuits as shown below.

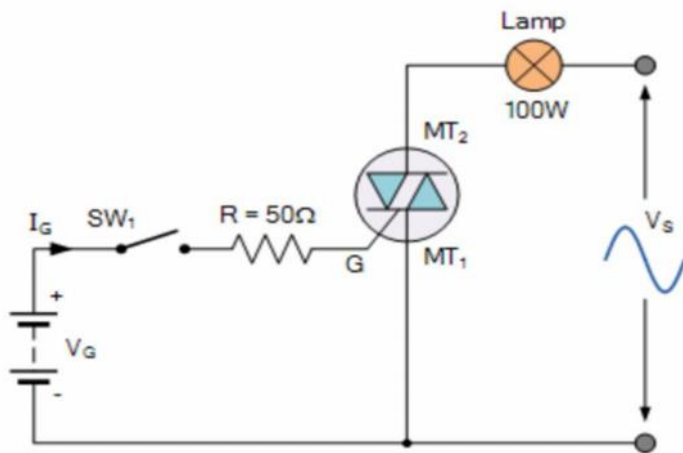


Figure 5: Triac basic driving circuits

When the switch is open, the current is not passed through the gate of the transistor and thus the lamp is off. When the switch is closed, gate current is supplied to the gate from the battery and the Triac is driven into full conduction acting like a closed switch and full power is drawn by the lamp from the sinusoidal supply.

2.7 processors

A processor is a device that controls the transfer of data from a computer to a peripheral device and vice versa and all the processes its designed to do.

2.7.1 microprocessors

A Microprocessor is a silicon chip that contains a central processing unit (CPU) and is a digital electronic component with miniaturized transistors on a single semiconductor integrated circuit. One or more microprocessors typically serve as a CPU in a computer system or handheld device. At the heart of all personal computers and most working stations sits a microprocessor as it also

controls the logic of almost all digital devices, from clock radios to fuel-injection systems for automobiles.

There are three basic characteristics that differentiate microprocessors:

- i) **Instruction set:** The set of instructions that the microprocessor can execute.
- ii) **Bandwidth:** The number of bits processed in a single instruction.
- iii) **Clock speed:** Given in hertz (Hz), the clock speed determines how many instructions per second the processor can execute.

In both cases, the higher the value, the more powerful the CPU. In addition to bandwidth and clock speed, microprocessors are classified as being either RISC (reduced instruction set computer) or CISC (complex instruction set computer).

2.7.2 microcontrollers

A Microcontroller is a highly integrated chip that contains all the components comprising a controller. Typically, this includes a CPU, RAM, some form of ROM, I/O ports, and timers.

Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task - to control a particular system.

Microcontrollers are sometimes called embedded microcontrollers, which just means that they are part of an embedded system that is, one part of a larger device or system such as automobiles, telephones, appliances, and peripherals for computer systems.

Typical input and output devices include relays, solenoids, switches. LEDs, small or custom LCD displays and sensors for data such as temperature, light humidity level etc. Embedded systems usually have no keyboard, disks, screens, printers, or other identifiable I/O devices of a personal computer, and may lack human interaction devices of any kind.

A Microcontroller must provide real time response to events in the embedded system they are controlling. When an event occurs, an interrupt system alerts the processor to postpone processing the current instruction sequence and to begin an interrupt service routine (ISR). The ISR carries out any processing required based on the origin of the interrupt, before going back to the original instruction sequence. Interrupt sources are appliance dependent, and often include events such as completing an analog to digital conversion, an internal timer overflow, data received on a communication link and a logic level change on an input such as from a button being pressed. Where power consumption is key as in devices operated using a battery, interrupts

may also awaken a microcontroller from a low power sleep state where the processor is stopped until required to do something by a nonessential event.

The microcontroller works a specific program to perform specific operations. Assemblers and compilers are used to convert assembler language codes and high level language into a solid machine code for storage in the microcontroller's memory. Depending on the appliance, the program memory may be field-alterable flash memory or erasable programmable read only memory or permanent read only memory that can only be programmed at the factory.

Advantages of microcontrollers over microprocessors

- i)** The great advantage of microcontrollers, as opposed to using larger microprocessors, is that the parts-count and design costs of the item being controlled can be kept to a minimum.
- ii)** They are typically designed using CMOS (complementary metal oxide semiconductor) technology, an efficient fabrication technique that uses less power and is more immune to power spikes than other techniques.
- iii)** A microcontroller differs from a microprocessor, which is a general-purpose chip that is used to create a multi-function computer or device and requires multiple chips to handle various tasks.
- iv)** A microcontroller is meant to be more self-contained and independent, and functions as a tiny, dedicated computer.

2.7.2.1 Types of microcontrollers

Microcontrollers can be classified on the basis of internal bus width, architecture, memory and instruction set. Figure below shows the various types of microcontrollers.

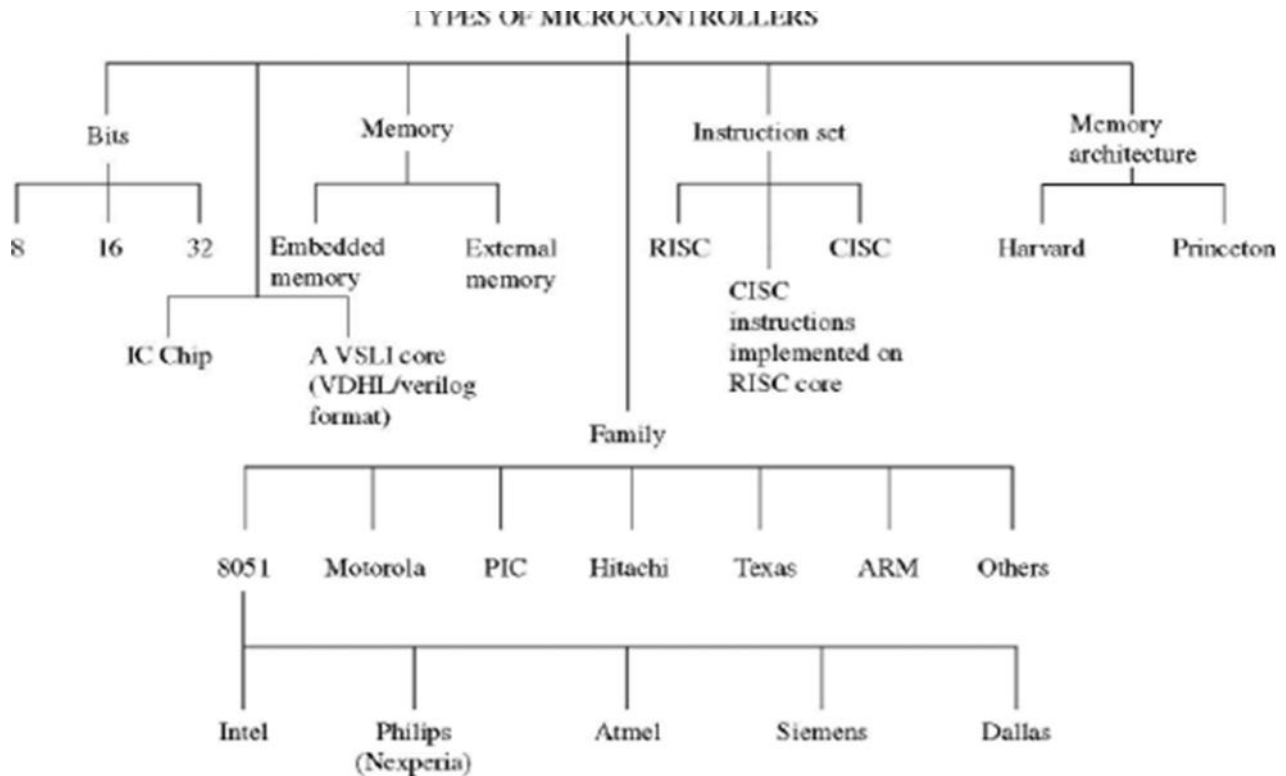


Figure 6: microcontroller classifications

2.8 Lighting Sources and Lighting Fixtures

The lighting controller achieves its objectives depending on its efficiency and quality of light level controlled as well as types of light source used.

Most luminaires consist of a lamp, lamp holder and control gear. The luminaire will also have a means of getting as much light as possible to leave the luminaire and travel in the required direction. This could involve reflectors, louvres, lenses or diffusers. The following are some of the typical lamps that are used in commercial applications.

2.8.1 General lighting service incandescent lamps (GLS lamps)

GLS lamps are no longer available to purchase due to their poor efficiency. These lights have often been used in auditoriums and theatres where dimming is needed.

2.8.2 Halogen lamps

Halogen lamps are also an incandescent lamp. Where most incandescent lamps contain a tungsten filament and some gasses (typically argon and/or nitrogen), the halogen lamps also contain iodine. This significantly prolongs lamp life and allows the filament to burn hotter and therefore whiter. Halogen lamps are generally more efficient than standard incandescent lamps.

2.8.3 Fluorescent Lamps

Fluorescent lamps come in a variety of forms. Linear lamps and compact lamps are the most common types. Fluorescent lamps contain mercury which causes the tube to produce light mostly in the UV region of the spectrum. UV light is not useful for general lighting and so the light is shifted to the visible spectrum by a combination of coatings. These coatings are seen as white on the inside of the tube and are known as phosphors. These can provide light in a variety of white shades, depending on the blend of phosphors used. The fluorescent tubes are sometimes known as low pressure mercury tubes.

All fluorescent lamps work in the same manner, regardless of their shape.

2.8.4 High Intensity Discharge (HID) Lamps

Mercury vapor lamps, sodium vapor lamps and some types of metal halide lamps can be very similar in appearance.

2.8.4.1 Mercury Vapor Lamps

These are very similar to fluorescent tubes as they use mercury and phosphors. They were commonly used in high bay fittings and old style street lights. They were occasionally used in downlights within large spaces, such as the foyers of tower buildings. These lamps produce a blueish light.

2.8.4.2 Sodium Vapor Lamps

Sodium vapor lamps are generally used in street lighting and occasionally in car park lighting. These lamps use sodium instead of mercury and the light they produce is very orange-yellow in color. Sodium vapor lamps have become less popular with lighting designers over recent years, most likely due to the better light quality of metal halide lamps.

2.8.4.3 Metal Halide Lamps

These lamps have become quite popular over the last ten years due to advances in technology. They contain a number of different metal halides which produce different wavelengths within the visible spectrum. A good white light is produced by metal halides. These lamps are used in a variety of applications because they are efficient and have long operating lives.

2.8.5 Induction Lamps

These lamps are similar to florescent lamps, except that they do not receive their energy by electrodes creating an arc. The mercury in a typical induction lamp is excited into producing light by the use of a powerful magnetic field. The lamps are operated by electronic control gear.

2.8.6 Light Emitting Diodes (LED)

Electricity is passed through a semiconductor, which produces photons (a basic unit of light). The semiconductor can be made from many different mixes of materials, which means that photons can be produced in a variety of colors. LED can produce more useable white light per unit of energy than metal halide, sodium vapor, florescent and halogen light sources. LED produce a lot of light from a very small source, which helps to control where the light shines. LED can cause a great deal of glare if not managed properly.

2.8.6.1 Benefits of LEDs

- i. LED technology can be dimmed.
- ii. LED, though expensive initially, has a very low energy consumption level.
- iii. No UV radiation from LED lights and also it doesn't contain mercury making it safer.
- iv. They have high luminous efficiency (at least 90-100lm/W),
- v. LEDs produce more light per watt than do incandescent bulbs; this is useful in battery powered or energy saving devices.
- vi. LEDs can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs.
- vii. When used in applications where dimming is required, LEDs do not change their color tint, unlike incandescent lamps which turn yellow.
- viii. LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.
- ix. LEDs, being solid state components, are difficult to damage with external shock. Fluorescent and incandescent bulbs are easily broken if subjected to external shock.
- x. LEDs can have a relatively long useful life. Reports estimates 60,000 hours of useful life, though time to complete failure longer.

CHAPTER THREE: DESIGN

3.1 Introduction

This chapter seeks to explain in depth the process used in the implementation and operation of the mains supply voltage monitoring and logging system. This system design mainly consists of two modules which are:

- i. Hardware module
- ii. Software module

The hardware module mainly entails the components used in the design whereas the software module consists of the logic used in the execution of the project and this will be explained in detail later on.

The project design can be summarized in form of a block diagram as shown in fig 3.1 below.

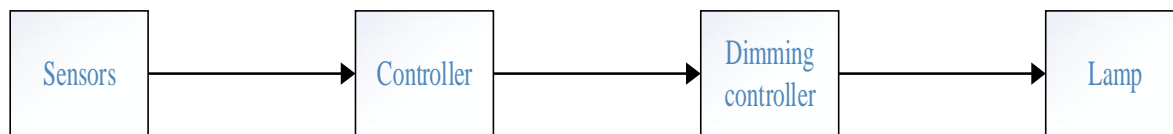


Figure 7: General design concept of energy saver lighting control system

3.2 Hardware module

This consists of components used in the design which include the following:

- i) Sensors.
- ii) Dimming controller
- iii) Lamp
- iv) Controller
- v) Power supply.

3.3 Sensors

Sensors used in the implementation of the project are:

- i) Ambient light monitor
- ii) Passive infrared based motion sensor

3.3.1 Ambient Light Monitor

The ambient light monitor is used to sense the lighting condition of the specified space.

The output of the sensor should vary linearly with illumination.

The light-sensitive component we will use is the **BH1750**.

Features

- i) Inter-Integrated Circuit(I²C) bus Interface.
- ii) Spectral responsibility is approximately human eye response
- iii) Illuminance to Digital Converter
- iv) Wide range and High resolution. (1 - 65535 lux)
- v) Low Current by power down function
- vi) 50Hz / 60Hz Light noise reject-function
- vii) Adjustable measurement result for influence of optical window
- viii) Small measurement variation.
- ix) The influence of infrared is very small.

Placing Considerations

- i) This product should not be exposed to electromagnetic and ionized particle radiation.
- ii) It is recommended that the light which falls on the device illuminate it uniformly.
- iii) For the most reliable sensing, guard the device from stray incident light.
- iv) Avoid windows as windows receive most of the natural lights during the day.
- v) Placed near or on the working area such as desks where the lighting is needed during working hours.
- vi) Placed away from the lighting fixture as light is brighter near the fixture.
- vii) Placed clear off the curtains and any other thing blocking lights to the sensor
- viii) Placed away from the reflecting surfaces as they may impair the performance of the sensor.

Our supply voltage is 5V, we need to obtain any value between 2.4V- 3.6V that will be used to bias our sensor, we do voltage division using two resistors.

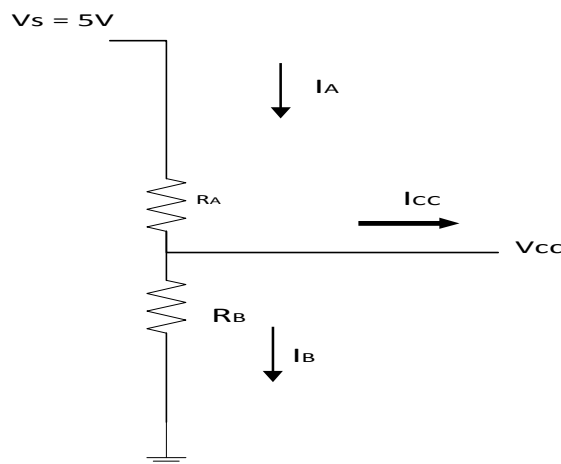


Figure 8: Illustration of voltage division to obtain 3.3V

$$V_{cc} = \frac{R_B * V_S}{R_A + R_B} \dots\dots\dots (3.1)$$

$$V_{cc} = \frac{R_B * 5}{R_A + R_B}$$

$$I_A = I_{cc} + I_B; \dots\dots\dots (3.3)$$

(I_A is the current through resistor R_A while I_B is the current through resistor R_B)

$$I_A = \frac{V_S - V_{CC}}{R_A} \dots\dots\dots (3.4)$$

$$I_A = \frac{5 - V_{CC}}{R_A} \dots\dots\dots (3.5)$$

$$I_B = \frac{V_{CC} - 0}{R_B} \dots\dots\dots (3.6)$$

$$\frac{5 - V_{CC}}{R_A} = I_{cc} + \frac{V_{CC}}{R_B} \quad (\text{from equation 3.3})$$

$$5 - V_{CC} = R_A(I_{cc} + \frac{V_{CC}}{R_B})$$

$$-V_{CC} = R_A(I_{cc}) + (R_A \frac{V_{CC}}{R_B}) - 5 \dots\dots\dots (3.7a)$$

$$V_{CC} = -R_A(I_{cc}) - (R_A \frac{V_{CC}}{R_B}) + 5 \dots\dots\dots (3.7b)$$

$$V_{CC} \left(1 + \frac{R_A}{R_B}\right) = -R_A I_{cc} + 5$$

$$V_{CC} = \frac{-R_A R_B I_{CC}}{R_A + R_B} + 5 \left(\frac{R_B}{R_A + R_B}\right) \dots\dots\dots (3.8)$$

$I_{cc} = 120 \mu A$ (recommended from the datasheet);

From equation 3.1 and 3.8, we see that we have Three unknowns (V_{CC}, R_A, R_B). we thus fix $V_{CC} = 3.3V$, that is a figure between 2.4V-3.6V as stipulated in the datasheet of the sensor in order to evaluate the values of R_A and R_B .

From equation 3.1, we obtain

$$R_B = 2R_A \dots\dots\dots (3.9)$$

Substituting the value of $R_B = 2R_A$ in equation 3.9 into equation 3.8, we obtain $R_A = 416.67$

and $R_B = 833.34$. We choose the standard values $R_A = 430$ and $R_B = 820$.

Choosing the standard resistor values above,

$$V_{CC} = \frac{820 * 5}{820 + 430} = 3.28V, \text{ which is still approximately } 3.3$$

$$I_A = \frac{V_S - V_{CC}}{R_A} = \frac{5 - 3.28}{430} = 4 \text{ mA}$$

$$I_B = \frac{V_{CC}}{R_B} = \frac{3.28}{820} = 3.81395 \text{ mA}$$

$$I_{CC} = I_A - I_B = 4 - 3.81395 = 186\mu A$$

The typical $I_{CC} = 120\mu A$ and maximum is $190\mu A$, we need to limit the value obtained to the typical value for optimum operation of the sensor,

Desired supply current, $I_{CC} = 120\mu A$

$$V_{CC} = 3.28V$$

From Ohms' law,

$$V_{CC} = I_{CC}R_{LIMIT}$$

$$R_{LIMIT} = \frac{3.28}{120\mu A} = 27,333$$

$$R_{LIMIT} = 27\text{ k}$$

Final value of supply current, I_{CC} after limiting is thus,

$$I_{CC} = \frac{3.28}{27000}$$

$I_{CC} = 121\mu A$ which is approximately the desired value.

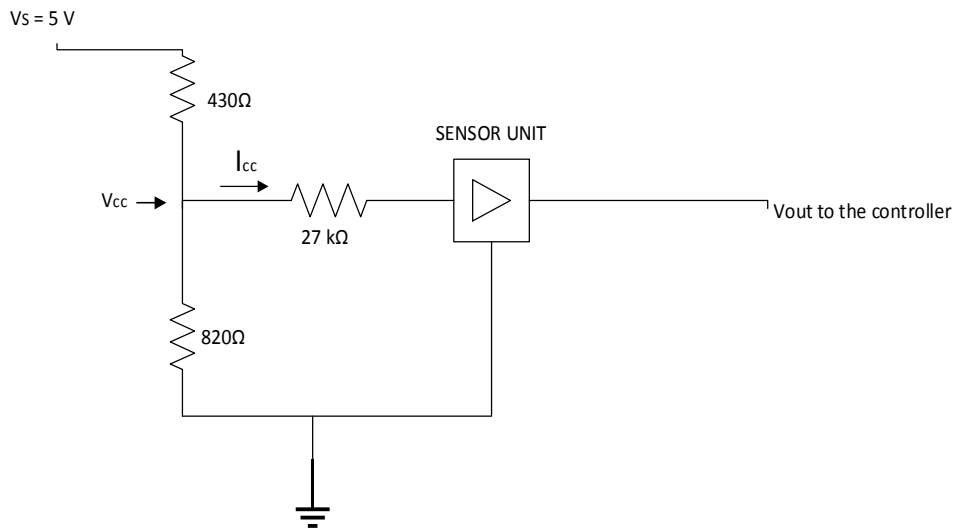


Figure 9: Light sensor circuit

3.3.2 Passive Infrared(PIR) Based Motion Sensor

This is used to sense if an occupant is available in a specified space.

Maximum output to the controller should be 5V.

It is desired that the sensor has a wider circular view.

The PIR based motion sensor module used here is the DSUN model.

Features

- i) Operates with voltages 4.5V – 5V
- ii) It has a built in amplifier. Extremely compact. Ideal for use in miniaturized devices.
- iii) Both digital output and analog output (with adjustable sensitivity) are available.
- iv) Detects slightest motion. Even slight motions made by people will be detected easily.
Fine motion detection capability within approximately 2 meters of sensor
- v) Noise withstanding capability. Circuitry is contained in a transistor outline (TO) metal package, providing at least twice the noise withstanding capability as conventional type.
- vi) A wide view of 110 degrees.

Placing Considerations

- i) Heating registers are often located under windows, so when your heating system turns on and off, the temperature will change rapidly just there. Avoid placing the sensor near these heating registers.
- ii) The lenses in PIRs are designed to admit infrared light and block visible light, but they're not perfect. The more ambient light in the field of view, the less sensitive they'll be thus sensor placed away from direct sunlight or illumination.
- iii) Placed in such a way to avoid picking the effect of pets in the field of view.
- iv) Placed strategically to see a monitored field of view if the motion sensor is used for security purposes.
- v) Avoid pointing towards Heating Ventilation and Air Conditioning (HVAC) vents or other quick sources of temperature change.
- vi) Avoid pointing them towards the windows since infrared can pass through glass.
- vii) In order to ensure proper detection, install it with the lens exposed.

3.4 Dimming Controller

The dimming controller is used to control the brightness of the lamp based on the conditions obtained from the controller.

The dimming controller is composed of:

- i) Zero crossing detector
- ii) Optocouplers
- iii) Switching device

3.4.1 Zero crossing detector

A zero crossing detector detects the transition of a signal waveform from positive and negative, ideally providing a narrow pulse that coincides exactly with the zero voltage condition.

In alternating current, the zero-crossing is the instantaneous point at which there is no voltage present. In a sine wave or other simple waveform, this normally occurs twice during each cycle.

The circuit is also sensitive to level, and for acceptable performance the AC waveform needs to be of reasonably high amplitude because if the voltage is too low, the pulse width will increase.

The zero crossing detector comprises of:

- i) Optocoupler
- ii) Full wave bridge rectifier

3.4.1.1 Optocoupler

The function of the optocoupler is to provide electrical isolation between stages of the electronic system but still permit signal coupling, in this case the pulsating AC voltage is isolated from the DC input into the microcontroller which is limited to 5V since the microcontroller works with voltages below 5V.

Optocoupler incorporates the light emitting diode, and a phototransistor enclosed in single package. When current flows through the LED, light from the LED activates the photosensitive PN junction of the transistor.

Whenever we have an output from the LED, the transistor will turn ON and give a low output and when an ac crossing zero volt, the transistor goes off and gives a high output.

The optocoupler used here is **4N35**

features

- i) Isolation test voltage 5000VRMS
- ii) Industry standard dual-in-line 6pin package

Typical AC voltage into the optocoupler is 12V-15V.

According to the datasheet, the maximum current into the optocoupler is 50 mA. We need to limit this current to about 20 mA since the Emitting diode trigger current is given as from 5mA.

Voltage supplied after rectification is, $V_{out} = V_{in} * 2 = 12 * 1.414 = 17V$

Current limiting resistor required is calculated as,

voltage will drop by 1.2V due to the forward biasing of the diode as specified in the datasheet,

$$V = 17 - 1.2 = 15.8 \text{ V}$$

$$R_1 = \frac{V}{I} \text{ (according to Ohms' law)}$$

$$R_1 = \frac{15.8}{20mA} = 788.4$$

$$R_1 = 820 \text{ } \Omega \text{ (standard value)}$$

(the chosen standard resistor value is approximately equal to the calculated value, thus causes a very negligible change in currents and voltages which are not worthwhile noting)

The current transfer ratio of 4N35 is 20%- 50%. Input current was limited to 20 mA thus the

Current output from the optocoupler, $I_{CPLR} = 0.4 * 20mA$.

$I_{CPLR} = 8 \text{ mA}$ (this is the current obtained at the output of the optocoupler). Let's confine the input to the controller to be about 10 mA since the maximum is about 40mA as the controller is not expected to sink much current.

$I_{MAX} = 10 \text{ mA}$ (this is the current that should be sunk by the microcontroller). Maximum current contribution due to biasing voltage ($V_{supply} = 5V$), I_{bias} is the current contributed by the 5V supply used to bias the BJT inside the optocoupler.

$$I_{bias} = 10 \text{ mA} - I_{CPLR} \text{ (from Kirchhoff current law at the node).}$$

$$I_{bias} = 10 - 8 \text{ mA} = 2 \text{ mA}$$

Current limiting resistor value connected between V_{supply} and the collector of the BJT is calculated as,

$$R_c = \frac{V}{I} \text{ (according to Ohms law)}$$

$$R_c = \frac{5}{2 \text{ mA}} = 2500$$

$$R_c = 2.7 \text{ K } \Omega \text{ (standard value)}$$

The standard value chosen affects I_{bias} ,

$$I_{bias} = \frac{5V}{2.7 \text{ k}\Omega}$$

$$I_{bias} = 1.85mA.$$

This is current limiting and has no effect on other current contributions since there is a wide range of acceptable voltage into the controller that is up to 40mA.

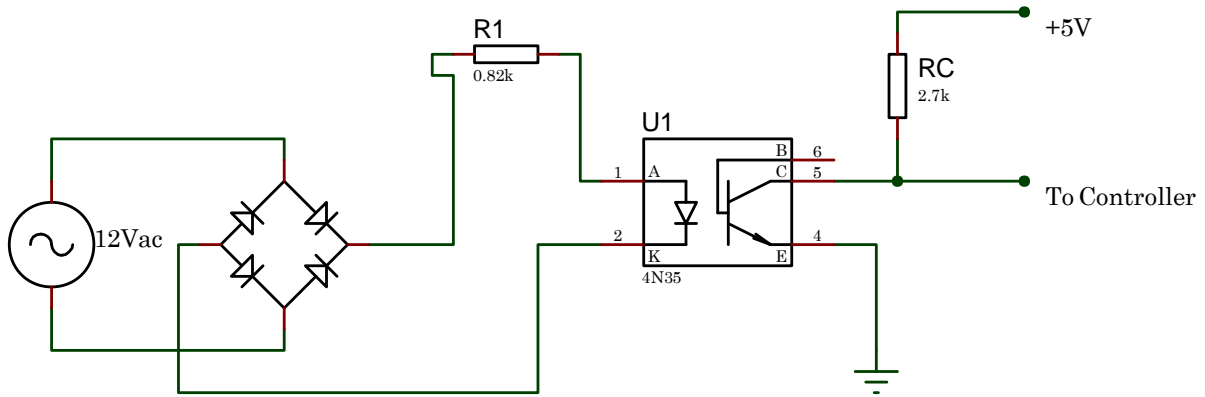


Figure 10 : circuit diagram of the zero crossing detector with full wave diode bridge.

3.5 The Controller

The controller to be used here is the microcontroller.

The program for the control logic is smaller in size that is 1.25KB.

For this project, Arduino Uno will be used. It is based on the ATmega328

Features

- i) Microcontroller ATmega328
- ii) Operating Voltage is 5V
- iii) Digital I/O Pins 14(of which 6 provide PWM output)
- iv) Analog Input Pins are 6
- v) DC Current per I/O Pin is 40mA
- vi) DC Current for 3.3V Pin is 50mA
- vii) Flash Memory 32KB of which 0.5KB used by bootloader
- viii) Static Random Access Memory (SRAM) of 2KB
- ix) Clock Speed 16 MHz

3.5.1 The Arduino Board



Figure 11: The Arduino board

3.5.1.2 Digital Pins

In addition to the specific functions listed below, the digital pins on an Arduino board can be used for general purpose input and output via the `pinMode ()`, `digitalRead ()`, and `digitalWrite ()` commands. Each pin has an internal pull-up resistor which can be turned on and off using `digitalWrite ()` (value of `HIGH` or `LOW`, respectively) when the pin is configured as an input. The maximum current per pin is 40 mA.

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value using the `attachInterrupt ()` command.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the `analogWrite ()` function.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is `HIGH` value, the LED is on, when the pin is `LOW`, it's off.

3.5.1.3 Analog Pins

In addition to the specific functions listed below, the analog input pins support 10-bit analog-to-digital conversion (ADC) using the `analogRead ()` function. Most of the analog inputs can also be used as digital pins: analog input 0 as digital pin 14 through analog input 5 as digital pin 19.

- **I²C: 4 (SDA) and 5 (SCL).** Support Inter-Integrated Circuit (I²C) communication using the `Wire` library.

3.5.1.4 Power Pins

- **VIN.** The input voltage to the Arduino board when it's using an external power source.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board.

- **3.3.** volt supply generated by the on-board chip.
- **GND.** Ground pins.

3.5.1.5 Other Pins

- **AREF.** Reference voltage for the analog inputs. Used with analogReference ().
- **Reset.** Typically used to add a reset button to shields which block the one on the board.

3.6 The Dimmer

The dimmer is composed of;

- i) Triac based Optocoupler
- ii) Triac driving the load

3.6.1 Triac based optocoupler

The optocoupler to be used here is K3022P optocoupler

Features

- i) 400V blocking voltage
- ii) Isolation test voltage, 5300 VRMS, t = 1 s

Design considerations

Trigger current = 10mA

Forward current maximum = 80mA

Forward voltage = 1.3 to 1.6 V

Current transfer ratio = 20%-50%

We let the output from the controller to be 20mA since maximum is 40mA and we don't want to get to that critical limit and the also the minimum trigger current for the diode is about 10mA.

We limit current to the optocoupler as follows,

5V is the maximum obtainable from the controller.

Voltage will drop by 1.3 V specified in the datasheet,

$$V = 5 - 1.3 = 3.7 \text{ V}$$

$$R_B = \frac{V}{I} \text{ (according to Ohms' law)}$$

$$R_B = \frac{3.7}{20mA} = 185$$

$$R_B = 220 \text{ (standard value)}$$

From the standard resistor chosen, the maximum current from the controller which was limited to 20mA will be,

$$I = \frac{V}{R_B} = \frac{5}{220\Omega} = 22.7\text{mA}$$

This current has no impact on other components connected to the optocoupler, initial current limitation was done purposely for security reasons in order to prevent unnecessarily excessive currents.

The current output from the optocoupler is subject to the current transfer ratio given above,

$$I_{\text{out}} = 0.4 * 22.7 = 9\text{mA}$$

3.6.2 Triac

Triacs are used in applications requiring high bidirectional transient and blocking voltage capability and high thermal cycling performance.

Typical applications include motor control, industrial and domestic lighting, heating and static switching.

The Triac to be used is the BT137-600E.

Features

- i. Lower typical Gate trigger current 2.5mA or lower.
- ii. Operates under a wide range of voltage without damage.
- iii. Very high repetitive off-state voltages.
- iv. Wide operating ambient temperature.

The latching current (current circulating through anode and cathode to keep the device conducting), $I_{AK} = 3\text{mA}$ to 25mA .

We limit it to 5mA.

$$V_{\text{max}} = 5\text{V}$$

$$R_{AK} = \frac{V}{I} = \frac{5\text{V}}{5\text{mA}}$$

$$R_{AK} = 1\text{K} \Omega$$

3.7 Lamp

The lamp to be used should be:

- i. Controllable without change in color
- ii. Long life span
- iii. Use ac voltage supply, 240Vrms
- iv. Produce more lumens per watt

Owing to the advantages of LED lamps as reviewed in chapter 2, An LED bulb was chosen for this project.

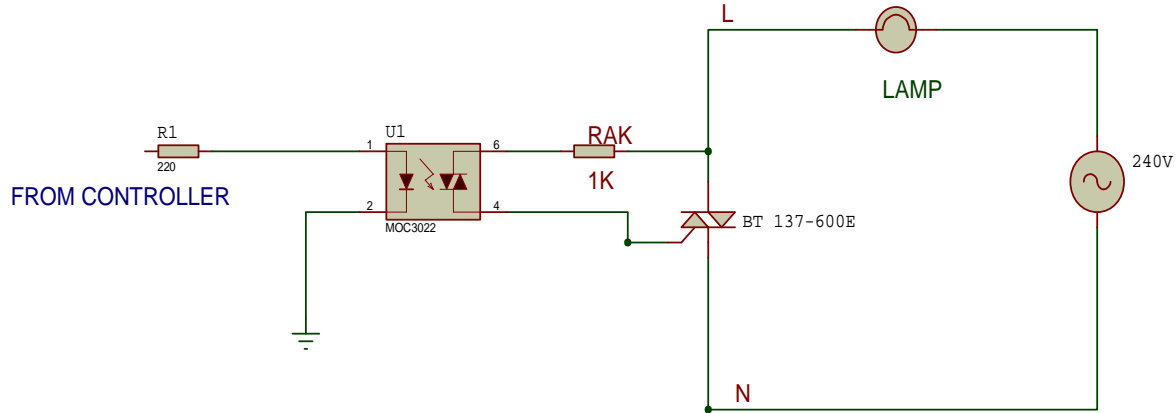


Figure 12: The Dimmer and the Lamp.

3.8 Power Supply

We need to power most of the components making up the system.

Mains power supply is many a times 240Vac whereas most of the components need a lower ac voltage and others need 5Vdc for biasing and switching.

Because of the above stated reasons, Power supply block consists of following units:

- i. Step down transformer.
- ii. Bridge rectifier circuit.
- iii. Input filter and output filters before and after the regulator.
- iv. Voltage regulators.

3.8.1 Step Down Transformer

The step-down transformer is used to step down the supply voltage of 240Vac from mains to lower values, as the various IC's and components used require smaller voltages. The secondary side of the transformer has fewer turns. The outputs from the secondary coil is the ac values of 12 V AC.

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{12 V}{240 V}$$

3.8.2 Rectifier Unit

Sensors supply voltage is 5Vdc thus need for rectification. Rectifier diodes are connected to form a bridge. For both positive and negative swings of the ac supply, there is a forward path through the diode bridge. Both conduction paths cause current to flow in the same direction

accomplishing full-wave rectification. While one set of diodes is forward biased, the other set is reverse biased and effectively eliminated from the circuit.

Diodes are connected as shown to achieve the desired output.

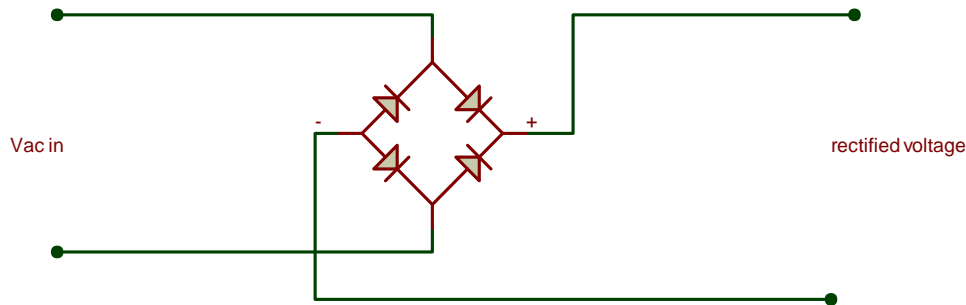


Figure 13: Full wave bridge rectifier

3.8.3 Filters

The ripples from the ac voltages are removed and pure dc voltage is obtained. So it allows only dc voltage and does not allow the ac voltage. This filter is fixed before the regulator.

The amount of ripple voltage is given (approximately) by

$$V_{\text{pk-pk ripple}} = \frac{I_{\text{LOAD}}}{f C}$$

Where f is frequency after rectification, C is the value of the capacitor. As a rule of thumb, it is always desired to have ripple voltages of less than 100mV peak-to-peak.

$$I_{\text{LOAD}} = I_{\text{MOTION SENSOR}} + I_{\text{LIGHT SENSOR}} + I_{\text{COLLECTOR OF OPTOCOUPLER}}$$

$$I_{\text{LIGHT SENSOR}} = I_A = 4\text{mA from section 3.3.2}$$

$$I_{\text{COLLECTOR OF OPTOCOUPLER}} = I_{\text{bias}} = 2\text{mA, from section 3.4.2}$$

$I_{\text{MOTION SENSOR}}$ will be approximated to be smaller since it is not expected to source a lot of current during its operation.

$$I_{\text{LOAD}} = 10\text{mA (approximately).}$$

$$C = \frac{0.01}{2 \times 50 \times 0.1}$$

$$C = 1,000 \mu\text{F}$$

3.8.4 Regulator unit

Whenever there are any ac voltage fluctuations, the dc voltage also changes, and to avoid these regulators are used.

3.8.4.1 μ A7805C voltage regulator

For optimum operation of the μ A7805C voltage regulator, we need to bring voltages down from 12Vdc to about 5Vdc before it is fed into the regulator.

Features

- i. Output voltage is 4.8V-5.2V
- ii. Very small output resistance of 0.017 ohms
- iii. Minimal output noise voltage 40 μ V
- iv. Operation with a Wide range of temperature
- v. Pulse-testing techniques maintain the junction temperature close to the ambient temperature.
- vi. Internal Short-Circuit Current Limiting
- vii. Output Transistor Safe-Area Compensation
- viii. Output Current up to 1.5A
- ix. Internal Thermal-Overload Protection

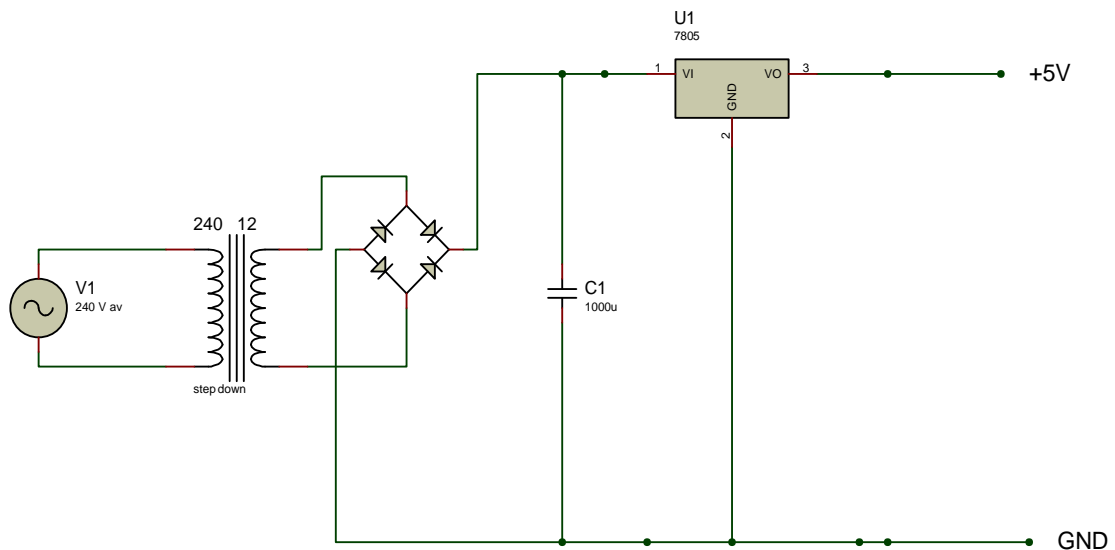


Figure 14: The power supply circuit

3.9 Software Description

For software development, we choose the desired maximum illumination to be 2000lux for the purposes of this project.

The firing angle is set according to the illumination level (given by the variable x) of the specified area: Beyond 2000lux, the light falling on the light sensor is brighter than what we have chosen as desired maximum. Therefore, the light should be set off by the dimmer.

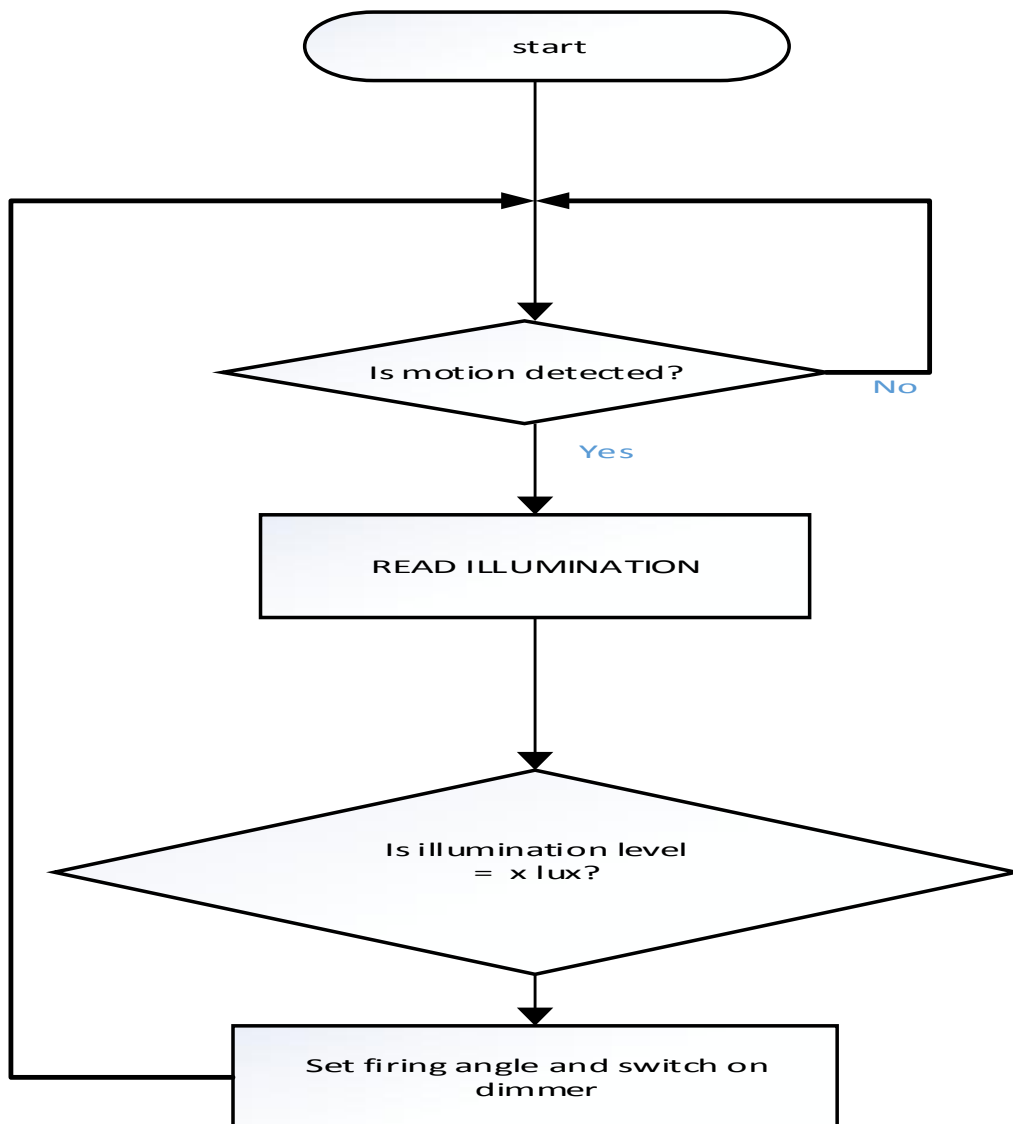


Figure 15: The flowchart showing software description of the microcontroller logic

CHAPTER 4: IMPLEMENTATION

4.1 Implementation of the zero crossing detector

The following circuit was implemented,

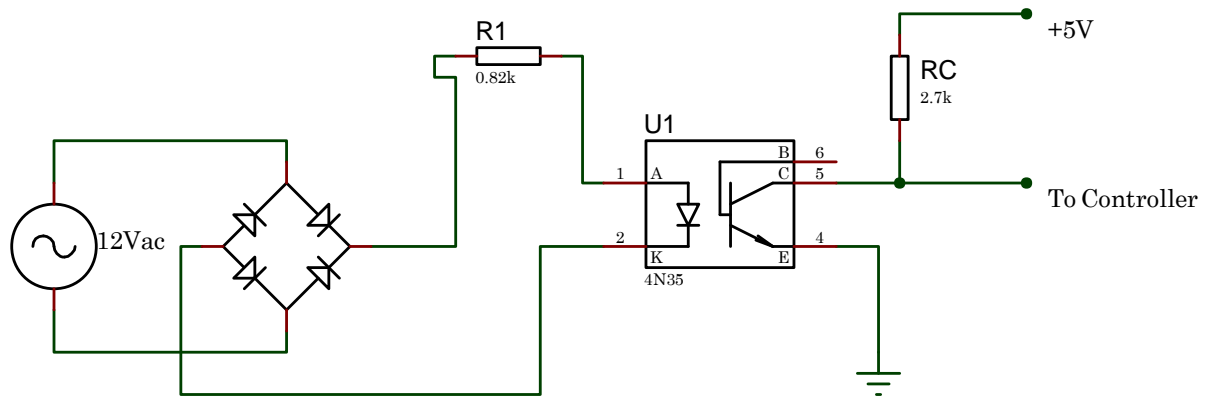


Figure 16: Implementation of the zero crossing detector

Optocoupler pin configuration is as shown below

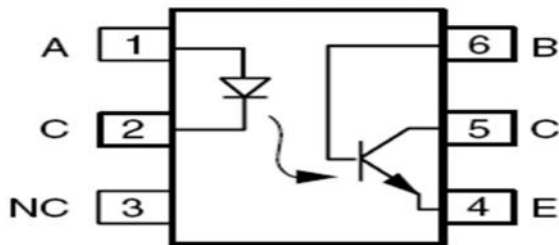


Figure 17: Pin configuration of the 4N35 optocoupler

- Pin 1 is Anode
- Pin 2 is C is cathode
- Pin 3 is Not connected
- Pin 4 is Base
- Pin 5 is Collector
- Pin 6 is emitter

4.1.1 findings

The following waveforms were obtained,

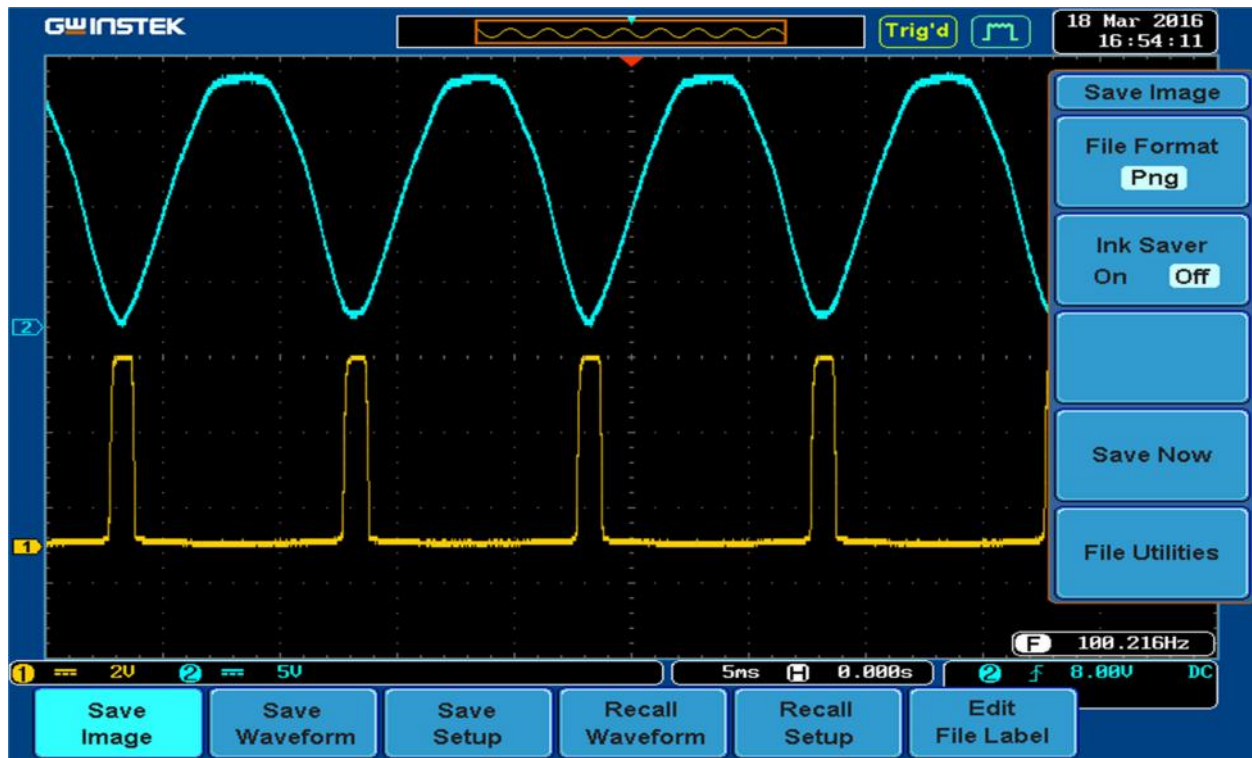


Figure 18: The input and the output waveforms of the 4N35 optocoupler

The fully rectified wave crosses zero every 10ms, since the frequency is about 100Hz,

$$T = \frac{1}{f} = \frac{1}{100} = 0.01\text{s} = 10\text{ms}$$

At every zero crossing instant, the output of the optocoupler gives a pulse of 5V DC,

4.3 Implementation of the light detector

From the design in chapter three, the sensor will be supplied a voltage of 3.3V.

4.3.1 Terminal connections

The sensor has five terminals connected as follows;

VCC is connected to the supply = 3.3V

SDA is connected to the A4 analog input pin of the controller.

SCL is connected to the A5 analog input pin of the controller.

ADDR is connected to the A3 analog input pin of the controller.

GND is connected to the ground terminal of the power source.

The following circuit was connected,

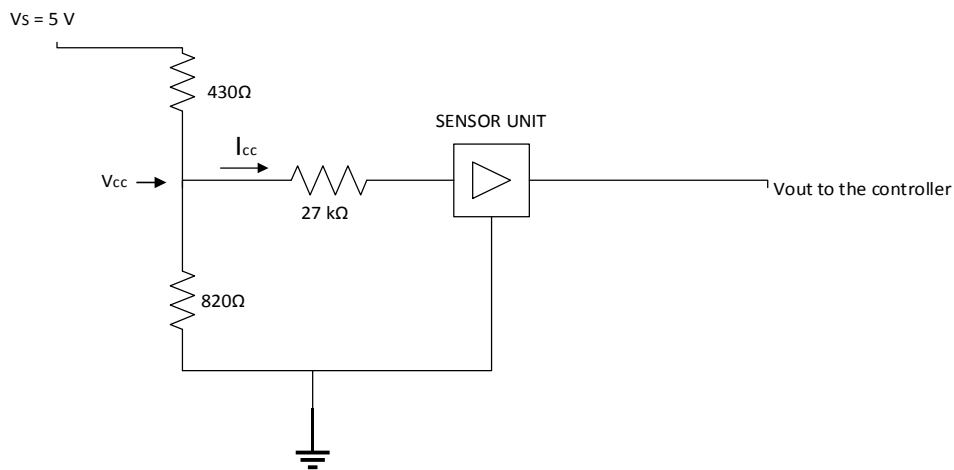


Figure 19: Circuit diagram of light sensor implementation

4.3.4 Code

```
#include <Wire.h>
#include <BH1750FVI.h>
BH1750FVI LightSensor;
void setup () {
    Serial.begin(9600);
    LightSensor.begin();
    LightSensor.SetAddress(Device_Address_H);
    LightSensor.SetMode(Continuous_H_resolution_Mode);
    Serial.println("Running...");
}
void loop () {
    uint16_t lux = LightSensor.GetLightIntensity() ;// Get Lux
    value
    Serial.print("Light: ");
    Serial.print(lux);
    Serial.println(" lux");
    delay (1000);
}
```

4.3.5 Findings

The sensor reading is obtained at the serial monitor of the Arduino programming terminal.

The sensor outputs the value of light level in lux.

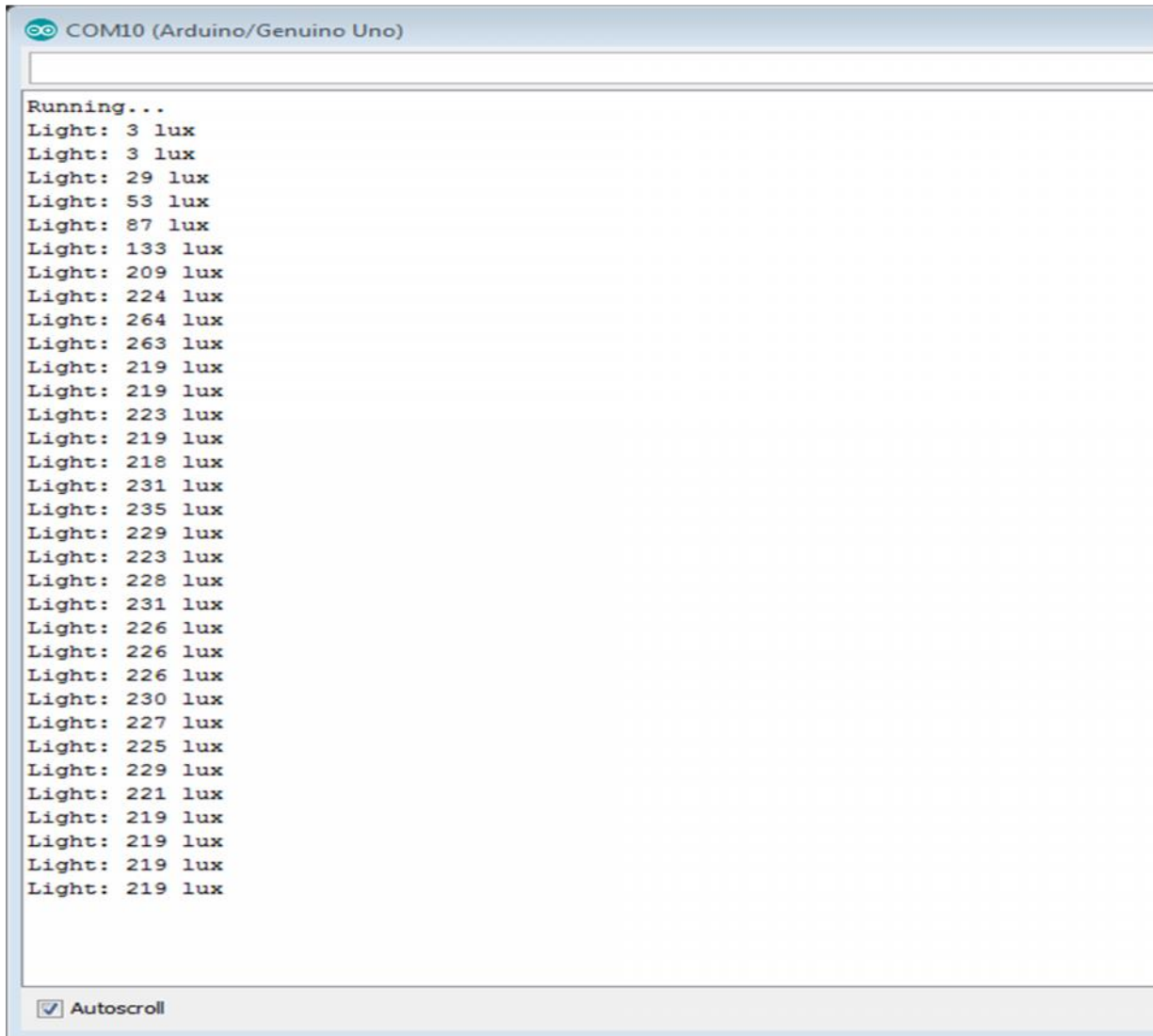


Figure 20: A snapshot of the serial monitor of the Arduino IDE showing light intensity readings

When subjected to bright light, the value of light level obtained is larger while in comparatively less lit places the value of lux obtained is smaller.

4.4 Implementation of the motion sensor

The sensor has three pins, GND connected to ground terminal, VCC connected to +5V supply and the output terminal connected to the A2 input pin of the Arduino board.

4.4.1 Code:

```
int sensorInput = A2;
void setup ()
{
  Serial.begin(9600);
  pinMode (sensorInput, INPUT);
}
void loop ()
{
  int motion = digitalRead (sensorInput);
  Serial.print("MOTION ="); Serial.println(motion);
  delay (1000);
}
```

4.4.2 Findings

The sensor reading is obtained at the serial monitor of the Arduino programming terminal as pictured below.

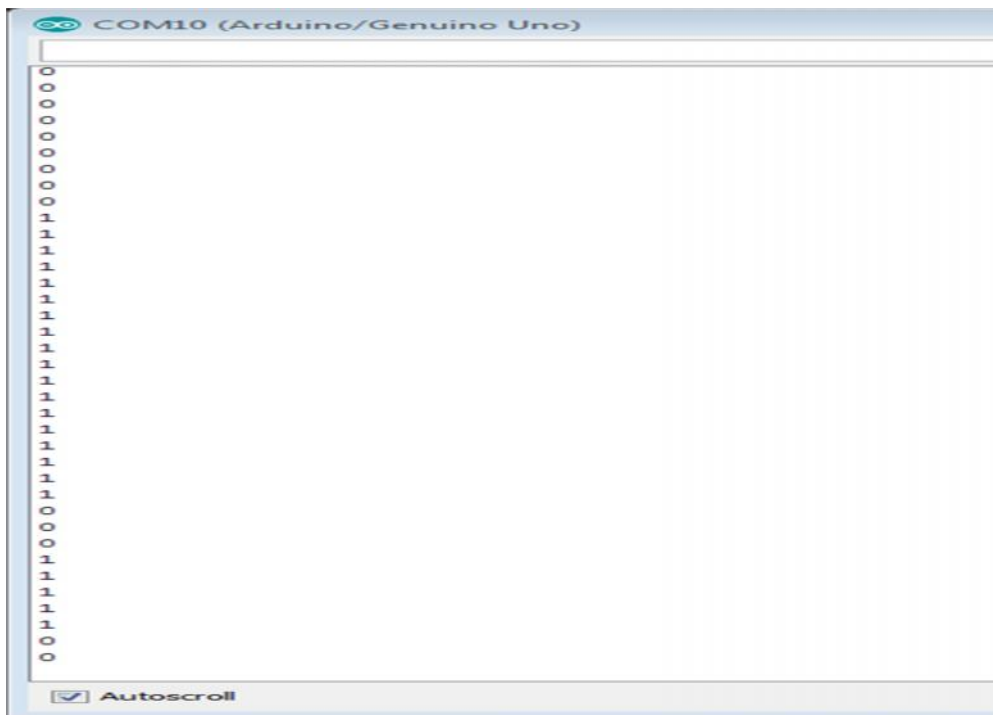


Figure 21: A snapshot of the serial monitor of the Arduino IDE showing motion sensor digital values readings

The sensor outputs a “1” when there is motion and a “0” when there is no motion.

4.5 Implementation of The light dimming

4.5.1 sensor information

The controller reads the digital value of pin A2, if it is “1” the motion is detected and if it is “0” then there is no motion detected.

The lux value is obtained and according to a combination of the availability of an occupant and certain lux value, a firing angle is set and light is turned on or off.

4.5.1 Code:

In the main loop, the motion is checked, if motion is detected, then lux value is read.

```
int motion = digitalRead (sensorInput);  
if (motion = 1)  
uint16_t lux = LightSensor.GetLightIntensity();
```

4.5.1.1 Interrupts

We will use an interrupt to tell the program that there was a zero crossing. After the zero crossing is detected the program needs to wait for a specified amount of time and then switch on the TRIAC. Each sine wave thus takes $1000\text{ms}/50=20\text{ms}$ (milliseconds)

To use an interrupt, first we need to set that up. On the Arduino that is as follows:

```
void setup ()  
{  
  pinMode (AC_LOAD, OUTPUT) ;// Set AC Load pin as output  
  attachInterrupt (0, zero_crossss_int, RISING);  
}
```

That is, the interrupt is attached to interrupt 0, it goes to a function called “zero_crossss_int” and it reacts to a rising flank on the pin.

In the “Zero_cross_int” function that the program jumps to after the interrupt, we determine the time we need to wait (firing angle) before firing the TRIAC.

4.5.1.2 Firing Angle

For that I have chosen the fully arbitrary amount of 100 steps for the purposes of implementing the zero crossing detector. That means that every step is $10\text{ms}/100 = 10000\mu\text{s}/100 = 100\mu\text{s}$. The total dimtime then is calculated from $100\mu\text{s} \times (1 \text{ to } 100 \text{ steps})$. The number between 1-100, which determines our level of dimming, we assign to the variable integer ‘dimming.’


```

int dimming = 100;
void zero_crossss_int () // function to be fired at the zero
crossing to dim the light
{
    int dimtime = (100*dimming);
    delayMicroseconds(dimtime); // Off cycle
    digitalWrite (AC_LOAD, HIGH); // triac firing
    delayMicroseconds (10); // triac On propagation delay
    digitalWrite (AC_LOAD, LOW); // triac Off
}

```

What happens here is that the program first calculates the dimtime (that is time to wait before the triac is fired). It then waits that amount of time and fires the Triac. The Triac will switch off again at the following zero crossing, but we are going to already write a low on the TRIAC pin to avoid accidental ignition in the next cycle. We need to wait a bit however to know for sure the TRIAC is ON, so we wait 100µs.

In the main program, we set the level at which we want the lamp to burn:

```

void loop ()
{
    int motion = digitalRead (sensorInput);
    if (motion == 1) {
        uint16_t lux = LightSensor.GetLightIntensity();
        Serial.println(lux);
        if(lux>0 && lux<200) {dimming = 0;} //Fully ON
        else if(lux>=200 && lux <400) {dimming = 10;}
        else if(lux>=400 && lux <600) {dimming = 20;}
        else if(lux>=600 && lux <800) {dimming = 30;}
        else if(lux>=800 && lux <1000) {dimming = 40;}
        else if(lux>=1000 && lux <1200) {dimming = 50;}
        else if(lux>=1200 && lux <1400) {dimming = 60;}
        else if(lux>=1400 && lux <1600) {dimming = 70;}
        else if(lux>=1600 && lux <1800) {dimming = 80;}
        else {dimming = 100;} // OFF
        delay (100);
    }
}

```

4.6 Results

The proposed system has been implemented with one LED bulb. When the motion sensor sees an occupant, the light level is obtained from the light monitor and the appropriate firing angle set. When there is no occupant, light remains off and when lighting level exceeds the set maximum, the systems automatically turns light off. Thus on using this system a large amount of energy can be saved.

4.7 Conclusion

In this project, a complete working model using an Arduino microcontroller was studied and implemented. The programming and interfacing of Arduino microcontroller has been mastered during the implementation. This work includes the study of energy saving system in many applications.

Energy Saver Lighting Control System is not limited to any particular application; it can be used anywhere in a process industry with little modifications in software coding according to the requirements. This concept not only ensures that this work will be usable in the future but also provides the flexibility to adapt and extend, as needs change.

The main advantage of the developed lighting control system is that it can fitted in existing wiring setup and thus saves the initial installation cost of a system. The developed system is simple and cost effective as it is based on basic microcontroller. The daylight is integrated with the artificial light system which saves energy and LED lamp gives more lumen per watt thus greatly saving energy.

4.8 Recommendations for Future Work

In this project we connected all the sensors to microcontroller with the wires. This can be developed with wireless such that we can place different sensors in different places. This sensor will activate the micro controller with the signals instead of using wires.

In this system the number of persons present in the room (Person counter) can be included and also the data transmission from sensors to microcontroller can be implemented through wireless such that the system will become a scalable one in the sense a single system can able to control a large number of rooms.

References

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APPENDIX.

Appendix A: Final Light Dimming Controller Code

```
#include <avr/interrupt.h>
#include <BH1750FVI.h>
#include <Wire.h>
const int BUTTON_INT =0;
int AC_LOAD = 3;
int dimming = 100;
int sensorInput= A2;
BH1750FVI LightSensor;
void setup ()
{
  LightSensor.begin();
  Serial.begin(9600);
```

```

    Serial.println("Ready!");
pinMode (AC_LOAD, OUTPUT);
pinMode (sensorInput, INPUT);
LightSensor.SetAddress(Device_Address_H);
LightSensor.SetMode(Continuous_H_resolution_Mode);
attachInterrupt (0, zero_crossss_int, RISING);
}
void zero_crossss_int ()
{
    int dimtime = (100*dimming);
    delayMicroseconds(dimtime);
    digitalWrite (AC_LOAD, HIGH);
    delayMicroseconds (100);
    digitalWrite (AC_LOAD, LOW);
}
void loop () {
int motion = digitalRead (sensorInput);
if (motion = 1) {
uint16_t lux = LightSensor.GetLightIntensity();
Serial.println(lux);
if(lux>0 && lux<200) { dimming = 0;}//Fully ON
else if(lux>=200 && lux <400) { dimming = 10;}
else if(lux>=400 && lux <600) { dimming = 20;}
else if(lux>=600 && lux <800) { dimming = 30;}
else if(lux>=800 && lux <1000) { dimming = 40;}
else if(lux>=1000 && lux <1200) { dimming = 50;}
else if(lux>=1200 && lux <1400) { dimming = 60;}
else if(lux>=1400 && lux <1600) { dimming = 70;}
else if(lux>=1600 && lux <1800) { dimming = 80;}
else { dimming = 100;}// OFF
    delay (100);
}
}

```

Appendix B: Overall circuit diagram and Datasheets

As shown in the following printouts.

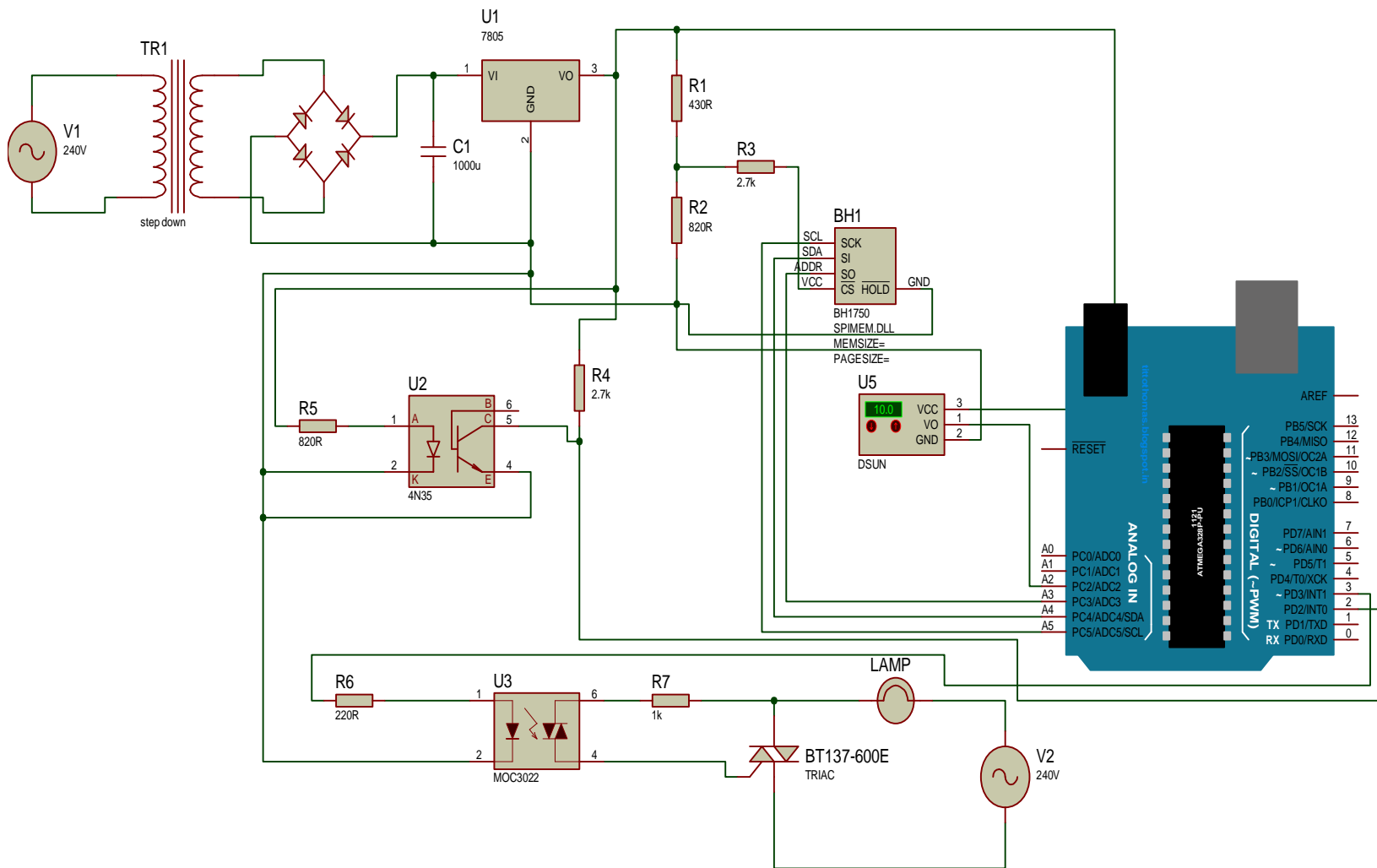


Figure 22: The overall circuit diagram of the project.