INTELLIGENT ZEBRA CROSSING SYSTEM

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Submitted in partial fulfilment of the requirements for the degree of

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ABSTRACT

The purpose of this study is to design an Intelligent Zebra Crossing system using Arduino. The main objective of the study is to manage and prioritise a smooth flow of the road users without causing any accidents at the zebra crossings, and to enforce the road rule to all those who have been vandalizing it. The system incorporates the concept of passive pedestrian detection to sense the presence of pedestrians and in turn automatically controls the traffic lights. It also makes use of an override pushbutton for in case of the failures faced by the PIR sensor on human detection. A surveillance camera is banded into the system to constantly manage the pedestrian crossing site and provide instant updates on any danger that may occur. Observations have been made to gather information for the study and hence the need to solve problems of the existing system using the proposed system was discovered. Relevant information gathering and electronic designing were incorporated into the designing of the system. Various tools have been used to design the proposed system and these may include Arduino IDE, C++, Arduino Uno microcontroller and sensors. A camera module was also part of the tools that were used in the design. Electric calculations were made on the components so that there will be proper power supply that will not damage the components. Each component was tested during the interfacing of the Arduino board and the components. The proposed intelligent system was tested and the results for all the experiments were recorded, the results confirmed that the system functionality was in agreement with the stated objectives. Finally, the proposed system was implemented hence solving the problems caused by the current system.

DECLARATION

I, **Kingdom Chevure,** hereby declare that I am the sole author of this dissertation. I authorize the **Midlands State University** to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature: ……………………………………………. Date: ………………………………...

APPROVAL

This dissertation, entitled **"Intelligent Zebra Crossing"** by **Kingdom Chevure** meets the regulations governing the award of the degree of **BSc Computer Science Honours Degree** of the **Midlands State University,** and is approved for its contribution to knowledge and presentation.

Supervisor's Signature: ……………………………………………….

Date: ………………………………………………………………...

ACKNOWLEDGEMENTS

I'm indebted by the guidance that the Almighty God gave me throughout this project. My heartfelt appreciation goes to all Midlands State University academic staff for the knowledge they have equipped me with. I would like to thank Mr. S. S. Furusa my supervisor for his unwavering support to the completion of this project. I also want to thank my family and friends for their support and encouragements.

DEDICATION

I dedicate this project to my beloved son Tatenda. Your smile kept me going.

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LIST OF ACRONYMS

ACRONYM	DEFINATION
I/O	Input and Output
IDE	Integrated Development Environment
V	Voltage
OS	Operating System
DC	Direct current
LED	Light Emitting Diode
PIR	Passive Infra-Red sensor
SRAM	Static Random Access Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
V_{CC}	Voltage at the Common Collector
GND	Ground

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CHAPTER ONE

1.0 Introduction

The project focuses on the Arduino-based intelligent zebra crossing system to be used by the Zimbabwean road users, thus the pedestrians and the motorists. The system aims on prioritising between both the hurrying motorists and the pedestrians, forcefully avoiding the vehicle-pedestrian crashes.

Zebra crossings are place designed for the pedestrians to legally cross the roads, usually found in towns and residential areas of Zimbabwe. The crossings are marked in transverse white lines across the roadway, located either at the intersections or mid-block sections.

The researcher intends to develop an intelligent zebra crossing; which is an automated pedestrian crossing operated by traffic and pedestrian light system triggered by PIR sensors. The system will be an Arduino based prototype, supported by a set of traffic lights controlled by a PIR sensor and a pushbutton. The sensor detects the presence of a pedestrian standing in the detection zone and triggers a red signal to the vehicular traffic, and a green signal to the pedestrians. The amber signal goes first and blinks three times before the red signal goes on to the traffic. This amber signal will be a warning to the motorists to stop and give a right of way to the pedestrians as the red signal progresses.

Once the pedestrian light system has been triggered green, there is a countdown of ten seconds and the red signal goes on for the pedestrians. As the pedestrian red signal goes on, the green will open up for the motorists and thus giving them a right of way. The system will repeat its loop whenever a pedestrian is detected by the PIR sensor.

The intelligent zebra crossing also has a buzzer that makes ten beeps accordingly with the ten seconds of count down during the pedestrian green signal. This buzzer is triggered once the pedestrians are granted the right of way. There is also a pushbutton that triggers the system in cases where the PIR sensor fails to detect the presence of a pedestrian.

There is a surveillance camera incorporated in the system to monitor the pedestrian crossing site. The cameras are operated and monitored by the police. Each and every police station will have a Surveillance Control department where all the cameras at every nearby pedestrian crossing are monitored.

1.1 Background of Study

Walking mode is widely used in everyday activities of Zimbabwe, and due to its advantages over motorized transport modes (over short distances); it has received attention from transportation professionals. However, in developing countries like Zimbabwe, the most vulnerable road users are being found to be pedestrians. The mostly reported cases for vehicle-pedestrian crashes in Zimbabwe happen to have a pedestrian crossing the roadway.

The currently used zebra crossing system suffers low vehicle drivers' respect. Evidently, vehicle drivers desire not to stop on the zebra crossings although the law stated that the pedestrian has the right of way once on the zebra crossing. Furthermore, most of the Zimbabwean zebra crossings have faded out and no longer noticeable hence most of the traffic drivers are bound to overrun the marks, and this put the pedestrians on danger.

In recognition to the pedestrian safety problem in Zimbabwe, the Ministry put road humps in help of controlling the motorists on over speeding in most of the residential places of the country. These two currently implemented methods of vehicle-pedestrians control are not perfect especially in the residential areas of Zimbabwe where more pedestrians are found to be school children, and the disabled who totally lack respect of most of the motorists.

Measures have been taken in trying to reduce the pedestrian to vehicle crushes, yet no positive changes have been reaped. However, the automation of the zebra crossings will help on securing the lives and safety of the pedestrians in Zimbabwe. It is of high expectation that the pedestrians will be restored of their confidence and pride as road users once the intelligent zebra crossing is implemented.

1.2 Problem Statement

Currently the Zimbabwean zebra crossing system consist of only the white transverse markings which has no engineering designs or modifications and or even any supplemental traffic control. The major setback on the current zebra crossings is found to be the significance of the drivers who hardly yield any right-of-way to the pedestrians. The majority of the motorists blame the pedestrians over zebra crossings and at the same time the pedestrians blame the motorists for marginalizing the pedestrians.

This is resulting in a continuous crisis of pedestrian hit by vehicles on zebra crossings especially during pick hours when the vehicular traffic and pedestrian flow will be somewhat higher. Currently the vehicular traffic is being favoured over the pedestrians, thus the pedestrians are vulnerable yet they are the legitimate users of the transportation system and require safe zebra crossing facilities.

Currently the Zimbabwean zebra crossings are being death traps for the pedestrians. Most of the reported cases of the pedestrian hit by an unidentified vehicle or motorists happen to have a pedestrian wanting to or already crossing the roadway. The motorists (invaders) are usually unidentified since they quickly run away once they hit a pedestrian. Those injured pedestrians (victims) usually suffers late help since it may take a while before anybody sees them, and this result in deaths.

The majority of the Zimbabwean pedestrian tend to use the controlled traffic junctions as their preferred crossing sites, yet the junctions are not designed for the pedestrians to use for crossing the roads. This is because the pedestrians lack confidence in using the designated pedestrian crossing facilities since they hardly have any electronic engineering which can help controlling the vehicular traffic. This tendency of using the controlled traffic junctions as crossing sites is causing a lot of traffic jam in towns.

1.3 Aim of the Study

The study focuses on the effectiveness of The Intelligent Zebra Crossing in Zimbabwe. This is an automatic digital controller system for the pedestrian crossings, which use the passive infra-red sensor to detect humans in a stationary or moving state on the detection zone. This system controls both the vehicular and pedestrian traffic signals at the automated zebra crossing. Road order is going to be maintained as the system eliminates jaywalking along the roadways and also enhances the safety of pedestrians.

1.4 Objectives of the Study

- The system detects and identifies pedestrian wanting to cross the road at the zebra crossing and triggers the red signal to the vehicular traffic on the road and gives the right of way to the pedestrians.

- The system has a buzzer that sounds to notifying the blind pedestrians if the system has detected their presence.

- The system uses an override button that is pressed in case that the sensors have failed to detect the presence of the pedestrian or is falsely triggered.

- The system has a surveillance camera that is monitored at the nearest police station and is used to forcefully control the law-breaking motorists and also to give a live report of any emergence that may arise at the crossing.

- The system prioritizes between the vehicular and pedestrian traffic by giving equal chances of using the road in times of continuous flows, though it always gives the right of way to the vehicular traffic.

- The major objective of this research is to manage and prioritise a smooth flow of the road users without causing any accidents at the zebra crossings, and to enforce the road rule to all those who have been vandalizing it.

1.5 Instruments

1.5.1 Arduino Uno

Stewart (2015) asserts that an Arduino Uno is a microcontroller board that is built on the ATmega328P datasheet. It contains fourteen input/output pins of which the six of these can be used as PWM outputs, and the other six as analog inputs. It is built up of many components that support a microcontroller and is powered through a Universal Serial Bus cable that connects it to the computer. The device accepts various programming languages, and some are C, C++ and C#.

1.5.2 PIR sensor

This is a motion sensor that is triggered by the infrared changes. This electronic device is widely used in the modern alarm systems for movement detection and surveillance. The device is of a small size that it can be fit in the prototyping projects and is not costly to obtain.

1.5.3 LED

LEDs are small electronic devices that emit light whenever supplied by a current. The device is a small component that can be integrated into prototyping projects to serve a lighting source. For this case, the LEDs will serve as the traffic light system.

1.5.4 Buzzer

This is an electronic product for sound devices. It is usually extensively used by printers, computers, alarms, telephones, photocopiers, etc. the device works as an external connection to the Arduino circuit board that will command to sound.

1.5.5 Pushbutton

This is an electric component used as an override button module in prototypes. It is a small four-legged button that can be driven by an Arduino circuit board to serve it function as commanded. The component is of small size and is affordable in microchip shops.

1.5.6 Arduino based camera

This serves the ordinary duty of cameras in general but will be controlled from the Arduino board, thus controlled by the Arduino code comments. The camera is a small component that is normally used on the Arduino based prototypes.

1.6 Justification

The majority of pedestrian crossing facilities used in Zimbabwe are the Zebra crossings, which hardly suffice since most of the vehicle drivers disrespect them. These zebra crossings are again not automated but simply a faded white transverse lined pavement across the roadway. The crossings are not time conscious and disadvantage the pedestrians in times of continuous flows of vehicles. Thus, the pedestrians are in need of a system that allocates some time for their traffic without necessarily inconveniencing the vehicular traffic as well.

1.7 Assumptions

- The pedestrian traffic is mostly at pick during the day time and very low during nights
- The pedestrians should not wear any special clothing for them to be detected by the PIR sensors
- There are no special weather conditions which can trigger the sensors
- Users are trained to be able to use the technology in context

1.8 Conclusion

The problems that have been tormenting Zimbabwean pedestrians will be solved by the proposed Intelligent Zebra Crossing. The study focuses on the development of the Intelligent Zebra Crossing that will improve the currently implemented pedestrian crossing facility. This thesis outlines whether it is worthy doing the research or not, through analysing the costs and benefits of carrying out the study and the need for a new system by the users.

CHAPTER TWO
Literature Review

2.0 Introduction

According to Turner et al (2011) travellers are invigorated to assume walking as a means of travel due to its numerous economic, physical and environmental benefits. This can be effectively achieved through the provision of a safer and attractive pedestrian facility that encourages more travellers to use walking mode. Safe and more reliable pedestrian crossing facilities are of importance in this context.

Many of our cities have hundreds of the pedestrian crosswalks which are regularly used on crossing the street. The setting up of road signals would hardly help strengthening the road rules, but rather an unapparent danger. For as long as the zebra crossing remained a “generalised” block of striped road section, the right of way policy between the road users remained a cause of the accidents. The pedestrians would demand that they have the right of way for as long as they are using the zebra crossing section, yet on the other hand the motorists blamed the pedestrians of recklessly use of the road.

The majority of traffic drivers hardly respect the pedestrians on the roads and neither do they observe the marked zebra crossings despite the fact that some of the markings have faded out over the years. This Literature Review will survey the literature in the automation and engineering of the zebra crossing intersections. The Zimbabwean Road Traffic Act states that the pedestrian crossings should be observed and be given the right of way to any pedestrian within the crossing.

This section of the thesis will cover the background studies that led to the ideology of automating the zebra crossing in Zimbabwe and also looked in detail the intelligent zebra crossing as to how it has been brought about. These background studies cover the crash studies; where the author analysed the possibilities of the crashes along the roadways and their causes, the behavioural studies of both the pedestrians and the motorists concerning the road use and how they observed the road rules concerning the zebra crossings.

2.1 Crash Studies

Officially the data of road users’ crashes is collected and maintained by The Ministry of Road Traffic Accidents of Zimbabwe. According to Dr.Mutabazi (2008), most of the roadway crash sites, specifically the geographical locations are considered too general to have detailed researches, and hence there are limitations on ascertaining the pre-crash conditions and the crash locations in relation to marked crosswalks.

Zegeer et al (2002) stated that some factors that cause the vehicle-pedestrian crashes are the site location, type of crosswalk, area type and the speed limiters provided. Their studies found that the presence of a zebra crossing on a two-lane road had high pedestrian crashes. Furthermore, having only a marked crosswalk without any other engineering on a multilane road with high volumes of traffic was associated with high pedestrian crashes. The authors suggested the following as improvement measures at the signalised crosswalks:

- The provision of raised medians on multilane roads to facilitate safer street crossing
- The installation of traffic and pedestrian indicators where pedestrian crossing problems regular exists
- Reducing the crossing distance through the installation of raised pedestrian islands at the central point of wide/multilane roads.
- The installation of speed humps as the road approaches a pedestrian crossing site.
- Facilitating the use of advanced symbols, indicators and patterns publicized to be operative.

For the time period of 1989 to 2002 it was found that children were often injured at the sites with no marked pedestrian crossings in Finland as compared to other age groups. Similar statistics were obtained at the marked crossings on multilane road sections due to overtaking vehicles (Leden et al, 2006). The study has proven that children are of concern when it comes to pedestrian-vehicle crashes and this is due to a number of factors which include:

- Smaller body structure; they may be old enough to be mobile, yet they are too small to be easily visible from the driver’s position.
- Lack of experience as road users; which is also characterised by their unpredictable actions and overestimated cognitive skills. They happen to have difficulties in perceiving the speed, direction and sound of vehicles and they also easily distracted.
- Their inability to drive which makes them heavily depended on walking modes.

MacGregor et al. (1999) stated that children believe that running is the safest way of crossing a roadway and it is safe to cross against a red signal. They also believe that adults will always be kind of them by instantly stopping the vehicle whenever there is a child ahead. The studies have proved that a proportion of younger children walking from primary schools is higher than that of older children (from secondary schools), implying that more young pedestrians, particularly school children, are highly vulnerable to vehicular traffic crashes (Mutabazi and Akberali, 2008). According to Connelly et al. (1998) older children usually make safer decisions when crossing the roadways than younger children.

2.1.1 Behaviour Studies

Herms (1992) stated that the reputable problems of the marked pedestrian crosswalks hardly depend on the markings but also the different behaviours of the ro0ad users, particularly the pedestrians and the motorists. Pedestrian behaviour is also important when explaining why pedestrian collisions occur. Basically, pedestrian collisions are caused by such behaviours as crossing speed, individual choice of crossing places, as well as the individual compliance at the designated crossing sites, poor attention to traffic, and alcohol abuse (Martin, 2006).

Figure 2.1: Unsafe motorists' behaviour at marked crosswalks

Crossing Speeds

The time a pedestrian takes to cross the roadway is determined by the road-width and one's walking speed. Pedestrian's walking speed will be affected with quite a number of factors such as age, infirmity, or carrying heavy objects. Elderly pedestrians would require more time to cross a roadway irrespective of its width (Baass, 1989). According to Bennett et al. (2001)

Pedestrians are said to cross more quickly at signalised junctions than at the mid-block pedestrian crossings. Most of the Zimbabwean pedestrian have a tendency of using the signalised junctions as the crossing passage than the designated pedestrian crossings that have no engineering control facilities. This is because the pedestrians feel more confident and secure at the controlled sections of the roadway. These pedestrians and motorists are at conflicts over the pedestrian crossings as to who should have the right of way and for how long.

Most Zimbabwean pedestrians are hit by the vehicles at the designated pedestrian crossings due to their pride and the abusive spirit over the privileges offered by the zebra crossing and road rules. Due to this poor behaviour by the Zimbabwean pedestrian, the motorists happen to abuse the zebra crossing rules too and they behave miscellaneously. As a result, the majority of our local pedestrians use the road junctions controlled by traffic lights as their crossing places, yet these sections are not designed as to accommodate pedestrians crossing the roadway. This tend to cause confusion and traffic congestions at the controlled junctions.

Choice of Crossing Place

Motorists generally give away to pedestrians at the designated crossing sites, whereas as of away from the formal sites the male pedestrians tend to compete with the vehicles; they tend to speed up in avoidance of the conflicts with the vehicle (Ghee et al. 1998). The choice of crossing sites has a great impact on the risk associating with the crossing manoeuvre.

Most of the Zimbabwean school children suffer on the choice of the crossing places as the majority of them blindly cross the road way at any point they feel to. This is causing a lot of school children to be hit by the vehicles along the road ways. There is need for controlled pedestrian facilities for school children in Zimbabwe. Such facilities will encourage them to have a better choice of the crossing sites and hence reduce the pedestrian to vehicle accidents in Zimbabwe.

Non-compliance at Designated Crossings

Many of the Zimbabwean pedestrian collisions happen due to negligence by pedestrians (intentionally or not). According to Sisiopikuet al (2003) most pedestrians cross the road when it suits them in terms of convenience and time saving, and hardly think of the potential safety implications. Pedestrians happen to ignore the road signals for danger and this is usually a problem with the adult pedestrians and those who thinks they have stayed in the area for quiet longer. The knowledge of how to safely utilise the designated crossing sites is encouraged and inspired by the parents, yet the children may well copy “rule-breaking” adults.

Failure to Attend to Traffic

The statistics for London in 2002 stated that the most contributory factor in the pedestrian casualties was the pedestrians crossing the roadway heedless of the traffic (Transport for London, 2003). Wall (2000) reported that the pedestrian error accounted up to seventy-five percent of the collisions by which lack of observation was a significant factor. It can be summed up that pedestrians’ carelessness, particularly pedestrians standing in centre of the roadway, causes a lot of road accidents (McLean, 1978). Elderly pedestrians happen to compete with vehicular traffic on the roads (AA Foundation, 1995).

This problem usually happens with the Zimbabwean adult pedestrians who will be rushing for work during the pick hours. They hardly care about the busy roads or the fast flow of the vehicular traffic, and all that they value is getting to their work places in time. This causes a lot of road accidents in Zimbabwe.

Pedestrian Alcohol Consumption

The national data for Great Britain shows that the reputation of alcohol amongst fatally injured adult pedestrians is gradually increasing: 46% of fatally injured pedestrians had abuses alcohol in 1997 compared with 39% within a decade earlier (DETR, 1999). These studies prove that alcohol abuse has a lot of effect on the pedestrian casualty. The National Centre for Social Research (2003) added that the problem of alcohol abuses by the pedestrians have got more wide spreading as the drinking culture in Britain worsens in the recent years.

In 2017, The Zimbabwean Government nearly passed a law that bans the selling of alcohol during the week days, and this was to avoid the Zimbabwean people who use the roadways whilst drunk. This has been a severe problem particularly in the Zimbabwean towns where you find beer halls along busy roadways.

2.2 Intelligent Zebra Crossing Background

The studies have endorsed that through quite a momentous number of researches that has been made on such topics that focus on the pedestrian behaviour and safety improvements, it has a limited research diameter. The establishment of more safe and reliable pedestrian facilities helps in achieving a lot of desired developments (Turner et al, 2011). It was further elaborated as improving roadway infrastructures to facilitate efficient transport network through the improvement of journey time reliability, easy severe congestion and as well better use of the existing transport capacity.

In June 1999 a Pedestrian Crossing improvement was launched in Washington, USA; which aimed at increasing the visibility and safety of the pedestrians across St Everett. The treatment aimed at constructing the cross way with passive infrared sensors which automatically detects the presence of pedestrians at the crossing site. The survey contacted in comparisons of the before and after the construction proved that there was a downfall of the pedestrians who cross the road at undesignated areas than the designed sport, although the number of pedestrians hit by the vehicles was found to increase. The system could not solve some of the conflicts such as the delay time on prioritising the right of way between the pedestrians and the traffic at the automated crossing. The pedestrians could abuse the privilege by crossing the roadway slowly and this raised more complains from the abused motorists.

Knoblauch et al (2001) embarked on some studies examining the outcome of crosswalk markings on the motorists and pedestrian behaviour at the unsignalized nodes. Studies carried out considered vehicular and pedestrian capacities, automobile rapidity and the behaviour of motorists as well as walkers at the zebra crossings. The individual characteristics of the pedestrians were taken into consideration, some of which are age, sex, travel trail, pace, incidence and observing behaviour; frequently dictated them using a pedestrian facility. It was proposed that these features joint with the on-site road services such as lighting may perhaps provide the degree of the likelihood of walkers going out of their way to use the prescribed passage. Their researches also revealed that the pedestrians walking alone tend to use the marked passages, particularly at eventful nodes and pick hours when the vehicular traffic will be high. This research also gave the evidence that pedestrians felt protected when they are in multitudes hence they disobey the crossing points and attempt to cross the roads at any location, leading to the accidents.

Shaples et al (2001) carried out a research in identification of the issues related with the variety of pedestrian crossing services that might inspire or depress walking in the cities. The survey consisted of pedestrians who regularly use the cross walks in multitudes such as in general public places and school children. It was notably that the school children in particular would cross the roads at other locations other than the designated pedestrian crossing due to light vehicular traffic or that the traffic could take long.

A recent study about Smart Spike System in Traffic Signal focused on the automation of the zebra crossing to enhance the safety of the pedestrians. Merlinrose et al (2017) in their study used the traffic lights at the zebra crossing and reinforced the system with a spike facility that would be triggered by the relative traffic lights. The system strictly controlled the motorists since they could be forced to stop and give right-of-way to the pedestrians. The vivid idea could hardly deal with the issue of the motorist safety though it has won on securing the pedestrians. The studies carried out in response to the idea have proven that the spike system caused a lot of damage to the motorists who would happen to have failed in the breaking distance, hence this idea was not safe enough to be employed as the solution to the crosswalks' safety facility.

The mentioned researches automated the pedestrian crossings but none of them gave a strict surveillance to the law breakers, particularly the motorists who fails to yield to the red signal. The disabled and the blind were never considered in the building up of the automated pedestrian crossings lately, hence the systems never accommodated them. The automation also ignored the issue of prioritising equal and fair chances of using the roadway between the pedestrians and the motorists during the busy hours. The automations were centred at the detection of the pedestrian by the PIR motion sensors, yet they are capable of failing to detect. Thus, the pedestrian can hardly be granted the right of way. They also concentrated on the safety of the pedestrians only and hardly considered the safety of the motorist; this is seen at the recent system that cooperated spike system to forcefully stop the vehicles.

2.2.1 Strengths of the Intelligent Zebra Crossing

Where there are both high vehicle and pedestrian flows, it is ideal to add some engineering to the zebra crossing since a simple zebra crossing is not sufficient to prioritise between these road users (Dean, 1982).

2.2.2 Benefits of the Study

When properly implemented, traffic lights are an important signal for vehicular control on the roads. They assign the right-of-way to a choice of the traffic movement and thereby strongly influence a smooth traffic flow. This kind of engineering will help securing the pedestrian safety on the crossings which have been mare zebra crossing sites that hardly earn any respect from the majority of the motorists. The traffic signals which are properly designed, located, operated, and well maintained provide one or more advantages as:

- orderly traffic movement
- providing confidence to the vehicular drivers
- allocate equal and fair opportunities to the road users

The physical engineering such as the buzzer will be a great safety assurance to the blind people in particular. The case of blind people has been a crisis for decades since the currently implemented pedestrian crossing never favoured any but only the stubborn motorists. We have had quite a number of reports to our local authorities about the pedestrian to vehicle crashes which would be found the pedestrian to be blind.

The proposed intelligent zebra crossing will also cater for the young ages as well as the disabled (using wheel chairs) who are likely to be in need of the push button that alerts the intelligent crossing system that there is a pedestrian at the sport who might have been missed due to some physical disadvantages like height.

The system will be aided by a camera module that captures snap shots of all the intruders, particularly motorists who would violet the red-signal policy at the pedestrian crossing. Thus, every vehicle that proceeds into a red signal whether has caused an accident or not will face the charges of violating the pedestrian crossing rule. The Zimbabwe Republic Police is the law enforcing department in Zimbabwe, which has been facing a lot of challenges with stubborn motorists who would violet the road traffic policy and goes on to deny it since there will be no evidence. This camera module will be monitored by the ZRP who have been doing the law enforcement as usual, thus this is an advantage to the ZRP department in consideration.

2.2.3 Drawbacks

Signal controlled crossings averagely increase the delay of the pedestrians, thus the pedestrians would not take as much care as they take once crossing a simple zebra crossing or a site short of somewhat assigned crossing (Hunt , 1994).

One other disadvantage of the proposed system is that it has problems with unreliable detectors, particularly kerbside detectors (Kenned and Sexton, 2009). Faulty detectors at the kerbside increases the pedestrian delay time, leading to pedestrian’s non-compliance and possibly leading to false conclusions regarding the safety of the crossing.

The intelligent zebra crossing is expensive on both the initial installations and maintenance. The system requires expensive construction engineering and also demands regular maintenance since the sensory components may fail due to changes in weather conditions.

2.3 Current Implementations

It has been predicted that the Zimbabwe's National Transport Policy hardly favours walking since there are no pedestrian tracks in the designing of Zimbabwean infrastructures. This might be one of the menace experiences of the pedestrians who are currently contributing the subsequent peak percentages of the traffic bereavements. Road injuries tent to be increasing in many countries, such that in around a million dying in road accidents, sixty-five percent are found to be pedestrians, and thirty-five percent of it being children (UNECA et al, 2011). Mostly low and middle-income counties account for about eighty-five percent for all road traffic deaths (Arumugam, 2007).

2.3.1 Raised Crosswalk

This is a speed table with cross walk marks and signage to channelize pedestrians crossing a road. The table will be raised to the level of the sidewalk so that it will be visible to the motorist and improves the visibility of the pedestrians. Such is one of the currently used pedestrian crossing points in Zimbabwe and is mostly found on the streets in the residential areas. Raised crosswalks are effective on slowing the travel speeds of the vehicles, thus improving safety for pedestrians. Its major disadvantage is that of drainage issues since it can block the running water during the rainy seasons and cause unnecessary pools of water on the roads.

Figure 2.2: Raised crosswalk sign

2.3.2 Zebra Crossing

Most of the pedestrian crossings used in Zimbabwe are the Zebra crossing incorporating stripes of black and white across the road surface (Mambondiani, 2015). These zebra crossings are placed at the points where pedestrians can cross the road legally at the same level with the vehicular traffic (Dr.Mutabazi, 2008). Guidelines have been given governing the use of the zebra crossing as follows: - (Guardian, 2004)

- Pedestrians have the right of way on the zebra crossing, and therefore the vehicular drivers should stop and permit the pedestrians to cross the roadway.
- There is a set speed limit when approaching pedestrian crossing regions and the drivers are strictly ordered to obey the speed limits along the roads.
- Although the pedestrians have the right of way over the zebra crossing sites, they must also exercise caution when using these facilities.

According to Defour (2004) some road users understood these guide lines as to be the first to permit pedestrians the right-of-way when crossing roadways at the zebra crossing sites. Prior to the given guide lines, pedestrians were given the right-of-way only at the crossing sites controlled by a police officer, according to article 23 of the Highway Code (Ministry of Works, 1972). Speed limiters puts the drivers on a position to stop easily before the zebra crossings, however the measures hardly protect the pedestrians in their over-confidence at the zebra crossings, a phenomenon that may lead to unsafe crossing behaviour on some pedestrians (Mambondiani, 2015).

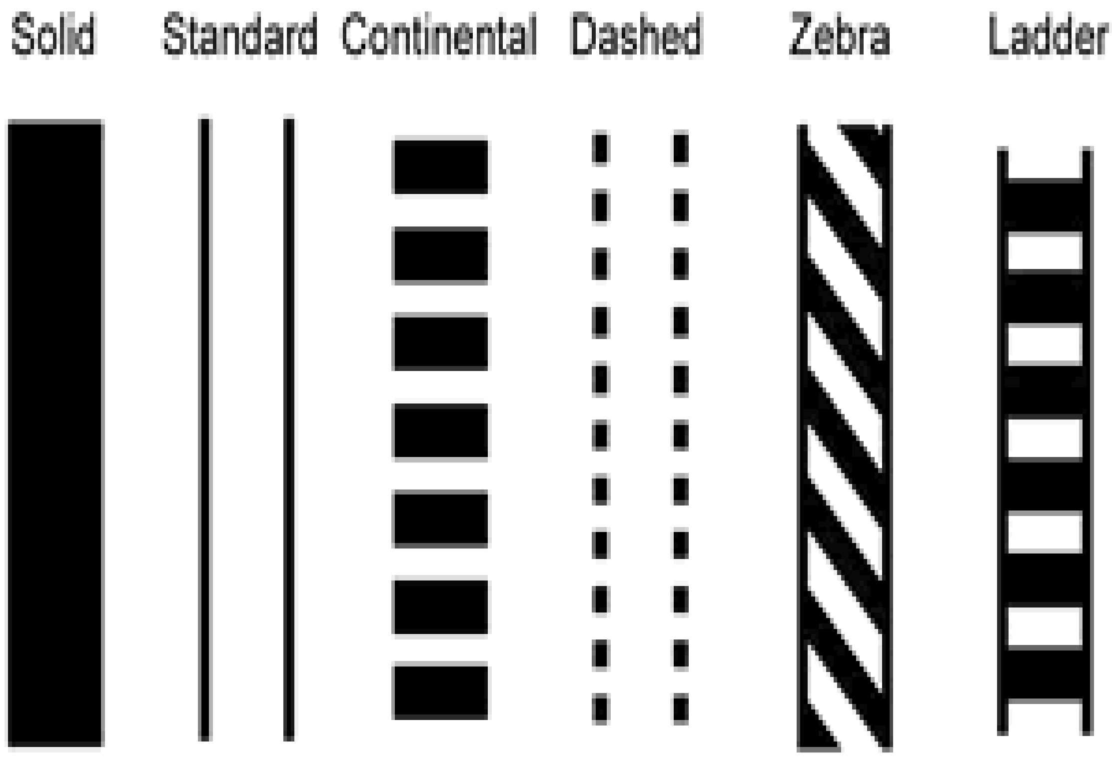

Figure 2.3: Crosswalk marking patterns Crossings

2.4 Intelligent Zebra Crossing in Block Diagram

The input comprises of PIR motion sensors and a pushbutton switch. The central processing part is the Arduino UNO circuit board and the output has three LED traffic lights, buzzer, and a camera module.

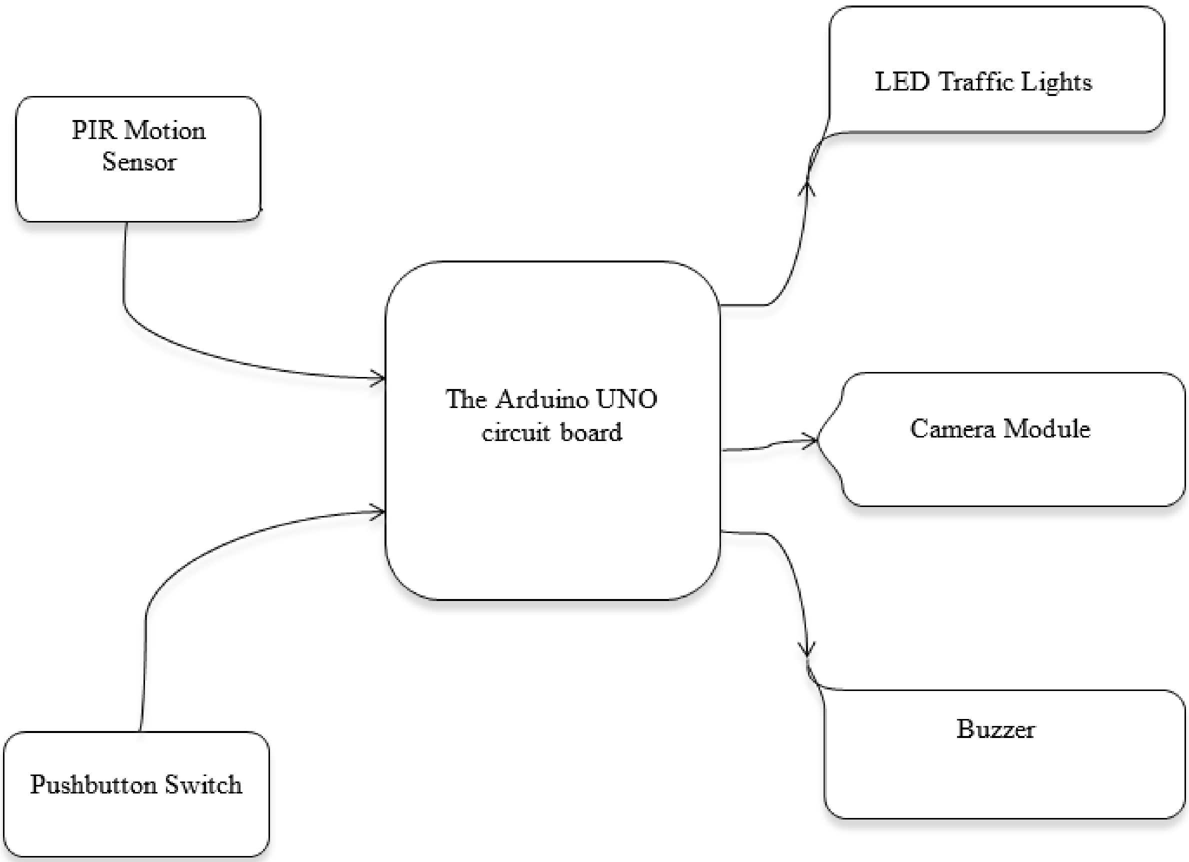

Fig 2.4: Block Diagram of the proposed system

2.5 Conclusion

Simple universal solutions for the safety of the Zimbabwean pedestrian casualties are difficult to find, basically due to the large numbers of pedestrians and the high vehicular traffic flows. However, the proposed zebra crossing would greatly work for the good of the pedestrians, as well as reinforcing the ZRP traffic policy. Enforcement measures which has been discussed in this chapter such as the safety camera at the pedestrian crossing, if well allied, would greatly reduce the capacity of stubborn behavioural amongst motorists. The weakness of the currently implemented pedestrian crossing facility has been taken into consideration and discussed in this chapter and the alternatives, particularly brought in by the Intelligent Zebra Crossing, will be further be elaborated as the author progresses to the next chapter.

CHAPTER THREE

Techniques and Methods

3.0 Introduction

The section focuses on a deep examination of all the hardware and software cooperated in the intelligent zebra crossing. It also embraces the data collection methods and how the author came-about with the solutions in relation to the gathered data. Methodology is a theoretical aspect of the project which thoroughly explains the idea at hand, that any system developer can easily gain an understanding of how to best integrate the components. The proposed is a PIR Motion Sensor driven system that integrates sensory modules, pushbuttons, traffic light circuits and a camera module.

The PIR sensors for pedestrian detection will be set on both of the kerbside as shown on the picture below. The sensor system will be focussed on a small section of the kerbside to reduce bias detection of the pedestrians wanting to cross the roadway. The other set of sensors will be focussed on the zebra crossing marks to cater for the pedestrian already crossing the roadway, thus giving them a grace period to cross before the traffic if granted the right-of-way.

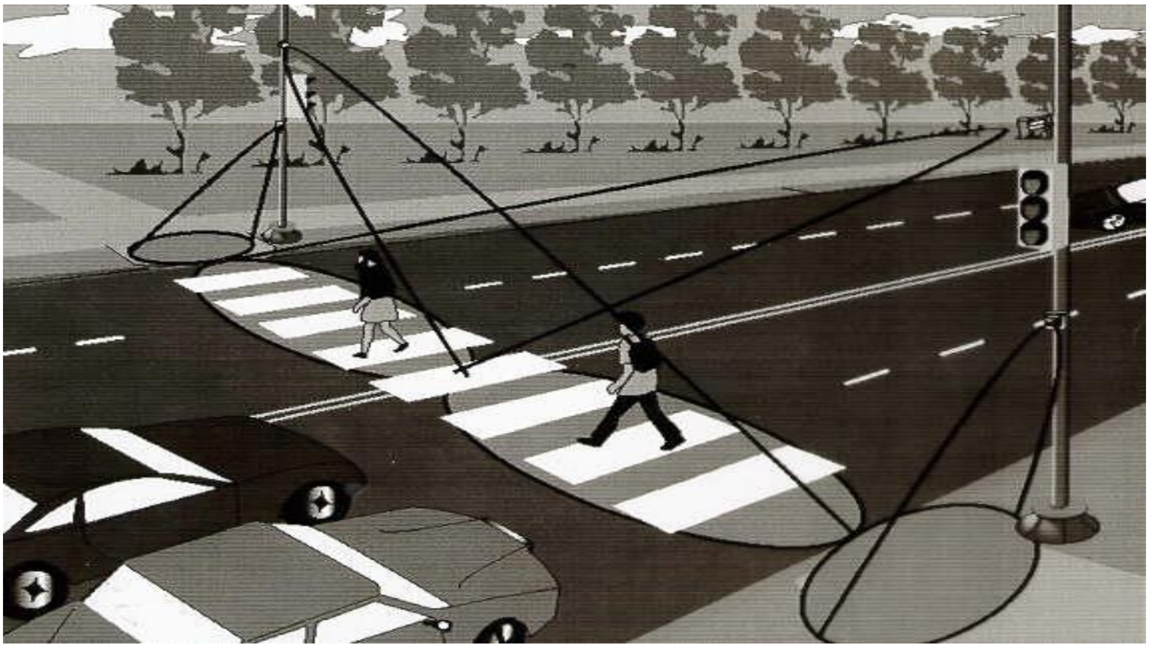

Figure 3.1: The PIR Sensors focus and setup

3.1 Interfacing the Hardware

The intelligent zebra crossing comprises of input devices which triggers the actuators in the output side of the system. These input devices mostly comprise of PIR sensors for pedestrian detection which control the traffic lights, a pushbutton to be used in case that the pedestrian is uncertain that the system has detected his/her presence (particularly the blind), and the motion sensors for the traffic control at the stop-line which will trigger the camera to capture snap shots whenever a vehicle attempts to cross the stop-line during a red signal. The Inputs and the Outputs devices are integrated at the Arduino Circuit Board which facilitates a smooth flow of command sets to-and-from the input-output devices. The output devices comprise of the traffic lights which simulates the basic green-amber-red circuit that controls the traffic as well as the pedestrians, a buzzer that produces a buzzing sound in response of a pushbutton, and also a camera module that triggers to capture the vehicles that intrudes the red-signal rule of the traffic light.

3.2 Arduino

According to Goranson and Ruiz (2013) Arduino is basically an open-source electronics platform originated in 2005 that tried bringing digital electronics to education, research studies and the community. It is grounded on hardware and software which is easy to use and that has boards which reads input and can turn it into an output according to the instructions sends on the microcontroller residing on the board. Arduino programming language and arduino software (IDE) are usually used alongside the arduino board.

For the Arduino based project, a variety of boards are used depending on the amount of the components associated in the application setup. Shown below is a comparison chart with the commonly used boards expressed alongside their most important characters.

ARDUINO BOARD	Microcontroller	Input voltage	Operating voltage	Output current	Clock frequency	Flash memory	SRAM	EEPROM	Digital I/O	PWM outputs	Analog inputs
DUE	AT91SAM3X8E	7-12 V	3,3 V	130 mA	84 MHz	512 KB	96 KB		54	12	12
LEONARDO	ATmega32u4	7-12 V	5 V	40 mA	16 MHz	32 KB	2,5 KB	1 KB	20	7	12
MEGA	ATmega2560	7-12 V	5 V	20 mA	16 MHz	256 KB	8 KB	4 KB	54	12	16
PRO	ATmega328	5-12 V	5 V	40 mA	8 MHz	32 KB	2 KB	1 KB	14	6	6
UNO	ATmega328P	7-12 V	5 V	20 mA	16 MHz	32 KB	2 KB	1 KB	14	6	6

Figure 3.2: Arduino Boards Comparison Chart

The board's electronic parameters are as follows:

1) Pins:

   It is important to keep in mind the number of inputs and outputs required in the project when choosing the Arduino board to use. For this case, Arduino Uno has been the best choice since the project contains fewer components, hence fewer pins will be used on the board.

2) Memory:

   Flash memory is where the program is stored, thus, the program space. The flash memory is the storage space for the program and for this system, Arduino Uno has a sufficient memory space to run the application program. The SRAM (Static Random Access memory) is a volatile memory that stores the program and manipulates the variables during program execution. If either the power is lost or the SRAM has run out of space, the program will unexpected fall even though it has been well compiled and correctly uploaded into the board. The EEPROM (Electrically Erasable Programmable Read-Only Memory) is a programmable and electrically erasable RAM memory. It is a non-volatile memory; thus, it can always retrieve data after power failures.

3) Clock Frequency:

This is an indicator of the processor's speed. It refers to which the CPU (Central Processing Unit) is running.

4) Operating Voltage:

   This is the voltage at which the components are set to operate at and should be sufficient enough to run and drive the components as required. Mostly the 5V is the standard amount for the majority of the components.

3.2.1 Arduino Uno

Arduino Uno is an Arduino built microcontroller, which in other terms is a mini-computer on a distinct, cohesive circuit with a processor and memory, set between some manageable input and output pins. It facilitates the writing of programmes and creation of interfaces that read switches sensors and control of electronic devices such as motors with a very little effort (Olsson, 2012). Arduino Uno supports programming languages such as c and C++.

The term Arduino Uno is Italian and is interpreted as "one". The Uno was released on the 25th of September 2010. The microcontroller is quite expensive and ranges around $30.

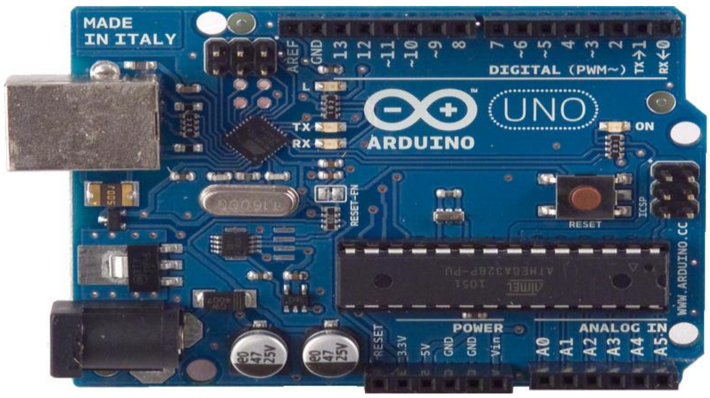

Figure 3.3: Front view of the Arduino Uno Board (Di Justo and Gertz, 2013)

3.2.2 Technical Specifications of Arduino Uno

Microcontroller	ATmega328 (8-bits Architecture)
Operating voltage	5V
Input Voltage (recommended)	7 – 12
Input Voltage(limits)	6 – 20V
Digital I/O Pin	6 – 20V
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50mA
Flash Memory	32 KB (ATmega328) 0.5 KB for bootloader
SRAM	2KB (ATmega328)
EEPROM	1KB (ATmega328)
Clock Speed	16 MHz

Table 3.1: Technical Specifications of Arduino

The figure below shows the hind side of the Arduino Uno board with inscription printed on it and four apparent mounting holes.

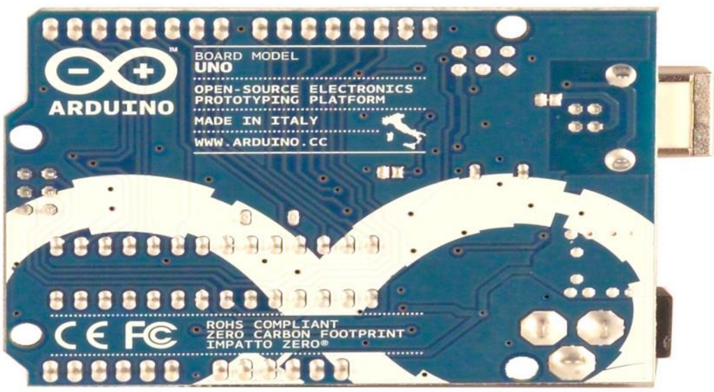

Figure 3.4: Hind side of the Arduino Uno Board (Di Justo and Gertz, 2013)

3.2.3 Arduino Uno Parts

The Arduino Uno has two connectors on its left side and a Universal Serial Bus (USB) connector on the far left. The board connects to the computer for the following reasons:

- Power supply to the board
- Instructions uploading to the board

- To transfer dta between the computer and the board

There is a power connector on the right side of the board that powers the Uno from the mains power adapter.

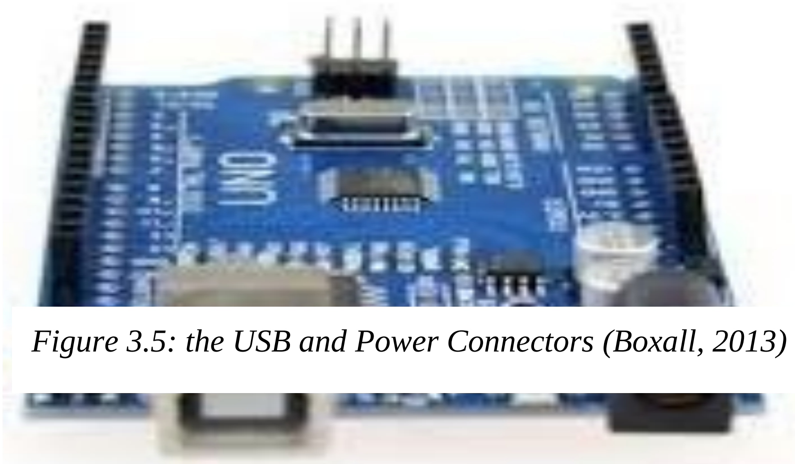

Figure 3.5: the USB and Power Connectors (Boxall, 2013)

The microcontroller, which is a tiny computer located at the lower central part of the Arduino board, acting as the brains of the board and contains a processor that executes instructions. This tiny computer has several categories of memory used to grasp data and instructions, providing various avenues whereby data is send and received (Boxall, 2013).

Figure 3.6: The ATMEGA 328 Microcontroller (Boxall, 2013).

Barret (2012) expressed the ATmega 328 microchip as a 28 pin and 8-bit microcontroller chip. Its structural design is formed by the Reduced Instruction Set Computer (RISC). It can run up to 20 million commands per second when it is working at 20 MHZ. This microcontroller's features can be categorised as follows:

- Memory scheme
- Port scheme
- Timer scheme
- Analog-to-digital converter (ADC)
- Interrupt scheme
- Serial communications

Two rows of small sockets are found bellow the microcontroller. The first one containing the power connections, capable of using an outer RESET button whereas the second row has six analog inputs to measure the electrical signal that vary in voltage. Pins A4 and A5 specialise with the sending and receiving of data from external devices.

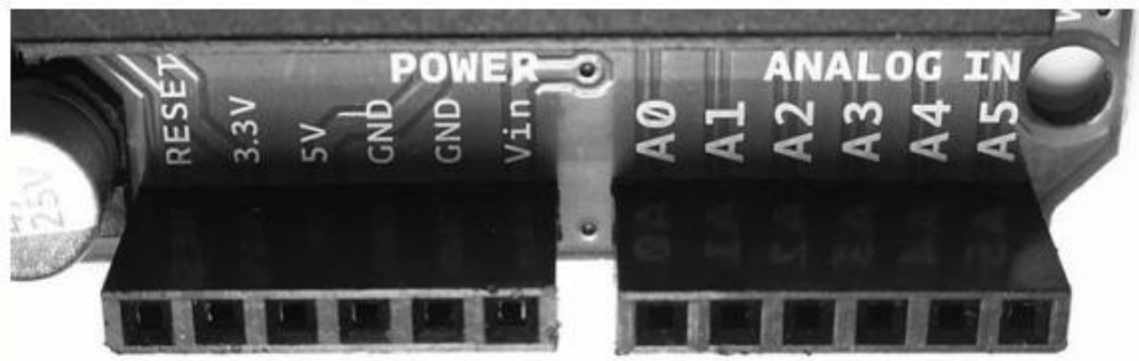

Figure 3.7: Power and Analog Sockets (Boxall, 2013)

Sockets on the top marked 0 up to 13 are digital (I/O) pins which can perceive the existence of an electrical signal and create a signal on command. The serial port, thus pins 0 and 1, can be used on sending and receiving data from outside devices through a USB connection. The pins that are characterised by a tilde (~) can produce a fluctuating electric signal too and can be used on creating lighting effects and the controlling of motors (Boxall, 2013).

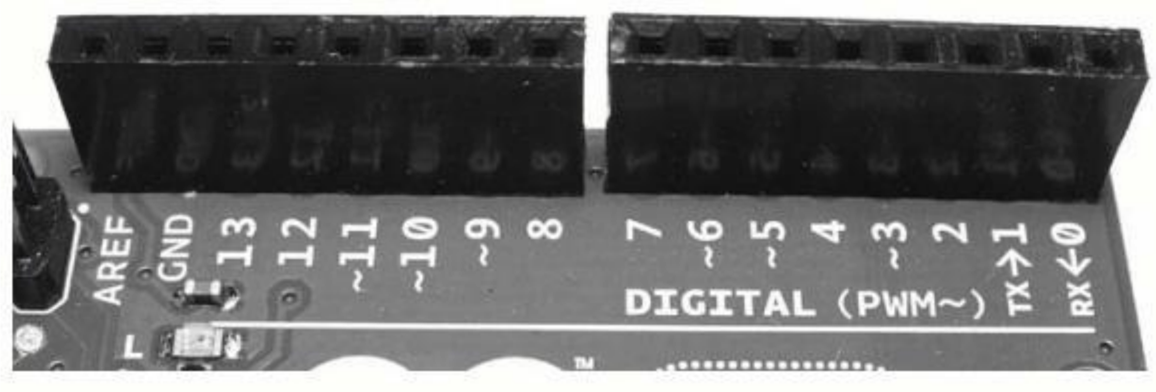

Figure 3.8: Digital Input/output Pins (Boxall, 2013)

There are four LEDs on the board which includes the ON label that indicates show that power is received at the board, and the other three are TX, RX and L. TX and RX are used to indicate whenever data is transferred from the Uno to the external devices using the USB and serial port. The other L led is linked to the I/O pin and is for the operator’s use. There is another tiny dark square portion on the LED’s left side which is a microcontroller for the control of the USB interface for sending and receiving of data between the Uno and the computer (Boxall. 2013).

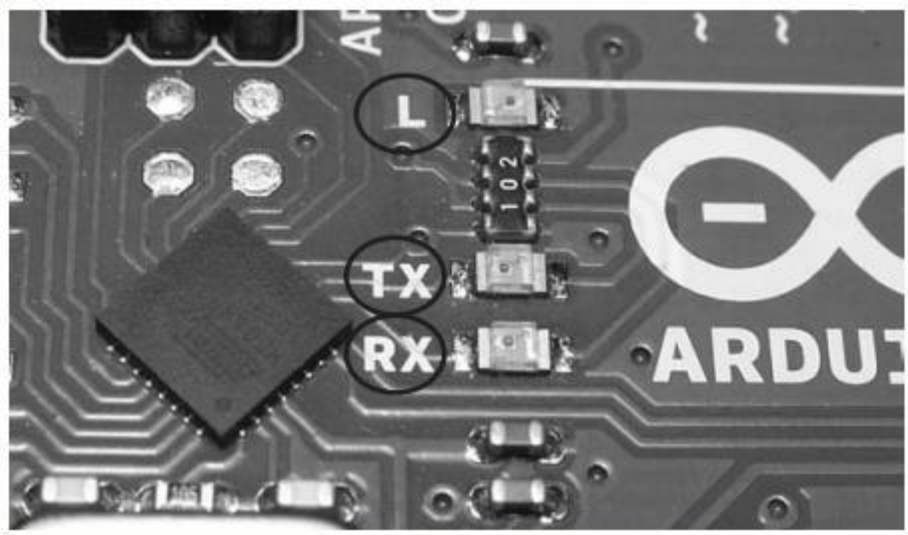

Figure 3.9: LEDs on boards (Boxall, 2013)

There is a RESET button used to reset the Uno to resolve problems pending if there is any.

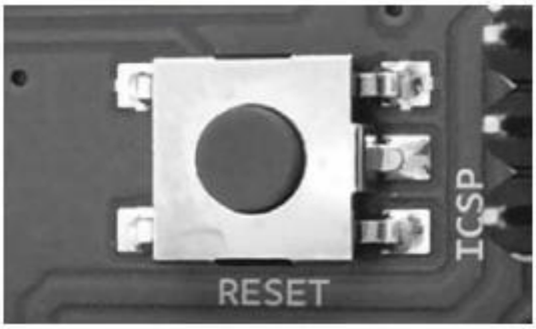

Figure 3.10: RESET button (Boxall, 2013)

3.2.4 Powering Arduino

The Arduino Uno gets powered by either an isolated power source or a USB connection from a computer. An AC-to-Dc connector or a buttery can be used as the outward power source. The Arduino board can safely operate on a 6 to 20volts supply, and anything besides this range will result in a failure of the board.

The board has the following power pins: Vin – which allows the user to power the board from an external power supply like a buttery. Components attached to the Arduino board can also be powered through this very pin. It is not advisable to power the board through the 5V or 3.3V pins in the analog side since this bypass the regulator and can permanently damage the board

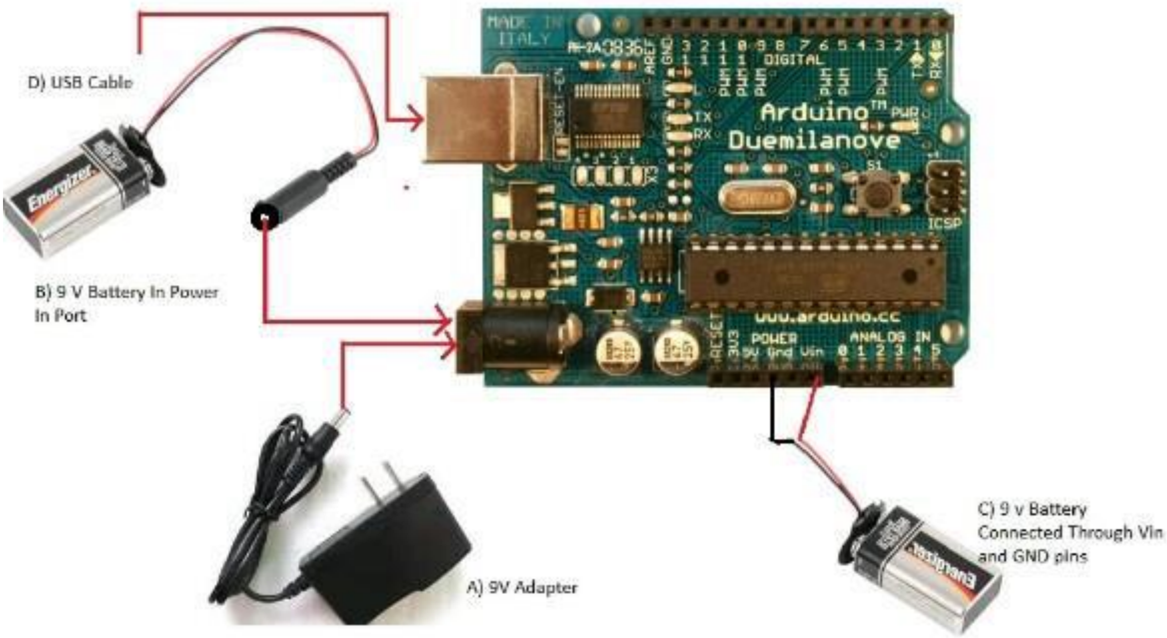

Figure 3.11: Power Supplies for the Arduino Board

3.2.5 Aduino Uno Advantages

- Expandability – it allows easy of additional hardware functionalities. The board has its sockets in two rows on both sides of the Arduino Uno that allows assembly of added circuit boards through its pins that plug into the board.
- Programmable USD chip – this feature helps in the flashing of the chip such that it shows up once plugged into the computer the way any other USB device would do. This means that one can use the Uno as an interface to create USB devices.

3.2.6 Arduino Uno Disadvantages

- No direct communication with any android device – thus it has no USB Host functionality. However, the use of shields comes in to give the USB Host the ability to perform its tasks and also add Bluetooth communication.

3.3 Arduino Software

This is simply a set of orders that commands the hardware to perform its required job. Two software types are:

- The Integrated Development Environment (IDE)
- The Arduino Sketch (one creates)

The Arduino Integrated Environment is set up in the computer to be used on the composition and sending outlines to the Uno board (Boxall, 2013).

3.3.1 The Arduino Integrated Development Environment

The IDE bear a resemblance to a simple word processor that is allocated into three major sectors:

- Command sector
- Text sector
- Message window sector

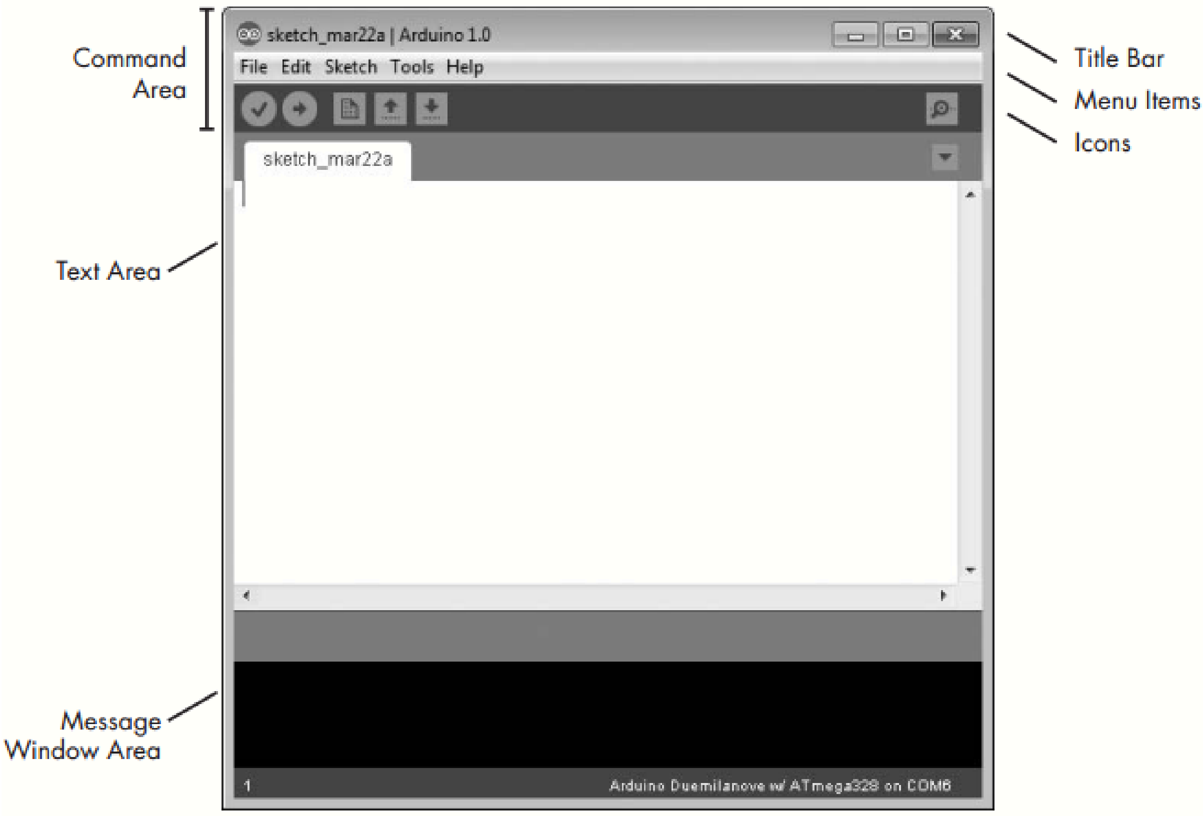

Figure 3.12: the Arduino Uno IDE (Boxall, 2013)

Command sector – this contains a title bar, menu and icons. The title bar is the one to display filename of a sketch and the IDE version. It has a sequence of items below, (File, Edit, Sketch, Tools, and Help).

The Text sector – a sketch is created here, and the name of the currently displayed sketch will be in the higher left corner of the text sector. The subjects are entered just as in any other text sector.

The Message window sector – the mails from the IDE are displayed in the dark space. These mails differ and they embrace verification of drafts and status updates. The lowermost right area of the message sector displays the label of the Arduino board and its attached USD port.

Programming the Arduino Uno

The Integrated Development Environment was used to inscribe outlines to the Arduino Board which controls the sub components. The written sketches were uploaded to the microcontroller using the USB cable.

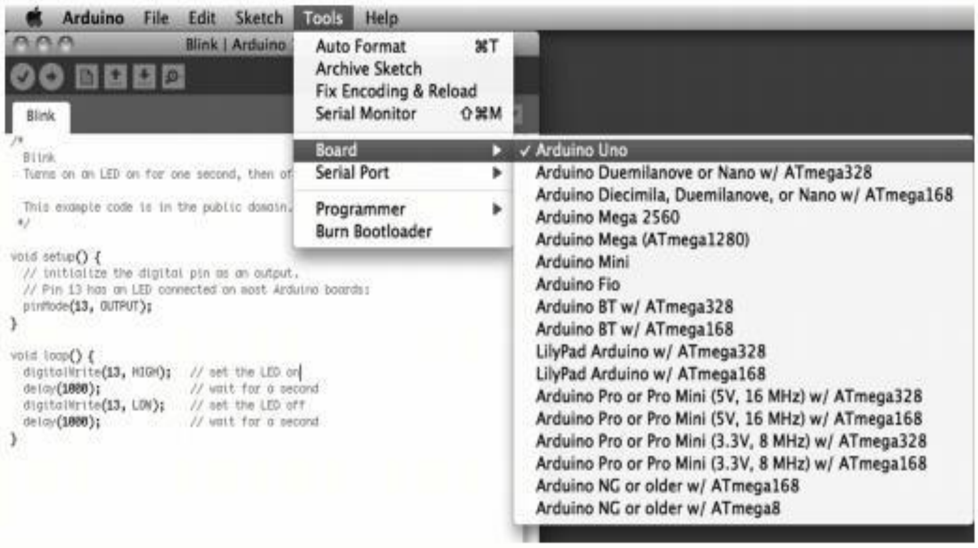

Figure 3.13: Arduino IDE with C++ Code waiting for Upload

3.3.2 Arduino Sketch

According to Boxall (2013) the Arduino sketch is a set or program that contains created instructions to accomplish a task. It possesses attributes such as:

- Comments – are notes of any length written for the user understanding which is found in the sketch? The comments are useful to both the owner of the program and to the other users as the provide notes and instructions on miscellaneous details. Comments begin with two forward slashes such as "//" and or "/*".
- Setup Function – this contains a set of instructions for the single execution of the Arduino once it is restarted or powered on. It is also referred to as the void setup() function.
- Loop Function – sometimes referred to as the void loop() function and serves to maintain the execution of the Arduino instruction again and again once it is powered on.

3.4 The Passive Infrared-red Sensor (PIR)

The Passive Infrared sensor in this context is used to detect the presence of the pedestrian, as well as the movement of the vehicular traffic past the stop-line during a red signal. This type of a sensor uses the changes in infrared radiation that is using the changes in temperature to detect movement. According to Turner et al (2011) the passive infrared sensors can be used to detect the presence of walkers at the landing of the crossing provided the site is located at the near side of the roadway.

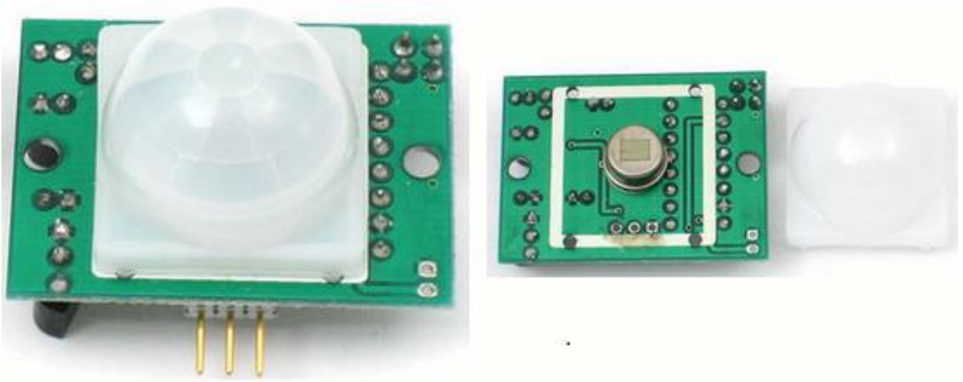

Figure 3.14: The Top and Inside of the PIR sensor

Specifications

The PIR Sensor measure up to distance of 9m. In such a situation its sensitivity will have to upsurge. This type of a sensor uses 3-6 VDC and its uses 12mA at 3V, and also 23mA at 5V. The sensor is termed “Passive” in this context, meaning that it hardly sends any signal but rather reads in infrared light (Kelly and Tunis, 2013). These PIR Sensors comes in different styles and are sensitive over a variety of angles and distance. The sensor is covered in a dome-shaped lens that focuses light at the core for easier detection of infrared variations (Riley, 2012).

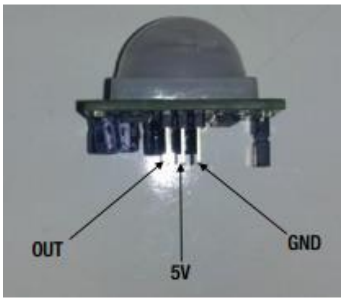

Figure 3.15: the side view of a PIR Sensor

Structure of the PIR Sensor System

The PIR Sensor circuit has three pins namely the GND, OUT and VCC. The GND is allied on to the ground pin of the microcontroller, the OUT pin attached to the Arduino Uno digital input 2, and the VCC joined to the optimistic 5V source of the microcontroller. Once the PIR detects fluctuates in infrared intensities it directs signals to the Arduino digital pin 2 as HIGH or LOW (Riley, 2012).

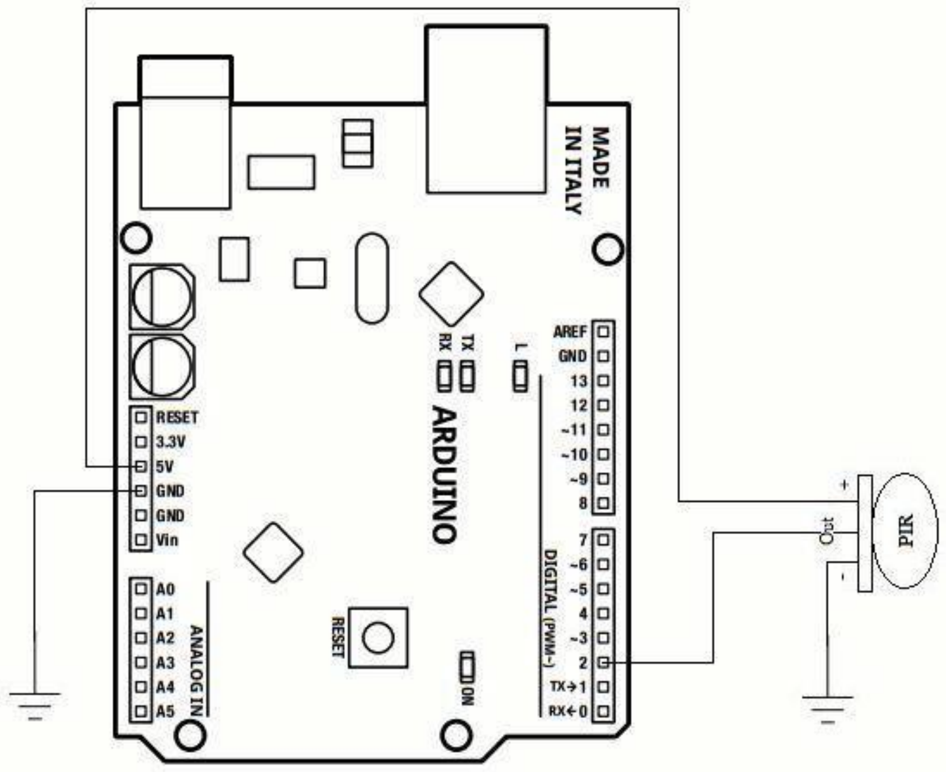

Figure 3.16: PIR Sensor Schematic

Detection of Movement

There is a crystalline material at the centre of the rectangle shape of the sensor's face which is used to detect the infrared emission. This sensor is designated in two so that it detects the changes in state that happens when a target reaches its field. The variations in the infrared emission quantity at the PIR sensor cause the changes in the produced voltages. The sensor perceives any shattered field in a normal temperature, and the field should not be shattered by any item that endures a different temperature for it to record a change. Some extremely sensitive PIR sensors trigger from movement itself and are intended to work within a temperature range of 15 to 20 degrees Celsius. The field of view widens at temperatures lower than 15 degrees Celsius and it narrows at higher temperatures, thus distance objects are easily detected at lower temperatures. According to Mathas (2012) the PIR outputs a high signal at its output pin whenever it detects a motion, and this will be read by the microcontroller.

3.4.1 Advantages of PIR Sensors:

- The sensor is small in size, light in weight and easy to connect
- It is sensitive over a variety of angles and distances

- It is not costly

3.4.2 Disadvantages of PIR Sensors:

- It requires a lot of care when calibrated and positioned since it can easily be triggered by insects and animals
- It requires route of sight

3.5 Light Emitting Diodes (LEDs)

These are semi-conductor, forward biased p-n junction diodes with dual leads, a cathode and an anode. Basically, the anode is the elongated lead; the cathode is regularly indicated with a flat plug on the frame. The colour of the LED depends on the construction of the diode. These LEDs exists in numerous formats though popularly found in their round types.

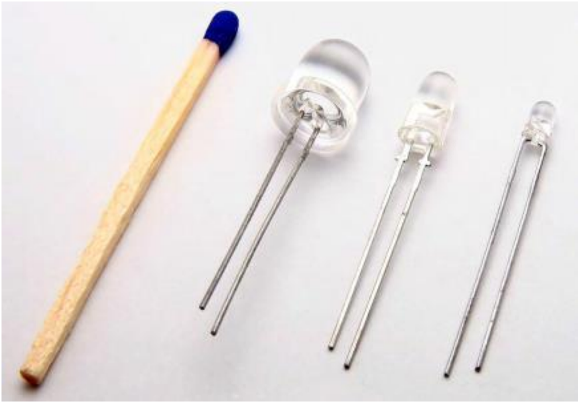

Figure 3.17: LEDs in their different sizes

Light Emission

The device emits light (photons) whenever more voltage happens to be on the anode than the cathode. This condition is referred as forward voltage. The photons (light) are emitted through a spontaneous emission by a phenomenon called electroluminescence (Phillip and Laplante, 2000). Basically, a LED will provide a reasonable light intensity when it is supplied with a forward current of about 5mA to 20mA.

Pedestrian and Traffic Light System Designing

A set of ten LEDs, 10mm in lengths makes up the lighting system, where three of the pairs (2 RED, 2 AMBER and 2 Green) are connected in analogous and in sequence with a 50kΩ resistor. The three pairs of LEDs serve as the road traffic light scheme with their anodes coupled to the Arduino board at the digital pins 12, 11, and 10 in that order. Since LEDs only light up when connected to the right polarity, the pairs in context have their cathodes grounded. The remaining two sets of RED and Green pairs act as the pedestrian traffic lights. Each of which is allied in succession with a 100kΩ resistor. The pairs are linked on the digital pins 9, 8, 7, and 6 of the microcontroller with their cathodes grounded.

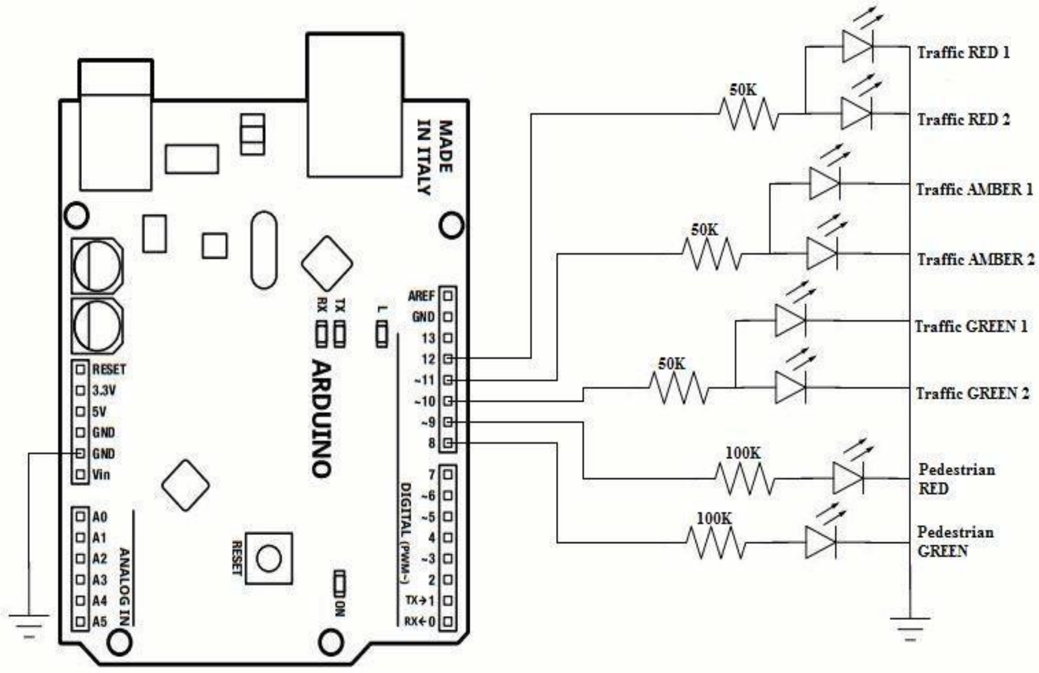

Figure 3.18: Lighting Representations

3.5.1 Advantages of LED:

- They are efficient; they emanate supplementary lumens per watt, yet hardly affected by figure or scope
- They are tiny in size that they can be integrated into smaller devices
- They have a very quick response time; thus, they quickly light up
- They are shock resistant since they are in solid state, they are tough to damage with external shock
- They have a relatively longer life

3.5.2 Disadvantages of LED:

- They are temperature depended since their performance rely on the operating environmental
- They are voltage sensitive; they essential need the voltage beyond the verge and the current which is lower than the rating

- They are electrical polarity since their lighting goes well with a right polarity construction
- They are initially expensive

3.6 Pushbutton

A pushbutton is simply an electric mechanism that controls some aspects of a machine or process. These buttons are usually made with hard plastic or metallic materials. They have a flat surface that accommodate a human hand or finger to depress or push.

Figure 3.19: Pushbutton

There are three wires connected to the Arduino board. The first one extends from the leg of the pushbutton to the 5V supply. The second extends from the parallel leg of the pushbutton to the ground. The third wire stretches from the leg of the pushbutton to the input/output pin which reads the button’s state.

3.7 Buzzer

This is a piezoelectric transducer device that converts electrical signals into sound. It has the possibility of varying the sound volume as the electrical current is passed by.

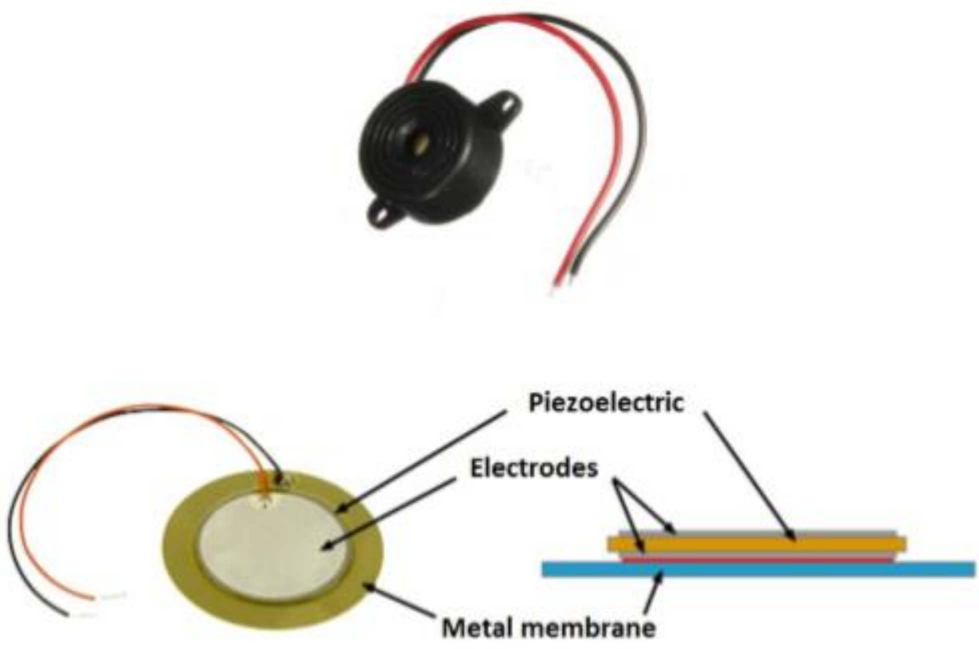

Figure 3.20: Buzzer and its Structure

This device vibrates a membrane by navigating a piezoelectric material with an electric signal.

3.8 Camera

For this project, a LinkSprite camera has been chosen and connected to the Arduino Uno. This camera is capable of capturing pictures even at night. The camera has 6 infrared LEDs that are automatically activated in case of low light. The camera captures high resolution images and sends them as JPEG through its serial port.

Figure 3.21: Camera

3.9 Data Collection Methods

The evaluation of the Intelligent Zebra Crossing was done through a trilateral method where interviews were done on the motorists and the pedestrians as well as observations taken on the yielding behaviour of the drivers.

3.9.1 Yielding Behaviour of Motorists

The motorists' yielding behaviours at the walkers was observed in the field and the factors considered to influence the behaviours were accounted for. The motorists' way of approaching when the pedestrian is already on the crosswalk was measured and taken into account. In response to the phenomenon of having a pedestrian on the crosswalk and a fast-moving vehicle approaching, it was observed that: 1) driver's actions of stopping, slowing down and doing nothing were of great importance, 2) the vehicle size and its registration type was also of great importance, 3) the pedestrian's responsive walking direction, into or away from the vehicle trajectory path was of great importance.

Apart from field observations, drivers' yielding behaviour was alternatively measured through asking of questions to drivers themselves – self-reported behaviour. This form of data gathering is characterised with a lot of bias as the drivers will be trying to impress the interviewer, though it is less costly. To minimise the magnitude of bias on self-reporting, the questions were well worded. The motorists were asked to indicate their responsibilities at the zebra crossings when pedestrians wanting to cross the roadway are present.

Few questions were included in the questionnaires for the drivers, testing their understanding of the zebra crossing. Of the zebra crossing main elements, on three were prioritised in the questionnaires, which are 1) zebra markings, 2) warning signs and 3) flashing lights. A photograph of the zebra crossing was provided with the questionnaires for easy referencing to the stated crossing elements. The respondents were asked if their understanding of the zebra crossing markings is based on their understating of the road traffic rules and regulations.

Response Variable

The response variable was demarcated as the quantity of the driver's yielding behaviour to the walkers on the crossing area. The regulations on the use of the priority pedestrian crossings call for the driver to accord pedestrian a precedence when he/she is already crossing. The regulations basically require the driver to yield to the pedestrian but not necessarily stopping. The proportion of the motorists who at least slows down and not stopping for the pedestrians is the same as those who do nothing on allowing the pedestrian crossing.

3.9.2 Demographic Factors

The demographic factors sought were the respondent's age, gender, and the driving experience. Those drivers who have had some experience of driving from quiet long back are expected to have learnt from the past driving environments and must be safer drivers. On the other hand, young drivers, particularly teen are well known for their high-risky taking behaviours that degrade road safety, since they lack driving experience and sufficient knowledge. Higher crash rates involving younger drivers proved that the effect of age and experience is a vital aspect on the drivers' behaviour on road safety. Furthermore, male drivers were found to be more risky takers than the female drivers, yet men are mostly reported to have driven while alcoholic controlled; running over red traffic signals and over-speeding unnecessarily.

3.10 Conclusion

The third chapter has offered a synopsis of the research methods and techniques that were used in the Intelligent Zebra Crossing. The data collection was discussed in detail. The chapter has also discussed how the hardware modules are allied to each other and how the software is encumbered into the Arduino Uno microcontroller.

CHAPTER FOUR

Electronic Design and Schematics

4.0 Introduction

Detailed analysis on the project research, system modelling, and the electronic designs as well as the circuits schematics will be the discussion of the chapter. Interfacing of the system components to the Arduino Uno board and the simulation of the system using a computer application namely Proteus is done here. The connections and wiring between each component of the system and the microcontroller so as to achieve the desired goal is the core of this chapter.

4.1 Intelligent Zebra Crossing Block Diagram

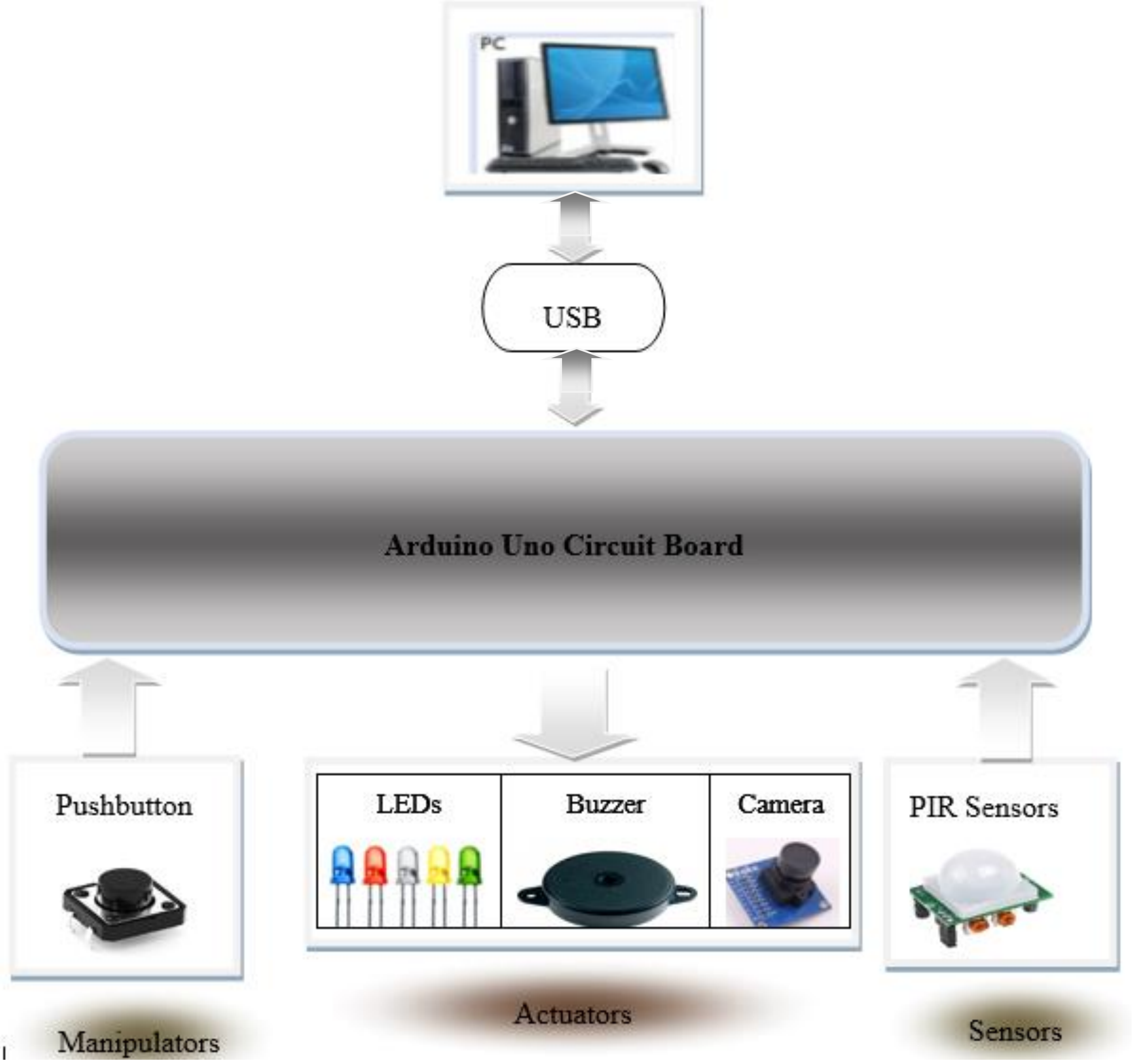

Figure 4.1: Block Diagram of the system

The system is centralised at the microcontroller, which is hosted in the Arduino Uno circuit board. This is the core of the system, where all the information is processed and allocated as per function. A continuous execution of the code is done here, collecting all function modes and the information from the environment through the sensors, processing all the acquired data and governing the relative actuators consequently.

4.2 Intelligent Zebra Crossing Flow Chart

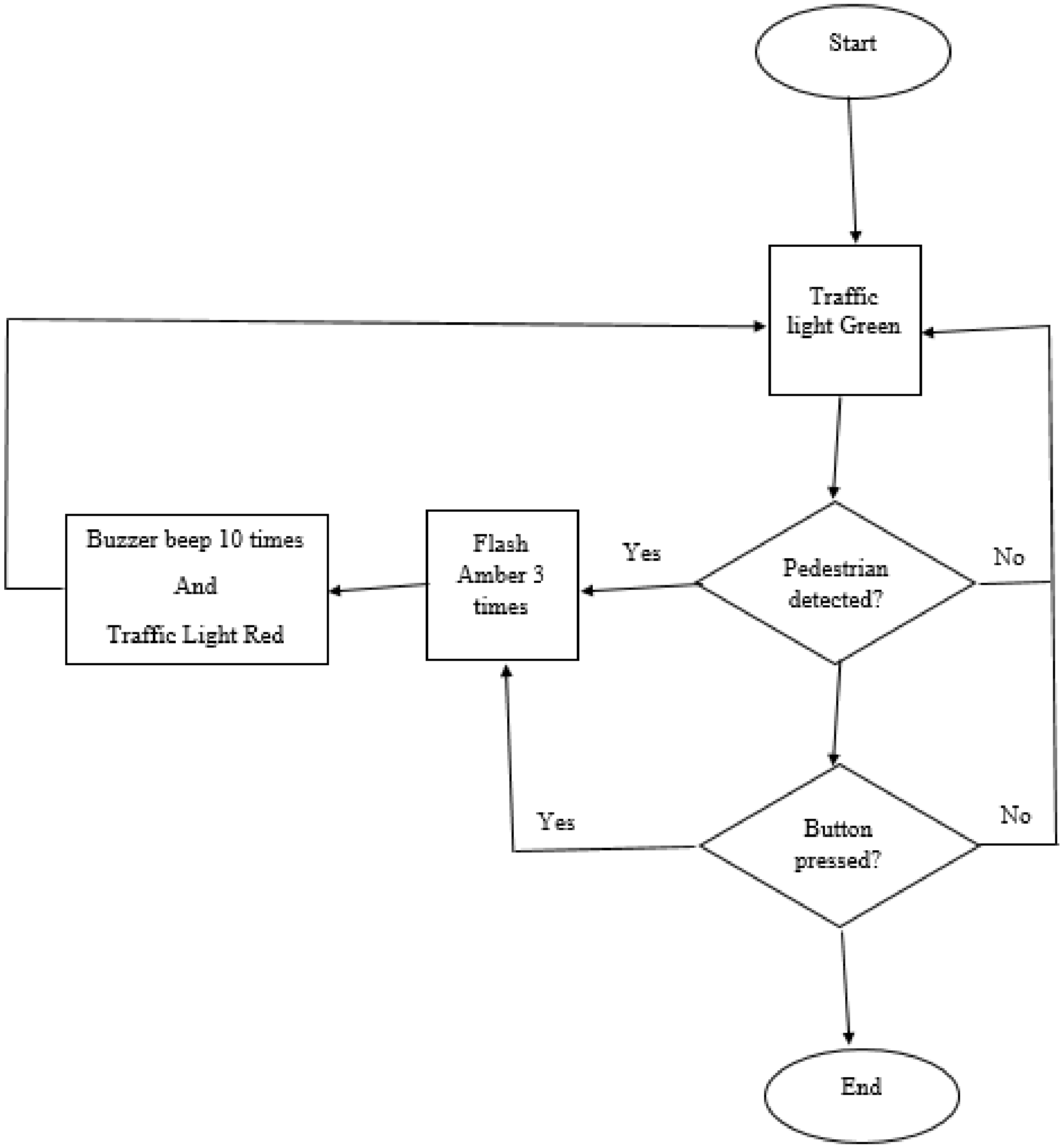

Figure 4.2: Flow chart Diagram of the proposed system

A flowchart is a diagrammatic representation of the ongoing progress of a system or computer algorithm. According to Oriel (2014) a flow chart shows the detailed stages in a process and the entities involved in each step. Flow charts are broadly employed by several fields for documenting a study or a project hence providing room for planning and improving processes. They give a clear view of compound processes through diagrams that are easy to read and understand.

4.3 Breadboard

This is a solder-less electronic device that is used for temporary prototyping and testing circuits designs. Most electronic components are cooperated into circuits designs through inserting their leads terminals into the breadboard and make the wiring appropriately. The board has strips of metal underneath and connected holes on its top.

Figure 4.3: Breadboard

The top and the bottom rows of the breadboard holes are linked horizontally and split in the middle while the remaining holes are connected vertically.

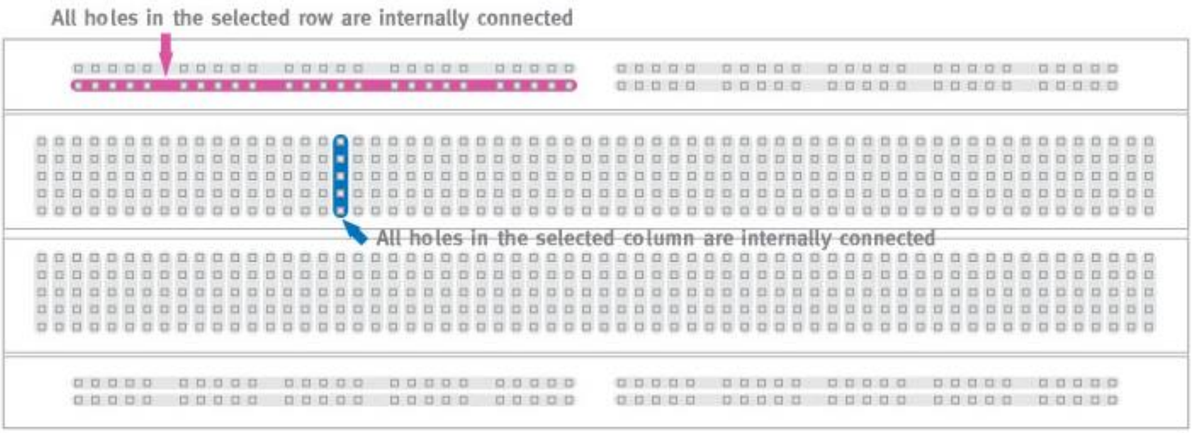

Figure 4.4: Breadboard holes schematics

No soldering is required on the breadboard. The internal structure of the holes are designed in a way that it can temporarily hold the wires connected and are interlinked with the buried metal strips to complete the circuit.

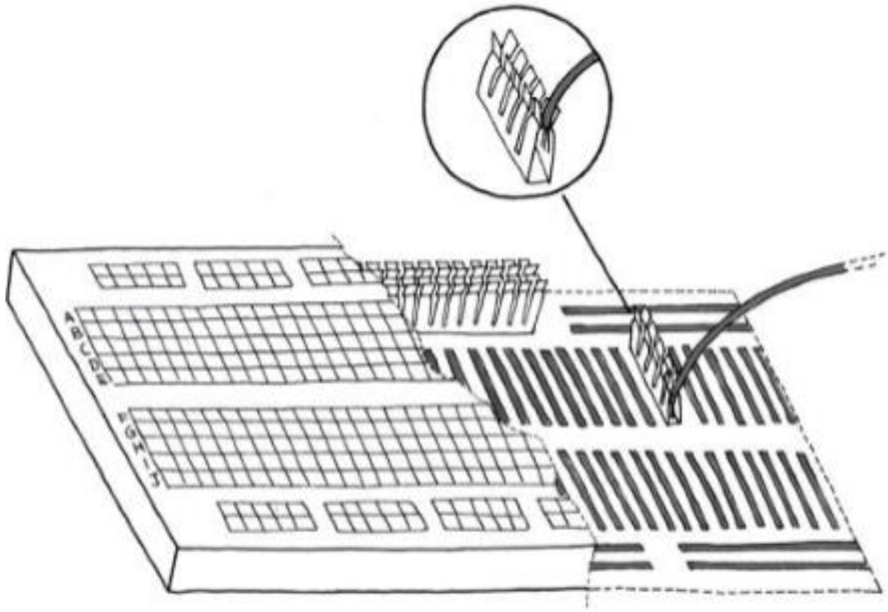

Figure 4.5: Internal wiring of the Breadboard

4.4 Jumper Wires

Jumper wires are used to connect the electronic components to the Arduino board and the breadboard. They are 1mm core diameter (AWG 20 or AWG 22) wires also known as hook-up wires. They have solid metallic strips which are designed to perfectly fit into the Arduino and the breadboard pins. They come insulated in various colored wires and are grouped into males and male to female wires.

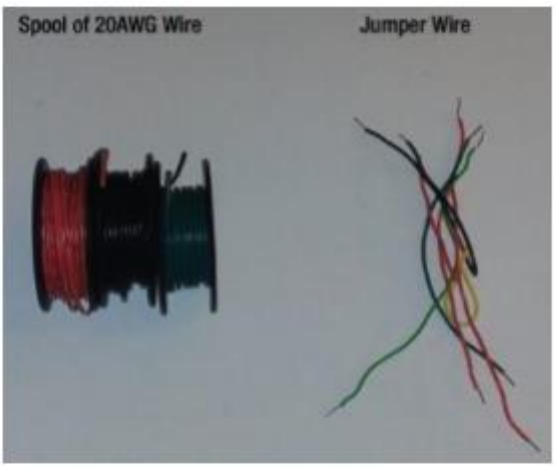

Figure 4.6: Jumper wires

4.5 Interfacing PIR Sensor with Arduino Uno

PIR sensors have been chosen for most of the security and energy management systems project due to their smaller size, less power consumption and their simple compatibility with hardware such as Arduino (Fraden, 2016). A PIR sensor contain a pair of pyroelectric sensors that detect infrared radiation. Where there is no motion, these two sensors' output cancels out. The environmental changes in movement produces different levels of infrared radiation by these two pyroelectric sensors and the difference triggers an output signal of HIGH (+5V) (Pratik, 2015).

The PIR sensor has 2 knobs, one for response delay and the other one for sensitivity adjustments through increasing and decreasing the range of notion detection. According to the tests at hand, the PIR motion sensor offers about 6metres of detection range.

Figure 4.7: PIR sensor physical representation

The line of code that commands a PIR sensor system is the one that logically determines the extent to which the sensor detects the motion. Thus, the efficiency of the sensory system is determined by the commands written in the microcontroller.

Just like any other sensor, a PIR motion sensor has 3 pins: the Vcc, the Signal and the Ground pin. The pins configuration is as follows:

1. The Vcc is a supply pin that is used to connect +5 DC voltages

2. The signal pin is of output that is used to collect the output signal collected by the PIR sensor.
3. The Ground pin, marked as the GND is used to provide ground to the internal circuit of PIR sensor.

A simplified circuit of interfacing Arduino Uno to a PIR motion sensor is shown below.

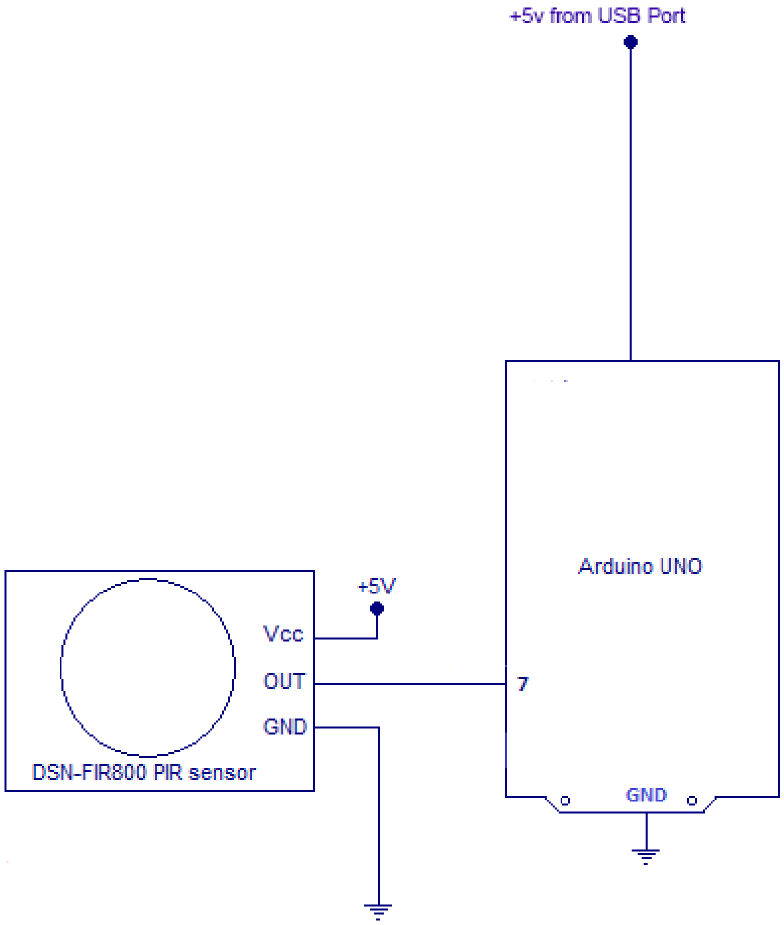

Figure 4.8: Simplified Block Diagram PIR to Arduino interfacing

The schematic diagram showing the interfacing of the PIR sensor to the Arduino Uno board is shown below. This diagrammatic representation has been modelled using a circuit drawing platform namely fritzing.

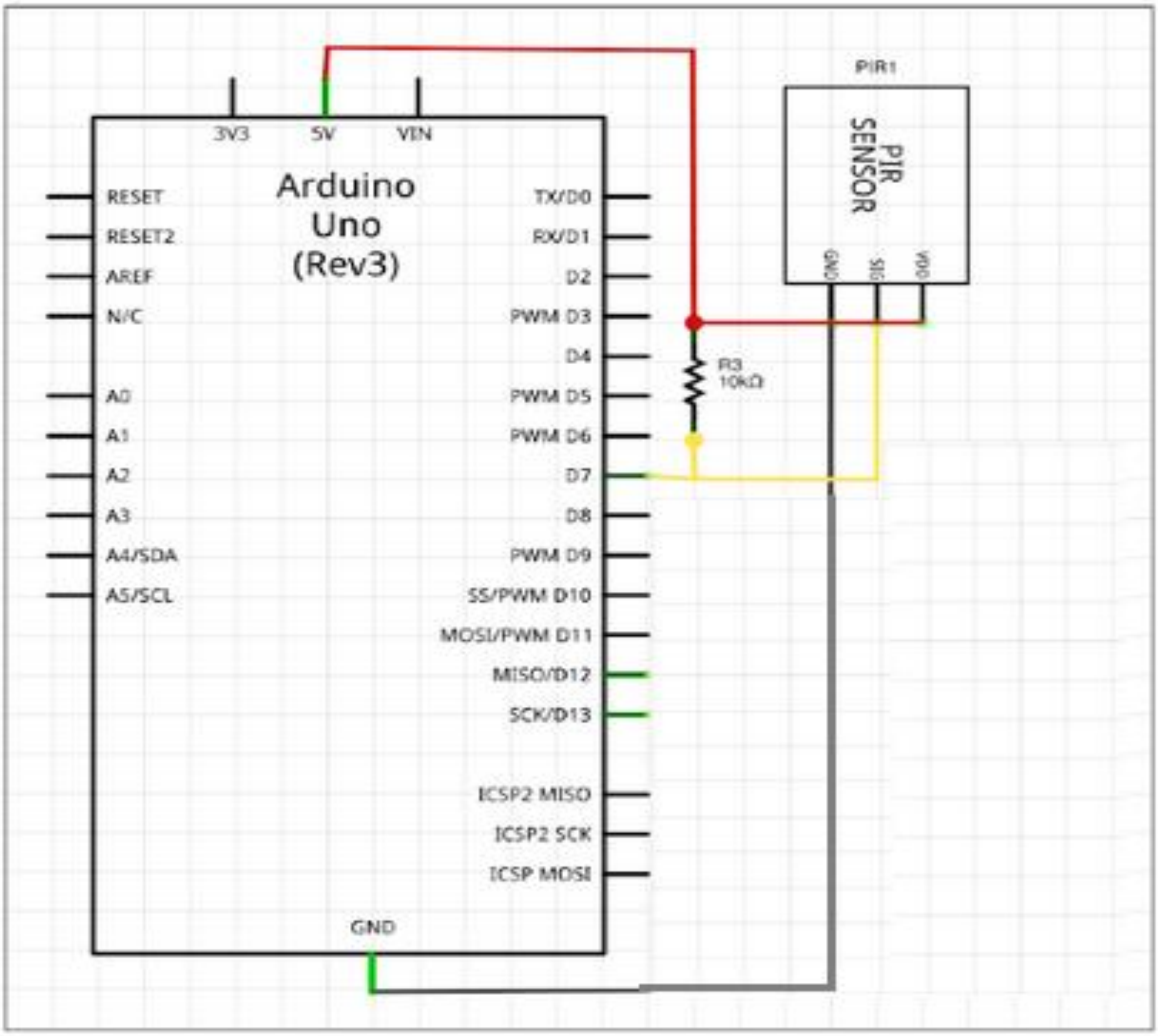

Figure 4.9: Schematic Diagram of the PIR to Arduino Circuit system

Possible Outputs on a PIR Sensor module

This sensor has got a single digital output only. It has got only two possible output values which are either it is a HIGH or a LOW. Its default form and whenever there is no object to be detected in its detection range it is always a LOW value or a 0V at the output. When the PIR detects an object it quickly outputs a HIGH value or a +5V at the output. This logic simply means that for the pin to flip high it means detected or low meaning that not detected.

4.6 Interfacing Buzzer with Arduino Uno

Figure 4.10: Pictorial representation of an Arduino board and a piezo Buzzer

A piezo buzzer is used in this project, which is a special type of a buzzer with a built-in circuitry that produce an audible buzzing tone. According to Boloor et al (2016), a buzzer produces sound when it is supplied with a digital HIGH value (+5V), which can be simply provide by using Arduino digital pins. The kind of a buzzer is very easy to interface with Arduino Boards. Wilcher (2012), stated that this type of a buzzer has a built in crystal or ceramic material inside a cylindrical package that produces a clicking sound whenever subjected to a mechanical stress. The mechanical stress is triggered when a voltage is passed through its terminals and the crystal material inside the cylindrical package deforms. According to Runberg et al (2017), when the crystal deforms, the disc vibrates the air hold inside the cylindrical package and this produces a sound.

A piezo buzzer has two legs, the longer one being the positive leg and the shorter one being the negative leg.

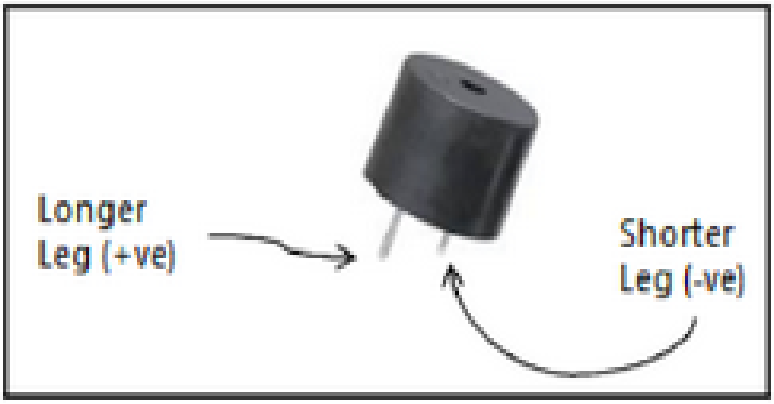

Figure 4.11: Electrical nodes of the piezo Buzzer

The shorter leg is grounded and the longer one is connected to the Arduino digital pin 6, where it acquires power from the Arduino Board. According to Kuber et al (2017), a buzzer usually has a positive sign (+) on it that indicate the positive lead, and if not marked, it will have a red wire for the positive lead. The positive terminal of the buzzer is connected to the pin 6 via a 100Ohm resistor.

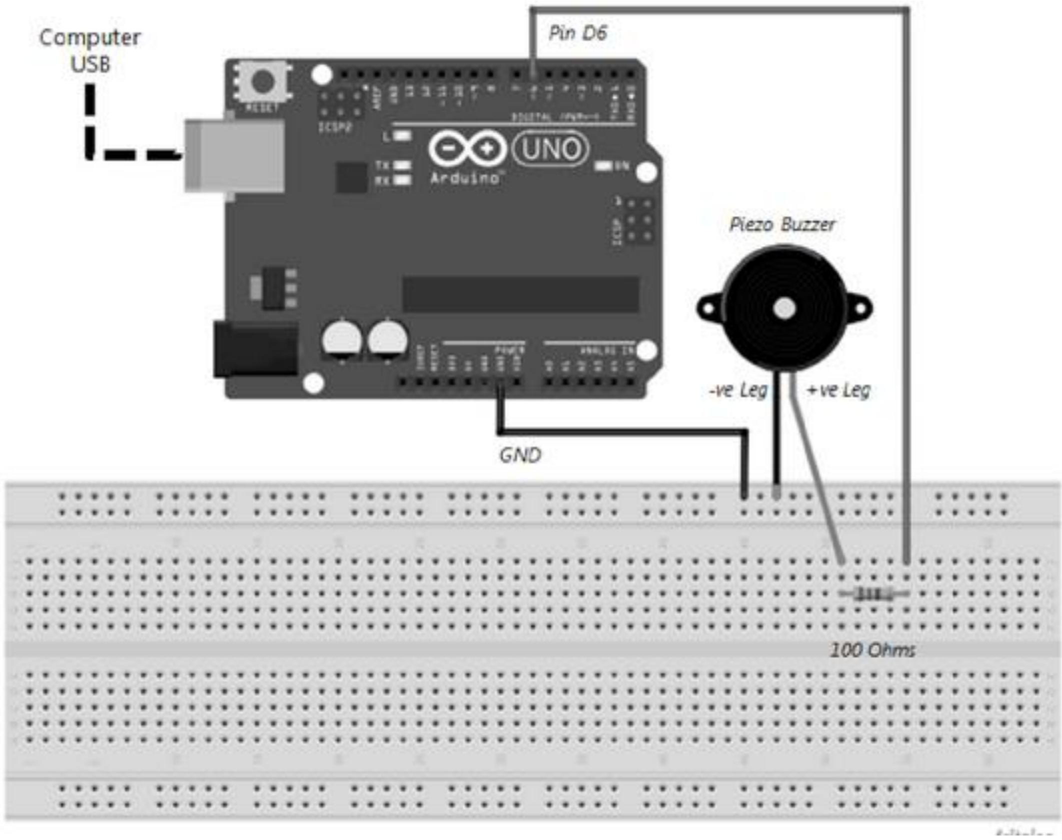

Figure 4.12: Circuit interfacing of the Arduino board and the buzzer

It is to be noted when making the connections not to connect any wires to the Rx and the Tx pins of the Arduino board while loading the sketch, (Choudhuri, 2017). The connections between the buzzer and the Arduino Uno Circuit board are tabulated below:

Arduino Uno Pin	Buzzer pin(s)
Digital pin 6	+ve (longer) le
GND	_ve (shorter) leg of the Buzzer

Table 4. 1: Pin nodes of the Arduino and Buzzer

4.7 Interfacing Pushbutton with Arduino Uno

A pushbutton has got a set of four terminal legs and it allows current to flow through it whenever it is pressed down.

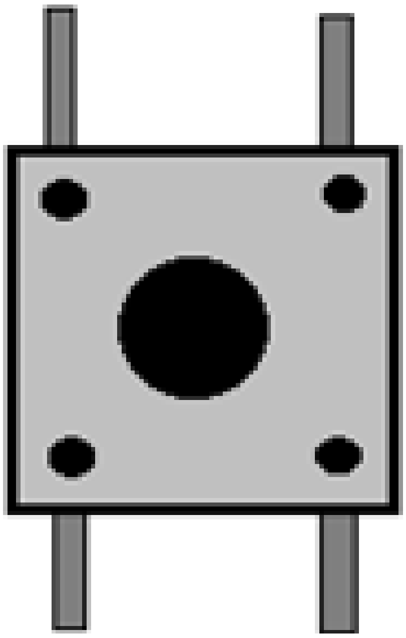

Figure 4.13: Physical representation of a Pushbutton and its legs

Three wires are connecting the pushbutton to the Arduino Board where the first wire goes from a leg of the button and passes by a pull-up resistor to a 5V supply. The second wire extends from a corresponding leg to the ground. Then the third leg connects the digital input/output pin which read the state of the pushbutton.

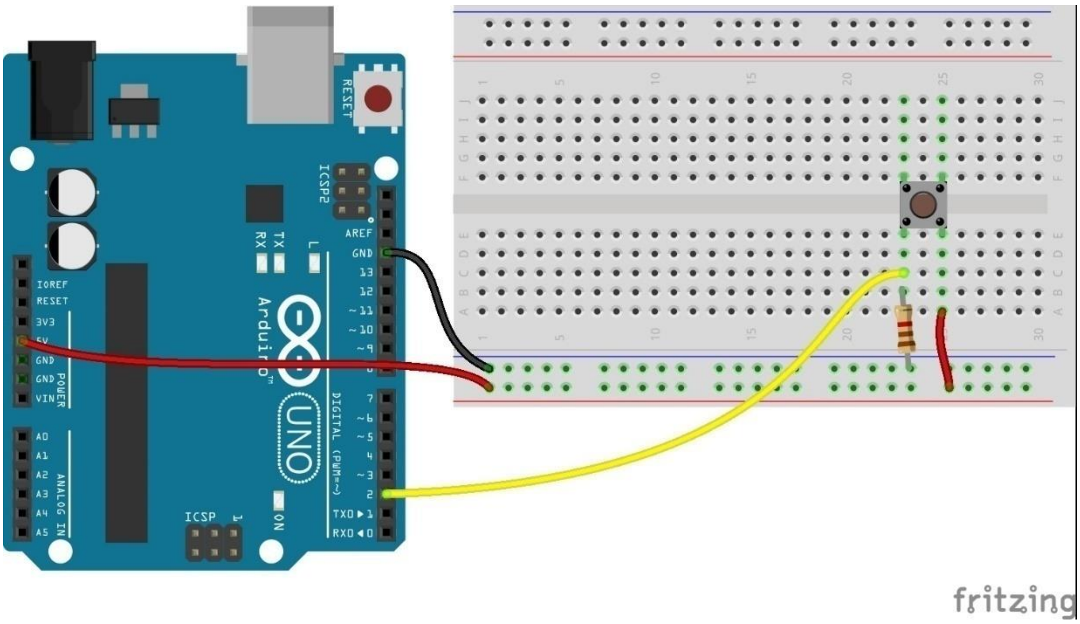

Figure 4.14: Circuit connection of the Arduino and a pushbutton

The schematic representation of the components setup given above has been presented using fritzing. This schematic circuit shows how the wiring has been made and the corresponding ports that has been used to interface the two electronic components. This circuit diagram is made easy to follow and has been displayed below:

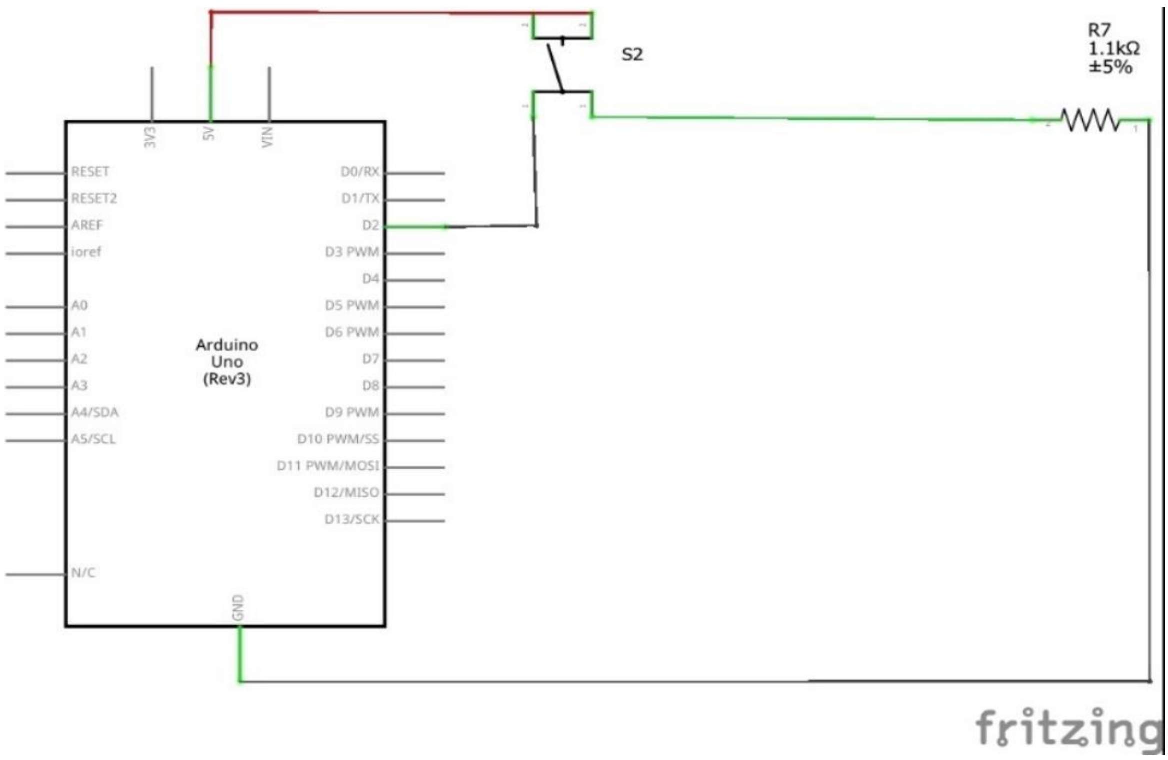

Figure 4.15: Schematic diagram of the Arduino to pushbutton interfacing

The contacts A-D and B-C are short legs of the pushbutton in context. The circuit is connected between A and C and whenever the switch is pressed, the switch is complete and it allows current to pass through. The input is read from the button using the function *digitalRead().*

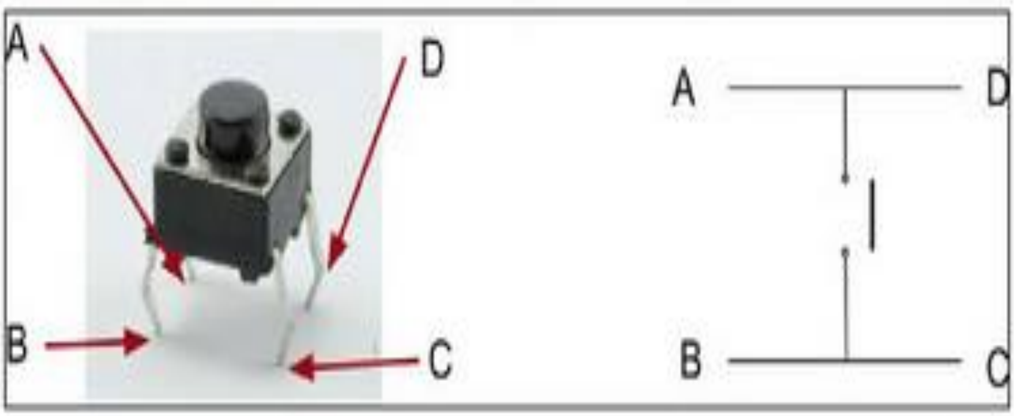

Figure 4.16: Terminal representation of the pushbutton nodes

Input using Pull-Down Resistor

A pull-up resistor of 10Kohms is connected along with the switch in the first circuit there; and it gives a signal of LOW at the output when it is pressed.

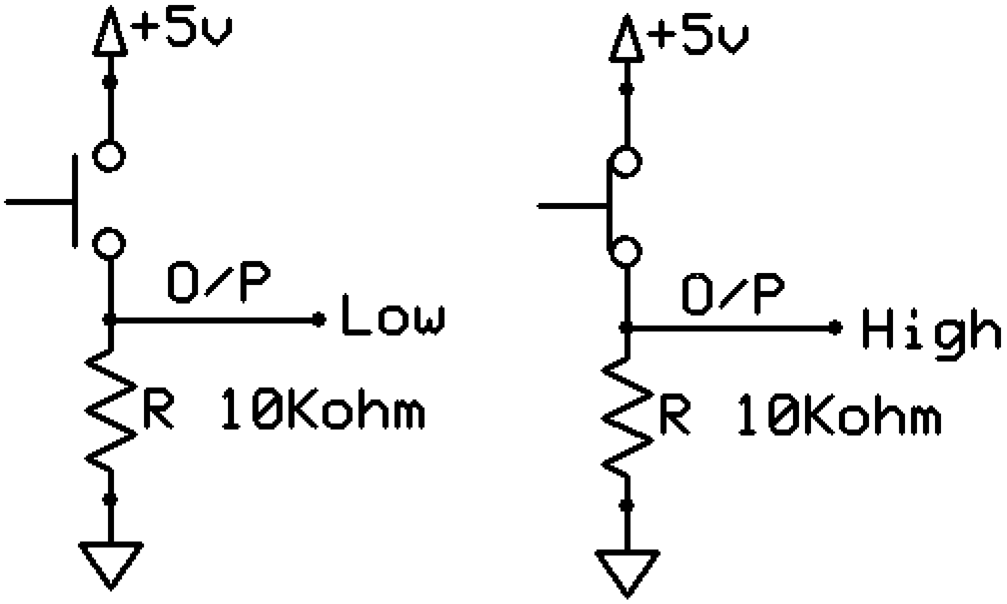

Figure 4.17: Open and Closed Pull-Down resistors

The second circuit shows a switch pressed and it will give an output signal of HIGH. The High or Low signal is fed into the Arduino input pin 8 (in this context). When this pin 8 is set to be the input of the Arduino by this instruction, pinMode(8, LOW), the Arduino will read the input signal.

Input using Pull-Up Resistor

A pull-up resistor of 10Kohms is connected along with a switch in the first circuit, and it gives an output signal of HIGH when it is pressed.

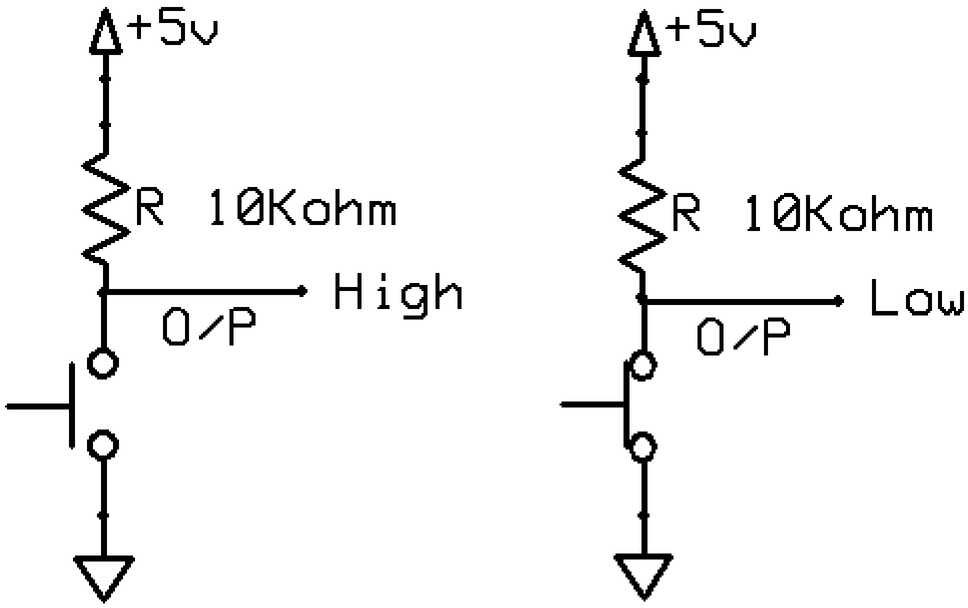

Figure 4.18: Open and Closed Pull-Up resistors

In the second circuit diagram, the output signal is a LOW which comes after the switch is pressed. This signal status goes to the Arduino pin. The program will follow that the pushbutton is connected to either a pull-up or pull-down mode.

A wire is connected to the ground and another wire to the input pin. If using multiple buttons, they can share a common ground. When the circuit has run out of the digital pins, analog input pins can be used as bonus digital pins

4.8 Interfacing LEDs with Arduino Uno

LED is an abbreviation for Light Emitting Diode, and that diode emits light whenever sufficient voltage passes across its anode and cathode, (Boloor et al, 2016). For testing the purposes, a LED was connected to the Arduino digital pin 13. The longer leg is plugged into the Arduino pin 13 and the other shorter leg to the GND. This pin has an in-built pull-up resistor that is used to limit the current supplied to the LED. For connections other than pin 13 of the Arduino Board, resistors are essential in the circuit.

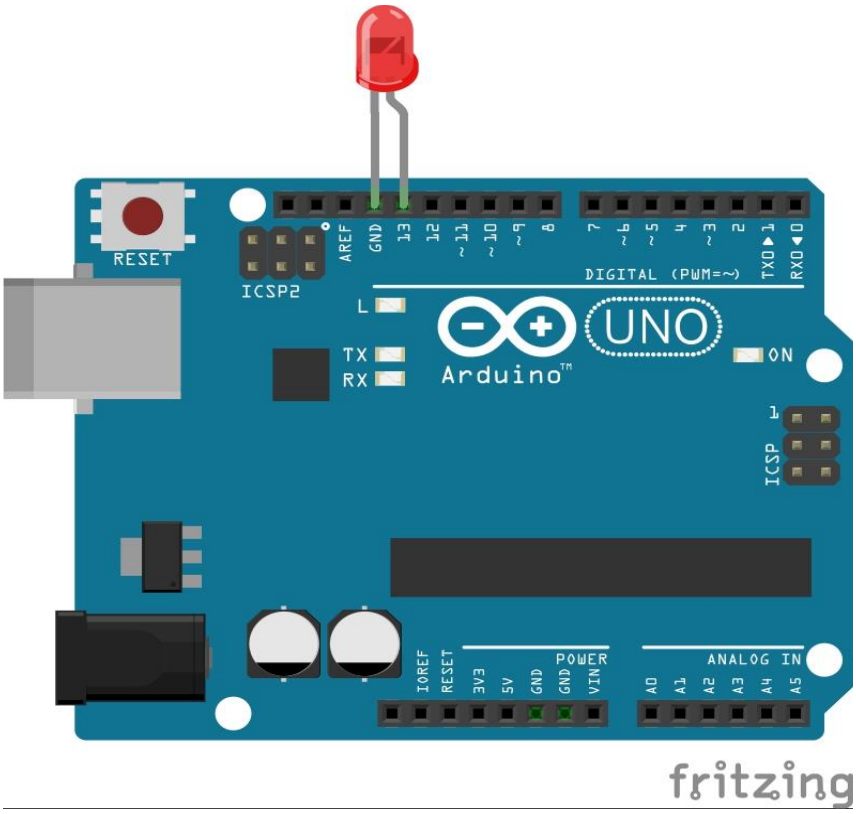

Figure 4.19: Testing a LED on the Arduino Board

For two or more LEDs to be interfaced on the single Arduino Board, an additional tool like a bread board in this context comes into play. The GND connection is denoted by a black wire, the VCC/5V/PWR is denoted with a red wire. The Longer leg of the LED is connected top the positive terminal of the power source of the breadboard. These positive terminals of the LEDs are connected to the digital pins of the Arduino board. The Arduino Circuit board will be providing the required current to make the LEDs glow. The shorter leg of the LED is the negative leg and is connected to the ground (GND) of the Arduino board. The three of the shorter negative legs of the LEDs are connected via a common wire of the breadboard, and this concept is known as common grounding. The basic idea behind this concept is that all the components in a circuit should have a common ground or reference for as correct operation.

After the assembling of the circuit, a sketch has been loaded into the Arduino Board to test the connection of the LEDs. It has been taken note of that no wire was connected to the pins Rx (pin D0) and Tx (pin D1) of the Arduino Board during the loading of the sketch. This is because the two pins are used internally as hardware serial lines, whilst the sketch is being loaded through the USB port into the Arduino's memory.

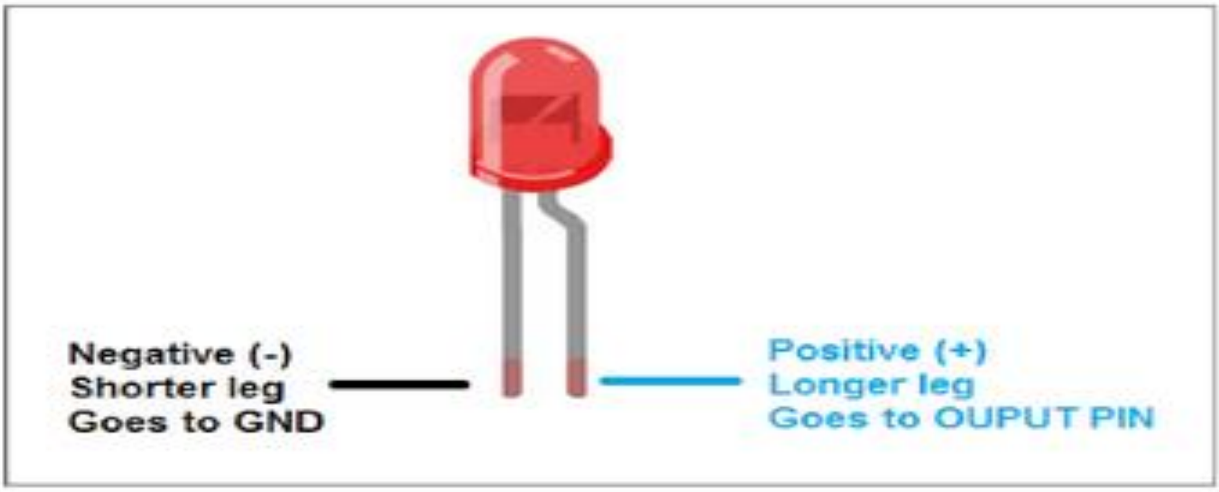

Figure 4.20: Red LED and its legs

According to Choudhuri (2017), a red LED is typically rated to work normally at 20mA, and it has a voltage drop of 1.4V across it. Thus, to calculate the adequate resistance to be employed here Ohm's law formula has been used, that states that:

Resistance = Voltage/Current.

Resistance = (Supply voltage – LED voltage drop)/Current

= (5V- 1.4V)/0.020amps

= 3.6V/0.020amps

= 180Ohms

= 220ohms to the nearest Standard Resistor Value

When receiving current from the Arduino pins (50mA source), the current should be reduced before it flows through the LED. This is important since it protects the LED from burning out.

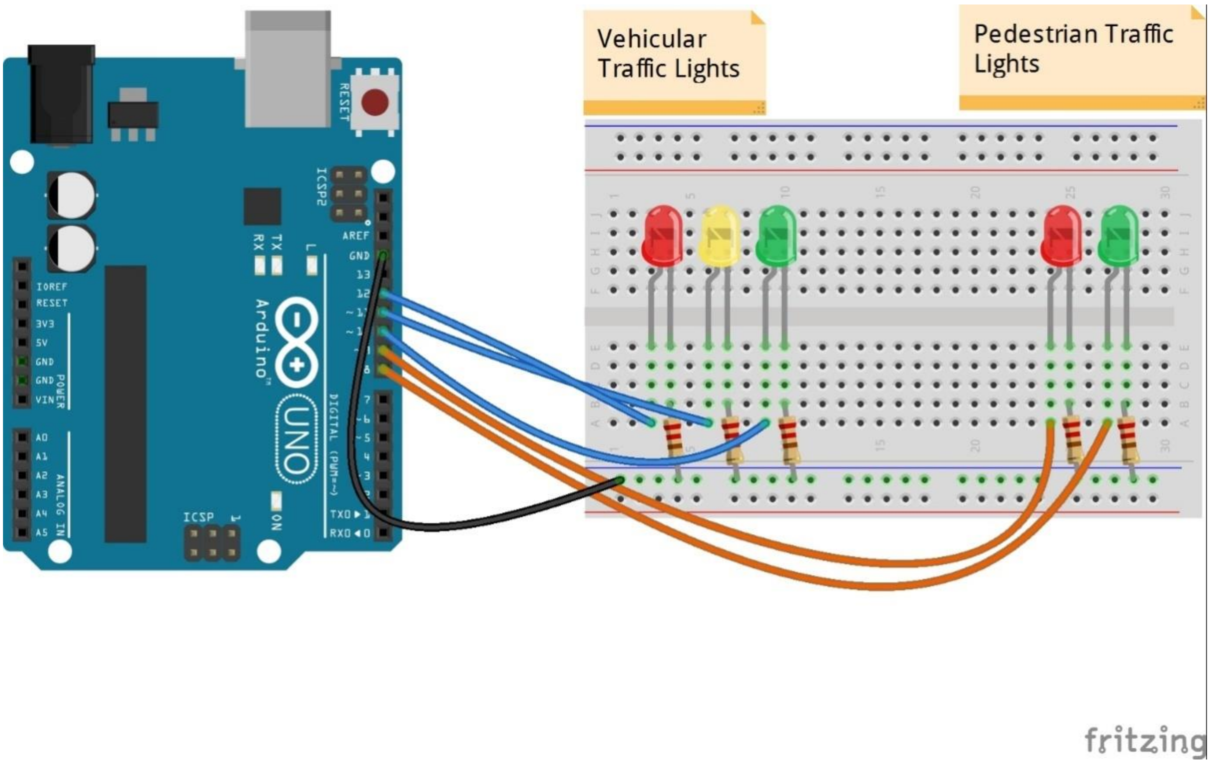

Figure 4.21: Physical representation of the Arduino to LEDs interfacing

The three LEDs in context are working as traffic lights and have the respective colour codes of the traffic lights; Red, Green, Amber. The red, yellow and green LEDs were connected to the Arduino digital pins 9,10, and 11 respectively. The connection details of the LEDs and the Arduino Uno circuit board are tabulated below:

Arduino Uno pin	LED pin(s)
Digital pin 9	+ve (longer) leg of the 1st LED
Digital pin 10	+ve (longer) leg of the 2nd LED
Digital pin 11	+ve (longer) leg of the 3rd LED
GND	-ve (shorter) legs of the 3 LEDs

Table 4.2: Pin connections of Arduino and LEDs

The schematic of the above circuit system is given below:

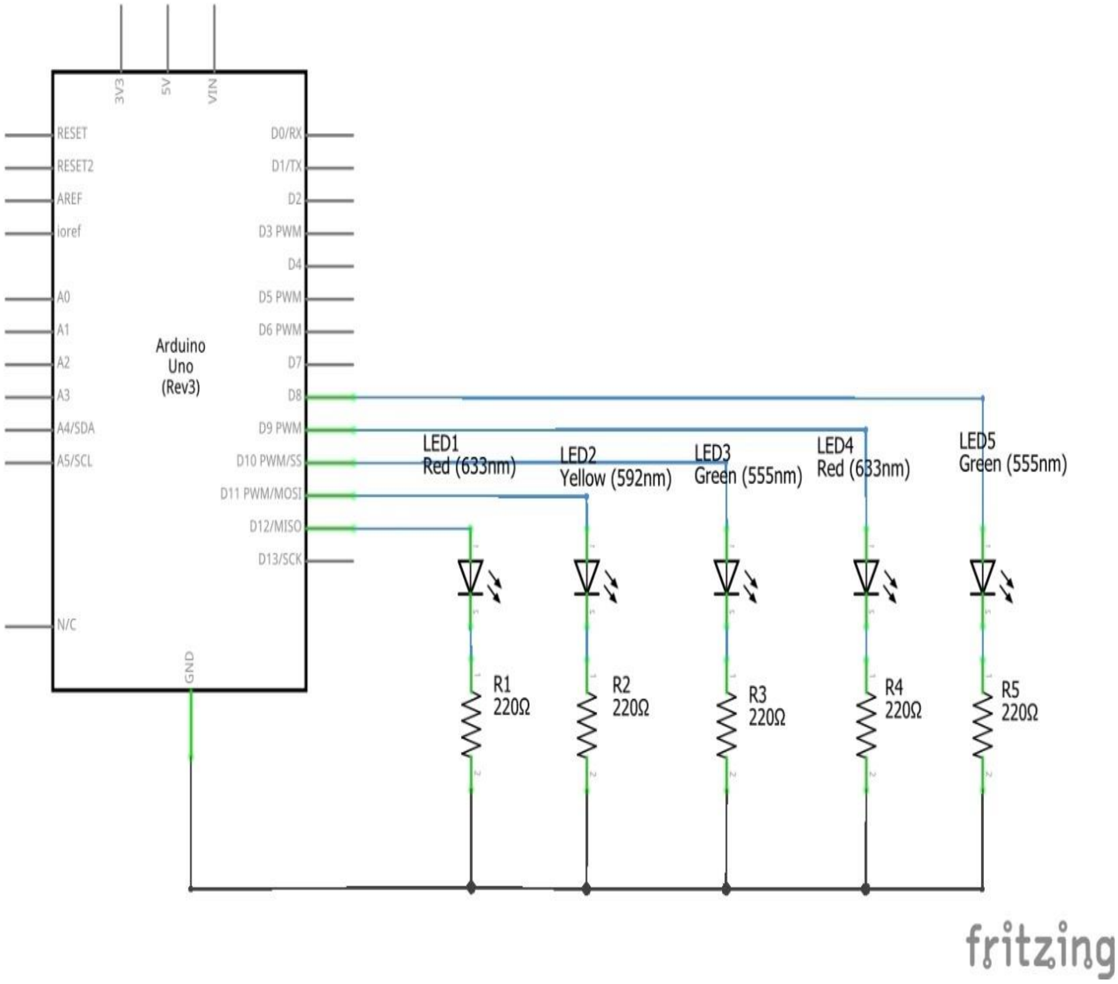

Figure 4.22: Schematics of the Arduino to LEDs

4.9 Interfacing camera with Arduino Uno

The camera system is used for surveillance and monitoring of the site for intrusion and danger. According to Landon (2015), miniaturized cameras that has serial communication interface has been launched into the market and these offers easier integration with the Arduino boards or any other microcontroller-based circuit boards. Basically, these cameras use their serial port to send setup commands, view taken images through appropriate bytes sequences.

Figure 4.23: LinkSprite Camera

It has a four-pin connector of which the two of them are for power supply (+5V and GND) and the other two for serial port (RX and TX). For the serial communication between the camera and the Arduino board, a software serial port has been chosen, which is mapped on the digital pin 2 and 3 of the Uno board.

The red wire (RXD) is connected to the Arduino digital pin 3, the brown wire (TXD) to the digital pin 2, the grey wire connected to the +5V signal and the violet wire connected to the GND.

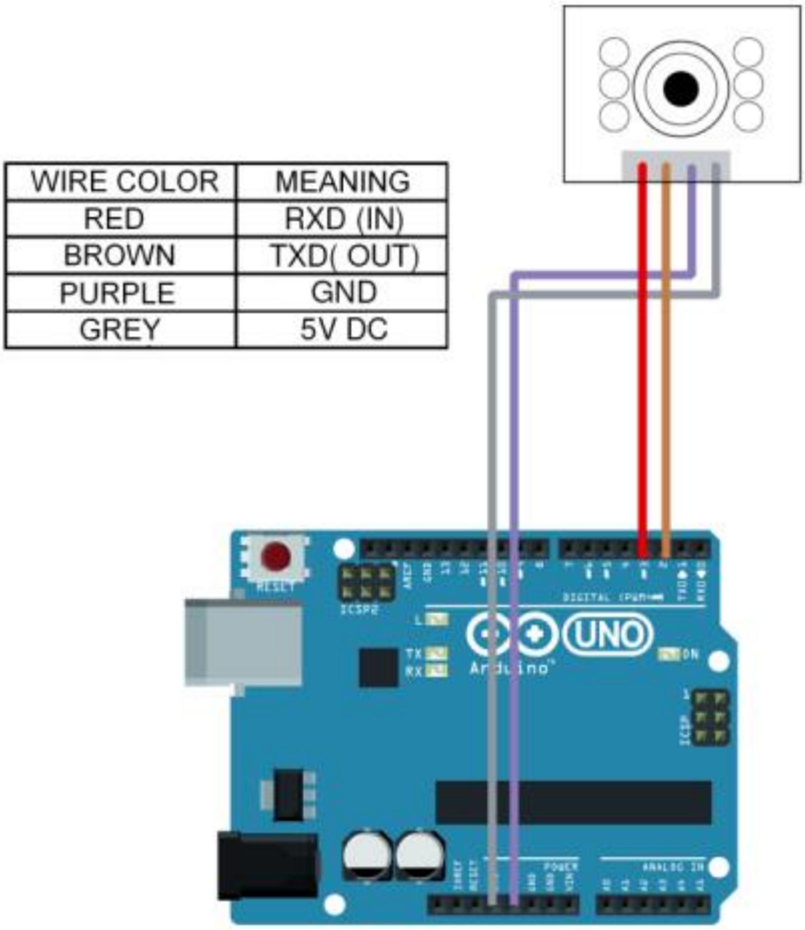

Figure 4.24: Block Diagram of the Arduino to Camera **connections**

4.10 Results and Analysis

A number of checks were made on the system to observe the results given by each parameter. Results were recorded as the Arduino microcontroller process instructions from each input sensor to the output sensors.

4.10.1 Intelligent Zebra Crossing Complete Setup

The components were interfaced with the Arduino Uno circuit board and the system tested against the objectives. The system functioned according to the requirements and the complete system setup is given as bellow:

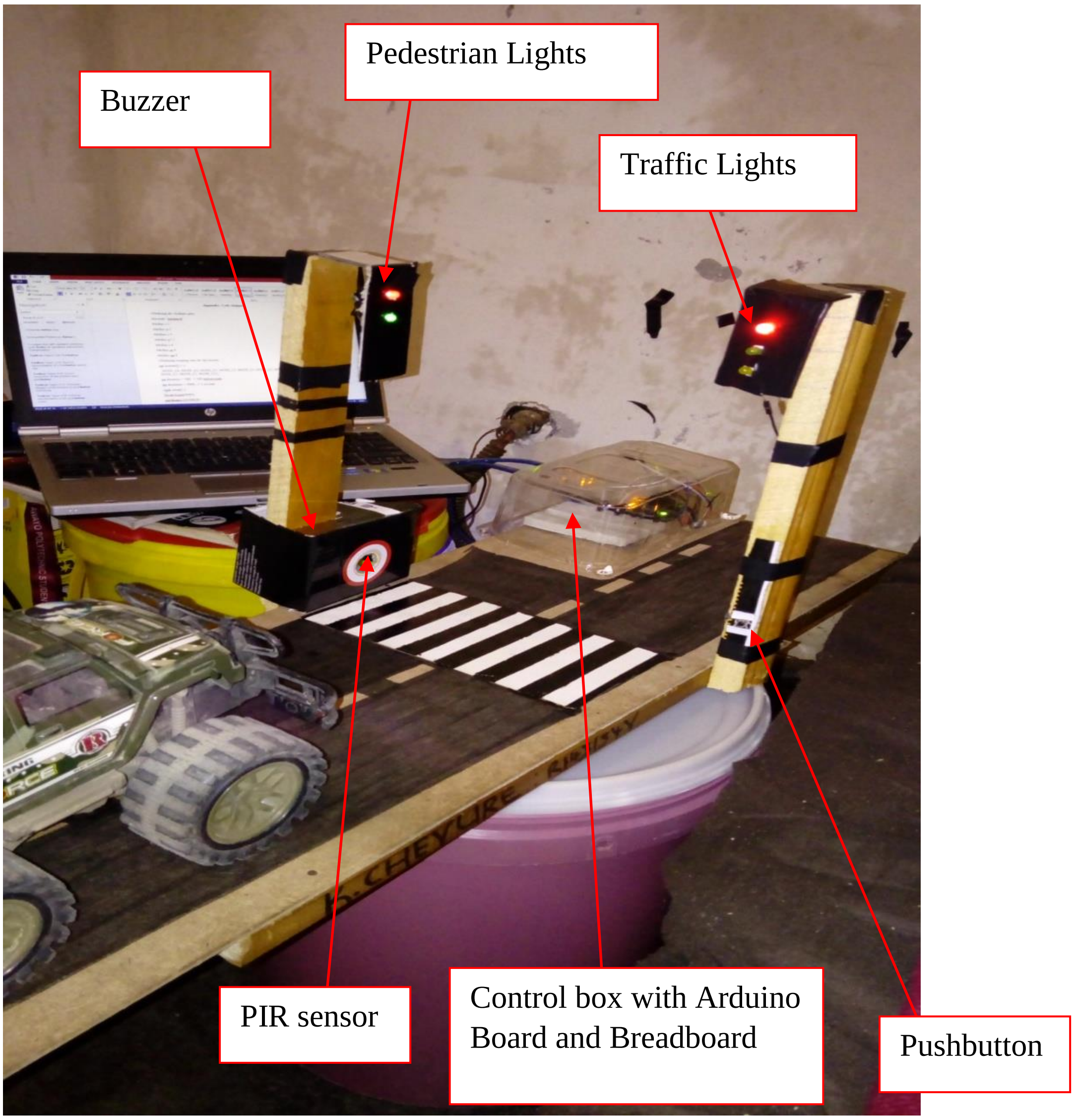

Figure 4.25: Intelligent Zebra Crossing Complete Setup

4.10.2 Intelligent Zebra Crossing Complete Schematic Diagram

The full system setup has been built according to the schematic diagrams that have been used on the integration of the Arduino Board and the system components. Some of the components like resistors were shared to minimize the costs and labor on the building of the setup. The three LEDs on the traffic lights shared one resistor and the two LEDs on the pedestrian side shared likewise. Separate schematic diagrams where finally compiled to form the complete circuit diagram of the actual system setup and the diagram is given below:

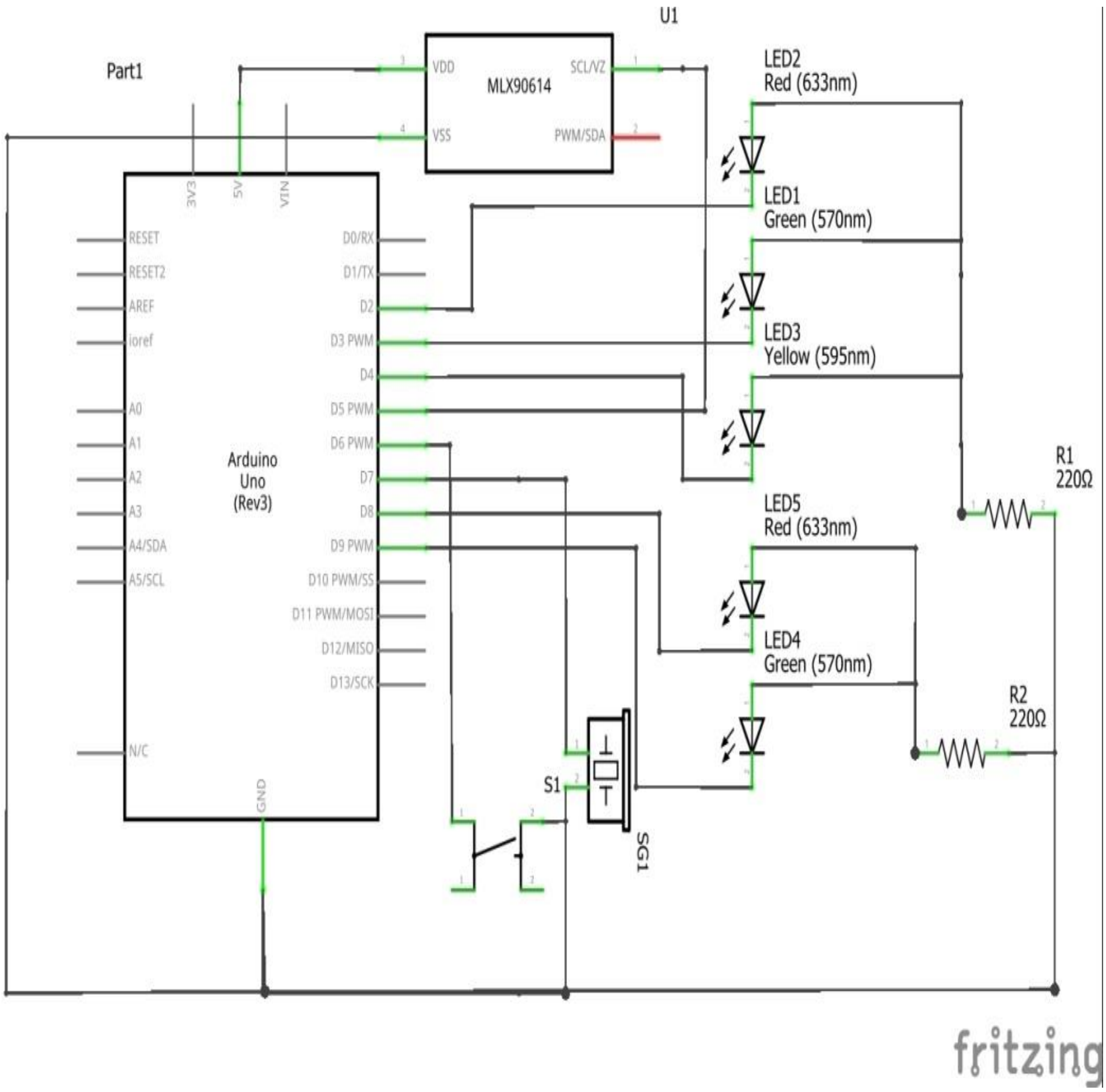

Figure 4.26: Intelligent Zebra Crossing Complete Schematic Diagram

4.11 Conclusion

The electronic designs of the Intelligent Zebra crossing were discussed in this chapter. Electronic designs, diagrams and schematic circuits were also made, analysed and presented as the physical setup of the system looks like. Interfacing of the physical components that made the system was discussed, and the pin setup noted.

CHAPTER FIVE

Conclusions and Recommendations

5.0 Introduction

In accordance to the project report at hand, all the objectives highlighted earlier have been accomplished. The project has combined the three main electronic parts; the hardware which is the electronic design, the software which is the programming part and the communication between the devices. The choice of modifying a zebra crossing as the subject to work on has been fulfilling since it has been an issue under full expansion with a promising future. This technology is in a constant expansion which covers the security and safety of every road user and grand users' comfort.

This chapter discusses the findings on the topic at hand and gives recommendations as per the area of further research. An overall conclusion is eventually provided as per the whole study.

5.1 Findings and Recommendations

As the objectives set to achieve the idea of the study were met, findings and recommendations were brought about as follows:

1) When a pedestrian approaches the detection, zone walking very slowly the system fails to detect. This issue is associated with the detection parameters of the type of the motion sensor used.
2) The obtained results after testing every component interfacing with the Arduino Uno has matched the theory, hence the system is feasible.
3) The buzzing sound produced after pressing the buzzer is not sufficient enough to be heard during noisy idling of the vehicles, hence the configuration of the buzzer needs to be reinforced some speakers.

5.2 Areas of Application

The Intelligent Zebra Crossing can be implemented in all roads in Zimbabwe, particularly at every section that a pedestrian crossing has been administered lately. This is to keep safe the lives of all pedestrians of Zimbabwe and as well enforce the vehicular traffic rule of observing the pedestrian crossing and giving the right of way to the pedestrian crossing a roadway.

5.3 Limitations of the system

1) The PIR sensor looks for temperature change for it to detect motion. If a pedestrian is slowly moving directly into the sensor's field of view, the sensor is likely to fail to detect that pedestrian since there is an insignificant temperature change that can be detected by the sensor.
2) The pushbutton is positioned where every pedestrian can access, hence suffers the abusive use and vandalism by naughty citizens, particularly children.
3) The intelligent zebra crossing systems can hardly be installed near each other on a roadway since traffic gem can occur during pic hours when both vehicular and pedestrian traffic will be high.
4) The camera module used in hardly robust, hence the system requires a lot of servicing and maintenance for its optimum functionality.

5.4 Recommendations

- The use of radar or electromagnetic detectors that measure the speed of oncoming vehicles is needed. These detectors project red signals from the road surface to enforce speed limit and stop the speeding vehicles at the pedestrian crossing.
- There should also be the use of countdown timers for the motorists and the pedestrians. These timers notify them on the remaining time left to be granted the right of way.
- A module that support C++ programming should be made available and confined to Arduino IDE only and this will aid future developers to improve the designs.
- The researcher also recommends that for any further studies or modifications on the intelligent zebra crossing, the camera system to be reinforced by at least a text sending facility that instantly notifies the police at the nearest station, per every intrusion by the vehicular traffic. This facility will reduce the delaying time taken by the authorities to attend to the scene; thus, the mobile clinic can be quickly summoned in case of pedestrian car crushes.
- The university also recommended to familiarize Arduino based projects at an earlier stage of the students' course. This will definitely help the scholars with some knowledge on basic functionalities of the Arduino and as well instil confidence in the scholars; thus, they will be able to tackle the interesting hardware project ideas without any hesitation.

- The university is also recommended to provide enough hardware components for such hardware-based projects. This encourages the students to bring brighter ideas and project topics.

5.5 Conclusion

A successful designing and implementation of the system has been done, outcomes weighed against the theoretical objectives and the satisfactory results were obtained. Analysis to the results was made and a few deviations from the actual expectation was found. However, the intelligent zebra crossing has been a success to the Zimbabwean road users since pedestrian safety and confidence on using the designated crossings has been a victory.

Appendix: Code Snippet

```
//Defining the Arduino pins
#include "pitches.h"
#define r 2
#define g 3
#define y 4
#define p1 5
#define s 6
#define pr 8
#define pg 9
//Defining beeping tone for the buzzer
int melody[] = {
  NOTE_C6, NOTE_C5, NOTE_C5, NOTE_C5, NOTE_C5, NOTE_C5, NOTE_C5,
NOTE_C5, NOTE_C5, NOTE_C5};
int duration = 500;  // 500 miliseconds
int durations = 1000;  // 1 second
void setup() {
Serial.begin(9600);
pinMode(r,OUTPUT);
pinMode(g,OUTPUT);
pinMode(y,OUTPUT);
pinMode(p1,INPUT);
pinMode(pr,OUTPUT);
pinMode(pg,OUTPUT);
pinMode(s,INPUT_PULLUP);
}
//Override button loop
void loop() {
  if(digitalRead(s)== LOW){
Serial.println("Pedestrian Button");
```

```
delay(1000);
digitalWrite(y,HIGH);
digitalWrite(g,LOW);
digitalWrite(pg,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
delay(1000);
digitalWrite(pg,LOW);
digitalWrite(pr,HIGH);
digitalWrite(r,HIGH);
digitalWrite(y,LOW);
delay(1000);
digitalWrite(y,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
digitalWrite(pg,HIGH);
delay(1000);
digitalWrite(y,LOW);
digitalWrite(r,HIGH);
digitalWrite(pr,HIGH);
digitalWrite(pg,LOW);
delay(1000);
digitalWrite(pg,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
digitalWrite(y,HIGH);
delay(1000);
digitalWrite(y,LOW);
digitalWrite(pr,HIGH);
digitalWrite(r,HIGH);
```

```
digitalWrite(pg,LOW);
delay(1000);
digitalWrite(pr,LOW);
digitalWrite(r,HIGH);
digitalWrite(pg,HIGH);
    for (int thisNote = 9; thisNote>=0; thisNote--) {
    // pin7 output the voice, every scale is 0.5 sencond
   // 10 seconds count down before activating the robot
tone(7, melody[thisNote], duration);
Serial.println(thisNote);
delay(1000);
  }
// Right of way to the traffic
digitalWrite(r,LOW);
digitalWrite(pg,LOW);
digitalWrite(pr,HIGH);
digitalWrite(g,HIGH);
delay(1000);
Serial.println("Cars Proceed");
delay(1000);
    }
//PIR sensor detection
if(digitalRead(p1) == HIGH){
Serial.println("Pedestrian Motion");
delay(1000);
digitalWrite(y,HIGH);
digitalWrite(g,LOW);
digitalWrite(pg,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
```

```
delay(1000);
digitalWrite(pg,LOW);
digitalWrite(pr,HIGH);
digitalWrite(r,HIGH);
digitalWrite(y,LOW);
delay(1000);
digitalWrite(y,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
digitalWrite(pg,HIGH);
delay(1000);
digitalWrite(y,LOW);
digitalWrite(r,HIGH);
digitalWrite(pr,HIGH);
digitalWrite(pg,LOW);
delay(1000);
digitalWrite(pg,HIGH);
digitalWrite(pr,LOW);
digitalWrite(r,LOW);
digitalWrite(y,HIGH);
delay(1000);
digitalWrite(y,LOW);
digitalWrite(pr,HIGH);
digitalWrite(r,HIGH);
digitalWrite(pg,LOW);
delay(1000);
digitalWrite(pr,LOW);
digitalWrite(r,HIGH);
digitalWrite(pg,HIGH);
for (int thisNote = 9; thisNote>=0; thisNote--) {
```

```
    // pin7 output the voice, every scale is 0.5 sencond
   // 10 seconds count down before activating the robot
tone(7, melody[thisNote], durations);
Serial.println(thisNote);
delay(1000);
  }
digitalWrite(r,LOW);
digitalWrite(pg,LOW);
digitalWrite(pr,HIGH);
digitalWrite(g,HIGH);
delay(1000);
Serial.println("Cars Proceed");
delay(1000);
    }
else{

Serial.println("******Do not Cross*****");
digitalWrite(g,HIGH);
digitalWrite(pr,HIGH);
digitalWrite(r,LOW);
digitalWrite(y,LOW);
delay(1000);
      }
}
```

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