DESIGN AND CONSTRUCTION
OF
AN AUTOMATIC SINGLE PHASE TRANSFER SWITCH

BY

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EEE/12/0839

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DEDICATION

This project is dedicated to God Almighty who has been faithful thus far in my academic pursuit and to my parents Mr. & Mrs. F.A Agbramu for their love, guidance, moral support and financial support.

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ABSTRACT

This project presents the design and construction of a microcontroller based **Automatic Transfer Switch** (ATS) for a single phase system. The ATS, which is based on a switch gear control system, gives a functional system that provides an automatic switching of power supply between a primary source (public utility) and a secondary power source (generator). The methods employed in designing the ATS involve the use of switching and power relays, Atmega8 microcontroller, diodes, resistors, L7805 voltage regulator, optocouplers, a buzzer alarm, NPN transistors, and an LCD which indicates which power source is available. The microcontroller [receives a regulated 5v DC from the 12v battery which is attached to the generator and with the aid of the optocoupler senses the public utility power supply to initiate the 30A power relay which is driven by a transistor to initiate output load. An interruption in the supply from the public utility initiates generator start up and this is achieved using switching relays driven by NPN transistors for the kick and start position of the secondary power supply (generator). This signal is sensed by the microcontroller through the optocoupler to initiate the 30A power relay which gives the output for loading, a failure in this operation initiates an alarm by the buzzer. This entire process when achieved is displayed on the liquefied crystal display. This project performs perfectly with a functional generator possessing an automatic choking system when tested.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Project

Automation is of great essence in the society today at large. This project is centered on the construction of an Automatic Transfer Switch designed to automate power flow in homes working on a single phase between a public utility source and a secondary source of supply usually the generating sets in our homes. This project majorly focuses on the average man on the quest to automate power in their homes.

The poor state of power supply in developing countries, calls for alternative sources of power generation and automation of electrical power generation to back up the utility supply. Over time, automation of electrical power supply has become vital as the rate of power outage is predominantly high and as a result of this power outage, developing countries like Nigeria, experience slow development processes in both the public and private sectors of their economy (Ahmed, Mohammed, & Agusiobo., 2006). This has led to a downward trend in the economy because a robust power supply infrastructure drives the industrial initiative of any viable clime. Automating the power supply process is imperative owing to the value chain it creates (Emerole, Ogbuu, Nwogu, & Ezennaka, 2015).

Investors from foreign lands do not feel secure to come and set up business or industries in the country despite the large market made available in such populated nations, because of frequent power failures experienced. Therefore, for this reason changeover or transfer switches were developed. Initially, these switches were designed for manual operations, but with an increase in the technological advancement of electrical power control and automation that, Automatic transfer switches (ATS) were created. It eliminates the element of manpower interaction in starting a generator and changing power supply from one source to another (Agbetuyi, Adewale, Ogunluyi, & Ogunleye, 2015).

An Automatic transfer switch (ATS) is an electrical/electronic switch that senses when the mains or public utility supply is interrupted and automatically starts up a secondary supply (i.e. a generator) if the utility remains unavailable. ATS also known as "Generator Transfer Switches, has an additional circuit component which is normally in the form of a computer that monitors the incoming power supply (Agbetuyi, Adewale, Ogunluyi, & Ogunleye, 2015). The main problems associated with manual switching mechanism are as follows: interrupted power supply, device damage due to frequent commutations, possible causes of fire outbreak due to switching sparks and frequent high maintenance cost due to changeover action and wear and tear of mechanical parts (Amuzuvi & Addo, 2015) and as a result of this, there is a call for automation in switching of load in the society today.

The background of this project lies on the discomfort that power outage brings to our homes, offices and loss of revenue due to down time in the industries. The depreciation caused by such instability reduces efficiency of the organization and leads to a great deal of frustration. Sequel to the rate at which more sophisticated electrical/electronic gadgets are being procured and installed in our homes, hospitals and business premises, there is a justifiable need for a faster and more reliable transfer system in the event of power outage. This Power transfer switch is a device that detects when the electrical energy from the mains power supply is cut off and subsequently switches on the power generator. Basically it is aimed at switching on a more convenient power supply to the load because of its automation and as such the requirement of physical presence is not mandatory in its operation. Since it switches on power to the load, precautions have to be taken while choosing the type of transfer switch of power generators to supply electrical energy that would power their homes whenever the supply from the electricity company is cut off. A transfer switch enables this operation (Jonathan, 2007).

The project implements an automatic switching or starting of the power generator whenever the main power fails (Jonathan, 2007), with the design taking into consideration both real and practical situations and for this purpose, a prototype is developed to automatically transfer power supply back to the mains supply and initiate generator shutdown moments after the mains supply has been restored and initiate generator startup when the power from the mains supply is lost with high efficiency.

The purpose of this device is to maintain constant supply to the loads that is being supplied by eliminating time delay that usually accompanies manual switching from one source to another wherever continuity of supply is necessary. The switching between the mains supply and the generator occurs in milliseconds. The design and construction of an automatic transfer switch would solve the problem of manpower and the danger likely to be encountered in load transfer. The optocoupler serves as a monitoring or sensing mechanism that detects voltage and triggers the microcontroller process in the allocation of load, if the mains supply is off the generator automatically comes on and load is transferred back to the house. Also, if the mains supply comes back on the load switches from the generator to the mains supply and this initiates generator shutdown.

1.2 Statement of the Problem

Appliances and sensitive equipment get damaged due to the power failure often experienced in our society today. In our domestic homes in Nigeria today there exists disruption in the power supplied and this could result in loss of work if there is no source to give back the lost power from the public utility and also any immediate power supply of a very high voltage may end up damaging our household appliances, we are also faced with the problem of laziness as well as theft.

Also, the electric power generated by utility supply authority in developing countries is inadequate to meet the demands of their customers; thus, power instability and outage are very frequent. Since most industrial and commercial applications depend on electricity, many investors do not feel secure to come and set up businesses in the country. Consequently, this limits the industrial growth in the country.

The project "***an automatic transfer switch***" would help to cater for power automation as it would initiate an automatic startup of the secondary utility source when there is loss of power thereby putting an end to time wastage and creating revenue.

1.3 Motivation

Power failure is predominantly high in the society we find ourselves today and as a result, there exists blackout when there is loss of power. I was motivated to build this project in the course of my industrial training, during this period the plant I worked with had power related problems and this stopped productivity for months and led to loss in business as no revenue was generated during this period. The work force was also reduced because they could no longer cater for all the workers on site.

I deemed it necessary to build this automatic transfer switch for a single phase system so that an average man in the society can effectively and efficiently automate power processes in domestic homes, and it can also be applied for industrial purposes. This project is of great relevance and is required by people in the society due to the benefits it offers. This includes;

i. Increase in productivity,
ii. Increase in revenue,
iii. Reduces time wastage,
iv. Eliminates complete power failure,
v. Cost effectiveness, and
vi. Provision of comfort in homes

1.4 Project aim and objectives

The aim of this project is to design and construct an automatic single phase transfer switch for an average man in the society.

The objectives of this project are to:

i) Design a system that senses mains supply and a secondary supply source initiating a transfer when anomaly is detected.
ii) Implement the designed automatic transfer switch system on a hardware prototype.
iii) Evaluate the performance of the developed automatic transfer switch system.

1.5 Scope of the project

The scope employed in the design and construction of the automatic transfer switch took into consideration the hardware design (designing, testing and modeling). This covers the AC and DC power supply unit, relay switching and loading unit, display and indicating unit, and the microcontroller unit. These units work in harmony to help in automating power between a primary and a secondary supply source.

1.6 Project Organization

Chapter one presents the introduction of this project work. The rest of this work is organized as follows: Chapter two reviews the current related literature to the work, while Chapter three describes the methodological approaches and design specifications. Chapter four presents simulation results and analysis, followed by Conclusion, Recommendations, Limitations, and Future work directions in Chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The Automatic transfer switch, automatically switches over to the alternative source of power supply (generator) when there is a power outage. It equally switches over to the mains supply when power is restored and turns off the generator automatically. This automatic power change-over switch links the load and mains supply or the alternative supply together. This enables the use of either the mains supply or an alternative source when there is outage on the mains source. This can either come in with three phase or single phase. This device maintains constant power supply to the load by automatically activating the generator when there is need. (Ezema, Peter, & Harris, 2012).

Ahmed, Mohammed, & Agusiobo (2006) identified power instability calling for a need for automation. This automation is required as the rate of power outage is really high and most industrial and commercial processes are dependent on power supply and if change-over process is manual, the downtime created would incur great loss. They designed a system with automatic phase change-over switch that switches electrical power supply from public supply to generator in the event of a power outage or insufficient voltage. Jonathan (2007) later designed a prototype on an automatic power changeover switch with basic operation of switching using a relays and transistors for this purpose.

In 2008, a Malaysian scholar thought of incorporating solar energy as an alternative power supply source due to the rise in the price of fuel. Sunlight presence in nature as a limitation to this research, his thesis presented a way to keep 12V battery device powered by solar power to get the continuous power required, he called his an "Automatic main failure system" which can automatically switch from solar to battery making use of a voltage sensor, microcontroller and a relay switch (Alwi, 2008).

Ezema, Peter, & Harris (2012) developed an automatic transfer switch with generator control mechanism while Lanre & Rasheed (2014) worked on the development of a low cost automatic transfer switch with an over voltage protection.

In 2015, there was an increase in the publication and development of automatic transfer switch. Amuzuvi & Addo (2015) worked on the unreliable nature of electric power supply which has given rise to the excessive increase in the use of generators, they developed a microcontroller based automatic transfer switching system which eliminates the challenges of a manual changeover system, they made use of the PIC6F877A microcontroller in incorporating the peripheral devices used in achieving this and the delay was 20 seconds which would create a lag.

Agbetuyi, Adewale, Ogunluyi, & Ogunleye (2015) teamed up to work on an automatic transfer switch for a single phase power generator, they employed the use of electromechanical relays as the main component, a digital multimeter, a precision rectifier unit, current transformer and a PIC16f877 which aided in converting the measured alternating current (AC).

Obasi, Olufemi, John, Ibiam, & Ubadike (2015) worked on the design and implementation of a microcontroller based programmable power changeover, their work possessed the auto mode, manual mode and timed mode of operation and this was achieved with the use of 8051 microcontroller. Similarly, Emerole, Ogbuu, Nwogu, & Ezennaka, (2015) worked on a microcontroller based power changeover switching system with generator shutdown, this device possessed relative advantage of high switching speed, analogue voltage meter displaying on a seven segment display using a PIC16F873A microcontroller to achieve this goal.

Osaretin, Ibhadode, & Igbinovia (2016) in their work identified the pertinent problem faced in the society today due to the instability in power supply and thought of the need for alternative sources of power to enable the switching of load between two or more sources. The automatic changeover eliminates the need for manual or human intervention by sensing mains supply and switching to an available source. Automation eliminates the delay and the cost of inefficiency associated with manual operation. The device automatically switches between the power sources and also indicates if utility power is restored when an alternative power is in use. They designed a system that automatically changes over with step loading for renewable energy systems with the aid of an 8052 microcontroller.

This project is also centered on the previous research works shown but with better modifications. The use of Atmega8 which has better advantages as a microcontroller was used in the process of developing this project which possesses higher switching speed compared to that of Emerole, Ogbuu, Nwogu, & Ezennaka (2015) in its application, the lag of 20 seconds before loading in Amuzuvi & Addo (2015) has been catered for, the use of timing delay units as seen in the work of Lanre & Rasheed (2014) was taken care of by the microcontroller. This project designed, automatically switches on or off a secondary source of supply which is the generator in the presence or absence of the public utility supply. This design has so many advantages over other published works in terms of cost, complexity in design, material availability and most importantly the fact that it works on a single phase system though Ahmed, Mohammed, & Agusiobo (2006) and Agbetuyi, Adewale, Ogunluyi, & Ogunleye (2015) worked on a single phase but this project is focused on the average man in the society on the quest for power stability, this project possesses better functionality to the afore mentioned.

2.2 Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor, memory, and programmable input/output peripherals. Program memory is also included on chip and a small amount of RAM. Microcontrollers are designed for embedded applications (Bhupesh Aneja et al., 2011).

A microcontroller already contains all components which allow it to operate standalone, and it has been designed in particular for monitoring and/or control tasks. In consequence, in addition to the processor it includes memory, various interface controllers, one or more timers, an interrupt controller, and last but definitely not least general purpose I/O pins which allow it to directly interface with its environment. Microcontrollers also include bit operations which allow you to change one bit within a byte without touching the other bits. Today, microcontroller production counts are in the billions per year, and the controllers are integrated into many appliances we have grown used to, (Gridling & Weiss, 2007)

I. Household appliances.

II. Telecommunication.

III. Automotive industry.

IV. Aerospace industry.

V. Industrial automation.

The basic internal designs of microcontrollers are pretty similar. The figure below shows the block diagram of a typical microcontroller. All components are connected via an internal bus and are all integrated on one chip. The modules are connected to the outside world via I/O pins.

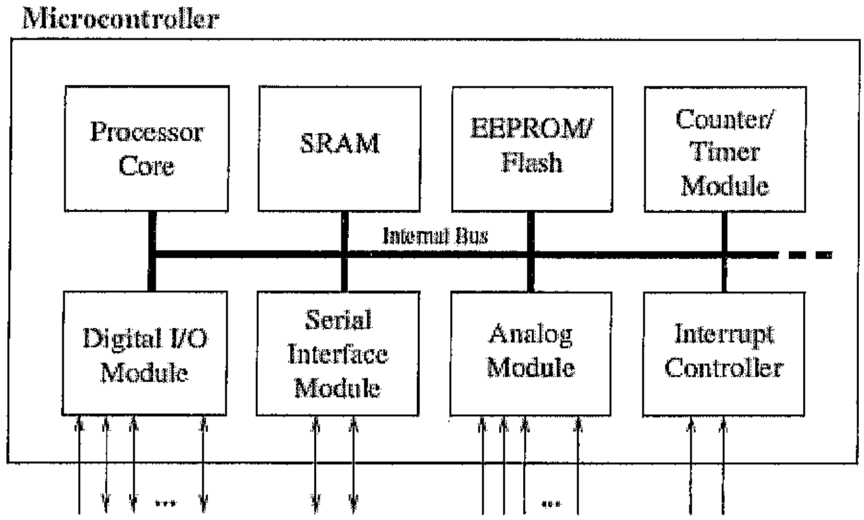

Fig 2.1.1 Basic layout of a microcontroller (Gridling & Weiss, 2007)

1. **Processor Core:** The CPU of the controller. It contains the arithmetic logic unit, the control unit, and the registers.

2. **Memory:** The memory is sometimes split into program memory and data memory. In larger controllers, a DMA controller handles data transfers between peripheral components and the memory.

3. **Interrupt Controller:** Interrupts are useful for interrupting the normal program flow in case of external or internal events. In conjunction with sleep modes, they help to conserve power.

4. **Timer/Counter:** Most controllers have at least one and more likely 2-3 Timer/Counters, which can be used to timestamp events, measure intervals, or count events. Many controllers also contain PWM (pulse width modulation) outputs, which

can be used to drive motors or for safe breaking (antilock brake system, ABS). Furthermore the PWM output can, in conjunction with an external filter, be used to realize a cheap digital/analog converter.

5. **Digital I/O:** Parallel digital I/O ports are one of the main features of microcontrollers. The number of I/O pins varies from 3-4 to over 90, depending on the controller family and the controller type.
6. **Analog I/O:** Apart from a few small controllers, most microcontrollers have integrated analog/digital converters, which differ in the number of channels (2-16) and their resolution (8-12 bits). The analog module also generally features an analog comparator. In some cases, the microcontroller includes digital/analog converters.
7. **Interfaces:** Controllers generally have at least one serial interface which can be used to download the program and for communication with the development PC in general. (Gridling & Weiss, 2007)

2.3 ATMEGA8 Microcontroller

The ATmega8 MCU is an AVR MCU family and it is a low-power CMOS 8bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves through ports approaching 1 MIPS per MHz, allowing the system designer optimize power consumption versus processing speed. The basic features of the ATmega8 MCU include:

1. High-performance and Low-power,
2. Advanced RISC Architecture,
3. High Endurance Non-volatile Memory segments,
4. 32 x 8 general purpose working registers,

5. It addressed 512 bytes of EEPROM and 1k byte of SRAM.

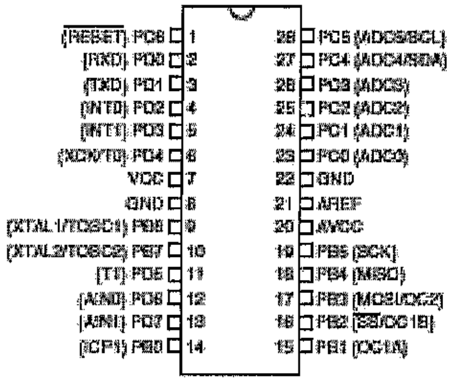

Fig 2.3.1 Pin Configuration (Atmel, 2013)

2.4 Pin Descriptions

I. **VCC:** Digital supply voltage.

II. **GND:** Ground.

III. **Port B (PB7...PB0) XTAL1/XTAL2/TOSC1/TOSC2:** Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit. Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier. If the Internal Calibrated RC Oscillator is used as chip clock source, PB7...6 is used as TOSC2...1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

IV. **Port C (PC5...PC0):** Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

V. **PC6/RESET:** If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL fuse is not programmed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running.

VI. **Port D (PD7...PD0):** Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

VII. **RESET:** Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running.

VIII. AV_{CC} is the supply voltage pin for the A/D Converter, Port C (3...0), and ADC (7...6). It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter. Note that Port C (5...4) use digital supply voltage, V_{CC}.

IX. **AREF:** AREF is the analog reference pin for the A/D Converter.

X. **ADC7...6 (TQFP and QFN/MLF Package Only):** In the TQFP and QFN/MLF package, ADC7...6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels. (Atmel, 2013).

2.5 Pin Configuration

I. **Pin -1** is the RST (Reset) pin and applying a low level signal for a time longer than the minimum pulse length will produce a RESET.

II. **Pin-2 and Pin-3** are used for serial communication

III. **Pin-4 and pin-5** are used as an external interrupt. One of them will activate when an interrupt flag bit of the status register is set and the other will activate as long as the intrude condition succeeds.

IV. **Pin-9 & pin-10** are used as timer counters oscillators as well as an external oscillator where the crystal is associated directly with the two pins. Pin-10 is used for low-frequency crystal oscillator or crystal oscillator. If the internal adjusted RC oscillator is used as the CLK source & the asynchronous timer is allowed, these pins can be utilized as a timer oscillator pin.

V. **Pin-19** is used as a Master CLK o/p, slave CLK i/p for the SPI-channel.

VI. **Pin-18** is used as Master CLK i/p, slave CLK o/p.

VII. **Pin-17** is used as Master data o/p, slave data i/p for the SPI-channel. It is used as an i/p when empowered by a slave & is bidirectional when allowed by the master. This pin can also be utilized as an o/p compare with match o/p, which helps as an external o/p for the timer/counter.

VIII. **Pin-16** is used as a slave choice i/p. It can also be used as a timer or counter1 comparatively by arranging the PB2-pin as an o/p.

IX. **Pin-15** can be used as an external o/p of the timer or counter compare match A.

X. **Pin-23 to Pins-28** have used for ADC (digital value of analog input) channels. Pin-27 can also be used as a serial interface CLK & pin-28 can be used as a serial interface data

XI. **Pin-12 and pin-13** are used as an Analog Comparator.

XII. **Pin-6 and pin-11** are used as timer/counter sources. (Agarwal, Elprocus, 2015)

2.6 ATMEGA Architecture

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 are directly connected to the ALU, allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ATmega8 internal architecture block diagram is represented in Figure 2.6.1

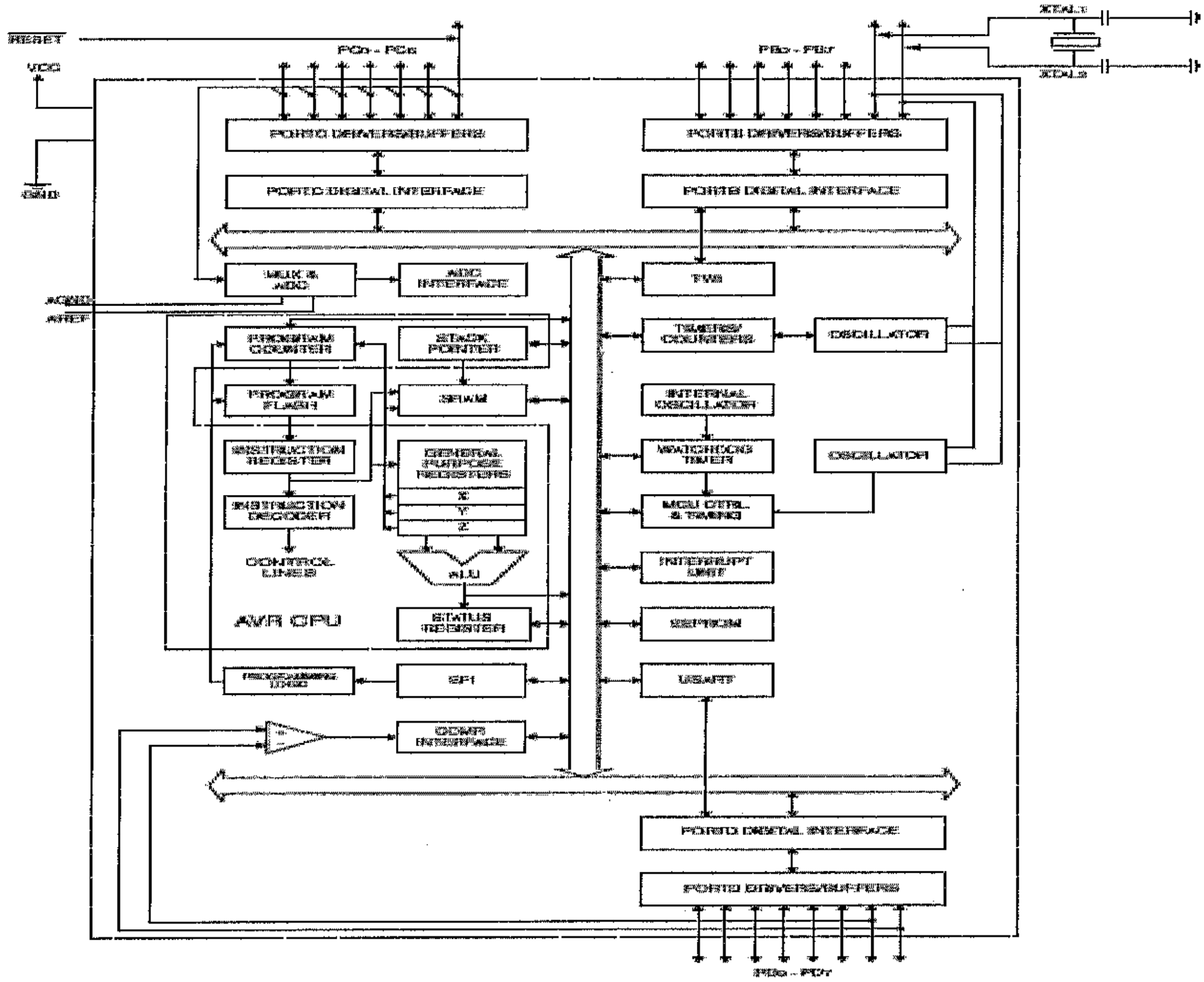

Fig 2.6.1 Internal Architecture Block Diagram (Atmel, 2013)

2.7 Optocoupler

An optocoupler is an optical link and it connects two circuits via this link. The optical link is contained within a chip. An optocoupler is a component that transfers electrical signals between two isolated circuits by using light. A light emitting diode inside the chip shines on a photo-diode, photo-transistor or other photo device. When the photo devices see illumination, the resistance between the terminals reduces. This reduced resistance can activate another circuit. (Bharadwaj, 2016).

Optocoupler packages include but are not limited to; dual-in-line, surface-mount, and ball-grid. The optocoupler application or function in the circuit is to:

1. Monitor high voltage.
2. Output voltage sampling for regulation.
3. System control micro for power ON/OFF.
4. Ground isolation (Tarun, 2015).

Mode of operation

An optocoupler contains a source of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel, and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photoresistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a triac.

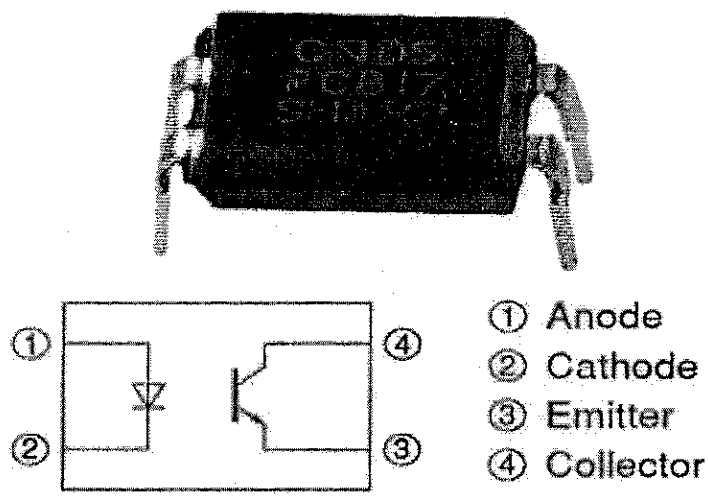

Fig 2.7.1 A PC817 Optocoupler (Nerokas, 2016)

2.8 Diode

A diode is an electrical device allowing current to move through it in one direction with far greater ease than in the other. The most common kind of diode in modern circuit design is the semiconductor diode, although other diode technologies exist.

Semiconductor diodes are symbolized in schematic diagrams such as Figure below. The term "diode" is customarily reserved for small signal devices, $I \leq 1$ A. The term rectifier is used for power devices, $I > 1$ A. Diodes are often used as rectifiers (EEtech, 2016).

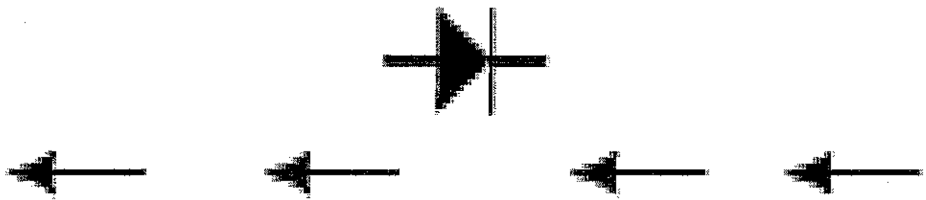

Fig 2.8.1 Semiconductor diode schematic symbol and arrows indicate the direction of electron current flow (EEtech, 2016).

The diode equation is given by;

$$\mathbf{I_D} = \mathbf{I_S}(e^{\frac{qV_D}{Nkt}} - \mathbf{1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where,

I_D = Diode current in amps

Is = Saturation current in amps (typically 1 x 10^{-12})

e = Euler's constant (~ 2.718281828)

q = charge of electron (1.6 x 10^{-19} coulombs)

V_D = Voltage applied across diode in volts

N = "Nonideality" or "emission" coefficient (typically between 1 and 2)

k = Boltzmann's constant (1.38 x 10^{-23})

T = Junction temperature in Kelvins

When placed in a simple battery-lamp circuit, the diode will either allow or prevent current through the lamp, depending on the polarity of the applied voltage. (Figure 2.8.2 below)

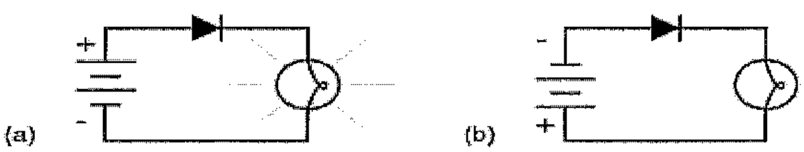

Fig 2.8.2 Diode operation: (a) Current flow is permitted; the diode is forward biased.

(b) Current flow is prohibited; the diode is reversed biased. (EEtech, 2016)

Rectification is the process of converting an A.C voltage into pulsating D.C voltage. The circuit responsible for rectification is known as a rectifier circuit. Rectification can be achieved by connecting semiconductor diodes in the order shown in Fig which shows a full wave rectification.

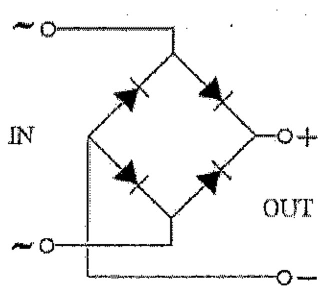

Fig 2.8.3 Full wave rectifier (EEtech, 2016)

2.9 Capacitor

A capacitor is a passive element designed to store energy in its electric field. Capacitors are used extensively in electronics, communications, computers, and power systems they are used in the tuning circuits of radio receivers, in filtering circuits and as dynamic memory elements in computer systems.

A capacitor consists of two conducting plates separated by an insulator (or dielectric). Capacitance is the ratio of the charge on one plate of a capacitor to the voltage difference between the two plates, measured in farads (F). The capacitance of a capacitor is given by;

$$C = \frac{\epsilon A}{d} \dots\dots\dots\dots\dots\dots \text{(2)}$$

Where

C- Capacitance of the capacitor,

A - Is the surface area of each plate,

d - Is the distance between the plates, and

$\mathcal{E}$ -is the permittivity of the dielectric material between the plates. (Alexander & Sadiku, 2012)

2.10 Resistor

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators (Harder, 2014).

The resistivity of a material is an intrinsic property indicating how resistive a material is to the flow of electrical current. This is given as

$$R = \frac{\rho l}{A} \text{.......................} (3)$$

R is the electrical resistance of the material.

l is the length of the piece of material

A is the cross-sectional area of the material.

ρ is the resistivity of the material.

2.11 Buzzer

A buzzer also called a beeper, is an audio signaling device which may be mechanical, electromechanical or piezoelectric. The piezoelectric type is used for this project, typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input. Buzzer is an integrated structure of electronic transducers with DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronic equipment, telephones, timers and other electronic products for sound devices. Active buzzer 5v rated power can be directly connected to a continuous sound, this section dedicated sensor expansion module and the board in combination, can complete a simple circuit design, to "plug and play."

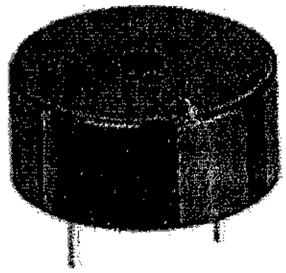

Fig 2.11.1 A Buzzer (Shallowsky, 2016)

2.12 Liquid Crystal Display

A **liquid-crystal display (LCD)** is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.

LCD (liquid crystal display) is the technology used for displays in notebook and other smaller computers. Like light-emitting diode (LED) and gas-plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it (Rouse, 2015; Lampa, 2016). LCD screen is an electronic display module and has a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters, animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD (Xiamen, 2008). The data is the ASCII value of the character to be displayed on the LCD. A typical LCD is shown in figure 2.12.1

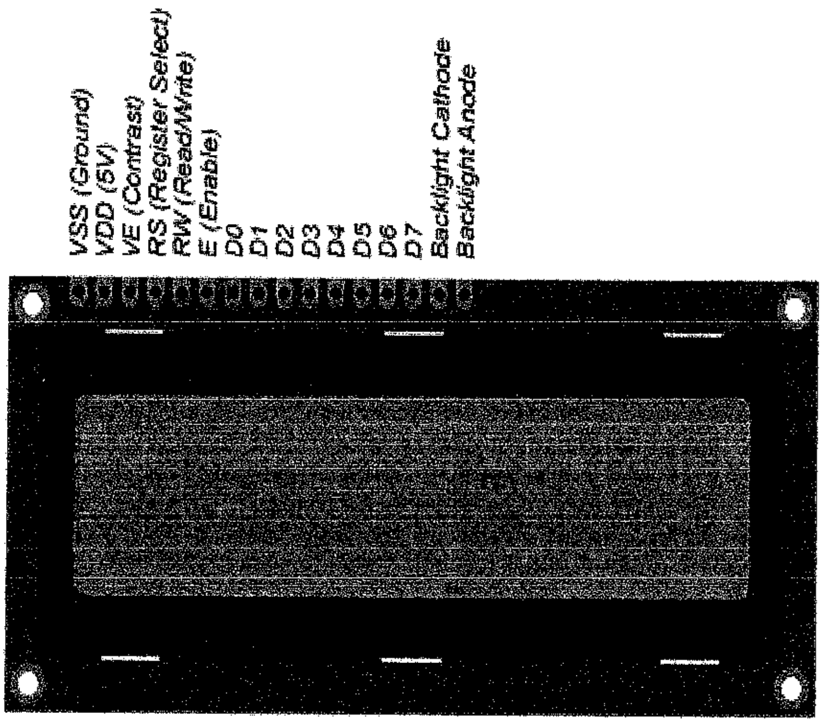

Fig 2.12.1 An LCD (Electronicsforu, 2016)

Features

I. 5 x 8 dots with cursor

II. Built-in controller.

III. + 5V power supply.

IV. 1/16 duty cycle (Electronicsforu, 2016)

Pin Description

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor such as a potentiometer.	V_{EE}
4	Selects command register when low; and data register when high	RS (Register Select)
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8- bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight Vcc (5V)	Led +
16	Backlight Ground (0V)	Led -

2.13 Transistor

A **transistor** is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals.

Transistor is an active component and that is establishing in all over electronic circuits. They are used as amplifiers and switching apparatus. As amplifiers, they are used in high and low level, frequency stages, oscillators, modulators, detectors and in any circuit needed to perform a function. In digital circuits they are used as switches (Agarwal, Elprocus, 2015).

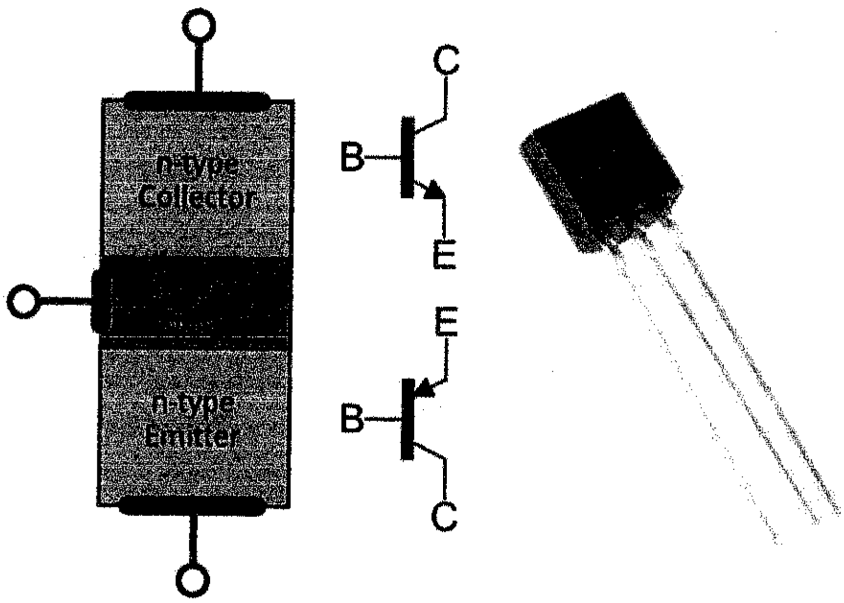

Fig 2.13.1 BJT 2N222A NPN transistor (Jimbo, 2016)

Types of basic transistors

1. **Bi-polar junction (BJT):** BJT's are transistors which are built up of 3 regions, the base, the collector, and the emitter. A small current entering in the base region of the transistor causes a much larger current flow from the emitter to the collector region. Bipolar junction transistors come in two major types, NPN and PNP. A NPN transistor is one in which the majority current carrier are electrons. Electron flowing from the emitter to the collector forms the base of the majority of current flow through the transistor. The further types of charge, holes, are a minority. PNP transistors are the opposite. In PNP transistors, the majority current carrier is holes.
2. **Field Effect Transistor (FET)**: FET's are made up of 3 regions, a gate, a source, and a drain. A voltage placed at the gate controls current flow from the source to the drain of the transistor. Field Effect transistors have a very high input impedance, from several mega ohms (MΩ) of resistance to much, much larger values. This high input impedance causes them to have very little current run through them (Agarwal, Elprocus, 2015)

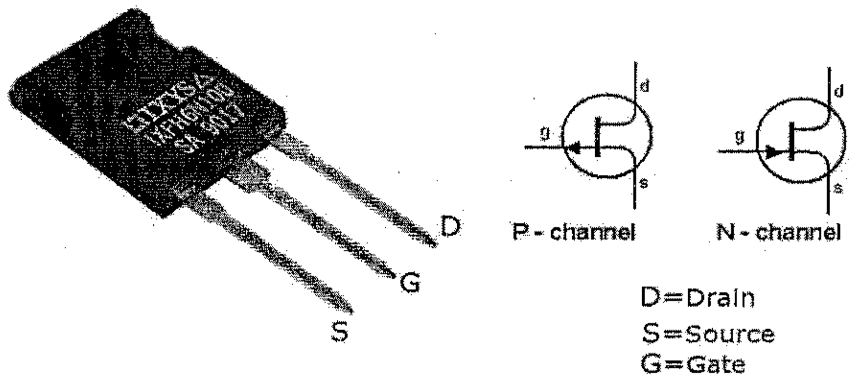

Fig 2.13.2 Field Effect Transistor (Agarwal, Elprocus, 2015)

Transistor Action

The emitter-base junction of a transistor is forward biased whereas collector-base junction is reverse biased. If we ignore the presence of emitter-base junction, then practically, no current would flow in the collector circuit because of the reverse bias. However, if the emitter-base junction is also present, then forward bias on it causes the emitter current to flow. It is seen that this emitter current almost entirely flows in the collector circuit. Therefore, the current in the collector circuit depends upon the emitter current (Chand & Mehta, 2016).

PNP TRANSISTOR

The circuit below is a connection of PNP transistor with supply voltages. The base terminal has negative bias with respect to emitter and the emitter terminal has positive bias voltage with respect to both base and collector because of PNP transistor.

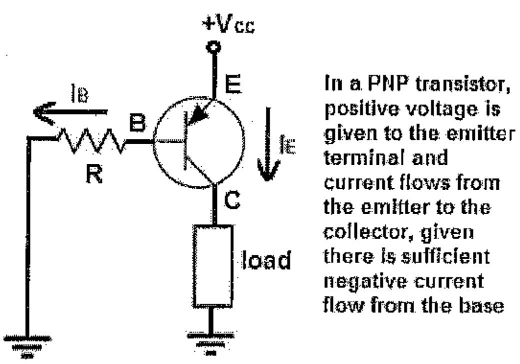

Fig 2.13.3 PNP Configuration Circuit (Administrator, Electronicshub, 2015)

The polarities and current directions are reversed here compared to NPN transistor. If the transistor is connected to all the voltage sources then the base current flows through the transistor but here the base voltage needs to be more negative with respect to the emitter to operate transistor. The base- emitter junction acts as a diode. The small amount of current in the base controls the flowing of large current through emitter to collector region. The base voltage is generally 0.7V for Silicon and 0.3V for Germanium devices. The base terminal acts as input and the emitter- collector region acts as output. The supply voltage V_{CC} is connected to the emitter terminal and a load resistor (R_L) is connected to the collector terminal. This load resistor (R_L) is used to limit the maximum current flow through the device. One more resistor (R_B) is connected to the base terminal which is used to limit the maximum current flow through the base terminal and also a negative voltage is applied to the base terminal. The collector current is always equal to the subtraction of base current from emitter current (Administrator, Electronicshub, 2015).

NPN TRANSISTOR

NPN transistor circuit with supply voltages and resistive loads. The collector terminal is always connected to the positive voltage, the emitter terminal is connected to the negative supply and the base terminal controls the ON/OFF states of transistor depending on the voltage applied to it.

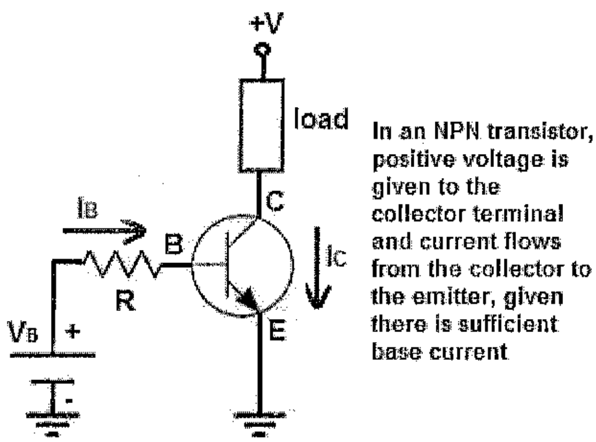

Fig 2.13.4 NPN Configuration Circuit (Administrator, Electronicshub, 2015).

The working of NPN transistor is quite complex. In the above circuit connections, the supply voltage V_B is applied to the base terminal through the load R_B. The collector terminal connected to the voltage V_{CC} through the load R_L, both the loads R_B and R_L can limit the current flow through the corresponding terminals. Here the base terminal and collector terminals always contain positive voltages with respect to emitter terminal.

If the base voltage is equal to the emitter voltage then the transistor is in OFF state. If the base voltage increases over emitter voltage then the transistor becomes more switched until it is in fully ON state. If the sufficient positive voltage is applied to the base terminal i.e. fully-ON state, then electrons flow generated and the current (IC) flows from emitter to the collector. Here the base terminal acts as input and the collector-emitter region acts as output.

To allow current flow between emitter and collector properly, it is necessary that the collector voltage must be positive and also greater than the emitter voltage of transistor. Some amount of voltage drop presented between base and emitter, such as 0.7V. So the base voltage must be greater than the voltage drop 0.7V otherwise the transistor will not operate. The equation for base current of a bipolar NPN transistor is given by,

$$\mathbf{I_B = \frac{V_B - V_{BE}}{R_B}} \quad \text{.........................} \quad \mathbf{(4)}$$

Where,

V_B = Base bias voltage

V_{BE} = Input Base-emitter voltage = 0.7V

R_B = Base resistance

The output collector current in common emitter NPN transistor can be calculated by applying Kirchhoff's Voltage Law (KVL).

The equation for collector supply voltage is given as

$$V_{CC} = I_C R_L + V_{CE} \text{ .... } (5)$$

From the above equation the collector current for common emitter NPN transistor is given as $I_C = \frac{V_{CC} - V_{CE}}{R_L}$ ....(6)

In a common emitter NPN transistor the relation between collector current and emitter current is given as

$$I_C = \beta I_B \qquad \text{....................... } (7)$$

In active region the NPN transistor acts as a good amplifier. In common emitter NPN transistor total current flow through the transistor is defined as the ratio of collector current to the base current I_C/I_B. This ratio is also called as "DC current gain" and it doesn't have any units. This ratio is generally represented with β and the maximum value of β is about 200. In common base NPN transistor the total current gain is expressed with the ratio of collector current to emitter current I_C/I_E. This ratio is represented with α and this value is generally equal to unity (Administrator, Electronicshub, 2015).

Applications of NPN transistors

1. NPN transistors are mainly used in switching applications.
2. Used in amplifying circuit applications.
3. Used in the Darlington pair circuits to amplify weak signals.
4. NPN transistors are used in the applications where there is a need to sink a current.
5. Used in some classic amplifier circuits, such as 'push-pull' amplifier circuits.
6. In temperature sensors.
7. Very High frequency applications.
8. Used in logarithmic convertors (Administrator, Electronicshub, 2015).

2.14 Voltage Regulator

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

The type of IC voltage regulator used in this project is a fixed positive linear voltage regulator, the 78XX series IC voltage regulators. It has three terminals labeled as input, output and ground. The two digits (marked XX) in the part number designate the output voltage. For example IC 7805 is a +5v regulator.

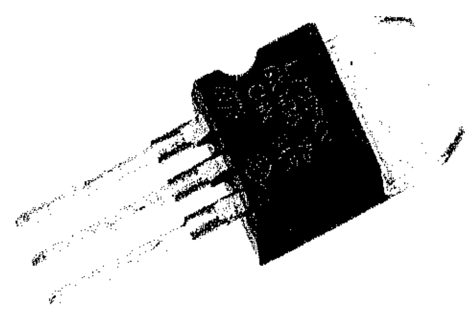

Fig 2.14.1 Voltage Regulator (Media.rs-online, 2016)

2.15 Relays

A relay is a switching device that has a coil and contact operation, when voltage is induced to the coil on the relay it alters the contact point. There are three major contact points in a relay. A relay coil is a set of wound cables put together often times with two lids for powering. A relay has;

- Moveable contact point (reference point)
- Stationery contact point (normally closed)
- Stationery contact point (normally open)

The normally open contact point is open to the reference point when no voltage is induced. The normally closed contact point is close to the reference point when no voltage is induced.

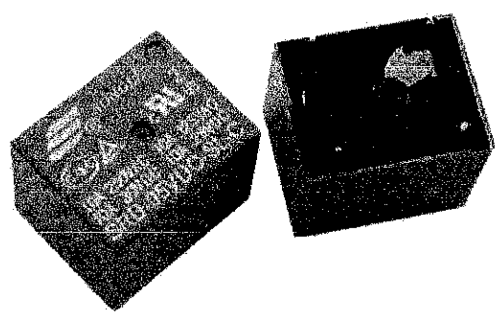

Fig 2.15.1 Relays (Lampa, 2016)

Functions of a relay

Relay are used for;

1. Making the signal in a circuit flow continuously

2. Breaking signal (when no voltage is induced, the contact points are said to be in shelf position).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In Electrical and Electronic systems, performance and reliability depends on the system designs and specifications, the designed parameter will conform to the operating conditions of the system. This design is centered on solving power failure and power related problems in homes and industries at large. A modular approach is employed in achieving the major objective of sustaining power in a case of loss to prevent loss of works, lives and prevent equipment damage with the use of a secondary power supply source as backup. This chapter covers the detailed design and selection of the components used in the construction of this project.

3.2 Design Block Diagram

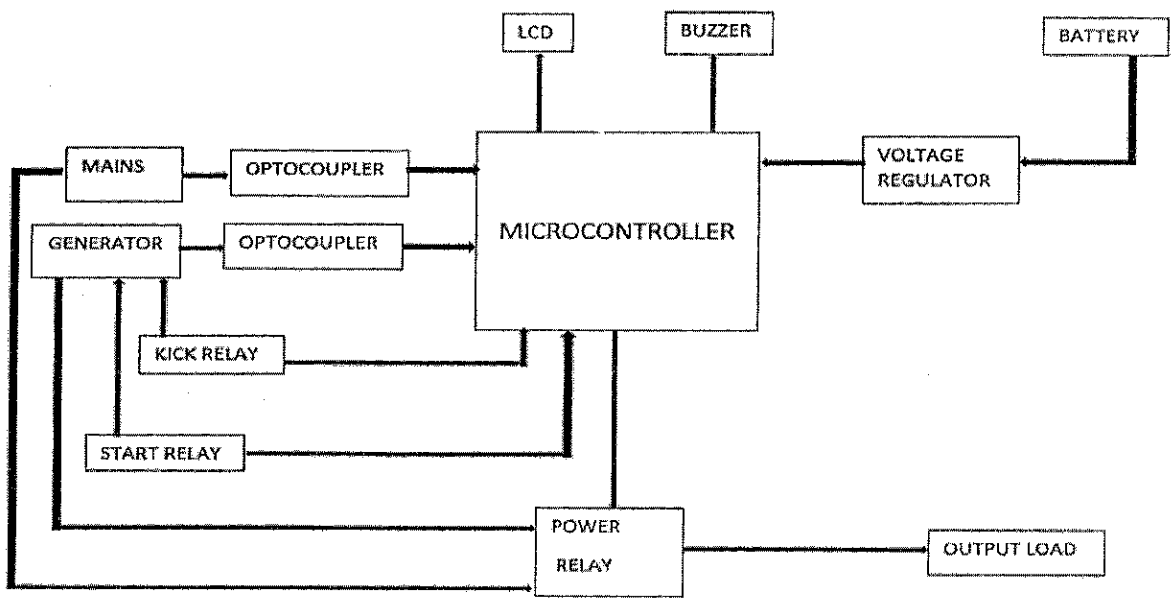

Fig 3.2.1 Block Diagram of the ATS

3.3 Principle of Operation

The ATS design is based on a microcontroller which is the brain of the device and all other functional or peripheral elements are tied to the microcontroller for prompt interpretation. The microcontroller requires a power source (5v DC) to be turned **ON**, this power source is derived from a regulated 12v battery. The microcontroller when turned on performs the sensing function, it senses a signal and sends an appropriate signal in return. The microcontroller senses mains AC supply voltage with the aid of an optocoupler and gives output load (220v @ 30A on full load) through a relay. An interruption in the power supply from the mains calls for a secondary source of supply to be initiated, the generator serves as the secondary source of supply, the microcontroller sends signal to the kick and start relay which are normally open and closed respectively to turn on the generator, when the generator comes on, a voltage feedback of 220v is sent back to the microcontroller through the optocoupler to stop the kick relay and give output load. This operation continues in this same fashion until the mains supply comes back **ON** and the load automatically switches to the mains while the generator shuts down through the start relay which is de-energized and becomes normally open. This operation repeats itself whenever the mains goes **off** or comes **on** respectively in as much as the microcontroller is powered.

3.4 Components of the Block Diagram

The block diagram of this project is made up of several components which are mains power supply unit, gen set unit, generator starter/shut down, relay switching control unit and load output.

1. Mains Unit: This is the power supply that comes from public utility, it flows into switching control unit through the optocoupler before passing into the output unit.

2. Generator set Unit: This is the power supply from the generator set which also flows into the switching control unit through another optocoupler before passing into the output unit.

3. Generator starter/shut down Unit: This is the section of the circuit that controls the starting and shut down of the circuit through the help of relays which switches on the generator when there is power outage from the public utility source.

4. Relay switching Unit: This unit performs all switching functions and is controlled by the microcontroller, it aids in the generator startup and shut down.

5. Load Output Unit: This unit is concerned with giving the required output load to the appliances connected to it at a maximum rated load capacity of 30A.

3.5 DESIGN SPECIFICATIONS

The design of an automatic transfer switch has the following specifications:

- Input voltage 220/240 VAC
- Operating voltages 5V and 12VDC
- Operating current 1295.7mA
- Input frequency 50Hz

A modular approach is employed in the design of this project, it encompasses

1. Power Supply unit (AC and DC source),
2. Relay Switching and Loading unit
3. Atmega8 Microcontroller unit, and
4. Display and Indicating Unit.

3.6 Power Supply Unit (DC Source)

The DC power source is derived from a 12v battery which is stepped down to 5v DC for the ATmega8 microcontroller which requires 5v for operation. The power supply circuit mainly consists of;

- The clipping circuit which allows only the positive half waveform to be passed under forward biased condition and for reverse polarity it does not conduct. This clipping circuit is achieved with the aid of a diode which by design allows flow only in one direction and blocks the reverse direction.
- The L7805 voltage regulator which gives a constant regulated 5v at its output end.
- The filtering circuit which consists of smoothening capacitors (ceramic and electrolytic capacitors).

3.7 Selection of the Bridge Rectifier

The rectification circuit used in the design is a full-wave bridge rectifier which comprises four diodes. This is shown in the figure below;

D1 - D4 = IN4007

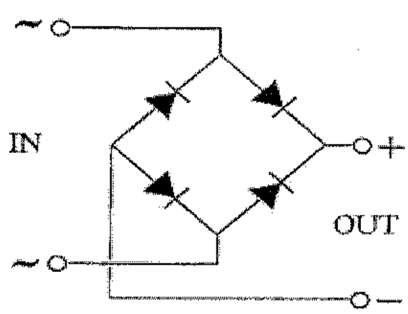

Fig 3.7.1 The Bridge Rectifier (EEtech, 2016)

The four diode full wave bridge rectifier is used due to its added advantage over a two diode center-tapped full-wave rectifier as well as a one diode half-wave rectifier. The choice of diodes used was based on:

i. The forward current rating: The diode forward current rating is the maximum that the diode can conduct before failing. The diode is selected in such a way that the current passing through is less than the forward current rating.

ii. The Peak Inverse Voltage (PIV) the diodes would withstand: The peak inverse voltage is the maximum reverse voltage that a diode can withstand without destroying the junction. If the reverse voltage across a diode exceeds this value, the reverse current increases sharply and breaks down the junction due to excessive heat. Peak inverse voltage is extremely important when diode is used as a rectifier. In rectifiers, it has to be ensured that reverse voltage across the diode does not exceed its PIV during the negative half-cycle of input ac voltage. Hence, PIV consideration is generally the deciding factor in diode rectifier circuit. The peak inverse voltage of a rectifier diodes lies between 10V and 10kV depending upon the types of diodes.

Vpeak = $\sqrt{2}$ Vrms is the 12v which the battery gives

$\therefore$Vpeak = $\sqrt{2} \times 12 = 16.97$V

For a bridge rectifier, the peak voltage equals the peak inverse voltage. Therefore, the calculated PIV is 16.97V.

Thus, the IN4007 diode was chosen for the rectifier since it satisfies the above stated requirements according to its datasheet.

Voltage drop across diodes= (2 x 0.7) = 1.4V

Where 0.7 is the forward conducting voltage of a silicon diode.

Voltage drop= 7.07 - 1.4= 15.57V

For the design of the optocoupler,

I_F = Forward current = 60mA

V_{CEO} =70V

Max Power = 60mA x 70v =4.2 watt

3.8 The Capacitor Selection

The filter used in this power supply is a single shunt capacitor. The choice of the filter capacitor depends on:

i. The ripple factor allowed

ii. The capacitor breakdown voltage

i. **The Ripple Factor Allowed**

The output of a rectifier consists of a dc component and an AC component (also called ripple). The ripple is undesirable and causes pulsations in the rectified output the effectiveness of a rectifier depends on the amount of ripple in its output, the smaller this is, the more effective is the rectifier. The ripple factor is an indication of the effectiveness of the filter capacitor and is defined as:

$$\text{Ripple Factor} = \frac{\text{rms value of ac component}}{\text{value of dc component}} = \frac{V_{rms}}{V_{dc}} = \frac{I_{ac}}{I_{dc}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

The smaller the ripple factor, the lesser the amount of ripples and hence more effective is the rectified output signal. These ripples have a frequency of twice the input supply frequency. The ripple factor for full-wave rectifiers and thus allowed for this project is given as:

$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

$I_{DC} = \frac{2I_m}{\pi}$

$\therefore R = \sqrt{\left(\frac{I_m}{\sqrt{2}} \times \frac{\pi}{2I_m}\right)^2 - 1} = 0.48$

This shows that the DC component of the full-wave rectifier output is more than the ripples, making full wave rectifiers more suitable for rectifying ac to dc.

ii. **The Capacitor Breakdown Voltage**

The capacitor breakdown voltage can be determined by applying Kirchhoff's voltage law at the output of the rectifier to the terminal of the filter capacitor.

$V_{peak} - 2(\text{Diode drop } (V_D)) = \text{Voltage at filter capacitor}$

For silicon made diode $V_D = 0.7V$

$\therefore V_C = 16.97 - 2\ (0.7) = 15.57V$

Taking a safety factor of two, the capacitor voltage, V_C becomes 31.14V, and since this is not a common capacitor voltage, a 25V capacitor was chosen

The capacitance of the capacitor used is gotten using the relationship

$V_{max} = \frac{I_L}{2fC}$

I_L = load current = 895.7mA (as calculated)

f = frequency = 2 × supply frequency = 2 ×50Hz = 100Hz

C = capacitance

Maximum peak = 11.33V

Obtaining capacitance, we have that:

$V_{max} = \frac{I_L}{2fC} = \frac{895.7 \times 10^{-3}}{2 \times 50 \times C}$

$11.33 = \frac{895.7 \times 10^{-3}}{2 \times 50 \times C}$

$C = \frac{895.7 \times 10^{-3}}{1133} = 0.000790556F = 791\mu F$

From the calculated value, 791µF is not a standard capacitance value; hence a 1000µF, 25V capacitor was selected. The 47uF capacitor was used to further smoothen the output to reduce the ripples which result in spike current when the theft load is connected to the circuit.

3.9 The Voltage Regulator Selection

The importance of voltage regulator is to ensure that a fixed voltage output is obtained at the output of the power supply regardless of the variations from the supply input or load connected. The regulation used is the IC voltage regulator LM7805. This implies that a positive fixed +5volts regulator was used to provide the fixed positive voltage level required by the circuitries. The rating of the voltage regulator from the datasheet is as given below:

I. Input voltage range 5~25V

II. Maximum current rating 5mA-1.5A

III. Output voltage range 4.8~30V

IV. Operating temperature range 0~125°C

The fixed positive IC voltage regulator was chosen from the 78xx family of fixed positive voltage as they are more efficient in providing the much-needed constant voltages for the interconnected circuitries of the design.

3.10 Relay Switching and loading unit

This unit is the most important of this entire design, in the design of this unit I used NPN transistor which acts as a switch and receives 5v from the microcontroller to switch on the relay connected to it which would in turn kick the generator. The design followed the working principle of an NPN transistor requiring a voltage at the base of the transistor to control its ON and OFF state while the collector is connected to the positive voltage and the emitter to ground.

3.11 Design Calculation for NPN Transistor

Input Voltage = $V_{BE} = V_B - V_E \simeq 5v$

Maximum Collector current = I_C = 100mA

Maximum Output Voltage = V_{EE} = 60v

Power Rating = I x V

100mA x 60v = 6W

Resistor value = $\frac{V}{I} = \frac{5v}{100mA} = 50\ ohms$

The resistor value calculated is 50 ohms, this indicates the minimum value of resistance that can be used in the design of this project, 1k ohm resistor was chosen because BJT's are current controlled devices at the base and as such, high current at the base could easily destroy the base of the terminal whereas a little voltage as low as 0.7v could easily trigger the base. The 1k ohm resistor value was chosen because it is high enough to limit current at the base for better functionality.

3.12 Display and Indicating Unit

The LCD used in this project serves as an indicator of the operation process of the entire project, it will display whenever the public utility supply is available or not (Mains) and also when the standby generator is initiated once there is power outage from the public utility source. If there is a failure from the generator, the LCD and a buzzer would help in indicating the failure. The LCD uses 5v and consumes a current of 23mA, the buzzer uses an NPN transistor to aid it in its switching operation and has same calculation as used in the design for the transistor.

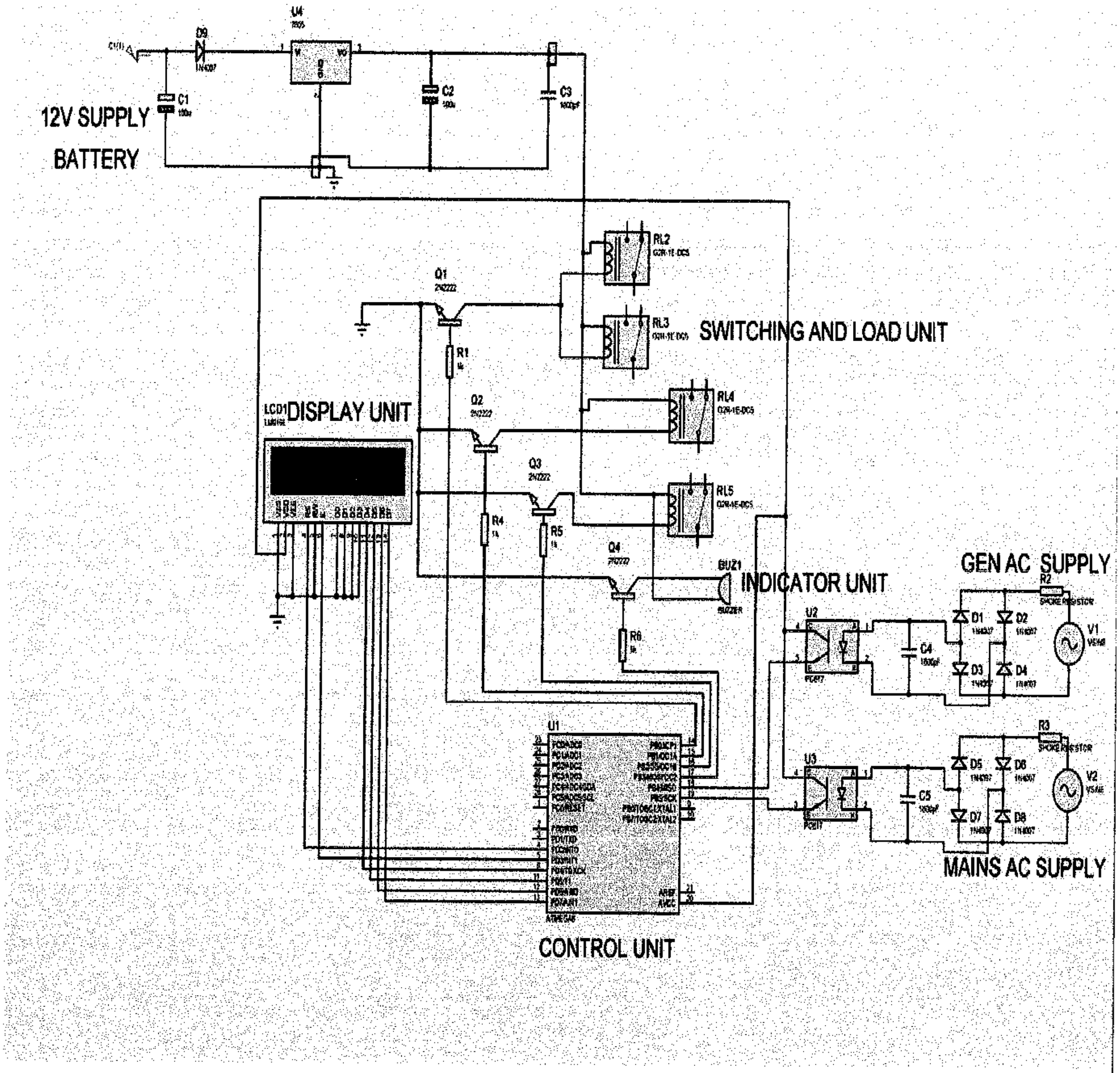

Fig 3.12.1 Complete ATS Circuit diagram

CHAPTER FOUR

TESTING, ANALYSIS OF RESULTS AND DISCUSSION

4.1 Introduction

This project is a prototype which is designed to curtail 30A load on full loading, a modular approach was employed in the design of this project from the basis by using a breadboard to design the respective components which were attached to the microcontroller for automation and after working perfectly were transferred to the Vero board to make the design permanent. The microcontroller used is the Atmega8 which has high performance characteristics, C programming language is used in programming the microcontroller on an Atmel studio software. The program is loaded into the Atmega8 for the automation of the transfer switch.

This automatic transfer switch has been completely designed and implemented on a household appliance rated 15 watt and it performed optimally on loading.

4.2 Construction of the Project

The construction of this project is achieved with the aid of a Vero board, the design followed a specific approach and all the components were interconnected to the microcontroller with the soldering iron and the soldering lead. A circuit diagram is poses as a guide and all components are made available. The components are firstly placed on a breadboard which serves as a temporary platform, its purpose was to ascertain the workability of the proposed design before transferring permanently to the Vero board. I ensured continuity where needed and also broke continuity where not required at the bottom of the Vero board to ensure a compact and neat design, the continuity on the Vero board was made possible with lead lining on the board. The construction of the project is completed and a casing which provides aesthetics for the project is used in wrapping the project to exhibit a neat work.

This project was implemented on three different platforms, on Proteus software, breadboard, and lastly on the Vero board. A 12v battery is usually tied to the generator with a key cranking system, this serves as our DC voltage source for the ATS, and the terminals are connected to the public utility source, the generator and a bulb which serves as output load. The project was tested and it performed optimally and even with an induced fault, the buzzer and the LCD displayed the problem.

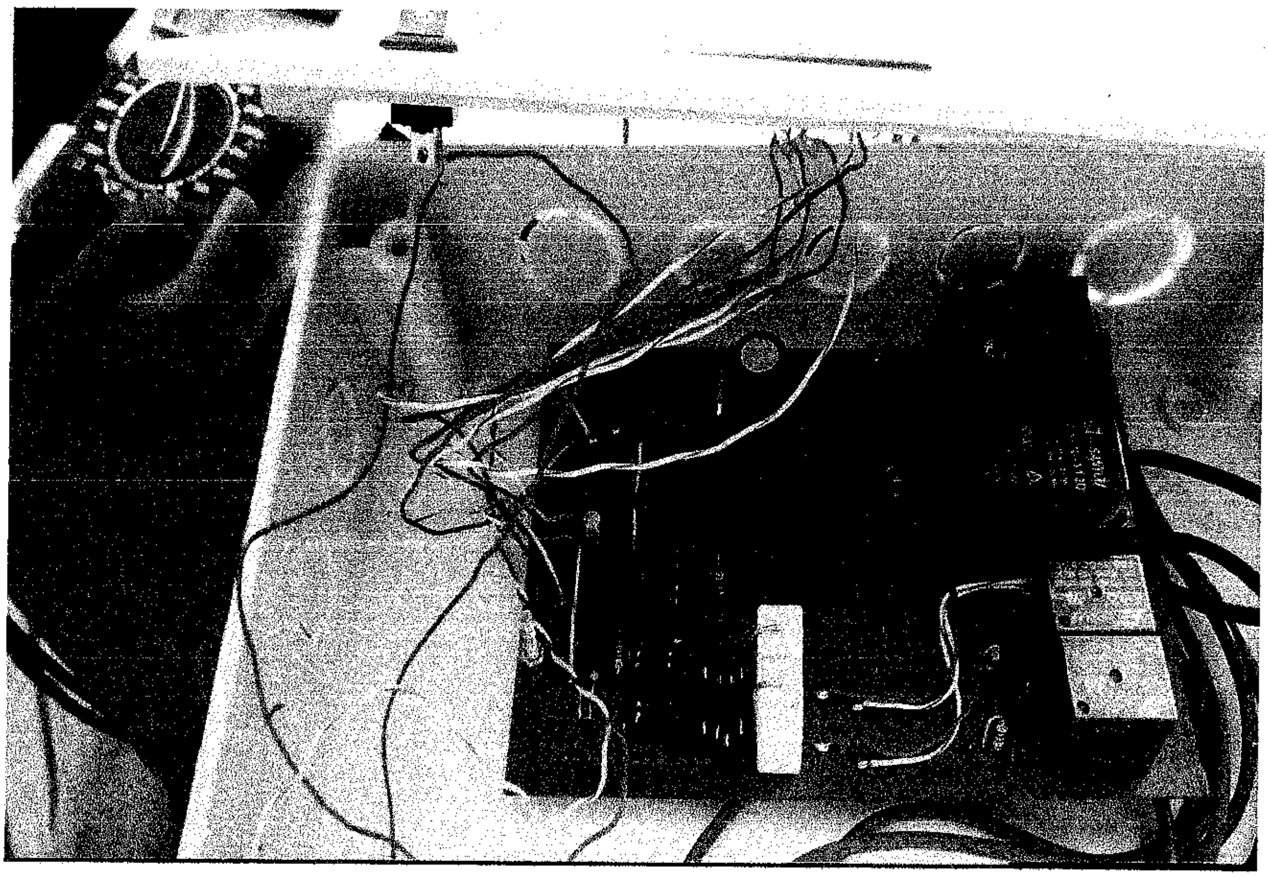

Fig 4.2.1 Project Construction

4.3 Design Stages

A systematic approach is used in achieving the major goal of the project from start to completion. The stages used in completing the project are drafted below;

STAGE ONE

C programming language on an Atmel studio software is used in coding the Atmega8 microcontroller at 1MHz clock frequency. This code is simulated on a proteus software to check if the HEX file will conform to the required hardware design in place before implementation.

STAGE TWO

The components are placed appropriately on a breadboard and tested and transferred onto the Vero board and soldered perfectly to ensure there is no bridge in the circuit.

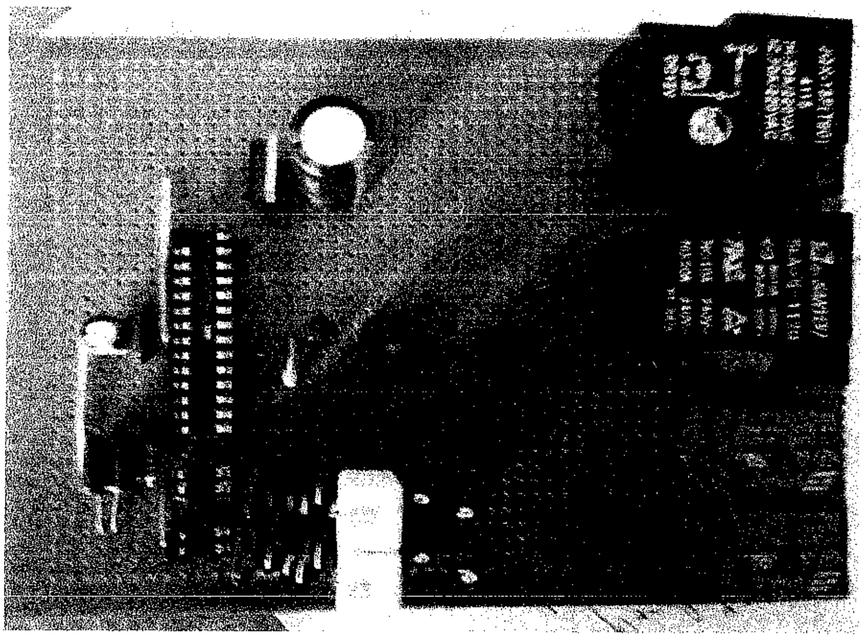

Fig 4.3.1 Components on Vero Board

STAGE THREE

The soldering in complete and the design is housed with a casing to make the work presentable and marketable.

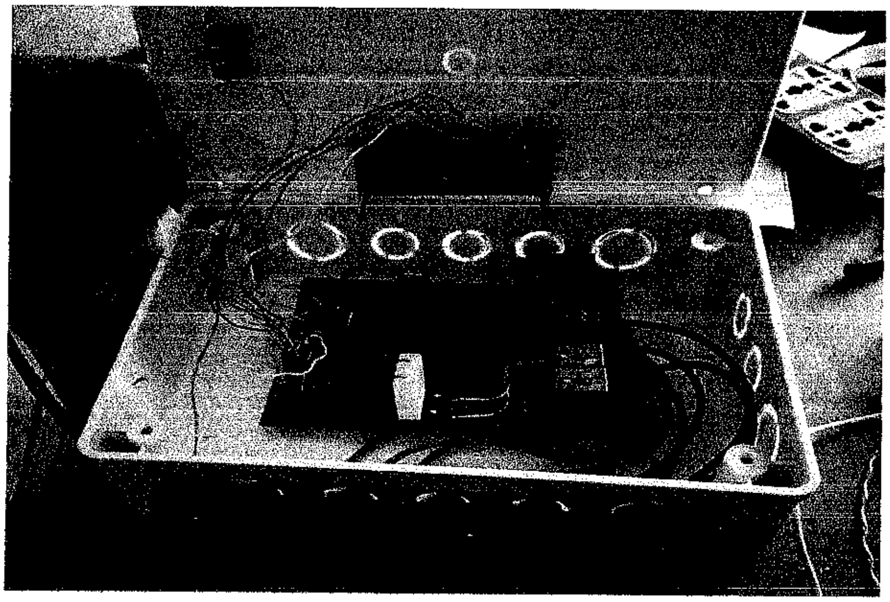

Fig 4.3.2 Soldered Components in Casing

4.4 Testing

The testing of the project was first done on the proteus simulation software and implemented on bread board where all components followed the pattern as seen on the simulation diagram. Each component is firmly affixed on the board and all subdivisions are tested with the aid of a multimeter.

The components are transferred to the Vero board for a permanent fitting and the continuity test is performed to ensure that there is no bridge and the project is performing the desired function. The figure 4.4.1 shows the preparation for hardware testing. The second generator serves as the public utility supply while the decoupled generator serves as the generator supply.

Fig 4.4.1 Testing Preparation

4.5 Analysis

In the analysis of this work, the results gotten from the simulation of this project as well as the real – time testing of the work clearly indicates that this device thrives better in underdeveloped and developing countries of the world today charged with power related issues because in other parts of the world there is constant power supply.

These results show that the secondary power supply must always be in good working condition for optimal performance of the device, the device can only take a maximum load of 30A. For further improvement on this design more attributes should be attached to the secondary supply like a motorized choke or a fuel level sensor for better functionality.

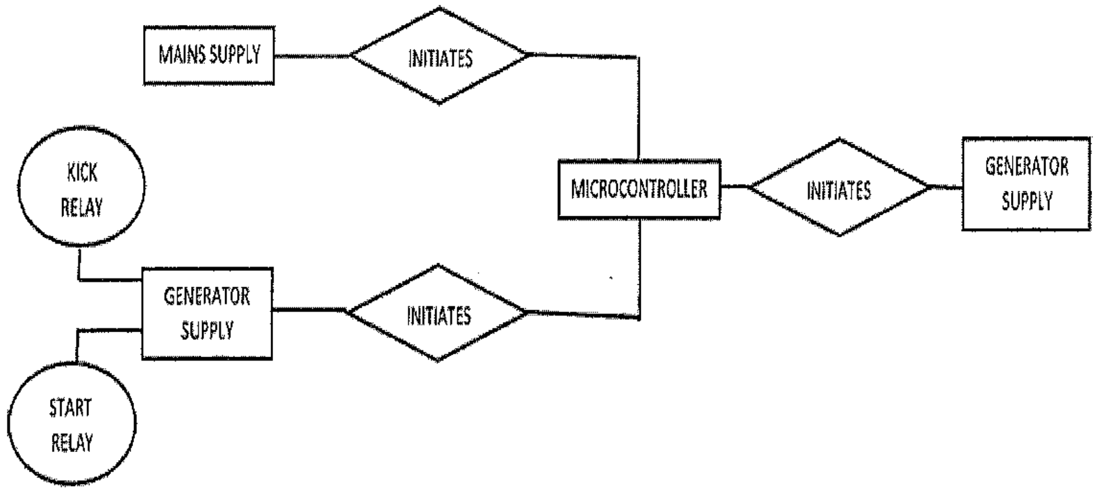

Fig 4.5 ATS Entity – Relationship Diagram

4.5.1 Circuit simulation

The latest proteus simulating software is used in the testing of this project and also in the entire design stage. Figure 4.5.1 shows the complete circuit diagram which is adhered to in the design of the hardware, figure 4.5.2 shows the HEX file simulation when the public utility supply is present, while figure 4.5.3 shows the HEX file simulation when the public utility supply is OFF and the generator automatically comes ON, figure 4.5.4 shows the HEX file simulation when the public utility supply is OFF and the generator fails to come ON, a buzzer alarm comes on and the LCD indicates that the generator has failed.

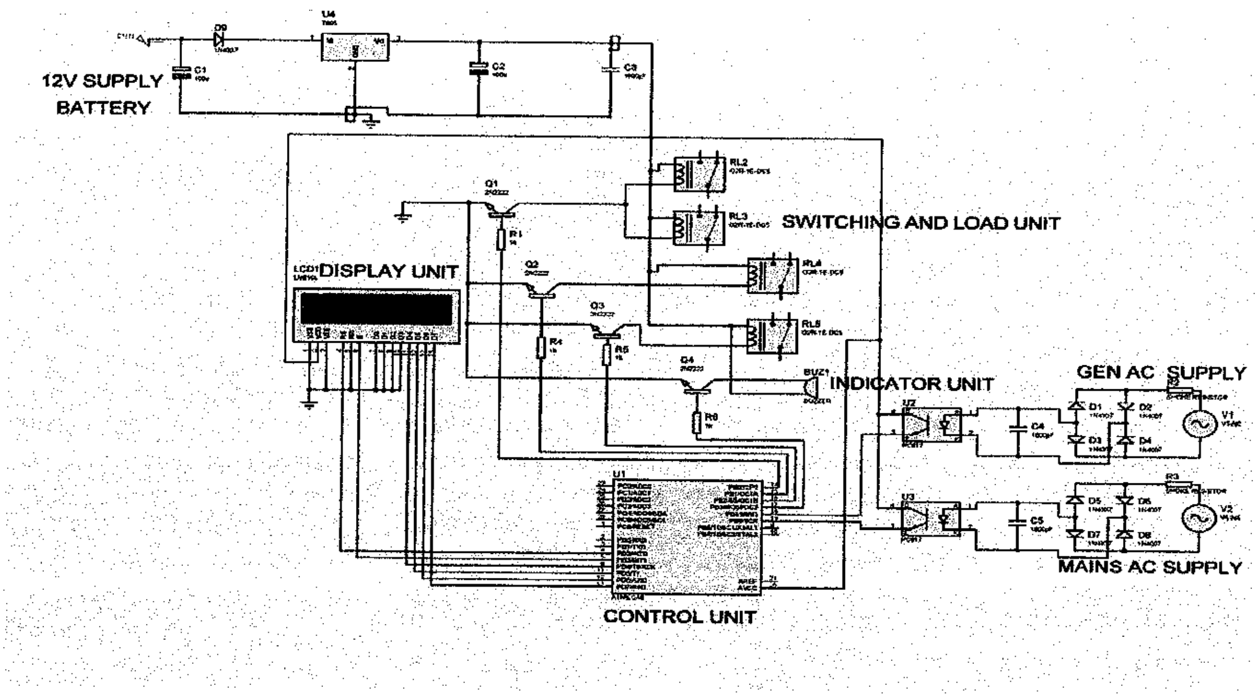

Fig 4.5.1 Complete ATS Circuit Diagram

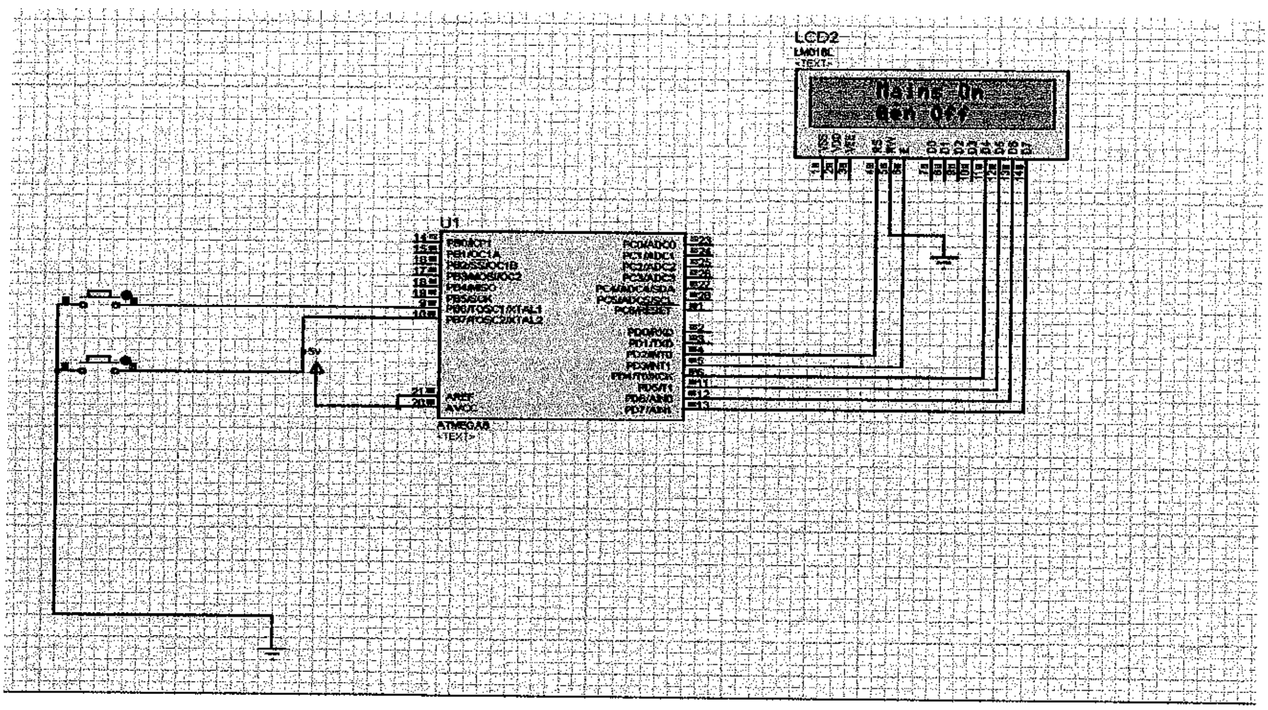

Fig 4.5.2 Public Utility Supply Present

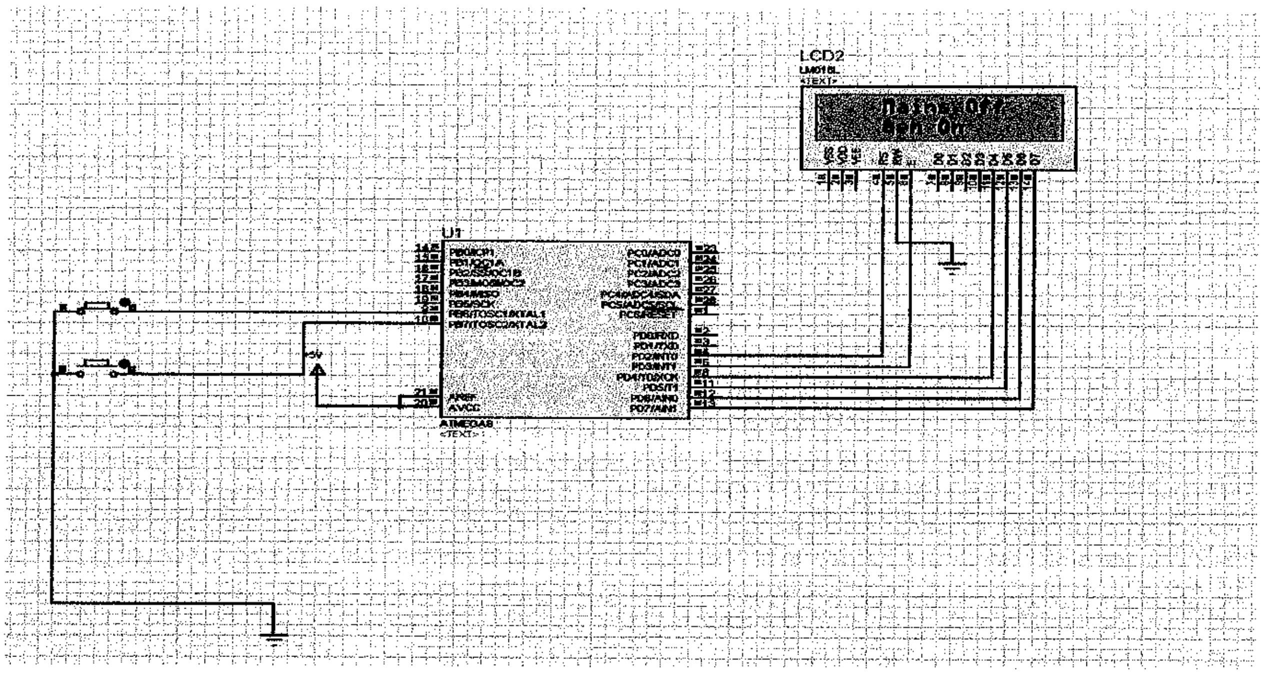

Fig 4.5.3 Generator Present

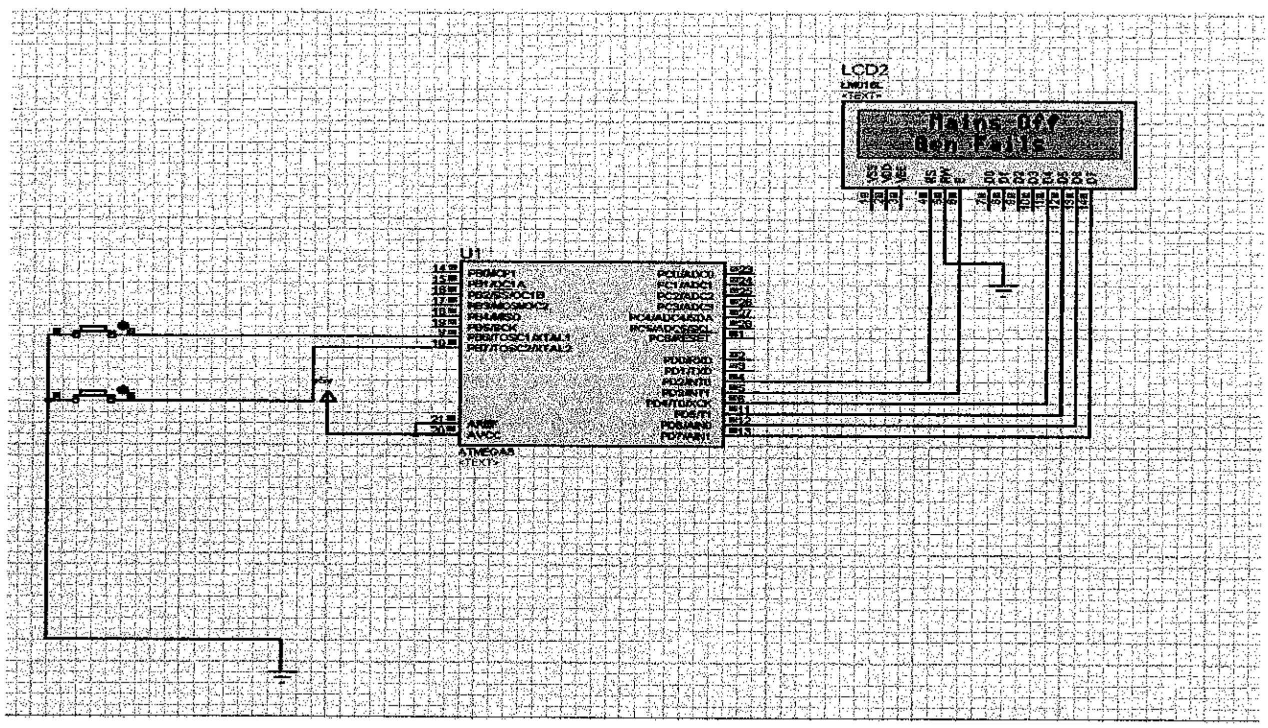

Fig 4.5.4 Generator Fails

4.5.2 Oscilloscope Reading

The reading gotten from the oscilloscope proved that the output of the Automatic Transfer Switch is a sinusoidal waveform this signifies that the output of the device is AC voltage as seen in Fig 4.5.5. Fig 4.5.6 gives the measured parameters obtained from the oscilloscope while Fig 4.5.7 shows the complete project setup during the process of Oscilloscope analysis

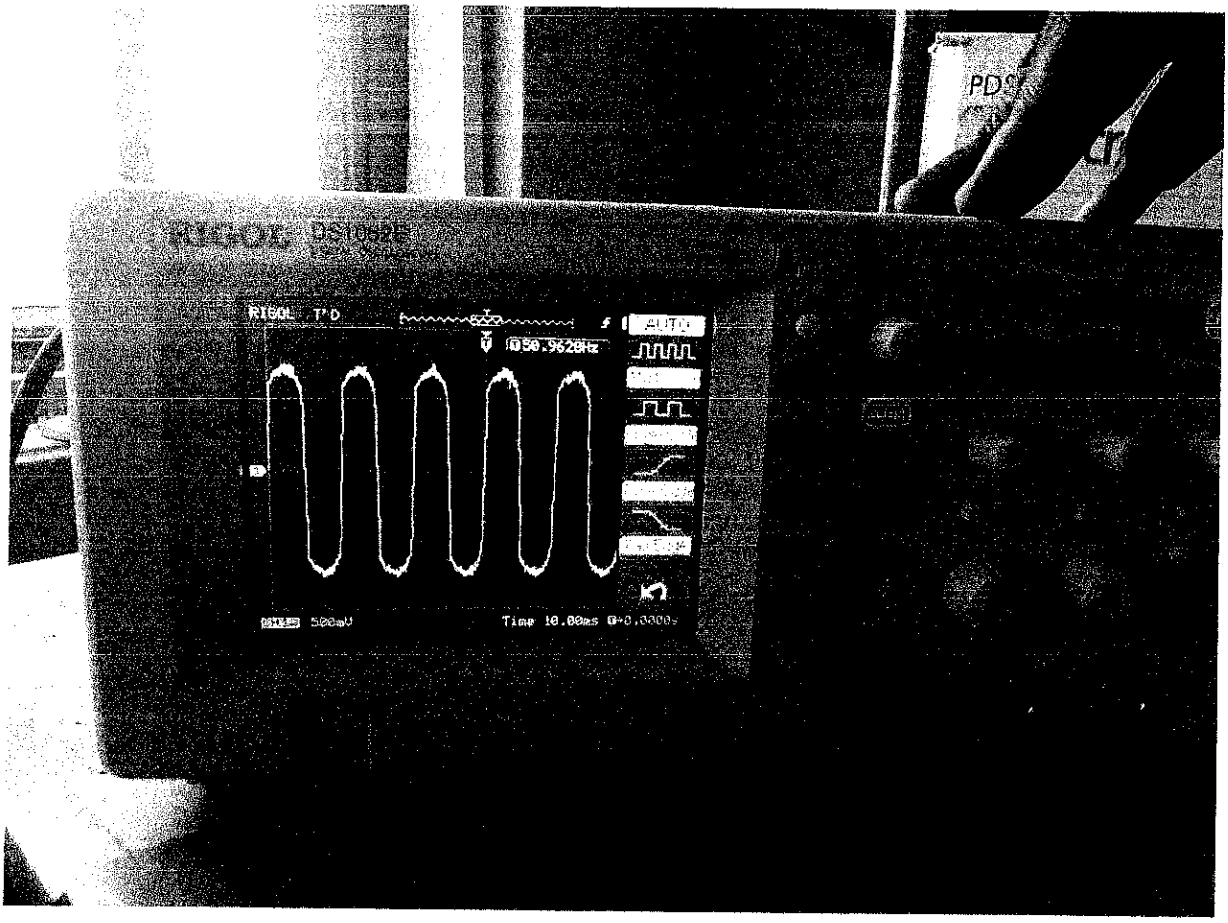

Fig 4.5.5 Oscilloscope Waveform

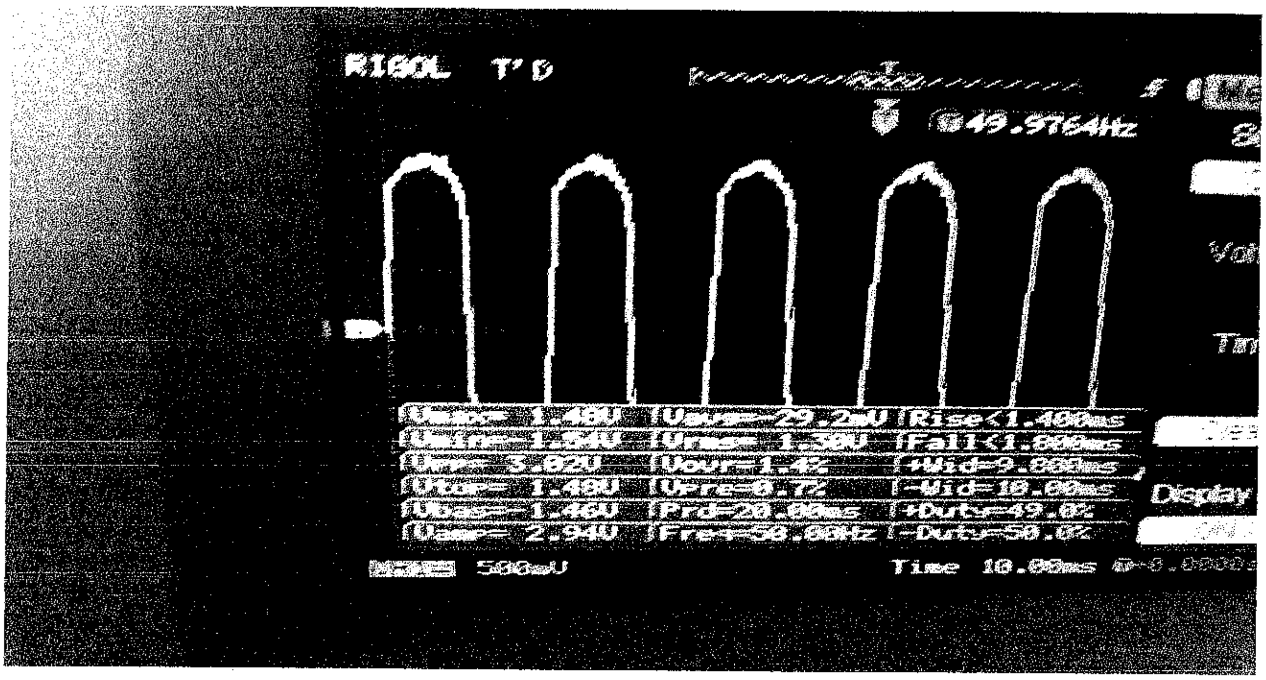

Fig 4.5.6 Measured oscilloscope values

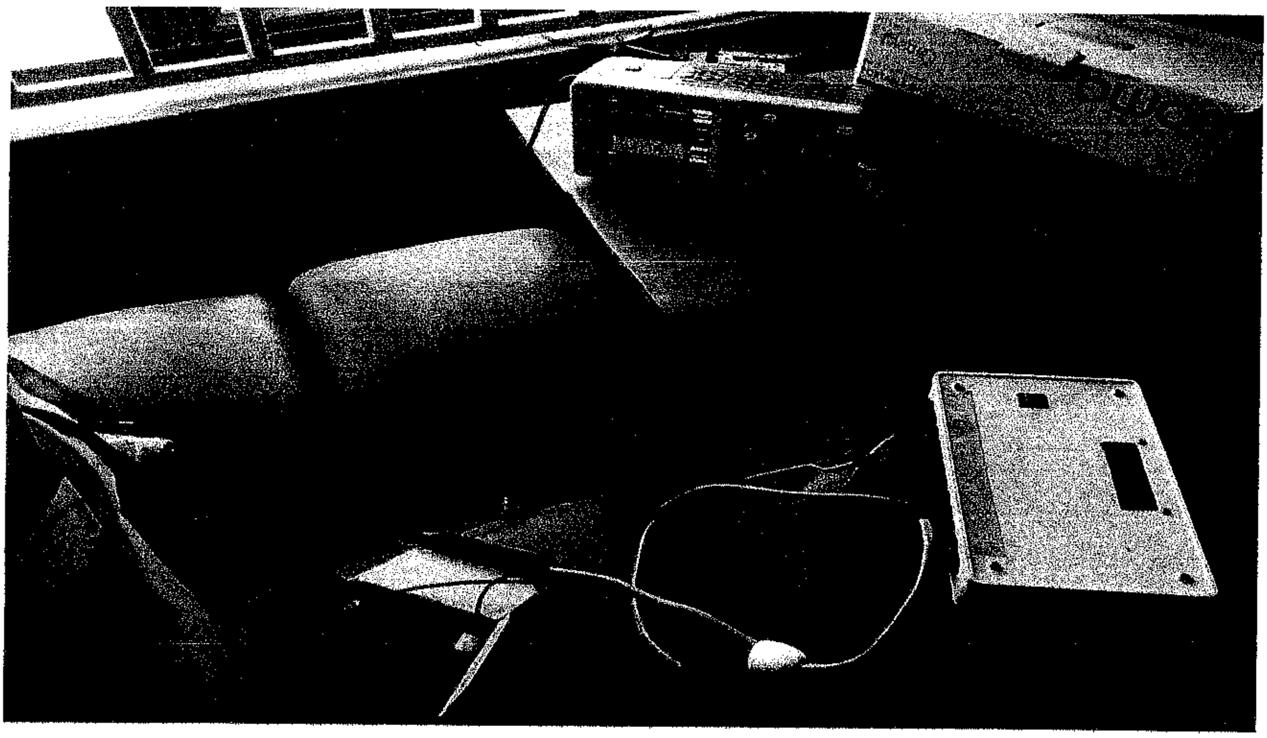

Fig 4.5.7 Oscilloscope testing setup

4.5.3 Graph Analysis

The graph on Fig 4.5.8 shows the relationship between voltage in volts and time in minutes. The voltage delivered to the circuit is constant a 220V at any varying time. This clearly indicates the reliability of this device. A successive increase in load will yield a corresponding decrease in the frequency of operation of the device. Fig 4.5.9 shows the relationship between current in amperes and load in watts as it relates to the ATS, it is observed from the graph that an increase in the current drawn from the device has a corresponding increase in the load consumed by the device. This obeys the equation $P = IV$ when the voltage delivered is constant.

TIME (minutes) X – axis	VOLTAGE (Volts) Y – axis
30	220
60	220
90	220
120	220
150	220
180	220
210	220
240	220
270	220
300	220

Values for the graph of Voltage against Time

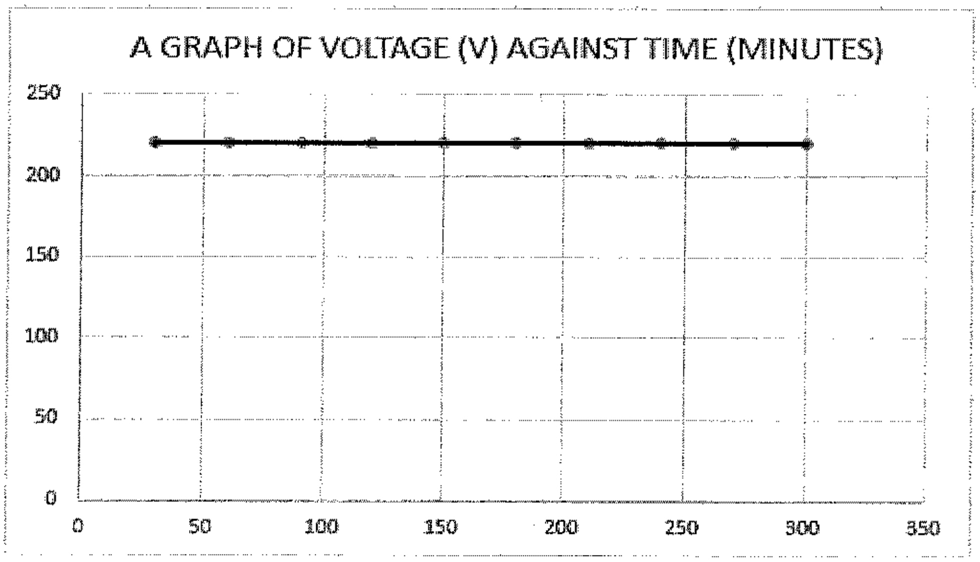

Fig 4.5.8 Graph of Voltage against Time

X-axis Load (Watts)	Y-axis Current (Amperes
60	0.27
100	0.45
160	0.73
200	0.91
260	1.18
300	1.36
360	1.64
400	1.82
500	2.27

Values for the graph of current against load

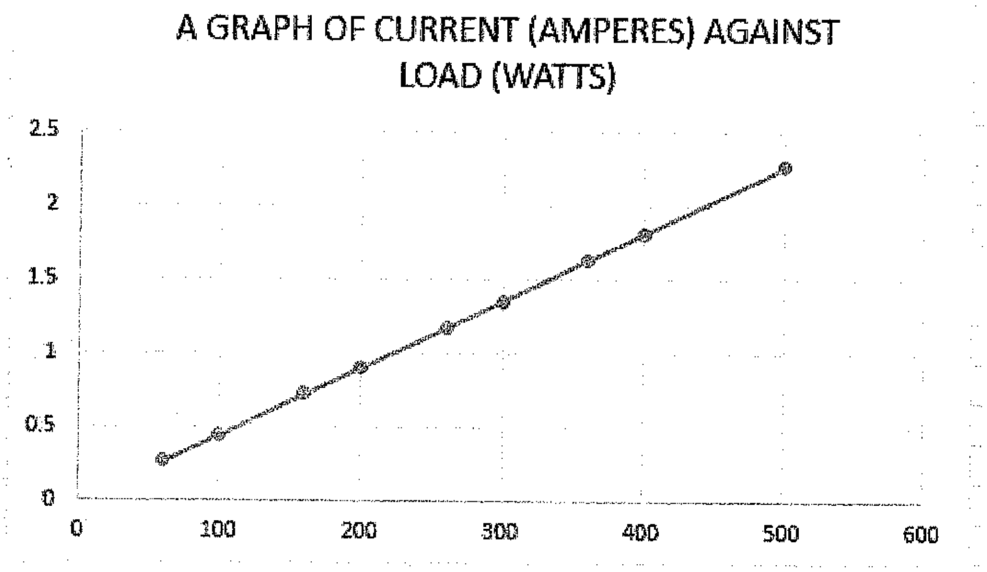

Fig 4.5.9 Graph of Current against Load

4.6 Digital Multimeter

The digital multimeter is a measuring tool used by engineers and technicians in measuring voltage, resistance, continuity, current, frequency, temperature, and transistor hfe. The multimeter is essential in the implementation and testing process of the ATS, parameters like voltage, resistance value and also continuity were carried out with the aid of the multimeter on the hardware.

Fig 4.6.1 A Digital Multimeter

4.7 Performance Evaluation

The performance of the system was thoroughly evaluated and the device was made to work for long duration to ascertain how well the device works and if it would eventually overheat. The performance was measured on the output load which gave an output voltage of 219V.

The Automatic Transfer switch performed optimally on loading and the IC did not overheat on loading, this is a desired property in every project involving a programmable IC because when burnt, it is hard to replace without the design code present. The device was loaded to 90% of its rated capacity to check its yield and it did not break down nor fail in operation.

Fig 4.7.1 Performance Test

Fig 4.7.2 Project testing

4.8 Project Management

4.8.1 Project Schedule

Work Breakdown Structure

The Design and Construction of an Automatic Single Phase Transfer Switch was not achieved in a day, it was broken down into different tasks of which each task had its respective period for completion. The span for the project was thirty-six (36) weeks, the structure did not follow each other in a successive manner but each allotted time took into consideration all factors required in executing the task including the likely problems to occur and subsequent troubleshooting measures and I adhered to the plan because time was a limiting factor and as such everything needed to be achieved at the specific time.

The first week was for the submission of my proposal. The later seven (7) weeks of the project was dedicated to the gathering of resources, relevant materials and also relevant works. The introduction of this report took a span of a week while the literature review was developed in three weeks afterwards my supervisor went through the work and gave necessary corrections and contributions within the next week. The methodology of this report took a span of two weeks. Then later, three (3) weeks was dedicated to the development of a workable design for the project with the interplay of using the relays for performing the desired function in a unique but simple way, once this was completed the software aspect was faced squarely for three (3) weeks, this involved the complete simulation of the work on proteus software using the embedded C programming code hex file in simulating the work and it performed as expected though a little troubleshooting ensued, in the next week I met with my supervisor to show him the progress I have made for approval. The next week the components for the main project was purchased.

Development on the bread board including the troubleshooting and challenges associated with the work took a span of two (2) weeks, it took a longer span because this is where the main work lies and as a result all challenges would surface in this stage and it needs to be catered for before proceeding to making it permanent on a Vero board. After the implementation on the breadboard I met with my supervisor to show him the work for permission to make the design permanent on the Vero board. The design components were transferred to the Vero board and properly soldered and well housed providing beauty to the work, this took a span of a week. The testing of the project is also part of the project plan and this was done during the design phase and after the completion, and extra week was used to test the work. The testing, analysis of results section of this report took a span of two weeks for completion. The conclusion and recommendation section of this report took a week span after which the entire report was given to my supervisor for proof reading and necessary corrections this took a span of three weeks. The report was approved for printing and binding and this took a span of a week.

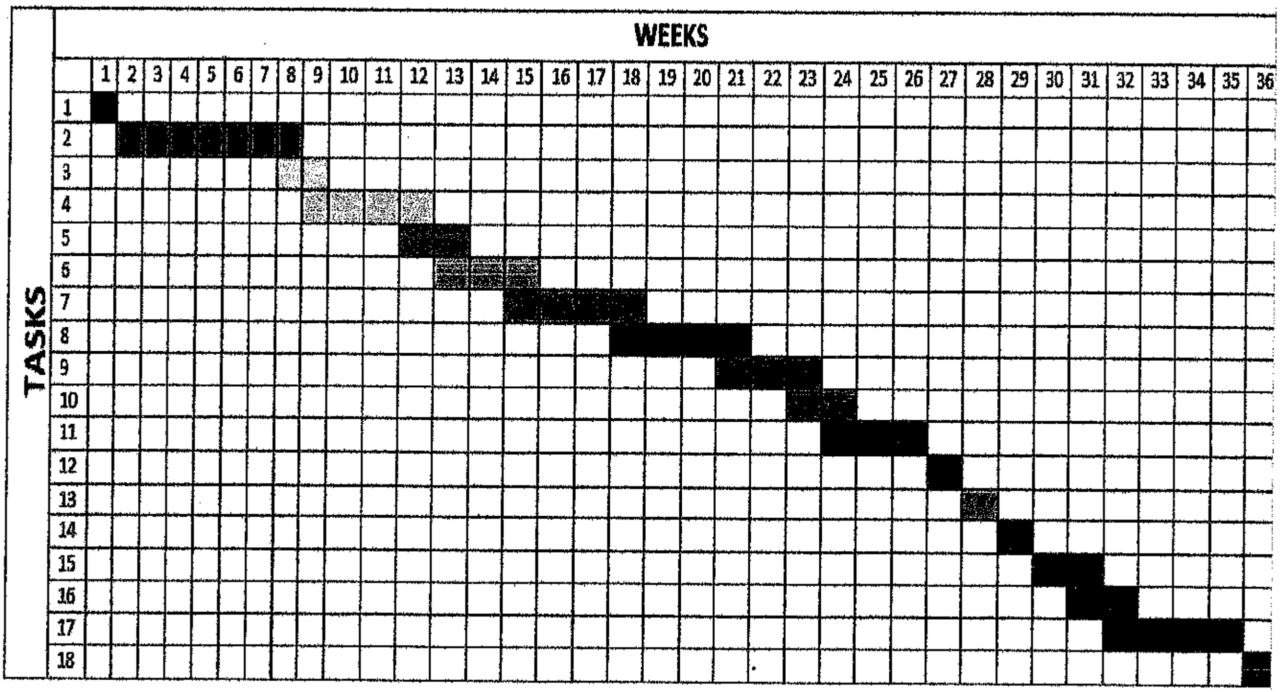

Fig 4.8.1.1 Gantt chart showing work progress

Task 1 – Proposal submission

Task 2 – Gathering of resources for project.

Task 3 – Introduction section

Task 4 – Literature Review section

Task 5 – Scheduled meeting with Supervisor.

Task 6 – Methodology section.

Task 7– Design consideration of circuit.

Task 8 – Programming and Simulation.

Task 9 – Scheduled meeting with Supervisor.

Task 10 – Purchase of components.

Task 11 – Implementation of circuit on breadboard.

Task 12 – Scheduled meeting with Supervisor.

Task 13 – Soldering on Vero board.

Task 14 – Testing of the device.

Task 15 – Result and Analysis section.

Task 16 – Conclusion and Recommendation section.

Task 17 – Proof reading and correction by Supervisor

Task 18 – Printing and Binding of the report.

4.9 Risk Management

The risk associated with this project is that of AC voltage from a single phase supply which is relatively high and its resulting effect could be disastrous. This risk was effectively mitigated in the design of this project with the use of proper insulated connectors and also by ensuring tight connections from the device to the connectors, each terminal was adequately labelled to ensure proper connections to DC and AC components respectively.

4.10 Ethical Issues

The size of cables used in the design of this project conformed to the required standard to prevent cable damage due to heating in the device. This design does not infringe on any existing patent as it is a unique design built on an existing idea but with better functionalities.

4.11 Applications

The automatic transfer switch is very important in our society today as it has found numerous applications in different spheres of life, its applications include but are not limited to;

1. Industrial use
2. Domestic use
3. Medical use

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter focuses on the conclusive part of this report in its entirety. It contains the conclusion, contribution to knowledge, limitations to the work, recommendations on future work development, and a critical appraisal of the entire design process.

5.2 Conclusion

This project takes into consideration a great use of relays in performing switching function in order to control automation between a public utility supply and a secondary source of supply. The microcontroller receives regulated DC voltage which powers ON the entire automation process hereby initiating the relays which aid to startup of the generator when there is a power failure and this is displayed on the LCD screen. This device makes it possible to automatically transfer load to a secondary source of supply when a failure occurs from the public utility source.

Conclusively, in eliminating human intervention as well as introducing speed and precision in the operation of power supply sources there is need to automate power switching between sources and with the aid of this design power failure has been effectively minimized and the maximum bearing capacity of this device is 30A on full load.

5.3 Contribution to Knowledge

This design on an automatic transfer switch is a unique one, with consideration on cost, speed and efficiency. In designing this automatic transfer switch I took into consideration the need of an average man in the society and his inability to create a comfortable living for himself like the rich in the society, this design is a very simple one performing same function as the industrial automatic transfer switch but it can be used on a small generator with a rating as low as 3.5kVA with key system for ignition with great accuracy so long the generator is in good working order.

The benefits of this device are numerous as well as its relevance and it could be used in the Electrical department to maintain power supply when there is power outage so that normal operations in offices can be carried out, this reduces time loss and man power required to power on the generator and also switch over to the generator supply when the generator is on.

5.4 Limitations

In the course of this project some problems arose and these issues where effectively mitigated and solved. Some of the problems encountered include;

1. Programming the Atmega8 IC.
2. Reverse polarity from 12v battery.
3. Financial constraint.

5.5 Design Constraints

In the course of the design of this project there were some constraints which ensued during the analysis of this device. This includes;

1. The generator must have electrical 'start and stop' facility to aid the kick and start relay to function.
2. The generator's battery has to be in good condition always for ignition.
3. The inter-connecting cables must be in good order.
4. The ATS does not function with a faulty generator.
5. The ATS does not function with generators that have a manual starter.

6. The device has a maximum load bearing capacity of 30A and should not be loaded above its limit.

5.5 Future Works

This work could be developed further because its interfaces are not limited to just automation between two power supply sources but more resources can be incorporated into this to make the design more comforting. Thus, for technological advancement I would recommend that for future enhancement of this project the following should be considered, this includes;

1. Generator synchronization to accommodate more standby generators,
2. Motorized choker for generators without automatic choking system,
3. Wireless communication system for troubleshooting,
4. Battery charger introduced in design,
5. Fuel level and temperature sensors,
6. Introducing inverter or solar panel as third power supply source,
7. Use of contactors increasing the rated capacity to accommodate more load.

5.6 Critical Appraisal

In the design of this Automatic Transfer Switch, I worked on gathering related works to the subject matter at hand and this was not an easy task because there were no working circuits on the internet which could serve as a guide for the project work so I had to make the entire design myself. The design was a successful one and what was left was to implement it on proteus simulation software which was not an easy task but I scaled through and implemented the design on a bread board, unlike simulation the building on bread board was a little bit tough as some of the components used were damaged which we noticed by testing in bits and replacing each damaged component respectively. In the initial design there was no diode to combat reverse polarity and this did not allow the voltage regulator perform properly, the diode was implemented to clip the negative half voltage waveform if there exist reverse polarity while connecting the battery to the ATS.

The design of this Automatic Transfer Switch has helped in broadening my horizon on circuit designs and the importance relays play in the design of circuits. This design has also taught me the importance of certain components in circuits, their respective roles, and how to use them as an interface to a microcontroller in a coordinated manner. In the design I also faced challenges in my connection because I did not ascertain how the generator switches were connected and this has shown me how to properly connect my device for it to work perfectly in case of future work.

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APPENDIX

Source Code

```
/*
 * AutomaticGenStarter.c
 *
 * Created: 4/16/2017 12:22:57 PM
 *  Author: AGBRAMU WATSON
 */
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <avr/io.h>
#include <avr/interrupt.h>
#define  F_CPU 1000000UL
#include <util/delay.h>
#include <avr/wdt.h>
#define  Usart_BaudValue 9600
#define  BaudValue (F_CPU / 4UL / Usart_BaudValue - 1) / 2
#define LCD_RS     2       //define MCU pin connected to LCD RS
#define LCD_RW     5       //define MCU pin connected to LCD R/W
#define LCD_E      3       //define MCU pin connected to LCD E
#define LCD_D4     4       //define MCU pin connected to LCD D3
#define LCD_D5     5       //define MCU pin connected to LCD D4
```

```
#define LCD_D6     6        //define MCU pin connected to LCD D5
#define LCPP PORTC
#define LCDRR DDRC
#define LCD_D7     7        //define MCU pin connected to LCD D6
#define LDP PORTD           //define MCU port connected to LCD data pins
#define LCP PORTD           //define MCU port connected to LCD control pins
#define LDDR DDRD           //define MCU direction register for port connected to LCD
data pins
#define LCDR DDRD           //define MCU direction register for port connected to LCD
control pins
#define LCD_CLR          0//DB0: clear display
#define LCD_HOME          1       //DB1: return to home position
#define LCD_ENTRY_MODE     2          //DB2: set entry mode
#define LCD_ENTRY_INC      1  //DB1: increment
#define LCD_ENTRY_SHIFT    0 //DB2: shift
#define LCD_ON_CTRL        3     //DB3: turn lcd/cursor on
#define LCD_ON_DISPLAY     2 //DB2: turn display on
#define LCD_ON_CURSOR      1 //DB1: turn cursor on
#define LCD_ON_BLINK       0     //DB0: blinking cursor
#define LCD_MOVE           4       //DB4: move cursor/display
#define LCD_MOVE_DISP      3   //DB3: move display (0-> move cursor)
#define LCD_MOVE_RIGHT     2 //DB2: move right (0-> left)
#define LCD_FUNCTION       5    //DB5: function set
#define LCD_FUNCTION_8BIT  4          //DB4: set 8BIT mode (0->4BIT mode)
```

```
#define LCD_FUNCTION_2LINES 3      //DB3: two lines (0->one line)
#define LCD_FUNCTION_10DOTS 2      //DB2: 5x10 font (0->5x7 font)
#define LCD_CGRAM         6    //DB6: set CG RAM address
#define LCD_DDRAM         7    //DB7: set DD RAM address
// reading:
#define LCD_BUSY        7      //DB7: LCD is busy
#define LCD_LINES                  2      //visible lines
#define LCD_LINE_LENGTH            16     //line length (in characters)
// cursor position to DDRAM mapping
#define LCD_LINE0_DDRAMADDR        0x00
#define LCD_LINE1_DDRAMADDR        0x40
#define LCD_LINE2_DDRAMADDR        0x14
#define LCD_LINE3_DDRAMADDR        0x54
// progress bar defines
#define Mains           6
#define Gen             7
#define OutputRelay     1
#define StartRelay      2
#define KickRelay       3
#define Buzzer          4
#define Output        PORTB
#define OutputDDR       DDRB
#define Input        PINB
```

```
#define InputDDR        DDRB
void CheckSms();
char Min,Hour,VoltsErro,Alert;
int
Adc0,Adc1,InputRef1,InputRef2,Ampers2,AdcSwap,AdcCount,i,output_volt_memo,outp
ut_volt_memo2,setP_temp,Ac,input[15],k[10],MgsCount,RecString[200],askey[]={'0','1','
2','3','4','5','6','7','8','9'};
int j,m,l;
int Time;
float  current,total_unit,watt,
kilowattHour,kWhTime,last_kWhTime,MeterPower1,MeterPower2;
int watts,unit_place,fract,watts_fract;
void LCDsendChar(uint8_t ch)            //Sends Char to LCD
{
LDP=(ch&0b11110000);
LCP|=1<<LCD_RS;
LCP|=1<<LCD_E;
_delay_ms(1);
LCP&=~(1<<LCD_E);
LCP&=~(1<<LCD_RS);
_delay_ms(1);
LDP=((ch&0b00001111)<<4);
LCP|=1<<LCD_RS;
LCP|=1<<LCD_E;
```

```
_delay_ms(1);
LCP&=~(1<<LCD_E);
LCP&=~(1<<LCD_RS);
_delay_ms(1);
}
void LCDsendCommand(uint8_t cmd)        //Sends Command to LCD
{
LDP=(cmd&0b11110000);
LCP|=1<<LCD_E;
_delay_ms(1);
LCP&=~(1<<LCD_E);
_delay_ms(1);
LDP=((cmd&0b00001111)<<4);
LCP|=1<<LCD_E;
_delay_ms(1);
LCP&=~(1<<LCD_E);
_delay_ms(1);
}
void LCDinit(void)//Initializes LCD
{
_delay_ms(15);
LDP=0x00;
LCP=0x00;
```

```
LDDR|=1<<LCD_D7|1<<LCD_D6|1<<LCD_D5|1<<LCD_D4;
LCDR|=1<<LCD_E|1<<LCD_RS;
LCDRR|=1<<LCD_RW;
//---------one------
LDP=0<<LCD_D7|0<<LCD_D6|1<<LCD_D5|1<<LCD_D4; //4 bit mode
LCP|=1<<LCD_E|0<<LCD_RS;
LCPP|=0<<LCD_RW;
_delay_ms(1);
LCP&=~(1<<LCD_E);
_delay_ms(1);
//-----------two-----------
LDP=0<<LCD_D7|0<<LCD_D6|1<<LCD_D5|1<<LCD_D4; //4 bit mode
LCP|=1<<LCD_E|0<<LCD_RS;
LCPP|=0<<LCD_RW;
_delay_ms(1);
LCP&=~(1<<LCD_E);
_delay_ms(1);
//-------three-------------
LDP=0<<LCD_D7|0<<LCD_D6|1<<LCD_D5|0<<LCD_D4; //4 bit mode
LCP|=1<<LCD_E|0<<LCD_RS;
LCPP|=0<<LCD_RW;
_delay_ms(1);
LCP&=~(1<<LCD_E);
```

```
_delay_ms(1);
//---------4 bit--dual line---------------
LCDsendCommand(0x28);//(0b00101000);
LCDsendCommand(0x28);
LCDsendCommand(0x28);
  //-----increment address, cursor off-----
   LCDsendCommand(0x0c);
}
void LCDclr(void)                    //Clears LCD
{
LCDsendCommand(1<<LCD_CLR);
}
void LCDhome(void)                   //LCD cursor home
{
LCDsendCommand(1<<LCD_HOME);
}
void initLcd(void)
{
LCDinit();//init LCD bit, dual line, cursor right
LCDclr();//clears LCD
}
void LCDstring(char *var)
{
```

```
while(*var)            //till string ends
LCDsendChar(*var++);  //send characters one by one
}
void LCDsNumPrint(unsigned fig,unsigned int datas){
for(i=fig;i>=0;i--){// load freq values into k[];
        k[i]=datas%10;
        datas=datas/10;
}
for(i=0;i<=fig;i++)
LCDsendChar(askey[k[i]]);
}
/*
example
   init();
LCDsendCommand(LCD_CLR);
   LCDsendCommand(LCD_HOME);
   LCDsendCommand(0x80+0);
   LCDstring("dis[]");//("...project...");
   LCDsendCommand(0xc0+0);
   LCDstring("project.e.org");
*/
void MainsInput(){
while(Input&(1<<Mains)){
```

```
        LCDsendCommand(0x080);LCDstring("   Mains On    ");
        LCDsendCommand(0x0c0);LCDstring("   Gen Off     ");
        Output|=(1<<OutputRelay);                  // switch on load
        Output&=~((1<<StartRelay)|(1<<KickRelay)|(1<<Buzzer));// switch off key start,
buzzer
        while(Input&(1<<Mains));                   // wait here while mains present
 }
 Output&=~(1<<OutputRelay);                        // switch off load
 }
 void GenInput(){
 while(!(Input&(1<<Mains))){
        LCDsendCommand(0x080);LCDstring("   Mains Off   ");
        LCDsendCommand(0x0c0);LCDstring("   Gen Off     ");
        Output|=(1<<StartRelay)|(1<<KickRelay);        // switch on key start, kick
        for(char i=0;i<5;i++){
               Output|=(1<<KickRelay);                 // switch on key kick
               _delay_ms(5000);                     // delay for 5sec
               Output&=~(1<<KickRelay);                // switch off key kick
               _delay_ms(2000);                     // delay for 2sec
               if(Input&(1<<Gen)){                   // feedback from gen
                      LCDsendCommand(0x0c0);LCDstring("   Gen On      ");
                      while(!(Input&(1<<Mains)));          // wait here while mains is
not present
                      Output|=(1<<OutputRelay);            // switch on load
```

```
                    break;
                    }
        }
        if(!(Input&(1<<Gen))){
                LCDsendCommand(0x0c0);LCDstring("   Gen Fails    ");
                for(char i=0;i<3;i++){
                Output|=(1<<Buzzer);                    // buzzer on
                _delay_ms(1000);                        // delay for 1sec
                Output&=~(1<<Buzzer);                   // buzzer off
                _delay_ms(1000);                        // delay for 1sec
                  }
                  while(!(Input&(1<<Mains)));           // wait here while mains is not
present
        }
 Output&=~(1<<StartRelay);                      // switch on key start
 }
 }
 int main(void)
 {
 OutputDDR|=(1<<OutputRelay)|(1<<StartRelay)|(1<<KickRelay)|(1<<Buzzer);
 InputDDR&=~((1<<Mains)|(1<<Gen));
 Output&=~((1<<OutputRelay)|(1<<StartRelay)|(1<<KickRelay)|(1<<Buzzer));
 Output|=(1<<Mains)|(1<<Gen);
 initLcd();
```

```
while(1){
 MainsInput();
 GenInput();
 LCDsendCommand(0x080);LCDstring("    Mains Off   ");
 LCDsendCommand(0x0c0);LCDstring("    Gen Off     ");
//_delay_ms(1500);
 }
 }
//*******************************************************************
*****//
```

Cost Evaluation

Cost evaluation in every project is essential because it presents the expensed ensued in the completion of the project from start to completion, this evaluation projects the cost effectiveness of the project designed and gives an average amount required in developing the project indicating how cheap it could be easily purchased and designed in bulk if necessary. The cost of the project below excluded miscellaneous and also workmanship because it centers on only the components used in the design and this cost when compared to other existing costs was at least 50% more economical.

S/N	COMPONENT/ITEM	QUANTITY	UNIT AMOUNT (₦)	TOTAL AMOUNT (₦)
1	Voltage Regulator	1	100	100
2	Atmega8 Microcontroller	1	1500	1500
3	PC817 Optocoupler	2	100	200
4	1N4007 Diode	9	20	180
5	2N2222 Transistor	4	100	400
6	LCD Display	1	2000	2000
7	Buzzer	1	200	200
8	Capacitor 1000uF/35v	1	200	200
	Capacitor 47uF/25v	1	100	100
	Ceramic Capacitor 104F	5	100	500
9	Resistor 10kΩ	2	20	40
	Resistor 1Kω	4	20	80
	Resistor 18kΩ/ 5w	2	100	200
10	Relay	2	200	400
11	Changeover	2	300	600
12	Connectors and Cables	1	3000	3000
13	Casing	1	2000	2000
	GRAND TOTAL			11700

Operational Flow Chart