DESIGN AND CONSTRUCTION OF A WIRELESS SPEED CONTROL OF AN INDUCTION MOTOR

BY

ANDREW OGECHUKWU IFEANYI

NAU/2013234176

SUBMITTED TO:

THE DEPARTMENT OF ELECTRICAL ENGINEERING

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY, AWKA, ANAMBRA STATE

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL ENGINEERING

AUGUST, 2018.

CERTIFICATION

This is to certify that this project was researched, written and presented by **ANDREW OGECHUKWU IFEANYI** with Reg. No. 2013234176 to the Department of Electrical Engineering, Nnamdi Azikiwe University, Awka.

……………………………………. …………………

Andrew Ogechukwu Ifeanyi Date

Successor.andrew94@gmail.com

APPROVAL PAGE

This is to certify that this project titled "**DESIGN AND CONSTRUCTION OF WIRELESS SPEED CONTROL OF INDUCTION MOTOR**" was carried out by **IFEANYI, ANDREW OGECHUKWU** with Reg. No. 2013234176 in partial fulfilment of the requirement for the award of Bachelor of Engineering (B. Eng.) Degree in Electrical Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

………………………………..   …………..

Engr. Kingsley Obute Chibueze   Date

(Project Supervisor)

……………………………..   ……………

Engr. Dr. J. C. Onuegbu   Date

(Head of Department)

……………………………..   ……………

External Examiner   Date

DEDICATION

This work is dedicated to my Parents, **Mr. and Mrs. Clement Chiekwe I.** for their love, moral and financial support.

ACKNOWLEDGEMENT

My profound gratitude goes to **God Almighty**, for the unmerited favour, grace and wisdom He bestowed unto me all through my five (5) years of study.

My sincere gratitude also goes to my supervisor, **Engr. Obute Kingsley Chibueze** for his support, efforts and immeasurable contributions to the successful completion of this work. I am very much grateful for his fatherly love, discipline and perseverance in guiding me to accomplish this project. May God continually strengthen and sustain you.

I also acknowledge the Head of Department, **Engr. Dr. J.C. Onuegbu** and other lecturers who imparted a lot on me during the course of my studies. This include, **Engr. M. N. Eleanya, Engr. Dr. E. A. Anazia, Engr. Dr. F.O. Enemuoh, Engr. T.F. Uketui, Engr. Dr. V.N. Agu, Engr. Dr. O. A. Ezechukwu, Engr. Alex Anya, Engr. S. O. Ezennaya, Engr. S. N. Onyedikachi, Engr. Ogboh Victor, Engr. Emma Nwangugu**, **Engr. C. O. Olisakwe, Engr. C. O. Okoye, Engr. T. I. Alade** and other members of staff of Electrical Engineering Department. May God continually strengthen you.

ABSTRACT

Pulse Width Modulation (PWM), as it applies to Electric Motor Control, is a way of delivering energy through a succession of pulses rather than a continuously varying (analogue) signal. By increasing or decreasing the pulse width, the microcontroller regulates the energy flow into the motor shaft. The motor's own inductance acts like a filter, storing energy during the "on" cycle while releasing it at a rate corresponding to the input or reference signal. In this project, Pulse Width Modulation (PWM) technique was used for controlling the speed of the Single Phase Induction Motor. This was achieved by programming a microcontroller **AT89C52**, using embedded **C language** to produce PWM pulses according to the switching of buttons, achieved wirelessly, using **433.92MHz** Transmitter and Receiver.

TABLE OF CONTENT

CHAPTER FIVE: RECOMMENDATION AND CONCLUSION

CHAPTER ONE

INTRODUCTION

1.1 Background

For various industrial applications, the induction motor is mostly used. The loads on induction motor always vary as per its application but speed of induction motor is constant and cannot match with the load demand. If the load on an induction motor decrease, the speed of induction motor cannot be decreased as per the load. Hence it takes rated power from supply, so the energy consumed by the motor is same. Hence energy consumption is same during load variation period also. To overcome this problem, a Variable Frequency Drive is used in industrial application to save the energy consumption and electricity tariff. [1].

There are various application of Variable Speed Control (VSC), since starting current is reduced by making use of Variable Frequency Drive (VFD), large energy is saved. Examples like fans, pumps, tower cooling systems, micro-wave ovens, air conditioners and ship propulsion systems. It has been said that from the energy consumed by AC motors, 10% goes idle and 12-15% is lost when the motor does not run at full load. Hence, there is great need for speed control, to save energy. [2].

1.2 Aim of Project

The aim of this work is to design and construct a wireless variable speed control for an induction motor.

1.3 Objectives of Project

The objectives of the Project are:

A. To operate an induction motor kept at remote location.
B. To improve power factor of motors using VFD's since power factor is reduced when motors run at full load.
C. To describe how to vary the frequency of induction motors so as to control its speed with the help of a microcontroller, wirelessly.
D. To establish that minimum energy can be consumed by induction motors at varying load.

1.4 Significance of Project

This work demonstrates that an induction motor working in a hazardous environment can be controlled, with great quantity of energy saved at varying load conditions, during operation.

1.5 Scope of Project

This project covers the history of speed control for induction motors/Variable Frequency Drive (VFD), three phase induction motors, wireless communication and the design and component description of wireless speed control of induction motor, using pulse width modulation technique.

1.6 Organization of Project

This work consists of five (5) chapters. Chapter one (1) is introduction, where I portrayed the importance/need of using a wireless speed control for induction motor. Chapter two (2) deals with the literature review. It discusses work done on the project previously. Chapter three (3) is Methodology, which talks about the steps/method taken to achieve this project. Chapter four (4) shows the component description and design analysis. Chapter five (5), portrays problems encountered, recommendations, conclusion and references.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Background of Variable Frequency Drive (VFD)

Variable Frequency Drive, is typically a tool of power electronics, without having a great understanding of power electronics we can never get the depth of variable frequency drive.

The history of power electronics tells us that its evolution started in the very beginning of 20th century. And the first invention that was brought before the world by Peter Cooper was mercury-arc rectifier.[1]. With the passage of time power electronics had under gone many changes and in the 3rd and 4th decade of 20th century it was evolved to gas tube electronics, and saturated core magnetic amplifiers in the mid of 20th century many advancement were seen in field of power electronics and the work which came forward was silicon controlled rectifier (SCR) and thyristor. The first Variable Frequency Drive (VFD) was based on mechanical principles because power electronics had not made great advancements till that day. It consisted of adjustable pitch diameter pulleys. [2].

AC induction motors were firstly designed in 1924 and the speed of motors were dependent upon frequency and poles of motors. After the invention of motors it was thought that motors could be run on variable speed, for that matter the only possible solution was to vary the frequency, In order to run the motor on a variable speed, because frequency has direct relation with motor speed. Variable frequency drive based on pulse width modulation was firstly invented in early 60’s in Finland. [3]

Different techniques and methods used to improve the efficiency and working of AC induction motors like soft starters [4], voltage reduction method [5], slip compensation [6], and vector control [7]. But all these methods are not proved feasible for avoiding slip already present in the motor. Because this slip in the motor signifies the amount of energy that is dissipated in the form of heat and may harm many other sensitive component and windings of the motor thus the life time of motor is reduced [8].

In early 1957, Mr Leonard was developing the dc variable speed drives; Nikola Tesla was amazing the world with the AC induction motor. During this period, the AC induction motor became universally accepted as the device for converting AC electrical power to fixed-speed mechanical power.

Unlike the DC motor, the AC motor required both variable frequency and voltage to operate at a constant torque, variable-speed device. Because of the technical and economic limitations of rotating variable-frequency power conversion units, the AC variable-speed system has had limited application. These applications normally involved multi-motor systems where a narrow speed range and low dynamic performance was acceptable.

In 1957, the silicon controlled rectifier was introduced. This product of modern solid-state physics gave the drive designer at economic power device with amazing capabilities:

- Ability to close and open a power circuit in microseconds.
- Ability to control large amount of current with minimal control current

- Ability to operate with high efficiency

One of the first uses of this new device, now referred to as a thyristor, was to replace the AC motor, DC generator set in the Ward-Leonard system. This substitution permitted significant reductions in equipment size and weight, plus improved efficiency.

2.2 Three Phase Induction Motor (IM)

The three phase induction motors are also called asynchronous motors, which are most commonly used type of motor in industrial applications. In particular, the squirrel cage induction motors are widely used electric motor in home and industrial applications, because these machines are very economical, rugged and reliable. They are available in the ranges of Fractional Horse Power (FHP) to multi-megawatts capacity. Fractional Horse Power motors are available in single phase as well as poly phase. The three phase machines are used most often in variable speed drives where the torque requirement is more.

A three phase induction motor consists of two parts, stator and rotor. A stator is the stationary part while the rotor is the rotating part of the motor and they are separated by a small air gap depending on the rating of the motor.

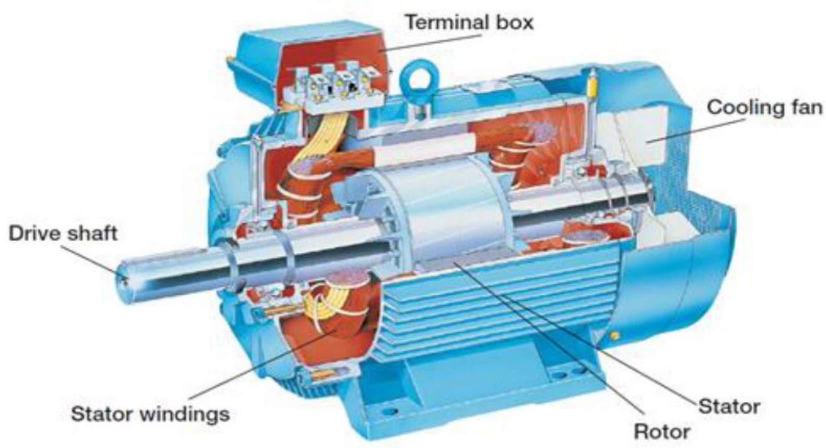


Plate 2.1 Three Phase Squirrel Cage

2.2.1 Stator

The stator consist of a steel frame which encloses a hollow cylindrical core made up of thin laminations of silicon steel to reduce eddy current and hysteresis loss. A larger number of uniform slots are cut on the inner periphery of the core. The stator conductors are placed in these slots which are insulated from one another and also from the slots. These conductors are connected as a balance three phase star or delta winding. The windings are wound for a definite number of poles depending on the requirement of speed. It is wound for more number of poles, if speed required is less and vice versa. According to the relation:

$$Ns=120F/P \qquad \text{…2.1}$$

Where Ns is the synchronous speed in RPM

F is the supply frequency

P is the number of pole

When a three phase supply is given to stator winding a magnetic field of constant magnitude and rotating at synchronous speed is produced. This rotating magnetic field is mainly responsible for producing torque, so that it can rotate at the rated speed.

2.2.2 Rotor

The rotor is the rotating part of the induction motor and is mounted on the shaft of the motor to which any mechanical load can be connected. Based on the construction of the rotor, induction motors are broadly in two categories; squirrel cage motors and slip ring motors. The stator construction is the same in both motor. Almost 90% of induction motors are squirrel cage motors. This is because the squirrel cage motor has a simple and rugged construction. It consists of cylindrical laminated core with axially placed parallel slots for carrying rotor conductors. The rotor conductors are heavy bars of copper or aluminium. Each slot carries a copper, aluminium or alloy bar. If the slots are semi closed, then these bars are inserted from the ends. These rotor bars are permanently short circuited at both ends and inserted from the ends. As rotor bars are short circuited on themselves, it is not possible to add external resistance in series with rotor circuit during starting. The slots are slightly skewed, which helps in two ways that is:

- It reduces noise due to magnetic hum and makes motor run quietly.
- It reduces locking tendency between rotor and stator.

2.2.3 Slip

The slip can be defined as the ratio of the difference between the synchronous speed and actual speed of the machine to the synchronous speed. It can be expressed in percentage. Based on this slip speed, the voltage induced in the rotor winding changes, which in turn changes the rotor current and also the torque. As slip increases, the rotor current and the torque also increases. The rotor moves in the same direction as that of the rotating magnetic field to reduce the induced current (Lenz law). The slip can be expressed as given below.

Slip $S = (N_s - N_r)/N_s$ ...2.2

or

$N_r = N_s(1-S)$ ...2.3

Synchronous speed is given by $N_s = 120f/P$ …2.4

where P represents the number of poles and f is stator frequency in Hz

therefore equation 2.3 becomes,

Rotor speed $N_r = (120f)/p(1-S)$ ...2.5

Thus, the speed of an induction motor depends on the slip ‘S’, stator frequency f and the number of poles for which the windings are wound.

2.3 Different Speed Control Methods

From equation 2.5 , the speed of IM can be varied by varying the slip 'S' or number of poles 'p' or frequency of supply. The different methods of speed control of induction motor can be broadly classified in to scalar and vector methods. In this work, scalar control methods are used. Hence only details of scalar are discussed here. The explanation of vector control method is beyond the scope of this thesis. The scalar methods of speed control can be classified as:

- Stator voltage control
- Frequency control
- Stator voltage and frequency control that is, volts-Hz control
- Rotor voltage control

The first three methods are the basic methods of speed control and are explained in details as follows:

2.3.1 Stator Voltage Control Method

A very simply and economic method of speed control is to vary the stator voltage at constant supply frequency. The three-phase stator voltage at line frequency can be controlled by controlling the switches in the inverter.

The salient features of stator-torque control method are:

- For low-slip motor, the speed range is very low
- Not suitable for constant torque load
- Poor power factor

- Used mainly in low power application, such as fans, blowers, centrifugal pumps, etc.

2.3.2 Frequency Control Method

The torque and speed of induction motors can be controlled by changing the supply frequency but keeping the voltage constant, and then saturation of air-gap flux takes place. At low frequency, the reactance will decrease and the motor current may be too high. If the frequency is increased above its rated value, then the air gap flux and rotor current decreases correspondingly, the developed torque also decreases. Due to these reasons, this method of control is rarely used.

2.3.3 Volts-Hertz (V/F) control method

The constant V/F control method is the most popular method of scalar control. If an attempt is made to reduce the supply frequency at the rated supply voltage, the air gap flux will tend to saturate, causing excessive stator current and distortion of flux wave.

Therefore, the region below the base or rated frequency should be accompanied by the proportional reduction of stator voltage so as to maintain the air gap flux constant. If the ratio of voltage to frequency is kept constant, the flux remains constant. By varying the voltage and frequency the torque and speed can be varied. The torque is normally maintained constant while the speed is varied. This arrangement is widely used in the locomotives and industrial applications. The purpose of the volts hertz control scheme is to maintain the air gap flux of AC induction motor constant in order to achieve higher run-time efficiency. The magnitude of stator flux is proportional to the ratio of stator voltage and the frequency. If ratio is kept constant the stator flux remains constant and motor torque will only depends upon slip frequency. In variable-frequency, variable-voltage operation of drive system, the machine usually has low slip characteristics (i.e. low rotor resistance), given high efficiency. In spite of the low inherent starting torque for base frequency operation, the machine can always be started at maximum torque for base frequency operation, the machine can always be started at maximum torque. The absence of high in rush starting current in a direct start drive reduces stress and therefore improves the effective life of the machine. By far the majority of variable speed ac drives operate with variable frequency, variable voltage power supply.

Other than the variation in speed, the torque-speed characteristics of V/F control reveal the following:

- The starting current is low
- The stable operating region of the motor is increased. Instead of simply running at its based/rated speed (N_b), the motor can be run typically from 5% of the synchronous speed (N_s) up to the base speed. The torque generated by the motor can be kept constant throughout this region.
- Since almost constant rated torque is available over the entire operating range, the speed range of the motor becomes wider. User can set speed as per the load requirement, thereby achieving the higher efficiency.
- One of the most advantages is soft start capability in which motors are ramped up to speed instead of being abruptly thrown on line. This useful feature

reduces mechanical stresses on the motor and leads to lower maintenance cost as well as a longer motor life. [9]

2.4 Wireless Communication

Wireless communication is the transmission of information without using electrical conductors. Distances involved is probably several meters such as in the television remote control or thousands kilometres for radio communications. In general, wireless communication is regarded as a branch of telecommunications. It covers wide range of fixed radio, portable two ways radio and wireless networking.

Wireless operation allows services such as long distance communication which is impossible to implement with the use of wires. Wireless communication depends on limited resources which is radio spectrum. Those that allowed higher frequencies to be used are more efficient, the use of spectrum for wireless communication required the key complimentary technologies that have been developed and also more sophisticated. A systematic development standard is also required to get the most efficient of wireless communication. Wireless communication starts with a message that swapped into electronic signals by a device called transmitter. These systems are involving either one way of transmission or two-way transmission. The principles technologies involved in wireless communication are infrared (IR), Bluetooth and Radio Frequency (RF).

CHAPTER THREE

METHODOLOGY

3.1 Methodology

Methodology is the systematic and theoretical analysis of the methods applied to a field of study. It has to do with the theoretical analysis of the body of methods and principles associated with a branch of knowledge.

The method adopted in this project can be sub-divided into four (4) stages. They include: Planning, Analysis, Design and Implementation.

3.1.1 Planning Stage

This stage was done after the approval of my Project Supervisor and basically, it involves collection of data's from various sources like textbooks, journals, research papers from libraries and most especially the internet, needed in the project design.

3.1.2 Analysis Stage

This stage involves defining the design specifications which would serve as a guide during the course of the design. Furthermore, the theory of components was discussed, that will be used for the project. The bottom-up approach was adopted for this project. This method explains all the blocks in the block diagram such as indicator, keypad, Encoder, Radio Frequency (RF) Transmitter, RF Receiver, Decoder, microcontroller, Switching Unit and Motor, that is from the less significant to the most significant item.

3.1.3 Design Stage

This involves derivations and calculations adopted to achieve the component specifications used in the implementation of this project system design. System design helps in defining overall system architecture.

3.1.4 Implementation Stage

With respect to the results from the design stage, inclusive are other stages, the circuit diagram was drawn using live wire, after which the various components was put together on a bread-board. After all the units were tested and were working, the components were soldered into a vero-board. The work was further put in a casing and was ready for dispatch.

CHAPTER FOUR

COMPONENT DESCRIPTION/DESIGN ANALYSIS

4.1 Component Description

This section, discusses the principal electronic components and devices that were put together in designing the hardware of this project. The functions, mode of operation and other features are also explained here.

4.1.1 Resistors

Resistors are simply passive devices made from semiconductor materials. They are basically used in circuits to limit current flow and provide voltage drop where necessary. The resistance of a resistor is directly proportional to the potential difference (PD) across its terminals, and it is given as:

$$R=V/I \qquad ...4.1$$

Where; R=Resistance of the resistor

V=voltage across the resistor

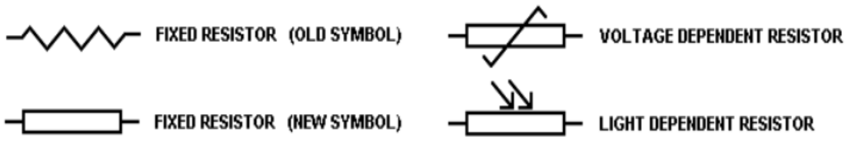
I=current across the resistor

Types of resistor

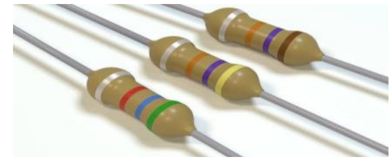
I Fixed Resistor

II Light Dependent Resistor (LDR) and other types, whose resistance are dependent on temperature and pressure.

III Variable Resistor (Potentiometer).



(a)
Plate 4.1a Resistor Symbols



(b)
Plate 4.1b Resistor Images

The carbon deposition type of resistors is used for this project. Resistors are available in a range of different values and tolerances and in a power that the resistor can dissipate in form of heat. The amount of energy dissipated can be calculated by this formula;

$$P=VI \text{ (watts)} \qquad \ldots 4.2$$

Where; P=Power

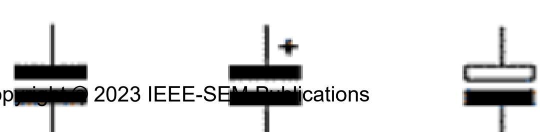
V=Voltage across the resistor

I=Current.

4.1.2 Capacitors

A capacitor is an electrical device that can store energy in the electrical field between a pair of closely spaced conductors (called plates). When voltage is applied to the capacitor, electrical charges of equal magnitude but opposite polarity, build up on each side. They can be used to differentiate between high frequency and low frequency signals and this makes them useful in electronic filters.

The common symbol of a capacitor in a circuit diagram is shown below in Plate 4.2



(a) (b)

Plate 4.2a Capacitor Symbols Plate 4.2b Capacitor Image

The capacitor's capacitance, is a measure of the amount of charge (Q) stored on each plate for a given potential difference or voltage (V) which appears between the plates. Below is the relationship between them:

$C = Q/V$ (Farads) ...4.3

Where; Q=charge

V=voltage applied

C=capacitance

The factors affecting the values of the capacitance of a capacitor are;

I Area of plates

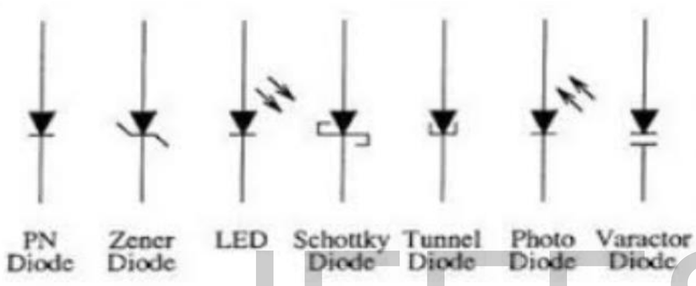
II Nature of dielectric

III Distance between the plates.

4.1.3 Diodes

Diodes are semiconductor devices which can be described as passing current in one direction only. Diodes however, are far more versatile devices than that. Diodes can be used as voltage regulators, turning devices in Radio Frequency (RF) tuned circuits, frequency multiplying devices in RF circuits, mixing devices in RF circuits, switching applications or can be used to make logic decisions in digital circuits. Diodes that emit lights are known as Light Emitting Diodes (LED). Current can only flow from anode to cathode and not in the reverse direction, except for some special diodes, like zener diodes.

A few schematic symbols for diodes are:



(a)

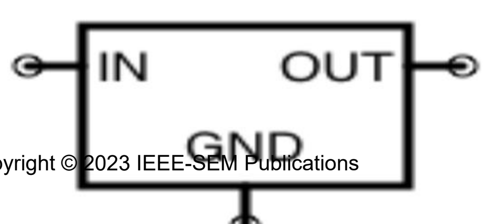
Plate 4.3a Different Diodes

(b)

Plate 4.3b Diode Image

4.1.4 Voltage Regulator

A voltage regulator has only three (3) legs and appears to be a comparatively simple device but it is actually a very complex integrated circuit. A regulator converts varying input voltage and produces a constant "regulated" output voltage. They are available in varieties of outputs, typically 5, 9 and 12 volts. The last two (2) digits in the name indicate the output voltage. The "LM78XX" series of voltage regulators are designed for positive input.

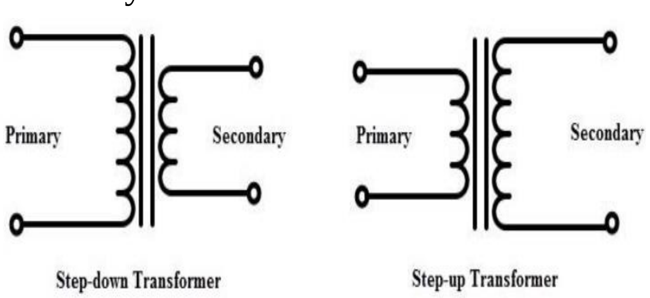


(a)
Plate 4.4a Circuit Symbol of a Voltage Regulator

(a)
Plate 4.4b Image of a Voltage Regulator

4.1.5 Transformers

A transformer is a device consisting of two closely coupled coils (primary and secondary) connected magnetically. An AC voltage applied to the primary appears across the secondary due to electromagnetic induction, with a voltage multiplication proportional to the turn's ratio of the transformer and a current multiplication inversely proportional to the turns ration. Power is conserved. Plate 4.5 shows the circuit symbol for a laminated core transformer.



(a)
Plate 4.5a Circuit Symbol of a Transformer

(b)
Plate 4.5b Image of a Transformer

Transformers are quite efficient (output power is very nearly equal to input power); thus a step-up transformer gives higher voltage at lower current. A transformer of turns ratio n, increases the impedance by n^2. There is very little primary current if the secondary is unloaded.

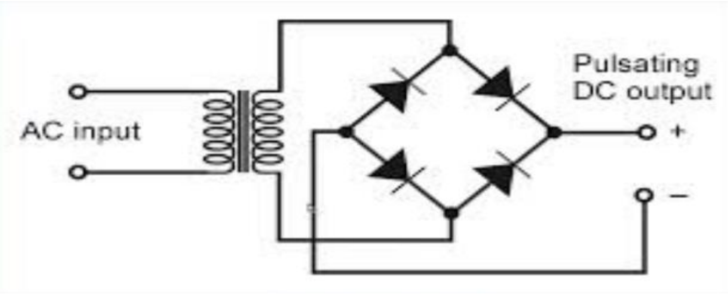
Transformers, serve two (2) important functions in electronic instruments:

They change the AC line voltage to a useful (usually lower) value that can be used by the circuit and they isolate the electronic device from actual connection to the power line, because the windings of a transformer are electrically insulated from each other. Power transformers (meant for use from the 220V power line) come in an enormous variety of secondary voltages and current output as low as 1 volt or so up to thousand volts, current ratings from a few milliamps to hundreds of amps.

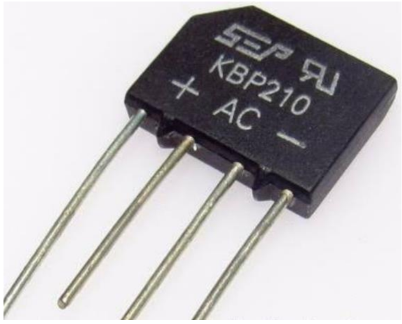
4.1.6 Bridge Rectifier

A Bridge Rectifier can be made using four individual diodes, but it is also available in special packages (Like the one used in this design) containing the four diodes required. It is also called a full wave rectifier because it uses the entire AC wave (both positive and negative sections). 1.4V is used up in the bridge because each diode uses 0.7V when conducting (two diodes at a time), as shown in the Fig below, Bridge rectifiers are rated by the maximum current they can pass and the maximum reverse voltage they can withstand (this must be at least three (3) times the supply RMS voltage so the rectifier can withstand the peak voltages).

In contrast, rectifier diodes and bridges for use in power supplies are hefty objects with current ratings going from 1 to 25amps or more and breakdown voltages going from 100 to 1000volts. They have relatively high leakage currents (in ranges of micro amps to milliamps) and plenty of junction capacitance.



(a)
Plate 4.6a Circuit Symbol of a Bridge Rectifier



(b)
Plate 4.6b Image of a Bridge Rectifier

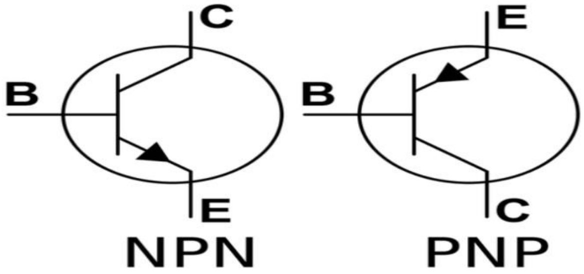
4.1.7 Transistor

Transistors can be regarded as a type switch. They are used in a variety of circuits. They are central in electronic engineering and there are mainly of two types NPN and PNP. Most circuits (example is this project), tend to use NPN. There are hundreds of transistors which work at different voltages but all of them fall into these two categories.

Types of Transistor

There are two (2) types of standard transistor, NPN and PNP, with different circuit symbols. The letters refer to the layers of semiconductor material used to make the transistor. Most transistors used today are NPN because this is the easiest type made from silicon.

The legs are labelled Base (B), Collector (C) and Emitter (E). These terms refer to the internal operation of a transistor but, they are not much helpful in understanding how a transistor is used, so just treat them as labels.



(a)
Plate 4.7a Circuit Symbols of a Transistor

(b)
Plate 4.7b Image of a Transistor

Functional Model of an NPN Transistor:

It is more helpful to use this functional model in the explanation of the operation of internal structure of an NPN transistor. [10].

- The base-emitter junction behaves like a diode.
- A base current I_B flows only when the voltage V_{BE} across the base-emitter junction is 0.7V or more.
- The small base current I_B, controls the large collector current I_C.
- $I_C = h_{FE} \times I_B$ (unless the transistor is fully on and saturated), h_{FE} is the current gain (Direct Current DC), a typical value for h_{FE} is 100 (it has no unit because it is a ratio).
- The collector-emitter resistance R_{CE} is controlled by the base current I_B. such that when $I_B = 0$, R_{CE} = infinity, transistor OFF, when I_B is small, R_{CE} is reduced, transistor is partially on and when I_B is increased, $R_{CE} =0$ and the transistor is fully ON (saturated).

Notes:

- A resistor is often needed in series with a base connection to limit the base current I_B so as to prevent the transistor from being damaged.
- Transistors have a maximum collector current I_C rating.
- The current gain h_{FE} can vary widely, even for transistors of the same type.
- A transistor that is fully ON (with $R_{CE} = 0$) is said to be saturated.
- When a transistor is saturated, the collector-emitter voltage V_{CE} is reduced to 0V.
- When a transistor is saturated, the collector current I_C is determined by the supply voltage and the external resistance in the collector circuit, not by the transistor current gain. As a result the ratio I_C/I_B for a saturated transistor is less than the current gain h_{FE}.
- The emitter current $I_E = I_C + I_B$, but I_C is much larger than I_B, so approximately, $I_E = I_C$.

4.1.8 Relay

A relay is an electrically operated switch. Current flowing through the coils of the relay creates a magnetic field which attracts a lever and changes the switch contacts.

The coil current can be ON or OFF so relays have two switch positions and they are double throw (changeover) switches.

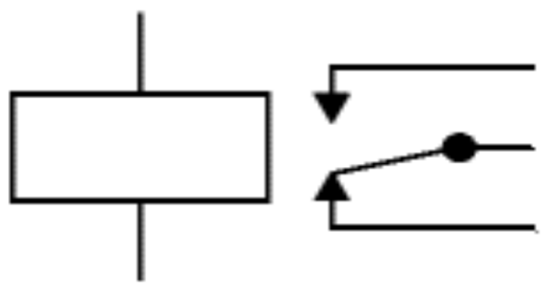
Relays allow one circuit to switch a second circuit which can be completely separable from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical. The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as much 100mA for relays designed to operate from lower voltages. Most Integrated Circuit IC chips cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

The supplier's catalogue should show you the relay's connections. The coil will be obvious and it may be connected either way round. Relay coils produce brief high voltage spikes when they are switched off, and this can destroy transistors and IC's in the circuit. To prevent damage, you must connect a protection diode across the relay coil.

The Relay's switch connections are usually labelled COM, NC and NO.

- COM, common always connected to this, it is the moving part of the switch.
- NC, Normally closed, COM is connected to this when the relay coil is OFF
- NO, Normally open, COM is connected to this when the relay coil is ON.

- Connect to COM and NC if you want the switch circuit to be ON when the relay coil is OFF.



(a)

Plate 4.8a Circuit Symbol of a Relay

(b)

Plate 4.8b Image of a Relay

4.1.9 Micro Controller

A microcontroller (MCU) is a computer on-a-chip, used to control electronic devices. It is a type of microprocessor emphasizing self-sufficiency and cost effectiveness in contrast to general purpose microprocessor (the type used in a Personal Computer PC). A typical microcontroller contains all the memory and interfaces needed for a simple application, whereas a general purpose microprocessor requires additional chips to provide these functions.

A microcontroller is a single Integrated Circuit (IC) with the following key features:

- Central processing unit-ranging from small and simple 8-bit processors to sophisticated 32 or 64bit processors.
- Input/output interfaces such as serial ports.
- Peripherals such as timers.

- RAM for data storage.
- ROM, EEPROM or flash memory for program storage.
- Clock generator often an oscillator for a quartz timing crystal, resonator or RC circuit.

This integration, drastically reduces the number of chips and the amount of wiring and Printed Circuit Board (PCB) space that would be needed to produce equivalent system using separate chips.

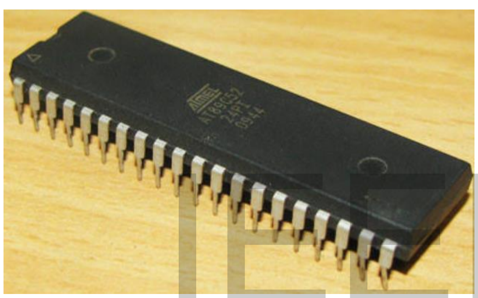


Plate 4.9 Image of AT89C52 Microcontroller

The microcontroller (AT89C52) was used for the project and will be described below.

4.1.9.1 Description of Atmel AT89C52 Microcontroller

The AT89C52 is a low-power, high performance CMOS 8-bit microcontroller with 8K bytes of flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high density non-volatile memory technology and is compatible with the industry standard 80C51 and 80C52 instruction set and pin-out. The on-chip flash allows the program memory to be reprogrammed in system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provided a highly flexible and cost effective solution to many embedded control applications.

The AT89C52 provides the following standard features; 8K bytes of flash, 256 bytes of RAM, 321/0 lines, three 16-bit timer/counters, a six-vector two level interrupt architecture, a full duplex serial port on-chip oscillator and clock circuitry. In addition, the AT89C52 is designed with static logic for operation down to zero frequency and supports two software selectable power savings modes. The idle mode stops the Central Processing Unit (CPU) while allowing the Random Access Memory (RAM), timer/counters, serial port and interrupt system to continue functioning. The power down Mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next hardware reset.

It has the following features:

- Compatible with MCS-51TM products.
- 8K bytes of in-system Reprogrammable flash memory

- Endurance: 1000 write/erase cycle.
- Fully static operation: 0hz to 24hz.
- Three-level program Memory Lock.
- 256x8 Bit internal RAM
- 32 programmable input/output ports.
- Three (3) 16-Bits Time/counters.
- Eight (8) interrupt sources.
- Programmable Serial Channel.
- Low power idle and power Down Modes.

4.1.9.2 Pin Description

VCC Supply voltage

GND Ground

Port 0: is an 8-Bit open drain bidirectional input/output (i/o) port. As an output port, each pin can sink eight (8) TTL input. When 1's are written on port 0 pins, the pins can be used as high impedance inputs. Port 0 can also be configured to be multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, port 0 has internal pull ups. External pull ups required during program verification.

Port 1: is an 8-Bit bi-directional i/o port with internal pull ups. The port 1 output buffers can sink/source four TTL inputs. Port 1 also receives the low-order address bytes during flash programming and verification.

Port 2: is an 8-Bit bi-directional i/o port with internal pull ups. The port 2 output buffers can sink/source four TTL inputs. Port 2 also receives the high order address Bits and some control signals during flash programming and verification.

Port 3: is an 8-Bit bi-directional i/o port with internal pull ups. The port 3 output buffers can sink/source four (4) TTL inputs. When are written to port 3 pins, they are pulled high by the internal pull ups and can be used as inputs. As inputs, port 3 pins that are externally being pulled low will source current because of the pull ups. Port 3 also serves the functions of various special features of the AT89C52 and also receives some control signals for flash programming and verification.

RST: Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/PROG: Address Latch Enable is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during flash programming. In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. Note however, that one ALE pulse is skipped during each access to external data memory. If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is weakly pulled high. Setting the ALE disable bit has no effect if the microcontroller is in external execution mode.

PSEN: Program Store Enable is the read strobe to external program memory. It is activated twice each machine cycle, except that two (2) PSEN actuations are skipped during each access to external data memory.

EA/V_{pp}: External Access Enable (EA) must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH.

Note that if lock bit 1 is programmed, EA will be internally latched on reset. This pin also receives the 12volts programming enable voltage (Vpp) during flash programming when 12volts programming is selected.

XTAL 1: input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL 2: Output from the inverting oscillator amplifier.

Oscillator Characteristics

XTAL 1 and XTAL 2 are the input and output respectively of an inverting amplifier that can be configured for use as an on-chip oscillator, either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL 2 should be left unconnected while XTAL 1 is driven. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is though a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Note: C1, C2=30PF ± 10 PF for crystals while

IEEE-SEM, Volume 11, Issue 9, September-2023
ISSN 2320-9151

C1, C2=40PF ± 10PF for ceramic resonators.

4.1.10 Transmitters and Receivers

Transmitters and Receivers are used for Radio Transmission. The demands placed on the transmitter and receivers are clearly distinct since the transmitter must process only the desired signal while the receiver must separate the desired signal from the frequency mixture received by the antenna. Furthermore, the transmitter handles signal level which are constant or which vary very slightly, while the receiver copes with extremely large level differences that depend on the distance to the transmitter.

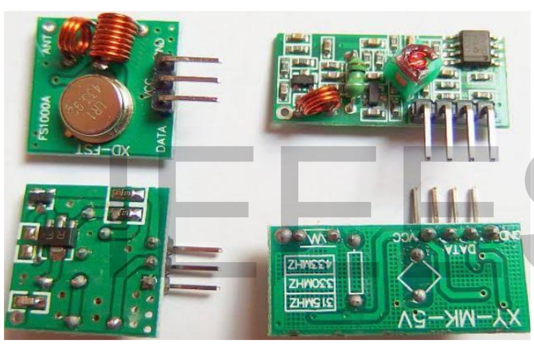


Plate 4.10 Image of 433.92Mhz Transmitter and Receiver

The main task for the transmitter include the task of converting the useful signal into a high frequency transmission to amplify this signal with the highest possible efficiency and to amplify this signal with the highest possible efficiency and to minimize the transmission of undesirable interference signals generated by the conversion or amplification. The main challenges for the receiver are to filter out the desired signal from adjacent frequency ranges and producing a clear signal with a high signal-to-noise ratio and minimum intermodulation distortions. Thus, the main obstacle for concern in transmitters is efficiency, while receivers face issues of selection, dynamics and noise.

The wireless used for this project is 433Mhz Radio Frequency (RF) Transmitter with Receiver kit for Arduino ARM Microcontroller wireless.

The specification for the receiver module is as follows:

- Product Model: XD-RF-5V
- Operating Voltage: DC 5V
- Quiescent Current: 4MA
- Receiving Frequency: -105DB
- Size: 30X14X7mm

The specification for the transmitter module is as follows:

- Product Model: XD-FST
- Launch Distance: 20-200 meters (different voltage, different results).
- Operating Voltage: 3.5-12V
- Dimensions: 19*19mm
- Operating Mode: Amplitude Modulation
- Transfer Rate: 4KB/S
- Transmitting Power: 10mW
- Transmitting Frequency: 433Mhz
- Pin out from left-right: (DATA; VCC; GND)

Applications include; Remote Control sockets, Electric Doors, Automobile Anti-theft products, Remote Control Gate, Remote Control LED, Garage Door Remote Control. E.t.c.

4.2 Design Analysis

The wireless speed control of AC Drive system, consist of a AT89C52 microcontroller, power supply unit, 433Mhz Transmitter and Receiver, Switching Circuit, Keypad and Indicator Unit. The microcontroller is programmed to generate Pulse Width Modulation pulses, based on the switching assigned to the keypad (buttons), of the single phase motor. Plate 4.0 below, shows the block diagram of the project.

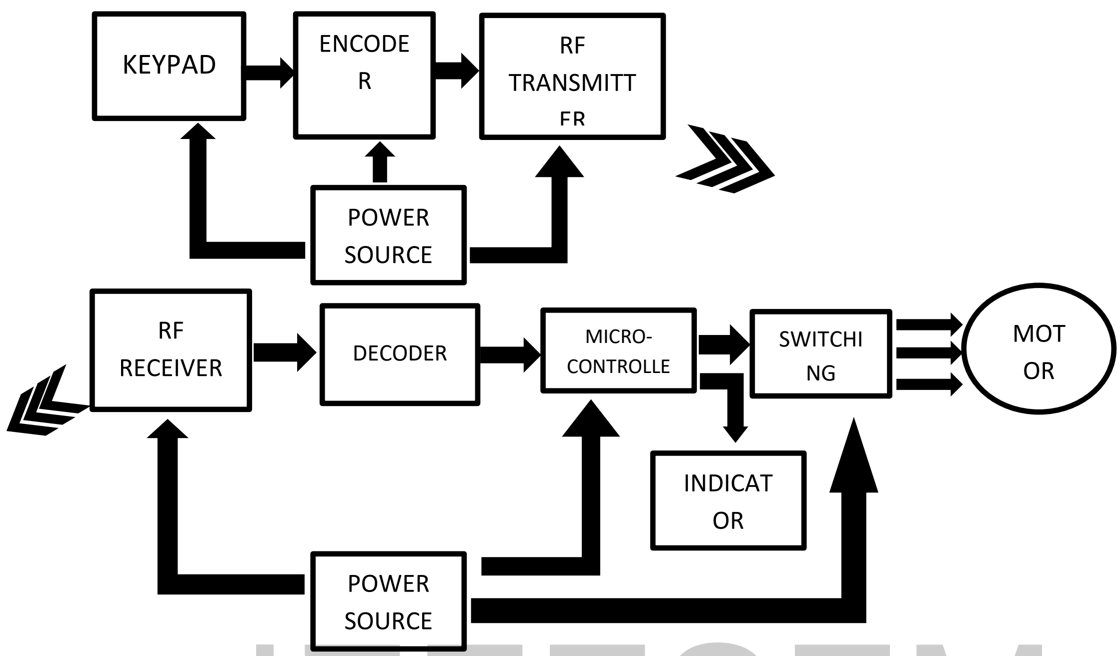


Plate 4.0 Block diagram of the Project

Plate 4.22 below, shows the circuit diagram of the project.

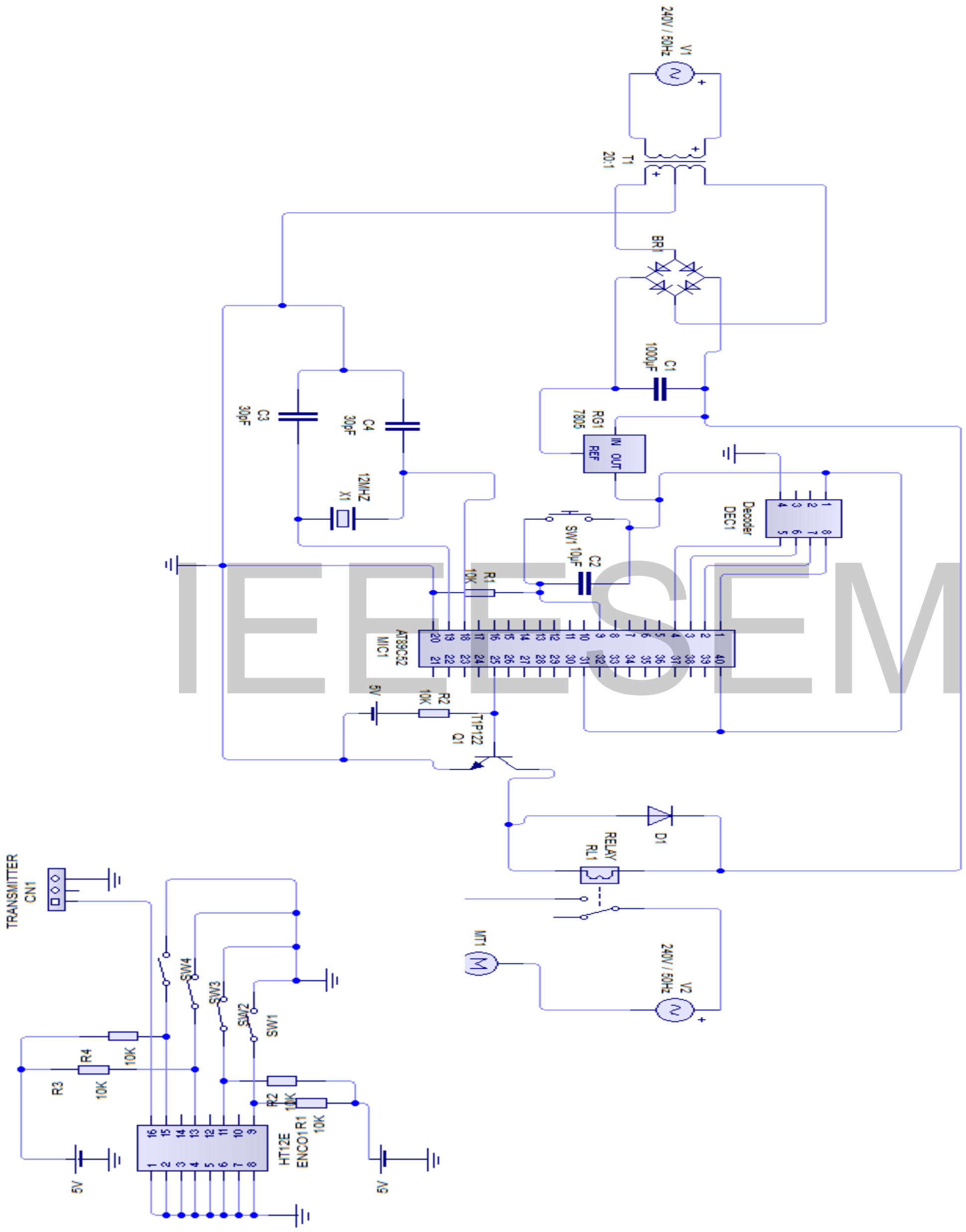


Plate 4.1 Circuit diagram of the Project

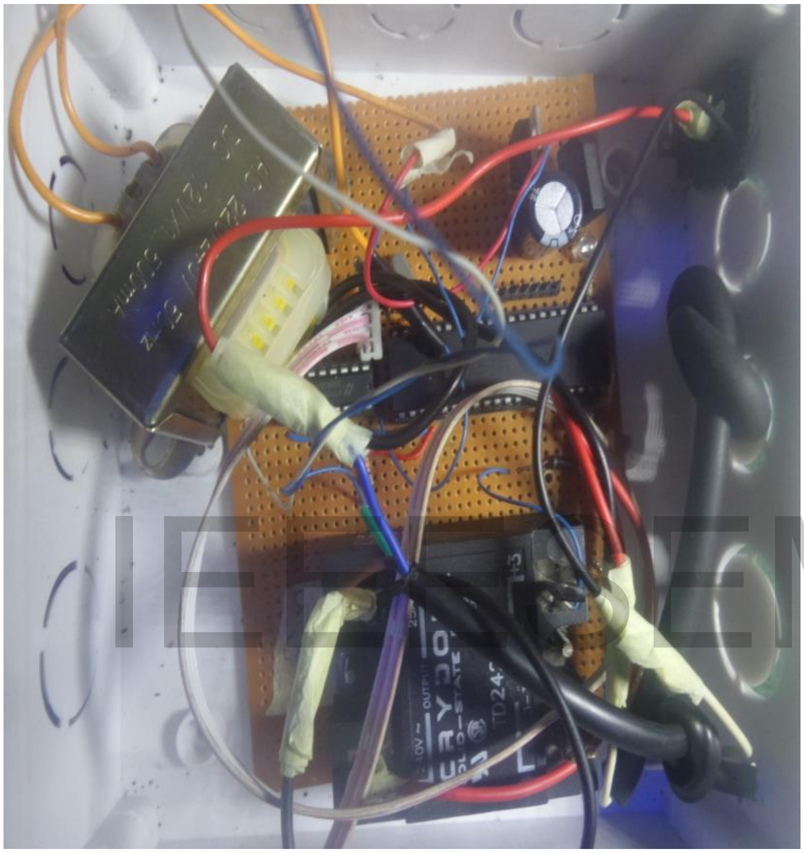


Plate 4.2 Internal Circuitry of the Project

4.2.1 The Power Supply Unit

The Power Supply Unit is the basic foundation of any Electrical Design. It is a circuit that converts the AC Voltage that comes from the lines PHCN to a DC level, it supplies a rectified and a regulated DC voltage to all the sub-units and interfaces in this project, even the brain of the system (microcontroller).

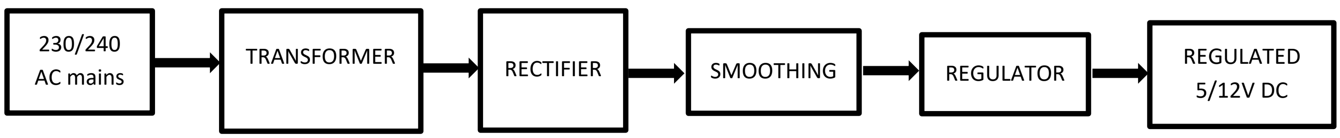
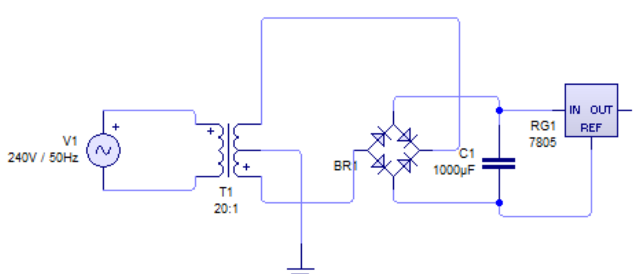


Plate 4.3 Block diagram for the power supply unit

The transformer used is 240/12V 300mA. My choice of transformer is due to the voltage needed to drive the DC Relay (12V). D_1 is a four-in-one IC bridge rectifier diode for full wave rectification of the stepped down voltage from the secondary side of the transformer. C_1 is an electrolytic capacitor for smoothing of the rectified voltage, where the 7805/7812 is a three terminal fixed voltage regulator that provides a regulated +5V and +12V respectively.



(a)
Plate 4.4a A full wave rectification

(b)
Plate 4.4b Image of rectification

Since we are expecting a voltage of 12V at the output after each half cycle according to the data sheet, V_{out} will be 12V while the ripple voltage will be $3V_{DC}$ at least. The maximum current in the circuit is about 300mA.

4.2.1.1 Calculation values for Transformer Voltage (Vr.m.s) and Capacitor value

1 Transformer Voltage

During rectification and filtration, using a bridge diode, there will always be 2-diode drop of 0.9V. Therefore, the peak value of V_{out} plus the two diode drops during one half cycle will be given by:

$V_{out}=12V_{DC}$

Diode drop=0.9=1V

This implies that, 1V x 2=2V

$V_{peak}=12+2=14V$

But, $V_{r.m.s}= V_{peak}$/square root of 2 …4.2.1

From equation 4.2.1,

14/square root of 2

= 10V.

This is the least voltage expected to be supplied by the secondary of the transformer, to guarantee a rectified voltage of 12V.

2 Capacitor Value (Filter Capacitor)

This value is usually chosen to be large enough to provide acceptable low ripple voltage also to withstand surge voltage. Note however, that capacitor filters are used for lower power applications while inductor filters are used in high power applications.

V_{ripple} = Tdv/dt ...4.2.2 [11]

Since dv/dt=I/C …4.2.3

Implies that V_{ripple} =IT/C …4.2.4

Where I=maximum current in the circuit,

T=time during capacitor discharge

C=capacitor value and V_{ripple}= Ripple voltage

But discharge is given by 0.5xF …4.2.5

Implies that 0.5x1/T = 0.5x1/50

=10mS

Substituting values into equation 4.2.4,

C= IT/V

$=300x10^{-3}x10x10^{-3}/3$ =1000uF.

Hence, capacitor 1000uF value was used in this design.

3 Voltage Rating of Capacitor

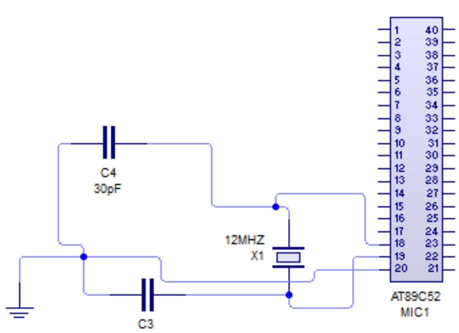
The voltage rating of the capacitor should be at least Two (2) times the $12V_{DC}$ rectified voltage.

Therefore, 12x2=24V

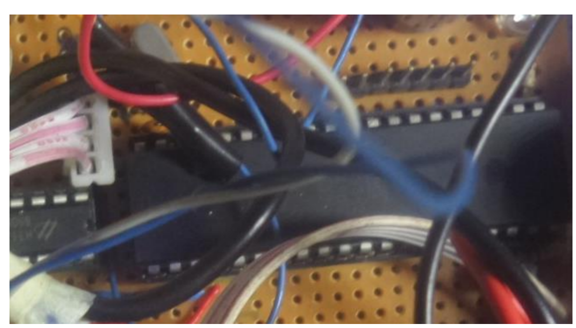
However, the capacitor used for filtering is 1000uF/35V.

4.2.2 Design related to the AT89C52 microcontroller

For proper execution of program, an external 12MHz crystal oscillator is used, which generate the clock signal for the controller, which is accompanied with two capacitors of rating 30pf/33pf, to filter noise during oscillation. The values are used here in accordance with the manufactures specification.



(a)
Plate 4.5a Crystal Oscillator



(b)
Plate 4.5b Image of Crystal Oscillator

4.2.3 Resistor Value Calculation in Relay Circuitry (Bias Resistor)

In this project, A Solid State Relay was used (TD2425f), it controls the ON/OFF switching of the signal from the buttons. A transistor (T1P122), in turn amplify and switch the electronic/electrical signals to further control the relay. The Transistor used in this project is T1P122 darlington with high gain. This is shown in the figure below.

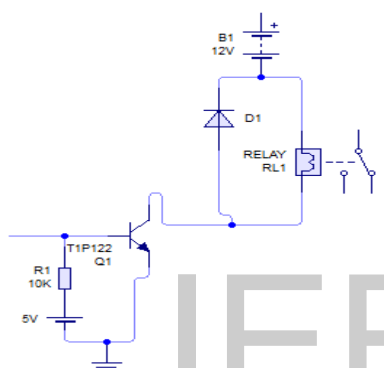


Plate 4.6 Circuit Diagram of the Switching Circuitry

In this design, a biasing resistor R_b, was used to ensure proper switching. The value was calculated thus using the transistor biasing theorem [12].

$$I_bR_b=V_{in}-V_{be} \quad \text{... 4.2.6}$$

$$I_b=I_c/H_{fe} \quad \text{...4.2.7}$$

where, I_c=Collector Current, known as current in the circuit,

H_{fe}=DC gain (1000) from data sheet,

V_{be}=Base-Emitter Voltage (0.3) from data sheet,

V_{in}=Input Voltage (at lease 3.30) from data sheet.

Therefore, from equation viii above,

$I_b=300x10^{-3}/1000$

I_b=0.3mA

Also, from equation 4.2.6,

$R_b= V_{in} – V_{be}/I_b$

$= 3.30-0.3/0.3x10^{-3}$

=10,000ohms

The value of Bias Resistor used for this project is 10 kilo ohms.

4.2.4 Coupling and Packaging

Understanding of the internal connections on a bread-board was considered first before the insertion of the components.

The coupling was initiated by the transfer of components from bread-board to vero-board. This was done orderly in stages for simplicity, starting from the brain of the system which is the microcontroller, followed by the interfacing circuits and the power supply all precisely implemented as clearly represented in this project circuit diagram. The integrated circuit (IC) socket was used to connect the AT89C52 microcontroller. This was to ensure ease access to the microcontroller to avoid frequent soldering and de-soldering during faults.

The circuitry was further inserted into a plastic box and was ready for dispatch.

CHAPTER FIVE

RECOMMENDATION AND CONCLUSION

5.1 Challenges Encountered

- Scarcity of components; most components were expensive. However, components of very close values and characteristics were used as substitutes with the aid of electronic data book.
- Interruption of power supply which hindered the swift progress of the project.
- Non availability of the software development in the school; the microcontroller program device used to integrate the C language software into the AT89C52 is very expensive.

5.2 Recommendation

This project is highly recommended for various industries because of its efficiency in overload protection, control over motor starting and stopping, reduction in the inrush current to full load current, energy saving capabilities, improvement in the power factor as a result low power loss and most especially great reduction in tariff. Furthermore, miniaturized speed control using nano-technology is highly needed, so as to incorporate them into smaller devices. In doing so, large quantity of energy will be saved at small levels.

5.3 Conclusion

The economic importance of this project cannot be overemphasized. When an Induction Motor is connected to the supply directly, it runs at rated speed at no load. If the motor is loaded, the speed of the motor starts to drop. So, to operate the motor below its rated speed constantly, with or without load from a remote location, a wireless speed control device is used. To achieve this, pulse width modulation (PWM) is generated from the microcontroller (AT89C52) used, according to the switching effects (ON/OFF) from the button. This design has a major restriction which is that it can only be applied in domestic and light industrial use, since most machines in the major industries are mainly three phase supply.

References

[1] B. K. Bose, “Power Electronics and Motor Drives Recent Progress and Perspective,” IEEE Trans. Ind. Electron., vol. 56, no. 2, pp. 581–588, Feb. 2009.

[2] B. K. Bose, Power Electronics and Motor Drives: Advances and Trends. Amsterdam: Academic, 2006.

[3] T. Sawa and T. Kume, “Motor drive technology-history and visions for the future,” in Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual, 2004, vol. 1, pp. 2–9.

[4] J. A. Kay, R. H. Paes, J. G. Seggewiss, and R. G. Ellis, “Methods for the control of large medium voltage motors; application considerations and guidelines,” in Petroleum and Chemical Industry Conference, 1999. Industry Applications Society 46th Annual, 1999, pp. 345–353.

[5] T. Jones and T. Lalemand, Motor Efficiency, Selection, and Management. Boston: Consortium for Energy Efficiency, 2013.

[6] L. Ben-Brahim, M. Trabelsi, T. Yokoyama, and T. Ino, “Real Time Digital Feedback Control For VFD Fed by Cascaded Multi-Cell Inverter,” in Power Electronics Conference (IPEC), 2010 International, 2010, pp. 2493–2500.

[7] J. N. Nash, “Direct torque control, induction motor vector control without an encoder,” Ind. Appl. IEEE Trans. On, vol. 33, no. 2, pp. 333–341, 1997.

[8] R. Lateb, J. Enon, and L. Durantay, “High speed, high power electrical induction motor technologies for integrated compressors,” in Electrical Machines and Systems, 2009. ICEMS 2009. International Conference on, 2009, pp. 1–5.

[9] M. Malinowski, M. P. Kazmierkowski, and A. M. Trzynadlowski, “A comparative study of control techniques for PWM rectifiers in AC adjustable

speed drives," Power Electron. IEEE Trans. On, vol. 18, no. 6, pp. 1390–1396, 2003.

[10] Theraja B.L. and Theraja A.K. "A textbook of electrical technology", S.Chaud and Company Limited, Ramnagar, New Delhi. 2002, pp919-990.

[11] BL Theraja, AK Theraja, Electrical Technology 2nd Edition, S.Chand and Company LTD. 1999, pp178-179, 284, 715, 914.

[12] Horowitz p and Winfield h…….Art of Electronics. Cambridge University press, Great Britain 4th edition…. 1997, pp44-51, 919, 1934 – 1945.

APPENDIX A

Component Cost Analysis Table

S/No.	Components	Quantity Used	Cost per one (₦)	Total cost (₦)
1	AT89C52 Microcontroller	1	2000	2000
2	Transformer	1	300	300
3	Bridge Rectifier	1	100	100
4	7805 Regulator	2	50	100
5	Capacitor (1000uF)	1	50	50
5b	Capacitor (30pF)	2	50	100
5c	Capacitor (10uF)	1	50	50
6	Diode (N4001)	1	10	10
7	Connecting wires	10 yards	5	50
8	Casing		4,000	4,000
9	Relay	1	500	500
10	NPN Transistor(T1P122)	1	50	50
11	Programming the Micro Controller (software)			12,000
12	Resistors	9	10	90
13	LED	2	10	20
14	Transmitter and Receiver (433.92Mhz)	1	3,500	3,500
15	Induction Motor (Single Phase)	1	1500	1500
16	Transportation		2,000	2,000
17	Labour		3,500	3,500
18	**Total**			**29,920.00**

APPENDIX B

THE SOFTWARE PROGRAMME

```
#include<reg51.h>

sbit Pwm_Pin=P0^0;

sbit Pwm_B_00=P2^0;

sbit Pwm_B_20=P2^1;

sbit Pwm_B_40=P2^2;

sbit Pwm_B_50=P2^3;

sbit Pwm_B_60=P2^4;

sbit Pwm_B_80=P2^5;

sbit Pwm_B_500=P2^6;

sbit Pwm_B_800=P2^7;

sbit Pwm_B_1000=P1^7;

void Pwm_Low()

{

Pwm_Pin=0;

TH0=0xFF;
```

```
TL0=0x47;

TR0=1; //Run Timer-0

While(!TF0);//Wait for T0 interrupt

Flag

TF0=0; //Clear Interrupt Flag

TF0=0; //Stop Timer-0

}

void delay(int a)

{

int j;

int i;

for(i=0;i<a;i++)

   {

   }

 }

}

void Pwm_High()
```

```
{
TR0=1; //Run Timer-0
while(!TF0); //Wait for T0 interrupt
Flag
TF0=0; //Clear Interrupt Flag
TR0=0; //Stop Timer-0
Pwm_Low();
}
void main()
{
P0=0x00; //**** Port-0 Declared
Input
P1=0xFF; //**** Port-1 Declared
Output
P2=0xFF; //**** Port-2 Declared
Input
P3=0x00; //**** Port-3 Declared
```

Output

//P0=0xFF; //**** Port-0 Declared

Input

TMOD=0x01; //Timer-0, As 16-bit Timer.

while(1){

if(Pwm_B_00==0){

Pwm_Pin=1;

TH0=0x00;

TL0=0x00; Pwm_High();

}

else if(Pwm_B_20==0){

Pwm_Pin=1;

TH0=0xFF;

TL0=0xDA; Pwm_High();

//Pwm_Low();

//Pwm_High();

//Pwm_Low();

```
//Pwm_Low();

//Pwm_High();

}

else if(Pwm_B_40==0){

Pwm_Pin=1;

TH0=0xFF;

TL0=0xB5; Pwm_High();}

else if(Pwm_B_50==0){

//delay(1);

Pwm_Pin=1;

Th0=0xFF;

TL0=0x47; Pwm_High();

Pwm_Low();

Pwm_Low();

}

else if(Pwm_B_60==0){

Pwm_Pin=1;
```

```
TH0=0xFE;

TL0=0xD8; Pwm_High();

}

else if(Pwm_B_80==0){

Pwm_Pin=1;

TH0=0xFE;

TL0=0xB3; Pwm_High();}

else if(Pwm_B_500==0){

Pwm_Pin=1;

TH0=0xFC;

TL0=0x65; Pwm_High();}

else if(Pwm_B_800==0){

Pwm_Pin=1;

TH0=0xFA;

TL0=0x3C; Pwm_High();

}

else if(Pwm_B_1000==0){
```

```
Pwm_Pin=1;

TH0=0xF8;

TL0=0xCC; Pwm_High();}

else

{}

}

}
```

Plate 5.1 Image of Packaged Work