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REMOTE CONTROL HUMLESS FAN CONTROLLER UNIT

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
in partial fulfillment of the requirements for the
degree of Master of Science.

By

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MAHATHANTHILAGE DON AJITH KUMARA WIJERATHNA

Supervised by: Dr. J.P. Karunadasa

Department of Electrical Engineering
University of Moratuwa, Sri Lanka

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DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated,

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CONTENTS

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Abstract

Domestic fans are a widely used appliance all around the world. There are several types of fan controllers available for the speed controlling of the fans. Since the cost is a dominant factor when the relevant market is concerned, low cost fan controllers are popular among them even though there are several drawbacks. This thesis discusses design and implementation of a utility friendly hum less remote control fan controller unit at an affordable price.

Electronic fan controllers are used due to the compact design and the low cost. It allows speed reduction through out the range. Most of the available fan controllers use voltage controlling while keeping the frequency constant to control the speed. The mostly available dimmer circuits consist of Triacs as the switching device. Wave form is chopped by an electronic circuit to reduce the line voltage. This generates low order harmonics which affect the utility power while making irritating noise especially at low speeds.

The proposed system designed with a power circuit with power IGBTs as the switching device which uses microprocessor based control system as the signal generator. The algorithm is developed under Harmonic Elimination PWM scheme which switches the power circuit in firing angles which avoids low order harmonics at the predefined speed levels.

The designed system fire the power IGBTs at pre defined firing angles at selected speed levels. It avoids the 3rd 5th and 7th order harmonics below 80% of the line voltage at the operation while avoiding 3rd and 5th above 80% of the line voltage. This reduces the irritating noise and the speed pertabations at the low speed while ensuring a linier speed control action with utility friendly operation.

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I highly appreciate the great support extended by the staff members of the electrical engineering department, machine lab and the instrumentation lab during this tenor.

I would like to thank my family members and friends for the encouragement and the support during this exercise.

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List of Figures

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University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Tables

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Chapter 1
Introduction

1.1 Overview

Electricity plays a major role in the modern world. Significant portion of the generated electricity is processed through power electronics for various applications such as residential, commercial, and industrial. With the development of the power semiconductor devices with high power rating and good switching performance have led to achieve the development in modern drive systems. Also the micro electronics, advance control techniques, microcomputer technology as had a great impact on the control strategy for the power semiconductor devices.

To make easy our life electric motors energize machines which clean our cloths, wash our dishes and heat and cool our homes. Due to the nature of these products it is a challenging endeavor to design electronics for these appliances. Civilin mounted fans are a widely used house hold appliance all around the world.

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This thesis investigates an optimal strategy to control domestic fans with a methodology to control the speed in a utility friendly manner. This fan controller unit consists of a remote controller unit for convenient operation.

1.2 Motor drives and control methods

With the technical development in power electrical, lot of control methodologies are developed for motor controlling.

Modern power electronics development has been opened new areas for improvement in several markets together with the development of advance high energy batteries, together with the development of smaller and more powerful motors. Portable appliances, entertainment equipment, electric vehicles are some of the examples. Laser based audio equipments, cameras, robotic applications, medical equipment needs sophisticated high performance motion control systems. One emphasis for new designs has concentrated on low power consumption in order to extended battery life, providing longer hours of operation. Improved performance and more efficient operations are not limited to portable operations are not limited to portable appliances. The next generation of motors in many stationery applications will take further advantage of changes that are occurring in both the motors and the drive electronics that control and protect them. [11] Motor drive electronics is experiencing improvements in the packaging, control and power as well as in the interconnectivity and communication that will allow motors to run more efficiently, adapt to new applications more quickly and operate with fewer down time hours in home office and industrial applications.

Electrical machines are used for current motion control applications can be categorized as follows. [11]

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(i) DC machines; Shunt, series, compound, separately-exited dc motors and switched reluctance machines.

(ii) AC machines; Induction, wound-rotor synchronous, permanent-magnet synchronous, synchronous reluctance and switched reluctance machines.

(iii) Special machines – Special reluctance machines.

Most of the machines are available from fraction of kW to MW ranges. Permanent magnet synchronous, synchronous reluctance, and switched reluctance machines are normally available up to 150kW range. There are several factors which are taken in to consideration, when a motor is selected for an application. Cost, Thermal Capacity, Efficiency, Torque-speed profile, Acceleration, Power density-volume of motor, Ripple – cogging torques, Availability of spare and second sources, Robustness, Suitability for hazardous environment [9] are major considerations among them. From the above mentioned considerations, some could make precedence over others according to the application. DC, induction, permanent-magnet synchronous, and brushless dc machines are the types of motors that are commonly used in the industry.

In general grid power supply consists of a fixed voltage and a frequency which allow the motors to run with the rated speeds. Motor control methodologies are developed over decades to provide applications with variable speeds. This is accelerated with the current trends in the world. Increased energy cost, public concern for unnecessary energy consumption and the resulting environment impact, and legislation that requires manufactures design for improved efficiency are among the key forces that are driving the development and implementation of new motor controls other than the demand by the industrial development.

The controllers embody the control laws governing the load and motor characteristics and their intention. Motor controller controls the input power supply with its architecture to match the load and the motor. Many control strategies are formulated for various motor drives. Several inputs are taken in to the controller as follows according to the control requirement.

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Figure 1.2-1 Schematic of a motor controller

- Torque, flux, speed and/or position commands
- Their rate of variations, to facilitate soft start and preserve the mechanical integrity of the load
- The measured torque, flux, speed, and / or position for feedback control
- Limiting values of currents, torque, acceleration and so on
- Temperature feedback and instantaneous currents and/or voltage in the motor and/or converter

- The constants in the speed and position controllers, such as proportional, integral, and differential gains.

The controller output control the voltage amplitude and the frequency to determine the speed. Controller may also perform the protection and other monitoring functions and deal with emergencies such as sudden field loss or power failure.

1.3 Switching devices in modern power electronics applications

It is clear that the current development of the power electronic area is obtained through the development of the semiconductor devices with innovative semiconductor material. [4] It makes the controlling of the voltage, current, power and frequency more cost effective.

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Power semiconductor devices first appeared in 1952 with the introduction of the power diode by R.N. Hall. It was developed with germanium. Thyristor was developed in 1957. Bipolar transistors with high current carrying capacity has been introduced in 1960s. This started a new era in modern power electronic devices. Power Mosfets were introduced in 1970s with the improvements of metal oxide semiconductor devices. This device can operates high frequency than bipolar transistors. This was a turning point of the power semiconductor devices development. With the advantage of the isolated gate drive of the Mosfet drive Insulator Gate Bipolar Transistor (IGBT) developed in 1980s. It became commonly available in 1990s. [4]

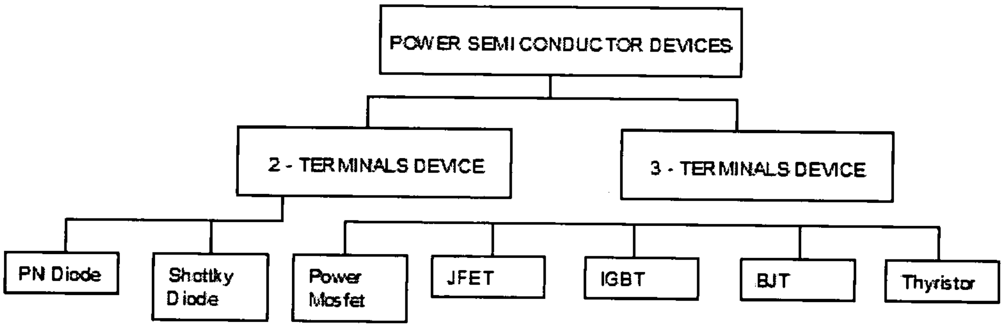

Figure 1.3-1 Commonly used power semiconductor devices

Some of the popular power switching devices are described with their features follows.

- Power Diode;

This is a PN device. When the anode potential is higher than the cathode potential the device turns on and conduct currents. It turns off and goes in to blocking mode when the device is reverse biased. This is available in kA and kV range. Its switching frequency is limited to the line frequency. Power diodes are used in line rectifier applications. For fast switching applications, fast recovery diodes with reverse recovery times in tens of nanoseconds with rating of several 100A, at several 100V, but with a higher on state drop of 2 to 3V are available.

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- Power Transistor

Power transistor is a three-element device. It's available in PNP and NPN with NPN being the more prevalent. The most preferred operation is that the transistor be in quasi-saturation mode. It is at knee operating point, during it's conduction stage. Then it can be pulled back in to non-conduction state in shorter time. The maximum available rating at present for the device is 1000V, 1400V with on state drop of 2V.This is very commonly used in low power application.

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- Silicon Control Rectifier (SCR) / Thyristor

It is a four elements (PNPN) device with three junctions. The device is turned on with a current signal to the gate. The device can be turn off only by reverse biasing. During the reverse biasing the device reverses the voltage between its anode and cathode. In reverse biasing the device acts as a diode. The thyristes are rated up to 8kA,12kV range. The switching frequency of the device is limited to 300to400Hz. Inverter grade SCR, Light activated thyristor, asymmetrical SCR, Reverse-conducting thyristor, MOS controlled thyristor, Gate turn off thyristor belong to the family.

- MOSFET

This device is a class of field effect transistors and this can be operated in lower gate voltage and can be operated in higher frequencies 30kHz to 1MHz range. Device is rated up to 10A, 1000V. The device comes with an anti parallel body diode, some times referred to as a parasitic diode. Mosfet does not have the reverse voltage blocking capacity.

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- Insulated gate Bipolar Junction Transistor (IGBT)

This is a three element device with the desirable characteristics from the view point of gate and it consists of reverse voltage blocking capability. The currently available rates are 1.2kA at 3.3kV and 0.6kA at 6.6kV. Switching frequency is available up to 20kHz. [4]

1.4 Existing fan control systems

Ceiling fans come with different controls. Some can be found on the side of the wall, some have remote controls and others have a pull chain. Remote controls were designed to make our lives easier and to change or switch ceiling fan speeds. Since ceiling fans are placed on a high place and are hard to reach, manufacturers had thought of using ceiling fan controls. An idea and make more familiar of the different types of ceiling fan control.

The way in which a fan is operated depends on its manufacturer, style, and the era in which it was made. Operating methods include:

- Pull-chain / pull- cord control.

This is the most common method of operation for household fans. This style of fan is equipped with a metal-bead chain or cloth cord which when pulled, cycles the fan through the operational speed(s) and then back to off. These fans typically have three speeds (high, medium, and low); however, the speed range can be anywhere from one through four.

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- Variable-speed control.

During the 1970s and 1980s, fans were often produced with a variable-speed control. This was a dial mounted on the fan which, turned in either direction, continuously varied the speed at which the blades rotated similar to a dimmer switch for a light fixture.

- Wall-mounted control.

Some fans have their control(s) mounted on the wall instead of the fans themselves; such controllers and are usually proprietary and/or specialized switches. This consists of step fan controllers and dimmer circuits. Currently this is the most commonly used method for fan controllers.

- Wireless remote control.

In recent years, remote controls have become an affordable option for controlling ceiling fans. While some models do employ this as their sole form of operation, it is more common for a person to purchase an after-market kit and install it on an existing fan. The hand-held remote transmits radio frequency or infrared signals to a receiver unit installed in the fan, which interprets and acts on the signals.

When the controlling methodology is concerned, it consists of electronic and electrical controllers. In the wall mounted controllers voltage level is varied by increasing the line resistance. Resistance variation done by wounded coils or fixed resistors. The major disadvantage of this type of controllers is the large size of the controller box.

Another controlling method is to vary the system capacitance of the controller. Capacitors with fixed values are connected according to the required speed levels. This is a widely used stepped fan controller method which is compact in design. The major disadvantage is, this allows few predefined speeds. This does not vary the speed equally in most of the fan models. As shown in the Table 3.1-1 and Table 3.1-2, different types of fans gives different speed levels in the same voltage level. This produces discomfort for the end user.

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In electronic fan dimmers most of the commonly used controllers are operated in Voltage controlling method. In this method voltage level is varied by chopping the sine according to the set speed value. There is a common circuit which consists of a triac as the power switch. In this circuit variable resistor is connected with the operator knob. This defines the expected voltage level. Since the cost is a major factor where the fan controller is concerned, there are limitations in controller design.

There are few frequency inverter models are in the market. These are mainly used for large fan models which are used for non domestic applications. The main disadvantages are the cost and the size of the control module. These modules consist of microelectronic circuits mainly with microprocessor based systems. Most of them are software implemented systems with lot of control features.

1.5 Remote control system

Remote control facilitates the operation of fan regulators around the home or office from a distance. It provides a system that is simple to understand and also to operate, a system that would be cheap and affordable, a reliable and easy to maintain system of remote control and durable system irrespective of usage. It adds more comfort to everyday living by removing the inconvenience of having to move around to operate a fan regulator. The system seeks to develop a system that costs effective while not under mining the need for efficiency.

The first remote control, called "lazy bones" was developed in 1950 by Zenith Electronics Corporation (then known as Zenith Radio Corporation). The device was developed quickly, and it was called "Zenith space command", the remote went into production in the fall of 1956, becoming the first practical wireless remote control device.

Today, remote control is a standard on other consumer electronic products, including VCRs, cable and satellite boxes, digital video disc players and home audio players. And the most sophisticated TV sets have remote with as many as 50 buttons. In year 2000, more than 99 percent of all sold TV sets and 100 percent of all VCR and DVD players are equipped with remote controls. The average individual these days probably picks up a remote control at least once or twice a day.

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Basically, a remote control works in the following manner. A button is pressed. This completes a specific connection which produces a Morse code line signal specific to that button. The transistor amplifies the signal and sends it to the LED which translates the signal into infrared light. The sensor on the appliance detects the infrared light and reacts appropriately.

The objective of the project consists of a development of a remote controller as the user interface. It made the operation more user friendly while avoiding rewiring of the wiring system. If the controller comes as a wall mounted unit to get the neutral power in to the control circuit the wiring system should be modified. Remote controller add

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1.6 Harmonics

Harmonics are undesirable currents and or voltages. They exist at some multiple or fraction of the fundamental frequency. Harmonic pollution in static power converters is a serious problem. For example in many residential, commercial and office buildings the triplen harmonics create high neutral currents to the extent that they may start fires, although the fundamental neutral current is within allowable limits. The harmonics can arise in three ways [9]

(a) Through the application of a non sinusoidal driving voltage to a circuit containing nonlinear impedance.
(b) Through the application of a sinusoidal driving voltage to a circuit containing nonlinear impedance.
(c) Through the application of a non sinusoidal driving voltage to a circuit containing linear impedance.[9]

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The harmonic orders and magnitudes depend on the converter type and the method of control. For example in single-phase voltage-source inverters, the output voltage waveform typically consists only of odd harmonics. The even harmonics are absent due to the half wave symmetry of the output voltage harmonics. In three phase voltage-source inverters, in addition to the even harmonics, the triple (third and multiples of third harmonics) are also absent. The harmonic spectra depends on the switching frequency and the control method.

1.7 Pulse Width Modulation for motor control

In most of the motor control techniques speed, torque and direction are managed by electronically switching or modulating the supply voltage to the motor. Pulse Width Modulation is the most commonly used method to control the supply voltage to the motor. Indirectly the current level also can be controlled by modulating the supply voltage. [1]

In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as Pulse-Width Modulation (PWM) Control.

The duty cycle directly affects to the amount of energy applied to the motor. The frequency also influence the motors operation and the long term reliability of the power electronics devices.

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The advantages possessed by PWM techniques are as follows:

(i) The output voltage control with this method can be obtained without any additional components.

(ii) With the method, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimized. [2]

The main disadvantage of this method is that SCRs are expensive as they must possess low turn-on and turn-off times.

PWM inverters are quite popular in industrial applications. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain inverter output voltage control and to reduce its harmonic content.

Pulse width modulation can be used to eliminate harmful low order harmonics in motor control methodologies. PWM does not reduce the total distortion factor of the current or the voltage.

Present day the PWM techniques can be classified as carrier modulated sinusoidal pulse width modulation and pre calculated programmed PWM schemes. In SPWM scheme a triangular waveform of certain amplitude and frequency is compared to a sinusoidal wave form in phase with the out put voltage of the inverter. In this method the lower order harmonics are eliminated. With the increase of switching frequency higher order harmonics can be eliminated. Switching device speed, power losses and the power ratings are the limiting factors to reach higher frequencies.

Programmed PWM techniques provide distinct advantages comparing to carried modulated sinusoidal pulse width modulation. Minimizing losses, reducing torque pulsation, elimination of selective harmonics are dominant advantages which can be obtained by particular objective functions. Computing of the specific switching angles are the difficult task associated with the programmed PWM technique.

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Following are the dominant advantages form programmed PWM technique.

1) Higher utilization of power consumption can be achieved with higher voltage gain through over voltage modulation.
2) Low operating switching frequencies comparing to the SPWM scheme.
3) Permits (GTO) gate-turn-off switches for high power inverters while reducing the switching losses.
4) Eliminate of low order harmonics results in reduced harmonic interference such as resonance with external lines in network typically employed in inverter poaer supplies.
5) Pre-calculated optimized PWM switching patterns avoids on line computations. [6]

This thesis is basically a study in eliminating several lower order harmonics by a PWM scheme. Unlike SPWM which is a 'real time ' control technique in this technique pre calculated switching instants use as the gating signals for the power switches.

There are several types of PWM techniques are used to control the motors below the rated speed. Following describes the most popular schemes among them.

- Sinusoidal PWM
- Regular Sample PWM
- Voltage vector PWM
- Current control PWM
- Harmonic elimination PWM

In this thesis development is done based on the Harmonic elimination PWM algorithm. This is a software implemented PWM. This avoids the selected lower order harmonics while the switching signals are generated.

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1.8 Noise filtering in the power circuits

An electrical noise filter is a circuit that is designed to design, reshape or reject all unwanted frequencies of an electrical signal and pass only those signals wanted fro the relevant application. In this application passive low pass filter design activities are taken in to consideration.

Passive analogue filters are the oldest for of the electronic filters. This is constructed with resistors and capacitors (RC Filters) or resistors and inductors (RL Filters). Combination of analogue amplifiers mechanical resonators or delay lines which is called hybrid filters are also used commonly. [10]

(i) Passive Filters

Passive filters does not contain active components such as transistors and it does not depends upon external power supplies. Passive implementation of linear filters are based on combination of Resistors (R), Inductors (L) and Capacitors (C).

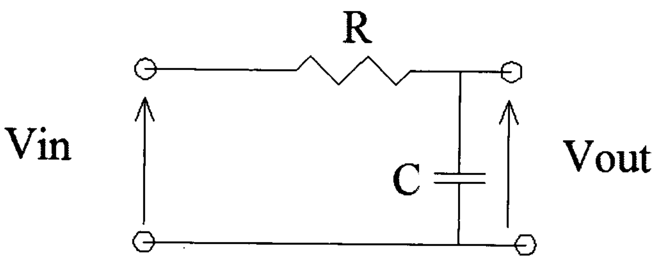

Figure 1.5-1 RC Passive filter

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Inductors block high frequency signals where capacitors block the low frequency signals. Resistors do not have their own frequency selective properties. It is added to determine the time constant of the circuit. It determines the frequency which the circuit response. In filter applications, capacitors provide a path to ground the signals where signal passes through an inductor presents less attenuation to low frequency signals and is a low pass filter. If a signal passes through a capacitor or has a path to ground through an inductor then the filter presents less attenuation to high frequency signals than low frequency signals and is a high pass filter.

(ii) Active filter

Active filters are a type of analogue electronic filter implemented using combination of active and passive components. Voltage amplifiers, buffer amplifiers are examples of active components of the active amplifier. This depends on an external power supply.

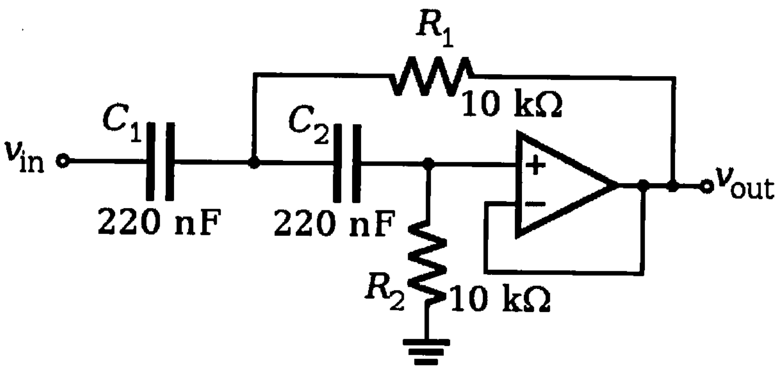

Figure 1.5-2 Active filter

Following are the major advantages of the passive filters,,

- Inductors can be avoided. In the passive filters inductors are used to obtain low damping. This is quit expensive and has high internal resistance and it may tends to pick up surrounding electromagnetic signals.
- By varying the resistors quality factor and the tuned frequency can be set easily.
- The amplifier powering the filter can be used to buffer the filter from the electronic components if drives or is fed form, variations in which could otherwise significantly affect the shape of the frequency response.

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(iii) Digital Filters

Wide verity of filters are available in digital filters. It converts the signal in to a stream of numbers by a analogue to digital converter. A computer program running on a CPU (Central Processing Unit) or a DSP (Digital Signal Processor) calculates the output number stream and with a digital to analogue converter out put signal is generated. Conversion may generate noises and it is taken in to consideration when a digital filter is designed. Input frequency has limitations since sampling is taken place. [7]

1.9 Snubber Circuits

Snubbers are commonly used in the electrical systems with inductive loads where the sudden interruption in voltage spikes and current flow often creates interruptions for the device operation. This may lead to failure of the control device and when the arching occurs may create electromagnetic interferences for the other circuits as well.

(i) RC Snubbers

This is a simple form of the snubbers. It comprces a small resistor and in series with a small capacitor. This form of snubbers are commonly used in inductive loads such as electric motors. Snubbers are also often used to prevent arcing across the contacts of the relays and switches and the electrical interference and welding/sticking of the constants that can occur.

Voltage across the capacitor does not change instantaneously, so a decreasing transient current passes through a fraction of a second. The capacitor and the resistor value should be calculated according to the application. This type of snubbers are often coming as combined single modules.

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(ii) Diode Snubbers

For DC current flowing applications diode snubbers are often used. The snubber diode is connected parallel with inductive load such as motor relay coils. In normal condition it does not conduct. When the inductive load is rapidly interrupted a large voltage spike would be produced in the reverse direction. This is known as the inductive kick and it allows the current to pass through the diode by protecting the load. [4]

1.10 Finite element method for stress analysis

Finite element method will be used to develop an optimal design for the circuit mounting box. It will optimize the material usage while ensuring the strength for a reliable usage.

Finite element analysis is a numerical technique for finding approximate solutions of partial differential equations and integral equations. There are two methods which are used for the solution approach. One is to eliminate the differential equation completely. The other method is to rendering the partial differential equation in to an approximating system of ordinary differential equations. These numerical equations are integrated using standard techniques such as Euler's method, Runge-Kutta.

Solving these partial differential equations is a challenge. The primary challenge is to creating equations which approximates the equation such a way that it does not accumulates the input and intermediate errors which make the result meaning less. There are several methods to do this. Finite element method is a good choice for solving partial differential equations over complicated domains (such as oil pipe lines), when the domain changes (such as during a solid state reaction with a moving boundary), when the desired precision varies over the entire domain or when the solution lacks smoothness. Eg, In a simulation of a car model front side the prediction accuracy can be increased while reducing the rear side of the car.

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Fig. 1.10-1 shows the solution for a magnetostatic configuration. In this figure lines denotes the direction of calculated flux density and colors sows its magnitude. Fig 1.10-2 shows the 2D mesh of the solution where mesh is denser around of interest.

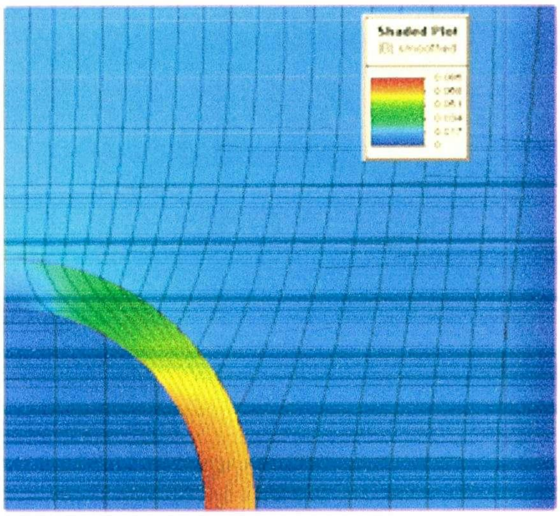

Figure 1.10-1 2D FEM Solution for a magneto static configuration

Source : http://en.wikipedia.org/wiki/Finite_element_method

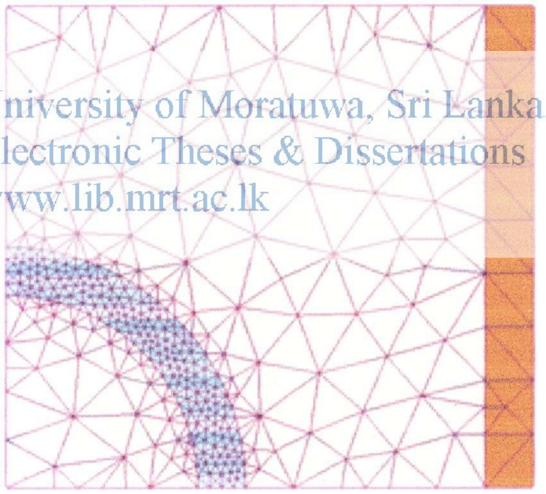

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Figure 1.10-2 2D mesh which is denser around the object of interest

Source : http://en.wikipedia.org/wiki/Finite_element_method

Finite element method originated for solving elasticity and structural analysis problems in civil and aeronautical engineering. When the history is traced back Alexander Hrenikoff (1941) and Richard Courant (1942). While the approaches used by these pioneers are dramatically different, both have used mesh discrimination of a continuous domain in to a set of discrete sub domains, usually called elements.

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Development of the finite element method began in earnest in the middle to late 1950s for air frame and structural analysis and gathered momentum through the work by Jorhn Angyris (University of Stuttgart) for use in civil Engineering. By late 1950s the key concepts of stiffness matrix and element assembly existed essentially in the form used today. With the several initiates taken by several companies and personals finite element method has been developed as a very useful tool in numerical modeling of physical systems in a wide variety of Engineering disciplines.

In modern Mechanical Engineering designs such as aeronautical, biomechanical automotive plays a major role. With the development of modern computer software industry several packages were innovated including specific components thermal, electromagnetic, fluid and structural working environments. In mechanical designs FEM provides facility to producing stiffness and strength visualization and also in minimizing weight materials and cost.

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FEM allows entire design to be constructed, refined and optimized before the0020design is manufactured. It mainly allows visualization of where structures bend or twist, and indicates the distribution of stresses and displacements. In most engineering applications FEM software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system requirement. Required level of Accuracy and the computational time are the factors when the analysis is considered. Fig 1.9-3 shows a visualization of deforms in an asymmetrical crash for a designed car model in finite element analysis. In summary benefits of FEM includes increased accuracy, enhanced design and better insight on to critical design parameters, virtual prototyping, fewer hardware prototypes, a factor and less expensive design cycle, increased productivity and increased revenue.

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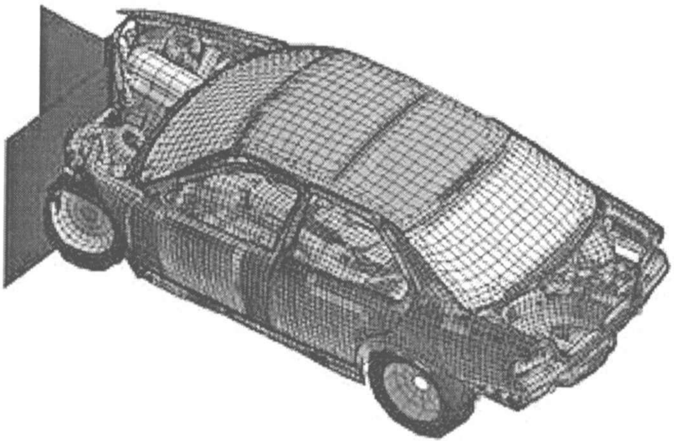

Figure 1.10-3 Visualization of deforms in an asymmetrical crash using finite element analysis

Source : http://en.wikipedia.org/wiki/Finite_element_method

In the fan controller mounting box design finite element method is used to develop a reliable design to withstand the stresses developed when the box is mounted in several sizes of diameters fan hanging shafts. It allows a economical design with optimized material usage while ensuring the durable usage.

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1.11 Scope of present work

This thesis is to investigate and implement a control system for single phase domestic ceiling fans. Algorithm is developed to eliminate low order harmonics while controlling the speed as required. Microcontroller based control circuit is designed to generate the switching signals according to the developed algorithm. The pre calculated switching angles are stored in a look-up table. According to the set value of the speed it reads the table and generates the switching signals accordingly. Power IGBTs are used as the power switches due to high performance and robustness. Mosfet drive ICs are used to drive the IGBTs in pairs. The project theme includes follows,

- Study of the characteristics of the existing triac based electronic fan dimmer circuits, identify the draw backs.
- Study the data and parameters of fan motors in the market to model the system.
- Development of control algorithm to drive the motor in harmonic elimination mode.
- Calculation of switching angles to avoid selected low order harmonics. This executes to preserve 20 different speeds in the motor.
- Development of the control algorithm using PIC 16f628 microcontroller. Coding of the system to switch the pre calculated switching angles according to the set value by the remote controller.
- Development of the microelectronic and power electronic circuits to check the system performance.
- Development of the microcontroller program and the circuit diagram for the remote controller.
- Testing of the developed system with a domestic fan and compare the results.

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Above mentioned activities are described in this research thesis and the results are discussed accordingly.

Chapter 2

Statement of the problem

2.1 Preliminaries

The main objective of the project is to develop a low cost hum free fan controller as a replacement for the existing electronic fan dimmer with chopping circuit and the triac as the switching device.

There are fan dimmers available in the market with advance technologies. Most of them are frequency inverters which used in for industrial applications. Due to the high cost these are not popular among the users. When a fan controller circuit is designed the main challenge is the cost. The average cost for the commonly available fan controller vary from Rs. 750/= to Rs. 1250/=. The objective is to design the new control methodology less than Rs. 2000/=.

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2.2 Issues with the existing fan controller

Fig 2.2-1 shows the electronic fan dimmer circuit which is commonly used in Sri Lanka. This chops the wave form at different angles according to the potentiometer value. When the calibration is done for the fan controller the variable resistor is adjusted to the power level of the fan speed.

The wave form chopping point is defined by the variable resistor value of the fan dimmer in an arbitrary manner. In this operation, sinusoidal wave form gets distorted and at the low speeds it is dominant. This generates harmonics which affects the fan controller performance especially at low speeds. The harmonic generation and the wave for distortion is practically observed and results are described in chapter 2.2.

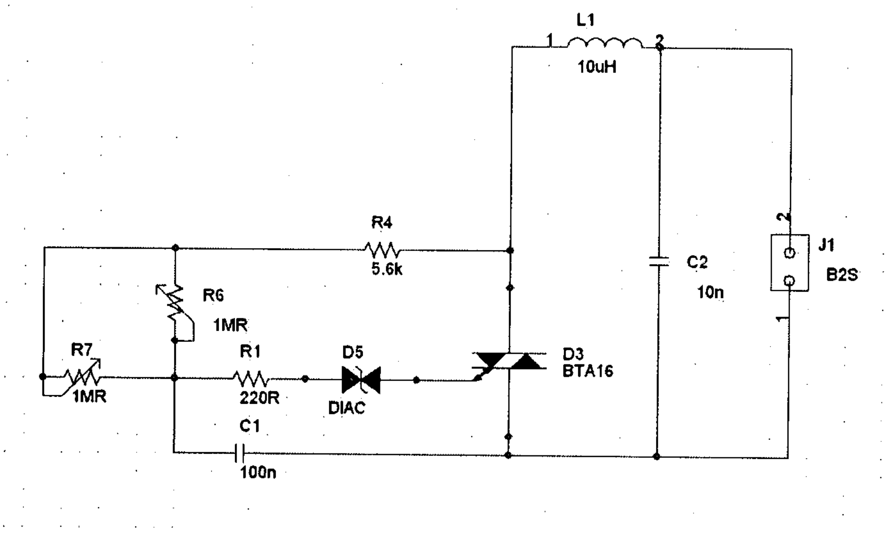

Figure 2.2-1 Most commonly used electronic fan controller circuit

This circuit chops the sinusoidal waveform as follows to control the supply voltage.

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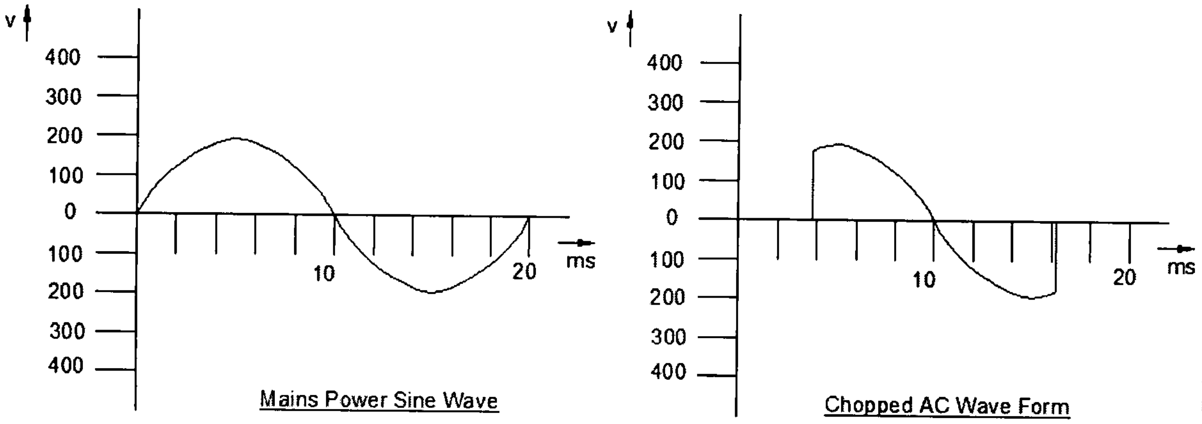
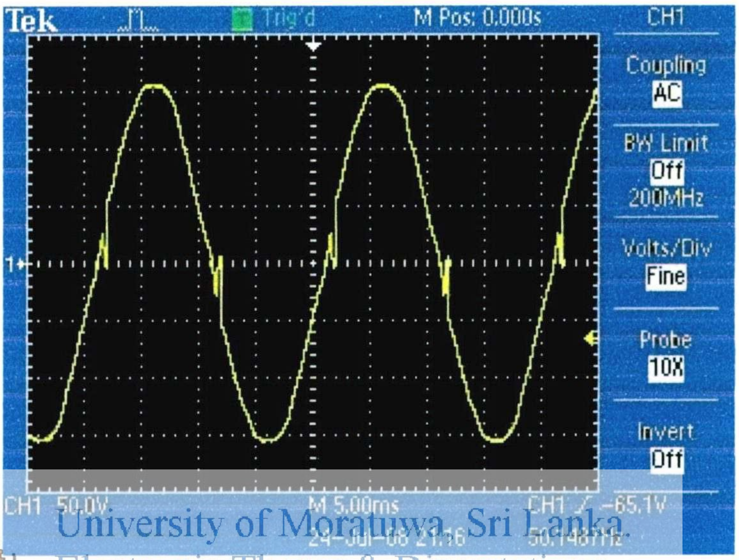


Figure 2.2-2 Sine wave form and chopped wave form.

Fig 2.2-1 to Fig 2.2-2 shows the wave forms of the existing electronic dimmer circuit at the different speed levels. This shows that how it distort the wave form at low speeds. This leads to generate low order harmonics while generating irritating noise at low speeds.



M Pos: 0.000s
CH1
Coupling AC
BW Limit Off 200MHz
Volts/Div Fine
Probe 10X
Invert Off
CH1 50.0V
M 5.00ms
CH1 ∫ -65.1V
24-Jul-08 21:16
50.1487Hz

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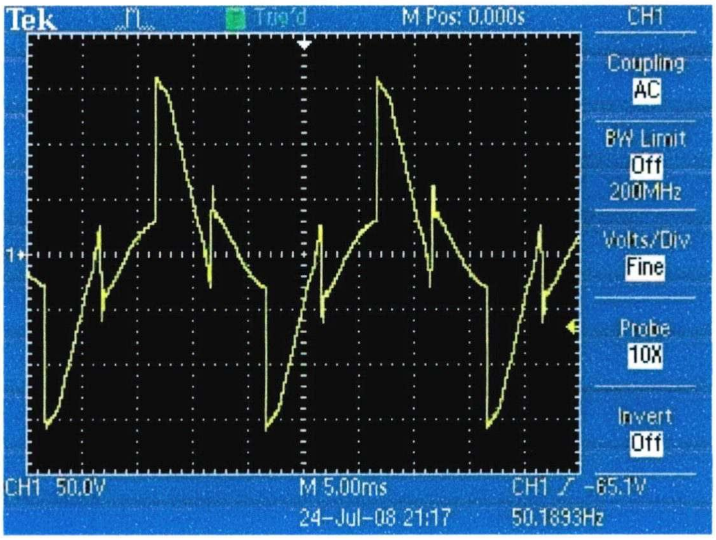
Figure 2.2-3 Wave form at the full speed



M Pos: 0.000s
CH1
Coupling AC
BW Limit Off 200MHz
Volts/Div Fine
Probe 10X
Invert Off
CH1 50.0V
M 5.00ms
CH1 ∫ -65.1V
24-Jul-08 21:17
50.1893Hz

Figure 2.2-4 Wave form at150rpm

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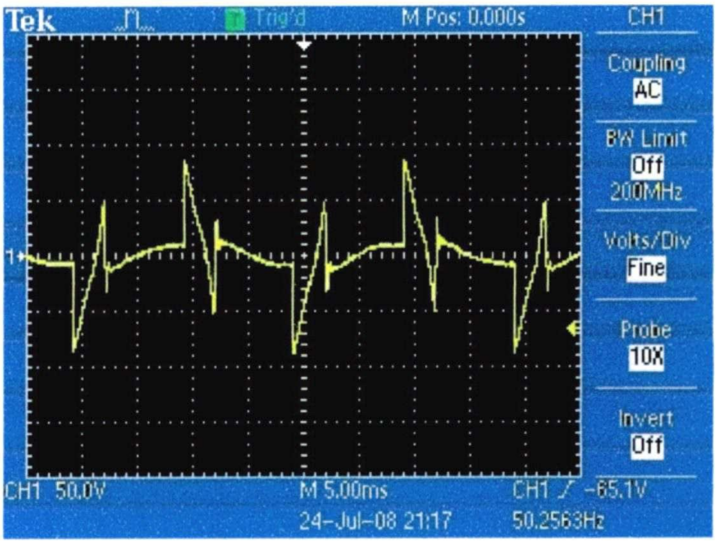

Figure 2.2-5 Wave form at 90 rpm

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Fig 2.2-6 and 2.2-7 shows the generated harmonic level at the utility and the harmonic level of the commonly used electronics fan controller unit. This clearly shows how the harmonics and low frequency noise is generated by the triac based electronic fan dimmer. Chapter 6.3 describes the comparison of harmonic distortion factor of Triac based electronic fan dimmer and the developed circuit at different speed levels.

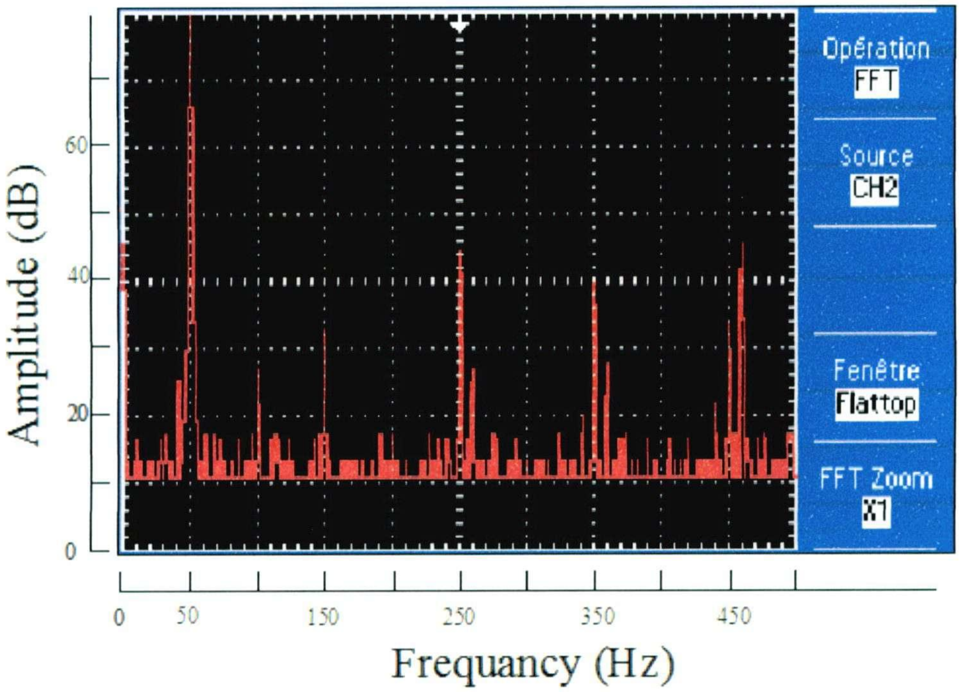

Figure 2.2-6 Harmonics of the utility

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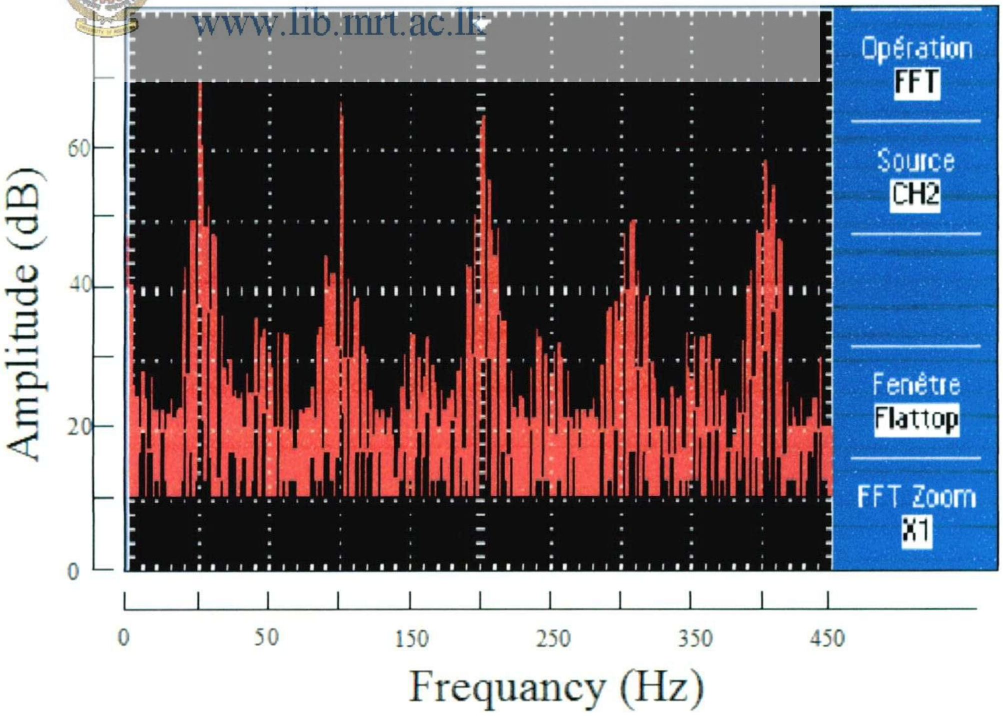

Figure 2.2-7 Harmonics when the motor is rotated at low speed (100 rpm)

Chapter 3

Theoretical Development

3.1 Data analysis of the domestic fan

Table 3.1-1 and Table 3.1-2 show a data analysis of commonly available domestic fans in the Sri Lankan market. Data was observed for two types of fans and it compares the rotation speed, current consumption and power factor at pre selected voltage supply levels. Voltage is varied with a voltage regulator. (Variac) This shows that, different types of fans are having different speed levels at different voltage levels. This is a very important factor which should be considered when a fan dimmer is developed.

Table 3.1-1 Data analysis at 5 different voltage levels (Fan type 1)

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Speed Setting	Supply Voltage	Out Put Voltage	Current (mA)	Wattage (W)	Speed 01	Speed 02	Speed 03	Avg. Speed (rpm)	Power Factor
1	234	50	160	9	97	100	99	98.67	0.99
2	234	100	222	23	151	153	153	152.33	0.99
3	234	150	292	44	221	224	233	226.00	0.99
4	234	200	332	66	270	270	269	269.67	0.99
5	234	234	366	85	295	296	296	295.67	0.99

Table 3.1-2 Data analysis at 5 different voltage levels (Fan type 2)

Speed Setting	Supply Voltage	Out Put Voltage	Current (mA)	Wattage (W)	Speed 01	Speed 02	Speed 03	Avg. Speed (rpm)	Power Factor
1	234	50	159	10	39	41	40	40.00	0.99
2	234	100	233	24	134	134	135	134.33	0.99
3	234	150	347	52	209	210	210	209.66	0.99
4	234	200	446	89	254	253	255	254.00	0.99
5	234	233	624	143	381	379	381	380.33	0.99

3.2 Optimal harmonic elimination in full bridge single phase inverter

In this scheme control system generates the switching signals to prevent specific orders of lower order harmonics. Switching is done to preserve quarter cycle symmetry. This avoids even harmonics.

Figure 3.1 shows the circuit diagram for a 4 pulse full bridge voltage source inverter. Four IGBTs are used as the switching devices.

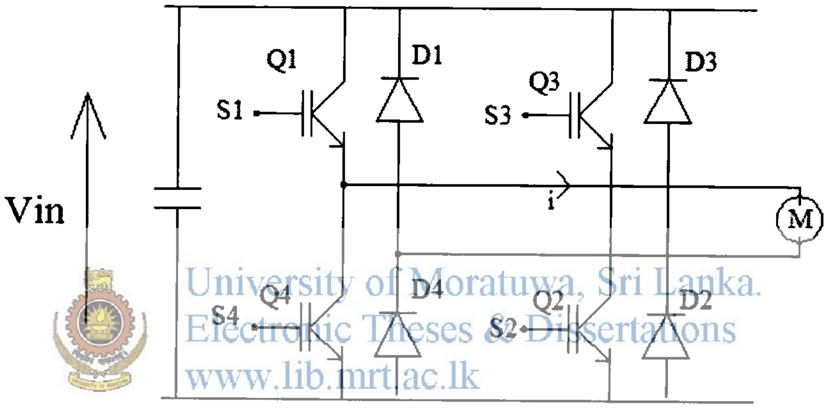

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Figure 3.2-1 Full bridge circuit diagram

Switching of the power IGBTs is executed to preserve quarter cycle symmetry. S1 and S2 is switched as a pair where S3 and S4 are switched as the other pair. As shown in the Fig 3.2.2 and Fig 3.2.3 switching signals are generated for both power switching pairs. Fig 3.2.4 shows the output from the power IGBTs. It gives the output such a way that the resultant is in a sine wave form.

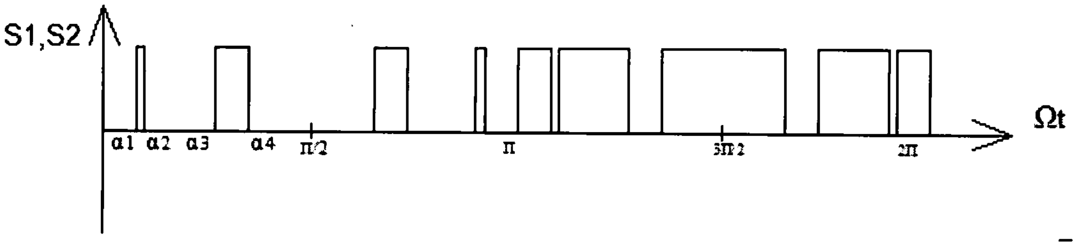

Figure 3.2-2 Switching signal first IGBT pair

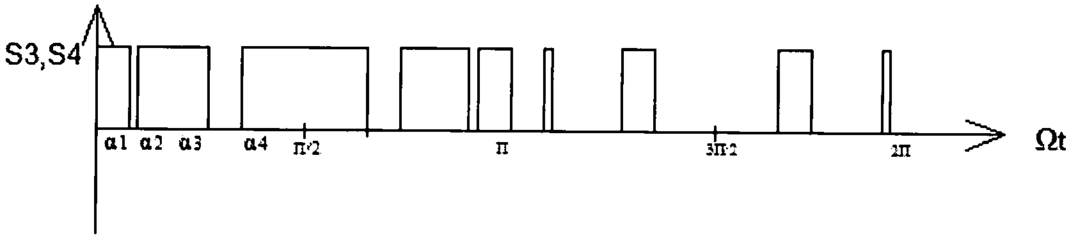

Figure 3.2-3 Switching Signal for second IGBT pair

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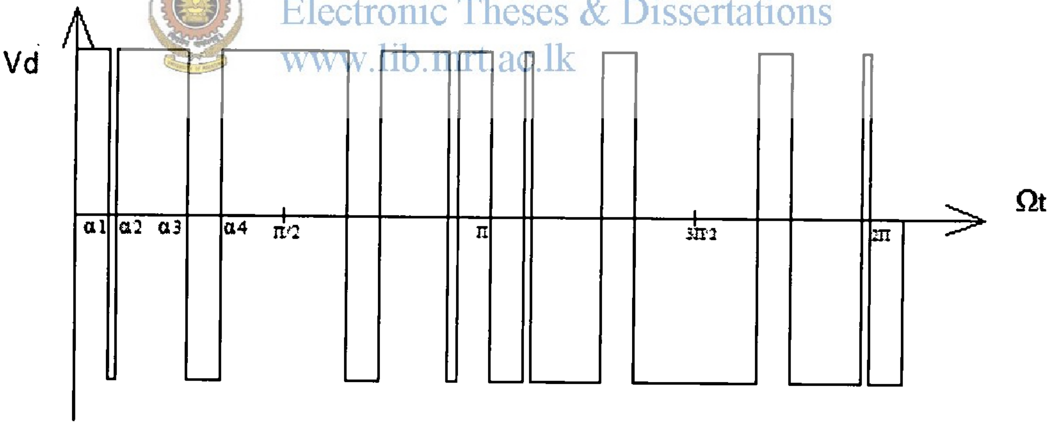

Figure 3.2-4 Output wave form from the power circuit

Theoretical development of the relevant switching angles is described in the following section. Harmonic elimination PWM algorithm is used as the switching method. A set of simultaneous equations are derived by the following derivation.

Furier sine series of VAO (Pole Voltage, Figure 3.2-5) is given by;

$$V_{AO} = \sum_{n=1}^{\infty} bn \operatorname{Sin} n\theta \quad ; [\theta = 2\pi fot]$$

$$bn = 8/2\pi \int_{n=1}^{\pi/2} V_{AO} \operatorname{Sin} n\theta \, d\theta$$

$$= (4/\pi)(V_d/2)\left(\int_{0}^{\alpha_1} \operatorname{Sin} n\theta \, d\theta - \int_{\alpha_1}^{\alpha_2} \operatorname{Sin} n\theta \, d\theta \ldots\ldots\ldots\ldots + \int_{\alpha_{n-1}}^{\pi/2} \operatorname{Sin} n\theta \, d\theta\right)$$

$$= (2V_d / n\pi)\left(1 - \operatorname{Cos} n\alpha_1 + \operatorname{Cos} n\alpha_2 \ldots\ldots\ldots\ldots \operatorname{Cos} n\alpha_n - \operatorname{Cos} n\pi/2\right)$$

$$=(2Vd / (n\pi)\left[1 + 2 \sum_{K=1}^{m} (-1)^{k} \operatorname{Cos} n\alpha_k\right] \qquad (1)$$

Equivalent model of a 3Ph motor;

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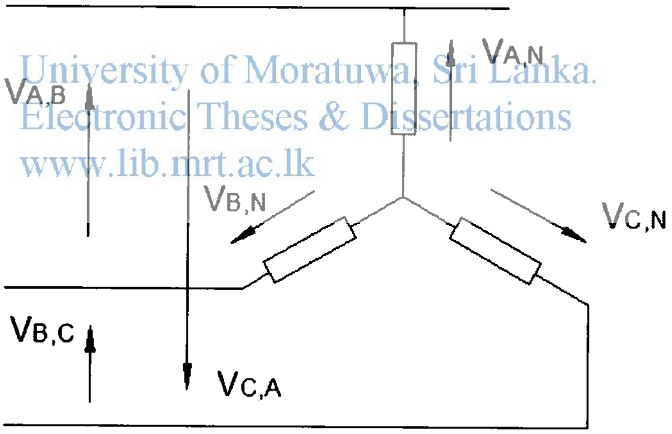

Figure 3.2-5 Equivalent model of a 3p motor

Using the kerchoff voltage low

$$V_{AN} = V_{AO} + V_{ON}$$
$$V_{BN} = V_{BO} + V_{ON}$$
$$V_{CN} = V_{CO} + V_{ON}$$

$$V_{AN} + V_{BN} + V_{CN} = V_{AO} + V_{BO} + V_{CO} + 3V_{ON}$$

$$V_{ON} = -1/3\ [V_{AO} + V_{BO} + V_{CO}]$$

Hence;

$$V_{AN} = V_{AO} - 1/3\ [V_{AO} + V_{BO} + V_{CO}]$$
$$V_{BN} = V_{BO} - 1/3\ [V_{AO} + V_{BO} + V_{CO}]$$
$$V_{CN} = V_{CO} - 1/3\ [V_{AO} + V_{BO} + V_{CO}]$$

Mathematical model of an inverter can be given as,

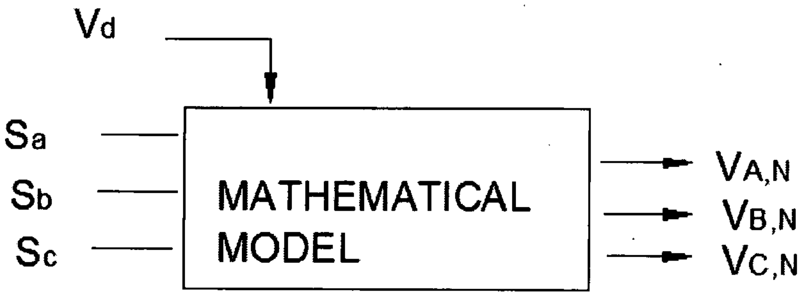

Figure 3.2-6 A mathematical model

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Where Sa,Sb,Sc are digital signals and Vd is the supply DC voltage,

$$\begin{bmatrix} V_{AN} \\ V_{AN} \\ V_{AN} \end{bmatrix} = 1/3 \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} V_{AO} \\ V_{BO} \\ V_{CO} \end{bmatrix}$$

$$\begin{bmatrix} V_{AN} \\ V_{AN} \\ V_{AN} \end{bmatrix} = V_d/3 \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} S_a \\ S_b \\ S_c \end{bmatrix}$$

Mathematical analysis can be done on phase voltage,

$$V_{AN} = (2V_d/\pi)\ [\ \sin \omega t + 1/5 \sin 5\omega t + 1/7 \sin 7\omega t + 1/11 \sin 11\omega t\ )$$

$$V_{AB} = (2\sqrt{3}\_V_d/\pi)\ [\ \sin \omega t - 1/5 \sin 5\omega t + 1/7 \sin 7\omega t - 1/11 \sin 11\omega t\ )$$

Where;

$\omega \quad = 3\pi/T$

RMS value of fundamental line voltage $= \dfrac{(2\sqrt{3}\,V_d)/\pi}{\sqrt{2}}$

b1 = Peak value of fundamental pole voltage
$= \sqrt{2/3} \times (\beta \times$ RMS value of fundamental line voltage)
$= \sqrt{2/3} \times (\beta\sqrt{6}\,V_d)/\pi \qquad (2)$

β = Percentage value of line voltage

In this Scheme line voltage will be defined to preserve constant torque according to the motor manufacturer's specifications.

Average maximum speed is considered as 300rpm

By equ 1 and equ 2 following equations can be taken to remove 3, 5, 7 low order harmonics following equations can be derived,

$$\begin{aligned}
\sqrt{2/3} \times (\beta\sqrt{6}\,V_d)/\pi &= (2V_d/\pi)\,(1 - 2\cos\alpha_1 + 2\cos\alpha_2 - 2\cos\alpha_3 + 2\cos\alpha_4)\\
0 &= (2V_d/3\pi)\,(1 - 2\cos 3\alpha_1 + 2\cos 3\alpha_2 - 2\cos 3\alpha_3 + 2\cos 3\alpha_4)\\
0 &= (2V_d/3\pi)\,(1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 - 2\cos 5\alpha_3 + 2\cos 5\alpha_4)\\
0 &= (2V_d/3\pi)\,(1 - 2\cos 7\alpha_1 + 2\cos 7\alpha_2 - 2\cos 7\alpha_3 + 2\cos 7\alpha_4)
\end{aligned}$$

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Following equations can be derived from above equations to get the expected switching angles for several percentage lone voltages.

$$\begin{aligned}
\beta &= 1 - 2\cos\alpha_1 + 2\cos\alpha_2 - 2\cos\alpha_3 + 2\cos\alpha_4\\
0 &= 1 - 2\cos 3\alpha_1 + 2\cos 3\alpha_2 - 2\cos 3\alpha_3 + 2\cos 3\alpha_4\\
0 &= 1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 - 2\cos 5\alpha_3 + 2\cos 5\alpha_4\\
0 &= 1 - 2\cos 7\alpha_1 + 2\cos 7\alpha_2 - 2\cos 7\alpha_3 + 2\cos 7\alpha_4 \qquad (3)
\end{aligned}$$

At the higher speeds it is decided to avoid 3 and 5 harmonic levels due to a computation limitation. To avoid 3 and 5 low order harmonics following equations can be derived,

$$\begin{aligned}
\beta &= 1 - 2\cos\alpha_1 + 2\cos\alpha_2 - 2\cos\alpha_3\\
0 &= 1 - 2\cos 3\alpha_1 + 2\cos 3\alpha_2 - 2\cos 3\alpha_3\\
0 &= 1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 - 2\cos 5\alpha_3 \qquad (4)
\end{aligned}$$

At the high speed levels the effect from the harmonics is not dominant as low speeds. Since the theme of the project is to develop a hum less fan controller unit three switching angles may sufficient to full fill the requirement.

3.3 Modeling of the system in the Mathlab Simulink environment

The system was modeled in Mathlab simulink environment to asses the behavior of the developed algorithm.

Generation of the signal from a pulse generator is a challenge since the firing angle varies over the selected time period. It should have the capability to generate the pulses with multiple switching timings. The pulse generator in the simulink library allows only a constant pulse rate. It does not allow generating the required pulse train with different switching timings.

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- Generation of the required pulse train with multiple generators.

In this trial 8 numbers of generators were integrated to get the required pulse train. This is a successful method to develop a pulse train for a multiple firing intervals. The disadvantage of the model is, there is a computation limitation which slow down the simulation.

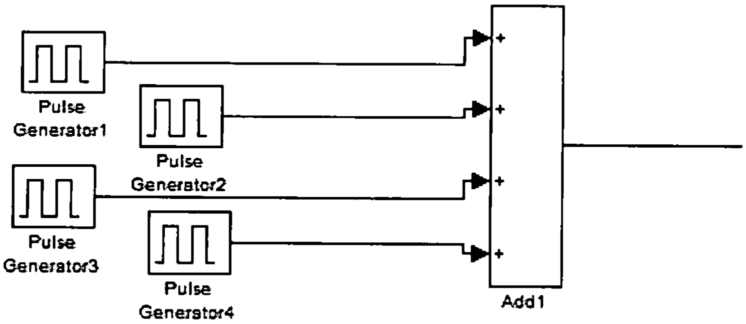

Figure 3.3-1 Pulse generator of the Simulink environment with multiple signal generators

- Generate the signal from a programmed single block.

  To avoid unnecessary computation delay, one single pulse generator was used to get the required pulse train. It simplifies the data entering process while optimizing the computation for simulation.

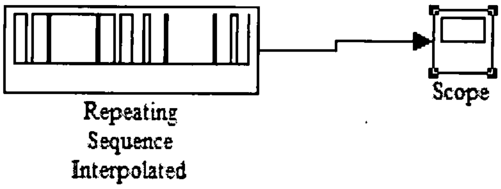

Figure 3.3-2 Pulse generation with developed pulse generator with multiple switching angles.

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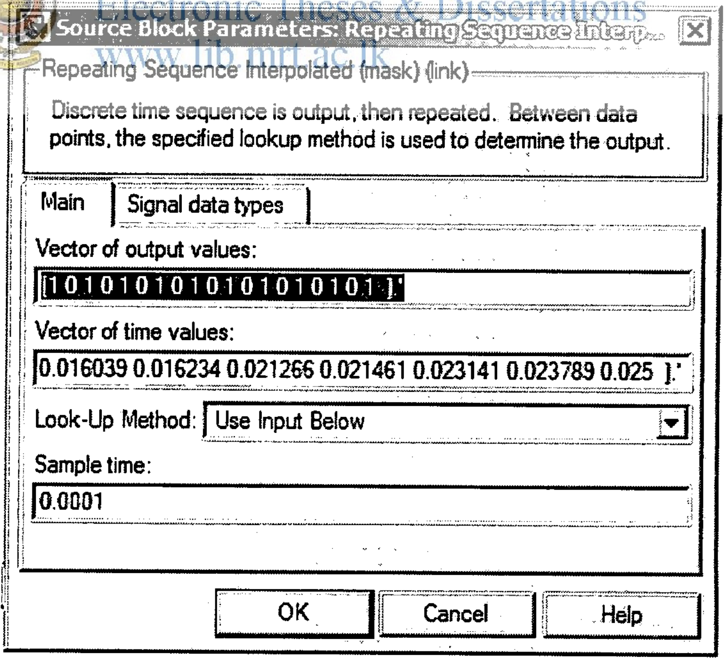

Repeating Sequence Interpolated (mask) (link)

Discrete time sequence is output, then repeated. Between data points, the specified lookup method is used to determine the output.

Vector of output values: [1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1]'

Vector of time values: 0.016039 0.016234 0.021266 0.021461 0.023141 0.023789 0.025]'

Look-Up Method: Use Input Below

Sample time: 0.0001

Figure 3.2-3 Data stream of the developed pulse generator

Chapter 4
Proposed Solution

4.1 Switching angles for range of operating speeds

This chapter describes the proposed PWM algorithm, power electronics circuit development, microelectronic circuit development and microprocessor program development.

It was planned to develop the switching angles for different speed levels. For the convenience it was selected to develop the speed levels in 4% steps for the fundamental line voltage. Table 4.1-1 shows the range of operating frequencies and the relationship with the fundamental line voltage and the percentage of the fundamental line voltage. In a single phase induction motor for a constant torque application, voltage and the frequency vary in a linear manner as follows.

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Table 4.1-1 Fundamental line voltages relate to the operating frequencies

Operating Frequency	Fundamental line voltage	Percentage
10	46	20
12	55.2	24
14	64.4	28
16	73.6	32
18	82.8	36
20	92	40
22	101.2	44
24	110.4	48
26	119.6	52
28	128.8	56
30	138	60
32	147.2	64
34	156.4	68
36	165.6	72
38	174.8	76
40	184	80
42	193.2	84
44	202.4	88
46	211.6	92
48	220.8	96
50	230	100

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In the domestic fan motor exact design parameters are not commonly available. Its relationship with frequency and the voltage is linier at the high speed levels. [6] Since the fan is not operated below 10Hz, it was decided to get the variation as linier at the relevant speed levels.

Following graph shows the variation between frequency and voltage at considerably higher speeds.

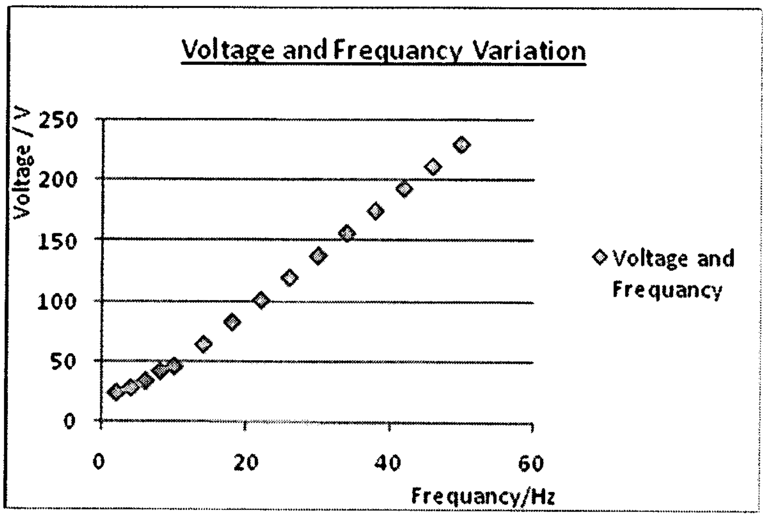

Figure 4.1-1 Variation of the voltage and the frequency for a constant torque operation

It was found that there are computation limitations in Matlab software when it is solved for higher percentage line voltages. It is required some advance solution methods to get the higher no of switching angles after 80% of percentage line voltage. In this thesis for the higher speeds exceeding 80% of percentage line voltage, 3 switching angles were calculated to preserve quarter cycle symmetry.

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Table 4.1.2 shows the result of the solution matrix by solving the equations for 60% percentage line voltage. Developed set of simultaneous equations were solved with MatLab software and the result matrix were observed for a compatible set of solutions.

Table 4.1-2 Solution matrix for 60% of percentage line voltage,

α1 (Rad)	α2(Rad)	α3(Rad)	α4(Rad)
1.11798	2.77753	2.56334	1.22973
1.91189	2.02365	2.56334	2.77754
0.36409	2.02366	2.56334	1.22975
1.11798	1.22974	2.56334	2.77753
0.36409	1.22976	2.56334	2.02365
2.56333	2.77758	1.91189	2.02362
1.11798	2.77756	1.91189	0.57826
2.56333	2.02364	1.91189	2.77757
0.36409	2.02363	1.91189	0.57826
1.11798	0.57826	1.91189	2.77757
0.36409	0.57828	1.91189	2.02368
2.56333	2.77757	1.11799	1.22975
1.91189	2.77755	1.11799	0.57826
2.56333	1.22973	1.11799	2.77756
0.36409	1.22972	1.11799	0.57826
0.36409	0.57821	1.11799	1.22976
2.56333	2.02364	0.36409	1.22974
1.91189	2.02362	0.36409	0.57826
2.56333	1.22975	0.36409	2.02366
1.11798	1.22974	0.36409	0.57826
1.91189	0.57821	0.36409	2.02367

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This is a series of solutions exists for the equations relate to 60% of percentage line voltage. A suitable set of firing angles can be selected to preserve the first quarter cycle. In this example 0.36409, 0.57828, 1.91189, 2.02368 set of solutions are selected. A set of firing angles are selected in each set of solution matrices for each percentage of line voltage.

Table 4.1-3 shows the relevant switching angles for selected speed levels in 4% steps. This includes switching angles up to 80% of percentage line voltage. Table 4.1-4 shows the switching angles above 80% of percentage line voltage. As described in the chapter 3 switching angles were calculated to avoid 3rd and 5th low order harmonics above 80% of percentage line voltage.

Table 4.1-3 Switching angles for relevant fundamental line voltages up to 80% of percentage line voltage,

Percentage Line Voltage (%)	α1(Rad)	α2(Rad)	α3(Rad)	α4(Rad)
20	0.361804	0.666239	1.082637	
24	0.363674	0.659056	1.088923	1.341322
28	0.365276	0.651587	1.094884	1.331466
32	0.366584	0.643818	1.100472	1.321293
36	0.367570	0.635730	1.105623	1.310732
40	0.368200	0.627295	1.110244	1.331466
44	0.368431	0.618481	1.114209	1.288022
48	0.368214	0.609243	1.117331	1.275552
52	0.367482	0.599522	1.119334	1.262000
56	0.366149	0.589235	1.119787	1.246944
60	0.364091	0.578255	1.117989	1.229698
64	0.361110	0.566375	1.112707	1.209071
68	0.356855	0.553199	1.101560	1.182775
72	0.350526	0.537798	1.079242	1.145764
76	0.339520	0.517043	1.030874	1.084110
80	0.304460	0.467338	0.889914	0.938849

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Table 4.1-4 Switching angles for relevant fundamental line voltages above 80% of percentage line voltage.

Percentage Line Voltage (%)	α1(Rad)	α2(Rad)	α3(Rad)
84	0.412151	0.580882	1.571078
88	0.387942	0.546831	1.582309
92	0.355484	0.506275	1.593719
96	0.310161	0.4561736	1.605342
100	0.46035	0.874265	1.373862

Table 4.1-5 and Table 4.1-6 shows the converted switching angles in the time axis. This preserves the quarter cycle symmetry and program is developed to generate the switching angles for the complete amplitude of the wave. At the microelectronics circuit, microprocessor program is developed to execute these firing angles in the time axis.

Table 4.1-5 Switching timing for relevant switching angles up to 80% of percentage line voltage

Percentage Line Voltage(%)	Amplitude /4 (Sec)	t1(Sec)	t2(Sec)	t3(Sec)	t4(Sec)
20	0.025	0.00575597	0.010599	0.017224	0.021492
24	0.02083	0.00482144	0.008737	0.014436	0.017783
28	0.01786	0.00415086	0.007404	0.012442	0.01513
32	0.01563	0.00364501	0.006402	0.010942	0.013138
36	0.01389	0.00324872	0.005619	0.009772	0.011585
40	0.0125	0.00292886	0.00499	0.008831	0.010591
44	0.01136	0.00266427	0.004472	0.008057	0.009314
48	0.01042	0.00244081	0.004039	0.007407	0.008455
52	0.00962	0.00224858	0.003668	0.006849	0.007722
56	0.00893	0.00208039	0.003348	0.006362	0.007085
60	0.00833	0.00193079	0.003067	0.005929	0.006521
64	0.00781	0.00179529	0.002816	0.005532	0.006011
68	0.00735	0.00166978	0.002588	0.005154	0.005534
72	0.00694	0.00154904	0.002377	0.004769	0.005063
76	0.00658	0.00142144	0.002165	0.004316	0.004539
80	0.00625	0.00121092	0.001859	0.003539	0.003734

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Table 4.1-6 Switching timing for relevant switching angles above 80% of percentage line voltage

Percentage Line Voltage(%)	Amplitude/4 (Sec)	t1(Sec)	t2(Sec)	t3(Sec)
84	0.00595	0.00156	0.0022	0.00595
88	0.00568	0.00140	0.00197	0.00572
92	0.00543	0.00122	0.00175	0.00551
96	0.00520	0.00102	0.00151	0.00532
100	0.005			

Control circuit and the remote control circuit diagrams and the developed PCBs are shown in the following figures. Fig 4.1-2 shows the circuit diagram of the developed control circuit. This circuit is developed for testing purpose only. When the original circuit is developed, it can be developed with the surface mount components with multiple layers to reduce the size of the Printed Circuit Board.

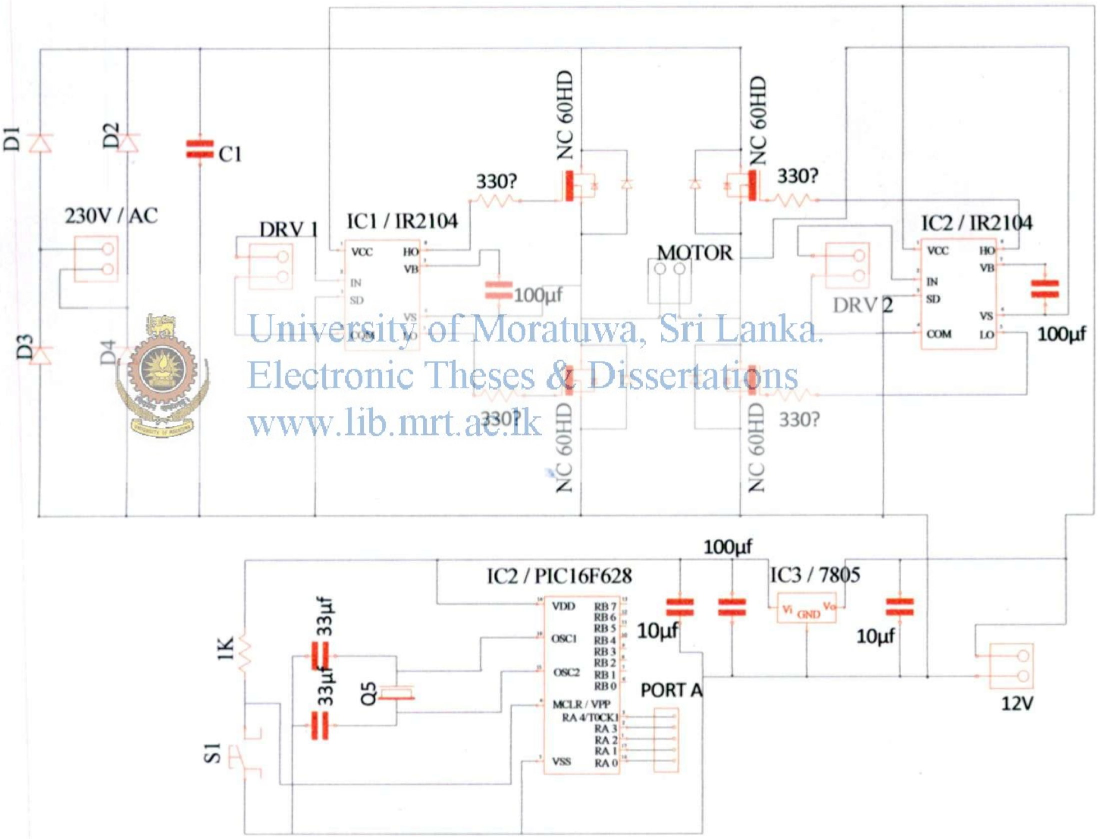

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Figure 4.1-2 Schematic view of the Controller unit

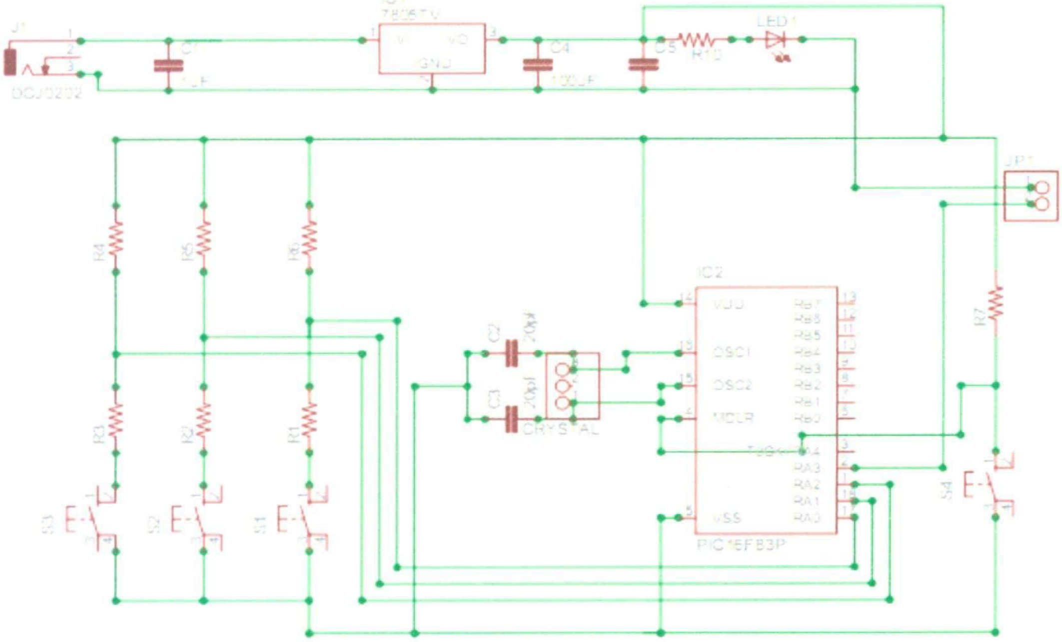

Figure 4.1-3 Schematic view of the Remote controller circuit

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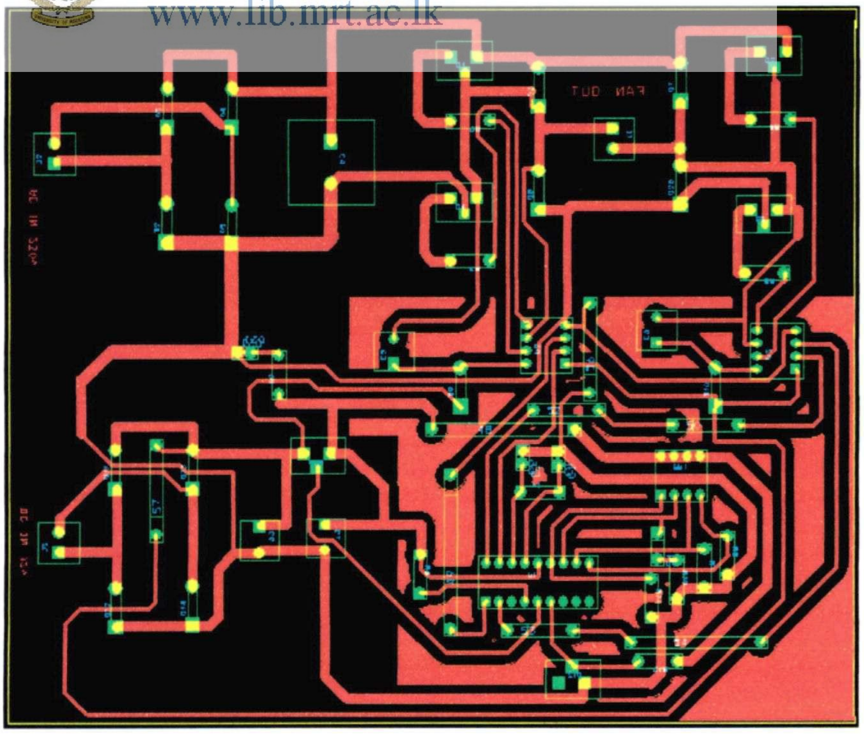

Figure 4.1-4 PCB Layout of the control circuit

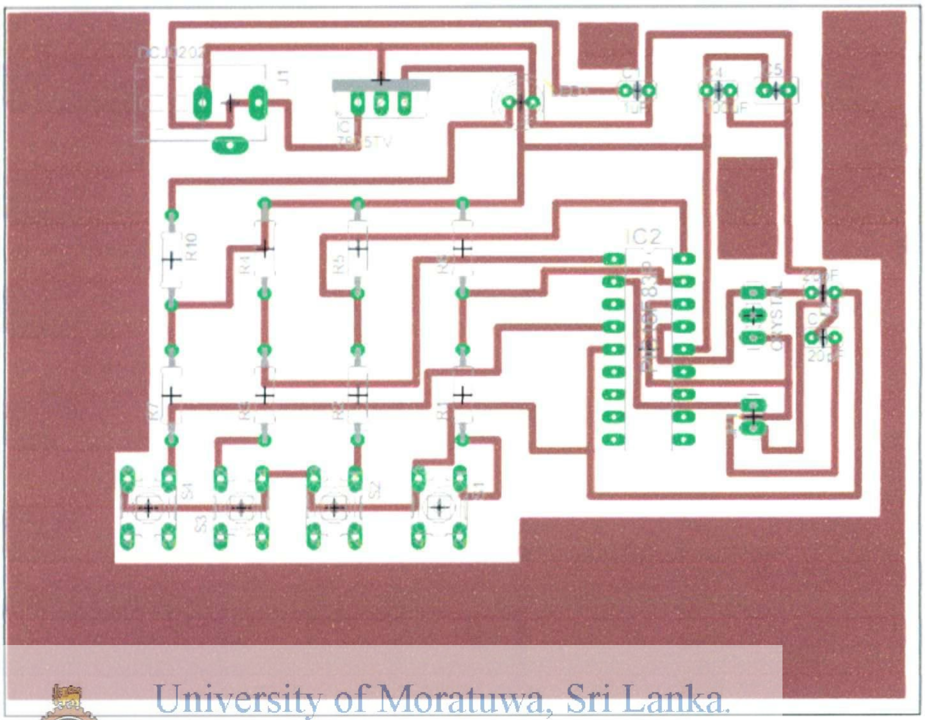

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Figure 4.1-5 PCB Layout of the remote controller circuit

Printed circuit boards and the circuit diagrams were developed with Orcad soft ware. It is an integrated design environment which enables the designers to develop circuits to suit with the application. PCBs were developed by dipping the copper boards in the Ferric Chloride solution. As a further development it can be made with engraving for a durable operation.

4.2 – Development of the control algorithm

The main control system is developed by using a PIC 16F628 microcontroller. Pre calculated switching angles for required speed levels are stored in a lookup table. According to the set speed value by the user the power switches are fired.

Following flow chart shows the sequence of the operation.

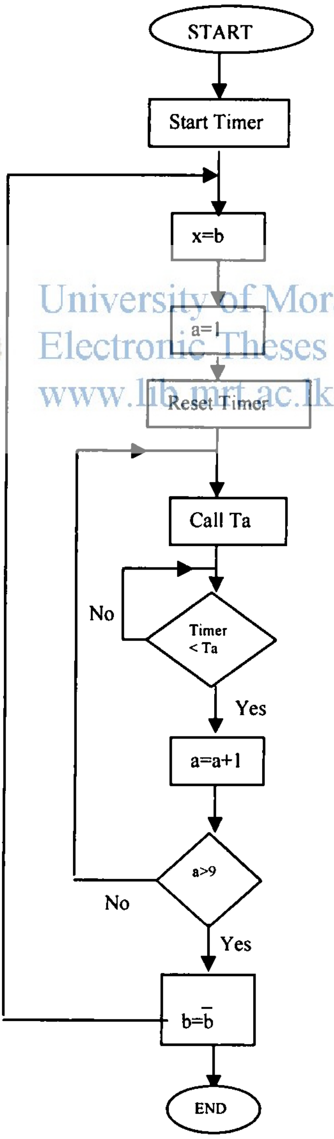

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Figure 4.2-1 Flow chart of the main control algorithm

Ta – Timer value from the data table
b – Execute in the positive direction

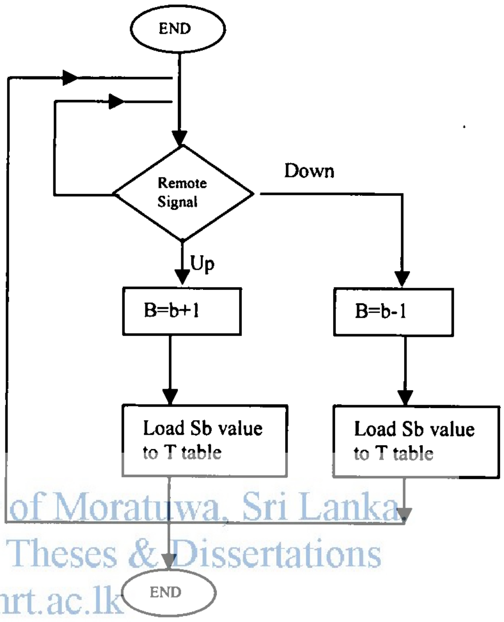

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Figure 4.2-2 Flow chart of the data receiver circuit

Sb – Half cycle switching signals range number.

4.3 - Software Description

Software development is done to execute the switching operation for relevant speeds. It consists of 2 programs which are for the microelectronic circuit of the motor controller and for the remote controller. Program is developed for PIC16f628 microcontroller for both motor controller and the remote controller. Program was developed with MPlab integrated development environment.

MPLAB integrated development environment (IDE) is a free integrated tool set for the development of embedded applications employing Microchips PIC and dsPIC microcontrollers. It is designed for the windows environment and MPlab IDE runs as a 32bit application. MPLAB IDE also serves as a single, unified graphical user interface for additional microchip and third-party software and hardware development tools. This software consists of fully integrated debugging capability with menus for break points, trace and editor functions.

The program is developed for the PIC 16F628 microcontroller using Assembly language. The software is coded to switch the power switches according to the predefined switching to serve quarter cycle symmetry while eliminating considered orders of harmonics. The data is called from a look up table which stored the switching angles for the selected speed levels.

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Time is calculated based on the instruction cycle time. It is developed such a way that the data can be loaded in to the counting program. It generates the required switching time according to the recalled value of the selected speed. For the testing circuit the oscillator is selected with the value of 4MHz. Time accuracy can be further improved by selecting high frequency oscillator.

Following assembly codes shows the time calculation method to get the relevant time intervals. It is possible to increase the accuracy by reducing the least count of the counter.

```
*****************Counter for time calculation****************
time_1
            bsf         T2CON,02            ;5.7ms counts
            movlw d'57'
            movwf 45

aaa         bsf         T2CON,02
            btfss   PIR1,01
            goto    aaa
            nop
            nop
            nop

            bcf         PIR1,01
            bcf         T2CON,02
            decfsz  45,f
            goto    aaa
            nop
            nop
                        return
******************************************************
```

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Basic programming techniques were used to develop the program. It is possible to add more features to the control system as future development since the microcontroller is capable of handling more inputs and outputs than utilized. By using advance programming techniques more accurate firing angles can be achieved which increase the performance of the system.

Chapter 5

Cad Design for the Circuit Mounting Box

5.1 – Conceptual development

In most of the domestic power electric systems 2 wire power supply is drawn to the fan mounting point. Phase supply wire is drawn through the wall mounted mounting box to fix the fan controller unit.

When the fan controller is designed the main objective is to design the system such a way with the ability to replace the existing electronic fan controller. Instead of the wall mounted fan controller user can fix normal one gang switch as the on-off switch for the fan. The fan controller assembly box is designed to fix to the fan hanging pipe. Power wiring which comes to the fan directly goes to the fan controller circuit. Power output comes from the control circuit wired to the fan power supply terminals.

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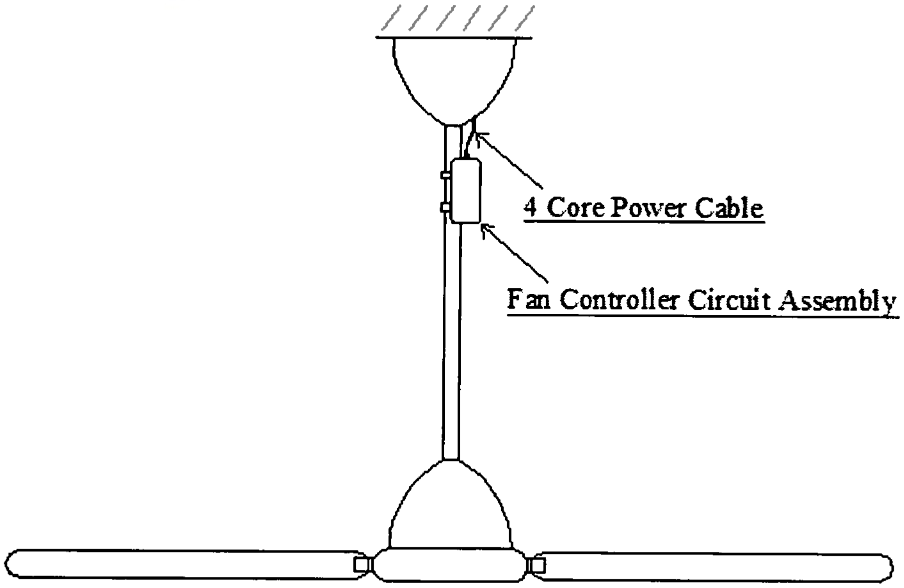

Figure 5.1-1 Control circuit assembly and cable connection

Followings are the design considerations for the CAD design of the power circuit mounting box.

- Aesthetic design to match with modern fan designs and architectural concepts
- Power indicator to show the power availability to fan controller.
- Green color indicator for fan run condition.
- Indicator led set to show the current set speed level of the fan.
- Power inlet and outlet cable supply.
- Mounting brackets to suit with most of the fans available in the market.
- Low cost design to manufacture with simple plastic mold design and low material weight.

5.2 – 3D Design Software - Solid Works

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Solid works is used as the CAD software for the circuit assembly box model development.

The solid works software is a mechanical design application which can operates in Microsoft Windows graphical user interface. The software is developed by Dassualt Systems Solidworks Corp, a subsidiary of dassault Systems, S.A. (Velizy, France.) Solid works cooperation was founded 1993 by Jon Hirschtick and released it's first product in 1995, Solid Works 95. Solidworks is currently usd by over 3.4 million engineers and designers at more than 100,000 companies world wide.

Solidworks is a parasolid – based solid modeler. It utilizes a parametric feature based approach to create models and assemblies. Soild Works premium is the currently used design environment. It is having additional modules like Simulation Design Study, FEM module which is used for designing. In this design FEM module was used to optimize the design.

5.3 – Design of the control circuit mounting module

Following figures shows the basic design of the proposed model.

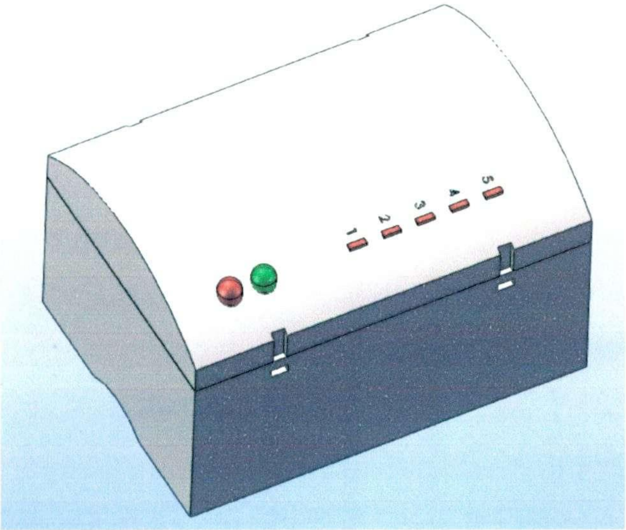

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Figure 5.3-1 Isometric view of the model

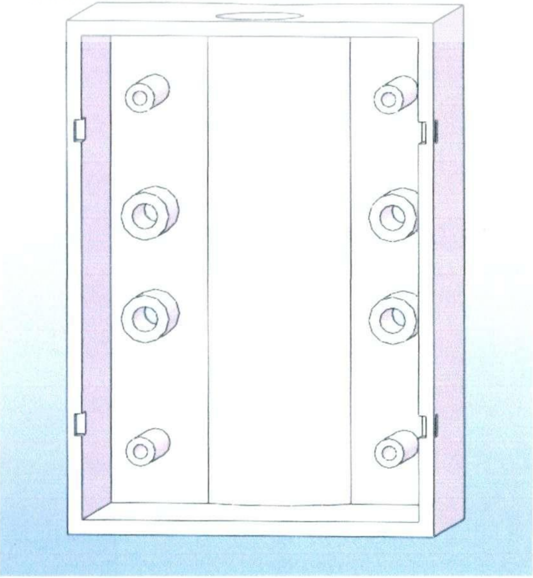

Figure 5.3-2 Part Views of the Design

Analysis of the developed model was planned to optimize the design while ensuring the durable and stedy design. The design was analysed using finite element method. FEM model of the SOLID WORKS soft ware is used for the analysis. Apllied pressyre when the screwing is done is the critical force applied on the monuting box. If this pressure can be withstand, then the system may withstand the other apllied forces.

Fig 5.3-3 shows the apllied pressure on the mounting box screw mounting brackets when the screws are tightnning. Since the sizes of the mounting bars of the fans are differ each other, hole size canot be designed exactly. When the box is mounted on the bar there will be forces applied as shown in the fig 5.3-3. Fig 5.3-4 Shows the deformation of the basic design. The design was revised according to the deformation values. Fig 5.3-5 shows the deforation with the developed model. This avoids the deformations at the screwing operation.

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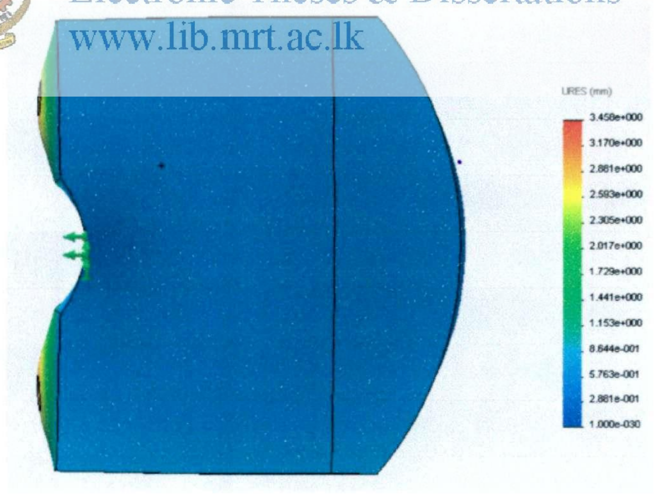

Figure 5.3-3 Pressure application points when the screws are tightening.

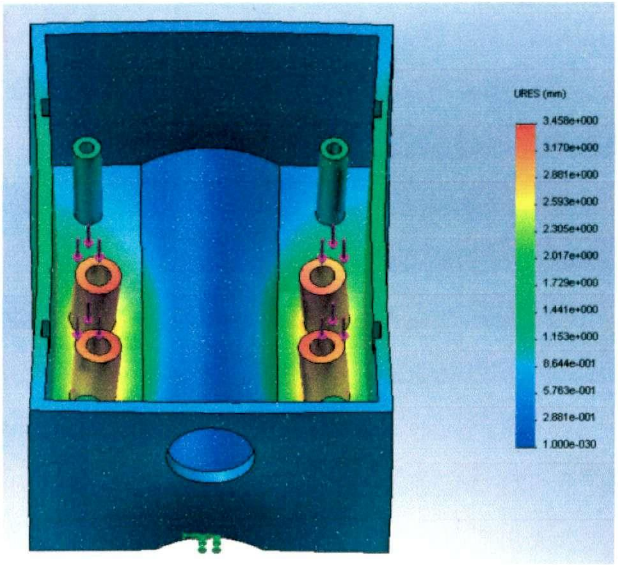

Figure 5.3-4 Stress distribution and deformations of the basic design

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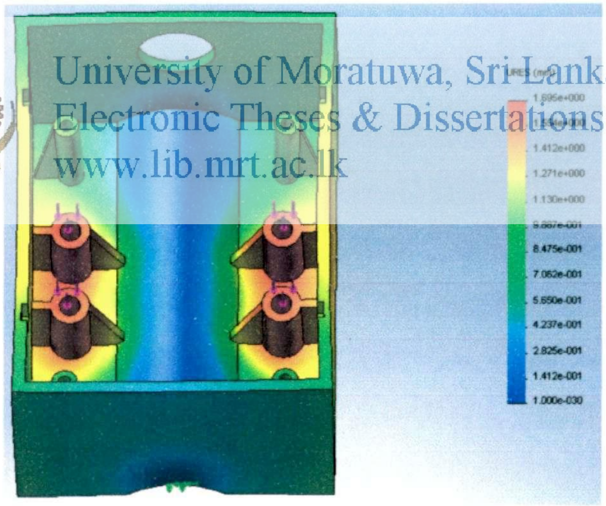

Figure 5.3-4 Stress distribution and the deformations of the further developed design

Chapter 6

Results and Analysis

6.1 – Methods used for results analysis

As discussed in the previous chapters the theme of the project is to develop hum less fan controller unit for domestic fan. The algorithm was developed by solving the simultaneous equations which avoids the selected harmonics. Electronic circuits were developed to generate the regulated power supply for the fan and to generate the remote control signal. Microprocessor program was developed to switch the relevant switching angle according to the set value from the remote controller. Microprocessor program for the remote controller was developed to emit the relevant pulse for the speed up and speed down signal.

The results analysis activity is executed in two methods.

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- Simulation of the switching angles with a developed model by MatLab soft ware.
- Execution of the switching angles on the developed electronics circuits with actual domestic fan.

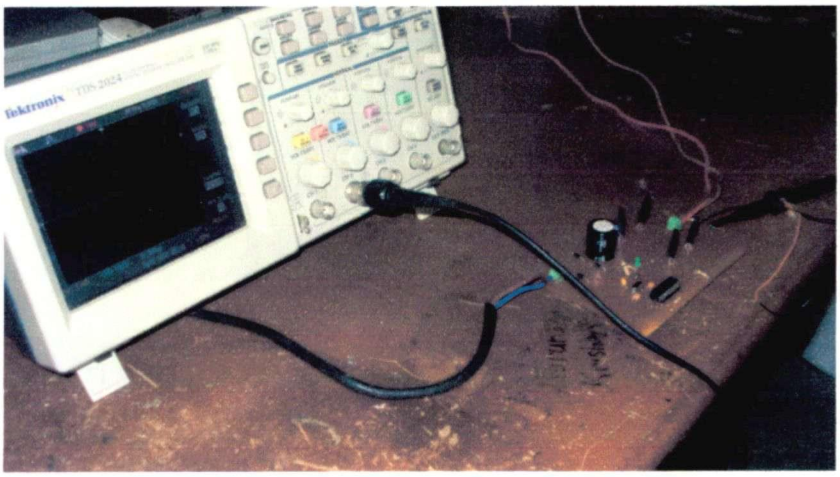

Figure 6.1-1 Testing assembly with the circuit and the oscilloscope

6.2 – Matlab simulation and results

The main objective of the modeling is to see the performance of the developed algorithm with a motor model. Domestic motor parameters were loaded in to a suitable motor model in Matlab simulink.

Required pulse is generated through a programmed PWM generator. The PWM generator is designed with the possibility to configure 8 pulse angles with different values. Generated pulse is amplified by an amplifier to switch the IGBT.

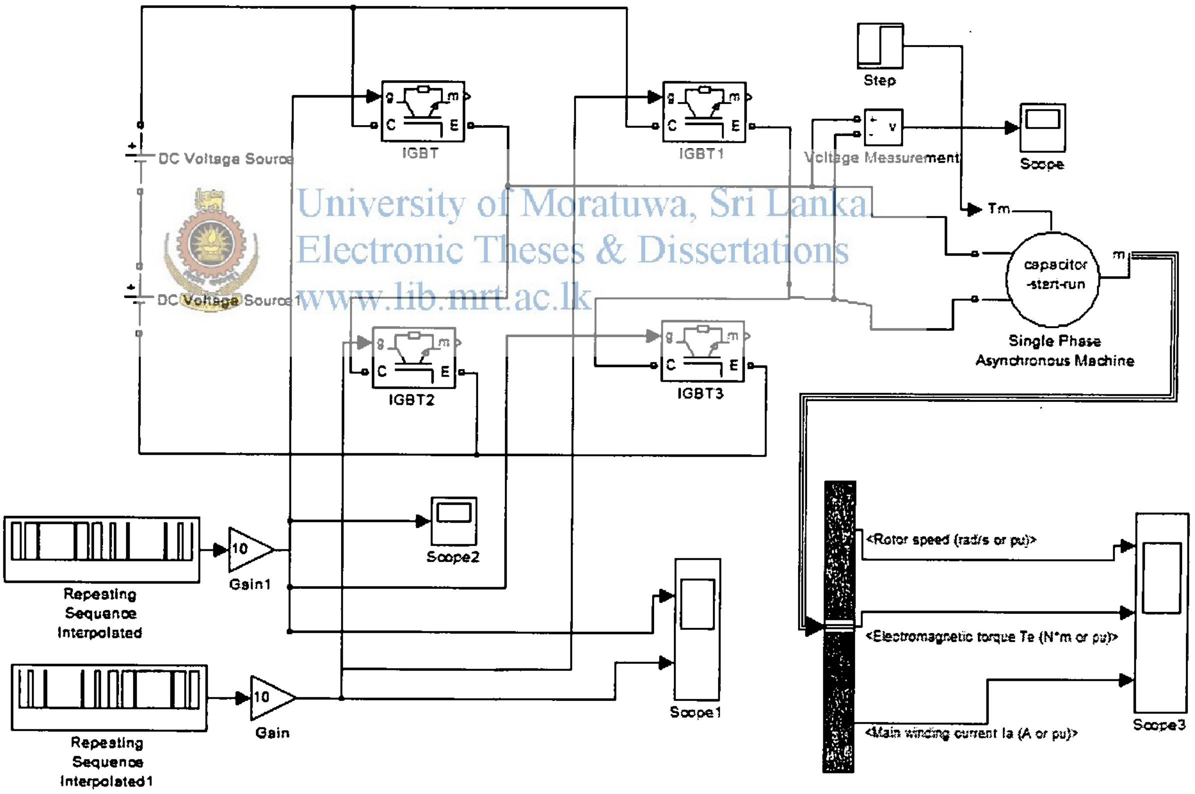

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Figure 6.2-1 Modeling of the circuit and the motor in the simulink environment

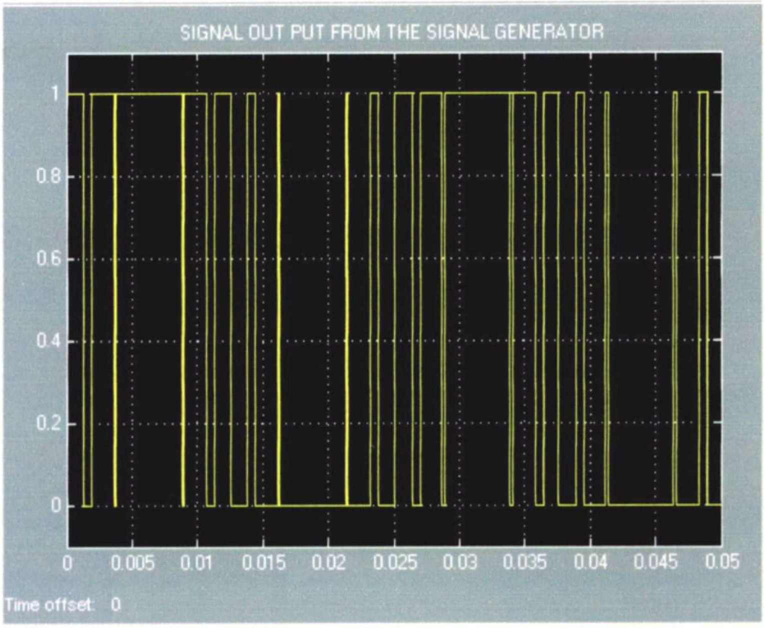

Figure 6.2-2 Generated PWM of the pulse generator at 40Hz on the time line

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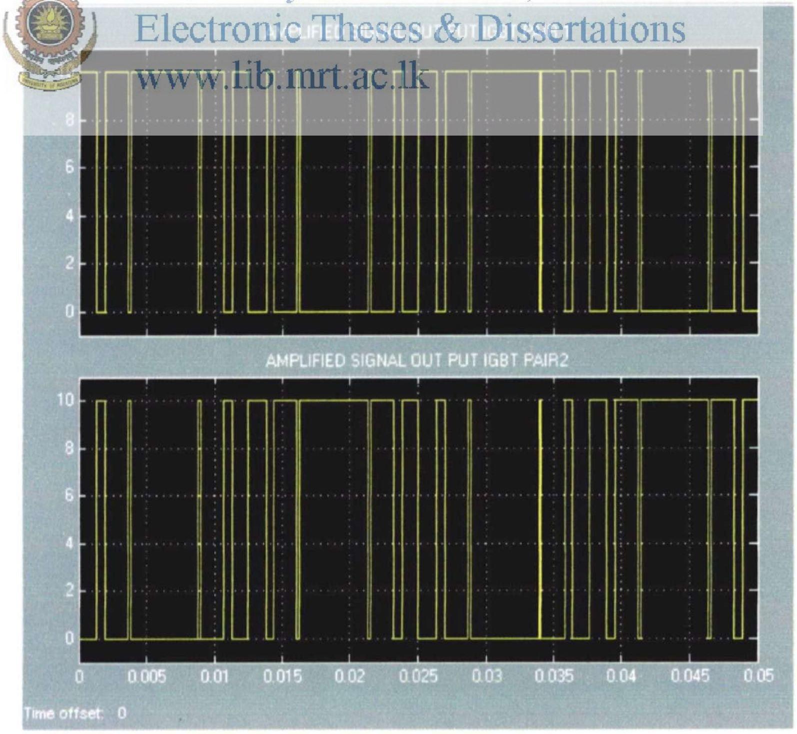

Figure 6.2-3 Generated PWM of the signal amplifier

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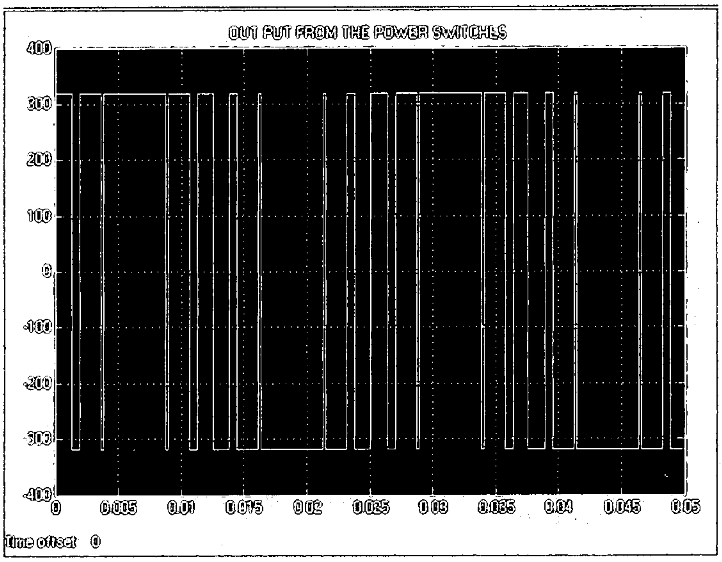

Figure 6.2-4 Generated PWM of the power switches at 40Hz on the time line

Fig 6.2-2 shows the signal out put from the pulse generator. Amplified signal through the amplifier is shown in the fig 6.2-3. Power output from the IGBT module is shown in the fig 6.2-3.

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6.3 – Results of the electronic circuit and the microprocessor program

Developed electronic circuit for the power circuit is operated with the developed switching angles for several speeds. As the first step the circuit is connected with an oscilloscope and the pulse was observed by the screen. It was observed that the microprocessor program executes the required pwm for 2 microprocessor pins to generate positive and negative wave lengths of the sine wave. Fig. 6.3.1 shows the output pwm from the microprocessor circuit at the 40Hz speed level. Fig 6.3.2 shows the output pwm at 36Hz speed level.

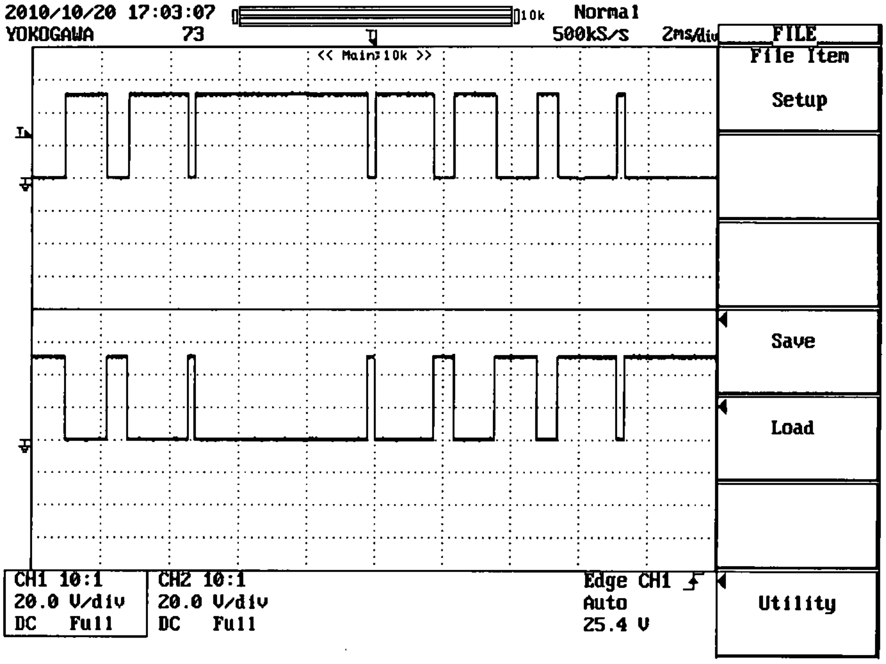

Figure 6.3-1 Generated signal from the microprocessor program – 80% Percentage line voltage (Chanel 1 – IGBT pair 1, Chanel 2 – IGBT)

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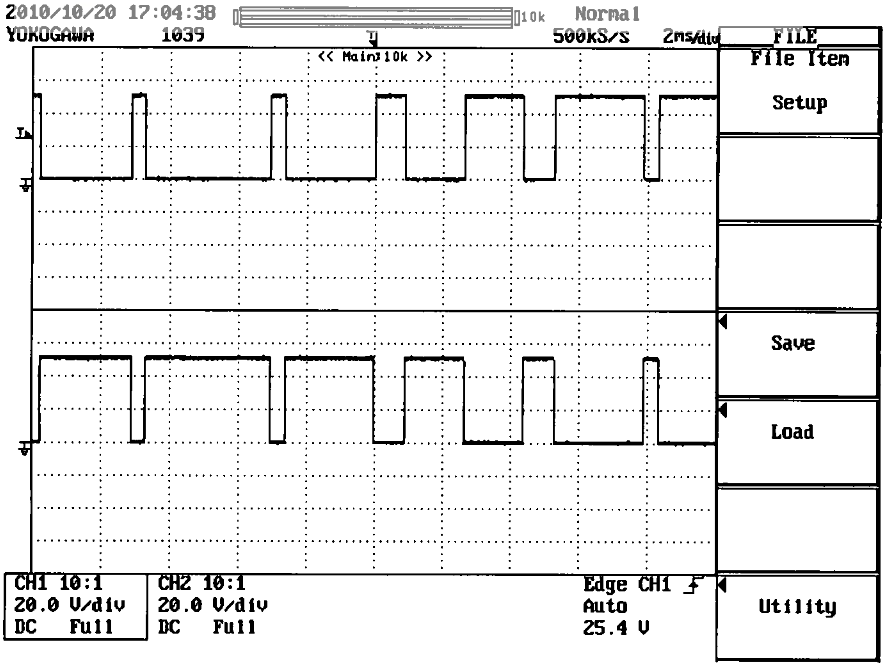

Figure 6.3-2 Generated signal from the microprocessor program – 72% percentage line voltage (Chanel 1 – IGBT pair 1, Chanel 2 – IGBT)

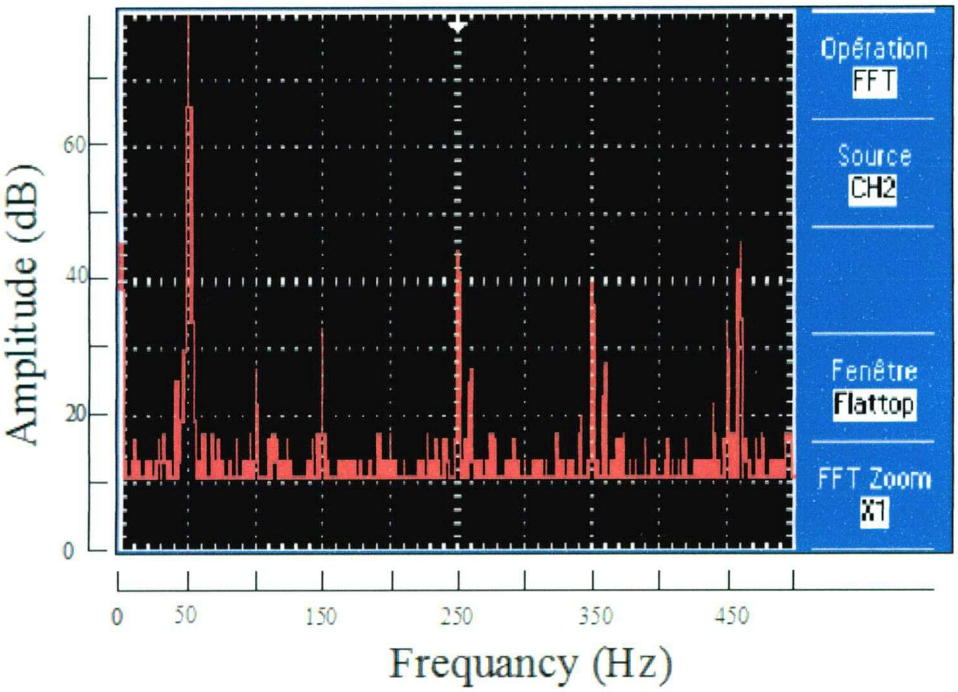

Figure 6.3-3 Harmonic at utility power supply

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The circuit is connected to a domestic fan and the power output to the fan was observed with an oscilloscope and a power analyzer. To get a comparison with the electronic fan dimmer one domestic fan was tested with the triac based commonly available fan dimmer. This is to check the harmonic level generated while at the operation of the developed system. This gives an idea about the generated harmonic level at each level of operation.

Following figures shows a sample set of graphs saved from the power analyzer and the oscilloscope for the speed of 120 rpm.

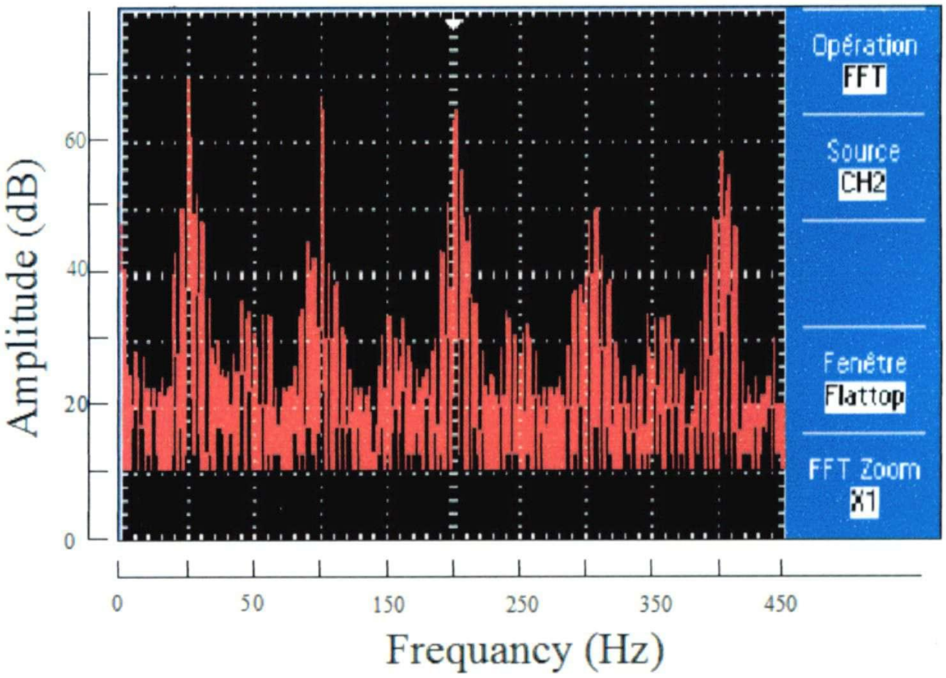

Figure 6.3-4 Harmonic level at 120rpm with normal electronic fan controller (oscilloscope view)

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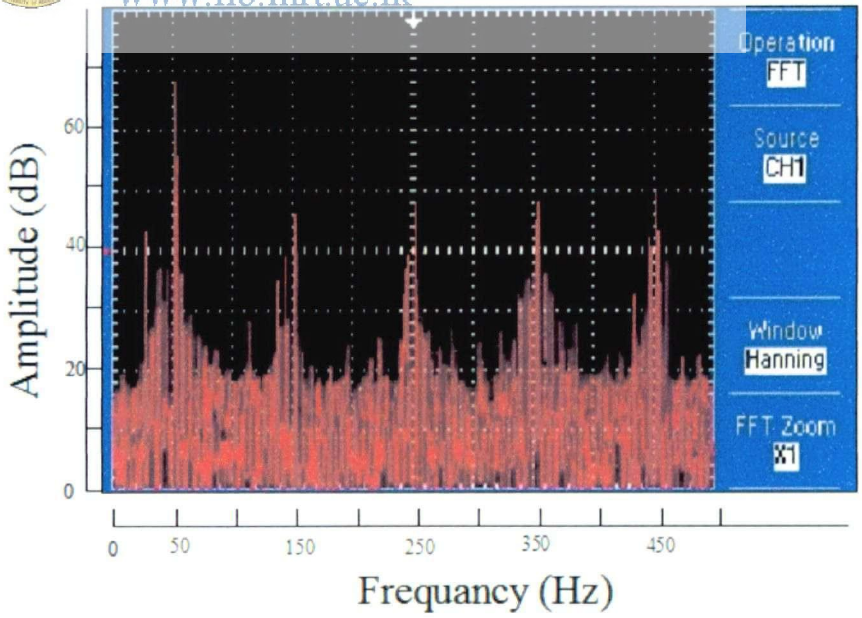
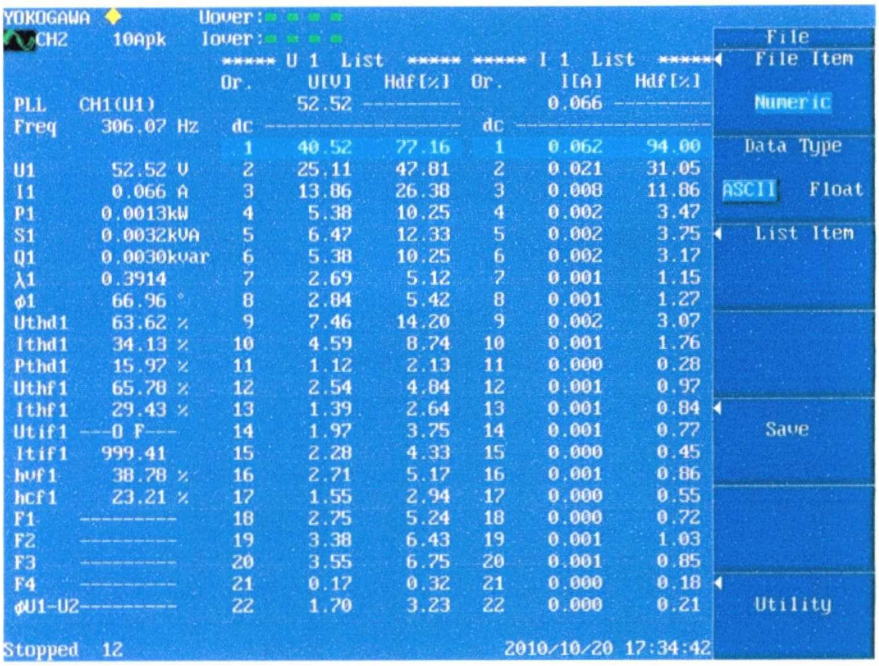


Figure 6.3-5 Harmonic level at 120rpm with developed algorithm (oscilloscope view)



```
YOKOGAWA          Uover:
  CH2     10Apk   Iover:
                  ***** U 1  List  ***** ***** I 1  List  *****
                   Or.     U[V]    Hdf[%]  Or.     I[A]   Hdf[%]
PLL    CH1(U1)             52.52 ---------         0.066 ---------
Freq    306.07 Hz   dc ------------------- dc -------------------
                    1      40.52    77.16   1      0.062    94.00
U1       52.52 V    2      25.11    47.81   2      0.021    31.05
I1       0.066 A    3      13.86    26.38   3      0.008    11.86
P1     0.0013kW     4       5.38    10.25   4      0.002     3.47
S1     0.0032kVA    5       6.47    12.33   5      0.002     3.75
Q1     0.0030kvar   6       5.38    10.25   6      0.002     3.17
λ1     0.3914       7       2.69     5.12   7      0.001     1.15
φ1      66.96 °     8       2.84     5.42   8      0.001     1.27
Uthd1   63.62 %     9       7.46    14.20   9      0.002     3.07
Ithd1   34.13 %    10       4.59     8.74  10      0.001     1.76
Pthd1   15.97 %    11       1.12     2.13  11      0.000     0.28
Uthf1   65.78 %    12       2.54     4.84  12      0.001     0.97
Ithf1   29.43 %    13       1.39     2.64  13      0.001     0.84
Utif1 ---0 F---    14       1.97     3.75  14      0.001     0.77
Itif1  999.41      15       2.28     4.33  15      0.000     0.45
hvf1    38.78 %    16       2.71     5.17  16      0.001     0.86
hcf1    23.21 %    17       1.55     2.94  17      0.000     0.55
F1    ---------    18       2.75     5.24  18      0.000     0.72
F2    ---------    19       3.38     6.43  19      0.001     1.03
F3    ---------    20       3.55     6.75  20      0.001     0.85
F4    ---------    21       0.17     0.32  21      0.000     0.18
φU1-U2---------    22       1.70     3.23  22      0.000     0.21

Stopped  12                              2010/10/20 17:34:42
```

Figure 6.3-6 Analysis results of the developed circuit with a power analyzer low speed (Without friction Load)

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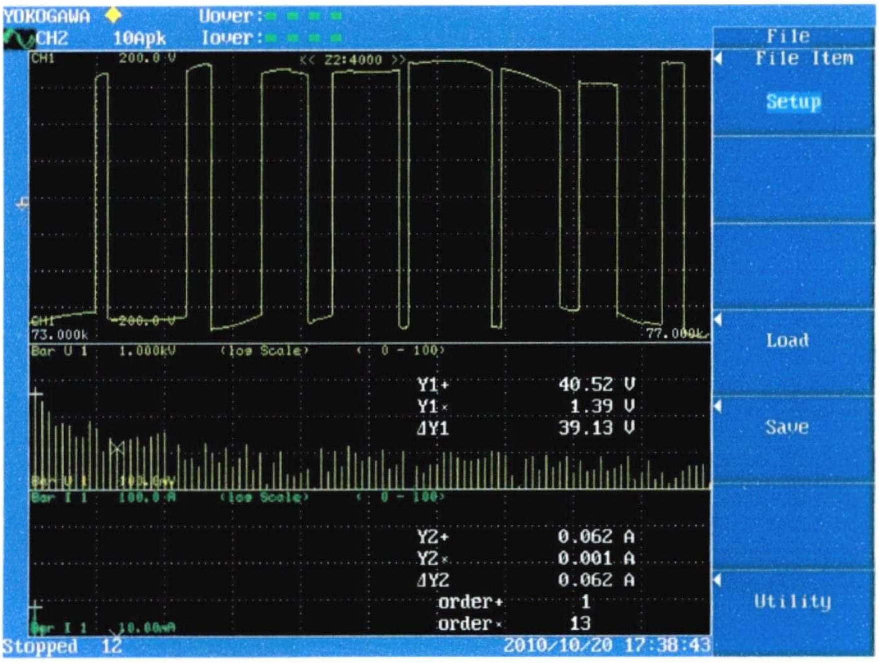

```
Y1+       40.52 V
Y1×        1.39 V
ΔY1       39.13 V

Y2+       0.062 A
Y2×       0.001 A
ΔY2       0.062 A
  order+      1
  order×     13
Stopped  12                2010/10/20 17:38:43
```

Figure 6.3-7 Voltage output of the developed circuit

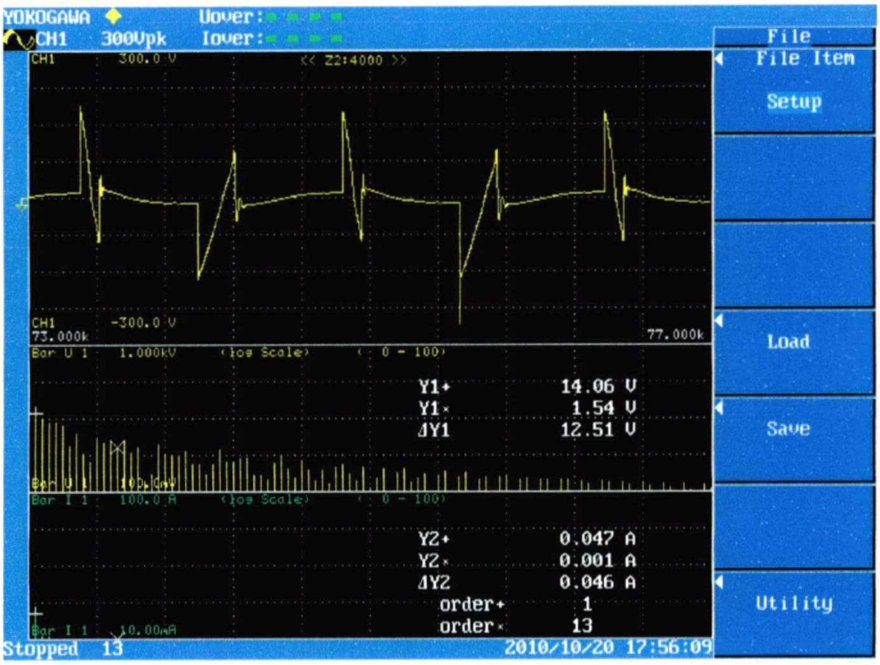

Figure 6.3-8 Voltage output with the existing electronic fan dimmer

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By studding the above attached figures we can understand that the low order harmonics level is reduced in the developed control algorithm. It is clear that the noise filtering should be implemented in order to reduce the existing noise in the system. Table 6.3.1 shows a comparison of low order harmonic levels at 120rpm and 160rpm of the developed circuit and the generally used electronics fan dimmer. 9th and

Table 6.3-1 Comparison of the low order harmonics levels of the developed circuit and the general electronics fan dimmer

Harmonics Level	120 rpm Level		180 rpm Level	
	Developed Circuit Hdf(%)	Electronic Fan Dimmer Hdf(%)	Developed Circuit Hdf(%)	Electronic Fan Dimmer Hdf(%)
3	22.23	33.25	26.38	31.47
5	29.53	27.71	12.33	3.18
7	9.74	17.41	5.12	11.25
9	4.23	2.87	14.20	6.59
11	1.78	9.20	2.13	2.78

Chapter 7
Conclusion

7.1 – Conclusion Remarks and Discussion

This thesis investigates and implements a motor controlling algorithm which can be used for domestic fan. This can be used to control other single phase motors as well. Optimal switching angles to avoid low order harmonics were generated through fundamental equations. Then a simple low cost control system was developed to implement control strategies.

Implementation of the developed system consists of a motor controller unit which mounts on the fan and a remote controller is used and the user interface. The remote control device sends an infra-red beam, which is received by the infra-red sensor on the regulator, the display on the regulator indicates a change in fan speed and the fan controller mounting box also indicates the speed level by a set of indicators. The main advantage of the system is, it can be used with the existing wiring system with an additional on off switch mounted on the wall and the remote control system mounted on the fan it self. The expected manufacturing cost of the unit is Rs, 1600/=.

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In my research, I developed the control program by using assembler language with pic16f628 microprocessor. Remote controller was developed by using the same microcontroller. This allows future modifications and improvements easily. Mosfet drive IC is used to drive the IGBTs in an optimal manner. Power circuit is developed with IGBTs and the power conversion is done through a rectifier bridge. Testing model was developed in a large size PCB and a Separate 12V supply was used to power up the microelectronic circuit to avoid signal interferences. System was modeled in Matlab environment to check the switching angles and the output parameters.

Computer simulation is done to check the signal generation and the power switch output. Developed model was checked and compared the results with the existing electronics fan dimmer. It was found that the developed system generates low order harmonics less than the commonly used electronics fan dimmer.

In my scope of work I was able to develop the algorithm to avoid less no of low order harmonics due to the computation limitations in Matlab. It was found that swithching noise is generated at the operation. This can be reduced by increasing the no of switching angles. I hope that the content of this thesis will open a path to develop a utility friendly high performance fan dimmer.

7.2 – Recommendation for future work

This research is executed to develop the system to eliminate the selected lower order harmonics. This was done to eliminate lesser no of lower order harmonics due to computation limitations. The system can be further developed by increasing the switching angles.

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It is required to asses the high frequency noises generated through the switching and filtration method can be developed to avoid them. By increasing the speed levels an smooth speed controlling capability can be served.

There is a possibility to develop the system based on an intelligent system such as Fuzzy Logic. The fan characteristics can be monitored and switching can be improved to preserve smooth controlling for the motor. The same control algorithm can be developed as a low cost inverter for single phase induction motors. This may allows advance controlling over the motors while ensuring better utility side interface.

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Appendix A ;

Microprocessor program for the motor controller (PIC 16f628)

```
;**********************************************************************
;                                                                    *
;   Filename:      Fan controller pwm.asm                            *
;   Date:          23/8/2010                                         *
;   File Version:  5                                                 *
;                                                                    *
;   Author:        M.D.A.K.Wijerathna                                *
;   Project:       Development of a remote control hum less fan dimmer *
;                                                                    *
;**********************************************************************
;                                                                    *
;   Files required:                                                  *
;                                                                    *
;**********************************************************************
;                                                                    *
;   Notes:  The program is developed for 72%, 76%, 80% percentage line *
;           voltages.                                                *
;                                                                    *
;**********************************************************************
```

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```
        list      p=16f628A           ; list directive to define processor
        #include <p16F628A.inc>       ; processor specific variable definitions

        errorlevel  -302              ; suppress message 302 from list file

__CONFIG   _CP_OFF & _DATA_CP_OFF & _LVP_OFF & _BOREN_OFF &
_MCLRE_OFF & _WDT_OFF & _PWRTE_ON & _INTOSC_OSC_NOCLKOUT

; '__CONFIG' directive is used to embed configuration word within .asm file.
; The lables following the directive are located in the respective .inc file.
; See data sheet for additional information on configuration word settings.


;***** VARIABLE DEFINITIONS******************************************
w_temp        EQU     0x71        ; variable used for context saving
status_temp   EQU     0x72        ; variable used for context saving

;**********************************************************************
        ORG     0x000             ; processor reset vector
        goto    main              ; go to beginning of program
```

```
        ORG     0x004                ; interrupt vector location
        movwf   w_temp               ; save off current W register contents
        movf    STATUS,w             ; move status register into W register
        movwf   status_temp          ; save off contents of STATUS register

; isr code can go here or be located as a call subroutine elsewhere

        nop
        nop

        movf    status_temp,w        ; retrieve copy of STATUS register
        movwf   STATUS               ; restore pre-isr STATUS register contents
        swapf   w_temp,f
        swapf   w_temp,w             ; restore pre-isr W register contents
        retfie                       ; return from interrupt

main
                bsf             STATUS,RP0
                movlw b'10000000'
                movwf OPTION_REG
                clrf    INTCON
                clrf    TRISB
                clrf    TRISA
;*************************************************************
                movlw b'00000010'
                movwf PIE1

                movlw d'96'
                movwf PR2

;*************************************************************

                bcf             STATUS,RP0
                clrf    PORTB
                movlw 0x07
                movwf CMCON
                clrf    24
;*************************************************************
                movlw b'00000000'
                movwf PIR1

                clrf    TMR2
                movlw b'00000000'
                movwf T2CON
;*************************************************************
                clrf    25  ;
```

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```
          clrf    26
          clrf    27
          clrf    28
          clrf    29
          clrf    30
          clrf    31
          clrf    32
          clrf    34
          clrf    35

          clrf    40
          clrf    41
          clrf    45


;*****************************************************************
;               Pulse Generation
;********************************************* 1 **************
@_1

          bsf             PORTA,03      ;SD pin
          bsf             PORTA,04      ;SD pin



          bsf             PORTA,00      ;1.2ms timer
          bcf             PORTA,01
          call      time_1


;*****************************************2****************

          bcf             PORTA,00      ;0.6ms timer
          bsf             PORTA,01
          call      time_2

;**************************************** 3 ****************

          bsf             PORTA,00      ;1.7ms timer
          bcf             PORTA,01
          call      time_3

;**************************************** 4 ****************

          bcf             PORTA,00      ;0.2ms timer
          bsf             PORTA,01
          call      time_4
```

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```
;**************************************** 5 ****************

        bSf         PORTA,00    ;5.0ms timer
        bcf         PORTA,01
        call    time_5

;**************************************** 6 ***************

        bCf         PORTA,00    ;0.2ms timer
        bSf         PORTA,01
        call    time_6

;**************************************** 7 *****************

        bSf         PORTA,00    ;1.7ms timer
        bcf         PORTA,01
        call    time_7

;*************************************** 8 ****************

        bCf         PORTA,00    ;0.6ms timer
        bSf         PORTA,01
        call    time_8

;************************************** 9 ******************

        bSf         PORTA,00    ;1.2ms timer
        bcf         PORTA,01
        call    time_9

        bsf         PORTA,03

;*********************************************************
;               Timer Calculation

;***************************************** 1 **************

        bsf         PORTA,02    ;

        bsf         PORTA,04    ;SD pin

        bcf         PORTA,00    ;1.2ms timer
        bsf         PORTA,01
        call    time_1
```

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```
;******************************************2**************

        bsf         PORTA,00    ;0.6ms timer
        bcf         PORTA,01
        call    time_2

;***************************************** 3 ****************

        bcf         PORTA,00    ;1.7ms timer
        bsf         PORTA,01
        call    time_3

;***************************************** 4 ****************

        bsf         PORTA,00    ;0.2ms timer
        bcf         PORTA,01
        call    time_4

;***************************************** 5 ****************

        bcf         PORTA,00    ;5.0ms timer
        bsf         PORTA,01
        call    time_5

;***************************************** 6 ***************

        bsf         PORTA,00    ;0.2ms timer
        bcf         PORTA,01
        call    time_6

;***************************************** 7 *****************

        bcf         PORTA,00    ;1.7ms timer
        bsf         PORTA,01
        call    time_7

;***************************************** 8 ****************

        bsf         PORTA,00    ;0.6ms timer
        bcf         PORTA,01
        call    time_8

;***************************************** 9 ******************
```

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```
                    bcf              PORTA,00      ;1.2ms timer
                    bsf              PORTA,01
                    call      time_9

                    bsf              PORTA,03      ;

                    goto      @_1

;*******************************************************
;                   timer sub program ; Speed at 40Hz
;********************************** 1 ********************

time_1

                    bsf              T2CON,02

                    btfsC            PORTB,04
                    movlw d'12'                   ;1.2ms counter

                    btfsc            PORTB,05
                    movlw d'17'                   ;1.7ms counter

                    btfsc            PORTB,06
                    movlw d'21'                   ;2.1ms counter

                    movwf 45

aaa                 bsf              T2CON,02
                    btfss     PIR1,01
                    goto      aaa
                    nop
                    nop
                    nop

                    bcf              PIR1,01
                    bcf              T2CON,02
                    decfsz  45,f
                    goto      aaa
                    nop
                    nop
                    return

;*******************************************************


time_2
```

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```
                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'6'                      ;0.6ms counter

                btfsc           PORTB,05
                movlw d'9'                      ;0.9ms counter

                btfsc           PORTB,06
                movlw d'13'                     ;1.3ms counter

                movwf 45

bbb             bsf             T2CON,02
                btfss   PIR1,01
                goto    bbb
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    bbb
                nop
                nop
                return

;*****************************************************

time_3

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'17'                     ;1.7ms counter

                btfsc           PORTB,05
                movlw d'26'                     ;2.6ms counter

                btfsc           PORTB,06
                movlw d'30'                     ;3.0ms counter

                movwf 45
```

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```
ccc             bsf             T2CON,02
                btfss   PIR1,01
                goto    ccc
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    ccc
                nop
                nop
                return


;*****************************************************

time_4

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'2'                      ;0.2ms counter

                btfsc           PORTB,05
                movlw d'4'                      ;0.4ms counter

                btfsc           PORTB,06
                movlw d'7'                      ;0.7ms counter

                movwf 45

ddd             bsf             T2CON,02
                btfss   PIR1,01
                goto    ddd
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    ddd
                nop
                nop
```

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```
                return

;***************************************************

time_5

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'50'                     ;5ms counter

                btfsc           PORTB,05
                movlw d'36'                     ;3.6ms counter

                btfsc           PORTB,06
                movlw d'37'                     ;3.7ms counter

                movwf 45

eee             bsf             T2CON,02
                btfss   PIR1,01
                goto    eee
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    eee
                nop
                nop
                return

;***************************************************

time_6

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'2'                      ;0.2ms counter

                btfsc           PORTB,05
                movlw d'4'                      ;0.4ms counter
```

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```
                btfsc           PORTB,06
                movlw d'7'                      ;0.7ms counter

                movwf 45

fff             bsf             T2CON,02
                btfss   PIR1,01
                goto    fff
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    fff
                nop
                nop
                return

;*****************************************************
time_7

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'17'                     ;1.7ms counter

                btfsc           PORTB,05
                movlw d'26'                     ;2.6ms counter

                btfsc           PORTB,06
                movlw d'30'                     ;3.0ms counter

                movwf 45

ggg             bsf             T2CON,02
                btfss   PIR1,01
                goto    ggg
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
```

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```
                decfsz  45,f
                goto    ggg
                nop
                nop
                return
;*****************************************************

time_8

                bsf             T2CON,02

                btfsC           PORTB,04
                movlw d'6'                      ;0.6ms counter

                btfsc           PORTB,05
                movlw d'9'                      ;0.9ms counter

                btfsc           PORTB,06
                movlw d'13'                     ;1.3ms counter

                movwf 45

hhh             bsf             T2CON,02
                btfss       PIR1,01
                goto        hhh
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    hhh
                nop
                nop
                return

;*****************************************************

time_9

                bsf             T2CON,02

                btfsC           PORTB,04        ;1.2ms counter
                movlw d'12'
```

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```
                btfsc           PORTB,05
                movlw d'17'                     ;1.7ms counter

                btfsc           PORTB,06
                movlw d'21'                     ;2.1ms counter

                movwf 45

iii             bsf             T2CON,02
                btfss   PIR1,01
                goto    iii
                nop
                nop
                nop

                bcf             PIR1,01
                bcf             T2CON,02
                decfsz  45,f
                goto    iii
                nop
                nop
                return
END                                     ; directive 'end of program'
```

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Appendix B ;

Microprocessor program for the Remote Controller Receiver (PIC 16f628)

```
;**********************************************************************
;   Filename:     Receiiver.asm                                       *
;   Date:         15/6/2010                                           *
;   File Version: 6                                                   *
;                                                                     *
;   Author:       M.D.A.K.Wijerathna                                  *
;   Project:      Development of a remote control hum less fan dimmer *
;                                                                     *
;**********************************************************************
;                                                                     *
;   Files required:                                                   *
;                                                                     *
;**********************************************************************
;                                                                     *
;   Notes:  The program is developed for 72%, 76%, 80% percentage line *
;           voltages.                                                 *
;                                                                     *
;**********************************************************************

        list    p=16f628A       ; list directive to define processor
        #include <p16F628A.inc>     ; processor specific variable definitions

        errorlevel  -302        ; suppress message 302 from list file

;       __CONFIG  _CP_OFF & _DATA_CP_OFF & _LVP_OFF & _BOREN_OFF &
_MCLRE_OFF & _WDT_OFF & _PWRTE_ON & _INTOSC_OSC_NOCLKOUT

; '__CONFIG' directive is used to embed configuration word within .asm file.
```

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```
; The lables following the directive are located in the respective .inc file.
; See data sheet for additional information on configuration word settings.

;**********************************************************************

        list      p=16f628A         ; list directive to define processor
        #include <p16F628A.inc>      ; processor specific variable definitions
        errorlevel  -302            ; suppress message 302 from list file

__CONFIG   _CP_ON & _DATA_CP_OFF & _LVP_OFF & _BOREN_OFF &
_MCLRE_ON & _WDT_OFF & _PWRTE_ON & _XT_OSC;_NOCLKOUT

; '__CONFIG' directive is used to embed configuration word within .asm file.
; The lables following the directive are located in the respective .inc file.
; See data sheet for additional information on configuration word settings.

;***** VARIABLE DEFINITIONS*****************************************

w_temp       EQU     0x7E        ; variable used for context saving
status_temp   EQU     0x7F        ; variable used for context saving

time1_bit1          EQU          0x21
time1_bit2          EQU          0x22
time1_bit3          EQU          0x23
time2_bit1          EQU          0x24

;**********************************************************************
        ORG     0x000           ; processor reset vector
        goto    main            ; go to beginning of program
```

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```
          ORG     0x004            ; interrupt vector location
          movwf   w_temp           ; save off current W register contents
          movf    STATUS,w         ;  move status register into W register
          movwf status_temp        ; save off contents of STATUS register

test_1    call    time_t
          btfss   PORTB,00
          goto    reset
          call    time_t
          btfss   PORTB,00
          goto    reset
          call    time_t
          btfss   PORTB,00
          goto    reset
          call    time_t

          call    time_t
          btssc   PORTB,00
          goto    reset
          call    time_t
          call    time_t
          btssc   PORTB,00
          goto    reset
          call    time_t

          call    time_t
          btfss   PORTB,00

reset
reset
```

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```
; isr code can go here or be located as a call subroutine elsewhere

        movf    status_temp,w       ; retrieve copy of STATUS register
        movwf   STATUS              ; restore pre-isr STATUS register contents
        swapf   w_temp,f
        swapf   w_temp,w            ; restore pre-isr W register contents
        retfie                      ; return from interrupt

main
; remaining code goes here

;       goto    main                ;loop forever, remove this instruction, for test only

ini     clrf    STATUS
        bsf     STATUS,05           ;Change to Bank1
      movlw     b'00000000'         ;GIE=1,TOIE=1
      movwf     OPTION_REG

      bcf               STATUS,05   ;Change to Bank0

main_1bsf       PORTA,00            ;test indicator
        call    time_d              ;1s time
        bcf     PORTA,00
        call    time_d              ;1s time
        goto    main_1
time
        return

time_a call     time_t
        call    time_t
```

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```
          call    time_t
          call    time_t
                  return

time_b    call    time_t
          call    time_t
          return

time_c                                  ;250mS
          return
time_t
          return

          END                           ; directive 'end of program'
```

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Appendix C ;

Microprocessor program for the Remote Controller Emitter (PIC 16f628)

```
;**********************************************************************
;   Filename:      Emmiter.asm                                        *
;   Date:          20/5/2010                                          *
;   File Version:  6                                                  *
;                                                                     *
;   Author:        M.D.A.K.Wijerathna                                 *
;   Project:       Development of a remote control hum less fan dimmer *
;                                                                     *
;**********************************************************************
;   Files required:                                                   *
;                                                                     *
;**********************************************************************
;                                                                     *
;   Notes:   The program is developed to emit the signals from        *
;            the remote  controller.                                  *
;                                                                     *
;**********************************************************************

        list      p=16f628A          ; list directive to define processor
        #include <p16F628A.inc>      ; processor specific variable definitions

        errorlevel  -302             ; suppress message 302 from list file

        __CONFIG   _CP_ON & _DATA_CP_OFF & _LVP_OFF & _BOREN_OFF &
        _MCLRE_ON & _WDT_OFF & _PWRTE_ON & _XT_OSC;_NOCLKOUT

; '__CONFIG' directive is used to embed configuration word within .asm file.
; The lables following the directive are located in the respective .inc file.
```

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```
; See data sheet for additional information on configuration word settings.

;***** VARIABLE DEFINITIONS*****************************************

w_temp      EQU    0x7E       ; variable used for context saving
status_temp EQU    0x7F       ; variable used for context saving

time1_bit1          EQU          0x21
time1_bit2          EQU          0x22
time1_bit3          EQU          0x23
time2_bit1          EQU          0x24

;**********************************************************************
        ORG     0x000           ; processor reset vector
        goto    main            ; go to beginning of program

        ORG     0x004                 ; interrupt vector location
        movwf   w_temp                ; save off current W register contents
        movf    STATUS,w              ; move status register into W register
        movwf   status_temp           ; save off contents of STATUS register

; isr code can go here or be located as a call subroutine elsewhere

        movf    status_temp,w         ; retrieve copy of STATUS register
        movwf   STATUS                ; restore pre-isr STATUS register contents
        swapf   w_temp,f
        swapf   w_temp,w              ; restore pre-isr W register contents
        retfie                        ; return from interrupt

main
```

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```
; remaining code goes here

;       goto    main                    ;loop forever, remove this instruction, for test only

ini     clrf    STATUS
        bsf     STATUS,05               ;Change to Bank1
      movlw     b'00000000'             ;GIE=1,TOIE=1
      movwf     OPTION_REG

      bcf               STATUS,05               ;Change to Bank0
main_1
        btfss   PORTB,05                ;on
        call    on
        btfss   PORTB,06                ;off
        call    off
        btfss   PORTB,07                ;speed
        call    speed
        call    time
        goto    main_1
on      movlw b'00000011'
        movwf28
on_1    decfss  28
        goto    $1
        return
        bsf     PORTB,00                ;Hedar1
        call    time_a
        bcf     PORTB,00
        call    time_a
        call    time_b                  ;Data
        call    time_b                  ;Data
        bsf     PORTB,00                ;Data
```

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```
        call    time_b
        bcf     PORTB,00
        call    time_a
        bsf     PORTB,00            ;End bit
        call    time_a
        bcf     PORTB,00
        call    time_c              ;250mS timer
        goto    on_1

off     movlw b'00000011'
        movwf 29
off_1   decfss  29
        goto    $1
        return
        bsf     PORTB,00            ;Hedar1
        call    time_a
        bcf     PORTB,00
        call    time_a
        call    time_b              ;Data
        bsf     PORTB,00            ;Data
        call    time_b              ;Data
        bcf     PORTB,00
        call    time_b              ;Data
        call    time_a
        bsf     PORTB,00            ;End bit
        call    time_a
        bcf     PORTB,00
        call    time_c              ;250mS timer
        goto    off_1

speed   movlw b'00000011'
```

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```
            movwf 30
speed_1     decfss  30
            goto    $1
            return
            bsf     PORTB,00            ;Hedar1
            call    time_a
            bcf     PORTB,00
            call    time_a
            call    time_b              ;Data
            bsf     PORTB,00            ;Data
            call    time_b
            call    time_b              ;Data
            bcf     PORTB,00
            call    time_a
            bsf     PORTB,00            ;End bit
            call    time_a
            bcf     PORTB,00
            call    time_c              ;250mS timer
            goto    speed_1
time
            return
time_a
            time_t
            time_t
            time_t
            time_t
                    return
time_b
            time_t
            time_t
```

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```
          return
time_c                                  ;250mS
          return

time_t
          loop_11     movlw b'01000111'
                  movwf time2_bit1

          loop_12     decfsz  time2_bit1
                  goto    loop_12
                  return

          END                           ; directive 'end of program
```

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