Faculty of Electrical and Electronic Engineering Technology

THE DEVELOPMENT OF SPEED CONTROLLER OF UNIVERSAL MOTOR USING MICROCONTROLLER-BASED CYCLOCONVERTER

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Bachelor of Electrical Engineering Technology with Honours

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**A project report submitted
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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

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DEDICATION

To my beloved mother, Mariani, and hardworking father, Fadzil
whose unwavering encouragement has been my pillar throughout this academic journey.
and
To my dedicated Supervisor, Dr. Badril, whose wisdom and guidance have shaped my intellectual growth.
Your belief in me has been a driving force.
Thank you.

ABSTRACT

A universal motor is widely used for home appliances and portable tools due to its compact size. Nonetheless, it is necessary to vary the speed of the motor for the usage of specific applications. The supply frequency and number of poles have the biggest impact on a motor's speed. However, the frequency can be easily altered without affecting the motor's whole structure, while the number of poles cannot. This project will analyze how single-phase universal motors can have their speed changed using cycloconverters. Cycloconverters will be used to adjust the supply frequency to alter the motor's speed. The speed of the motor was adjusted in three increments at F, F/2, and F/3 with the assistance of a selector switch attached to the microcontroller and the program that is written on it. The microcontroller triggers the thyristors in a twin bridge configuration to provide the alternating signal required to operate the motor by sending the gating pulse. For safety purpose, a low power AC motor is used as a testbed which represent a real universal motor to verify the efficacy of the device. In the experimental results, it is found that the developed device is able to produce the waveform as expected and able to control the speed of AC motor.

ABSTRAK

Motor universal digunakan secara meluas untuk peralatan rumah dan alat mudah alih kerana saiznya yang padat. Namun begitu, kelajuan motor perlu diubah untuk kegunaan aplikasi tertentu. Bekalan frekuensi dan bilangan kutub mempunyai kesan terbesar pada kelajuan motor. Walau bagaimanapun, bekalan frekuensi boleh diubah dengan mudah tanpa menjejaskan keseluruhan struktur motor, manakala bilangan kutub tidak boleh. Projek ini akan menganalisis bagaimana motor universal fasa tunggal boleh menukar kelajuannya menggunakan penukar "cycloconverter". "Cylcoconverter" akan digunakan untuk melaraskan kekerapan bekalan bagi mengubah kelajuan motor. Kelajuan motor telah dilaraskan dalam tiga kenaikan pada F, F/2, dan F/3 dengan bantuan suis pemilih yang dipasang pada mikropengawal dan kod program yang ditulis padanya. Pengawal mikro akan memacu "thyristor" dalam konfigurasi jambatan berkembar untuk memberikan isyarat berselang-seli yang diperlukan untuk mengendalikan motor dengan menghantar isyarat "gating". Untuk tujuan keselamatan, sebuah motor AC berkuasa rendah digunakan sebagai alat ujian bagi mewakili motor universal yang sebenar bagi mengesahkan keberkesanan peranti ini. Dalam keputusan eksperimen, adalah didapati peranti yang dibangunkan ini mampu mengeluarkan bentuk gelombang seperti yang dijangkan dan boleh mengawal kelajuan motor AC.

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CHAPTER 1

INTRODUCTION

1.1 Background

A universal motor is a motor that can run both AC and DC power supplies. It is a series-wound type of motor where the armature and field windings are connected in series. As they are connected in series, universal motors generate high torque. Most of the universal motors operated at speeds as high as 3500 RPM.

A cycloconverter is a device that converts the constant voltage and frequency of the AC waveform to a lower frequency. The conversion of the waveform is done by using power electronic switches like thyristors which made it very efficient. The thyristors will be split into a positive half and a negative half and each half enables bi-directional power flow. The main reason for using a cycloconverter is for speed control since we can easily manipulate the output frequency. This will assist large motors to start at minimum speed during full load since the output frequency of the cycloconverter can be reduced to a minimum zero.

A universal motor is widely used in various home appliances such as vacuum cleaners, blenders, and hair dryers since it is cheap and able to operate at high speed and high torque. The speed control of the motor by using the phase angle technique, inverter, or cycloconverter.

1.2 Problem Statement

A universal motor is most widely used in many applications since it is cheaper than an induction motor in high-power applications, hence suitable to be used in domestic appliances such as blender machines, vacuum cleaners, and air blowers, to name a few. To control the speed of the universal motor, a speed controller is needed. Speed controllers such as an inverter or any other TRIAC-based controllers are mainly expensive. Cycloconverters are circuits that convert the frequency of AC to a lower frequency with the same voltage amplitude without any intermediate DC link. A cycloconverter-based speed controller is suitable to be used to control the speed of a universal motor since it is low cost and has low losses as compared to another type of speed controller.

In recent years, energy efficiency has become a main focus in developing electrical and electronic products. Therefore, a cycloconverter-based speed controller of AC motors is suitable to meet the requirement of green technology, specifically for energy efficiency.

1.3 Project Objective

The main aim of this project is to propose and develop an efficient speed controller of universal motor using microcontroller-based cycloconverter. Specifically, the objectives are as follows :

a) To apply a speed controller using microcontroller-based cycloconverter circuit.

b) To develop a hardware prototype of a speed controller using microcontroller-based cycloconverter circuit.

c) To analyze the performance of the developed device by using oscilloscope.

1.4 Scope of Project

The scopes of this project are as follows:

a) Type of Motor

b) A single-phase universal motor with power less than 1500w will be used in this project.

c) Parameter of Control

d) Controlling the speed of a universal motor is the focus of this project. The control of position and acceleration for the motor is not covered.

e) Microcontroller

f) An Arduino microcontroller will be used as a main controller to control the speed of a universal motor using a cycloconverter.

g) Software

h) Proteus software will be used for circuit development and simulation purposes.

i) Hardware prototype

j) A hardware prototype will be developed to verify the efficacy of the designed circuit.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review a historical analysis of a body of academic literature, including journal articles and theses, that are relevant to a particular area of study or topic. Circles in the project's scope and environment. For the purpose of using them as guidelines for this project, the researcher will use the literature reviews to educate herself on other people's practices. It will enable the researcher to have a deeper understanding of the subject and to devise or implement new approaches.

2.2 Concern with Cultural Issues

The degree of awareness and education present in culture can have an impact on cultural attitudes toward energy efficiency. The promotion of energy efficiency may be limited by a lack of information about energy conservation techniques, technology, and the advantages they offer. The incentive to prioritize energy conservation may be lower in some societies when energy costs are low or significantly subsidized. Hence, by integrating the project's chosen method with energy efficiency, society can have a greater comprehension of its impact on the environment.

A study [13] proved that the method for converting AC to AC power that uses cycloconverters succeeded in reducing the total harmonic distortions to the usage of using conventional inverter-based AC to AC converter. According to the simulation results, the converter reduces overall harmonic distortions by about 18.85% and 23.67% for 50 Hz frequency conversions of one-third and one-fourth, respectively. According to [16] due to the cycloconverter's operation in the circulating current mode, there is a constant current source, which lowers the harmonic content of the output voltage. Lower conversion losses were achieved due to the frequency conversion in one step. By cutting down on unnecessary energy transfers, more of the input energy can be transferred efficiently.

2.3 Types of motor

To select the best motor to employ in the project, a study and comparison on universal motor, AC motor and DC motor was made.

2.3.1 Universal motor

A universal motor is a single-phase series excited motor. It is made to operate on either a single phase of AC power or a DC supply. It often has series wound armatures and field windings, which result in high beginning torque. As a result, universal motors usually come pre-installed in the equipment they were made to drive. According to [1], typically, portable equipment like hand tool machines, hoover cleaners, and most domestic devices are driven by universal motors. This is due to the Universal motor's unique benefits, including its high beginning torque, and variable speed, quite powerful for its small size, and is less expensive.

A universal motor powered by voltage can be represented by the equivalent circuit in Figure 2.1, in which the rotor windings and magnetizing windings located in the stator are connected in series. As a result, the field current and armature current is equal [2].

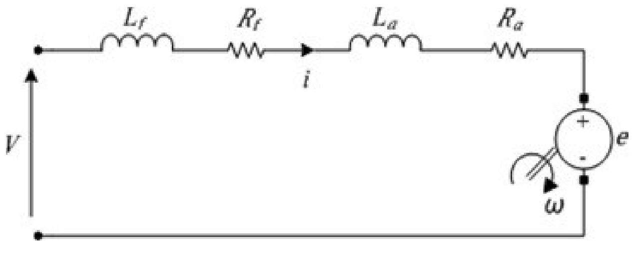

Figure 2.1 Universal motor equivalent circuit [2]

Due to the reactance voltage loss that exists in AC but not in DC, they operate at a slower pace under an AC source than they do under a DC supply of the same voltage. The diagram below shows the construction circuit of a universal motor**. Figure 2.2** shows the construction circuit of a universal motor.

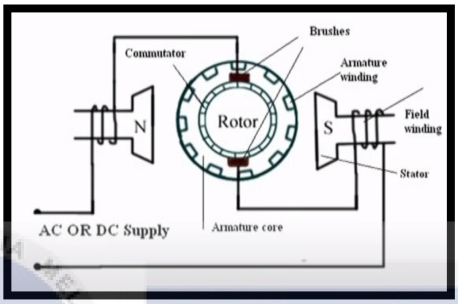

Figure 2.2 The construction circuit of the universal motor [3]

A DC machine's construction is astoundingly comparable to that of a universal motor. Field poles are installed atop a stator, which is what it comprises. On the field poles are woven field coils. However, the entire magnetic route, including the armature and the stator field circuit, is laminated.

The commutator has brushes sitting on it, and the rotary armature is of the wound kind with straight or skewed slots. The brushes that are being used have high resistance to reduce commutation. When we supplied a DC, it will work as a DC series motor where the currents will flow in the winding and produce an electromagnetic field. Then, the current will be fed into the armature conductors. As the current-carrying conductor enters the magnetic field, mechanical forces are produced. This causes the rotor to rotate. The direction of force can be determined by using Fleming's Left-hand rule. **Figure 2.3** shows the illustration of using Fleming's left-hand rule to know the direction of the force.

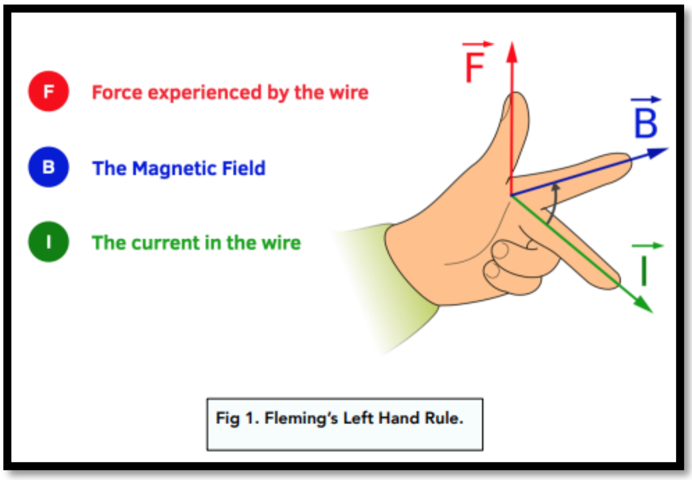

Figure 2.3 Fleming's Left-Hand Rule [4]

On the other hand, when AC power is supplied to the motor, a unidirectional torque is produced. The polarity of the AC power will affect the direction of current in the armature and field windings simultaneously.

2.3.2 General Comparison of Universal Motor with AC Motor and DC Motor

Table 2.1 shows the comparison between universal motor, AC motor, and DC motor in terms of torque, weight, and cost.

Table 2.1 Comparison between Universal Motor, AC Motor, and DC Motor

Type	Universal Motor	AC Motor	DC Motor
Torque	High starting torque	Low starting torque	High starting torque
Weight	Compact and lightweight due to simple construction.	Typically designed with a sturdy build and additional components with more complex rotor	Heavy due to robust construction, large magnets, and additional components

		designs. Hence, it tends to be heavier than a universal motor.	(brushes and commutators).
Costing	Cost-effective, and more affordable compared to other types of motor due to mass production (widely used in consumer appliances)	Simpler built than a DC motor, thus lowering material cost. More cost-effective due to higher demand and large-scale production.	Higher maintenance as brush replacement and commutator cleaning is needed. Hence, adding to the maintenance costs.
Market price (1000-watt power rating)	\$50 – USD 200	\$100 – USD 500	\$200-USD 1000

2.4 Speed control of motor

Speed control in a motor is vital in the making of an electric motor drive as it will define the motor's performance and efficiency. It can be grouped into two different categories which are AC and DC. For AC motor speed, speed control can be achieved by modifying the frequency by using a device called Variable Frequency Drive, also known as VFD. The two types of VFD are 'V/Hz' drive and 'vector' drive but the most commonly used is the first. Controlling the speed of an AC motor can enhance overall motor operation.

VFD can be utilized to decrease the motor's frequency and voltage in case the motor's application does not require it to run at full speed. This will help to meet the motor's load requirement. Apart from meeting the load's requirement, it also leads to reduced energy consumption, and cost and provides longevity. To control the speed of a DC motor, we can vary the supply voltage, the current through field winding, the flux, the armature voltage, and the armature resistance. The rotor speed of a single-phase AC motor is shown in the equations in **Figure 2.4** below :

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

But,

$N_s = {120f}/{p}(2)$

Therefore, equation I becomes

$N_r = \frac{120f}{p}(1 - S)(3)$

Where, N_r = rotor speed

N_s = Synchronous speed

f = Supply frequency

p = Number of poles

S = Slip

Figure 2.4 Equation rotor speed [9]

Hence, the speed of an AC motor depends on the supply frequency, the number of poles, and the slip.

2.4.1 AC Power Control Devices

The best device to employ depend on the particular application needs, motor type, power rating, and required control features. Each of these devices has advantages and limits.

2.4.1.1 Inverter

A device known as an inverter transforms DC electricity into AC power with adjustable frequency and voltage. It quickly turns on and off the DC power, creating a mimicked AC waveform, using electronic switches such as insulated gate bipolar transistors (IGBTs). An inverter may regulate the speed of AC motors by changing the frequency and voltage of the output AC waveform.

In situations where precise speed control is necessary, such as motor drives for industrial and commercial applications, inverters are frequently employed. **Figure 2.5** shows the inverter circuit followed by **Table 2.2** which shows the advantages and disadvantages of inverter motor control.

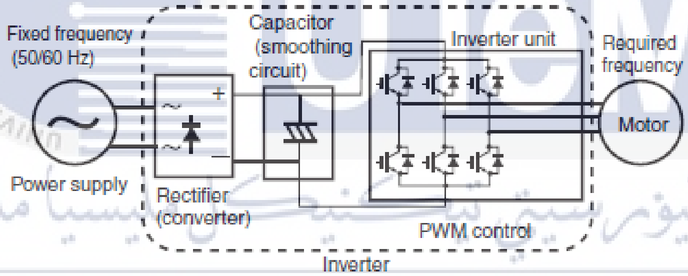

Figure 2.5 Inverter motor control circuit [6]

Table 2.2 Advantages and disadvantages of inverter motor control

Advantages	Disadvantages
• Precise speed control • Wide range of application • Advanced features	• Costing. Relatively expensive. • Complex installation and setup • Harmonic distortion at the power supply

2.4.1.2 TRIAC-based controller

An electrical switch that can regulate the flow of AC is known as a TRIAC (Triode for Alternating Current). The firing angle at which the TRIAC is triggered inside each half-cycle of the AC waveform allows the voltage to be regulated by using TRIAC controllers for phase control of AC power. Simple speed control of AC motors, such as those found in small appliances and light-dimming applications, is frequently accomplished with TRIAC controllers.

However, because of its difficulty in managing high currents, TRIAC control is often only used in low-power applications. **Figure 2.6** shows the TRIAC motor control circuit followed by **Table 2.3** which shows the advantages and disadvantages of TRIAC-based controllers.

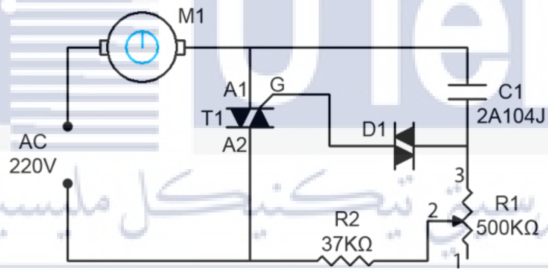

Figure 2.6 TRIAC motor control circuit [14]

Table 2.3 Advantages and disadvantages of TRIAC-based controllers

Advantages	Disadvantages
• Simple control • Compact sized • Generally Affordable	• Cannot handle high currents • Limited motor compatibility

2.4.1.3 Cycloconverter

An electronic device known as a cycloconverter is used to change the frequency of AC power from one frequency to another. It is capable of switching from fixed-frequency AC power to variable-frequency AC electricity. To produce the desired output frequency, cycloconverters split the input AC waveform into smaller chunks and reassembled them.

They are frequently employed in applications including industrial machinery, lifts, and traction systems where accurate speed control of big AC motors is necessary. **Figure 2.7** shows the cycloconverter circuit followed by **Table 2.4** which shows the advantages and disadvantages of cycloconverter.

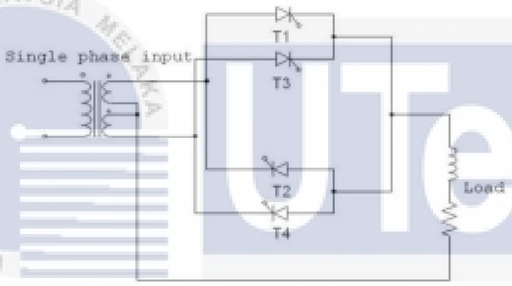

Figure 2.7 Single-phase input cycloconverter circuit [15]

Table 2.4 Advantages and disadvantages of cycloconverter

Advantages	Disadvantages
• Precise frequency control • Applicable for high-power applications	• Complexity • Limited frequency range • Harmonic distortion

2.5 Types of Cycloconverter

A cycloconverter (CCV) synthesizes the output waveform from segments of the AC supply without an intermediate DC link, altering one constant amplitude, constant frequency AC waveform into another AC waveform of a lower frequency. The two primary categories of cyclo converters are single-phase and three-phase. Single-phase cycloconverters are used to change the frequency of single-phase AC, and three-phase cycloconverters are used to change the frequency of three-phase AC.

Cycloconverters are power converters that function to convert single-phase or three-phase AC to vary the magnitude and variable frequency. It is made up of two rectifiers that are back-to-back and linked such that the positive converter (P-type) conducts positive currents and the negative converter (N-type) conducts negative currents. Commonly used components in the manufacture of cycloconverters are TRIAC. TRIAC is a family of power electronic components.

Cycloconverters are frequently used in machinery where variable-speed operation is required, such as in fans, pumps, and conveyors, and are recognized for being capable of running at different speeds. **Figure 2.8** shows the basic principle of a cycloconverter.

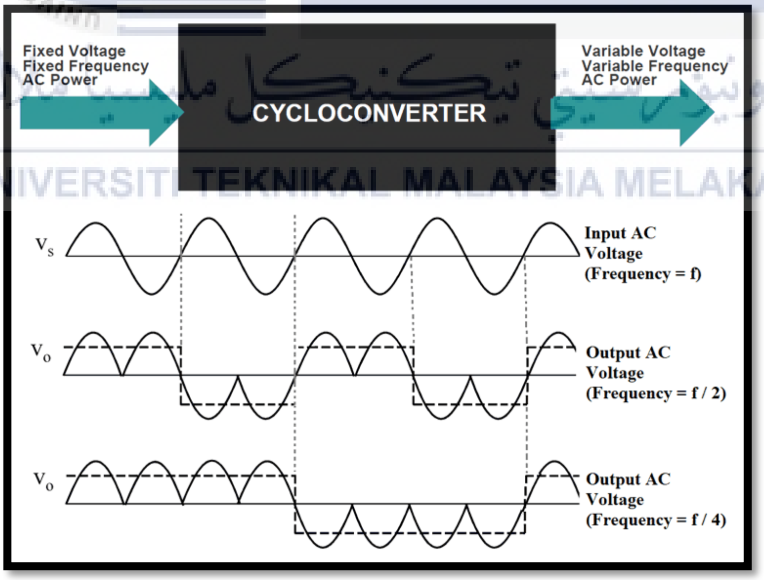

Figure 2.8 Basic principle of cycloconverter [12]

Figure 2.9 shows a cycloconverter circuit for a single-phase AC supply. The circuit is divided into two sides which are the positive bridge and the negative bridge. SCR has frequently been employed in cycloconverters because it makes it simple to alter phases. To regulate the flow of power, the SCRs in the cycloconverter circuit are triggered and commutated in a particular order. The desired output frequency and phase angle are used to generate the triggering signals. At the positive bridge, the cycloconverter will operate between 0 to 180 degrees of the input cycle while at the negative bridge, it will operate between 180 and 360 degrees. To produce the desired output waveform, the SCRs are switched on and off as necessary.

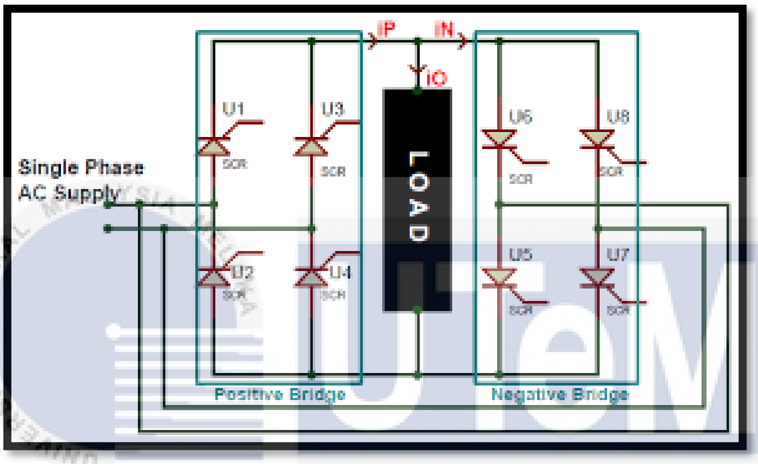

Figure 2.9 Cycloconverter circuit

2.5.1 Step-down cycloconverter

The input of a fixed-frequency power supply is stepped down into a lower frequency via a step-down cyclo-converter. It is comparable to a step-down transformer in that it provides an output frequency that is lower than the input frequency. The output frequency of a step-down cyclo-converter is limited to a subset of the input frequency (below 20Hz in the case of a 50Hz supply frequency). Since SCRs (silicon-controlled rectifiers) are line-commutated devices in this instance, no additional commutation circuits are required.

2.5.2 Step-up cycloconverter

A step-up cycloconverter converts an input AC frequency to an output frequency that is greater than the input frequency. It is a single-phase to single-phase device. It produces an output frequency that is greater than the input frequency. Forced commutation circuits are required in step-up cycloconverters to turn off SCRs (silicon-controlled rectifiers) at the proper frequency. As a result, step-down family cycloconverters make up the majority.

2.6 Comparison of components

2.6.1 Microcontrollers

A microcontroller is a tiny computer on a single integrated circuit (IC) that has programmable input/output peripherals, memory, and a CPU core. It is frequently employed in electrical devices and embedded systems since it is made to carry out certain duties.

	Arduino Uno	PIC 16F877	ESP8266 Wi-Fi Module
Processor core	1	1	1
Memory	RAM 2KB	368 B, Flash 14KB	RAM 160KB, Flash 16MB
Input/output peripherals	14 pins	3 timers, 8 channel ADC, PWM output	1 analog pin, 11 digital pins
Wi-Fi	No	No	Yes

Advantages	• Extensive Library support • General-purpose microcontroller	• Versatile microcontroller • High performance	• Low cost • Small size • Embedded microcontroller
Price	RM28.50	RM26.50	RM19.90

Table 2.5 Comparison between Arduino Uno, PIC 16F877 and ESP8266 Wi-Fi Module microcontrollers

In many different applications, including household appliances, automotive systems, industrial automation, medical equipment, and consumer electronics, microcontrollers are widely employed. Microcontrollers offer a convenient and affordable method of managing and regulating these devices' operations.

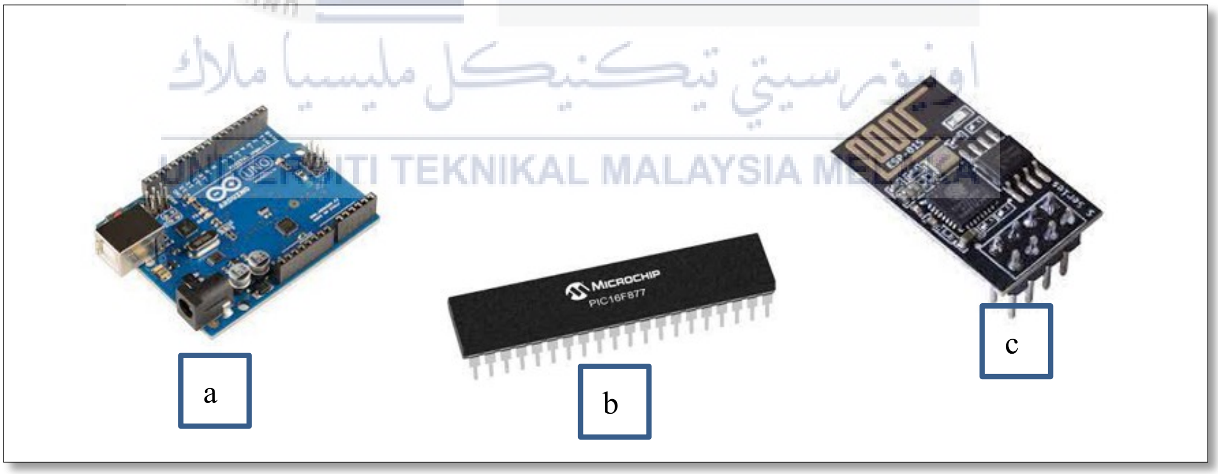

Figure 2.9 (a) Arduino Uno, (b) PIC 16F877, (c) ESP8266 Wi-Fi Module

2.7 Related previous works on speed controller of A/C Universal Motor

Research [9] uses a PIC 16F877 Microcontroller to control the speed of an induction motor and to supply the motor with variable frequency, the Pulse Width Modulation (PWM) technique is being employed for the inverter. By changing the frequency, the speed can vary between 11rps to 25rps. In this work, the output pulses are counted by the microcontroller by using a proximity sensor in an inbuilt PWM generator.

According to [10], the speed of a motor will depend on the supplied frequency and number of poles of the motor. It studies the function of cyclo converters in varying the speed of single-phase induction motors. In this project, three push buttons are connected to the microcontroller to aid the changing of speed. Gating pulses will be sent by the microcontroller via an optocoupler to trigger the thyristors. Apart from the proposed techniques to control the speed of the induction motor such as varying the output voltage and fuzzy logic control, cycloconverters are being used in this project.

Sathish, Jagadeesh, and Mahesh [11] designed and constructed a single-phase induction motor speed control by using a thyristor thyristor-controlled cycloconvertor. Similar to the later work [10], this project also used switches interfaced with the microcontroller to select the speed range in three steps (F, F/2, and F/3).

This [8] final project's purpose is to develop a single-phase cycloconverter with four TRIACs acting as its switching circuit. With a 50 Hz input frequency, the resulting output frequency is 25 Hz, 16.7 Hz, and 12.5 Hz. The power supply serves as the voltage source for the Arduino Uno microcontroller, and the zero-crossing detector serves as a sensor for the junction point where the polarity of the AC signal changes. The Arduino Uno microcontroller chooses the startup order of the four TRIACs in a cycloconverter circuit made up of four of them to produce the desired output frequency.

In this project [12], the speed of an induction motor is controlled in three steps by using an AC-to-AC conversion, cycloconverter, and thyristors. The three steps are F, F/2, and F/3. A step-down Bridge type cyclo-converter has been used in this project. As a result, the authors reached speeds below the induction motor's rated speed. Here, an ESP8266 Wi-

Fi module is utilized to receive instructions from an Android smartphone. Four separate operating modes for the motor each change the frequency in four stages.

2.8 Summary of Literature Review

Table 2.6 Summarization of past projects.

Author	TITLE	STATEMENT/ FUNCTION	REMARKS
C. Oancea, V.C. Petre, V.A. Boicea (2019) [1]	Educational and experimental study for evaluation of a universal motor.	Stated that portable equipment like hand tool machines and most domestic devices are driven by universal motors due to the Universal motor's high beginning torque, and variable speed, quite powerful for their small size, and are less expensive.	
Imran O.A, Abed W.N.A.D,	Speed control of universal motor	A universal motor powered by voltage can be represented by the equivalent circuit as in Figure 2. The rotor	

Jharah A.N (2019) [2]		windings and magnetizing windings located in the stator are connected in series. As a result, the field current and armature current is equal.	
Erlanda; Toni (2018) [7]	Design a Cycloconverter as a 1-Phase Induction Motor Rotation Regulator Based on Arduino R3 Microcontroller	Designing and building a single-phase cycloconverter with four TRIACs as its switching circuit. With an input frequency of 50 Hz, the resulting output frequency is 25 Hz, 16.7 Hz, and 12.5 Hz.	The cyclo converter control unit circuit consists of Arduino Uno as controller, the power supply as a voltage source for the Arduino Uno microcontroller, the zero crossing detector as sensor point of intersection change of polarity of AC signal, and the TRIAC driver as Arduino Uno.
Sanket R. Shyamkul; Devid B.Jambhulkar;	Adjustable Speed Control Of Single Phase Induction	Designed and fabricated the speed control of the induction motor using	Using the Pulse Width Modulation technique combined with microcontroller-based

Prof. Mandar Isasare (2022) [8]	Motor Using Microcontroller	PIC 16F877 Microcontroller.	variable frequency motor speed control (to help solve the issue of a motor's beginning performance)
Ayebatonye Epemu ; Kingsley Enalume (2018) [9]	Speed Control of a Single Phase Induction Motor Using Step-down Cycloconverter	The authors focus on changing the speed of a single-phase induction motor using cycloconverters.	The motor's speed was adjusted in three steps at F, F/2, and F/3 using three push buttons connected to the microcontroller and the program running on it.
Sathish Bakaganari; Jagadeesh Peddapudi; A.Mahesh Kumar (2013) [10]	A Novel Approach to Speed Control of Induction Motor by Cycloconverter with Thyristors	The project uses a cycloconvertor approach with thyristors to adjust the speed of a single-phase induction motor in three steps.	A pair of slide switches are used to choose the appropriate speed range (F, F/2, and F/3) of operation for the induction motor, which is controlled by the 8051 family of microcontrollers. The microcontroller is interfaced with these switches. The microprocessor sends the

			pulses needed to activate the SCRs in a dual bridge based on the status of the switches. As a result, the induction motor's speed can be increased in three stages, namely (F, F/2, and F/3).
M. Krishna; S.Sujeeth; Bh. Sai; TG. Devika (2022) [11]	Android-Based Speed Control Of Induction Motor Using Cycloconverter	The primary goal of this work is to build a model for an Android-based smartphone to control the speed of an induction motor, such as a fan.	Android phone acts as a transmitter. The signal is received by a PIC controller that is connected to a WIFI module receiver. Every time, data is sent via the Android app (Blynk) by the written code, which is then executed by the microcontroller to give the supply signal to the TRIAC through opto isolators. As a result, the speed of the induction motor and the power to a

			load connected in series with a TRIAC are both controlled by the signal that is received. A speed counter is connected to the induction motor's load to show the user the speed. The induction motor is controlled via the Android app Blynk, which also shows the possibilities for adjusting the motor's speed. The authors used a cycloconverter, also known as an AC-to-AC converter, along with thyristors to sequentially control the speed of an induction motor. The three steps in question are F, F/2, and F/3

Anis Ahmad, Muhammad Sohaib Azeem, Imran Siddiq, Touqir Ahmad (2023) [12]	V/F Method to Control the Speed of a Three-Phase Induction Motor Using Micro Compiler	Examined the V/F approach to regulate the speed of the induction motor.	Using rectifier, inverter, and Microcontroller DSPIC30F2010. Controlling the speed of the three-phase induction motor.
Tariqul Islam, Hady H. Fayek, Eugen Rusu, and Fayzur Rahman (2021) [13]	Triac-Based Novel Single Phase Step-Down Cycloconverter with Reduced THDs for Variable Speed Applications	A revolutionary step-down AC to AC converter built on TRIACs has been proposed. • Reduction of overall harmonic distortion, size, and weight of the cycloconverter. • Reduction of difficulties associated with conventional inverter-based AC to AC converters.	
Omar A. Imran, Wisam Najm Al-Din	Speed Control of Universal Motor	This article studies universal motor speed control with variable	

Abed, Ali N. Jbarah (2019) [13]		loading. A universal motor mathematical model is created.	

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will cover the approaches and procedures used in this project, as well as the hardware and software required to complete it, with a focus on the development of a speed controller of the universal motor using a microcontroller-based cycloconverter. To ensure the success of this project, an Arduino Uno microcontroller and appropriate software will be used.

3.2 Methodology

There will undoubtedly be difficulties in the study, such as using specialized methods or approaches, analyzing data, and so forth. The definition of methodology is either a technique of achieving something or a family of logic used to examine reasoning.

A flow chart will be used to display a basic graphical depiction of this project and the project's programming. It displays the processes in a sensible order. The project's development from start to finish is shown in the flow chart.

Research and data gathering phases, as well as an understanding of all programming languages and functional design, are all included in pre-development. Following the pre-development step, the data collection mechanism is integrated into the Arduino coding. In the post-development phase, the simulation results are output into hardware and apps for the final time. **Figure 3.1** shows the flowchart of project planning.

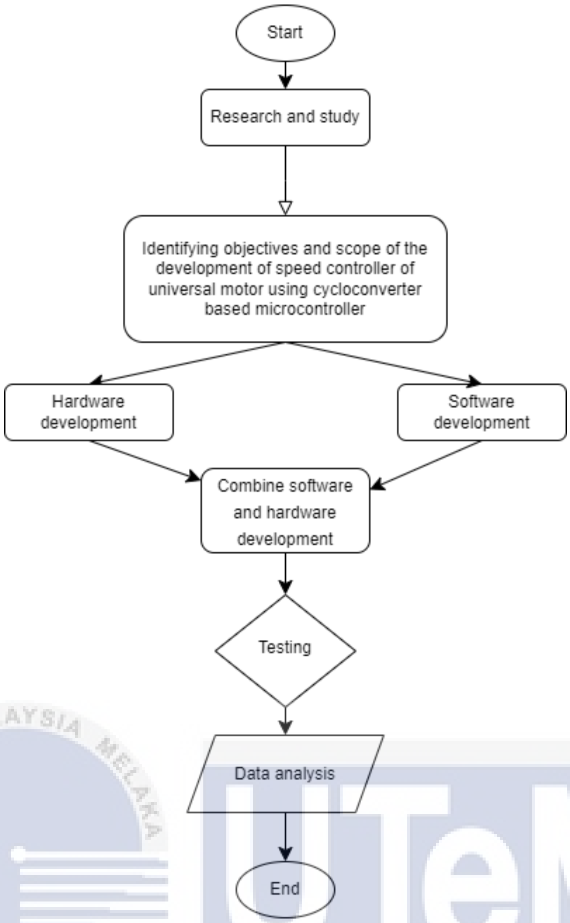

Figure 3.1 Flowchart of project planning

a) Design hardware prototype

This project was developed by using a universal motor, a zero-crossing detector, Arduino Uno, a cyclo converter circuit , rocker switches, and an optoisolator.

b) Performance test

AC power was supplied to the universal motor that is connected to the cycloconverter circuit.

c) Performance analysis

The efficacy of the developed hardware prototype of the universal motor speed control system was analyzed by using oscilloscope and tachometer.

3.3 System architecture

The design of this system is in the form of a control unit that functions to control the speed of the universal motor by changing the input frequency. This system consists of a cycloconverter circuit, zero crossing detector, and power supply used to supply the Arduino uno and zero crossing detector circuit.

The proposed circuit for this project viewed as a field diagram is shown in **Figure 3.2.**

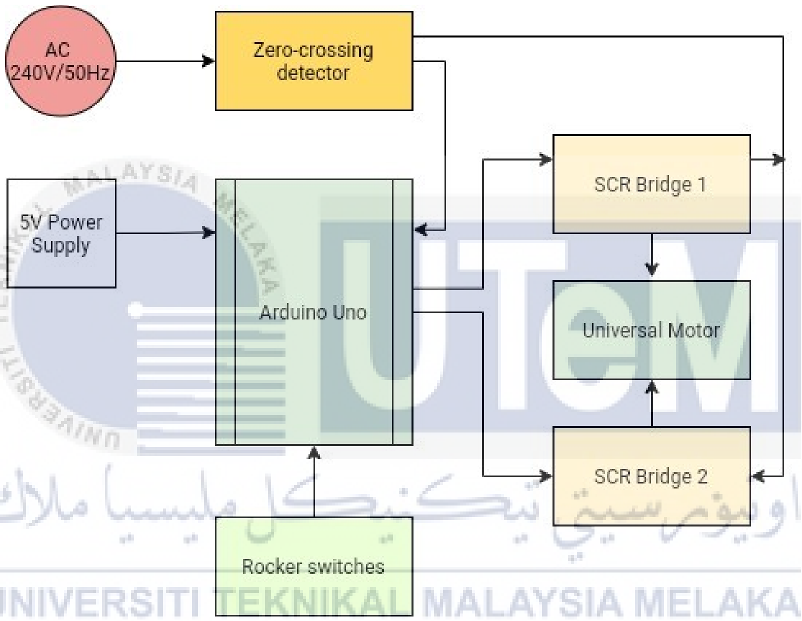

Figure 3.2 The proposed circuit for this project

As illustrated in Figure 3.2, AC (Alternating Current) is directly supplied to the zero-crossing detector. The overall system is powered by Malaysia's standard single-phase supply voltage which is 240VAC 50Hz supply. For the microcontroller to know when the zero point (zero crossing) from the voltage of the AC supply, a zero crossing detection is implied. A zero-crossing detector is used to detect the intersection of AC 240-volt sine waves the moment it passes through the point of zero stress. It will provide a pulse to the Arduino board as soon as the AC waveform crosses zero. Due to this, the firing angle can be measured from zero. The rocker switches connected to the Arduino board will enable the user to select the four-way operations of the motor in terms of speed (F, F/2, F/3, F/4).

The Dual SCR Bridge will be connected to the universal motor to vary the frequency through the Arduino Uno board. The Arduino Uno board will be installed with programming codes from Arduino IDE to control the operation of the cycloconverter circuit. The thyristors in the first bridge operate during the positive half cycle at the AC power supply, while the second SCR bridge will operate at the negative half cycle, as depicted in **Figure 2.8**. The number of positive cycles and negative cycles is controlled by the microcontroller based on the rocker switch set by the user.

The flowchart of programming for the microcontroller is depicted in **Figure 3.3.**

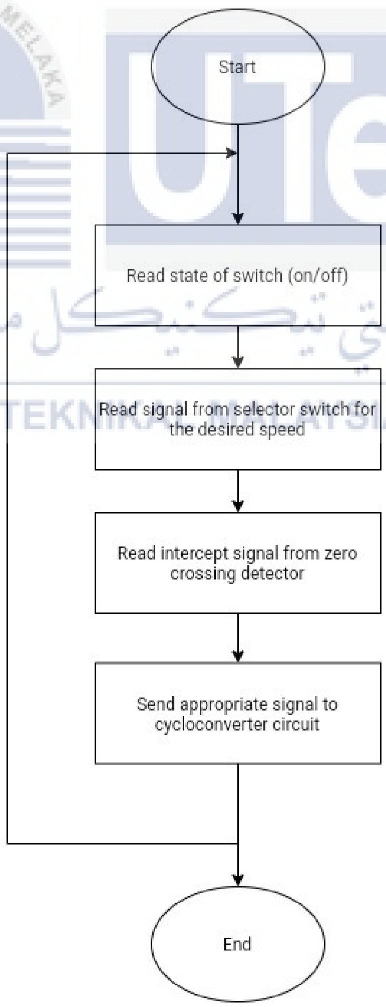

Figure 3.3 The flowchart of programming for the microcontroller

3.4 Hardware components

After planning the system architecture, the next step is to determine the components needed for further processing. The general functionality of each component in the circuit is written in **Table 3.1.**

Table 3.1 List of hardware components

No.	Component/modules	Function
1	Arduino Uno	As a main controller- read signal from zero crossing detector and give an appropriate signal to cycloconverter circuit
2	Cycloconverter circuit (Dual SCR Bridge)	As a driver of the universal motor by controlling the positive and negative deliver to the motor
4	Zero crossing detector	Used to detect the intersection of AC 240-volt sine waves the moment it passes through the point of zero state
5	Rocker switch	To choose frequency variation
6	Light Emitting Diode	As an indication during the switching period
8	Opto isolator	To isolate two circuits, prevent voltage changes.

3.4.1 Arduino Uno Board

An Arduino microcontroller ATmega328P has a 16 MHz ceramic resonator,6 analog inputs, 14 digital input/output pins (6 of them can be used as PWM outputs), a USB port, a power jack, and a reset button. It comes with everything required to support the microcontroller; to get started, just use a USB cable to connect it to a computer, or an AC-to-DC adapter or battery to power the circuit. In this project, an Arduino board is used to determine the firing angle of SCRs and to receive an intercept signal from the zero-crossing detector.

Figure 3.4 Arduino Uno Board

3.4.2 Cycloconverter circuit

Cyloconverter is used to transform AC electricity from one frequency to another. It enables the output frequency to be controlled. Controlled switching components used in this project are thyristors for the cyclo converter's basic functionality. Hence, the SCR bridge is applied.

SCR BT151 is a type of thyristor, which is a semiconductor device used in power electronics. Both require a small gate current to turn them on and are commonly used in various applications such as power control circuits, light dimmers, and other systems that require controllled switching of electrical power.

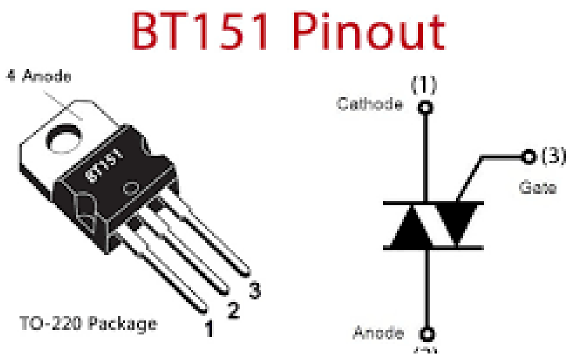

Figure 3.5 BT151 SCR Module

3.4.3 Zero-crossing detector

To be able to accurately determine the delay time to get accurate power regulation, the microcontroller must know when the zero point (zero crossing) from the voltage of the AC supply is. Zero crossing detector is a network used to detect the intersection of AC 240-volt sine waves the moment it pass through the point of zero stress. Thus a frequency equal to twice the frequency of the source sinusoidal wave is obtained.

To manipulate the AC Voltage, the detection of the zero-crossing point is crucial. In Malaysia, the input frequency of the AC signal is 50 Hz, and as it is alternating naturally, the detection will occur when the signal comes across the zero point.

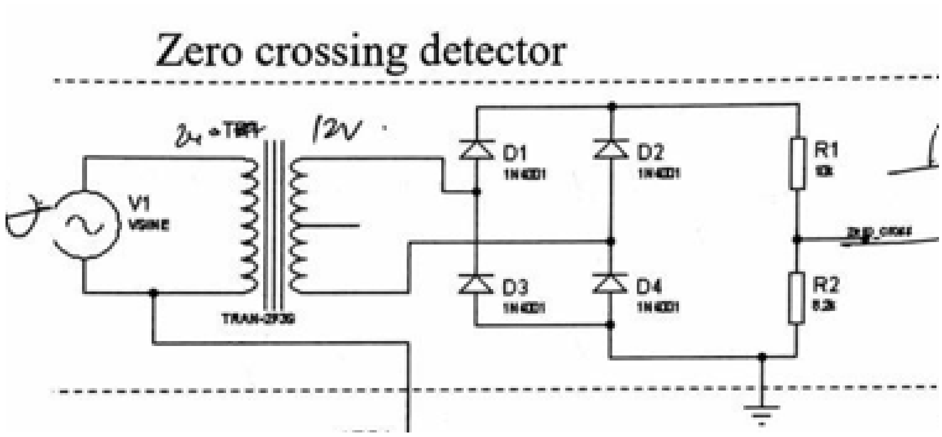

Figure 3.6 Zero crossing detector circuit

3.4.4 Rocker switch

Rocker switches were connected to the Arduino board to choose the frequency variation for the speed control of the universal motor. It allows a person to select a position by pressing it on the '1' condition or the '0' condition. A total of 4 rocker switches are being used on this project to signify each frequency chosen for the output. Every position corresponds to a distinct input or output value that the Arduino microcontroller can read or modify.

Figure 3.7 Rocker switch

3.4.5 Light Emitting Diode (LED)

LED stands for Light Emitting Diode. It is a semiconductor device that emits light when an electric current passes through it. LEDs are widely used in various applications due to their energy efficiency, durability, and versatility.

LEDs have a longer lifespan compared to traditional lighting technologies. They can last tens of thousands of hours, reducing the need for frequent replacements and contributing to lower maintenance costs. They are compact and come in mostly small sizes, making them suitable for applications where space is limited. The small size allows for flexibility in design and placement.

Other than that, LEDs light up instantly making them ideal for applications where quick lighting is essential. As they emit very little heat in comparison to traditional bulbs hence they are suitable for applications where heat generation is a concern, and it contributes to energy efficiency.

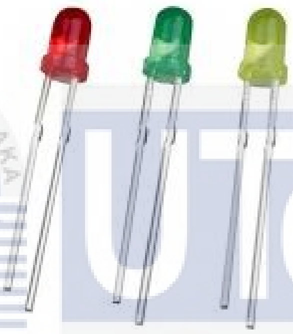

Figure 3.8 LEDs

3.4.6 Opto isolator

An optoisolator's main function is to create electrical isolation between two circuits. Sensitive components are protected by this isolation from noise, voltage spikes, and other electrical disturbances that may occur in one circuit but should not influence the other. The MOC3021 opto isolator as in Figure 3.9 consists of 6-pins which are anode, cathode, NC, two main terminals, and a substrate part.

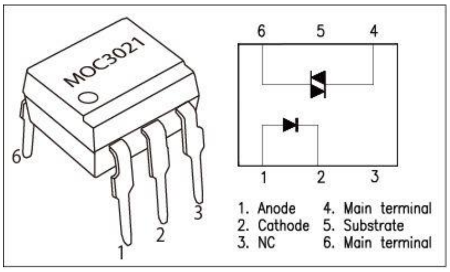

Figure 3.9 Optoisolator MOC3021

3.5 Software Requirements

For software development, some software applications are being used to simulate the project system. Circuits are designed and the functionality is tested in the simulation built into the software system.

3.5.1 Proteus 8 Professional

The circuit of this project will be simulated using Proteus 8 Professional as in Figure 3.11 before being applied to real-time circuits for hardware development. It is employed to simulate microprocessors, record schematics, and create printed circuit boards (PCBs). Two crucial elements are the ARES, the circuit board designer, and ISIS, the circuit design environment.

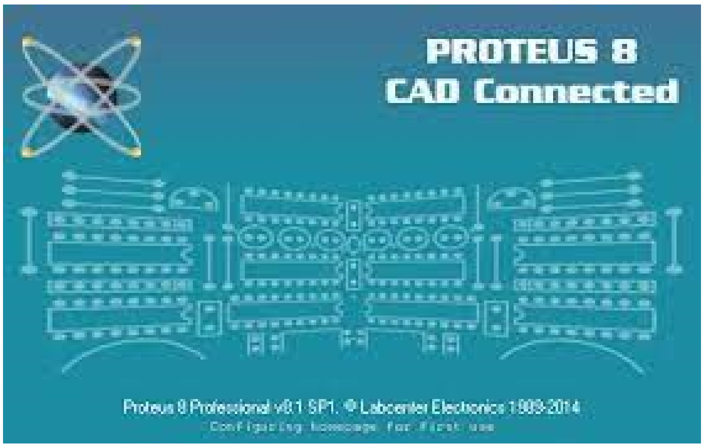

Figure 3.11 Proteus 8 Professional

3.5.2 Arduino IDE

For programming on Arduino boards, a software program called the Arduino IDE (Integrated Development Environment) is being used. The process of creating, building, and uploading code to Arduino microcontrollers is made simpler by the user-friendly interface and a collection of tools provided by this program.

To be short, the Arduino IDE as in Figure 3.12 acts as a user-friendly development environment. It offers key functionality and tools for writing, compiling, and uploading code, making it simpler to create projects and communicate with the Arduino platform.

Figure 3.12 Arduino IDE Logo

3.6 Summary

This chapter outlines the suggested process to start development on the project. If the project is to achieve its final purpose, each of the chapter's suggested changes must be carried out successfully. By describing each step in detail, a flowchart and a block diagram are also utilized to illustrate how the processing system works. The hardware and software used for this project, as well as the justification for its implementation, were covered in more detail in this chapter.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and discussion on the development of a speed controller of the universal motor using a microcontroller-based cycloconverter project. The outcomes of the project were shown.

4.2 Project Prototype

A hardware prototype of this project is constructed as shown in **Figure 4.1** and **Figure 4.2** . For the circuit to be tested, the input voltage of 240VAC is lowered to 12V using a step-down transformer before being supplied to the circuit. A zero-cross circuit is built and connected to the transformer to detect the zero-cross point and the output is connected to digital pin 3 Arduino.

To test, probes are connected to the output of the circuit to observe the output signals on the oscilloscope. The microcontroller being used is the Arduino Uno and it is being supplied with an independent power source, which in this case, a power bank is employed.

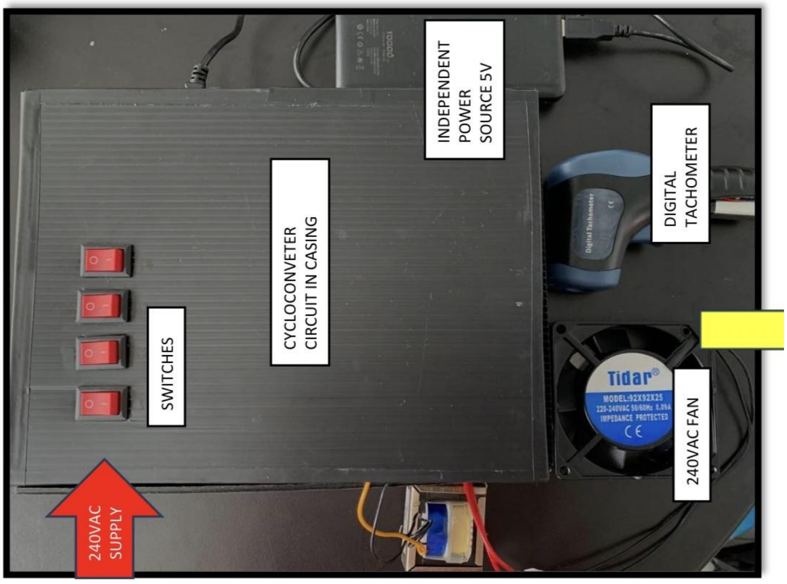

Figure 4.1 Casing interface of the project prototype

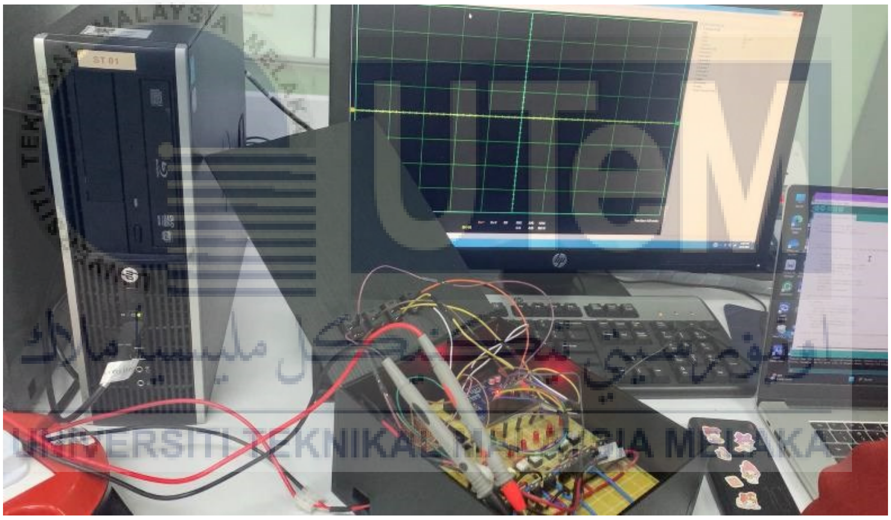

Figure 4.2 Project is being tested in the laboratory

Four rocker switches are installed on the cover of the constructed black box as in **Figure 4.1** to allow easier user access. These switches are connected to digital pins number 10 to 13 of the Arduino UNO microcontroller. Each switch signals the Arduino to implement different switching techniques for the SCRs that specify the desired output frequency. Switch 1 is connected to pin 10 for 50 Hz. Switch 2 is connected to pin 11 for

25 Hz. Switch 3 is connected to pin 12 for 16.67 Hz and Switch 4 is connected to pin 13 for 12.5 Hz.

To prevent feedback, as shown in **Figure 4.3**, digital isolators MOC3021 are connected between the Arduino and the SCR bridges as in **Figure 4.2**. A resistor and LED are wired in series for each of the isolators as an indication SCR is on during switching periods. The main terminals of the isolator pin are connected in series to prevent feedback.

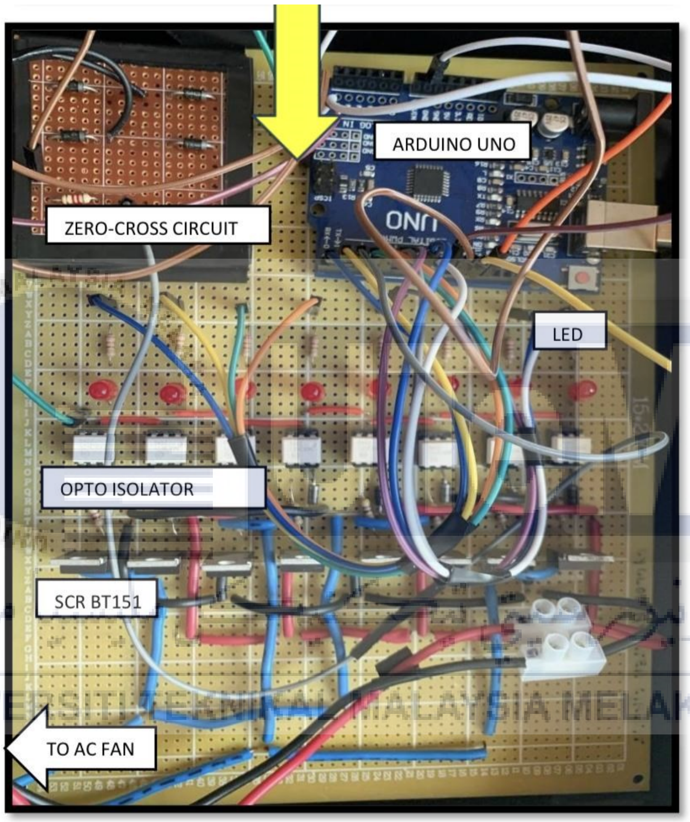

Figure 4.3 Project prototype – The circuit

4.3 Project Design

Four rocker switches are being used to represent the four conditions of the frequencies. There are four conditions desired to be achieved in this project: 50Hz, 25Hz, 16.66Hz, and 25Hz. These conditions correspond to f, $f/2$, $f/3$, and $f/4$ respectively where

f is the Malaysian standard input frequency of 50Hz. In terms of programming, zero-cross is being used to count the zero-cross points.

The goal is for each group of the SCRs to turn on at specific time values to replicate an AC waveform. For the project, two bridges of SCR are applied which are the negative bridge (consists of 4 SCRs) and the positive bridge (consists of another 4 SCRs). Each SCR will be indirectly connected to respective Arduino digital pins. These two bridges must not turn on at the same time, hence a short delay needs to be applied between the switching of the two bridges.

By calibrating the time delays by using the oscilloscope and Arduino coding, the specific time delays for each selected frequency are obtained. The bridge configuration of the SCR can be seen in **Figure 4.4.**

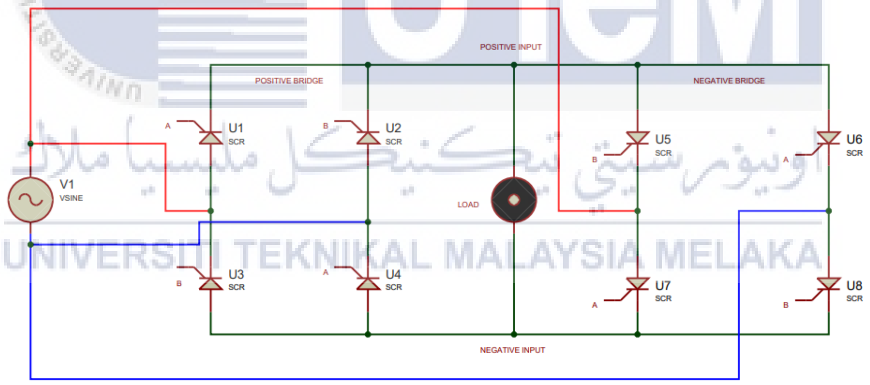

Figure 4.4 SCR Bridge configuration

Table 4.1 shows each switch corresponds to the selected frequency and the time delays applied to the SCR for the switching action.

Table 4.1 The desired frequency correspoding to time delay of SCR bridges switching

Switch	Frequency of output voltage (Hz)	Time Delays for SCR Bridges Switching (ms)
1	50	9
2	25	19
3	16.67	29
4	12.5	39

Figure 4.5 Rocker switches installed on the top of the box, denoted as S1, S2, S3, and S4

4.4 Experimental Results

To verify the efficacy of the prototype, it is being tested in the Power Electronics And Drives Laboratory with the supervision of the supervisor. A 240-watt AC fan is used as a testbed for the developed device. **Figure 4.6** to **Figure 4.9** shows the output waveform of the developed device when connected to the fan.

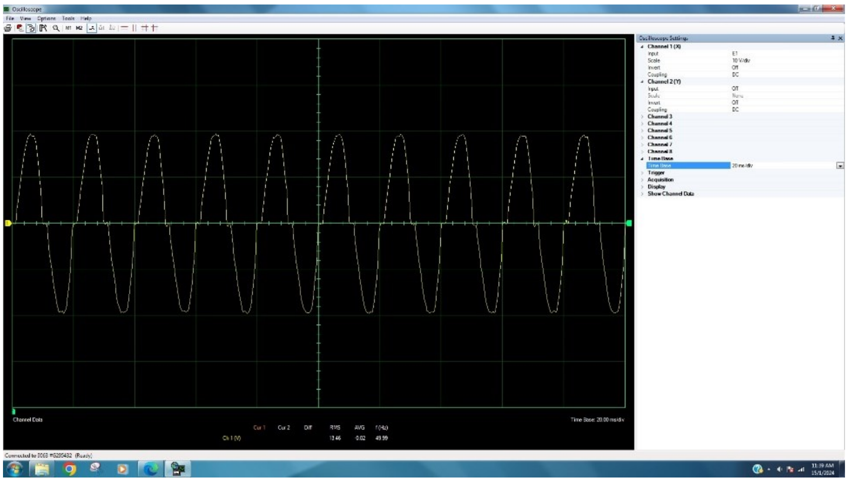

Figure 4.6 The waveform of output voltage when switch S1 is activated (output voltage frequency is equal to supply frequency f = 50 Hz)

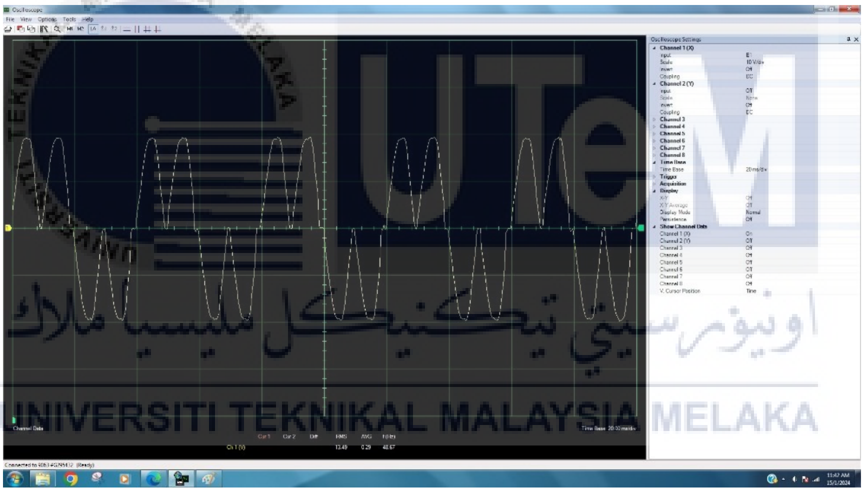

Figure 4.7 The waveform of output voltage when switch S2 is activated (output voltage frequency is set to f/2 = 25 Hz)

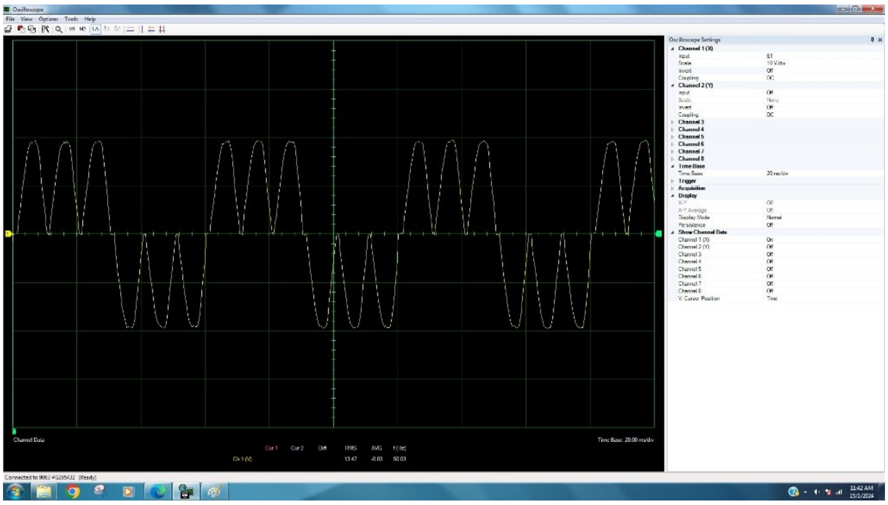

Figure 4.8 The waveform of output voltage when switch S3 is activated (output voltage frequency is set to f/3 = 16.7 Hz)

Figure 4.9 The waveform of output voltage when switch S4 is activated (output voltage frequency is set to f/4 = 12.5 Hz)

Table 4.2 shows the speed of the fan corresponding to the frequency that is generated by the cycoloconverter circuit based on the switches.

Table 4.2 The speed of the fan in RPM based on the switches

Switch setting	Frequency (Hz)	Reference figure of the output voltage waveform	Fan Speed
f (S1)	50	Figure 4.5	Highest speed
$f/2$ (S2)	25	Figure 4.6	High speed
$f/3$ (S3)	16.67	Figure 4.7	Medium Speed
$f/4$ (S4)	12.5	Figure 4.8	Low speed

Switch	Frequency	Data 1 (RPM)	Data 2 (RPM)	Data 3 (RPM)	Avg. RPM
S1	50Hz	694.6	669.3	697.6	687.17
S2	25Hz	536.1	551.5	548.4	545.33
S3	16.67Hz	295.8	305.6	305.3	302.23
S4	12.5Hz	173.1	179.8	177.8	176.90

From the results above, it can be seen that the developed device can control the speed of the fan. It is proven in **Figures 4.6** to **Figure 4.8** that the output waveform matched the theoretical expectation. The cycloconverter can decrease the frequency of the output voltage of the device, subsequently decreasing the speed of the motor.

The universal motor is not being applied to the circuit after many considerations and discussions with the supervisor. This is due to unexpected explosions that occurred during the testing and a few trials that led to the same consequences. Safety, budget, and the high current of the universal motor were also taken into consideration.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This report presents a method for speed control of a motor based on the cycloconverter operation, researching past studies that correlate to the project and developed a hardware prototype of the project.

To ensure safety and further damage, the thyristors are being tested first before being soldered to the board. The zero-cross circuit is built to detect the zero-cross point of the sine wave. Voltage is supplied to the SCR gate for gate triggering. Arduino Uno is programmed with specific coding to implement the conditions of the selected switch to manipulate the frequency. To prevent feedback, MOC3021 and diodes are used between the Arduino and SCR. Two SCR bridges will turn on and off controlled by the Arduino. 8 LEDs are soldered to the board to indicate the switching activation of the SCRs.

The cycloconverter circuit is being tested to AC Fan with output waveforms of 50Hz, 25Hz, 16.67Hz, and 12.5Hz. From the experimental results, it is found that the developed device can change the voltage and control the speed of the fan.

5.2 Future Works

For further improvement on this project, there are a few recommendations that can be applied to obtain better performance of The Speed Controller of the Universal Motor Using Microcontroller-based Cycloconverter.

To reduce harmonics and improve power quality in cycloconverter systems, techniques need to be developed by using passive and active filters and modulation techniques. Other than that, renewable energy systems such as solar power can be applied to the circuit for sustainability.

A user-friendly interface can be developed to monitor and control the speed of the motor. For example, the usage of Liquid Crystal Display (LCD). Wireless communication capabilities can also be implanted to enhance the versatility and accessibility of the system. The device also should be equipped with a short-circuit protection circuit. During the operation of the cycloconverter, there is a probability both SCR bridges are activated at the same time which subsequently causes short circuit in the device. A short circuit can cause fire hazard or circuit breaker tripping thus can interrupt the operation of other equipment.

5.3 Potential of commercialization

If the developed device is improved in accordance with the suggestion delineated in Section 5.2, it will possess a marketable worth and serve as an economical way to control the speed of an AC motor with less effect of EMI and harmonic problem.

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APPENDICES

Appendix A Arduino coding

Arduino Coding :

```
#define ZCD 3
const int scrbridge2[] = {1, 2, 4, 5};//negative bridge
const int scrbridge1[] = {6, 7, 8, 9};//positive bridge
const int switchPins[] = {10, 11, 12, 13}; // Pins for the switches
int counter = 0; // Counter variable

void setup() {
  pinMode (ZCD, INPUT_PULLUP);
  //Serial.begin(9600);
  //attachInterrupt(digitalPinToInterrupt(ZCD),zerocross, RISING);
  // Set SCR bridge pins as output
  for (int i = 0; i < 4; i++) {
    pinMode(scrbridge2[i], OUTPUT);
    pinMode(scrbridge1[i], OUTPUT);
  }

  // Set button pins as input
  for (int i = 0; i < 4; i++) {
    pinMode(switchPins[i], INPUT_PULLUP);
  }
}

void loop()
{
  if (digitalRead(3) == LOW && digitalRead(switchPins[0]) == LOW &&
digitalRead(switchPins[1]) == HIGH && digitalRead(switchPins[2]) == HIGH &&
digitalRead(switchPins[3]) == HIGH)
    {
      for (int i = 0; i < 4; i++) {
        //delay(1);
        digitalWrite(scrbridge1[i], HIGH);
        digitalWrite(scrbridge2[i], LOW); }
        delay(9);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], LOW); }
        delay(1);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], HIGH); }
```

```
        delay(9);

        }

   else if (digitalRead(3) == LOW && digitalRead(switchPins[0]) == HIGH &&
digitalRead(switchPins[1]) == LOW && digitalRead(switchPins[2]) == HIGH &&
digitalRead(switchPins[3]) == HIGH)
   {
      for (int i = 0; i < 4; i++) {
        //delay(1);
        digitalWrite(scrbridge1[i], HIGH);
        digitalWrite(scrbridge2[i], LOW); }
        delay(19);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], LOW); }
        delay(1);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], HIGH); }
        delay(19);

        }

   else if (digitalRead(3) == LOW && digitalRead(switchPins[0]) == HIGH &&
digitalRead(switchPins[1]) == HIGH && digitalRead(switchPins[2]) == LOW &&
digitalRead(switchPins[3]) == HIGH)
   {
      for (int i = 0; i < 4; i++) {
        //delay(1);
        digitalWrite(scrbridge1[i], HIGH);
        digitalWrite(scrbridge2[i], LOW); }
        delay(29);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], LOW); }
        delay(1.5);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], HIGH); }
        delay(29);

        }


   else if (digitalRead(3) == LOW && digitalRead(switchPins[0]) == HIGH &&
digitalRead(switchPins[1]) == HIGH && digitalRead(switchPins[2]) == HIGH &&
digitalRead(switchPins[3]) == LOW)
   {
```

```
      for (int i = 0; i < 4; i++) {
        //delay(1);
        digitalWrite(scrbridge1[i], HIGH);
        digitalWrite(scrbridge2[i], LOW); }
        delay(39);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], LOW); }
        delay(1);
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], HIGH); }
        delay(39);

        }

    else {
          for (int i = 0; i < 4; i++) {
        digitalWrite(scrbridge1[i], LOW);
        digitalWrite(scrbridge2[i], LOW); }


       }

   }

//void zerocross()
//{
// ++counter;
//
//  // Serial.println(counter);
//}
```

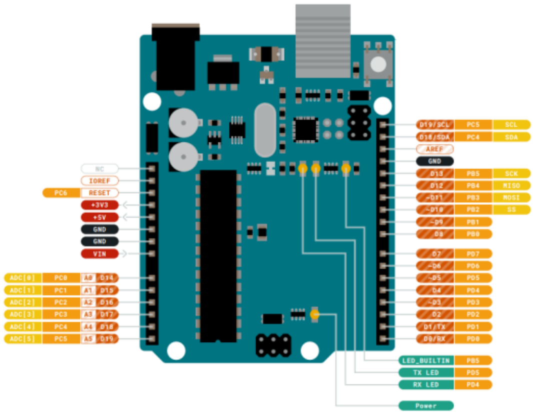
Appendix B Datasheet Arduino UNO

Arduino® UNO R3

Features

- **ATMega328P** Processor
  - **Memory**
    - AVR CPU at up to 16 MHz
    - 32KB Flash
    - 2KB SRAM
    - 1KB EEPROM
  - **Security**
    - Power On Reset (POR)
    - Brown Out Detection (BOD)
  - **Peripherals**
    - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
    - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
    - 1x USART with fractional baud rate generator and start-of-frame detection
    - 1x controller/peripheral Serial Peripheral Interface (SPI)
    - 1x Dual mode controller/peripheral I2C
    - 1x Analog Comparator (AC) with a scalable reference input
    - Watchdog Timer with separate on-chip oscillator
    - Six PWM channels
    - Interrupt and wake-up on pin change
  - **ATMega16U2 Processor**
    - 8-bit AVR® RISC-based microcontroller
  - **Memory**
    - 16 KB ISP Flash
    - 512B EEPROM
    - 512B SRAM
    - debugWIRE interface for on-chip debugging and programming
  - **Power**
    - 2.7-5.5 volts

5 Connector Pinouts



Pinout

5.1 JANALOG

Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

Appendix C Datasheet BT151

Thyristors BT151 series

GENERAL DESCRIPTION

Glass passivated thyristors in a plastic envelope, intended for use in applications requiring high bidirectional blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching.

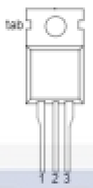
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	MAX.	MAX.	UNIT
	BT151-	500R	650R	800R	
V_{DRM}, V_{RRM}	Repetitive peak off-state voltages	500	650	800	V
$I_{T(AV)}$	Average on-state current	7.5	7.5	7.5	A
$I_{T(RMS)}$	RMS on-state current	12	12	12	A
I_{TSM}	Non-repetitive peak on-state current	100	100	100	A

PINNING - TO220AB

PIN	DESCRIPTION
1	cathode
2	anode
3	gate
tab	anode

PIN CONFIGURATION



SYMBOL

LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.			UNIT
				-500R	-650R	-800R	
V_{DRM}, V_{RRM}	Repetitive peak off-state voltages		-	500[1]	650[1]	800	V
$I_{T(AV)}$	Average on-state current	half sine wave; $T_{mb} \leq 109$ ˚C	-	7.5			A
$I_{T(RMS)}$	RMS on-state current	all conduction angles	-	12			A
I_{TSM}	Non-repetitive peak on-state current	half sine wave; $T_j = 25$ ˚C prior to surge					
		t = 10 ms	-	100			A
		t = 8.3 ms	-	110			A
I^2t	I^2t for fusing	t = 10 ms	-	50			A^2s
dI_T/dt	Repetitive rate of rise of on-state current after triggering	I_{TM} = 20 A; I_G = 50 mA; dI_G/dt = 50 mA/μs	-	50			A/μs
I_{GM}	Peak gate current		-	2			A
V_{GM}	Peak gate voltage		-	5			V
V_{RGM}	Peak reverse gate voltage		-	5			V
P_{GM}	Peak gate power		-	5			W
$P_{G(AV)}$	Average gate power	over any 20 ms period	-	0.5			W
T_{stg}	Storage temperature		-40	150			˚C
T_j	Operating junction temperature		-	125			˚C

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$R_{th\ j\text{-}mb}$	Thermal resistance junction to mounting base		-	-	1.3	K/W
$R_{th\ j\text{-}a}$	Thermal resistance junction to ambient	in free air	-	60	-	K/W

STATIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{GT}	Gate trigger current	V_D = 12 V; I_T = 0.1 A	-	2	15	mA
I_L	Latching current	V_D = 12 V; I_{GT} = 0.1 A	-	10	40	mA
I_H	Holding current	V_D = 12 V; I_{GT} = 0.1 A	-	7	20	mA
V_T	On-state voltage	I_T = 23 A	-	1.4	1.75	V
V_{GT}	Gate trigger voltage	V_D = 12 V; I_T = 0.1 A	-	0.6	1.5	V
		$V_D = V_{DRM(max)}$; I_T = 0.1 A; T_j = 125 ˚C	0.25	0.4	-	V
I_D, I_R	Off-state leakage current	$V_D = V_{DRM(max)}$; $V_R = V_{RRM(max)}$; T_j = 125 ˚C	-	0.1	0.5	mA

DYNAMIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
dV_D/dt	Critical rate of rise of off-state voltage	V_{DM} = 67% $V_{DRM(max)}$; T_j = 125 ˚C; exponential waveform;				
		Gate open circuit	50	130	-	V/∝s
		R_{GK} = 100 Ω	200	1000	-	V/∝s
t_{gt}	Gate controlled turn-on time	I_{TM} = 40 A; $V_D = V_{DRM(max)}$; I_G = 0.1 A; dI_G/dt = 5 A/∝s	-	2	-	∝s
t_q	Circuit commutated turn-off time	V_D = 67% $V_{DRM(max)}$; T_j = 125 ˚C; I_{TM} = 20 A; V_R = 25 V; dI_{TM}/dt = 30 A/∝s; dV_D/dt = 50 V/∝s; R_{GK} = 100 Ω	-	70	-	∝s

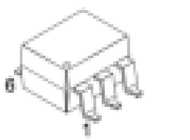
Appendix D Datasheet MOC3021

MOC3010M, MOC3011M, MOC3012M, MOC3020M, MOC3021M, MOC3022M, MOC3023M

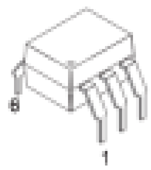
6-Pin DIP Random-Phase Triac Driver Output Optocoupler (250/400 V Peak)

ON Semiconductor®

www.onsemi.com



PDIP6 8.51x6.35, 2.54P
CASE 646BY



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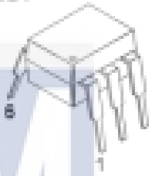
CASE 646BZ



PDIP6 8.51x6.35, 2.54P
CASE 646BX

Description

The MOC301XM and MOC302XM series are optically isolated triac driver devices. These devices contain a GaAs infrared emitting diode and a light activated silicon bilateral switch, which functions like a triac. They are designed for interfacing between electronic controls and power triacs to control resistive and inductive loads for 115 V_{AC} operations.

Features

- Excellent I_{FT} Stability – IR Emitting Diode Has Low Degradation
- Peak Blocking Voltage
  - 250 V, MOC301XM
  - 400 V, MOC302XM
- Safety and Regulatory Approvals
  - UL1577, 4,170 VAC_{RMS} for 1 Minute
  - DIN EN/IEC60747–5–5
- These are Pb–Free Devices

Applications

- Industrial Controls
- Solenoid/Valve Controls
- Traffic Lights
- Static AC Power Switch
- Vending Machines
- Incandescent Lamp Dimmers
- Solid State Relay
- Motor Control
- Lamp Ballasts

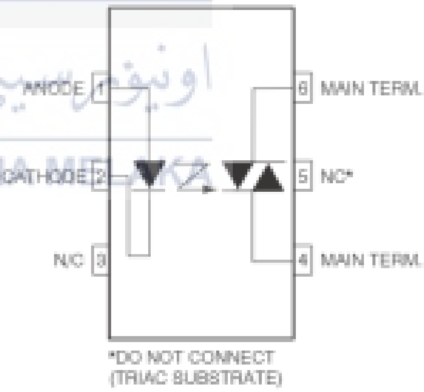


Figure 1. Schematic

ORDERING INFORMATION

See detailed ordering and shipping information on page 8 of this data sheet.