DESIGN OF PULSE WIDTH MODULATOR USING NE-555

A Report

Submitted By

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ABSTRACT

In Power Electronics, Pulse-Width Modulation (PWM) is the core for control and has proven effective in driving modern semiconductor power devices. Majority of power electronic circuits are controlled by PWM signals of various forms. Pulse Width Modulation is effective and commonly used as control technique to generate analog signals from a digital device like a micro controller. This report will discuss Pulse Width Modulation, various types of modulation techniques, signal generation, its applications, advantages and disadvantages.

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ABBREVIATIONS

IC	Integrated Circuits
LED	Light Emitting Diode
MCU	Micro-controller Unit
MPPT	Maximum Power Point Tracking
PDM	Pulse Duration Modulation
PWM	Pulse Width Modulation
SPWM	Single Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. Along with maximum power point tracking (MPPT), it is one of the primary methods of reducing the output of solar panels to that which can be utilized by a battery. PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.

The rate (or frequency) at which the power supply must switch can vary greatly depending on load and application. For example, switching has to be done several times a minute in an electric stove; 120 Hz in a lamp dimmer; between a few kilohertz (kHz) and tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

In electronics, many modern microcontrollers (MCUs) integrate PWM controllers exposed to external pins as peripheral devices under firmware control by means of internal programming interfaces. These are commonly used for direct current (DC) motor control in robotics and other applications.

Some machines (such as a sewing machine motor) require partial or variable power. In the past, control (such as in a sewing machine's foot pedal) was implemented by use of a rheostat connected in series with the motor to adjust the amount of current flowing through the motor. It was an inefficient scheme, as this also wasted power as heat in the resistor element of the rheostat, but tolerable because the total power was low. While the rheostat was one of several methods of controlling power (see autotransformers and Variac for more info), a low cost and efficient power switching/adjustment method was yet to be found. This mechanism also needed to be able to drive motors for fans, pumps and robotic servos, and needed to be compact enough to interface with lamp dimmers. PWM emerged as a solution for this complex problem.

One early application of PWM was in the Sinclair X10, a 10 W audio amplifier available in kit form in the 1960s. At around the same time PWM started to be used in AC motor control.

Of note, for about a century, some variable-speed electric motors have had decent efficiency, but they were somewhat more complex than constant-speed motors, and sometimes required bulky external electrical apparatus, such as a bank of variable power resistors or rotating converters such as the Ward Leonard drive.

1.2 REVIEW OF THE LITERATURE

Various studies and research has been carried out over PWM design, and PWM techniques. Some of the research works which inspired this project are mentioned below.

"A review on different PWM techniques for five leg voltage source inverter," by A. Dixit, N. Mishra, S. K. Sinha and P. Singh. Presently, many industrial processes require high performance switching control of a number of inverter-fed induction machines. Multi-motor drives employ various methods to reduce complexity and minimize the cost. Independent control of motors is required as these motors are subjected to frequently changing operating conditions. Recent researches have ascertained the independent control of parallel connected dual induction motor drive system fed through a five leg voltage source inverter (FLVSI). Implementation of suitable Pulse Width Modulation (PWM) technique to the inverter fed system is of paramount importance. This paper reviews the execution method of recently proposed PWM schemes for independent control of dual induction motor drive system employing a Five Leg Inverter (FLI).

"A novel multiple modes PWM controller for LEDs," by J. Lu and X. Wu, A monolithic controller for pulse width modulation (PWM) DC-DC converter was presented in this paper. The controller was designed specially for LED (light emitting diode) driver circuit with four operation modes, current feedback mode, constant current mode, no sense resistor mode and PWM dimming mode. The controller can be adapted to almost all current DC-DC topologies such like Boost, Buck-Boost and etc.. It also features the different load current sense methods for different topologies. For LED lighting, both the digital and analog dimming modules were integrated onto the chip, which were used to meet the demands of two kinds of dimming applications respectively. The controller integrated circuit (IC) was designed, simulated and fabricated in 1.5 mum BCD process. And both the simulation and test results were consistent with expectations well.

1.3 MOTIVATION FOR THE PROJECT

In Power Electronics, Pulse-Width Modulation (PWM) is the core for control and has proven effective in driving modern semiconductor power devices. Majority of power electronic circuits are controlled by PWM signals of various forms. Pulse Width Modulation is effective and commonly used as control technique to generate analog signals from a digital device like a micro controller. It is used to control DC motors, transformers, and many more electrical and electronic machines.

This project’s focus is to design an effective and economic pulse width modulator, which would cost less than Rs. 50/-.

CHAPTER 2

PWM PRINCIPLES

2.1 PWM TECHNIQUES

In many industrial applications, the control of the output voltage of inverters is often necessary (1) to cope with the variations of dc input voltage, (2) to regulate voltage of inverters, and (3) to satisfy the constant volts and frequency control requirement. There are various techniques to vary the inverter gain. The most efficient method of controlling the gain (and output voltage) is to incorporate PWM control within the inverters. The commonly used techniques are:

1. Single-pulse-width modulation
2. Multiple-pulse-width modulation
3. Sinusoidal pulse-width modulation
4. Modified sinusoidal pulse-width modulation
5. Phase-displacement control

Among all these techniques, the sinusoidal pulse-width modulation (SPWM) is commonly used for a voltage control. However, the multiple-pulse-width modulation provides a foundation for better understanding of the PWM modulation techniques. The modified SPWM gives limited ac output voltage control. The phase-displacement control is normally used for high-voltage applications, especially phase displacement by transformer connections.

2.2 DUTY CYCLE

The term *duty cycle* describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. When a digital signal is on half of the time and off the other half of the time, the digital signal has a duty cycle of 50% and resembles a "square" wave. When a digital signal spends more time in the on state than the off state, it has a duty cycle of >50%. When a digital signal spends more time in the off state than the on state, it has a duty cycle of <50%. Here is a pictorial that illustrates these three scenarios:

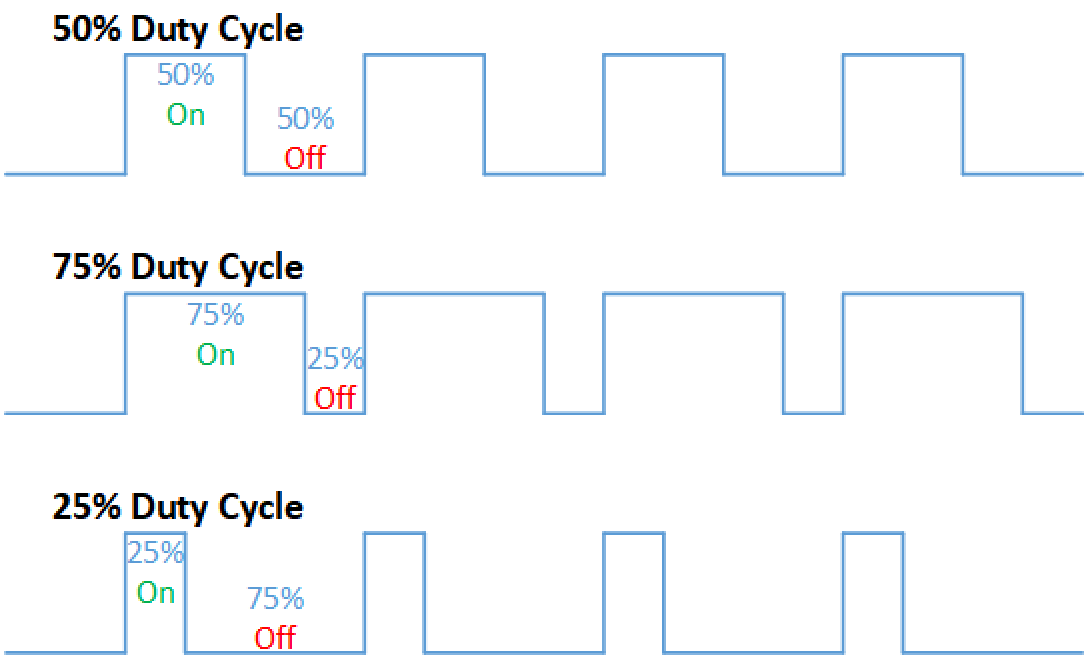

Fig. 2.1 50%, 75%, 25% Duty cycle

2.3 FREQUENCY OF PWM

The frequency of a PWM signal determines how fast a PWM completes one period. One Period is complete ON and OFF of a PWM signal as shown in the above figure. In our tutorial we will set a frequency of 5KHz.

We can notice if LED being OFF for half second and LED being ON for other half second. But if Frequency of ON and OFF times increased from ‘1 per second’ to ’50 per second’. The human eye cannot capture this frequency. For a normal eye the LED will be seen, as glowing with half of the brightness. So with further reduction of ON time the LED appears much lighter.

2.4 OPERATION OF PULSE WIDTH MODULATOR

Pulse Width Modulation (PWM) is a digital signal which is most commonly used in control circuitry. This signal is set high (5v) and low (0v) in a predefined time and speed. The time during which the signal stays high is called the “on time” and the time during which the signal stays low is called the “off-time”. There are two important parameters for a PWM as discussed. The percentage of time in which the PWM signal remains HIGH (on time) is called a duty cycle. If the signal is always ON it is in 100% duty cycle and if it is always of it is 0% duty cycle. Duty Cycle =Turn ON time/ (Turn ON time + Turn OFF time) The frequency of a PWM signal determines how fast a PWM completes one period. One Period is complete ON and OFF of a PWM signal as shown in the above figure. In our tutorial, we will set a frequency of 5KHz. We can notice if LED being OFF for half second and LED being ON for another half-second. But if Frequency of ON and OFF times increased from ‘1 per second’ to ’50 per second’. The human eye cannot capture this frequency. For a normal eye, the LED will be seen, as glowing with half of the brightness. So with the further reduction of ON time, the LED appears much lighter.

CHAPTER 3

COMPONENTS AND APPARATUS DESCRIPTION

3.1 POWER SUPPLY

The Power Supply is a Primary requirement for the project work. The required DC power supply is 0-30 volt & 0-5 volt can be available from the DC Power supply else can be rectify by means of rectifier circuit through diode or thyristors.

Components	Ratings	Quantity	Use
Resistors	1K	3	It decides charging and discharging time of a capacitor and hence can change the frequency by changing the capacitor
	30K	2	Voltage Divider
	3.9k	1	RC Filter
Capacitors	100uf	1	RC Filter
	30u	1	
Voltmeter	0-500V(DC)	1	To measure output voltage
Ammeter	0-5A(DC)	2	To measure current
CRO		1	To check the output waveform
Function Generator		1	To generate sine and pulse wave
Power Supply	0-30V(DC)	1	To provide Vcc supply
NE-555		1	To generate PWM signal
Potentiometer	50K(50%)	3	To vary duty cycle

Table 3.1 Circuit components

3.2 TIMER IC: NE-555

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element. Derivatives provide up to four timing circuits in one package.

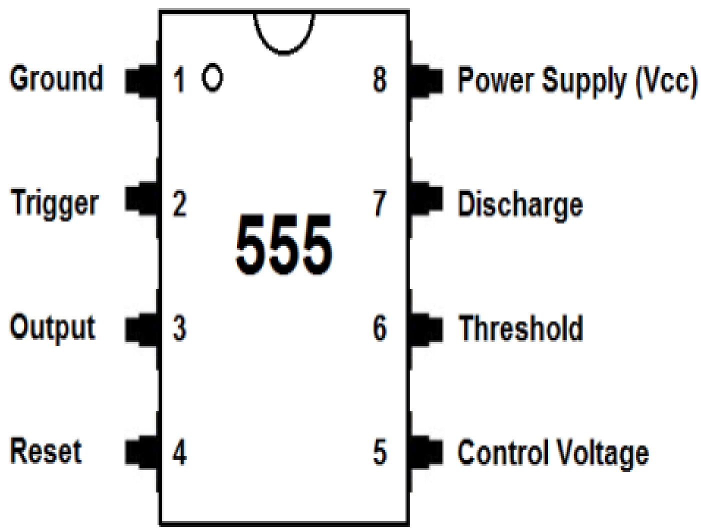

Fig. 3.1 Pin diagram of NE-555

Pins	Name	Purpose
1	GND	Ground reference voltage, low level (0 V)
2	TRIG	The OUT pin goes high and a timing interval starts when this input falls below 1/2 of CTRL voltage (which is typically 1/3 V_{CC}, CTRL being 2/3 V_{CC} by default if CTRL is left open)
3	OUT	This output is driven to approximately 1.7 V below $+V_{CC}$, or to GND.
4	RESET	A timing interval may be reset by driving this input to GND, but the timing does not begin again until RESET rises above approximately 0.7 volts. Overrides TRIG which overrides THR
5	CNTL	Provides "control" access to the internal voltage divider (by default, 2/3 V_{CC})
6	THR	The timing (OUT high) interval ends when the voltage at THR ("threshold") is greater than that at CTRL (2/3 V_{CC} if CTRL is open)
7	DIS	Open collector output which may discharge a capacitor between intervals. In phase with output.
8	OUT	Positive supply voltage, which is usually between 3 and 15 V depending on the variation

Table 3.2 Pin description of NE-555

Modes

The IC 555 has three operating modes

1. **Bistable**

Fig:3.1 Schematic diagram of a 555 in bistable mode

In bistable (also called Schmitt trigger) mode, the 555 timer acts as a basic flipflop. The trigger and reset inputs (pins 2 and 4 respectively on a 555) are held high via pull-up resistors while the threshold input (pin 6) is simply floating. Thus configured, pulling the trigger momentarily to ground acts as a 'set' and transitions the output pin (pin3) to Vcc (high state). Pulling the reset input to ground acts as a 'reset' and transitions the output pin to ground (low state). No timing capacitors are required in a bistable configuration. Pin 5 (control voltage) is connected to ground via a small-value capacitor (usually 0.01 to 0.1 μF). Pin 7 (discharge) is left floating.

2. **Monostable**

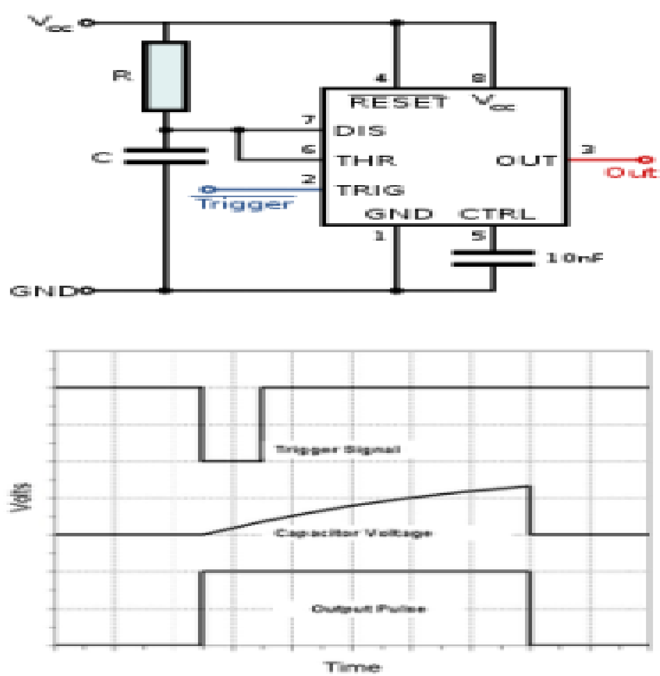

Fig. 3.2 Schematic and operation for Monostable mode.

The output pulse ends when the voltage on the capacitor equals 2/3 of the supply voltage. The output pulse width can be lengthened or shortened to the need of the specific application by adjusting the values of R and C.
The output pulse width of time *t*, which is the time it takes to charge C to 2/3 of the supply voltage, is given by

$$t = 1.1RC$$

Where t is in seconds, R is in ohms (resistance) and C is in farads (capacitance). While using the timer IC in monostable mode, the main disadvantage is that the time span between any two triggering pulses must be greater than the RC time constant. Conversely, ignoring closely spaced pulses is done by setting the RC time constant to be larger than the span between spurious triggers.

3. Astable

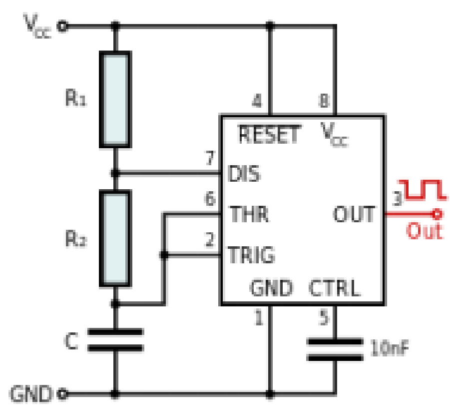

Fig. 3.3 Schematic of NE-555 in Astable mode

In astable mode, the 555 timer puts out a continuous stream of rectangular pulses having a specified frequency. Resistor R1 is connected between VCC and the discharge pin (pin 7) and another resistor (R2) is connected between the discharge pin (pin 7), and the trigger (pin 2) and threshold (pin 6) pins that share a common node. Hence the capacitor is charged through R1 and R2, and discharged only through R2, since pin 7 has low impedance to ground during output low intervals of the cycle, therefore discharging the capacitor.

3.3 POTENTIOMETER

A **potentiometer** informally a **pot**, is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a **variable resistor** or **rheostat**. A potentiometer measuring instrument is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name.

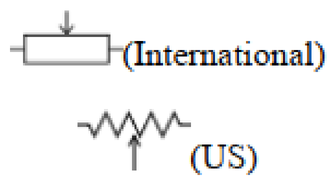

Fig. 3.4 Electrical symbol of potentiometer

3.4 RESISTOR

A **resistor** is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. In electronic circuits resistors are used to limit current flow, to adjust signal levels, bias active elements, terminate transmission lines among other uses.

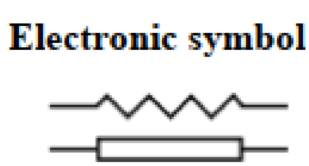

Fig. 3.5 Electrical symbol of resistor

3.5 CAPACITOR

A **capacitor** (originally known as a **condenser**) is a passive two-terminal electrical component used to store energy electro statically in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. insulator). The conductors can be thin films, foils or sintered beads of metal or conductive electrolyte, etc. The "non-conducting" dielectric acts to increase the capacitor's charge capacity. A dielectric can be glass, ceramic, plastic film, air, vacuum, paper, mica, oxide layer etc. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.

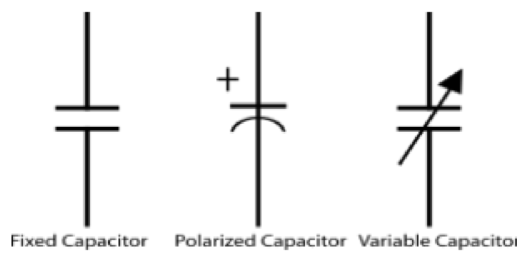

Fig. 3.6 Electrical schematic for capacitor

3.6 FUNCTION GENERATOR

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine wave , square wave, triangular wave and sawtooth shapes. These waveforms can be either repetitive or single-shot (which requires an internal or external trigger source). Integrated circuits used to generate waveforms may also be described as function generator ICs.

In addition to producing sine waves, function generators may typically produce other repetitive waveforms including sawtooth and triangular waveforms, square waves, and pulses. Another feature included on many function generators is the ability to add a DC offset.

Although function generators cover both audio and RF frequencies, they are usually not suitable for applications that need low distortion or stable frequency signals. When those traits are required, other signal generators would be more appropriate.

Some function generators can be phase-locked to an external signal source (which may be a frequency reference) or another function generator.

Function generators are used in the development, test and repair of electronic equipment. For example, they may be used as a signal source to test amplifiers or to introduce an error signal into a control loop. Function generators are primarily used for working with analog circuits, related pulse generators are primarily used for working with digital circuits.

Fig. 3.7 Function Generator

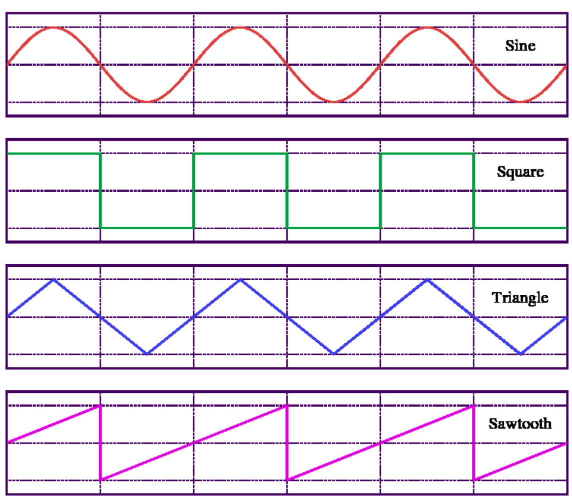

Fig. 3.8 Output waveforms from a function generator

CHAPTER 4

CIRCUIT AND OPERATION

4.1 HOW THE CIRCUIT FUNCTIONS

In this PWM generator circuit, as mentioned previously 555 Timer IC is used for generating PWM signal. Here the output frequency of the PWM signal is controlled by selecting resistor R1 and capacitor C1. A variable resistor in place of fixed resistor is used for changing duty cycle of the output signal. PWM signal is generated at 555 timer's output pin. On the label Output-1: we get the original PWM signal generated by NE-555. Potentiometer is used in voltage divider to get variable peak to peak voltage PWM signal on the labels Output-2 and Output-4. A high pass RC filter is used to get the negative peak to peak voltage signal of the PWM.

Below formula is used for deriving the frequency of the PWM signal:

$$F = 0.639 \times R_1 \times C_1$$

A 5V DC supply is connected to V_{cc} pin of NE-555. From function generator sine wave and pulse signal are generated at 5V peak to peak and 500 Hz.

4.2 CIRCUIT DIAGRAM

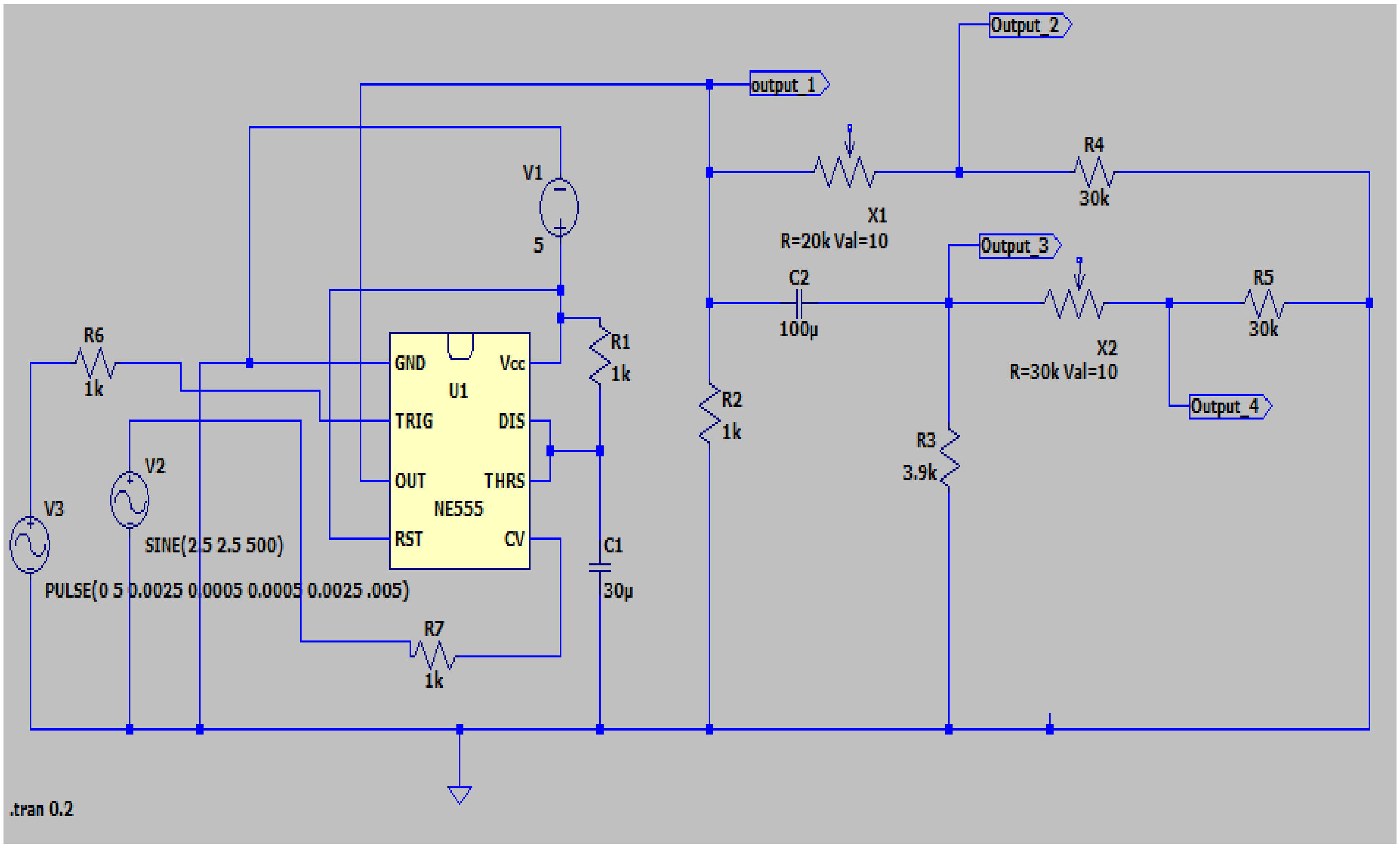

Fig. 4.1 Circuit diagram of PWM generator

4.3 SIMULATION RESULTS

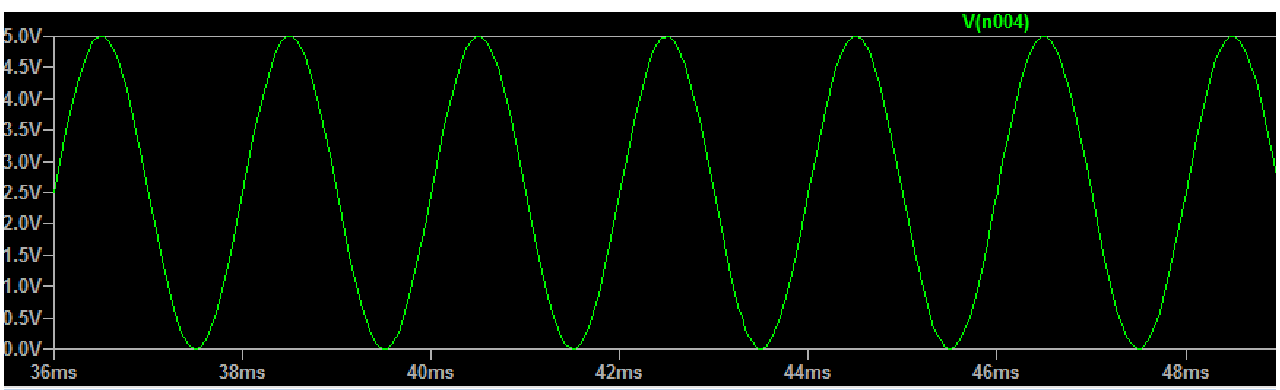

Fig. 4.2 Sine wave input

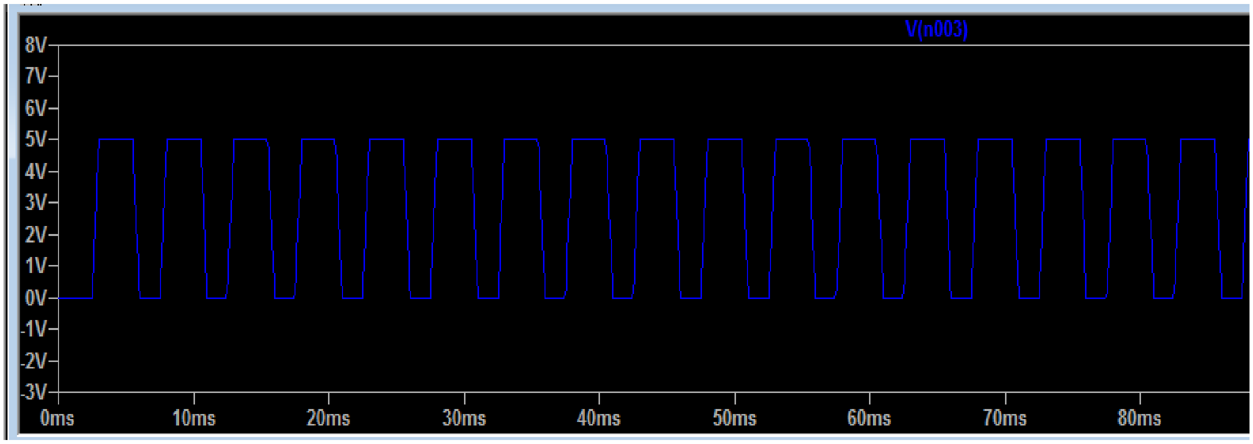

Fig. 4.3 Pulse signal input

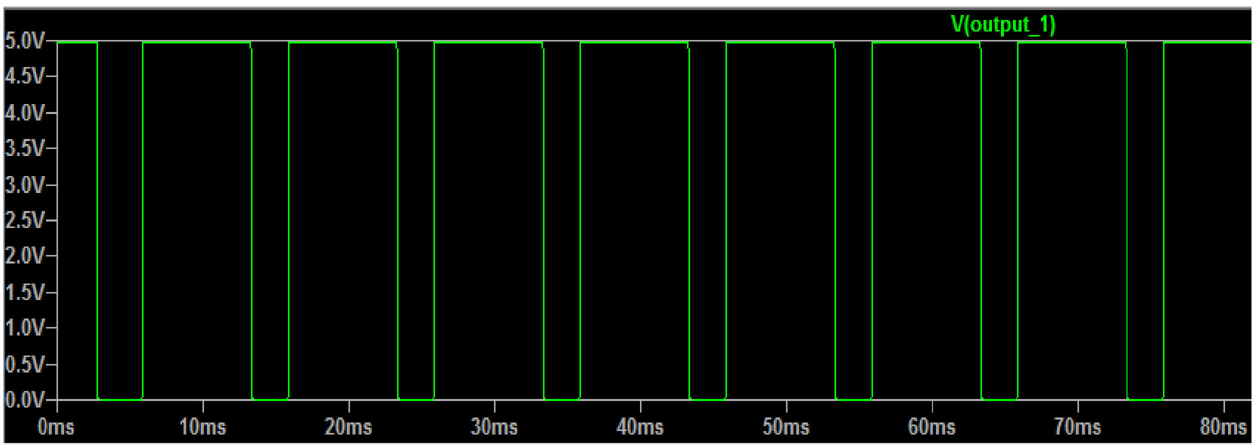

Fig. 4.4 PWM signal at label Output-1

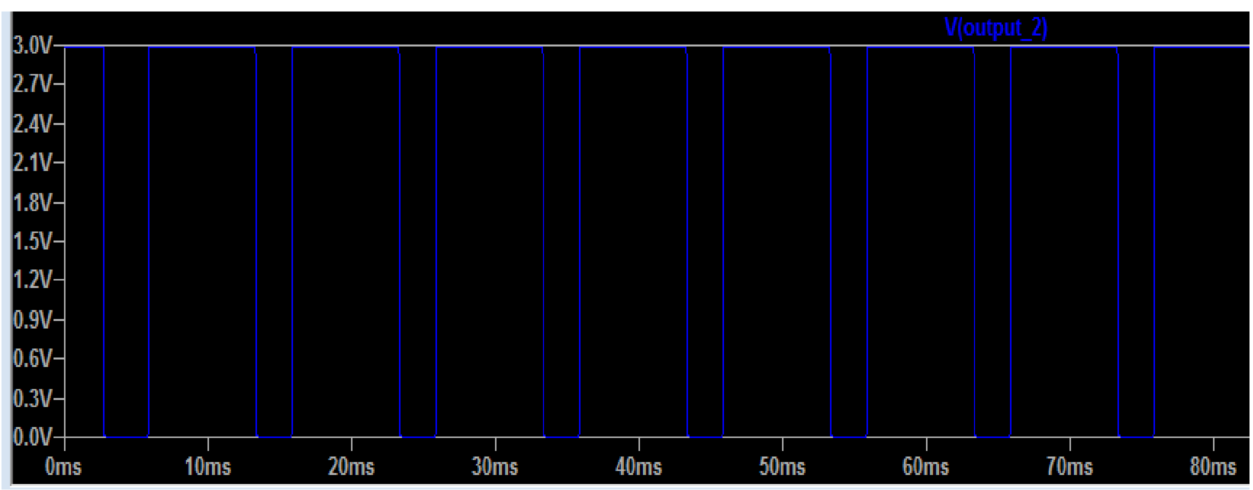

Fig. 4.5 Voltage controlled PWM signal at label Output-2

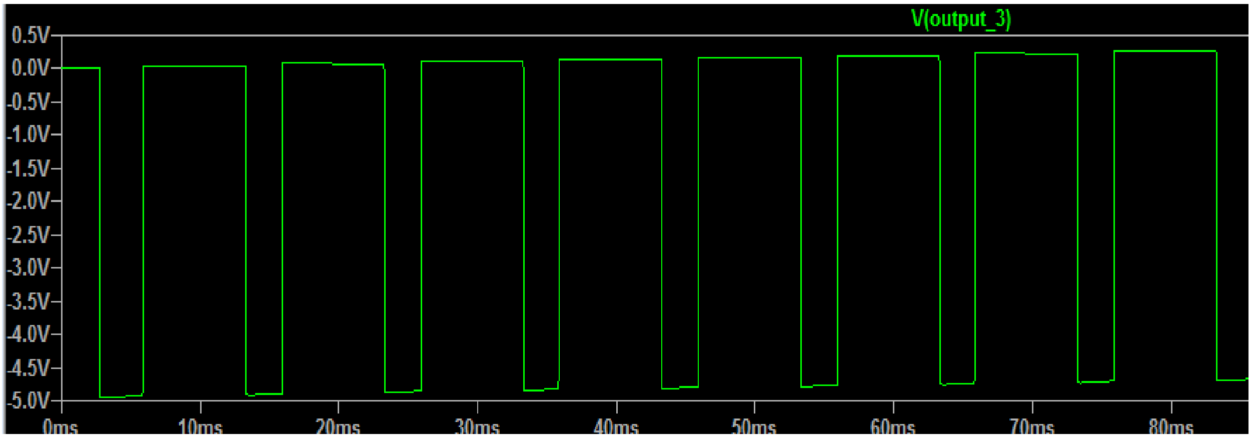

Fig. 4.6 Inverse PWM signal at label Output-3

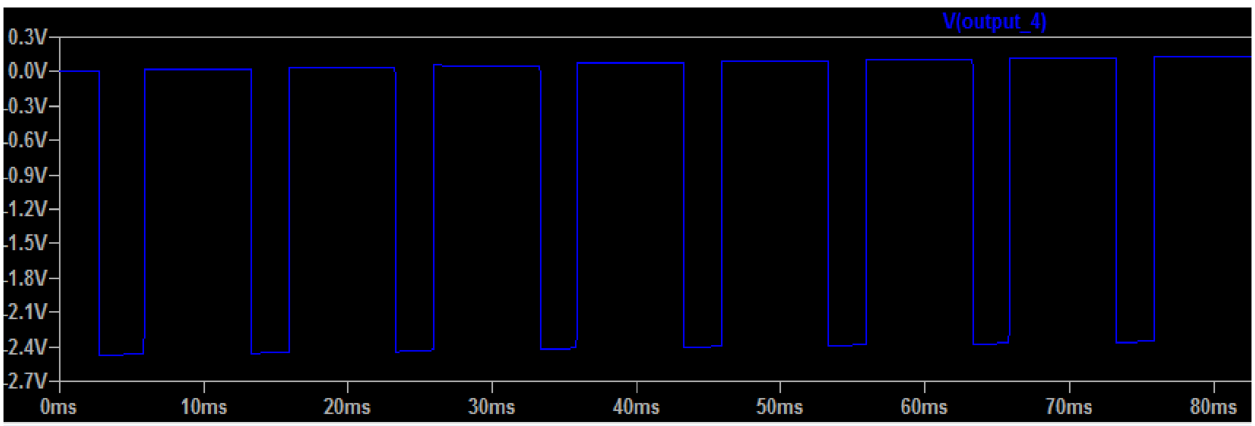

Fig. 4.7 Inverse voltage controlled PWM signal at label Output-4

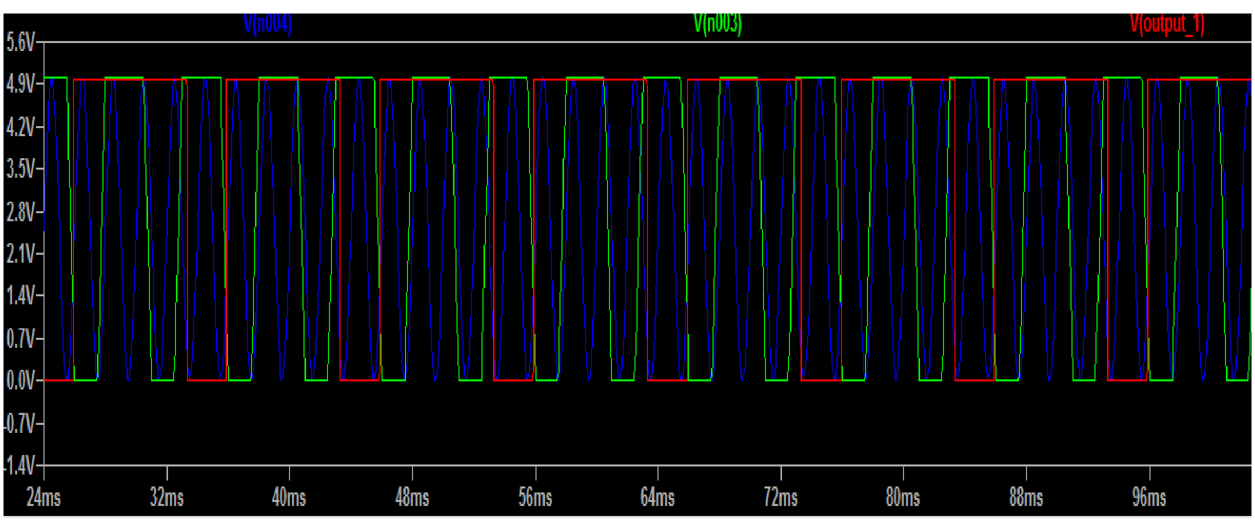

Fig. 4.8 PWM signal output along with input

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 APPLICATION

- PWM Techniques are used in Telecommunications for encoding purposes.
- Pulse Width Modulation helps in voltage regulation and thus finds its use in controlling Brightness in Smart Lighting Systems and also controls the speed of motors.
- Computer Motherboard requires PWM Signals that controls the heat generated in the board. 4 Pin PWM header is embedded in the fan that helps to dissipate the heat from the motherboard.
- It is also used in Audio/Video Amplifiers.
- Control the speed of DC motor and other power electronic devices.

5.2 UTILITIES

- PWM technique helps in preventing overheating of LED’s while maintaining its brightness.
- Pulse Width Modulation provides accuracy and quick response time.
- It provides high input Power Factor.
- Initial cost is low.
- PWM technique helps the motors to generate maximum torque even when they are running at lower speeds.

5.3 LIMITATIONS

- As the PWM frequency is high, switching losses is considerably high.
- It induces Radio Frequency Interference (RFI).

5.4 CONCLUSION

The Pulse Width Modulator is designed using NE-555 timer IC. The frequency of the PWM can be set by changing the resistance and capacitance value. The duty cycle is varied by varying the potentiometer resistance. This circuit is useful to operate the dc motors at required speed with very low losses and low cost. The circuit response time is fast. Hence high reliability can be achieved. The designed circuit was tested for various frequency inputs satisfactorily.