PWM Based Speed Control of DC Motor

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Abstract: The electric drive systems used in many industrial applications require higher performance, reliability, variable speed due to its ease of controllability. The speed control of DC motor is very crucial in applications where precision and protection are of essence. Purpose of a motor speed controller is to take a signal representing the required speed and to drive a motor at that speed. Pulse width modulation (PWM) can provide easy control of DC motor. Our aim of this paper is to give a new technique based on PWM to control the speed of DC motor.
Keywords- DC motor, Speed control, circuit, PWM.

1. INTRODUCTION

Direct current (DC) motors have been widely used in many industrial applications such as electric vehicles, steel rolling mills, electric cranes, androbotic manipulators due to precise, wide, simple, and continuous control characteristics. Traditionally rheostat armature control method was widely used for the speed control of low power DC motors.

However the controllability, cheapness, higher efficiency, and higher current carrying capabilities of static power converters brought a major change in the performance of electrical drives. The desired torque-speed characteristics could be achieved by the use of conventional pulse width modulation controllers (PWM).

In recent years PWM were effectively introduced to improve the performance of nonlinear systems. The application of PWM is very promising in system identification and control due to learning ability, massive parallelism, fast adaptation, inherent approximation capability, and high degree of tolerance.

A constant-power field weakening controller based on load-adaptive multi-input multi-output linearization technique has been proposed to effectively operate a separately excited DC motor in the high-speed regimes.

A single-phase uniform PWM DC-DC buck-boost converter with only one switching device able to produce a controllable DC voltage ranging from zero to more than the maximum value of input dc voltage has been used for armature voltage control method of a separately excited DC motor the drives using poly-phase brushless DC motors fed by a PWM inverter with current regulation.

2. Relative Work

In the past few years, when only partial power was needed (such as for a sewing machine motor), a rheostat (located in the sewing machine's foot pedal) connected in series with the motor adjusted the amount of current flowing through the motor, but also wasted power as heat in the resistor element. It was an inefficient scheme, but tolerable because the total power was low.

This was one of several methods of controlling power. There were others some still in use such as variable autotransformers, including the trademarked 'Autrastat' for theatrical lighting; and the Variac, for general DC power adjustment. These were quite efficient, and also relatively costly. 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 converter such as Ward Leon rd drive.

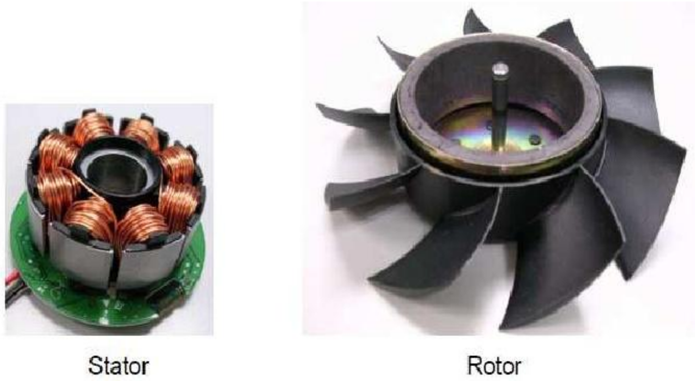

Fig 2.1 Internal structure of dc motor

However, in addition to motor drives, pumps and robotic servos, there was a great need for compact and low cost means for applying adjustable power for many devices, motors, such as electric stoves and lamp dimmers. One of early applications of PWM was in the Sinclair X10, a 10W audio amplifier available in kit form in the 1960's. At around the same time PWM started to be used in DC motor control for some time ASD has been in use for motor speed control.

An adjustable-speed drive (ASD) or variable-speed drive (VSD) is an interconnected combination of equipment that provides a means of driving and adjusting the operating speed of a mechanical load. An electrical adjustable-speed drive consists of an electric motor and a speed controller or power converter plus auxiliary devices and equipment. In common usage, the term drive is often applied to just the controller. This technique give superior power control of the motor because there are no moving or passive parts involved hence power consumption is reduced.

3. TECHNOLOGY

A reasonable number of works have found in the literature, regarding the employment of solid-state devices for the control of dc drives. The paper of Kurnera, Dayananda and Jayawikrama, elucidated the use of chopper in collaboration to PC for the control of dc motor speed. Software was developed, fed into a PC and consequently, commands were given to the chopper via the computer for control of motor speed [3].The use of standalone micro controller for the speed control of DC motor is past gaining ground. Nicolai and Castgnct have shown in their paper how a microcontroller can be used for speed control. The operation of the system can be summarized as: the drive form rectified voltage; it consists of chopper driven by a PWM signal generated from a microcontroller unit (MCU). The motor voltage control is achieved by measuring the rectified mains voltage with the analog to-digital converter present other micro controller and adjusting the PWM signal duty cycle accordingly [5]. Another system that uses a microprocessor is reported in the work of khoel and Hadidi a brief description of the system is as follows: The microprocessors computes the actual speed of the motor by sensing the terminal voltage and the current, it then compares the actual speed of the motor with the reference speed and generates a suitable signal control signal which is fed into the triggering unit. This unit drives an H bridge Power MOSFET amplifier, which in turn supplies a PWM voltage to the DC motor [6].

In this paper, a DC motor with fixed speed control system is presented, which has high precision, reliability and adaptability. By simply varying the voltage across the motor speed of the motor can easily be controlled. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal Pulse Width Modulation (PWM) Basics.

There are many forms of modulation used for communicating information. When a high frequency signal has amplitude varied in response to a lower frequency signal we have AM (amplitude modulation). When the signal frequency is varied in response to the modulating signal we have FM (frequency modulation).

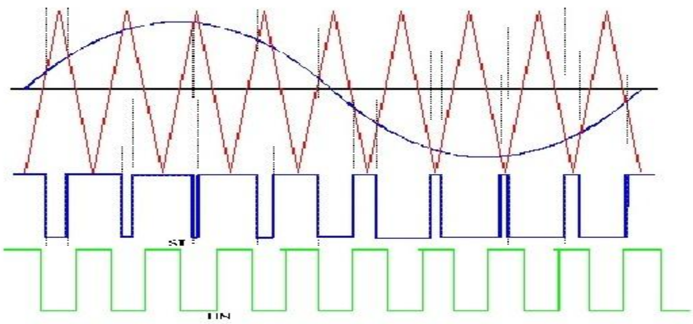

Fig.3.1 Unmodulated, sine modulated pulses

These signals are used for radio modulation because the high frequency carrier signals needs for efficient radiation of the signal, when communication by pulses was introduced, the amplitude, frequency and pulse width become possible modulation option. In many power electronic converters where the output voltage can be one of two values the only option is modulation of average condition time.

3.1 .Linear Modulation

The simplest modulation to interpret is where the average ON time of the pulses varies proportionally with the modulation signals. The advantage to linear processing for this application lies in the case of de-modulation. The modulating signal can be recovered from the PWM by loe pass filtering. For a single low frequency sine wave as modulating signal modulating the width of a fixed frequency (fs) pulse train the spectra is as shown in Fig-3.1(a) clearly a low pass filter can extract the modulating component fm.

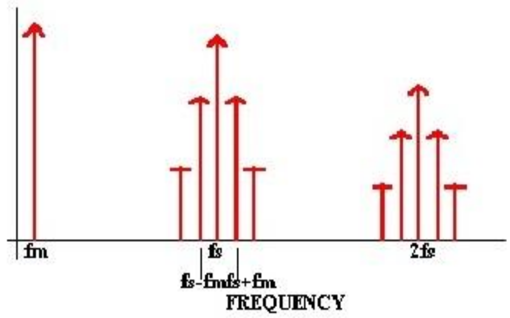

Fig 3.1(a) Spectra of PWM

3.2 Saw tooth PWM

The simplest analog form of generating fixed frequency PWM is by comparison with a linear slope waveform such as a saw tooth. As seen in Fig 3.1 the output signal goes high when the sine wave is higher than the saw tooth. This is implemented using a comparator whose output voltage goes to logic HIGH when input is greater than the other. Other signals with straight edges can be usedfor modulation a rising ramp carrier will generate PWM with Trailing EdgeModulation.
It is easier to have an integrator with a reset to generate the ramp in Fig-3.2(a) but the modulation is inferior to double edge modulation.

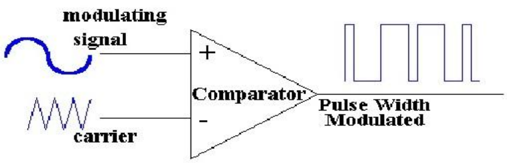

Fig 3.2(a) Saw tooth PWM

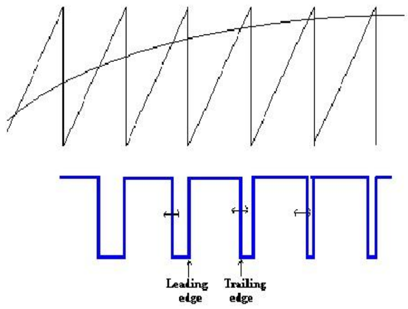

Fig 3.2(b) modulation

3.3 APPLICATIONS

i. Dc motors of all range can be controlled, which are used for the production of materials.
ii. Dc motors using precise job preparations.
iii. Various motors requiring smooth speed control.
iv. Electric locomotives.
v. Conveyor belt carrying loads.
vi. Traction application.

3.4 DISADVANTAGES

i. The main disadvantage of PWM circuits is the added complexity and the possibility of generating radio frequency interference.
ii. It can give speed below the full speed, not above.
iii. It cannot be used for fast controlling of speed.

3.5 ADVANTAGES

i. PWM duty cycle control technique enables greater efficiency of dc motor.
ii. PWM switching control methods improved speed control and reduced the power losses in the system.

iii. The pulse reaches the full supply voltage and will produce more torque in a motor by being able to overcome the internal motor resistance more easily.

4. PROPOSED SCHEME

A scheme that address on building up such a system as described above is presented in here. As the system is based on the speed controlling of a DC motor, so the desired goal is to achieve a system with constant speed at any load condition. That means motor will run at fixed speed at any load condition. It will not vary with the amount of load. The hardware is made in such a way that even an unskilled operator can operate it. Our proposed block diagram is as follows,

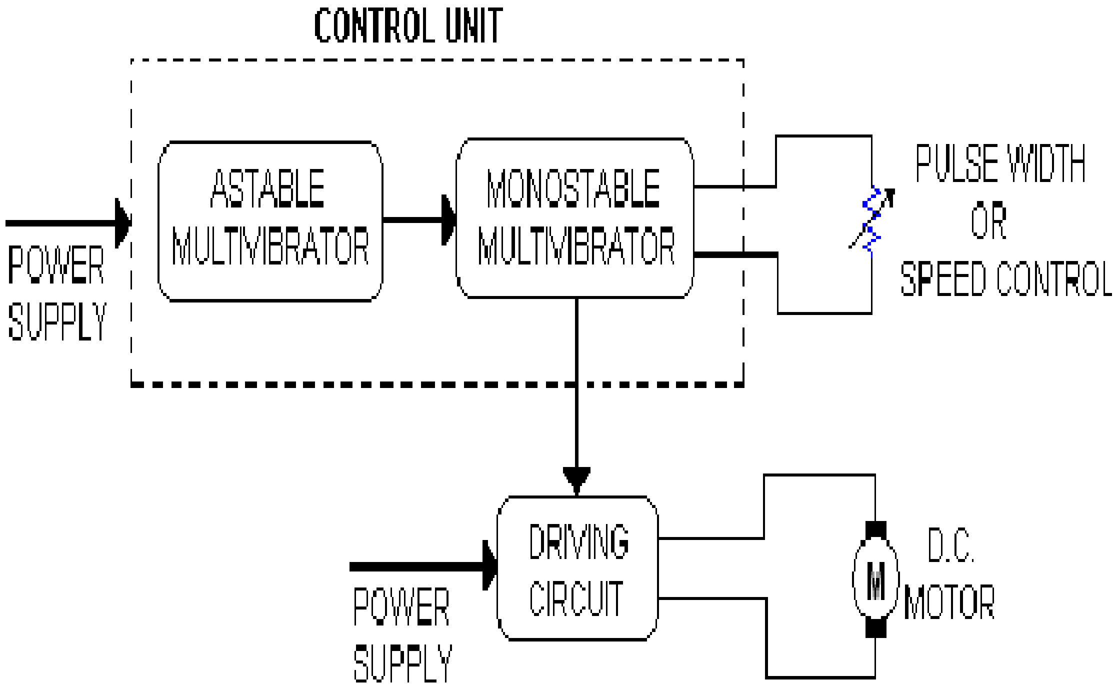

Fig 4.1 Block diagram

4.1 EXPLANATION OF BLOCK DIAGRAM

The explanation of block diagram is given below. This block consists two parts which are as follows,

i. Astable multivibrator
ii. Monostable multivibrator

Astable multivibrator produce square pulses of same frequency. it is used to fed to next block as triggering pulses. Monostable multivibrator produce square pulses of variable frequencies. The frequency of output pulse can be varied by changing the value of resister. It is fed to the driver circuit.

4.2 DRIVER CIRCUIT:

This block provides power required to drive motor. As the frequency of output pulses of monostable multi vibrator changes the average voltage supplied to motor change hence the speed of motor change.

5. IMPLIMENTATION

In this section we give overview of our proposed circuit diagram.

5.1 CIRCUIT DIAGRAM

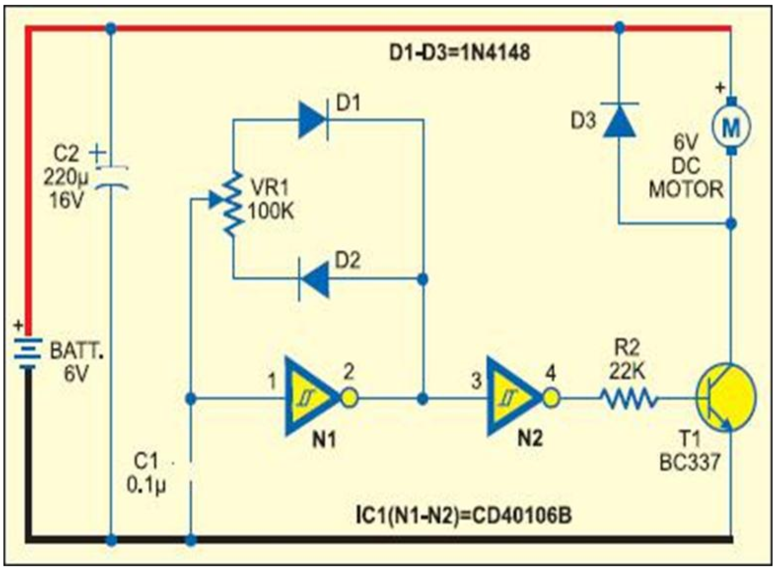

Fig 5.1 Circuit diagram

5.2 EXPLANATION OF DIAGRAM

Pulse-width modulation (PWM)or duty-cycle variation methods are commonly used in speed control of DC motors. The duty cycle is defined as the percentage of digital 'high' to digital 'low' plus digital 'high' pulse-width during a PWM period.

The PIC12F683, IC1 has an internal hardware PWM peripheral that is used to generate the PWM signal. The duty cycle of the PWM signal is controlled by VR1 which via R1 presents a voltage on pin 3 of IC1. With 0V on the input the duty cycle is 0% (off) up to 100% with 5 volts at the input.

The PWM signal is output from pin 5 of IC1 and drives the gate terminal of Q1 through R3. Resistor R4 connects the gate terminal of Q1 to ground. This ensures that Q1 remains off when the circuit is first powered on as the I/O pins of IC1 are all set to inputs until the firmware initialises them as outputs. Diode D1 is required when driving inductive loads and provides a path for the inductive fly back current. For loads up to 3 amps Q1 does not require a heatsink, above this you may need to use one.

Power for the logic is provided by IC2, a 78L05 5 volt regulator. It connects to the input voltage source via diode D2 which provides protection against reverse polarity connection of the supply. The 3-way jumper JP1 allows the input voltage for the 78L05 to be taken from either the main power input or an auxiliary supply.

When a jumper is connected between pins 1 and 2 power comes from the main DC input. Since the maximum input voltage for a 78L05 is 30 volts there may be applications where a separate power supply is needed for the logic. This is catered for by connecting a jumper between pins 2 and 3 of JP1 and connecting an alternate power supply to JP2.

Switch SW1 allows one of three PWM remap tables to be selected. To avoid accidental changes to the map table in use the firmware requires the switch to be held for at least 500mS before switching to the next map data table. The table selected is indicated by LED1 and the value is saved to EEPROM so it always powers up using the last used setting.

CON1 provides a digital input which is polled by the firmware. When this input goes low the duty cycle is set to 0% from the start of the next PWM period, this turns MOSFET Q1 off. when the input returns high the PWM restarts using the duty cycle set by the input from VR1.

The connector also provides 5v and GND connections to allow connection of a small off-PCB control circuit. If it is used to power another circuit, ensure it doesn't draw more than 40mA from the supply. If the shutdown control isn't required, leave the connector open and the PICs internal weak-pull-up will hold the input high enabling the PWM output.

The circuit as shown will work with input voltages from 9 to 20 volts. If you choose to use it with a higher input voltage you may need to select different components.

5.3 WORKING PROCESS

The speed of a DC motor is directly proportional to the supply voltage, so if we reduce the supply voltage from 12Volts to 6 Volts, the motor will run at half the speed. How can this be achieved when the mains voltage is fixed at 12Volts ?

From the fore going, the speed of the motor is directly proportional width of the pulse. That is to say the wider the width of the pulse the greater the maximum power transferred to the motor hence the greater the revolution or speed of the motor thus resulting in an increased fan speed. Also, when the width is reduced the fan runs at a low speed owing to a less power transfer to the motor.

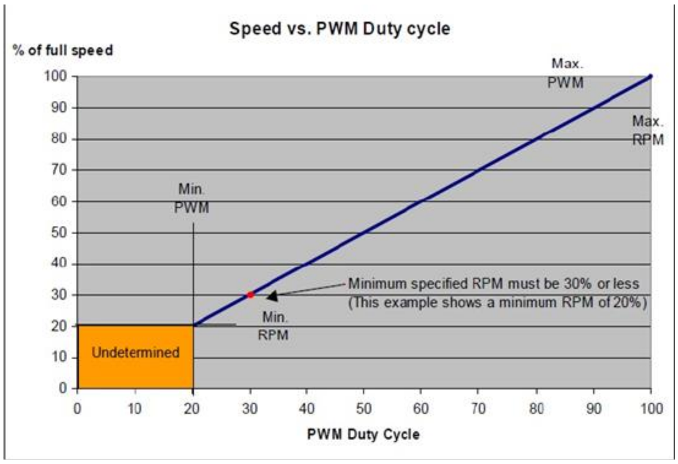

Fig 5.3 PWM duty cycle

The time that it takes a motor to speed up and slow down under switching conditions is dependent on the inertia of the rotor (basically how heavy it is),and how much friction and load torque there is. The graph below shows the speed of a motor that is being turned on and off fairly slowly: From the above, the average speed is around 1500, although it varies quite a bit. If the supply voltage is switched fast enough, it wont have time to change speed much, and the speed will be quite steady. This is the principle of switch mode speed control. Thus the speed is set by PWM 菖 Pulse Width Modulation. The microcontroller generates the PWM control signal that is used to control the fan speed in this regards the motor. Because there can be no fan without the motor.

5.4 CONTROLS

In use, VR1 controls the duty cycle (and period) of the PWM output. The analogue input from VR1 is used as an index to the map table which returns the required PWM duty cycle and period. This means a linear input at the ADC can be used to generate a non-linear change in duty cycle at the output.

An example of where this can be useful is controlling the brightness of an LED. The apparent brightness of an LED does not respond in a linear fashion to increases in duty cycle. By creating a suitable remap table, a linear change at the ADC input can be remapped to a duty cycle curve that produces an apparent linear increase in brightness of the LED.

Another significant feature of using the ADC input as an index to a lookup table is that not only does it allow the duty cycle to be remapped but the PWM period can also vary in response to the input at the ADC.

Taking advantage of the available memory in the PIC MCU, three remap tables can be programmed into the PIC. Switch input S1 is used to select the map table to be used. Pressing S1 for > 500mS will cycle through three map tables; this is to avoid accidental operation. The table in use is indicated by the LED as shown below. The map table selected for use is also saved to EEPROM so when the PIC is next powered on it will use that last selected table.

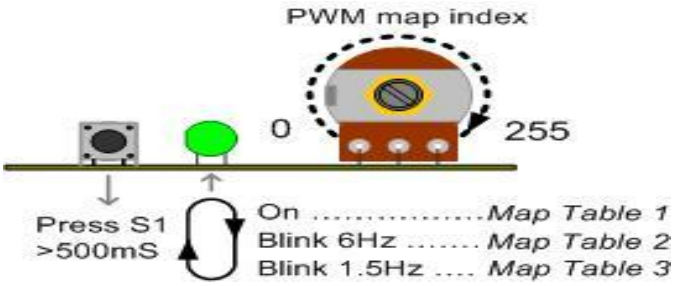

Fig 4.3 PWM map index

5.5 PCB DESIGN

A printed circuit board or PCB is used to mechanically support electrically connect electronic component using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate .It is also referred to as a printed wiring board or etched wiring board. A populated with electronic components is a printed circuit assembly, also known as a printed circuit board assembly.

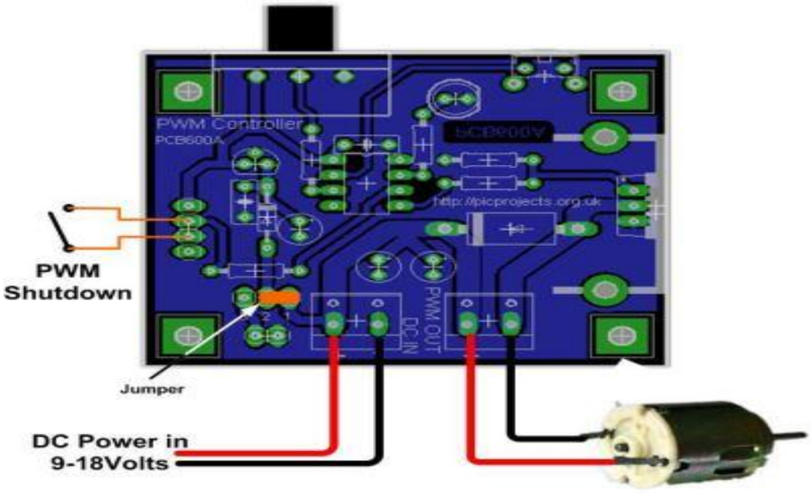

Fig 5.5 PCB structure

Printed circuit boards are used in virtually all but the simplest commercially produced electronic devices. PCBs are inexpensive and can be highly reliable. They require much more layout effort and higher initial cost than either wire wrap or point to point construction, but are much cheaper and faster for high volume production; the production and soldering of PCBs can be done by totally automated equipment.. Much of the electronic industry's PCBs design, assembly and quality control needs are set by standards that are published by the IPC organization. PCB is made of one or more layer of insulating material with electrical conductors. The insulator is typically made on the base of fiber reinforced resins, ceramics, plastic or some other dielectric materials .During manufacturing the portions of conductor that are not needed are etched off ,leaving printed circuit that connect electronic components.

Currently the main generic standard for the design of printed circuit boards , regardless of materials, is IPC-2221A.Whether a PCB board is single-sided, double-sided or multilayer, this standard provides rules for manufacturability and quality such as requirements for materials properties ,criteria for surface plating, conductor thickness ,component placement ,dimensioning and tolerance rules, and more. For a specific technology. a designer can then choose an appropriate sectional standard from the IPC-2220 series.

5.6 PCB manufacturing process

It is important element in the fabrication to electronic equipment in the design of property laid out PCBs that printed circuit board are certainly the most determine many of the limiting properties immunity to fast pales high frequency and low level characteristic of the equipment.

1. **Etching process:**

Etching process require the use of acid resistance dishes and running water supply .ferric chloride is the most used solution but other chemical such as ammonium sulphate can be used. Nitric can be used but in general, it is not used due to poisonous fames. Etching is the process of using strong acid or mordant to cut into the unprotected parts of a metal surface to create a design in intaglio in the metal. As an intaglio method of printmaking it is along with engraving the most important technique for old master prints and remains widely used today.

2. **Drilling:**

Drilling is one of those operations that call for great care because most of the holes will be made by a very small drill for most purpose a 1mm drill is used. Drill all holes with the size first those that need to be larger can be easily drilled again with the appropriate larger size. Drilling is a cutting process that uses a drill bit to cut or enlarge a hole in solid materials. The drill bit is a multipoint, end cutting tool. It cuts by applying pressure and rotation to the work piece, which forms chips at the cutting edge. Drilled holes are characterized by their sharp edge on the entrance side and the presence of burrs on the exit side. Also inside of the hole usually have helical feed marks. Drilling may affect the mechanical properties of the work piece by creating low residual stresses around the hole opening and a very thin layer of highly stressed and disturbed material on the newly formed surface. This causes the work piece to become more susceptible to corrosion at the stressed surface, for fluted drill bits, any chips are removed via the flutes. chips may be long spirals or small flakes depending on the material and process parameters. the type of chips formed can be an indicator of the machine ability of the material.

3. **Soldering:**

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a lower melting point then the work piece .Soldering differs for welding in that the work pieces are not melted. There are three forms of soldering, each requiring higher temperature and each producing and increasingly stronger joint strength; soft soldering which originally used a tin-lead alloy as the filler metal. Silver soldering which uses an alloy containing silver and brazing which uses a brass alloy for the filler. The alloy of the filler metal for each type of soldering can be adjusted to modify the melting temperature of the filler.

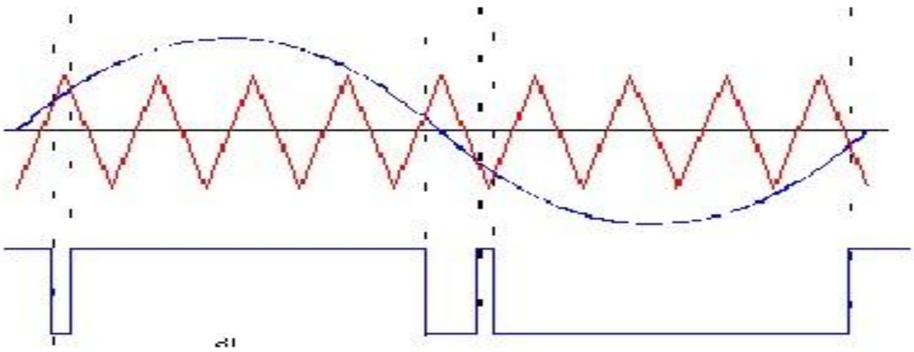

Fig.5.6 Width of modulation

6. CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

From the presented above work, following points can be concluded.

i. It fulfils all the requirements for its application.
ii. The motor responds to the average value of the pulses and not the individual pulses as the chopper works at high frequency.
iii. Changing the duty-cycle of the pulse by changing the potentiometer changes the average voltage level.
iv. It is possible to improve overall performance of the chopper drive.

5.2 FUTURE WORK

i. To highlight possible modifications that can be made in the project for improving performance.
ii. Use of micro-controller/micro-processor for closed loop operation Constant speed variation.
iii. Use of MOSFET or IGBT higher voltage and power requirement.

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