

H-Bridge Configuration for Wide Range Speed Control of DC Motor

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Abstract: Majority of the industrial drives are AC drives, due to their robust construction, low power loss, low maintenance and simple starting arrangement. However, these motors are constant speed drives and do not allow smooth speed control over a wide range and operation in either direction. Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. The ease of control and excellent performance of the DC motors will ensure that the number of applications using them will continue grow for the foreseeable future. To operate motor in either direction DC motor can be used because of its simplicity. Although conventional methods are available for speed control, modern high speed switching power devices have opened new area in this field. The major advantages of power electronic control of drives are compactness, flexibility and greater precision in speed control. A simple, cost effective and efficient method of controlling the speed of DC motor is to incorporate PWM control. Use of microcontroller reduces the control hardware, increases the reliability and brings in flexibility to the control scheme. To study the efficiency of such systems, in the present work it is planned to design and test PWM controlled H- Bridge Converter for DC motor. The design of converter, generation of PWM pulses and microcontroller programs developed in the present work are discussed in detail in this report.

Keywords: H-Bridge, PWM, DC motors, MOSFET, MICROCONTROLLER.

1. Introduction

One can look forward to an era where every application in the industry will be driven by highly efficient and reliable drives. Most of the drives used in the industries today are electrical. Electric drives are widely used in the industry because of high reliability and versatility of speed control. Speed control over a wide range in a very smooth manner is possible with the advent of modern power electronic devices such as POWER TRANSISTER, SCR, MOSFET etc. Optimization and automation have improved the static and dynamic behavior of these drives.

Motor control applications span everything from washing machines to fans, hand-held power tools, and automotive window lift and traction control systems. In most of these applications there is a move away from analog motor control to precision digital control of motors. Digital control of motors permits a much more efficient operation of the motor, resulting in longer life, lower power dissipation, and a lower overall system cost. The most common expectation from any industrial drive is precise control of speed and torque, position with long-term stability, good transient performance and high efficiency.

Modern technology offers various alternatives in the selection of drive system. Depending on the application, some of them are fixed speed and some of them are variable speed. The variable speed drives, till a couple of decades back, had various limitations such as poor efficiency, larger space requirement, lower speeds etc. However, the advent of power electronics transformed the scene completely. Today variable drive systems are smaller in size but also very efficient, highly reliable and meet all the stringent demands of various industries of modern era.

2. Objectives

- 1) To design and implement H-Bridge configuration for DC drive.
- 2) To control speed of separately excited DC motor in either direction using H-Bridge configuration.

3. Methodology

To control speed of DC motor in either direction using microcontroller involves various stages and use of various components. The procedure of integrating different stages is explained below.

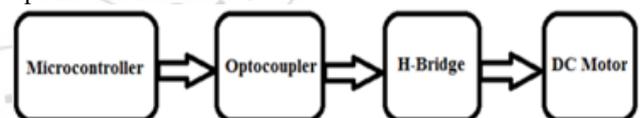


Figure 1: Block diagram

3.1. Microcontroller

A microcontroller (sometimes abbreviated μC , uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Voltage transients with speeds up to $10 \text{ kV}/\mu\text{s}$. A common type of opto-isolator consists of an LED and a phototransistor in the same package. Opto-isolators are usually used for transmission of digital (on/off) signals, but some techniques allow use with analog (proportional) signals.

3.2. OPTO-COUPLER

Opto-coupler MCT2E consists of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package.

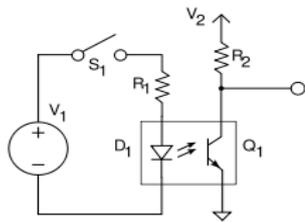


Figure 2: Circuit which is used for gate drive.

In the above circuit the voltage V_1 is the output of microcontroller pulse. This is used when data need to be transferred from one subsystem to another without making a direct 'ohmic' electrical connection. Often this is because source and destination are (or may be at times) at very different voltage levels, like a microcontroller which is operating from 5V DC, but being used to control a power equipment like MOSFET, SCR, Triac etc, which are switching from 240V AC or DC. In such situations the link between the two must be an isolated one, to protect the microcontroller from over voltage damage. Relays can of course provide this kind of isolation, but even small relays tend to be fairly bulky compared with IC's and many of today's other miniature circuit components, because they are electromechanical in nature. Where small size, higher speed and greater reliability are important, a much better alternative is to use an opto-coupler.

This uses a beam of light to transmit the signals or data across an electrical barrier and achieve excellent isolation. Opto-coupler typically come in a small 6pin or 8pin IC package, but are essentially a combination of two distinct devices; an optical transmitter, typically a Gallium arsenide LED (Light Emitting Diode) and an optical receiver such as a phototransistor or light triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between the two, but does allow the passage of light. Opto-coupler are essentially digital or switching devices, so they are best for transferring either on-off control signals or digital data. Analog signals can be transferred by means of frequency or pulse width modulation. The MCT2E is a NPN Silicon planar photo transistor optically coupled to a gallium arsenide infrared emitting diode.

3.3. H-Bridge

In general an H-bridge figure is a rather simple circuit, containing four switching element, with the load at the centre in an H-like configuration.

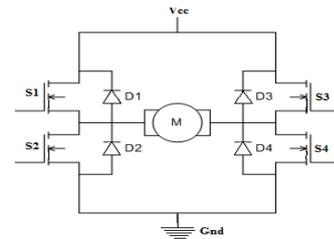


Figure 3: H-Bridge Circuit

MOSFET are used as power switches which are indicated as S1, S2, S3 and S4 in the circuit. The diodes (D1, D2, D3 and D4) are usually of a Schottky type. The basic operating mode of an H-bridge is fairly simple: if S2 and S3 are turned on, the left lead of the motor will be connected to ground, while the right lead is connected to the power supply. Current starts flowing through the motor which energizes the motor in (let's say) the forward direction and the motor shaft starts spinning. If S1 and S4 are turned on, the converse will happen, the motor gets energized in the reverse direction, and the shaft will start spinning in that way. If less than full-speed (or torque) operation is intended one of the switches are controlled in a PWM fashion. The average voltage seen by the motor will be determined by the ratio between the 'on' and 'off' time of the PWM signal.

3.4. DC Motor.

A DC motor is an electric motor that runs on DC electricity. It works on the principle of electromagnetism. A current carrying conductor when placed in an external magnetic field will experience a force proportional to the current in the conductor. This H-Bridge technique can be used for both shunt type and separately excited DC motor. We are using Separately excited DC Motor of 220V, 2.3 A, 1500 RPM.

4. Data Flow Diagram of Reset

A. Initialize the program to set the duty cycle for 10% and clockwise for 1 and counter clockwise (CCW) for 0.

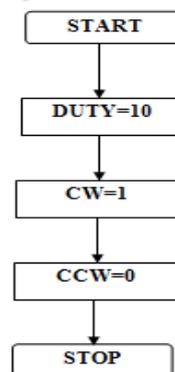


Figure 4: Data Flow Diagram of Reset.

B. Data Flow Diagram of Increment or Decrement of Duty Cycle.

Initially as per reset, duty cycle will be set to 10%, CW will be set to 1 and CCW will be set to 0. Then check whether duty cycle is less than 100% if not then go to stop, if yes check whether CW is set to 1. If it is 1 then increment duty

cycle by 10% for each step upto 100%. If CW is not equal to 1, then CCW will be 1 then increment duty cycle by 10% for each step upto 100%. If duty cycle is more than 100% stop the program.

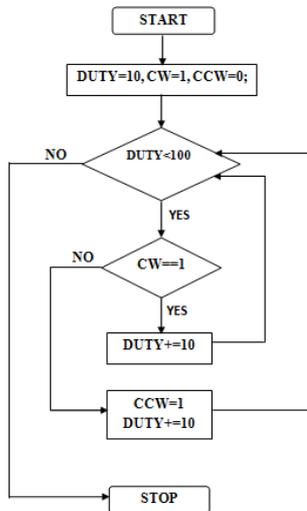


Figure 5: Data Flow Diagram of Increment or Decrement of Duty Cycle

5. Result

H-Bridge Setup with Resistive Load:

Experiments were conducted to find the influence of M, number of pulses on the output voltage of the H-Bridge. The result sheet consists of two types of outputs.

- 1) Output in forward direction for different duty cycles.
- 2) Output in reverse direction for different duty cycles.

In all these cases, DC input was maintained constant. H-Bridge converter was rigged up and tested for our convenience. The H-Bridge converter is tested with 20V DC supply with rheostat of 5A. Experimental setup used for resistive load is as shown in figures.

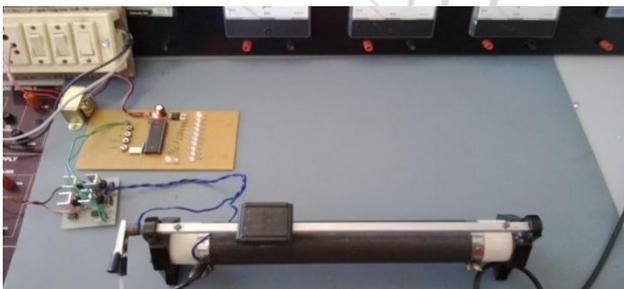


Figure 6: Experimental Setup for Resistive Load

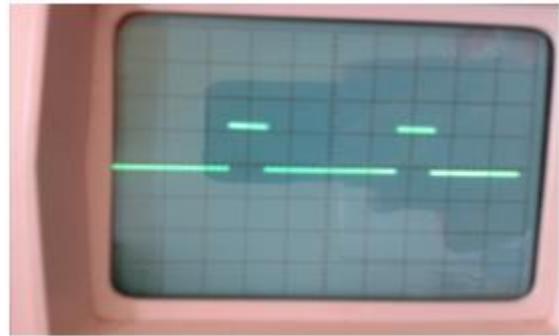


Figure 7: Microcontroller output for 20% duty cycle.

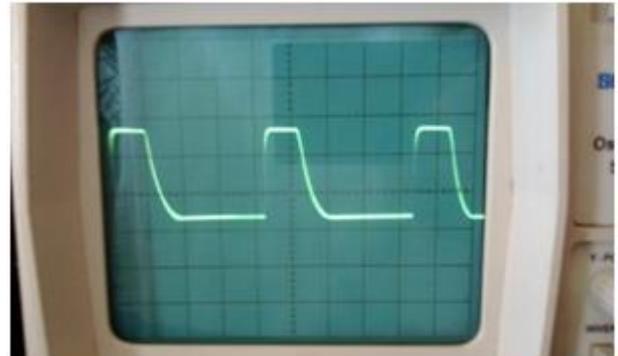


Figure 8: H-Bridge output across rheostat for 20% duty cycle in forward direction when S1 and S4 Conducting.

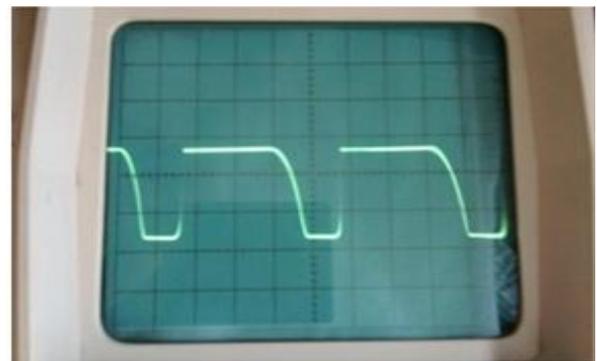


Figure 9: H-Bridge output across rheostat for 20% duty cycle in reverse direction when S3 and S2 Conducting.

Table 1: Speed and Duty Cycle in Forward Direction

Duty Cycle in %	Speed in rpm
	Forward Direction
10	82
20	159
30	220
40	260
50	295
60	311

Table 2: Speed and Duty Cycle in Reverse Direction

Duty Cycle in %	Speed in rpm
	Reverse Direction
10	73
20	151
30	224
40	266
50	295
60	314

Table 1 and Table 2 shows the speed and duty cycle in forward and reverse direction of DC motor it can be observed that the speed of the DC motor was increasing with increase in the duty cycles and characteristic of the DC motor was found to be same in forward and reverse direction.

6. Conclusion

To run and control the motor in both forward and reverse with a processor, we need more circuitry. H-Bridge circuit is a popular circuit for driving DC motors. The great ability of an H-Bridge circuit is that the motor can be driven forward or backward at any speed, optionally using a completely independent power source. The H-Bridge design can be really simple for prototyping or really extravagant for added protection and isolation.

The present work is mainly focused on generating PWM of H-Bridge Bridge with different pulse input at the gates of MOSFET. We have checked and confirmed the results by giving pulse for resistive load and a DC motor. In this project the experiments conducted for universal motor. A comparison can be done between the present MOSFET module and other power semiconductor device modules to get best out of the two.

7. Future Work

A comparison can be done between the present MOSFET module and other power semiconductor device modules to get best out of the two. With the efficient use of the same microcontroller, the feedback can be taken out from motor to run it at constant speed or at desired speed.

A comparison can be done between the present MOSFET module and other power semiconductor device modules that could be IGBT based .Using IGBT switches with proper design of the circuit it is possible that it can be adapted to higher rating devices.And it is possible to implement the present circuit on shunt motors, this can be achieved by making appropriate changes in the circuit which can visualized as the further step in the improvement of the present circuit.

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