

Controlling DC Brush Motors with H-bridge Driver ICs

Objective

The Objective of this laboratory is to get knowledge in the design, functionality and use of a full H-Bridge for the driving of a DC motor angular speed.

Materials

Principales Materiales a Utilizar. Oscilloscope, multimeter, signal generator, regulated voltage source, DC motor, MOSFETs transistors, capacitors, resistors, bread board for electronic circuit prototyping.

Introduction

DC brush motors are increasingly required for a broad range of applications including robotics, portable electronics, sporting equipment, appliances, medical devices, automotive applications, power tools and many others. The motor itself is a preferred alternative because it is simple, reliable and low cost. Equally important, advanced, fully-integrated "H-bridge" driver ICs are available to control the motor's direction, speed and braking. This lab will explore the basics of H-bridge drivers and discuss the advancement of the technology from discrete solutions to highly-integrated ICs. It will compare linear motor speed control with more advanced, higher-efficiency pulse-width modulation (PWM) techniques.

H-bridge Basics

The H-bridge circuit derives its name from the full-bridge circuit shown in Figure 1. The motor forms the cross-piece in the “H.” Speed and direction are controlled as current flows through the motor in the direction determined by the position of the switches in the bridge. In this example, with switches “A” and “D” closed, the motor will operate in a clockwise (CW) direction. With “B” and “C” closed, the motor will operate in the counterclockwise (CCW) direction.

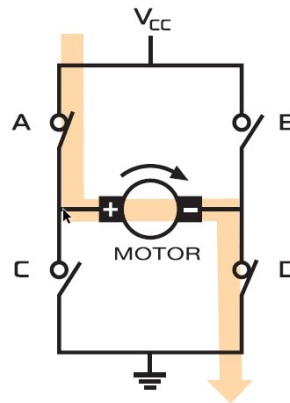


Figure 1. Simplified H-bridge Schematic.

In the linear output control implementation, the motor speed control is determined by the voltage applied across the motor. In the PWM implementation, the speed is controlled by the width of series of pulses of equal voltage. In either case, motor direction is controlled via separate logic inputs.

While the concept is simple, implementation is anything but simple if discrete components are employed. Controlling the operation of the switches and preventing simultaneous closure of the CW and CCW control outputs, particularly when reversing the direction of the motor or changing speed by dynamic braking requires an H-bridge controller. The H-bridge controller is then connected to four devices forming the legs of the bridge. In a discrete solution the designer must deal with voltage control levels, timing to prevent shoot-through. The shoot-through current usually leads to catastrophic damage in an H Bridge. Shoot through happens when both the High Side and Low Side Power MOSFETs or IGBTs are ON at the same time. Even in well-designed systems logic propagation, delays and MOSFET gate capacitances can create a situation where both the High and Low Side devices are concurrently switched ON. When this condition occurs the current flows directly to ground and bypasses the load. The discrete solution also requires additional circuitry for functions including overvoltage, overcurrent, overtemperature and electrostatic discharge (ESD) protection and the proper selection of the semiconductor switches.

All of this translates to a fairly complex design process resulting in a higher component count, larger footprint, and less reliable design solution than a fully-integrated LSI circuit solution.

H-bridge Driver Topology

Integrated H-bridge drivers are constructed by combining a controller, output drivers and protection circuits into a single package. The first H-bridge drivers used bipolar power transistors and bipolar control circuitry. The bipolar outputs were typically operated in the linear mode to provide speed control. Simple IC processing made the circuit practical even though die sizes were large to optimize power dissipation. A limitation of the bipolar output devices was higher power dissipation, especially in the speed control mode.

The use of power MOSFETs for the output devices was a natural transition for H-bridge drivers. In addition to the lower losses for a given voltage rating and smaller die size, voltage-controlled MOSFETs are easier to drive than the current-driven bipolar switches, facilitating efficient PWM control. In addition to higher efficiency, PWM provides tighter motor speed control as well as faster response. BiCMOS design for the control portion takes advantages of the strengths of bipolar and CMOS design providing high drive capability and low power dissipation. A comparison of the power dissipation characteristics of linear H-bridge drivers vs. the latest PWM output drivers is shown in Figure 2.

Ongoing improvements in power MOSFETs have increasingly shrunk the die size to handle a particular voltage and low on-resistance. Today, control circuitry and the four output drivers are offered in surface mount packages comparable to or only slightly larger than only one of the output switches required in a discrete implementation.

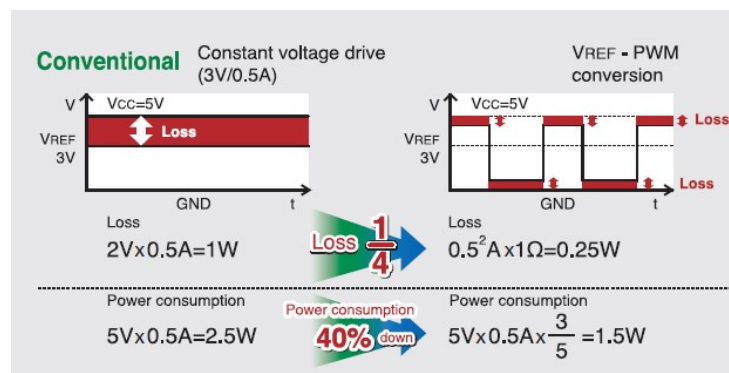


Figure 2. Comparison of linear vs. PWM implementation. In the linear implementation, at anything but full speed, the voltage drop across the control transistors results in significant power dissipation.

In summary, the H-bridge motor driver IC provides a monolithic solution to the control and output functions required to control the direction and speed of DC brush motors. Allowing Designers to utilize a variety of control strategies, both analog and digital, while providing the precision and efficiency of PWM control.

The Ideal H-bridge Driver

Figure 3 shows a block diagram of the functional elements. To handle either analog or digital inputs, the unit provides dual-mode speed control. V_{REF} provides the analog input. The chip converts the linear input at V_{REF} into efficient speed control using its internal PWM conversion circuitry. F_{IN} and R_{IN} are used with a microcontroller (MCU) or other digital logic inputs to control direction and speed.

The control logic takes input from the analog and digital source and efficiently controls the forward / reverse directions, speed and braking of the motor by switching the appropriate integrated power MOSFETs. P-Channel / N-Channel high-power CMOS output provides low on-resistance without requiring a charge pump and the associated external capacitors needed for the N-Channel MOSFETs in the high side switches common in many integrated H-bridge drivers. Rugged recovery diodes built into the structure eliminate the need for additional external recovery diodes. Combined bipolar and CMOS processing in a single chip design could achieves less than 1 μA current likage in standby mode. This is an important consideration for portable, battery-powered applications.

To protect the motor and the driver, protective circuitry should includes:

- Overvoltage protection (OVP)
- Undervoltage lockout (UVLO)
- Overcurrent protection (OCP)
- Thermal shutdown (TSD)
- Overlap (shoot-through) protection
- High ESD protection (3-4 KV)

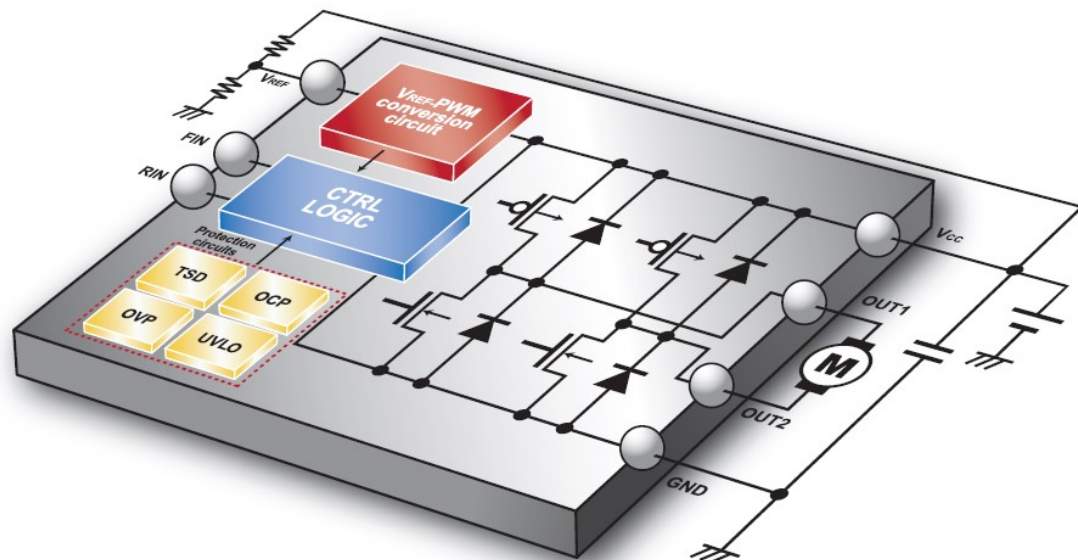


Figure 3. The ideal H-bridge driver includes flexibility for analog or digital operation and extensive protection circuitry.

Over- and undervoltage circuits keep the IC within its proper voltage operating range. OCP limits the current draw and essentially shuts the device down by forcing all driver outputs into a high impedance state in the event of a short circuit or other excessive current event such as a locked rotor. TSD protection can provide longer term protection when the chip is operating within its current capability but some other fault has occurred, such as an extremely high operating temperature environment or loss of adequate cooling in an enclosure or a deteriorated

PWM Speed Control Techniques Using H-bridge Drivers

Procedure [MCU Control]

With an MCU or other digital logic providing the PWM input, a circuit like the one in Figure 4 would be appropriate. The pulse train applied to the F_{IN} and R_{IN} lines controls the direction and the speed digitally from the MCU. Table 1 shows the logic for implementing PWM in the forward and reverse directions as well as brake and idle values. To complete the application, two external decoupling capacitors are connected from V_{CC} to IC ground.

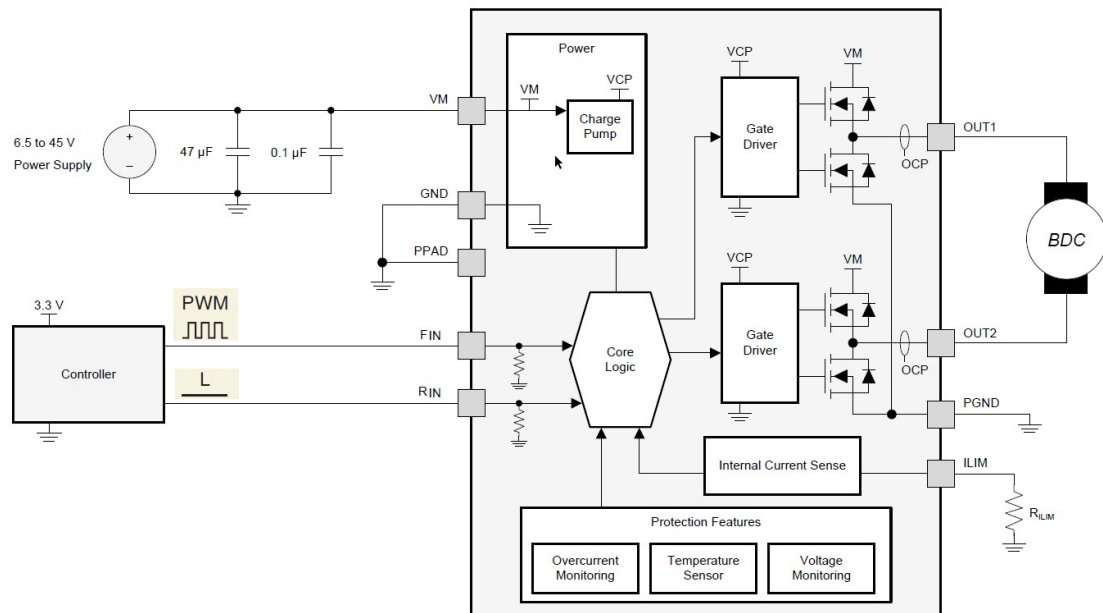


Figure 4. A digital controller, such as an MCU, can directly drive the control logic circuitry in the H-bridge driver.

Direct PWM control

Input		Output
F_{IN}	R_{IN}	
PWM	L	Forward
L	PWM	Reverse
H	H	Brake
L	L	Idle

Table 1. This table shows the application of the PWM pulse train and logic inputs to control speed, direction, and brake and idle status.

In []:

