H-BRIDGE

Electronics Project Report

Presented to: Eng. Mahmoud Yahia

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Table Of Contents:

1- Introduction:

What is an H-bridge?

An **H-bridge** is an electronic circuit that enables a voltage to be applied across a load, such as a motor, in either direction. This allows the motor to rotate clockwise and counterclockwise, making it an essential component in many motor control applications.

Why is it Important?

The **H-bridge** circuit is essential because it allows for full control over the direction in which a DC motor rotates. Without it, a motor would only spin in one direction unless the power wires are manually reversed. By using an H-bridge, we can automate this process electronically, enabling the motor to move forward or backward based on control signals. This is especially important in applications like robotics, electric vehicles, and automation systems, where precise and reversible motion is required. It also provides the foundation for more advanced motor control techniques, such as speed regulation using pulse-width modulation (PWM).

Applications:

H-bridge circuits are widely used in various fields, especially in:

- Motor Driver, for controlling the movement and direction of wheels or arms.
- Drones, to manage motor direction and speed.
- Power inverters, to switch the direction of current flow.

2- Objective:

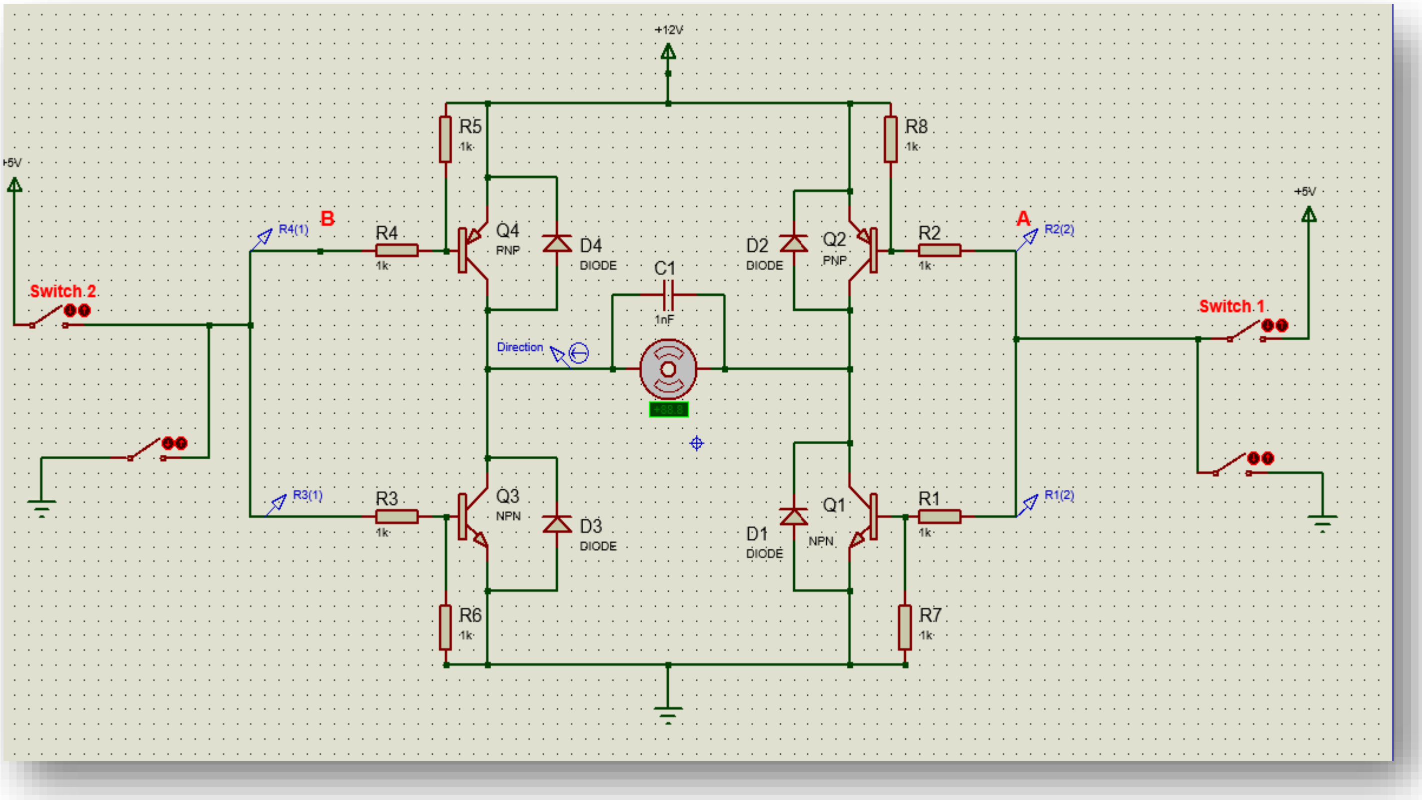

Figure 1

The H-Bridge circuit shown in Figure 1 is designed to control the direction of a DC motor by altering the polarity of the voltage applied to the motor terminals. The H-Bridge consists of **four power transistors (Q1, Q2, Q3, Q4)** arranged in an "H" configuration, with the motor placed in the center between the two legs. An additional 4 **control switches** (**Switch 1 and Switch 2)** are used to control the upper transistors (Q2 and Q4) safely from low-voltage logic inputs and the lower transistors (Q1 and Q3) from High-voltage logic inputs.

3- Components:

Component	Description
2N3904 (NPN) & 2N3906 (PNP) Transistors	Used as switches to control motor direction. NPNs (low-side) connect to ground, PNPs (high-side) connect to VCC.
1kΩ Resistors	Limit the base current to protect transistors and ensure proper switching.
Flyback Diodes	Protect transistors from voltage spikes caused by the motor's back-EMF.
DC Gear Motor with Wheel	Acts as the load. Drives the wheel forward or backward based on switch control

Table 1: Table of Components

4- Physical Implementation

Showcase video for simulation and real-life circuit:

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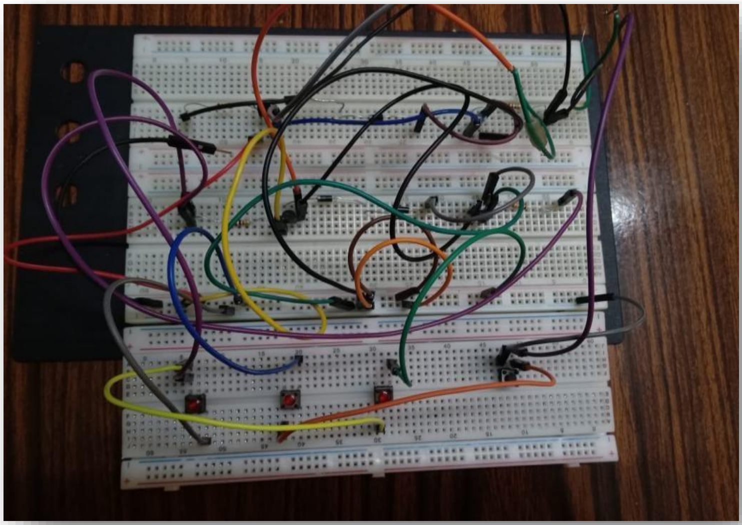


Circuit on breadboard

5- Circuit Description:

This H-Bridge circuit utilizes **4 transistors in an H-configuration** to allow bidirectional control of a DC motor, with two additional control transistors (Q5 and Q6) for level shifting and safe control.

- The **upper arms** of the bridge (**Q2 & Q4 - PNP 2N3906**) are activated when their bases are pulled LOW through Q5 or Q6.
- The **lower arms** (**Q1 & Q3 - NPN 2N3904**) are activated directly through base resistors.
- **Switches** act as user inputs to drive the appropriate control transistors.

5.1-Transistor Behavior:

- When a transistor is **turned ON**, it is in **saturation mode** and behaves like a **short circuit**.
- When a transistor is **turned OFF**, it is in **cut-off mode** and behaves like an **open circuit**.
- This ON/OFF behavior determines the current path through the motor.

5.2-Operation Logic:

Switch 1	Switch 2	Active Transistors	Motor Direction
ON	OFF	Q2 , Q3	Forward (CW)
OFF	ON	Q4 , Q1	Reverse (CCW)
OFF	OFF	None	Motor OFF
ON	ON	Causes a Short-Circuit	N/A

5.3-Forward Rotation:

- Switch 2 closes → Q2 ➔ **ON**
- Q3 ➔ **ON**

Current flows: **Q2** → **Motor** → **Q3**

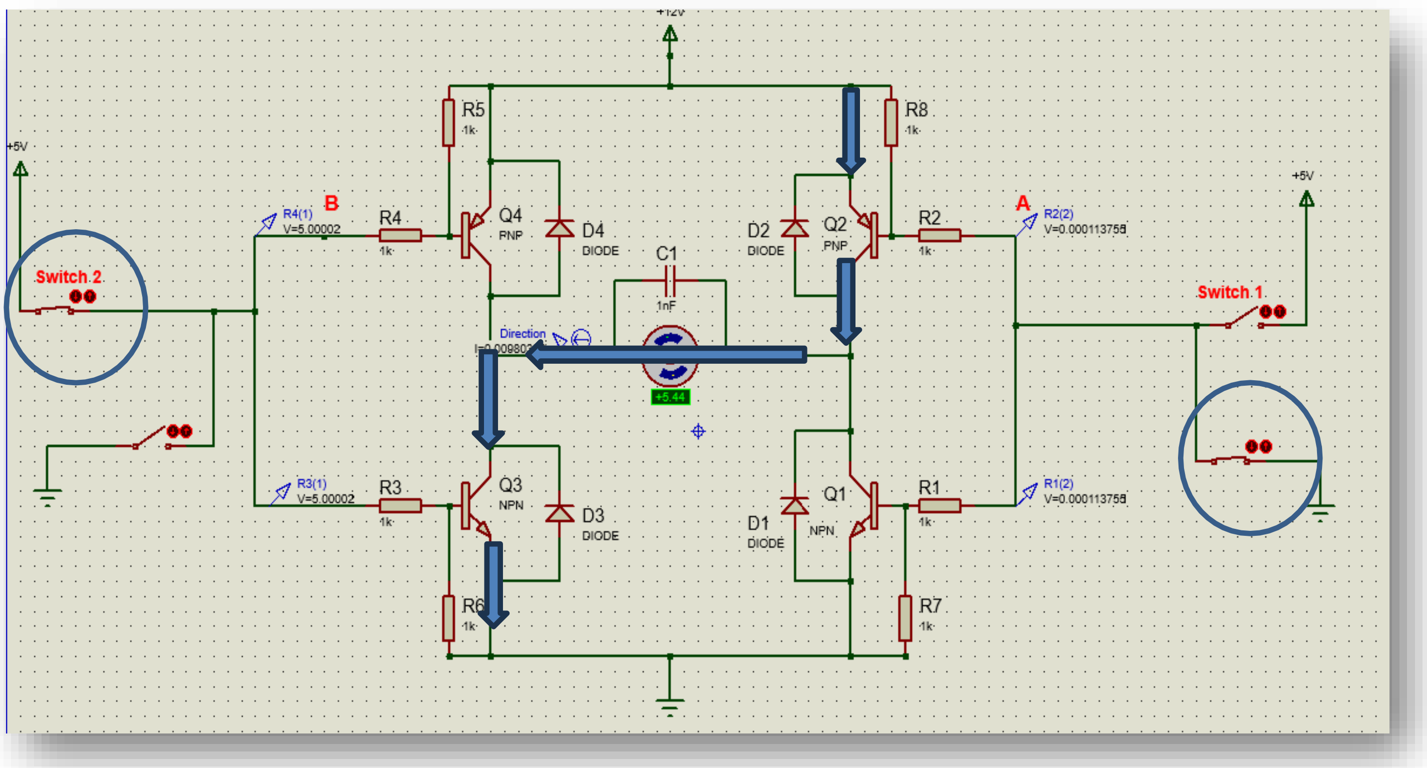


Figure 2

To find the relationship between the Motor Voltage *VMotor* and the Input Voltage *VCC*, we write KVL equations following the path labeled by the arrows in Fig.2:

$$V_{CC} = V_{EC(Sat,Q2)} + V_{Motor} + V_{CE(Sat,Q3)}$$

Hence:

$$V_{Motor} = V_{CC} - V_{EC(Sat,Q3)} - V_{CE(Sat,Q2)} = V_{CC} - 0.25 - 0.2 = V_{CC} - 0.45$$

5.4-Reverse Rotation:

- Switch 1 closes → Q4 ➔ **ON**
- Q1 ➔ **ON**

Current flows: **Q4** → **Mot**

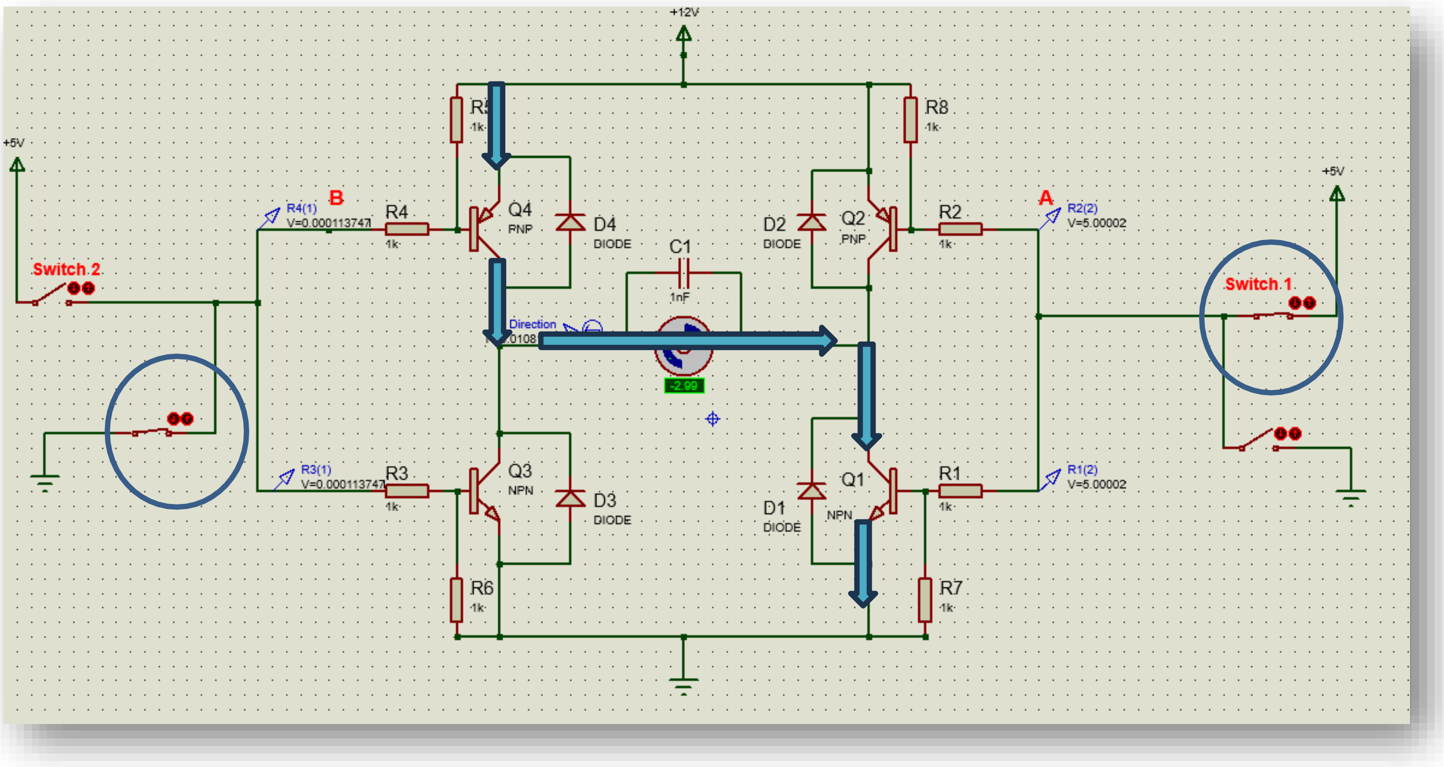


Figure 3

The same method can be used to find the Motor Voltage, *Motor,* and the Input Voltage *VCC* When the other path is active, we write a KVL equation following the arrows in Fig.3:

$$V_{CC} = V_{EC(Sat,Q4)} + V_{Motor} + V_{CE(Sat,Q1)}$$

Hence:

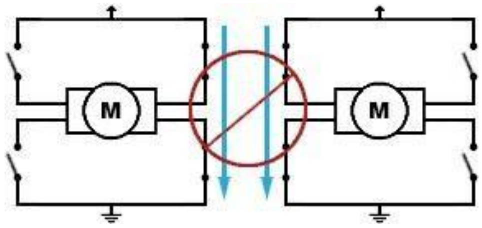
$$V_{Motor} = V_{CC} - V_{EC(Sat,Q4)} - V_{CE(Sat,Q1)} = V_{CC} - 0.25 - 0.2 = V_{CC} - 0.45$$

This shows the Motor Voltage. V_{Motor} equals $V_{Motor} = \pm(V_{CC} - 0.45)\ V$.

The plus or minus depends on the reference voltage polarity of the motor.

Both switches OFF: All main transistors are OFF → Motor stops.

Both Switches ON: Risk of **shoot-through** (both legs conducting simultaneously), shorting the supply to ground, must be avoided in hardware or controlled via software logic.



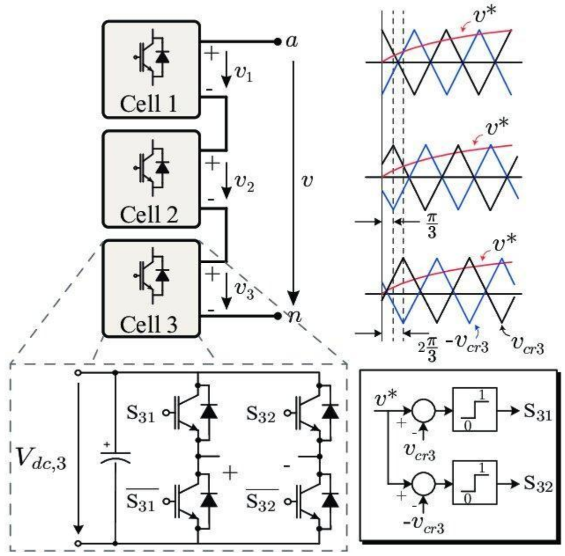
5.5-Additional Features:

- **Diodes (D1: D4)** protect transistors from inductive kickback.
- **Capacitor C1** across the motor suppresses high-frequency noise.
- **Base resistors** (1kΩ) ensure appropriate current limiting to protect BJT bases and ensure clean switching.

6- Speed Control Methods

6.1-PWM Implementation:

PWM controls motor speed by adjusting
The **average voltage** delivered to the motor while maintaining full voltage peaks. This is achieved by rapidly switching the transistors in the H-bridge on and off at a fixed frequency while varying the **duty cycle**.



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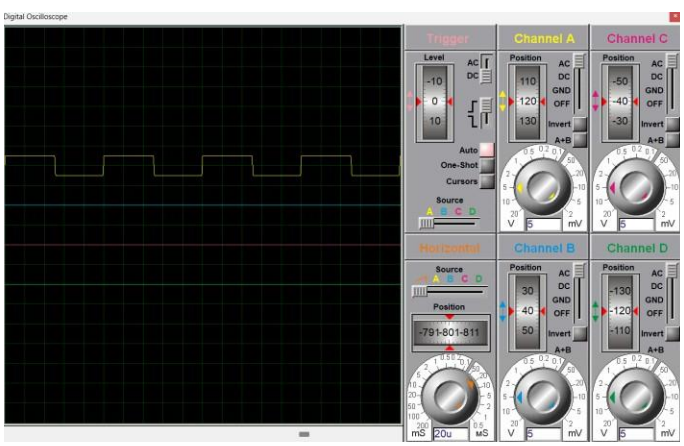
6.2- How PWM Works:

- High Duty Cycle (e.g., 80%) → Motor receives near-full
  voltage → Higher speed
- Low Duty Cycle (e.g., 20%) → Motor receives a low average
  voltage → Lower speed
- 0% Duty Cycle → Motor stops (no power)
- 100% Duty Cycle → Full voltage (maximum speed)

6.3-Simulation:



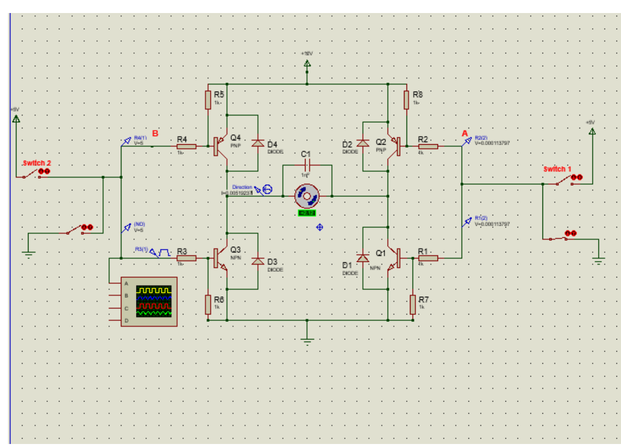


Figure 4

When applying **low voltage** to Q2 and **PWM is applied** to Q3, as we see in Fig. 4, the motor rotates **forward**, and its speed varies according to the PWM duty cycle.
When applying **low voltage** to Q4 and **PWM is applied** to Q1, the motor rotates in **Reverse**, and its speed varies according to the PWM duty cycle.
The **oscilloscope** shows the PWM waveform corresponding to the signal applied to the transistor bases.

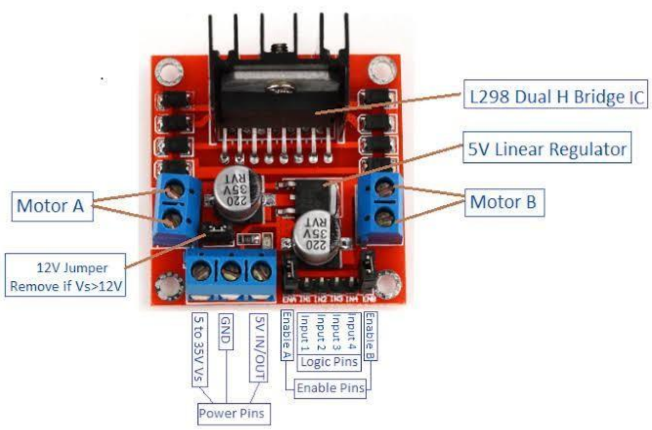
7- Application

One of the main applications of the H-Bridge circuit is in the design of motor driver modules. The most common module is the **L298N**, which is based on the **H-Bridge** concept to control the direction of DC motor rotation.

The **L298N** module uses two pairs of transistors arranged in an H-Bridge configuration, allowing control over the current flow through the motor, and thus controlling its rotation direction. The module has two input pins (IN1 and IN2) for each motor. By sending digital signals to these pins, it is possible to control which transistors are activated.

For example:

- When IN1 = HIGH and IN2 = LOW, the motor rotates in one direction.
- When IN1 = LOW and IN2 = HIGH, the motor rotates in the opposite direction.
- When both IN1 and IN2 are either HIGH or LOW, the motor stops.



8-Conclusion

- In this project, we built a practical H-Bridge circuit to control a DC motor. The design uses four transistors arranged in an H-Bridge configuration, along with manual switches to control the motor's direction, and flyback diodes to protect the circuit from voltage spikes caused by the motor’s inductance.

- Building the H-Bridge with transistors was especially beneficial because it applied the theoretical knowledge we studied about transistor operation. By using transistors as switches, we could control high current to the motor safely and efficiently, which would not have been possible using simple mechanical switches alone. This project helped us practically understand how transistors work in switching applications and how they can be used to control large loads like a motor.

- It is possible to use MOSFETs instead of Bipolar Junction Transistors (BJTs) to build the H-Bridge circuit. Using MOSFETs offers several advantages, the most important of which is that a MOSFET has a very low resistance when in the ON state, which reduces power loss and the resulting heat. Additionally, a MOSFET requires a very small gate current to control it, unlike a BJT, which requires a larger base current. However, we preferred not to work with MOSFETs because we had not studied them at the time we started the practical implementation of the project.

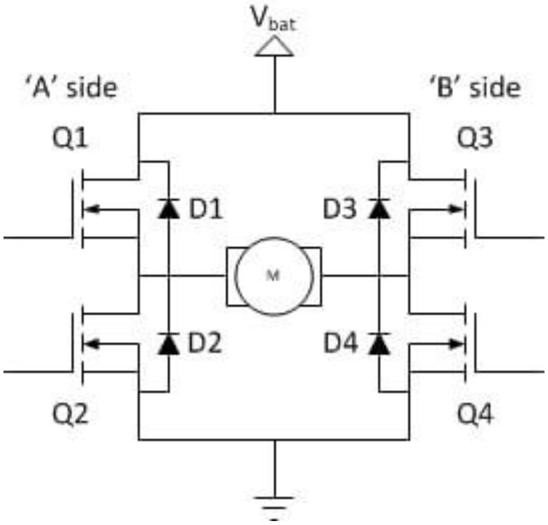


Figure 5: H-Bridge With MOSFETs

H-BRIDGE

9-Reference:

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