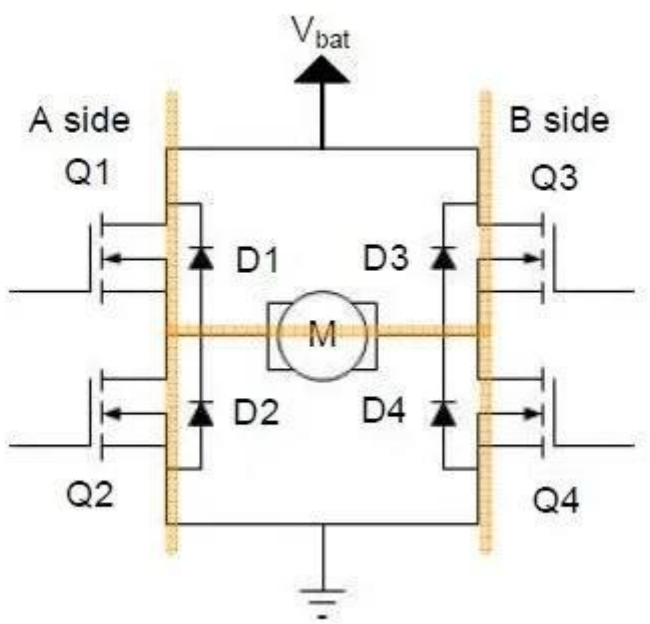
H-bridge Concept Introduction

An **H-bridge** is an electronic circuit that reverses the voltage/current at both ends of the load or output to which it is connected. These circuits are used in robots and other real-world applications for DC motor inversion control and speed control, stepper motor control (bipolar stepper motors must also contain two H-bridge motor controllers), most DC-AC converters in electrical energy conversion (such as inverters and inverters), some DC-DC converters (push-pull converters), and other power electronics devices.

H-bridge is a typical DC motor control circuit because its circuit shape resembles the letter H, so it is named with "H-bridge". 4 transistors form the 4 vertical legs of H, and the motor is the horizontal bar in H.

The H-bridge circuit can be built as discrete components or integrated into **an integrated circuit** and is often used in inverters (DC-AC conversion). Through the opening and closing of switches, DC power (from batteries, etc.) is inverted into AC power of a certain frequency or variable frequency, which is used to drive AC motors (asynchronous motors, etc.).

The H-bridge is shown in detail in the following figure.



H-bridge circuit

Here there are four switching components Q1, Q2, Q3, Q4, in addition to a DC motor M. D1, D2, D3, D4 are MOS-FET continuity diodes.

Ⅱ Working principle

The operating principle of a single-phase bridge inverter circuit as shown in the figure H-bridge inverter (single-phase)

H-bridge inverter circuit (single phase)

Switch T1, T4 on, T2, T3 off: u0 = Ud.

Switch T1, T4 off, T2, T3 on: u0 = -Ud;

When switching switches T1, T4 and T2, T3 alternately at frequency fS, an alternating voltage waveform (square wave alternating positive and negative) is obtained at the load **resistor** R with period Ts=1/fS. In this way, the DC voltage E is turned into AC voltage uo. uo contains all harmonics and can be filtered by a filter if a sinusoidal voltage is desired.

The main circuit switches T1 to T4, which is actually an ideal model for various **semiconductor** switching devices. The common switching devices used in inverter circuits are fast thyristor, turn-offable **thyristor** (GTO), power **transistor** (GTR), power **field-effect transistor** (MOSFET), and insulated gate transistor (IGBT).

In practice, there are losses in switching devices: conduction losses and commutation losses, and gate losses. The gate losses are negligible, while the conduction losses and phase change losses increase with the switching frequency.

Ⅲ Control method

The control of the H-bridge is mainly divided into approximate square wave control and pulse width modulation (PWM) and cascaded multi-level control.

Approximate square-wave control

The output waveform has one more zero level (3-level) than the alternating positive and negative square wave, and the harmonics are greatly reduced.

The advantage is that the switching frequency is lower, but the disadvantage is that the harmonic component is high and the cost of the filter is large.

Pulse width modulation

Pulse width modulation is divided into unipolar and bipolar PWM. As the switching frequency increases, the output voltage and current waveform tends to be sinusoidal and the harmonic components are reduced, but the high switching frequency brings a series of problems: large switching losses, high insulation pressure on the motor, heat generation, etc.

Cascaded multi-level control

The multi-level inverter is a cascaded H-bridge, which minimizes harmonic distortion at the same switching frequency, even without a filter, to obtain a good approximation of a sinusoidal output waveform.

Ⅳ Switching state

The following is a brief introduction to several switching states of the H-bridge, taking a DC motor as an example, where forward and backward are artificially specified directions, and the actual engineering can be divided according to the actual situation.

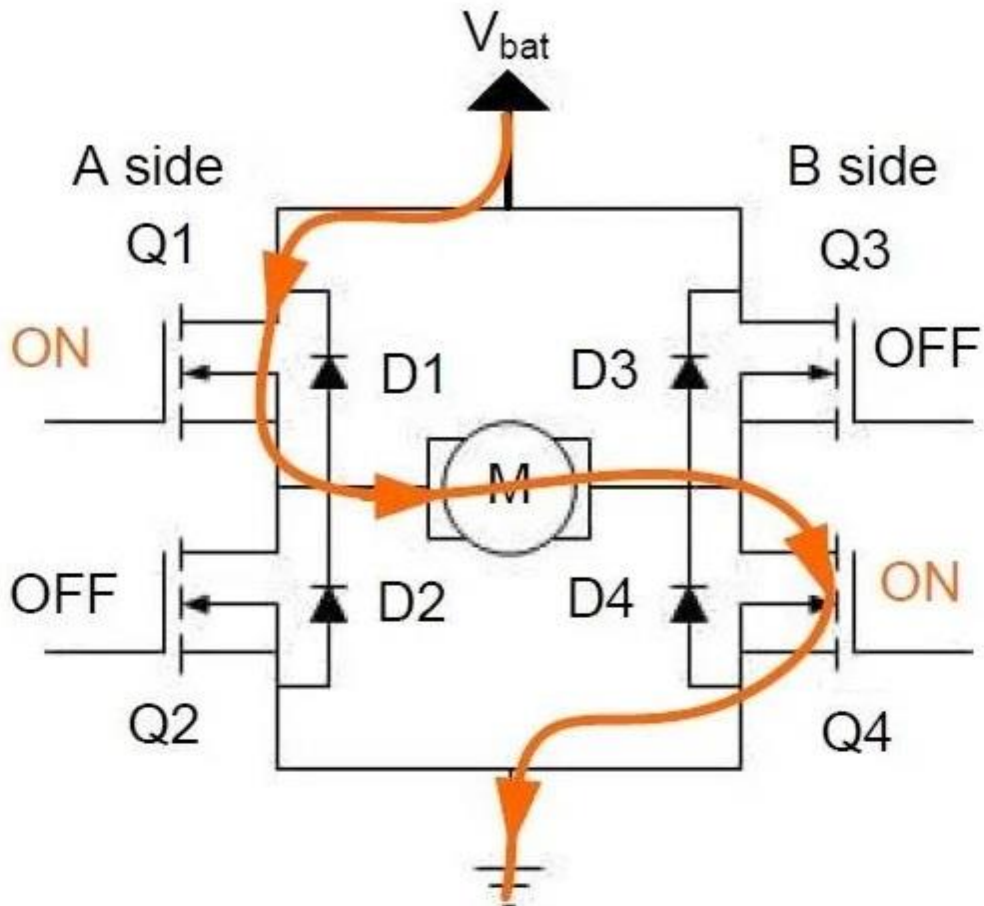
Forward

Usually, the H-bridge is used to drive inductive loads, here we drive a DC motor.

Turn on Q1 and Q4.

Turn off Q2 and Q3.

At this point, assuming the motor is forward, this current passes through Q1, M, Q4 in turn, marked in the diagram using the yellow line segment, as shown below.



H-bridge motor forward circuit

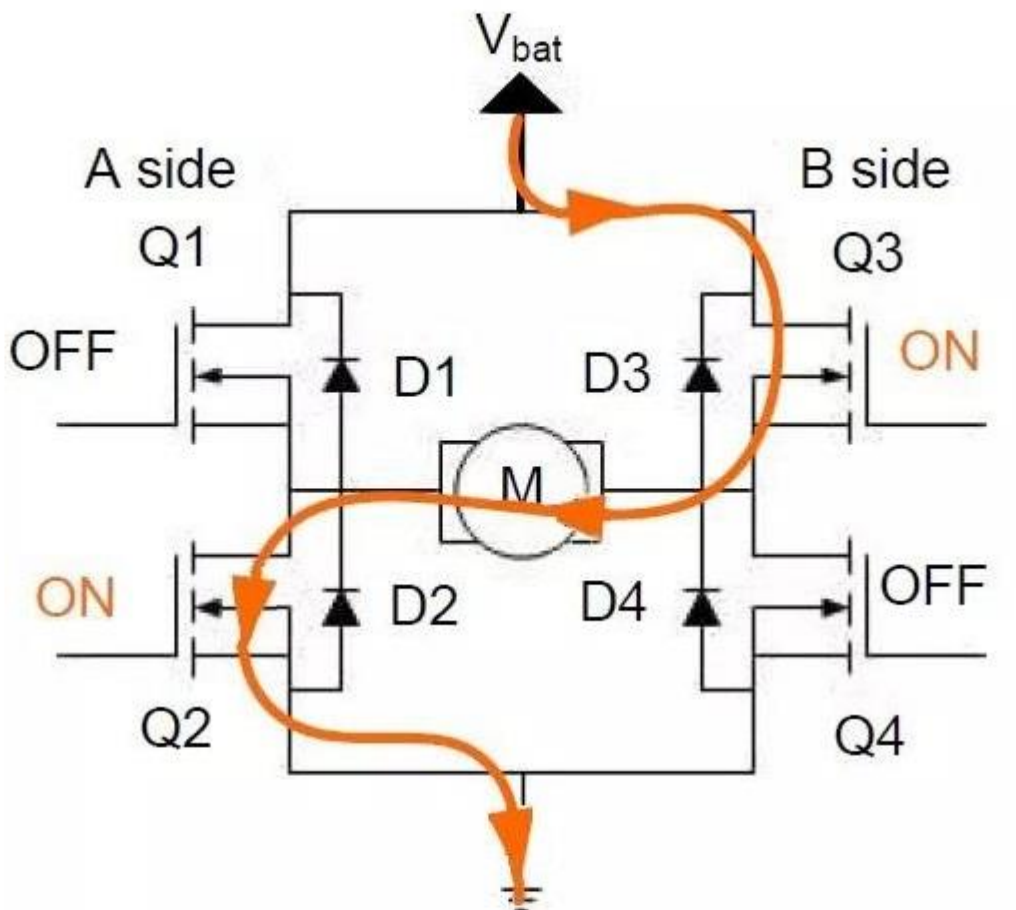
Backward

Another state is the motor backward; at this time the state of the four switching components are as follows.

Turning off Q1 and Q4.

Turning on Q2 and Q3.

At this point the motor reverses (opposite to the case described earlier), which current passes through Q2, M, and Q3 in turn, marked in the diagram using yellow lines, as shown in the figure below.



H-bridge motor reverse circuit

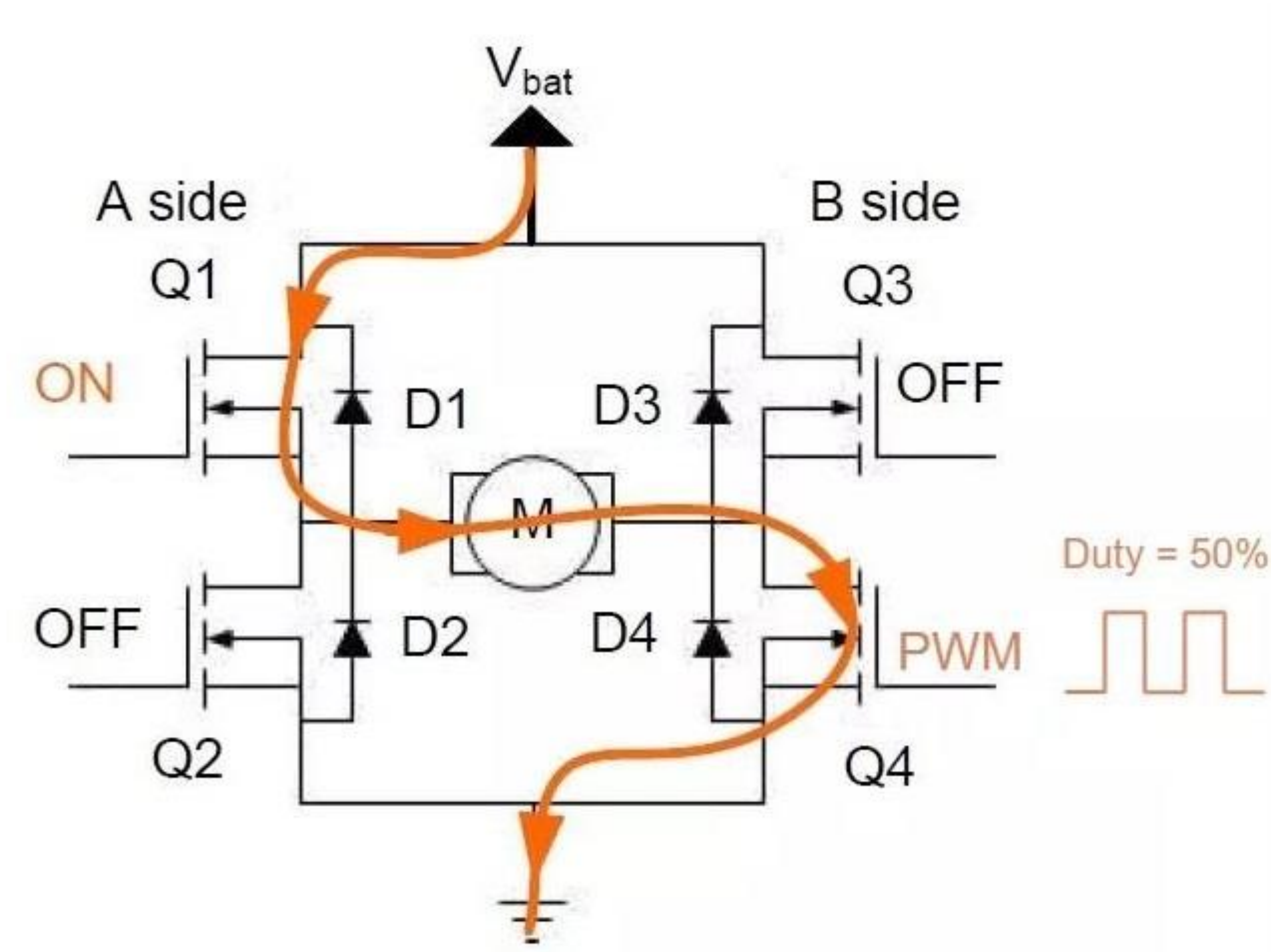
Speed regulation

If the DC motor is to be speed regulated, one of the options is.

Turning off Q2, Q3.

Turning on Q1, giving it a 50% duty cycle PWM waveform on Q4 so that the effect of reducing the speed is achieved, and if the speed needs to be increased, setting the duty cycle of the input PWM to 100%.

As shown below.



DC motor speed control circuit

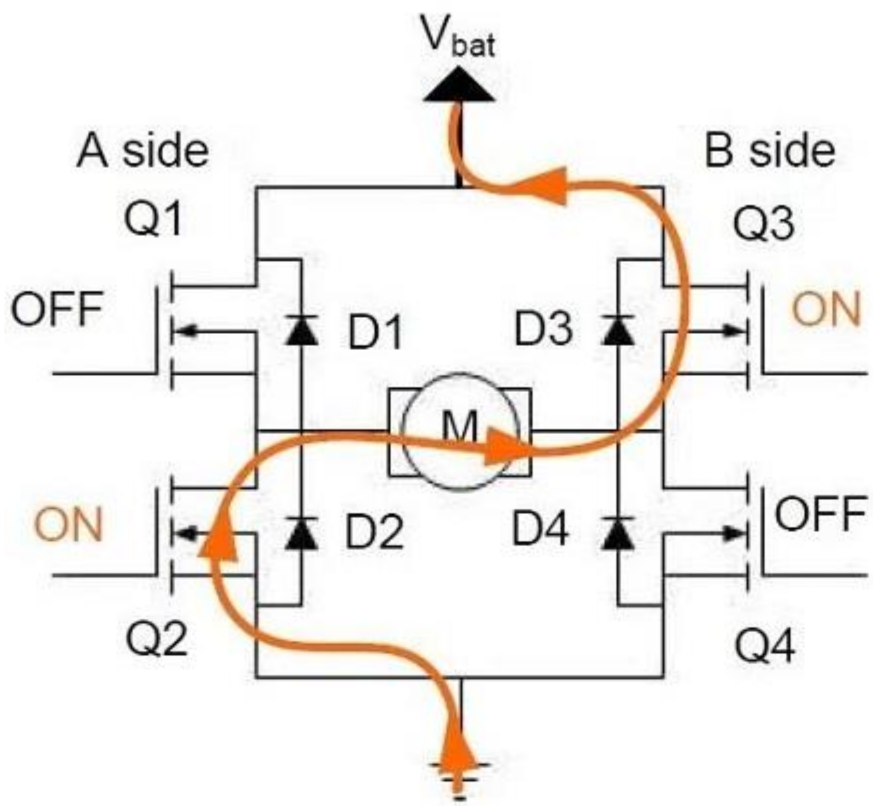
Stop state

Here the motor is switched from forward to stop state as an example.

- In the case of forward, Q1 and Q4 are open.
- At this time, if Q1 and Q4 are turned off, the DC motor internal can be equivalent to an inductor, that is, inductive load, the current will not change suddenly, then the current will continue to maintain the original direction of flow.

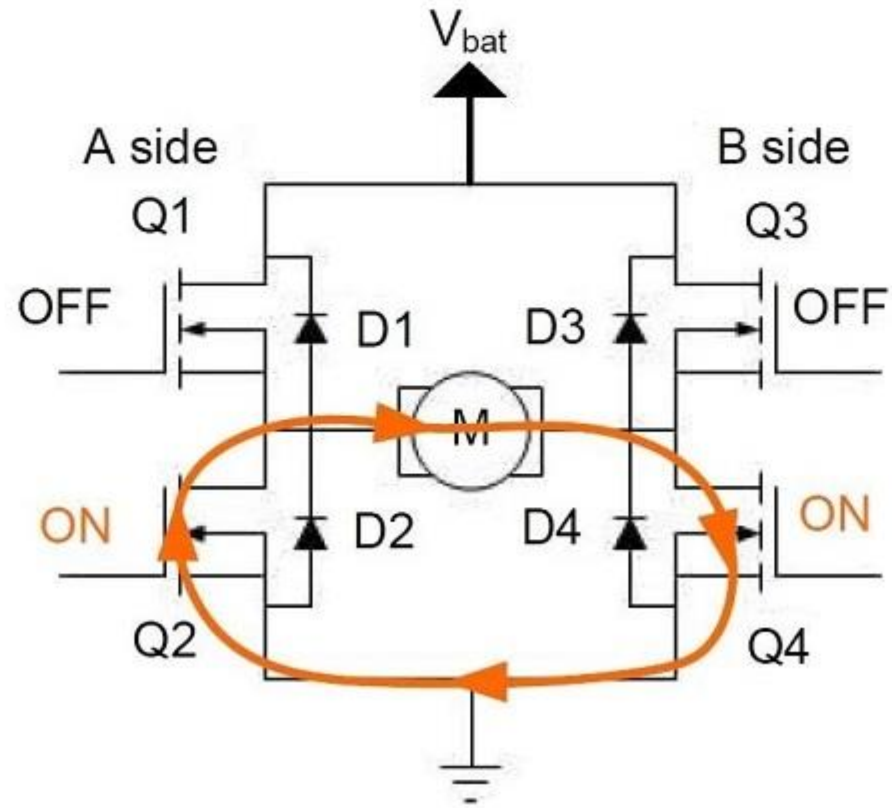
Now, we hope that the current in the motor can be quickly decayed. There are two approaches here.

The first: close Q1 and Q4, when the current will still flow through the reverse continuity diode, then briefly open Q1 and Q3 so as to achieve the purpose of rapid decay of the current.



Motor stop state circuit (1)

The second: when preparing to stop, turn off Q1 and turn on Q2. At this time, the current does not decay very quickly. The current circulates between Q2, M, and Q4, and the power is consumed by the internal resistance of the MOS-FET.



Motor stop state circuit (2)

Ⅴ Applications

The actual use of discrete components to make an H-bridge is very troublesome, there are already many more commonly used IC solutions on the market, such as the commonly used L293D, L298N, TA7257P, SN754410, etc... Connect the power supply and the motor, and then the motor can be driven by inputting the control signal.

The following is the L298N module, which is relatively common, very friendly to novice players, and the wiring is very simple.