Electronics
H-Bridges and DC Motors

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DC motor

Permanent Magnet DC Motor (PMDC)

PMDC (Permanent Magnet DC) uses permanent fixed magnets. An armature on the shaft has an electromagnet. A commutator on the shaft reverses the current direction every half rotation. Speed is controlled by current, and direction is controlled by polarity. This results in continuous motion.
DC motor

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H-Bridge

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Allows a DC motor to run in either direction with a single supply

uses four transistors

either BJTs or FETs can be used

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Transistors

There are several types of transistor; each is a three terminal device. The most common types of transistors are BJTs and FETs. Transistors are often used in voltage dividers to act as variable resistors.
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- source
- gate
FET symbol
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\[ \text{drain} \]
FET symbol

\[
\begin{array}{c}
\text{drain} \\
\text{source}
\end{array}
\]
FET symbol

gate \quad \| \quad \text{drain}

source
FET operation

- FETS are *voltage* amplifiers; a small *gate voltage* controls a much larger *drain/source current*.
FET operation

- FETS are voltage amplifiers; a small gate voltage controls a much larger drain/source current.

Actually it’s the voltage between the gate and the source which matters.
D and E MOSFETs

There are two kinds of MOSFET:

- **Enhancement mode (E type)**: When \( V_{gs} \) is below \( V_{th} \), \( I_{D} = 0 \). As \( V_{gs} \) increases above \( V_{th} \), \( I_{D} \) increases.

- **Depletion mode (D type)**: To get \( I_{D} \) to zero, a negative \( V_{gs} \) off must be applied.

In an H-bridge, you want E-MOSFETS so no current flows with no applied gate-source voltage.
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Bipolar Junction Transistors
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- base

The current from the collector to the emitter is controlled by the *current* into the base.
collector
BJT operation

BJTs are current amplifiers; a small base current controls a much larger collector/emitter current. You should always have a base resistor with a BJT!
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H bridge (shown with BJTs)
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Current flows from left to right.
H bridge (shown with BJTs)

Current flows from right to left.
EMF considerations
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- inductive loads require a few special considerations
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- a motor is an inductive load
Induced EMF

Quickly changing voltage across inductor produces induced EMF. Induced voltage tries to counteract change in current and can produce big voltage spikes.

A diode across a coil will limit voltages to $\approx 0.7$ V. A zener diode can limit voltages the other way to about the zener voltage.
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No diode to reduce induced EMF

Initially $I = 0$. 
No diode to reduce induced EMF

Induced voltage tries to maintain $I = 0$. 
No diode to reduce induced EMF

Eventually current is established determined by resistance in circuit.
No diode to reduce induced EMF

Induced voltage tries to maintain $I$ at the previous value.
No diode to reduce induced EMF

Eventually current is reduced to $I = 0$. 
Diode to reduce induced EMF

Initially $I = 0$. 

$I = \bar{0}$
Diode to reduce induced EMF

Induced voltage tries to maintain $I = 0$, *but cannot exceed* $V_Z$. 
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Eventually current is established determined by resistance in circuit.
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Induced voltage tries to maintain $I$ but cannot exceed $\approx 0.7\,V$. 
Diode to reduce induced EMF

Eventually current is reduced to $I = 0$. 
H bridge with diodes included

![H-bridge circuit diagram]

1. V+
2. GND
3. Motor
4. 1, 2, 3, 4
Diodes across the transistors

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L9110 H-bridge
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- There are several H-bridge chips available.
- The L9110 is one example.
- There are boards with two allowing independent control of two motors.
All the two motors have in common are the supply voltages.
If the 1A input is HIGH and the 1B input is LOW, the motor will run in one direction.
If the 1A input is LOW and the 1B input is HIGH, the motor will run in the other direction.
Controlling Speed

Controlling the base current or gate voltage may be difficult. However, pulse-width-modulation allows you to control the average power. This is the easy way to control speed. As long as the frequency is high enough, mechanical inertia will make the motion smooth.
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Pulse width modulation to limit current

PWM can be used on one input.
Pulse width modulation to limit current

Motor A

or the other.
Pulse width modulation to limit current

Alternatively, you can use PWM on one input.
Pulse width modulation to limit current

and control direction with the other.
Pulse width modulation to limit current

In this case *decreasing* the duty cycle will *increase* power in one direction.