How to drive a DC Motor

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L. S. M. Course
An **Electric Motor** is a machine that transforms **electric energy** into **mechanical energy**

- This is obtained by exploiting some magnetic properties of materials and electric current.
- There are different kinds of electric motors:
  - **DC Motors** (DC=direct current) or **brushed motors**
  - **AC Motors** (AC=alternate current) or **brushless motors**
  - Special brushless motors (**stepper motors**)
Any electric motor is made of two parts:

- **Stator**, a static part
- **Rotor**, the part which is made rotating thus generating the mechanical energy

One of the two parts is made of **permanent magnets**

The other part is made of **coils of copper wire** that generate magnetic field when the electric current flows

The rotation is generated by the **contrast** of the magnetic fields generated by the stator and the rotor

In order to ensure rotation, the magnetic field **must change continuously**

The **angular velocity** of the motor is proportional to the **intensity of the magnetic field** which, in turn, is proportional to the voltage applied to the motor
In a direct current motor:
- the stator is the *external container*, it is made by permanent magnets
- the rotor is a set of *copper wire coils*

A system of "brushes" (crawling contacts) are able to continuously change the *polarity* of the voltage applied to the coils, thus causing the *continuous inversion of the magnetic field*.
The basics of DC motor driving is made of an electronic based on **four electronic switches (transistor MOSFET)** $A, B, C, D$ connected as in figure.

The configuration is called **H-bridge** because it has the shape of the letter “H”.

![H-Bridge Diagram](image)
Clock-wise and Counter-clock-wise rotation

- By activating switches A and D, the current will flow in the direction depicted at the left → the motor will rotate clock-wise.
- By activating switches B and C, the current will flow in the direction depicted at the right (opposite to the previous case) → the motor will rotate counter-clock-wise.

Rotazione CW (Clockwise)  
Rotazione CCW (Counter-Clockwise)
In order to modulate the speed of the rotor, we must change the **voltage** applied to the motor.

As in any other power system, the technique used is based on a periodic sequence of **power-on** and **power-off** of the motor.

This is made possible by using a **Pulse Width Modulation\(^1\)**=PWM signal.

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\(^1\) Pulse Width Modulation
The H-bridge is implemented in a integrated circuit called **DC motor driver**

It acts a an interface between the microcontroller (logic part) and the **power part**, usually at high voltages (12V and above)

The MCU has only to provide a **PWM Signal** and a **Direction signal**
The H-bridge is implemented in a integrated circuit called **DC motor driver**

It acts a an interface between the microcontroller (logic part) and the **power part**, usually at high voltages (12V and above)

The MCU has only to provide a **PWM Signal** and a **Direction signal**

- **CW** → Dir1=1, Dir2=0
- **CCW** → Dir1=0, Dir2=1
- **STOP** → Dir1=0, Dir2=0
Reading Speed and Position
Electric motors can have a **position sensor** called **encoder**

An encoder translates the **angular position** of the axis in a numeric value (properly scaled)

Encoders can be:
- Resistive
- Optical
- Magnetic
An optical encoder is made of a disc with a set of holes (e.g. 500, 1000, 2000, etc.) that rotates with the motor axis.

In the area of the holes, there are a LED and a photodiode that can detect holes.

Disc rotation causes the photodiode to generate a burst of pulses: the higher the rotation speed, the higher the frequency of the pulse signal.

The pulse signal is connected to a hardware interface that can count the generated pulses thus providing the numeric value to the software in a proper variable.
Optical encoder can determine:

- **angular position**, by counting “ticks”
- **Speed**, by computing the tick difference between two subsequent time instant, divided by the time interval

However, it **cannot** determine the rotation direction.
An optical **quadrature encoder** is made of a disc with two concentric series of holes.

There are two pairs LED/photodiode, called channels “A” e “B”.

The holes are displaced of “half a tick” (see figure).

*Note: this type of encoder is commonly used in computer mice with a roller ball.*
The “half tick” displacement causes a different generation of the pulses in the channel A and B, on the basis of rotation direction CW or CCW.

The signal sequences generated on channels A and B are:
- CW: $AB = 01 \rightarrow 11 \rightarrow 10 \rightarrow 00 \rightarrow 01 \rightarrow 11 \rightarrow \ldots$
- CCW: $AB = 01 \rightarrow 00 \rightarrow 10 \rightarrow 11 \rightarrow 01 \rightarrow 00 \rightarrow \ldots$
Hardware interfaces for this type of sensors are called **QEI - Quadrature Encoder Interface**

These interfaces identify the different sequences:
- **CW**: $AB = 01 \rightarrow 11 \rightarrow 10 \rightarrow 00 \rightarrow 01 \rightarrow 11 \rightarrow \ldots$
- **CCW**: $AB = 01 \rightarrow 00 \rightarrow 10 \rightarrow 11 \rightarrow 01 \rightarrow 00 \rightarrow \ldots$

The counter value is
- incremented if CW
- decremented if CCW
STM32 MCU provide a **QEI mode** for TIMERS

The **QEI mode** is a particular functionality of the **Capture Circuit**

In each timer, **Channels 1 and 2** can be configured in QEI Mode

In QEI Mode, signals from Channels 1 and 2 are “interpreted by the hardware” and the value of the **CNT** register is properly incremented or decremented
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