How to drive a DC Motor

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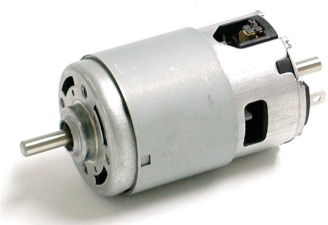
L. S. M. Course

Electric Motors

- 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 kind of electric motors
  - DC Motors (DC=direct current) or **brushed motors**
  - AC Motors (AC=alternate current) or **brushless motors**
  - Special brushless motors (**stepper motors**)

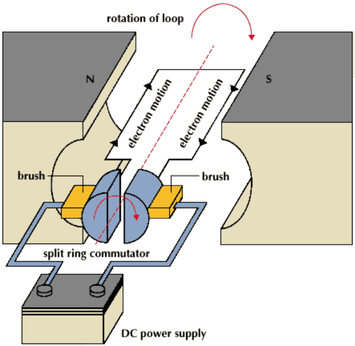


Electric Motors

- 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

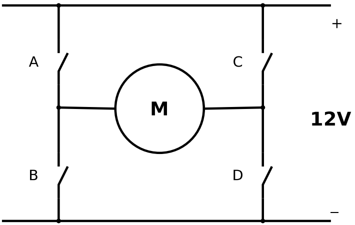
Direct Current (Brushed) Motor

- 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**



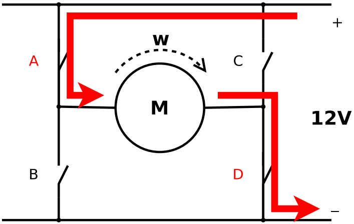
DC Driving - H Bridge

- 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”

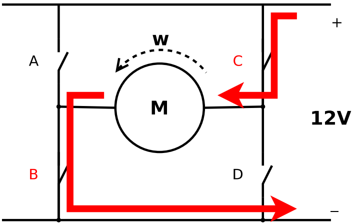


Clock-wise and Counter-clock-wise rotation

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



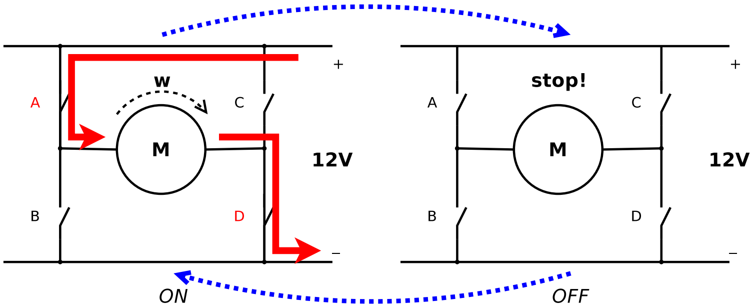
Rotazione CW (Clockwise)



Rotazione CCW (Counter-Clockwise)

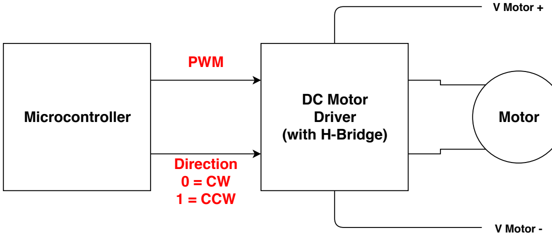
Modulating rotation speed

- 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=PWM** signal



Connecting a DC Motor to a Microcontroller

- 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**



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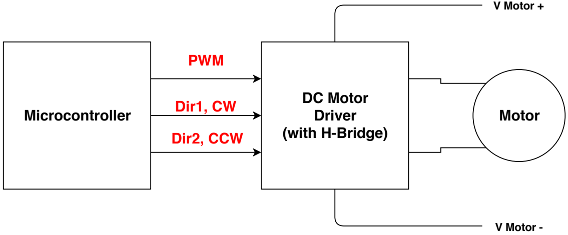
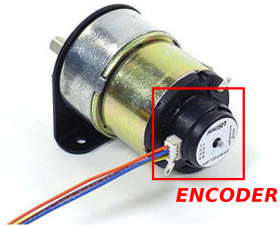


- **CW**→Dir1=1, Dir2=0
- **CCW**→Dir1=0, Dir2=1
- **STOP**→Dir1=0, Dir2=0

Reading Speed and Position

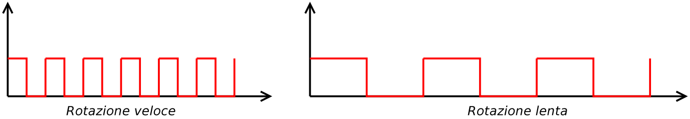
Encoder

- 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

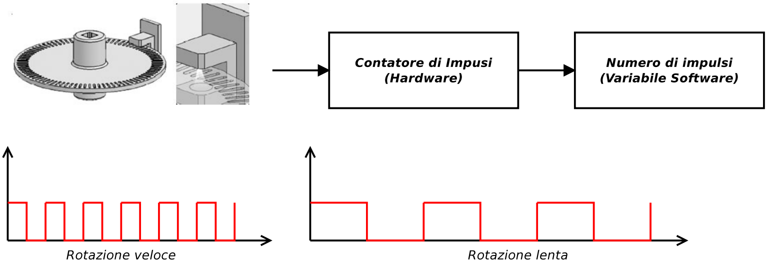


Optical Encoders

- 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 detected 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**



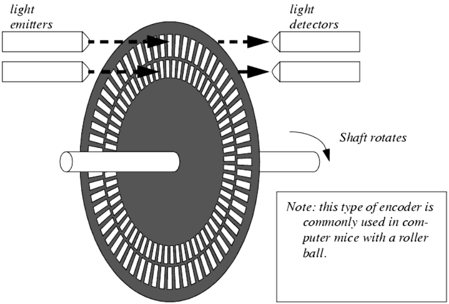
Encoders and measures

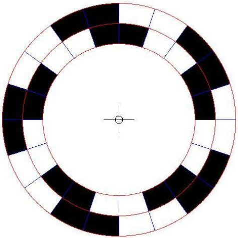


- Optical encoder can determine:
  - **angular position**, by counting “ticks”
  - **Speed**, by computing the tick difference between two subsequent time instant, divided by the time interval
- However, **it cannot** determine the **rotation direction**

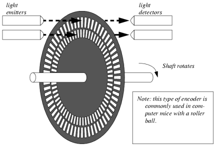
Quadrature Encoders

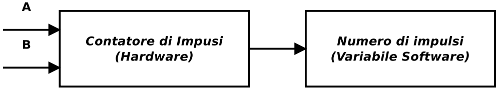
- An optical **quadrature** encoder is made of a disc with **two concentric series of holes**
- There are **two pairs LED/photodiode**, called channels “A” e “B”
- The holes are **displaced of “half a tick”** (see figure)

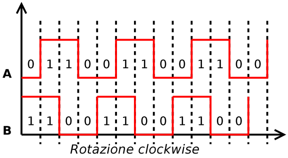


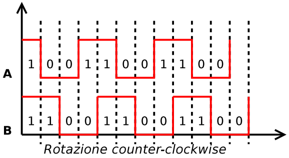


Quadrature Encoders



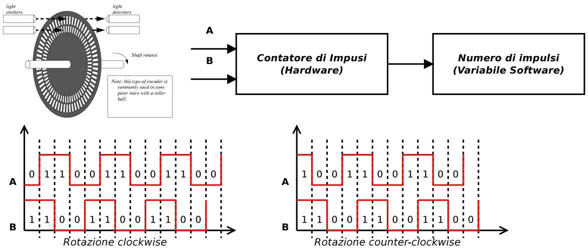






- The “half tick” displacement causes a different generation of the pulses in the channel A and B, on the basis of rotation direction CW or CCW
- The signal sequences generated on channels A and B are:
  - CW: $AB = 01 \rightarrow 11 \rightarrow 10 \rightarrow 00 \rightarrow 01 \rightarrow 11 \rightarrow \ldots$
  - CCW: $AB = 01 \rightarrow 00 \rightarrow 10 \rightarrow 11 \rightarrow 01 \rightarrow 00 \rightarrow \ldots$

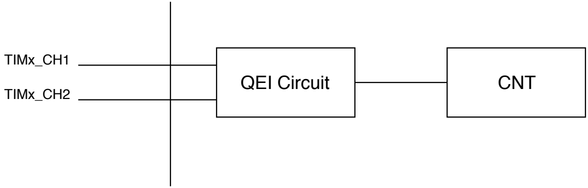
Quadrature Encoders



- 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**

QEI Interface and STM32

- 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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