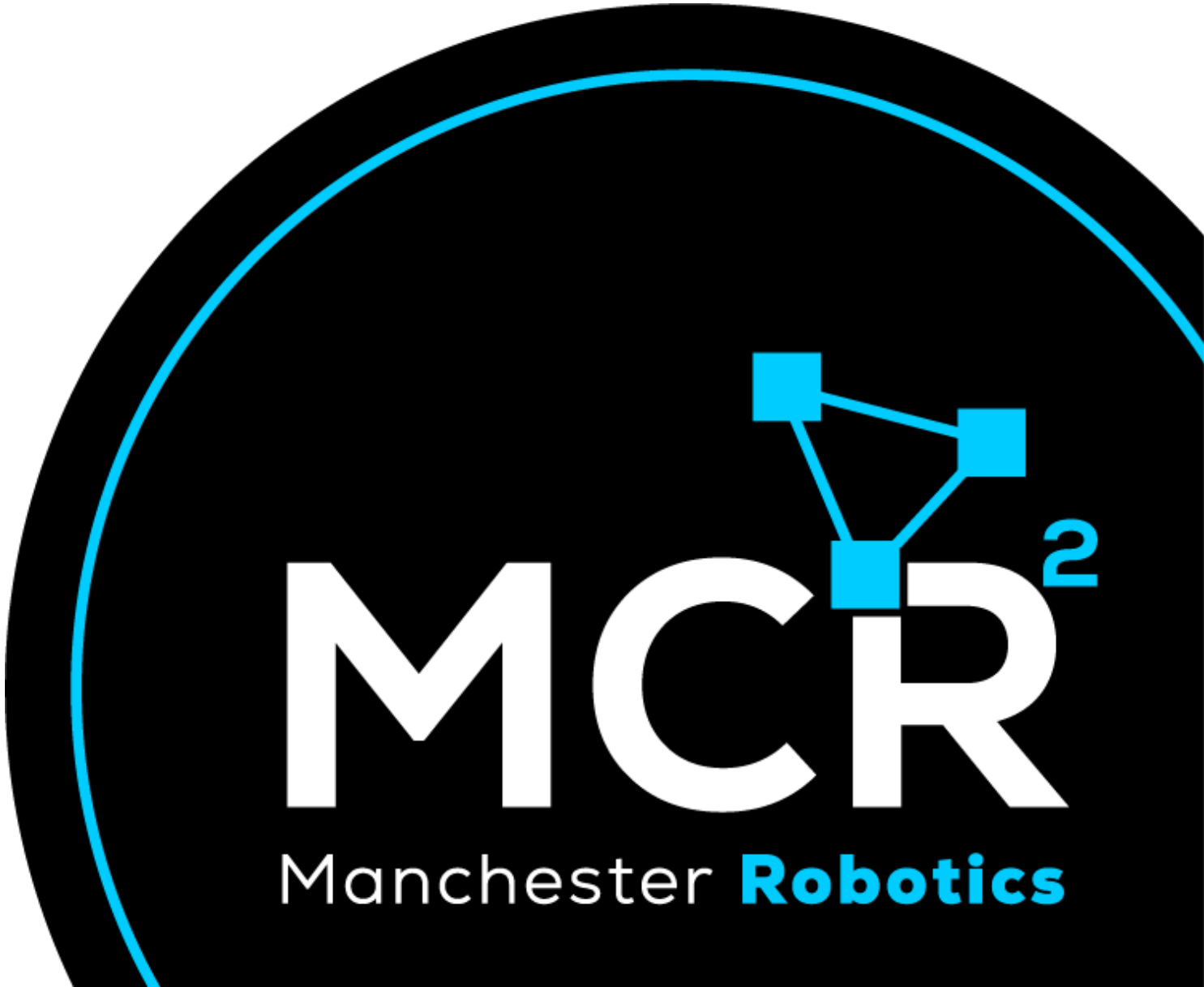
{Learn, Create, Innovate};

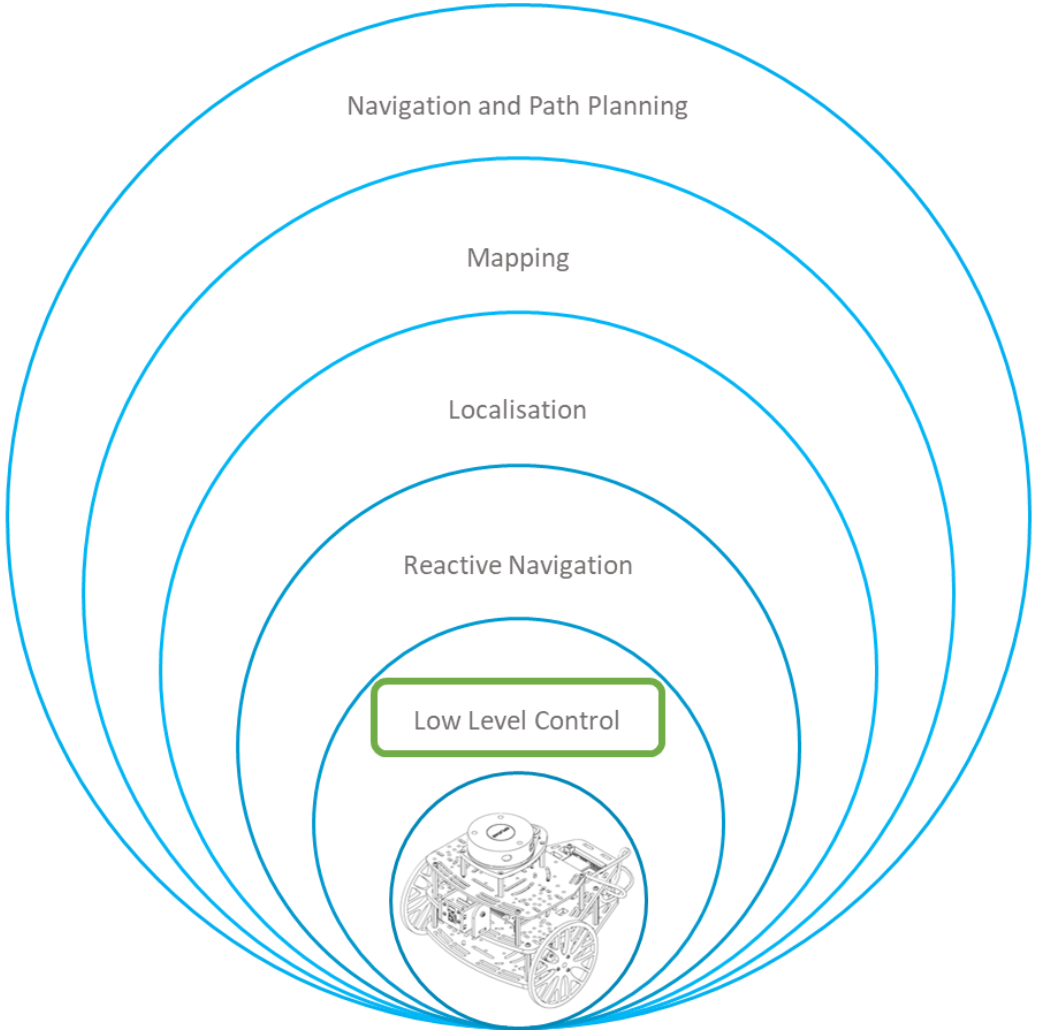
DC Motor Control

Introduction

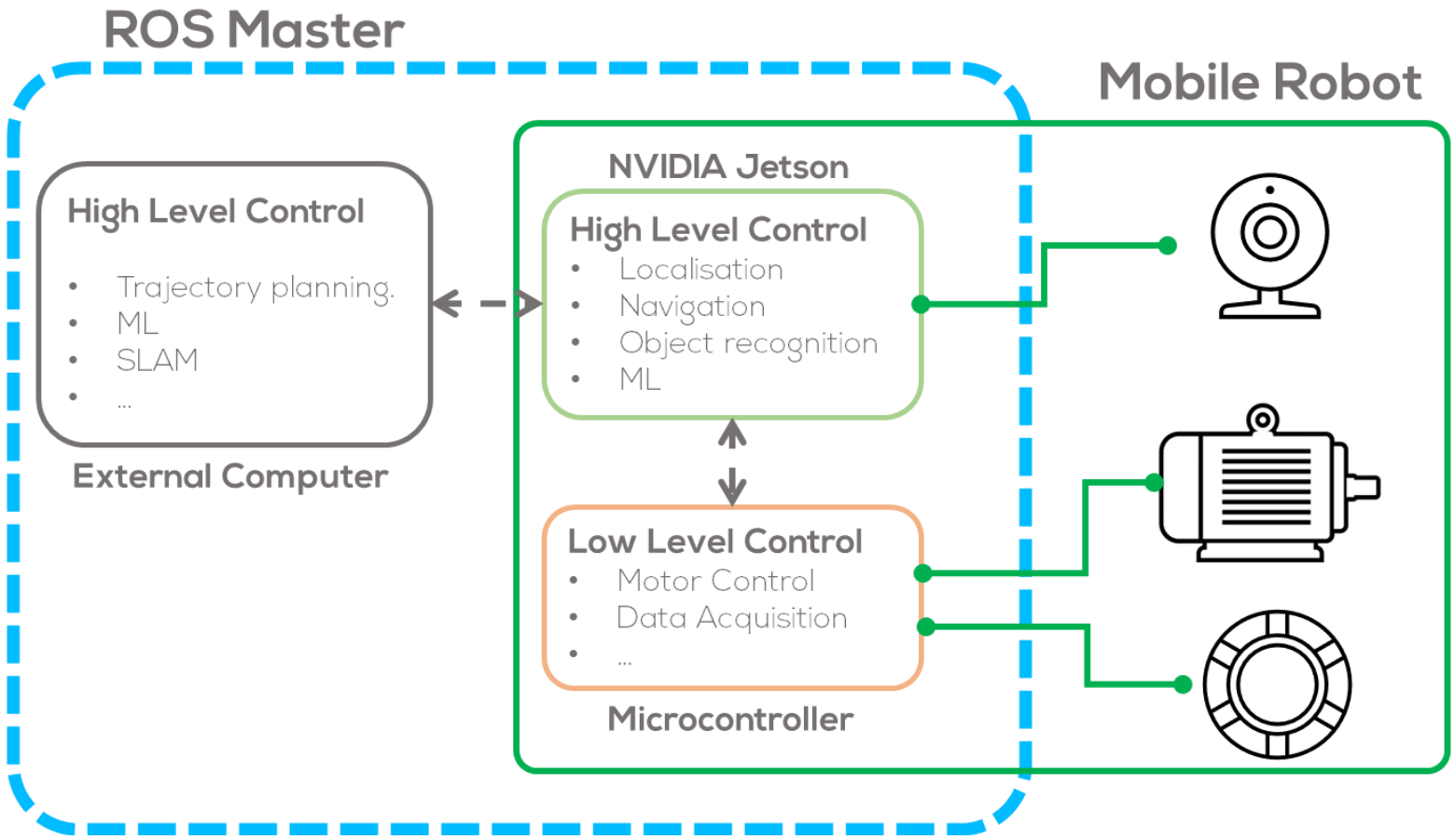


Control Hierarchy

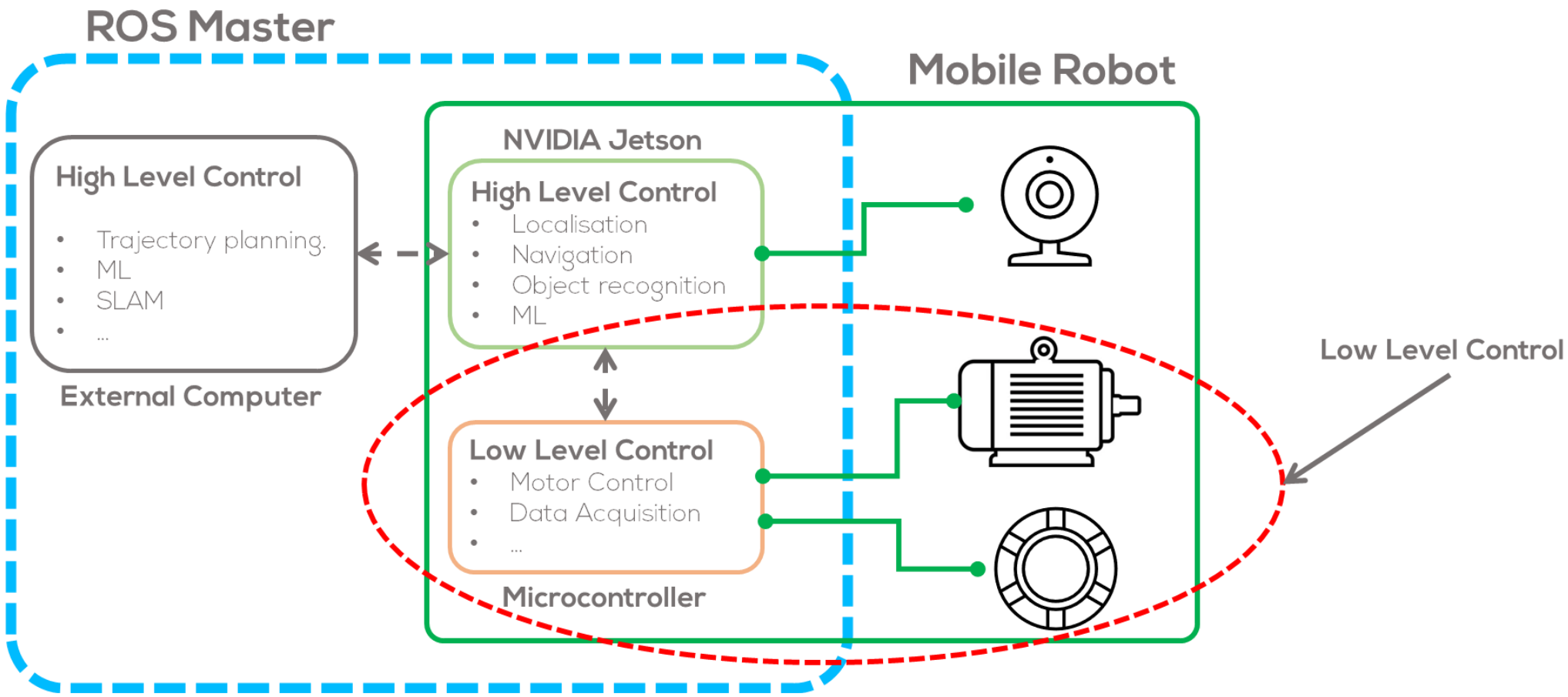
- Robotics systems, are intended to perform complicated tasks in different environments. Such tasks, can be performed autonomously, semi-autonomously or remote controlled.
- The control of such systems can become very complex depending on the task to perform.
- The HCS divides the control into layers, dividing each complex task into subtasks (goals) to be achieved by a dedicated layer.
- This course is dedicated to the Low-Level control layer using ROS.



ROS Control Hierarchy

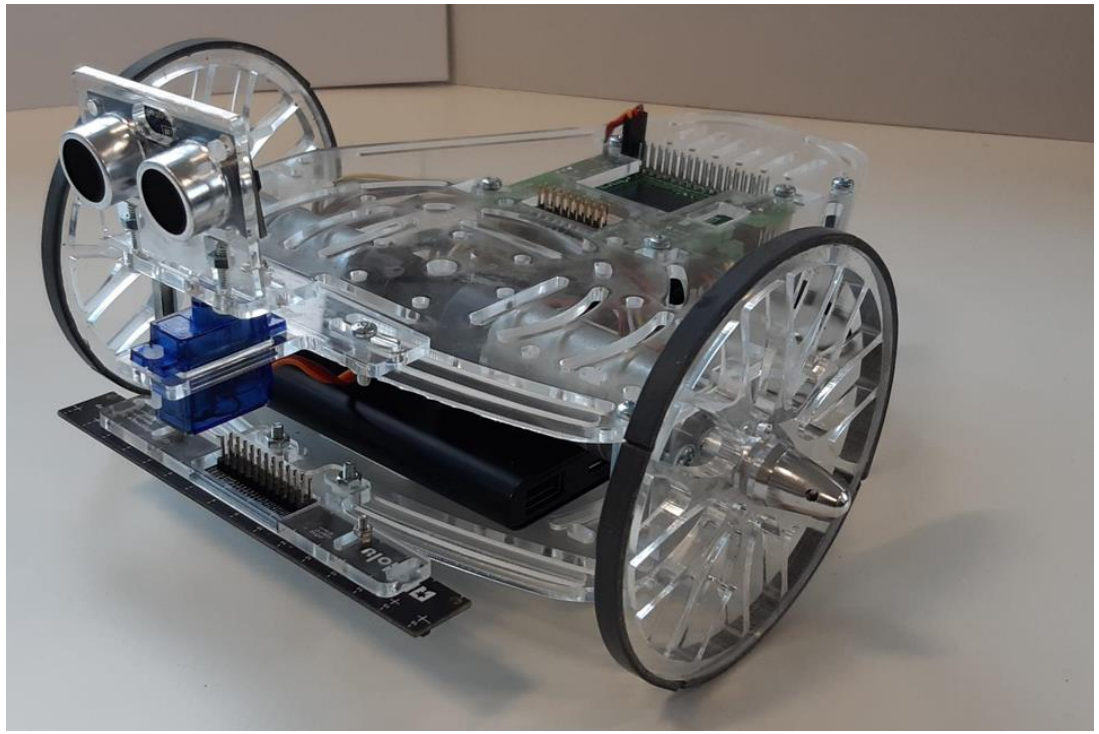


ROS Control Hierarchy



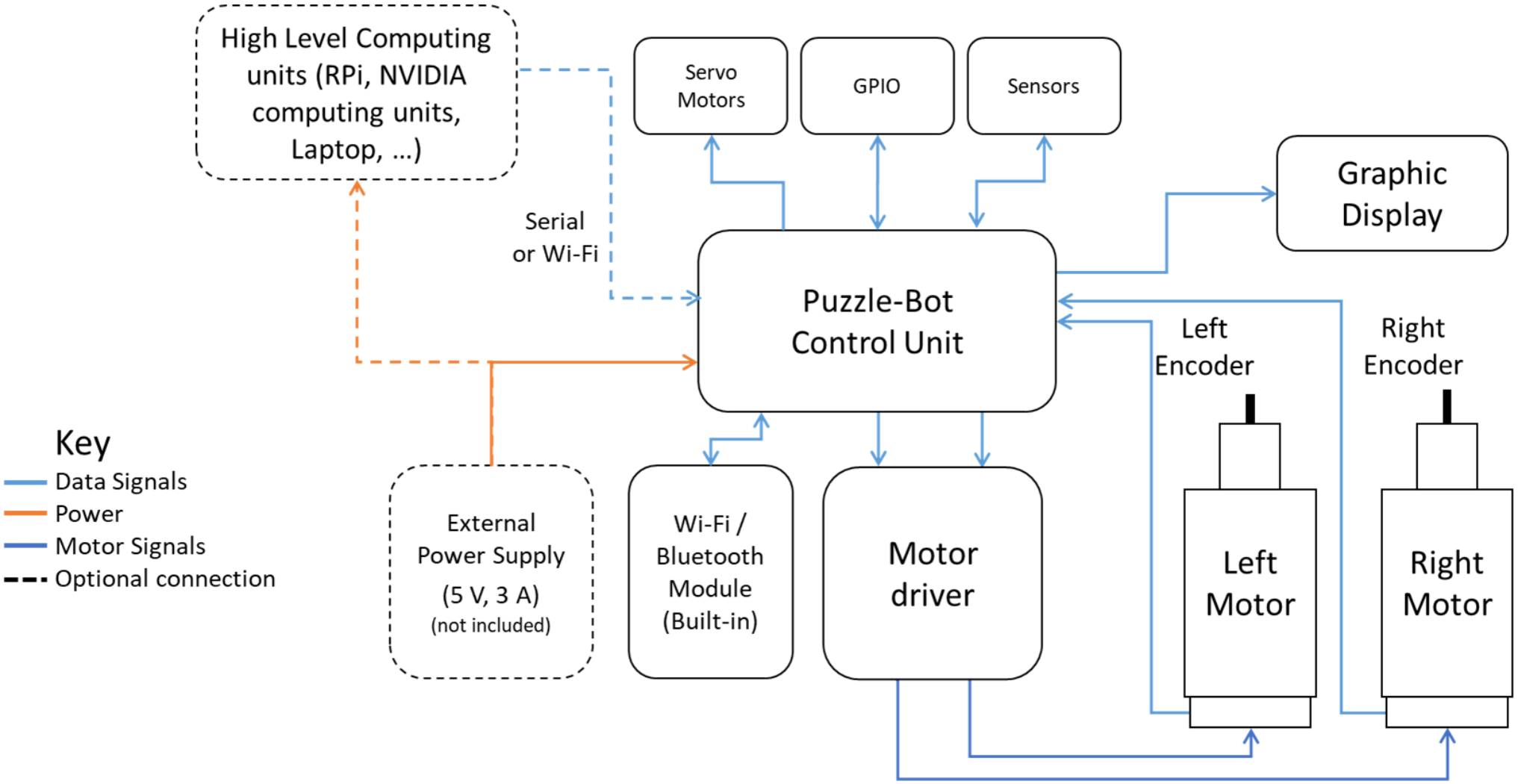
Mobile robots

- Mobile robots, require different sensors and actuators to read information from the environment, and to interact with it.
- One of the most common actuators found in most robotic systems are DC motors.
- DC Motors are found in different robotics applications from wheeled mobile robots, to robotic manipulators and unmanned aerial vehicles.
- One example of a wheeled mobile robot is the Puzzlebot, which uses two DC motors one for each wheel.
- DC motors, are a widely studied in different fields of science from electromechanical systems to control engineering.



Puzzlebot by Manchester Robotics.

Puzzlebot sensors and actuators



DC Motors

Introduction

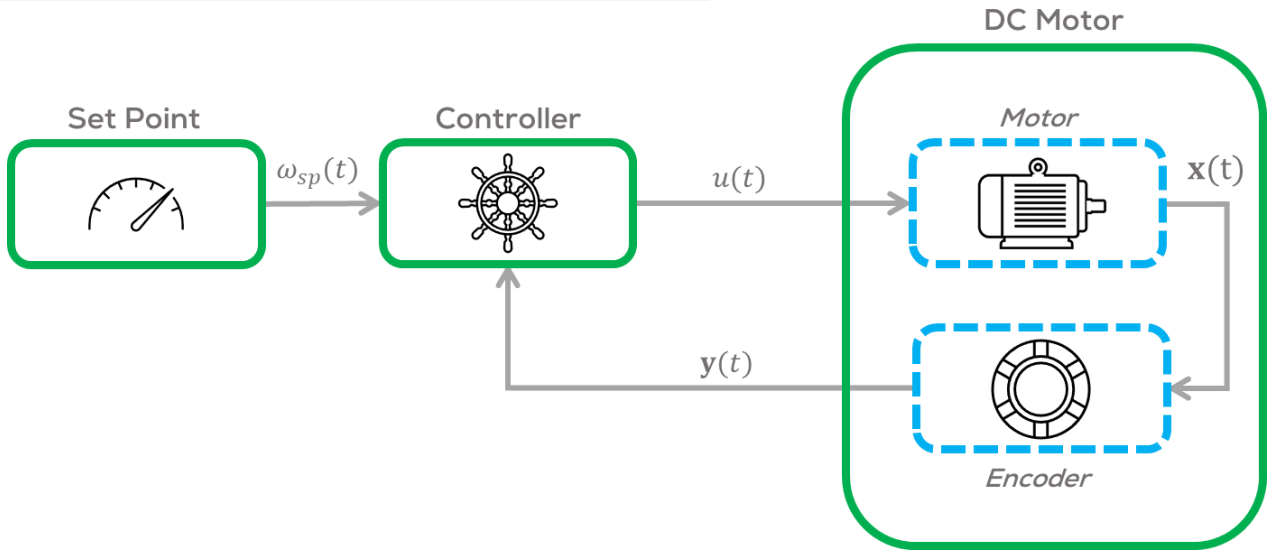
- A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy.
- DC motors take electrical power through direct current and convert this energy into mechanical rotation.
- This is done by using generated magnetic fields from the electrical currents, powering the movement of a rotor fixed within the output shaft.
- The output torque and speed depends upon both the electrical input and the design of the motor.

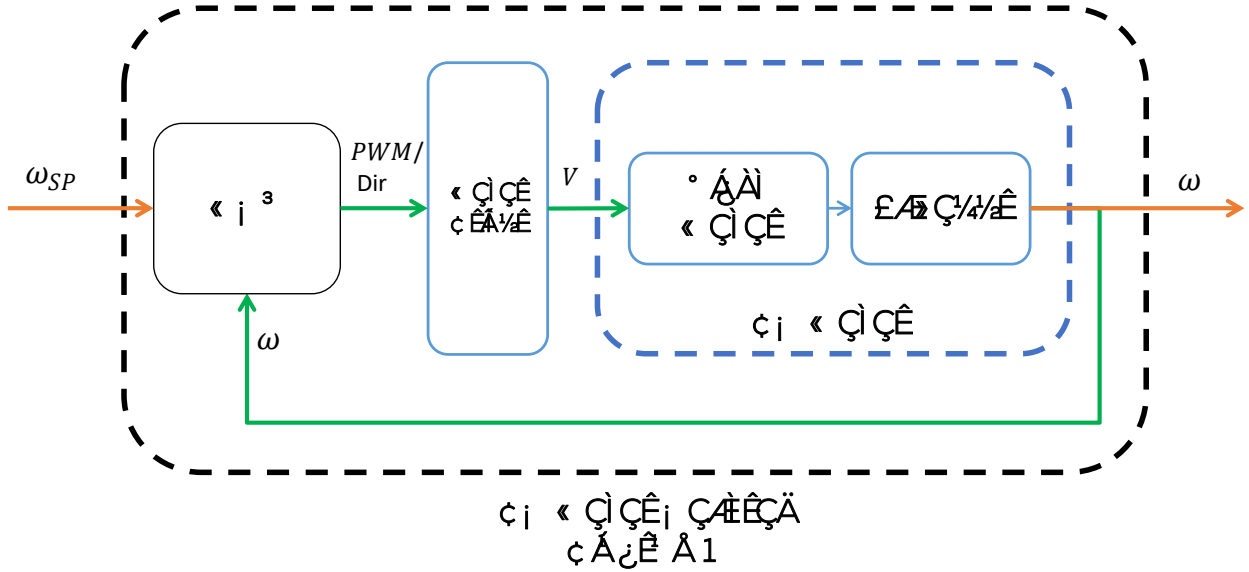
DC Brushed Motor with Encoder.

DC Motor Model Representation.

DC Motors

- In robotics, controllers are used to regulate the rotational speed, angular position or torque, required by the application.
- In robotics this is called low level control.
- For the case of a wheeled mobile robot is a common practice to implement a PID control to regulate the angular speed of the DC motors.
- The regulation of the angular speed or position of a motor, requires different stages.
  - Controller Stage
  - Power Stage (Driver)
  - Plant
  - Sensor Stage

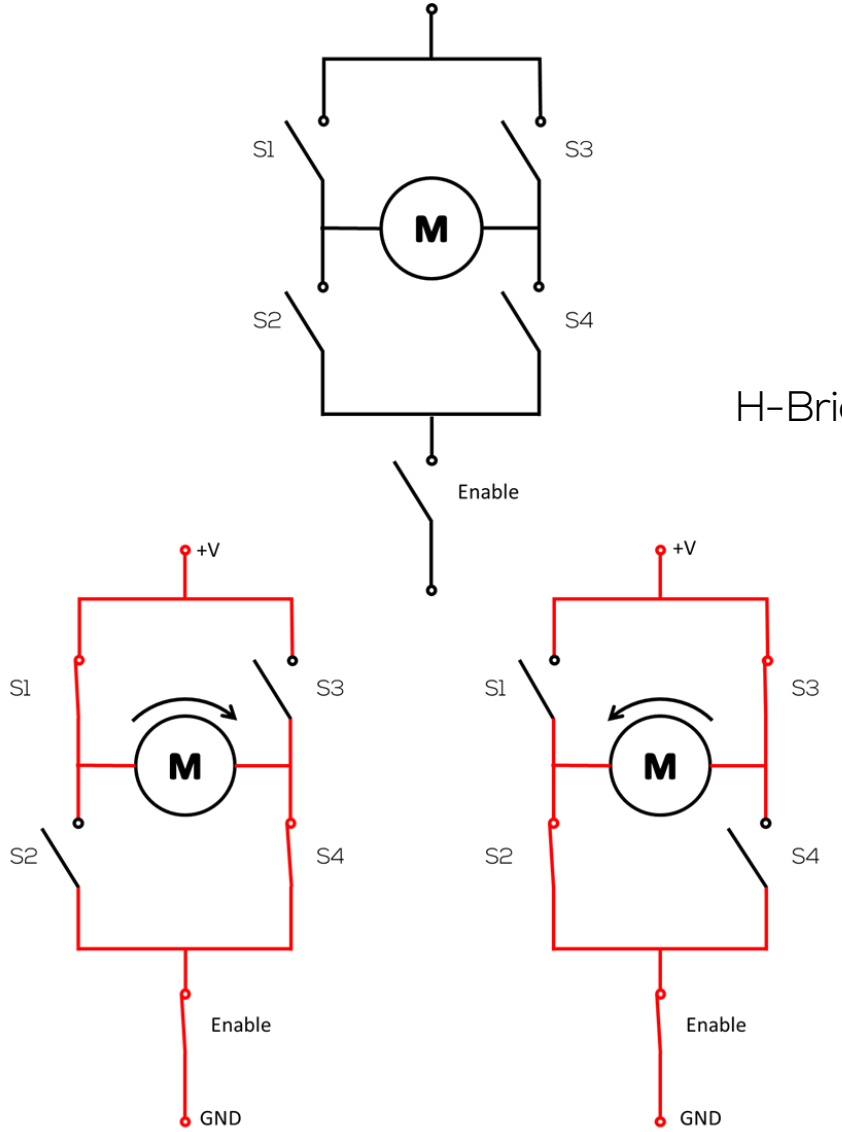




Motor Driver

- H-bridge is an electronic circuit that switches the polarity of a voltage applied to a load.
- They work using a combination of switching components (mechanical switches, transistors, etc.), as shown in the diagram, to change the polarity to the load.
- H-Bridge Drivers are some of the most common motor drivers used in the control DC motors to run forwards or backwards.

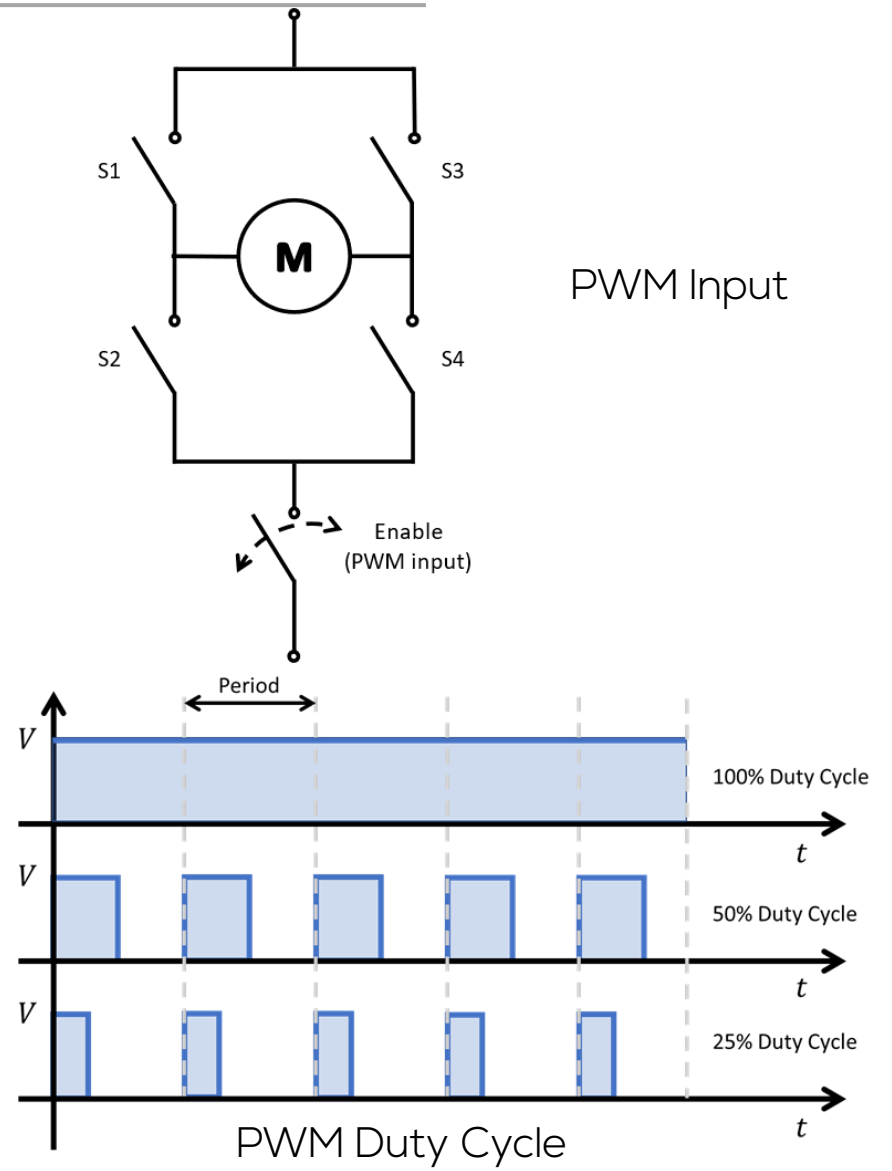
S1	S2	S3	S4	Motor
0	0	0	0	Motor Off
1	0	0	1	Right Turn
0	1	1	0	Left Turn
1	1	0	0	Short Circuit
0	0	1	1	Short Circuit



H-Bridge motor Driver Diagram

Motor Driver

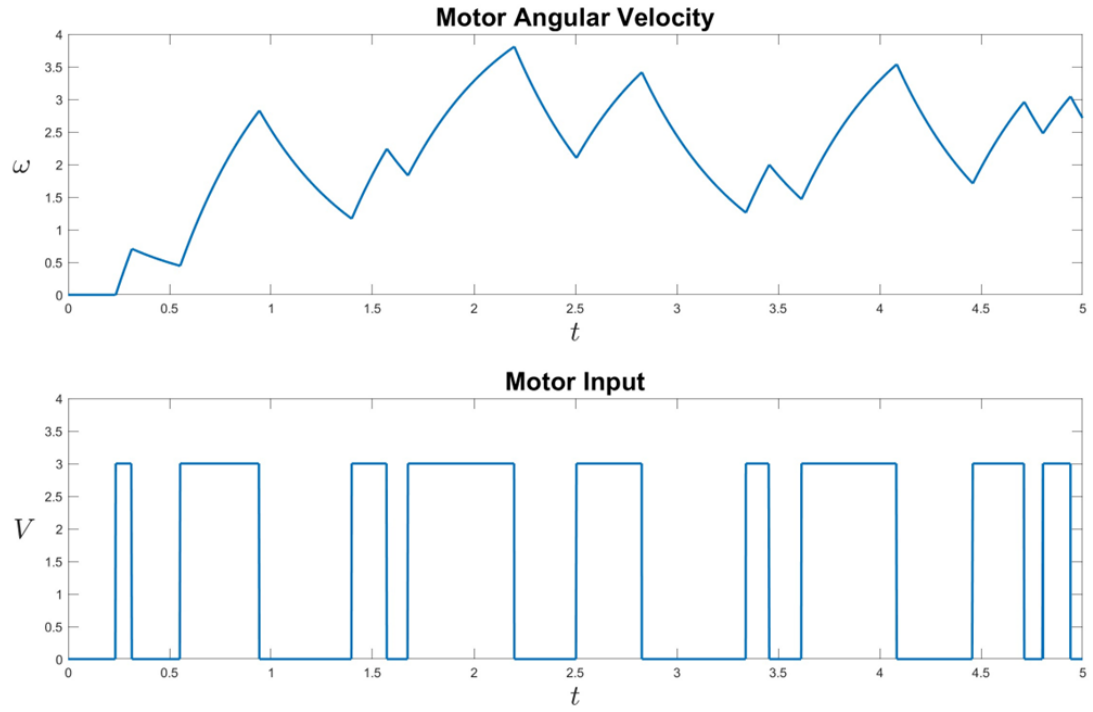
- Another capability of the motor driver is to regulate the angular speed of the motor.
- There are many ways to obtain this result, one of the most common one is to send a PWM (Pulse width modulated signal) to the enable pin of the H-Bridge.
- PWM (Pulse Width Modulation): Is a technique used in engineering to control the average power delivered by an electrical signal, by dividing it into discrete parts.
- In practice this is accomplished by rapidly turning the switch between the load and the source (enable switch), ON and OFF.



Motor Driver

- Given that the motor can be modelled as a second order systems, when applying a PWM voltage as an input, it is possible to observe the output behaviour as in the figure.

- This behaviour, can be used to control the power give to the motor and therefore controlling the motor angular speed.

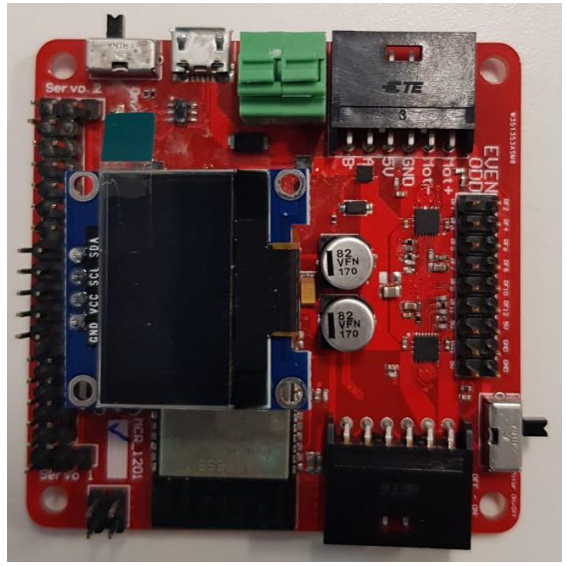


Motor Output/Input

MCU

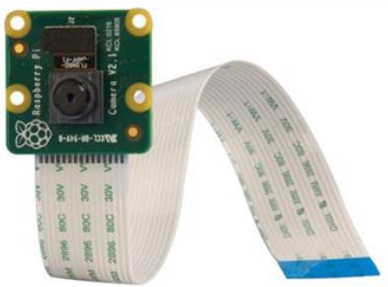
- A microcontroller is a compact integrated circuit. They are made to perform a specific operation in an embedded system.
- In robotics they are usually in charge of the low-level control of the robot, such as motors, and sensors or actuators that require a dedicated and fast controller to work.
- A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

- For the case of the PuzzleBot:
  - ESP32-based Microcontroller
  - Xtensa dual-core 32-bit LX6 microprocessor
  - 520 KB of SRAM
  - WiFi & Bluetooth
  - DC-DC Converter
  - Motor Driver
  - 0.96” I2C LCD Display



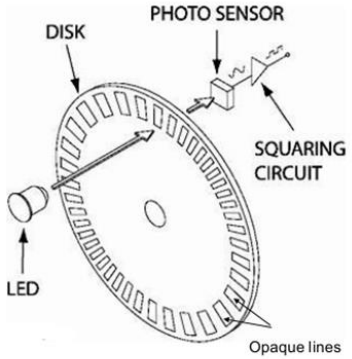
Robotic Sensors

- For the case of the sensors, they can be classified as Exteroceptive and Proprioceptive.
- Exteroceptive: Used to measure the environment or the state of the environment, topology of the environment, temperature, etc. Some examples are Sonar, LiDAR, Light sensors, bumper sensors, magnetometers.
- Proprioceptive: Used to measure the state of the robot such as wheel position, velocity, acceleration, battery charge, etc. Some examples include, encoders, battery level, gyrometers, accelerometers.

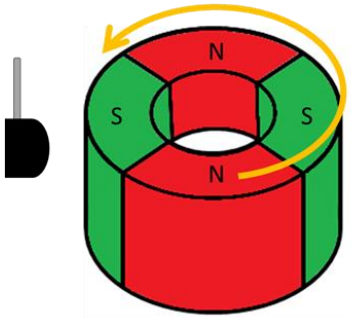


Encoders

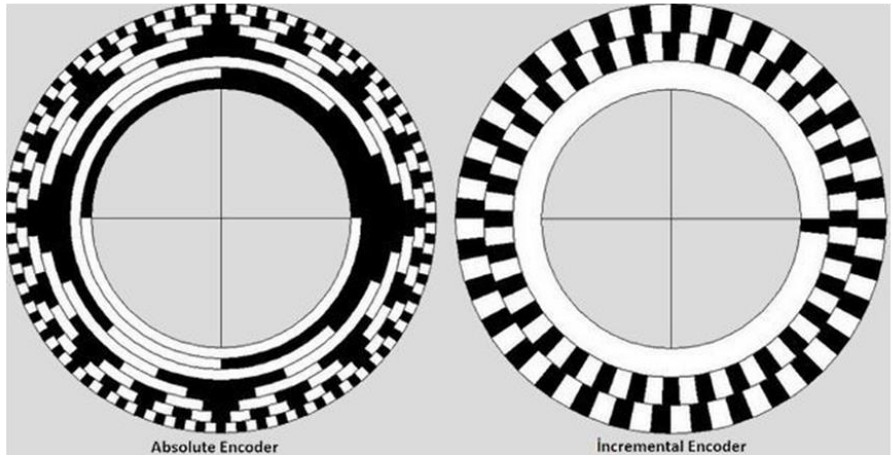
- Device that converts the angular position of a shaft (motor shaft) to an analogue or digital signal.
  - **Absolute:** Indicates the position of the shaft at all times, by producing a unique digital code for each angle (Angle transducers).
  - **Incremental:** Record the changes in position of the motor shaft with no indication or relation to any fixed position of the shaft.
- Encoders in mobile robots are considered proprioceptive sensors because they only acquire information about the robot itself, not the structure of the environment.



Optical Rotary Encoder

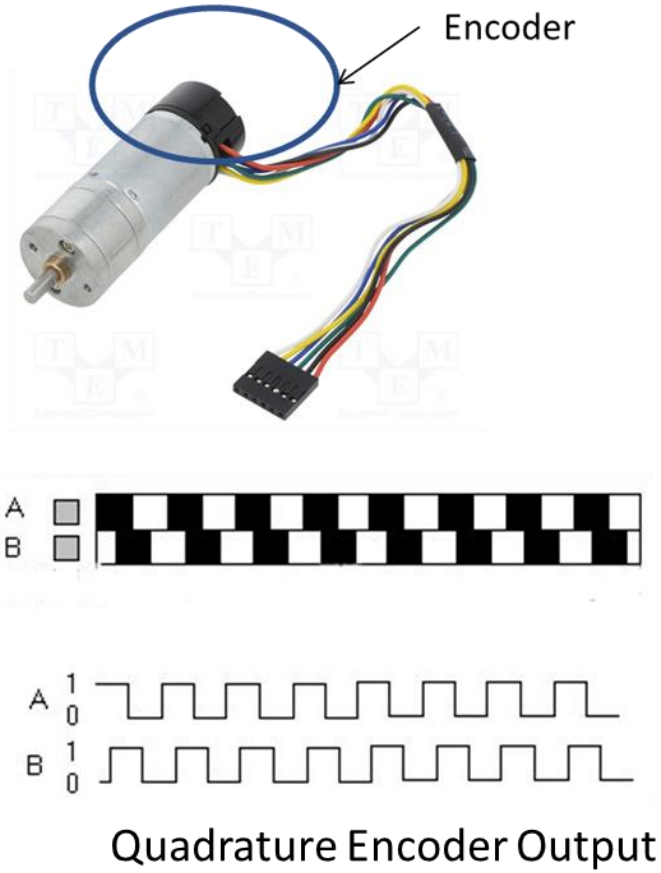


Magnetic Rotary Encoder



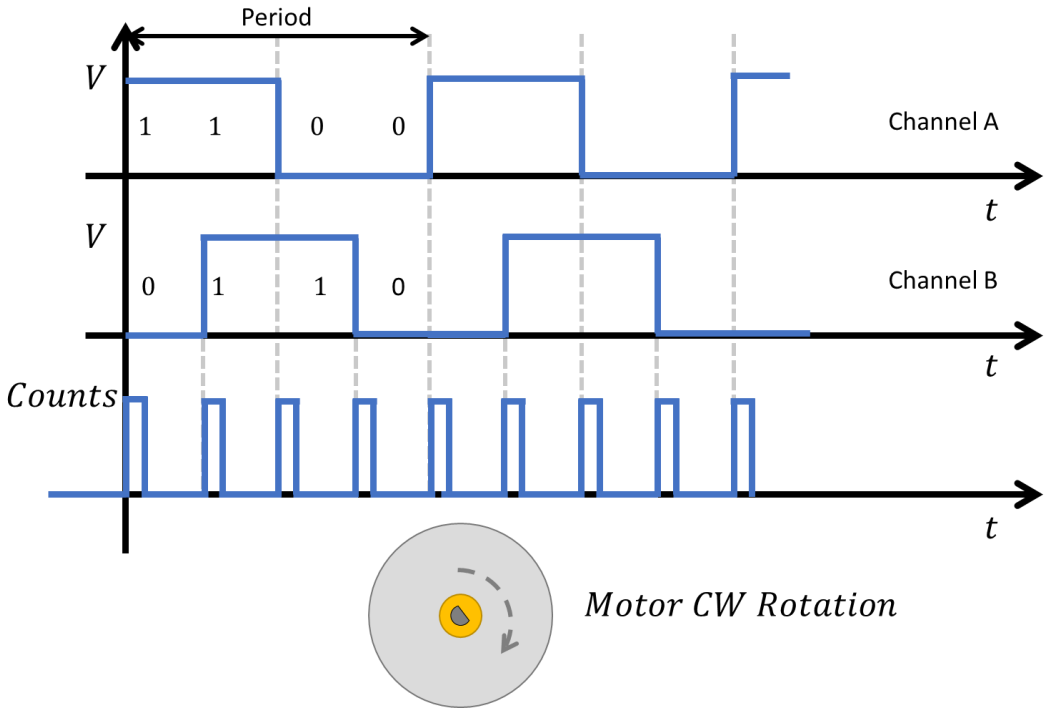
Encoders

- Incremental encoders, produce a series of electrical high-low pulses. These pulses, allows to obtain information such as the angular rotation of the shaft or the angular speed of the motor by counting the number of pulses that occur in a certain period (Δt) .
- In robotics, when an encoder is attached to the axle of each wheel in a differential-drive robot, it is possible to convert the number of pulses into useful information, such as the velocity or distance travelled by each wheel.
- With a single set of pulses (single channel / Channel A), it is impossible to know if the motor is rotating clockwise (CW) or counterclockwise (CCW).
- Therefore, a second line (dual channel / channel B) is attached, having its signal shifted by 90 electrical degrees (°e) with respect to channel A.



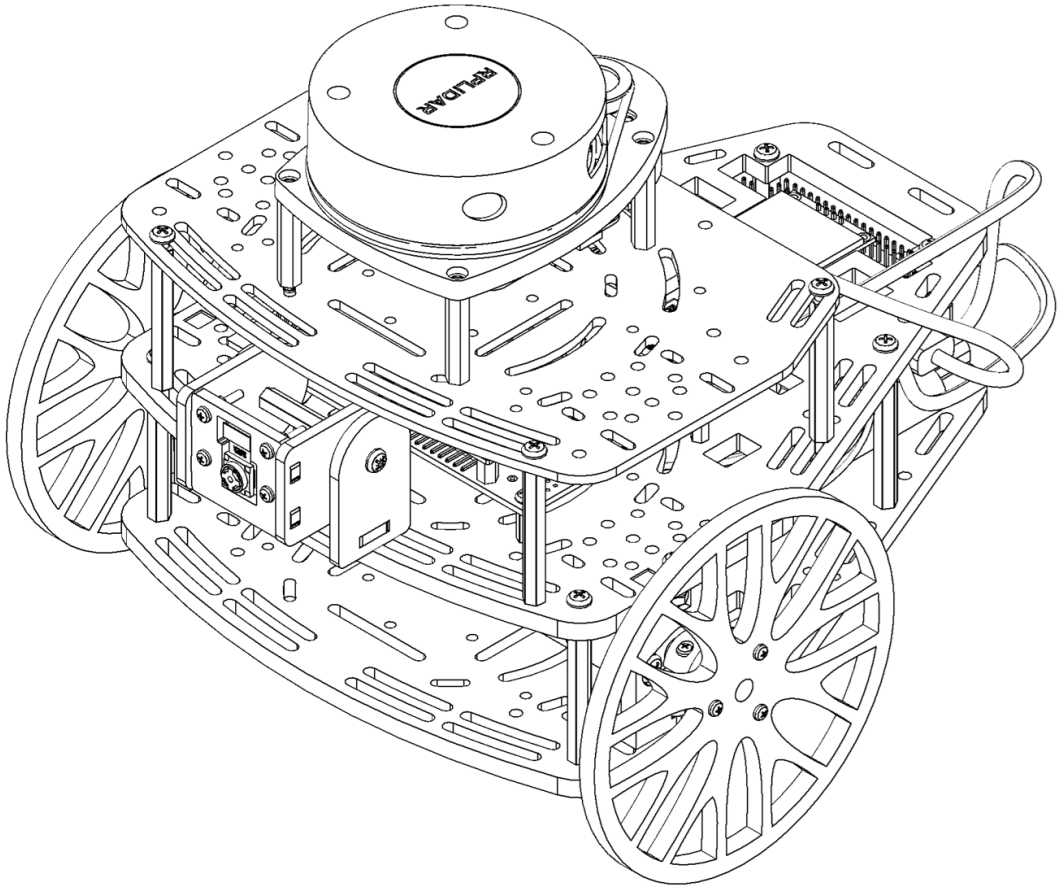
Encoders

- This phase shift allows to determine the direction of rotation.
- Depending on direction of rotation the signal of channel A is preceding channel B or vice versa.
- A simple estimation of the direction would be to verify the previous inputs (Channels A and B) and compare it with the actual inputs, the “code” will change dependant on the rotation direction.
- Counting the pulses of both channels, also leads to a more accurate angular velocity estimation.
- To count the pulses using a MCU, the most common methodology is to use interrupts so that no information is lost.



Encoders

- Puzzlebot motors use an incremental dual channel, quadrature encoders with 13 pulses per revolution, attached to the motor shafts before the reduction (35:1).
- The encoder is used to estimate the speed of the motors.
- Since the encoders can have a lot of noise, it is recommended to use a filter (low pass or band pass) to avoid having a noisy signal that affects the controller.



Q&A

Questions?

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Thank you