Natural, Mathematical & Physical Sciences

7/2/2022

Dr Francesco Ciriello

Department of Engineering

4CCE1MCP: Design, Making a Connection

Week 25

Hardware interfacing in Simulink

Housekeeping

Confluence Pages

- [User limits](#) and charge fees

Individual Coursework

- Live Demo on how to get started

Office Hours

- Office location is 1.24 Strand building

Design, Build & Test Group Project

- Next week, we will hold a live session on the group design project
- You can any question live on delivery

Bill estimate

USD 0.00 (tax inclusive)

View full estimate

Before the session

📢 Submit questions
Ask us a question about the Group Project before the Live Session

Confluence Pages – User double-counting issue

From you team website, for example https://francescociriellokcl.atlassian.net/wiki/

Individual Coursework

I have completed the tutorials, but how do I get started on the individual coursework?
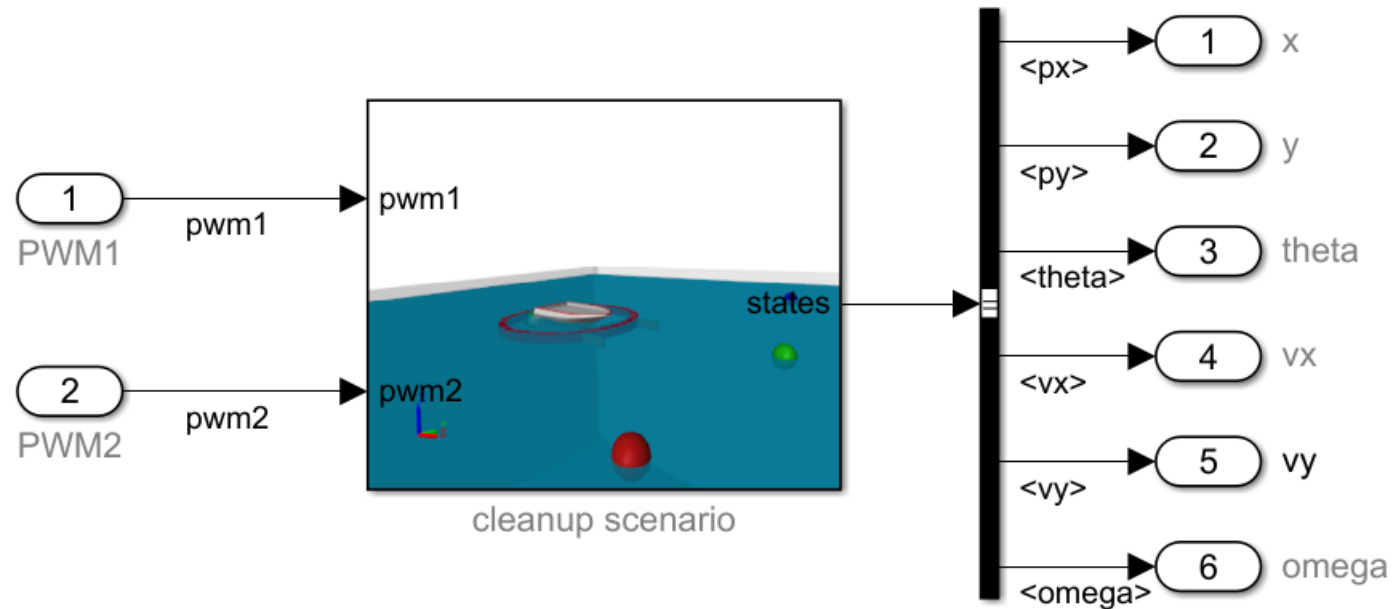
Office Hours

Module Teaching Support

Dr Francesco Ciriello

Email: francesco.ciriello@kcl.ac.uk

Office Hours: Monday 11:00-12:00 (on campus), Room 1.24 Strand Building

Wednesday 10:00-11:00 (virtual), MS Teams link
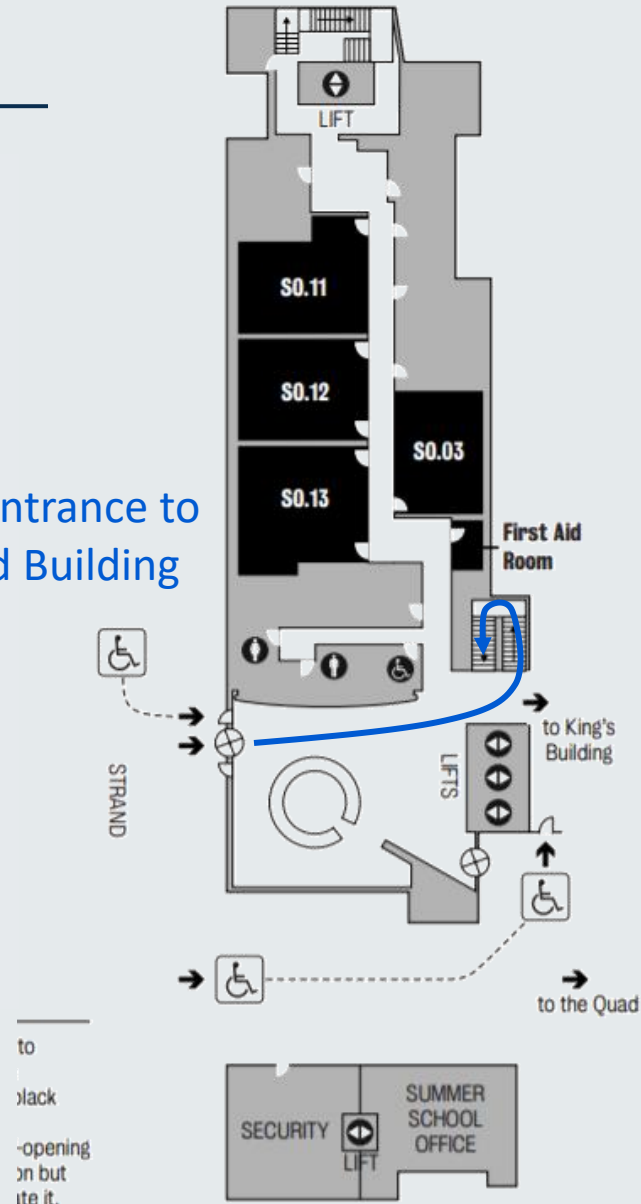
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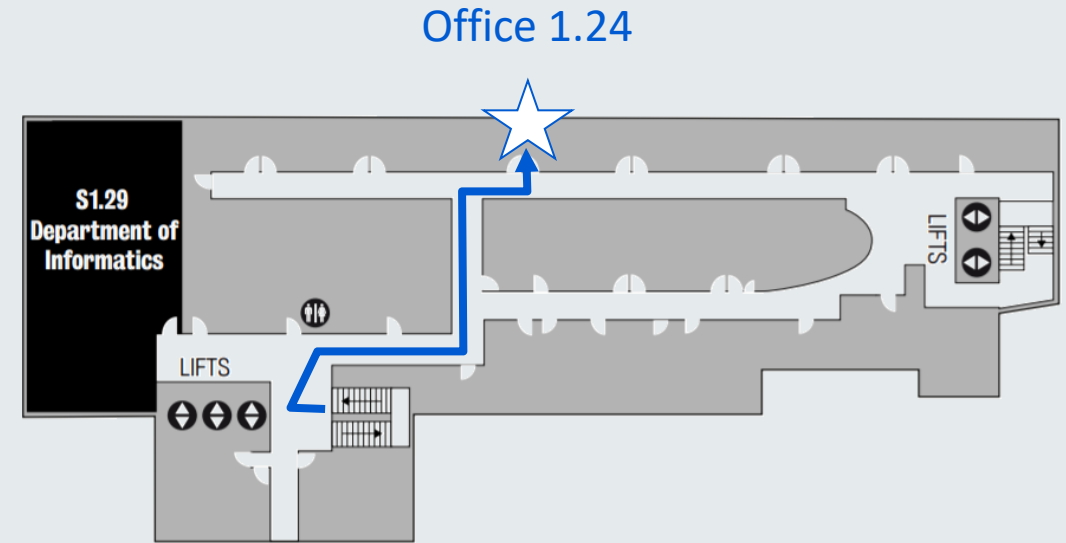**Email**: francesco.ciriello@kcl.ac.uk

Office Hours: Monday 11:00-12:00 (on campus), Room 1.24 Strand Building

Wednesday 10:00-11:00 (virtual), MS Teams link

Main Entrance to Strand Building

Ground Floor

Office 1.24

Message me in MS Teams if you get lost or cannot access the area

Learning Outcomes

- Describe the electromechanical components available for the group project and practice how to interface with them via Simulink and / or Arduino IDE

- Troubleshoot common hardware connectivity problems

- Characterise the behaviour of a component from acquired data.

- Control a component in open-loop

- Explain what is meant by rate control and critique time resolution trade-offs for embedded system design

Agenda

Descriptions of Available Hardware Components
- Arduino board
- Motor carrier, DC motor, Servo
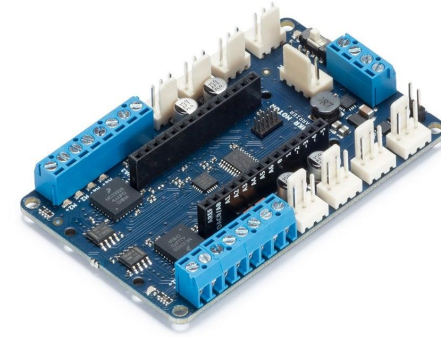- Battery
- Communication module

Simulink for embedded systems
- Installation
- Troubleshooting - resets and bootloader mode
- Deployment - External mode vs Build, Load and Run
- Arduino Support Package driver blocks
- PWM for DC motor
- PWM for Servomotor
- Rate control

Components
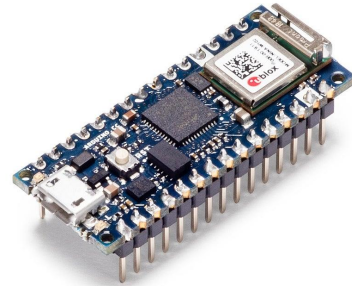
Arduino boards
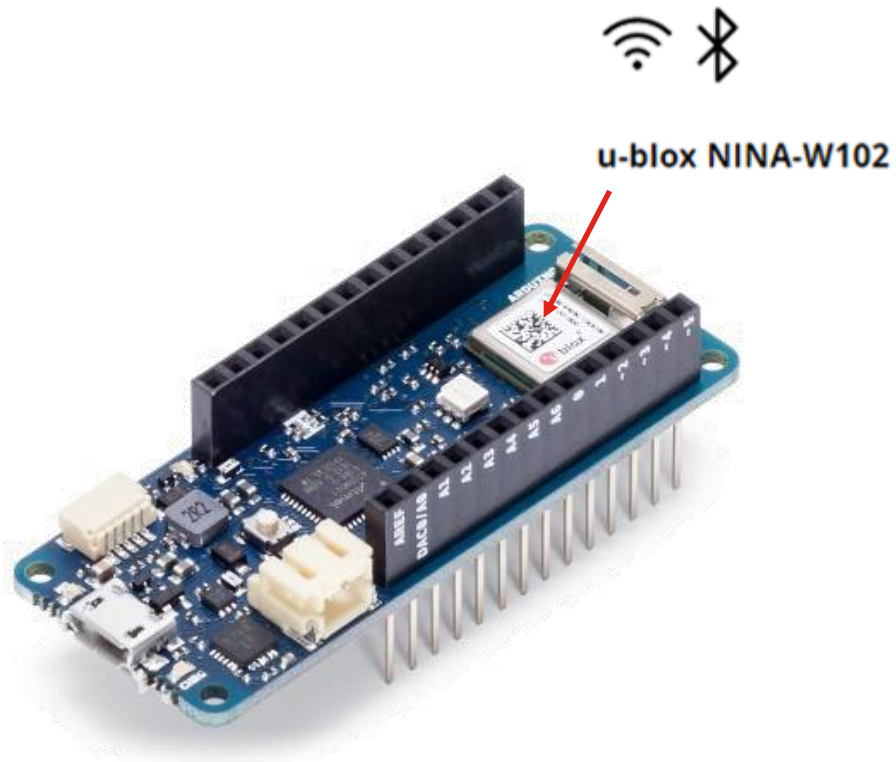
Arduino Motor Carrier

Brushed DC motors

Servomotor

Power Supply

Arduino MKR WiFi 1010 Board

u-blox NINA-W102

Part Name	Arduino MKR WiFi 1010 Code: ABX00023
Part Doc	https://store.arduino.cc/products/arduino-mkr-wifi-1010
Coding in Arduino	https://docs.arduino.cc/hardware/mkr-wifi-1010
Coding in Simulink	https://uk.mathworks.com/help/supportpkg/arduino/setup-and-configuration.html
Intended Use	On-ship receiver and micro-controller

Arduino Nano 33 IoT Board

u-blox NINA-W102
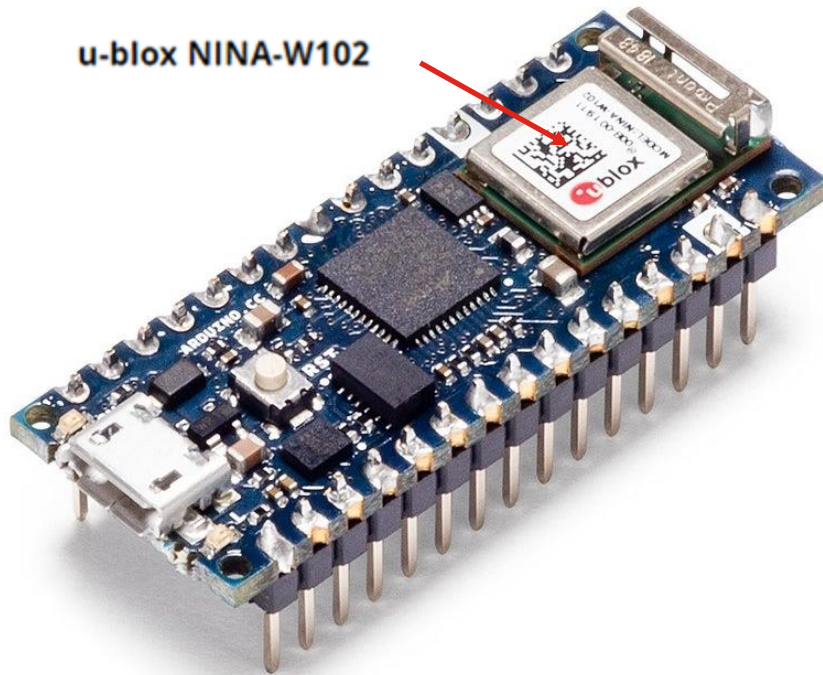
| Part Name	Arduino Nano 33 IoT with headers Code: ABX00032
Part Doc	https://store.arduino.cc/products/arduino-nano-33-iot-with-headers
Coding in Arduino	https://docs.arduino.cc/hardware/nano-33-iot
Coding in Simulink	https://uk.mathworks.com/help/supportpkg/arduino/setup-and-configuration.html
Intended Use	Ground control transmitter. Connect to potentiometers to make an RC joystick.

Arduino MKR Motor Carrier
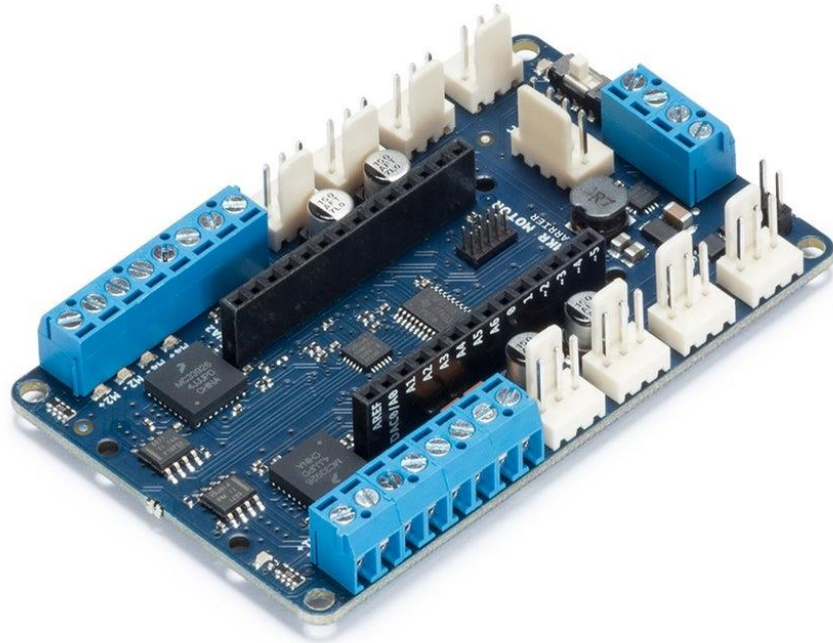
Warning: We have modified the motor carriers so that you can connect them to a power supply or battery using a single plug DC connector. Please do not tamper with these connectors.

| Part Name	Arduino MKR Motor Carrier Code: ASX00003
Part Doc	https://store.arduino.cc/products/arduino-mkr-motor-carrier
Coding in Arduino	https://docs.arduino.cc/hardware/mkr-motor-carrier
Coding in Simulink	https://uk.mathworks.com/help/supportpkg/arduino/arduino-motor-carrier.html
Intended Use	Arduino MKR board slots into the carrier, which acts as voltage divider and H-bridge between the board and motor circuits.

Arduino MKR Motor Carrier

servos   Encoder   DC motor

power →

IMU
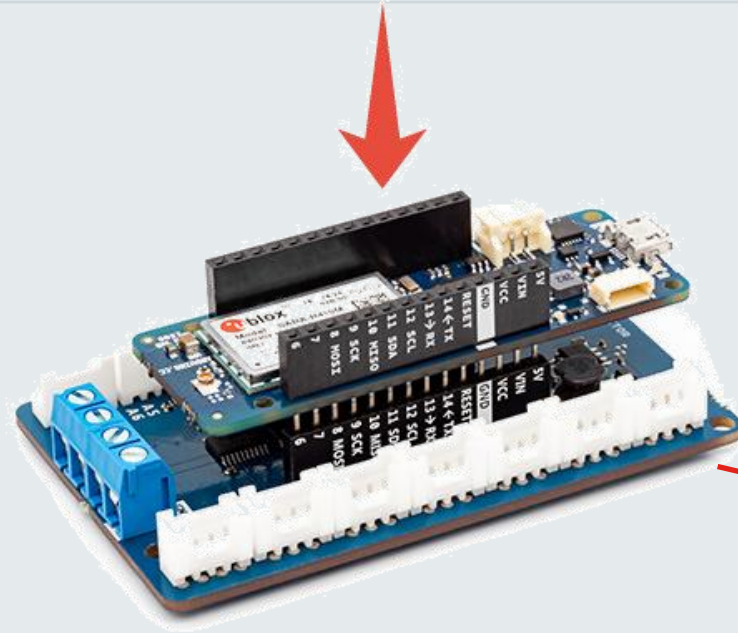
Carrier acts as a voltage divider and H-bridge

power switch →
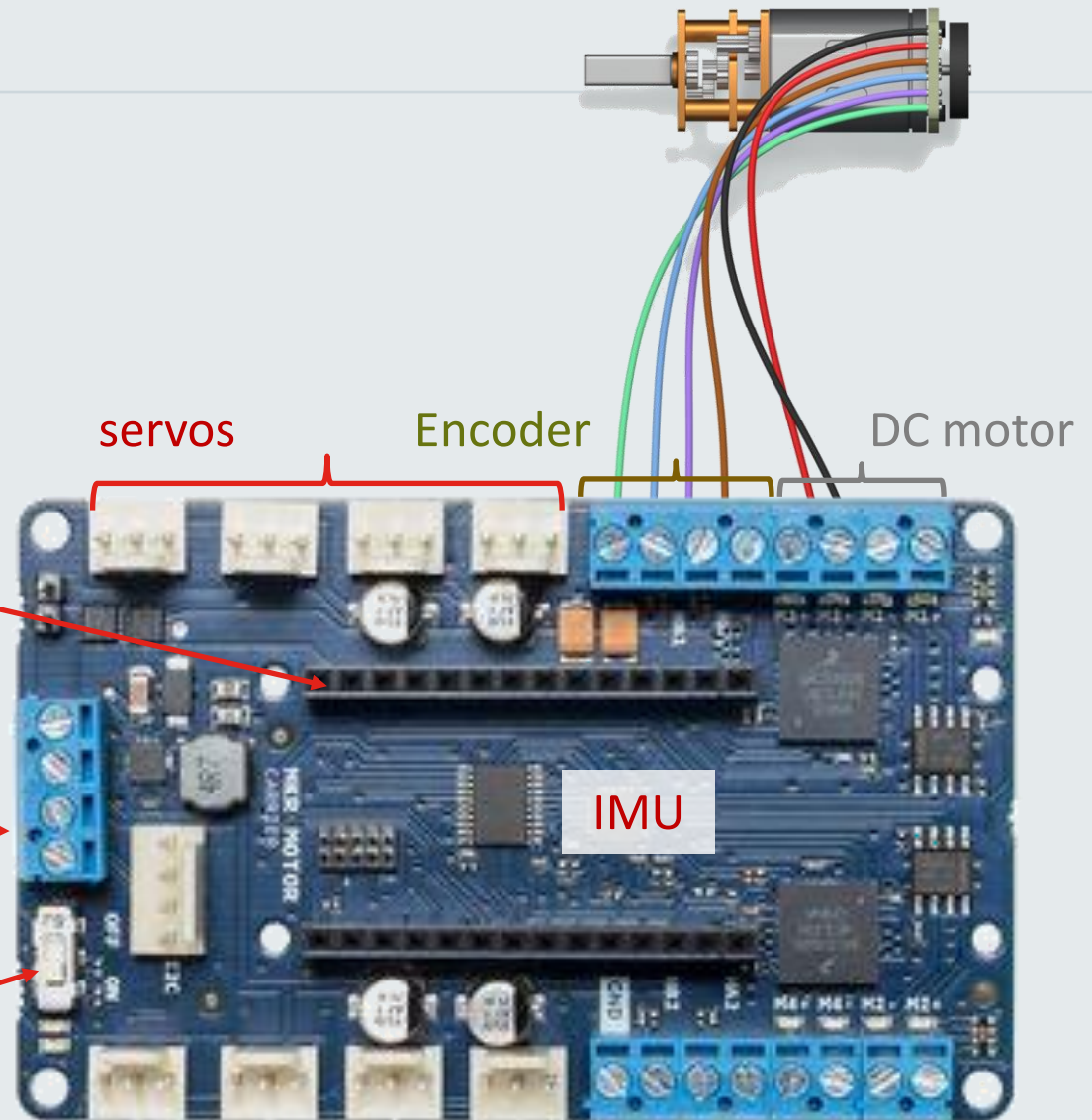
PWM

0% DUTY CYCLE

analogWrite (0)

25% DUTY CYCLE

analogWrite (64)

50% DUTY CYCLE

analogWrite (127)

75% DUTY CYCLE

analogWrite (191)

100% DUTY CYCLE

analogWrite (255)

DC motor

General Specifications

Output Speed	9869rpm
Maximum Output Torque	78.4gcm
Applications	Vacuum cleaners, Air Compressors, Hair Dryers, Power Tools

Electrical Specifications

Supply Voltage	4.5V – 15V
Power Rating	7.98W
Current Rating	990mA
Stall Current	Stall Current RE-385 at 12v = 5.55A

Mechanical Specifications

Shaft Diameter	2.31mm
Core Construction	Iron Core
Dimensions	27.7mm (Dia.) x 38mm
Length	38mm
Width	27.7mm
Weight	66g

Geared DC Motor

SHAFT   GEARBOX   MOTOR   ENCODER   MAGNET
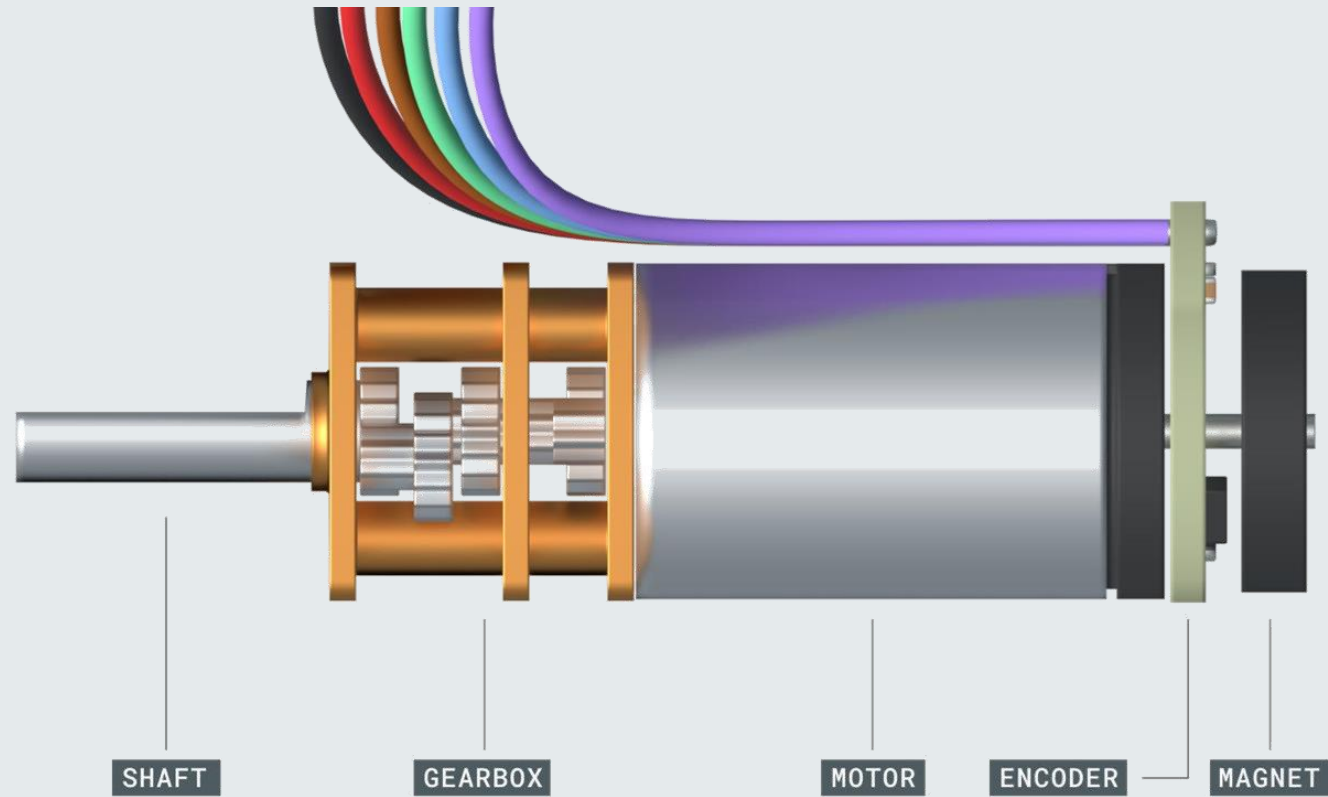
Geared DC Motor

SPECIFICATION

Rated Voltage: 6.0 V

Motor Speed: 15000 RPM

Gear Reduction Ratio: 100:1

Reducer Length: 9.0 mm

No-Load Speed: 155 rpm@6v

No-Load Current: 60 mA

Rated Torque: 0.7 kg.cm

Rated Speed: 90 rpm@6V

Current Rating: 170 mA

Instant Torque: 1.5 kg.cm

Hall Feedback Resolution: 1400

Weight: 18g

DOCUMENTS

Motor Interface

Motor Dimension

SHIPPING LIST

Micro Metal Gearmotor 100:1 w/Encoder x1

6-pin connection cable x1

2-pin 1.5 mm JST connector x1

4-pin 1.5 mm JST connector x1

Rotary Encoder

Vcc

C1 & C2

GND
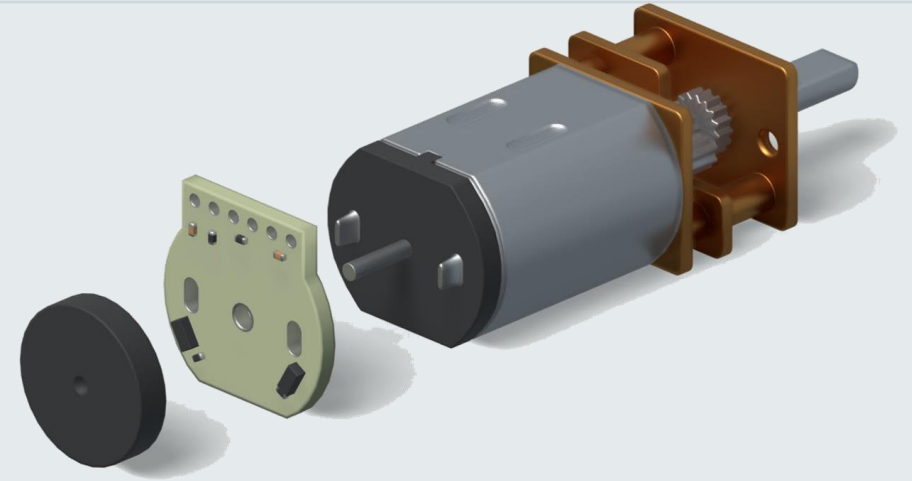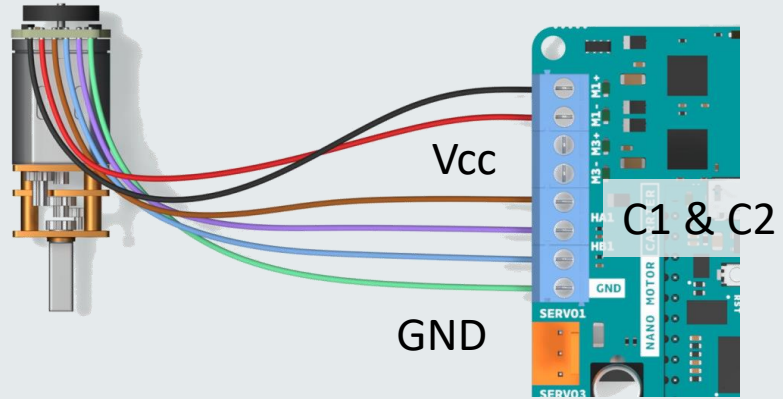
Magnet spins with rotor

HALL SENSOR

N

S
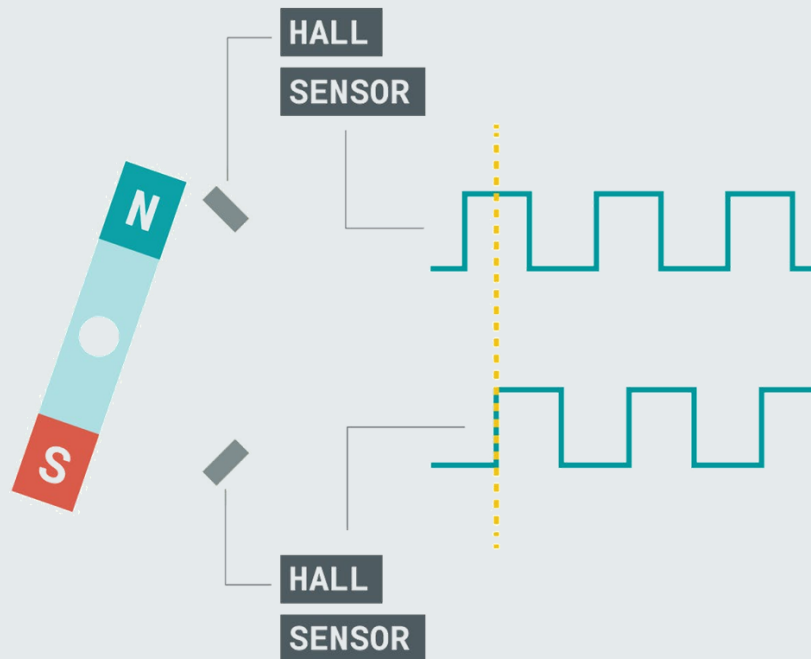
HALL SENSOR

Hall sensors **count** number rotations

Servomotor

1 MS → 0°
1,5 MS → 90°
2 MS → 180°
20 MS

SHAFT
GEARBOX
POTENTIOMETER
DC MOTOR
CONTROL CIRCUIT
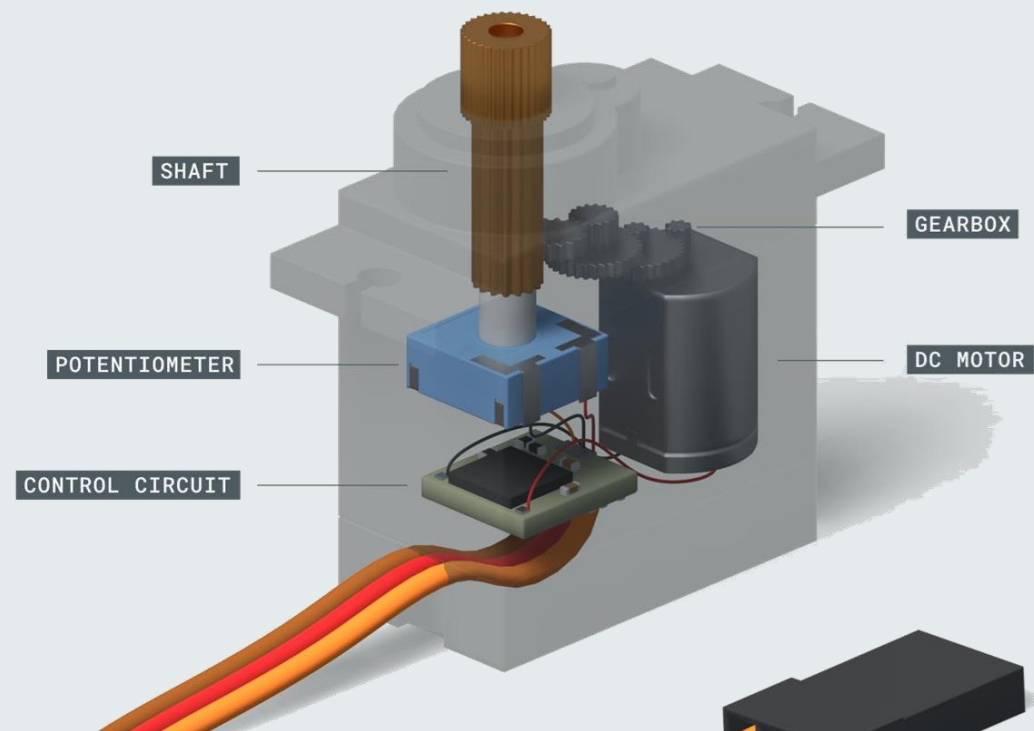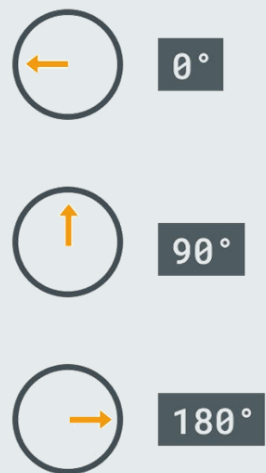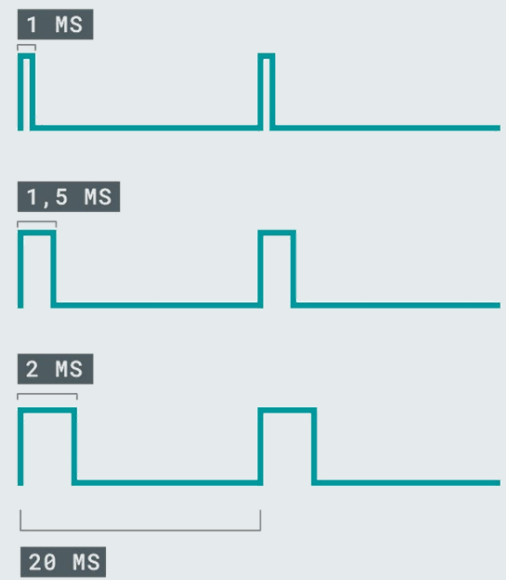
PWM signal sets angular position of shaft

50 → angle in degrees

ARDUINO
Servo Motor: 1
Servo Write
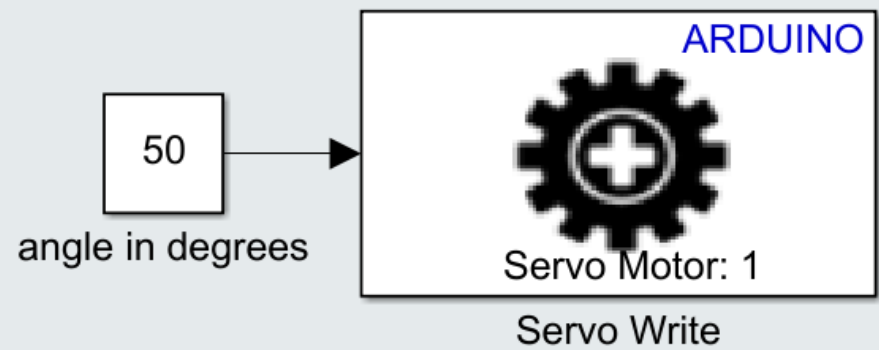
Servomotor

Mechanical Specification

Size	: 23.2mm, 12.5mm & 22mm
Weight	: 9g ±0.2
Gear type	: Plastic Gear (Nylon & POM)
Limit angle	: 360°
Bearing	: No Ball bearings
Horn gear spline	: 20T (4.8mm)
Horn type	: Plastic, POM
Case	: Nylon & Fiberglass
Connector wire	: 200mm ±5 mm
Motor	: Metal brush motor
Splash water resistance	: No

Electrical Specification (Function of the Performance)

Operating Voltage Range	4.8V	6V
Idle current(at stopped)	5mA	6mA
No load speed	110RPM	130RPM
Running current(at no load)	100 mA	120 mA
Peak stall torque	1.3kg.cm	1.5kg.cm
	18.09oz.in	18.09oz.in
Stall current	550mA	650mA

Battery

- Polarity warning

- Each Battery is 1.2V (So 6 batteries is 7.2V)

- Check charge using battery read block

Battery Read
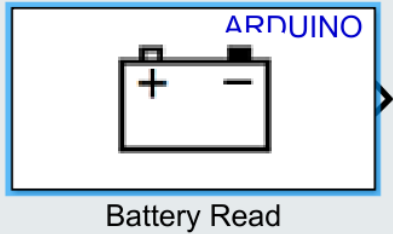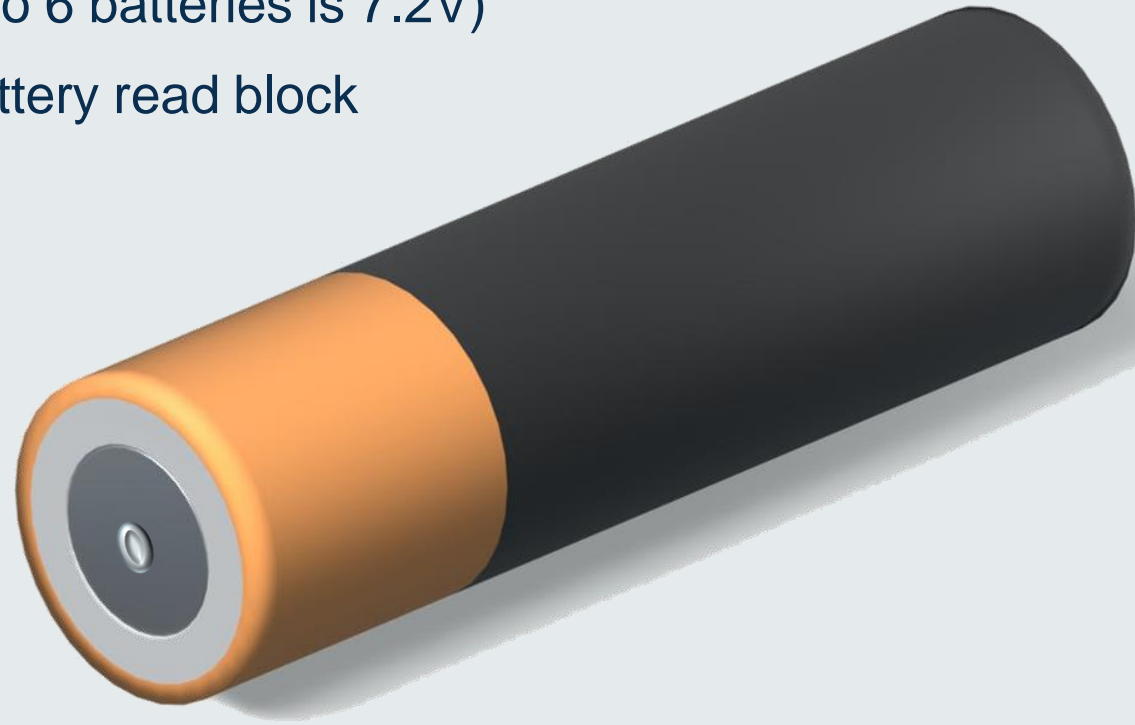
negative terminal -

positive terminal +

Warning: Ensure you use the correct polarity when you place battery in holder during the lab sessions
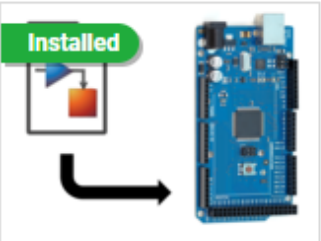
Simulink to Arduino Setup

Demonstration: Support Package, Configuration and Drivers
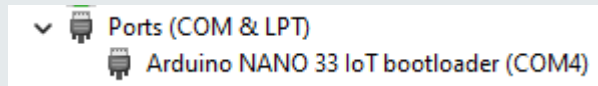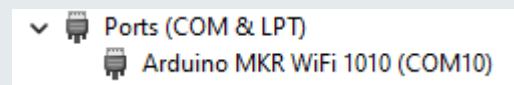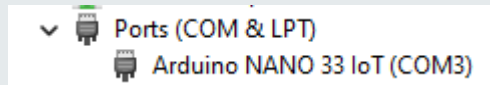
Guided setup

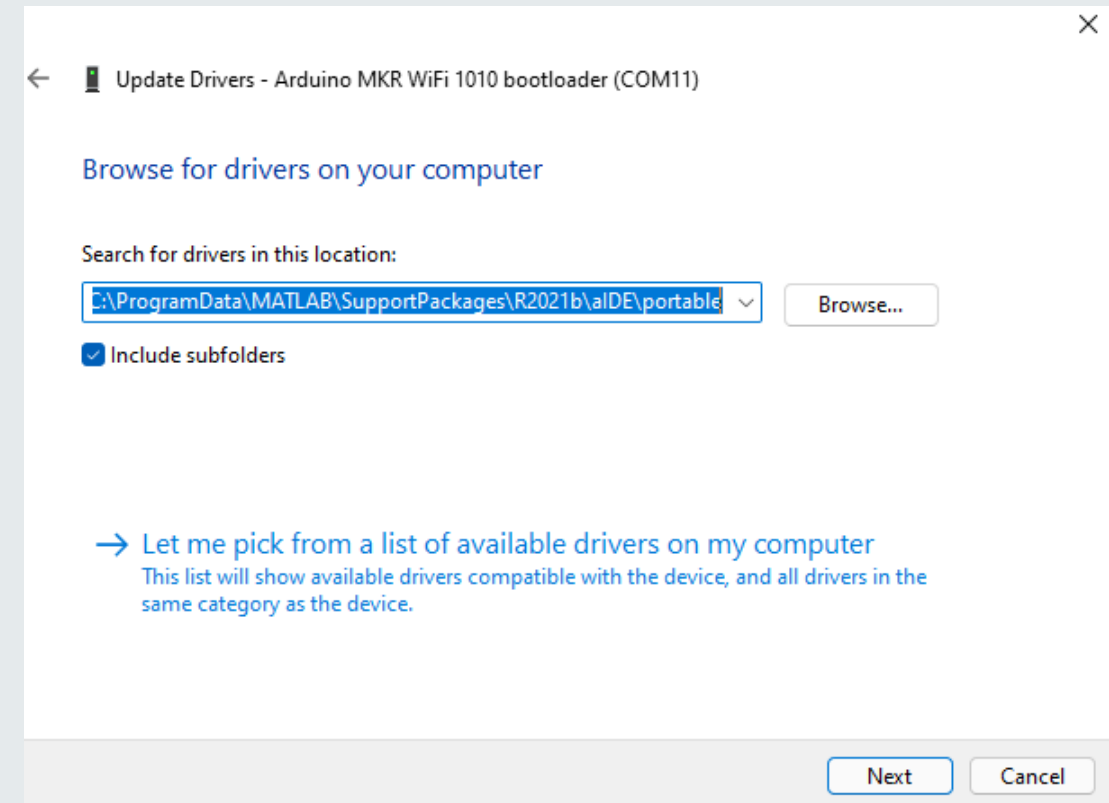# Drivers – Confirm setup completed successfully
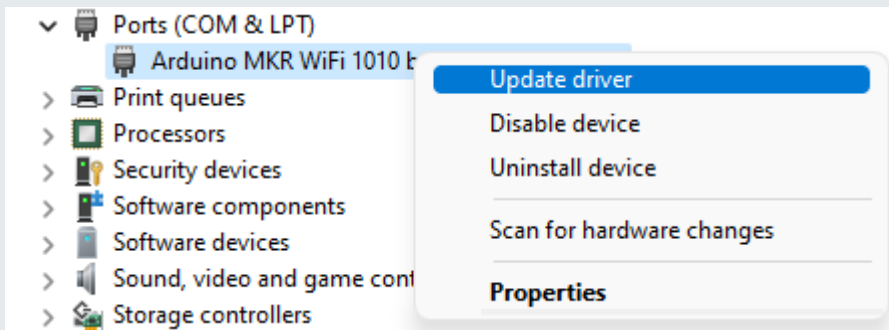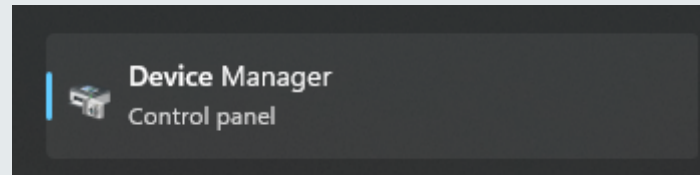
If not, install drivers manually
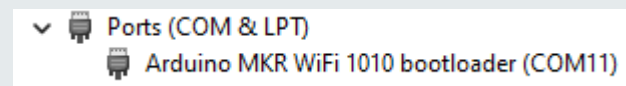
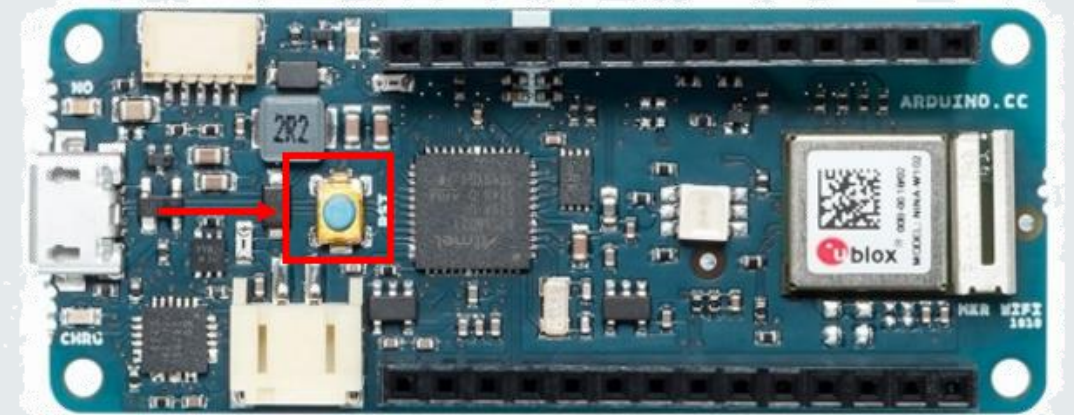If board names are displayed in Device Manager then setup is correct

RST Button and Bootloader mode

1. Press RST once for reset
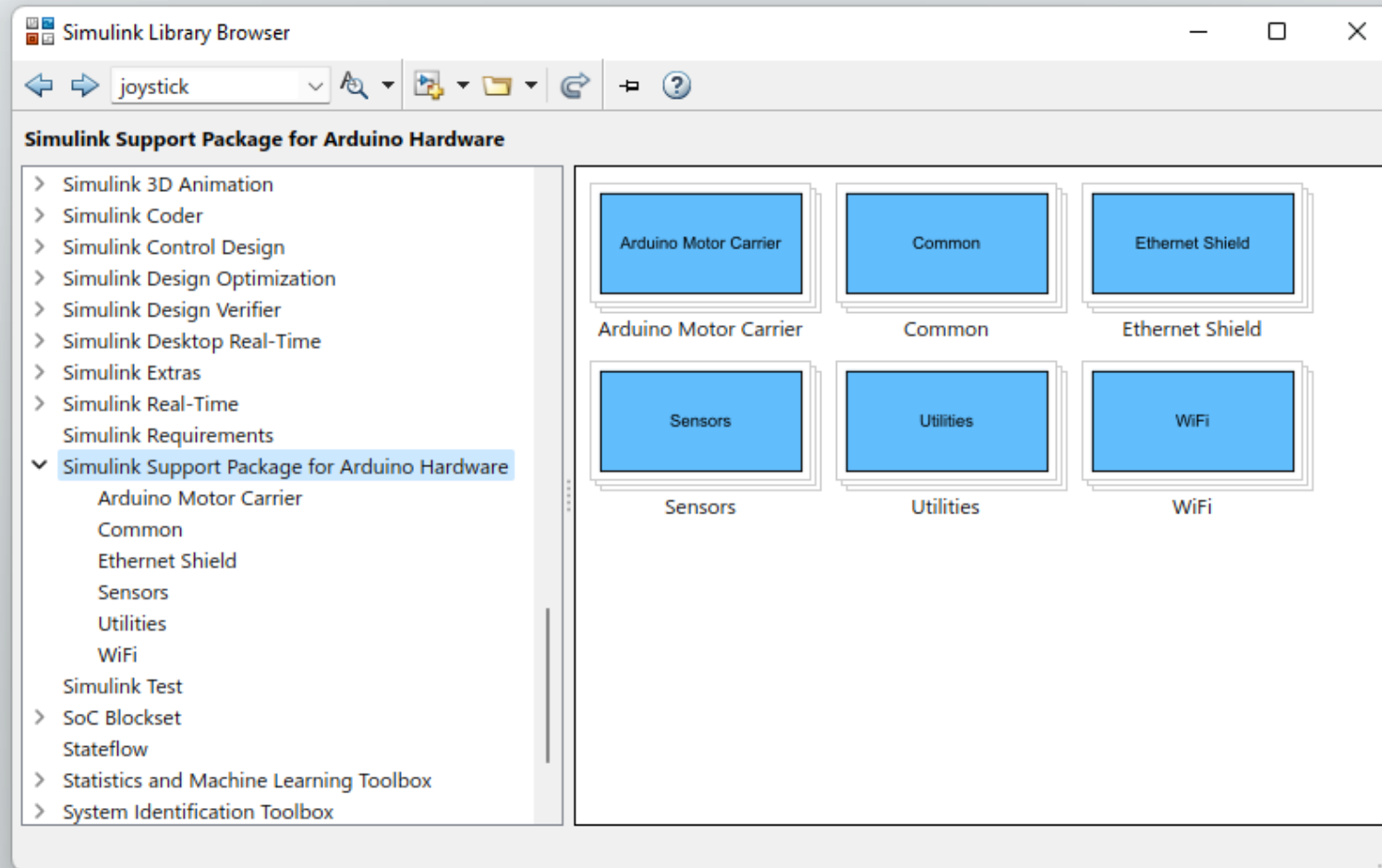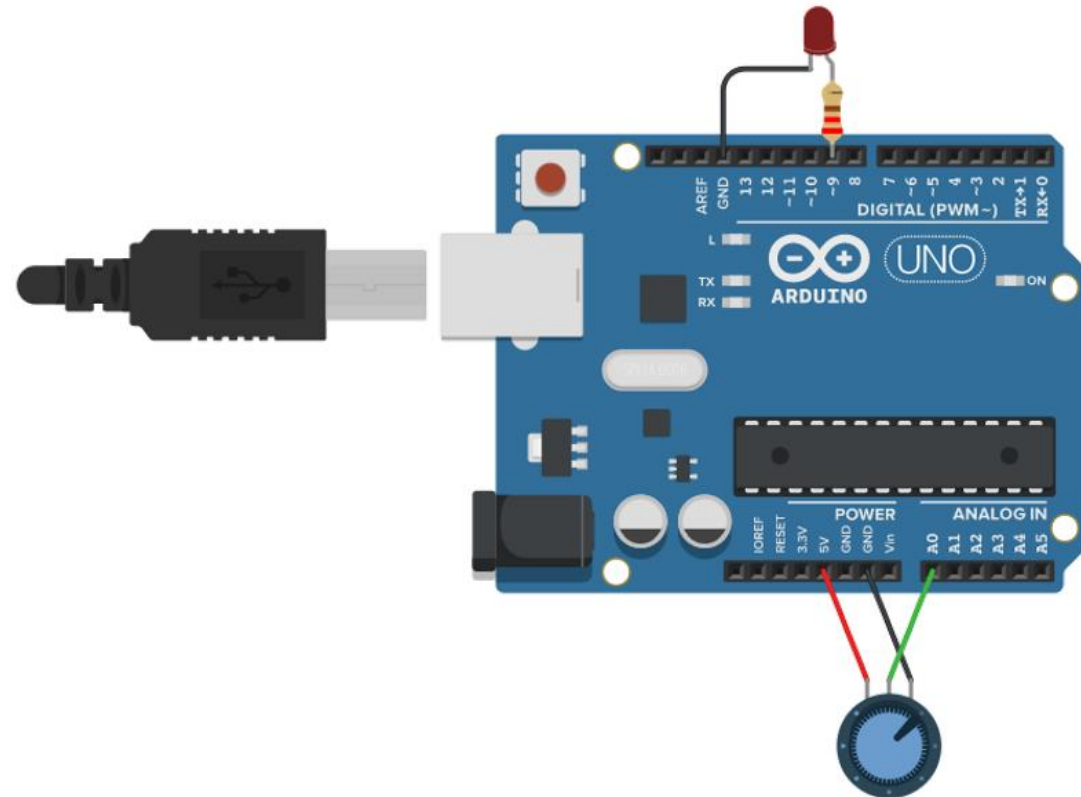2. Press RST twice for bootloader mode

1. Run the board in bootloader mode whenever upload persistently fail
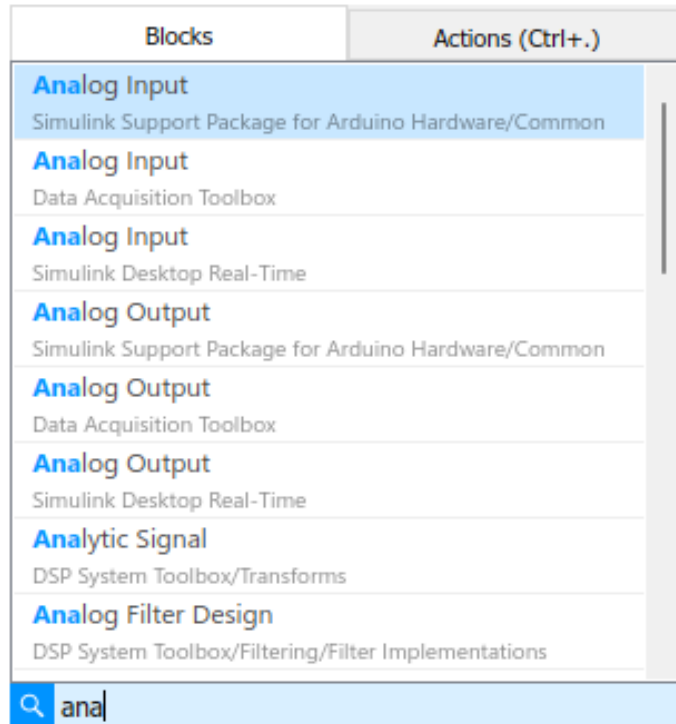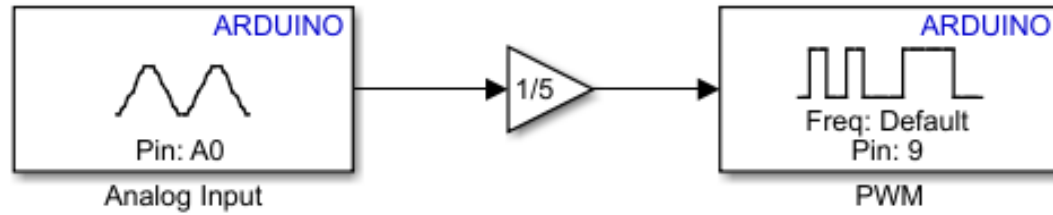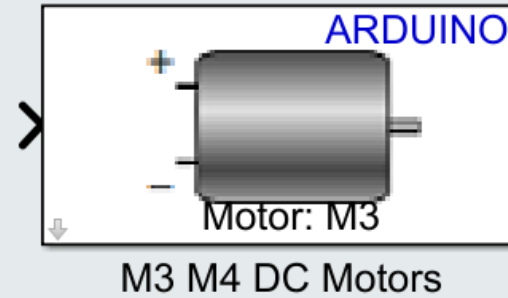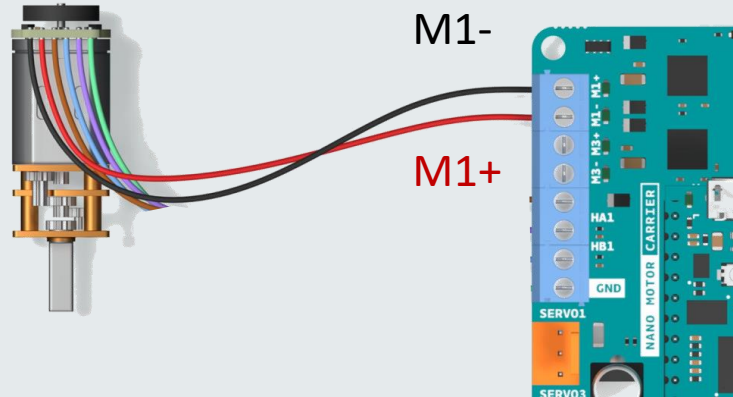2. Upload an empty sketch from Arduino IDE

Simulink Support Package for Arduino Library

Driver blocks

DC Motor

M1-

M1+

ARDUINO

Motor: M3

M3 M4 DC Motors

ARDUINO
Position

Encoder: 1   Speed

Encoder

ARDUINO

Motor: M1

M1 M2 DC Motors

Block Parameters: M3 M4 DC Motors   ✕

The block accepts an input between 255 to -255:
* 255 = Full speed forward
* 0 = No power
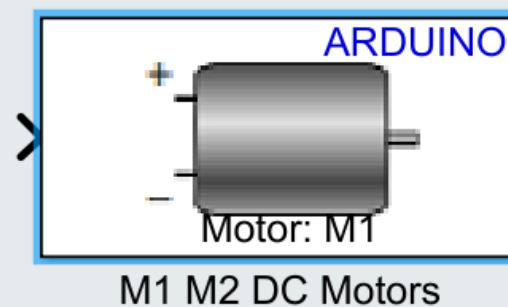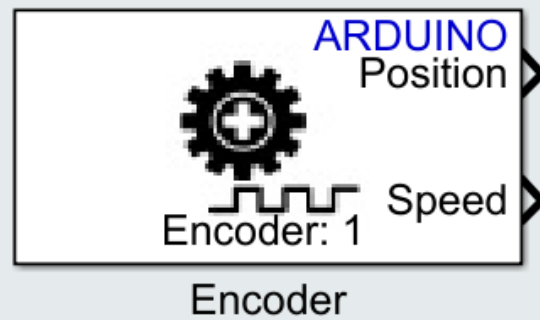* -255 = Full speed reverse

Motor port: M3 ▾

OK   Cancel   Help   Apply

Block Parameters: M1 M2 DC Motors   ✕

DC Motor

Set the speed and direction of the DC motor on the selected port.

The block accepts an input between 100 to -100:
* 100 = Full speed forward
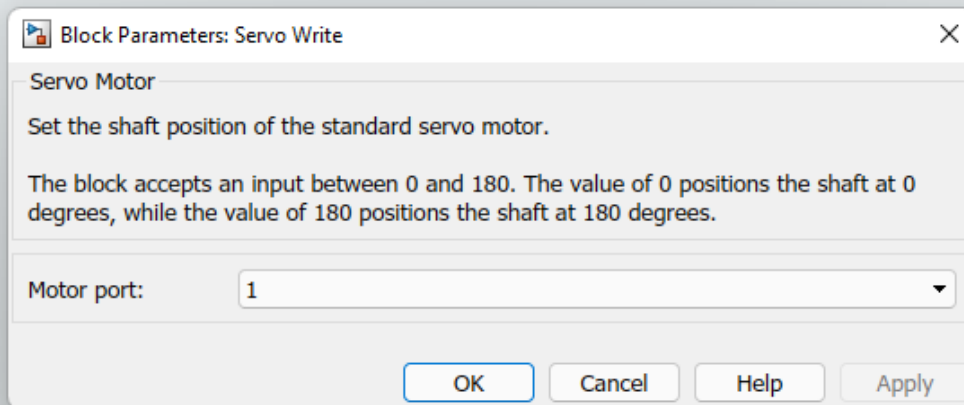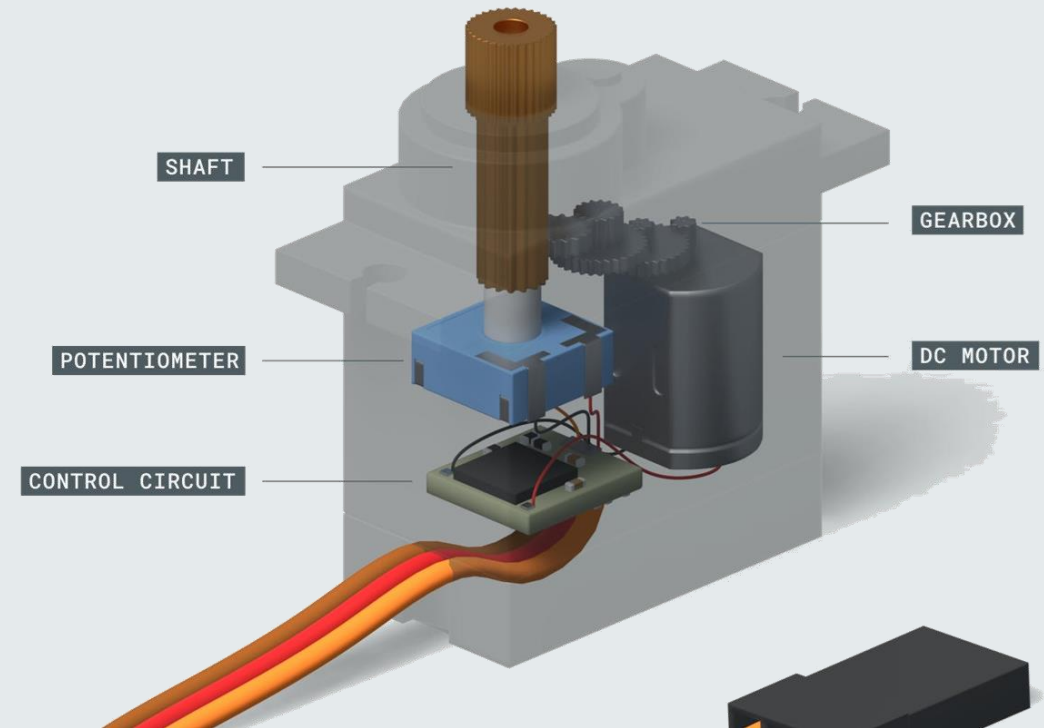* 0 = Stop
* -100 = Full speed reverse

Motor port: M1   ▾

OK   Cancel   Help   Apply

Servomotor

angle in degrees

ARDUINO

Servo Motor: 1

Servo Write

Block Parameters: Servo Write

Servo Motor

Set the shaft position of the standard servo motor.

The block accepts an input between 0 and 180. The value of 0 positions the shaft at 0 degrees, while the value of 180 positions the shaft at 180 degrees.

Motor port: 1

OK   Cancel   Help   Apply

SHAFT

GEARBOX

POTENTIOMETER

DC MOTOR

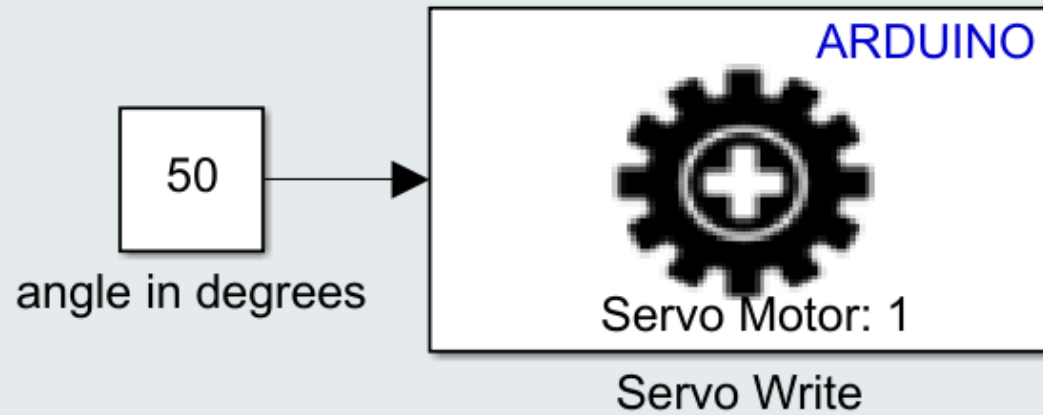CONTROL CIRCUIT
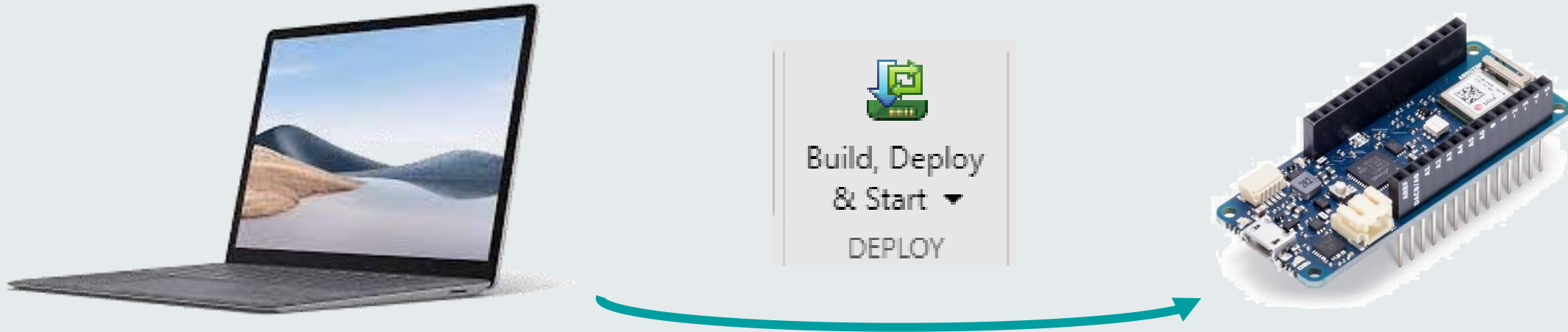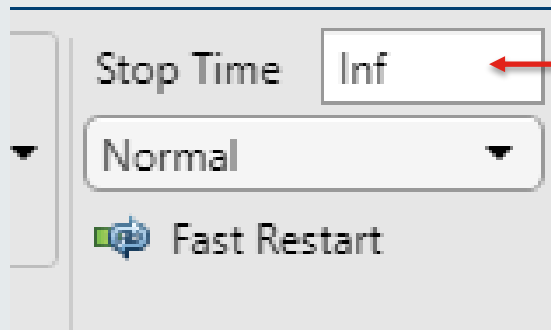
Standalone vs External Mode

In **Standalone mode**, upload Simulink model to Arduino to run in a loop

set Stop time to Infinity for continuous operation
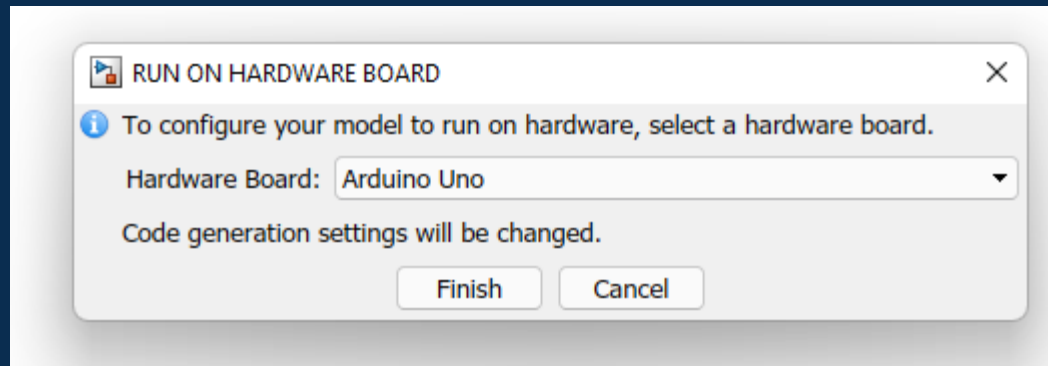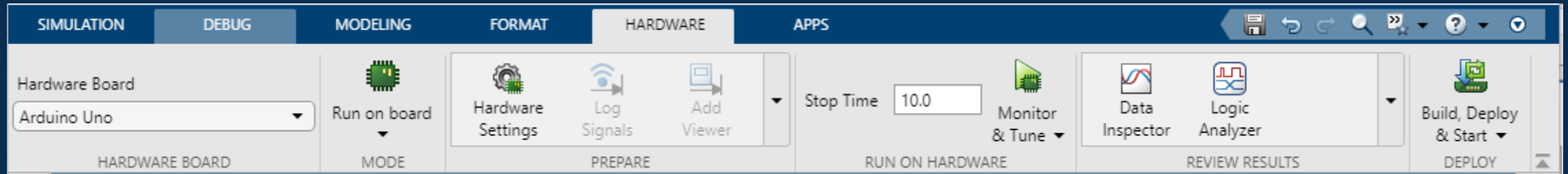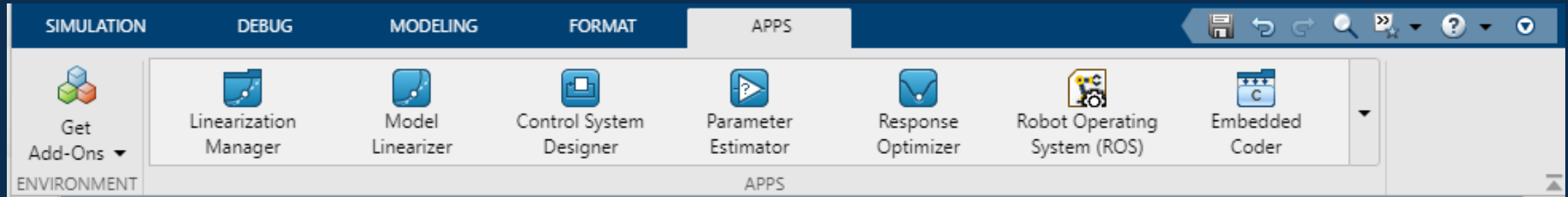
Standalone vs External Mode

In **External mode**, upload Simulink model to Arduino to run in a loop and maintain a **live serial connection** to read board data from Simulink
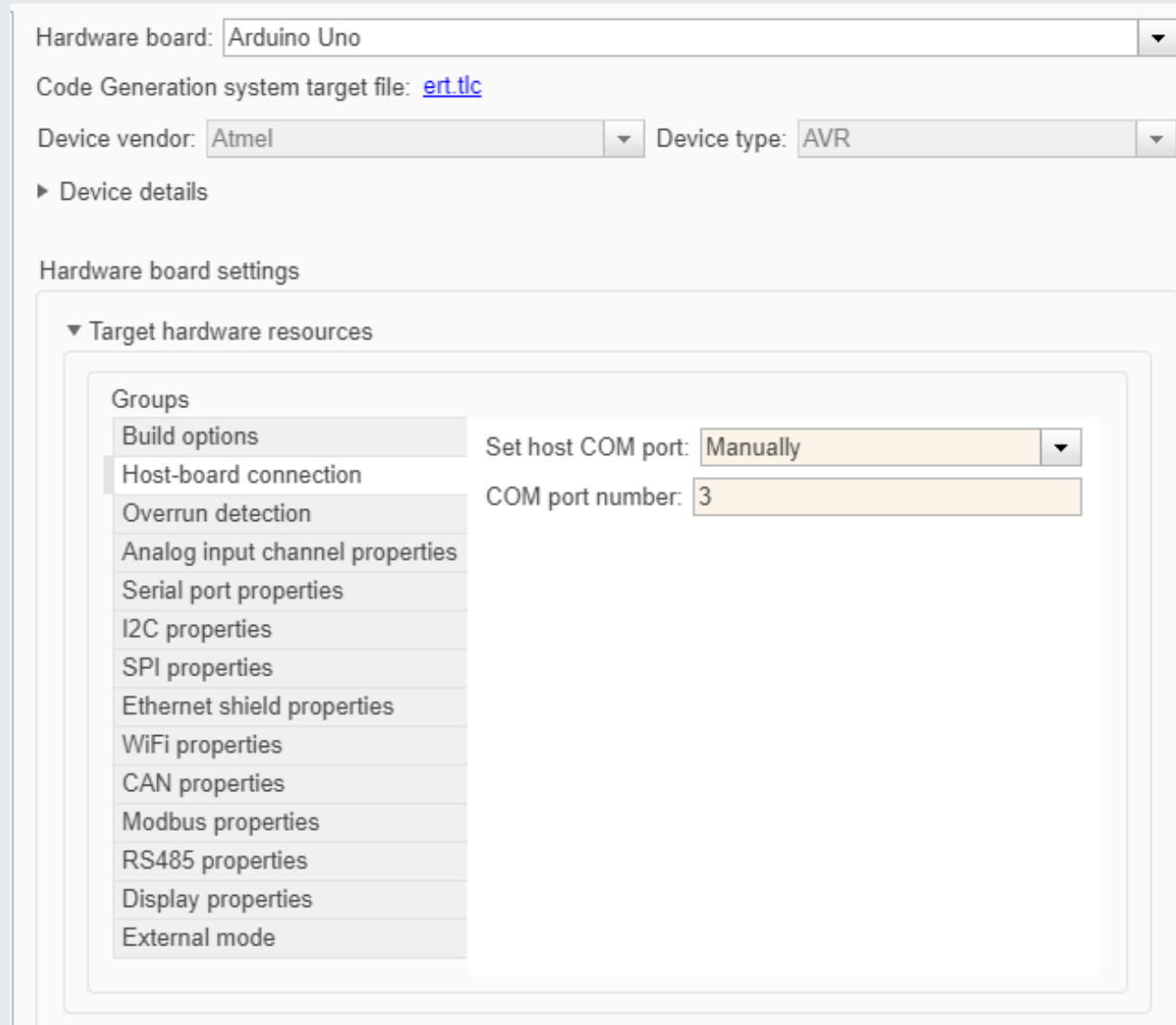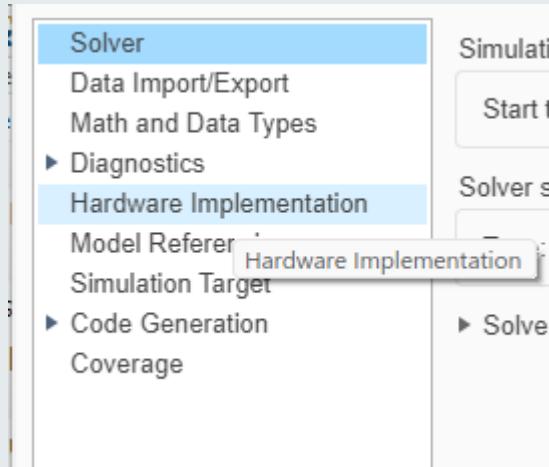
Useful for **Desktop Prototyping**

Hardware Settings

Hardware Tab and Hardware Configuration Options

Demonstration: Simulink Hardware Implementation Menu

Solver
Data Import/Export
Math and Data Types
▶ Diagnostics
Hardware Implementation
Model Referer
Simulation Target
▶ Code Generation
Coverage

Simulati
Start t

Solver s

▶ Solve

Hardware Implementation

Hardware board: Arduino Uno

Code Generation system target file: ert.tlc

Device vendor: Atmel   Device type: AVR

▶ Device details

Hardware board settings

▼ Target hardware resources

Groups
Build options
Host-board connection
Overrun detection
Analog input channel properties
Serial port properties
I2C properties
SPI properties
Ethernet shield properties
WiFi properties
CAN properties
Modbus properties
RS485 properties
Display properties
External mode

Set host COM port: Manually

COM port number: 3

Rate Control

- Continuous vs discrete time

- Variable vs fixed step solvers

- Managing global sample time in Simulink

- Using sample times in blocks

- Information overlays in Simulink to analyse multi-rate models

Sample Time
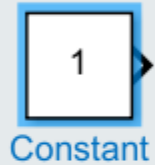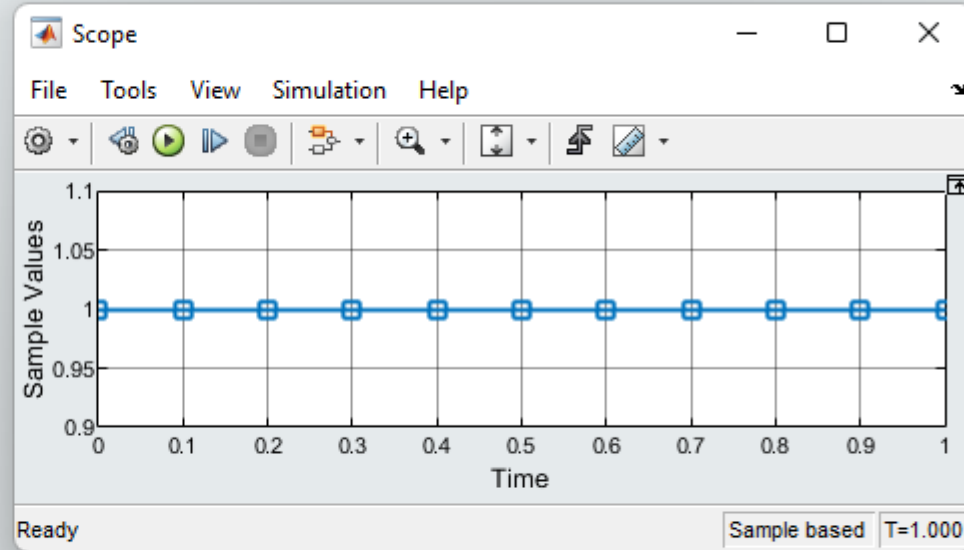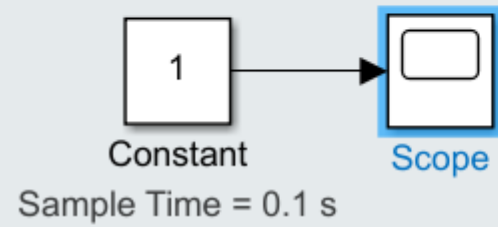
Sample Time

Continuous vs Discrete

Global Sample Time

FixedStepAuto
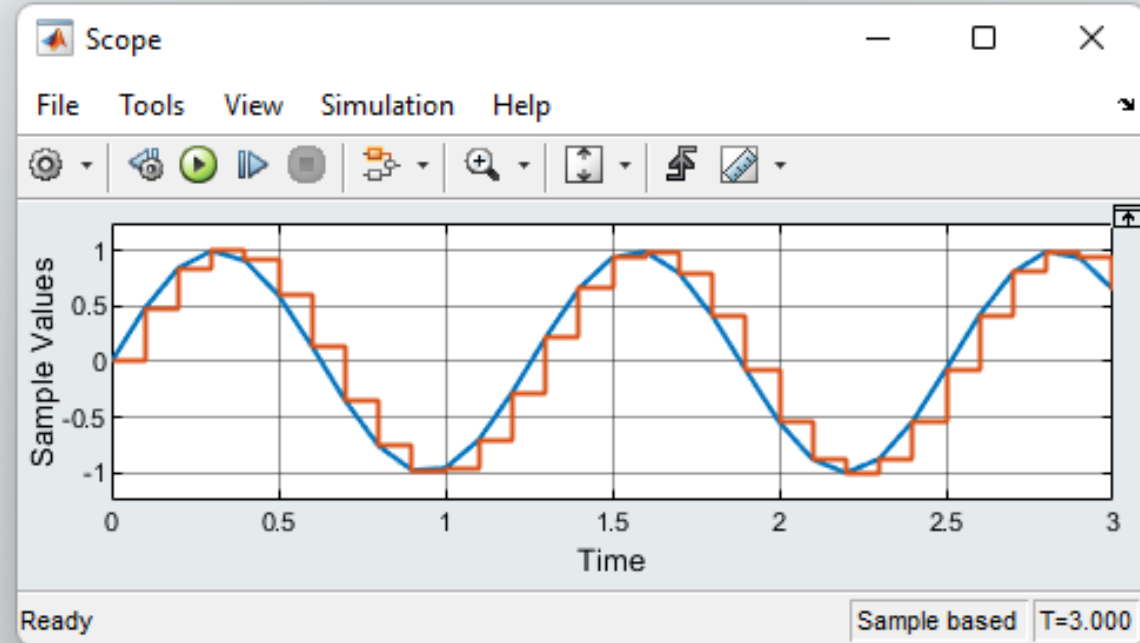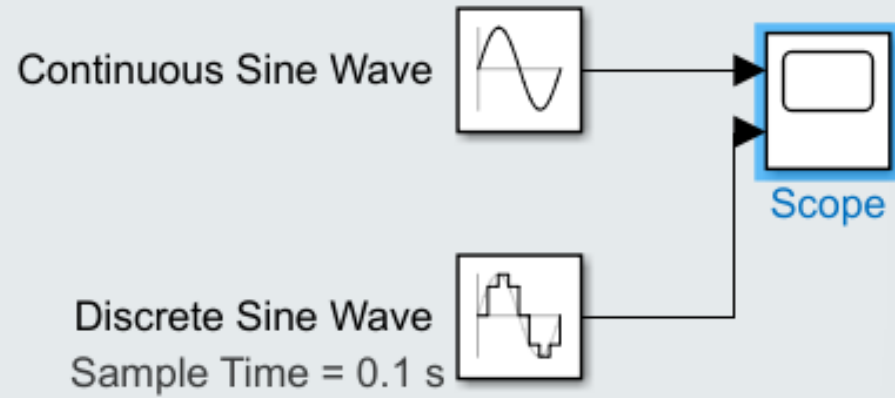
By default model will execute with global sample time

e.g. run in a loop every 0.1 s

Configuration Parameters: rate_control/Configuration (Active)

Search

- Solver
- Data Import/Export
- Math and Data Types
- ▶ Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- ▶ Code Generation
- Coverage

Simulation time

Start time: 0.0   Stop time: 10.0

Solver selection

Type: Fixed-step   ▼   Solver: auto (Automatic solver selection) ▼

▼ Solver details

global sample time

Fixed-step size (fundamental sample time): 0.1

Tasking and sample time options

Periodic sample time constraint: Unconstrained   ▼

☐ Treat each discrete rate as a separate task
☐ Allow tasks to execute concurrently on target
☐ Automatically handle rate transition for data transfer

OK   Cancel   Help   Apply
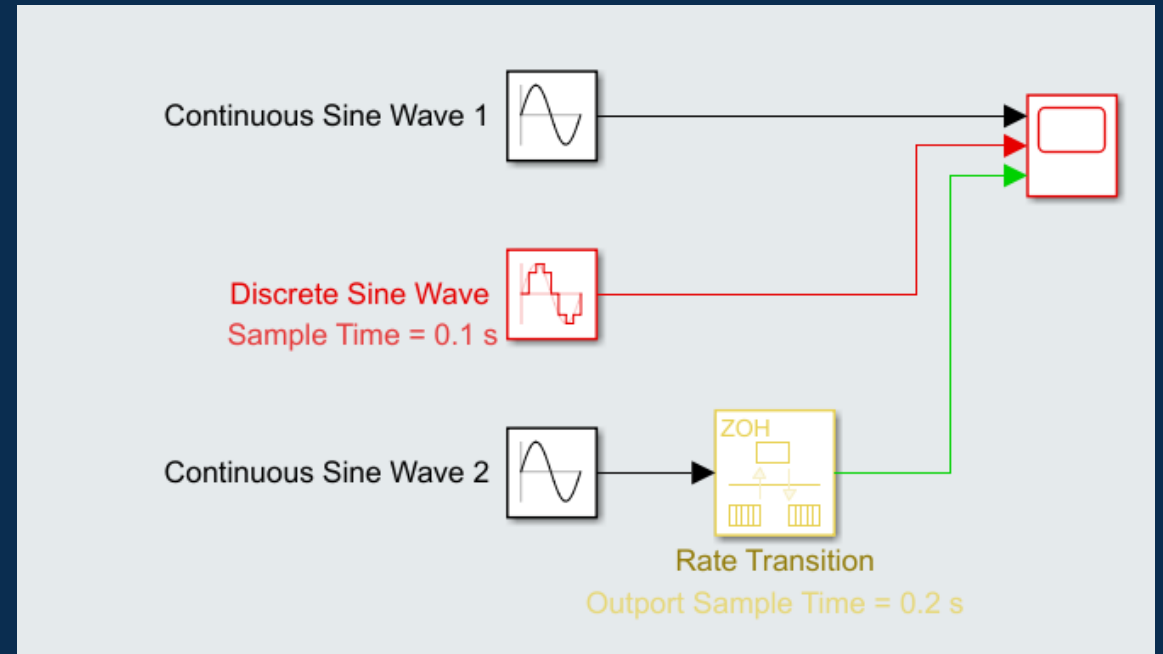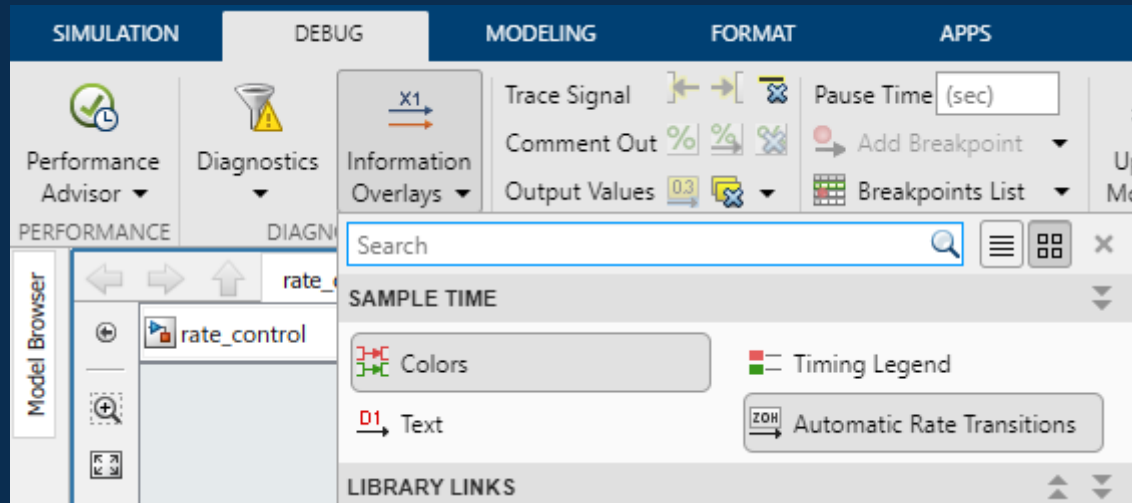
Microcontrollers run at fixed time steps

Rate Control
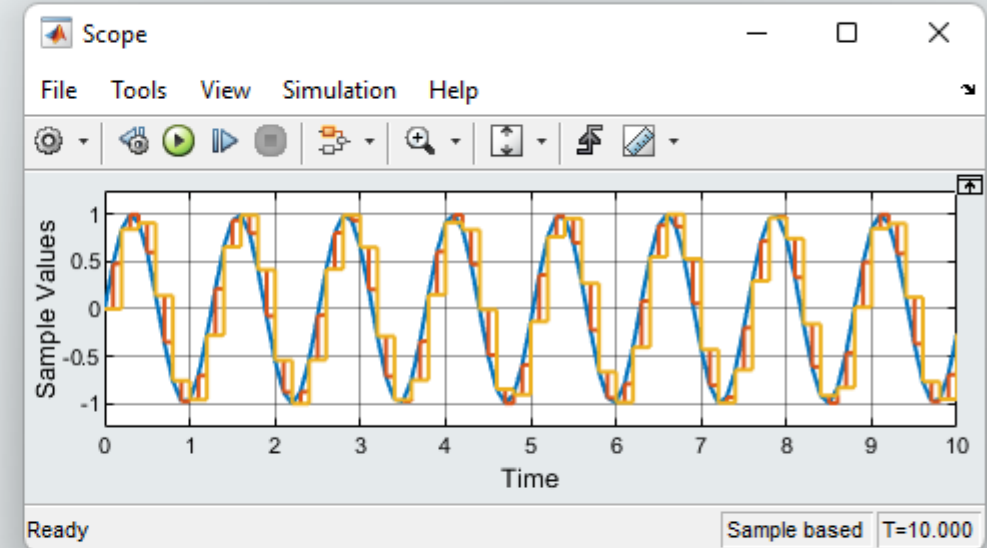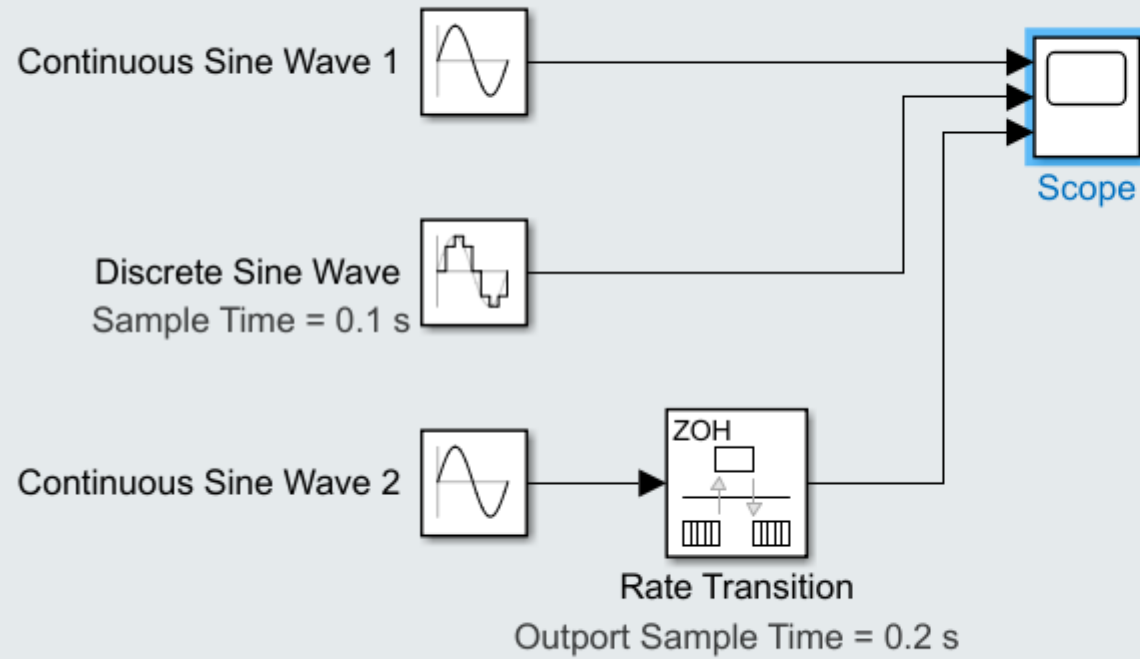
Rate transition block can be used to control the execution rate of a Simulink model

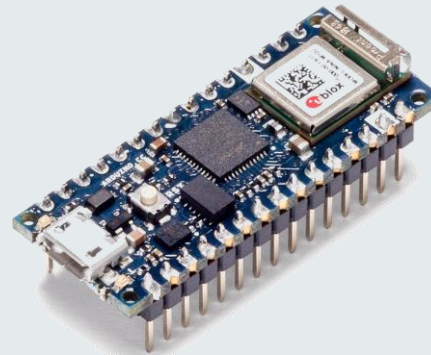# Multi-rate Systems

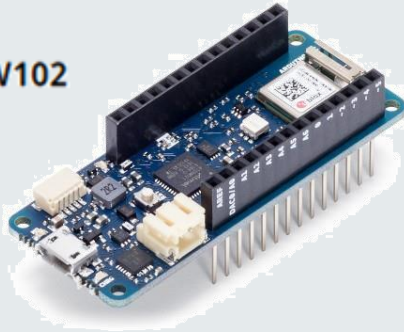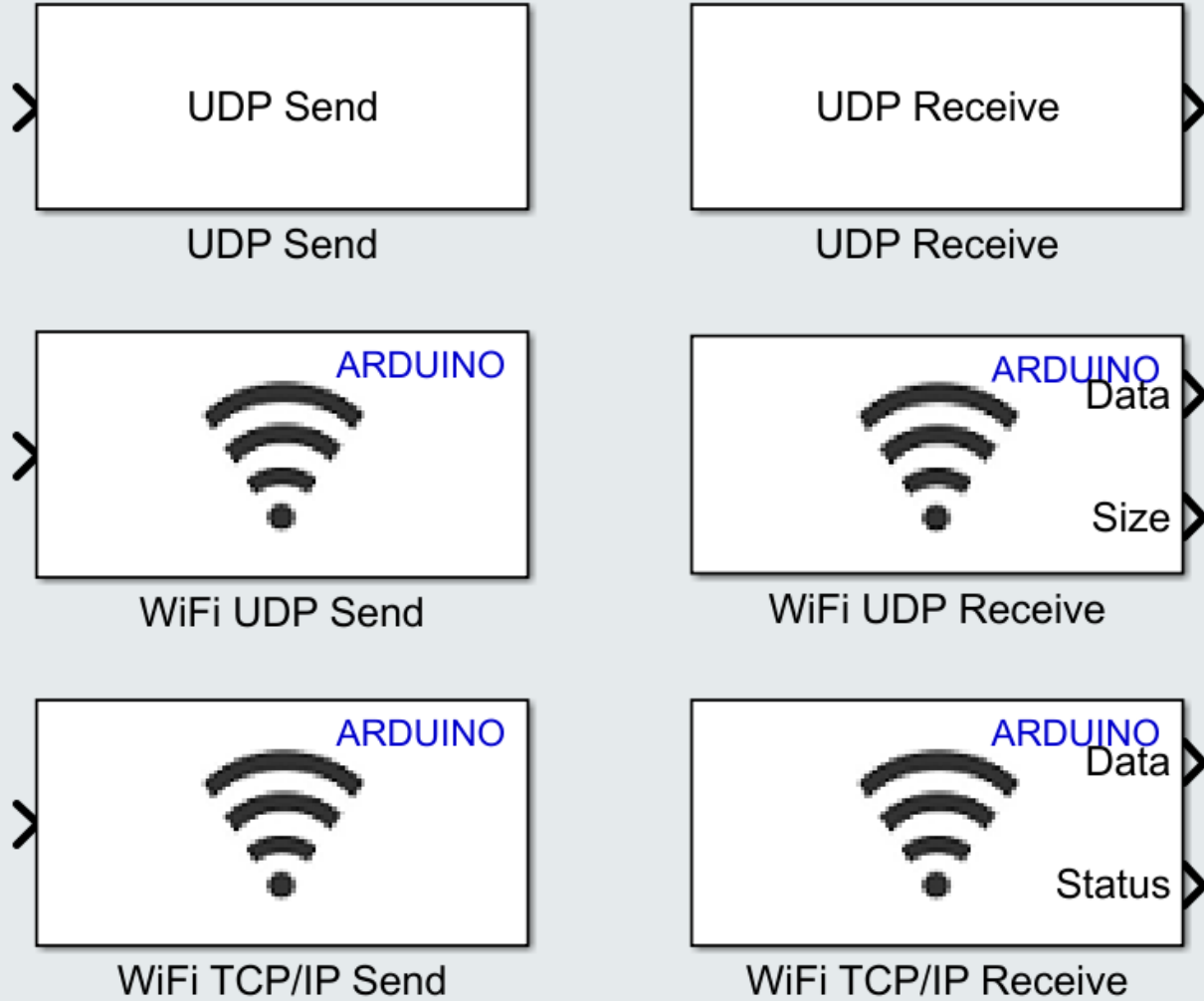**Demonstration:** Fixed rate systems

Communication

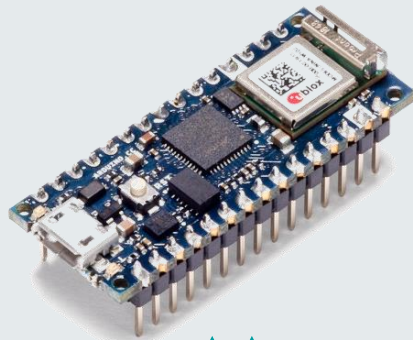Both Arduino boards have the same BLE & WiFi radio module

Communication

UDP Send

UDP Receive

WiFi UDP Send

WiFi UDP Receive

WiFi TCP/IP Send
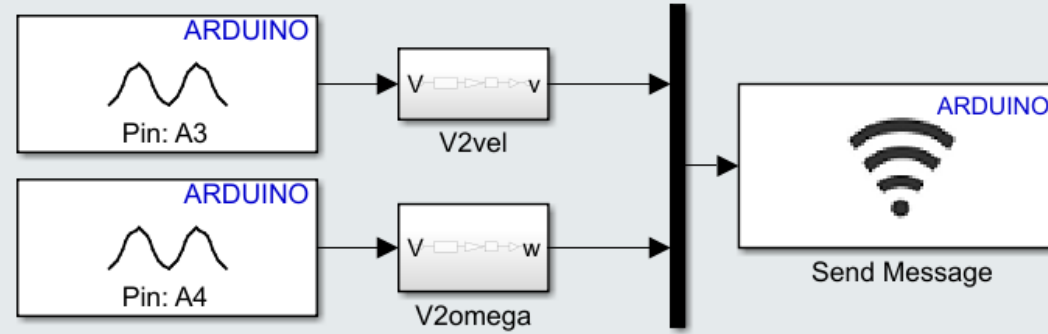

WiFi TCP/IP Receive

Ship Transmitter

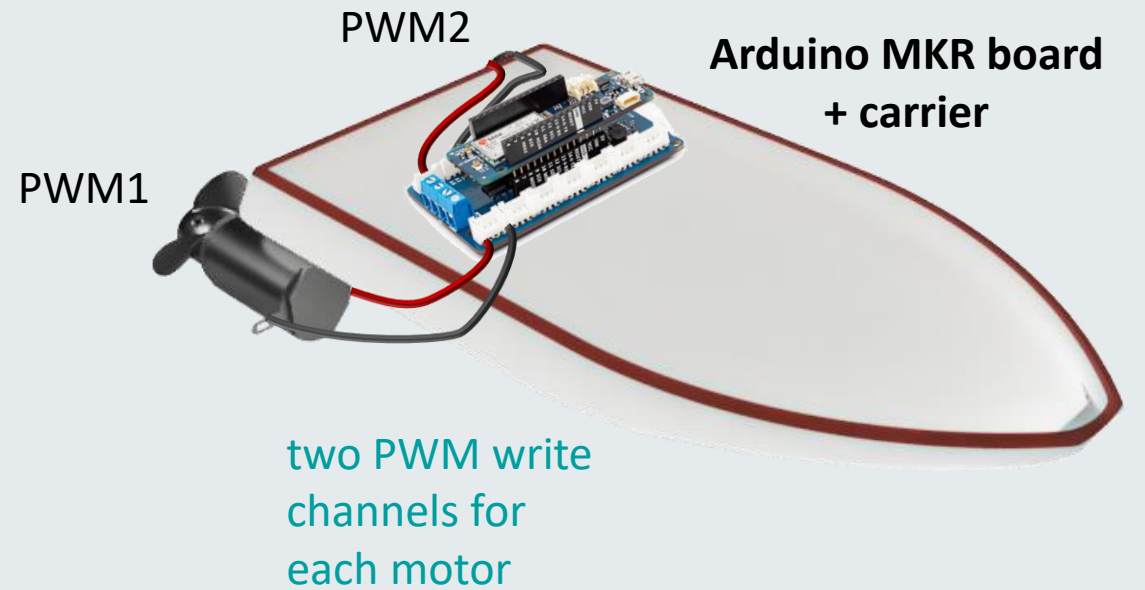**Arduino Nano 33 IoT**
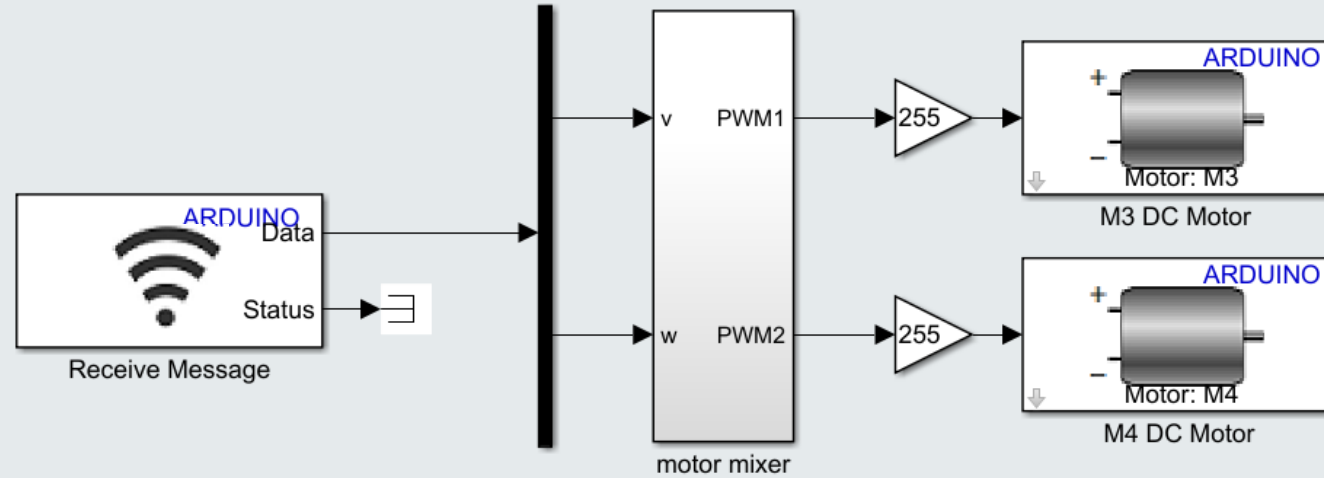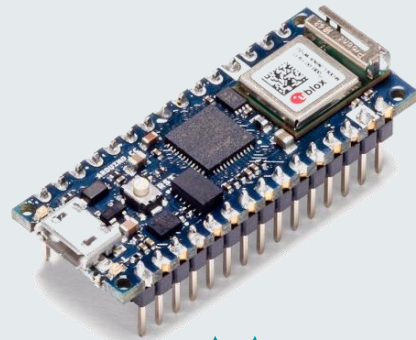
two analog read channels for v and ω

V1 V2

Arduino MKR board + carrier
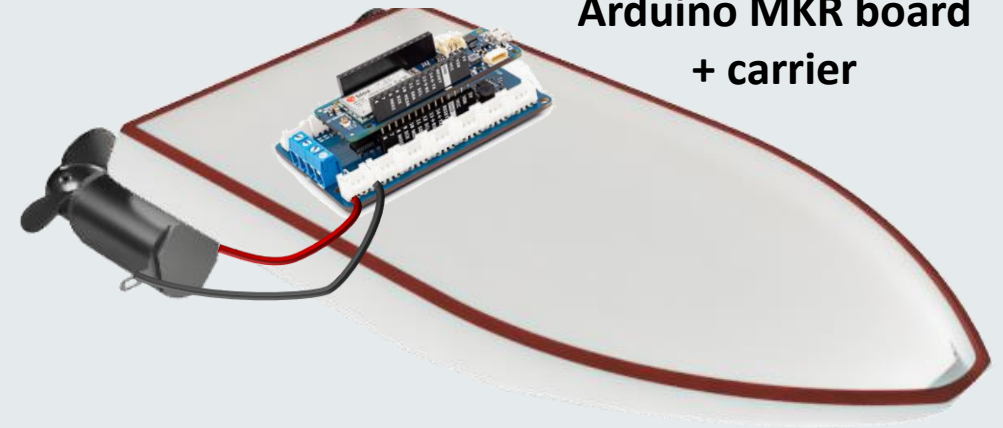
Ship Receiver

Arduino Nano 33 IoT

V1 V2

Arduino MKR board + carrier

PWM2

PWM1

two PWM write channels for each motor

IPv4 Addresses

Command Prompt
App
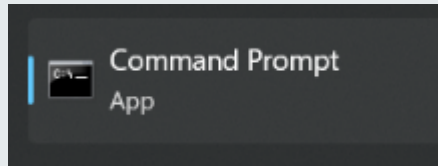
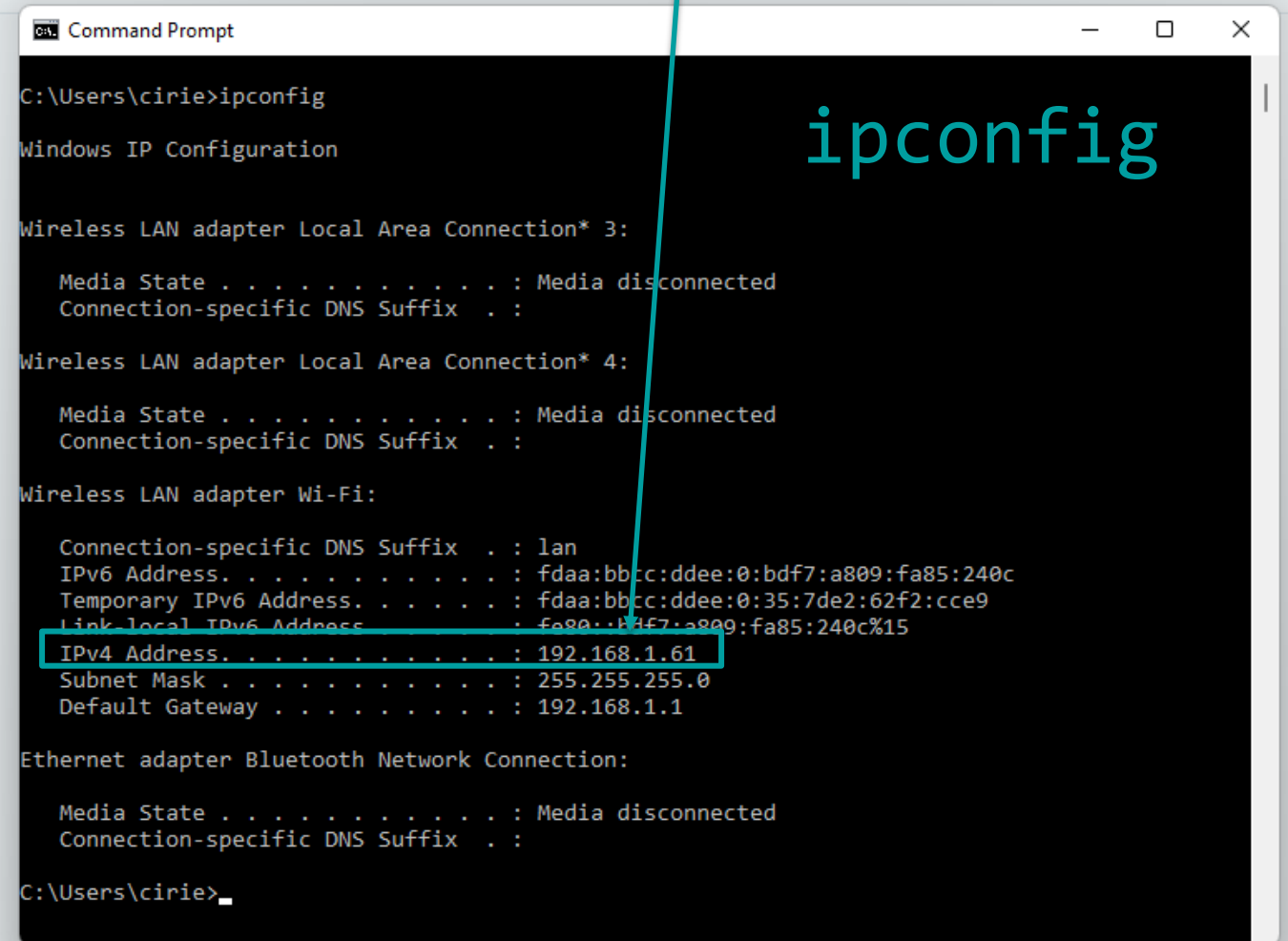**Private IP Addresses** identify devices in a local network

Public IP Addresses identify devices over the internet

Use the following commands in a terminal to find your **Private IP Address:**

- Windows: `ipconfig`

- Mac: `ipconfig getifaddr en0`

- Linux: `ifconfig`


```
Command Prompt                                    —    □    ✕

C:\Users\cirie>ipconfig

Windows IP Configuration

Wireless LAN adapter Local Area Connection* 3:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Local Area Connection* 4:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . : lan
   IPv6 Address. . . . . . . . . . . : fdaa:bbcc:ddee:0:bdf7:a809:fa85:240c
   Temporary IPv6 Address. . . . . . : fdaa:bbcc:ddee:0:35:7de2:62f2:cce9
   Link-local IPv6 Address . . . . . : fe80::bdf7:a809:fa85:240c%15
   IPv4 Address. . . . . . . . . . . : 192.168.1.61
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.1.1

Ethernet adapter Bluetooth Network Connection:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

C:\Users\cirie>_
```
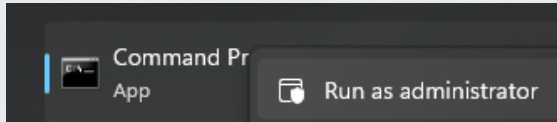
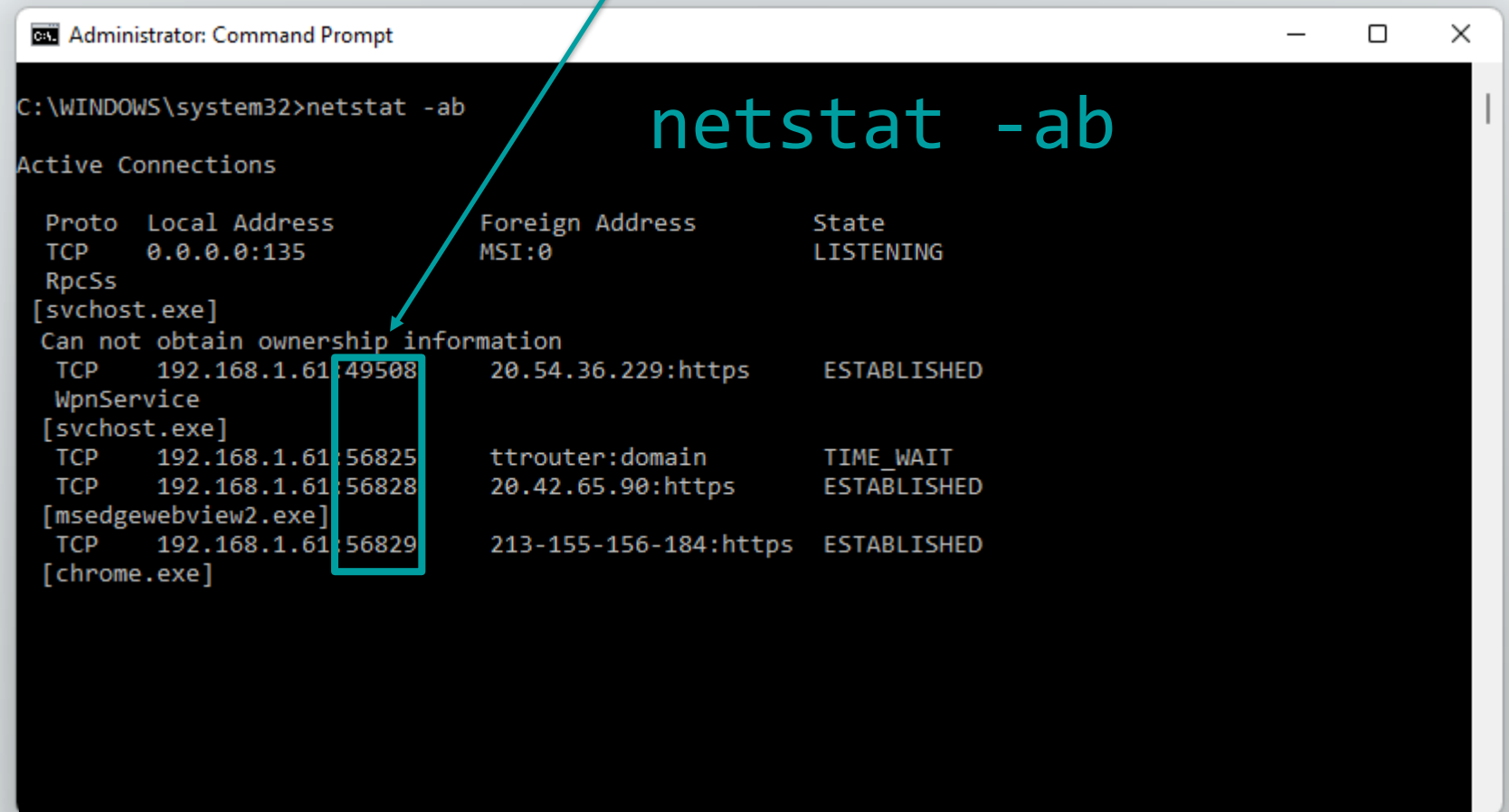ipconfig

Ports

$$192.168.1.61 : 59508$$

Messages are passed between **Devices** through **Ports**

Ports provide a useful way to organise your communication

Example default ports
- SSH uses Port 22
- HTTP uses Port 80
- HTTPS uses Port 443


```
Administrator: Command Prompt                                    — □ ✕

C:\WINDOWS\system32>netstat -ab          netstat -ab

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    0.0.0.0:135            MSI:0                  LISTENING
 RpcSs
[svchost.exe]
 Can not obtain ownership information
  TCP    192.168.1.61:49508        20.54.36.229:https     ESTABLISHED
 WpnService
[svchost.exe]
  TCP    192.168.1.61:56825        ttrouter:domain        TIME_WAIT
  TCP    192.168.1.61:56828        20.42.65.90:https      ESTABLISHED
[msedgewebview2.exe]
  TCP    192.168.1.61:56829        213-155-156-184:https  ESTABLISHED
[chrome.exe]
```

50

Communication PC

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Communication Arduino

Block Parameters: WiFi UDP Send

Arduino WiFi UDP Send

Send UDP packets to another UDP host.

The block accepts a 1-D array of type boolean, uint8, int8, uint16, int16, uint32, int32, single or double.

Set the Remote IP address and Remote IP port parameters to the IP address and port number of the receiving UDP host, respectively.

Set the Local IP Port parameter to the desired local port to be used.

Parameters

Remote IP address: 192.168.1.2

Remote IP port: 50002

Local IP port: 50001

OK   Cancel   Help   Apply

Block Parameters: WiFi UDP Receive

Arduino UDP Receive

Receives UDP packets from another UDP host.

The block outputs the values received as an [Nx1] array.

The sending UDP host must send UDP packets to the Local IP port specified.

Parameters

Local IP Port: 50001

Data type: uint8

Data size (N):   1

Sample time: 0.1
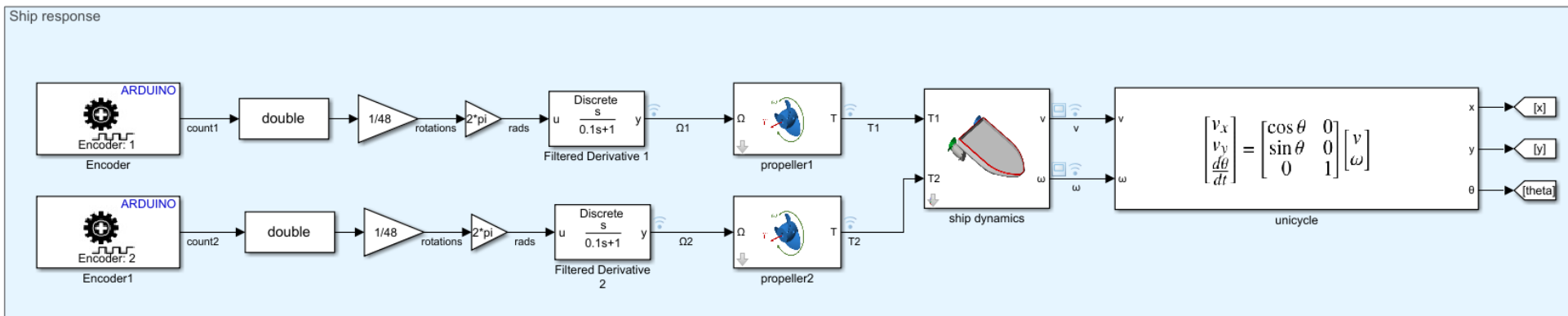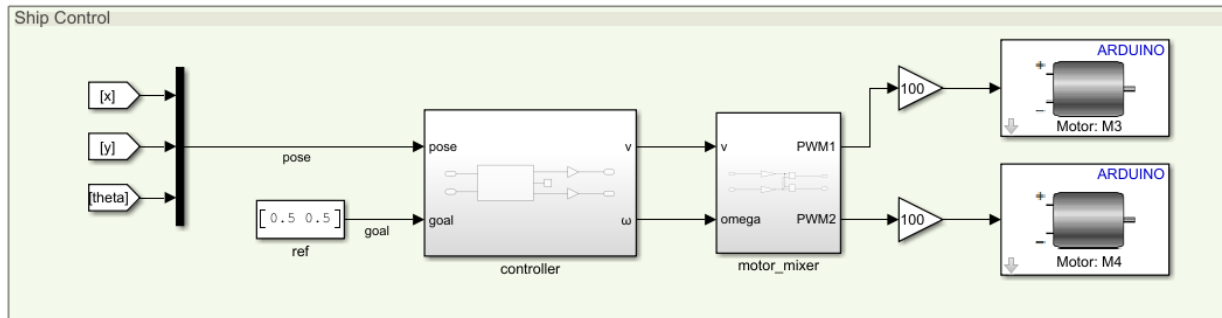
OK   Cancel   Help   Apply

ARDUINO

WiFi UDP Send

ARDUINO
Data

Size

WiFi UDP Receive

Lab Preview

In the fourth and final lab, you will use Simulink to program components connected to an Arduino.
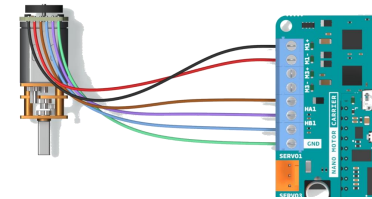
Lab Preview

This is a special lab in which you are expect to work with your team

Subteam 1: Motor control

Members: *Control Engineer (leads), Propulsion Engineer, Ship Builder, Project Manager*

Subteam 2: Communication

Members: *Communication Engineer (leads), Robotic Engineer, Ship Designer, System Architect, Quality Control Engineer*

Lab Preview

Please bring your First Year at Home Kit