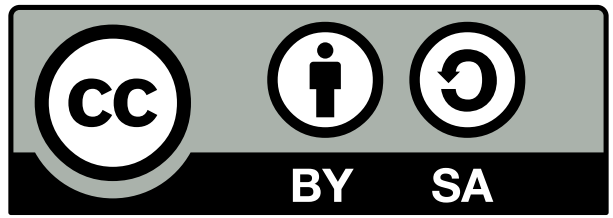
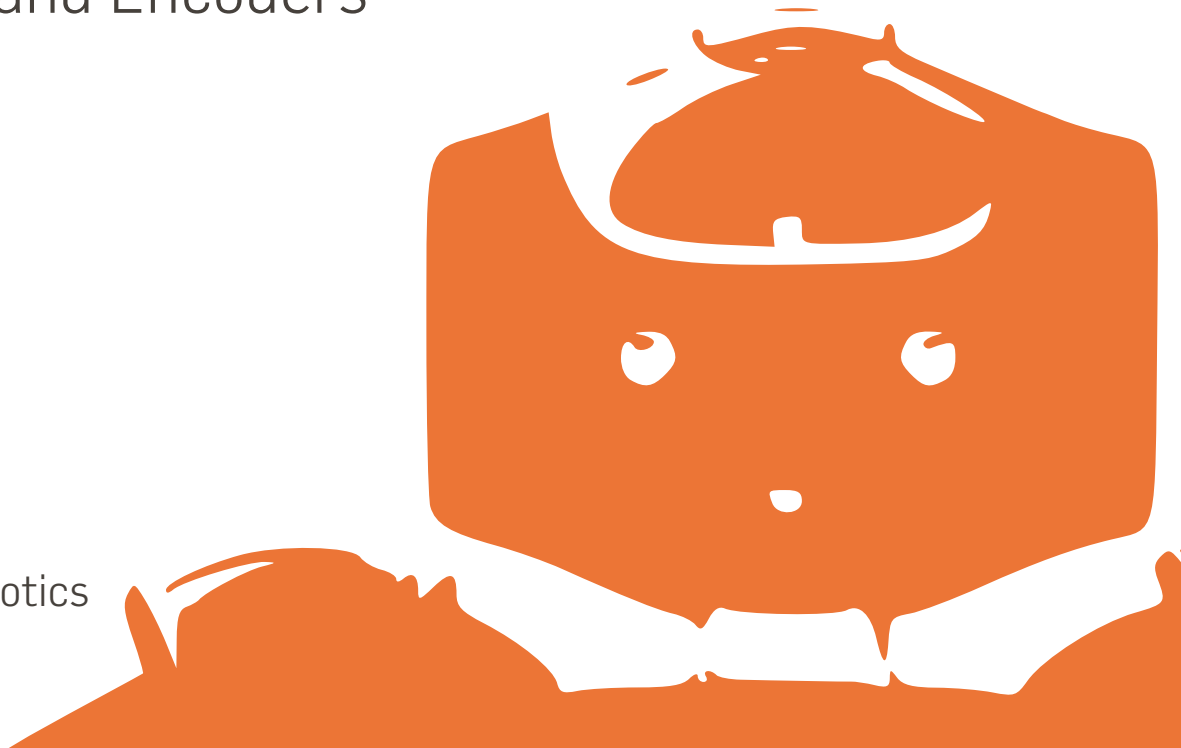


You can download the sources of this presentation here:
github.com/severin-lemaignan/module-introduction-sensors-actuators

ROBOTICS WITH PLYMOUTH UNIVERSITY

ROCO222
Intro to Sensors and Actuators
Introduction, Arduinos and Encoders



Séverin Lemaignan

Centre for Neural Systems and Robotics
Plymouth University

WHO AM I?

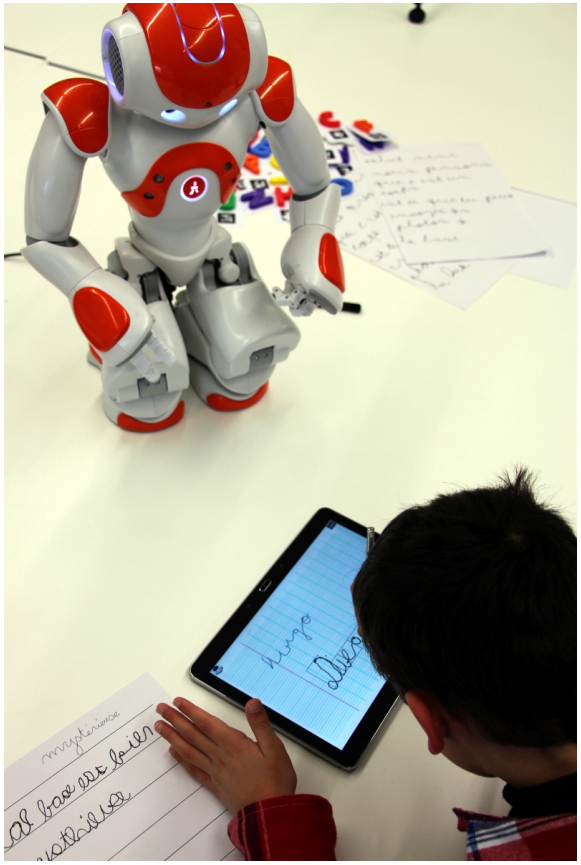
Séverin Lemaignan, B316 Portland Square

Cognitive robotics

Building robots and their artificial intelligence inspired on natural systems, such as developing children

Human-Robot Interaction

Building robots that can work alongside people, using social cues that people use to communicate



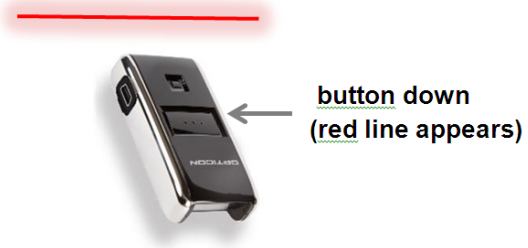
AVAILABILITY

- I have lots of time (2 hours) to deal with your queries in the laboratory sessions
- Otherwise, the best thing to do is to email me first and see if I can sort out your query. If not then I will arrange a time to meet up with you.
- Don't forget – if you have any problems, or even if you are not sure about something - just email me

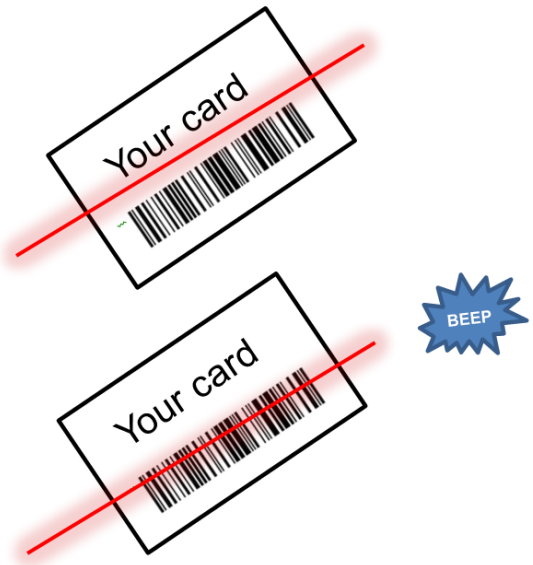
severin.lemaignan@plymouth.ac.uk

REGISTRATION

STEP 1 – Activate the device



STEP 2 - Move red line across the barcode …



SPECIAL NEEDS

- Anyone with dyslexia or any other special needs that requires any form of support during examinations and tests should email me immediately.
- Please do not ASSUME that I know of your condition. It takes the University some weeks to process data and forward it to the correct members of staff.
- Even if you are currently undergoing assessment, it is advisable to contact me and I will organize suitable support for you during your tests and exams.
- Contact me if any issues relating to harassment, inclusivity or if language/cultural difficulties arise.

LABS

- ROCO222 is also taught and supervised in a computer laboratory for TWO HOURS EACH WEEK.
- There are 2 labs so please go to your timetabled group and pair up with someone

Day?	Time?	Where?	Who?
Monday – Lab 1/**02**	09:00–11:00	SMB 307	Jake & myself
Thursday – Lab 1/**01**	11:00–13:00	SMB 307	Jake & myself

ASSESSMENT

ASSESSMENT

Formative vs Summative

Formative: during the term; **Summative**: at the end of the term.

- There will be practical assessments in the form of laboratory practical work (60%)
- **First practical needs to be submitted by 16:00, 13th October 2017**
- Feedback within 20 working days
- Complete lab journal submitted **Thursday 16:00, 11th January 2018**
- There will be a final written exam (40%) – **note that the exam questions may touch upon material discussed during the labs**

ROBOTICS: WHAT ARE YOUR EXPECTATIONS?

Go to www.menti.com and use the code 60 34 45

MODULE OVERVIEW

MODULE AIMS

- Develop an in-depth understanding of **what electrical motors are**, **how they work** (hands-on!), how they are characterised

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- **We have a bit of room to touch additional topics**

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4. Understand the fundamentals of the **ROS middleware**, and use it to control motors and run simple robot visualisations
5. Acquire the **basics of software engineering**; feel confident when using the **Linux command-line**; know how to use and reflect on **document/code versioning and sharing** (with git)

IN YOUR CURRICULUM

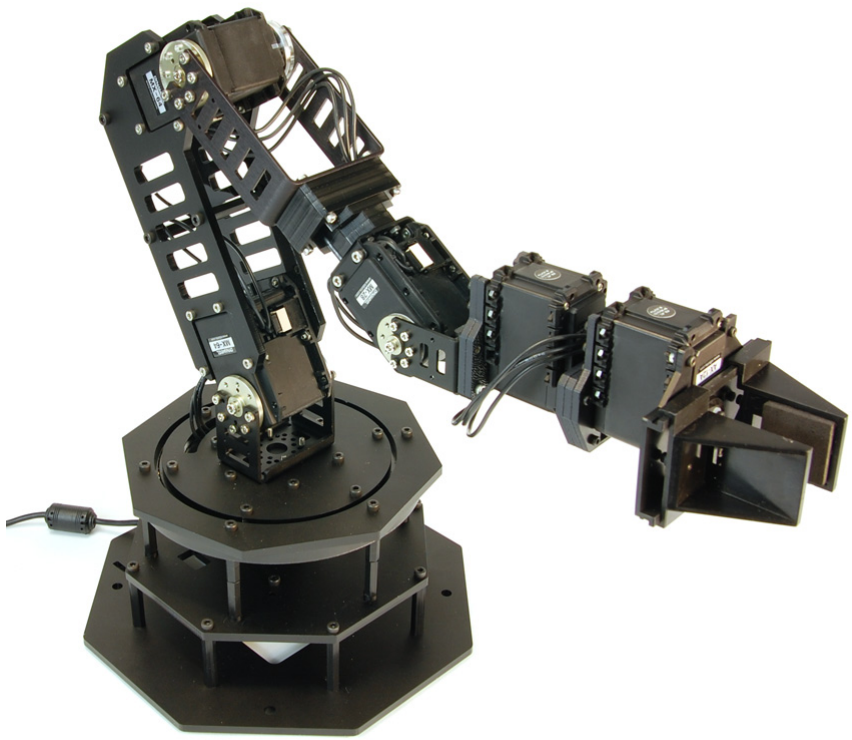
- Last year: quite a lot of electronics, **ROCO103PP**?
- Next term: **ROCO224** (Martin Stoelen) – kinematics, mechanical engineering, robot control
- Next year: **ROCO318** – sensors, algorithms, AI (path planning, localisation)

THIS YEAR: ROCO222 AND ROCO224

From...

THIS YEAR: ROCO222 AND ROCO224

...to



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- **Week 11** – Sensors

LABORATORY COURSEWORK

THIS WEEK: LAB JOURNAL & COMMAND-LINE 101

- Document versioning: what is GIT?
- Creating & managing a lab journal with GIT and markdown
- Linux command-line
- Remotely connecting to a robot

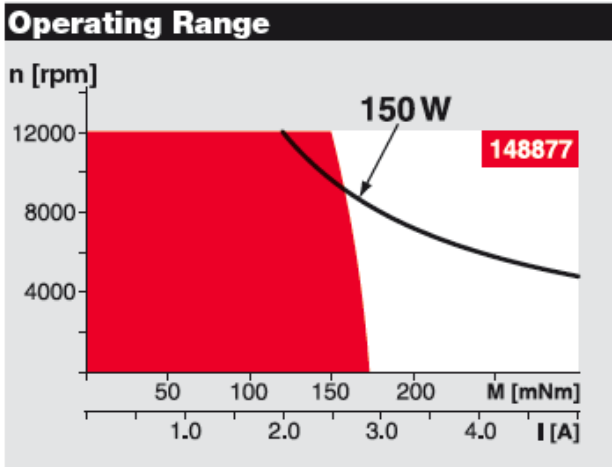
Tomorrow's practical

If you want to, you can come from 11:00 to 13:00 to finish Monday's practical (including connecting to the robot)

BUILD A DC MOTOR

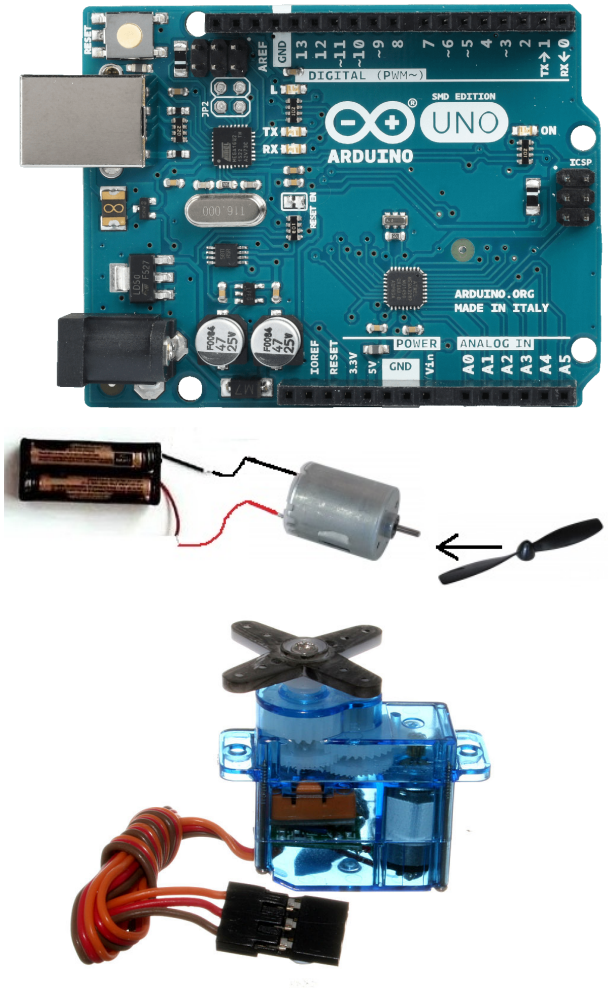
Build a DC brushed motor from first principles

- Wind armature
- Position field magnets
- Build commutator
- Test operation
- Measure characteristics



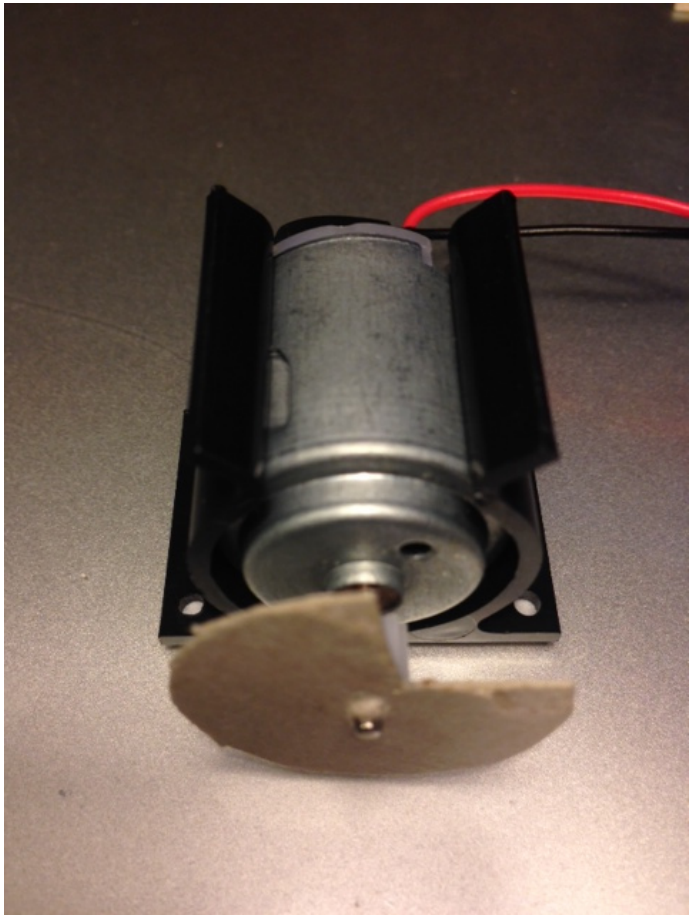
INTRODUCTION TO ARDUINO AND SIMPLE MOTOR CONTROL

- Controlling your DC motor using an Arduino
- Build a speed-controlled electric fan e.g. use temperature sensor
- Control an RC servo using an Arduino

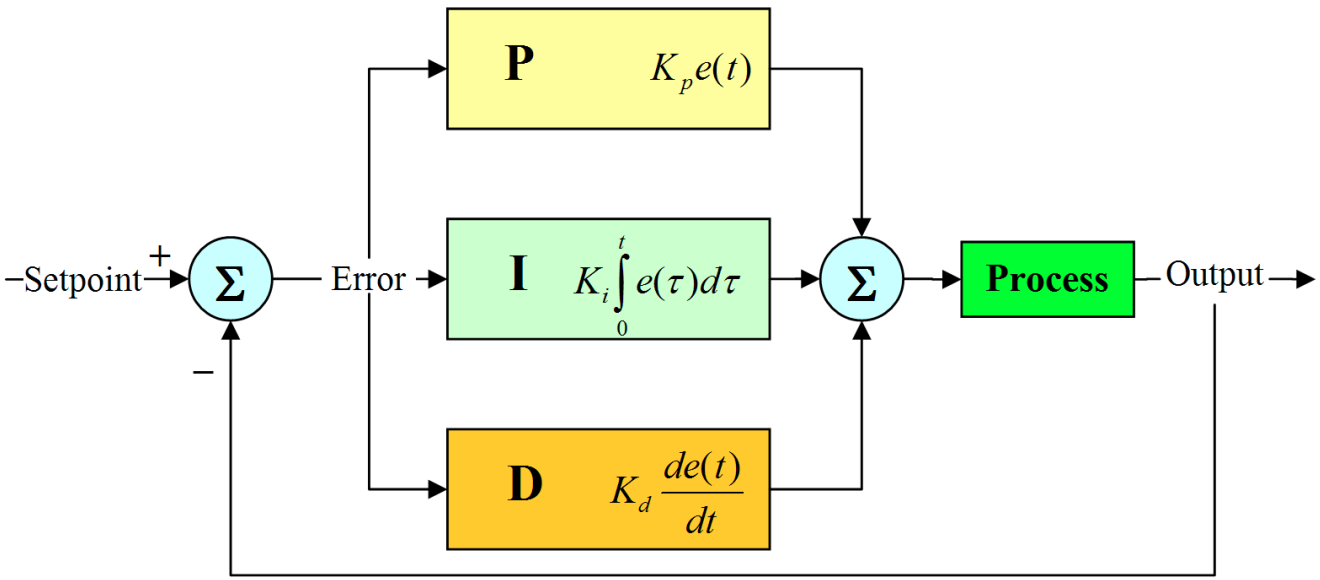


BUILD AN INCREMENTAL ENCODER

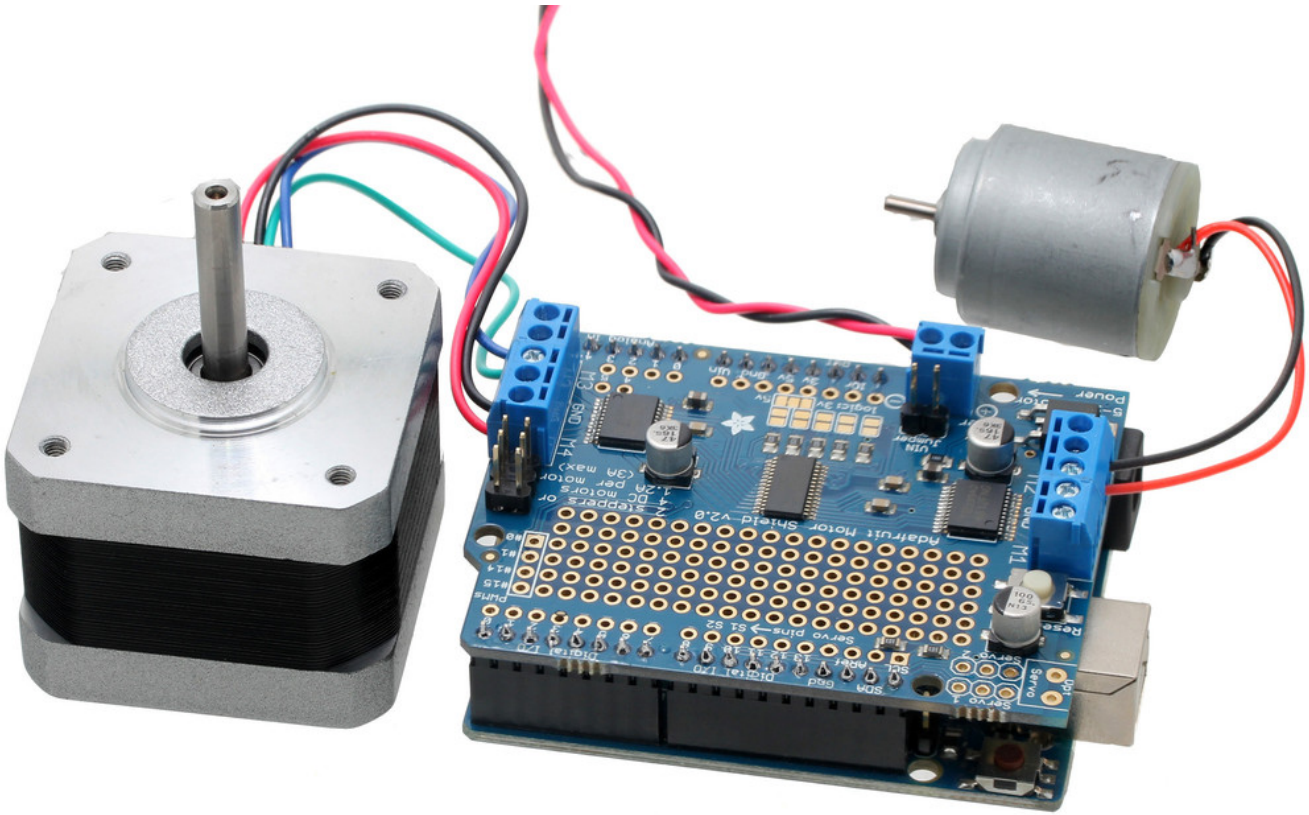
- Build a simple encoder from first principles
- Use a LED and phototransistor
- Measure rotational speed of a small DC motor
- Integrate it with the Arduino



WRITE A PID CONTROLLER FOR YOUR DC MOTOR

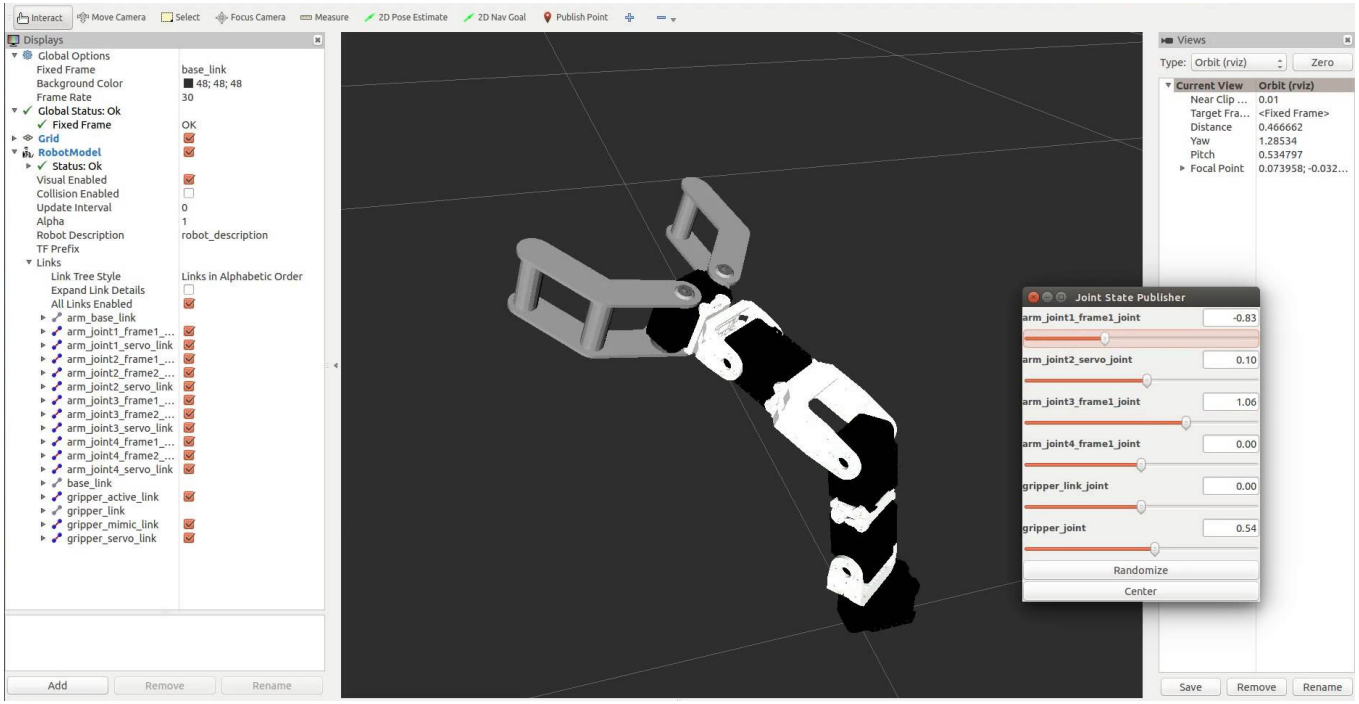


CONTROL A STEPPER MOTOR WITH AN ARDUINO



- Control a stepper motor from the Arduino
- Implement stepper modes from first principles

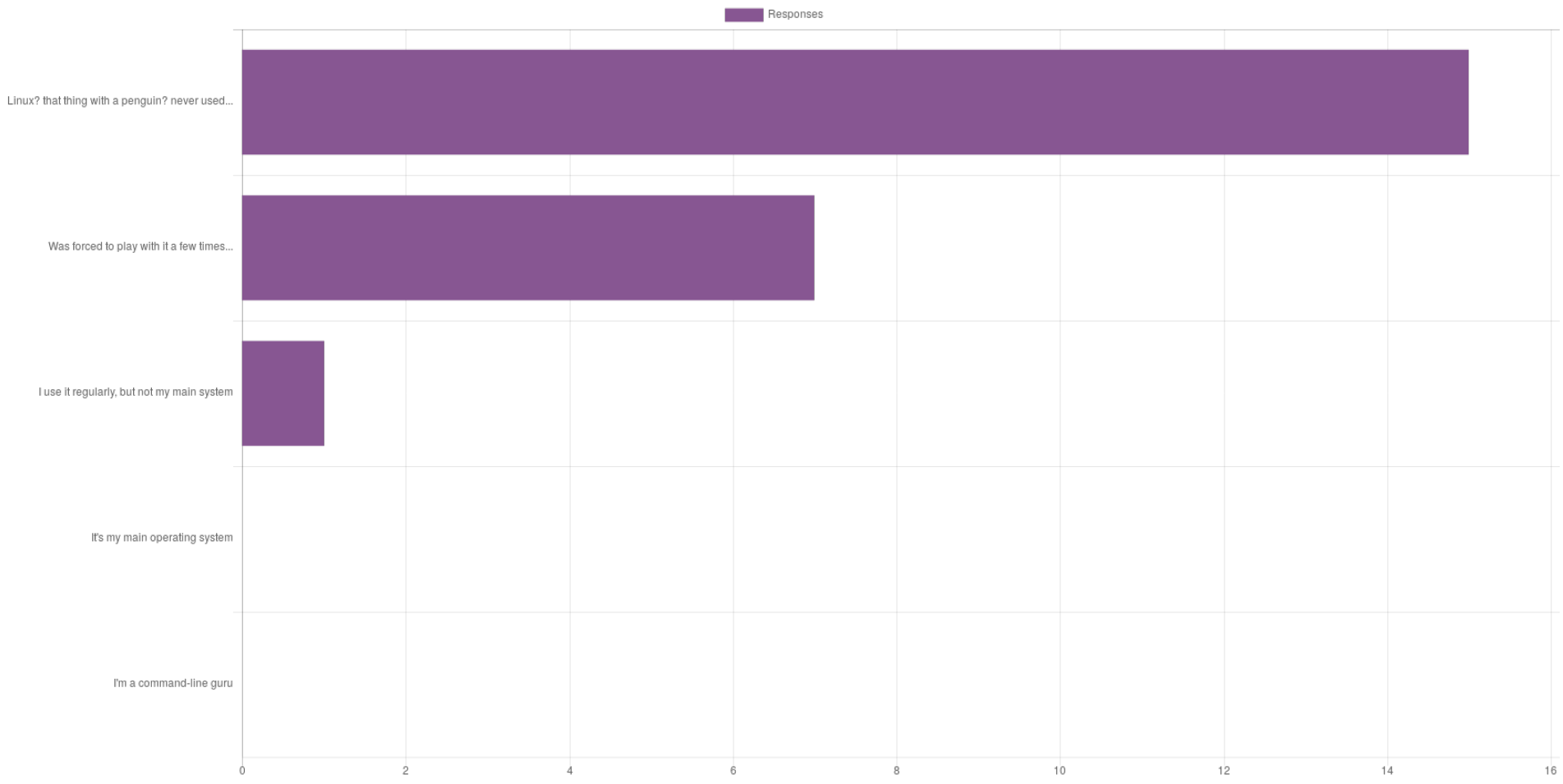
MINI PROJECT: A 3DOF ROBOT ARM CONTROLLED FROM ROS

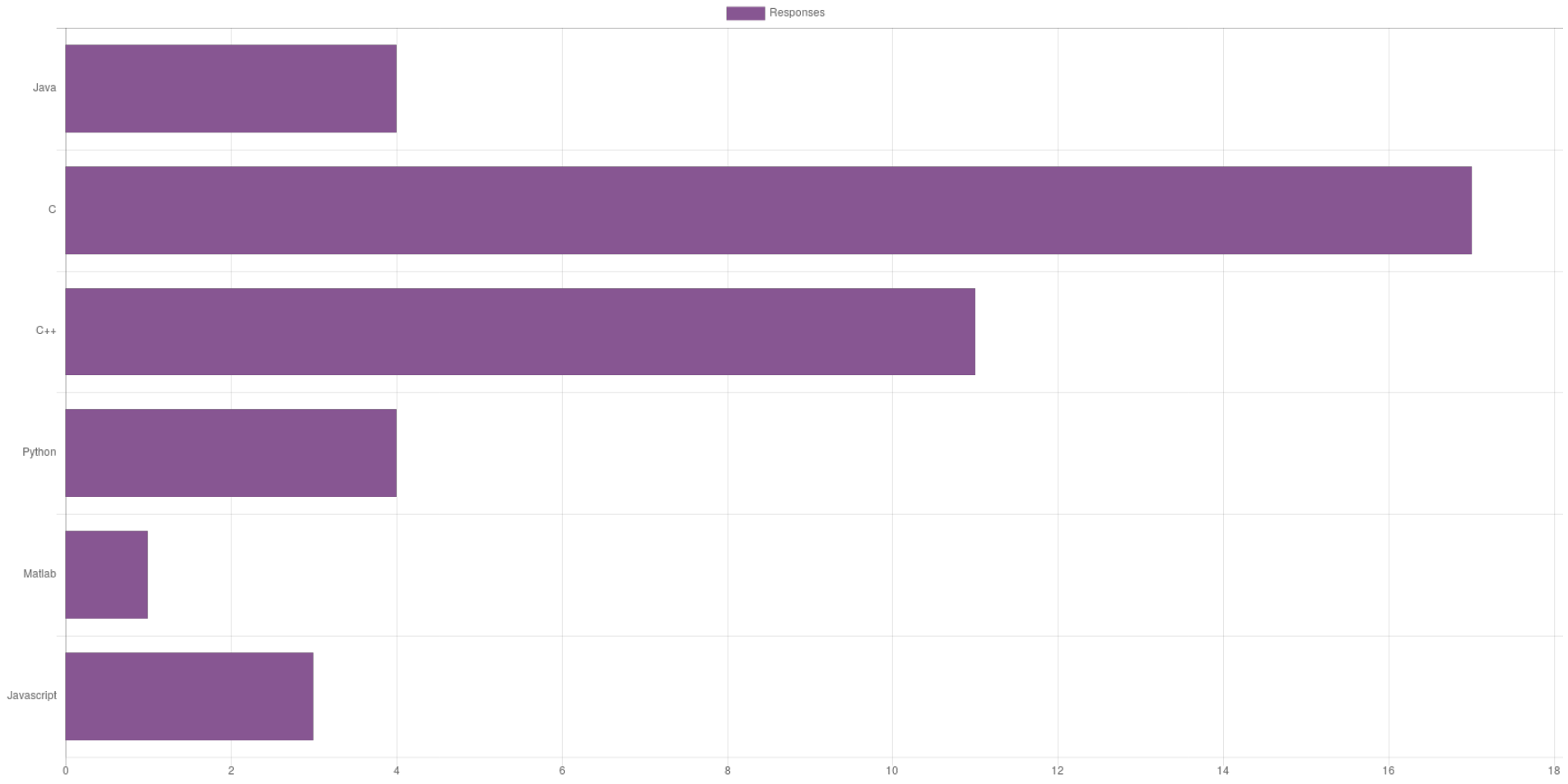


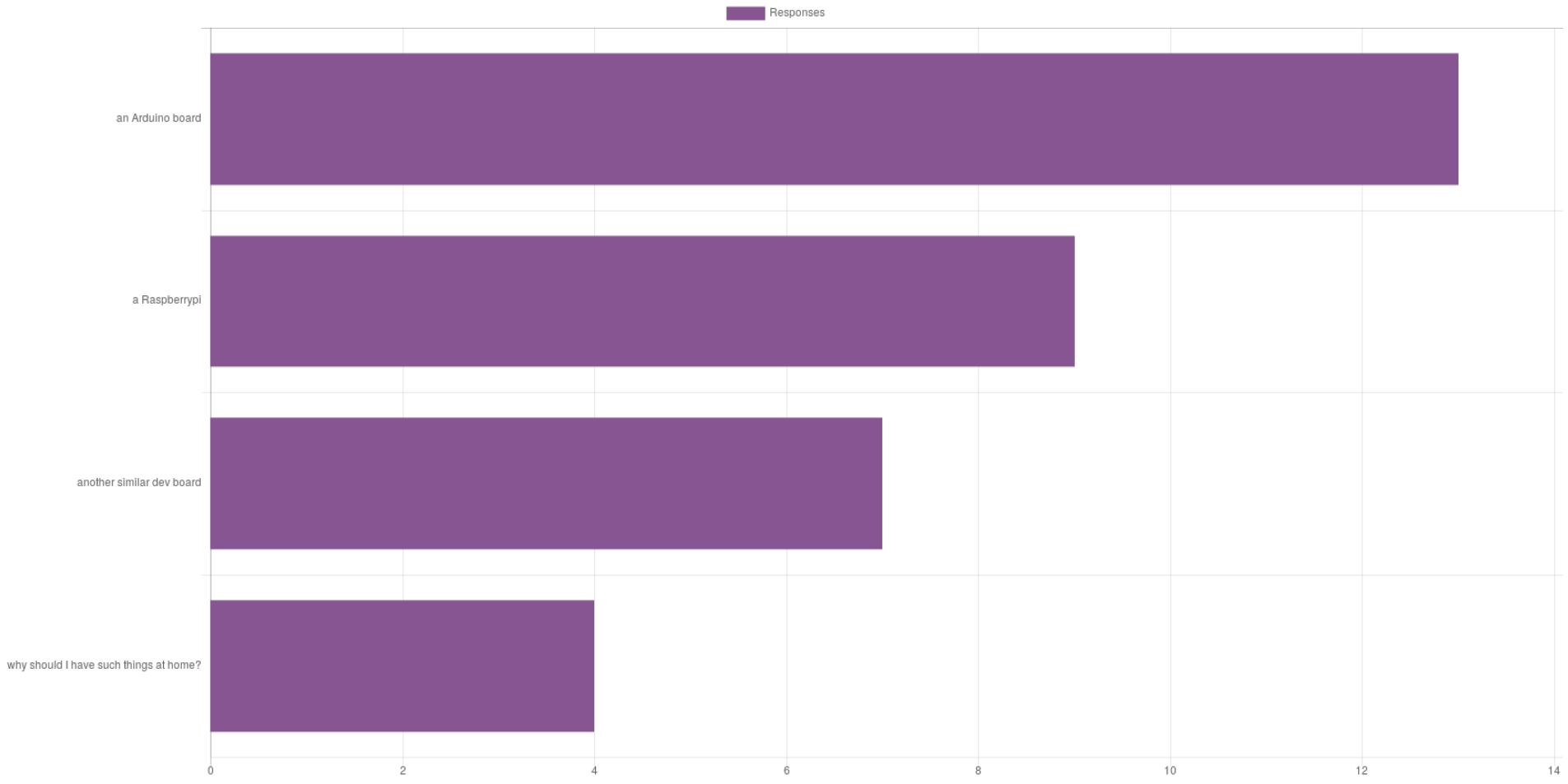
3 weeks to:

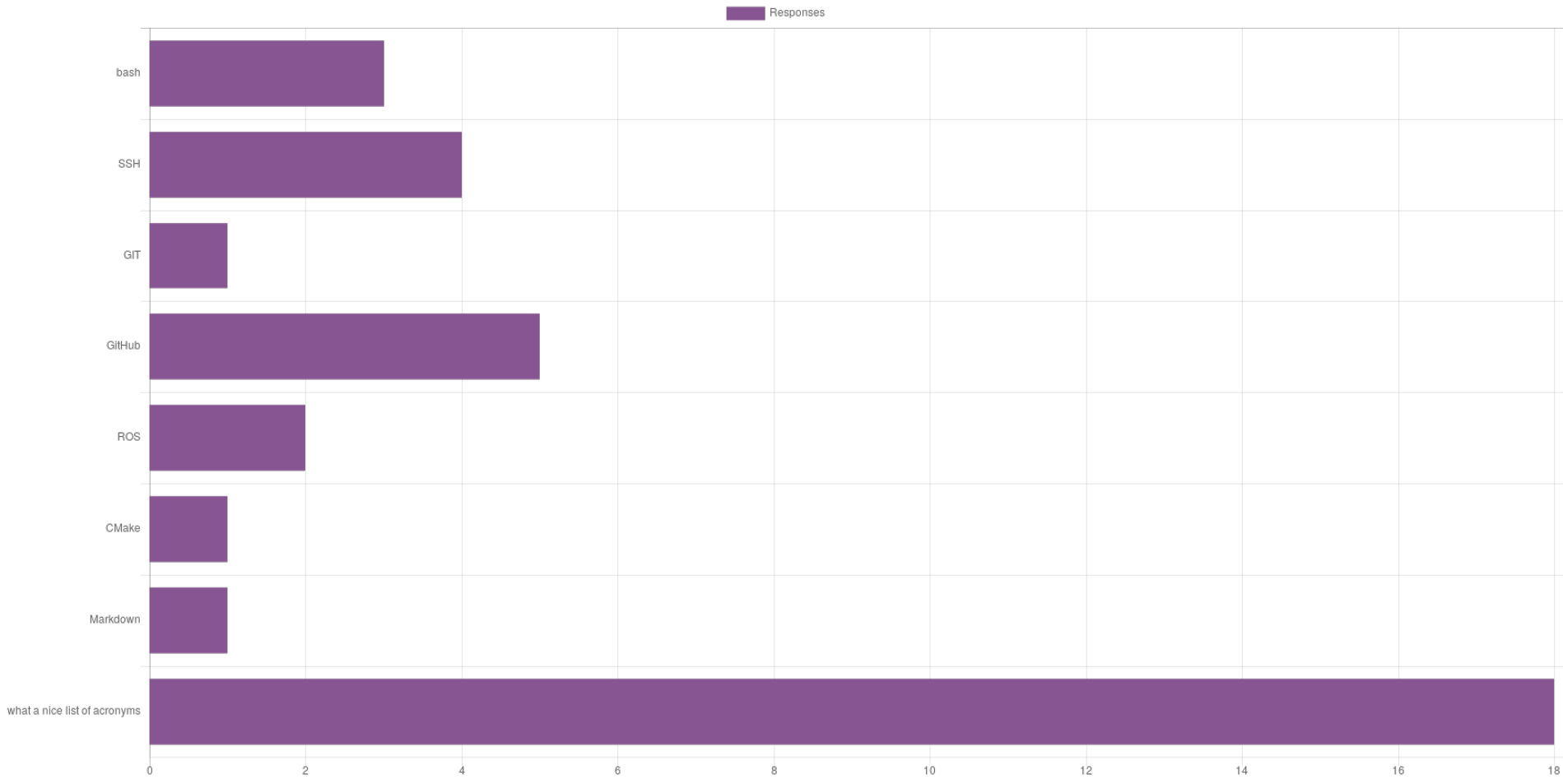
- Design and build a 3DoF (one stepper, 2 servos) robot arm
- Create a 3D model and visualise it
- Control it with ROS

"HOMEWORK"


Responses
Linux? that thing with a penguin? never used...
Was forced to play with it a few times...
I use it regularly, but not my main system
It's my main operating system
I'm a command-line guru
0
2
4
6
8
10
12
14
16


Responses
Java
C
C++
Python
Matlab
Javascript
0
2
4
6
8
10
12
14
16
18


Responses
an Arduino board
a Raspberrypi
another similar dev board
why should I have such things at home?
0
2
4
6
8
10
12
14


Responses
bash
SSH
GIT
GitHub
ROS
CMake
Markdown
what a nice list of acronyms
0
2
4
6
8
10
12
14
16
18

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- **Install Linux** (and use it!) – alongside Windows as a dualboot, or inside a VM
- Get involved in an **open-source project**

ATTENTION: I AM AWAY ON THE 11TH OF OCTOBER

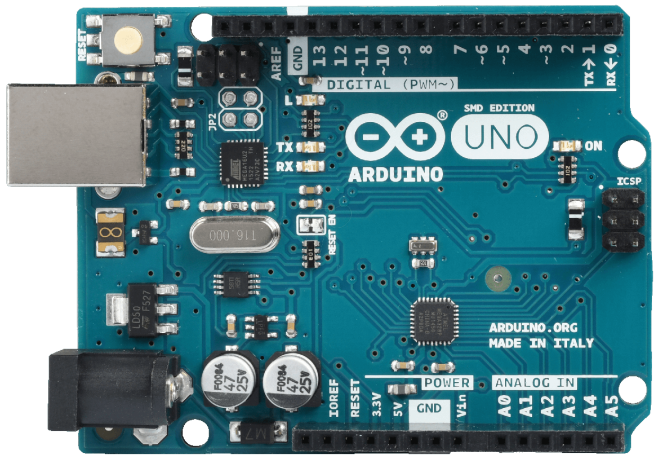
- On 11th October: no lecture
- On 12th October: practical with Jake

10 min break, and off we start!

INTRO TO ARDUINO

THE ARDUINO MICROCONTROLLER

- What is an Arduino board?
- Developing programs
- Inputs and outputs
- Running control loops
- Using PWM to control motors



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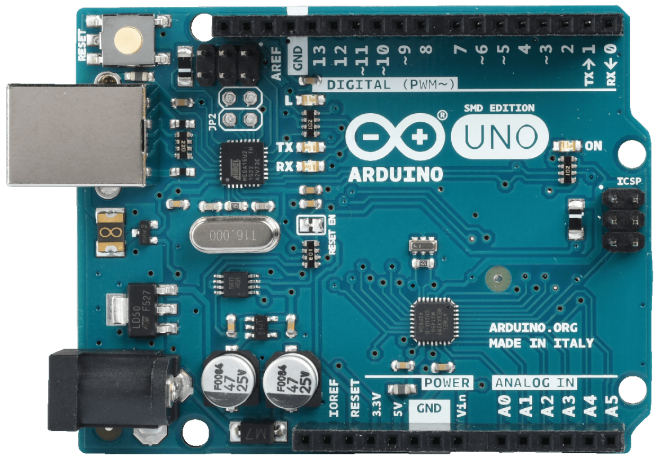
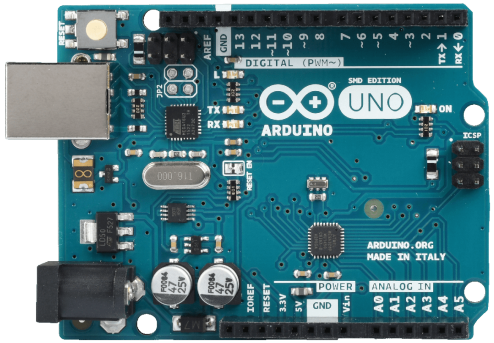
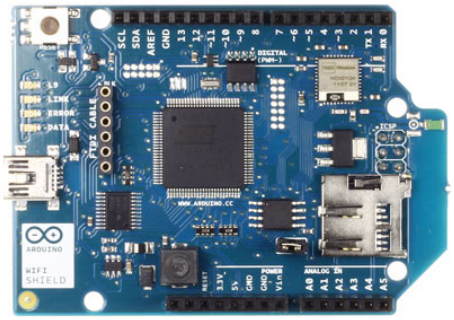


- Arduino is an open-source electronics platform based on easy to use hardware and software
- it is intended for anyone making interactive projects
- very relevant to robotics, including professional-grade projects!

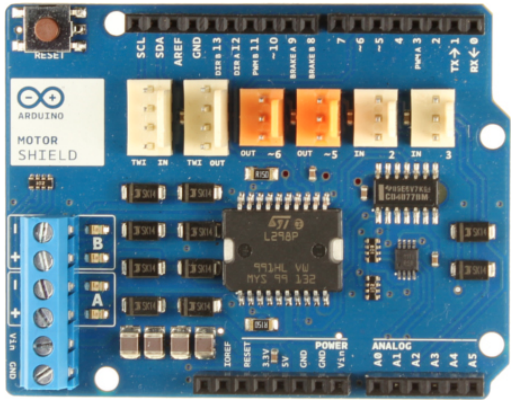
THE ARDUINO MICROCONTROLLER ECOSYSTEM



Controller



Wifi shield



Motor shield

Ultrasonic sensor

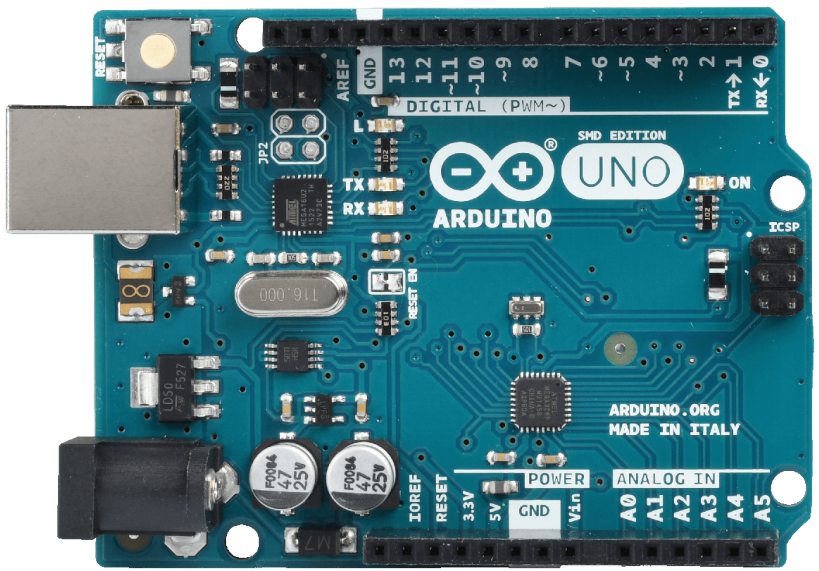
Robot car

"Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments"

Name	Processor	Operating Voltage/Input Voltage	CPU Speed	Analog In/Out	Digital IO/PWM	EEPROM [KB]	SRAM [KB]	Flash [KB]	USB	UART
Uno	ATmega328	5 V/7-12 V	16 Mhz	6/0	14/6	1	2	32	Regular	1
Due	AT91SAM3X8E	3.3 V/7-12 V	84 Mhz	12/2	54/12	-	96	512	2 Micro	4
Leonardo	ATmega32u4	5 V/7-12 V	16 Mhz	12/0	20/7	1	2.5	32	Micro	1
Mega 2560	ATmega2560	5 V/7-12 V	16 Mhz	16/0	54/15	4	8	256	Regular	4
Mega ADK	ATmega2560	5 V/7-12 V	16 Mhz	16/0	54/15	4	8	256	Regular	4

ARDUINO UNO

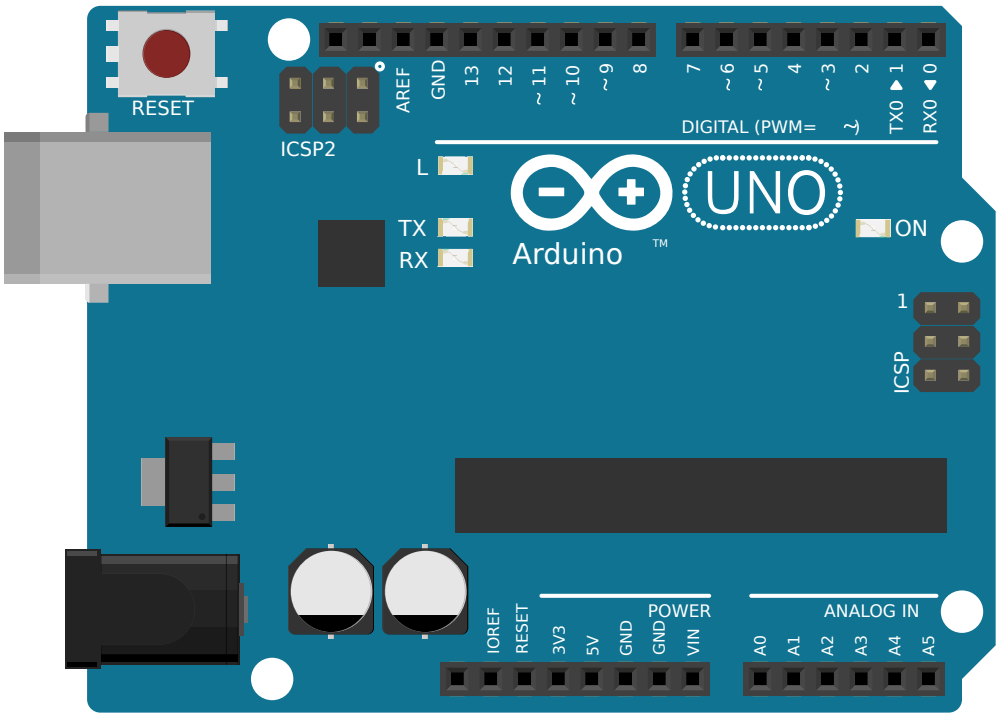
- Relatively robust board
- Microcontroller board based on the ATmega328
- 14 digital Input/Output pins
- 6 outputs can be used as PWM outputs
- 6 analog inputs
- 16MHz ceramic resonator
- USB connection
- power jack
- ICSP header
- reset button



ARDUINO UNO

Digital I/O

USB input



9V external power supply

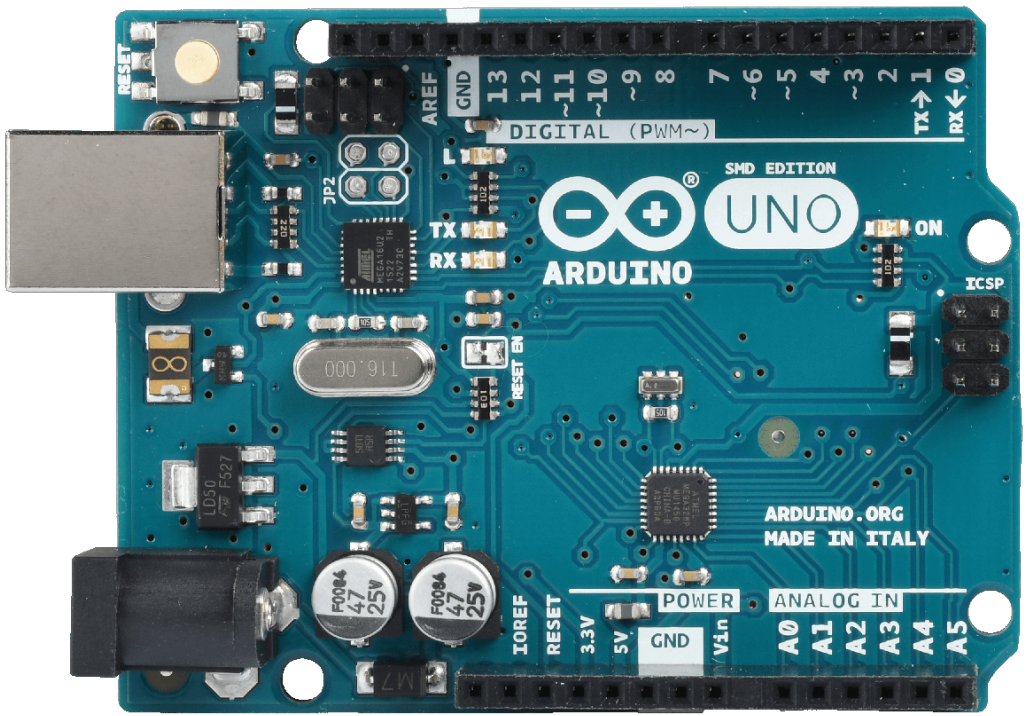
Power outputs

Analog inputs

ARDUINO UNO

Digital I/O

USB input



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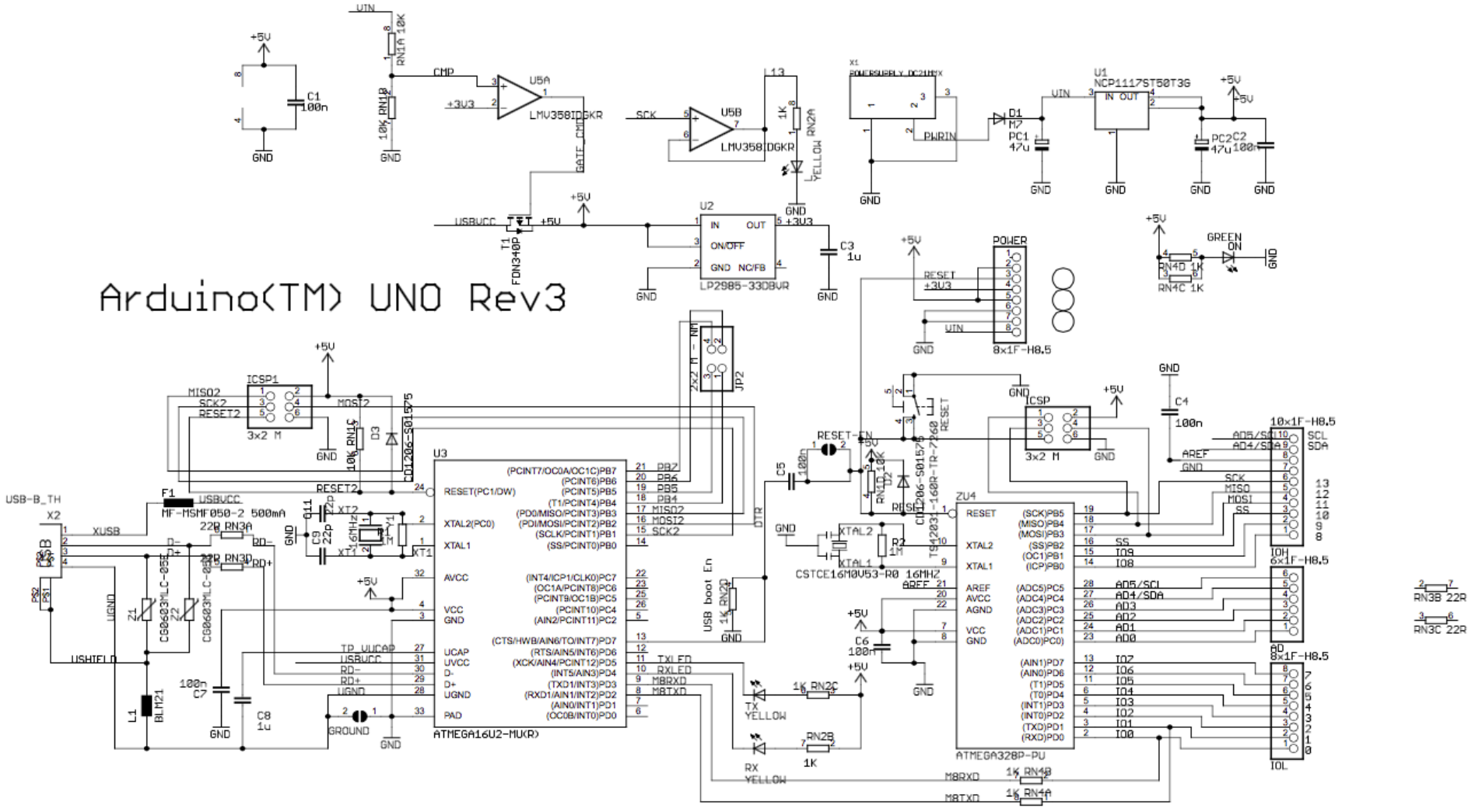

Arduino(TM) UNO Rev3
ATMEGA16U2-MUR
ATMEGA328P-PU
LMV358IDGKR
LP2985-33DBVR
NCP1117ST50T3G
CSTCE16M0V53-R0 16MHZ
USB-B_TH
ICSP1
ICSP
POWER
8x1F-H8.5
10x1F-H8.5
6x1F-H8.5
JP2
F1
MF-MSMF050-2 500mA
RESET-EN
USB boot En
TX YELLOW
RX YELLOW
GREEN ON
RN3B 22R
RN3C 22R

ARDUINO UNO SUMMARY

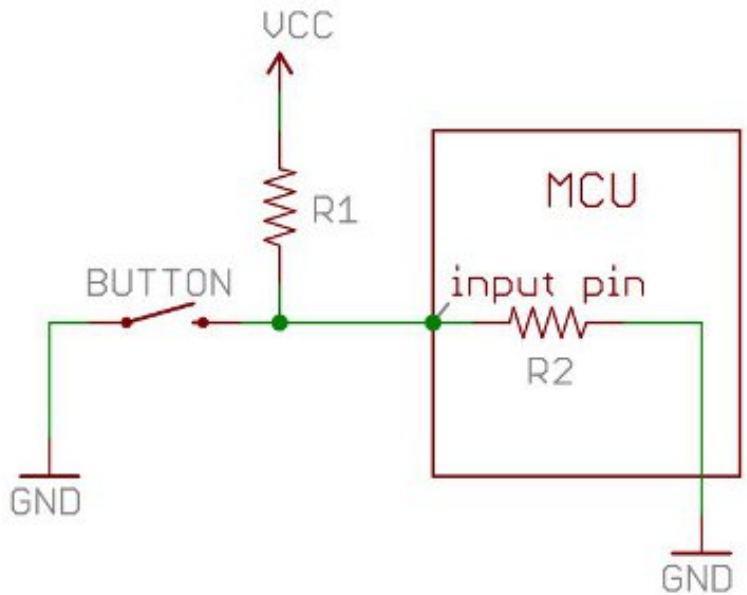
- Microcontroller: **ATMega328**
- Operating voltage: **5V**
- External input voltage (recommended): 7-12V
- External input voltage (limits): **6-20V**

- Digital I/O pins: 14, of which 6 provide PWM output
- Analog input pins: 6
- DC current per I/O pin: 40 mA
- DC current for 3.3V pin: 50mA
- pins have internal pull-up resistors (off by default) of 20-50 kΩ

- RAM: **2KB**
- Flash memory: **32KB**, of which 0.5KB used by boot loader
- EEPROM: 1KB
- Clock speed: **16MHz**

WHAT IS A PULL-UP RESISTOR?

Prevent ***floating*** values on the input pins.



The ATmega328 microcontroller has internal pull-ups that can be enabled and disabled:

```
pinMode(5, INPUT_PULLUP); // Enable internal pull-up resistor on pin 5
```

POWERING ARDUINO UNO

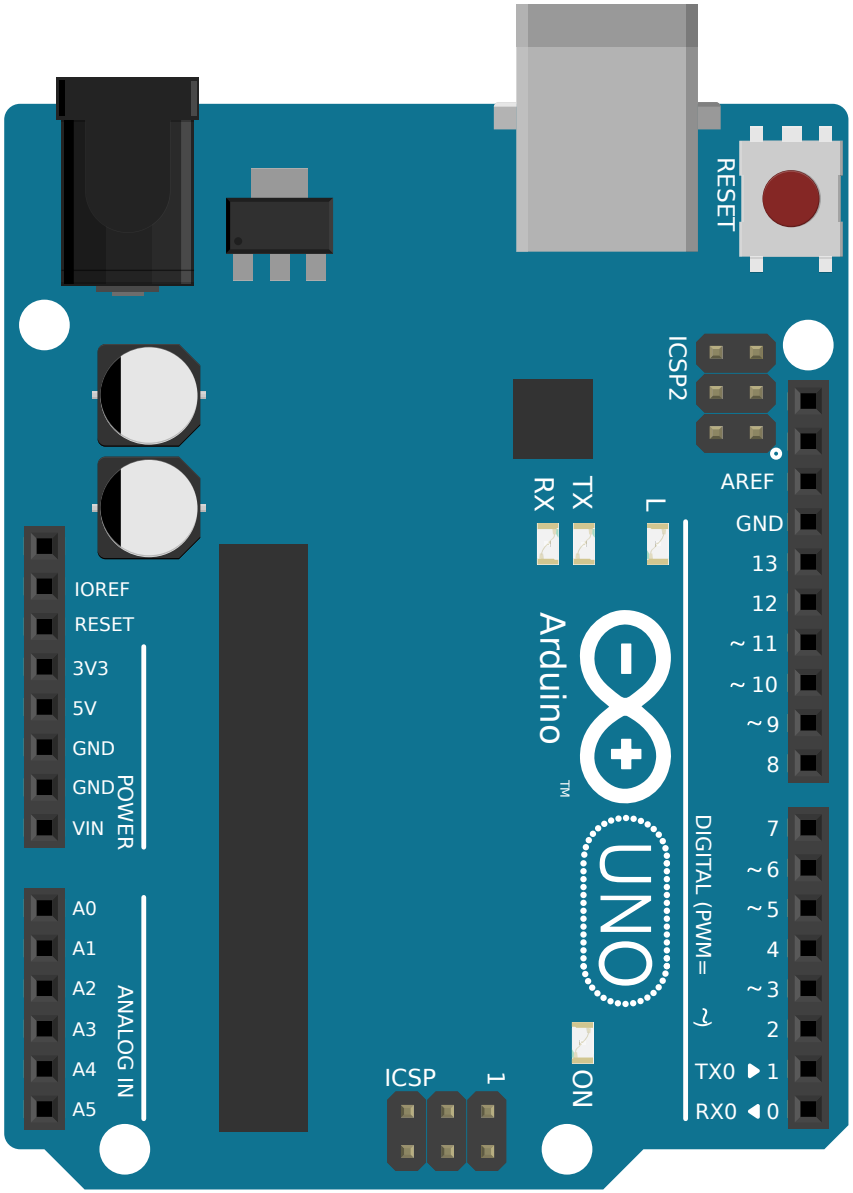
- via the USB connection
- external power supply
- the power source is selected automatically
- external (non-USB) 2.1mm centre-positive plug into the board's power jack
- leads from a battery can be inserted in the `Gnd` and `Vin` pin headers of the `POWER` connector
- recommended range is 7 to 12 volts

POWER COMPARISON

Board	Power Consumption
RaspberryPI A+	80 mA (0.4W)
RaspberryPI A+	160 mA (0.8W) with Wifi dongle
RaspberryPI B+	180 mA (0.9W)
RaspberryPI2 B	200 mA (1.0W)
RaspberryPI Zero	80 mA (0.4W)
RaspberryPI Zero	120 mA (0.7W)
Arduino Uno	30-50mA, can go down to <1mA

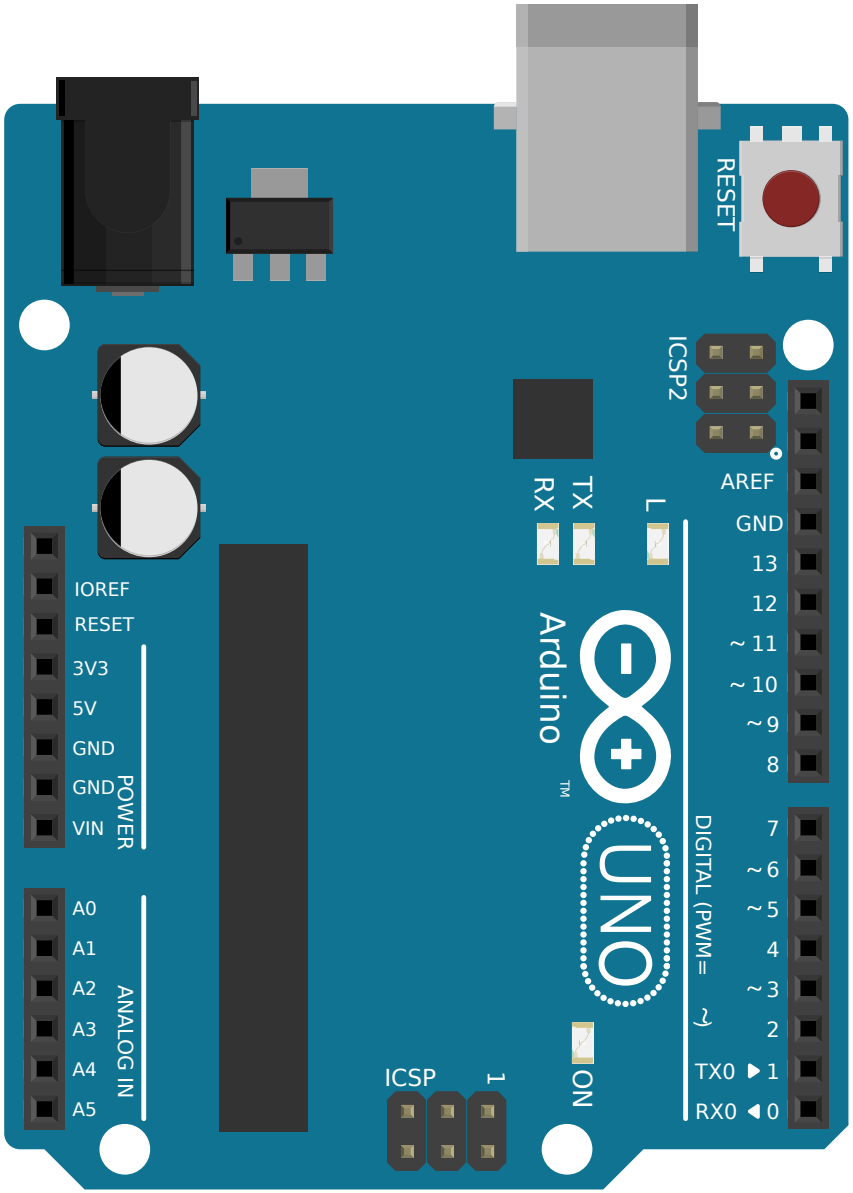
→ Arduino for a year on a coin cell

SOME PINS HAVE SPECIALIZED FUNCTIONS



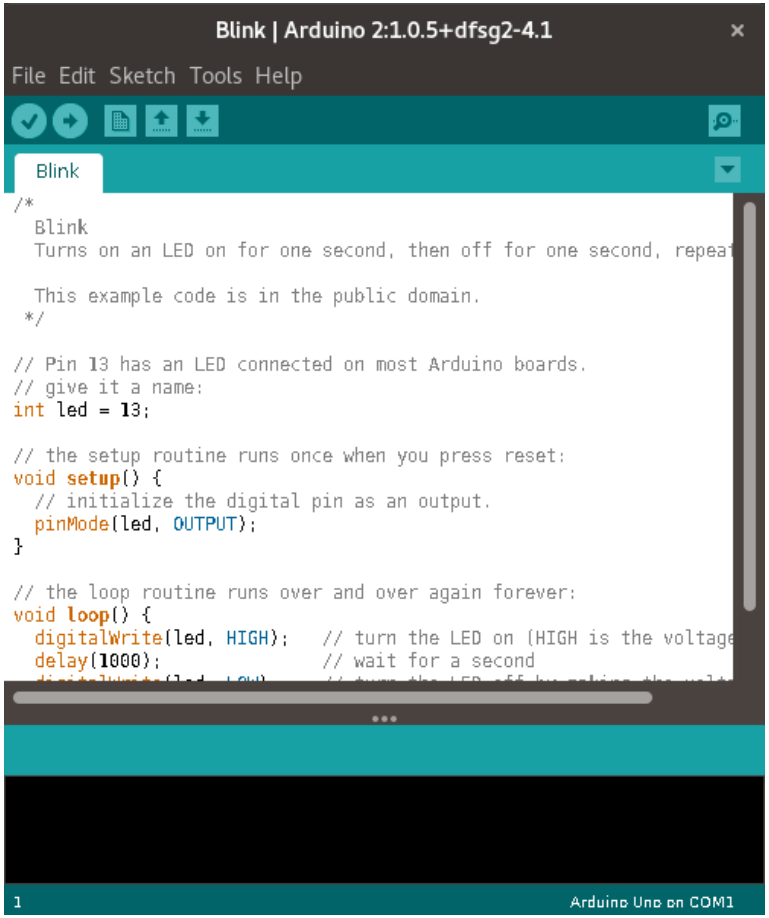
- Serial: 0 (`RX`) and 1 (`TX`)
  Used to receive (`RX`) and transmit (`TX`) TTL serial data
- external interrupts: 2 and 3
  Can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value
- PWM: 3, 5, 6, 9, 10 and 11
  Provide 8-bit PWM output with the `analogWrite()` function

SOME PINS HAVE SPECIALIZED FUNCTIONS



- SPI: 10 (`SS`), 11 (`MOSI`), 12 (`MISO`), 13 (`SCK`)
  Support SPI communication using the SPI library
- LED: 13. Built-in LED connected to digital pin 13
- The Uno has 6 analog inputs, labeled `A0` through `A5`
- I^2C: `A4` or `SDA` pin and `A5` or `SCL` pin
  Support I^2C communication using the `Wire` library

HOW TO START CODING: SOFTWARE SETUP



- install the IDE (download from **www.arduino.cc** or `apt install arduino`)
- open the Arduino IDE
- use a USB A to B cable to plug the board into your computer
- setup the board type and serial port from the *Tools* menu

PROGRAMMING THE ARDUINO

- Arduino's programming language is a version of C++ with a bit of magic (pre-processing) to make it look simpler
- Arduino calls a program a **sketch**. Sketches are saved by default in your **sketchbook** (cf *File* > *Preferences*)
- Most C/C++ commands work in the sketch editor
- 4 basic components of an Arduino program:
  - initialization
  - setup
  - loop
  - user defined functions
- Arduino Uno is designed to allow it to be remotely reset by software

PROGRAMMING THE ARDUINO: INITIALIZATION

- Include any extra libraries you are using
- All variables need to be initialized
- `a=4;` will not work, `int a=4;` will
- Declare variables you will assign later: `int a, b, c;`
- Remember datatypes: `bool`, `int`, `double`, `float`, `char`, `String`...
- Full reference: **https://www.arduino.cc/en/Reference**

PROGRAMMING THE ARDUINO: SETUP

- Initialization for the Arduino board
- Usually initiate Serial communication
- Usually assign digital pins to input or output
- For example:

```
void setup() // 'void' means setup() does not return anything
{
    pinMode(13, OUPUT); // pinMode sets the state of a digital pin,
    pinMode(12, INPUT); // either to OUPUT or to INPUT

    Serial.begin(9600); // initialises a serial console at 9600 bauds
}
```

PROGRAMMING THE ARDUINO: MAIN LOOP

- The loop is the main portion of your program
- The microcontroller runs it forever
- For instance:

```
void loop()
{
    digitalWrite(13, HIGH); // set the LED on
    delay(1000);            // wait for one second
    digitalWrite(13, LOW);  // set the LED off
    delay(1000);            // wait for one second
}
```

PROGRAMMING THE ARDUINO: USER DEFINED FUNCTIONS

- These functions can be called in the loop and are usually responses to conditions that are met in the loop
- These functions must be declared with a *name*, a *return type* and optional *input parameters* with their types

The following function maps a user input `x` from one range to a new range:

```
float map(float x,
          float in_min, float in_max,
          float out_min, float out_max)
{
    return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}
```

PROGRAMMING THE ARDUINO: USER DEFINED FUNCTIONS

```
float map(float x,
          float in_min, float in_max,
          float out_min, float out_max)
{
    return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}
```

The function is defined over ***single precision floating numbers***, represented by the `float` C type.

The `return` statement defines what the function outputs (here, a floating number)

The curly brackets `{}` define what is inside the function (the function ***body***). Curly brackets are generally required to separate blocks of code.

The indentation of the code is up to you and does not matter (contrary to other languages like Python!)

PROGRAMMING THE ARDUINO: DIGITAL I/O

Each of the 14 digital pins on the Uno can be used as an input or output.

- `pinMode(<pin>, <mode>)`: set a digital pin as `INPUT` or `OUTPUT`
- `digitalWrite(<pin>, <state>)`: writes to a digital pin `HIGH` (5V) or `LOW` (`GND`)
- `digitalRead(<pin>)`: reads digital pin and returns `HIGH` or `LOW`

PROGRAMMING THE ARDUINO: ANALOG I/O

- `analogReference(<type>)`

  `DEFAULT`: 5V

  `EXTERNAL`: voltage applied to `Vref`

  http://arduino.cc/en/Reference/AnalogReference

- `analogRead(<pin>)`: reads voltage on given pin, 10 bits resolution (1024 values)

PROGRAMMING THE ARDUINO: SERIAL COMMUNICATIONS

- The ATMega328 provides UART TTL serial communication
- Available on the digital pins 0 (`RX`) and 1 (`TX`)
- `RX` and `TX` LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and the the USB connection to the computer

- The Arduino IDE includes a serial monitor
- It prints out whatever data is received on the serial port
- You can also use it to send data using the keyboard

PROGRAMMING THE ARDUINO: SERIAL LIBRARY

- `Serial.begin(<baudrate>)`: opens serial port at **`baudrate`**
- `Serial.available()`: returns the nb of bytes available to read
- `Serial.read()`: returns the first byte of incoming serial data available (or `-1` if no data is available)
- `Serial.print(<data>, <format>)`: prints data to the serial port as readable ASCII text
- `Serial.println(<data>, <format>)`: prints data to the serial port as readable ASCII text and adds a line ending

http://arduino.cc/en/Reference/Serial

PROGRAMMING THE ARDUINO: CONTROL FLOW

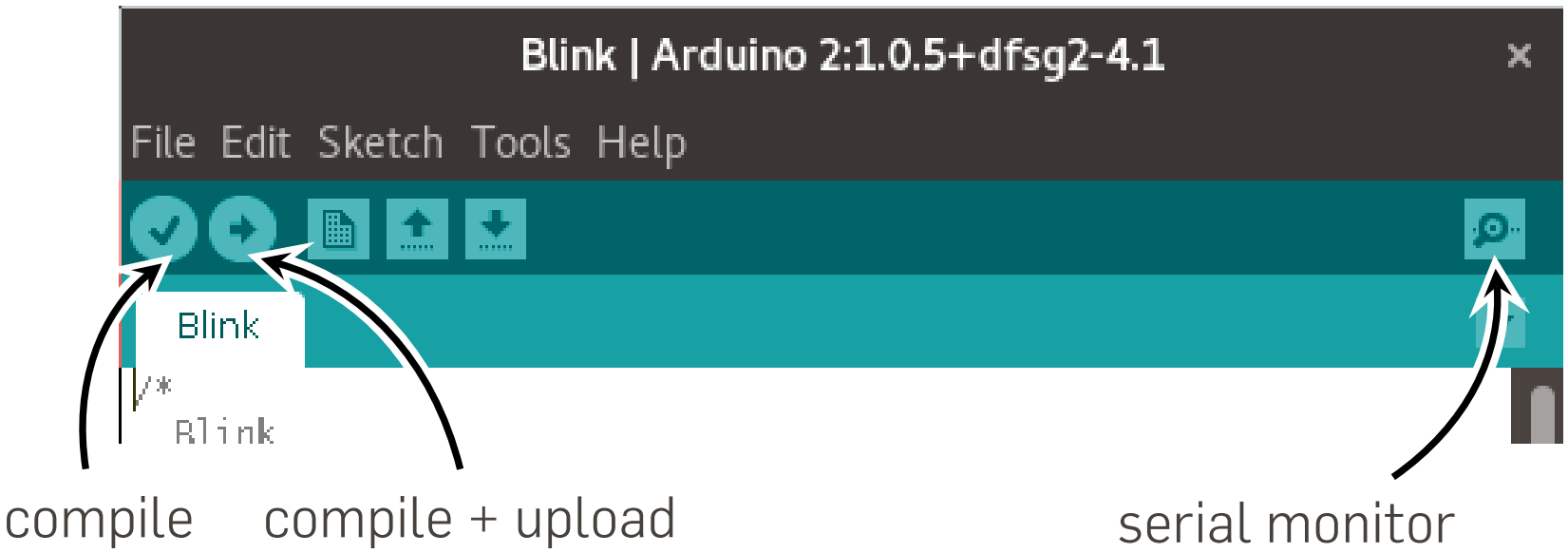
```
if(<variable> <comparison operator> <condition>)
{
    // do something
}
else
{
    // do something else
}
```

→ the MCU checks the condition and responds accordingly.

```
for(<initialization>; <condition>; <increment>)
{
    // do something
}
```

→ the MCU repeats something for a certain number of time. For example, read 500 chars on the serial port.

COMPILING AND UPLOADING CODE

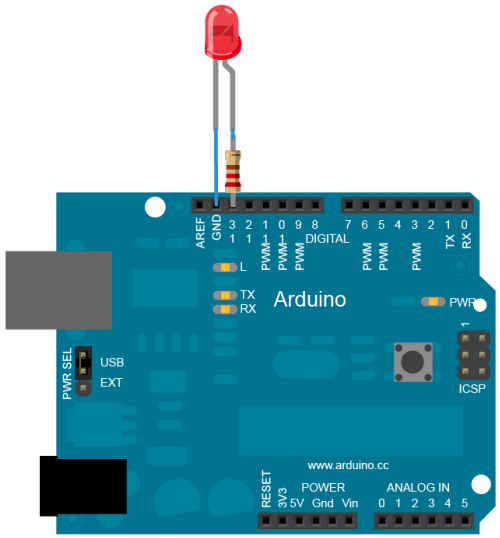


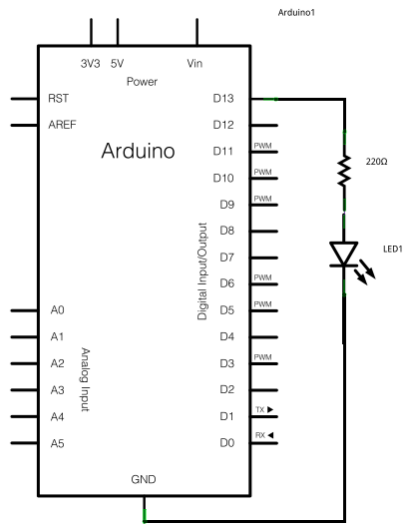
Under tools, make sure `Board` matches the actual board you are using and `Serial port` is the correct one.

PROGRAM EXAMPLES

LED BLINKING

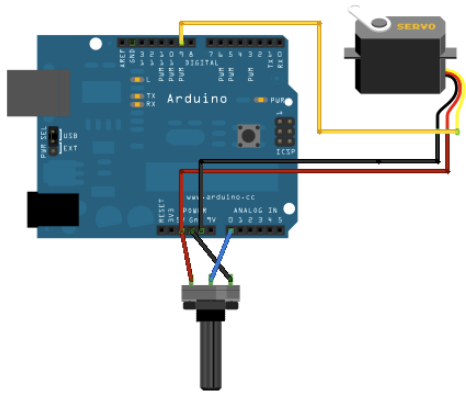
```
// Pin 13 has an LED connected on most Arduino boards
// give it a name:
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off
  delay(1000);               // wait for a second
}
```

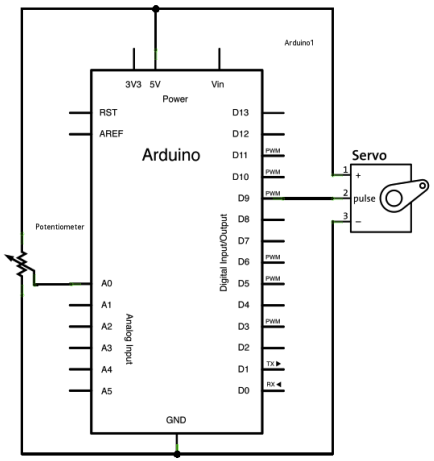




KNOB

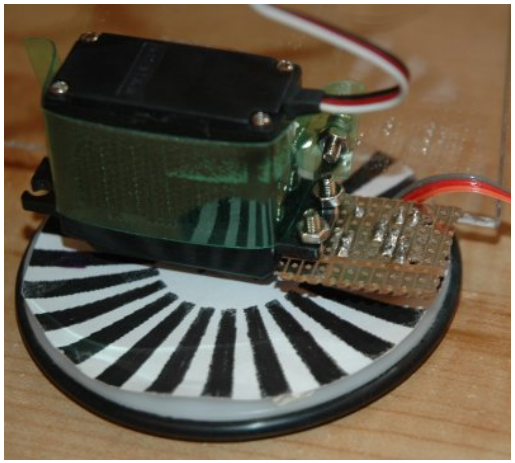
```
#include <Servo.h>

Servo myservo;  // create servo object

int potpin = 0;  // analog pin used for potentiometer
int val;    // variable to read analog value

void setup() {
  myservo.attach(9);  // attaches the servo on pin 9
}

void loop() {
  val = analogRead(potpin); // reads potentiometer
  val = map(val, 0, 1023, 0, 180); // map it to servo
  myservo.write(val); // sets the servo position
  delay(15); // waits for the servo to get there
}
```





ENCODER

```
#include <Encoder.h>

// Change these two numbers to the pins connected to your encoder.
Encoder myEnc(5, 6);
//   avoid using pins with LEDs attached

void setup() {
  Serial.begin(9600);
  Serial.println("Basic Encoder Test:");
}

long oldPosition  = -999;

void loop() {
  long newPosition = myEnc.read();
  if (newPosition != oldPosition) {
    oldPosition = newPosition;
    Serial.println(newPosition);
  }
}
```



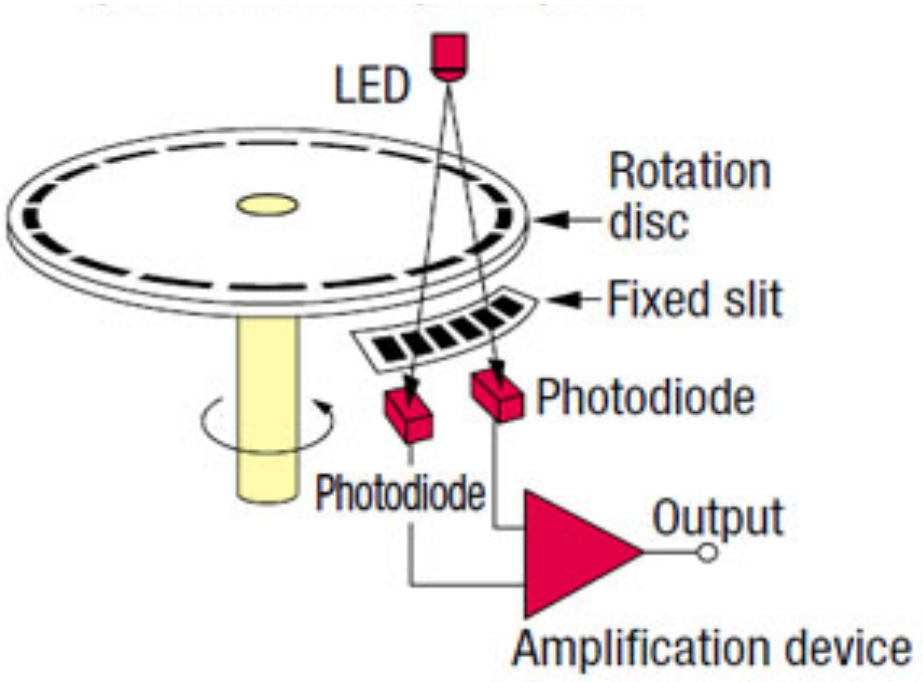
MEASURING POSITION: ENCODERS

DIGITAL INCREMENTAL ENCODER

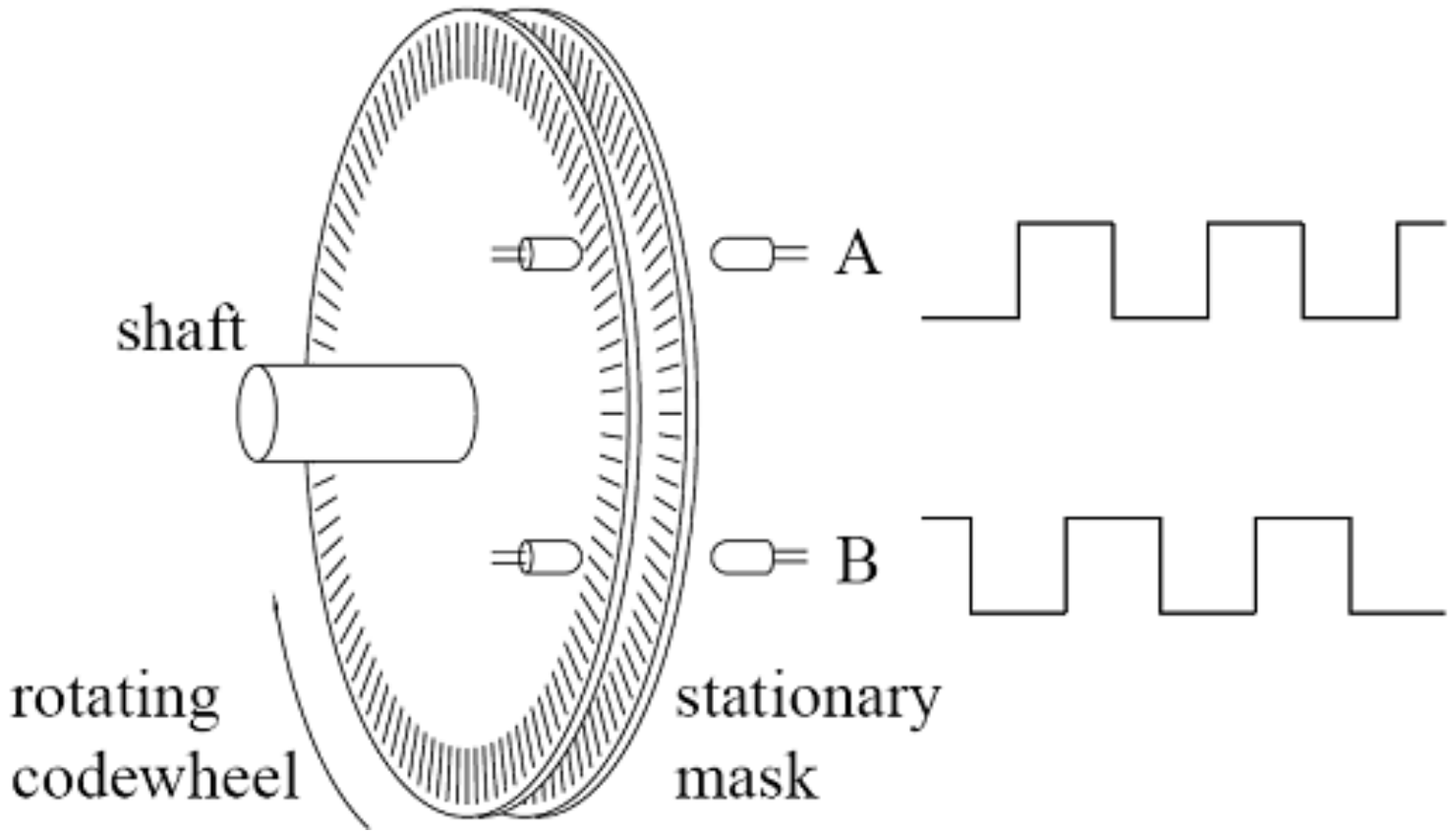
- Generates a relative position signal suitable for positioning tasks
- Rotation direction recognition
- Speed information from number of pulses per time unit
- Standard solution for many applications
- Single output types only used to determining the speed

OPTICAL INCREMENTAL ENCODER

- Slotted discs interrupt the light beam
- Photo emitter-detector pair detect pulses of light
- Amplifier then generates output pulses as slot passes light path
- Pulses counted to provide a position estimate
- Secondary LED photo emitter-detector pair provide direction of rotation
- Quadrature encoder generates two square wave pulses 90 degrees apart

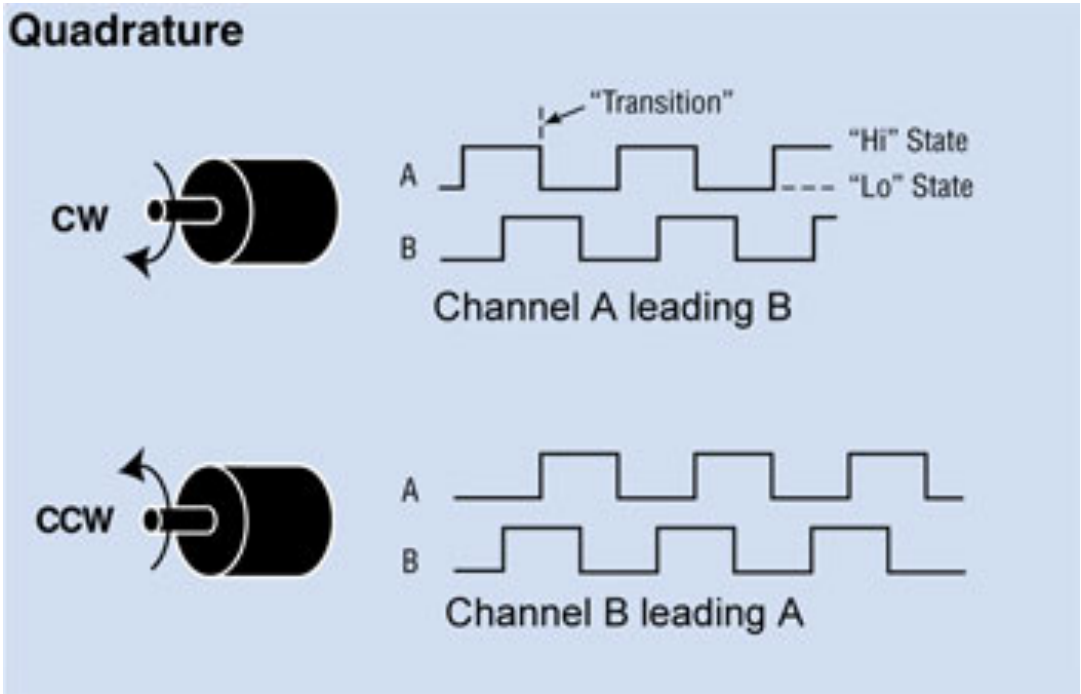


QUADRATURE OUTPUT SIGNAL GENERATION



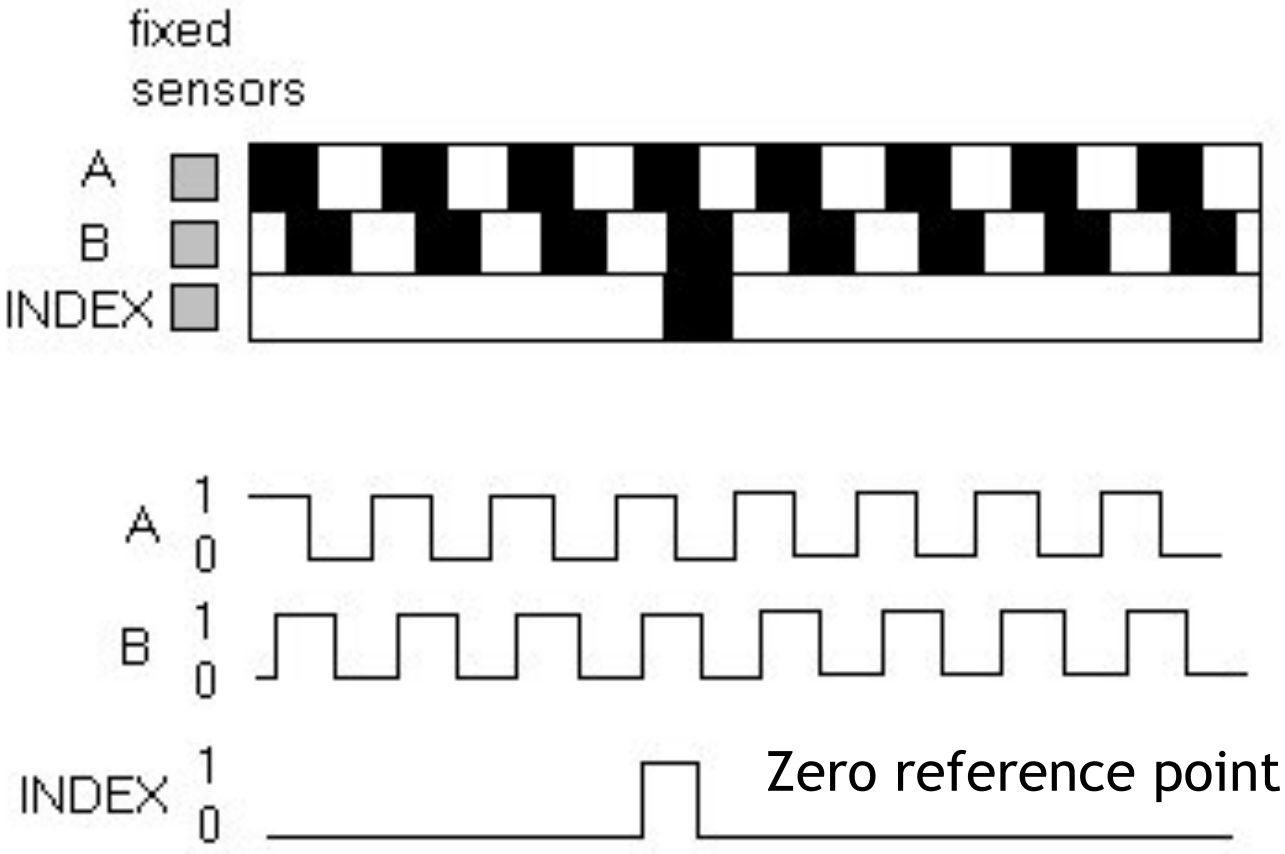
Output of two photo detectors are phase shifted by 90 degrees[35]

QUADRATURE OUTPUT SIGNAL USAGE



- A quadrature encoder generates two pulse streams that are 90° out of phase with one another
- The possible to determine directionality by monitoring which channel leads in phase

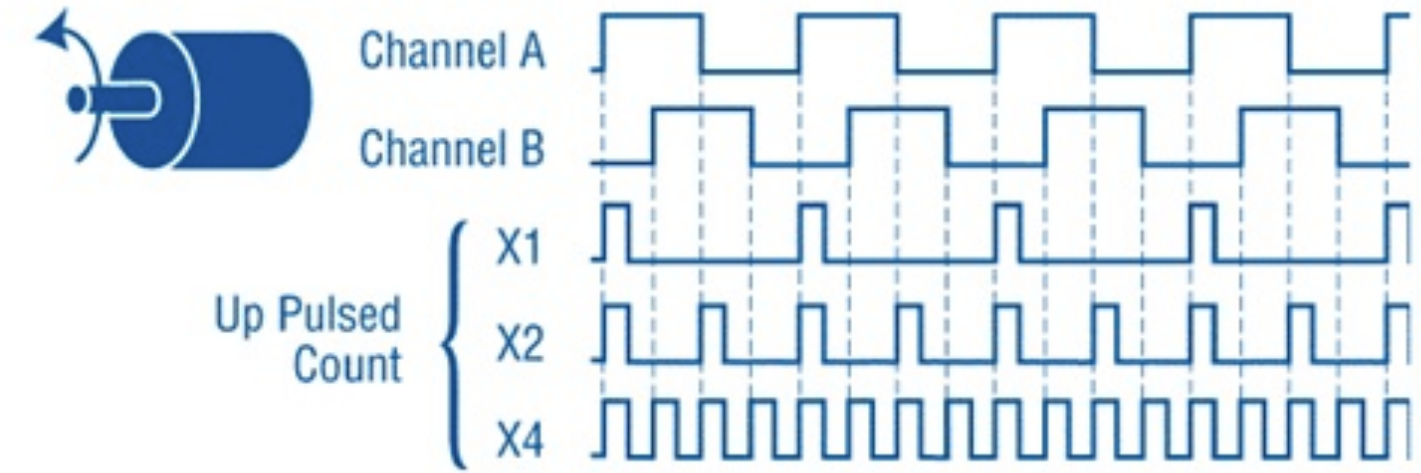
INCREMENTAL ENCODER INDEX SIGNAL



- Gives an absolute position signal at a single reference location
- Can be use to assist calibration

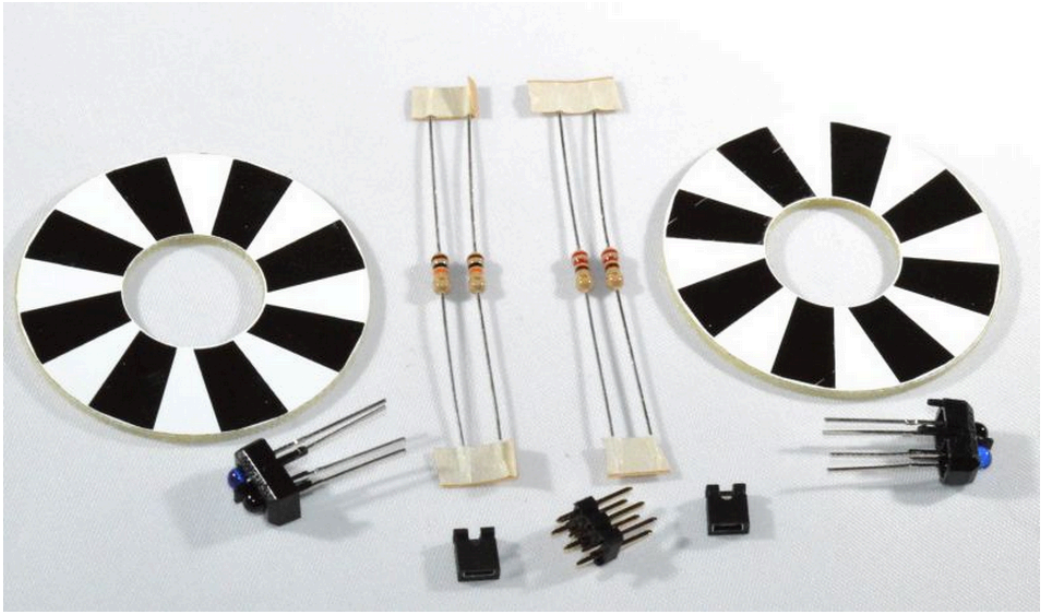
37

USING ALL EDGES INCREASES RESOLUTION



- Triggering off of the leading and or trailing edges of the pulses can increase resolution by up to four times
- More transition to count if use all edges!
- But more sensitive to noise

BUDGET WHEEL ENCODERS/SENSORS



- 2 wheel encoder discs for fitting inside the wheel drive
- 2 optical reflectance sensors
- Count 16 pulses per revolution
- very cheap - £5
- Use with Arduino systems

TYPICAL DATASHEET FOR ENCODER

CONNECTIONS

FUNCTION	CABLE	PLUG
0 Volts	Black	Pin 1
+ Volts	Red	Pin 2
A Channel	White	Pin 3
B Channel	Blue	Pin 4
Z Channel	Yellow	Pin 5
$\overline{A}$ Channel	Green	Pin 6
$\overline{B}$ Channel	Violet	Pin 7
$\overline{Z}$ Channel	Brown	Pin 8

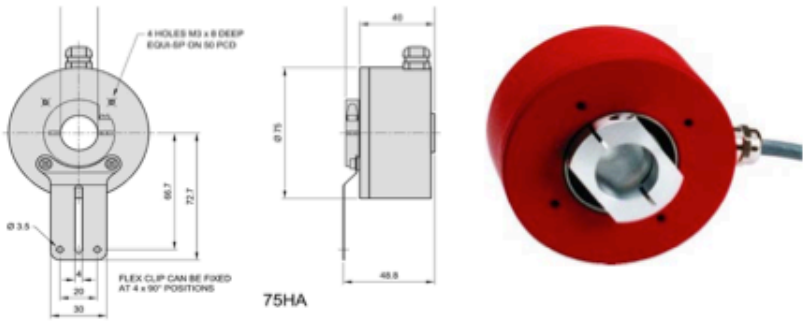
ACCESSORIES AVAILABLE

- COUPLINGS
- BRACKETS & FLANGES
- MEASURING WHEELS

SERIES 75HA LUMINIUM

ROTARY INCREMENTAL SHAFT ENCODER

The *75HA Series* is a precision, yet versitile hollow shaft encoder, machined from solid aluminium. Its choice of versatile spring mounting clip or front face mounting holes, makes the encoder compatible with many industrial formats.



SPECIFICATIONS

Body:
Precision Machined Aluminium

Cover:
Precision Machined Aluminium
(Powder Coated)

Shaft:
Stainless Steel

Bearings:
Ballraces

Shaft Sealing:
Front: Sealed bearing
Rear: Single lip seal on rear of cover

Protection:
IP65

Operating Temp:
-20 to +60°C
(higher on request)

Maximum Speed:
3000 RPM
(Higher on request)

Torque:
2Ncm (typical)

Inertia:
100gcm^2 (typical)

Shaft Loading:
Designed to support its own weight

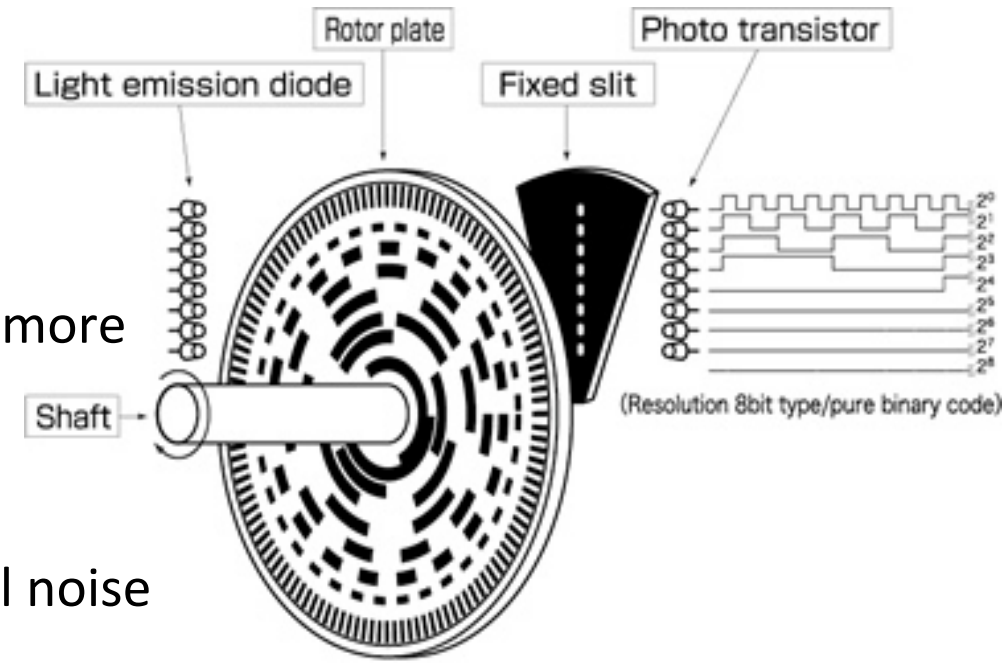
Cable:
Screened, oil and salt water proof

Impulse Frequency:
Up to 300KHz
(depending on model)

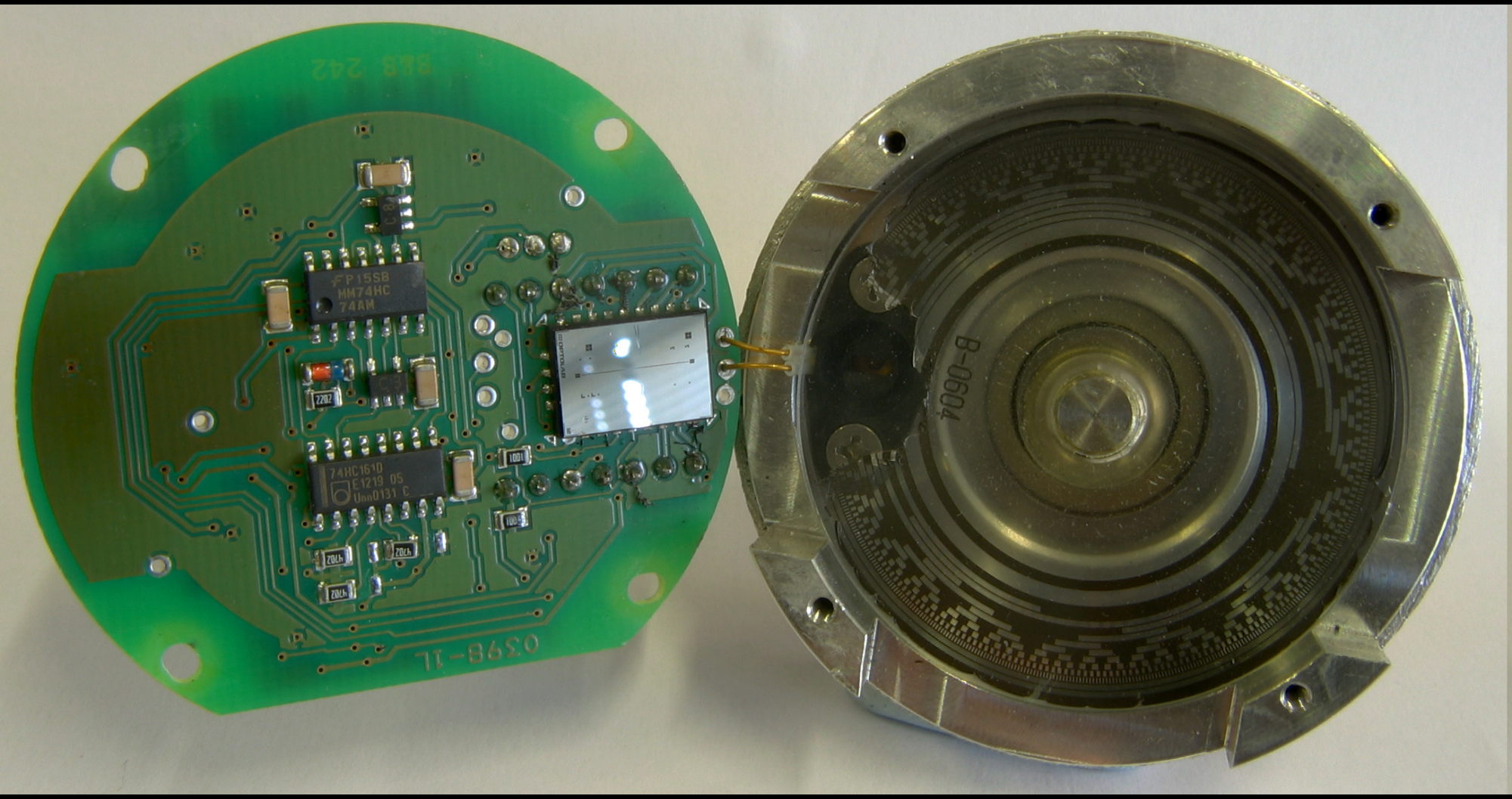
Current Consumption:
60mA
(typical - without load)

ABSOLUTE OPTICAL ENCODERS

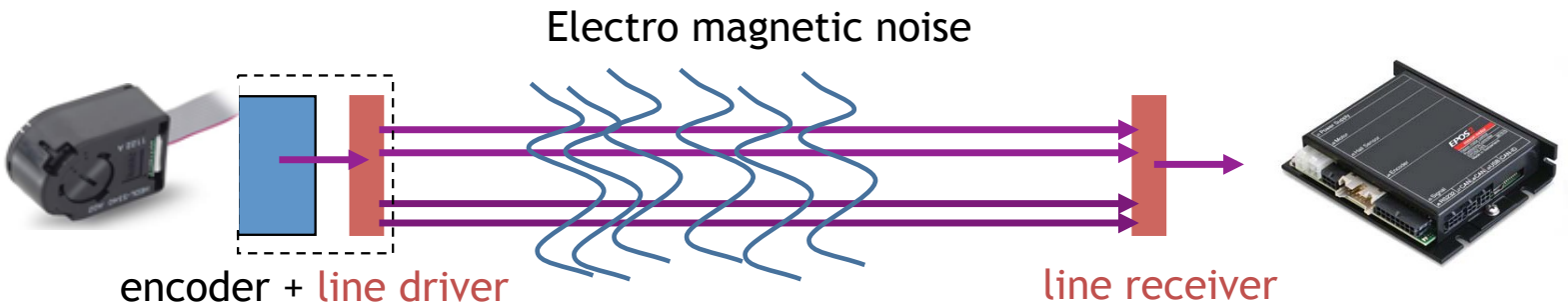
- Absolute encoders record the unique values of each shaft position
- Especially important in the event of a power failure
- Gray and binary codes most common

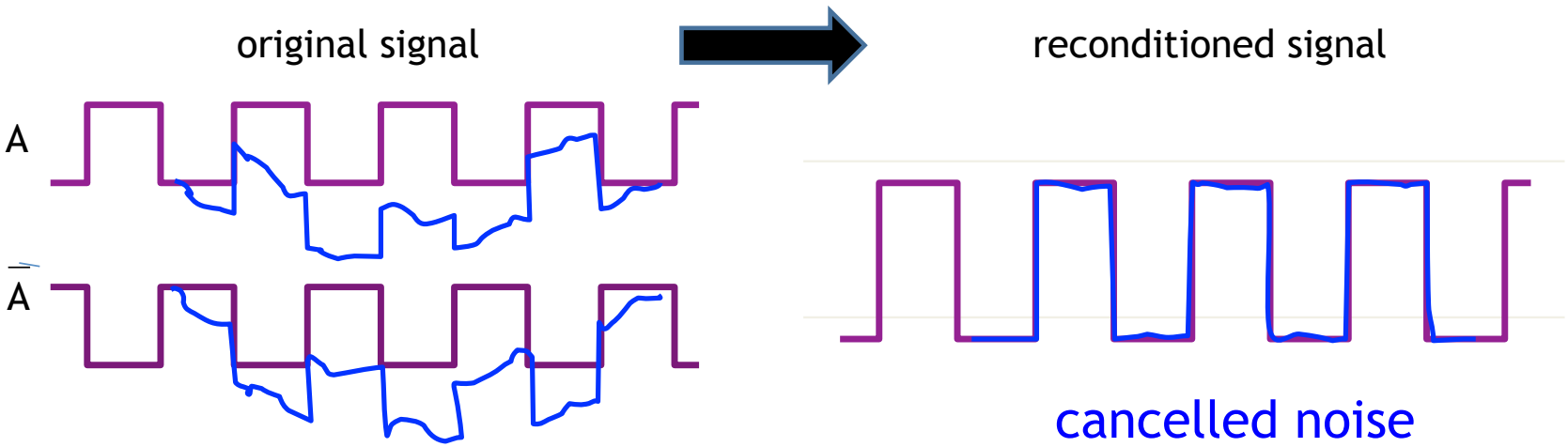


- Incremental rotary encoders more common
- Low cost
- Provides easy to use signals
- More susceptible to electrical noise


74HC161D
B-0604

ENCODER SIGNAL CONDITIONING





- Use differential output drivers
- Twisted pairs suppress interference better than single wires

INTERFACE TO ENCODERS

- E.g. Sensoray 626
- Interfacing encoder signals e.g. to a PC

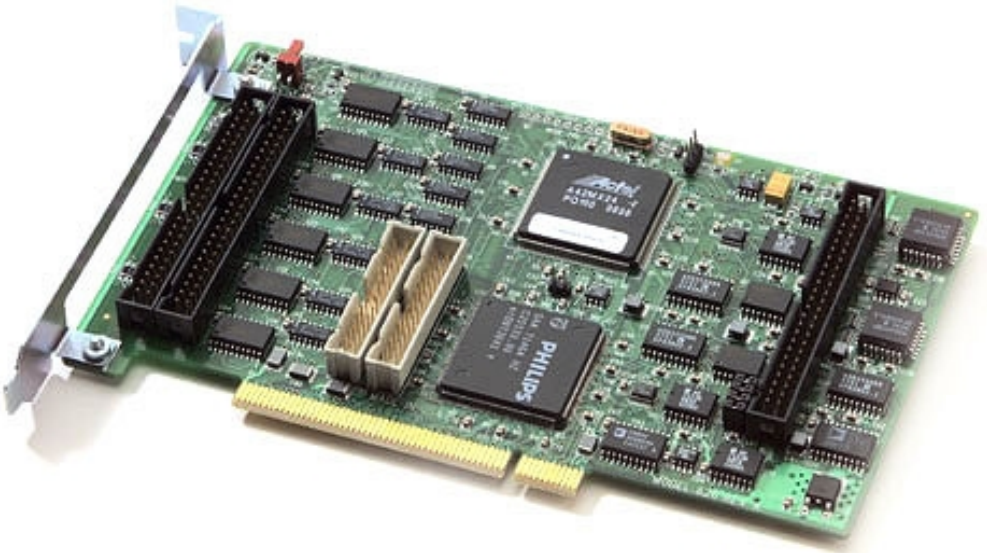
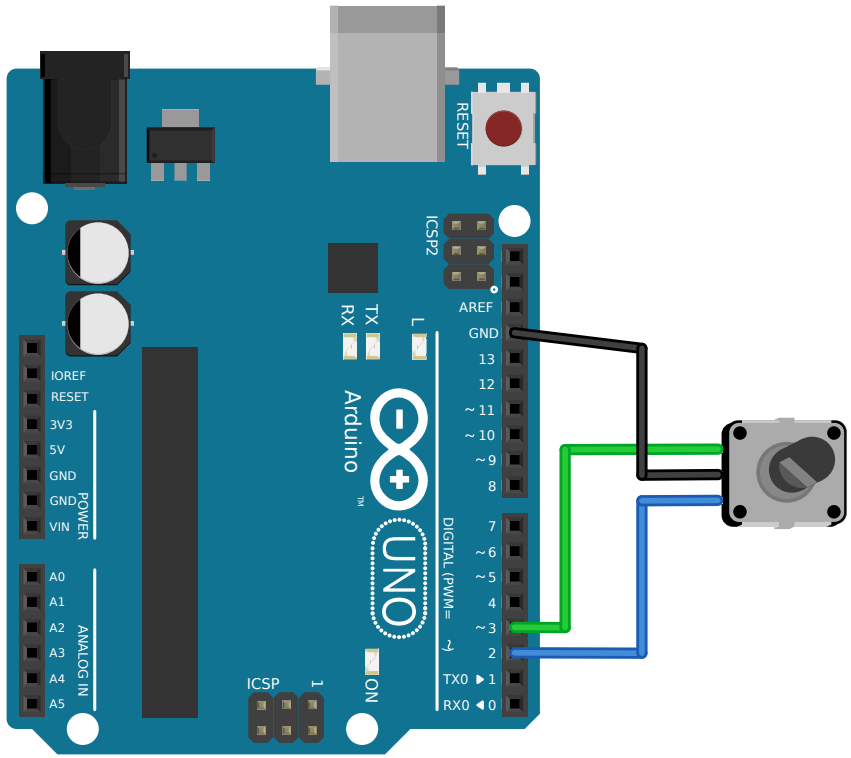


Table 24 Encoder Connectors					
J5					
26 pin IDC ribbon connector					
Encoder 1A – 3A					
Pin	Function	User Designation	Pin	Function	User Designation
1	Encoder (0A) A-		2	Encoder (0A) A+	
3	GND		4	Encoder (0A) B-	
5	Encoder (0A) B+		6	5V	
7	Encoder (0A) I-		8	Encoder (0A) I+	
9	GND		10	Encoder (1A) A-	
11	Encoder (1A) A+		12	5V	
13	Encoder (1A) B-		14	Encoder (1A) B+	
15	GND		16	Encoder (1A) I-	
17	Encoder (1A) I+		18	5V	
19	Encoder (2A) A-		20	Encoder (2A) A+	
21	GND		22	Encoder (2A) B-	
23	Encoder (2A) B+		24	5V	
25	Encoder (2A) I-		26	Encoder (2A) I+	

INTERFACE TO ARDUINO

- use interrupt inputs
- count the pulses

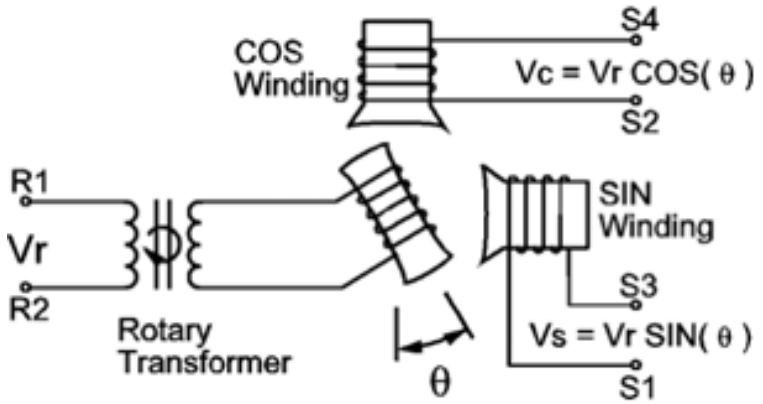


RESOLVER POSITION MEASUREMENT

Source: Maxon

Electromechanical device with a mechanical design similar to a motor.

RESOLVER POSITION MEASUREMENT

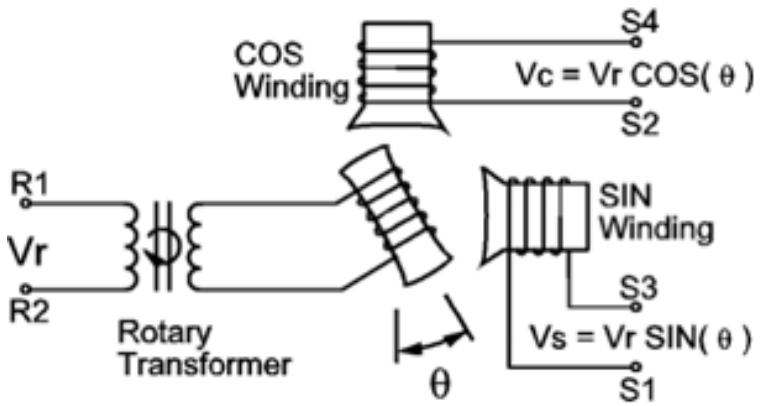


Source: Advanced Micro Controls, Inc.

Electromechanical device with a mechanical design similar to a motor.

- Analog rotor position signal
- Indicates absolute position within a single revolution
- Requires interfacing electronics
- Resolvers are “excited” by an AC reference sine wave

RESOLVER POSITION MEASUREMENT

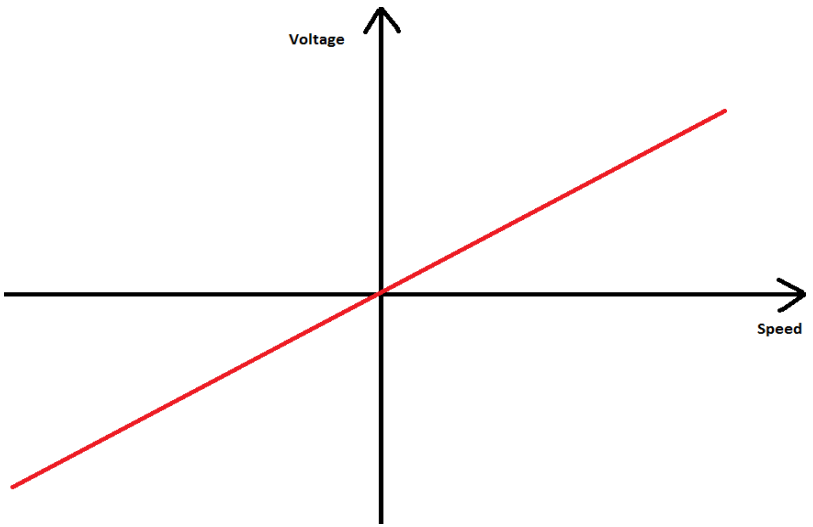


Source: Advanced Micro Controls, Inc.

Compared to an encoder:

- more rugged: no sensitive optics → withstand higher vibrations/shocks; resistant to electrical noise; withstand higher temperatures; higher durability
- encoders are cheaper; more accurate; smaller, lighter, less inertia

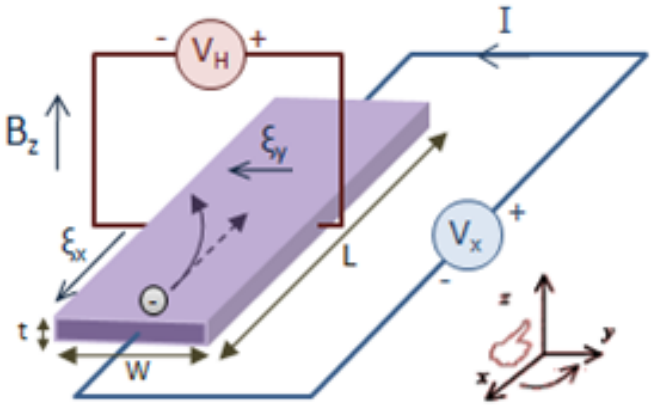
TACHOMETER VELOCITY MEASUREMENT

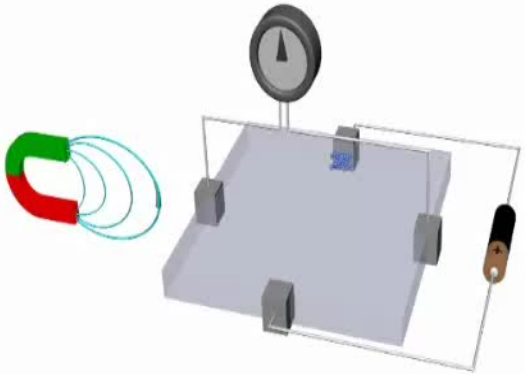


- A tacho is a small generator
- A coil that revolves about a magnet.
- Much like the motor it too has an speed constant
- Measures velocity not position and there for not an encoder
- Analog speed signal
- Rotation direction recognition
- Not suitable for positioning tasks

HALL EFFECT MAGNETIC SENSOR

The **Hall effect** is the production of a potential difference across an electrical conductor when a magnetic field is applied perpendicular to the flow of current.

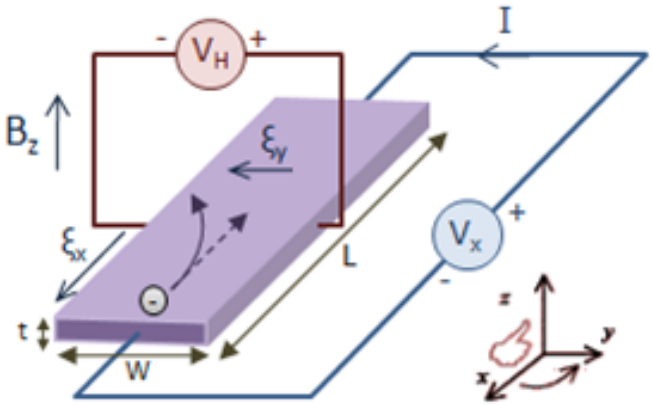


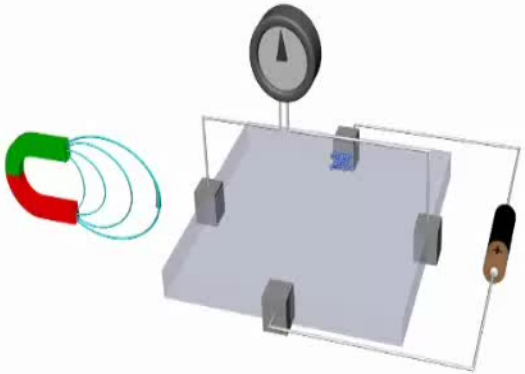


Source: *Wikipedia*

HALL EFFECT MAGNETIC SENSOR

Can be taken advantage of in semiconductor devices to implement a switch activated by the application of a magnetic field.
→ Hall effect sensors can be used for proximity switching.

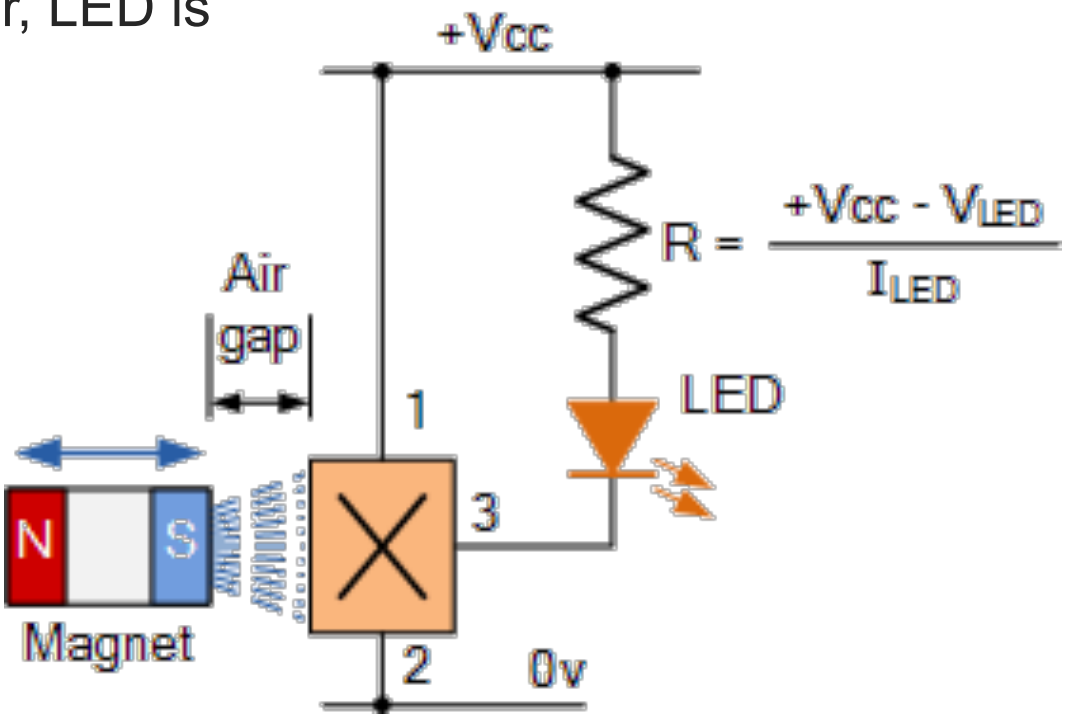




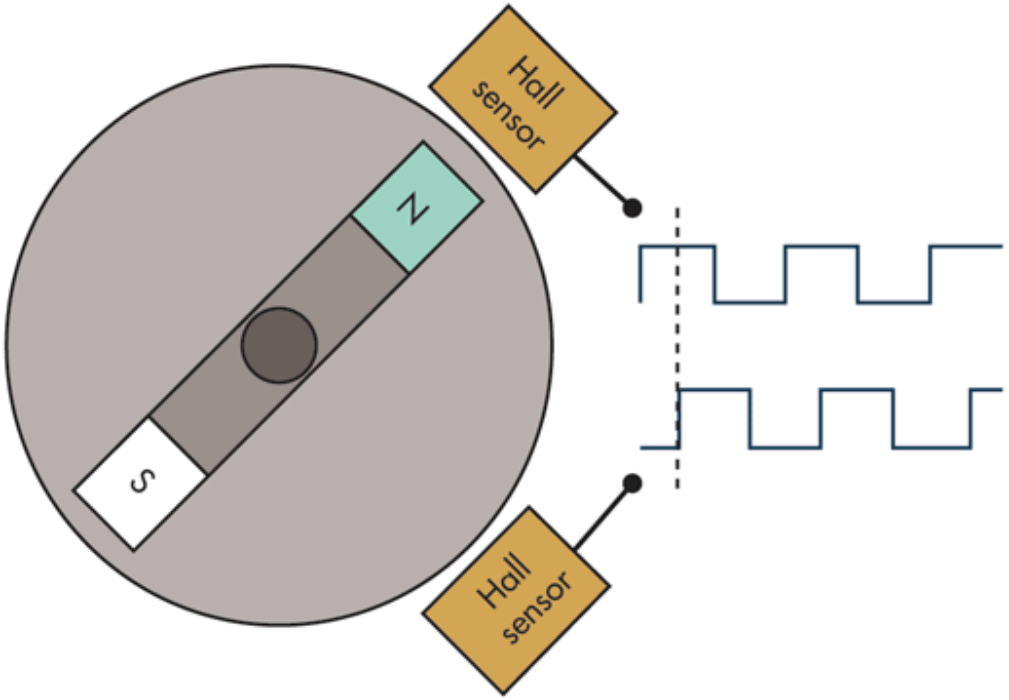
Source: *Wikipedia*

HALL EFFECT MAGNETIC SENSOR CIRCUIT

- Simple switch activated by the application of a magnetic field
- When south pole of magnet brought up to this sensor, LED is switched on

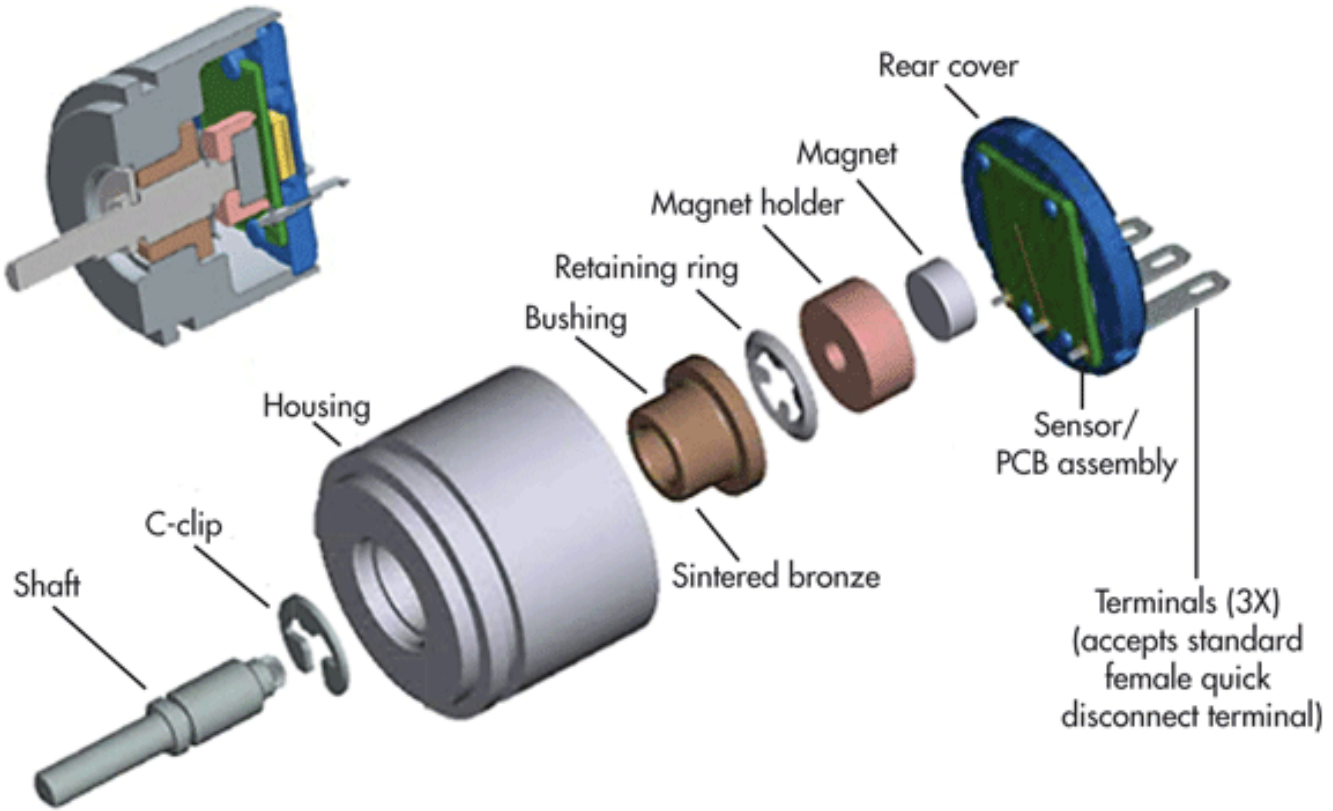


HALL EFFECT MAGNETIC ROTARY ENCODER



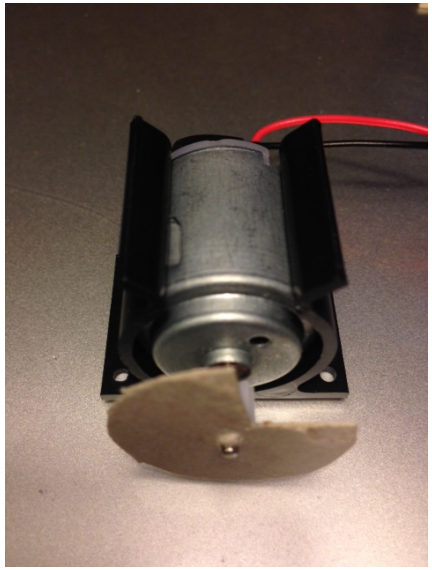
- Magnetic rotary encoder that comprises two poles and two sensors
- The second sensor makes it possible to not only detect the direction of rotation but also to interpolate the absolute position of the shaft

MAGNETIC ROTARY ENCODER



- Construction of a typical magnetic rotary encoder
- This types of encoder is often more robust than an optical encoder

That's all, folks!



Questions:
Portland Square B316 or **severin.lemaignan@plymouth.ac.uk**

Slides:
github.com/severin-lemaignan/module-introduction-sensors-actuators
...or the DLE!