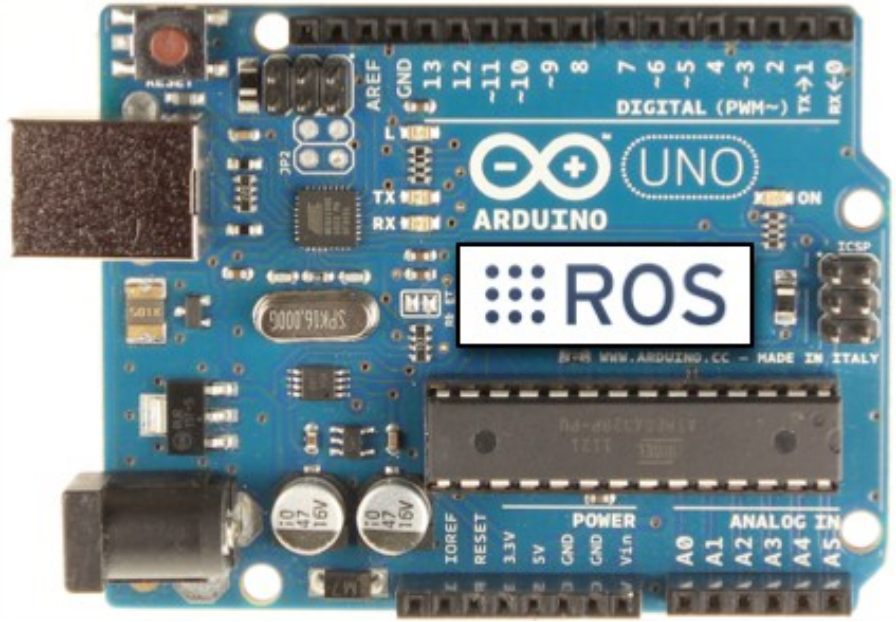
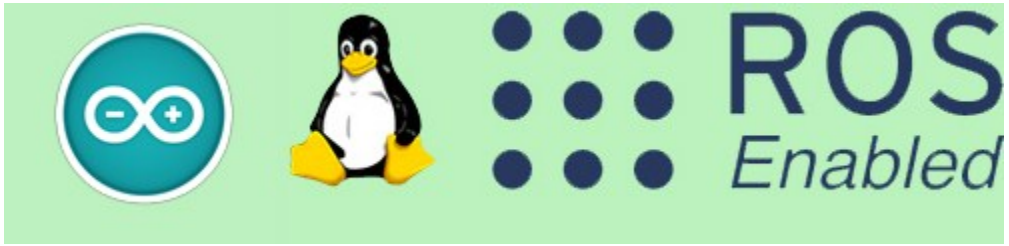
EE-565-Lab3
ROS Interface with Low Level Control - Arduino



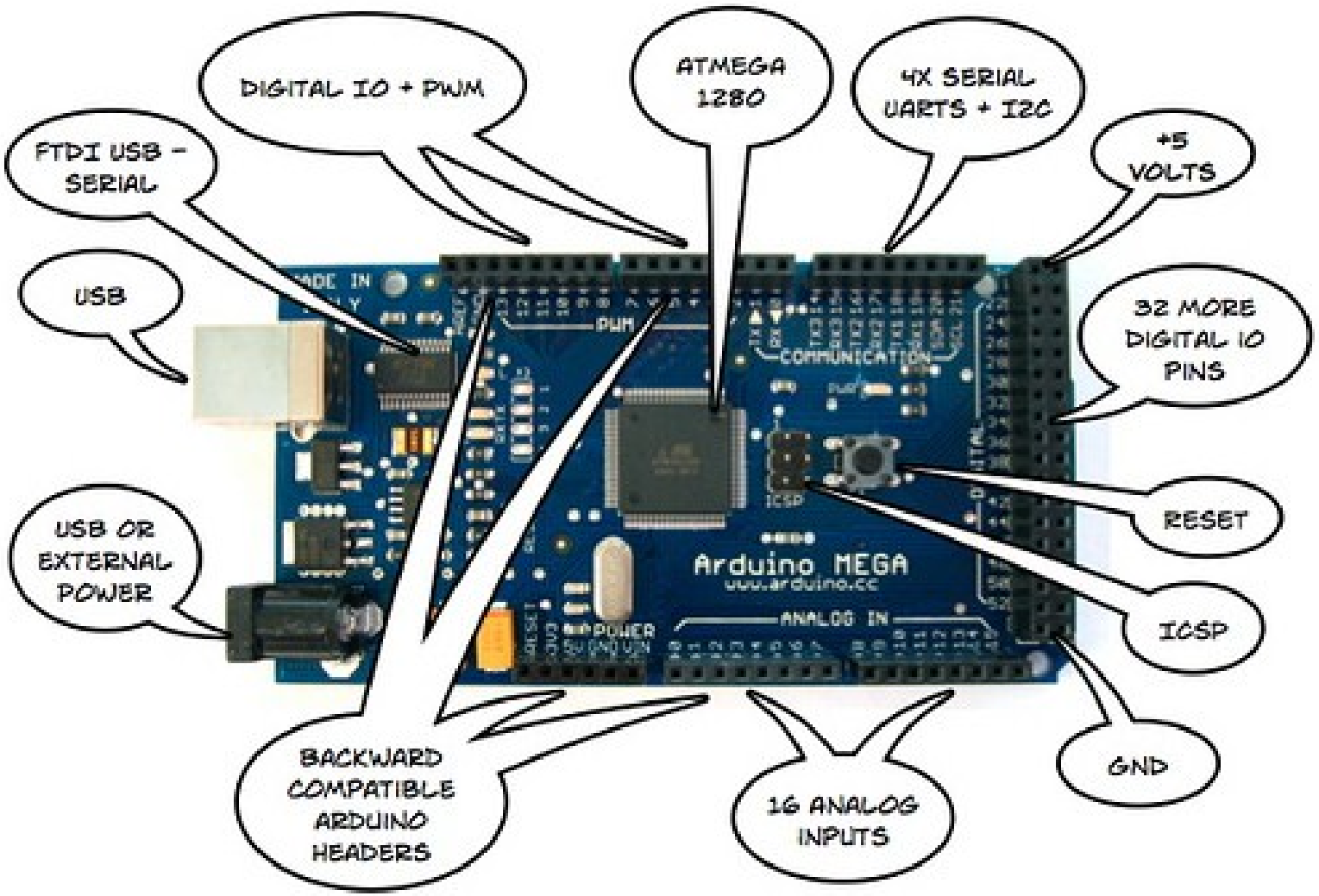
Dr. –Ing. Ahmad Kamal Nasir

Today's Objectives



- Introduction to Arduino
- Writing simple Arduino sketches
  - Serial Communication
  - Motor Speed Control
  - Quadrature Encoder Interface
  - PID Library
- Interface with ROS
- Writing a publisher/subscriber node

Arduino Mega- Hardware



Arduino IDE- Software

Two required functions

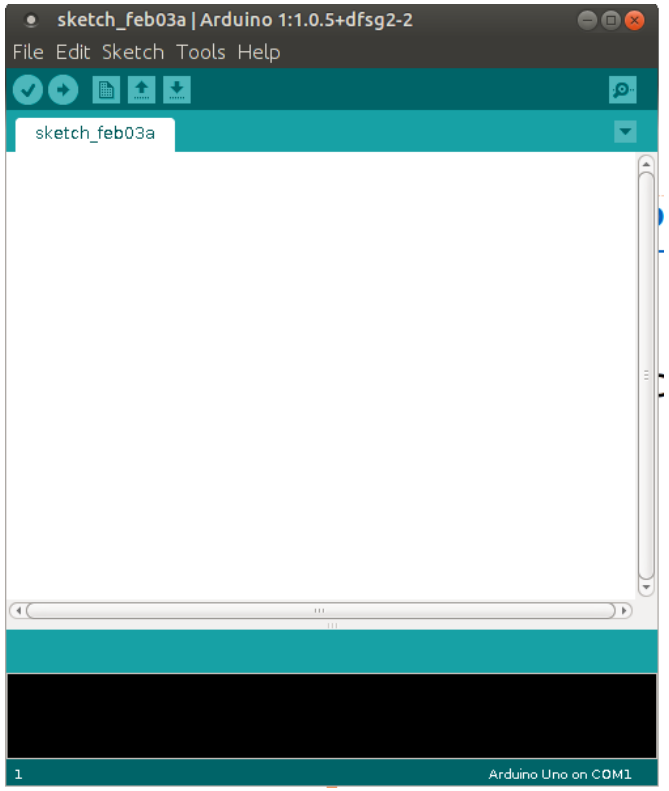
```
void setup()
{
      // runs once
}

void loop()
{
      // repeats
}
```

Programming Reference

Digital I/O • pinMode(pin, mode) • digitalWrite(pin,value) • digitalRead(pin)	**Analog I/O** • analogReference(EXTERNAL) • analogRead(pin) • analogWrite(pin,value)- PWM	**Time** • millis() • micros() • delay(ms) • delayMicroseconds(us)
Math • min() • max() • abs() • constrain() • map() • pow() • sqrt()	**Trigonometry** • sin() • cos() • tan() Random Numbers • random() • randomSeed()	**Bits and Bytes** • lowByte() • highByte() • bitRead() • bitWrite() • bitSet() • bitClear() • bit()
External Interrupts • attachInterrupt() • detachInterrupt()	**Interrupts** • interrupts() • noInterrupts()	**Communication** • Serial.available() • Serial.read() • Serial.print() • Serial.println()

Getting Started

- Check out: http://arduino.cc/en/Guide/HomePage
  1. Install Arduino environment
     - sudo apt-get install arduino
  2. Connect the board to your computer using USB cable
  3. Launch Arduino IDE



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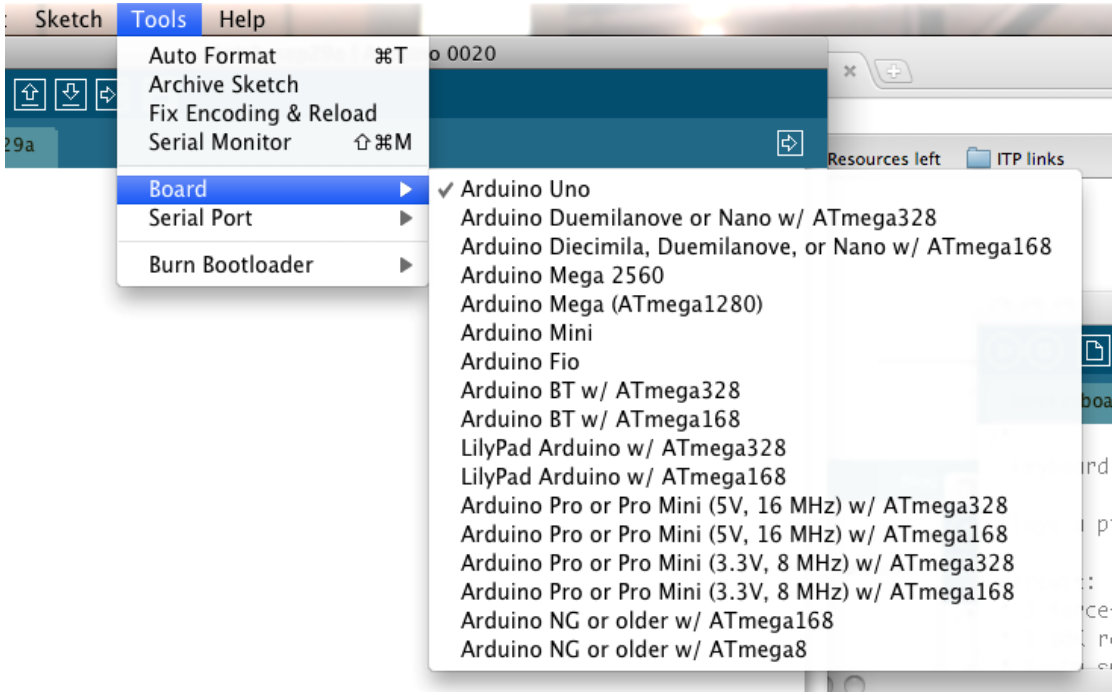

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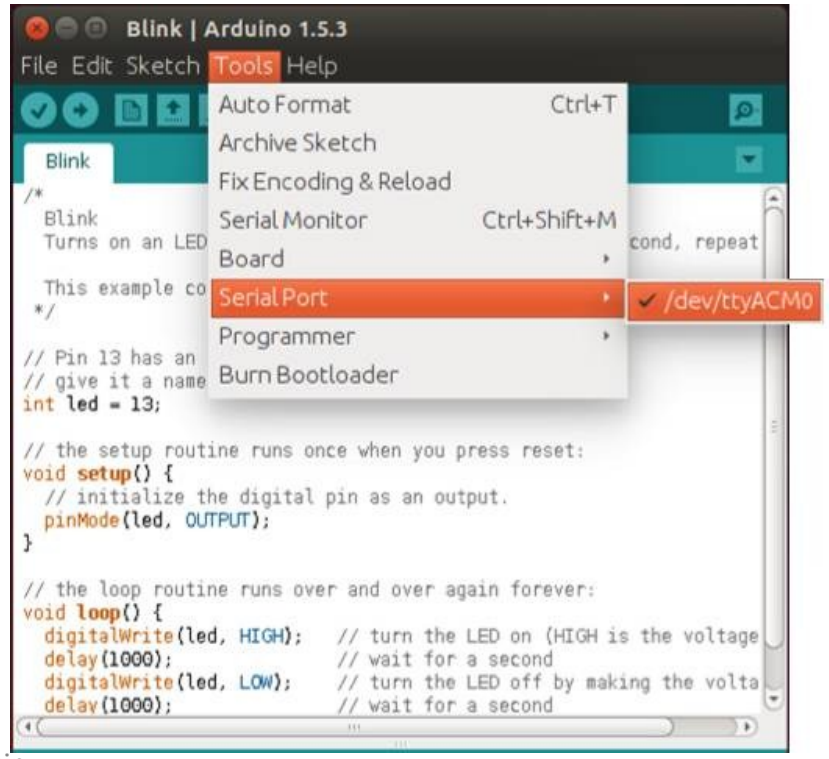
  4. Select Board
  5. Select your serial port



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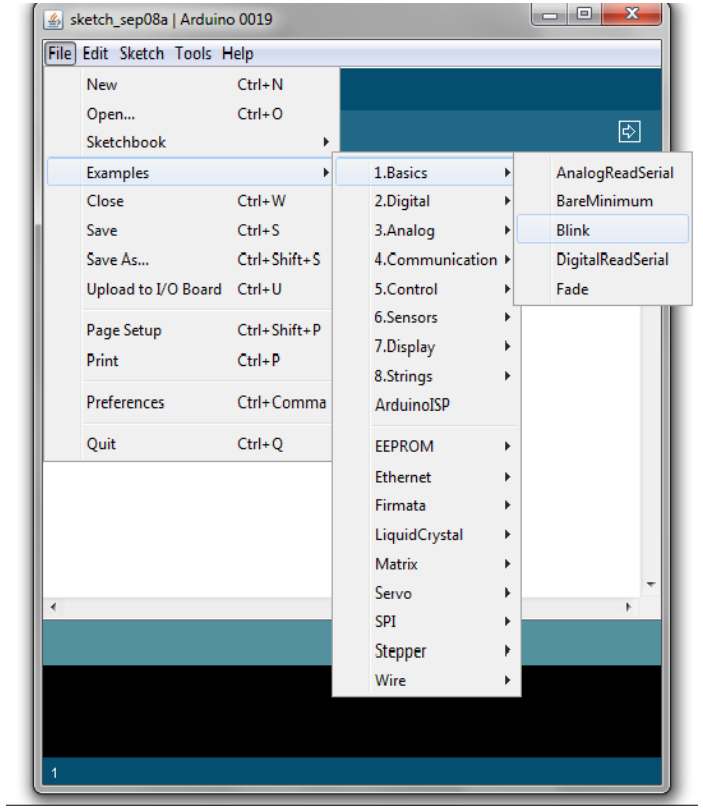
  6. Open the blink example



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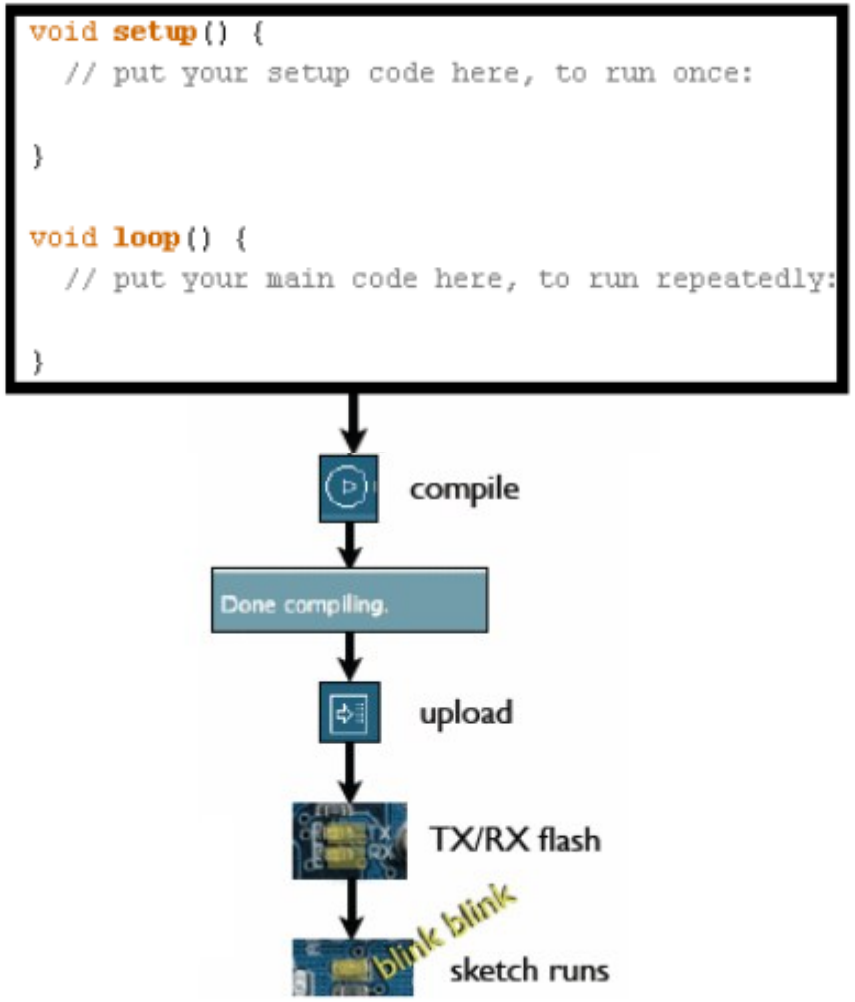
  3. Launch Arduino IDE
  4. Select Board
  5. Select your serial port
  6. Open the blink example
  7. Upload the Program

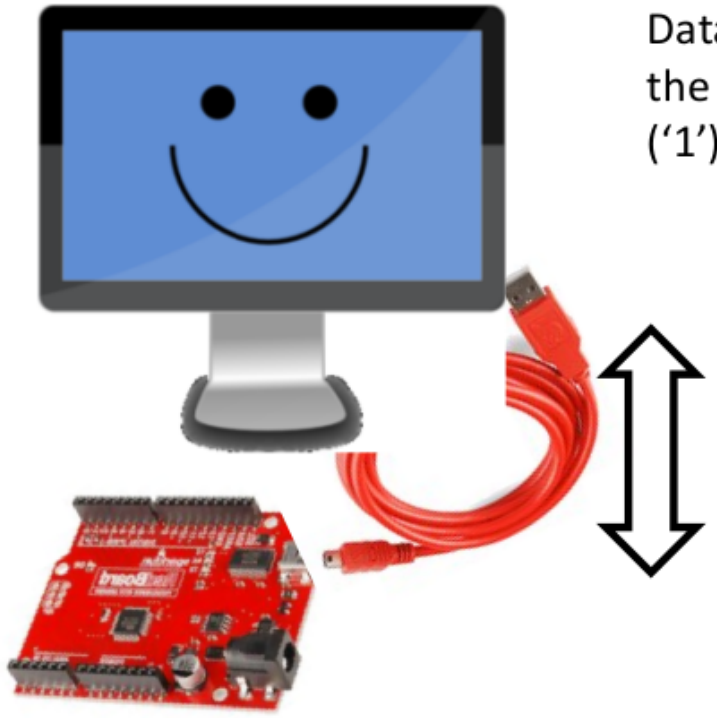
Development Lifecycle

- Write your sketch
- Press Compile button
- Press upload button to download your sketch into the microcontroller

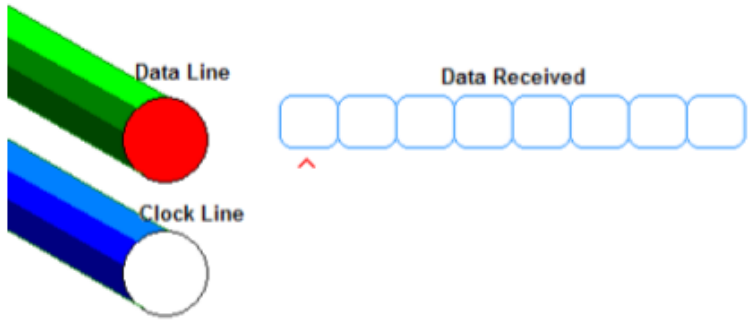


Serial Communication

Method used to transfer data between two devices.



Data passes between the computer and Arduino through the USB cable. Data is transmitted as zeros (‘0’) and ones (‘1’) sequentially.



Arduino dedicates Digital I/O pin # 0 to receiving and Digital I/O pin #1 to transmit.

Task 1: Arduino Getting Started

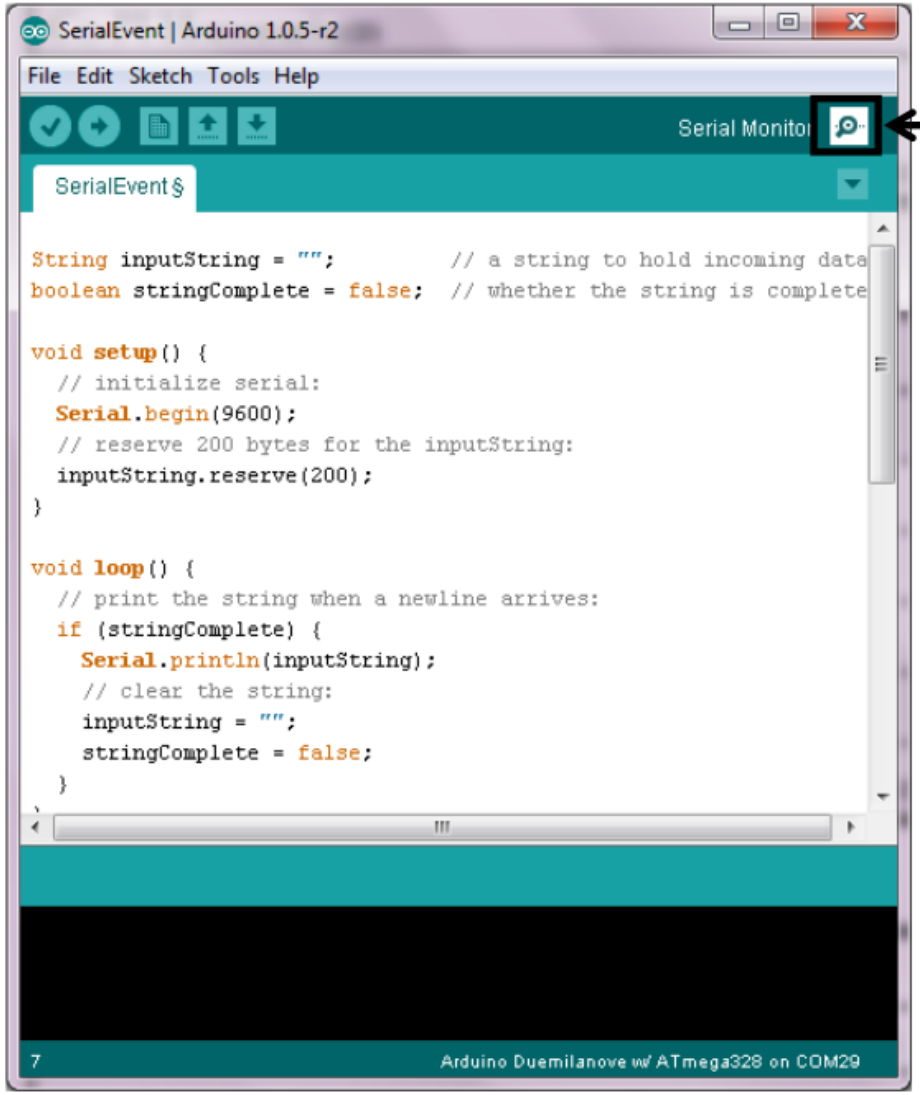
- Try it out with the **“SerialEvent”** sketch
- Run by executing arduino in terminal
- Load **“File-> Examples-> Communication->SerialEvent”**
- Select the correct **Tools->Board**
- And then right Serial Port. If your Serial Port option is greyed out, run **sudo chmod a+rw /dev/ttyACM0**

Serial Event - Sketch

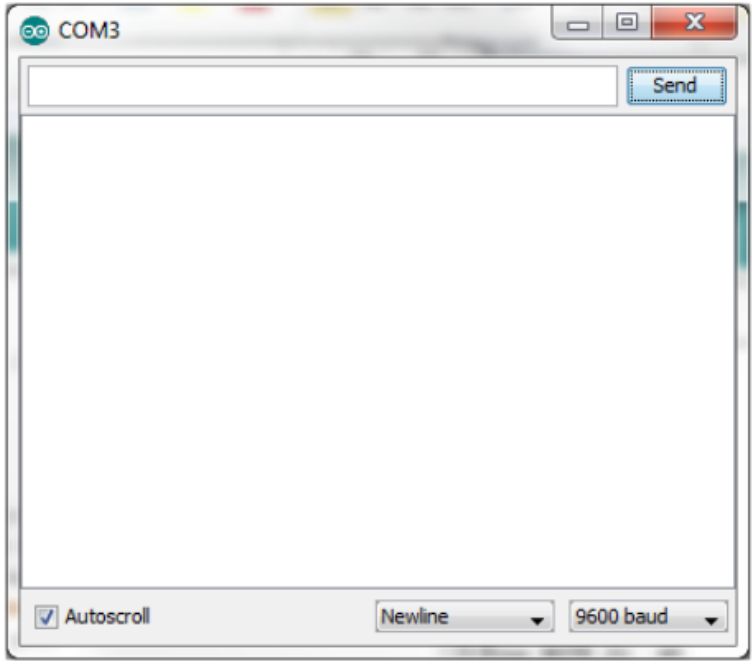
```
String inputString = "";
boolean stringComplete = false;

void setup()
{
  Serial.begin(9600);
  inputString.reserve(200);
}

void loop()
{
  if (stringComplete)
  {
    Serial.println(inputString);
    inputString = "";
    stringComplete = false;
  }
}
```

```
void serialEvent()
{
  while (Serial.available())
{

    char inChar = (char)Serial.read();
    inputString += inChar;
    if (inChar == '\n')
    {
      stringComplete = true;
    }
  }
}
```

Serial Monitor



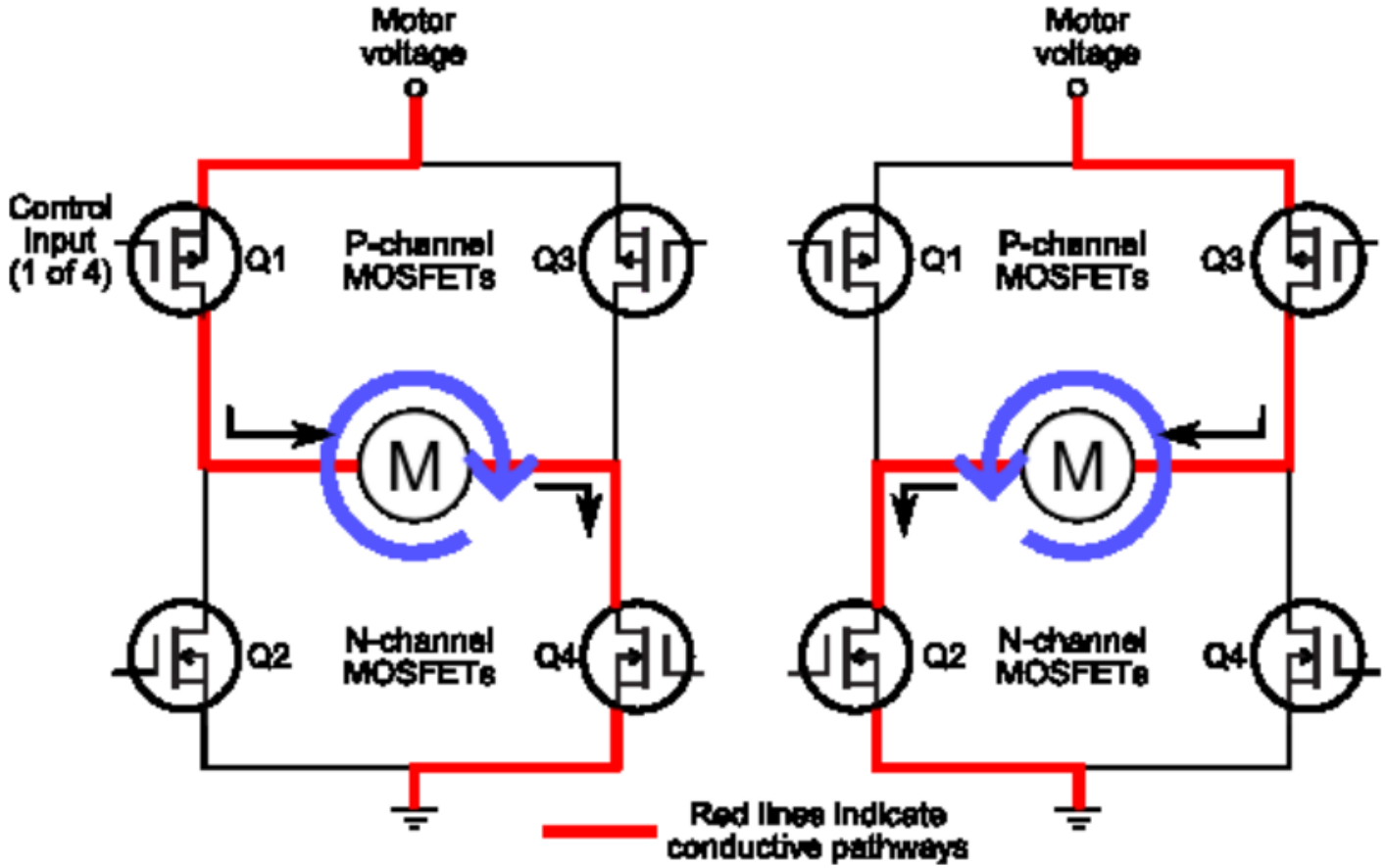
Opens up a Serial Terminal Window



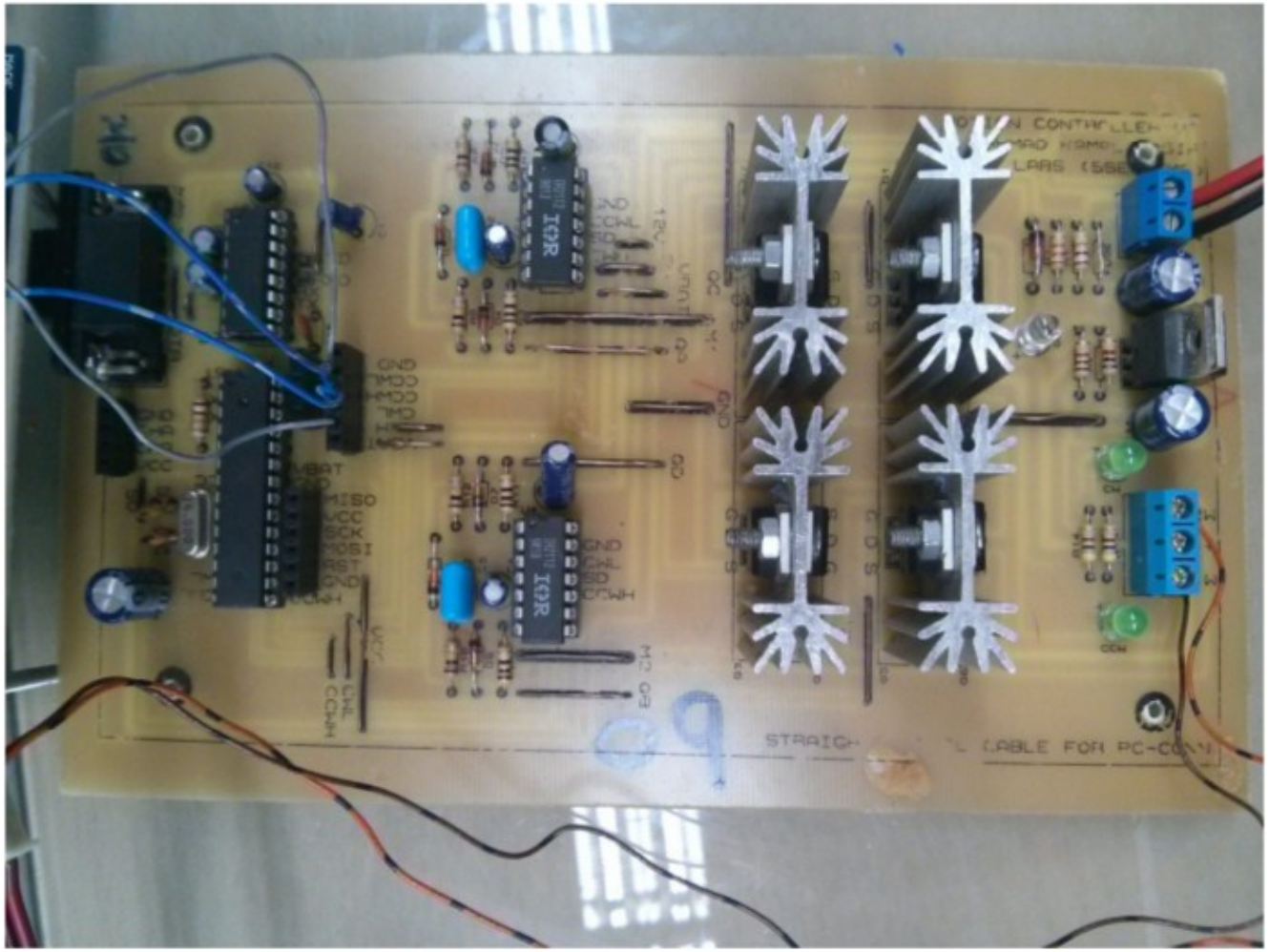
Task 2: Open Loop Speed Control

- Download and modify "motorSpeed" sketch
- Concepts to be learned
  - DC Motor Speed Control (open-loop)
    - H-Bridge
  - Digital Outputs & PWM generation

H-Bridge- Concept



H-Bridge- Hardware



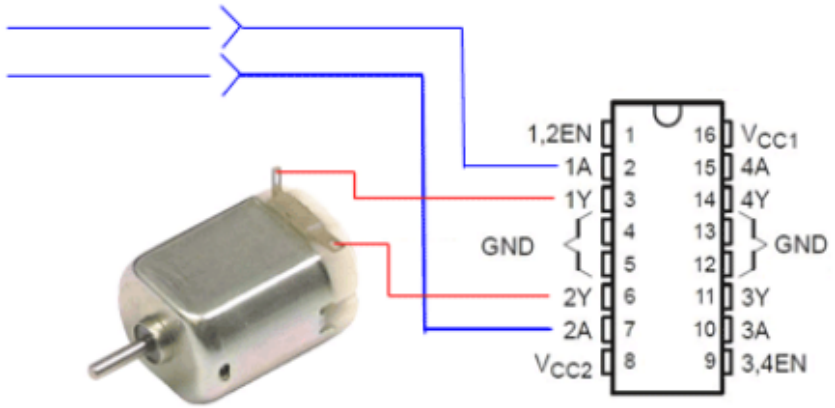
Generating PWM

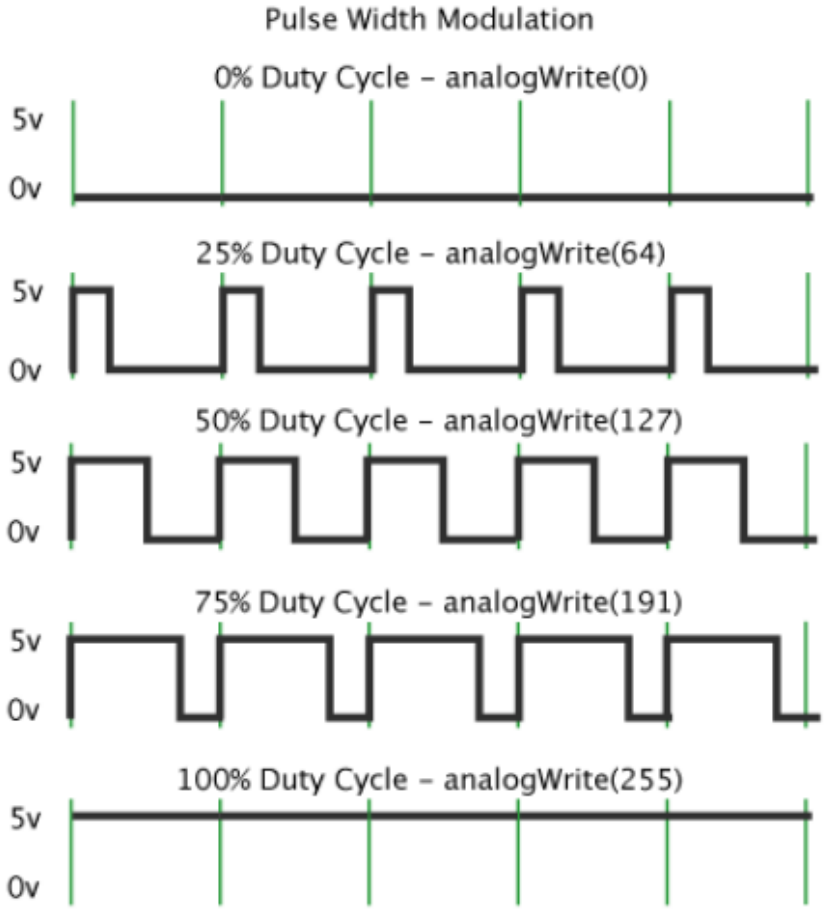
`analogWrite``(pin, val);`

`pin` – refers to the OUTPUT pin (limited to pins 3, 5, 6, 9, 10, 11.) – denoted by a ~ symbol

`val` – 8 bit value (0 – 255).

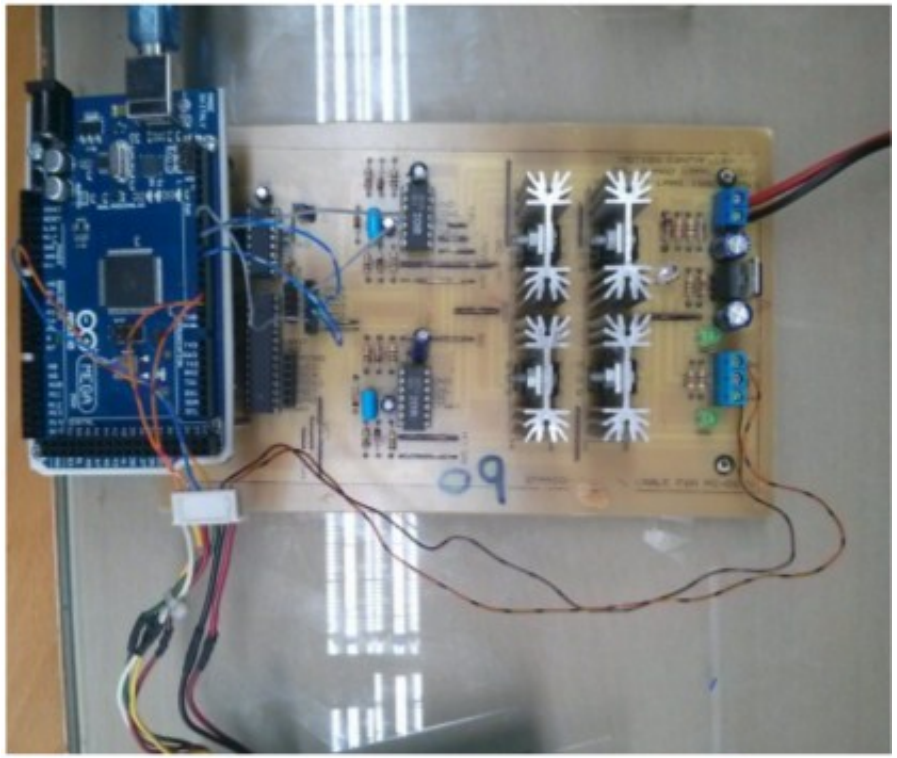
0 => 0V | 255 => 5V

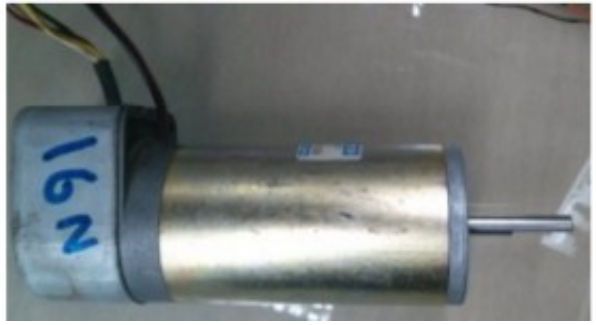




Hardware + Software Setup

- Download
  "motorSpeed" sketch
  from LMS
- Connect the motor
  power wires to the H-Bridge output
- Connect the arduino
  control signals to the H-Bridge input





Motor Speed Control (Open-Loop)

```
int motorDirection, motorPWM;
int CCWH = 9;
int CCWL = 8;
int CWH = 10;
int CWL = 7;
void setup()
{
  pinMode(CWH, OUTPUT);
  pinMode(CWL, OUTPUT);
  pinMode(CCWH, OUTPUT);
  pinMode(CCWL, OUTPUT);
  motorDirection = 2;
  motorPWM = 128;
}
void loop()
{
  MotorControl(motorDirection, motorPWM);
}
```

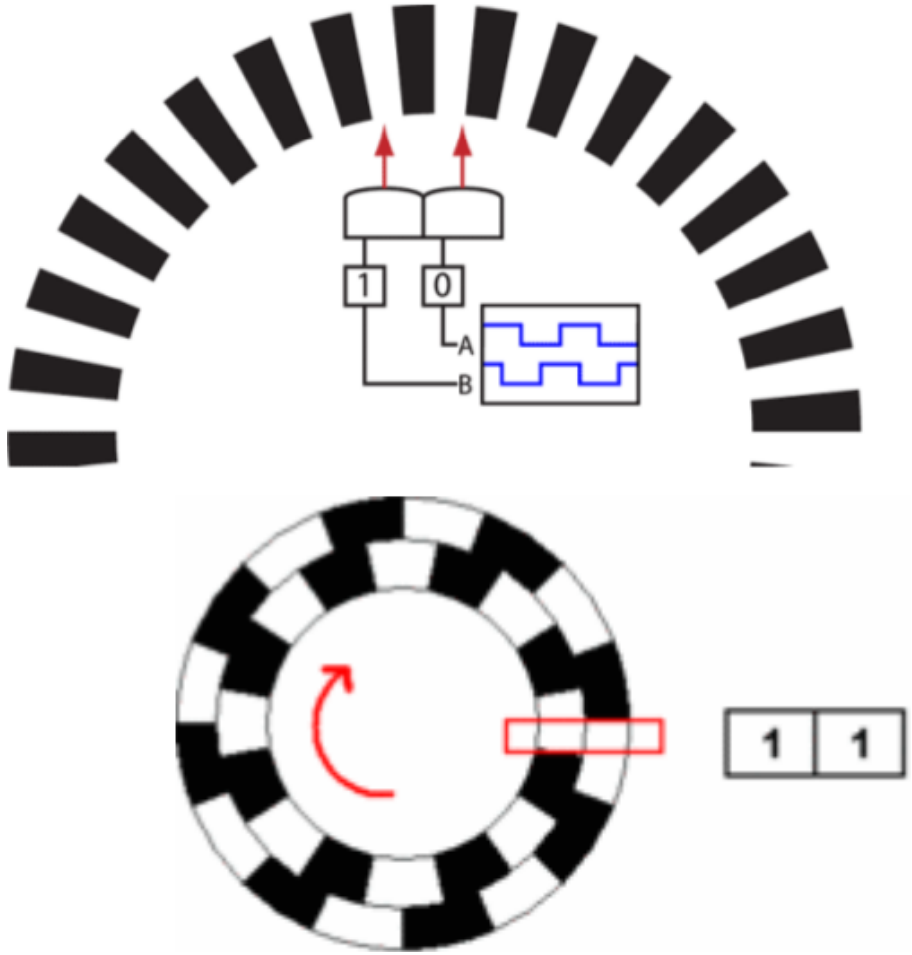
```
void MotorControl ( int dir, int pwm ) {
  if ( dir == 1){
    digitalWrite(CCWL, LOW);
    digitalWrite(CCWH, LOW);
    digitalWrite(CWL, HIGH);
    analogWrite(CWH, pwm);
  }  else if (dir == 2) {
    digitalWrite(CWL, LOW);
    digitalWrite(CWH, LOW);
    digitalWrite(CCWL,HIGH);
    analogWrite(CCWH, pwm);
  }  else {
    digitalWrite(CWL, LOW);
    digitalWrite(CCWL, LOW);
    analogWrite(CWH, 0);
    analogWrite(CCWH, 0);
  }
}
```

Task 3: Velocity Feedback using Quadrature Encoder

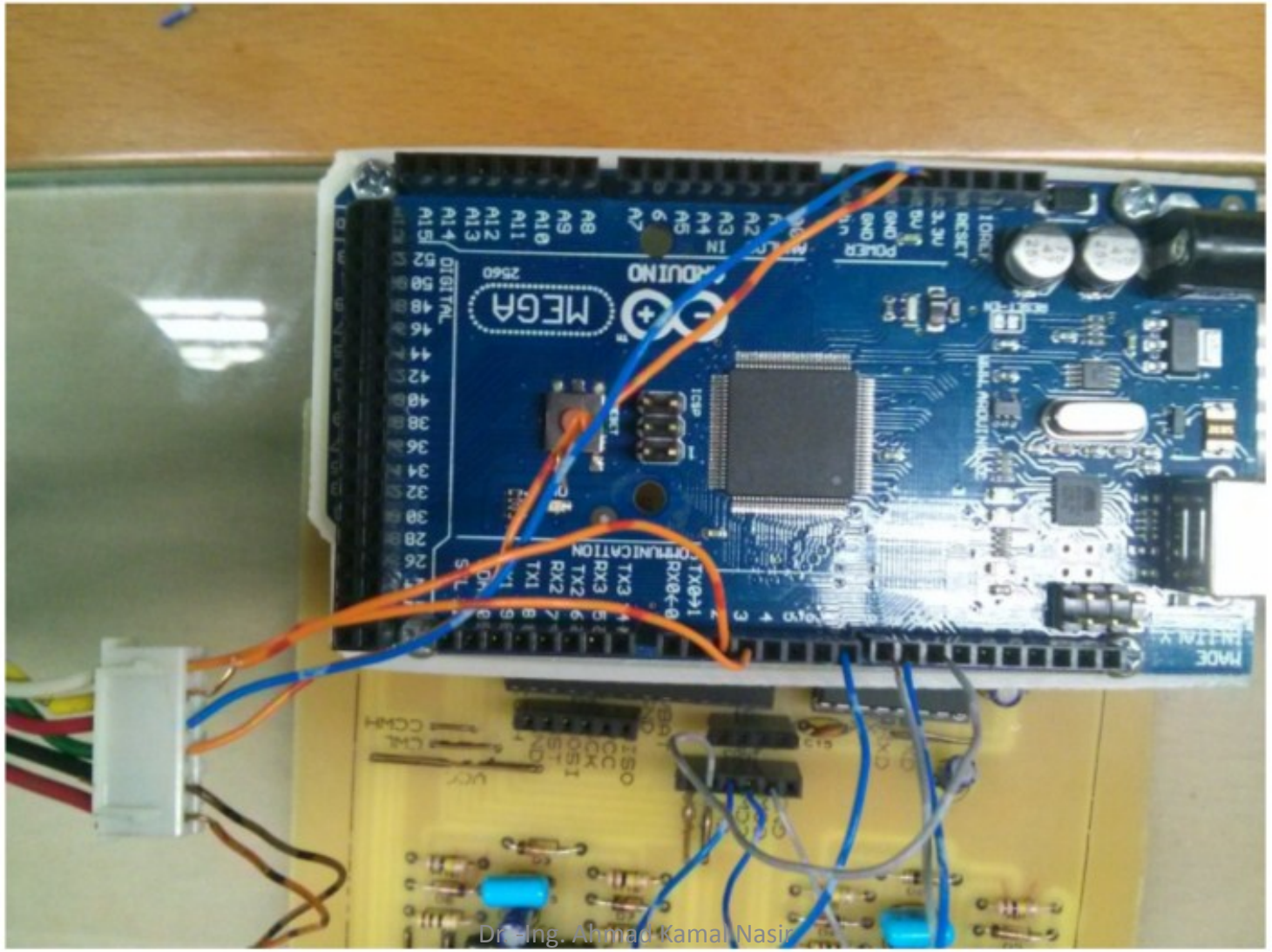
- Download and modify “encoder” sketch to periodically transmit calculated velocity
  - Quadrature encoder interface
  - Interrupts processing

Quadrature Encoder

- Measure rotation direction and velocity
- Specified by the number of pulses per revolution
- Some recent microcontrollers have specialized hardware unit for interface



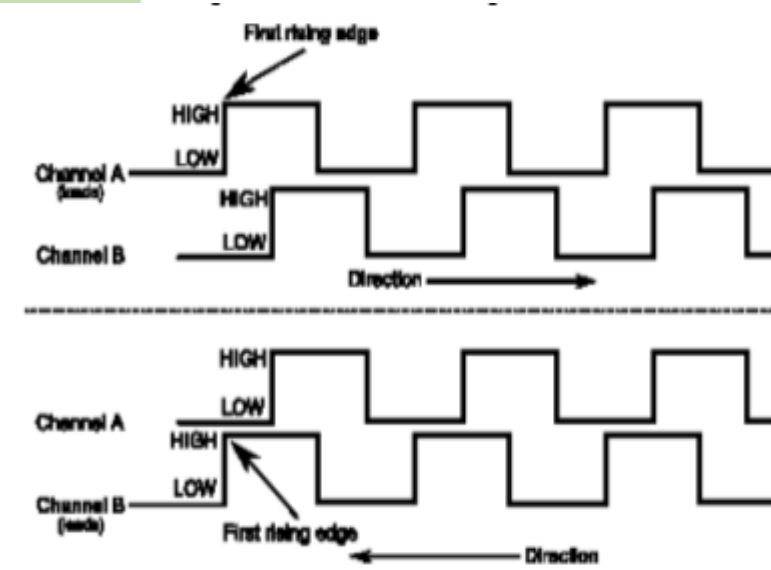
H-Bridge Control + Encoder Wiring Setup



Quadrature Encoder for velocity measurement

```
#define encoder0PinA 2
#define encoder0PinB 3

volatile signed long encoder0Pos = 0;
float currTicks=0, prevTicks=0, dTicks=0,
velDPS=0 ,velRPS=0;

unsigned long currentTime, prevTime, dTime,
finalTime;

void setup()
{
  pinMode(encoder0PinA, INPUT);
  pinMode(encoder0PinB, INPUT);
  attachInterrupt(0, doEncoderA, CHANGE);
  attachInterrupt(1, doEncoderB, CHANGE);
  finalTime = micros();
}
```

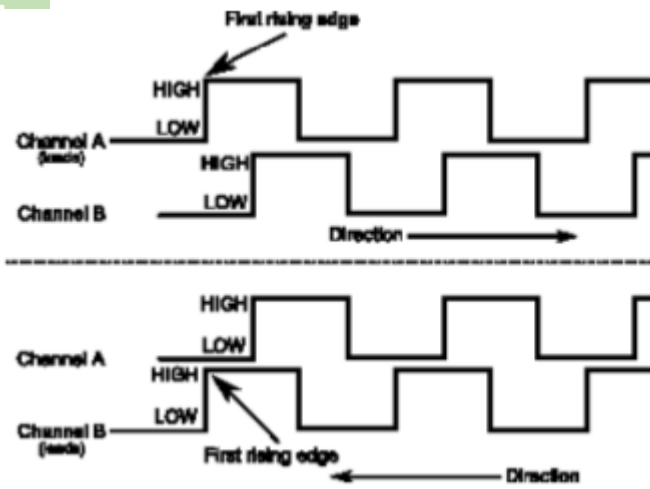
```
void loop()
{
  currentTime = micros();
  dTime = currentTime - prevTime;
  prevTime = currentTime;
  currTicks = encoder0Pos;

  dTicks = currTicks-prevTicks;
  prevTicks = currTicks;

  velDPS = (dTicks*360/400)*1000000/d
  velRPS = velDPS/360;
  if ( currentTime >= finalTime ){
      Serial.println (velRPS);
      finalTime = currentTime + 1e6;
   }
}
```



Quadrature Encoder for velocity measurement (Cont.)

```
void doEncoderA()
{
// look for a low-to-high on channel A
if (digitalRead(encoder0PinA) == HIGH) {
  // check channel B to see which way
encoder is turning
  (digitalRead(encoder0PinB) == LOW) ?
encoder0Pos++ : encoder0Pos-- ;
  }

else // must be a high-to-low edge on channel
A
{
// check channel B to see which way encoder
is turning
  (digitalRead(encoder0PinB) == HIGH) ?
encoder0Pos++ : encoder0Pos-- ;
   }
}
```

```
void doEncoderB()
{
// look for a low-to-high on channel B
if (digitalRead(encoder0PinB) == HIGH) {
// check channel A to see which way encoder
is turning
(digitalRead(encoder0PinA) == HIGH) ?
encoder0Pos++ : encoder0Pos-- ;
}
else // Look for a high-to-low on channel B
{
// check channel B to see which way encoder
is turning
(digitalRead(encoder0PinA) == LOW) ?
encoder0Pos++ : encoder0Pos-- ;
  }
}
```

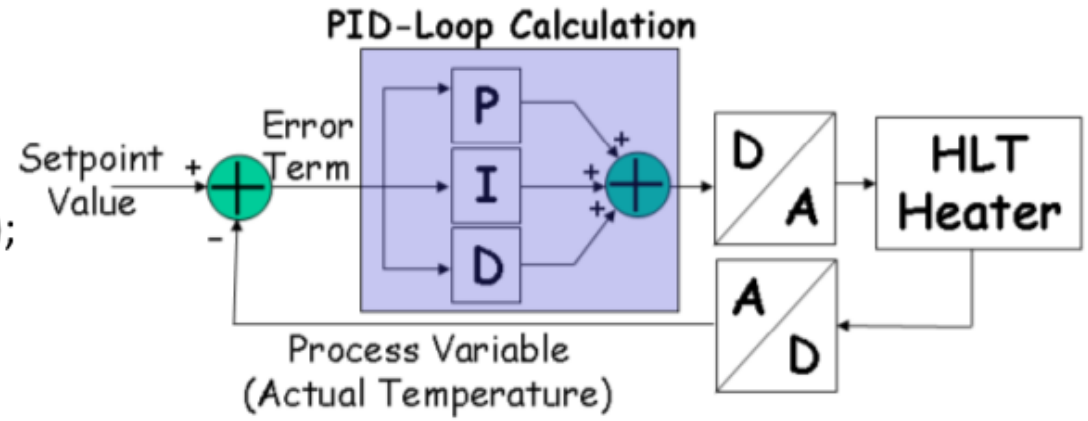


PID in Arduino

- PID arduino library
  - **PID** (&Input, &Output, &Setpoint, Kp, Ki, Kd, Direction)
  - **Compute**()
  - **SetMode** (AUTOMATIC or MANUAL)
  - **SetOutputLimits** (min, max)
  - **SetTunings** (Kp, Ki, Kd)
  - **SetSampleTime** (SampleTime)
  - **SetControllerDirection** (DIRECT or REVERSE)

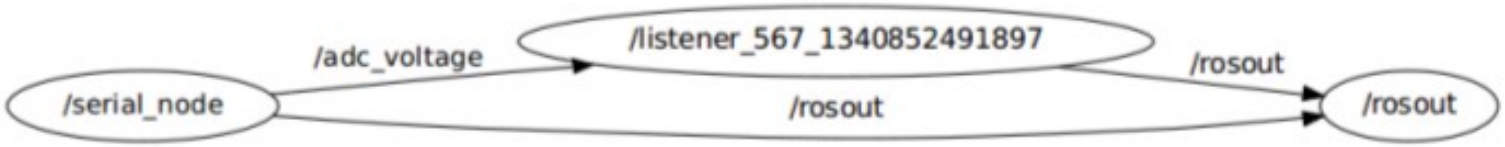
PID Library Example

```
#include <PID_v1.h>

double Setpoint, Input, Output;
PID myPID(&Input, &Output, &Setpoint,2,5,1, DIRECT);

void setup()
{
Input = analogRead(0);
 Setpoint = 100;
myPID.SetMode(AUTOMATIC);
}

void loop()
{
 Input = analogRead(0);
 myPID.Compute();
 analogWrite(3,Output);
}
```

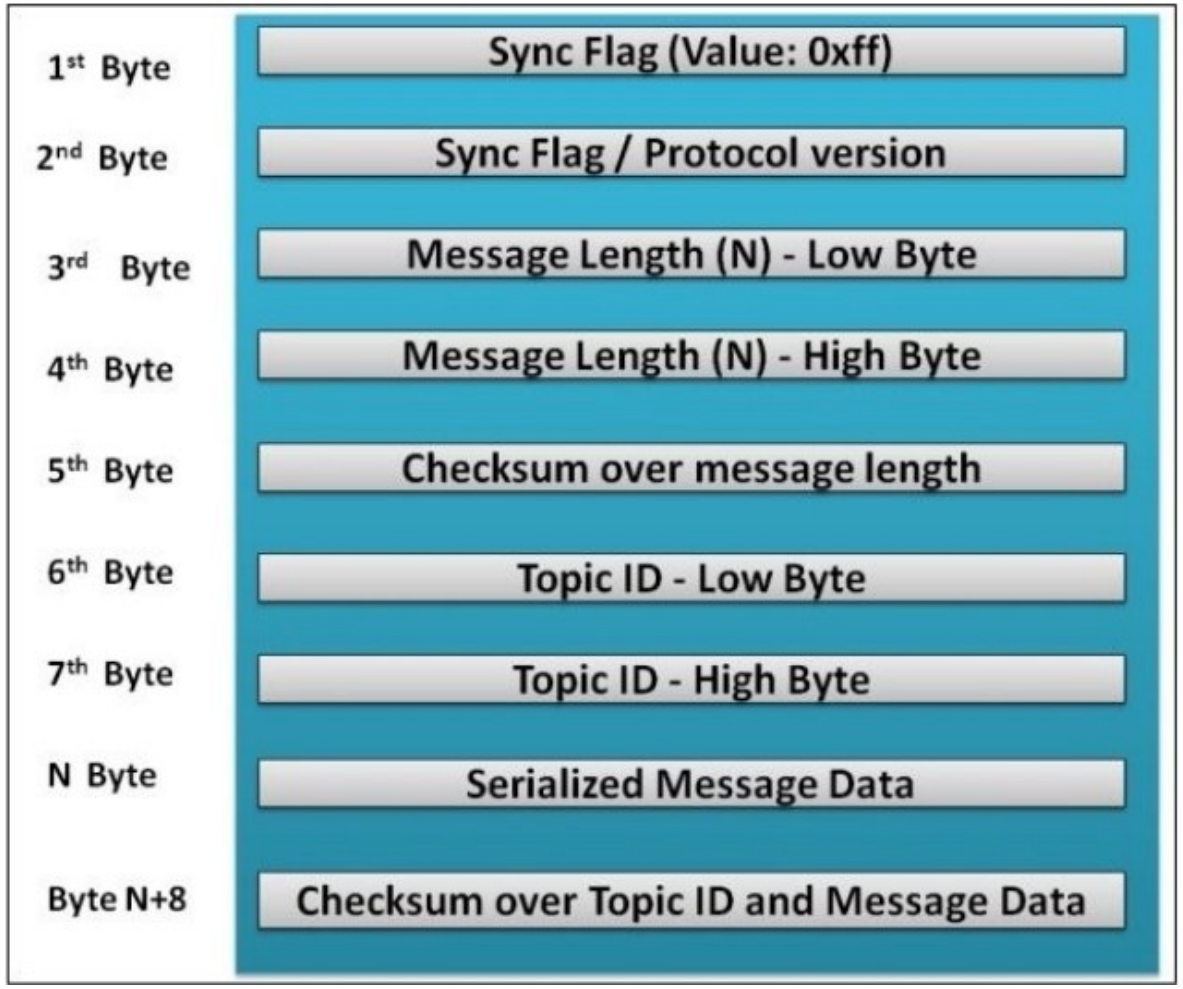


Arduino with ROS

- We can interface Arduino with ROS using **rosserial** node

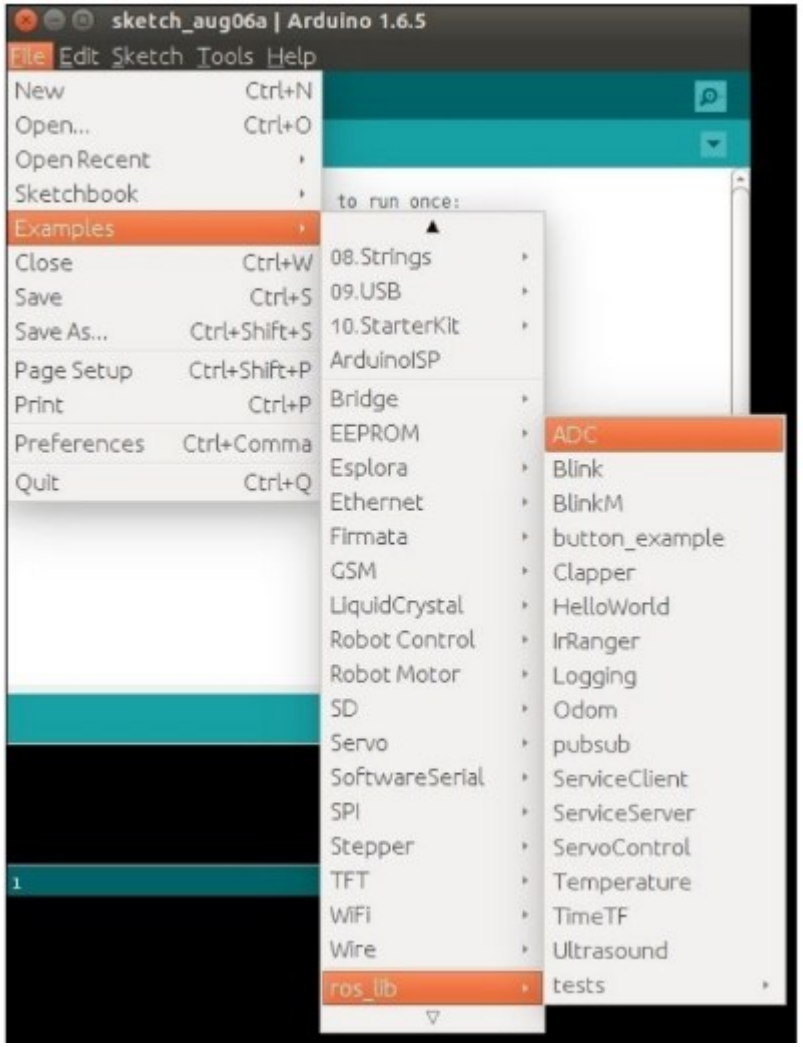


Rosserial Package



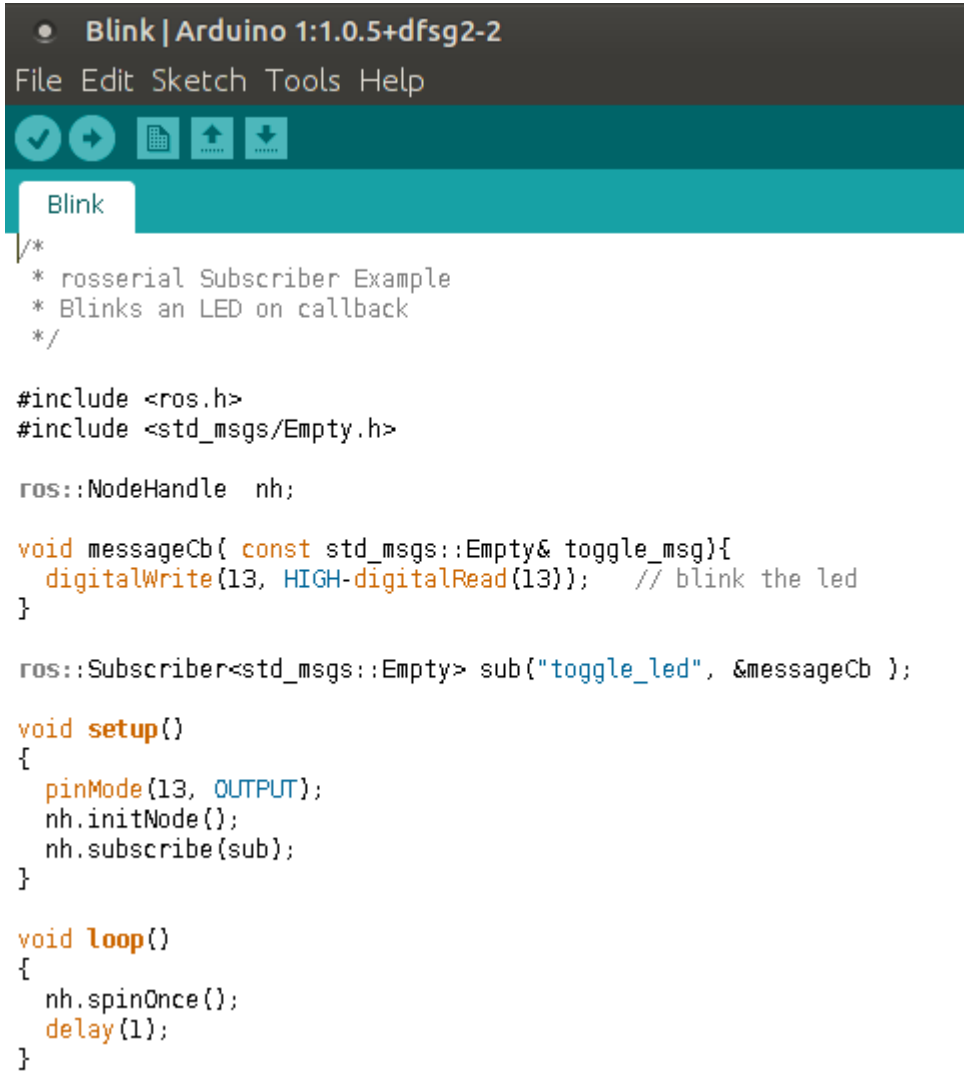
Installing Rosserial Packages in Ubuntu

- Install
  - **sudo apt-get install ros-indigo-ros-serial ros-indigo-rosserial-arduino ros-indigo-rosserial-server**
- Go to your sketchbook folder (/home/user/sketchbook)
  - cd **libraries**
  - **rosrun rosserial_arduino make_libraries.py .**
  - **rosserial_arduino** is ROS client for arduino which communicates using UART and publish topics/services/TF like a ROS node.
  - **make_libraries.py** will generate libraries for Arduino



Understanding ROS node API in Arduino

- ros::NodeHandle nh
  - should be declared before setup()
- nh.initNode()
  - Initializes Handle Node.
- nh.spinOnce();
  - should be in loop()
- ros::subscribe<std_msgs::string>...
  - subscribe to any ROS topic



Task-4: ROS Publisher Node in Arduino

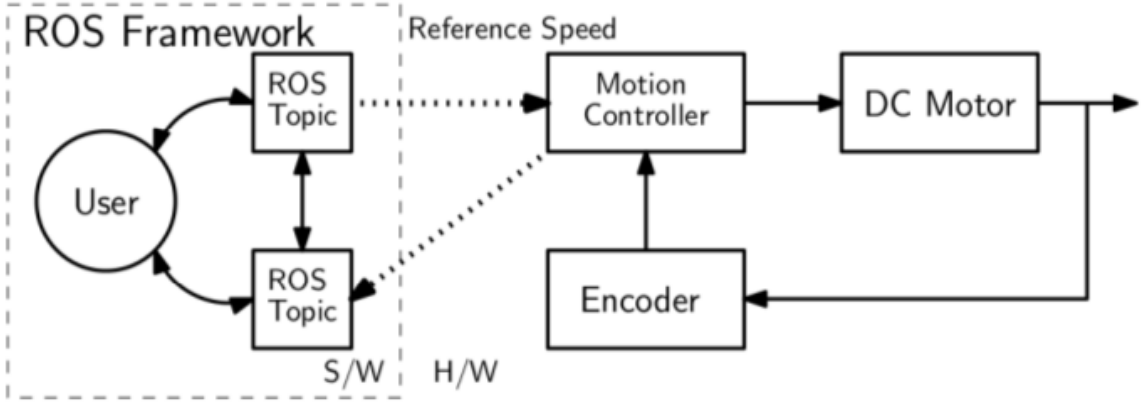
```
// Open example "Helloworld" in arduino roslib
#include <ros.h>
#include <std_msgs/String.h>
ros::NodeHandle nh;
std_msgs::String str_msg;
ros::Publisher chatter("chatter", &str_msg);
char hello[13] = "hello world!";
void setup()
{
   nh.initNode();
   nh.advertise(chatter);
}
void loop()
{
  str_msg.data = hello;
  chatter.publish( &str_msg );
  nh.spinOnce();
  delay(1000);
}
```

- **rosrun rosserial_python serial_node.py /dev/ttyACM0**
- **rostopic list**
  - we will see topics of "chatter" and "talker"
- **rostopic pub -r 5 talker std_msgs/String "Hello World"**

```
lentin@lentin-Aspire-4755:~$ rostopic echo /chatter
data: Hello World
---
data: Hello World
---
data: Hello World
---
data: Hello World
---
data: Hello World
---
data: Hello World
---
data: Hello World
---
data: Hello World
---
```

Lab Assignment

- Build a complete DC Motor Speed Control application, interfaced with ROS. Use the Arduino code available on LMS. Each group will be provided with the following equipment:
  - Motion controller board (H-Bridge + Arduino Board)
  - DC Motor having an attached encoder sensor.
  - Cable for serial communication between PC and Arduino
- Boiler code for Motor Speed Control (using PID library) is available on LMS. This should be interfaced with ROS framework, through ROS Topics. Motion controller will take a reference motor speed as input from the serial port, and with its built-in feedback loop, control the DC Motor. The controller will also publish the Odometery data (current motor speed) to another topic for internal ROS use (as geometry_msgs/Twist).



Lab Assignment

- DELIVERABLES :
  - Publish motor encoder data as rostopic. This will require writing a publisher node in Arduino code that will take the encoder's data to publish to a ROS topic (geometry_msgs/Twist in revolutions/second). This topic may not be used inside ROS for now, but it should be visible and working. [For this deliverable you can write your own Arduino code as well.]
  - Using the sign of linear velocity (x-axis) (i.e. +ve/-ve) from turtlebot's cmd_vel to decide the direction of motor rotation. This will require a subscriber node. Move the motor with any constant speed with the given direction.
  - Implement speed control. Based on turtlebot's linear velocity (x-axis), specifiy reference speed and direction for your motor. In the end, your motor should move according to the speed and direction of turtlebot. [It is highly recommended to use turtlebot_teleop package instead of turtlesim.]