Introduction to Biomedical Engineering

Section 3: **Microcontrollers/Arduino**

Lecture 3.3: PID controller

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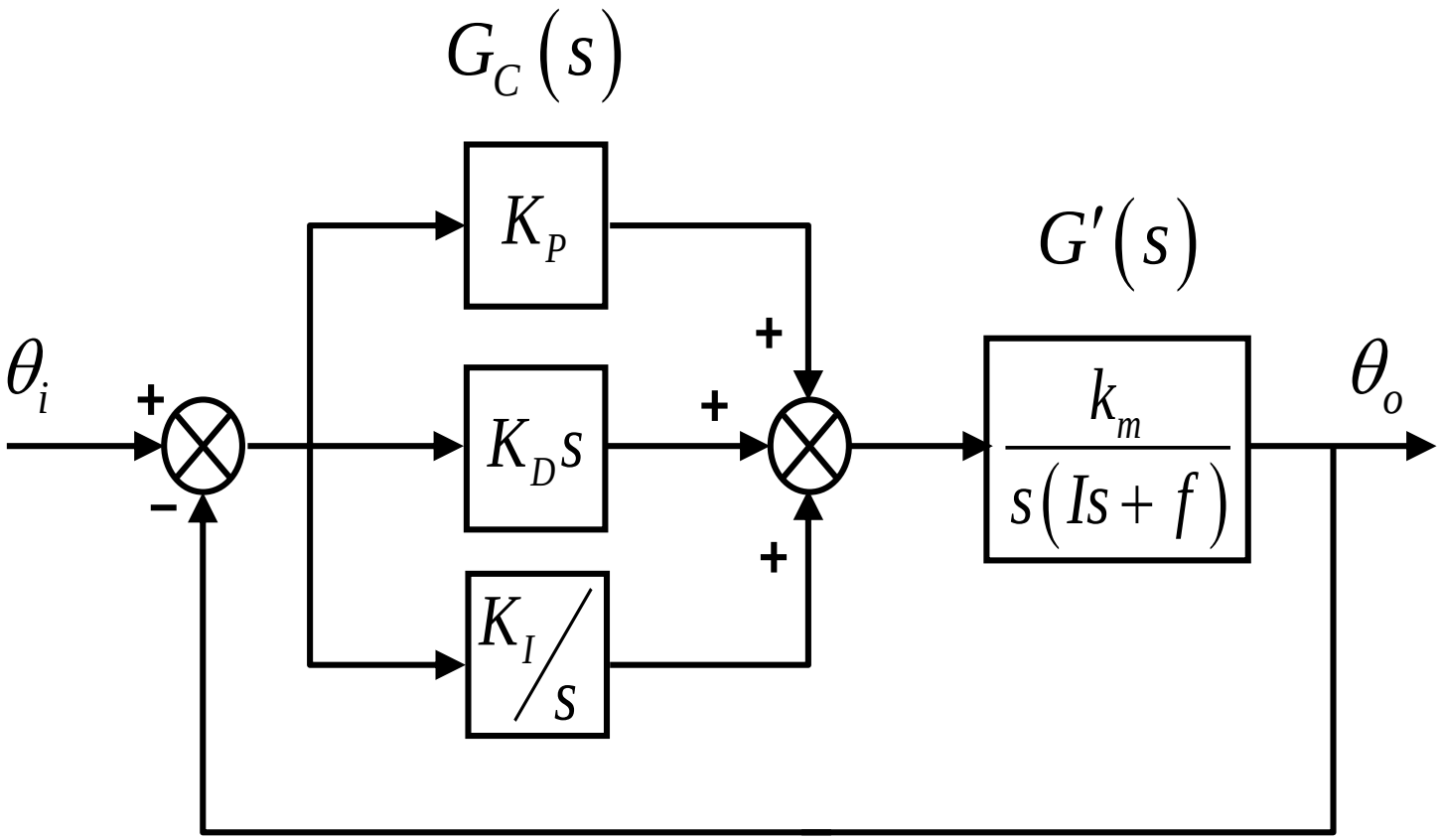
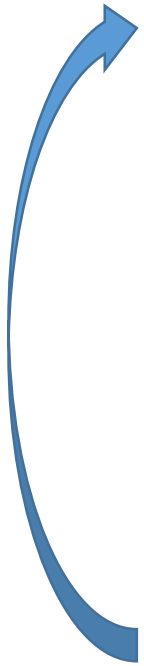
PID controller

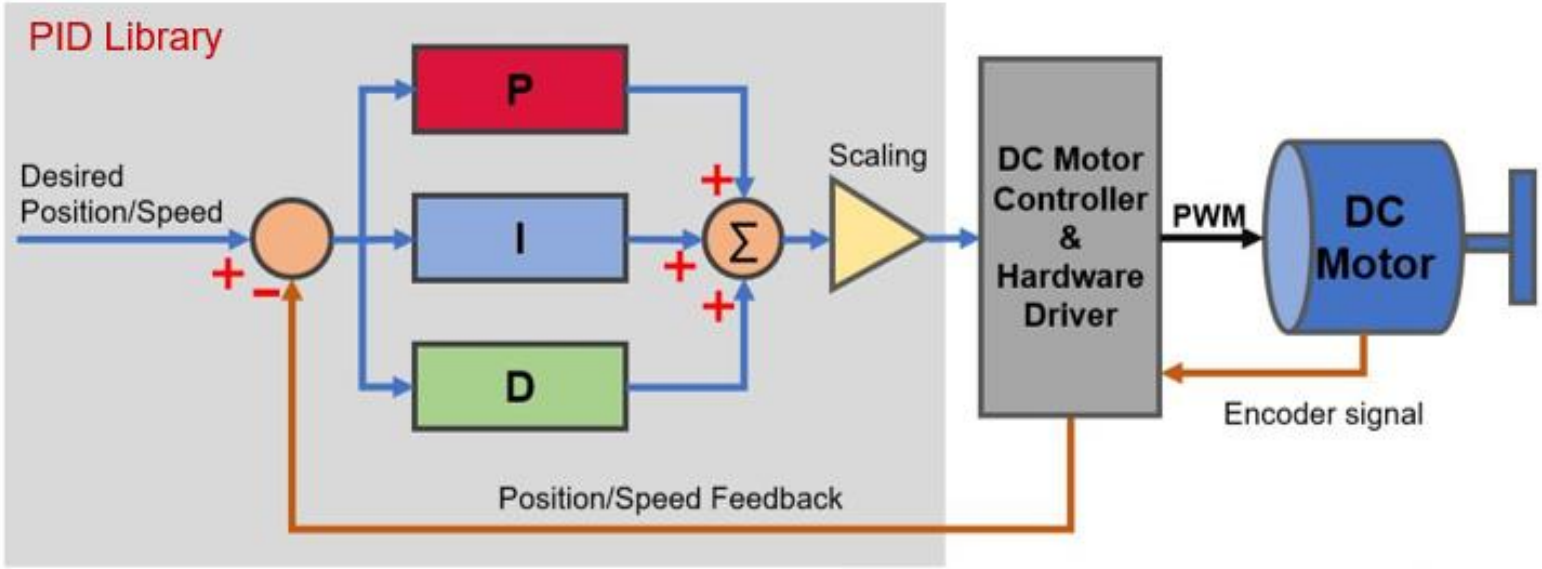


Basic algorithm



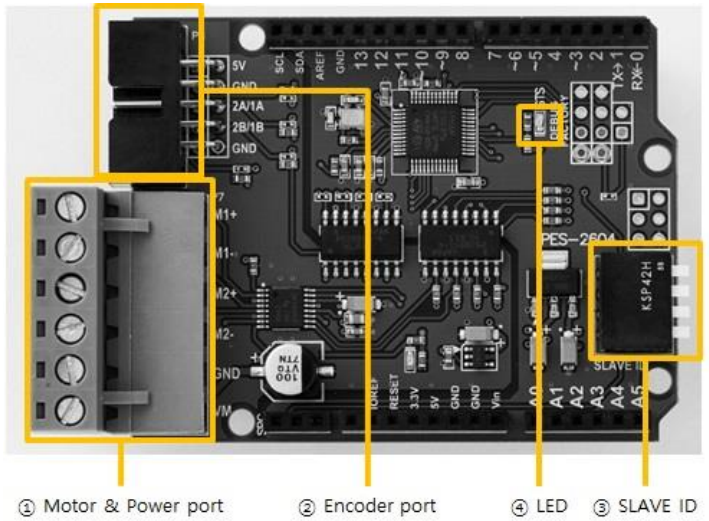
- Compute error
  - E = Set_value – actual_value
- Compute differential error
  - dE = (E-E_previous)/time_between_measurements
- Compute integral error
  - sE = sE+E*time_between_measurements
- Correct output
  - OUTPUT = OUTPUT + Kp*E + Kd*dE + Ki*sE

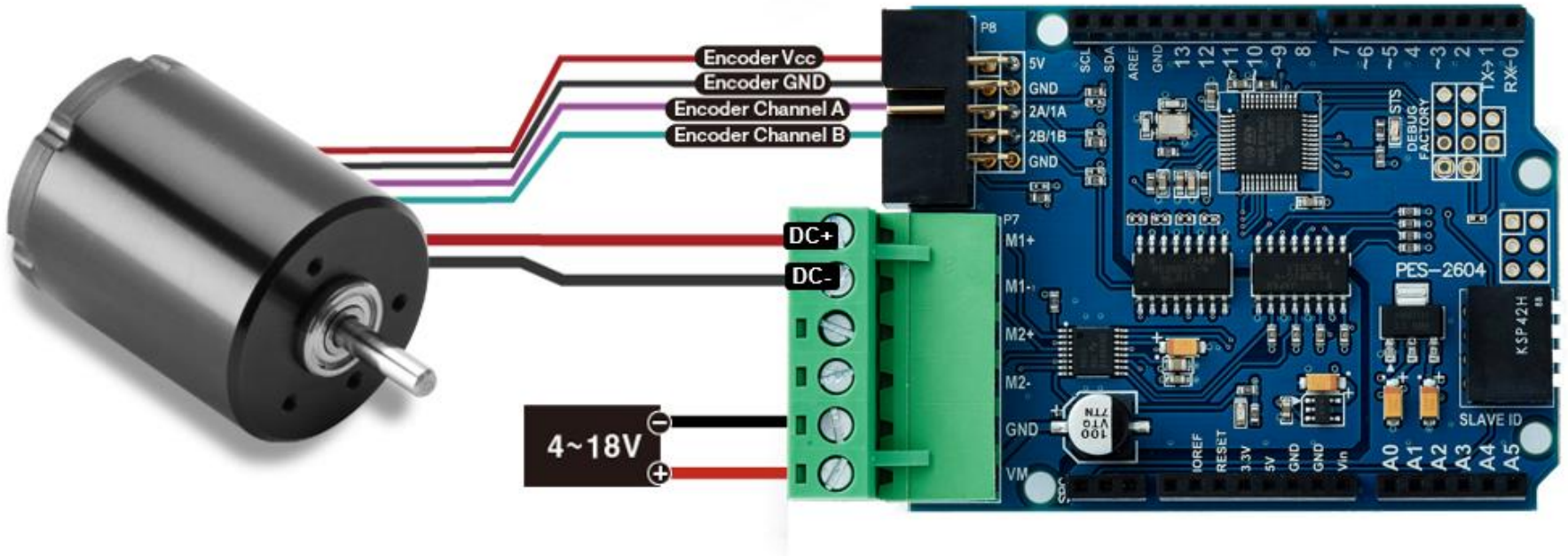
One way of doing it



Possible quick and reliable solution

https://www.phpoc.com/support/manual/pes-2604_user_manual/contents.php?id=layout

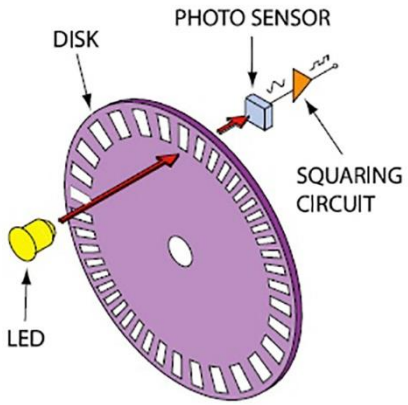


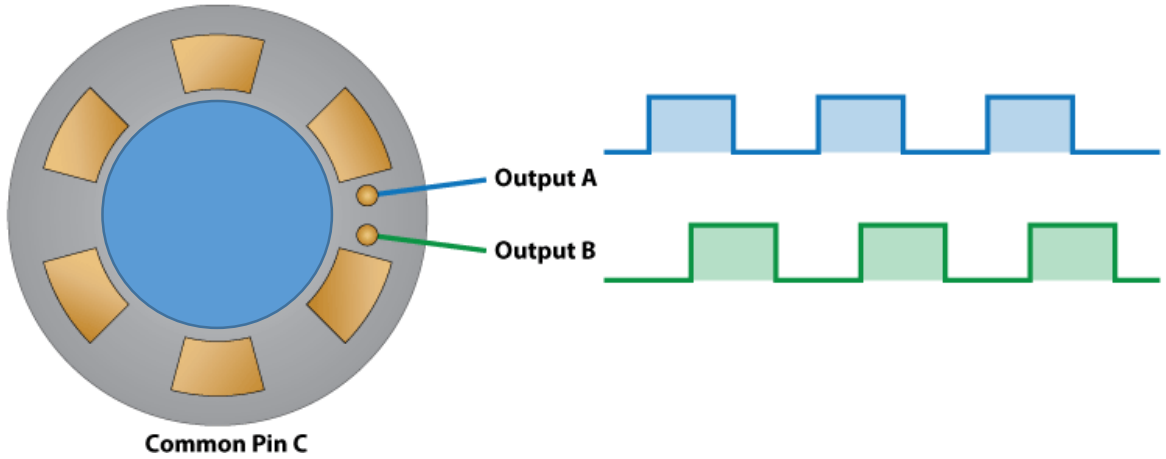


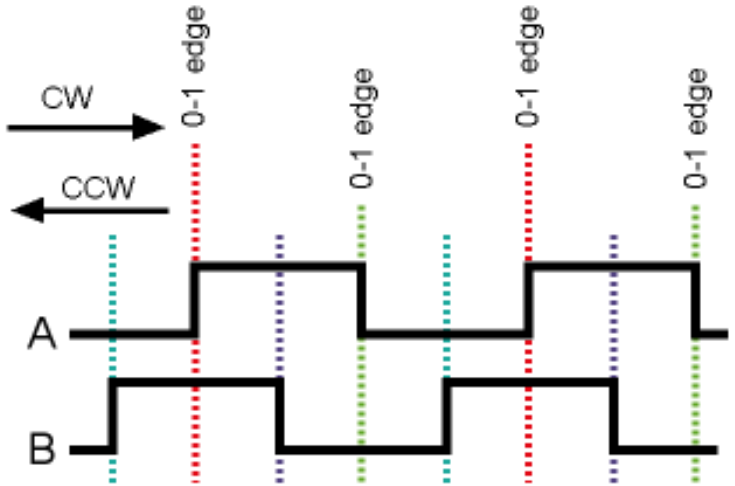
Components we need

- Arduino Uno
- Motor
- Rotary encoder
- Power supply
- TIP120 transistor (for PWM control of speed) and resistor

Rotary encoder

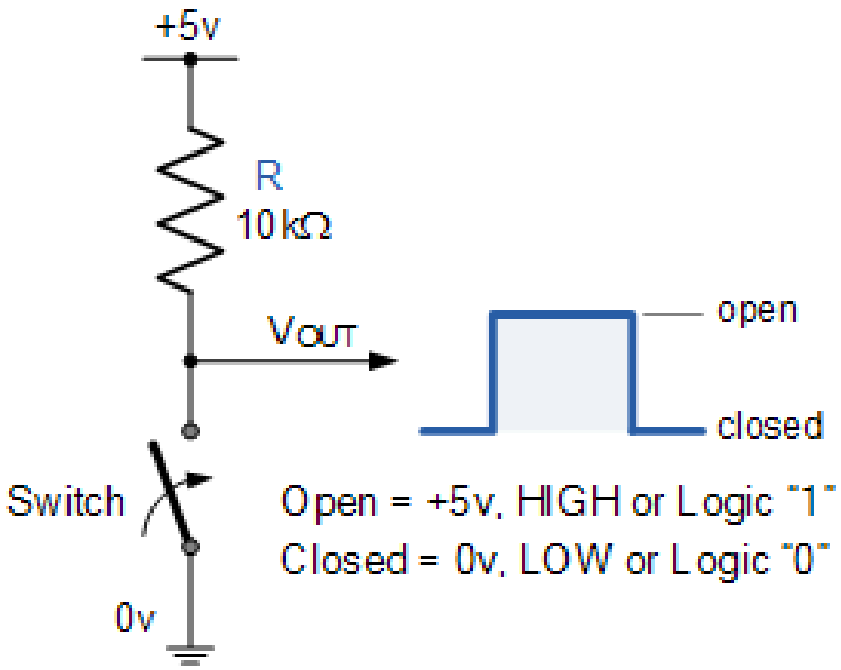




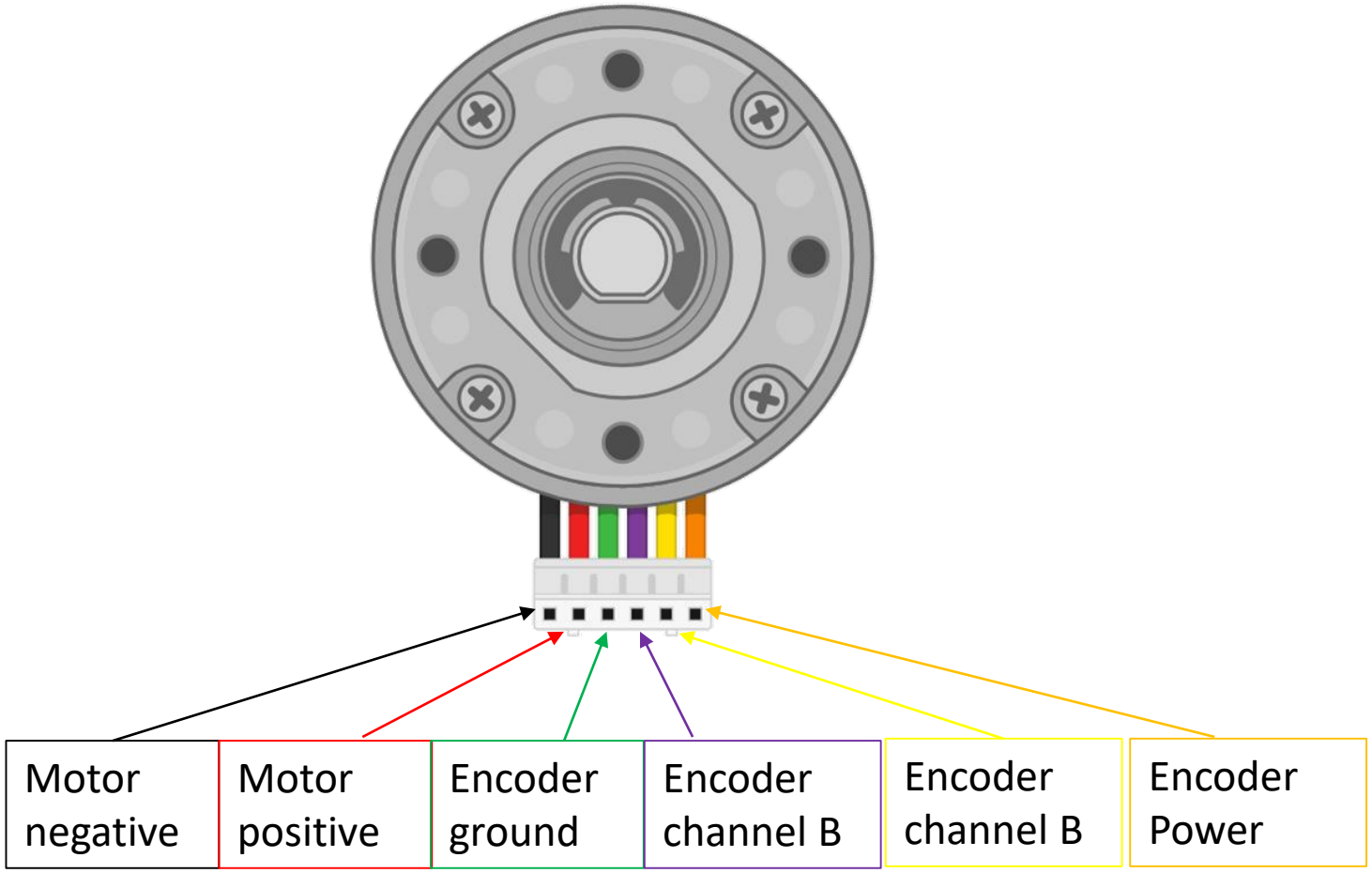


Simplest way to read the speed (not the best, but simplest)

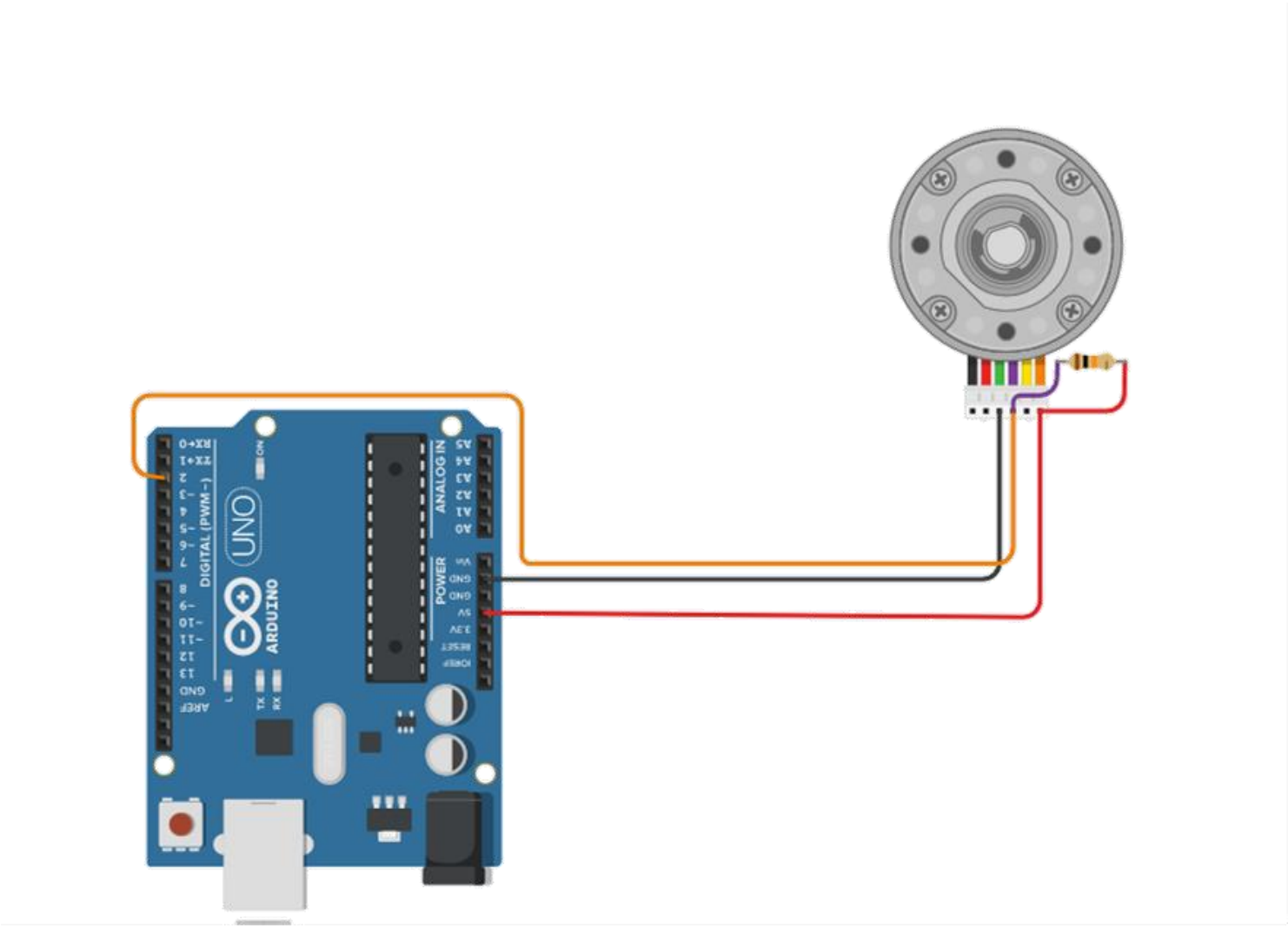
- Just use one counter output A



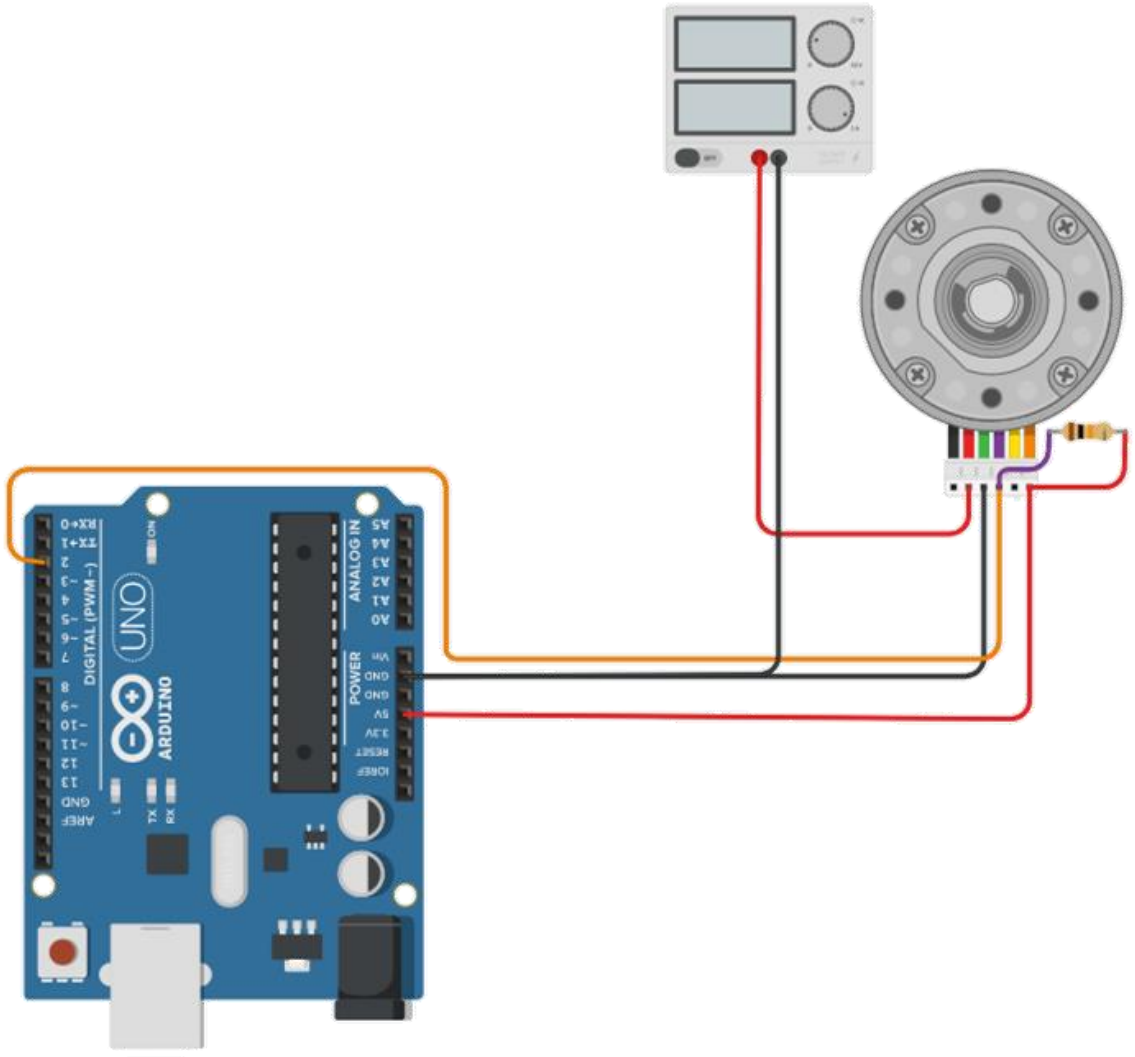
Motor with encoder



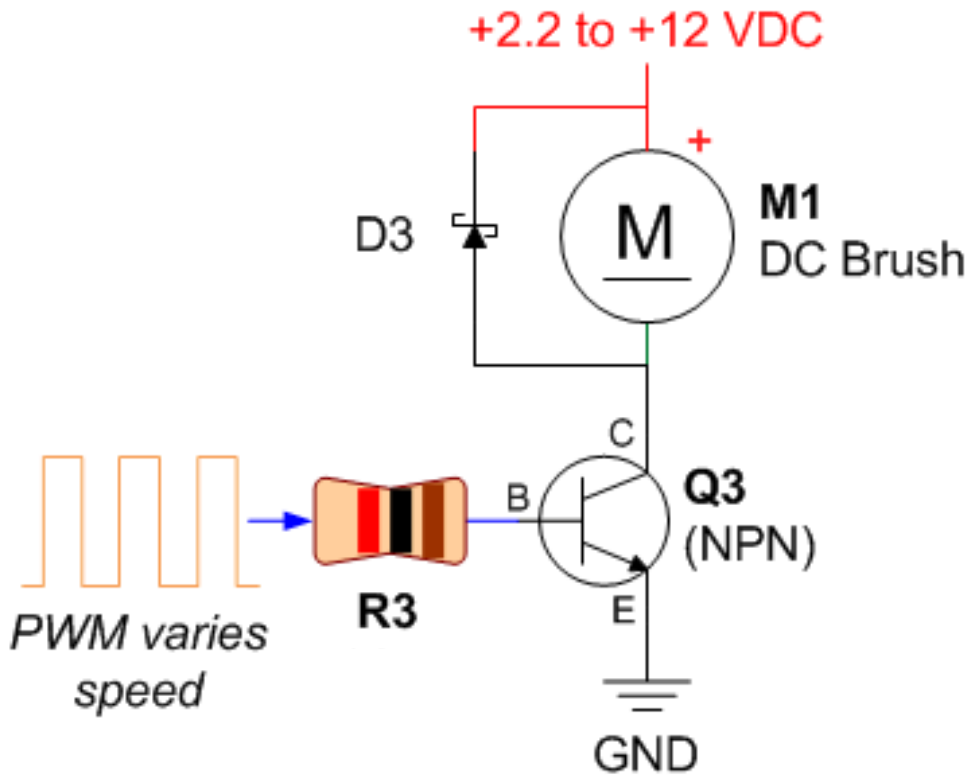
Lets start playing

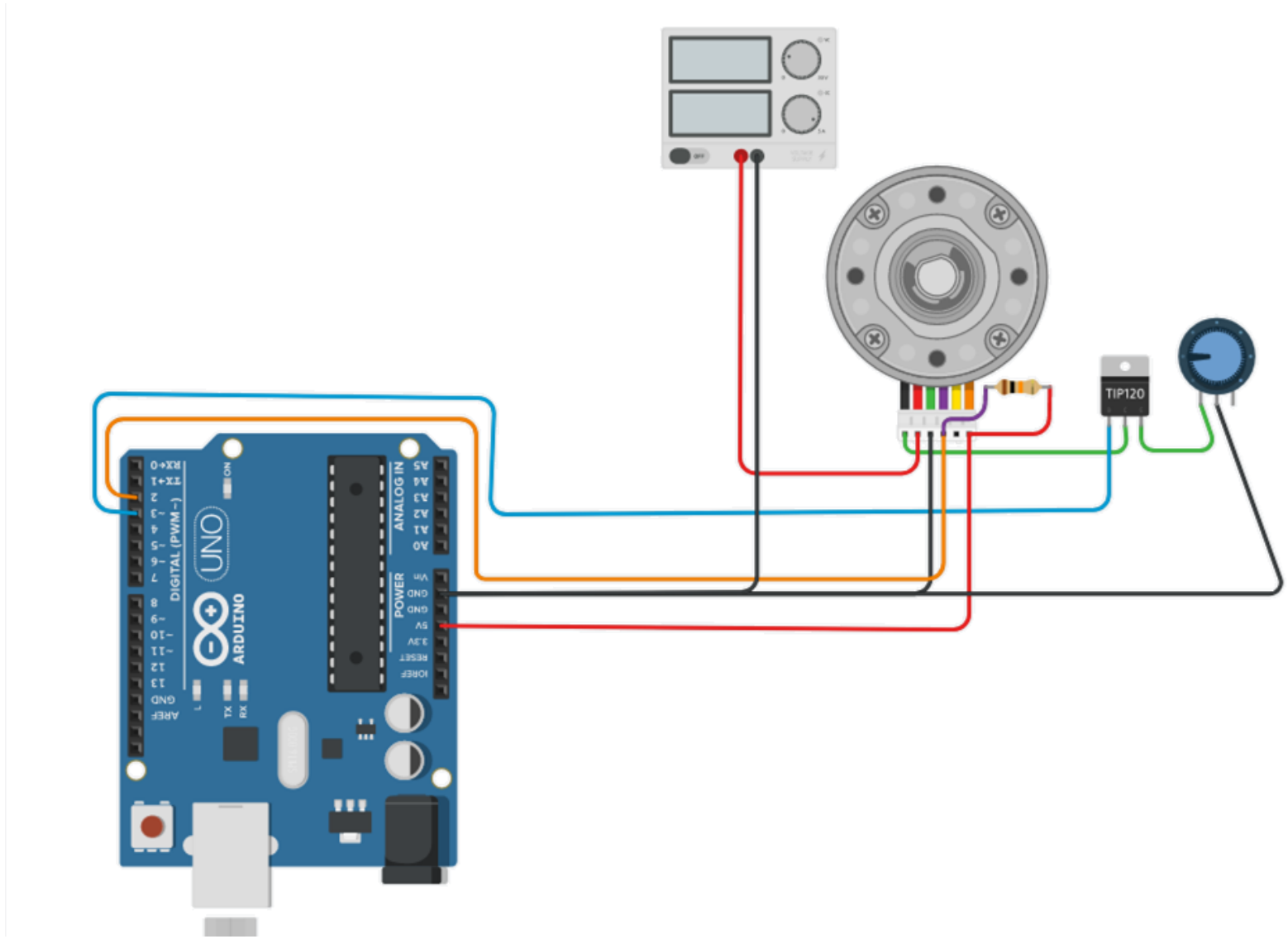


Add some power

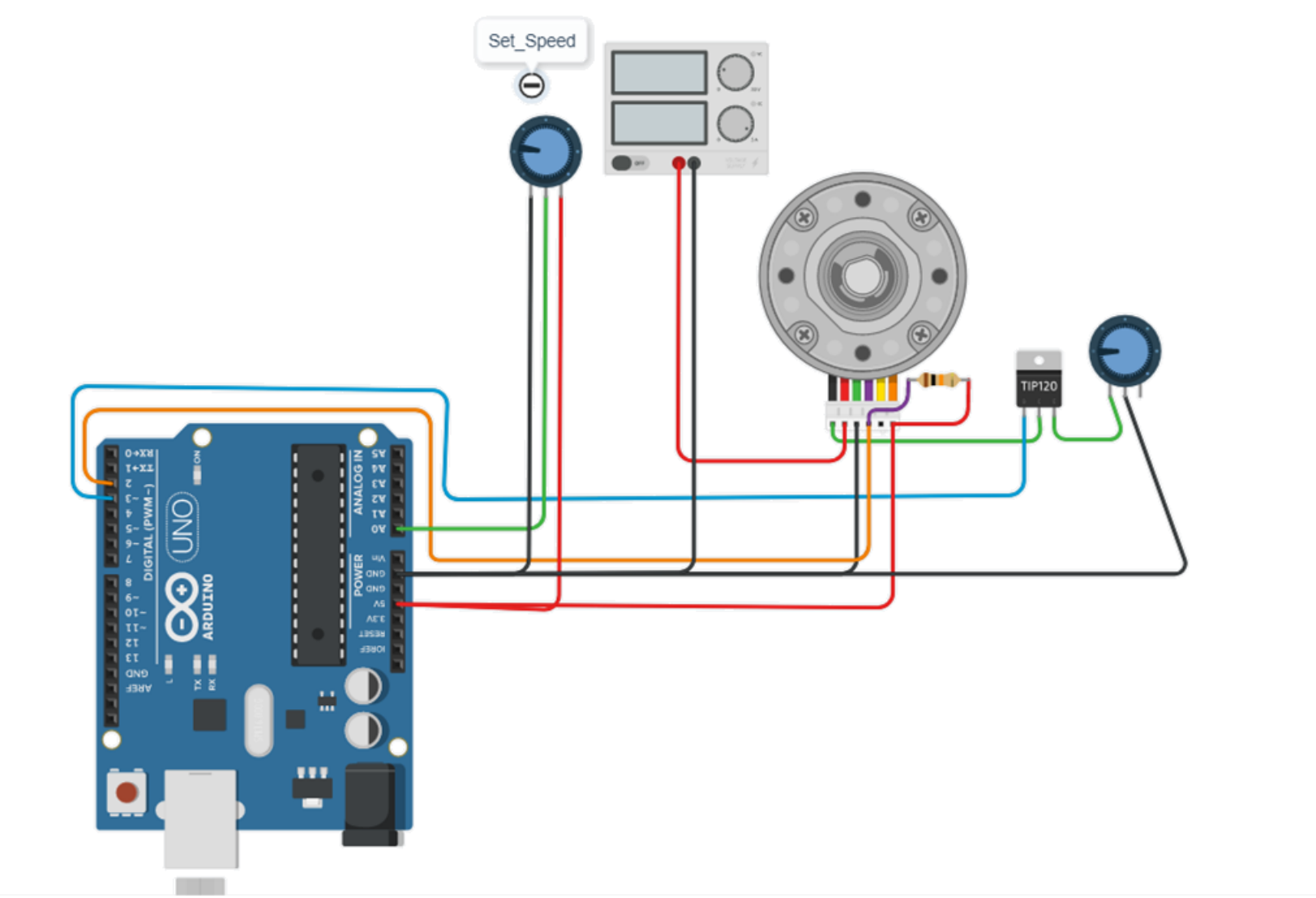


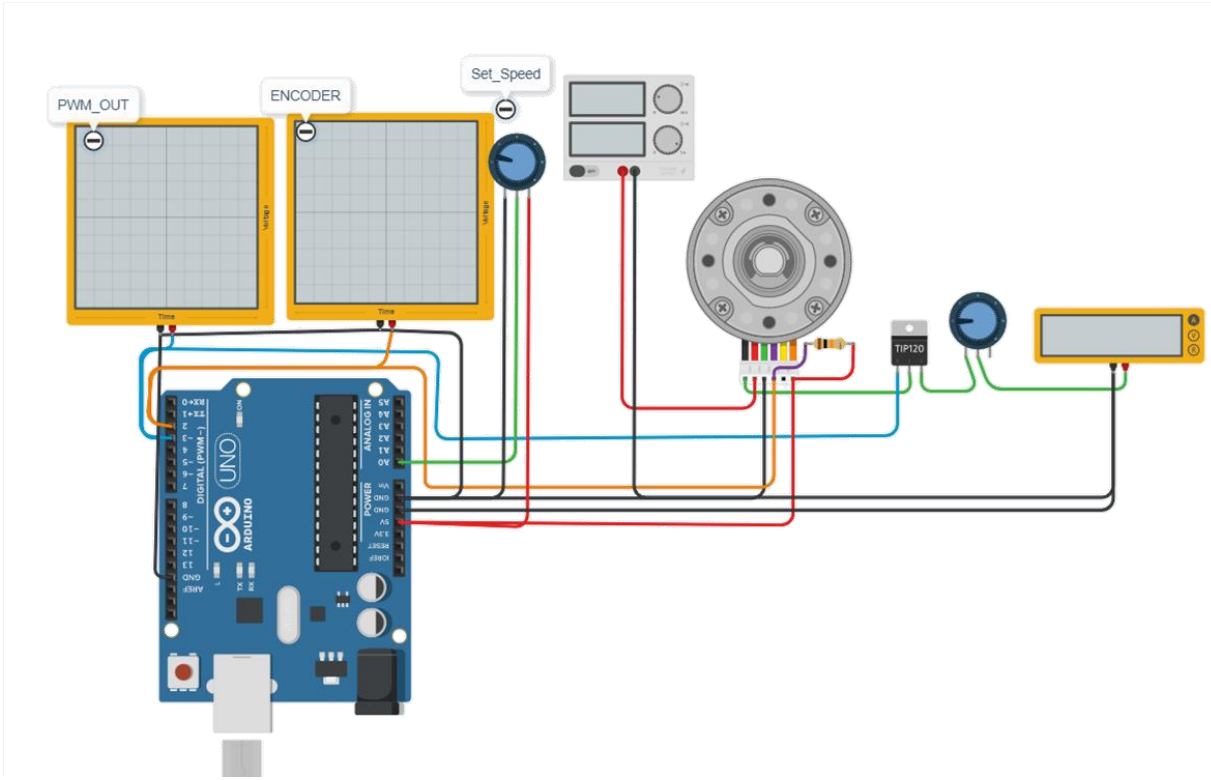
Output to the motor: PWM




TIP120
UNO
ARDUINO
DIGITAL (PWM~)
ANALOG IN
POWER

Final Assembley





https://www.tinkercad.com/things/cHusPUHIboN-dc-motor-pid-velocity-control

```
#define pwm_out       3
#define encoder_in    2
#define potentiometer A0

int PWM_value;
int rpm_set, rpm;
int past_error=0;
int error=0;
int I_error=0;
int D_error=0;
float KP=0.1; //try values: kp=0.1, ki=0.000001, kd=0,001
float KI=0.0001;
float KD=0.000;

void setup()
{
  Serial.begin(9200);

  pinMode(encoder_in,    INPUT);
  pinMode(potentiometer,INPUT);
  pinMode(pwm_out,       OUTPUT);

  PWM_value=10;
  analogWrite(pwm_out,   PWM_value);
}

void loop()
{
  rpm_set=map(analogRead(potentiometer),0,1013,10,600);

  rpm=9.55*((60*1000*10)/pulseIn(encoder_in,HIGH));

  //compute error
  past_error = error;
  error=rpm_set - rpm;
  I_error=I_error+error ;
  D_error=past_error-error;

  //pwm
  PWM_value =
    PWM_value
    +
    (KP*error)
    +
    (KI*I_error)
    +
    (KD*D_error);

  if(PWM_value>254){PWM_value=255;}else{if(PWM_value<10){PWM_value=10;}}

  analogWrite(pwm_out,   PWM_value);

  Serial.println(rpm);

  //Serial.print("error=");Serial.println(error);
  //Serial.print("D_error=");Serial.println(D_error);

}
```

Tuning the PID controller

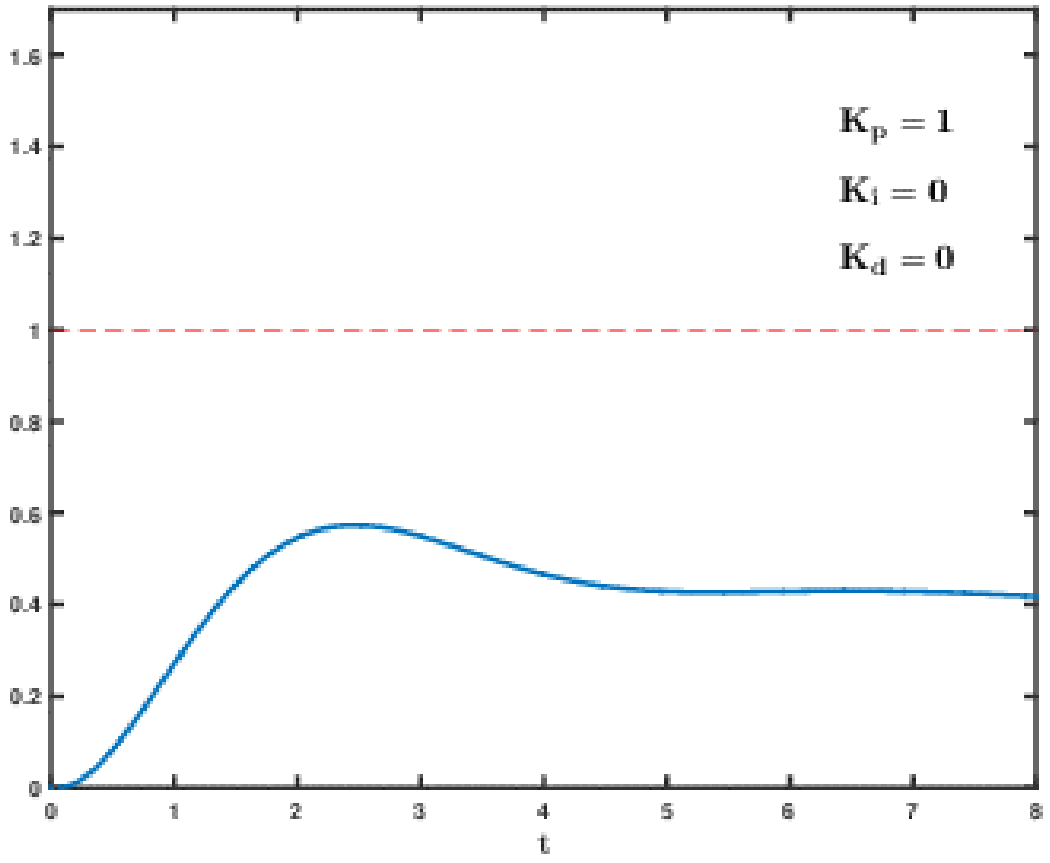
Choosing a tuning method

Method	Advantages	Disadvantages
Manual tuning	No math required; online.	Requires experienced personnel.[citation needed]
Ziegler–Nichols [b]	Proven method; online.	Process upset, some trial-and-error, very aggressive tuning.[citation needed]
Tyreus Luyben	Proven method; online.	Process upset, some trial-and-error, very aggressive tuning.[citation needed]
Software tools	Consistent tuning; online or offline - can employ computer-automated control system design (*CAutoD*) techniques; may include valve and sensor analysis; allows simulation before downloading; can support non-steady-state (NSS) tuning.	Some cost or training involved.[20]
Cohen–Coon	Good process models.	Some math; offline; only good for first-order processes.[citation needed]
Åström-Hägglund	Can be used for auto tuning; amplitude is minimum so this method has lowest process upset	The process itself is inherently oscillatory.[citation needed]

Manual tuning

- Set Ki=0 and Kd=0
- ↑ Kp until oscillates, set to half that value
- ↑ Ki until any offset is corrected in sufficient time (too much will cause instability)
- ↑ Kd until acceptably quick to reach the reference (too much will cause excessive response and overshoot)

Tuning the PID controller



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