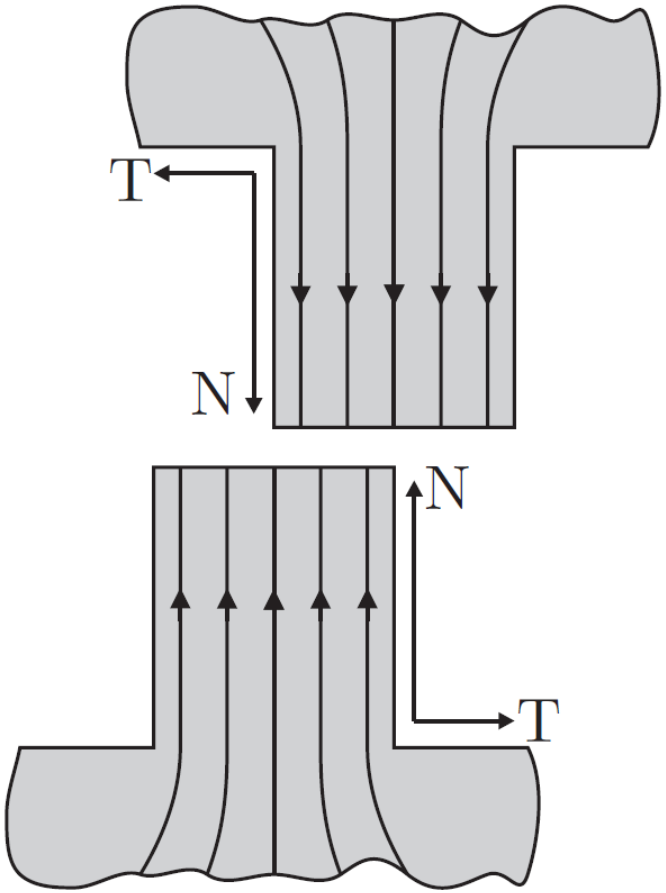
Mechatronic Actuators

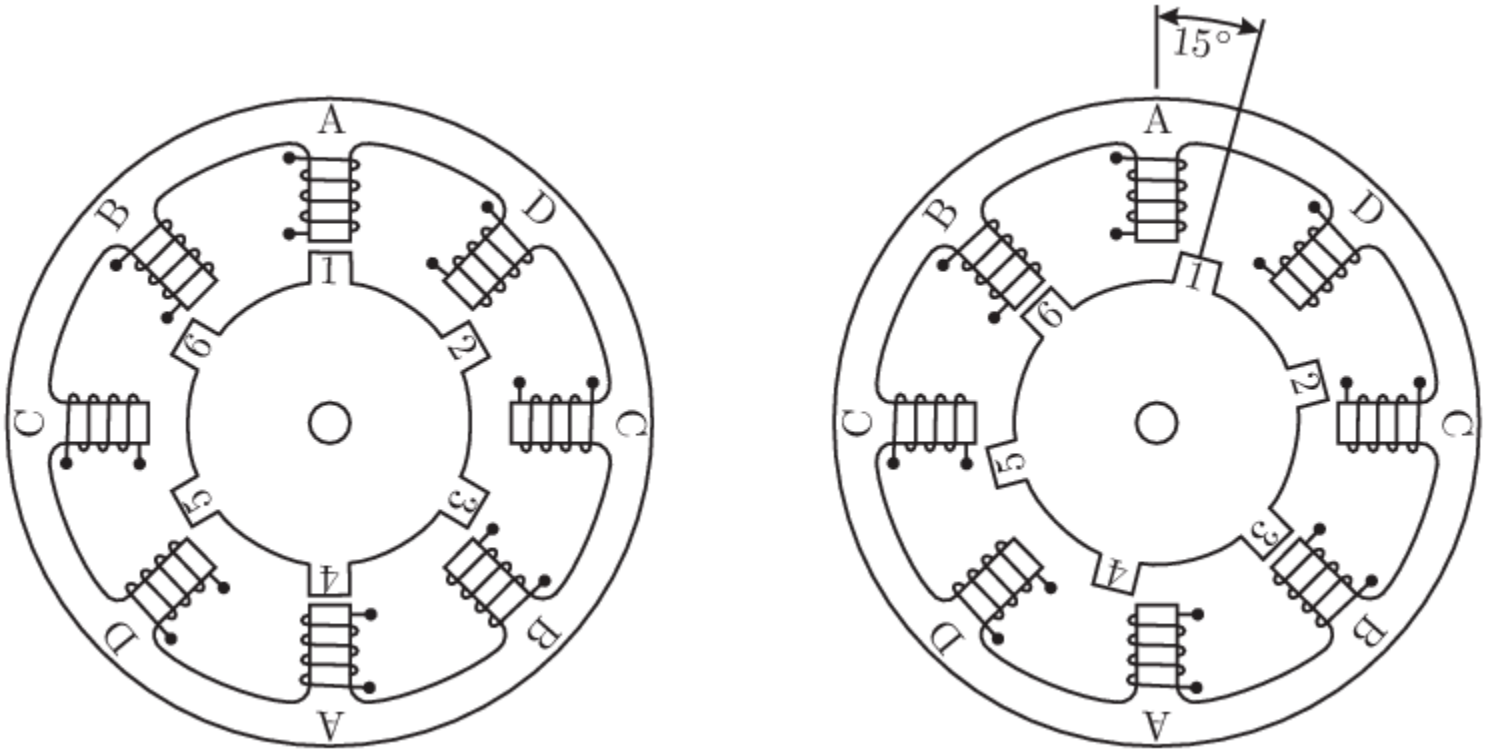
Lecture 6

Stepper motors

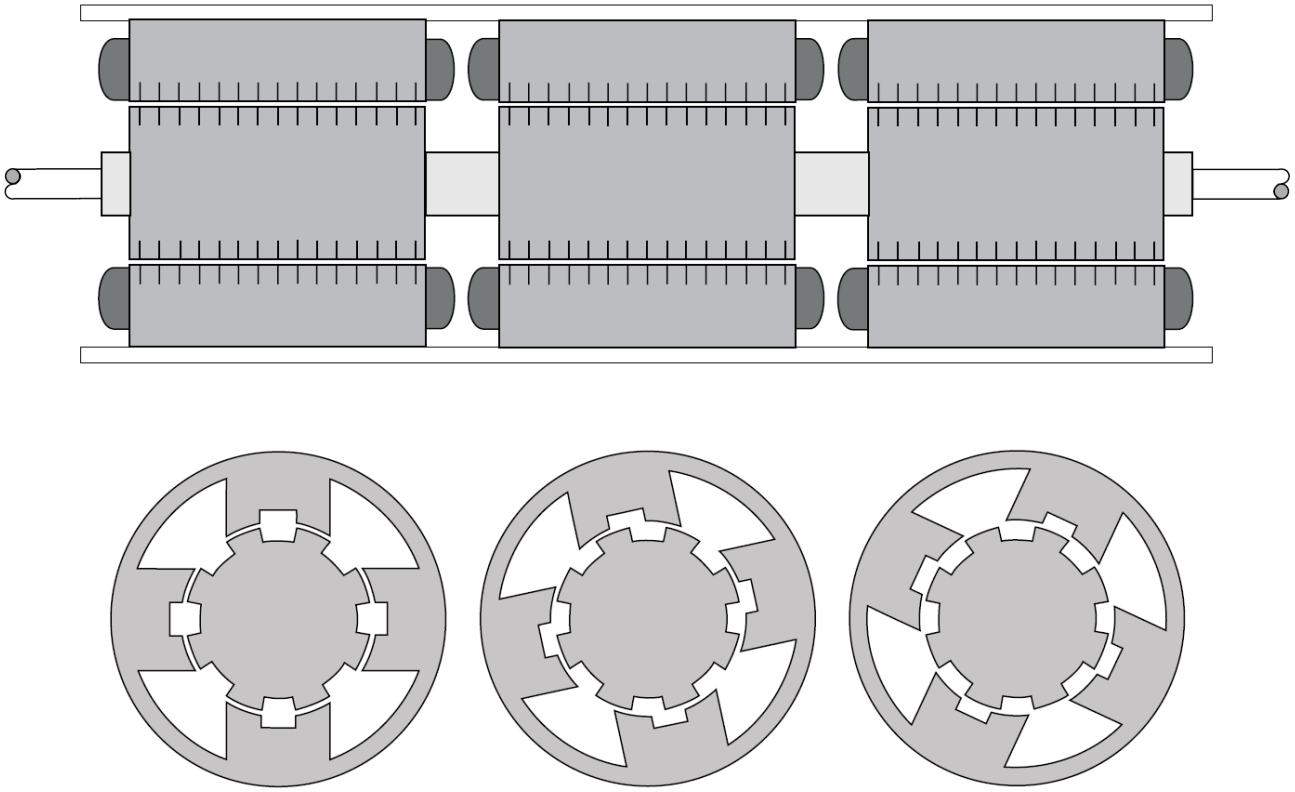
Physical basis



Stepper motor with variable reluctance (VR)



Multi-section stepper motor with variable reluctance(VR)

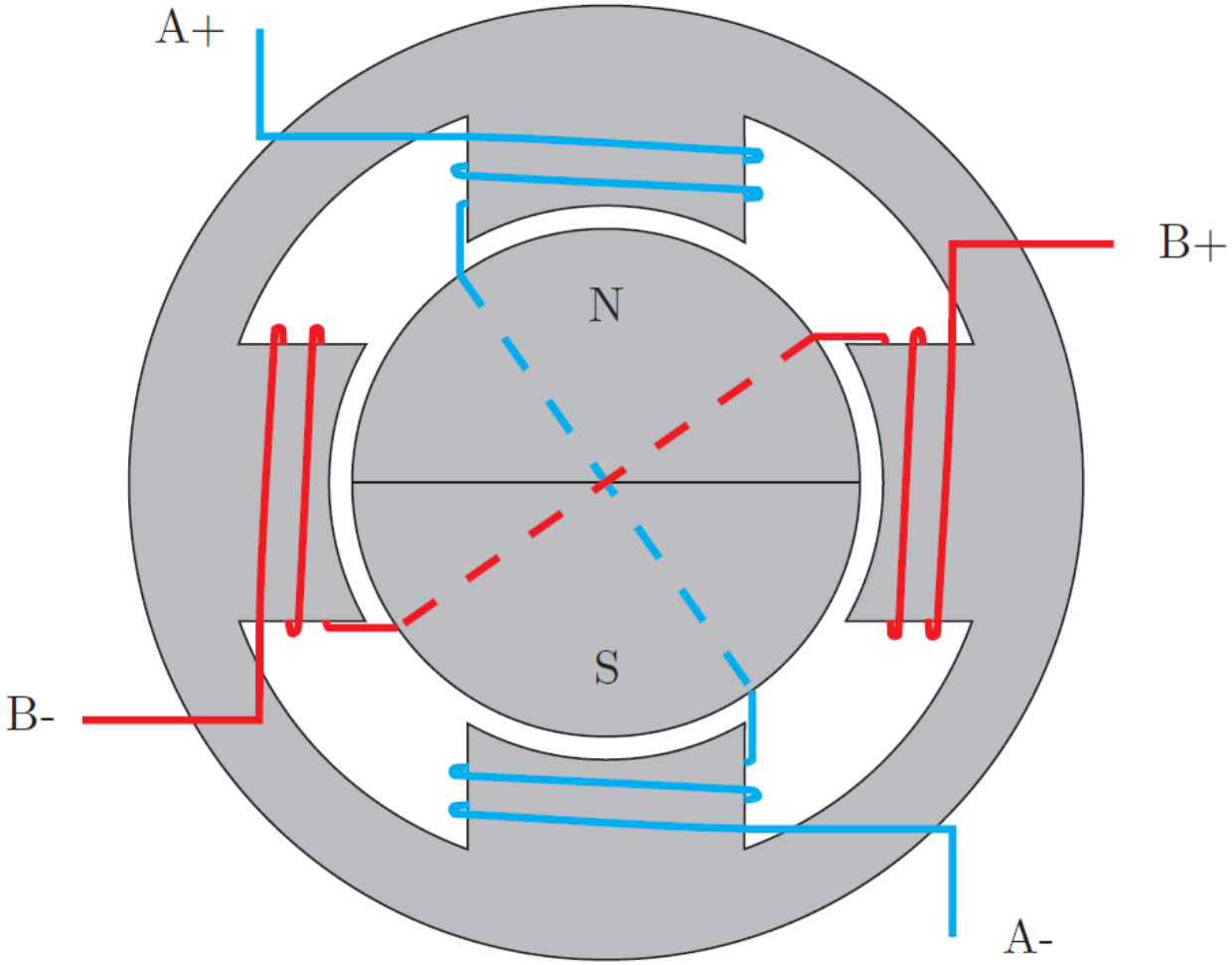


Step definition

$$\varphi_0 = \frac{360^\circ}{N \cdot p}$$

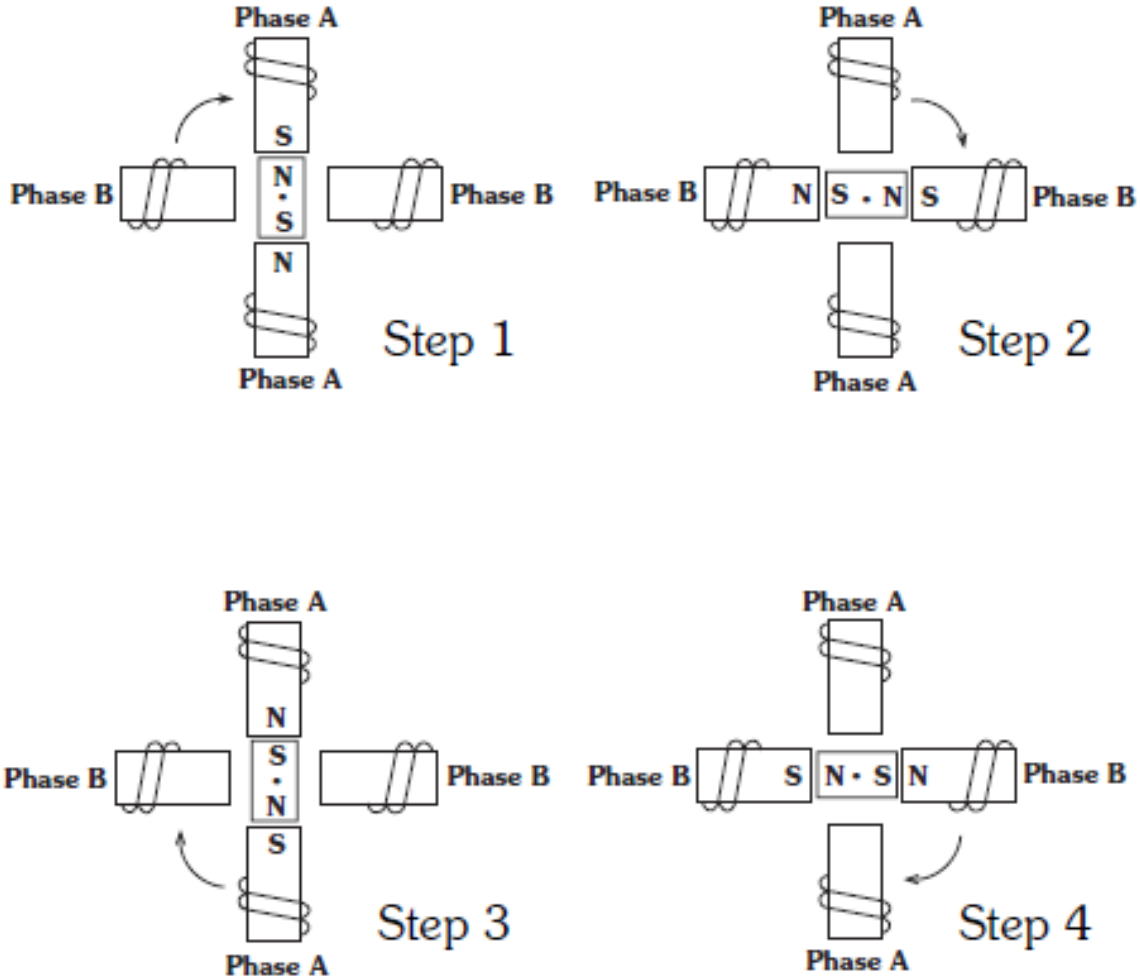
p the number of teeth on the rotor
n the number of pairs of windings, or the number of sections

Stepper motor with permanent magnet (PM)

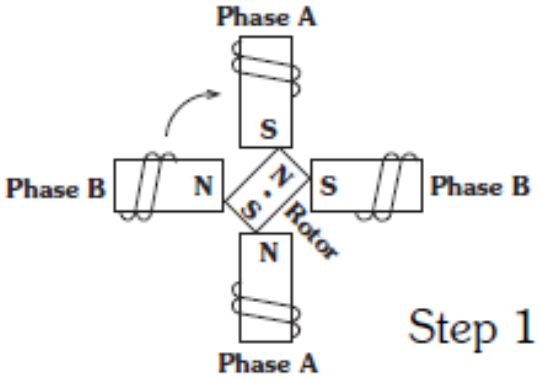


Stepper motor with permanent magnet (PM)

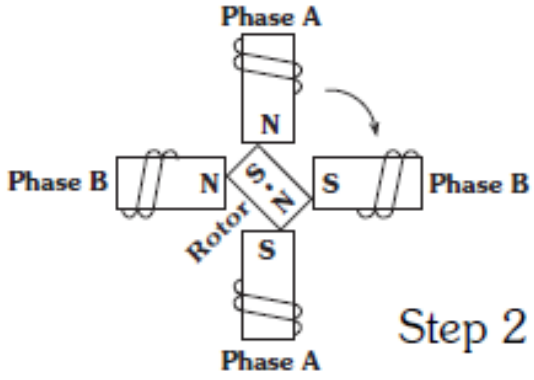
a.) Using only one phase



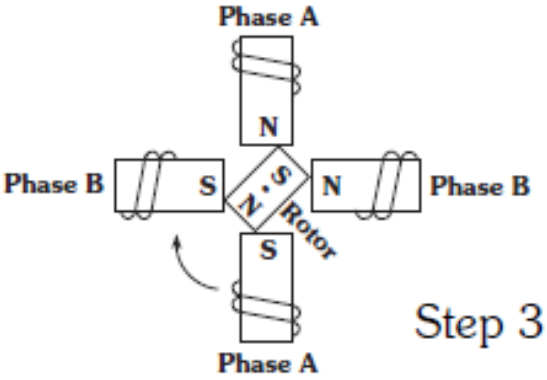
Stepper motor with permanent magnet (PM)
b.) Use of two phases



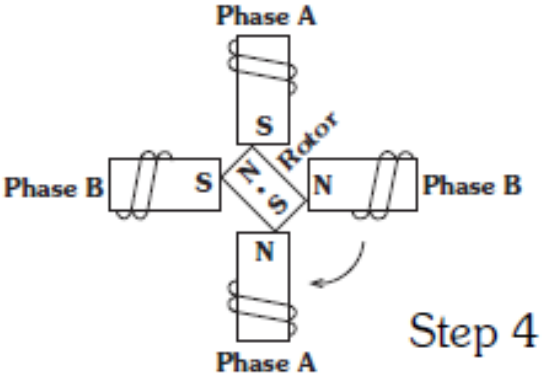
Step 1



Step 2

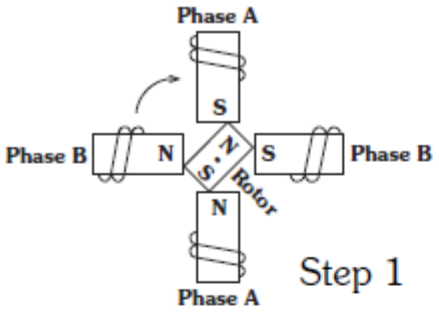


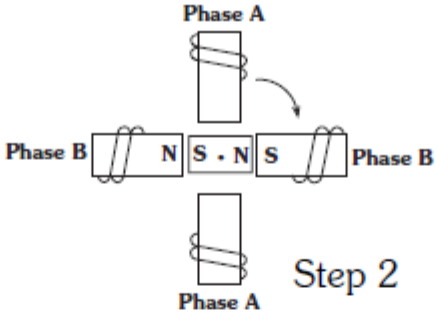
Step 3

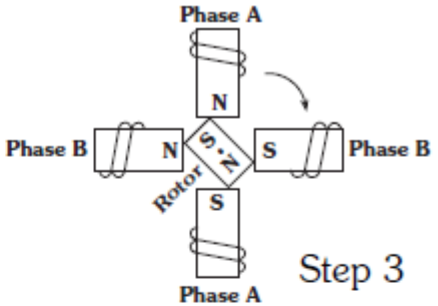


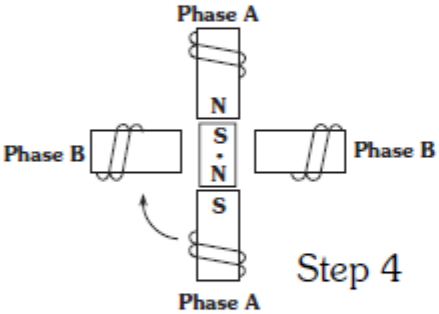
Step 4

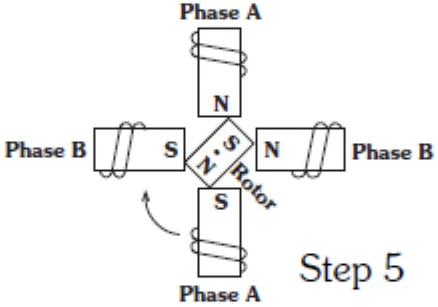
Half steps

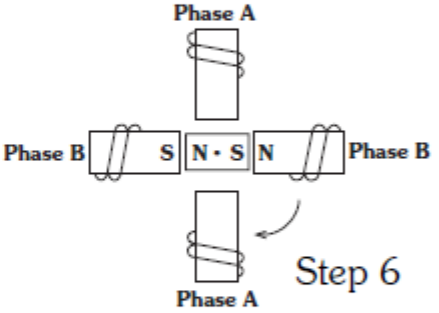

Phase A
S
Phase B
N
S · N
S
Phase B
Rotor
N
Phase A
Step 1

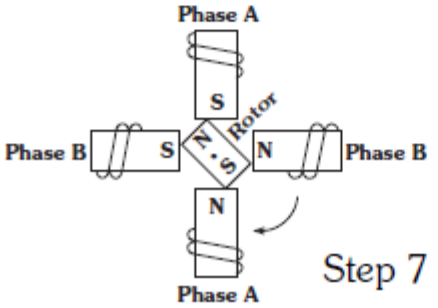

Phase A
Phase B
N
S · N
S
Phase B
Phase A
Step 2

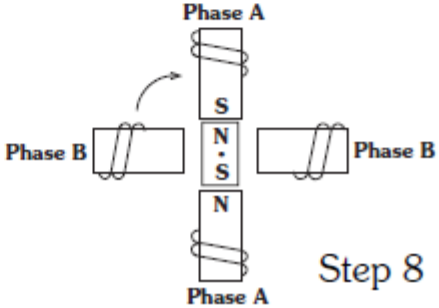

Phase A
N
Phase B
N
S · N
S
Phase B
Rotor
S
Phase A
Step 3


Phase A
N
Phase B
S
·
N
Phase B
S
Phase A
Step 4

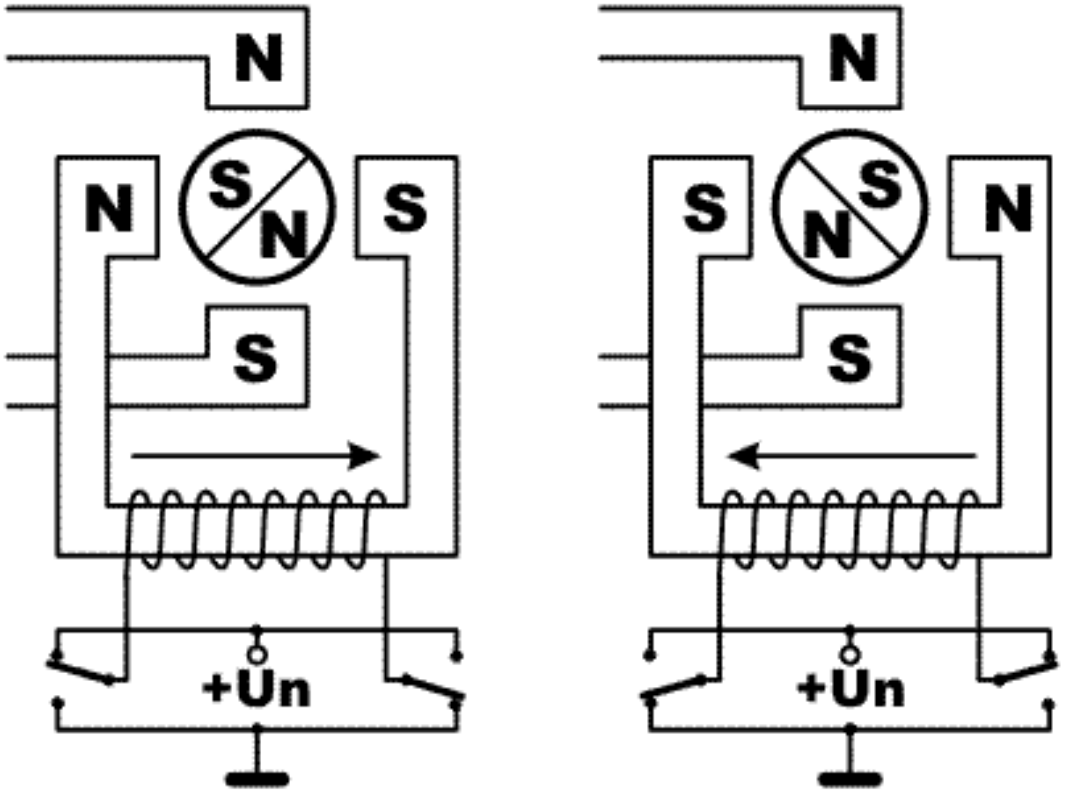

Phase A
N
Phase B
S
N · S
N
Phase B
Rotor
S
Phase A
Step 5


Phase A
Phase B
S
N · S
N
Phase B
Phase A
Step 6

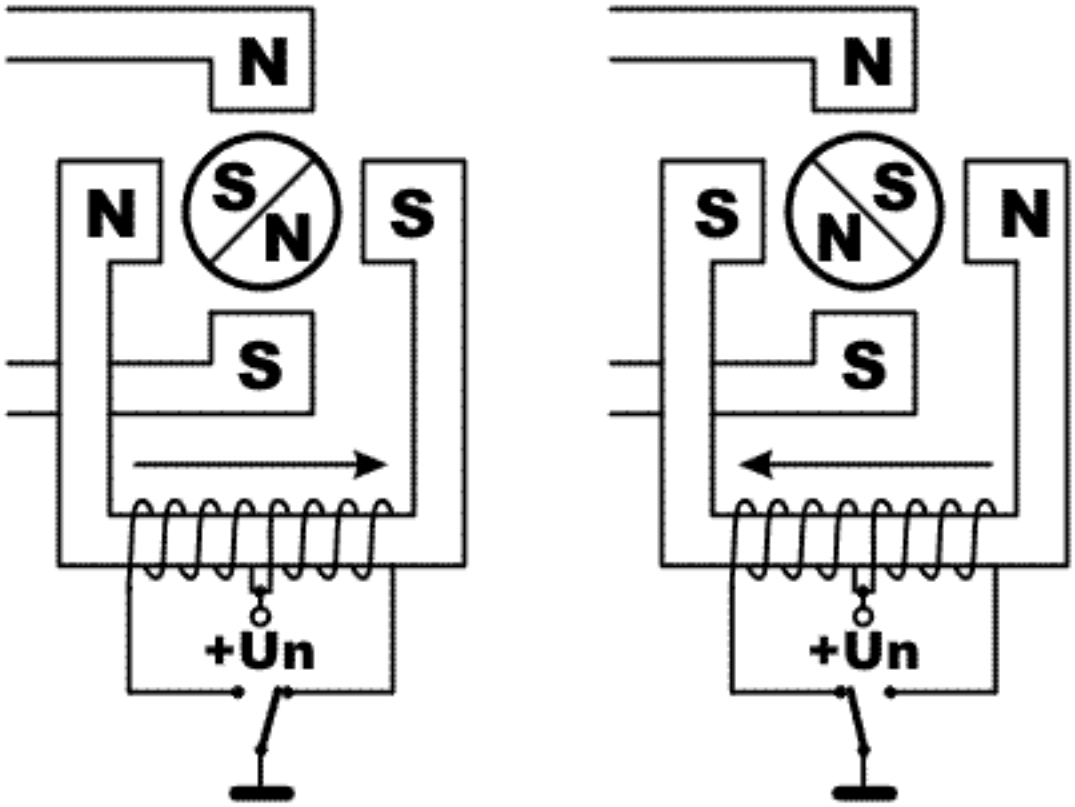

Phase A
S
Rotor
Phase B
S
N · S
N
Phase B
N
Phase A
Step 7


Phase A
S
Phase B
N
·
S
Phase B
N
Phase A
Step 8

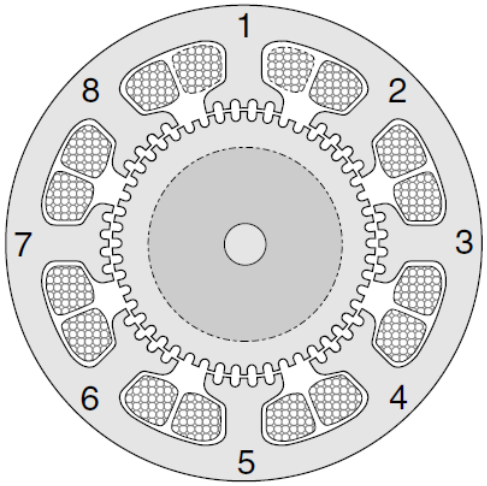
Bipolar stepper motor

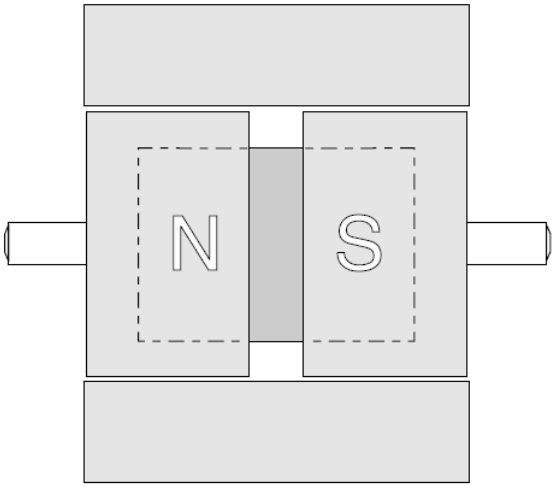


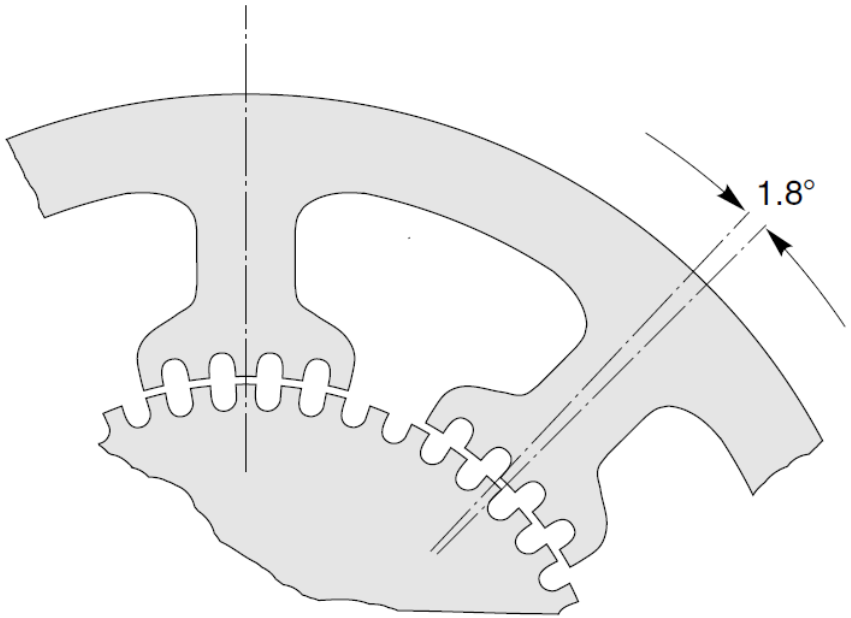
Unipolar stepper motor



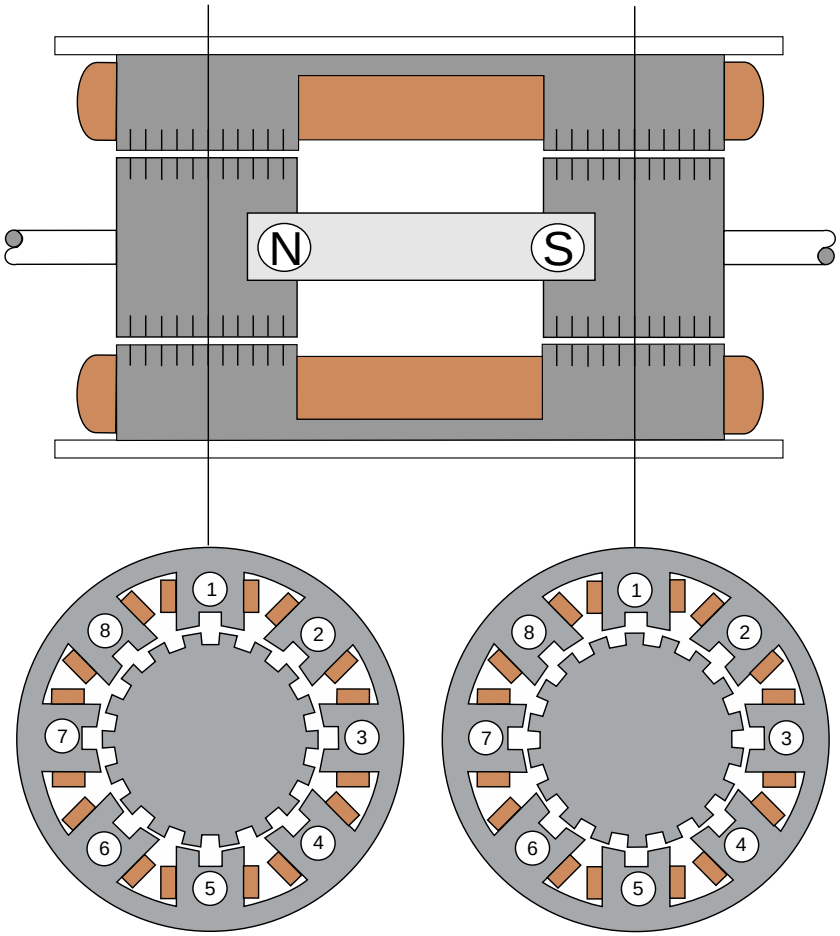
Hybrid stepper motor 1



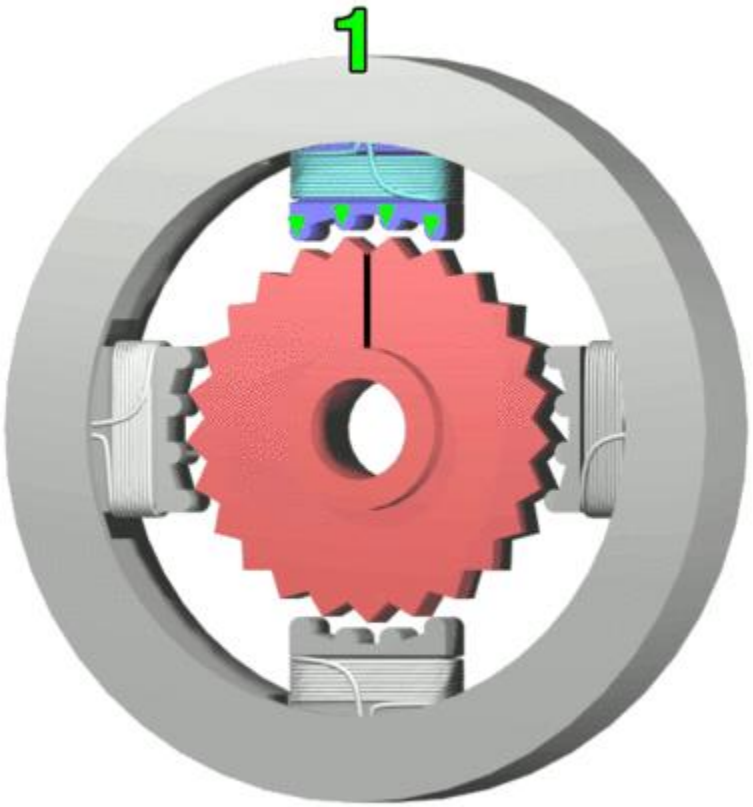




Hybrid stepper motor 2



Hybrid stepper motor

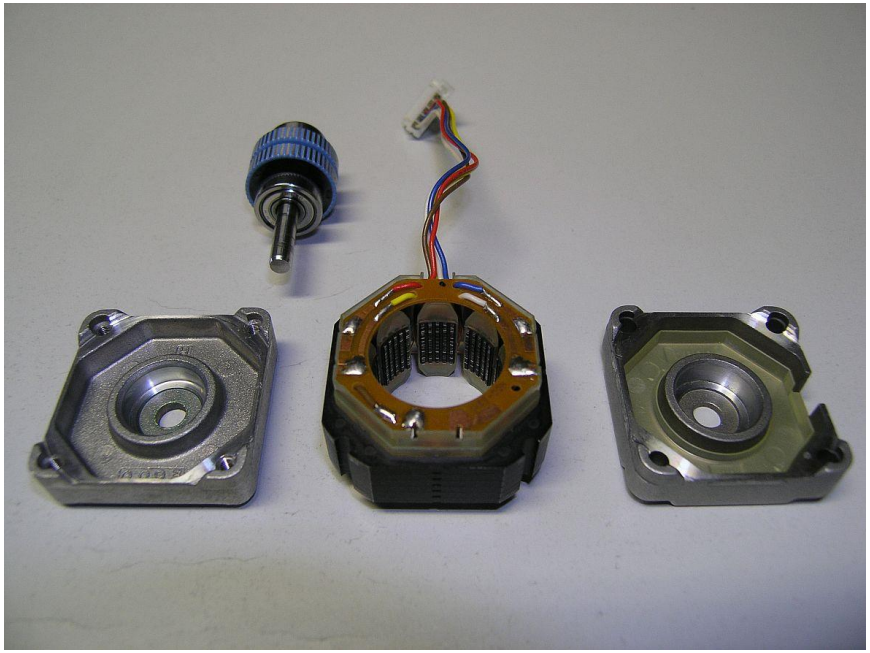


Actual composition

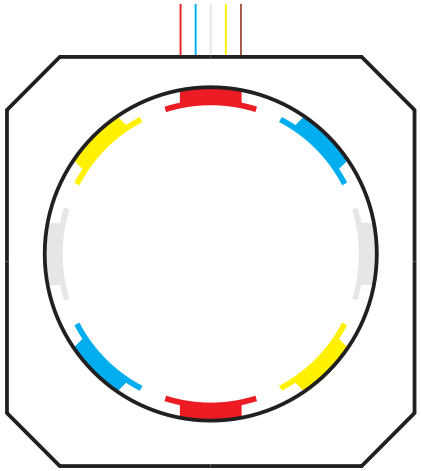
How the Stepper motors are made and how they operate - Part 1.mp4

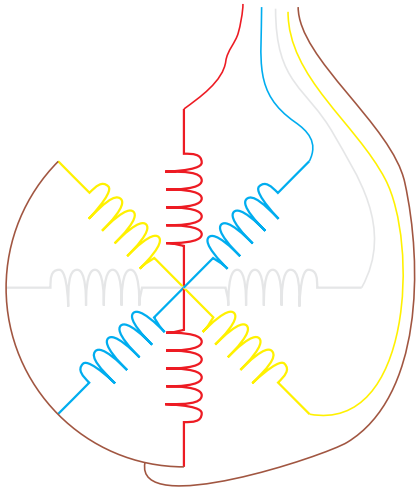
How the Stepper motors are made and how they operate - Part 2.mp4

Hybrid stepper motor

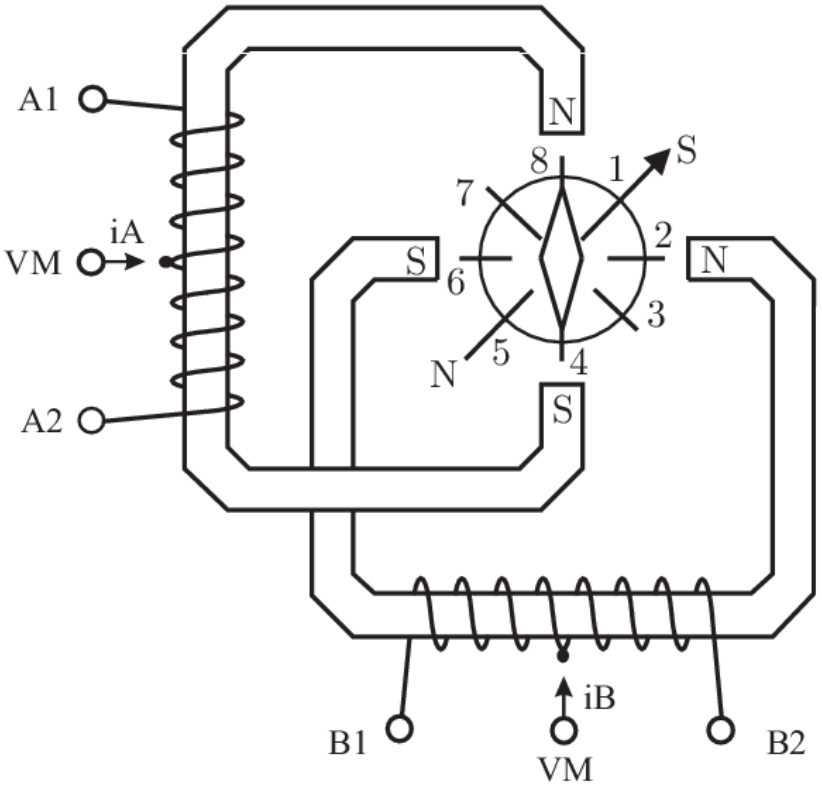


Electrical connections



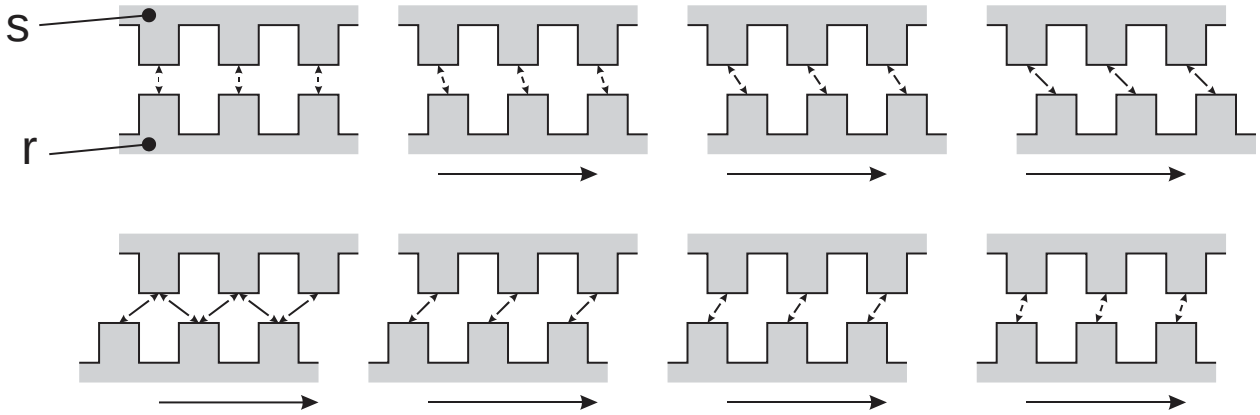


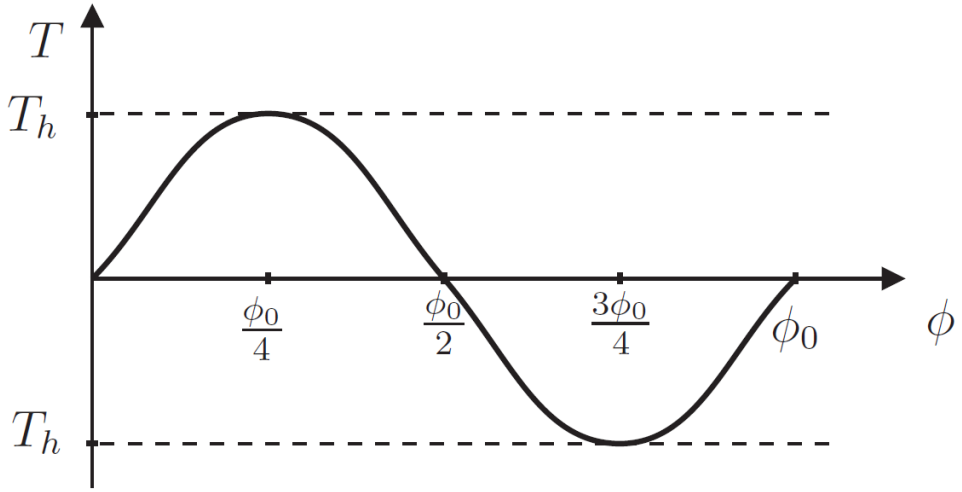
Control principle



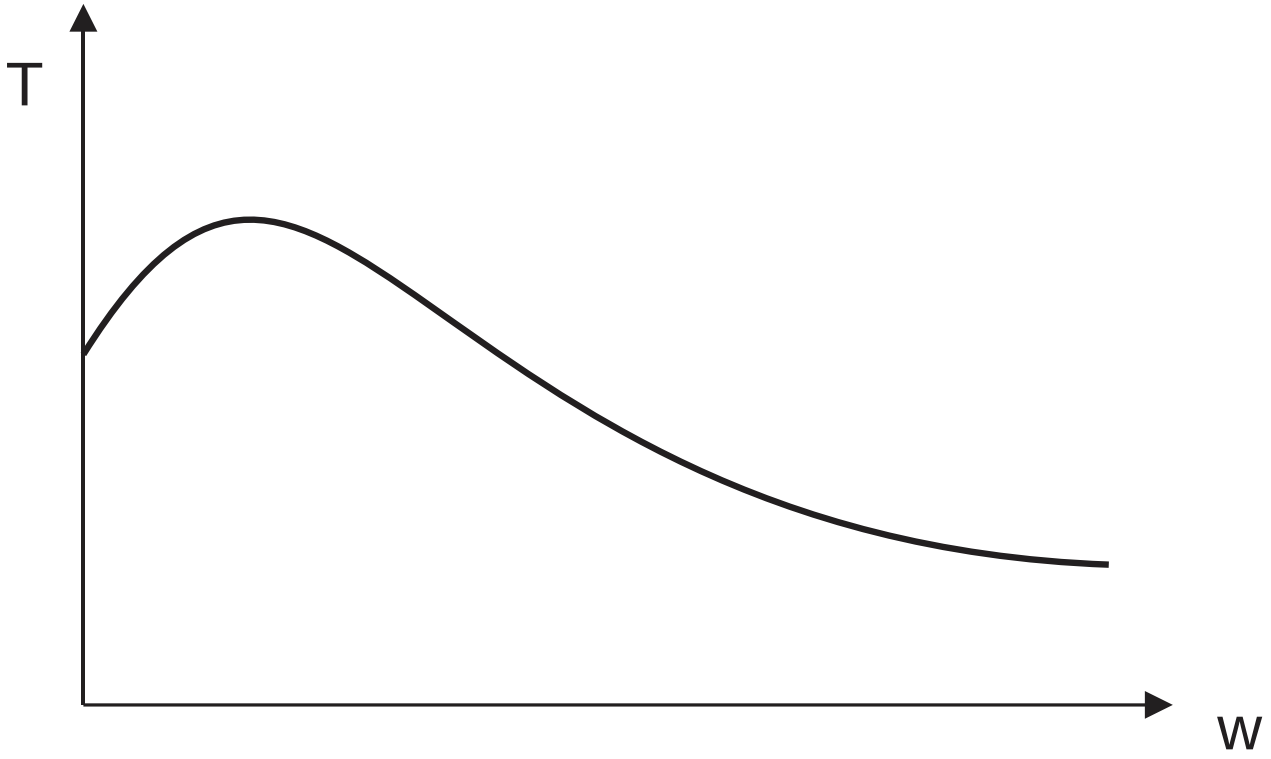
Navitje	Polni korak								Polovični korak							
	Prvi način				Drugi način											
A_1	•				•			•	•						•	•
B_1		•			•	•			•	•	•					
A_2			•			•	•				•	•	•			
B_2				•			•	•					•	•	•	

Static characteristic



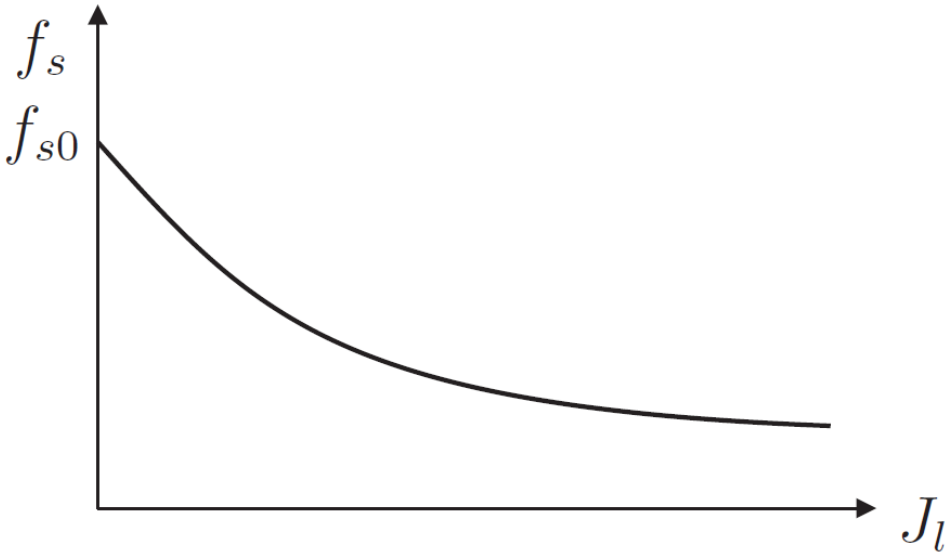


Dynamic characteristic

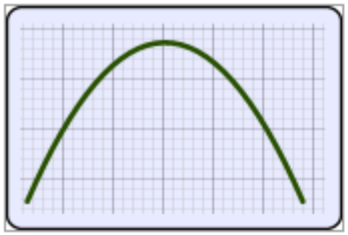


Dependence of the initial (start) frequency on the moment of inertia of the load

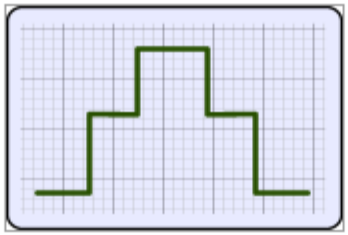
$$f_s = \frac{f_{s0}}{\sqrt{1 + \frac{J_l}{J_0}}}$$



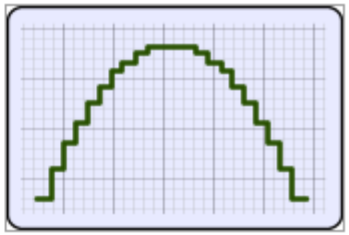
Microstepping



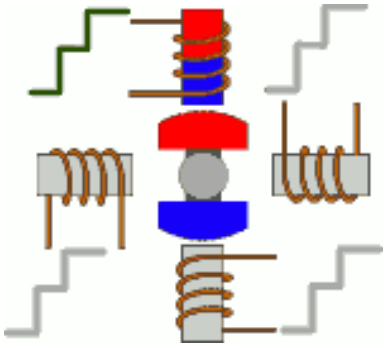
Powering with sine wave



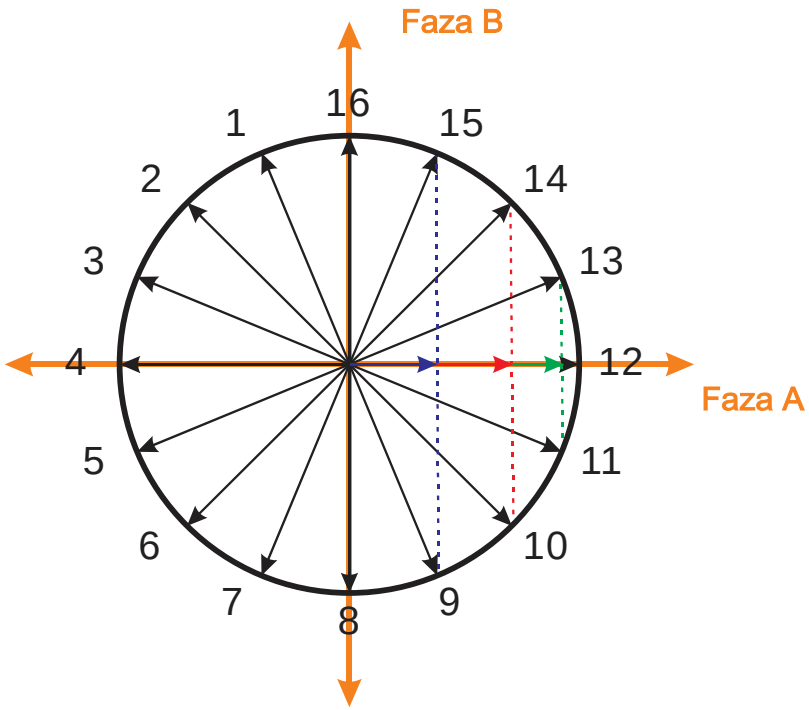
Powering with digital signal

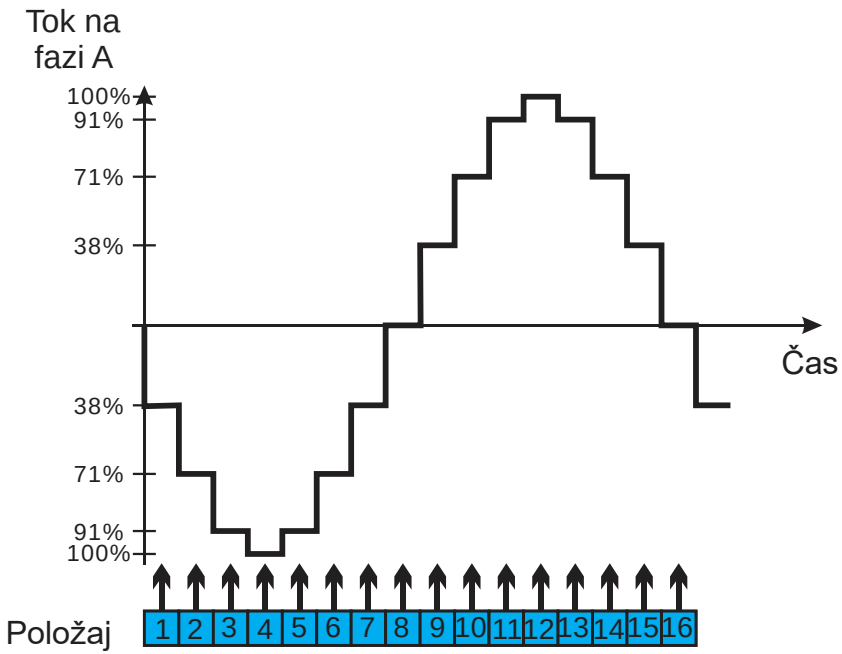


Powering with high resolution digital signal

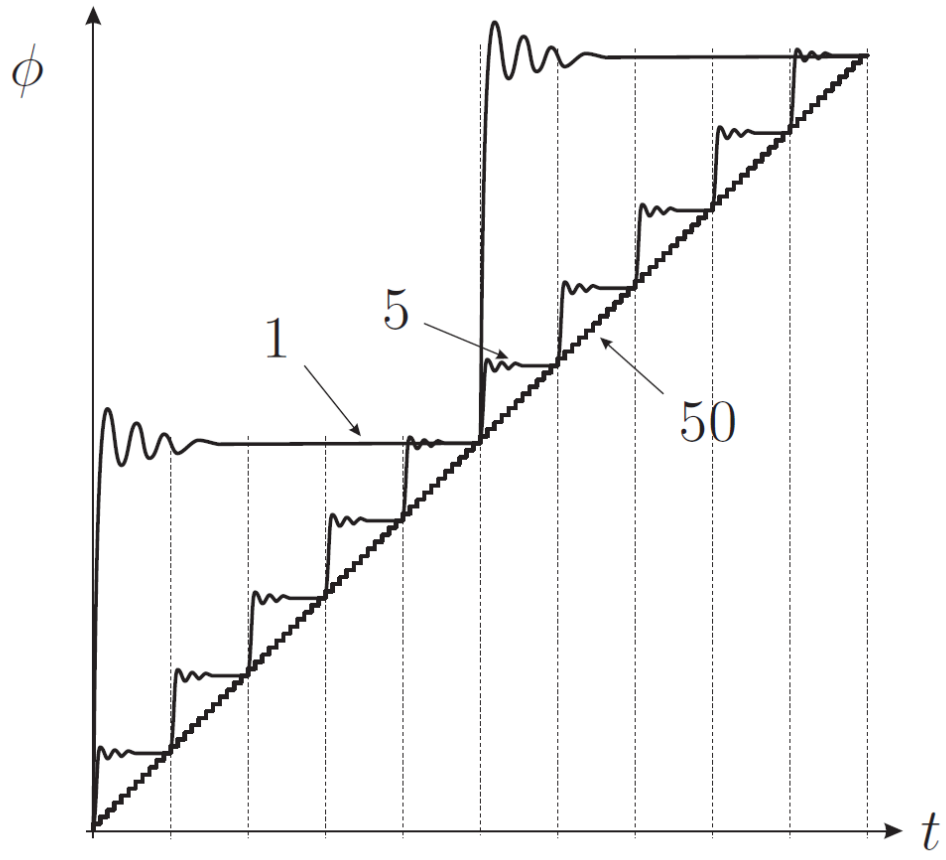


Microstepping 2

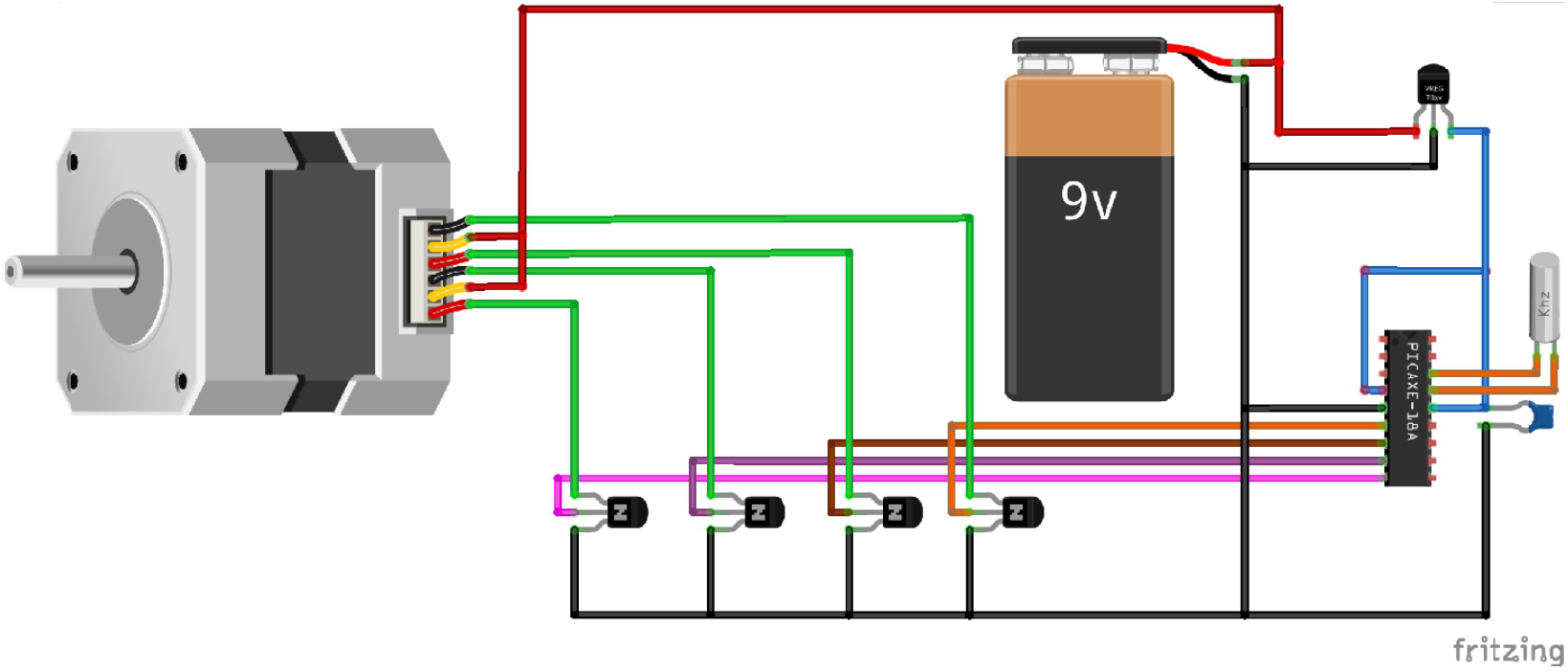




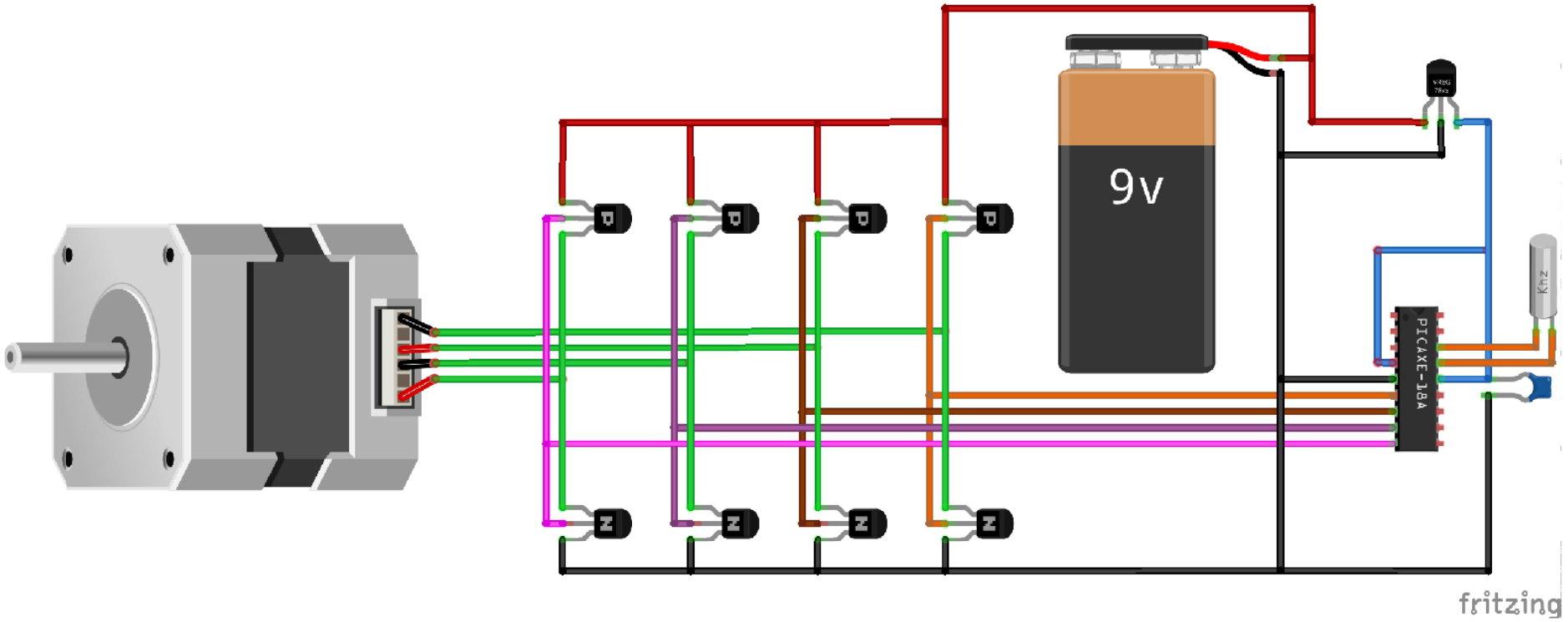
Result



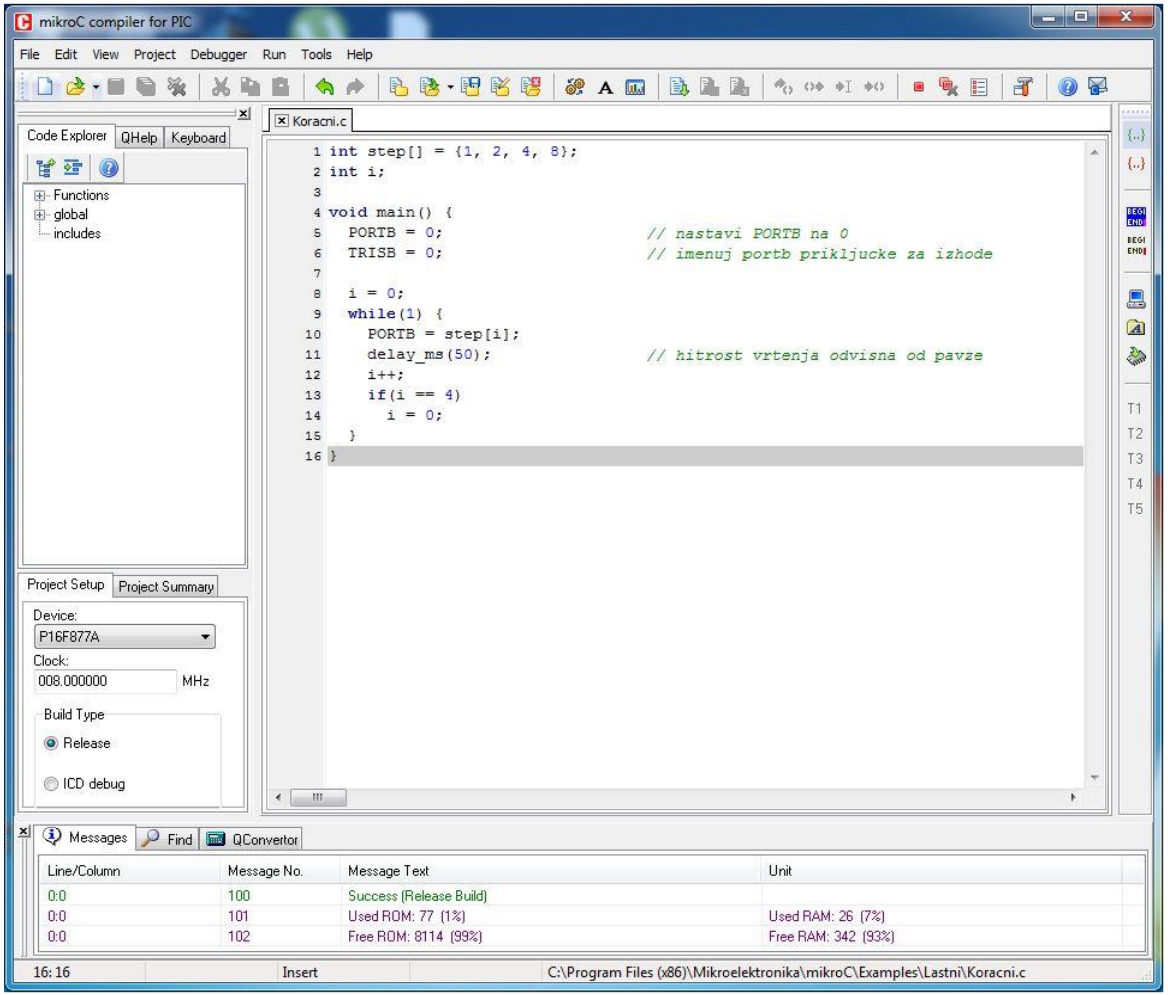
Connecting a unipolar stepper motor to a PIC microcontroller



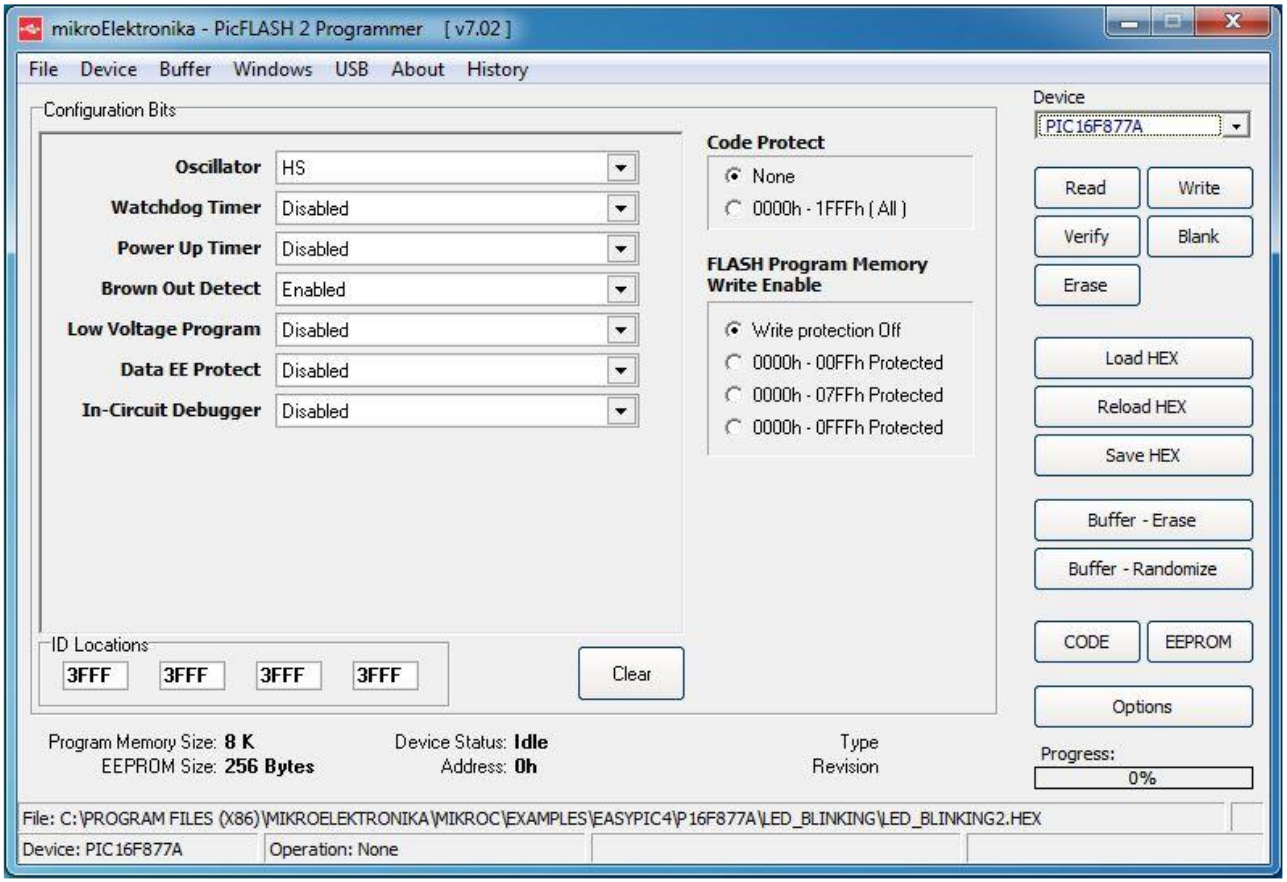
Connecting of a bipolar stepper motor to a PIC microcontroller



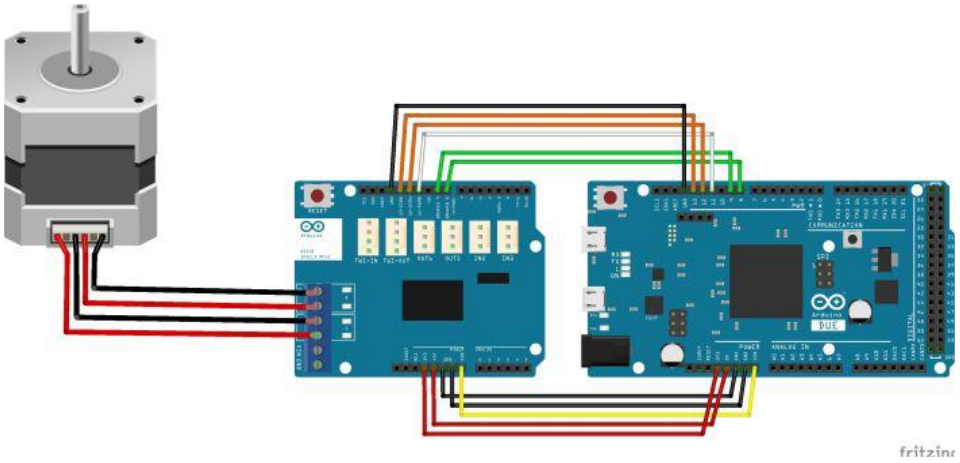
A simple program - PIC



PicFLASH program



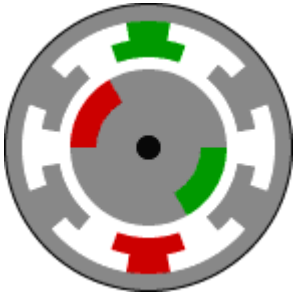
Arduino Motor Shield expansion board connection for stepper motor control



Arduino program

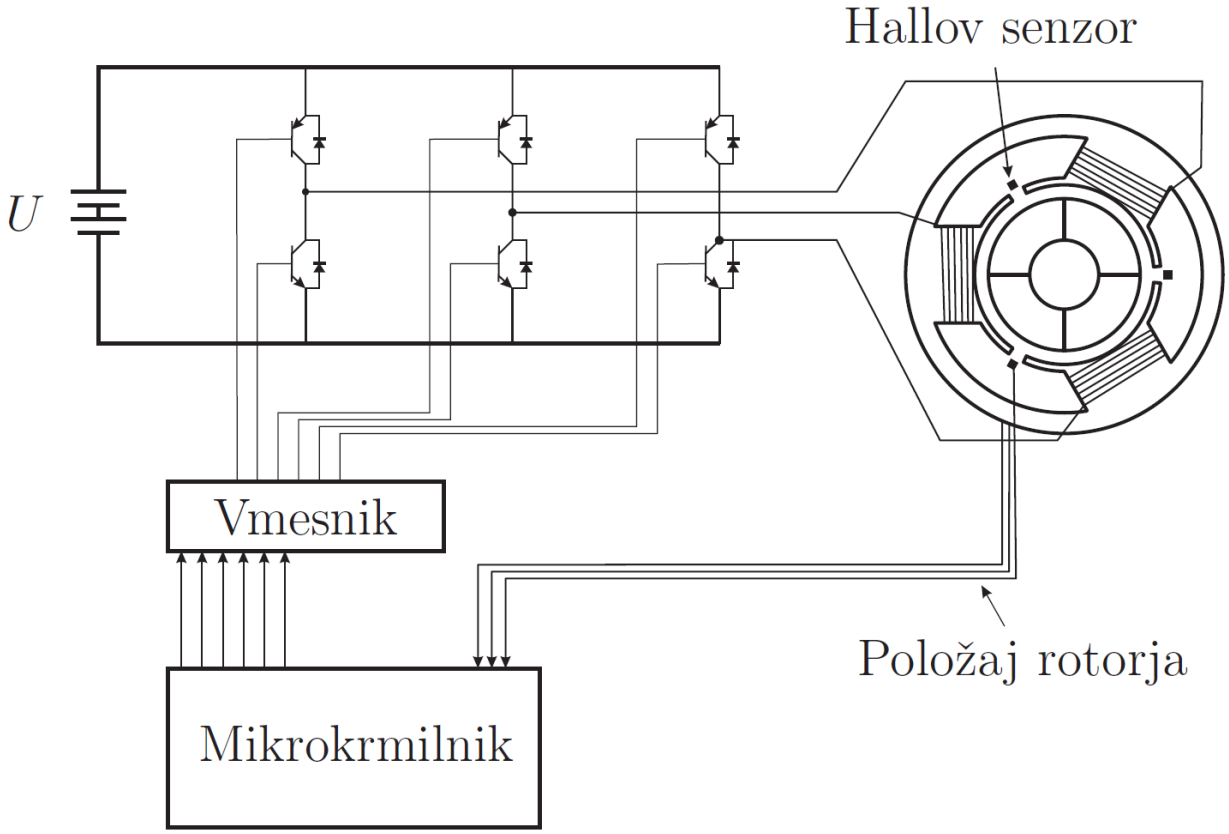
```
#include <Stepper.h>

// Define number of steps per revolution:
const int stepsPerRevolution = 200;

// Give the motor control pins names:
#define pwmA 3
#define pwmB 11
#define brakeA 9
#define brakeB 8
#define dirA 12
#define dirB 13

Stepper myStepper = Stepper(stepsPerRevolution, dirA, dirB);

void setup() {
  pinMode(pwmA, OUTPUT);
  pinMode(pwmB, OUTPUT);
  pinMode(brakeA, OUTPUT);
  pinMode(brakeB, OUTPUT);
  digitalWrite(pwmA, HIGH);
  digitalWrite(pwmB, HIGH);
  digitalWrite(brakeA, LOW);
  digitalWrite(brakeB, LOW);
  myStepper.setSpeed(60);
}

void loop() {
  // Step one revolution in one direction:
  myStepper.step(200);
  delay(2000);
  //Step on revolution in the other direction:
  myStepper.step(-200);
  delay(2000);
}
```

Brushless direct current electric motor (BLDC)



How the Brushless motors are made (BLDC).mp4

Brezkrtačni enosmerni elektromotor (Brushless DC – BLDC)



Characteristic