Διασύνδεση ρελέ και ηλεκτρικών κινητήρων στο Arduino

Magnetic field

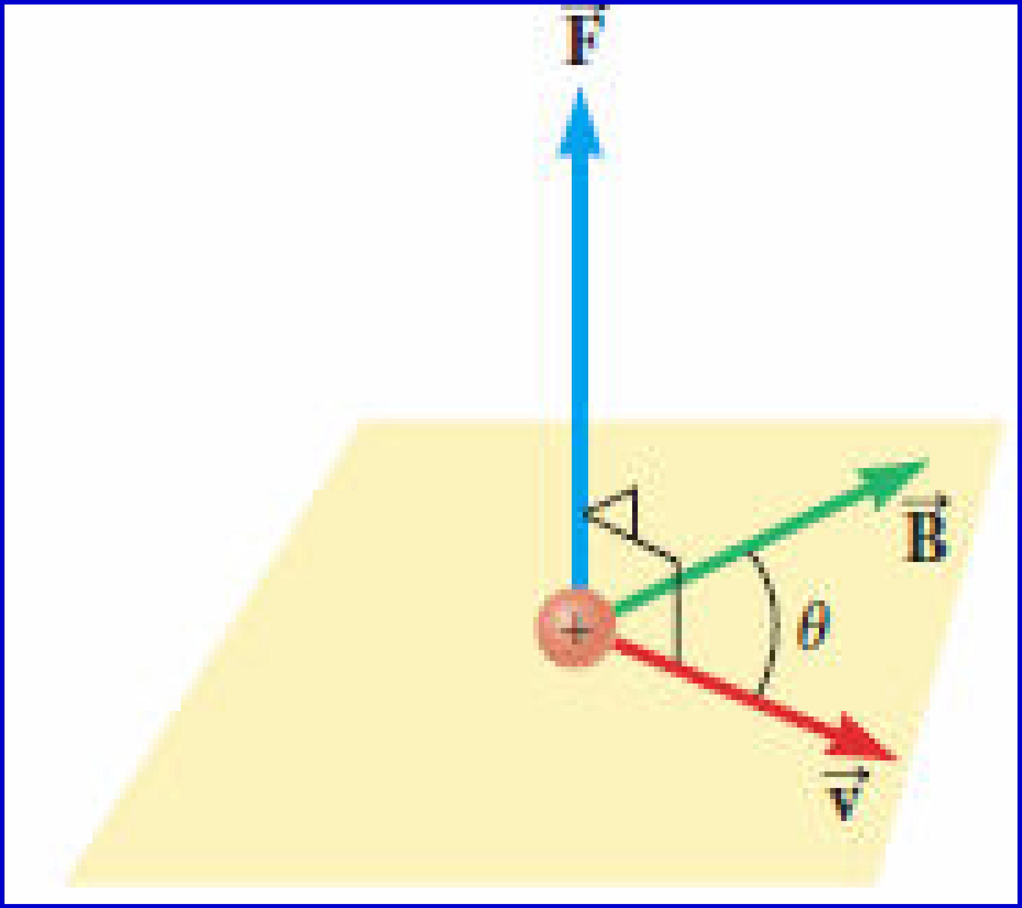
A **magnetic field** exists in a otherwise empty region of space if a charge moving to that region can experience a force due to its motion.

The strength of the magnetic force on the particle is proportional to the magnitude of the charge **q**, the magnitude of the velocity **v**, the strength of the external magnetic field **B**, and the sine of the angle θ between the direction of **v** and the direction of **B**.

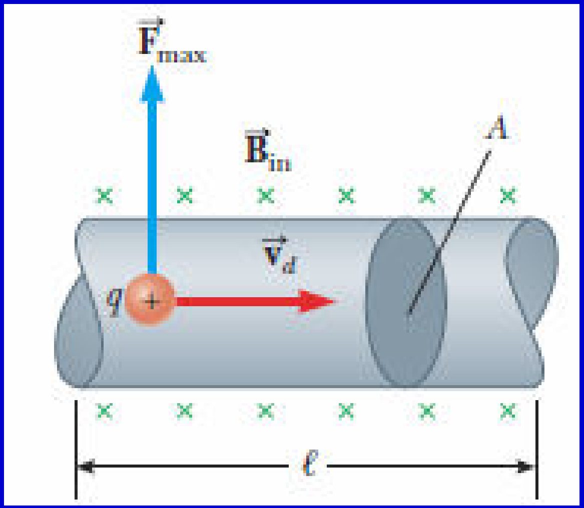
$$F = qvB\sin\theta$$

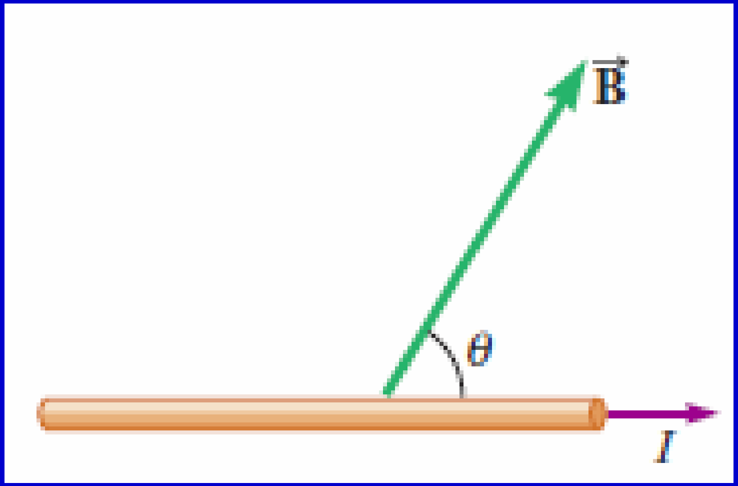
B: measured in **Tesla**

Force on a particle moved in a magnetic field



Magnetic force on a current carrying conductor



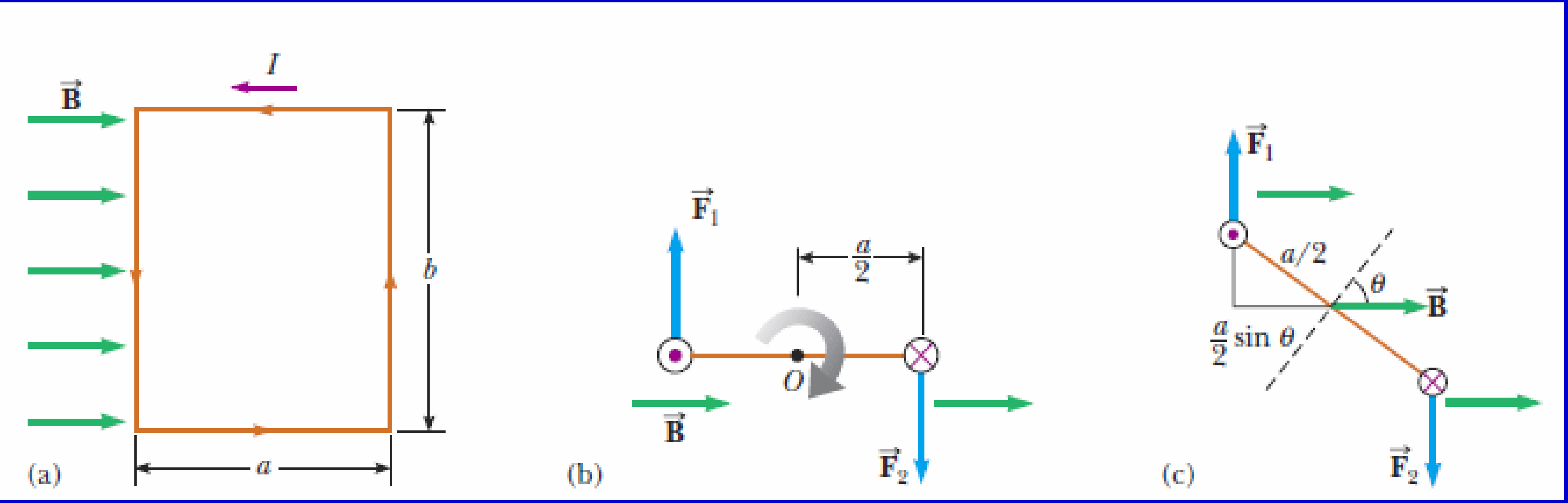


F = Bil

F = Bilsinθ

θ is the angle between **B** and the direction of the current **i**.

Torque on a current loop



$$F_1 = F_2 = BIb$$

$$\tau_{\max} = F_1 \frac{a}{2} + F_2 \frac{a}{2} = (BIb)\frac{a}{2} + (BIb)\frac{a}{2} = BIab$$

$$\tau_{\max} = BIA$$

$$\tau = BIA \sin\theta$$

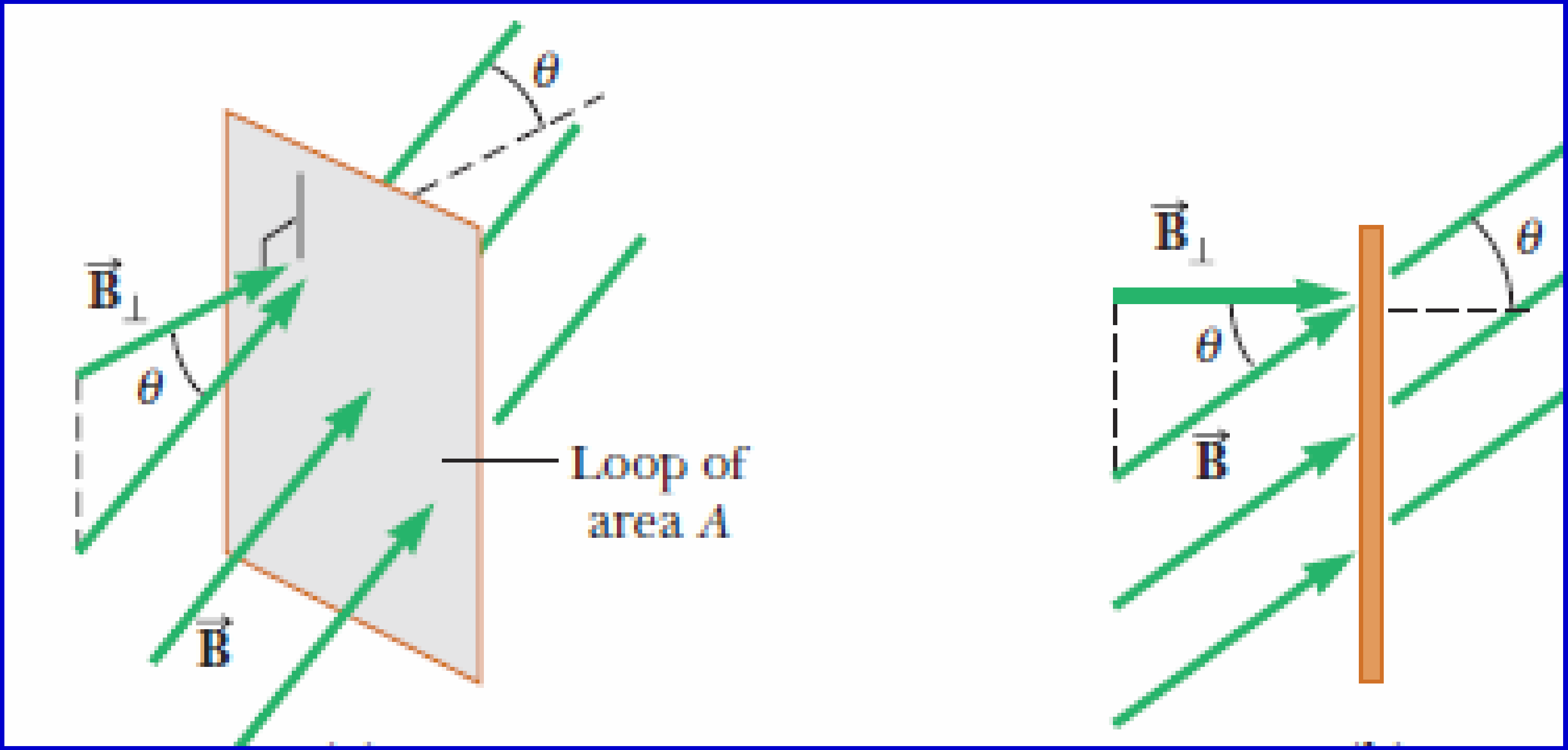
Magnetic flux

Magnetic flux is proportional to both the strength of the magnetic field B passing through the plane of a loop of wire and the area **A** of the loop. The **magnetic flux** through a loop of wire is defined by

$$\boldsymbol{\Phi = BA\cos\theta}$$

In SI magnetic flux is measured in **Weber**

Magnetic flux



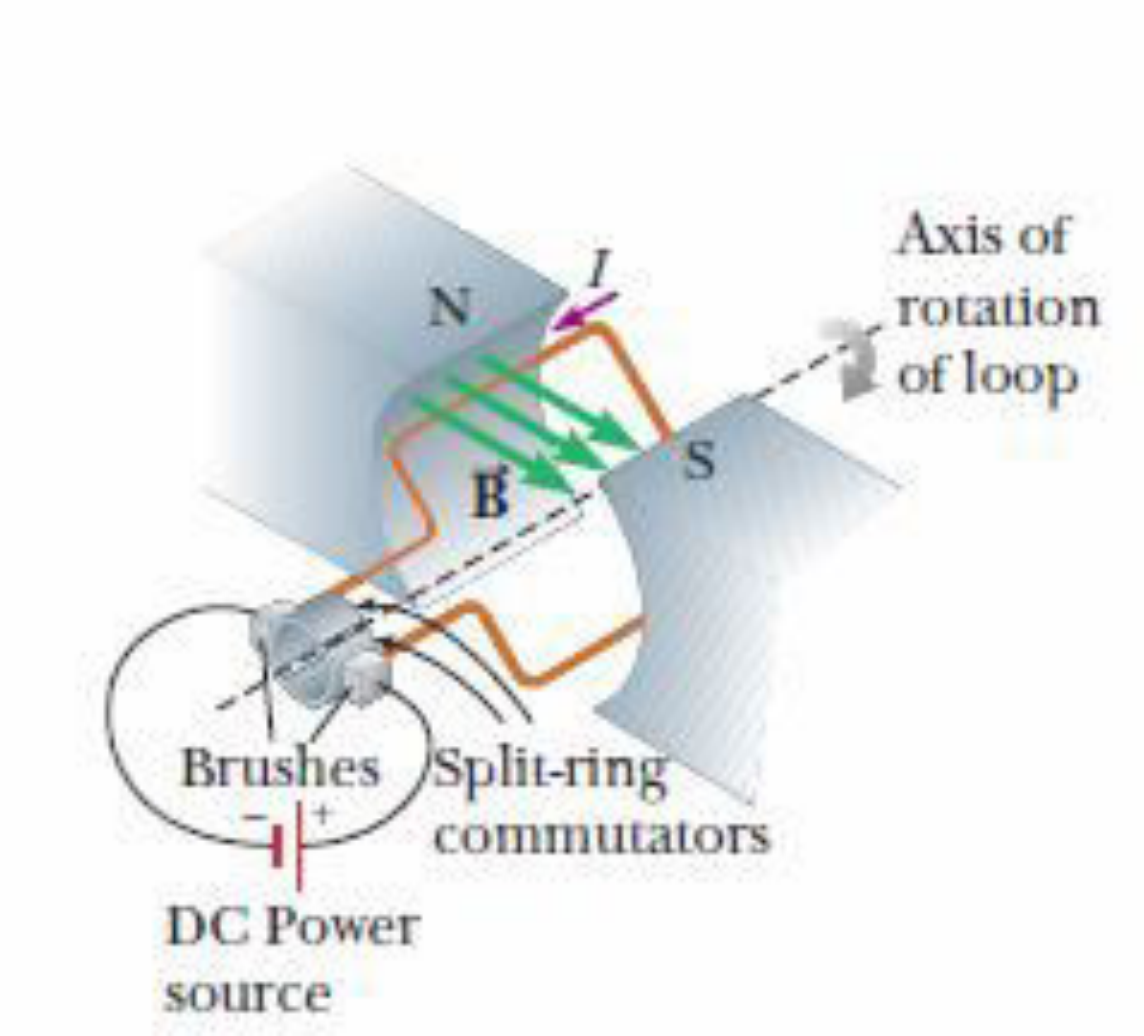
Νόμος των Faraday-Lentz

If a circuit contains ***n*** tightly wound loops and the magnetic flux through each loop changes by the amount **dΦ** during the interval d*t*, the average emf induced in the circuit during time d*t* is

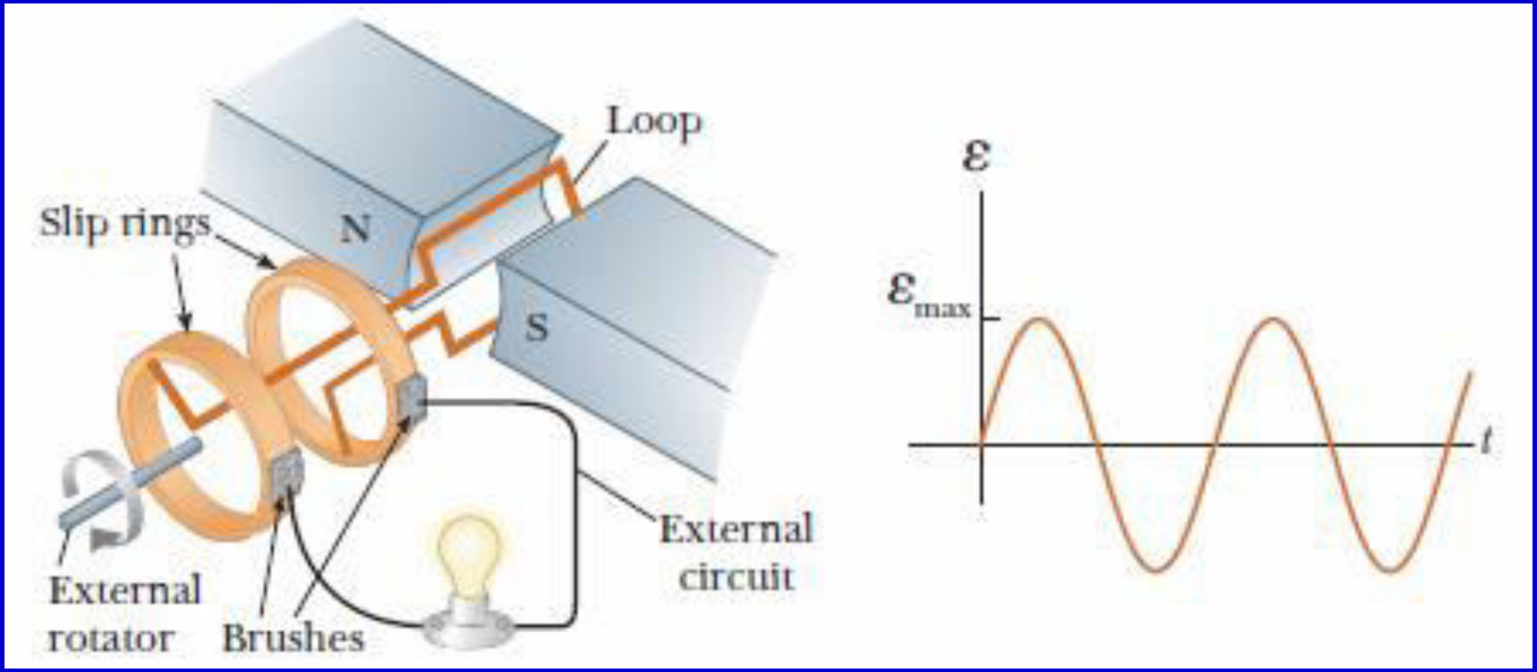
$$E = -n\frac{d\Phi}{dt}$$

The current caused by the induced **emf** travels in the direction that creates a magnetic field with flux opposing the change in the original flux through the circuit.

Simplified sketch of a DC electric motor



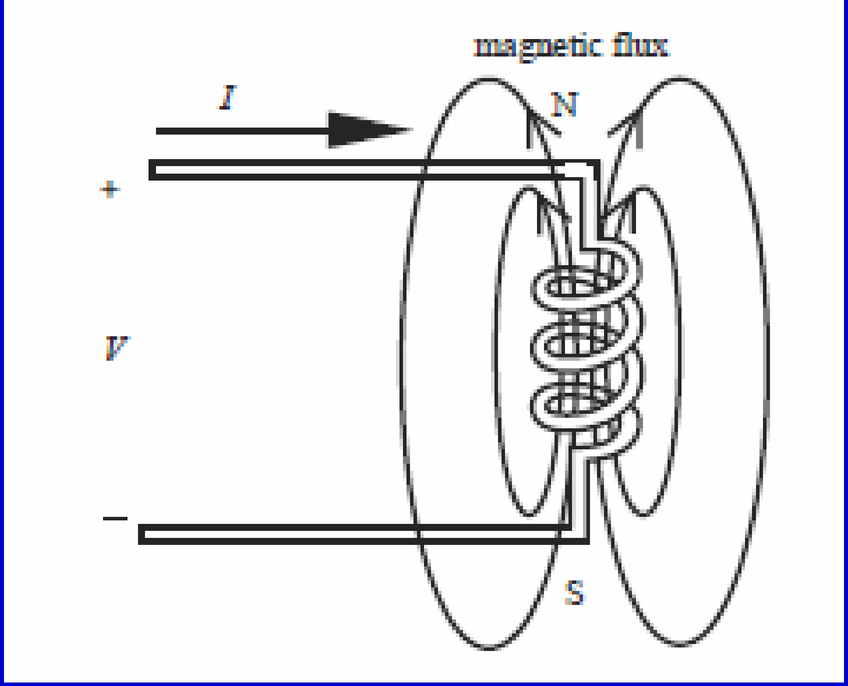
Simplified sketch of a DC electric generator



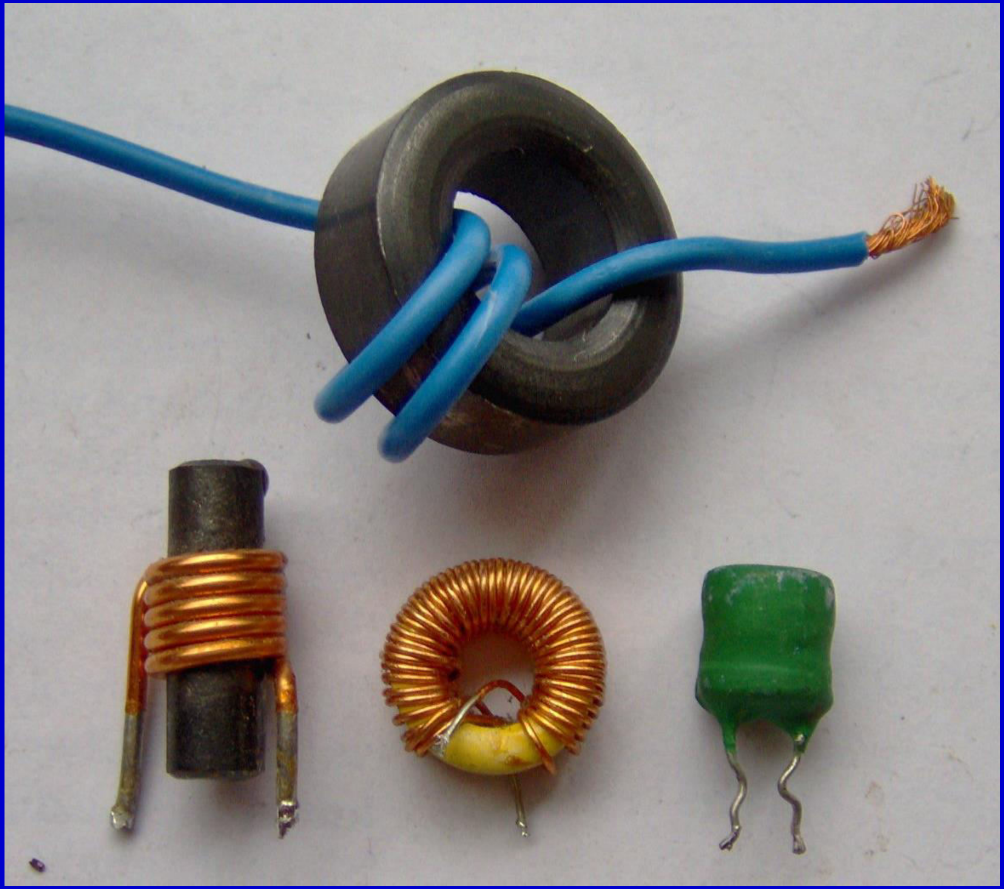
$$\mathcal{E} = NBA\omega \sin \omega t$$

Inductor

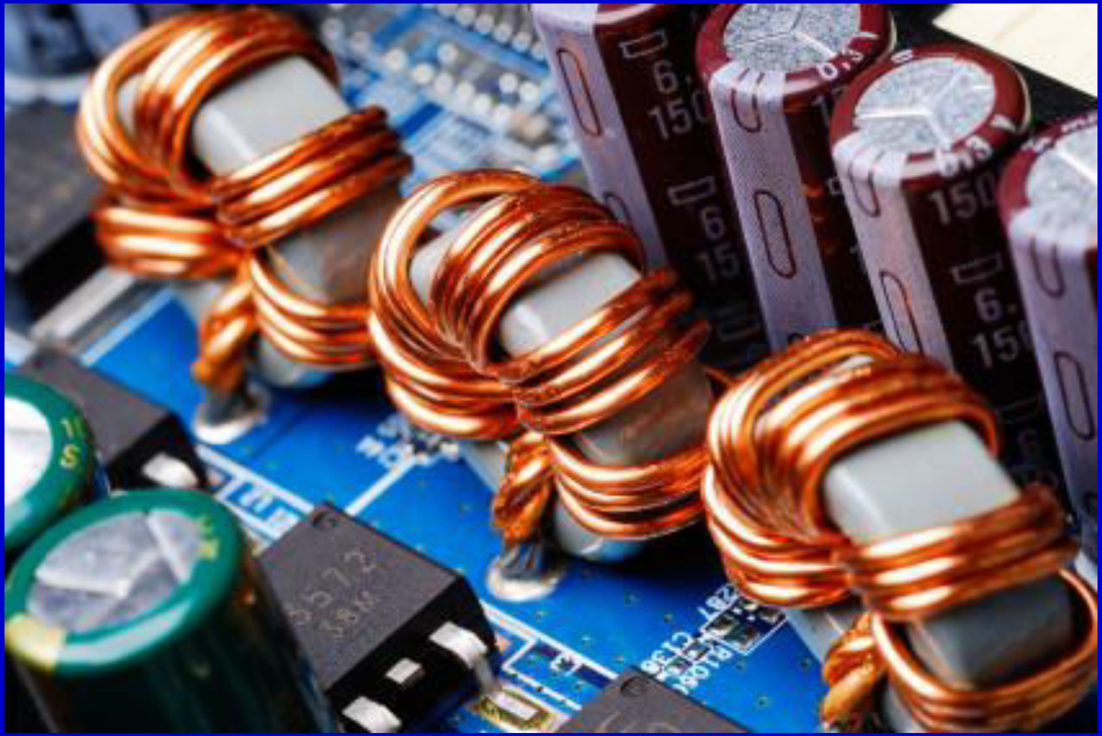
An **inductor** is a passive energy storage element that stores energy in the form of a magnetic field. The simplest form of an inductor is a wire coil, which has a tendency to maintain a magnetic field once established.



Types of Inductors



Inductors on a motherboard



Self-Inductance

A coil can induce a emf by itself. If the current in the coil changes, the flux through the coil changes. As a result the changing current induces an emf in the coil.

The magnetic flux is proportional to the magnetic field, which is proportional to the current in the coil. Therefore, the **self-induced emf** is proportional to the rate of change of the current with time

$$E = -L\frac{di}{dt}$$

L is a constant called the **inductance** of the device

In SI L is measured in **Henry**

Energy stored in a inductor

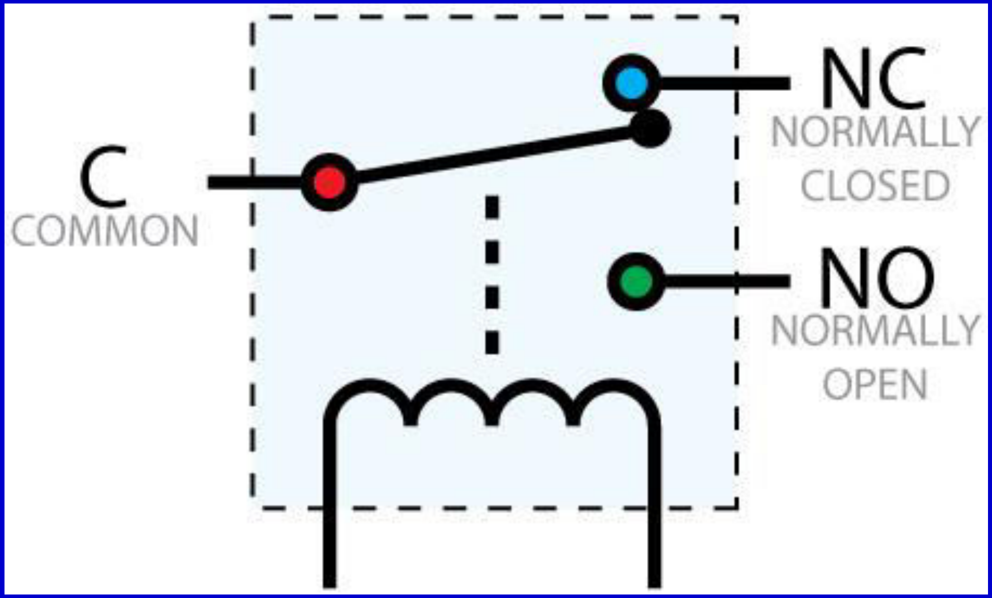
$$dw = pdt = Eidt$$

$$dw = L\frac{di}{dt}idt = Lidi$$

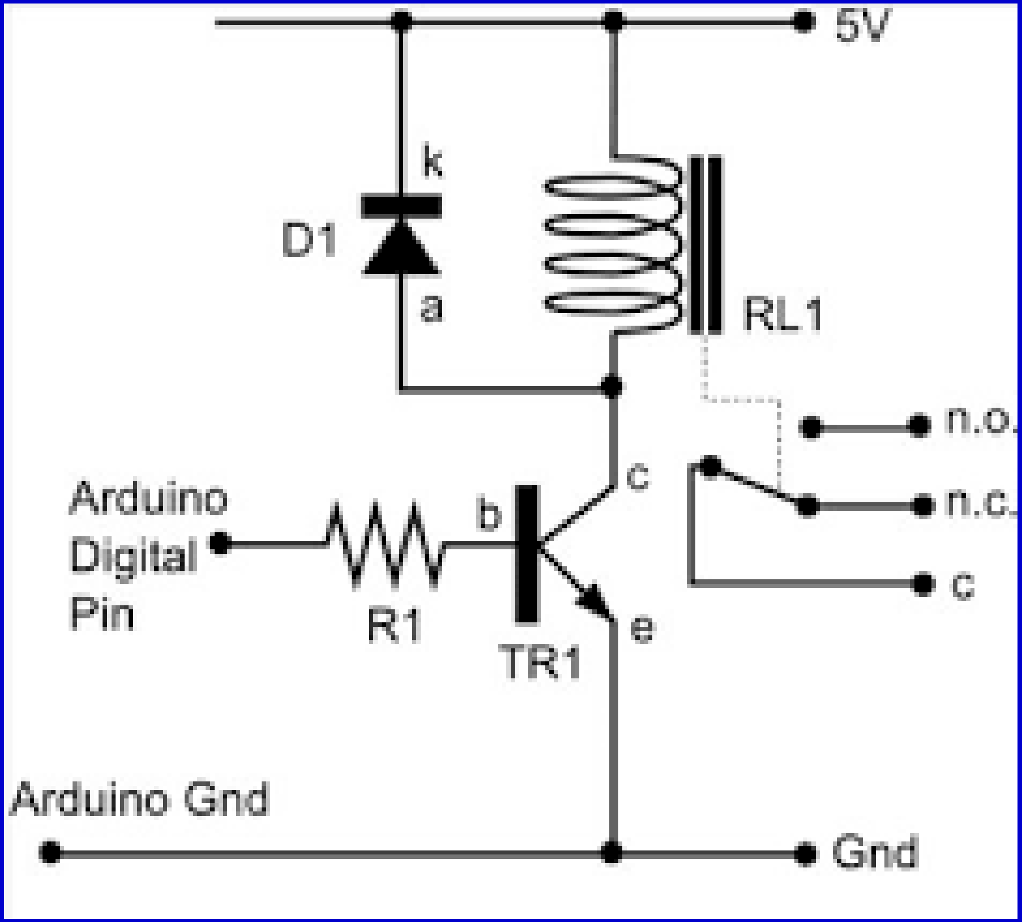
$$W = \int_0^I Lidi$$

$$W = \frac{1}{2}LI^2$$

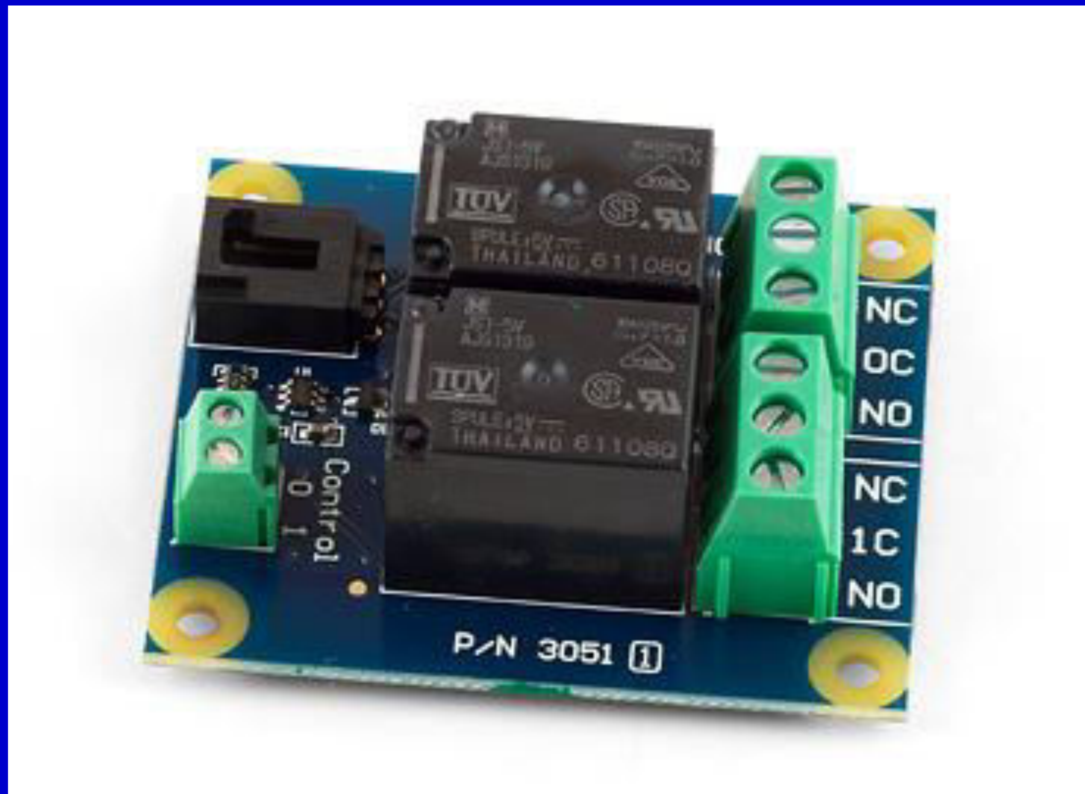
Conventional relay



Σύνδεση relay σε Arduino

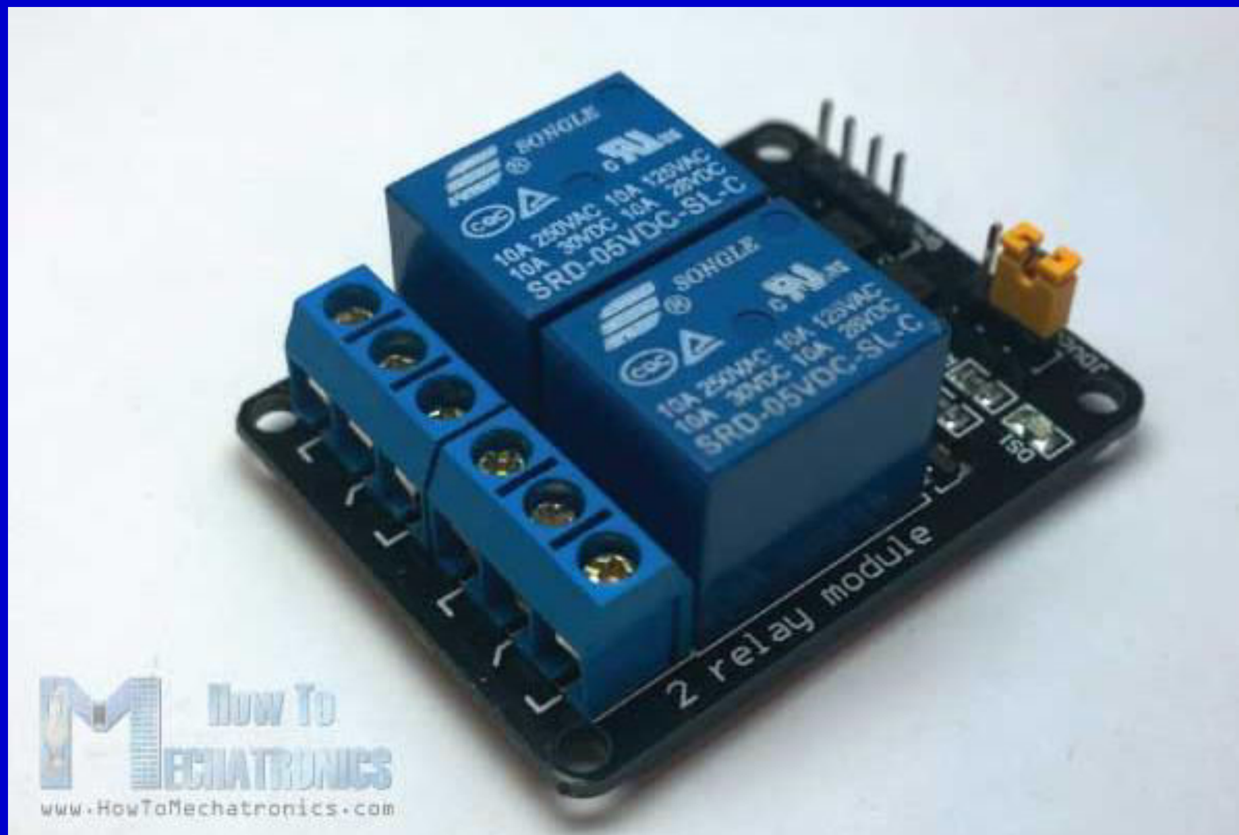


Double Relay



This board has 2 SPDT mechanical relays rated at 240VAC/10A or 100VDC/5A.

Double Relay

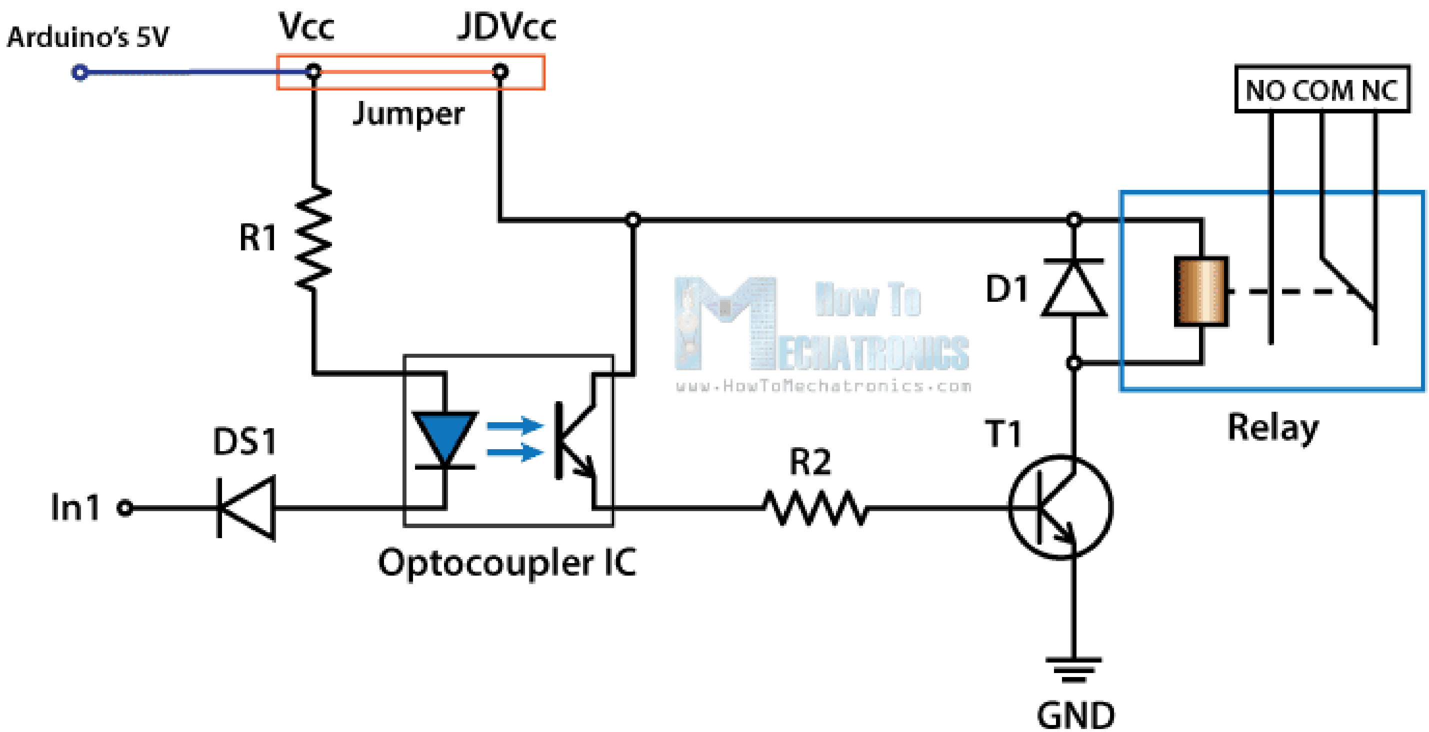


Double Relay

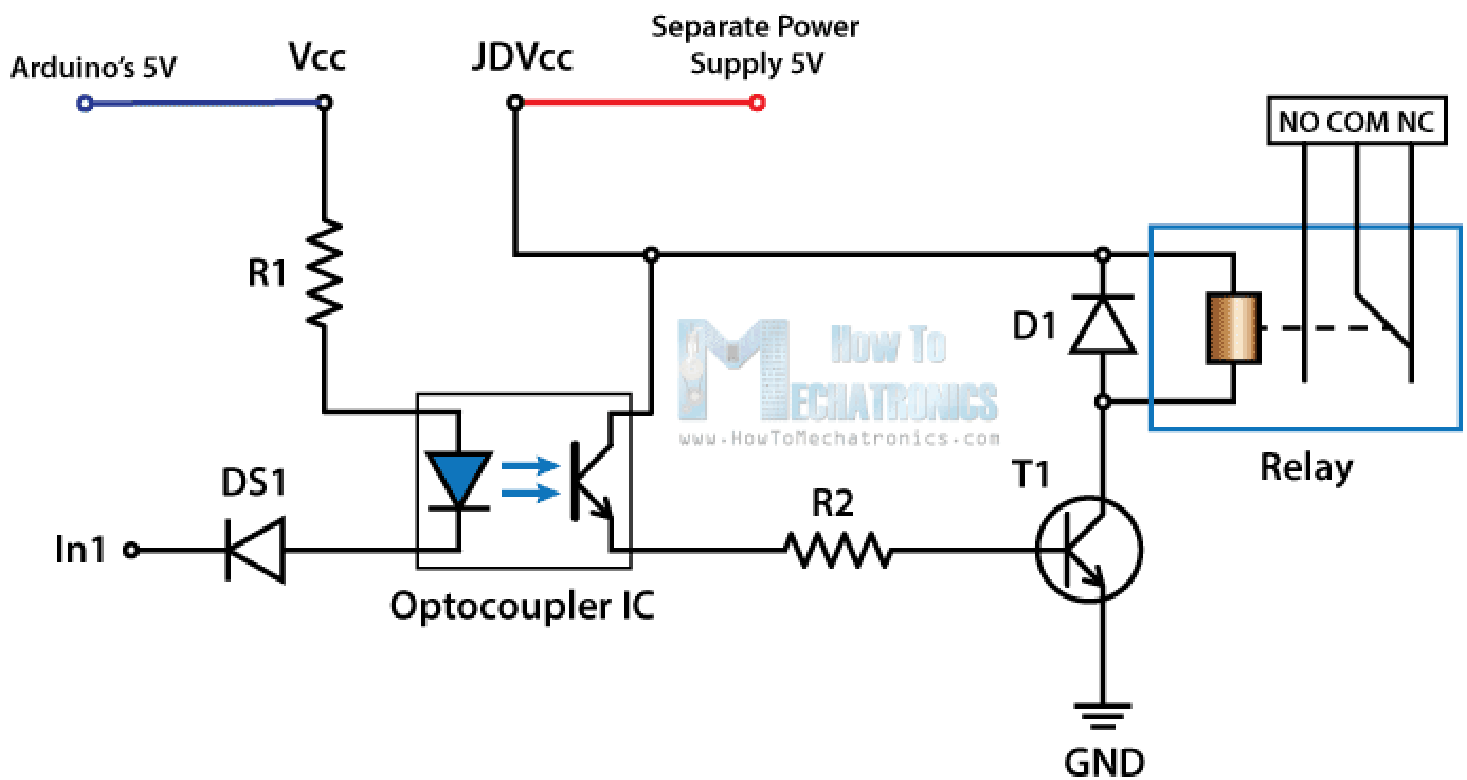
Specifications

5V SONGLE relay 250V 10A
Input low level effective.
Input sign.
GND power supply.
VCC signal power supply.
IN1, IN2 line
JD-VCC relay power supply.

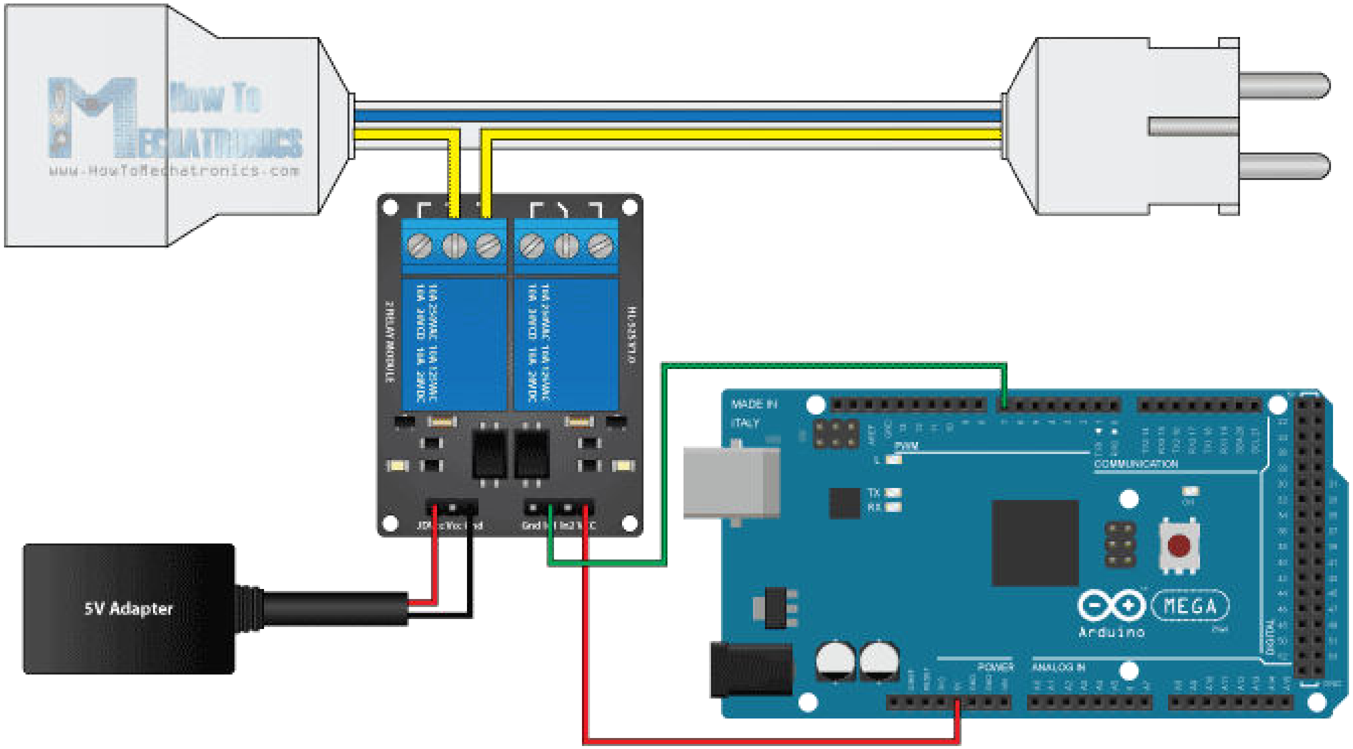
Λειτουργία relay με τροφοδοσία από το Arduino



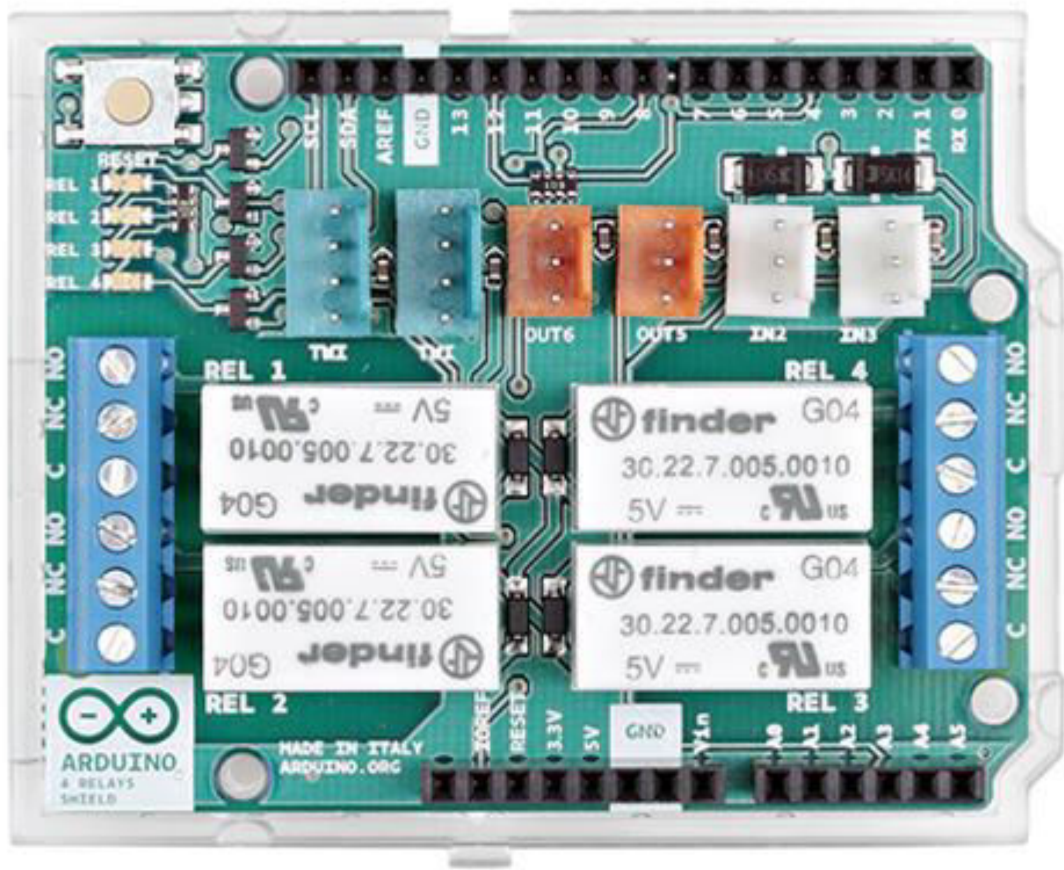
Λειτουργία relay με εξωτερική τροφοδοσία



Σύνδεση relay στο Arduino



Arduino shield με 4 relay



Relay 1 = Arduino pin 4
Relay 2 = Arduino pin 7
Relay 3 = Arduino pin 8
Relay 4 = Arduino pin 12

Operating Voltage 5V

Coil current consumption140 mA (with all releays on, about 35 mA each)

Single pole charge over contact maximum current@ 30 V DC 2A

Maximum load voltage 48 V

Maximum switching capacity 60 V

Electric motor

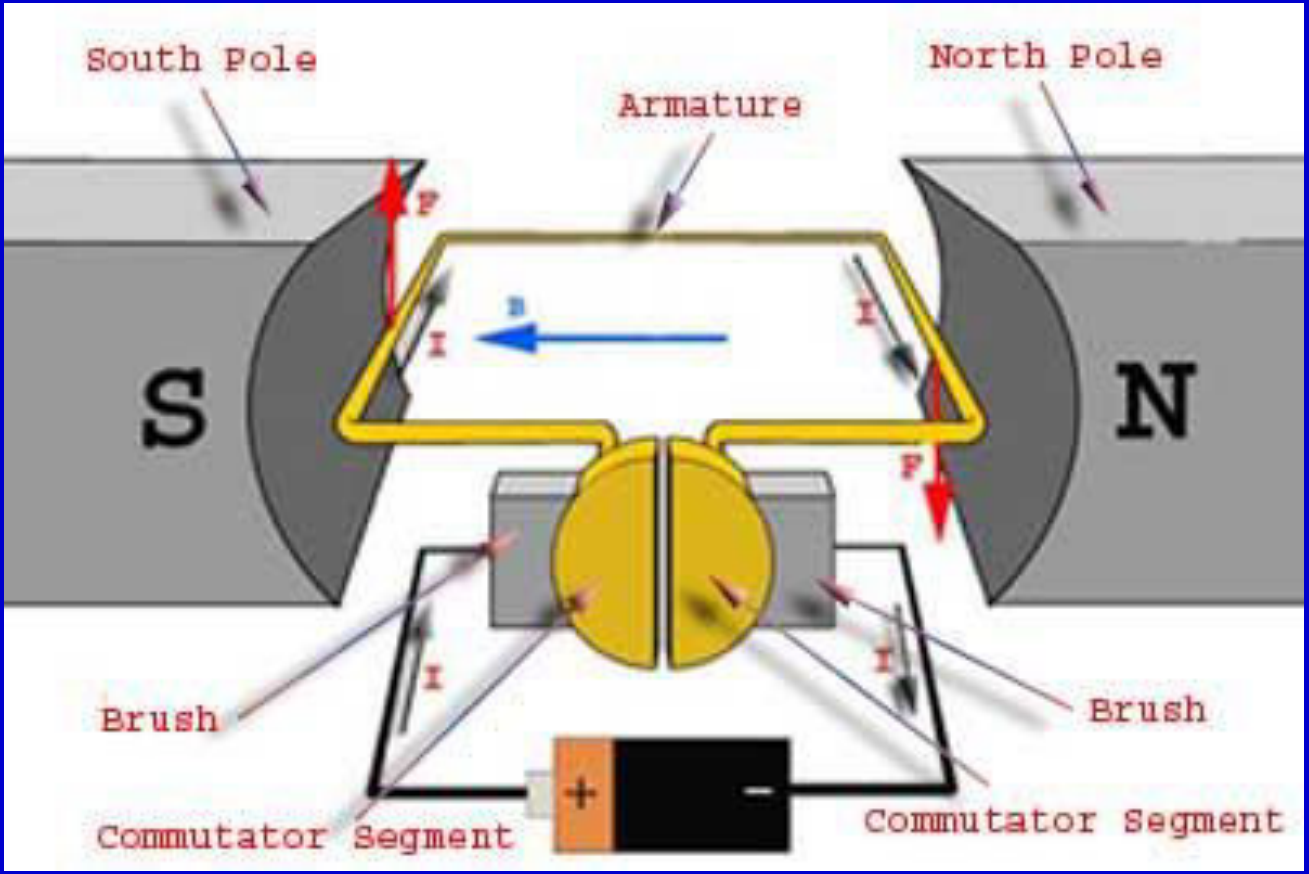
An **electric motor** is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and winding currents to generate force in the form of rotation. Electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators.

DC motor

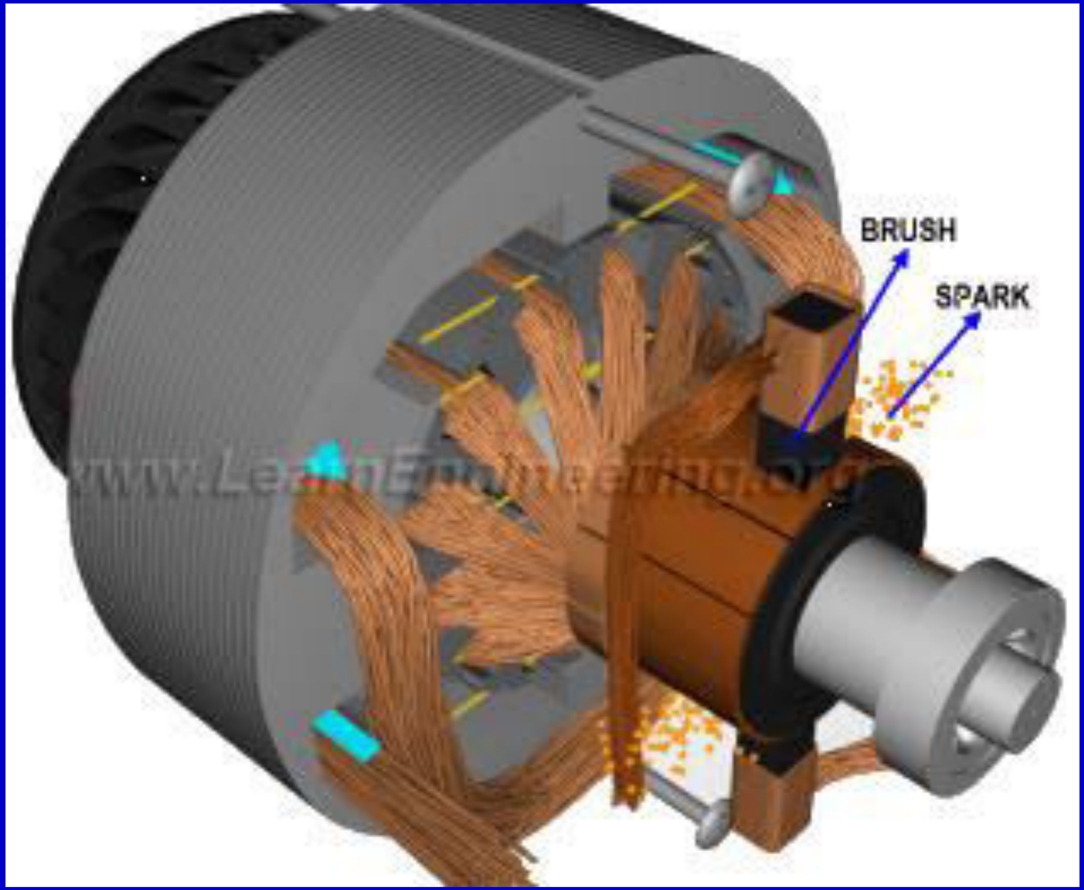
A **DC motor** is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields.

Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.

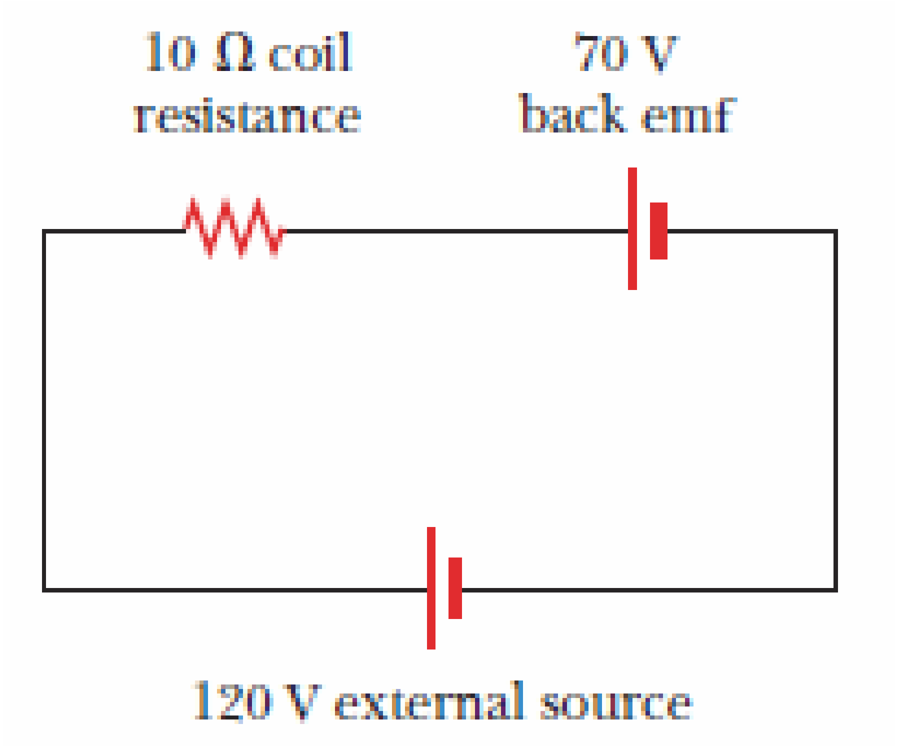
Αρχή λειτουργίας κινητήρα συνεχούς ρεύματος



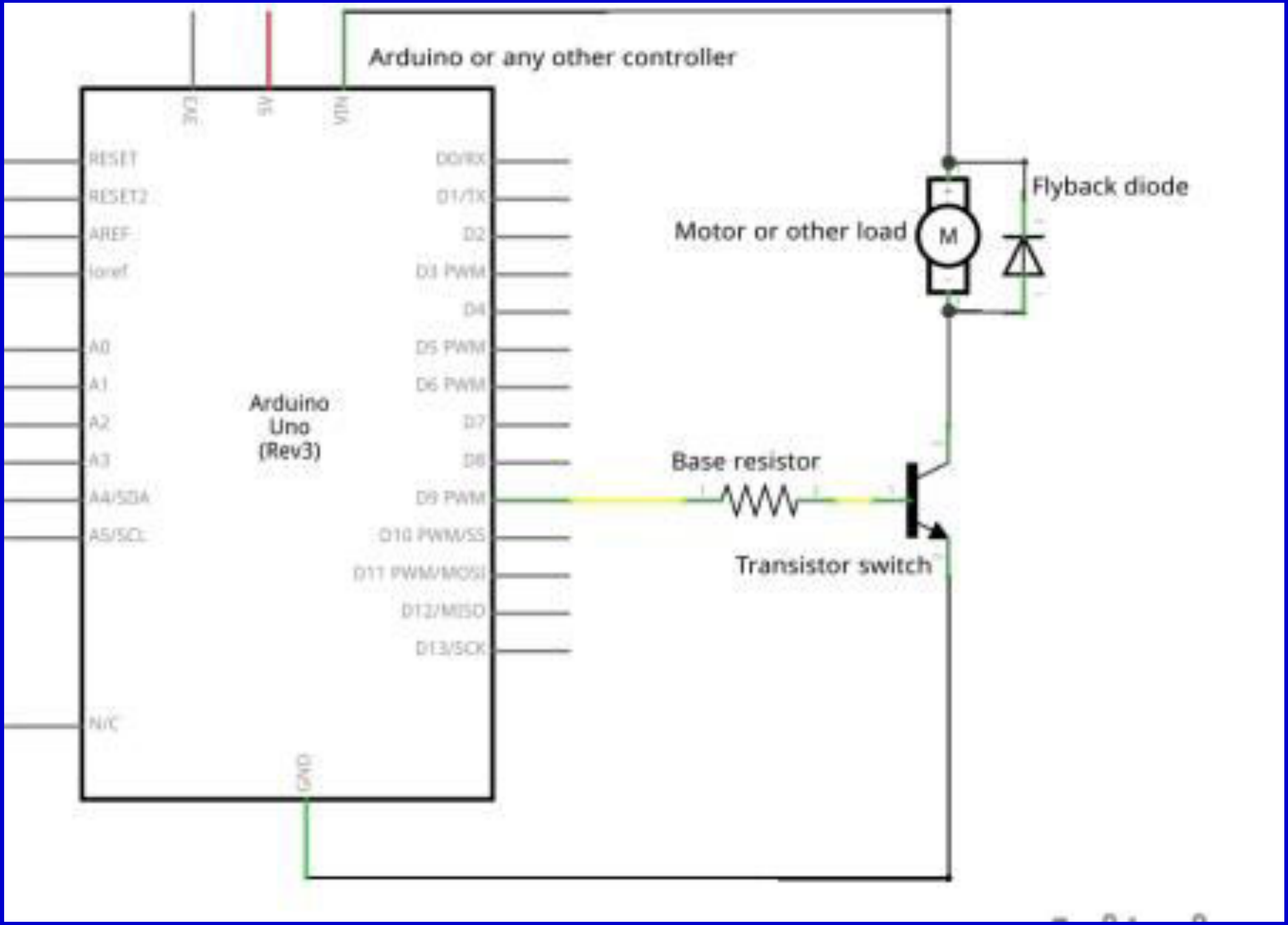
Δομή DC motor



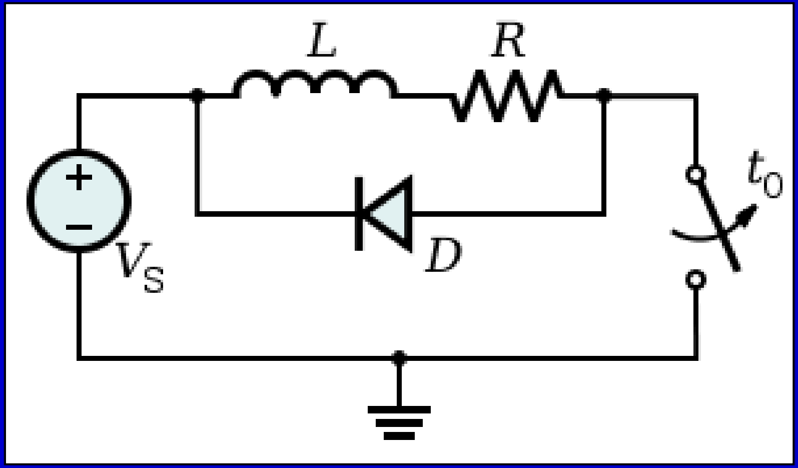
DC Motor equivalent circuit



Σύνδεση Arduino με DC motor με τρανζίστορ NPN



A **flyback diode** (sometimes called a **clamp diode** or **catch diode** is a dode used to eliminate flyback, which is the sudden voltage spikes seen across an inductive load when its supply current is suddenly reduced or interrupted.



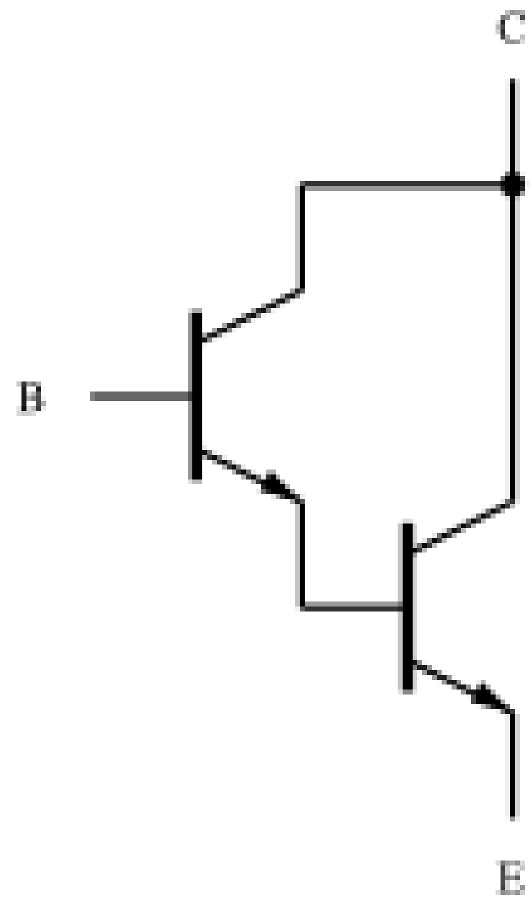
DC motor

Voltage (Range): 1.5 - 6Volt
Current (Stall): 280mA
Ταχύτητα: 12000RPM
Ροπή: 0.25kg.cm

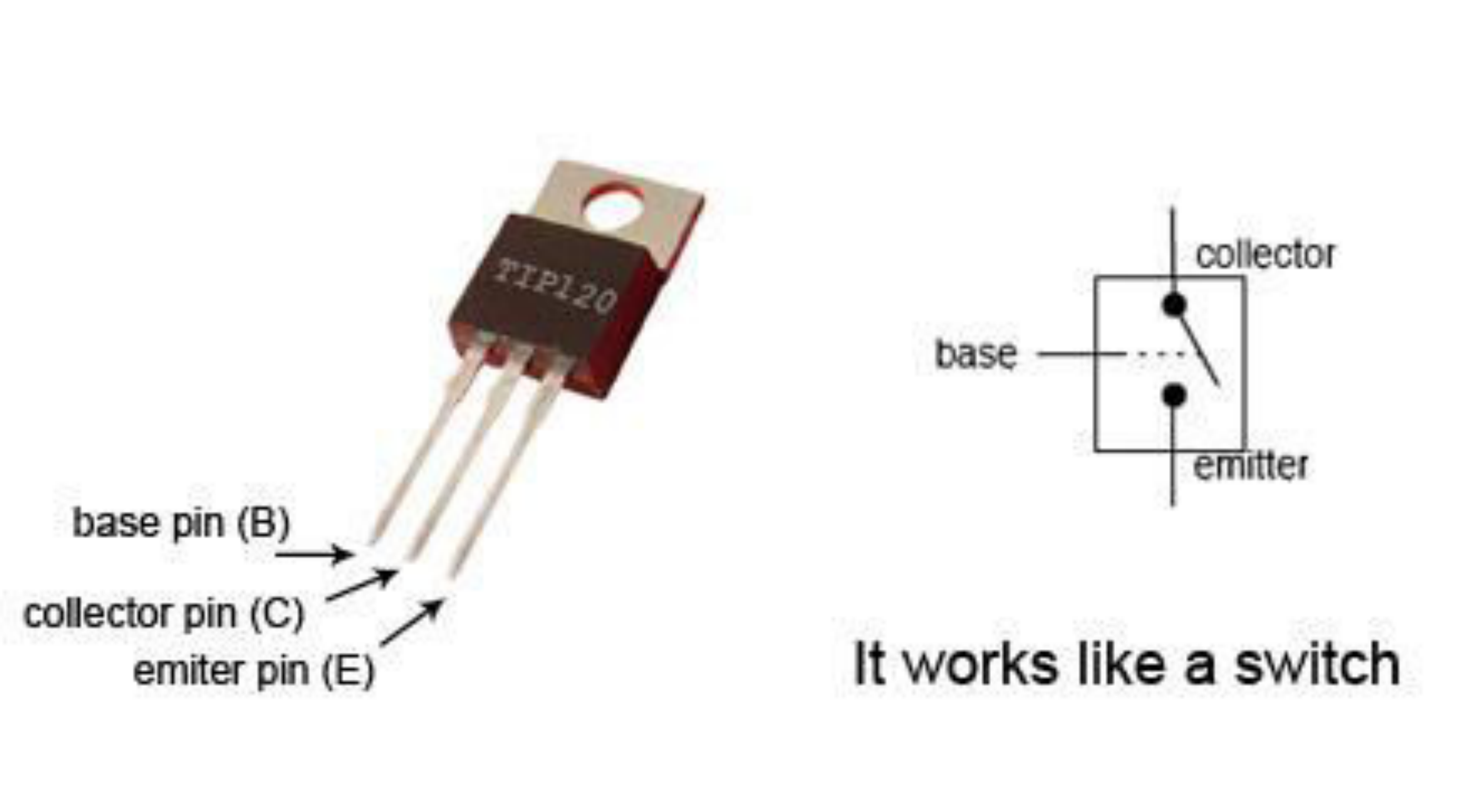
Darlington

Darlington transistor (or **Darlington pair**) is a compound structure **consisting of two bipolar transistors** connected in such a way that the current amplified by the first transistor is amplified further by the second one. This configuration gives a **much higher current gain** than each transistor taken separately and, in the case of integrated devices, can take less space than two individual transistors because they can use a *shared* collector. Integrated Darlington pairs come packaged singly in transistor-like packages or as an array of devices (usually eight) in an IC.

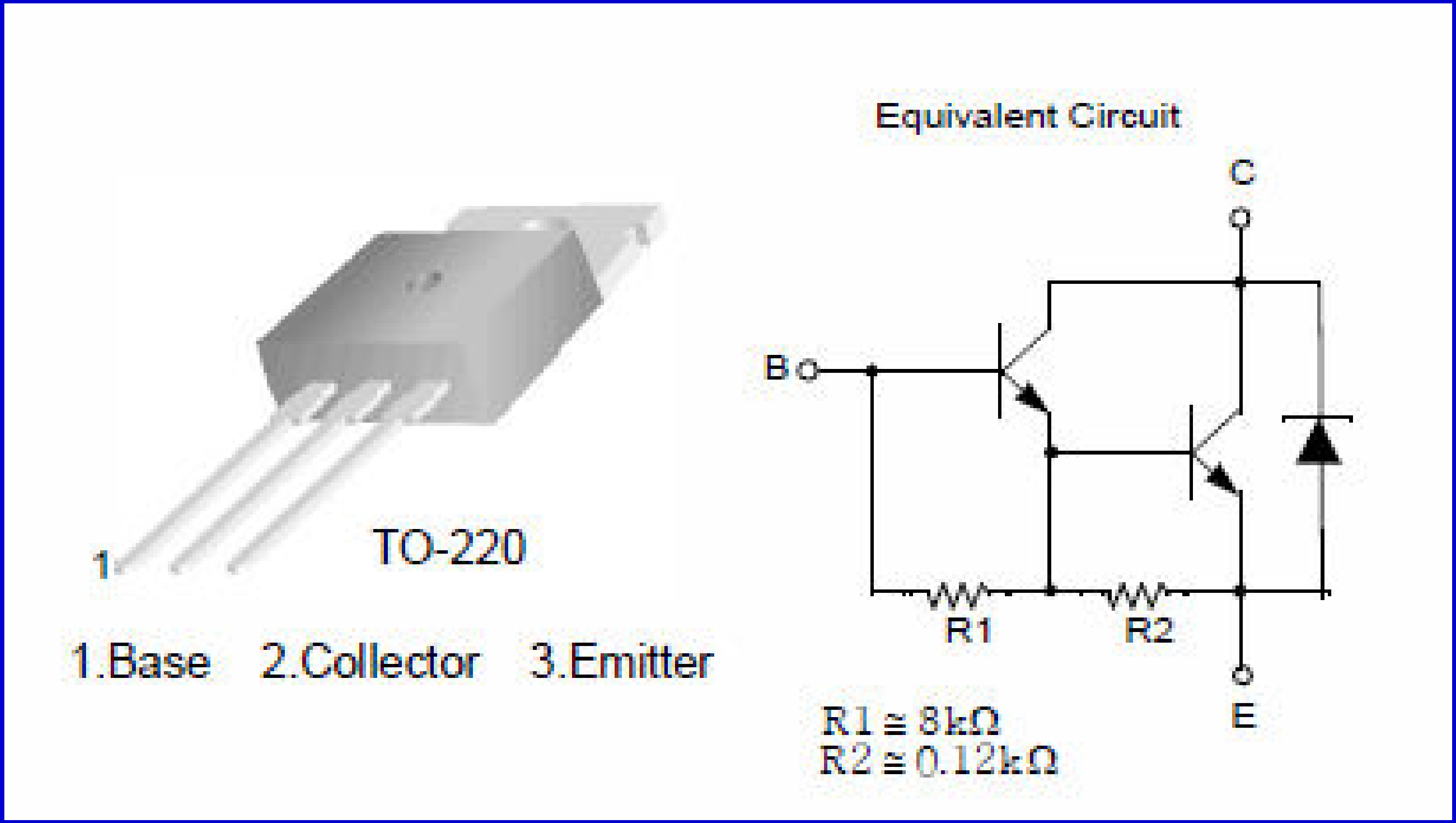
Darlinghton



TIP120 (Darlington)



TIP120 (Darlington)



MPN: TIP120

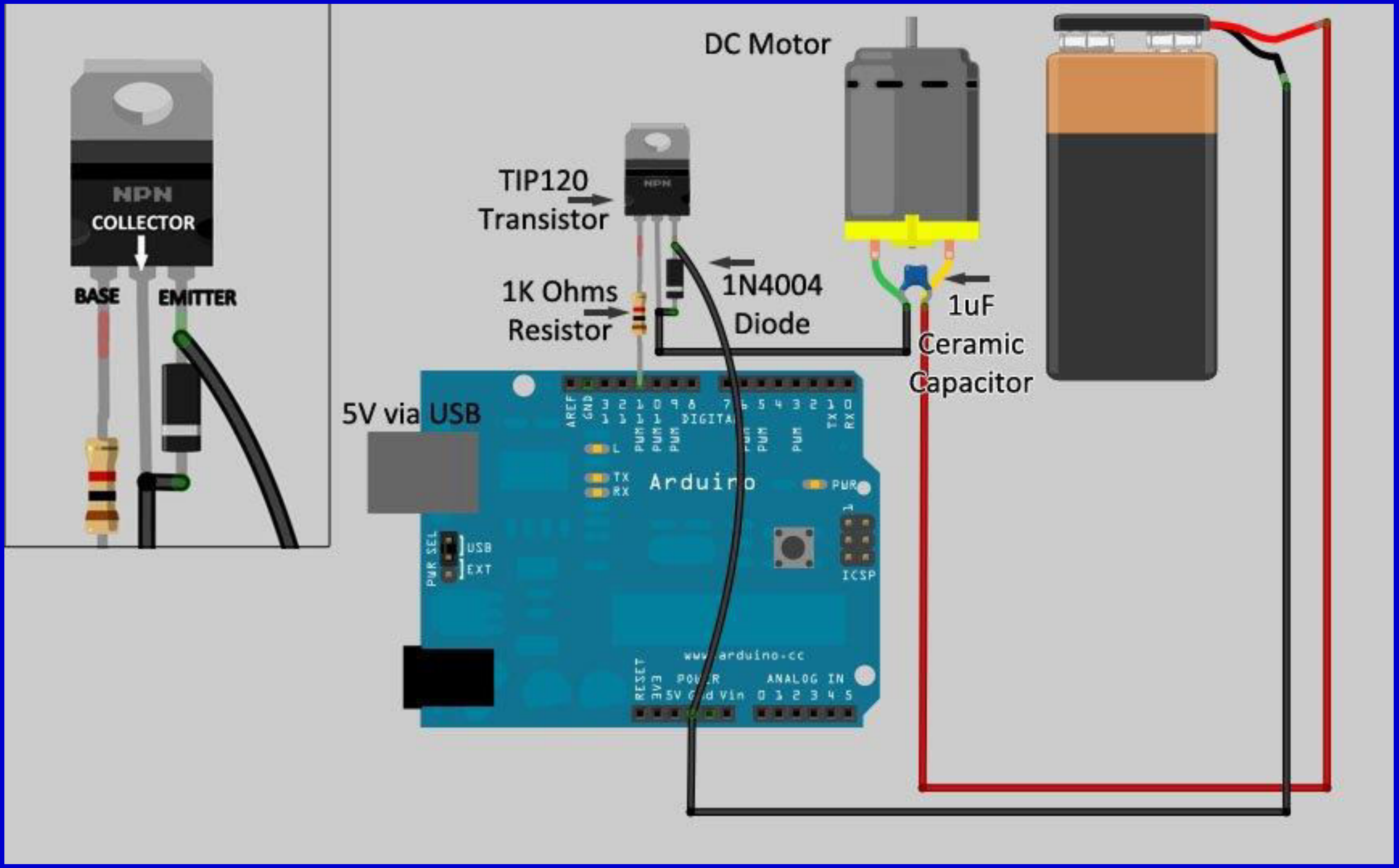
Power: 2 Watt

Τύπος Τρανζίστορ: Darlington NPN

Max. Collector Current: 5000 mA

Max. VCEO: 60 V

Οδήγηση DC motor με το TIP120



Επιλογή τρανζίστορ για οδήγηση DC motor

Οδήγηση του Jameco 400995 DC gear motor.

According to the datasheet for this motor, at **12 VDC** with no load it only draws 76 mA, but if you **stall** the motor it shoots up to 1250 mA, or 1.25 A. A motor always consumes the maximum current when stalled.
Thus the load voltage is 12 VDC and the maximum load current is 1.25 A

$V_{load} = 12V$
$I_{load}(max) = 1.25A$

Let's pretend we have a PN2222A, a TIP31 and a TIP120. First we need to make sure that the transistor can safely handle the worst current we might draw. The parameter we are looking for is the maximum collector current, **Ic(max)**.

PN2222A shows Ic(max) = 0.6 A, which is too little for our needs.

TIP31shows Ic(max) = 3 A, which is safely above the 1.25 A our motor will draw if it is stalled. So the TIP31 is a contender.

Next we have to verify that the transistor can safely handle the supply voltage we plan to use. The parameter we are looking for is the maximum collector emitter voltage, **Vceo (max)**.
The TIP31 comes in 4 versions, with Vceo(max) ranging from 40 V to 100 V, all safely above the 12 V we plan to use. So the TIP31 is still a contender.

According to the datasheet, **Ic/Ib = 10** or Ic = 10 * Ib. This means that for our collector current of 1.25 A, we would need to deliver a base current of .125 A, which is too much for our Arduino, which can deliver (safely) at most 40 mA.

For the TIP120 we see that Ic(max) = 5 A, and that Vceo(max) is 60, 80, or 100 V, so we are fine so far.

Next we check the base current. Again this is indicated in the datasheet **Ic=250 * Ib** or our collector current of 1.25 A requires a base current of 5 mA (5 * 250 = 1250), which is well below the maximum of 40 mA the Arduino can put out.

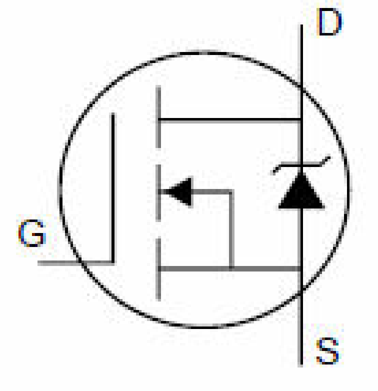
In the datasheet we see that when the collector current is 1 A, Vbe(sat) is about 1.5 V. Now if the Arduino is putting out 5 V, and Vbe is 1.5 V, that means that the resistor has a voltage drop of (5 – 1.5) or 3.5 V across it. Using Ohm's law, R = V/I = 3.5/(20 mA)= 175 Ohms.

MOSFET

The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**) is a type of transistor used for amplifying or switching electronic signals.

Although the MOSFET is a four-terminal device with source (S), gate (G), drain (D), and body (B) terminals, the body (or substrate) of the MOSFET is often connected to the source terminal, making it a three-terminal device. Because these two terminals are normally connected to each other (short-circuited) internally, only three terminals appear in electrical diagrams.

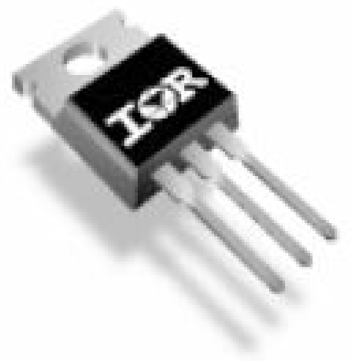
MOS Transistor IRF540



V_{DSS} = 100V

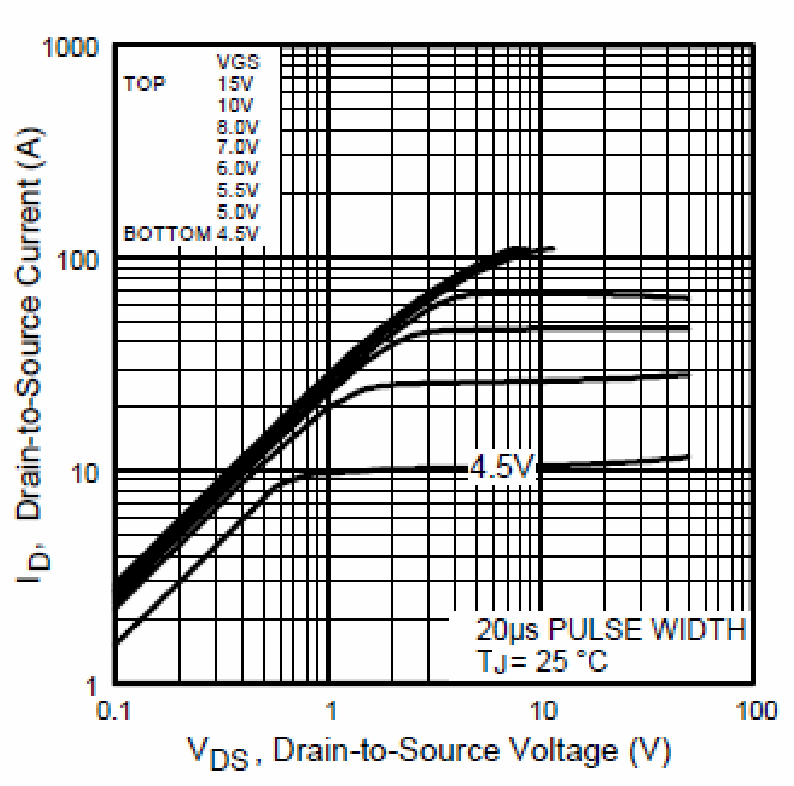
$R_{DS(on)}$ = 44mΩ

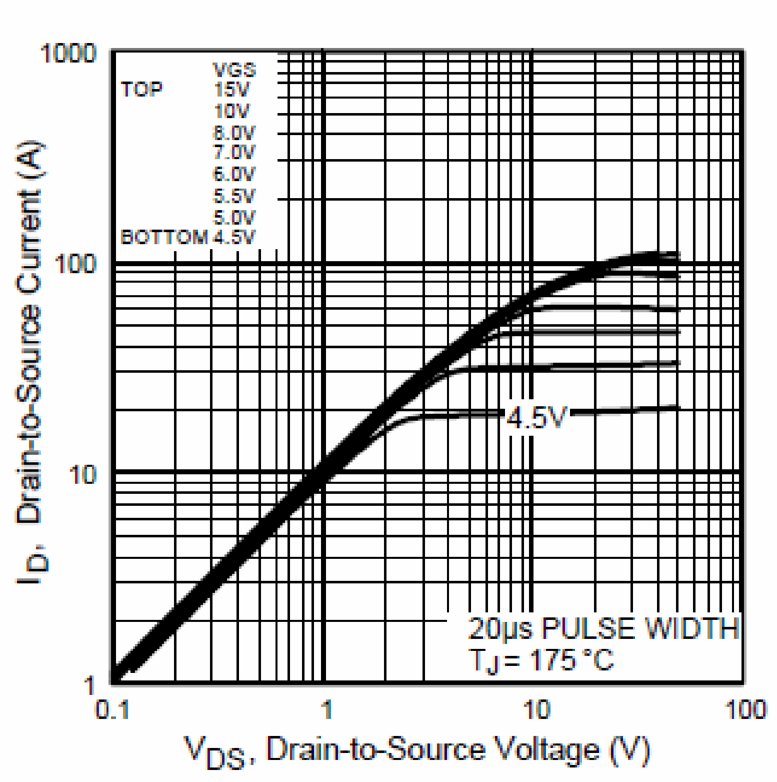
I_D = 33A



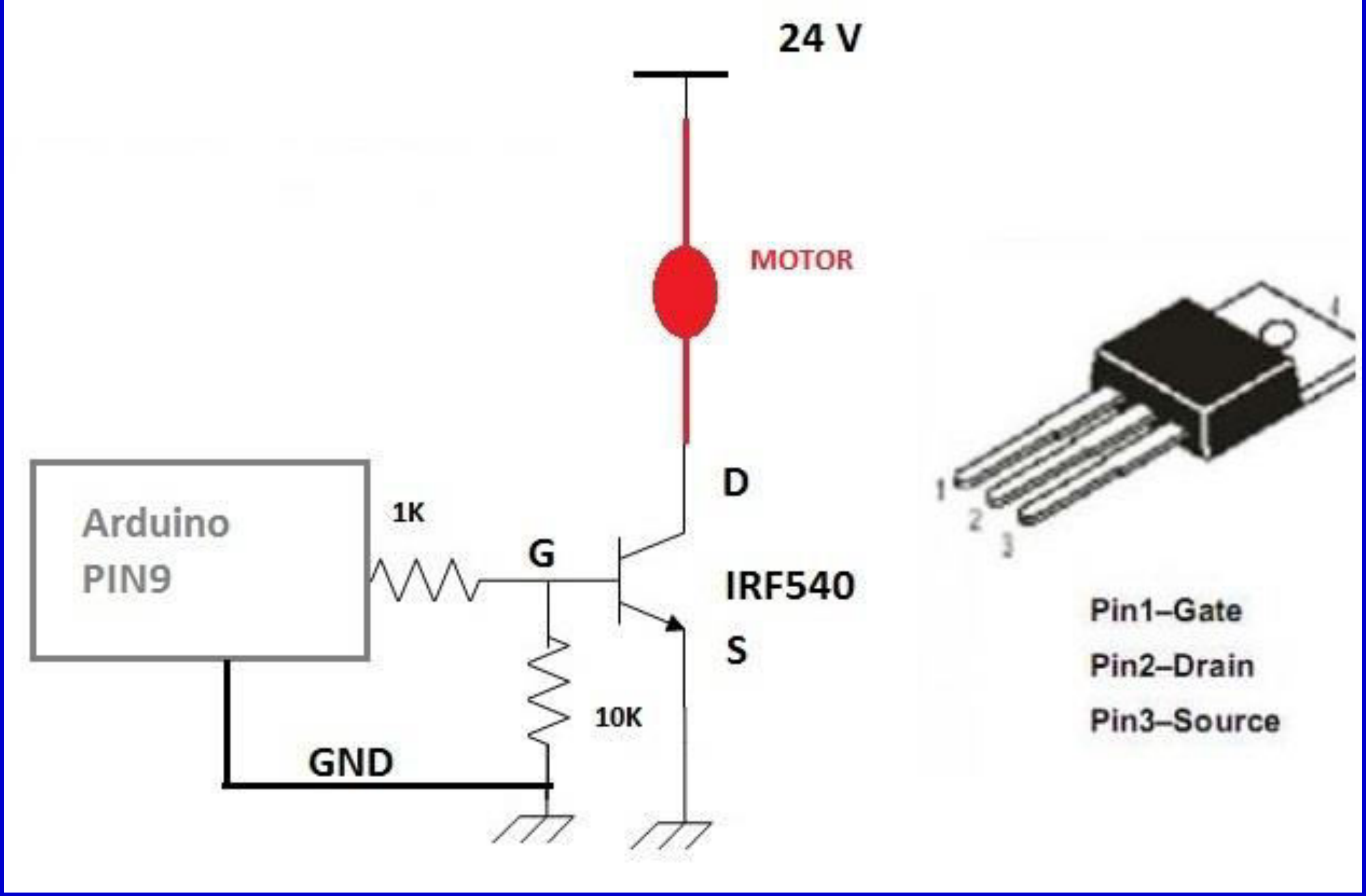
TO-220AB

Χαρακτηριστικές καμπύλες του MOS transistor IRF540



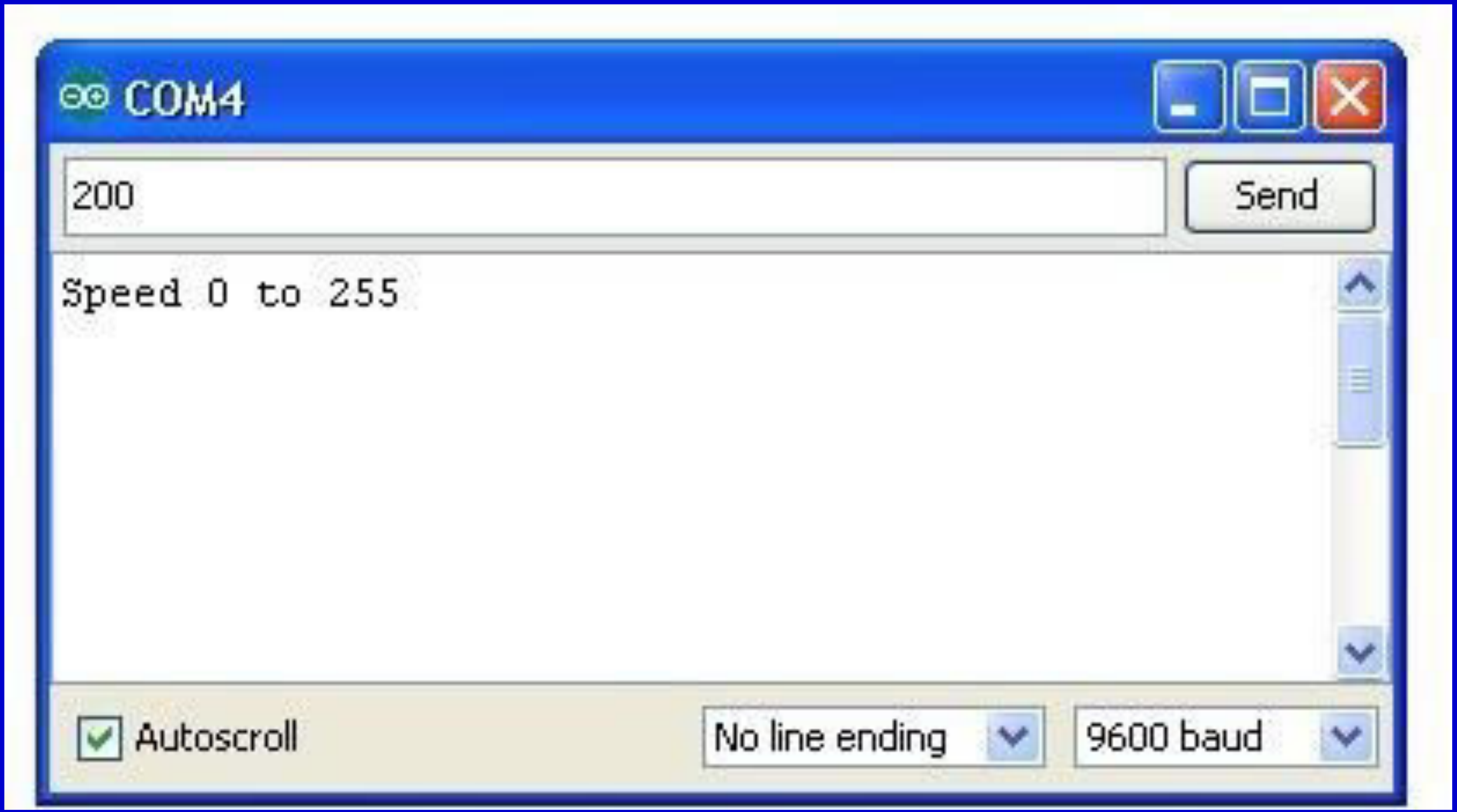


Οδήγηση DC motor με το MOS τρανζίστορ IRF540



Πρόγραμμα ελέγχου DC motor

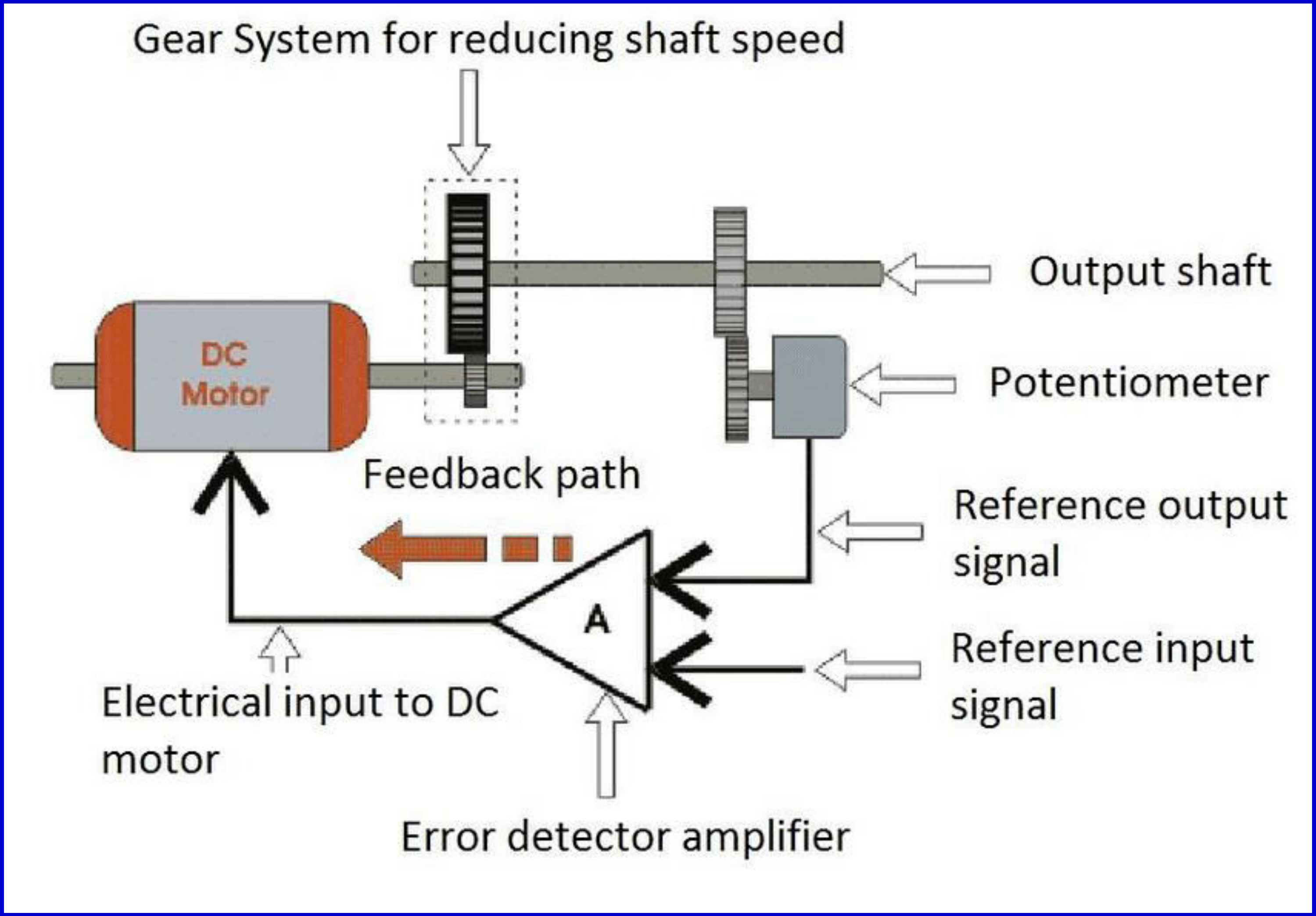
```
int motorPin = 3;
void setup()
{
   pinMode(motorPin, OUTPUT);
   Serial.begin(9600);
   while (!Serial);
   //wait for serial port to connect//
   Serial.println("Speed 0 to 255");
}
void loop()
{
  if (Serial.available())
    {
      int speed =Serial.parseInt();
      if (speed >= 0 && speed <= 255)
        {
         analogWrite(motorPin, speed);
        }
    }
}
```


COM4
200
Send
Speed 0 to 255
Autoscroll
No line ending
9600 baud

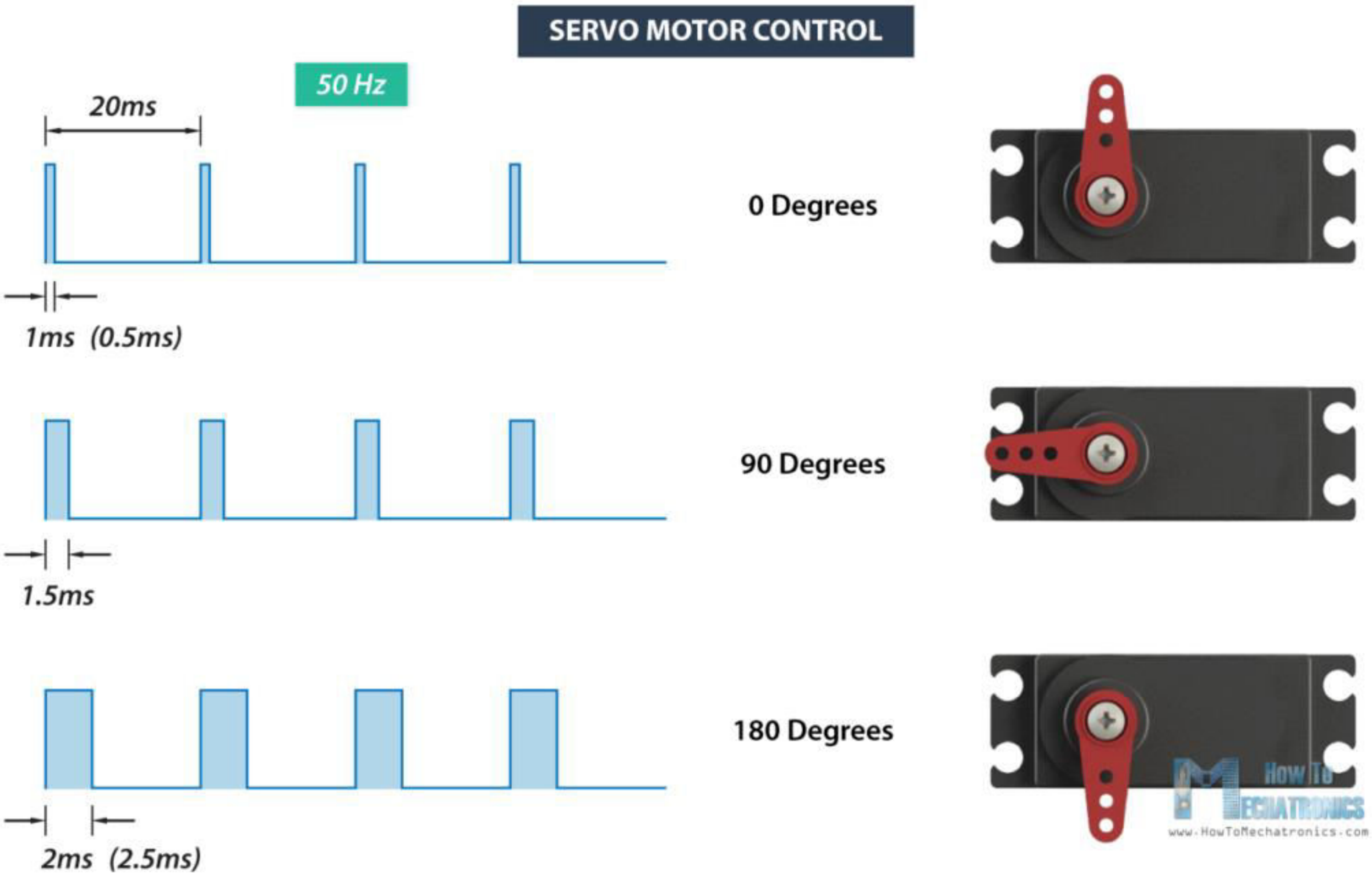
Servomotor

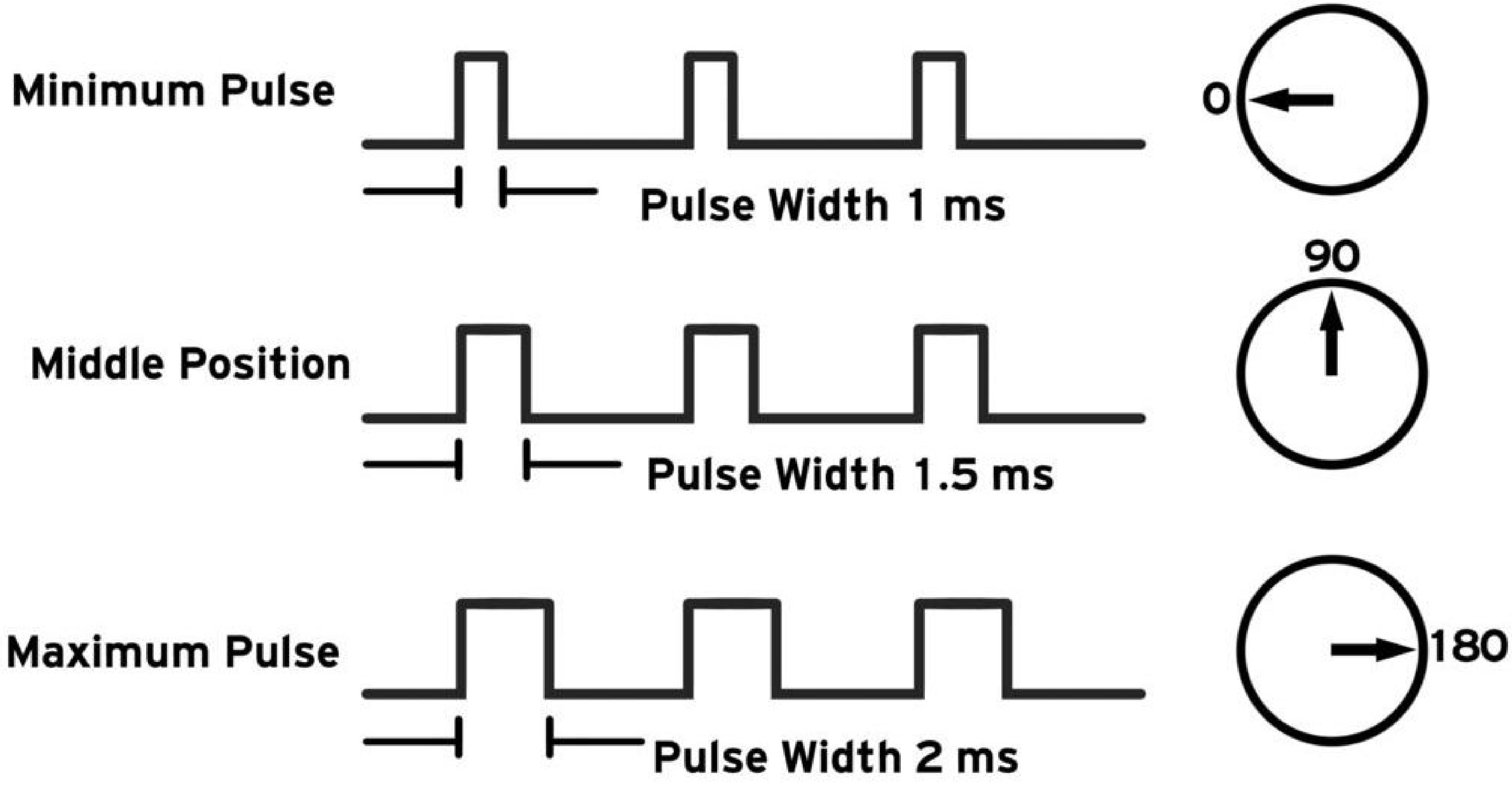
A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.
Servomotors are not a specific class of motor although the term *servomotor* is often used to refer to a motor suitable for use in a closed-loop control system.
Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

Δομή servomotor

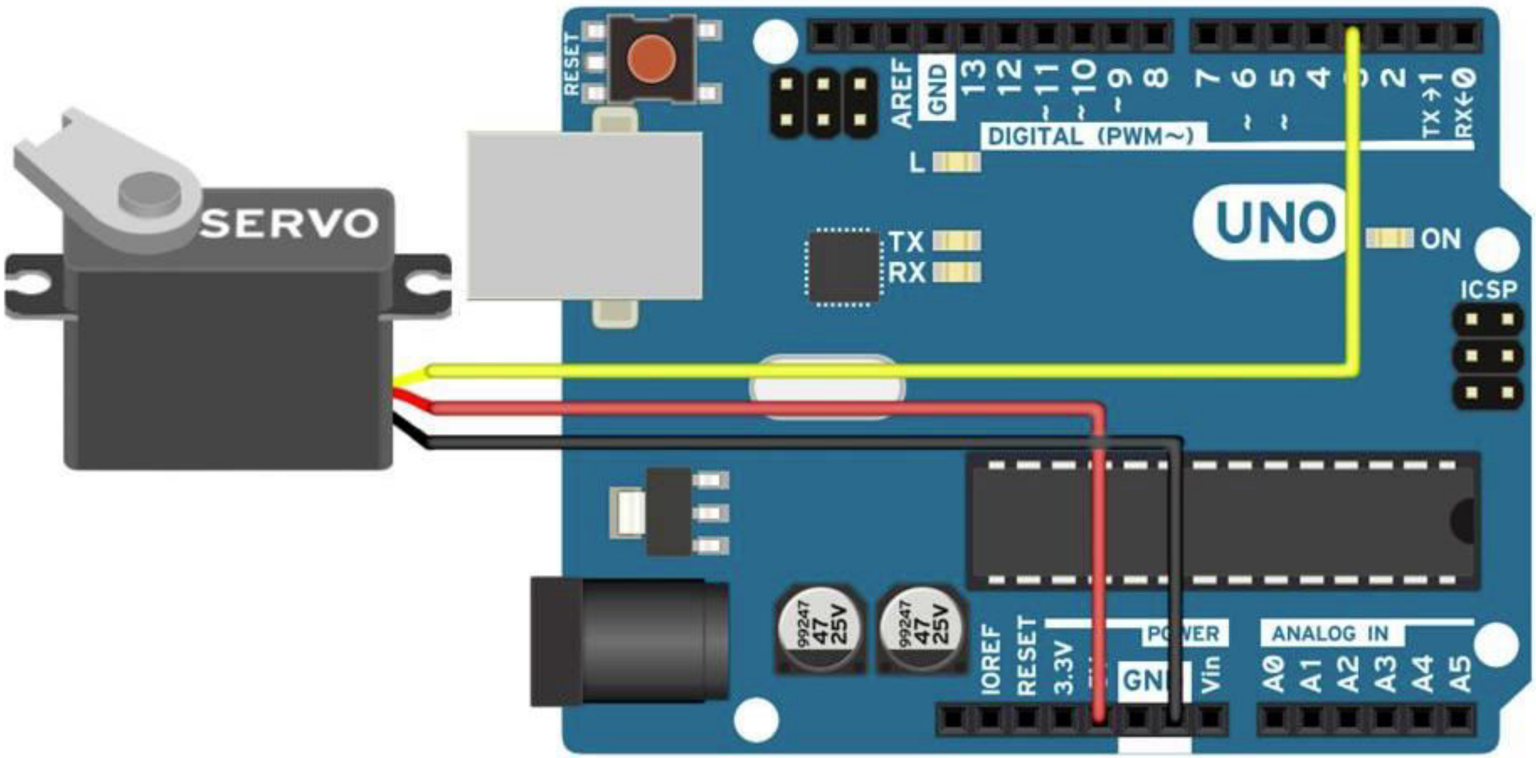


Έλεγχος servomotor




Minimum Pulse
Pulse Width 1 ms
0
Middle Position
Pulse Width 1.5 ms
90
Maximum Pulse
Pulse Width 2 ms
180

Σύνδεση servo motor στο Arduino



```
// Include the Servo library
 #include <Servo.h>
// Declare the Servo pin
 int servoPin = 3;
// Create a servo object Servo Servo1;
 void setup() {
// We need to attach the servo to the used pin number
 Servo1.attach(servoPin);
}
 void loop(){
// Make servo go to 0 degrees
 Servo1.write(0);
 delay(1000);
// Make servo go to 90 degrees
 Servo1.write(90);
 delay(1000);
// Make servo go to 180 degrees
 Servo1.write(180);
 delay(1000);
}
```

Servo Micro 1.8kg.cm Metal Gears (Feetech FS90MG)

Operating Speed:
- 0.12sec/60degree (4.8V)
- 0.10sec/60degree (6V)

Stall Torque:
- 1.5kg.cm/20.87oz.in(4.8V)
- 1.8kg.cm/25.04oz.in(6V)

Operating Voltage: 4.8V~6V
Control System: Analog
Direction: CCW
Operating Angle: 120degree
Required Pulse: 900us-2100us
Bearing Type: None
Gear Type: Metal
Motor Type: Metal

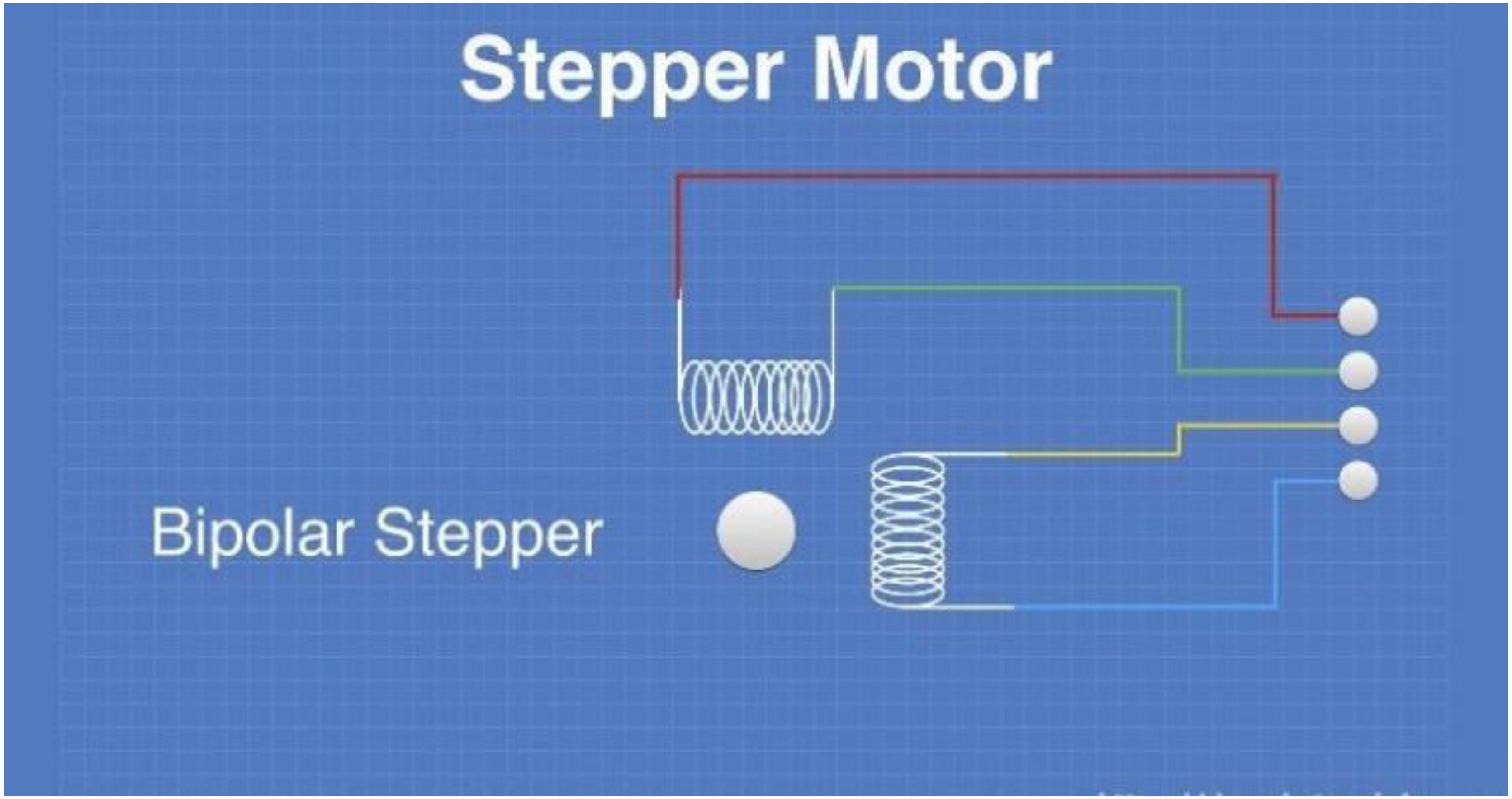
Stepper Motor

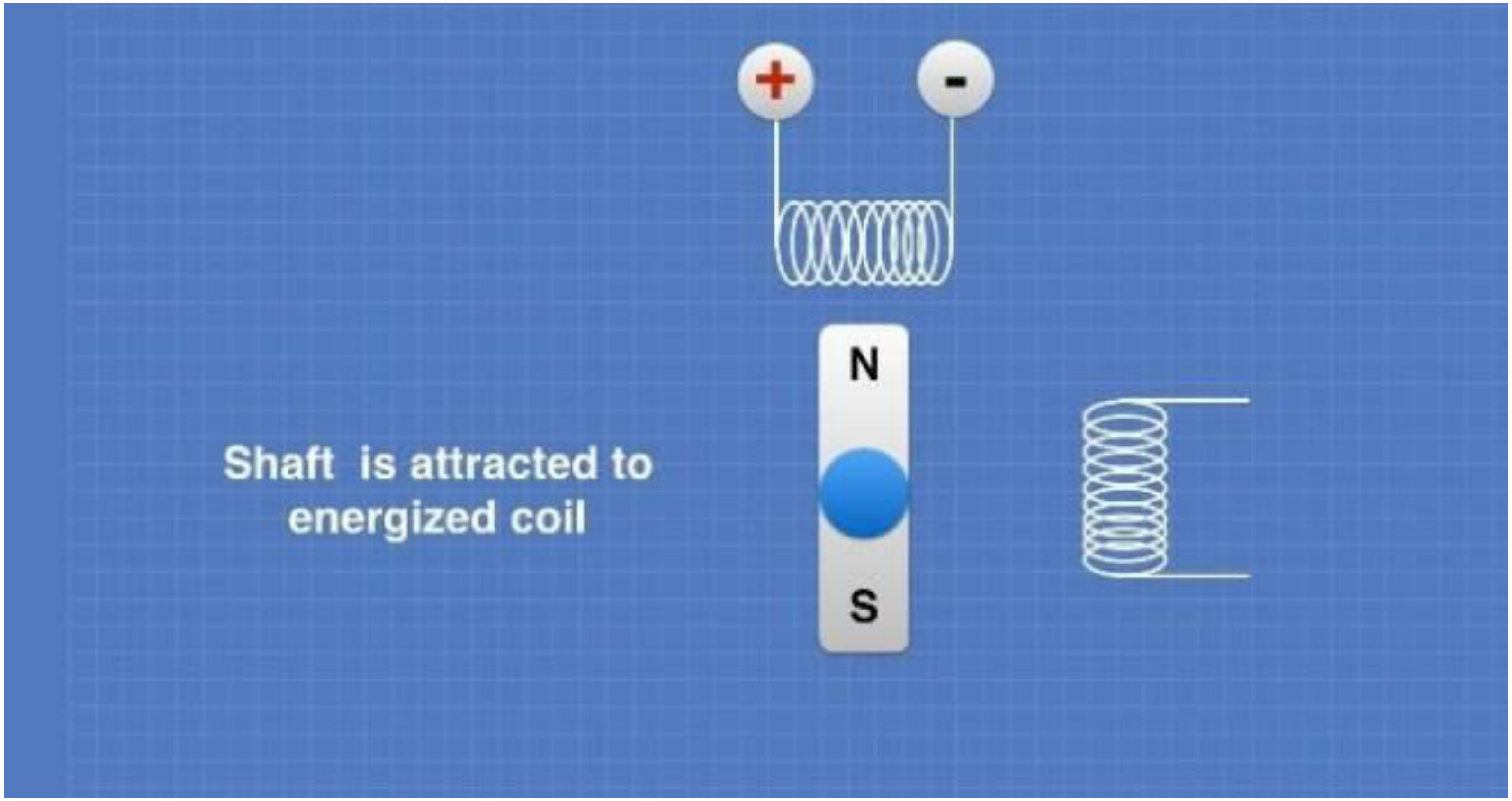
A stepper motor (or step motor) is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application.

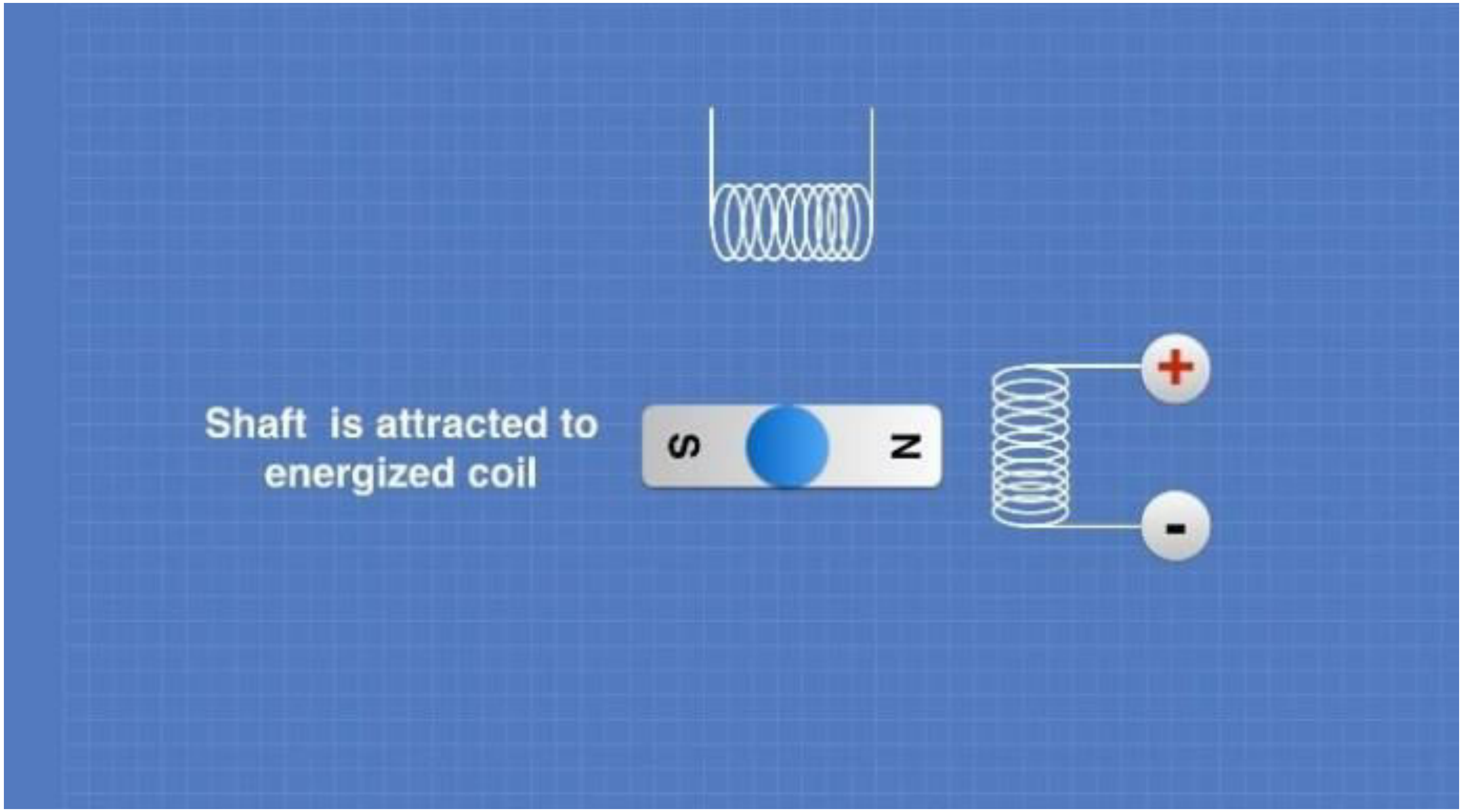
Computer controlled stepper motors are a type of motion-control positioning system. They are typically digitally controlled as part of an open loop system for use in holding or positioning applications.

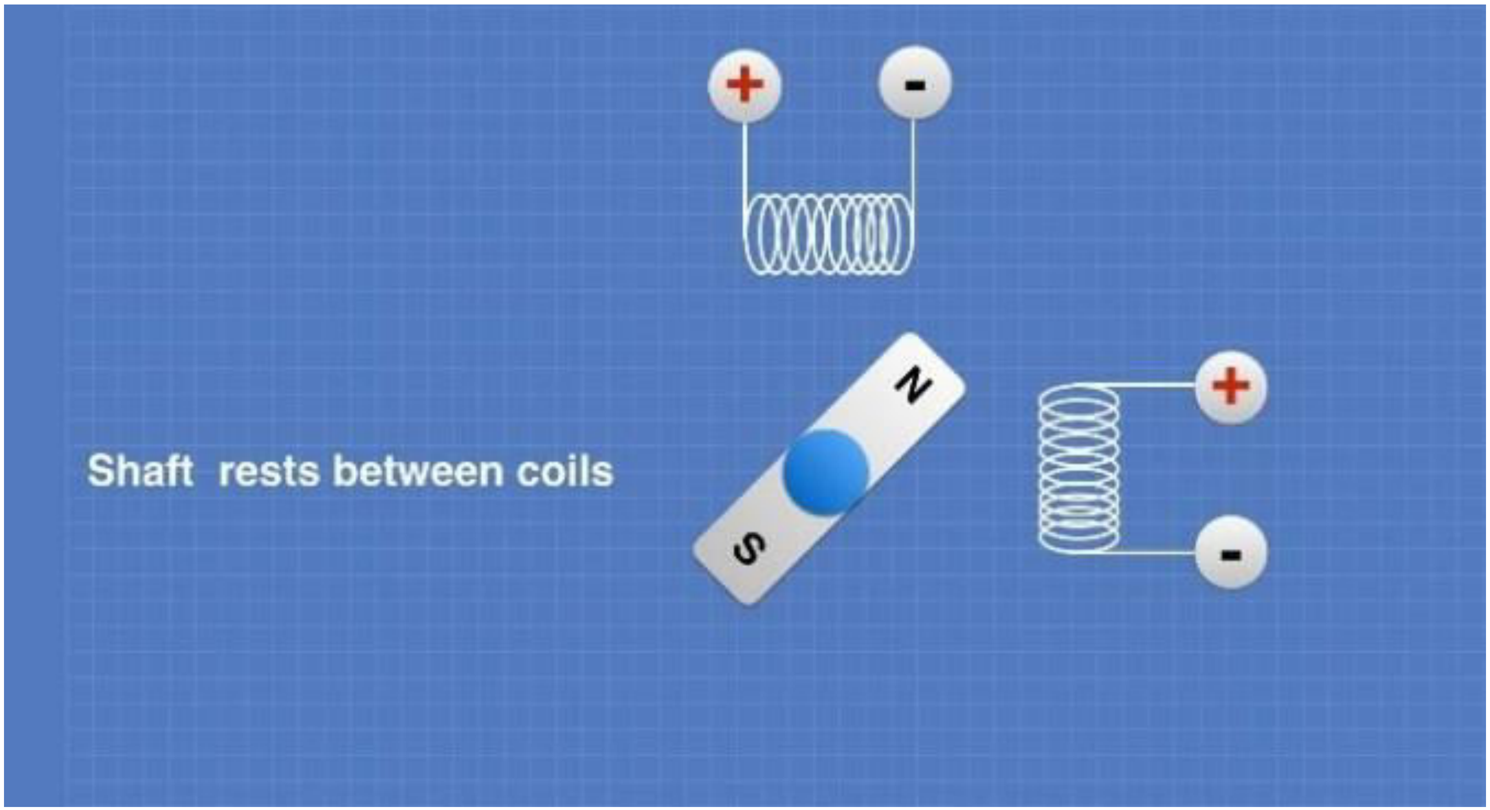
Stepper motor applications

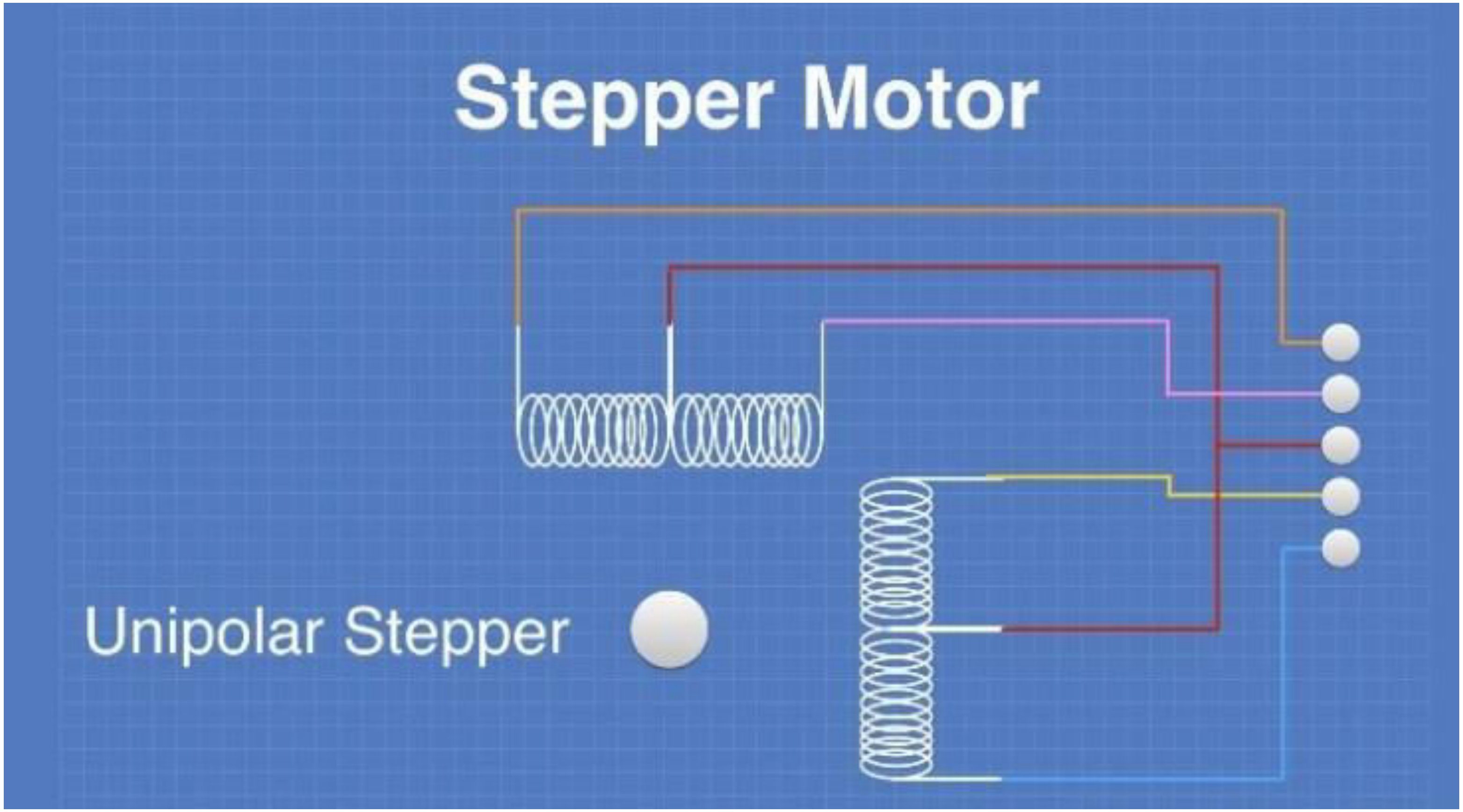
Commercially, stepper motors are used in floppy disk drives, flatbed scanners, computer printers, plotters, slot machines, image scanners, compact disc drives, intelligent lighting, camera lenses, CNC machines and, more recently, in 3D printers.
In the field of lasers and optics they are frequently used in precision positioning equipment such as linear actuators, linear stages, rotation stages, goniometers, and mirror mounts. Other uses are in packaging machinery, and positioning of valve pilot stages for fluid control systems.

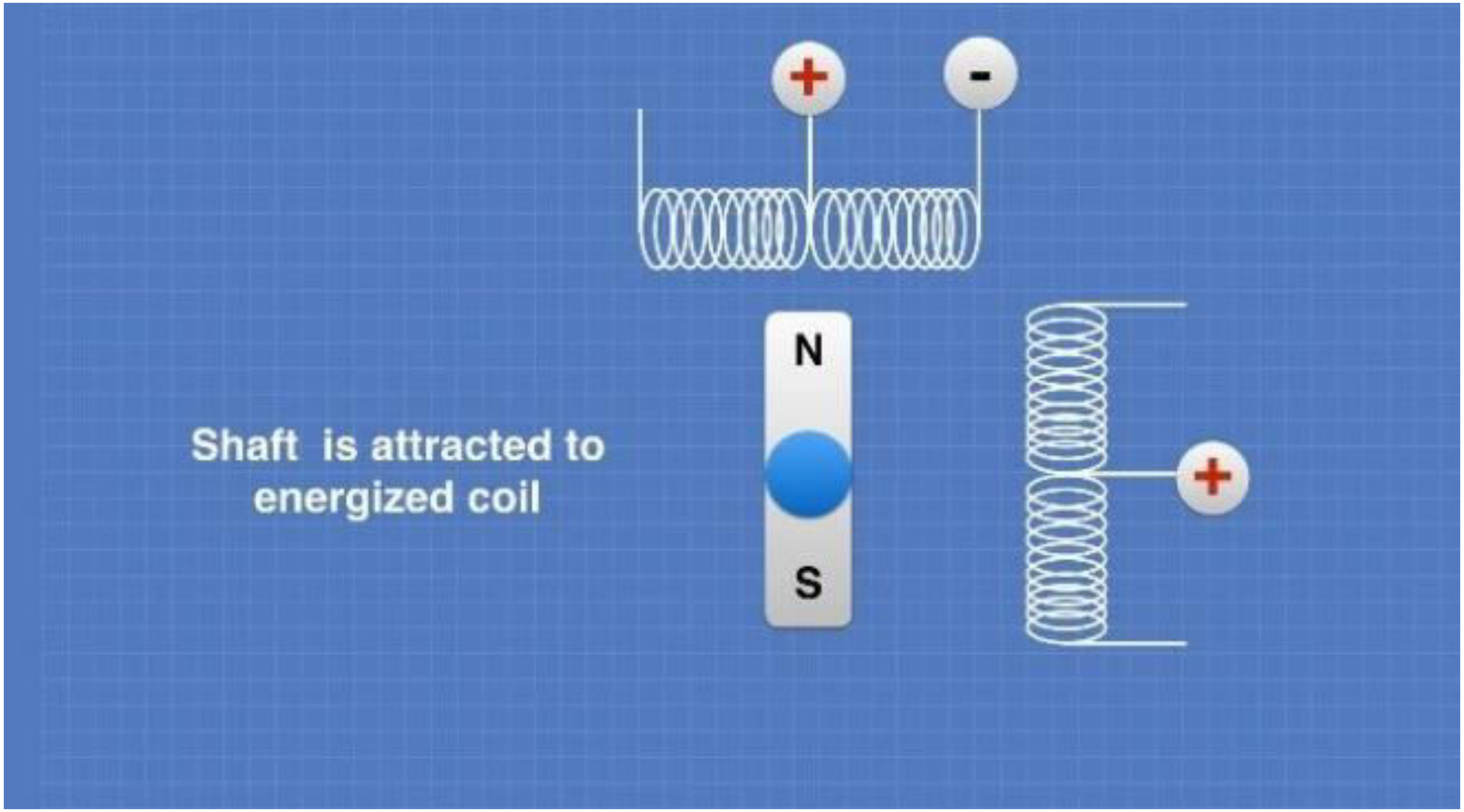

Stepper Motor
Bipolar Stepper


+
-
N
S
Shaft is attracted to
energized coil

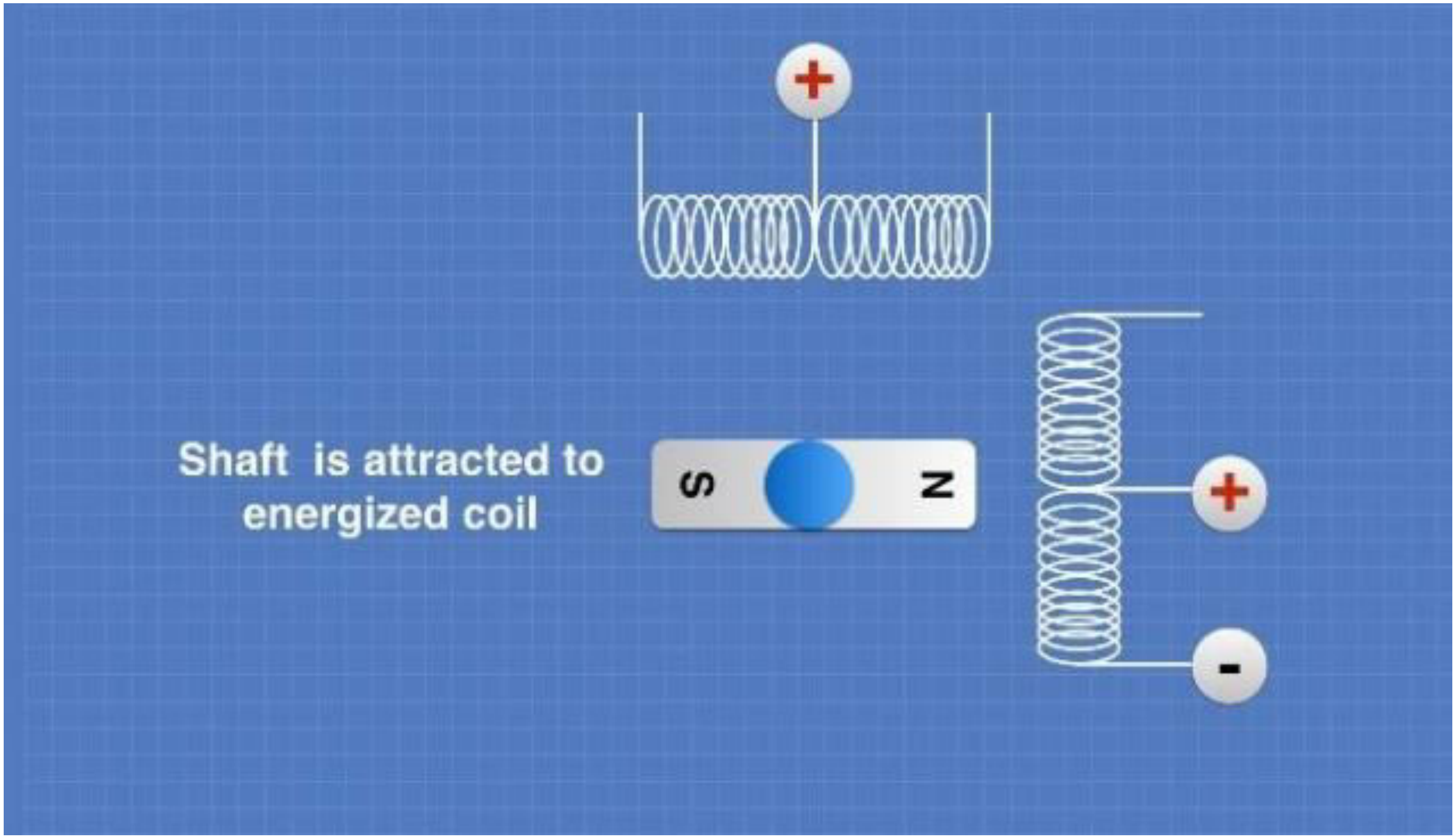

Shaft is attracted to energized coil
S
N
+
-

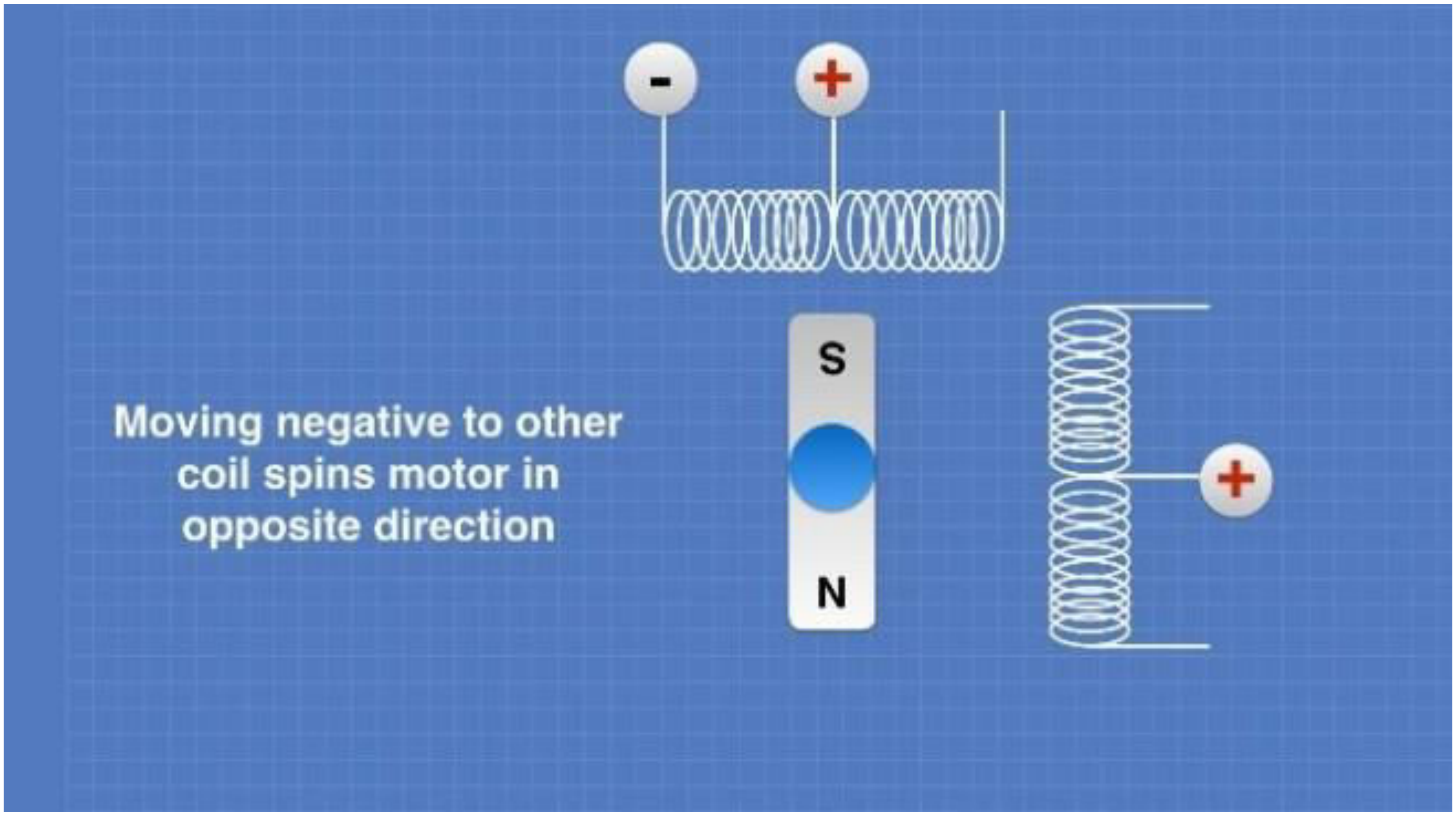

Shaft rests between coils
+
-
N
S
+
-


Stepper Motor
Unipolar Stepper



+
-
N
S
+
Shaft is attracted to
energized coil


Shaft is attracted to energized coil
S
N
+
+
-


-
+
S
Moving negative to other coil spins motor in opposite direction
N
+

28-BYJ-48 Stepper motor

Rated voltage: 5V DC

Number of pole: 4

Speed variation ratio: 1/64

Stride angle: 5.625°/64

DC resistance: 200 Ohm±7% (25°C)

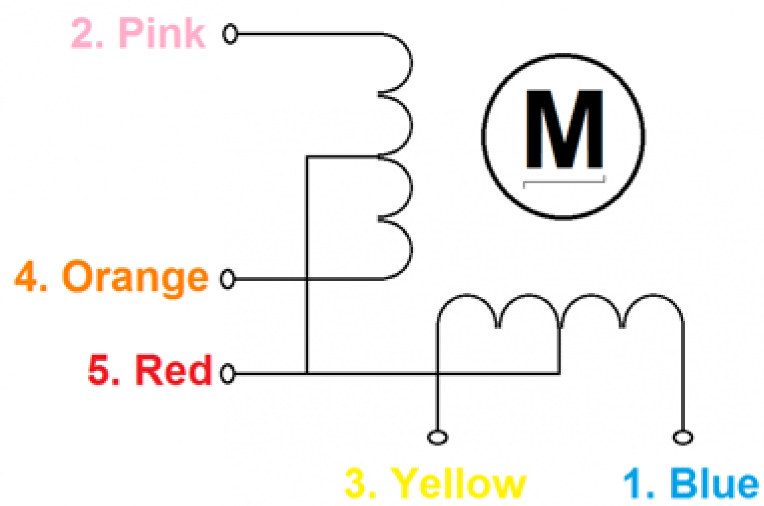
Idle in-traction frequency: >600Hz

Idle out-traction frequency: >1000Hz

In-traction Torque: 0.35 kg.cm (34.3mN.m)

Self-positioning Torque: 0.35 kg.cm (34.3mN.m)

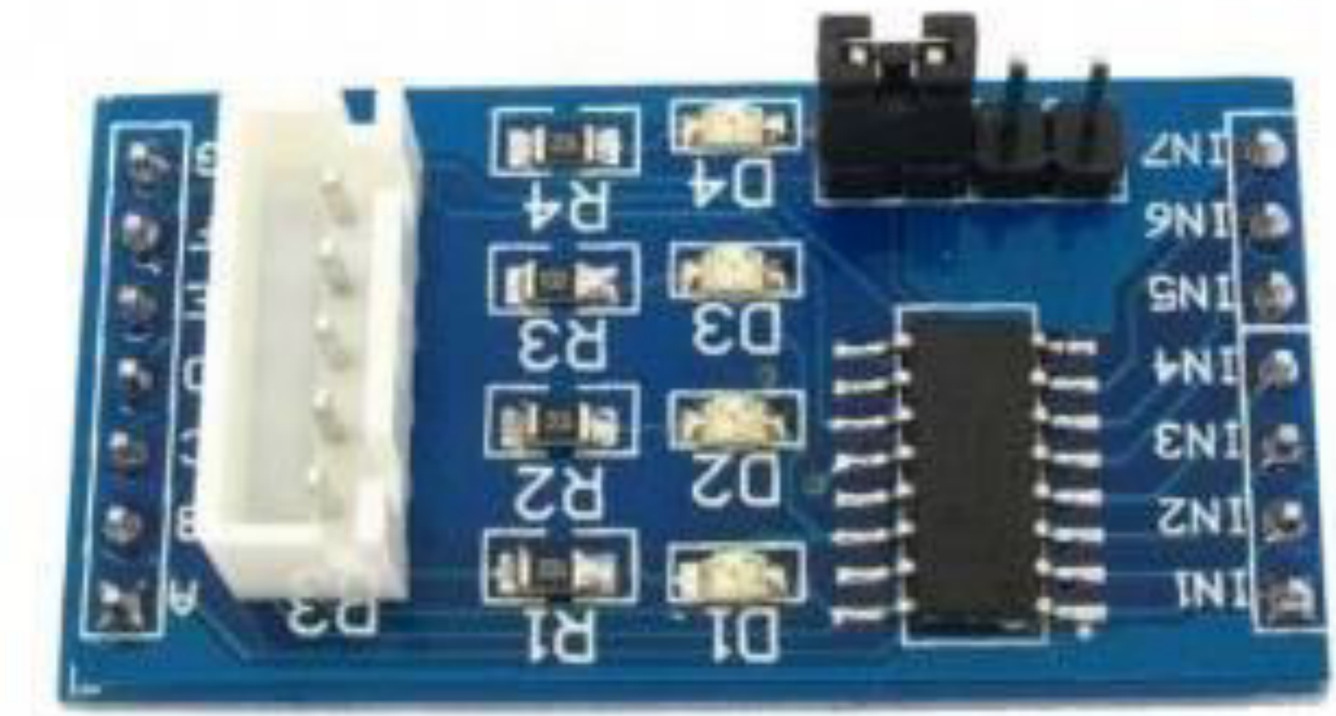
Motor Type	Unipolar stepper motor
Connection Type	5 Wire Connection (to the motor controller)
Voltage	5-12 Volts DC
Frequency	100 Hz
Step mode	Half-step mode recommended (8 step control signal sequence)
Step angle	**Half-step mode: 8 step control signal sequence (recommended)** 5.625 degrees per step / 64 steps per one revolution of the internal motor shaft. **Full Step mode: 4 step control signal sequence** 11.25 degrees per step / 32 steps per one revolution of the internal motor shaft
Gear ratio	Manufacturer specifies **64:1**.
Wiring to the ULN2003 controller	A (Blue), B (Pink), C (Yellow), D (Orange), E (Red, Mid-Point)
Weight	30g



SWITCHING SEQUENCE

Lead Wire Color	---> CW Direction (1-2 Phase)							
	1	2	3	4	5	6	7	8
4 Orange	-	-						-
3 Yellow		-	-	-				
2 Pink				-	-	-		
1 Blue						-	-	-

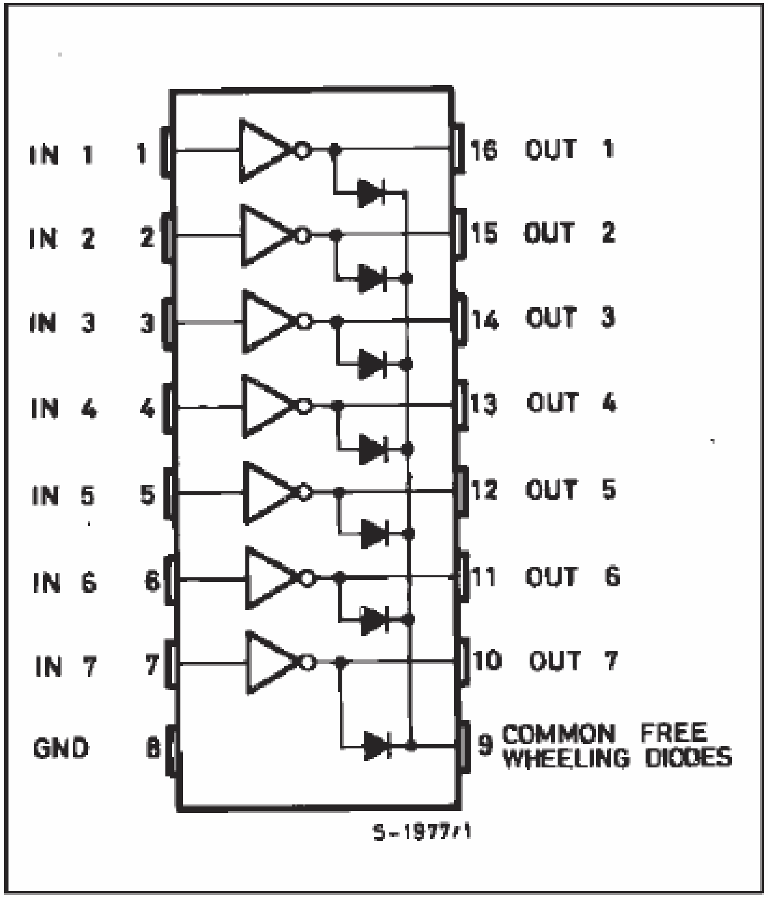
Stepper motor Driver



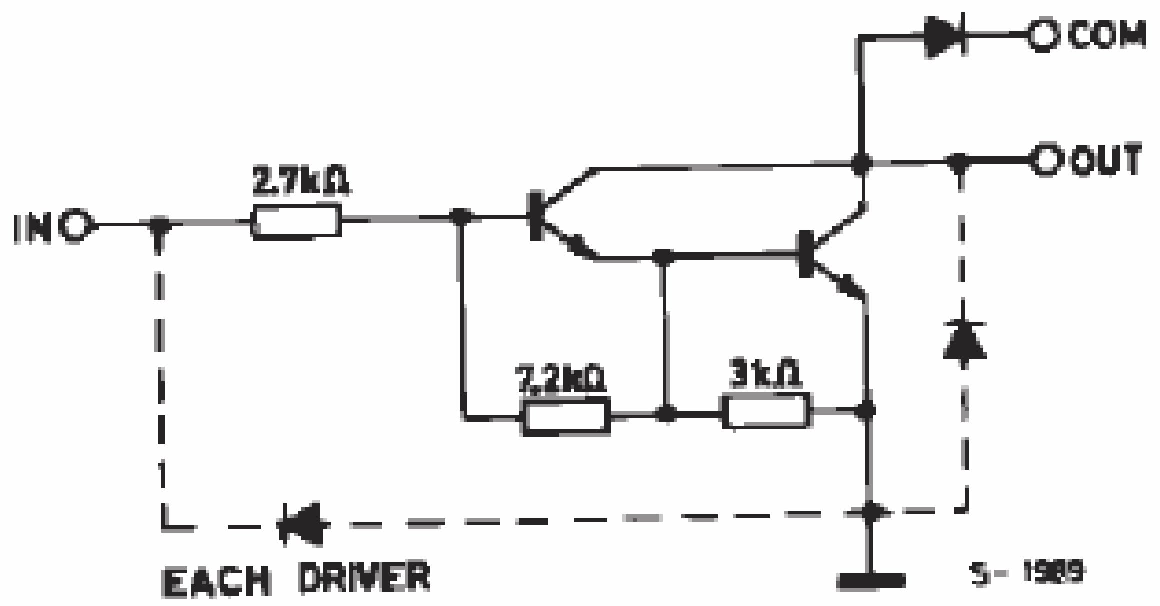
Stepper motor Driver

ULN2001A	General Purpose, DTL, TTL, PMOS, CMOS
ULN2002A	14-25V PMOS
ULN2003A	5V TTL, CMOS
ULN2004A	6–15V CMOS, PMOS

PIN CONNECTION

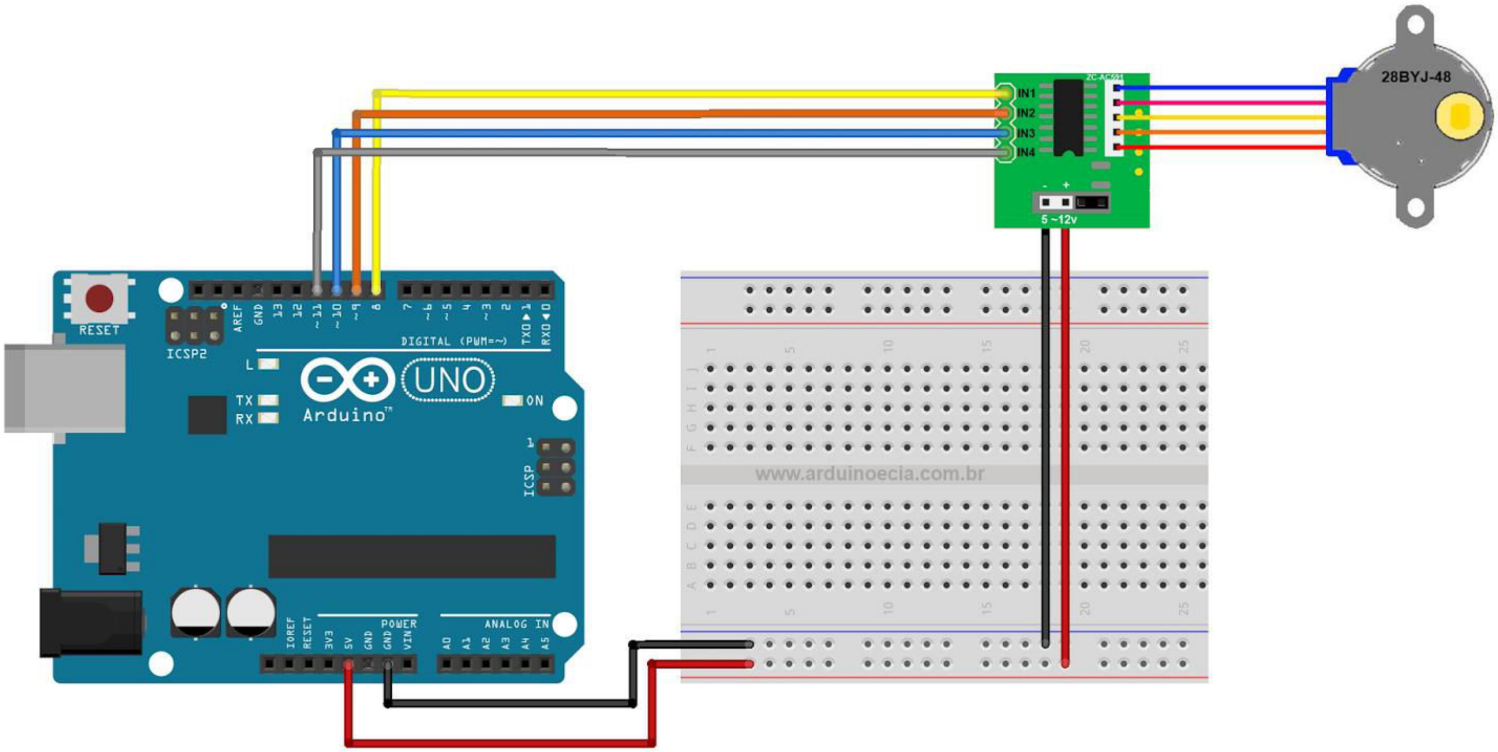


Stepper motor Driver

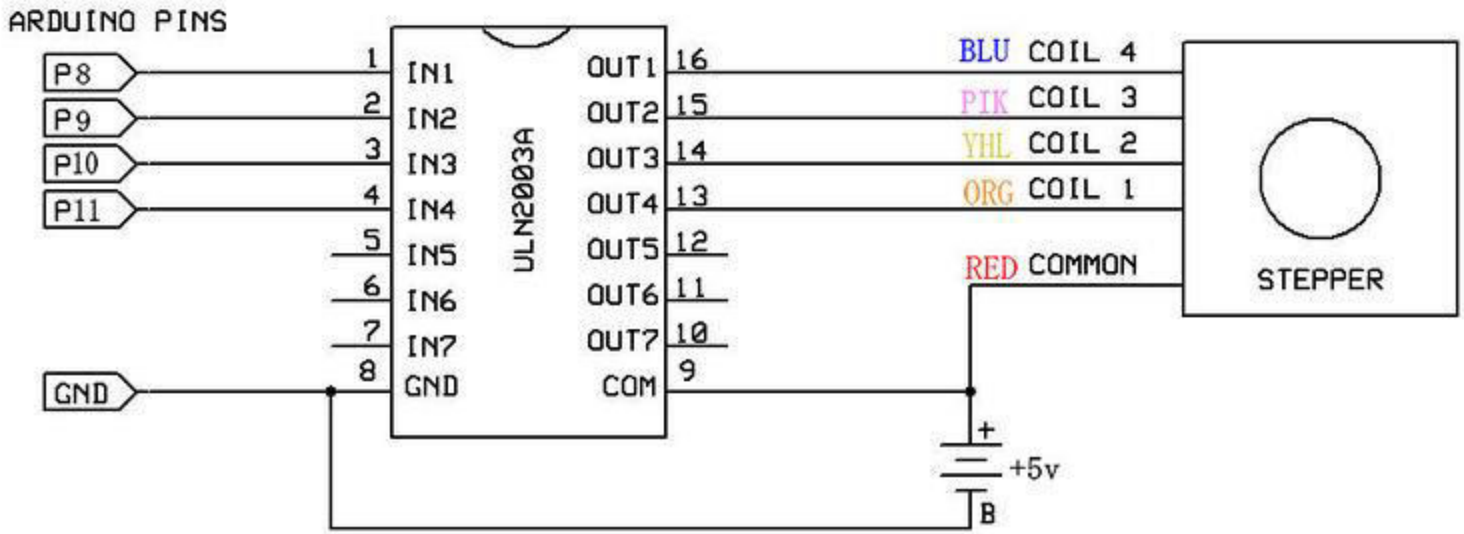


Series ULN-2003A
(each driver)

Σύνδεση Arduino με stepper motor



Σύνδεση Arduino με stepper motor



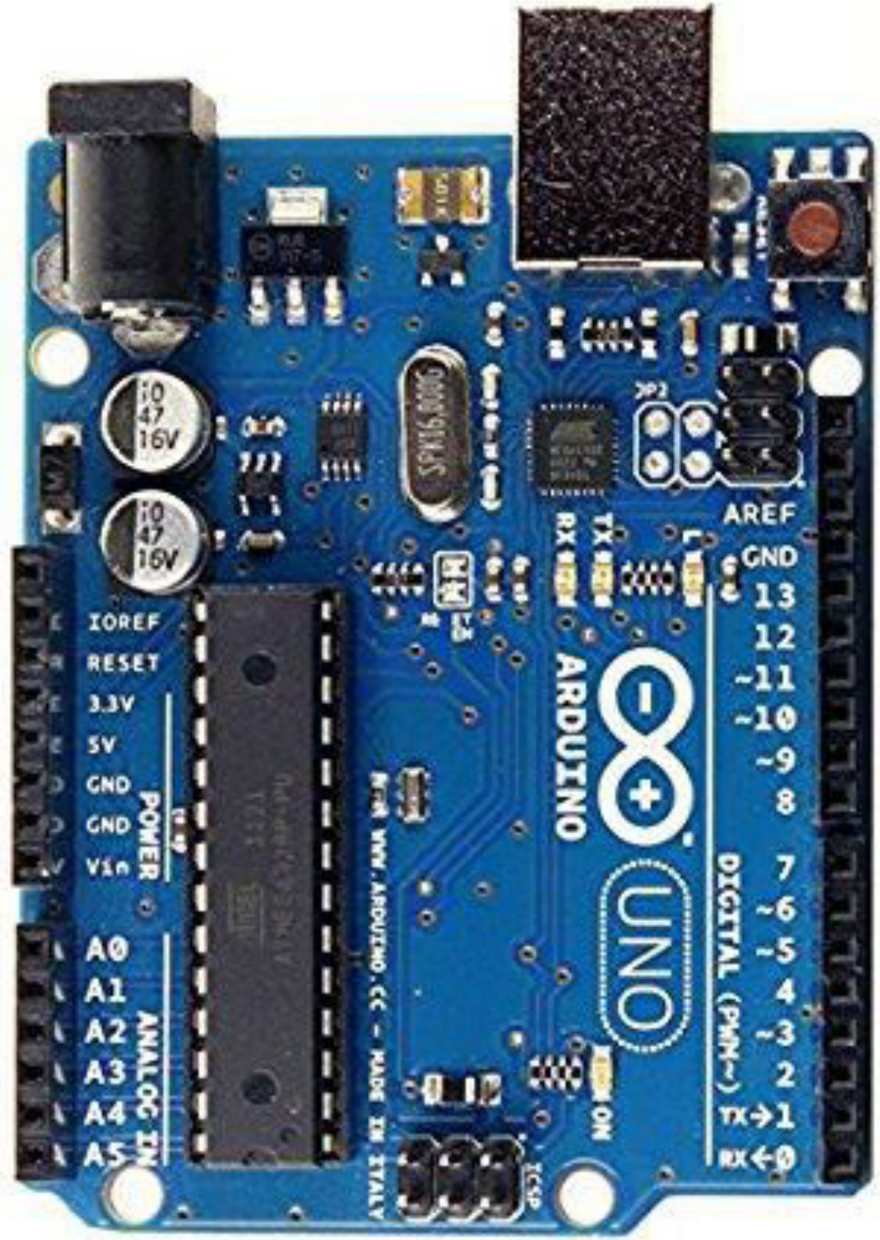
An important data to notice is the **Stride Angle: 5.625°/64.** This means that the motor when operates in 8-step sequence will move 5.625 degree for each step and it will take 64 steps (5.625*64=360) to complete one full rotation.

In Arduino we will be operating the motor in 4-step sequence so the stride angle will be 11.25° since it is 5.625°(given in datasheet) for 8 step sequence it will be 11.25° (5.625*2=11.25).
Steps per revolution = 360/step angle
Here, 360/11.25 = **32 steps per revolution.**

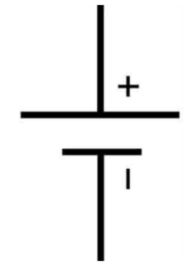
```
/ Arduino stepper motor control code
#include <Stepper.h> // Include the header file
// change this to the number of steps on your motor
#define STEPS 32
// create an instance of the stepper class
// using the steps and pins
Stepper stepper(STEPS, 8, 10, 9, 11);
int val = 0;
void setup() {
  Serial.begin(9600);
  stepper.setSpeed(200);
}
```

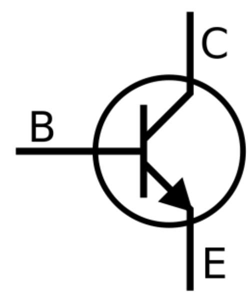
```
void loop() {
  if (Serial.available()>0)
  {
    val = Serial.parseInt();
    stepper.step(val);
    Serial.println(val); //for debugging
  }
}
```

8.1. Στα κυκλώματα που δίδονται στην συνέχεια να γίνουν οι κατάλληλες συνδέσεις ώστε να γίνεται έλεγχος της ταχύτητας του βηματικού κινητήρα με το Arduino.


ARDUINO
UNO
AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TX→1
RX←0
DIGITAL (PWM~)
RX
TX
L
IOREF
RESET
3.3V
5V
GND
GND
Vin
POWER
A0
A1
A2
A3
A4
A5
ANALOG IN
ICSP
ON
WWW.ARDUINO.CC - MADE IN ITALY


M
M1
+
-


+


C
B
E