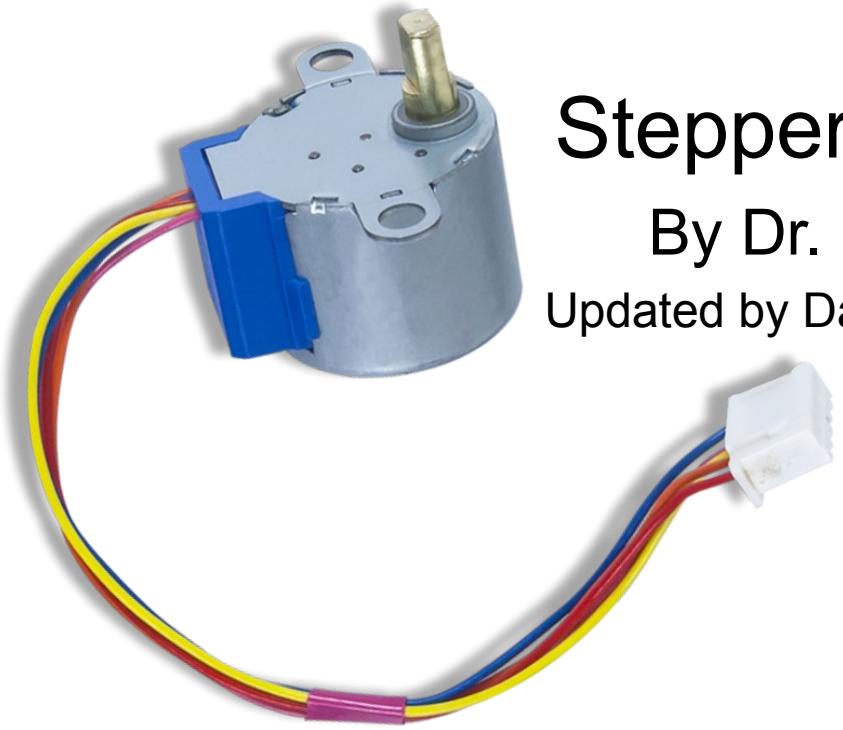
Lecture 8



Stepper Motors

By Dr. Min He

Updated by David Mahakian

Outline

- Introducing three types of motors
- Stepper motors and how they work
- References

Motors

- DC Motors
  - Fast, continuous rotation motors – Used for anything that needs to spin at a high RPM e.g. car wheels, fans, etc.
- Servo Motors
  - Fast, high torque, accurate rotation within a limited angle. Suited for robotic arms/legs or rudder control etc.
- Stepper Motors
  - Slow, precise rotation, easy set up & control. Suited for 3D printers and similar devices where position is fundamental.

Stepper Motors

- Advantages
  - Stable. Can drive a wide range of frictional and inertial loads.
  - Needs no feedback. The motor is also the position transducer.
  - Inexpensive relative to other motion control systems.
  - Standardized frame size and performance.
  - Plug and play. Easy to setup and use.
  - Safe. If anything breaks, the motor stops.
  - Long life. Bearings are the only wear-out mechanism.
  - Excellent low speed torque. Can drive many loads without gearing.
  - Excellent repeatability. Returns to the same location accurately.
  - Overload safe. Motor cannot be damaged by mechanical overload.

Stepper Motors

- Disadvantages
  - Low efficiency. Motor draws substantial power regardless of load.
  - Torque drops rapidly with speed (torque is the inverse of speed).
  - Low accuracy. 1:200 at full load, 1:2000 at light loads.
  - Prone to resonances. Requires microstepping to move smoothly.
  - No feedback to indicate missed steps.
  - Low torque to inertia ratio. Cannot accelerate loads very rapidly.
  - Motor gets very hot in high performance configurations.
  - Motor will not "pick up" after momentary overload.
  - Motor is audibly very noisy at moderate to high speeds.
  - Low output power for size and weight.

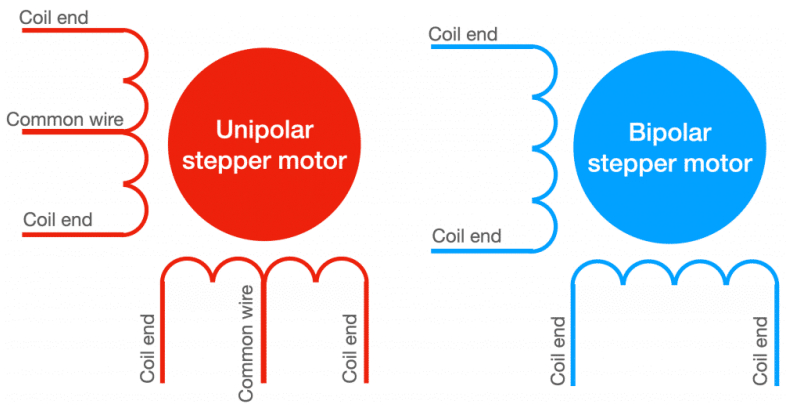
Bipolar vs. Unipolar Stepper Motors

Bipolar Stepper Motor:

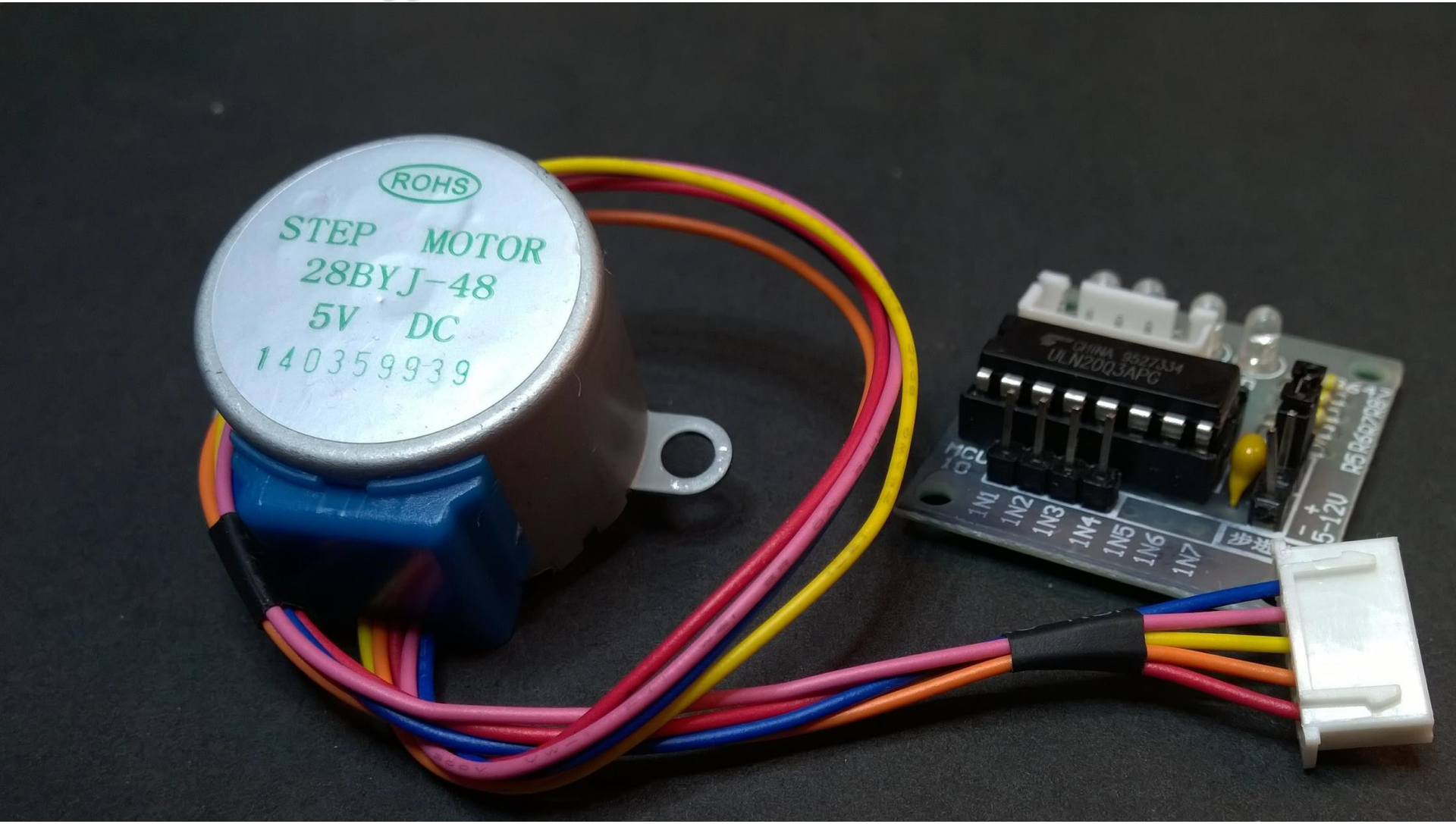
- A bipolar stepper motor needs four control lines, and
- its speed and angle can be adjusted according to the size and frequency of the control signal;
- have more torque and are more efficient.
- more complicated to drive because they need reverse current.

Unipolar Stepper Motors:

- needs only two control lines, and
- its speed and angle can be adjusted by the pulse frequency of the control signal.

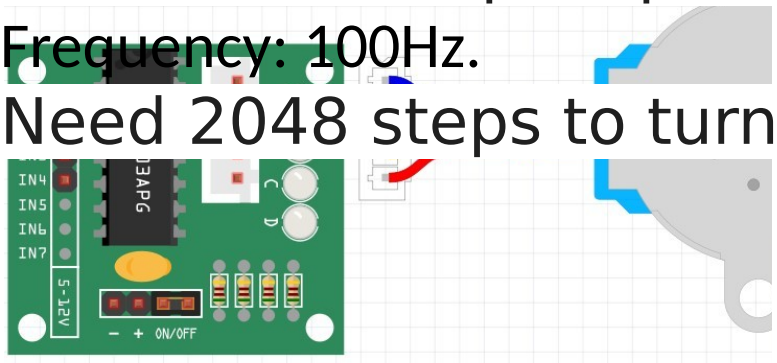


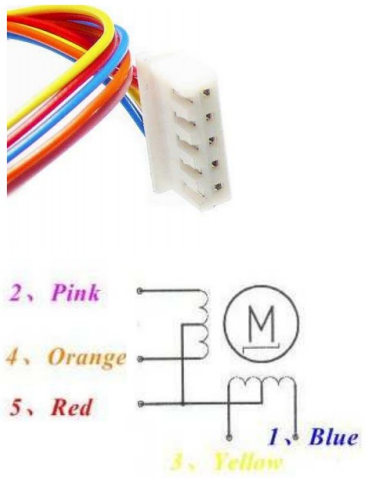
THE 28byj-48 Motor and ULN2003 Drive



How 28BYJ-48 Stepper

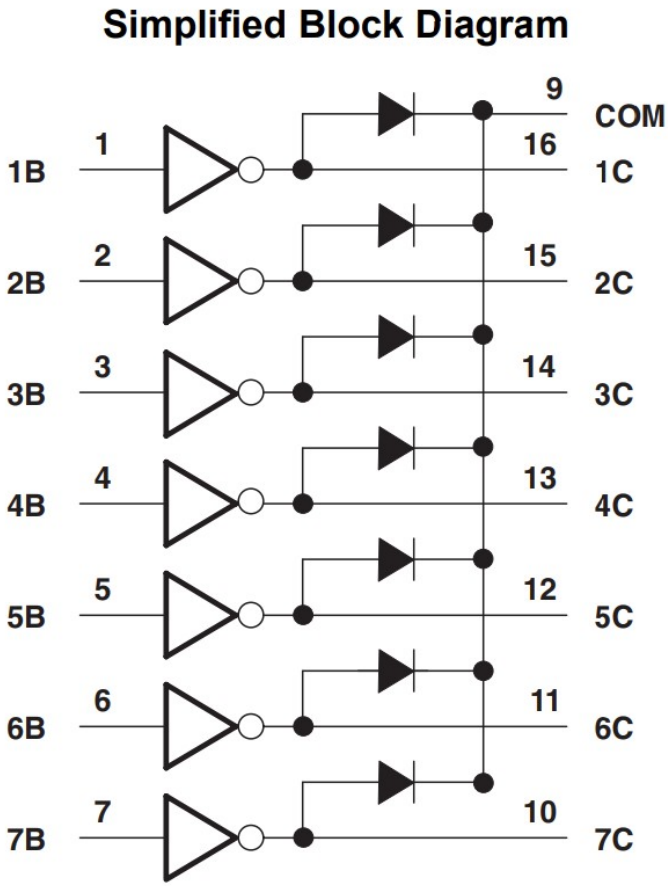
- Unipolar stepper motor
- One end of the coil and the center tap form a Phase.
- 28BYJ-48 has a total of four phases.
- The red wire is always pulled HIGH, so when the other lead is pulled LOW, the phase is energized.
- The stepper motor rotates only when the phases are energized in a logic known as a step sequence.
- Frequency: 100Hz.
- Need 2048 steps to turn 360 de



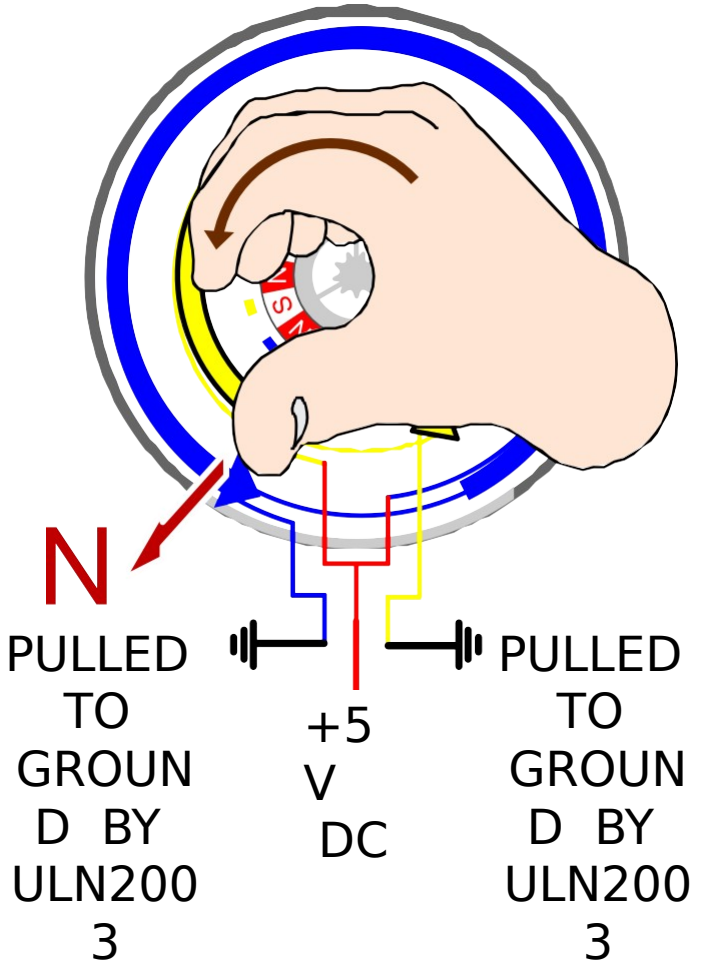


ULN2003 Driver

- Consists of an array of seven NPN Darlington transistors capable of 500 mA, 50 V output.
- Provides proper current amplification required by the load.



28BYJ-48 Motor Electormagnetics

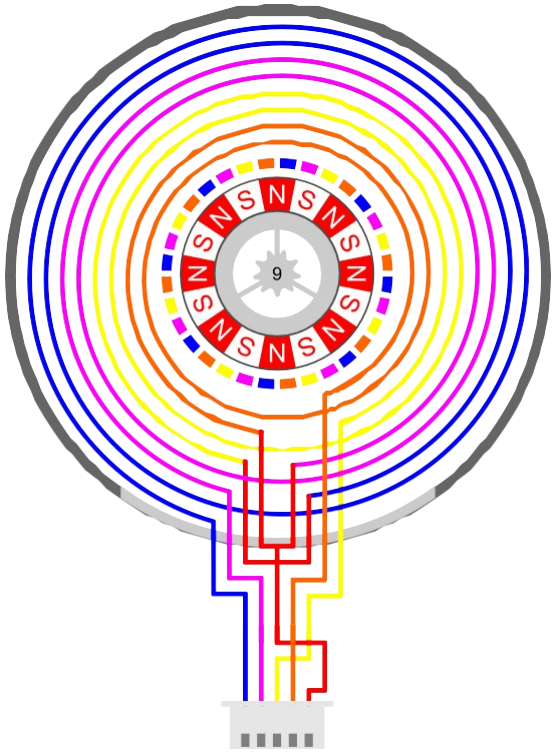


The 28BYJ-48 is a Unipolar Stepper Motor (as opposed to Bipolar).

With Unipolar motors, you don't need to change the polarity of the voltages on any give lead. That means that you don't need an H-Bridge to reverse the polarity.

The common center taps are connected to +**5VDC**. You then use some circuitry (the ULN2003 Array in this case) to pull the appropriate coil ends to ground to energize their respective half of the coil.

28BYJ-48 motor electrOmagnetics



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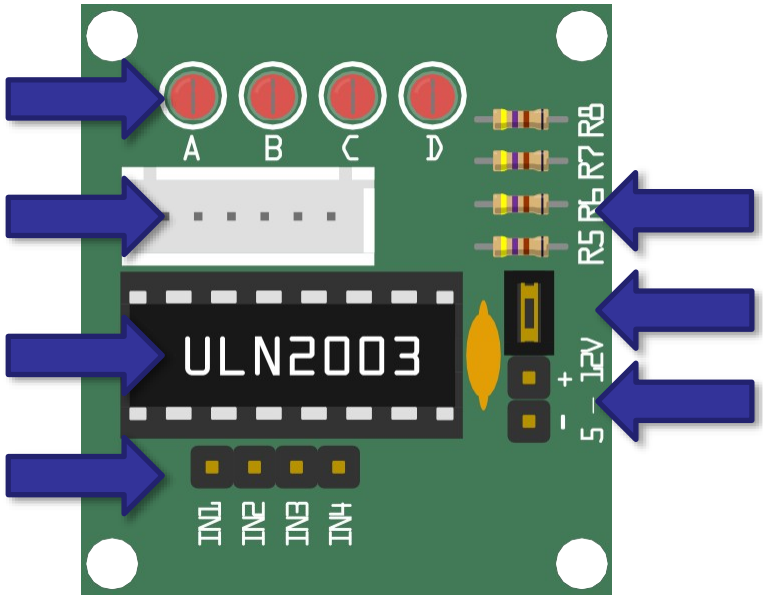
ULN2003 Darlington Array Driver



The ULN2003 houses an array of 7 Darlington Pairs

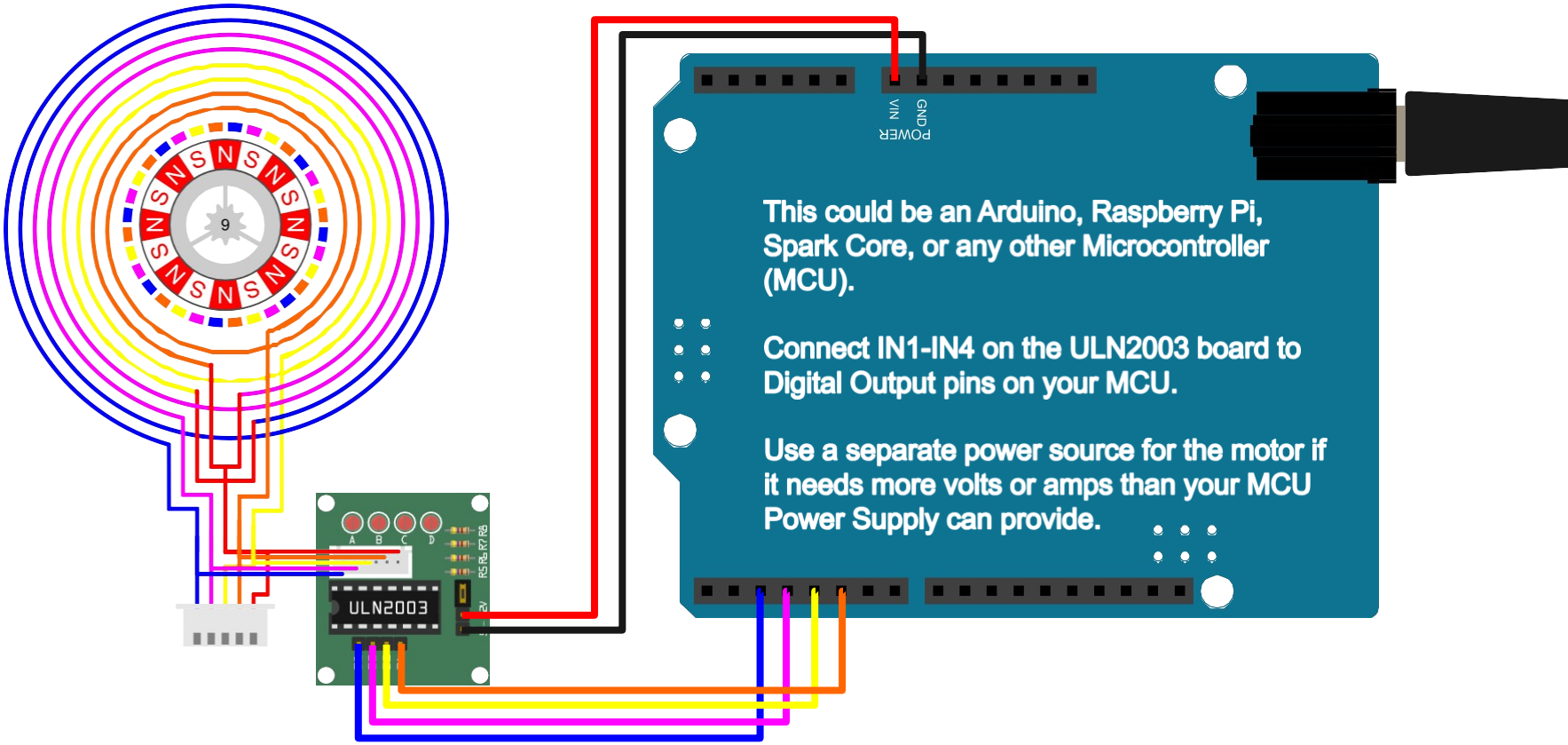
A Darlington Pair is basically a pair of transistors where the second transistor amplifies the output current of the first transistor.

This gives you a higher current gain than a single transistor and allows the low voltage, low current output of a microcontroller to drive the higher current stepper motor.

The board includes convenient IO and power headers, as well as coil power indicator LEDs

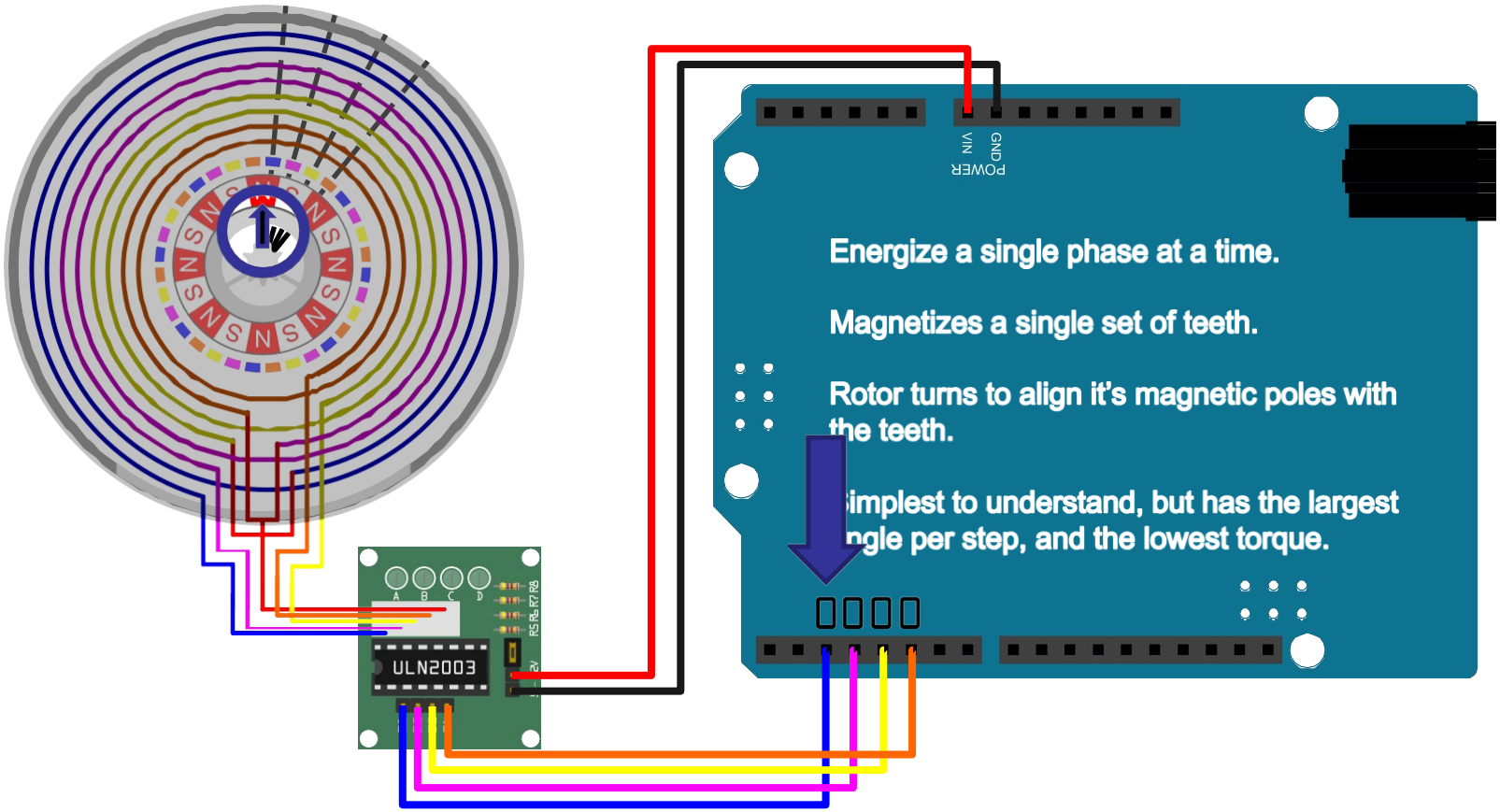
The ULN2003 actually supports seven input/output pairs, but the 28BYJ-48 only needs four (four phases) so only four pins are exposed.

Connecting it all up...



WAVE DRIVING…

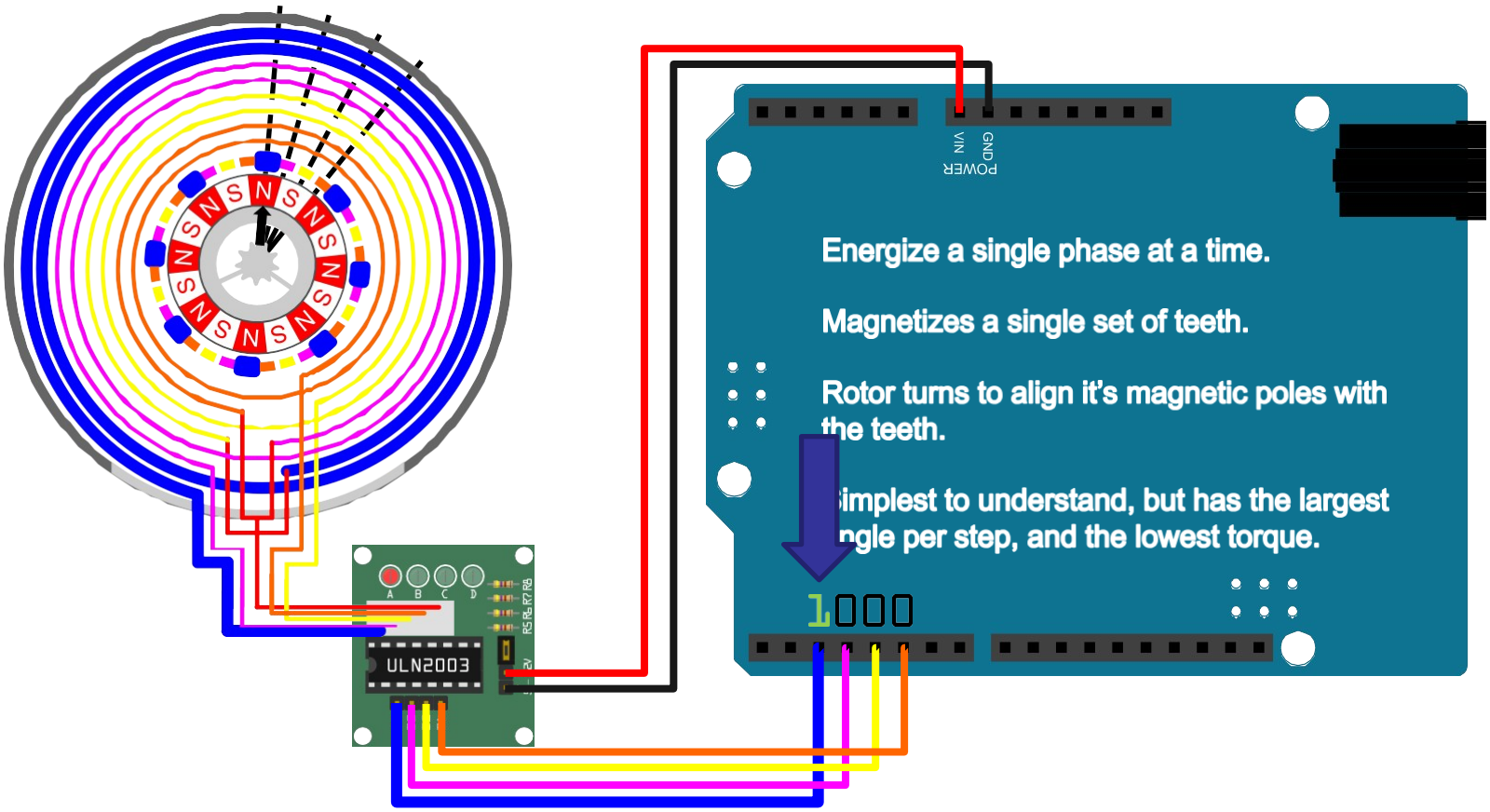
11.25° Step Angle – 32 Steps needed for a single rotor rotation of 360°



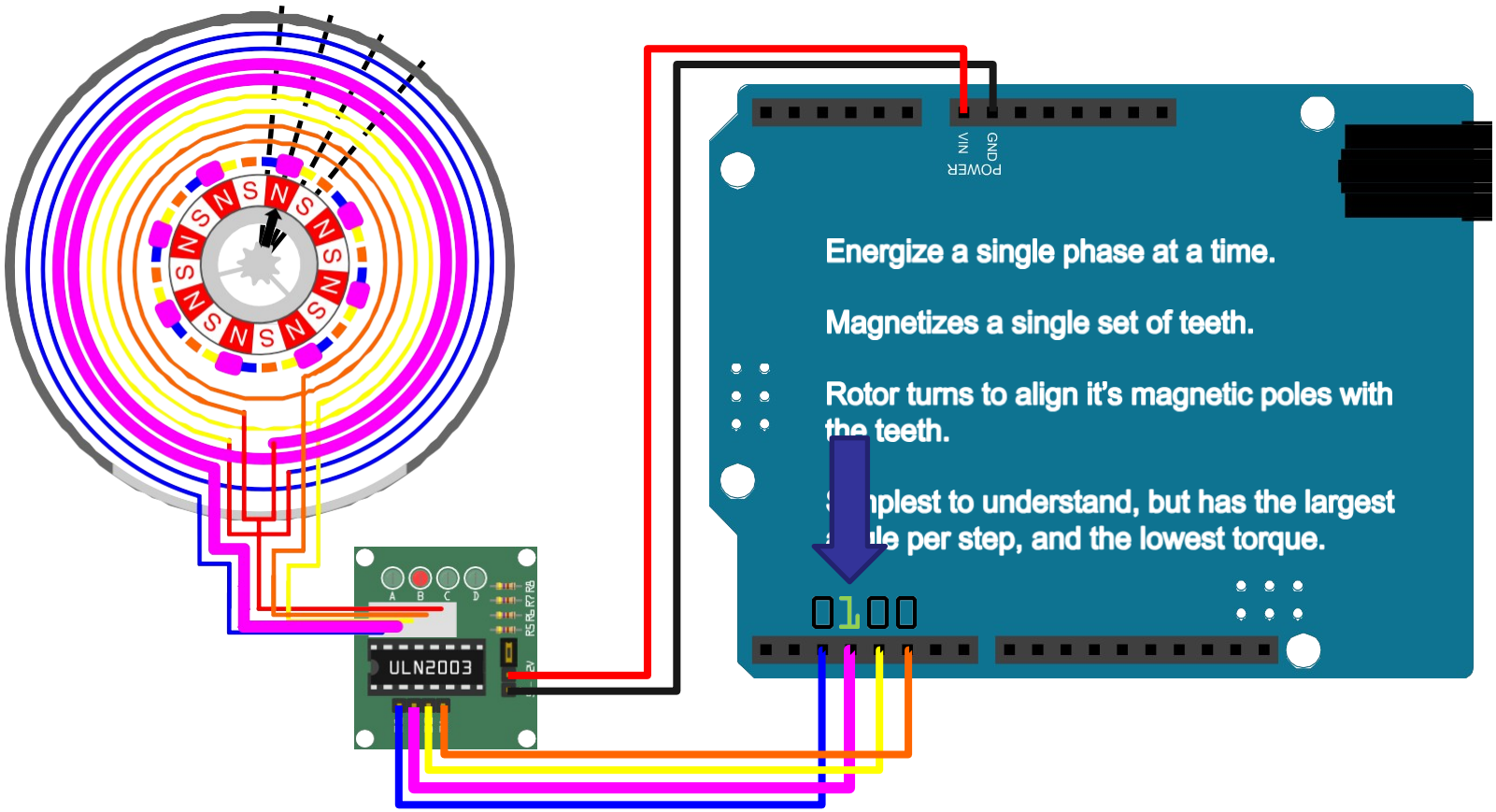
Wave Drive Step Sequence

Steps	A	B	C	D
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

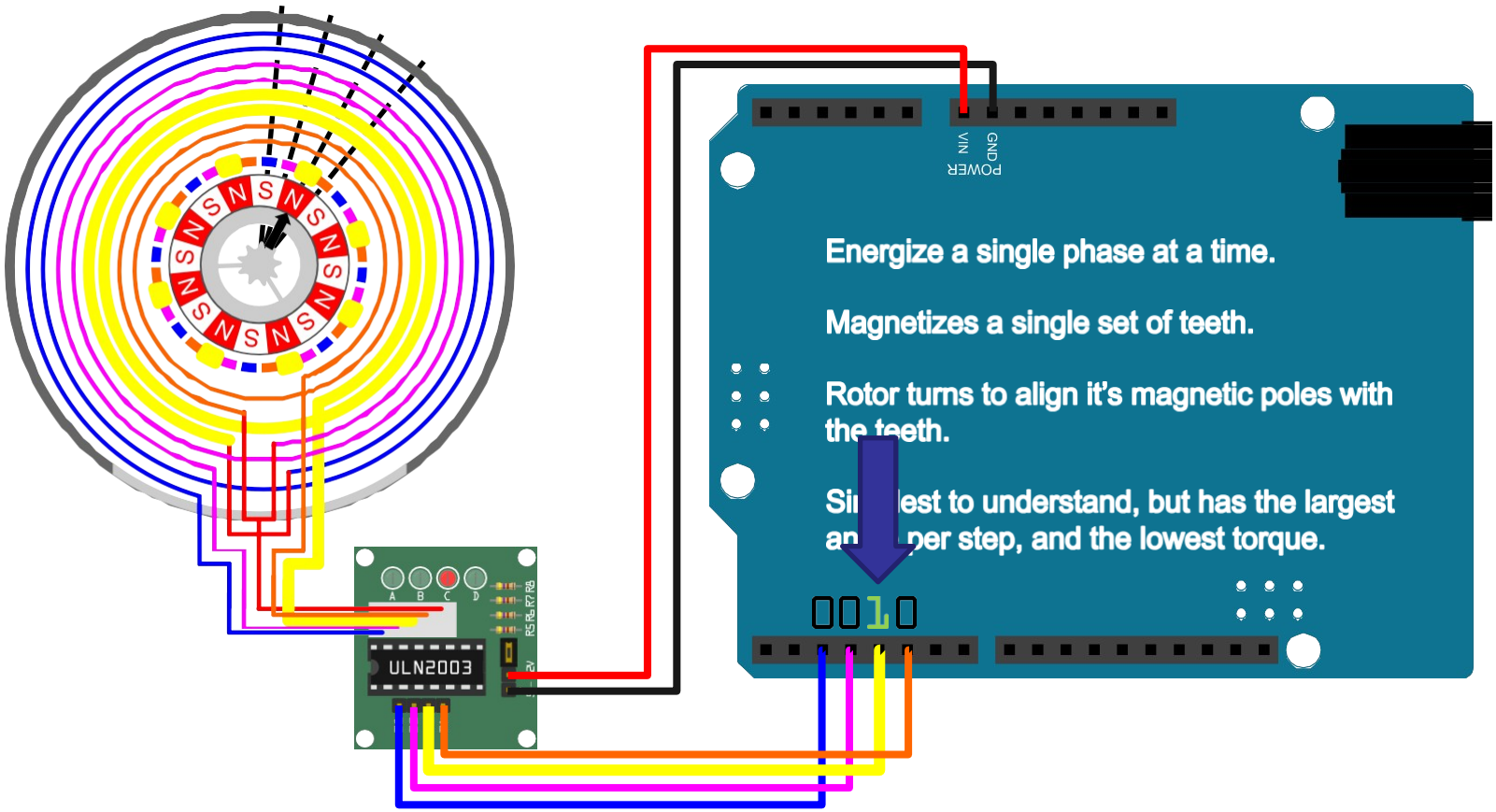
WAVE DRIVING – STEP 1



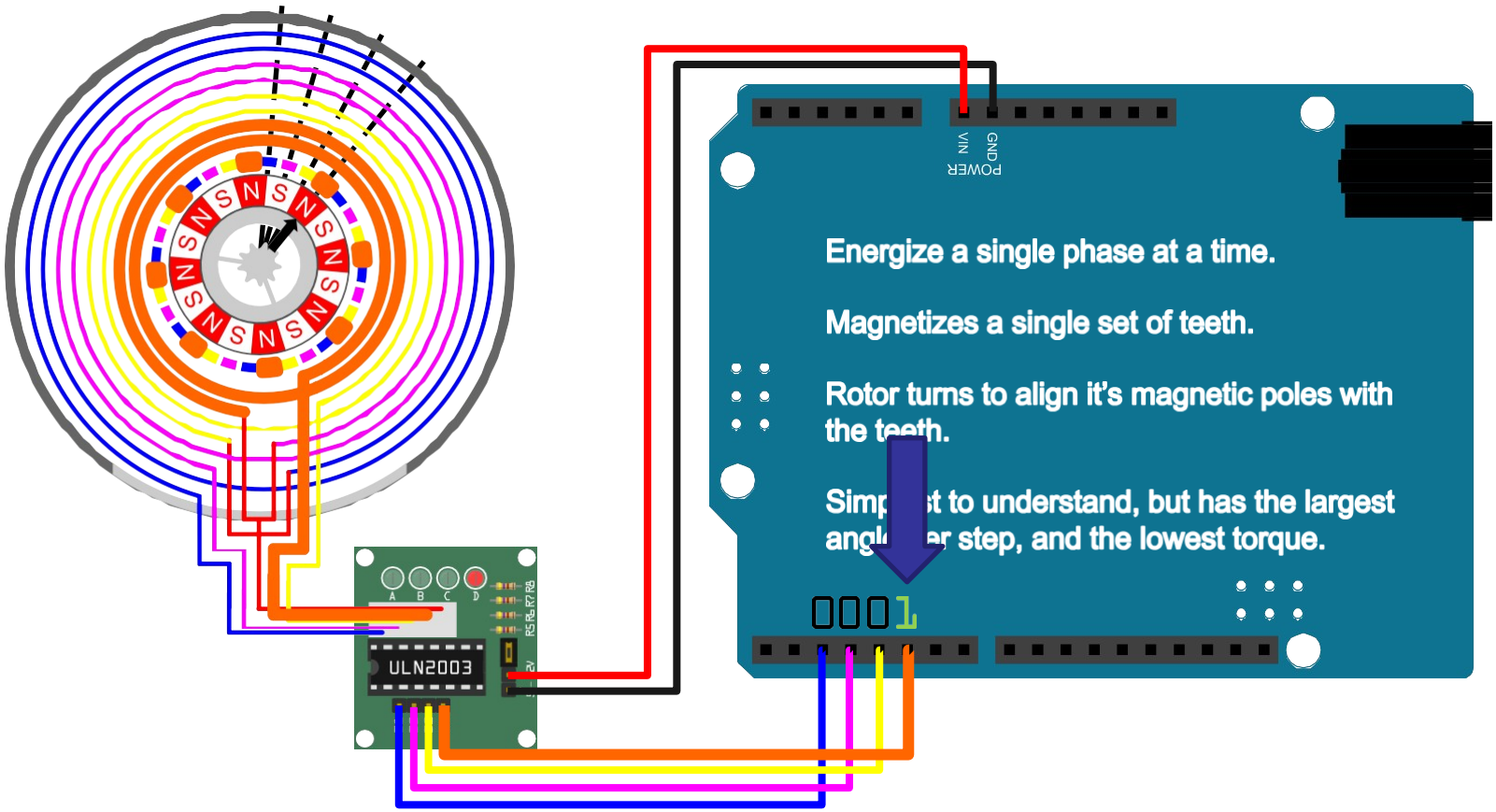
WAVE DRIVING – STEP 2



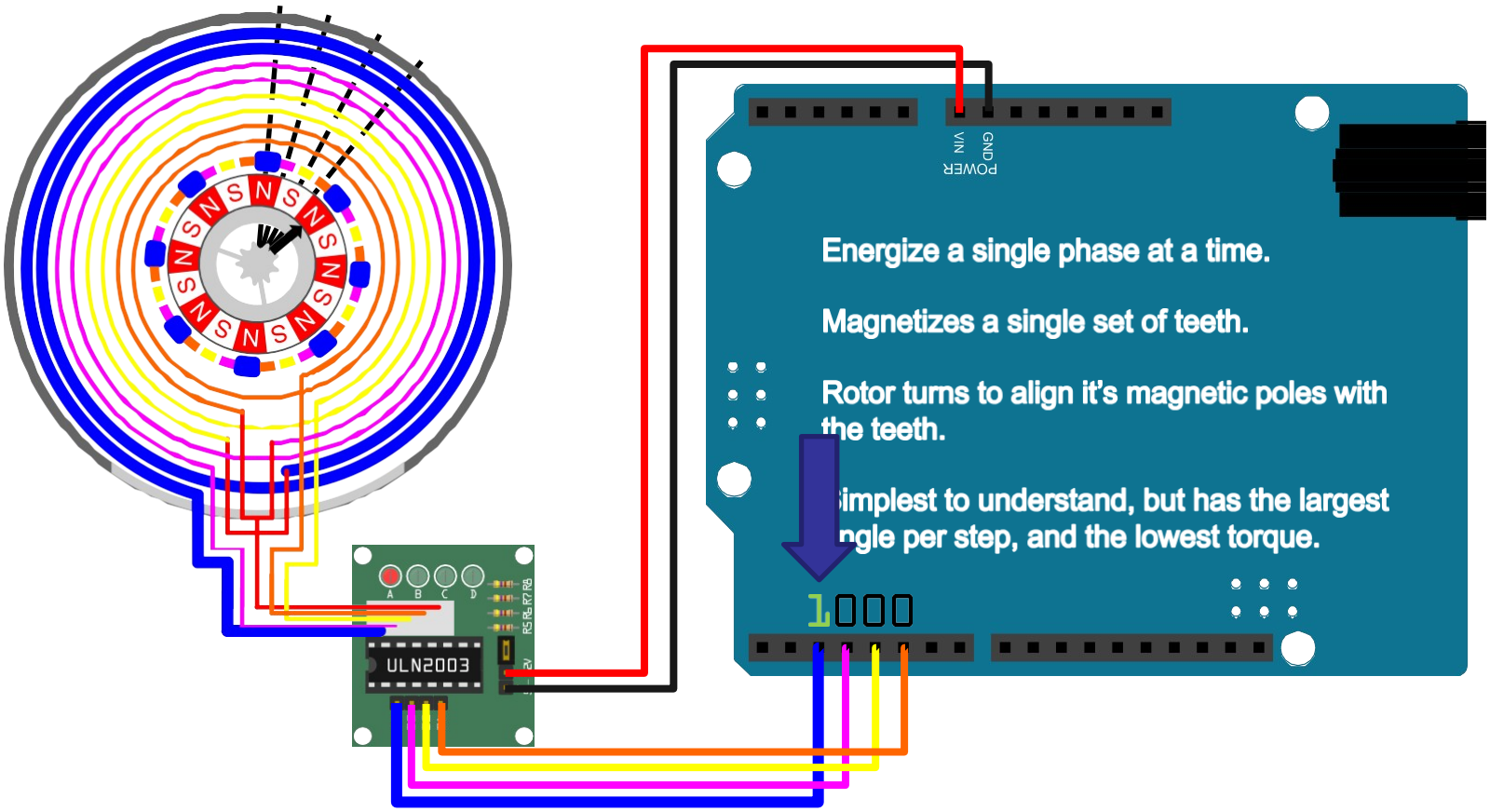
WAVE DRIVING – STEP 3



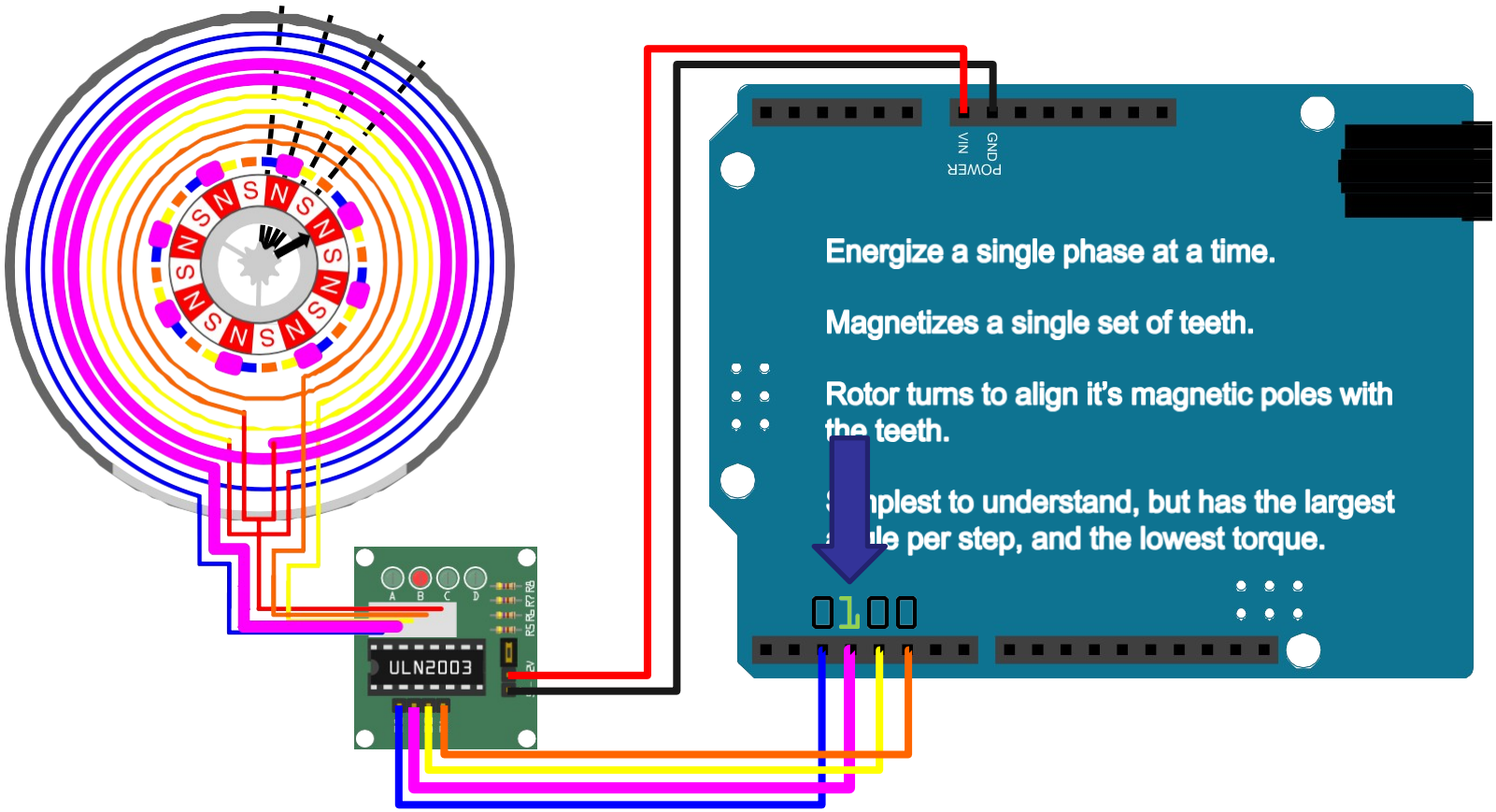
WAVE DRIVING – STEP 4



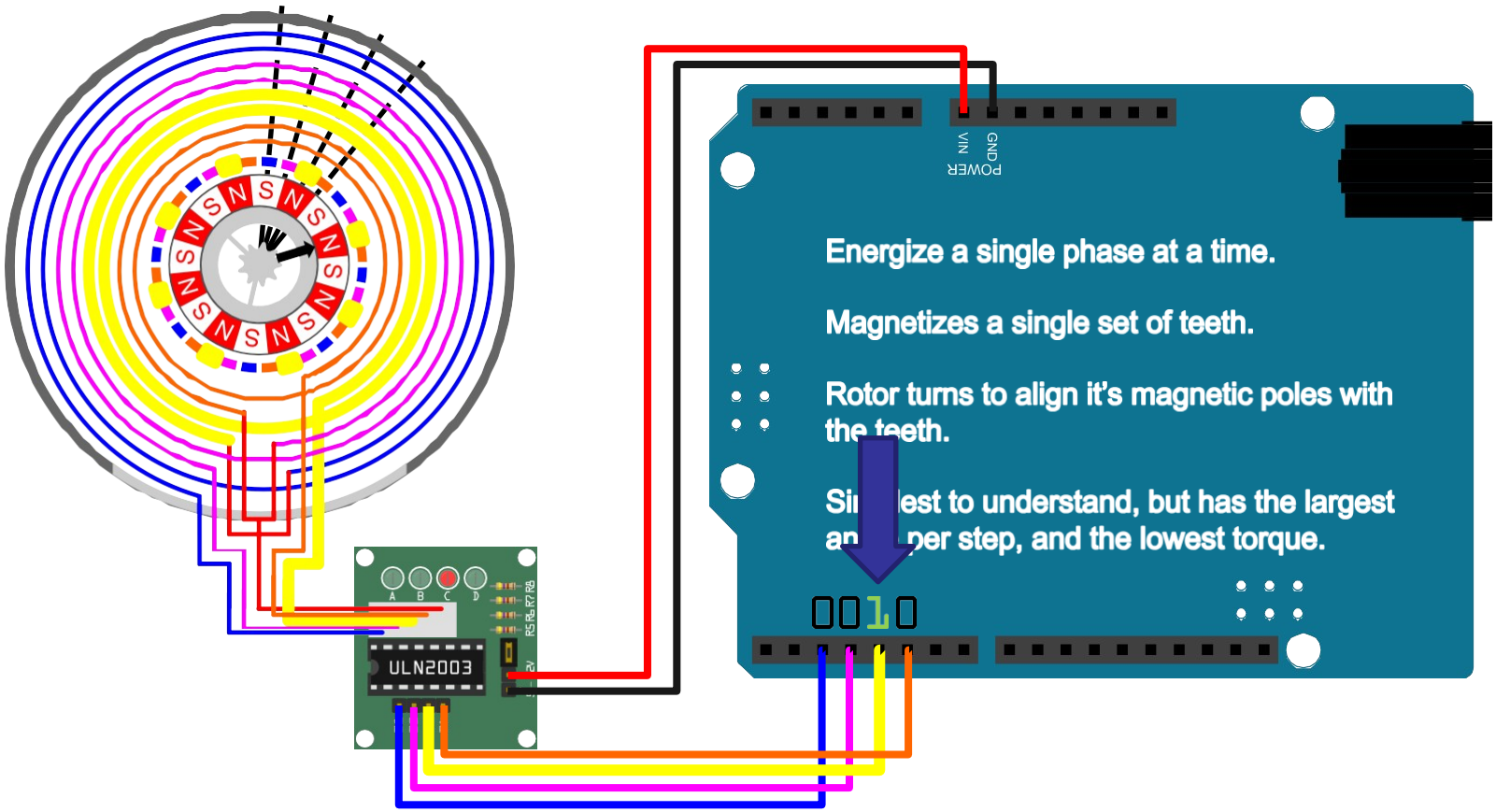
WAVE DRIVING – STEP 5



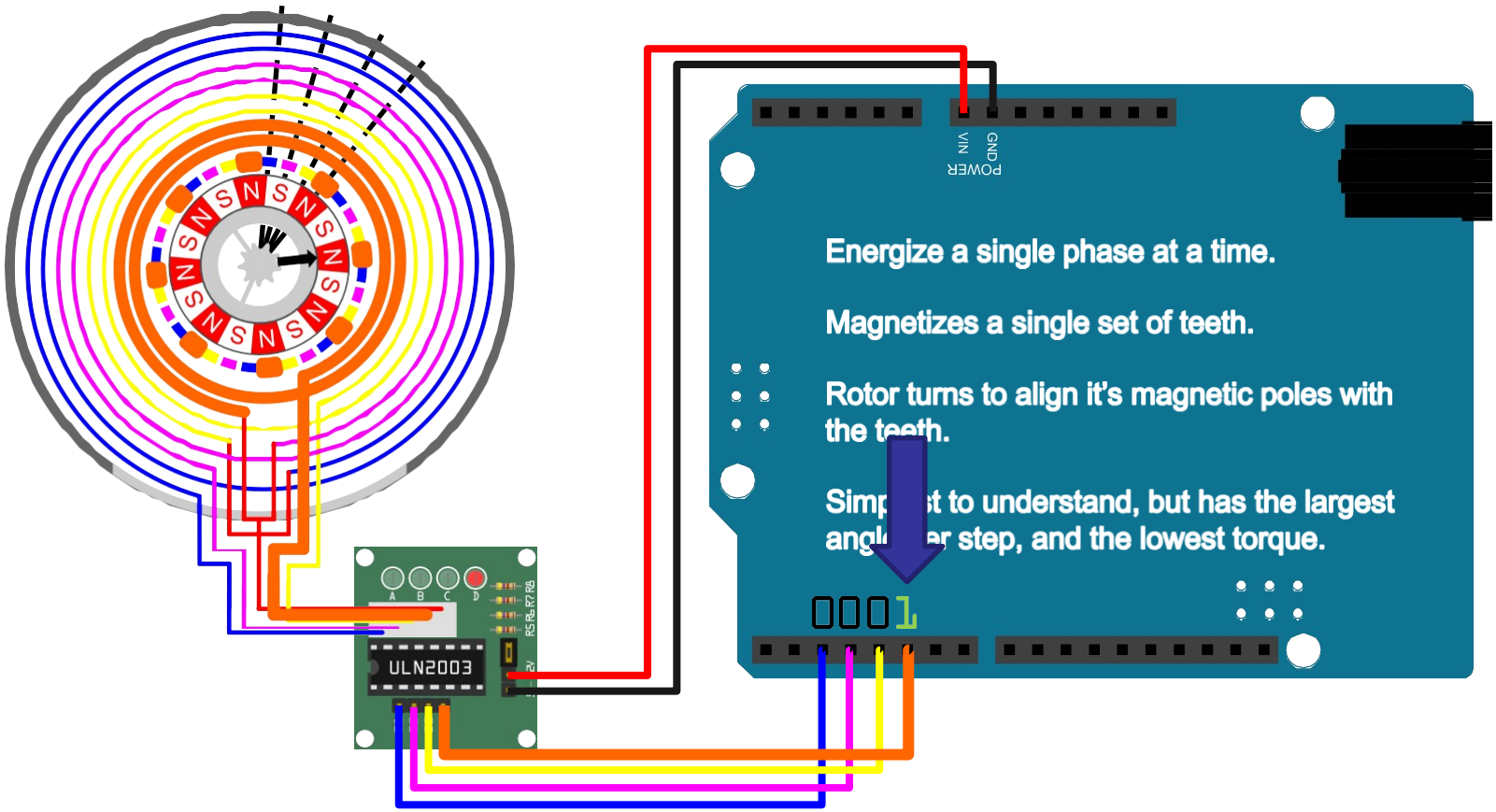
WAVE DRIVING – STEP 6



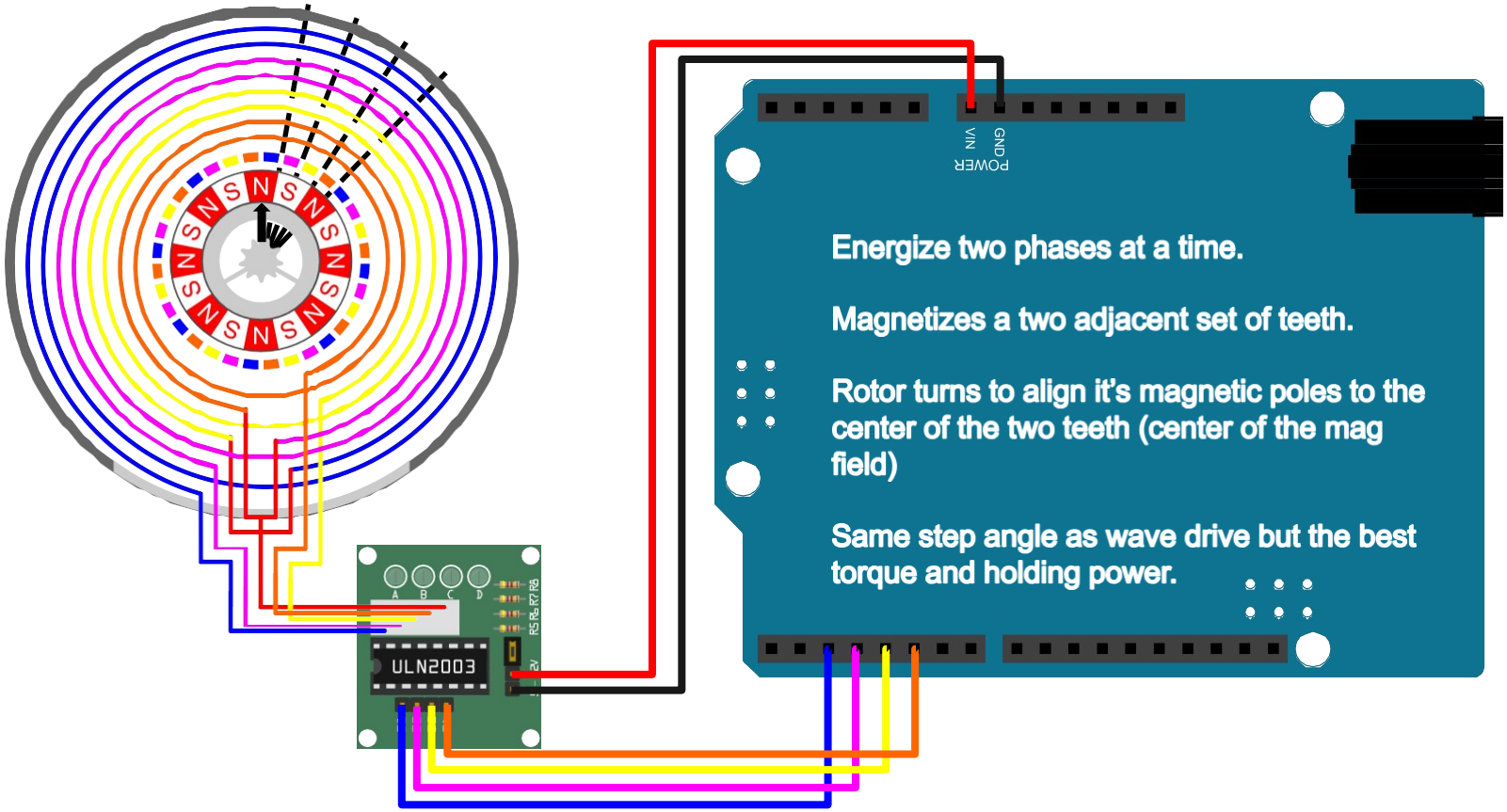
WAVE DRIVING – STEP 7



WAVE DRIVING – STEP 8



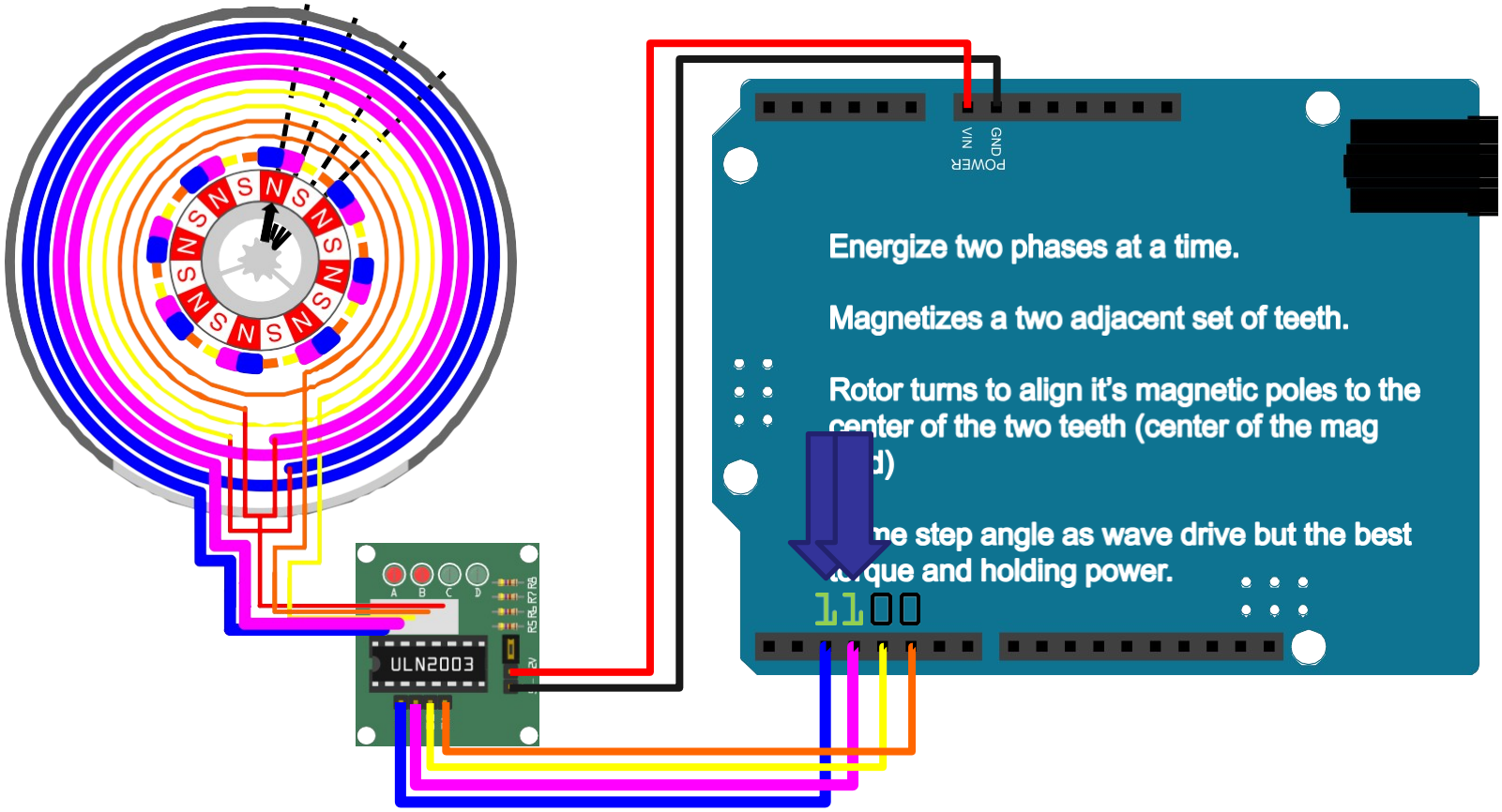
FULL STEPPING…



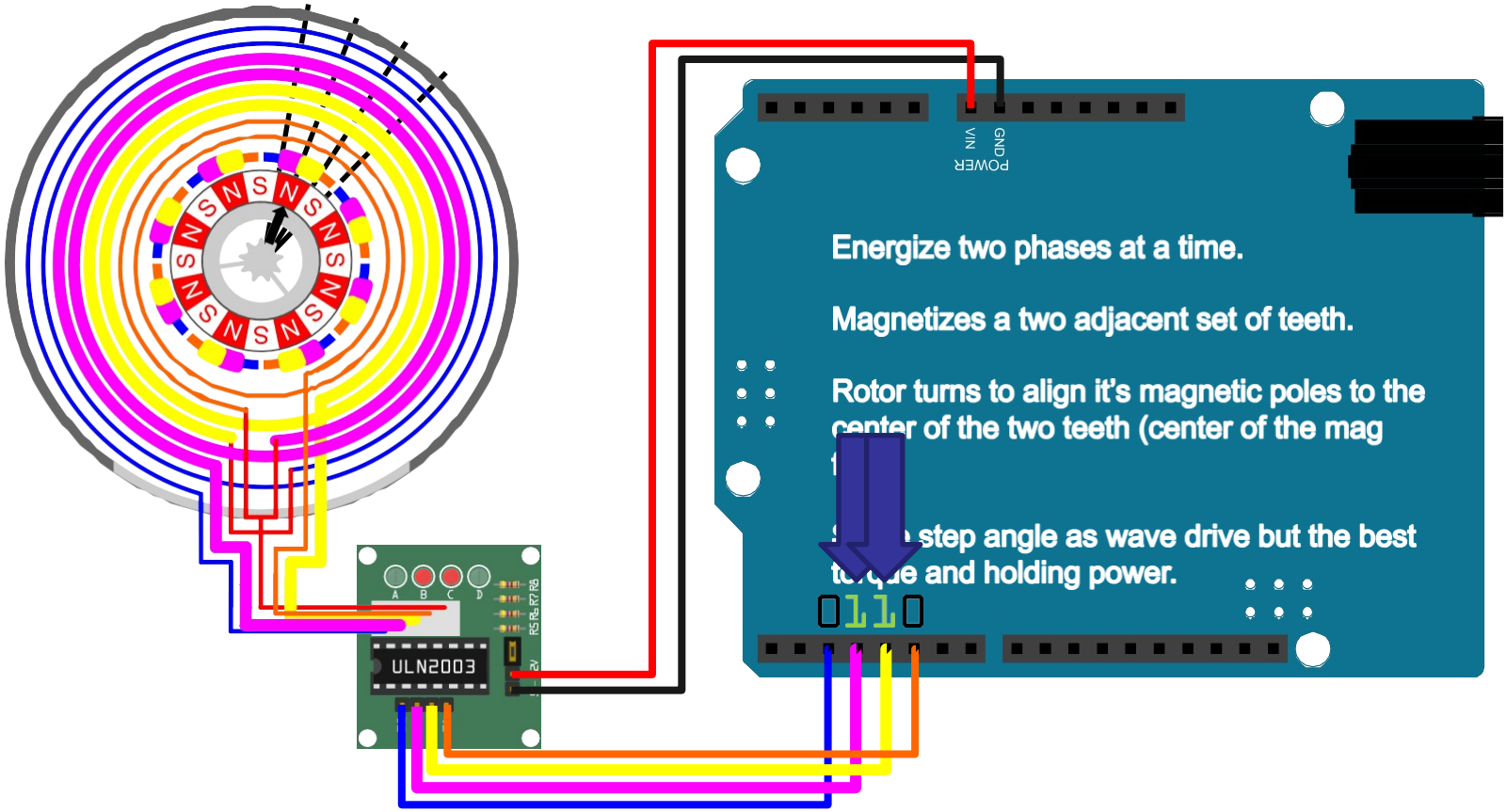
Full Stepping Step Sequence

Steps	A	B	C	D
1	1	1	0	0
2	0	1	1	0
3	0	0	1	1
4	1	0	0	1

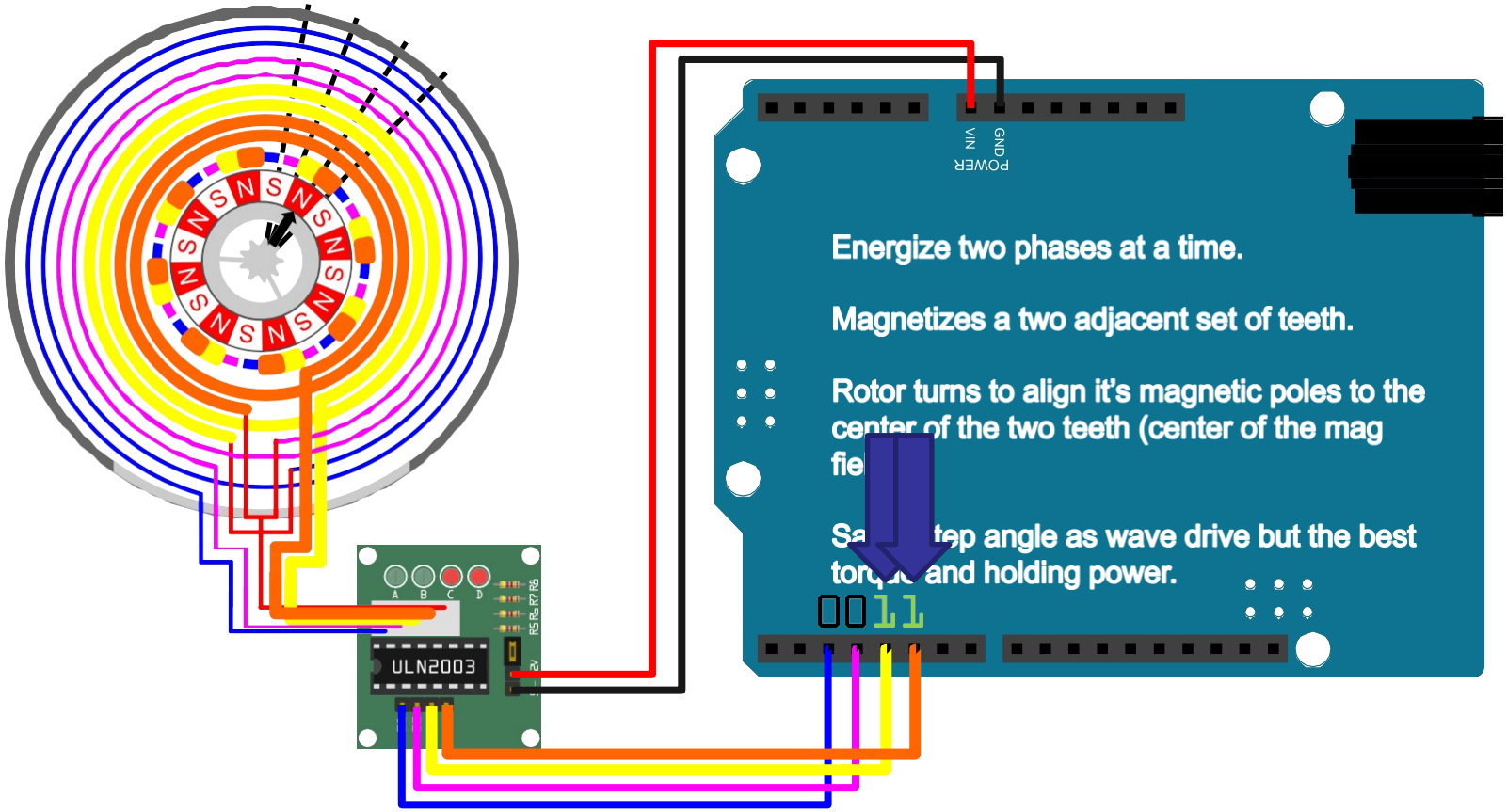
FULL STEPPING – Step 1



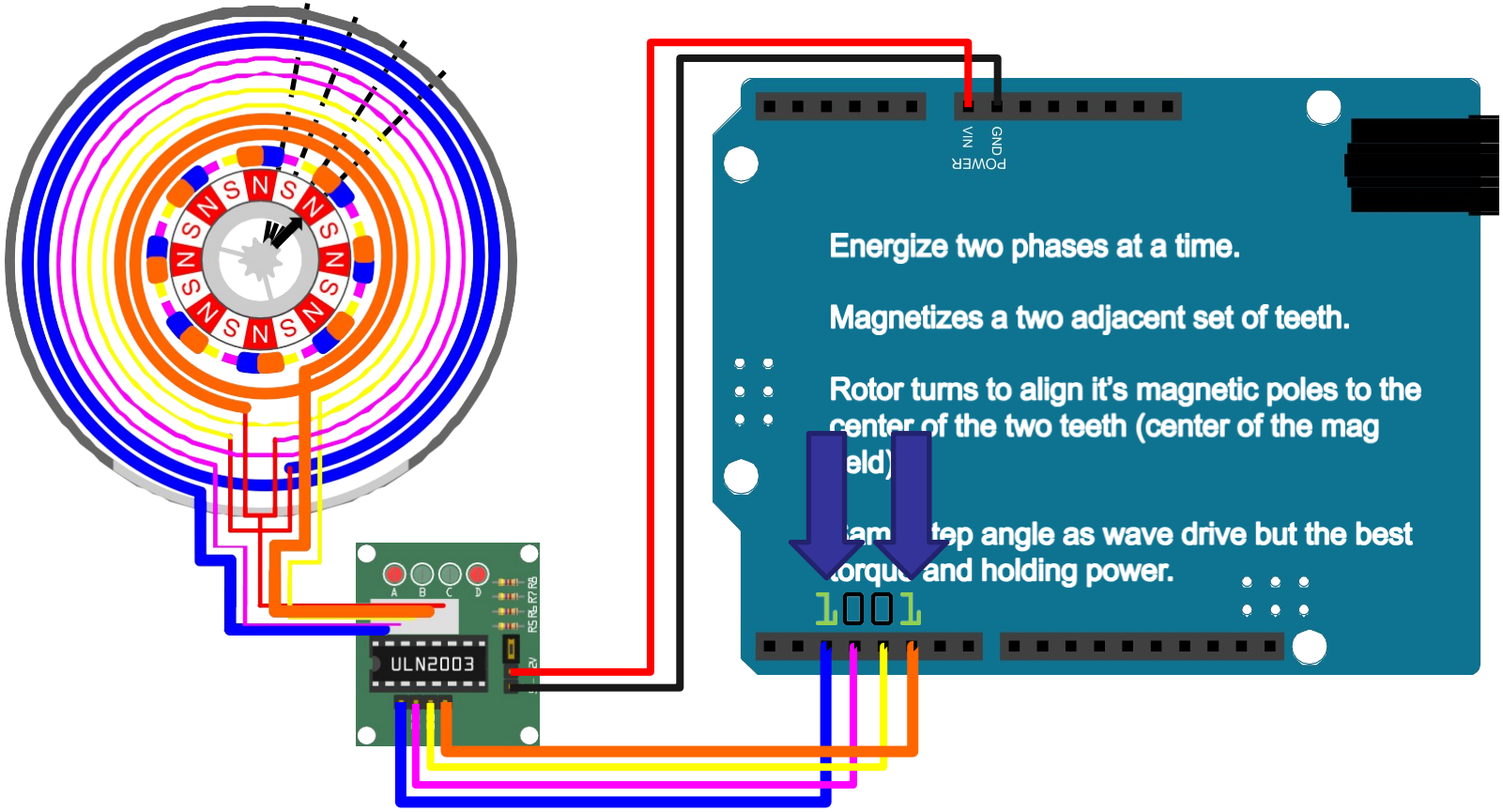
FULL STEPPING – Step 2



FULL STEPPING – Step 3



FULL STEPPING – Step 4



Stepping in Wave Drive and Full Step

Pseudocode – Wave Drive

```
//Wave Drive Mode (Single Coil Energized)
//Less torque compared to Full Drive Mode, lower power consumption
 while(1)
{
        GPIO_PORTB_DATA_R = 0x01; //0001
        delay(1);
        GPIO_PORTB_DATA_R = 0x02; //0010
        delay(1);
        GPIO_PORTB_DATA_R = 0x04; //0100
        delay(1);
        GPIO_PORTB_DATA_R = 0x08; //1000
        delay(1);
}
```

Pseudocode – Full Step

```
//Full Drive Mode (Two Coil Energized at the same time)
//Higher Torque, more power consumption
while(1)
{
        GPIO_PORTB_DATA_R = 0x03;
        //0011
        delay(1);
        GPIO_PORTB_DATA_R = 0x06;
        //0110
        delay(1);
        GPIO_PORTB_DATA_R = 0x0C;
        //1100
        delay(1);
        GPIO_PORTB_DATA_R = 0x09;
        //1001
        delay(1);
}
```

Reference

- How to use the 28byj-48 Motor and ULN2003 Drive: https://www.youtube.com/watch?v=B86nq_DRskVU