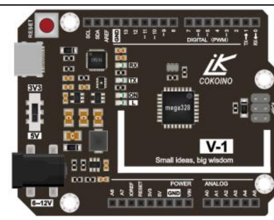
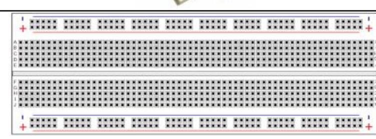
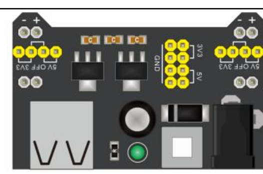
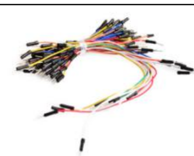
16.ULN2003 stepper motor

ABOUT THIS PROJECT：

You will learn：

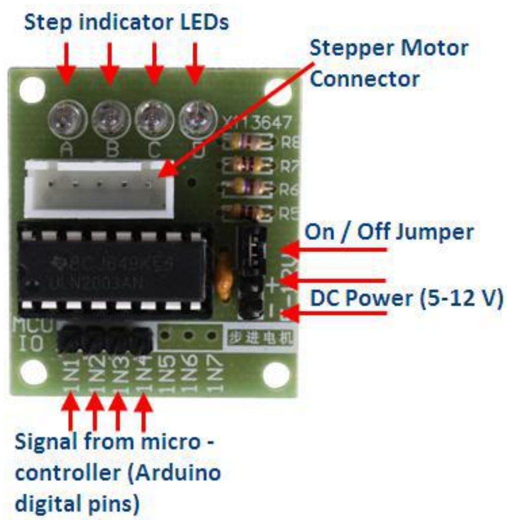
- Drive the stepper motor rotate forward and reverse

1.Things used in this project：

Name	Picture	Quantity
V-1 board		1 PCS
30CM USB cable		1 PCS
Breadboard		1 PCS
9V Battery Snap Connector		1 PCS
Breadboard power module		1 PCS
Male to Male DuPont Line		2 PCS
Male to Female DuPont Line		6 PCS
A ULN2003 Motor Module and a 28BYJ-48 Stepper Motor		1 PCS

1、Introduction to ULN2003 Stepper motor

The ULN2003 stepper motor driver board allows you to easily control the 28BYJ-48 stepper motor from a microcontroller, like the Arduino Uno. One side of the board side has a 5 wire socket where the cable from the stepper motor hooks up and 4 LEDs to indicate which coil is currently powered. The motor cable only goes in one way, which always helps. On the side you have a motor on / off jumper (keep it on to enable power to the stepper). The two pins below the 4 resistors, is where you provide power to the stepper. Note that powering the stepper from the 5 V rail of the Arduino is not recommended. A separate 5-12 V 1 Amp power supply or battery pack should be used, as the motor may drain more current than the microcontroller can handle and could potentially damage it. In the middle of the board we have the ULN2003 chip. At the bottom are the 4 control inputs that should be connected to four Arduino digital pins.



2、Classification of motor

There are many ways to classify motors， from the perspective of use, it can be divided into drive motors and control motors. DC motors belong to drive motors, this motor converts electrical energy into mechanical energy, it is mainly used in electric drills, wheels of the small car, electric fans, washing machines and other equipment. The stepper motor belongs to the control type motor. It is a motor that converts the pulse signal into a rotation angle. In the case of non-overload, the speed and stop position of the motor only depend on the frequency and pulse number of the pulse signal. It is mainly used in automatic instruments, robots, automatic production lines, Rotating equipment for air-conditioning fan blades and other equipment. Stepper motors are divided into three types: reactive, permanent magnet and hybrid:
Reactive stepper motor: Its advantages are simple structure and low cost. Its disadvantages are poor dynamic performance, low efficiency, high heat generation, and its reliability is difficult to guarantee, so it has basically been eliminated.
Permanent magnet stepper motor: It has the advantages of good dynamic performance and large output torque. The disadvantage is that its angular error is relatively large, but it is widely used in consumer products because of its low price.
Hybrid stepper motor: It combines the advantages of reactive and permanent magnet type, it has large torque, good dynamic performance, small step angle, high precision, but its structure is relatively complicated, the price is also high, the main application For industry.

In this chapter, we will explain the meaning of the 28BYJ-48 stepper motor model:
28: The effective maximum outer diameter of the stepper motor is 28 mm
B: indicates a stepper motor
Y: indicates permanent magnet type
J: indicates that it is a deceleration type
48: indicates four phases and eight beats

3、The principle of 28BYJ-48 stepper motor:

28BYJ-48 is a 4-phase permanent magnet type stepping motor, its appearance is shown in Figure 1:

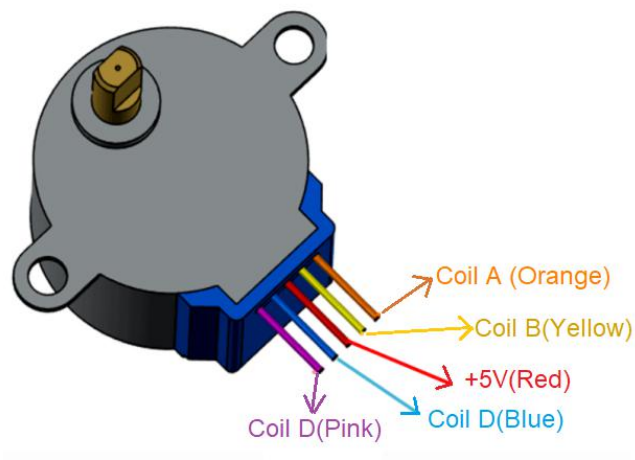


Figure 1

Let's first explain the concept of "4-phase permanent magnet type". The internal structure diagram of 28BYJ-48 is shown in Figure 1.First look at the inner ring, it has 6 teeth on it, labeled 0 to 5, which are called rotors. Each tooth of the rotor has permanent magnetism and is a permanent magnet. Looking at the outer ring again, this is the stator. It stays stationary. It is fixed with the housing of the motor. It has 8 teeth on it, and a coil winding is wound on each tooth, and the windings on the 2 teeth facing each other are connected in series, which means they will always turn on or off at the same time It is broken, so that 4 phases are formed, which are marked as ABCD in the figure, which is the concept of "4 phases".

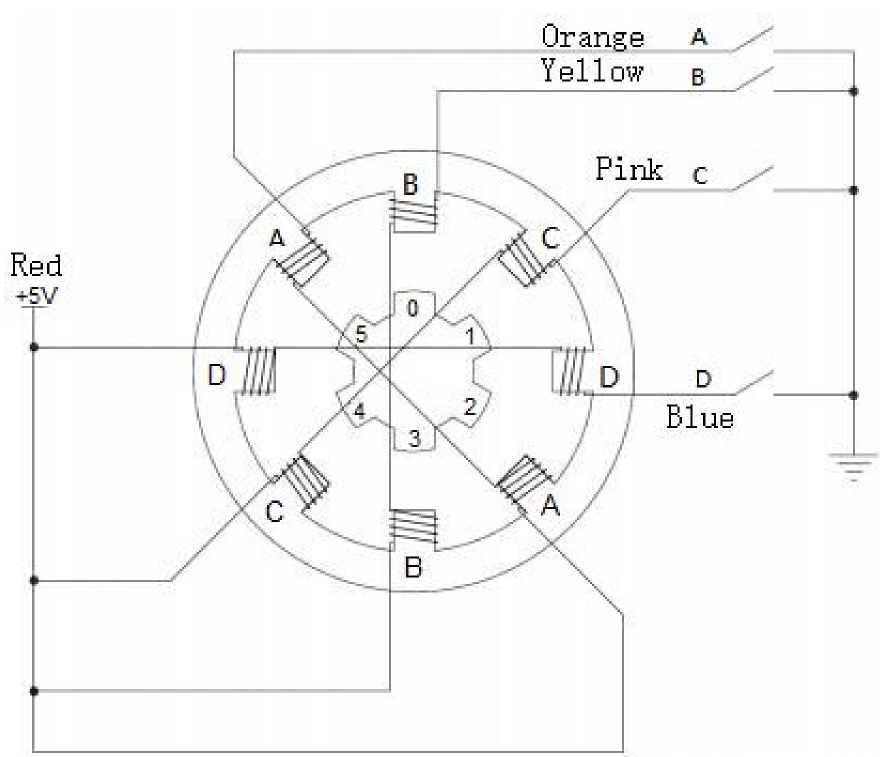


Figure 2 Schematic diagram of the internal structure of the stepper motor

First we analyze its working principle: assuming that the initial state of the motor is rotating counterclockwise. At the beginning, the switch of the B-phase winding is closed, and the conducted current will generate magnetism on the two stator teeth near the B-phase winding. These two stator teeth will have the strongest attraction to the 0th and 3rd teeth of the rotor. It will be in the state shown in the figure, the No. 0 tooth of the rotor is directly above, and the No. 3 tooth is directly below; at this time, we will find that the No. 1 tooth of the rotor and the stator teeth of the C-phase winding show a small angle , The stator of the No. 2 tooth and the D-phase winding presents a slightly larger angle. Obviously this angle is twice the angle between the No. 1 tooth and the stator wound by the C winding.

Next, the B-phase winding is turned off, and the C-phase winding is turned on. The stator teeth of the C-phase winding will have the greatest attraction to the No. 1 and No. 4 teeth of the rotor, and the No. 1 and No. 4 teeth of the rotor will be aligned to the stator teeth of the C-phase winding.
In this way, the rotation angle of the motor rotor is equal to the angle between the No. 1 tooth and the phase C winding in the previous step.

Third, disconnect the C-phase winding and turn on the D-phase winding. The teeth No. 2 and No. 5 of the rotor are aligned with the stator of the D-phase winding, the rotation angle of the motor rotor is equal to the angle between the No. 1 tooth and the phase C winding in the previous step.

So obviously, when the A-phase winding is on, we complete a four-beat operation of B-C-D-A.
The No. 0 and No. 3 teeth of the rotor will be aligned to the two stator teeth of the A-phase winding. Compared with the position of No. 0 and No. 3 teeth in the first step, the rotor turns one stator tooth (45 degrees). The angle that the rotor rotates through a single beat is: 45/4 = 11.25 degrees, this value is called the step angle. This mode of operation is the single quadruple mode of the stepper motor (single-phase winding energized four beats).

Single four-beat mode control timing and angle: (1: indicates on, 0 indicates off)

Coil / Angel	A（orange）	B(yellow)	C(pink)	D(blue)
0	0	0	0	0
11.25	1	0	0	0
22.5	0	1	0	0
33.75	0	0	1	0
45	0	0	0	1
56.25	1	0	0	0
67.5	0	1	0	0
75.75	0	0	1	0
78.75	0	0	0	1
90	1	0	0	0
101.25	0	1	0	0
112.5	0	0	1	0
123.75	0	0	0	1
135	1	0	0	0
146.25	0	1	0	0
157.5	0	0	1	0
168.75	0	0	0	1
180	1	0	0	0
...	...	...	...	...

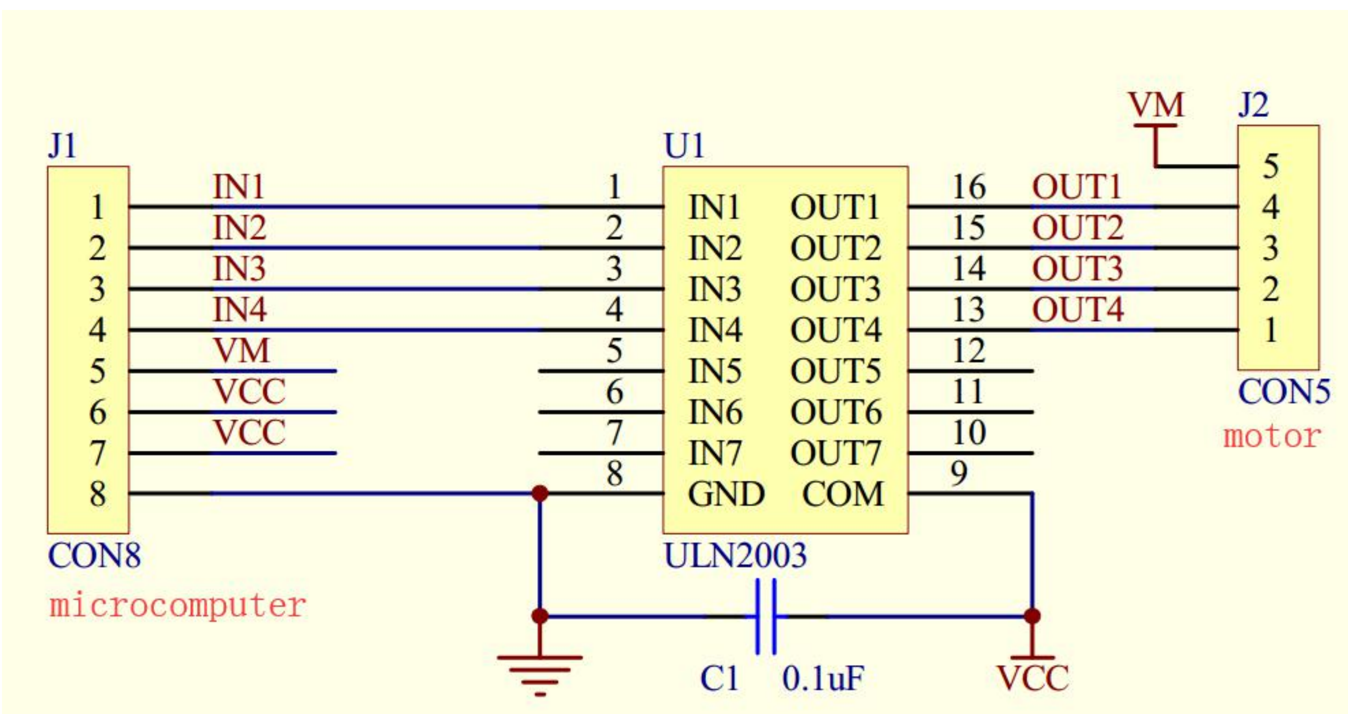
We will explain a working mode with better performance, that is, insert another beat between every two beats of the four beats to form an eight beat mode. Between phase B conduction and phase C conduction, a beat is inserted, that is, phase B and phase C are turned on at the same time. Since the stator teeth of the two windings of B and C have the same attractive force to the nearby rotor teeth, this will cause the center lines of the two rotor teeth to align with the center lines of the two windings of B and C. The newly inserted beat makes the rotation angle half that of the above single four-beat mode, which is 5.625 degrees. In this way, the rotation accuracy of the motor is doubled, and the rotor needs 8 * 8 = 64 beats for one revolution. In addition, the newly added intermediate beat can greatly increase the overall torque output of the motor, making the motor more "vigorous".
The 8-beat mode is the best working mode for this type of 4-phase stepper motor. It can maximize the performance of the motor and is also the mode selected in most practical projects.

4、Let the 28BYJ-48 stepper motor rotate (8-beat mode)

The stepper motor has a total of 5 wires, of which the red is the common terminal and is connected to the 5 V power supply. The orange, yellow, pink, and blue wires correspond to the A, B, C, and D phases; If you want to turn on the phase A winding, you need to ground the orange wire. If you want to turn on the phase B winding, you need to ground the yellow wire；So on and so forth; The sequence of winding control is shown in the following table:

(1: indicates on, 0 indicates off)

Coil / Angel	A（orange）	B(yellow)	C(pink)	D(blue)
0	0	0	0	0
5.625	1	0	0	0
11.25	1	1	0	0
16.875	0	1	0	0
22.5	0	1	1	0
28.125	0	0	1	0
33.75	0	0	1	1
39.375	0	0	0	1
45	1	0	0	1
50.625	1	0	0	0
56.25	1	1	0	0
61.875	0	1	0	0
67.5	0	1	1	0
73.125	0	0	1	0
78.75	0	0	1	1
84.375	0	0	0	1
90	1	0	0	1
...	...	...	...	...



ULN2003 stepper motor module schematic

The IO port of the single-chip microcomputer can directly output the voltage of 0 V and 5 V, but its current driving capacity / loading capacity is very limited, so we use ULN2003 inverter chip to improve its driving capacity. It can be seen from the figure that if the phase A is to be turned on, IN1 needs to be high. At this time, OUT1 outputs a low level, and the orange line is equivalent to ground, so the phase A winding is turned on;

If A and B are turned on at the same time, then IN1 and IN2 should be high level, OUT1 and OUT2 output low level, and A and B phase are turned on. So on and so forth, we can get the following IO control code array of eight beats:

(1: indicates high level signal, 0 : indicates low level signal)

Coil / Angel	IN1	IN2	IN3	IN4
0	0	0	0	0
5.625	1	0	0	0
11.25	1	1	0	0
16.875	0	1	0	0
22.5	0	1	1	0
28.125	0	0	1	0
33.75	0	0	1	1
39.375	0	0	0	1
45	1	0	0	1
50.625	1	0	0	0
56.25	1	1	0	0
61.875	0	1	0	0
67.5	0	1	1	0
73.125	0	0	1	0
78.75	0	0	1	1
84.375	0	0	0	1
90	1	0	0	1
...	...	...	...	...

At this point, the values in this array are sent to P1 cyclically. It seems that all the logic problems have been solved. However, as long as you think about it, there is still a question: How often do you send data, that is, how long is it suitable for a beat to last? Is it random? Of course not, this time is determined by the starting frequency of the stepper motor. The starting frequency is the highest pulse frequency that the stepper motor can start normally under no-load conditions. If the pulse frequency is higher than this value, the motor cannot start normally. Table 9-2 is the stepper motor parameter table provided by the manufacturer.

Supply voltage	Phase	Phase resistance	Step angle	Reduction ratio	Start frequency P.P.S	Torque/g.cm	Noise/dB	Dielectric strength
5V	4	50±10%	5.625/64	1:64	≥550	≥300	≤35	600VAC

The parameter given in the table is ≥550, and the unit is P.P.S, which is the number of pulses per second. The meaning here is: the motor can start normally if you give 550 step pulses per second. So the duration of a single beat is 1 s / 550 = 1.8 ms. In order to allow the motor to start, we control the beat refresh time to be greater than 1.8 ms.

5、Rotation accuracy of 28BYJ-48 Stepper motor

According to the principle explained at the beginning of this chapter, in the eight-beat mode, the stepper motor needs 64 beats for one revolution, and in our program, each beat lasts 2 ms, then one revolution should take 128 ms, in 1 second The motor rotates more than 7 revolutions within the time. But it seems that the motor only made a turn in more than 7 seconds?

So, it is time to understand the concept of "deceleration" in the "permanent magnet deceleration stepper motor". Figure 4 is a disassembly diagram of this 28BYJ-48 stepper motor. As you can see from the picture, the white gear at the center is the rotor output of the stepper motor. 64 beats just let this gear turn a circle, and then it drives the big blue gear, which is the first deceleration. Looking at the other gears, every two gears constitute a one-stage reduction, and there are a total of four stages of reduction. So what is the total reduction ratio? That is, how many revolutions does the rotor have to make and the final output shaft rotates one revolution?

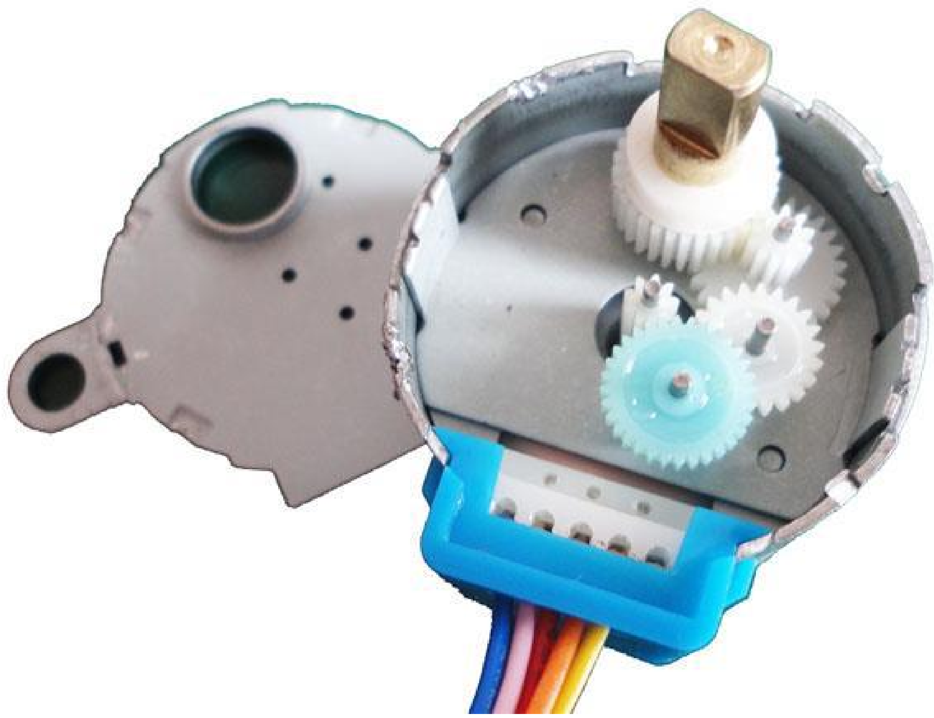


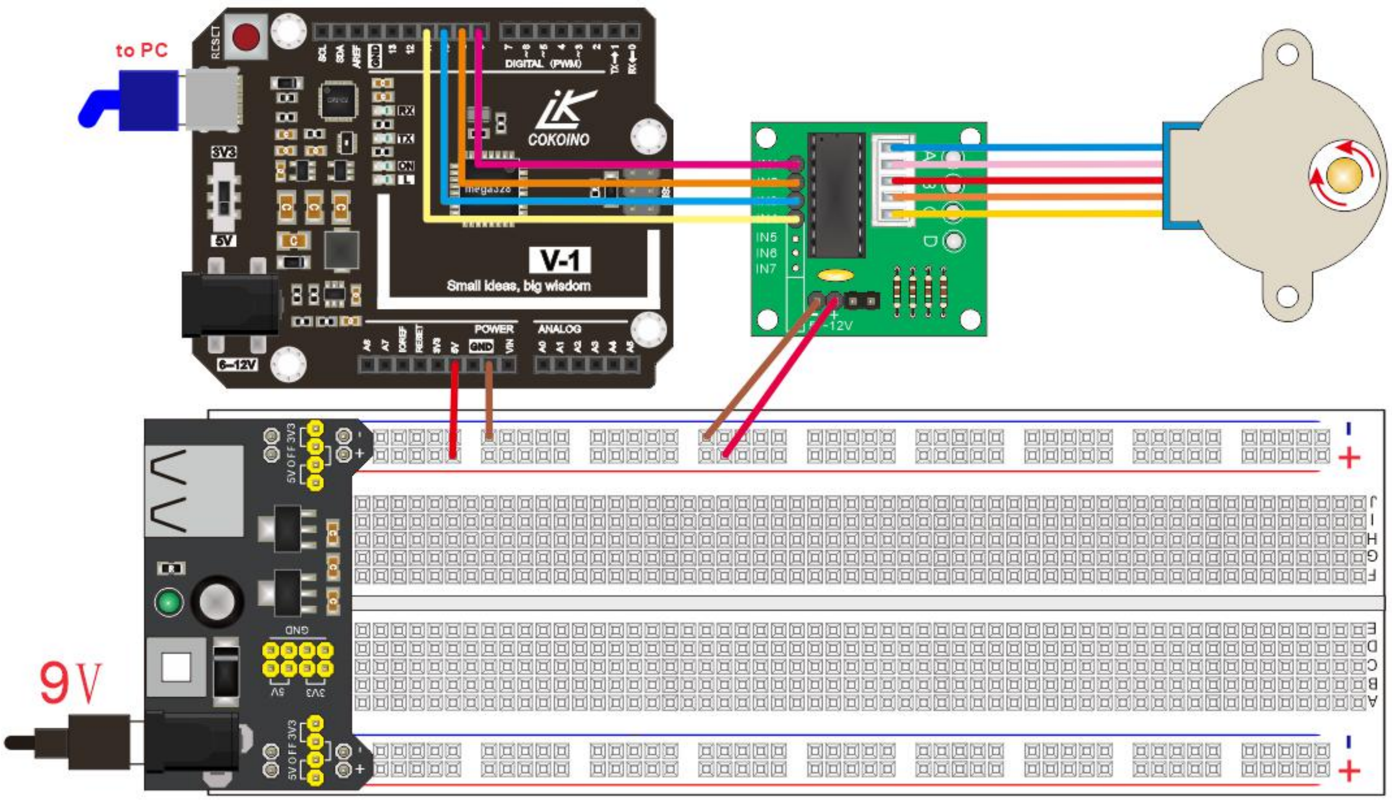
Figure 4 Schematic diagram of the internal gear of the stepper motor

Take a look back at the reduction ratio parameter 1:64 in the motor parameter table. When the rotor turns 64 times, the final output shaft will turn one turn, that is, 64 * 64 = 4096 beats output. 2 * 4096 = 8192 ms, the shaft of the motor only rotates one circle in more than 8 seconds, which coincides with the experimental results just now. 4096 beats rotate one circle, then the angle / step angle of one beat rotation is 360/4096, look at the step angle parameter 5.625 / 64 in the table, the two values are equal, and everything is consistent.

The explanation of the basic control principle of the motor is over, but we hope that everyone can cultivate a way of thinking that "practice is the only standard for testing truth"! What are the biggest characteristics of stepper motors? Precisely control the amount of rotation! So should we test whether it is accurate? How accurate is it? How to test it? Let it turn 90 degrees, and then let's measure it? OK, but if it only has an error of 1 degree or less, can you measure it accurately? It is difficult to measure without precision instruments. We let it turn a few more complete circles to see if it finally stops at its original position.

6. 28BYJ-48 Stepper Motor with ULN2003 driver and V-1 board

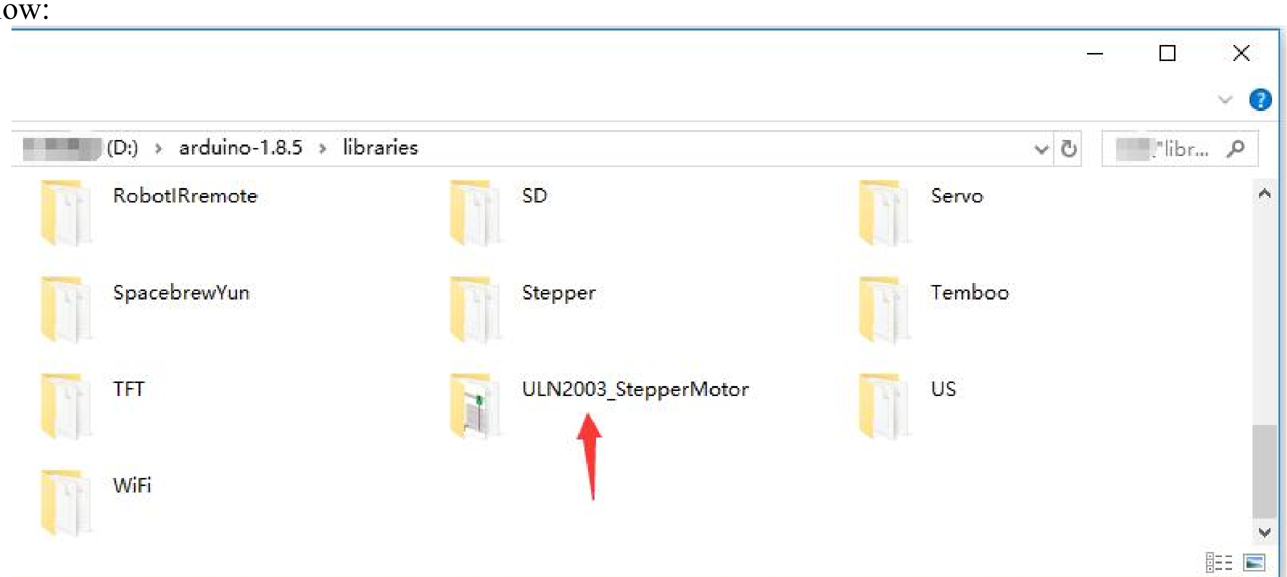
6.1 Wiring the ULN2003 stepper motor driver to V-1 board



6.2 Arduino stepper code and the Stepper library

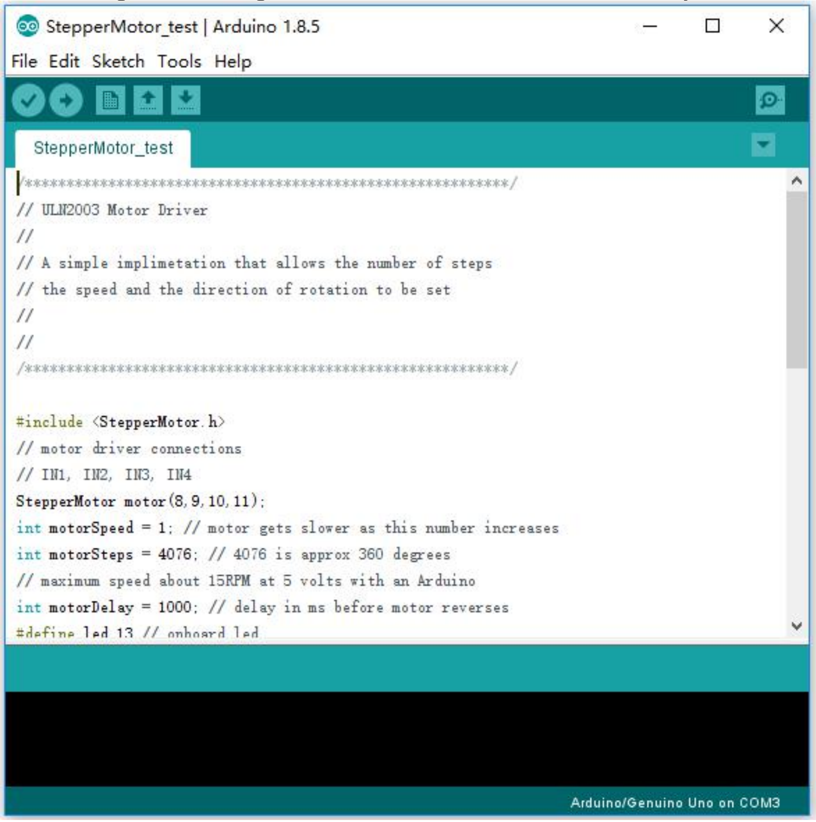
make sure you download and install the ULN2003_StepperMotor library first!

Copy the entire folder of ULN2003_StepperMotor to the libraries folder of the Arduino IDE installation directory, as shown below:

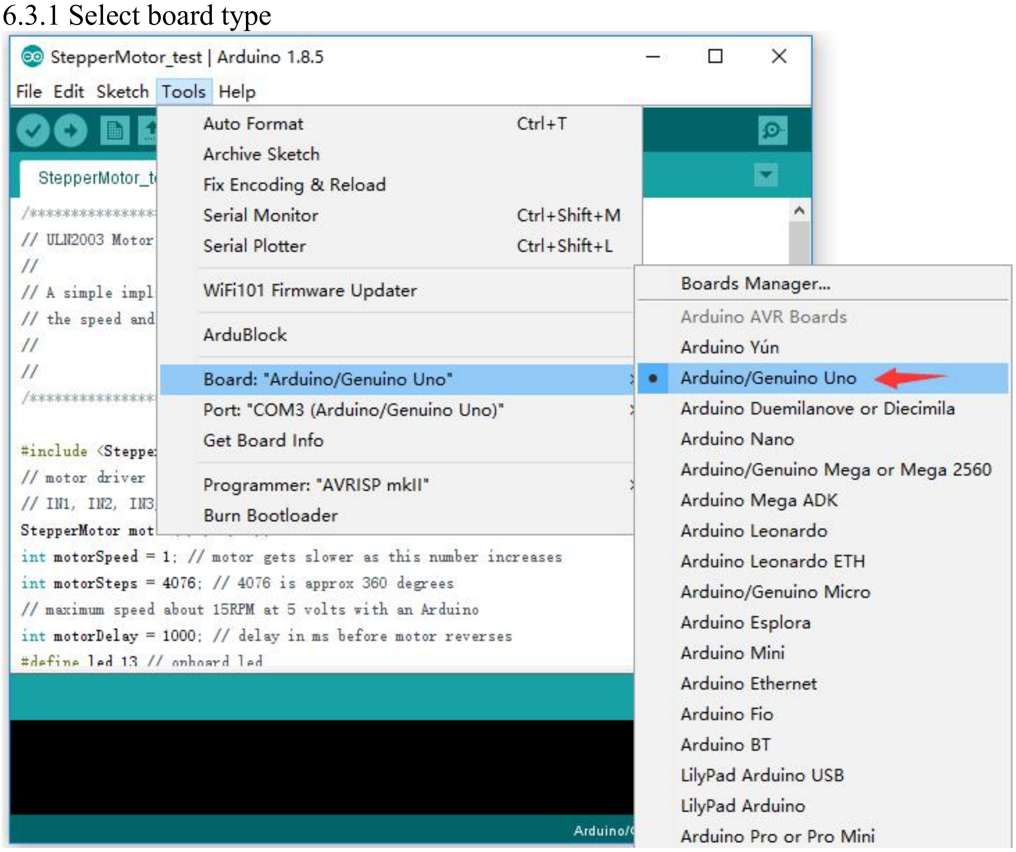


6.3 Experiment

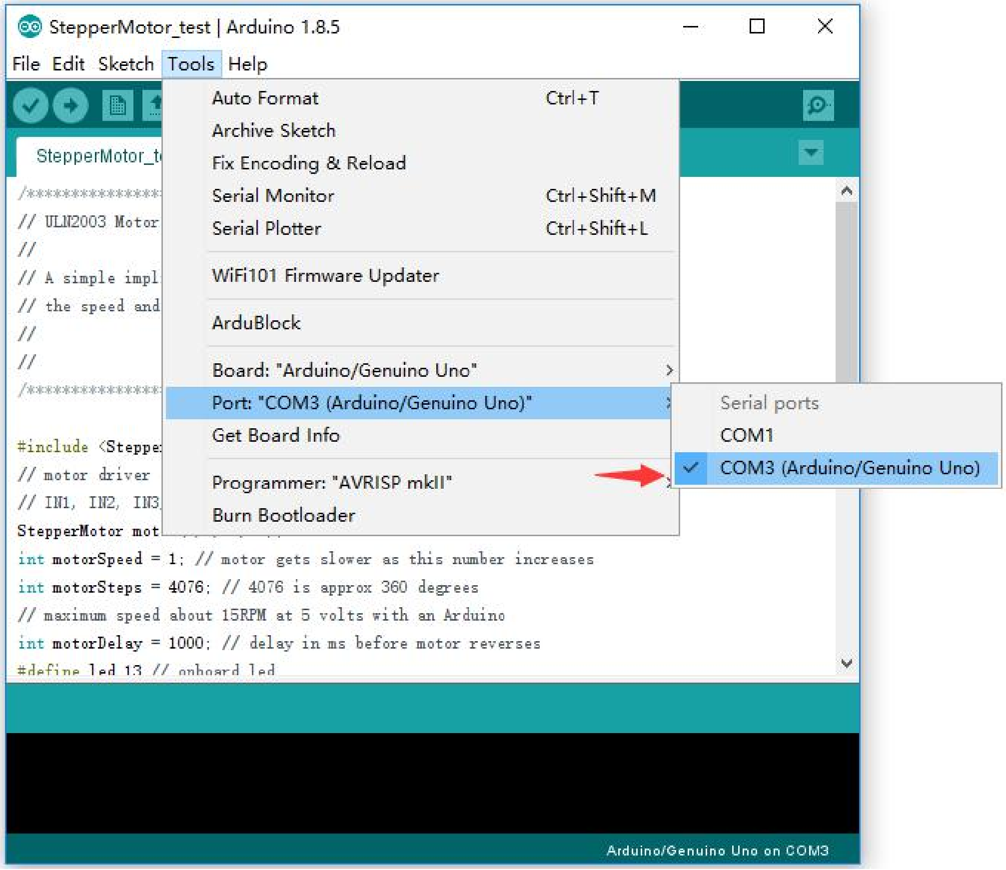
Open the arduino IDE and click File--->Examples--->ULN2003_StepperMotor--->Examples--->StepperMotor_test,
You can open the sample sketch that comes with the library file, as shown below:



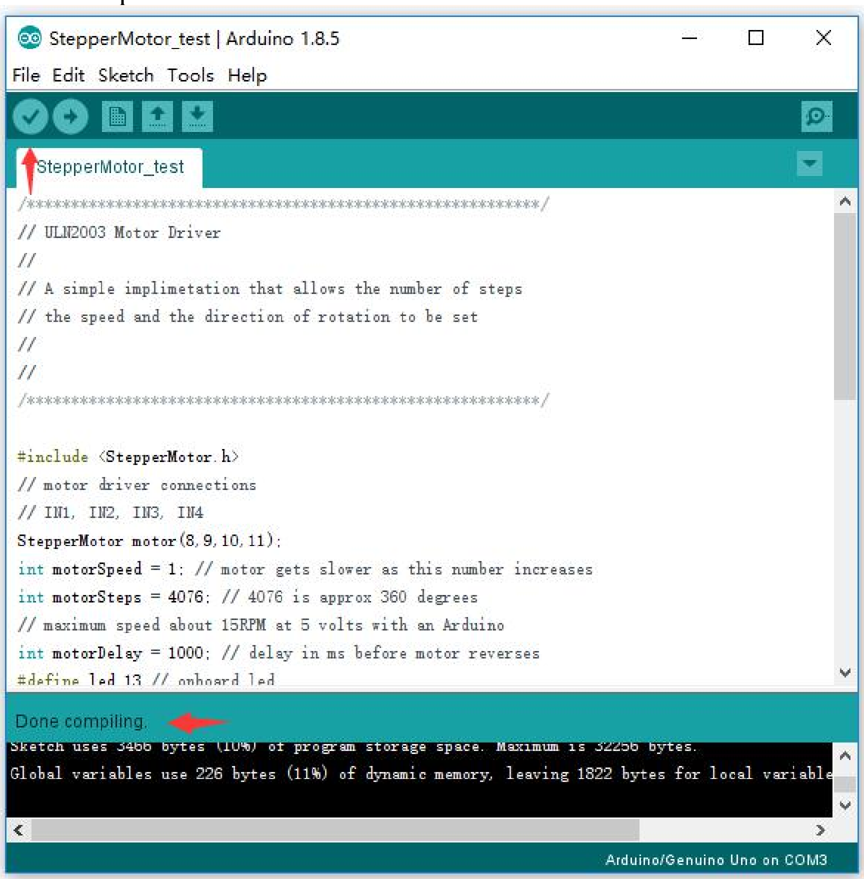
6.3.1 Select board type



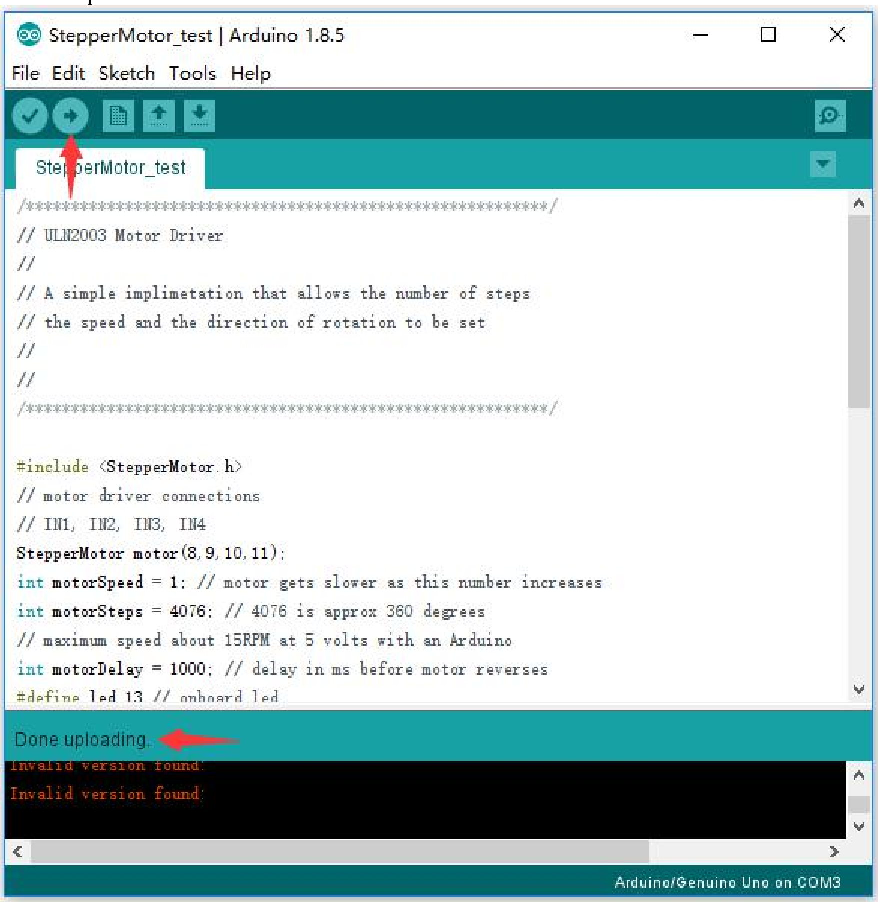
6.3.2 Select port



6.3.3 Compile the sketch



6.3.4 Upload the sketch



6.3.5 Result

Unplug the USB cable from the V-1 board, connect the power module to the external power supply, and then turn on the switch of the power module on the breadboard. The stepper motor will always rotate forward and reverse, as shown below: