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REMOTE CONTROL SYSTEM OF STEPPER MOTOR BASED ON THE ESP32 DEVELOPER BOARD

C. XUAN*, I. VERBYTSKYI

Department of Electronic Devices and Systems, Faculty of Electronics, National Technical University of Ukraine ''Igor Sikorsky Kyiv Polytechnic Institute'', Kyiv, UKRAINE
**e-mail: xuanc274@gmail.com*

ABSTRACT *The stepper motor is a unit of a control system to achieve the goal of convenient use and precise control, which greatly facilitates our life and improves the level of the modern high-tech industry. In particular, multiple stepper motors may be joined in a system and work together with a remote-control program, which greatly improves the flexibility and applicability of the equipment. In real life, multiple stepper motors are used together more often. For example, a 3D printer, using three stepping motors at the same time, the x-axis, the y-axis, and the z-axis, can determine the left side of the space and accurately print the 3D three-dimensional object we need. By adding a remote-control system, we can control the movement of the motor in real time and can replace humans to complete complex and high-precision work. For example, endoscopes are often used in medicine, when the endoscope needs to make micro adjustments in position, we can use remote control to make real-time adjustments. The project of using ESP32 to control multiple stepper motors and uses python language to write programs based on microPython firmware to realize remote control of multiple stepper motors is introduced. The speed and direction of the stepper motor can be adjusted and controlled by pulse signals. The clock system of ESP32 can generate pulse signal PWM, ESP32 comes with a WiFi module, which can support remote control. The speed of the stepper motor can be adjusted by adjusting the duty cycle of the PWM by the program. Combined with ESP32 products, the performance of this designed product can be stable and reliable. The clock system of ESP32 has multiple timers and with their use with the interrupt system, multiple stepper motors can be efficiently controlled simultaneously. And the WiFi module of ESP32 can realize remote control easily and conveniently. According to the principle of the stepping motor, the half-step control, and full-step control are realized. Additionally, a micro step mode with PWM signal with cosine function is designed to control the stepper motor. A user-friendly web application has been developed to control the system of four motors, allowing you to remotely control a four-engine system in a simple and convenient way*
Keywords: *ESP32; stepper motor; remote control; WiFi module; microPython*

СИСТЕМА ДИСТАНЦІЙНОГО КЕРУВАННЯ КРОКОВИМ ДВИГУНОМ НА БАЗІ ПЛАТИ РОЗРОБНИКА ESP32

Ч. СЮАНЬ, Є.В. ВЕРБИЦЬКИЙ

Кафедра електронних пристроїв та систем, факультет електроніки, Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського» Київ, УКРАЇНА

АНОТАЦІЯ *Кроковий двигун – це блок системи управління для досягнення мети зручного використання та точного керування, що значно полегшує наше життя та підвищує рівень сучасної високотехнологічної промисловості. Зокрема, кілька крокових двигунів можуть бути об'єднані в систему і працювати разом з використанням програми дистанційного керування, що значно покращує гнучкість та застосовність обладнання. У реальному житті кілька крокових двигунів використовуються разом частіше. Наприклад, 3D-принтер, використовуючи одночасно три крокові двигуни, вісь x, вісь y та вісь z, може визначити ліву частину простору та точно надрукувати потрібний нам тривимірний об'єкт. Додавши систему дистанційного керування по WiFi можна керувати рухом двигуна в режимі реального часу та повністю автоматизувати процес. Наприклад, ендоскопи, які часто використовуються в медицині, коли ендоскопу потрібно внести мікрокоригування в положення, ми можемо використовувати дистанційне керування для внесення змін у режимі реального часу. Представлено проект використання ESP32 для керування кількома кроковими двигунами та використовує мову Python для написання програм на основі мікропрограмного забезпечення microPython для реалізації віддаленого керування кількома кроковими двигунами. Швидкість і напрямок крокового двигуна можна регулювати і керувати за допомогою імпульсних сигналів. Система годинника ESP32 може генерувати імпульсний сигнал ШІМ, ESP32 поставляється з модулем WiFi, який може підтримувати дистанційне керування. Швидкість крокового двигуна можна регулювати, регулюючи робочий цикл ШІМ програмою. У поєднанні з продуктами ESP32 продуктивність цього розробленого продукту може бути стабільною та надійною. Система відліку часу ESP32 має кілька таймерів, використання яких з системою переривань, дає можливість ефективно керувати кількома кроковими двигунами одночасно. А модуль WiFi ESP32 може реалізувати дистанційне керування легко та зручно. Відповідно до принципу дії крокового двигуна, реалізовано півкрокове керування та повнокрокове керування кроковим двигуном, а також мікрокрокове керування з використанням ШІМ сигналу, що змінюється за законом косинусної функції. Для керування двигуном було розроблено зручний веб-додаток, що дозволяє здійснювати дистанційне керування системою, що складається з чотирьох двигунів, у простий і зручний спосіб*
Ключові слова: *ESP32; кроковий двигун; дистанційне керування; WiFi модуль; microPython*

Introduction

The stepper motor cooperates with the remote control system to achieve the goal of convenient use and precise control, which greatly facilitates our life and improves the level of the modern high-tech industry.

In particular, multiple stepper motors work together and use the remote control program, which

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greatly improves the flexibility and applicability of the equipment. In real life, multiple stepper motors are used together more often. For example, a 3D printer, using three stepping motors at the same time, the x-axis, the y-axis and the z-axis, can determine the left side of the space and accurately print the 3D three-dimensional object we need [1].

By adding a remote-control system, we can control the movement of the motor in real time and can replace humans to complete complex and high-precision work. For example, endoscopes are often used in medicine, when the endoscope needs to make micro-adjustments in position, we can use a remote control to make real-time adjustments.

Stepper motors can run accurately and stably and are widely used in modern industry. Remote control of multiple stepper motors has a very wide range of uses. It can be adjusted according to specific usage conditions and can be applied in many fields [2,3].

The goal of the work

Study the principle of the stepper motor, according to the principle of stepper motor, and then based on micro python, use Python to write programs into ESP32 to realize remote control of multiple stepper motors.

Principle of stepper motor operation

There are several ways to control the phases of a stepper motor.

The first method is provided by variable switching of phases, thus they do not overlap, at one moment of time only one phase is included, Fig.1 a). The rotor equilibrium points for each step coincide with the "natural" rotor equilibrium points of a non-supply motor. The disadvantage of this control method is that for a bipolar motor at the same time 50% of the windings are turned on and for a unipolar motor only 25%. This means that full torque cannot be obtained in this mode.

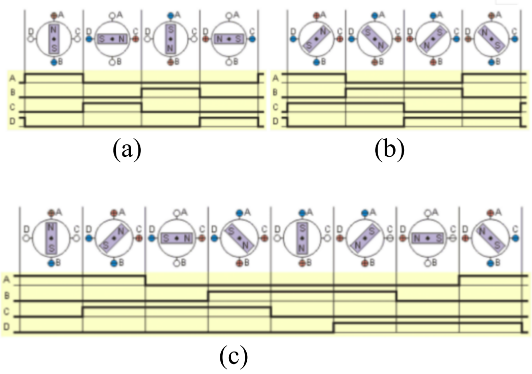

Fig. 1 – Modes of the stepper motor: a) full-step mode, one phase is included; b) full-step mode, two phases are included; c) half-step mode

The second method is overlapping phase control: the two phases are included at the same time. In this control method, the rotor is fixed at the intermediate position between the stator poles, Fig. 1 b) and provides approximately 40% greater torque than in a single contained phase. This control method provides the same step angle as the first method, but the position of the rotor balance point is moved to half a step.

The third method is a combination of the first two, called the half-step mode. This method is quite common, because the cost of a few-step motor is higher, and it is very attractive, from a 100-step motor to 200 steps per revolution. In each second step, only one phase is used for feeding, and in other cases, two are used for feeding, Fig. 1 c). As a result, the angular displacement of the rotor is the half-step rotation angle of the first two control methods. In addition to reducing the step size, this control method also allows part of the resonance phenomenon to get rid of. The half-step mode usually does not allow full torque to be obtained, although the most perfect drive implements a modified half-step mode in which the engine provides almost full torque while the power dissipated does not exceed the rated power [4, 5].

Design of remote stepper motor control system

With the development of the times, the functions of microprocessors are becoming more and more powerful, and many chips that can complete complex control functions. To carry out this project, the system design needs to be carried out first, and a complete scheme is required. After the processor is selected, a program needs to be written to complete the control of the stepper motor. At the same time, to achieve remote control, a microprocessor and computer communication are required to achieve better human-computer interaction, as shown in Fig. 2.

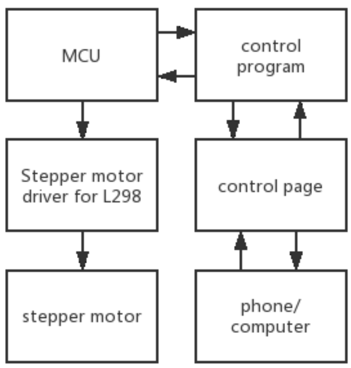

Fig. 2 – System design framework

Therefore, combined with the development board, we can use the development board to generate pulse signals to control the stepper motor and adjust the speed and direction of the motor. The project is developed based on stepper motor NEMA14 with current per winding 1 A.

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It is typically used in 3D printers, laser engraving, and small CNC machines. The stepper motor structure is shown in Fig. 3. The main characteristics of NEMA14 are as follow: model – J K35HS34-1004; turning angle in one step: 1.8^o; current per winding is 1 A.

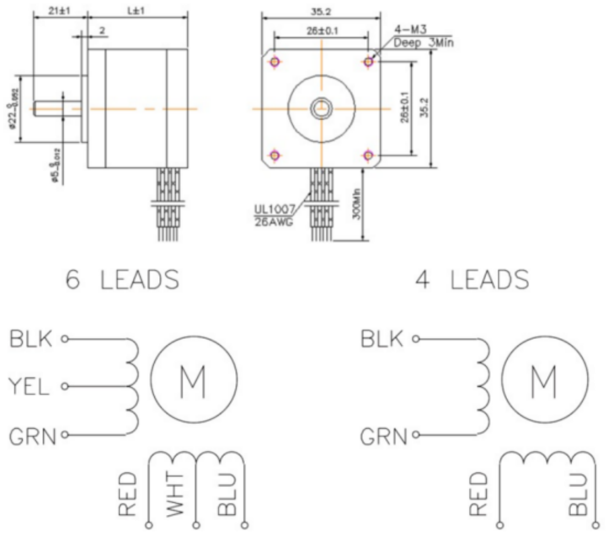

Fig. 3 – Schematic diagram of stepper motor structure

After designing the project and writing the relevant code, you need to have a detailed understanding of the state of the stepper motor when it is running, and you need to master data such as voltage and current [5].

When the stepper motor is running, it requires a change in the direction of the magnetic field, which is independent for each phase. The direction of the magnetic field can be changed in many ways. In a unipolar motor, the windings have a middle off-pole, or there are two independent windings for each phase. The direction of the magnetic field is changed by switching to half-winding or full-winding [6]. And here only two simple power switches A and B of electric drive for each stage are needed, Fig. 4.

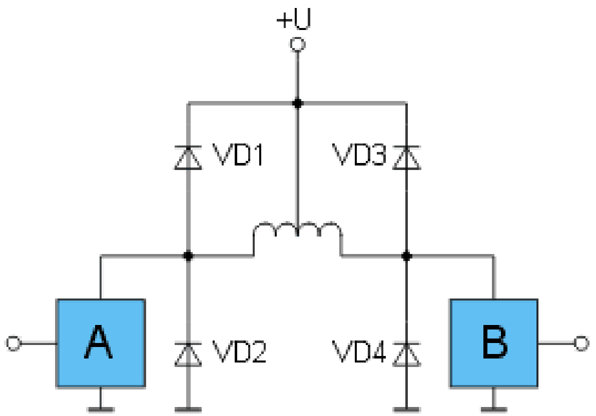

Fig. 4 – Electric drive of the unipolar motor

In a bipolar motor, the direction is changed by the output pole shift of the winding. For such an over-pole, an inverter bridge circuit is carried out for an electric drive shown in Fig. 5.

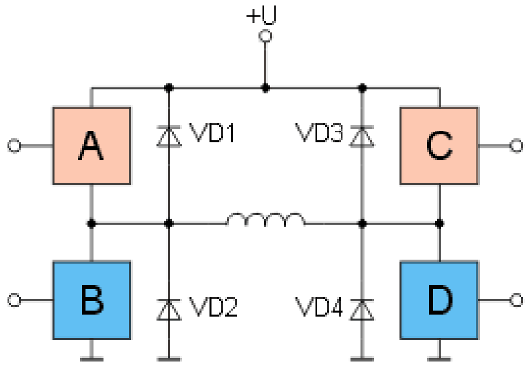

Fig. 5 – Electric drive of the bipolar motor

Program software of the control system

The data we use in the program are shown in the following Fig. 6.

```
import machine
import time
from machine import Pin
motor0=Pin(33,Pin.OUT)
motor1=Pin(25,Pin.OUT)
motor2=Pin(26,Pin.OUT)
motor3=Pin(27,Pin.OUT)
while True:

    motor0.value(1)
    motor1.value(0)
    motor2.value(0)
    motor3.value(0)
    time.sleep(0.1)
```

Fig. 6 – Half step program and data used

Here we use the delay function to write the code.

$$1.8 \div 2 = 0.9^{\circ};$$
$$360 \div 0.9 = 400 \text{ steps}; \quad (1)$$
$$400 \times 0.1 = 40 \text{ s},$$

By calculation we can conclude that each revolution of the stepper motor takes 40 seconds.

The voltage is 3.3 volts, So we can calculate the current:

$$3.3 \div 2.7 = 1.22 \text{ A}, \quad (2)$$

So the current is 1.22 amps. Rotational angular velocity:

$$360 \div 40 = 9^{\circ}, \quad (3)$$

So the rotational angular velocity is 9 degrees per second.

We can change the rotation speed by adjusting the time of the delay function without changing the voltage and current [7]. Here we also can use the delay function to write the code.

$$360 \div 1.8 = 200\,\text{steps}; \quad 200 \times 0.5 = 100\,\text{s}, \qquad (4)$$

By calculation, we can find that the time for each 360 rotation of the stepper motor is 200 seconds.

The voltage is 3.3 volts. So we can calculate the current:

$$3.3 \div 2.7 = 1.22\,\text{A}, \qquad (5)$$

So the current is 1.22 amps. Rotational angular velocity:

$$360 \div 100 = 3.6^{\circ}, \qquad (6)$$

So the rotational angular velocity is 3.6 degrees per second. We can change the rotation speed by adjusting the time of the delay function without changing the voltage and current [8].

Considering the torque problem of the stepper motor, PWM output signal whose duty ratio changes as a cosine function is designed, can make the acceleration of the stepper motor increase slowly and protect the stepper motor. The data we use in the program are shown in the following Fig. 7.

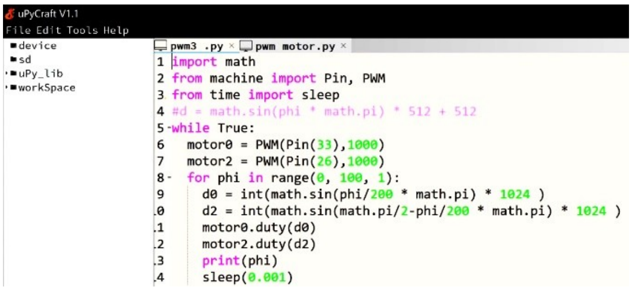

Fig. 7 – PWM program and data

In the program, the designed PWM frequency is 1000 Hz, so the period is 0.001 seconds. In this program, every time a pulse signal is given, the motor rotates a full step.

Due to the design of the PWM signal in the program, the duty cycle of the PWM changes according to the cosine function, so the delay function is used to adjust the speed. Thus, the current and voltage also change from time to time, and the cosine function also changes [9].

The number of pulse signals and the time for one rotation of the motor are required to calculate the number of pulse signals that the motor does not rotate once:

period of PWM:

$$T = \frac{1}{f} = \frac{1}{1000} = 0.001\,\text{s}, \qquad (7)$$

So the period of PWM is 0.001 seconds.

$$360 \div 1.8 = 200\,\text{steps}, \qquad (8)$$

$$200 \times (0.001 + 0.001) = 0.4\,\text{s}, \qquad (9)$$

It takes 0.4 seconds for each revolution of the stepper motor [10].

After the project is designed, it needs to be tested, and the code needs to be debugged. All functions need to be done to achieve the desired effect.

Using a computer for remote control, the test results are as expected in Fig. 8.

Fig. 8 – Written control page, computer display

Using a mobile phone for remote control, the test results are as expected. It's the same as using a computer in Fig. 9.

Fig. 9 – Written control page, phone display

Using the written code, download the program into esp32, and conduct debugging and testing experiments. The experimental results are good and the expected goals are achieved, Fig. 11.

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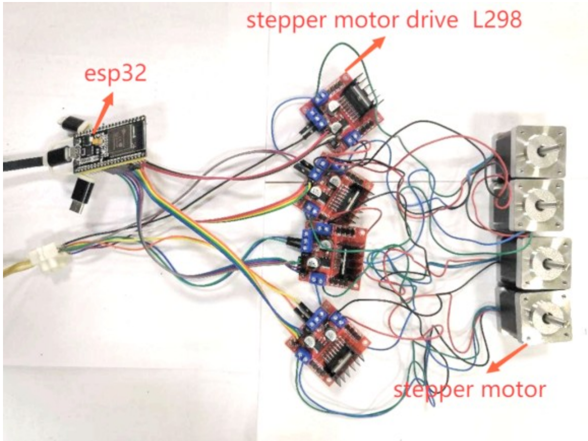

Fig. 11 – Physical test experiment

Discussion of results

Micropython is very convenient to use on ESP32, so it is more convenient and concise to use python to program this project. There are many control methods for stepper motors. Half-step control and full-step control. Combined with chip functions, using PWM to control stepper motors is more accurate and efficient. Design a PWM signal whose duty cycle changes according to the cosine function, which can effectively control the step. The torque problem of the incoming motor is solved, and the stepping motor is better protected [11].

In terms of control pages, HTML is used, which is concise and convenient and can display program functions well and realize good human-computer interaction functions [12].

Conclusions

The remote-control project of multiple stepper motors based on micro Python firmware and ESP32 has been completed, realizing the real-time remote control of stepper motors, which is a convenient, fast, practical, and highly expandable advantage [13].

The chip clock system is used, the interrupt system is used, and the pulse signal whose duty cycle of PWM changes according to the cosine function is successfully designed.

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Відомості про авторів (About authors)

Cheng Xuan – student, The department of Electronic Devices and Systems, Faculty of Electronics, National Technical University of Ukraine ‘‘Igor Sikorsky Kyiv Polytechnic Institute”, Kyiv, Ukraine; ORCID: 0000-0001-6235-7089; e-mail: xuanc274@gmail.com.

Чен Сюань – студент кафедри електронних пристроїв та систем, факультет електроніки, Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», Київ, Україна; ORCID: 0000-0001-6235-7089; e-mail: xuanc274@gmail.com.

Ievgen Verbytskyi – Doctor of Science, Docent, Department of Electronic Devices and Systems, National Technical University of Ukraine ‘‘Igor Sikorsky Kyiv Polytechnic Institute”, Kyiv, Ukraine; ORCID: 0000-0001-7275-5152; e-mail: verbitskiy@bigmir.net.

Вербицький Євген Володимирович – доктор технічних наук, доцент, Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», доцент кафедри електронних пристроїв та систем, факультет електроніки, м. Київ, Україна; ORCID: 0000-0001-7275-5152; e-mail: verbitskiy@bigmir.net.

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