AN-1
APPLICATION NOTE

Federal University of Minas Gerais

Using a Step Motor with SMT32F401RE

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Contents

1. Introduction

This application note was developed as a work in the discipline of Embedded Systems Programming at UFMG - Prof. Ricardo de Oliveira Duarte - Department of Electronic Engineering. This document gives an example of how to use the 28BYJ-48 Step Motor and the Operational Amplifier, ULN2003 with an SMT32F401RE microcontroller, and explains the concepts involved in the project and the steps you need to follow to develop an application equal or similar to this one.

The application example project was developed to be used with STM32F family and was tested using STM32 Nucleo-64 development board with STM32F401RE MCU. It can be found at the following link: `https://github.com/guihaleles/STM32_Step_Motor_AN`

2.Microcontroller Overview

The STM32F401XD/XE devices are based on the high-performance ARM® Cortex® -M4 32- bit RISC core operating at a frequency of up to 84 MHz. Its Cortex®-M4 core features a Floating point unit (FPU) single precision which supports all ARM single-precision dataprocessing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security. The STM32F401xD/xE incorporate high-speed embedded memories (512 Kbytes of Flash memory, 96 Kbytes of SRAM), and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix. All devices offer one 12-bit ADC, a low-power RTC, six general-purpose 16-bit timers including one PWM timer for motor control, two general-purpose 32-bit timers. They also feature standard and advanced communication interfaces.

3. Stepper Motor

3.1. Operation principle

The stepper motor is characterized by the ability to control the angular position of the axis by energizing the stator coils, so that we can move the axis in any desired angular position.

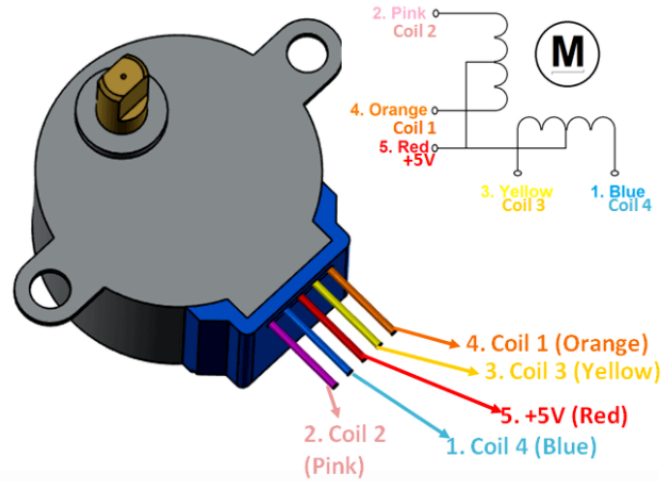

Figure 1: Step Motor

As shown in figure FIG.1, by energizing the coils, it is possible to position the shaft only in certain positions. Thus it is necessary to use a gearbox to increase the angular precision, or number of steps per revolution, thus the number of steps per revolution is the result of the gear ratios of the gearbox.

For the 28BYJ-48 we will have approximately 2040 steps / revolution.

3.2. Electrical specifications

An important characteristic of the stepper motors is its current consumption, normally the microcontrollers are not able to supply these currents, so it is necessary to use an operational amplifier.

The engine model used in this work has the following specifications:

Rated voltage = 5VDC
Number of Phase = 4
Speed Variation Ratio = 1/64
Stride Angle = 5.625° /64
Frequency = 100Hz
DC resistance 50Ω±7% (25°C)
Idle In-traction Frequency > 600Hz
Idle Out-traction Frequency > 1000Hz
In-traction Torque > 34.3mN.m(120Hz)
Self-positioning Torque > 34.3mN.m
Friction torque = 600-1200 gf.cm
Pull in torque = 300 gf.cm

Insulated resistance > $10M\Omega(500V)$
Insulated electricity power = 600VAC/1mA/1s
Insulation grade = A
Rise in Temperature < 40K(120Hz)
Noise < 35dB(120Hz,No load,10cm)

This is a unipolar motor and by the ohm law we have that the peak current is the input voltage divided by the DC resistence $I = 5V/25\Omega, I = 200mA$

3.3. Operation Modes

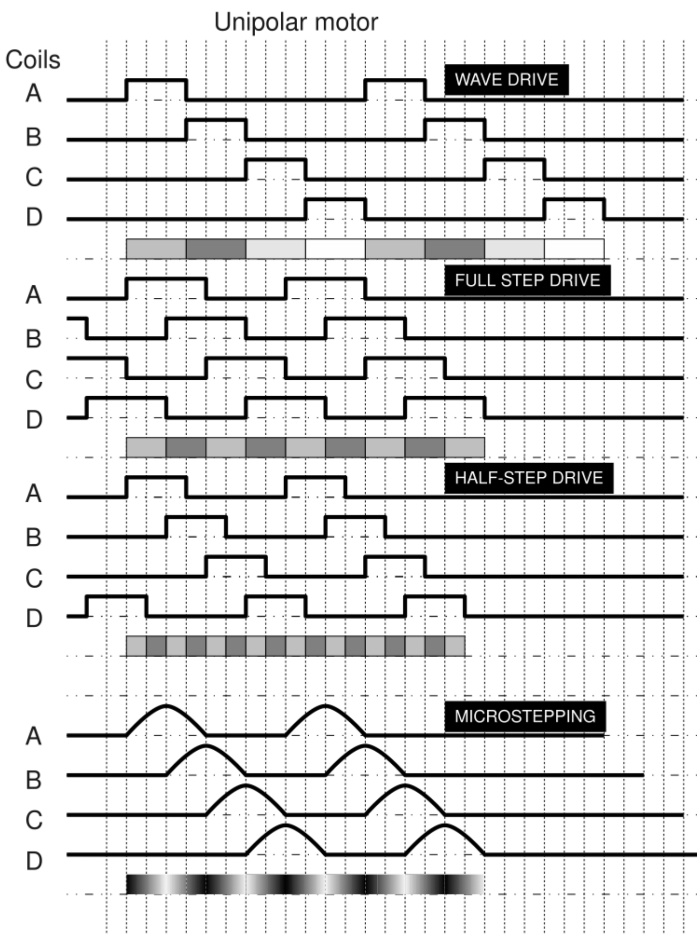

Figure 2: Different drive modes

3.3.1 Wave drive (one phase on)

In this drive method only a single phase is activated at a time. It has the same number of steps as the full-step drive, but the motor will have significantly less torque than rated. It is rarely used.

3.3.2 Full-step drive (two phases on)

This is the usual method for full-step driving the motor. Two phases are always on so the motor will provide its maximum rated torque. As soon as one phase is turned off, another one is turned on. Wave drive and single phase full step are both one and the same, with same number of steps but difference in torque.

3.3.3 Half-stepping

When half-stepping, the drive alternates between two phases on and a single phase on. This increases the angular resolution. The motor also has less torque (approx 70%) at the full-step position (where only a single phase is on). This may be mitigated by increasing the current in the active winding to compensate. The advantage of half stepping is that the drive electronics need not change to support it.

3.3.4 Microstepping

What is commonly referred to as microstepping is often sine–cosine microstepping in which the winding current approximates a sinusoidal AC waveform. The common way to achieve Sine-cosine current is with chopper-drive circuits. Sine–cosine microstepping is the most common form, but other waveforms can be used.[5] Regardless of the waveform used, as the microsteps become smaller, motor operation becomes more smooth, thereby greatly reducing resonance in any parts the motor may be connected to, as well as the motor itself. Resolution will be limited by the mechanical stiction, backlash, and other sources of error between the motor and the end device. Gear reducers may be used to increase resolution of positioning.

4. Operational Amplifier, ULN2003

The ULN2003 is high-voltage, high-current Darlington array, containing seven open collector Darlington pairs with common emitters. Each channel is rated at 500 mA and can withstand peak currents of 600 mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. The minimum current gain of this model is 1000.

As already mentioned above, the objective of this driver is to amplify the supply current in the coils.

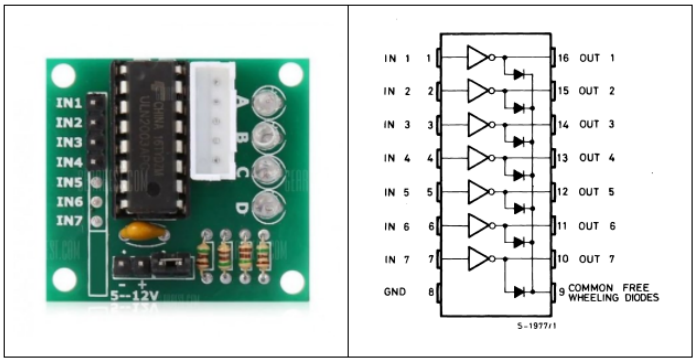

Figure 3: UNL2003

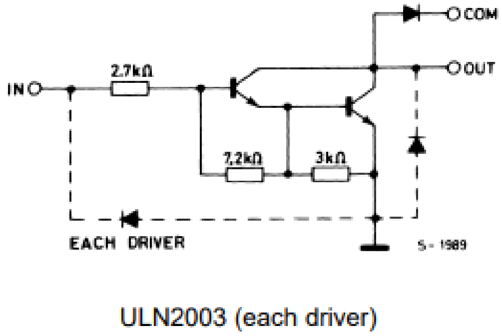

Figure 4: UNL2003 Circuit

5. Practical example

First, the CubeMax software was used to configure the GPIO's as shown in the pin table.

Pin Name	Signal on Pin	GPIO output l...	GPIO mode	GPIO P...	M...	User Label
PA0-WKUP	n/a	Low	Output Push ...	No pull-...	Low	F1
PA1	n/a	Low	Output Push ...	No pull-...	Low	F2
PA4	n/a	Low	Output Push ...	No pull-...	Low	F3
PA5	n/a	Low	Output Push ...	No pull-...	Low	LD2 [Green Led]
PB0	n/a	Low	Output Push ...	No pull-...	Low	F4

Figure 5: Pin Table

The output pins were connected to inputs of the UNL2003.

PA0 → IN1

PA1 → IN2

PA4 → IN3

PB0 → IN4

And the Moto was connected to UNL2003 Pins A,B,C and D. A 5V source was used to power the circuit.

In this example, the Full-Step operation mode was

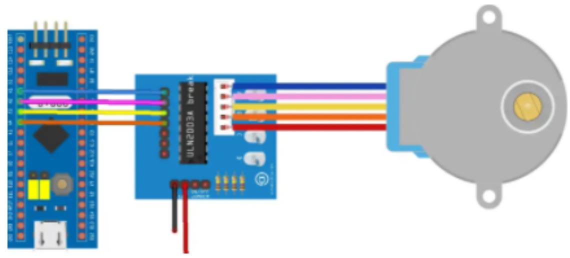

Figure 6: Exemple Circuit

used. Then, to create a waveform as shown in figure 2, a function called "stepper_full_drive" was created with the following output:

Step	1	2	3	4
PA0	1	0	0	1
PA1	1	1	0	0
PA4	0	1	1	0
PB0	0	0	1	1

Figure 7: Step Table

As shown in section 3.2, the Stride Angle is equal to 5,625°/64. Thus, the total number of steps required for a revolution is 4096.

As in Full Step mode we have two coils energized at a time, the total number of sequences needed in this mode for the revolution is 512.

A function has also been created that implements a wire delay with the desired speed.For each minute (60 seconds), 4096/2 steps are required to perform the revolution in 1 minute. The function is called "stepper_step_angle".

Finally, a function was created that uses the previous two to rotate the motor at a defined speed, angle and direction.The function is called "stepper_step_angle".

In the main loop of this application, the motor rotates 360 degrees, alternating the directions of rotation, with a speed of 10 rpm.

6. Toubleshooting

When starting the engine at a very fast speed, there may not be enough time for the mechanics to keep up with that frequency.

If the motor does not rotate, but is vibrating, check that the phase connection is correct and that the rotation speed is not below 1 rpm.

Make sure that your source is capable of supplying a sufficient current for the motor starting current and the microcontroller power.

7. References

Table 1: Revision history.

Date	Revision	Changes
08-Mar-2021	1	Initial release