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Controlling the Movement of Three Stepper Motors

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Abstract

Stepper motors will be used in industrial applications, such as robotic arm movement and printers. Stepper motors are well suited for moving from one point to another and then returning to the starting point with extreme precision. The purpose of this study is how to control the movement of three stepper motors to obtain movement in space, i.e. three-dimensional, so that we obtain movement to move from the starting point to the end point and then return to the starting point again without losing data, and because the motors step into a set of data to obtain the desired movement, a MATLAB program will be used to obtain that data that gives the best results.

Keywords: Stepping motor- Step Angle-starting point- end point-rotational movement-step increment-Step Inc.

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التحكم في حركة ثلاثة محركات للخطوة

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الملخص

سيتم استخدام محركات الخطوة في التطبيقات الصناعية، مثل حركة الذراع الآلية والطابعات. تعتبر المحركات الخطوة مناسبة تمامًا للانتقال من نقطة إلى أخرى ومن ثم العودة إلى نقطة البداية بدقة متناهية. الغرض من هذه الدراسة هو كيفية التحكم في حركة ثلاثة محركات للخطوة للحصول على حركة في الفراغ أي ثلاثية الأبعاد بحيث نحصل على حركة للانتقال من نقطة البداية إلى نقطة النهاية ومن ثم العودة إلى نقطة البداية مرة أخرى دون فقدان البيانات، ولأن المحركات تمر بمجموعة من البيانات للحصول على الحركة المطلوبة، سيتم استخدام برنامج MATLAB للحصول على تلك البيانات التي تعطي أفضل النتائج.

الكلمات المفتاحية: محرك الخطوة – زاوية الخطوة – نقطة البداية – نقطة النهاية – حركة دوارنية – زيادة الخطوة .

1. Introduction

The motors are connected according to the process required in the industrial process or according to movement or moving from one point to another. The number of motors required in a process is determined according to the type of movement required, one-step motor, two or three motors. Connection methods can be classified according to the quantity of motors used.

In this paper, three stepping motors will be used when we want movement from point to point in a straight line, a curved line, or in the form of a circle, semi-circle, or spiral movement to move a specific product. The required movement in this process is obtained by installing the three motors. Each of them is perpendicular to the other, that is, perpendicular to the direction (X У Z) so that we can obtain movement in space [1], and figure (1) shows this.

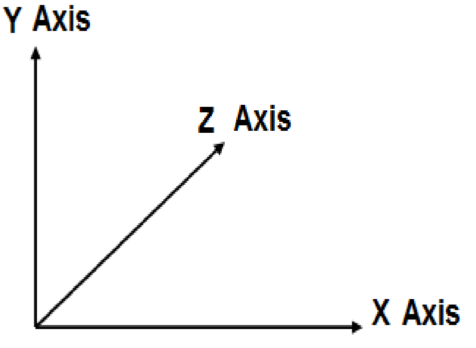

Figure 1. The direction (X У Z)

Methods of driving stepper motors

There are many styles of driving stepper motors, each of which has its own use, depending on the type of motor used (in terms of the number of poles for the fixed section and the rotating section), as well as according to the application in which this motor is used [2]. Among the common and frequently used methods are:

- Full step methods.
- Half-step methods.
- Micro step methods.

In this paper, the full step method is used.

2. Stages of motor control

As seen in figure (2), there are several stages to operate the stepper motors so that we can obtain the desired movement.

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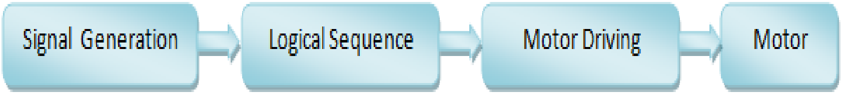

Figure 2. Stages of motor control.

- **In the first stage** (signal generation), the signal is generated through some data such as speed, direction, distance of movement, and time of stopping and moving.
- **In the second stage** (logical sequence), the generated or designed signal is converted from an analogue signal into a digital signal that carries all the data, including speed, direction, and distance.
- **As for the third stage** (driving the motor), in this stage the low-voltage digital signal is converted into a high-voltage signal (high power) according to the specifications of the stepper motor.
- **In the fourth stage**, the required movement, direction, and speed are obtained [3].

3. Signal generation.

The process of generating or designing the signal is considered one of the most important processes when operating a stepper motor and using it in industrial processes. Therefore, we will discuss in some detail the process of generating the signal. Through the process of generating the signal, we can control the speed of the rotor and the direction of movement in relation to the motor. When we want to generate a signal for any motor, the next points must be known:

- The starting and ending points of the movement.
- The form of movement required.
- The required speed.
- The number of steps per cycle of the motor.
- The number of engine revolutions to cover the required distance.
- Longitudinal distance per step.
-

3.1 Signal generation for three engines.

In the case of three motors, the signal is generated or designed by specifying the path and type of movement required by the three motors to be performed.

First, movement in a straight line [4].

If the motors have the same specifications, the distance (S) equals the distance (R), equals the distance (P), and equals 2.5 cm. Since the distances are equal, it can be considered, x = 2.5 cm, as in the figure below.

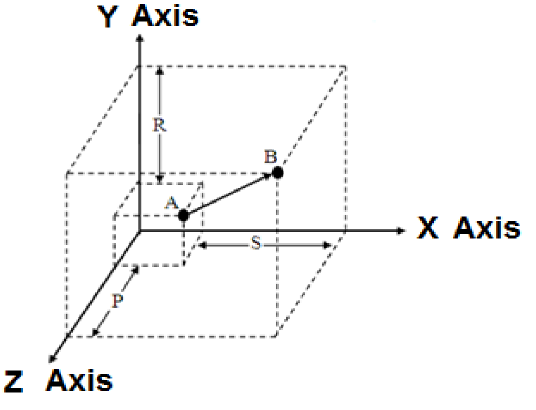

Figure 3.The type of movement required

When starting to design or generate the signal, it is necessary to know how many steps the motor needs to complete one cycle, through the following law.

Number of steps in a cycle = 360 / step angle

Pitch angle: The pitch angle varies from one engine to another and is part of the engine specifications. In this study, an engine with pitch angle specifications equal to 1.8 degrees will be used.

Through the number of revolutions required for the engine, the total steps required to cover the distance X are calculated.

The required distance X = 2.5 cm and the step angle is 1.8. The design of the signal is as follows:

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- **Number of steps** in a cycle = 360 / 1.8 = 200 steps

By calibrating the motor, it was found that it cuts 1.2 mm per cycle.

- **Data Size**: Total number of steps to cover the distance.

  Data Size = 200 * 25 mm / 1.2 = 4166 steps

- **Step Inc:**The longitudinal distance in one step is 25/ 4166 = 0.006 mm

The following equation is used to obtain data for the signal.

$$Signal\ array = \sum_{n=1}^{n=data\ size} \text{Step Inc} \tag{1}$$

The following program explains how to analyze the mathematical equation (1) using MATLAB.

```
Sum data=0;
Time=0;
Step Inc=0.006;
For loop Counter = 0 to 4166
Time= Time + 0.001
Sum Data = Sum Data + Step Inc
Plot (Time, Sum Data);
End
```

The following program explains how to analyze the previous mathematical equation using MATLAB.

```
Sum data=0;
Time=0;
Step Inc=0.006;
For loop Counter = 0 to 4166
Time = Time + 0.001
Sum Data = Sum Data + Step Inc
Plot (Time, Sum Data);
End
```

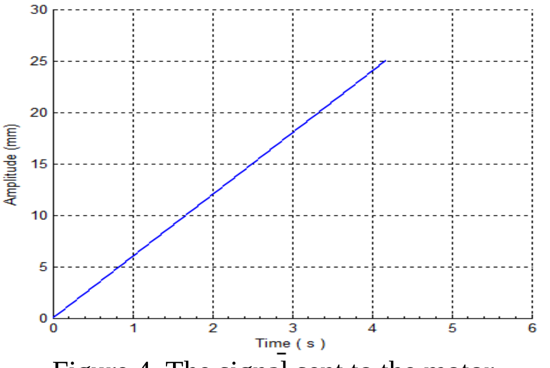

Figure 4. The signal sent to the motor

Through the figure (4), we have obtained a signal that represents the signal sent to the motor to rotate forward at the engine's maximum speed.

4. Motor speed control.

The minimum sampling time is 0.001. This means that the number of samples is 1000 samples per second. We can take 500 samples per second, meaning a sampling time of 0.002, and 333 samples per second at 0.003... etc., but we cannot obtain a sampling time between 0.001 and 0.002. When we want to do this, we use repetition to obtain a delay time so that we get numbers between 0.001 and 0.002.

4.1 Highest motor speed.

The number of steps per cycle is 200 steps, and it covers a longitudinal distance of 1.2 mm per cycle

The highest motor speed is 5 * 1.2 = 6 mm per second

It is possible to reduce the speed of the motor when generating or designing the signal, either by setting different speeds during design or by giving a variable that is controlled during operation. We will discuss this in some detail through future studies.
In the same previous case, if it was required to generate a signal to obtain a distance, the point of origin was returned.

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This is expressed mathematically by the following relationship:

$$A(n) = \begin{pmatrix} n < Array\ Size/2 & \sum_{k=1}^{n=\text{Array Size}/2} & \text{Step Inc} \\ n > Array\ Size/2 & \sum_{k=\text{Array Size}/2}^{n=\text{Array Size}} & -\text{Step Inc} \end{pmatrix} \quad (2)$$

The MATLAB language was used:

Signal Array = 0
Time = 0
Array Size = 8332
Sum Data=0;
Step Inc = 0.006;
For loop Counter =1 to Array Size/2
Time = Time + 0.001
Sum Data = Sum Data + Step Inc
A(Counter) = Sum Data
Plot (Time, Sum Data)
End
For loop Counter =Array Size/2 to Array Size
Time =Time +0.001
Sum Data = Sum Data – Step Inc
A (Counter) = Sum Data
Plot (Time , Sum Data)
End

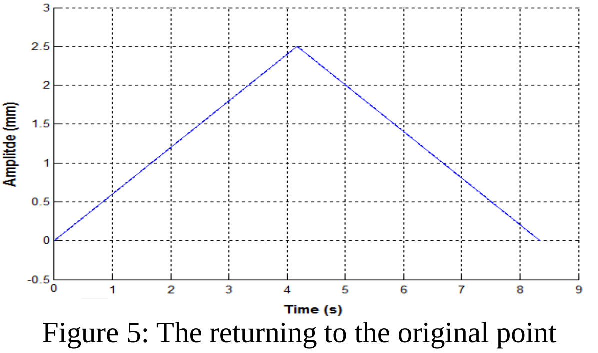

Figure 5: The returning to the original point

From the shape of the signal in figure (5), we notice that the speed of the motor moving and returning to the original point is at the same speed, i.e. the maximum speed of the engine.
In the same previous case, if it was required to generate a signal to obtain a distance, the point of origin was returned. So that the return speed is half the speed of travel, with the motor stopping time before returning, the MATLAB language was used and the program used in this process is as shown below.

```
Time =0
Sum data=0
Step Inc=0.006;
For loop Counter = 0 To 4166
Time = Time +0.001
Sum Data = Sum Data + Step Inc
Plot (Time, Sum Data)
End
For loop Counter =1To1000
Time=Time+0.001
Plot (Time, Sum Data)
End
For loop Counter = 1 To 8332
Time = Time + 0.002
Sum Data = Sum Data – Step Inc
Plot (Time, Sum Data)
End.
```

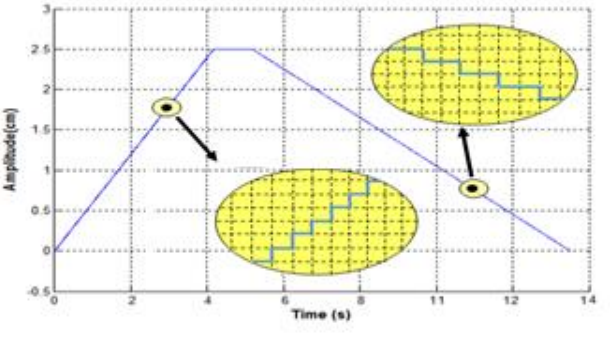

Figure 6.The returning by half speed

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We notice from the figure (6) that the motor speed in the reverse state is less than the motor speed in the forward state, in addition to the stopping time.

5. Logical sequence.

At this stage, the generated signal is converted into a digital signal or a series of pulses to be sent to the motor to stimulate the motor coils to obtain the rotor's intended motion. Four pulses are sent at the same time in each case to obtain a full step or half a step. In the case of a full step, Sending pulses according to the cases assigned to each schedule. When the number of cases expires, the schedule is repeated again until the requested movement is obtained [5].

Step				
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

forward

	1	2	3	4
Phase 1	1	0	1	0
Phase 2	0	1	0	1
Phase 3	0	1	1	0
Phase 4	1	0	0	1
Phase 1	1	0	1	0

Reverse

Figure 7. Shows the tables of Forward and Reverse motion of the stepper motor

As seen in figure (7), in the case of forward rotation, the table states are sent from top to bottom, while in the case of reverse rotation, the table states are sent from bottom to top.

At this stage, one of the previously generated signals will be taken and converted into a series of pulses through the use of one of the programming languages. In this study, the MATLAB language was used and the program used in this process is as shown below.

```
Signal Array=0
Time = 0
Sum Data=0;
```

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```
Step Inc = 0.006
A = Zeros(0,9333)
B = Zeros(0,9333)
D = Zeros(93,4)
C = Zeros(4,4)
C(1,1) =1; C(1,2) = 0 ; C(1,3) = 1; C(1,4) = 0 ; C(2,1) = 0 ;
C(2,2) = 1 ;
C(2,3) = 0 ; C(2,4)=1 ;C(3,1) = 0 ;C(3,2) = 1 ; C(3,3) = 1 ;
C(3,4) = 0 ; C(4,1) = 1 ; C(4,2) = 0;C(4,3) = 0 ; C(4,4) = 1 ;

For Loop Counter = 1 To 4167
   Time = Time + 0.001
   A(Counter) = Sum Data
   Sum Data = Sum Data + Step Inc
   hold on
   plot (Time, Sum Data)
End

 For Loop Counter = 1To1002
   Time = Time + 0.001
    A(i+4167) = Sum Data
    hold on
    plot (Time, Sum Data)
End

 For Loop Counter = 0 To 4166
   Time = Time + 0.001;
   Sum Data = Sum Data – Step Inc
  A (Counter +5167) = Sum Data
   hold on
  plot (Time, Sum Data)
End

For Loop Counter1 = 1 To 9335
   Time = Time +0.001;
 If (A (Counter 1+1) - A(Counter1)  > 0)
```

B (Counter1) =1;
Else
If (A (Counter 1+1) – A (Counter1) == 0)
B (Counter1) = 0
Else
B (Counter1) = -1
End
End
End

The result obtained is as in the following tables: Table (1a) represents the signal sent to the engine in the case of forward rotation, while Table (1b) represents the signal sent to the engine in the state of parking, and table (1c) represents the signal sent in the case of reverse rotation.

Table 1. The signal sent to the motor

	1	2	3	4
4168	0	0	0	0
4169	0	0	0	0
4170	0	0	0	0
4171	0	0	0	0
4172	0	0	0	0
4173	0	0	0	0
4174	0	0	0	0
4175	0	0	0	0
4176	0	0	0	0
4177	0	0	0	0
4178	0	0	0	0
4179	0	0	0	0
4180	0	0	0	0
4181	0	0	0	0
4182	0	0	0	0
4183	0	0	0	0
4184	0	0	0	0
4185	0	0	0	0
4186	0	0	0	0
4187	0	0	0	0

(a)

	1	2	3	4
5169	1	0	0	1
5170	0	1	1	0
5171	0	1	0	1
5172	1	0	1	0
5173	1	0	0	1
5174	0	1	1	0
5175	0	1	0	1
5176	1	0	1	0
5177	1	0	0	1
5178	0	1	1	0
5179	0	1	0	1
5180	1	0	1	0
5181	1	0	0	1
5182	0	1	1	0
5183	0	1	0	1
5184	1	0	1	0
5185	1	0	0	1
5186	0	1	1	0
5187	0	1	0	1
5188	1	0	1	0

(b)

	1	2	3	4
1	1	0	1	0
2	0	1	0	1
3	0	1	1	0
4	1	0	0	1
5	1	0	1	0
6	0	1	0	1
7	0	1	1	0
8	1	0	0	1
9	1	0	1	0
10	0	1	0	1
11	0	1	1	0
12	1	0	0	1
13	1	0	1	0
14	0	1	0	1
15	0	1	1	0
16	1	0	0	1
17	1	0	1	0
18	0	1	0	1
19	0	1	1	0
20	1	0	0	1

(c)

After obtaining the serial signal shown in the previous table, which represents the signal designed according to the required movement of the engine, it is sent to the motor drive circuit.

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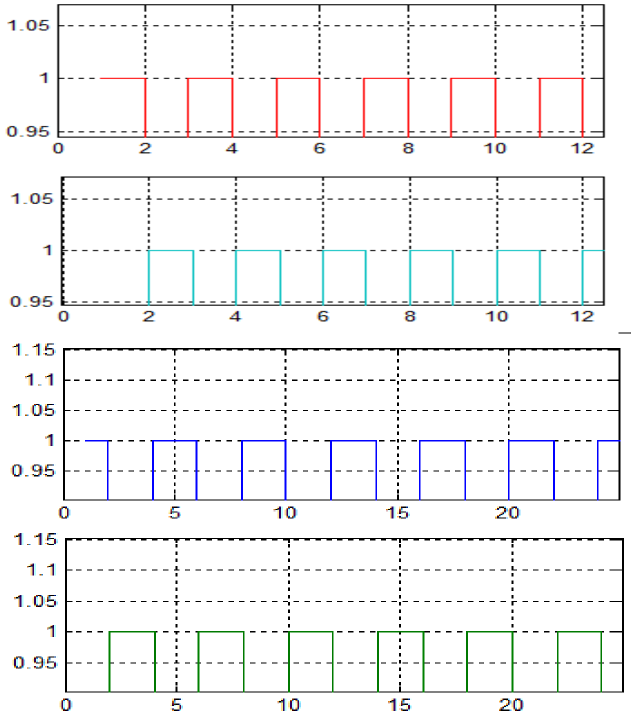

Figure 8. The series of pulses.

The previous set of shapes in figure (8) represents a set of a series of pulses with a voltage ranging from 3.5 to 5 volts that are sent to the motor drive stage to obtain high-voltage pulses. The previous set of shapes is specific to a single motor with four stimulation wires in addition to the ground wire.

6. Driving the motor

The basic function of the motor drive circuit is to provide the required voltages for the motor, and the value of the voltages required to be provided is according to the specifications of the motor.

After obtaining a series of pulses, the voltage value of the pulses will be low, not exceeding 5 volts. This value cannot be sent directly to the motor directly to the motor, because the motor needs a high

voltage exceeding 5 volts, in addition to needing to draw a current. Therefore, it is necessary to enlarge the voltage value of the motor in addition to the current in it. This stage we will focus on the final circuits in control and driving in some detail, and in particular focus on one thing, which is switching the current in each winding between the two states (on and off) and controlling the direction of flow of that energy. While, on the other hand, the control mechanism is carried out through a digital signal or a series of pulses that were produced in the stage.
The process of amplifying the voltage is done through the use of witches, and the idea of how the switches work is as shown in figure (9) [6].

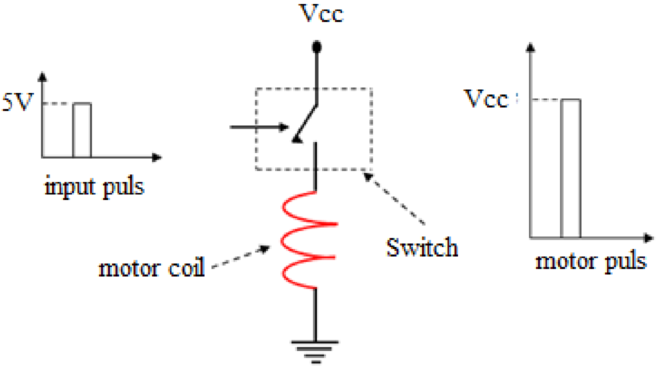

Figure 9. The motor driving circuit.

When the value of the pulse or generated signal is 1, i.e. 5 volts, the witch will be closed, which allows or secures a high voltage (Vcc) for the motor, that is, the motor is directly connected to the high voltage during the same time period as the pulse width. Now the pulse is controlling the process of closing and opening the switch. In this the shape of switches expresses the function of each of them opening or closing the circuit and thus passing or closing. They are controlled through a series of pulses generated from the logical sequence stage. At this stage, transistors can be used and relays cannot be used as switches.

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7. Conclusions

In this research, we studied how to operate three stepper motors in the correct way to obtain 3D movement.

This was done by identifying the desired movement and converting that movement into a signal.

Through the signals we were able to obtain digital data to send to those three stepper motors and obtain the desired movement that had been prepared for them in advance.

Sampling and quantification are also demonstrated when moving from one point to another, without any data loss, meaning that returning to the starting point is extremely accurate.

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