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A Transistor Based Fast Driving Circuit for Bipolar Step Motor Driving

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Abstract

This work involves developing a transistor based driving circuit for a bipolar step motor. TIP41 and TIP42 transistors are used to construct the driving circuit. The control circuit is constructed based on PIC 18F452 microcontroller. The overall system is first tested in simulation using Proteus program and then implemented experimentally on the breadboard. Experimental results showed that the driving circuit successfully runs the bipolar step motor in both directions and at various speeds.

Key words: Bipolar step motor; Transistor based driving circuit

Bipolar Adım Motorları Sürmek İçin Transistör Tabanlı ve Hızlı Bir Sürücü Devresi

Özet

Bu çalışma bipolar adım motorları için transistör tabanlı ve hızlı bir sürücü devre tasarımı geliştirilmesi aşamalarını içermektedir. Sürücü devresi TIP41C ve TIP42C transistörleri kullanılarak geliştirilmiştir. Kontrol devresi PIC 18F452 mikrodenetleyicisi kullanılarak gerçeklenmiştir. Sistemin tamamı önce bilgisayar ortamında Proteus programı kullanılarak simule edilmiş daha sonra ise bord üzerinde kurularak gerçeklenmiştir. Deneysel sonuçlar sürücü devresinin biplar adım motorunu her iki yönde ve farklı hızlarda başarılı bir şekilde çalıştırdığını göstermiştir.

Anahtar Kelimeler: Bipolar adım motoru, Transistör tabanlı sürücü devresi

1. Introduction

Step motors are electrical motors where only stator has windings. Rotor is usually made of either a magnetic material or magnetically soft material such as iron. They differ from DC motors in the sense that step motors work with voltage pulses applied to its windings in the correct order whereas DC motors work with continuous application of DC voltage to its windings. Each pulse applied to windings of the step motor is independent of the others and causes the motor shaft to turn a fixed degree which is called step size. A step size can change from 90 degrees to 1.8 or even to 0.72 degrees depending on type of the step motor and the control architecture used. These types of motors are highly preferred in robotics and other applications where accurate positioning is needed.

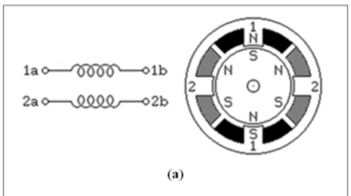
There are several types of step motors. 3 of them are commonly used. These are unipolar, bipolar and variable reluctance. Operation of step motors can be controlled by either open loop or closed systems. Open loop systems are easy to implement and generally preferred in those applications which have static load and low acceleration requirement. When high acceleration, variable load or both are associated whit an application, closed loop control is used. Closed loop control of a step motor requires more sophisticated driving circuit and is costly [4].

In our previous work, we had developed a relay based driving circuit for a PCB machine [1]. The movable mechanical parts of the PCB machine were operated by two bipolar step motors. In that work we had mentioned that although the relay based driving circuit had successfully ran the PCB machine, the operation of the machine was slow and noisy. In this work, we will demonstrate development of a transistor based driving circuit for a bipolar step motor. Our future works will concentrate on application of this driving circuit to the PCB machine we had developed to overcome those limitations and also make its operation faster.

This study involves developing an open loop control driving mechanism for a bipolar step motor. We require the driving circuit to run the step motor adequately fast to enable the motor to be used in real time applications and to supply strong torque to the motor’s shaft which enables the motor to operate under large amount of load conditions.

2. Material and Methods

A bipolar step motor can be modeled with two windings that consist of a coil and a resistor. The resistor value is small and corresponds to the resistance of the wire that constitutes the winding. One complete cycle through these two windings involves 4 steps. To obtain a continuous motion of the motor shaft, the steps have to be applied in an orderly and repeated manner. A motion in the reverse direction is accomplished by application of the same 4 steps in the reverse order, i.e. from step 4 to step 1. The Figure 1 demonstrates an ideal bipolar step motor model and 4 steps of one complete cycle.



	1a	2a	1b	2b
STEP 1	1	0	0	0
STEP 2	0	1	0	0
STEP 3	0	0	1	0
STEP 4	0	0	0	1

(b)

Figure 1(a). An ideal bipolar step motor model. (b) The order of 4 steps for one complete cycle.

In practice, the steps given in the Figure 2(b) are considered as reference pulses. There has to be a circuit generally called driving circuit in order to receive these pulses from a controller unit and translate them into actual voltage requirements of windings with correct polarities. The controller unit can be digital circuit or a single microcontroller. In our study, we have chosen to utilize a microcontroller to control/perform all duties of the driving circuit. The Figure 2 shows the reference pulses corresponding electronic circuits that need to be generated at terminals of the bipolar step motor. The reference pulses are obtained from RD0-RD3 pins of a PIC 18F452.

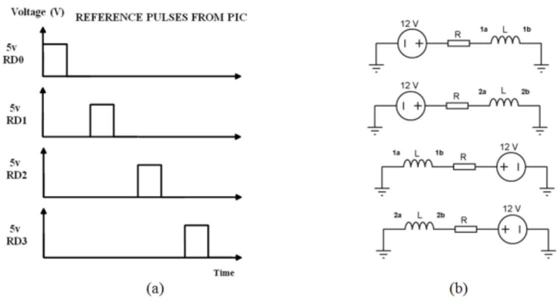


Figure 2. Reference pulses sent from a PIC 18F452. (b) Corresponding voltage requirements that are generated at windings of the bipolar step motor.

In order to provide voltage requirements specified in the Figure 2b to the terminals of the motor, we have developed a circuit containing 1 TIP41C and 2 TIP42C transistors and a resistor [2, 3]. The circuit can be considered as current amplification circuit where the current flowing through the motor winding (in between **1a** and **1b** terminals) is put into on or off state by transistor labeled as T2. The Figure 3 shows the schematic of the current amplifier circuit.

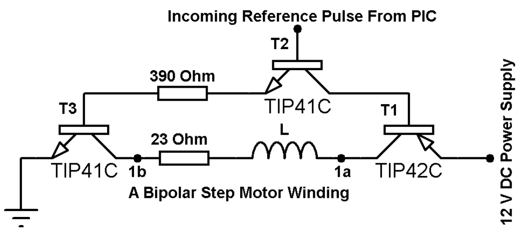


Figure 3. Schematic of the current amplifier circuit.

The above figure shows that the step motor used in this study has 23 ohm internal resistance on each winding. 12 V voltages are supplied to the amplifier input. A pin of microcontroller is connected to the base terminal of the transistor labeled T2. The reference pulse on this pin puts both T1 and T3 transistors into **on** or **off** state at the same time. While operating in the **on** state, the transistors labeled as T1 and T3 works in the saturation region. Consequently, voltage drops in between emitter-collector terminals of T1 (V_{T1EC}) and collector-emitter terminals of T3 (V_{T3CE}) are almost zero. Hence almost all voltages applied from input drop on the motor terminal which is connected in between 1a and 1b. This causes maximum amount of current to be supplied to motor winding which in turn would generate the maximum torque on the motor shaft.

The driving circuit for the bipolar step motor is constructed from above current amplifiers. 4 current amplifiers are used. Each one provides voltage requirements of a motor winding with correct polarity as stated in the Figure 2b. To run the motor, reference pulses generated by the microcontroller are applied to the T1 transistors of each amplifier with the order shown in the Figure 2a. To run the step motor in the opposite direction, the steps given in the Figure 2a are applied in the reversed order. The schematic of the microcontroller based driving circuit is given in the Figure 4.

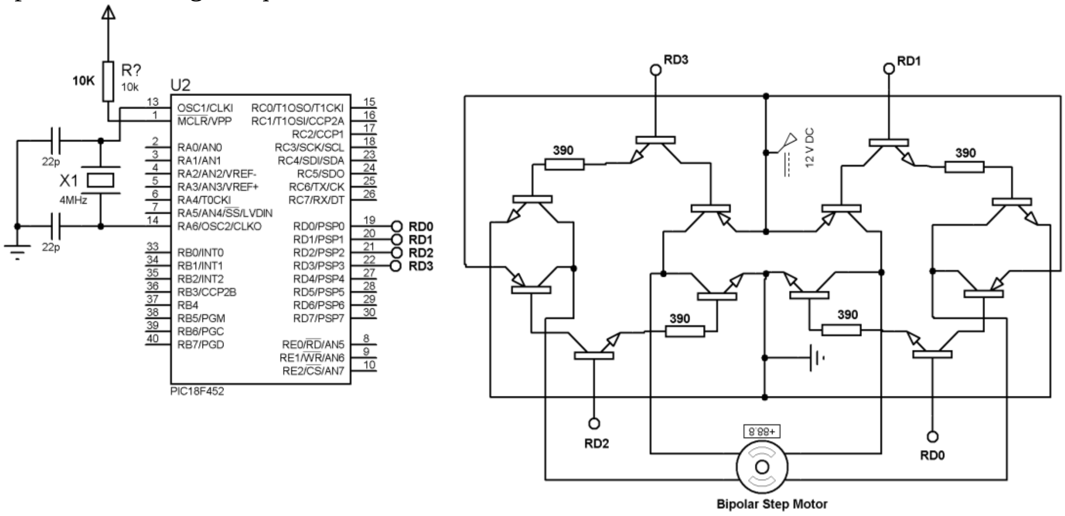


Figure 4. The schematic of the bipolar step motor driver.

The speed of the motor is controlled by duration of reference pulses. It is important to select right duration for pulses which can differ from a motor produced by one company or another. Short pulse durations either do not operate the bipolar step motor or produces a weak torque on the shaft. On the other hand, large pulse durations cause noise, vibration and draw large amount of current from source while the motor is running.

3. Results

We have implemented the above driving circuit on the breadboard and connected it to the terminals of the bipolar step motor at our Control & Instrumentation Lab. The step motor used in our study is obtained from mechanical parts of a broken textile machine. 12 V is applied from DC source to the input of the amplifier circuits as shown in the Figure 4. Reference pulse of each step is obtained from PORTD pins of a PIC 18F452 microcontroller. A picture of the experimental setup is shown in the Figure 5.

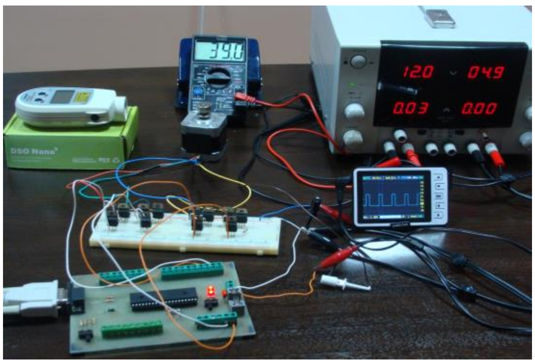
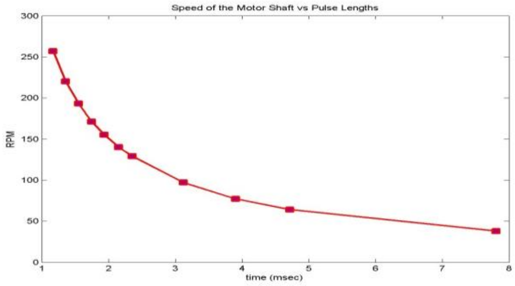
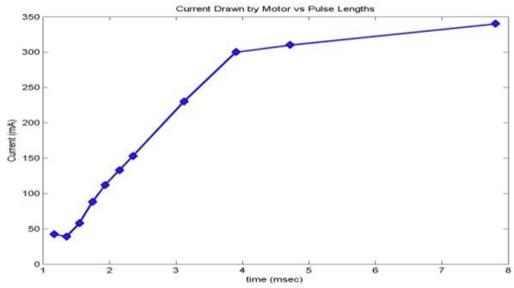


Figure 5. A picture of the experimental setup.

The experiment is conducted as follows: A constant value is used to generate pulses shown in the Figure 2(a) with the PIC. The pulse length of all four pulses is kept at the same level. When these pulses are sent to the terminals of the step motor, consecutive pulses are sent as soon as the previous pulse was completed, i.e. there was no delay in between consecutive pulses. Then, we have measured the speed of the motor shaft and the current drawn by the step motor from the 12V power supply. The speed measurement is performed in RPM unit by a Shimpo PH-200L digital tachometer. The current measurement is done with DT860D digital multimeter. The experiment is repeated for 11 different values of pulse lengths and results are shown in the Figure 6.



(a)



(b)

Figure 6. (a) Speed of the Motor v.s. pulse length, (b) Current drawn by the motor v.s. pulse length

The driving circuit we have developed successfully ran the bipolar step motor at our lab. We were able to drive the motor in both way and at various speeds. The best value of the pulse length that resulted in the maximum torque, the fastest speed and almost no amount of vibration was around 2.2 msec. When pulse length of less than 1 msec was used, the motor did not work. The pulse length of greater than 10 msec caused the motor to work slowly with some amount of vibration, noise and large amount of current. The Figure 7 shows oscilloscope readings of voltages on the motor windings for two consecutive reference pulses.

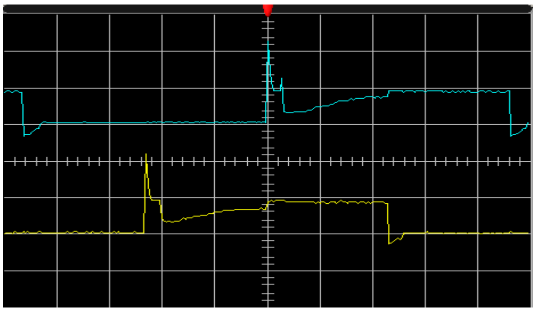


Figure 7. Oscilloscope readings of two consecutive pulses applied to the bipolar step motor.
Probe Attenuation: 10 Times; Volt/Div: 1V;
Time/Div: 1 msec.

4. Conclusion

We have designed and implemented a transistor based driving circuit for a bipolar step motor. The driving circuit successfully ran the bipolar step motor at our lab with adequate amount of torque, fast speed and low operation noise.

Our future works will concentrate on application of this driving circuit to the PCB machine we had developed earlier in order to improve PCB machine's operation in terms of both speed and smoothness.

5. References

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