Microcontroller based stepping motor controller

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Abstract—**This article is focused on a microprocessor based stepper motor controller system. In the past few decades automation took over manufacturing more and more and this tendency will probably continue. However, automation is an expensive process, this work presents an affordable solution. First it will briefly discuss the different types of stepper motors, their advantages and compare their most common control methods. Then it will present the developed system and the control circuit's implementation.**

I. Introduction

Automation is a growing industry. It is much cheaper at large quantities and the there are fewer errors. Machines can do the same tasks over and over with high precision. Robots can be moved by pneumatic or hydraulic systems, motors, etc. Unfortunately, small companies can not afford professional manufacturing systems. The aim of this project was to develop a multifunctional, precise and cheap control system, especially for small applications. A controller circuit has been designed which can store and execute the required moving tasks. It uses stepper motors because their wide variety, high precision and relatively low price. It implements the most common control techniques.

II. Stepping Motors

In robotics and automation there are two basic types of motors, steppers and servo motors. Both solutions have their advantages and disadvantages. The main advantage of steppers over servo motors is that servo motors require some kind of feedback in order to determine the actual position of the shaft while steppers can be controlled very precisely without any feedback. Stepper motors are widely used in applications like CNC machines, robots, etc.

A. *Variable-reluctance motors*

Variable reluctance (VR) motors are the simplest type of steppers. They are not commonly used because of their poor performance. The most typical VR motors have 3 windings, but motors with 4 or 5 windings are also available. The rotor is usually made from laminated soft iron because of its good magnetic characteristic. These motors tend to spin free when there is no current on the windings because in this case the rotor has not got a magnetic field. VR motors usually have low torque and medium-high speed.

B. *Permanent magnet motors*

Permanent magnet (PM) motors use a magnet as a rotor. These motors have higher torques than VR motors because of the increased magnetic field in the rotor, especially with neodymium magnets. These motors are available with two fundamental windings; unipolar and bipolar.

In the case of unipolar motors the middle of the winding has an output node. This is called centre tap. The structure of the motor is more complex because of the centre tap but the control circuit is simpler. Usually the centre tap is connected to the positive power supply and the winding endpoints are connected to the ground in a specific sequence.

Bipolar motors have not got central taps so the motor's structure is simpler but requires a controller that can alternate the current on the windings. This is done by using H-bridges in the control circuit.

C. *Hybrid motors*

From the controller's point of view hybrid (HB) motors are identical to permanent magnet motors. As their name implies these motors use the advantages of both PM and VR motors. HB motors have toothed rotor with an axial magnet on it. The teeth of the rotor help increase the magnetic flux therefore increasing the torque. The number of teeth determines the motor’s resolution. Usual values are 0.72°, 0.9°, 1.8° and 3.6°. These motors require high precision manufacturing so they relatively expensive. However, this is the most common type of steppers in the field of robotics.

III. Control Methods

The performance and precision of steppers is highly depends on the control circuit. With an appropriate controller also the speed and the motor’s resolution can be increased. In this chapter these methods will be discussed.

A. *Wave Step*

This is the simplest control method. In this case only one winding is powered at a time. With this method the motor’s performance is very poor so it is not often used.

B. *Full Step*

In full step mode two winding is powered at the same time what increases the torque of the motor but also increases the power consumption. It also has a side effect. The shaft’s equilibrium point is shifted by half a step. This is a very often used control method and datasheets usually specify the motor’s characteristic using this method.

C. *Half Step*

Half step control method combines the previous two solutions. It alternately uses the wave and full step methods. Because the full step mode shifts the shaft by half a step compared to the wave step method the resolution is doubled. However, this has a big disadvantage because the instability of motor's torque.

D. Micro Step

Micro stepping is the most advanced control method. It requires a complex control circuit with current feedback from the windings. By driving through different currents on the windings it is able to divide one step in many steps. In theory one step could be divided into infinite number of steps but in practice this can not be done e.g. because the shaft's friction.

IV. Control System

The control system consists of three main components; a PC application what sends the instruction to the device, the main control circuit what controls the motors and additional peripherals and a driver circuit what converts the control signal into high voltage signals.

The user interface has a 4x16 character LCD and 4 pushbuttons. The purpose of this interface is to show basic information about the running process and let the user to change the configuration of the device.

A. PC Software

A simple PC application has been created in order to test and debug the control circuit. The software's task is to send information to the device such as speed, torque, direction, control method, etc. In future development the aim is to create a highly customizable DLL based software package what is able to control more than one device in the same time.

B. Control Circuit

The control circuit responsible for calculate the outputs for the motor. Besides that it also controls the LC Display and the communication with the PC.

Fig. 1, shows the control circuits block diagram. IC1 is a dsPIC33FJ256MC710 Digital Signal Controller (DSC). This is the main part of the board. It is capable of run at 80Mhz. It has 4 Pulse Width Modulation (PWM) module what can produce 8 outputs altogether. These outputs are used to drive the driver circuit. IC2 is a PIC 18F4550 microcontroller. Its main job is the communication with the PC what is done over USB. It has been configured as a custom class device so it requires the Microchip's USB driver. On the board there is a power regulator (IC4) what produces the required 3.3V for IC1. IC2 runs from 5V.

The communication between the two controllers is done with a two wire bus using Inter-Integrated Circuit (I^2C) protocol. I^2C uses open collector outputs what is a big advantage because the different voltage levels. An external pull-up resistor is enough on both lines an additional level shifter is not necessary.

The motor control is done by PWM. The duty cycle of the output is proportional to the current on the windings. The controller implements very powerful PWM modules. One PWM module can drive two outputs simultaneously. In complementary output mode the outputs can directly drive the H-bridge two sides. There is a possibility to set up a dead time in this mode in order to prevent short-circuits. Additionally, the outputs can be overwritten what increases the flexibility of the programming.

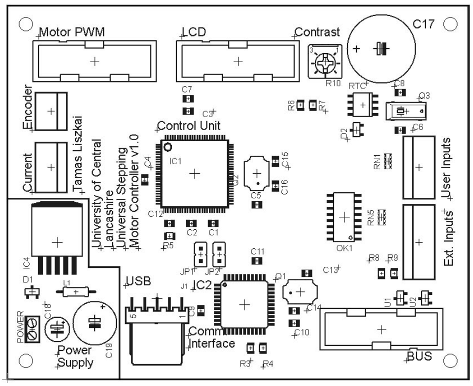

Figure 0. Block diagram of the control circuit

C. Driver Circuit

The control circuit can provide only a 3.3V signal level. This is not enough to drive the motor so an additional circuitry is required. This is ideally done by high power H-bridges, but for the first tests it uses a Darlington array to drive the motor. The rising time of the current depends on the applied voltage so this has to be high enough to produce a fast rising time.

V. Test Resultes

Test has been done using a fine resolution unipolar stepper motor. The motor's speed has been measured in three different control method and the results have been compared. Table 1, contains the results from the test. It clearly shows the difference between the wave step and full step methods. Also a slight increase of performance can be observed with half step technique. This is a beneficial consequence of the higher resolution.

TABLE I.
CONTROL METHOD COMPARISON

Control technique	Maximum start frequency	Compensated maximum start frequency	Calculated RPM	Percentage
wave	1.377kHz	1.377kHz	103.28	89.36%
full step	1.541kHz	1.541kHz	115.58	100.00%
half step	3.135kHz	1.568kHz	117.56	101.72%

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