

MICROSTEPPING TEST BOARD WITH SPECIALIZED CIRCUITS

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Abstract: The paper presents a control system for low speed stepper motor control in a microstepping mode, which was designed and performed with a high performant specialized integrated circuit LMD 18245, made by National Semiconductor company. The microstepping control system improves the positioning accuracy and eliminates low speed ripple and resonance effects in a stepper motor electric drive. The same microstepping system is ideal for robotics, printers, plotters, X-Y-Z tables and can facilitate the construction of very sophisticated positioning control systems while significantly reducing component cost, board space, design time and systems cost. The microstepping card is designed for continuous operation.

Key words: microstepping, digital control, stepper motor, power driver.

1. INTRODUCTION

The stepper motors are used in many applications because of their advantages. Thus, they move in quantified increments (steps) which lands them easy to digital control motion systems in open-loop mode. In addition, their drive signals are square waves which are easily generated by the digital circuits with relatively high efficiency [1]. But stepper motors are not free of problems. Their large pulse driver waveforms create mechanical forces which excite and aggravate the mechanical resonance's in the system. These are load dependent and difficult to control since stepper motors have very little damping of their own. At resonance a stepper motor system is likely to lose synchronization and therefore skip or gain a step. Being an open loop system, this would imply loss of position information and would be unacceptable. A common method of solving this problem is to avoid the band of resonance frequencies altogether, but this might put severe limitations on system performance.

The paper presents a microstepping system using a high performance LMD 18245 integrated circuit made by National Semiconductor. The LMD 18245 full-bridge power amplifier incorporates all the circuit blocks required to drive and control current in a brushed type DC motor or one phase of a bipolar stepper motor. The LMD 18245 controls the motor current via a fixed off-time chopper technique. An all DMOS H-bridge power stage delivers continuous output currents up to 3A at supply voltages up to 55V. A four-bit digital-to-analog converter (DAC) provides a digital path for controlling the motor current, and, by extension, simplifies implementation of full, half and microstep stepper motor drives. For higher resolution applications, an external DAC can be used.

2. MICROSTEPPING MODE

One way to avoid the problems associated with stepper motors while still retaining their open loop advantages is to use them in the microstepping mode. In this mode each of the steps is subdivided into smaller steps or “microsteps”. Applying currents to both phases of the motor creates a torque phasor which is proportional to the vector sum of both currents. When the phasor completes one “turn” (360 electrical degrees), the motor moves exactly four full steps or one torque cycle. Similarly, when that phasor moves 22.5 electrical degrees the motor will move $(22.5/90) \cdot 100 = 25\%$ of a full step. Thus the position of the motor is determined by the angle of the torque phasor. When used with an appropriate motor a positioning accuracy of 2% of a full step can be achieved, equaling 0.036 degrees for a 200 full steps per revolution motor. In this manner the motor can be positioned to any arbitrary angle. A common way to control the angle of the torque phasor is by applying to the motor’s phases two periodic waveforms shifted by 90 electrical degrees. Let the phase current equations be:

$$i_A = I_o \cdot \cos\theta e \quad (1)$$

$$i_B = I_o \cdot \sin\theta e \quad (2)$$

Note that θe is the electrical position.

The resulting torque generated by the corresponding phases would then be:

$$T_A = K_o \cdot i_A = K_o \cdot I_o \cdot \cos\theta e \quad (3)$$

$$T_B = K_o \cdot i_B = K_o \cdot I_o \cdot \sin\theta e \quad (4)$$

where K_o is the torque constant of the motor. Substituting equations (1), (2) into (3),(4) and doing vector summation the resulting total generated torque measured on the motor shaft is given by:

$$T_g = K_o \cdot I_o \quad (5)$$

Note that in this case we have zero torque ripple. Using this technique one can theoretically achieve infinite resolution with any stepper motor. Since the drive current waveforms are sinusoidal instead of square, the step to step oscillations are eliminated and the associated velocity ripple. This greatly improves performance at low rotational speeds and helps avoid resonance problems. In an actual application, the extent to which these things are true depends on how the two sinusoidal reference waveforms are generated. Seemingly we have lost the quantized motion feature of a stepper when used in this mode. This can be regained by defining the term microsteps per step. Each full step is subdivided into microsteps by applying to the motor’s phases those intermediate current levels for which their vector sum tracks the circle of figure 2 and divides the full step (90 electrical degrees) into the require number of microsteps. An example of the required phase currents for full step and four microstep per step operation are shown in figure 1 and figure 2 respectively.

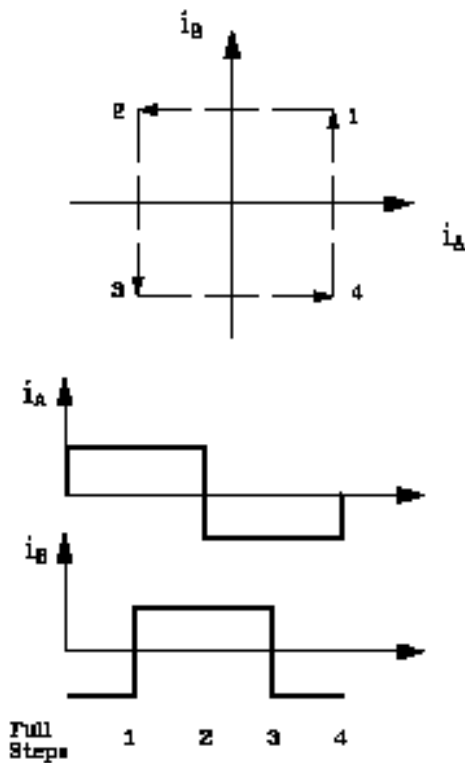


Figure 1–Full Step Drive Waveforms

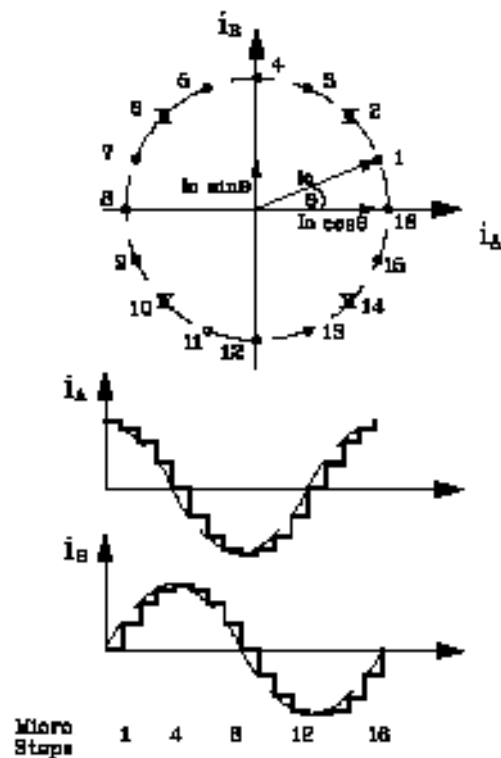


Figure 2–Four Microstep per Step Drive Waveform

3. MICROSTEPPING SYSTEM DESCRIPTION

Figure 3 shows complete microstepping control system. In this circuit the LMD 18245 controller commands a two phases stepper motor in microstepping mode. To obtain this mode the current has to be as much sinusoidal as is possible in the two phases of the motor. A correct command is obtained when the two sinusoidal current's waves corresponding to the phases are 90 electrical degrees shifted. For this goal it has to be applied to the LMD 18245 controller's inputs (DIRECTION A, BREKE A, M1A, M2A, M3A, M4A, DIRECTION B, BREKE B, M1B, M2B, M3B, M4B) two reference signals (SINE, COSINE) obtained using the two programmable memories (PROM-MH 74188). . A up/down counter (MMC 4029) is used to generate the most appropriate address location in PROM' s . Pulses from a programmable divider (PROG. DIV.) are used to increase or decrease the counter. The pulses frequency can be modified by specialized dedicated microsystem to computer based command (IBM-PC 586+ ISA interface)[3][4][5], programming to vary the motor's speed, finally.

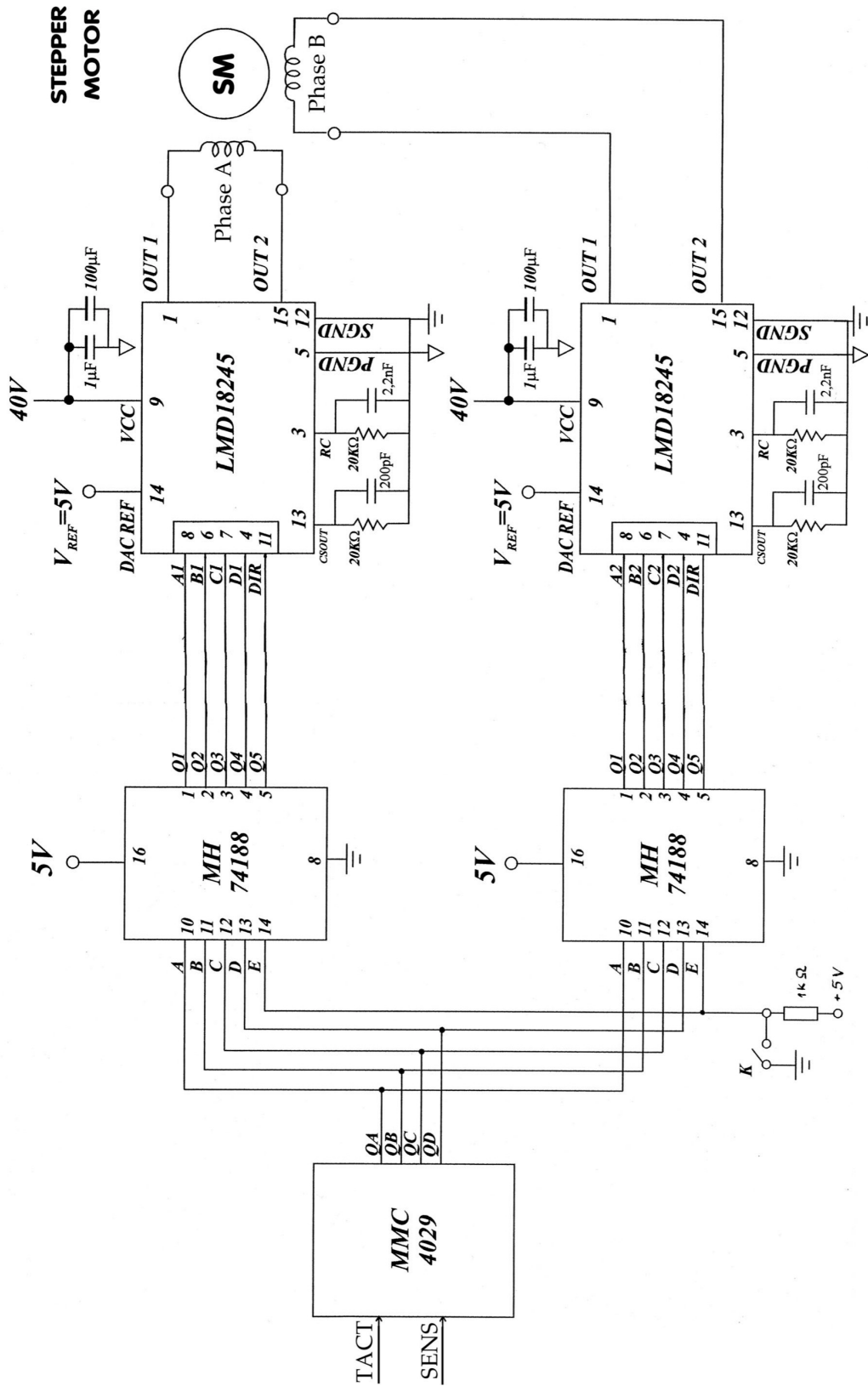


Figure 3– The complete microstepping control system

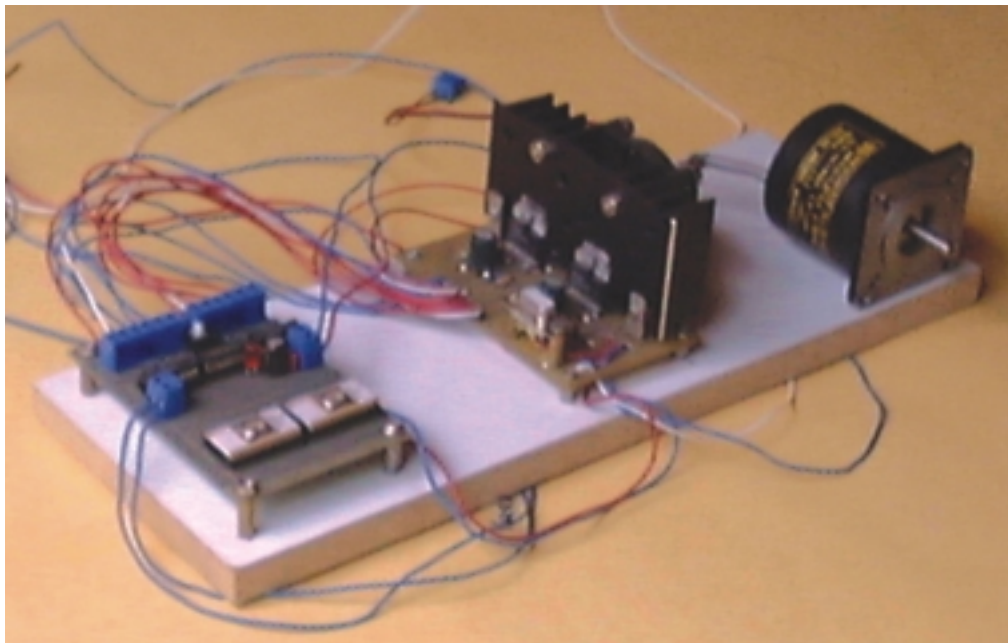


Figure 4–The general view of microstepping system

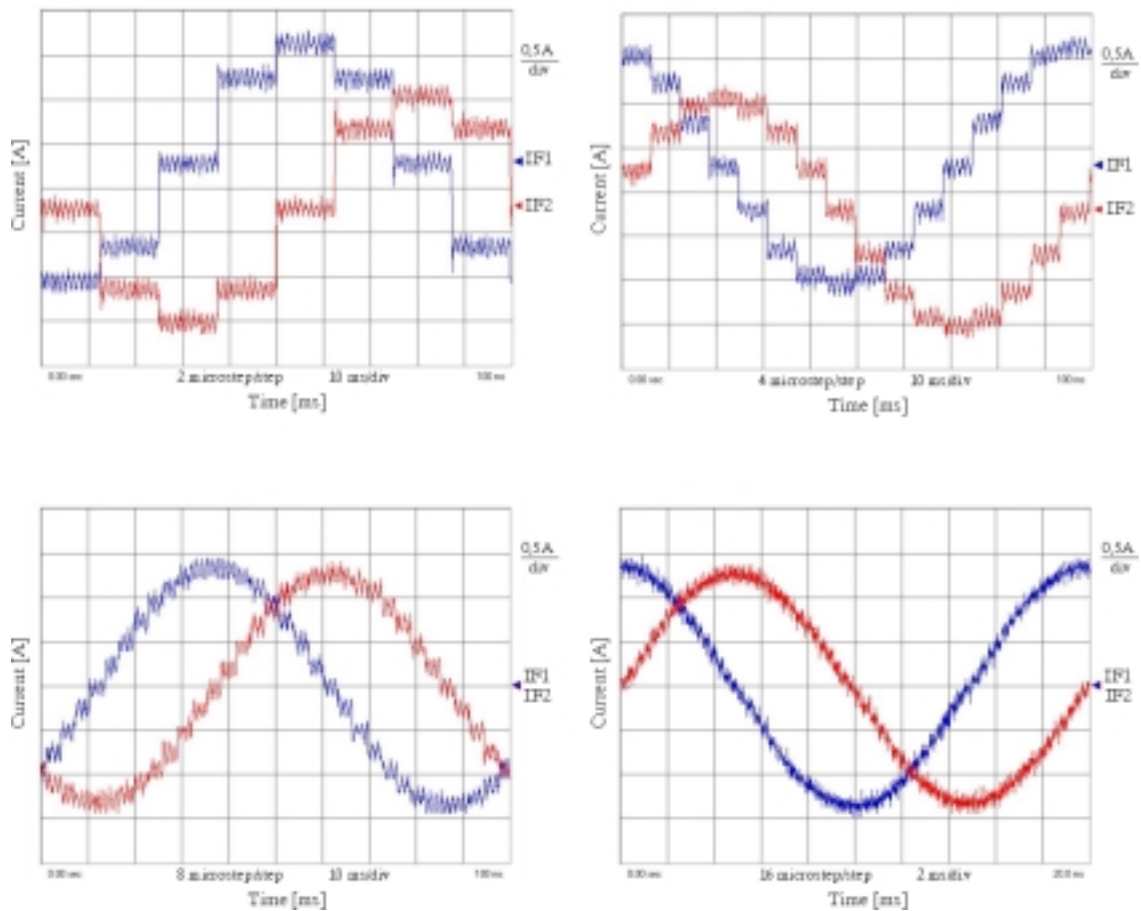


Figure 5–Experimental results, the phase currents of a two phase bipolar stepper motor (2,4,8,16 microstep/step)

4. EXPERIMENTAL RESULTS

Figure 4 exposes the developed system which was achieved by Electrical Drive Laboratory of the Engineering Faculty, “Petru Maior” University of Târgu -Mureş.

In order to measure the phase currents, two hall sensors (LEM modules – LA25NP) were used, and a data acquisition numerical system (PCL 711) dedicated to the electric drives as in [3] [4].

As experimental results, the phase currents of a two-phase bipolar stepper motor-MPPH 1.8° - 0.2 cod N-86047/MEDIAŞ/ROMÂNIA-(2, 4, 8, 16, microstep/step) are shown in figure 5.

5. CONCLUSIONS

The last progress both in control in motor drive domain impose on the researchers a continuous reorientation in order to solve the design problems with the newest technical means. In this sense the author have developed an original microstepping board for the open-loop control stepper motors. Among the facilities offered by this card we mention:

- motor acts almost like a d.c. motor
- resonance's are significantly reduced
- noise generation is considerably reduced
- very high step resolution
- bipolar switching operation

6. REFERENCES

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