M.E. 530.420 Lab 5: Step Motors
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This lab is due 5:30PM Wednesday October 11, 2010 at 115 Hackerman Hall

Reading: Section 10.6 of your textbook
Control of Stepping Motors by Douglas W. Jones, online here:
Your class lecture notes.
M42SP-5 50Ω (or 100Ω) step motor spec sheet.
Parallax spec sheet for M42SP-5 (Parallax #27964).
ULN2803A Darlington array IC spec sheet.
Green LED Digi-Key Part Number P584-ND spec sheet available online at
Red LED Digi-Key Part Number P582-ND spec sheet available online at

The following C concepts/functions:
• Arrays
• Signed/unsigned variables
• abs() [stdlib.h]
• Relational operators {>, <, >=, <=}
• & - Reference Operator

MaEvArM manual pages as required for the following commands:
• usb_scanf() [maevarmUSB.h/c]
• IO_mode, multiple pins [maevarmGEN.h/c]
• IO_out, multiple pins [maevarmGEN.h/c]

Apparatus: MaEvArM, AVR Studio 4 on a PC, Flip 3.4.3 on a PC, Power Generator, RS232
cable, Oscilloscope, ULN2803A Darlington array IC, M42SP-5 50Ω (or 100Ω) step motor

Read all as noted above.

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1) **Pre-Lab:** Design a step motor drive circuit based on the circuit as shown in Figure 1 (located page 4).
   a) Note that the step motor control IC operates with a +12V supply, not +5V.
   b) Design your circuit to include five additional LEDs with resistors: one for each of the four step motor phases to indicate when the phases are energized and one LED which indicates the presence of the +12V supply.
   c) Your LEDs should be ON when its corresponding phase is energized, and OFF when the corresponding phase is de-energized.
   d) Include a 100uF bypass capacitor for your +12V supply.
   e) Your circuit should be designed to be assembled on a proto-board, with a 5-pin ribbon cable connecting it to the MaEvArM. One pin connects your board’s ground to the MaEvArM’s ground. The other four pins connect the MaEvArM output pins D4-D7 to the ULN2803 input pins 1B-4B.
   f) **HI:** a circuit drawing of your complete circuit with your lab report.

2) **Q:** questions about your circuit:
   a) For the LEDs noted above, calculate the value of the resistors necessary to provide about 20mA of LED current with the 12V power supply.
   b) When pin D4 is at logical 1 (+5V), is the corresponding step motor phase *energized* or *deenergized*?
   c) When pin D4 is at logical 0 (0V), is the corresponding step motor phase *energized* or *deenergized*?

3) Review the sample circuit constructed by your TAs. Note how the 12V power supply is connected with banana-bannana test leads.

4) Construct your circuit on the JHURSAEB proto board. Refer to the sample board constructed by the TA for layout ideas. Being neat in your layout and construction will save you time.

5) **Have your TA check your circuit diagram and your constructed circuit BEFORE you energize the 12V power supply or attempt to run your code.**

6) Write a program to control the motor using the **full-step high-torque** commutation as shown on the Parallax spec sheet for M42SP-5 (Parallax #27964).
   a) Your program should prompt the user for signed integer number of steps, and then move the motor the commanded number of steps.
   b) Program the device so that positive numbers rotate the motor clockwise and negative numbers rotate the motor counterclockwise.
   c) Your program should delay for 15 ms after each step.
   d) Use your program to turn the step motor one step at a time in both the positive (clockwise) and negative (counterclockwise) directions to verify that you have the correct commutation pattern.
   e) **HI:** Test your program and hand in a hardcopy. All programs must have comments written into the program, it is not ok to add comments in later by hand.
Here is a sample program which uses a signed integer for user input:

```c
#include "maevarmUSB.h" //contains USB functions
#include "maevarmGEN.h" //contains general IO functions
#include <stdlib.h> //contains abs function
#include "binary.h" //contains 4 bit binary definitions

int main()
{
    usb_initialize(); //initialize usb
    while(!usb_configured()); //wait for usb
    IO_mode(UPPERD,0xF); //set upper 4 D pin modes to 0xF (1111)
    IO_out(UPPERD,0x0); //set upper 4 D pin out to 0x0 (0000)
    unsigned char currentstep = 0; //current step variable
    int cmdstep = 0; //commanded step variable
    //array containing full torque, low speed configurations
    char config[4] = {b0011,b0110,b1100,b1001};

    while(1)
    {
        //prompt for input
        usb_printf("Awaiting command: ");
        //receive and store input as decimal in cmdstep
        usb_scanf("%d", &cmdstep);
        //echo input back to user
        usb_printf("received %d\n",cmdstep);
        //for the input number of steps
        for (int i = 0;i<abs(cmdstep);i++)
        {
            //if input steps is positive
            if (cmdstep>0)
            {
                //add one to current step config with max of 4
                currentstep = (currentstep+1)%4;
                //output the corresponding configuration on upper D pins
                IO_out(UPPERD,config[currentstep]);
                //delay
                delay_ms(250);
            }
            //if input steps is negative
            else if (cmdstep<0)
            {
                //subtract one from current step config with max of 4
                currentstep = (currentstep+3)%4;
                //output the corresponding configuration on upper D pins
                IO_out(UPPERD,config[currentstep]);
                //delay
                delay_ms(250);
            }
        }
        usb_printf("Finished.\n"); //finished message
    }
}
```

7) Q: For **full-step high-torque** commutation, how many degrees does the motor turn for each step?
8) **Q:** What happens when you command a, say, 48 step command with set the step delay set to  
   a) 10ms?  
   b) 5ms?  
   c) 1ms?  
   d) What is happening here? For each case, briefly describe in words the behavior of the step  
      motor, and an explanation for this behavior.  
9) Write a program to control the motor using the **half-step** commutation as shown on the  
   Parallax spec sheet for M42SP-5 (Parallax #27964).  
   a) Your program should prompt the user for signed decimal number of steps, and then move  
      the motor the required number of steps.  
   b) **HI:** Test your program and hand in a hardcopy.  
10) **Q:** For **half-step** commutation, how many degrees does the motor move for each step?  
11) Write a program (modified from the program above) to accept the motor commands as a  
    signed decimal number of **degrees**, and then move the motor the corresponding number of  
    steps.  
    a) **HI:** Test your program and hand in a hardcopy.  

Demonstrate your final program to the TA and have the TA sign your cover sheet.

![Step Motor Control Circuit](image)  

<table>
<thead>
<tr>
<th>SIGNAL NAME</th>
<th>WIRE COLOR</th>
</tr>
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<tbody>
<tr>
<td>Common</td>
<td>Red</td>
</tr>
<tr>
<td>Phase 1</td>
<td>Black</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Orange</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Brown</td>
</tr>
<tr>
<td>Phase 4</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

*Figure 1: Step Motor Control Circuit*
• For each question be sure hand in a copy of your program, relevant circuit diagrams and derivations, and a printout of the oscilloscope plot (and/or PC Debug screen) that demonstrates operation of your program.
• Note your secret code on your lab report.
• Note your lab partner’s secret code on your lab report.
• Note your workstation number on your lab report.
• Remember to show your work.
• Typed or hand-written lab reports are OK. Messy or ambiguous lab reports will be rejected.

<table>
<thead>
<tr>
<th>Here are some additional more specific requirements for your lab writeup:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. You must include code, plots and screen shots in the correct order. It is very time consuming for the grader looking around for the code &quot;attached.&quot;</td>
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<tr>
<td>2. The code should be commented before it is printed out – hand written comments squeezed in-between lines are NOT OK.</td>
</tr>
<tr>
<td>3. Always include the whole program (even if it only varies from the previous question by a single line).</td>
</tr>
<tr>
<td>4. If the lab asks for DEBUG command in your code, include a screen shot of the debug screen.</td>
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<tr>
<td>5. If there is a circuit associated with the functionality of your program, include a circuit diagram.</td>
</tr>
<tr>
<td>6. Do not include the answers to questions in comments embedded within the code. Answers should be written up separately as part of your lab writeup.</td>
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</tbody>
</table>
Cover Sheet for 530.420 Lab #5
Step Motors

My Secret Code: _______
Fill in the secret code which was provided to you on your graded lab#1.

My Lab Station: _______

My Partner’s Secret Code: _______

Question #11 Demonstration!
TA’s Signature & Date: ______________________________________
Your TA will sign here after you have demonstrated your working half-step motor controller.

Lab Station Clean!
TA’s Signature & Date: ______________________________________
Your TA will sign here after you have finished your lab, cleaned up your lab station to perfection, and shown your lab station to your TA.