WEEK -2-

1. Objective

Design a controller for a stepper motor that will be capable of:

- Making the motor rotate with variable speed (the user should be able to adjust the rotational speed easily and without powering down the controller or the motor);
- Making the motor change direction of rotation;

2. Parts & Equipment

Part description	Part number	Quantity
Square Wave Oscillator/ Monostable Multivibrator	CD4047	1
UP/DOWN Binary Counter	CD4516	1
Quad 2-input NAND gates	CD4011	2
Hex Buffer (Inverting)	CD4009UBE	1
Quad Darlington Power Driver	UDN2540B	1
Resistor Network - 220Ω/8 140mW; Resistor in DIP	221G	1
Red LED	P300-ND, 25mA max	5
NPN General Transistor, Vceo 40V; hfe 100 min.	2N2222A	1
Capacitors (**for decoupling**)	0.1μF, 50Vdc	10
Current Limiting Resistor (for LED)	220Ω ; ¼ W	1
Trimmer Pot; Top Adjust	100KΩ, ½ W	1
Current Limiting Resistors	4.7KΩ, ¼ W	3
Capacitor	10μF, 25Vdc, 20% tolerance	1
Airpax Mechatronics Stepper Motor	26M048B2U	1
Single Pole Double Throw Switch; 1A @ 24Vdc.	202972CD	1

- **Equipment:**
  - Agillent 54261D Oscilloscope (for troubleshooting)
  - NI5411 Arbitrary Waveform Generator (optional)
  - NI4060 Multimeter (for troubleshooting)
  - 8102 Lodestar Power Supply

3. Continuation from Week 1

By now you have built almost half of the controller circuit. This week you will **design** and wire up the rest of the circuit and finally demonstrate the operation of the controller by connecting it to a stepper motor. Keep in mind! **This is not an easy lab! Start early, read through this handout before you come to class, and MAKE SURE you have a good idea of what is going on and what you need to do once you start working.** If you get stuck contact

your T.A. prior to your lab session, he is there to help you understand the concepts used in this lab.

4. Circuit Design

Last week you wired up the clock and the binary counter chips. This week you will have to design part of the circuit, and then implement it using CMOS NAND gates. Refer to the CD4xxxx data sheets to gain better understanding about how to use these chips. **You are allowed two Quad 2-input NAND chips (a total of 8 two-input NAND gates) to implement your circuit. You are not permitted to use any other devices to implement the logic. From your Digital Logic class you know that any circuit can be built using only NAND gates.** If you recall, in last week's lab handout we pointed out that we will use only the two lower bits from the binary counter. It is your job to design a circuit that will use these two bits as input to generate the 4 data bits that will interface/control the motor. To assist you with the design we will provide you with the truth table (Table 4.1), showing you the two input bits, i.e. O(0) and O(1), and output bits, D0-D3.

Input Bits (lower 2 bits from CD4516)		**Output Bits (taken from the stepper motor data sheet)**			
S1	S0	D0	D1	D2	D3
0	0	1	0	1	0
0	1	1	0	0	1
1	0	0	1	0	1
1	1	0	1	1	0

Table 4.1

Figure 4.1 shows the second part of the controller circuit. Refer to this figure to help you logically organize your circuit.

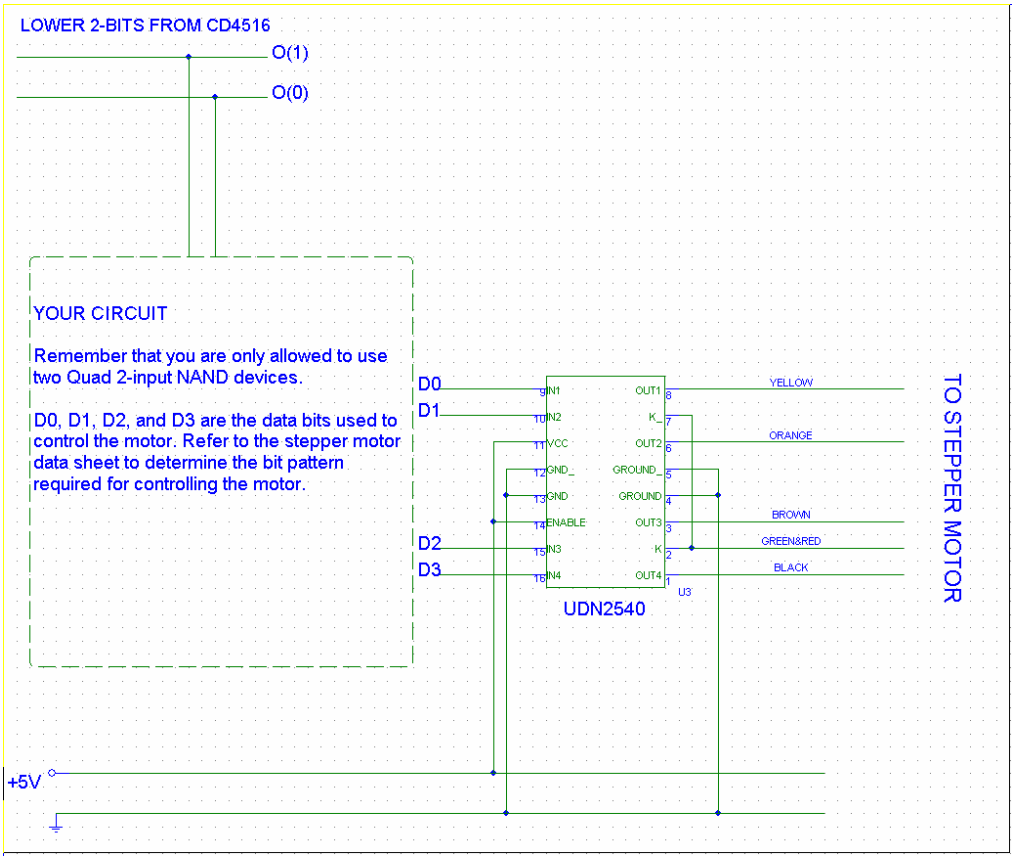

Figure 4.1

5. Wiring the Circuit

Wire up the circuit shown in Figure 4.1. Here are the guidelines that you **must follow** when wiring up the circuit. **These guidelines are set in place so you will learn how to wire up neat and organized circuits on a breadboard!** We recommend that you follow these guidelines in all successive lab courses you take at MTU. **If you choose not to follow these guidelines, your T.A. will not help you with debugging your circuit.**

- **The blue line (top and bottom of the breadboard) is a common ground;**
- **The red line (top and bottom of the breadboard) is a common rail (+5V);**
- **All connections going to ground are one consistent color (green, or black);**
- **All connections going to rail are one consistent color (red or orange);**

Figure 5.1 shows an example of a neatly wired circuit. While you are wiring up your circuit keep in mind that you have to preserve space on the breadboard. You can easily run out of room on the breadboard if you are sloppy with your layout. You will not be allowed to use more than one breadboard for implementing the controller so pay attention to details and think ahead!

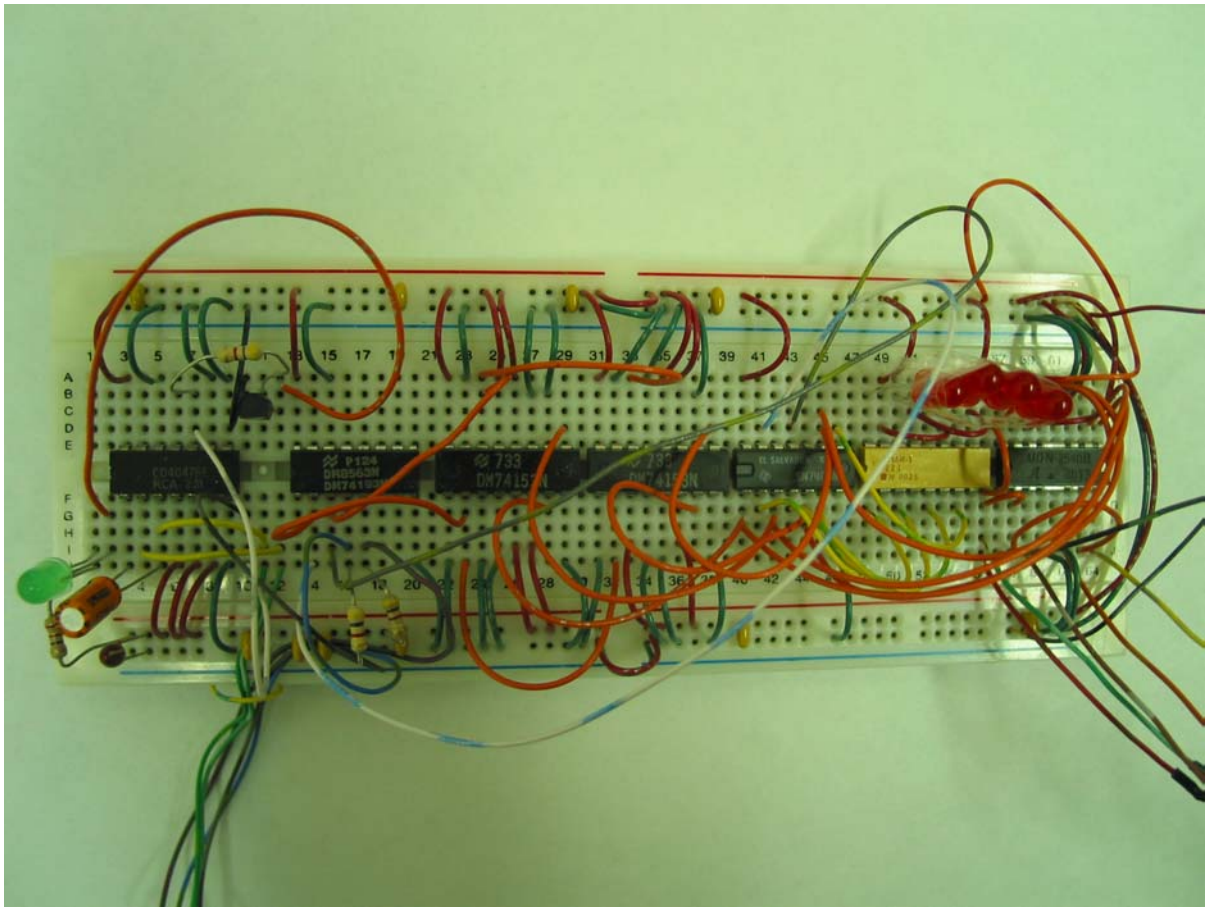

Figure 5.1

6. Testing Your Circuit

Before you power on your circuit have your T.A. inspect the circuit and sign the signoff sheet. When your T.A OKs your circuit, power it on! You should see the LED that is part of the "clock indicator circuit" (see figure 4.1) blink on every tick of the clock. The 4 LEDs should be turning on and off, representing the bit sequence as the counter chip counts. Your stepper motor should now rotate. Change the variable resistance in order to speed up/slow down the rotation. Use the switch to change the direction of rotation.

If your circuit is not functioning start debugging. Here are some helpful tips for debugging your circuit.

- Make sure the power is turned on;
- Using a voltmeter confirm that all chips on the breadboard are getting +5V on the proper pins. Refer to figure 4.1 to see which pins, on each chip, should be wired to +5V;
- Using the oscilloscope confirm that the CD4047 device is generating a clock on pin 10;
    - If you are not seeing a 50% duty cycle square wave (clock) make sure that your Pot is not set to 0Ω, if it is increase the resistance and check for a clock signal;

- Make sure that the interconnections between the chips is correct. Specifically, make sure that pin 10 from CD4047 is connected to pin 15 on the CD4516.
- Connect the digital channel of the oscilloscope to read the stepper motor control bits, D0-D3. Confirm that the circuit you designed indeed generates the proper sequences of 4 bits.

7. Consideration Questions

When writing your lab report, please answer the following questions:

1. What was the hardest part of this lab? Please elaborate.
2. Elaborate on the circuit you designed. Is it an optimal solution to the problem?
   Note: You should include a diagram of the circuit you designed.
3. Is it possible to implant your circuit using multiplexers rather than NAND gates?

8. References

UDN2540 – Darlington Power Driver, data sheet
Airpax Stepper Motor Data Sheet
CD4009 – Hex inverting buffer, data sheet
CD4047 - Square Wave Oscillator (Variable Frequency), data sheet
CD4516 - UP/DOWN Binary Counter, data sheet
2N2222A - NPN General Transistor, data sheet

T.A. Sign-off Sheet; Week - 2 -

Group Members: _____

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1. The circuit shown in Figure 4.1 is wired properly;

_____

2. Demonstrate the capability of controlling the rotational speed using the controller.

_____

3. Demonstrate the capability of controlling the direction of rotation using the controller.

_____

Pre-lab Questions – Week 2

Student Name: _____

1. Draw the circuit that you designed in Section 4.

(Note: In order to answer this question you may consider using Karnaugh maps to minimize your circuit design. This is just a suggestion, there is more than one way to design and implement the circuit and it is up to you to decide how you want to do it. After you answer this question you are left with nothing more than wiring up the circuit, which should't take you more than 1 hr. ***Make sure you have this problem done before entering the lab. By not doing so you are risking a very low grade because you will most certainly run out of time in the lab.****)*