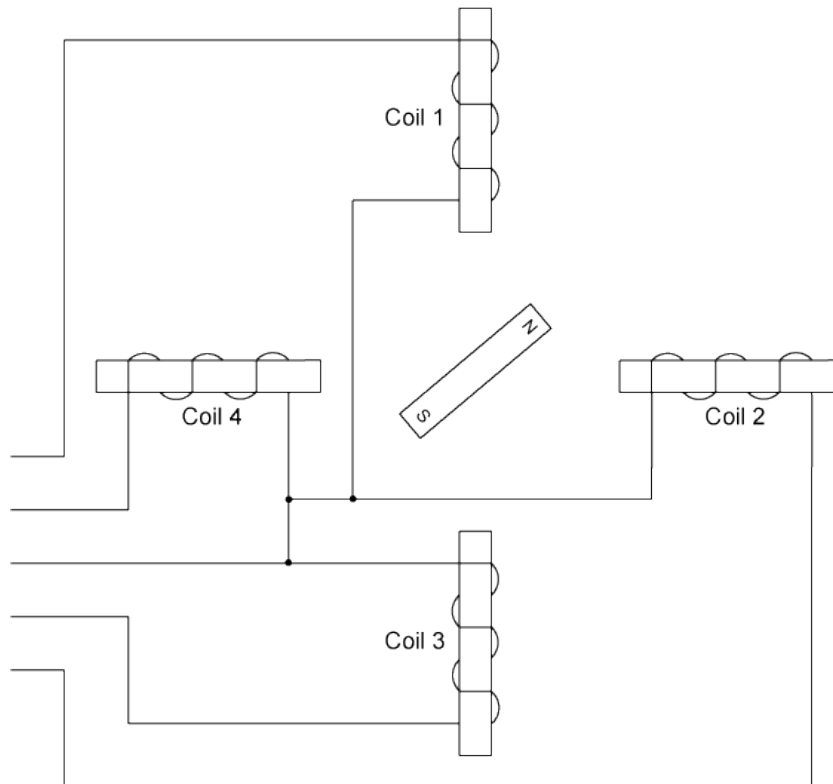


## Stepper Motor Control with a PIC Microcontroller Programmed in PicBasic Pro Cornerstone Electronics Technology II and Robotics

- **Administration:**
  - Prayer
- **PicBasic Pro Programs Used in This Lesson:**
  - General PicBasic Pro Program Listing:  
<http://www.cornerstonerobotics.org/picbasic.php>
  - Lab 1: step\_mot1 as .pdf file:  
[http://www.cornerstonerobotics.org/code/step\\_mot1.pdf](http://www.cornerstonerobotics.org/code/step_mot1.pdf)
  - Lab 1: step\_mot1 as .pdf file:  
[http://www.cornerstonerobotics.org/code/step\\_mot\\_hi\\_torque.pdf](http://www.cornerstonerobotics.org/code/step_mot_hi_torque.pdf)
- **Stepper Motors:**
  - For applications where precise measuring of a motors' rotor position is critical, a stepper motor is the best choice. Stepper motors operate differently from other motors; rather than voltage being applied and the rotor spinning smoothly, stepper motors turn on a series of electrical pulses to the motor's windings. Each pulse rotates the rotor by a discrete amount or "step", hence the name "stepper motor".
  - We will use a PIC microcontroller to activate drive transistors in the right order to rotate the stepper motor.
- **How a Stepper Motor Works:**
  - See: <http://www.imagesco.com/articles/picstepper/02.html> or
  - <http://www.solarbotics.net/library/pdflib/pdf/motorbas.pdf>
- **Stepping Modes:**
  - Simplified Unipolar Stepper Motor Connections:



- **Single Stepping** - the simplest mode turns one coil ON at a time. The pulse sequence for single stepping follows: (Used in [http://www.cornerstonerobotics.org/code/step\\_mot1.pdf](http://www.cornerstonerobotics.org/code/step_mot1.pdf))

Pulse	Coil 1	Coil 2	Coil 3	Coil 4	Number in Binary	Decimal Equivalent
1	On (1)	Off (0)	Off (0)	Off (0)	1000	8
2	Off (0)	On (1)	Off (0)	Off (0)	0100	4
3	Off (0)	Off (0)	On (1)	Off (0)	0010	2
4	Off (0)	Off (0)	Off (0)	On (1)	0001	1

Perform Stepper Motor Control Lab 1 – Making a Stepper Motor Turn.

- **High Torque Stepping** - high power / precision mode turns ON two coils on at a time. The pulse sequence for high-torque stepping follows: (Used in [http://www.cornerstonerobotics.org/code/step\\_mot\\_hi\\_torque.pdf](http://www.cornerstonerobotics.org/code/step_mot_hi_torque.pdf))

Pulse	Coil 1	Coil 2	Coil 3	Coil 4	Number in Binary	Decimal Equivalent
1	On (1)	On (1)	Off (0)	Off (0)	1100	12
2	Off (0)	On (1)	On (1)	Off (0)	0110	6
3	Off (0)	Off (0)	On (1)	On (1)	0011	3
4	On (1)	Off (0)	Off (0)	On (1)	1001	9

- **Half Stepping** - stepping is doubled and motor needs 96 pulses to complete one revolution. The pulse sequence for half stepping follows: (Used in [http://www.cornerstonerobotics.org/code/step\\_mot\\_half\\_step.pdf](http://www.cornerstonerobotics.org/code/step_mot_half_step.pdf))

Pulse	Coil 1	Coil 2	Coil 3	Coil 4	Number in Binary	Decimal Equivalent
1	On (1)	Off (0)	Off (0)	Off (0)	1000	8
2	On (1)	On (1)	Off (0)	Off (0)	1100	12
3	Off (0)	On (1)	Off (0)	Off (0)	0100	4
4	Off (0)	On (1)	On (1)	Off (0)	0110	6
5	Off (0)	Off (0)	On (1)	Off (0)	0010	2
6	Off (0)	Off (0)	On (1)	On (1)	0011	3
7	Off (0)	Off (0)	Off (0)	On (1)	0001	1
8	On (1)	Off (0)	Off (0)	On (1)	1001	9

- **Solving Unknown Leads:**

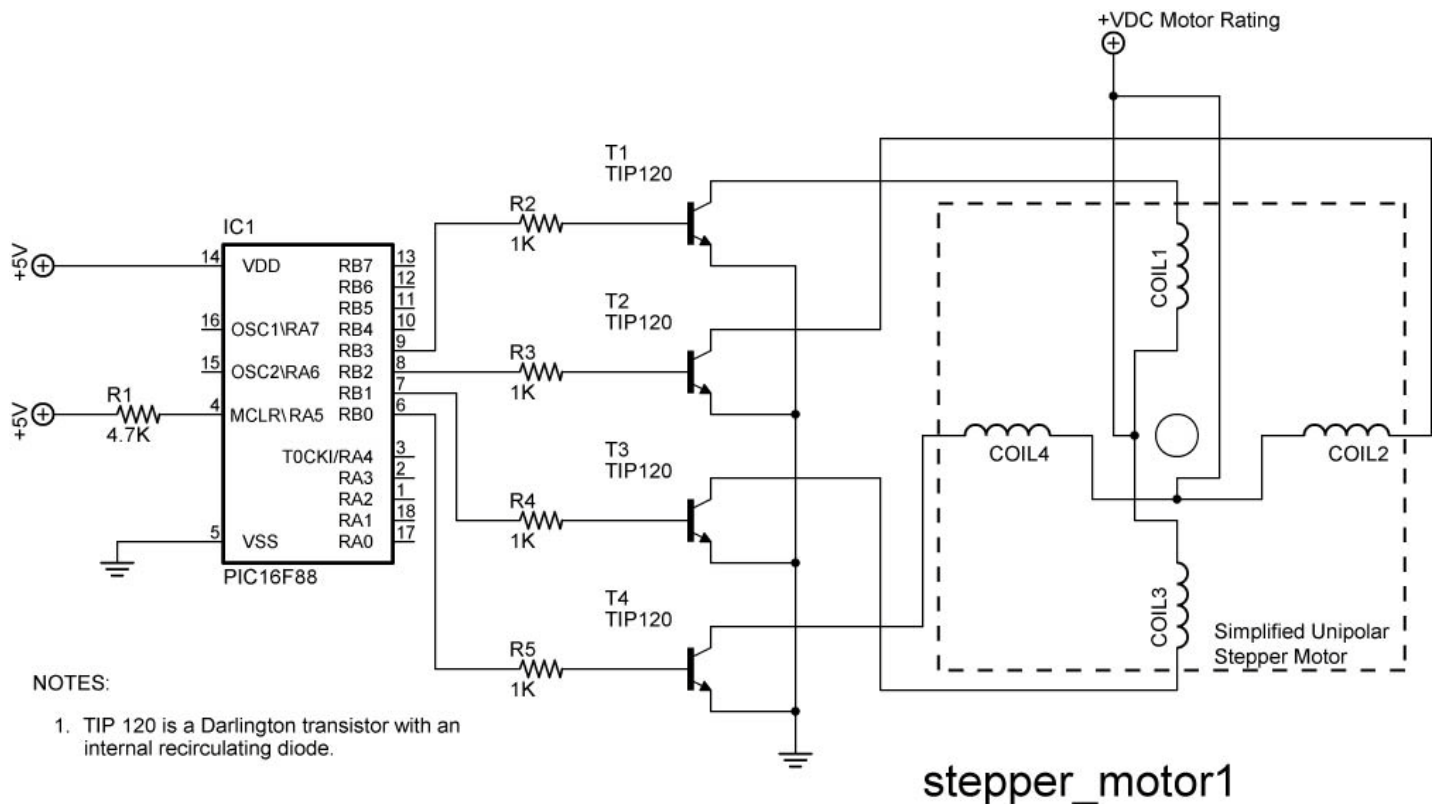
- If you do not have an equivalent diagram for the motor you want to use, you can make a resistance chart to decipher the mystery of the connections. There is a 13 ohm resistance between the center-tap wire and each end lead, and 26 ohms between the two end leads. Wires originating from separate coils are not connected, and therefore would not read on the ohm meter. For a more detailed approach, perform Stepper Motor Control Lab 2 – Stepper Motor Windings

- **Other Web Site References:**

- [http://hades.mech.northwestern.edu/wiki/index.php/Unipolar\\_Stepper\\_Motor\\_Driver\\_Circuit](http://hades.mech.northwestern.edu/wiki/index.php/Unipolar_Stepper_Motor_Driver_Circuit)
- <http://www.imagesco.com/articles/picstepper/03.html>
- <http://www.solarbotics.net/library/pdf/lib/pdf/motorbas.pdf>
- [http://www.electronics-diy.com/stepper\\_motors.php](http://www.electronics-diy.com/stepper_motors.php)

## Cornerstone Electronics Technology and Robotics II Stepper Motor Lab 1 – Making a Stepper Motor Turn

- **Purpose:** The purpose of this lab is to make a PIC drive a stepper motor to turn using PicBasic Pro.
- **Apparatus and Materials:**
  - 1 – Breadboard with +5V Power Supply and a Power Supply Matching the Voltage Rating of the Stepper Motor. **Note:** The stepper motor power supply must be sufficiently robust or the motor will not rotate properly.
  - 1 – Jameco #237623 Unipolar Stepper Motor or Equivalent (#237623 – 4.8V, 1500mA)
  - 1 – Extech # 461895 Combination Contact/Photo Tachometer
  - 1 – PIC16F88
  - 1 – 4.7K Resistor
  - 4 – 1K Resistors
  - 4 – TIP 120 NPN Darlington Transistors
- **Procedure:**
  - Wire the stepper\_motor1 circuit below.
  - Program the PIC16F88 with **step\_mot1.pbp**.
  - Change the values of Delay and note the change in rpm.
  - Set the value of Delay to 250 and count the number of steps the motor takes to complete one revolution. From number of steps/revolution, calculate the angle in degrees of each step. Record your results.
  - Program the PIC16F88 with **step\_mot\_hi\_torque**. Compare the new torque generated with that generated in **step\_mot1.pbp**.



- **Results:**

- Delay vs RPM:

Delay	RPM

- Number of Steps/Revolution:

Number of steps per revolution = \_\_\_\_\_ steps.

One revolution = \_\_\_\_\_ degrees.

The angle in degrees of each step = \_\_\_\_\_ degrees/step.

- **Challenge:**

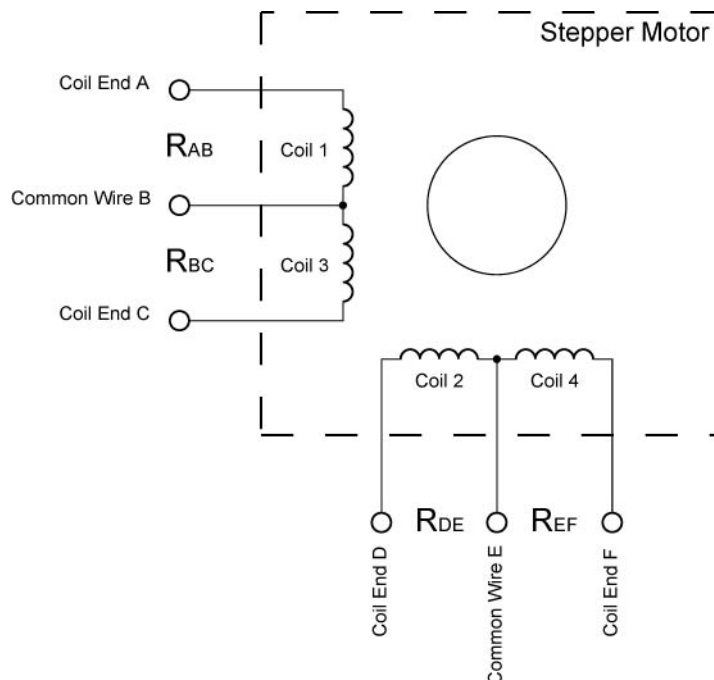
- Create a program called **step\_motor\_1\_sec.pbp** such that the stepper motor makes one revolution per second. First calculate the time for each step.
- Now write a program named **step\_motor\_1\_rev.pbp** so that the stepper will make only one revolution then stop. Knowing the number of steps in one revolution, use a FOR...NEXT loop to solve the challenge.

## Cornerstone Electronics Technology and Robotics II Stepper Motor Lab 2 – Figuring Out Stepper Motor Windings

- **Purpose:** The purpose of this lab is to figure out how to hook up a stepper motor with six leads when a data sheet for the motor is unavailable.
- **Apparatus and Materials:**
  - 1 – Breadboard with +5V Power Supply and a Power Supply Matching the Voltage Rating of the Stepper Motor. **Note:** The stepper motor power supply must be sufficiently robust or the motor will not rotate properly.
  - 1 – Ohmmeter
  - 1 – Jameco #237623 Unipolar Stepper Motor or Equivalent (#237623 – 4.8V, 1500mA, 1.8 Degree Step Angle or 200 Steps/Revolution )
  - 1 – PIC16F88
  - 1 – 4.7K Resistor
  - 4 – 1K Resistors
  - 4 – TIP 120 NPN Darlington Transistors
- **Procedure:**
  - Before hooking up the leads to the stepper motor, we must first determine the order of the lead connections. We do this by measuring resistances of the coils.
  - The resistance between common wire and coil-end wire is always about half of what it is between coil-end and coil-end wires. This is due to the fact that there is actually twice the length of coil between the ends and only half from center (common wire) to the end. From the figure below:

$$R_{AB} = R_{BC} = \frac{1}{2} R_{AC} \text{ and}$$

$$R_{DE} = R_{EF} = \frac{1}{2} R_{DF}$$



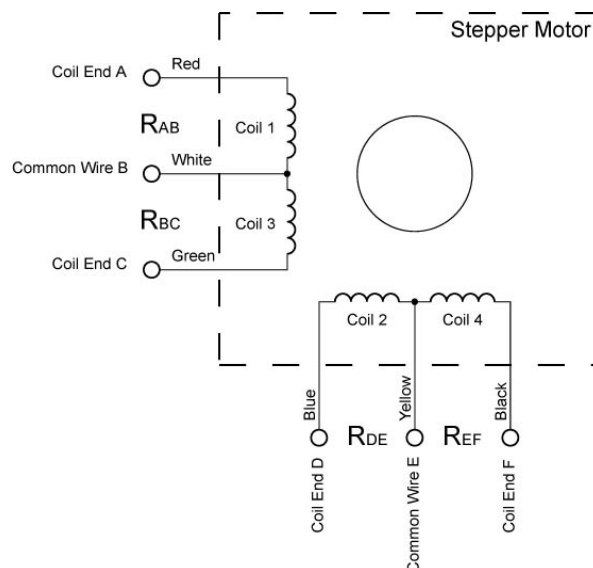
- There are no connections between Coils 1 & 2 and Coils 3 & 4; therefore the resistance between any of their leads is infinite.
- **Example:**
  - Assume we have a stepper motor with its colored leads and no data sheet to tell us how they are connected. The colors were chosen at random.

Test Stepper Motor	
Lead Colors	-
Black	
White	
Red	
Yellow	
Green	
Blue	

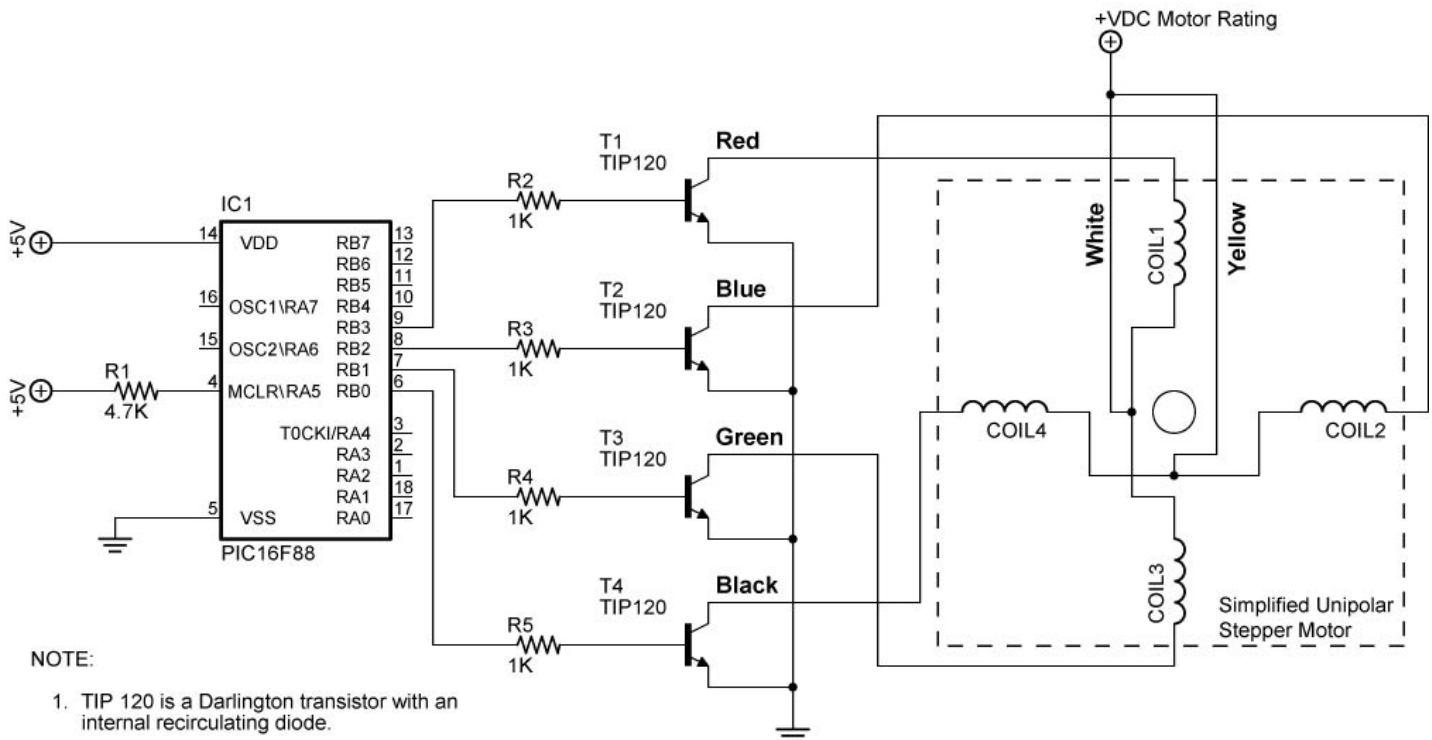
- Measure the resistances of different combinations of leads until you arrive at six lead combinations with measured resistances. See the example table below. Determine which groupings of three leads are interconnected.

Test Stepper Motor	
Lead Combinations	Resistance
Red - White	3.7 $\Omega$
Green - White	3.8 $\Omega$
Red - Green	6.9 $\Omega$
Blue - Yellow	3.6 $\Omega$
Black - Yellow	3.7 $\Omega$
Blue - Black	6.8 $\Omega$
All Other Combinations	Infinite

- From these resistance values, we see that the white lead is the common lead for one coil grouping and yellow lead is the common lead for the other coil grouping. Our stepper motor configuration is as follows:



- Now we can connect the stepper motor leads to the PIC driver circuit.
- First, the two common leads are both connected to a power source equal to the voltage rating of the stepper motor. See the stepper\_motor1\_lab2 schematic below.
- The other four leads are connected in a staggered manner to the TIP 120 transistors. In our example, if the red lead is connected to T1 in the following schematic (stepper\_motor1), then the other coil end lead in that grouping, green, must be connected to T3. If blue is connected to T2, then the other coil end lead in that grouping, black, must be connected to T4. See the stepper\_motor1\_lab2 schematic below.



stepper\_motor1\_lab2

- Now take the stepper motor furnished and determine the connection sequence. Use the tables furnished in results to organize your measurements.
- Connect to the PIC driver circuit.
- Program the PIC16F88 with **step\_mot1.pbp** and run the program. The stepper motor should rotate in a clockwise or counter-clockwise direction. Record the direction of rotation.
- Switch the leads connected to T2 and T4. Note the direction of rotation.

- **Results:**

- Lead Combination Resistances:

<b>Lab 2 Stepper Motor</b>	
<b>Lead Combinations</b>	<b>Resistance in Ohms</b>
All Other Combinations	

- Direction of Rotation:

- The original direction of rotation: \_\_\_\_\_
- The direction of rotation after switching leads T2 and T4:  
\_\_\_\_\_