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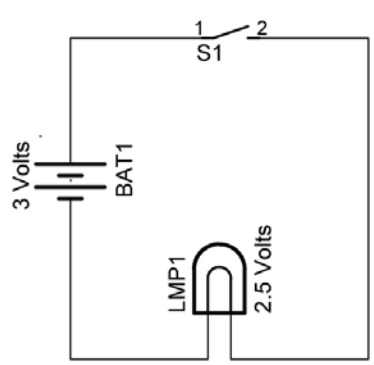
Electronics Technology and Robotics I Week 1
Simple Circuits and Solderless Breadboards LAB 1 – Wiring Simple Circuits

- **Purpose:** The purpose of this lab is to acquaint the student with elementary electrical circuit symbols and wiring.

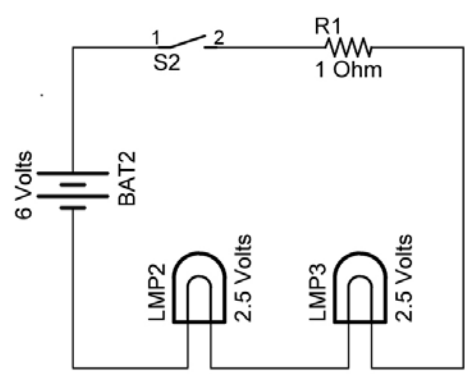
- **Apparatus and Materials:**

    - 1 – 3 Volt Battery Power Supply
    - 1 – 6 Volt Battery Power Supply
    - 1 – 9 Volt Battery Power Supply
    - 2 – 2.5 Volt Lamps
    - 1 – 6 Volt Lamps
    - 1 – 7.5 Volt Lamps
    - 1 – 1 Ohm Resistor (Brown, Black, Gold)
    - 1 – 22 Ohm Resistor (Red, Red, Black)
    - 1 – 68 Ohm Resistor (Blue, Gray, Black)
    - 1 – Knife Switch
    - Alligator Clips

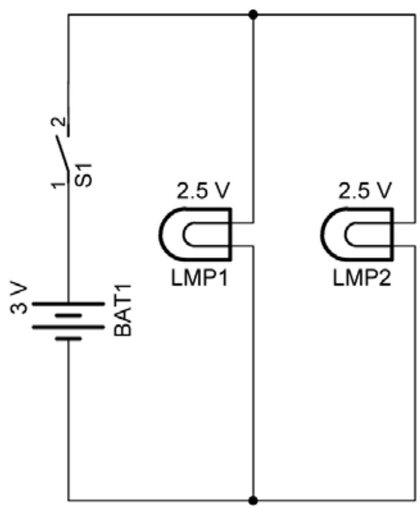
- **Procedure:**
    - Wire the following circuits by connecting alligator clips to the circuit components.
    - Have your instructor check your circuit before closing the switch.



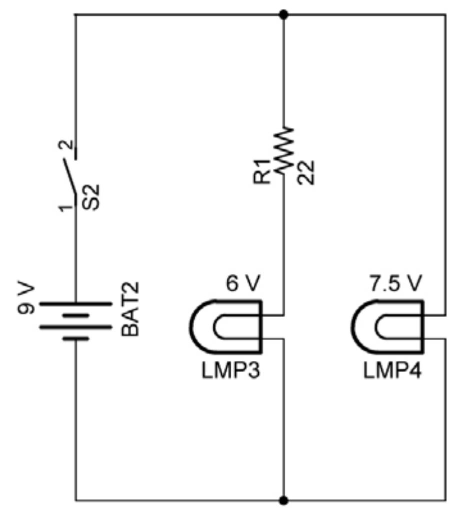
Circuit 1



Circuit 2



Circuit 3



Circuit 4

- **Results:**
  - In Circuit 1, close the switch then disconnect any of the alligator clips and record what happens to the lamp.
  - In Circuit 2, unscrew one of the lamps and record what happens to the other lamp:
  - In Circuit 3, unscrew one of the lamps and record what happens to the other lamp:
  - In Circuit 4, replace the 22 ohm resistor (red, red, black) with a 68 ohm resistor (blue, gray, black) and record the change in the 6 V lamp.

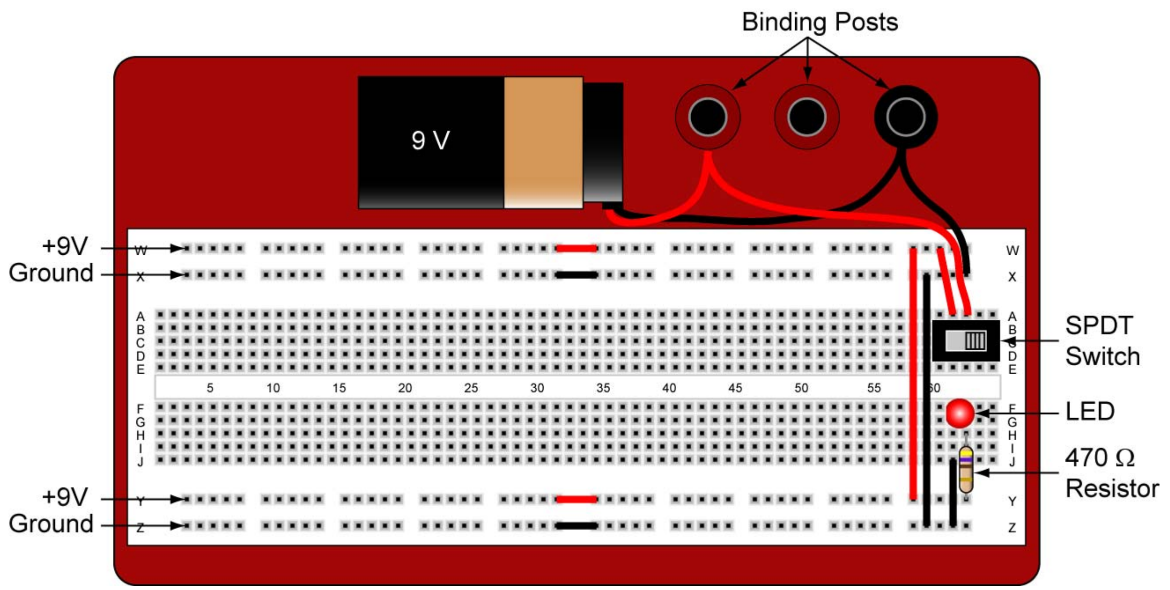
Electronics Technology and Robotics I Week 1

Simple Circuits and Solderless Breadboards LAB 2 – Power to the Breadboard

- **Purpose:** The purpose of this lab is to have the student wire the breadboard for a +9 V and + 5 V power strips.

- **Apparatus and Materials:**
    - 1 – 840 Pin Solderless Breadboard (Radio Shack #276-169)
    - 1 – 1660 Pin Solderless Breadboard (Electronix Express #03MB104)
    - 1 – 9 Volt Battery
    - 1 – 9 Volt Battery Snap
    - 1 – SPDT Switch (Electronix Express #17SLDH251)
    - 1 – LED
    - 1 – 470 Ohm Resistor (Yellow, Violet, Black)
    - 1 – 78L05 Voltage Regulator
    - 1 – 0.1 uF Capacitor
    - # 22 Solid Wire (Black and Red)

- **Procedure:**
    - 840 Pin Solderless Breadboard:
        - Power to binding posts: Install the battery snap and wire to the binding posts.
        - Layout the switch, LED, and resistor.
        - Power to buses: Connect the binding posts to the breadboard as shown. Buses are used for distribution of electrical power to components of a system.
        - Connecting the bus strips: Connect the top two bus strips (+9 V and Ground) to the bottom two bus strips.
        - Power indicator LED: Install the final connections as shown. Be sure that the flat side of the LED is facing toward ground.
        - Check voltages at points on the two bus strips.



840 Pin Solderless Breadboard Setup

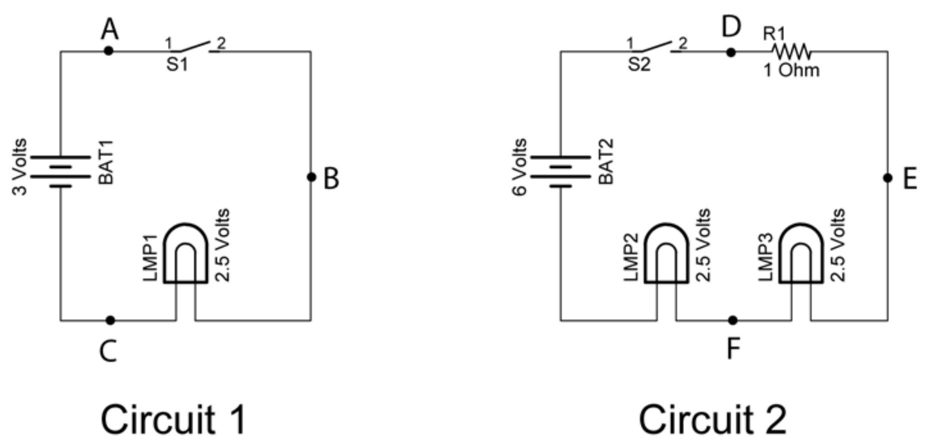
Electronics Technology and Robotics I Week 2
Basic Electrical Meters and Ohm's Law Lab 1 – Ammeter

- **Purpose:** The purpose of this lab is to acquaint the student with measuring current using an ammeter and to become acquainted with current relationships in a series circuit.

- **Apparatus and Materials:**

  - 1 – Digital Multimeter (DMM)
  - 1 – Battery Holder and Battery
  - 1 – SPST Switch
  - 1 – 1 Ohm Resistor
  - 2 – Lamp Holders
  - 2 – 2.5 V Lamps
  - Alligator Clips

- **Procedure:**
  - Wire the following circuits and then use your ammeter to measure the current at each point labeled.
  - Record your results in the tables below.
  - Write your conclusions regarding your results.



- **Results:**

Point	Current in mA
A	
B	
C	

Circuit 1

Point	Current in mA
D	
E	
F	

Circuit 2

- **Conclusions:**
  - Is the current the same at every point in the circuit?

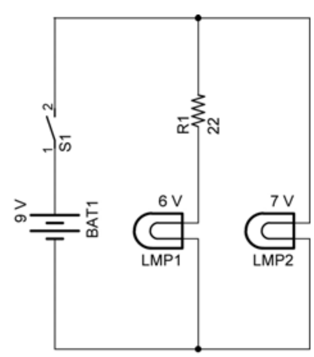
Electronics Technology and Robotics I Week 2
Basic Electrical Meters and Ohm's Law Lab 2 – Voltmeter

- **Purpose:** The purpose of this lab is to acquaint the student with measuring voltage using a voltmeter.

- **Apparatus and Materials:**

    - 1 – Digital Multimeter (DMM)
    - 1 – Battery Snap and 9 V Battery
    - 1 – SPST Switch
    - 1 – 22 Ohm Resistor (Red, Red, Black)
    - 2 – Lamp Holders
    - 1 – 6 V Lamp and 1 – 7.5 V Lamp
    - Alligator Clips

- **Procedure:**
    - In the Circuit 3 below, close the switch then measure and record the voltage:
        - Across the battery terminals
        - Across the resistor
        - Across the 6 volt lamp. Add the voltage drops across the resistor and the 6 volt lamp, then compare the sum with the voltage drop across the battery.
        - Across the 7.5 volt lamp. Compare this reading with the voltage drop across the battery.
        - In the conclusions, describe how the sum of the voltage drops across the 6 V lamp and the resistor compare to the battery.



Circuit 3

- **Results:**

Component	Voltage in Volts
Battery	
Resistor	
6 V Lamp	
7.5 V Lamp	

Electronics Technology and Robotics I Week 2
Basic Electrical Meters and Ohm's Law Lab 3 – Ohmmeter

- **Purpose:** The purpose of this lab is to acquaint the student with measuring resistance using an ohmmeter.

- **Apparatus and Materials:**

    - 1 – Digital Multimeter (DMM)
    - Assortment of Resistors

- **Procedure:**
    - Measure and record the value of each resistor.

- **Results:**

Resistor	Resistance in Ohms
A	
B	
C	
D	
E	
F	
G	
H	

Electronics Technology and Robotics I Week 2
Basic Electrical Meters and Ohm's Law Lab 4 – Measurements and Calculations

- **Purpose:** The purpose of this lab is to have the student apply Ohm's Law to several circuits and then verify the calculated results.

- **Apparatus and Materials:**

  - 1 – Digital Multimeter (DMM)
  - Circuits by the Instructor

- **Procedure:**
  - Use Ohm's law to analyze Circuits 1 - 6. Measure and record the quantities in the white cells of Table 1 then using Ohm's Law, calculate the unknown quantities of the shaded cells. Show your calculations in the text box.
  - Copy the calculated quantities from Table 1 into the shaded cells in Table 2.
  - Measure those unknown quantities using a DMM and compare with the calculated values.
  - Determine the differences in Table 2.

- **Results:**

Ohm's Law Calculated			
Circuit	Voltage in Volts	Resistance in Ohms	Current in A
1			
2			
3			
4			
5			
6			

Table 1

Ohm's Law Measured				
Circuit	Unknown Quantity	Calculated	Measured	Difference
1	Voltage			
2	Resistance			
3	Current			
4	Voltage			
5	Resistance			
6	Current			

Table 2

Show calculations:
1.

2.

3.

4.

- **Conclusions:**
    - The calculated and measured values should be close to each other. Are they?

- **Challenges:**
    - Design a voltage source where the single load resistance is 100 ohms and the current through the resistor is 50 mA.

Electronics Technology and Robotics I Week 3
Schematics, Conductors, and Insulators Lab 1 – Drawing Schematics

- **Purpose:** The purpose of this lab is to have the student practice drawing schematics.

- **Apparatus and Materials:**

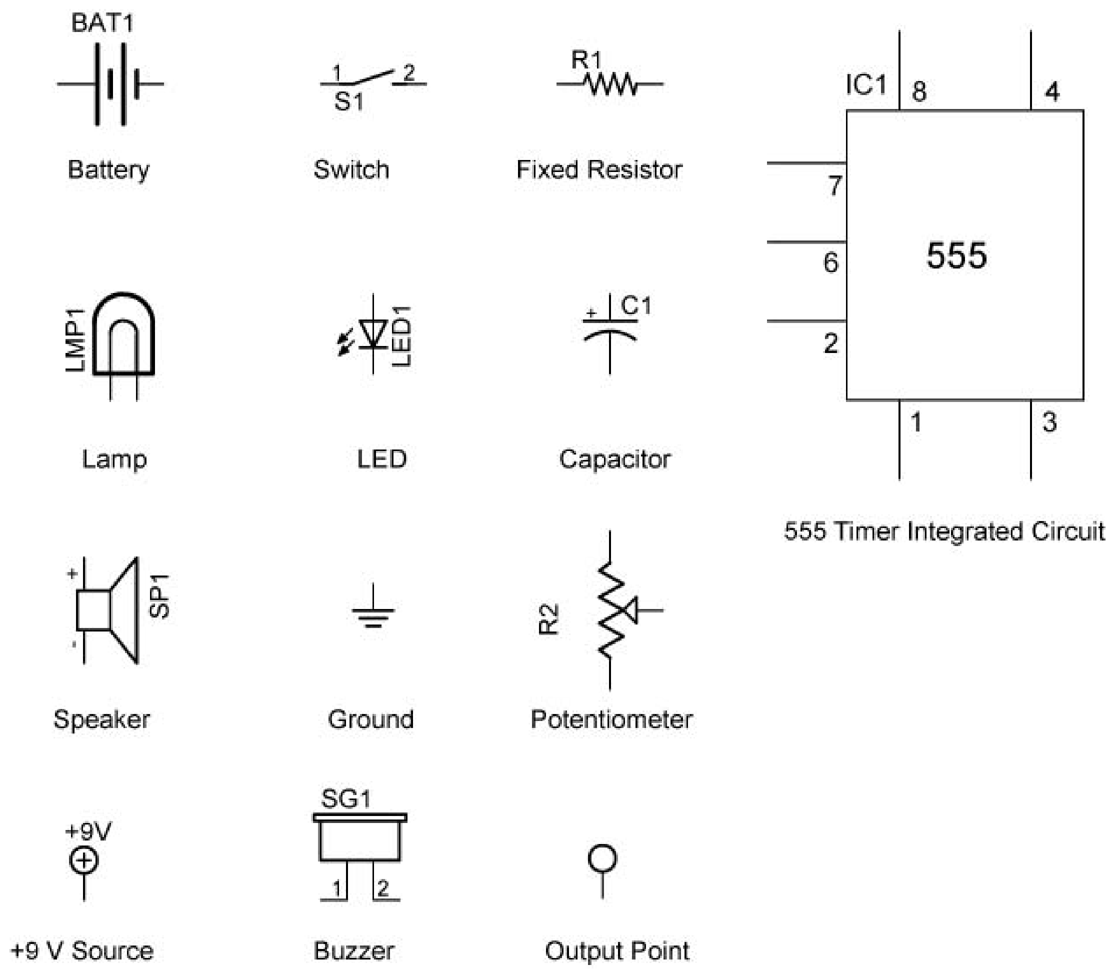
  - 1 – Digital Multimeter
  - 7 Circuits Provided by the Instructor

- **Procedure:**
  - Draw schematics for the 7 circuits displayed.
    - In Circuit 6, measure the voltage between Point A and ground. Compare it to the source voltage.

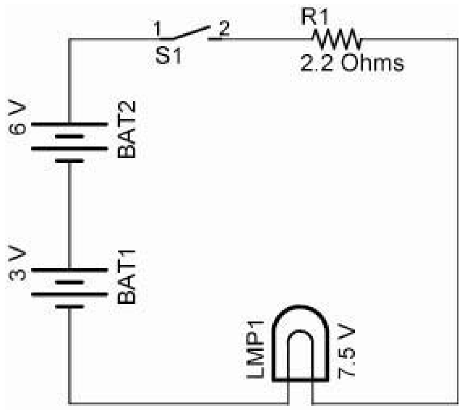
      Source Voltage = ____________________________

      Point A to GND = ____________________________

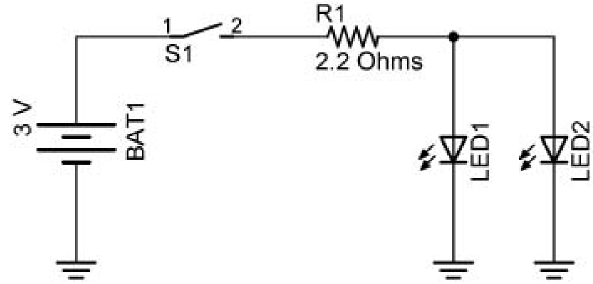
    - Use the integrated circuit (IC1) below when drawing Circuit 4, the electronic cricket.
  - Component Symbols Needed:



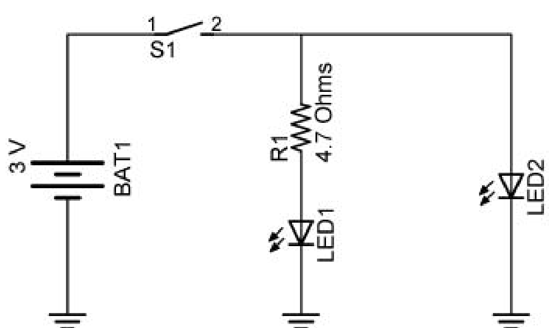
Seven Circuit Schematics



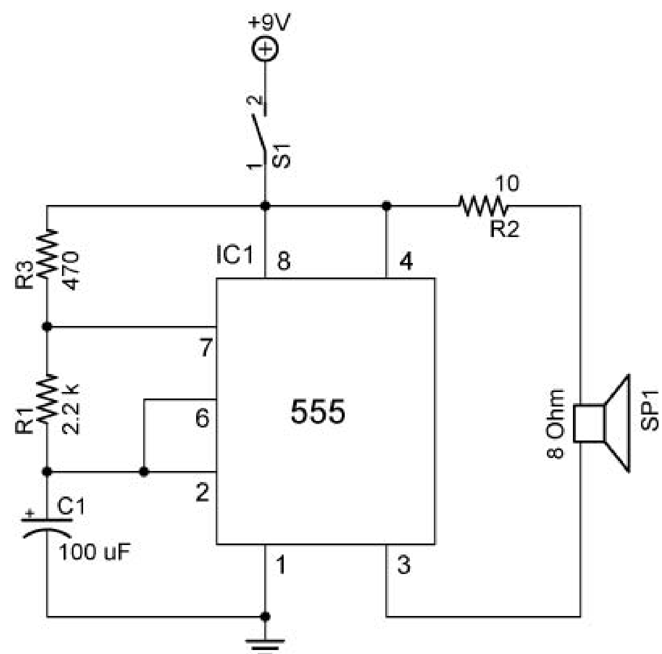
Circuit 1



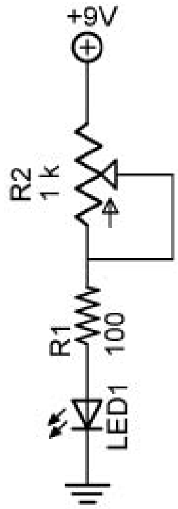
Circuit 2



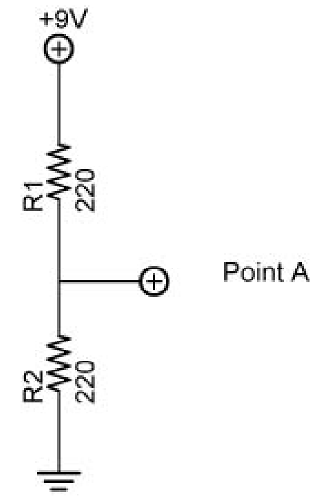
Circuit 3



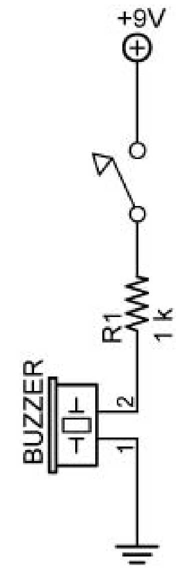
Circuit 4



Circuit 5



Circuit 6



Circuit 7

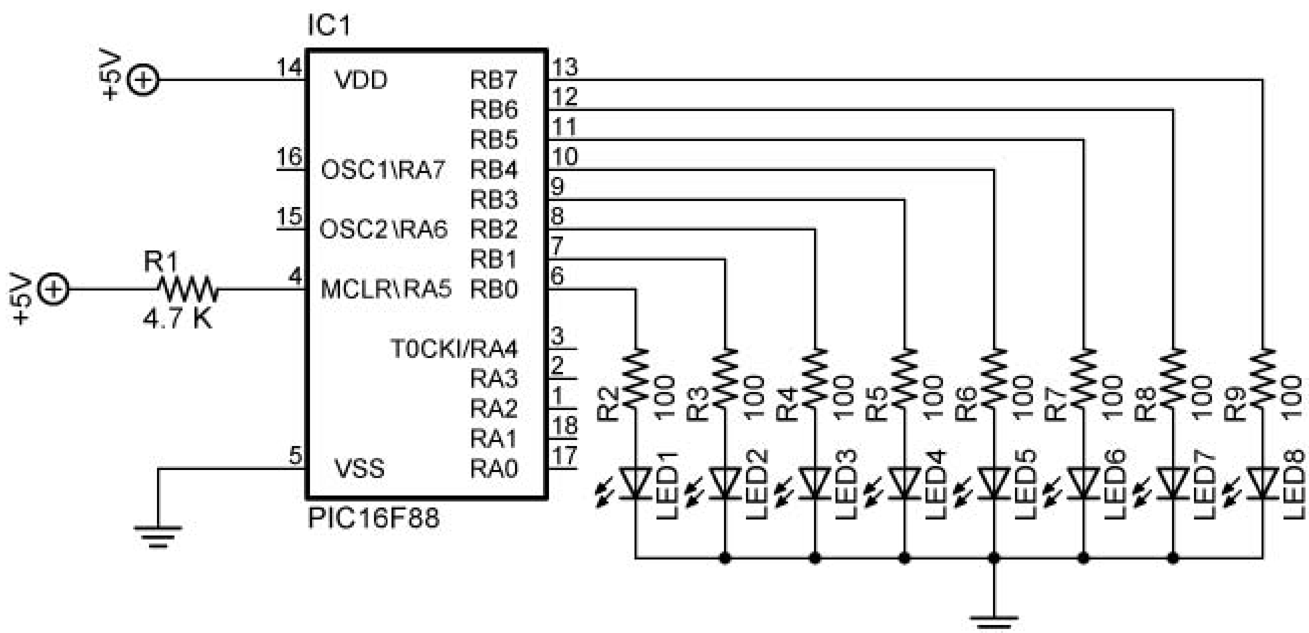
Electronics Technology and Robotics I Week 3
Schematics, Conductors, and Insulators Lab 2 – Bounce1.pbp

- **Purpose:** The purpose of this lab is to have the student practice wiring a circuit from a schematic drawing.

- **Apparatus and Materials:**

    - 1 – Breadboard with +5 V Power Source
    - 1 – PIC16F88 with PicBasic Pro Program: http://www.cornerstonerobotics.org/code/bounce1.pdf
    - 1 – 4.7 K Resistor DIP
    - 8 – LEDs
    - 8 – 100 Ω Resistors or 1 – 100 Ohm DIP Resistor Package

- **Procedure:**
    - Wire the circuit Bounce1:



Bounce1

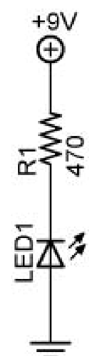
Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering Lab 1 – Forward/Reverse Bias

- **Purpose:** The purpose of this lab is to acquaint the students with forward and reverse bias of LEDs.

- **Apparatus and Materials:**
  - 1 – Breadboard with 9 V Battery
  - 2 – Digital Multimeters
  - 1 – 470 Ohm Resistor
  - 1 – Red LED

- **Procedure:**
  - Wire Circuits 3 and 4
  - Record the results and write your conclusions

Circuit 3
Forward Biased



Circuit 4
Reversed Biased

- **Results:**

Circuit	Results
3	
4	

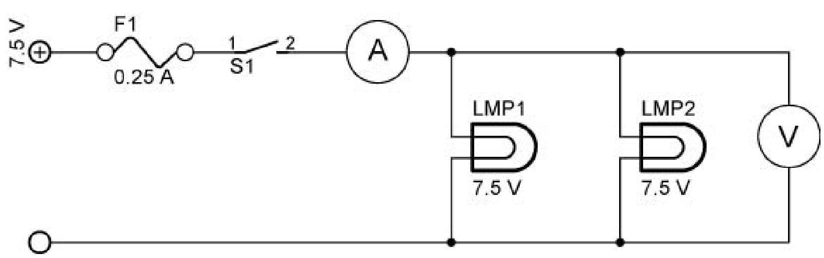
- **Conclusions:**

Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering Lab 2 – Fuses

- **Purpose:** The purpose of this lab is to acquaint the student with the function of a fuse.

- **Apparatus and Materials:**
    - 1 – DC Power Supply
    - 1 – 0.25 A Fuse (Radio Shack #270-1002)
    - 2 – 7.5 V Lamps
    - 2 – Lamp Holders
    - 2 – Digital Multimeters
    - 1 – Knife Switch
    - Alligator Leads

- **Procedure:**
    - Wire the circuit below using alligator leads.
    - Insert the Lamp 1 only and adjust the DC power supply to bring the lamp to the 7.5 V rating. Record the current reading when the lamp is at 7.5V.
    - Insert Lamp 2 lamp and adjust the DC power supply to bring both lamps to their 7.5 V rating. Watch the current readings as you increase the voltage.
    - If necessary, add a third lamp in parallel to "blow" the fuse.
    - Write your conclusions



- **Results:**

Lamps in Circuit	Current in A
Lamp 1 Only	
Lamp 1 + Lamp 2	
Lamp 1 + Lamp 2 + Lamp 3	

- **Conclusions:**

Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering LAB 3 – Tinning a Wire

- **Purpose:** The purpose of this lab is to tin the end of a stranded wire.

- **Apparatus and Materials:**

    - 1 – Soldering Iron and Holder with Moistened Sponge
    - 1 – 0.022 Resin-Core Solder
    - 1 – 0.50 Resin-Core Solder
    - 1 – Wire Cutting Pliers
    - 1 – Wire Strippers
    - 1 – Helping Hands
    - 2 – 5 cm #22 Gauge Stranded Wires

- **Procedure:**
    - Follow all safety precautions.
    - Turn on the soldering iron.
    - Moistened the sponge with distilled water.
    - Cut a two pieces of stranded wire about 5 cm long.
    - Stripe 1 cm of insulation from all ends of the wires.
    - Place the ends of one wire into the helping hands. The bare wire should be free of the alligator clip.
    - Clean the soldering iron tip off on the sponge.
    - Hold the soldering iron against the bare wire.
    - Apply a small amount of fresh 0.022 solder between the soldering iron tip and the bare wire to help conduct heat to the wire faster.
    - As the wire heats, apply more solder to the wire away from the tip of the soldering iron.
    - The solder should be heated by the wire so it will flow into the stranded wire.
    - After the bare portion of the wire is soldered, continue to hold the soldering iron against the wire for about a half of a second then pull away.
    - Inspect the tinned wire for:
        - Shiny surface
        - Wire strands – they should be visible
        - Excess insulation damage
    - Tin the other end of the wire of the wire.
    - Tin both ends of the other wire.
    - Tinning the tool tip: Just after turning the soldering iron off, apply a generous amount of 0.050 solder to your soldering iron tip.

Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering LAB 4 – Component PC Boards

- **Purpose:** The purpose of this lab is to solder to a component PC board.

- **Apparatus and Materials:**

    - 1 – Soldering Iron and Holder with Moistened Sponge
    - 1 – 0.022 Resin-Core Solder
    - 1 – 0.50 Resin-Core Solder
    - 1 – Wire Cutting Pliers
    - 1 – Wire Strippers
    - 1 – Helping Hands
    - 1 – Component PC Board
    - Miscellaneous Wires and Components

- **Procedure:**
    - Follow all safety precautions.
    - Turn on the soldering iron.
    - Moistened the sponge with distilled water.
    - Clean the component leads and component PC board with rubbing alcohol.
    - Tin the end of a wire.
        - Insert the end of the wire through a hole in the component PC board.
    - Clean the soldering iron tip off on the sponge.
    - Hold the soldering iron against the copper pad and the wire.
    - Apply more solder directly to the wire and copper pad. Stop applying solder after the connection looks like a miniature volcano.
    - Don't move the wire or the connection for a few seconds to allow the solder to cool.
    - Practice with other wires and components.
    - Tinning the tool tip: Just after turning the soldering iron off, apply a generous amount of 0.050 solder to your soldering iron tip.

Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering LAB 5 – Soldering Components to a PC Board

- **Purpose:** The purpose of this lab is to solder components to a PC board.
- **Apparatus and Materials:**
  - 1 – Soldering Iron and Holder with Moistened Sponge
  - 1 – 0.022 Resin-Core Solder
  - 1 – 0.50 Resin-Core Solder
  - 1 – Wire Cutting Pliers
  - 1 – Wire Strippers
  - 1 – Helping Hands
  - 2 – 5 cm #22 Gauge Stranded Wires
  - 2 – 5 cm #22 Gauge Solid Wires
  - 5 – Resistors
  - 1 – PC Board
- **Procedure:**
  - Follow all safety precautions.
  - Turn on the soldering iron.
  - Moistened the sponge with distilled water.
  - Clean the component leads with rubbing alcohol and the PC board with steel wool.
  - If needed, tin the component leads.
  - Insert the component leads through the holes of the PC board.
  - To hold the component in place while you are soldering, you may want to bend the leads on the bottom of the board at about a 45 degree angle.
  - Place the PC board into the helping hands.
  - Bring the soldering iron tip so that it rests against both the component lead and the board.
  - Apply a small amount of fresh 0.022 solder between the soldering iron tip and the component lead and solder pad to help conduct heat to the connection faster.
  - Allow the component lead and solder pad to heat up for about one second.
  - Feed the 0.022 solder to the component lead and solder pad, but not the tip of the iron.
  - Once the surface of the pad is completely coated, stop adding solder and remove the soldering iron. The soldered connection should look like a miniature Hershey kiss, not a rounded ball.
  - Don't move the wire or the connection for a few seconds to allow the solder to cool.
  - If the connection looks like a rounded ball, remove the solder by following the instructions in Lab 4 and resolder.
  - Cutoff the excess wire on the leads.
  - Inspect the PC board for:
    - Cold solder joints
    - Solder bridging across the conductive pathways, or traces.

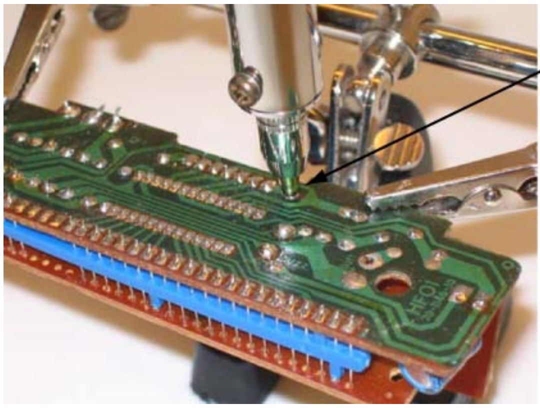
Electronics Technology and Robotics I Week 4
Lighting, Switches, and Soldering LAB 6 – Desoldering Components on a PC Board

- **Purpose:** The purpose of this lab is to remove solder from a soldered connection on a PC board.

- **Apparatus and Materials:**

  - 1 – Soldering Iron and Holder with Moistened Sponge
  - 1 – Electric Desoldering Tool (Electronix Express # 060848) http://www.elexp.com/sdr_0848.htm
  - 1 – 0.022 Resin-Core Solder
  - 1 – 0.50 Resin-Core Solder
  - 1 – Helping Hands
  - 1 – PC Board from Lab 3

- **Procedure:**
  - Follow all safety precautions.
  - Plug in the electric desoldering tool.
  - Place the PC board from Lab 3 into the helping hands.
  - Set the pump by pushing the plunger down until it locks.
  - Insert the tip of the desoldering tool over the lead to be desoldered.



Insert the electric desoldering tool directly over the lead.

  - Heat the joint and push the button on the pump to release the plunger.
  - The pump will need empting occasionally.
  - Resolder the lead.
  - Tinning the tool tip: Just after turning the soldering iron off, apply a generous amount of 0.050 solder to your soldering iron tip.

Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 1 – Resistor Color Code

- **Purpose:** The purpose of this lab is to acquaint the student with the resistor color code and tolerance calculations.

- **Apparatus and Materials:**

    - 10 – Fixed Resistors Labeled 1 – 10

- **Procedure:**
    - Using the resistor color code, determine the value of 10 resistors and record the values in the table below.
    - Calculate the limits that are within tolerance
    - Measure the resistance of each resistor and compare with the coded value.

- **Results:**

Resistor	Coded Value	Product of Tolerance x Value	Upper Limit	Lower Limit	Measured Value
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

- **Conclusions:**
    - Are the measured values of each resistor within the tolerance limits?

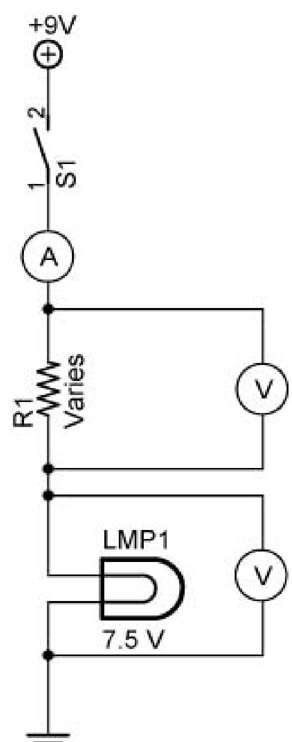
Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 2 – Resistors and Current

- **Purpose:** The purpose of this lab is to demonstrate to the student that resistors restrict current and that an increase in resistance increases the voltage drop across the resistor.

- **Apparatus and Materials:**

  - 1 – Breadboard with 9 V Supply
  - 3 – Digital Multimeters
  - 1 – 1, 10, 22, 47, 68, and 100 Ohm Resistor
  - 1 – 7.5 V Lamp with Lamp Base
  - 1 – SPDT Switch

- **Procedure:**
  - Assemble the circuit below on the breadboard using 1, 10, 22, 47, 68, and 100 ohm resistors as R1.
  - Measure the current for each change in resistor value.
  - Calculate the voltage drop across R1 using Ohm's law.
  - Now measure the voltage drop across R1 and the lamp.
  - Compare the calculated voltage drop across R1 with the measured value.
  - Add the measured voltage drops across R1 and the lamp to get the total measured voltage drop.
  - Compare the total measured voltage drop with the measured source.
  - Note the brightness variation in each case.



- **Results:**

Voltage Drops Lab 2						
Circuit	**R1**	**Current**	**Calculate Voltage Drop R1**	**Measured Voltage Drop R1**	**Measured Voltage Drop LMP1**	**Total Measured Voltage Drop**
1						
2						
3						
4						
5						
6						

- **Conclusions:**
    - Is the calculated voltage drop across R1 close to the measured voltage drop across R1?
    - As the value of R1 is increased, what happens to the voltage drop across R1?
    - As the value of R1 is increased, what happens to the brightness of the lamp? Why?

Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 3 – Making a Resistor

- **Purpose:** The purpose of this lab is to demonstrate to the student that carbon is a suitable material to make resistors.

- **Apparatus and Materials:**

    - 1 – Digital Multimeter
    - 1 – Piece of 5" x 8" Index Card
    - 1 – #2 Pencil

- **Procedure:**
    - Using a standard No. 2 pencil draw about a 7" long line on the blank side of the index card. Mark the 0" and 6" points about a half of an inch in from the ends of the line. It should look like this:

    - **Place all pencil filings from your work into a wastepaper basket.**
    - In 2 minutes using only the #2 pencil, make the line thicker and/or wider to give you the lowest resistance possible between the 0" and 6" points.
    - The student that measures lowest resistance between the 0" and 6" points at the end of the 2 minute period will be rewarded. The instructor must verify the measurement.

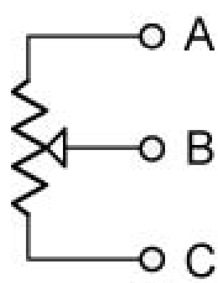
Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 4 – Potentiometers

- **Purpose:** The purpose of this lab is have the student read tripot values and to help the student understand the function of a potentiometer.

- **Apparatus and Materials:**

    - 7 – Tripots furnished by the instructor
    - 1 – Digital Multimeter
    - 1 – 5 K Ohm Potentiometer

- **Procedure:**
    - Read and record the labeled values of 7 tripots. Measure the resistance of each tripot using a DMM and record its value.
    - Testing potentiometers:
        - Test for maximum resistance of the potentiometer with a DMM, and compare with value printed on the side of the potentiometer.
        - Turn the potentiometer shaft and then flip the DMM leads. How does the maximum resistance value of the potentiometer react?
        - Using the DMM, measure and record the resistance R_{AB}, R_{BC}, and R_{AC} at three different positions of the potentiometer.



- **Results:**
    - Tripot Values:

Tripot	Printed Value	Measured Value
1		
2		
3		
4		
5		
6		
7		

- Testing potentiometers:

Potentiometer Test			
	Position 1 (Ohms)	**Position 2 (Ohms)**	**Position 3 (Ohms)**
R_{AB}			
R_{BC}			
R_{AC}			

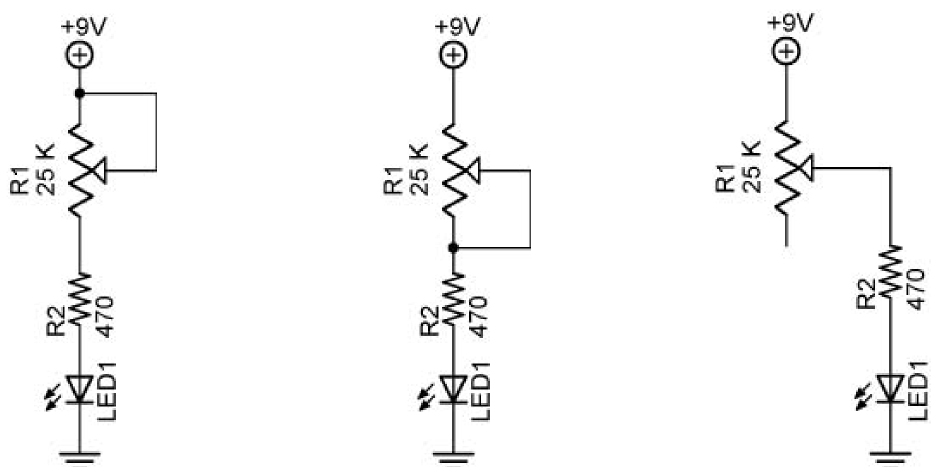
- **Conclusions:**
  - In the potentiometer test, how does R_{AC} relate to R_{AB} and R_{BC}?
  - Is R_{AC} consistent in the potentiometer test?

Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 5 – Rheostats

- **Purpose:** The purpose of this lab is to help the student understand the function of a rheostat.

- **Apparatus and Materials:**
    - 1 – Breadboard with a 9 V Power Supply
    - 1 – 25 K Ohm Potentiometer
    - 1 – 470 Ohm Resistor
    - 1 - LED

- **Procedure:**
    - Variable brightness LED circuit:
        - Wire each circuit below, adjust R1, and compare the results.



Circuit 1 **Circuit 2** **Circuit 3**

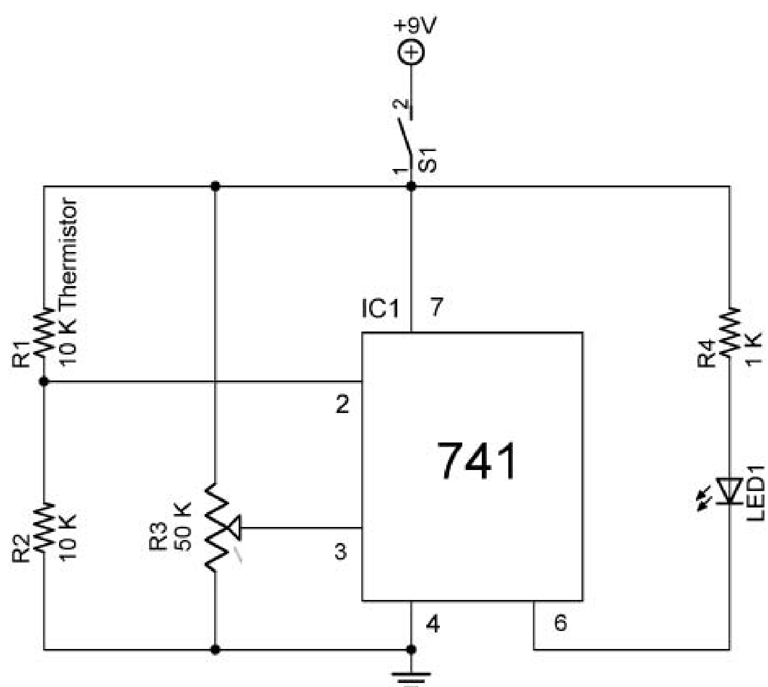
- **Results:**

- **Conclusions:**
    - Does it matter which of the three circuits is used to control the LED?

    - What is the purpose of the 470 ohm resistor?

Electronics Technology and Robotics I Week 5
Resistors and Potentiometers Lab 6 – Thermistor

- **Purpose:** The purpose of this lab is to acquaint the student with the basic operation of a thermistor.
- **Apparatus and Materials:**
  - 1 – Lab Thermometer
  - 1 – Lab Beaker
  - 1 – DMM
  - 1 – Breadboard with a 9 V Power Supply
  - 1 – Switch
  - 1 – 10 K Ohm Thermistor
  - 1 – 10 K Ohm Resistor
  - 1 – 50 K Ohm Potentiometer
  - 1 – 1 K Ohm Resistor
  - 1 – 741 Op Amp Integrated Circuit
  - 1 - LED
- **Procedure:**
  - First, measure the resistance of the thermistor as it is taken from room temperature and placed in a beaker filled with ice water. Note the changes in resistance as it cools.
  - Now using a 10 K thermistor, wire the thermistor circuit found below.
  - At room temperature, adjust R3 until the LED turns off. Place the thermistor between your fingers to heat it up and to turn on the LED.
  - If the LED remains off, reverse the connections to pins 2 and 3 which will reverse the operation.



Thermistor Used in an Op Amp Comparator Circuit

Batteries and Other Energy Sources Lab 1 – Hand Battery

- **Purpose:** The purpose of this lab is to acquaint the student with the fact that the human body can generate an electrical potential.

- **Apparatus and Materials:**

  - 1 – Digital Multimeter
  - 2 – 5" x 6" Single Sided Copper Clad Circuit Board (Electronix Express # 97BS16)
  - 2 – Aluminum Plate the Size of a Palm
  - Alligator Clips

- **Procedure:**
  - Your skin and two different metals create a battery.
  - Connect an aluminum and a copper plate to the DMM set to 2 volt range. Connect the positive lead to the copper plate.
  - Place one hand on each plate and read the meter.
  - When you touch the two metal plates, the thin film of sweat on your hands acts like the acid in a battery, reacting with the copper plate and with the aluminum plate. In one of these reactions, your hand takes negatively charged electrons away from the copper plate, leaving positive charges behind. In the other reaction, your hand gives electrons to the aluminum plate, causing it to become negatively charged. This difference in charge between the two plates creates a flow of electrical charge, or electrical current.
  - Try using the same type of metal for each plate. Place one hand on each plate and read the meter.
  - You can sometimes get a small current even between two plates made of the same metal. Each plate has a slightly different coating of oxides, salts, and oils on its surface. These coatings create slight differences in the surfaces of the metals, and these differences can produce an electrical current.

- **Results:**
  - Copper/aluminum maximum voltage generated: ______________ V

  - Copper/copper maximum voltage generated: ______________ V

  - Aluminum/aluminum maximum voltage generated: ______________ V

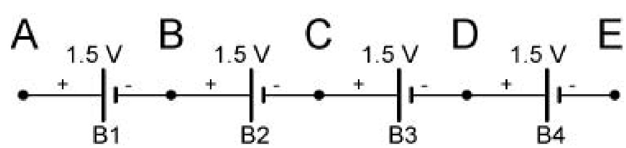
- **Conclusions:**

Electronics Technology and Robotics I Week 6
Batteries and Other Energy Sources Lab 2 – Series and Parallel Batteries

- **Purpose:** The purpose of this lab is to acquaint the student with how voltages add when placed in series and parallel.

- **Apparatus and Materials:**
  - 1 – Digital Multimeter
  - 4 – AA Batteries and Battery Holders
  - TBD – Potatoes
  - TBD – #16 hot-dipped galvanized nail
  - TBD – # 6 bare copper wire
  - 1 – LED
  - Alligator Leads

- **Procedure for Series Batteries:**
  - Connect the four AA batteries as shown in the schematic.



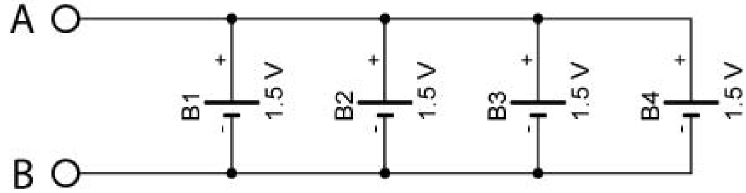
Batteries in Series

  - Measure and record the voltages V_{AB}, V_{BC}, V_{CD}, and V_{DE}.
  - Calculate the voltages V_{AC}, V_{AD}, and V_{AE} then measure and record the same voltages.
  - Compare the calculated and measured results in the conclusions.

- **Results for Series Batteries:**

Individual Voltage	Measured	Added Voltage	Calculated	Measured
V_{AB}		V_{AB}	-	
V_{BC}		V_{AC}		
V_{CD}		V_{AD}		
V_{DE}		V_{AE}		

- **Procedure for Parallel Batteries:**
  - Connect the four AA batteries as shown in the schematic and measure V_{AB}.



  - Remove one battery at a time and measure and record V_{AB}.

- **Results for Parallel Batteries:**

V_{AB} Measured	Batteries Connected
	B1, B2, B3, B4
	B1, B2, B3
	B1, B2
	B1

- **Procedure for Parallel and Series Batteries:**
  - Take a potato and insert a #16 hot-dipped galvanized nail and a # 6 bare copper wire to create a "potato cell".
  - Experiment to find a combination of potato cells in series and parallel that provides enough voltage and current to light an LED.

- **Results for Parallel and Series Batteries:**
  - Draw the schematic of the battery layout used to light the LED.

- **Conclusions:**
  - Drycell Batteries in Series:
    - Compare the calculated and measured results in the batteries in series experiment.
    - Do the experimental results conform to the formula for batteries in series?
  - Batteries in Parallel:
    - Do the experimental results conform to the formula for batteries in parallel?

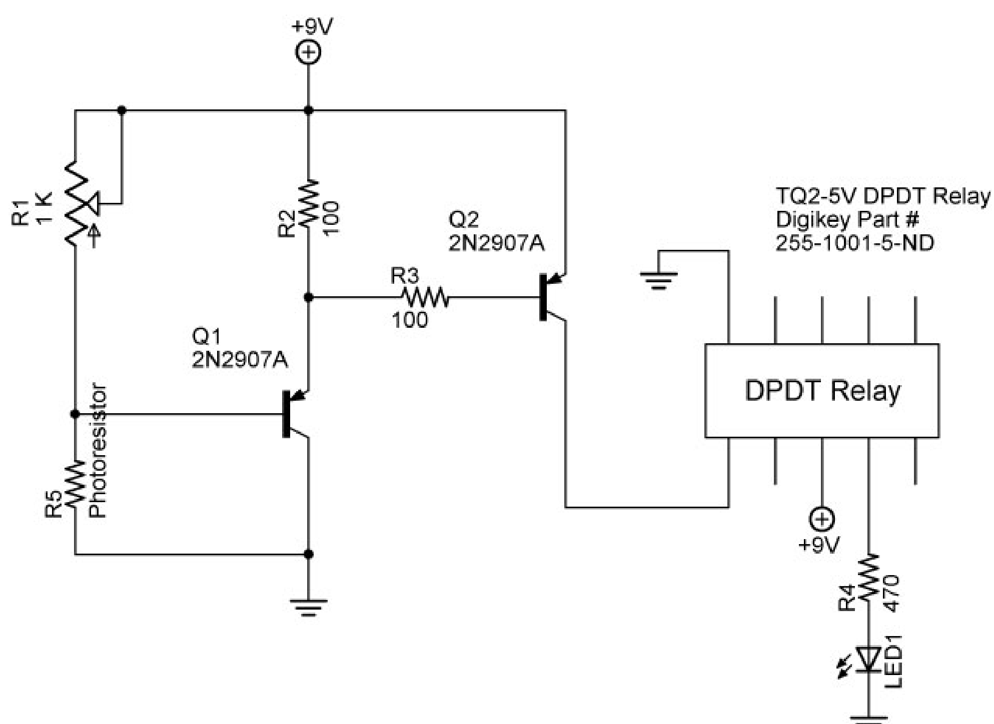
Electronics Technology and Robotics I Week 6
Batteries and Other Energy Sources Lab 3 – Photoresistors

- **Purpose:** The purpose of this lab is to acquaint the student with:
  - Photoresistor and how their resistance varies at different light levels and
  - A practical application for a photoresistor

- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 1 – Digital Multimeter
  - 3 – Cds photocells
  - 1 – 1 K Tripot
  - 2 – 100 Ohm Resistors
  - 1 – 470 Ohm Resistor
  - 2 – 2N2907A PNP Transistors
  - 1 – LED
  - 1 – DPDT Relay (Digikey # 255-1001-5-ND)

- **Procedure:**
  - Using the DMM, measure and record the maximum and minimum resistances for 3 photoresistors.
  - Wire the following photoresistor control circuit using a photoresistor as the sensor:



- Using a photoresistor, design a light controlled circuit to vary the brightness of an LED. Wire the circuit on your breadboard and draw the schematic in the results. Remember, 9 volts applied directly to an LED will burn it out.

- **Results:**
  - Cds Photocell Resistances:

Cds Photocell	Minimum Resistance	Maximum Resistance
1		
2		
3		

  - Schematic of Variable Brightness LED Circuit:

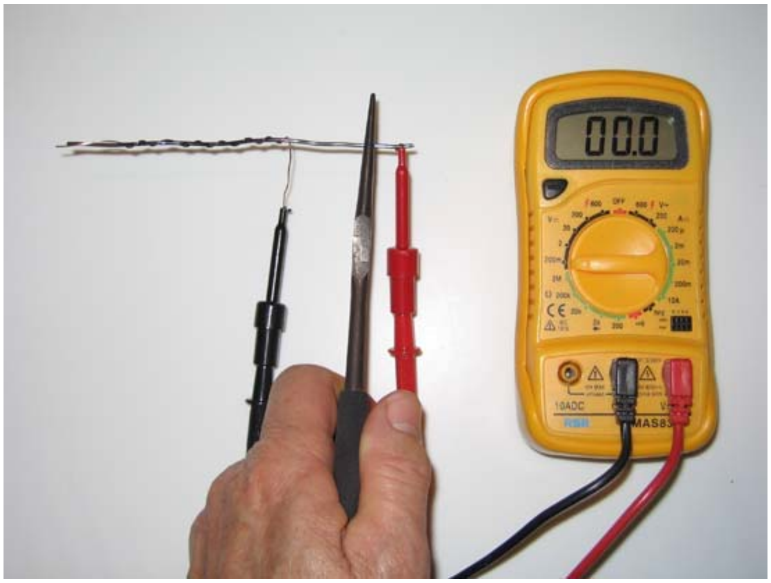
Electronics Technology and Robotics I Week 6
Batteries and Other Energy Sources Lab 4 – Thermocouples

- **Purpose:** The purpose of this lab is to acquaint the student with the basic construction of a thermocouple.

- **Apparatus and Materials:**

    - 1 – Digital Multimeter
    - 1 – Piece of Copper Wire
    - 1 – Piece of Steel Wire
    - 1 – Pair of Pliers
    - 1 – Match or Gas Lighter

- **Procedure:**
    - Twist the copper and steel wires together.
    - Connect the multimeter leads to the two twisted wires. Hold the steel wire as shown to protect the positive multimeter lead.
    - Measure and record the voltage before heat is applied.
    - Apply the flame to the far end of the twisted wires to protect the negative multimeter lead. Record the voltage output of this thermocouple as heat is applied and after cool down.



- **Results:**

Condition	Voltage
Before Heat	
Heat Applied	
After Cool Down	

Electronics Technology and Robotics I Week 7
Series Circuits Lab 1 – Series Resistors

- **Purpose:** The purpose of this lab is to verify, by experiment, the formula for total resistance for resistors in series.
- **Apparatus and Materials:**
  - 1 – Solderless Breadboard with 9 V Supply
  - 1 – Digital Multimeter
  - 1 – 220 Ohm Resistor
  - 1 – 330 Ohm Resistor
  - 1 – 470 Ohm Resistor
  - 1 – 1 K Ohm Resistor
  - 1 – 2.2 K Ohm Resistor
- **Procedure:**
  - Total Resistance of Series Resistors Using Ohm Meter:
    - Measure the resistance of each resistor and record.
    - Wire the series resistor network in Figure 1.
    - Add the individual resistances to determine the total resistance of the network.
    - Now measure the total resistance of the resistor network and record.

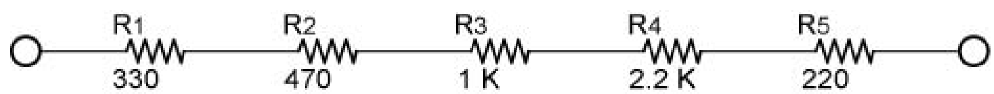


Figure 1

  - Total Resistance of Series Resistors Using Ohm's Law:
    - Connect a 9 V battery to the resistor network as shown in Figure 2.

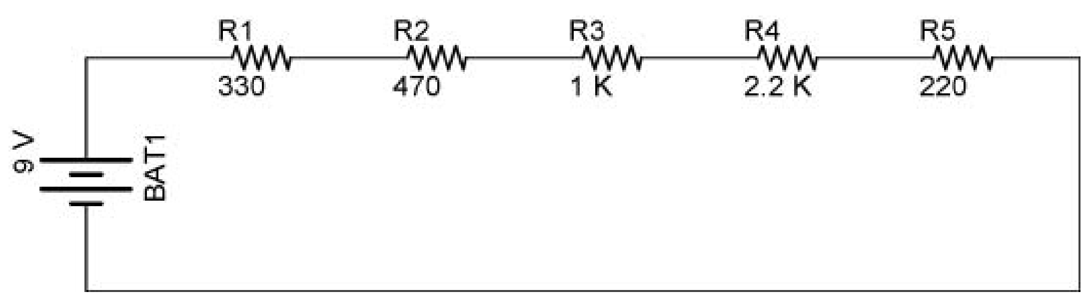


Figure 2

    - Measure the source voltage V_T and the current I_T through the series resistor network.
    - Knowing V_T and I_T, calculate the total resistance R_T using Ohm's Law.

- **Results:**

Resistor	Resistors Nominal Value (Ω)	Resistors Measured Value (Ω)	Total Resistance Measured (Ω)	Total Resistance Ohm's Law (Ω)
R1	220			
R2	330			
R3	470			
R4	1K			
R5	2.2K	______		
	R_T = 4,220	R_T =	R_T =	R_T =

- **Conclusions:**
  - Do the four values of R_T equal one another? Explain any discrepancies.
  - If a 1 M Ohm resistor is in series with a 100 Ohm resistor, which resistor affects the total resistance more?

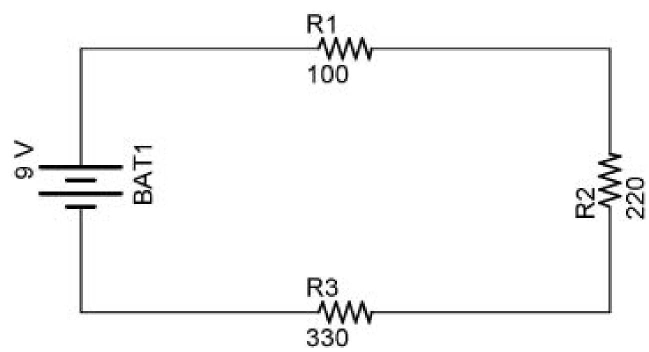
Electronics Technology and Robotics I Week 7
Series Circuits Lab 2 – Kirchhoff's Voltage Law

- **Purpose:** The purpose of this lab is to experimentally verify Kirchhoff's Voltage Law for a series resistor circuit.

- **Apparatus and Materials:**

    - 1 – Solderless Breadboard with 9 V Power Supply
    - 1 – Digital Multimeter
    - 1 – 100 Ohm Resistor
    - 1 – 220 Ohm Resistor
    - 1 – 330 Ohm Resistor

- **Procedure:**
    - Wire the following series circuit and measure the voltage drop across each resistor.
    - Compare the sum of the voltage drops with the voltage source:



- **Results:**

	Voltage (V)
V_1	
V_2	
V_3	______
$V_1 + V_2 + V_3$	
V_{SOURCE}	

- **Conclusions:**
    - Does $V_{SOURCE} = V_1+V_2+V_3$?

    - Or put another way, does $V_{SOURCE} - V_1 - V_2 - V_3 = 0$? Explain any discrepancies.

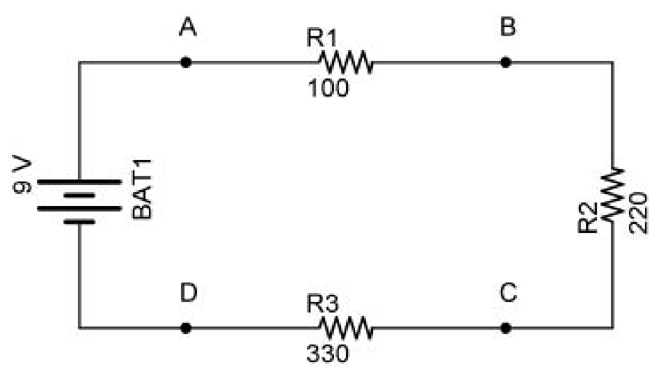
Electronics Technology and Robotics I Week 7
Series Circuits Lab 3 – Current in Series Circuits

- **Purpose:** The purpose of this lab is to verify, by experiment, the formula for total current for resistors in series.

- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 1 – Digital Multimeter
  - 1 – 100 Ohm Resistor
  - 1 – 220 Ohm Resistor
  - 1 – 330 Ohm Resistor

- **Procedure:**
  - Using the same circuit from Lab 2, measure and record the current at each Point A - D.



- **Results:**

	Current (mA)
I_A	
I_B	
I_C	
I_D	

- **Conclusions:**
  - How do the 4 current readings relate to one another?

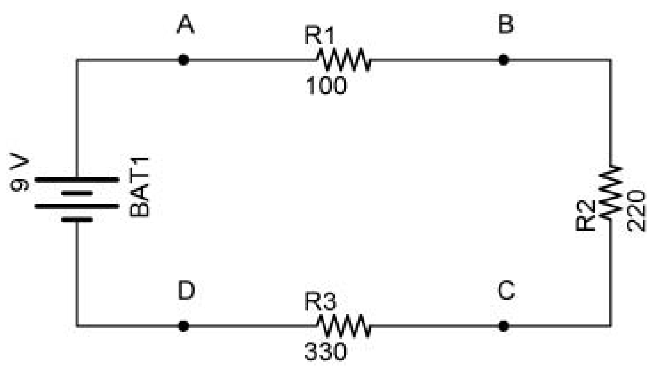
Electronics Technology and Robotics I Week 7
Series Circuits Lab 4 – Power in Series Circuits

- **Purpose:** The purpose of this lab is to verify, by experiment, that the total power consumed in series circuit is equal to the sum of the power consumed by each resistor.

- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 1 – Digital Multimeter
  - 1 – 100 Ohm Resistor
  - 1 – 220 Ohm Resistor
  - 1 – 330 Ohm Resistor

- **Procedure:**
  - Calculate the power for each resistor and then the total power consumed for the following circuit:



- **Results:**

Resistor	Resistance (Ω)	Voltage (V)	Current (A)	Power (W) P = V * I
R1	100	V1 =	I1 =	P1 =
R2	220	V2 =	I2 =	P2 =
R3	330	V3 =	I3 =	P3 =
				$P_1 + P_2 + P_3 =$
		$V_T =$	$I_T =$	$P_T =$

- **Conclusions:** Does $P_T = P_1 + P_2 + P_3$?

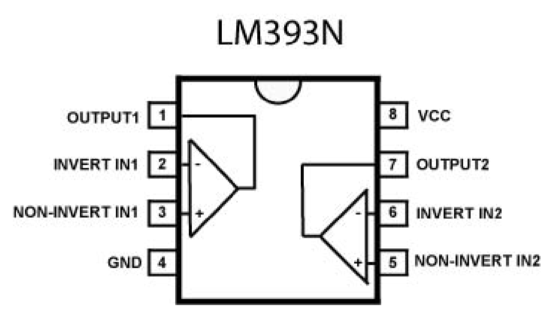
Electronics Technology and Robotics I Week 8
Comparators and Transistors Lab 1 – LM393N Comparator

- **Purpose:** The purpose of this lab is to acquaint the student with the LM393N comparator and its inverting and non-inverting modes.

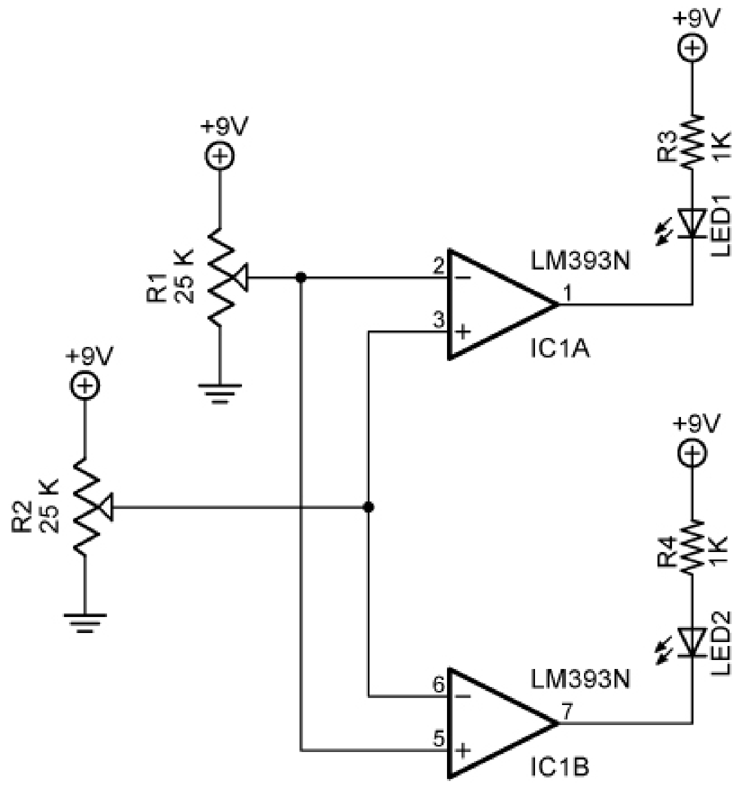
- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 2 – Digital Multimeters
  - 1 – LM393N Comparator
  - 2 – 25 K Potentiometers
  - 2 – 1 K Ω Resistors
  - 2 – LEDs

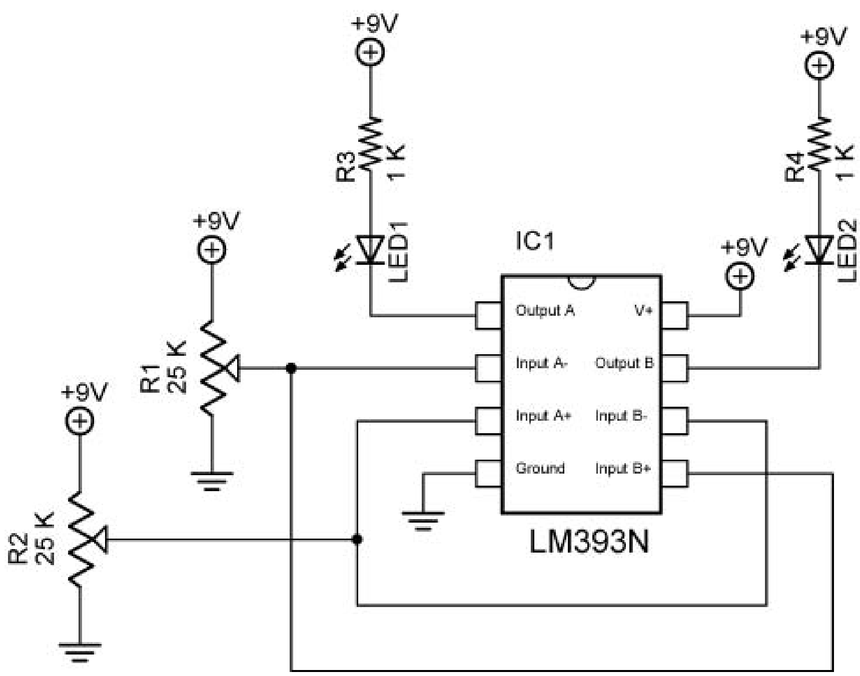
- **Procedure:**
  - Build Circuit 2. Wiring Diagram 1 may assist in the assembly of the circuit.
  - In this test, let pins 2 and 5 be the reference voltage (V_{REF}). Adjust R_1 to set pins 2 and 5 to about 4.5 V.
  - Adjust R_2 so that the voltage input (V_{IN}) into pins 3 and 6 varies from 0 to 9V. If V_{IN} is less than V_{REF} are the LEDs on or off? If V_{IN} is more than V_{REF} are the LEDs on or off? Record your results.
  - At what voltage does the LED change state? Record your results.
  - LM393N Pinout:



  - <u>Always</u> use the IC extractor when removing ICs.



Circuit 2



Wiring Diagram 1

- **Results:**
    - Pins 2 and 5 reference voltage (V_{REF}): __________V
    - Pins 3 and 6 (V_{IN}) less than V_{REF}: LED1 on or off   LED2 on or off
    - Pins 3 and 6 (V_{IN}) more than V_{REF}: LED1 on or off   LED2 on or off
    - V_{IN} where the LED changes state? __________V
- **Conclusions:**
    - If Pin 5 of IC1B is set as V_{REF}, what mode is IC1B in? Inverting or non-inverting?

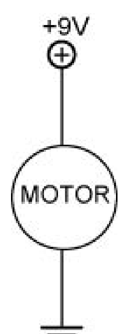
Electronics Technology and Robotics I Week 8
Comparators and Transistors Lab 2 – LM393N Current Limitations

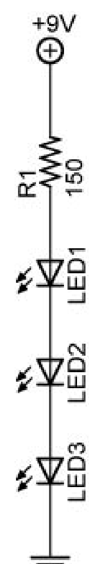
- **Purpose:** The purpose of this lab is to acquaint the student with the current limitations of the LM393 voltage comparator.

- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 1 – Digital Multimeter
  - 1 – Gearhead Motor, HNGH12-1324Y-R
  - 1 – 150 Ohm Resistor
  - 3 – Yellow LEDs
  - 3 – Green LEDs

- **Procedure:**
  - Sandwich (a line following robot built in the Year 1 full course) current requirements:
    - Measure and record the maximum current used by the gearhead motor in Sandwich. Use a DMM that saves the maximum current value. See schematic below.
    - Measure and record the current to power three series yellow and then three green LED's.
    - Total the maximum currents of the components.





  - Review the attached data sheet for the LM393 comparator. Note the typical Output Sink Current value. Record and determine the difference.

- **Results:**

Part	Maximum Current (mA)
2 Gearhead Motors	
3 Yellow LEDs	
3 Green LEDs	+ ________________
Total Current Required by Sandwich	
Typical Output Sink Current of LM393	- ________________
Difference	

- **Conclusions:**
  - Does the LM393 provide sufficient current output to handle the load requirements of Sandwich?

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 Vdc, $T_{low} \le T_A \le T_{high}$,* unless otherwise noted.)

Characteristic	Symbol	LM393A Min	LM393A Typ	LM393A Max	Unit
Output Leakage Current	I_{OL}				μA
V_{in-} = 0 V, $V_{in+} \ge$ 1.0 Vdc, V_O = 5.0 Vdc, T_A= 25°C		–	0.1	–	
V_{in-} = 0 V, $V_{in+} \ge$ 1.0 Vdc, V_O = 30 Vdc, $T_{low} \le T_A \le T_{high}$		–	–	1.0	
Supply Current	I_{CC}				mA
R_L = ∞ Both Comparators, T_A = 25°C		–	0.4	1.0	
R_L = ∞ Both Comparators, V_{CC} = 30 V		–	1.0	2.5	

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 Vdc, $T_{low} \le T_A \le T_{high}$, unless otherwise noted.)

Characteristic	Symbol	LM392, LM393 Min	LM392, LM393 Typ	LM392, LM393 Max	LM2903, LM2903V Min	LM2903, LM2903V Typ	LM2903, LM2903V Max	Unit
Input Offset Voltage (Note 2)	V_{IO}							mV
T_A = 25°C		–	±1.0	±5.0	–	±2.0	±7.0	
$T_{low} \le T_A \le T_{high}$		–	–	9.0	–	9.0	15	
Input Offset Current	I_{IO}							nA
T_A = 25°C		–	±5.0	±50	–	±5.0	±50	
$T_{low} \le T_A \le T_{high}$		–	–	±150	–	±50	±200	
Input Bias Current (Note 3)	I_{IB}							nA
T_A = 25°C		–	25	250	–	25	250	
$T_{low} \le T_A \le T_{high}$		–	–	400	–	200	500	
Input Common Mode Voltage Range (Note 3)	V_{ICR}							V
T_A = 25°C		0	–	V_{CC} –1.5	0	–	V_{CC} –1.5	
$T_{low} \le T_A \le T_{high}$		0	–	V_{CC} –2.0	0	–	V_{CC} –2.0	
Voltage Gain $R_L \ge$ 15 kΩ, V_{CC} = 15 Vdc, T_A = 25°C	A_{VOL}	50	200	–	25	200	–	V/mV
Large Signal Response Time V_{in} = TTL Logic Swing, V_{ref} = 1.4 Vdc V_{RL} = 5.0 Vdc, R_L = 5.1 kΩ, T_A = 25°C	–	–	300	–	–	300	–	ns
Response Time (Note 5) V_{RL} = 5.0 Vdc, R_L = 5.1 kΩ, T_A = 25°C	t_{TLH}	–	1.3	–	–	1.5	–	μs
Input Differential Voltage (Note 6) All $V_{in} \ge$ Gnd or V– Supply (if used)	V_{ID}	–	–	V_{CC}	–	–	V_{CC}	V
Output Sink Current $V_{in} \ge$ 1.0 Vdc, V_{in+} = 0 Vdc, $V_O \le$ 1.5 Vdc T_A = 25°C	I_{Sink}	**6.0**	**16**	–	6.0	16	–	**mA**
Output Saturation Voltage	V_{OL}							mV
$V_{in} \ge$ 1.0 Vdc, V_{in+} = 0, $I_{Sink} \le$ 4.0 mA, T_A = 25°C		–	150	400	–	–	400	
$T_{low} \le T_A \le T_{high}$		–	–	700	–	200	700	
Output Leakage Current	I_{OL}							nA
V_{in-} = 0 V, $V_{in+} \ge$ 1.0 Vdc, V_O = 5.0 Vdc, T_A = 25°C		–	0.1	–	–	0.1	–	
V_{in-} = 0 V, $V_{in+} \ge$ 1.0 Vdc, V_O = 30 Vdc, $T_{low} \le T_A \le T_{high}$		–	–	1000	–	–	1000	
Supply Current	I_{CC}							mA
R_L = ∞ Both Comparators, T_A = 25°C		–	0.4	1.0	–	0.4	1.0	
R_L = ∞ Both Comparators, V_{CC} = 30 V		–	–	2.5	–	–	2.5	

*T_{low} = 0°C, T_{high} = +70°C for LM393/393A
LM293 T_{low} = –25°C, T_{high} = +85°C
LM2903 T_{low} = –40°C, T_{high} = +105°C
LM2903V T_{low} = –40°C, T_{high} = +125°C

NOTES:
2. At output switch point, $V_O \simeq$ 1.4 Vdc, R_S = 0 Ω with V_{CC} from 5.0 Vdc to 30 Vdc, and over the full input common mode range (0 V to V_{CC} = –1.5 V).
3. Due to the PNP transistor inputs, bias current will flow out of the inputs. This current is essentially constant, independent of the output state, there fore, no loading changes will exist on the input lines.
5. Response time is specified with a 100 mV step and 5.0 mV of overdrive. With larger magnitudes of overdrive faster response times are obtainable.
6. The comparator will exhibit proper output state if one of the inputs becomes greater than V_{CC}, the other input must remain within the common mode range. The low input state must not be less than –0.3 V of ground or minus supply.

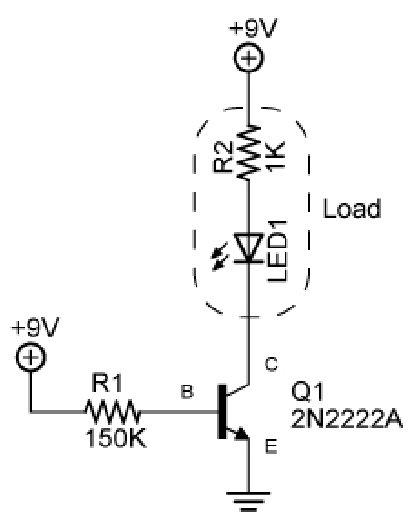
Electronics Technology and Robotics I Week 8
Comparators and Transistors Lab 3 – NPN and PNP Transistor Load Placement

- **Purpose:** The purpose of this lab is to demonstrate that the placement of the load in a NPN transistor switch is critical.

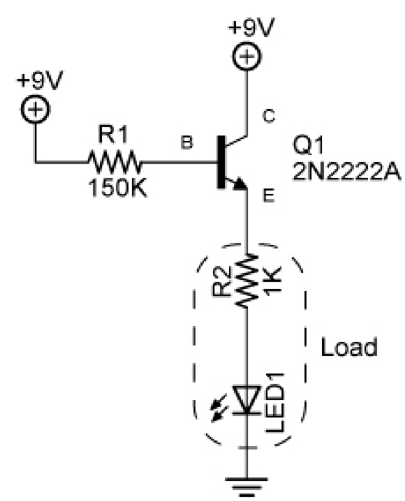
- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 2 – Digital Multimeters
  - 1 – 2N2222A NPN Transistor
  - 1 – SPST Switch
  - 1 – 470K Resistor
  - 1 – 1K Resistor
  - 1 – LED

- **Procedure:**
  - Build the first NPN test circuit. Note the placement of the load (the resistor R2 and the LED). Measure and record the collector, emitter, and base currents. Also measure and record the collector-emitter voltage.
  - Now move the load to the emitter side of the transistor and measure and record all three currents again and the collector-emitter voltage.



NPN Transistor as a "Low Side" Switch



NPN Transistor as a "High Side" Switch

- **Results:**
  - Load connected to collector: Load connected to emitter:

	Current (mA)
Collector I_C	
Base I_B	
Emitter I_E	

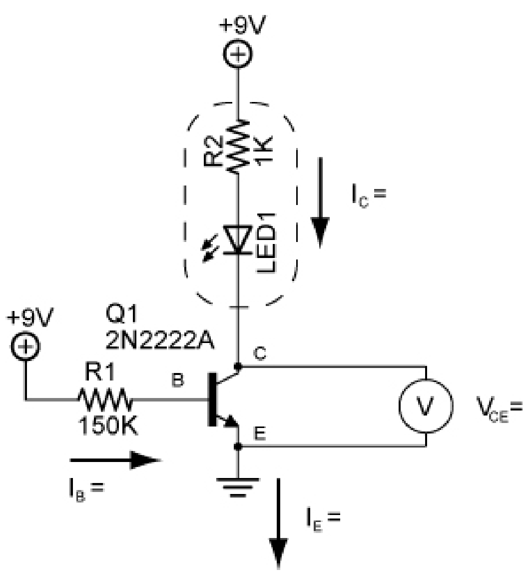
V_{CE}	

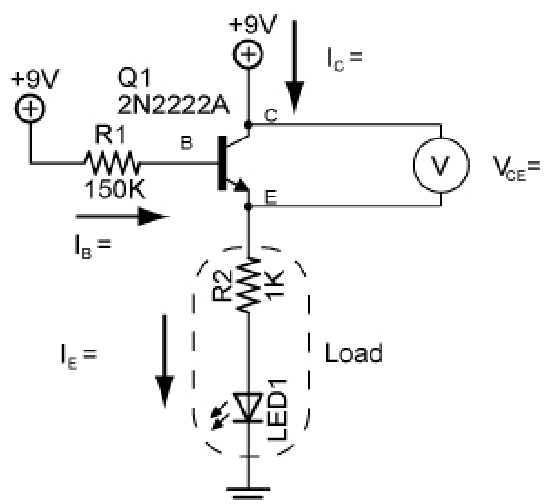
	Current (mA)
Collector I_C	
Base I_B	
Emitter I_E	

V_{CE}	

- **Conclusions:**
  - Insert your results in the circuits below:

Load connected to collector: Load connected to emitter:





  - If the 2N2222A NPN transistor is serving as a switch, what problem does the collector-emitter voltage cause in the right circuit?
  - Which circuit functions better as a switch? Why?
  - Draw a PNP transistor circuit showing the proper position for the load.

- **Sample Readings:**

	Current (mA)
Collector I_C	6.74
Base I_B	0.055
Emitter I_E	6.80
V_{CE}	0.21 V

Load Connected to Collector

	Current (mA)
Collector I_C	3.59
Base I_B	0.018
Emitter I_E	3.60
V_{CE}	3.40 V

Load Connected to Emitter

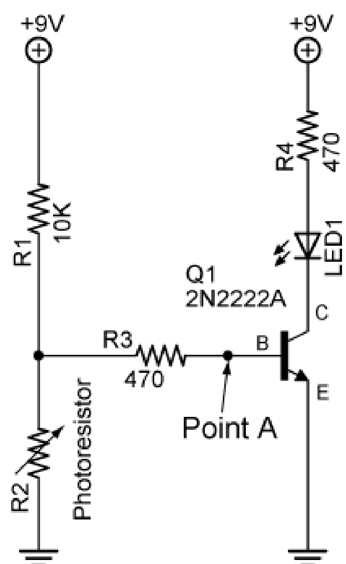
Electronics Technology and Robotics I Week 8
Comparators and Transistors Lab 4 – NPN Transistor Switch Circuit Application

- **Purpose:** The purpose of this lab is to demonstrate a practical use of a transistor switch.

- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 1 – Digital Multimeter
  - 1 – 2N2222A NPN Transistor
  - 1 – 10K Ω Resistor
  - 1 – Photoresistor
  - 2 – 470 Ω Resistor
  - 1 – LED

- **Procedure:**
  - Wire the following circuit on a breadboard.
  - Vary the amount of light entering the photoresistor using a flashlight.
  - Measure and record the highest and lowest voltage readings at Point A, V_A, with respect to ground.
  - Also measure and record the voltage at Point A when the LED just lights.



- **Results:**

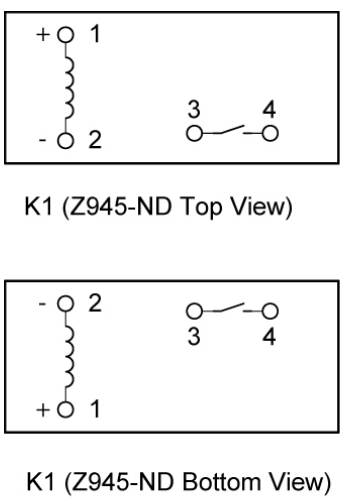
Point A	Voltage (V)	State of LED
Lowest Reading		
Highest Reading		
LED Just Lights		

Electronics Technology and Robotics I Week 9
Electrical Relays Lab 1 – Voltage Separation

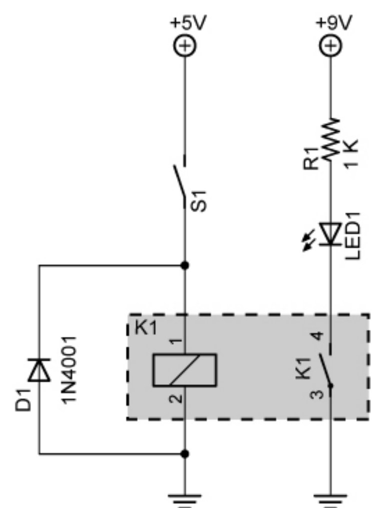
- **Purpose:** The purpose of this lab is to demonstrate that the voltage source which controls a relay coil can be separate from the voltage source that controls the secondary circuit.

- **Apparatus and Materials:**
  - 1 – Breadboard with a +5 V and +9 V Power Supplies
  - 1 – 1N4004 Diode
  - 1 – SPST Relay (Digikey # Z945-ND) http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=Z945-ND
  - 1 – SPST Switch
  - 1 – 1K Resistor
  - 1 – LED

- **Procedure:**
  - Build Relay Circuit 1 on your breadboard. The circuit uses a voltage source of +5 V to energize the relay coil and a separate a voltage source of +9 V to power the LED circuit.
  - Notice that the two circuits in Relay Circuit 1 are not connected electrically. Their interaction is by the coil generating a magnetic field which closes the contacts (switch) in the relay.



SPST Relay Wiring Diagram



Relay Circuit 1

- **Results:**

Position of Switch	LED Response
S1 Open	
S1 Closed	

- **Conclusions:**
  - The data sheet for the relay states, “When mounting two or more relays side by side, provide a minimum space of 3 mm between relays.” Why?

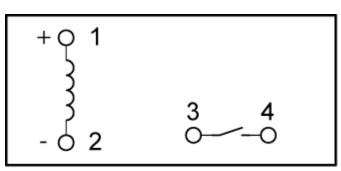
Electronics Technology and Robotics I Week 9
Electrical Relays Lab 2 – Relay Application 1

- **Purpose:** The purpose of this lab is to demonstrate an application of a relay.

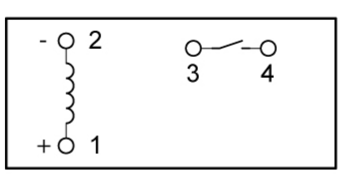
- **Apparatus and Materials:**

    - 1 – Breadboard with a +5V and +9V Power Supply
    - 1 – 1 K Tripot
    - 1 – Photoresistor
    - 1 – 4.7 K Resistor
    - 2 – 1 K Resistors
    - 1 – 2N2222A NPN Transistor
    - 1 – 1N4001 Diode
    - 1 – LED
    - 1 – SPST Relay (Digikey # Z945-ND) http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=Z945-ND

- **Procedure:**
    - Wire the following light activated relay circuit:

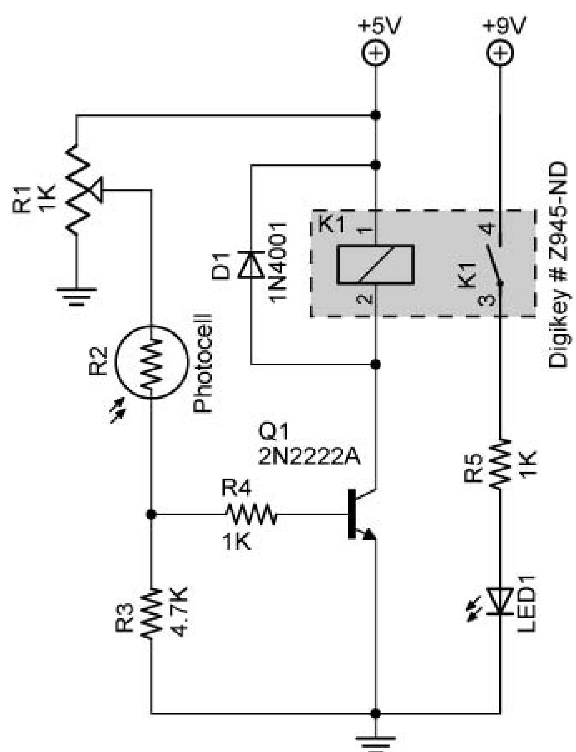


K1 (Z945-ND Top View)



K1 (Z945-ND Bottom View)

SPST Relay Wiring Diagram



Light Activated Relay Circuit

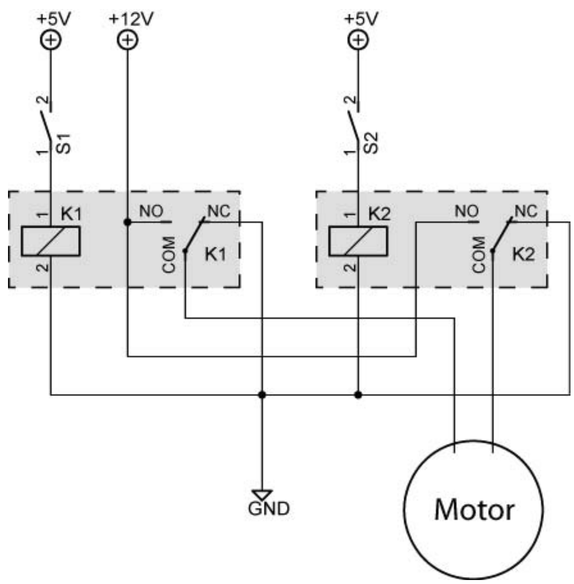
Electronics Technology and Robotics I Week 9
Electrical Relays Lab 3 – Controlling a DC Motor's Direction with Relays

- **Purpose:** To demonstrate how relays can be used to control the polarity of a dc motor.

- **Apparatus and Materials:**

  - 1 – Breadboard with a +5V and +12V Power Supply
  - 1 – 12V DC Motor (Jameco #155855 or similar)
  - 2 – SPDT DC Reed Relays 5V DC Coil Voltage, (Digi-Key #HE112-ND)
    - Source: http://www.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&keywords=he112-nd&x=0&y=0&cur=USD
    - Datasheet (Part #HE721C0500): http://www.hamlin.com/specsheets/HE700.pdf

- **Procedure:**
  - Build the circuit below:
  - Turn Switches S1 and S2 ON and OFF and fill in the table in results.

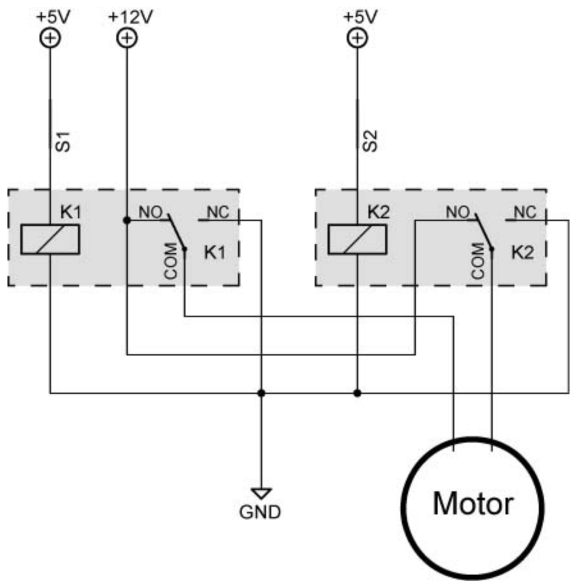


Motor Control Using Two SPDT Relays

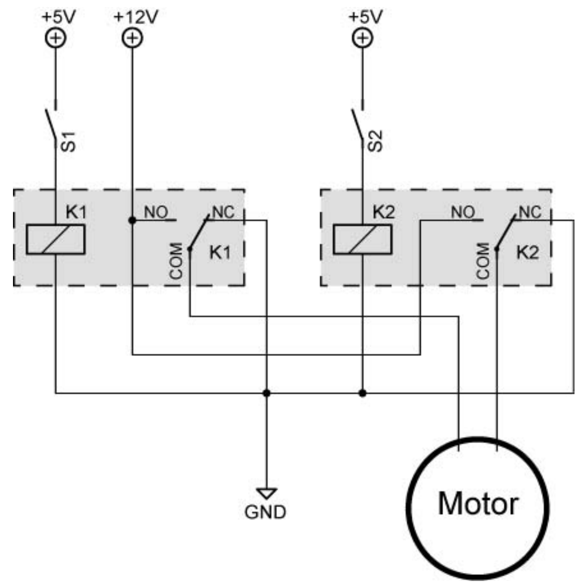
- **Results:**

Motor Relay Logic		
Relay 1	Relay 2	Motor Status

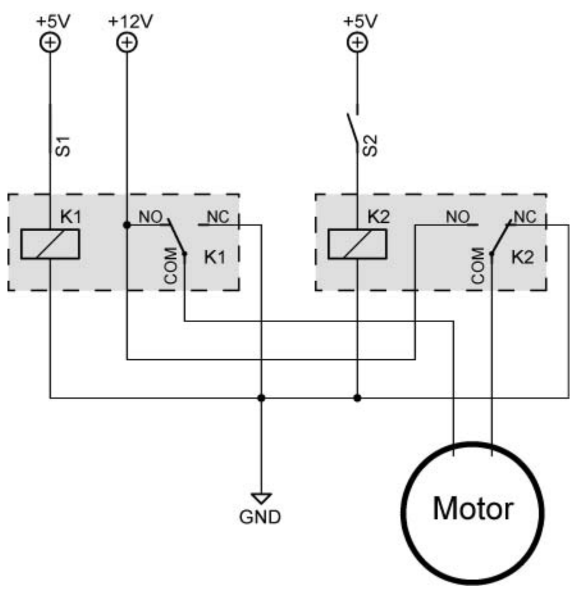
- **Conclusions:**
    - o Using arrows to represent current, draw the current through the relays and motor in each schematic below. Also show the polarity at the motor terminals and the direction of the motor rotation. If there is no current, just show the polarity at the motor terminals.



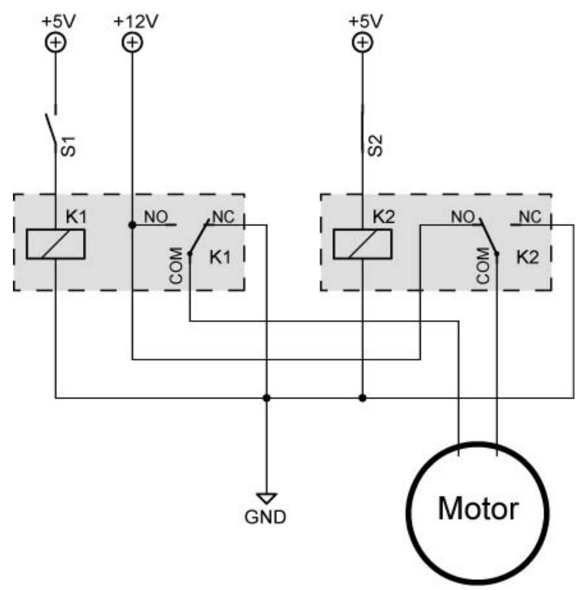
S1 and S2 Closed, Relays 1 and 2 ON



S1 and S2 Open, Relays 1 and 2 OFF



S1 Closed, S2 Open,
Relay 1 ON, Relay 2 OFF



S1 Open, S2 Closed,
Relay 1 OFF, Relay 2 ON

Electronics and Robotics I Week 11
Capacitance Lab 1 – Storing and Releasing Charge

- **Purpose:** The purpose of this lab is to verify that a capacitor stores electrical charge when a voltage is applied and that when the voltage source is removed, the capacitor returns its stored electrical charge to the circuit.

- **Apparatus and Materials:**
  - 1 – Digital Multimeter
  - 1 – 3 Volt Battery Power Supply
  - 1 – 2.5 Volt Lamp
  - 1 – Lamp Holder
  - 1 – 30,000 Microfarad Capacitor (http://www.skycraftsurplus.com/index.asp?PAGEACTION=CONTACTUS)
  - 1 – 140,000 Microfarad Capacitor (http://www.skycraftsurplus.com/index.asp?PAGEACTION=CONTACTUS)
  - 1 – 1,000,000 Microfarad or 1Farad Capacitor (http://sciencekit.com/one-farad-capacitor/p/IG0024229/)
  - Alligator Clips

- **Procedure:**
  - Take an alligator clip and short the terminals of each capacitor.
  - Measure and record the voltage across each shorted capacitor.
  - Charge each capacitor with the 3 volt battery power supply.
  - Measure and record the voltage across each charged capacitor.
  - Connect the 2.5 v lamp to each of the capacitors and remain connected until the lamp dims. Measure and record the time the lamp is illuminated.
  - Measure and record the voltage across each discharged capacitor.

- **Results:**

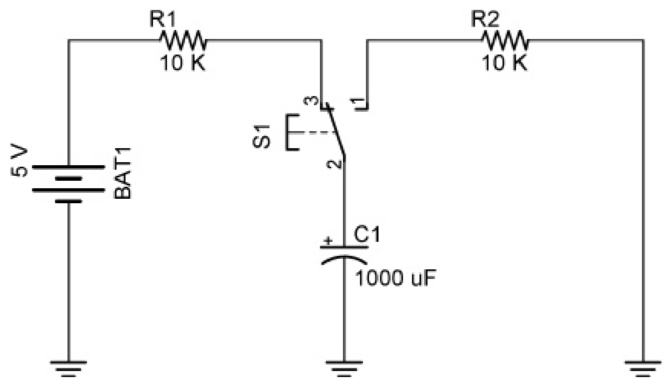
Capacitor Condition	30,000 uF Capacitor	140,000 uF Capacitor	1 F Capacitor
Voltage after Shorted	V	V	V
Voltage after Charged	V	V	V
Voltage after Discharge	V	V	V
Time for Discharge	S	S	S

- **Conclusions:**
  - Which capacitor takes longer to discharge? Explain why.

Electronics and Robotics I Week 11

Capacitance Lab 2 – Charging and Discharging a Capacitor through a Resistor

- **Purpose:** The purpose of this lab is to verify the formula for the time constant, τ.
- **Apparatus and Materials:**
  - 1 – Breadboard with a 5 VDC Power Source
  - 2 – Digital Multimeters
  - 1 – Oscilloscope
  - 1 – Stop Watch
  - 2 – 10 K Resistors
  - 2 – 22 K Resistors
  - 1 – SPDT Switch
  - 1 – 1000 uF Capacitor
- **Procedure:**
  - Build the following circuit and place a voltmeter across the capacitor C1 and an ammeter between S1 and C1.
  - Qualitative Results:
    - Slide the switch toward the battery to charge the capacitor through resistor R1, and then slide the switch to the other position to discharge the capacitor through resistor R2.
    - Observe the voltage across and the current through the capacitor while switching back and forth. Record your observations.



$\tau = R\,C$

$\tau = 10.0 \times 10^{3}\text{ ohms} \times 1.0 \times 10^{-3}\text{ farads}$

$\tau = 10\text{ sec}$

Charging and Discharging a Capacitor through a Series Resistor

  - Quantitative Results:
    - Measure and record the voltage across the power source.
    - Calculate and record 63.2% of the source voltage.
    - Measure and record the time in seconds it takes the capacitor to charge to 63.2 % of the source voltage (the definition of the time constant, τ).
    - Charge the capacitor until it is fully charged to the source voltage.
    - Subtract 63.2% of the source voltage from the value of the source voltage and record the result.
    - Measure and record the time in seconds it takes the capacitor to lose 63.2 % of its full charge (the definition of the time constant, τ).
  - Replace the 2 – 10 K resistors with the 2 – 22 K resistors and repeat the Quantitative Results procedure used for the 10 K resistors.

- **Results:**
  - Qualitative Results:
    - When charging the capacitor, how does the voltage increase across the capacitor change with time?
    - When charging the capacitor, how does the current decrease through the capacitor change with time?
    - When discharging the capacitor, how does the voltage decrease across the capacitor change with time?
    - When discharging the capacitor, how does the current decrease through the capacitor change with time?
  - Quantitative Results:

Measurement	10 K Circuit	22 K Circuit
Power Source Voltage	V	V
63.2% of Power Source Voltage	V	V
Calculated Time to Charge 63.2% of Power Source Voltage	sec	sec
Measured Time to Charge 63.2% of Power Source Voltage	sec	sec
Power Source Voltage - 63.2% of Power Source Voltage	V	V
Calculated Time to Loose 63.2% of the Full Charge	sec	sec
Measured Time to Loose 63.2% of the Full Charge	sec	sec

- **Conclusions:**
  - Compare the calculated and measured times for the capacitor to charge to 63.2% of the power source (the time constant, τ). If the two values are not equal, explain the discrepancy.
  - Compare the calculated and measured times for the capacitor to discharge to 63.2% of the power source (the time constant, τ). If the two values are not equal, explain the discrepancy.

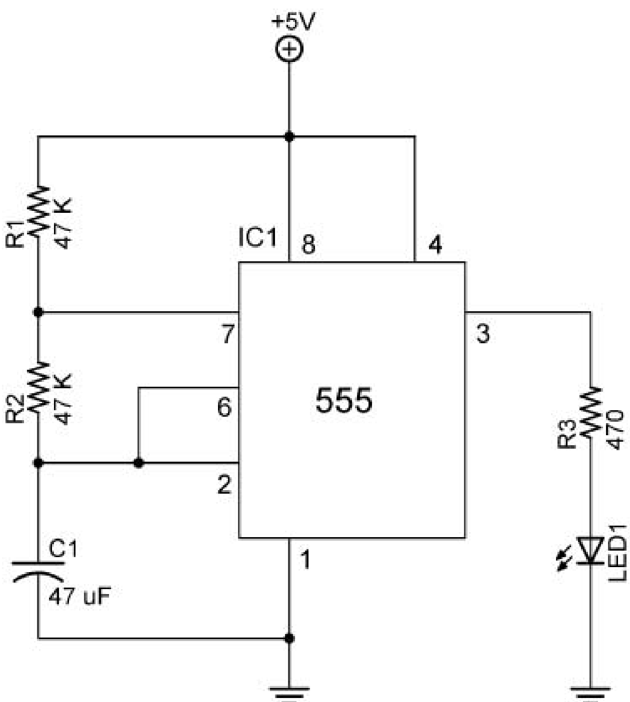
Capacitance Lab 3 – Application of an RC Circuit

- **Purpose:** The purpose of this lab is to demonstrate an application of a capacitor in a 555 timer circuit.

- **Apparatus and Materials:**

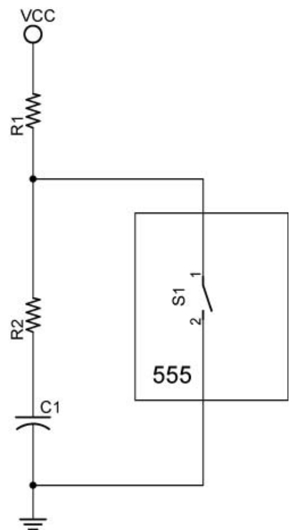
    - 1 – Breadboard with a 5 VDC Power Source
    - 1 – Oscilloscope
    - 1 – 555 Timer IC
    - 2 – 47K Resistors
    - 1 – 470 Ohm Resistor
    - 1 – 47 Microfarad Capacitor
    - 1 - LED

- **Procedure:**
    - Wire the circuit in Figure 30 – 13.
        - Using an oscilloscope, observe the waveform across the capacitor on Channel 1 of the oscilloscope and compare it with the waveform on the output pin 3 on Channel 2.
        - Replace C1 with a 10 microfarad capacitor. Note the difference in waveform.

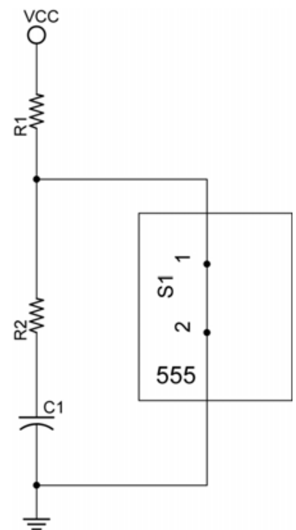


Basic 555 Astable Circuit

- When charging C1, the current must pass through R1, R2, and C1. See Figure 30 – 14.
- When discharging, the current passes through only R2 and C1.
- With C1 = 10 microfarads, calculate and record the time constants for the charge and discharge cycles.

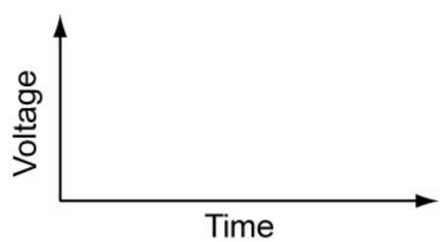


Simplified Diagram of
C1 Charging through R1 & R2

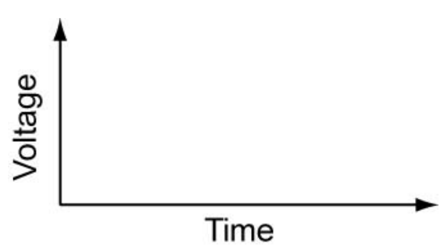


Simplified Diagram of
C1 Discharging through R2

- **Results:**
  - Sketch the waveform across the capacitor.



  - Sketch the waveform at the output pin 3.



- **Conclusions:**
  - Why does it take more time for the LED to light the first time than for the rest of the cycles?
  - Is the time the LED is on equal to the time it is off? Why or why not?

Electronics and Robotics I Week 12
Logic Gates LAB 1 – Counting in Binary

- **Purpose:** The purpose of this lab is to develop the student's skill in counting in binary.
- **Materials:**
  - 1 - Pencil
- **Procedure:**
  - In Table 1, fill in the binary equivalent for the decimal given:
  - In Table 2, fill in the next binary number if you are counting:
- **Results:**

Decimal Number	Binary Number
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Table 1

Binary Number	%1001
Next Binary Number	
Binary Number	%0001101
Next Binary Number	
Binary Number	%100100111
Next Binary Number	
Binary Number	%00001111
Next Binary Number	
Binary Number	%10001001010
Next Binary Number	
Binary Number	%11111111111
Next Binary Number	

Table 2

Electronics and Robotics I Week 12
Logic Gates LAB 2 – NOT Gates (Inverters)

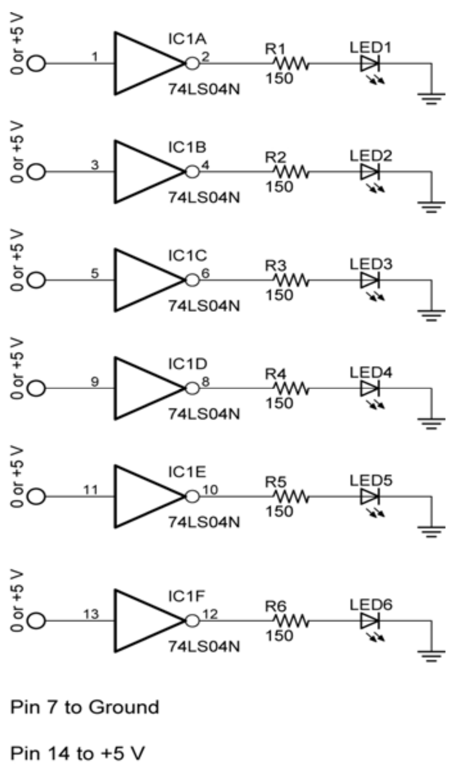
Purpose: The purpose of this lab is to acquaint the student with a Hex-Inverter

Materials:

1 – Analog/Digital Trainer or Breadboard
1 – 74LS04N Hex-Inverter
1 – 150 Ohm DIP Resistor Package (For Breadboard Only)
6 – LEDs (For Breadboard Only)

Procedure:

Wire the circuit below. See the photos on the next page.
Connect the six inputs to the HI/LOW toggles on the analog/digital trainer.
The LEDs on the analog/digital trainer may be used for LED1-LED6; R1-R6 may be eliminated in this case.



Results:

Input Pin	State	Output Pin	State
1	HIGH	2	
3	LOW	4	
5	LOW	6	
9	HIGH	8	
11	HIGH	10	
13	LOW	12	

Photo of layout on the analog/digital trainer using discrete LEDs:

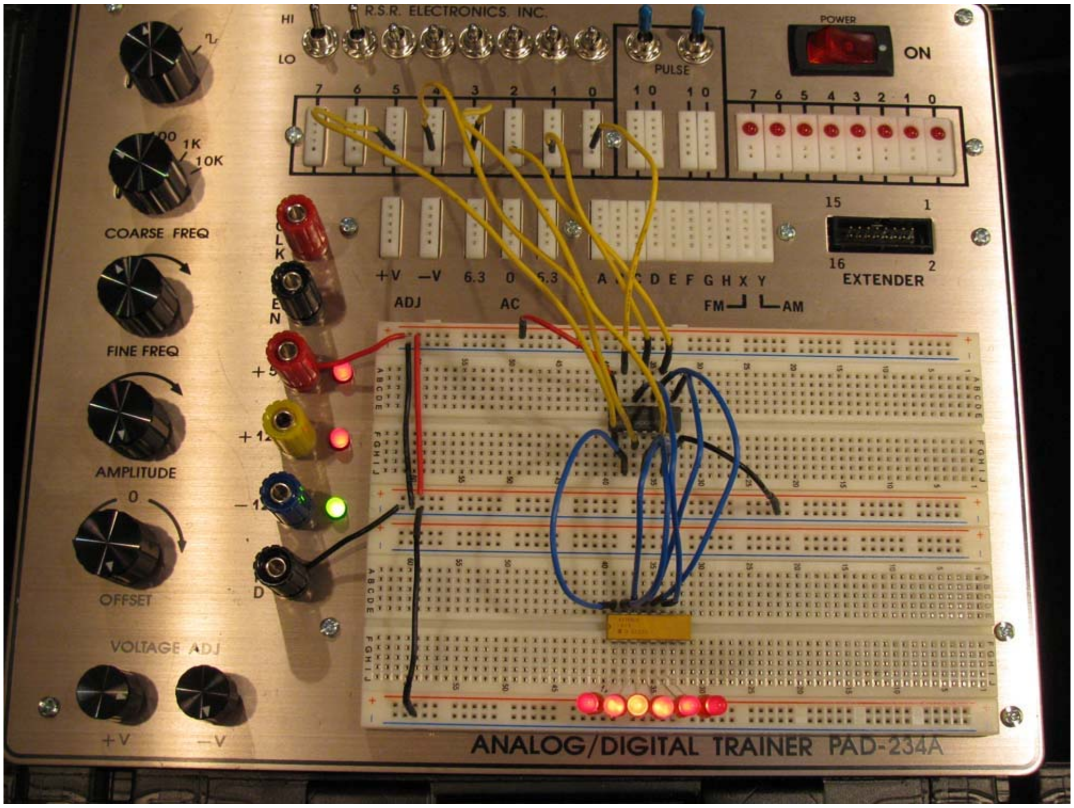
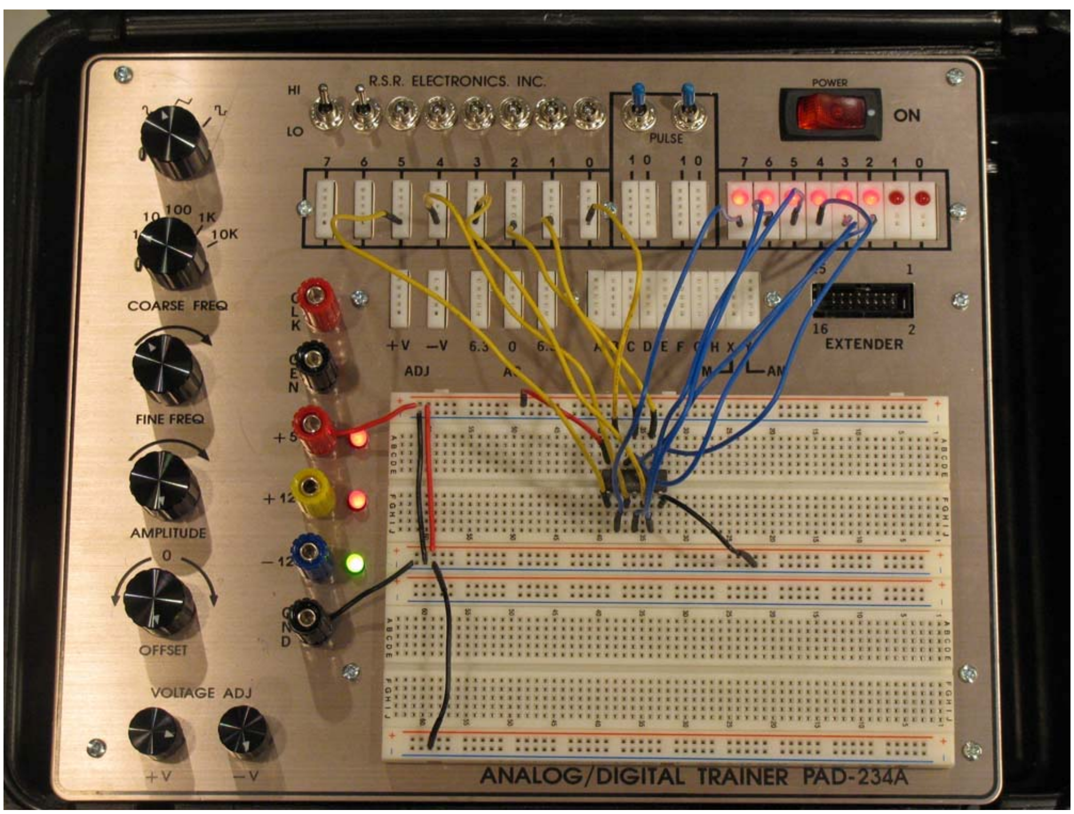


Photo of layout on the analog/digital trainer using LEDs on trainer:



Electronics and Robotics I Week 12
Logic Gates LAB 3 – AND Gates

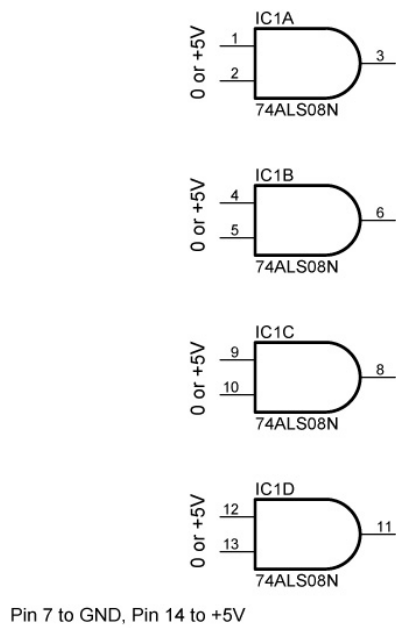
Purpose: The purpose of this lab is to challenge the student to become acquainted with the basic operation of an AND gate.

Materials:

1 – Analog/Digital Trainer
1 – 74LS08, 2 – Input AND Gate

Procedure:

Connect the eight inputs to the HI/LOW toggles on the analog/digital trainer.
Use the LEDs on the analog/digital trainer as the outputs.
Fill in the table in the result section.



Quad 2-Input AND Gate

Results:

Pin	HIGH/LOW
1	LOW
2	LOW
3	
4	LOW
5	HIGH
6	
9	HIGH
10	LOW
8	
12	HIGH
13	HIGH
11	

Electronics and Robotics I Week 12
Logic Gates LAB 4 – AND Gates and NOT Gate

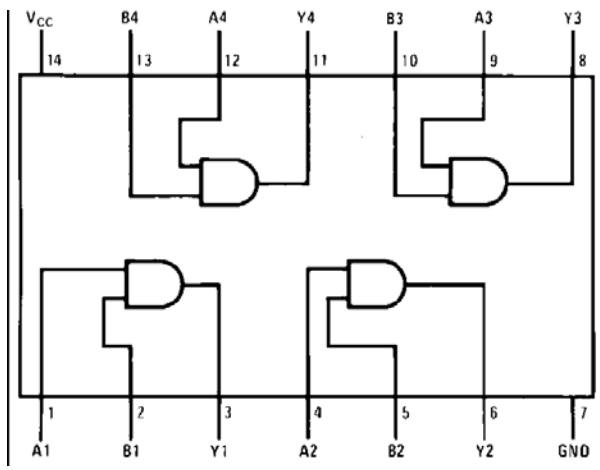
Purpose: The purpose of this lab is to challenge the student to solve a real life design problem using hex-inverter (NOT gate) and an AND gate.

Materials:

1 – Analog/Digital Trainer
2 – SPDT Switches (for ignition and seat belt switches)
1 – 74LS08, 2 – Input AND Gate
1 – 74LS04 Hex-Inverter (NOT Gate)
1 – Piezo Buzzer

Procedure:

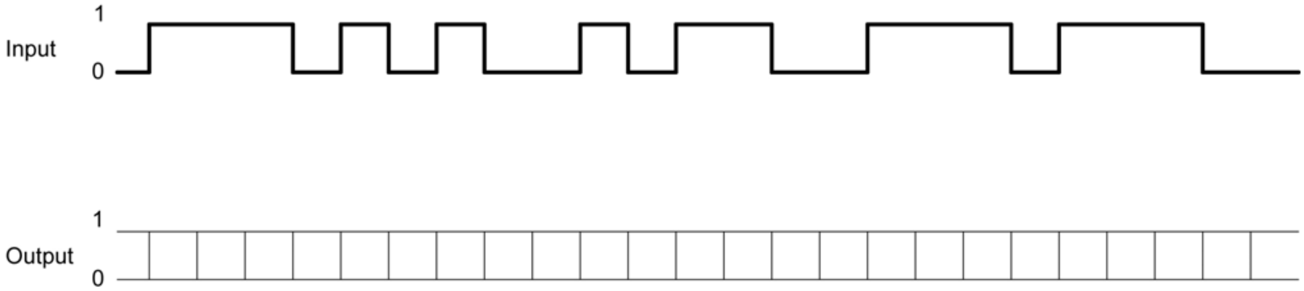
- Design and build a circuit using a hex-inverter and an AND gate to simulate a seat belt alarm. The alarm (piezo buzzer) must turn on only when the following conditions are met:
  - When the ignition switch is on
  - When the seat belt switch is off (the seat belt is unbuckled)
  - Use the HI/LOW toggle switches for the two switches.
  - 74LS08 pin layout:



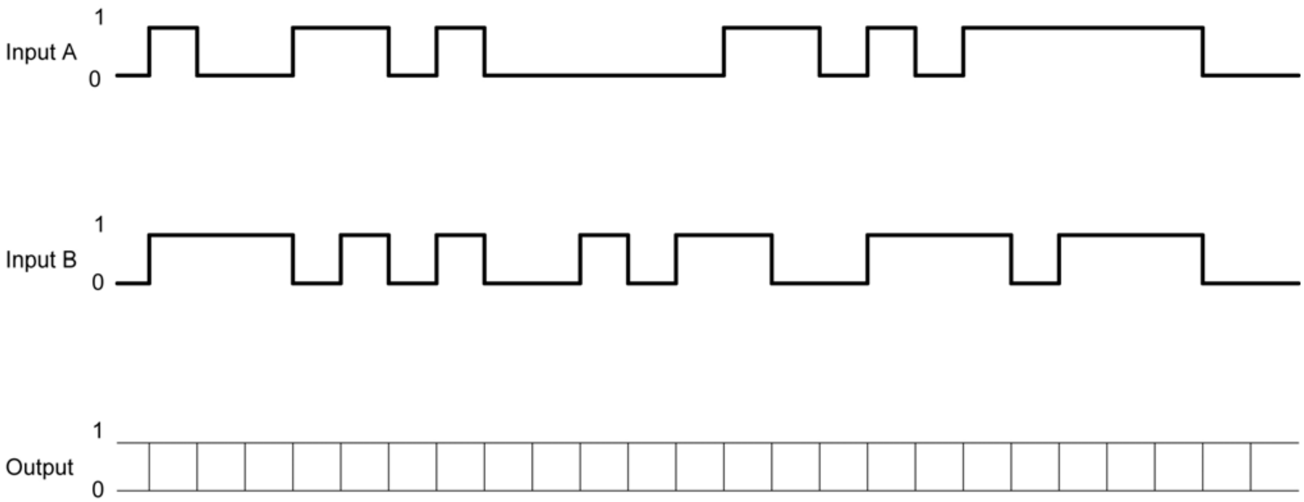
74LS08 Triple 2-Input AND Gate

Class Exercises

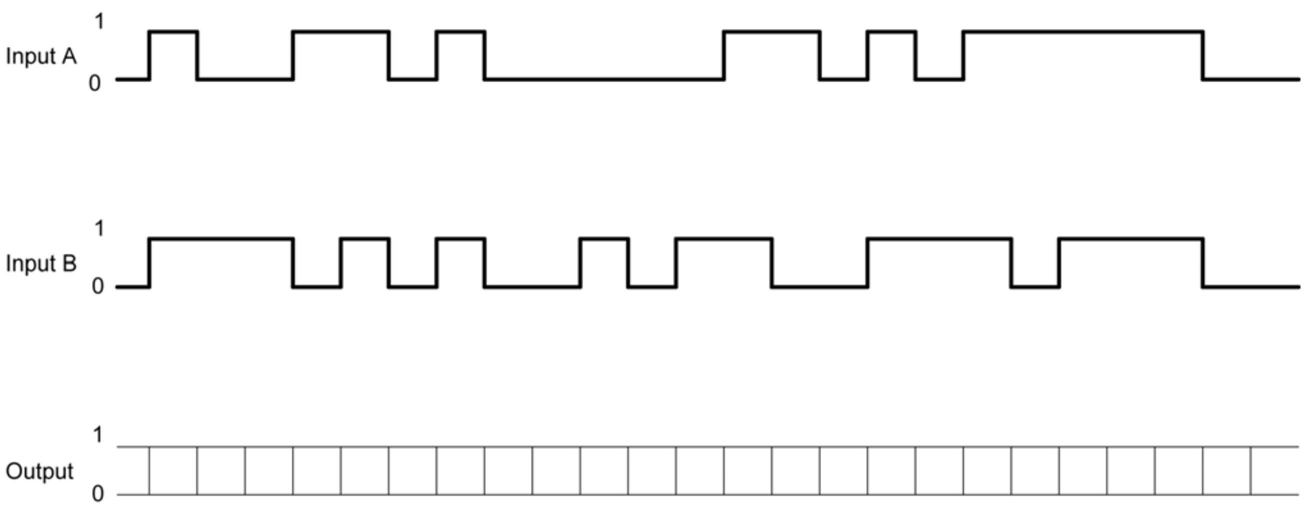
- Draw the output waveform for a NOT gate with the input shown below:



- Draw the output waveform for an AND gate having the inputs shown below:



- Draw the output waveform for an OR gate having the inputs shown below:



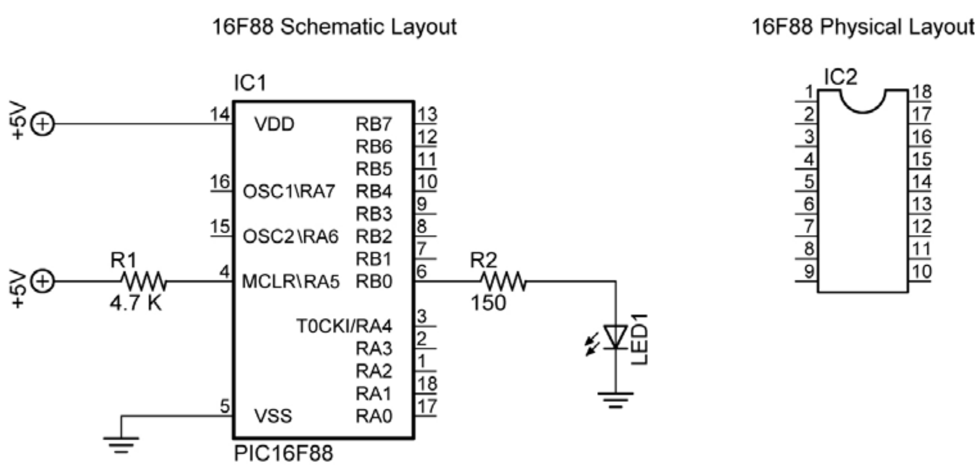
Electronics and Robotics I Week 15

PIC Microcontrollers Programming 1 LAB 1 - blink1.pbp Program

- **Purpose:** The purpose of this lab is to acquaint the student on how to:
  - Compile a PICBASIC PRO program
  - Download a PICBASIC PRO into a PIC16F88 microcontroller
  - Structure a program using three PICBASIC PRO commands
  - Make simple modifications to a PICBASIC PRO program
  - Make modifications to the TRIS register

- **Apparatus and Materials:**
  - 1 – Robotic Car by Student
  - 1 – Breadboard with +5V and +9V Power Supplies
  - 1 – 150 Ohm, ½ Watt Resistors
  - 2 – 470 Ohm, ½ Watt Resistors
  - 1 – 1K, ½ Watt Resistor
  - 1 – LED
  - 2 – DC Motors
  - 2 – 2N2222A NPN Transistors
  - 1 – 78L05 Voltage Regulator
  - 1 – 0.1 uF Capacitor

- **Procedure:**
  - Wire the blink1 circuit below on your robotic car's breadboard.



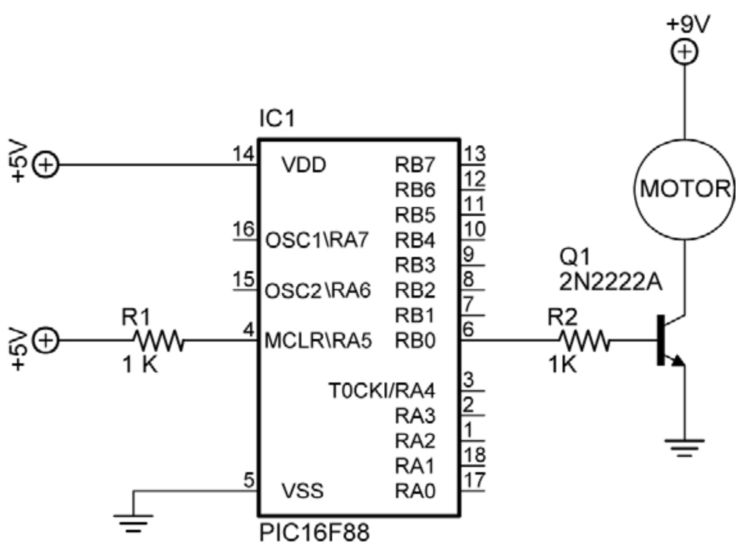
blink1

  - Program **blink1.pbp** into the PIC16F88 following the procedure to write, compile and download your program into the PIC chip at the end of the lesson.
  - Install the 16F88 and test the circuit and program
  - Change the PAUSE values (timing values) and reprogram the chip.

Electronics and Robotics I Week 15

PIC Microcontrollers Programming 1 LAB 1, Continued

- **Challenges:**
  - Connect the resistor and LED to RB1 and make it blink. Save the program as **blinkrb1**. Remember to change the TRISB register to make RB1 an output.
  - **Railroad Crossing:** Wire a circuit using RB0 and RB1 as outputs and program the chip so that two LEDs alternate flashes like a railroad crossing. Let the flash time be 0.75 seconds. Save the program as **railrd1**.
  - **Drive a Motor:** Design a circuit and program a PIC16F88 which will drive a motor in one direction only. Name the new program **road1**.
    - Use a 9 vdc power source on a separate breadboard to drive the motor.
    - Tie the **grounds** of the +5 vdc and +9 vdc breadboards together, **but NOT the +5V and +9V power sources**. Use two batteries for the power sources; one for the +5 vdc and the other for the +9 vdc bus rows.
    - Step down the +9 vdc to +5 vdc using a 78L05 voltage regulator circuit. Verify the +5 vdc and +9 vdc bus rows with a DMM.
    - You may use notes from prior classes to review NPN transistor switches.
    - Hints:
      - Keep wires away from the 16F88 chip since it will be removed frequently from the circuit.
      - Place the motor on the on the collector side of the NPN transistor. Place a 1K ohm resistor between the 16F88 drive pin and the base of the NPN transistor. See the circuit below:



Transistor Switch as a Motor Driver

- **Drive a Robot:** Now combine this lesson's circuitry and programming to drive your robotic car through the taped course without crossing the inside boundaries of the tape. Revise the program **road1.**
  - You will have to use the process called dead reckoning since the robot is not equipped with any sensors. Wikipedia definition of dead reckoning: Dead reckoning is the process of estimating one's current position based upon a previously determined position, or fix and advancing that position based upon known speed, elapsed time, and course.
  - Hints:
    - Put the following code at the end of the program:

      ```
      PORTB.0 = 0          ' Set PORTB, bit 1 to a LOW (0V)

      PORTB.1 = 0          ' Set PORTB, bit 2 to a LOW (0V)

      PAUSE 1              ' Pause 1 millisecond
      ```

      This code will stop the robotic car.

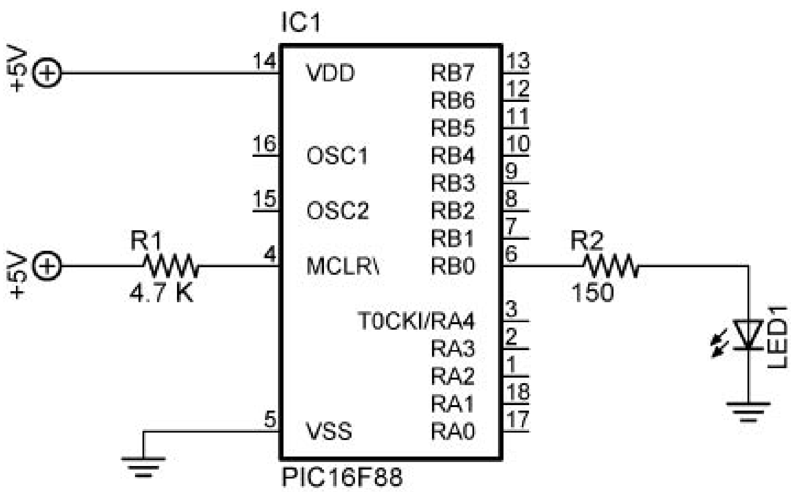
Electronics and Robotics I Week 16
PIC Microcontrollers Programming 2 LAB 1 – blink2

- **Purpose:** The purpose of this lab is to acquaint the student with the PicBasic Pro commands: HIGH, LOW, and FOR..NEXT.

- **Apparatus and Materials:**

  - 1 – Analog/Digital Trainer
  - 1 – Breadboard with 9 V Supply
  - 1 – 150 Ohm, ½ Watt Resistors
  - 2 – 470 Ohm, ½ Watt Resistors
  - 1 – 1K, ½ Watt Resistor
  - 1 – LED
  - 2 – DC Motors
  - 2 – 2N2222A NPN Transistors
  - 1 – 78L05 Voltage Regulator
  - 1 – 0.1 uF Capacitor

- **Procedure:**
  - Open **blink2.pbp** and download to your chip. Wire your digital trainer or robotic car for blink2.
  - Change the pin location and blinking times.



blink2 and blink3

  - Open **blink3.pbp** and download to your chip.
  - Change the number of times the LED blinks.

- **Challenges:**
    - **LED Flashing:** Write a program using the **FOR..NEXT** command to make an LED connected to PORTB.7 flash on 4 times and then turn off. Have the LED turn on for 0.2 seconds and off for 0.8 seconds each time. Save the program as **flash1.pbp**.
    - **Piezo Buzzer:** Write a program that makes an LED blink every second (on 500 ms and off 500 ms) and a buzzer to sound on every fifth LED blink. The buzzer is to sound twice then the LED and buzzer are to turn off. Save the program as **buzz1.pbp**.
    - **Knight Rider:** Write a program to make the 8 LED's scroll back and forth. Utilize a 100 ohm DIP resistor package. Save the program as **knight1.pbp**.
    - **Duplicate Laps:** Write a program so that your robotic car will navigate the rectangular track twice. The instructions for the first lap must be identical to the second lap, i.e., use a **FOR…NEXT** command. After the second lap is completed, activate Knight Rider. Save the program as **indy1.pbp**.

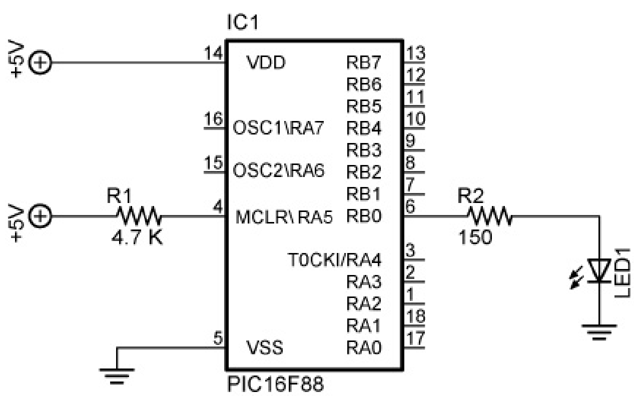
Electronics and Robotics I Week 17
Programming PIC Microcontrollers in PicBasic Pro – Servos
LAB 1 – Blink – 3 Ways

- **Purpose:** The purpose of this lab is to reinforce the three different ways to blink an LED.

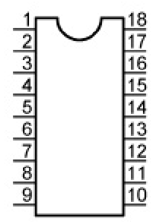
- **Apparatus and Materials:**
  - 1 – Breadboard or Analog/Digital Trainer
  - 1 – PIC16F88
  - 1 – 4.7K Resistor
  - 1 – 150 Ohm Resistor
  - 1 – LED

- **Procedure:**
  - o Wire the circuit blink1 below on a breadboard.
  - o Turn on and off the LED using the following three sets of commands:

PORTB.0 = 1 & PORTB.0 = 0
HIGH 0 & LOW 0
PORTB = %00000001 & PORTB = %00000000



16F88 Pin Layout



blink1

- **Challenge:**
  - o Wire an LED and a current limiting resistor to each pin in PORTB.
  - o Program the PIC16F88 to display binary counting from 0 to 255 using a FOR…NEXT loop and a variable “x” set up in the following manner:

PORTB = x

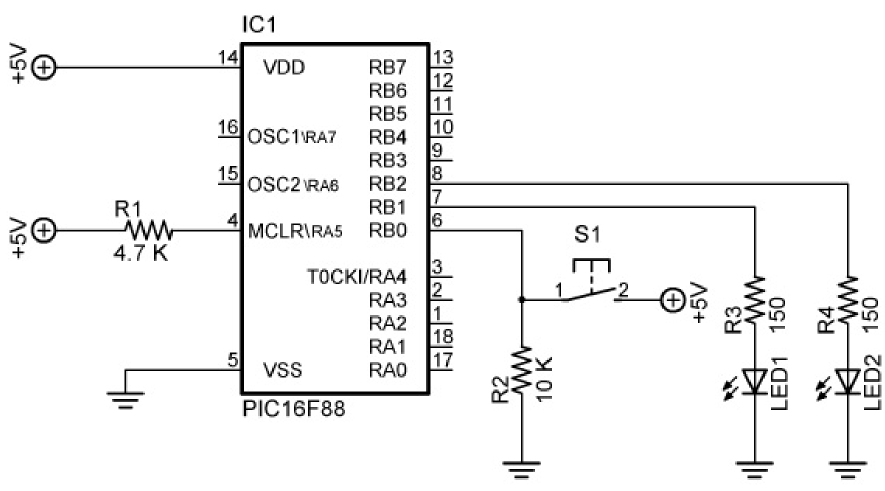
PORTB = %00000000 may be written as PORTB = 0 since %00000000 in binary is equal to 0 in decimal.
PORTB = %11111111 may be written as PORTB = 255 since %11111111 in binary is equal to 255 in decimal.

Electronics and Robotics I Week 17
Programming PIC Microcontrollers in PicBasic Pro – Servos
LAB 2 – switch1.pbp

- **Purpose:** The purpose of this lab is to acquaint the student with the PicBasic Pro command **IF…THEN** and their first input device into a PIC MCU.

- **Apparatus and Materials:**
    - 1 – Breadboard or Analog/Digital Trainer
    - 1 – PIC16F88
    - 1 – 1K Resistor
    - 1 – 10K Resistor
    - 2 – 150 Ohm Resistors
    - 2 – LEDs
    - 1 – NO Momentary Switch

- **Brief Discussion of Pull-Down Resistor, R2:**
    - o Pull-down resistor (R2) is used to hold the input to a zero (low) value when no other component is driving the input, i.e., the switch is open. If nothing is connected to pin RB0, the value of the input is considered to be floating. R2 will allow the pin to keep a steady state at zero until the switch is closed.
- **Procedure:**
    - o Wire the circuit switch1 & switch2 below on a breadboard and program the 16F88 with **switch1.pbp** (NOT 16F877A_switch1.pbp).
    - o Remember, the switch connected to RB0 is considered an **input device**. Input devices will allow your robotic car to interact with its environment. This is the first input device discussed to date.
    - o Demonstrate the program using the circuit switch1.



switch1 and switch2

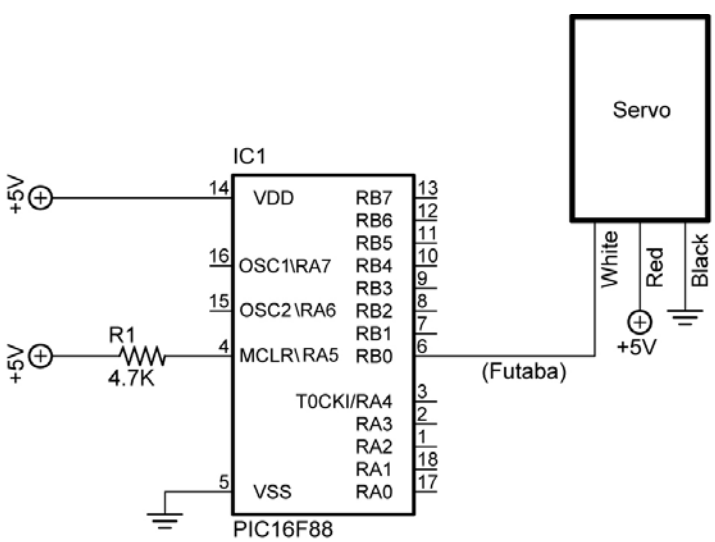
- **Challenge:**
    - o Design a circuit and program such that a momentary switch connected to the PIC turns on and off a dc motor. Save the program as **switch10.pbp**.

Electronics and Robotics I Week 17
Programming PIC Microcontrollers in PicBasic Pro – Servos
LAB 3 - servo1.pbp, servo2.pbp, servo3.pbp, and servo4.pbp

- **Purpose:** The purpose of this lab is to acquaint the student with:
  - PicBasic Pro commands **GOSUB** and **PULSOUT**.
  - The basic operation of a hobby servo.

- **Apparatus and Materials:**
  - 1 – Breadboard or Analog/Digital Trainer
  - 1 – Oscilloscope
  - 1 – PIC16F88
  - 1 – 1K Resistor
  - 3 – 10K Resistors
  - 3 – NO Momentary Switches
  - 1 – Futaba 3003 Servomotor

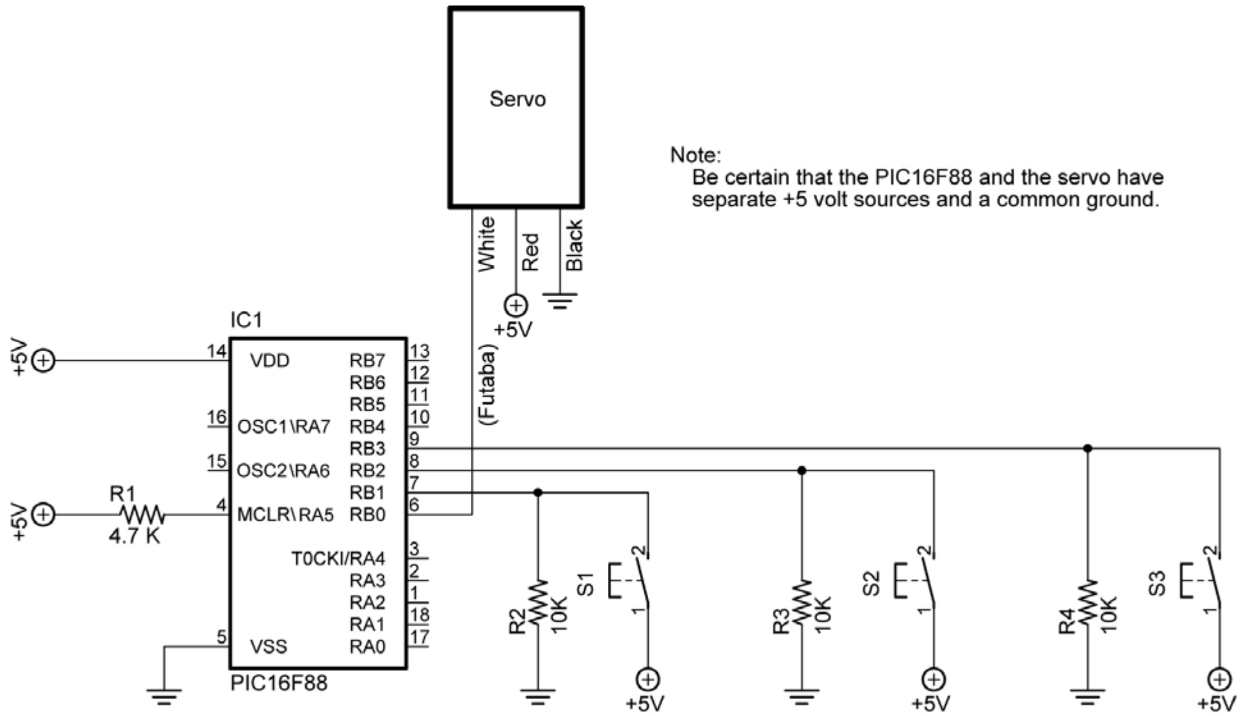
- **Procedure:**
  - Wire your breadboard for servo1 shown below. Program the 16F88 with **servo1.pbp** (NOT 16F877A_servo1.pbp).
  - **Make certain that the servo power supply is separate from the PIC power supply, i.e., have two +5V power supplies.** Otherwise, if the servo spikes the single power line supplying power to both the servo and the PIC, the 16F88 may reset.
  - Relate the program code to the observed servo motions.



servo1, servo2, and servo3

  - Open **servo2.pbp** and download to your chip. Use the same schematic as for servo1.pbp above.
  - Observe the servo behavior. This servo action is suitable for panning sensor devices such as sonar sensors.

- Open **servo3.pbp** and download to your chip. Use the same schematic as for servo1.pbp above.
- Observe the waveforms on the oscilloscope. Verify that the waveforms are consistent with the program code.
- Open **servo4.pbp** and download to your chip. Wire your breadboard for servo4 shown below.
- Observe the waveforms on the oscilloscope. Verify that the waveforms are consistent with the program code.



servo4

- **Challenge**:
  - Write a program that slows the panning motion of **servo3.pbp**. Save the program as **pan1.pbp**.
  - Design and build brackets to mount a servo and SRF04 sonar module onto your robotic car. The sonar must be mounted atop the servo horn. Remember when mounting the sonar that it is not accurate at ranges closer than 3 cm.
  - If you mount the SRF04 sonar module lower than 12” above the floor, point it slightly upwards to avoid reflections from the flooring material.

Conditional Statement Summary: Conditional statements allow programs to branch to another part of the program when a conditional comparison is true.

Formats:	**Examples:**
IF Comparison(s) **THEN** Statement	**IF** PORTB.0 = 1 **THEN** HIGH 2

Formats:

```
IF Comparison(s) THEN
   Statement
   Statement
   Statement
ENDIF
```

Examples:

```
IF PORTB.0 = 1THEN
   HIGH 2
   LOW 3
   HIGH 6
ENDIF
```

Formats:

```
IF Comparison(s) THEN
   Statement
   Statement
   Statement
ELSE
   Statement
   Statement
   Statement
ENDIF
```

Examples:

```
IF PORTB.0 = 1THEN
   HIGH 2
   LOW 3
   HIGH 6
ELSE
   LOW 2
   LOW 5
   LOW 7
ENDIF
```

Formats:

```
SELECT CASE Variable

   CASE Value
      Statement
      Statement

   CASE Another Value
      Statement
      Statement

   CASE IS Comparison
      Statement
      Statement

   CASE ELSE
      Statement
      Statement

END SELECT
```

Examples:

```
SELECT CASE x

   CASE 1
      LCDOUT $FE, 1, “x = “, DEC x
      x = x + 1

   CASE 2
      LCDOUT $FE, 1, “x = “, DEC x
      x = x + 2

   CASE IS > 10
      LCDOUT $FE, 1, “x > 10 “
      x = 0

   CASE ELSE
      LCDOUT $FE, 1, “Problem number”
      x = 0

END SELECT
```

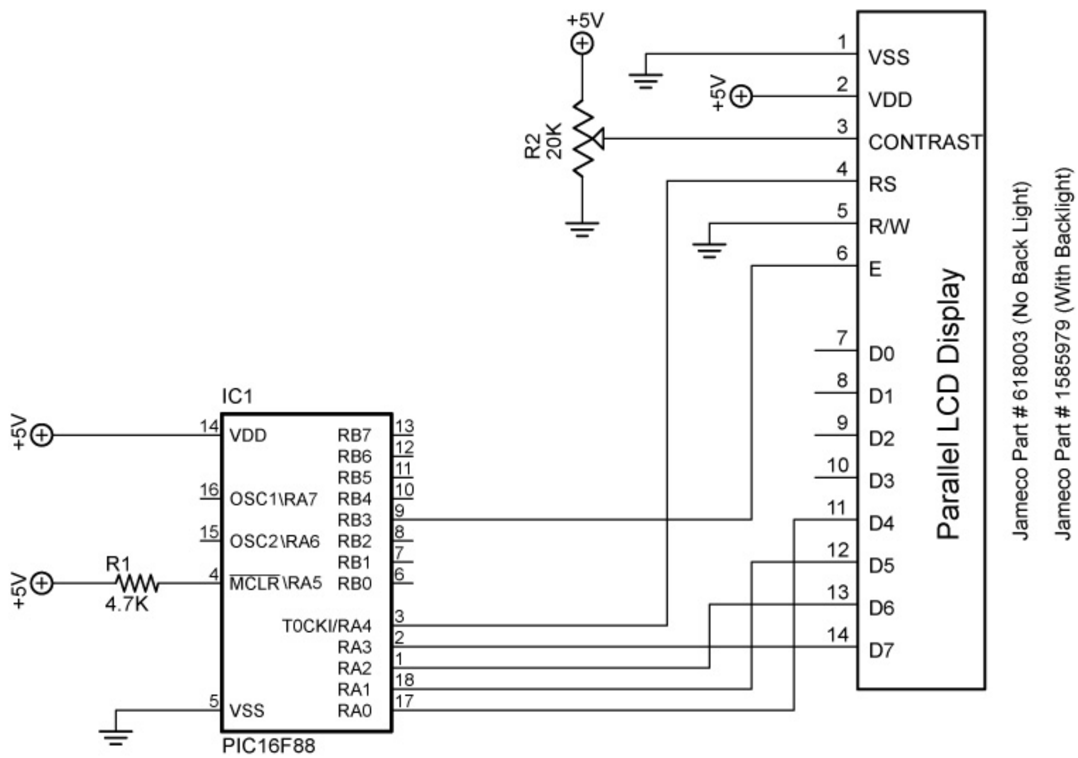
Electronics and Robotics I Week 18
LCD Lesson 1 LAB 1 – lcd1.pbp and lcd2.pbp, LCD Commands

- **Purpose:** The purpose of this lab is to acquaint the student with the PicBasic Pro command **LCDOUT** .

- **Apparatus and Materials:**

  - 1 – Analog/Digital Trainer or Breadboard
  - PIC16F88 Microcontroller
  - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
  - 20 K Potentiometer
  - 4.7 K Resistor

- **Procedure:**
  - o Wire the following circuit:



lcd1 and lcd2

  - Notice that only D4 – D7 data inputs are used; we will use 4-bit data transfer to save pins.
  - o Open lcd1.pbp from your folder and program your chip. Add your own text. Save your program as **lcd10.pbp**.
  - o Open lcd2.pbp from your folder and program your chip. Run the program on the breadboard.

Command	Operation	Activity	Completed
$FE, 1	Clear display	1	
$FE, 2	Return home	2	
$FE, $0C	Cursor off	2	
$FE, $0E	Underline cursor on	2	
$FE, $0F	Blinking cursor on	2	
$FE, $10	Move cursor left one position	5	
$FE, $14	Move cursor right one position	5	
$FE, $18	Display shift left	4	
$FE, $1C	Display shift right	4	
$FE, $80	Move cursor to beginning of first line	3	
$FE, $C0	Move cursor to beginning of second line	3	
$FE, $94	Move cursor to beginning of third line	**-**	n/a
$FE, $D4	Move cursor to beginning of fourth line	**-**	n/a

- LCD Command Table Experiments: Use the table above to check off each command as it is completed.
  - Activity 1:
    - Open **lcd1.pbp**; save it as **lcd11.pbp**.
    - Revise the program so that “Hello World” remains on the LCD screen for 2 seconds, then make the LCD blank using the $FE,1 command.
  - Activity 2:
    - Start with **lcd11.pbp** and save the new program as **lcd12.pbp**
    - Revise **lcd12.pbp** such that:
      - “Hello World” remains on the LCD for 2 seconds
      - Clear Display
      - Return the cursor home and blinking for 2 more seconds. Each LCD command may be put on a separate line.
      - Now underline the cursor for 2 seconds
      - Clear display
  - Activity 3:
    - Start again with **lcd11.pbp** and save the new program as **lcd13.pbp**
    - Remember:

      LCDOUT $FE, $80 + 4

      sets the display to start writing characters at the forth position of the first line.

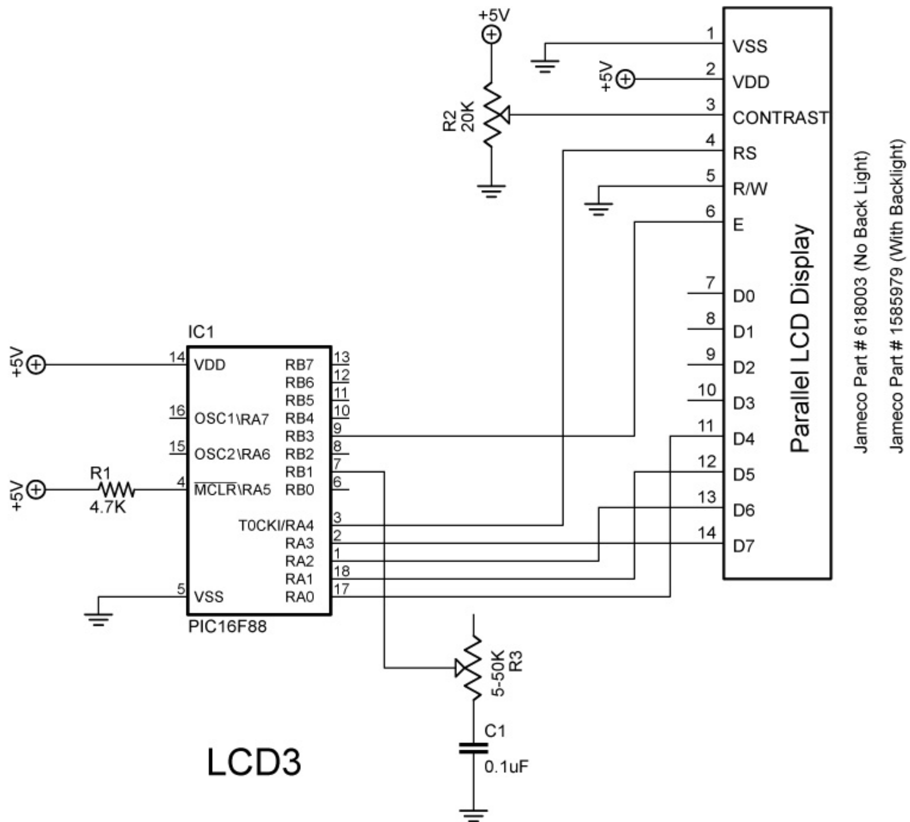
- Activity 3 Continued:
    - Revise **lcd13.pbp** such that:
        - “Hello” begins on the first line, 6 positions in from the right.
        - Pause 1 second
        - “World” begins on the second line, 6 positions in from the right
        - Pause 1 second
        - Clear display for 1 second
        - Repeat the whole sequence 3 times
- Activity 4:
    - Start with **lcd1.pbp** and save the new program as **lcd14.pbp**
    - Revise **lcd14.pbp** such that:
        - “Hello World” shifts to the right one position at a time for 4 positions
        - “Hello World” shifts to the left one position at a time for 4 positions
        - Repeat both shifts 3 times
- Activity 5:
    - Start with **lcd1.pbp** and save the new program as **lcd15.pbp**
    - Delete the main code in **lcd15.pbp**
    - Revise **lcd15.pbp** such that:
        - Display a variable name “Resistor1 = ”
        - Move over to the right one blank space and display the value of the variable r. At this point, you will have to input a value for r, such as, r = 330. To display the value of r in the **LCDOUT** command, place a # sign immediately before r.

LCDOUT $FE,1,“ Resistor1 = ”, #r

- **Challenge:** Display your first name on the first line and your second name on the second line. The first letters of your first and last names are to appear in the far right positions on the LCD and remain for 2 seconds. Then your first and last names are to scroll across the screen right to left.

Electronics and Robotics I Week 19
LCD Lesson 2 LAB 1 – lcd3.pbp

- **Purpose:** The purpose of this lab is to acquaint the student the PicBasic Pro command **POT** and the use of an LCD to monitor variable input values.
- **Apparatus and Materials:**
  - 1 – Analog/Digital Trainer
  - PIC 16F88 Microcontroller
  - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
  - 20 K Potentiometer
  - 10K Potentiometer (R3)
  - 4.7 K Resistor
  - 0.1 uF Capacitor
- **Procedure:**
  - Wire the in-circuit serial programming connections before proceeding. See Lesson 15A, In-Circuit Serial Programming for details.
  - Now add the following circuitry. Use a 10K trimpot for R3:



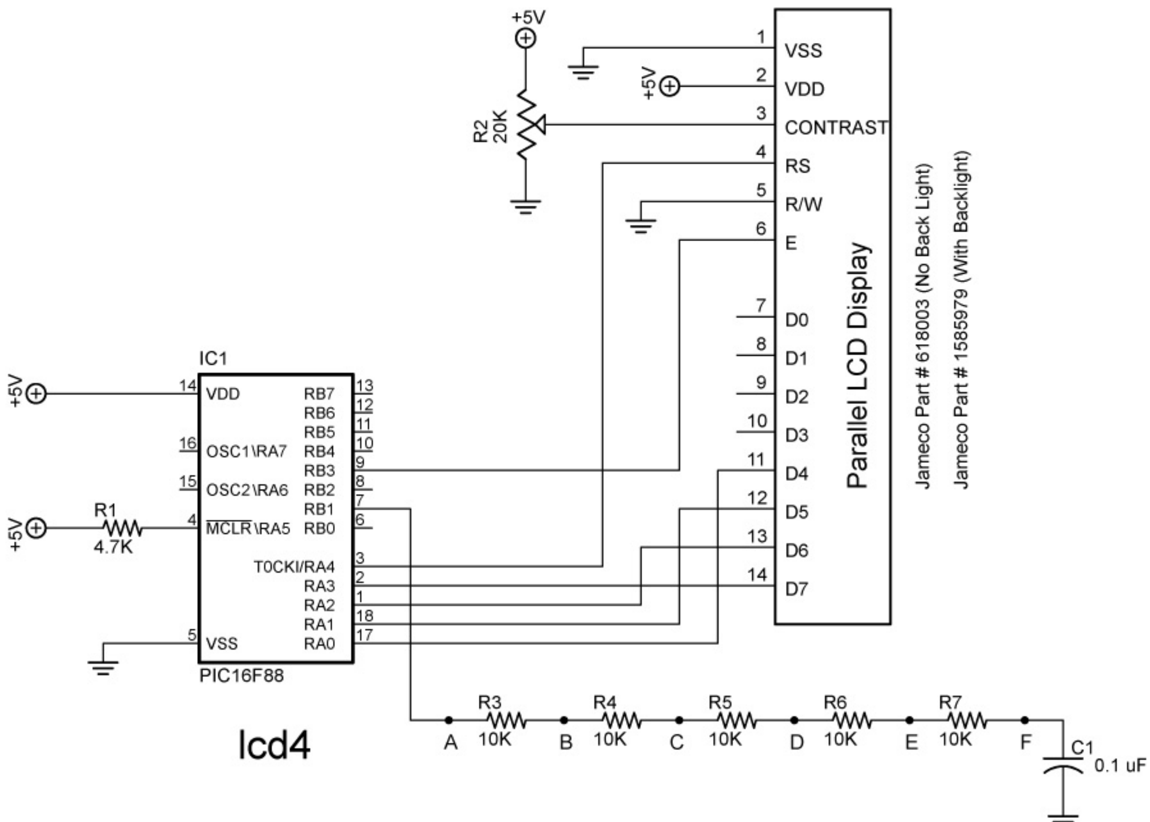
  - Open **lcd3.pbp** and download into the PIC16F88.
    - Adjust the 10K potentiometer R3 to see if the full range of the potentiometer is engaged.
    - If the full range is not active, adjust the Scale value in the POT command to make the full range active. Do this by empirically (through observation and experimentation) setting the Scale value to its lowest number while the LCD displays 255.

Electronics and Robotics I Week 19
LCD Lesson 2 LAB 2 – Five 10K Series Resistors

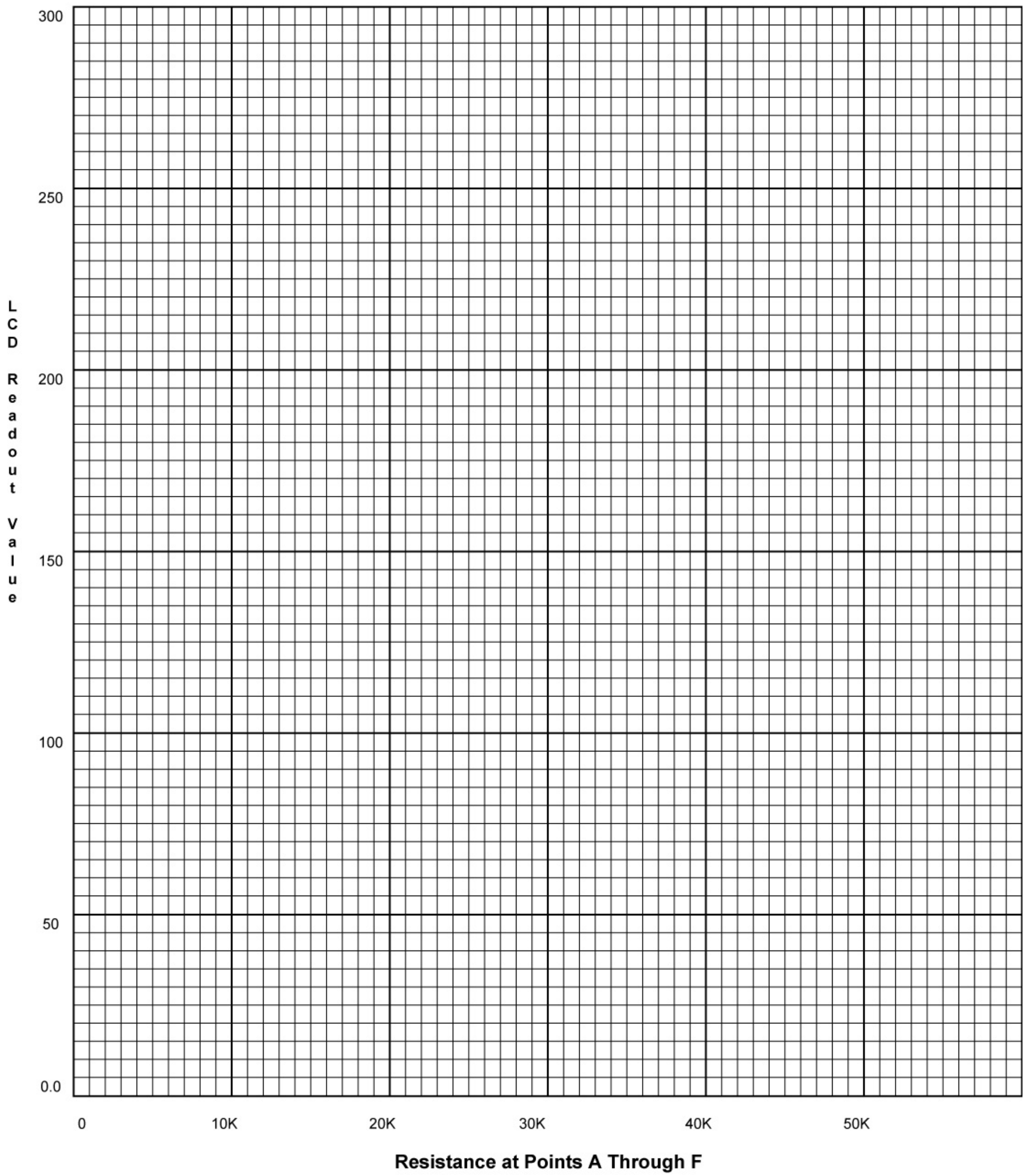
- **Purpose:** The purpose of this lab is to demonstrate to the student that the PicBasic Pro command **POT** is non-linear in nature.

- **Apparatus and Materials:**

    - 1 – Analog/Digital Trainer
    - PIC 16F88 Microcontroller
    - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
    - 20 K Potentiometer
    - 5 - 10K Resistors
    - 4.7 K Resistor
    - 0.1 uF Capacitor
- **Procedure:**
    - o Wire the circuit LCD4 below and program the chip with **lcd3.pbp**.
    - o Connect pin RB1 to Point A as shown in the schematic below. Set the **POT** command Scale value such that the 255 is the full range for the 5 – 10K resistors. Start by setting the Scale low so the LCD reads a number below 255, and then raise the Scale until you reach a full range reading of 255.
    - o Now connect RB1 to Points B through F and plot the results on the accompanying graph. Observe the non-linear nature of the plot.

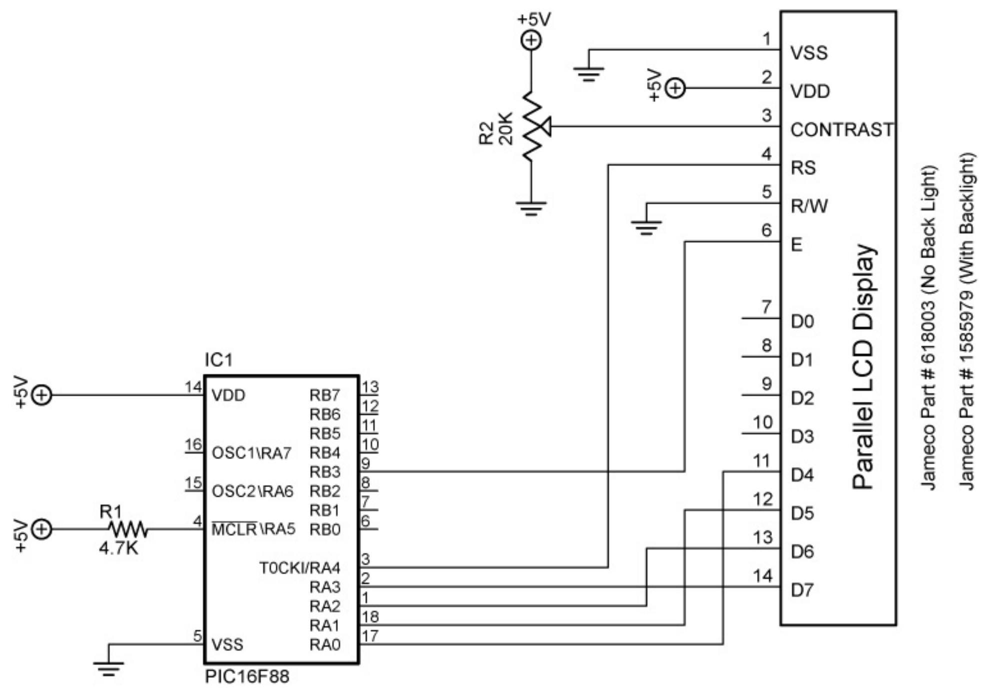


Resistance vs. LCD Readout for lcd4.pbp



Electronics and Robotics I Week 19
LCD Lesson 2 LAB 3 – LED Status on LCD

- **Purpose:** The purpose of this lab is to show the student how to use an LCD to display the state of an output.
- **Apparatus and Materials:**
  - Analog/Digital Trainer or Breadboard w/ 5VDC Supply
  - PIC 16F88 Microcontroller
  - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
  - 1 – 4.7K Resistor
  - 2 – 150 Ohm Resistors
  - 20 K Potentiometer
  - 2 – LEDs
- **Procedure:**
  - Wire the following circuit lcd1.
  - Open **blink1.pbp** from your folder and run the program.



lcd1 and lcd2

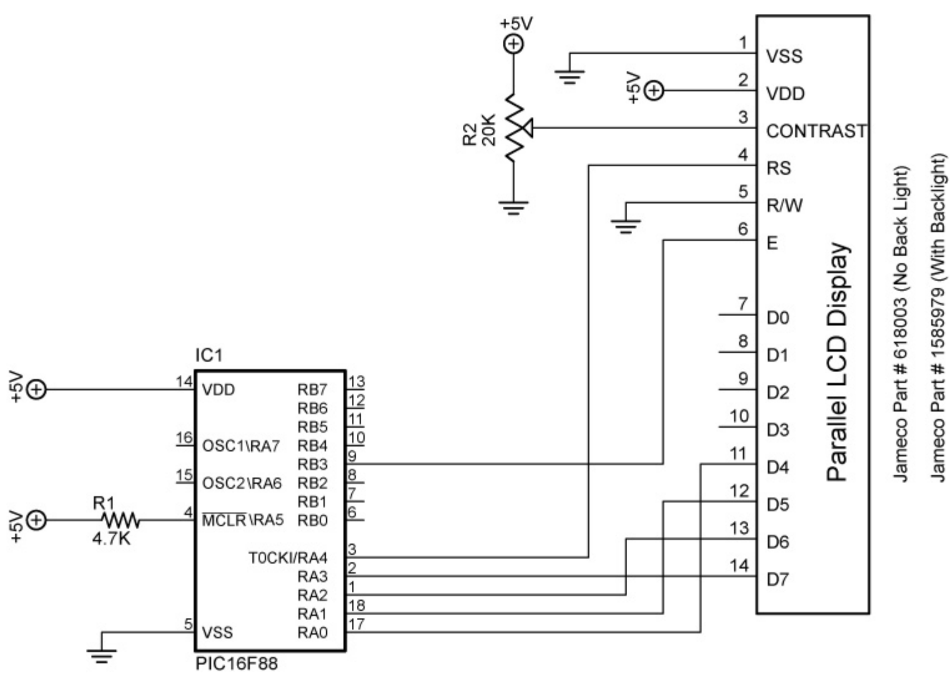
- **Challenges**:
  - Connect one LED (LED1) with a 150 ohm resistor to PORTB.1 and program it to blink on and off every second. Display "LED1" and its state (0 or 1) as a variable on the LCD. Save the program as **lcd16.pbp**. Don't forget to set the proper bits in the TRISB register to outputs as needed.
  - Connect a second LED (LED2) to PORTB.2 and program it to blink opposite LED1. Display "LED1" on the first line and "LED2" on the second line with their respective states as variables. Save the program as **lcd17.pbp**.

Electronics and Robotics I Week 19
LCD Lesson 2 LAB 4 – Changing LCD Pins on a PIC

- **Purpose:** The purpose of this lab is to acquaint the student with changing the default connections of an LCD to a PIC chip.

- **Apparatus and Materials:**
  - Analog/Digital Trainer or Breadboard w/ 5VDC Supply
  - PIC 16F88 Microcontroller
  - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
  - 1 – 4.7K Resistor
  - 1 – 20 K Potentiometer

- **Procedure:**
  - Wire the following circuit lcd1.
  - Download **lcd1.pbp** into the PIC16F88
  - Change the LCD pin connections from their default settings to:
    - Data port: PORTB
    - Starting data bit: 0
    - Register Select port: PORTB
    - Register Select bit: 4
    - Enable port: PORTB
    - Enable bit: 5
    - 4 or 8-bit bus: 4-bit bus, the PBP default setting
    - Lines on LCD: 2, the PBP default setting
  - Save the revised **lcd1.pbp** as **lcd18.pbp**
  - Rewire the circuit to reflect the change in LCD pin connections.



lcd1 and lcd2

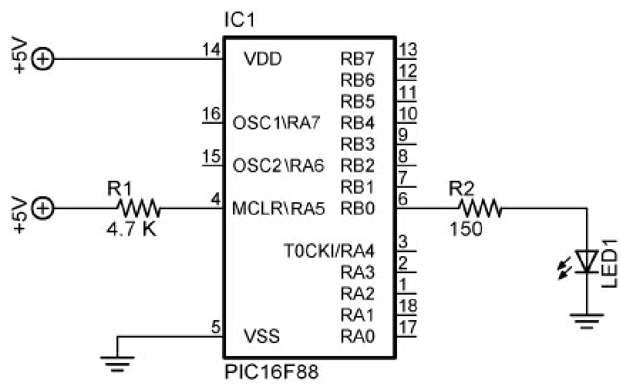
Electronics and Robotics I Week 20
Sink and Source Outputs / Active High and Active Low Inputs

LAB 1 – PIC16F88 as a Source and Sink

- **Purpose:** The purpose of this lab is to acquaint the student with the PIC microcontroller serving as a source and a sink.

- **Apparatus and Materials:**

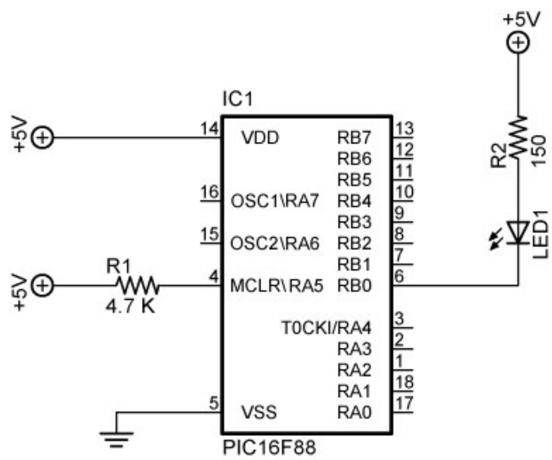
  - 1 – Breadboard with 5 V Power Supply
  - 1 – PIC16F88 Microcontroller
  - 1 – 150 Ohm, ½ Watt Resistors
  - 1 – 4.7K Ohm, ½ Watt Resistors
  - 1 – LED
- **Procedure:**
  - **PIC as a Source:**
    - Wire the circuit below that makes the PIC16F88 function as a source.



pic_as_source

    - Program the PIC16F88 with the program **pic_as_source.pbp**.
    - The PicBasic Pro **HIGH** command on RB0 (**HIGH** 0) supplies +5 volts to pin RB0 so a current of about 13 mA sources from pin RB0 through the resistor R2 and LED to ground. The PIC microcontroller acts as an automatic switch turning the LED on and off; pin RB0 acts as a current source.
    - The circuit may turn on and off an LED, a piezo buzzer, or a dc motor driven by a NPN transistor. Program the PIC16F88 (acting as a source) to turn on and off a piezo buzzer from pin RB4. Name the program **pic_as_source_piezo.pbp**
    - Do not proceed to the next section until instructed to do so.

- **PIC as a Sink:**
  - Wire the circuit below that makes the PIC16F88 function as a sink.



pic_as_sink

  - Program the PIC16F88 with the program **pic_as_sink.pbp**.
  - The conventional current goes from the +5 volt bus through the resistor R2 and LED and then sinks into the PIC pin RB0. In this case, when the PIC pin RB0 is programmed to go LOW (**LOW** 0) the LED turns on because the pin "sinks" the current into itself. The PIC microcontroller acts as an automatic switch turning the LED on and off; pin RB0 acts as a current sink.
  - Program the PIC16F88 (acting as a source) to turn on and off a piezo buzzer from pin RB1. In the same program, have the PIC act as a sink and turn on and off an LED from pin RB2. Name the program **pic_as_source_and_sink.pbp**

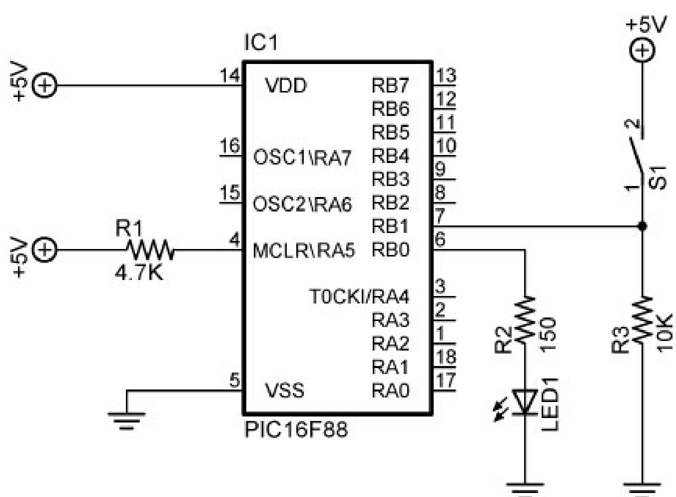
Electronics and Robotics I Week 20
Sink and Source Outputs / Active High and Active Low Inputs
LAB 2 – Active High and Active Low Inputs

- **Purpose:** The purpose of this lab is to acquaint the student with the PicBasic Pro command **IF..THEN** and the principles of active HIGH and active LOW. In addition, the student is challenged to use the logical operator AND.

- **Apparatus and Materials:**

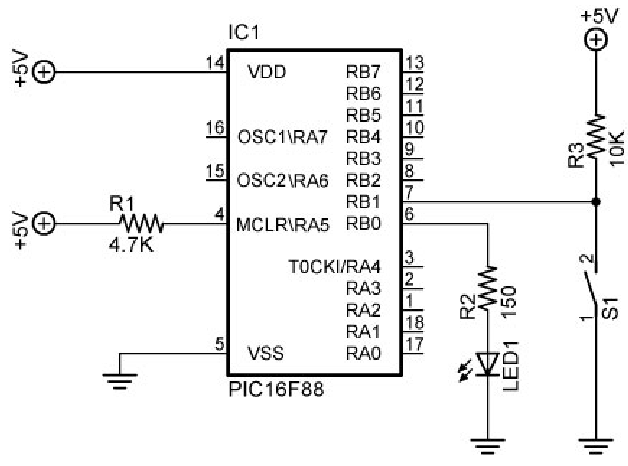
  - 1 – Analog/Digital Trainer
  - 1 – PIC 16F88 Microcontroller
  - 1 – 4.7K Ohm, ½ Watt Resistors
  - 1 – 150 Ohm, ½ Watt Resistors
  - 1 – 10 K Ohm, ½ Watt Resistor
  - 1 – 1K, ½ Watt Resistor
  - 1 – NO Momentary Switch
  - 1 – LEDs
  - This list does not contain the parts needed for the challenges.

- **Procedure:**
  - Open active_high.pbp and download to your 16F88. Wire your breadboard for the active_high schematic below. Review the program code and observe the command functions.



active_high

- Open active_low.pbp and download to your 16F88. Wire your breadboard for the active_low schematic below. Review the program code and observe the command functions.



active_low

- **Challenges:**
  - Write a program for the PIC16F88 and wire a circuit such that an LED will light only when two normally open (NO) momentary switches are pressed simultaneously. Use two pins (RB0 and RB1) as the switch inputs. Set one switch input (RB0) to the PIC microcontroller as an active HIGH and the other switch input (RB1) as an active LOW. The output pin (RB2) connected to the LED must be wired as a sink. Save the program as **active_high_low_led1.pbp**.
  - Now accomplish the same task using only one input pin (RB0) as an active HIGH to the PIC microcontroller and a 2 – input AND gate (74LS08).

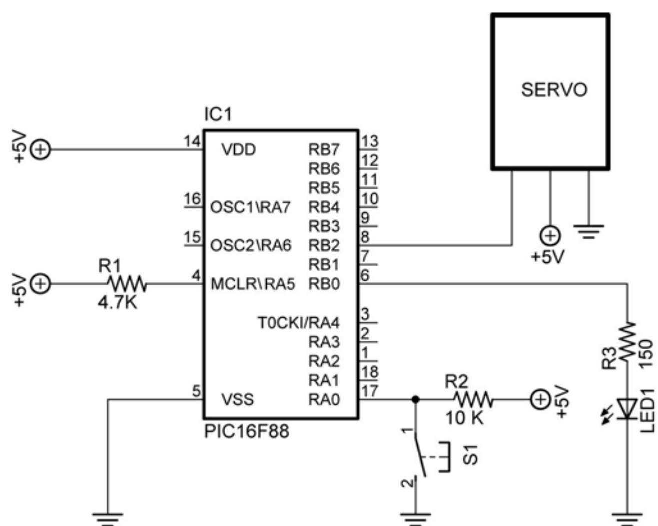
Electronics and Robotics I Week 20
Sink and Source Outputs / Active High and Active Low Inputs
LAB 3 – switch2.pbp

- **Purpose:** The purpose of this lab is to reinforce the principles of active HIGH and active LOW. In addition, the student is challenged to use the logical operator OR.

- **Apparatus and Materials:**

  - 1 – Breadboard or Analog/Digital Trainer
  - 1 – PIC16F88 Microcontroller
  - 1 – 150 Ohm, ½ Watt Resistors
  - 1 – 10 K Ohm, ½ Watt Resistor
  - 1 – 4.7K Ohm, ½ Watt Resistor
  - 1 – NO Momentary Switch
  - 1 – LED
  - 1 – Servomotor(not "hacked")
  - This list does not contain the parts needed for the challenges.

- **Procedure:**
  - Open switch2.pbp and download to your chip. Wire switch2 on the digital trainer. Review the program code and observe the command functions.



switch2

- **Challenges:**
  - Write a program and wire a circuit so that when either one of two normally open (NO) switches is pressed, an LED will light. Use two pins (RB0 and RB1) as the switch inputs. Set one switch input (RB0) to the PIC microcontroller as an active HIGH and the other switch input (RB1) as an active LOW. The output pin (RB2) connected to the LED must be wired as a sink. Save the program as **active_high_low_led2.pbp**.
  - Now accomplish the same task using only one input pin on the PIC microcontroller and a 2 – input OR gate.
  - Write a program and wire the robotic car to make it turn left if the left lever switch is pressed and to turn right if the right lever switch is pressed. If both switches are pressed, make the car travel forward.

Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 1 – Four States of a Motor

- **Purpose:** The purpose of this lab is to have the student verify the four states of a motor.

- **Apparatus and Materials:**

    - 1 – DC Motor
    - 1 – 9 Volt Battery

- **Procedure:**
    - Connect the motor in the following manner and record the response of the motor:
        - Connect motor terminal A to GND and terminal B to +9 VDC

          Motor Response:______________________

        - Connect motor terminal A to +9 VDC, and terminal B to GND

          Motor Response:______________________

        - Disconnect terminals A & B

          Motor Response:______________________

        - Connect terminal A to terminal B

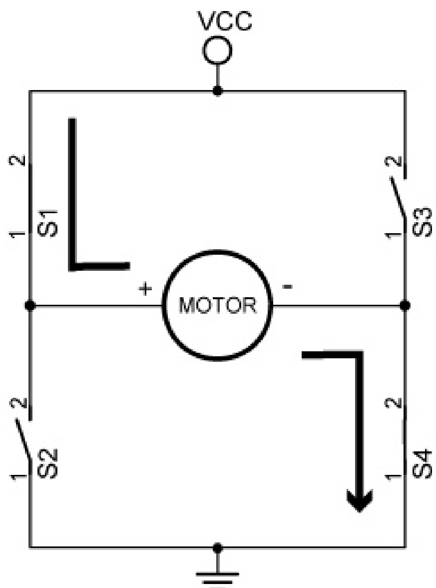
          Motor Response:______________________

Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 2 – H-Bridges with SPST Switches

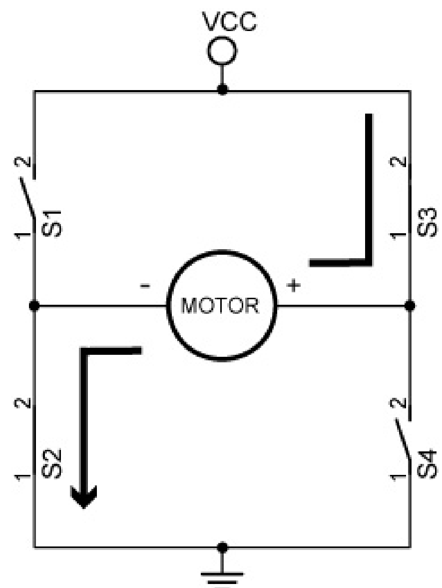
- **Purpose:** The purpose of this lab is to have the student manually verify the basic function of an H-bridge.

- **Apparatus and Materials:**
  - 1 – DC Motor
  - 1 – 9 Volt Battery
  - 4 – SPST Switches

- **Procedure:**
  - Wire the follow circuit.
  - Close the switches in the manner listed in the results table (**Do *not* close S1 and S2 or S3 and S4 simultaneously – it will create a short circuit)**.
  - Document your results.



Motor Runs Clockwise
(Switches 1 and 4 Closed)



Motor Runs Counter-Clockwise
(Switches 2 and 3 Closed)

- **Results:**

Switch State				
S1	**S2**	**S3**	**S4**	**Motor Operation**
Closed	Open	Open	Closed	
Open	Closed	Closed	Open	
Closed	Open	Closed	Open	
Open	Closed	Open	Closed	

Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 3 – Bipolar Transistor H-Bridges Motor Driver

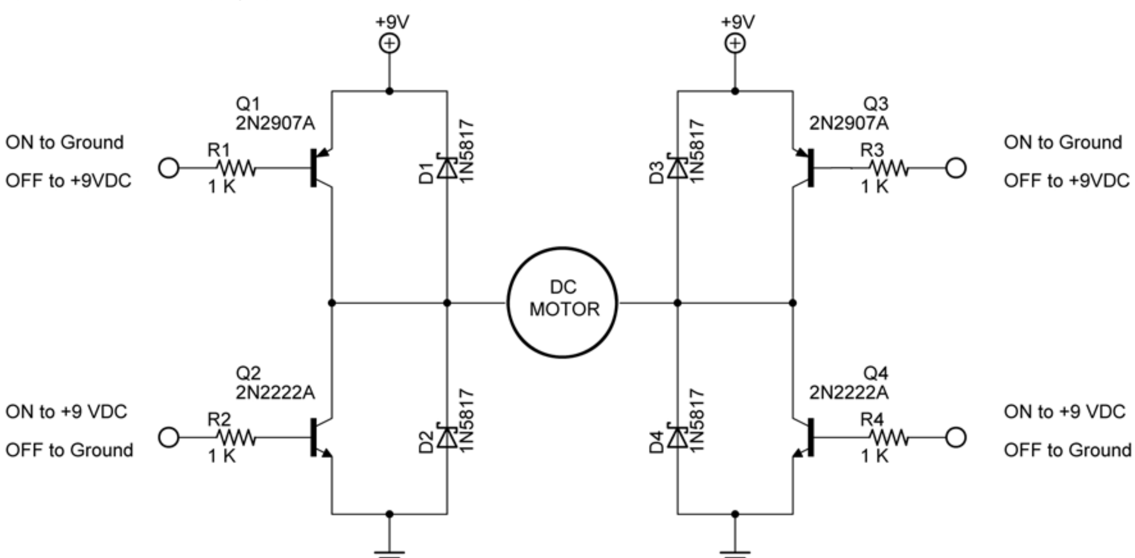
- **Purpose:** The purpose of this lab is to have the student setup an electronic H-bridge and to operate it manually.

- **Apparatus and Materials:**
  - 1 – DC Motor
  - 1 – 9 Volt Battery
  - 2 – 2N2907A PNP Transistors
  - 2 – 2N2222A NPN Transistors
  - 4 – 1N5817 Diodes

- **Procedure:**
  - **As with switches, do <u>not</u> short circuit through the transistors (<u>Q1 & Q2</u> or <u>Q3 & Q4</u>).**
  - Wire the following circuit the robotic car breadboard.
  - Connect the inputs to the transistor bases according to the following table and record the action of the motor:

Transistor Connections				
Q1	**Q2**	**Q3**	**Q4**	**Motor Operation**
+9V	+9V	GND	GND	
GND	GND	+9V	+9V	
GND	Disconnected	GND	Disconnected	
Disconnected	+9V	Disconnected	+9V	
Disconnected	Disconnected	Disconnected	Disconnected	

CHECK LINES 3 & 4 FOR +9 AND GND RESPECTIVELY



- Tie the inputs of Q1 and Q2 together and also connect the inputs of Q3 and Q4 together. What purpose do these connections serve?

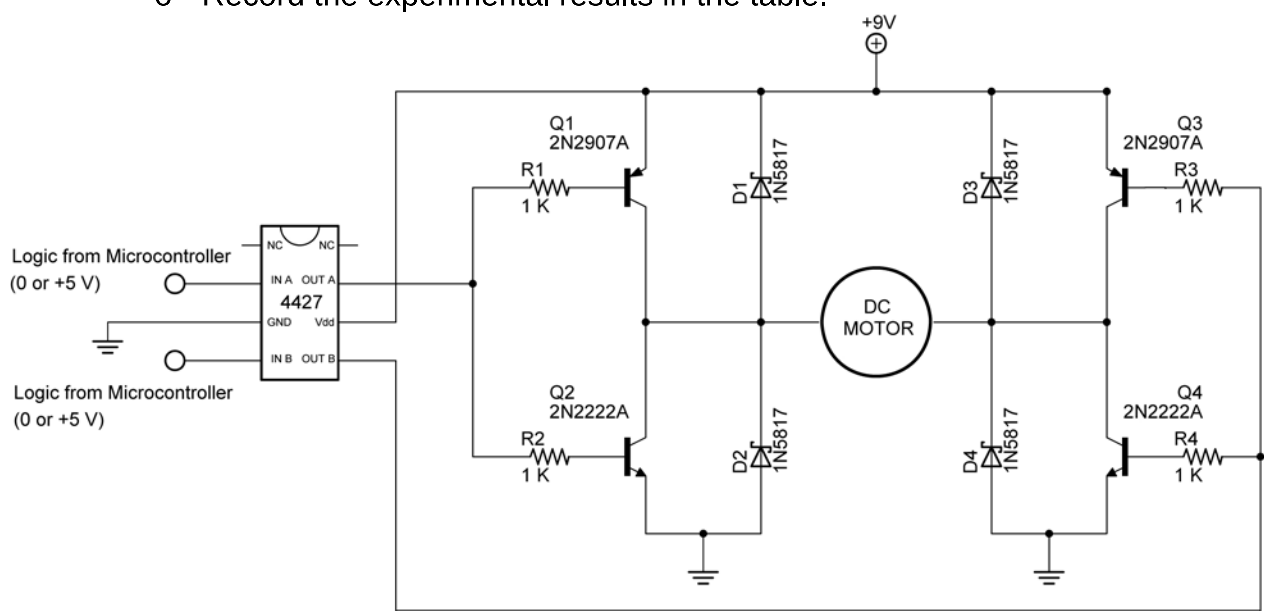
Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 4 – 4427 Interface IC

- **Purpose:** The purpose of this lab is to have the student insert a 4427 interface IC to simplify the control of an H-bridge.

- **Apparatus and Materials:**

  - 2 – DC Motors
  - 1 – 4427 Interface IC
  - 2 – 2N2907A PNP Transistors
  - 2 – 2N2222A NPN Transistors
  - 4 – 1N5817 Diodes

- **Procedure:**
  - Refer to the 4427 Interface IC H-Bridge Output Results Table below. Given the inputs for A and B, fill in the states of Q1-Q4 (On or off), then predict the action of the motor (Clockwise, counter-clockwise, braking, or coasting).
  - Now wire the 4427 interface IC circuit below.
  - Apply a HIGH, Low, or Disconnect to the inputs A and B of the 4427 IC.
  - Record the experimental results in the table.



4427 Interface IC Circuit

- **Results:**

4427 Interface IC H-Bridge Output Results							
Input A	**Input B**	**Q1**	**Q2**	**Q3**	**Q4**	**Predicted Results**	**Experimental Results**
HIGH	HIGH						
HIGH	LOW						
LOW	HIGH						
LOW	LOW						

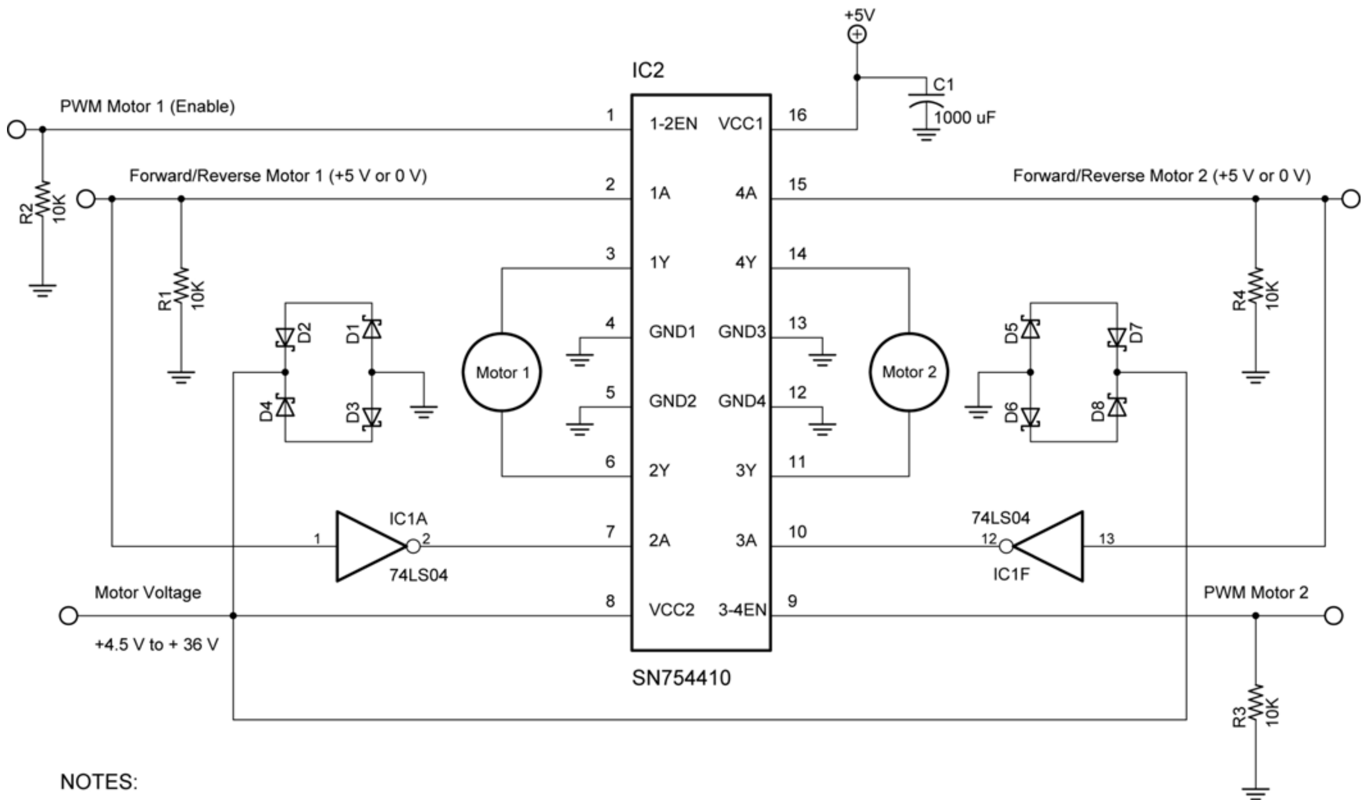
Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 5 – SN754410 H-Bridges Motor Driver

- **Purpose:** The purpose of this lab is to acquaint the student with the operation of a single chip motor driver – SN754410 by Texas Instrument.

- **Discussion:**
  - PWM has yet to be covered so the PWM ports are either set HIGH (100% duty cycle) or LOW (0% duty cycle) See the lesson on PWM to adjust values between 100% and 0%.

- **Apparatus and Materials:**
  - 2 – Gearhead DC Motors, Jameco #155855
  - 1 – SN754410 Quadruple Half-H Driver, Pololu #0024
  - 1 – 74LS04 Hex-Inverter
  - 8 – 1N5817 Diodes
  - 4 – 10K Resistors
  - 1 – 1000 uF Capacitor

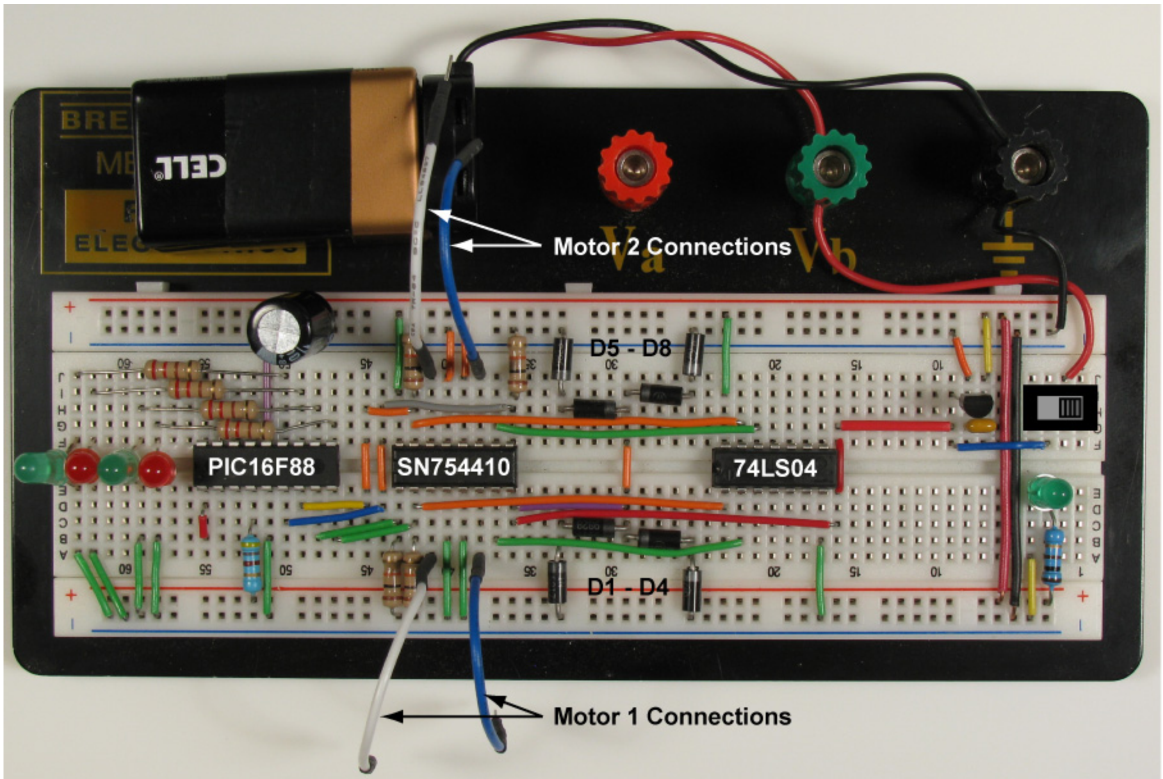
- **Procedure:**
  - Wire the circuit below and make the input connections as follows:
    - Motor + Voltage to +9V
    - PWM Motor 1 and 2 to 0V or +5V
    - Forward/Reverse Motor 1 and 2 to 0V or +5V
    - Complete the table below.



NOTES:

1. D1 - D8 1N5817
2. 74LS04 Pin 7 GND
   74LS04 Pin 14 Vcc +5V
3. SN754410 GNDS Also Act As
   Heatsinks, Ground Separately

Texas Instrument SN754410 H-Bridge Motor Driver



Breadboard Layout Includes PIC16F88 (Lab 6)

- **Results:**

SN754410 H-Bridge Motor Driver Results		
PWM Motor 1	**F/R Motor 1**	**Motor Operation**
HIGH	HIGH	
HIGH	LOW	
LOW	HIGH	
LOW	LOW	

SN754410 H-Bridge Motor Driver Results		
PWM Motor 2	**F/R Motor 2**	**Motor Operation**
HIGH	HIGH	
HIGH	LOW	
LOW	HIGH	
LOW	LOW	

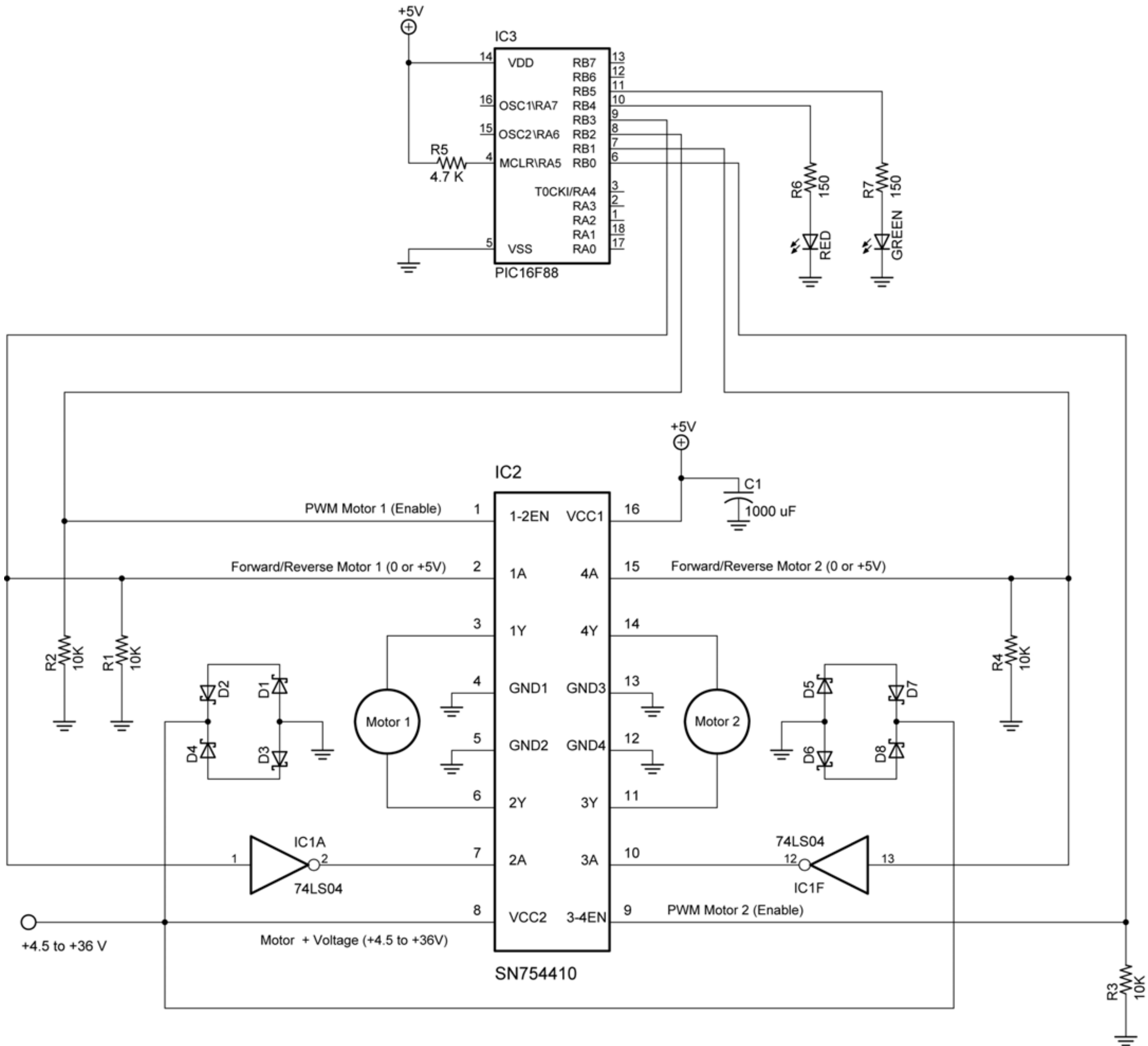
Electronics and Robotics I Week 21
Motor Control, H-Bridges LAB 6 – PIC16F88 Driving the SN754410 H-Bridges Motor Driver

- **Purpose:** The purpose of this lab is to acquaint the student with using a PIC microcontroller to drive a single chip motor driver – SN754410 by Texas Instrument.

- **Apparatus and Materials:**

  - 1 – Robotic Car Platform
  - 2 – Gearhead DC Motors, Jameco #155855
  - 1 – SN754410 Quadruple Half-H Driver, Pololu #0024
  - 1 – 74LS04 Hex-Inverter
  - 1 – PIC16F88
  - 8 – 1N5817 Diodes
  - 1 – 4.7K Resistor
  - 4 – 10K Resistors
  - 2 – 150 Ohm Resistors
  - 2 – LEDs
  - 1 – 1000 uF Capacitor

- **Procedure:**
  - Wire the following circuit on the robotic car breadboard. See the photo in Lab 5 for one possible layout.
  - Make sure that the motor is from a power supply separate from the PIC16F88.
  - Program the PIC16F88 with **h_bridge_sn754410_1.pbp**.



NOTES:

1. D1 - D8 1N5817
2. 74LS04 Pin 7 GND
   74LS04 Pin 14 Vcc +5V
3. SN754410 GNDS Also Act As
   Heatsinks, Ground Separately

Texas Instrument SN754410 H-Bridge Motor Driver

- **Challenge:**
  - The robotic car must navigate the given course.
  - Dead reckoning may be used to navigate the course.
  - An LCD must display which direction the car is traveling, such as, forward, right, left, or backup.
  - Create and call up subroutines for each direction of movement including backup. Do not use the word “reverse” since it is a reserved word in PicBasic Pro.
  - Save the new program as **sn754410_navigate.pbp**.

Switch State				
S1	**S2**	**S3**	**S4**	**Motor Operation**
Closed	Open	Open	Closed	Clockwise
Open	Closed	Closed	Open	Counterclockwise
Closed	Open	Closed	Open	Braking
Open	Closed	Open	Closed	Braking

Motor Control, H-Bridges LAB 2 – H-Bridges with SPST Switches

4427 Interface IC H-Bridge Output Results							
Input A	**Input B**	**Q1**	**Q2**	**Q3**	**Q4**	**Predicted Results**	**Experimental Results**
HIGH	HIGH	Off	On	Off	On	Braking	Braking
HIGH	LOW	Off	On	On	Off	Clockwise	Clockwise
LOW	HIGH	On	Off	Off	On	Counterclockwise	Counterclockwise
LOW	LOW	On	Off	On	Off	Braking	Braking

Results to Motor Control, H-Bridges LAB 4 – 4427 Interface Chip

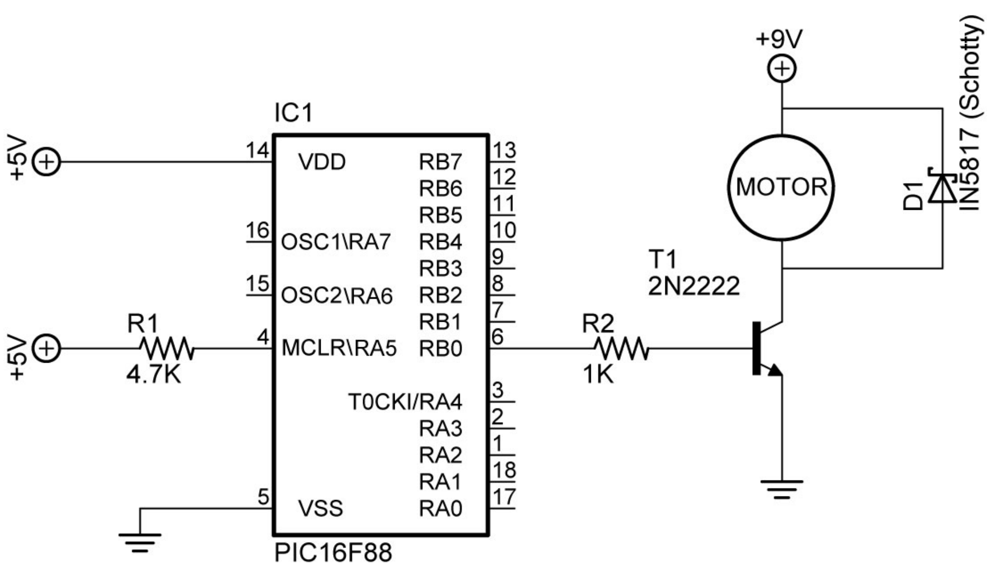
Electronics and Robotics I Week 22
Motor Control PWM LAB 1 – pwm1.pbp

- **Purpose:** The purpose of this lab is to acquaint the student the PicBasic Pro command **PWM** and how to make basic connections of a motor to a PIC programmed with **PWM**.

- **Apparatus and Materials:**

  - 1 – Breadboard or Robotic Car Platform
  - 1 – PIC16F88
  - 1 – 1K Resistors
  - 1 – 4.7K Resistor
  - 1 – 2N2222 NPN Transistor
  - 1 – 1N5817 Diode
  - 1 – DC Motor

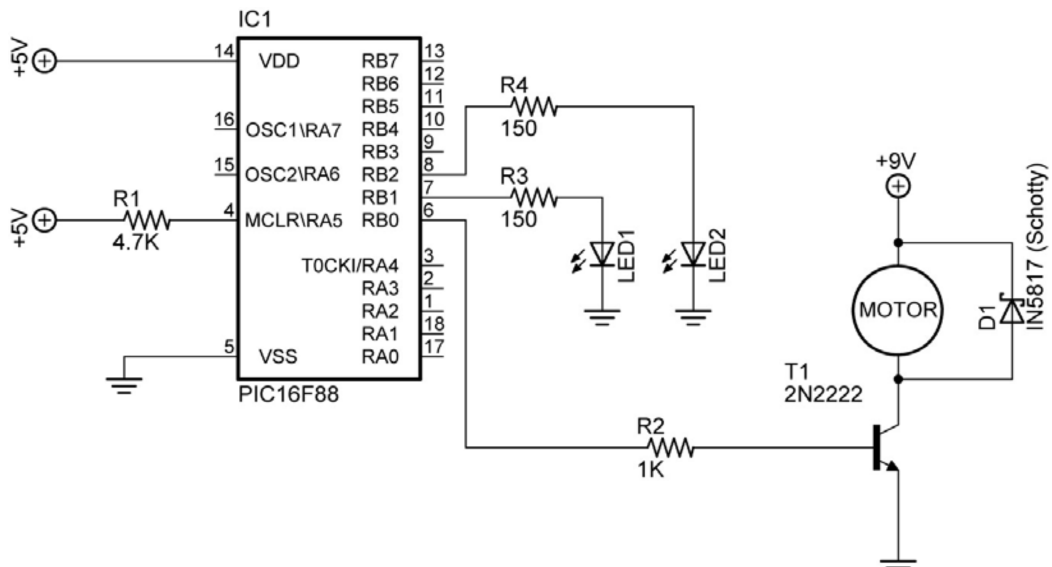
- **Procedure:**
  - o Wire the circuit below on your breadboard:
  - o Open **pwm1.pbp** from your folder and download to the PIC. The **pwm1.pbp** program changes the motor speed to three levels.
  - o Run the program and observe the motor speed changes
  - o Now save **pwm1.pbp** as **pwm10.pbp**.
  - o Experiment by changing the values of Duty first, and then Cycle in the **PWM** command.



Circuit for pwm1.pbp

Electronics and Robotics I Week 22
Motor Control PWM LAB 2 – hpwm1.pbp

- **Purpose:** The purpose of this lab is to acquaint the student with the command **HPWM** and how it runs in the background while the program executes other commands.
- **Apparatus and Materials:**
    - 1 – Breadboard or Robotic Car Platform
    - 1 – PIC16F88
    - 1 – 1K Resistors
    - 1 – 4.7K Resistor
    - 1 – 2N2222A NPN Transistor
    - 1 – 1N5817 Diode
    - 1 – DC Motor – The Class Used the Jameco #155855 Gearhead 72 RPM Motor
- **Procedure:**
    - Wire the circuit as shown below.
    - Load **hpwm1.pbp** into the PIC16F88. The **hpwm1.pbp** program runs the HPWM command in the background while executing other PicBasic Pro commands.
    - Take note that the motor continues to run as the program executes the other program commands.

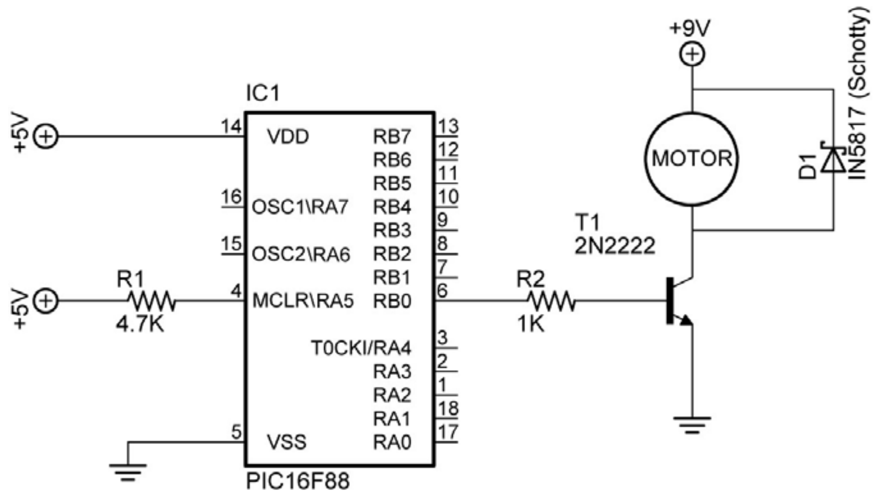


Circuit for hpwm1.pbp

- Now save **hpwm10.pbp** as **hpwm10.pbp** and change the Dutycycle values.
- Open **hpwm2.pbp** and load into the PIC16F88. This program changes the value of the Dutycycle from 90 to 255 and then to 0. The motor speed responds accordingly.

Electronics and Robotics I Week 22
Motor Control PWM LAB 3 – PWM Calibration

- **Purpose:** The purpose of this lab is to acquaint the student with the process of calibrating PWM-driven motor rotational speeds.
- **Apparatus and Materials:**
  - 1 – RPM Meter
  - 1 – Robotic Car Platform
  - 1 – PIC16F88
  - 1 – 1K Resistors
  - 1 – 4.7K Resistor
  - 1 – 2N2222A NPN Transistor
  - 1 – 1N5817 Diode
  - 2 – DC Gearhead Motors – Jameco #155855
- **Procedure:**
  - o Use the same circuit that was used in Lab 1 for Lab 3.



Circuit for PWM and HPWM Calibration

  - o Motor 1 Calibration with **PWM** Command:
    - Label the motors Motor 1 and 2 and connect the power supply positive lead to the + terminal on Motor 1 and the negative lead to the other terminal on Motor 1. This will be considered forward for Motor 1. Make sure the car does in fact travel forward, not in reverse.
    - Using **pwm10.pbp**, empirically determine the smallest Duty value before Motor 1 stops rotating. This number will be used as the smallest Duty value in the remaining discussion.

        - Calculate Input Values:
            - Divide the range from the smallest Duty value to 255 into 9 almost equal parts. For example, if the smallest Duty value is 140, subtract 140 from 255 to yield 115. Divide 115 by 9 to get 12.77, or rounded, 13. Start the input values at 140. Write each of these input values down. Now add 13 to 140 to get the second input value, 153. To calculate the remaining input values, continue adding 13 to the previous total until you arrive at approximately 255. In this example, the input values would be: 140, 153, 166, 179, 192, 205, 218, 231, 244, and 257.
        - Setting the Calibration Graph Scales:
            - Set the horizontal scale from your smallest Duty value (at the graph origin) to 255. Adjust the placement of the 255 value so that the lines on the scale make sense when plotting the other input values.
            - Program the PIC16F88 with the Duty value 255 so you can determine the highest rpm that you will measure. Set the vertical scale using this rpm value as the maximum value. Again, adjust this maximum value so the lines on the scale make sense.
        - For each input value, measure the rpm of Motor 1 and plot the coordinates on the calibration graph. Label this plot as Motor 1 Forward.
        - Switch the polarity of the motor leads and repeat the whole calibration process for Motor 1 in reverse. Plot the results on the same calibration graph as Motor 1 Forward.
    - Motor 2 Calibration with **HPWM** Command:
        - Connect the positive lead to the - terminal and the negative lead to the + terminal on Motor 2. This will be considered forward for Motor 2.
        - Repeat the whole calibration process for Motor 2 except use **hpwm3.pbp**. Plot the results on a new calibration graph and label this plot as Motor 2 Forward.
        - Switch the polarity of the motor leads and repeat the whole calibration process for Motor 2 in reverse. Plot the results on the same calibration graph as Motor 2 Forward.
        - Save these plots for motor calibration in the coming weeks.

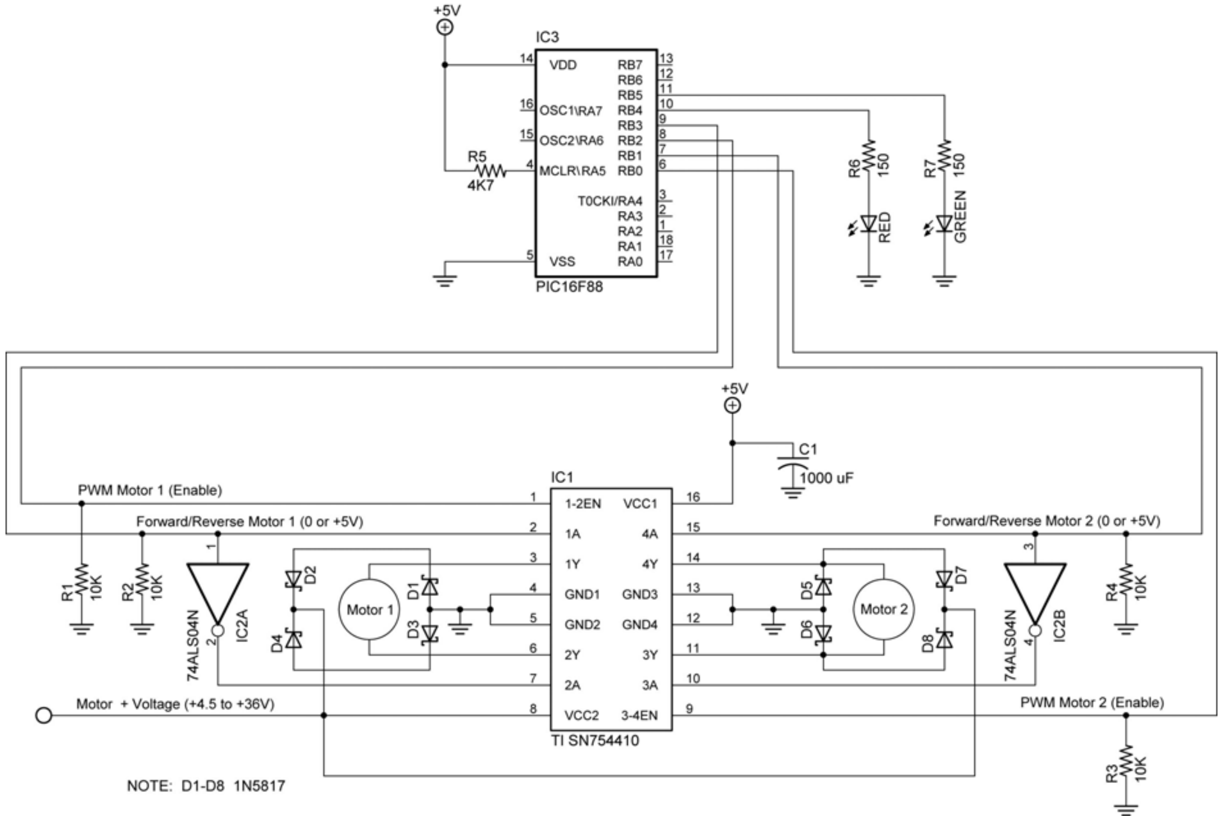
Electronics and Robotics I Week 22
Motor Control PWM LAB 4 – Using PWM for Speed Control with the SN754410

- **Purpose:** The purpose of this lab is to have the student use PWM to change the speed of their robotic car.

- **Apparatus and Materials:**

    - 1 – Robotic Car Platform
    - 2 – Gearhead DC Motors, Jameco #155855
    - 1 – SN754410 Quadruple Half-H Driver, Pololu #0024
    - 1 – 74LS04 Hex-Inverter
    - 1 – PIC16F88
    - 8 – 1N5817 Diodes
    - 1 – 4.7K Resistor
    - 4 – 10K Resistors
    - 2 – 150 Ohm Resistors
    - 2 - LEDs
    - 1 – 1000 uF Capacitor

- **Procedure:**
    - Wire the following circuit on the robotic car breadboard. This is the identical circuit that was used in the H-Bridge lesson.
    - Program the PIC16F88 with **pwm_hpwm_sn754410.pbp**.



Texas Instrument SN754410 H-Bridge Motor Driver

- **Challenge:**
  - Using the calibration data just collected, program the robotic car to travel forward along the straight taped line.
  - Use the calibration graphs to make the robotic car travel at ½ its maximum speed.
  - Program the robotic car to follow the straight taped line in reverse.

Electronics and Robotics I Week 23
Sonar Car 1 – Servo Positioning
LAB 1 – Set Servo into Starting Position

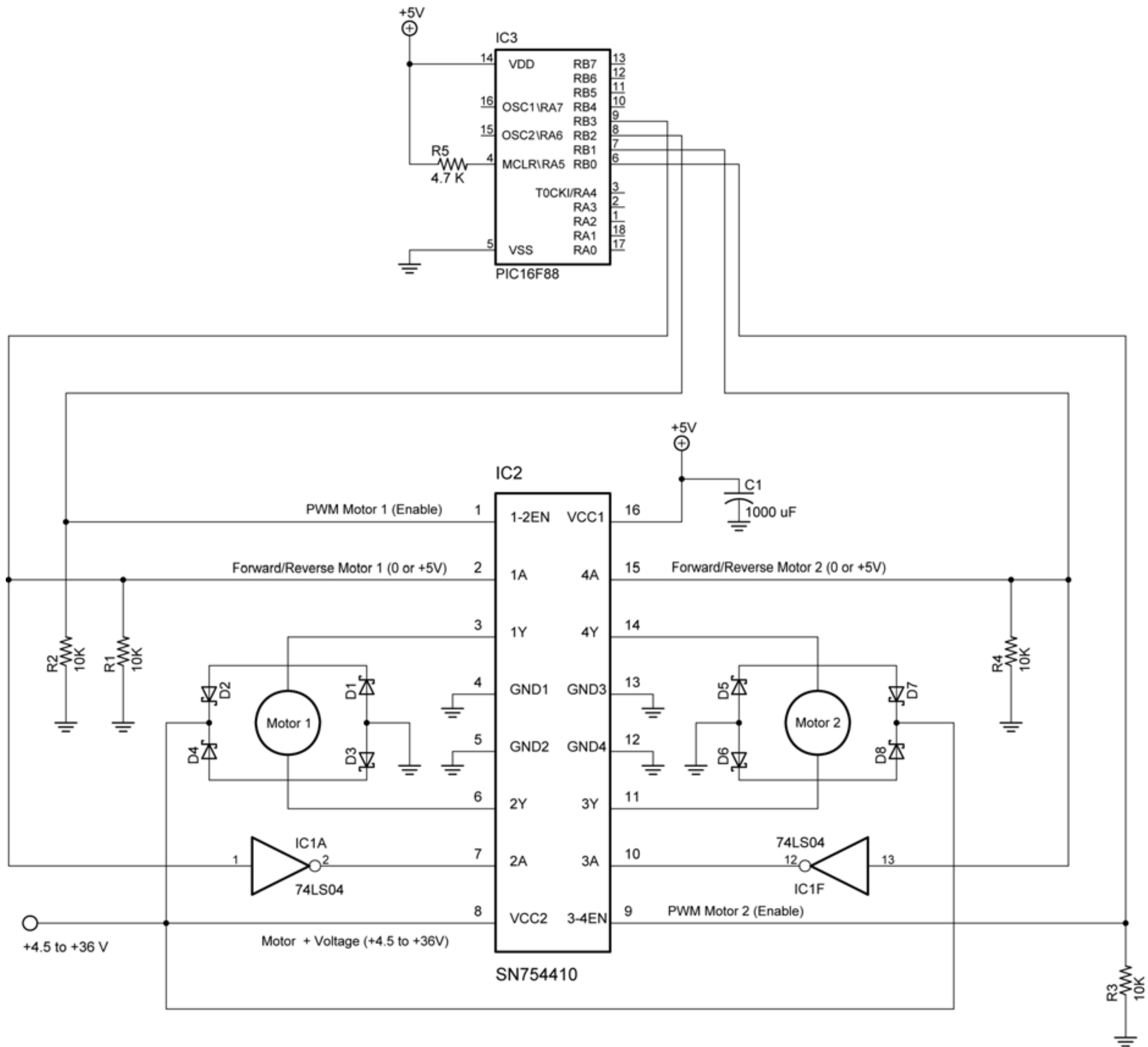
- **Purpose:** The purpose of this lab is to set the servo on the sonar car into the starting position.

- **Apparatus and Materials:**

    - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics below.

- **Procedure:**
    - You can import **servo1.pbp** to provide the basic program code. You will need to make modifications to this program. See: http://cornerstonerobotics.org/code/servo1.pbp.
    - Save the imported program as **sonar_car1.pbp**. You will keep adding to this program in the coming weeks until your sonar car is fully functional.
    - Give the output pin PORTB.6 the name servo_pin. It can be assigned a name using the **VAR** command. This pin will send the program signal to the servo.
    - Using the **PULSOUT** command, set the Period to 70. Remember the format for **PULSOUT** is: **PULSOUT** *Pin, Period*
    - Shorten the time to move the servo by reducing the **FOR..NEXT** loop to 20 loops.

Sonar Car Circuitry 1

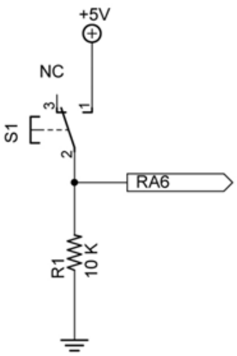


NOTES:

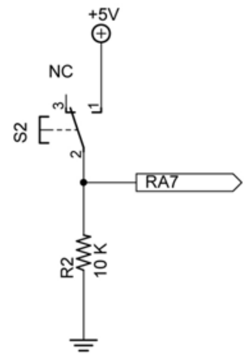
1. D1 - D8 1N5817
2. 74LS04 Pin 7 GND
   74LS04 Pin 14 Vcc +5V
3. SN754410 GNDS Also Act As
   Heatsinks, Ground Separately

Texas Instrument SN754410 H-Bridge Motor Driver

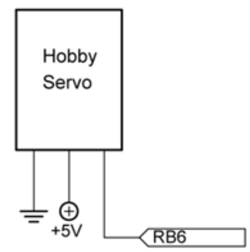
Sonar Car Circuitry 2



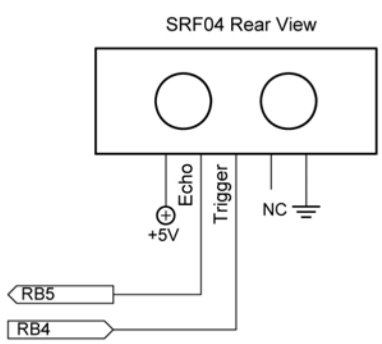
Left Bumper Switch



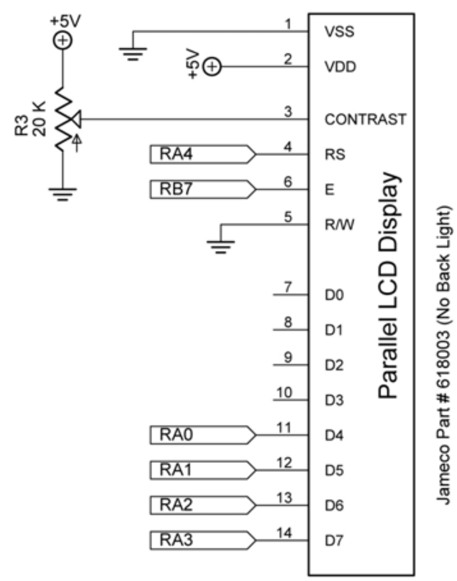
Right Bumper Switch



Servo



Ultrasonic Range Finder



LCD

Electronics and Robotics I Week 23
Sonar Car 1 – Servo Positioning
LAB 2 – Pan Servo across the Front on the Sonar Car

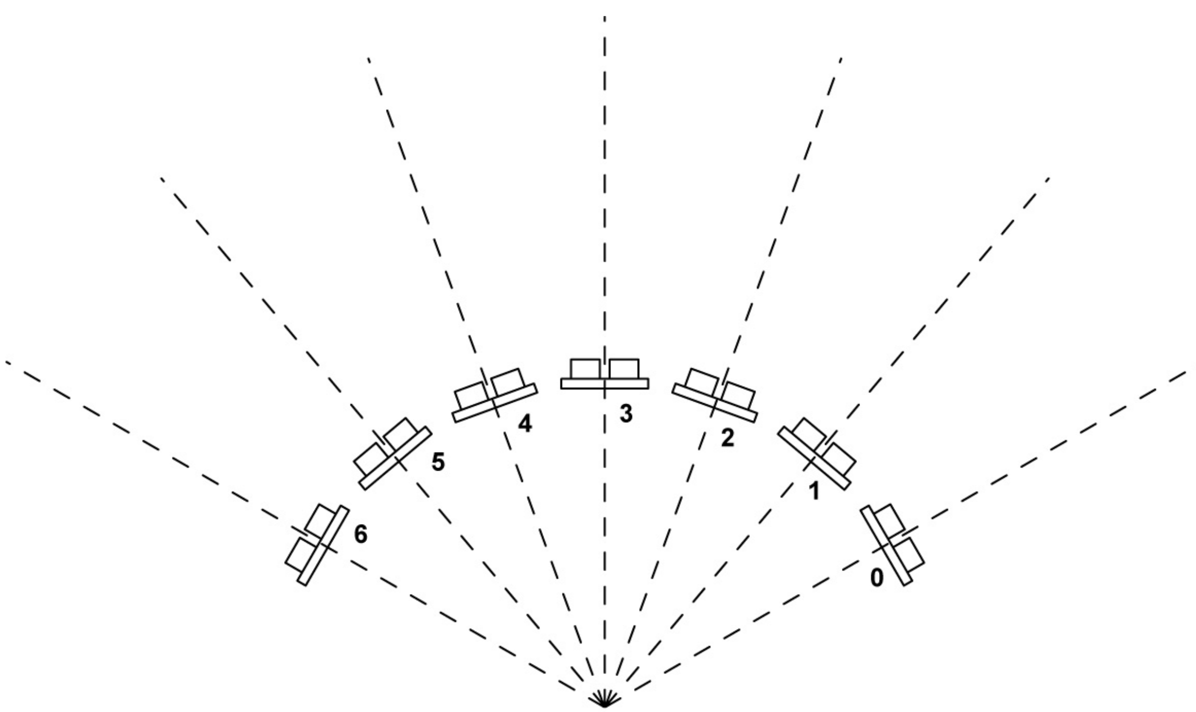
- **Purpose:** The purpose of this lab is to make the servo pan across the front of the sonar car in six discrete steps.

- **Apparatus and Materials:**
  - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics in Lab 1.

- **Procedure:**
  - Declare the following variables

```
p0    VAR   BYTE     ' BYTE to store servo pulse period
c0    VAR   WORD     ' WORD for counter
```

  - Start the servo at the position generated by Period = 70 (see Lab 1) and then rotate through to Period = 208 in 6 discrete steps. Hint: Nest two **FOR..NEXT** loops.
  - Shorten the time to move the servo to each new position by reducing the **FOR..NEXT** loop to 15 loops.
  - Set up a loop to make the servo return to the starting position and then pan across the front of the car again. The



7 Servo Positions with Ultra-sonic Range Finder

  - Compare your program to **sonar_car_a.pbp**. See: http://cornerstonerobotics.org/code/sonar_car_a.pbp

Electronics and Robotics I Week 24
Switch Sensor LAB 1 – Wall Alignment

- **Purpose:** The purpose of this lab is to acquaint the student with the ability of robots equipped with switches to align themselves to a wall.
- **Apparatus and Materials:**
    - 1 – Robotic Car Platform
    - 2 – Lever Micro-switches
- **Procedure:**
    - For the student to determine
- **Challenge:**
    - Install two lever switches on your robotic car platform and program the PIC for the car to square up with a wall. <u>Keep your PAUSE command periods short</u>, otherwise when a switch is activated, the program may be executing another command with a lengthy PAUSE and not recognize the activated switch.

Electronics and Robotics I Week 24
Switch Sensor LAB 2 - Maze Navigation

- **Purpose:** The purpose of this lab is to acquaint the student with the use of a switch as a robotic touch sensor and how to use the information returned to the robot for the robot reaction. In particular, the student uses a switch (or switches) sensor mounted on their robotic car to navigate a maze.
- **Apparatus and Materials:**
    - 1 – Robotic Car Platform
    - 1 or 2 – Lever Micro-Switch(es)
- **Procedure:**
    - For the student to determine
- **Challenge:**
    - Install lever switch or switches on your robotic car platform and program the PIC for the car to navigate through the given maze. <u>Again, keep your PAUSE command periods short</u>, otherwise when a switch is activated, the program may be executing another command with a lengthy PAUSE and not recognize the activated switch.

Electronics and Robotics I Week 24
Switch Sensor LAB 3 – Collision Avoidance

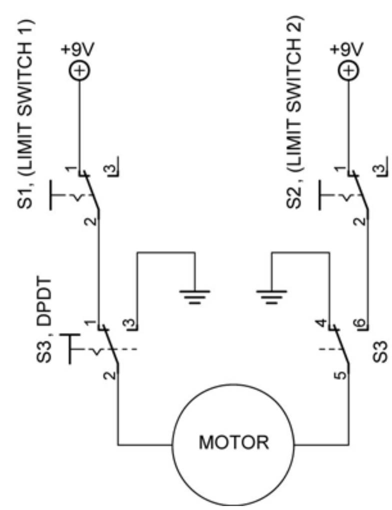
- **Purpose:** The purpose of this lab is to acquaint the student on the use of switches mounted on the robotic car for object avoidance.
- **Apparatus and Materials:**
    - 1 – Robotic Car Platform
    - 2 – Lever Micro-switches
- **Procedure:**
    - For the student to determine
- **Challenge:**
    - Install two lever switches on your robotic car platform and program the PIC so the car will avoid objects placed in front of the vehicle. Keep your PAUSE command periods short.

Electronics and Robotics I Week 24
Switch Sensor LAB 4 – Limit Switch1

- **Purpose:** The purpose of this lab is to acquaint the student with wiring limit switches to a DPDT switch that is operated manually.
- **Apparatus and Materials:**
    - 1 – Breadboard
    - 2 – Lever Micro-Switches
    - 1 – DIP DPDT Switch
- **Procedure:**
    - Wire the circuit below.
    - Operate the circuit and observe the results.

Basic Limit Switch Circuit:

- S1 and S2 serve as limit switches
- S3 changes the direction of the motor.

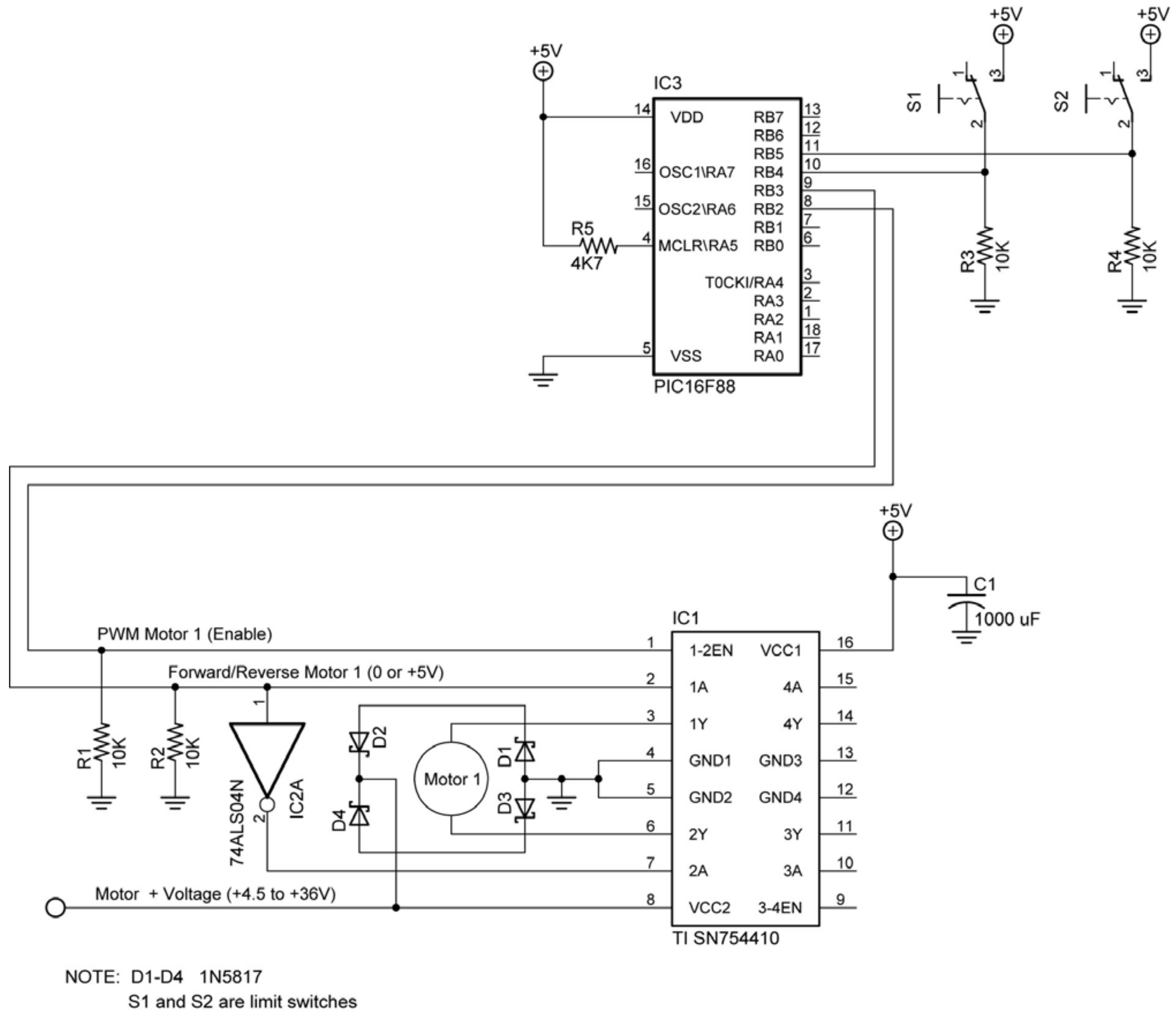


Electronics and Robotics I Week 24
Switch Sensor LAB 5 – Limit Switch2

- **Purpose:** The purpose of this lab is to acquaint the student with programming a PIC microcontroller to control a pair of limit switches.

- **Apparatus and Materials:**
  - o 1 – Breadboard
  - o 2 – Lever Micro-Switches
  - o 1 – DIP DPDT Switch

- **Procedure:**
  - o Wire the circuit below. Use the SN754410 circuit wired in the PWM lesson.



- **Challenge:** Program the PIC16F88 to continuously run the given motor and lever system back and forth between the two limit switches.

Electronics and Robotics I Week 25
Resistive Sensors LAB 1 – Reading a Potentiometer

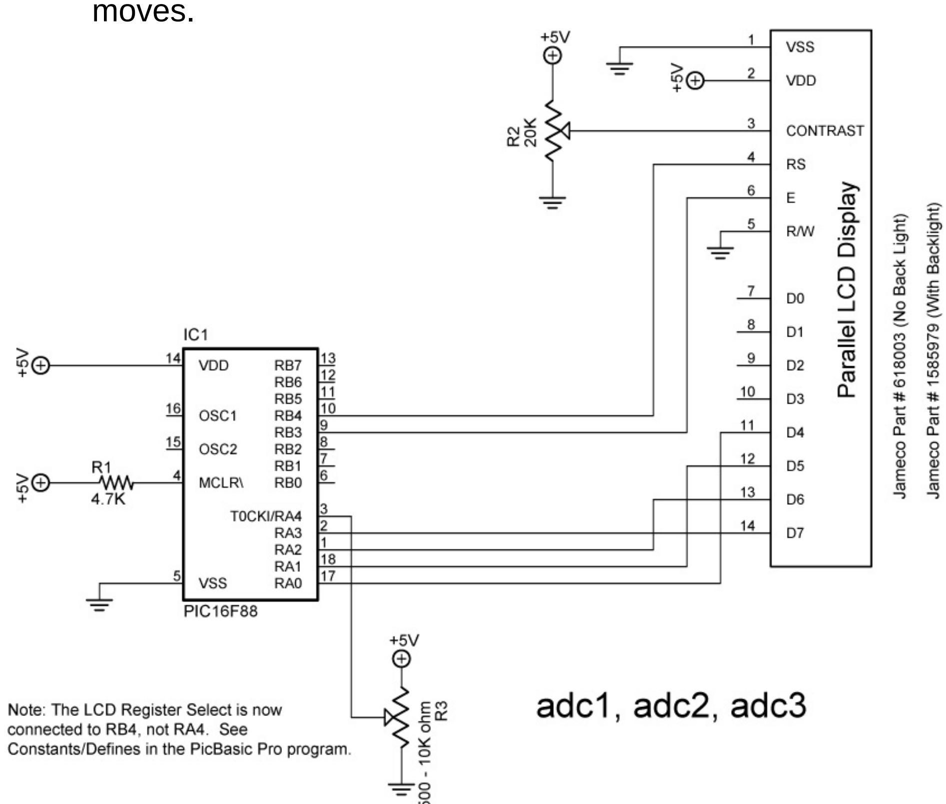
- **Purpose:** The purpose of this lab is to teach the student how to wire a PIC18F88 for analog/digital conversion, to expose the student to the PicBasic Pro command ADCIN, and to introduce the linear slide sensor.

- **Apparatus and Materials:**
  - 1 – Breadboard with +5V supply or an Analog/Digital Trainer
  - 1 – PIC 16F88 Microcontroller
  - 1 – 10 K Tripot
  - 1 – Phidgets Slide Sensor, Product # RB-Phi-20 from:

http://www.robotshop.ca/home/products/robot-parts/sensors/linear-rotary-resistors/index.html

  - 2 – 150 Ohm, ½ Watt Resistors
  - 1 – 10 K Ohm, ½ Watt Resistor
  - 1 – 1K, ½ Watt Resistor
  - 1 – NO Momentary Switch
  - 2 – LEDs

- **Procedure:**
  - Wire the circuit below. Use a 10K tripot for R3. Make sure to read the note in the schematic.
  - Program the PIC16F88 with **adc1.pbp**, **adc2.pbp**, and then **adc3.pbp**. Adjust R3 and note the values on the LCD screen for each program.
  - Now substitute the slide sensor for the 10K tripot. Note the changes in the LCD value as the linear position of the slide sensor moves.



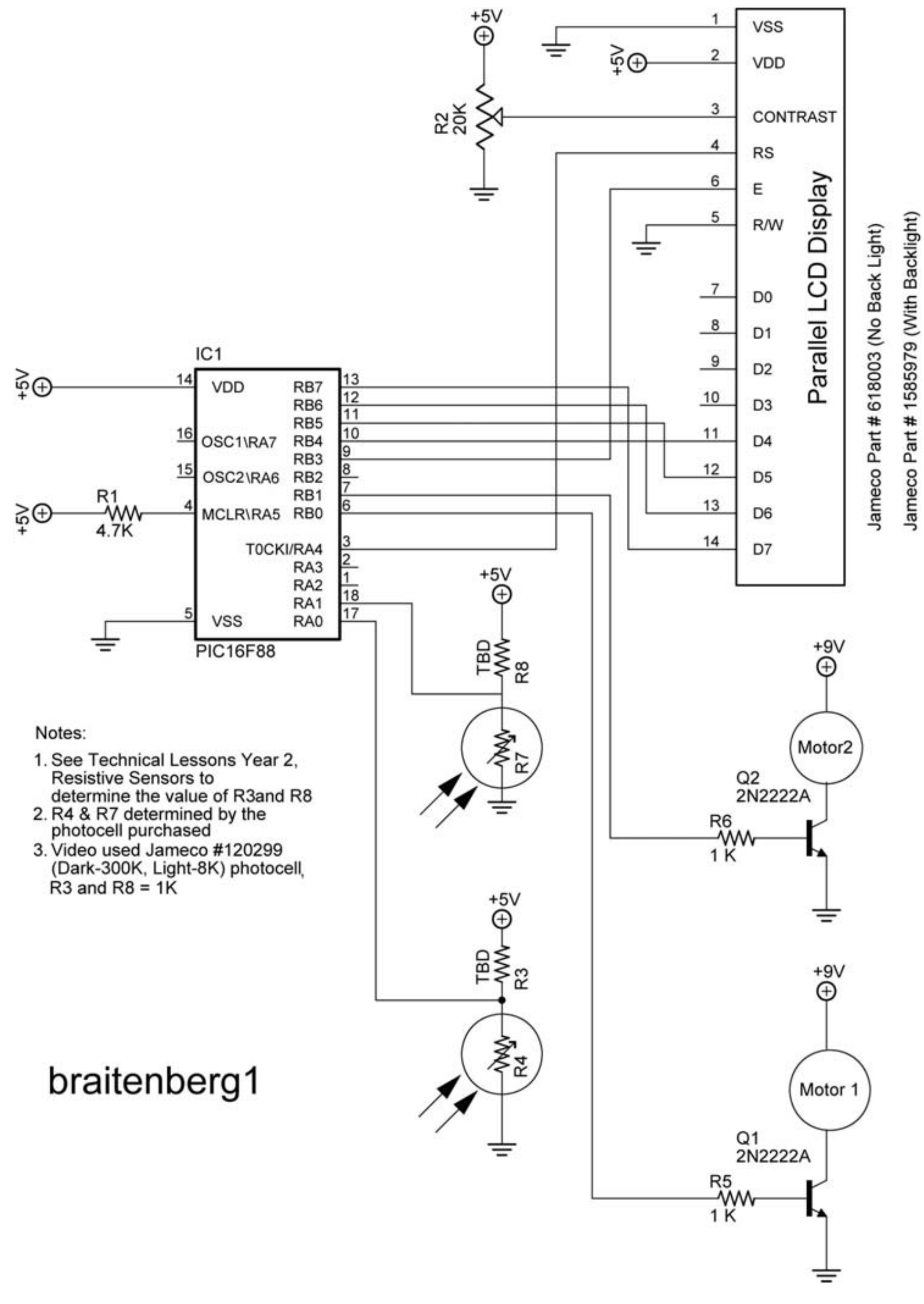
Electronics and Robotics I Week 25
Resistive Sensors LAB 2 – CdS Photoresistors

- **Purpose:** The purpose of this lab is to acquaint the student with the use of a CdS photocell as a resistive sensor.

- **Apparatus and Materials:**

    - 1 – Robotic Car Platform
    - 1 – PIC 16F88 – I/P Microcontroller
    - 1 – LCD Screen, Jameco #618003
    - 1 – 20 K Ohm Potentiometer
    - 2 – CdS Photoresistors, Jameco #120299 (300K-Dark, 8K-Light)
    - 1 – 4.7K Resistor
    - 4 – 1K Resistor, Includes R3 and R8
    - 2 – 2N2222A NPN Transistors

- **Procedure:**
    - Wire the following circuit.
    - Program the PIC16F88 with **braitenberg1.pbp**.
    - Adjust the CdS photocells for the car to be attracted to the light. See: http://www.youtube.com/watch?v=N_X4_VVxOrE
- **Challenges:**
    - **Line-follower:** Mount CdS sensors on your robotic car for the car to follow a taped line. See: http://www.youtube.com/watch?v=ut0iTLZykog
    - **Light-Steering:** Use one photocell to activate steering or forward motion for the robotic car. Use a second photocell to turn the robotic car off. The car must begin in the starting box and come to a complete stop in the finish box.
    - **CdS switch:** Wire a circuit and program a PIC16F88 to serve as a light activated switch which turns on and off an LED.

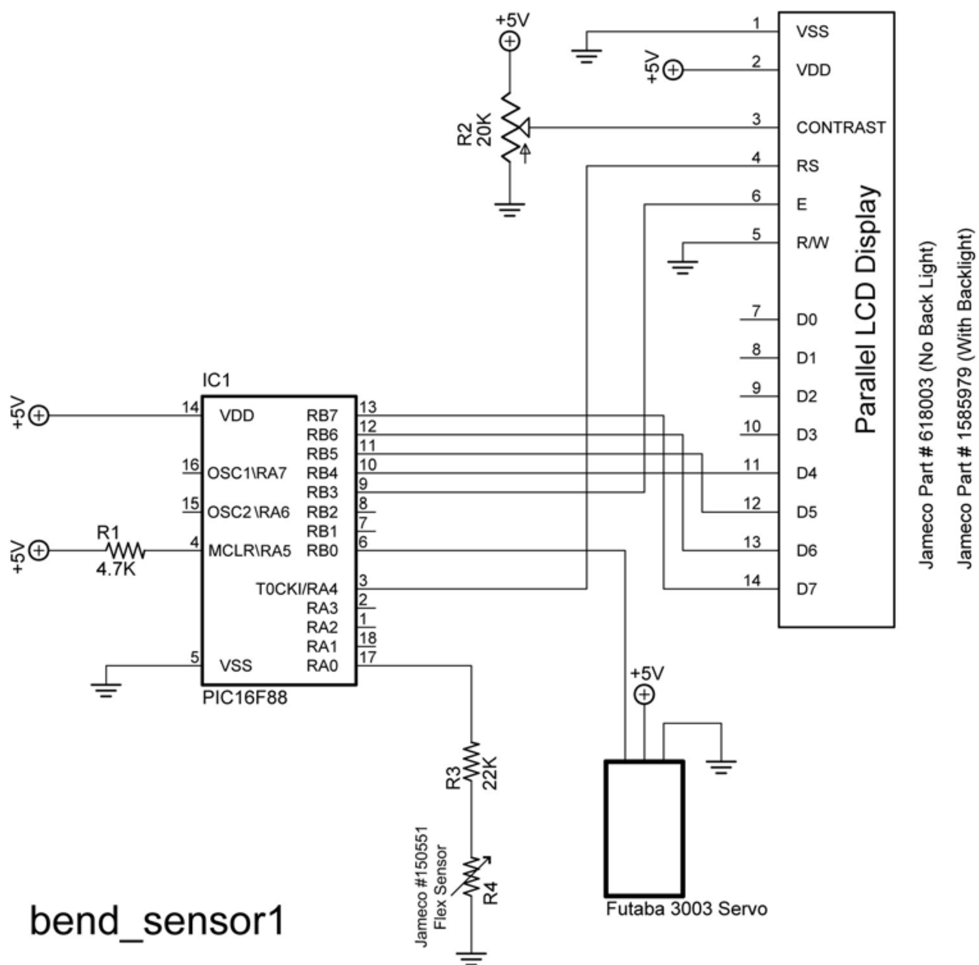

Parallel LCD Display
Jameco Part # 618003 (No Back Light)
Jameco Part # 1585979 (With Backlight)
VSS
VDD
CONTRAST
RS
E
R/W
D0
D1
D2
D3
D4
D5
D6
D7
+5V
R2
20K
IC1
VDD
OSC1\RA7
OSC2\RA6
MCLR\RA5
VSS
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0
T0CKI/RA4
RA3
RA2
RA1
RA0
PIC16F88
R1
4.7K
TBD
R8
R7
TBD
R3
R4
+9V
Motor2
Q2
2N2222A
R6
1 K
Motor 1
Q1
2N2222A
R5
1 K
Notes:
1. See Technical Lessons Year 2, Resistive Sensors to determine the value of R3and R8
2. R4 & R7 determined by the photocell purchased
3. Video used Jameco #120299 (Dark-300K, Light-8K) photocell, R3 and R8 = 1K
braitenberg1

Electronics and Robotics I Week 25
Resistive Sensors LAB 3 – Bend Sensors

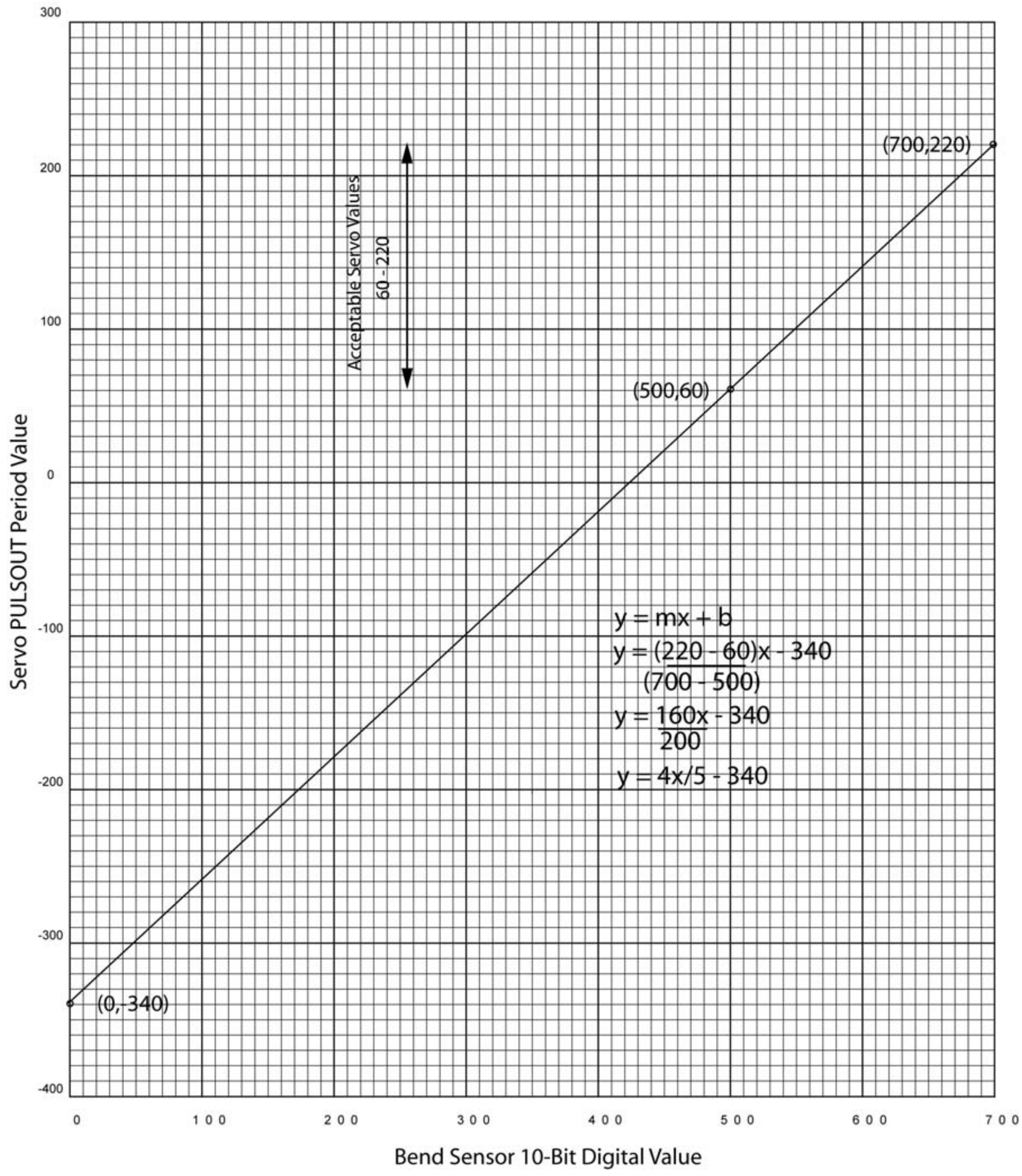
- **Purpose:** The purpose of this lab is to acquaint the student with the function of a bend sensor.

- **Apparatus and Materials:**
    - 1 – Breadboard
    - 1 – PIC 16F88 Microcontroller
    - 1 – 4.7K Ohm Resistor
    - 1 – 22K Resistor
    - 1 – 20K Tripot
    - 1 – Bend Sensor, Jameco #150551
    - 1 – LCD Screen, Jameco # 618003
    - 1 – Futaba 3003 Hobby Servo

- **Procedure:**
    - Wire the circuit bend_sensor1.
    - Program the PIC16F88 with **bend_sensor1.pbp**
    - Bend flex sensor and note servo movement.
    - Review the derivation of the equation in the graph below.



bend_sensor1



Derivation of Formula Used in bend_sensor1.pbp

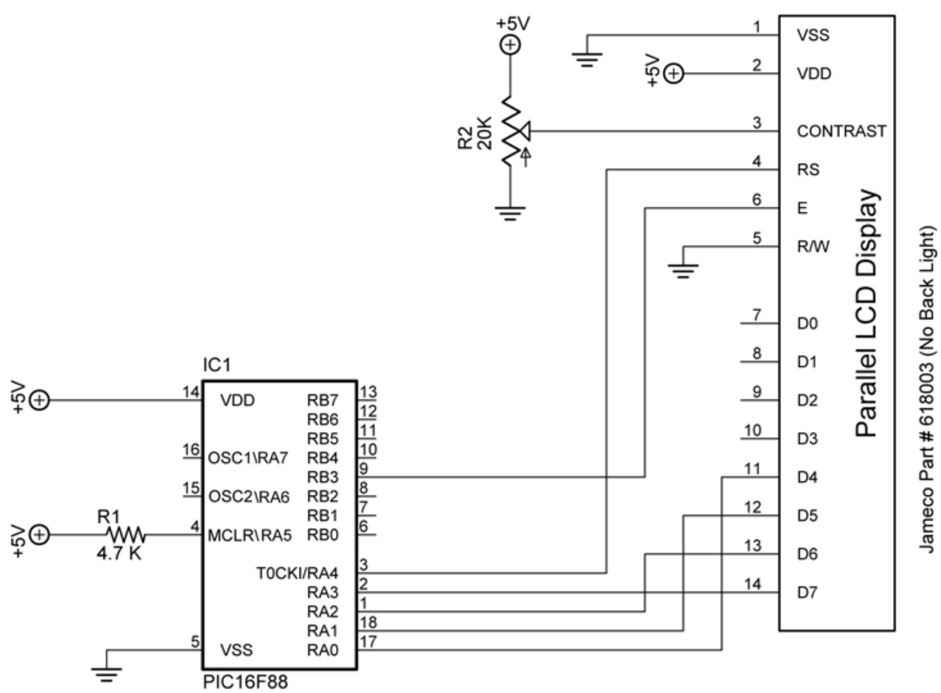
Electronics and Robotics I Week 26
Ultra-Sonic LAB 1 – array1 and array2.pbp

- **Purpose:** The purpose of this lab is to acquaint the student with the PicBasic Pro variable arrays.

- **Apparatus and Materials:**

  - 1 – Breadboard
  - 1 – PIC 16F88 Microcontroller
  - 1 – 4.7K Ohm Resistor
  - 1 – 20K Tripot
  - 1 – LCD Screen, Jameco # 618003

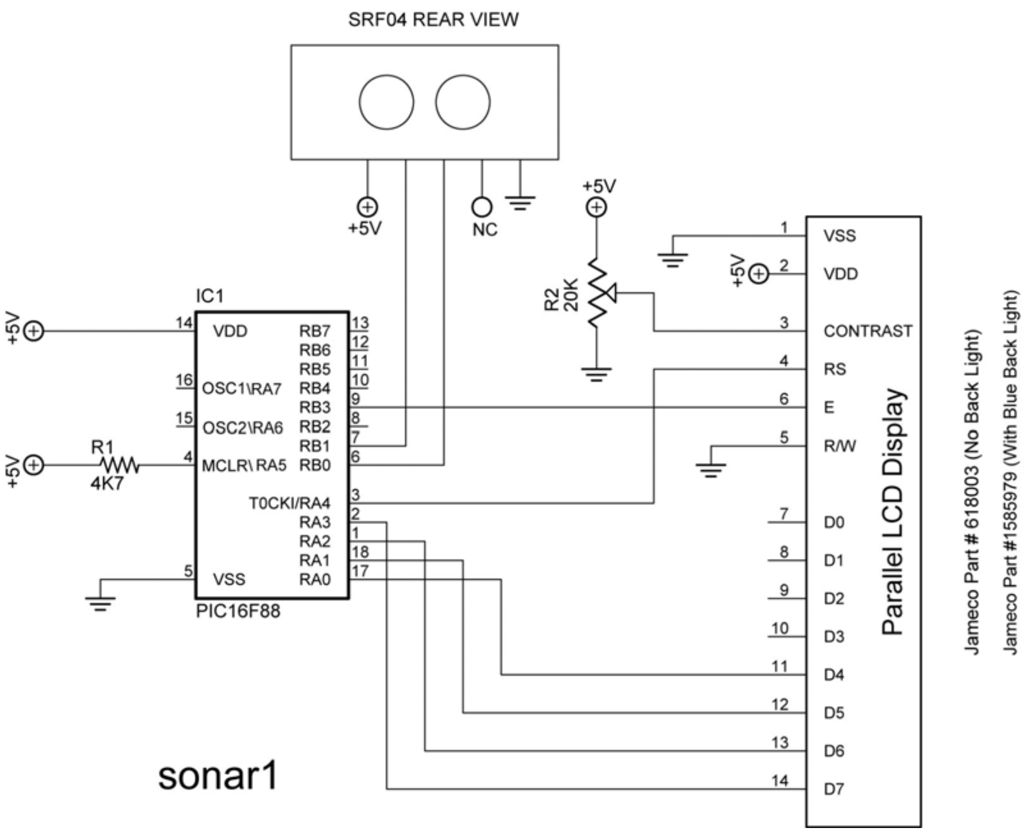
- **Procedure:**
  - Wire the circuit array1 as shown below.
  - Program the PIC16F88 with **array1.pbp** and power the chip.
  - Program the PIC16F88 with **array2.pbp** and power the chip.
  - Program the PIC16F88 to three take CdS photoresistor readings and record the sample number and CdS reading in two arrays, sample[3] and cds[3]. Display all of the results of the two arrays at one time on an LCD. Save the program as **array10.pbp**.

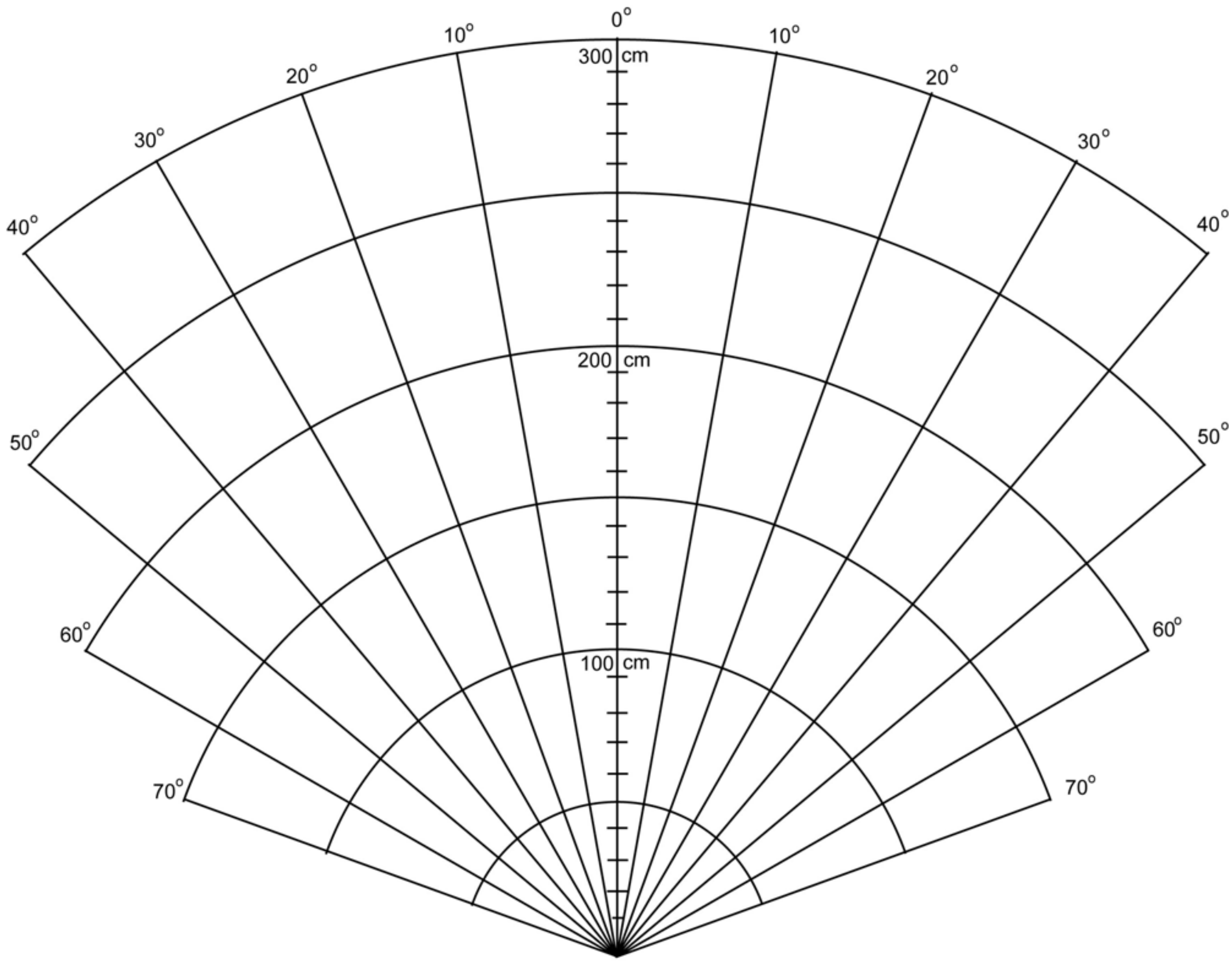


array1 and array2

Electronics and Robotics I Week 26
Ultra-Sonic LAB 2 – sonar1.pbp

- **Purpose:** The purpose of this lab is to acquaint the student with the basic function of the SRF04 ultra-sonic range finder and the PicBasic Pro commands to drive the range finder.
- **Apparatus and Materials:**
  - 1 – Breadboard or Robotic Car
  - 1 – PIC 16F88 Microcontroller
  - 1 – 4.7K Ohm Resistor
  - 1 – 20K Tripot
  - 1 – LCD Screen, Jameco # 618003
- **Procedure:**
  - Wire the circuit sonar1.
  - Open **sonar1.pbp** and download to your chip.
    - Place an object about 10 inches from the sonar and let the sonar take readings over time. Observe any changes in the readings.
    - Use the attached SRF04 Beam Pattern Plot sheet to plot the sensitivity of the SRF04 module detecting a 2"x 4" piece of lumber. Keep the wood perpendicular to the radial lines that converge at the SRF04. Record only readings that are valid and consistent with the range of the sonar.





SRF04 Beam Pattern Plot

- **Challenge:**
  - o Using a servo and a SRF04 for obstacle avoidance:
    - ▪ Use a SRF04 mounted on a servo to sweep through 180 degrees and navigate your robot to avoid obstacles. At this point, do not use an interrupt, but rather use pauses in your forward movement.

Electronics and Robotics I Week 26
Ultra-Sonic LAB 3 – Completion of Sonar Car

- **Purpose:** The purpose of this lab is to have the student complete the robotic sonar car project.

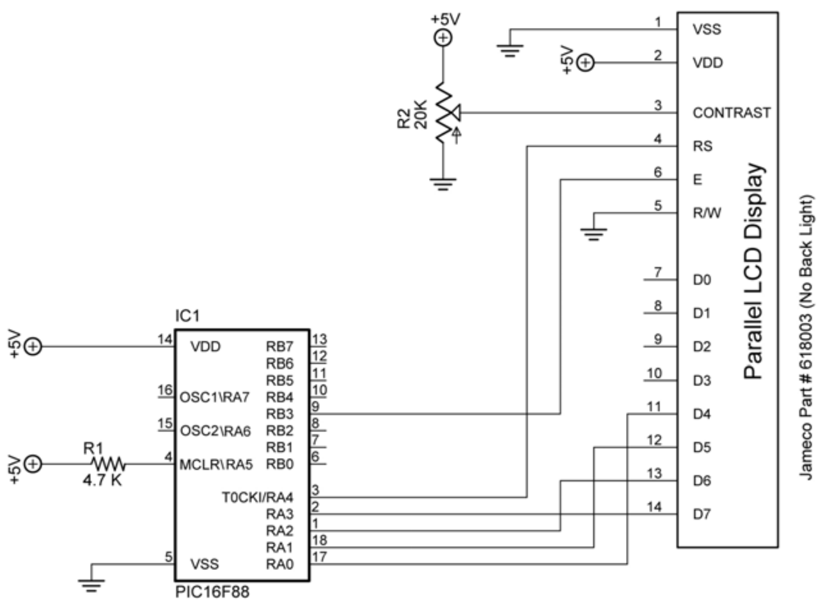
- **Apparatus and Materials:**

  - See parts list at: http://www.cornerstonerobotics.org/excel%20doc/robotics_2_parts_list.pdf

- **Procedure:**
  - Complete the mechanical and electronic systems on the car. For the schematics see:
    - Sonar Car Circuitry 1: http://www.cornerstonerobotics.org/schematics/pic_programming_sonar_car1.pdf
    - Sonar Car Circuitry 2: http://www.cornerstonerobotics.org/schematics/pic_programming_sonar_car2.pdf
  - Program the car with sonar_car1:
    - Format in .pbp: http://www.cornerstonerobotics.org/code/sonar_car1.pbp
    - Format in .pdf: http://www.cornerstonerobotics.org/code/sonar_car1.pdf
- **Photos:**
  - To see past project solutions see: http://www.cornerstonerobotics.org/sonar_car_2008.php

Electronics and Robotics I Week 27
Sonar Car 2 – Arrays and SRF04 Ultra-Sonic Ranger Finder Readings
LAB 1 – Simple Arrays in PicBasic Pro

- **Purpose:** The purpose of this lab is to acquaint the student with the use of arrays in a PicBasic Pro program.
- **Apparatus and Materials:**
  - 1 – Analog/Digital Trainer or Breadboard w/ +5V Power Supply
  - PIC16F88 Microcontroller
  - Hantronix HDM16216H-5-300S 16x2 LCD, Jameco #618003
  - 20 K Potentiometer
  - 4.7 K Resistor
- **Procedure:**
  - Wire the circuit "array1 and array2" shown below:



array1 and array2

  - Import and run **array1.pbp**. See: http://cornerstonerobotics.org/code/array1.pbp
  - Discuss the operation of the program.
  - Import and run **array2.pbp**. See: http://cornerstonerobotics.org/code/array2.pbp
  - Discuss operation of the program.

- **Challenge:**
  - Using **array2.pbp** and **sonar1.pbp**, write a program that takes 4 ultra-sonic readings one second apart, then display each reading on an LCD for one second. For **sonar1.pbp**, see: http://cornerstonerobotics.org/code/sonar1.pbp

Electronics and Robotics I Week 27
Sonar Car 2 – Arrays and SRF04 Ultra-Sonic Ranger Finder Readings
LAB 2 – Programming the Sonar Car with sonar_car_b.pbp

- **Purpose:** The purpose of this lab is to review the second in a series of four programs that takes the class through the development of the final program sonar_car1.pbp. This lab reviews the program that adds taking ultra-sonic readings at each servo position then records data in dx_in & position arrays.

- **Apparatus and Materials:**

    - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics at: http://cornerstonerobotics.org/schematics/pic_programming_sonar_car1.pdf and http://cornerstonerobotics.org/schematics/pic_programming_sonar_car2.pdf

- **Procedure:**
    - Open the program as **sonar_car_b.pbp.** See: http://cornerstonerobotics.org/code/sonar_car_b.pbp
    - Discuss operation of the program.

Electronics and Robotics I Week 28
Sonar Car 3 – Select Case Command / Obstacle Avoidance
LAB 1 – SELECT CASE Command

- **Purpose:** The purpose of this lab is to acquaint the student with the use of **SELECT CASE** in a PicBasic Pro programming.

- **Apparatus and Materials:**

    - 1 – Breadboard w/ +5V Power Supply
    - PIC16F88 Microcontroller
    - 4.7 K Resistor
    - Other materials to be determined by student

- **Procedure:**
    - Connect 4 LEDs to pins RB0 – RB3 on a PIC16F88. Don't forget the current limiting resistors.
    - Write a new PicBasic Pro program that accomplishes the following task:
        - Create a **FOR..NEXT** loop to run 100 times.
        - Use the **SELECT CASE** command to:
            - Light the LED connected to RB0 only when the loop number is less than 50.
            - Light the LED tied to RB1when the loop number equals 50.
            - Light the LED on RB2 when the loop number is greater than 90.
            - Light the LED on RB3 when the LED on RB0, RB1, and RB2 are not lit.
        - Have the program run forever.

Electronics and Robotics I Week 28
Sonar Car 3 – Select Case Command / Obstacle Avoidance
LAB 2 – Programming the Sonar Car with sonar_car_c.pbp

- **Purpose:** The purpose of this lab is to review the third in a series of four programs that takes the class through the development of the final program sonar_car1.pbp. This lab reviews the portion of the program that adds rotating the car to align with the longest sonar reading.

- **Apparatus and Materials:**

    - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics at: http://cornerstonerobotics.org/schematics/pic_programming_sonar_car1.pdf and http://cornerstonerobotics.org/schematics/pic_programming_sonar_car2.pdf

- **Procedure:**
    - Open the program as **sonar_car_c.pbp.** See: http://cornerstonerobotics.org/code/sonar_car_c.pbp
    - Discuss operation of the program.

Electronics and Robotics I Week 29
Sonar Car 4 – Collision Detection LAB 1 – Backup Routine

- **Purpose:** The purpose of this lab is to challenge the student to solve a common problem in robotics, collision detection.

- **Apparatus and Materials:**

  - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics at: http://cornerstonerobotics.org/schematics/pic_programming_sonar_car1.pdf and http://cornerstonerobotics.org/schematics/pic_programming_sonar_car2.pdf

- **Procedure:**
  - Program your ultra-sonic car such that when the car travels forward and an object presses one of the switches mounted on the front then the car:
    - Will backup for 1 second,
    - Turn slightly in the direction opposite of the activated switch,
    - Pan through the 7 servo positions again and take new readings.
  - Hint:
    - If the car is programmed to travel forward for a long time using a long **PAUSE** and the front switch is pressed during the long **PAUSE**, the PIC will not recognize the pressed switch event. You must design the program to move forward in short increments so the program can keep monitoring (polling) the front switches. Use an **IF..THEN** loop.

Electronics and Robotics I Week 29
Sonar Car 4 – Collision Detection
LAB 2 – Programming the Sonar Car with sonar_car_d.pbp

- **Purpose:** The purpose of this lab is to review the fourth in a series of four programs that takes the class through the development of the final program sonar_car1.pbp. This lab reviews the portion of the program that detects collisions with obstacles when the ultra-sonic sensor fails to detect an object.

- **Apparatus and Materials:**

    - 1 – Sonar car with Sonar Car Circuitry 1 & 2 on breadboard – see schematics at: http://cornerstonerobotics.org/schematics/pic_programming_sonar_car1.pdf and http://cornerstonerobotics.org/schematics/pic_programming_sonar_car2.pdf

- **Procedure:**
    - Open the program as **sonar_car_d.pbp** (the same program as sonar_car1.pbp)**.** See: http://cornerstonerobotics.org/code/sonar_car_d.pbp
    - Discuss operation of the program.