Cornerstone Electronics Technology and Robotics I Week 15
Voltage Comparators Tutorial

- Administration:
  - Prayer
- Robot Building for Beginners, **Chapter 15**, Voltage Comparators:
  - Review of Sandwich's Circuit: To this point we have:
    - 9 Volt Power supply
    - LED power indicator
    - Photoresistor sensors
    - Now we will add an integrated circuit - the brains.
  - Voltage Comparators:
    - A comparator is a device whose output is HIGH when the voltage on the positive (+) input is greater than the voltage on the negative (-) input and LOW when the positive input voltage is less than the negative input voltage. This is true regardless whether the comparator is set up for inverting or non-inverting operation.
    - Another way of defining a comparator is to say that a comparator circuit is used to compare two voltage inputs and determine which is the larger of the two.
    - Inputs into a comparator can be an analog voltage; the output is digital.
    - Two Basic Comparator Operations:
      - Inverting Operation: V_{REF} (the reference voltage) assigned to the positive input. When V_{IN} (the input voltage) exceeds V_{REF}, the output V_{OUT} goes from HIGH to LOW.

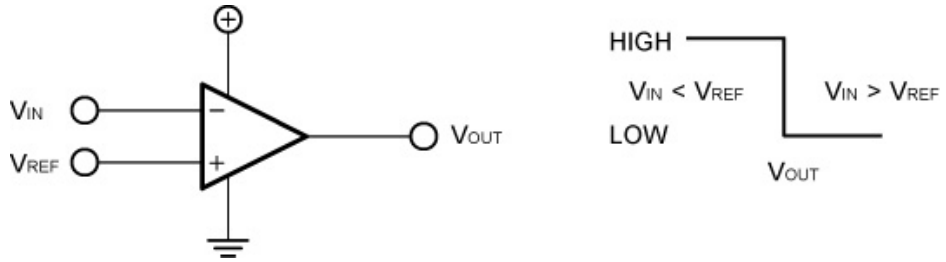


Figure 1 – Basic Inverting Operation

The inverting operation can be represented in another graphical form:

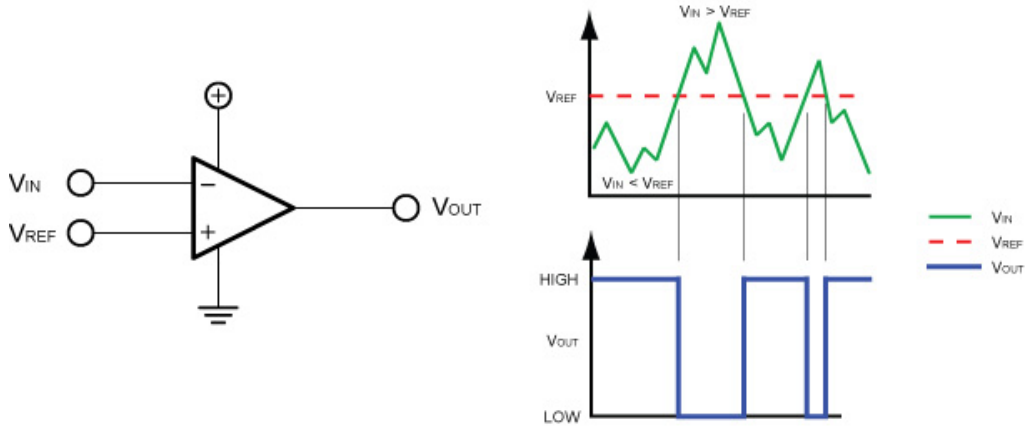


Figure 1 – Basic Inverting Operation

- Non-inverting Operation: V_{REF} (the reference voltage) assigned to the negative input. When V_{IN} exceeds V_{REF}, the output V_{OUT} goes from LOW to HIGH.

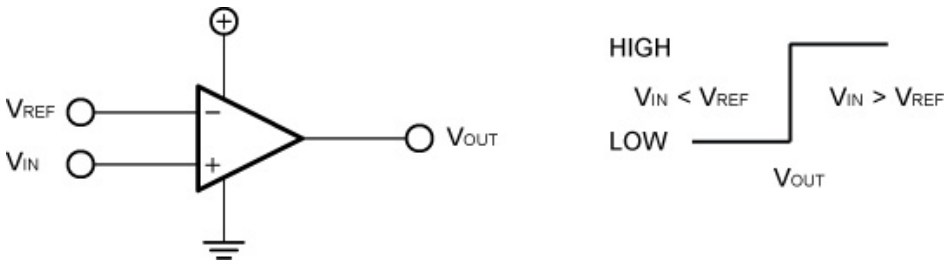


Figure 2 – Basic Non-inverting Operation

The non-inverting operation can be represented in another graph:

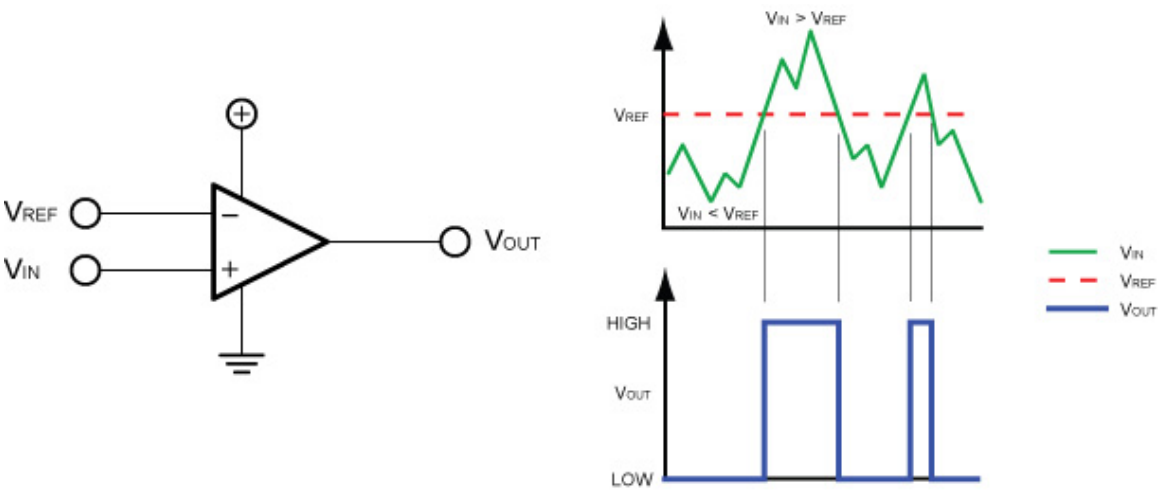


Figure 2 – Basic Non-inverting Operation

- 741 Op Amp:
  - A 741 op amp can be used to function as a comparator.
  - The 741 functions as a comparator when it is operated in an open-loop mode, that is, there is no feedback resistor.
  - The output varies from full on to full off with very small changes in the input voltage due to the high gain.
  - Perform Voltage Comparators Lab 1 – 741 Comparator
- LM393 Dual Comparator:
  - LM393 consist of two independent voltage comparators designed to operate from a single power supply over a wide voltage range.
  - LM393 datasheets:
    - http://www.onsemi.com/pub/Collateral/LM393-D.PDF
    - http://downloads.solarbotics.com/PDF/LM393.pdf
    - http://www.fairchildsemi.com/ds/LM%2FLM393.pdf
  - LM 393 Characteristics:
    - Two independent voltage comparators
    - Single power supply, 2V – 36V
    - Operate over a wide range of voltages, up to about 36 V
    - Low input offset voltages in the mV range. This means that the LM393 can compare voltages that are very close to each other.
    - Like many older chips, the LM393 can not source as much current as it can sink. The terminology source and sink is from the water analogy, where water comes out of the source and then goes into the sink.
      - **Chip as a Source:** In Figure 3 below, when the pin connected to R1 goes HIGH, the chip connects the source voltage (+9V) to the load (the LED), similar to the switch in Figure 4.

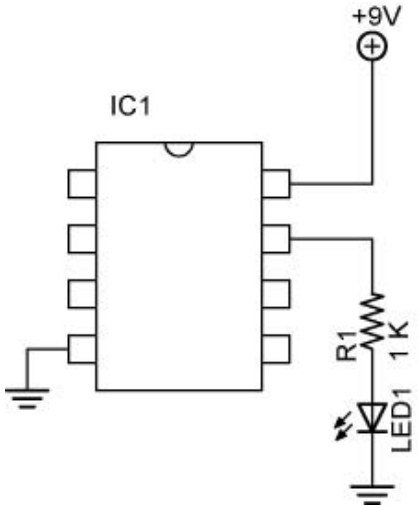


Figure 3 - Chip Acting as a Source

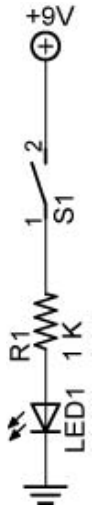


Figure 4 - Chip Acts Similar to Switch S1

- **Chip as a Sink:** In Figure 5, when the pin connected to the LED goes LOW, the chip connects the load to ground, similar to the switch in Figure 6.

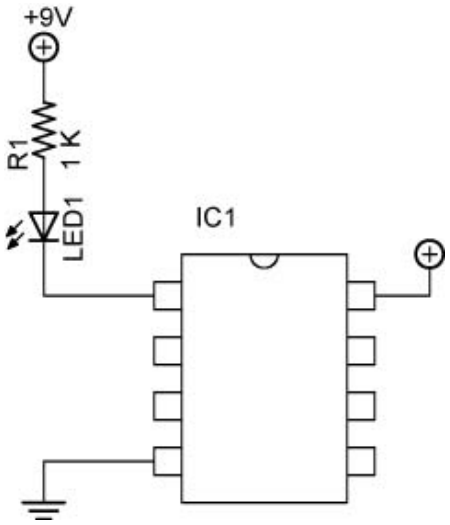
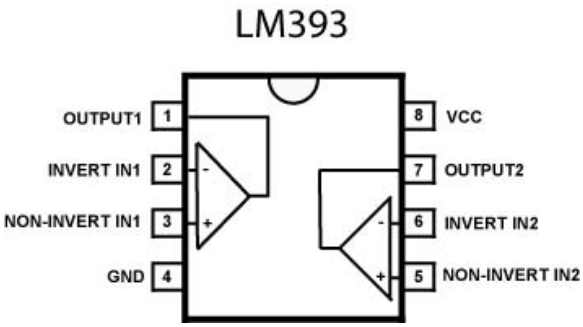


Figure 5 - Chip Acting as a Sink **Figure 6 - Chip Acts Similar to Switch S1**

- Pin Layout:



The semi-circle notch in the chip locates pin 1.

- Perform Voltage Comparators Lab 2 – LM393N Comparator
- Perform Voltage Comparators Lab 3 – Brightness Comparison Circuit

o Other web references:

- http://www.techitoutuk.com/knowledge/electronics/buildingblocks/opamp/index.html
- http://www.technologystudent.com/elec1/opamp3.htm
- http://www.uoguelph.ca/~antoon/gadgets/741/741.html
- http://booksbybibin.14.forumer.com/a/ic741-tutorial_post38.html

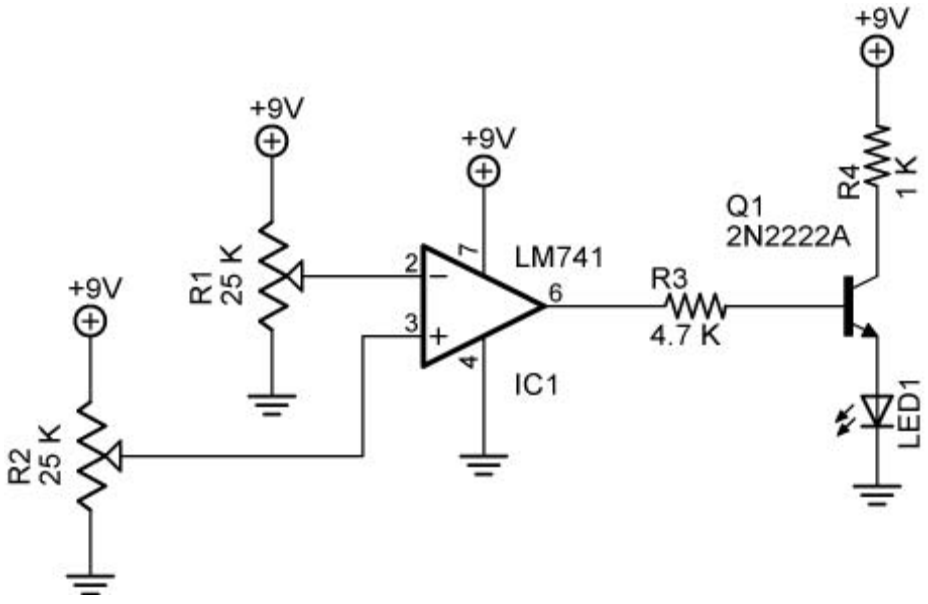
Electronics Technology and Robotics I Week 15
Voltage Comparators Lab 1 – 741 Comparator

- **Purpose:** The purpose of this lab is to test the 741 IC as a comparator.

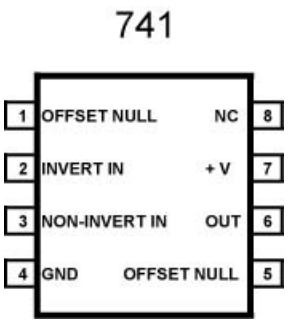
- **Apparatus and Materials:**

  - 1 – Solderless Breadboard with 9 V Power Supply
  - 3 – Digital Multimeters
  - 1 – 741 Op Amp
  - 2 – 25 K Potentiometers
  - 1 – 4.7 K Ω Resistor
  - 1 – 1 K Ω Resistor
  - 1 – 2N2222A NPN Transistor
  - 1 – LED

- **Procedure:**
  - Build Circuit 1 and use three multimeters to measure V_{REF}, V_{IN}, and V_{OUT}.
  - Non-inverting Operation:
    - In the first test, let pin 2 be the reference voltage (V_{REF}). Adjust R_1 to set pin 2 to about 4.5 V.
    - Adjust R_2 so the voltage input (V_{IN}) into pin 3 varies from 0 to 9V. If V_{IN} is less than V_{REF} is the LED on or off? Measure V_{OUT}. If V_{IN} is more than V_{REF} is the LED on or off? Measure V_{OUT}. Record your results.
    - At what voltage does the LED change state? Record your results.
  - Inverting Operation:
    - In the second test, let pin 3 be the reference voltage (V_{REF}). Adjust R_2 to set pin 3 to approximately 4.5 V.
    - Adjust R_1 so the voltage input (V_{IN}) into pin 2 varies from 0 to 9V. Make the same observations and measurements as in the first test.



Circuit 1



741 Pin Layout or Pinout

Results:

- Test 1:
  - Pin 2 reference voltage (V_{REF}): _____V
  - Pin 3 (V_{IN}) less than V_{REF}: LED on or off V_{OUT} = _____ V
  - Pin 3 (V_{IN}) more than V_{REF}: LED on or off V_{OUT} = _____ V
  - V_{IN} where the LED changes state? _____V
- Test 2:
  - Pin 3 reference voltage (V_{REF}): _____V
  - Pin 2 (V_{IN}) less than V_{REF}: LED on or off V_{OUT} = _____ V
  - Pin 2 (V_{IN}) more than V_{REF}: LED on or off V_{OUT} = _____ V
  - V_{IN} where the LED changes state? _____V

- **Conclusions:**
  - How do the results from Test 1 differ from the results of Test 2?

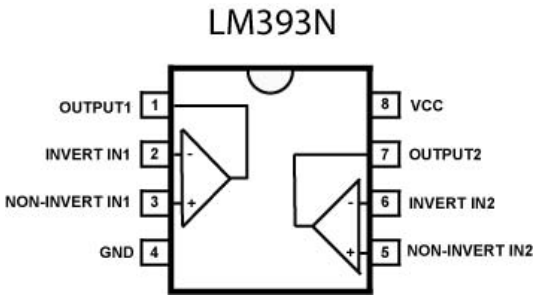
Electronics Technology and Robotics I Week 15
Voltage Comparators Lab 2 – LM393N Comparator

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

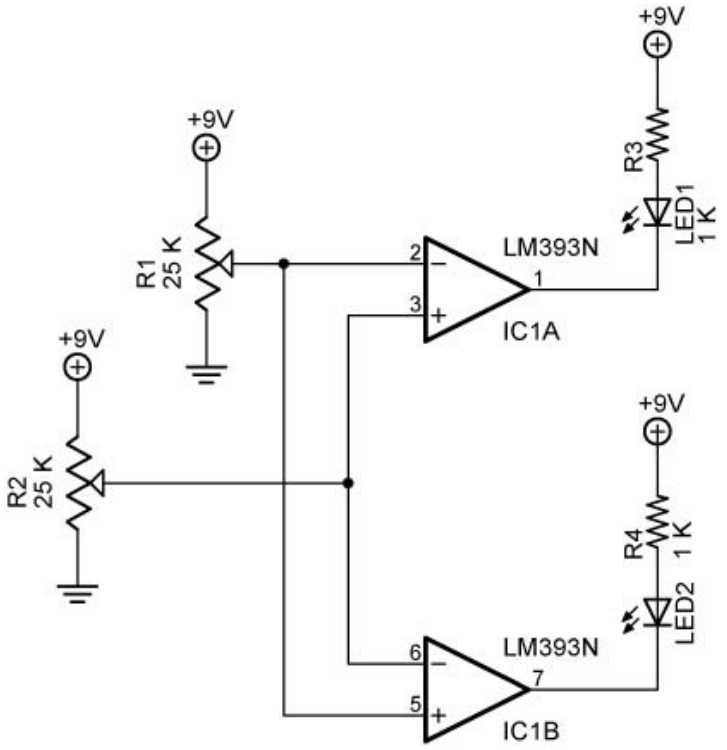
- **Apparatus and Materials:**

  - 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

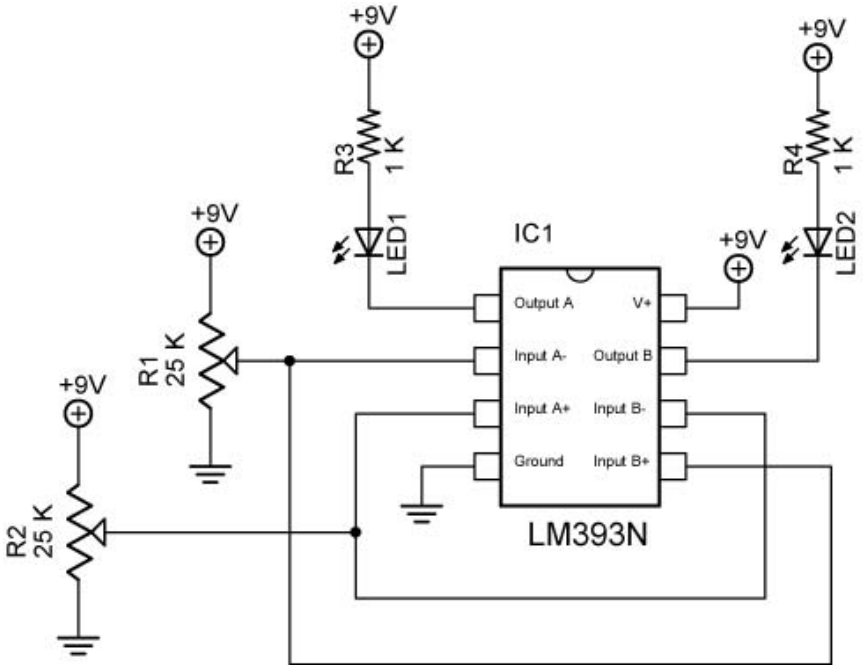
- **Procedure:**
  - Build Circuit 2. Wiring Diagram 1 may assist in the assembly of the circuit.
  - In this test, let pins 2 and 5 be the reference voltage (V_{REF}). Adjust R_1 to set pins 2 and 5 to about 4.5 V.
  - Adjust R_2 so that the voltage input (V_{IN}) into pins 3 and 6 varies from 0 to 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 Pin Layout:



  - Always 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 2 of IC1A is set for non-inverting mode, what mode is IC1B in?

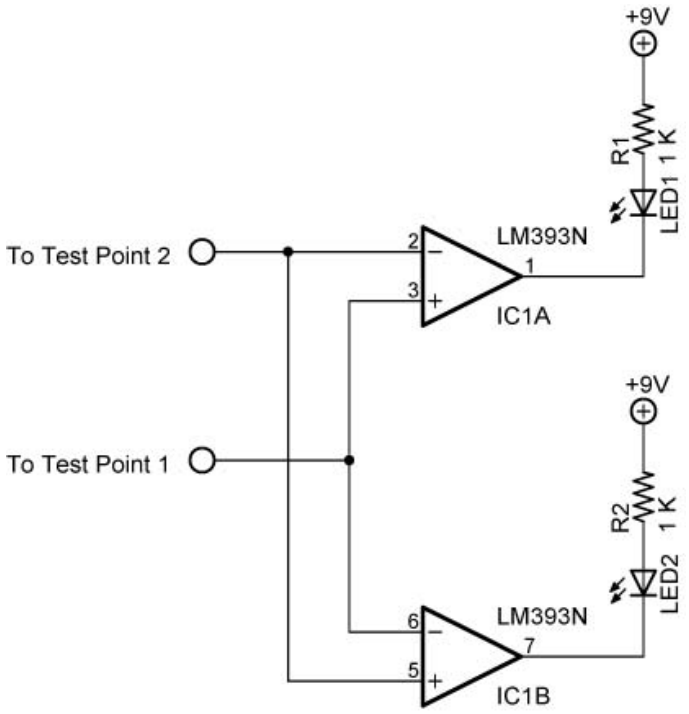
Electronics Technology and Robotics I Week 15
Voltage Comparators Lab 3 – Brightness Comparison Circuit

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

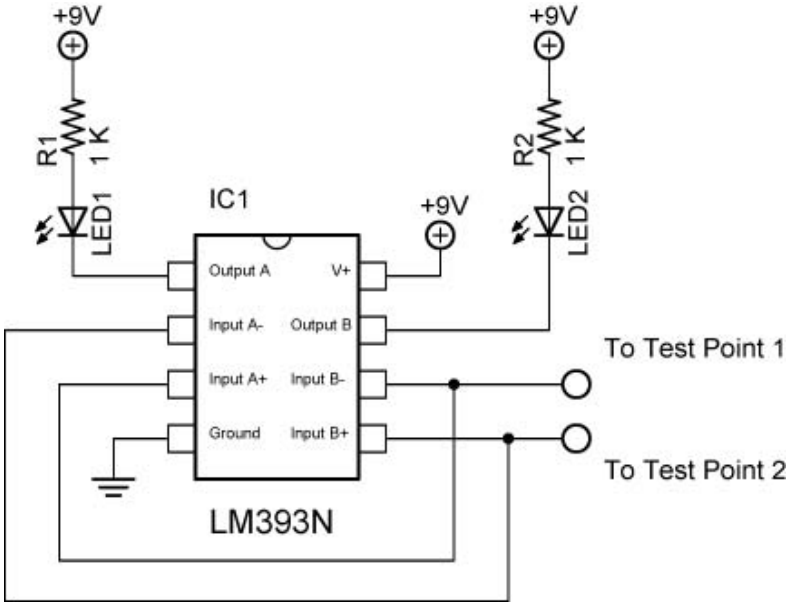
- **Apparatus and Materials:**

    - 1 – Solderless Breadboard with 9 V Power Supply
    - 1 – LM393N Comparator
    - 2 – 25 K Potentiometers
    - 2 – 1 K Ω Resistors
    - 2 – 470 Resistors
    - 2 – LEDs (Regular)
    - 2 – LEDs (Bright White)

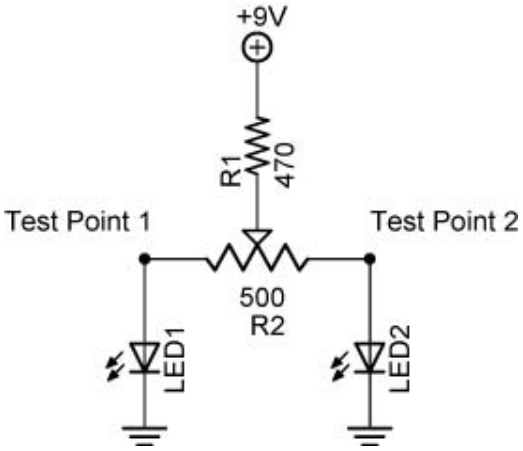
- **Procedure:**
    - Build Circuit 3. Wiring Diagram 2 is available to assist in the assembly of the circuit.
    - The test points 1 and 2 are connected to the brightness circuit from Week 8. Refer to Circuit 4 for connections.
    - Move your hand over the photoresistors in the brightness circuit and observe the LED output of the LM393N IC.



Circuit 3

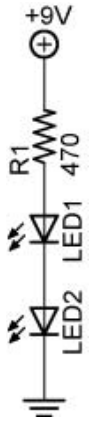


Wiring Diagram 2



Circuit 4 (from Week 8)

- The Headlight Circuit:
  - Wire the schematic Circuit 5 using the bright white LEDs.



Circuit 5

- **Conclusions:**
  - Sandwich will compare the voltages at Test Points 1 and 2 when following a black electrical tape line. Which side of the Sandwich will the motors 1 and 2 be connected to the have it follow the line?