

## Voltage Comparator Information And Circuits

This page provides basic information about voltage comparator integrated circuits and is to act as reference material for other circuits. The circuits shown are based on the LM339 Quad Voltage Comparator chip or the LM393 Dual Voltage Comparator chip. These devices are functionally identical. The LM311 Voltage Comparator can be used for these applications as well and also has a number of unique features.

[LM339 Data sheet - National Semiconductor \(PDF\)](#)

[LM393 Data sheet - National Semiconductor \(PDF\)](#)

[LM311 Data sheet - National Semiconductor \(PDF\)](#)

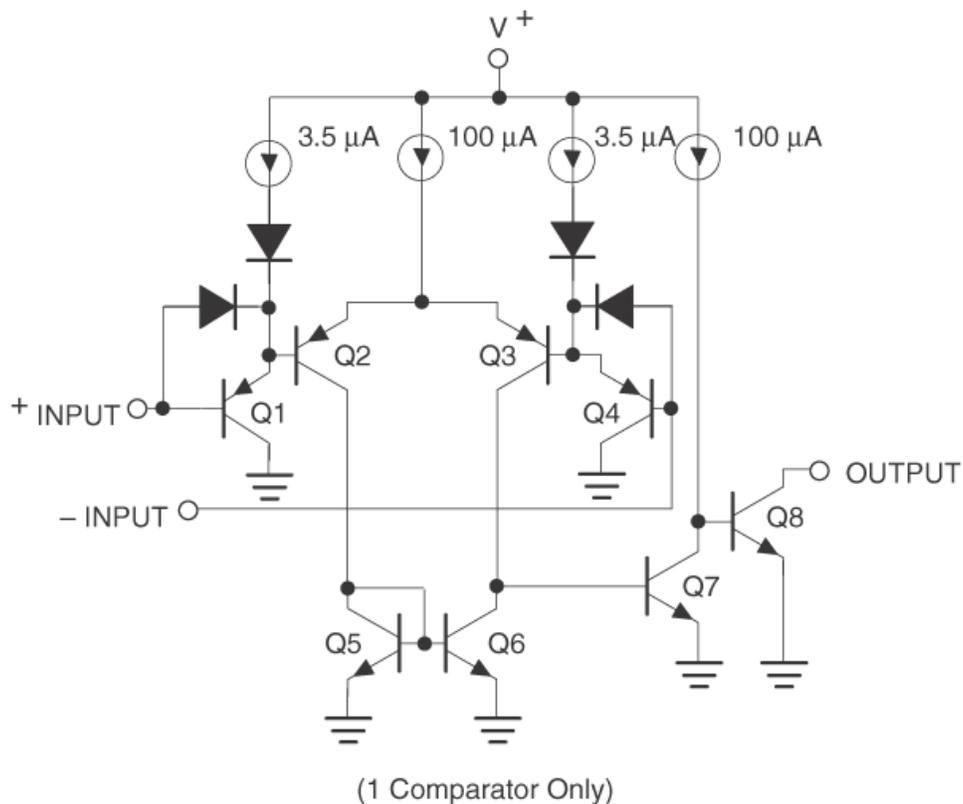
**NOTE:** Operational Amplifiers (OPAMPS) such as LM324, LM358 and LM741 cannot be used directly in many voltage comparator circuits. OPAMPS can often be used as voltage comparators if a diode or transistor is added to the amplifiers output. There is a diagram showing these additions further down this page.

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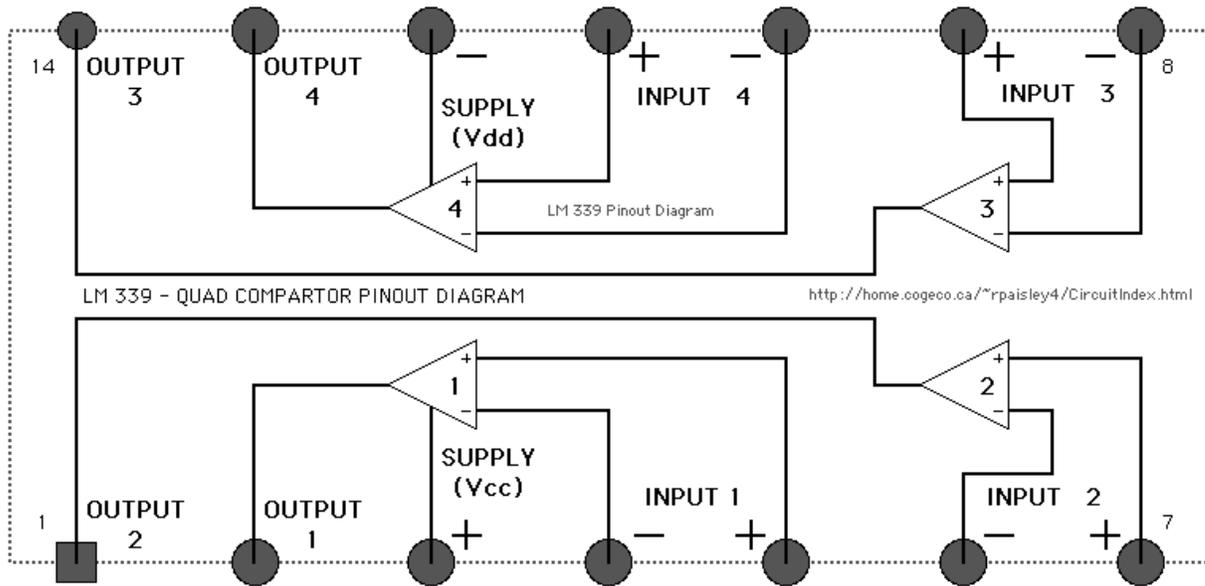


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### Internal Circuitry For 1/4 Of An LM339

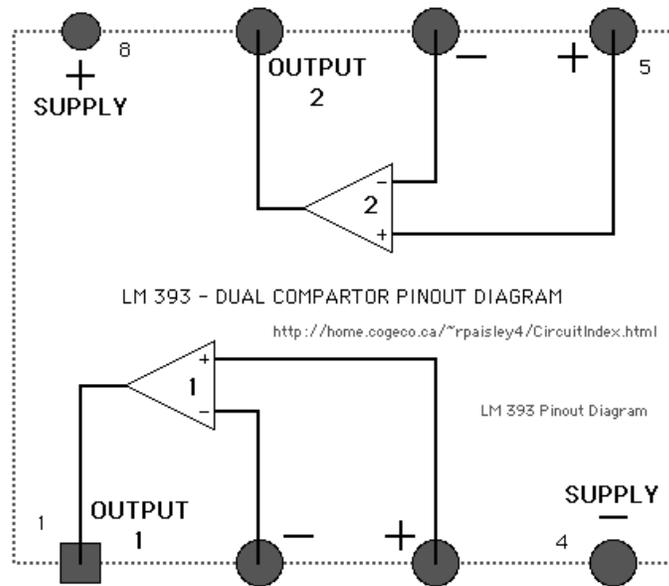


### Pin Diagram For An LM339



Print the diagram in the centre of a sheet of paper and then draw a circuit using the ICs pin locations.

### Pin Diagram For An LM393



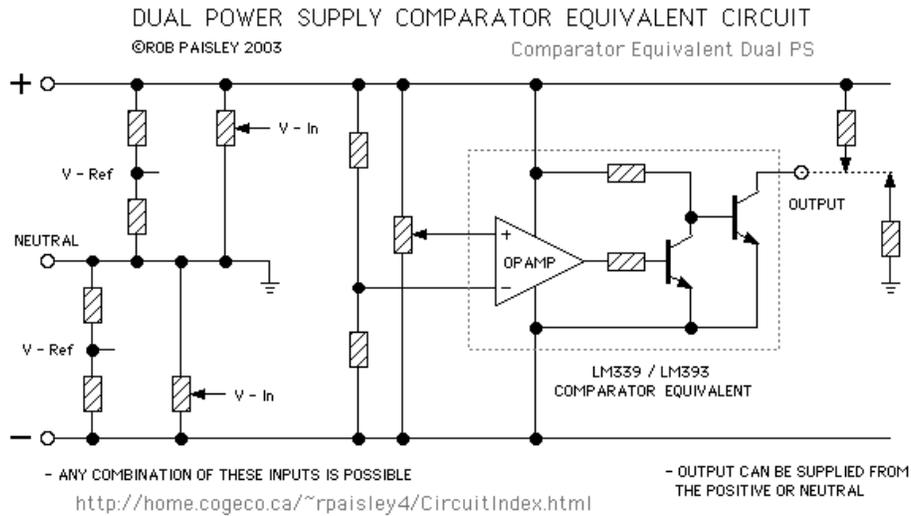
Print the diagram in the centre of a sheet of paper and then draw a circuit using the ICs pin locations.

### Pin Diagram For An LM311



connected to either the minus or neutral of the supply.

### Dual Supply Comparator Equivalent schematic



When operated from Dual or Split power supplies the input voltages can be above or below the common or zero voltage of the supply. Also, one of the comparator's inputs can be connected to the common so that a 'Zero Crossing' detector is created.

## Comparator Operation

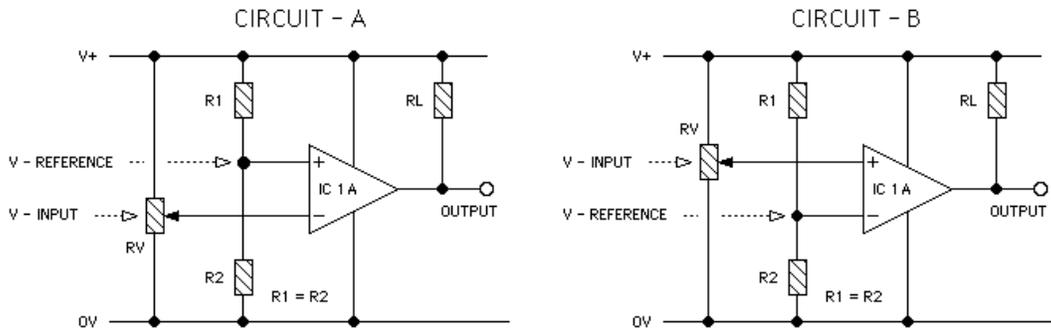
The following drawing show the two simplest configurations for voltage comparators. The diagrams below the circuits give the output results in a graphical form.

For these circuits the REFERENCE voltage is fixed at one-half of the supply voltage while the INPUT voltage is variable from zero to the supply voltage.

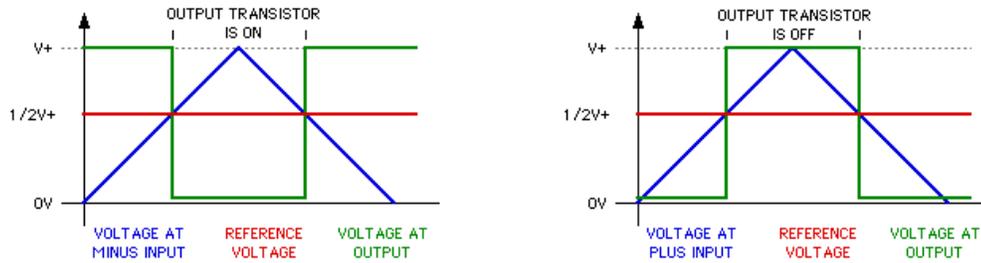
In theory the REFERENCE and INPUT voltages can be anywhere between zero and the supply voltage but there are practical limitations on the actual range depending on the particular device used.

## BASIC OPERATION OF VOLTAGE COMPARATORS

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Comparator Operation  
07 January, 2012

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

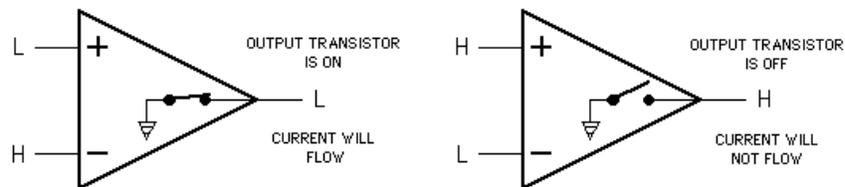


## Input Vs. Output Results

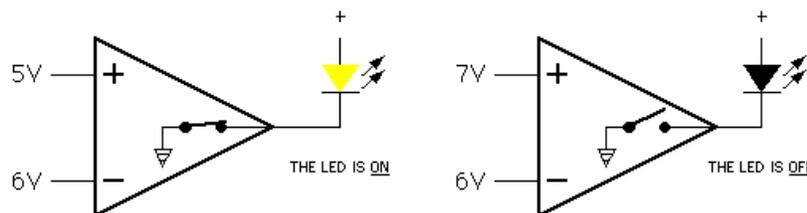
1. Current WILL flow through the open collector when the voltage at the PLUS input is lower than the voltage at the MINUS input.
2. Current WILL NOT flow through the open collector when the voltage at the PLUS input is higher than the voltage at the MINUS input.

## COMPARATOR - INPUT Vs. OUTPUT RULES

Comparator Rules Sheet 2a



## IN OTHER PICTOGRAMS



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

## Input Offset Voltage

Voltage comparators are not perfect devices and their performance may suffer from the effects of a parameter known as the Input Offset Voltage. The Input Offset Voltage for many comparators is only a few millivolts and in most circuits can be ignored.

Problems related to the Input voltage normally occur when the Input voltage changes very slowly.

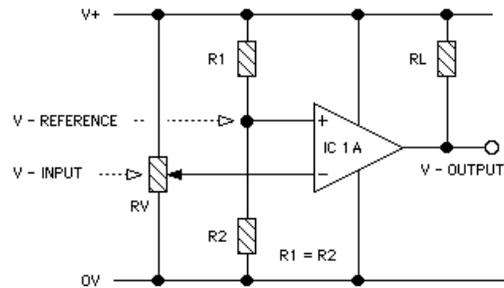
The net result of the Input Offset Voltage is that the output transistor does not fully turn on or off when the input voltage is close to the reference voltage.

The following diagram attempts to illustrate the effect of the input offset voltage with a slowly changing input voltage. This effect increases as the output transistor current increases so keeping the value of  $R_L$  high will help reduce the problem.

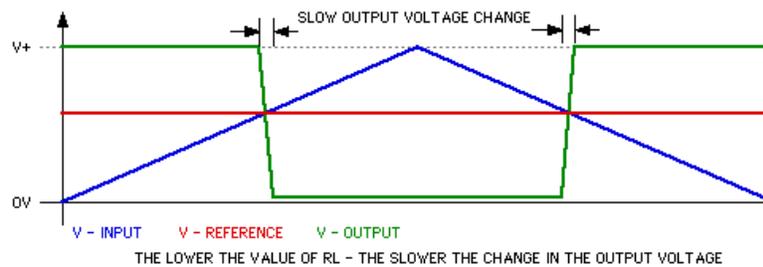
### EFFECT OF INPUT VOLTAGE OFFSET ON THE OUTPUT VOLTAGE

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Comparator Input Offset  
24 July, 2010



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>



The effects of the input offset voltage can be countered by adding hysteresis to the circuit. This causes the reference voltage to change when the comparators output goes high or low.

## Input Offset Voltage And Hysteresis

For most comparator circuits *Hysteresis* is the difference between the input signal voltages at which a comparator's output is either fully ON or fully OFF. Hysteresis in comparators is generally undesirable but it can also be added to a circuit to reduce the sensitivity to noise or a slowly moving input signal.

Internal hysteresis that is normal for comparators causes the output of the comparator to go from OFF to ON and vice-versa relatively slowly.

External hysteresis uses positive feedback from the output to the non-inverting input of the comparator. The resulting Schmitt trigger type circuit gives additional noise immunity and a cleaner output signal.

The effect of added hysteresis is that as the input voltage slowly changes, the reference voltage will quickly change in the opposite direction. This gives the comparator's output a "snap" action.

A mechanical analog of added hysteresis can be found in many toggle switches: As the handle moves past its center point, a spring in the switch forces the contacts of the switch to open or close, ensuring that the switch's contacts snap to the ON or OFF position.

## HYSTERESIS IN VOLTAGE COMPARATORS

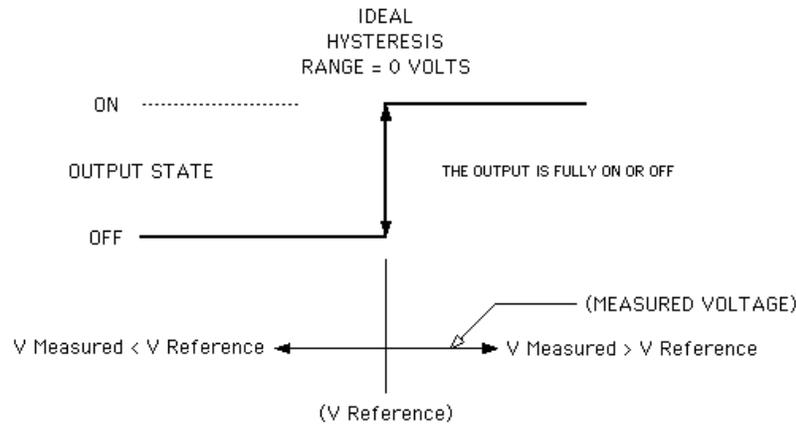
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Comparator Hysteresis 08

16 December, 2011

### IDEAL HYSTERESIS

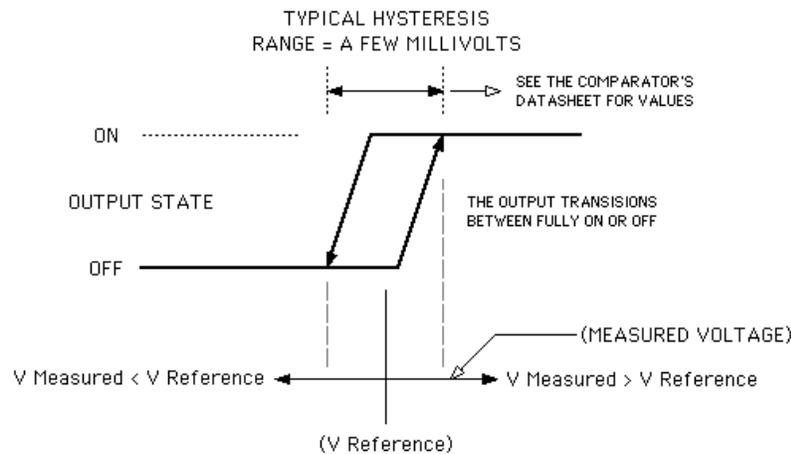
- IN AN IDEAL COMPARATOR, THE HYSTERESIS VOLTAGE RANGE WOULD BE ZERO VOLTS AND THE OUTPUT IS FULLY ON OR OFF.



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

### TYPICAL HYSTERESIS

- IN A TYPICAL COMPARATOR, THE HYSTERESIS VOLTAGE RANGE MAY BE A FEW MILLIVOLTS AND THE OUTPUT HAS A RANGE WHERE IT IS BETWEEN FULLY ON OR OFF.



The width of the loop outlined by an OFF-ON-OFF cycle is the input hysteresis voltage.

The inheint hysteresis voltage for most comparators is only a few millivolts and usually only affects circuits where the input voltage rises or falls very slowly or has voltage spikes known as "noise".

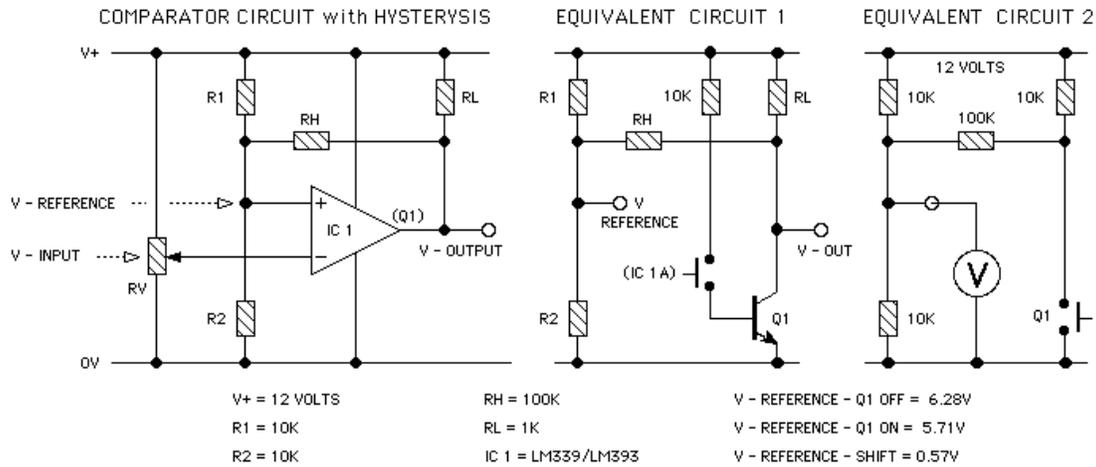
## Adding Hysteresis To A Comparator Circuit

A comparator's Hysteresis range can be increased by adding a resistor between the comparator's output and the PLUS input terminal. This creates a feedback loop so that when the output makes a transition the feedback changes the voltage at the positive which increases the voltage difference between the PLUS and MINUS inputs.

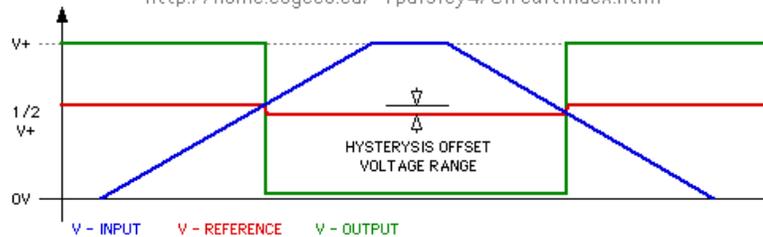
The feedback can only be made to the PLUS input terminal.

## ADDING HYSTERESIS TO THE PLUS INPUT OF A COMPARATOR

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Comparator Hysteresis E  
04 May, 2012

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### FINDING COMBINED RESISTANCES

OUTPUT TRANSISTOR - OFF

$$\frac{1}{\frac{1}{R1} + \frac{1}{RL + RH}} = R1 \text{ combined}$$

OUTPUT TRANSISTOR - ON

$$\frac{1}{\frac{1}{R2} + \frac{1}{RH}} = R2 \text{ combined}$$

( RL IS IGNORED )

- R1 combined = 9.099K

### CALCULATING REFERENCE VOLTAGES

OUTPUT TRANSISTOR - OFF

$$\frac{V+}{R1 \text{ combined} + R2} \times R2 = V - \text{REFERENCE}$$

OUTPUT TRANSISTOR - ON

$$\frac{V+}{R1 + R2 \text{ combined}} \times R2 \text{ combined} = V - \text{REFERENCE}$$

- R2 = combined = 9.091K

- THE VOLTAGE LOSS ACROSS THE COMPARATOR'S OUTPUT TRANSISTOR HAS BEEN IGNORED IN THE ABOVE CALCULATIONS.

### Increasing The Input's Hysteresis Range

If the comparator's output is initially 'OFF', the MINUS input voltage has to become above the PLUS input voltage by the hysteresis voltage range before the comparator output turns 'ON'.

If the comparator is 'ON', the MINUS input voltage needs to drop slightly below the PLUS input voltage by the hysteresis voltage range before it turns 'OFF'.

The hysteresis voltage range can be made large in order to force the comparator's output to change as quickly as possible. The FLIP-FLOP circuits shown later on this page make use of a large hysteresis to create the memory effect with large input voltage changes needed to trigger a change in the output.

## Hysteresis Resistor Calculator Page At AKAWA Electric Design

(Vref is the supply voltage)

## Adding Isolation Diodes To A Comparator's Output

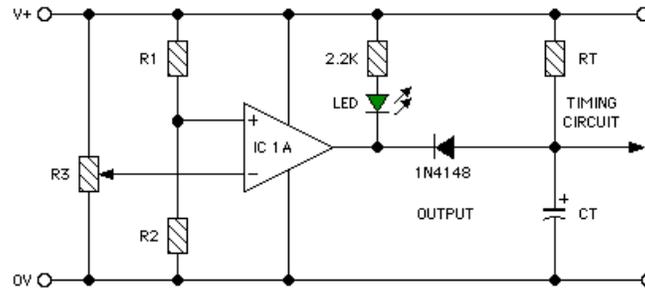
A diode can be added to the output of a comparator to allow a LED to indicate if the output of the comparator is HIGH or LOW without affecting the circuit that the comparator is connected to.

Diodes can also be used to separate multiple circuits connected to a single comparator.

### VOLTAGE COMPARATOR WITH ADDED DIODE AND LED

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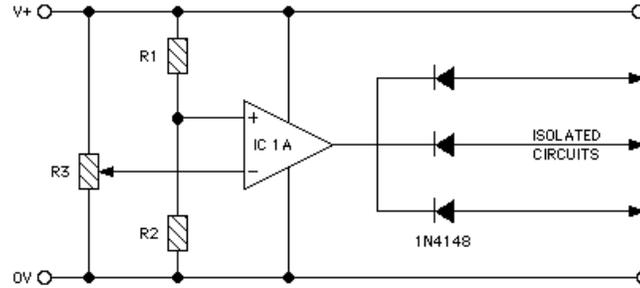
Comparator Output Diode  
03 May, 2012



- THE 1N4148 DIODE AT THE OUTPUT ALLOW THE USE OF A LED AT THE OUTPUT WITHOUT AFFECTING THE REST OF THE OUTPUT CIRCUIT.

- THE TIME CONSTANT OF THE RC CIRCUIT WILL BE AFFECTED SLIGHTLY.

### VOLTAGE COMPARATOR WITH ISOLATED OUTPUTS

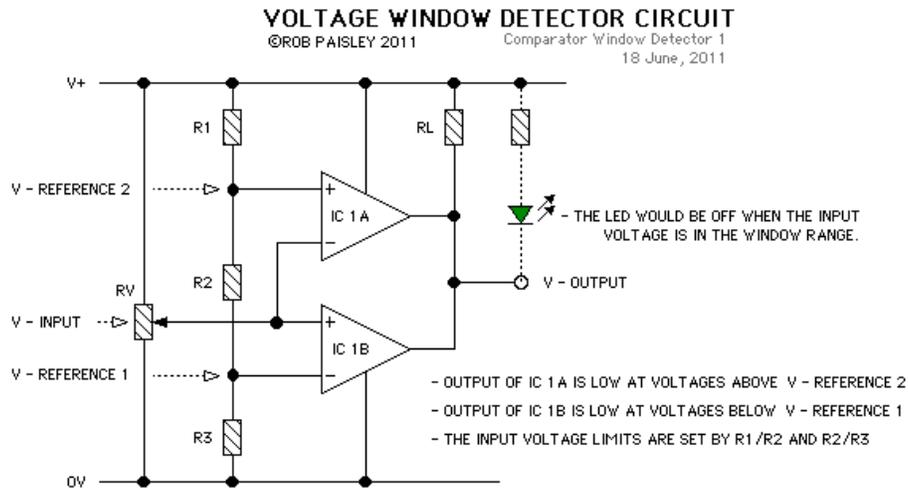


<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

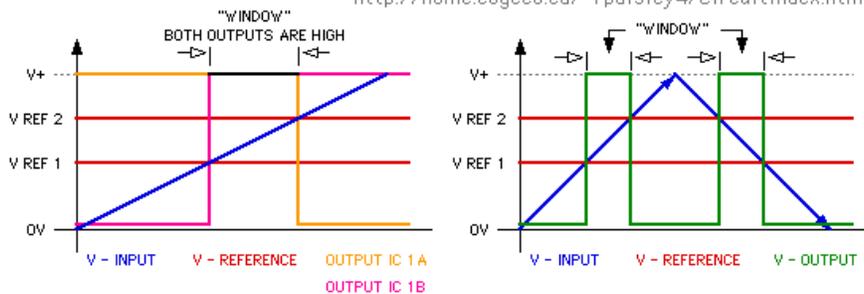
### Output Diodes

## Voltage Window Detector Circuit

Comparators with Open Collector outputs such as the LM339 or LM393 must be configured so the both outputs are HIGH when the voltage is within the desired limits. The LM311 comparator can have other output arrangements as it has both an open collector and open emitter on the output transistor.



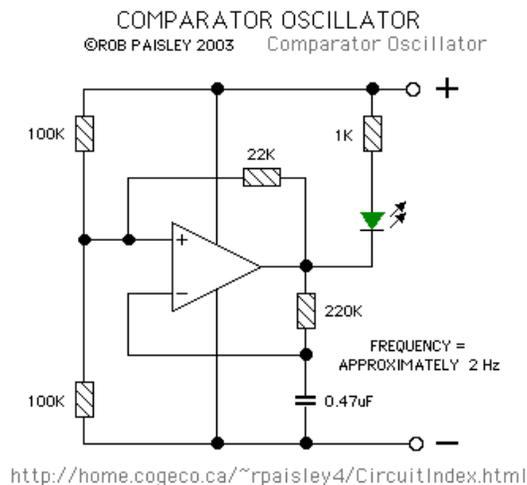
<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>



**Window Comparator**

## Comparator Oscillator Circuit

Comparators can also be used as oscillators but are not well suited for this type of application.



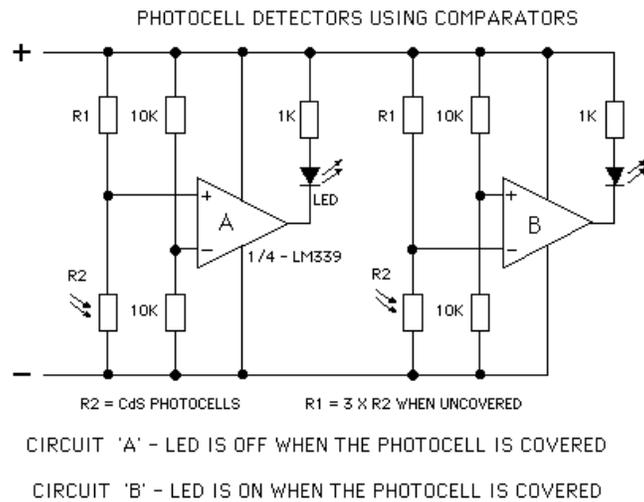
**Oscillator Made From A Comparator**

## Basic Comparator Circuits

The following diagrams are of some basic comparator circuits. Most have a Cadmium Sulfide photocell input but could just as easily use a phototransistor or a voltage signal from another circuit as an input. The resistance

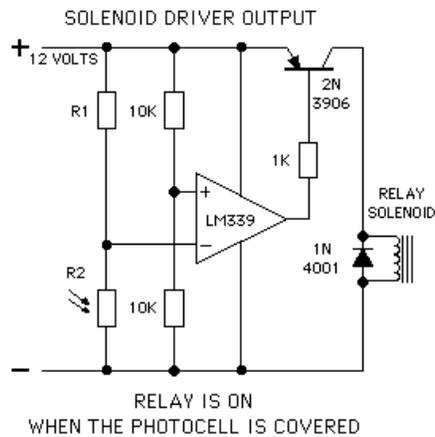
values are not critical but should be used as a guide. In most comparator circuits the ratio of the resistances is more important than their actual values.

## Photocell Circuits



### Photocell Circuits Schematic

If higher current loads are to be driven a PNP transistor can be added to the comparators output this will allow loads of up to 300Ma. to be controlled.

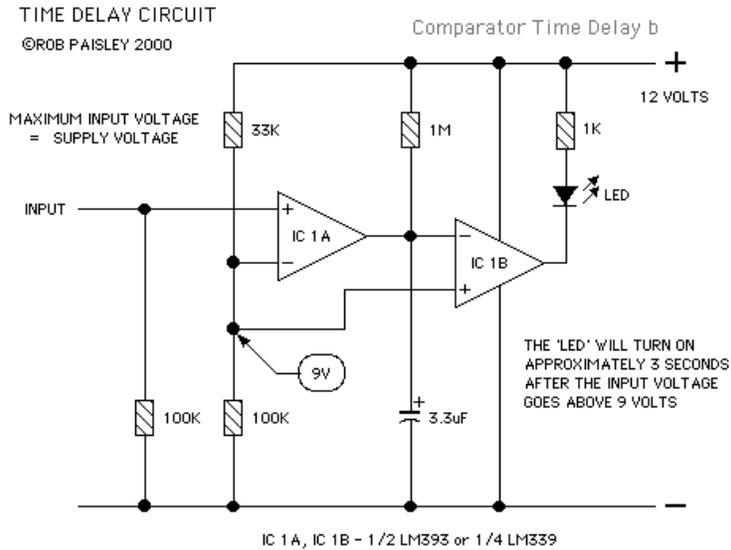


### Relay Driver Output Schematic

## Time Delay Circuits

Short timing functions such as a pulsed outputs or time delays can also be created with one or two comparator sections.

### Comparator Time Delay Schematic 1



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

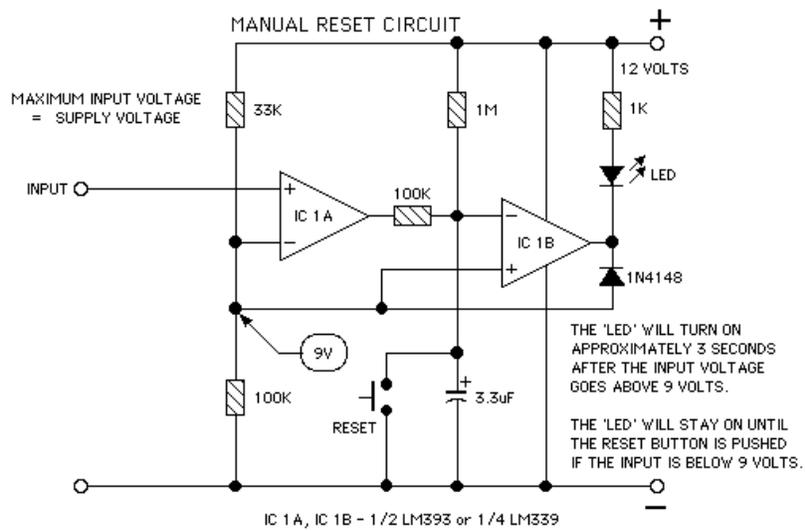
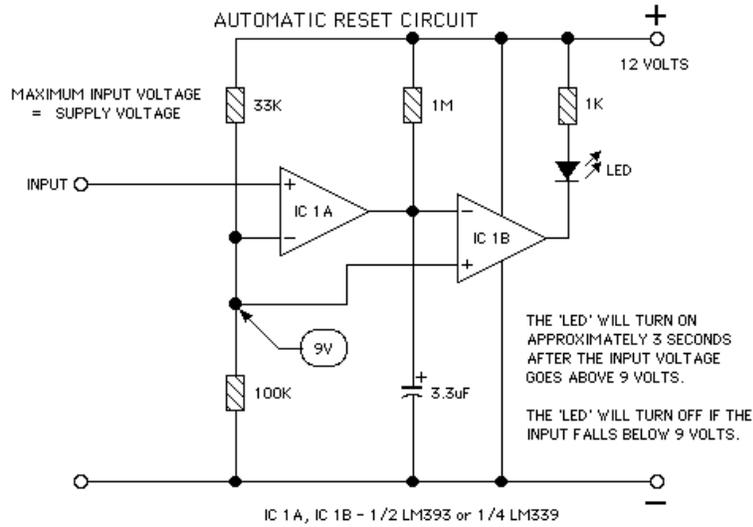
Notice that the second comparator section in the time delay circuit shares the same reference voltage input as the first. In most cases any number of comparators can have the same voltage source at one input, this can make circuits much less complicated.

More Delay circuits.

### Comparator Timer Delay Schematic 2

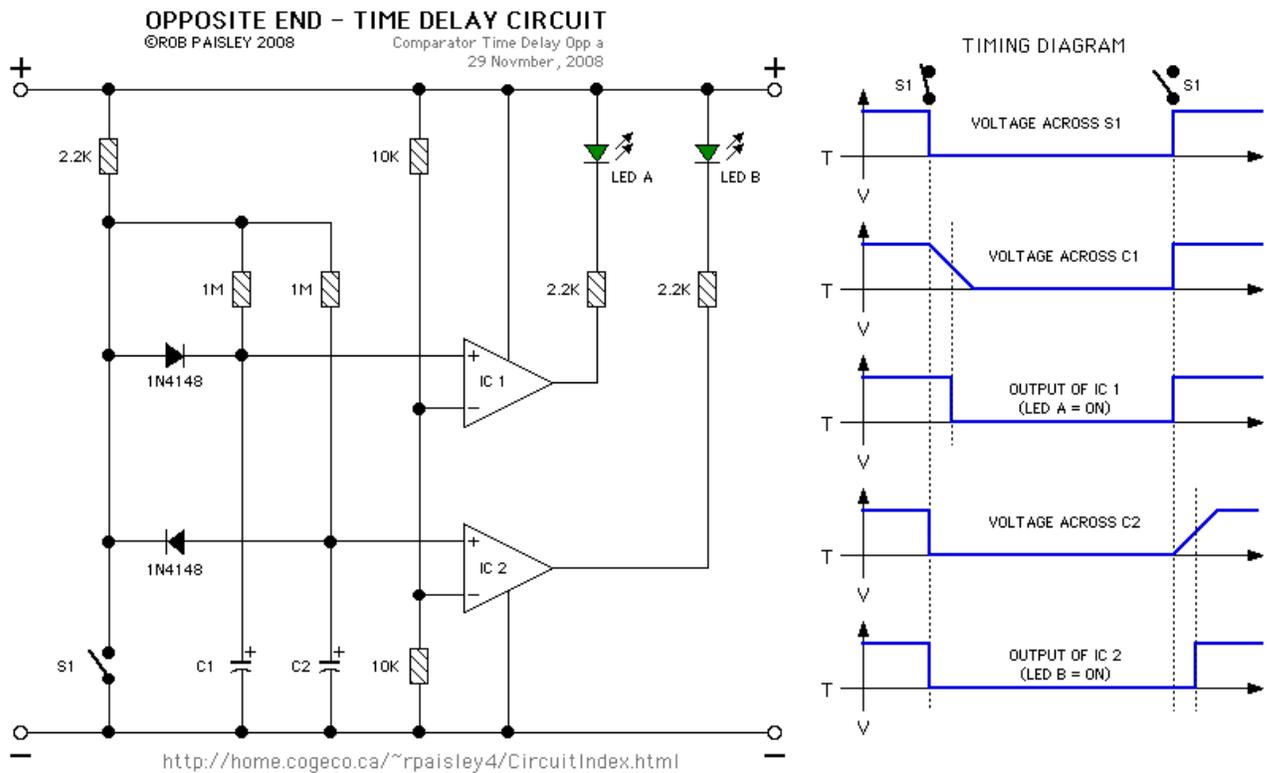
## TIME DELAY CIRCUITS - AUTOMATIC AND MANUAL RESET

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Comparator Time Delay o  
23 September, 2010

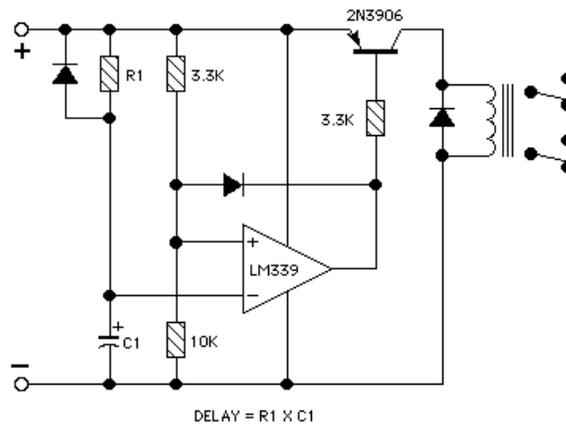
<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

**Comparator Timer Delay Schematic 3**



**Comparator Power-On Delay Circuit**

**COMPARATOR - POWER ON - DELAY CIRCUIT**  
©ROB PAISLEY 2010      Comparator Power On Delay  
23 February, 2010

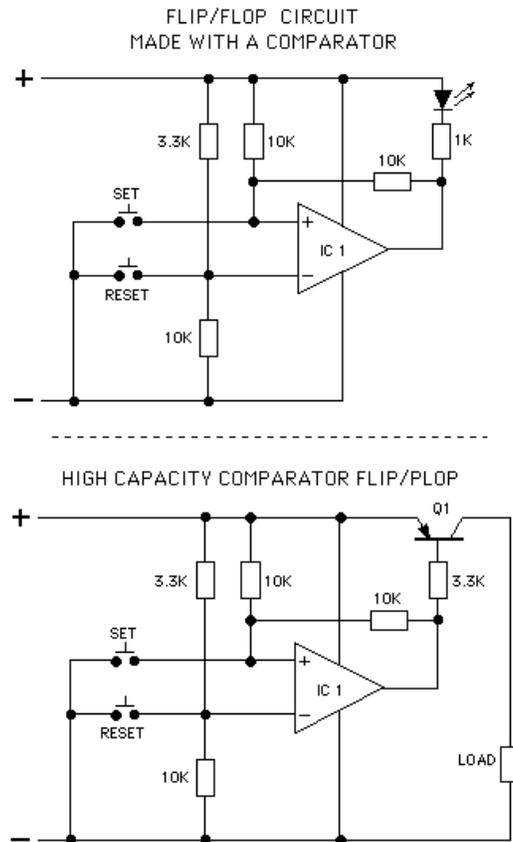


<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

THE RELAYS TURN ON 'X' SECONDS AFTER POWER IS APPLIED TO THE CIRCUIT

## Basic Memory Functions

Comparators can be made to perform a basic memory function by wiring them as a 'SET / RESET' type of FLIP/FLOP. This type of circuit can be used in unpluggable walk around throttles to remember the direction of the train when the controller is disconnected. In the next diagram the comparator will remember which switch was pushed last. If the 'SET' button is pushed the LED will be on, the 'RESET' button will turn the LED off. A higher current version is also shown.



**Comparator FLIP/FLOP Schematic**

How the Flip Flop works. A very basic description.

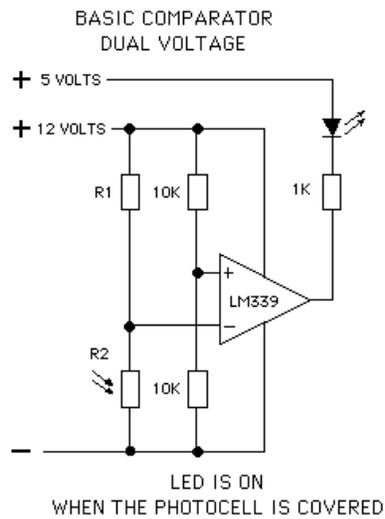
1. When the output of the comparator is off the voltage at the PLUS input will be the same as the supply voltage. With the PLUS input voltage higher than the MINUS input voltage the output will remain off.
2. When the SET button is pushed the voltage at the PLUS input will go to zero and the output will turn on.
3. When the SET button is release the voltage at the PLUS input will rise to 1/2 of the supply voltage and the output will remain turned on because the voltage at the PLUS input is remains below the voltage at the MINUS input.
4. When the RESET button is pressed voltage at the MINUS input will go to zero from its normal level of 3/4 of the supply voltage. The output will turn off because the voltage at the MINUS input is below the voltage at the PLUS input. When the output turns off the voltage at the PLUS input will rise to the supply voltage level.
5. When the RESET button is released the voltage at the MINUS input will rise to 3/4 of the supply voltage. The PLUS input voltage will stay above the voltage at the MINUS input and the output will stay turned off.

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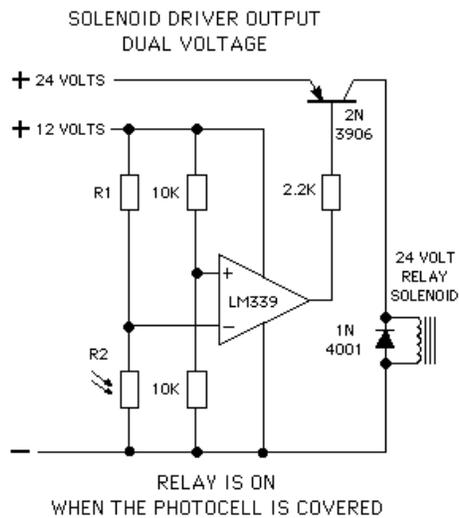
## Open Collector Output Transistors

Because the output transistor of the comparator has an open collector the supply and load voltages do not have to be the same. This means that the comparator could use a 12 Volt power supply while the load could be a 24 Volt relay or 5 Volt LED circuit.

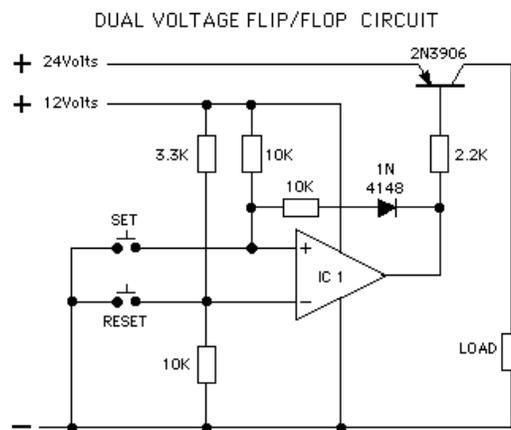
The following three diagrams are some examples of Dual voltage circuits. In the first two the voltage at the output of the comparators could even be full wave direct current.



**Dual Voltage Output Schematic**



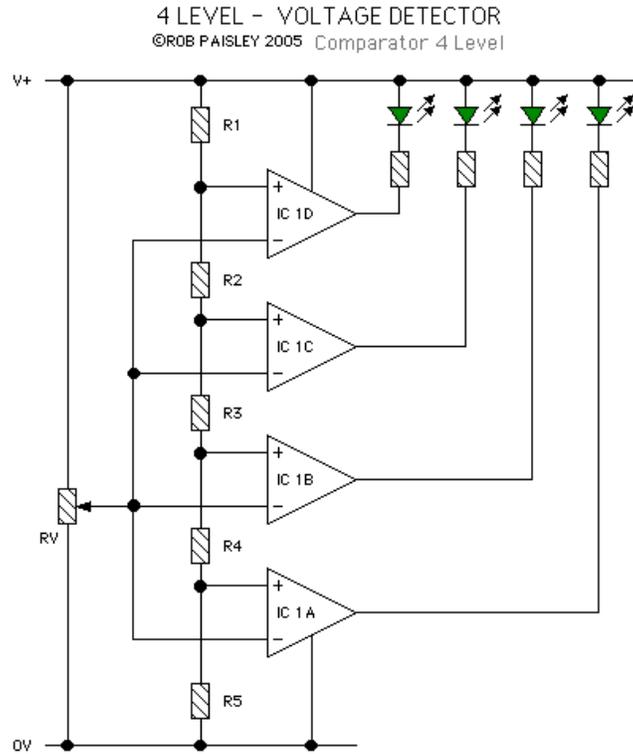
**Dual Voltage Relay Driver Output Schematic**



**Dual Voltage FLIP/FLOP Schematic**

## 4 Level - voltage Detector

This circuit can sequentially indicate 4 voltage levels. The voltages that the LEDs turn on at are determined by the values of resistors R1 through R5 arranged in a simple voltage divider circuit.



R1, 2, 3, 4, 5 - SELECTED TO GIVE THE DESIRED DETECTION VOLTAGE LEVELS  
AS EACH LEVEL IS PASSED THE CORRESPONDING LED TURNS ON

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

#### 4 Level Detector Schematic

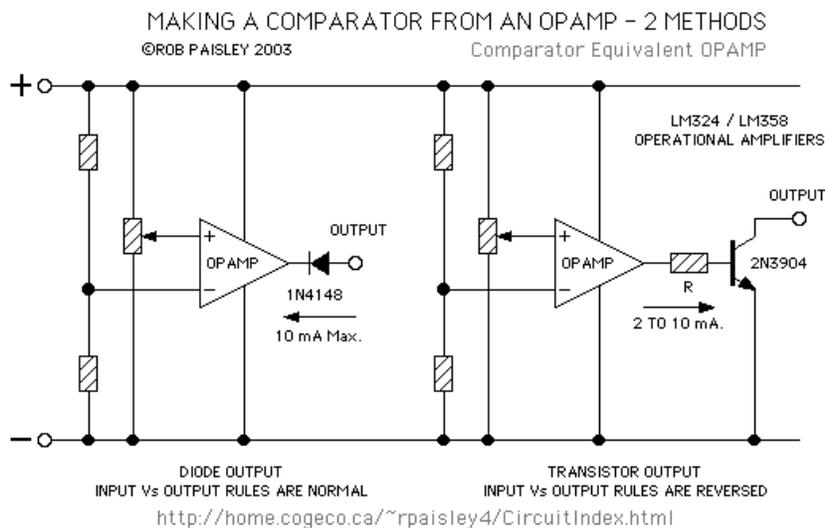
This circuit lacks a stable reference voltage and is therefore not suitable for indicating the voltages of batteries as the reference voltages will decrease as the battery voltage decreases.

An IC that is designed for voltage level indication is the LM3914 - Dot/Bar Display Driver. The LM3914 is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display.

There is also the LM3915 - Dot/Bar Display Driver. The LM3915 is a monolithic integrated circuit that senses analog voltage levels and drives ten LEDs, LCDs or vacuum fluorescent displays.

## Using An OPAMP As A Comparator

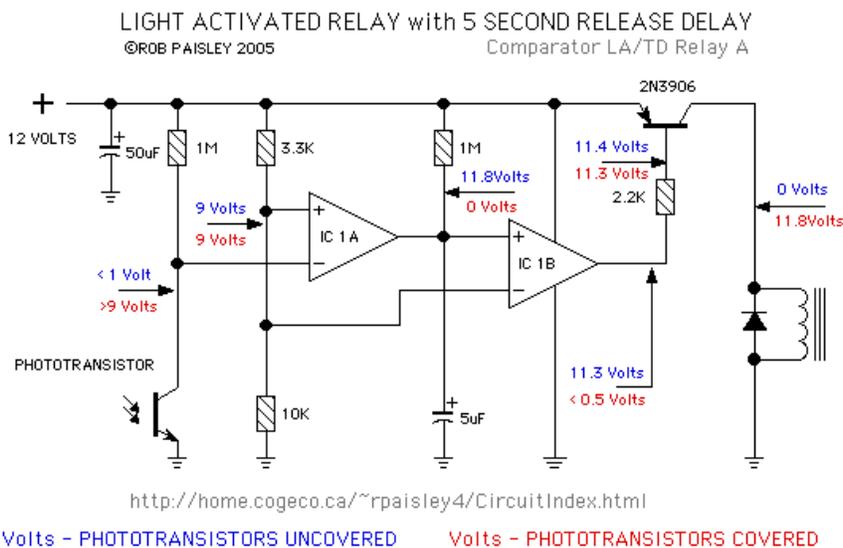
Operational Amplifiers can be used as comparators by adding a diode or transistor to the OPAMP's output. Using a transistor allows for a greater output current capacity than that of a typical comparator.



### Comparator Made From An Operational Amplifier

## Some Other Circuits

### LM311 Comparator Used To Control An 'H-Bridge Circuit



### Light Activated Relay With 5 Second Release Delay

[Voltage Comparator Page On Wikipedia](#)

[Return to the Main Page](#)

## Please Read Before Using These Circuit Ideas

The explanations for the circuits on these pages cannot hope to cover every situation on every layout. For this reason be prepared to do some experimenting to get the results you want. This is especially true

**of circuits such as the "Across Track Infrared Detection" circuits and any other circuit that relies on other than direct electronic inputs, such as switches.**

**If you use any of these circuit ideas, ask your parts supplier for a copy of the manufacturers data sheets for any components that you have not used before. These sheets contain a wealth of data and circuit design information that no electronic or print article could approach and will save time and perhaps damage to the components themselves. These data sheets can often be found on the web site of the device manufacturers.**

**Although the circuits are functional the pages are not meant to be full descriptions of each circuit but rather as guides for adapting them for use by others. If you have any questions or comments please send them to the email address on the Circuit Index page.**

**[Return to the Main Page](#)**

04 May, 2012