## **Real World Comparators**

Fortunately, we can buy much better comparators than we can make ourselves. Shown below is the LM339, a popular quad comparator. For fifteen cents, we get four comparators with great specifications. With its gain of 200,000, it can detect a differential input voltage of just a few tenths of a millivolt!



The schematic symbol for a single comparator is shown below. It has a two inputs; the noninverting and the inverting. The non-inverting input is marked with the plus sign. The inverting terminal is marked with a minus sign. These marks do not restrict the component's connections as you would see on an electrolytic capacitor. They are only there to indicate the polarity of the inputs that will cause the output to go to a high voltage potential.



The operation of the comparator can be summarized as follows:

- \* When the non-inverting terminal is at a higher voltage than the inverting terminal, the output goes to a "high" level.
- \* When the non-inverting terminal has a higher voltage on it than the non-inverting terminal, the output goes to ground or the "low" level.
- \* The input resistance to the comparator is essentially infinite thus no current flows into it.



The use of "high" and "low" to describe the output voltage is intentional. The output stage of a comparator is shown below. The comparator input amplifier is connected to an NPN transistor with the collector connected directly to the output. If the comparator output was connected to nothing, we would never see the output go to a high voltage state. It can only "sink" curent.



To allow the output to go to a high voltage potential, an external "pullup" resistor must be used at the output. Thus the output "low" corresponds to 0V and the output "high" corresponds to whatever the upper terminal of the resistor is connected to. The comparator pulls down the lower end of the resistor to Vce (sat) to define the "low" level and the resistor pulls the output up to a "high" level whenever the output transistor goes "off". Thus "high" is good name for the level that is ultimately user defined.

It should be noted that if both comparator inputs are exactly the same voltage, the comparator output may become unstable. Usually this is not a problem since the internal gain of the comparator is so high, its nearly impossible for the two inputs to appear to be at the same potential. However if this is the case, some clever tricks using positive feedback may be employed to avoid an unstable output.

Below is shown the internal schematic of one of the LM339 comparators. The different parts of the comparator are shown. Note that in the integrated form transistors are able to be configured to appear as constant current sources or high-value resistors. The diodes clustered around the input differential amplifier are for protecting the sensitive input stage. Note the uncommitted output transistor collector connected directly to the output.

