Voltage Comparators:

A comparator compares the voltages at the + and – inputs. If the + input is more positive than the – input the comparator output will be high. If the – input is more positive than the + input the comparator output will be low.

Comparator uses:
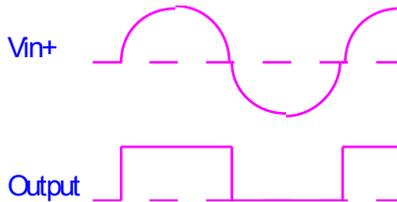
Convert a sine wave to a square wave (usually with a TTL output, i.e. a digital output, 0-5V). This can be used to make a frequency counter by sending the output into a counter and counting the number of pulses in one second.
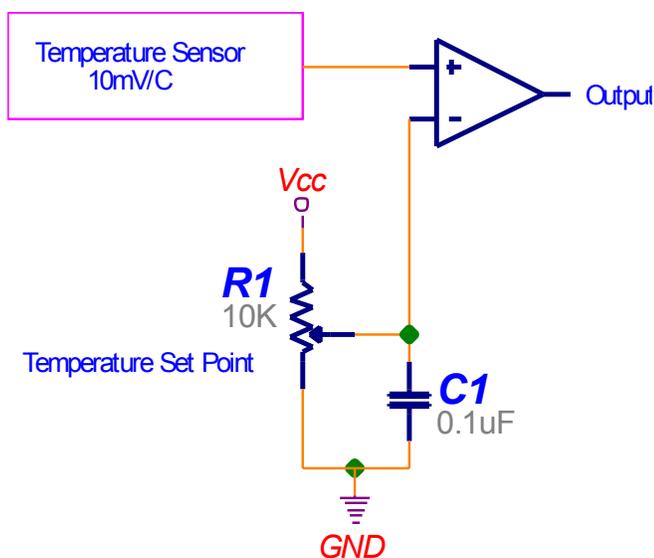
This is an example of a thermostat circuit. The temp sensor puts out 10mV/C. The pot (short for potentiometer) lets the user dial in desired temperature. The capacitor helps to short any high frequency noise on the set point voltage to ground. Note: The cap isn't needed but it's a good idea to have it.

Ex: Adjust the pot to so the wiper is at 0.25V. When the temp rises above 0.25V (25C) the comparator output will go high and the AC unit will come on to cool the room. Once the temp falls below 25C the output will go low and the AC unit will go off. This is an example of an on/off controller. Note: If you swap the comparator inputs (i.e. temp sensor to – and set point to +) the output will go high when the temp is below the set point (could be used to turn on a heater).

Some comparators have TTL or CMOS outputs that will go to high or low without a pull-up resistor. We'll be using the LM311 comparator in our circuits. The output is open-collector which requires a pull-up resistor for the output to go high. Note: The rise time of open-collector outputs depend on the size of the pull-up resistor and the load connected to the output. The smaller the pull-up resistor the quicker the rise time will be.

LM35 temp sensor datasheet:
http://www.ti.com/lit/ds/symlink/lm35.pdf
LM311 comparator datasheet:
http://www.ti.com/lit/ds/symlink/lm311.pdf

Hysteresis:

In the above example the AC unit would turn on the instant the temp dropped below the set point and go off the instant the temp rose above the set point. In the real world this would cause excessive wear on the AC unit. By adding a small percentage of the output to the input (feedback) the temperature can rise a little above the set point before the AC unit comes on and drop a little below the set point before the AC unit goes off. A home thermostat operates with hysteresis.

Hysteresis Example using the LM311:
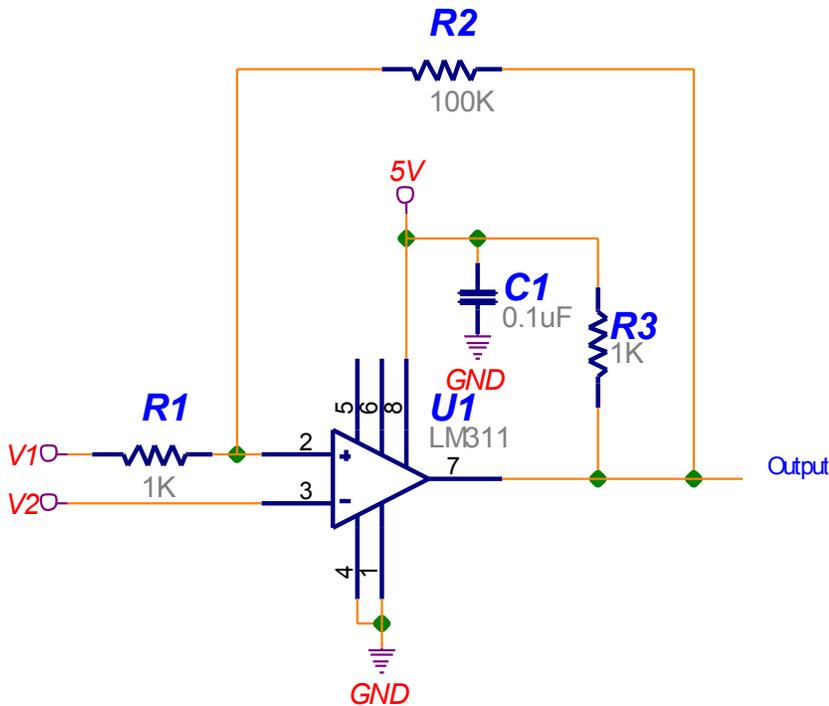
This circuit will compare two voltages, V1 & V2, and will add a little hysteresis so the output doesn't oscillate when V1 = V2. Note: Since the comparator is powered from a 0-5V supply the two input voltages should be between 0 & 5V.

Pins 5 & 6 are to adjust the input offset voltage and won't be used in this example. C1 is the decoupling cap. This cap should be placed as close as possible to the power pins of the IC. R3 is the pull-up resistor. When the output goes low the output transistor inside the IC will pull the output low. For the output to go high the output transistor switches to the off state and the output is left floating. R3 pulls the output high.

How to adjust the amount of hysteresis:
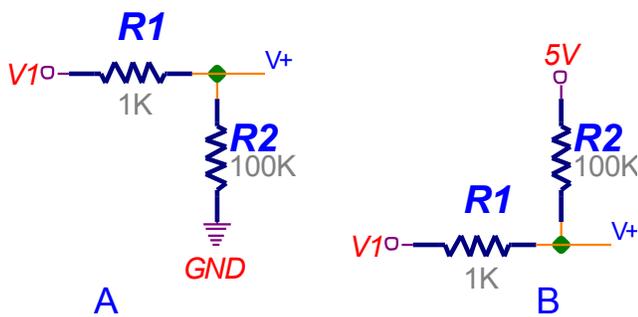
Ex: Assume V2 is 1V and V1 is 0.5V. Because V+ is less than V- the output is low. R2 feeds back some of the output voltage to the V+ input (Fig A). This makes the voltage at V+ slightly lower than V1. The larger the ratio of R2/R1 the smaller the hysteresis will be. In this case V+ will be about 1% less than V1. Because of the feedback V1 must now increase to 1.01V before V+ will reach 1V and cause the comparator output to go high. When the output goes high the voltage at V+ jumps from the 1V to 1.04V (Fig B) even though V1 is still at 1.01V. This positive feedback keeps the output from oscillating by moving the + input in the opposite direction to V1 when the output switches. Now V1 has to decrease to 0.96V to get V+ to reach 1V and cause the comparator output to go low. In this example there is 50mV of hysteresis (1.01V-0.96V).

Note: If the power supply were 10V instead of 5V the high output part of the hysteresis would increase. Instead of 1.01V & 0.96V it would be 1.01V and 0.91V resulting in 100mV of hysteresis. Hysteresis = (R1/R2)*Vps = (1K/100K)*5V = 50mV (or 100mV with a 10V power supply). This assumes R3<<R2. If R3 and R2 are closer in size then the hysteresis will be smaller.

The above calculation assumes the comparator output swings to ground and 5V. In reality the low is ~0.2V and the high ~5V. The output depends on the pull-up resistor and load. Ex: If there is a 1KΩ from the output to ground, and R3 is 1KΩ, the output will only be 2.5V when high. R3 should be much smaller than the load resistance (but don't use a 100Ω for R3 because the comparator may not be able to draw enough current to pull the output low – and it wastes a lot of power). Note: Open collector outputs can sink much more current than they can source through a pull-up resistor. Consider putting low current loads (i.e. a relay) between the power supply and comparator output and reversing the + & - inputs (i.e. relay is on when output is low, not high).