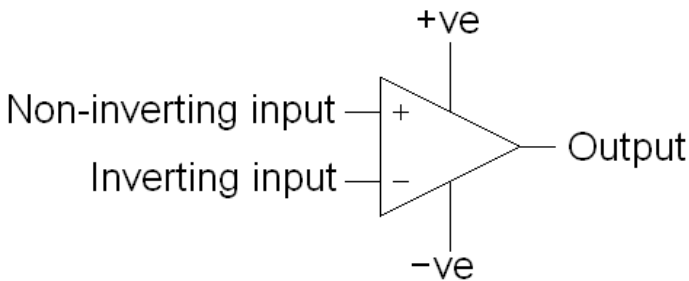
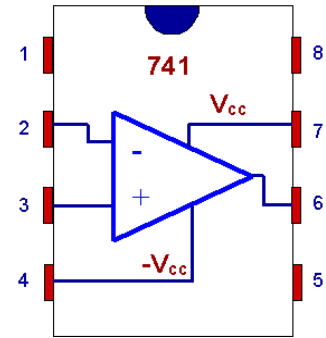


### Operational Amplifiers

An op-amp is a differential amplifier, that is, it amplifies the difference in two voltages. An op-amp generally needs two supply voltages: a positive one and a negative one. It can be used to perform a variety of very useful circuits including amplifying signals and comparing voltages.



Op-Amp Symbol



Pin layout of a 741 Op-Amp

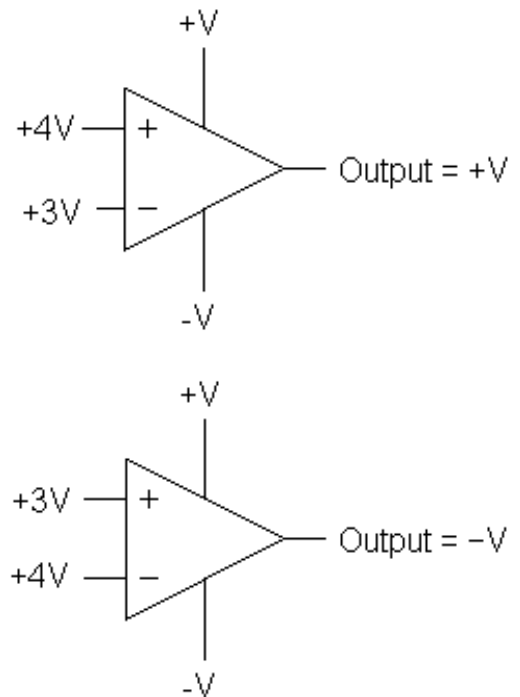
### Voltage Comparators

A comparator compares two input voltages and provides an output depending on the conditions:

When the voltage on the non inverting input is higher than the voltage on the inverting input then the voltage will be equal to the supply voltage +V.

When the voltage on the non-inverting input is lower than the inverting input then the output voltage will be equal to the supply voltage -V.

If both input voltages are equal then, in theory the output voltage will equal 0V.



### Practical comparator circuits

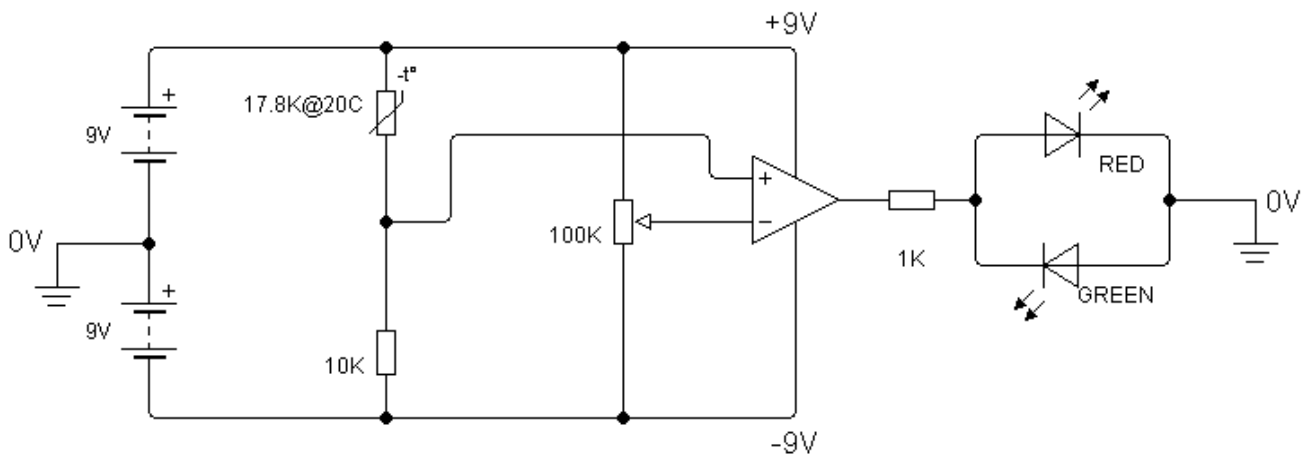
The comparator circuit can be used with an input transducer to switch on an output when certain conditions exist. It can be used to measure the voltage developed by an input transducer such as an LDR or thermistor and switch an output on and off as desired. The circuit on the following page explains such a circuit.

### Comparator used in a temperature sensing circuit

At 20°C the thermistor has a **low resistance** so the voltage at the non-inverting input is higher than the voltage at the inverting input. The voltage at the output pin increases towards 9V thus lighting the **red** LED to indicate heat.

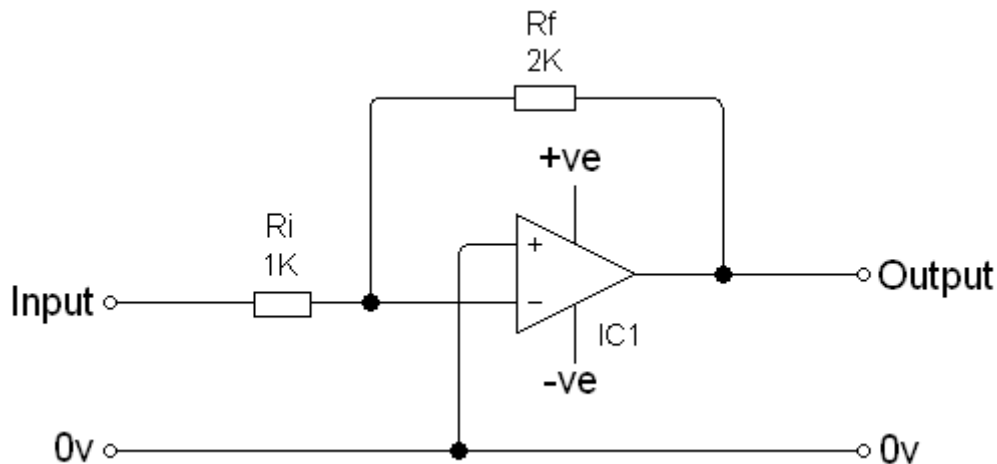
When the temperature is -20°C the thermistor has a **high resistance** so the voltage at the non-inverting input is lower than the voltage at the inverting input. The voltage at the output pin decreases towards -9V supply lighting the **green** LED to indicate cold.

The **variable resistor** allows you to pre-set a trigger voltage level (and therefore trigger temperature) at which the LEDs will swap, indicating hot and cold.



## Inverting Amplifiers

Op-amps are often used as inverting amplifiers. The op-amp takes an input voltage, amplifies it by a certain amount. Amplifiers can be used to amplify voltages and signals by a desired amount. They can be used to amplify DC and AC signals.



The amount of amplification is called the gain. Op-amps have a natural gain of a few million times but this can be controlled with the use of **negative feedback**. This means that a proportion of the inverted output voltage is fed back to the input. The more feedback, the lower the amplifications will be.

The gain in this amplifier depends upon the value of Rf (the feedback resistor) and Ri (the input resistor).

The gain is a ratio of the output voltage over the input voltage and can be calculated by dividing the feedback resistor by the input resistor.

Because this is an inverting amplifier it means the output will be the opposite polarity of the input. For example if the input voltage is a positive one then the output voltage will be negative and vice versa.

In the circuit shown above:

$$\text{Gain} = - R_f / R_i$$

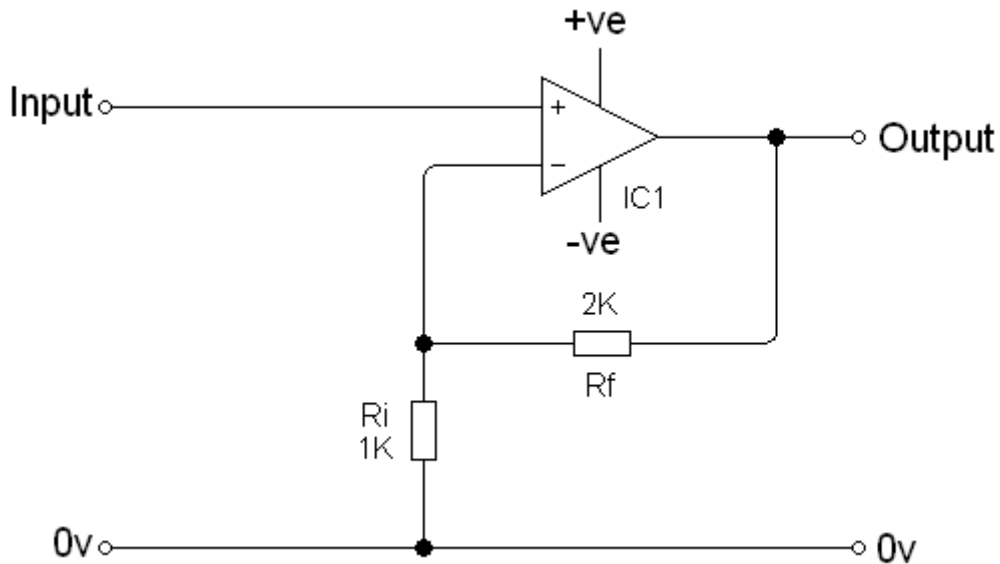
$$\text{Gain} = - 2k / 1k$$

$$\text{Gain} = - 2$$

Therefore if a voltage of 5V is put on the input, the output voltage will be -10V.

### Non-Inverting Amplifiers

Non-inverting amplifiers amplify the input voltage but do not invert the output voltage. The circuit still employs negative feedback but the formula for calculating the gain is slightly different:



This operated in a similar way but the output voltage is not inverted. The gain in this case is calculated as follows:

$$\text{Gain} = 1 + R_f / R_i$$

For example:

$$\text{Gain} = 1 + 2000 / 1000$$

$$\text{Gain} = 3.$$

### Buffers

The gain of a buffer amplifier is 1. This means if you put 2V in you will get 2V out. It is used because it has a very high input resistance. It is used to isolate the input from the signal source where the source has a high output resistance.

