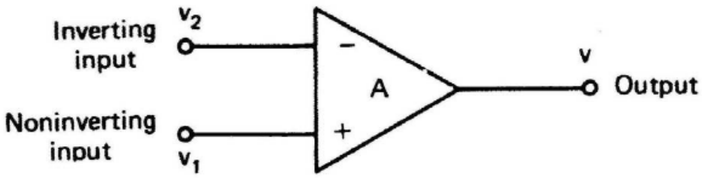
Electrified: Session 5

Operational Amplifiers

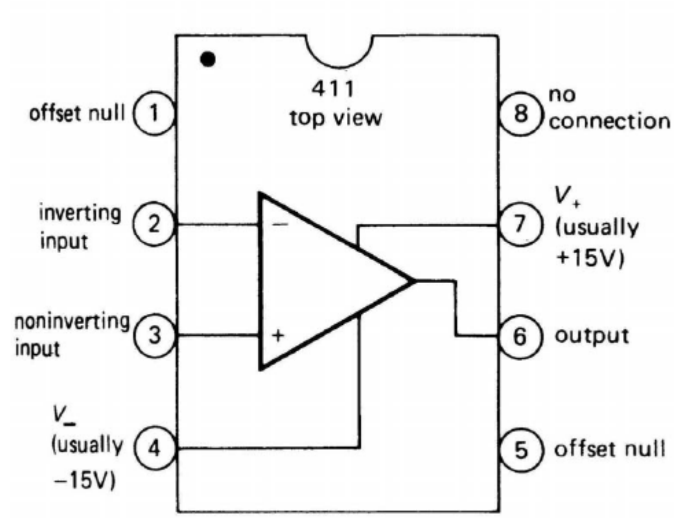
An operational amplifier (or an op-amp) can be defined as a very high gain difference amplifier. In schematics, it is represented as follows.



Every opamp has an inverting input, a non-inverting input and an output. Moreover, it should be given both a positive and a negative voltage at the pins shown.

- Your first activity in this session is to connect the power supplies available to you such that you have two terminals one of +15V and the other of -15V.

The pin diagram of the opamp LM741 given to you is as shown here. You will not be using pins 1 and 5 for circuits in this session.



Op-Amp Properties

Referring to the schematic if v_2 is the inverting input and v_1 is the non-inverted input, the output of the opamp is $v = A(v_1-v_2)$, where A is called the open loop gain and its value is very large (of the order of 10^5). This justifies why an opamp is a **very high gain difference amplifier.** (Note that the output of an ompamp can never exceed the supply voltage. Hence, if $v = A(v_1-v_2)$ is greater than the supply voltage, the output will get saturated at the supply voltage)

But an opamp is rarely used in an open-loop form. Its more common to find them used with some kind of a **feedback** i.e. the output is connected back to one of its inputs. In this mode, an ideal opamp obeys the following **golden rules.**

1. The output attempts to do whatever is necessary to make the voltage difference between the inputs zero.
2. The inputs draw no current.

We leave it as an exercise for you to use these rules and Kirchoff's laws to justify the behavior of all the circuits that follow.

Common OpAmp circuits

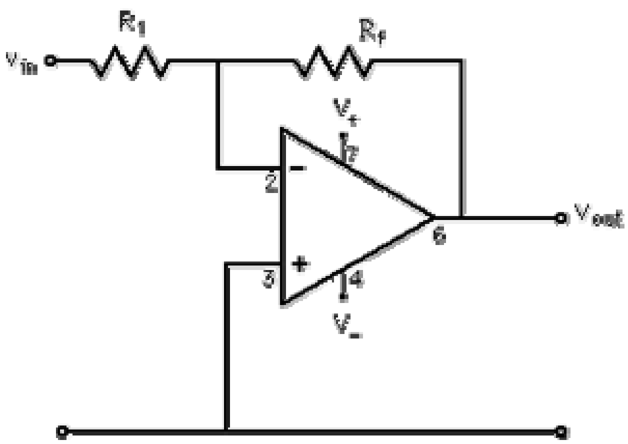
Opamps can be used to perform quite a lot of mathematical operations with voltages. Its because of this property of theirs that they came to be known as 'Operational Amplifiers'. We present a few examples below.

- Comparator

  The extremely large open-loop gain of an op-amp makes it an extremely sensitive device for comparing its input with zero. For practical purposes, if $v_2 > v_1$ the output is positive and $v_2 < v_1$, the output is negative. This helps us compare any two voltages.

  - How can you use an op-amp as a comparator to convert a sinusoidal wave form into a square wave?

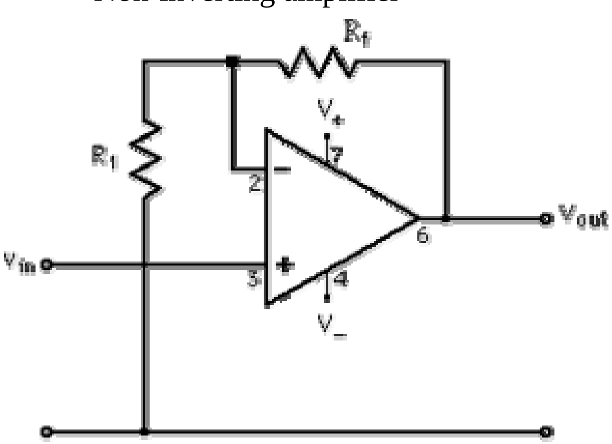
- Inverting Amplifier



This is a simple amplifier with a negative gain. The output voltage is given by,

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_1}$$

- Non-inverting amplifier

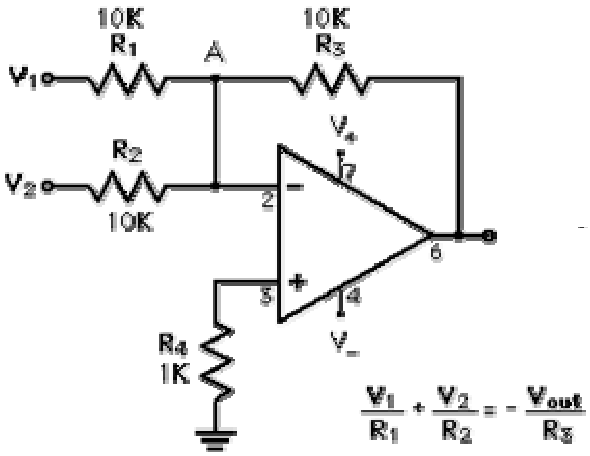


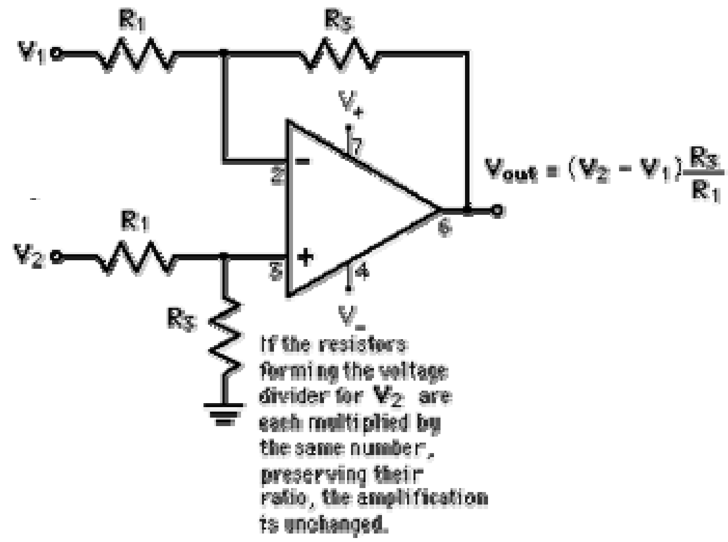
An amplifier similar to above but with a positive gain. The output voltage this time is given by,

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$$

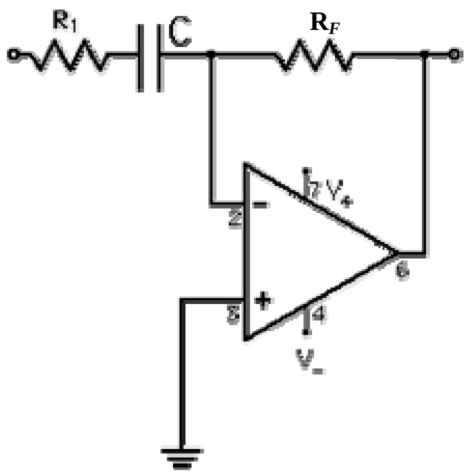
  - Voltage follower is a circuit wherein $V_{out} = V_{in}$. Design one using opamps. Of what use could such a voltage follower be?

- Summing & Difference Amplifier





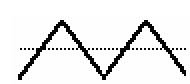
- Differentiator



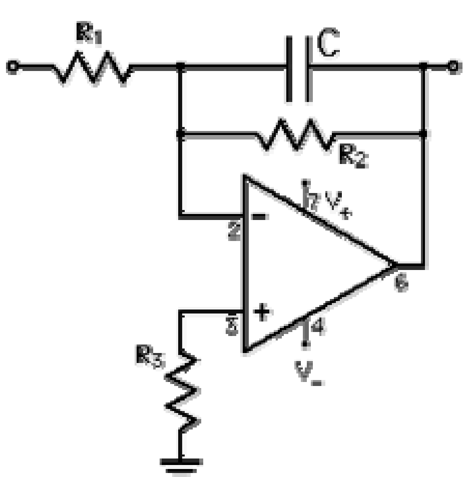
This circuit can used to perform differentiation on the incoming voltages.

$$V_0 = -R_F C_1 \frac{dV_{in}}{dt}$$

  - What will be the output if the input is a triangular wave as shown below?



- Integrator



This circuit can used to perform integration on the incoming voltages.

$$V_0 = -\frac{1}{C_F R_1}\int_0^t v_{in}\,dt$$

  - What will be the output if the input is a square wave as shown below?