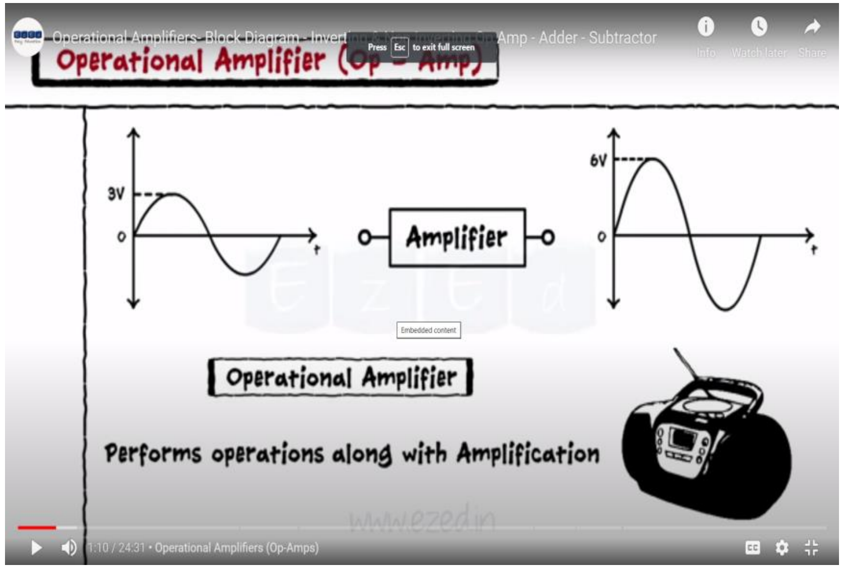
Unit 6

Overview of Analog Circuits

- The term *“**operational amplifier**”* *denotes a special type of amplifier that, by proper selection of its external components, could be configured for a variety of operations.*

HISTORY

- *First developed by **John R. Ragazzine** in **1947** with vacuum tube.*
- *In 1960 at **FAIRCHILD SEMICONDUCTOR CORPORATION**, **Robert J. Widlar** fabricated op amp with the help of IC fabrication technology.*
- *In 1968 FAIRCHILD introduces the **op-amp** that was to become the industry standard.*



Op-amp pin diagram

There are 8 pins in a common Op-Amp, like the 741 which is used in many instructional courses.

Pin 1: Offset null
- Pin 2: Inverting input terminal
- Pin 3: Non-inverting input terminal

Pin 4: –VCC (negative voltage supply)
Pin 5: Offset null
- Pin 6: Output voltage

Pin 7: +VCC (positive voltage supply)
Pin 8: No Connection

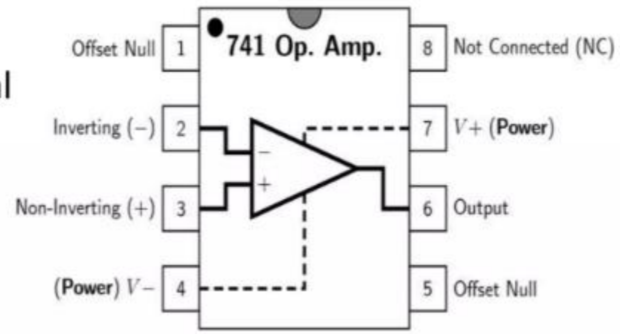
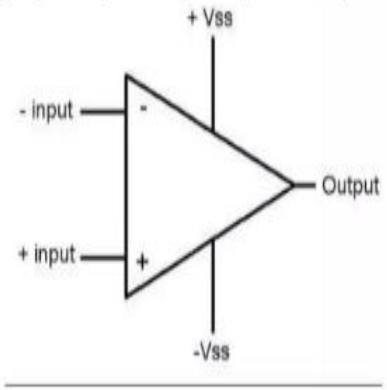


Figure : Pin connection, LM741.

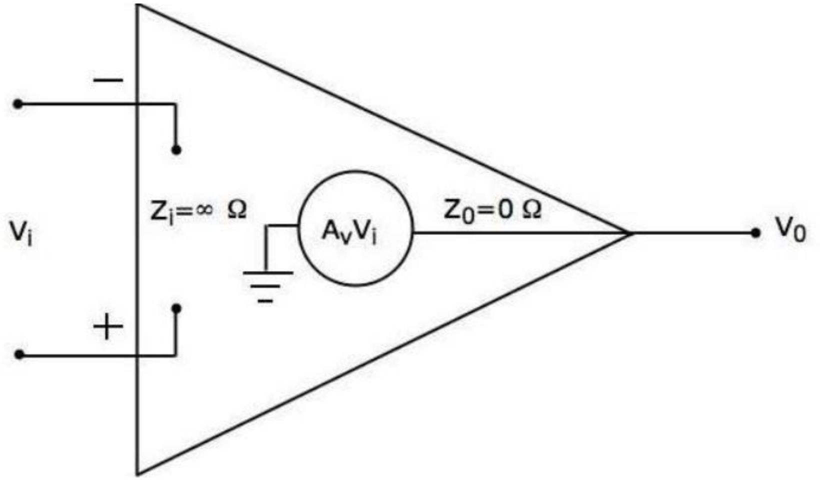


√ *Op amps are differential amplifiers, and their output voltage is proportional to the difference of the two input voltages. The op amp's schematic symbol is shown in the above figure*

√ *The two input terminals, called the inverting and non-inverting, are labeled with - and +, respectively.*

Ideal Op-Amp

An ideal op-amp exists only in theory, and does not exist practically. The **equivalent circuit** of an ideal op-amp is shown in the figure given below –



1. Infinite voltage gain a
2. Infinite input resistance r_d so that almost any signal source can drive it and there is no loading of the preceding stage.
3. Zero output resistance r_o so that the output can drive an infinite number of other device.
4. Zero output voltage when input is zero.
5. Infinite common mode rejection ratio so that the output common mode noise voltage is zero.
6. Infinite slew rate so that output voltage changes occurs simultaneously with input voltage changes.

An **ideal op-amp** exhibits the following characteristics –

- Input impedance $Z_i = \infty\Omega$
- Output impedance $Z_0 = 0\Omega$
- Open loop voltage gaine $A_v = \infty$
- If (the differential) input voltage $V_i = 0V$, then the output voltage will be $V_0 = 0V$
- Bandwidth is **infinity**. It means, an ideal op-amp will amplify the signals of any frequency without any attenuation.
- Common Mode Rejection Ratio **(CMRR)** is **infinity**.
- Slew Rate **(SR)** is **infinity**. It means, the ideal op-amp will produce a change in the output instantly in response to an input step voltage.

Open loop voltage gain

The open loop voltage gain of an op-amp is its differential gain without any feedback path.

Mathematically, the open loop voltage gain of an op-amp is represented as –

$$A_v = \frac{v_0}{v_1 - v_2}$$

Common Mode Rejection Ratio

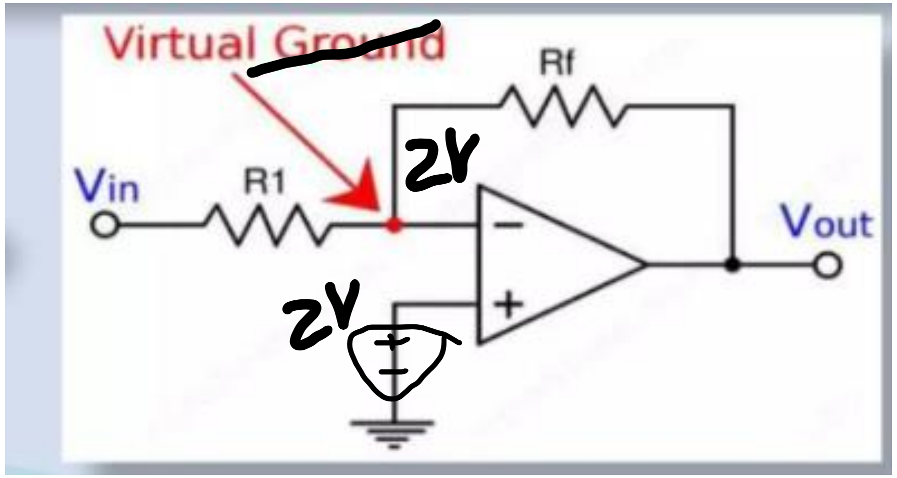
Common Mode Rejection Ratio (**CMRR**) of an op-amp is defined as the ratio of the closed loop differential gain, A_d and the common mode gain, A_c .

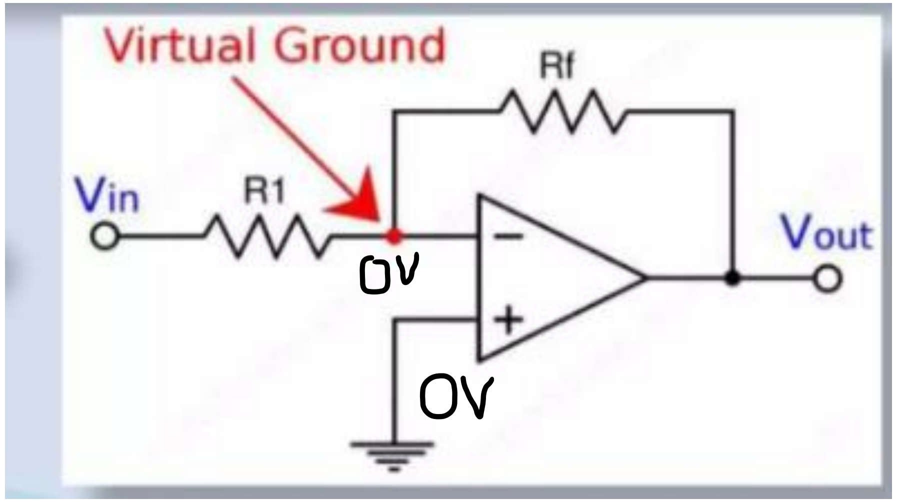
Mathematically, CMRR can be represented as –

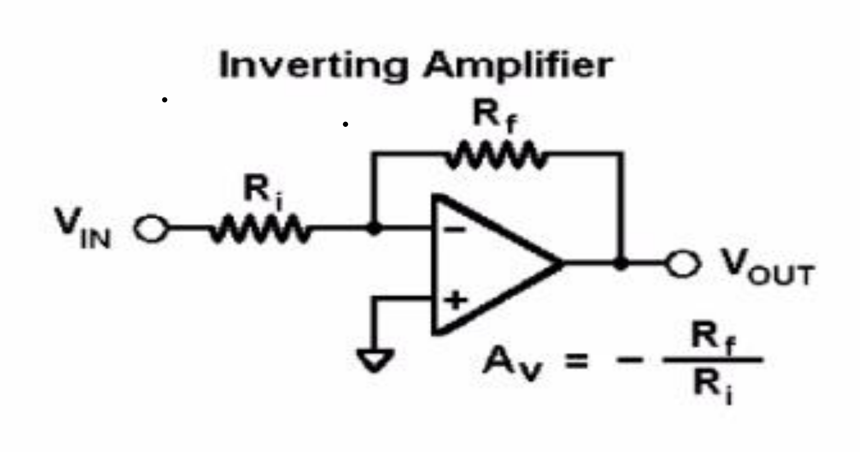
$$CMRR = \frac{A_d}{A_c}$$

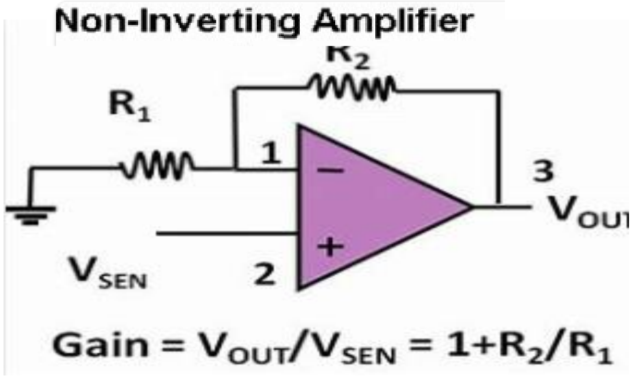
Note that the common mode gain, A_c of an op-amp is the ratio of the common mode output voltage and the common mode input voltage.

Short









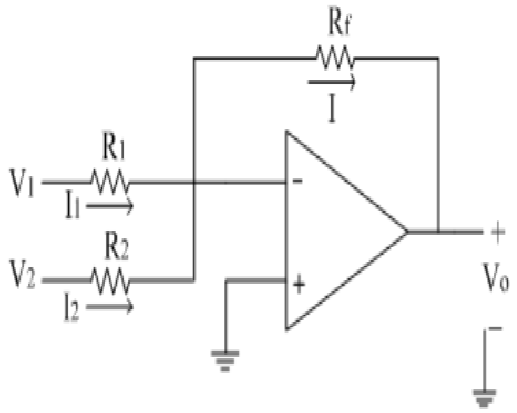
Calculation done in class(check class note)

Op amp as an adder

Op amp as an adder

Inverting adder:

The input signals to be added are applied to the inverting input terminal of op-amp. The following figure shows the inverting adder using op-amp with two inputs V1 and V2.



Let us assume currents I1 and I2 are flowing through resistances R1 and R2 respectively. Since input current to the op-amp is zero, the two currents are added to get current I, which flows through the feedback resistance Rf.

Thus by KCL at inverting terminal, we get

$$I=I_1+I_2$$

Substituting for the currents,

$$\frac{0-V_o}{R_f}=\frac{V_1-0}{R_1}+\frac{V_2-0}{R_2}$$

$$\therefore \frac{-V_o}{R_f}=\frac{V_1}{R_1}+\frac{V_2}{R_2}$$

$$\therefore V_o=-\left[\frac{R_fV_1}{R_1}+\frac{R_fV_2}{R_2}\right]$$

Thus the above equation gives the weighted addition of the two input signals (in the form mX + n Y, where m and n are the weights of inputs X and Y respectively)

If R1=R2=R

$$\therefore\ V_o=-\frac{R_f}{R_1}[V_1+V_2]$$

Thus the addition of the two input signals obtained with gain [-Rf/R]

If Rf=R,

$$\therefore\ V_o=-[V_1+V_2]$$

Thus the addition of two inputs obtained. The negative sign indicates that input and output are having 180° phase shift.