Electronic Principles and Devices

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ELECTRONIC PRINCIPLES AND DEVICES

Operational Amplifier

Op-Amp parameters and its values for Op-Amp 741 – Input and output offset voltages, Input and output resistances, GBW, SR, CMRR (Definitions and significance only), Ideal Op-amp, Negative feedback.

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Operational Amplifier – Parameters and The 8pin DIP package of IC 741

The 8 pin DIP package of IC 741 is shown in the Fig. 1.59.

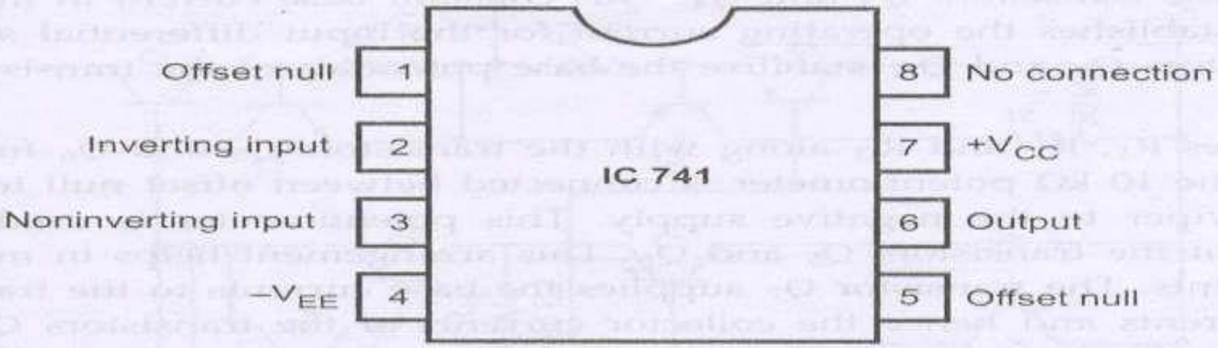


Fig. 1.59 8 Pin diagram

1.26.3 Ideal Vs Practical Characteristics of IC 741 Op-Amp

The Table 1.7 lists the ideal op-amp characteristics and the typical characteristics of 741 IC, a popular general purpose op-amp IC.

Sr. No	Parameter	Symbol	Ideal	Typical for 741 IC
1	Open loop voltage gain	A_{OL}	∞	2×10^5
2	Output impedance	Z_{out}	0	75 Ω
3	Input impedance	Z_{in}	∞	2 MΩ
4	Input offset current	I_{ios}	0	20 nA
5	Input offset voltage	V_{ios}	0	1 mV
6	Bandwidth	B.W	∞	1 MHz
7	CMRR	ρ	∞	90 dB
8	Slew rate	S	∞	0.5 V/μsec
9	Input bias current	I_b	0	80 nA
10	PSRR	PSRR	0	30 μV/V

Operational Amplifier -Parameters

Characteristics and performance parameters of Op-amp

Input offset Voltage
Input offset current
Input bias current
Output Offset voltage
Input and output impedances and Differential input resistance
CMRR
Output voltage swing
PSRR
Slew rate
Gain Bandwidth product
Negative feedback

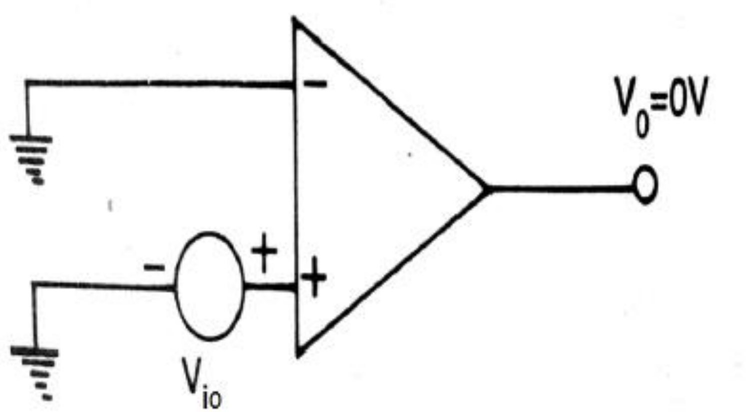
Operational Amplifier -Parameters

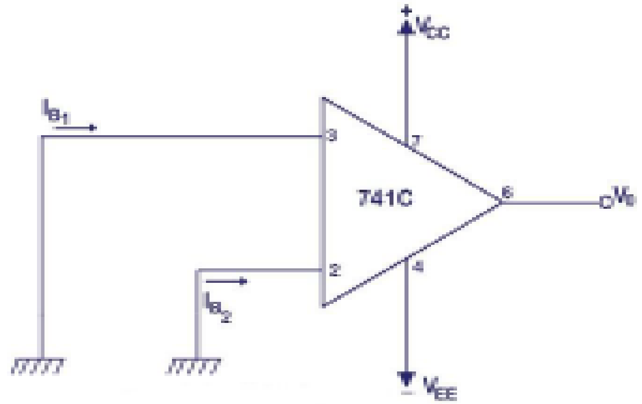
1. Input offset Voltage :

The differential voltage that must be applied between the two input terminals of an op-amp, to make the output voltage zero.

It is denoted as $\mathbf{V_{ios}}$

For op-amp 741C the input offset voltage is 6mV





2. Input offset current :

The algebraic difference between the currents flowing into the two input terminals of the op-amp

It is denoted as I_{ios}= | I_{b1}–I_{b2}|

For op-amp 741C the input offset current is 200nA

Operational Amplifier -Parameters

3. Input bias current :

The average value of the two currents flowing into the op-amp input terminals

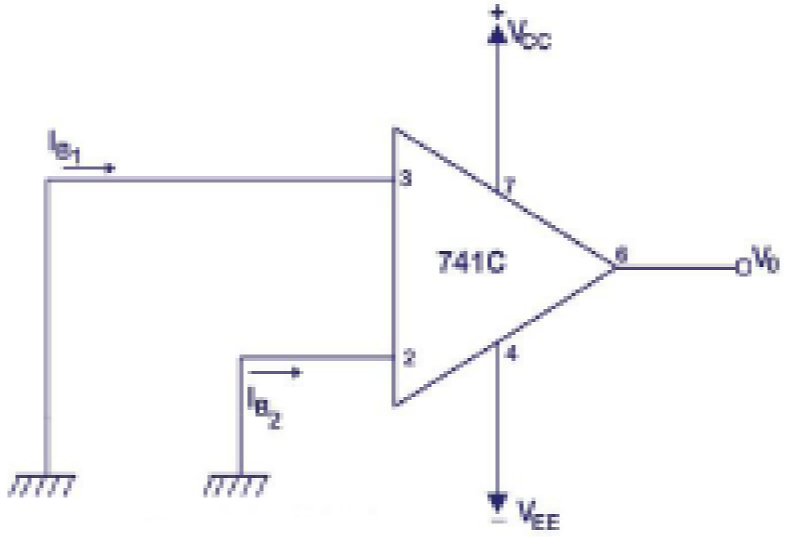
It is expressed mathematically as

$$\frac{I_{b1} + I_{b2}}{2}$$

For 741C the maximum value of Ib is 500nA

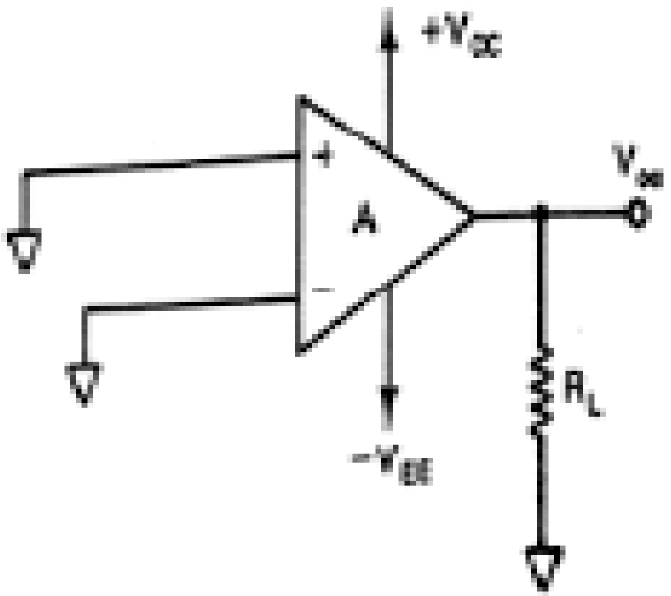
Where Ib1= DC bias current flowing into the non-inverting input

Ib2 = DC bias current flowing into the inverting input



Operational Amplifier -Parameters

4. Output Offset voltage : The output offset voltage is the dc voltage present at the output terminals when both the input terminals are grounded.
It is denoted as Voos



Operational Amplifier -Parameters

5. Input and output impedances

Ideal Op-Amp Input impedance of op-amp is ∞ – No current flow in or out of input terminals Output impedance of op-amp (with respect to ground) is ‘0’.

Input impedance : It is the ratio of the input voltage to input current. It should be infinite without any leakage of current from the supply to the inputs. But there will be a few Pico ampere current leakages in most Op Amps.

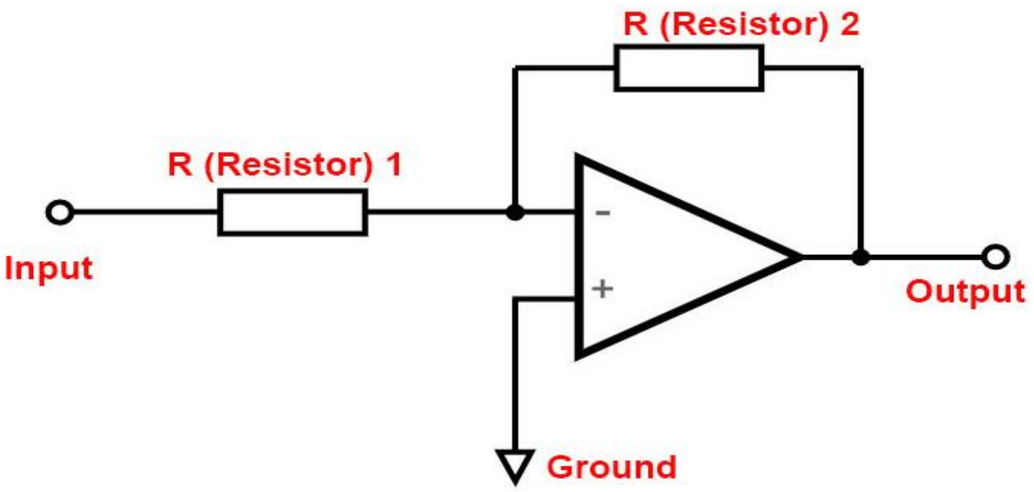
Output impedance : The ideal Op Amp should have zero output impedance without any internal resistance. So that it can supply full current to the load connected to the output.

6. Differential Input Resistance

It is the equivalent resistance measured at either the inverting or non inverting input terminal with the other input terminal grounded.

It is denoted as R i

For 741C it is of the order of 2MΩ



Operational Amplifier -Parameters

7. CMRR

It is the ratio of differential voltage gain Ad to common mode voltage gain Ac

CMRR= Ad / Ac

Ad is open loop voltage gain AOL and Ac = V_{OC}/ V_c

For op-amp741C CMRR is 90 dB

Common-Mode Operation

When the same input signals are applied to both inputs, common-mode operation results, as shown in Fig. 10.8 . Ideally, the two inputs are equally amplified, and since they result in opposite-polarity signals at the output, these signals cancel, resulting in 0-V output. Practically, a small output signal will result

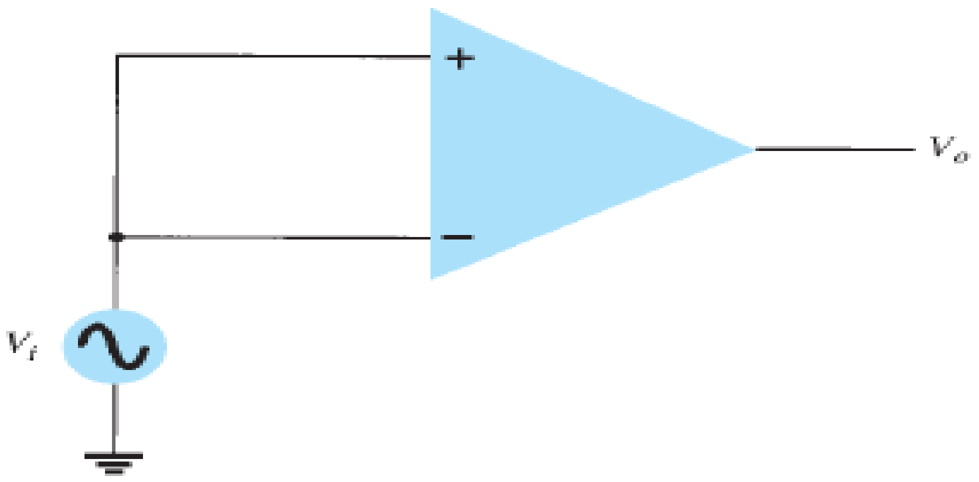


FIG. 10.8
Common-mode operation.

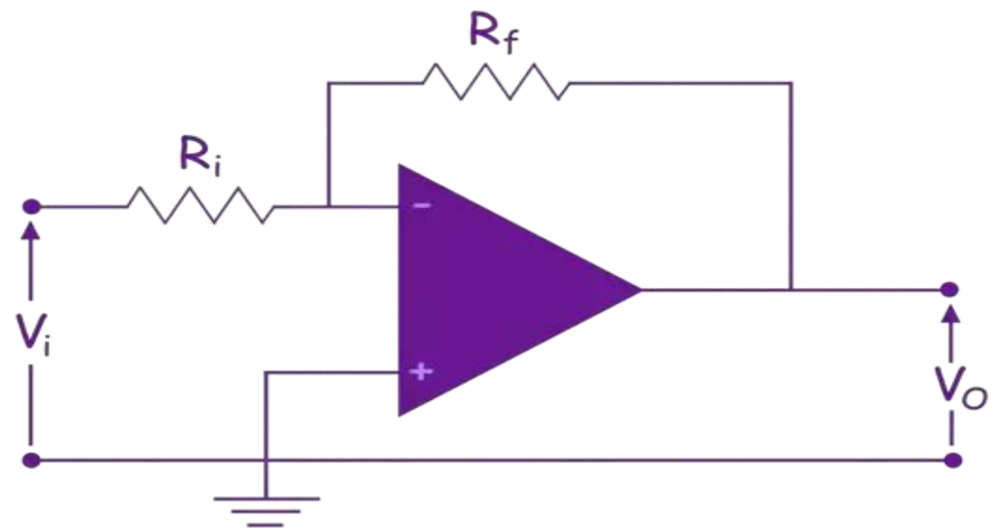
Operational Amplifier – Negative Feedback

Open loop gain

- The open-loop gain of an electronic amplifier is the gain obtained when no overall feedback is used in the circuit.
- An ideal operational amplifier (op-amp) has infinite open-loop gain.
- Typically an op-amp may have a maximal open-loop gain of around 10^{5}, or 100 dB.
- An op-amp with a large open-loop gain offers high precision when used as an inverting amplifier. The definition of open-loop gain (at a fixed frequency) is

$$A_{OL} = \frac{V_{out}}{V^{+} - V^{-}},$$

Where $V^{+} - V^{-}$ is the input voltage difference that is being amplified. (The dependence on frequency is not displayed here.)



Operational Amplifier -Parameters

Difference Mode

In this mode two opposite polarity (out of phase) signals are applied to the inputs as shown in Figure (c).

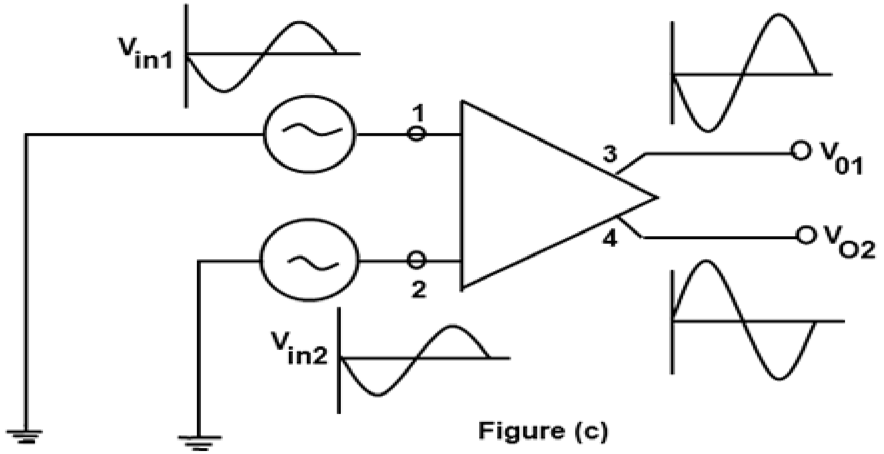


Figure (c)

Common-Mode Rejection

A significant feature of a differential connection is that the signals that are opposite at the inputs are highly amplified, whereas those that are common to the two inputs are only slightly amplified—the overall operation being to amplify the difference signal while rejecting the common signal at the two inputs.

Since noise (any unwanted input signal) is generally common to both inputs, the differential connection tends to provide attenuation of this unwanted input while providing an amplified output of the difference signal applied to the inputs. This operating feature is referred to as **common-mode rejection .**

Operational Amplifier -Parameters

8. Output Voltage swing

The opamp output voltage gets saturated at + V_{cc} and - V_{EE} and it cannot produce output voltage more than + Vcc and - V_{EE}. Practically voltages +V sat and - Vsat are slightly less than + V cc and - V_{EE}

For op amp 741C the saturation voltages are + 13V for supply voltages of 15V

9. Power supply rejection ratio

PSRR is defined as the ratio of the change in input offset voltage due to the change in supply voltage producing it, keeping the other power supply voltage constant. It is also called as power supply sensitivity (PSV)

PSRR= (Δvios/ ΔVcc)|constant VEE

PSRR= (Δvios/ ΔVEE)|constant Vcc

The typical value of PSRR for op-amp 741C is 30µV/V64

Operational Amplifier -Parameters

9. Slew rate

It is defined as the maximum rate of change of output voltage with time. The slew rate is specified in V/µsec

Slew rate = S = dVo /dt max

It is specified by the op amp in unity gain condition.

The slew rate is caused due to limited charging rate of the compensation capacitor and current limiting and saturation of the internal stages of op amp, when a high frequency large amplitude signal is applied.

10. Gain –Bandwidth product

It is the bandwidth of op-amp when voltage gain is unity (1). It is denoted as GB.

The GB is also called unity gain bandwidth (UGB) or closed loop bandwidth

It is about 1MHz for op-amp 741C68

Operational Amplifier – Negative Feedback

Negative Feedback :

Negative feedback in an op amp is defined as connecting the output to the inverting input through a resistor to control the gain

We obtain Negative feedback in an op amp by connecting output terminal of an op amp to its inverting input terminal through a suitable resistance as shown Fig.

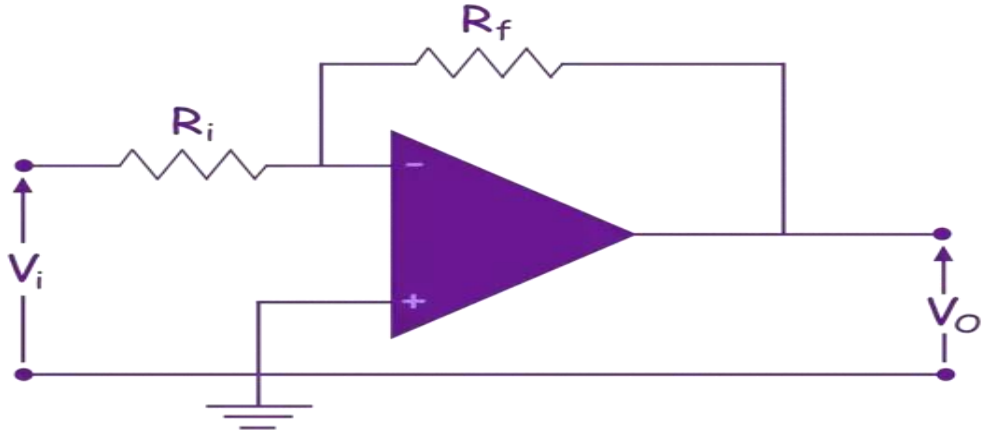
The gain of an op amp with negative feedback is called closed loop gain.

Closed Loop Gain of Op Amp

When we connect a feedback resistor and a resistance in series with the inverting input terminal of an op amp, the system's gain becomes the negative ratio of the feedback resistance to the input resistance.

The op amp has its own very large gain, ideally infinite. By choosing the appropriate values of series input resistance (Ri) and feedback resistance (Rf), we can set the system's gain regardless of the op amp's own gain (open loop gain).

$$-\frac{R_f}{R_i}$$



Operational Amplifier – Negative Feedback

Open loop gain

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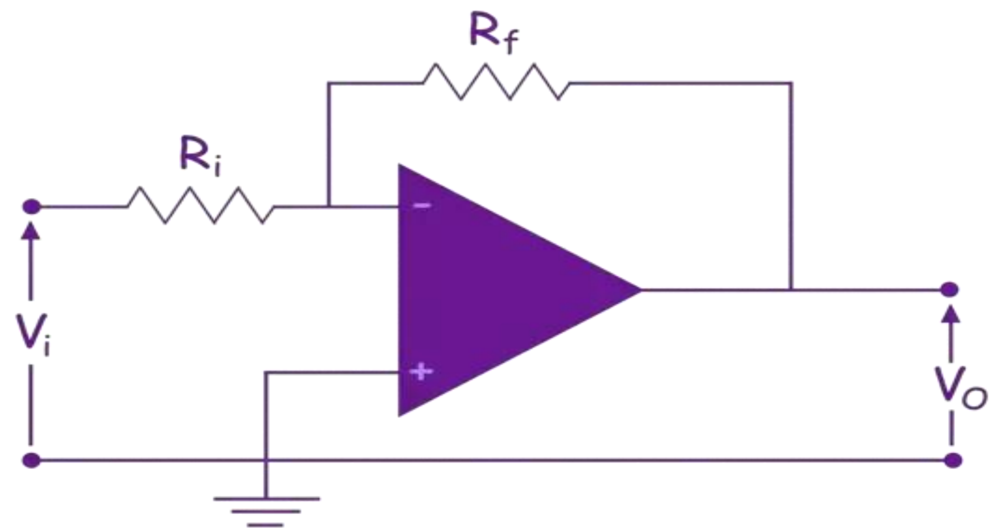
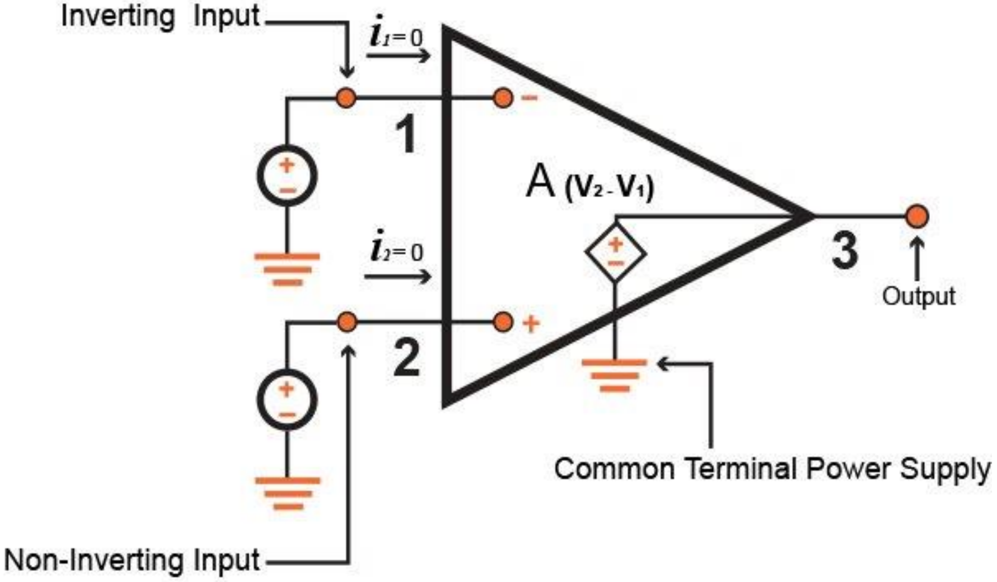


Operational Amplifier - Op Amp Equivalent Circuit

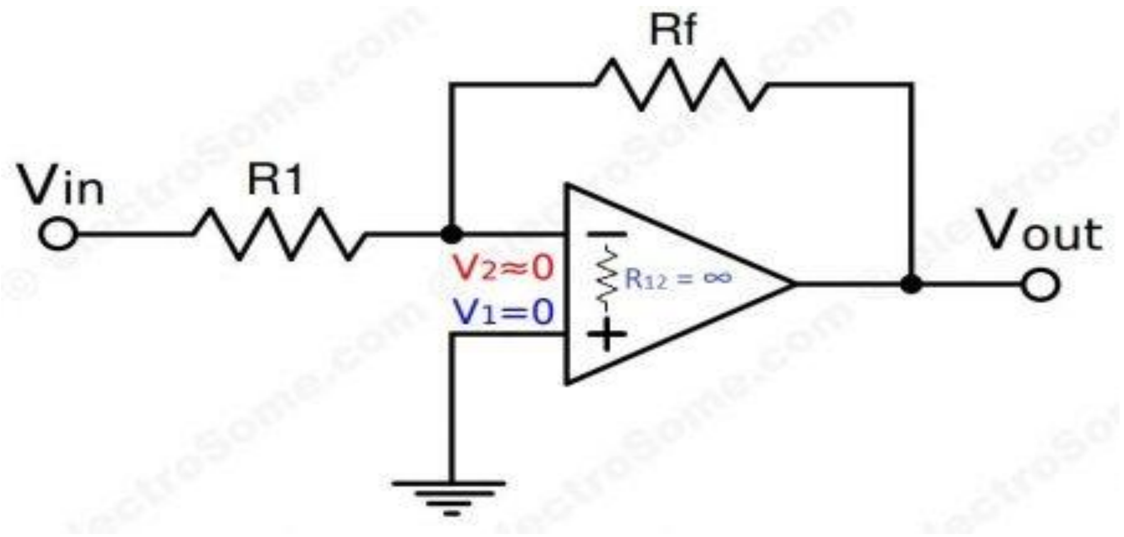
The output of the Op Amp should be zero when the voltage difference between the inputs is zero. But in most Op Amps, the output will not be zero when off but there will be a minute voltage from it



Circuit model of ideal op-amp

Operational Amplifier – Virtual Ground

As the name indicates it is virtual, not real ground.
For some purposes we can consider it as equivalent to ground.
In op-amp the term virtual ground means that the voltage at that particular node is almost equal to ground voltage (0V).
It is not physically connected to ground.
This concept is very useful in analysis of op-amp circuits and it will make a lot of calculations very simple.



Operational Amplifier – Virtual Ground

Virtual Ground – Opamp

Lets see how the virtual ground concept is employed in inverting amplier.

Virtual Ground – Inverting Amplifier using Op-amp

We can explain this concept in two different ways using two different characteristics of an ideal op-amp.

Using Infinite Voltage Gain

We already know that an ideal op-amp will provide infinite voltage gain. For real op-amp also the gain will be very high such that we can consider it as infinite for calculation purposes.

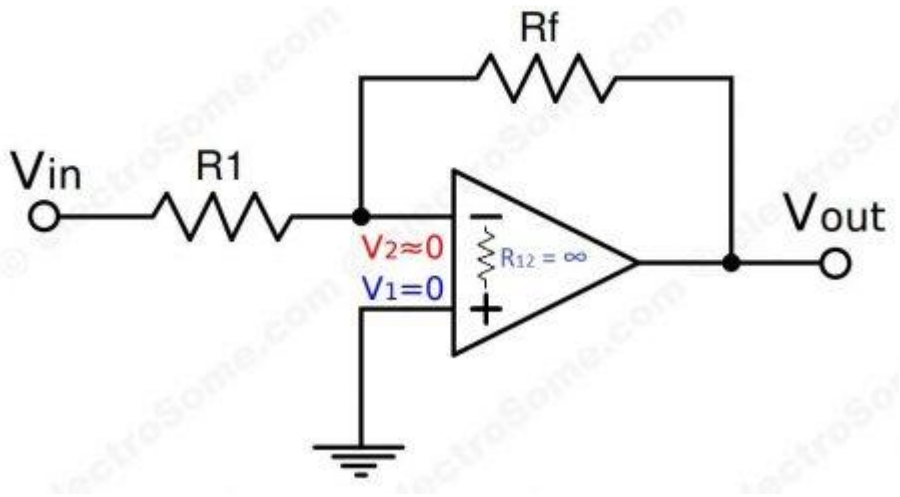
- Gain = Vo/Vin

As gain is infinite, Vin = 0

Vin = V2 – V1

In the above circuit V1 is connected to ground, so V1 = 0. Thus V2 also will be at ground potential.

V2 = 0



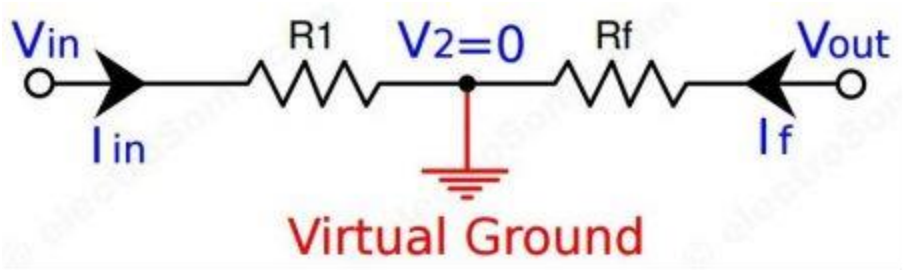
Operational Amplifier – Virtual Ground

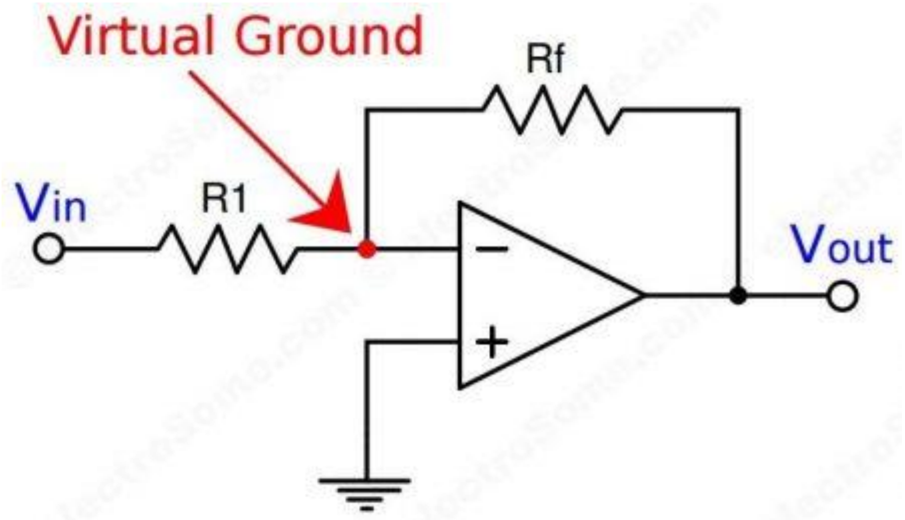
Virtual Ground – Inverting Amplifier using Opamp

Why we need Virtual Ground ?

Virtual Ground concept is very useful in analysis of an opamp when negative feedback is employed.

It will simply a lot of calculations and derivations.





Equivalent Circuit – Inverting Amplifier – Virtual Ground – Opamp

THANK YOU

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