Al-Mustaqbal University.
College of Engineering and Technical Technologies.
Biomedical Engineering Department.

Subject: Biomedical Instrumentation Design.

Class (code): 4th (MU0114103).

Lecture: *3.*

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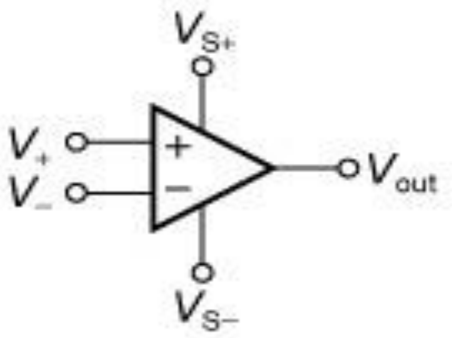
Biomedical Instrumentation Design

› Operational amplifiers are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.



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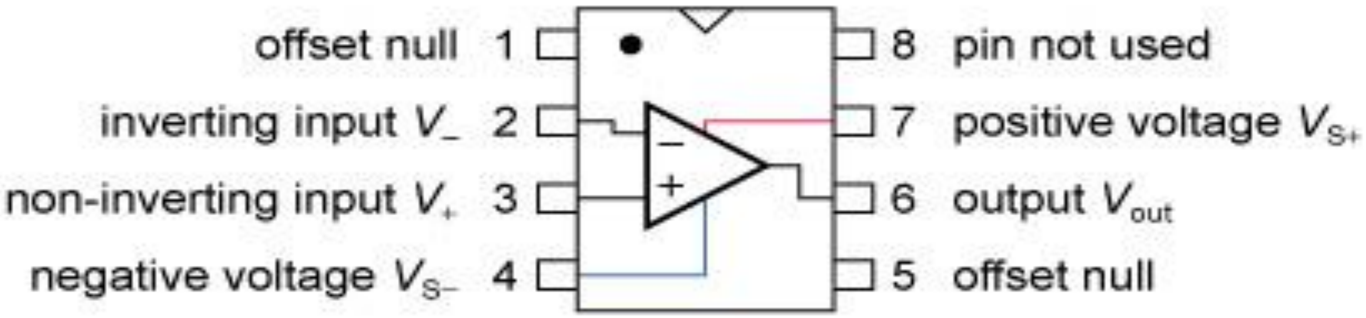

(c)

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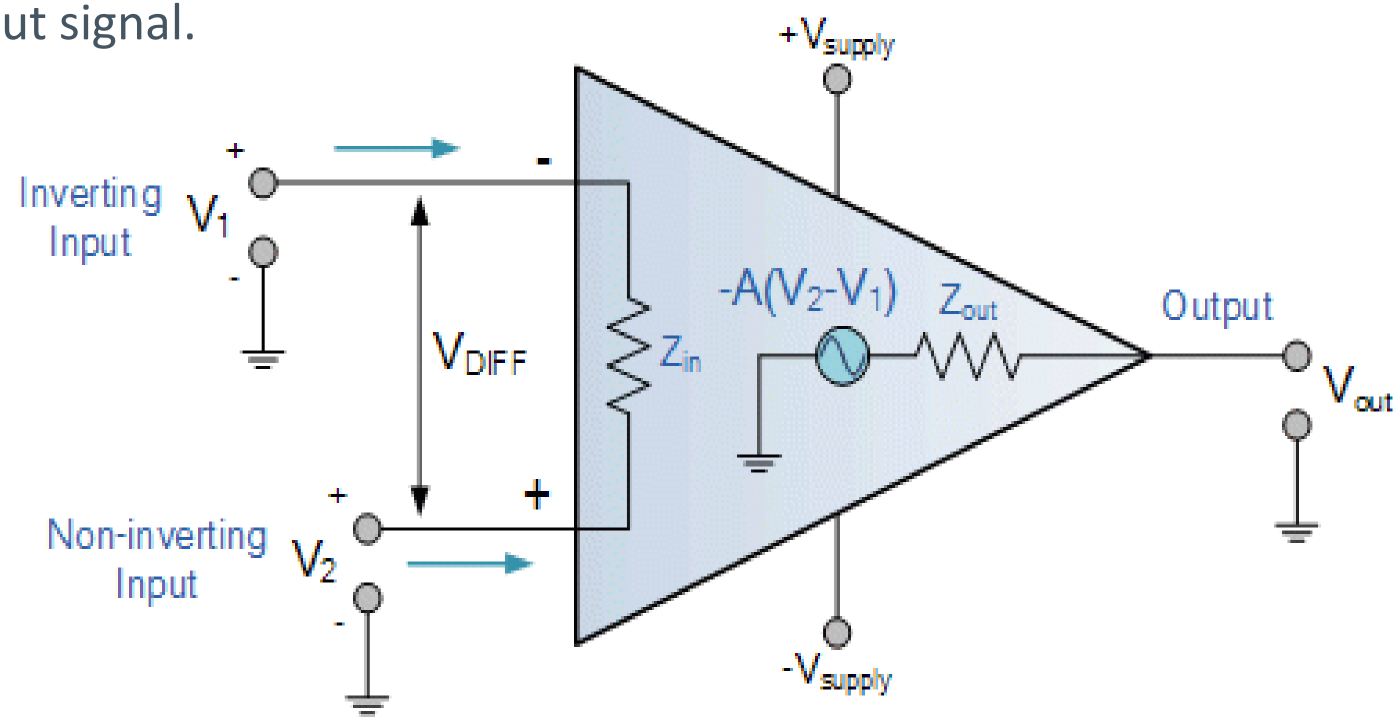
- Op-Amp. is a three-terminal device which consists of:
- Two high impedance inputs, one is the Inverting Input (-) and the non-inverting Input (+).
- The third terminal represents the op-amp. output port which can sink and source *a voltage or a current.*
- The output signal of a linear op-amp.: is the amplification factor (gain (A)) multiplied by the value of the input signal.



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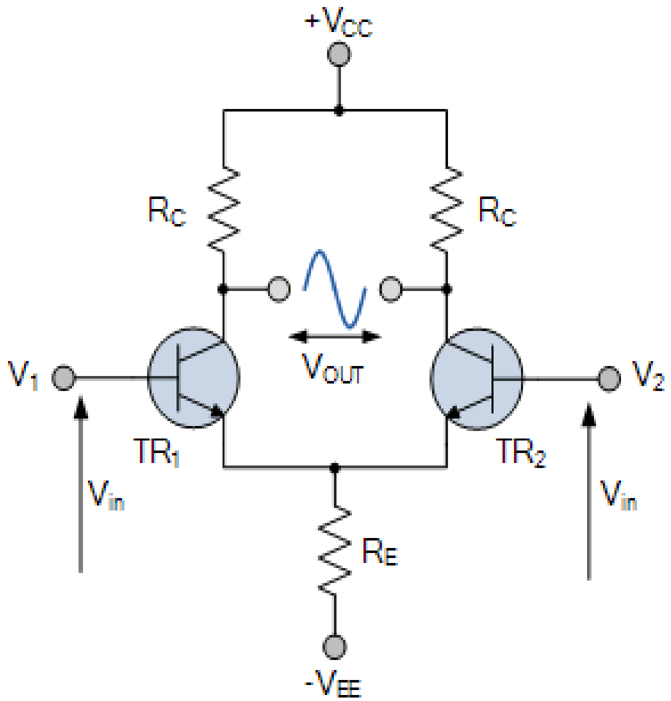
- ***Differential Amplifier***
- The differential amplifier have two inputs marked V1 and V2, two identical transistors TR1 and TR2 are both biased at the same operating point with their emitters connected together and returned to the common rail, -Vee by way of resistor Re.
- The circuit operates from a dual supply +Vcc and -Vee.
- The output voltage (Vout) of the amplifier is the difference between the two input signals.



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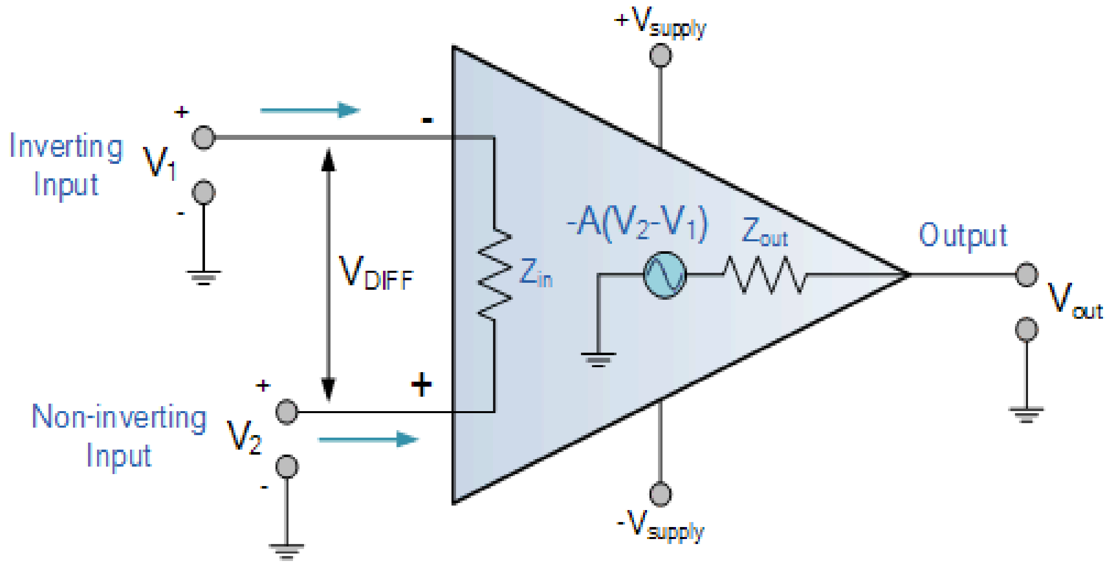
› Equivalent Circuit of an Ideal Operational Amplifier

› Open Loop Gain, (Avo): ***Infinite*** – Open-loop gain is the gain of the op-amp without positive or negative feedback, and for such an amplifier, the gain will be infinite, but typical real values range from about 20,000 to 200,000.

› Input impedance, (Z_{IN}): ***Infinite*** – Input impedance is the ratio of input voltage to input current and is assumed to be infinite to prevent any current from flowing from the source supply into the amplifiers input circuitry (I_{IN} = 0). Real op-amps have input leakage currents from a few pico-amps to a few milli-amps.



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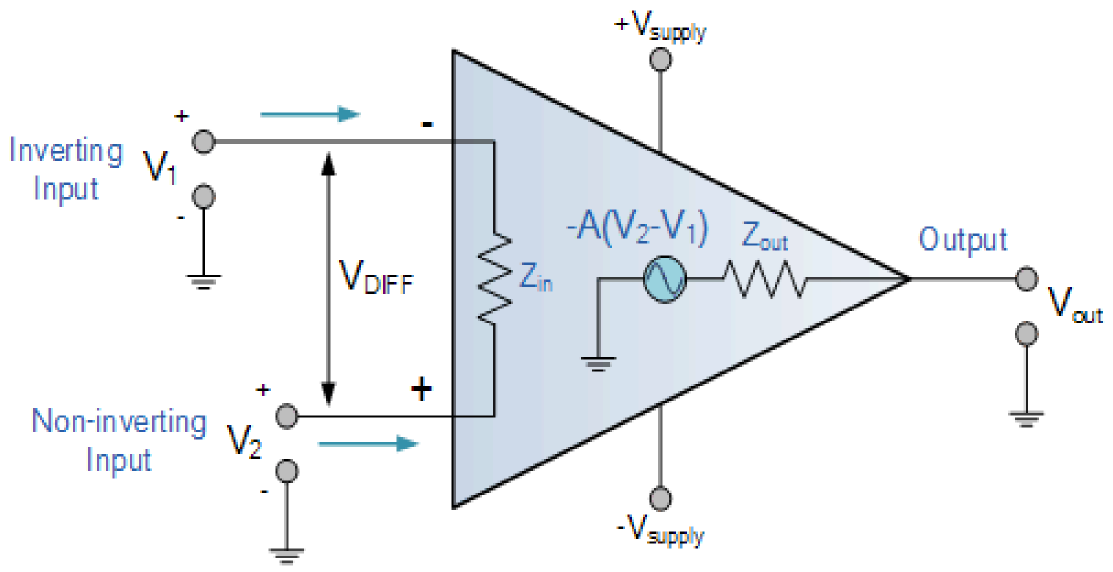
› Output impedance, (Z_{OUT}): Zero – The output impedance of the ideal operational amplifier is assumed to be zero acting as a perfect internal voltage source with no internal resistance so that it can supply as much current as necessary to the load. This internal resistance is effectively in series with the load, thereby reducing the output voltage available to the load. Real op-amps have output impedances in the 100-20kΩ range.



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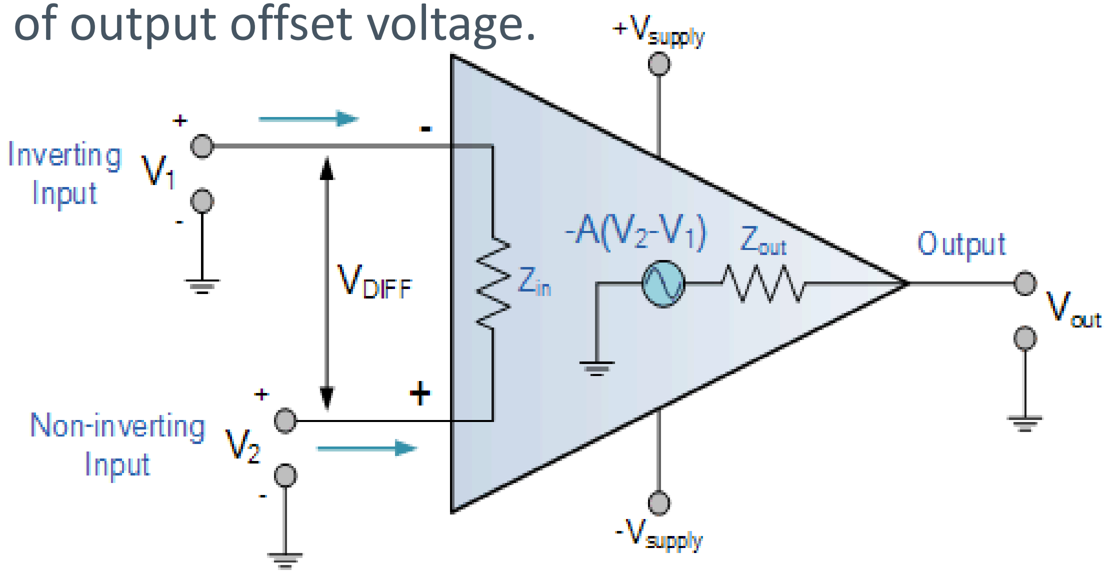
- Bandwidth, (BW): Infinite – An ideal operational amplifier has an infinite frequency response and can amplify any frequency signal from DC to the highest AC frequencies, so it is therefore assumed to have an infinite bandwidth. BW of real op-amps is limited by the Gain-Bandwidth product (GB), which is equal to the frequency where the amplifier's gain becomes unity.
- Offset Voltage, (V_{IO}): Zero – The amplifier's output will be zero when the voltage difference between the inverting and the non-inverting inputs is zero, the same or when both inputs are grounded. Real op-amps have some amount of output offset voltage.



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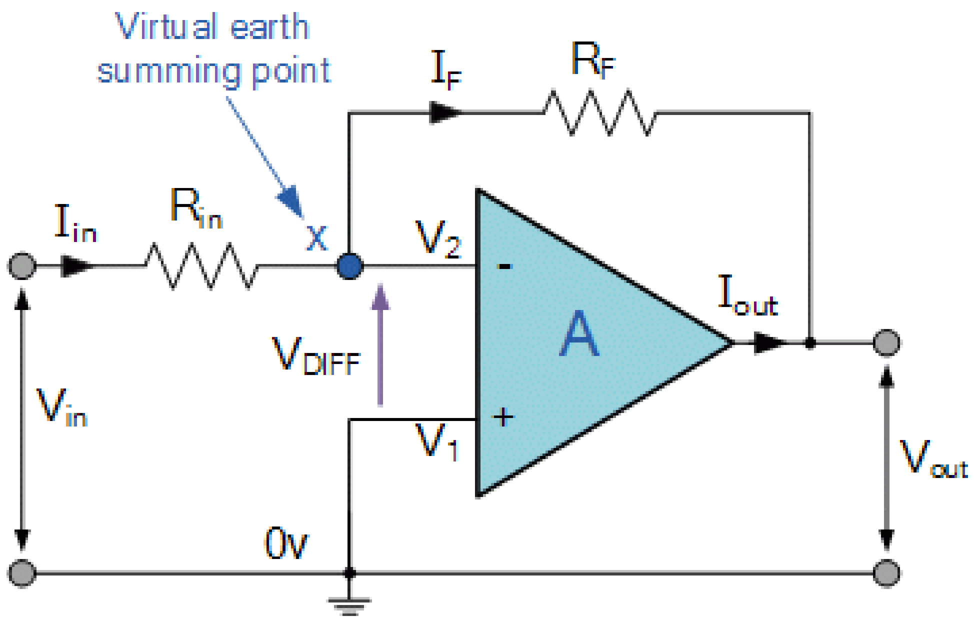
› **Inverting Operational Amplifier**

› The Inverting Operational Amplifier configuration is one of the simplest and most commonly used op-amp topologies.

› Since the Open Loop Gain, (A_{VO}) of an operational amplifier can be very high, as much as 1,000,000 or more, a few micro-volts, (µV) would be enough to cause the output voltage to saturate and swing towards one or the other of the voltage supply rails losing complete control of the output.



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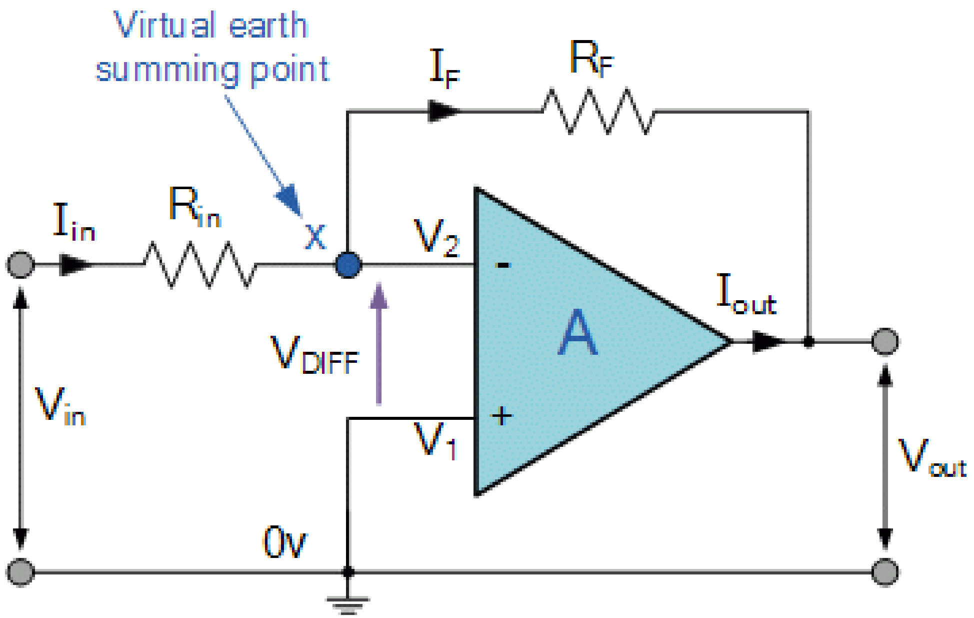
- Inverting Operational Amplifier
- To control the amplifier's overall gain, a suitable resistor is connected across the amplifier from the output terminal back to the inverting input terminal to both reduce and control the amplifier's overall gain.
- This then produces an effect known commonly as Negative Feedback, and thus produces a very stable Operational Amplifier based system.



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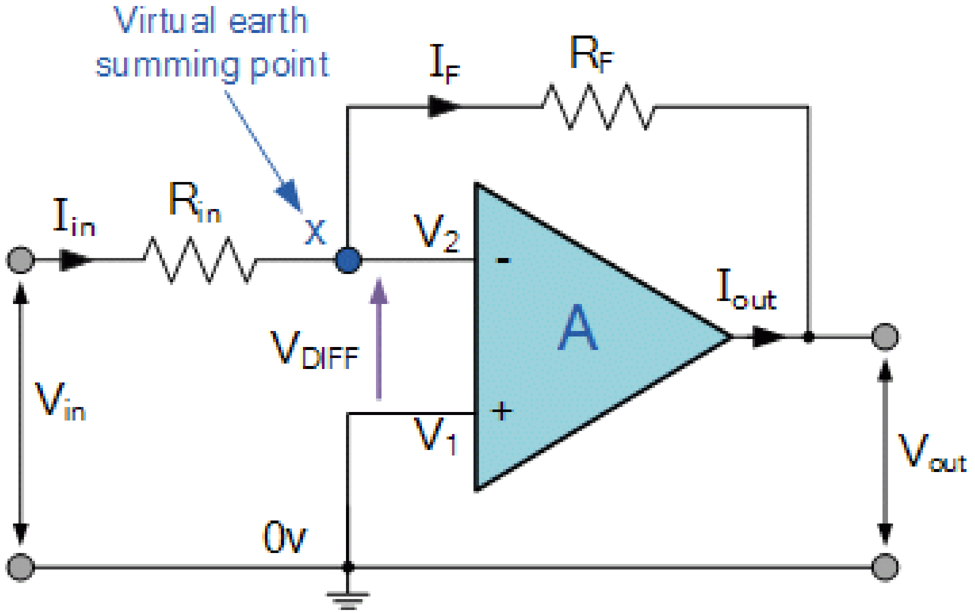
- Inverting Operational Amplifier Configuration
- The operational amplifier is connected with feedback to produce a closed-loop operation.
- The Closed-Loop Voltage Gain of an Inverting Amplifier is given as.

$$Gain\,(Av) = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

- and this can be transposed to give Vout as:

$$Vout = -\frac{Rf}{Rin} \times Vin$$



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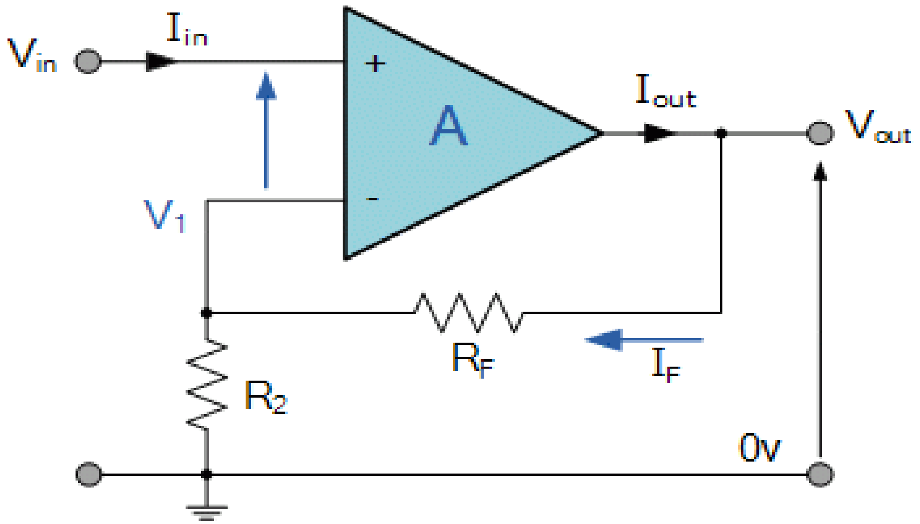
- Non-inverting Operational Amplifier
- The result of this is that the output signal is "in-phase" with the input signal.
- the closed-loop voltage gain of a Non-inverting Operational Amplifier will be given as:

$$A_{(V)} = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_2}$$



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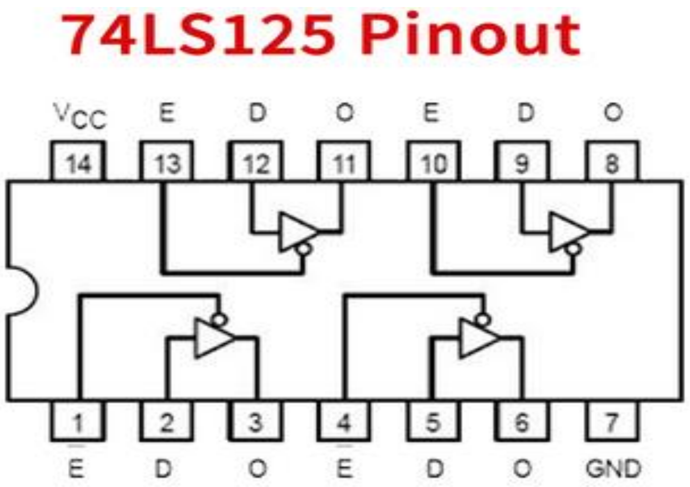
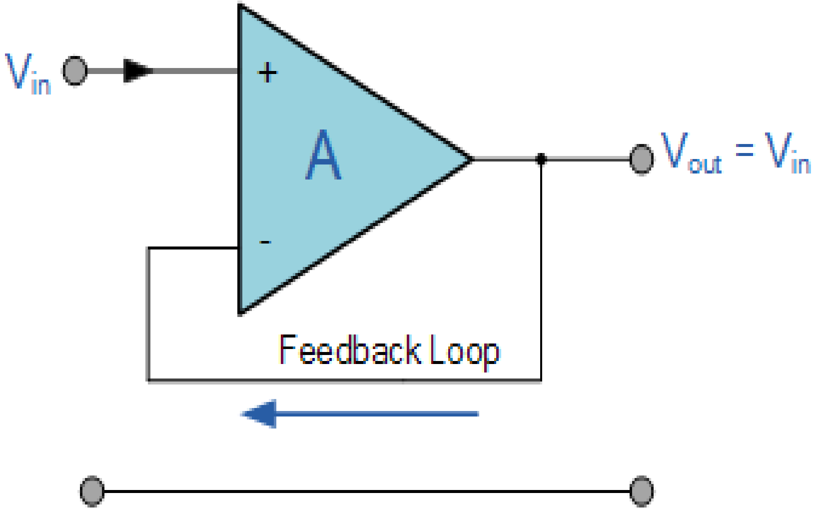
- Non-inverting Voltage Follower
- As the input voltage, Vin, is applied to the non-inverting input, the voltage gain of the amplifier is therefore given as:

$$V_{out} = A(V_{in})$$

$$(V_{in} = V+) \text{ and } (V_{out} = V-)$$

$$\text{therefore Gain, } (A_V) = \frac{V_{out}}{V_{in}} = +1$$





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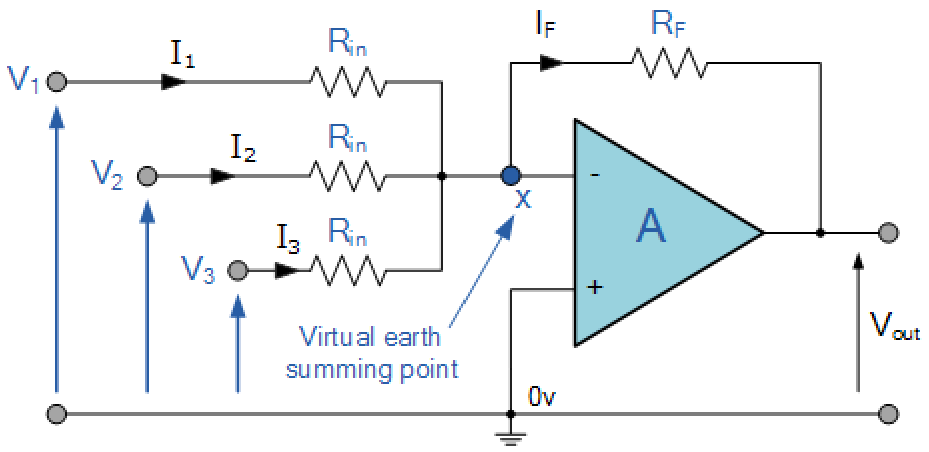
› The Summing Amplifier

$$I_F = I_1 + I_2 + I_3 = -\left[\frac{V1}{Rin} + \frac{V2}{Rin} + \frac{V3}{Rin}\right]$$

Inverting Equation: $Vout = -\frac{Rf}{Rin} \times Vin$

then, $-Vout = \left[\frac{R_F}{Rin}V1 + \frac{R_F}{Rin}V2 + \frac{R_F}{Rin}V3\right]$

$$-V_{OUT} = R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) \text{....etc}$$



› if all the input impedances, (RIN) are equal in value, we can simplify the above equation to give an output voltage of:

$$-Vout = \frac{R_F}{R_{IN}}\left(V1 + V2 + V3 \ldots.\text{etc}\right)$$

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› Non-inverting Summing Amplifier

› Here we use the non-inverting input of the operational amplifier to produce a non-inverting summing amplifier.

› The standard equation for the voltage gain of a non-inverting summing amplifier circuit is given as:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_{OUT}}{V+} = 1 + \frac{R_A}{R_B}$$

$$\therefore \quad V_{OUT} = \left[1 + \frac{R_A}{R_B}\right] V+$$

$$\text{Thus:} \quad V_{OUT} = \left[1 + \frac{R_A}{R_B}\right] \frac{V_1 + V_2}{2}$$