Part1: Voltage Follower or Buffer

Voltage Follower or Buffer

What is a Voltage Follower?

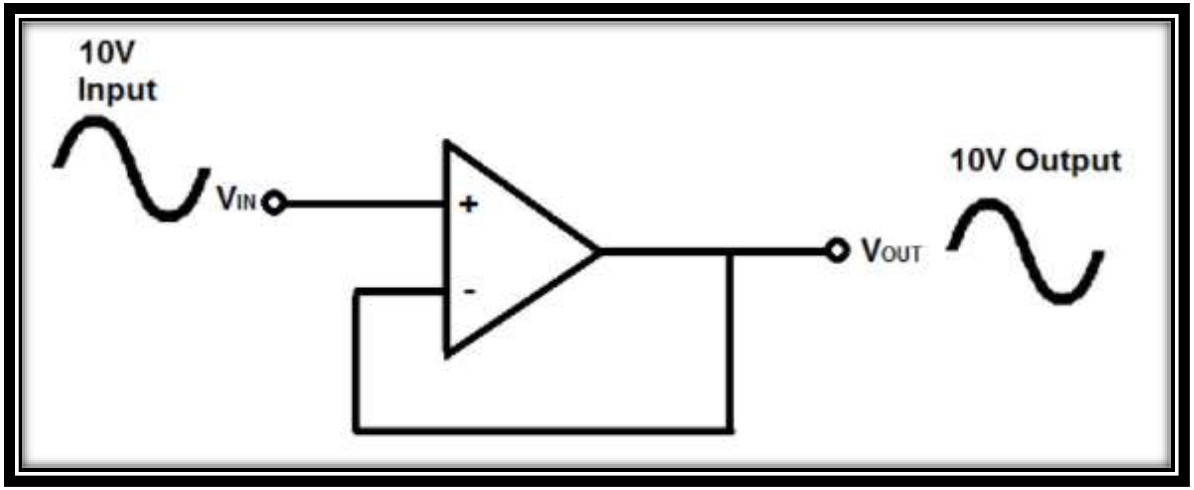
- A voltage follower is also known as a buffer amplifier, unity gain amplifier, or isolation amplifier
- Is an Op-Amp circuit whose output voltage is equal to the input voltage , so the output voltage follows the input voltage (V_{out}=V_{in})
- A voltage follower Op Amp does not amplify the input signal and has a voltage gain of 1
- Gain with feedback or closed loop gain of this circuit is 1

Part1: Voltage Follower or Buffer

- The voltage follower provides no attenuation or amplification-only buffering

- It is a special case of non-inverting Op-Amp, therefore, in this circuit the output signal is in phase with the input signal

- The feedback resistance Rf = 0 and the input resistane Ri = ∞



Part1: Voltage Follower or Buffer

Advantages of Voltage Followers:

1) Provides power gain and current gain (voltage gain Av = 1)
2) Low output impedance to the circuit, which uses the output of the voltage follower
3) High input impedance, Op-Amp takes no current from the input
4) Loading effects can be avoided
5) Isolator purpose, to isolate one circuits to another circuit
6) Impedance matching

Part1: Voltage Follower or Buffer

Applications of Voltage Followers:

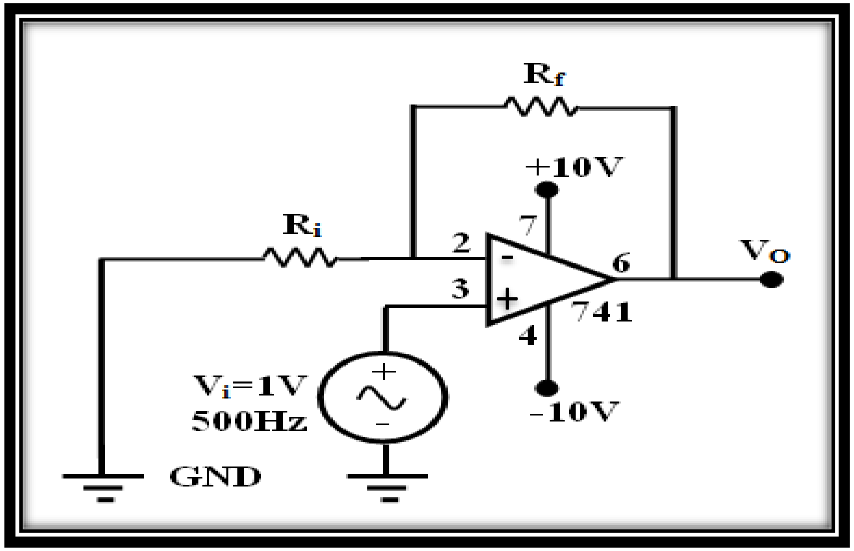
1) **Buffers for logic circuits**

2) **Sample and hold circuits**

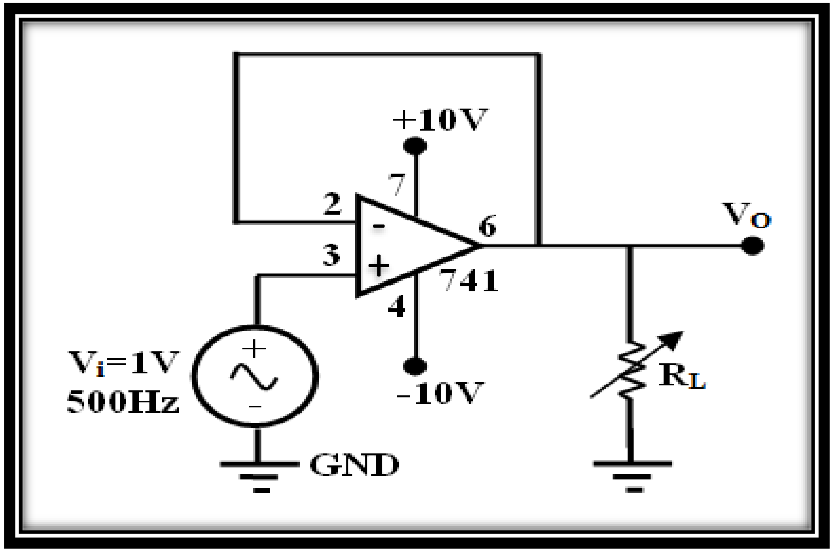
3) **Active filters, voltage followers can be used to isolate filter stages from each other, when building multistage filters**

4) **Bridge circuit via a transducer**

Part1: Voltage Follower or Buffer



Non-Inverting Circuit



Voltage Follower (Buffer) Circuit

$$A_v = \frac{V_o}{V_i} = 1 + \frac{R_f}{R_i}$$

$$V_o = A_v V_i$$

$$A_v = \frac{V_o}{V_i} = 1 + \frac{0}{\infty} = 1$$

$$R_f = 0,\ R_i = \infty$$

$$V_o = V_i$$

Part1: Voltage Follower or Buffer

The input impedance of the op-amp is **very high** when a voltage follower or unity gain configuration is used. Sometimes the input impedance is **much higher than 1 Megohm**. So, due to high input impedance, we can apply **weak signals** across the input and **no current** will flow in the input pin from the signal source to amplifier. On the other hand, the **output impedance** is **very low**, and it will produce the **same signal input**, in the output.

Voltage follower circuit is used to **create isolation** between two different kind of circuits. Due to high input impedance,, so the **input current is much lower than the output current** while the output voltage follows the input voltage. So the voltage follower provides **large power gain** across its output. Due to this behavior, Voltage follower used as a buffer circuit and can be used to isolate stages while building multistage filters or some other multistage circuit.

Part2: Integrator Op Amp Circuit

- An **integrator** is an electronic circuit that produces an output that is the integration of the applied input. This section discusses about the op-amp based integrator.
- An op-amp based integrator produces an output, which is an integral of the input voltage applied to its inverting terminal.
- It is a circuit designed with Op-Amp in such a way that it performs the mathematical Integration operation
- its output is proportional to the amplitude and time duration of the input applied.
- The integrator circuit layout is same as a inverting amplifier but the feedback resistor is replaced by a capacitor which make the circuit frequency dependent.

Part2: Integrator Op Amp Circuit

- In this case the circuit is derived by the time duration of input applied which results in the charging and discharging of the capacitor.

- Initially when the voltage is applied to integrator the uncharged capacitor allows maximum current to pass through it and no current flows through the Op-Amp due to the presence of virtual ground,
- the capacitor starts to charge at the rate of RC time constant and its impedance starts to increase with time and a potential difference is develops across the capacitor resulting in charging current to decrease.
- This results in the ratio of capacitor's impedance and input resistance increasing causing a linearly increasing ramp output voltage that continues to increase until the capacitor becomes fully charged.

Part2: Integrator Op Amp Circuit

Since, the Output voltage is the potential difference across capacitor.

$$V_C = \frac{Q}{C}, \; Q = CV, \; I_f = \frac{dQ}{dt} = C\,\frac{dV_c}{dt}$$

$$I_i = I_f$$

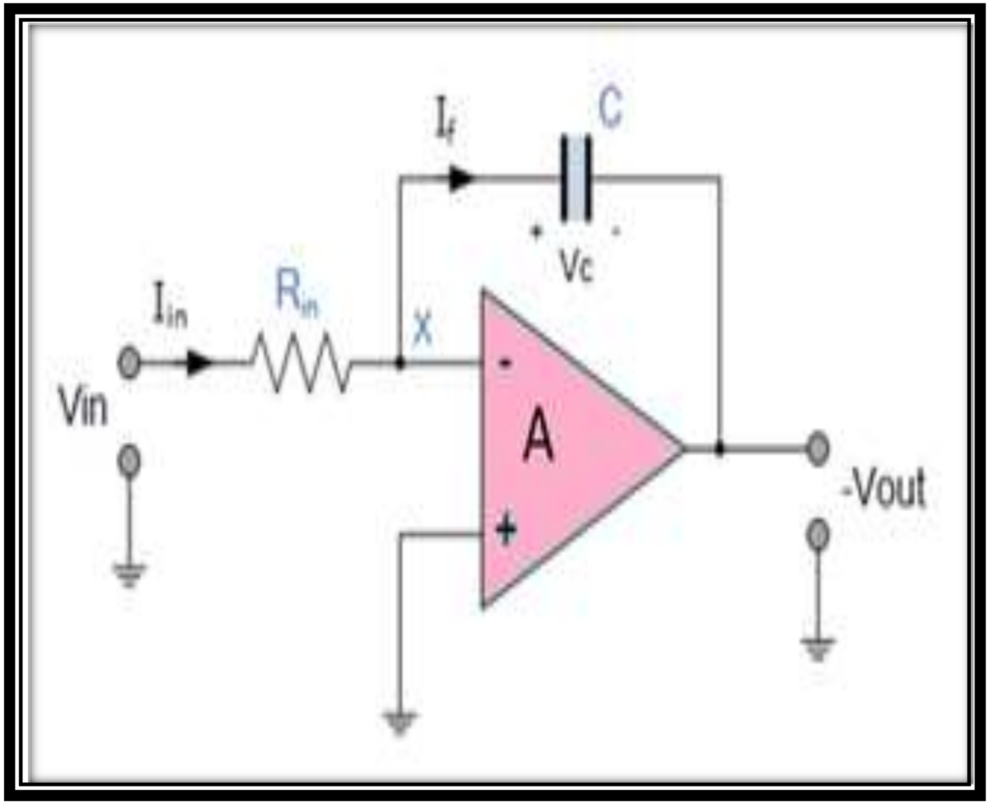
$$I_i = \frac{V_{in} - V_x}{R_{in}} = C\,\frac{d\,(V_x - V_{out})}{dt}$$

$$V^+ = V^- = V_x = 0$$

$$\frac{V_{in}}{R_{in}} = -\,C\,\frac{dV_{out}}{dt}$$

$$dV_{out} = -\,\frac{1}{R_{in}C}\,V_{in}\,dt$$

$$V_{out} = -\,\frac{1}{R_{in}C}\int V_{in}\,dt$$



$$V_o = -\,\frac{1}{R\,C}\int V_i\,dt$$

Part3: Differentiator Op Amp Circuit

- A **differentiator** is an electronic circuit that produces an output equal to the first derivative of its input. This section discusses about the op-amp based differentiator in detail.
- An op-amp based differentiator produces an output, which is equal to the differential of input voltage that is applied to its inverting terminal.
- In the differentiator circuit the input is connected to the inverting output of the Op-Amp through a capacitor(C) and a negative feedback is provided to the inverting input terminal through a resistor(R_f)
- which is same as an integrator circuit with feedback capacitor and input resistor being replaced with each other.
- Here the circuit performs a mathematical differentiation operation, and the output is the first derivative of the input signal, 180' out of phase and amplified with a factor R_f*C.

Part3: Differentiator Op Amp Circuit

- The capacitor on the input allows only the AC component and restrict the DC, at low frequency the reactance of capacitor is very high causing a low gain and high frequency vice versa but and high frequency the circuit becomes unstable.

Part3: Differentiator Op Amp Circuit

$V_C = \frac{Q}{C}$, Q = CV,

$I_i = \frac{dQ}{dt} = C\,\frac{dV_c}{dt}$

$I_i = I_f$

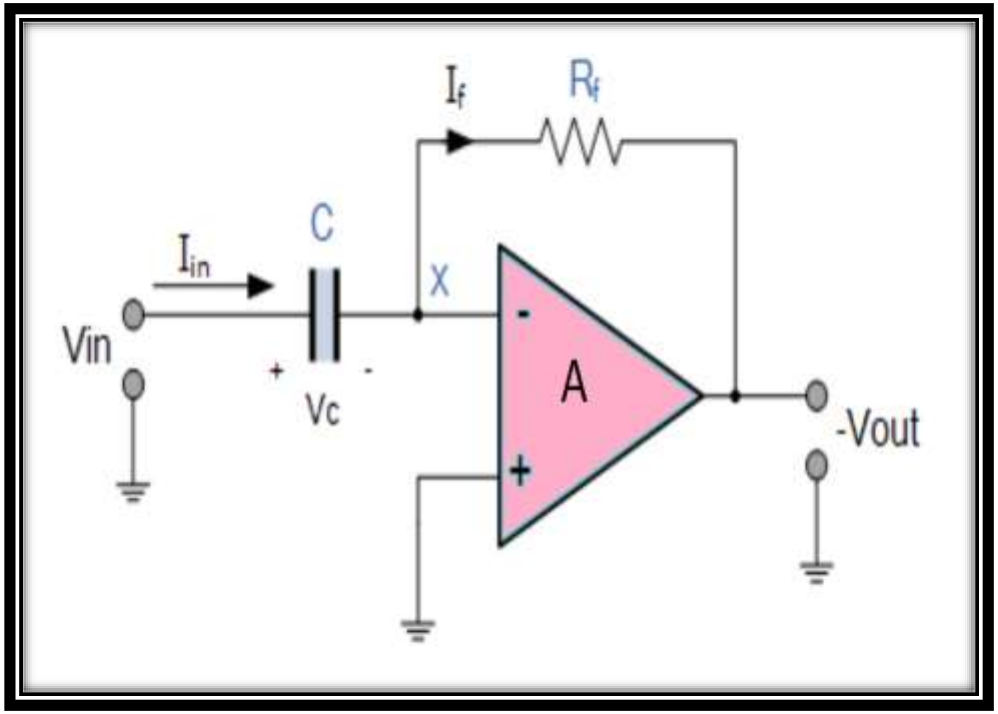
$I_i = C\,\frac{d\,(V_{in} - V_x)}{dt} = \frac{V_x - V_{out}}{R_f}$

$V^+ = V^- = V_x = 0$

$C\,\frac{dV_{in}}{dt} = -\,\frac{V_{out}}{R_f}$

$V_{out} = -R_f C\,\frac{dV_{in}}{dt}$

$V_{out} = -R\,C\,\frac{dV_{in}}{dt}$



$$V_{out} = -R\,C\,\frac{dV_{in}}{dt}$$

Example: A 5mV, 1-kHz sinusoidal signal is applied to the input of an OP-AMP integrator, for which R = 100 K and C = 1 μF. Find the output voltage.

Solution:

$$-\frac{1}{CR} = \frac{1}{10^5 \times 10^{-6}} = \mathbf{-10}$$

The equation for the sinusoidal voltage is

$$v_1 = 5 \sin 2\pi f t = 5 \sin 2000\,\pi t$$

Obviously, it has been assumed that at $t = 0$, $v_1 = 0$

$$v_0(t) = -10 \int_0^t 5 \sin 2000\,\pi t = -50 \left| \frac{-\cos 2000\,\pi t}{2000} \right|_0^t$$

$$= -\frac{1}{40\,\pi}(\cos 2000\,\pi t - 1)$$

Example: The input to the differentiator circuit is a sinusoidal voltage of peak value of 5 mV and frequency 1 kHz. Find out the output if $R = 1000\ K\Omega$ and C = 1 μF.

Solution:

The equation of the input voltage is

$v1 = 5 \sin 2\pi \times 1000\, t = 5 \sin 2000\,\pi t$ mV

scale factor = $CR = 10^{-6} \times 10^{5} = 0.1$

$$v_o = 0.1 \frac{d}{dt}(5 \sin 2000\pi t) = 0.1 \times 5 \times (\cos 2000\pi t) \times 2000\pi$$

$$= 1000\,\pi\,(\cos 2000\,\pi t)\ \text{mV}$$