Voltage Series Feedback & Operational Amplifiers

Introduction

Voltage Series Feedback

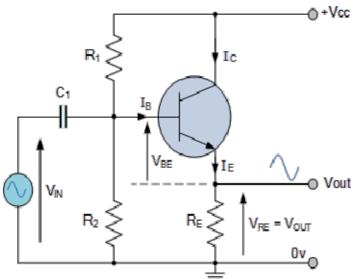
Example: Common Collector Amplifier

The common-collector or emitter follower amplifier

The Common Collector Amplifier is another type of bipolar junction transistor, (BJT) configuration where the input signal is applied to the base terminal and the output signal taken from the emitter terminal.

Thus the collector terminal is common to both the input and output circuits.

This type of configuration is called Common Collector, (CC) because the collector terminal is effectively "grounded" or "earthed" through the power supply.



Common Collector Amplifier Voltage Gain

$$V_{OUT} = \frac{V_{IN} \times R_E}{r'_e + R_E}$$

Thus:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{I_e \times R_E}{I_e(r'_e + R_E)}$$

Since R_E is much greater than r'_e, $(r'_e - R_E) \cong R_E$

and the two emitter currents, I_e cancel, thus:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{R_E}{R_E} \cong 1$$

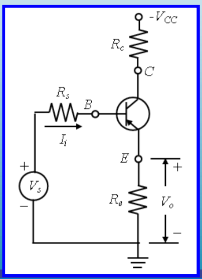
Thus since the output signal closely follows the input and is in-phase with the input the common collector circuit is therefore a non-inverting unity voltage gain amplifier.

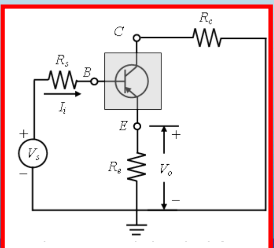
https://www.electronics-tutorials.ws/amplifier/common-collector-amplifier.html

The Emitter Follower: Example of Voltage Series Feedback

Equivalent circuit for ac analysis is shown in **the right**

The terminals ***B*** and ***E*** are used for input and ***C*** and ***E*** are used for output. The feedback is the voltage V_f across R_e, and the sampled signal is the output voltage V_o across R_e.

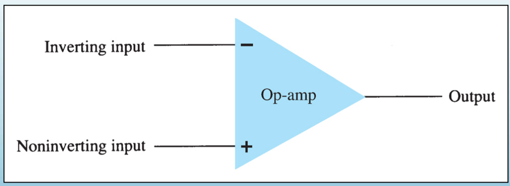




Equivanlent ckt for AC analysis

Hence, this is the case of voltage-series feedback.

The Basic Op-Amp



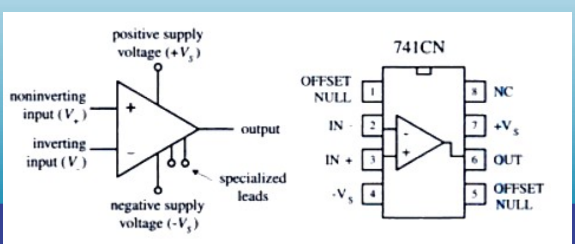
Operational amplifier (Op-amp): A high gain differential amplifier with a high input impedance (typically in MΩ) and low output impedance (less than 100Ω).

Note the op-amp has two inputs and one output.

Operational Amplifier

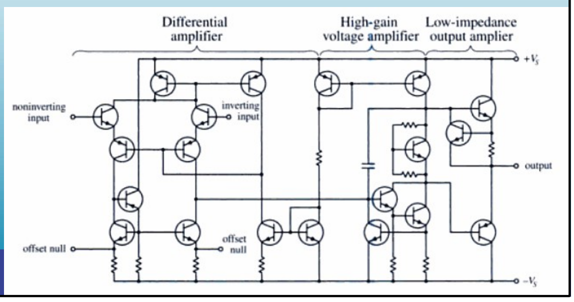
A typical op amp is an integrated circuit which has

1. Noninverting input
2. Inverting input
3. Two DC power supply leads (positive and negative)
4. An output terminal
5. Some other leads for fine tuning



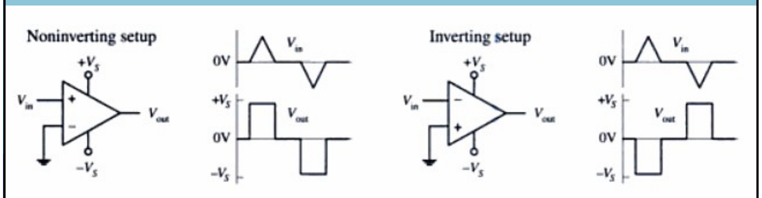
Operational Amplifier

- Op amp is an integrated circuit consist of a large number of transistors, several resistors and a few capacitors
- It has three stages : 1. A high input impedance differential amplifier. 2. a high gain voltage amplifier with a level shifter and 3. a low impedance output amplifier.



Operational Amplifier: Basic Operation:

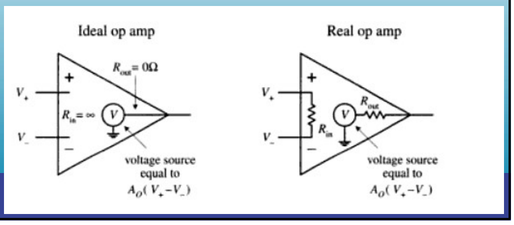
- If the inverting input V_ is more positive than the noninverting input V_+ than the output voltage saturates towards the negative supply voltage $-V_s$.
- If the noninverting input V+ is more positive than the inverting input V_- then the output voltage saturates towards the positive voltage supply $+V_s$



Ideal and Real op amp, some rules:

For an ideal op amp the open loop voltage gain is infinite. For a real op amp, the gain is typically 10^4 to 10^6

- Ideal input impedance infinite, real input impedance is between 10^6 Ω.
- Ideal output impedance zero, real output impedance is between 10 to 1000 Ω.
- Input terminal current for ideal op amp is zero whereas in reality it draws a very small amount of current which is in pico ampere range.



ALWAYS LEARNING

Op-Amp Gain

Op-Amps can be connected in *open-loop* or *closed-loop* configurations.

Open-loop: A configuration with no feedback from the op-amp output back to its input. Op-amp open-loop gain typically exceeds 10,000.

Closed-loop: A configuration that has a negative feedback path from the op-amp output back to its input. **Negative feedback** reduces the gain and improves many characteristics of the op-amp.

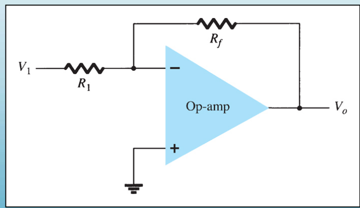
- Closed-loop gain is always lower than open-loop gain.

Inverting Op-Amp

The input signal is applied to the **inverting (–) input**

The **non-inverting input (+)** is grounded

The **feedback resistor** (R_f) is connected from the output to the negative (inverting) input; providing *negative feedback*.



Inverting Op-Amp Gain

Gain is set using external resistors: R_f and R_1

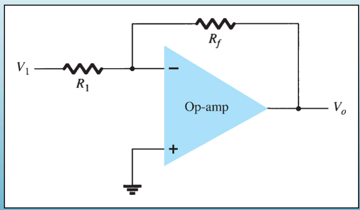
$$A_v = \frac{V_o}{V_i} = \frac{R_f}{R_1}$$

Gain can be set to any value by manipulating the values of R_f and R_1.

Unity gain ($A_v = 1$):

$$R_f = R_1$$

$$A_v = \frac{-R_f}{R_1} = -1$$

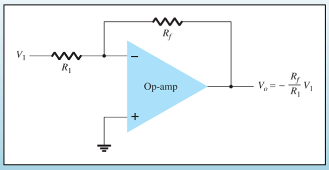


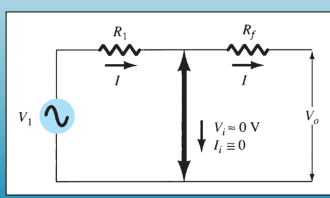
The negative sign denotes a 180° phase shift between input and output.

Virtual Ground

Virtual ground: A term used to describe the condition where $V_i \cong 0$ V (at the inverting input) when the noninverting input is grounded.

The op-amp has such high input impedance that even with a high gain there is no current through the inverting input pin, therefore all of the input current passes through R_f.





Common Op-Amp Circuits

Inverting amplifier

Noninverting amplifier

Unity follower

Summing amplifier

Integrator

Differentiator

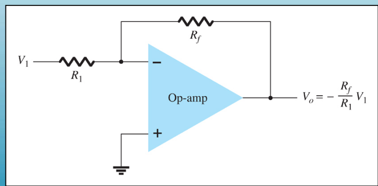
Inverting/Noninverting Amplifiers

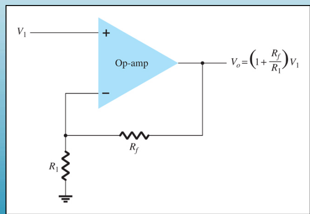
Inverting Amplifier

$$V_o = \frac{-R_f}{R_1} V_1$$

Noninverting Amplifier

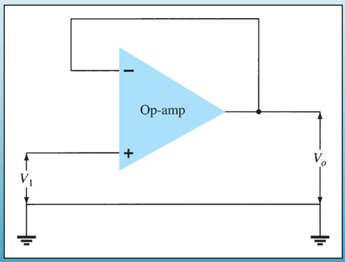
$$V_o = (1 + \frac{R_f}{R_1}) V_1$$





Unity Follower: Buffer Amplifier

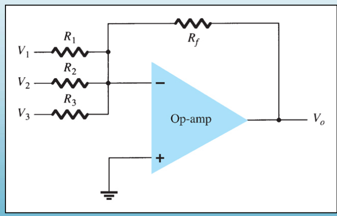
$$V_o = V_1$$



Summing Amplifier

Because the op-amp has a high input impedance, the multiple inputs are treated as separate inputs.

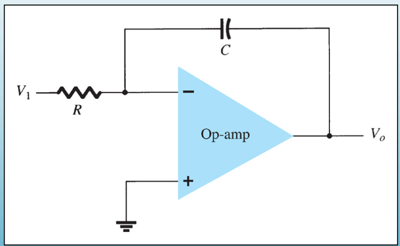
$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$



Integrator

The output is the integral of the input; i.e., proportional to the area under the input waveform. This circuit is useful in low-pass filter circuits and sensor conditioning circuits.

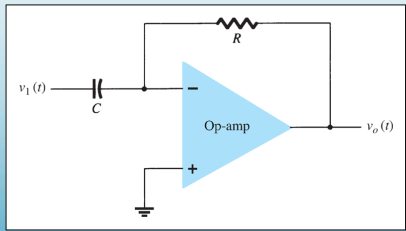
$$v_o(t) = -\frac{1}{RC}\int v_1(t)dt$$



Differentiator

The differentiator takes the derivative of the input. This circuit is useful in high-pass filter circuits.

$$v_o(t) = -RC\frac{dv_1(t)}{dt}$$



Comparator

•Essentially compares two signals

•Output goes high when the input signal is greater than a reference signal.