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Engineering Design Project-II
(UTA 024)

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
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Engineering Design Project-II
(UTA 024)
Buggy Lab

Dr. Amit Mishra

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Block diagram of operational amplifier

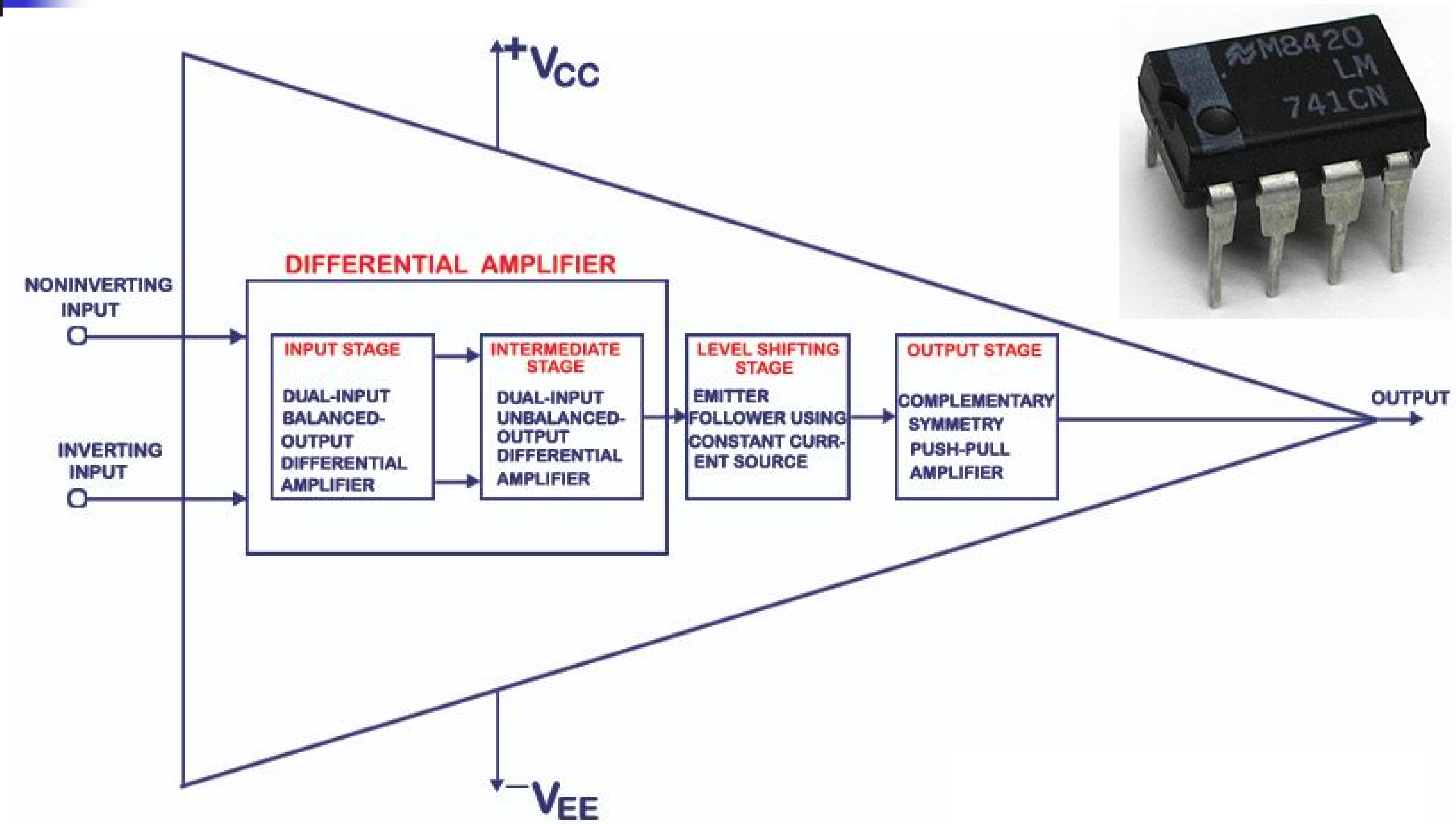
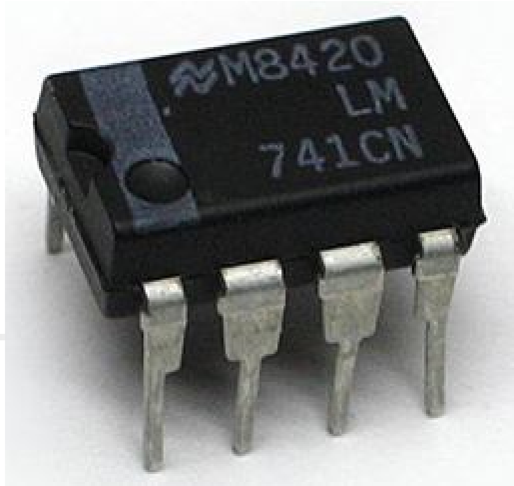


Image source: Google

Pin diagram of operational amplifier



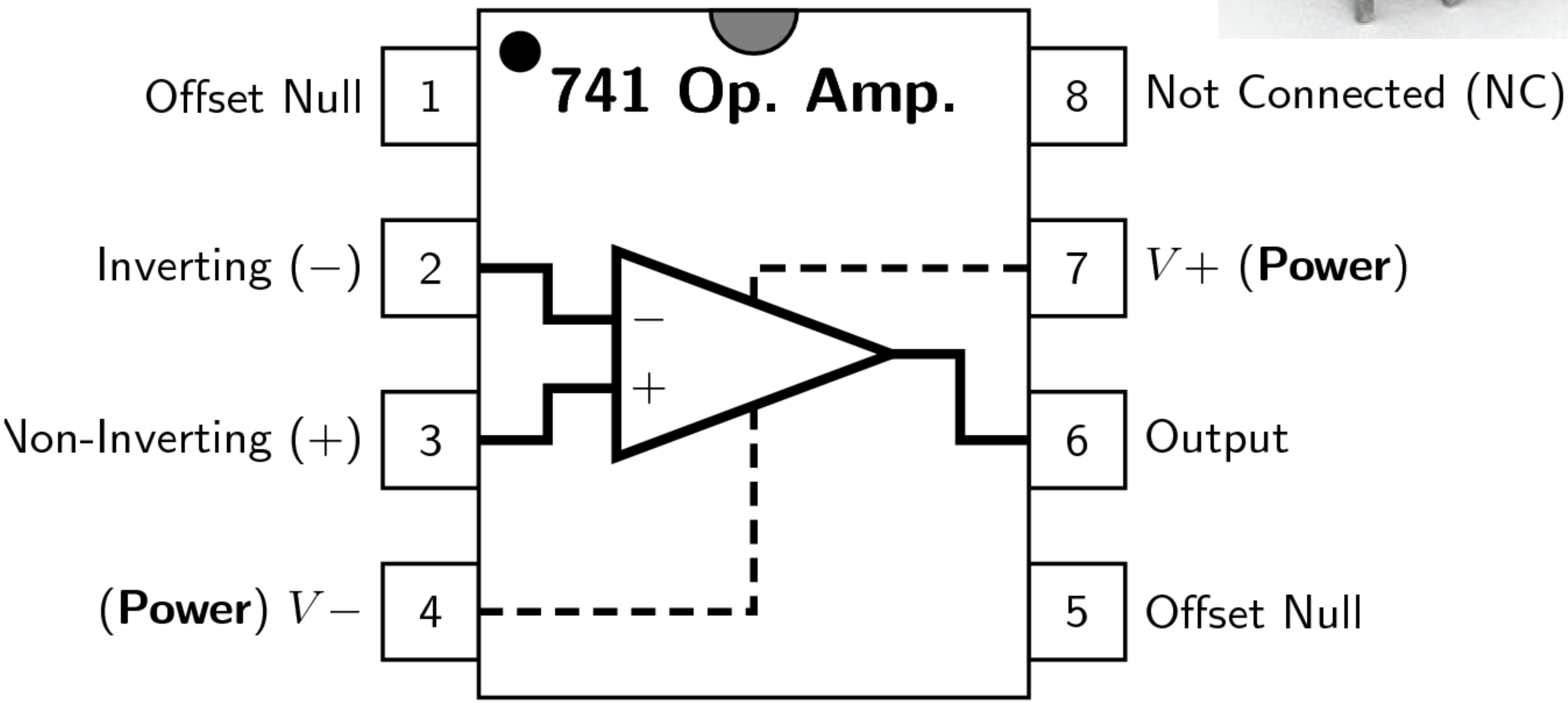


Image source : Google

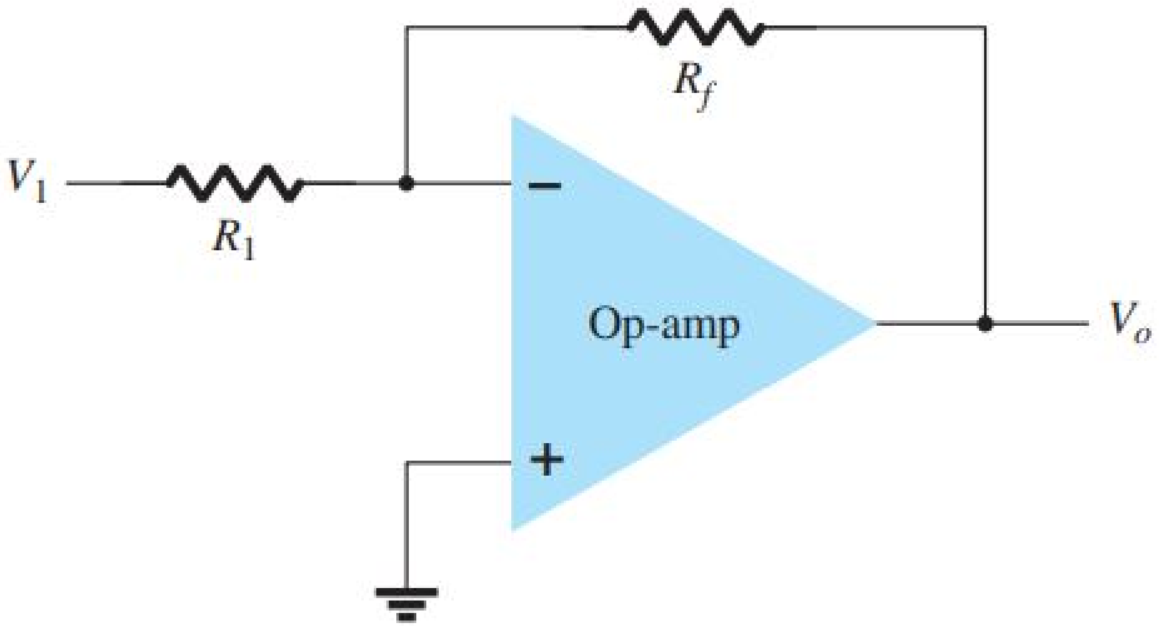
Ideal characteristics of an operational amplifier and typical values

- Infinite input impedance ≈ 1-2 MΩ
- Zero output impedance ≈ 10-100 Ω
- Infinite open loop gain ≈ more than 1,00,000
- Infinite slew rate ≈ 0.5 V/µs
- Infinite Bandwidth ≈ 1 MHz
- Infinite Common mode rejection ratio (CMRR) ≈ 10,000
- Zero Supply voltage rejection Ratio (SVRR) ≈ 150 µV/V

Configurations of operational amplifier

- **Inverting amplifier**
- **Non inverting amplifier**

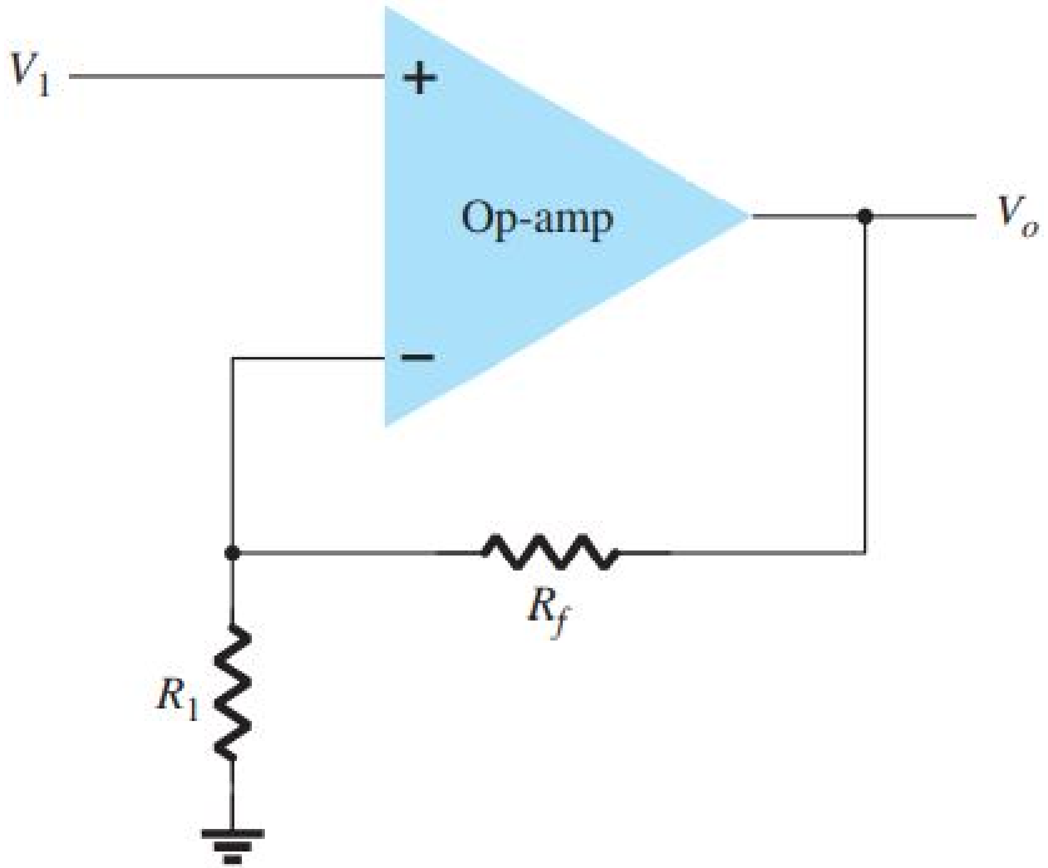
Inverting amplifier



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

Image source: Electronics devices and circuit theory by R. L. Boylestad

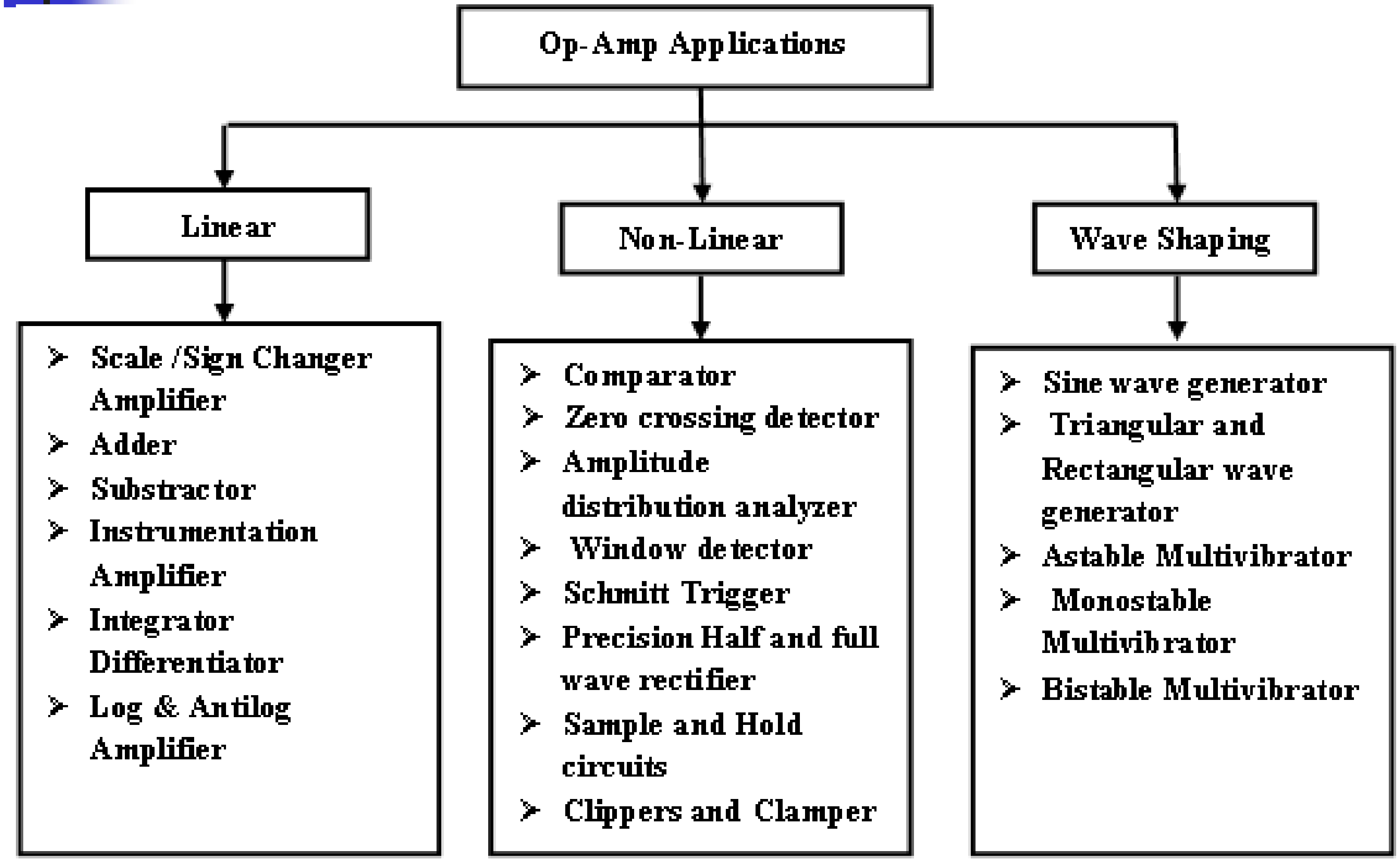
Non inverting amplifier



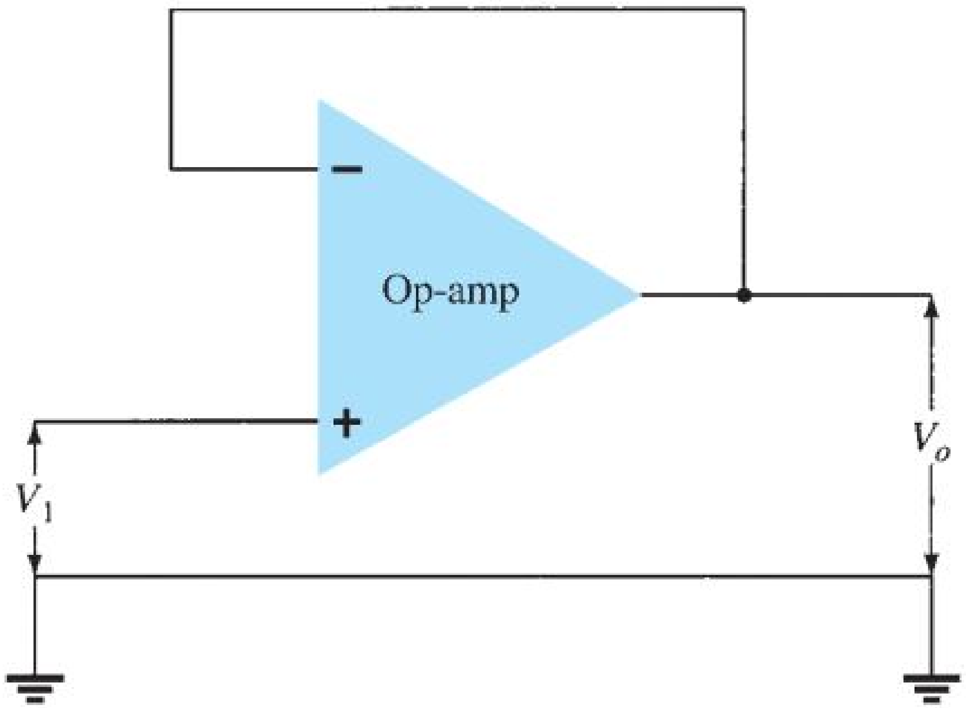
$$V_o = \left(1 + \frac{R_f}{R_1}\right)V_1$$

Image source : Electronics devices and circuit theory by R. L. Boylestad

Applications



Unity follower



$$\boxed{V_o = V_1}$$

Non inverting amplifier

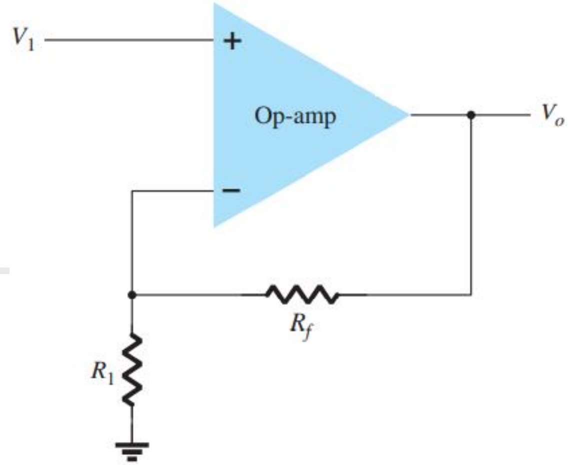
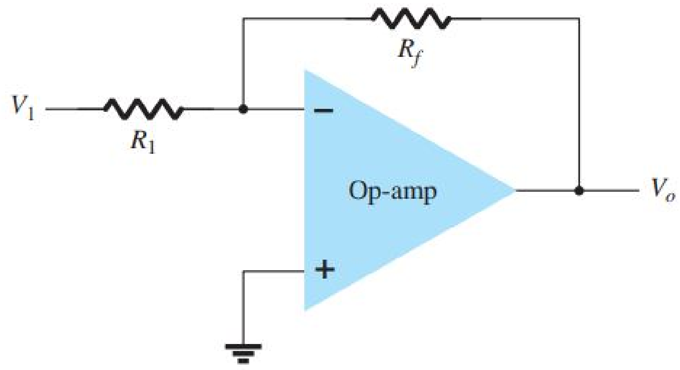
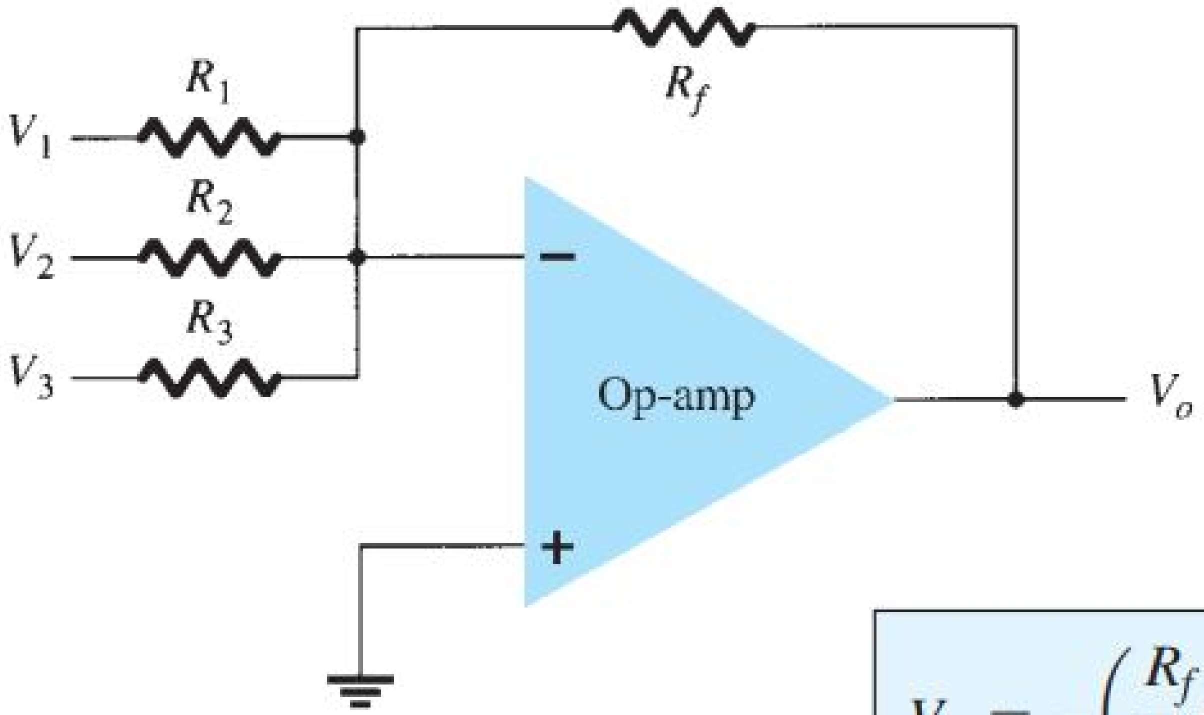


Image source : Electronics devices and circuit theory by R. L. Boylestad

Inverting amplifier



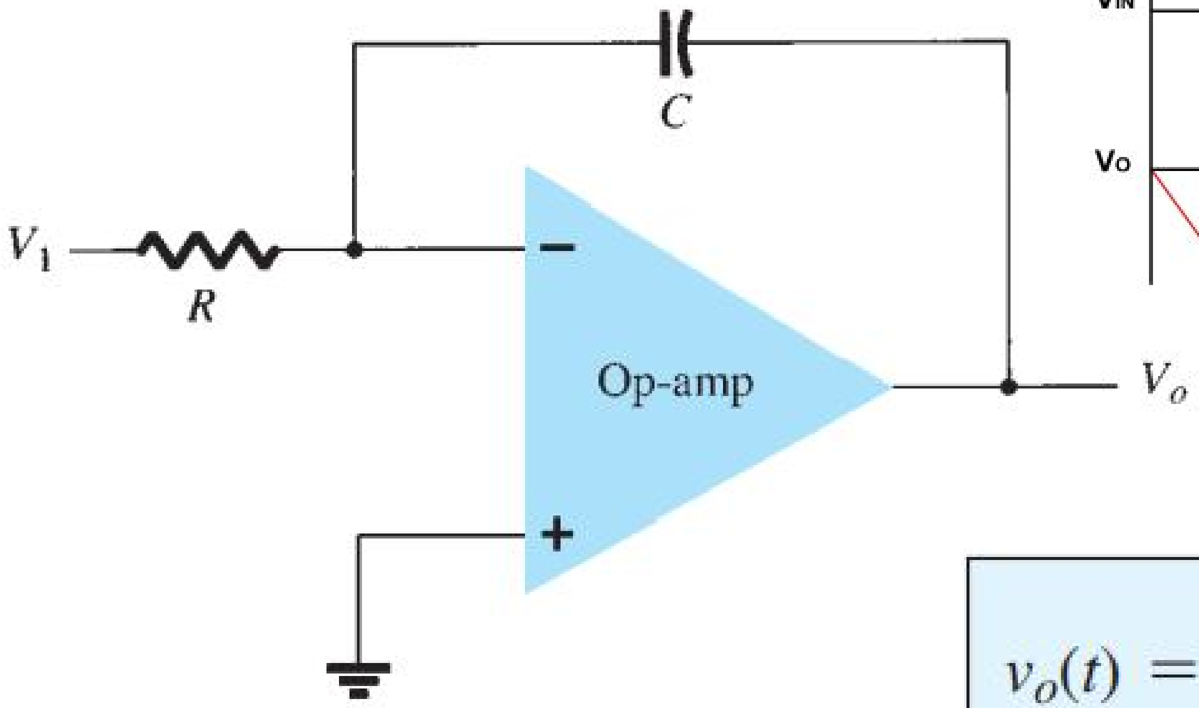
Summing amplifier

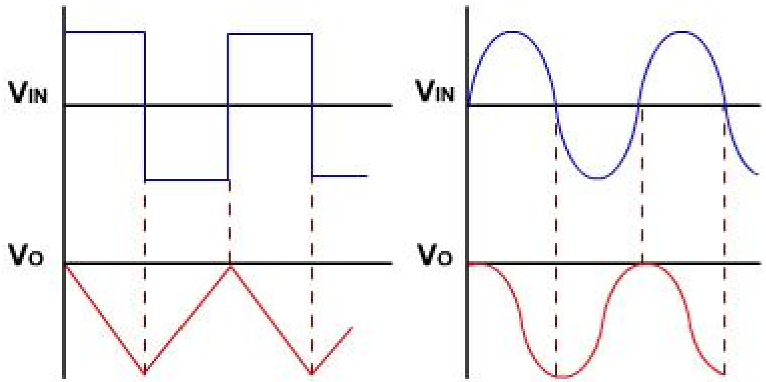


$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

Image source : Electronics devices and circuit theory by R. L. Boylestad

Integrator

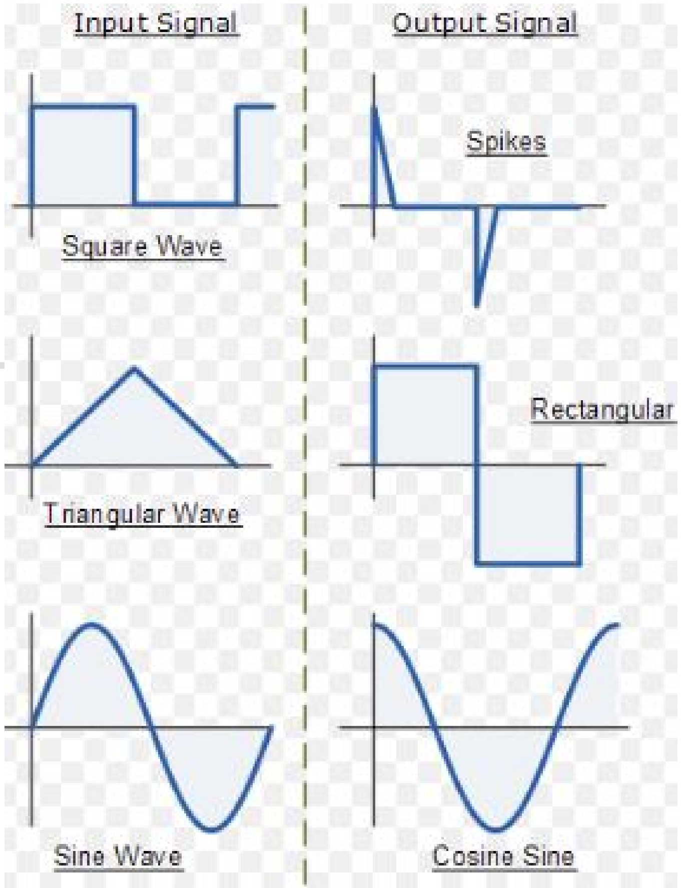


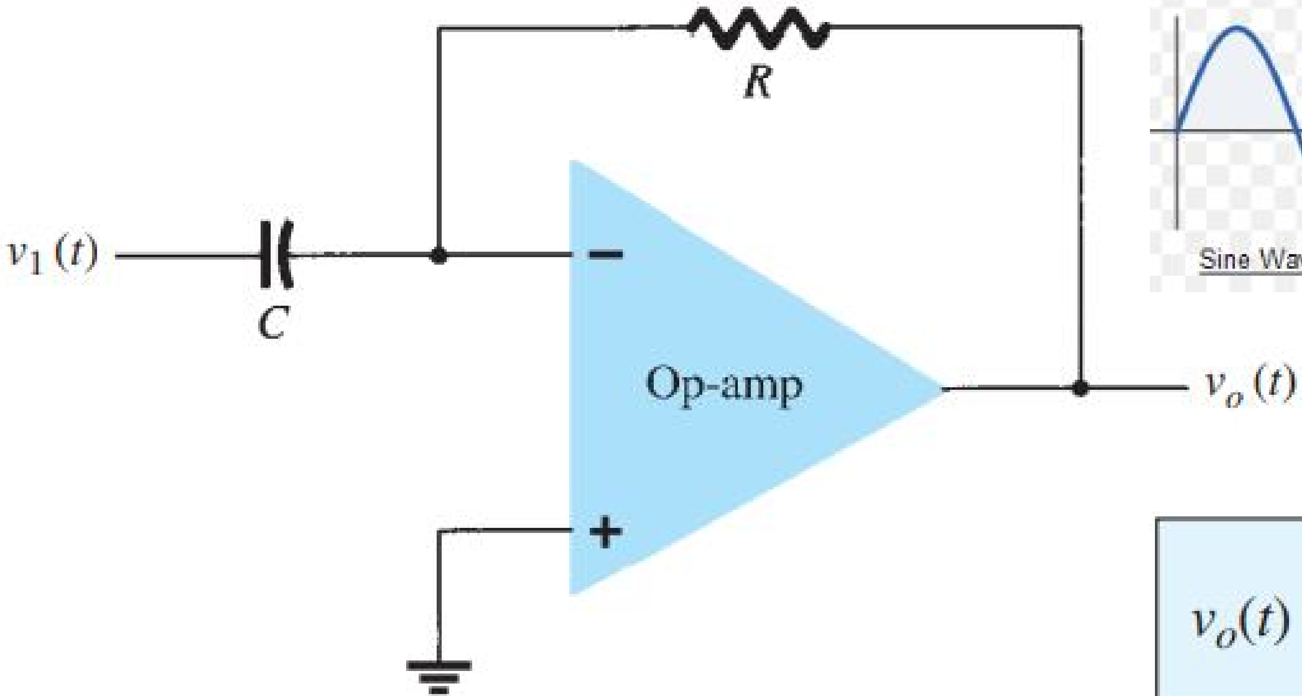


$$v_o(t) = -\frac{1}{RC}\int v_1(t)\,dt$$

Image source : Electronics devices and circuit theory by R. L. Boylestad

Differentiator



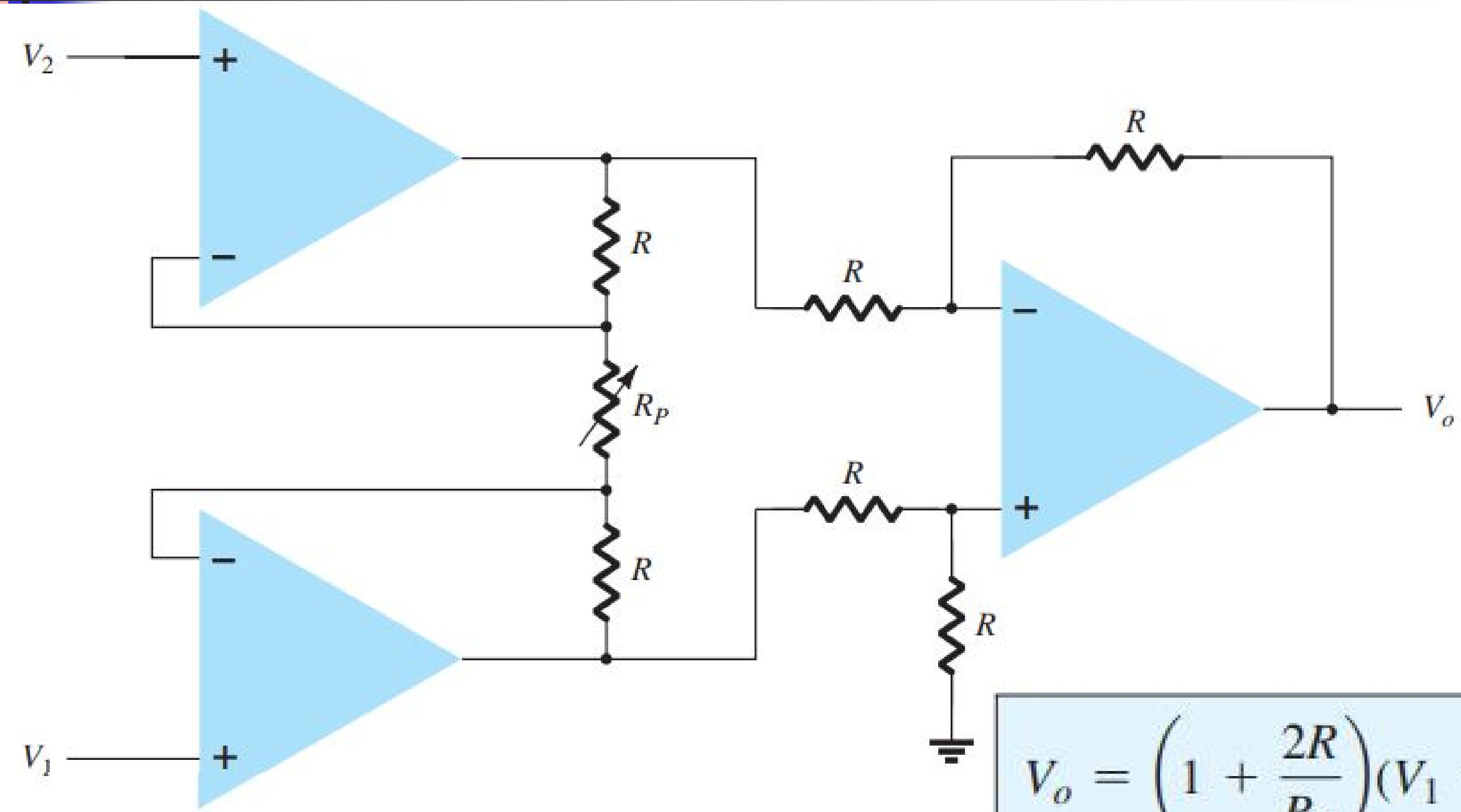


$$v_o(t) = -RC\frac{dv_1(t)}{dt}$$

Image source : Electronics devices and circuit theory by R. L. Boylestad

Instrumentation amplifier

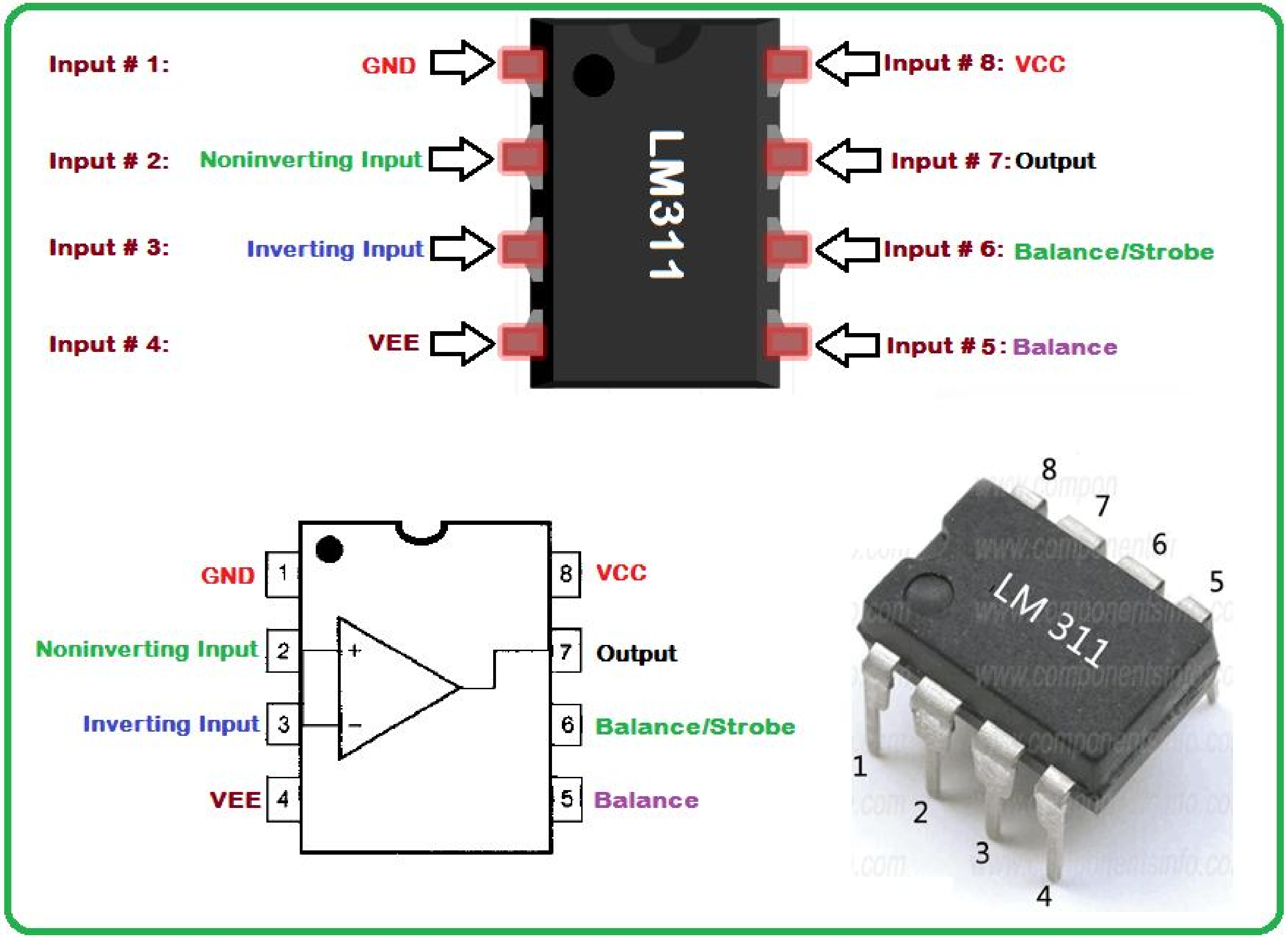
An ***instrumentation amplifier*** is a differential op-amp circuit providing high input impedances with ease of gain adjustment through the variation of a single resistor.



$$V_o = \left(1 + \frac{2R}{R_P}\right)(V_1 - V_2)$$

Image source : Electronics devices and circuit theory by R. L. Boylestad

LM311-Differential amplifier IC



Balance: This pin can be used to turn off the DC-offset voltage
Balance/Strobe: This pin can be used to turn off the output stage

Image source : Google

LM358-Low Power Dual Operational Amplifier IC

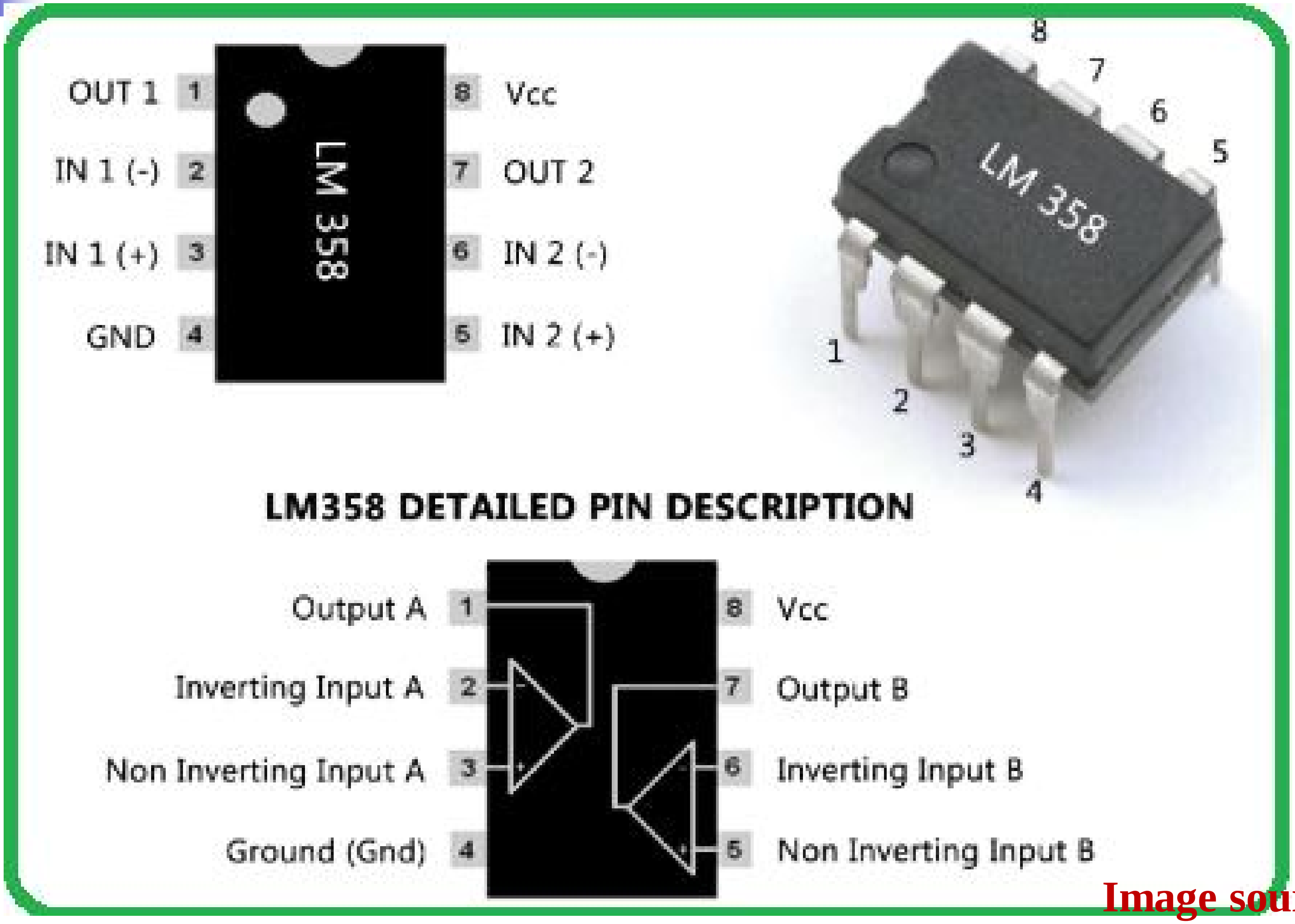


Image source : Google

References

- Boylestad, R. L., & Nashelsky, L. (1978). Electronic devices and circuit theory. Englewood Cliffs, N.J: Prentice-Hall.
- https://www.electronics-tutorials.ws/opamp/opamp_1.html
- https://www.circuitstoday.com/introduction-to-ua-741-op-amp
- https://components101.com/ics/lm311-differential-comparator-ic
- https://www.onsemi.com/pub/Collateral/LM358-D.PDF

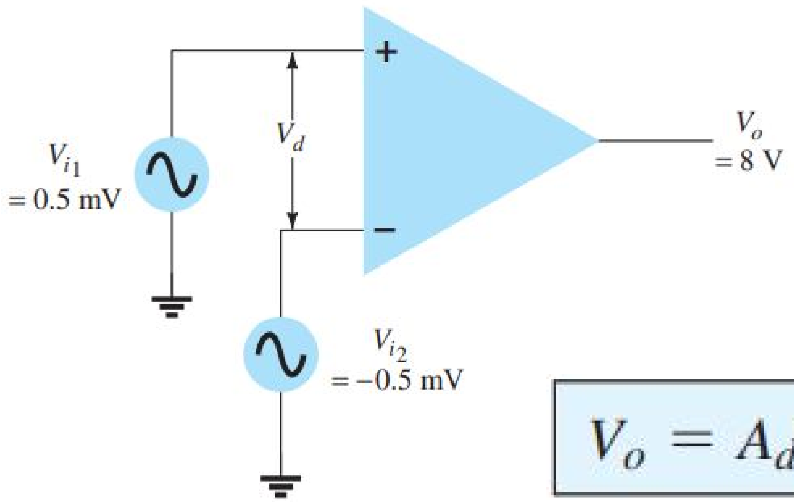
Thanks !

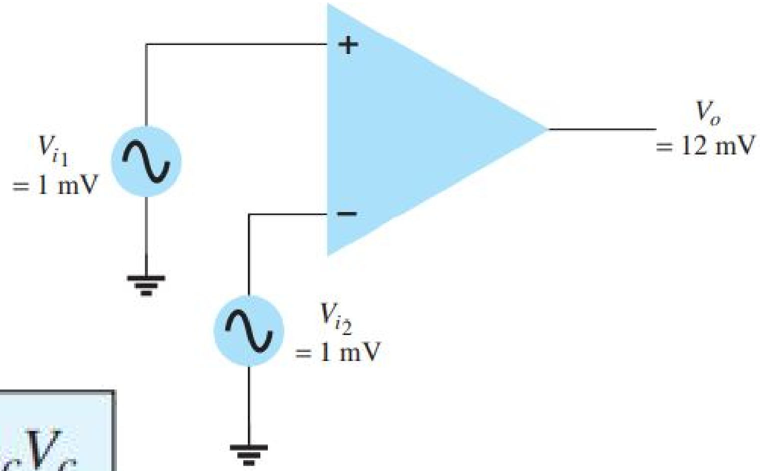
Common mode rejection ratio (CMRR)

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

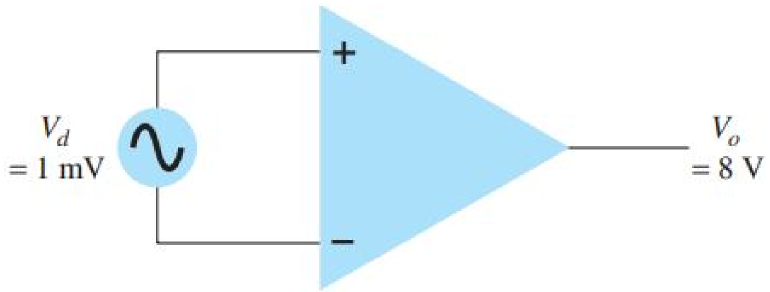
A high CMRR is **required** when a differential signal must be **amplified** in the **presence** of a possibly large **common-mode input**, such as strong electromagnetic interference (**EMI**). An example is audio transmission over balanced line in sound reinforcement or recording.

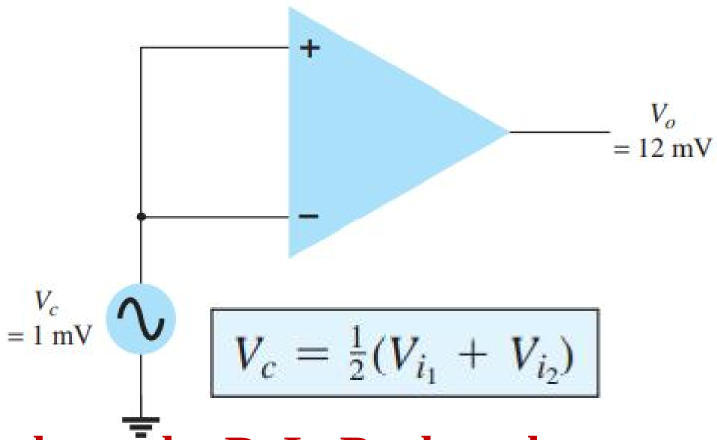
Example: Calculate CMRR





$$V_o = A_d V_d + A_c V_c$$





$$V_d = V_{i_1} - V_{i_2}$$

$$V_c = \tfrac{1}{2}(V_{i_1} + V_{i_2})$$

Courtesy: Electronics devices and circuit theory by R. L. Boylestad

Continued…

$$\boxed{V_o = A_d V_d + A_c V_c}$$

$$A_d = \frac{V_o}{V_d} = \frac{8\text{ V}}{1\text{ mV}} = 8000$$

$$A_c = \frac{V_o}{V_c} = \frac{12\text{ mV}}{1\text{ mV}} = 12$$

$$\text{CMRR} = \frac{A_d}{A_c} = \frac{8000}{12} = \mathbf{666.7}$$

$$\text{CMRR} = 20\log_{10}\frac{A_d}{A_c} = 20\log_{10}666.7 = \mathbf{56.48\ dB}$$

Power Supply rejection ratio (PSRR)

PSRR describe the capability of an electronic circuit to suppress any power supply variations to its output signal.

$$\mathrm{PSRR[dB]} = 10\log_{10}\left(\frac{\Delta V_{\mathrm{supply}}{}^2 A_v{}^2}{\Delta V_{\mathrm{out}}{}^2}\right)\mathrm{dB}$$

where A_v is the voltage gain.

Example: An amplifier with a PSRR of 100 dB in a circuit to give 40 dB closed-loop gain would allow about 1 millivolt of power supply ripple to be superimposed on the output for every 1 volt of ripple in the supply. This is because

$$100\ \mathrm{dB} - 40\ \mathrm{dB} = 60\ \mathrm{dB}.$$

And since that's 60 dB of rejection, the sign is negative so:

$$1\ \mathrm{V} \cdot 10^{\frac{-60}{20}} = 0.001\ \mathrm{V} = 1\ \mathrm{mV}$$

Supply Voltage rejection ratio (SVRR)

9.Supply Voltage Rejection Ratio (SVRR)

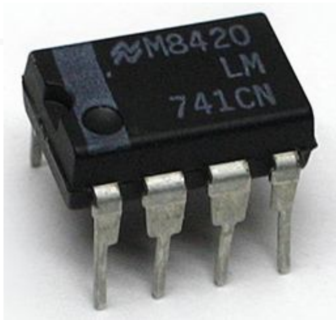
The change in the op-amp's offset voltage caused by variations in supply voltage is called SVRR. The change in supply voltage can be denoted by dV and the corresponsing change in input ffset voltage can be denoted by dVio.

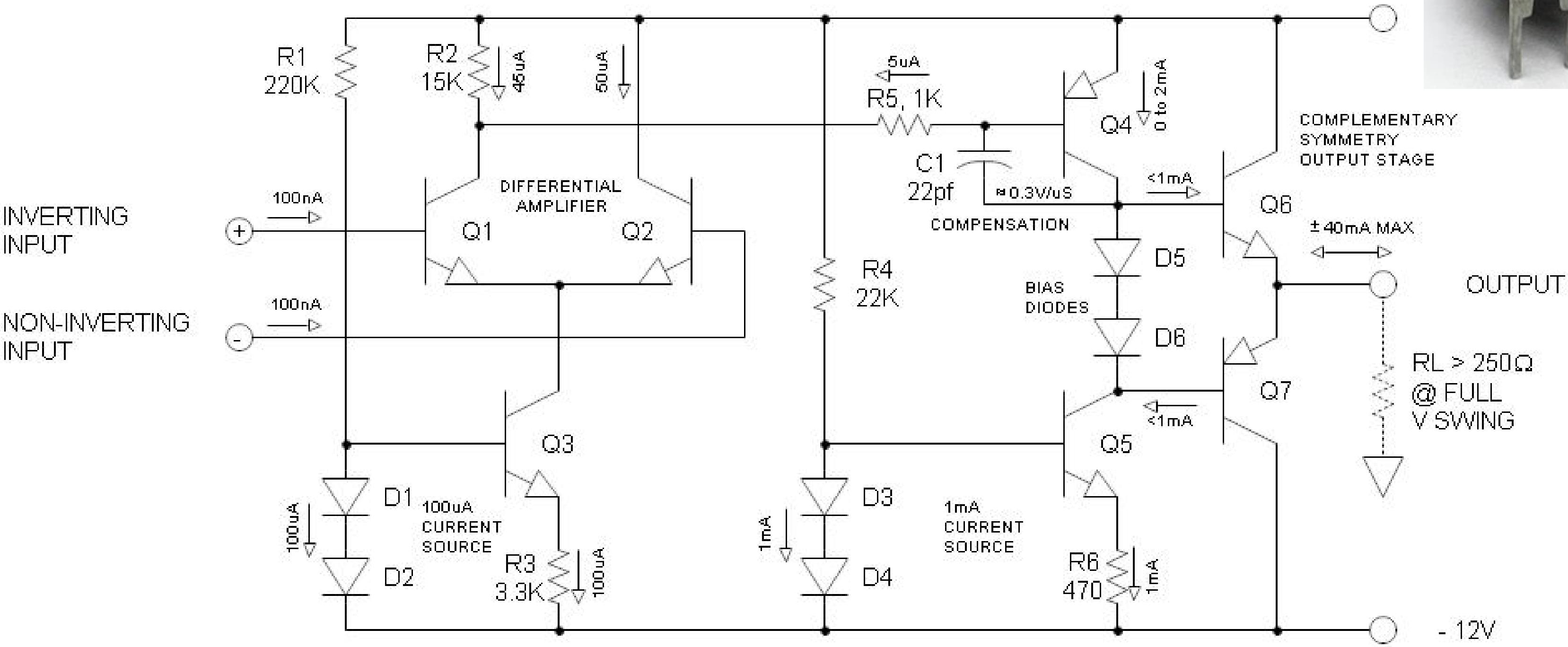
SVRR = Change in input offset voltage (dVio) / Change in supply voltage (dV)

For 741 IC, SVRR = 150uV/V.

The lower the value of SVRR, the better will be the op-amp performance.

Internal circuit diagram of operational amplifier





NPN TRANSISTORS:	BC547C
PNP TRANSISTORS:	BC557C
DIODES:	1N4148
RESISTORS:	5%, 0.25W

Image source : Google