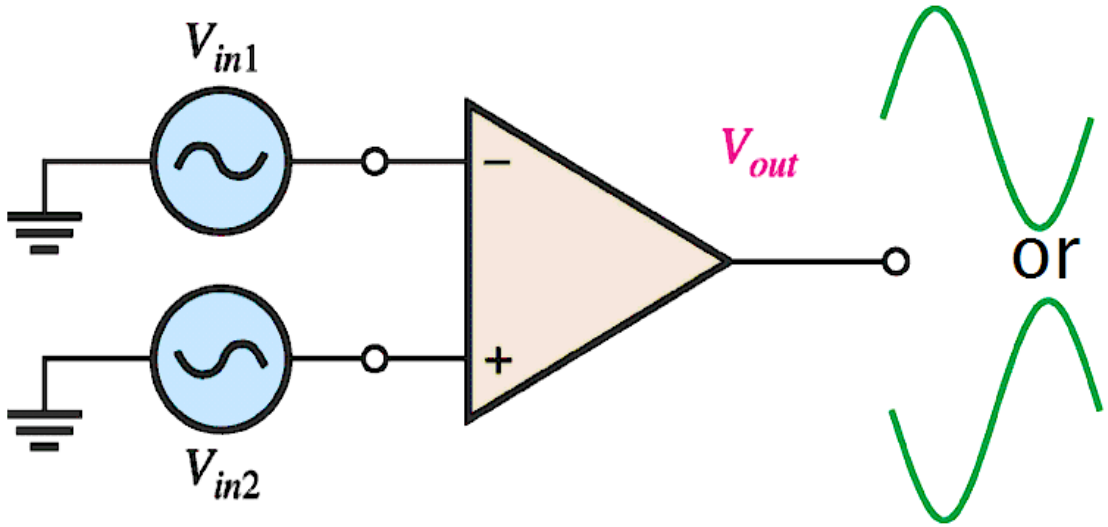
# OP AMP Characteristics

# Op-Amp Differential Mode

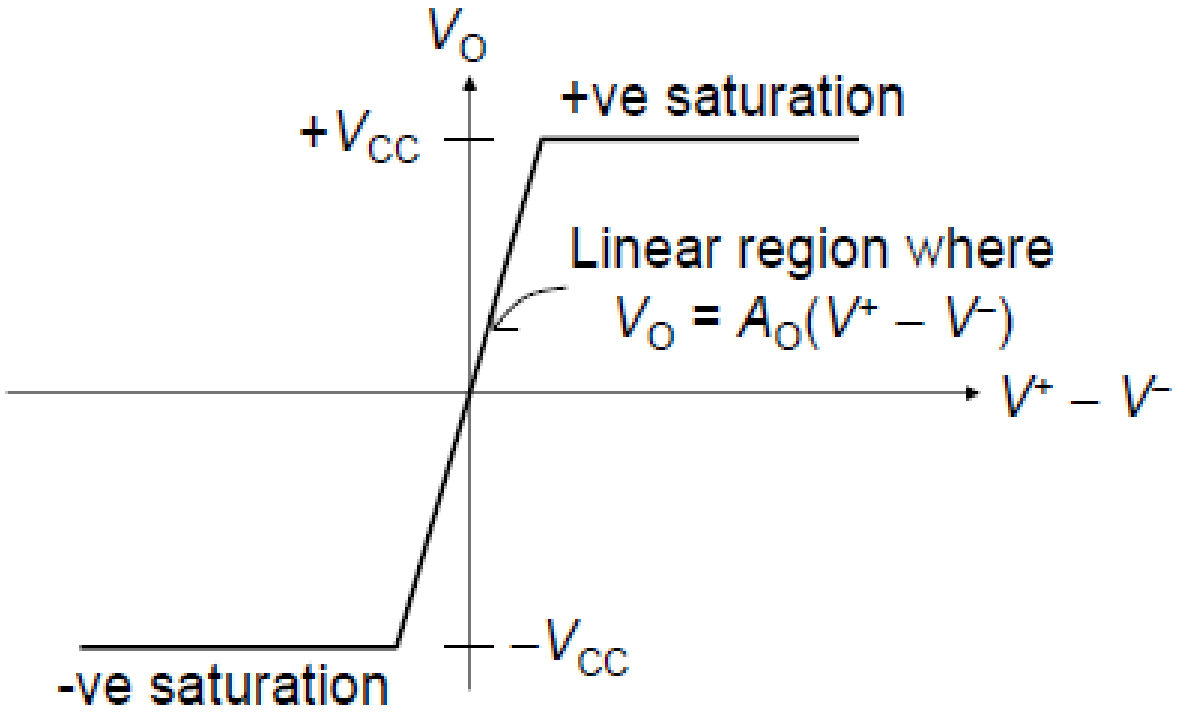



$$V_{out} = A_d V_d$$

$$V_d = V_{in1} - V_{in2}$$

In this mode two out-of-phase signals are applied with the difference of the two amplified is produced at the output.

# The Op-Amp Transfer Curve



# Op-Amp Specifications

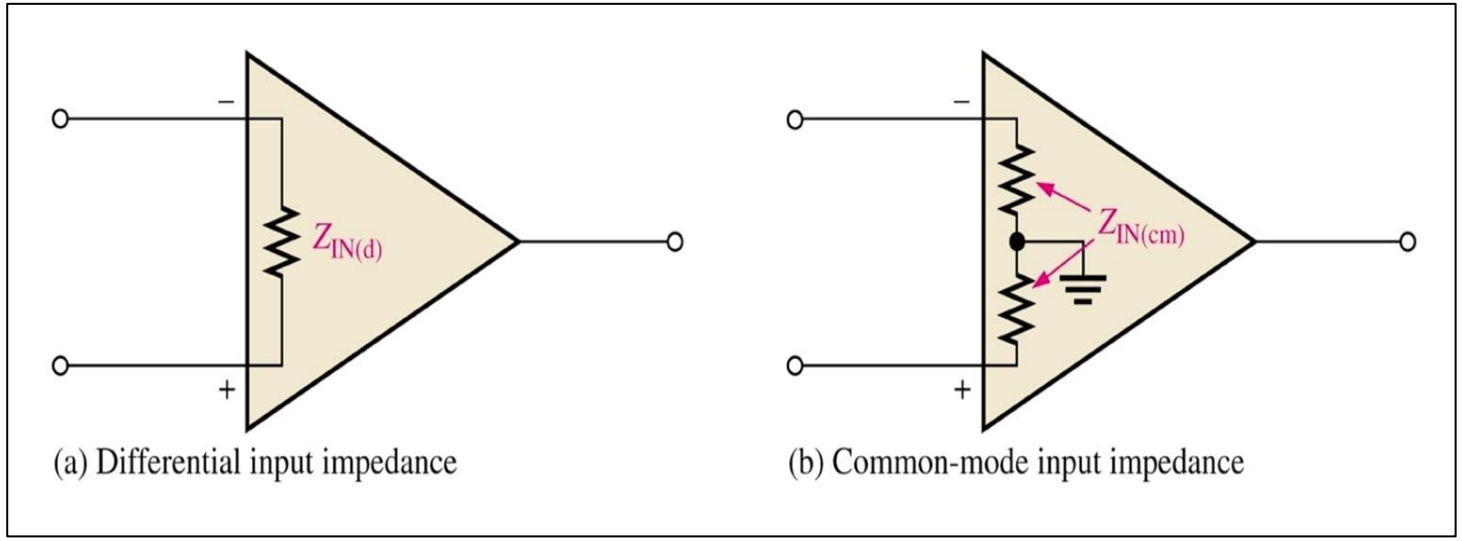
**DC Offset Parameters**

Even when the input voltage is zero, there will be an output called **offset.**

**1. Input Offset Voltage**

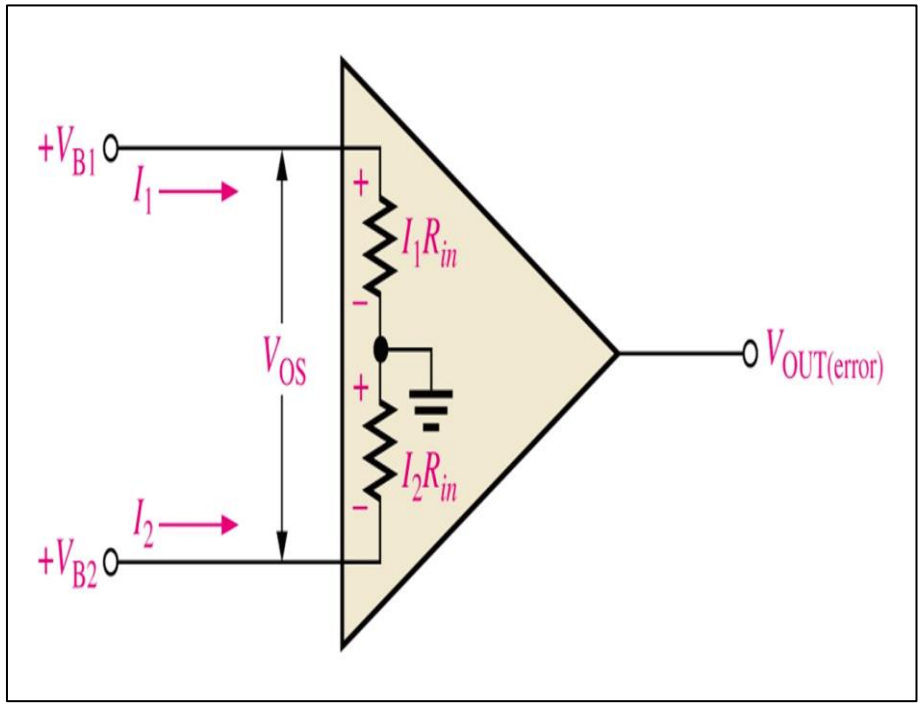
- Ideally, output of an op-amp is 0 Volt if the input is 0 Volt.
- Realistically, a small dc voltage will appear at the output when no input voltage is applied.
- Thus, differential dc voltage is required between the inputs to force the output to zero volts.
- This is called the Input Offset Voltage, Vos. Range between 2 mV or less.
- However, due to manufacturing process, the differential input transistors of real op-amps may not be exactly matched.
- This causes the output to be zero at a non-zero value of differential input, called the input offset voltage.
- This can be reduced to several microvolts if nulled using the IC's offset null pins or using higher-quality or laser-trimmed devices.
- However, the input offset voltage value may drift with temperature or age.

# 2. Input Impedance




- It is the total resistance between the inverting and non-inverting inputs.
- Differential input impedance : total resistance between the inverting and non-inverting inputs
- Common-mode input impedance: total resistance between each input and ground

# 3.Input Offset Current




**Input Offset Current**

It is the difference of input bias currents.

Input offset current

$$I_{os} = |I_1 - I_2|$$

Thus, error

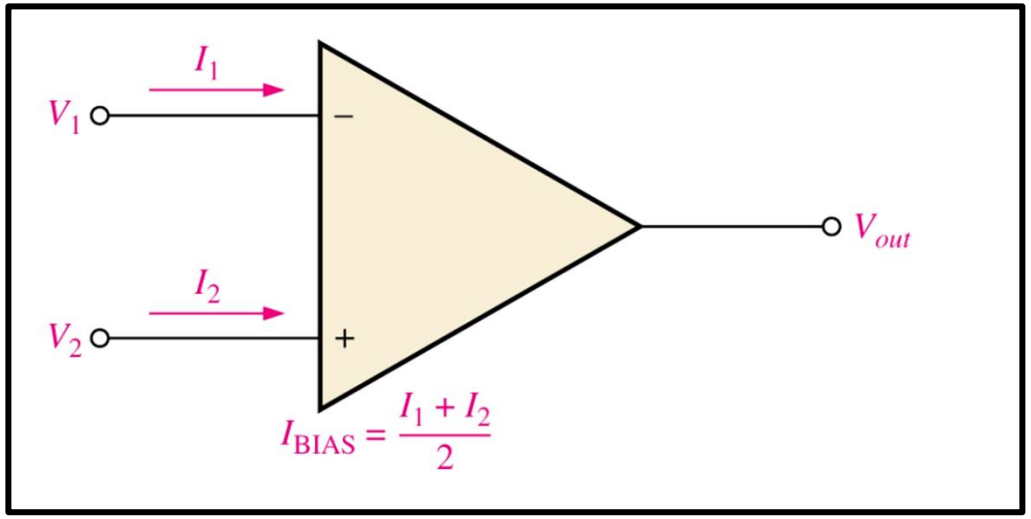
$$V_{out(error)} = A_v I_{os} R_{in}$$

Offset voltage

$$V_{os} = I_1 R_{in} - I_2 R_{in} = (I_1 - I_2) R_{in}$$

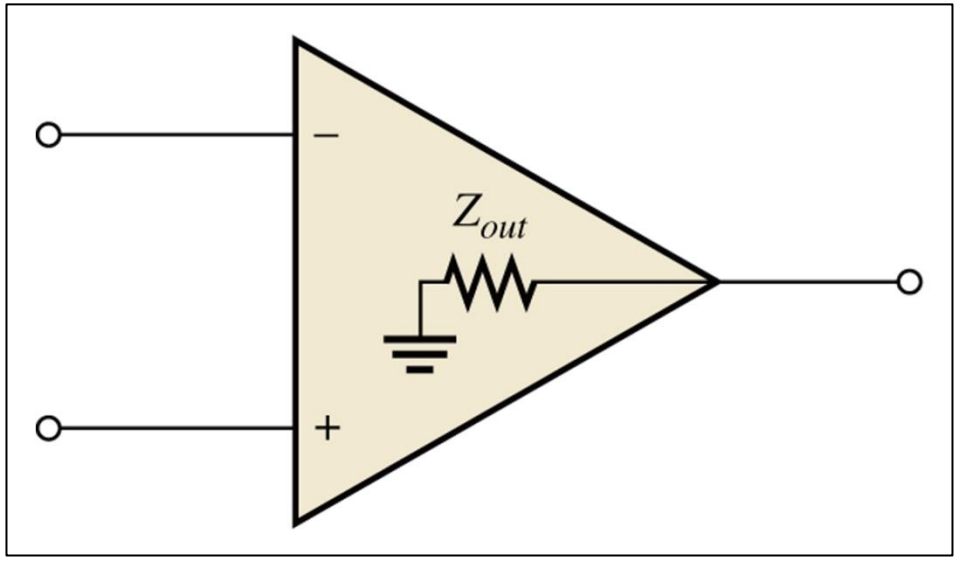
$$V_{os} = I_{os} R_{in}$$

# Input Bias Current




- Ideally should be zero
- The current required by the inputs of the amplifier to properly operate the first stage.
- Is the average of both input currents

# Output Impedance




- Ideally should be zero
- Is the resistance viewed from the output terminal of the op-amp.
- In reality, it is non-zero.

# Common-Mode Rejection Ratio (CMRR)

One rating worth mentioning that is unique to op-amps is CMRR or **common-mode rejection ratio**.

Because the op-amp has two inputs that are opposite in phase (inverting input and the non-inverting input) any signal that is common to both inputs will be cancelled.

*A measure of the ability to cancel out common signals is called CMRR.*

- The higher the CMRR, the better, in which the open-loop gain is high and common-mode gain is low.
- CMRR is usually expressed in dB & decreases with frequency

$$CMRR = \frac{A_{ol}}{A_{cm}}$$

$$CMRR = 20\log\left(\frac{A_{ol}}{A_{cm}}\right)$$

# OP AMP Frequency Characteristics

An op-amp is a wide-bandwidth amplifier.

The following affect the bandwidth of the op-amp:

- Gain
- Slew rate

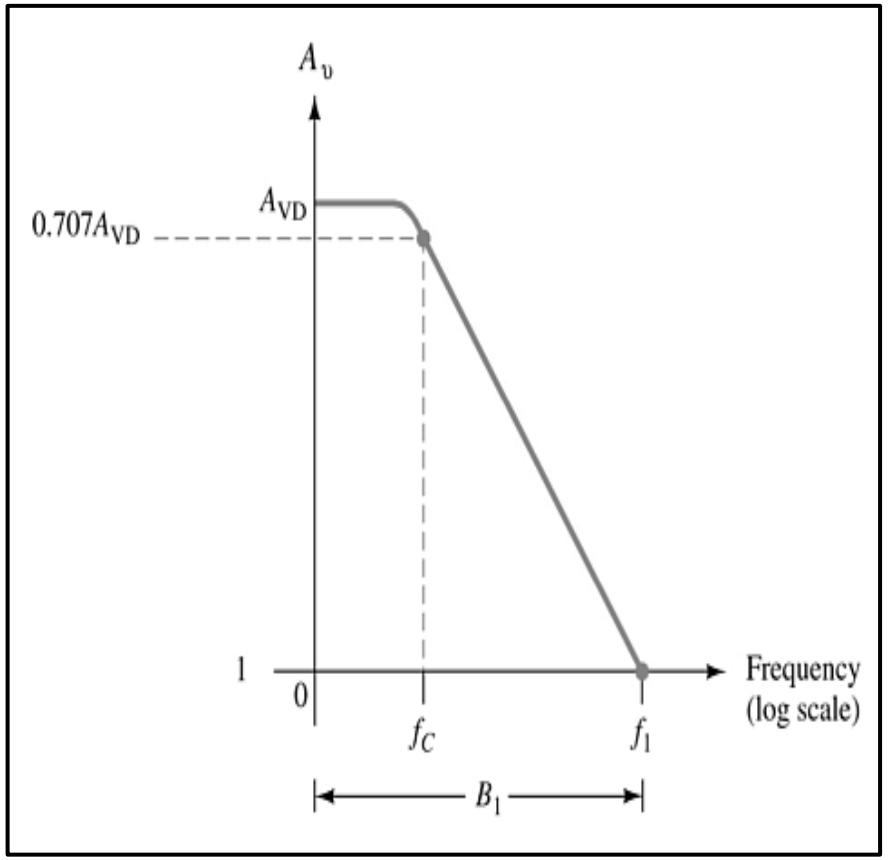
➢ The op-amp's high frequency response is limited by internal circuitry.

➢ The plot is for an open loop gain ($A_{OL}$ or $A_{VD}$).

➢ This means that the op-amp is operating at the highest possible gain with no feedback resistor.

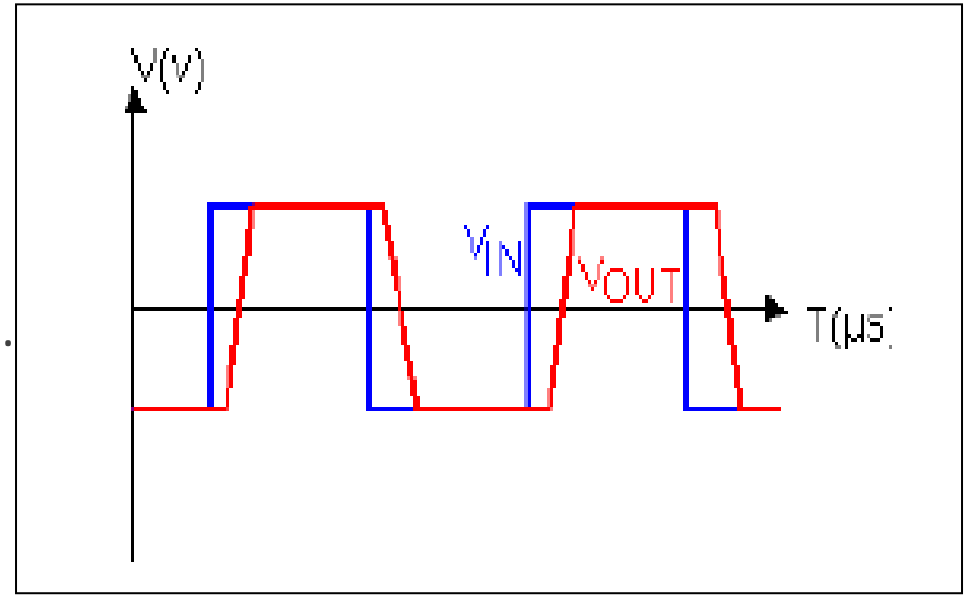
➢ In the open loop, the op-amp has a narrow bandwidth.

➢ The bandwidth widens in closed loop operation, but the gain is lower.



# Slew Rate

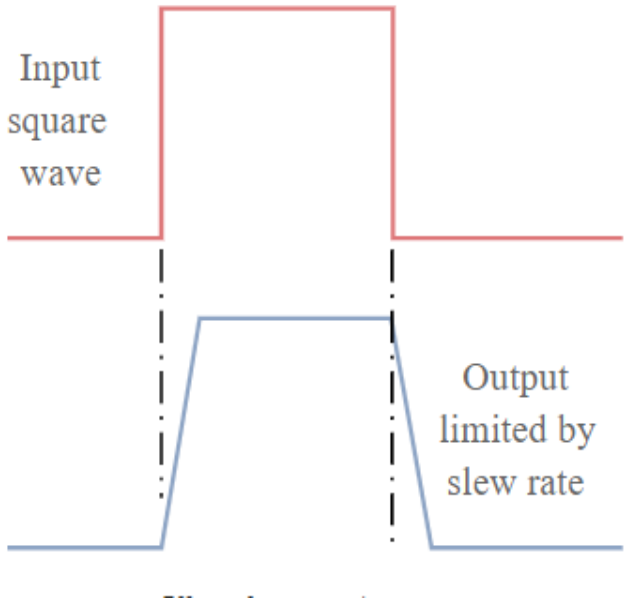
- It is the maximum rate at which an op-amp can change output without distortion.
- Slew Rate is independent of the closed-loop gain of the op-amp.
- It's a measure of how fast the output can "**follow**" the input signal.
- The SR rating is given in the specification sheets ***V/ s*** as **V/µs**.

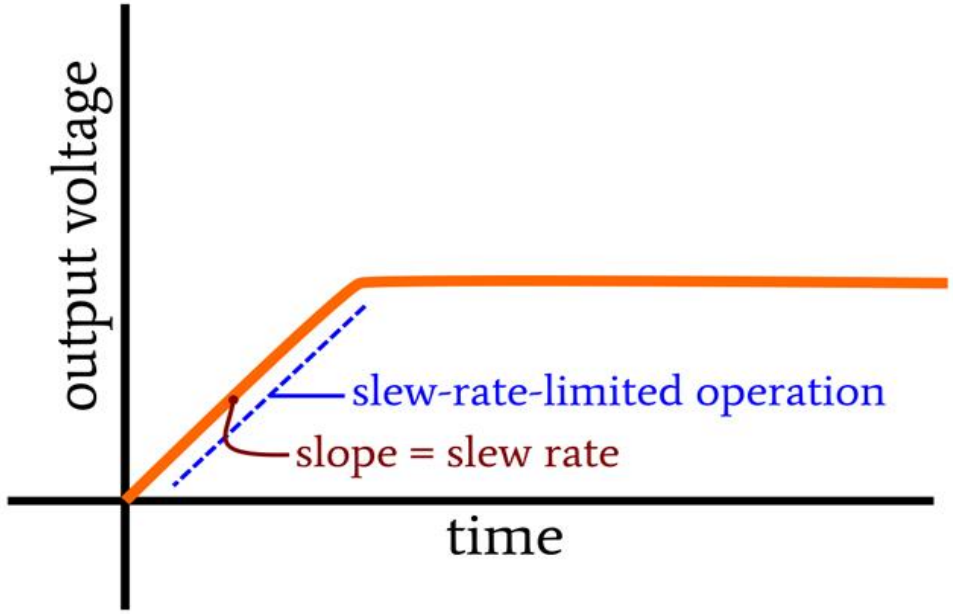



$$SlewRate = \frac{\Delta V_{out}}{\Delta t}$$

$$\text{where} \quad \Delta V_{out} = +V_{\max} - (-V_{\max})$$

# Contd..


Input
square
wave
Output
limited by
slew rate


output voltage
slew-rate-limited operation
slope = slew rate
time

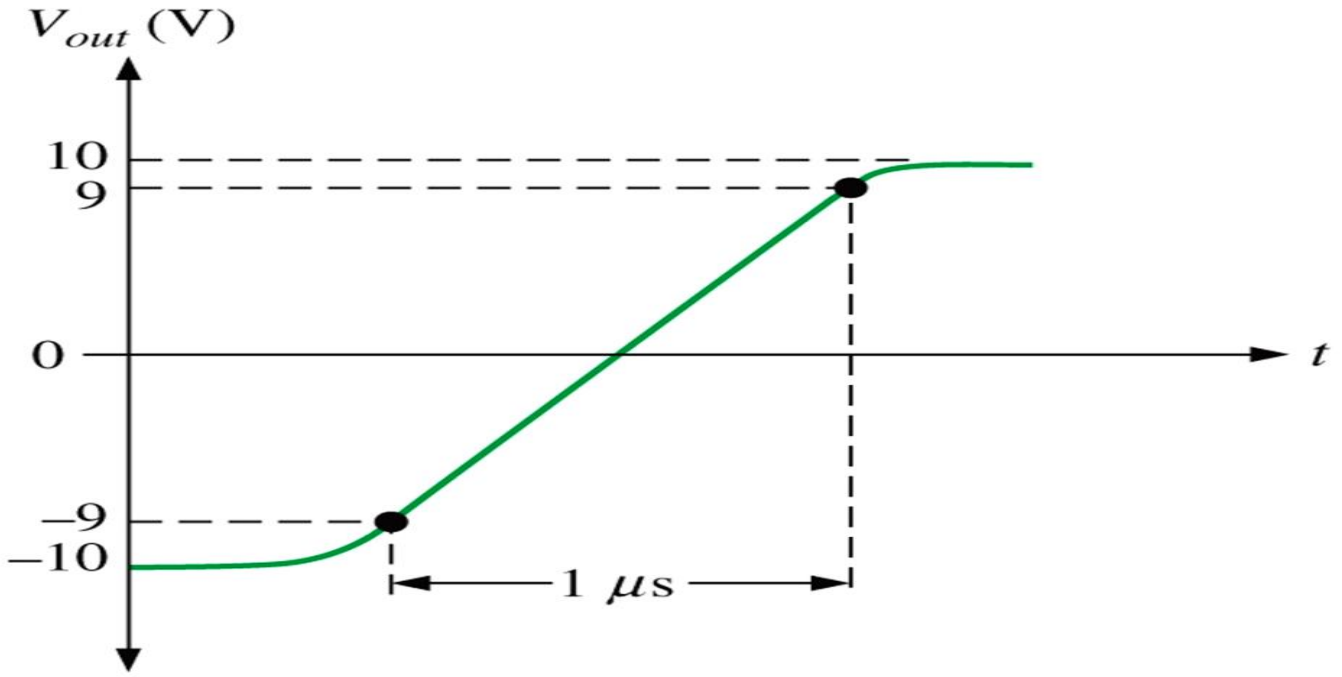
# Maximum Signal Frequency

The slew rate determines the highest frequency of the op-amp without distortion.

$$f \leq \frac{SR}{2\pi V_p}$$

An op-amp has SR = 0.60V/μs and a supply voltage ±15V. What is the maximum frequency before distortion occur?

# Determine the Slew rate?




$$f \leq \frac{SR}{2\pi V_p}$$

# Slew Rate of Common OP AMPS

| Op amp | Slew Rate (typ) |
|---|---|
| OPA369 | 0.005 V/µs |
| OPA333 | 0.16 V/µs |
| OPA277 | 0.8 V/µs |
| OPA129 | 2.5 V/µs |
| OPA350 | 22 V/µs |
| OPA211 | 27 V/µs |
| OPA827 | 28 V/µs |
| OPA835 | 110 V/µs |
| OPA847 | 850 V/µs |

# *References*


- ***Coughlin, R.F., Operational Amplifiers and Linear Integrated Circuits, Pearson Education (2006).***
- ***Gayakwad, R.A., Op-Amp and Linear Integrated Circuits, Pearson Education (2002).***
- **Franco, S., Design with Operational Amplifier and Analog Integrated circuit, McGraw Hill (2016).**
- ***Terrell, D., Op Amps Design Application and Troubleshooting, Newness (1996).***