# SNS COLLEGE OF TECHNOLOGY

**(An Autonomous Institution)**

**COIMBATORE-35**

**Accredited by NBA-AICTE and Accredited by NAAC – UGC with A++ Grade**

**Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai**

# 23EET202 / DIGITAL ELECTRONICS AND LINEAR INTEGRATED CIRCUITS

## II YEAR / III SEMESTER

## UNIT-IV: OPERATIONAL AMPLIFIER

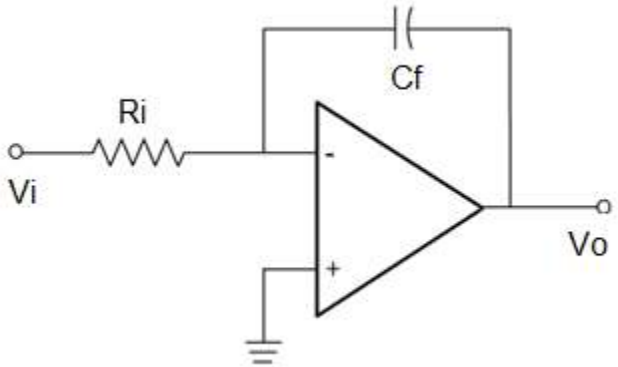
## OP-AMP BASIC APPLICATIONS

# TOPIC OUTLINE

Basics Applications-1
Integrator
Differentiator
Summer
Subtractor
Differential Amplifier

# INTEGRATOR OP-AMP

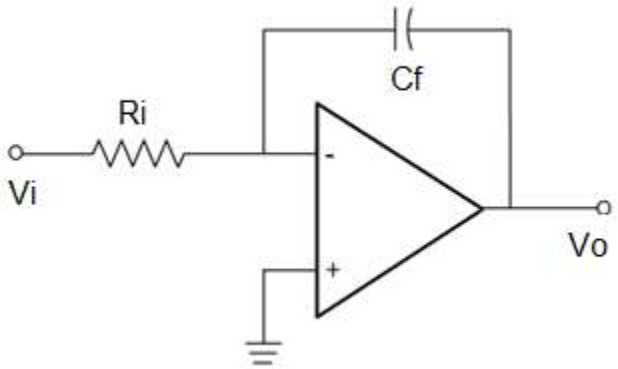
- Integrates the inverted input signal over time
- Closed loop op-amp
- Voltage output is connected to inverting input through a *capacitor*
- The resistor and capacitor form an RC circuit
- Magnitude of the output is determined by length of time voltage is present at input
- The longer the input voltage is present, the greater the output



# INTEGRATOR OP-AMP

- At node ‘a’: the nodal eqn is,

  $(V_i/R_i)+(C_f\,(dV_o/dt)) = 0$
- $(dV_o/dt) = -[V_i/(R_i\,C_f]$
- Integrating both sides of the above equation, then



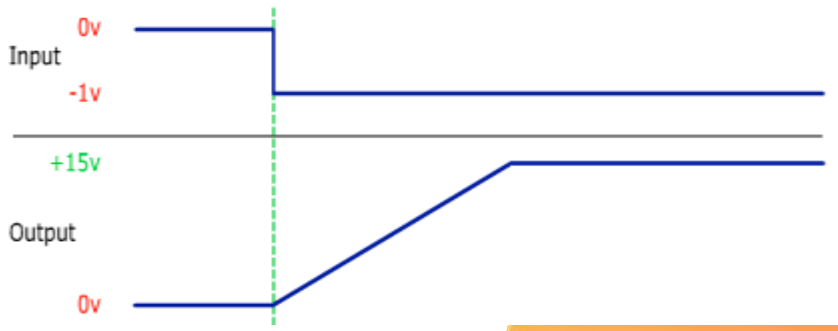

$$V_o = -\frac{1}{R_i C_f}\int_0^t V_i(\tau)\,d\tau$$

# INTEGRATOR OP-AMP

- When the circuit is first connected the capacitor acts as a short. Gain is less than 1, $V_{out}$ is 0
- As time progresses, and the capacitor charges, it's effective resistance increases. Now $V_{out}$ is increasing as well
- When the capacitor is fully charged it acts as an open circuit with infinite resistance. Now $V_{out}$ goes into saturation (~80% power supply voltage)
- The rate of voltage output increase depends on the RC time constant

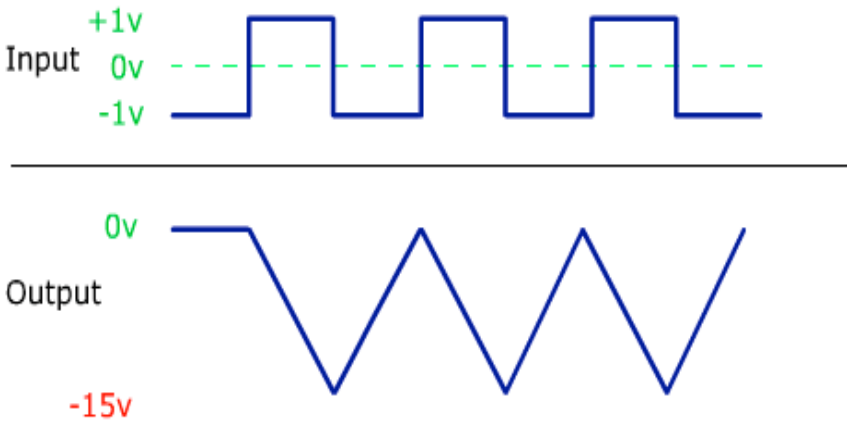
$$V_{out}=-V_{in}R_C/R_{in}$$

$$V_o = -\frac{1}{R_i C_f}\int_0^t V_i(\tau)d\tau$$



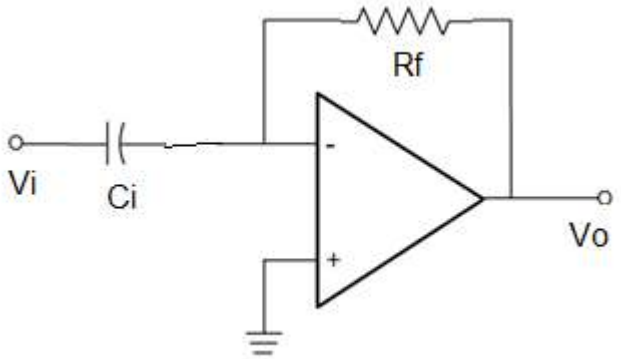
# INTEGRATOR OP-AMP

- An integrating op-amp circuit can create a sawtooth signal if a square wave is applied at $V_i$



# DIFFERENTIATOR OP-AMP

- Differentiates the inverted input signal over time
- Closed loop op-amp
- Voltage output is connected to inverting input through a *resistor*
- The resistor and capacitor form an RC circuit
- Magnitude of the output is determined by length of time voltage is present at input
- The longer the input voltage is present, the greater the output.
- If INPUT is SQUARE – OUTPUT is SPIKE wave.



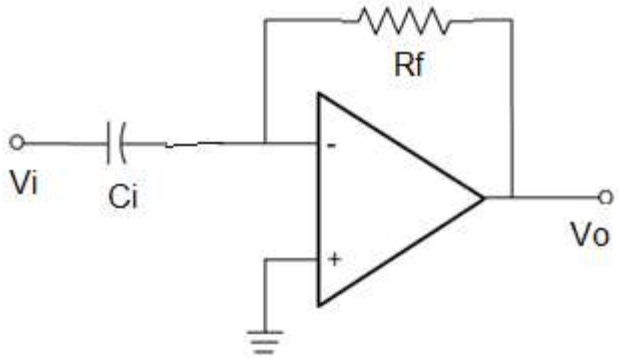
# DIFFERENTIATOR OP-AMP

- At node ‘a’: the nodal eqn is,

  $[C_i(d/dt)(V_i - V_a)]-[(V_a - V_o)/R_f]= i_c$
- Since $V_a$ is virtual gnd, ie = 0
- $C_i(dV_i/dt)+(V_o/R_f)= 0$

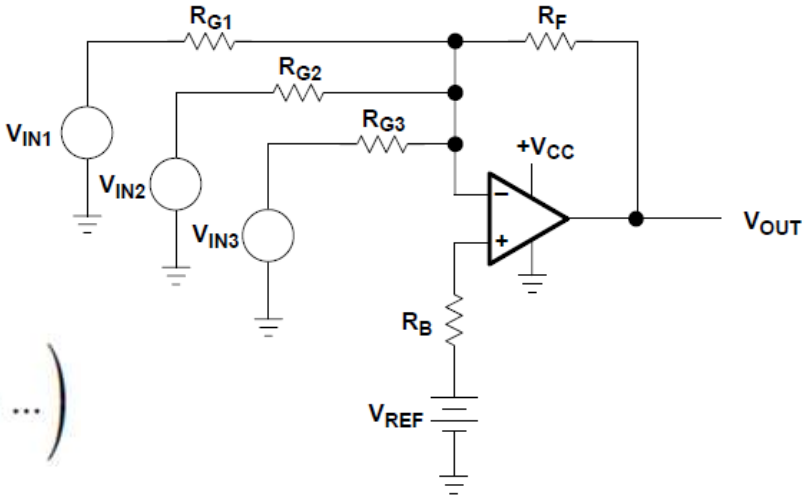
  assuming $i_c = 0$

$$V_o = -R_fC_i(dV_i/dt)$$




- A differentiator op-amp circuit can create a cosine wave signal with 180 degree phase shift if a sine wave is applied at $V_i$

# SUMMING OP-AMP



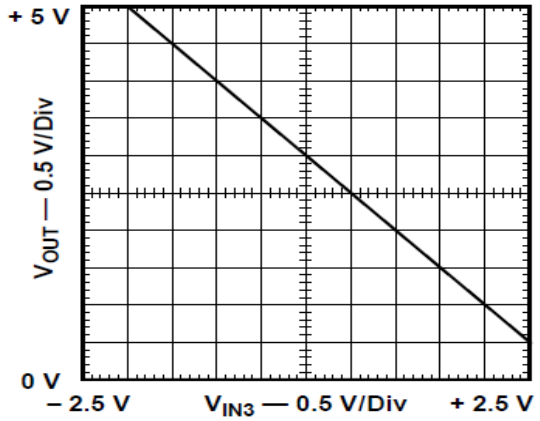

Output voltage

$$V_{OUT} = -\left(V_{IN1}\frac{R_F}{R_{G1}} + V_{IN2}\frac{R_F}{R_{G2}} + V_{IN3}\frac{R_F}{R_{G3}} + \ldots\right)$$

**If $R_{G1}=R_{G2}=R_{G3}=R_F$, then**
**$V_{OUT}= -(V_{in1} +V_{in2}+V_{in3})$**

The summing amplifier does exactly as the name suggests by adding up the voltages given to it and producing an output voltage which is the sum of the input voltages scaled by the feedback resistance and input resistance

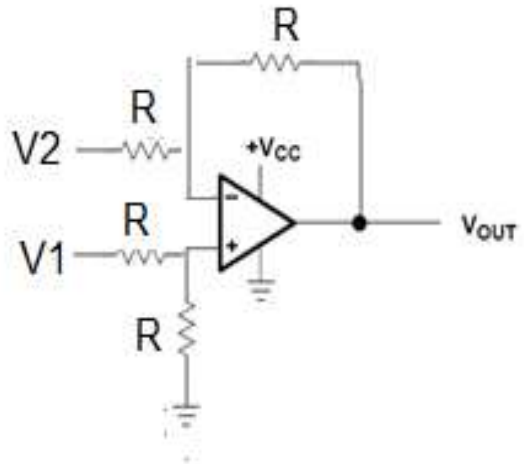
# SUMMING OP-AMP




$$V_{OUT} = -\left(V_{IN1}\frac{R_F}{R_{G1}} + V_{IN2}\frac{R_F}{R_{G2}} + V_{IN3}\frac{R_F}{R_{G3}} + \ldots\right) + V_{REF}\left(1 + \frac{R_F}{R_{G1} \parallel R_{G2} \parallel R_{G3} \ldots}\right)$$

The graph shown above is a plot of output voltage $V_{out}$ vs input voltage $V_{in}$ 3

# SUBTRACTOR OP-AMP




**Using Superposition principle:**

If Vo1 is output due to V1 alone (making V2 grounded), then, input is V1/2

**for non inv i/p: Vo= [1+Rf/Ri]Vi**

Vo1 = V1/2 [1+R/R] = V1.

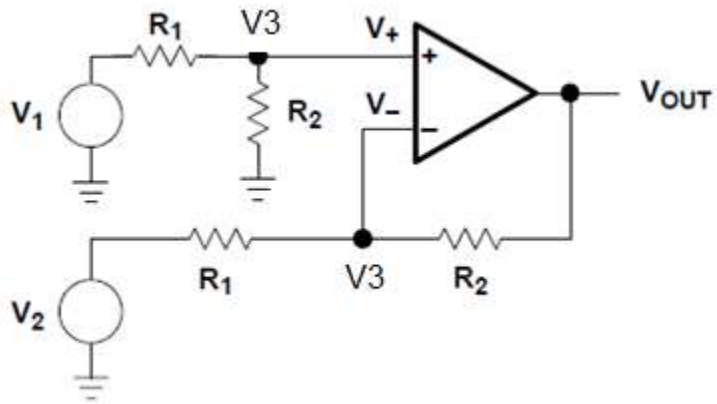
Similarly, IfV02 is the output for V2 alone, then

Vo2 = -(R/R)V2 = -V2.

**for inv i/p: Vo = Vi(Rf/Ri)**

**Now, Vo=Vo1+Vo2 = V1-V2. Therefore the output is the difference between the inputs.**

# DIFFERENTIAL OP-AMPLIFIER




Voltage relations

at node 'a': $\frac{V3-V2}{R1} + \frac{V3-Vo}{R2} = 0$

at node 'b': $\frac{V3-V1}{R1} + \frac{V3}{R2} = 0$

- The purpose of the differential amplifier is to produce an output proportional to the difference of the input voltages
- $V_+$ is given by the voltage divider equation

# DIFFERENTIAL AMPLIFIER

Output voltage

$$V_{OUT2} = V_2\left(-\frac{R_4}{R_3}\right)$$

$$V_{OUT} = V_1 \frac{R_2}{R_1 + R_2}\left(\frac{R_3 + R_4}{R_3}\right) - V_2 \frac{R_4}{R_3}$$

$$V_O = (V_1 - V_2)\frac{R_2}{R_1}$$

$V_{out}$ as we see is the difference of voltage V1 & V2 multiplied by the resistance R2 & R1 which scales the difference

# RECOLLECT

**IC 741.....**
**Application?**

**Thank You**