

## Lecture 5D

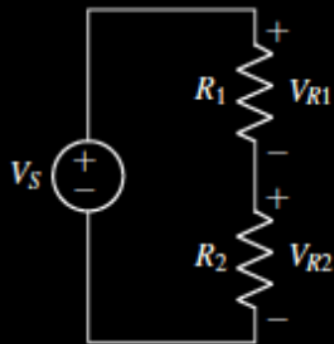
### Agenda:

→ Circuit Design (Examples)

→ Intro to GPS

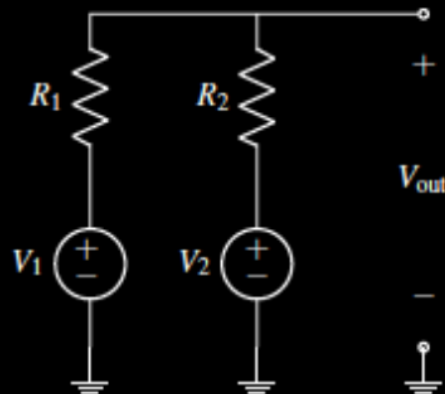
# OP-AMP CHEAT SHEET

### Voltage Divider



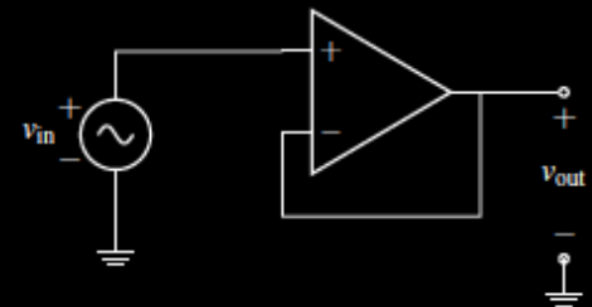
$$V_{R2} = V_S \left( \frac{R_2}{R_1 + R_2} \right)$$

### Voltage Summer



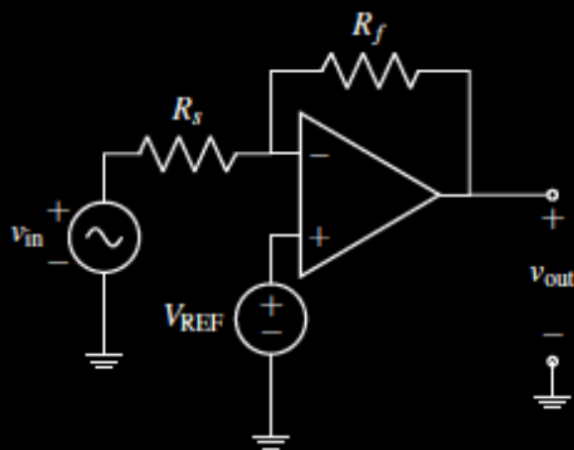
$$V_{out} = V_1 \left( \frac{R_2}{R_1 + R_2} \right) + V_2 \left( \frac{R_1}{R_1 + R_2} \right)$$

### Unity Gain Buffer



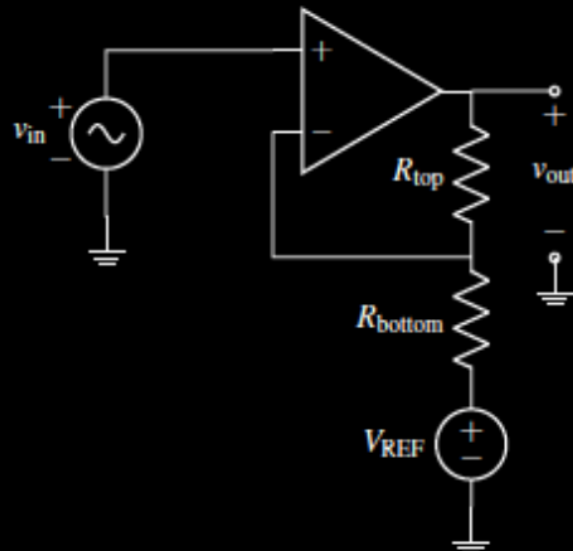
$$\frac{v_{out}}{v_{in}} = 1$$

### Inverting Amplifier



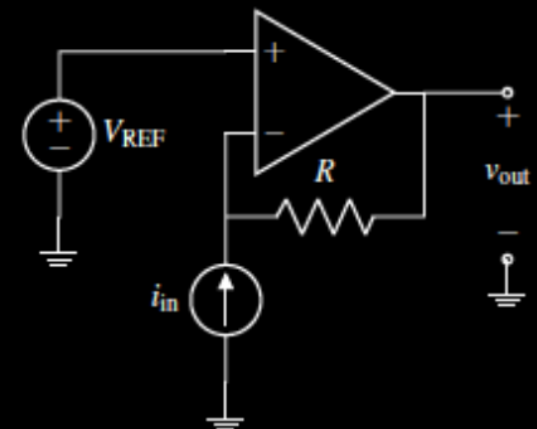
$$v_{out} = v_{in} \left( -\frac{R_f}{R_s} \right) + V_{REF} \left( \frac{R_f}{R_s} + 1 \right)$$

### Non-inverting Amplifier



$$v_{out} = v_{in} \left( 1 + \frac{R_{top}}{R_{bottom}} \right) - V_{REF} \left( \frac{R_{top}}{R_{bottom}} \right)$$

### Transresistance Amplifier

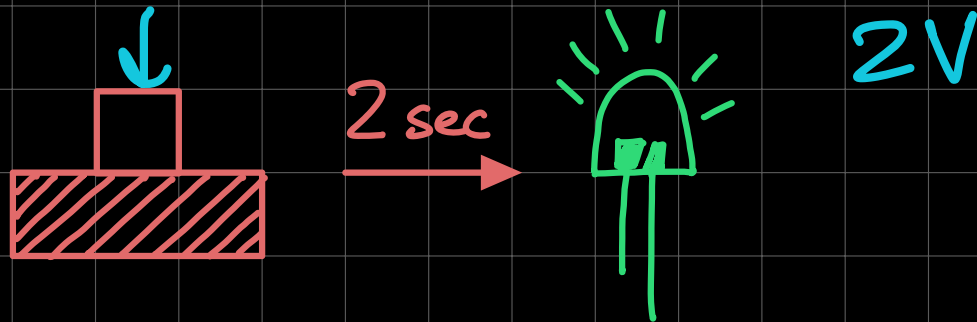


$$v_{out} = i_{in}(-R) + V_{REF}$$

# Design

- ① Specification - Restate your design goals
- ② Strategy - Describe your strategy
- ③ Implementation - Implement components of your strategy
- ④ Verification - Check your design from step 3

# Countdown Timer



Objective →

Delay

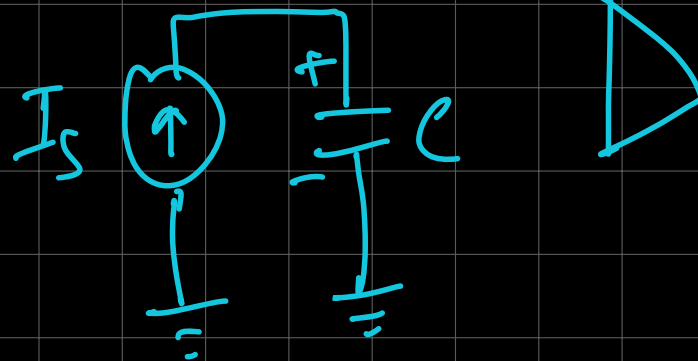
LED Toggle OFF/ON

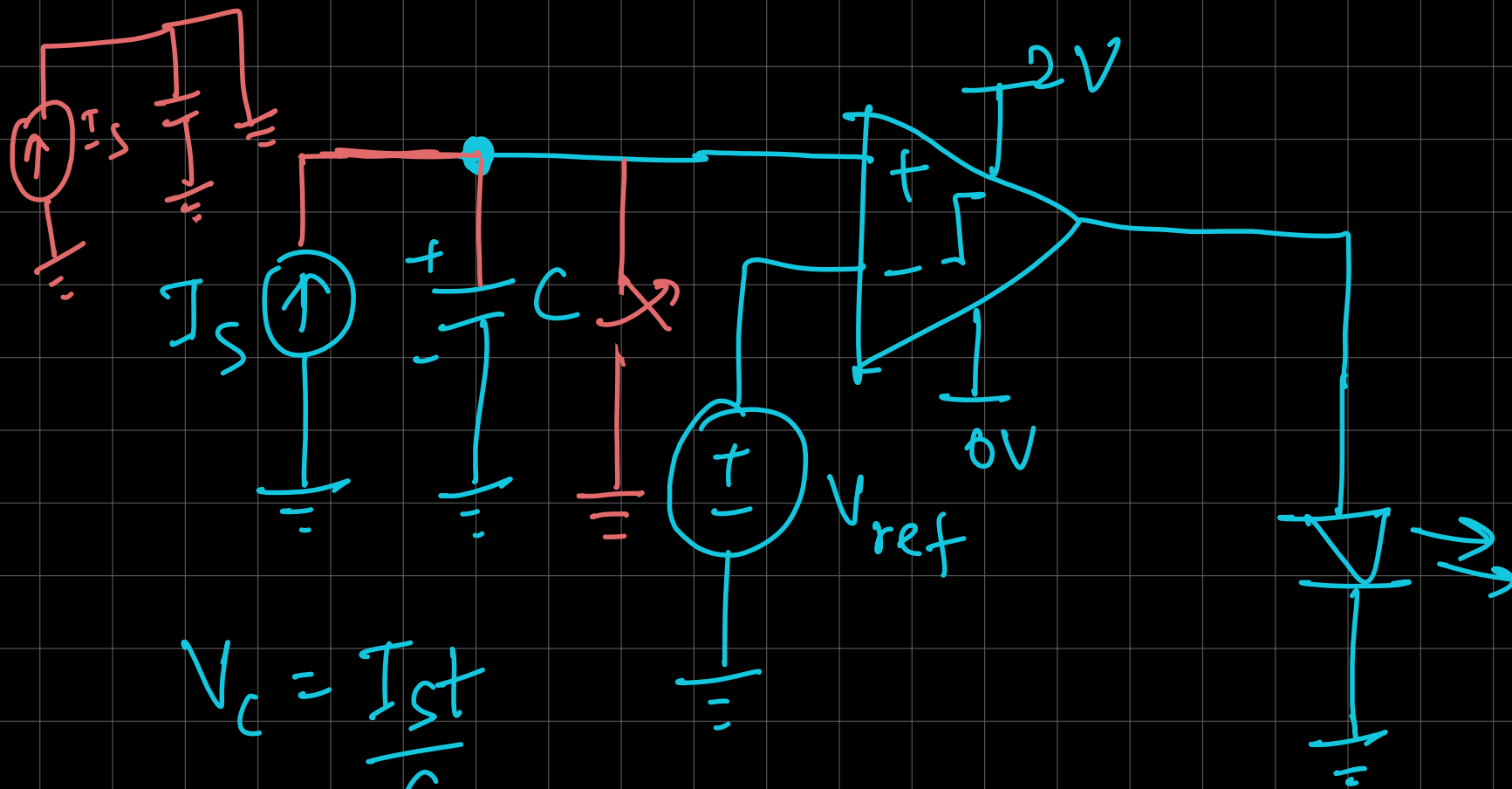
Strategy

Mechanical Switch

2 sec delay

+2V  
LED  
ON



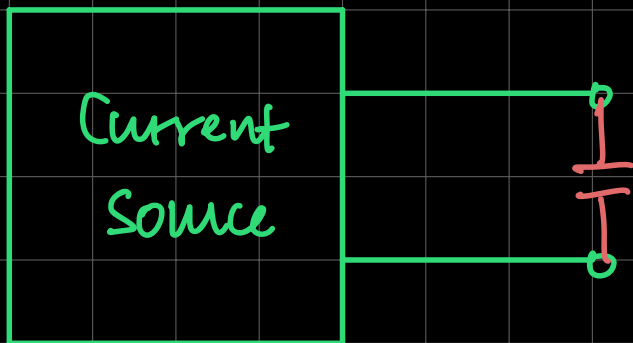


$$V_C = \frac{I_S t}{C}$$

$$V_{ref} = \frac{2I_S}{C}$$

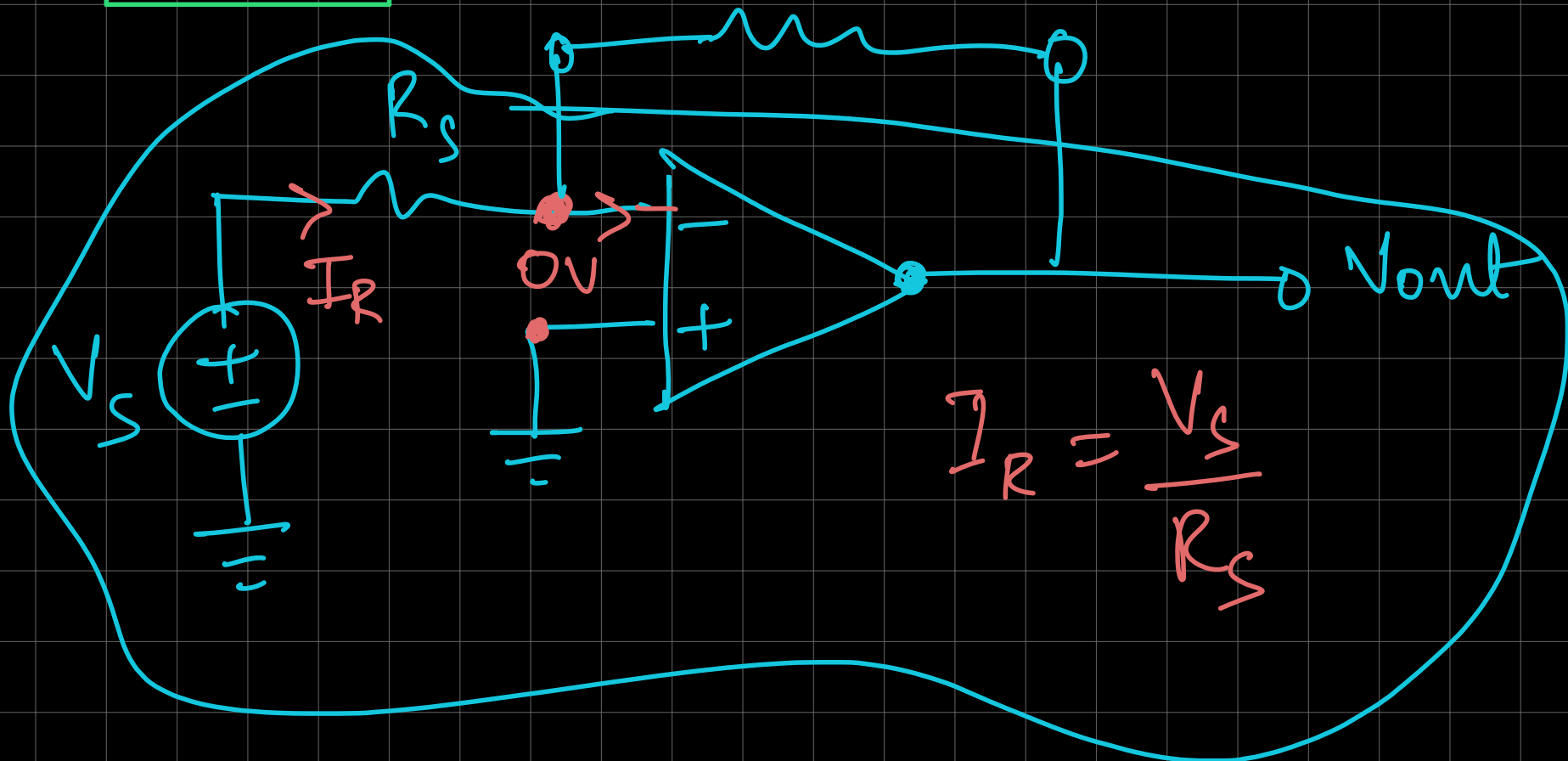


# Current Source



$$V_{R_f} = I_R \cdot R_f = \frac{V_s R_f}{R_s}$$

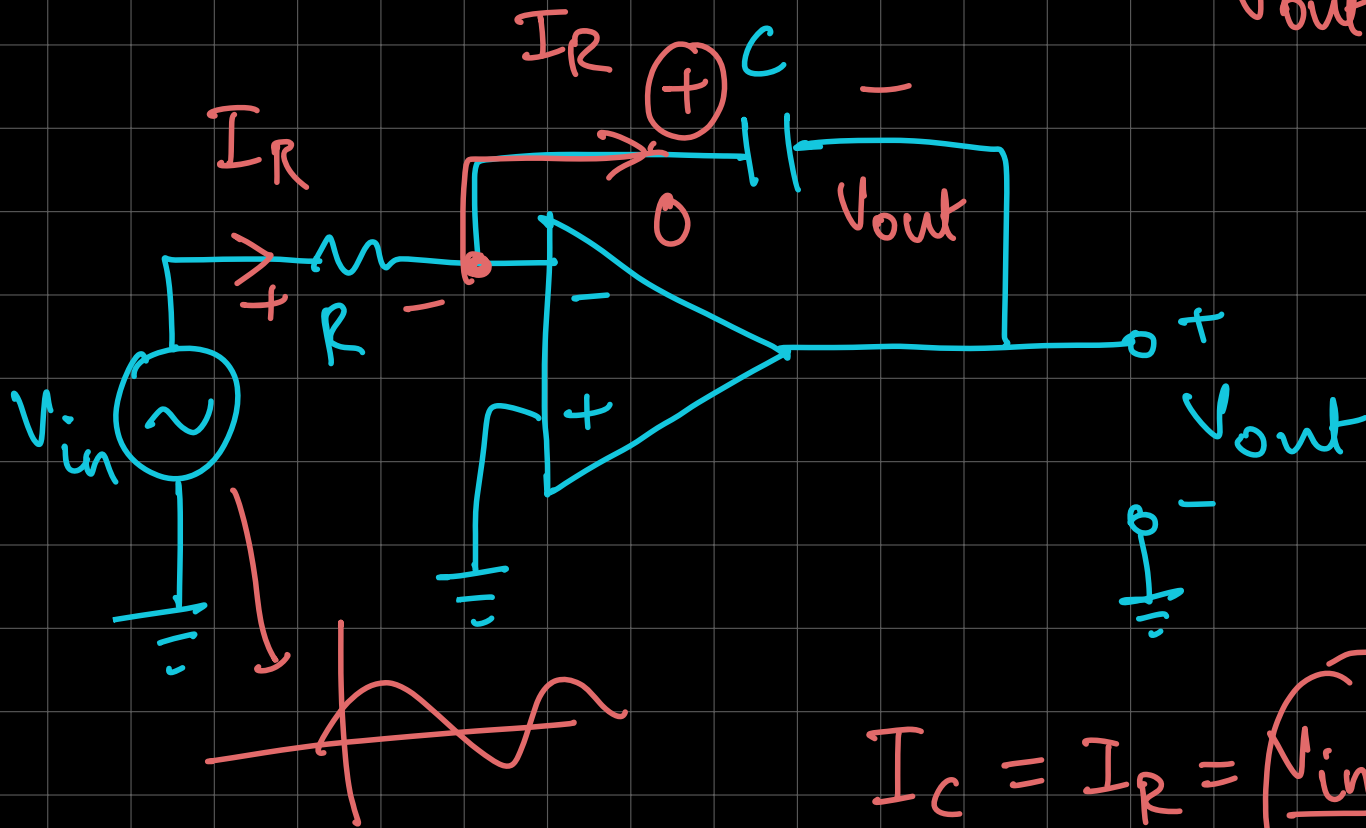
$$V_{out} = -\frac{R_f}{R_s} V_s$$



$$I_R = \frac{V_s}{R_s}$$



# Integrator



$$V_{out} = \left( \frac{V_{in}}{RC} t \right)$$

$$I_R = \frac{V_{in} - 0}{R} = \frac{V_{in}}{R}$$

$$I_C = I_R = \frac{V_{in}}{R}$$

$$I_C = C \frac{dV_C}{dt} = C \frac{-dV_{out}}{dt}$$

$$\frac{V_{in}}{R} = -C \frac{dV_{out}}{dt} \quad \int dV_{out} = -\frac{1}{RC} \int V_{in} dt$$

$$V_{out} = -\frac{1}{RC} \int V_{in} dt$$



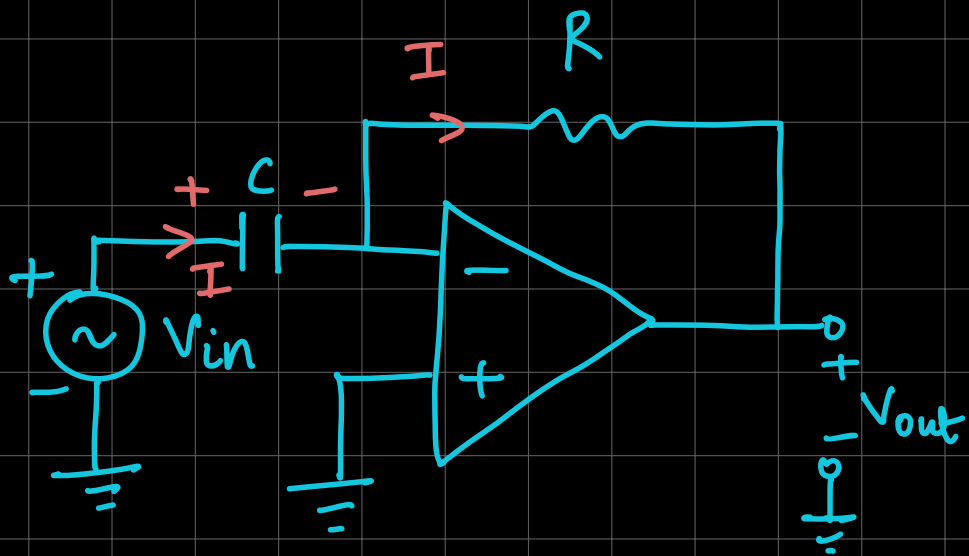
$$\frac{V_{in}}{R} = - \frac{dV_{out}}{dt}$$

$$\frac{V_{in}}{RC} = - \frac{dV_{out}}{dt}$$

$$dV_{out} = - \frac{V_{in} dt}{RC}$$

$$V_{out}(t) - V_{out}(0) = \left[ \frac{-1}{RC} \int V_{in} dt \right]$$

# Differentiator



$$u^+ = u^- = 0$$

$$I = C \frac{dV_C}{dt}$$

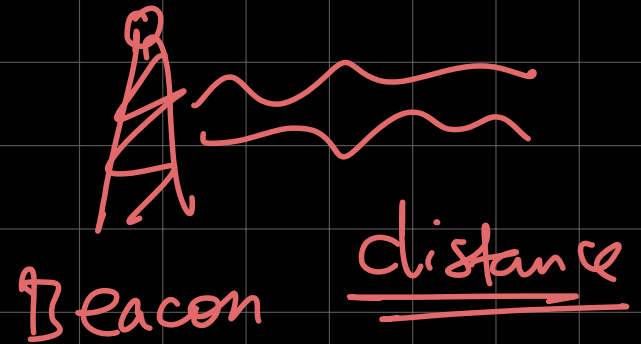
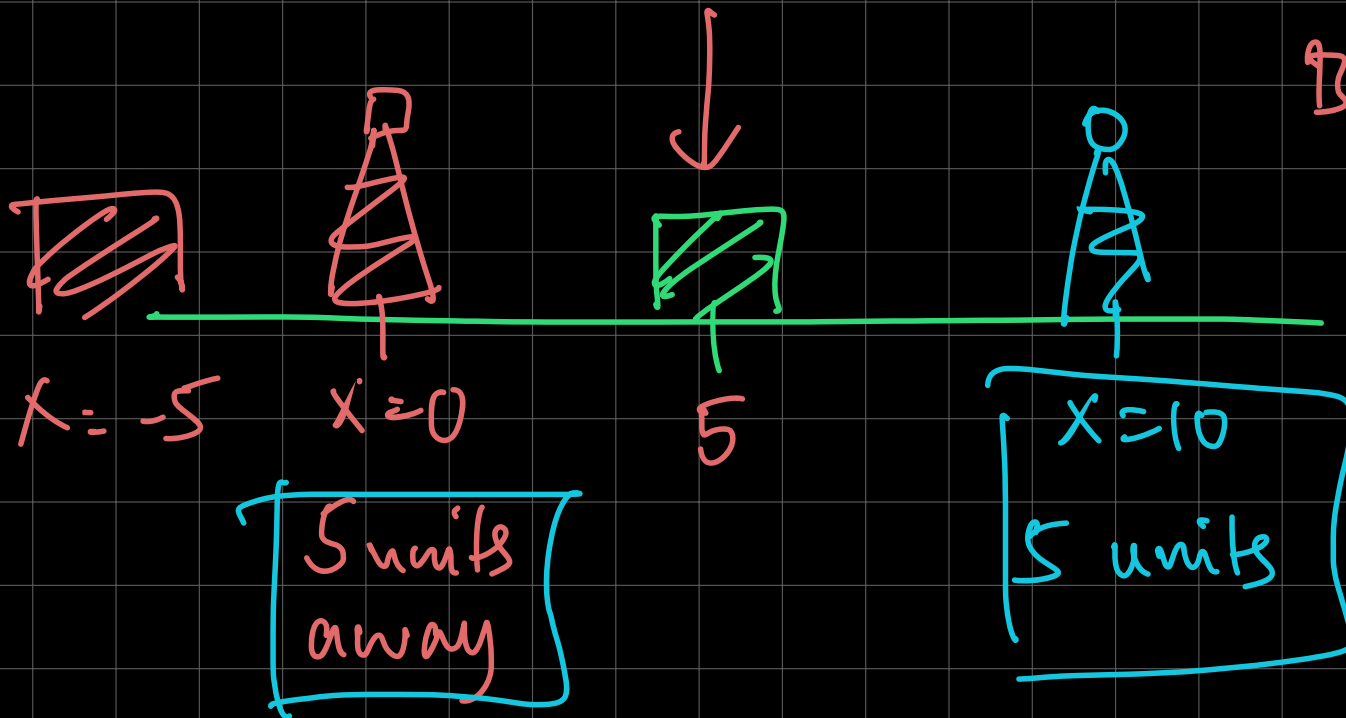
$$V_C = V_{in} - u^- = V_{in} - 0 = V_{in}$$

$$I = C \frac{dV_{in}}{dt}$$

$$V_{out} = 0 - IR = -RC \frac{dV_{in}}{dt}$$

# Navigation (Intro to GPS)

## # In 1 Dimension



# # In 2 Dimension

