SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)
Approved by AICTE, New Delhi, Affiliated to Anna University, Chennai
Accredited by NAAC-UGC with 'A++' Grade (Cycle III) &
Accredited by NBA (B.E - CSE, EEE, ECE, Mech & B.Tech.IT)
COIMBATORE-641 035, TAMIL NADU

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Course Name: 23ECT203 LINEAR INTEGRATED CIRCUITS

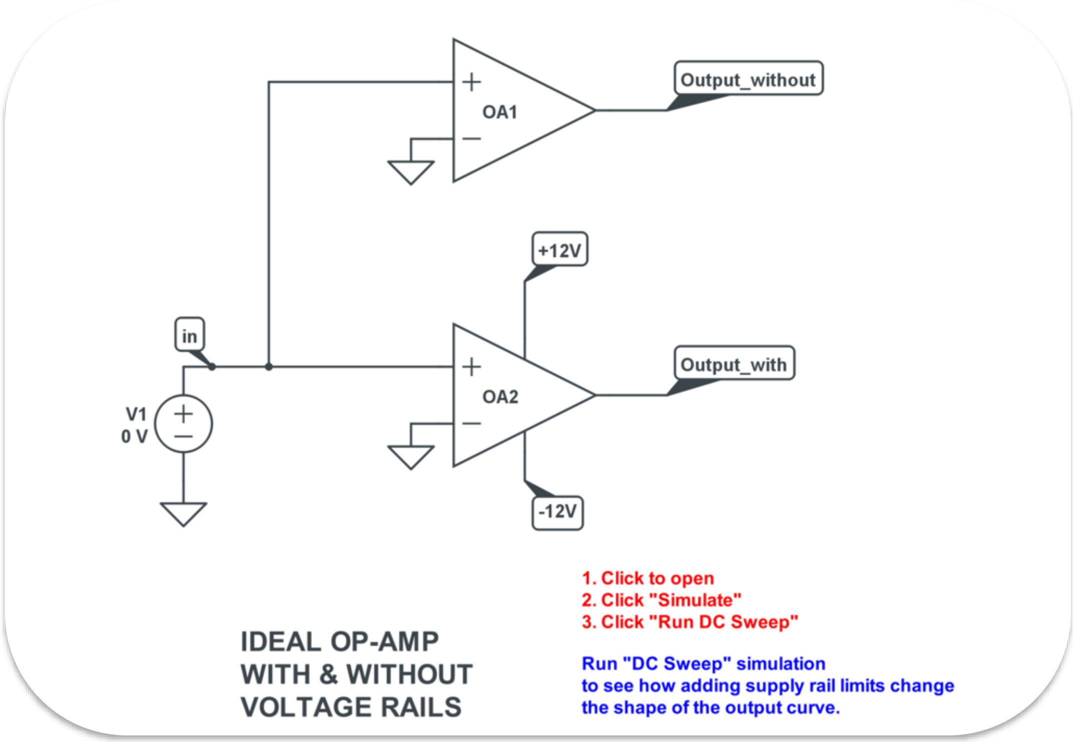
II YEAR/VI SEMESTER

UNIT I –BASICS OF OPERATIONAL AMPLIFIERS

Topic : Ideal OP-AMP characteristics

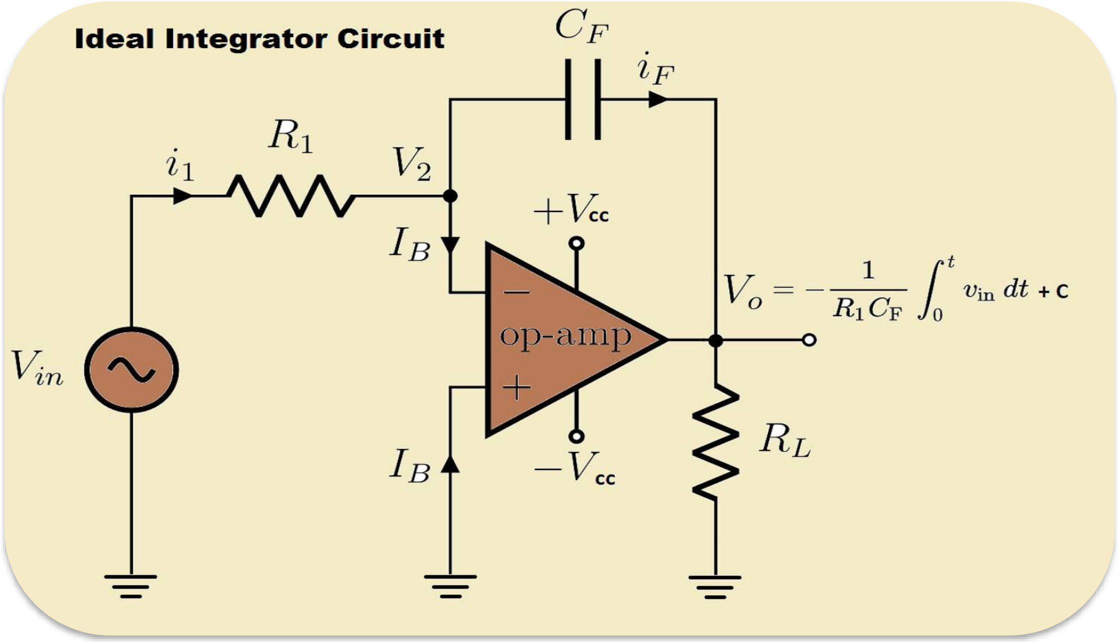
Introduction to Ideal OP-AMP

- Infinite open-loop gain ($A = \infty$)
- Infinite input impedance ($Z_{in} = \infty$)
- Zero output impedance ($Z_{out} = 0$)
- Infinite bandwidth ($BW = \infty$)
- Zero offset voltage ($V_{io} = 0$)
- Zero input bias current ($I_b = 0$)
- Infinite CMRR (Common-mode rejection ratio)



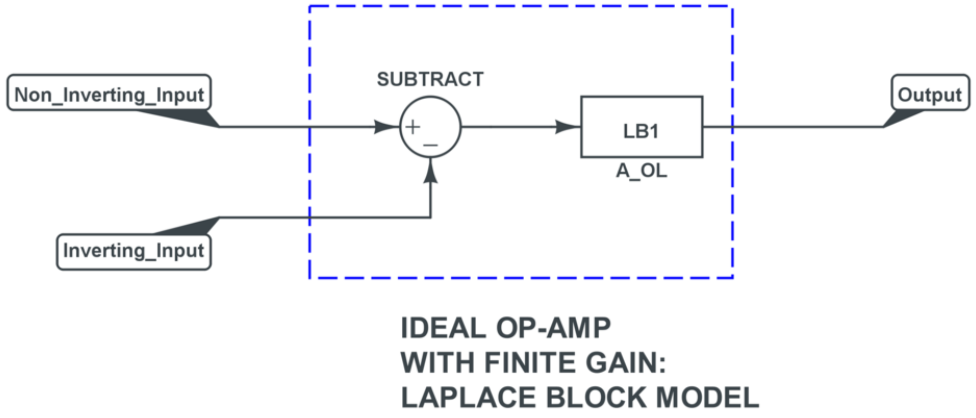
Empathize

- **Real-world constraints:** Finite gain, bandwidth, and power supply limitations
- **Signal distortion:** Non-ideal characteristics cause output errors
- **Temperature effects:** Parameter drift affects circuit performance
- **Noise considerations:** Practical op-amps generate noise
- **Power consumption:** Ideal assumptions ignore energy requirements
- **Cost factors:** Higher performance increases component cost



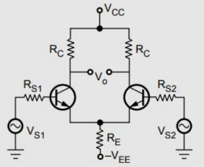
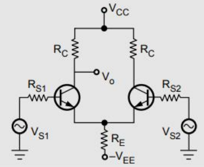
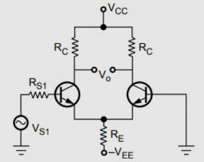
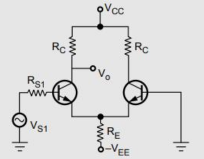
2 Define

- **Open-loop gain: ∞** - Unlimited amplification capability
- **Input impedance: ∞** - No current draw from input source
- **Output impedance: 0Ω** - Perfect voltage source
- **Bandwidth: ∞** - Equal gain at all frequencies
- **Input offset voltage: 0V** - Zero output with zero input
- **Slew rate: ∞** - Instantaneous response
- **CMRR: ∞** - Perfect common-mode rejection



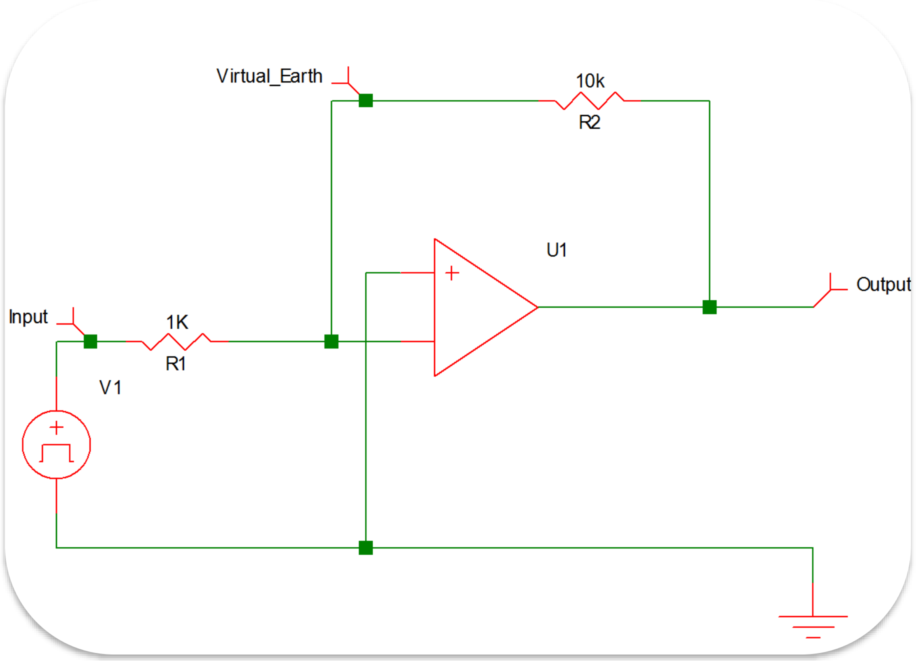
3 Ideate

- **Cascaded amplifiers:** Multiple stages to increase gain
- **Feedback techniques:** Negative feedback to improve stability
- **Buffer stages:** Input/output isolation for impedance matching
- **Frequency compensation:** Improving bandwidth response
- **Differential input:** Canceling common-mode signals
- **Precision trimming:** Reducing offset voltage and bias current
- **Hybrid configurations:** Combining multiple op-amp topologies

Configuration	Circuit	A_d Voltage Gain	R_{in} Input Resistance	R_o Output Resistance
Dual Input Balanced Output		$\frac{h_{fe} R_C}{R_S + h_{ie}}$	$2(R_S + h_{ie})$	R_C
Dual Input Unbalanced Output		$\frac{h_{fe} R_C}{2(R_S + h_{ie})}$	$2(R_S + h_{ie})$	R_C
Single Input Balanced Output		$\frac{h_{fe} R_C}{R_S + h_{ie}}$	$2(R_S + h_{ie})$	R_C
Single Input Unbalanced Output		$\frac{h_{fe} R_C}{2(R_S + h_{ie})}$	$2(R_S + h_{ie})$	R_C

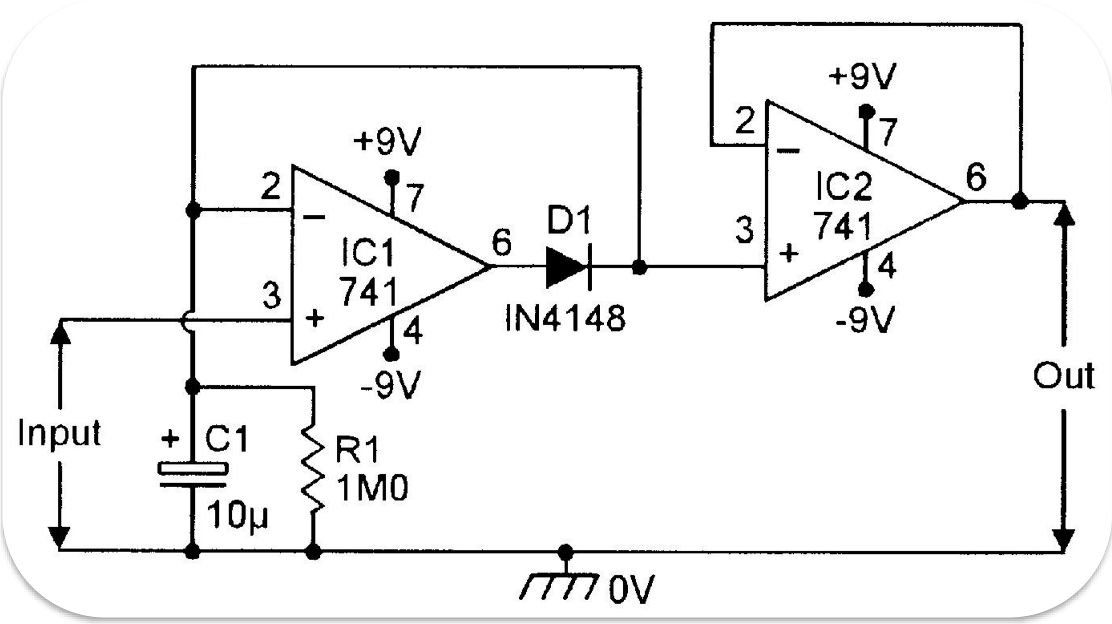
4 Prototype

- **Breadboard implementation:** Quick circuit assembly and testing
- **SPICE simulation:** Virtual testing before physical build
- **Component selection:** Choosing parts with ideal-like characteristics
- **Precision measurement:** Using test equipment to verify performance
- **Iterative refinement:** Adjusting values to approach ideal behavior
- **Temperature testing:** Evaluating performance across conditions
- **Documentation:** Recording circuit behavior and deviations



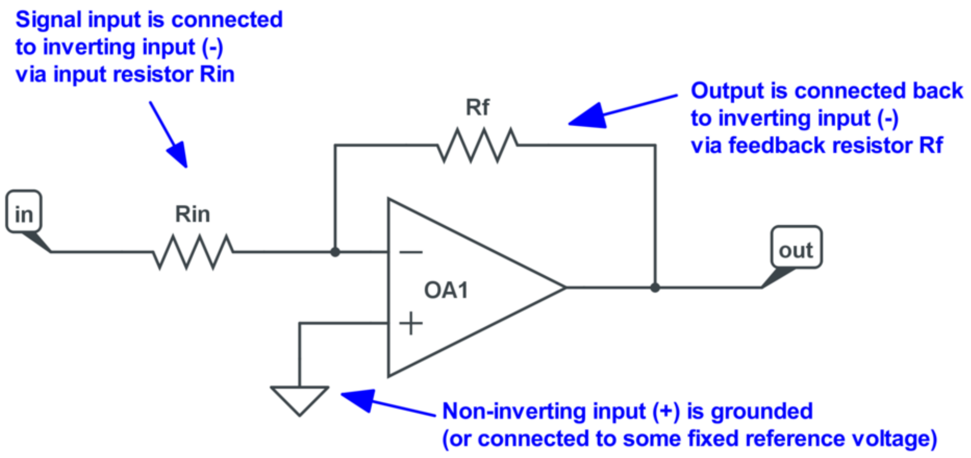
5 Test

- **Frequency response analysis:** Bode plot measurement
- **Slew rate testing:** Square wave response measurement
- **Input offset voltage:** Null circuit measurement
- **CMRR verification:** Common-mode vs. differential gain
- **Temperature drift:** Performance across temperature range
- **Noise analysis:** Output noise spectral density
- **Load regulation:** Output impedance measurement



Key Ideal OP-AMP Parameters

- **Open-loop gain (A):** ∞ Unlimited amplification
- **Input impedance (Zin):** ∞ No current draw
- **Output impedance (Zout):** **0Ω** Perfect voltage source
- **Bandwidth (BW):** ∞ Equal gain at all frequencies
- **Input offset voltage (Vio):** **0V** Zero output with zero input
- **Slew rate:** ∞ Instantaneous response
- **CMRR:** ∞ Perfect common-mode rejection



OP-AMP INVERTING AMPLIFIER

Real-world Applications

Precision Amplifiers

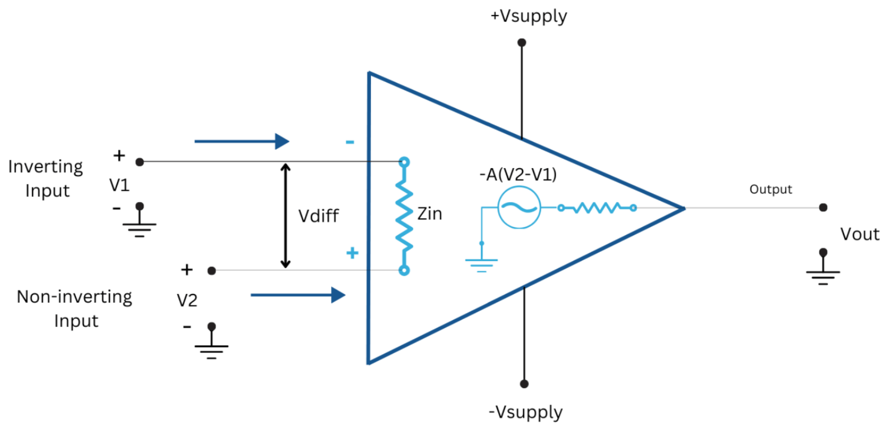
- **High-gain stages:** Exploiting near-infinite gain
- **Instrumentation:** Accurate sensor signal conditioning

Active Filters

- **Frequency shaping:** Precise cutoff frequencies
- **Q-factor control:** Adjustable filter characteristics

Signal Processing

- **Buffering:** High input impedance, low output impedance
- **Integrators/Differentiators:** Mathematical operations on signals



Equivalent Circuit of an Ideal Op-Amp

Activity

Activity Instructions

- Form groups of 3-4 students
- Discuss real-world limitations of ideal op-amp characteristics
- Propose circuit solutions to compensate for non-ideal behavior
- Prepare a 1-minute summary of your findings

Group Discussion

5 min

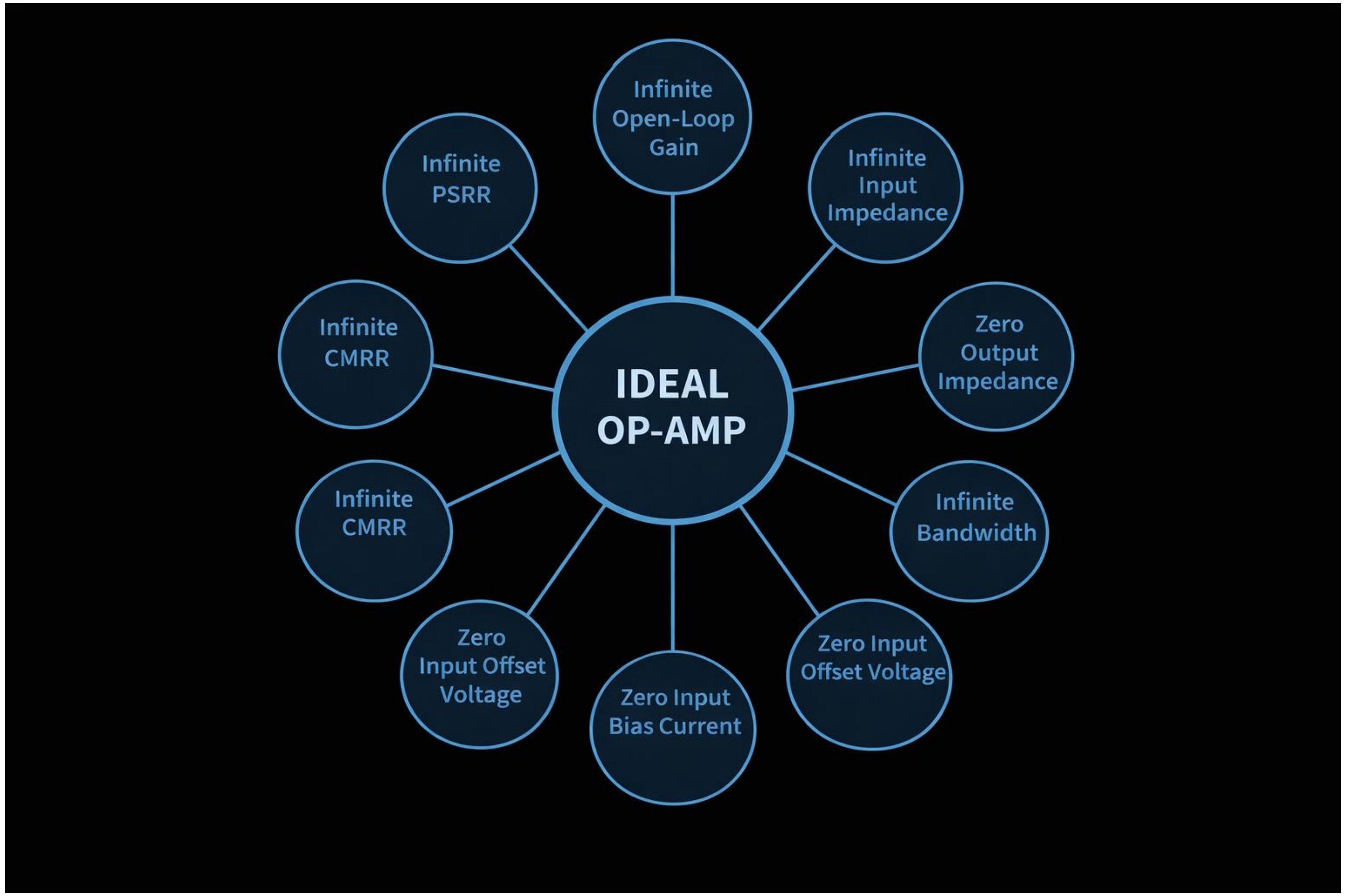
Expected Outcome

- Identify key **practical limitations** in real op-amps
- Develop **compensation techniques** for non-ideal behavior
- Connect theory to **real-world applications**

Topic Focus

- **Finite gain** vs. infinite gain
- **Bandwidth limitations** and frequency response
- **Input/output impedance** effects on circuit performance

Summary : MIND MAP



ASSESSMENT

Conceptual Questions

- Explain why **infinite input impedance** is important in op-amp circuits
- Compare **ideal vs. real** op-amp bandwidth characteristics

Numerical Problems

- Calculate output voltage of an ideal op-amp with V+ = 2.5V, V- = 1.5V, and gain = 10^5
- Determine CMRR for an op-amp with differential gain = 10^5 and common-mode gain = 0.1

Application-Based Questions

- Design a circuit to compensate for **finite input impedance** in a sensor interface
- Explain how **slew rate limitations** affect high-frequency signal processing

REFERENCE

Textbooks

- **Linear Integrated Circuits** - D. Roy Choudhry, Shail Jain, New Age International Pvt. Ltd., Fifth edition 2018
- **Design with Operational Amplifiers and Analog Integrated Circuits** - Sergio Franco, Tata Mc Graw-Hill, Fourth Edition 2014
- **OP-AMP and Linear ICs** - Ramakant A. Gayakwad, Prentice Hall/Pearson Education, 4th Edition 2001

Online Resources

- **NPTEL**: Linear Integrated Circuits - https://onlinecourses.nptel.ac.in/noc24_ee73/preview
- **Texas Instruments**: Operational Amplifier Basics - https://www.ti.com/lit/an/sloa011a/sloa011a.pdf
- **Analog Devices**: Op Amp Applications Handbook - https://www.analog.com/en/education/education-library/op-amp-applications-handbook.html

THANK YOU