

SNS COLLEGE OF TECHNOLOGY



(An Autonomous Institution)

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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

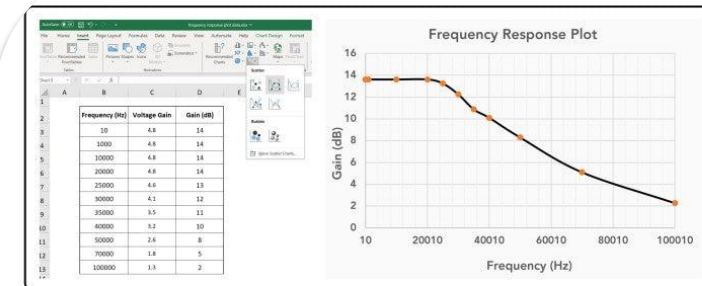
Topic :AC Characteristics

② What are AC Characteristics?

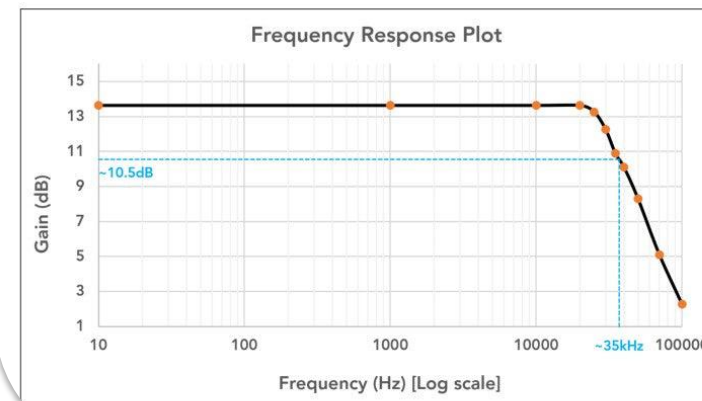
- Parameters describing op-amp behavior with **AC signals**
- Performance varies with **frequency**

! Why are they important?

- Real op-amps have **frequency limitations**
- AC imperfections cause **signal distortion**
- Critical for **high-frequency applications**
- Essential for **signal integrity** and **stability**



Gain in Linear Scale



Gain in Log Scale

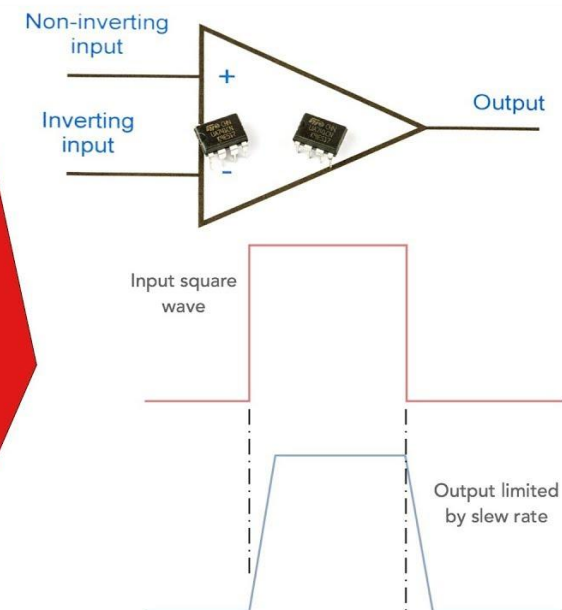
Stage 1: Empathize

Understanding challenges in analyzing AC errors

💡 Student Challenges

- ! **Frequency-dependent** behavior is complex
- ! **Slew rate** limitations cause distortion
- ! **Phase shift** affects stability in feedback circuits
- ! **Bandwidth limitations** impact high-frequency performance

Op Amp Slew Rate
- What slew rate is and how to design for it



Stage 2: Define

Defining requirements for understanding AC parameters

Learning Goals

- ✓ Define key parameters: **Frequency Response**, **Slew Rate**, **Phase Margin**
- ✓ Understand **physical origin** of each parameter
- ✓ Learn to **analyze their effect** on circuit performance
- ✓ Calculate resulting **AC output errors** and limitations



Frequency Response

Gain variation with frequency



Slew Rate

Maximum rate of voltage change



Phase Margin

Stability indicator in feedback circuits

Stage 3: Ideate

Brainstorming approaches to analyze AC errors

💡 Approaches

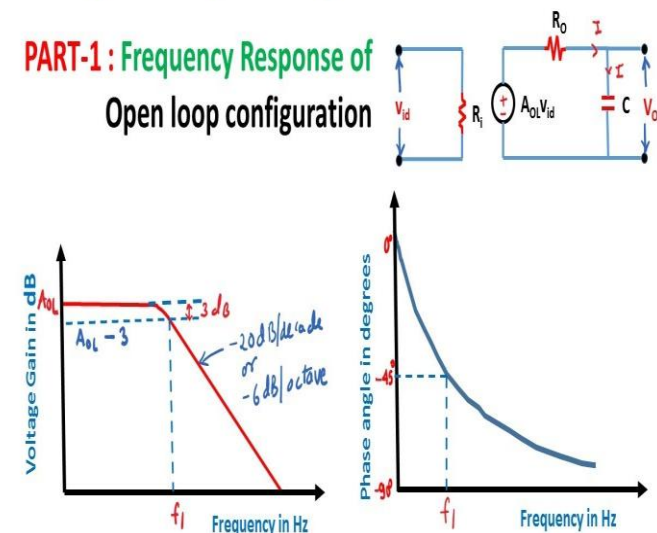
📊 Perform **frequency response analysis** using Bode plots

📏 Calculate **slew rate limitations** for high-speed signals

📈 Measure **phase margin** to ensure stability

🖥️ Use **simulation tools** to verify AC performance

Frequency Response of OPAMP

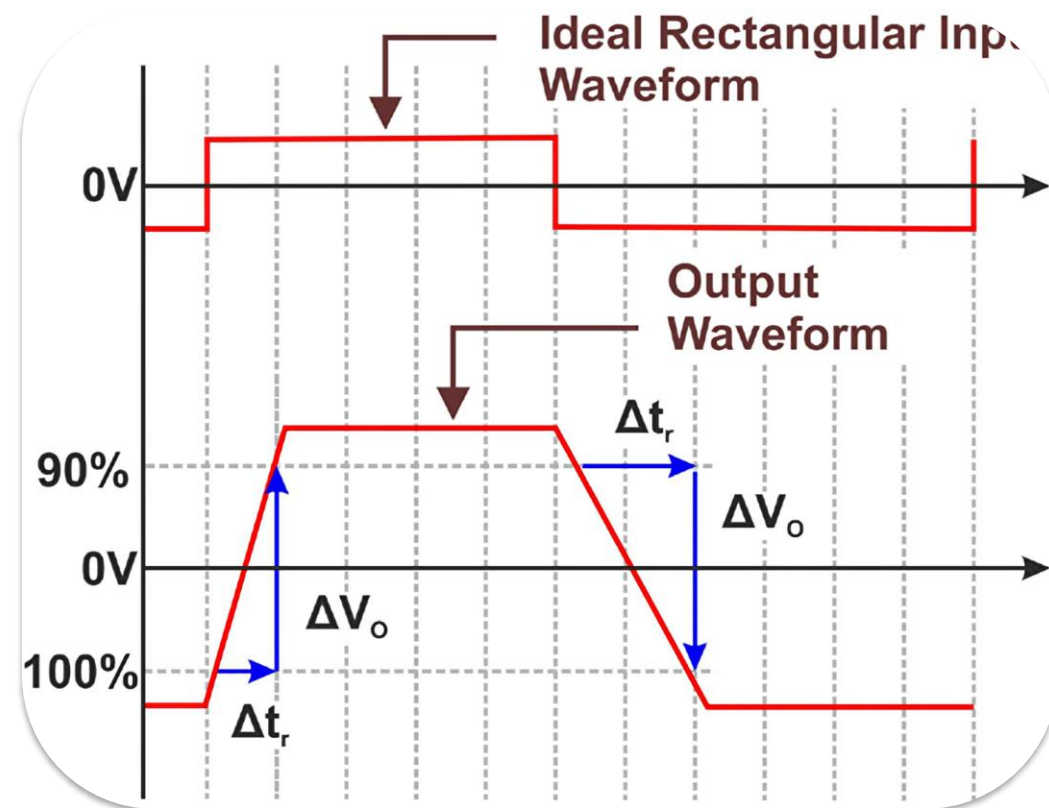


Stage 4: Prototype

Creating an AC error model of an op-amp

🔗 The Model

- 1 Start with **ideal op-amp symbol**
- 2 Add **frequency-dependent elements** (capacitance)
- 3 Include **slew rate limitations** for high-speed signals
- 4 Model helps **predict AC behavior** and limitations



Stage 5: Test

Testing and evaluating AC error calculations

Testing Method

- 1 Select a **test circuit** (e.g., non-inverting amplifier)
- 2 Measure **frequency response** using Bode plot
- 3 Test **slew rate** with step input signals
- 4 Compare measured results with **theoretical predictions**

Slew Rate – Full Power Bandwidth

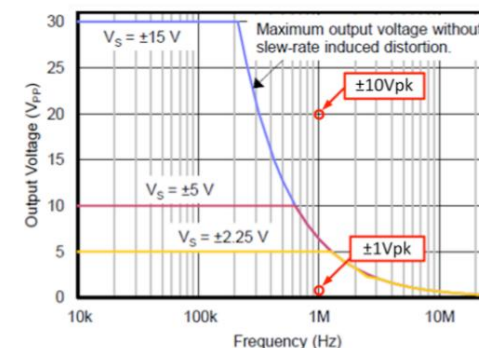
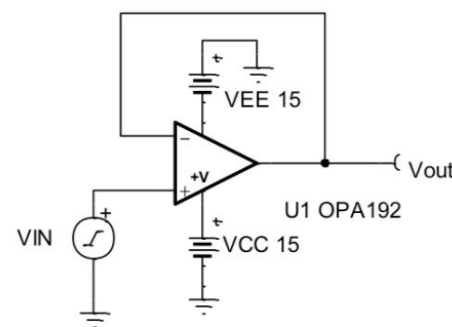


Figure 37. MAXIMUM OUTPUT VOLTAGE vs FREQUENCY

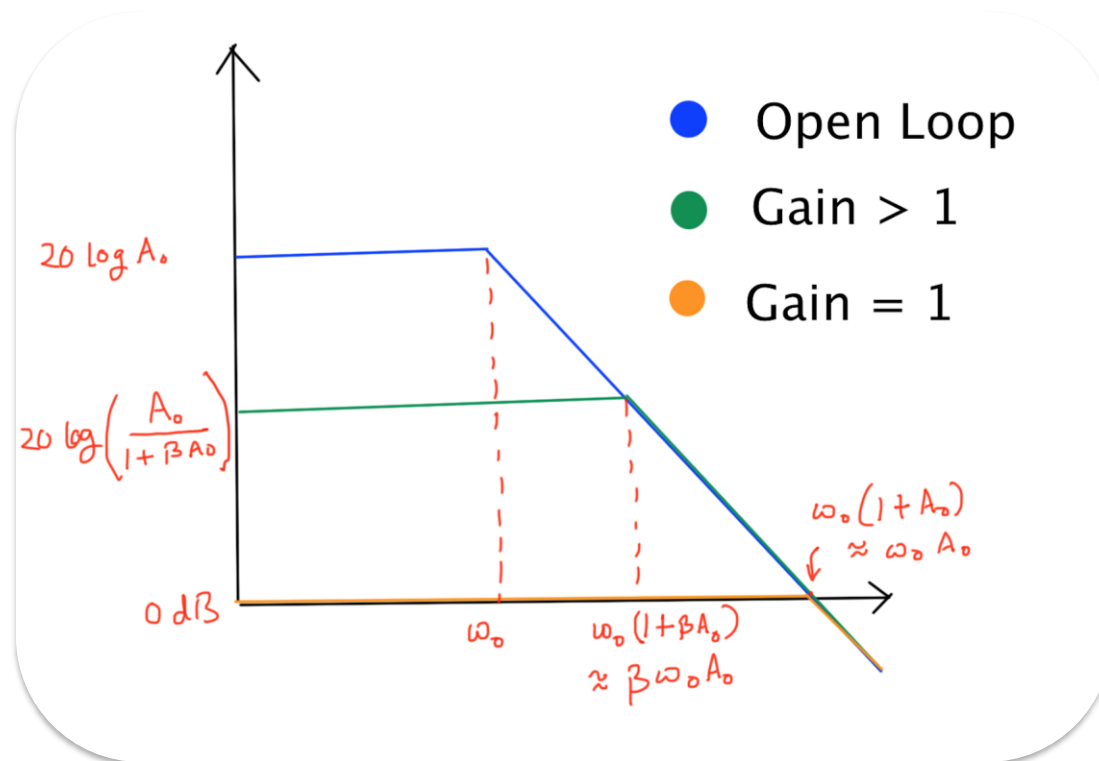
Maximum peak output based on Slew Rate & Input Frequency

$$V_{p_max} = \frac{SR}{2 \cdot \pi \cdot f} = \frac{20 \frac{V}{\mu s}}{2 \cdot \pi \cdot (1MHz)} = 3.183V_{pk} \quad \text{or} \quad 6.3V_{pp}$$

Frequency Response






Key Concepts

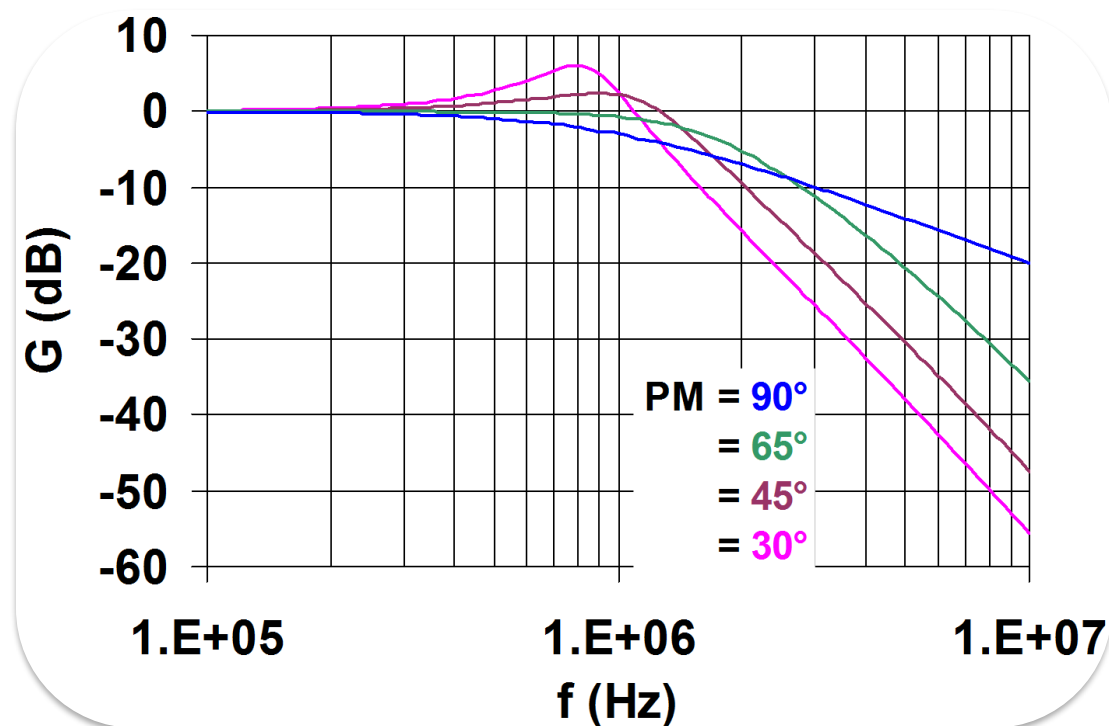
- ↘ **Gain decreases** with increasing frequency
- 📏 **Bandwidth:** Frequency range where gain is within 3dB of DC gain
- ↔ **Gain-Bandwidth Product:** $GBW = A_{DC} \times f_{3dB}$
- ⚡ **Trade-off:** Higher gain reduces bandwidth



Phase Margin and Stability

~ Key Concepts

-  **Phase Margin:** Difference from -180° at unity gain frequency
-  **Stability Indicator:** Higher PM = more stable
-  **Measurement:** From Bode plot at 0 dB gain point
-  **Gain Margin:** Complementary stability parameter
-  **Design Rule:** PM $> 45^\circ$ for stable feedback



Activity: THINK-PAIR-SHARE

THINK (2 min)



An op-amp has a **slew rate** of $0.5 \text{ V}/\mu\text{s}$. What is maximum frequency for a 5V peak-to-peak sine wave output?



Individual Thinking

PAIR (3 min)



Discuss your calculation and method with a partner



Partner Discussion

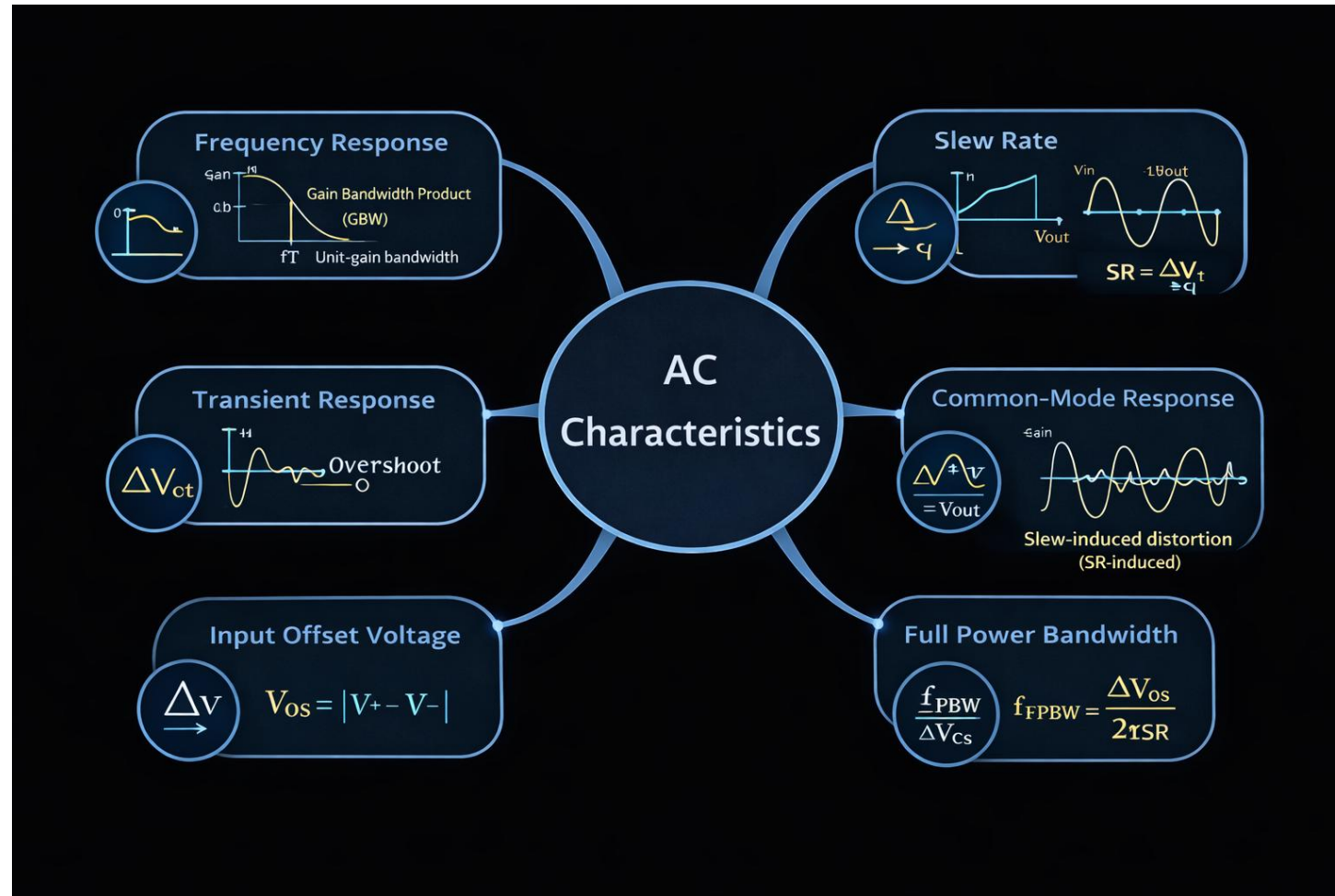
SHARE (5 min)



Be ready to share your answer and formula you used



Group Sharing



Exam-Oriented Questions

- 1 Define **slew rate** and explain its effect on high-frequency signals.
- 2 Explain the relationship between **bandwidth and gain** in an op-amp.
- 3 Draw a **frequency response curve** and label key parameters.
- 4 Calculate the maximum frequency for a 5V peak sine wave with a slew rate of $1\text{V}/\mu\text{s}$.



Textbooks

 D.Roy Choudhry, Shail Jain, "**Linear Integrated Circuits**", New Age International, 5th edition, 2018. (Unit I, Section 1.5)

 Sergio Franco, "**Design with Operational Amplifiers and Analog Integrated Circuits**", 4th Edition, Tata Mc Graw-Hill, 2014. (Chapter 3)

Online Resource

 Texas Instruments, "**Op-amp AC Characteristics: Frequency Response and Slew Rate**", [Link to TI E2E or technical document]



Textbooks



Online Resources

Thank You