EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Converging:

Beginner

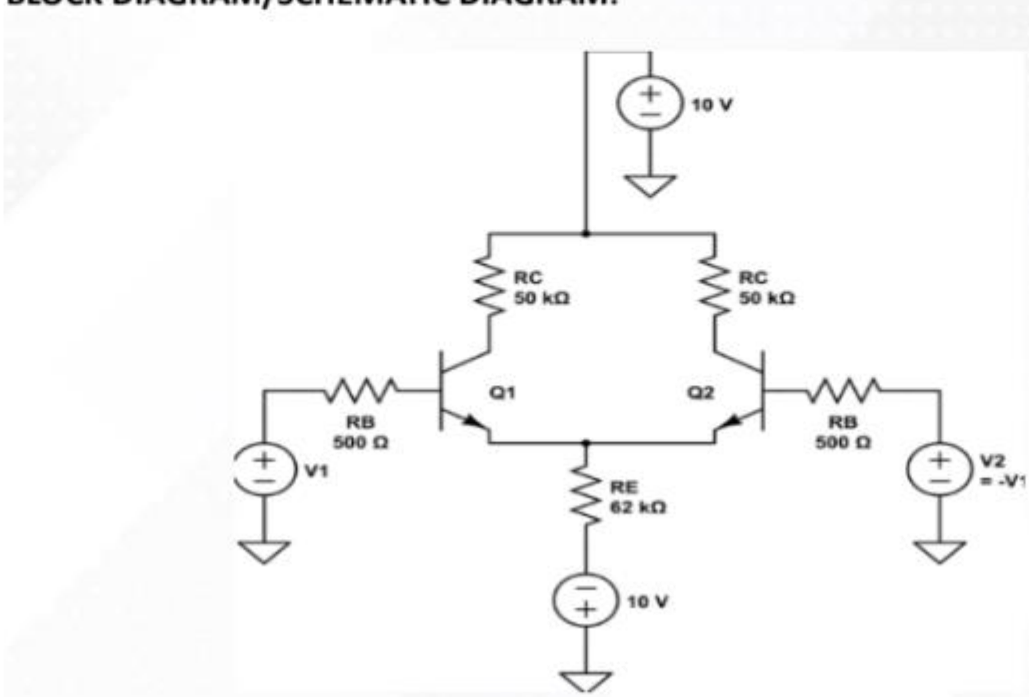
Main Objectives:

- Understand the operation of a differential amplifier.
- Build the differential amplifier using BJTs resistors.
- Assemble the differential amplifier accurately using the given schematic diagram.
- Draw block diagrams showing the connection of all measuring instruments in the experiment.

Procedure:

1. Build the differential amplifier using BJTs resistors, and a shared emitter/source resistor.
2. Apply two input signals using a function generator (one positive, one inverted)
3. Use a virtual oscilloscope to view both input and output waveforms.
4. Measure how much the signal difference was amplified.
5. Observe how noise or common-mode signals are reduced.

BLOCK DIAGRAM/SCHEMATIC DIAGRAM:



OBJECTIVES:

A. Content Standards

- Understand the operation of a differential amplifier under AC signal conditions.
- Apply correct wiring techniques and ensure safe handling of test instruments like the function generator and oscilloscope.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

B. Performance Standards

- Assemble the differential amplifier accurately using the given schematic diagram.
- Measure and compare voltage signals at different nodes of the circuit.
- Analyze the relationship between input and output waveforms and calculate differential voltage gain effectively.

C. Learning Competencies/Objectives

- Identify suitable transistors and resistor values based on the circuit's voltage and current requirements.
- Accurately measure differential input and output voltages using the oscilloscope.
- Interpret waveform symmetry, phase relationships, and signal amplification behavior.
- Draw block diagrams showing the connection of all measuring instruments in the experiment.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION:

In this activity, you'll explore how a Differential Amplifier works a powerful and widely used circuit in analog electronics. A Differential Amplifier amplifies the difference between two input signals. It's commonly found in audio devices, sensors, and communication systems, and it forms the core of many op-amp circuits.

This experiment will help you see and measure how the circuit reacts to changes at both input terminals and how it produces a clean, amplified output.

PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

A Differential Amplifier uses two transistors often BJTs that share a common emitter (or source) resistor. Each transistor gets its own input signal. The amplifier compares these two signals and boosts only the difference between them. It's perfect for reducing noise, since any common signals (called "common mode") cancel out. This makes differential amplifiers ideal for clean signal amplification.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Simple Points to Remember:

It takes two input signals (V_1 and V_2)

It amplifies the difference: (V_1 - V_2)

It rejects common signals (noise that appears on both inputs)

Requires matched components and proper biasing.

PART 2: WHAT YOU'LL DO

- Build the differential amplifier using BJTs or FETs, resistors, and a shared emitter/source resistor.
- Apply two input signals using a function generator (one positive, one inverted)
- Use a virtual oscilloscope to view both input and output waveforms.
- Measure how much the signal difference was amplified.
- Observe how noise or common-mode signals are reduced.

By building and testing this circuit, you'll understand how differential amplifiers behave and why they're so important in real-world applications.

PART 3: TOOLS AND COMPONENTS

- Two matched transistors BJTs
- Resistors (for load and biasing)
- Power supply (dual supply or virtual ±10V)
- Function generator (for V_1 and V_2 inputs)
- Oscilloscope (to observe input/output signals)

The VR lab will guide you step-by-step, so don't worry if this is your first time working with this type of circuit.

PART 4: BASIC FORMULA

In a differential amplifier, the key idea is to amplify the difference between two input signals. To measure how strong the amplification is, we calculate something called the Voltage Gain.

$$A_v = \frac{V_{\text{out}}}{V_{\text{in(difference)}}}$$

Where:

- Vout= Difference between the two output voltages (Vout1 - Vout2)
- Vin= Difference between the two input voltages (V1 - V2)

PART 5: WHAT TO EXPECT

If your circuit is working correctly:

- The output wave will be larger than the input difference.
- Signals that are common to both inputs will be minimized and canceled.
- You may see inversion, depending on which output you observe.

- The output should be clean and stable, not distorted.

If the output doesn't look right, double-check:

- Transistor orientation
- Resistor values
- Signal connections.

INTERMEDIATE

Main Objectives:

- Demonstrate understanding of Differential Amplifier
- Assemble and operate a Differential Amplifier using matched transistors and a guided schematic.
- Construct a functioning Differential Amplifier using appropriate biasing techniques and symmetrical component selection.
- Create a clear block diagram of the setup, showing power supplies, input signal sources, and measurement instruments.

PROCEDURE:

1. Bias the differential amplifier correctly using the given power supplies and resistor values.
2. Apply the same input signal to both bases V1 = V2 and observe the outputs.
3. Apply a signal to only one input V1 ≠ V2 while keeping the other at 0 V.
4. View the waveforms using the VR oscilloscope.
5. Change the input mismatch by slightly adjusting one input and keeping the other constant.
6. Check phase and amplitude accuracy by swapping input signals (apply the same signal to V2 instead of V1).
7. Adjust resistor values or bias current change RC or RE and observe the output.

OBJECTIVES:

A. Content Standards

- Demonstrate understanding of Differential Amplifier operation under AC conditions through direct circuit assembly and testing.
- Apply theoretical concepts of differential amplification to practical measurement, signal behavior, and waveform analysis.

B. Performance Standards

- Assemble and operate a Differential Amplifier using matched transistors and a guided schematic.
- Accurately measure input and output voltages and observe signal symmetry and phase relationships using an oscilloscope.
- Compute differential voltage gain and evaluate inconsistencies between theoretical predictions and experimental results.

C. Learning Competencies/Objectives

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Construct a functioning Differential Amplifier using appropriate biasing techniques and symmetrical component selection.
- Measure dual AC input and output voltages and interpret how the amplifier rejects common-mode signals.
- Apply the differential gain formula to assess amplifier performance and identify any circuit imbalances or deviations.
- Create a clear block diagram of the setup, showing power supplies, input signal sources, and measurement instruments.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION: Today, we're moving beyond single-stage amplification and diving into a powerful configuration used in analog systems — the Differential Amplifier. In this experiment, you'll assemble and analyze a differential amplifier, observe how it reacts to different inputs, and understand how it suppresses noise while amplifying useful signals.

PART 1: WHY USE A DIFFERENTIAL AMPLIFIER?

A differential amplifier is the foundation of many advanced analog circuits, from operational amplifiers to sensor interfaces. What makes it special?

- It amplifies the difference between two input signals.
- It rejects common-mode noise (the same signal on both inputs)
- It provides accurate signal amplification in noisy environments.

PART 2: WHAT TO EXPECT FROM THE CIRCUIT?

Once your differential pair is correctly biased, you should observe these behaviors:

- If both inputs are the same, the output should stay near zero (noise rejection).
- If one input is higher than the other, the output will swing in proportion to the voltage difference.
- The waveform should reflect amplification of signal differences, not common patterns.

As you work through the experiment, pay attention to:

- How input mismatches influence output amplitude
- Whether the output signal reflects accurate phase and amplitude differences
- How the gain changes when you adjust the resistor values or bias current

You'll use measurement tools in VR to compare theoretical gain to measured gain and optimize the setup if needed.

PART 3: PRACTICAL TIPS

- Balance is everything make sure your input signals are clean and symmetrical. Uneven inputs will affect performance.
- Double-check connections FET orientation, biasing resistors, and the shared current source must be correct.
- Watch the common-mode rejection apply the same signal to both inputs. The output should stay low if the circuit is working properly.
- Take repeat measurements to confirm consistency and rule out noise or user error.

PART 4: CONCLUSION

You've now explored how a differential amplifier works not just on paper, but in action. You observed how differences in input voltage get amplified, how noise can be suppressed, and how real-world results compare with theoretical models. This task is about applying knowledge, testing predictions, and refining your understanding through hands-on interaction.

DIFFICULT

Main Objectives:

- Learners demonstrate expert-level understanding of differential amplifier principles, including biasing strategies, common-mode rejection, and AC small-signal behavior.
- Learners accurately construct and bias a differential amplifier ensuring both transistors operate in the active region under symmetric conditions.
- Learners analyze output waveforms under differential and common-mode inputs, interpreting phase shifts, imbalance, and non-linearities using an oscilloscope.
- Draw a simple diagram, explain your setup, how you measured things, what happened, and how well it worked.

PROCEDURE:

1. Build the differential amplifier using two matched BJTs, identical collector resistors (RC = 50 kΩ), base resistors (RB = 500 Ω), and a shared emitter resistor (RE = 62 kΩ).
2. Connect the ±10 V power supplies as shown.
3. Bias the amplifier properly by ensuring both transistors are turned on and share current evenly through the emitter resistor.
4. Apply the same input signal to both V1 and V2 (matched inputs).
5. Introduce a small difference between V1 and V2 (sine wave to V1 and its inverse to V2).
6. Check the symmetry of the output waveforms from both transistors.
7. Vary the input difference and observe the change in output amplitude.

8. Test how the circuit handles common-mode signals by applying the same signal to both inputs again.
9. Try changing one resistor slightly change one RC or RB value.

OBJECTIVES:

A. Content Standards

- Learners demonstrate expert-level understanding of differential amplifier principles, including biasing strategies, common-mode rejection, and AC small-signal behavior.
- Learners integrate theoretical analysis with experimental validation, using both simulation and physical measurement techniques to evaluate circuit performance.

B. Performance Standards

- Learners accurately construct and bias a differential amplifier ensuring both transistors operate in the active region under symmetric conditions.
- Learners analyze output waveforms under differential and common-mode inputs, interpreting phase shifts, imbalance, and non-linearities using an oscilloscope.
- Learners conduct rigorous gain and CMRR (Common-Mode Rejection Ratio) calculations, comparing theoretical predictions with empirical data and discussing observed deviations.

C. Learning Competencies/Objectives

By the end of this lesson, students will be able to:

- Design and implement a differential amplifier circuit with balanced inputs and matched loads.
- Measure and analyze voltage gain (differential and common mode) using oscilloscope waveform data.
- Identify and interpret real-world deviations such as signal imbalance, distortion, thermal drift, and parasitic effects.
- Compute and evaluate voltage gain and CMRR using small-signal model theory and waveform measurements.
- Document results through a detailed block diagram and engineering report that outlines design rationale, measurement methodology, observed outcomes, and critical analysis of performance.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION:

We're moving beyond single-input amplification. We're diving into the Differential Amplifier a powerful circuit that compares two input signals, amplifying the difference between them while rejecting common noise. This experiment challenges you to construct, analyze, and optimize a differential amplifier using real-world signals.

PART 1: WHY USE A DIFFERENTIAL AMPLIFIER?

The differential amplifier is the backbone of analog systems — used in op-amps, sensor interfaces, and communication circuits. Why?

- It amplifies the voltage difference between two input signals.
- It rejects noise common to both inputs (common-mode rejection)
- It offers high linearity and precision in signal processing.

In this experiment, you'll input two AC signals — either equal or slightly different — and observe how the amplifier responds. You're not just checking if it works; you're testing how well it works and why.

PART 2: WHAT TO EXPECT FROM THE CIRCUIT?

In a well-biased differential amplifier:

- Matched inputs (same signal on both sides) should yield minimal output
- A difference between the inputs should create a clear, amplified output
- If components are not balanced, you'll see distortion or offset in the output

As you power up and test the circuit, focus on:

- The symmetry between the two transistor branches
- How the output waveform changes as you vary the input difference
- Whether common-mode signals are rejected as expected
- How gain varies with input amplitude or resistor mismatch

PART 3: WHAT TO MEASURE?

You'll measure and analyze:

Differential Voltage Gain using:

$$A_v = \frac{V_{out}}{V_1 - V_2}$$

Then, **compare this to the theoretical gain**:

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

$$A_{v_{theory}} = \frac{R_C}{2r_e}$$

(where R_C is the collector resistor and r_e is the intrinsic emitter resistance)

Use an oscilloscope to observe the waveforms, noting:

- Output symmetry.
- Amplitude changes
- Phase relationship between input and output

PART 4: TIPS FOR DIFFICULT TASKS

- Balance matters – Use matched transistors and resistors.
- Adjust bias current via the tail current source (or shared emitter resistor) for optimal linearity.
- Check common-mode rejection – Use identical inputs and verify output stays low.
- Trace anomalies – If distortion appears, review component symmetry or input mismatch.

PART 5: CONCLUSION

This isn't just a lab task — it's a systems challenge. You're analyzing how multiple variables interact in a precision amplifier. From signal symmetry to gain stability, everything counts.

Diverging (Reflector)

Beginner

Main Objectives:

- Learners need to watch the video of Differential Amplifier to understand hot it uses.
- Learners demonstrate an understanding of how a differential amplifier works by comparing two input signals.
- Learners recognize how the difference between two AC input signals affects the output.
- Learners understand the role of each component in the differential amplifier by observing how it behaves in a working circuit setup.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION: Hello, everyone! I'm glad to welcome you to another exciting learning session in the Electrosphere! Today, we're going to gently explore the idea of amplification using a Differential Amplifier. This might sound tricky at first, but don't worry — we'll take our time to observe, reflect, and understand how this amplifier compares two signals and shows the difference as output.

PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

- A Differential Amplifier is a circuit that compares two input signals. Instead of amplifying just one signal like a regular amplifier, it amplifies the difference between two signals — we call them V_1 and V_2.
- If both input signals are the same, the output is close to zero. But if they're different, the amplifier shows how much one is bigger than the other. This kind of amplifier is very useful in things like sensors, sound systems, and data processing — where detecting small differences matters a lot.

PART 2: WHY IS IT IMPORTANT?

Differential amplifiers help electronics focus only on what matters — the changes or differences in signals. That means they can filter out noise and give a cleaner, more useful output.

Think about this as you observe the simulation:

- What happens when V_1 and V_2 are equal?
- What if V_1 is higher than V_2?
- What does the output signal look like in each case?

This amplifier is like a smart listener it tunes in only to what's changing and ignores what's the same.

PART 3: WHAT TO FOCUS ON

During the simulation or guided activity, you'll see:

- Two AC signals coming from a function generator - these go into the V_1 and V_2 inputs.
- A differential amplifier circuit made with transistors and resistors.
- An oscilloscope showing the input signals and the output signal.

- How the output reacts when V_1 and V_2 change look closely at the waveform shapes and sizes.

PART 4: WHAT WILL YOU LEARN?

- Understand how a Differential Amplifier compares and amplifies the difference between two input signals.
- Recognize how the output changes when one input is higher or lower than the other.
- Measure real waveforms using an oscilloscope and calculate voltage gain.

PART 5: CONCLUSION

This experiment is your opportunity to observe, reflect, and apply. You'll watch how each part of the differential amplifier works, think about why the signals change, and understand what the circuit is really doing.

Once you feel ready, you'll get to build the circuit yourself and see how the amplifier responds to real signals bringing your observations to life.

INTERMEDIATE

Main objectives:

- Watch the video of Differential Amplifier AC Analysis
- Identify and apply small-signal models to determine the AC response of differential amplifiers.
- Analyze and interpret the importance of CMRR in AC analysis and its effect on signal integrity.
- Observe how a differential amplifier processes two AC input signals and produces an output based on their difference.

Objectives:

A. Content Standards

- Learners demonstrate understanding of differential amplifier operation in response to two AC input signals.
- Learners identify key behaviors such as differential gain, common-mode rejection, and signal symmetry through guided observation and analysis.
- Learners develop insights into the relationship between theoretical gain and observed output through measurement and reflection.

B. Performance Standards

- Learners observe and analyze a differential amplifier setup (virtual or hands-on) before attempting calculations or circuit building.
- Learners interpret oscilloscope readings and sketch waveform behavior, focusing on how the output reflects the difference between the two inputs.
- Learners calculate voltage gain using measured values and compare their results to expected theoretical performance.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

C. Learning Competencies / Objectives

- By the end of this activity, learners should be able to:
- Observe how a differential amplifier processes two AC input signals and produces an output based on their difference.
- Identify and describe the functions of key components, including input resistors, transistors, load resistors, and current source, in a differential amplifier.
- Use oscilloscope data to compute voltage gain.
- Reflect on how waveform shape, amplitude, and balance are influenced by circuit symmetry, biasing, and input signals.
- Create a block diagram illustrating the signal flow from the function generator inputs to the amplifier and oscilloscope, reinforcing system-level understanding.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION: Welcome back to another insightful session in the Electrosphere! Today, we'll go beyond single-ended amplification and explore something even more powerful: the differential amplifier. This time, instead of focusing on how a single signal is amplified, we'll observe how a pair of input signals are compared — and how the circuit amplifies the difference between them. This is a big step forward, and you'll approach it by watching, reflecting, and then trying it yourself.

PART 1: WHY STUDY A DIFFERENTIAL AMPLIFIER?

A differential amplifier is a foundational building block in analog electronics, used in systems like operational amplifiers, sensors, and communication circuits. It has two inputs, and it focuses only on the difference between them. This makes it great at:

- Ignoring common noise (common-mode signals)
- Amplifying small differences in voltage
- Providing balanced signal processing

By studying this circuit, you'll begin to understand:

- How two inputs interact to produce one output
- What makes differential amplification useful in real-world systems?
- How circuit symmetry, biasing, and resistor values affect performance

PART 2: WHAT TO LOOK FOR?

Before you build the circuit or perform any measurements, observe carefully during the demonstration or simulation. Focus on:

- How the two input signals (V_1 and V_2) are applied to the bases or gates of the transistors
- How the tail current source or shared emitter/source resistor affects symmetry.
- How the output responds when one input rises and the other stays constant (or when both change)
- What the oscilloscope displays when you monitor both the inputs and the output

Pause and reflect:

- When both inputs are the same, what happens to the output?
- What changes when one input increases and the other decreases?
- Is the output stronger when the inputs are opposite?

PART 3: INTERPRETING THE SIGNALS

On the oscilloscope, observe how:

- The output waveform grows when there's a difference between the two inputs.
- If the inputs are equal, the output is minimal or zero (common-mode rejection)
- The waveform may or may not be inverted, depending on which input is leading.

Sketch both input waveforms and the output. Identify:

- Where amplification happens
- What kind of phase relationship exists between inputs and output?
- Whether the gain remains steady across different input levels

PART 4: WHAT WILL YOU LEARN?

By the end of this session, you will:

- Understand how a differential amplifier amplifies the difference between two signals.
- Identify which parts of the circuit contribute to balance and stability.
- Calculate voltage gain.
- Reflect on how changing input conditions affect the output response.

PART 5: CONCLUSION

This experiment lets you think like a designer. You'll observe first, reflect on how the circuit works, and then apply your understanding to testing and building.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Take note of patterns between theory and practice and use those insights as steppingstones to mastering more advanced amplifier concepts.

DIFFICULT

Main Objectives:

- Watch the video of Differential Amplifier DC Analysis
- Learners demonstrate deep understanding of differential amplifier DC biasing, symmetry, and operating regions under ideal and non-ideal conditions.
- Learners apply theoretical modeling of BJT operation to determine node voltages, collector currents, and tail current distribution.
- Learners explore how transistor matching, tail resistance, and power supply symmetry affect DC performance and stability.

Objectives:

A. Content Standards

- Learners demonstrate advanced understanding of differential amplifier operation in response to differential and common-mode AC inputs.
- Learners analyze key behaviors such as differential signal amplification, common-mode rejection, and output symmetry through critical observation and theoretical modeling.
- Learners synthesize theoretical gain models with experimental data, developing insights into real-world non-idealities and limitations of amplifier circuits.

B. Performance Standards

- Learners observe and evaluate a differential amplifier configuration prior to circuit assembly, paying close attention to biasing, symmetry, and expected signal response.
- Learners interpret oscilloscope readings from both input channels and output nodes, and critically assess phase, gain, and linearity based on their understanding of transistor behavior and circuit topology.
- Learners calculate differential-mode gain and common-mode rejection ratio (CMRR) using theoretical models and compare them with measured values.
- Learners document circuit design with detailed block diagrams and annotate signal paths, measurement points, and feedback loops.

C. Learning Competencies / Objectives

- Observe and interpret how a differential amplifier processes signals applied at two input terminals, emphasizing both differential and common-mode conditions.
- Identify and explain the roles of critical components including matched transistors, tail current source, load resistors, and biasing networks in the behavior and stability of the amplifier.
- Analyze oscilloscope waveforms to evaluate amplitude, phase relationships, and linear operating regions of the amplifier.
- Calculate and compare theoretical and measured values of:

Differential-mode voltage gain:
Common-mode gain
common-mode rejection ratio (CMRR)

- Diagnose discrepancies between theory and practice by reflecting on:
    - Transistor mismatches
    - Non-ideal tail current sources
    - Parasitic effects and temperature sensitivity

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION: In this advanced session, we go beyond circuit construction our aim is to deeply understand the complex behavior of the differential amplifier, a foundational building block in analog electronics and integrated systems.

PART 1: WHY STUDY A DIFFERENTIAL AMPLIFIER?

- Amplification of differential signals
- Rejection of common-mode noise
- Symmetrical signal handling due to matched transistor pair design

However, textbook behavior is idealized. In this experiment, you'll challenge those assumptions by analyzing:

- What mismatched transistors or tail current sources affect output?
- The influence of input amplitude and frequency on signal linearity
- The practical limits of Common-Mode Rejection Ratio (CMRR)

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Ask yourself:

- How does the amplifier behave with small vs. large differential inputs?
- What causes deviation from symmetry in output waveforms?
- What are the practical consequences of a limited CMRR?

PART 2: OBSERVATION BEFORE ACTION

- The differential input waveform from a function generator
- The tail current source's role in setting the operating point.
- The output waveform at each collector/drain under matched and mismatched conditions
- The effect of a common-mode input (both inputs rising/falling together)

Sketch the full setup, noting signal paths, power supplies, biasing resistors, and output measurement points. Predict and reflect:

- How would increasing input frequency affect phase integrity?
- Where does the amplifier begin to saturate or distort?
- Is the gain constant across the entire input range?

PART 3: THEORETICAL INSIGHT VS. PRACTICAL RESULTS DIFFERENTIAL AMPLIFIER

The differential amplifier theoretically offers:

- High differential gain
- Excellent common-mode rejection
- Symmetrical output for balanced inputs
- Predictable behavior based on transistor parameters and bias currents.

But in practical scenarios, you may observe deviations due to non-ideal factors, including:

- Gain roll-off at high frequencies due to parasitic capacitances and layout limitations.
- Imbalance in output swing due to mismatched transistors or resistor tolerances
- Reduced CMRR when tail current source lacks high output impedance.
- Waveform distortion from overdrive or insufficient bias headroom

Use your dual-trace oscilloscope and measurement tools to record key parameters:

- Measure and compare input and output amplitudes.
- Observe common-mode vs. differential-mode behavior.
- Evaluate phase accuracy and linearity across input amplitudes and frequencies.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Reflect critically:

- How does measured gain compare with your theoretical small-signal analysis?
- Are discrepancies systematic (due to design) or input-dependent (load effects, frequency response)?
- Which real-world non-idealities (finite transistor beta, thermal drift, supply noise) seem most influential?

PART 4: CRITICAL THINKING THROUGH COMPARISON

This experiment isn't just a build-test cycle it's a guided comparative study. Maintain a detailed engineering notebook or reflection journal. Use it to capture your thought process at each phase:

- What did you expect from the differential amplifier under ideal bias?
- What did you observe, and under what conditions?
- Were waveform asymmetries due to input mismatch or circuit imbalance?
- If used in a real-world application (e.g., an instrumentation front-end), would the observed distortion or offset be acceptable?

Ask deeper-level questions:

- Did the transistors stay in the active region throughout the test?
- How does tail current source quality impact gain stability and rejection of noise?
- What would happen if this stage were cascaded into a larger system would imperfections amplify?

PART 5: CONCLUSION FROM CIRCUITS TO CONCEPTS

This lab is more than a chance to test a theory it's a critical journey into the subtle, often messy reality of analog electronics.

By observing first, measuring carefully, and thinking reflectively, you've engaged not just with circuits, but with the engineering mindset.

You now understand that:

- Theory and practice often diverge and the reasons why matter.
- Component variation, layout, and bias stability are not footnotes, but central to performance.
- Insight grows when you embrace observation, analysis, and synthesis as equal parts of learning.

You're not just completing an experiment.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Assimilating (Theorist)

Beginner

Main Objective: To understand the theoretical foundation of a differential amplifier circuit, derive its voltage gain, and analyze input-output relationships using formulas and circuit symmetry.

🛠 Procedure

1. **Construct the differential amplifier** using matched NPN BJTs, collector resistors $R_C = 50\,k\Omega$, base resistors $R_B = 500\,\Omega$, and shared emitter resistor $R_E = 62\,k\Omega$.
2. **Bias the circuit** with dual supplies: $+10\,V$ at the collectors and $-10\,V$ at the shared emitter node.
3. **Apply matched inputs** ($V_1 = V_2$) and observe the output. Note the minimal differential output due to common-mode rejection.
4. **Apply a differential input** ($V_1 = +v(t),\ V_2 = -v(t)$). Use an oscilloscope to view amplified output across the collectors.
5. **Calculate theoretical differential gain** using:

$$A_d = \frac{R_C}{2r_e}, \quad \text{where } r_e = \frac{V_T}{I_E},\ V_T \approx 25\,mV$$

6. **Compare measured gain** from the oscilloscope to the theoretical gain and reflect on differences.
7. **Adjust resistor values** and observe how gain and symmetry change, then explain using theoretical models.

OBJECTIVES

A. Content Standards

- Learners understand the operation and analysis of differential amplifiers using DC and small-signal models, including effects of component mismatches and common-mode inputs.

B. Performance Standards

- Learner's compute and verify theoretical gain, simulate, and model signal behavior under varied conditions, and assess output accuracy.

C. Learning Competencies / Objectives

Learners will:

- Analyze and derive differential gain, input resistance, and output resistance.
- Compute CMRR using theoretical and measured values.
- Explain phase response and balance.
- Predict circuit behavior under imbalance or input skew.

PROCEDURE Navigation of Virtual Laboratory:

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

Discussion:

Welcome to today's experiment. Before we begin building the circuit, it's important to understand the theory behind what we're doing. This session focuses on a fundamental analog circuit: the differential amplifier. As Theorists, your strength lies in grasping underlying principles, making logical connections, and applying structured models to real systems. This experiment will give you the opportunity to validate theoretical concepts such as differential gain, common-mode rejection, and biasing symmetry using practical circuit behavior.

PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

A **differential amplifier** is a circuit that amplifies the difference between two input voltages, rejecting any voltage that is common to both inputs.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Key Concepts:

- **Differential Input:** $V_{in(diff)} = V_1 - V_2$
- **Common-Mode Input:** $V_{in(cm)} = \frac{V_1+V_2}{2}$
- **Output Voltage:** Ideally proportional to the differential input only.

Small Signal Analysis:

- The input transistors share a common emitter current source, splitting current according to input difference.
- Assuming perfectly matched transistors:

$$I_{C1} = \frac{I_E}{2} + \Delta I, \quad I_{C2} = \frac{I_E}{2} - \Delta I$$

- The output voltage at collector of Q1:

$$V_{o1} = V_{CC} - I_{C1} \cdot R_C$$

🔧 PART 2: CORE CIRCUIT PRINCIPLES

1. Voltage Gain

The differential-mode gain is:

$$A_d = \frac{V_{out}}{V_{in(diff)}} = \frac{R_C}{2r_e}, \quad \text{where } r_e = \frac{25\,mV}{I_E}$$

2. Common-Mode Rejection Ratio (CMRR)

$$\text{CMRR} = \frac{A_d}{A_{cm}}, \quad A_{cm} \text{ ideally } \approx 0$$

3. Symmetry Principle

If Q_1 and Q_2, and R_{C1} and R_{C2} are perfectly matched, the amplifier is balanced:

- Matched inputs → minimal output
- Differential input → amplified output

4. Effect of Resistor Imbalance

- Imbalanced R_C or R_E causes uneven collector currents and offset at output.
- Gain becomes unequal for each transistor side.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

ONCLUSION & REFLECTION

The differential amplifier serves as a fundamental building block in analog electronics. By applying theoretical formulas and understanding circuit symmetry, one can:

- Predict output behavior.
- Confirm signal amplification only when inputs differ.
- Recognize how balance and matching affect performance.

Reflection Questions

- How does the gain formula explain the output swing in your experiment?
- What effect did match, or mismatching components have on your output?
- How does theory help you detect and fix distortion or asymmetry in the circuit?

Intermediate

Main Objective: To analyze the operation of a BJT differential amplifier using both DC and small-signal models, and to evaluate the impact of component mismatches on gain, output symmetry, and common-mode rejection.

🛠 Procedure

1. **Assemble the differential amplifier** circuit using matched BJTs, precise resistors ($R_C = 50\,k\Omega$, $R_B = 500\,\Omega$, $R_E = 62\,k\Omega$).
2. **Power the circuit** with dual supplies: $+10\,V$ (collector) and $-10\,V$ (emitter).
3. **Input two signals**: $V_1 = +v(t)$, $V_2 = -v(t)$, using a function generator to produce a differential input.
4. **Use an oscilloscope** to measure collector voltages V_{C1}, V_{C2}, and compute the output difference $V_{out} = V_{C2} - V_{C1}$.
5. **Calculate theoretical differential gain**:

$$A_d = \frac{R_C}{r_e}, \quad \text{where } r_e = \frac{V_T}{I_E}$$

6. **Apply common-mode input**: $V_1 = V_2 = v_{cm}(t)$, and observe output for CMRR analysis.
7. **Test mismatched components** by changing R_C or unbalancing inputs. Note the changes in symmetry and output offset.
8. **Record and compare** theoretical vs. measured gain, phase response, and output swing under different input and component conditions.

OBJECTIVES

A. Content Standards

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Learners understand the operation and analysis of differential amplifiers using DC and small-signal models, including effects of component mismatches and common-mode inputs.

B. Performance Standards

- Learner's compute and verify theoretical gain, simulate, and model signal behavior under varied conditions, and assess output accuracy.

C. Learning Competencies / Objectives

Learners will:

- Analyze and derive differential gain, input resistance, and output resistance.
- Compute CMRR using theoretical and measured values.
- Explain phase response and balance.
- Predict circuit behavior under imbalance or input skew.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

Discussion:

In this experiment, you will explore the behavior of a differential amplifier, a fundamental building block in analog electronics. Before constructing the circuit, it is essential to understand the theoretical foundations that govern its operation. Differential amplifiers amplify the difference between two input signals and are key to rejecting unwanted noise and common-mode signals. They are commonly used in op-amps, analog signal processing, and sensor front ends. As an assimilating learner, your focus will be on understanding how each circuit component contributes to differential operation, how gain is mathematically derived using small-signal models, and how practical measurements compare with theoretical predictions.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

🔎 PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

A **differential amplifier** amplifies the voltage difference between two input signals while rejecting common-mode signals. It is central in analog front-end designs like operational amplifiers.

Key Concepts:

- **Differential input:** $V_{id} = V_1 - V_2$
- **Common-mode input:** $V_{cm} = \frac{V_1+V_2}{2}$
- **Ideal Output:** Only responds to V_{id}

PART 2: THEORETICAL MODEL AND GAIN DERIVATION

1. DC Analysis

- Assuming symmetrical biasing:

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}, \quad I_{C1} = I_{C2} = \frac{I_E}{2}$$

- $V_{C1}, V_{C2} = V_{CC} - I_C R_C$

2. Small-Signal Differential Gain

$$A_d = \frac{V_{out}}{V_{id}} = \frac{R_C}{r_e}, \quad \text{where } r_e = \frac{V_T}{I_E}$$

3. Common-Mode Gain

Assuming ideal current source at emitter:

$$A_{cm} \approx 0 \Rightarrow \text{Perfect CMRR}$$

With finite emitter resistance R_E:

$$A_{cm} = \frac{R_C}{2R_E + 2r_e}, \quad \text{CMRR} = \frac{A_d}{A_{cm}}$$

4. Phase Analysis

- Output at Q_1 and Q_2 are **180° out of phase** under differential input.
- Symmetry ensures balanced phase and amplitude response.

5. Imbalance Effects

- Unequal R_C values → offset output voltage.
- Uneven transistor gain ($\beta_1 \neq \beta_2$) → CMRR degradation.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Part 3: CONCLUSION

At the intermediate level, differential amplifier analysis extends beyond simple voltage difference amplification. The learner explores:

- The role of symmetry in accurate signal reproduction.
- What real-world imperfections (resistor mismatches) impact output.
- The importance of calculating both differential and common-mode gain to evaluate amplifier performance.

DIFFICULT

Main Objectives: To derive and analyze the complete DC and AC behavior of a differential amplifier under both ideal and non-ideal conditions, model its frequency response, and evaluate the impact of mismatched components and finite gain parameters on CMRR and linearity. Interpret amplifier behavior through small-signal differential models.

🛠 Procedure

1. **Design the differential amplifier** with precise BJT parameters using data sheet values (e.g., β, $V_{BE(on)}$, r_o).
2. **Bias the transistors** using dual power supplies and simulate the bias point using Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL).
3. **Apply small-signal AC analysis**:
   - Use r_π, g_m, and r_o models for both Q1 and Q2.
   - Derive A_d, A_{cm}, and CMRR.
4. **Include mismatch effects**:
   - Simulate offset if $R_{C1} \neq R_{C2}$, or $\beta_1 \neq \beta_2$.
   - Add emitter degeneration and observe gain linearization.
5. **Perform frequency response analysis**:
   - Derive f_{-3dB}, f_H, and plot Bode plots for $A_d(f)$.
6. **Compare theoretical and simulated results** using MATLAB, LTspice, or Multisim.
7. **Present full small-signal equivalent model** and justify every assumption.

OBJECTIVES:

A. Content Standards

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Learners demonstrate advanced understanding of transistor-level differential amplifier modeling, including full AC equivalent circuit analysis, distortion behavior, and frequency dependence.

B. Performance Standards

Learners derive, simulate, and verify complex circuit behaviors using both analytical and computer-based tools, evaluating the effects of real-world non-idealities.

C. Learning Competencies / Objectives

Learners will:

- Derive expressions for A_d, A_{cm}, and CMRR from first principles.
- Analyze the impact of r_o, finite β, and mismatches.
- Construct a small-signal equivalent model for the full amplifier.
- Evaluate how frequency, temperature, and bias current affect amplifier performance.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

DISCUSSION:

🔎 PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

A differential amplifier amplifies the difference between two input signals while rejecting common-mode noise. It's the heart of op-amps, ADCs, and analog front ends.

Key equations:

- **Differential Input**:

$$V_{id} = V_1 - V_2$$

- **Common-Mode Input**:

$$V_{cm} = \frac{V_1 + V_2}{2}$$

- **Differential Output**:

$$V_{out} = A_d \cdot V_{id}$$

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

🔧 PART 2: CORE CIRCUIT PRINCIPLES

1. **DC Analysis**

Assume symmetrical operation:

- $I_E = \frac{V_{EE} - V_{BE}}{R_E}$
- $I_{C1} = I_{C2} = \frac{I_E}{2}$
- $V_{CE1}, V_{CE2} = V_{CC} - I_C R_C$

2. **AC Small-Signal Analysis**

For each transistor:

- Transconductance:

$$g_m = \frac{I_C}{V_T}$$

- Input resistance:

$$r_\pi = \frac{\beta}{g_m}$$

- Output resistance (Early effect):

$$r_o = \frac{V_A}{I_C}$$

Differential gain:

$$A_d = g_m R_C = \frac{I_C}{V_T} R_C$$

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Common-mode gain (finite R_E):

$$A_{cm} = \frac{R_C}{2R_E + 2r_e}$$

CMRR:

$$\text{CMRR} = \frac{A_d}{A_{cm}} = \left(\frac{2R_E + 2r_e}{r_e}\right)$$

3. Unbalanced Conditions

- When $R_{C1} \neq R_{C2}$, output becomes asymmetric:

$$V_{out} = \frac{(R_{C2} - R_{C1})}{2} I_d$$

- If $\beta_1 \neq \beta_2$, the current division is altered:

$$I_{C1} \neq I_{C2}, \quad \text{leading to differential offset}$$

4. Emitter Degeneration

Adding resistors r_E improves linearity:

$$A_d = \frac{g_m R_C}{1 + g_m r_E}$$

5. Frequency Response

Using Miller approximation and hybrid-π model:

- Dominant pole:

$$f_H \approx \frac{1}{2\pi(r_o \parallel R_C)C_C}$$

- Bandwidth influenced by:
  - Load capacitance
  - Emitter bypassing
  - Internal transistor capacitances (C_π, C_μ)

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

Conclusion:

At this advanced level, the differential amplifier is not just a functional block but a system whose performance depends on the balance, biasing, and device limitations. The student is expected to fully model, analyze, and predict its response to real-world constraints and component variances.

ACCOMODATING (ACTIVITIES)

Beginner

Main Objectives: To help learners build and explore a differential amplifier through hands-on simulation or lab activity, focusing on how the circuit responds to input differences and common-mode signals.

A. Content Standards

- Learners understand how a differential amplifier reacts to input signal differences and common-mode signals through practical activity.

B. Performance Standards

- Learners successfully build and test the circuit, identify noise rejection behavior, and observe output changes by adjusting inputs and components.

C. Learning Competencies / Objectives

Learners will:

- Build a differential amplifier using basic components.
- Observe the effect of matched and mismatched inputs.
- Identify noise rejection and differential gain visually.
- Relate circuit behavior to simple real-world use cases.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

DISCUSSION

Get ready to dive into a real-world experiment where you'll build and explore a differential amplifier a special kind of amplifier that compares two input signals. You won't just follow instructions you'll tweak, test, and learn by doing. This activity is all about exploration and action. You'll feed different signals into the amplifier, watch how it reacts, and see what changes when you play with components.

🔎 PART 1: WHAT IS A DIFFERENTIAL AMPLIFIER?

A **differential amplifier** compares two input signals and amplifies the **difference**. If the inputs are the same, it **cancels them out**—this is how it rejects noise. It's like having a friend who listens only when your voices are different, but ignores both when you say the same thing.

🔧 PART 2: CORE CIRCUIT PRINCIPLES (LEARN BY DOING)

🧩 In Your VR Lab, Try This:

- Step 1: Connect **same signal** to both inputs.
  📝 Observation: Output should be nearly zero.
- Step 2: Connect **inverted signal** to one input.
  📝 Observation: Output shows strong signal = amplified difference.
- Step 3: Increase the **resistor values.**
  📝 Observation: Output amplitude changes → Gain is affected.
- Step 4: Disconnect the emitter resistor.
  📝 Observation: More noise at the output → Less rejection.

PART 3: CONCLUSION

This isn't just a lesson it's an interactive discovery session. You're not memorizing how amplifiers work you're building one, testing it, and seeing it in action. Keep experimenting. Ask questions. Break stuff (carefully). That's how real engineers learn.

Remember: in the Electro sphere, curiosity leads the circuit and every mistake powers your progress.

INTERMEDIATE

Main Objective: To explore how a Differential Amplifier processes and amplifies signals by constructing the circuit, applying dynamic input signals, and observing output behavior through real-time testing and adjustment. This activity helps learners understand signal amplification and symmetry by experimenting with component changes and dual-input configurations.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

🛠️ Procedure (Action-Based Steps)

1. **Rebuild the differential amplifier** using matched BJTs, collector resistors R_C, and a tail resistor R_E.
2. **Bias the amplifier properly** using a current source or resistor in the emitter leg (simulate if needed).
3. **Apply differential input signals**: a 1 kHz sine wave and its 180° inverted version.
4. **Measure collector voltages** V_{C1} and V_{C2}, and compute $V_{out} = V_{C2} - V_{C1}$.
5. **Introduce a mismatch** in either input amplitude or resistor values and observe how the symmetry and output shift.
6. **Use sliders or dials in VR** to adjust:
   - R_C, R_E
   - Input frequency and amplitude
   - Tail current (by changing R_E)
7. **Record how gain and output change** for each variation.
8. **Respond to interactive challenges**, e.g., "Restore symmetry with adjusted components," or "Match output gain to 50."

OBJECTIVES

A. Content Standards

- Learners understand how component tolerances and input differences affect the differential amplifier's gain and common-mode rejection.

B. Performance Standards

- Learners successfully tune a differential amplifier to maintain symmetry, maximize gain, and reduce common-mode output under real-world variations.

C. Learning Competencies / Objectives

Learners will:

- Build and bias a functional differential amplifier.
- Observe and analyze output changes due to input and resistor mismatches.
- Adjust circuit parameters to restore balance and optimize gain.
- Understand the link between tail current and amplifier linearity.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION:

Welcome back to the Electrosphere! This time, you're diving into the powerful world of differential amplifiers a circuit where two signals battle it out and only the difference gets amplified. You won't just build it you'll tweak it, test it, and see how every change shapes the output.

This lab is about learning by doing. You'll try out ideas, experiment with resistor swaps, adjust input conditions, and discover how this balanced amplifier handles real signals. Ready to make some noise and make sense of it?

PART 1: WHAT ARE YOU WORKING WITH?

A differential amplifier uses two identical transistors to amplify the difference between two input signals while canceling out signals they have in common (like noise or interference). It's widely used in audio equipment, sensor systems, and even in the heart of operational amplifiers.

Each transistor receives its own input, and together they share a common emitter or source resistor that helps maintain symmetry. The magic? Balanced design = better noise rejection and precise amplification.

You'll apply a signal to one input and ground the other then try giving both the same signal to explore common-mode rejection.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

⚙️ PART 2: CORE CIRCUIT PRINCIPLES (EXPERIMENT & TUNE)

Activities to Try:

- **Activity 1**: Mismatch R_C1 and R_C2 slightly (e.g., 10kΩ and 9.1kΩ).
  🔍 Question: What happens to the output? Where is the offset?
- **Activity 2**: Keep resistor values equal but increase the input difference from 0.1 V to 0.5 V.
  🔍 Question: How does output swing change?
- **Activity 3**: Increase tail current by lowering R_E.
  🔍 Question: Does gain improve? Does linearity stay intact?
- **Activity 4**: Switch to common-mode input (same signal to both bases).
  🔍 Question: How well does the circuit reject it?

PART 3: CONCLUSION

You're not just learning about differential amplifiers you're uncovering how signal conditions, transistor matching, and circuit balance all impact performance. This hands-on experiment is your chance to build, break, and rebuild your understanding from the ground up.

Let curiosity lead. And remember: the best insights often come from the setups that didn't work because they teach you how to make the next one better.

DIFFICULT

Main Objective: To explore advanced behavior of a differential amplifier by applying non-ideal conditions, analyzing signal integrity, and optimizing gain, symmetry, and common-mode rejection through hands-on tuning.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

🛠 Procedure (Experimental Activities)

1. **Build a fully biased differential amplifier** with a current mirror as a constant current source for high CMRR.
2. **Simulate mismatches** in transistor beta (β), collector resistors, or input amplitude.
3. **Feed dual input signals**:
   - Mode 1: Differential input (1 kHz sine, 180° out of phase)
   - Mode 2: Common-mode input (same signal to both inputs)
   - Mode 3: Unequal amplitude or phase difference
4. **Measure outputs**:
   - Collector voltages: V_{C1}, V_{C2}
   - Differential output: $V_{out} = V_{C2} - V_{C1}$
   - CMRR: $\mathrm{CMRR} = 20 \log \left(\frac{A_d}{A_{cm}} \right)$
5. **Use VR dials/sliders** to vary:
   - Tail current (mirror or R_E)
   - Load resistors
   - Transistor mismatch (simulate with models)
6. **Log performance metrics**:
   - Gain, offset, distortion
   - Phase shift
   - Output swing limits
7. **Respond to advanced challenges** like:
   - "Fix offset caused by ΔR_C mismatch"
   - "Maximize gain without distortion"
   - "Restore symmetry after β mismatch"

OBJECTIVES

A. Content Standards

- Learners understand advanced performance factors of differential amplifiers in realistic, non-ideal setups and know how to optimize them through iterative hands-on tuning.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

B. Performance Standards

- Learners identify and correct non-ideal behavior in a differential amplifier circuit, achieving high gain and common-mode rejection while minimizing offset and distortion.

C. Learning Competencies / Objectives

Learners will:

- Construct a high-performance differential amplifier with a current mirror.
- Analyze and fix imbalance due to component mismatches.
- Measure and interpret CMRR, gain, and phase accuracy.
- Use VR tools to iteratively tune performance and meet design targets.

PROCEDURE Navigation of Virtual Laboratory:

- Students enter the Virtual Reality (VR) laboratory environment and are given 5 minutes to practice basic navigation.
- The teacher facilitates the activity by giving instructions, answering questions, and ensuring students are comfortable with the VR interface and controls.
- Students complete a 5-minute Learning Style Questionnaire to identify their preferred approach to learning: Pragmatist, Theorist, Reflector, or Activist.
- This helps tailor the differential amplifier activity to match their cognitive strengths.
- A 10-minute pre-test is administered to evaluate students' prior understanding of differential amplifier concepts, including biasing, signal behavior, and gain computation.
- Based on their scores, students are classified as Beginner, Intermediate, or Advanced.
- Using the combined results of the learning style and knowledge level, students are assigned a differentiated version of the VR-based Differential Amplifier experiment, with matching instructions, pacing, and depth of analysis.
- Each track ensures students receive content and challenges appropriate to their skill set and style of learning.

DISCUSSION

Welcome to the next high-impact challenge in the Electrosphere! This time, you're diving into the world of Differential Amplifiers the foundation of analog signal processing in everything from sensors to audio gear. But this isn’t just about building a textbook circuit. You're going to build it, modify it, stretch it, break it, and fine-tune it — learning by doing every step of the way. You’ll inject signals, tweak biasing, and explore how real-world imperfections shape amplifier performance.

This is where practical electronics meets real experimentation and where you take the lead.

PART 1: WHAT ARE YOU EXPLORING?

A differential amplifier amplifies the difference between two input signals. When properly balanced, it cancels out any signal common to both inputs this is called common-mode rejection.

In this advanced lab, you’ll explore:

- What happens when transistor pairs are mismatched.

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- How resistor values influence gain and symmetry
- How common-mode and differential-mode signals behave.
- What signal distortion looks like when biasing isn't ideal.
- How to push the amplifier to and past its linear operating range

You won't just observe behavior you'll manipulate it, monitor it, and make sense of it in real time using your oscilloscope and function generator.

⚙️ PART 2: CORE CIRCUIT PRINCIPLES (ADVANCED ACTIVITIES)

🔬 Try These in the VR Lab:

- **Task 1**: Introduce a 10% mismatch in R_C, observe offset

  🔍 Challenge: Adjust the other side to regain symmetry.

- **Task 2**: Increase tail current.

  🔍 Observation: Gain rises—but where is the linear limit?

- **Task 3**: Swap in transistors with β = 100 and β = 200.

  🔍 Question: What happens to collector voltages?

- **Task 4**: Test CMRR using a common-mode input.

  🔍 Formula Check: $\mathrm{CMRR} = 20 \log \left(\frac{A_d}{A_{cm}} \right)$

PART 3: CONCLUSION

This lab is about experimentation, curiosity, and hands-on discovery. You're not just testing a differential amplifier you're interacting with it, tweaking every knob and resistor to see how far it can go. As an activist learner, you thrive by trial, error, and iteration. Keep asking:

- "What if I change this?"
- "Why did that happen?"
- "How do I make this better?"

Every signal distortion, every gain shift, every improvement is a result of your direct input — and that's what makes this experiment truly yours.

LESSON PLAN:

[Insert Module Basis/Pictures here/Reference Images/Lesson Plan]

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

EXPERIMENT NO:	7
EXPERIMENT TITLE:	Differential Amplifier

- **OBJECTIVES:**
  1. To design a differential amplifier based on theory discussed.
  2. To assemble the designed circuit.
  3. To prove that the practical analysis of the differential amplifier is the same with the theory.
  4. To draw the input and output voltage as seen from oscilloscope with proper label.

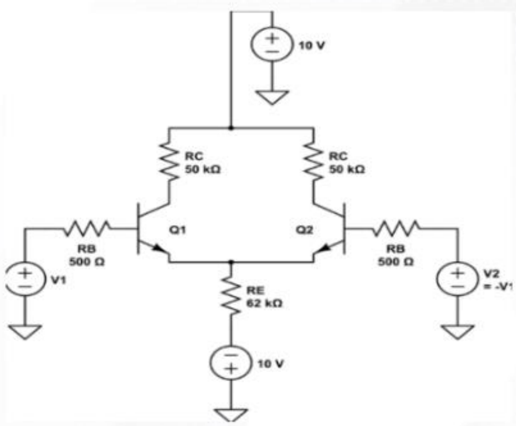
- **Discussions:**

A differential amplifier is one of compound circuits that gives an output voltage equal to the difference of two input signals that are out of phase and of the same amplitude.

There are three modes of operation of a differential amplifier namely: Single Ended Input Operation, in which one input signal is connect to one input terminal of

the circuit while the other input terminal is grounded. Another mode of operation is called Double ended Input Operation, here both input terminals are supplied with input signals the same amplitude but out of phase and result to the difference of the two inputs measure at the output terminal of the differential amplifier. The last mode of operation is a Common Mode Operation wherein both inputs terminal are connected to one single source meaning same amplitude and same phase signal that gives an output signal of zero.

- **BLOCK DIAGRAM/SCHEMATIC DIAGRAM:**



EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

- MATERIALS:
  - Design Circuit
  - DC supply
  - Transistors
  - Resistors
  - Function Generator/Signal Generator
  - Oscilloscope
- PROCEDURES:
  1. Arbitrarily choose the transistors that you will connect to the circuit. Have the specification sheets of the device as your guide.
  2. Compute the values of resistors that you are going to use. Apply DC analysis. Note that you should not exceed maximum limits.
  3. Show your computation in designing the circuit.
  4. Connect a dual polarity power supply to the circuit.
  5. Connect a signal source using Function Generator/ Signal Generator.
  6. Measure the output voltage by using Oscilloscope.
  7. Write the measured values on a given table below.
  8. Draw the input and output signal and take note of phase reversal.

ELECTRONICS ENGINEERING (ECE) DEPARTMENT

- TABLES1:

Input Signal VPP (V)		Single Ended		Double Ended		Common Mode	
V1	V2	VO 1	VO 2	VO 1	VO 2	VO 1	VO 2
2mv/500HZ 20mV/1KHZ	2mV/500HZ 20mV/1KHZ						
50mV/5KHZ	50mV/5KHZ						
100mV/10KHZ 1V/2KHZ	100mV/10KHZ 1V/2KHZ						
2V/5KHZ 5V/10KHZ	2V/5KHZ 5V/10KHZ						

- Computation:
- GRAPHS/Sketches:
- OBSERVATION:
- CONCLUSION:

ELECTRONICS ENGINEERING (ECE) DEPARTMENT

Converging (Pragmatist)

Learning Style: Pragmatists learn best by applying ideas directly and testing concepts in practical setups. They like to find out what works through real-world experimentation.

Application:

Objectives and procedures are crafted to let learners immediately apply theoretical knowledge by building the differential amplifier circuit and observing its performance. By connecting theory with hands-on results, pragmatists reinforce their understanding through direct experimentation and problem-solving.

Diverging (Reflector)

Learning Style: Reflectors prefer to watch, gather information, and think carefully from different angles before forming conclusions.

Application:

Objectives are designed to encourage careful observation of how the differential amplifier behaves. Learners will study waveform changes, sketch results, and reflect on patterns they notice, supporting a thoughtful and creative learning process without pressure to act immediately.

Assimilating (Theorist)

Learning Style: Theorists focus on building a deep, logical understanding of concepts and appreciate structured, well-explained information.

Application:

The activities highlight the theoretical foundation of differential amplifiers, such as deriving voltage gain equations and using simulations. By connecting mathematical models to real-world amplifier behavior, theorists can systematically analyze and internalize the knowledge.

Accommodating (Activist)

Learning Style: Activists learn best through action, hands-on experience, and trying new tasks right away.

Application:

Objectives and procedures promote active building, testing, and troubleshooting of the differential amplifier. Learners are encouraged to explore freely, adjust, collect data, and quickly see how changes affect the results, matching their energetic and experimental approach to learning.

Additional References:

[1] Maam Noriega Module

[2] https://files.eric.ed.gov/fulltext/EJ1436754.pdf

[3] https://scite.ai/reports/development-of-an-experiential-learning-D1gYmJl9p

[4] https://www.researchgate.net/publication/263059926_Experiential_learning_and_management_education

[5] https://www.researchgate.net/publication/247920250_Learning_together_Kolb%27s_experiential_theory_and_its_application

[6] https://eric.ed.gov/?id=EJ392587#:~:text=The%20Student%20Directed%20Classroom%3A%20A%20Model%20for%

EXPERIMENT 7: DIFFERENTIAL AMPLIFIER

20Teaching,syllabus%2C%20regulating%20commitment%2C%20facilitating%20sessions%2C%20and%20evaluati ng%20course