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Course: M.Sc Physics
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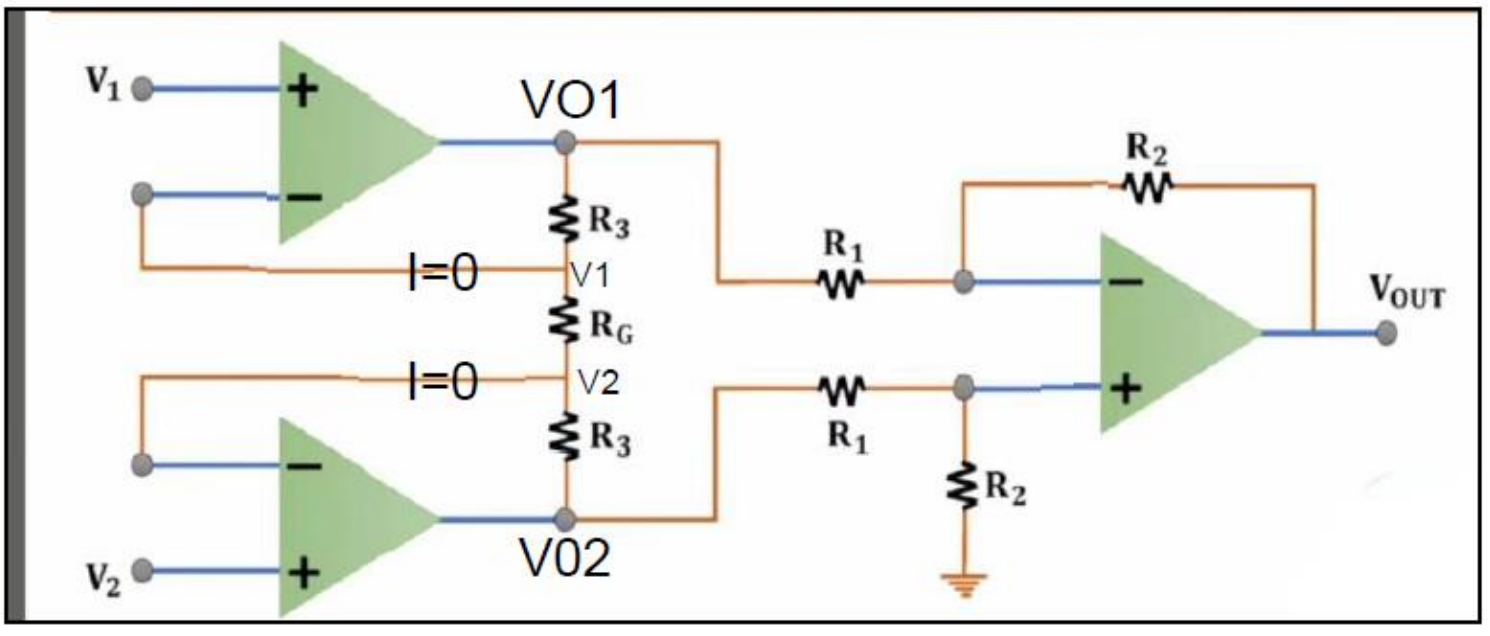
Project – Three Op-Amp Instrumentation Amplifier (IA) Design & Simulation Report:

- **Theory:**
- An **Instrumentation Amplifier (IA)** is an electronic circuit designed to **amplify very small signals accurately**. It is called an “instrumentation” amplifier because it behaves like an **instrument that amplifies** tiny input signals and converts **low-level signals into high-level outputs**.
- In this project, we use a **three op-amp instrumentation amplifier**, which means the circuit is built using **three operational amplifiers**. We simulate this circuit in eSim.The core working principle is based on a **differential amplifier**, which amplifies the **difference between two input signals** while rejecting anything common to both.

- Three Op-Amp Instrumentation Amplifier (IA) amplifier is preferred because it offers important characteristics:
- **High Common-Mode Rejection Ratio (CMRR)** – it rejects noise and interference.
- **High input impedance** – it does not load or disturb the sensor.
- **Low output impedance** – it can easily drive the next stage of a circuit.
- Because of these properties, instrumentation amplifiers are widely used in **temperature measurement, humidity sensing, biomedical instruments, and precision sensor applications**, where small and sensitive signals must be measured cleanly.

- **Gain:**



As shown in image,

- Current passing through $\mathbf{I_G = (V_2-V_1) / R_G}$ ⟶ [1]
- Current in inverting terminal for both op-amps **I=0**
- So current passing between V_{01} to V_{02} is also $\mathbf{I_G = (V_{02} - V_{01}) / (2R_3 + R_G)}$ ⟶ [2]
- So from the Equation 1 & 2,

$$V_{02} - V_{01} = (2R_3 + R_G) \cdot (V_2-V_1) / R_G$$

- Final Output $V_O = (R_2/R_1) \cdot (V_{02} - V_{01})$
- Final Output $\mathbf{V_O = (R_2/R_1) \cdot (2R_3 + R_G) \cdot [(V_2-V_1) / R_G]}$
- Gain $\mathbf{V_O/(V_2-V_1) = (R_2/R_1) \cdot (2R_3 + R_G) / R_G}$

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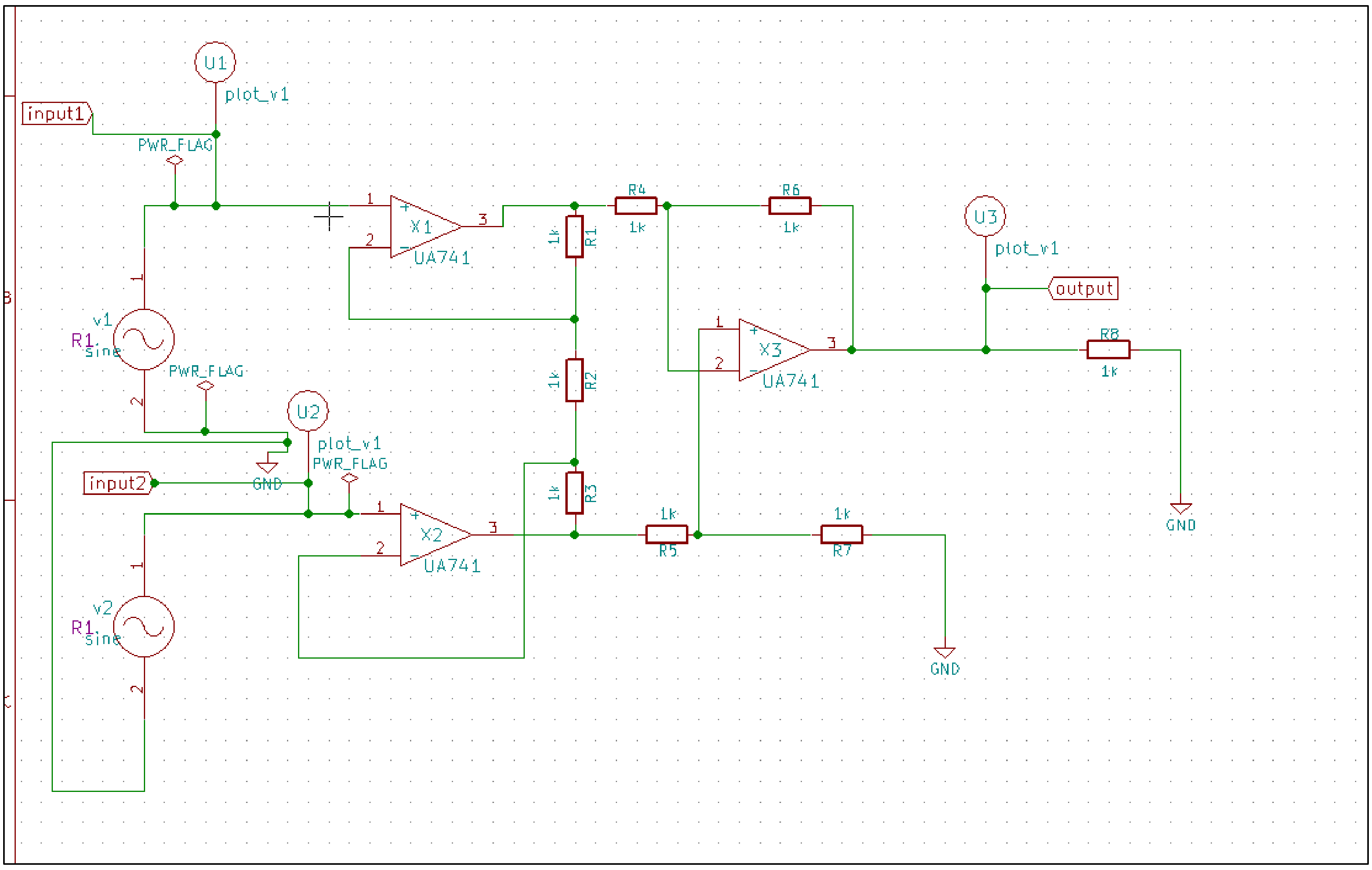
- **Schematic Diagram & It's explaination & Result:**



- Upper input source → V_1
- Lower input source → V_2
- Upper op-amp output → V_{O1}
- Lower op-amp output → V_{O2}
- Last (right side) op-amp output → V_{out}

- Transient Parameters:

  - All the resistors used in the circuit have a value = 1kΩ.
  - The input (voltage signal) V_1 is set at 10mV at 100Hz.
  - The input (voltage signal) V_2 is set at 20mV at 100Hz.
  - The output signal is observed across the load R8 (1kΩ).
  - The output (voltage signal) V0 is given by the,

$$\mathbf{V_O = (R_2/R_1) \cdot (2R_3 + R_G) \cdot ((V_2 - V_1) / R_G)}$$

So $(R_2/R_1) \cdot (2R_3 + R_G) / R_G = \mathbf{3}$

$$\boxed{V_{\text{out}} = 3(V_2 - V_1)}$$

$$\boxed{V_{\text{out}} = 3 \times (20\ \text{mV} - 10\ \text{mV}) = 30\ \text{mV}.}$$

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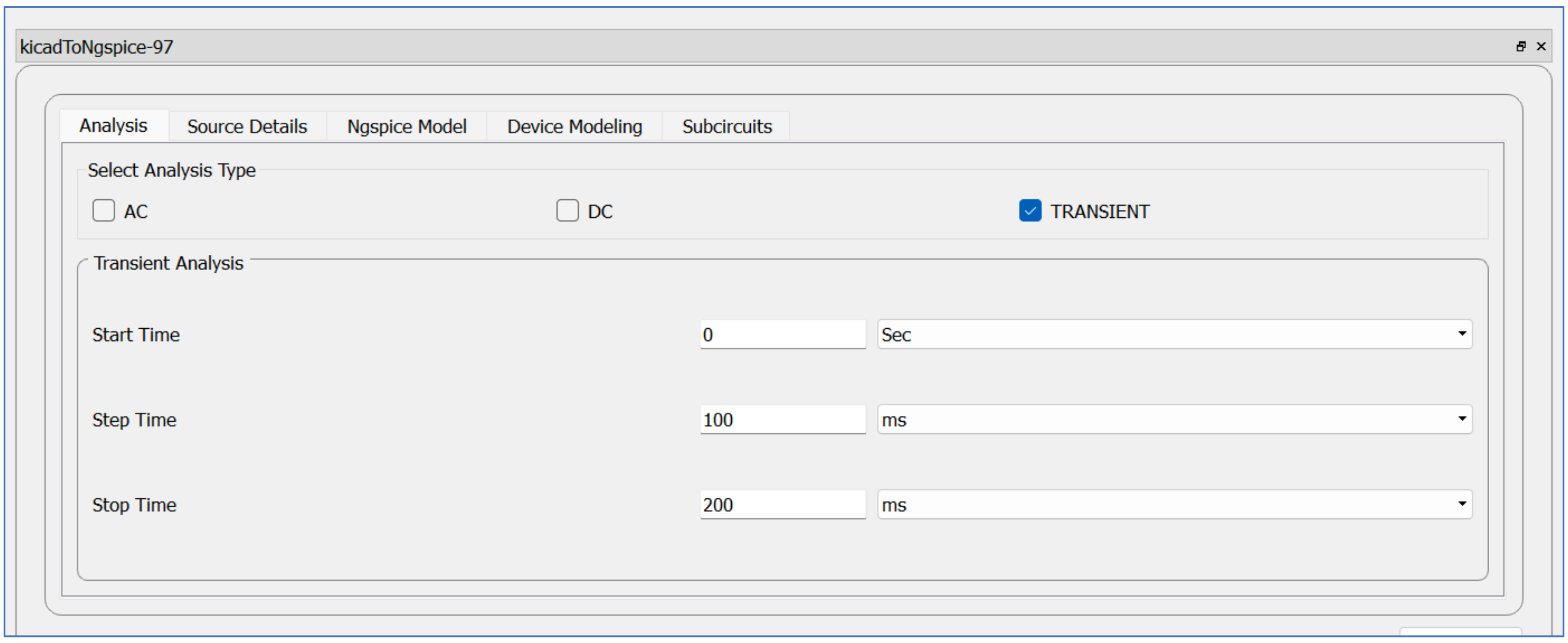
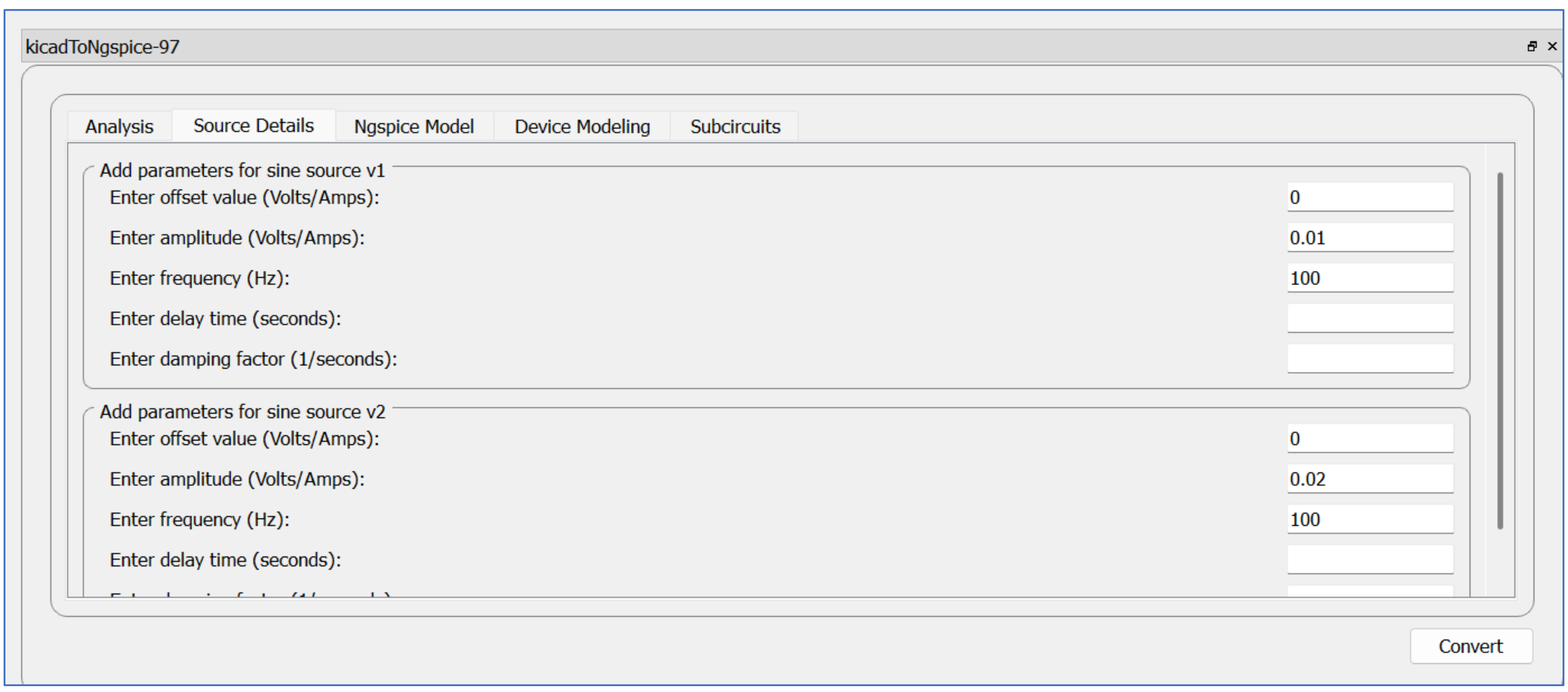
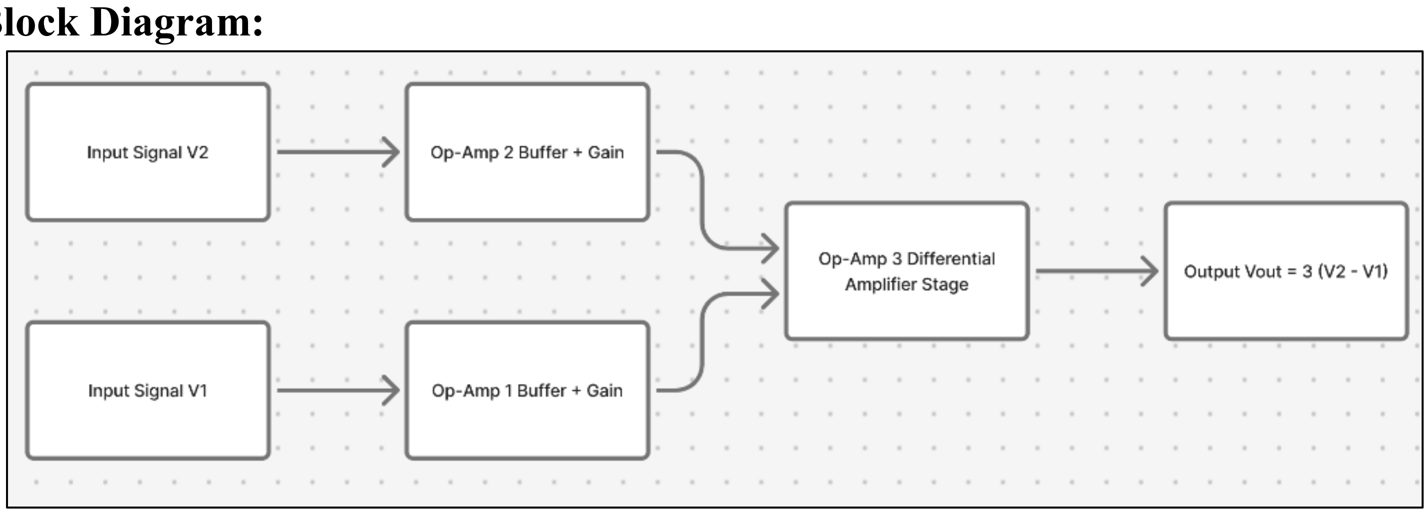
- **Source details & Analysis:**





- **Block Diagram:**



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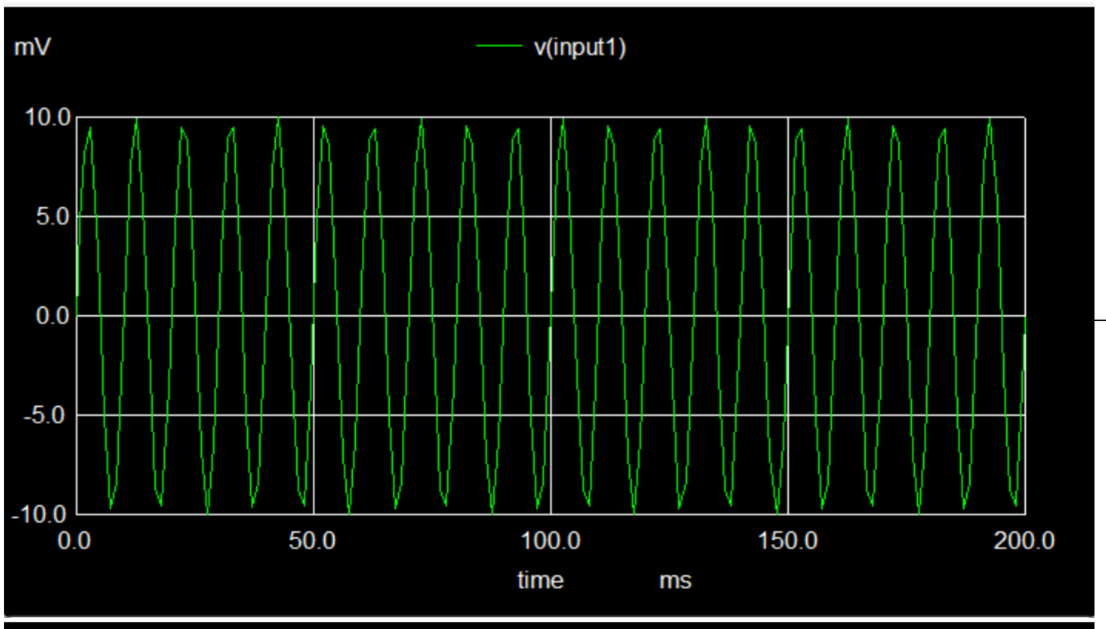
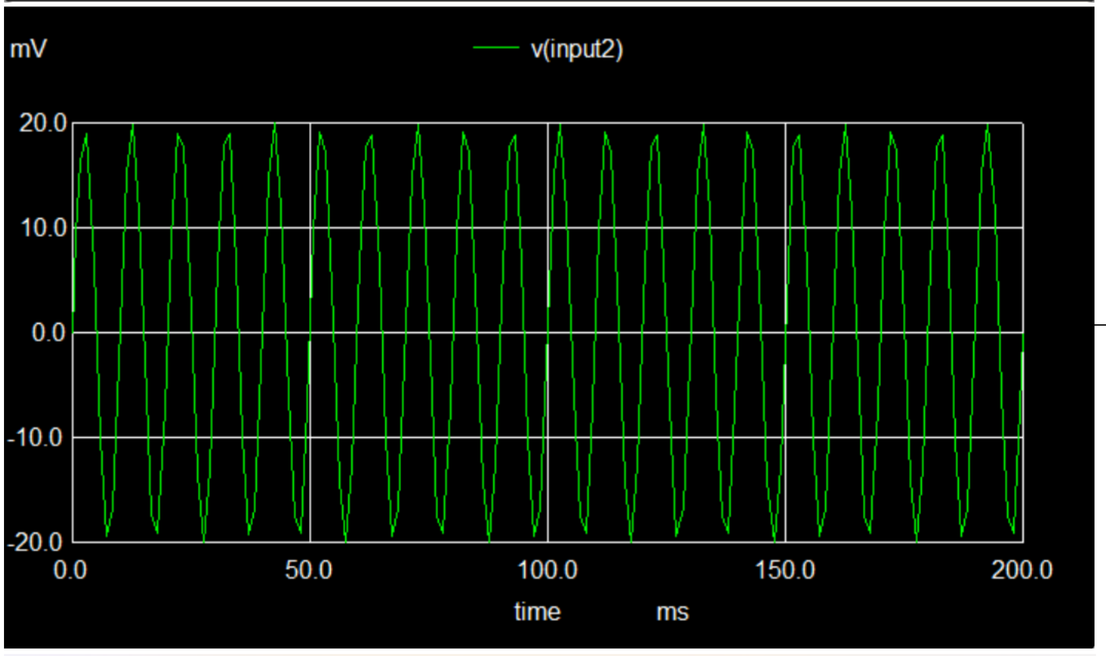
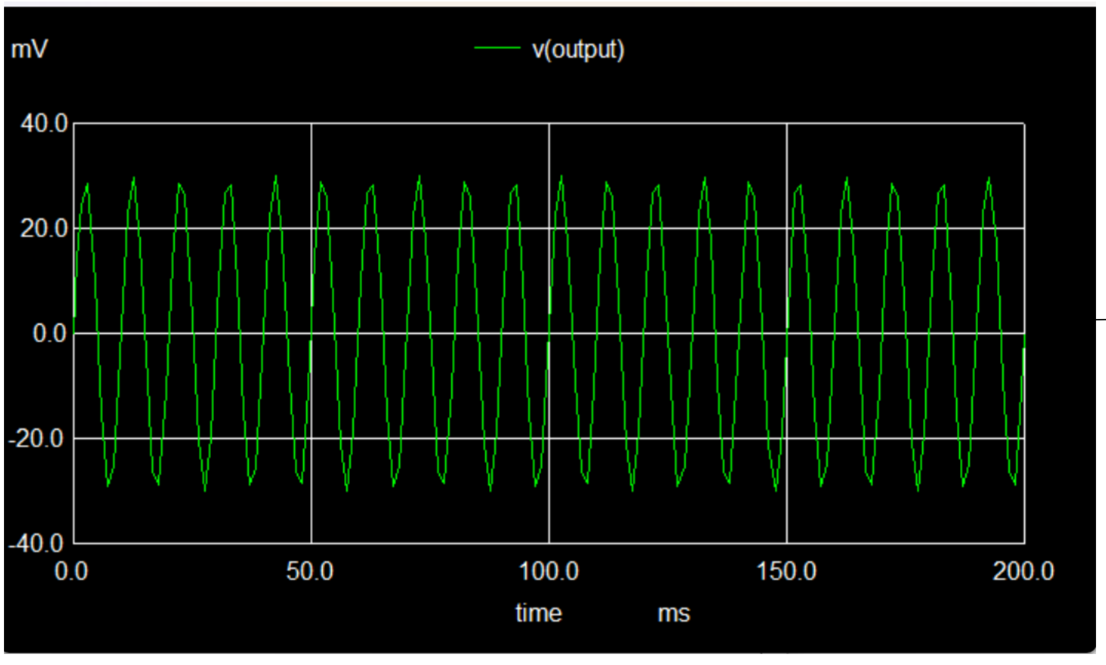
- **Result:**



[Fig-3 input-1 10mv at 100Hz]



[Fig-4 input-2 20mv at 100Hz]



[Fig-5 output 30mv at 100Hz]

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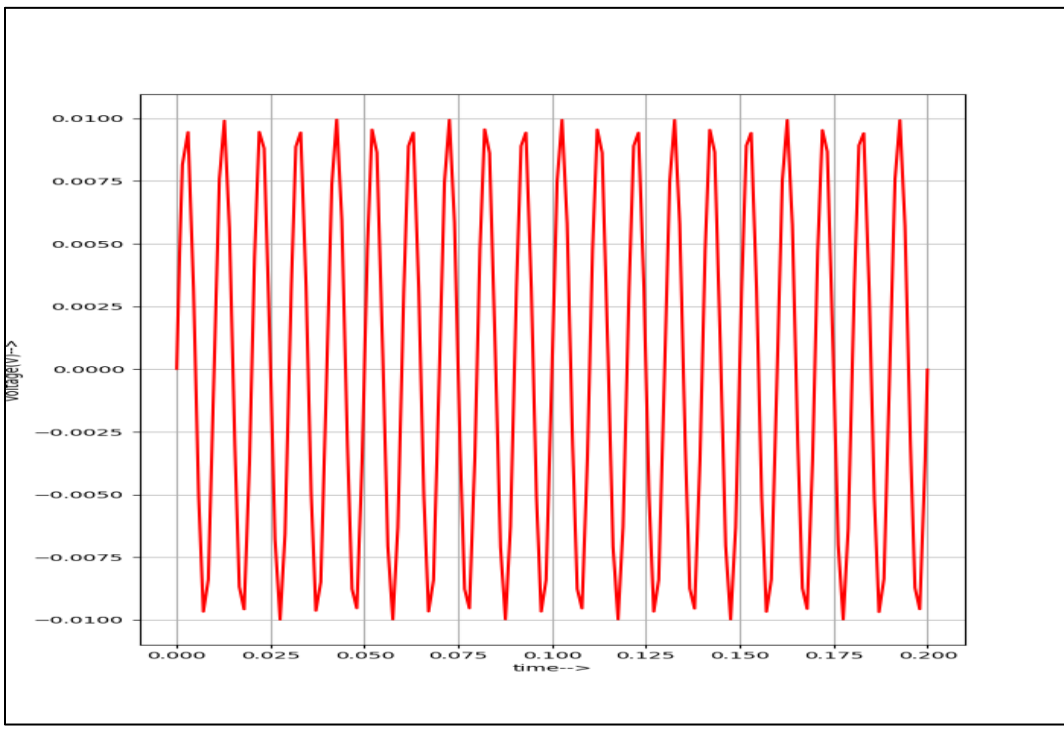
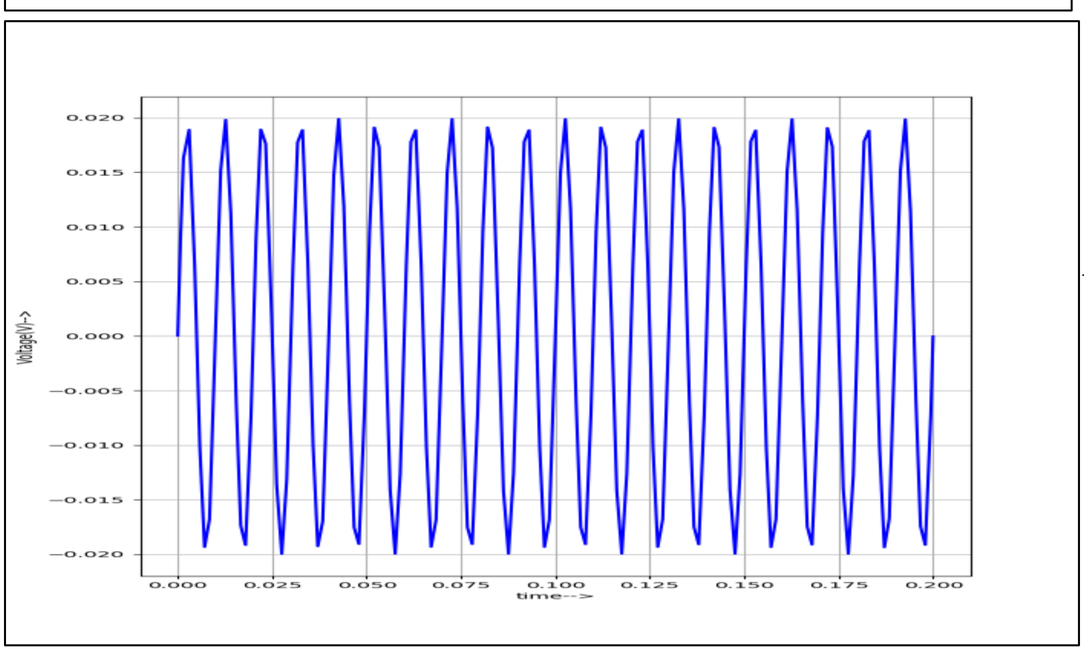
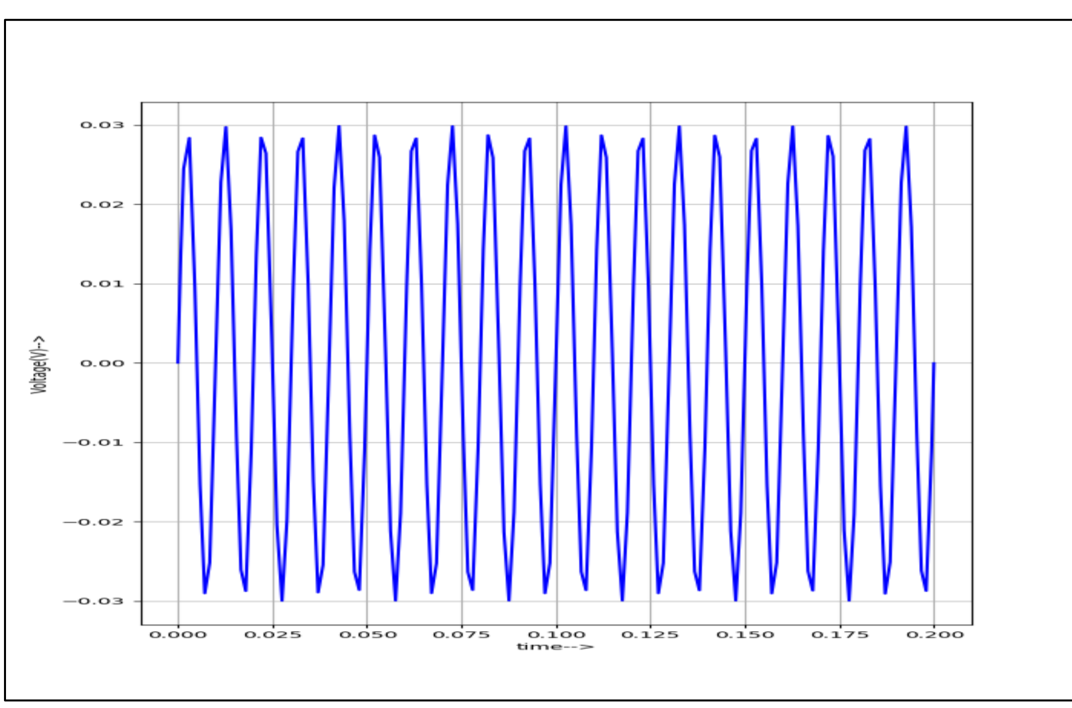
- **Python plot:**



[Fig-6 input-1 10mv at 100Hz]



[Fig-7 input-2 20mv at 100Hz]



[Fig-8 output 30mv at 100Hz]

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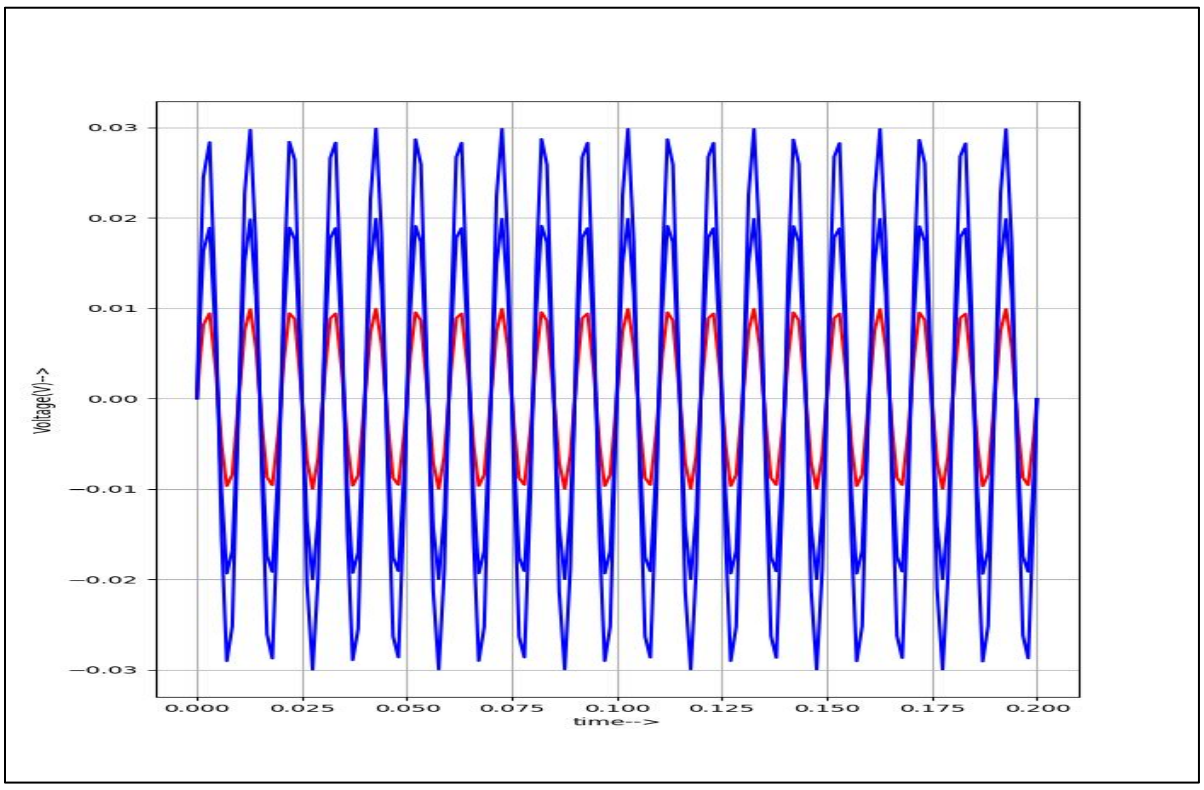

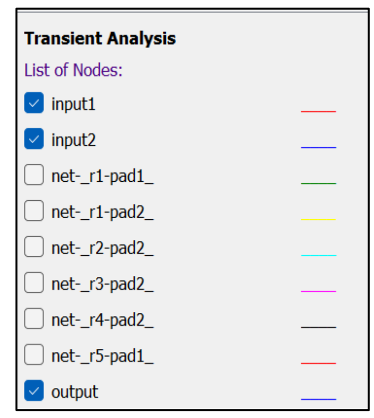

- The **input difference** is **10 mV(because 20 mV − 10 mV)**, and the overall gain of the three-op-amp system is **3**. So when this gain is applied to the 10 mV difference, the **final output** becomes **30 mV**, matching the practical value.

- **Conclusion:**
- The three-op-amp instrumentation amplifier was successfully designed and simulated. The circuit accurately amplified the differential input while rejecting common-mode noise, and the final output matched the theoretical gain expression.

[Reference]

- R. D. White, "Phase Compensation of the Three Op-Amp Instrumentation Amplifier," IEEE Transactions on Instrumentation and Measurement, 1987.
- **Direct PDF Link (Accessible):**
- https://www.researchgate.net/profile/David-White-74/publication/258422382_Phase_Compensation_of_the_Three-Op-Amp-Instrumentation-Amplifier/links/5524eecd0cf22e181e73b30c/Phase-Compensation-of-the-Three-Op-Amp-Instrumentation-Amplifier.pdf
- [Note: This paper is originally published in IEEE Transactions (IEEE Journal), but the free-access version is available via ResearchGate.
- Link for esim- **https://esim.fossee.in/**