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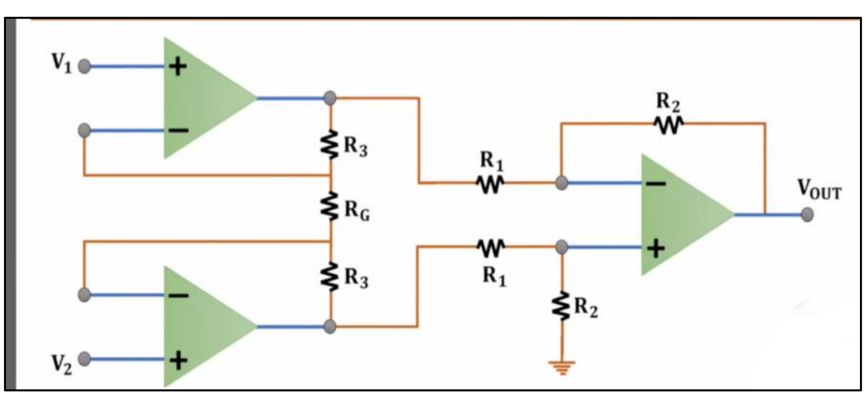
Project – Three Op-Amp Instrumentation Amplifier (IA) Design & Simulation

Abstract

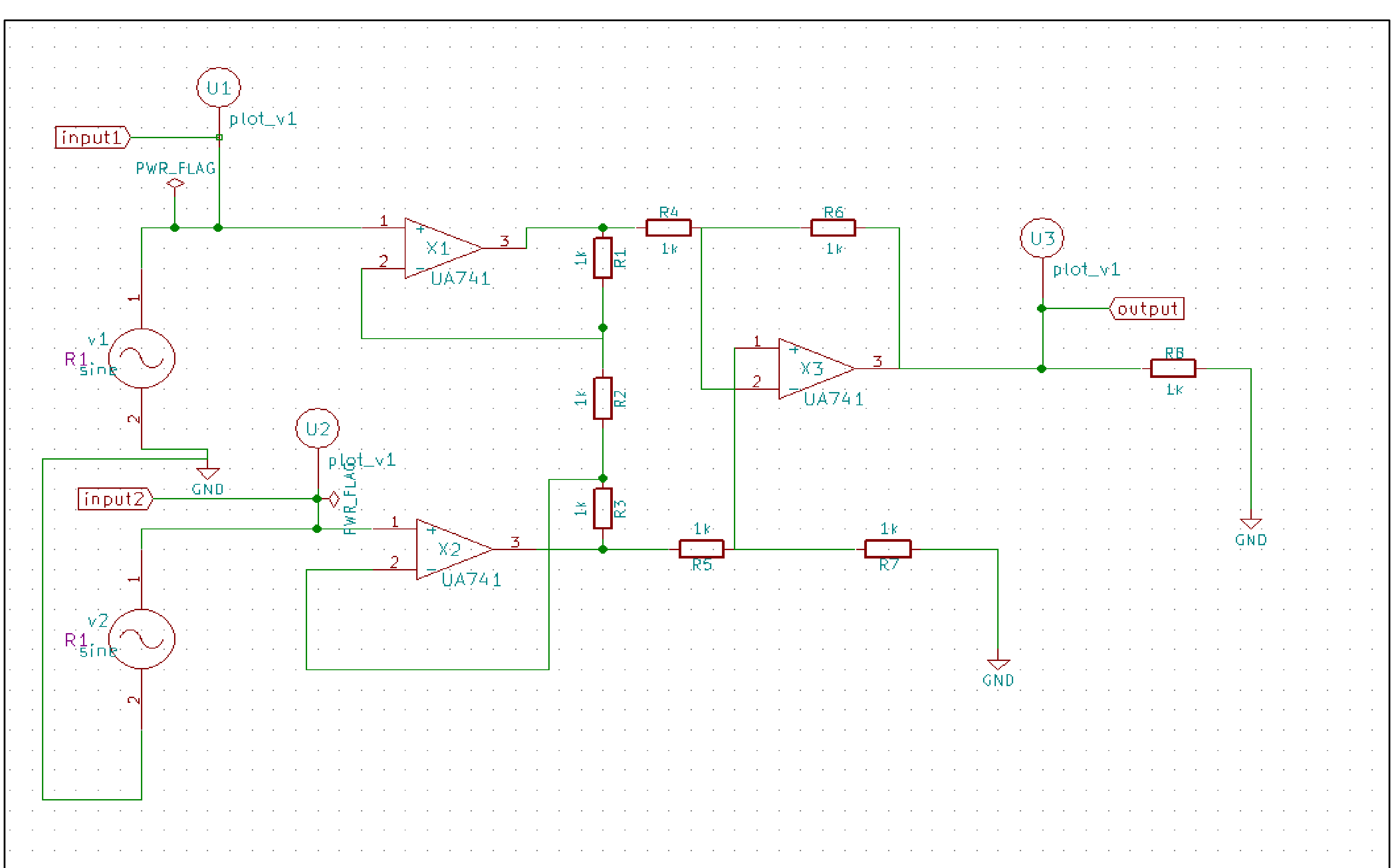
- **Theory:**
  - An **Instrumentation Amplifier (IA)** is an electronic circuit designed to **amplify very small signals accurately**. It is called an “instrumentation” amplifier because it behaves like an **instrument that amplifies** tiny input signals and converts **low-level signals into high-level 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.

- **Schematic Diagram:**

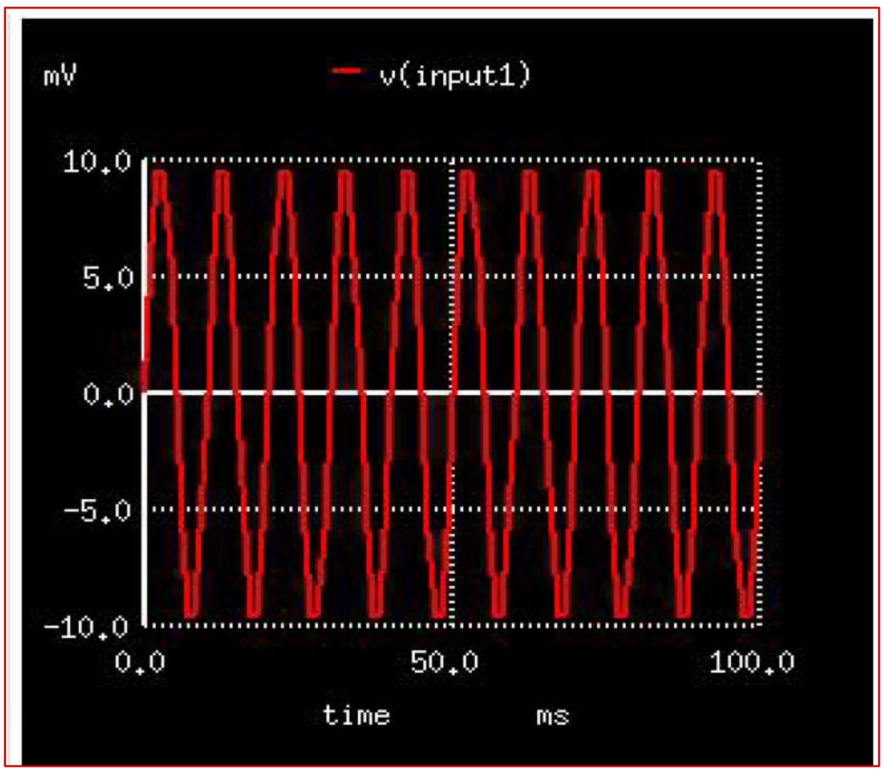


[Fig-1 schematic diagram of 3opamp IA]

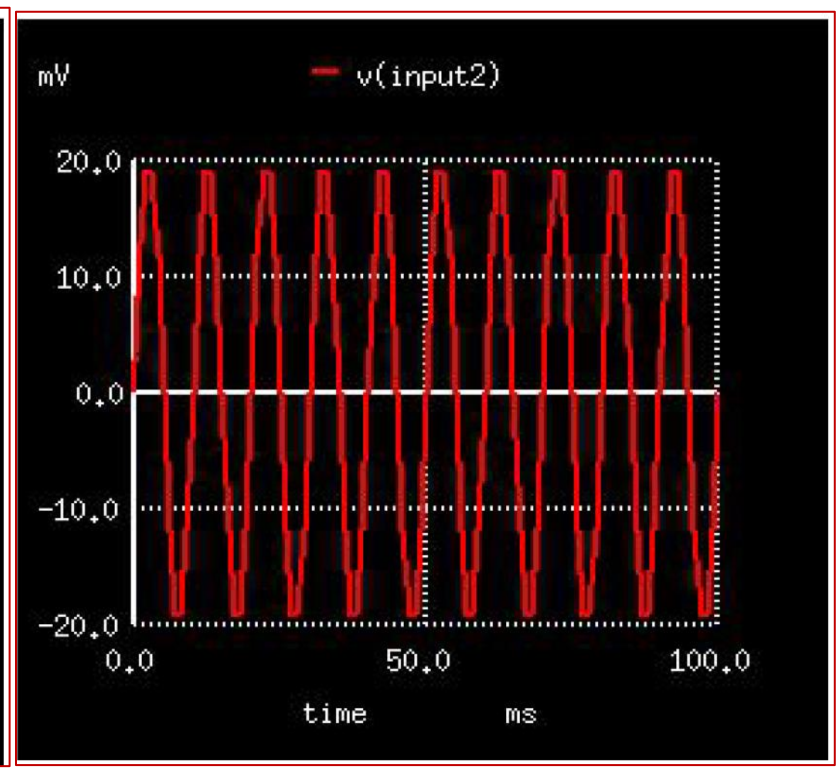


[Fig:2 Circuit Designed in esim]

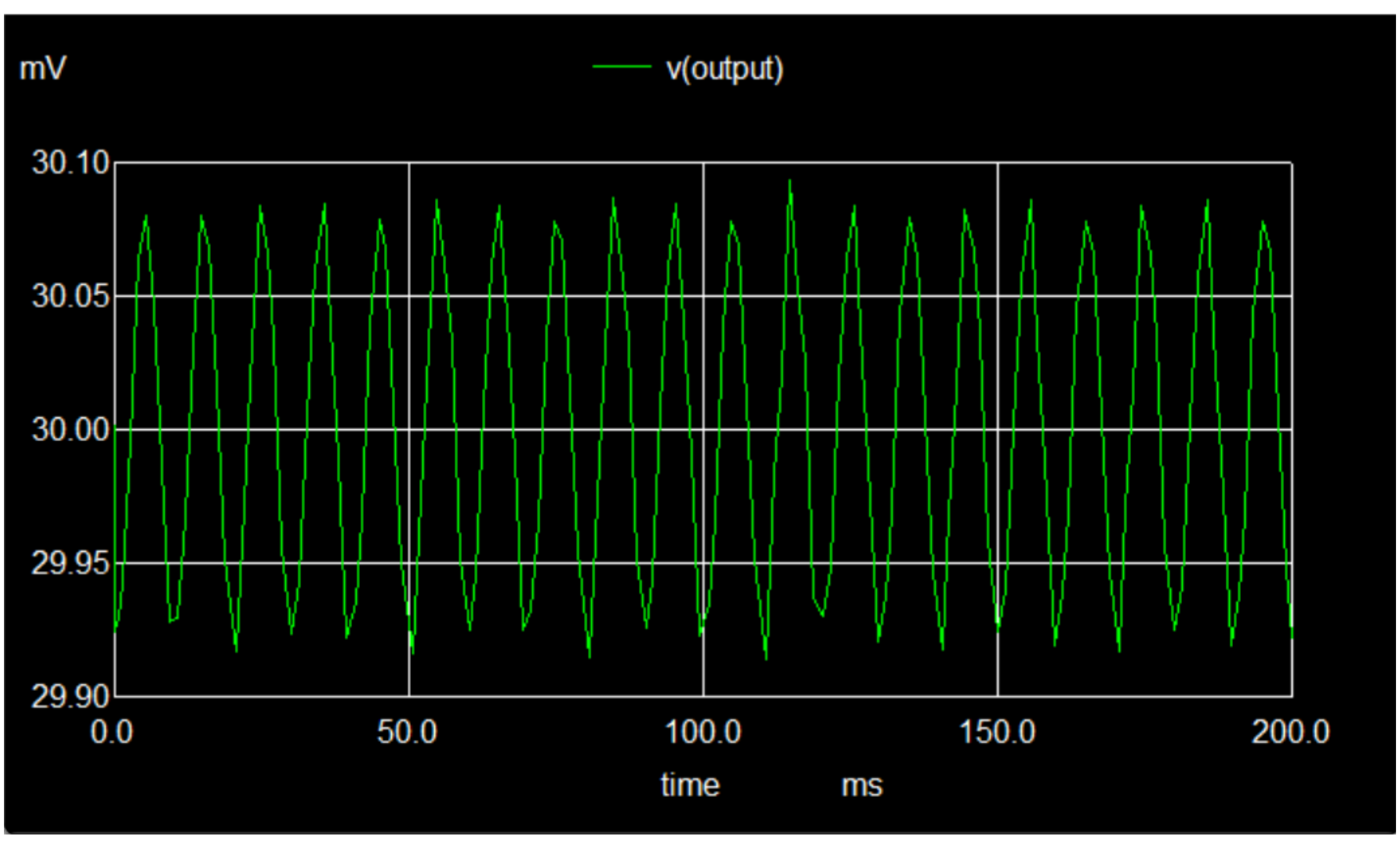
- **Output:**



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

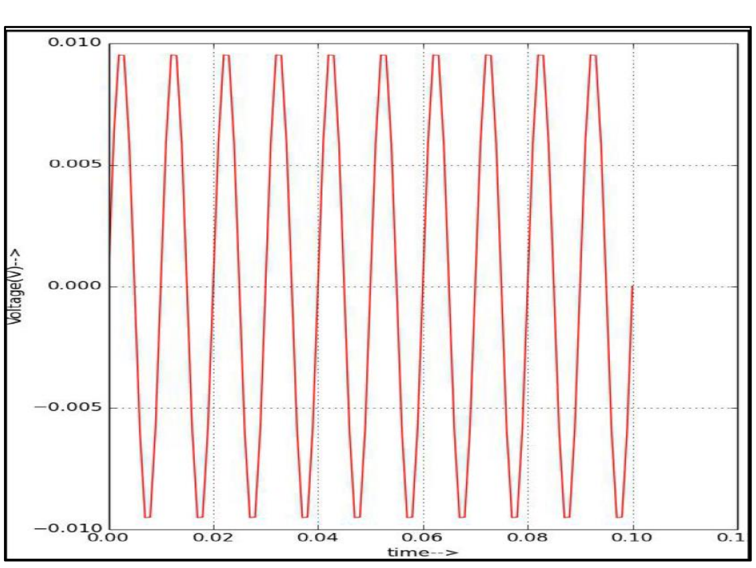


[Fig-4 input-2 20mv at 100Hz]

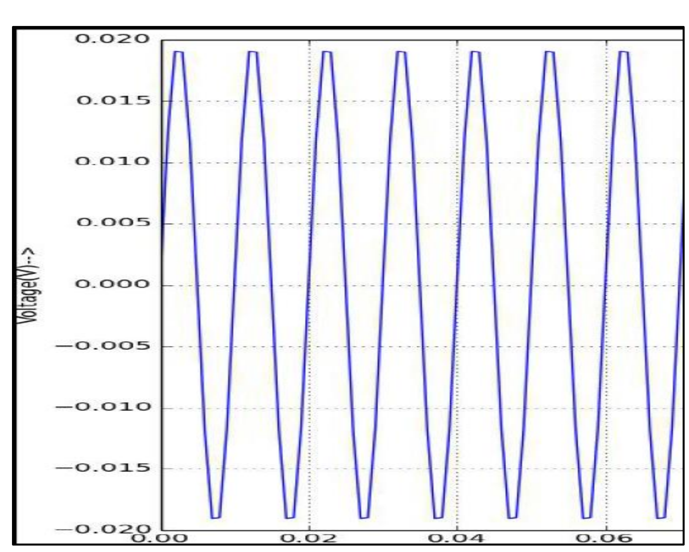


[Fig-5 Output]

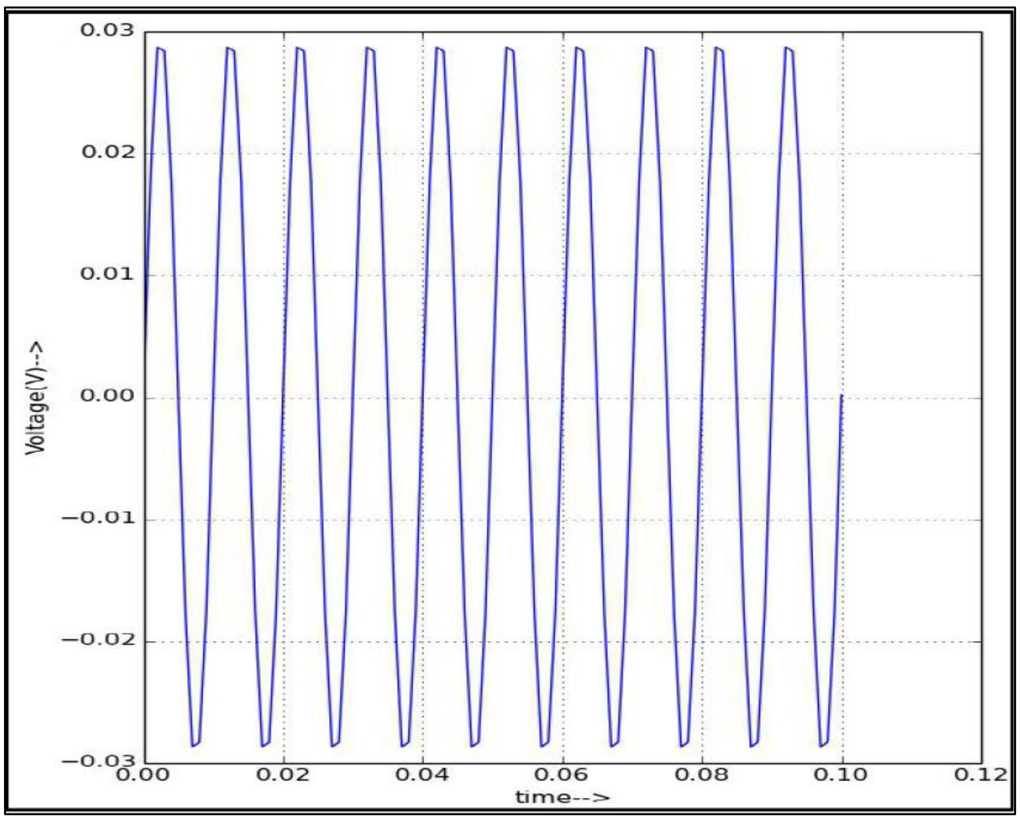
- **Python plot:**



[Fig-6-input1 plot(10mv at 100Hz)]



[Fig-7-input2 plot(20mv at 100Hz)]



[Fig-8 Output]

- **Formula of Gain:**

$$V_{\text{out}} = \left(1 + \frac{2R_1}{R_G}\right)\left(\frac{R_3}{R_2}\right)(V_2 - V_1)$$

- **Result:**
  - 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 successfully amplifies small differential signals while rejecting common-mode noise, making it ideal for precision measurements. Its high input impedance and adjustable gain allow accurate signal conditioning even for low-level sensor outputs. The simulation results confirm stable operation and a clear, noise-free amplified output waveform. Overall, this design proves to be reliable, efficient, and suitable for real-world instrumentation applications.

- **Keywords:**
  - Instrumentation Amplifier (IA), Op-Amp, Differential Amplifier, CMRR, Gain, eSIM, Signal

[Reference]:

- R. D. White, "Phase Compensation of the Three Op-Amp Instrumentation Amplifier," IEEE Transactions on Instrumentation and Measurement, 1987.
- **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.]
- Simulation reference : **https://esim.fossee.in/**