Circuit Simulation Project

https://esim.fossee.in/circuit-simulation-project

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Title of the circuit: Design and Simulation of a Programmable Transimpedance Amplifier Using eSim

Theory/Description: Transimpedance amplifiers (TIAs) are commonly used to convert low-level sensor currents, such as photodiode currents, into proportional voltage signals. In a TIA, the output voltage is related to the input current by the feedback resistance according to:

$$V_{out} = -I_{in} \times R_f$$

To accommodate a wide range of input currents, a programmable transimpedance amplifier is desirable. In such a design, the effective transimpedance gain is changed by selecting different feedback resistor–capacitor networks.

In the proposed design, a low-input-bias CMOS operational amplifier (AD8605) is configured as a transimpedance amplifier. Multiple feedback networks are provided, each corresponding to a different transimpedance gain. Only one feedback network is active at a time, ensuring stable closed-loop operation.

In the hardware implementation, feedback network selection is performed using a digitally controlled analog switch (ADG715). In the simulation environment, the switching function of the ADG715 is abstracted using ideal analog switches, allowing the analog behaviour of each programmable gain mode to be evaluated without simulating the digital control interface.

Circuit Diagram(s):

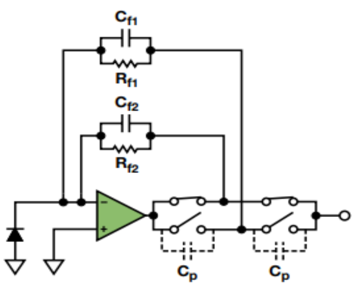

Figure 1

The photodiode is modelled as an ideal current source connected to the inverting input of the operational amplifier, in parallel with a small capacitance representing the photodiode junction capacitance. The non-inverting input of the op-amp is grounded, establishing a virtual ground at the summing node.

Two feedback paths are implemented, each consisting of a feedback resistor in parallel with a compensation capacitor. These feedback networks correspond to different transimpedance gain settings. Ideal voltage-controlled analog switches are used in the simulation to enable one feedback network at a time, emulating the behaviour of a programmable feedback selection mechanism.

In the actual hardware realization, these switches are replaced by an ADG715 digitally controlled analog switch, which allows software-based gain selection via an I²C interface. The simulation therefore focuses on validating the analog transimpedance behaviour and stability of each gain mode, rather than the digital control logic.

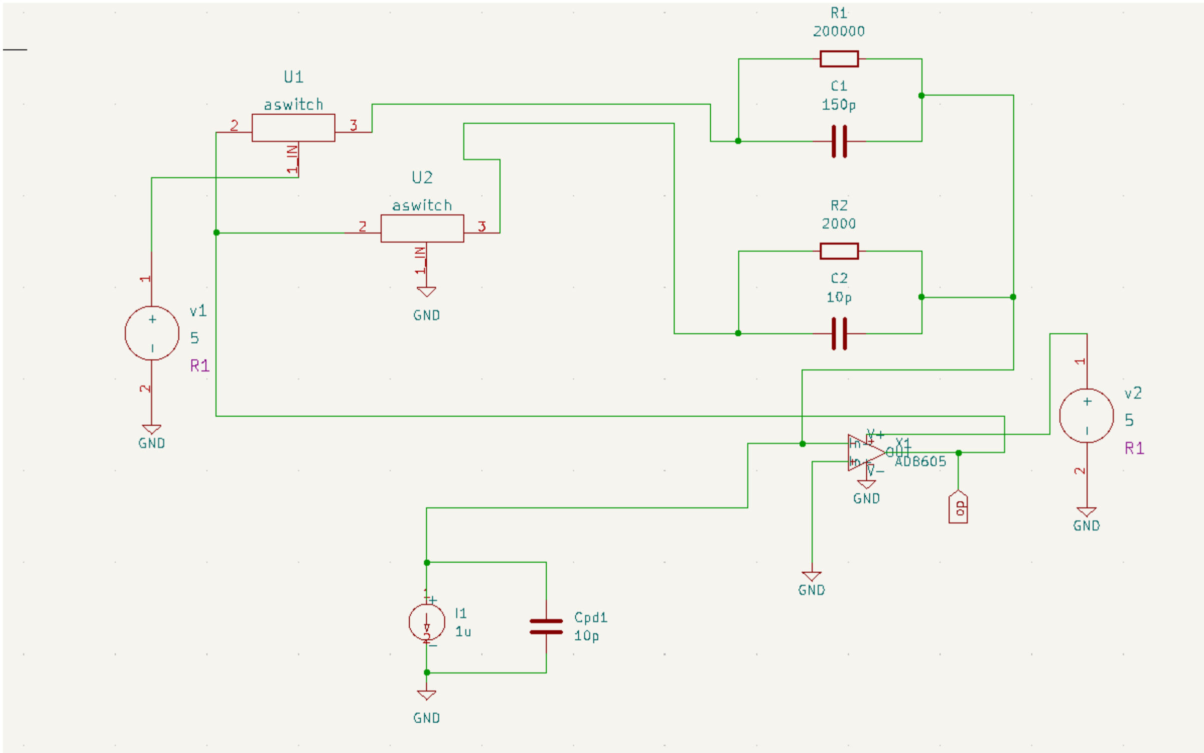

Figure 2

Results (Input, Output waveforms and/or Multimeter readings):

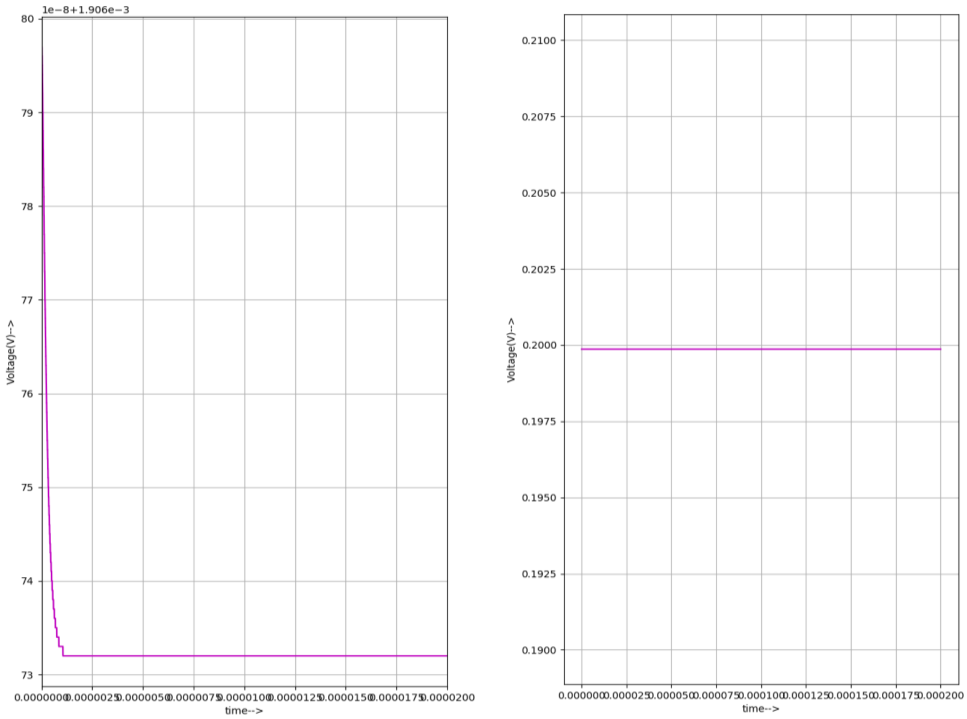

Figure 3

Transient analysis was carried out to evaluate the behaviour of the programmable transimpedance amplifier. Although the input current is DC, transient simulation is required due to the presence of capacitive elements in the feedback network, which prevent a unique DC operating point.

In the simulation, ideal analog switches are used to selectively enable one feedback network at a time. For a constant input current of 1 μA, the low-gain configuration (2 kΩ feedback) produces an output voltage of approximately 2 mV. When the high-gain feedback network (200 kΩ) is selected, the output voltage increases proportionally to approximately 0.2 V.

The steady-state output waveforms appear as flat lines, which is expected for a DC input current. The absence of oscillations confirms stable transimpedance operation. These results validate the programmable nature of the transimpedance gain and demonstrate correct current-to-voltage conversion.

Source/Reference(s):

1. L. Orozco, "Programmable-Gain Transimpedance Amplifiers Maximize Dynamic Range in Spectroscopy Systems," *Analog Dialogue*, vol. 47, no. 5, May 2013. [Online]. Available: Analog Devices.
2. Texas Instruments, "Transimpedance Considerations for High-Speed Amplifiers," Application Note SBOA122, Nov. 2009.
3. A. Romanova and V. Barzdenas, "A design methodology for programmable-gain low-noise TIA in CMOS," *Journal of Electrical Engineering*, vol. 72, no. 3, pp. 147-157, 2021.