Lab 6 TIA Design in Cadence

1 Introduction

Transimpedance amplifiers (TIA) are amplifiers that convert input currents into amplified output voltage signals. This type of amplifier has many applications. One of them is to convert photocurrent of a diode into an amplified voltage in an optical link. Optical links are widely used in optical communication and interconnections, which are essential for the development of the internet and data center applications.

In this lab, you will use Cadence to design and simulate a TIA and compare two designs: one based on simple RC circuit and one based on the OTA designed in Lab 5. By using ac simulation, you will be able to see how the optimized 5-OTA-based TIA outperform the one based on direct RC circuit. Also, your understand of bandwidth will be strengthened by using trans simulation.

Assume that in the optical link, the input light is amplitude modulated such that the generated photocurrent is either zero or $100\mu A$. Also assume that the diode has a parasitic capacitance of 100fF which is formed by the device capacitance and the interconnections in between the photodiode and the circuit.

2 Direct current-to-voltage conversion

Suppose that we need to amplify this photocurrent to generate the peak voltage of 1V at the output. The simplest approach is to connect a resistor R_F to the output of photodiode, as shown in fig.1.

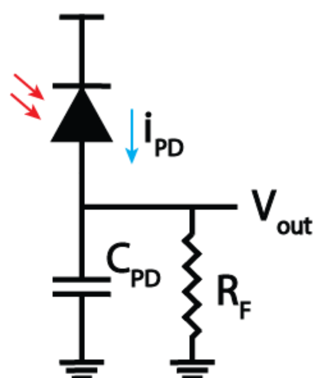


Fig.1 Direct I-V conversion using a resistor

Before we dive into Cadence experiment, do some simple hand calculation to answer the following questions. Note: you need to include this in the report.

- What would be the value of R_F?
- What is the bandwidth of this circuit? What is the rise time?

Now, let us test this structure in Cadence! Do the following simulations:

- Measure the rise/fall time by applying a pulsed current source (functioning as the diode current) with to simulate 10Mb/s (what frequency does this entail?) and running trans sims. Do the same at the appropriate frequency to simulate a bit rate of 2 Gb/s. Does the rise time change when you change the bit rate?

- Do an AC simulation to determine the bandwidth of the circuit, again using a current source to replace the photodiode)
- Now we want to simulate the random nature of the bit stream. Use a pseudo-random bit source from “analogLib” and cell “vprbs” to generate a random binary sequence and use a voltage-controlled current source (“analogLib”-> “vccs”) to mimic the photocurrent. Set the *One value* in “vprbs” as 1 and *Transconductance* of “vccs” as *100u*. You also need to set the Bit period in vprbs correctly (according to 2Gb/s). The schematic in cadence is shown in Fig.2. Note that the bits from the pseudo-random bit source may not appear “random” at first – this may not happen until ~30 cycles in. Run a transient simulation and show a section where the bits appear random (no obvious pattern). Look at the rise times here – do they match the rise time you calculated earlier?

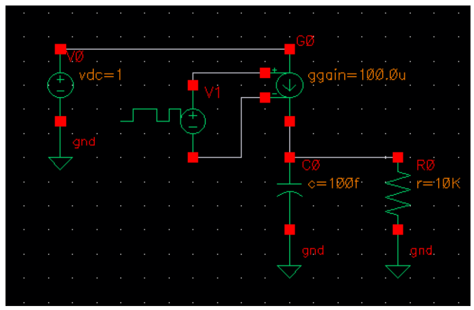


Fig.2 Direct RC design schematic with prbs source

3 Design a TIA based on 5-OTA amplifier

Now to increase the bandwidth we will use a feedback TIA using 5T-OTA from Lab 5. Set C_L to 10fF which will be the loading from the next circuit stages.

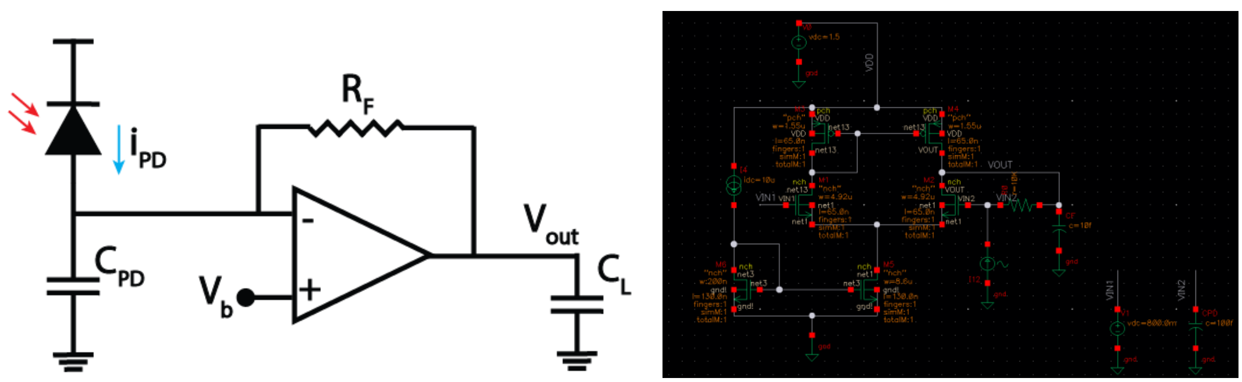
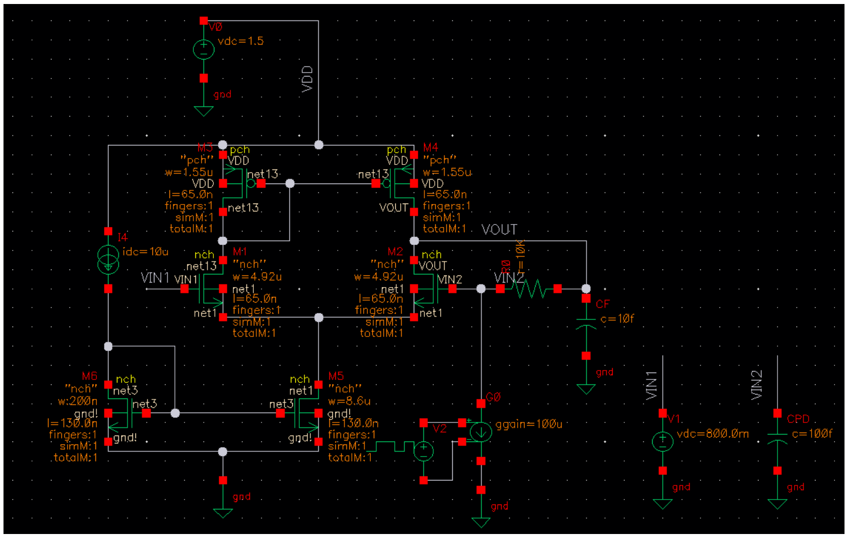


Fig 3. Schematic of 5-OTA-based TIA

Do the ac and trans simulation and answer the following questions:

- What is the gain V_{out}/i_{PD}?
- What are the unity gain bandwidth and 3-db bandwidth, respectively?
- Explain how the dominant pole is changed in this feedback topology compared with previous circuit from Section 2. How does the amplifier’s original pole (which should be around 500MHz) change in this topology?

- Use the “vprbs” and “vccs” with 2Gb/s data rate to apply an input to the circuit, and perform trans simulation. Compare the result with that from section 2. As shown below.
- Measure the bandwidth with an AC simulation like the one you did for the RC circuit.



4 Deliverable

Direct RC design

- Show calculations for R_f and 3-dB bandwidth, the ac simulation plot showing the 3-dB bandwidth. Also show the settings you applied on your current source to achieve this. Do the calculations match with the simulation? If not, why?
- Show calculations for the rise time and screenshots of how you verified this in Cadence.
- Using PRBS and voltage controlled current source, show the trans sim plot with 2Gb/s data rate.

5-OTA based design

- Show screenshot of 5-OTA based TIA schematic.
- Show plot of ac magnitude and determine the gain, unity gain bandwidth and 3-db bandwidth.
- Answer the questions about the poles.
- Using PRBS and voltage controlled current source, show the trans sim plot with 2Gb/s data rate. Compare the result with what you get from direct RC design.