A Project on Current Sense Amplifier With a Sense Margin Of 50mA using Cadence

Submitted for requirements for the practical coursework

of

M Tech (VDN)

by

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I hereby certify that the work which is being presented in the report entitled **A Project on Current Sense Amplifier With a Sense Margin Of 50mA** submitted for requirements of the practical coursework of **M Tech (VDN)** and submitted in the Discipline of Electrical Engineering**, Indian Institute of Technology Indore**, is an authentic record of my work carried out during the time period from Aug2023 to Nov 2023 under the supervision of Dr. Santosh Kumar Vishwakarma. The matter presented in this report has been cited properly wherever necessary.

(Shivam Vaish)

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

(Dr. Santosh Kumar Vishvakarma)

ACKNOWLEDGEMENTS

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SYNOPSIS

A current-sense amplifier is an amplifier that measures current by measuring the voltage drop across a resistor placed in the current path. The current sense amp outputs either a voltage or a current that is proportional to the current through the measured path.

This project includes making schematic and layout of current sense amplifier and comparing different designs by changing value of (W/L) ratio of Pmos with respect to Nmos. Model library SCL 180nm has been used to make schematic and layout. Pmos18 and Nmos18 have been used from model library to design. Analog library has been used for voltage source and ground.

Further, verification of the schematic and layout has been carried out to verify the functionality of the current sense amplifier.

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1.INTRODUNCTION

Current Sense Amplifiers are special-purpose amplifiers that output a voltage that is proportional to the current flowing in the power rail. Current sense amplifiers are also called **current shunt amplifiers** because it uses a shunt resistor in the power rail that provides a small voltage drop when current flows through the resistor. This voltage drop is converted and amplified by the current sense amplifier into the small output voltage.

These amplifiers are designed for the special purpose, so that the amplifier could amplify a very small amount of sensed voltage across the shunt resistor, typically in 10 to 100 mV range. Current Sense amplifiers are made for **DC precision** (For example, low input offset voltage) and high common-mode rejection ratio (CMRR). Current sense amplifiers can measure the current flowing in a single direction or it can measure current flow in both directions through the **sense resistor**. In such a case, if the amplifier is capable to detect current flow in both directions, it is called **bidirectional current sense amplifiers**

2. Current Sense Amplifier– THEORY

2.1Difference between Current Sense Amplifier and Normal Amplifier

Normal amplifiers could not amplify a very small amount of voltage and have **low CMRR**. On the other hand, precision current-sense amplifiers could detect and amplify a very small amount of voltages as well as the CMRR is relatively high.

For the normal differential amplifiers or standard operational amplifiers, the power source is connected between two power supply rails (Vcc and Vee) and the amplifiers can only operate on the signals that lie behind the power rails or have common ground paths. An outside voltage of the used power rail could trigger the internal ESD protection diodes if an external voltage is applied into the input pin of the standard amplifier and could cause a large current to flow.

But, current sense amplifiers are designed in a way that despite the low-voltage power rail (such as Vcc = 3.3 V and V = 0V), the amplifier **can withstand a much higher pin voltage** than the supplied Vcc. The amplifiers use an excellent **power path protocol** for its operation. Whenever the input voltage is lower than the VCC, the amplifier changes its input supply and gets powered from the input voltages.

2.2Main Types of Current Sense Amplifiers

- **High-side Amplifiers**
  The current is measured between the supply rail and the load. The DC voltage applied on the input pins can be much higher than the power supply.
- 1) **Advantages**
  The high side current measurement has two benefits over the low side current measurement. Second, it serves as an interference for any short circuit with the field. In

order to detect short circuit in the power circuit, a shunt resistor is mounted at the neutral stage.

Secondly, this circuit measures voltages accurately to ensure the exact burden load present.

2) Disadvantages

However, since the small voltage that is produced across the current shunt resistor is below the load supply voltage, the high side current measuring technique requires high common-mode rejection.

- **Low-side Amplifiers**

  The current is measured between the load and the ground. The voltage applied on the input pins is close to the ground.

- 1) Advantages

  Low side current measurements are a convenient way to measure low level voltage. In this setup, an integral circuit can be used because of the slight voltage drop around the shunt resistor. Because of low threshold voltage, common-mode rejection is useless.

  2) Disadvantages

  One of the main problems of using the low side current calculation is that the measurement is reversible. In this way, this occurs because of series positioning of shunt resistor in the ground plane. Since the ground reference is broken, the whole thing will not work well.

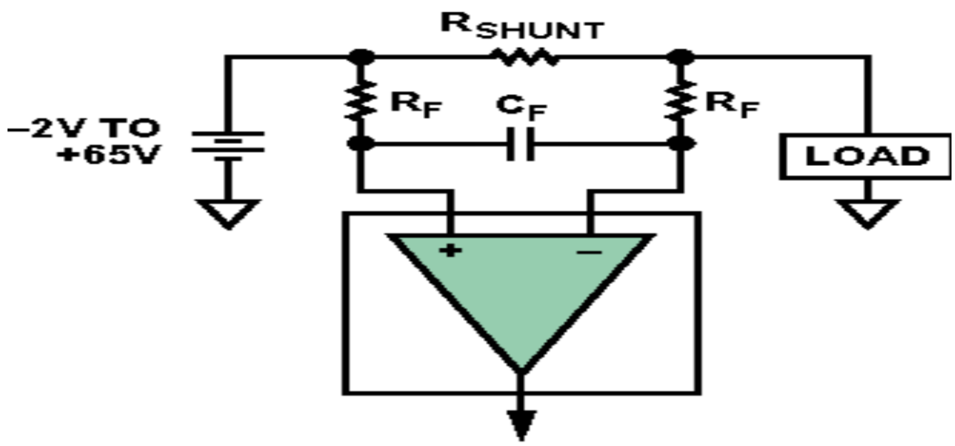

Fig1: Current sense amplifier

2.3Common Mode Voltage and CMRR

Common mode voltage is an important parameter for both normal amplifiers and current sense amplifiers. The common-mode voltage is the average voltage which is applied across the two inputs of the amplifier. This Voltage is so much important because the op-amp has limited capabilities to differentiate and produce output based on the common-mode voltage. A normal op-amp supports a small range of common-mode voltage that is not suitable for the precision level current sensing operations. But in the case of current sense amplifiers, the common-mode voltage ranges much wider than the actual supply voltage of the amplifier.

On the other hand, CMRR, the common-mode rejection ratio (CMRR) is the ratio of differential gain, and the common-mode gain. In the case of an ideal op-amp, the CMRR is infinite, but in practical circuits, it ranges typically 80 to 100 dB. The high CMRR denotes how much of the common-mode signal will reflect on the measurement. Thus, for a current sense amplifier, it is an important parameter as it will reflect the very low common-mode signal across the output, thus creating the possibilities to open up a wide range of current sensing capabilities. Current sense amplifiers have high CMRR and it could sense small common-mode signals. CMRR is also responsible for reducing noise on the current sense lines.

3. Cadence-Schematic

3.1 Schematic: Current sense amplifier

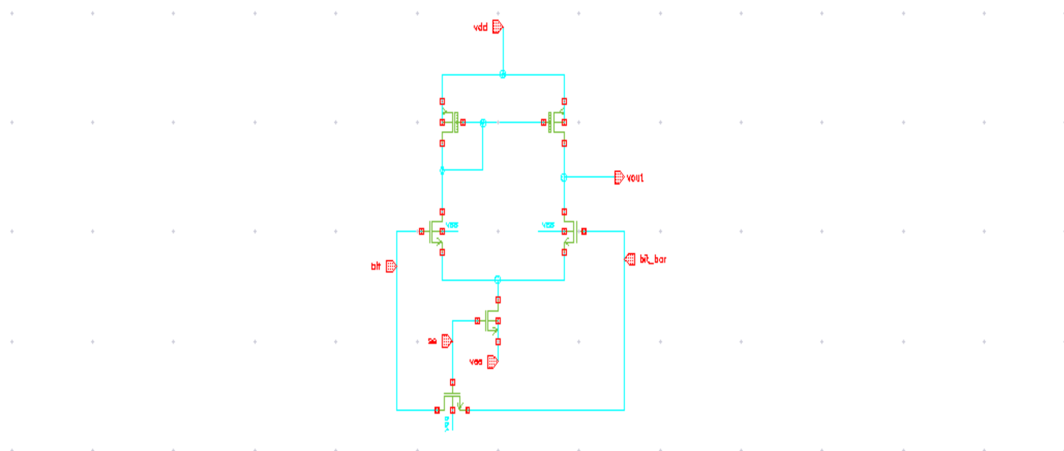

Fig2: schematic of current sense amplifier

	W/L
Standard (W/L)	2.33
Used (W/L)	5.55

Table 1: Standard and used W/L

3.2 Schematic: Test Bench of current sense amplifier

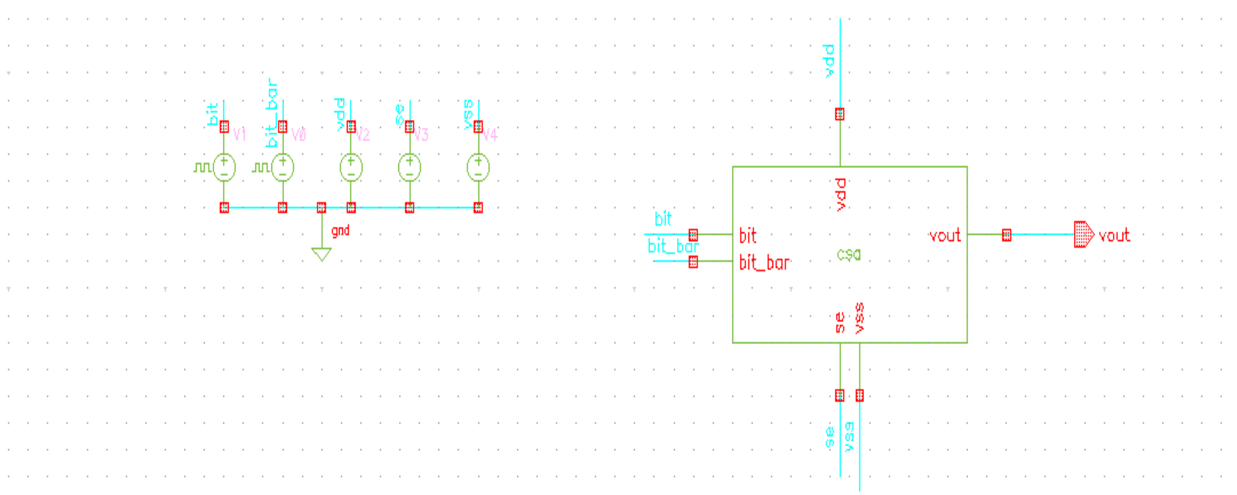

Fig3: Test Bench of current sense amplifier

3.3 ADE L window

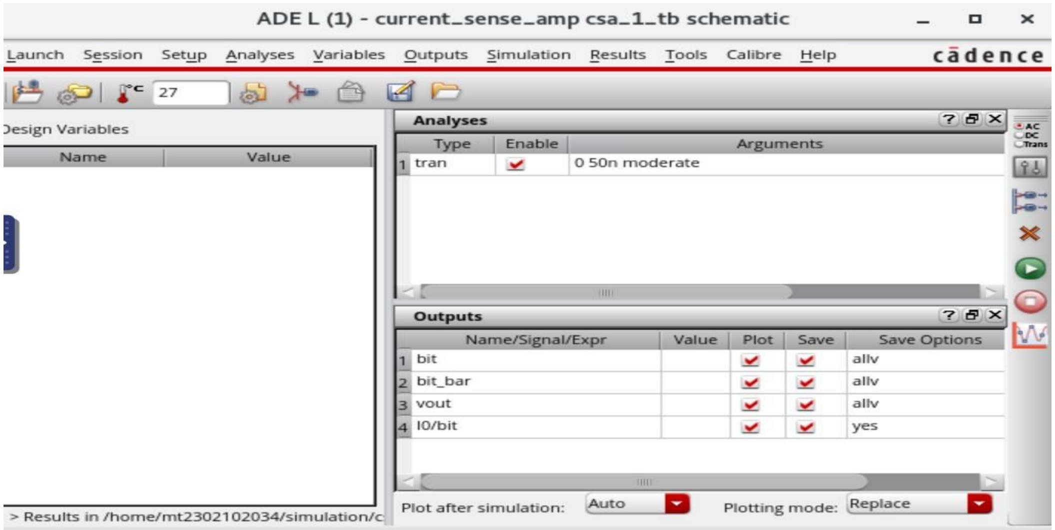

Fig4: ADE L window

<u>3.4 Transient analysis waveform</u>

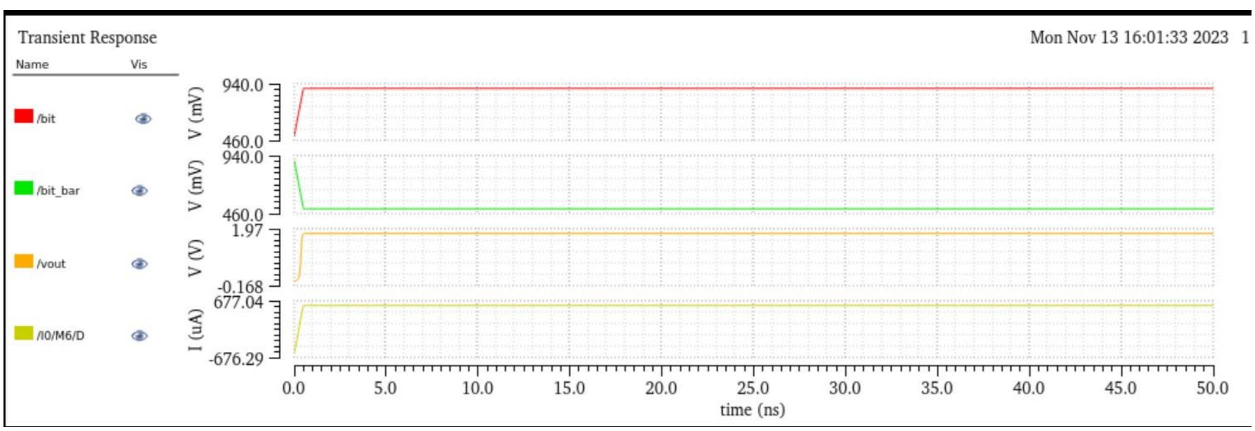

Fig5: Transient analysis waveform

Result: In above waveform we are able to detect small value of current (0.56mA) and amplified output voltage (1.79V)

4. Cadence-layout

4.1 Layout: current sense amplifier

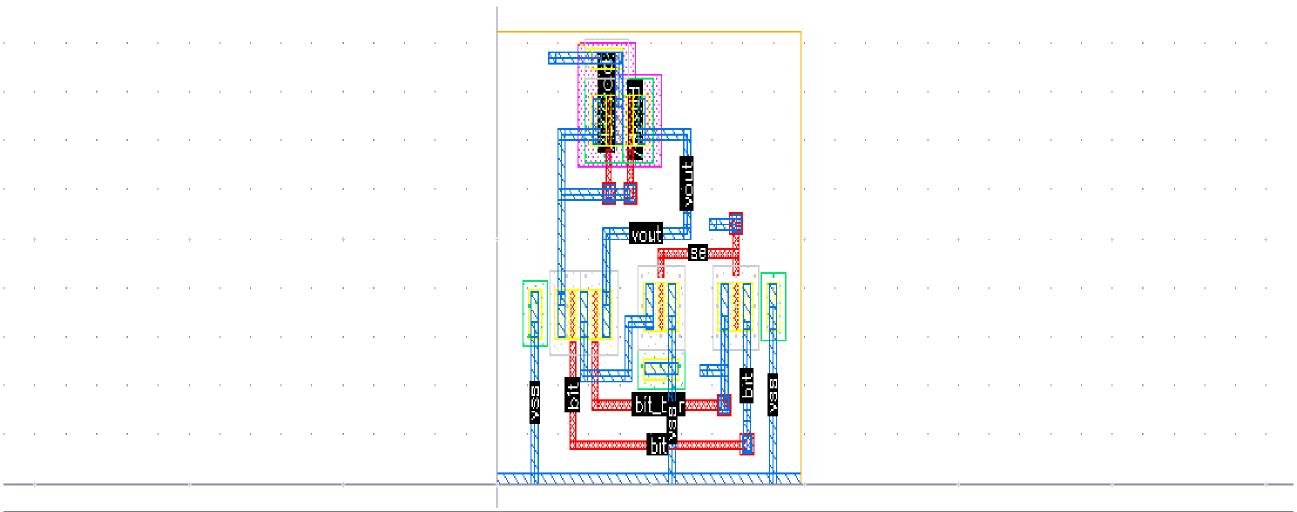

Fig6: Layout of current sense amplifier

4.2 Design Verification

4.2(a) Design rule check (DRC)

Here, I have performed the DRC step to check whether our schematic is according to design rule by using nmDRC tool provided by calibre software.

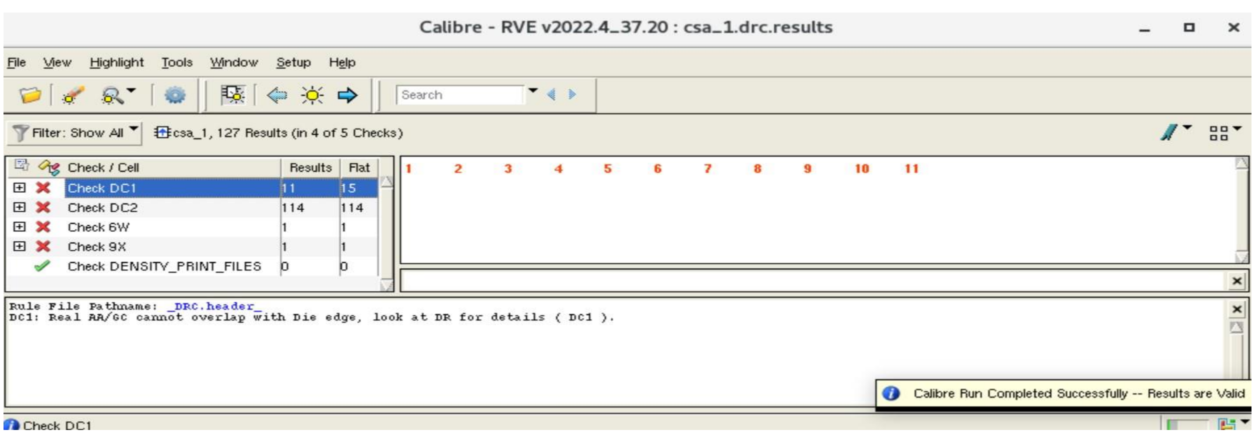

Fig7: Design rule check (DRC) window

4.2(b) Layout Vs Schematic (LVS)

Here, I have performed the LVS step to compare our designed layout with designed schematic using nmLVS tool provided by calibre software

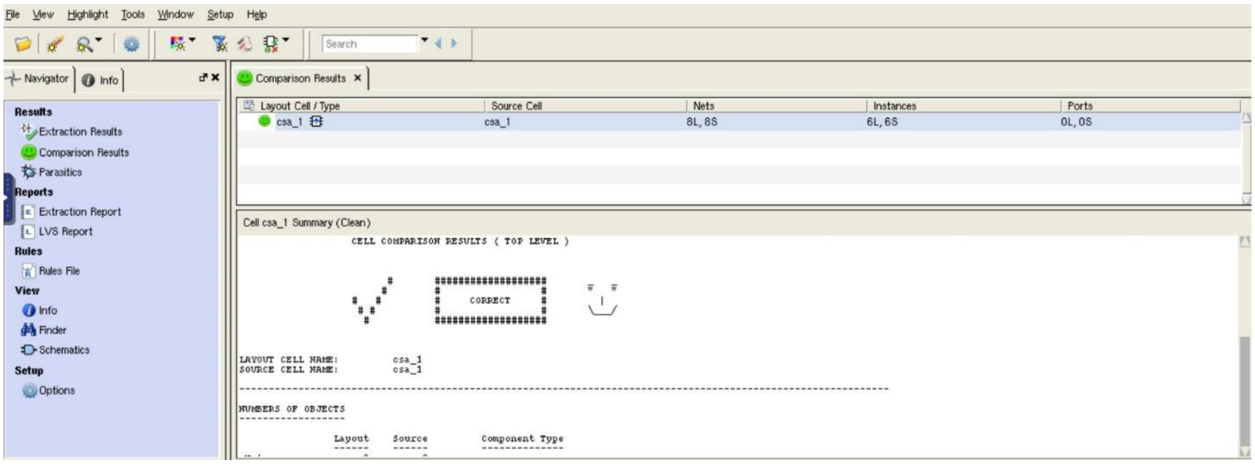

Fig8: Layout Vs Schematic (LVS)

4.2(c) Parasitic extraction (PEX)

Here, I have performed the PEX step to find out the parasitic extraction by the tool provided by calibre software

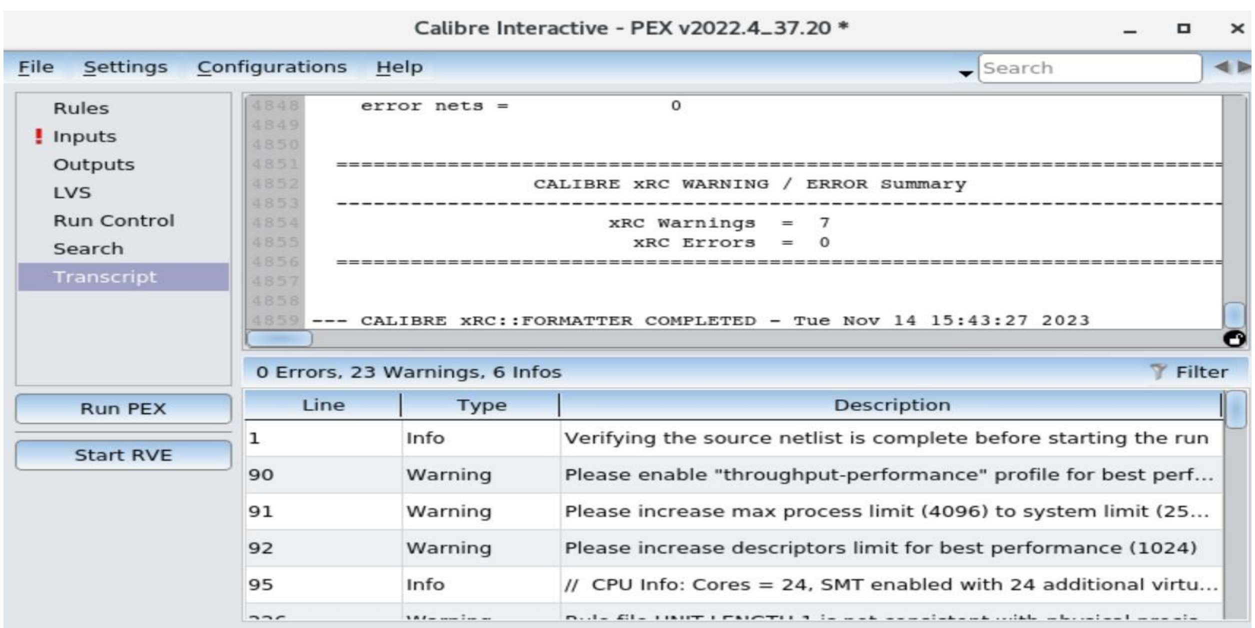

Fig9: Parasitic extraction (PEX)

4.3 Post Layout simulation- waveform

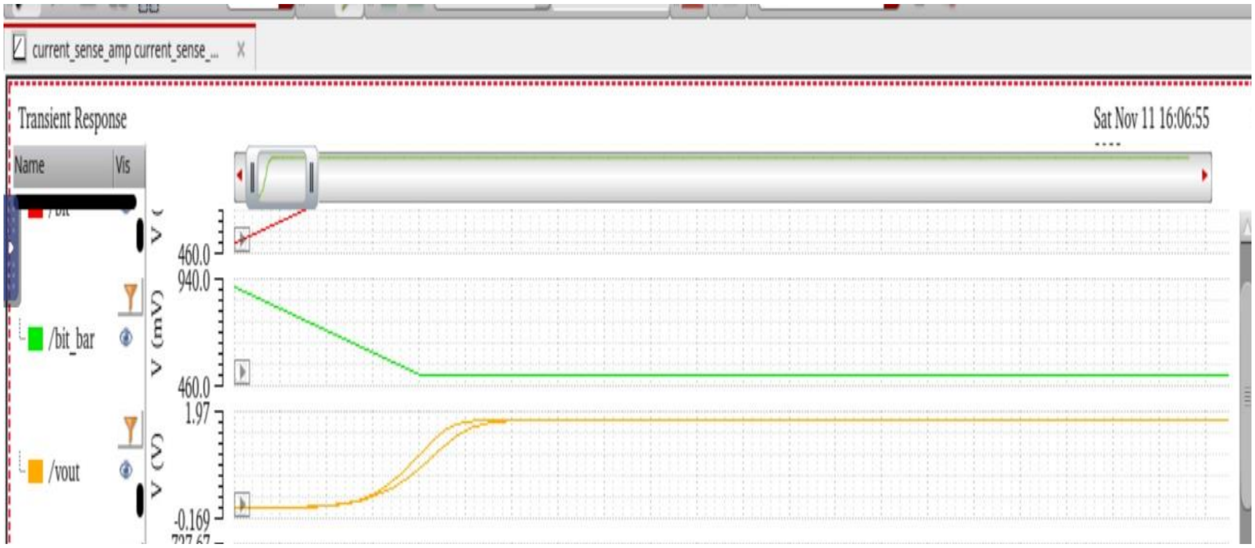

Fig10: Waveform of post layout simulation

5. Conclusion

In this report, we have implemented current sense amplifier that is capable to detect small amount of current. This small amount of current and amplified voltage we are getting by varying W/L of Pmos18 and Nmos18. Further, verification of the schematic and layout has been carried out to verify the functionality of the current sense amplifier.

Different values of width of Pmos and Nmos for different values of current is given in below table.

Width(um)	**Delta I**
W_p=0.42 W_n=0.42	0.257mA
W_p=2 W_n=1	0.59mA
W_p=1 W_n=1	0.56mA

Table 2: width vs delta I