EC 205 ANALOG ELECTRONICS END SEM PROJECT

DESIGN AND ANALYSIS OF PRECISION CURRENT PUMP

DONE BY:

ANIRRVHINYAN K : 191EC205

SHRAVYA HEGDE : 191EC247

AIM:

To access the precision aspects of Voltage controlled current source and Op-Amp based current source.

THEORY:

INTRODUCTION:

In circuit theory, voltage sources and current sources are equally ideal and equally easy to implement. You just draw a circle, and then you add plus and minus signs for voltage or an arrow for current.
Now you have a circuit element that generates a specified voltage under all conditions or that drives a specified current under all conditions.

In real life, sources are not ideal, and furthermore, approximating a theoretical voltage source is significantly easier than approximating a theoretical current source. Voltage sources are as simple as a battery, a Zener diode, or a resistive voltage divider combined with a buffer.

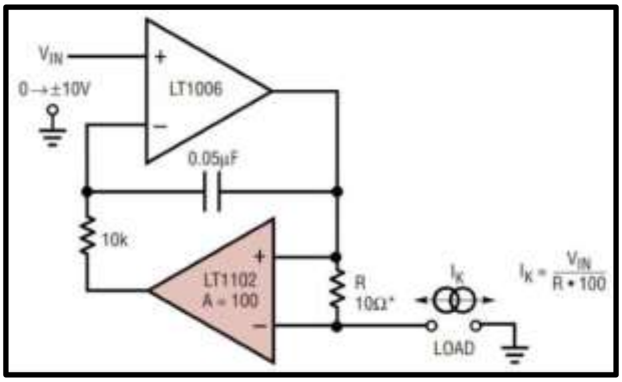
Current sources, on the other hand, usually require some clever circuit design and greater attention to operational details.

CURRENT SOURCE ARCHITECTURE:

There are various ways to design a current source. One interesting procedure is voltage regulator as current source.

Jim William Current source:

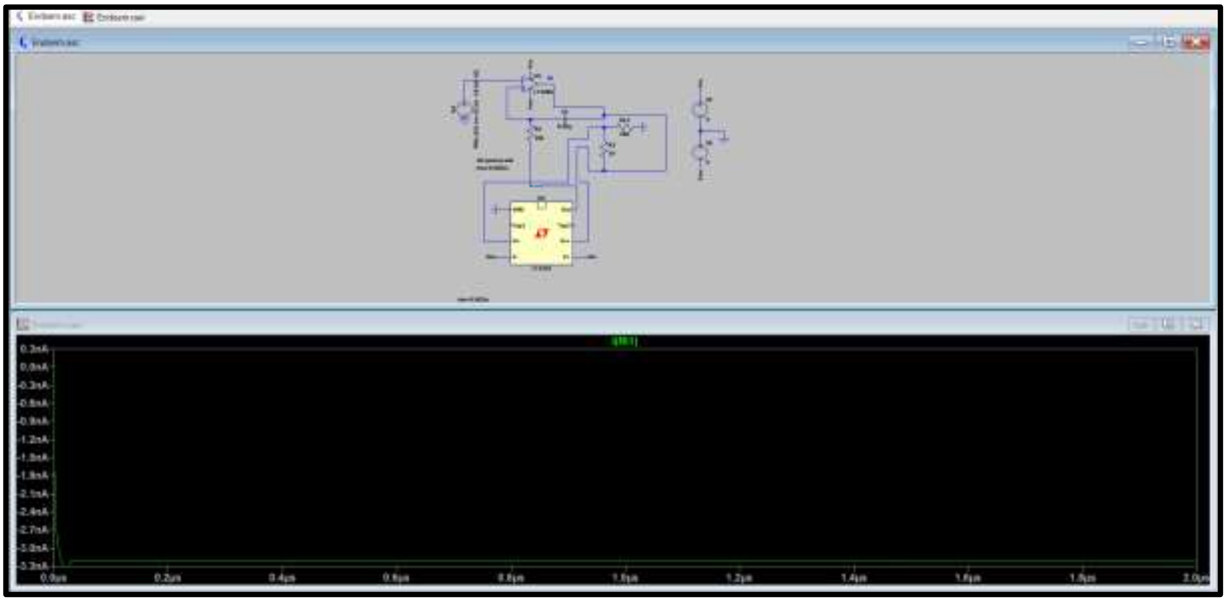
Diagram:



It is a voltage controlled and bidirectional circuit which is compatible with rapid changes in input voltage.

The LT1006 is a typical precision op-amp, and the LT1102 is a high-precision instrumentation amplifier.

Simulation to understand Jim William's current source:



Working:

The key to the operation of this current source is the use of the instrumentation amplifier. By sensing the voltage across a fixed resistance that is in series with the load, we can generate an output current that is not influenced by the value of the load resistance.

The op-amp (A1) is operating in a negative-feedback configuration. The presence of the instrumentation amplifier (A2) in the feedback path does not change the fact that the feedback loop has been closed.

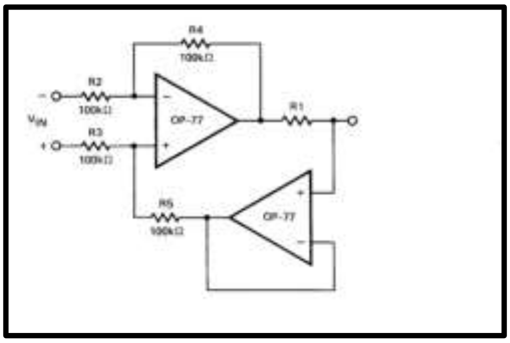
The presence of negative feedback allows us to use the virtual short assumption. Thus, the output of A2 must be equal to the input voltage.
The virtual short condition is imposed by the action of the op-amp's output terminal. Since A2 has a gain of 100, A1's output will do whatever is necessary to ensure that the voltage across R is equal to the input voltage divided by 100.

Since R is a fixed resistance, and since the voltage across R is always proportional to the input voltage, we know from Ohm's law that the current through R will always be proportional to the input voltage and also the load is in series with the resistor R, the output current is always proportional to the input voltage, regardless of the load.

The capacitor and the other resistor determine the circuit's frequency response.

PRECISION OF OUTPUT CURRENT:

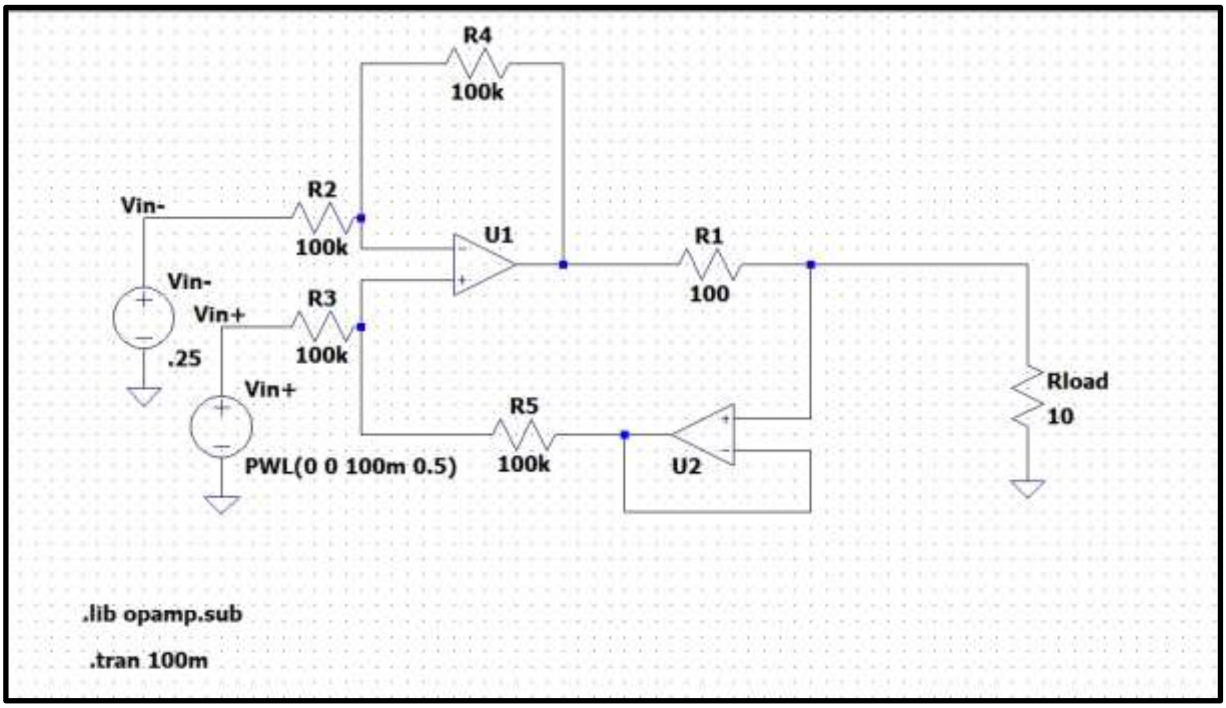
Diagram:



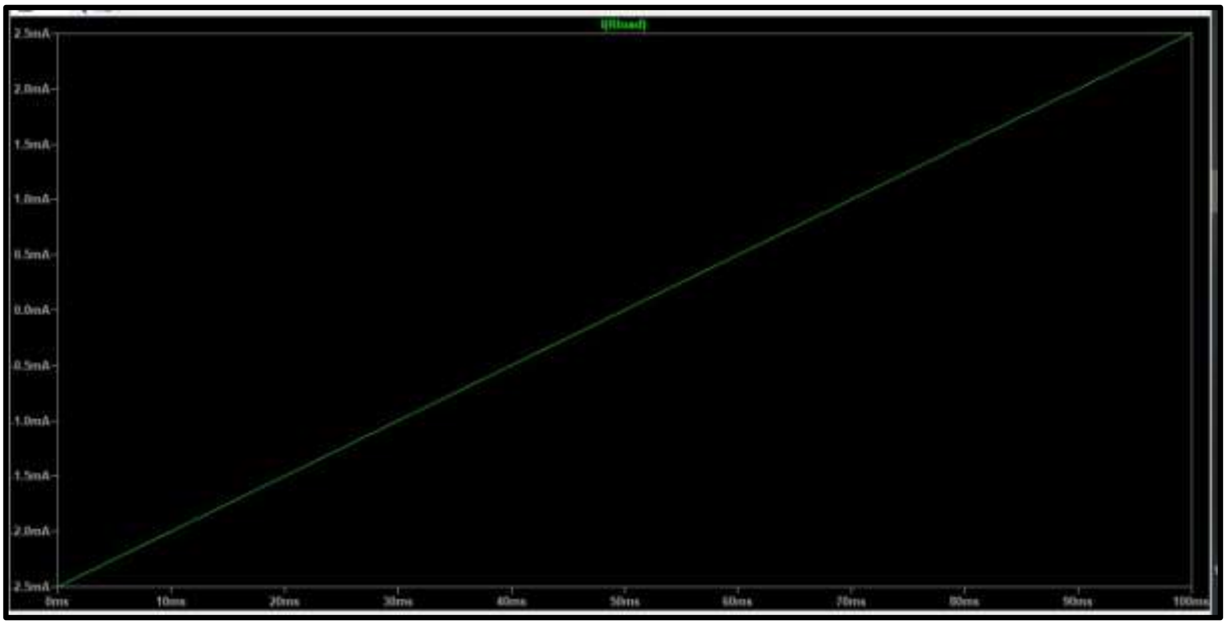
Under ideal conditions (Baseline Precision):

The voltage applied to the differential input changes from –250 mV to 250 mV during a 100 ms interval. The formula that relates input voltage to output current tells us that the current flowing through the load should be $V_{IN}/100$.

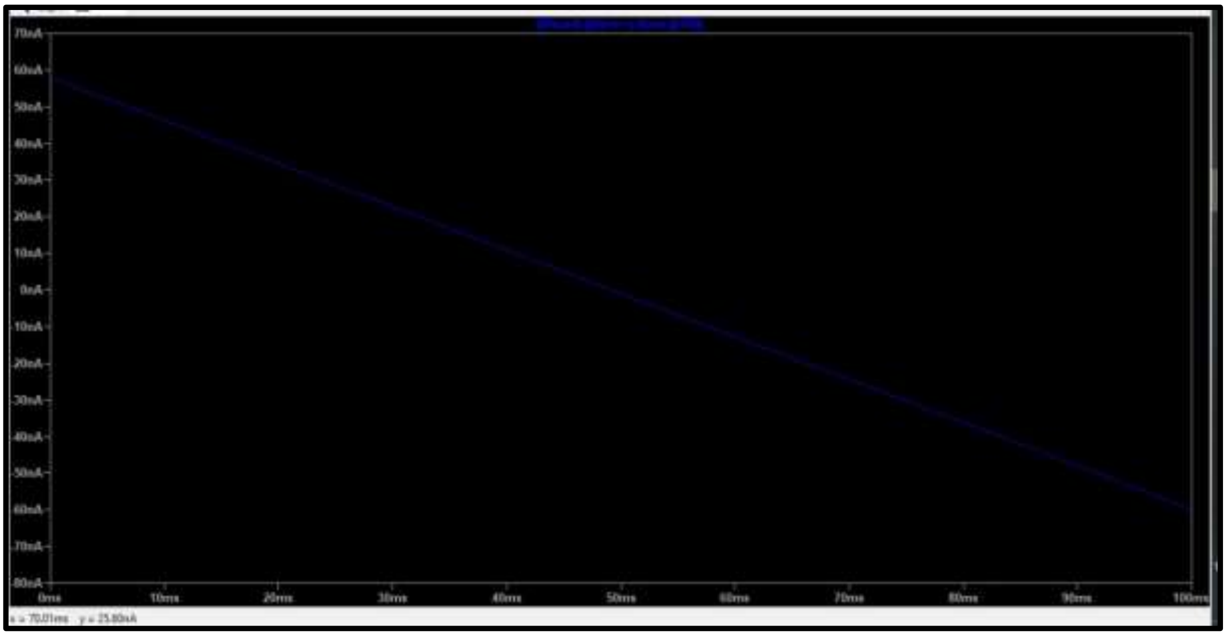
Circuit:



Simulation:



To see how closely the generated load current matches the theoretical prediction, we will plot the difference between the simulated load current and the mathematically calculated load current.



The error is extremely small, and its magnitude varies in proportion to the magnitude of the load current.

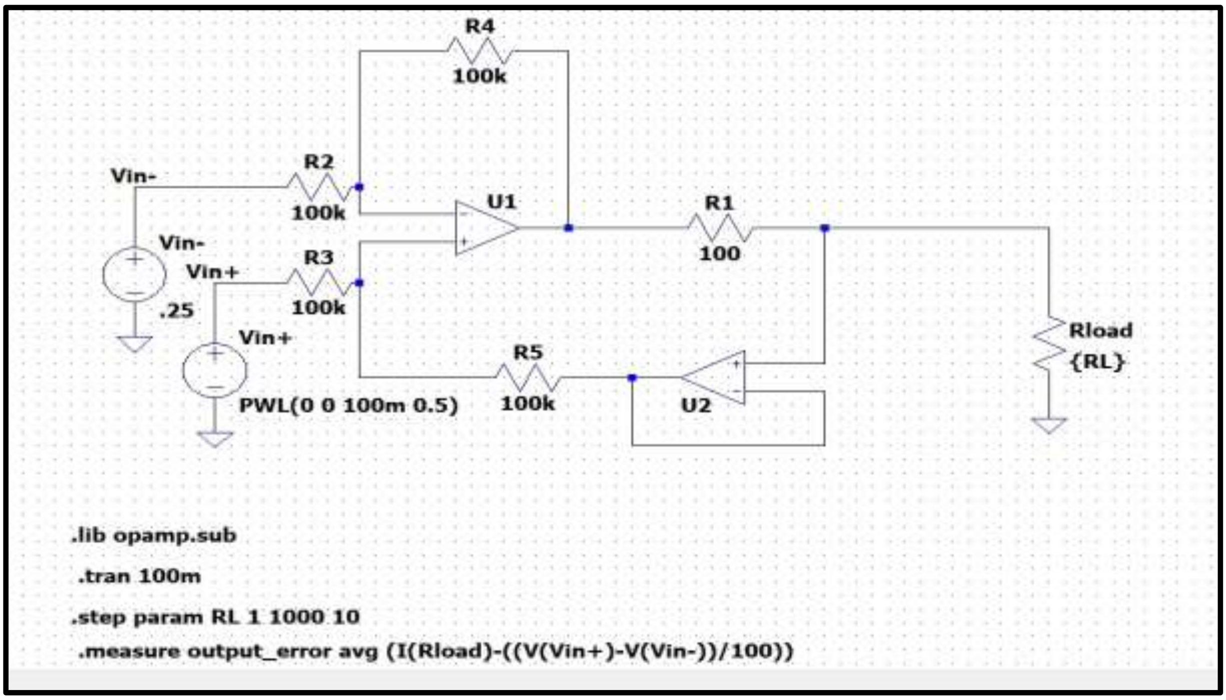
Under Load variations:

When we are talking about a voltage regulator, load regulation refers to the regulator's ability to maintain a constant voltage despite variations in load resistance.

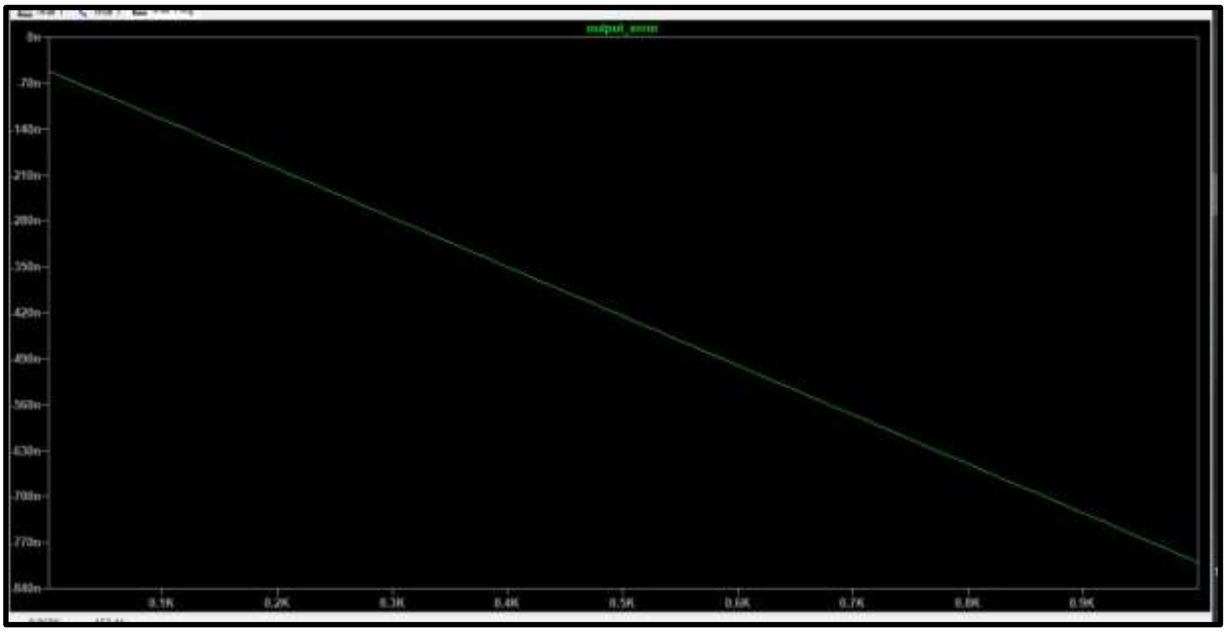
For this simulation, we'll provide a fixed input voltage of 250 mV, and we'll use a "step" directive to vary the load from 1 Ω to 1000 Ω in 10 Ω steps.

A "measure" directive allows us to plot error versus the stepped parameter (i.e., the load resistance) rather than versus time; this is accomplished by opening the error log (View -> SPICE Error Log), right-clicking, and selecting "Plot .step'ed .meas data."

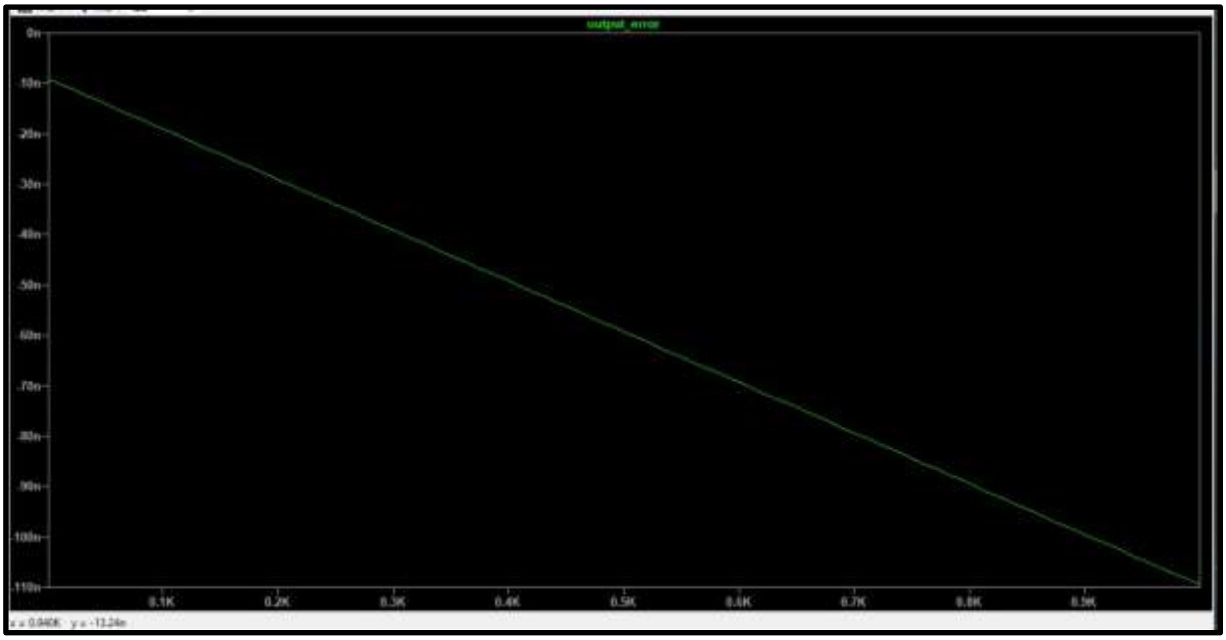
Circuit:



Simulation:



For larger load resistances, the output-current error does increase significantly from about 50 nA to 800 nA. However, 800 nA is still a very small error.



The percentage of variation in output error is quite similar. In the first simulation, the error increased by a factor of 15.7 over the range of load resistance. In the second simulation, where micromodel is used for the LT1001A, it increased by a factor of 12.1.

LT1001A performed better than the ideal single-pole operational amplifier the magnitude of the error was much lower over the entire range, and the error was more stable relative to load resistance.

The effect of resistor tolerance:

We don't need simulations to determine the effect of variations in the resistance of R_1, the mathematical relationship between input voltage and output current gives us a clear idea of how much error will be introduced by an R_1 value that deviates from the nominal value.

Also, the circuit diagram taken from the app note indicates how the ratio of R_4 to R_2 will affect output current, since this ratio determines A, and I_{OUT} is directly proportional to V_{IN} multiplied by A.

Less clear, however, is the effect of imperfect matching between resistors. The circuit diagram indicates that R_2 and R_3 should be matched and that R_4 and R_5 should be matched. We can investigate this by performing a Monte Carlo simulation in which resistor values are varied within their tolerance range.

If the simulation includes a large number of Monte Carlo runs, the maximum and minimum errors reported in the simulation results can be interpreted as the worst-case error associated with resistor tolerance.

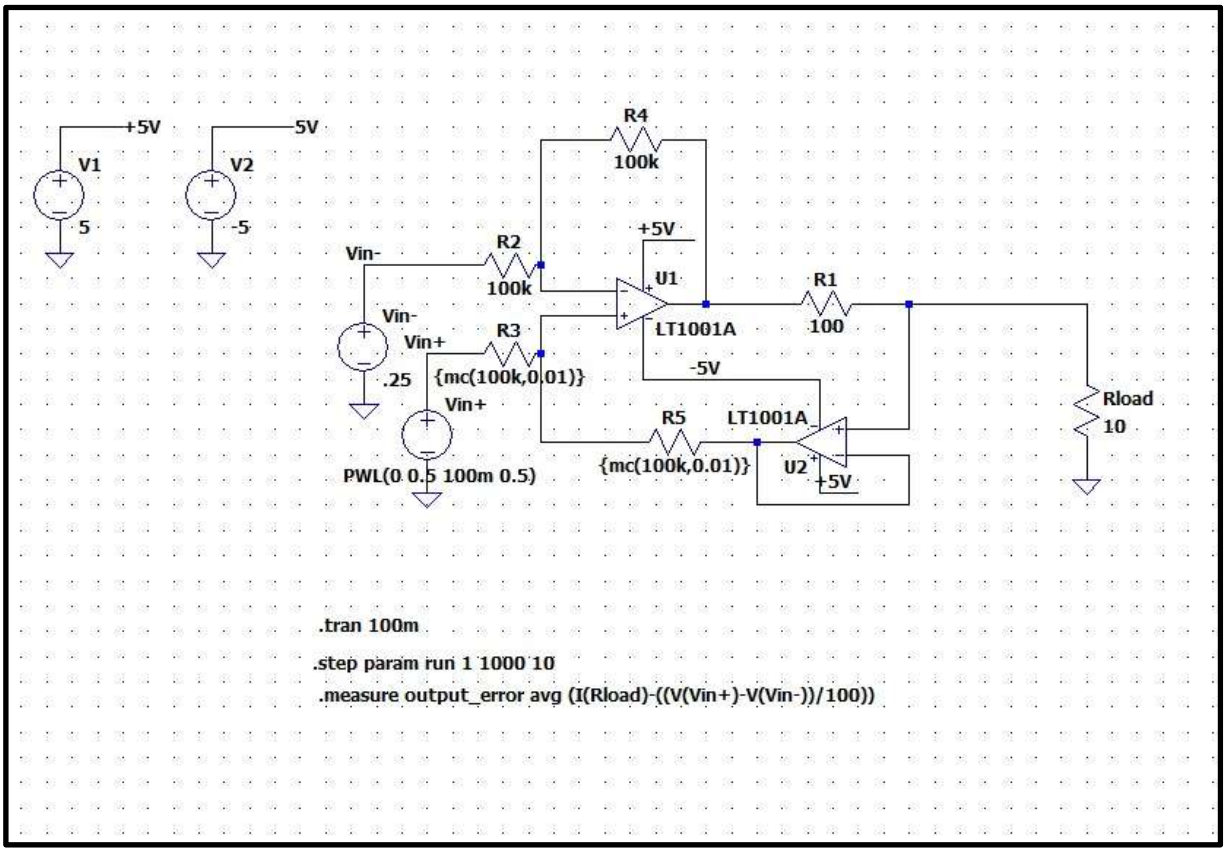
For this simulation, we will leave R_2 and R_4 fixed at 100 kΩ, this prevents variations in A. We will degrade the circuit's matching by applying the Monte Carlo function to the values of R_3 and R_5.

Current in $R_1 = I_{OUT} = (V_{IN} \times A)/R_1$

$A = (R_4 / R_2) = (R_5 / R_3)$

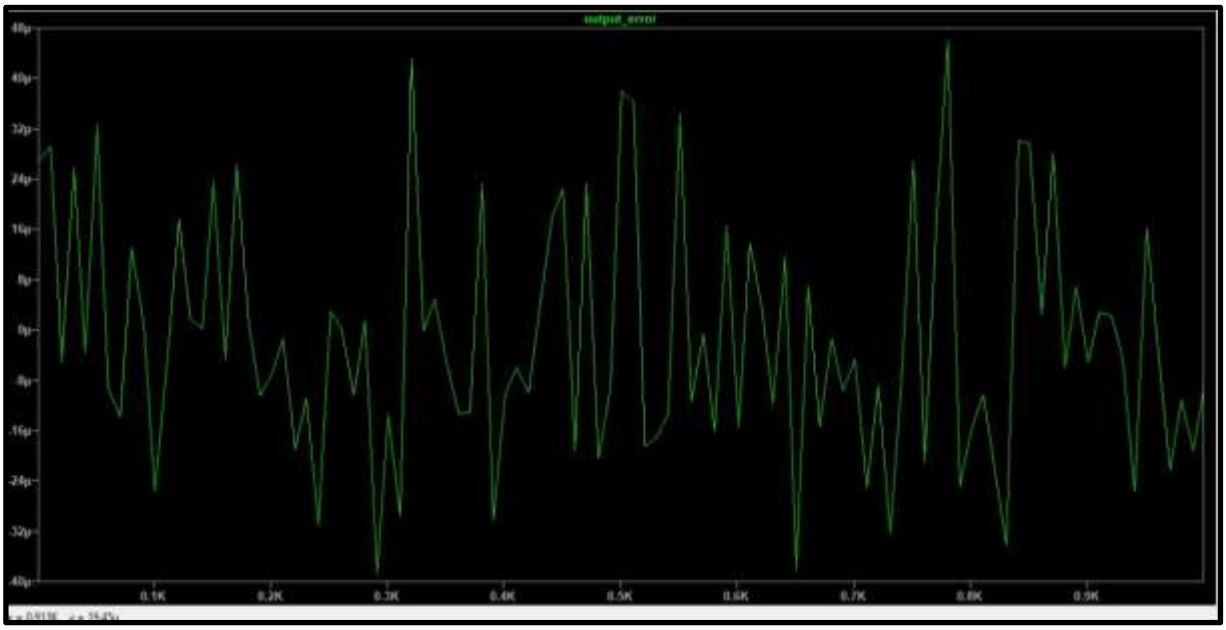
1% Tolerance:

Circuit:



As indicated by the "step" SPICE directive, one simulation consists of 100 runs. The value "mc(100k,0.01)" specifies a nominal resistance of 100 kΩ with a tolerance of 1%.

Here is a plot of output-current error for the 100 runs.

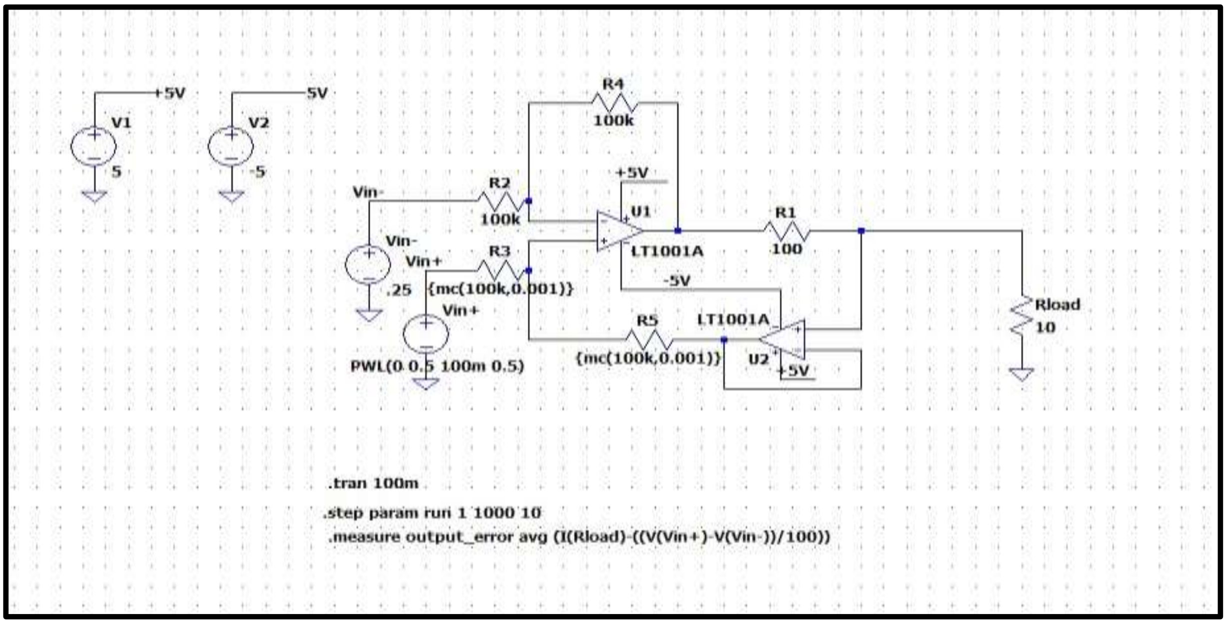


The average error is 15.6 µA, which is 0.6% of the expected 2.5 mA output current, and under worst-case conditions, the actual output current deviates from the expected current by approximately 40 µA.

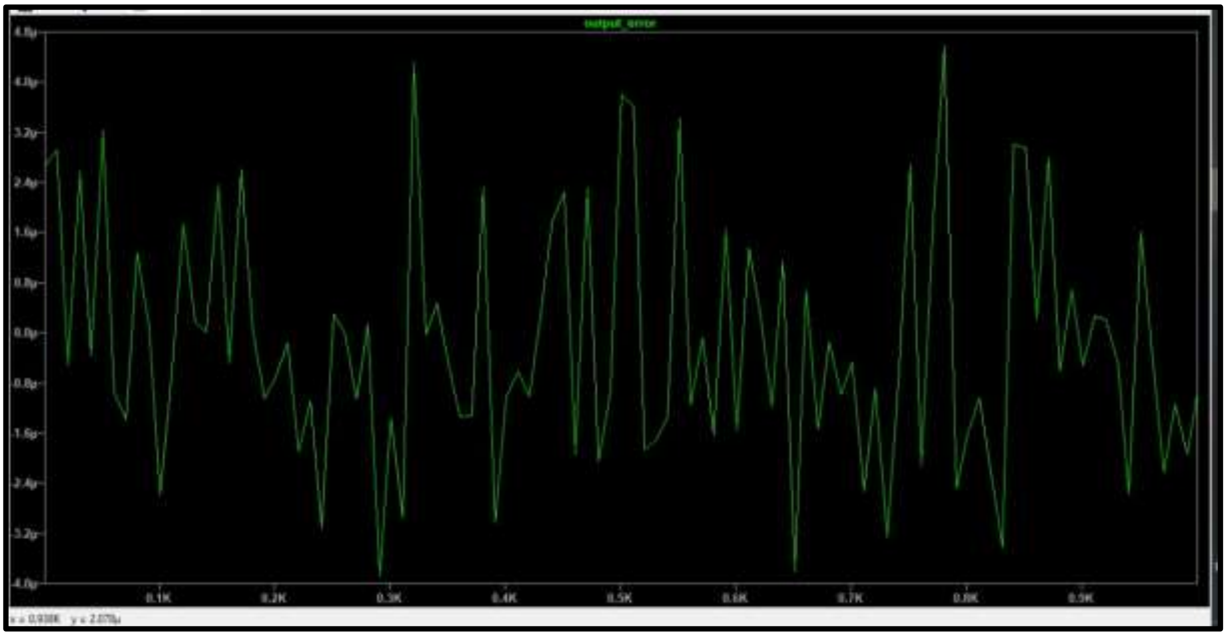
Let's see how the situation improves when we use 0.1% tolerance instead of 1%.

1% Tolerance:

Circuit:



Simulation:



Now the average error is 1.6 μA, which is only 0.06% of the expected output current, and the worst-case error has decreased into the 4 μA range.

Resistive tolerance of 1%, with the resistors that determine input gain fixed at their theoretical value, allows for high precision. A tolerance of 0.1% applied to all resistors would provide good performance, and since 0.1% resistors are readily available and not expensive.

Conclusion:

We've carried out simulations that have provided valuable insight into the performance of the two-op-amp current pump.

THE END