EE230: Experiment No.8
Logarithmic Amplifier

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March 20, 2022

1 Overview of the experiment

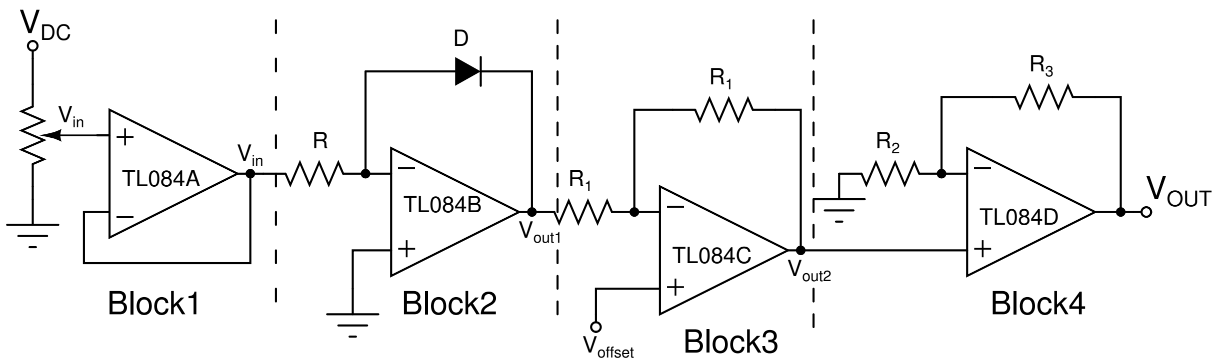
1.1 Aim of the experiment

The aim of this experiment is to understand Logarithmic Amplifier using op-amps (specifically TL084) about how it works and should be the circuit to implement this type of Amplifier. In this experiment, we have to find the linear region at which we can use the given circuit for our use, given the IV characteristics of the circuit. This circuit is simulated using NgSpice software, and these simulation results needs to be compared with the theoritical results.

1.2 Methods

First of all, the given IV characteristics are analyzed, we find the linear region to work upon the om-amp, and by using linear regression in python, we find the slope and the y-intercept (which is required for further calculations).
After that, circuit diagrams are made using XCircuit software of the required circuits. Now, as the circuits are formed, netlist codes are written for the circuit to completely describe the circuit and also describe what result ngspice should show to us. The readings are saved in a file and then, using this file, plots of the given parameters are made by matplotlib python script.
The lab work to be done was given in lab pdf, using that we got the circuit to be simulated.
After that, these plots were compared with the theoritical plot values and the changes are done to the circuit element values to refine the circuit.

2 Design



The equation for the terminal characteristics of a pn junction diode in forward bias is

$$I_D = I_S * e^{(V_D/nV_T)} \tag{1}$$

$$V_D = nV_T(ln(I_D) - ln(I_S)) \tag{2}$$

$$ln(I_D) = V_D/nV_T + ln(I_S) \tag{3}$$

$$V_{out1} = -V_D \tag{4}$$

$$V_{out1} = nV_T(ln(I_S R) - ln(V_{in})) \tag{5}$$

$$V_{out1} = a_1 ln(V_{in}) + a_2 \tag{6}$$

$$a_1 = -nV_T \tag{7}$$

$$a_2 = nV_T ln(I_S R) \tag{8}$$

We can remove the offset by subtracting a_2 from V_{out1}. The result can then be multiplied by $1/a_1$ using a suitable amplifier, to obtain at the output the true natural logarithm of V_{in}.
The third block is used for removing the offset from V_{out1} , set $V_{offset} = a_2/2$, so the input to block 4 would be -a_1 ln(V_{in}).

$$V_{out} = -a_1(1 + R_3/R_2)ln(V_{in}) \tag{9}$$

Choosing 1 + R_3/R_2 = -1/a_1, we get

$$V_{out} = ln(V_{in}) \tag{10}$$

The role of block 1 is to avoid loading the source of V_{in} by block 2.
If we assume that the maximum input voltage, $V_{in2} = 10$V , then R = $10/I_{D2}$.
Values:-
By observing the readings, we got linear region I_D values from 1.266E-4 to 5.55E-4 Amperes.
So,

$$R = 10/I_{D2} = 18k\Omega \tag{11}$$

By using linear regression in this region, we got slope = 20.5409, and y-intercept = -19.30584.

$$Slope = 1/(nV_T) \tag{12}$$

$$Y - intercept = ln(I_S) \tag{13}$$

$$n = 1/(slope * V_T) = 1.87 \tag{14}$$

$$I_S = e^{(y-intercept)} = 4.13nA \tag{15}$$

$$a_1 = -(1.87)(26)/1000 = -0.04862 \tag{16}$$

$$a_2 = (1.87)(26)ln(4.13 * 18/1000000)/1000 = -0.46 \tag{17}$$

$$V_{offset} = a_2/2 = (nV_T ln(I_S R))/2 = -0.23V \tag{18}$$

We set R_1 = 10kΩ.

$$R_3/R_2 = (-1/a_1) - 1 = 19.5 \tag{19}$$

We set R_2 = 1kΩ, and R_3 = 19.5kΩ.
Now, we are done with all the calculations for finding the values of all the required values and parameters.

3 Simulation results

3.1 Code snippet

Logarithmic Amplifier

V_{OUT} vs V_{IN}

```
.include TL084.txt
.include 1N4148.txt
x1 1 2 3 4 2 TL084
x2 0 5 3 4 6 TL084
x3 11 7 3 4 8 TL084
x4 8 9 3 4 10 TL084
r1 6 7 10k
rx 7 8 10k
r2 9 0 1.1k
r3 9 10 19.5k
r 2 5 18k
D 5 6 1N4148
vcc 3 0 15
vdd 4 0 -15
vin 1 0 dc 0
vo 11 0 -0.219
.dc vin 0 10 0.1
.control
run
plot v(10)
print v(10)
.endc
.end
```

$$V_{OUT} \text{ vs } \ln(V_{IN})$$

This is done by using python.

3.2 Simulation results

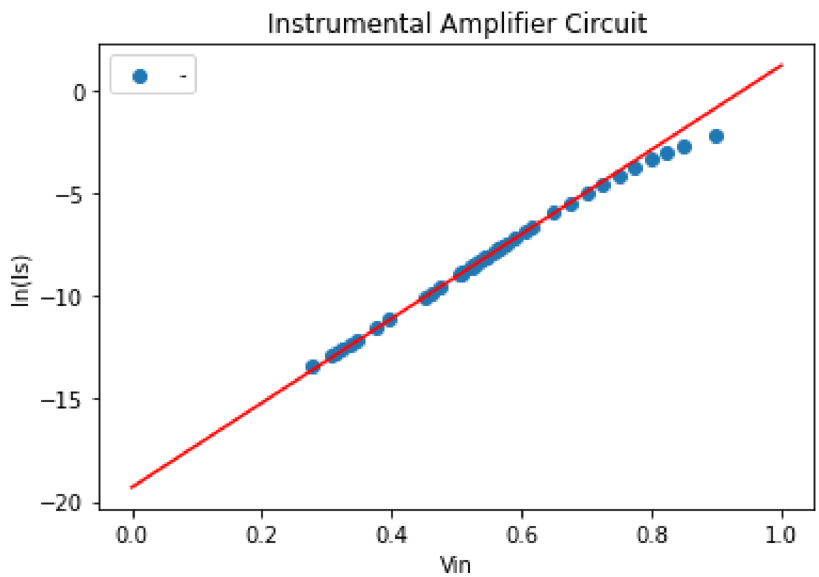


Figure 1: IV characteristics from the given data and also linear regression

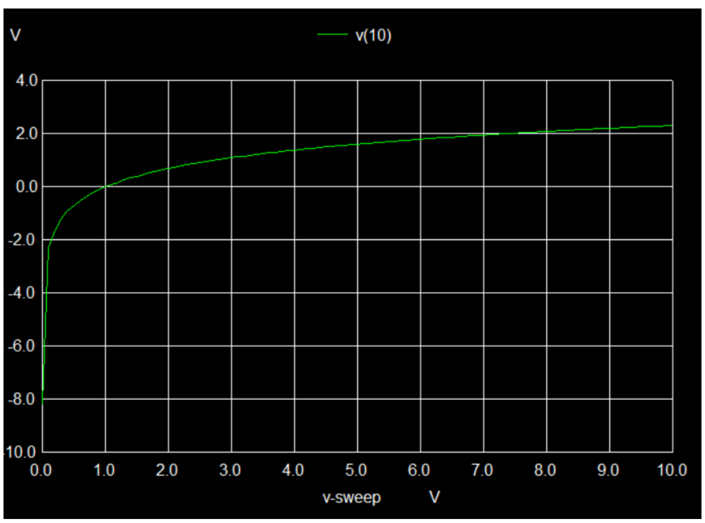


Figure 2: V_{out} vs V_{in} (ideal)

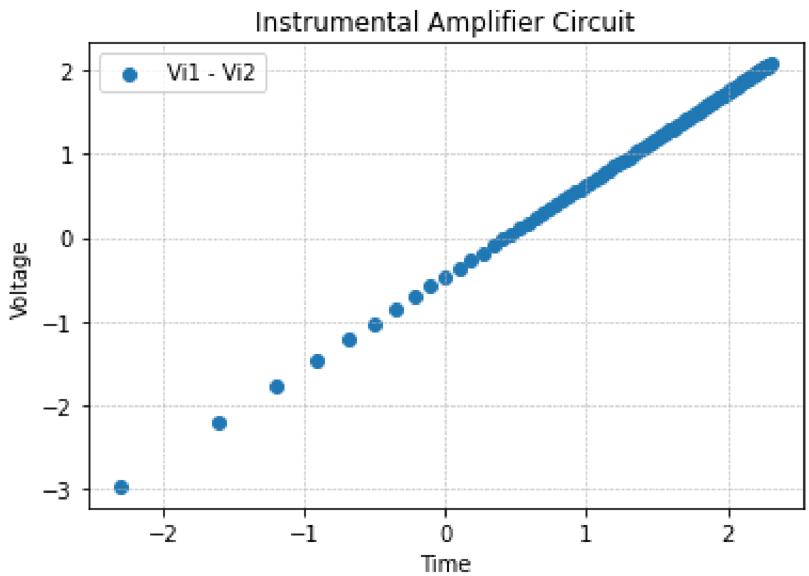


Figure 3: V_{out} vs $\ln(V_{in})$ initially

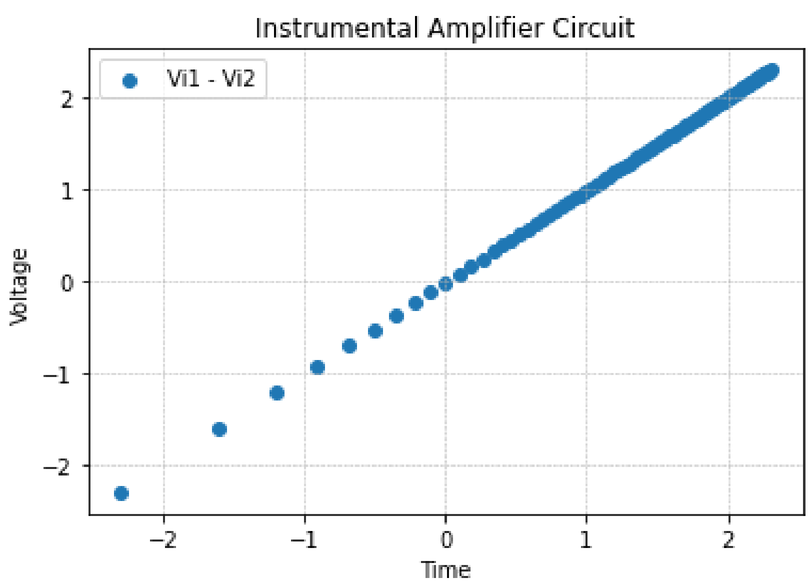


Figure 4: V_{out} vs $\ln(V_{in})$ after refining (ideal)

4 Experimental results

Our value of $V_{offfset}$, which came from the experimental IV data is -0.23V. But to make the V_{out} vs $\ln(V_{in})$ graph to pass through (0,0), we have to malke the $V_{offfset}$ = -0.219V.
To make the slope of this graph as 1, we had to change the value of R_2 from 1kΩ (came by experimental analysis), to 1.1kΩ.
So, because of changing $V_{offfset}$ from -0.23V to -0.219V, a_2 value changes from -0.46 to -0.438.
Due to changing of R_2 from 1k to 1.1k, a_1 value changes from -0.04862 to -0.05344.

5 Experiment completion status

All the parts of this experiment are completed successfully.