EE230: Analog Circuits Lab
Square Root Amplifier
Lab No. 4

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1 Aim of the experiment

Construct a square root amplifier and fine tune it to utmost precision

2 Design

The current through the diode in forward bias is given by the following equation

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

Rearranging the terms we get

$$V_D = n \cdot V_T * (ln(I_D) - ln(I_S)) \tag{2}$$

The output of Block-1 is given by V_{out1}:

$$V_{out1} = -V_D = n \cdot V_T * (ln(I_S R) - ln(V_{in})) \tag{3}$$

The output of Block-2 is given by V_{out2}:

$$V_{out2} = -n \cdot V_T \cdot ln(I_S R) + (ln(V_{in}))V_T \cdot n + 2V_{b1} \tag{4}$$

We can remove the offset terms which don't include V_{in} by choosing:

$$V_{b1} = \frac{n \cdot V_T \cdot ln(I_S \cdot R)}{2} \tag{5}$$

$$V_{out2} = n \cdot V_T \cdot ln(V_{in}) \tag{6}$$

The output of Block-3 can be given by:

$$V_{out3} = -\frac{R_{22}}{R_{21}} \cdot V_{out2} = -\frac{R_{22}}{R_{21}} \cdot V_T \cdot ln(V_{in}) = ln(V_{in}^{-\frac{R_{22}}{R_{21}} nV} T) \tag{7}$$

For Block-4, $V_x = V_{b2}$ (virtual ground) and:

$$V_{out} = R_3 \cdot I_{D2} + V_{b2} = R_3 \cdot T_{S2} \cdot e^{\frac{V_{b2}}{n_2 \cdot V_T}} V_{in}{}^{\frac{n_1}{n_2} \frac{R_{22}}{R_{21}}} + V_{b2} \tag{8}$$

We can simplify the circuit as:

$$V_{R3} = V_{out} - V_x = \beta_1 \cdot V_{in}^{\beta 2} \tag{9}$$

For square root amplifier, we can choose $\beta_1 = 1$ and $\beta_2 = \frac{1}{2}$

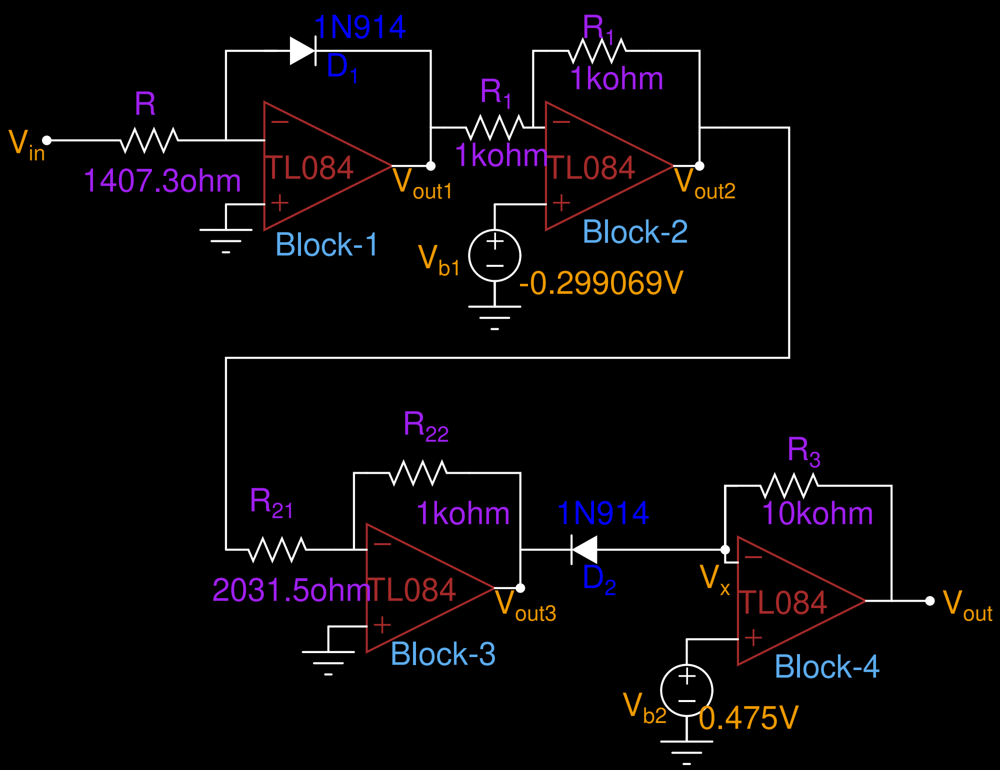
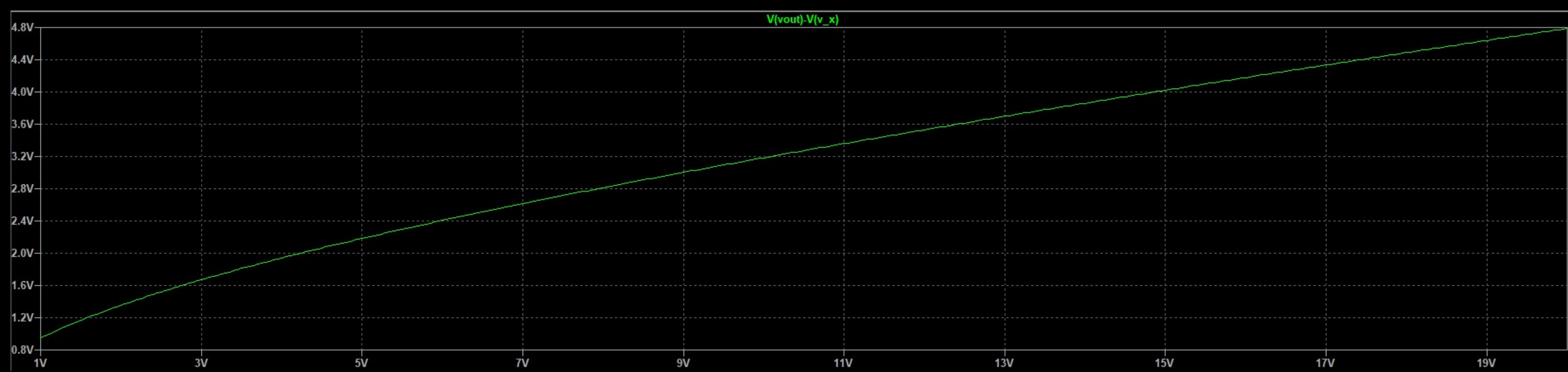
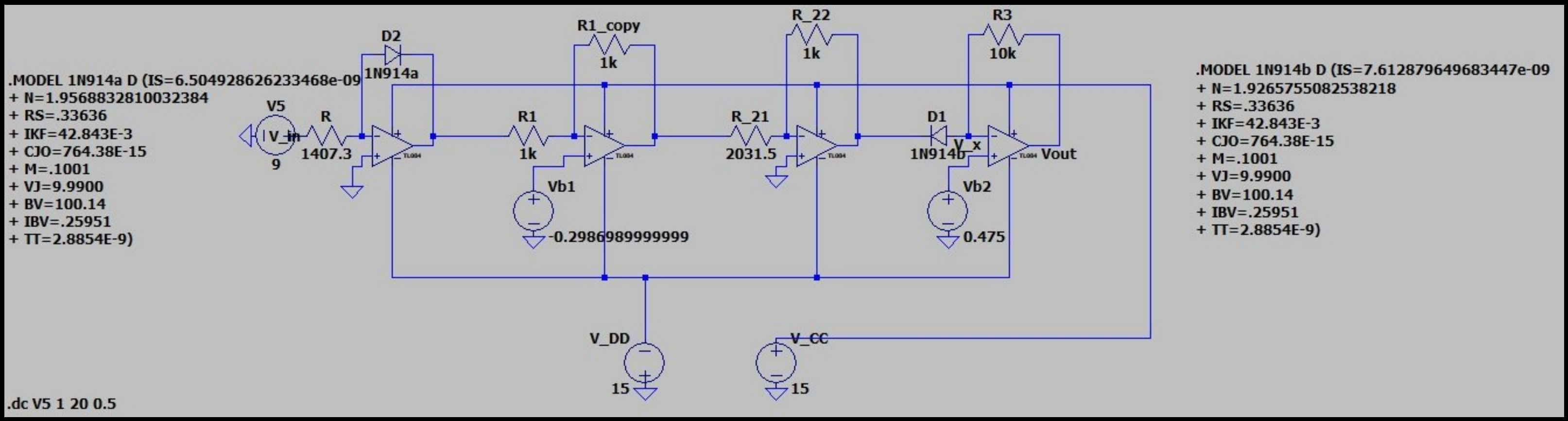


Figure 1: Circuit Diagram

3 Simulation Results

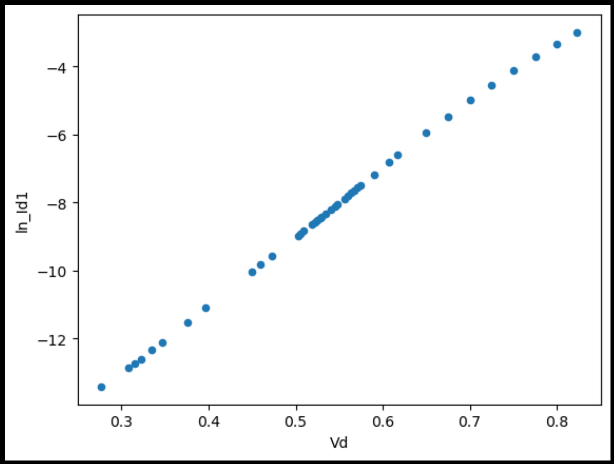


4 Circuit Schematics

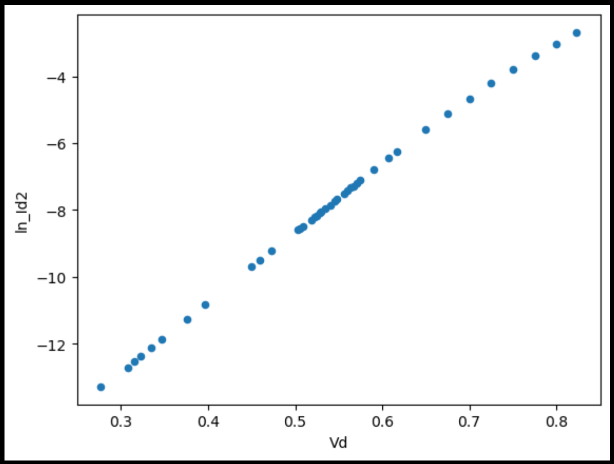


5 Experimental results

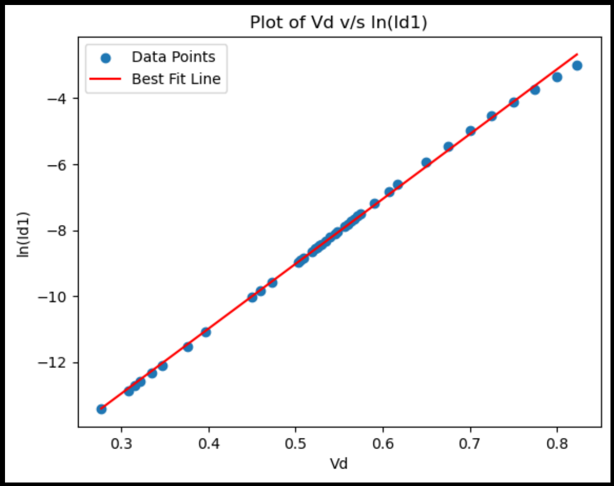
Plot $ln(I_D)$ ***v/s*** V_D:



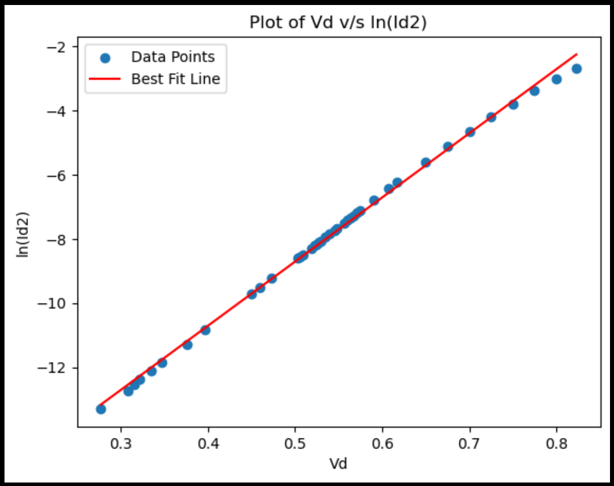
(a)



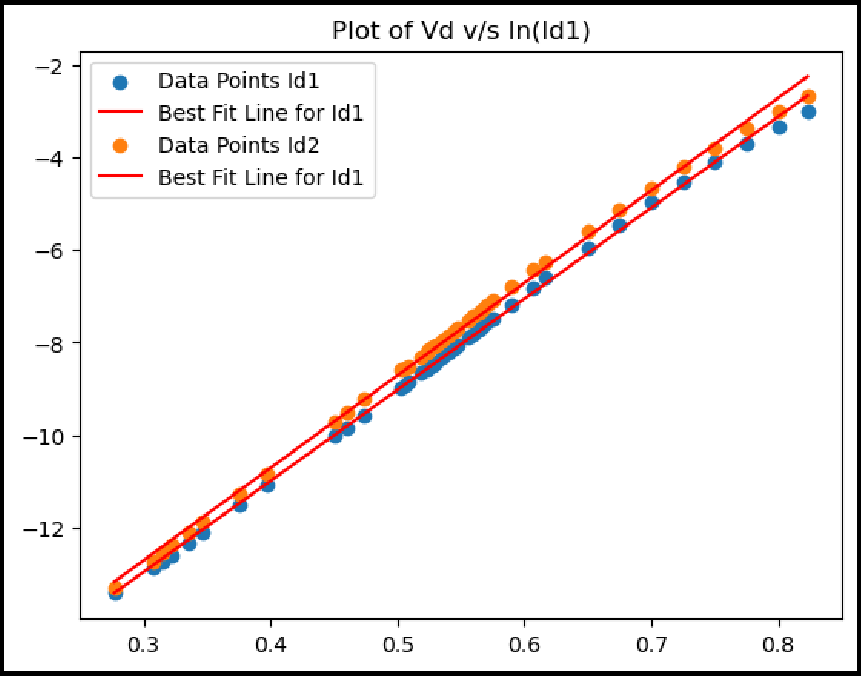
(b)



(a)



(b)



manually identify the range over which ln(I_D) is a linear function of V_D:

As it can be seen from the figure (a) on the top of this page, the last point to be on the line is, the values of which are - $V_D = 0.75$, $I_{D1} = 0.01633$ and

V_D = 0.725 and I_{D2} = 1.48e-02

determine I_S ***and n*****:**

The value of:
$I_{S1} = \frac{1}{e^1 8.8507}$ = 6.5e - 9 $\quad n_1 = \frac{1}{slope_1 \cdot V_T} = \frac{1}{19.65 \cdot 0.026} = 1.95$
$I_{S2} = \frac{1}{e^1 8.6934}$ = 7.6e - 9 $\quad n_2 = \frac{1}{slope_2 \cdot V_T} = \frac{1}{19.96 \cdot 0.026} = 1.926$

Choose diode for Block-1 and determine the value of R**:**

We'll choose Diode 1 since it's correlation is more i.e. it's linear over a larger range as compared to Diode 2. I_{D1} = 0.01066, R = $\frac{15}{I_{D1}} = \frac{15}{0.01066}$ = 1407.13Ω

Determine the expression for V_{out1}**:**

V_{out1} = n V_T (ln(I_S R) - ln(V_{in})) = 0.0508(-11.6 - ln(V_{in}))

Determine V_{b1} ***to remove offset and choose*** R_1 ***arbitrarily*****:**

$V_{b1} = \frac{nV_T ln(I_S R)}{2}$ = -0.0294 V and choosing R_1 = 1kΩ. Corresponding V_{out1} becomes -0.589V.

Select V_{b2} ***and*** R_3 ***such that*** V_{R3} ***= 1V*****:**

choosing R_3 = 10kΩ
and substituting the values in equation (8) and equation (9), we get, V_{R3} = 0.475 for R_3 = 10kΩ, I_{S2} = 7.6e-09, n_2 = 19.96 and V_T = 0.026.

Choose R_{21} ***and*** R_{22} ***and also fine tune for finding sqrt when*** V_{in}***=9V*****:**

We want $\beta_2 = \frac{1}{2}$ OR $\frac{n_1}{n_2} \cdot \frac{R_{22}}{R_{21}} = \frac{1}{2}$
R_{21} = 2.03 * R_{22}. Let's take R_{22} = 1kΩ, R_{21} = 2.03kΩ.
When we fine tune the circuit, we get, V_{b1} = -0.2980989999999V.

6 Experiment completion status

The full experiment along with the handwritten reports was completed during the lab hours.