ICA PROJECT GROUP 20

TEAM MEMBERS

-Suraj Shewale	612207077
-Suhani Shinde	612207079
-Shivansh Kaul	612207080
-Prerana Shinde	612207078

TOPIC - VOLTAGE SQUARE ROOT CIRCUIT

Abstract:

This report presents the design and analysis of a circuit capable of computing the square root of the applied voltage. The circuit employs logarithmic and antilogarithmic properties to achieve the desired functionality. Through a multi-stage process involving logarithmic amplification, voltage divider, and antilogarithmic amplification, the circuit accurately computes the square root of the input voltage. Detailed analysis, simulations, and experimental validation are provided to demonstrate the effectiveness of the proposed circuit.

Keywords:

Square root computation

Analog Square Root

Application of log/antilog

Introduction:

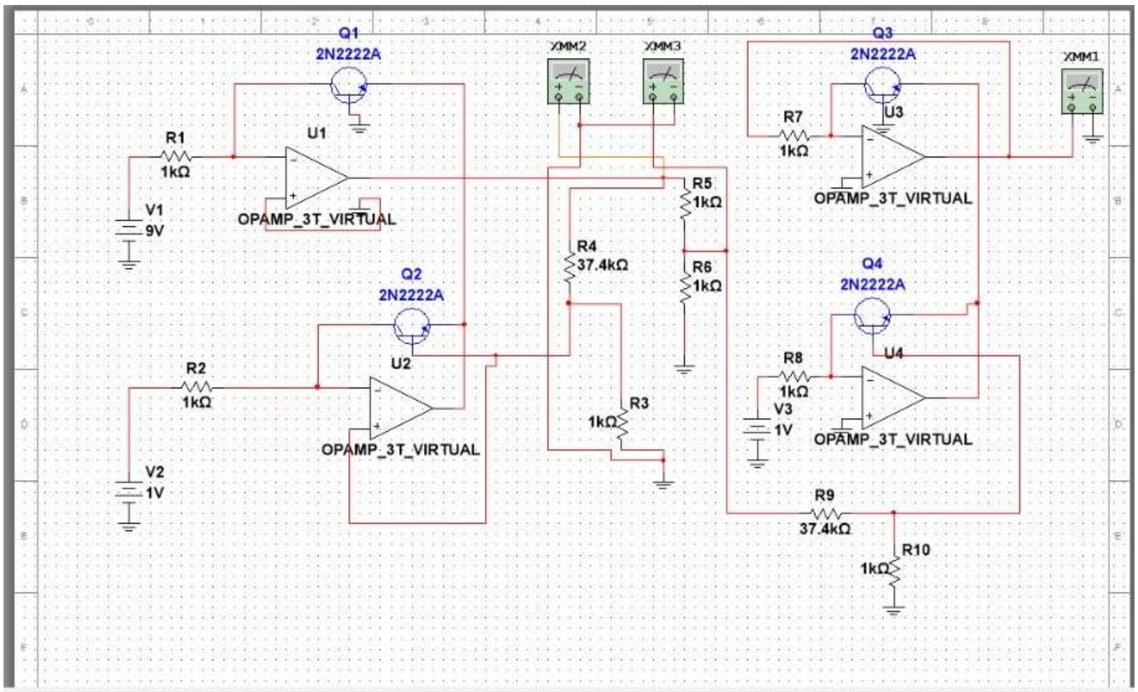
With reference of the book Linear Integrated Circuits by Roy Chowdhury[1] we have first and foremostly learned how to build logarithmic and antilogarithmic circuits using 741 operational amplifiers . Moreover, to compute the square root, we needed to divide the output by 2 so we have taken a resistive divider circuit in between log and antilog amplifier circuit inserted where the output gets divided by 2.

With the help of logarithmic properties, we get the square root of the applied voltage once we take the anti-log of the output of the parallel system. This way we have built a circuit that can find the square root of any input voltage.

Work Done:

The design process involved careful consideration of logarithmic properties and circuit components to achieve the desired square root computation. Extensive simulations were conducted using Multisim to verify the circuit's performance and optimize component values for accuracy. Subsequently, the circuit was implemented on a breadboard, and experimental testing was carried out to validate its functionality in a real-world environment.

Schematic:



Equations and Derivation

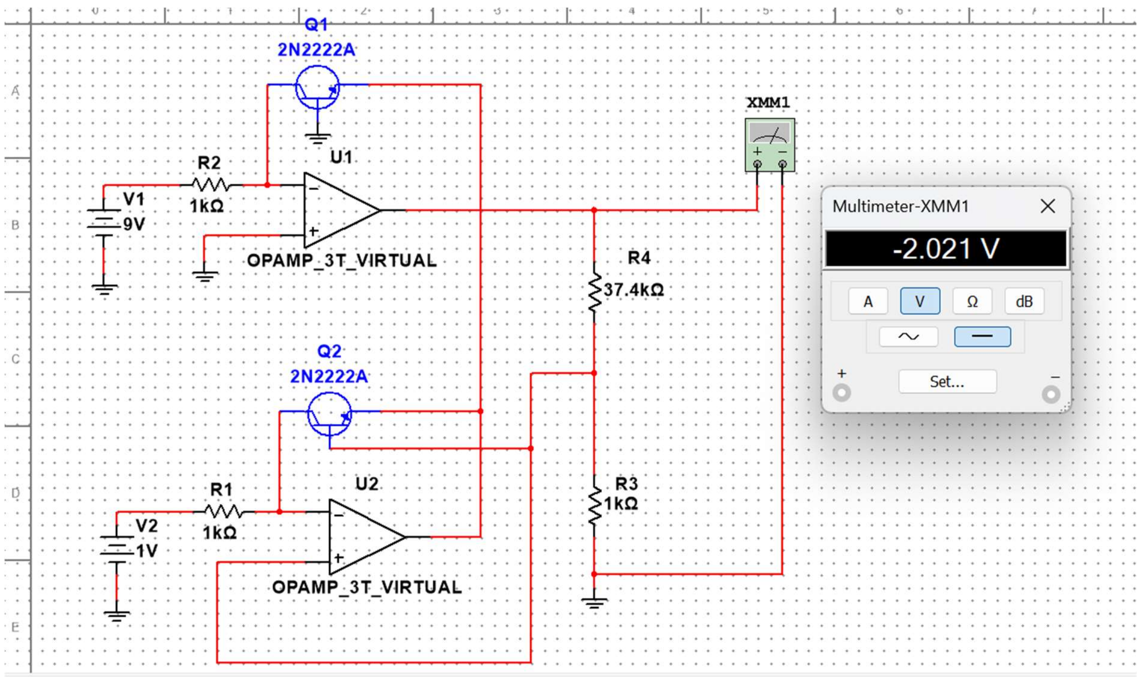
1. Logarithm operational amplifier

An op-amp based logarithmic amplifier produces a voltage at the output, which is proportional to the logarithm of the voltage applied to the resistor connected to its inverting terminal.

i.e. $V_o = -nV_T \ln \left(\frac{v_i}{R_1 I_S}\right)$

To remove the temperature dependent parameters like V_T and I_S the circuit is modified using two log amplifiers, differential amplifier and non inverting amplifier to get

$V_o = \ln(V_{in})$, with $V_{ref} = 1V$



2. Antilog operational amplifier

An op-amp based anti-logarithmic amplifier produces a voltage at the output, which is proportional to the anti-logarithm of the voltage that is applied to the diode connected to its inverting terminal.

i.e. $V_o = -R_f I_S \exp\left(\frac{vi}{nv_T}\right)$

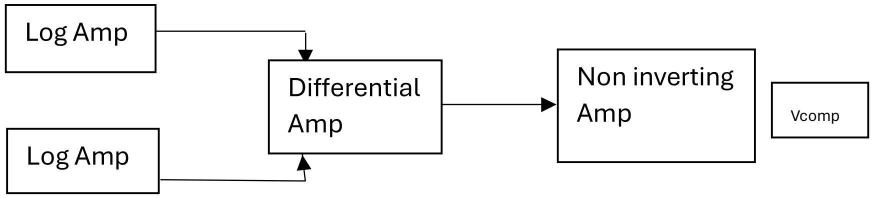
To remove the temperature dependent parameters like V_T and I_S the circuit is modified using two log amplifiers, differential amplifier and non inverting amplifier to get

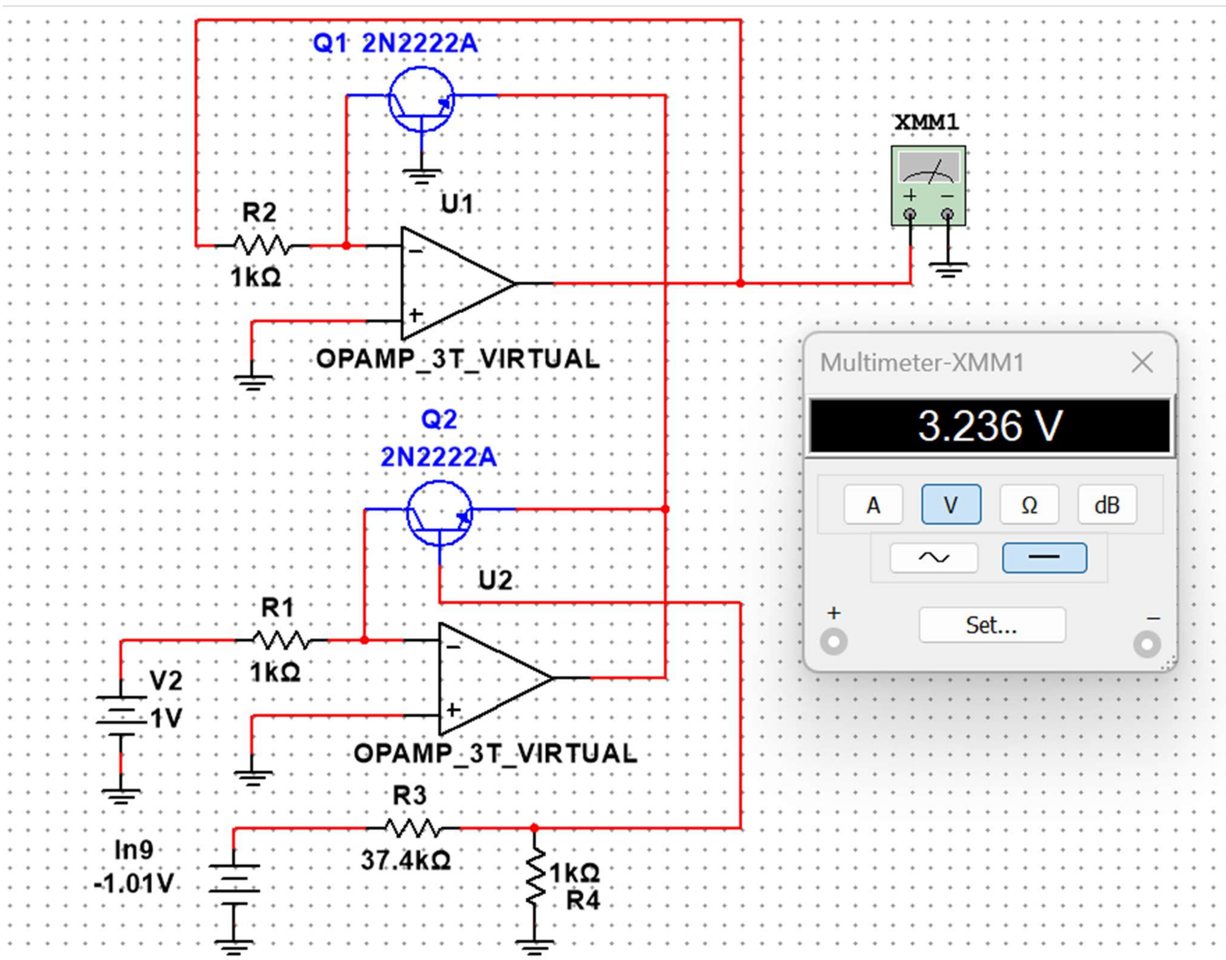
$V_o = e^{v_i}$,with $V_{ref} = 1V$

In the circuit shown above, the non-inverting input terminal of the op-amp is connected to ground. It means zero volts is applied to its non-inverting input terminal.

According to the **virtual short concept**, the voltage at the inverting input terminal of op-amp will be equal to the voltage present at its non-inverting input terminal. So, the voltage at its inverting input terminal will be zero volts.

Log amplifier with saturation current and temperature compensation:





Resistance Calculation

<u>Log Amplifier:</u>

(input to inverting terminal)

$$V_0 = -nV_T In\left(\frac{V_i}{R_1 I_s}\right)$$

$V_o = \frac{-kT}{q}\ln(\frac{Vi}{v_{ref}})$ where $V_{ref} = 1V$

$V_{o\ comp} = -\ (1+\frac{R_2}{R_{TC}})\ kt/q\ \ln(\frac{Vi}{v_{ref}})$

$V_T = \frac{-kT}{q} = -\ (\frac{RTC}{R_2+RTC})$

But $V_T = 26$ mv

$\frac{R_2}{R_{TC}} = 39.461$

$R_{TC} = 1$k ohm

$R_2 = 39$ k ohm

R_{TC} is a temperature sensitive resistance with a positive coefficient of temperature

<u>Antilog amplifier :</u>

$$V_0 = -R_f I_s e^{\left(\frac{V_i}{nV_T}\right)}$$

$V_o = -R_f I_S \exp\ (\frac{vi}{nv_T})$

$\frac{-kT}{q}\ (\frac{RT}{R_2+RTC})\ V_i = \ln(\frac{v_0}{v_{ref}})$

$\frac{-q}{kT} = \ (\frac{RTC}{R_2+RTC})$

$\frac{R_2}{R_{TC}} = 37.64$

$R_{TC} = 1$k ohm

$R_2 = 39$ k ohm

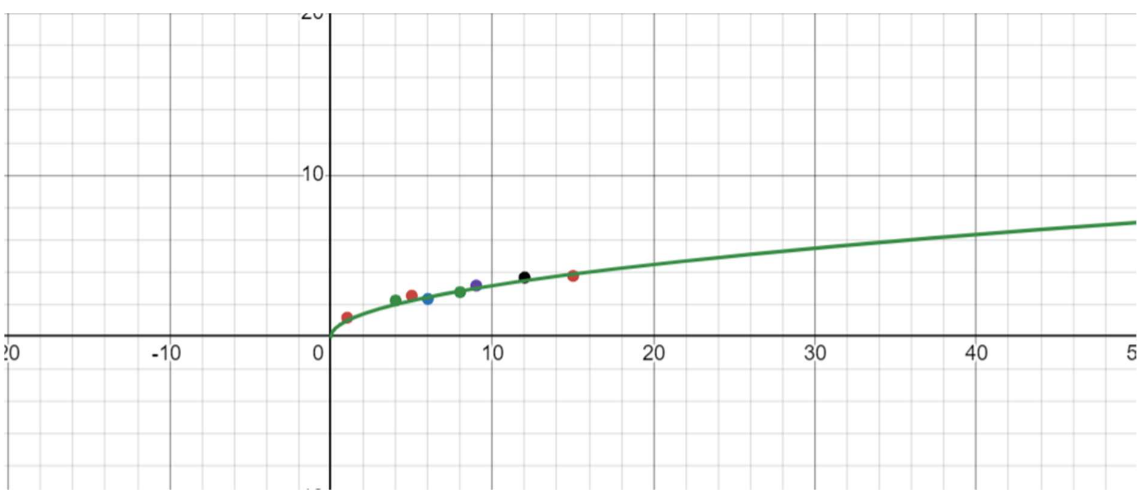
Results:

The designed circuit successfully computes the square root of the applied voltage with high accuracy. Simulation results demonstrate close between theoretical expectations and simulated values across a range of input voltages. Experimental validation further confirms the functionality and reliability of the circuit, with measured outputs closely matching simulated and theoretical values.

Observation Table:

Voltage (V_i)	Theoretical log	Practical log ($\ln(V_i)$)	Theoretical	Practical (square root)
1	0	0.2	1	1.18
4	1.38	1.40	2	2.24
5	1.60	1.72	2.23	2.54
6	1.79	1.81	2.44	2.34
8	2.079	2.06	2.82	2.76
9	2.19	2.09	3	3.16
12	2.48	2.53	3.46	3.66
15	2.708	2.8	3.87	3.76

Graph:



Conclusion:

The circuit design presented in this report effectively computes the square root of the applied voltage through a multi-stage process involving logarithmic amplification, multiplication, and antilogarithmic conversion. The results obtained from simulations and experiments demonstrate the accuracy and reliability of the circuit. This design holds significant potential for various applications requiring precise square root computation within electronic systems.

References:

1. Linear Integrated Circuits by Roy Chowdhury

2. Op-Amps and Linear Integrated Circuits by Ramakant Gayakwad

3. https://www.tutorialspoint.com/