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Roll Number: CB.EN.U4ECE19025
Subject: 19ECE212 Linear Integrated Circuits
Class / Batch: ECE-A
Assignment No.: **2**
Due Date: April 25, 2021

Honor Pledge

I, **Muthukumar L, CB.EN.U4ECE19025** hereby affirm on my honor as an Amritian, that I have neither received nor provided any assistance or used any unauthorized material, in completing this assignment.

(**Muthukumar L**)

LIC ASSIGNMENT-2

1(i). Given, $V_A = 100V, \beta = 200, I_o = 2mA\ and\ let\ V_{CC} = 5V$

$$I_o = \frac{I_{REF}}{1 + \frac{2}{\beta}}$$

Where I_o is the current that is being mirrored.

we get $I_{REF} = 2.02mA$

For transistor 2N2222, $V_{BE} \approx 0.6V$

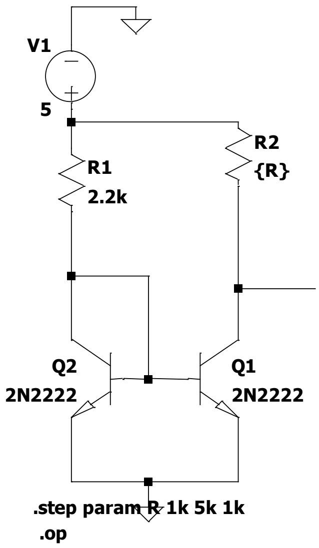

Fig 1.1

$$I_{REF} = \frac{V_{CC} - V_{BE}}{R_1}$$

$$R_1 = \frac{V_{CC} - V_{BE}}{I_{REF}}$$

$$R_1 = \frac{5 - 0.6}{2 \times 10^{-3}} = 2.2K\Omega$$

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--- Operating Point ---

V(n003):	0.714383	voltage
V(n002):	0.673013	voltage
V(n001):	5	voltage
Ic(Q2):	0.00194721	device_current
Ib(Q2):	9.79931e-006	device_current
Ie(Q2):	-0.00195701	device_current
Ic(Q1):	0.00194801	device_current
Ib(Q1):	9.79925e-006	device_current
Ie(Q1):	-0.00195781	device_current
I(R2):	0.00194801	device_current
I(R1):	0.00196681	device_current
I(V1):	-0.00391482	device_current

Therefore a current of 2mA flows through R_2 in fig 1.1

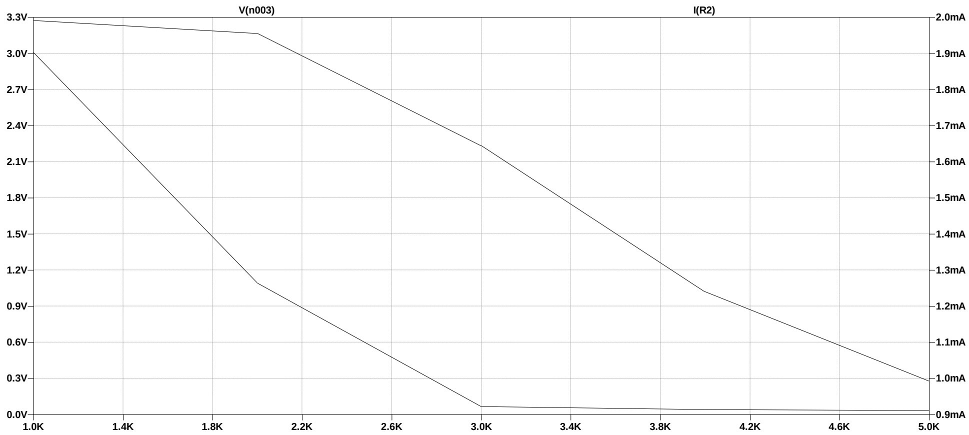

Fig 1.2

We can interpret from the graph in fig 1.2 that when R_2 = 3kΩ ,output voltage becomes minimum. Which means the maximum voltage across the load would be 3kΩ × 1.65mA = 4.95V.

The voltage compliance of the current source is 4.95V.

(ii) Given, for pnp transistor $V_A = 50V$,

For npn current source from fig 1.3, $V_A = 100V,\ I_C = 2mA$

We know, from theoretical calculation $A_V = g_m * (ro_1 \parallel ro_2)$

$ro_1 = \frac{V_A}{I_C}$ = 50kΩ

$ro_2 = \frac{V_A}{I_C}$ = 25kΩ

also, $g_m = \frac{I_C}{V_T} = \frac{2\text{mA}}{25\text{m}V}$ = 0.08A / V

$$A_v = 0.08 * \frac{50k\Omega*25k\Omega}{50k\Omega+25k\Omega}$$
$$A_v = 0.08 * 16.67k\Omega$$

$$A_v = 1333.33 \text{ V/V}$$

$$A_v(dB) = 20\, log_{10}(1333.33)$$
$$A_v \approx 62.5\text{dB}$$

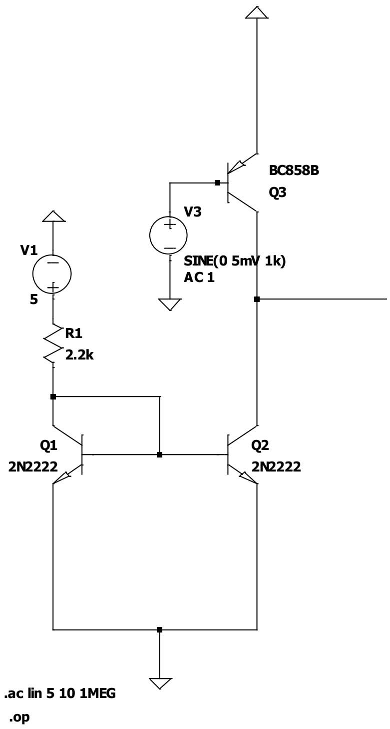

Fig 1.3

from simulation in fig 1.4 we get the gain approximately equal to 60db.

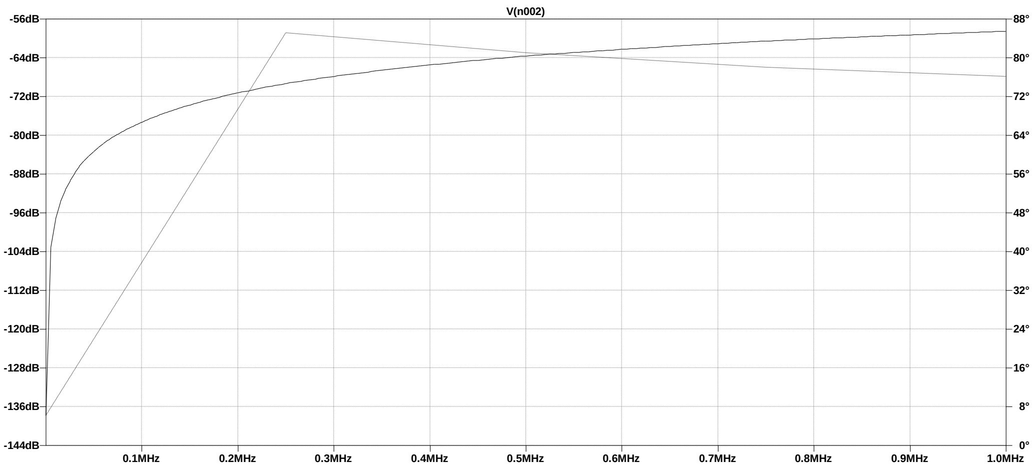

Fig 1.4

The maximum possible output is V_{CC}.

Therefore, the maximum input voltage that can be applied = $\frac{V_{CC}}{A_V}$

= 3.75mV.

2. A current source is modelled such that the current through the RTD is limited to 100µA.

We will use a variable resistor (RTD) whose resistance varies according to temperature, which can be calculated by using the formula

$$R = R_{ref}\left[1 + \alpha(T - T_{ref})\right] \qquad \rightarrow 1$$

$where\ R_{ref}$ is given as 100Ω at $T_{ref} = 0^0$ C.

α = 3.85*10^{-3} / ^{0}C.

So from 1 at temperatures:

-45^0C	R = 82Ω
400^0C	R = 256Ω
455^0C	R = 272Ω

At 400^0C we calculated R = 256Ω . After measuring the voltage at the non inverting terminal of the op amp, it is found to be 4.45mV. So to provide this voltage as the reference to the inverting terminal, we use a voltage divider circuit, we assume R_4 to be 30Ω and R_3 to be 99970Ω. This voltage divider is connected to the inverting terminal. So the diode will start to conduct when the temperature reaches 400^0C. A LED diode is connected to a 1kΩ resistor to limit the current to 10mA. The output is taken across R_6=500Ω so that the output voltage doesn't exceed 5V. We can from the fig 1. that the output is high after resistor increases more than 256Ω.

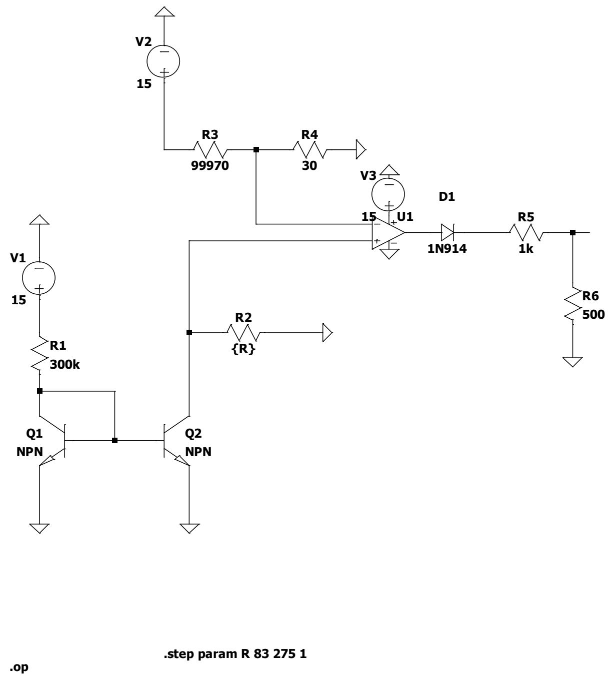

Fig 1.5

The fig 1.6 gives the relation between current through diode and the variable resistance.

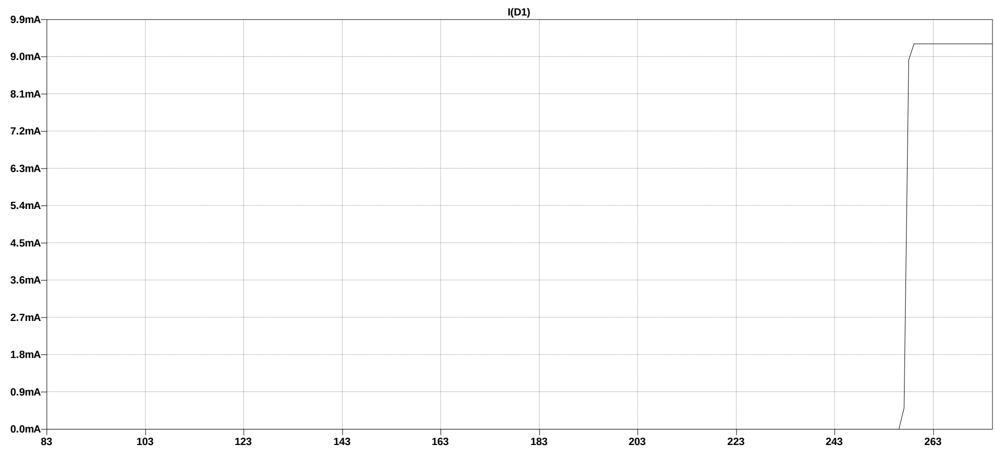

Fig 1.6

The fig 1.7 gives the relation between the output voltage and the variable resistance.

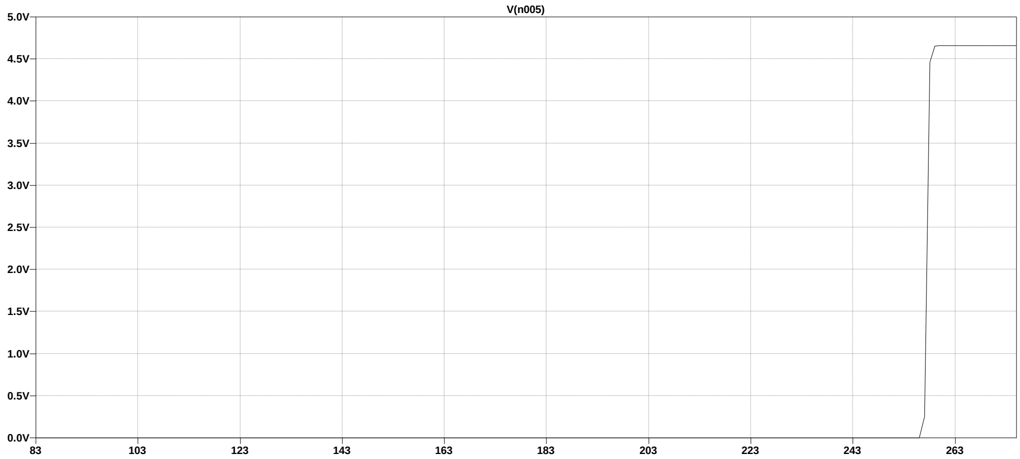

Fig 1.7

3. A current source is modelled such that the current through the RTD is limited to 100µA.

We will use a variable resistor (RTD) whose resistance varies according to temperature, which can be calculated by using the formula

$$R = R_{ref}\left[1 + \alpha(T - T_{ref})\right] \qquad \rightarrow \quad 1$$

$where\ R_{ref}$ is given as 100Ω at $T_{ref} =\ 0^0$ C.

α = 3.85*10^{-3} / ^{0}C.

So from 1 at temperatures:

25^0C	109.625Ω
45^0C	117.325Ω

Since the circuit should work and light the LED diode when the temperature is between 25^0C and 45^0C, we will implement based on the logic of window comparator. Therefore at 109.625Ω and 117.325Ω , we need to find out the corresponding voltages using the simulation. The voltage is around 2.25mV at 109.625Ω and at 117.325Ω the voltage is around 2.4mV . Therefore the reference voltages are 2.25mV and 2.4mV. To provide this voltage, we use voltage divider circuits. We assume R_4 to be 160Ω and find R_3 to be 999840Ω, similarly R_5 to be150Ω and R_6 to be 999850 Ω. An LED diode with 1kΩ resistance is connected to limit the current through the diode to 10mA. We can see that from fig 1.8 from 109.625Ω to 117.325Ω, output becomes high.

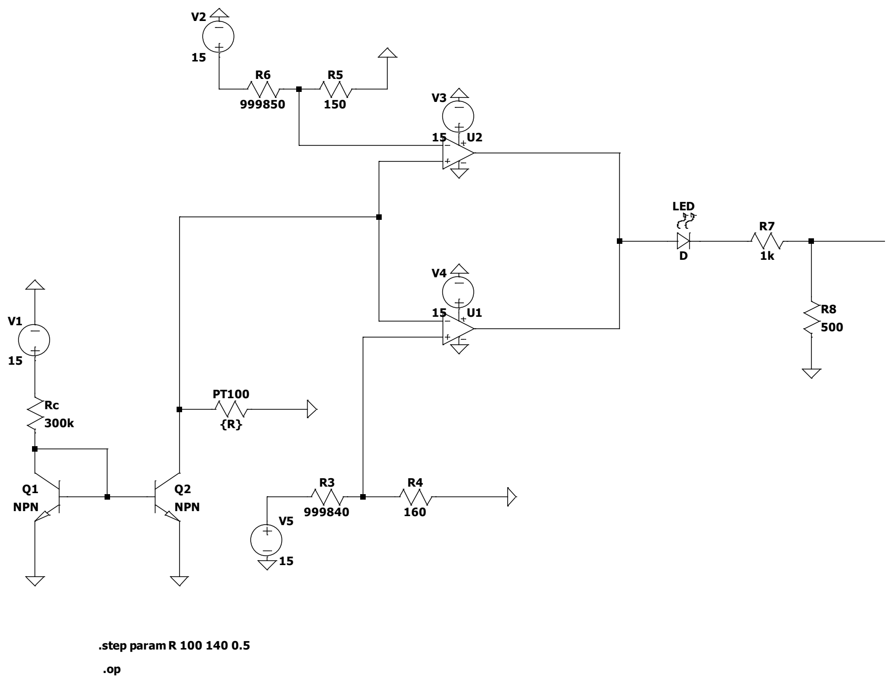

Fig 1.8

The fig 1.9 gives the relation between current through diode and the variable resistance.

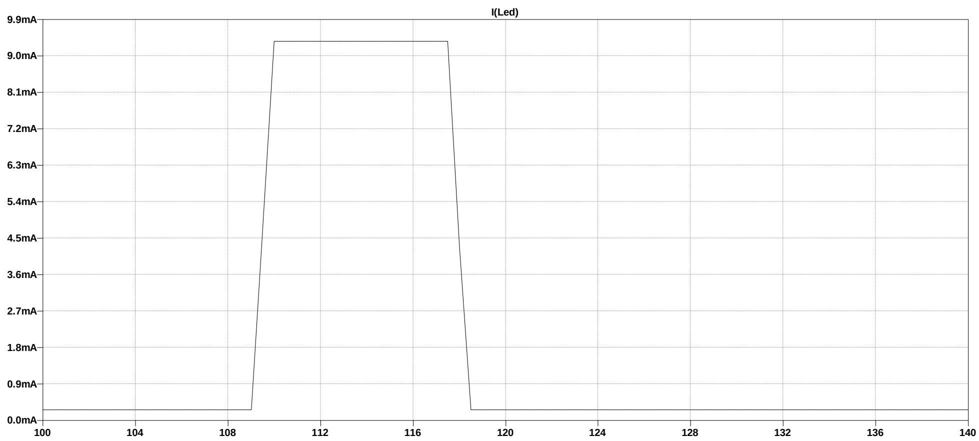

Fig 1.9

The fig 1.10 gives the relation between the output voltage and the variable resistance.

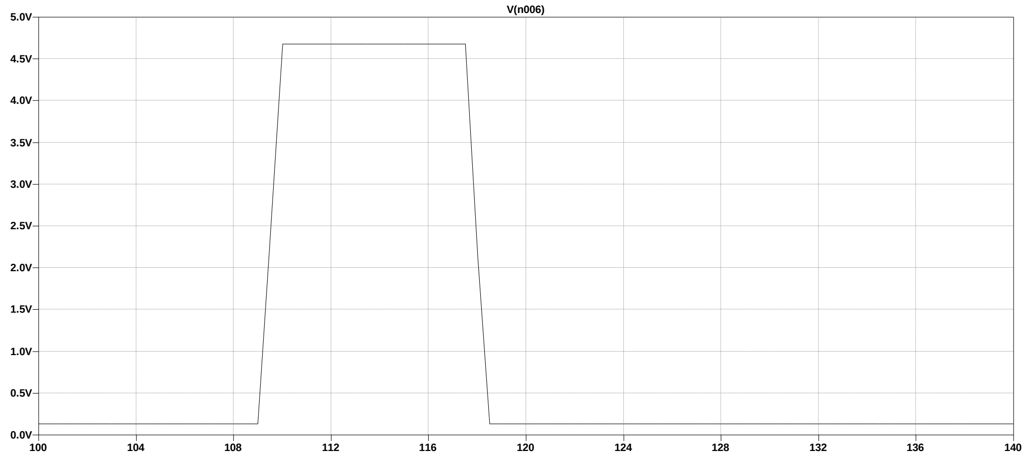

Fig 1.10

4. We use two varying voltage sources Vi1 and Vi2 to realize a pressure sensor. This is made possible with the help of .step parameter in LTspice. Vi_1 is the output from the pressure transducer and Vi_2 is used to measure changes in pressure.The gain of the instrumentation amplifier in fig 1.11 is given by,

$$v_0 = \frac{R_6}{R_5}\left(1 + \frac{R_1}{R_2}\right) v_{id}$$

Since R_6=R_5, R_1=R_2

$$v_0 = 2(v_{id})$$

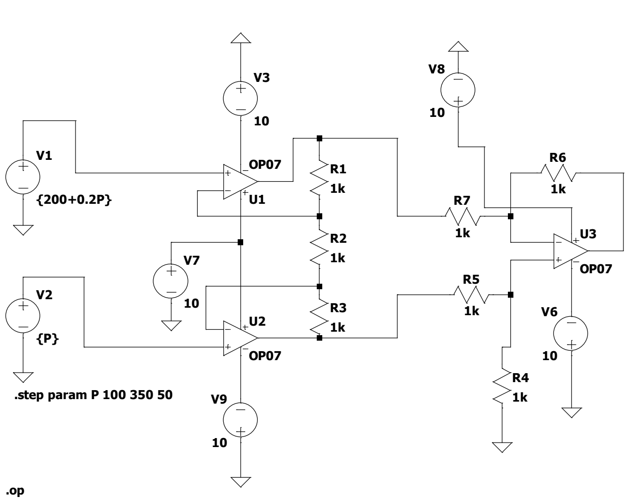

Fig 1.11

This circuit works similar to the temperature sensor but here when the pressure changes the differential input changes which changes the final output.

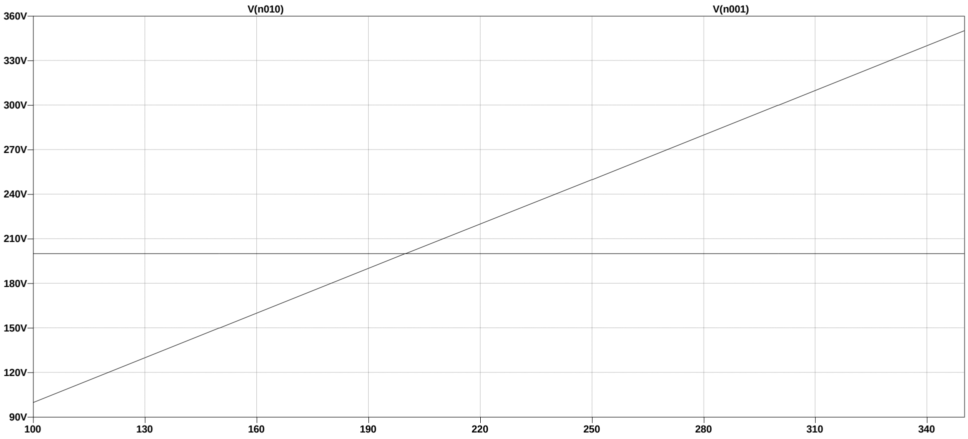

Fig 1.12

References:

[1] Neamen D A, Electronic Circuit Analysis and Design. New York: McGraw-Hill, 2001.

[2] Sedra A and Smith K C, Microelectronic circuits, 6th ed. New York: Oxford University Press, 2010.