Nutthawat Panyangnoi Student ID: G08285564

EGR 24L Introduction of Circuit Analysis Laboratory

Professor Yu Zheng

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Lab#2
Equipment/Supply Basics/ VDR, CDR

Introduction:

This is the second lab this week we explored the fundamental how to construct a circuit on a breadboard. We get to learn more equipment which are DMM, Power Supply Generator, wires, probes, Breadboard, fuses, and resistors. In the first part of the lab, professor teach us how to read the resistor color code and how to calculate its resistor value. Then, he explains how the DMM works, and brief explain functional and mode in DMM. Furthermore, he shows us how to connect a Breadboard in right way, connect transistor/resistor in the rail and briefly explain technique how breadboard make a connection and become a circuit. Then, we group up with a partner and start to do the lab following the spec sheet.

My partner and I started to grab cables and toolbox and we start off from measure all resistors value and record it. Then, construct a circuit follow the provided instruction. After we construct each circuit, we connect it to power supply then measure the value again compare them to calculate value. We constructed total of three circuits with the record of values. Later we apply Ohm's law, Voltage Division Rule (VDR) and Current Division Rule (CDR) to compare the experimental value to theoretical values whether it identical or not.

Procedure:

1. We begin the lab by learn how to read resistor color code and explore the connection pattern of a breadboard. After that we used DMM to measure resistance value from all resistors that we can found.

2. We draw a nodes and rails on a breadboard, visualize how to construct a circuit on the breadboard.

3. We follow the instruction on the spec sheet. Construct a first circuit (series resistors) and connect it with power supply then we measure voltage across, resistor values and determine current value. After that we calculate everything on a paper to compare the value from measurement to theoretical value. To validate that it is correct or why

the value is off. We found out that the value from theoretical and experiment were close. It just slightly off by 2%-5%, we expect it could come from components have its own tolerance and all equipment also has slightly resistance.

4. We continue by read the spec sheet and constructing a second circuit (parallel resistors) and connect it with power supply then we measure voltage across, resistor values and determine current value. After that we calculate everything on a paper to compare the value from measurement to theoretical value. We apply Current Division Rule (CDR) to determine the calculate values compare to the measurement. To validate the value, we investigate a data and find a conclusion whether value is off or matched. We found out that the value from theoretical and experiment were close. It just slightly off by 2%-5%, we expect it could come from components have its own tolerance and all equipment also has slightly resistance.

5. Lastly, we continue constructing a third circuit (3 parallel resistors) and connect it with power supply then we measure voltage across, resistor values and determine current value. After that we calculate everything on a paper to compare the value from measurement to theoretical value. We apply Current Division Rule (CDR) to determine the calculate values compare to the measurement. To validate the value, we investigate a data and find a conclusion whether value is off or matched. We found out that the value from theoretical and experiment were close. It just slightly off by 2%-5%, we expect it could come from components have its own tolerance and all equipment also has slightly resistance.

Conclusion:

In summary, this week we hand on learned how to construct the circuit in real world. We also got to use all different tools and equipment, but DMM is very stood out for me. We use DMM to measure the resistance value, voltage value, and current value. I found the lab is informative, significant, and fun, the more we learn about the circuit the more complexity it gets but also enjoyment.

Appendixes:

Part 1: Read resistor color code and explore the connection pattern of a breadboard.

a. Resistor are color-coded. Each color corresponds to a number:

Color	Values	Multiplier
Gold	N/A	10^{-1}
Black	0	10^{0}
Brown	1	10^{1}
Red	2	10^{2}
Orange	3	10^{3}
Yellow	4	10^{4}
Green	5	10^{5}
Blue	6	10^{6}
Violet	7	10^{7}
Grey	8	10^{8}
White	9	10^{9}

The value from the table presents the color value it each band. The first two band represent the mantissa/coefficient of a number; the third band is the exponential value. The last band is either gold or silver which represents the tolerance. None is $\pm$ 20%, Gold is $\pm$ 5%, and silver is $\pm$ 10%

1. Part 1: answer the following questions.

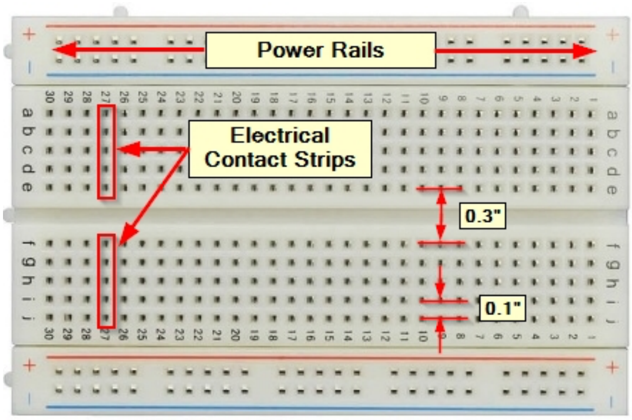
Resistor color band	Resistor Value (Ohm or kOhm)	Tolerance$\pm$
What is Red, Red, Red	$(22 \times 10^2) = 2.2\ kOhm$	$\pm 20\%$
What is Brown, Black, Orange?	$(10 \times 10^3) = 10\ kOhm$	$\pm 20\%$
What is Orange, Green, Black	$(35 \times 10^0) = 35\ Ohm$	$\pm 20\%$

Part1B is measuring resistance.

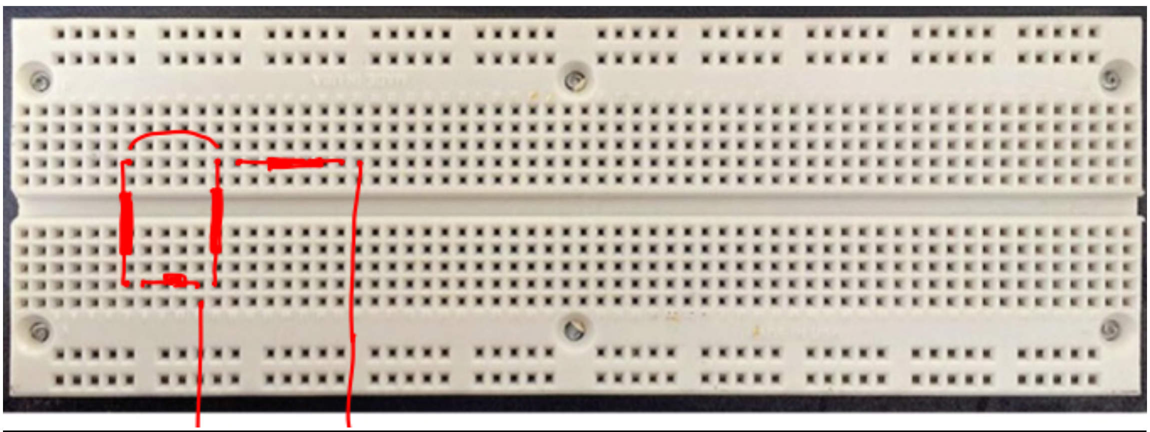
Nominal value(ohm)	Measured value(ohm)
1k	996 Ω
5k	4998.5 Ω

Part 1C drawing nodes and rails on a breadboard.

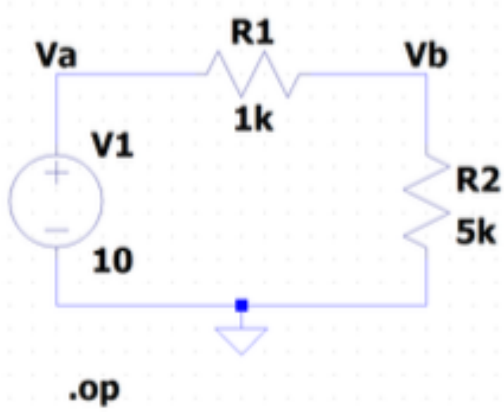
We know that.



Example drawing a node and rails



Part 2: Basic Series Measurement, Votlage Division Rule (VDR)



a. Why is it important limit the amperage and check ground connections before powering on a circuit?

ANSWER: It is important to limit the amperage because highest power can cause of burning circuit and equipment and can be harmful too. Even though the circuit and resistors have tolerance, but it would not be enough for higher amperage. Ground connection is also very important for the safety because ground wire creates to direct path for excess electrical current to flow to different direction instead though the electrical devices. The ground connection is protecting people from electric shock.

e. How does this measured series-resistance compare to the theoretical series-resistance (in part c)? Why must the power supply be physically disconnected from the breadboard when you measure the series-resistance value (hint: the power supply has its internal resistance)?

ANSWER: See the measurement value and theoretical value below. It is important to disconnected from breadboard because each component has its internal resistance it will cause the huge inaccurate of measurement values.

f. What is the voltage across the 1kOhm resistor? What is the voltage across the 5kOhm resistor? Record these two voltages. Do these two resistor voltages add up to the power supply voltage?

ANSWER:

$V(R1)_{exp} = 1.61\ V\ and\ V(R2)_{exp} = 8.25\ V$

yes, it add up to power supply voltage. 8.25+1.61= 9.86 close to 10V

$V(R1)_{th} = 1.6666667\ V\ and\ V(R2)_{th} = 8.3\ V = 10\ V$

Part 2: data record.

List	Series-Resistance(kOhm)
Theoretical: add two measure resistances	$R_{total} = 6\ kOhm$
Actual Measure the series resistance	5.989 kOhm
Ohm's Law voltage divide by current	$I(R1)$=1.61V/0.00167 = 0.996 kOhm $I(R2)$= 8.25V/0.00137 = 5.989 kOhm

Resistor in series, VDR

Vs(DMM)	9.98 V
R1(DMM)	996 Ohm
R2(DMM)	4997 Ohm
R1+R2(th calc)	$R_{total} = 6\ kOhm$
R1+R2(DMM)	5.989 kOhm
R1+R2(Ohm law calc)	$\approx$ 5.989 kOhm
V1(DMM)	1.61V
V2(DMM)	8.25V
V1+V2(DMM)	9.86 V
Is(DMM)	0.00164 A

Verify the value from experiment value to theoretical value

Source =10 V connect in series with Resistors 1 kohm and 5 kohm.

$$V_{th\,R1} = 10 * \left(\frac{1}{1+5}\right) = \frac{5}{3}V \approx 1.6667\,V$$

$$V_{th\,R2} = 10 * \left(\frac{5}{5+1}\right) = \frac{25}{3}V \approx 8.3\,V$$

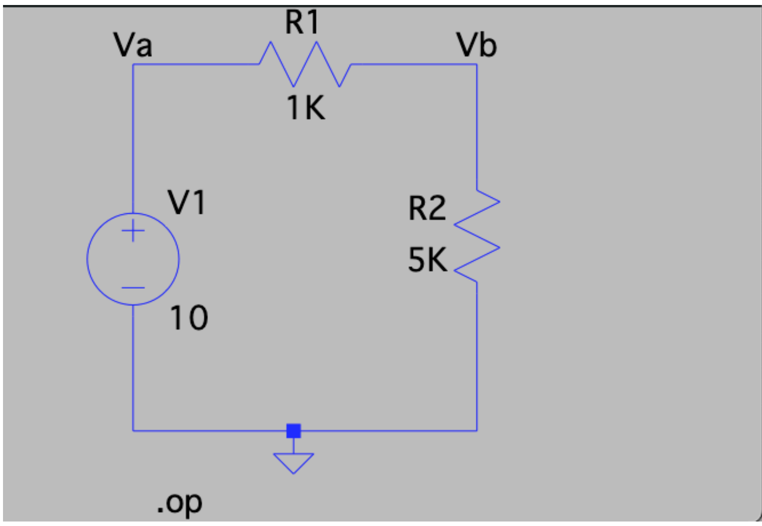
$$V(R1)_{exp} = 1.61\,V$$

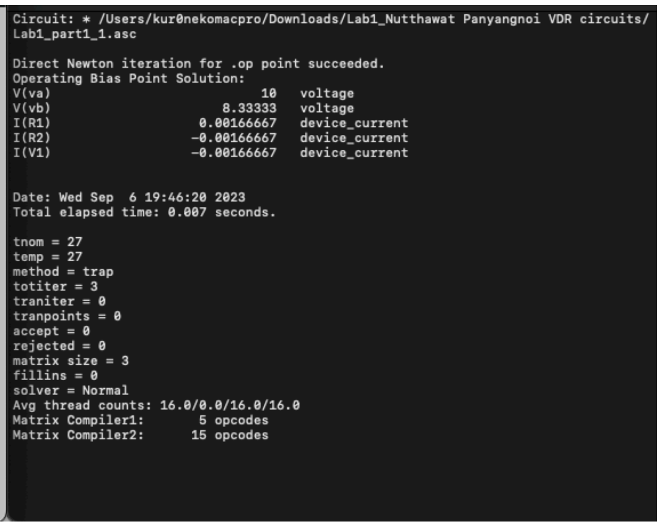
$$V(R2)_{exp} = 8.25\,V$$

Calculate value are very close to Experiment value!

Vs(calc)	10 V
R1(calc)	1000 Ohm
R2(calc)	6000 Ohm
R1+R2(th calc)	$R_{total} = 6\,kOhm$
V1(calc)	1.66667V
V2(calc)	8.3V
V1+V2(calc)	10 V
Is(clac)	0.0016666 A

Use Lt spice to compare and validate calculation value.





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Circuit: * /Users/kur0nekomacpro/Downloads/Lab1_Nutthawat Panyangnoi VDR circuits/
Lab1_part1_1.asc

Direct Newton iteration for .op point succeeded.
Operating Bias Point Solution:
V(va)                        10   voltage
V(vb)                   8.33333   voltage
I(R1)                0.00166667   device_current
I(R2)               -0.00166667   device_current
I(V1)               -0.00166667   device_current


Date: Wed Sep  6 19:46:20 2023
Total elapsed time: 0.007 seconds.

tnom = 27
temp = 27
method = trap
totiter = 3
traniter = 0
tranpoints = 0
accept = 0
rejected = 0
matrix size = 3
fillins = 0
solver = Normal
Avg thread counts: 16.0/0.0/16.0/16.0
Matrix Compiler1:       5 opcodes
Matrix Compiler2:      15 opcodes
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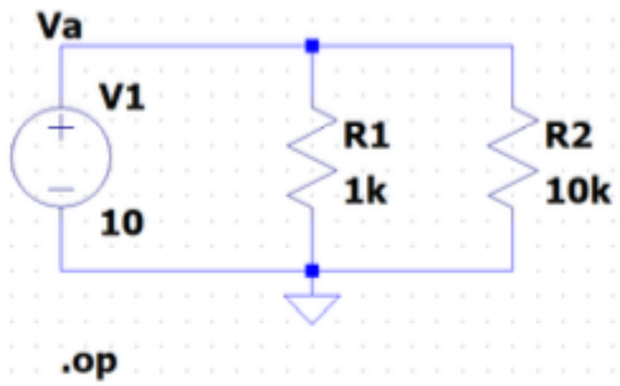
Ratio of Resistors $\frac{R_1}{R_2} = \frac{1}{5}$

Ratio in Voltage $\frac{VR_1}{VR_2} = \frac{\frac{5}{3}}{(\frac{25}{3})} = \frac{1}{5}$

VDR confirmed because the ratio of voltages drops and resistors are equal hence voltage division rule is confirmed.

Part3: Basic Parallel Measurements, Current Division Rule (CDR)



a. Use DMM to measure the actual resistance of the1kOhm and the 10kOhm resistors and record these values. Calculate the theoretical equivalent parallel resistance RP,thy using the measured resistor values. 1/Req = 1/R1 + 1/R2

ANSWER:

$$R_{P,thy} = \frac{1}{Rt} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1000} + \frac{1}{10000} = \frac{11}{10000}$$

$$\frac{1}{Rt} = \frac{Rt}{1} \rightarrow \frac{10000}{11} = 909$$

Therefore, $R_{P,thy} = 909\ Ohm$

b. Measure value from experiment How does this value compare to part a?

ANSWER:

We measure $Rt_{experiment} = 905\ Ohm$

d. Using the measured supply voltage and the measured current, calculate the equivalent parallel-resistance RP,Ohm using Ohm's law. How does this value compare to 3a and 3b?

<u>Theoretical calculation</u>

$$I_2 = I_{total} * \left[\frac{R_2}{R_1 + R_2}\right]$$

$$I_{total} = \left[\frac{V_1}{R_{eq}}\right] = \left[\frac{10}{909.09}\right] = 0.0110A = 11\ mA$$

Find current I_{R2} and I_{R1} by apply rule CDR.

$$I_{R2} = I_{total} * \left[\frac{R_1}{R_1 + R_2}\right]$$

$$I_{R2} = 11mA * \left[\frac{1000}{1000+10000}\right] = 1 \text{ mA}$$

$$I_{R1} = I_{total} * \left[\frac{R_2}{R_1 + R_2}\right]$$

$$I_{R1} = 11mA * \left[\frac{10000}{1000+10000}\right] = 01 \text{ mA}$$

Calculate Ratio of I_{R1} *and* I_{R2}

$$I_{R1} + I_{R2} = \left(\frac{10mA}{1mA}\right) = 10$$

$$\frac{1}{R1}:\frac{1}{R2} = \left(\frac{(\frac{1}{1000})}{\frac{1}{10000}}\right) = 10$$

ANSWER:

The result from the experimental and theoretical is very close with the ohm's law as well. The result is also close to 3a and 3b. Please see detail of the calculation below.

Part3: Data record

Vs(DMM)	9.96V
R1(DMM)	996 Ohm
R2 (DMM)	9859 Ohm
R1//R2 (theoretical cal)	909 Ohm
R1//R2 (DMM)	905 Ohm
R1 // R2 (Ohm's law calc)	1/996+1/9859= 900 Ohm
Is (DMM)	11 mA
I1(DMM)	1 mA
I2 (DMM)	10 mA

Using Ohm's law

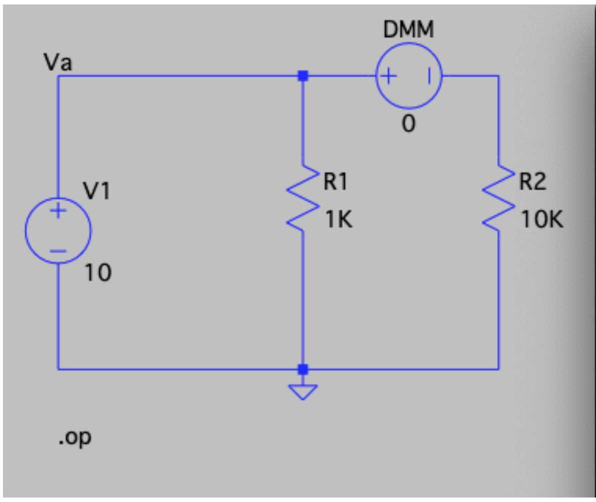
Find R1 V/I = R → 9.96V/0.01 A = 996 Ohm

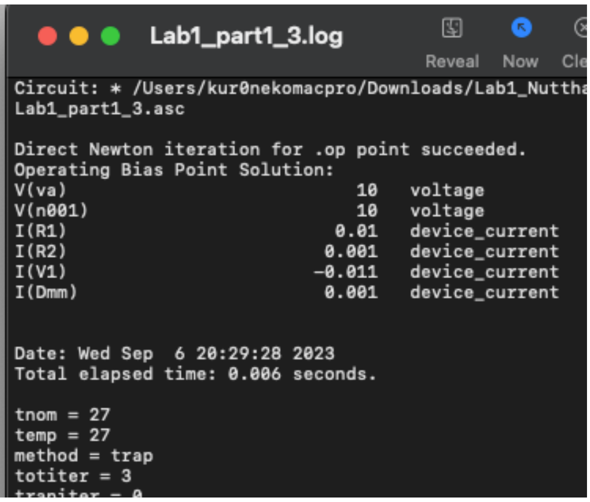
Find R2 V/I = R → 9.96V/0.001 A = 9859 Ohm

$$R_{P\ Ohm} = \frac{1}{Rt} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{996} + \frac{1}{9859} = 900\ Ohm$$

e. Now measure the current in 1kOhm branch and 10kOhm branch. Does the sum of the two branch currents equal the source current? How is the main current distributed among the two branch currents?

ANSWER: The value is identical. I did check result validation by using Ltspice data vs calculation data vs experiment data.





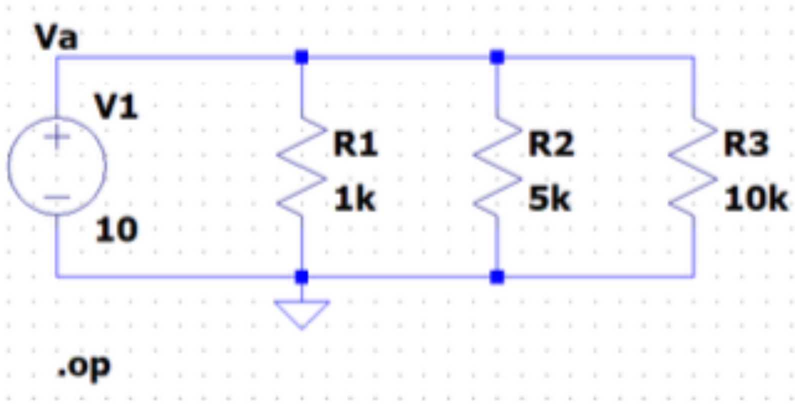
Explain the three current Is, I1, I2 with CDR:

I(R1)=10 mA and I(R2)= 1mA 10 mA+1 mA = 11 mA which is equivalent value of Is

This circuit is confirmed CDR because the ratio of opposite branch resistance to the sum of all resistances, multiple by the total current.

The result of the experimental values is identical to theoretical value.

Part 4: continue last circuit.



g. Without making any calculations, what approximate value would you estimate for each of the three-branch current through each resistor? Explain your reasoning.

ANSWER:
I will estimate current value of (I)R1+(I) R2+(I) R3 = Is according to CDR rule states that the current in any of the parallel branches of a parallel circuit is equal to the ratio of opposite branch resistance to the sum of all resistances, multiple by the total current.

CDR theoretical calculation of conductance G based on actual value of R1,R2,R3 (see detail calculation below)

Measured exp	Theoretical Value	G exp	G Theoretical
R1=996 Ohm	R1=1000 Ohm	G1=0.00100401	G1=0.001
R2=4996 Ohm	R2= 5000 Ohm	G2=0.00020016	G2=0.0002
R3=9859 Ohm	R3= 10000 Ohm	G3=0.0001043	G3=0.0001

CDR Current Division Calculation vs measurement

Is calculation mA	13 mA	Is measured (mA)	13 mA
I(1) calc	10 mA	I(1) measured	10 mA
I(2) calc	2 mA	I(2) measured	2 mA
I(3)calc	1 mA	I(3) measured	1 mA

h. Calculate the currents i1, i2, and i3 using the CDR from the measured values of R1, R2, R3, and the measured source current iS. Then use DMM to measure the individual branch currents i1, i2, and i3.

Theoretical value Calculation

Apply Ohm's law $V = IR, I = \frac{V}{R}$

$$I(R1) = \frac{10}{1K} = 10\ mA$$

$$I(R2) = \frac{10}{5K} = 2\ mA$$

$$I(R3) = \frac{10}{10K} = 1\ mA$$

Calculate the ratio we obtain the mA is 10:2:1

Find $I_{total} = I_{R1} + I_{R2} + I_{R3}$ → = 10+2+1 = 13 mA

Apply CDR

$I_{R1} = 13 * \left[\frac{10}{13}\right]$ ≈ 10 mA

$I_{R2} = 13 * \left[\frac{2}{13}\right]$ ≈ 2 mA

$I_{R1} = 13 * \left[\frac{1}{13}\right]$ ≈ 1 mA

CDR is verified due to the ration of current is the same per ratio of conductance.

<u>Experiment value measured.</u>

R1 = 996 Ohm G1= 1/996 =0.00100401

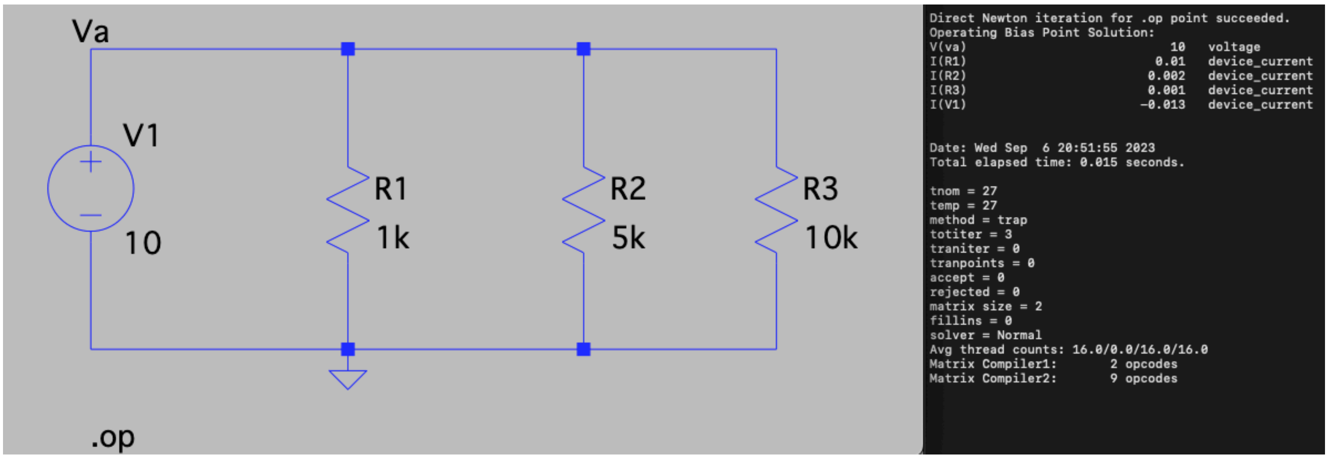
R2 =4996 Ohm G2=1/4996 = 0.00020016

R3 = 9859 Ohm G3=1/9859 = 0.0001043

Therefore, the value is identical to theoretical value.

General form of CDR based on conductance G:G=1/R

We verify the theoretical value and experimental value by check on Lt spice.



I(R1):I(R2):I(R3) units is in mA	I(R1)=10: I(R2)=2: I(R3)=1
Ratio of 1/R1: 1/R2:1/R3 unit is in mMohn	1/1000=0.001: 1/5000=0.0002: 1/10000=0.0001
Simplified ratio in integers	10:2:1
CDR confirm Yes or No	Yes