Laboratory 4 - Measuring Resistance Using the Wheatstone Bridge

SPICE Simulation

Problem 1

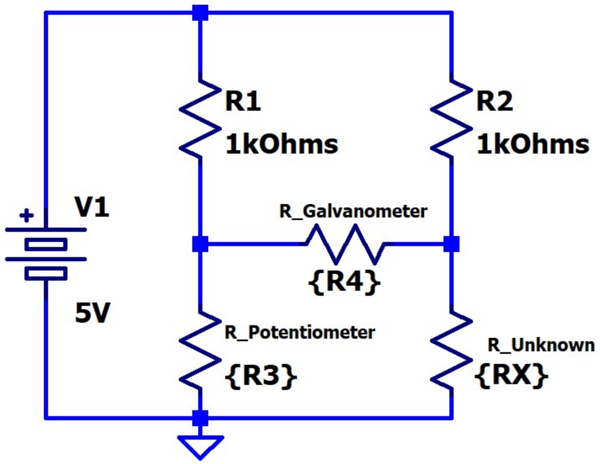

Fig 1. Circuit Diagram

1. Based on above mentioned procedure derive equation.

$$-I_1R_1 - I_gR_g + I_2R_2 = 0$$

$$I_gR_g - I_3R_3 + I_4R_4 = 0$$

$$I_g = 0$$

$$I_2 = I_4\ ;\ I_1 = I_3$$

$$\frac{I_1R_1}{I_1R_3} = \frac{I_2R_2}{I_2R_4}$$

$$\frac{R_1}{R_a} = \frac{R_2}{R_x}$$

$$\frac{R_1}{R_x} = \frac{R_2}{R_b}$$

$$\frac{R_2}{R_1} = \frac{R_x}{R_a} = \frac{R_b}{R_x}$$

$$R_x = \sqrt{R_a R_b}$$

2. The minimal current can be measured by the current meter and internal resistance of the current meter can play an important role for measurement accuracy. Using the following values for the components given in Figure 1, perform PSPICE simulation to obtain the resistance of R3 given current and resistance of R4 and complete **Table 1**.

For R4 1kOhms

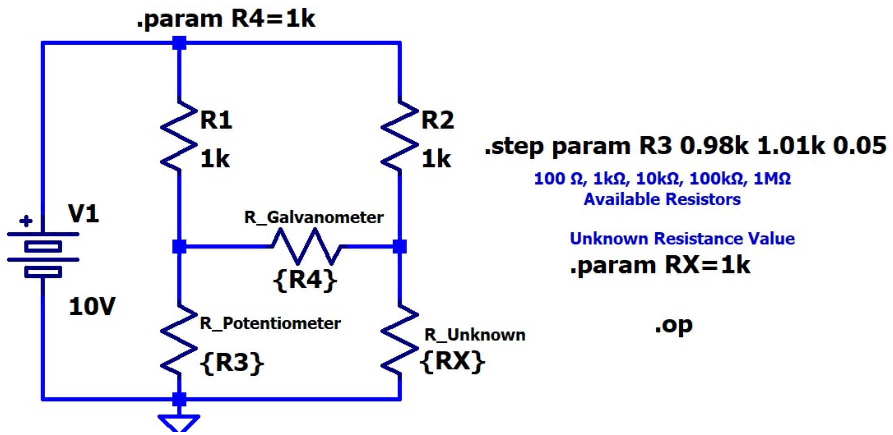

Fig 2a. Circuit Diagram in Reference with **Table 1**

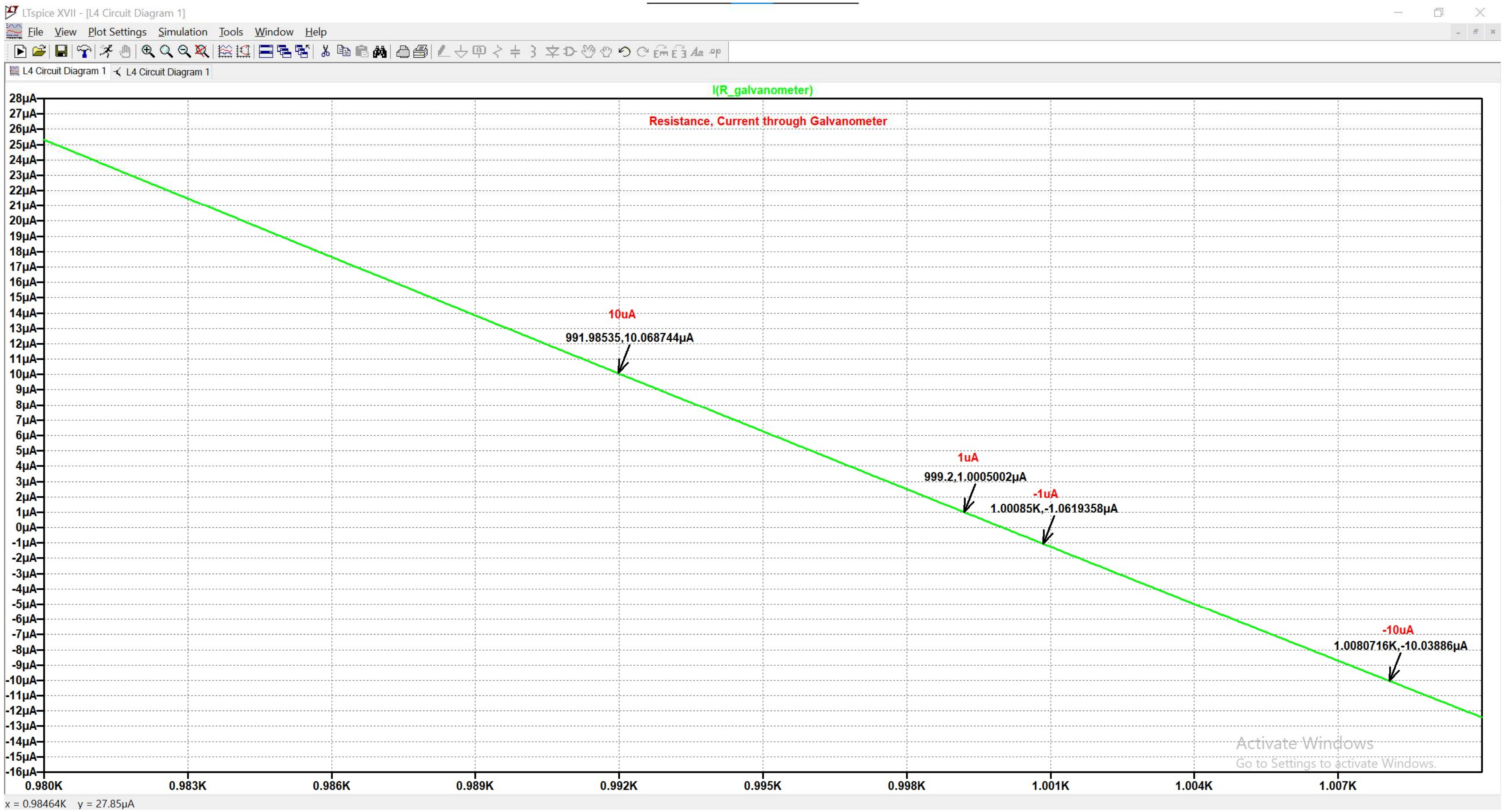

Fig 2b. Galvanometer Current Sensitivity

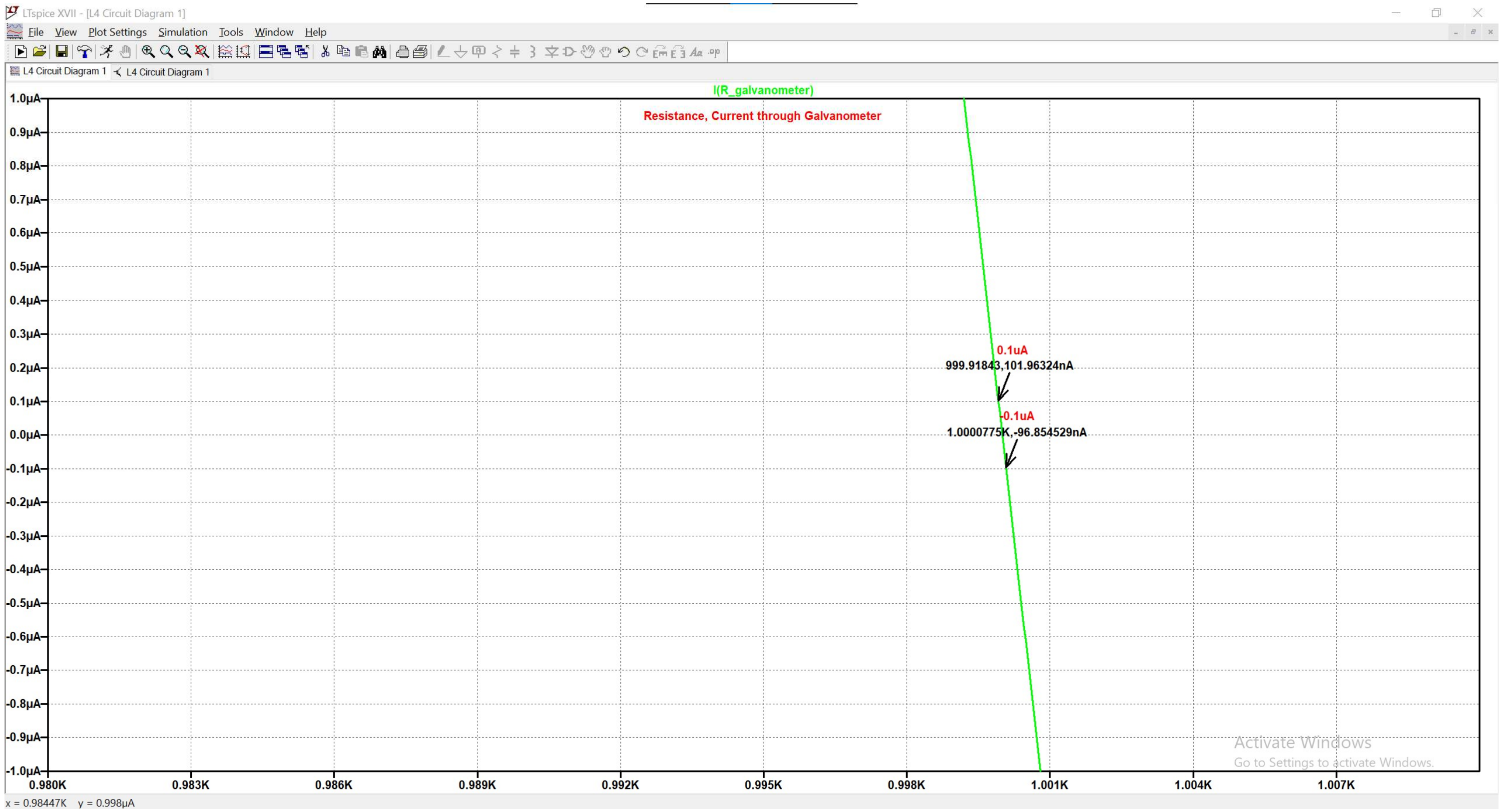

Fig 2c. Galvanometer Current Sensitivity

For R4 10 Ohms

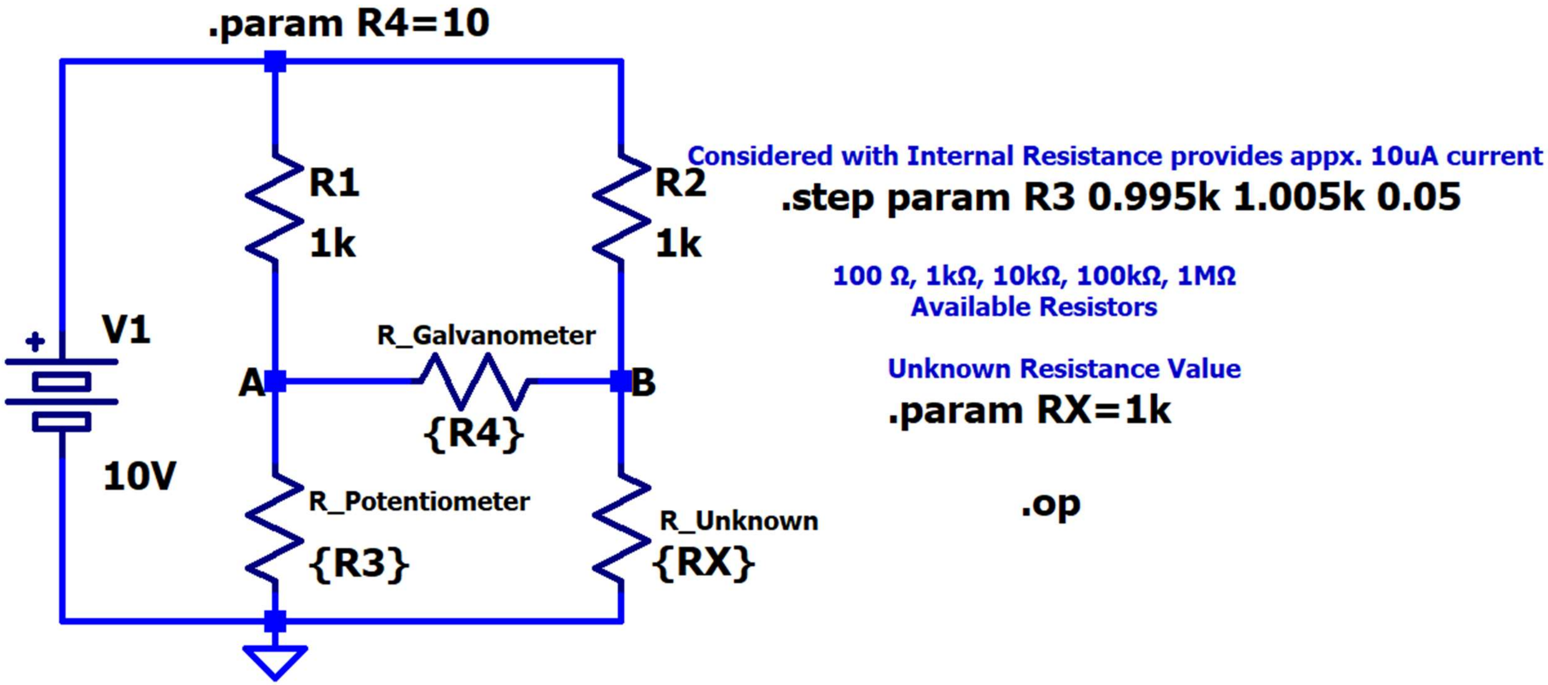

Fig 3a. Circuit Diagram

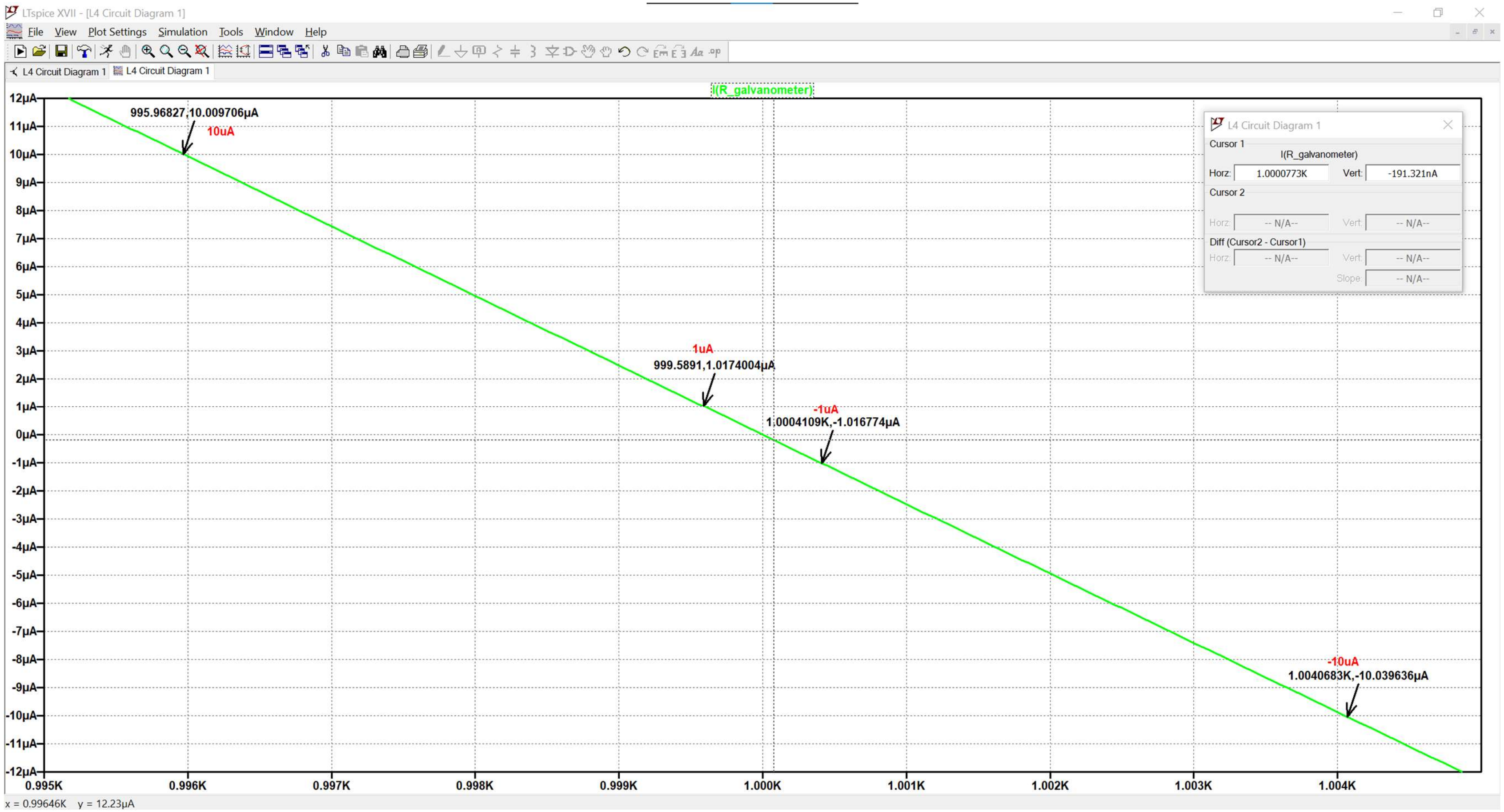

Fig 3b. Current Meter with Sensitivity R4 around 10Ohms

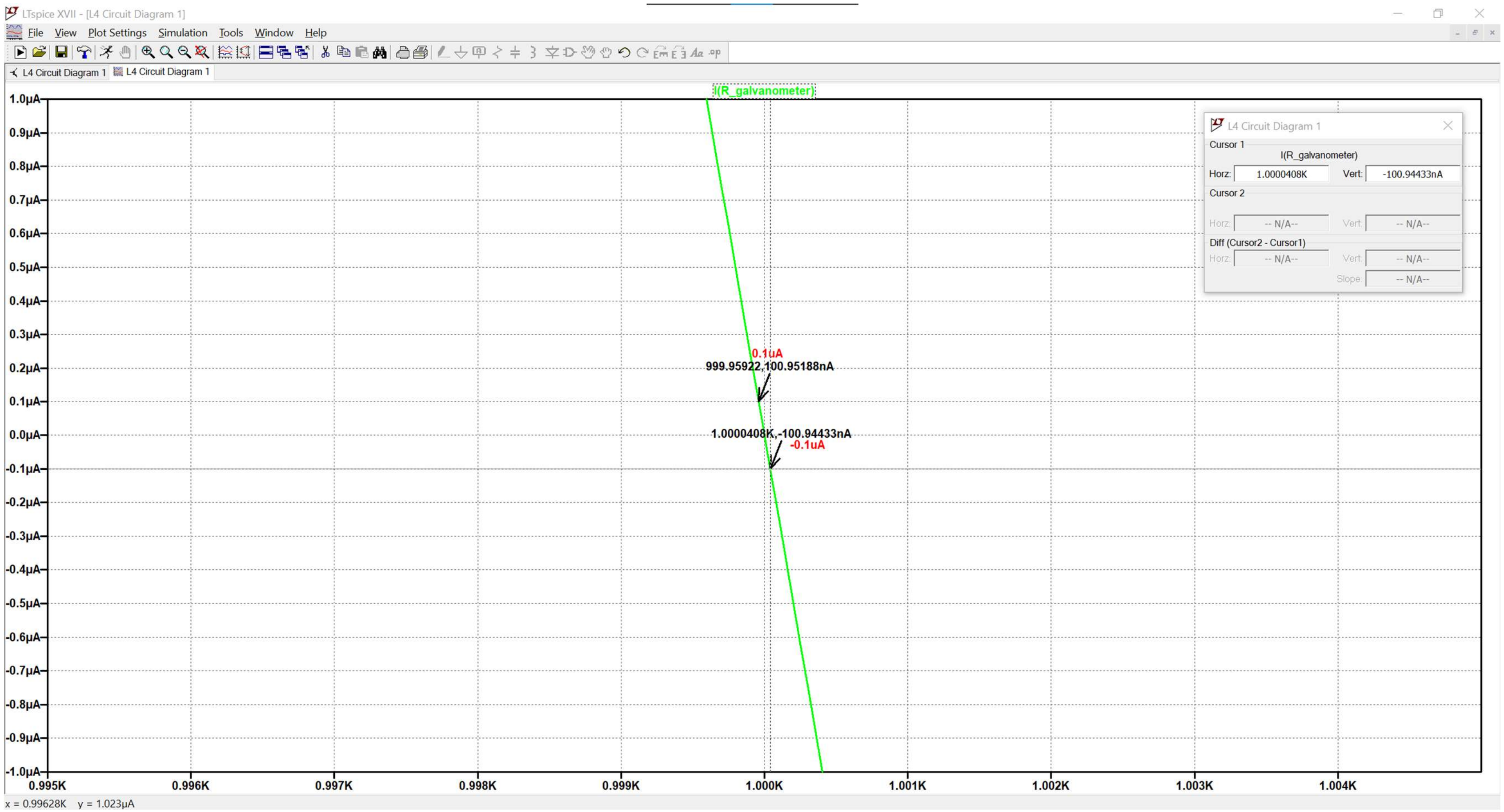

Fig 3c. Current Meter with Sensitivity R4 around 10Ohms

Table 1 (Approximate Values)

	R4	10uA	-10uA	1uA	-1uA	0.1uA	-0.1uA
R3	1kOhms	991.985	1.0080716K	992.2	1.00085K	999.91843K	1.0000775K
R3	10Ohms	995.96827	1.0040683K	999.5891	1.0004109K	999.95922	1.0000408K

3. Assuming the sensitivity of current meter is 10uA, using the circuit shown in Figure 1, design your own circuit to measure on resistor with resistance around 1kOhms as accurate as possible. In your design, provide a list of selected values for every single component and explain why you want to choose those values. Please take the internal resistance of current meter and the power rating of resistors into account in your design.

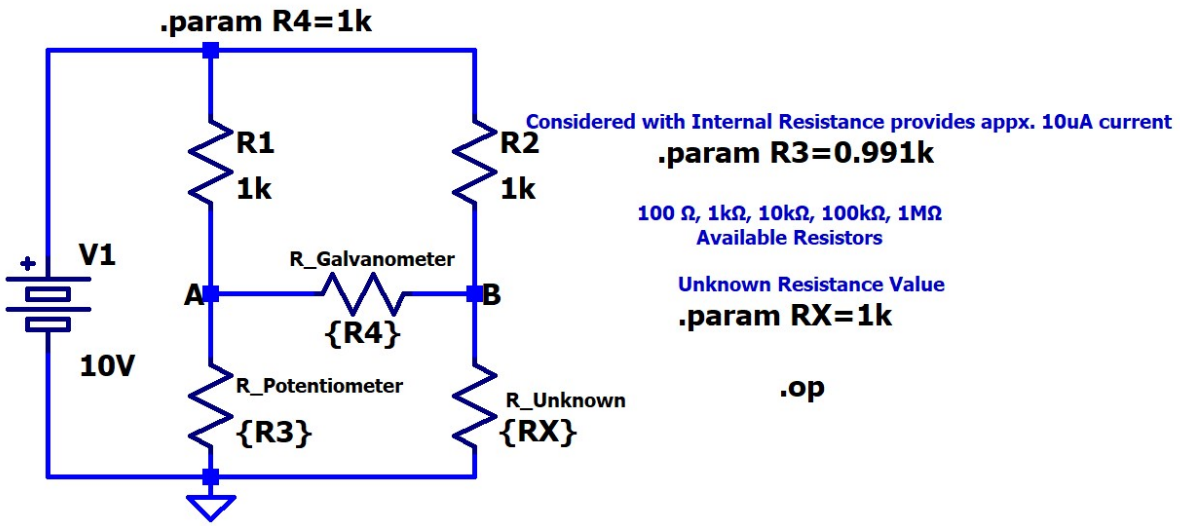

Fig 4. Circuit Design with Current Sensitivity 10uA

Resistance R1, R2 chosen as 1kOhm because in ideal case with R3 and RX being equal it would be easy to measure the resistance of an unknow value. Since, there is not much change compared to the ideal case except that the galvanometer is now sensitive and contains internal resistance of low orders, the ideal case values of resistances are retained. **Power Rating of 1kOhms resistor is 250mW**.

Here R3 is chosen as 0.991kOhm to include the current meters internal resistance, this allows a current flow of around 10uA through the galvanometer.

4. What is the maximum error for your design?

The maximum error in the design is about 9 Ohms which is around 0.9% for the circuit in **Fig 4**.

$$R_x = \frac{R_2}{R_1} R_3$$

$$\frac{\frac{1*10^3*1*10^3}{1*10^3} - \frac{1*10^3*0.991*10^3}{1*10^3}}{\frac{1*10^3*1*10^3}{1*10^3}} * 100 = 0.9\%$$

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--- Operating Point ---

V(n001):          10              voltage
V(a):             4.98303         voltage
V(b):             4.99434         voltage
I(R_unknown):     -0.00499434     device_current
I(R_galvanometer):                1.13136e-005   device_current
I(R_potentiometer):               0.00502828     device_current
I(R2):            0.00500566      device_current
I(R1):            0.00501697      device_current
I(V1):            -0.0100226      device_current
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Fig 5. Operating Point around 10uA flows in the Galvanometer