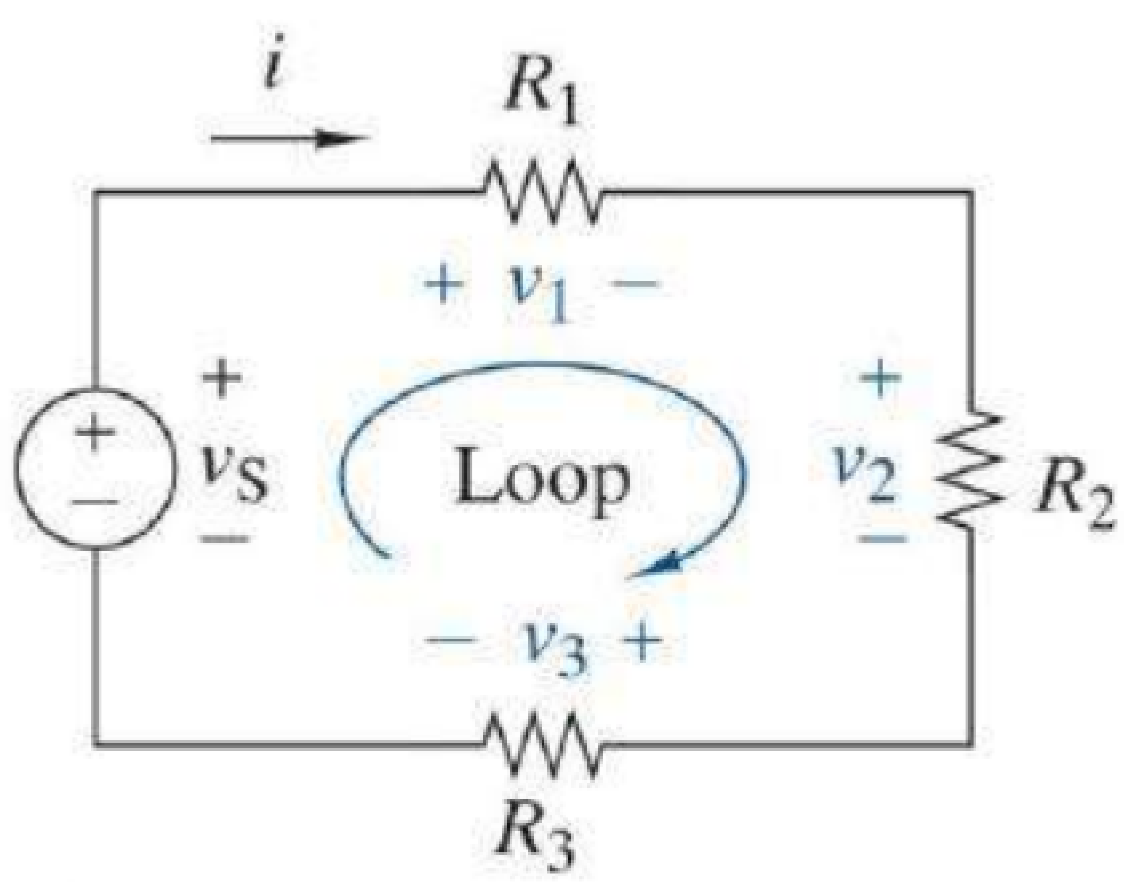
ECE 0101 – Linear Circuits and Systems
Laboratory # 2 – Series and Parallel Circuits, Current and Voltage Dividers

Objectives:

- Simulate a circuit with 4 resistors illustrating series and parallel resistances
- Construct a circuit with series and parallel resistances and compare it to the simulation

Introduction

Voltage dividers and current dividers are two of the most fundamental circuits in electronics. A voltage divider is a simple circuit that takes the voltage from a power source and can produce at the output voltages that are fractions of the input.

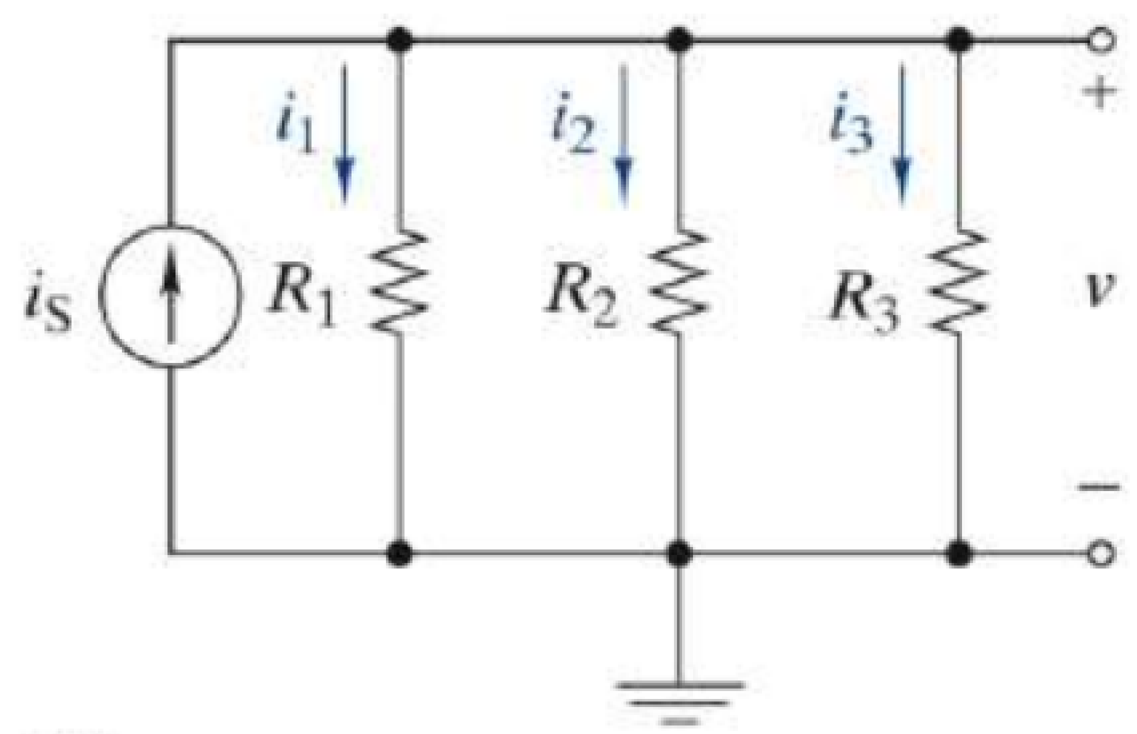


The **voltage divider** circuit on the left shows a voltage source v_s connected in series with three resistors $R_1 . R_2 . R_3$. The voltage division rule is as follows: the voltage drop across a resistor with index k is given by the ratio of its resistance to the total series resistance:

$$v_k = \left(\frac{R_k}{R_{total}}\right) v_s$$

In this case, $R_{total} = R_1 + R_2 + R_3$ and $k = \{1,2,3\}$.

There are many applications for voltage divider circuits; for example, a potentiometer is a variable voltage divider. A ‘Wheatstone bridge’ is a complex voltage divider circuit used in sensing applications, e.g. light (photocell), temperature (thermistor), and stress and strain measurement (force-sensitive resistors). ADC, or analog-to-digital converters, use resistor divider networks in the analog-to-digital conversion process.



The **current divider** circuit on the left shows a current source i_s connected in parallel with three resistors $R_1 . R_2, R_3$. The current division rule is: The current through any resistor with index k is given by the ratio of its conductance to the total conductance of the resistors:

$$i_k = \left(\frac{G_k}{G_{total}}\right) i_s$$

Where $G_k = \frac{1}{R_k}$. With respect to the current circuit, $G_{total} = G_1 + G_2 + G_3$ and $k = \{1,2,3\}$. Current divider circuits are also widely used in electric and electronic circuits, especially in home and civil infrastructure wiring.

HOW TO MEASURE CURRENT

Unlike measuring voltage, in which the voltmeter is placed in parallel with the element whose voltage you are measuring, an ammeter (current meter) must be placed in series with the element whose current you are measuring.

Homework

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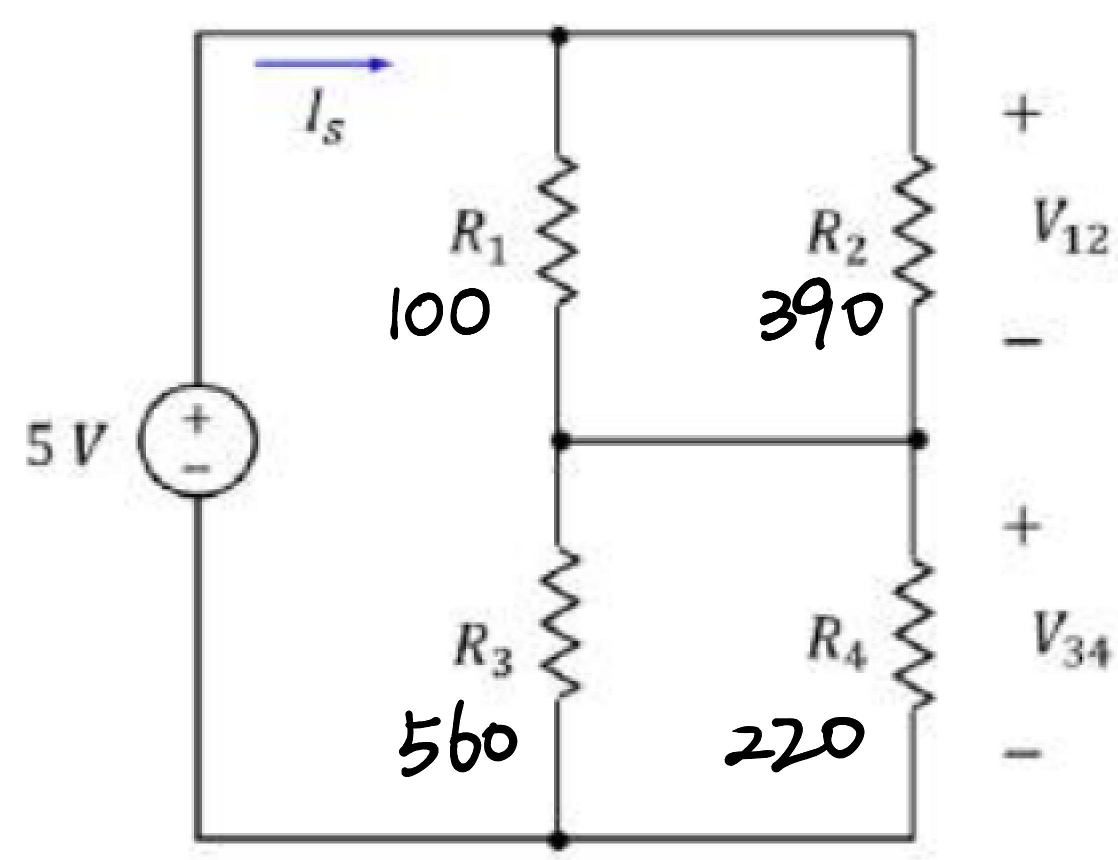
This lab has an introductory homework assignment to be completed before the actual hands-on lab session. You will be able to derive some expressions and simulate circuit behavior before comparing your results to a circuit you build during the lab session.

Go to the website http://www.falstad.com/circuit/e-resistors.html and analyze the circuit simulation. You will see a circuit with a voltage supply and several wires, switches, and resistors. You can click on a switch to open or close it, double click on a resistor to change its value, and right click on any component to delete it. Please set up the circuit in the simulation to match the diagram shown below, where $R_1 = 100\Omega$, $R_2 = 390\Omega$, $R_3 = 560\Omega$, and $R_4 = 220\Omega$.
(Or go to the website http://scratch.trtos.com/circuitjs.html.)



a. (8 points) Record the voltage across each resistor and the current through each resistor. You can find this information by holding the mouse over the respective component.

$V_{12} = 1.675V$ $V_{34} = 3.325V$

$I_1 = 16.753mA$ $I_2 = 4.296mA$ $I_3 = 5.937mA$ $I_4 = 15.112mA$

b. (6 points) Calculate the parallel resistances $R_{12} = R_1||R_2$ and $R_{34} = R_3||R_4$.

$$R_{12} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{100 \times 390}{100 + 390} = 79.592\Omega$$

$$R_{34} = \frac{R_3 \cdot R_4}{R_3 + R_4} = 157.949\Omega$$

c. (8 points) Calculate the voltages V_{12} and V_{34} across the theoretical parallel resistances R_{12} and R_{34}.

$$V_{12} = 5 \times \frac{R_{12}}{R_{12}+R_{34}} = 5\times \frac{79.592}{79.592+157.949} = 1.675V$$

$$V_{34} = 5\times \frac{R_{34}}{R_{12}+R_{34}} = 5\times \frac{157.949}{79.592+157.949} = 3.325V$$

d. (8 points) Solve for the current in each resistor R_1, R_2, R_3, R_4.

$$I_1 = \frac{V_{12}}{R_1} = \frac{1.675}{100} = 16.753\,mA \qquad I_4 = \frac{V_{34}}{R_4} = \frac{3.325}{220} = 15.114\,mA$$

$$I_2 = \frac{V_{12}}{R_2} = \frac{1.675}{390} = 4.295\,mA$$

$$I_3 = \frac{V_{34}}{R_3} = \frac{3.325}{560} = 5.938\,mA$$

e. (4 points) Write a few words comparing the calculations of parts b-d to the simulation results from part a.

the results are quite close, small difference are caused by simplification.

Laboratory Procedure

You will be building circuits using the same resistance values from the homework portion of the lab: $R_1 = 100\Omega$, $R_2 = 390\Omega$, $R_3 = 560\Omega$, and $R_4 = 220\Omega$.

a. (12 points) Obtain the required resistors from the lab supply. Use the multimeter to measure each resistor by setting it to measure ohms, making sure the leads are in the correct terminals, and placing them in parallel with the resistor. Record your measurements in the table below, then compute and record the %error for each.

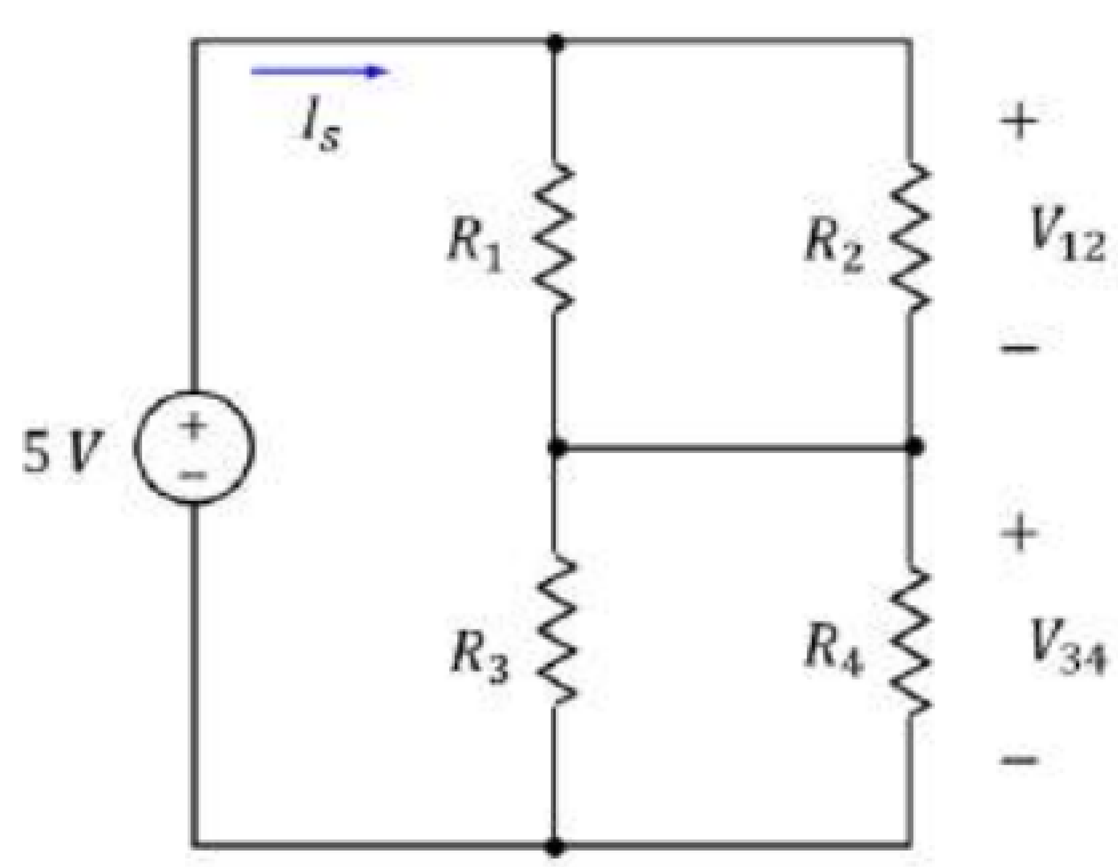
	R_1	R_2	R_3	R_4
Nominal value	100 Ω	390 Ω	560 Ω	220
Measured value	99.502 Ω	0.38669 kΩ	0.55522 kΩ	0.21809 kΩ
%error	0.500%	0.856 %	0.861 %	0.876 %

$$\%error = \left(\frac{|nominal - measured|}{measured}\right) \times 100$$

b. (12 points) Connect resistors R_1 and R_2 in parallel on your breadboard. Use the multimeter to measure the parallel resistance and record your measurement of $R_{12} = R_1||R_2$ in the table below. Repeat this measurement for $R_{34} = R_3||R_4$. Compute the %error for each measurement.

	R_{12}	R_{34}
Nominal Value	79.592 Ω	157.95 Ω
Measured Value	79.186 Ω	156.728 Ω
%error	0.513 %	0.780 %

c. (12 points) Fully construct the circuit shown below on the breadboard. Use the power supply set to 5V as the voltage source in the circuit. Using the multimeter, measure V_{12} and V_{34}. To measure these voltages, the multimeter leads must touch the nodes where the resistors meet in parallel. The easiest way to do this is simply to touch the leads to the metal leads of the resistors. Record your measurements and the %errors in the following table.



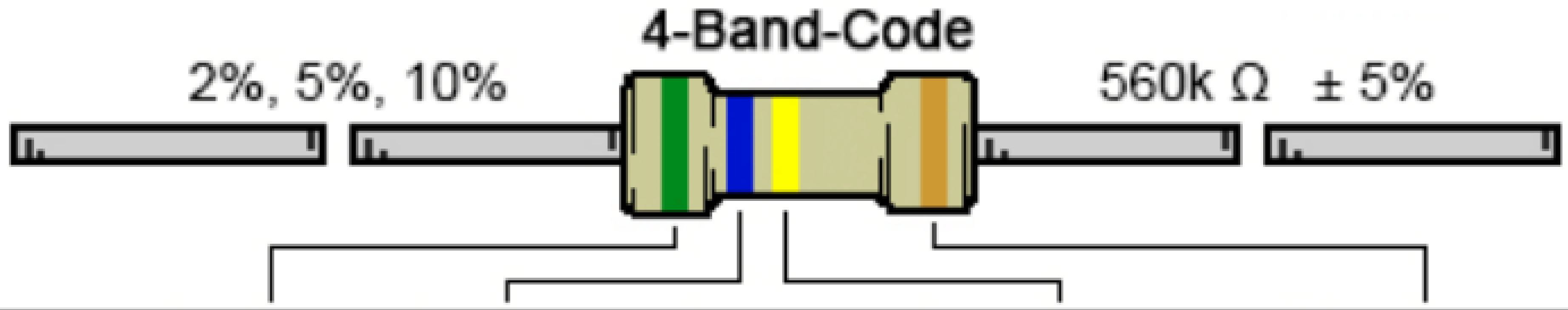
	V_{12}	V_{34}
Nominal Value	1.675V	3.325V
Measured Value	1.69491 V	3.3512V
%error	1.175%	0.7818%

d. (10 points) Using your voltage and resistance measurements, compute the current through each resistor I_{Ri} as well as the total amount of current drawn from the 5V source I_S. Record your computed values for the currents in the table below.

	I_{R1}	I_{R2}	I_{R3}	I_{R4}	I_S
Computed value	16.751mA	4.2951 mA	5.93735mA	15.113 mA	21.0461 mA

e. (20 points) Use the multimeter to measure the current in each resistor by setting the meter to measure DC current and connecting it in series with the resistor. For each measurement, you will have to break the circuit connection between the resistor and another device, then use the multimeter to complete the broken connection. The current from the source can be measured in a similar way. Record your measurements and compute the %error for each circuit element by comparing these values to those obtained in part (d) above.

	I_{R1}	I_{R2}	I_{R3}	I_{R4}	I_S
Measured value	16.9680mA	4.3737mA	6.0287mA	15.3458mA	21.3474mA
%error	1.2789%	1.7971%	1.5153%	1.5170%	1.4114%



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black		0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)