Experiment Name: Kirchhoffs_Laws

Overview

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Fundamental Concepts in Electrical Engineering Lab2 - Kirchhoff’s Voltage and Current Laws

Objectives

- Learn Kirchhoff's Voltage Law
- Learn Kirchhoff's Current Law
- Apply Kirchhoff's Voltage Law to the analysis of a series circuit
- Apply Kirchhoff's Current Law to the analysis of a parallel circuit

Components

- Resistors: 1Ohm (1%, 0.25W) 3 pieces,100Ohms (10%, 0.5W), 560Ohms(10%,0.5W), 820Ohms(10%, 0.5W)
- Circuit prototyping breadboard
- Electric wires

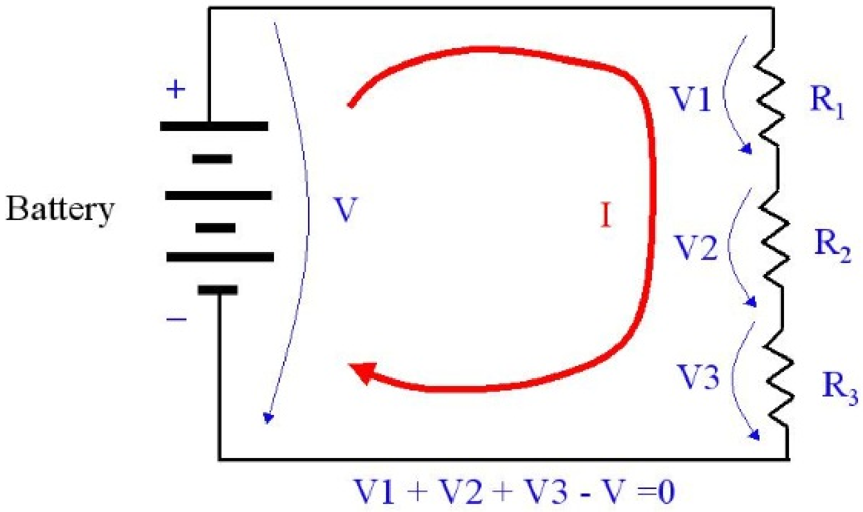
Equipment

- Adjustable power supply (at least 0 - 5V voltage range, and 0.5A maximum current)
- Tektronix TBS 1202B-EDU Oscilloscope

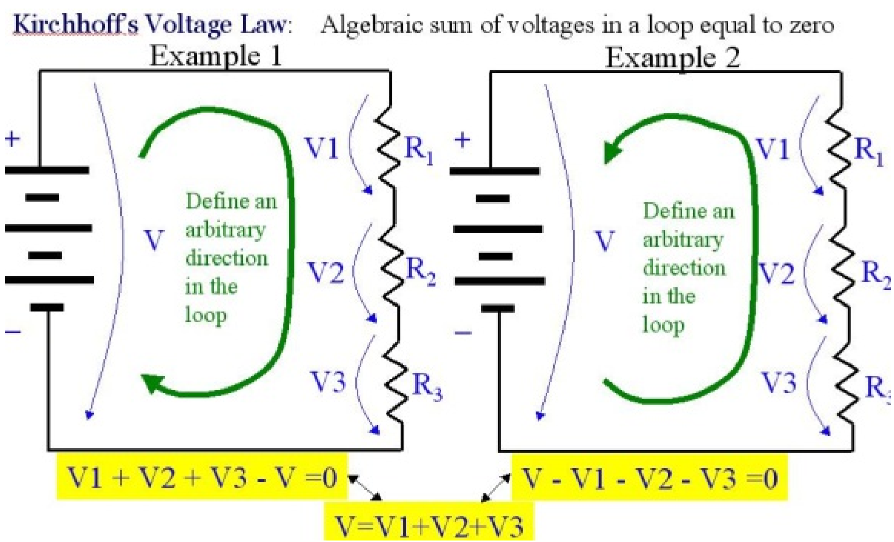
Theory

1. Kirchhoff’s Voltage Law

Kirchhoff’s voltage law describes the relationship between the voltage sources and voltage drops on loads in a circuit loop. A simple example is shown in the following figure. According to Kirchhoff’s voltage law the algebraic sum of voltages in a loop is equal to zero. Notice the polarities of voltages on the battery and the three resistors. In red it is shown the direction of electric current as flowing from the positive terminal of the battery through the three resistors and back into the battery. The voltage on the battery has polarity opposite to the direction of electric current and therefore it is algebraically added as negative value.

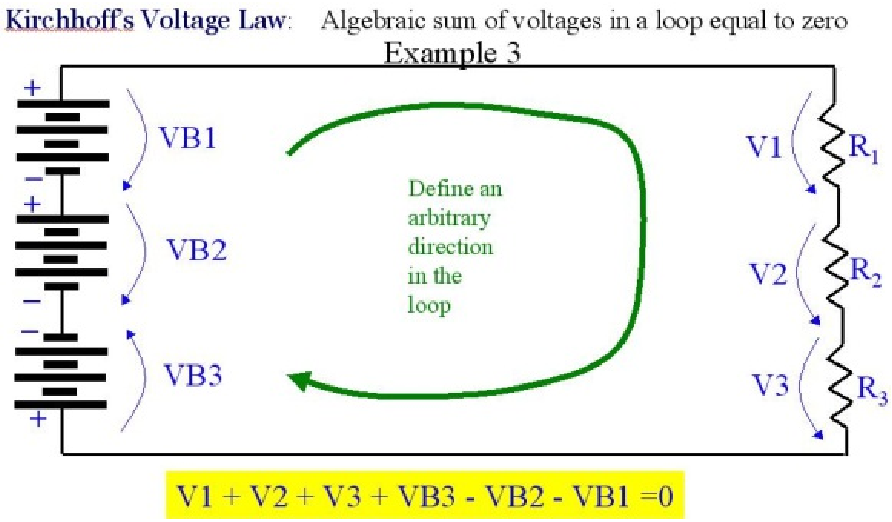


In the example above we knew the direction of electric current; however, there are often cases when we do not know the direction of electric current through the circuit loop. To apply Kirchhoff's voltage law we don't really need to know the actual direction of electric current; we can just define an arbitrary direction and write Kirchhoff's voltage for that direction. This is exemplified in the figure below:



In this example we defined an arbitrary direction through the loop, clockwise in the example 1 and counter-clockwise in example 2. Notice that the Kirchhoff's voltage laws written for these two opposite arbitrary directions result in the same equation.

To further clarify the Kirchhoff's voltage law let's look at the following example, which includes multiple voltage sources and connected with reverse polarities.



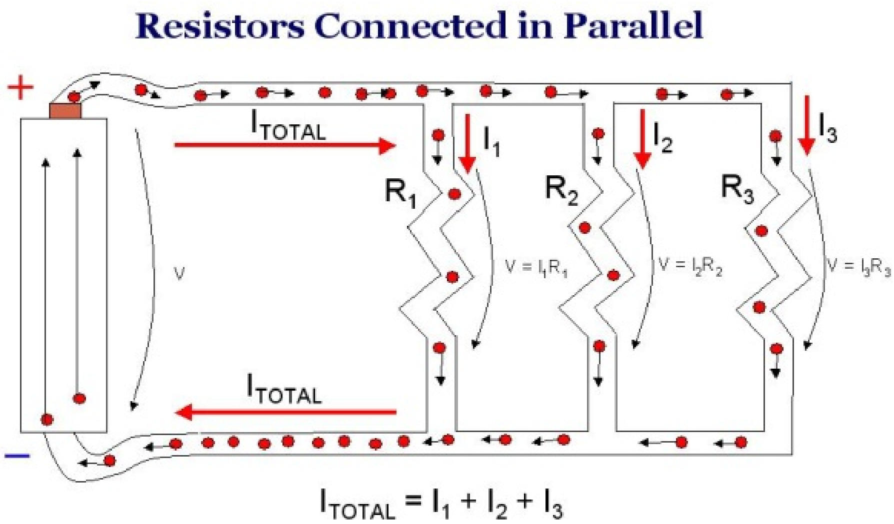
So depending on the arbitrary direction chosen, some supply voltages are summed with a positive sign and others with a negative sign.

2. Kirchhoff's Current Law

Kirchhoff's current law describes quantitatively the relationship between the intensity of electric currents that flow in and out of a circuit node. From an intuitive perspective, by looking at the figure below we can deduce that as I_total current splits into three currents, I1, I2, and I3, the number of charges of I_total that flow through the wire in a unit of time would have to split among the three paths of I1, I2, and I3. So if we combine the number of charges that flow in one second in I1, I2, and I3 currents the sum should be equal to I_total's number of charges that flow in one second (no charges are lost and no charges are created). This is exactly what Kirchhoff's current law states, that:

I_total = I1 + I2 + I3,

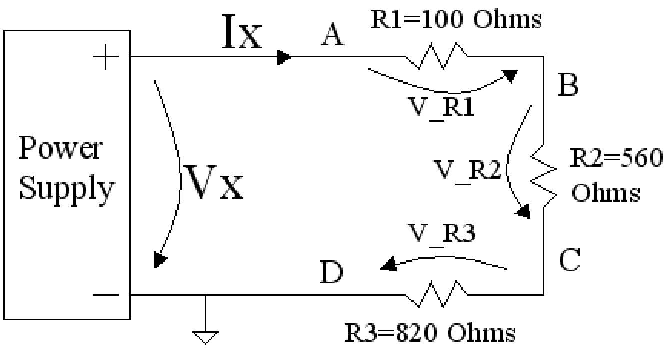
or in the general form: the algebraic sum of electric currents flowing into a circuit node is equal to zero.



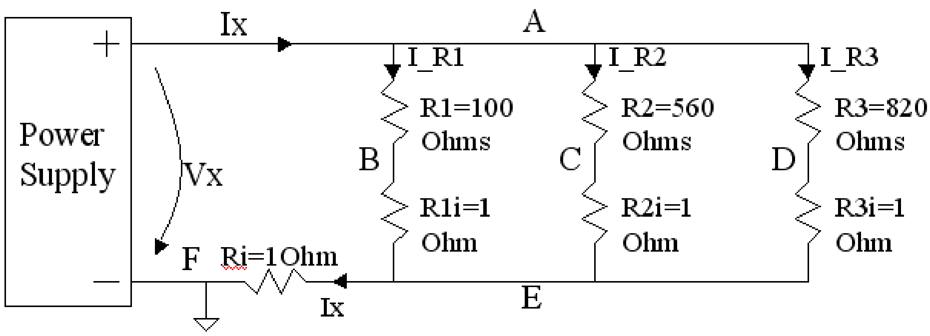
How does the current split? How much would it go through one resistor and how much through the others? Let's look at an example: R1 = 1kOhms, R2= 3kOhms and R3 = 9kOhms, all connected in parallel to a 9V voltage supply. Applying Ohm's law to each resistor, V=I1*R1, V=I2*R2, and V=I3*R3, we know V and R1, R2, R3, so we can calculate the value of each current: I1=9mA, I2=3mA, and I3=1mA.

Experimental Setup

Part 1: Kirchhoff's Voltage Law
Construct the circuit shown in the diagram below and continue with the steps listed in the "Procedure" section.



Part 2: Kirchhoff's Current Law
Construct the circuit shown in the diagram below and continue with the corresponding steps listed in the "Procedure" section.



In this circuit the 1Ohm 1% resistor is used as a current to voltage converter with the transfer function: 1A -> 1V, 100mA -> 100mV, 10mA -> 10mV,... This way we can use one channel of the oscilloscope to probe the current through the circuit.

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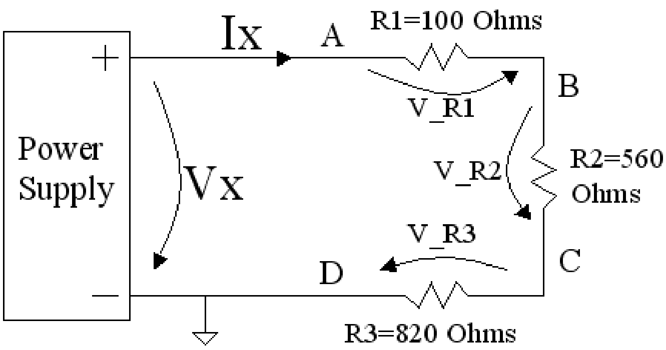
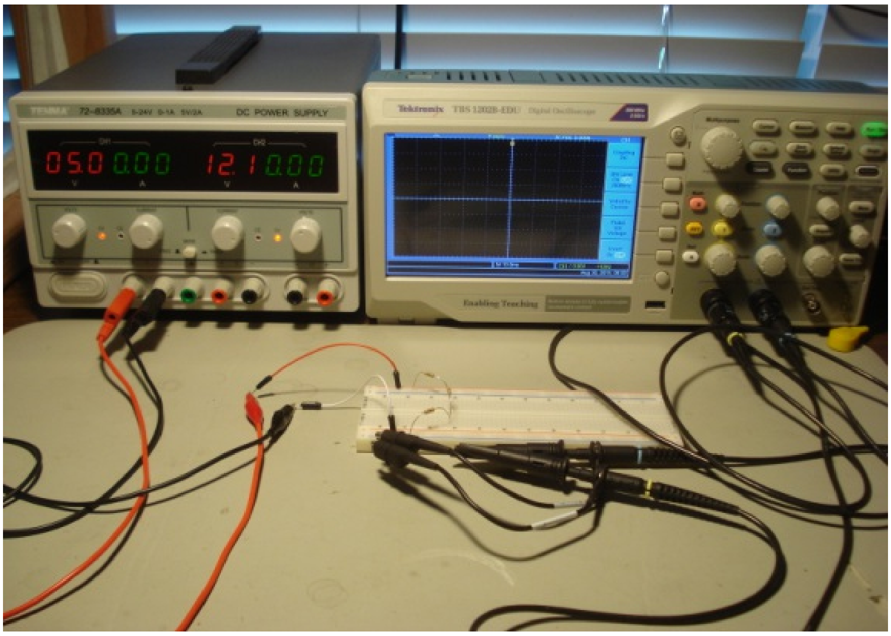
Procedure

Step 1

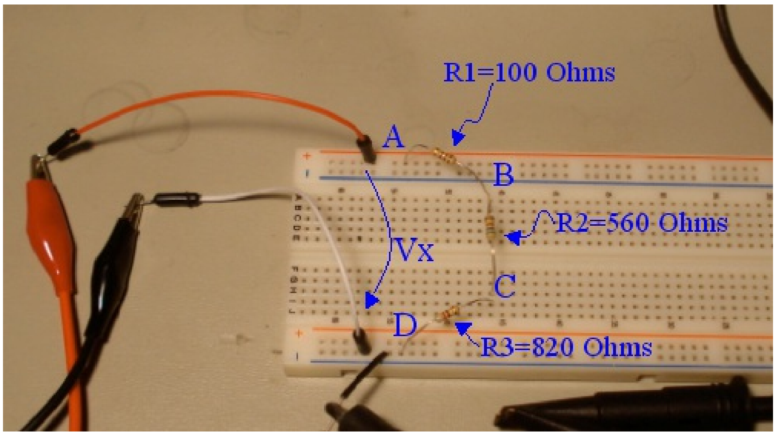
Construct the series circuit in the diagram below and connect it to the power supply.



Here is an example of testbench setup:

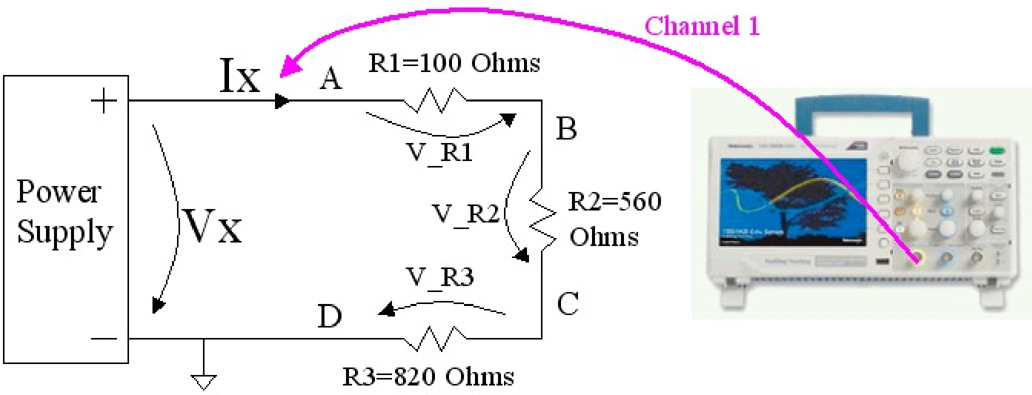


And here is a more detailed picture of the circuit:



Step 2

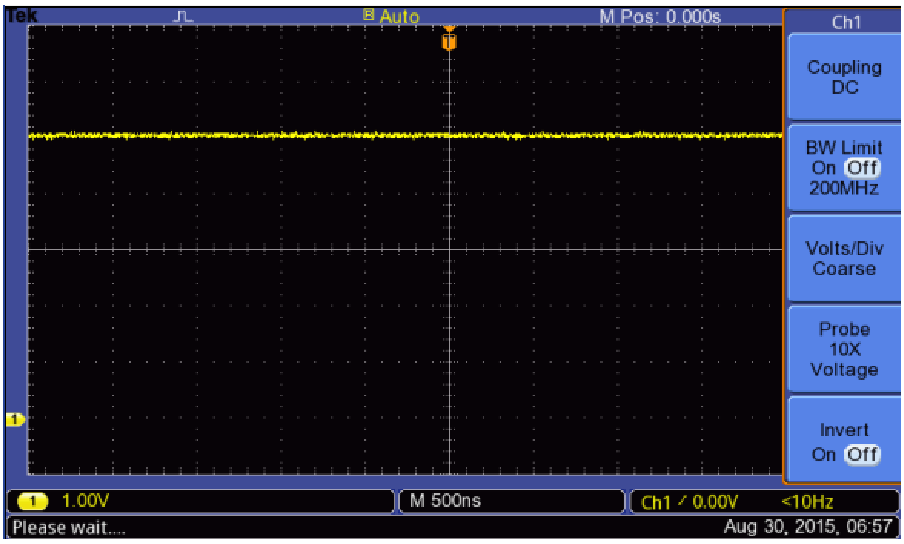
- Connect Channel 1 of the TBS1000B-EDU oscilloscope to node A (the ground clip of the probe will be connected to the ground node "D" of the circuit).



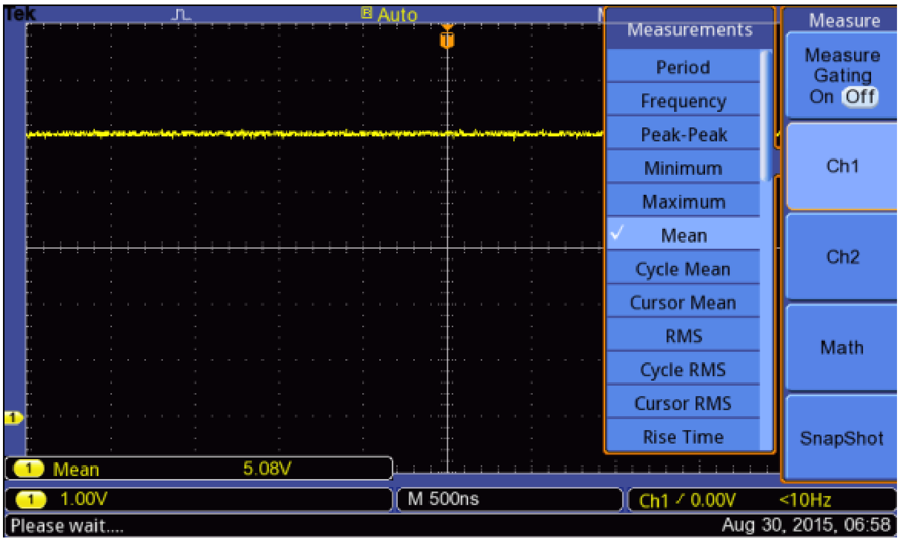
- Setup the power supply voltage to 5V.
- Setup the Oscilloscope Channel 1 Input to DC mode, Vertical scale =1V/div, and Channel 2 input to DC mode, Vertical scale = 1V/div.

- Setup the Oscilloscope time base to 500ns/div (this is not important here since we measure DC voltages that do not change in time and are represented as horizontal lines on the display)
- Setup the Oscilloscope Trigger to Auto mode.
- Alternately press the "Autoset" button and make the adjustments to settings after the oscilloscope displays the waveforms.

With this setup Channel 1 measures the voltage *Vx,* as shown in the screenshot below*:*



- Use the built-in "Measure" function of the oscilloscope to measure the voltage level of channel 1. Select "Mean" from the measure menu, like it is shown in the picture below:

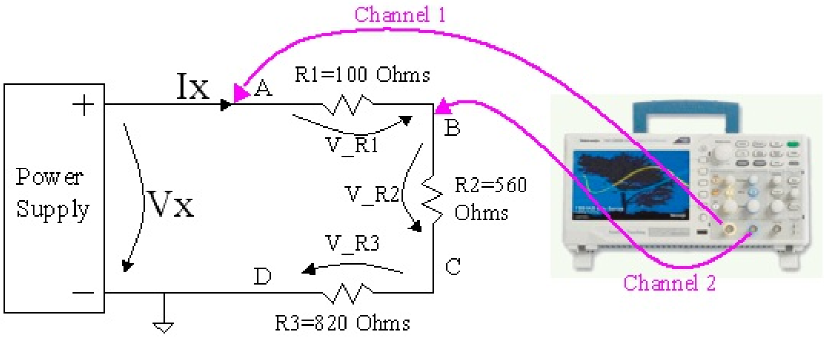


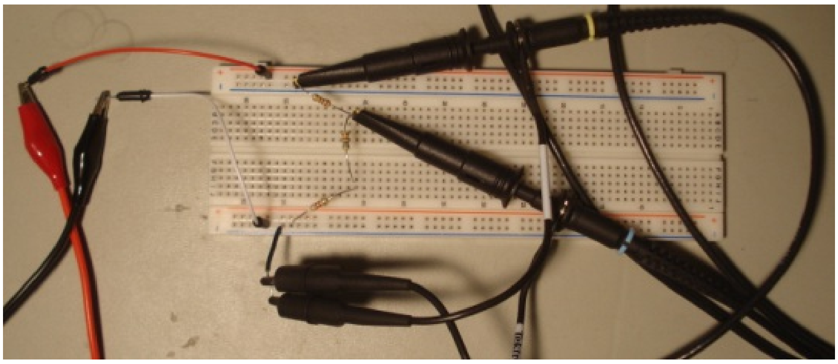
- The measured value represents the voltage Vx in the circuit schematic. Record this value since we will use it in Step 6 below.

- Insert a screenshot of your measurement in this step of the lab.

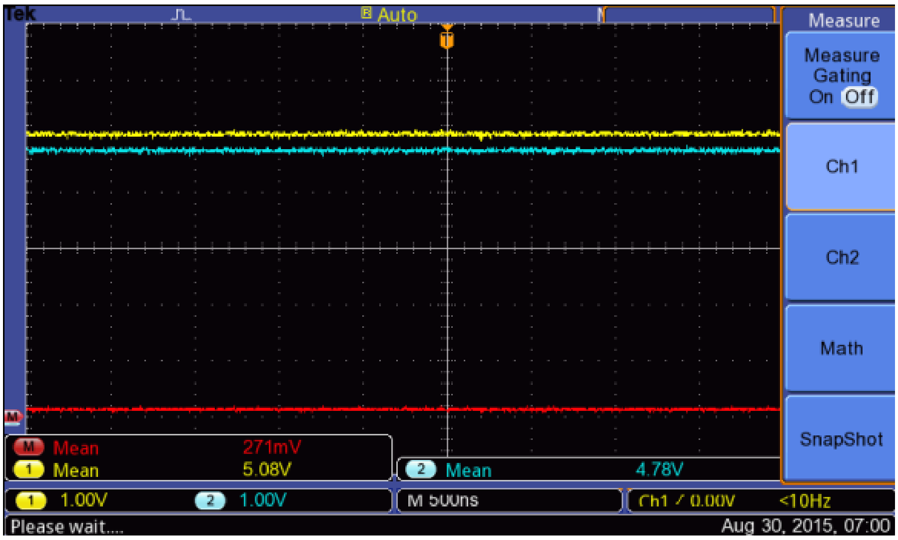
Step 3

- Connect Channel1 to node A and Channel2 to node B of the circuit. The ground clips are connected to the ground node of the circuit (Node D). Here is a picture of this setup on the schematic on the testbench:





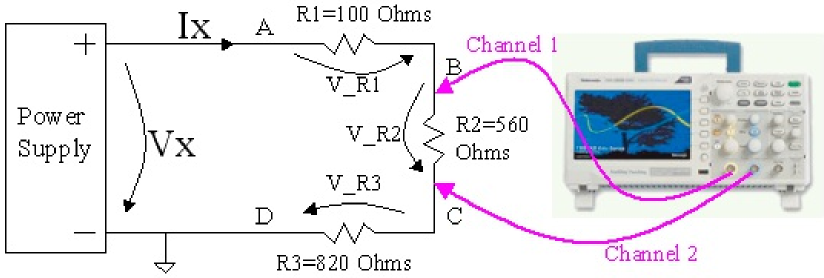
- In this picture Channel1 is the yellow marked probe and Channel2 is the blue marked probe. Set the "Math" built-in function of TBS1202B-EDU oscilloscope to display Channel1-Channel2. Align the zero Volts levels of Channel1, Channel2, and Math traces, and set the built-in measure function to display the "Mean" value of each trace, as shown in the picture below:

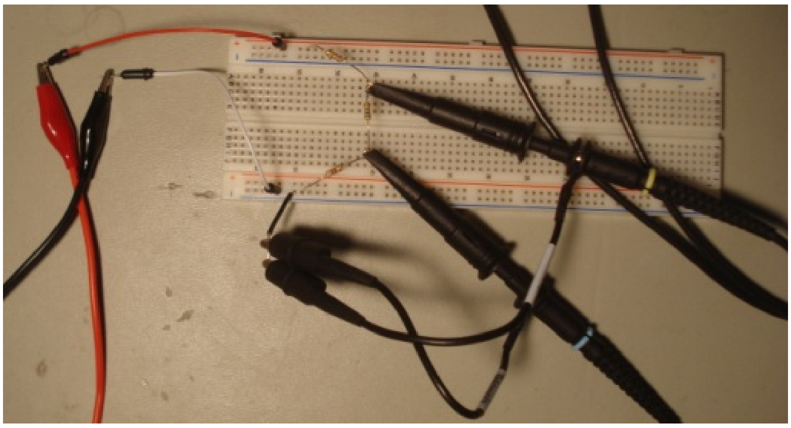


- The measured value of the Math trace represents the voltage drop on R1 resistor. Record this value since we will use it in Step 6 below.
- Insert a screenshot of the oscilloscope display in this step.

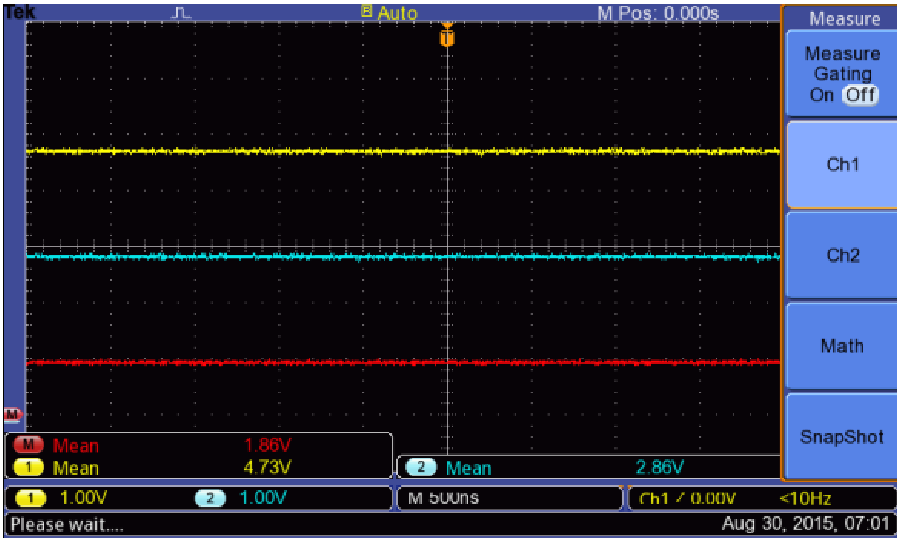
Step 4

- Connect Channel1 to node B and Channel2 to node C of the circuit. The ground clips are connected to the ground node of the circuit (Node D). Here is a picture of this setup on the schematic and on the testbench:





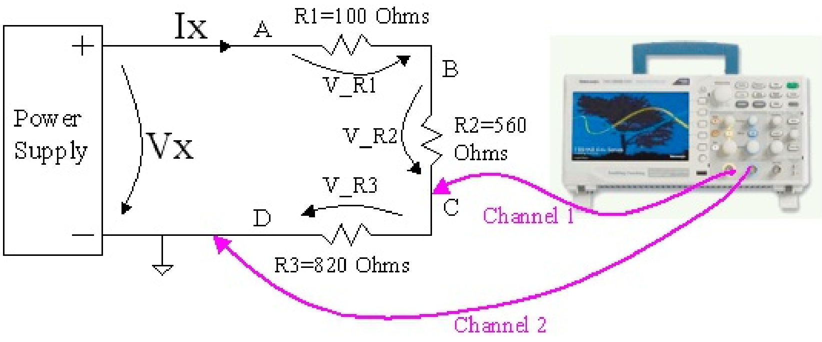
- In this picture Channel1 is the yellow marked probe and Channel2 is the blue marked probe. Set the "Math" built-in function of TBS1202B-EDU oscilloscope to display Channel1-Channel2. Align the zero Volts levels of Channel1, Channel2, and Math traces, and set the built-in measure function to display the "Mean" value of each trace, as shown in the picture below:

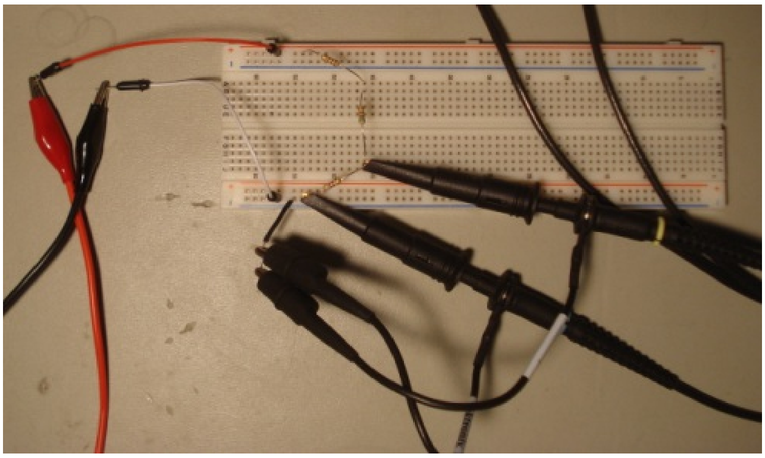


- The measured value of the Math trace represents the voltage drop on R2 resistor. Record this value since we will use it in Step 6 below.
- Insert a screenshot of the oscilloscope display in this step.

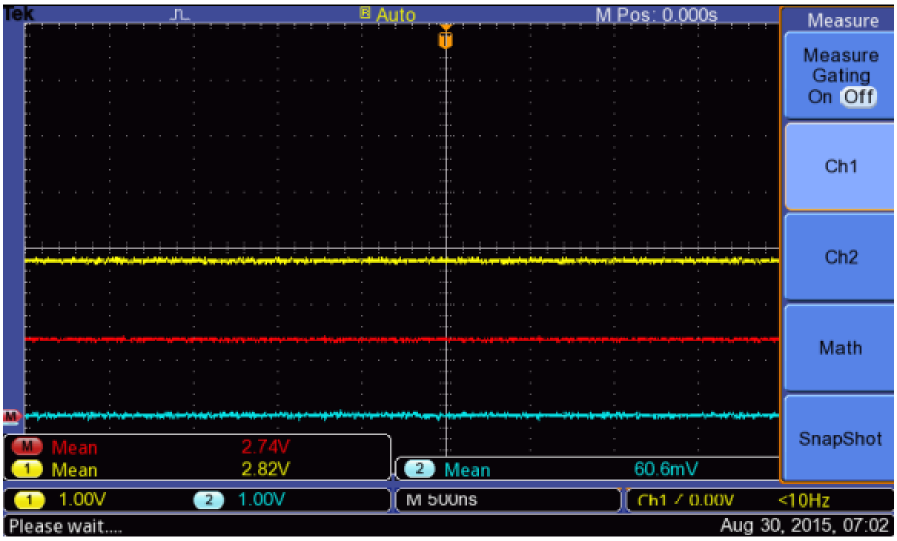
Step 5

- Connect Channel1 to node C and Channel2 to node D of the circuit. The ground clips are connected to the ground node of the circuit (Node D). Here is a picture of this setup on the schematic and on the testbench:





- In this picture Channel1 is the yellow marked probe and Channel2 is the blue marked probe. Set the "Math" built-in function of TBS1202B-EDU oscilloscope to display Channel1-Channel2. Align the zero Volts levels of Channel1, Channel2, and Math traces, and set the built-in measure function to display the "Mean" value of each trace, as shown in the picture below:



- The measured value of the Math trace represents the voltage drop on R3 resistor. Record this value since we will use it in Step 6 below.

- Insert a screenshot of the oscilloscope display in this step.

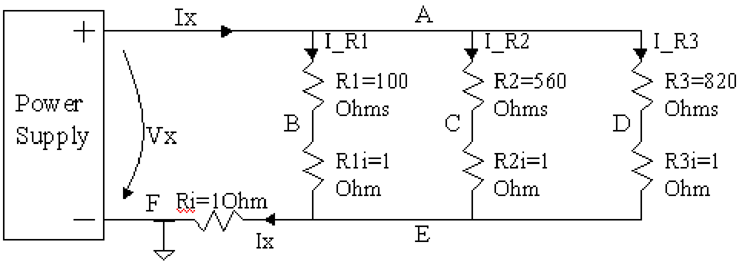
Step 6

- Calculate the sum of the voltages on R1, R2, and R3 resistors, measured in Steps 3,4, and 5.
- Compare this result with the measured voltage Vx in Step 2. Is voltage Vx equal to the sum V_R1 +

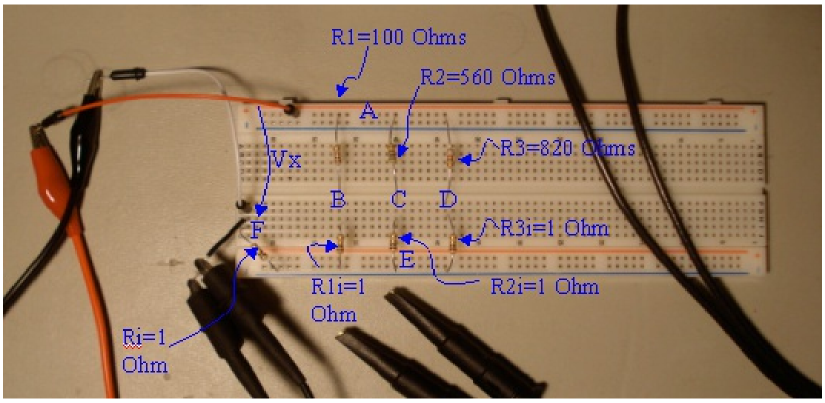
V_R2 + V_R3?
- Did we prove Kirchhoff's voltage law? Explain your answer.

Step 7

Construct the parallel circuit in the diagram below and connect it to the power supply.

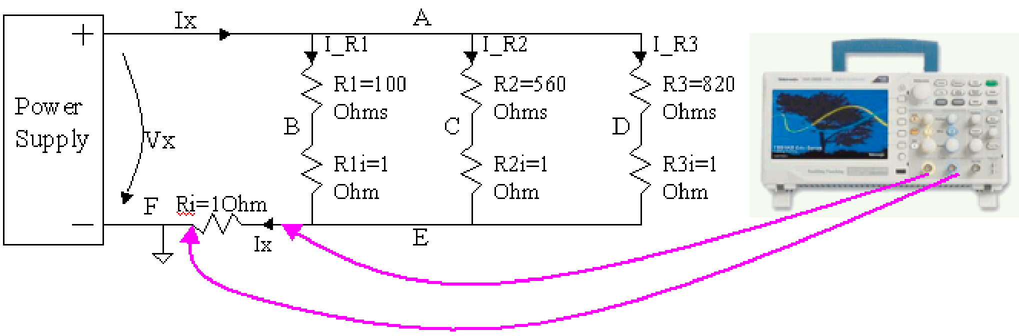


Here is a more detailed picture of the circuit:

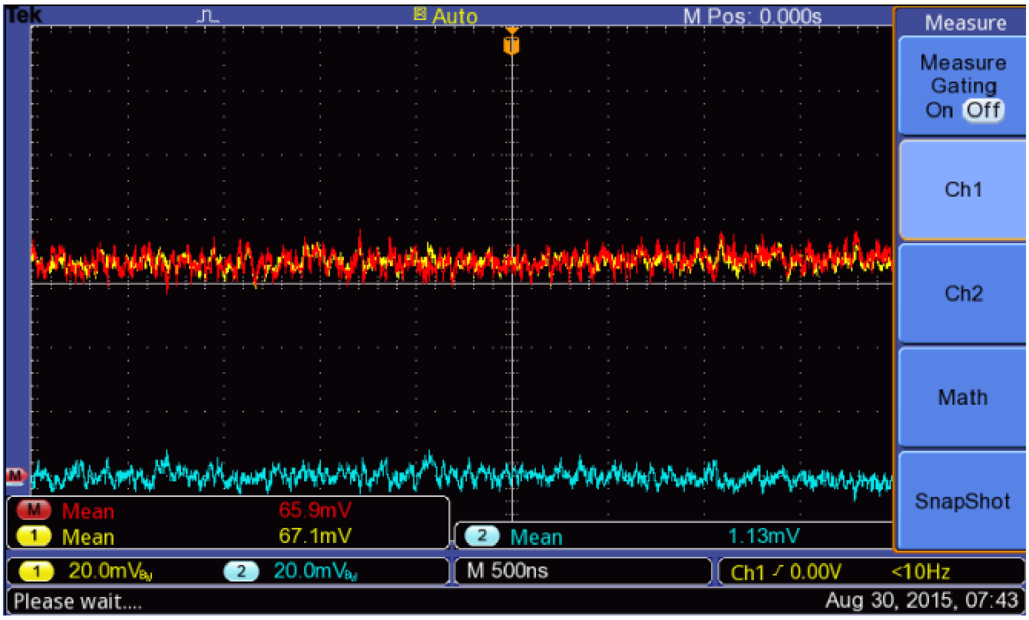


Step 8

- Setup the power supply voltage to 5V.
- Setup the Oscilloscope Channel 1 Input to DC mode, Vertical scale =20mV/div, and Channel 2 input to DC mode, Vertical scale = 20mV/div.
- Setup the Oscilloscope time base to 500ns/div (this is not important here since we measure DC voltages that do not change in time and are represented as horizontal lines on the display)
- Setup the Oscilloscope Trigger to Auto mode.
- Alternately press the "Autoset" button and make the adjustments to settings after the oscilloscope displays the waveforms.
- Connect Channel 1 to node E and Channel 2 to node F of the circuit, as shown in the diagram below:



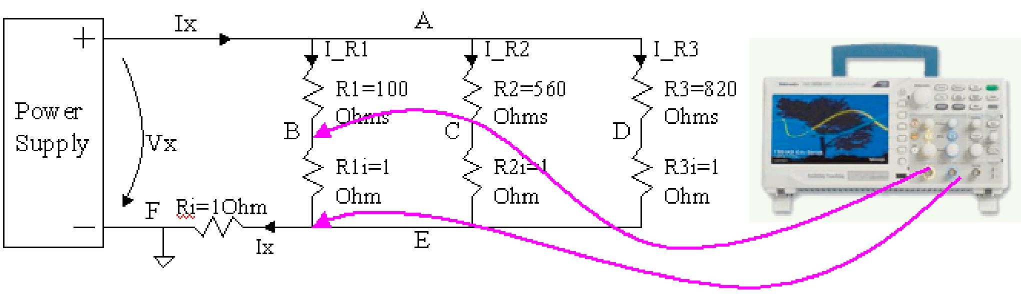
- Setup the Math built-in function of the oscilloscope to calculate and display Channel 1 - Channel 2 trace.
- With this setup the oscilloscope screen should display three horizontal lines representing the voltages at nodes E, F, and their difference.
- Use the built-in "Measure" function of the oscilloscope to measure the voltage levels of the channel 1, channel 2, and "Math" traces. Select "Mean" from the measure menu, like it is shown in the picture below:



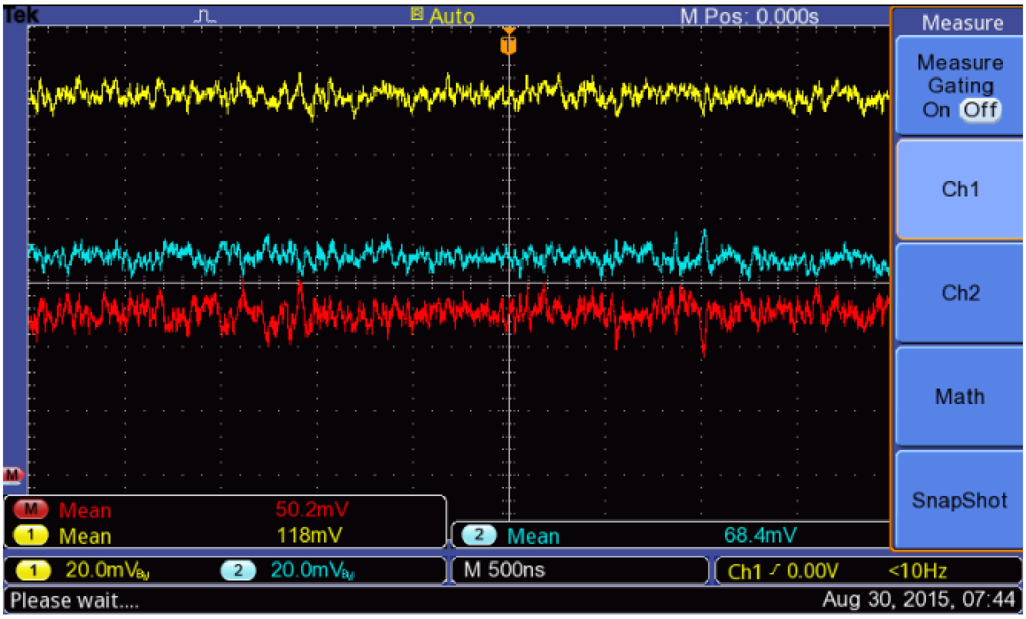
- These "Math" trace represents the voltage drop on Ri=1Ohms, and using Ohm's law we can translate this quantity into the current flowing through Ri by using a 1:1 conversion factor. In the waveform example above V_Ri=65.9mV which translates into 65.9mA flowing through Ri resistor. This current is equal to Ix in the schematic diagram.
- Insert a screenshot of the oscilloscope display showing channel 1, channel 2, Math signals, and the measured values.
- Determine *Ix* from the voltage measured for "Math" trace. Record this value since we will use it in Step 12 below.

Step 9

- Connect Channel 1 to node B and Channel 2 to node E of the circuit, as shown in the diagram below:



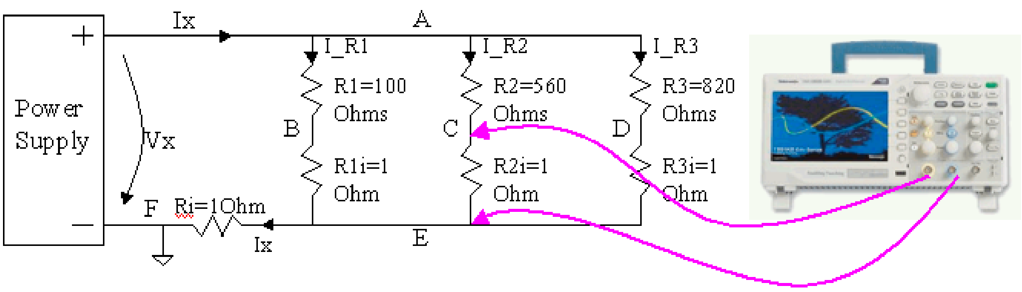
- Setup the Math built-in function of the oscilloscope to calculate and display Channel 1 - Channel 2 trace.
- With this setup the oscilloscope screen should display three horizontal lines representing the voltages at nodes B, E, and their difference.
- Use the built-in "Measure" function of the oscilloscope to measure the voltage levels of the channel 1, channel 2, and "Math" traces. Select "Mean" from the measure menu, like it is shown in the picture below:



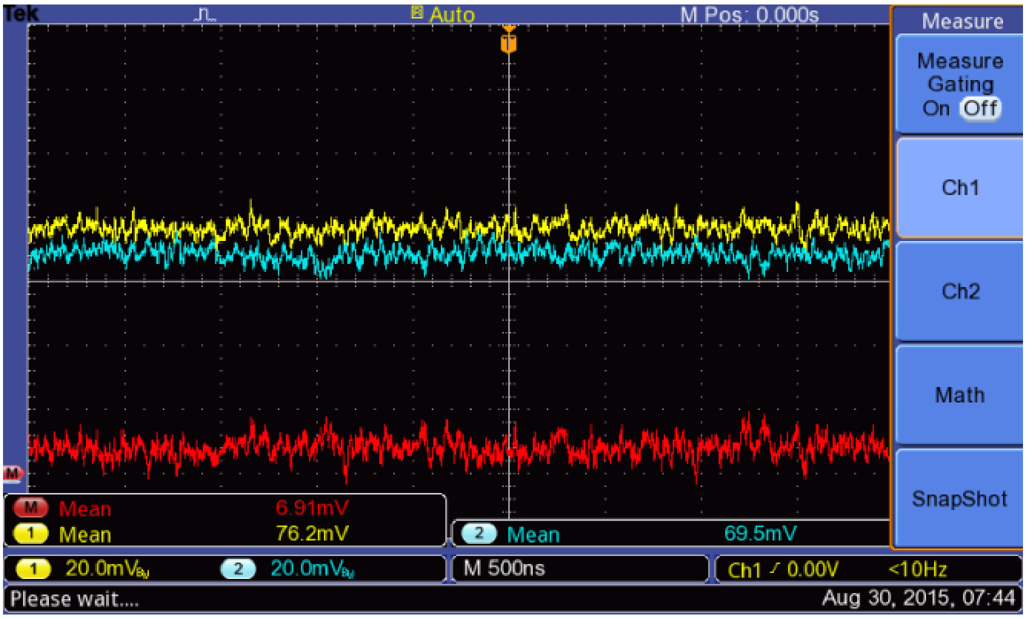
- These "Math" trace represents the voltage drop on R1i=1Ohms, and using Ohm's law we can translate this quantity into the current flowing through R1i by using a 1:1 conversion factor. In the waveform example above V_Ri=50.2mV which translates into 50.2mA flowing through R1i resistor. This current is equal to I_R1 in the schematic diagram.
- Insert a screenshot of the oscilloscope display showing channel 1, channel 2, Math signals, and the measured values.
- Determine *I_R1* from the voltage measured for "Math" trace. Record this value since we will use it in Step 12 below.

Step 10

- Connect Channel 1 to node C and Channel 2 to node E of the circuit, as shown in the diagram below:



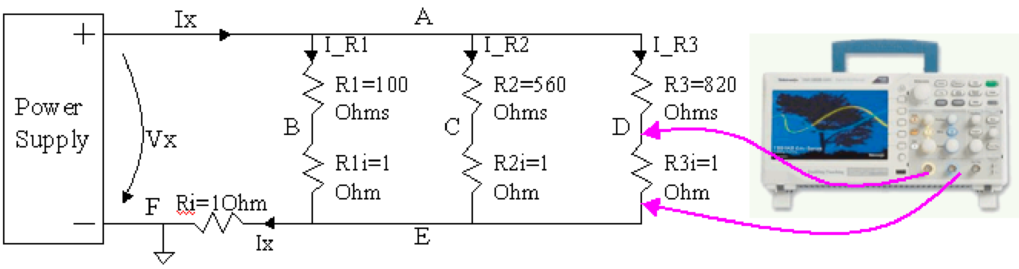
- Setup the Math built-in function of the oscilloscope to calculate and display Channel 1 - Channel 2 trace.
- With this setup the oscilloscope screen should display three horizontal lines representing the voltages at nodes C, E, and their difference.
- Use the built-in "Measure" function of the oscilloscope to measure the voltage levels of the channel 1, channel 2, and "Math" traces. Select "Mean" from the measure menu, like it is shown in the picture below:



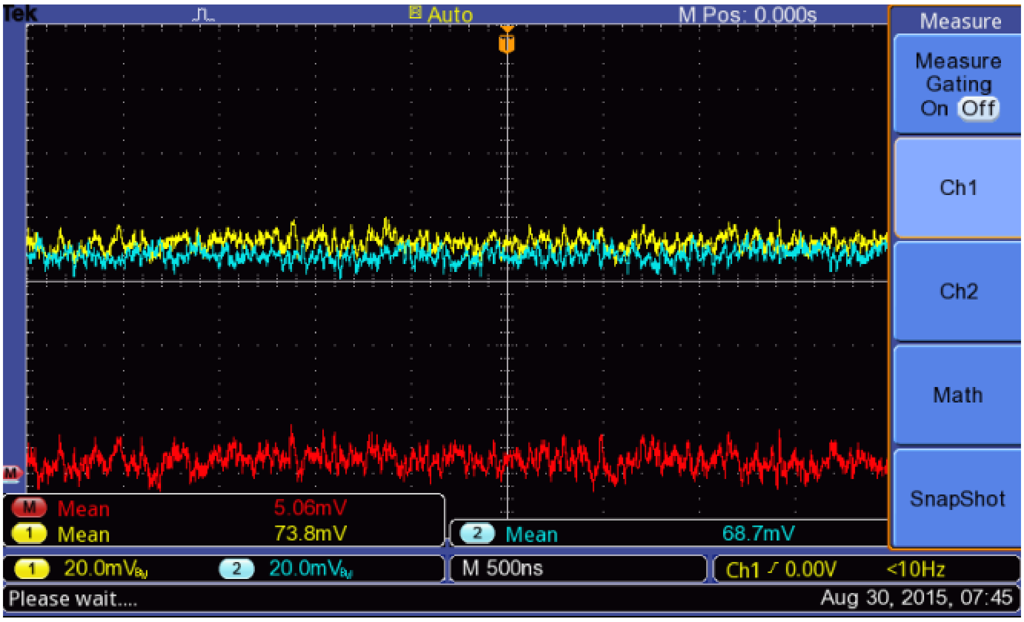
- These "Math" trace represents the voltage drop on R2i=1Ohms, and using Ohm's law we can translate this quantity into the current flowing through R2i by using a 1:1 conversion factor. In the waveform example above V_R2i=6.91mV which translates into 6.91mA flowing through R2i resistor. This current is equal to I_R2 in the schematic diagram.
- Insert a screenshot of the oscilloscope display showing channel 1, channel 2, Math signals, and the measured values.
- Determine *I_R2* from the voltage measured for "Math" trace. Record this value since we will use it in Step 12 below.

Step 11

- Connect Channel 1 to node D and Channel 2 to node E of the circuit, as shown in the diagram below:



- Setup the Math built-in function of the oscilloscope to calculate and display Channel 1 - Channel 2 trace.
- With this setup the oscilloscope screen should display three horizontal lines representing the voltages at nodes D, E, and their difference.
- Use the built-in "Measure" function of the oscilloscope to measure the voltage levels of the channel 1, channel 2, and "Math" traces. Select "Mean" from the measure menu, like it is shown in the picture below:



- These "Math" trace represents the voltage drop on R3i=1Ohms, and using Ohm's law we can translate this quantity into the current flowing through R3i by using a 1:1 conversion factor. In the waveform example above V_R3i=5.06mV which translates into 5.06mA flowing through R3i resistor. This current is equal to I_R3 in the schematic diagram.
- Insert a screenshot of the oscilloscope display showing channel 1, channel 2, Math signals, and the measured values.
- Determine *I_R3* from the voltage measured for "Math" trace. Record this value since we will use it in Step 12 below.

Step 12

- Calculate the sum of the currents through R1, R2, and R3 resistors, measured in Steps 9,10, and 11.
- Compare this result with the measured current Ix in Step 8. Is the current Ix equal to the sum I_R1 + I_R2 + I_R3?
- Did we prove Kirchhoff's current law? Explain your answer.