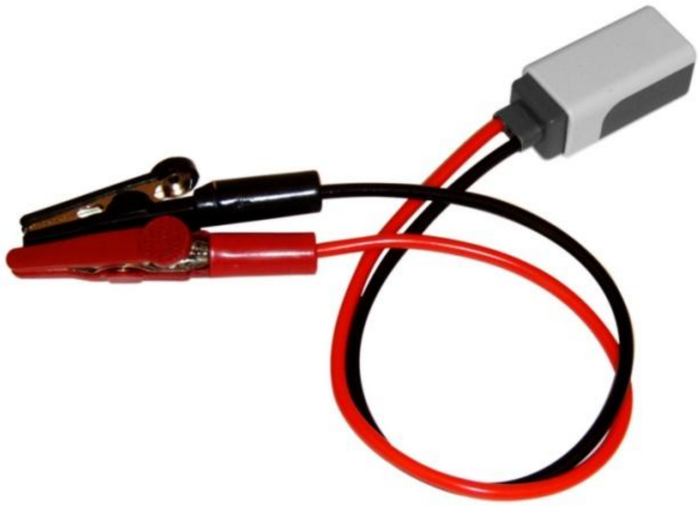
ScienceCube

K61A
Current
User Guide



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WARNING: SAFETY FIRST

For safety reasons and to avoid personal injury, read all operating guides and information in the product guide. DO NOT attempt to modify Mentor device and sensors in any way. This may result in fire, injury, electric shock or severe damage to you or them.

1. DO NOT operate Mentor device and sensors with wet hand, this may cause an electric shock.
2. DO NOT use Mentor device and sensors in close proximity to flammable or explosive gases, or chemical vapors. Use this product in a well ventilated area.
3. For safety reasons keep this sensor out of reach of children or animals to prevent accidents, for example swallowing small size of the sensor. DO NOT allow children to play on or around the sensor.
4. DO NOT use the sensor to check AC power circuits. DO NOT use the sensor in AC power outlet or sockets, this may cause a hazardous injury to you.

CAUTION:

1. DO NOT use Mentor device and sensors in extreme conditions which are over the operating range and short-term exposure limit conditions. Stresses above input range may cause permanent damage.
2. Exposure to absolute maximum conditions for extended periods may degrade sensor reliability.
3. The sensors are permanently sealed during construction and cannot be opened to any purpose. DO NOT attempt to decompose, modify or repair the sensor in any other ways. This may cause permanent damage to the sensor.
4. Liquids shall not come into direct contact with the sensor. DO NOT place sensor or cable in water, liquids, flame or on a hot plate.
5. DO NOT use this sensor in close proximity to flammable or explosive gases. Chemical vapors may interfere with the polymer layers used for capacitive this sensor and high levels of pollutants may cause permanent damage to this sensor.

Features and Specifications

Features

Item	Description
Feature	Two current clips with electric patch cords: red test clip(+), black test clip(-) Non volatile memory supported for user calibration.
Dimension	Sensor base housing: 42x18x16 (WxDxH) in mm Alligator clip: 6cm(L), Electric patch cords l : 35cm(L), 3mm(ϕ)
Usage	Use only in a dry place at room temperature below +40°C.

Specifications

Item	Description
Input range and Maximum over current	Current input: - 3.0A to +3.0A Max. over current[1]: ±5.0A
Resolution	14bit spacing, ±0.5mA
Accuracy and Sensitivity	Accuracy: Max. ±30mA Measurement deviation from linear correlation in full scale range: ±1.0%
Sampling rate	Default sampling periods: 0.2s (5samples/sec) Max. 20samples/s
Max. input and over voltage	Max. Voltage input: ±15V Over voltage: ±30V
Resistance between inputs	Insertion resistance: 0.01 Ω/2W
Calibration	Factory calibration stored and FC values recovery supported to restore factory calibration. Optional user calibration data can be wrote to non-volatile user memory.

[1] Maximum over current on any input without damage, stress above this range may cause permanent damage.

Item	Description
	User calibration methods: 1 or 2 points linear calibration
Zero offset	Zero-voltage offset drift: Typ. ±1mA@25°C Zero setting with non-volatile memory supported.

NOTE: You do not need the calibration when using the current sensor. But if you calibrate the sensor for your any purpose, the calibration data created by user does not erased after disconnecting the sensor or power off Mentor. The data set for calibration or zero setting with **MentorStart** is written to non-volatile memory in the sensor.

Additional equipment or application

Mentor device and **MentorStart** application software needed. If you are using Mentor application, consult your instructor for more information.

CAUTION:

1. DO NOT connect this sensor to over current anywhere in the circuit or power source. The power source such as battery in a circuit should NOT exceed +15V above or below earth ground.
2. Always use the sensor on a known live current under the maximum input range before proceeding with your test and measurements.
3. Make sure you are reasonably well grounded and isolated from the cable or any piece of equipment you are measuring.
4. In some cases, the sensor may falsely indicate the current value due to an incorrect circuit you use.
5. DO NOT connect the sensor to a power source such as a battery or power supply without a load. DO NOT connect the sensor directly across to an unloaded circuit.

Setup and Usage

1. Launch the **MentorStart** software and connect the sensor to the sensor port in your Mentor device. **MentorStart** will automatically detect the sensor.
2. To measure the current passing through the two input clips, connect the current clips to the circuit in series with a resistor.

To measure the current with an Ammeter-like reading

When you are reading one-shot data with Snapshot mode, you can use the sensor as an Ammeter which can be used to measure negative or positive current flowing through the sensor.

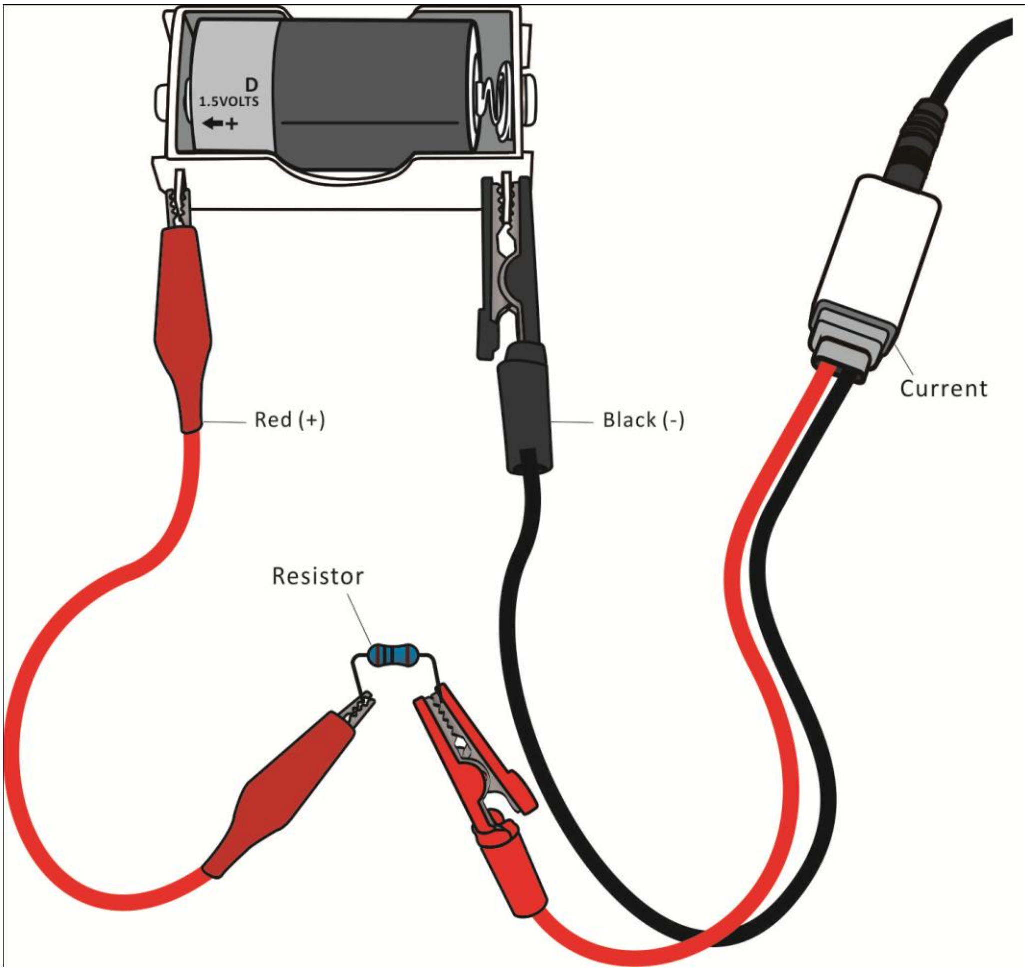

Fig.1 Connecting the Current sensor in series with a resistor to measure the current passing through a resistor. For resistors in the circuit, you can also use the everyday materials while the resistivity of them is constant over the input range of voltage or although they have the differential or variable resistance.

NOTE: The Current sensor is always connected in series with the part of the circuit to measure the current through the circuit element like a resistor. Connecting the Current sensor in parallel can damage the sensor.

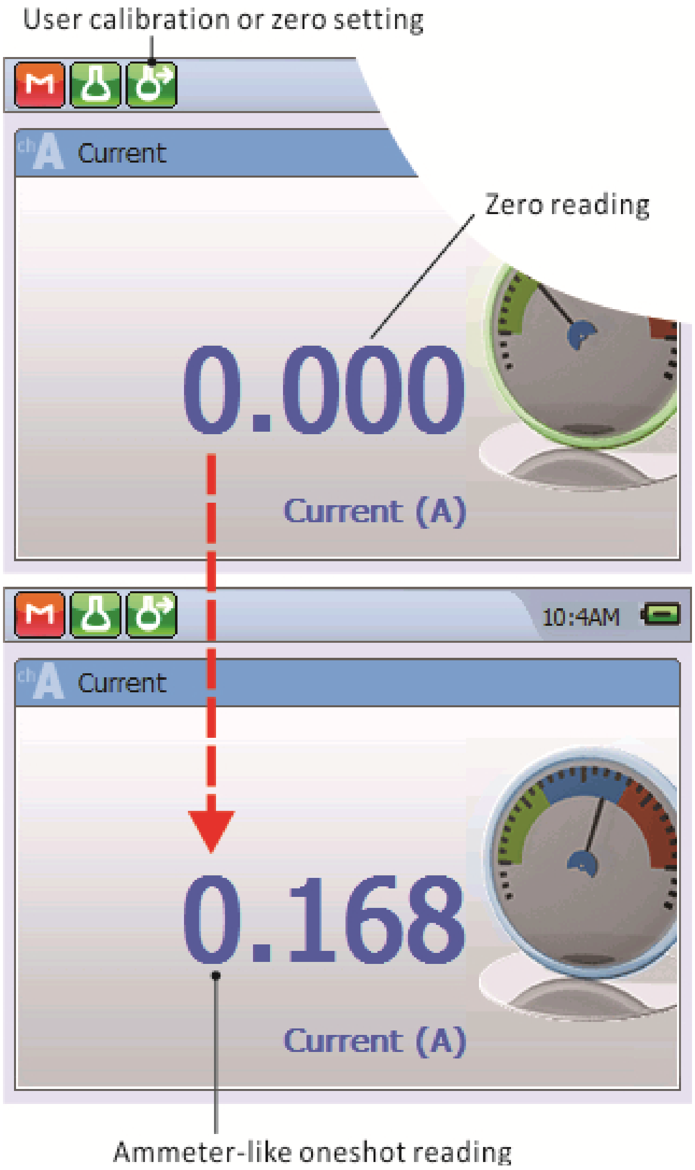

Fig.2 Testing the current with an ammeter-like one shot reading after setting Zero to the Current sensor.

Current and voltage measurement

In an application of Ohm's law, you can measure the voltage across an electrical resistance or Ohmic materials with the Voltage sensor and the current through it with the Current sensor. When you measure the current, the Current sensor is placed always in series and the Voltage sensor is connected in parallel. For an example of measuring the voltage and current, you use two 1.5volts batteries and the red LED[2] (See **Fig.3** and **Fig.4**).

[2] You can choose a LED referred to the supplier's catalogues. You might check the parameters such as the forward voltage and current, and then you use a proper resistor for LED.

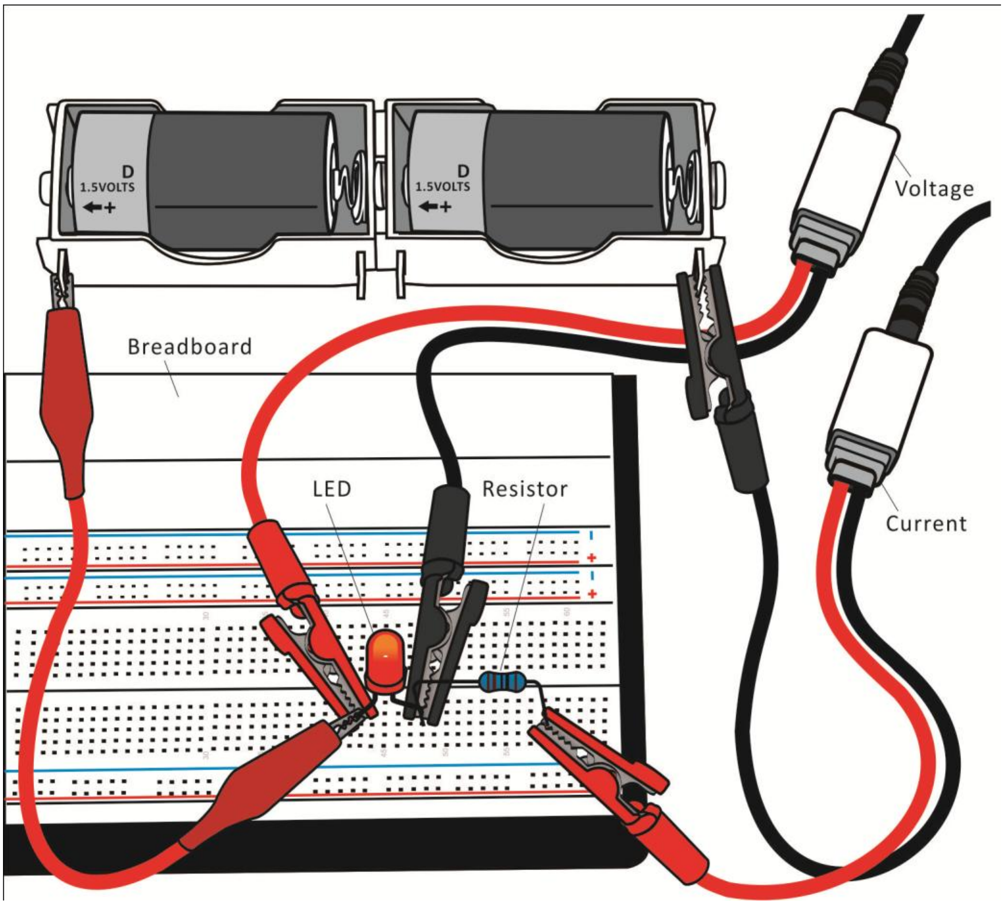

Fig.3 Measure the current passing through LED. Applying to Ohm's law which works even for non-Ohmic materials where the resistance depends upon the current, you can calculate the resistance for LED.

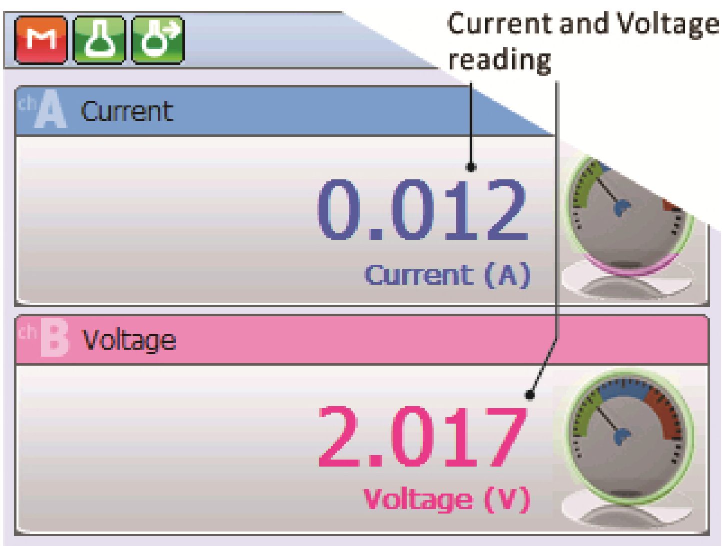

Fig.4 Current and voltage measurement with the Voltmeter/Ammeter-like one-shot reading.

Guide to Physics Experiments

Table.1 Science experiments using the Voltage sensor.

	Students' activity with practical physics experiments
1	Measure the current through the resistor in series
2	Test the Current law[3] and explore the Voltage law
3	Test the Ohm's law and explore the relationship[4] between the voltage and the current
4	Measure the power dissipated in a resistor
5	Measure the current in a circuit with two loops, two or multiple power sources
6	Test the combination rules for any number of resistors in series or parallel circuits
7	Measure the charging or discharging current on a capacitor
8	Investigate the behavior of LED or electrolytes with everyday household materials
9	Investigate the transient behavior of series RLC circuit

Measuring current passing through a resistor

In this activity, students can easily test the current while the current flows through the resistance in series circuit. As you can see **Fig.1** shown below, you can make the combination for a number of the resistors in series and you can measure the current flowing in the circuit while you change the number of resistors by the rules for combining resistors in series or parallel which can be derived with Ohm's law as the following calculation:

I=V/R=V/(R1+R2+…Rn) …Combining resistors in series
I=V/R=(I1*R1+I2*R2+…In*Rn)/(n*R) …Combining resistors in parallel

where **V** is the power voltage, **n** is the number of resistors, **I** is the current through the resistor.

[3] The current law is expressed as the sum of the currents into any junction is equal to the sum of the currents out. See the reference from: http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

[4] A correlation between voltage and current is an important problem that students critically face during a physics concept developing by inquiry. For example, a student correlates the direct relationship that voltage is the required energy driving the flow of current which will flow through conductors

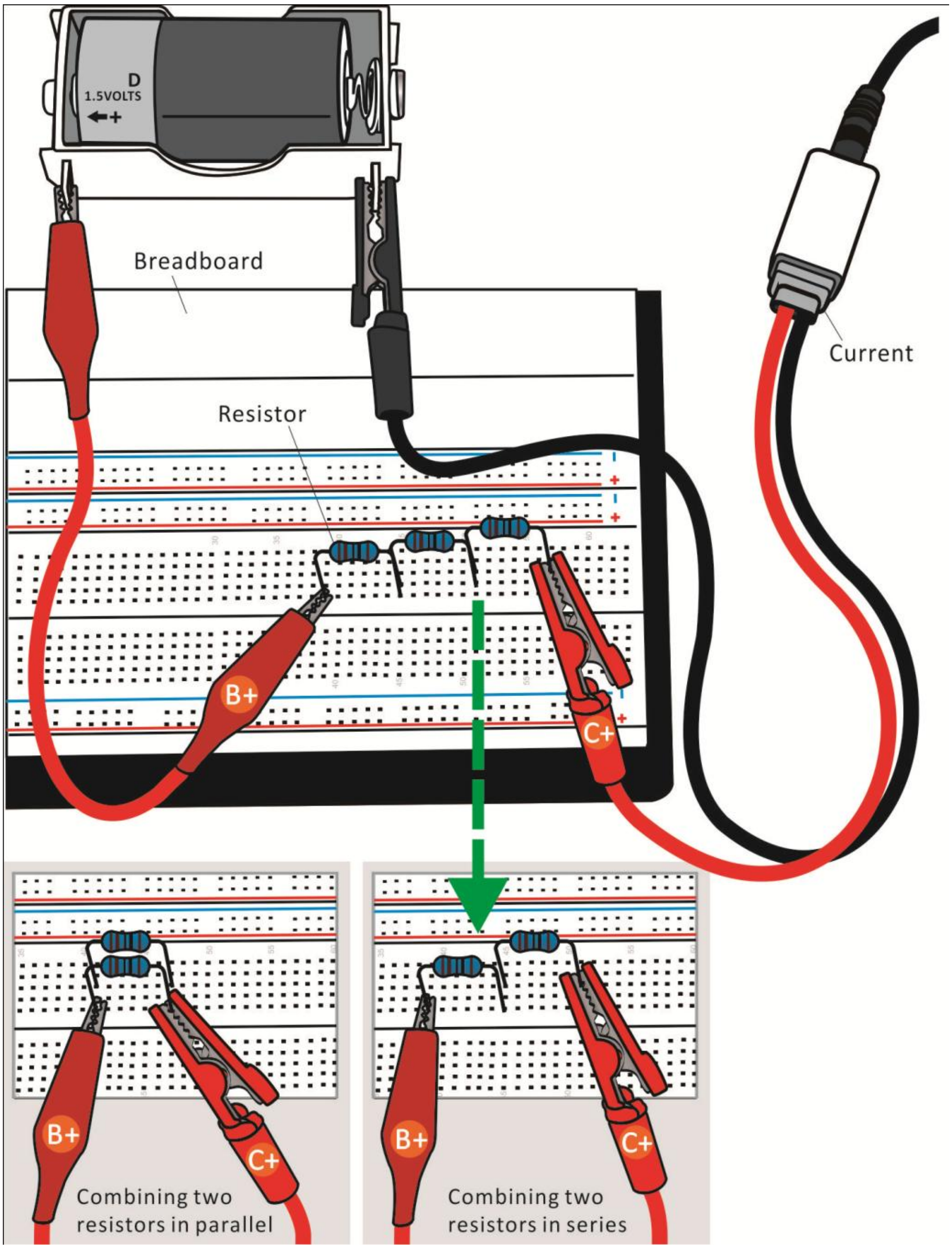

Fig.1 Testing the current law with the combination rules for a number of the resistors in series or parallel. You can test that the current is the same in each resistor in series and each current of **I1, I2,…In** is inversely proportional to each resistance[5] of **R1, R2,…Rn**.

CAUTION: If the current in the connected circuit exceed 10mA which is the minimum threshold for feeling the difficulties or pain, you should need to protect yourself and others from electrical shock.

[5] Equivalent R is R1+R2+…Rn in series and 1/(Equivalent R) is 1/R1+1/R2+…1/Rn in parallel.

Exploring the transient behavior of a capacitor

In this experiment, if you connect the battery using the clip (**B+)** and (**C-)** to the circuit as **Fig.2** shown, the current through the capacitor approaches zero reading simultaneously as the capacitor becomes fully charged up to the battery voltage **Vb**. Just after then, if you disconnect the battery and join two clips of **(B+)** and **(C-)** together, the current through the resistor will follow a type of an exponential decay curve.

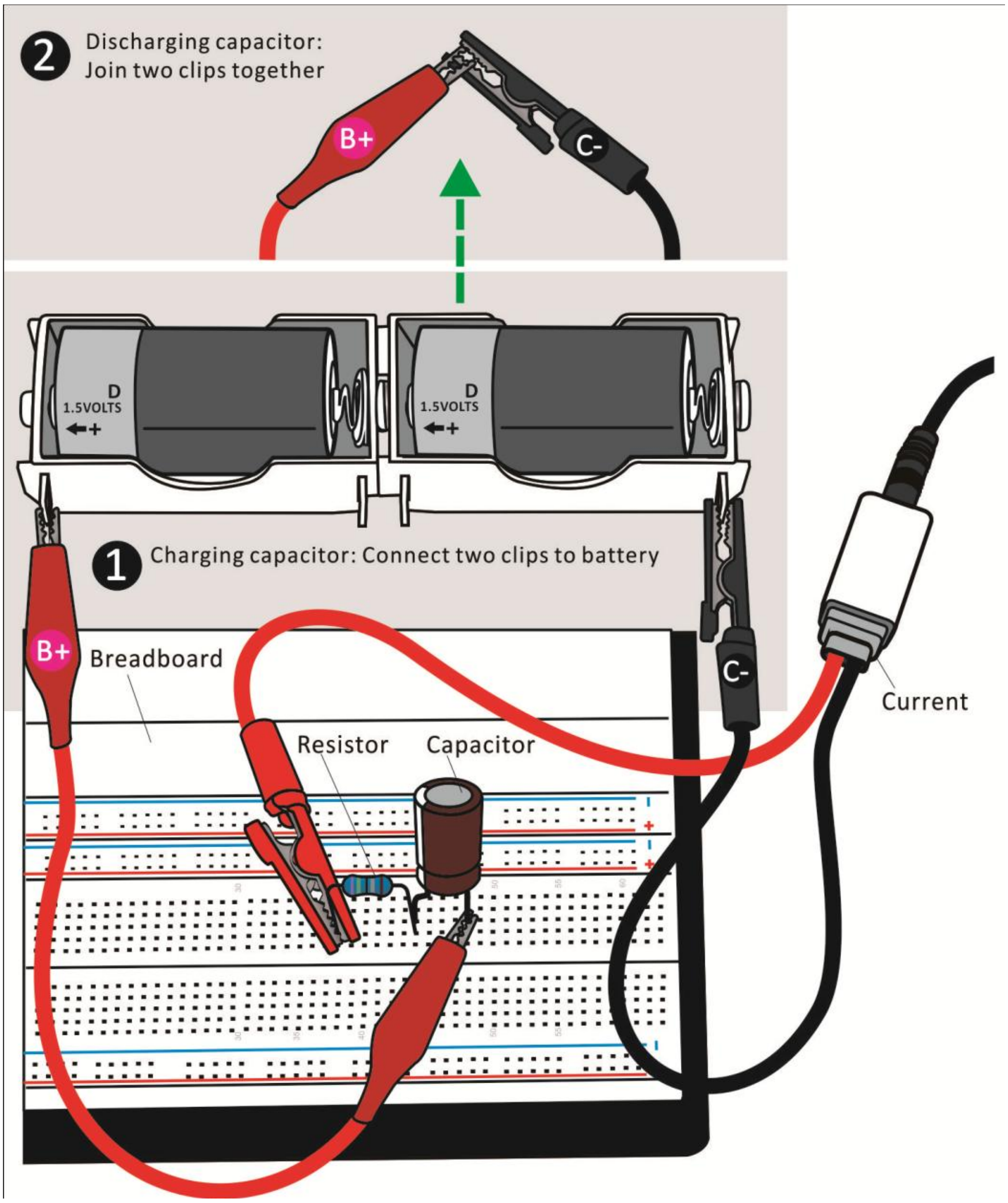

Fig.2 Testing the current behavior for charging and discharging a capacitor.

WARNING: Make sure the capacitor is discharged for your safety before testing a capacitor.

The mathematical model of charging and discharging a capacitor can be formed as the followings:

I=Vb*exp(-t/RC)/R …Charging capacitor
I=Vc*exp(-t/RC)/R …Discharging capacitor

where **Vb** is the battery voltage, **Vc** is the fully charged capacitor voltage, **R** is the resistance and **C** is the capacitance. The current rate of charging or discharging can be described in terms of a time constant **RC**.

Table.1 Analysis results of decaying current curve fit for charging a capacitor. The mathematical formula of this decaying model is defined as the following: **V=Vb*exp(-(t'+t0)/(RC'))+V0.** In according to experimental results, **RC'** is experimentally determined as **RC** and the uncertainty caused by the followings: natural decay, some non-zero conductivity, slowly discharging or leakage current (**δRC+Rn+…**) while RC is theoretically predicted .

Parameters	Analysis results
t0	5.5
t1	12.6
dt (Sampling periods in seconds)	0.1
R (Resistance in Ω)	284±0.05%
Calculated experimental value of (1/RC')	0.304465
Calculated experimental RC' (seconds)	3.284
δRC (Uncertainty of RC' in seconds) [6]	±0.509 to ±1.241
R-squared	0.999616
RMSE(Fit standard error)	0.000045

NOTE: In this experiment, it is important that you know the accuracy for the capacitance or the tolerance of the capacitor you use. There is a very large difference between the theoretical value and experimental value of RC time caused by the uncertainty. In this experiment (See Table.1 above), whereas the uncertainty of the polarized capacitor is larger (Minimum error>20% and up to Maximum error <50%), not only the capacitance of the capacitor is very high (>8700µF), but also you measure the current (>0.01A) higher than a lower capacitance you use. In this experiment, the calculated value of (1-RC/RC') is 0.247, and therefore you can define the experimental percentage error of δRC as <25%.

[6] You calculate the fractional error of δRC as the following equation: ±RC*sqrt[(δR/R)^2+(δC/C)^2]. See, Hyunsoo Kim, Computational Dynamics, 2008.

You can also fit the exponential curve with **MentorStart** program as **Fig.3** shown below and report the results if the curve fit, for example as you see **Table.1**.

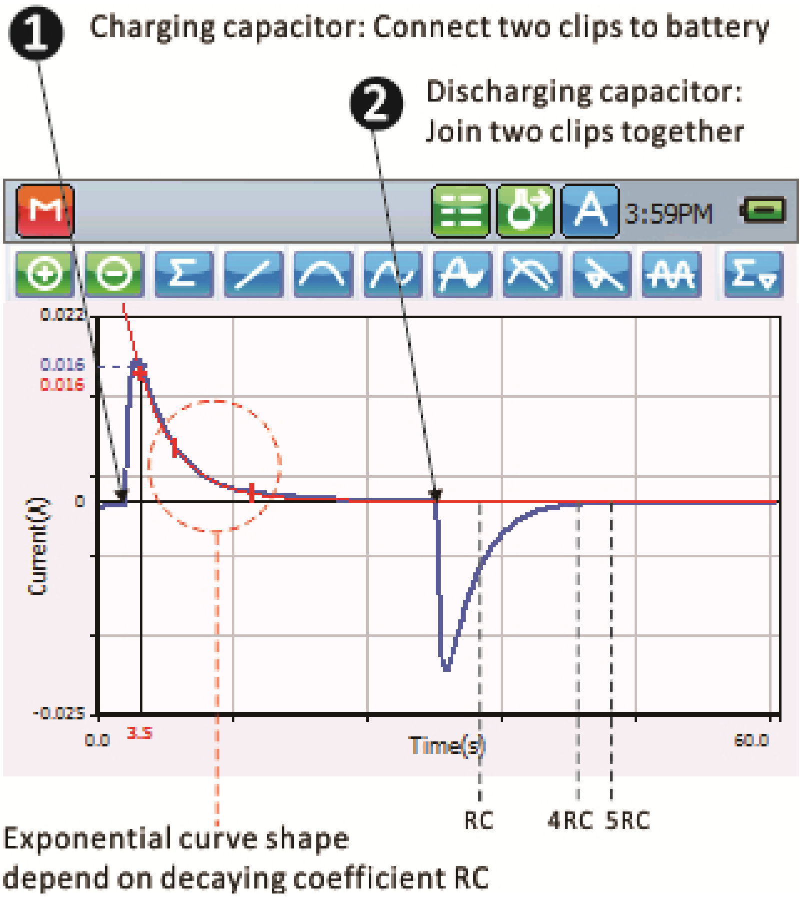

Fig.3 Measurement and analysis graph of the transient current through a capacitor. (See Fig.2) Exponential fit of decaying curve with **MentorStart**. When you press the curve fit icon on the screen of **MentorStart**, you can choose the equation of your model**, y=A*exp(B*x)+C** and calculated the parameters in the Table.1 above. To view the results of analysis, press the viewing results icon on the screen of MentorStart, not only you can get the results of the parameters such as the coefficients A, B and C with the fitting model, **y=A*exp(B*x)+C**, but also when you are trying to analyze the charging curve of a capacitor, you can choose the exponential decay model which depends on RC time.

NOTE: To get the best fit of the measurement data, you predict the equation and choose the proper curve fitting model on the screen of **MentorStart**.

Testing Ohm's law with ohmic or non-ohmic materials

In this activity, you measure the voltage and the current through the resistor, test and describe the relationship of Ohm's law. The slopes in Fig.5 shown below tell us how an unknown resistance can be measured with a closed circuit and this makes it very easy to represent and apply Ohm's law.

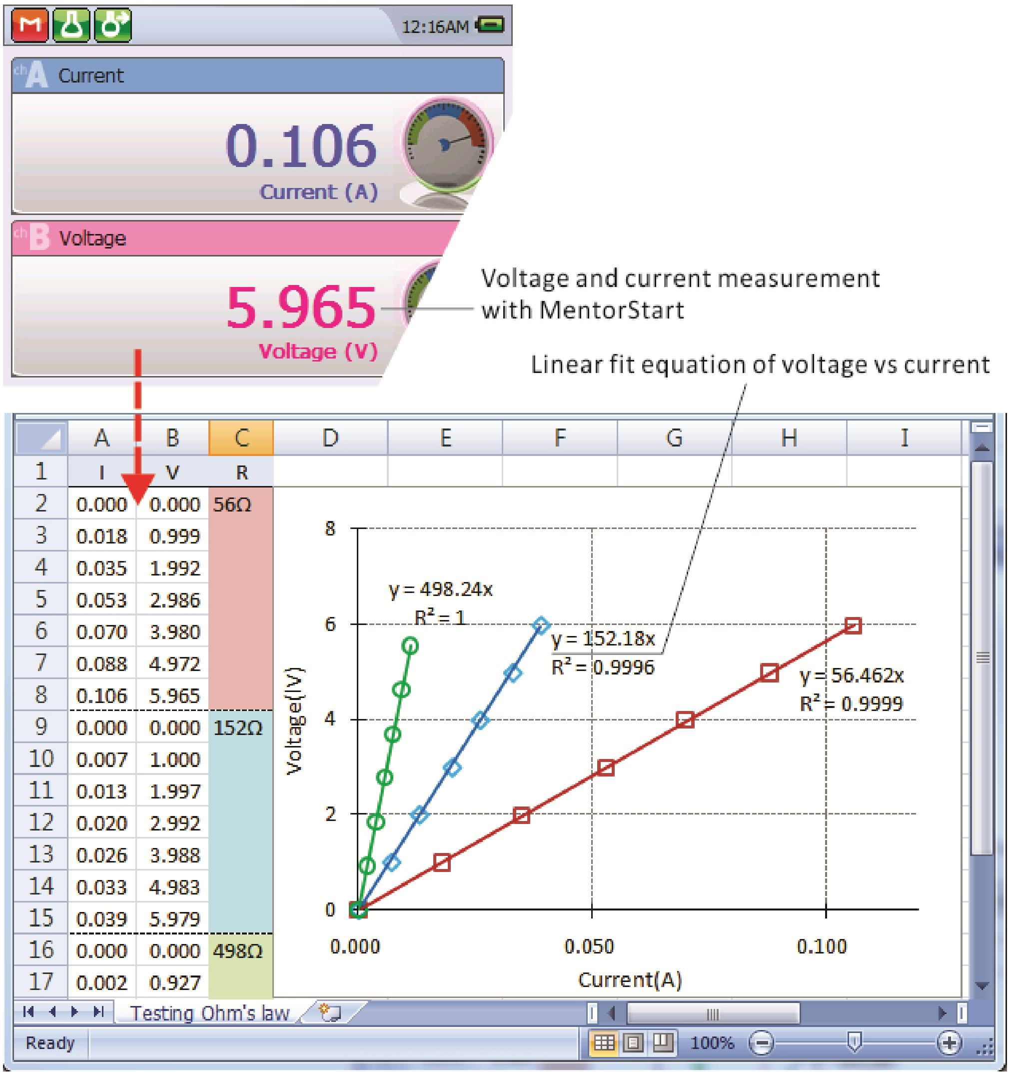

Fig.5 Measurement chart of voltage versus current. To test Ohm's law, you use the Voltage senor and the Current[7] or Galvanometer sensor. As the DC power source, you use the battery or power supply. Each slope of the linear fit equation on voltage versus current chart shows the resistance of 56Ω, 152Ω and 498Ω.

[7] In according to the results of the testing Ohm's law, you can describe a logistic equation as the following: $i=(E-V)/r$, where E is the EMF voltage of power source, V is the voltage drop through the test resistor and r is a very small equivalent resistance due to dissipation of the Current sensor.

In this activity, it is helpful to discuss the properties of the ohmic or non-ohmic materials[8] in terms of the relationship between the resistance and the voltage across it. Students inquire the relationship between the voltage and the current depends on the source of electricity and materials being used in the circuit.

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[8] Although you use non-ohmic materials, you can use Ohm's law to calculate the resistance across the non-ohmic materials. For example, you use LED and you can measure the voltage drop through LED.

LIMITED WARRANTY

Please check that this product is operating properly prior to when you intend to use it for educational purposes only. Use this device and sensors for teaching and learning. The information given in this electronic document shall not be regarded as a guarantee or warranty of physical characteristics and any conditions. We will not replace or cover the costs of a damaged sensor or probe due to negligent or destructive, improper use.

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For more information about installing Mentor, using other applications and getting the feedbacks, contact: ScienceCube international distributor.

If you have any questions about a guide to physics experiment using the sensor, please contact author at sooall@snu.kr