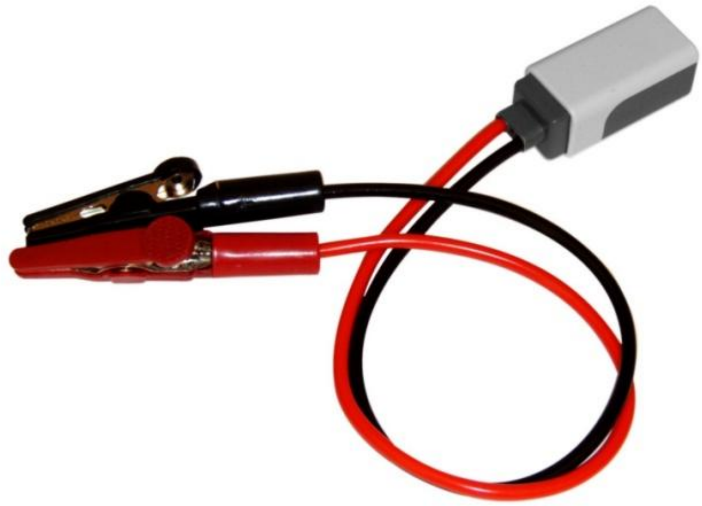
K60A
Voltage
User Guide



August 5 2010, Second Edition

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 voltage 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(ф)
Usage	Use only in a dry place at room temperature below +40°C.

Specifications

Item	Description
Input range	Differential: - 15V to +15V
Resolution	14bit spacing amplitude, Typ. ±2mV, Max. ±3mV
Accuracy	Typ. ±10mV, Min.±5mV @<±1.0V, Max. ±30mV Measurement deviation from linear correlation: -In full scale range: Typ.±0.2% -In lower range: Typ. ±0.05% @<±1.0V
Sampling rate[1]	Default sampling periods: 0.2s (5samples/sec) Max. 20samples/s
Max. over voltage[2]	±30V
Input impedance	5.3±1.5% MΩ @25°C
Calibration	Factory calibration stored and FC values recovery supported to restore factory calibration. Optional user calibration data can be wrote to non-

[1] If you need the sampling rate up to 1000samples/s, use the voltage sensor K60B. Or if you use the oscilloscope probe, you can view the waveform graph for voltage with max. 200kHz sampling rate in ±10V range.

[2] Maximum overload voltage without damage, stress above this range may cause permanent damage.

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

NOTE: You do not need the calibration when using the voltage 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 for calibration or zero setting with **MentorStart** is wrote 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 voltage anywhere in the circuit or power source. The voltage should NOT exceed +15V above or below earth ground.
2. Always use the sensor on a known live voltage 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 voltage value due to an incorrect circuit you use.

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 voltage between the V+(red) clip and the V-(black) clip, connect the voltage clips across a battery, DC power source, or circuit elements.

To measure the voltage with a voltmeter-like reading

When you are reading one-shot data with Snapshot mode, you can use the sensor as a voltmeter which can be used to measure negative or positive potential difference.

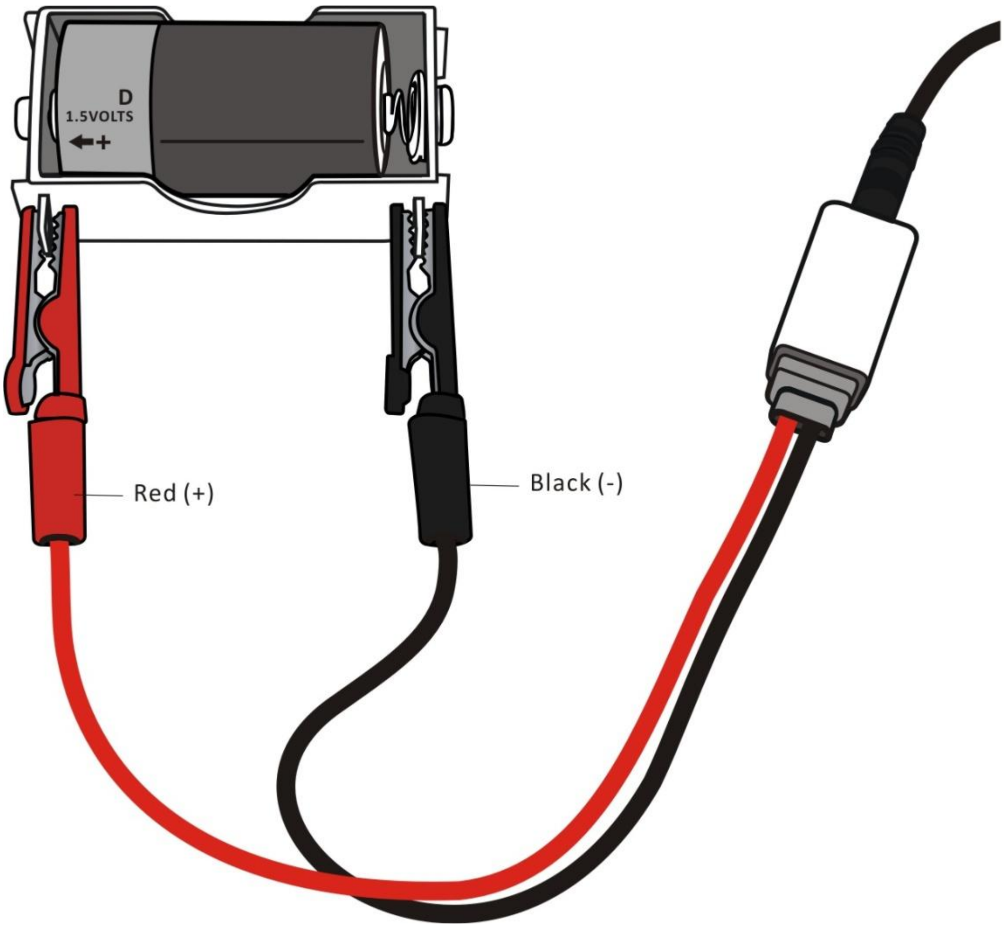


Fig.1 Testing a battery voltage with the Voltage sensor. You can check and test the most common type of household battery. For example, an AA battery is commonly used in electronic devices. When you replace the battery with an equal replacement battery to assure proper operation of your electronic device, you can check the battery which has enough voltage to power the device or not. In this activity, the voltage between the plus and minus on the battery have been referred to as EMF voltage generated by the battery.

NOTE: The Voltage sensor is always connected in parallel with the part of the circuit to measure the potential difference across a circuit element.

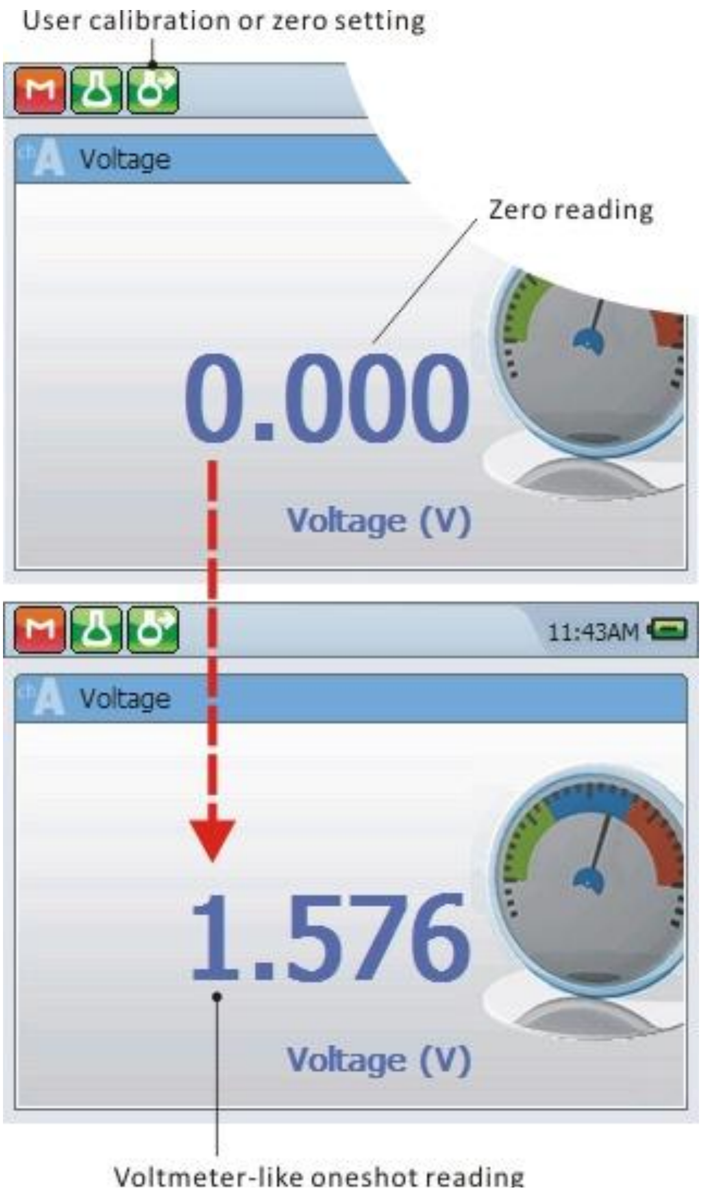


Fig.2 Testing the voltage with a voltmeter-like one shot reading after setting Zero to the voltage sensor.

Voltage and current 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[3] (See **Fig.3** and **Fig.4**).

[3] 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.

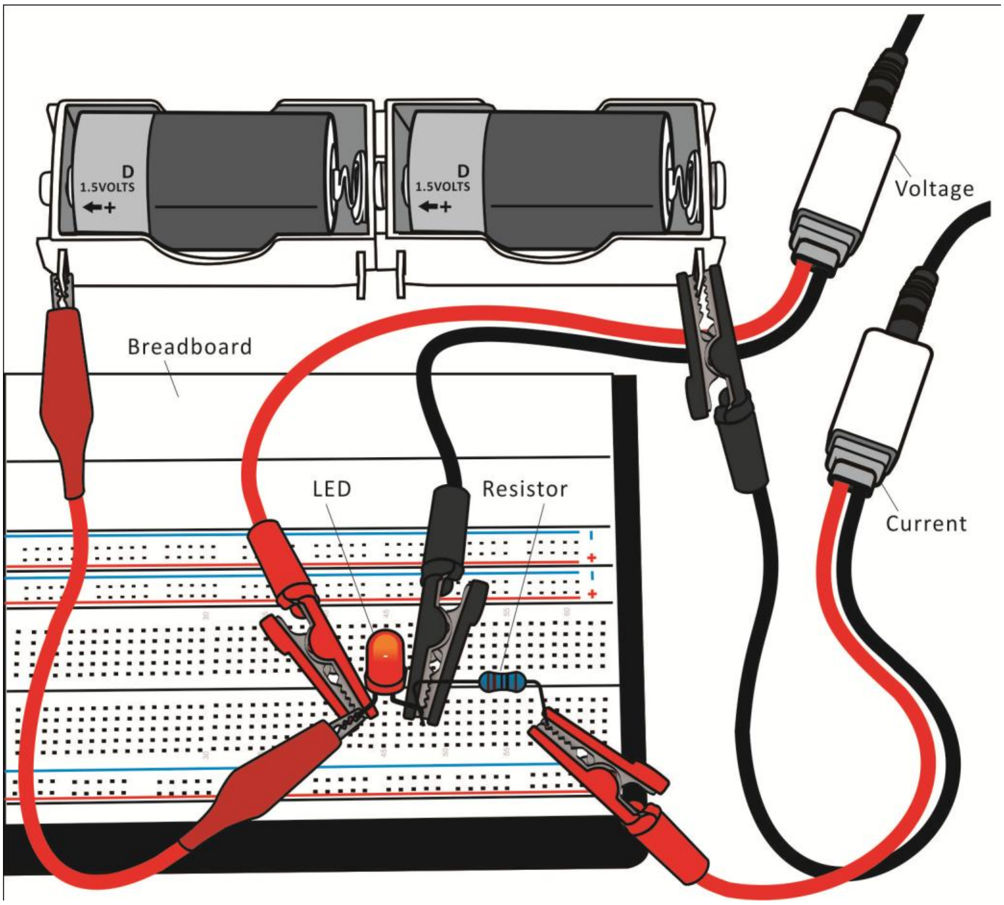


Fig.3 Measure the voltage and the current through LED. Using Ohm's law which works even for non-Ohmic materials where the resistance depends upon the current, you can calculate the resistance for LED.

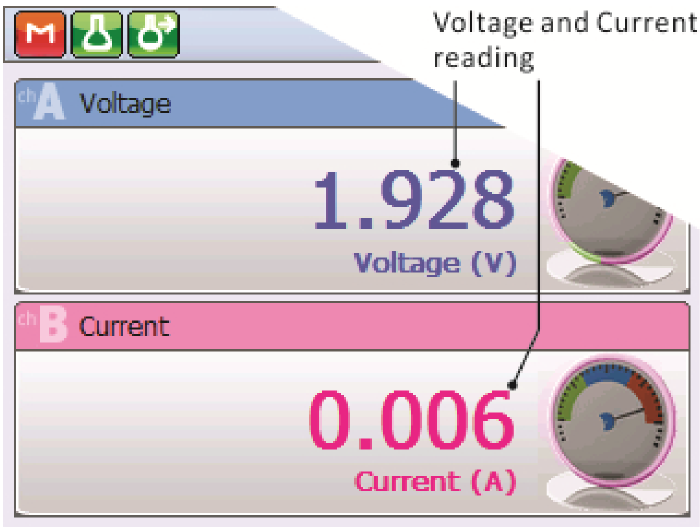


Fig.4 Voltage and Current measurement with the Voltmeter/Ammeter-like one-shot reading.

Guide to Physics Experiments

Table.1 Science experiments using the Voltage sensor.

	Students' activity with practical physics experiments
1	Measure the voltages across electrical elements in parallel
2	Test the Voltage law[4] and explore the Current law
3	Test the Ohm's law and explore the relationship[5] between the voltage and the current
4	Measure the power dissipated in a resistor
5	Measure the DC power voltage in series or parallel circuits
6	Test the combination rules for any number of resistors in series or parallel circuits
7	Measure the charging or discharging voltage on a capacitor
8	Investigate the behavior of LED or electrolytes with everyday household materials

Measure the voltage across a resistor in series

In this activity, students can easily demonstrate the voltage law with the relationship between the voltage and the electrical resistance which is defined as the ratio of the voltage applied to the electric current while the current flows through the resistance and the value of the current is the same in each resistor by the current law. Whether or not your material obeys Ohm's law, you can measure the potential difference with the resistors. 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 voltage across each or any number of resistors by the voltage law as the following calculation:

$$V = V1 + V2 + V3 + \dots Vn$$

[4] The voltage law is expressed as the net voltage drop around any closed loop path must be zero. See the reference from: http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

[5] 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 that drives the flow of current which will flow through conductors

Where **V** is the sum of the voltages around any closed loop**, V1, V2, … Vn** are the voltage drops across the resistors **r1, r2,…rn**.

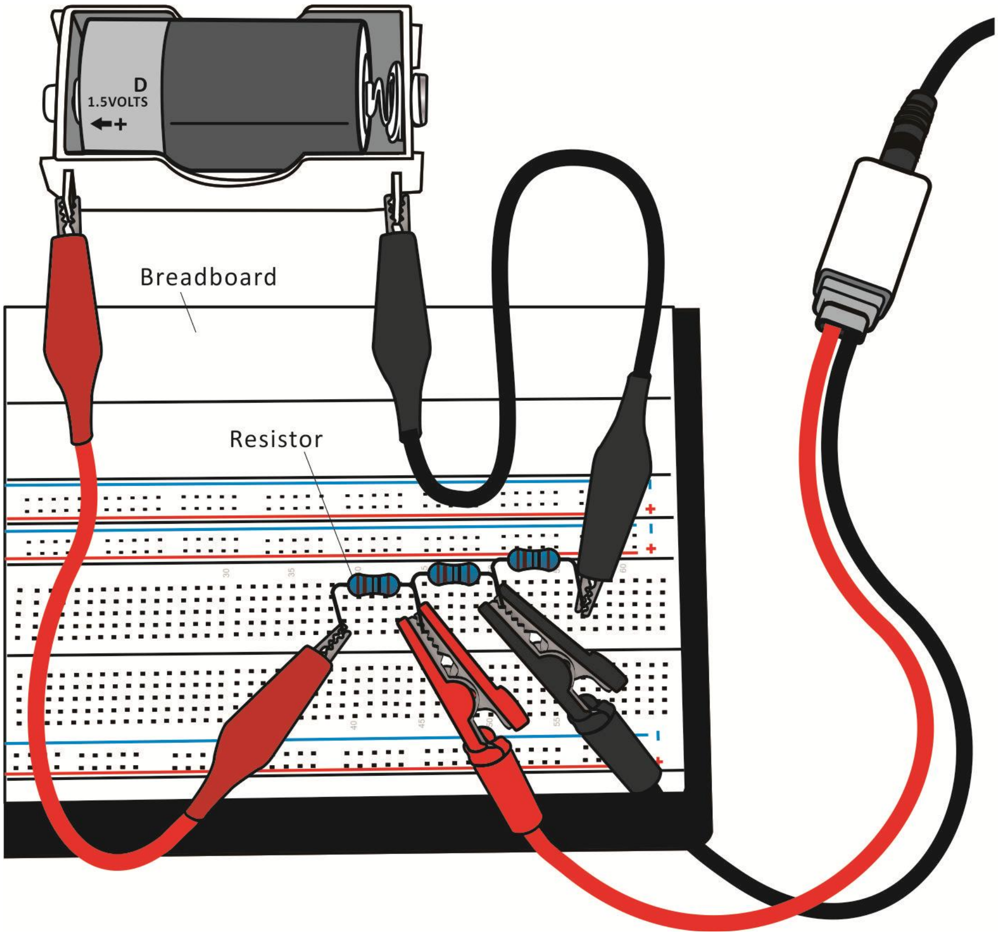


Fig.1 Testing the voltage law with the combination rules for a number of the resistors in series. Each resistor has 1kΩ and the voltage of a battery is 1.5V.

Exploring the transient behavior of a capacitor

In this experiment, if you connect the battery using the clip **B+** and **B-** to the circuit as **Fig.2** shown, the capacitor will be fully charged up to the battery voltage and the voltage reading will has a constant value of the maximum voltage. Just after then, if you disconnect the battery and join two clips of **(B+)** and **(B-)** together, the voltage reading will follow a type of an exponential decay curve. The mathematical model of a charging or discharging capacitor can be formed as the followings:

V=Vb[1-exp(-t/RC)]… Charging capacitor
V=Vc*exp(-t/RC)… Discharging capacitor

where **V** is the changing voltage, **R** is the resistance and **C** is the capacitor. The voltage rate of charging or discharging can be described in terms of a time constant **RC**.

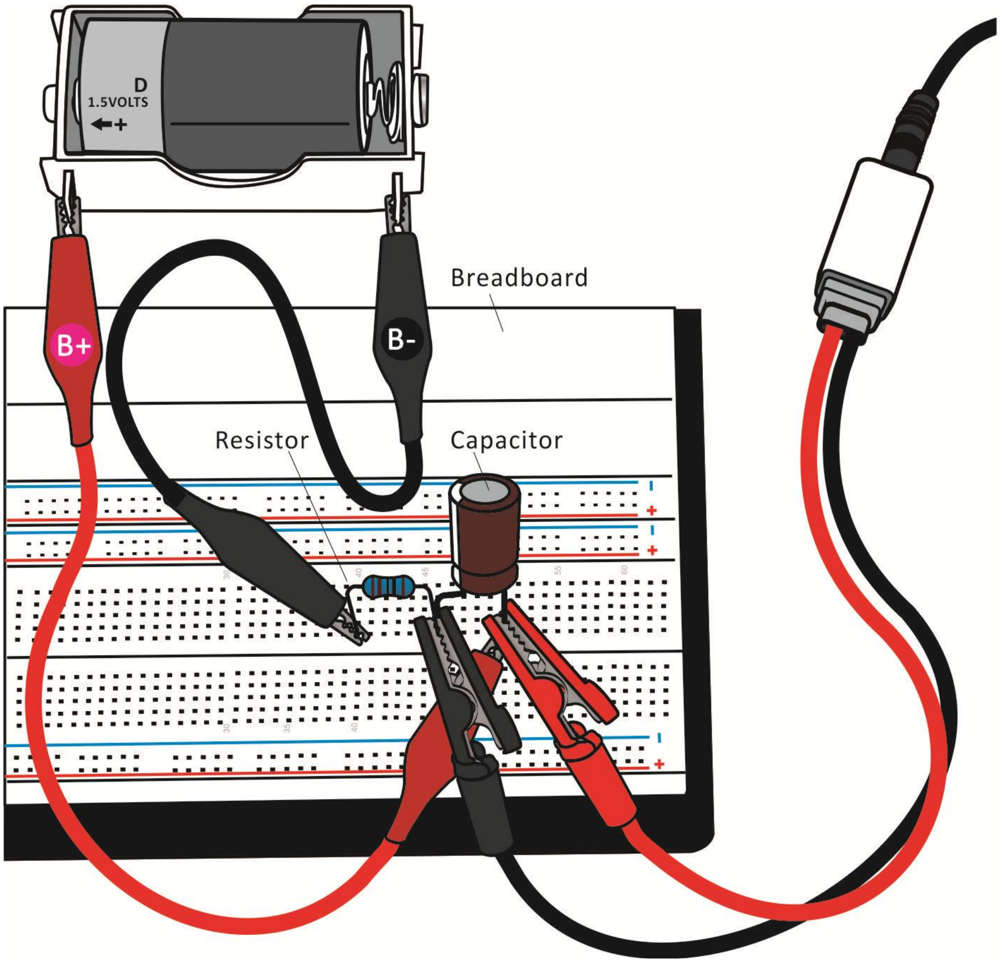


Fig.2 Testing the voltage rate for charging or discharging a capacitor. The resistor has 3000Ω and the capacitor is 1000μF.

Table.1 Analysis results of decaying curve fit for discharging a capacitor. The mathematical formula of this decaying model is **V=Vc*exp(-(t'+t0)/RC))+V0**. For circuit parameters in this experiment, the theoretical value of RC is 0.333 where R=3000Ω and C=0.001F, and the calculated value with the decaying model is 0.327.

Parameters	Analysis results
t0	30.2
t1	38.4
dt (Sampling periods in seconds)	0.2
Vc (Coefficient of best fit)	**0.796**

Parameters	Analysis results
Theoritical value of (1/RC)	0.333
Calculated value of (1/RC) with exponential decaying model	0.327
V0 (Intercept of best fit)	0.018
R-squared	0.999
RMSE(Fit standard error)	0.015

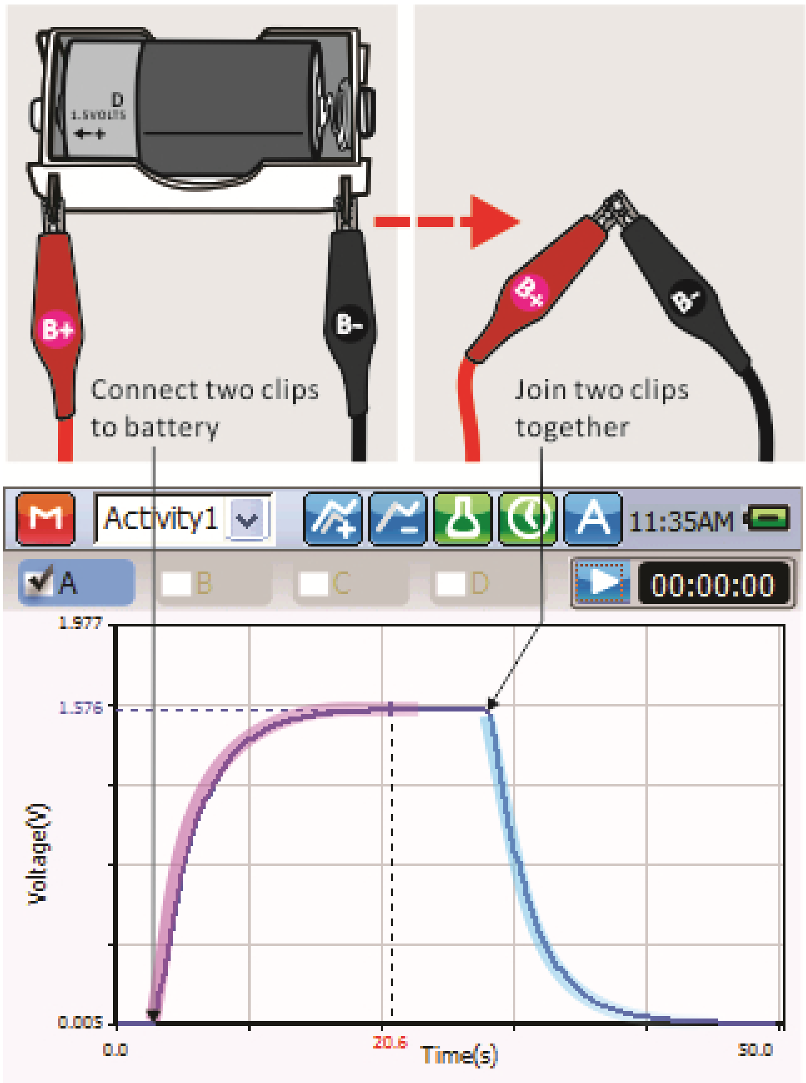


Fig.3 Voltage measurement graph of charging and discharging capacitor. You connect two voltage clips to the battery, and after reading the maximum voltage continuously, join two clips together to discharge the capacitor.

You can fit the exponential curve with **MentorStart** program as **Fig.4** shown below and report the results if the curve fit, for example as you see **Table.1**.

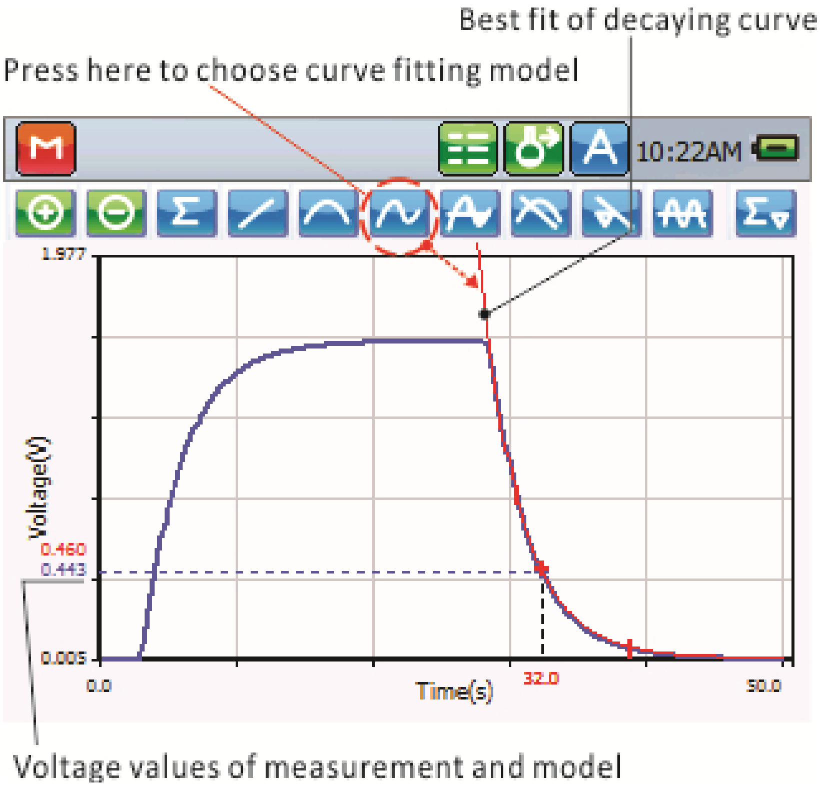
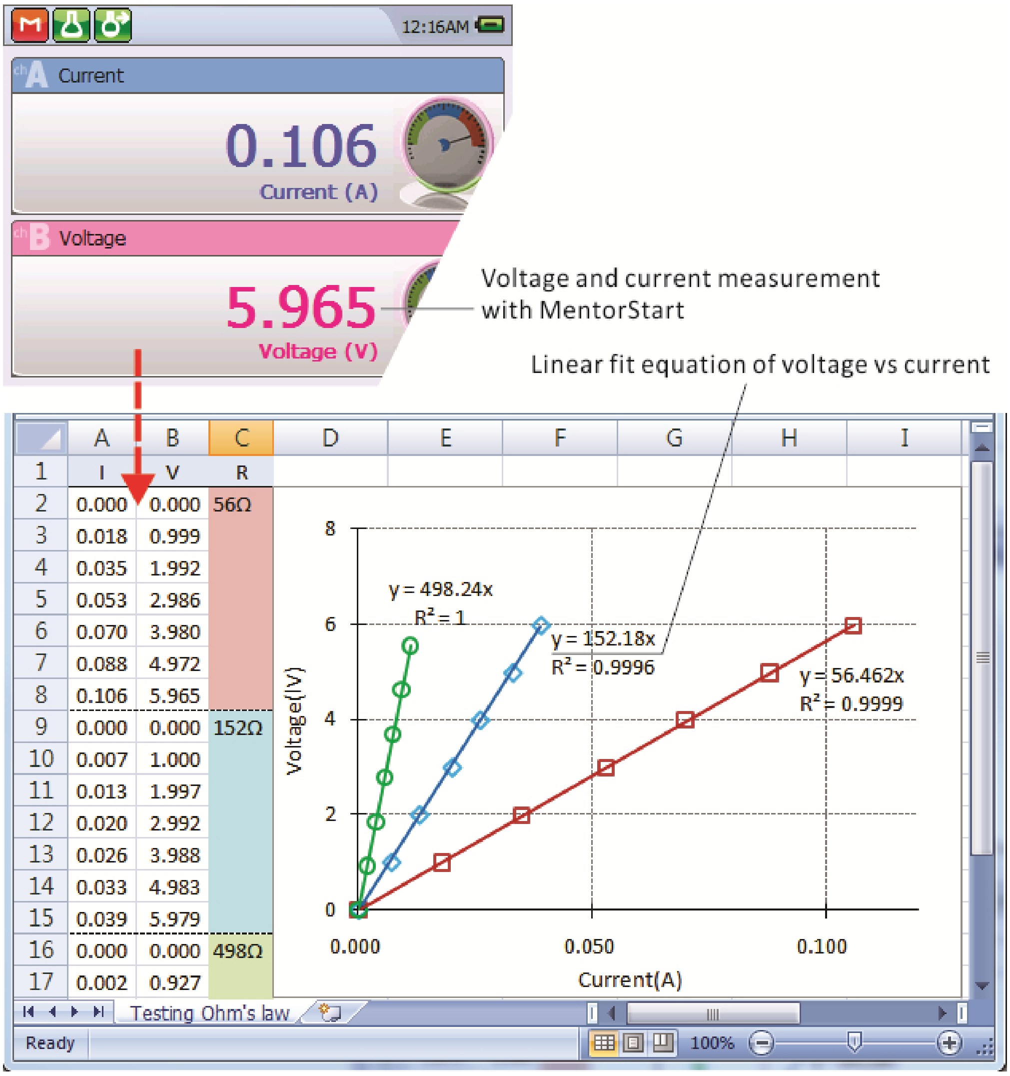


Fig.4 Exponential fit of decaying curve with **MentorStart**. When you press the curve fit icon on the screen of **MentorStart**, you can choose the equation of your model, y=A*exp(B*x)+C and calculated the parameters in the Table.1 above. To view the results of analysis, press the viewing results icon 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 model: y=A*(1-exp(B*x))+C.

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.



	I	V	R
2	0.000	0.000	56Ω
3	0.018	0.999	
4	0.035	1.992	
5	0.053	2.986	
6	0.070	3.980	
7	0.088	4.972	
8	0.106	5.965	
9	0.000	0.000	152Ω
10	0.007	1.000	
11	0.013	1.997	
12	0.020	2.992	
13	0.026	3.988	
14	0.033	4.983	
15	0.039	5.979	
16	0.000	0.000	498Ω
17	0.002	0.927	

Fig.5 Measurement chart of voltage versus current. To test Ohm's law, you use the Voltage senor and the Current[6] 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.

In this activity, it is helpful to discuss the properties of the ohmic or non-ohmic materials[7] 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.

[6] 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.

[7] 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