IERG1810 - Experiment 1
Basic Electric Circuit Measurements

Objectives

- To identify the equipment is floated or grounded.
- To know the limitations of equipment;
- To know doing measurement, should use
  - **suitable** equipment,
  - **suitable** settings,
  - **suitable** cables,
  - **suitable** methods
- To study measurements of Voltage and Current with Digital Multi-meter (DMM) and oscilloscope.
- To study some special cases of Ohm's law, Kirchhoff's circuit laws and Thevenin's equivalent circuits.

Equipment

- Oscilloscope
- DC Power Supply
- Digital Multi-meter (DMM), desktop model and handheld model
- Signal Generator
- Prototype Breadboard
- Battery Internal Resistance Meter

Components

- Battery
- Resistor
- Capacitor
- Diode
- LED
- Inductor
- Variable resistor

Introduction

Most equipment whether use two terminals to do measurement is called two-wire measurement. For precision cases, four-wire measurement is used. In two-wire measurement, one terminal is the *Reference* point (color code BLACK) and the other one is the *Measurement* point (color code RED).

In practice, some equipment's reference points are connected to the domestic electric power system **Protected EARTH for safety**, thus are regarded as "grounded". In contrast, if the equipment's reference points are isolated, they are regarded as "floated". It is important to know whether the equipment in use is **grounded** or **floated**. Otherwise, connecting a grounded reference point to any signal point will lead to wrong measurements or cause possible **damage** to the components or equipment when the current passes through the protected earth. In this experiment, we will use the equipment to measure voltage, current, resistance and investigate the equipment limitations of DC and AC circuits, as well as the characteristics of the components. We will further investigate the Ohm's laws, Kirchhoff's circuit laws, bridge circuit and Thevenin's equivalent circuit, with some simple circuits and their applications.

Experiment 1.1: Grounding of equipment

Here are a few technical terms to represent the reference points, signal ground, chassis ground, protected ground, EARTH, etc…

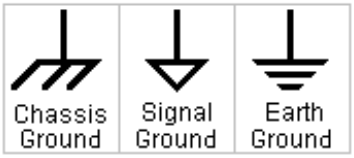


Fig. 1-1

Ref:

http://en.wikipedia.org/wiki/Ground_%28electricity%29

http://www.beam-wiki.org/wiki/Ground

- ***Signal ground*** represents the signal reference of a small part of the circuit. Components should be placed as close as possible to the respective signal ground for connection, so as to reduce common mode noise taken by the PCB traces.
- ***Chassis ground*** represents the reference point or the return path of a system, e.g. printed circuit board (PCB), car body. Some systems connect Chassis ground to the protected ground.
- ***Protected ground***, or ***the EARTH***, is the point which connects to the electric power system through wires, water pipes or phantom loop for protection. This is the reference point of our EARTH. Equipment which has got a metal case should connect to this EARTH to prevent any possible electric shock. In practice, the equipment's case connects to the EARTH through the biggest terminal of the British's standard power plug (Hong Kong 13A power plug). Some equipment's reference points (BLACK terminals) connect to the EARTH but some do not. Special attention has to be paid on this connection specification, otherwise, the components or equipment may be damaged by improper connections. The metal case of the equipment should connect to EARTH for safety reason.

  In this part of experiment, we will try to determine whether the equipment is grounded or floated.

Procedures

1. Set the DMM (handheld) for Conductivity Test (a "beeper" sign). Connects the black probe to the black terminal and the red probe to the red terminal with 'V'. DMM (handheld) must be a floated equipment. Check DMM conductivity test function; short (connect) the RED and BLACK probes of DMM, you should hear sound 'beep', it means the resistance between two terminals is very small (or zero ohm).
2. Our DC power supply has got a metal case, it must be connected to the EARTH to comply safety regulations. Connect the handheld DMM's black

probe to one of the screws on left or right side of the metal case (Figure-1.2). It means that the DMM is grounded now and you can use the red probe of DMM to find out other terminals that are grounded (if hear beep) or not.

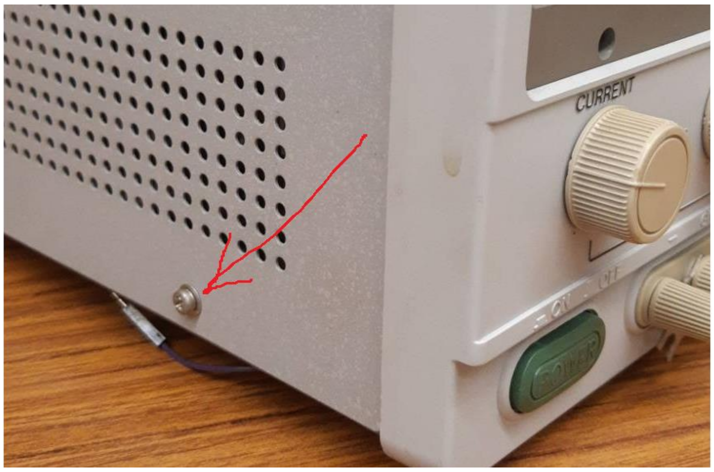


Figure-1.2 Grounded screw on the power supply

3. Check the terminals of Power Supply are grounded or floated. (No need to power on the power supply in this step.) The power supply provides three output channels with three sets of colored terminals; each channel has RED(+), BLACK(-) and with/without GREEN(GND). Connect the DMM's red probe to the DC power supply RED, GREEN and BLACK terminals one by one. You may hear the beeper sound when you connect to GREEN. This means that GREEN terminals are connected to the EARTH, but the RED and BLACK terminals are not. Hence, these show that our DC power supply is floated when you use the RED(+) and the BLACK(-) terminals only. Unless you need a grounded power supply, do not connect the GREEN and the BLACK terminals together.
4. As the table below, locate the terminals of the Oscilloscope (Figure-1.3), Signal Generator (Figure-1.4), resistor (Figure-1.5) and desktop DMM (Figure-1.6 and 1.7), check them are ground/floated.

Equipment / Component	Grounded / Floated	Terminal connects to Ground
Power Supply	Grounded	Green
Power Supply	Floated	Red
Power Supply	Floated	Black
Oscilloscope	Grounded	Channel shell
Oscilloscope	Floated -	Channel center
Signal Generator	Grounded	Channel shell

Signal Generator	Floated	Channel center
Resistor	Floated	pin-1
Resistor	Floated	pin-2
DMM DC voltmeter (desktop)	Floated	Red probe
DMM DC voltmeter (desktop)	Floated -	Black probe
DMM DC ammeter (desktop)	Floated	Red probe
DMM DC ammeter (desktop)	Floated .	Black probe
DMM ohm-meter (desktop)	Floated	Red probe
DMM ohm-meter (desktop)	Floated .	Black probe

Notes:

- DMM as DC voltmeter (switch to ‘V’ with dots) (Figure-1.6)
- DMM as DC ammeter (switch to ‘I’ with dots) (Figure-1.7)
- DMM as ohm-meter (switch to Ω) (Figure-1.6)

Figure-1.3 Terminals of Oscilloscope (2 test points)

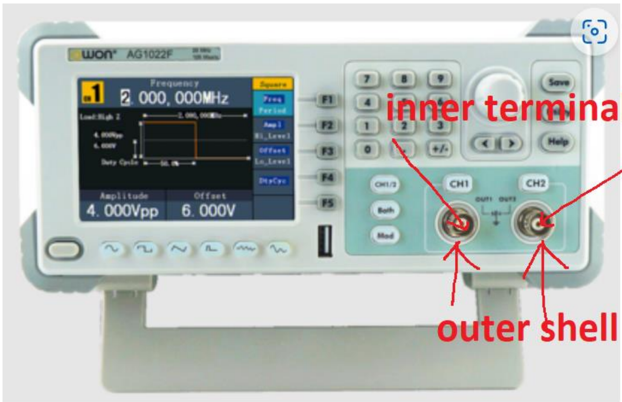


Figure-1.4 Terminals of Signal Generator (total 2 test points, either channel)

Figure-1.5 Terminals of Resistor (two test points)

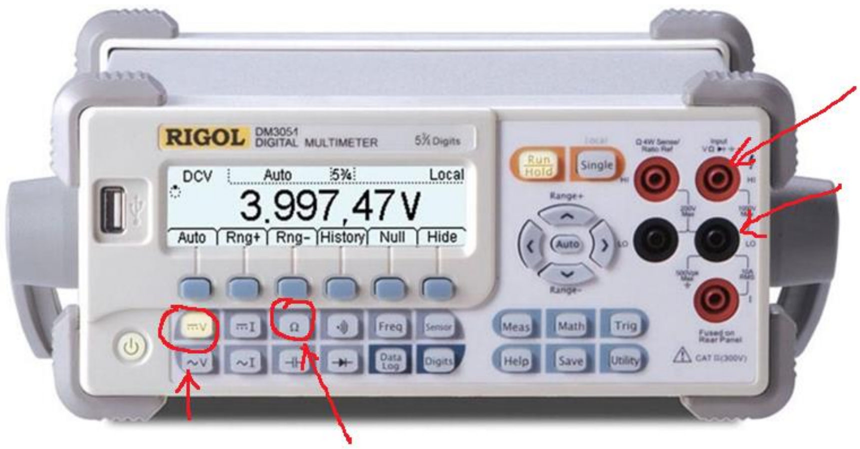


Figure-1.6 DMM as a DC voltmeter and ohm-meter

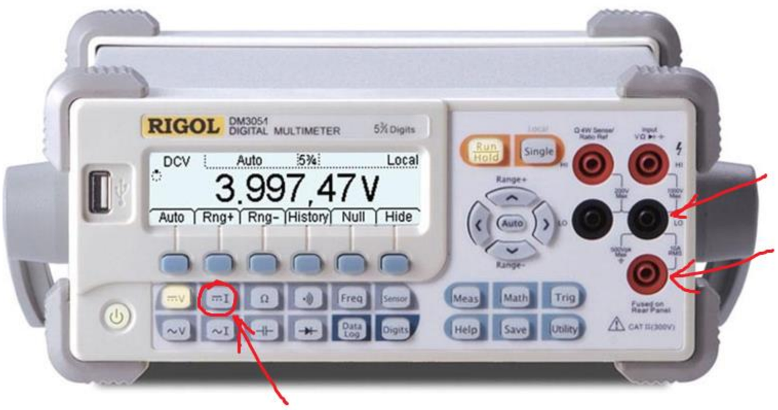


Figure-1.7 DMM as a DC ammeter

Experiment 1.2: DC Voltage Measurement

You can measure voltage with DMM or oscilloscope. DMM costs tens or hundreds but oscilloscope costs thousands. So, their specification and limitations are different. Oscilloscope provides three different methods to measure voltage:

1. Image on screen; (main objective of this course)
2. Measurement function in Oscilloscope. (press button [Meas])
3. DVM function. (DVM on screen, optional, if the license is paid)

Include handheld and desktop DMMs, totally we have five methods to measure voltage, you have to understand the pros and cons of them.

Important: Know how to measure signals with the images on oscilloscope and read the settings are main objective of this course.

Procedures

1. Set the DC power around to 5.0V.
   Important: Power Supply is not a measurement equipment, the output voltage is just the power supply shown, we should use a measurement equipment to measure (prove) it.
3. Set the DMMs as DC Volt-meter (a 'V' sign with dot mark). Connect the pair of the probes to DMM terminals, red probe to red terminal (marked 'V') and black to black.
4. Join the power supply, DMMs and oscilloscope (Figure-2.2 shows oscilloscope probe) together as Figure-2.1. (reference to reference, signal to signal).
   Notes: oscilloscope is grounded equipment.
5. Explain the DC power supply and DMMs are grounded in Figure-2.1 and different to experiment-1.1.

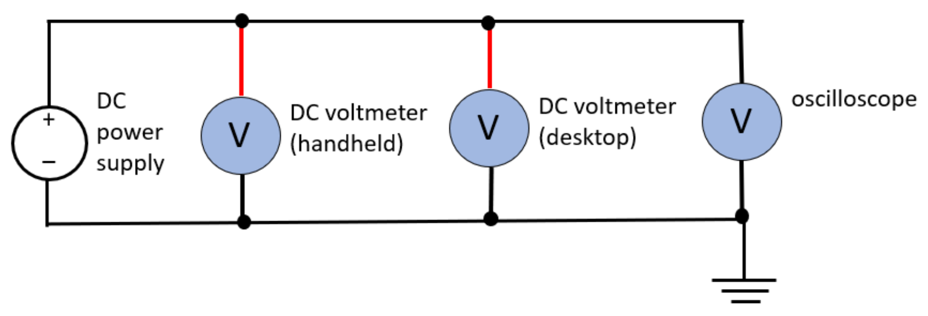


Figure-2.1 Measure voltage

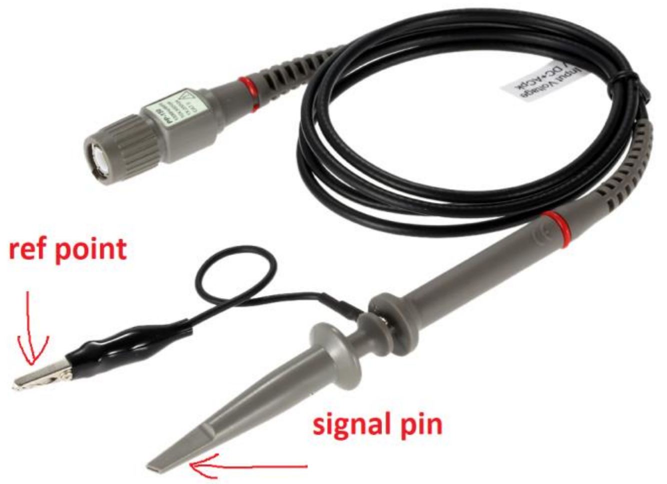


Figure-2.2 Signal and reference point of oscilloscope probe. Pull back the plastic cap of signal pin can see the metal clip. Black crocodile clip is reference point.

6. Measure the output voltage of the power supply with five measurement methods; (1) Handheld DMM, (2) Desktop DMM, (3) image on oscilloscope, (4) Measurement function of oscilloscope and (5) DVM function on oscilloscope (Figure-2.3), skip (5) if your oscilloscopes does not have this function (unpaid ☹). Compare the results in terms of precision and explain your conclusion (know pros and cons of each method).

Source = DC 5.0		
Equipment	*Reading*	*Precision*
E.g.	*5.015V*	*0.001V*
DMM (handheld)	5.059 V	0.001 V
DMM (desktop)	04.9532 V	0.0001 V
Screen on Oscilloscope	4.9 V	0.1 V
Measurement function on Oscilloscope	4.94 V	0.01 V
DVM on Oscilloscope (mode: DC RMS)	4.90 V	0.01 V

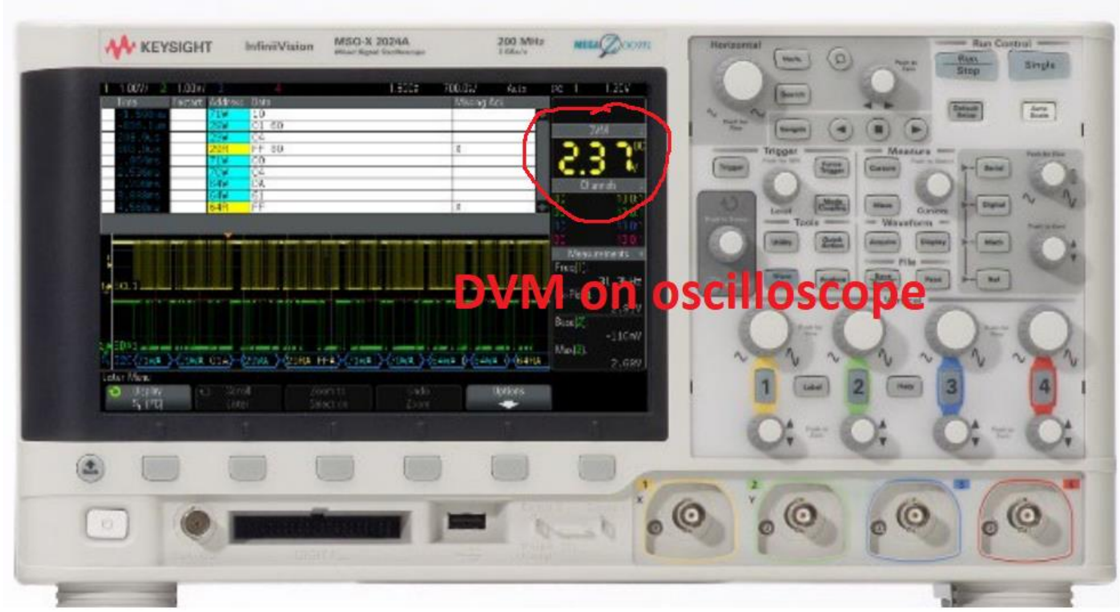


Figure-2.3 DVM on oscilloscope

Important: If say 'measure a point', it means that this point reference to the reference point of the circuit. So, you must know which is the reference point of the circuit.

7. Measure a battery cell voltage (unknown voltage, may be new, may be used) with the five voltage measurement methods. Compare the results in terms of precision and explain your conclusion.

Source = Battery Cell		
Equipment	*Reading*	*Precision*
DMM (handheld)	1.221V	0.001V
DMM (desktop)	1.21470 V	0.00001 V
Screen on Oscilloscope	1.2 V	0.1V
Measurement function on Oscilloscope	1.21V	0.01V
DVM on Oscilloscope (Mode: DC RMS)	1.21V	0.01V

Experiment 1.3: AC Voltage Measurement

You can see the waveform of a DC voltage is a horizontal line only on the screen when you measure it with oscilloscope, the magnitude is constant and easy to present.

An AC signal is different, you will see the waveform (sine, triangle, square or other patterns) swing up-down. The frequency and amplitude may not be constant. To present an AC voltage with a simple magnitude (a number) may not be good enough. In this experiment, measure an AC voltage with five measurement methods and know the equipment limitations and the meaning of presentation figures.

Procedures

1. Set the Signal Generator frequency to 1KHz Sine wave, amplitude to around 1Vp-p (peak-to-peak voltage), 0V offset. Connect the BNC (Figure-3.1) cable to the Signal Generator. Plug (and push) the cable to the outlet of the Signal Generator and turn around 90 degree (Figure-3.2), you will feel a snap when the cable is locked.

   Notes: Signal Generator is not a measurement equipment, it is a source.

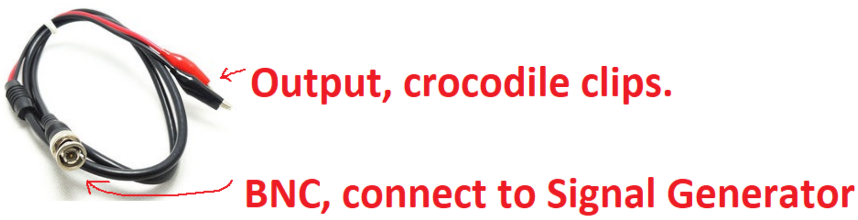


Figure-3.1 BNC cable (in the box beside the Signal Generator)

Figure-3.2 Match gap (on BNC cable) and lock pin on BNC outlet (on Signal Generator)

2. Set the DMM as an AC Volt-meter (a 'V' sign with a curve mark). Connect the Signal Generator output with a BNC cable. The crocodile clips are the extension of the Signal Generator. Check with DMM Conductivity Test to know the red and black crocodile clips connections.

3. Join the four equipment; Signal Generator, DMMs and oscilloscope together to measure the amplitude of the AC signal. Think, which are the signal and reference of each equipment.
   - Join references together,
   - Join signals together.
4. Draw your circuit and mark the reference point with corresponding symbol. Explain what will happen if following cases:
   - Interchange the terminals of DMM
   - Interchange the terminals of oscilloscope.
5. Measure the AC signal with five voltage measurement methods**.** If the measured figures are different (not just accuracy error), what are the units of figures?

   Hints: peak-to-peak, R.M.S

6. Compare the results in terms of precision and amplitude. Explain your conclusion.

Source = AC 1Vp-p, 1KHz		
Equipment	*Reading*	*Precision*
DMM (handheld)	0.354 V	0.001 V
DMM (desktop)	0.3537 V	0.0001 V
Screen on Oscilloscope	1.2V (p to p)	0.1V
Measurement function on Oscilloscope	1.17V (p to p)	0.01V
DVM on Oscilloscope (mode: AC RMS)	404 mV	1 mV

7. Set the Signal Generator frequency to 2MHz Sine wave, amplitude to around 1Vp-p, 0V offset.
8. Repeat the procedures of AC measurement. The results should not be same as previous measured.

Source = AC 1Vp-p, 2MHz		
Equipment	*Reading*	*Precision*
DMM (handheld)	0.220V	0.001V
DMM (desktop)	0.2200V	0.0001V
Screen on Oscilloscope	1.6V	0.1V
Measurement function in Oscilloscope	1.63V (P-P)	0.01V
DVM in Oscilloscope (mode: AC RMS)	228mV	1mV

9. What are the problems if the results are different? Which keywords should be used to explain it.

Hints: Compare the difference of the signal.

the frequency is not the same

Experiment 1.4: Resistance Measurement

The most common usage of DMM is ohm meter that can measure the resistances of stuffs. Resistance cannot represent all characteristics of a component. Sometime you will get meaningless are unstable results. (Suitable equipment is one of objectives of this lab)

Procedures

1. Set the DMM as an ohm-meter ('Ω' sign).
2. Measure the given components with an ohm-meter.

$\frac{1}{3300} + \frac{1}{1000}$

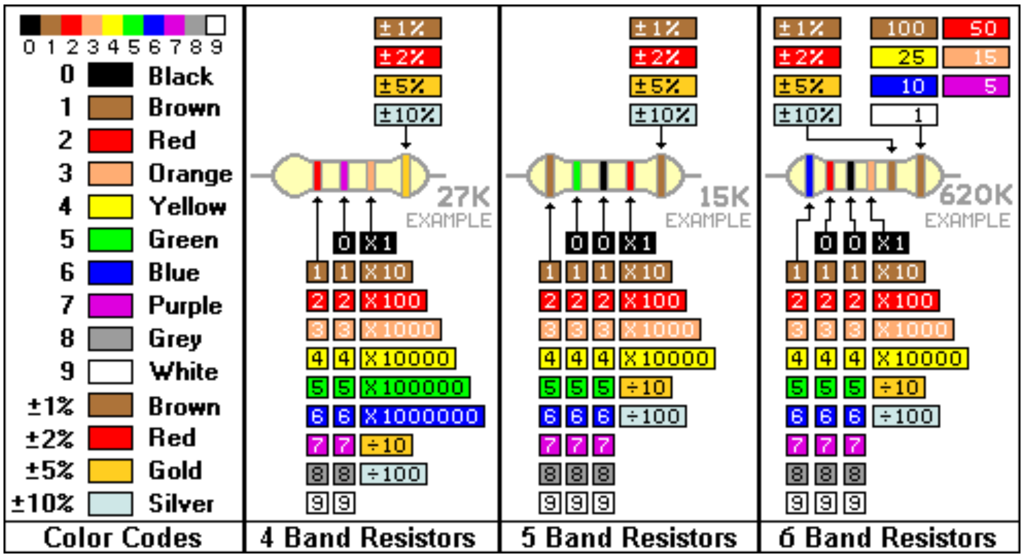
Component / device	***Type***	***Marked value and color code***	***Measured Resistance***	***Is measurement meaningful***
R1	Resistor	*100 Ω*	*100.5Ω*	*Yes*
R2	Resistor	3300 Ω	3272 Ω	yes.
R3	Resistor	1000 Ω	985.8 Ω	yes
R1 + R2 (in series)	Resistor	3400 Ω	3372 Ω	yes
R2 // R3 (in parallel)	Resistor	970.59Ω	757.9 Ω	yes.
R1 + (R2//R3)	Resistor	1070.59Ω	855.8 Ω	yes.
C1 (forward)	Capacitor	470 μF	5.037 M Ω	not stable
C1 (reverse)	Capacitor	470 μF	1.490 M Ω	stable
L1	Coil	no value	0.242 Ω	
D1 (forward)	Diode	1N4148	0.858 M Ω	
D1 (reverse)	Diode	1N4148	over range Ω	
LED (forward)	LED	no value	15.6 M Ω	
LED (reverse)	LED	no value	over range Ω	
Oscilloscope reference point to the earth point			Ω 1.100	
DC Power Supply reference point to the earth point			Ω over range	

Notes:

- The color code for resistors is show in Figure-4.1.
- Capacitor (forward): Capacitor positive pin connects to red probe. Negative pin connects to black probe.
- Capacitor (reverse): Capacitor positive pin connects to black probe. Negative pin connects to red probe.
- Diode (forward): Diode Anode connects to red probe. Cathode (with '-' or

round mark) connects to black probe.

- Diode (reverse): Diode Anode connects to black probe. Cathode connects to red probe.
- LED (forward): LED Anode (long pin) connects to red probe. Cathode (short pin) connects to black probe.
- LED (reverse): LED Anode connects to black probe. Cathode connects to red probe.
- Oscilloscope and DC Power Supply reference points: <u>Think, which terminals you will use them as reference points</u>.



Example: Brown, Black, Brown, Gold = 10 * 10^1 = 100Ω (±5%)

Figure-4.1 Color code of resistor

3. Explain your measured results for different components. <u>Which measurements are meaningless?</u> And <u>what kind of equipment should be used?</u> (surfing the web to find your answers)

Experiment 1.5: Current Measurement and Ohm's law

Important:

- The internal resistance of ammeter is extremely low (near to zero ohm).
- Place ammeter in series, not parallel to your circuit.
- If you place ammeter that parallel to any component/circuit, it means that short circuit to these two points. Incorrect connections will damage the ammeter, component or catch fire (overheat).
- Disconnect power first when you want to modify your circuit. Breaking and connecting the circuit will change the circuit characteristic, it may damage component.

To measure the current of a circuit path, an ammeter is placed in series into the circuit.

Procedures

1. Set the DC power to around 5V.
2. Set the DMM as a DC Ammeter ('I' sign with dots). Connect the RED probe to the RED terminal with 'I' mark (other than voltmeter and ohm-meter). Connect the BLACK probe to the Black terminal of DMM.
3. Measure the resistance of given resistors named **R4**. The resistances of them are the same but the packet power dissipation rates are different, the small is 0.25W and the large one is 5W.
4. Before building the circuit, do calculation first. You are doing engineering, experiments are used to prove your idea, not for finding out what will happen.
5. We are going to apply DC 5V to a resistor. Calculate the current and the power consumption of the resistors. Ensure you will use suitable component.

I = V / R,	5V / _85_ ohm = _58_mA
P = I^2 * R	(_58_mA) ^{2} * R 85 = _0.285_W
P = V^2 / R	$(5V)^2$ / _85_ ohm = _0.294_W

6. Setup a circuit as follows, using the resistor **R4** that you selected in Procedure-5.

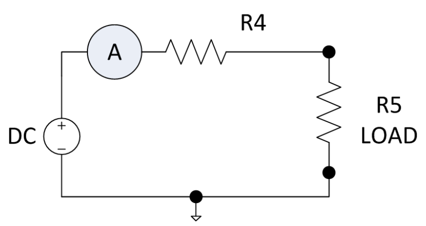


Figure-5.2

6. Measure the current flow in the circuit. 53 mA
7. Suspend the power supply when you modify the circuit.
8. Beware the heat dissipation of the resistor in this step. Replace **R4** with the other one. Measure the current flow in the circuit again.
9. Conclude your results of the selection of resistor. the high the resistent is, the lower the current
10. (Optional question, beware the heat dissipation) Short the resistor **R5 (LOAD)** in the circuit during current measuring to imitate accident short circuit (LOAD resistance goes zero). Measure the current changing. 60.2 mA
11. Explain the function of the resistor **R4** in this circuit if **R5 (LOAD)** is shorted by accident, from the point of view of the current.

if R5 is shorted, R4 protects the circuit from current being too high so that some component got burnt.

Experiment 1.6: Potential Divider and Kirchhoff's voltage law

Potential Divider circuit is the most popular circuit which takes up a part of voltage from the source. If one of the resistors (current limiter) is adjustable, the point between the two resistors can be controlled like linear voltage regulator.

Procedures

1. Measure the resistances of **R6** and **R7**.

Resistor	***Resistance***
R6	512 Ω
R7	987 Ω

2. Set the DC power to around 5V.
3. Set the DMM as a DC Volt-meter ('V' sign with dots).
4. Setup a circuit as Figure-6.1.

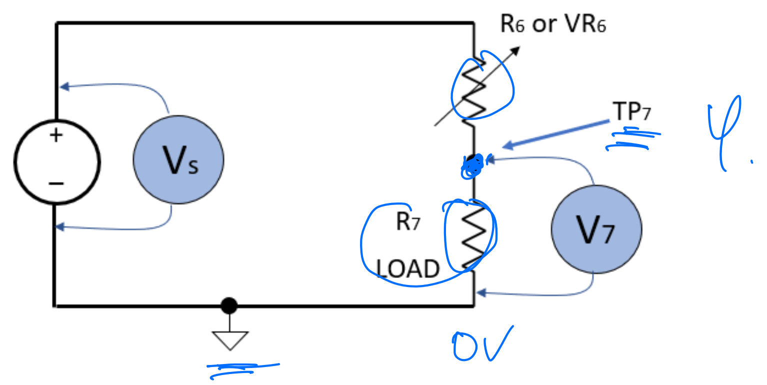


Figure-6.1 Potential divider and voltage regulator

Notes:

- Vs and V7 are volt-meters.
- If say to measure a floated two-terminal component (e.g. R6), measure the difference between two terminals of this component.
- If say to measure a two-terminal component (e.g R7) that one end is connected to reference point then measure the terminal (connected to TP7). Measure the terminal at reference point is meaningless.
- If say to measure a node (e.g TP7), measure the voltage of this point reference to the signal ground.
- All signals should reference to signal ground.

5. Measure the voltages of the DC power supply, **R6** and **R7**.

	Measured voltage
Vs (DC power supply)	5.062 V
R6	1.725 V
R7	3.324 V
V7	3.324 V

6. Conclude your measured results.
7. Replace **R6** with a 1-Kohm Variable Resistor (**VR6**) and adjust **VR6** until the voltage of **V7** is the same as that in procedure-5. Measure the value of **VR6**.
8. **R7** is the load of the circuit. Replace it with **R8**, **R9** and **R10**, one by one. Adjust **VR6** to keep the voltage of **TP7** same as that in procedure-5.

$I^2 \cdot R_{VR6}$ $\frac{(TP7)^2}{R_{load}}$ $\frac{TP7}{R_{load}}$

Circuit in series	***Voltage at TP7***	***VR6's resistance***	***VR6's power dissipation (by calculation)***	***Load's resistance***	***Load's power dissipation (by calculation)***
VR6 + R7	3.32 V	514.5 Ω	0.00587 W	982 Ω	0.0112 W
VR6 + R8	3.32 V	262 Ω	0.01089 W	514 Ω	0.0214 W
VR6 + R9	3.32 V	762 Ω	0.00389 W	1466 Ω	0.00751 W
VR6 + R10	3.32 V	920 Ω	0.00321 W	1776 Ω	0.00620 W

$I = 0.00338$
$I = 0.00645$
0.00226
0.001869

9. Conclude your measured results with Ohm's law. $\frac{V_{TP7}}{R_{load}} = \frac{V_{VR6}}{R_{VR6}}$
10. If the resistance **VR6** changes and keeps the voltage of TP7 automatically, what is the function of this system? Keep the voltage between load stable when R_{load} changes by changing VR6
11. <u>What is the relationship between potential divider and Kirchoff's voltage law?</u> $V_{TP7} + V_{VR6} - V_S = 0$ $\Rightarrow$ agrees with KVL
12. <u>(Optional question) What are the problems when the resistance of the load gets lower and lower? And, what happen when the load is shorted?</u>

the resistence of VR6 gets smaller and smaller and current gets bigger and bigger.
when load shorted, $R_{VR6} = 0\Omega$, the circuit gets shortened

Experiment 1.7: Bridge circuit

Bridge circuit is one of the advanced applications of potential divider. In experiment-1.5 the voltage between two resistors will be changed when supply voltage changed, it is a ripple voltage picked up from environment with cables named common mode noise, it is not good for sensitive sensor. To overcome the problem, engineers designed bridge circuit; another set of potential divider that parallel to original potential divider as a mirror or reference, both mid points will change synchronously to overcome the changing (ripple) of the power supply, the improvement is named **Common Mode Rejection Ration (CMRR)**. Other advantages are the dynamic range (reading range) and off set of the measured results (e.g. From 10 change to 11, 10% change; From 0 change to 1, 100% change).

Procedures

1. Set the DC power supply to around 5V.
2. Set the DMM as a DC voltmeter ('V' sign with dots).
3. Setup a circuit as Figure-7.1
   - **VR11**=2K ohm; **R12**=9.1K ohm; total 10K ohm when VR11 at the middle point (~1K ohm)
   - **R13**, **R14**, **R15**=10K.
4. Adjust **VR11** until the voltmeter reading between Va and Vb to zero. Then, the voltages at both potential dividers are the same.

U

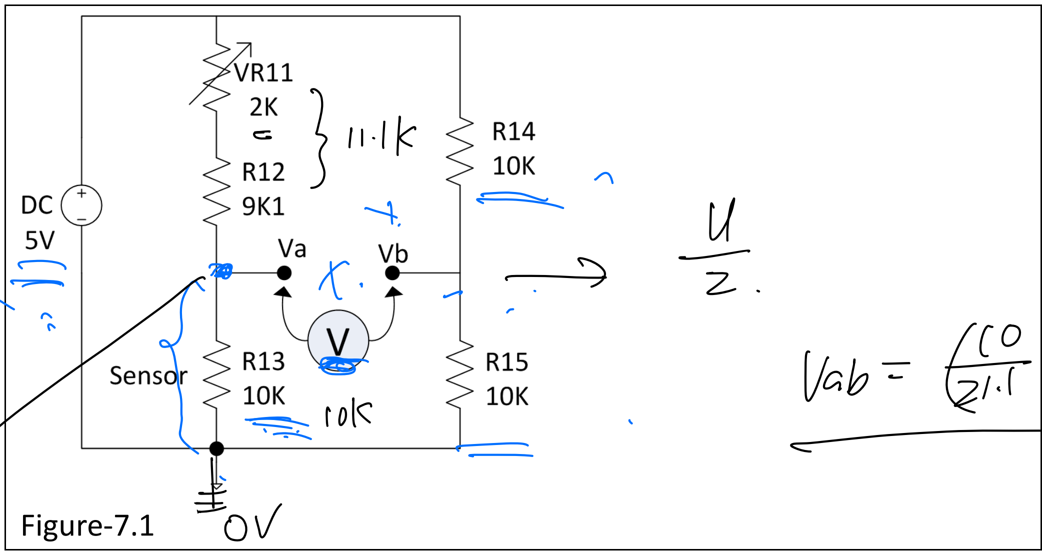


Figure-7.1

$\frac{U}{2}$

$V_{ab} = \left(\frac{10}{21.1} - \frac{1}{2}\right)U$

$\frac{10}{21.1}U$

2.525V 2.524V

5. Measure voltages of **Va** or **Vb**. Calculate their difference. 0.001V
6. Adjust the DC power supply to 7V and re-do procedure-4. Conclude your result. don't have to change VR. Va=Vb no matter how DC changes
7. Replace **R13** with a thermistor. Measure the voltmeter between **Va** and **Vb**. 155mV

Adjust **VR11** to fine tune both potential dividers, set **Va** equal to **Vb**.

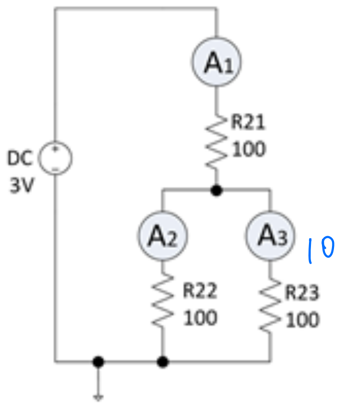
8. Use your hand to touch and heat up thermistor (don't touch the leads of the thermistor). From the voltmeter reading, explain the characteristics (positive /negative temperature coefficient) of the thermistor when you heat it up.
   Note: negative
   Positive temperature coefficient = resistance rise when temperature rise.
   Negative temperature coefficient = resistance fall when temperature fall.
9. Adjust the DC power supply back to 5V. Does it affect the reading of the voltmeter? Explain the function of the bridge circuit. it does not normalize environmental factors
10. (optional) What are the difference if the volt-meter measures at Va-Vb and at Sensor directly (across sensor).

Experiment 1.8: Kirchhoff's circuit laws

The sum of the currents at any point in the circuit is zero.

Procedures

1. Set the DC power supply to around 3V.
2. Setup the circuit, as Figure-8.1.



10 mA

Figure-8.1

9.1 mA

3. Measure the current at **A1**, **A2** and **A3**. Conclude your results with Kirchhoff's current law.

17mA 9.0mA

4. Setup the circuit, as Figure-8.2, where **R23** is replaced with a diode **D23**.

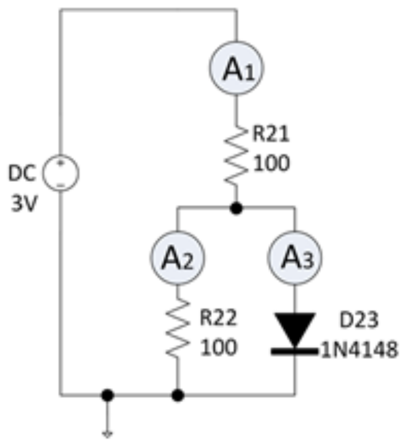


Figure-8.2

20.33mA 10mA

5. Measure the currents at **A1**, **A2** and **A3**. Conclude your results with Kirchhoff's current law.

8.33mA

6. (optional) Change the power supply voltage from 3V to 4V. The voltage at the point between two resistors does not follow Ohm's law (voltage divider). Surfing on web, find the characteristic of diode 1N4148.

Experiment 1.9: Thévenin's equivalent circuits

In circuit theory, everything can be represented with equivalent circuits (voltage/current source, resistance). For active circuit (with power source inside), you can use open-circuit method to find out its equivalent circuit. Find voltage with Open-circuit (Figure-9.1), current with short-circuit (Figure-9.2) and calculate the internal resistance.

Procedures

1. Set the DC power supply to around 5V and connect it in series with resistor **R31**. (Power supply's internal resistance is very small, it is dangerous if you short it. We assume **R31** (unknown value) is the internal resistance of this power supply.)
2. Setup the circuit as Figure-9.1. Measure the voltage at Open Circuit Test and current at Short Circuit Test.

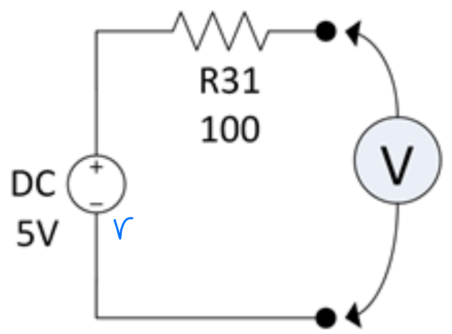


Figure-9.1 Open-circuit method

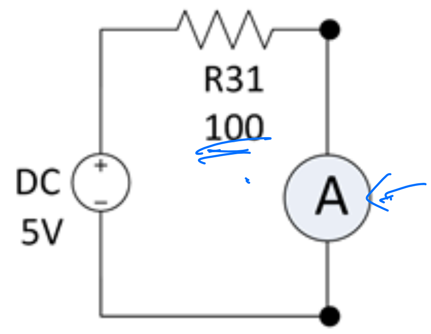


Figure-9.2 Short-circuit method

3. Use Ohm's law to calculate the internal resistance of the power supply. Conclude your result.
4. Draw the equvalent circuit of the power supply with Thevenis's equivalent circuits.

3. $V = 5.143V$

$I = 49.98\ mA$

$$R = \frac{V}{I} = \frac{5.143}{49.98 \times 10^{-3}} \approx 102.9\ \Omega$$

Experiment 1.10: A Thévenin's equivalent circuit application, measure internal resistance of battery cell

For extreme low internal resistance sources (e.g. battery, power supply), method Open-Short is dangerous (over heat). The resistance of cable is another issue that affect calculated results in Expeirment-1.9.

In this experiment, we will use open-short method to find internal resistance of a used battery (weak maximum current). And do it again with a special equipment for internal resistance measurement (use a suitable equipment).

Important and CAUTION:

- A used, aged & weak battery is used in this experiment. Don't use any new or fully charged battery in this experiment.
- If you feel the battery or wires are warm or hot during measurement, stop the experiment immediately, because the battery may be too strong.
- There are different equipment/methods for different circuits; AC, DC, high/low frequency, high/low voltage. Use suitable equipment and methods to do measurement.

Procedures

1. Measure the voltage and current of the used battery with Open-Short-Test method. (Figure-10.1) 0.6988.

	Voltage	Current
Open Circuit Test	1.302V.	
Short Circuit Test		1.863A

$V = IR$

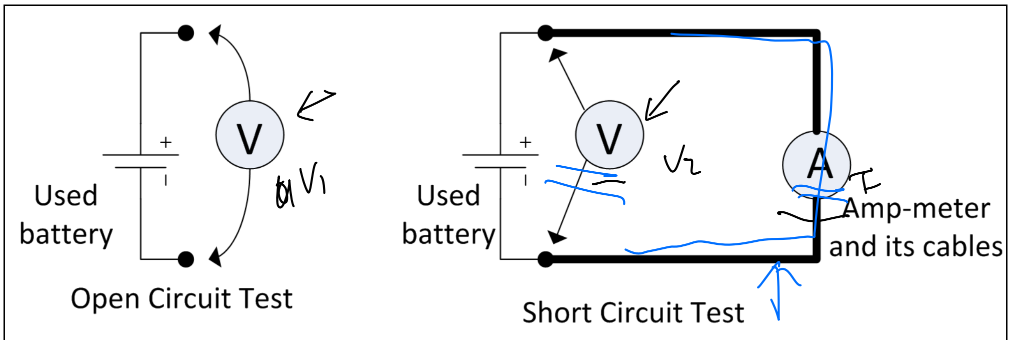


Figure-10.1 Open-Short test with a battery

2. Calculate the Battery internal resistance **Rb**, and cable resistance **Rw** with your measured data. ** **Rb** and **Rw** should be measured individually.

$R_w + R_b = \frac{V_1}{I} = \frac{1.302}{1.863} \approx 0.699\,\Omega.$

$R_W = \frac{V_2}{I} = \frac{0.8737}{1.863} \approx 0.469\ \Omega.$

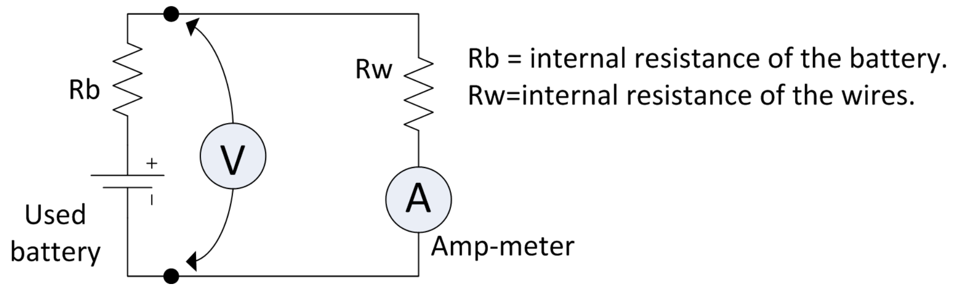


Figure-10.2

3. Measure the battery internal resistance with **Battery Internal Resistance Meter** (Figure-10.3). Select a suitable range (suitable settings). Compare the results between Open-short method and Battery Internal Resistance Meter. What parameters affect open-short method.

$R_b = 0.23\ \Omega$

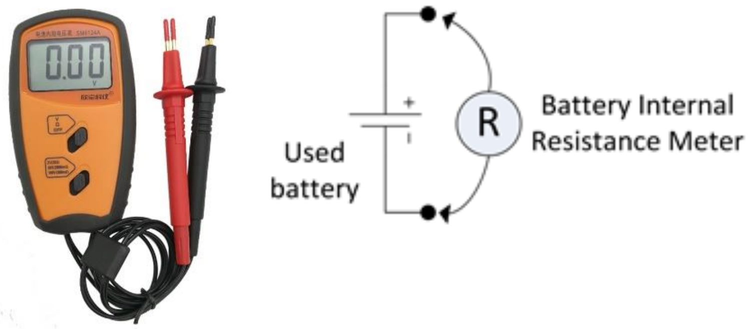


Figure-10.3 Battery Internal Resistance Meter

4. Explain the problem of measuring high current source with Open-Short Circuit Methods? (Think about with experiment 1.9)
5. (optional) *If you want to know the measurement method of Battery Internal Resistance Meter, use an oscilloscope to measure this meter's terminals. It is an application of Experiment-2.*

4. ~~the~~ if ~~big~~ current too high, then in short circuit test, the current might make the Amp-meter over range and harm device.

5.

Experiment 1.11: Maximum Power Transfer and Power lost

Due to an internal resistance in source, the energy consumed and taken (efficiency) not just relate to the resistance of the load. In a communication system, we hope that more power can be transferred to the load and no re-bonce from load to source (matching at high frequency).

Procedures

1. Set the DC power supply to around 5V
2. Assume **R41** is the internal resistance of the power source. Measure the voltage across and the current through the load **R42** when **R42** is changed from 50 to 150 ohm. (a 50Ω resistor in series with some 10Ω resistors)

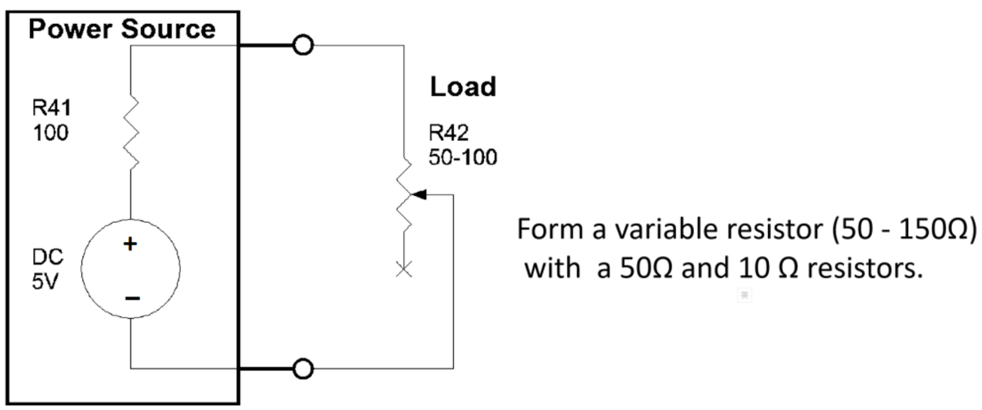


Figure-11.1 Test power transfer

3. Calculate the power dissipated at the **R41** and **R42**.

R42	Voltage (**R41**)	Power (**R41**)	Current	Voltage (**R42**)	Power (**R42**)	Power from Source
50 ohm	3.531 V	0.1129 W	0.032 A	1.460 V	0.04366 W	0.1595 W
60 ohm	3.227 V	0.1032 W	0.0317 A	1.60 V	0.0520 W	0.0837 W
70 ohm	2.876 V	0.0805 W	0.028 A	2.103 V	0.0588 W	0.1393 W
80 ohm	2.756 V	0.07165 W	0.026 A	2.240 V	0.05824 W	0.12989 W
90 ohm	2.700 V	0.0695 W	0.025 A	2.329 V	0.05822 W	0.12572 W
100 ohm	2.460 V	0.056 W	0.023 A	2.576 V	0.059 W	0.115 W
110 ohm	2.220 V	0.0466 W	0.021 A	2.755 V	0.0578 W	0.1044 W
120 ohm	2.148 V	0.0426 W	0.020 A	2.810* V	0.0562 W	0.0916 W
130 ohm	2.046 V	0.0388 W	0.019 A	2.986 V	0.0554 W	0.0942 W
140 ohm	1.973 V	0.0349 W	0.018 A	3.105 V	0.0559 W	0.09086 W
150 ohm	1.856 V	0.0289 W	0.016 A	3.207 V	0.0448 W	0.07396 W

4. Find the case and conclude the criterion that the power can be transferred from source to load with the maximum efficiency (maximum power transfer)?

Calculate $\frac{P_{R42}}{P_{source}}$: when R41 (resistance of source) is equal to R42 (resistance of load) ~~the~~ we have the maximum efficiency.

Experiment 1.12: Equipment Internal Resistance

Voltmeter, Ammeter and Ohm-meter have different input internal resistances. Incorrect usage of equipment may damage them and get incorrect data. So, you have to understand their characteristics before using them.

Procedures

1. Set the handheld DMM as a ohm-meter ('Ω' sign).
2. Measure the desktop DMM as voltmeter, ammeter and ohm-meter with forward (red to red, black to black) and reverse (red to black, black to red) conditions.

Meter type	***Internal Resistance of the meter***
DC Voltmeter (red to red, black to black)	10.02MΩ
DC Voltmeter (red to black, black to red)	10.02 MΩ
DC Ammeter (red to red, black to black)	11.8Ω
DC Ammeter (red to black, black to red)	11.7Ω
Ohm-meter (red to red, black to black)	out of range
Ohm-meter (red to black, black to red)	2.725 MΩ
Oscilloscope with x10 probe setting	10MΩ
Oscilloscope with x1 probe setting	0.998MΩ

Note:

- Cannot use ohm-meter to measure AC meter due to a capacitor inside in an AC meters.
- Ask tutors to get a x1 probe. The probes connected to oscilloscope are 10x.

3. What are the problems when you measure an ohm-meter? Explain your results.
   problem: different results doing red-red red-black ... and 0V
   ① reason: there is a source inside the ohm-meter, so the result is not the real resistence.
4. What kind of meter is high internal resistance?
   volt-meter
5. What kind of meter is low internal resistance?
   amp-meter
6. What kind of meter is active device (a power source inside)?
   ohm-meter
7. Conclude your measured results.
   if same ⇒ passive —
   not ⇒ active.

~ END ~

Image of Resistor color code is from http://www.diyaudioandvideo.com/Electronics/Color/