PLUSIVO

Mastering The Art of Measurement

User Guide for the Plusivo DM501D Multimeter

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Introduction

In this guide, you are going to learn how to measure AC/DC voltage, AC/DC current, resistance, capacitance, diode temperature and continuity test using DM501D 6000 Counts Autoranging T-RMS Digital Multimeter. We are going to study some basic concepts like Ohm's Law and Kirchhoff's Law. Please note that product color may slightly vary due to photographic lighting sources or your monitor settings.

1. Overview

The meter is a multi-functional instrument with high measurement accuracy, fast response and high safety level. Embedded in a dedicated IC up to 6000 counts, this IC consists of a high-precision A/D converter with a high-speed digital processor that can perform high-speed true-rms calculation for 1 kHz AC.

The appearance of the whole instrument is aesthetic and suitable for various industrial applications. The circuit is safe and reliable. The whole meter has a variety of measurement functions and a friendly HMI. It can meet the needs of various application groups such as professional and maintenance engineers.

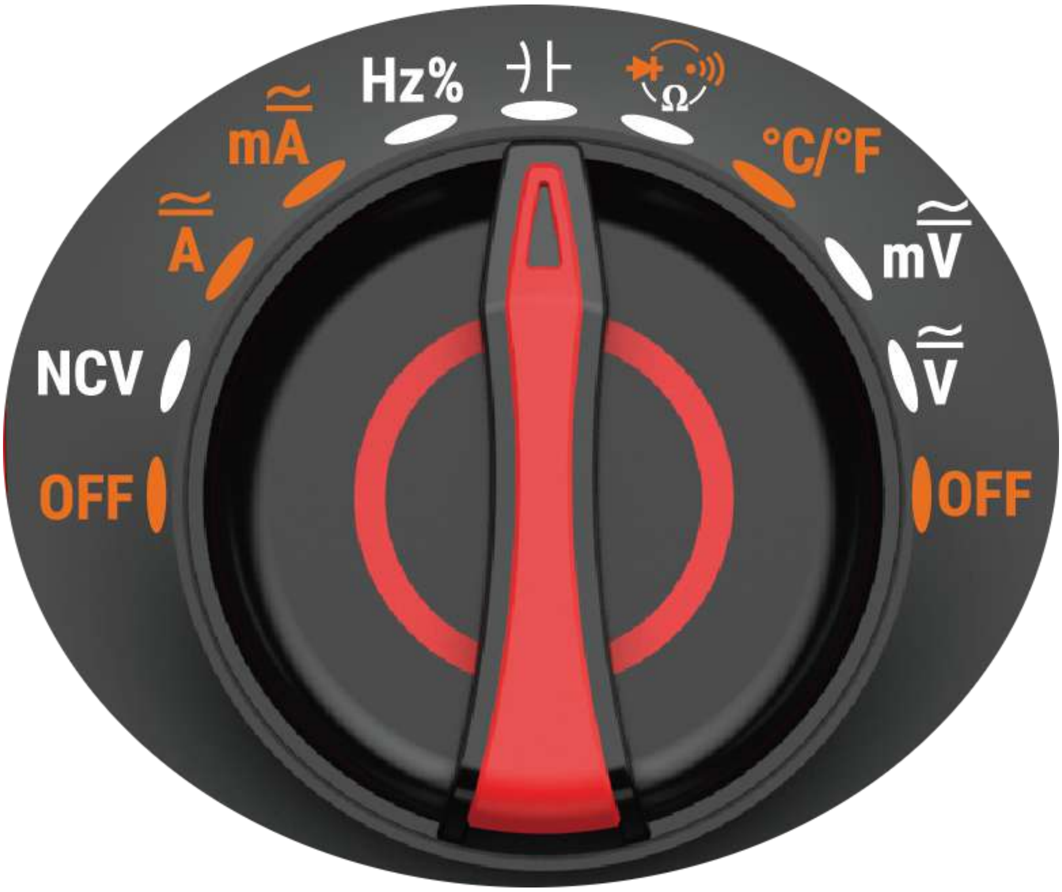
This meter can be used to measure AC/DC voltage, AC/DC current, resistance, capacitance, diode temperature and continuity test. The meter is equipped with a backlight that allows users to read the display in a dark place. It is the best choice for professional electricians, enthusiasts and families.

Please take the time and read the printed operating instructions manual that is inside the kit before use and pay attention to the safety information and retain them for future reference. Failure to follow these instructions may lead to serious injury and damage to property.

In general, if something unusual happens or if you suspect that something is wrong or has malfunctioned, do not do anything with the product and immediately contact the seller for assistance (email address: office@plusivo.com)

2. Parts

2.1 Rotary switch / Function Knob



OFF	Instrument turned OFF
$\mathrm{m}\overset{\eqsim}{\mathrm{V}}$, $\overset{\eqsim}{\mathrm{V}}$	AC/DC Voltage measurement
°C/°F	Temperature measurement
Ω •)))	Resistance/Diode/Continuity measurement
⊣⊢	Capacitance Measurement
Hz%	Frequency measurement
$\mathrm{m}\overset{\eqsim}{\mathrm{A}}$, $\overset{\eqsim}{\mathrm{A}}$	AC/DC Current measurement
NCV	Non Contact Voltage measurement (NCV)

2.2 Function keys description

FUNC/Hz	Function selection mode
HOLD	Hold Function for data or reading retention
MAX	Maximum value measurement mode
	Backlight / FlashlightFunction

2.3 LCD

AC	Alternating current measurement
DC	Direct current measurement
	Negative input polarity
	Low battery indicator
AUTO	Automatic measurement

▶|	Diode measurement
•)))	Buzzer / Continuity measurement
H	Hold function activated
NCV	NCV test activated
⏻	Auto power off indicator
mV, V	Voltage unit
μA, mA, A	Current unit
Ω, kΩ, MΩ	Resistance unit
MKHz	Frequency unit
mF, nF, μF	Capacitance unit
°C , °F	Temperature measurement (Celsius, Fahrenheit)

3. Safety Information

* When using this meter, the user must follow all standard safety precautions in the following two aspects.

• Electric shock protection
• Prevention of misuse of instrument safety procedures

* For your personal safety, please use the test pen supplied with the meter, check before use to make sure they are not damaged.

⚠ **Warning**

To avoid possible electric shock, personal injury or other accidents, please follow the instructions specified in the printed DM501D manual that comes with the DM501D Multimeter kit purchase.

- Please read this manual carefully before using the instrument and pay attention to the safety information.
- Strictly observe the operating instructions in this manual before using it. Otherwise, the protective function of the device may be damaged or weakened.

Complete safety instructions can be found in the DM501D manual that is inside the Multimeter Kit.

Input protection measures

- The limit voltage is 600 V in voltage measurement.
- The voltage limit is 250 ACV or equivalent RMS voltage when measuring frequency, resistor, buzzer or diode.
- Fuse (F200mA/250 V) to protect when measuring μA and mA.

⚠ **Warning**

Before opening the case or the battery cover, the meter and input signal must be turned off to avoid electric shock or damage to the instrument.

In general, if something unusual happens or if you suspect that something is wrong or has malfunctioned, do not do anything with the product and immediately contact the seller for assistance (email address: office@plusivo.com)

4. Technical Specifications

- Environmental conditions of use:

  CAT. III 600 V

  Pollution level: 2

  Altitude < 2000 m

  Working environment temperature and humidity:

  0~40°C (<80% RH, <10°C non condensing)

  Storage environment temperature and humidity:

  -10~60°C (<70% RH,remove the battery)
- Temperature coefficient: 0.1 x accuracy/°C (<18°C or >28°C)
- MAX. Voltage between terminals and earth ground: 600 V
- Fuse protection: mA: F600 mA/250 V fuse, 10 A: F10 A/250 V fuse
- Conversion rate: 3s/second
- Test or calibrate surrounding temperature: 20°C±2°C
- Sampling rate: about 3 times/second
- Display: 6000 counts LCD display with LED backlight. Automatically displays the unit symbols according to the shift of the measurement function.
- Over range indication: it displays "OL".
- Low battery indication: when the battery voltage is lower than the normal working voltage " " will be displayed.
- Input polarity indication: automatically displays " - ".
- Power requirement: 3 x 1.5 V AAA batteries.
- Dimension: 147 mm (L) x 71 mm (W) x 45 mm (H).
- Weight: about 220g (battery excluded)

5. Reference Table

5.1 Table of SI units

Quantity	SI Unit	Abbreviation
Voltage	Volts	V
Current	Ampere	A
Power	Watt	W
Energy	Joule	J
Electric charge	Coulomb	C
Resistance	Ohm	Ω
Capacitance	Farad	F
Inductance	Henry	H
Frequency	Hertz	Hz

5.2 Table of prefixes

Prefix	Power	Numeric Representation
Tera (T)	10^{12}	1 trillion
Giga (G)	10^{9}	1 billion
Mega (M)	10^{6}	1 million
Kilo (k)	10^{3}	1 thousand
No prefix	10^{0}	1 unit
Milli (m)	10^{-3}	1 thousandth
Micro (µ)	10^{-6}	1 millionth
Nano (n)	10^{-9}	1 billionth
Pico (p)	10^{-12}	1 trillionth

6. Instrument Specifications

Accuracy specifications

The accuracy applies within one year after the calibration.
Reference condition: the environment temperature is 18°C to 20°C, the relative humidity is no more than 80%.
Accuracy: ± (% reading + word)

6.1 DC Voltage

Range	Resolution	Accuracy
600 mV	0.1 mV	± (0.5% + 5)
6 V	1 mV	
60 V	10 mV	
600 V	100 mV	

Input resistance: 10 MΩ
Maximum input voltage: 600 V

6.2 AC Voltage

Range	Resolution	Accuracy
600 mV	0.1 mV	± (1% + 4)
6 V	1 mV	
60 V	10 mV	
600 V	100 mV	

Input resistance: 10 MΩ
Maximum input voltage: 600 V
Frequency response: 10 Hz to 1 kHz, TRMS

6.3 Resistance

Range	Resolution	Accuracy
600 Ω	0.1 Ω	±(0.8% readings + 5 digits)
6 kΩ	1 Ω	
60 kΩ	10 Ω	
600 kΩ	100 Ω	
6 MΩ	1 kΩ	
60 MΩ	10 kΩ	

Overload protection: 250 V DC/AC
Open circuit voltage: 2.4 V

6.4 Diode and Buzzer Test

	The display shows the forward voltage drop
	It buzzes when the resistor is less than 30 and the indicator lights

Overload protection: 250 V DC/AC

6.5 Direct Current DCA

Range	Resolution	Accuracy
60 mA	0.10 mA	±(1.2% + 5)
600 mA	0.01 mA	
10 A	10 mA	±(3% + 5)

- Overload protection: mA range with F 200 mA/250V and 20 A range with F10 A/250 V
- For currents greater than 5 A, the test time shall be less than 10 minutes and after such a measurement one minute shall be allowed to terminate the test.

6.6 Alternative Current ACA

Range	Resolution	Accuracy
60 mA	0.10 mA	±(1.2% + 5)
600 mA	0.01 mA	
10 A	10 mA	±(3% + 5)

- Overload protection: mA range with F 60 0mA/250 V and 20 A range with F10 A/250 V
- Max input current: mA: 600 mA RMS 10 A: 10 A RMS
- For currents greater than 5 A, the test time shall be less than 10 minutes and after such a measurement one minute shall be allowed to terminate the test.
- Frequency response: 10 Hz to 1 KHz true RMS

6.7 Frequency

Range	Resolution	Accuracy
9.999 Hz	0.001 Hz	±(1.5%+5)
99.99 Hz	0.01 Hz	
999.9 Hz	0.1 Hz	
9.999 KHz	0.001 KHz	
99.99 KHz	0.01 KHz	
999.9 KHz	0.1 KHz	
9.999 MHz	0.001 MHz	

Input voltage range: 200 mV-10 V AC RMS
Overload protection: 250 V DC/AC

6.8 Capacitance

Range	Resolution	Accuracy
60 nF	0.01 nF	±(4.0%+5)
600 nF	0.1 nF	
6 μF	1 nF	
60 μF	10 nF	
600 μF	100 nF	
6 mF	0.1 μF	
100 mF	0.001 mF	

Overload protection: 250 V

6.9 Temperature

Range	Resolution	Accuracy
-20°C ~ 1000°C	1 °C	± (1.0% + 3)
-4°F ~ 1832°F	1 °F	

7. Operation Instruction

Regular Operation

Press the “**FUNC-HZ**” button to enter into function selection mode.
The reading hold mode can save the current reading on the display, change the position of the measurement function, or press and hold the key again to exit the data hold mode.

Backlight and Flashlight Function

The meter has a backlight and flashlight function for easy reading of measurement results by users in the dark. To enter and exit this mode, please follow these steps:

- Short press the  key to turn on the backlight, and press again to exit. It will automatically turn off without any operation for 15s.
- Long press the  key to turn on the flashlight function and the backlight at the same time. Short press the key again to turn off the flashlight function. It turns off automatically without any operation for 30s.

Auto power off

About 15 minutes after turning on, if there is no operating instrument, it will give audible voice prompts, automatically turn off, and enter hibernation mode. You can press any key to restart the instrument.

7.1 AC and DC Voltage Measurement

1. Turn the switch to $\overset{\approx}{\text{mV}}$ or $\overset{\approx}{\text{V}}$, press “**FUNC-Hz**” to choose AC or DC.
2. Connect the black test pen to the **COM** jack and the red pen to the **V** jack.
3. Measure the voltage value of the circuit under test with the other two ends of the test pens.
4. The reading will be shown on the LCD display, as well as the polarity of the end connected to the red wire.

DC Voltage Measurement - set to DC Voltage measurement function

For AC Voltage Measurement, please see setup below:

⚠ **Do not measure voltages above 600 V to avoid electric shock or damage to the instrument.**

⚠ **Do not apply more than 600 V between common and ground to avoid electric shock or damage to the instrument.**

Notes:

- The meter shows readings in the DCV 600 mV and 6 V ranges even when there is no input voltage or no test pens connected. Then short circuit V-Ω and "**COM**" so that the meter shows zero.
- Please change the range to a higher one if "**OL**" is displayed.
- In ACV range, short press the "FUNC-Hz" key to check AC frequency. Please refer to frequency measurement.
- All AC voltage values measured with this meter are true RMS (square root). For sine waves and other waveforms (without DC offset) such as square waves, triangular waves, and step waves, these measurements are accurate.

7.2 Resistance Measurement

1. Turn the rotary switch to position and press "**FUNC-Hz**" to select **Ω**.
2. Connect the black test pen and the red test pen to the "**COM**" jack and the "**V-Ω**" input jack.
3. Use the test pen to check the resistance value of the circuit.
4. The resistance value is displayed on the display window.

The resistance measured in this figure is 9.276 kΩ

The resistance measured in this figure is 6.2 Ω

⚠ **To avoid damage to the meter or device under test, allpower to the circuit under test must be turned off before measuring resistance, and all high voltage capacitors must be fully discharged.**

Notes:

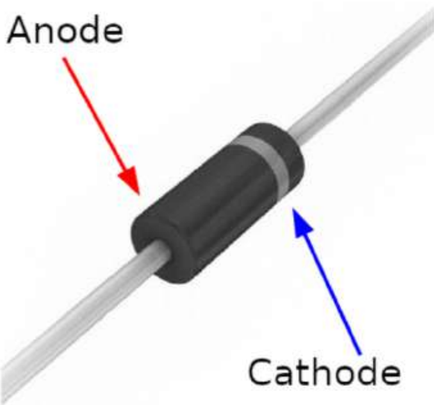
- The resistance value measured on the circuit is usually different from the rate resistance.
- To measure the low resistance accurately, please short- circuit the two test pens to read out the short-circuit resistance of the test leads, and subtract it by the readings to get an accurate resistance value.
- In the 60 MΩ range, readings stabilize after a few seconds, which is normal for high resistance measurements.
- When the meter is not connected to the circuit, the display shows "OL", which indicates that the measurement value is out of the measurement range.

7.3 Diode Measurement

Test a diode outside the circuit:

1. Turn the rotary switch to position and press "**FUNC-Hz**" to select
2. Connect the black test pen to the “**COM**” input socket and the red test pen to the “**V-Ω**” input socket.
3. Connect the black test pen and the red test pen to the negative and positive electrodes of the diode under test.
4. The meter will display the forward bias value of the diode under test. If the polarity is reversed, "**OL**" will be displayed.

* A normal diode in the circuit will still give a forward voltage drop of 0.5V to 0.8V, but the reverse bias reading will depend on the resistance value of the other channels between the two test knobs.



To avoid damage to the meter or device under test, all power to the circuit under test must be turned off before measuring resistance, and all high voltage capacitors must be fully discharged.

7.4 Buzzer Test or Continuity

For on-off state of the circuit:

1. Turn the rotary switch to position and press "**FUNC-Hz**" to select
2. Connect the black test pen to the "**COM**" input socket and the red test pen to "**V-Ω**" input socket.
3. Measure the resistance of the circuit under test at the other end of the test pen. If the resistance of the circuit being tested does not exceed approximately 50 Ω, the indicator will **light up** and the buzzer will sound continuously.

⚠ **To avoid damage to the meter or device under test, all power to the circuit under test must be turned off before measuring resistance, and all high voltage capacitors must be fully discharged.**

7.5 Frequency Measurement

1. Turn the switch to **Hz%**.
2. Connect the black test pen to the "**COM**" jack and the red pen to the **Hz** jack.
3. Measure the frequency value of the circuit under test with the other two ends of the test pens.
4. Press the **FUNC-Hz** button to display the frequency reading.

⚠ **Do not test any voltage higher than 250 V to prevent electric shock or damage to the instrument.**

7.6 Current Measurement

1. Turn the rotary switch to **A** or **mA** position and press "**FUNC-Hz**" to select AC/DC.
2. Connect the black test pen to the “COM” input socket. If the measured current is less than 600 mA, connect the red test pen to the mA input jack. If the measured current is between 600 mA and 10 A, connect the red test lead to the “**10 A**” input jack.
3. The circuit to be tested is disconnected, a black test pencil is connected to the disconnected circuit at its lower voltage end, and a red test marker is connected to the disconnected circuit at the higher voltage end.
4. Connect the circuit power supply and then read the displayed reading. If only "**OL**" is shown on the display, it means that the input exceeds the selected range. The rotary switch must be in the higher range.
5. Long press the “**FUNC-Hz**” to show the frequency of the alternative signal in the ACA mode.

In this set-up, the red probe is inserted in the 10A socket for DC current setting. The reading is 3.07 A.

⚠ **Do not attempt to measure current in a circuit when the voltage between open circuit voltage and ground is greater than 250 V. If the fuse blows during measurement, you may damage the meter or injure yourself. To avoid damage to the meter or test equipment, use the correct input jack, function mechanism, and range before making measurements. When the test pen is connected to the current input jack, do not connect the other end of the test pen in parallel to any circuit.**

7.7 Capacitance Measurement

1. Turn the rotary to " ⊣⊢ " position.
2. Connect the black test pen to the "**COM**" jack and the red pen to the ⊣⊢ jack.
3. Measure the capacitance value of the circuit under test with the other two ends of the test pens. The reading will be displayed in the LCD display window.

Notes:

- Measurement of a large capacitor takes a certain amount of time.
- Pay attention to the polarity of the capacitor to connect it correctly to protect the meter.

⚠ **To avoid damage to the meter or device under test, all power to the circuit under test should be cut off before measuring capacitance. All high-voltage capacitors should be fully discharged.**

7.8 NCV (Non Contact Voltage) Test

Turn the rotary switch to the **NCV** position and place the top of the meter close to the conductor. If the meter detects the AC voltage meter, the corresponding signal strength indicator will light according to the detected signal level (low-yellow, high-red), and the buzzer will send out alarms at different frequencies.

Notes:

- Even if there is no indication that voltage may still exist, do not rely on non-contact voltage sensors to determine if there is a voltage detection operation on the conductor, which may be affected by factors such as socket depth, insulation thickness and type, etc.
- Interference sources in the external environment, such as flashlights, motors, etc., may accidentally trigger non- contact voltage detection.

7.9 Temperature Measurement

1. Turn the rotary knob to "**°C/°F**" and the meter will display the surrounding temperature.
2. Remove the test pens and connect the "COM" and "VΩmA" leads to the ends of the thermocouples with the correct polarity.
3. The meter will display the approximate temperature from the thermocouple.

In the example below, the measured temperature is 426 °C**.**

To convert from °C to °F or vice versa, use the FUNC key.

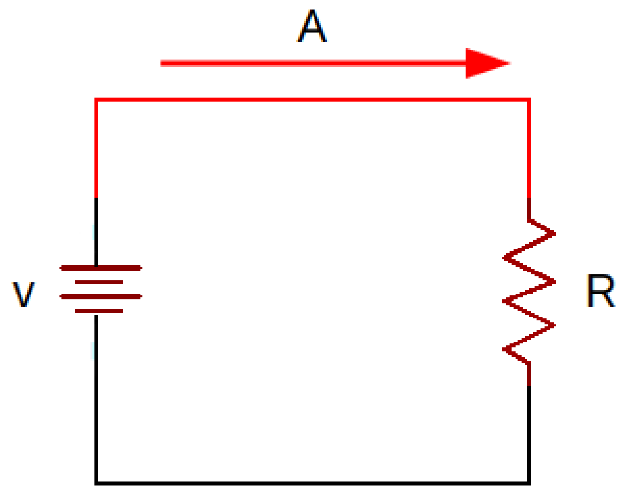
8. Basic Concepts

8.1 Ohm's Law

It is a law that illustrates the relationship between the voltage, the current, and the resistance.

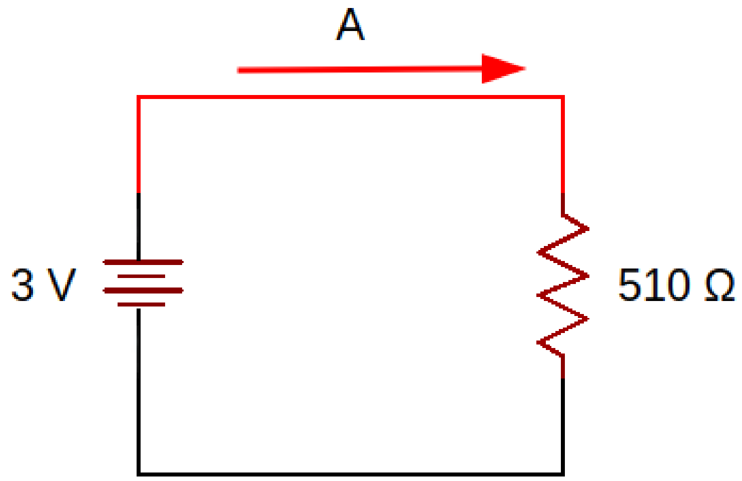
$$V = I \cdot R$$
$$R = \frac{V}{I}$$
$$I = \frac{V}{R}$$

I is the current through the resistor.
V is the voltage around the resistor.
R is the resistance.



8.1.1 Example

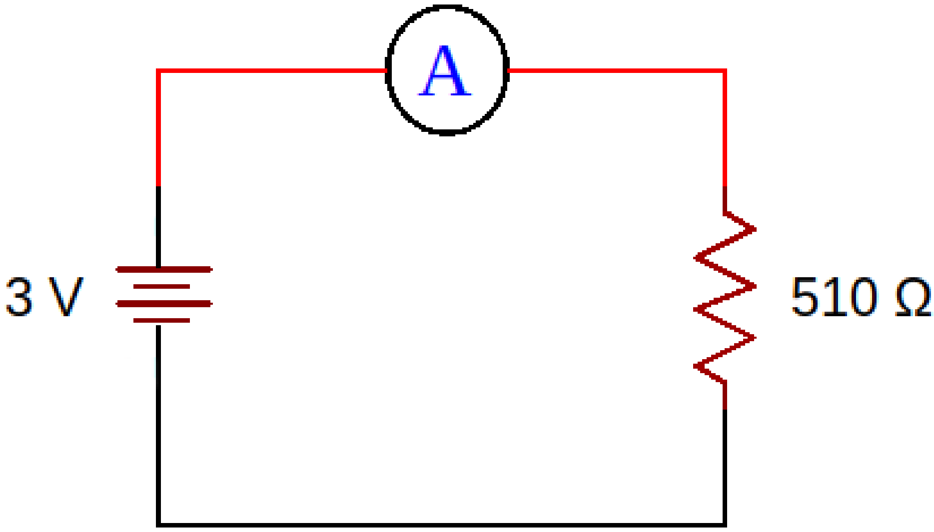
Calculate the current in this circuit.



Simply, we can use Ohm's law: $I = \frac{V}{R}$

$$\frac{3\,V}{510\,\Omega} = 0.00588\,A = 5.88\,mA$$

If we built this circuit in reality and measure the current using the multimeter as in the following schematic:



We should read on the screen of the multimeter: **5.88 mA**

But this is if we have an ideal circuit, in reality, we will not get this specific value because each component in this circuit has tolerance, for example, if we measure the resistance:

The measured resistance in this figure is 550.2 Ω.

Note:
Disconnect the battery when measuring the resistance, otherwise, the multimeter may be damaged.

If we measure the voltage around the resistor:

The measured voltage in this figure is 3.085 V DC.

If we calculate the new values: $\frac{3.085\,V}{550.2\,\Omega} = \ 5.61\,mA$

Based from the result of the calculation, the value is near the theoretical value of 5.88 mA

But in reality, it will be less than 5.61 mA because of the resistance of the multimeter itself:

But indeed, we can count on our calculation “$3\,V\,/\,510\,\Omega\ =\ 5.88\,mA$” because **5.88 mA** is almost equal to **5.61 mA**.

8.2 Joule's Law for Electrical Power

Electric power is the rate of the emitting power from a resistor per unit time, the unit of power is watt.

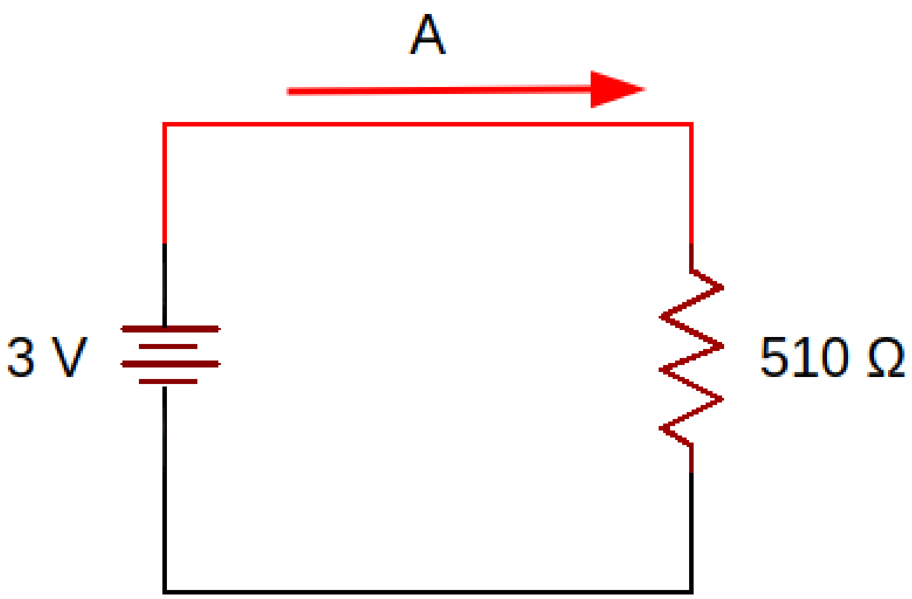
$$P = I \cdot V$$
$$P = I^2 \cdot R$$
$$P = \frac{V^2}{R}$$

P is the power on the resistor.
I is the current through the resistor.
V is the voltage around the resistor.
R is the resistance.

Note: There are many types of emitting power, it may be a rotary power, light, heat, etc.

8.2.1 Example

Calculate the power on the resistor.



To calculate the power on the resistor, we need any two values of these: **Voltage**, **Current** or **Resistance**.

In our example, we have the voltage and the resistance, so we can use this formula:

$$P = \frac{V^2}{R}$$
$$\frac{(3\,V)^2}{510\,\Omega} = 0.0176\,W = 17.6\,mW$$

Let us see what we will get if we built this circuit in reality and calculate the power using the multimeter.

The measured resistance in this figure is 550.2 Ω

Note:

Disconnect the battery when measuring the resistance, otherwise, the multimeter may be damaged.

The measured voltage in this figure is 3.085 V DC.

So if we calculate the new values: $\frac{(3.085\,V)^2}{550.2\,\Omega} = 17.3\,mW$

We can count on our calculation "$\frac{(3\,V)^2}{510\,\Omega} = 0.0176\,W = 17.6\,mW$" because the theoretical value of **17.6 mW** is near the value of **17.3 mW.**

If we want to use the current to calculate the power.

The measured current in this figure is 5.58 mA

We can use the first formula which is: $P = I \cdot V$
$5.58\ mA \cdot 3.085\ V = 0.0172W = 17.2\ mW$

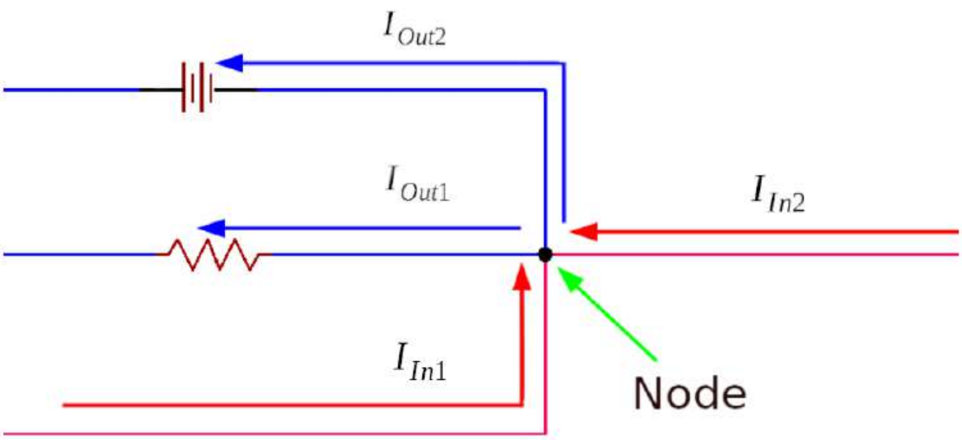
And the second formula which is: $P = I^2 \cdot R$
$(5.58\ mA)^2 \cdot 510\ \Omega = 0.0159\ W = 15.9\ mW$

So all the result of the calculations using the formulas above are near each other’s value: **17.3 mW, 17.2 mW, 15.9 mW**

8.3 Kirchhoff's Law

8.3.1 Kirchhoff's Current Law

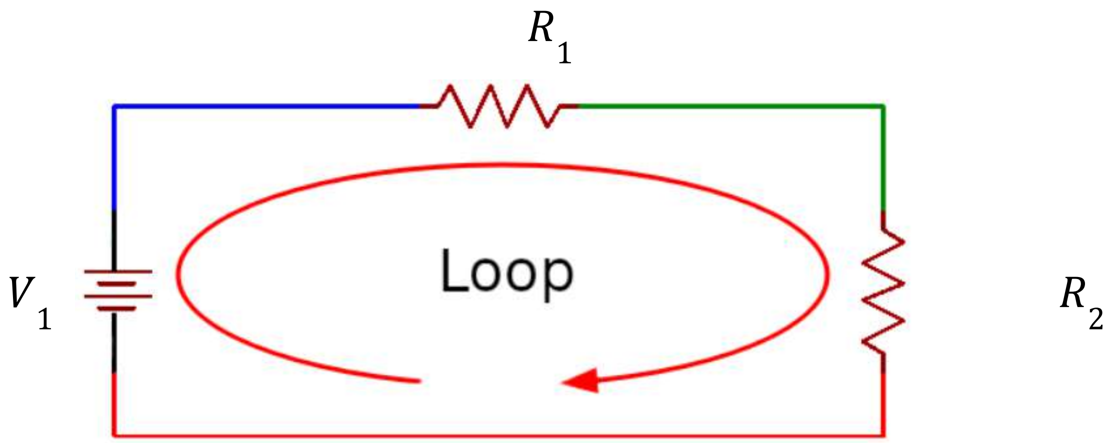
Currents entering the node equals currents leaving the node.



$$I_{In1} + I_{In2} = I_{Out1} + I_{Out2}$$

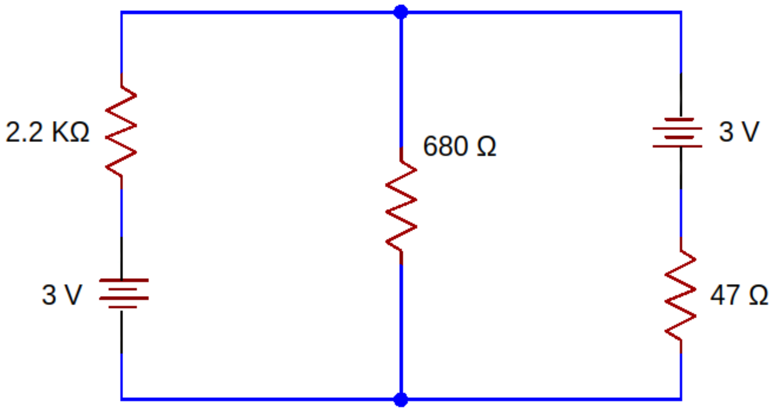
8.3.2 Kirchhoff's Voltage Law

The sum of all the voltages around the loop is equal to zero.

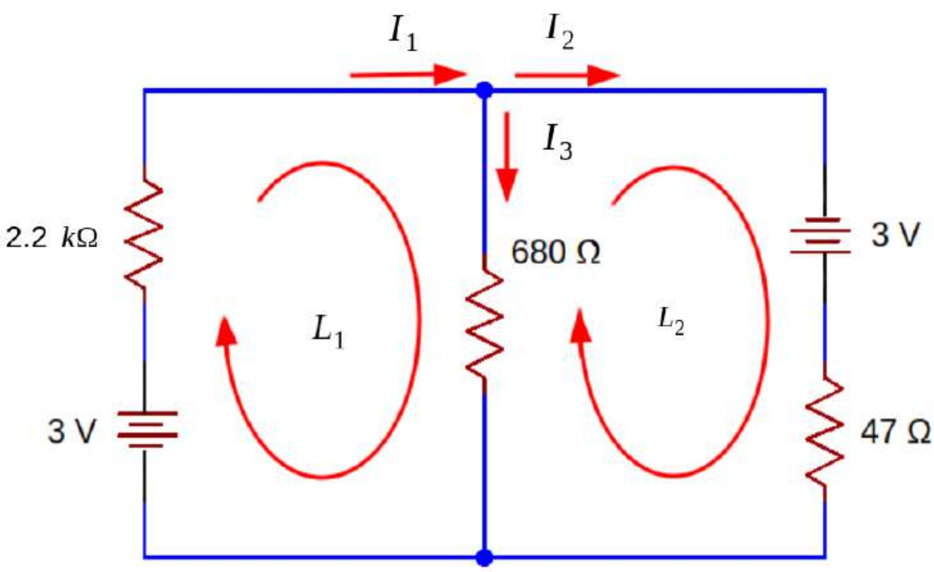


8.3.3 Example

Calculate the voltage around the resistors.



In this case, we are going to use Kirchhoff's law, we need to suppose the paths for the current to use Kirchhoff's current law, and we need to suppose two loops to use Kirchhoff's voltage law.



To use Kirchhoff's voltage law, we need to know some rules, for example, in L_1 if the loop passes the battery from - to + we write it in the equation (+3 V), but if the loop passes the battery from + to - we write it in the equation (-3 V). Let us take 2.2 $k\Omega$ resistor as an example, if the loop passes the resistor in the same direction with the current we write it $\left(-\ 2.2\ k\Omega \cdot I_1\right)$, but if the loop passes the resistor in the opposite direction with the current we write it $(+\ 2.2\ k\Omega \cdot I_1)$.

We get this equation from L_1.

Equation 1: $3\ V\ -\ (I_1 \cdot 2.2\ k\Omega)\ -\ (I_3 \cdot 680\ \Omega)\ =\ 0\ V$

We get this equation from L_2.

Equation 2: $(I_3 \cdot 680\ \Omega)\ +\ 3\ V\ -\ (I_2 \cdot 47\ \Omega)\ =\ 0\ V$

We get this equation from **the node**.

Equation 3: $I_1\ =\ I_2\ +\ I_3$

Now, let us do some math to calculate I_1, I_2 and I_3.

Equation 1: $3\ V\ -\ (I_1 \cdot 2.2\ k\Omega)\ -\ (I_3 \cdot 680\ \Omega)\ =\ 0\ V$

$$3\ V\ -\ (I_3 \cdot 680\ \Omega)\ =\ I_1 \cdot 2200\ \Omega$$

$$I_1 = \frac{3\ V}{2200\ \Omega} - \frac{I_3 \cdot 680\ \Omega}{2200\ \Omega}$$

$I_1\ =\ 0.001363\ A\ -\ (I_3 \cdot 0.3091) \rightarrow$ This becomes equation 4

Equation 2: $(I_3 \cdot 680\ \Omega)\ +\ 3\ V\ -\ (I_2 \cdot 47\ \Omega)\ =\ 0\ V$

$$I_2 \cdot 47\ \Omega\ =\ (I_3 \cdot 680\ \Omega)\ +\ 3\ V$$

$$I_2 = \frac{I_3 \cdot 680\ \Omega}{47\ \Omega} + \frac{3\ V}{47\ \Omega}$$

$I_2\ =\ (I_3 \cdot 14.468)\ +\ 0.0638\ A \rightarrow$ This becomes equation 5

Equation 4: $I_1\ =\ 0.001363\ A\ -\ (I_3 \cdot 0.3091)$

Equation 5: $I_2\ =\ (I_3 \cdot 14.468)\ +\ 0.0638\ A$

From **Equation 3:** $I_1\ =\ I_2\ +\ I_3$, we will use the derived I_1 and I_2 from previous calculation to get I_3, thus,

$$0.001363\ A\ -\ (I_3 \cdot 0.3091)\ =\ (I_3 \cdot 14.468)\ +\ 0.0638\ A\ +\ I_3$$

$$-\ I_3 \cdot 0.3091\ =\ (I_3 \cdot 14.468)\ +\ 0.0638\ A\ -\ 0.001363\ A\ +\ I_3$$

$$-\ I_3 \cdot 0.3091\ =\ (I_3 \cdot 14.468)\ +\ 0.062437\ +\ I_3$$

$$-\ 0.062437\ =\ (I_3 \cdot 0.3091)\ +\ (I_3 \cdot 14.468)\ +\ I_3$$

$$-\ 0.062437\ =\ 15.7771 \cdot I_3$$

$$I_3\ =\ -\ 0.003957\ A$$

Equation 4: $I_1 = 0.001363\,A - (I_3 \cdot 0.3091)$

$$I_1 = 0.001363\,A - (-0.003957\,A \cdot 0.3091)$$

$$I_1 = 0.001363\,A + 0.001223\,A$$

$$I_1 = 0.002586\,A$$

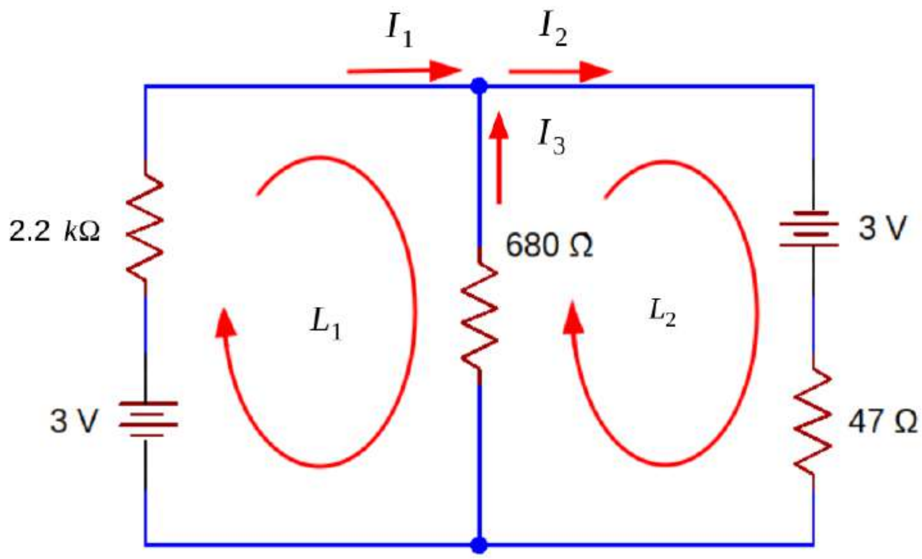
Equation 5: $I_2 = (I_3 \cdot 14.468) + 0.0638\,A$

$$I_2 = (-0.003957\,A \cdot 14.468) + 0.0638\,A$$

$$I_2 = -0.05725\,A + 0.0638\,A$$

$$I_2 = 0.00655\,A$$

Do not forget that we have supposed the directions of the currents, in the final answer if we get a positive answer, like I_1 and I_2 the direction we have supposed is true, but if we get a negative answer, like I_3 the direction we have supposed is wrong, so we must reverse it.



The equation $I_1 = I_2 + I_3$ will be changed to: $I_2 = I_1 + I_3$

Now, it is easy to calculate the voltage on the resistors using Ohm's law: $V = I \cdot R$

The voltage on 2.2 kΩ

$$V = I_1 \cdot 2.2\,k\Omega$$

$$V = 0.002586 \cdot 2200\,\Omega$$

$$V = 5.7\,V$$

The voltage on 680 Ω

$$V = I_3 \cdot 680\,\Omega$$

$$V = 0.003957 \cdot 680\,\Omega$$

$$V = 2.7\,V$$

The voltage on 47 Ω

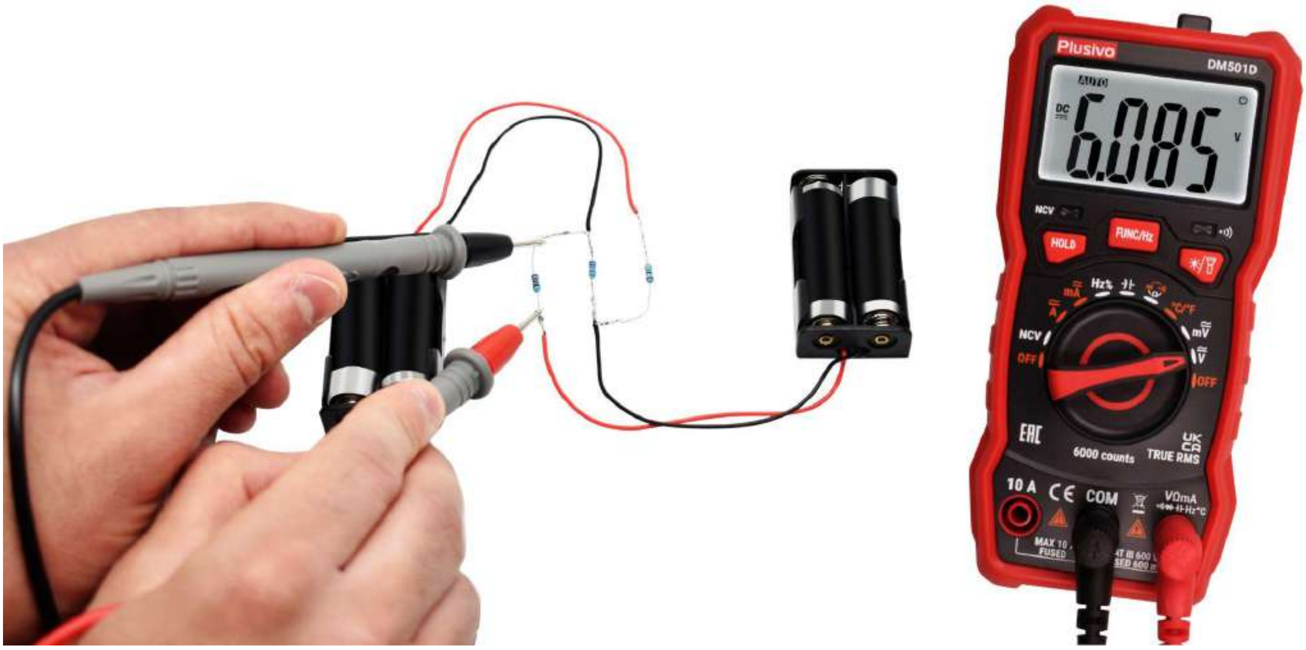
$$V = I_2 \cdot 47\,\Omega$$

$$V = 0.00655\,A \cdot 47\,\Omega$$

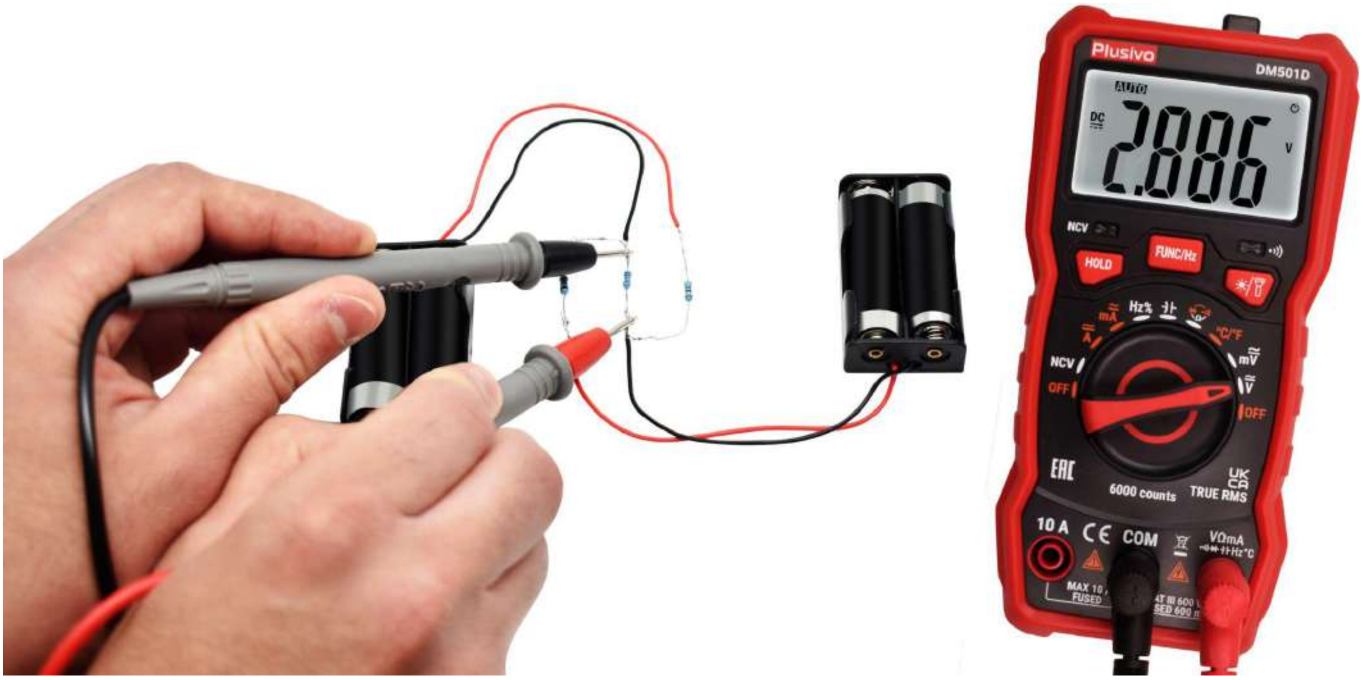
$$V = 0.3\,V$$

Now, let us make this circuit in reality and measure the voltage around the resistors using the multimeter.

The measured voltage around the 2.2 kΩ resistor is 6.085 V. Please see the set-up below.



The measured voltage around the 680 Ω resistor is 2.886 V. Please see the set-up below.

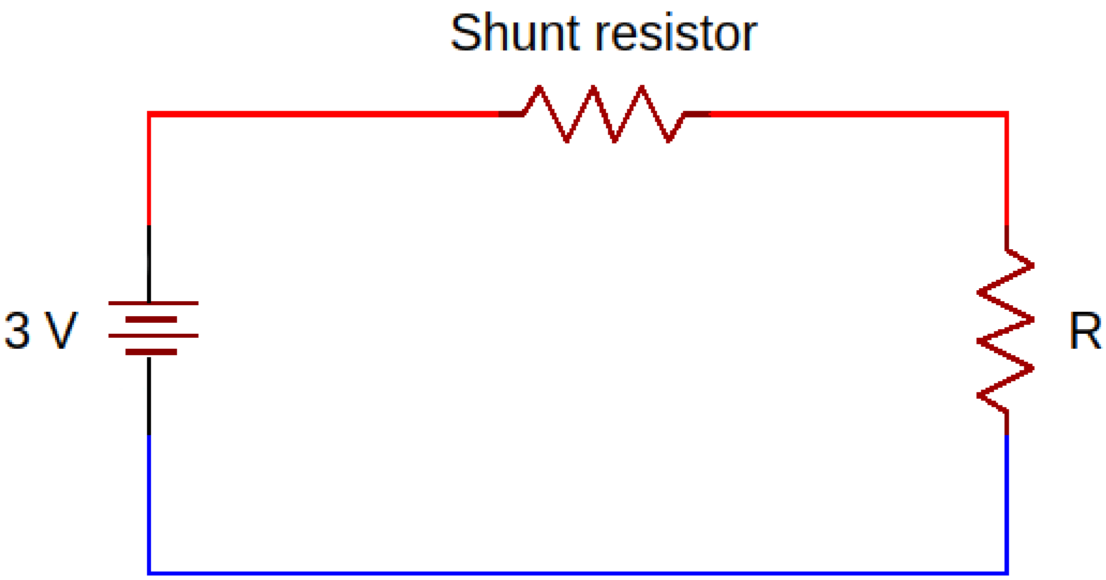


The measured voltage around the 47 Ω resistor is 0.386 V. Please see the set-up below.

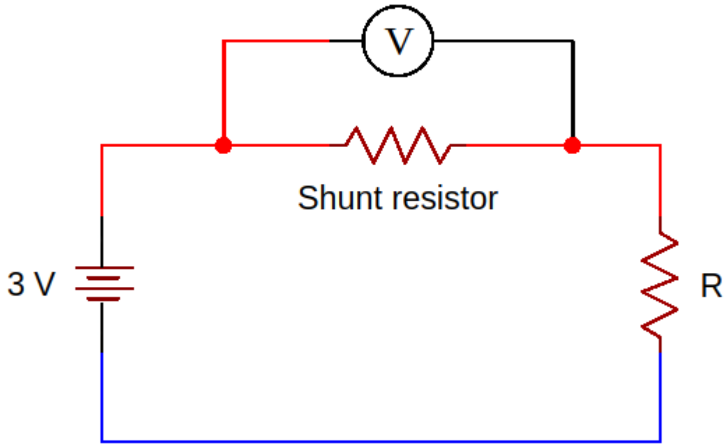
So we can count on our calculation, we will always find these small differences between the calculations and the real measurements because of the tolerance of the components.

8.4 Shunt Resistor

It is a way to measure current through a bath in the circuit using a small value resistor, we cut the circuit and connect it again using the shunt resistor. In most cases, it should be a high power resistor to handle the current passing through it.

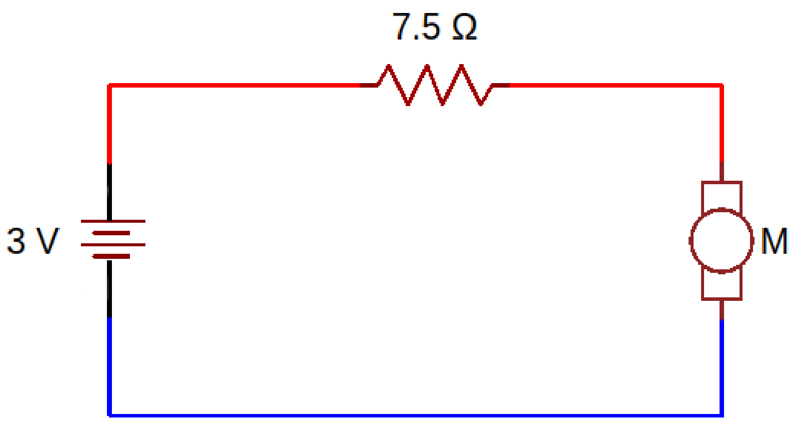


So depending on ohm’s law “$V = I \cdot R$”, we have a shunt resistor, and we have a current passing through it, so the voltage will be generated around it. And then we will measure this voltage using the multimeter, this way we have converted the current into voltage.



8.4.1 Example

In this circuit, we are going to use a 7.5 Ω resistor as a shunt, and calculate the current using Ohm's law.



Now, we need to measure the voltage around the 7.5 Ω shunt resistor using the multimeter.

The measured voltage in this figure is 1.865 V DC.

Using Ohm's law "$V = I \cdot R$"

$1.865\,V = I \cdot 7.5\,\Omega$

$$I = \frac{1.865\,V}{7.5\,\Omega} = 0.249A = 249\,mA$$

Now, let us measure the current using the multimeter to compare it with our calculations.

The measured current in this figure is 237 mA.

But there is a tolerance for the resistor, let us measure the resistor.

The measured resistance in this figure is 8.3 Ω.

If we calculate it again using Ohm's law "$V = I \cdot R$"

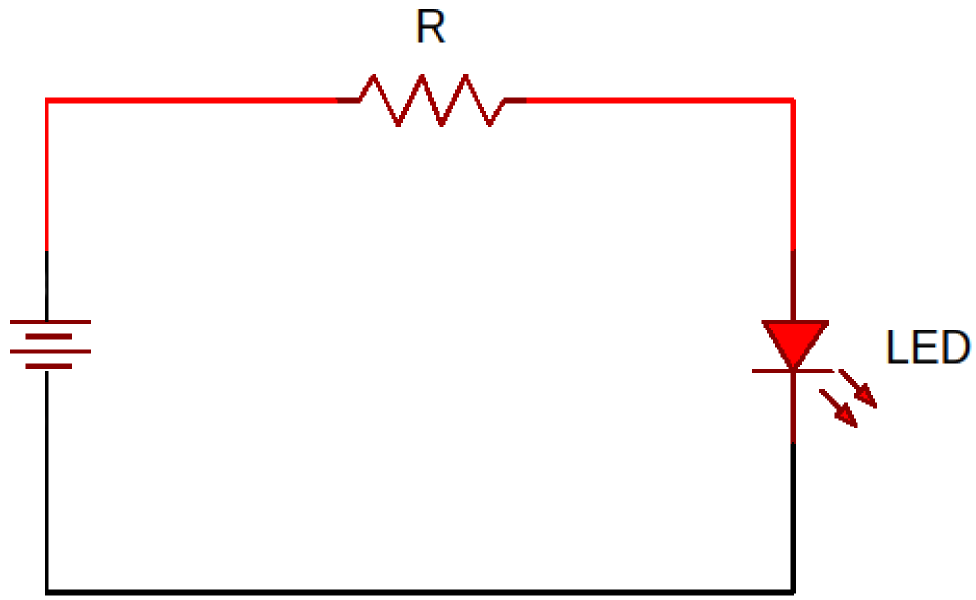
$1.865\,V = I \cdot 8.3\,\Omega$

$$I = \frac{1.865\,V}{8.3\,\Omega} = 0.225\,A = 225\,mA$$

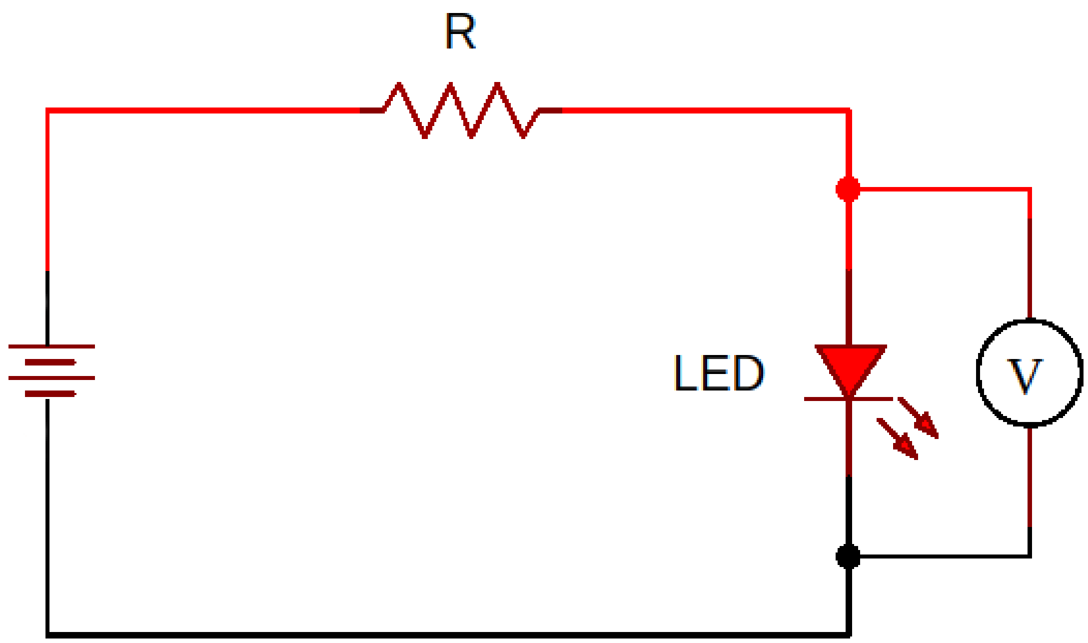
So, we can count on this way to measure the current, **225 mA** is near the value **237 mA**.

8.5 Choosing the Right Resistor for an LED

To calculate the resistor for an LED, we need to know the forward voltage for the LED. LEDs are different from the resistors, we need to limit the current passing through it because it does not work on Ohm's law.



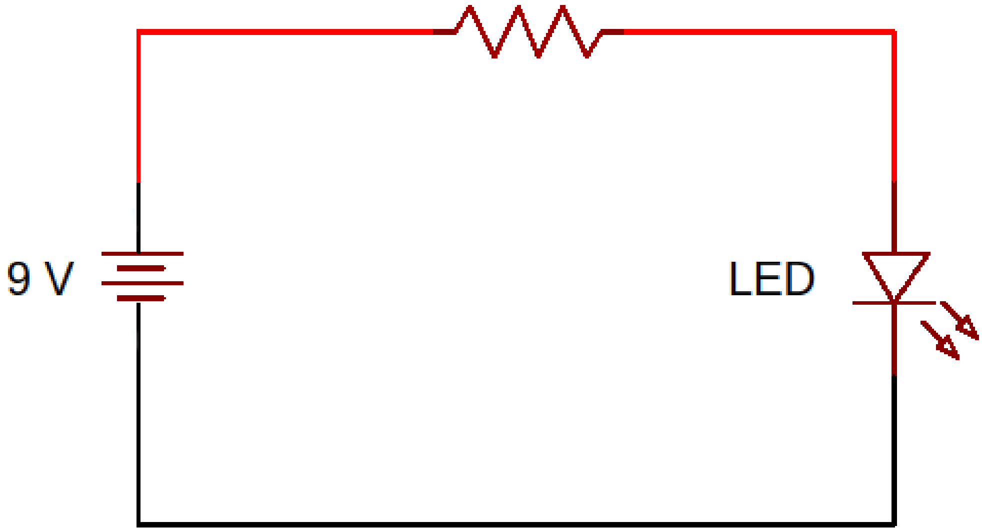
We need to know the voltage around the LED. Usually, a 5 mm LED needs 15 - 30 mA to be in good lighting. After knowing the forward voltage for the LED, it is easy to calculate the resistance.



To measure the forward voltage we connect a high value resistor, so we ensure that a low current will pass through the LED.

8.5.1 Example

Calculate the resistance in the following circuit for a red LED to make it consume around 20 mA.



Now, we need to build the circuit with a red LED, and we will use a high resistor, in our case, we will use a **2.2 kΩ** resistor and measure the forward voltage using the multimeter.

The measured voltage in this figure is 1.886 V DC

And if we measure the current in this circuit.

The measured current in this figure is 3.280 mA.

Now, let us calculate the value of the resistor. We have a **9 V** battery, the voltage on the LED is **1.886 V**, so the voltage on the resistor is: $9\,V - 1.886\,V = 7.114\,V$

Now, let us use Ohm's law:

$$R = \frac{V}{I}$$

$$R = \frac{7.114\,V}{20\,mA} = 355.7\,\Omega$$

And the closest standard value is 330 Ω.

Now, let us build the circuit again using a 330 Ω resistor and measure the forward voltage again and the current.

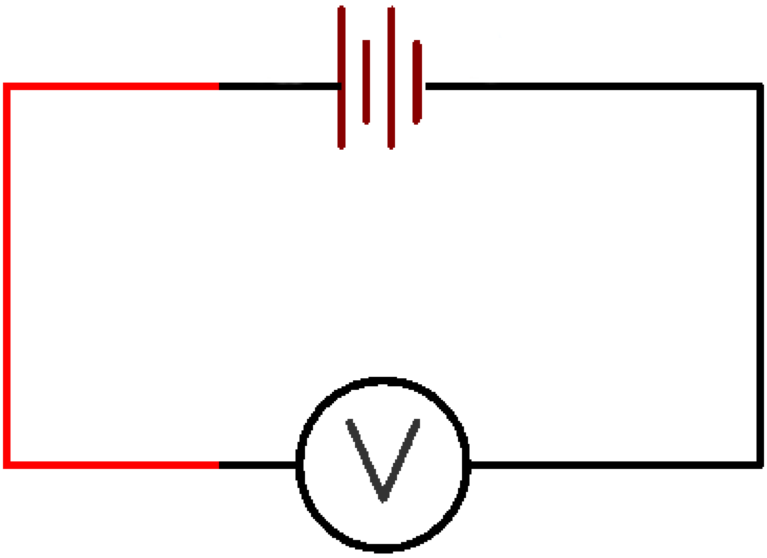
The measured voltage in this figure is 1.996 V DC

The measured current in this figure is 18.80 mA.

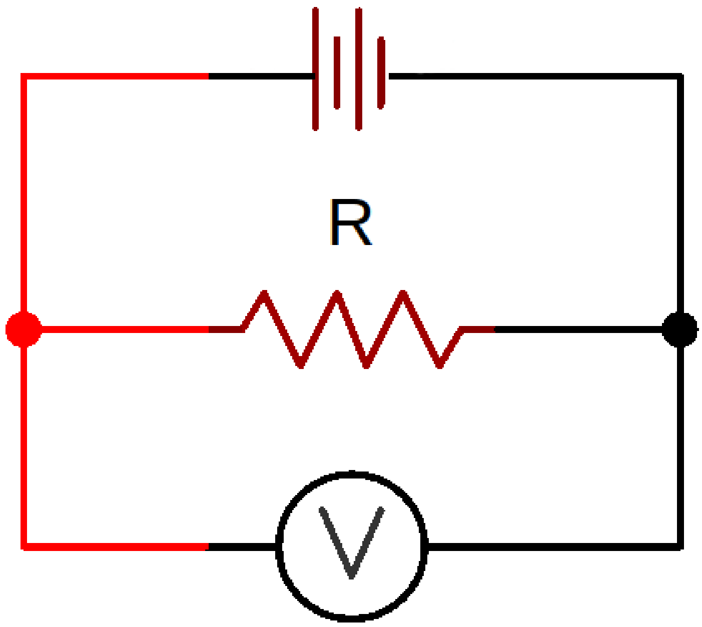
18.80 mA is so close to 20 mA.

8.6 Measuring Internal Resistance of a Battery

We need to follow these steps to measure the internal resistance of a battery using the multimeter. First, we need to measure the voltage of the battery.



Second, we connect a resistor with the battery and measure its voltage.



Third, we will do some calculations using Ohm's law.

- Calculate the current passing through the resistor: $\frac{R_V}{R} = I$
- Subtract the voltage of the battery from the voltage on the resistor: $B_V - R_V = B_{RV}$
- Now, we have the current and the voltage on the internal resistance, so we can calculate the value of the internal resistor: $\frac{V}{I} = I_{BR}$

8.6.1 Example

To measure the internal resistance of a 9 V battery, we need to measure the voltage of the battery first.

The measured voltage in this figure is 8.95 V DC.

Second, we connect a resistor with the battery and measure its voltage, in our case we will connect a 510 Ω resistor.

The measured voltage in this figure is 8.55 V DC.

Third, we will do some calculations using Ohm's law.

- Calculate the current passing through the resistor: $\frac{R_V}{R} = I$

$$\frac{8.55\,V}{510\,\Omega} = 0.0168\,A = 16.8\,mA$$

- Subtract the voltage of the battery from the voltage of the resistor: $B_V - R_V = B_{RV}$

$$8.95\,V - 8.55\,V = 0.40\,V$$

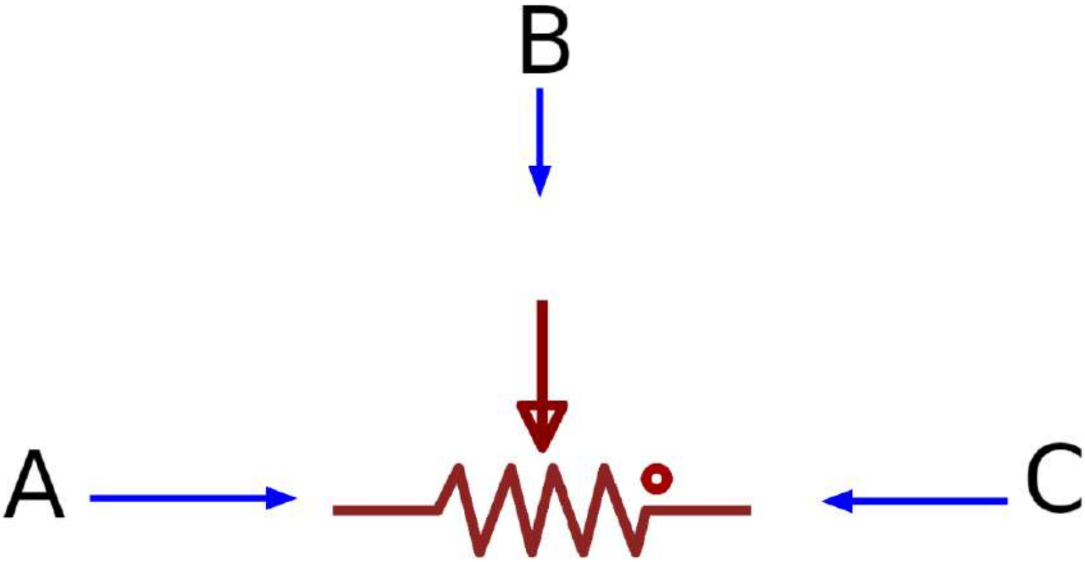
- Now, we have the current and the voltage on the internal resistance, so we can calculate the value of the internal resistor: $\frac{V}{I} = I_{BR}$

$$\frac{0.40\,V}{0.0168\,A} = 23.81\,\Omega$$

8.7 Testing Some Components Using Multimeter

In this section, we are going to test some components using a multimeter.

8.7.1 Potentiometer Test



First, we need to measure the resistance between A - C.

The measured resistance in this figure is 48.76 kΩ.

And then we measure the resistance between A - B and B - C, the sum of the two values must be equal to A - C.

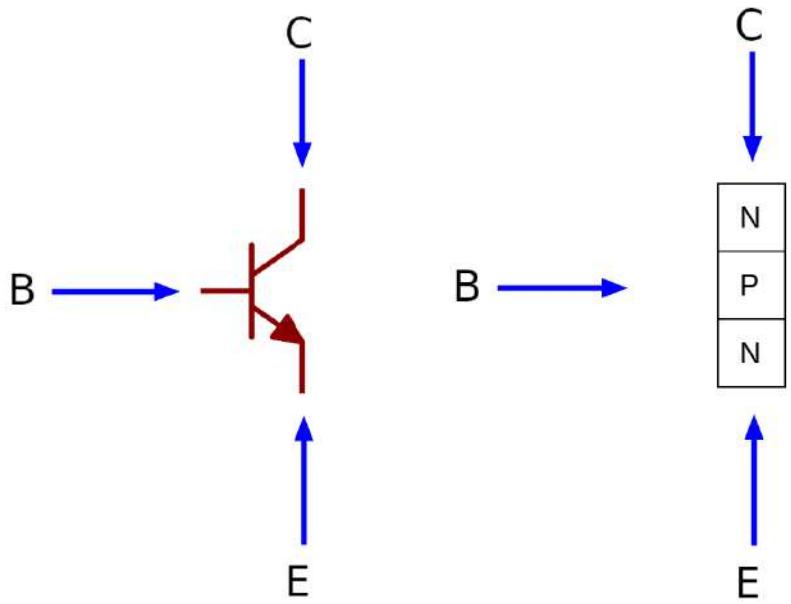
The measured resistance in this figure is 12.86 kΩ.

The measured resistance in this figure is 35.95 kΩ.

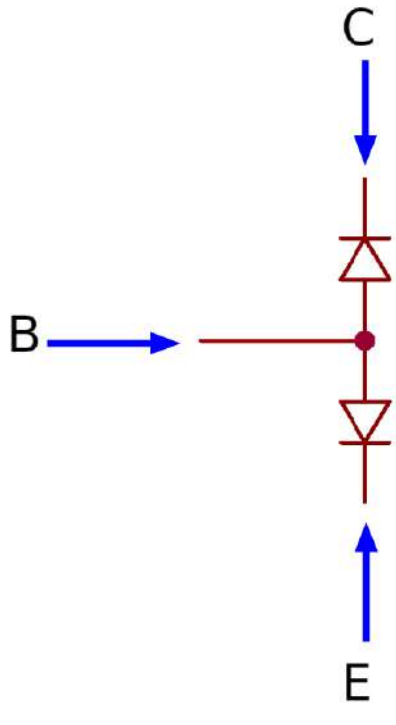
$12.86\ k\Omega\ +\ 35.95\ k\Omega\ =\ 48.81\ k\Omega$, which is almost equal to 48.76 kΩ

8.7.2 BJT Transistor Test

NPN



The NPN Type consists of two N-Regions separated by a P-Region, so we can suppose a diode between B - C and between B - E.



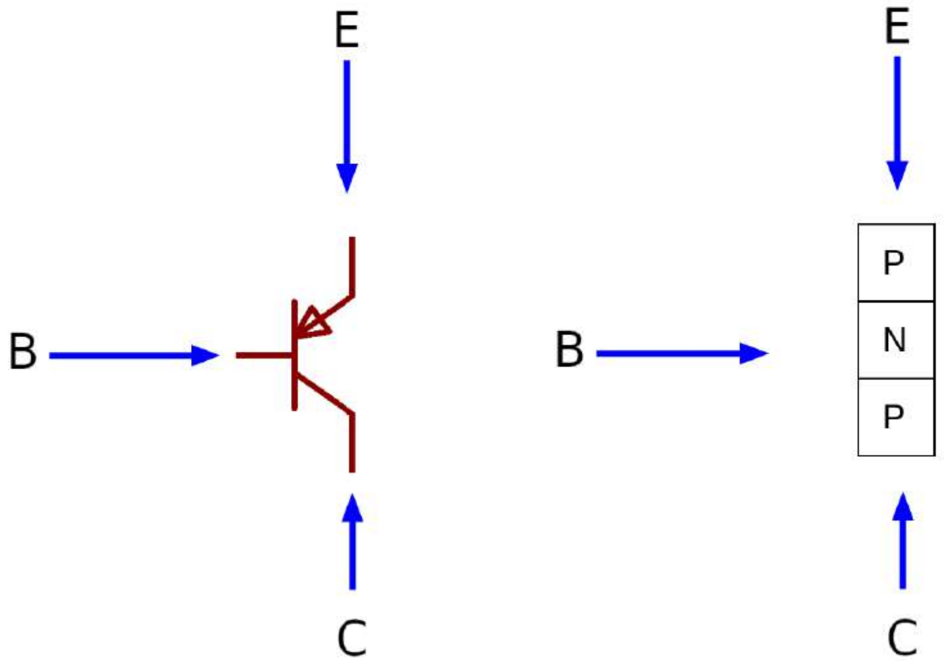
Now, we can test the NPN transistor as 2 diodes. To test the first diode (B - C), we need to connect the red probe to the anode which is the base of the transistor and connect the black probe to the cathode which is the collector of the transistor.

The measured forward voltage is 0.664 V.

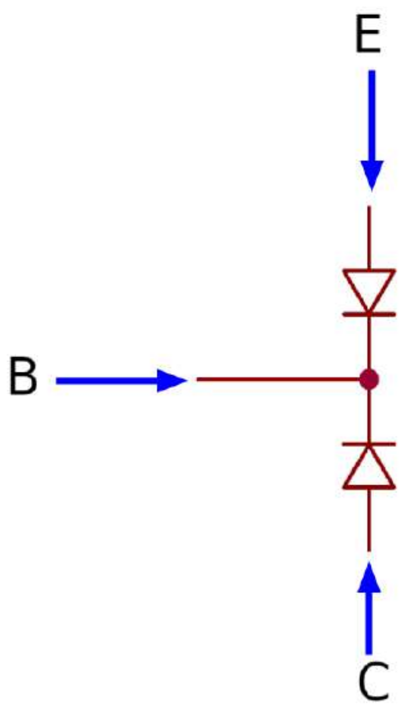
To test the second diode (B - E), we need to connect the red probe to the anode which is the base of the transistor and connect the black probe to the cathode which is the emitter of the transistor.

The measured forward voltage in this figure is 0.667 V.

PNP



The PNP type consists of two P-Regions separated by N-Region, so we can suppose a diode between B - C and between B - E.



Now, we can test the PNP transistor as 2 diodes. To test the first diode (B - E), we need to connect the black probe to the cathode which is the base of the transistor and connect the red probe to the anode which is the emitter of the transistor.

The measured forward voltage is 0.669 V.

To test the second diode (B - C), we need to connect the black probe to the cathode which is the base of the transistor and connect the red probe to the anode which is the collector of the transistor.

The measured forward voltage in this figure is 0.670 V.

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Digital Multimeter Kit	Digital Multimeter Kit with Enhanced Bonus	DM301B Digital Multimeter Kit with Enhanced Bonus	DM401B Digital Multimeter Kit with Enhanced Bonus	DM501D Digital Multimeter Kit with Enhanced Bonus
				

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Soldering Kit Model 4	Soldering Kit Model 5	Solder Wire and Paste Kit*	12 pcs Soldering Tips Kit
		 *Available in different solder weight (50g, 100g) and diameter (0.6mm, 0.8mm, 1mm)	

WIRE KITS
6 spools of different colors

Stranded Silicone Coated Wires	Gauge/No. of Strands	Length
	18 AWG / 150 strands	5 meters each color
	20 AWG / 100 strands	7 meters each color
	22 AWG / 60 strands	7 meters each color
	24 AWG / 40 strands	9 meters each color
	30 AWG / 11 strands	20 meters each color

Solid PVC Coated Wires	Gauge/No. of Strands	Length
	18 AWG	5 meters each color
	20 AWG	7 meters each color
	22 AWG	10 meters each color
	24 AWG	11 meters each color

B. 2 colors (Red and Black)

12 Gauge Silicone Wire Kit	Length / Number of Strands
	3 m each color / 680 strands
	8 m each color / 680 strands

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