MULTIMETER

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Contents

1 Introduction

A multimeter, also known as a volt-ohm meter, is a handheld tester used to measure electrical voltage, current, resistance, and other values. Depending on how advanced the multimeter is, you can also conduct continuity tests, diode tests, and temperature measurements. Some advanced multimeters even have infrared thermometers to measure temperatures from a distance. A multimeter that measures current, voltage, and resistance simultaneously functions as an ammeter, voltmeter, and ohmmeter. A simple turn of the circular knob on top of the multimeter will switch it from voltage measurement mode to current measurement and more. You can measure direct and alternating voltages separately with a multimeter, and the same goes for current. Therefore, one unit would be sufficient to measure current in household outlets (AC) and car batteries (DC).

2 Types of Multimeter

2.1 Analog Multimeters

An analog multimeter is based on a microammeter (a device that measures current) and has a needle that moves over a graduated scale. Analog multimeters are less expensive than their digital counterparts but can be difficult for some users to read accurately. Also, they must be handled carefully and can be damaged if they are dropped. Analog multimeters typically are not as accurate as digital meters when used as a voltmeter. However, analog multimeters are great for detecting slow voltage changes because you can watch the needle moving over the scale. Analog testers are exceptional when set as ammeters, due to their low resistance and high sensitivity, with scales down to $50\mu A$.

Analog multimeters are test instruments based around the use of a moving coil meter. This is an analogue form of display that uses the deflection of an indicator needle to indicate the level of the measurement being made.The analogue test meter typically contained a single meter and movement, and series and parallel resistors were used to provide the correct ranges. Typically a large rotary switch in the centre of the front panel under the meter was used to select the required range. There are sometimes a number of different connections used for the probes. There are normally a 'common' and a normal measurement probe connections. The normal one is often labelled Amps, Volts, Ohms or similar indicating it is for the normal measurements. Also for some measurements with either very high or low current, etc., a different probe connection may be used.

Figure 1: Analog Multimeter

2.2 Digital Multimeters

Digital multimeters are the most commonly available type and include simple versions as well as advanced designs for electronics engineers. In place of the moving needle and scale found on analog meters, digital meters provide readings on an LCD screen. They tend to cost more than analog multimeters, but the price difference is minimal among basic versions. Advanced testers are much more expensive. Digital multimeters typically are better than analog in the voltmeter function, due to the higher resistance of digital. But for most users, the primary advantage of digital testers is the easy-to-read and highly accurate digital readout.

Digital multimeters can measure a variety of different parameters within an electrical circuit. The basic digital multimeters can measure amps, volts and ohms, as the older analogue meters did, but with the ease of incorporating further functionality into an integrated circuit, many digital multimeters are able to make a number of other measurements as well. Many of them include functions enabling measurement of capacitance, frequency, continuity (with a buzzer to facilitate easy measurements when looking at the circuit board), temperature, transistor functionality, and often a number of other measurements as well. The analogue multimeters were able to measure only amps volts and ohms. However the introduction of integrated circuit technology and other technologies enabled analogue to digital converters to be made along with deploys like liquid crystal displays. This enabled test instruments to be made that could measure the basic measurements of amps volts and ohms to be made digitally. In addition to this, it was possible to add in additional measurements at very little cost, making these test instruments far more versatile than the old analogue counterparts.

Figure 2: Digital Multimeter

3 Using a Multimeter

The basic functions and operations of a multimeter are similar for both digital and analog testers. The tester has two leads—red and black—and three ports. The black lead plugs into the ”common” port. The red lead plugs into either of the other ports, depending on the desired function. After plugging in the leads, you turn the knob in the center of the tester to select the function and appropriate range for the specific test. To measure smaller voltages, you would set the knob to the 2V or 200mV range. To take a reading, you touch the bare metal pointed end of each lead to one of the terminals or wires to be tested. The voltage (or other value) will read out on the tester. Multimeters are safe to use on energized circuits and equipment, provided the voltage or current does not exceed the maximum rating of the tester. Also, you must be careful never to touch the bare metal ends of the tester leads during an energized test because you can receive an electrical shock.

3.1 Using a multimeter to measure the voltage

To measure the voltage across the terminals of the AA batteries(a small cylindrical cell battery of alkaline, lithium, or Ni-MH composition), connect the black probe into COM and the red probe into mAVohm. Set the multimeter to 2V in the DC (direct current) range. This is because most portable electronics use Direct Current (DC) and not Alternating Current (AC). Connect the black probe to the battery's ground or '-' and the red probe to power or '+'. Now press the probes against the positive and negative terminals of the AA battery. If you've got a new battery, you will see around 1.5V on the display.

3.2 Using a multimeter to measure the current

Reading current is tricky because you have to measure current in a series circuit. So while voltage is measured with the voltage common collector and ground in parallel circuits, to measure current you have to physically interrupt the flow of current and put the meter in-line. So you first turn the multimeter's dial/ knob to the Current mode, followed by pulling out the red wire going to the resistor, and connecting the black probe from the multimeter to it. You then connect the multimeter's red probe to the positive terminal of the power source, so you can measure the current flowing through the circuit.

3.3 Using a multimeter to measure the resistance

The resistance of an object itself depends largely on the material it is made of—objects made of electrical insulators like rubber have very high resistance and low conductivity, whereas objects made of electrical conductors such as metals have very low resistance and high conductivity. Resistance or conductivity then is used to quantify this material dependence. So, for measuring resistance with the multimeter, you begin by turning the knob / dial to the resistance mode. Then you connect the black and red probes of the multimeter to the two ends of the resistor.

3.4 Using a multimeter to check the conductivity

Conductivity testing refers to testing the resistance between two points. If there is very low (less than a few s) or no resistance between two points that have been connected electrically, a sound or tone is produced by the multimeter indicating the high conductivity. On the other hand, if there is resistance no tone is produced indicating less or no conductivity. This test helps to check if connections have been made correctly between two points. This test also helps us recognise if two points are connected that should not be. So to check for conductivity, turn the knob to the conductivity mode. Now you can check the conductivity between two points by placing the two probes on the two points. So, if you wish to check conductivity between the probes, you connect the two and you'll hear the sharp tone or sound that is produced, which means that the two probes are conductive.

4 Construction and Working

A multimeter is a permanent magnet moving coil galvanometer. There is an iron cored coil pivoted on two jeweled bearings. The coil is wound on an aluminum former or bobbin. And this coil is free to rotate in the field of a permanent magnet. An aluminum pointer is attached to the coil and bobbin assembly and moves on a graduated scale. There are two spiral springs attached to the coil assembly at the top and bottom, which provide a path for the flow of current and controlling torque.

A multimeter can measure voltage, current, and resistance for which its galvanometer is converted to a voltmeter, ammeter, and ohmmeter with the help of suitable circuits incorporated in it. The galvanometer used in a multimeter has always its pointer resting at zero position on the extreme left end various measurements are made on a multimeter.

4.1 Voltage measurement

Generally, a galvanometer has a current sensitivity of the order of 0.1 mA and a small internal resistance of about 500 ohms. As such, it cannot measure high voltages. To measure high voltages, its range is extended by connecting a high resistance in series with the galvanometer as shown in the figure 3.

If the galvanometer resistance is denoted by G and Ig is the full-scale deflection current and the voltage to be measured is V volts, then the value of series resistance RS is determined as under,

$$V = I_g R_s + I_g G$$

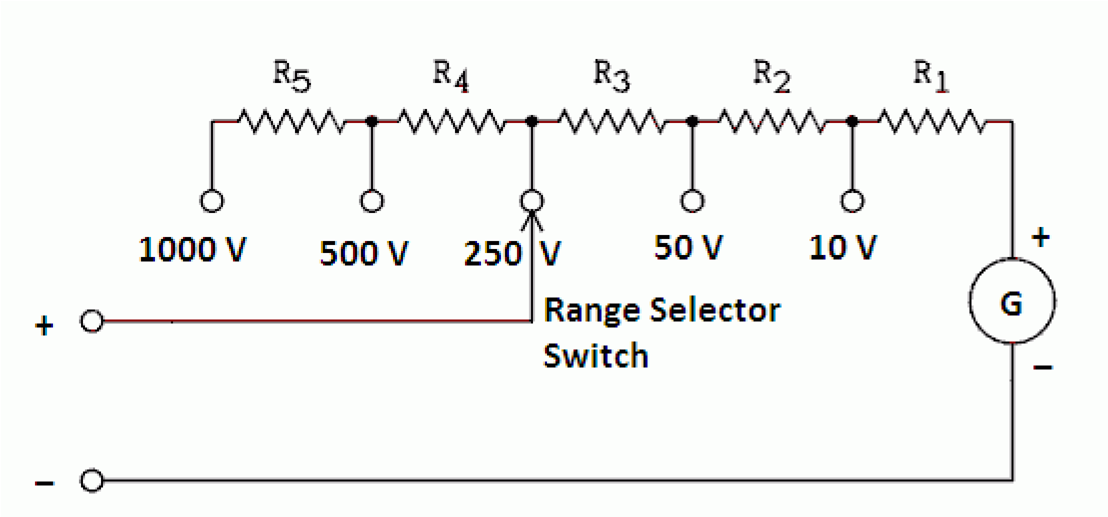

Figure 3: DC Voltage Measurement

This series resistance is also called the multiplier. The voltage range can be increased by increasing the number or value of multipliers. Either a selector switch is provided to select different ranges or some sockets indicating the voltage range are provided in a multimeter.

While making, measurement one lead is inserted in the common socket and the other lead in the required voltage range socket.

The multimeter can also measure AC. For this purpose, a full-wave rectifier is incorporated in the multimeter. The rectifier converts AC into DC for application to the galvanometer.

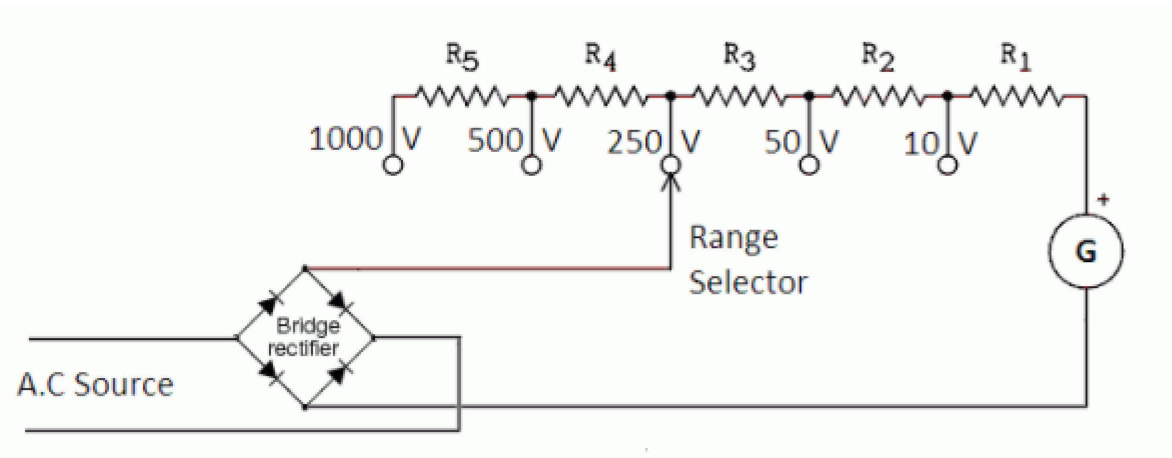

Figure 4: Ac Voltage Measurement

4.2 Current Measurement by Multimeter

The same galvanometer can be used for measuring current when it is converted into an ammeter by connecting a small resistance Rsh in parallel with the meter, as shown in the figure 5. If G is the internal resistance of meter, Ig its full-scale deflection current and I is the total current to be measured, then the value of shunt resistance Rsh required can be found as under:

$$(I - I_g)R_{sh} = I_g G$$

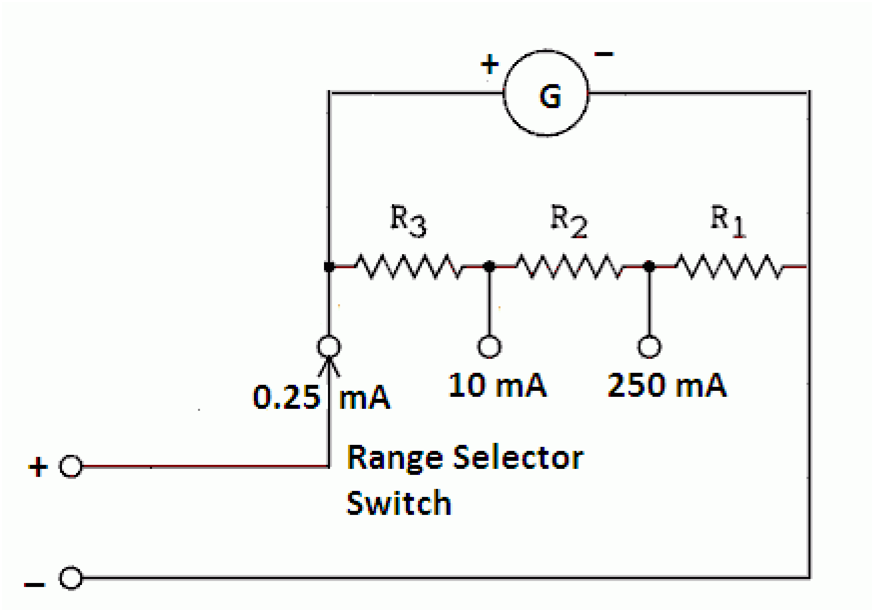

Figure 5: Current Measurement

The range of ammeter can be extended to any value within limits by reducing the value of shunt resistance. Some low resistances are connected in parallel with the meter through a selector switch, as shown in the figure. The desired range can be selected by moving the selector switch to a particular position.

If the total current to be measured, I is very high, the value of shunt resistance required Rsh becomes very low, which is sometimes practically not possible. In this case, connections are so arranged that as we move from low range to higher range, the meter resistance is also increased with the decrease in the value of shunt resistance.

4.3 Resistance Measurement by a Multimeter

The same basic instrument can be used as an ohmmeter to measure resistances. In this circuit, an internal battery is connected in series with the meter through an adjustable resistance r and the fixed resistances.

The fixed resistances limit the current within the desired range, and the variable resistance r is used for zero adjustments.

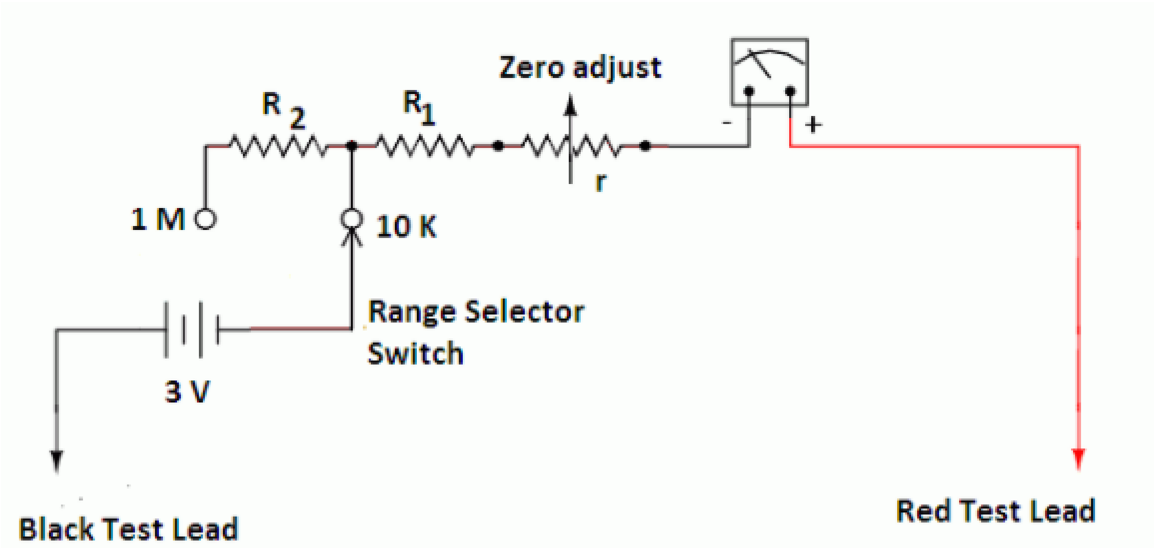

Figure 6: Resistance Measurement

The resistance to be measured (test resistance) is connected between test leads. The current flowing through the circuit depends upon the resistance of the test piece. The deflection of the needle indicates current, but the scale is calibrated in ohms to give the value of resistance directly. The ohmmeter is generally made multi-range instrument by using different values of fixed resistances.

To measure resistance by the multimeter, a suitable range is selected. Then the meter leads are shorted, and variable resistance r is adjusted to give full-scale deflection.

Under this condition, the resistance between test leads is zero; therefore, the scale of ohmmeter Indicates zero on the extreme right end. Then the resistance under measurement is connected between terminals test leads.

5 Applications

- **Testing voltage:** Use the voltage setting to measure voltage drop across circuit components and to measure total voltage across a circuit. You'll need the DC voltage setting for most small circuit components and for testing batteries and the AC voltage setting for testing residential circuit components, such as light switches, light fixtures and outlets. Note that you can measure voltage without disconnecting the circuit. Simply touch one probe to the negative terminal or, if testing AC voltage, to the hot terminal. Touch the other probe to the other terminal and record the reading.

- **Testing current:** You normally use the mA scale for testing current through a electronic circuits and the A scale for testing residential current. To test current, the meter must be part of the circuit. In most cases, you have to make a break in the circuit, and then connect one wire to one of the meter probes and the other wire to the other probe.

- **Testing resistance:** The meter has a built-in power source that is activated when you choose the resistance scale. It sends a small current from one probe, and the smaller the current recorded by the other probe, the higher the resistance. If the second probe records no current, the meter displays infinite resistance or the letters OL, which means open line. This function is useful for continuity testing. You can also use it to check a diode by checking the resistance in one direction across the device, then reversing the probes and checking resistance in the other direction. If the diode is good, you should get low resistance in one direction and near infinite resistance in the other.

6 Loading Effect

Loading effect is a term which describes the state of the electric circuit before and after connecting the voltage measuring instrument. When any voltage measuring instrument viz. Voltmeter, Multimeter etc. is connected across (parallel) any current carrying element in the circuit, it is expected that the instrument would show the correct (theoretical value) potential difference across it. Before connecting and after connecting the measuring instrument should not alter the condition of the circuit. However, if the input impedance of the instrument is small as compared to the impedance between the two point across which potential difference is to be measured, then the instrument acts as a shunt and draws more current, resulting in the reduction of the current through the element. Hence, the potential drop across the element would be smaller than expected (theoretical value). This happens because the measuring instrument has drawn an appreciable amount of current, on other words, the instrument has loaded the element and caused a loading effect; which is undesired. So, the instrument produces unreliable and erroneous reading when connected to a circuit whose resistance is comparable to the resistance of the circuit. Hence, the input impedance of the voltage measuring instrument must be very high, nearly infinite. The same is true for current measuring instrument i.e. ammeter. Since an ammeter is always connected in series with the current carrying circuit, it should have minimum impedance (practically zero ohm), so that even after connecting ammeter in the circuit, will not alter the condition i.e. current in the circuit.

The loading can also be explained in terms of sensitivity of the instrument. A low sensitivity multimeter/voltmeter may give correct readings only when measuring voltages in low-resistance circuits, however it becomes most unreliable in high resistance circuits. A voltmeter will then give a lower indication of the voltage drop than actually existed before the meter was connected. This effect is called, loading effect of an instrument.

7 Experiment: To observe the loading effect of a multimeter while measuring voltage across low and high resistance.

7.1 Formula Used

According to the voltage divider rule,

$$V_{R1} = \frac{R1}{R1 + R2} V$$

$$V_{R2} = \frac{R2}{R1 + R2} V$$

these are the *true values.*

Relative error in the measurement,

$$Error = \frac{V_{True} - V_{calculated}}{V_{True}}$$

and the percentage error,

$$Percentage\ Error = \frac{V_{True} - V_{calculated}}{V_{True}} \times 100$$

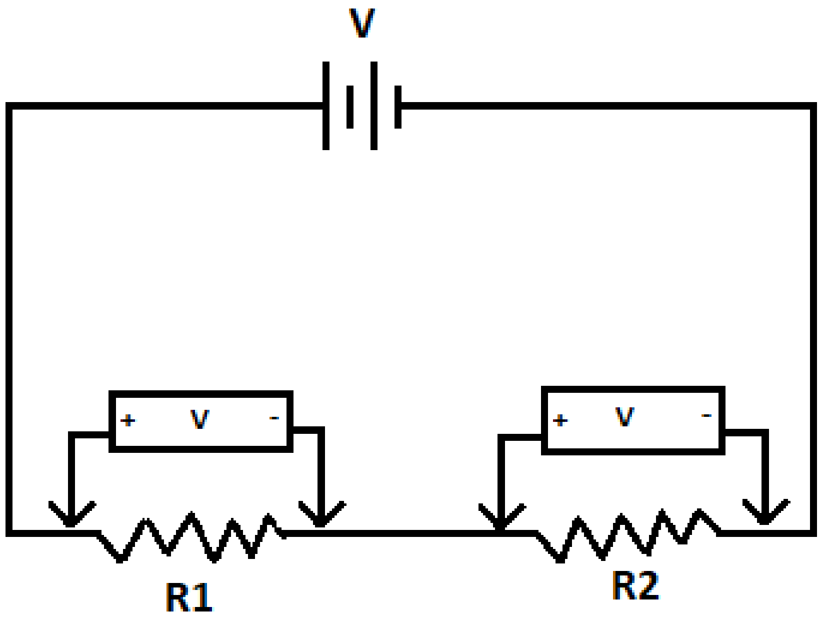

Figure 7: Circuit Diagram

7.2 Procedure

- Make the connections as shown in figure 7.
- Note the voltmeter readings . This is the observed potential drop (V) across R_1 and R_2 for different values of R_1 and R_2.
- Calculate the true value of V_{R1} and V_{R2} and find error in different measured values.

7.3 Observations and calculations

V = 15V

$R_{voltmeter}$ = 100 ohm

R_1 $(k\ ohm)$	V (V)	$V_{measured1}$	$V_{measured2}$	$V_{calculated1}$	$V_{calculated2}$	Error in V_1(%)	Error in V_2(%)
0.1	0.01	0.92	0.08	0.91	0.09	1	1
1	0.1	0.93	0.09	0.91	0.09	2	0
20	2	0.9	0.07	0.91	0.09	1	2
100	10	0.91	0.09	0.91	0.09	0	0

Table 1: Observation Table

7.4 Result

From table 1, it can be seen that for a given voltmeter, the error in the measured values is increasing as the resistance of circuit approaches internal resistance of the voltmeter. This helps us understand the loading effect of voltmeter. When the resistance of the voltmeter is comparable to the resistance of the component along which potential drop needs to be measured, it draws certain quantity of current from the circuit and thus alters the value of voltage across the component. So, it can be concluded that the impedence of an ideal voltage source should be nearly infinite.

7.5 Precautions

- Always disconnect the multimeter before adjusting the range switch.
- Be sure that the multimeter is switched to AC prior to trying to measure AC circuits.
- Never apply power to the circuit when measuring resistance with a multimeter.
- Choose a final range that enables a reading close the middle of the scale.
- Set the ideal current range before measuring higher current or else it will blow the digital multimeter fuse.
- Change the 0 ohms reading after changing resistance ranges and before creating a resistance measurement.