2141274 Electrical and Electronic Laboratory

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Basic Circuit Measurements (CIR)

Content

1. Objective

This laboratory helps you to understand basic measurements of direct current (DC) and alternating current (AC) quantities.

2. Theoretical Part

2.1) Conductors and Connectors

Conductors in our laboratory can withstand about 20 A. Connectors used can be classified into two main groups:

1) The connector with banana plugs (Figure 1a.) on both sides. This type of connector is suitable to connect an ammeter with a shunt switch (discussed later).

   A banana connector consists of a cylindrical metal pin which can be inserted into a matching socket to make an electrical contact. The pin has one or more lengthwise springs that bulge outwards slightly. These press against the sides of the socket, improving the electrical contact and preventing the pin from falling out. The curved profile of these springs is probably the origin of the name "banana plug". The other end of the plug has a hole that accepts a length of flexible insulated equipment wire, which is either screwed or soldered into place. An insulating plastic cover is usually fitted over this end.

2) The connector with one side is a banana plug and the other is a spade connector (Figure 1b.) or an alligator clip (Figure 1c.). This type of conductor is suitable to connect a voltmeter.

   An alligator clip is a temporary electrical connector, named for its resemblance to an alligator's jaws. Functioning much like a clothespin, the clip's two tapered, serrated jaws are forced together by a spring to make them grip a metal object, and one of the jaws usually has a wire permanently attached for connection to an electrical circuit. The clip may be partly covered by a plastic shroud or "boot" to prevent accidental short-circuits.

a. Banana plug b. Spade connector c. Alligator clip

Figure 1: Connectors.

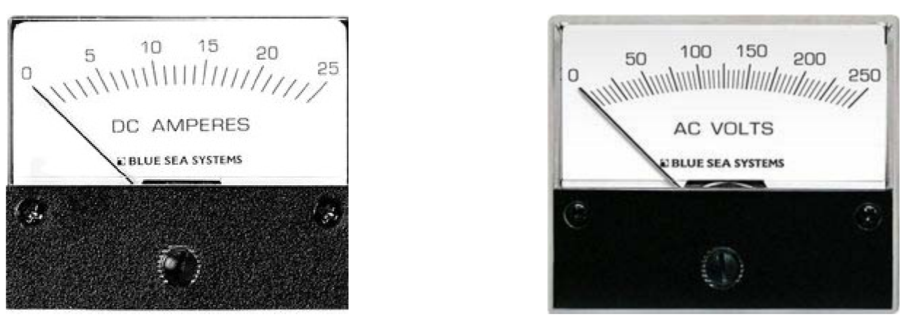
2.2) Meters

There are two kinds of meters, DC (with a symbol — or DC) and AC (with a symbol ~ or AC) types. For DC meters, we have to be careful about polarities when they are connected. If (positive and negative) polarities are not connected properly, the moving scale will move in the reverse direction (negative scale). This can result in a damage to meters and accuracy for the next measurement. It should be noted that both ammeters (through a shunt switch) and voltmeters should be connected to the circuit last. Ammeters, voltmeters and wattmeters will be described in this section.

1) Ammeter

An ammeter is a measuring instrument used to measure the flow of electric current in a circuit. We connect an ammeter ***in series*** with the circuit that we want to measure the current. A good ammeter should have a low resistance. In practice, we connect an ammeter through a shunt switch so the circuit is still working though we disconnect an ammeter (which connects in series). The sample of a DC ammeter is shown in Figure 2a.

The earliest design of an ammeter is the D'Arsonval galvanometer or moving coil ammeter. It uses magnetic deflection, where current passing through a coil causes the coil to move in a magnetic field. The voltage drop across the coil is kept to a minimum to minimize resistance in any circuit into which the meter is inserted. More modern ammeter designs are non-mechanical, or digital, and use an analog to digital converter to measure the voltage across the shunt resistor.



a. DC ammeter b. AC voltmeter

Figure 2: Ammeter and voltmeter.

2) Voltmeter

A voltmeter is a measuring instrument for measuring the voltage between two points in an electric circuit. We connect a voltmeter ***in parallel*** to the part of the circuit we want to know the voltage difference. A good voltmeter should have a high resistance. We can disconnect a voltmeter with no effect to the circuit (because it connects in parallel). The sample of an AC voltmeter is shown in Figure 2b.

The voltage can be measured by allowing it to pass a current through a resistance; therefore, a voltmeter can be seen as a very high resistance ammeter. One of the design objectives of the instrument is to disturb the circuit as little as possible and hence the instrument should draw a minimum of electric current to operate. This is achieved by using a sensitive ammeter in series with a high resistance. The moving coil galvanometer is one example of this type of voltmeter. It employs a small coil of fine wire suspended in a strong magnetic field. When an electrical current is applied, the galvanometer's indicator rotates and compresses a small spring. The angular rotation is proportional to the current that is flowing through the coil. For use as a voltmeter, a series resistance is added so that the angular rotation becomes proportional to the applied voltage.

3) Wattmeter

A wattmeter is used for measuring powers in AC circuits. For DC circuits, powers can be found simply from multiplying voltage by current.

A wattmeter consists of a current coil, connected in series with the line like an ammeter, and a potential coil, connected in parallel with the line like a voltmeter. The connection is shown in the Figure 3. There is a shunt switch for the current coil similar to an ammeter, while the potential coil has no shunt switch.

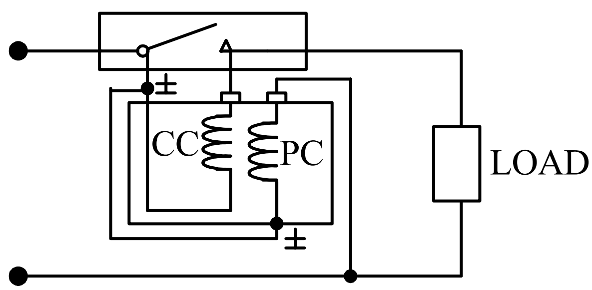


Figure 3: Wattmeter connection.

It should be noted that one polarity of the current coil and one polarity of the potential coil have the symbol '±', representing that they are common polarities. We have to connect them with an additional conductor as shown in the figure.

The average power measured from a wattmeter can be calculated from

$$P = IV\cos(\theta_V - \theta_I)$$

where

I	root-mean-square (RMS) value of the current
V	root-mean-square (RMS) value of the voltage
$\theta_V - \theta_I$	phase angle difference between voltage and current or power factor angle

2.3) Shunt Switch

A shunt switch should be used along with an ammeter. The proper way to connect a shunt switch together with an ammeter is shown in Figure 4.

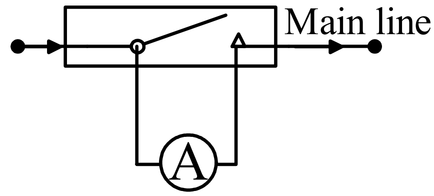


Figure 4: Connection of a shunt switch and an ammeter.

The shunt switch should be connected to the main circuit first and then an ammeter is connected to the shunt switch as shown in the figure. A voltmeter should not be connected with a shunt switch because a short-circuited condition can occur.

Advantages of a shunt switch can be summarized as follows:
1) To prevent a current passing through a DC ammeter when polarities are connected wrong. We can switch the polarities of the DC ammeter while the circuit is on.
2) To help changing the scale of an ammeter without interrupting the main circuit. When an ammeter (connects in series) is moved from the circuit without using a shunt switch, an arc or spark can happen. If the current is high, the damage can be serious.
3) To bypass an ammeter while it is not used for the measurement.

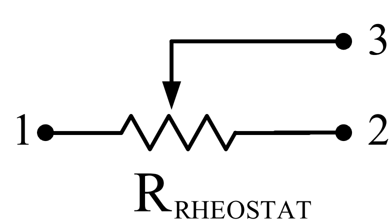
Therefore, use a shunt switch every time you want to change the scale, polarities, start or finish an experiment. And also note that a shunt switch used in our laboratory is normally closed circuited and is opened circuited when it is pressed (current will pass through an ammeter instead).

2.4) Rheostat

Rheostats are used as often as ammeters and voltmeters. Rheostats do not have moving scales as in ammeters and voltmeters, thus it can be damaged due to a high current.

A rheostat comprises of a layer of resistance wire wound on an insulating heat resistance tube (Porcelin) which is supported by cast metal feet. One terminal being connected to the sliding contact and the other two to the ends of the winding as shown in Figure 5a. Resistance value can be changed by adjusting the sliding contact. Maximum allowable current and rheostat's resistance are provided on the nameplate or the sliding contact. The current passing through a rheostat can be calculated from $I = \dfrac{V}{R_{RHEOSTAT}}$.

a. Physical appearance



b. Equivalent circuit

Figure 5: Rheostat.

A rheostat can be used for various applications such as

1) A fixed resistance
   If a sliding contact is not adjusted, a resistance will remain constant. Normally terminals 1 and 2 are used.
2) Variable resistance
   If a sliding contact is used by adjusting the position of terminal 3 (in Figure 5b), a variable resistance can be achieved. Only a pair of terminals 1 and 3 or a pair of terminals 2 and 3 is used.
3) Voltage divider
   All three terminals are used for this case. Terminals 1 and 2 must be connected to the supply. For the voltage that will be used, the sharing terminal has to be considered. For example, if terminal 2 is a shared terminal, the divided voltage will come from terminals 2 and 3 (supply voltage is connected between terminals 1 and 2).

2.5) Safety Issues

Circuits

1) Do not places conductors or wires near moving parts of the machine because all devices connected with conductors can be pulled and damaged.
2) Try to connect conductors using different color conductors and do not leave them as a big mess. This can prevent accidents from misplace the conductors and it is easy to check the circuit connections.

Students

1) Do not stay close to moving parts of a machine and active parts of the circuit where the current is flowing and there is no insulation. Also be aware of neckties or necklaces.
2) It is recommended not to wear the jewelry that can conduct the electricity such as metal rings, watches during the test.

Equipment or Devices

Be aware of the irregular light, sound, smell and heat from devices.

1) When a current pass through conductors which are not connected firmly, sparks or arcs or flash could be seen.
2) The spark or arc sound (like “ฟุบ” or “ฟับ”) and the sound of a short circuit (“ปัง”) should be very cautious.
3) When a high current passes through devices or conductors for a long time, their insulation can be very hot and the smell of the burn can be sensed.
4) When machines, rheostats or conductors carry high currents for a long time, we can feel that they are hot because the high amount of heat is generated.

2.6) Effective or RMS Values of AC Quantities

In DC circuits, current and voltage are constant at all times. Average values of current, voltage and power are I, V, and $P = VI = I^2R = V^2/R$, respectively. For AC circuits, these quantities are changing periodically all the time.

In order to reference with DC quantities, we equate the heat generated from supplying AC voltage to a resistor to the heat generated from supplying DC voltage to the same resistor. In other words, if we supply AC voltage to a resistor, we would get the same amount of average power as if we supply DC voltage to that resistor. This ‘*effective*’ value of AC voltage equals to the DC voltage value. This effective value is also called root-mean-square (RMS) value. RMS values can be calculated from

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2 dt} \qquad \text{and} \qquad I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2 dt}$$

where T is the period of the waveform.

For sinusoidal waveforms, RMS values can be found from maximum values (subscripts *m*) as $V_{RMS} = \frac{V_m}{\sqrt{2}}$ and $I_{RMS} = \frac{I_m}{\sqrt{2}}$.

For triangular waveform with the maximum value (V_m), $V_{RMS} = \frac{V_m}{\sqrt{3}}$ and for half-sine wave, $V_{RMS} = \frac{V_m}{2}$.

The D'Arsonval galvanometer-based meter (or permanent magnet moving coil, PMMC) might not be able to measure the sinusoidal current due to the fact that the average is zero. Dynamometers which rely on electrodynamometer movement can solve this problem and can measure RMS values correctly. Dynamometers do not have magnetic materials and the developed torque of the moving coil is proportional to the square of current. However, powers used for this type of meters are higher than D'Arsonval galvanometer-based meter.

2.7) Measuring Device Errors

Errors from measuring devices can be classified as follows:

1) Scale error
   The scale can be misplaced due to the calibration failure.
2) Zero error
   This error happens from the user not setting the scale at zero before measurements.
3) Reading error
   The user might read the scale incorrectly.
4) Parallax
   This error happens when the user do not read the scale perpendicular to the scale plane. This error can be reduced with the help of mirror under the scale and a knife-edge pointer as found in good quality meters.

2.8) Phasor

The phasor is the constant complex number that encodes the amplitude and phase of the sinusoid. To simplify the notation, phasors are often written in angle notation: $A\angle\theta$ where A is the magnitude and θ is the phase angle. Within electrical engineering, the phase angle is commonly specified in degrees rather than radians and the magnitude will often be the RMS value rather than a peak value of the sinusoid.

Instantaneous time-domain waveform can be converted to a phasor form using the following relationship:

$$i(t) = I_m \cos\omega t \ \text{ can be converted to } \frac{I_m}{\sqrt{2}}\angle 0° \text{ and}$$

$$v(t) = V_m \cos(\omega t - \theta) \ \text{ can be converted to } \frac{V_m}{\sqrt{2}}\angle -\theta° .$$

3. Experimental Part

This section describes experimental procedures, instructions and reports.

3.1) Experimental Instructions

Experimental Instrument and Details

1 DC Ammeter 0-30 A
1 DC Milli-ammeter 0-1000 mA
1 DC Voltmeter 0-300 V
1 AC Ammeter 0-5 A
1 AC Ammeter (PMMC type) 0-30 A
1 AC Voltmeter 0-300 V
1 Wattmeter
1 Rheostat 1170, 1 A
1 Rheostat 50, 5 A
1 Inductive load
1 Capacitor bank
1 Resistive load
1 Variac 0-240 V
1 Diode
1 Diode bridge
1 Oscilloscope (CRO)
1 Digital multimeter

Exp 1.1: DC Current and Voltage Measurements

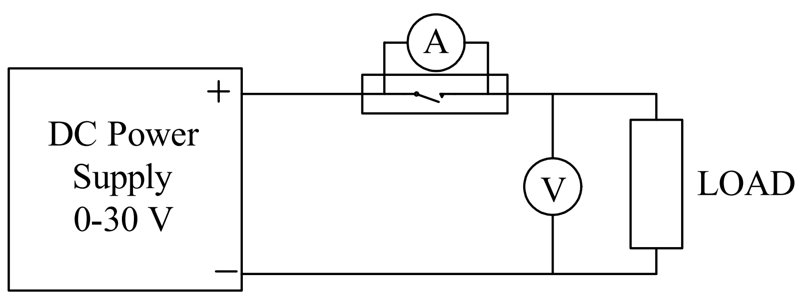


Figure 1.1: Test circuit

1) Connect the circuit as shown in Figure 1.1. Set load resistance at **50 ohms**.
2) Measure the current and voltage using a DC ammeter and a DC voltmeter and then vary four values (15, 20, 25 and 30 V) of the supply voltage and record readings.
   Note:
   a) Connect an ammeter *in series* with the circuit. There is no need to connect a voltmeter right away. Use alligator clips to gently touch the circuit first if the scale flips the wrong way, change the polarities. If polarities are correct, connect alligator clips firmly.
   b) A shunt switch will act like a wire connects between two points. It will be closed all the times and allow a small amount of current passes through an ammeter. If you want to read a current value, press the shunt switch if the scale flips in the wrong direction, change the polarities.
3) Measure resistor value using a digital multimeter and find the average value of the resistor.

Exp 1.2: DC Current and Voltage Measurements

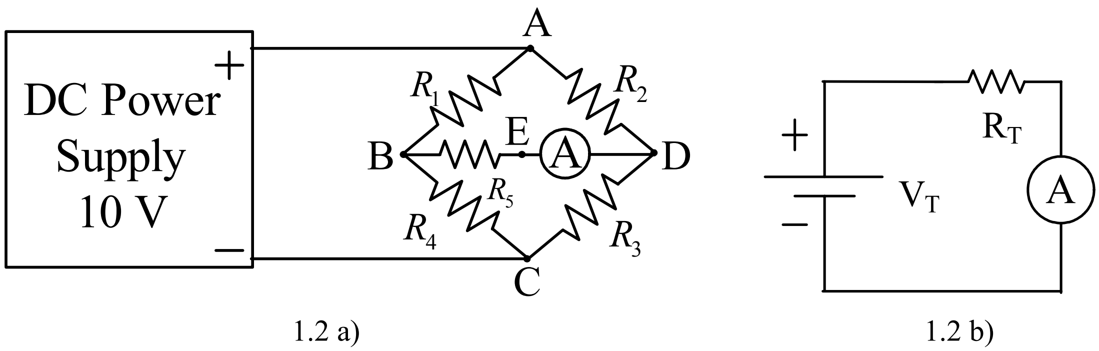


Figure 1.2: Test circuit

1) Connect the circuit as shown in Figure 1.2 a). Set the input DC voltage to be **10 V**.
2) Record all resistance values (for calculations).
3) Measure the current using a DC milliammeter.
3) The current can also be calculated from using a Thevenin circuit as shown in Figure 1.2 b).
   a) V_T can be computed by opening a circuit between E and D and using a voltmeter to measure the voltage between E and D.
   b) R_T can be computed by opening a circuit between E and D and turning off the DC power supply. Then **connect a wire between A and C**. Use a digital multimeter to record a resistance between E and D.
4) Compare result from the measurement and calculation.

Exp 2: Active Power Measurement of Resistors

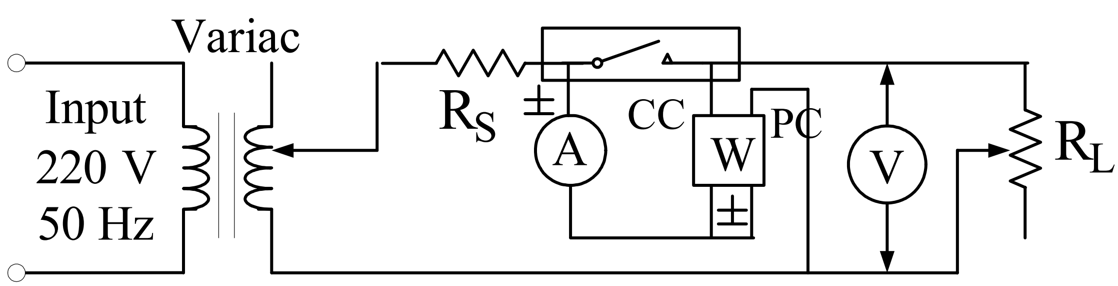


Figure 2.1: Test circuit

1) Connect the circuit as shown in Figure 2.1 (R_S = 50 ohm). Set the variac to zero.
2) Adjust R_L = 0 ohm.
3) Vary the variac until the current is **1 A**. Read the voltage drop across the load and the power.
4) Reduce the current in 0.1 A step by increasing R_L.
5) Calculate R_L value and plot a graph between *VI* and R_L and a graph between P and R_L on the same sheet.
6) Discuss the results.

Exp 3: Power Factor Correction in RL Circuit

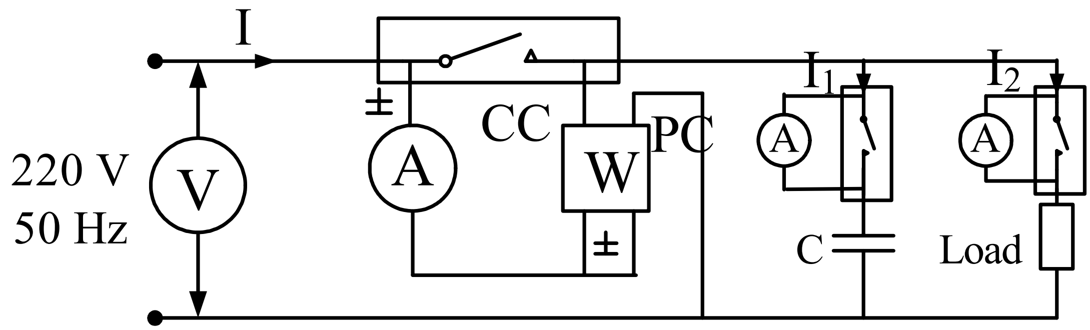


Figure 3.1: Test circuit

1) Connect the circuit as shown in Figure 3.1. Note that the variac is not needed!
2) Increase the capacitor values and record currents, voltage and power at various conditions.
3) Draw phasor diagrams between the current and voltage for three values of capacitor (at C = 0 μF, C that yields power factor ≈ 1 leading and lagging)
4) Plot a graph between power factors and values of capacitor

3.2) Experimental Report

Student name:____ ID: _________________

Date: ____________ Group: ______________ Instructor signature: ______________________

Exp 1.1: DC Current and Voltage Measurements

V (V)	15	20	25	30
I (A)				
R (Ω)				

Ravg (calculated) = ……..….. Ω

Ravg (from a digital multi-meter) = ……..….. Ω

Discussion

Exp 1.2: DC Current and Voltage Measurements

I (measurement) = …………….. A   I (calculated) = ………………. A

Compare results from the measurement and calculation (using loop current method)

V_T = …………. V R_T = …………. Ω

$$I_T = \frac{V_T}{R_T}$$

I_T = …………. A

Compare results from the measurement and calculation (using Thevenin circuit method)

Exp 2: Active Power Measurement of Resistors

I (A)	V (V)	VI (VA)	P (W)	R_L (Ω)
1				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				

Discussion

Exp 3: Power Factor Correction in the RL Circuit

C (μF)	0	1	2	3	4	5	6	7	8	9
I (A)										
I_1 (A)										
I_2 (A)										
P (W)										
pf										

V = ……………. V

Discussion

Conclusion