1.DC Series Circuits

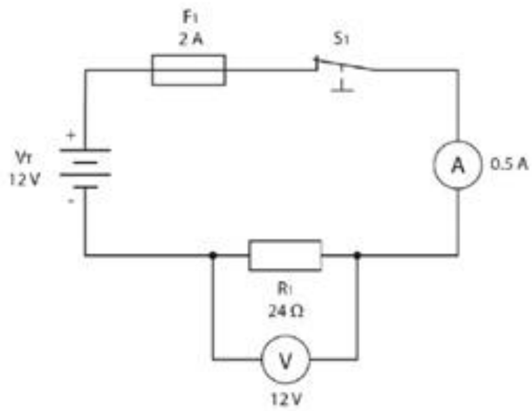
There are three basic circuit conditions that will be discussed in this topic, these are:

- Closed circuit.
- Open circuit.
- Short circuit.

We will see how each of these circuit conditions affects the parameters of a 12 V circuit supplying a 24 Ω load. The circuit is protected by a 2 A fuse, and an ammeter, voltmeter and control switch are also connected in the circuit.

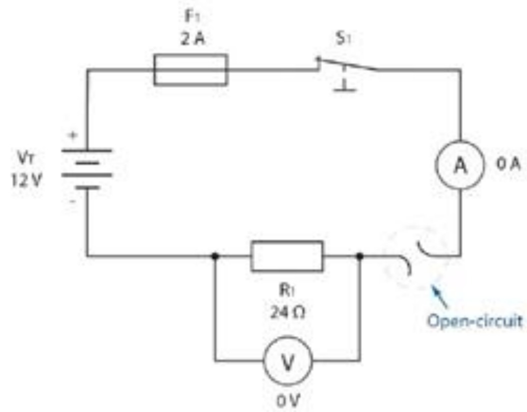
Closed Circuits

A closed circuit is when circuit controls are operated to energise a load. Closing the circuit switch creates a continuous conductive loop, through which electric current can flow. The following diagram shows the closed circuit condition. Note that the circuit switch is in the closed position, and the normal load current of 0.5 amperes is flowing in the circuit.



Open Circuits

An open circuit is a break in a conductor or component that should normally be electrically continuous. The following diagram shows the circuit with an open circuit in the positive wire.



When an open circuit occurs in a single-path circuit, the total circuit resistance becomes infinite causing the load current to drop to zero.

Introduction

In this topic you will explore the concepts of 'acceleration', 'force', 'work', 'power' and 'energy'. You will also learn about the significance of power ratings on electrical equipment, and practice using different methods to determine power in a d.c. circuit. It is of great importance for electrotechnology workers to understand power ratings, as they indicate what will happen in the circuit when the equipment is connected to a given supply. This information is commonly used in the selection of cables and other equipment that aims to ensure circuits don't end up overheating and causing electrical fires.

Electrical power

Electrical power can be defined as the rate at which electrical energy is converted into another form of energy (e.g. light, heat, mechanical). The power equation can be expressed in a number of ways:

$$P = VI$$

$$P = I^2R$$

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

Where:

- P = power measured in watts (W)
- V = voltage measured in volts (V)
- I = current measured in amperes (A)

Worked Example – Calculating Power 1

Calculate the power dissipated when a current of 2 amperes flows through a 230 V resistive load.

$$P = VI$$

$$P = 230 \times 2$$

$$P = 460 \text{ watts}$$

Worked Example – Calculating Power 2

Calculate the power dissipated when a current of 4 amperes flows through a load having a resistance of 32 Ω

$$P = I^2R$$
$$P = (4)^2 \times 32$$
$$P = 512\ watts$$

Worked Example – Calculating Power 3

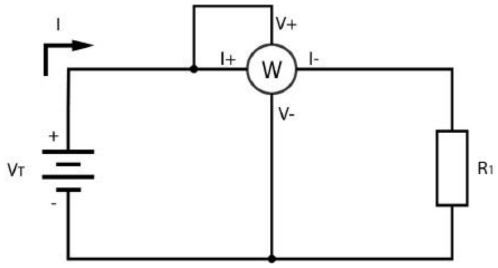
Calculate the power dissipated when a 120 V supply is applied across a 50 Ω resistive load.

$$P = \frac{V^2}{R}$$
$$P = (120)^2 \div 50$$
$$P = 288\ watts$$

Measuring Electrical Power

In order to measure electrical power, a wattmeter can be connected into a circuit. Wattmeters are designed to indicate the power used in a circuit based on the circuit voltage and current values. Another method of determining power is to connect a voltmeter and ammeter into the circuit, and simply multiply the two readings (P = VI).

The diagram below shows how a wattmeter is connected into a basic circuit.



Wattmeter Connection

Energy

Energy can be defined as the capacity to expend power over a period of time. The equation for energy can be expressed as:

$$E = Pt$$

Where:

- E = energy measured in joules (J)
- P = power measured in watts (W)
- t = time measured in seconds (s)

Worked Example – Calculating Energy

Calculate the amount of electrical energy that has been converted into light (and heat) energy when a 60 watt lamp is left on for 200 seconds.

$$E = Pt$$
$$E = 60 \times 200$$
$$E = 12{,}000\ joules$$

Work

Introduction

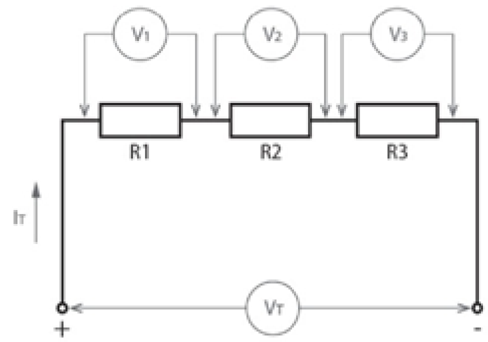
In this section, we will explore the characteristics of series circuits and the methods of determining series circuit operating parameters.

The voltages, currents and resistances in the different parts of a series circuit will always behave according to Ohm's Law, as discussed in Topic 3 Ohm's Law.

In addition, the power dissipated in a series circuit can be determined by applying the Power Equation, as discussed in Topic 4 Electrical Power.

Circuit Characteristics

The diagram below shows three resistive loads connected in series.



By examining the circuit, it can be seen that ***a series circuit has only one current path***. It is this feature that produces the unique current, resistance and voltage characteristics of series circuits.

Current in Series Circuits

Because there is only one current path, ***the value of current in any part of a series circuit will always be the same***. This can be represented by the equation:

$$I_T = I_1 = I_2 = I_3$$

Where:

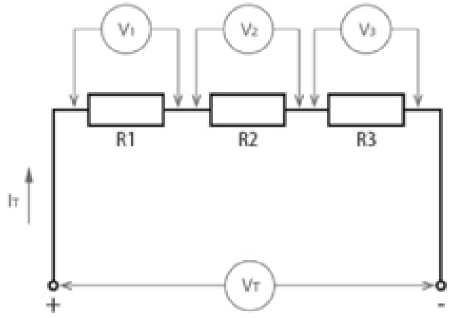
I_T = total circuit current

I_1 = current through R1

I_2 = current through R2

I_3 = current through R3

Worked Example – Calculating Current



For the circuit pictured above, calculate the total current drawn from the supply, if the current flowing in R2 is 2 amperes.

$$I_T = I_1 = I_2 = I_3$$
$$I_T = I_1 = 2 = I_3$$
$$I_T = 2\ amperes$$

In addition, it can be determined that there is 2 amperes flowing in R1 and 2 amperes flowing in R3.

Resistance in Series Circuits

When resistors are connected in series, ***the sum of the individual resistances is equal to the total equivalent resistance***. This can be represented by the equation:

$$R_T = R_1 + R_2 + R_3$$

Where:

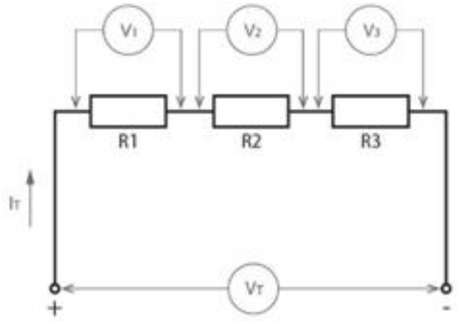
R_T = total resistance

R1 = resistance of R1

R2 = resistance of R2

R3 = resistance of R3

Worked Example – Calculating Resistance



For the circuit pictured above, calculate the total resistance if R1 has a resistance of 80 ohms, R2 has a resistance of 120 ohms, and R3 has a resistance of 200 ohms.

$$R_T = R_1 + R_2 + R_3$$
$$R_T = 80 + 120 + 200$$
$$R_T = 400 \text{ ohms}$$

Voltage in Series Circuits

Another important characteristic of series circuits is that when a voltage is applied, a portion of the voltage drops across each resistor, such that ***the sum of the individual voltage drops is equal to the total voltage***. This series circuit characteristic can be represented by the equation:

$$V_T = V_1 + V_2 + V_3$$

Where:

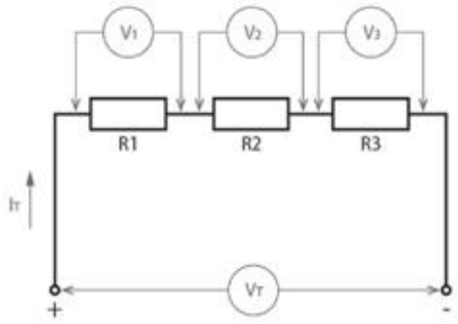
V_T = total circuit voltage

V_1 = voltage across R1

V_2 = voltage across R2

V_3 = voltage across R3

Worked Example – Calculating Voltage



For the circuit pictured above, calculate the total voltage if V1 is 8 volts, V2 is 24 volts, and V3 is 16 volts.

$$V_T = V_1 + V_2 + V_3$$
$$V_T = 8 + 24 + 16$$
$$V_T = 48 \text{ volts}$$

The values of voltage that drop across each series connected resistor will be proportional to the values of resistance. For example, if three resistors with respective resistance of 80 Ω, 120 Ω and 200 Ω, are connected in series to a 40 V supply, then:

- The voltage across the 80 Ω resistor will be 8 V.
- The voltage across the 120 Ω resistor will be 12 V.
- The voltage across the 200 Ω resistor will be 20 V.
- 8 + 12 + 20 = 40 V.

Power in Series Circuits

The total power dissipated in a series circuit is equal to the sum of the individual powers. This can be represented by the equation:

$$P_T = P_1 + P_2 + P_3$$

Where:

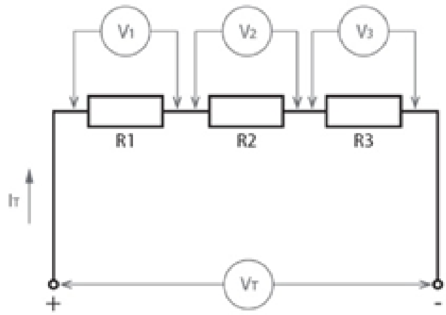
P_T = total circuit power

P_1 = power dissipated by R1

P_2 = power dissipated by R2

P_3 = power dissipated by R3

Worked Example – Calculating Power



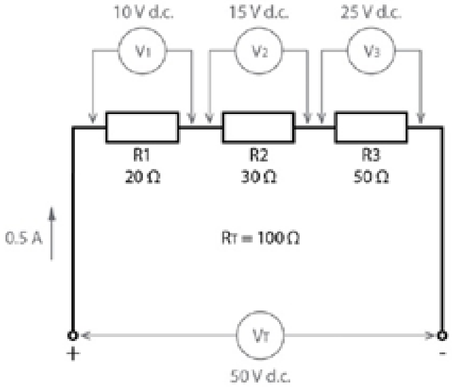
For the circuit pictured above, calculate the total power rating of the series circuit if each individual resistor has a power rating of 500 W.

$$P_T = P_1 + P_2 + P_3$$

$$P_T = 500 + 500 + 500$$

$$P_T = 1{,}500 \text{ watts}$$

To illustrate how all of these operating characteristics come together, consider the following series circuit:



- The total resistance is the sum of the individual resistances.
- The current flowing in each resistor will be 0.5 A.
- The voltage drop across each resistor is proportional to its resistance.
- The sum of the voltage drops is equal to the total supply voltage.
- The current, voltage and resistance values at each point in the circuit obey Ohm's Law.

Circuit Fault Conditions

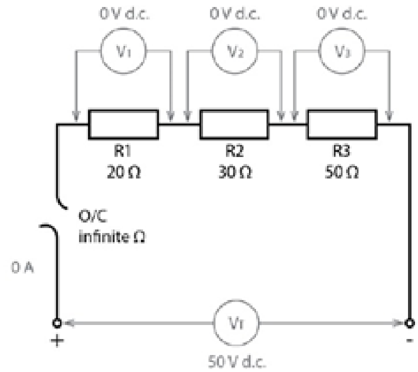
There are two basic fault conditions that will be discussed in this unit, these are:

- Open-circuits.
- Short-circuits.

We will see how each of these two fault conditions affects the parameters of a 50 V circuit supplying a series load with a total resistance of 100 Ω.

Open-circuits

An open circuit is a break in a conductor or component that should normally be electrically continuous. The following diagram shows the series circuit with an open-circuit in the positive wire.

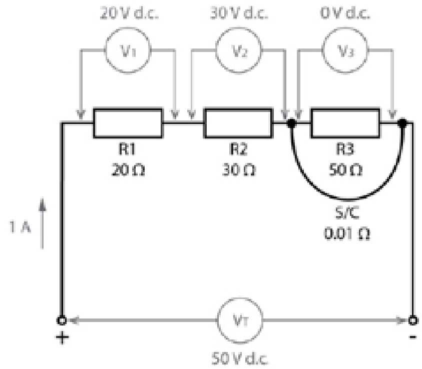


When an open-circuit occurs in a series circuit, the load current drops to zero, as the only current path has become broken, causing the total resistance to become infinite.

There can be many causes of open-circuits, for example a wire falling out of a terminal, or a component 'burning out' due to high temperatures or excessive currents.

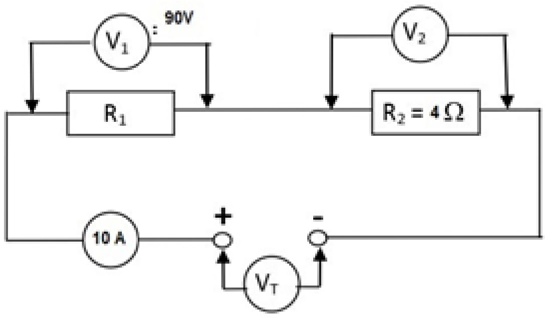
Short-circuits

A short-circuit is a connection occurring between two conductors that should not be directly connected together in normal operation. The following diagram shows the series circuit where a short-circuit has developed across R3.



When a short-circuit occurs in a series circuit, the total resistance is reduced, causing the total current to increase. In many cases, short-circuits increase the circuit current to dangerously high values, causing circuit protection devices to disconnect the circuit. In this case, the short-circuit current is 1 A, which is double the normal load current of 0.5 A.

Short-circuits are most commonly caused by the failure of insulation due to mechanical damage or some other form of stress



For the single path dc series circuit drawn above and using the circuit values shown:

a. The reading on the voltmeter V_2 will be = ____________ Volts

b. The reading on voltmeter V_T will be = ____________ Volts

c. The value of the resistance R_1 will be = ____________ Ohms

Show your calculations here...