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ELECTRICAL CIRCUITS AND ELECTRONICS

By:

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QUESTION PAPER

(June – 2018)

(Solved)

ELECTRICAL CIRCUITS AND ELECTRONICS

Time: 2 Hours] *[Maximum Marks: 50*

Note: *All questions are* ***compulsory****. Use of log tables and non-programmable calculators is allowed. Symbols have their usual meanings.*

Q. 1. Attempt the following parts:

(a) **A voltage 'V' is applied across an inductor of self-inductance 'L' and a capacitor of capacitance 'C'. Write the expressions for time-dependent voltages and currents across 'L' and 'C'.**

Ans. Where ϕ = flux, i = current

For inductor, the flux is given by:

$$\phi \, \alpha \, \mathrm{i}$$

$$\phi = \lambda \, \mathrm{i}$$

Where L is coefficient of self inductance. Differentiating the expression with respect to time. We obtain:

$$\frac{d\phi}{dt} = \mathrm{L}\frac{di}{dt}$$

Now Len's law states that rate of change of flux is equal to potential

$$\therefore \; \mathrm{V} = \mathrm{L}\frac{di}{dt}$$

In case of time dependance voltage and current

$$\frac{di}{dt} = 0$$

$$\mathrm{V}(t) = 0.$$

(b) **Explain Thermionic Emission.**

Ans. Thermionic Emission Definition: The process by which free electrons are emitted from the surface of a metal when external heat energy is applied is called thermionic emission.

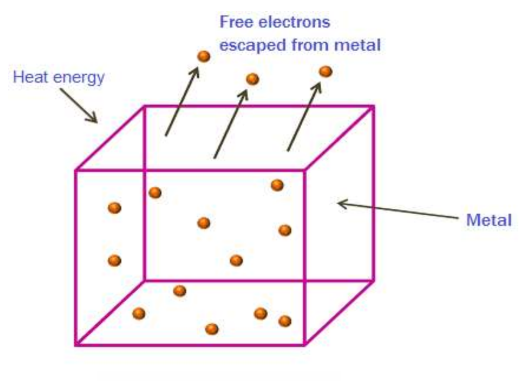
Thermionic emission occurs in metals that are heated to a very high temperature. In other words, thermionic emission occurs, when large amount of external energy in the form of heat is supplied to the free electrons in the metals.

Metals under normal temperature: When a small amount of heat energy is applied to the metal, the valence electrons gain enough energy and break the bonding with the parent atom. The valence electron, which breaks the bonding with the parent atom, becomes free. This electron, which breaks the bonding with the parent atom, is called as the free electron.

The free electrons in the metal have some kinetic energy. However, they do not have enough energy to escape from the metal. The attractive force of the atomic nuclei opposes the free electrons, which try to escape from the metal.

Free electrons in the metal have less energy compared to the free electrons in vacuum. Hence, free electrons require extra energy from the outside source in order to jump into the vacuum.

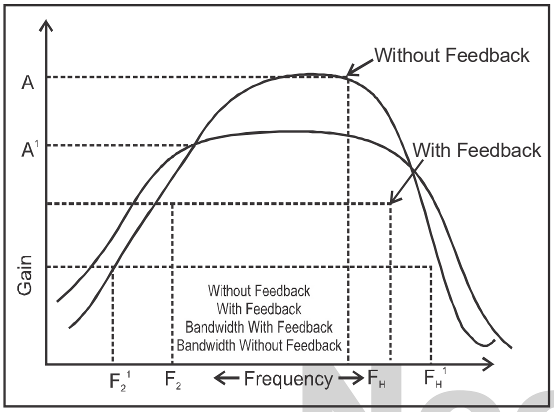
Metals under high temperature: When heat energy applied to the metal is increased to a higher value, the free electrons gain enough energy and overcome the attractive force of the atomic nucleus, which holds the free electrons in the metal. The free electrons, which overcome the attractive force of the nuclei, break the bonding with the metal and jumps into the vacuum.



Electron Emission

***(c)* Show that the gain of an amplifier with positive feedback is $Af = \dfrac{A}{1 - A\beta}$, where A is gain without feedback and β is feedback fraction.**

Ans. Ref.: See Chapter-5, Page No. 82, 'Positive Feedback Oscillators'.



Frequency response of feedback amplifier.

$$Af = \frac{A}{1 - A\beta}.$$

***(d)* What is ripple frequency? Write its value for a half-wave rectifier.**

Ans. Ripple Frequency: Ripple is a small amount of AC that results from less than perfect filtering of (usually) power supplies.

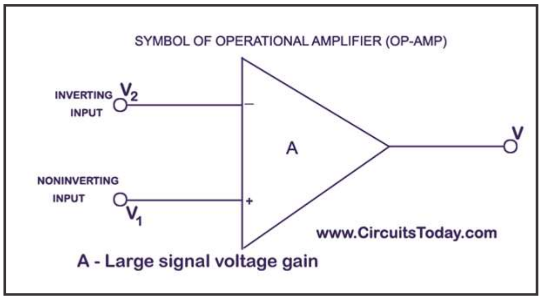
In many older electronics with linear power supplies that used full and half wave rectifers and a capacitor filter and linear regulator, ripple was defines an AC voltage riding upon the DC, at 60 or 120 Hz (50 or 100 Hz in non 60 Hz countries using 50 Hz). With equipment with audio sections (radios, TVs) you could hear a hum if the power supply had bad ripple and allowed it to get into the signal.

New SMPS power supplies don't rectify 60 Hz anymore, so ripple is usually at 100KHz and higher which means we can't hear it, plus its a lot easier to filter requiring smaller capacitors.

The half-wave rectifier gets its name from the fact that it conducts during only half the input cycle.Its output is a series of pulses with a frequency that is the same as the input frequency. Thus, when operated from a 60-hertz line, the frequency of the pulses is 60 hertz. This is called Ripple frequency.

***(e)* Draw the circuit symbol of an Op-Amp. Label it.**

Ans.



***(f)* Express 17.75_{10} in its binary equivalent.**

Ans. 1. First, convert to binary (base 2) the integer part: 17. Divide the number repeatedly by 2, keeping track of each remainder, until we get a quotient that is equal to zero:

division = quotient + remainder;

$17 \div 2 = 8 + 1;$

$8 \div 2 = 4 + 0;$

$4 \div 2 = 2 + 0;$

$2 \div 2 = 1 + 0;$

$1 \div 2 = 0 + 1;$

2. Construct the base 2 representation of the integer part of the number, by taking all the remainders starting from the bottom of the list constructed above:

$17_{(10)} =$

$1\,0001_{(2)}$

3. Convert to binary (base 2) the fractional part: 0.75. Multiply it repeatedly by 2, keeping track of each integer part of the results, until we get a fractional part that is equal to zero.

#) multiplying = integer + fractional part;

(1) $0.75 \times 2 = 1 + 0.5;$

(2) $0.5 \times 2 = 1 + 0;$

4. Construct the base 2 representation of the fractional part of the number, by taking all the integer parts of the multiplying operations, starting from the top of the constructed list above:

$0.75_{(10)} =$

$0.11_{(2)}$

Positive number before normalization:

$17.75(10) =$

$1\,0001.11_{(2)}$

Sample Preview
of
The Chapter

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ELECTRICAL CIRCUITS AND ELECTRONICS

NETWORK ANALYSIS AND DEVICES

Circuit Analysis

1

INTRODUCTION

Electronics and electrical engineering developments since the last decade of 19th century have revolutionized human life in the most astounding way. Indeed, they must be considered as one of the greatest success stories in the history of mankind. Starting with Thomas Alva Edison's invention of electric lamp and Tesla's A.C. power generation and transmission in the 1880s, in the early days engineers had to work with crude spark-gap transmitters and 'Cat's Whisker' detectors. Then came the era of much more sophistication in the form of vacuum tubes during the 1920s to 1950s. The most remarkable breakthrough was the emergence of solid state electronics during the 1950s. In the last five decades there have been a flood of marvellous advances in electronic technology and applications, and which continue to dazzle us unabated. In this chapter, we begin our study of electronics by understanding its basic laws, rules of the thumb and its basic circuits. First, we take up the concepts of voltage, current, power and various components related to electronic circuits.

A basic electronic or electric circuit consists of three parts:

1. Energy source like a battery or generator;
2. Load or sink like a lamp or motor; and
3. Wires connecting the components.

The purpose of such a circuit is to transfer the energy from its source to the load. We define an electric network as basically an interconnection of two or more simple circuit elements, i.e., voltage source, resistors, inductors, and/or capacitors. If the network contains at least one closed path, it is called an electric circuit.

Our learning in this chapter covers the basic laws that govern the transfer of energy from source to load, some important theorems about the circuits, and the simplifications, we get to understand the working of a given electric circuit. Such circuits form the basis of any modern electronic device or gadget.

In a nutshell, we will study and know the concepts of voltage and current sources; use Kirchoff's laws, Thevenin and Norton theorems to simplify a given network; and state and apply superposition, reciprocity and maximum power transfer theorem to a given network or electric circuit.

CHAPTER AT A GLANCE

CIRCUIT ELEMENTS

A network is defined as a circuit making desired performance Circuit analysis deals with electrical networks in which passive elements like resistors, inductors and capacitors suitably connected to voltage and current sources. These elements and sources are, however, idealisations of actual elements and sources that enable an effective analysis of the network. In network analysis, we determine the voltages and currents through the various elements. These elements are classified into following four groups:

1. Active or Passive elements
2. Unilateral or Bilateral elements
3. Linear or Non-linear elements
4. Lumped or Distributed elements

1. Active or Passive Elements

In a network, energy sources of voltage or current are active elements. They are able to deliver power to external devices. Apart from the energy sources, there are also many other elements, which are active elements. Such elements fall into two types:

(*i*) Tubes e.g. vacuum tubes and gas tubes,
(*ii*) Semiconductor devices e.g. junction diodes, transistors, field effect transistors, UJTs, SCRs, Zener diode, etc.

Passive elements are defined as those which are capable of receiving power. Examples are resistors, inductors, or capacitors. Some of these, i.e., inductors and capacitors can even store a finite amount of energy and give it afterwards to external elements.

2. Bilateral or Unilateral Elements

The electrical characteristics of passive elements are best shown by the voltage current relationship. In bilateral elements, voltage current relationship is same for current flowing in either direction e.g. resistors. However, in unilateral elements there is different relation between voltage and current for each of the two possible directions of current flow e.g. diodes.

3. Linear or Non-linear Elements

A linear element satisfies a linear voltage current relationship. This means that if the current through the element rises up by a factor-the voltage across the element also goes up by the same factor. As an example, the V=I relation for a resistor is V = IR and it is linear. An element that does not satisfy such a linear relationship is termed as non-linear element. A diode is an example of non-linear element. The V=I relation for a diode is:

$$I = I_0\,[e^{qv/kt} - 1],$$

which is a non-linear relationship.

V-I relations

(*a*) **Resistor:** Refer to Fig. 1.1

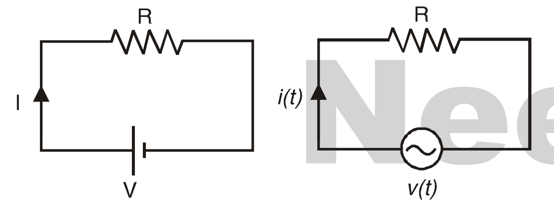


Fig. 1.1: V–I relationship for resistor

V = Voltage, I = Current, R = Resistance

(*i*) $V = IR \Rightarrow I = GV$

where $G = I/R$ = conductance. *V* and *I* are time independent voltage and current.

(*ii*) $V(t) = i(t)\,R$

where *V(t)* and i*(t)* are time dependent voltage and current.

(*b*) **Inductor:** Refer to Fig. 1.2

For inductor, the flux is given by:

$$\phi \,\alpha\, i$$

where ϕ = flux, i = current

$$\Rightarrow \quad \phi = Li$$

where L is coefficient of self inductance. Differentiating the expression with respect to time, we obtain

$$\frac{d\phi}{dt} = L\frac{di}{dt}$$

Now Lenz's law states that rate of change of flux is equal to potential,

$$\therefore \quad V = L\frac{di}{dt}$$

(*i*) In case of time independent voltage and current,

$$\frac{di}{dt} = 0$$

$$\therefore \quad V(t) = 0$$

This means that for DC voltages and currents, under steady state (after long lapse of time conditions, the voltage across an inductor will be zero. It will, in fact, behave like a short circuit.

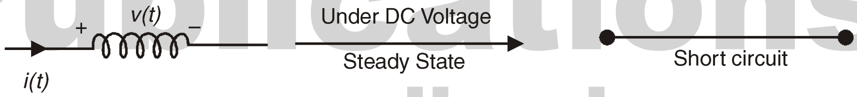


Fig. 1.2: *V-I* relationship for inductor

(*ii*) For time dependent voltage and current, the relationship is

$$V(t) = L\frac{di(t)}{dt}$$

(*c*) **Capacitors:** Refer to Fig. 1.3. For a capacitor, Q α V… where *Q* = Charge in Coulmbs

$$\Rightarrow \quad Q = CV$$

where *C* is called capacity of capacitor. Differentiating with respect to time, we have

$$i = \frac{dQ}{dt} = C\frac{dV}{dt}$$

(*i*) For time independent current and voltage (i.e., for dc circuits)

$$\frac{dV}{dt} = 0$$

Hence, for time independent current and voltage, the capacitor under steady state (after long lapse of time) behaves as open circuit because $i = 0$.

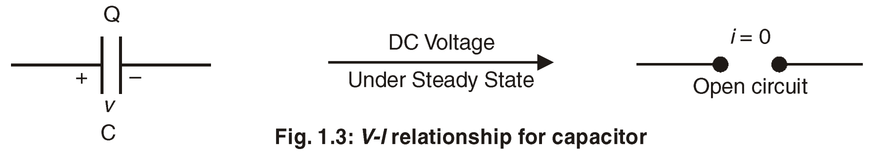


Fig. 1.3: *V-I* relationship for capacitor

(*ii*) For time dependent current and voltages the current-voltage relationship is as:

$$i(t) = C\frac{dV(t)}{dt}$$

(*d*) Energy sources:

There are two categories of energy sources:

(i) Independent Energy Source

(ii) Dependent Energy Source

***(i)* Independent Energy Source:** These are of two types: Voltage sources and current sources. Independent voltage or current sources are those for which voltage and current are fixed and are not affected by other parts of the circuit.

An ideal voltage source is a two terminal element with the voltage V_a completely independent of the current i_a through its terminals. The representation of such ideal voltage source is as marked in Fig. 1.4.

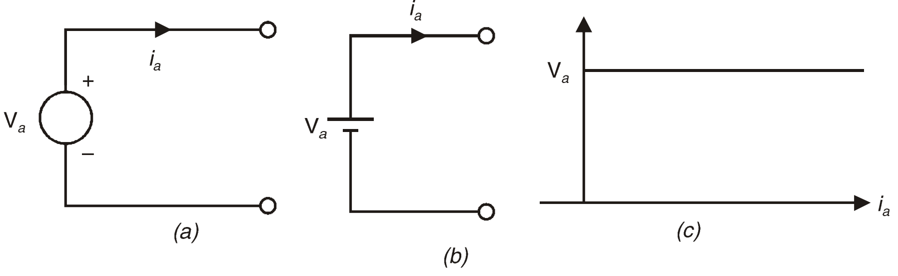


Fig. 1.4: Ideal voltage source

V-I characteristics for an ideal voltage source are shown in Fig. 1.4*(c)*. We note that at any time, the value of the terminal voltage V_a is constant with respect to the current value i_a. However, in a practical voltage source, its internal resistance is in series with the source (Fig. 1.5) and its terminal voltage falls when the current flowing through it increases. The terminal voltage thus depends on the source current since $V_{terminal} = V_s - i_s R$.

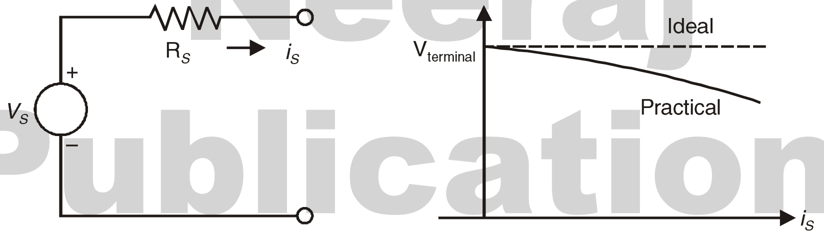


Fig. 1.5: Practical voltage source

An ideal independent current source is a two terminal element with the current completely independent of the voltage V_s across its terminals. The representative ideal current source is displayed in Fig. 1.6.

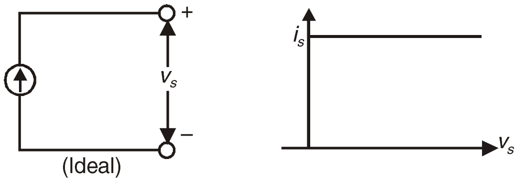


Fig. 1.6: Ideal current source

However, in practical current sources, the internal resistance is shown in parallel with the source (Fig. 1.7). Here, the magnitude of current goes down when the voltage across its terminals goes up. The terminal current equation is

$$I_{terminal} = i_{source} - \frac{\text{V SOURCE}}{R}$$

$$= i_s - \left[\frac{V_s}{R}\right]$$

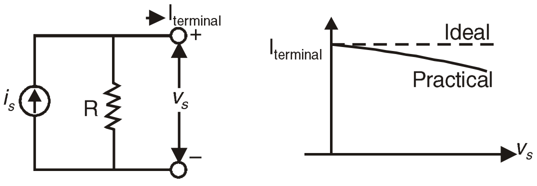
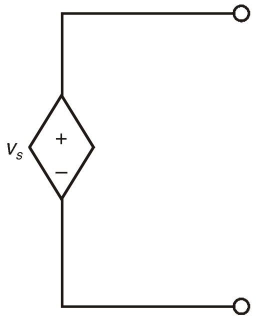


Fig. 1.7: Practical current source

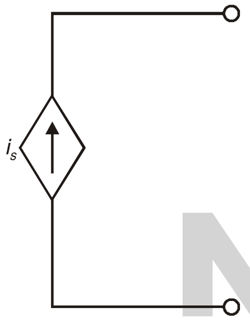
Dependent Sources

In case of dependent sources, the source voltage or current is not fixed. It depends on the voltage or current available in the circuit. We come across such sources mainly in the analysis of equivalent circuits of active devices like the transistors. The symbols used to represent dependent circuit voltage and current sources are as shown in Fig. 1.8.



Dependent Voltage Source

(a)



Dependent Current Source

(b)

Fig. 1.8 : *(a)* Dependent voltage source
***(b)* Dependent current source**

KIRCHOFF'S LAWS

Every electrical network satisfies two fundamental laws. These laws are:

1. Kirchoff's Current Law (KCL)
2. Kichoff's Voltage Law (KVL)

These also form the basis of circuit analysis.

1. Kirchoff's Current Law (KCL): This law states that the algebraic sum of currents at a node (or junction) is equal to zero. It can also be expressed in following ways:

Algebraic sum of currents entering a node = 0

Algebraic sum of currents leaving a node = 0

or Sum of currents entering a node = Sum of currents leaving a node

To apply KCL following convention for currents is made as we have to take algebraic sum.

Convention: All entering currents are treated positive (+) and leaving currents are treated as negative (–).

Example 1. In Fig. 1.9. write KCL for the various nodes (currents are marked).

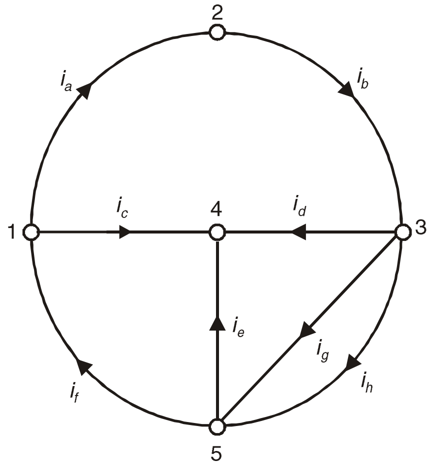


Fig. 1.9:

Sol. The nodes are 1, 2, 3, 4, 5. We have to write KCL for all these nodes.

At node 1, $-i_a - i_c + i_f = 0$ [Using the convention for KCL]

At node 2, $i_a - i_b = 0$

At node 3, $i_b - i_d - i_g - i_h = 0$

At node 4, $i_c + i_d + i_e = 0$

At node 5, $i_h + i_g - i_e - i_f = 0$

We find that the KCL at node 5 can be got just by summing the KCL equations for all other nodes from 1 to 4. We thus note the points as stated below about the use of KCL:

(*a*) We need write KCL for all nodes except one.

(*b*) The KCL for the excluded node is not independent since it can be directly obtained from the KCL written for other nodes.

In other words, it is enough to write KCL for (n–1) nodes for a network consisting of n nodes.

2. Kirchoff's Voltage Law (KVL): The KVL states that the algebraic sum of voltages in a closed network is zero. Proper sign must be used for each of the voltage term.

To apply this law, the magnitude and polarity of all the voltages in the closed network must be known. For the **KVL** the convention used is:

For any passive element (R, L, or C), if current is entering at a terminal, it will have +ve potential, and the terminal at which current is leaving it will be treated as –ve potential as shown in Fig. 1.10.

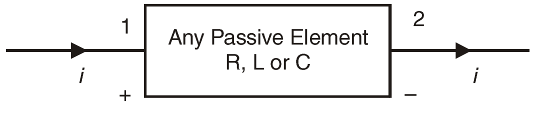


Fig. 1.10: Convention for KVL

Solved Example 1. Apply KVL to the network shown in Fig. 1.11. Voltage polarity is marked at each node and its value is also given.