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BASIC ELECTRONICS
FOR +2 SC STUDENTS OF ELECTRONICS



SADASIVA
BISWAL



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VOLUME 1



ATLANTIC

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Volume I

SADASIVA BISWAL

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*DEDICATED
TO
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12. A $10\ \mu\text{f}$ capacitor is charged to a potential of 400 volts and is then discharged through a conductor. Find the energy given to the conductor due to discharge of the capacitor.

Solution

$$C = 10\ \mu\text{f}$$

$$V = 400\ \text{volts}$$

Energy of the charged capacitor

$$= \frac{1}{2} CV^2$$

Energy given to the conductor

$$= \frac{1}{2} \times 10 \times 10^{-6} \times (4 \times 10^2)^2\ \text{Joule}$$

$$= \frac{1}{2} \times 10^{-5} \times 16 \times 10^4\ \text{Joule}$$

$$= 8 \times 10^{-1}\ \text{Joule}$$

$$= 0.8\ \text{Joule.}$$

13. A $2000\ \mu\text{f}$ capacitor is charged at a steady rate of $25\ \mu\text{C}$ per second. After what time the P.D. across the capacitor plates shall be 20 volts.

Solution

Total charge on the capacitor plates,

$$Q = CV$$

$$= 2000\ \mu\text{f} \times 20\ \text{volts}$$

$$= 4 \times 10^4\ \mu\text{C}$$

Time needed for charging the capacitor to 20 volts is

$$t = \frac{4 \times 10^4}{25} = 1600\ \text{S}$$



3

Inductors

Q. 1. What is an Inductor ?

Ans. Inductor : Inductor is a device that stores energy in the form of magnetic field. A straight wire bent into the form of a coil possesses inductance which is known as self inductance of the coil.

Q. 2. How does an inductor act ?

Ans. Function : An inductor offers resistance to the flow of a.c. through it. A pure inductance doesn't offer any resistance to the flow of d.c. through it.

Q. 3. Discuss on various types of inductors.

Ans. Types of inductors : Different types of inductors are :

- (a) An air core inductor
- (b) Iron core inductor
- (c) A special type of inductor called toroid

(a) An air core inductor. In most electronic applications of inductance where space is limited, wire is wound into either single-layer or multi-layer coils with air. Such an inductor is known as air core inductor.

(b) Iron core inductor. When an inductor has core made of powdered-iron compound (Ferrite) or laminated (thin iron sheet) cores, it is called an iron core inductor. Ferrite materials like zinc or manganese-iron oxides have magnetic permeability but are insulators. Therefore a coil with a ferrite core makes an inductor of inductance many times more than that of an air core inductor. In many applications, coils are wound around a ferrite cylinder that can be screwed into or out of the core space of the coil. This results in a controlled variations of inductance. The inductor has maxm. inductance when the iron core (slug) is screwed into the coil and the inductance is minimum when the slug is backed out.

(c) **A special type of inductor or toroid.** A special type of inductor called toroid which consists of a doughnut-shaper ferrite core, either single-layer-wound as shown in the figure below or multi-layer-wound. Such an inductor has high values of inductance with less wire and therefore little resistance in the coil. Moreover all the lines of force remain in the core. As a result of which, no shielding is required to prevent its field from surrounding circuits or electrical appliances. Even two toroids very close to each other will have no interaction between them.

Q. 4. Give the symbols of inductors.

Ans. Inductor symbols :

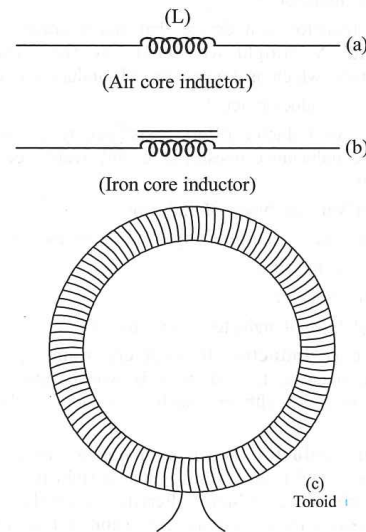


Fig. 3.1. (a) Air core inductor, (b) Iron core inductor, (c) A special type of inductor or toroid.

Q. 5. What are variable inductors ?

Ans. *Variable inductors* : There are some inductors, mainly iron core inductors whose inductance is required to be varied in accordance

with the need of the applications. In such inductors, coils are wound around a ferrite cylinder which is screwed into or out of the core space of the coil. Consequently, there is a controlled variations of inductance. In such cases, the inductance may be maximum or minimum depending upon the position of the "slug".

Q. 6. Deduce the law of combination of inductors in series and in parallel.

Ans. *Combination of inductors* : Inductors can be combined in two ways.

- (a) In series
- (b) In parallel

Self-inductances combine like the series and parallel combinations of resistances.

(a) Inductors in series. When inductances are placed in series. The total induced emf is the sum of the separate emf's. Hence, if 'i' is the current flowing through the inductances and 'L' is the resultant or equivalent inductance of the series, then

$$L \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + \dots + L_n \frac{di}{dt}$$

Since,

$$i_1 = i_2 = \dots = i_n = i$$

$$\text{So, } L = \sum_{j=1}^n L_j \quad \dots(29)$$

Where $j = 1, 2, 3, \dots, n$

Expanding eqn. (29) we have,

$$L = L_1 + L_2 + L_3 + \dots + L_n \quad \dots(30)$$

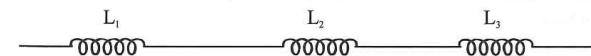


Fig. 3.2. Inductors in series

(b) Inductors in parallel : When inductors are joined in parallel the induced emf across each inductor is the same as the induced emf across the combination. But the currents are different in different inductors. Let the current in each inductor be $i_1, i_2, \dots, i_n$ respectively and the current across the combination is i . Then $i = i_1 + i_2 + i_3 + \dots + i_n = \text{total current}$

$$\text{Thus, } L \frac{di}{dt} = L_1 \frac{di_1}{dt} = L_2 \frac{di_2}{dt} = \dots = L_n \frac{di_n}{dt} \quad \dots(31)$$

From the above equation we get

$$\frac{di_1}{dt} = \frac{L}{L_1} \frac{di}{dt}$$

$$\frac{di_2}{dt} = \frac{L}{L_2} \frac{di}{dt}$$

$$\frac{di_n}{dt} = \frac{L}{L_n} \frac{di}{dt}$$

Adding the above relations we get,

$$\left(\frac{L}{L_1} + \frac{L}{L_2} + \frac{L}{L_3} + \dots + \frac{L}{L_n} \right) \frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt} + \dots + \frac{di_n}{dt}$$

$$\text{But } \frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt} + \dots + \frac{di_n}{dt}$$

$$\text{So, we have, } \frac{L}{L_1} + \frac{L}{L_2} + \frac{L}{L_3} + \dots + \frac{L}{L_n} = 1$$

$$\text{or, } \frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots + \frac{1}{L_n} \quad \dots(32)$$

$$\text{or, } \frac{1}{L} = \sum_{j=1}^n \frac{1}{L_j} \quad \dots(33)$$

Where, $j = 1, 2, 3, 4 \dots n$.

Therefore, the sum of the reciprocals of individual inductance is equal to the reciprocal of the combined inductance of all inductors joined in parallel.

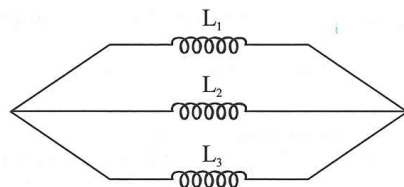


Fig. 3.3. Inductors in parallel

Q. 7. Define Inductance. Mention its units.

Ans. *Inductance* : A coil which produces induction effect in itself by a current flowing through it has co-efficient of self-induction or inductance L .

Definition of L : Self-inductance L of an inductor is defined as the magnetic flux linked with it when a unit current flows through it. Mathematically, it is given by

$$L = \frac{\phi}{i} \quad \dots(34)$$

$$\text{When } i = 1, \phi = L \quad \dots(35)$$

where ϕ is the flux linked with the coil when the current is unity.

Units of inductance

MKS — Henry

$$1 \text{ Henry} = \frac{1 \text{ volt}}{1 \text{ amp./sec.}}$$

CGS — Emu of inductance

$$1 \text{ Emu of inductance} = \frac{1 \text{ emu of potential difference}}{1 \text{ emu of current / sec.}}$$

Relation between Henry and emu of inductance

$$1 \text{ Henry} = 10^9 \text{ emu of inductance.}$$

Q. 8. Derive an expression for the energy stored in an inductor.

Ans. *Energy stored in an inductor* : When current through an inductor changes, the flux linked with inductor also changes. The rate of change of flux induces an emf in the inductor which opposes the inducing current. To increase the current in the inductor energy must be spent externally. This energy gets stored in the inductor.

From Faraday's law of electro magnetic induction, we have,

$$e = - \frac{d\phi}{dt}$$

$$\text{But } \phi = Li$$

$$\text{Hence } e = - \frac{d(Li)}{dt}$$

$$= -L \frac{di}{dt}$$

Electrical work done by the field = $ei \, dt$

$$= L \frac{di}{dt} (idt)$$

$$dw = Lidi$$

Total work done by a current i_0 in the inductor is given by

$$\int_0^w dw = \int_0^{i_0} Lidi$$

$$w = L \int_0^{i_0} idi$$

$$= L \left(\frac{i^2}{2} \right)_0^{i_0}$$

$$w = \frac{1}{2} Li_0^2 \quad \dots(36)$$

where 'L' is the self-inductance of the inductor and w is the total energy stored in the inductor.

Q. 9. What do you mean by d.c. and a.c. resistance of an inductor?

Ans. A.C. and D.C. resistance : As the inductor has negligible resistance it doesn't oppose the flow of d.c. But when alternating current passes through an inductor, induced emf is set up, which opposes the a.c. This opposition to a.c. is measured by inductive reactance X_L or a.c. resistance of an inductor.

$$X_L = \omega L = 2 \pi fL \quad \dots(37)$$

where 'L' is the self-inductance of the coil measured in Henry and 'f' is the frequency of applied a.c. measured in Hertz.

Q. 10. How does inductance vary with emf ?

Ans. Variation of L with emf : In an inductive circuit, the current is given by,

$$i = i_0 \sin \left(\omega t - \frac{\pi}{2} \right)$$

$$\text{where } i_0 = \frac{E_0}{\omega L}$$

$$\text{or, } L = \frac{E_0}{\omega i_0}$$

where E_0 is the peak value of alternating emf applied across L and i_0 is the peak value of alternating current flowing through L. ω is the angular frequency given by

$$\omega = 2 \pi f$$

where f is the frequency of the applied a.c. emf.

Thus inductance of the coil varies with the emf.

Q. 11. Write down the uses of an inductor.

Ans. Application of inductor : An inductor is generally used as a choke. An air core inductor maintains constant inductance even at a very high current while an iron core loses its ability to smooth out variations beyond that current. To prevent this, a small air gap may be left in the iron core to introduce sufficient reluctance in the magnetic circuit.

Q. 12. What is a choke coil? Mention various types of chokes.

Ans. Types of chokes : An inductor is known as a choke coil since it chokes out variation of amplitudes. There are different types of choke coils depending upon the reactances. These are :

- Radio frequency choke (RFC)
- Audio frequency choke (AFC)
- Power frequency choke (PFC)

(a) Radio frequency choke (RFC)

For radio frequency applications (20 KHz to 500 MHz), an air-core coil with low value of inductance is used as RFC.

(b) Audio frequency choke (AFC)

In case of lower frequency circuits, coils having greater inductance are required. For this reason iron core choke coils with higher inductance are used as AFC. Here the frequency is limited to 20 KHz.

A laminated iron core choke :

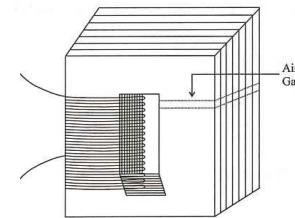


Fig. 3.4

Q. 8. Find an expression for the self-inductance of an inductor.

Ans. Self-inductance of an inductor : The value of 'L' for a straight wire is negligibly small. But if the same wire is made into the form of a coil, its inductance increases. The value of 'L' of a coil depends upon :

- (i) permeability of the material used in the core of the coil.
- (ii) number of turns in the coil.
- (iii) gap between the two adjacent turns of the coil.
- (iv) the area of each turn of the inductor.

From the above we have

$$L = \frac{\mu N^2 A}{l} \quad \dots(43)$$

where μ = permeability of the magnetic core on which one coil is wound to prepare the inductor.

N = Number of turns.

A = The area of each turn.

l = Total length of the inductor.

Q. 9. What is mutual induction ?

Ans. Mutual induction : When there is a current in one of two adjacent circuits, some of the magnetic flux associated with the first or primary circuit 'P' links the near by or secondary circuit 'S' (Fig. 4.3). If the current changes in 'P' there results a change of flux in 'S'. Hence an emf is induced in the secondary circuit. This phenomenon is called mutual induction.

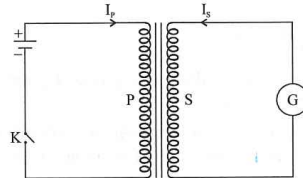


Fig. 4.3

Mutual induction of two circuits is the property by virtue of which a current changing in the first results in the induction of an emf in the second.

Q. 10. Define mutual inductance. Mention its units.

Ans. Mutual inductance : Let ϕ be the magnetic flux linked with the coil 'S' due to a current 'I' flowing through 'P'.

$$\phi \propto I$$

$$\text{or, } \phi = MI \quad \dots(44)$$

where M is called the co-efficient of mutual induction of two circuits. If $I = 1$, then $\phi = M$...(45)

Therefore, co-efficient of mutual induction of two circuits or mutual inductance is defined as the magnetic flux linked with the second circuit due to a unit current flowing through the first.

Differentiating equn. (44),

$$\frac{d\phi}{dt} = M \frac{dI}{dt}$$

According to Faraday's law of electromagnetic induction

$$e = -\frac{d\phi}{dt} \quad (\text{if } N \text{ is one})$$

where 'e' is the emf induced in the second circuit

$$\text{Now, } e = -\frac{d(MI)}{dt}$$

$$e = -M \frac{dI}{dt}$$

$$\Rightarrow M = -\frac{e}{\frac{dI}{dt}}$$

$$\text{when } \frac{dI}{dt} = 1, \quad M = -e \quad \dots(46)$$

The -ve sign comes from the Lenz's law. Hence from equn. (46), M is numerically equal to e .

Thus, co-efficient of mutual induction of two circuits or mutual inductance is defined as the emf induced in the second circuit due to current changing at a unit rate in the first.

Units

(i) *SI system* : Unit of co-efficient of mutual induction or mutual inductance in SI unit is 'Henry'.

$$1 \text{ Henry} = \frac{1 \text{ volt}}{1 \text{ amp / sec.}}$$

Coefficient of mutual induction of two circuits is said to be 1 Henry if an emf of 1 volt is induced in the secondary circuit due to a current changing at the rate of 1 amp/sec in the first.

5

A.C. Fundamentals

Q. 1. What do you mean by alternating emf and alternating current.

Ans. *Alternating emf* : The emf produced by a coil rotating in a uniform magnetic field is called an alternating emf. This emf is so named because it alternates between the +ve and -ve half cycle after each half time period. This emf alternates reversing direction twice in each rotation of the coil. This emf is periodic in nature. It is given by

$$E = E_0 \sin \omega t$$

where E_0 is the steady values of the emf and ω is the angular velocity of the coil.

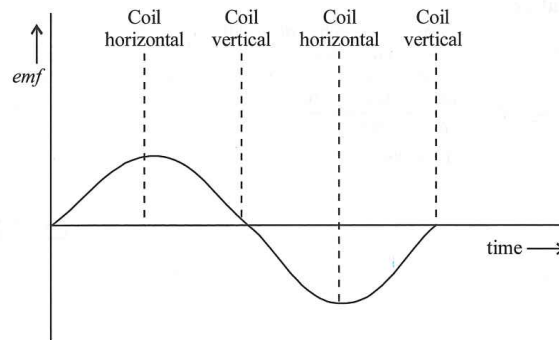


Fig. 5.1

Alternating current : It is the current which, when flowing through a conductor, changes continuously in magnitude and varies periodically in direction.

A graph between instantaneous value of a.c., ' I ' and ' t ' is shown in fig. 5.2. The graph indicates that magnitude of current varies continuously in between ' $+I_0$ ' and ' $-I_0$ '. Its direction also changes after equal intervals of time of $(T/2)$ second where T is the time period of a.c. The curve, ' I ' against ' t ' is a 'sine curve'.

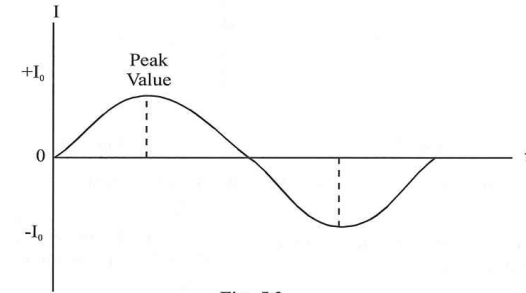


Fig. 5.2

Therefore instantaneous value ' I ' of current is given by

$$I = I_0 \sin \omega t$$

where ' I_0 ' is called the peak value and ' ω ' is the angular velocity of rotation of conductor.

$$\omega = \frac{2\pi}{T} = 2\pi f \quad \left(\because f = \frac{1}{T} \right)$$

' f ' being the frequency of a.c.

$$I = I_0 \sin 2\pi ft.$$

Q. 2. Distinguish between a.c. and d.c.

Ans. *Distinction between a.c. and d.c. :*

Alternating current	Direct current
1. An alternating current is a current which continuously changes in magnitude and periodically reverses in direction.	1. A direct current changes continuously in magnitude but does not change in direction.
2. It fluctuates between +ve & -ve half cycle.	2. It is unidirectional having only +ve or -ve half cycle.

$$\begin{aligned}
 &= \frac{E_0^2}{2\pi} \left[\frac{1}{2} \{\alpha\}_0^{2\pi} - \frac{1}{2} \left\{ \frac{\sin 2\alpha}{2} \right\}_0^{2\pi} \right] \\
 &= \frac{E_0^2}{2\pi} \left[\frac{1}{2} 2\pi - \frac{1}{4} \{\sin 4\pi - \sin 0\} \right] \\
 &= \frac{E_0^2}{2\pi} \left(\pi - \frac{1}{4} \times 0 \right) \\
 &= \frac{E_0^2}{2\pi} \cdot \pi \\
 &= \frac{E_0^2}{2} \\
 \text{i.e., } \overline{E^2} &= \frac{E_0^2}{2} \\
 \text{or, } \sqrt{\overline{E^2}} &= \sqrt{\frac{E_0^2}{2}} \\
 \text{i.e., } E_{rms} &= \frac{E_0}{\sqrt{2}} \quad \dots(54)
 \end{aligned}$$

Q. 5. Define virtual emf and virtual current.

Ans. Virtual emf : Virtual emf is defined as that potential difference which when maintained across a resistor produces the same heat as produced by a steady d.c. across the same resistor in the same time interval. The r.m.s. value of emf is the virtual emf.

Virtual current : Virtual current can be defined as that a.c. which produces the same heat as produced by a steady d.c. through the same resistance for the same time interval. The rms value of current is the virtual current.

Q. 6. What are different circuit elements ? Mention their functions.

Ans. Circuit elements and their functions : The circuit elements are :

- Resistance
- Inductance
- Capacitance

(a) Resistance. An electron current flows through a conductor, electrons move forward while they are colliding with each other also. Opposition offered by the conductor due to these collisions is called resistance. Schematic diagram of resistance is shown in fig. 5.5. It is denoted by R. It is equally effective in constant as well as variable currents.

Resistance of a conductor opposes the flow of current in the conductor.



Fig. 5.5

(b) Inductance. Let us consider a wire wound over a wooden cylinder having large number of turns. Let it have a negligible resistance. If a constant current flows through it, it offers no opposition ($\because R = 0$). In case of variable currents an induced emf is set up in such a direction that it opposes the changing current. This opposition to the flow of electricity is called inductive reactance and is denoted by ' X_L '.

$$X_L = \omega L$$

Where $\omega = 2\pi f$, f being frequency of a.c. and L = coefficient of self-induction of coil.

Schematic diagram of an inductor is shown in fig. 5.6.

Inductance in an electric circuit plays the role of friction in mechanics. Inductor is called as choking coil as it chokes a.c. The role of inductance in a.c. circuit is same as the role of resistances in d.c. circuit.

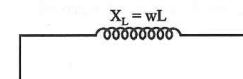


Fig. 5.6

Capacitance. When a condenser is inserted in a d.c. circuit, the plate gets charged up, and the electron current drops to zero. The capacitor (fig. 5.7), thereafter, acts as though it had an infinite resistance, when connected to an alternating source of emf, it acts differently. In reversing of emf reverses the flow of electrons to and from the plates of the capacitor and the alternating flow of charge constitutes an alternating current. The opposition offered by the capacitor to a.c. is called capacitive reactance. It is denoted by ' X_C '.

$$X_C = \frac{1}{\omega C}$$

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Group-A

1. (a)

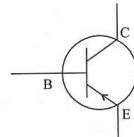


Fig. J : Circuit symbol of pnp transistor

- (b) Q-factor or quality factor of a coil is defined as the ratio of the reactance (X_L) of the coil at resonance to the resistance (R) of the coil.
- $$Q = \frac{\omega_o L}{R} = \frac{2\pi f_o L}{R}$$
- (c) Grey, Blue, Gold, Gold :
The resistance is $86 \times 10^{-1} \pm 5\%$
 $= 8.6 \Omega \pm 5\%$
- (d) The passive component is the transformer.
- (e) Three possible transistor connection are :
(i) Common Base (CB)
(ii) Common Emitter (CE)
and (iii) Common Collector (CC)
- (f) Positive feedback is employed in oscillator circuit.
- (g) The maximum efficiency of a full-wave rectifier is 81.2%.
2. (a) Maximum power will be transferred from a source of 10 ohm resistance to a load of 10 ohm.
- (b) Unit of reactance of a circuit is ohm.
- (c) The screen grid potential is somewhat lower than plate potential.
- (d) In an n-type semiconductor, current conduction takes place by free electrons.
- (e) The base of a transistor is lightly doped.
- (f) If the operating point is changed, unfaithful amplification results.

- (g) Negative feedback reduces distortion in amplifiers.
- (h) Output transformer is always a step down transformer.

Group-B

3. (a) The energy stored in a charged capacitor is given by

$$W = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

where, $C = \frac{Q}{V}$ = Capacitance of the Charged capacitor.

Q = Charge on the positive plate of the capacitor.

V = p.d. between the plates of the capacitor.

- (b) The resonant frequency in a series resonant circuit is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Where, L is the inductance and C is the capacitance.

- (c) A triode valve has following limitations :

- (i) Interelectrode capacitance :

The reactance of the plate to grid capacitance

$$X_c = \frac{1}{2\pi f C_{gp}}$$

reduces at high frequencies and provide an easy feedback path for the output energy to be feedback to the input and the feedback is negative. Thus, the gain is reduced.

- (ii) Insufficient amplification :

The amplification factor of a triode is usually small and less than 100. So, the amplification is not high.

- (d) We have $g_m = 1.5 \text{ mA/V} = 1.5 \times 10^{-3} \text{ A/V}$
 $= 1.5 \times 10^{-3} \text{ ohm}^{-1}$

$$r_p = 12 \text{ K}\Omega = 12 \times 10^3 \text{ ohm}$$

$$\text{So, } \mu = r_p \times g_m = 18$$

- (e) We know $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$$\text{Here, } \frac{4}{1} = \frac{240}{V_s}$$

$$\therefore V_s = \frac{240}{4} = 60 \text{ Volt (rms)}$$

$$\text{Hence, } (V_s)_{\text{peak}} = 60 \times V_2 = 84.84 \text{ Volts.}$$

- (f) $\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = \frac{0.99}{0.01} = 99$
- (g) Various methods of biasing a transistor are :
- Base Resistor method
 - Feedback method
 - Voltage divider method
 - Method of self-biasing
- (h) The different transistor amplifiers are :
- Direct coupled amplifier
 - R-C coupled amplifier
 - L-C coupled amplifier
 - Transformer coupled amplifier.
- (i) Voltage gain = 73
We know
Voltage gain = $20 \log_{10} 73 \text{ dB} = 37.27 \text{ dB}$
- (j) We know
- $$\left(\frac{N_p}{N_s}\right)^2 = \frac{Z_p}{Z_L} = \frac{0.9 \times 10^3 \Omega}{9} = 100$$
- So, $\frac{N_p}{N_s} = \text{Turns ratio} = \sqrt{100} = 10.$
- (k) Maximum a.c. power output = 30 watt.
The power rating of the transistor = ?
 $\eta = 50\% = 0.5$
- So, $0.5 = \frac{P_{out}}{P_{in}} = \frac{30 \text{ Watt}}{P_{in}}$
- or, $P_{in} = 60 \text{ Watts.}$
- (l) Gain without feedback = $A = 10^4$
Gain with feedback = $A_f = 50$
If feedback fraction is β , then

$$A_f = \frac{A}{1 + A\beta}$$

Since, the gain is reduced with feedback. We have negative feedback here.

$$\text{So, } 50 = \frac{10^4}{1 + 10^4 \beta}$$

$$\text{or, } 50 + (50 \times 10^4) \beta = 10^4$$

$$\text{or, } 5 \times 10^5 \beta = 10000 - 50 = 9950$$

$$\therefore \beta = \frac{9950}{500000} = \frac{0.0995}{5} \\ = 0.0199 \approx 0.02.$$



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Sadasiva Biswal, M.Sc., Ph.D., is retired principal and former Professor of Physics, Suddhananda Engineering and Research Centre (SERC), Bhubaneswar, India. He has also taught at Nayagarh Autonomous College, Nayagarh, Odisha, from 13th November 1971 to 31st July 2005. He has 33 years of teaching experience and produced nine Ph.Ds, published 68 papers, written 20 books, and penned more than 200 articles. He is at present engrossed in Magnetohydrodynamics, Plasma Physics, and the Physics of Fluids. He is associated with many Scientific and Research Organisations and Institutes of India and abroad. He has been enrolled as a member of the Research Board of Advisors of the American Biographical Institute, Inc., Raleigh, North Carolina, U.S.A.



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