Unit IV

Unit IV – Inductors and Transformers

Inductors: Introduction – working – Factors affecting Inductance – Types – Fixed Inductors - Variable Inductors - Self Inductance and Mutual Inductance – Difference between Self & Mutual inductance - Applications
Transformers: working principle – Types – Applications.

Inductors

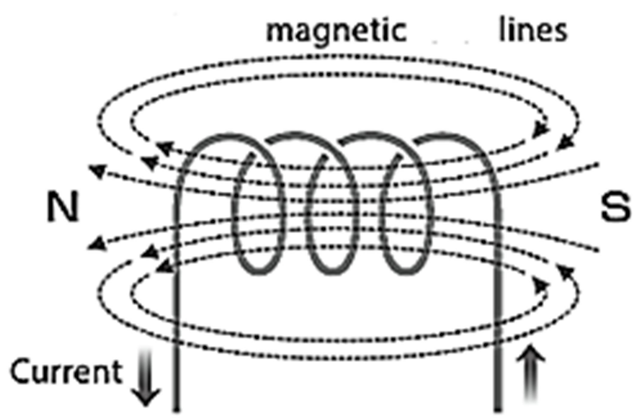
Inductor is a passive element that stores energy in the form of magnetic field. The inductance value depends on the number of turns in the coil. Its unit is Henry

Symbol:

Construction:

An inductor is constructed by wounding the coil on the core. The coil made of conducting material, typically copper wire. The cores are made of ceramic material, ferromagnetic material or by the air. The core may be Toroidal or E- shaped.

Working:



Description:

According to Faraday's law of electromagnetic induction, the current through an inductor will induce a magnetic field around it. The magnetic field produces an e.m.f (electromotive force) or voltage across an inductor. The induced voltage is directly proportional to the rate of change of current through the inductor. If the current is increased, the magnetic field will also increase.

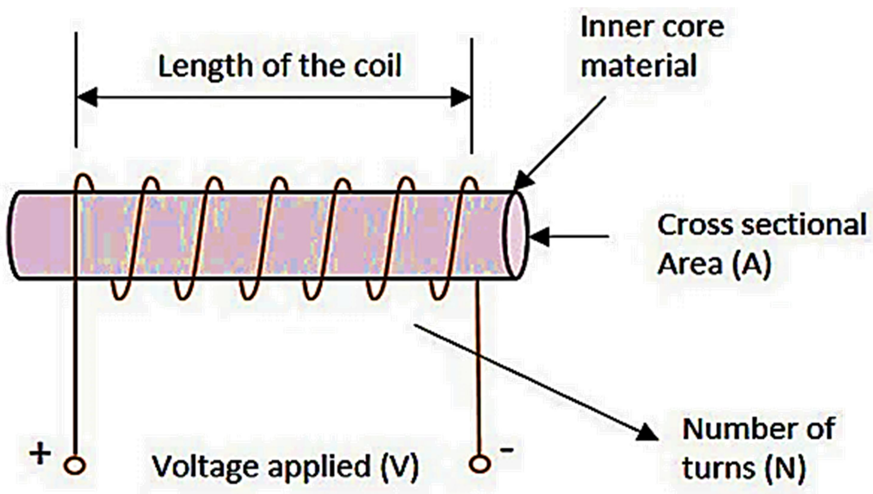
Factors affecting the inductance

The inductance of a coil is

➨ directly proportional to the area of cross section of core, Number of turns of coil and Permeability of core

➨ inversely proportional to the length of core

Diagram:



Inductance of a coil

$$\boxed{L = \frac{N^2 \mu A}{l}} \quad \text{-------- (1)}$$

$$\mu = \mu_o \, \mu_r \quad \text{-------- (2)}$$

Substitute equation 2 in equation 1

$$L = \frac{\mu_0 \mu_r . N^2 A}{l}$$

Where, l – length of coil (m)

A – Area of cross section of coil (m^2)

N – Number of turns of coil

μ – Permeability of core

μ_0 – Permeability of free space

μ_r – Relative Permeability of core

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Types of Inductors

- Fixed Inductors
- Variable Inductors

1. Fixed Inductors

Fixed inductor is an inductor whose inductance is fixed and cannot be changed.

Symbol:

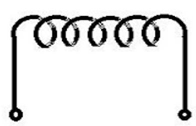
Types of fixed Inductors

- Air core inductor
- Iron core inductor
- Ferrite core inductor

1.1 Air core Inductor

The air core inductor has a very low inductance value.

Symbol



Description

In Air core inductor there is an air inside of the coil. The non-magnetic materials like plastic and ceramic are also used as core materials. Also, there exist no core losses as there is no solid core material. Its inductance value limits to μH to mH. It is used in radio frequency applications.

1.2 Iron core Inductor

Iron core inductor is also called as filter choke. It is used to remove unwanted ripple voltage in rectified ac.

Symbol:

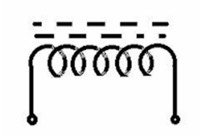
Description

An Iron core inductor consists of number of turns of coil wound on iron core. The iron core is made up of thin iron laminations pressed together, but insulated from each other. It is used in Audio frequency applications.

1.2 Ferrite core Inductor

Ferrite core inductor is made of coils wound on a Ferrite core

Symbol



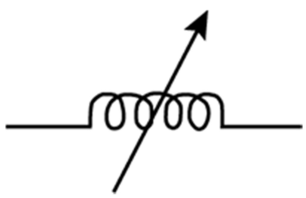
Description

A ferrite is a magnetic material consists of fine particles of iron, cobalt embedded in an insulating binder. The ferrite core has low eddy current loss Therefore ferrite core inductors are used in tape recorders, Radio receivers etc.,

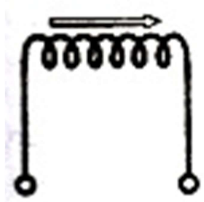
2. Variable Inductors

Variable inductor is an inductor whose inductance is varied and can be changed. It is also known as variable ferrite core inductor. It is used in tuning & filtering circuits

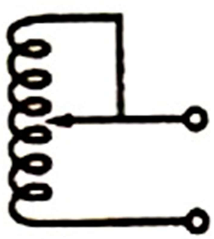
Symbol:



(i) Coil with a ferrite slug which can be screwed in or out of the coil to vary its inductance.



(ii) A variable inductor is made of long coil wound on ferrite core provided with a slider contact. Slider contact is used to vary the inductance of a coil. It is used for large coils.

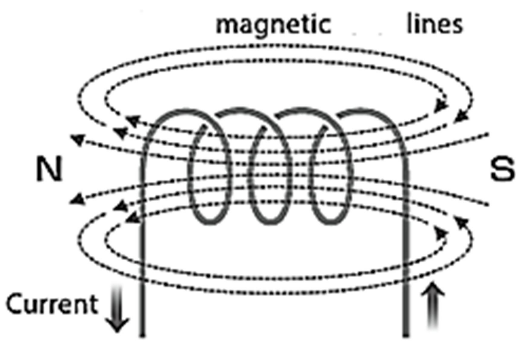


Unit IV

Self Inductance

Self-inductance is the measure of an electrical circuit's ability to store energy in a magnetic field when current flows through it. Its unit is Henrys (H). Example : Inductor.

Circuit diagram:



Description:

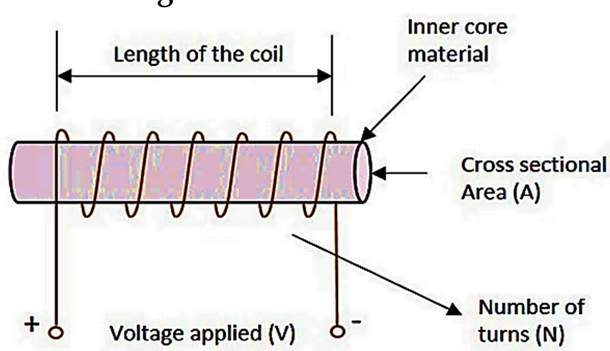
Self Inductance is defined as the ability to vary current in one coil induces an electromotive force (EMF) in the same coil. It's also known as "self-induction". The induced EMF is proportional to the rate of change of the current, and the proportionality constant is known as the self-inductance of the coil.

Factors upon which Self inductance depends:

The Self Inductance of a coil depends on the

- Area of cross section of core
- Number of turns in the coil
- Permeability of core
- Length of core

Diagram



Self Inductance of a coil

$$\boxed{L = \frac{N^2 \mu A}{l}} \text{ -------- (1)}$$

$$\mu = \mu_o \mu_r \text{ -------- (2)}$$

Substitute equation 2 in equation 1

$$L = \frac{\mu_0 \mu_r . N^2 A}{l}$$

Where, l – length of coil (m)

A – Area of cross section of coil (m^2)

N – Number of turns of coil

μ – Permeability of core

μ_0 – Permeability of free space

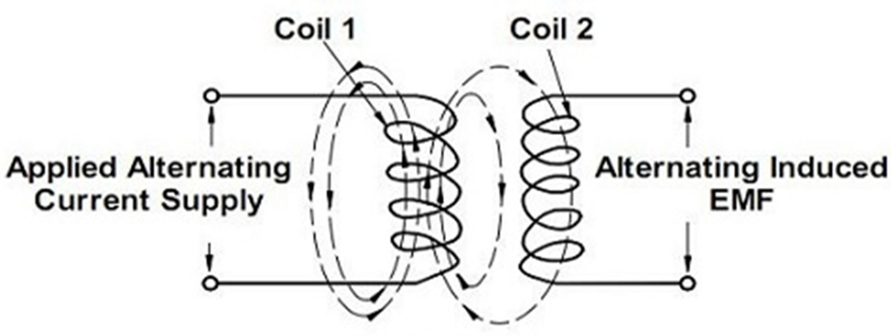
μ_r – Relative Permeability of core

Unit IV

Mutual Inductance (M)

Mutual inductance is the measure of an electrical circuit's ability to store energy in a magnetic field when current flows through it. It's also known as "mutual induction". Its unit is Henrys (H). Example : Transformer.

Circuit diagram:



Description:

Mutual Inductance is the ability of varying current in one coil induces an electromotive force (EMF) in a nearby coil. This effect is known as electromagnetic coupling and the strength of the coupling is determined by the number of turns in each coil, the distance between the coils, and the type of core material used.

For example, in a transformer the primary coil and secondary coil are coupled through mutual inductance, which allows the transformer to step up or step down the voltage in the electrical power system.

Mutual Inductance between two coils

The induced EMF is proportional to the rate of change of the current in the first coil, and the proportionality constant is known as the mutual inductance between the two coils.

Mutual inductance is given by

$$M = \mu A N_1 N_2 / l \text{ -------- } (1)$$

$$\mu = \mu_o \mu_r \text{ -------- } (2)$$

Substitute equation 2 in equation 1

$$M = \mu_0 \mu_r A N_1 N_2 / l \text{ -------- } (3)$$

Where, l – length of the magnetic path (m)

A – Area of cross section of coil (m^2)

N_1 – Number of turns in coil 1

N_2 – Number of turns in coil 2

μ – Permeability of core

μ_0 – Permeability of free space

μ_r – Relative Permeability of core

Difference between Self and Mutual Inductance

S.No	Self Inductance	Mutual Inductance
1	Self Inductance is defined as the ability to vary current in one coil induces an electromotive force (EMF) in the same coil.	The ability of varying current in one coil induces an electromotive force (EMF) in a nearby coil is known as Mutual Inductance.
2	It's also known as "self-induction".	It's also known as "mutual induction".
3	An example of Self inductance is Inductor.	Examples of Mutual inductance are Transformer, Motor and Generator.
4	Induced emf $e = -Ldi/dt$	Induced emf $e_1 = -Mdi_2/dt$ Induced emf $e_2 = -Mdi_1/dt$
5	It is the property of coils	It is the property of a pair of coils
6	L is the constant, also known as the coefficient of inductance	M is the constant, also known as the coefficient of Mutual inductance
7	Self inductance is given by $L = \mu_0\mu_r AN/l$	Mutual inductance is given by $M = \mu_0\mu_r AN_1N_2/l$
8	Self inductance of a coil depends on dimensions	For a pair of coils, Mutual inductance of a coil depends on dimensions their dimensions as well as orientations

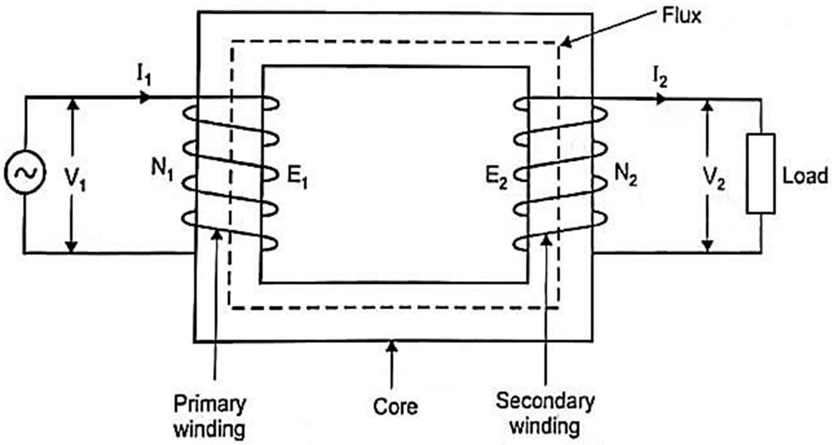
Applications

- The inductor is used to minimize the alternating current (AC) in a circuit.
- It is used in radio transmitters and radio receivers.
- Inductor is used for allowing the flow of direct current (DC).
- To minimize the ripple voltage or ripple factor it is used in filter circuits.
- It is used in the LC resonant circuits.
- It is used in tuning circuits, to select the frequency.
- It is used as RF choke in oscillators.
- It is used in fluorescent tube lights as AF choke.
- It is used for construction of IF and RF tuning coils.

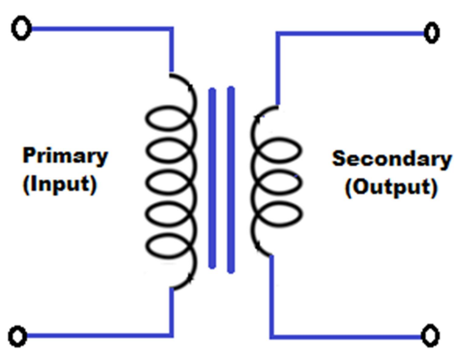
Transformer

Transformer is a static electrical device that transmits AC power from one circuit to another circuit through electromagnetic induction without changing frequency.

Circuit diagram:



Symbol:



Construction:

It consists of two coils of wire wound around a common iron core. The coil that is connected to the power source is called the primary coil, and the coil that is connected to the load is called the secondary coil.

Working:

The transformer operates on the principle of Faraday's law of electromagnetic induction or mutual induction between two coils. The function of a transformer is to change the voltage level of an AC power supply. When an alternating current is passed through the primary coil, it creates a magnetic field which induces a voltage in the secondary coil. The voltage in the secondary can be used to drive a load. Voltage can be stepped up or down depending on the ratio of the number of turns in the primary and secondary coils.

Types of Transformers

Transformer's classification is based on voltage levels, medium of core used, winding arrangement, Transformer's core, core design, insulation, number of phases & Application

- **Based on Voltage Levels**
  - Step-up Transformer
  - Step-down Transformer
- **Based on the Medium of Core Used**
  - Air Core Transformer
  - Iron Core Transformer
- **Based on the Winding Arrangement**
  - Autotransformer
- **Based on Usage**
  - Power Transformer
  - Distribution Transformer
  - Measurement Transformers
  - Protection Transformers
  - Instrument Transformer
- **Based on Core design**
  - Core type Transformer
  - Shell type Transformer
  - Berry type Transformer
- **Based on insulation used**
  - Dry type Transformer
  - Oil immersed Transformer
- **Based on No of Phases**
  - Single Phase Transformer
  - Three Phase Transformer

Applications

Transformers are used in a variety of applications, including power generation, transmission and distribution, lighting, audio systems, and electronic equipment.

➨**Power generation:** Transformers are used in power plants to increase the voltage of the electricity generated by the plant before it is sent to the grid.

➨**Transmission and distribution:** Transformers are used in the transmission and distribution of electricity to increase or decrease the voltage of electricity as it is sent from power plants to homes and businesses.

➨**Isolation:** Transformers are used to isolate two circuits electrically and to reduce the risk of electric shock.

➨**Lighting:** Transformers are used in lighting systems to decrease the voltage of electricity before it is sent to light bulbs.

➨**Audio systems**: Transformers are used in audio systems to increase or decrease the voltage of electricity before it is sent to speakers.

➨**Power Supplies:** Transformers are used in Power supplies to step up low voltages and step down high voltages

➨**Electronic equipment:** Transformers are used in a variety of electronic devices, including computers, TVs, radios, and cell phones.