Physics Department
Kuwait University
EXP. EIGHT
Course 127

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Transformer

Objective

- To study the operation of a transformer.
- To examine the effect of core configuration on the output voltage gain.
- To compare between step-up and step-down transformers.
- To compare between no-load and full-load operation.

Theory

In electric power distribution systems, it desirable at both the generating end (the electric power plant) and the receiving end (home or factory) to deal with relatively low voltages. For example, no one wants an electric toaster or a child's train to operate at, say, 10 kV.

On the other hand, in the transmission of electric energy from the generating plant to the consumer, we want the lowest possible current (and thus the largest possible potential difference) so as to minimize the i^2R ohmic losses in the transmission line. Therefore, there is a fundamental mismatch between the requirements for efficient transmission on the one hand and safe generation and consumption on the other hand. We need a device that can, as design considerations require, raise or lower the potential difference in a circuit, keeping the product iV essentially constant.

The transformer solves the problem (see Fig. 1). It consists of two coils wound around a soft iron coil. One is referred to as the primary coil, with N_1 turns, and the other is the secondary coil, with N_2 turns. The primary coil is connected to an alternating-current (ac) source with electromotive-force (emf), $\varepsilon\,(t)$, and the secondary is connected to a resistive load via a switch.

According to Faraday's law, an alternating current in the primary coil induces a self alternating magnetic flux $\Phi_B(t)$, such that

$$\varepsilon = V_1 = -\frac{N_1 d\Phi_B}{dt}, \tag{1}$$

where, V_1 is the potential difference developed across the primary coil. The magnetic flux

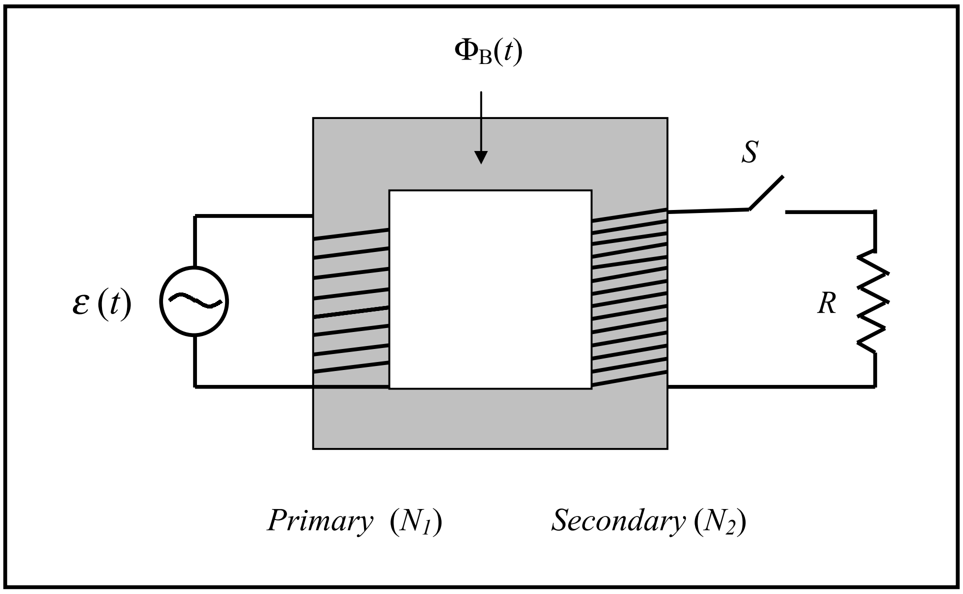

Figure 1: The basic Transformer

is linked to the secondary coil through the iron core. Thus, the magnetic flux rate is the same for both coils, therefore, using Eq.(1), we get

$$-\frac{d\Phi_B}{dt} = \frac{V_1}{N_1} = \frac{V_2}{N_2}, \tag{2}$$

where V_2 is the potential difference developed across the secondary coil, or,

$$V_2 = V_1\left(\frac{N_2}{N_1}\right). \tag{3}$$

Now, if $N_2 > N_1$, we speak of a step-up transformer; and if $N_2 > N_1$, we speak of a step-down transformer. The voltage gain, G, may be defined as the ratio between the output, to the input voltages, or

$$G = \frac{V_o}{V_{in}}. \tag{4}$$

When the switch is open (no load operation), no current exists in the secondary coil and therefore, no power is delivered to the transformer, and the primary coil acts as a pure inductance. Whereas, if the switch is closed a current, i_2, is set through the secondary coil, and the two windings appear to be as a fully coupled mutual inductance.

Actually, the closed switch operation is rather complex to analyze. Therefore we take advantage of the overall view provided by the conservation of energy principle. For an ideal transformer with a resistive load this tells us that

$$P_{\text{in}} = P_{\text{o}}, \quad (5)$$

Where P_{in}, and P_{o} are the input and output powers.

Transformer efficiency may be expressed as

$$Efficiency = \frac{P_o}{P_{in}} \times 100 . \quad (6)$$

In practice no transformer is of 100% efficiency due to power losses. Some of the main reasons for these losses are: the resistance of the coils, the magnetic leakage, and the hysteresis losses (due to magnetization properties of the core).

Equipment

- The PASCO SF-8616 Basic Coils Set.
- Low voltage ac power supply 0-6 VAC, 0-1 amp such as PASCO Model SF-9582.
- Resistance box.
- Banana connecting leads for electrical connections.
- Multimeter (2).

Procedure

Part one (*core configuration*)

1. Set up the two coils labeled 400-turn as shown in Fig. 2 (no core is used).
2. Set the voltage of the supply to 6 V.
3. Measure input and output voltages, calculate the voltage gain and record in Table I.
4. Repeat step 3, changing the core configuration as shown in Fig. 3.

Part two (*Step-up vs step-down transformer*)

1. Using the core configuration that gave the maximum voltage gain in part 1, set up the coils as shown in Fig. 2.
2. Measure input and output voltages, calculate the voltage gain and record in Table II.

3. Fixing the primary coil to 400-turns, repeat step 2, changing the secondary coil according to Table II.
4. Use the 3200-turn coil as your primary, repeat step 2, changing the secondary coil as given in Table III. Record the data.

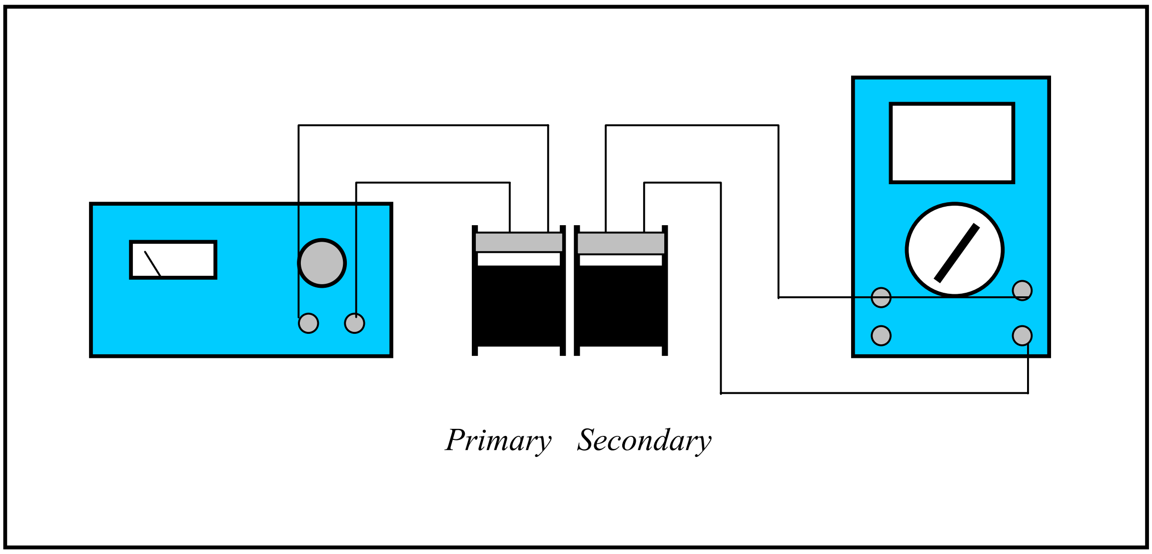

Figure 2: Input and output voltage measurements

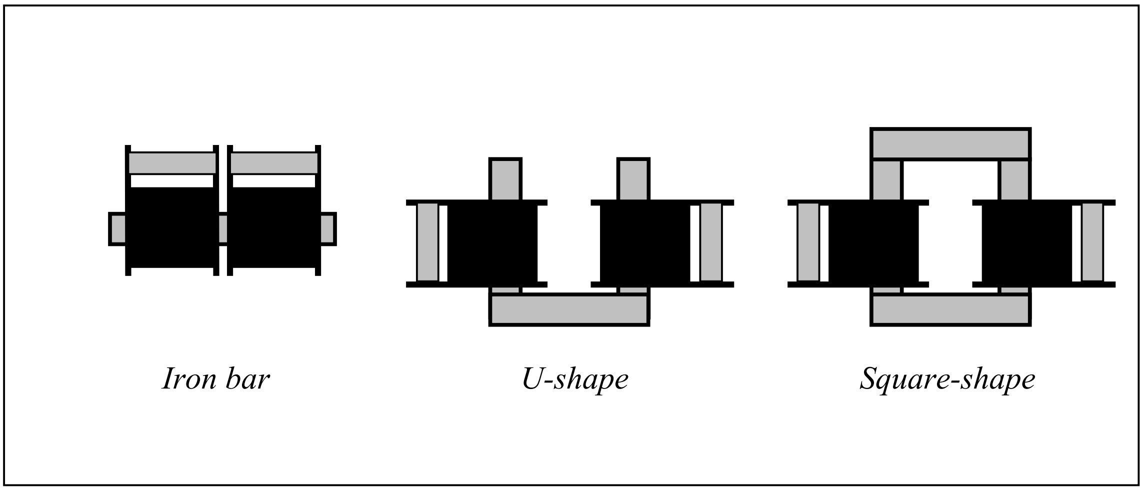

Figure 3: Core configurations

Table I (*both coils of 400-turns*)

Core	V_{in} (V)	V_o (V)	*G*
NO			
Iron bar			
U-shape			
Square-shape			

Table II (*step-up)*

Primary	*Secondary*	V_{in} (V)	V_o (V)	*G*
400	400			
400	800			
400	1600			
400	3200			

Table III (*step-down)*

Primary	*Secondary*	V_{in} (V)	V_o (V)	*G*
3200	1600			
3200	800			
3200	400			
3200	200			

Part three (*Power efficiency*)

1. Using a 400-turn as the primary, and 1600-turn as secondary, set up the coils as shown in Fig. 4, using the square core configuration.
2. Set the ammeters to milli-Amp range.
3. Set the resistor to the 1000 Ω.
4. Measure the input and output voltages and currents. Record in Table IV.
5. Calculate the input and output powers, voltage gain, and the power efficiency. Record in Table V.
6. Repeat steps 4 & 5 for resister values given in the table.

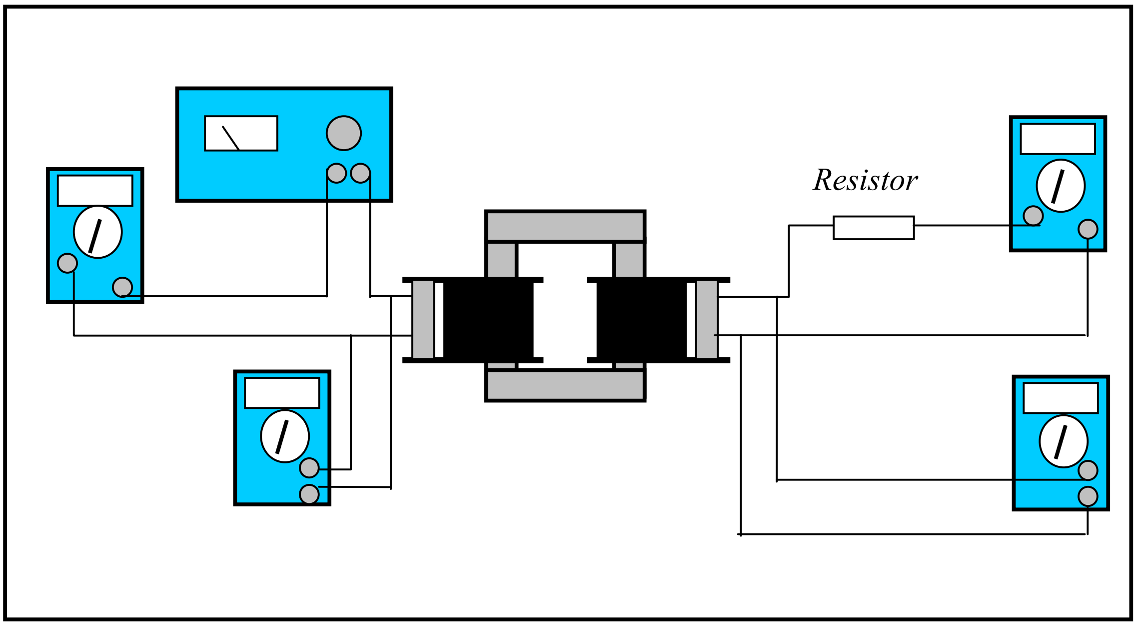

Figure 4: Current and voltage measurements

Table IV (*voltages & currents*)

R (Ω)	V_{in} (V)	I_{in} (mA)	V_o (V)	I_o (mA)
1000				
1100				
1200				
1300				
1400				
1500				

Table V (*power efficiency*)

R (Ω)	P_{in} (W)	P_o (W)	G	*Efficiency*
1000				
1100				
1200				
1300				
1400				
1500				

Questions

1. Explain why stepping–up the voltage in the beginning of the transmission lines, reduces the ohmic loses?
2. Which core configuration gives the maximum voltage gain? Explain?
3. When no load is connected to the secondary coil, does the transformer disipates energy? Why?
4. Is the power efficiency, that you got, equals 100%? If not, can you explain the reason?