Signal Training Bulletin

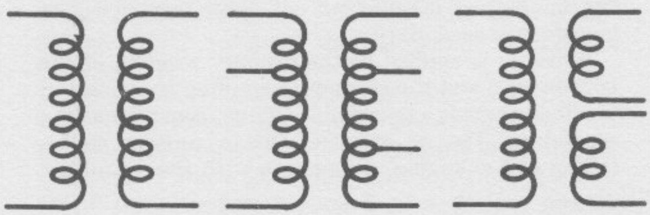
COMMITTEE G: Education & Training
Communication & Signal Section, AAR

B-6 Transformers

Approved January 1974

Definition: Transformer: An inductive device used for changing the ratio of voltage and current in two parts of an alternating current circuit or for insulating one part of a circuit from another.

Symbol:



Transformer — Tapped Transformer — Split Secondary Transformer

Description: A simple transformer consists of two coils very close together, electrically insulated from each other. The coil to which ac is applied (source) is called the primary. The coil from which the transformed ac is taken is called the secondary (load). The coils are not physically connected to each other. They are however, magnetically coupled by means of a common iron structure known as the core. The basic construction of a transformer is illustrated in Figure 1.

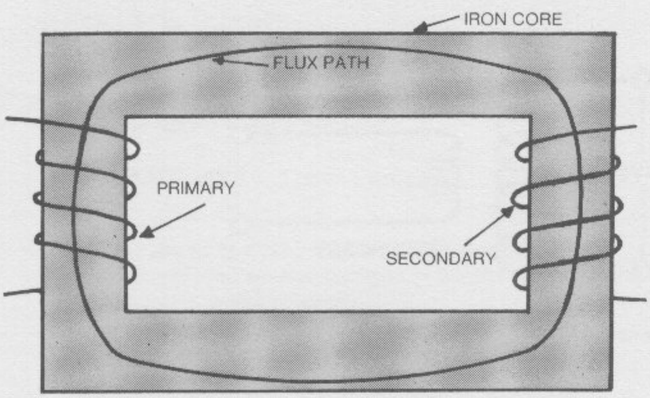


Figure 1

Figures 2(a) and (b) are examples of transformers in common use in railroad signaling.

Figure 2(a) shows a tapped transformer which is capable of supplying any whole voltage between 1 and

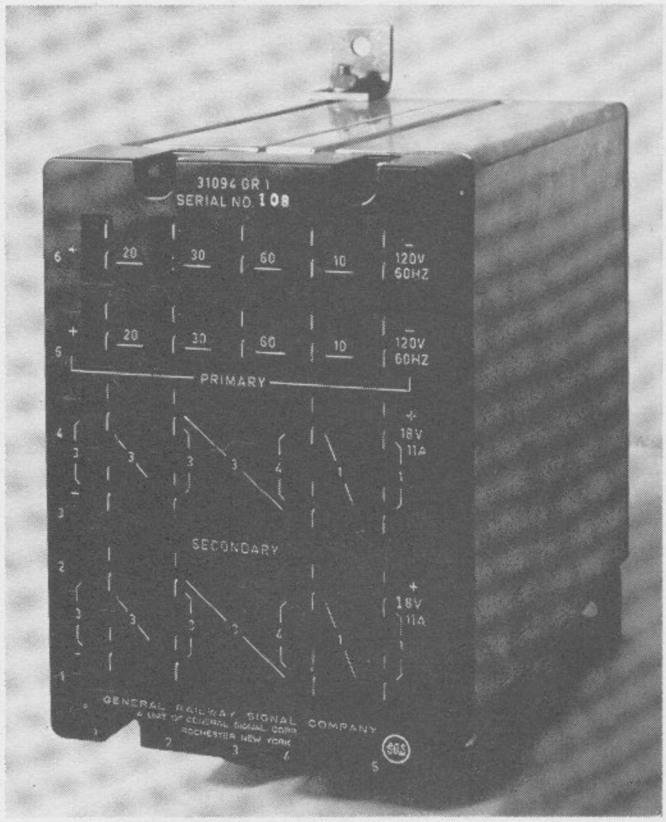


Figure 2(a) Tapped transformer

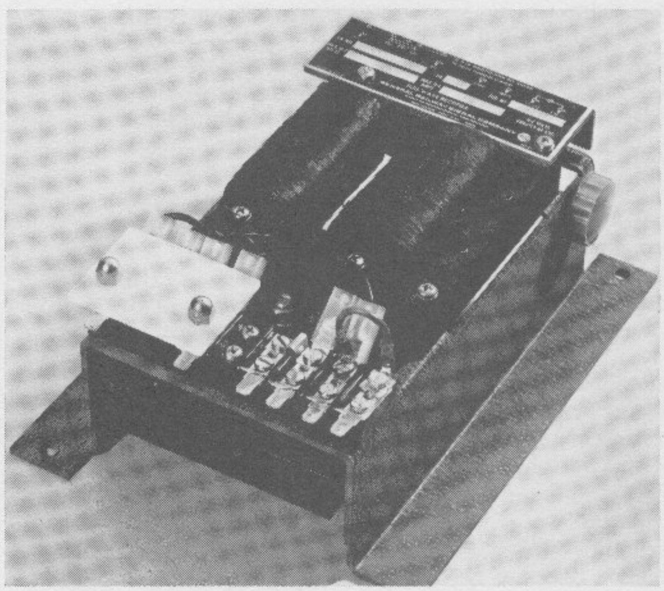


Figure 2(b) Signal rectifier (rectifier stacks removed)

15 volts ac from the secondary when the primary is connected to either 110 or 220 volts ac. This type is often used to supply signal lamp circuits.

Figure 2(b) shows a magnetic shunt type transformer—rectifier unit used for charging batteries. The output voltage from the secondary may be precisely adjusted by use of the adjusting knob. (upper right corner of illustration).

Purpose and Application: The most common signal application of the transformer is to increase or decrease ac voltage. When the voltage available at the secondary is lower than the voltage applied to the primary it is called a step-down transformer. A transformer that has higher secondary voltage than primary voltage is called a step-up transformer. The use of step-down transformers in signaling provide real savings in power and material costs.

The savings in power costs occur because the use of transformers makes it possible to transmit relatively high voltage ac (220 volts, 550 volts, etc.) over long distances with minimal power losses in the line. Although the line wires do have low resistance, high current through the wires will result in high power dissipation in the line.

Power in an electrical circuit is the circuit current squared, multiplied by circuit resistance. $P = I^2R$. By considering the formula it may be seen that any reduction in current will significantly reduce the power dissipated. By employing high voltage such as 550 volts ac and step-down transformers at the signal locations it is possible to transfer the energy from the commercial source to the remote signal location with low line currents and therefore low line losses.

The savings in materials occur because only one ac transmission line is used to supply many lower ac voltages required at the signal location. For example, a typical bungalow at a power switch signal location will often require 110 volts ac for bungalow lighting and appliance outlets, 10 volts ac for signal lamps, 30, 13.5 and 3 volts ac for storage battery chargers. If a separate pair of line wires had to be run from the ac source to provide each of these voltages the cost would be extreme. Each of the lower voltages may be obtained through the use of step-down transformers connected to the one high voltage transmission line.

General Information: Transformers are very efficient. They require little maintenance other than to be kept clean and dry. Terminals must be kept tight and clean.

Detailed Operation: The transformer functions on the principle of mutual induction. The term mutual induction refers to the condition in which two circuits are sharing the energy of one of the circuits. It means that energy is transferred from one circuit to another.

The following description is not intended to cover all the theory of self and mutual induction which are involved in transformer action. Instead, the basic operation of transformers is discussed followed by a brief application to two types of signal transformers.

First, induction only occurs when the current is changing. Two examples of changing currents are alternating current (ac) or pulsating direct current. Induction does not occur with steady direct current. Steady direct current should not be applied to a transformer winding because the resistance to dc is quite low and the transformer could be damaged by the resulting high current flow.

NOTE (1) When a changing current such as ac is passed through a coiled conductor a changing magnetic field of flux is produced about and within the coil. If a magnetic material core is placed within the coil so that the flux lines cut across the core the core becomes magnetized. Since the magnetizing force is produced by ac which is constantly rising and falling and changing direction the strength and direction of the magnetism in the core is in step with the ac. This occurs in a transformer primary.

(2) When a conductor is placed within a changing field of magnetic flux so that the flux lines cut across the conductor a voltage will be produced across the conductor. If the conductor is coiled so that many conductors are cut by the moving magnetic field a higher voltage will exist and will be in proportion to the number of conductors cut. This occurs in the transformer secondary.

When ac is applied to the primary winding of the transformer and the secondary winding is connected to a load there is a transfer of energy from primary to secondary. The ac entering the primary is rising, falling and changing in direction with the frequency

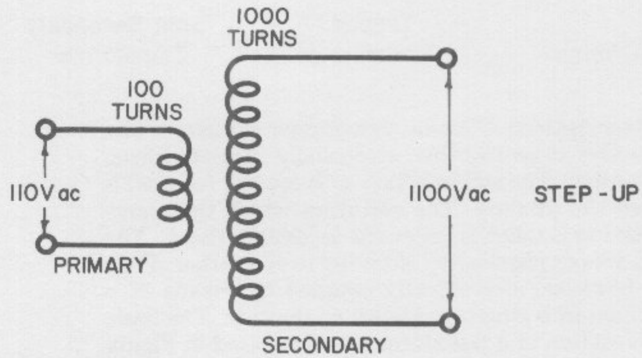


Figure 3(a)

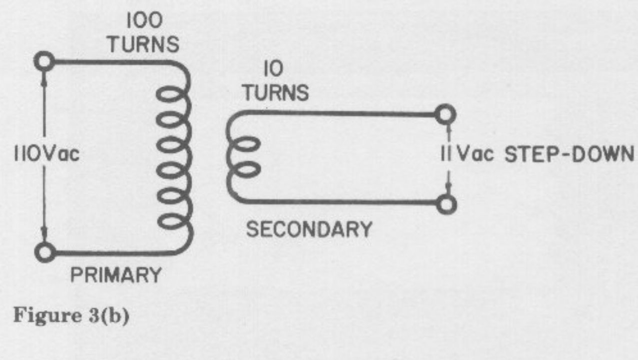


Figure 3(b)

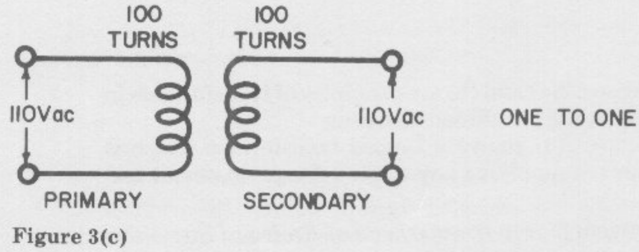


Figure 3(c)

(60 HZ). This action produces a magnetic field of flux in the core which is building up, collapsing and changing direction at the same rate as the ac source. The core is common to both primary and secondary therefore the changing magnetic flux field is cutting across the conductors of the secondary windings and an electric current is induced in the secondary.

As mentioned in the Note the more conductors that are cut by the magnetic flux the higher the voltage. In transformers the relationship between primary turns of wire to secondary turns determines if it is a step-up or step-down transformer. If the number of primary and secondary turns are equal, the voltage in equals the voltage out.

In Figure 3(a) the secondary has ten times more turns than the primary. The 110 volts ac at the primary is transformed to 1100 volts at the secondary (step-up transformer).

In Figure 3(b) the secondary has ten times fewer turns than the primary. The 110 volts ac is transformed to 11 volts at the secondary (step-down transformer).

In Figure 3(c) the primary to secondary turn ratio is equal. The voltage out equals the voltage in. This transformer is referred to as an isolating or insulating transformer and is sometimes used in signaling where an ac signal is superimposed on a dc line circuit network. The transformer will pass the ac but will block the dc from flowing in parts of the circuit where it is not wanted.

Transformers are also used to eliminate shock hazard by isolating the grounded source from the equipment circuits.

It would appear that a step-up transformer gives something for nothing. This is not true. Although a step-up provides more voltage at the secondary the current capacity is down. Power is the important consideration since this is the measurement of work. Because a transformer is such an efficient device the power in almost equals the power out. Therefore, if a 0.100 ampere load was connected to the secondary (Figure 3(a)) the power consumed would equal 110 watts since P (power) = E (voltage)xI (current) = 1100x0.100 = 110 watts.

If the secondary load is consuming 110 watts then primary must also be 110 watts. Entering the known values into the formula P = EI the current in the primary is found to be 1 ampere.

$$P = EI \text{ or } 110 = 110 \times I$$
$$\text{or, } I = \frac{110}{110} = 1 \text{ ampere.}$$

In the case of the step-down transformer in Figure 3(b) a 10 amp. load on the secondary would result in a 1 amp. current in the primary.

This is why use of high voltages and step-down transformers in transmission circuits reduces line losses. Even though the signal load requires high current at low voltage the current present in the transmission line is quite low and depends on the step-down ratio. If a 10 volt load is being supplied by a 550 volt transmission line and step-down transformers the line current is 55 times less than the load current.

Signal Application: Figure 4 schematically represents a tapped transformer. By connecting taps to the secondary at various points the primary to secondary turns ratio may be selected to suit the need.

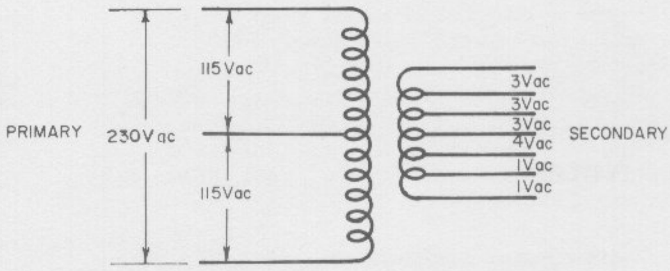


Figure 4

An ac voltmeter reading taken across the entire secondary would show 15 volts. A reading between the bottom two taps would indicate 1 volt. The position of the tap is selected so that any whole voltage between 1 and 15 is available. This type of transformer is used to light signal lamps and supply other ac equipment such as power off relays.

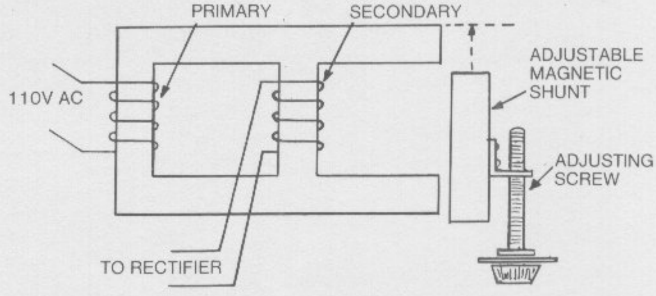


Figure 5

Figure 5 illustrates a transformer of the magnetic shunt type. The output voltage may be adjusted by moving the magnetic shunt. Suppose the primary to secondary turn ratio were such that 110 volts ac applied to the primary resulted in a maximum of 3 volts ac at the secondary. The 3 volts would be present when the adjustable shunt is in the position where the largest air gap exists between the shunt bar and the core structure. Note that the shunt provides an additional path for the magnetic flux developed in the primary. This path diverts some of the magnetic flux away from the secondary core and is not available to develop voltage in the secondary. By use of the adjusting screw the shunt may be moved until almost all the magnetism takes the shunt path. This feature provides a means to control the secondary voltage very precisely to obtain the voltage required for fine calibration of the battery charge rate.