UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 5 – PRINCIPLES OF TRANSFORMER OPERATION

OBJECTIVES

In this experiment the student will investigate

- The principles of transformer operation,
- How to establish the polarity of a transformer windings.

MATERIALS/EQUIPMENT NEEDED

Small transformer (Chip 78253/55VC)
Function Generator or NI ELVIS II
Multimeter

INTRODUCTION

A transformer is a multipurpose device with applications ranging from small audio sound systems to major large-power transmission systems. The transformer provides a method for magnetically coupling electrical energy from a primary winding to a secondary winding. Depending on the ratio of secondary windings to primary windings the voltage can be stepped up or down by a desired amount. Transformers are also very useful for the coupling of signals and the isolation of DC voltages and ground.

A transformer is usually considered to be a special form of inductive coupling. A simple transformer consists of two coils linked by a closed magnetic core which passes through the center of the coils (Figure 5-1). The coils are made of insulated copper wire looped and insulated by an outer cover. The core of the transformer is typically constructed from insulated steel laminations bonded and clamped together.

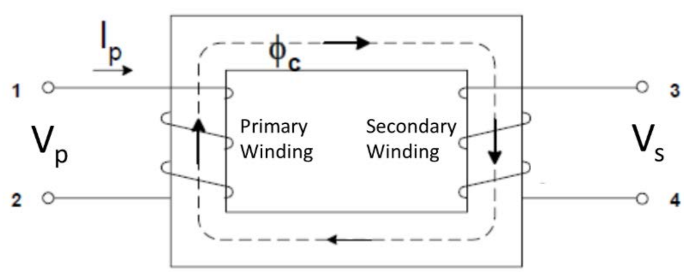

Figure 5-1 A simple transformer

When AC voltage is connected to the primary winding a flux is set up in the core which will alternate at the same frequency of the applied voltage. That flux will link to the secondary winding and induce an AC voltage. It is important to note that the voltage per turn in the primary and secondary is the same (depend on the same flux). Therefore the value of the induced voltage in the secondary will be dependent on the ratio of number of turns in the secondary to those in the primary. This is one of the most useful features of the transformer, its ability to relate the input voltage or current to its output voltage or current respectively (transformation ratio) while maintaining the power relationship the same (i.e. input power = output power).

Voltage Ratios

The voltage induced by the flux in any coil loop around the core may be expressed as a given value of volts/turn. Where

$$\text{Number of turns in primary} = N_1$$

$$\text{Number of turns in secondary} = N_2$$

$$\text{Volts per turn} = k$$

Then

$$\text{PrimaryVoltage} \;\; V_1 = kN_1$$
$$\text{SecondaryVoltage} \;\; V_2 = kN_2$$

Sinces k is constant the voltage ratio is given by

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = k$$

Transformer Polarity

The transformer polarity is an indication of the direction of current flowing through the primary winding with respect to the direction of current flow through the secondary winding at any given instant. In other words, the transformer polarity simply refers to the relative direction of induced voltages between the primary and the secondary windings so the dot-marked terminals have the same polarity.

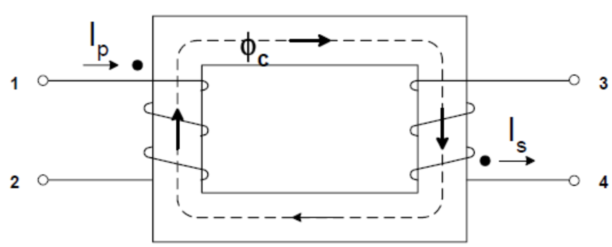

Figure 5-2 An example of transformer polarity marking

For example, in Figure 5-2 the terminals 1 and 4 have the same polarity since the primary terminal 1 is positive with respect to terminal 2 at the same time that terminal 4 is positive with respect to 3. The polarity marks in Figure 5-2 could equally well be placed beside terminals 2 and 3 because, as the voltage alternates, they too, become simultaneously positive every half-cycle. Consequently, the polarity marks may be shown beside terminals 1 and 3 or beside 2 and 4. The polarity marking has a direct relation with the right hand rule.

The polarity of a transformer may be additive or subtractive. A transformer is said to have additive polarity when the primary terminal is diagonally opposite secondary terminal with same polarity. Similarly, a transformer has subtractive polarity when primary dotted terminal is adjacent to secondary dotted terminal. The Figure 5-2 transformer has an additive polarity.

There are two commonly used methods for polarity determination: the inductive kick test and the alternating voltage test. The alternating voltage test is an AC test in which a small AC voltage is applied to the primary winding while primary and secondary are connected as shown in Figure 5-3. If the voltage across the non-connected winding terminals (V_{Test}) is greater than the applied voltage then the transformer polarity is additive and therefore the jumper wire is connecting different polarity winding terminals. If the voltage across those terminals (V_{Test}) is less than the input voltage, the polarity is then subtractive and therefore the jumper wire is connecting identical polarity winding terminals.

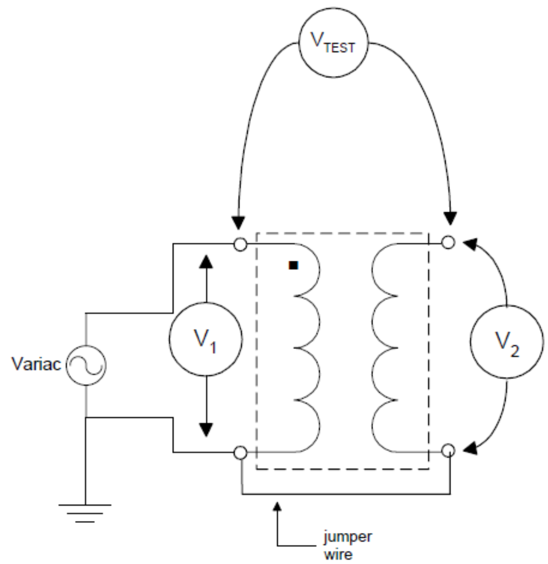

Figure 5-3 Alternative voltage test configuration

PRELAB

1. For the circuit shown in Figure 5-4, determine the theoretical values of the secondary voltage and voltage ratio if the primary voltage is $0.5V_{RMS}$, $1V_{RMS}$, $2V_{RMS}$, and $3V_{RMS}$ and record the results in Table 5-1.

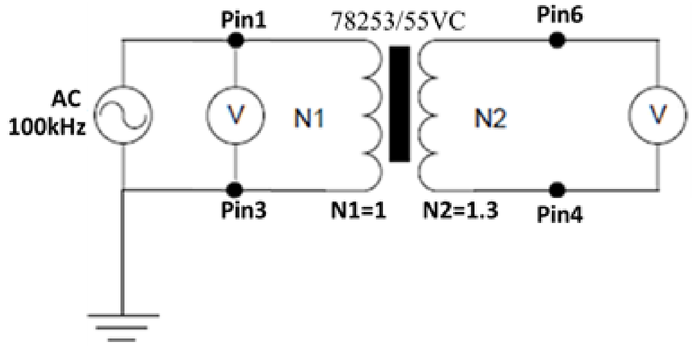

Figure 5-4 Circuit for voltage ratio on no load

2. For the circuit shown in Figure 5-5, determine the theoretical values of the secondary voltage V_2 and V_{Test}, assuming the dot for the secondary is on pin 6. Record the results in Table 5-2.

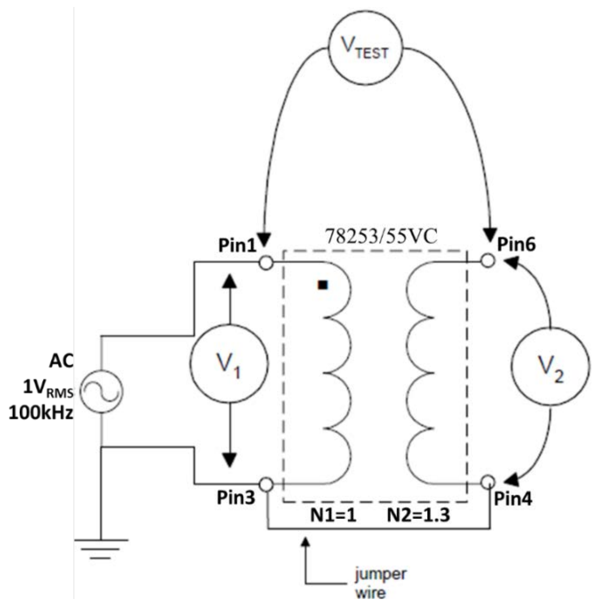

Figure 5-5 Circuit for polarity test

PROCEDURE

Voltage Ratio on No Load

1. Construct the circuit shown in Figure 5-4. **Caution:** Do not make changes in the circuit without first making sure the function generator output is switched off.
2. Use the function generator (or NI ELVIS function generator) set the primary voltage to a sinusoidal voltage of $0.5V_{RMS}$, $1V_{RMS}$, $2V_{RMS}$, and $3V_{RMS}$ at a frequency of 100kHz as read by instrumentation (multimeter).
3. Record the secondary voltage reading in Table 5-1.
4. Turn the function generator output to the off position (switched it off).

Transformer Polarity

1. Construct the circuit shown in Figure 5-5. **Caution:** Do not make changes in the circuit without first making sure the function generator output is switched off.
2. Using the function generator (or NI ELVIS) set the primary voltage to a sinusoidal voltage of $1V_{RMS}$ at a frequency of 100kHz as read by instrumentation (multimeter).
3. Record the primary voltage, secondary voltage and test voltage in Table 5-2.
4. Turn the function generator output to the off position (switched it off).

DATA/OBSERVATIONS

Table 5-1: Results for Voltage Ratio on No Load

Theoretical			Measurements		
Primary Voltage V_1	**Secondary Voltage V_2**	**Voltage Ratio V_1/V_2**	**Primary Voltage V_1**	**Secondary Voltage V_2**	**Voltage Ratio V_1/V_2**

Table 5-2: Results for Polarity Test

	Primary Voltage V_1	Secondary Voltage V_2	Test Voltage V_{Test}	Polarity (Additive/Substractive)
Theoretical				
Measurements				

INSTRUCTOR'S INITIALS:		DATE:	

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. Use the values from the Pre-Lab and the results from Table 5-1 to calculate percent error between the theoretical and measured voltage ratios and discuss your findings.
2. Draw a schematic of the transformer showing the winding polarities. Use the dot convention to represent the instantaneous positive terminals.

Be sure to include all items from the post-lab exercise above in your written lab report.