

DEVELOPMENT OF RECTIFIER CIRCUIT EXPERIMENT SET USING COMPUTER INTERFACE WITH ET-EASY168 STAMP

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Abstract

The development of a physics experiment set has become necessary in teaching physics in schools so that students are able to learn from their real experiences. The purpose of this study is to create and develop an experiment set of rectifier circuits using a computer interface with ET-Easy168 Stamp and the theory calculation of the output voltage of rectifier circuits. The experiment set is composed of a half-wave rectifier circuit, a center-tapped full-wave rectifier circuit, a full-wave bridge rectifier circuit, ET-Easy168 Stamp board, a USB port, a computer notebook, and the software of Arduino 1.5.7, Processing-2.2., and Mathematica9. The outcome of the research shows that the output voltage of the rectifier circuits is accurately relevant to the theory calculation. The experiment set was designed to be a medium of instruction in upper secondary schools or universities to help students understand physics easily.

Keywords: Rectifier circuits, Computer interface, AVR, ET-Easy168 Stamp.

1 INTRODUCTION

Learning and teaching physics in high schools or in universities are mostly conducted through listening and imagination which make the lessons hard to understand and the learners feel bored [11]. In general, the students studying physics have to measure all physics variables first, and use the results to draw graphs in order to explain the relationship of these variables. Sometimes the data cannot be constantly recorded because the experiments are done rapidly such as the motion of free falling objects, charging and discharging of a capacitor, and a rectifier circuit.

Microcomputer-based laboratory tools (MBL) are assigned to help students develop important physics concepts and acquire vital laboratory skills. MBL will help the students with different capacity take their time to do their own experiments repeatedly until they acquire the concept of physics and science skills through observation, recording, interpreting data, and so on [12]. It is believed that the implementation of computer-based laboratory experiments provide students and instructors with several advantages such as data collection and graph displays in real time, and interpretation of the data in a reasonably short time frame [4]. Data acquisition software and sensors are being widely used to allow students to spend more time exploring the data that are collected by the computer, which is able to convert about half of the traditional labs into microcomputer-based laboratories (MBLs) [9]. Computers are also helpful to students in the management of class time, which can be devoted to more detailed explanations of the physics concepts behind the experiments [13].

For the computer-based laboratory, AVR microcontroller was employed as the experimental controller. There are 3 advantageous characters to employ an AVR microcontroller because it is an open source, which can provide free downloads. In addition, AVR has developed its small hardware chips which have low cost [4, 7]. The ET-EASY168 STAMP is mini AVR8 Board costing 17.84 USD [5].

The purpose of this study is to create and develop an experiment set of rectifier circuits using a computer interface with ET-Easy168 Stamp in order to read the output voltage of half-wave, center-tapped full-wave, and full-wave bridge rectifiers and compare them with theory calculations. This experiment set is used to teach students in high schools and universities so that students are able to learn from their real experiences and understand and develop their learning skills in this twenty-first century. This experiment will lead them to the learning pyramid, which encourages the students to learn by doing and the students retention rate is about 75 %. If they are able to teach their peers, their retention rate may be as high as 90 % [10].

2 METHODOLOGY

2.1 Theory

A rectifier is an electrical device that converts an alternating current (AC) to a direct current (DC). The three basic rectifier circuits are the half-wave, the center-tapped full-wave, and the full-wave bridge rectifier circuits [2].

2.1.1 The half-wave rectifier circuit

The simplest half wave rectifier can be made by using a single diode as shown in Fig.1 below.

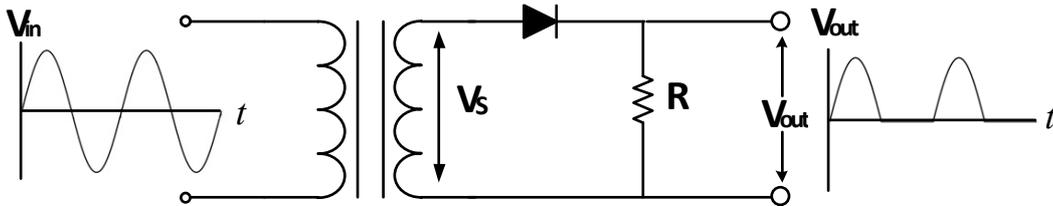


Figure 1. The half wave rectifier circuit

When the input signal is positive (V_s), the diode is forward biased and conducts the current. When the input signal is negative, the diode is reverse biased and does not conduct the current. Therefore the output waveform (V_{out}) is obtained. This is called “half rectified sine wave”.

2.1.2 The center-tapped full-wave rectifier

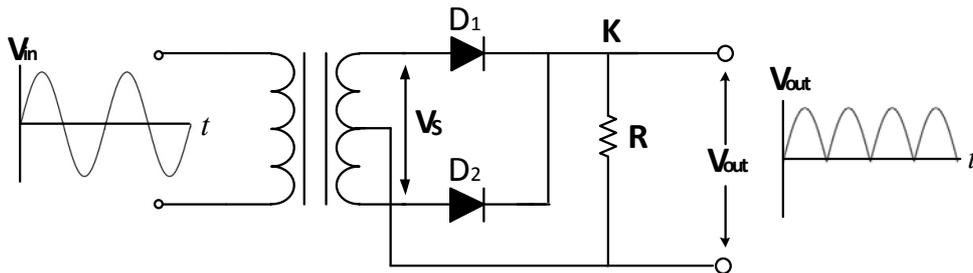


Figure 2. The center-tapped full wave rectifier

During the positive half cycle of the input signal, the diode D_1 is forward biased and the diode D_2 is reverse biased. Thus the current flows through D_1 and R . During the negative half cycle of the input signal, the diode D_1 is reverse biased and the diode D_2 is forward biased. Thus the current flows through D_2 and R . Thus, the voltage obtained across R is full-wave rectified as seen in Fig.2.

2.1.3 The full-wave bridge rectifier

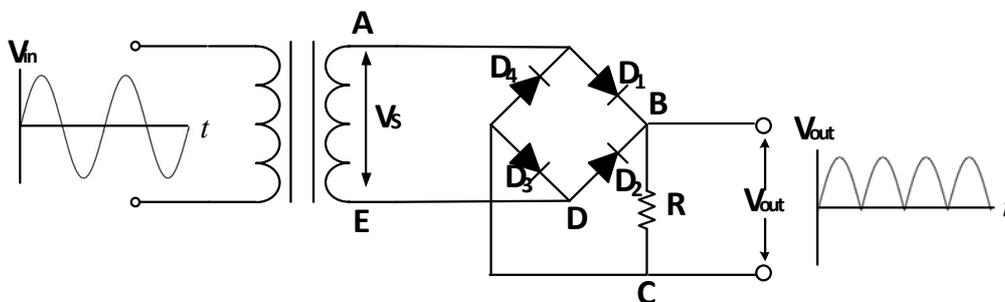


Figure 3. The full-wave bridge rectifier circuit

During the positive half cycle of the input signal, the diodes D_1 and D_3 are forward biased, and D_2 and D_4 are reverse biased. So, the current flows from A to B over diode D_1 , to C over R , to D over diode D_3 , and back to A over the secondary winding of the transformer.

During the negative half cycle, the diodes D_2 and D_4 are forward biased, and D_1 and D_3 are reverse biased. So, the current flows from E to D and B over D_2 , to C over R, to A over D_4 , and back to E over the secondary winding. Thus, the waveform shown in Fig.3 is again obtained

2.1.4 The theory calculations

Let V_s be the voltage to the secondary of the transformer. V_s is given by

$$V_s = V_{s(peak)} \sin \omega t \tag{1}$$

The root mean square A.C. voltage, or V_{rms} which A.C. meter is designed to directly read V_{rms} . $V_{s(peak)}$ is peak secondary voltage input.

$$V_{rms} = \frac{V_{s(peak)}}{\sqrt{2}} \tag{2}$$

The secondary voltage input is $3.10 V_{rms}$ and frequency, $f = 50 \text{ Hz}$.

The peak amplitude of the secondary voltage can be calculated as:

$$V_{s(peak)} = \sqrt{2} V_{rms} = \sqrt{2} \times 3.10 = 4.3841 \text{ V}$$

The V_s is in Fig.3. Table 1 shows the comparison of the three rectifiers and their properties.

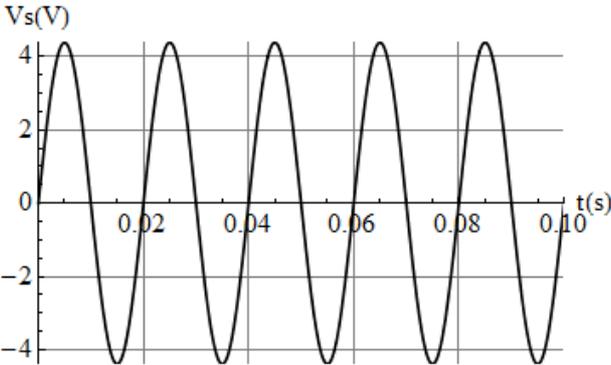


Figure 4. Secondary voltage input waveform

Table 1. Unfiltered rectifiers [2]

	Half-wave	Full-wave	Bridge
Number of diodes	1	2	4
Peak secondary voltage input	$V_{s(peak)}$	$0.5V_{s(peak)}$	$V_{s(peak)}$
Peak load voltage, $V_{out(peak)}$	$V_{s(peak)} - 0.7 \text{ V}$	$0.5V_{s(peak)} - 0.7 \text{ V}$	$V_{s(peak)} - 1.4 \text{ V}$
DC load voltage, V_{dc}	$V_{out(peak)} / \pi$	$2V_{out(peak)} / \pi$	$2V_{out(peak)} / \pi$

2.2 The Rectifier Circuit Experiment Set

2.2.1 Apparatus

Make the rectifier circuit experiment set using a computer interface with ET-Easy168 Stamp using the following parts: Rectifier Diodes 1N4007 (7), Resistor 1 K Ω , (3) AC Center-tap Transformer 3-0-3 Volt 300 mA 220 Volt AC Primary, Multimeter, Bread board, ET-Easy168 Stamp board, USB port,

computer notebook and the software of Arduino 1.5.7, Processing-2.2.1 and Mathematica9. The rectifier circuits for experiment have been shown in the section theory.

2.2.2 Design and construction

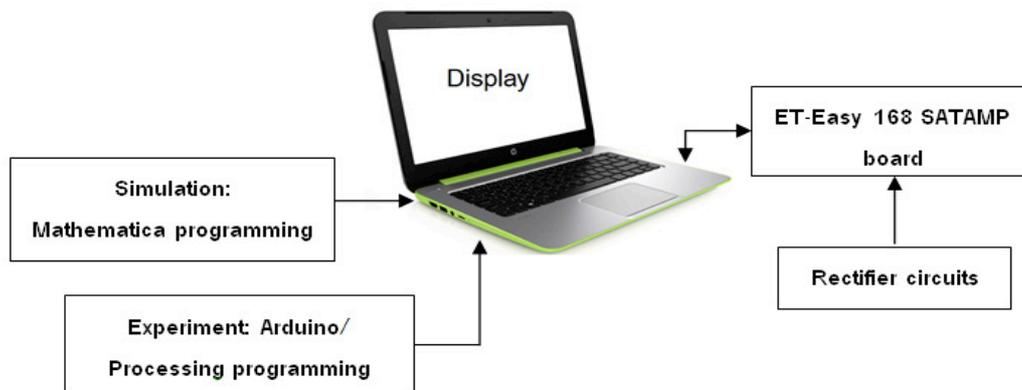


Figure 5. The rectifier circuit experiment set system

The rectifier circuit experiment set is shown in Fig.5 and Fig.6. The processes in developing ET-Easy 168 STAMP board are connected to a computer notebook via a USB port and the output voltage is connected to analog pins of ET-Easy 168 SATAMP board. Arduino1.5.7, Processing 2.2.1 and Mathematica9 are assigned to be the software of the experiment set.

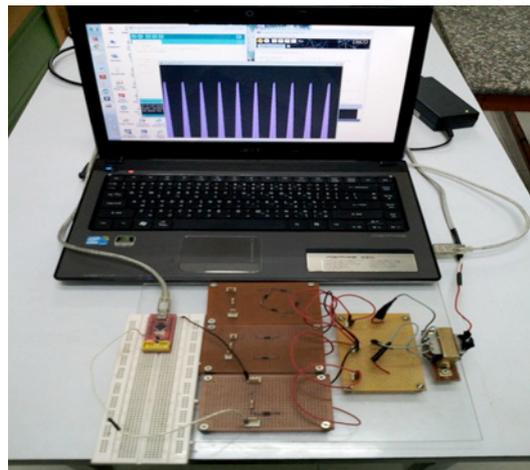


Figure 6. The rectifier circuit experiment set

2.2.3 Programming experiments

The Arduino program is used to read the output voltage of rectifier circuits and sends the results back to the computer serially in Fig.7. The Arduino board has a circuit inside called an analog-to-digital converter that reads this changing voltage and converts it to a number between 0 and 1023. This yields a resolution between readings of: 5 volts/1023 units or, 0.00488 volts (4.88 mV) per unit. The time delay to read each value of the voltage output equals the time period voltage output.

```

Arduino IDE: _5time | Arduino 1.5.7
File Edit Sketch Tools Help
...
long timestart;
long timestop;
void setup ()
{
  Serial.begin(9600);
}

void loop ()
{
  timestart=millis();
  int x=0;
  RepeatPrint:
  Serial.println(analogRead(A1));
  delay(10);
  x++;
  if(x>550)goto StopPrint;
  goto RepeatPrint;
StopPrint:
  timestop=millis()-timestart;
  Serial.println(timestop);
  while(1);
}

Serial Monitor: COM10
0
0
0
21
56
113
155
223
276
348
405
470
522
580
620
677
726
765
779
788
792
799
801
805
795
782
745

```

Figure 7. The Arduino Program

Processing Program displays the output voltage vs. time in real time graphs in Fig.8.

```

Processing IDE: Rectifier_Processing | Processing 2.2.1
File Edit Sketch Tools Help
Run
Rectifier_Processing
import processing.serial.*;

Serial myPort; // The serial port
int xPos = 1; // horizontal position of the graph

void setup () {
  // set the window size:
  size(450, 300);

  // List all the available serial ports
  println(Serial.list());
  myPort = ...
  // don't
  myPort.b
  // set i
  backgrou
}
void dra

Serial Monitor: COM4
9

```

Figure 8. The Processing Program

This example of Mathematica9 program is later analyzed by drawing a graph showing the relation between the output voltage and the duration of time and simulation graph theory. The half-wave program shown in below.

```

Vs = 3.10;
Vinrms = Vs;
Vinpeak =  $\sqrt{2}$  Vinrms;
Vloadpeak = Vinpeak - 0.7;
f = 50 ;
T =  $\frac{1.0}{f}$  // N;
Omaga = 2  $\times$   $\pi$   $\times$  f;
Plot[Vinpeak  $\times$  Sin[Omaga  $\times$  t], {t, 0, 5 T}, PlotStyle  $\rightarrow$  {Black, Thickness[0.0053]},
PlotRange  $\rightarrow$  {{0, 5 T}, {Vinpeak, -Vinpeak}}, LabelStyle  $\rightarrow$  Directive[{"Arial", 16}],
AxesLabel  $\rightarrow$  {"t(s)", "Vs(V)"}, GridLines  $\rightarrow$  Automatic]
HalfWaveThe = Plot[If[Vloadpeak  $\times$  Sin[Omaga  $\times$  t] < 0, 0, Vloadpeak  $\times$  Sin[Omaga  $\times$  t]],
{t, 0, 5 T}, PlotStyle  $\rightarrow$  {Red, Thickness[0.005]}, PlotRange  $\rightarrow$  {{0, 5 T}, {Vinpeak, 0}},
LabelStyle  $\rightarrow$  Directive[{"Arial", 16}], AxesLabel  $\rightarrow$  {"t(s)", "Vout(V)"},
GridLines  $\rightarrow$  Automatic]
HalfWaveExp1 = ListPlot[Import["D:\\T\\Halfwave1.xlsx", "Data"], Joined  $\rightarrow$  True,
PlotRange  $\rightarrow$  {{0, 5 T}, {Vinpeak, 0}}, PlotStyle  $\rightarrow$  {Blue, Thickness[0.053]},
PlotRange  $\rightarrow$  {{0, 5 T}, {Vinpeak, 0}}, LabelStyle  $\rightarrow$  Directive[{"Arial", 16}],
AxesLabel  $\rightarrow$  {"t(s)", "Vout(V)"}, GridLines  $\rightarrow$  Automatic]
Show[HalfWaveThe, HalfWaveExp1]

```

2.2.4 The supplemental Physics lesson

The supplemental physics lesson was designed based on the Constructivism Approach for students and teachers in order that the students chosen as a sample group would have their handbooks for the experiments and teachers were able to employ them in writing their lesson plans.



Figure 9. The students at Nakhon si Thammarat Rajabhat University of Thailand are doing an experiment with rectifier circuits

3 RESULTS

The rectifier output waveform, V_{out} vs. time in real time graphs are in the left hand figures which are the results of Processing 2.2.1 and the right hand figures are the results of Mathematica9 graphs in Fig.10-12 below.

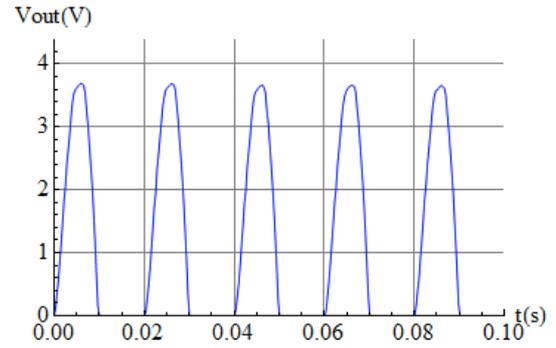
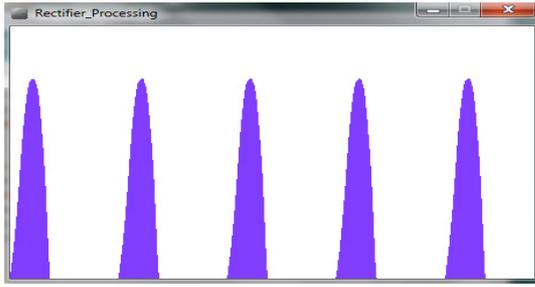


Figure 10. Half-wave

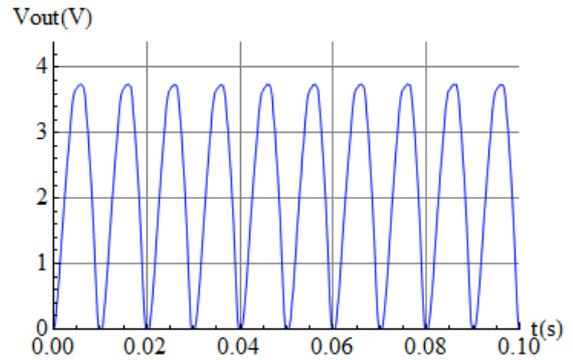
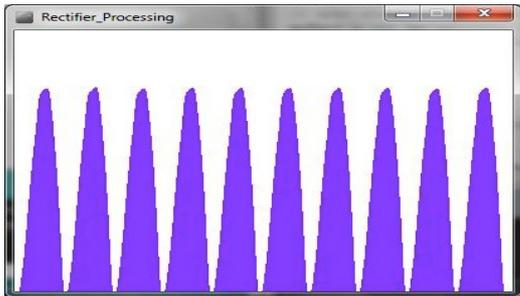


Figure 11. Center-taped full wave

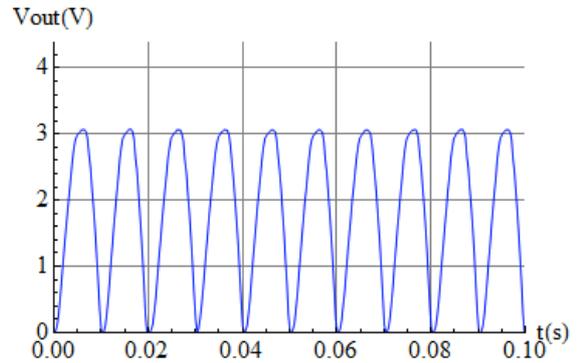
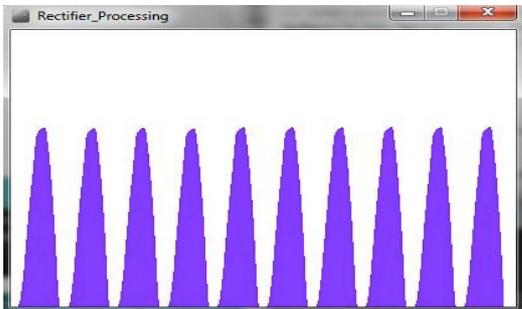


Figure 12. Full-wave bridge

The dc output voltage of the three rectifiers can be calculated as Table 1. Comparison of measured results and theory results are shown in Table 2.

Table 2. Comparison of measured results and theory results

Rectifier Type	Measured results (V)			Theoretical results (V)		% Error, V_{dc}
	$V_{s(peak)}$	$V_{out(peak)}$	V_{dc}	$V_{out(peak)}$	V_{dc}	
Half-wave	4.3841	3.6711	1.1681	3.6841	1.1722	0.3498
Full-wave (center tap)	8.7681	3.7043	2.3573	3.6841	2.3444	0.5502
Full-wave (bridge)	4.3841	3.0378	1.9331	2.9841	1.8990	1.7957

The measured results (blue line) are then compared with the theory calculation results (red line) by plotting graphs. The output voltage of rectifier circuits is accurately relevant to the theory calculation in Fig. 13-15.

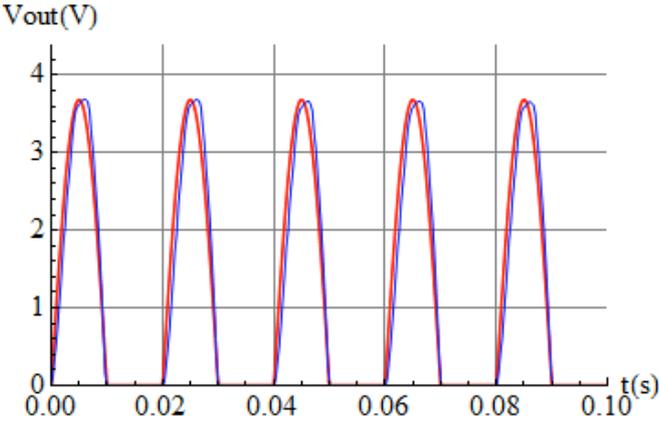


Figure 13. Half-wave

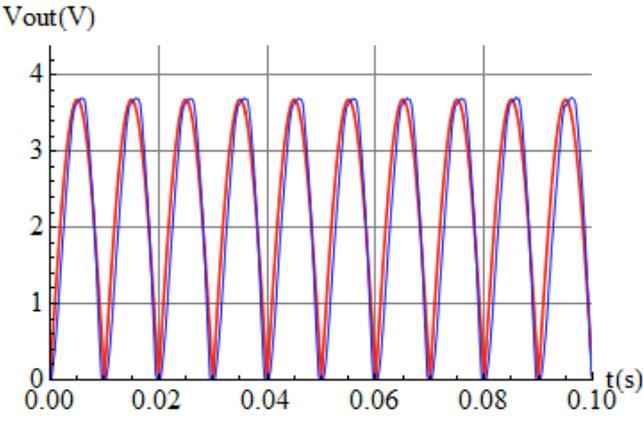


Figure 14. Center-taped full-wave

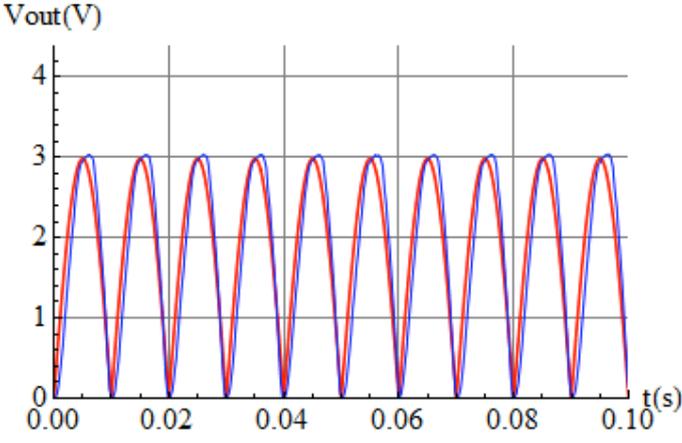


Figure 15. Full-wave bridge

4 DISCUSSION

The experiment set of rectifier circuits using a computer interface with ET-Easy168 Stamp could be used to teach and learn physics. MBL tools help students analyze their data quickly and efficiently. Students can spend more time interpreting their graphs, studying the relationships between the variables, and understanding the physics concepts being investigated [10]. An ET-Easy168 Stamp board has low cost [5] This experiment set can be used instead of an oscilloscope which is much

more expensive. Besides, the students are able to practice plotting graphs of the output waveform of a half-wave rectifier, a center-tapped full-wave rectifier, and a full-wave bridge rectifier, and they are able to compare the output voltage with the theoretical calculations. We found that the time delay to read each value of the voltage output equals the time period voltage output. For example, if the AC line voltage has a frequency of 50 Hz, the input period equals 20 ms and the period of half-wave equals 20 ms too. Thus the time delay to read each value of the voltage output equals 20 ms, 40 ms, 60 ms and so on.

5 CONCLUSION

The experiment set of rectifier circuits using a computer interface with ET-Easy168 Stamp was designed, developed, and tested for its output. The output voltage of rectifier circuits is accurately relevant to the theory calculation of a half-wave rectifier, a center-tapped full-wave rectifier, and a full-wave bridge rectifier. When the result was compared with that of theory calculation, there was an error of 0.3498 %, 0.5502 % and 1.7957 % respectively. When the experiment set was tested in classes with Constructivism Approach, students paid full attention to their experiments and performed their experiments actively. One noticeable advantage is that students could repeat the experiment as many times as they needed in shorter time to observe real time graphs. Therefore it might be a changing point that physics experiment is not difficult anymore. The experiment set of rectifier circuits was tested in physics classes for 12 physics students in Nakhon si Thammarat Rajabhat University of Thailand. The satisfaction of the purposive samples to their learning activity is at a high level and their pre-test and post-test scores are 5.0 and 88.6 % respectively.

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