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SQUARE WAVE GENERATOR CIRCUIT ANALYSIS USING MATLAB APPROACH

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Abstract

Oscillator is defined as an electronic circuit which is designed to be a signal wave generator or generator of other periodical waves. Further, there are some basic forms of oscillator wave, which are 1) square wave, 2) triangle wave, 3) sawtooth wave, and 4) Sinusoida. Yet, each of the wave has its own characteristic. However, this research paper's scope is analyzing square wave with Op-Amp version. In fact, this is a paper of experimental research whose objective is to compare the result achieved through manual calculating with a signal displayer of square wave oscillator especially with 1) Oscilloscope signal, 2) some kinds of software of electrical engineering, and 3) Matlab approach. Finally, the result yielded by this research is that there is a significant difference among those simulation renders.

Keywords: Electronic Software, Matlab, OP-AMP, Square Wave Generator

INTRODUCTION

Unwittingly, electronics technology nowadays has been growing so rapidly. Referring back to the past, the prototype of every type of electronic tool which was launched earlier was probable to come up in a big size, which, for sure, needed so many electronic software that it would consume much energy. Hereby, the today's electronic stuff is designed in a way which it is minimalist, smart, and energy saving. Therefore, the very booming electronic system that is widely used nowadays is switching the Direct Current energy to be Alternating Current. Yet, to switch the energy to the Alternating Current energy the circuit used is called Oscillator.

Oscillator is an electronic circuit whose function is as a signal generator that switches the DC voltage to be pulse wave, yet the switching the cycle to be per second is namely oscillator frequency. Furthermore, there are four basic types of oscillator wave, which are sinus wave, square wave, sawtooth wave, and triangle wave [1] [2]. However, this paper concerns square wave. Square wave, in fact, can be called Astable Multivibrator [3]. To help understand, the following is the principle of Astable Multivibrator:

> "Astable Multivibrator is a two stage switching circuit in which the output of the first stage is fed to the input of the second stage and vice versa. The outputs of both the stages are complementary. This free running multivibrator generates square wave without any external triggering pulse. The circuit has two states and switches back and forth from one state to another, remaining in each state for a time depending upon the discharging of a capacitor through a resistor".

This research is referring to a tupe experiment [19] entitled "Comparative Study of Different Spice Software's Using Astable Multivibrator in Different Spice Software". Still,

this research functions IC 741u as the square wave /astable multivibrator generator, and then it is simulated to many kinds of PSPICE software, some of which are PSpice, B2Spice, TOPSpice, TINA, and circuit maker. Further, each kind of software mentioned has its own feature, still each of the simulation shows the same result. Nevertheless, this research focuses only on the use of Pspice and is tried out by the use of oscilloscope, which has not yet been tried before because basically, software only holds its role is to ease the circuit, while the simulation disregards the real condition [20].

Moreover, in the experiment, the researcher chooses IC OP-AMP 741 as the square wave generator. Next, to analyze the signal, manual calculating with oscilloscope display will be used, and then the result is compared to electronic software which the analysis of signal uses Matlab 2012 version approach. To assume, the approach using Matlab is better than other approaches due to its program complexity in numerical [5].

Thus, some research problems are set up, which are (1) Whether there is any difference between calculating manually and the real condition stated in the form of oscilloscope or not, (2) Whether there is any difference between using Matlab and other kinds of electronic software or not, (3) Whether there is any difference between the use of Matlab approach and real condition using oscilloscope or not.

Due to the research problems above, the research objectives are (1) to prove whether there is any difference between manual calculating and real condition stated in the form oscilloscope, (2) to know whether there is any difference between using Matlab and other kinds of electronic software or not, (3) to explain whether there is any difference between the use of Matlab approach and real condition using oscilloscope or not.

1.1   MATRIX LABOLATORY (MATLAB) APPROACH

MATLAB is one of software brands developed by Mathworks.Inc.. Since it was firstly launched in December 1996, which was the MATLAB 5, it has been 24 times revised, thus the latest version is R2012b (MATLAB 7.13) [6].
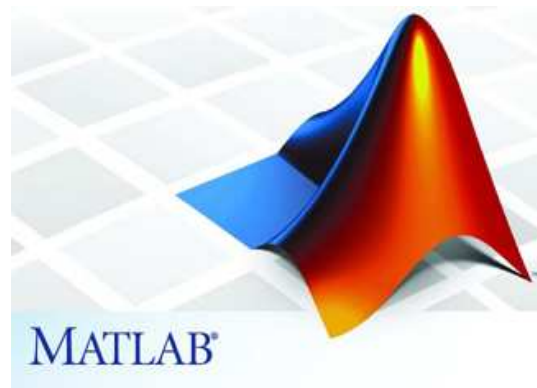

Figure 1. Matlab Software

MATLAB is one of computer programs that is capable to solve mathematical issues technically. Further, the user can use its ability to analyze any problem of numerical computation or matrix based problems quickly and accurately [5]. Moreover, Matlab can be used and applied to many disciplines of science, some of which are Geography, Biology, Informatics and Electronics, Mechanics, and Mathematics. Therefore, the following will give further information about Matlab's superiority:

1. High-Level Language matrix/array language for technical computing
2. Development environment managing code, files and data Interactive tools for iterative exploration, design, and problem solving

3. Mathematical functions for linear algebra, statistics, Fourier analysis,
4. filtering, optimization, and numerical integration
5. 2-D and 3-D graphics functions for visualizing data, Matlab is good to draw any types of graphic so that users can visualize any complex data and functions empunyai kemampuannya untuk menggambarkan berbagai jenis grafik, sehingga user bisa memvisualisasikan data dan fungsi yang kompleks.
6. Tools for building custom graphical user interfaces

To speak about predictions, Matlab is predicted to still be popular by the following years because of the expert complexity of the program, as a quote says. "It has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming"[7]. Malab, in fact, has been widely implemented in the field of technology research, for instance   processing signas [8], dealing with matrix cases [9], simulating controls and systems [10] [11] [13] [15], teaching technology [12] [17], integrating with other technology applications [14],and other applications.

1.2   SQUARE WAVE GENERATOR
1.2.1 Basic Oscillator
Before discussing square wave oscillator further, the bases of oscillator will come in prior. The following figure 2 shows sets of oscillator's amplifier as well as feedback, power supply, and frequency determining. The principle is actually straightforward, that first of all, a signal input is amplified by the amplifier. Then, it is fed back through the feedback. To make an isolation occur, the feedback is to have phase and appropriate value.
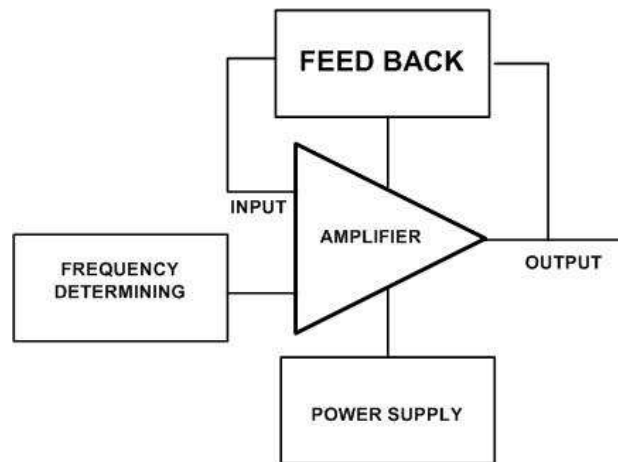

Figure 2. Main Component of Feedback Oscillator

In fact, in the implementation so many square waves may be found, for example in (1) an inverter to heat a small resistive load and a fluorescent lamp, (2) a signal for generator, and any other electronic circuits. Actually, the name of astable multivibrator is derived from its characteristic that there are no stable states in this circuit.
The circuit of square wave generator can be done using IC 74,1 like what the circuit gallery uses to its project [16] "A wide range square wave generator using IC uA741 uses positive feedback for Schmitt trigger action and negative feedback for timing of the wave form". Then, the circuit designed by Kartika [1], the oscillator uses R-C network as the frequency determiner and two resistors as thresholds. Next, the research is done by Tupe [19], which the circuit is in the following figure.
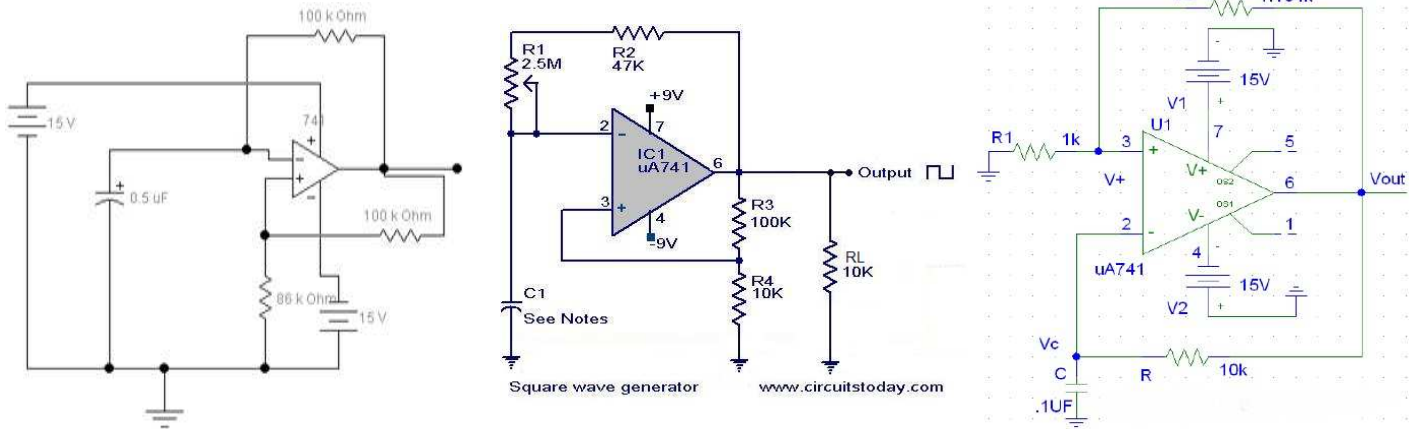
Figure 3. Square Wave Generator Circuit using OP-AMP 741 [1] [16] [19]

1.2.2 Square Wave Generator Theory
    The following figure shows two sets of feedback, which are R-C network as frequency determiner and two resistors as threshold determiners.

1. R1 = 100kΩ
2. R2 = 100Ω
3. R3 = 100Ω
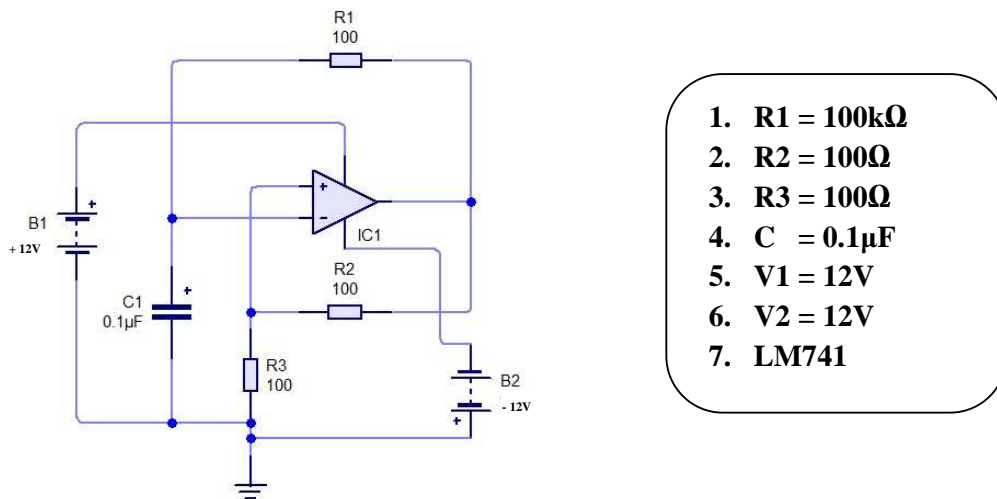4. C   = 0.1µF
5. V1 = 12V
6. V2 = 12V
7. LM741

Figure 4. Square Wave Generator Circuit Used in This Research

    R2 and R3 components are the circuit that divides the voltage and gives V reference (VRef) value at the non inverting input so that the circuit can be the voltage level detector. Thus, the threshold of +V and –V is determined by R2 and R3, which is stated in the following formula:

$$+V = \frac{R3}{R3 + R2} \cdot (+Vsat) \dots\dots\dots\dots\dots\dots\dots\dots \{1\}$$

$$V = \frac{R3}{R3 + R2} \cdot (Vsat) \dots\dots\dots\dots\dots\dots\dots\dots \{2\}$$

    From figure 4, it can be known that the way of the circuit working is that when the circuit is supplied by the input, the current is flowing out from the output of Op-Amp to the capacitor through R1. Firstly, the capacitor is not loaded so that the voltage is 0, and then it is

filled thus the voltage increases slowly exponentially until it reaches Vout. Output Op-amp will be + βV_{Sat}, and then the V_{Ref} at the non inverting input will be in the positive threshold voltage +$V_{Threshold}$ (+VT). Yet, when the capacitor voltage exceeds +VT so that the output of Op-amp will shift to the condition in which it is –βVsat. So now, V_{Ref} is at the input of non-inverting that it is at the negative threshold voltage or –VT. On the other hand, the capacitor now is filling in the opposite current which flows to –βVsat. Therefore, when the capacitor descends until below-VT, the output of op-amp will return to its normal condition and Vout will return to be +βVsat. In this particular case, one cycle has been completed and will always keep on ascending and descending regularly.

Let t = 0 be the instant when Vc = VLT = -βVsat
Therefore, the voltage across the capacitor during charging is given by

$$Vc(t) = Vsat - (Vsat + \beta sat)\, e^{-t/RC} \quad\quad \{3\}$$

Let T1 is the period for the first half cycle of the square wave i.e. t = T1

$$Vc(t) = +\beta Vsat \quad\quad \{4\}$$

$$\beta Vsat = Vsat - Vsat\,(1 + \beta)\, e^{-T1/RC} \quad\quad \{5\}$$

$$\beta Vsat = Vsat - Vsat\,(1 + \beta)\, e^{-T1/RC} \quad\quad \{6\}$$

During the discharging of the voltage across the capacitor , it can be expressed as it is below with t = 0 being the instant when:

$$Vc(t) = +\beta Vsat \quad\quad \{7\}$$

$$Vc(t) = -Vsat - (-Vsat - \beta sat)\, e^{-t/RC} \quad\quad \{8\}$$

Let T2 is the successive half cycle of the square wave that is the discharging will end at t = T2

$$Vc = -\beta Vsat \quad\quad \{9\}$$

$$T2 = RC \ln \frac{1+\beta}{1-\beta} \quad\quad \{10\}$$

$$T = T_1 + T_2 \quad\quad \{11\}$$

$$T2 = 2RC \ln \frac{1+\beta}{1-\beta} \quad\quad \{12\}$$

$$T2 = 2RC \ln \frac{1+2R1}{R2} \quad\quad \{13\}$$

$$T = 2RC \text{ for } R2 = 1.164R1 \quad\quad \{14\}$$

Then the frequency f_0 is given by

$$f0 = \frac{1}{T} = \frac{1}{2RC}$$

The square wave frequency can be adjusted by switching different capacitors and by contentiously varying R.

IMPLEMENTATION
This research is conducted in a laboratory with controlled system, at Electrical Department of State University of Malang for 21 up to 28 November 2012. The writing of this paper is actually a course project on signal processing system entitled "Analisa Pembangkit Sinyal Kotak Menggunakan Matlab R2012b". However, the analysis done was only bounded up by the use of Proteus software rather than Matlab. Yet, the result shows that the calculation by using Matlab is matched with the manual calculating result, while the calculating using Proteus shows the same result with minor difference. It is caused by the characteristics of each component of the software used.

The research mentioned in prior had been revised and completed in some days' grace before 25 February 2013. In fact, the researchers use more than three kinds of software to analyze in the newest research, which are MultiSIM, Proteus, Circuit Wizard, and YENKA. Not to mention, the following will explain further how the steps in the experiment are implemented.

1. **Analyzing Circuits Using Manual Calculation**
   The first thing first is that to calculate manually, in accordance with the formula of fourteen equation that can be calculated in such a way shown below:

$$f out \frac{1}{2.R1.C}$$

$$-Vpeak = \frac{R3}{R3 + R2} \cdot -Vsat$$

$$+Vpeak = \frac{R3}{R3 + R2} \cdot +Vsat$$

Note:		
f Out	:	Output Frequency
-V$_p$	:	Peak Under Voltage
+V$_p$	:	Peak Top Voltage

So, the following shows the results of Manual Calculation of **f Out, -V$_p$, +V$_p$** is:

$$fOut = \frac{1}{2 \cdot R_1 \cdot C}$$
$$-Vp = \frac{R_3}{R_3 + R_2} \times -Vsat$$
$$+Vp = \frac{R_3}{R_3 + R_2} \times +Vsat$$

$$fOut = \frac{1}{2 \cdot 100k\Omega \cdot 0.1\mu F}$$
$$-Vp = \frac{100\Omega}{100\Omega + 100\Omega} \times -12V$$
$$+Vp = \frac{100\Omega}{100\Omega + 100\Omega} \times +12V$$

$$fOut = 50Hz$$
$$-Vp = -6V$$
$$+Vp = +6V$$

2. **Testing Circuits Using Oscilloscope**
   This particular testing is administered at Electronic Laboratory, G4 building of Electrical Engineering, Faculty of Techniques of State University of Malang on 25 February 2013. To administer the test, the following components are important: Jumper Cable, R100Ω, R100KΩ, C0.1μF, Osciloscope, Power Supply, MainBoard and IC 741uA. Since the existence of IC or other components may cause the imperfect working, this experiment has been tried out for five times just to show the approximate value which could be seen through oscilloscope.

3. **Comparing Circuits Using Electrical Software**

A number of simulation of this comparative experiment used are MultiSIM, Proteus, Circuit Wizard, and YENKA. Then, the circuit is put in accordance with the schematic so that the output signal can be measured using oscilloscope in those kinds of software.

Comparing circuits using Matlab Approach
Figure 5 shows a Matlab script, which covers the input variable, frequency determining, maximal peak voltage, and minimal peak voltage.

```
%Variable of declaration
R1=input(input value R1 :'); R2=input(input value R2 :'); R3=input(input value R3 :');
C=input(input value C :');
v=input(input DC voltage value = ');
%--------------------------------------%
t=0:0.00001:0.05;
x=[ones(1,5001)];
fOut=1/(2*R1*C);                                    % Calculation of Frequency
vtP=(R3/(R2+R3))*v;                                 % Calculation of maximal peak Voltage
vtN=(R3/(R2+R3))*-v;                                %Calculation of minimal peak voltage
y=vtP*square(fOut*2*pi*t);                          %generating square signal

%Plotting input signal
subplot(2,1,1);
plot(t,v*x);                                        %Plotting square signal
title('Sinyal Masukan ');
xlabel('time (t)');
ylabel('voltage (v)');
axis([0 0.05 -v-3 v+3]);                            %Determining x and y axis

%Plotting output signal
subplot(2,1,2);
plot(t,y);
title(output signal ');
xlabel('time (t)'); ylabel('voltage (v)');
axis([0 0.05 -vtP-3 vtP+3]);                        %determining x and y axis
```

ANALYSIS
The analysis of circuit of manual calculation yields a value of frequency 50 Hz and threshold voltage which occur to be +6V and -6V. Meanwhile, the oscilloscope has shown a different value, see figure 6 and 7 below.

Figure 6. Output with V/Div = 5 V/Div
and Time/Div 20ms/Div

Figure 7. Output with V/Div = 2 V/Div
and Time/Div 50 ms/Div

In the experiment done, the researcher uses IC UA741 as Op-Amp. In the circuit arranged on a proto-board, the researchers measure the threshold voltage as well as its frequency. Further, the threshold voltage yielded is 4V for positive cycle and -6,4V for the negative one, while the frequency yielded is 40Hz (150ms for positive cycle and 100ms for negative cycle). The difference is caused by the existence of the characteristic of each component, still the real

condition, basically, is always different from the simulation. However, the value yielded in the experiment is approximate. For better understanding, figure 7 and 8 shows the result or output from software for simulation. Eventually, there are two out of four kinds of software which is completed with the signal displayer and VCC-Ground, therefore the two are the software whose output analyzed.
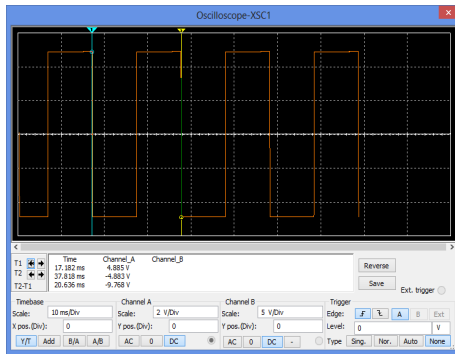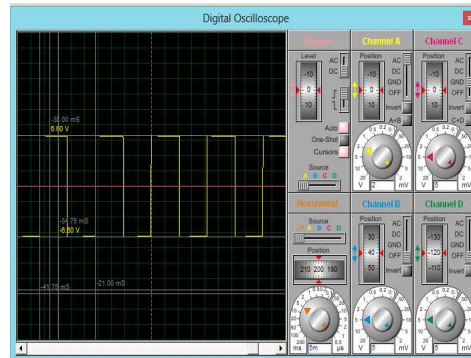

Figure 7. Output Software 1

Figure 8.Output Software 2

Moreover, the experiment shows that there is a difference betweem the result from the simulation with the experiment on real condition. An experiment using software 1 shows the threshold voltage as much as 6,6 V and -6,6V, while the frequency shown is 50,6 Hz (1/T=1/0.02s). Besides, an experiment done to software 2 shows that the threshold voltage is 4,88V and -4,88V, yet the frequency is 50,6 Hz (1/T=1/0.02s). Briefly, from the two experiments above, the threshold voltage from software 1 approximates the theoretical calculation better than the threshold voltage from software 2. On the other hand, the experiment to software 2 shows more approximate frequency value rather than the experiment from software 1. Meanwhile, figure 9 below shows the plotting program result of Matlab.
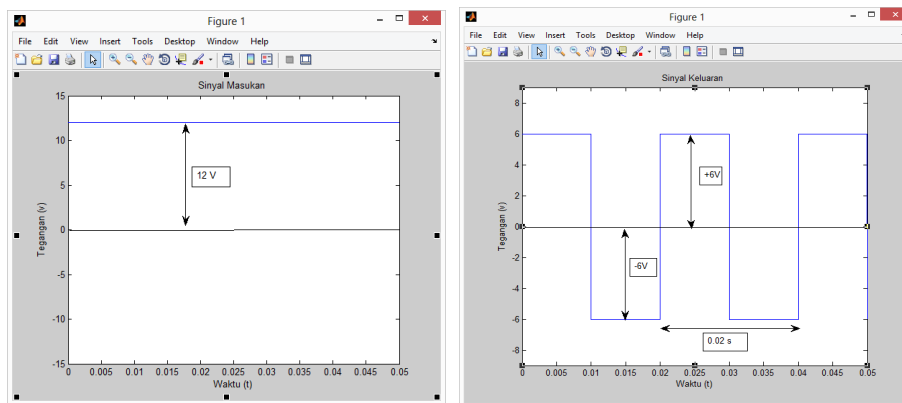

Figure 9. Matlab Input and Output Signal

In brief, there is a difference among the result of experiment of software, analysis of manual calculation, real oscilloscope, and Matlab. In fact, Matlab is more precise and ideal according to the theoretical calculation disregarding the characteristics of the components just like the other simulations and experiment on real condition. For more details, see the difference in table 1 below:

No	Name	f	Input	+Vin	-Vin
1	Software 1	47,6Hz	12V	6,6V	-6,6V

2	Software 2	50,6Hz	12V	4,88V	-4,88V
3	Software 3	-	12V	-	-
4	Software 4	-	12V		-
5	Manual Calculation	50Hz	12V	6V	-6V
6	Real Worklab	40Hz	12V	4V	-6,4
7	Matlab	50Hz	12V	6V	-6V

Table 1. Compared input and output signal from the experiments

DISCUSSION

Understanding this research deeper, it is about not only proving the analysis of manual calculation and some kinds of software but also to relate this research to any field, like education. For example, a teacher of school or university applies the result of the research to the teaching and learning process, so he or she can 1) asks students to analyze the real calculation using software simulation, 2) asks students to choose which of the software is fun to be used for learning electronics, 3) asks students to choose which of the software is more appropriate to layout PCB (Printed Circuit Boards) and 4) asks students to be diligent in dealing with numerical analysis with manual calculation.

CONCLUSSION AND SUGGESTION

In conclusion, every kind of software has its own strength and weakness, which may meet the need of users. First, Circuit Wizard software is interactive for educational use. There we can find a displayer of current behavior, voltage, and the logics of electronic circuit designed. Still, users can see in a complete enough presentation on how a circuit system and components work. Besides, an export of schematic to PCB's layout is also presented. However, the writers recommend the use of this software to design an electronic system of prototype of tools. On the other hand, the weakness of this software is at its signal displayer, in which it is still incapable of showing signals maximally due to too many noises.

Second, Yenka is a kind of software which is user friendly and interactive, too. This software provides simulation for not only electronics but also programming, chemistry, physics, mechanics, mathematics, and so on. Thus, it is suitable for beginners who are learning electronics since Yenka gives users the real description of the field. The writers, however, recommend this software to them who intend to learn and deepen the understanding about the basic of electronics or who are no expert in electronic stuff. Still, it has a weakness that is the features provided are still incomplete for simulation use compared to Proteus, which is about to be explained in the next paragraph.

Next, Proteus is the most suitable software for simulation purposes due to the fact that the components are complete that they can simulate even more complex system, for instance microcontroller. Besides, it is also helpful for a work on schematic conversion and lay outing to PCB, as well as MultiSIM. Thus, the writers recommend this Proteus for them who have mastered electronics, either the concept or implementation. Still, it has a weakness which is less interactive, compared to Yenka and Circuit Wizard.

Finally, Matlab is a program that helps users improve their logical thinking in solving algebraic matrix operations and numerical analysis. Recalling the analysis result of all experiments mentioned in preceding sub chapter, Matlab's result approximates the manual calculation result better than other experiments do, for the manual mathematical calculation is inputted directly with the algorithm constructed before. However, users have to comprehend the basic concepts of using this software, including the mastery of coding, before deciding to make a try.
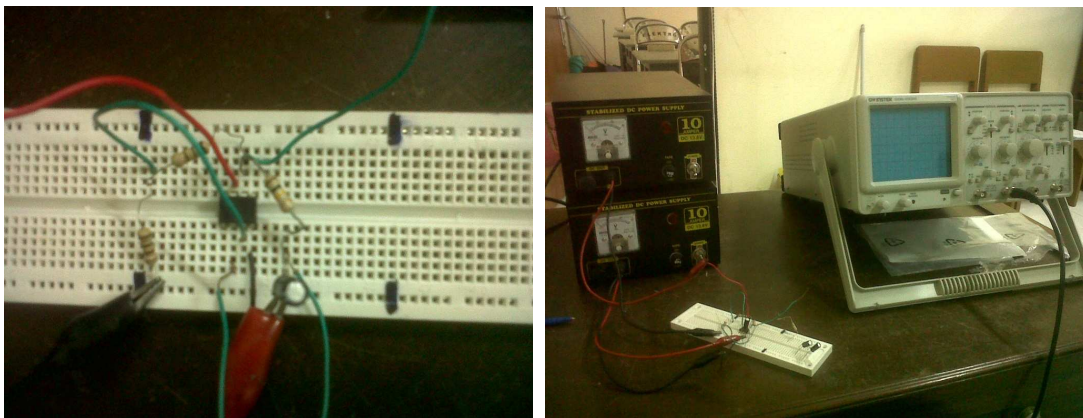
APPENDIX

Figure 10. Electronic Labolatory at Electrical Engineering, State University of Malang

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