Teaching IC Timer through simulation for future STEM teacher

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Abstract. Teaching in the STEM field based on the simulation is the necessary for students to understand the concepts and materials that have been given. This paper presents a simulation performed using IC Timer to generate a square signal using a virtual laboratory circuit wizard simulation software. In conducting the simulation, there are stages that will be given to students. There are 10 stages that will be explained in the lab experiments section. The method used consists of design for simulation. With this paper, it is expected that future teachers can provide simulated teaching to their students well. The results obtained in the simulation using this IC Timer are square signals that can be generated by the IC Timer circuit, and the results of frequency calculations, both through theoretical calculations and calculations with an oscilloscope do not show significant results. Teachers can provide teaching to students through simulation with a virtual laboratory first before carrying out practice directly, so students can use real devices properly and can reduce the risk of damage.

1. Introduction
In an age that is increasingly advanced and technology is increasingly developing, the teaching process must follow the times. Educators also began to look for ways and were challenged to teach students by utilizing existing technology, but teaching with technology remains as a challenge for STEM teacher [1]. Learning that only conveys theory is not sufficient to support students' understanding, so that educators (one of which is a STEM teacher) need to provide simulations to their students so that it is easier for them to understand theory of learning given. The learning method through simulation needs to be applied because this method can describe the actual state of a situation, a simplification of a phenomenon in the real world [2]. By doing simulations, students can at least find out a picture of the theory they are learning. Simulation helps students turn an abstract concept to a materialized form. In addition, by adjusting the parameters repeatedly, students can test, compare, and observe the changes of scientific phenomena and understand the influence of extreme values of parameters [3].

One of the simulations that can be taught to students, especially elementary school students, is to create a blinking LED circuit with an interesting circuit wizard software with flashing lights and can generate square signal. Even at the elementary school level, electronic extracurriculars have been found and usually use electrical circuits. To make a multivibrator circuit, the main component we use is IC 555. Compared to the 741 Op Amp and flip-flop circuits, IC 555 is easier to use. IC NE555 components are widely implemented in the field of electronics, including being used to trigger ultrasonic transducers [4], as a timer circuit [5], and converters for charging capacitor banks [6].
This paper proposes a set of materials for STEM teachers, with the topic NE555 (IC timer) which can be used as blanking LEDs, and can form square signals using circuit wizard software. Similar simulations have also been previously done by other researchers using software such as Multism [7], PS-PICE, SIMetrix, and TINA PRO [8]. In this course, there are several stages in the implementation of the simulation which are divided into 10 meetings as stages of educators in teaching IC Timer through the system for students which will be explained in the results section.

2. Methods
The IC NE555 circuit on Figure 1(a) is used as an astable multivibrator circuit in this course which can function as a square wave generator that will continue to beat with a certain duty cycle. This circuit consists of several components including one IC NE555, two resistors and capacitors, one ground, one 9V battery, and 2 Terminal Blocks arranged in a media simulator wizard circuit as shown in Figure 2. The working principle of a monostable circuit is triggered with a high to low logic voltage (less than 1/3 Vcc) on pin-2, the Astable circuit is made to trigger itself [4]. The understanding of this circuit is to utilize the principle of charging and discharging the capacitor through a resistor [9].

The circuit on Figure 1(b) is the circuit in circuit diagram menu on circuit wizard. The circuit is then converted to PCB Layout menu, added battery 9V and Oscilloscope Virtual, then connected to the probe as in the Figure 1(c).

Supporters of learning this course are using virtual simulator software, which is in the practice of astable multivibrator simulation with IC Timer NE555 will be explained through several meetings such as in figure 4. This course contains package materials of square signal and the implementation packaged in 10 meetings are as follows (figure 2):

![Figure 1. Pin diagram (a), Astable multivibrator circuit with IC 555 (b), NE555 IC Circuit arrangement (c).](image)

![Figure 2. Lab experiment.](image)
3. Results and discussion

3.1. Introduction signal and shape of signal

The signal consists of the two kinds, namely digital signal and analog signal. There are several forms of the signal as shown in figure 3. In this simulation, a circuit will be created to generate a square signal.

![Figure 3. Shape of signal](image)

3.2. Theory of calculation F and T

Electrical signals are continuous so that they have a period (T). In this simulation, the period can be seen on the Virtual Oscilloscope, so the frequency (f) of signals can be searched. Periode (T) is the time it takes for one-time vibration, and frequency (f) is the number of vibrations per unit of time within 1s Hertz. Here is a formula of calculation F and T that will be used in the calculation of simulation results:

\[ T = \text{DIV} \times \frac{T}{\text{DIV}} \]

\[ T = 0,693 (R1 + 2R2) C1 \]

\[ f = \frac{1}{T} \]

\[ f = \frac{1}{0,693 (R1 + 2R2) C1} \quad \text{or} \quad f = \frac{1,44}{(R1 + 2R2) C1} \]

With a description:

- F = Frequency (Hz)
- R = Resistor (Ohm)
- C = Capacitor (F)
- T = Period (s)

It is expected that students at this step can understand theoretical formulas stipulated for the calculation of the analysis of results.

3.3. Introduction frequency measuring instrument

In this simulation, the measuring instrument used to calculate frequency is a virtual-based oscilloscope (Figure 4). It is expected that students at this step can get to know that frequency measuring instrument by knowing the types and how to use it.

![Figure 4. Oscilloscope virtual on circuit wizard](image)
3.4. Introduction to the electronic components of a square wave signal generator

Square wave signals are commonly used in electronic microcircuits for timing control. The Astable Multivibrator can produce a continuous square wave without an external trigger source to perform the oscillations. The astable multivibrator circuit can be made using three types of electronic components, including Op Amplifier, IC NE555, and BJT transistor. In this simulation, the square wave signal is generated from the astable multivibrator circuit with IC NE555 with other electronic components such as resistors, capacitors, batteries, ground, and oscilloscope. In figure 5, an example of the square wave signal generated in this simulation is shown. At this stage, it is hoped that students will understand the electronic components that can be used for square wave signal generators.

![Square wave on a Virtual Oscilloscope.](image)

**Figure 5.** Square wave on a Virtual Oscilloscope.

3.5. Measuring frequency with measuring instruments

In this simulation, the measuring instrument used to calculate the frequency is the Virtual Oscilloscope, by looking at the results of the signal formed on the Virtual Oscilloscope, then is calculated based on the formula. Here is an illustration of the frequency measurement in this simulation (Figure 6).

![Illustration of the frequency measurement.](image)

**Figure 6.** Illustration of the frequency measurement.

Calculation of F on the oscilloscope:

\[ T = \text{DIV} \times \frac{T}{\text{DIV}} \]
\[ = 2 \times 25 \text{ ms} \]
\[ = 50 \text{ ms} \]
\[ F = \frac{1}{50 \times 10^{-3}} \]
\[ = 20 \text{ Hz} \]

3.6. Introduction to virtual laboratory simulation media

Doing a practicum, we recommend to use a virtual laboratory (virtual laboratory), which is quite simple in use because it only requires a laptop with the simulator software installed to be used. Virtual laboratories are also considered easy to use, practical, economical, and effective. In this simulation, the software used is the Circuit Wizard. The advantages of the circuit wizard simulator software include the PCB layout feature that makes components look real when simulated, the operation of the circuit wizard is relatively easy, the gallery and its features are quite complete and animated so that they do not get bored when doing practical work, and when operated for a long time, the circuit wizard continues to operate properly. Besides that, the circuit wizard also does not require massive data quota. It is hoped...
that students will be able to understand the circuit wizard features and be able to operate it properly during the simulation.

3.7. Providing simulation practicum modules
After the learning materials are given, before carrying out the simulation, students are provided with a practical module first. To increase students' enthusiasm in learning so that they do not get bored quickly when studying the module, a practical simulation module is given, which is attractively packaged in the form of a PPT with the right choice of fonts, colors, and animations. The practical module consists of a cover, practical objectives, theoretical basis, and the formula used for the simulation, work steps equipped with illustrative images of the circuit, and examples of calculations that make it easier for students to carry out simulations. At the end of the module, assignments are given that can improve students understanding. By giving this module, students are expected to be able to carry out practical simulations more easily.

3.8. Simulation of making square wave signals with 555 Timer IC
After the learning materials and practical modules are given to students, students are then given a simulation project to make a square wave signal from a series of astable multivibrators with IC Timer 555. During the simulation, students can discuss and ask educators if they experience problems. Regarding the details of the simulations carried out, it has been explained in section 2. Simulation Design. At this stage, students are expected to be able to understand the material that has been given and be able to implement it in a simulation. Through simulation, students are given an overview when carrying out practical work on hand.

3.9. Analysis and observation simulation
After the circuit simulation was complete, analysis and observation must be carried out from the result of the simulation. The result of this simulation is a signal and the form of the signal like a square and that has been successfully generated with IC NE 555 circuit. Besides that, the resulting calculation from the frequency on the Virtual Oscilloscope with the theoretical calculation only have a small difference. This is shown by the result of observation and calculation during the simulation (Table 1 and Figure 7):

| NO | R1   | R2   | C1 & C2          |
|----|------|------|-----------------|
| 1  | 1 kΩ | 1 kΩ | 10 µF & 10 nF   |
| 2  | 1 kΩ | 1,5 kΩ| 10 µF & 10 nF   |
| 3  | 1 kΩ | 2 kΩ | 10 µF & 10 nF   |
| 4  | 1 kΩ | 2,7 kΩ| 10 µF & 10 nF   |
| 5  | 1 kΩ | 3,3 kΩ| 10 µF & 10 nF   |
| 6  | 1 kΩ | 4,7 kΩ| 10 µF & 10 nF   |
| 7  | 1 kΩ | 6,8 kΩ| 10 µF & 10 nF   |
| 8  | 1 kΩ | 8,2 kΩ| 10 µF & 10 nF   |

Table 1. Observation of the box signal generated on the Virtual Oscilloscope.
At this stage, students are expected to be able to observe the square signal generated by Virtual Oscilloscope to find a frequency, after that student can calculate and enter it in to the observation table as in the following table 2.

**Table 2. Observation of the output frequency on the NE555 timer circuit with R1 = 1KΩ.**

| No | R1  | R2  | C1 & C2 | f Calculate | f Oscilloscope f=1/T | Difference | D = [(R1 + R2) x 100] / R1 + R2 |
|----|-----|-----|---------|-------------|-----------------------|------------|---------------------------------|
| 1. | 1 kΩ| 1 kΩ| 10 µF & | 1.44       | T = 22.5 ms f = 0.6 Hz | 48 - 44.4 | (10^2 x 10^3 x 100) / (10^3 x 2x10^3) = 66,6 % |
|    |     |     | 10 nF   | 1.44       | T = 1/22.5 ms f = 0.3 Hz | 3,6 Hz     |                                                |
| 2. | 1 kΩ| 1.5 kΩ| 10 µF & | 1.44       | T = 30 ms f = 0.6 Hz | 36 - 33,3 | (10^4 x 1.5 x 10^3 x 100) / (10^6 x 2x10^3) = 62,5 % |
|    |     |      | 10 nF   | 1.44       | T = 1/30 ms f = 0.3 Hz | 2,7 Hz     |                                                |
| 3. | 1 kΩ| 2 kΩ| 10 µF & | 1.44       | T = 40 ms f = 0.6 Hz | 28,8 - 25 | (10^4 x 2 x 10^3 x 100) / (10^6 x 2x10^3) = 60 % |
|    |     |      | 10 nF   | 1.44       | T = 1/40 ms f = 0.3 Hz | 3,8 Hz     |                                                |
| 4. | 1 kΩ| 2.7 kΩ| 10 µF & | 1.44       | T = 47.5 ms f = 0.6 Hz | 22.5 - 21 | (10^4 x 2.7 x 10^3 x 100) / (10^6 x 2x10^3) = 57,8 % |
|    |     |      | 10 nF   | 1.44       | T = 1/47.5 ms f = 0.3 Hz | 1,5 Hz     |                                                |
| 5. | 1 kΩ| 3.3 kΩ| 10 µF & | 1.44       | T = 60 ms f = 0.6 Hz | 18.9 - 16,6 | (10^4 x 3.3 x 10^3 x 100) / (10^6 x 2x10^3) = 56,5 % |
|    |     |      | 10 nF   | 1.44       | T = 1/60 ms f = 0.3 Hz | 2,3 Hz     |                                                |
| 6. | 1 kΩ| 4.7 kΩ| 10 µF & | 1.44       | T = 75 ms f = 0.6 Hz | 13,8 - 13,3 | (10^4 x 4.7 x 10^3 x 100) / (10^6 x 2x10^3) = 54,8 % |
|    |     |      | 10 nF   | 1.44       | T = 1/75 ms f = 0.3 Hz | 0,5 Hz     |                                                |
| 7. | 1 kΩ| 6.8 kΩ| 10 µF & | 1.44       | T = 105 ms f = 0.6 Hz | 9,8 - 9,5 | (10^4 x 6.8 x 10^3 x 100) / (10^6 x 2x10^3) = 53,4 % |
|    |     |      | 10 nF   | 1.44       | T = 1/105 ms f = 0.3 Hz | 0,3 Hz     |                                                |
| 8. | 1 kΩ| 8.2 kΩ| 10 µF & | 1.44       | T = 130 ms f = 0.6 Hz | 8,2 - 7,6 | (10^4 x 8.2 x 10^3 x 100) / (10^6 x 2x10^3) = 52,8 % |
|    |     |      | 10 nF   | 1.44       | T = 1/130 ms f = 0.3 Hz | 0,6 Hz     |                                                |
3.10. Finish course
At this stage, students are expected to understand the concept of the Astable Multivibration circuit and be able to apply it as significantly using with the actual tools and materials. The final stage of this practice of making Astable Multivibration circuit is the analysis of the IC Timer 555 can be used in the Astable Multivibration which can generate square signal like during simulation, connecting Astable Multivibration circuit with the battery and the Virtual Oscilloscope via tools called Probe. Furthermore, educators will be estimation based on the success, understanding, and practicing IC Timer 555 concept simulation from the practical report by the student. After that, the educators conveying evaluation of the simulation result to the student, so the student can find out the correct result for their self-evaluation.

4. Conclusion
Teaching IC Timer through simulation can provide knowledge to prospective STEM teachers about how the stages of teaching simulation are good for their students in the future. There are 10 stages used in this course, including 1) Introduction to signals and signal forms, 2) The theory and calculation of the f and T, 3) Introduction to frequency measuring instruments, 4) Introduction to electronic components of square signal generator 5) Measuring frequency with measuring instruments, 6 ) Introduction to the virtual laboratory simulator media, 7) Providing practical simulation modules, 8) Simulation of making square signals with IC Timer NE555, 9) Analysis and observation of simulation results, and 10) Finish course. With this IC Timer simulation, students will understand the concept and implementation NE555 on circuit and know an overview of the practicum that will be carried out with the on hand device, so that it can reduce the risk of damage.

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