# Novel Learning Platform of Wave Superposition using Music: An Architecture Design

Dwi Edi Setyawan[1], Billy Montolalu[2], Ardiansyah Al Farouq[3], Ubaidillah Umar[4], and Helmy Widyantara[5]

[1,2,3,4,5]Computer Engineering Department, Institut Teknologi Telkom Surabaya, Surabaya, Indonesia
ediset@ittelkom-sby.ac.id, billy@ittelkom-sby.ac.id, alfarouq@ittelkom-sby.ac.id, ubaidillahumar@ittelkom-sby.ac.id, helmywid@ittelkom-sby.ac.id

**Abstract.** This paper discusses about sound generators which produce sounds through superposition of several sine waves such that it may be composed as a musical melody. The primary purpose of this research is to employ sound generators as learning media for electrical engineering students, especially in understanding of electrical waves including its parameters. This is motivated by situation that common learning methods of waves often simply utilize function generator then display the results to the oscilloscope which may lead to unattractive learning. This paper overviews several applications of sound generators elucidated in the literature review section. An appropriate and simple architecture design is proposed by which built from a microcontroller as the main processor and some passive RC integrator circuits to convert square waves into sine waves. The algorithm deployed in the microcontroller contains pitch scenario and durations between changing pitch on four sine waves that have been generated. Meanwhile, in making of the algorithm, the ability to compose pitch sound scenarios is required to yield a good rhythm. Finally, the use of this practicum tool as a learning media is discussed as well.

**Keywords:** Sine wave, Superposition, Sound Generator, Music, Education 4.0

## 1 Introduction

Basic Physics is studied by most electrical engineering students. In Basic Physics, engineering students are required to understand electrical waves. The easiest waves to learn are sine waves. Some examples of sine waves in everyday life are the AC (Alternating Current) electrical line, Waves on the carrier frequency of AM radio (Amplitude Modulation) or FM (Frequency Modulation), Sound waves produced by tuning forks, and others. In studying electrical waves, the students generally use an Oscilloscope and Function Generator. In this case, the Oscilloscope functions as a display and measurement of wave parameters. Meanwhile, Function generator functions as an electric wave generator in the low-frequency range of AF (Audio Frequency) to a range of high-

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frequency RF (Radio Frequency). With these two tools, students are required to be able to learn wave parameters such as wave frequency, wave amplitude, wave period, wave phase, wave distortion and so on. This learning method is sometimes very boring. In learning activities, students often observe a wave to simply record the results of measurements of wave parameters without motivation to understand. An appropriate phrase is "Do it and then forget it". In the education world, of course, this is very sad. On the other hand, in the education era 4.0, generation Z students were less interested in formula-based learning methods. There are few researches about learning method aimed to ease the students at understanding the contents of the class. Particularly in learning about wave, the early researches were dominated by an effort to meet the requirements of practicum tools [1], adding feature in practicum tools [2], and effort to create an affordable practicum tools [3].

For this reason, this paper proposes music as a learning media for a student especially when studying electrical waves. Music can stimulate student curiosity in studying electrical waves. For that, a sound generator is needed that can generate electric waves to produce a sweet melody. In this case, the melodic sound of music is produced from the superposition of a sine wave, so that the sound produced is not monophonic but polyphonic.

## 2 Literature Review

This section discusses how sound generators can be built and how to the superposition of sine waves can produce sweet melodies according to the user's wishes. In this case, the selection of simple and proper architecture is very needed. Some architectures example are oscillator-based sound generators, IC (Integrated Circuits) based sound generators, PC (Personal Computer) based sound generators using computers sound cards, mobile device- based sound generators, and microcontroller-based sound generators.

Oscillator-based sound generators are the oldest among the other architectures. This architecture is applied to children's toys for a long time [4], [5]. The disadvantage of using this architecture is required too many electronic components. IC-based sound generators have been proposed to minimize the number of components needed [6]. But along with the development of the microcontroller, this architecture began to be abandoned. A newer IC- based sound generator is using PCM 2904 audio chip with PLL (Phase Locked Loop) technology and can be integrated with PC software [7]. However, this technology is only limited to replacing the function generator which commonly used in laboratories. Sound generator based on mobile devices has been proposed to replace the function generator in the laboratory if damage occurs [8]. However, the mobile device is not suitable to be repackaged into the function generator product. Microcontroller-based sound generators have also been applied to vehicles [9]. This architecture has a disadvantage, that is requiring a recording process because it uses MP3 or WAV audio formats that are stored in microSD (micro- Secure Data). Even so, the architecture of using a microcontroller is very beneficial because the operating system is simple and can stand alone. Thus, it can be packaged in one practicum module package. Or it can also be packaged in one product package for doorbell with custom sound, marketing tools for road sellers, and ultrasonic mosquito repellant. So that the architecture chosen in this study is a microcontroller-based sound generator.

## 3 Architecture Design

### 3.1 Microcontroller Based Sound Generator

Sound generators can be built from a microcontroller minimum system. In this study, the microcontroller used is Atmel AT Mega 8535 A. Some features of the microcontroller that play an important role are PORT I / O and Timer functions. Figure 1 shows the block diagram of the sound generator architecture proposed. The sound generator block diagram is designed for educational purposes, especially Basic Physics courses on electrical waves chapter.

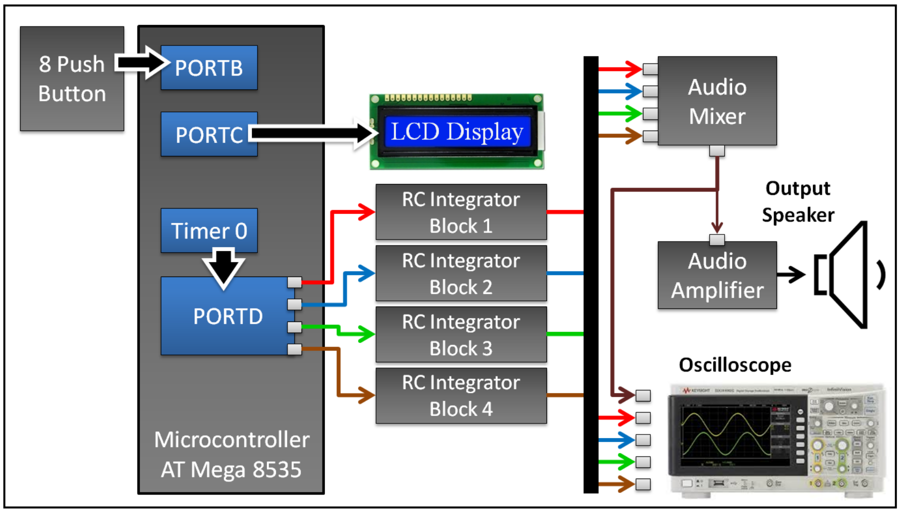


**Fig. 1.**Architecture Design

AT Mega 8535 microcontroller has 4 PORT I / O (PORTA, PORTB, PORTC, and PORTD), each of which has 8 I / O PINs. In this case, only 3 PORTs are used (PORTB, PORTC, PORTD). PORTB is connected with 8 push buttons, in this case, PORTB is used to receive command input from users. PORTC is used fully to display data on a 2 x 16 LCD Display. 4 pins on PORTD are used to produce square waves, while the other 4 pins are not used. 4 PORTD Pins are then connected with 4 passive RC (Resistor-Capacitor) Integrators blocks to convert the square wave generated by the microcontroller into a sine wave. 4 sine waves which generated by the RC integrator block are then mixed using an audio mixer circuit. The audio mixer output is connected to the audio amplifier then feed to the speaker as a sound display. From this speaker sound will be heard the result of the superposition of sine waves. Oscilloscopes are used for students to observe sine waves generated by 4 RC integrator blocks and superposition of them.

### 3.2 Squarewave to Sine Wave Converter

The microcontroller output especially 4 Pin in PORTD (Refer to Figure 1) produce a square wave. To convert a square wave into a sine wave, a conversion circuit is needed. In this study, the circuit used as a converter is an RC integrator. Figure 2 shows the scheme of the RC integrator block. In architecture, one RC integrator block consists of two passive RC integrators. the first is used to convert square waves into triangular waves, while the second RC integrator functions to convert triangular waves into sine waves.

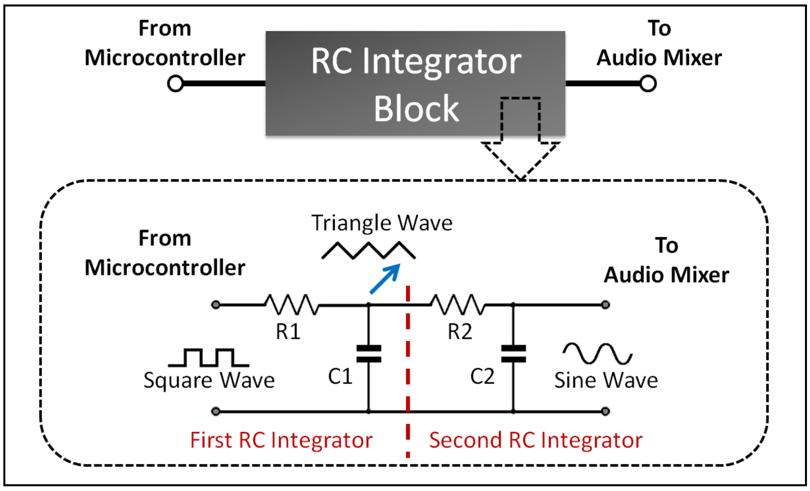


**Fig. 2.**RC Integrator

### 3.3 Multi Sine Waves Super Position

After the process of converting a square wave into a sine wave has been successfully carried out, the next process is mixing using an audio mixer block. In the audio mixer block, the superposition of sine wave formula applies. If the first sine wave is up to the fourth one is initialized as *w1*,*w2*,*w3*, and *w4*. And if the result of the superposition is expressed as a *wresult*, the rule of superposition is simply stated in equation (1).

$$w_{result} = w_1 + w_2 + w_3 + w_4 \quad (1)$$

In this study, the superposition rule in equation (1) is implemented in the audio mixer block. Figure 3 shows the passive audio mixer block. The main reason for using a passive audio mixer is because even though this series is simple, it can be achieved functionally as a superposition of wave.

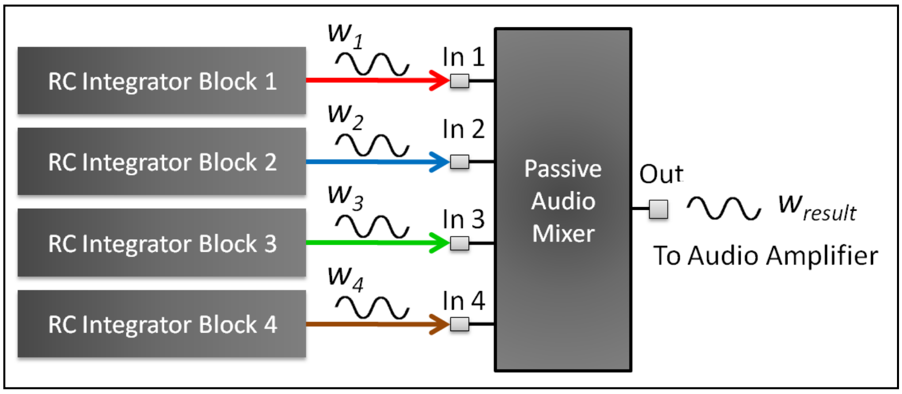


**Fig. 3.** Audio Mixer for Superposition of Wave

### 3.4 Advantage and Disadvantage of Passive RC Integrator

Passive RC integrators have the advantage of requiring less and simple components. Even so, passive RC integrators have characteristics as low pass filters. In this case, the output wave amplitude of passive RC integrator will vary according to the input wave frequency. By default, the low pass filter applies rules (2). Where capacitive reactance is initialized as Xc and expressed in Ω (Ohm).

$$X_c = \frac{1}{2}\pi f C \quad (2)$$

Frequency is expressed in Hz (Hertz). Capacitance is initialized as C and expressed in Farad. By following the rule (2), the higher the frequency (pitch), the smaller the capacitor resistance to ground will be. Thus, the wave amplitude produced by the passive RC integrator output block will be smaller. This is a disadvantage when using a passive RC integrator as a converter. Even though it has disadvantages, the passive RC integrator is still feasible to use in the sound generator architecture.

For a comprehensive analysis, the passive RC integrator response is tested on several frequencies. Figure 4 shows the trial method. The trial was carried out by measuring the amplitude of waves on several frequencies using an oscilloscope. In this case, the wave amplitude is stated in Volt Peak to Peak (Vpp). During the trial run, the oscilloscope probe is connected to the first and second RC integrator outputs to observe the wave amplitude at each step. Table 1 shows the results of the trial, while Figure 5 shows the graphical visualization of the test results in table 1. The trial results show that the higher frequency at passive RC integrator block input, the smaller the wave amplitude at the output.

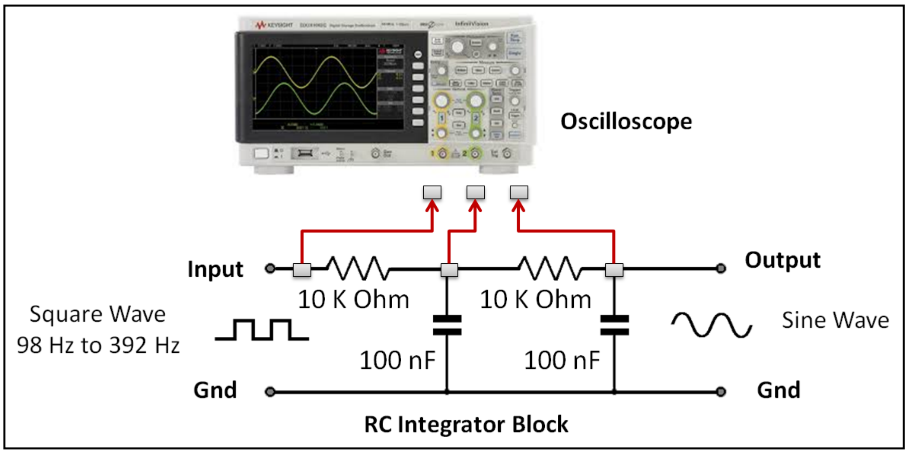


**Fig. 4.** Trial Method

# 4 Implementation to the learning process

## 4.1 Utilization Method in Class

While delivering a lecture in class, this tool is demonstrated along with oscilloscope simultaneously. Every music tone is displayed using the push button alternately. Oscilloscope probe connected to every test point. Then, students are instructed to observe the wave shape displayed through the oscilloscope while listening to the music generated by the tool. Students can also be instructed to save, take a picture or draw the shape of the wave to facilitate the off-class learning.

## 4.2 Effectiveness of Learning Media

Effectiveness of learning media can be rated by giving questionnaire of this tool. Students can fill the questionnaire containing questions about convenience, understanding, function and comfort while using this tool. The result will be used as future development of the tool, both in packaging aspect and feature.

## 4.3 Embedding Music to The Tool

In order to embed music to the tool, microcontroller programming ability, preferably C language, is needed. Every tone, interlude between the tone, and sound mixing scenario are built through a program code scripted by programmer. In this case, programmer act as a composer. On the learning process, students only asked to interact and observe the shape of the sinus wave through oscilloscope. So that the incorporation of the music can only be done by advanced students who have programming skill background.

### 4.4 Security and Convenience

The tool is designed as easy and as safe as possible for students who may not have the basic of electronical or computer science. Safety is determined by the type of power supply. The tool works at voltage 12 Volt and maximum current 500 mA which made it safe for students while having interaction. Push button feature (see figure 1) resulting in the convenience of student in utilizing and changing the sinus wave from the desired music.

## 5 Conclusion

This study contains efforts to improve learning in the education era 4.0. In detail, efforts to improve teaching methods in physics courses especially the introduction of electric waves for electrical engineering students. Sound generators that produce music sound by utilizing wave superpositions are expected to stimulate learning interest for students. In this research, the sound generator architecture has been proposed. Includes architectural design, the concept of superposition of waves, pitch scenarios of the song to produce melodious sounds. The weakness in the architecture is passive RC integrators that have characteristics such as low pass filters. For that, in future work, a method will be developed to solve that weakness problem.

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