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Preliminary Study of Ultrasonic Generator Design Based on Microcontroller

Alluma[1], Siti Indyah Sari[2], Tri Aprilia Lita[3], Rista Putri Nur Ifa[4], Taryudi[5*]

[1,2,3,4]*Physics Study Program, Faculty of Mathematics and Natural Sciences, Jakarta State University, Jakarta, Indonesia*

[5]*Electronic Engineering Study Program, Faculty of Enginering, State University of Jakarta, Jakarta, Indonesia*

[1] lumalluma24@gmail.com, [5*]taryudi@unj.ac.id

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ABSTRACT

Ultrasonic waves have been used in various fields such as cleaning, purification, and homogenization of particles by cavitation in liquid mediums. Cavitation is the formation, growth, and destruction of micro-sized gas bubbles. In this study, an ultrasonic generator based on an Arduino microcontroller has been designed. This research aims to produce square waves by utilizing the PWM method from Arduino Uno, where the frequency and duty cycle generated can be changed according to user needs. The method used in this study is an experimental method with components consisting of Arduino Uno, Mono Digital Audio Amplifier TPA3118, Power Supply 12 V, and Ultrasonic Transducer 40 kHz 60 W. Frequency and duty cycle are regulated using push buttons. The Arduino wave output will be amplified using an amplifier which is then used to produce the ultrasonic transducer. In the test of the generators made, several variations of duty cycles of 15%, 25%, 50%, 75%, and 85% were used. The result of this study is that ultrasonic generators can produce output frequencies of up to 58 kHz with error values of 0.83%, 0.97%, 0.92%, 0.70%, and 15% for each duty cycle.

Keywords: *Cavitation; Frequency; Ultrasonic Generator*

ABSTRAK

Gelombang ultrasonik telah digunakan dalam berbagai bidang seperti pembersihan, pemurnian, dan homogenisasi partikel dengan kavitasi dalam medium cair. Kavitasi adalah pembentukan, pertumbuhan, dan penghancuran gelembung gas berukuran mikro. Pada penelitian ini telah dirancang generator ultrasonik berbasis mikrokontroler Arduino. Penelitian ini bertujuan untuk menghasilkan gelombang persegi dengan memanfaatkan metode PWM dari Arduino Uno, dimana frekuensi dan duty cycle yang dihasilkan dapat diubah sesuai kebutuhan pengguna. Metode yang digunakan dalam penelitian ini adalah metode eksperimen dengan komponen yang terdiri dari Arduino Uno, Mono Digital Audio Amplifier TPA3118, Power Supply 12 V, dan Ultrasonic Transducer 40 kHz 60 W. Frekuensi dan duty cycle diatur menggunakan push button. Keluaran gelombang Arduino akan diperkuat menggunakan amplifier yang kemudian digunakan untuk menghasilkan transduser ultrasonik. Dalam pengujian generator yang dibuat digunakan beberapa variasi duty cycle sebesar 15%, 25%, 50%, 75%, dan 85%. Hasil penelitian ini adalah generator ultrasonik dapat menghasilkan frekuensi keluaran hingga 58 kHz dengan nilai error setiap duty cycle 0,83%, 0,97%, 0,92%, 0,70%, dan 15%.

Kata kunci: Kavitasi; Frekuensi; Generator Ultrasonik

1. INTRODUCTION

Ultrasonic waves are acoustic waves with frequencies above the threshold of human hearing, i.e. more than 20 kHz (Zubair et al., 2018). In its development, ultrasonic waves are widely utilized in various fields, such as in the medical field for ultrasonic imaging and particle homogenization, in the field of chemistry to help the atomization process, and in the industrial field for cleaning processes (Junaidi et al., 2020). This is due to several advantages of ultrasonic waves over other radiation, namely non-invasive, small radiation risk, relatively low price, and low energy use of power generation (Zubair et al., 2017).

Power Ultrasonic Technology has a wide range of frequency levels. Frequencies 20 kHz – 100 kHz include low frequencies, 100 kHz – 1 MHz include intermediate frequencies used for high-power applications, and 1 MHz – 1 GHz includes high-frequency for micro-power applications. All these applications are still constrained by the limitations of ultrasonic generators, especially in responding to frequency changes (K. Zhang et al., 2023). There are two main components in the use of ultrasonics, namely ultrasonic generators and ultrasonic transducers. Ultrasonic generators have a working principle by converting electrical energy into vibrations at specific ultrasonic frequencies (Sultanova et al., 2021). Ultrasonic generators serve to generate electrical energy to be used by ultrasonic transducers. Meanwhile, ultrasonic transducers function as a device that converts electrical energy from ultrasonic generators into ultrasonic energy (Acevedo et al., 2015).

In its application, this method is greatly influenced by the phenomenon of cavitation. Cavitation is the formation, growth, and destruction of micro-sized gas bubbles in a liquid medium (Hoo et al., 2022). During the cavitation process, the large size of the gas bubbles growing in the liquid depends on the amplitude and frequency of the signal applied to the ultrasonic transducer (Zhang et al., 2023).

Various studies have developed ultrasonic wave devices for various applications. Yakut et al. designed a microcontroller-based ultrasonic generator that has a temperature and time control function for the application of ultrasonic cleaning in machines with an output frequency of up to 28 kHz (Yakut et al., 2009). Another study has designed a pulse generator for food processing technology using the PWM method with a frequency that can be set up to 3 MHz (Kasri & Piah, 2018).

In this study, a microcontroller-based ultrasonic generator will be designed using the PWM method with a frequency value that can be adjusted up to 58 kHz, and the duty cycle used is 15%, 25%, 50%, 75%, and 85%. In this study, the output results will be compared with commercial ultrasonic generator devices.

2. METHOD

The method used in this study is an experimental method with a circuit scheme as follows.

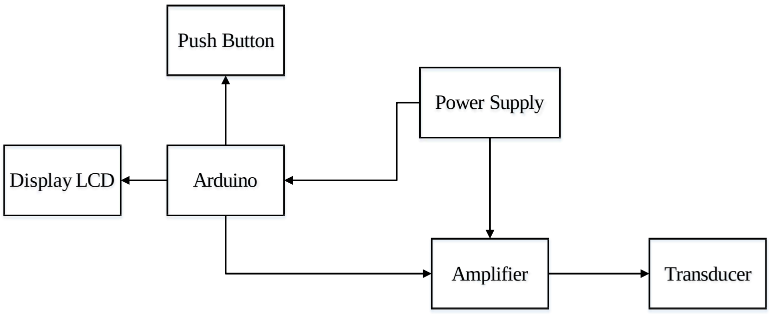


Figure 1. Block diagram of ultrasonic generator systems

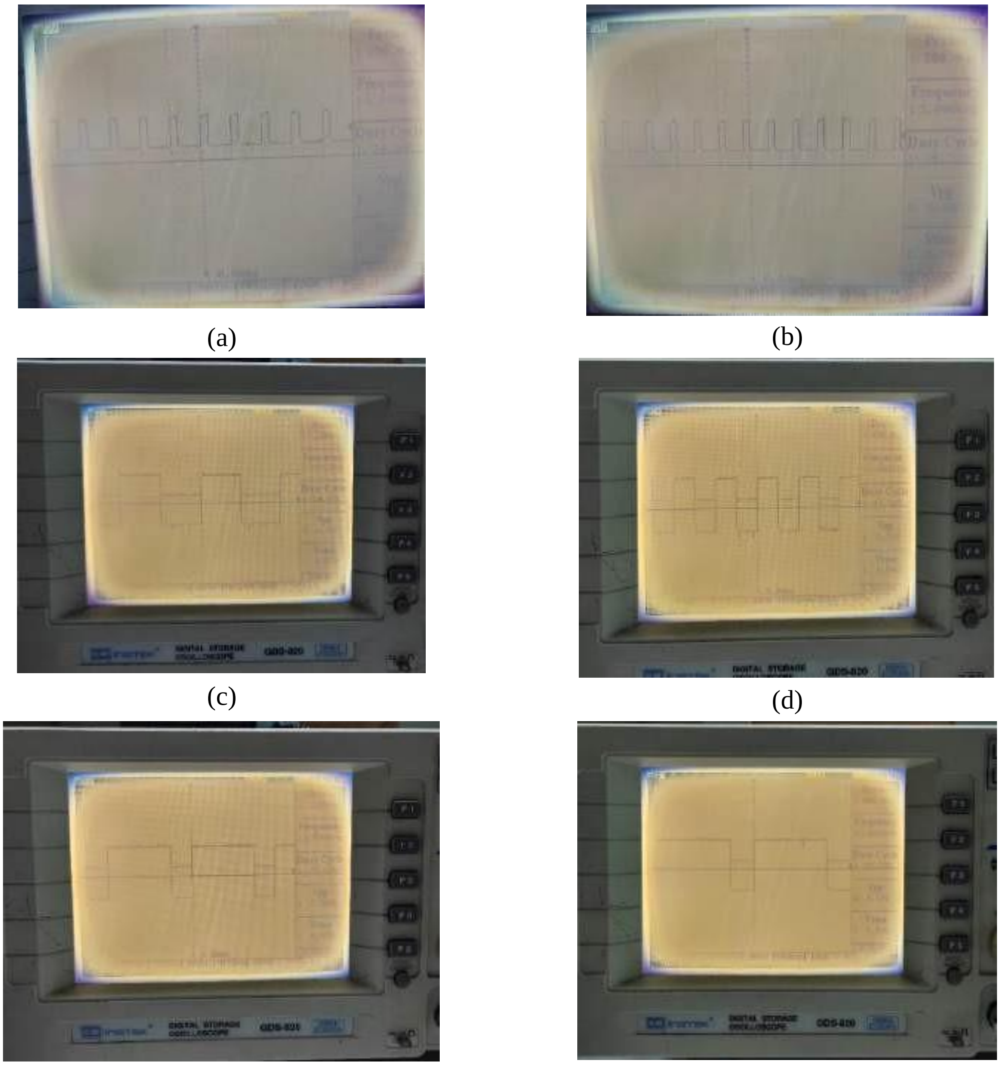
Based on the scheme above, the generator circuit consists of several components including Arduino Uno, TPA3118 Digital Mono Audio Amplifier, 12 V Power Supply, Transducer Ultrasonic 40 kHz 60 W, LCD 16x2 I2C, and push button. The microcontroller functions as a generator of analog output frequency up to 58 kHz which then the output signal from the Arduino will be amplified using an amplifier to power the ultrasonic transducer. For setting the frequency value can be applied using a push button while the duty cycle value has been set in the program by 15%, 25%, 50%, 75%, and 85%. Then the values of the frequency, period and duty cycle will be displayed on the LCD. The frequency output results obtained based on the oscilloscope will be processed and then compared with the frequency input value in the duty cycle variation used.

3. RESULT AND DISCUSSION

3.1. Result

In the Arduino-based generator circuit, the value of the frequency parameter is set using push button. Arduino as a tool control centre and analog signal generator according to a program that has been created using Arduino IDE software. The frequency, period and duty cycle parameters are displayed on the I2C 16x2 LCD. The Arduino output signal will drive the ultrasonic transducer that has previously been reinforced by the amplifier.

Based on the results of the research that has been carried out, a frequency variation that can be adjusted by users with an output frequency of 1 kHz to 58 kHz and duty cycle values that have been set in the program by 15%, 25%, 50%, 75%, and 85%. In the figure 2 is an oscilloscope display of the form of an output signal with a frequency of 1 kHz, 2 kHz, 4 kHz, 5 kHz with a duty cycle of 25%, 50%, 75%.



(a) (b) (c) (d) (e) (f)

Figure 2. Arduino output wave display on the oscilloscope with a frequency of (a) 4 kHz at a 25% duty cycle, (b) 5 kHz at a 25% duty cycle, (c) 1 kHz at a 50% duty cycle, (d) 2 kHz at a 50% duty cycle, (e) 1 kHz at a 75% duty cycle, (f) 2 kHz at a 75% duty cycle.

The frequency value of an Arduino based generator is set using push button with an input frequency with range of 1 kHz-58 kHz and an output frequency that is read by an oscilloscope close to the input frequency value is obtained. The following is a graph of the relationship of the input frequency to the output frequency read by the oscilloscope with duty cycle variations of 15%, 25%, 50%, 75%, and 85%

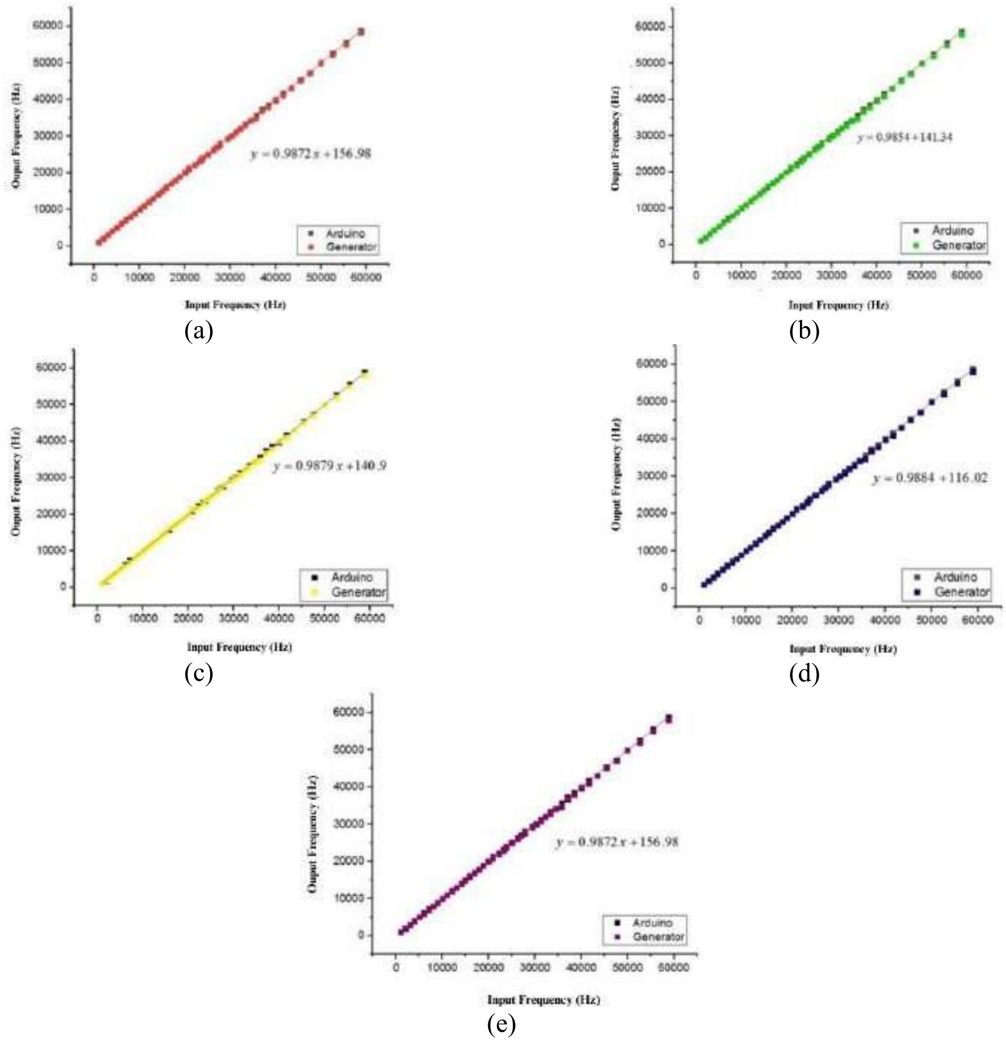


Figure 3. Graph of the relationship of input frequency to output frequencies on arduino and commercial generators with duty cycles (a) 15%, (b) 25%, (c) 50%, (d)75%, and (e) 85%.

Based on figure 3 of the output graph on the three duty cycle variations, it shows the results of the frequency output form which is not much different between Arduino and commercial generator. In the generator design that was made, the error value obtained based on the equation 1 was obtained.

$$Error = \left| \frac{Frequency(generator) - Frequency(Arduino)}{Frequency(generator)} \right| \quad (1)$$

The output frequency error value was obtained, namely in the 15% duty cycle of 0.83%, 25% of 0.97%, 50% duty cycle of 0.92%, 75% duty cycle of 0.70%, and 85% duty cycle of 1%. The relationship between the size of the duty cycle and frequency errors is shown in the following graph.

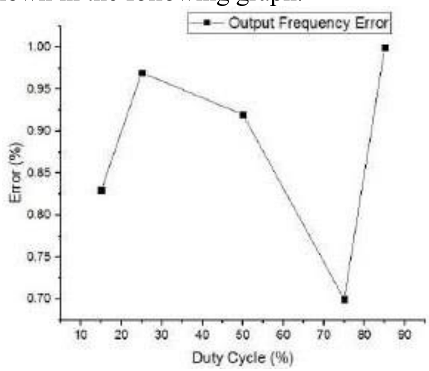


Figure 4. Graph of the relationship between duty cycle magnitude and frequency errors

3.2. Discussion

The frequency of the PWM signal determines how quick the signal completes one cycle period. The period is inversely proportional to the frequency. The smaller the period, the greater the frequency and vice versa. As shown in figure 2, it appears that the greater the frequency, the smaller the period value will be, so the distance between the pulses is getting smaller. One period consists of on and off cycles as shown in figure 2. The on cycle is the time when the signal is at a high position (5V) and the off cycle is the time when the signal is at a low position (0V). The percentage of time when the PWM signal on is called the duty cycle.

4. CONCLUSION AND RECOMMENDATION

Based on the test results of the ultrasonic generator that has been designed, the generator can generate pulses with a maximum frequency of 58 kHz. The frequency setting is set using push button. The results of the comparison of the output frequency on Arduino-based generators with commercial generators are not much different. Arduino-based generator error values in the three duty cycle variations were 0.83%, 0.97%, 0.92%, 0.70%, and 1%. It can be concluded that the generator works according to the design.

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