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# A Study on High Power Amplifier of Sound Fire Extinguisher Using Pseudo Sinusoidal Wave

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***Abstract:***

*Existing extinguish methods, which rely solely on chemical reactions of fire extinguishing agents, are limited in overcoming the rapidly changing fire fighting environment. A Sound Fire Extinguisher that supplies sound energy to the flame can be an alternative. The Sound Fire Extinguisher, first released by DARPA, is too heavy and bulky to be suitable for fire fighting environments. In this study, we proposed the application of pseudo sinusoidal wave using switching power to achieve high power, compact and lightweight of Sound Fire Extinguisher. As a result of the experiment in chapter 5, when a general sinusoidal oscillator and amplifier are used, a weight of 0.5 Kg is output at 100 watts, and a heat sink of more than 0.5 Kg is required. On the other hand, in case of pseudo sinusoidal wave using switching power, the weight of amplifier required to output 150 watts was only 0.2 Kg. Experimental results show that the Sound Fire Extinguisher is compact and lightweight with high output by applying pseudo sinusoidal wave method using switching power.*

***Keyword:*** *Fire Fighting Environment, Sound Fire Extinguisher, Switching Power, Sound Energy, pseudo sinusoidal wave*

## 1. INTRODUCTION

With the rapid development of human civilization, buildings are becoming larger and skyscraper. This environmental change maximizes the damage when conflagration occurs. The conflagration of Daegu subway in 2003 with 192 casualties clearly shows how conflagration damage is caused by the changed fire fighting environment. The extinguish methods so far mainly depend on the chemical action of fire extinguishing agents. The extinguish method by fire extinguishing agents is generally effective in suppressing the flame of a burning object. However, fire extinguishing agents destroy fire extinguishing objects. There is also a limit to the fire fighting activity in large-scale, skyscraper buildings. Therefore, a new extinguish method suitable for the changed fire fighting environment is needed [1-3].

Sound Fire Extinguisher is a new extinguish method applicable to the changed fire fighting environment. Sound Fire Extinguisher was first released by US Defense Advanced Research Projects Agency (DARPA) and George Mason University students. However, the Sound Fire Extinguisher that they first released was inadequate for use in real fire fighting fields because it was too large and heavy to supply sufficient sound energy to the flame [4-6].

In order for the Sound Fire Extinguisher to supply very loud sound energy to the flame, it is necessary to drive the speaker with a low distortion and high output electric power. On the other hand, compact and lightweight must be achieved to apply to actual fire fighting field. Therefore, it is essential to develop compact and lightweight high power oscillator and amplifier for Sound Fire Extinguisher. The Sori Sound Engineering Research Institute (SSERI) is researching and developing a new concept Sound Fire Extinguisher that improves the problems of Sound Fire Extinguisher that DARPA first released. SSERI is actively researching Sound Fire Extinguisher for practical use by developing compact and lightweight Sound Fire Extinguisher while outputting high sound energy [7-9].

**Fig 1.** Sound Fire Extinguisher from SSERI

In this study, we aimed to achieve high power oscillation and amplification and compact and lightweight by using pseudo sinusoidal wave using switching power. In Chapter 2, we explain the basic principle of high power sin wave oscillation. In Chapter 3, we propose a pseudo sinusoidal wave applying method using switching power. Chapter 4 explains the experiment and the results. Chapter 5 concludes with conclusion.

## 2. BASIC PRINCIPLE OF HIGH POWER SINE WAVE OSCILLATOR

### 2.1 High power oscillation of the AC generator

The Sound Fire Extinguisher requires an oscillation system that can deliver high power and minimize distortion while delivering loud energy to the flame to suppress conflagration. There is a sin wave oscillator consisting of a prime mover and an AC generator that can minimize distortion while achieving high power. An AC generator is a device that converts constantly lasting energy into electrical energy whose direction changes continuously. Figure 2 shows the principle of the AC generator. When the area through which the magnetic field passes is A, the magnetic field is B, the coil is wound N, and the coil is constantly rotated at the angular velocity ω, the electromotive force E induced in the coil can be expressed as equation (1) [10].

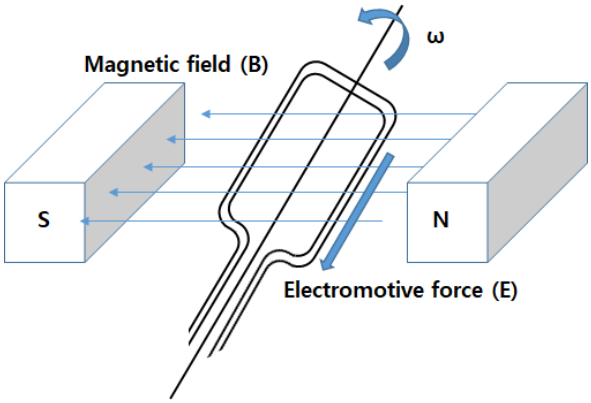


**Fig 2.** Principles of AC generator [10]

$$E = -\frac{d}{dt}(N\emptyset) = -BAN\omega sin\omega \qquad (1)$$

When the coil is rotated at a constant speed, the magnitude and direction of the current are output in the form of a sin wave at regular intervals. That is, in the case of the AC generator using the prime mover, it can be said that it is a high power sin wave oscillator which converts DC type electric energy having a constant current direction into AC type electric energy in which the direction of current changes.

### 2.2 Sin wave oscillator

The sin wave oscillator outputs sin wave by control signal. It is usually designed by vacuum tube, TR, or IC method. Figure 3 shows a typical sin wave oscillator, the RC phase shift oscillator [11].

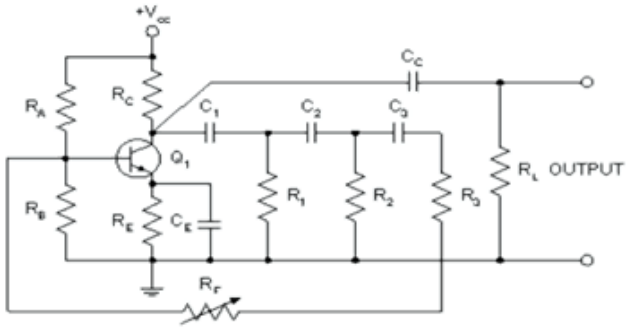


**Fig 3.** RC phase shift oscillator [11]

However, a typical sin wave oscillator as shown in Fig. 3 requires a separate high-performance amplifier for high power because the output is very small due to the characteristics of the device. A high performance amplifier for high power uses a vacuum tube type amplifier and a transistor type amplifier. Therefore, a multistage power source is needed to drive the amplifier and a very large heat sink is required. As a result, the weight and volume of the oscillator and the amplifier are greatly increased.

### 2.3 Types of wave form

Wave forms are divided into sin wave, square wave, stair wave, etc. The sin wave is the most fundamental form of AC, and its name comes from the same shape as Sinθ. The AC voltage and electric current obtained from the AC generator can be called a sin wave. A square wave is a square waveform that changes between plus and minus. The case where the duty cycle is 50% is called a symmetric square wave. The others are called asymmetric square waves. When an AC device is to be driven using a DC power source, a very complex device is required to oscillate the sin wave and the volume becomes large. Instead of a complex process for sin wave oscillation, it is a pseudo sinusoidal wave that changes the polarity in a stepwise manner to produce AC [12].

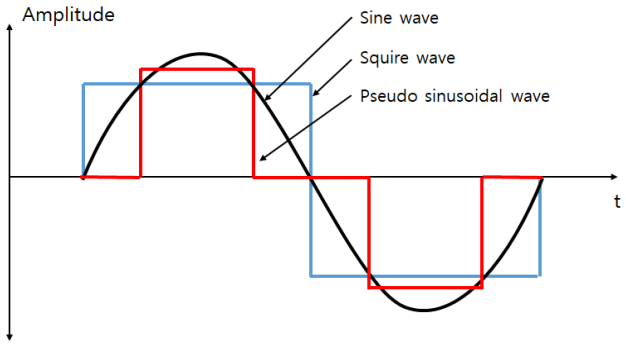


**Fig 4.** Pseudo sinusoidal wave

## 3. APPLICATION OF PSEUDO SINUSOIDAL WAVE USING SWITCHING POWER

For the efficiency of Sound Fire Extinguisher, it is advantageous to supply high power sin wave. However, there is a disadvantage in that the weight and volume of the Sound Fire Extinguisher increase to supply a high power sin wave. In this paper, we propose a pseudo sinusoidal wave using switching power to achieve high power, compact and lightweight. The pseudo sinusoidal wave has some square wave characteristics and distortion can be caused by the harmonic component. However, even with a small control signal, high power is available, which makes it easy to reduce weight and volume. In addition, the Sound Fire Extinguisher can output a pure tone or narrow band low frequency signal instead of a complex sound component, so that a pseudo sinusoidal wave alone can achieve the desired purpose.

### 3.1 Pseudo sinusoidal wave output according to FET pulse method

The FET inverter consists of four symmetrical MOSFET devices. MOSFETs have low driving power and are easy to drive with voltage driving system, have high temperature stability and very little heat generation. In addition, the output impedance is less than 1 ohm, which allows very high power and has high switching characteristics. Due to the nature of these MOSFET devices, FET inverters operate well with low power while amplifying at high power. And because there is little heat, very small heat sink is no problem for operation [13].

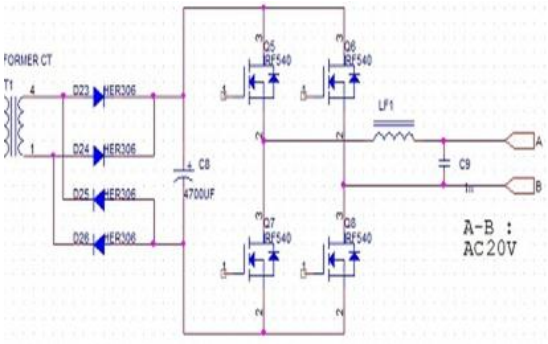


**Fig 5.** FET inverter circuit

The MOSFET device of the FET inverter outputs a square wave by the switching operation. Figure 6(a) shows the output phase-to-phase voltage with a difference of 60o in the FET inverter. In Figure 6(a), the output line-to-line voltage is obtained and a pseudo sinusoidal wave as shown in Figure 6(b) can be output. The period of the pseudo sinusoidal wave is determined by the frequency of the control signal driving the MOSFET.

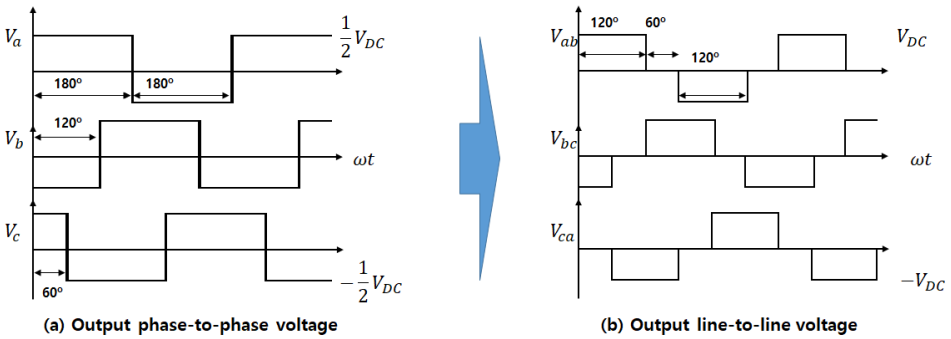


**Fig 6.** Output of pseudo sinusoidal wave by FET inverter

### 3.2 Switching control signal

The Sound Fire Extinguisher outputs very loud sounds below 100Hz, but oscillation and amplification using a FET inverter allows high power oscillation with very low power control signals alone. In this study, only the control signal output through the TL494 chip was used. The TL494 chip is a pulse width modulation control circuit that has an easy-to-synchronize circuit architecture and is widely used, from desktop PCs and washing machines to solar mic inverters. The oscillation frequency can be obtained by adjusting the $R_T$ and $C_T$ of pin 5 and pin 6 of the TL494 chip, and a wide oscillation frequency ranging from 1 to 300 kHz can be obtained. Figure7 is a block diagram of TL494, and the oscillation frequency ($f_{osc}$) can be obtained from TL494 as shown in equation (2) [14].

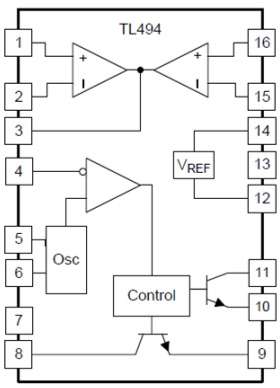


**Fig 7.** TL494 Block Diagram [14]

$$f_{osc} = \frac{1}{R_T \cdot C_T} \quad (2)$$

## 4. EXPERIMENTS AND RESULTS

In Chapter 4, we demonstrated the high power compact and lightweight effect of a pseudo sinusoidal wave using the proposed switching power by comparing it with a general sin wave oscillation amplification circuit. We compared the output and the weight with Sound Fire Extinguisher composed of RC phase shift oscillator and TR amplifier and Sound Fire Extinguisher composed of pseudo sinusoidal wave oscillator and amplifier according to FET pulse method. In this case, except for the oscillator, amplifier, and heat sink of each component of Sound Fire Extinguisher, the same applies to both cases. The signal generated from each oscillator was a pure tone of 60Hz and the output level was measured using Acoustilyzer AL1 from NTi Audio. Figure 8 shows two cases of Sound Fire Extinguisher applied to the experiment.

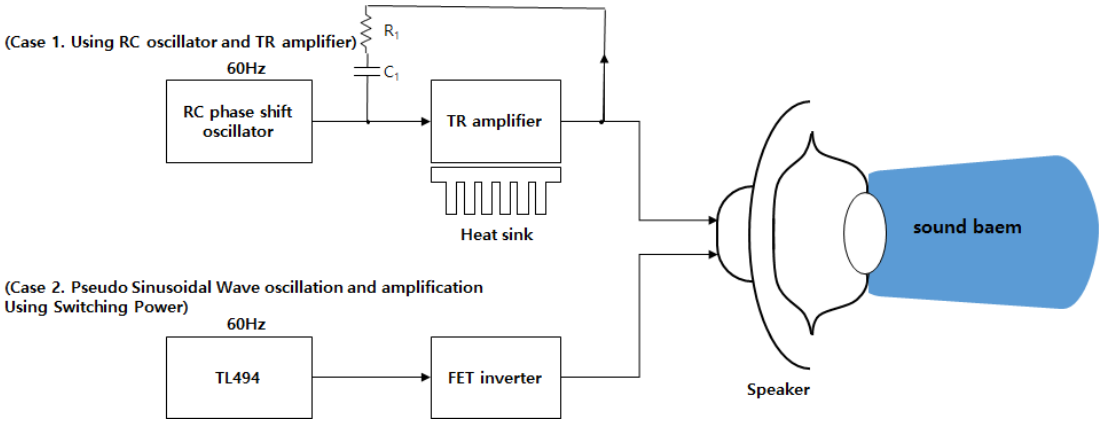


**Fig 8.** Configuration of the Sound Fire Extinguisher used in the experiment

In the first case of Figure 8, a TR amplifier and a multistage power source were constructed to increase the power of the sin wave. Due to excessive heat generation of the TR amplifier, a separate heat sink had to be used. On the other hand, in the second case of Figure 8, a pseudo sinusoidal wave oscillator is oscillated and amplified by using a FET inverter, so that a separate device is not required. And since the heat of the MOSFET device is low, only the PCB copper plate is used for heat sinking. Figure 9 shows a pseudo sinusoidal wave oscillator and amplifier of a FET pulse type.

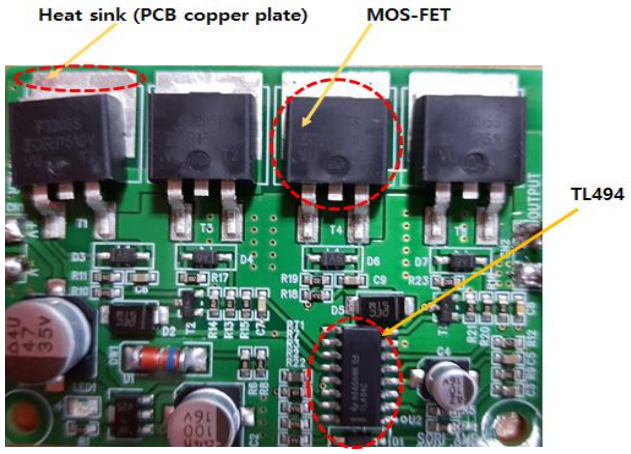


**Fig 9.** FET pulsed pseudo sinusoidal wave oscillator, amplifier

Experimental results show that oscillator and amplifier of pseudo sinusoidal wave by FET pulse output 150watt while oscillator and amplifier weigh only 0.2kg. On the other hand, the sin wave oscillator and amplifier require a multistage power source and a high power amplifier, which weighs 0.5 kg even though it outputs 100 watts. Even a heat sink of over 0.5 Kg was required separately.

## 5. CONCLUSION

The development of human civilization changed the fire fighting environment by skyscraperization and enlargement of buildings. To overcome the changed fire fighting environment, a new method of extinguish method is needed. Sound Fire Extinguisher, first released by DARPA, uses sound energy instead of fire extinguishing agents and can be an alternative to the new extinguish method. But Sound Fire Extinguisher, first released by DARPA, is very heavy and bulky, making it unsuitable for use in real fire fighting fields. For the Sound Fire Extinguisher to provide sound energy to the flame, it is advantageous to drive the speaker with a sin wave. However, in order to output a sin wave of high power, an increase in weight and volume is inevitable.

In this study, we proposed the application of pseudo sinusoidal wave using switching power to achieve high power, compact and lightweight of Sound Fire Extinguisher. The proposed method is compared with the conventional sin wave oscillator and amplifier. Experimental results show that the oscillator and

the amplifier's weight required to output the 150 watt with a pseudo sinusoidal wave using switching power are only 0.2 Kg. On the other hand, when using the sin wave oscillator, the oscillator and the amplifier weighed 0.5 kg while outputting 100 watt, and a separate heat sink of 0.5 Kg or more was required due to excessive heat generation. From these experimental results, we confirmed that the application of pseudo sinusoidal wave using switching power can achieve high power, compact and lightweight of Sound Fire Extinguisher.

After that, we apply various voice signal processing techniques to make Sound Fire Extinguisher more compact and lightweight.

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