

# THE DESIGN OF AUDIO DELAY MODULE TO CREATE STAGING AND IMAGING EFFECT

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## ABSTRACT

*Humans have the ability to determine the location of a sound source using two ears as a comparison called sound localization, just like the eyes when viewing a 3D movie. In the car, there are two sources of sound that left and right speakers. Both of these sound sources can lead to the creation of staging and imaging effects. However, unlike the home multimedia system that can be placed symmetrically to the listener. Therefore, the device needs to set the delivery time of the sound by the speaker.*

*This research is done by designing a module to determine the accuracy of the module is carried out experiments using two different power supply. Power supply is contained in the adapter laboratory control system and the battery 9 V. From the research conducted, it was found that there was a difference delay generated IC PT2399 when it gets electricity from the power supply source is different. In this study also found that the time difference of the sound of each speaker to the ear affects the quality of staging and imaging effects, audio systems that use delay has a staging location in front of the driver.*

*Keywords: Audio, design, car, staging and imaging, delay*

## 1. Introduction

Along with the technological development of the automotive world, the new features become the top choice of car consumers. One of the features most requested feature is the multimedia system. In Indonesia the country itself, the multimedia features is one of the features that must exist, in order to reduce boredom and stress when there is congestion. The multimedia system consisting of headunit, speakers, power, and cross over.

There are several things that affect the sound quality in the car cabin, for example, the quality of the multimedia components, as well as staging-imaging effect on the car's cabin. Staging-imaging effects greatly affect the quality of sound in the cabin, these effects may lead to the impression of a real (live) even when you are listening to the recording. Staging-imaging effect is caused by our brain calculates the incoming sound through both ears. In the car, the sound will go into both ears at different times. The time difference between right ear and left ear in accepting this sound that causes the brain can calculate and provide conclusions on the distance and the sound source (Benson & Whitaker, 2002).

In the car, there are two sources of sound that left and right speakers, so that the effect of staging can be made. However, unlike the home multimedia system that can be placed symmetrically to the listener. Car audio system can't be laid out symmetrically, where the right speakers located closer than the left speaker, so sounds enter the ear has a time difference. Audio or stereo music sound produced obliging both left and right speakers up to each ear simultaneously. This acceptance of differences can

cause the brain fails to calculate and provide conclusions.

Therefore, the device needs to set the delivery time of the sound by the speaker. In the market, there are headunit and processor that can do the job and the time delay setting time (digital time alignment). One example Processor on the market is the Alpine PXA-H800. This processor features 8 channel Time Correction, Cross Over, Graphic Equalizer, and the gain and output adjustment (Alpine, 2012, para. 3). However, the device is equipped DTA still require a large fee. In this study, the author will make a device that allows sound speakers come together.

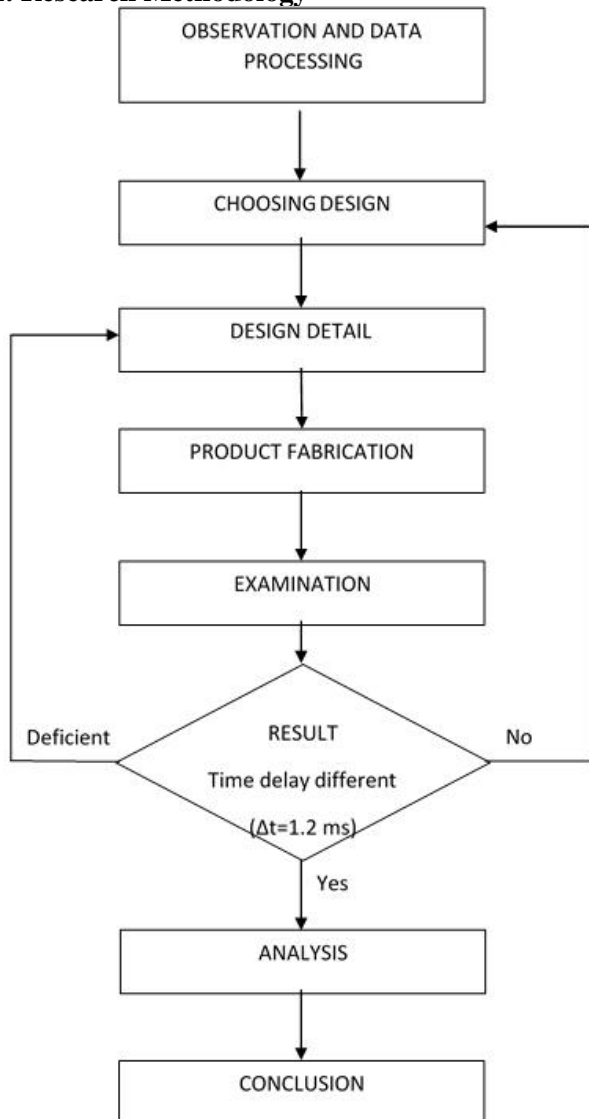
### Research purposes

The purpose of this study is to make a series of delaying the signal timing so that the sound from both speakers until the second individual listener's ears simultaneously.

### Benefits of research

The benefits of this research is able to eliminate the presence speakers, so the sound looks like being in front of the listener.

## 2. Research Methodology



Picture 1 The Flow Chart of Delay Modul Making

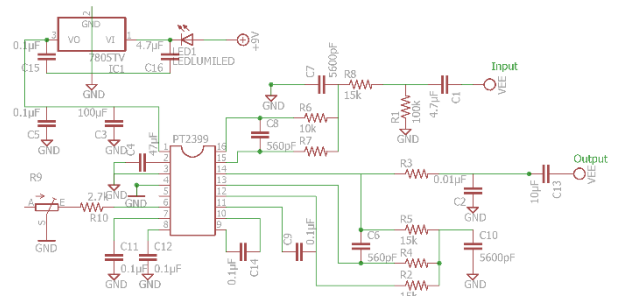
### The Calculation of Distance and Time of Speakers

To calculate the distance of speakers, measure tape is used and to calculate the time of sound travel from speakers to ear the formula is,

$$t = \frac{S \text{ cm}}{C \frac{\text{cm}}{\text{ms}}}$$

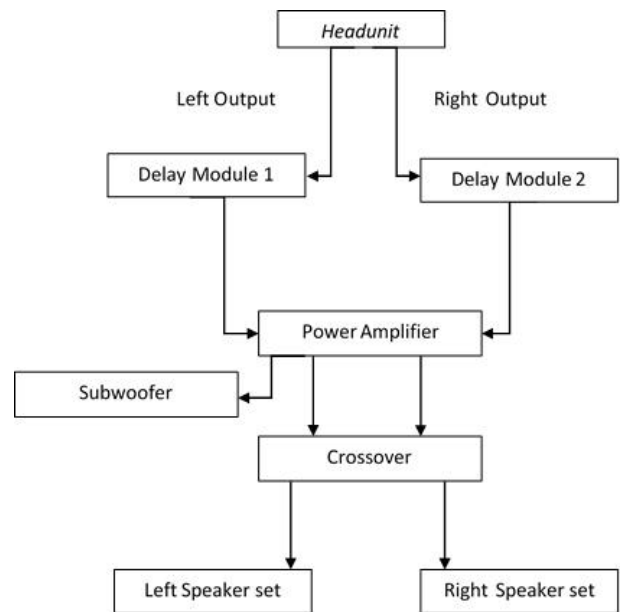
### Delay Module Design

This delay module's design is based on IC PT2399, with IC LM7805 as a regulator to regulate the 9V battery voltage into 5V power supply. The design created as shown below:



Picture 2 Audio Delay Module Schematic Design

### Delay Module Installation Diagram



Picture 3 Delay Module Installation Diagram

Due to the IC ability to process low voltage input signal and the limitation of output voltage, this modul is installed before the power amplifier. The power amplifier will amplified the low input signal into higher output signal to drive the speakers. If the modul installed after the power amplifier, the signal wont be enough to drive the speakers. It has been tried, and the result is the speakers produce very quiet sound almost nothing can be heard at 5 cm.

### Validation of IC PT2399

IC PT2399 is measured in order to know its accuracy by comparing data that has been provided by the IC datasheet with data obtained by comparing the original signal and the signal that has been in delayed on the oscilloscope. Validation is done by using two different voltage sources, namely adapters Laboratory Control System and 9V battery.

### Testing by the Respondent

A total of 30 respondents are asked to get into the car to listen to sound produces by two system and compare the sound quality and sound staging quality of audio. This two system is an audio system without delay module and

an audio systems that use delay module. Indicators of success audio design of this module is more than 50% of respondents said staging the audio is in front of the driver.

### 3. Data Analysis

#### The Speaker's Distance and Time Data

From the results of tests performed, the distance of the speakers and the time range of a sound travels from the speaker to ear data obtained as shown at table 1 and 2.

Table 1 Distance of Speakers

Speakers Name	Distance (cm)
Right Speakers	93
Left Speakers	134
Subwoofer	135

Table 2 Time Requirement for Sound to Travel from Speakers to Ears

Speakers Name	Time (ms)
Right Speakers	2.69
Left Speakers	3.87
Subwoofer	3.90

Table 2 shows that the time difference between the right speaker and the subwoofer is 1.21 ms and the time difference between the left speaker and the subwoofer is 0.03 ms. From the data obtained, the goal of the design should be the modul can make a delayed signal that count roughly 1.2 ms for the right speaker. Its a different treatment for the left speakers, due to the limitance of the IC, the accuracy of 0.03 ms delay cant be achieved.

#### Data Validation of IC PT2399

The delay data that is provided by the manufacturer is:

Table 3 The Relationship of Resistance Value and Time Delay

R	27.6K	21.3K	17.2K	14.3K	12.1K	10.5K	9.2K	8.2K
fck	2.0M	2.5M	3.0M	3.5M	4.0M	4.5M	5.0M	5.5M
td	342ms	273ms	228ms	196ms	171ms	151ms	136.6ms	124.1ms
THD	1.0%	0.8%	0.63%	0.53%	0.46%	0.41%	0.36%	0.33%
R	7.2K	6.4K	5.8K	5.4K	4.9K	4.5K	4K	3.4K
fck	6.0M	6.5M	7.0M	7.5M	8.0M	8.5M	9.0M	10M
td	113.7ms	104.3ms	97.1ms	92.2ms	86.3ms	81ms	75.9ms	68.1ms
THD	0.29%	0.27%	0.25%	0.25%	0.23%	0.22%	0.21%	0.19%
R	2.8K	2.4K	2K	1.67K	1.47K	1.28K	1.08K	894
fck	11M	12M	13M	14M	15M	16M	17M	18M
td	61.6ms	56.6ms	52.3ms	48.1ms	45.8ms	43ms	40.6ms	38.5ms
THD	0.16%	0.16%	0.15%	0.15%	0.15%	0.15%	0.14%	0.14%
R	723	519	288	0.5				
fck	19M	20M	21M	22M				
td	36.6ms	34.4ms	32.6ms	31.3ms				
THD	0.14%	0.13%	0.13%	0.13%				

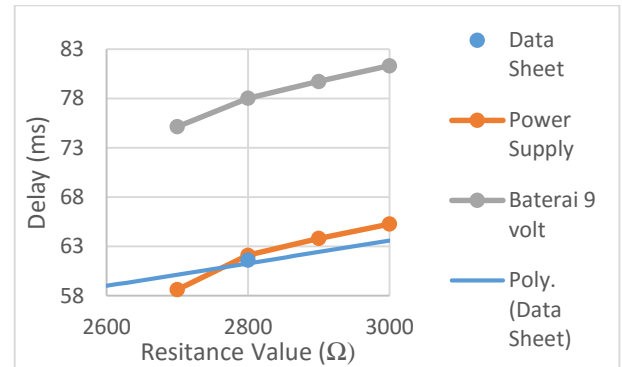
Notes:  
 1. R = VCO External Resistor (R), please refer to PT2399 Application Circuit.  
 2. fck = VCO Clock Frequency (Hz)  
 3. td = Delay Time  
 4. THD = Total Harmonic Distortion  
 5. We do not recommend the "R" value below 1KΩ when power on.

This table shows the relationship among the resistance value, clocking frequency, distortion and time delay. The one that is blacked out is a danger range that can cause damage to the IC, it can make the IC not start.

From the research conducted with measuring and comparing 2 signals by the oscilloscope we can know that:

Table 4 The Average of Time Delay Research

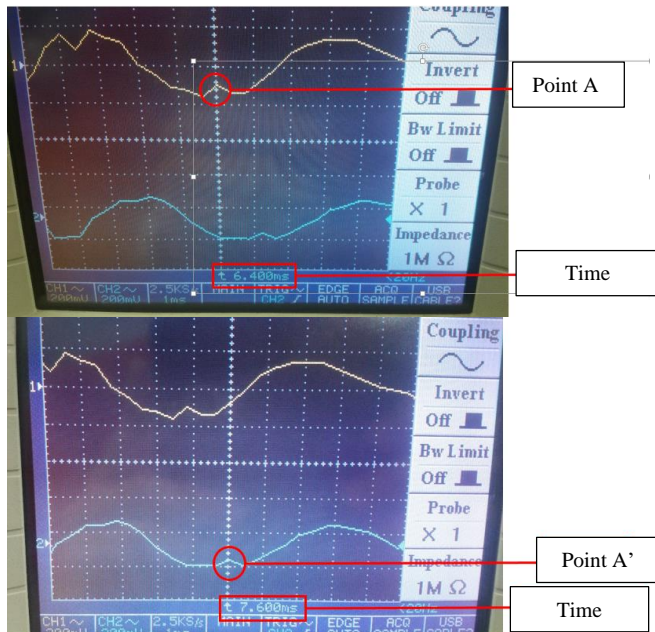
Resistance Value (Ω)	With Adaptor (ms)	With Battery 9V (ms)
2700	58.60	75.13
2800	62.10	78.03
2900	63.80	79.73
3000	65.27	81.33



Picture 4 The Chart of Delay Data Comparison

From table 3, table 4 and picture 4, it is shown that with adaptor, that has a pure 5V voltage its accuracy close to the datasheet that is given by the manufacturer. The difference can be caused by the component that used in this research is different with the component tested by the manufacturer. The data obtained through the research with the 9V Battery as a power supply shows some number of difference, its around 17 ms. It is caused by the voltage drop. When the IC PT2399 is not installed the potential differences between IC LM7805 output and ground is 5V, but as the IC PT2399 installed, the voltage drops into 4V. This degradation makes the clock which is driven by voltage, oscillated with lower frequency so the the clock starts longer and makes the delay increase.

**Time Delay Differences Between Two Speakers**

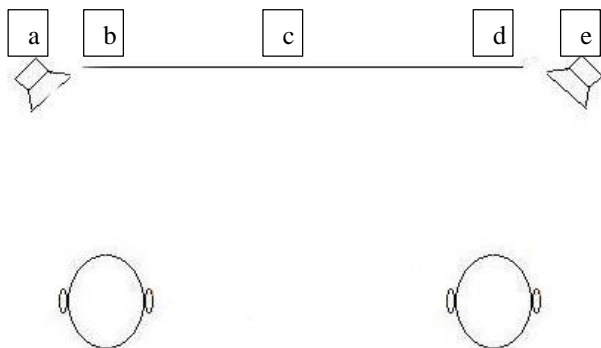


Picture 5 Comparison of Two Delayed Signal over Time

The point A at the orange signal in channel 1 is recorded at the time frame 6.4 ms, at the same time, the point A' in blue signal (which is the shadow of point A) is recorded in the time frame 7.6 ms. The differences between the two signal is 1.2 ms which was the delay requirement of sound travel from right speaker in order to reach the ear at the same time as the left speaker's sound.

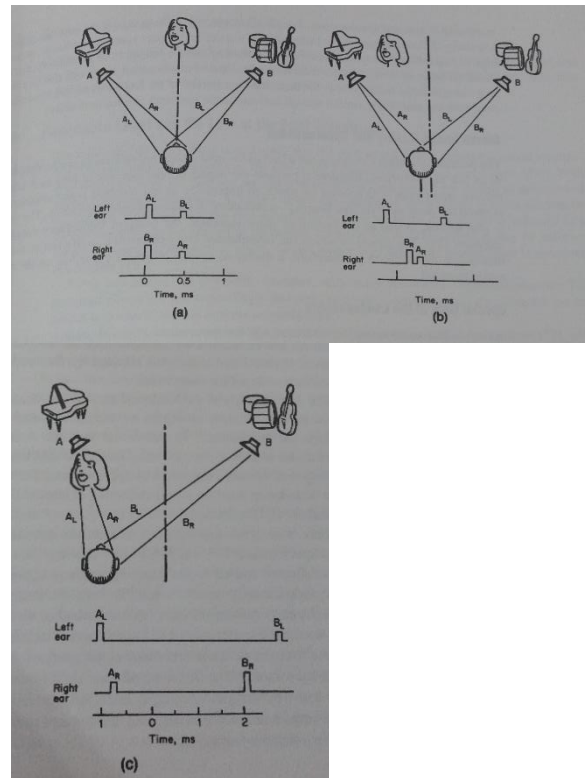
The graph on orange signal and the blue signal isn't identical, but the two of them has similarity. They are 2 signal comes from left speaker and right speaker. Right and left speaker doesn't has the identical signal/sound but complement each other to create some 3D looking. Just like the 3D movie in movie theater.

**The Research Result Conducted on People**



Picture 6 The Guideline for Staging Location

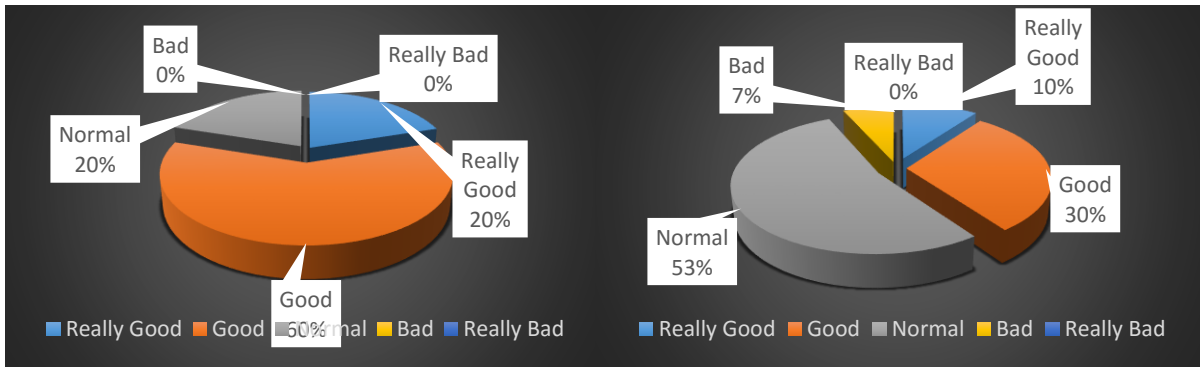
This research use 5 point of location to generalize the source of the sound. The listeners will be seated at the right seat as a driver. The listeners will guess where the location of the sound they heard, based on the 5 spots that shown above.



Picture 7 Illustration by Benson & Whitaker  
 a) centered listening b) a bit left listening  
 c) near the left speaker listening

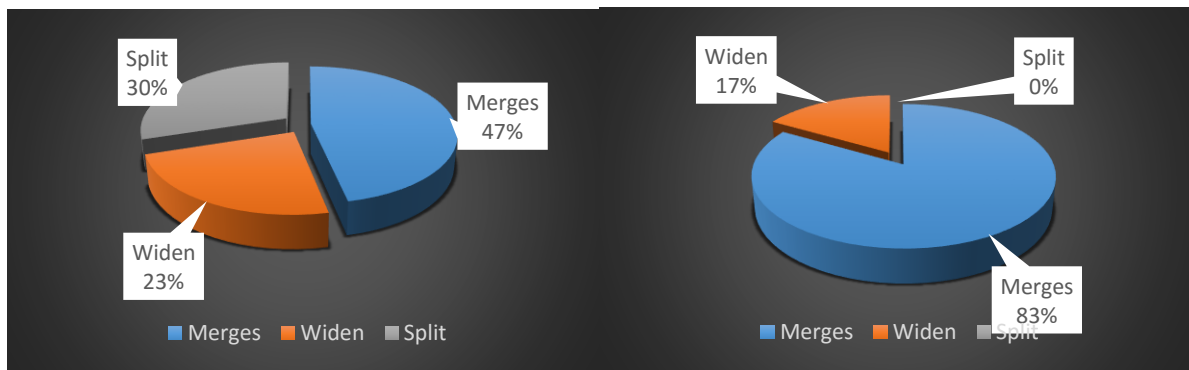
A good staging occurs when the listener hears the sound located in front of the listener. In normal audio system, it can only happen if the listener sits in the center, where the distance of listener from both speakers is the same. But, in the car the listener sits in the left/right seat resulting the distance between nearby speaker greater than another speaker. This condition lead into human brain conclude that the source of the sound is at the nearby speakers. It is supported by the illustration by Benson & Whitaker. So if the listener want to listen the sound that located in front of him, the nearby speaker signal must be delayed.

**The Research Result Conducted on People**



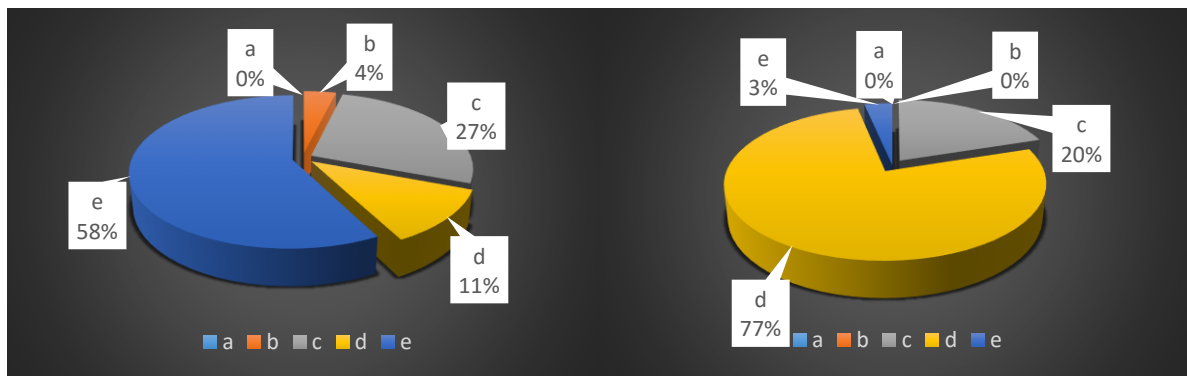
Picture 8 Audio Quality Comparison  
Left: Without Delay Modul, Right: With Delay Modul

Both of the picture above shows the changes that occur from the original audio quality is good (60%), with this delay module, the sound quality decreases (were seen on 53% of respondents said that the quality is normal). This is caused by IC limitations in producing high-frequency sound, so that at frequencies above 1 kHz, the sound intensity decrease with slow rate of 6dB / octave. Reduction of 6dB / octave means any 2 multiplier of 1kHz, sound intensity value will decreased by 6dB. For example, at 2 KHz the osund intensity level is -6 dB, at 4 KHz the sound intensity is -12 dB, and so on.



Picture 9 Audio Staging Quality Comparison  
Left: Without Delay Modul, Right: With Delay Modul

The Audio Staging quality without delay modul can not be concluded, because there is no a definitive number (more than 50%), it shows that the system that without delay modul doesn't have a good staging quality. The audio system with delay more shows improvement with 83% of the votes says that the sound has merges. This condition means the vocal sound can be heard only in 1 place. Widen means the vocal sound can be heard in the area between two speakers with no clear point. Split means sound is heard at the two speakers, resulting there is two sources of sound.



Picture 10 Audio Staging Location Comparison  
Left: Without Delay Modul, Right: With Delay Modul

Through the research conducted, the sound location of the audio system without delay modul is located on the nearby speakers, which is the right speakers in this research (shows by the the 58% of the votes). The sound location of the audio system with delay modul is located in front of the listener (shows by the 77% of the votes). This clearly similar with the illustration by Benson & Whitaker as shown before. The other vote can be caused by the difference of hearing ability that every human has. One human has more sensitivity on the right ear, and the other human has more sensitivity on the left ear. As the ability of sound localization not only affected by the time delay, it also affected by the difference of intensity and the frequency differences (for vertical localization).

#### 4. Conclusion

1. The time difference of the sound coming from the speakers left and right speakers are 1.2 ms
2. The time differences cause sounds look like coming from the right hand speaker only
3. Good Staging and good imaging occurs when both voices come together, so that the perception of the human brain can capture the sound coming from the front of the audience.
4. IC PT2399 is one of the solutions to resolve the problem is a time difference of the sound right and left
5. IC PT2399 has a weakness in the resulting sound quality, these ICs have a decreased intensity of sound that occurs at frequencies above 1 kHz at 6 dB / octave
6. The location of the sound by using delay module with IC PT2399 is the central front position of the listener is in the driver's position.

#### 5. Daftar Pusaka

1. Alpine Electronics. (2016). PXA-H800 Sound Processor. Retrieved from Alpine Asia: <http://www.alpine-asia.com/product/Sound-Processor>
2. Benson, B., & Whitaker, J. (2002). Standart Handbook of Audio and Radio Engineering. New York: Mc Graw-Hill.
3. Blocher, R. (2004). Dasar Elektronika. Yogyakarta: Andi.
4. Fair Child. (2014). LM78XX/LM78XXA 3 Terminal 1 A positif Voltage Regulator.
5. Good Will. (2004). Digital Storage Oscilloscope GDS-800 Series Opertaion Manual.
6. Grob, B., & Schultz, M. E. (2003). Basic Electronics. New York: McGraw-Hill.
7. Halliday, D., & Resnick, R. (1987). Fisika. Jakarta: Erlangga.
8. Mandl, M. (1980). Handbook of Electronic Circuits and Systems. Virginia: Reston .
9. Princeton Technology. (2010). PT2399 Echo Processor IC.
10. Sears, F. W., & Zemansky, M. W. (1994). Fisika untuk universitas 1 Mekanika. Panas. Buni. Jakarta: Binacipta.
11. Synthrotek. (2015). PT2399 Dev Delay Assembly Instructions. Retrieved may 20, 2016, from [http://store.synthrotek.com/assets/images/PT2399\\_Dev\\_Delay\\_Complete\\_01.jpg](http://store.synthrotek.com/assets/images/PT2399_Dev_Delay_Complete_01.jpg)
12. Thompson, D. M. (2005). Understanding Audio: Getting the Most Out of Your Project Or Professional Recording Studio.
13. Washington Education. (2007). Chapter 12: Sound Localization and the Auditory Scene.