SWITCH MODE AUDIO AMPLIFIER

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"I hereby declare that I have read this thesis and my opinion, it is suitable in terms of scope and quality for the purpose of awarding a Bachelor Degree Of Electronic Engineering (Industrial Electronic)"

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"I hereby declare that this thesis entitled

Switch Mode Audio Amplifier

is the result of my own research and idea except for works that I have been clearly cited in the references."

Signature : 

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For my beloved parents and family who have spent money and time to see me standing here in success.

For my humorous and brilliant supervisor who taught me a lot.

For my fellow friends who guided me when I'm lost.

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ABSTRACT

In fulfilling the condition to be awarded the Bachelor of Degree, the Switch-mode audio amplifier 1kW has been chosen as the title for the undergraduate project. This project involves a complex circuit design based on the audio amplifier switching circuit, which is combined with high gain linear amplifier circuit, to achieve the 1000 watt output target. This system can be applied or implemented in any audio electronic devices that give out a low power output. A class D amplifier will be used at the Switch-mode stage, which is the first stage of the system. This system may be connected to the input of the low power audio system's output. Such connection can be found in devices such as mp3 player, walkman and Discman. This audio amplifier is connected to the five band frequency filter or better known as the equalizer. The purpose of this filter is to filter and control gain at the set five band frequency in order to obtain a better output and with less noise. After the filtering process, circuit will then be connected to a load of an 8Ω (Ohm) speaker. The filtering and noise control process will determine whether the speaker can carry a high output.

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ABSTRAK

Switch-mode audio amplifier 1kW telah dipilih sebagai tajuk projek ijazah sarjana muda bagi memenuhi syarat pengijazahan. Ia merupakan satu projek yang memlibatkan rekaan litar yang agak komplek dengan berasaskan litar penguat pensuisan yang digabungkan bersama litar penguat linear yang bergandaan tinggi bagi mencapai sasaran keluaran 1000 watt. Projek ini boleh diaplikasikan pada mana-mana sistem audio elektronik yang menghasilkan keluaran yang rendah. Dalam rekaan projek ini, penguat kelas D digunakan bagi peringkat pensuisan yang merupakan peringkat pertama litar. Sistem ini boleh disambungkan pada input dari keluaran sistem audio berkeluaran rendah contohnya pemain mp3, *walkman* dan *Discman*. Selain itu, sistem penguat kuasa ini di bina dengan gabungan penguat pensuisan dengan penguat linear. Penguat audio ini di sambungkan ke penapis 5 jalur frekuensi atau dikenali sebagai *equalizer*, penapis ini bertujuan bagi menapis dan mengawal frekuensi rendah (Bass) dan frekuensi tinggi (treble). Penapis ini juga boleh mengawal gandaan pada 5 jalur frekuensi yg telah ditetapkan bagi mendapatkan keluaran yang lebih baik dan kurang hingar. Selepas proses penapisan, litar in disambung pada beban yg mempunyai galangan sebanyak 8Ω, untuk memastikan pembesar suara ini boleh menampung keluaran yang tinggi.

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CHAPTER 1

1.1 INTRODUCTION

This chapter introduces an overview about the switch mode audio amplifier circuit. This chapter also contains background of the project, scope of the project, project methodology and summary. This chapter will also explain briefly about the steps that will be taken during the project execution.

1.2 PROJECT BACKGROUND

An Amplifier is an important element in an audio system since it amplifies the input signal to a certain desired power to drive the speaker. However, there still no existing amplifier that can deliver the full input power to the output load i.e.100% power efficiency operation. Even the dominating class AB amplifier can only achieve at most around 70% ~ 80% power efficiency. Theoretically a Class D amplifier can achieve high efficiency provided there is an ideal transistor with no turn-on resistance and etc.

Although the output efficiency of a class D amplifier can be higher than Classical amplifier, distortion level is still higher than the classical amplifier. Hence,

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the class D amplifier is being limited to a few applications only such as subwoofer system. On the other hand, due to the fact that most of the classical amplifiers are huge in size and weight (heat sink required) this make the Switch mode Class D amplifier more popular and in demand for the portable personal audio system, such as mobile phone, PC audio system and smaller size audio system. The Class D operation required only a smaller size of heat sink compared to the classical amplifier. Furthermore, due to it superior performance on the output power efficiency, this makes it even better for implementation in battery operated system. However, the draw back is that design for this kind of amplifier is very complicated compare to those classical amplifiers.

1.3 RECOGNITION OF PREVIOUS WORK

Four projects related to switch mode audio amplifier is suitable and will be used for references in our project. In 1998, Tng Chee Wan developed a Multilevel *Switch Mode Class D Power amplifier* and in 1999, Christopher N. Hemmings. *Improving Class D Audio Amplifier.* Where in Tng's thesis, an open loop 3-level Class D amplifier was designed with 94% power efficiency. While in 1999, Hemmings thesis project implement on Tng's 3 level Class D amplifiers with an addition of close loop design to compensate the inherent nonlinearities as well as the distortion problem in the amplifier design.

The advantages of this project are, it has a higher efficiency of 94% and low in cost. However, the project do not produce high power and have no equalizer. In addition, the filter used is the common filter which did not have any special characteristic.

In October 2001, Chiew Tiam Boon built a Multilevel Switch Mode Class D Power amplifier. Chiew improved the Class D design to produced 30W, based on the

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Tng Chee Wan and Hemmings project. The 5 level Class D amplifier was designed with the close loop, PWM and the use the H Bridge. This project uses new approaches and techniques where MOSFET and multilevel switching is used. Despite all this it still have disadvantages where the output power is low and the cost is expensive.

In July 1999, Ronan A. R. van der Zee and Ed (A. J. M.) van Tuijl have developed a switch mode amplifier to improve and increase the power efficiency of audio amplifier. The design uses the combination of the switching method and the linear amplifier. It has a flat frequency response -0.3dB, heat dissipation that is up to five times lower than a traditional class-AB audio amplifier, and a distortion of <0.02% over power and frequency range. Though the project is to improve and increase the power efficiency ratio, this project failed to achieve its objective, where this design uses an inefficient filter.

In February 2004, Alejandro R. Oliva, Simon S. Ang and Thuy V. Vo have discussed that the design and implementation of a low-cost filterless class-D, unipolar pulse-width modulation switching audio amplifier have a multiloop voltage feedback scheme. The simulation results show that a total harmonic distortion (THD) of 0.005% exists in their design using an efficient filter. This circuit fails to function properly where one of the causes is also the application of in efficient filter. However, the project manages to reduce the THD and cost.

As for this final year project, a combination of switching amplifier with high gain amplifier and comparator as a PWM will be used to produce the required result. The filter is design by using a five band equalizer. Therefore, this project should be able to produce a high gain power of 1kW. Distortion should be reduced by the implementation of five band equalizer and this project should be cost effective because it uses a less then five stages of circuit.

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1.4 PROBLEM STATEMENT

Out in the audio amplifier market, there are thousands of audio amplifiers. Most of these amplifiers produces low power output, even if there is an audio amplifier has a high power output, its still has its weakness.

Audio amplifiers are one of the most important building blocks of sound reproduction in the Millennium Era. With an emphasis on sound quality in the design of an amplifier, most amplifiers are inefficient. For many amplifiers, poor efficiency is not really a problem. However, there are situations where a more efficient amplifier would be extremely beneficial. One example is a battery-powered amplifier. When batteries powers up electronic equipment, the amount of power saved by the amplifier will almost be proportional to the time allowed between battery charges. Most high power amplifiers in use today are relatively inefficient. The need to use large heat sinks to dissipate the wasted power, as well as the need to use a large power supply, results in an extremely heavy unit.

In many live concert scenarios, audio technicians need to transport the heavy amplifier to the necessary position. The need for a helper in carrying the amplifier is something they could do without. Consider if the amplifier was more efficient. The heat sinks could be made much smaller. The power supply could also be smaller. A smaller power supply also needs less heat sink, and a smaller transformer (with much less heavy iron). The case can be made much lighter as it does not need to support heavy components. The result would be an extremely happy audio technician, excited about setting up with physical ease and having more time for other jobs, such as lifting the heavy speakers.

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1.5 SCOPE OF PROJECT.

The scope of this project is divided into few parts. These scopes are to design and understand the circuits and including the function of the circuits, where the main objective is to produce the **Switch mode audio amplifier 1kW** using class D amplifier; to design and construct the circuits with 100% stability and efficiency and to make sure that the circuits have a filter to reduce the distortion and reduce loses of signal; to design the circuits that with the most suitable gain to reach the needed output, where the gain must be stable and there is no loses of gain; to produce a project that can be applied following the requirement of customers and so that the project is compatible with any audio electronic devices; to learn more about audio amplifier with the application of switch mode method; to design an amplifier with a filter or equalizer, with audio level indicator.

1.6 PROJECT OBJECTIVE

The main objective of the project is to design and construct a compact size, workable, Switch Mode Audio amplifier (Class D) for an audio system application. The power supply voltage range is about 12V and an output load resistance of 8Ohms speaker will be used, where an output power around 1kW will be expected. By applying the combination of switching amplifier mode with linear high gain amplifier, the audio quality (high fidelity) of the Class D amplifier design will be increased.

The design will based on the existing Class D amplifier and implementation on PWM system, such as the switching transistor and the push pull type amplifier. With this implementation, the design will be able to produce a higher fidelity performance and eventually reduce the nonlinearities and distortion characteristic

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in the design. The switch mode amplifier will be filtered with 5 band equalizer which will cause the amplifier to produce high quality signal. The design will be described in chapter 3.

1.7 THESIS STRUCTURE

This thesis includes seven chapters that are explaining detailed about the Switch mode audio amplifier circuit. Chapter one is the introduction chapter which gave a brief description about objective, scope, and methodology of the project.

Second chapter discuss about the research and information that related to the project. Each facts and information that earned from the different references will be collected and select the best method for the project.

The third chapter discuses the designing process of the project. Techniques and method of designing that are selected divided into two parts that are calculation and simulation.

The fourth chapter is about the construction method of the project including all methods that produce this project.

The fifth chapter describes circuit testing and result of the test part. The test method and the result of the test stage is explained comparison of the best result obtained using both methods is also discussed in this chapter.

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The sixth chapter explaining the analysis and discussion of results. The best results will be compared with those simulations of results that have been carried out.

The final chapter of this thesis is conclusion and suggestion. In this chapter conclusion will be drawn based on achievement and learning that gained from the preliminary stage until the completion of the project. Other than that suggestion is also offered to upgrade and improve the performance of the project.

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION OF AMPLIFIER.

An amplifier is capable of delivering a large amount of power to the output load without any losses incur in the process. Among the existing audio amplifier are the classical amplifier such as Class A, AB and linear device amplifier where their power efficiency can only achieve up to 70~80% at most,(most of the power was wasted as a heat dissipation). However, Class D amplifiers are based on the switch mode operation, where it can achieve a theoretical 100% power efficiency. The fact that there is virtually no (zero) power dissipation occur in the operation, the system (circuit design) can be reduced to a compact size, as bulky heat sink element is not needed.

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2.2 CLASS D POWER AMPLIFIER OPERATION

The transistors in the Class D amplifier design are either ON or OFF through out the operation which reduces their region to a finite switching time between saturation and cut off, thus reducing the power losses in the circuit.

Due to the recent portable audio market, computer multimedia access (especially the arising MP3 digital audio file) as well as the need for car audio system, the demand for a high efficiency power amplifier is very high. Having zero power dissipation in the circuit design (in this case the power amplifier), the power supply will be efficiently delivered a full power to the output stage, thus power supply is fully utilize as required instead of wasting through the heat dissipation.

2.3 INTRODUCTION TO SWITCH MODE AUDIO AMPLIFIER.

During the last few years switch mode audio power amplifiers (class-D) are introduced in more audio products to reduce cost and size and increase power efficiency compared to linear power amplifiers. As the case with switch mode power supplies, audio amplifiers can take benefit of the compactness caused by efficiency, which means a reduction in need for bulky heat sinks, with a still higher demand for multi channel audio products.

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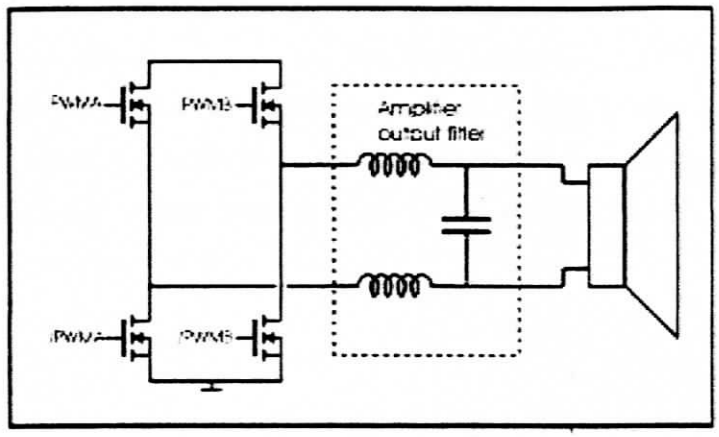

Figure 1.1 Combination of switch mode audio amplifier and loudspeaker

Switch mode amplifiers are essential for the multi channel surround sound amplifiers and receivers. Most commercial switch mode audio power amplifiers on market are having an output filter to attenuate the high frequency content of the amplified PWM signal from the power stage before reaching the output terminals of the amplifier. Only amplifier solutions for low power amplifiers are made without output filter, but with restrictions for maximum cable length between amplifier and loudspeaker due to EMC.

By integrating switch mode audio power amplifiers and electro dynamic speakers into one single unit the advantages that can be achieved are:

i. By using the inductive behavior of the speakers voice coil as output filter, the expensive parts for an output filter for the amplifier could be omitted

ii. By dedicating amplifier and loudspeaker, the standard interface between is broken down, giving a new degree of freedom of choosing amplifier voltages and currents and speaker impedance

iii. Mechanical and thermal integration neglect the need for additional cooling of the amplifier, and cost will be reduced

iv. Power efficiency from electrical input to acoustic output can be significantly increased.

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This operation is somehow similar to the DC-DC switch mode converters operation. As in both operations, the input signal is modulated using the PWM (Pulse Width Modulation) method. That is, the input signal was modulated such that the duty ratio of the modulated signal is proportional to the instantaneous input voltage. This modulated signal is then used to drive a switch (or a set of switches) to perform/produce an amplified PWM waveform.

This amplified and modulated waveform is then fed into the output stage where demodulation of the modulated signals takes place. Usually this stage will consist of an output filter to perform the demodulation task. Theoretically, Class D amplifier can produce an impressive 100% power efficiency. However, in the practical mode that is impractical to achieve that due to the imperfection in both circuit and design realization.

2.4 DIFFERENTIAL BETWEEN LINEAR MODE AND SWITCH MODE AMPLIFIER

Most of the circuit element can be classified into resistive, capacitive element, magnetic devices including inductor and transformer, and semiconductor devices operate in linear mode or switch mode. If a circuit is operating in a linear mode, usually they operate under the conventional signal processing application where frequency is not the primary concern. Hence, magnetic devices can be avoided in linear mode operation. Since the output of a linear mode operation is in a linear relationship with the input where the output is directly derived from it thus it is able to provide a minimal output distortion.

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