MOSFET STEREO AUDIO AMPLIFIER DESIGN

RUDY THADDEUS

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Dr. Mohamad Kadim Hj. Suaidi
Ketua Program
Kejuruteraan Elektronik dan Telekomunikasi

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………………………………………
Dr. Mohammad Kadim Suaidi
Supervisor

……………………
Date

KHIDMAT MAKLUMAT
UNIMAS
0000072692

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RUDY THADDEUS

This Thesis is presented to the
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For My Beloved Family

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Also, thanks to all my colleagues who have helped me to finish this thesis especially to Mr. Awang Musa bin Hassan who had kindly let me use his computer and to Mr.BadrulHisham for letting me use his printer.

ABSTRAK

Pada masa kini penggunaan sistem amplifier audio stereo kuasa tinggi telah digunakan dengan meluas mengikut teknologi semasa. Sistem ini boleh didapati di pasaran dalam berbagai bentuk dan kelebihan. Kelebihan-kelebihan yang biasa diambil berat ialah dari segi penghasilan bunyi sistem tersebut dan kebolehannya untuk memainkan pelbagai alat-alat muzik. Tesis ini membincangkan dalam mereka sebuah modul sistem audio amplifier stereo MOSFET. Ciri-ciri dan faktor-faktor yang mempengaruhi spesifikasi alat diperbincangkan. Kaedah dan masalah yang dihadapi dalam pembinaan sistem ini juga akan turut diperbincangkan.

ABSTRACT

Today, the high performance stereo audio amplifiers have been widely use according to the technology. The system can be found in the market in various forms and advantages. The considerable advantages of this system are in terms of its output sound and application to many musical input devices. The purpose of this thesis is to explain the building of a MOSFET stereo audio amplifier module. The characteristics and factors that has effect on the specifications of the system are discus. Method and problems that arise in constructing it are also discus.

CONTENTS

TABLE LIST

Table **Page**

FIGURE LIST

ABBREVIATIONS

Ω	-	Ohm (resistive unit)
AC	-	Alternating current
dB	-	Decibal (unit for gain)
DC	-	Direct current
di/dt	-	Difference of current with respect to time
ESR	-	Equivalent series resistance
HF	-	High frequency
Hz	-	Hertz (Frequency unit)
IC	-	Integrated circuit
MOSFET	-	Metal-oxide semiconductor Field-effect transistor
PA	-	Power amplifier
PCB	-	Printed circuit board
PSU	-	Power supply unit
PU	-	Pick-up
r.m.s.	-	Root mean square
RF	-	Radio Frequency
RIAA	-	Record Industry Association of America
SNR	-	Signal to noise ratio
TID	-	Transient intermodulation distortion
Vout	-	Output Voltage
W	-	Watt (unit for power)

APPENDICES LIST

CHAPTER 1

INTRODUCTION

This chapter covers the basic about audio amplifiers that related to the project of the designing of a MOSFET stereo audio amplifier system. The basic about audio amplifier will be briefly explained along with the classifications include and also some considerations to the output signal of the power amplifier. Here, also some introduction to the concept of the stereo sound will be briefly discussed.

1.0 Audio Amplifier Classifications

Audio amplifiers are classified in many ways. The two most common methods are by operating-point or bias-point and circuit connections. Audio amplifiers are also classified by their function or purpose (voltage amplifier, power amplifier, etc.).

1.1 Audio Amplification Principle

Figure 1.1 shows the typical common-emitter (CE) audio circuit. Under no signal (or quiescent) conditions, current flows in the input circuit (across R1), causing a steady value of current to flow in the output circuit (across R3).

A voltage is developed across R1 during the first half of the audio signal applied to the input. This voltage, positive at the base end of R1, adds to the bias voltage at the junction of R1 and R2, causing the base-to-emitter voltage (Vbe) to increase.

Under these conditions, the voltage from the collector to emitter (Vce) increases but with the phase inverted (the collector goes negative when the base goes positive). Amplification occurs because the collector current (Ic) is many times greater than the base-emitter current (Ibe). When the second half of the audio signal is applied across R1, the voltage across R3 also alternates but in the opposite direction (a negative swing at the input produce a positive swing at the output and vice versa).

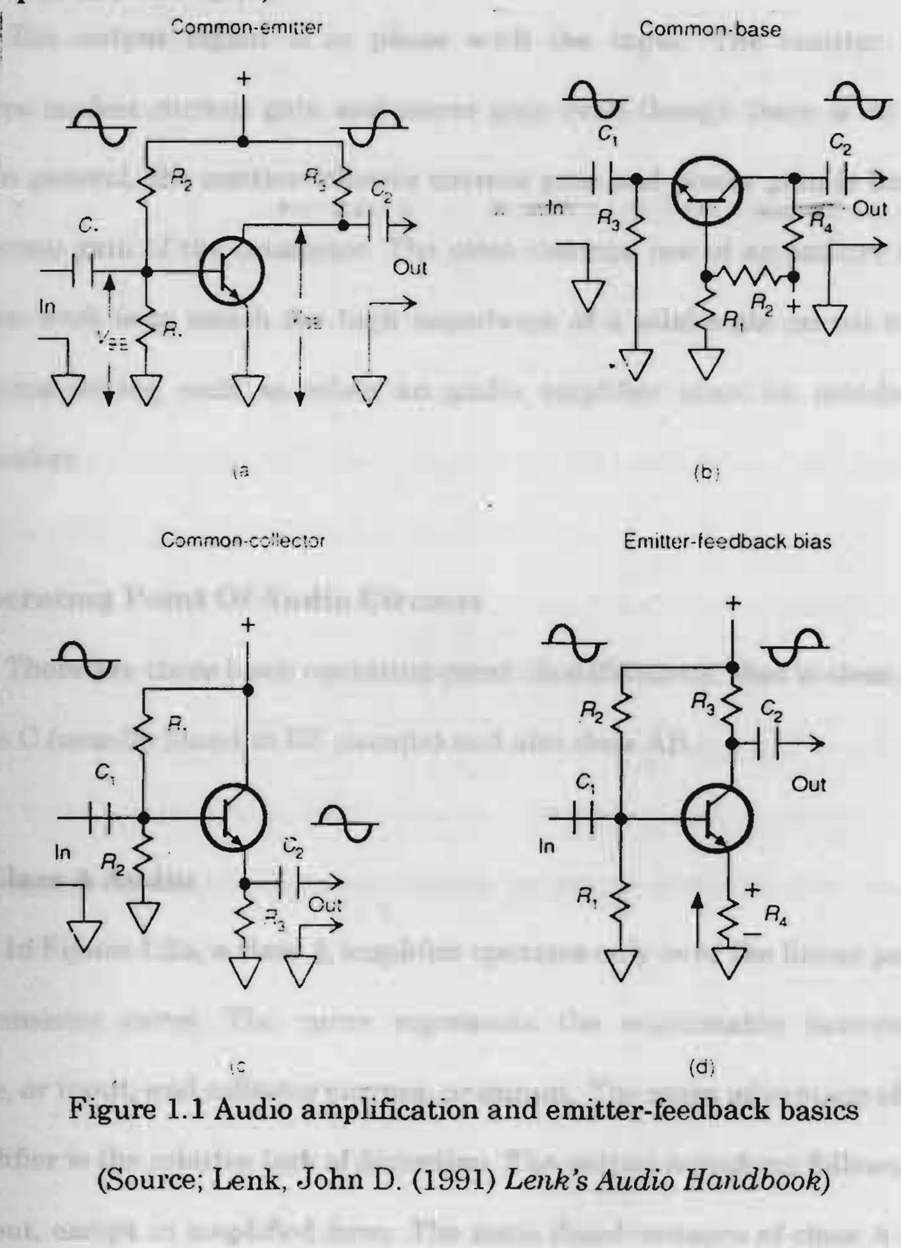

Figure 1.1 Audio amplification and emitter-feedback basics

(Source; Lenk, John D. (1991) *Lenk's Audio Handbook*)

1.2 Common-Collector Audio Amplifiers

Although, the common-emitter (CE) circuit is the most widely used, but in our stereo audio amplifier are using the common-collector audio amplifiers (CC) which is also known as an emitter follower since the output is taken from the emitter resistance, and the output follows the input (in phase relationship). In the emitter follower, the input signal is applied to the base (across R2) and the output signal appears at the emitter (across R3). This provides extremely high input impedance and a very low output impedance (usually set by the value of R3).

The output signal is in phase with the input. The emitter follower produces modest current gain and power gain even though there is no voltage gain. In general, the emitter follower current gain and power gain is limited by the current gain of the transistor. The most common use of an emitter follower in audio work is to match the high impedance of a solid-state circuit to a low-impedance device, such as when an audio amplifier must be matched to a loudspeaker.

1.3 Operating Point Of Audio Circuits

There are three basic operating-point classifications, that is class A, class B, class C (usually found in RF circuits) and also class AB.

1.3.1 Class A Audio

In Figure 1.2a, a class A amplifier operates only over the linear portion of the transistor curve. The curve represents the relationship between base voltage, or input, and collector current, or output. The main advantage of a class A amplifier is the relative lack of distortion. The output waveform follows that of the input, except in amplified form. The main disadvantages of class A circuits are relative inefficiency (lower power output for a high-power input that must be dissipated by the transistor) and the inability to handle large signals. Class A amplifier is always below 35% efficient. If the power input to a class A amplifier is 1W, the output is less than 0.3W.

The input voltage swing of a class A audio amplifier is limited by the output voltage swing and the voltage amplification factor. For example, if the output is limited to $\pm$ 10 V and the voltage amplification factor is 100, the input is limited to $\pm$ 0.1 V (100mV).

Because of these limitations, class A audio circuits are generally used as a voltage amplifiers rather than power amplifiers. Typically, a class A amplifier stage is used ahead of a power amplifier stage.

1.3.2 Class B Audio

A class B amplifier operates only on one-half of the input signal (Figure 1.2b). Class B is produced when the base-emitter bias is set so that the operating point coincides with the transistor cut-off point. When the input signal voltage is zero, there is no flow of collector current.

There is considerable distortion if a single transistor is operated as class B. This is because the waveform of the resulting collector current resembles that of one input half-cycle and does not resemble the complete wavwform at the input. Class B is generally used when two transistors are connected in push-pull. This makes it possible to reconstruct an output waveform that resembles the full waveform of the input.

The peak output voltage swing of a class B amplifier is slightly less than the supply voltage. Since the output appears only on half-cycles, it is possible to operate class B amplifiers at a higher current (or power) rating than class A with equal factors. The peak output of a class B amplifier is equivalent to the p-p output of class A amplifier. So, if two transistors are connected in push-pull and operated as class B, the output voltage can be twice that of class A. Due to the voltage and power factors, class B amplifiers are generally used as power amplifiers rather than voltage amplifiers.

In a typical audio amplifier using discrete components, two push-pull transistors are operated in class B, preceded by a single class A stage. The class A stage provides voltage amplification, whereas the class B stage produces the necessary power amplification.

1.3.3 Class AB audio

Class AB operation is used in audio amplifiers to minimize the effects of crossover distortion, shown in Figure 1.2c. In pure class B, the transistor remains cut off at very low signal inputs and turns on with a large input signal. In class B push-pull operation, during the instantaneous pause when one transistor stops conducting and the other transistor starts conducting, the output waveform is distorted. This instantaneous cutoff of collector current can also set up large voltage transients equal to several times the supply voltage, possibly, resulting in transistor breakdown.

By using class AB amplifier these undesired effects can be minimize, where the transistors are forward biased enough for a small amount of collector current to flow at the Q-point, and there is no cutoff turn on.

1.3.4 Class C audio

The characteristic of a typical class C amplifier are shown in Figure 1.2d. The transistor is reversed biased well below the cutoff point and that there is collector-current flow for only a portion of half the input signal. From Figure 1.2d obviously shows the waveform of the output signal cannot resemble to the input signal even if it is restored by push-pull operation such as in class A or AB. Class C is limited to those applications where distortion is of no concern which usually means RF circuits rather than audio circuits.

1.4 Power Amplifiers

1.4.1 History

In Figure 1.3 shows a British 14W amplifier of 1938 vintage, which is used for domestic high quality sound reproduction. The retail price at that time is £20 which yield a figure of approximately 0.7W per £1. In Figure 1.4 shows the Quad 15W valve amplifier cost about £22 in 1960, which also gives a figure of around 0.7W per £1. The purchasing value of the pound had meanwhile had fallen by a factor of at least 2, so that the maintenance of the 0.7W per £1 clearly resulted mainly from the more economical design of the later amplifier, which employed beam tetrodes with negative feedback to obtain low distortion and a low hum level.

However, the advent of transistors enabled a far more striking economy of engineering to be effected. The Quad 405-2 transistor amplifier shown in Figure 1.5 gives a total output of 200W, sold in 1988 for around £300, again yielding a figure of about 0.7W per £1. But the large financial inflation of that time since 1960 clearly shows the true cost per watt with modern semiconductor technology is indeed down and clearly shows a major engineering advance.

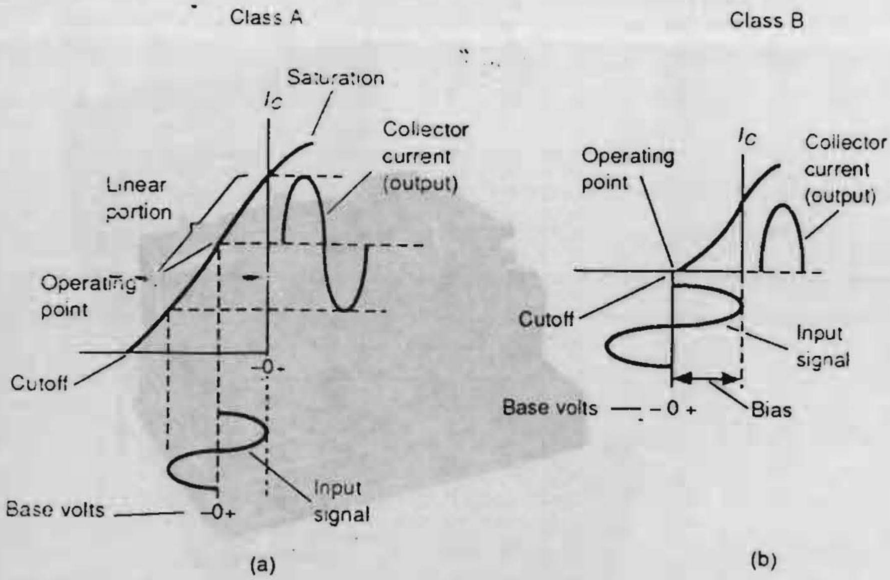

Figure 1.2(a)&(b): Audio operating-point classifications.

(Source; Lenk, John D. (1991) *Lenk's Audio Handbook*)

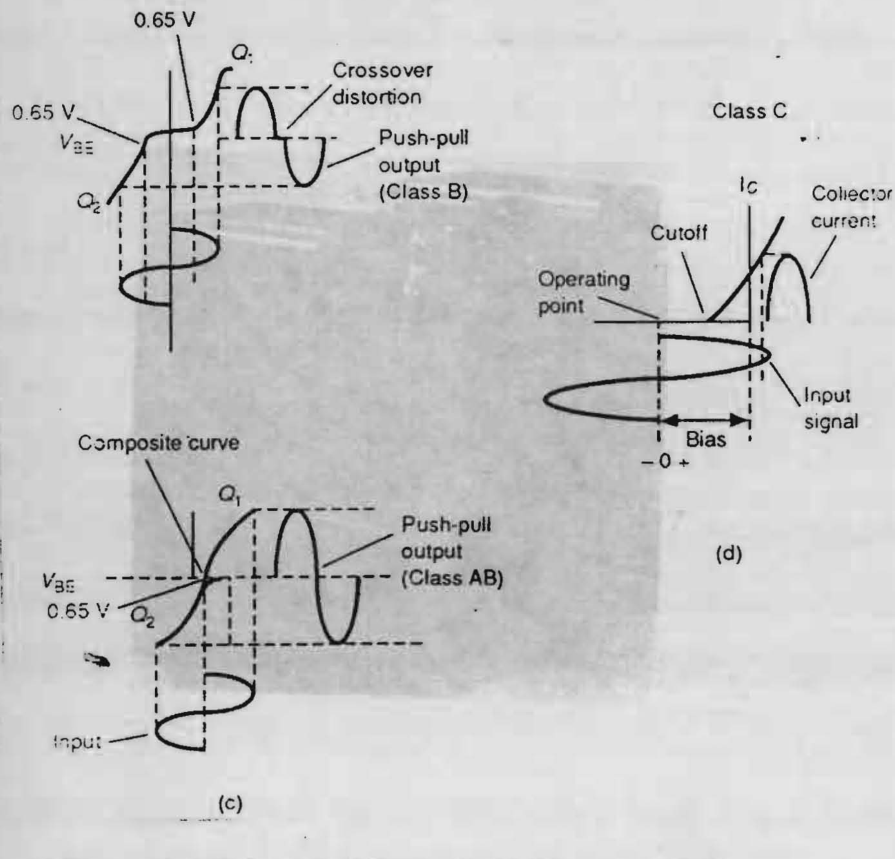

Figure 1.2(c)&(d): Audio operating-point classifications.

(Source; Lenk, John D. (1991) *Lenk's Audio Handbook*)

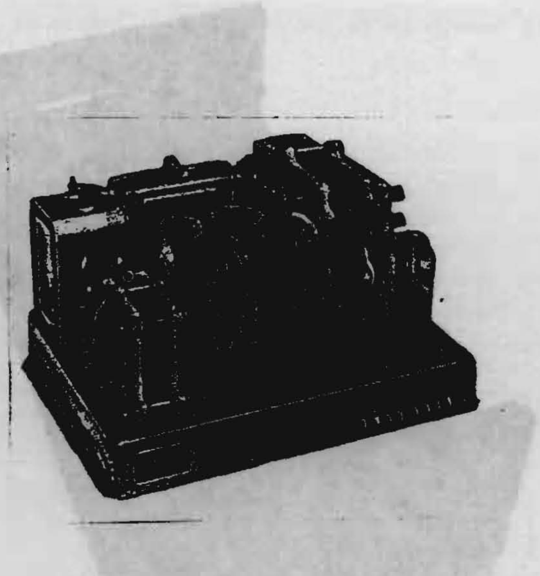

Figure 1.3 Valve amplifier with 15W rating, 1938.

(Source; Smith, Michael Talbot (1994) *Audio Engineering's Reference Book*)

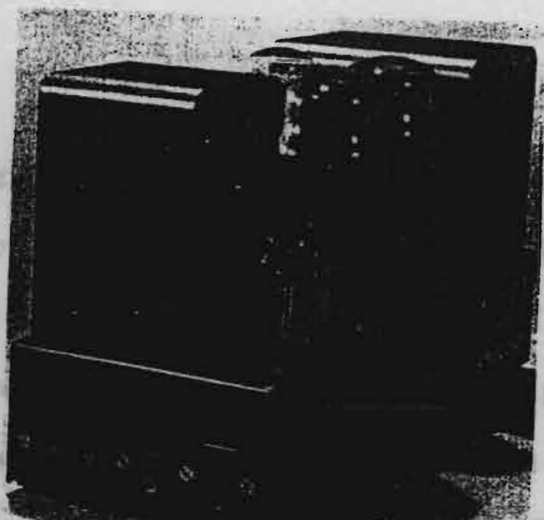

Figure 1.4 Valve amplifier with 15W rating, 1960

(Source; Smith, Michael Talbot (1994) *Audio Engineering's Reference Book*)

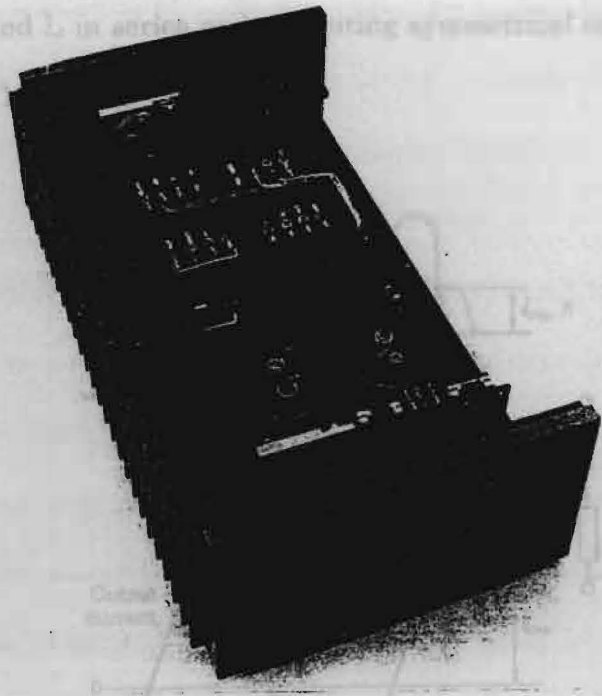

Figure 1.5 Quad 405-2 100W+100W transistor stereo amplifier, 1988.

(Source; Smith, Michael Talbot (1994) *Audio Engineering's Reference Book*)

1.4.2 Clipping

When a program input level to a power amplifier is turned up, a point is reached at where overloading begins to occur. There two kinds of overloading and that is;

a) The amplifier cannot produce the required highest peak instantaneous output voltages, even though it may still have something in hand with regard to supplying the peak instantaneous current demands. This is called voltage clipping.

b) The amplifier cannot produce the required highest peak output currents, even though it may still have something in hand for the peak voltages. This is called current clipping