TWO STAGE AMPLIFIER DESIGN FOR UHF APPLICATION (460MHZ-530MHZ)

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This project is dedicated to my mum and dad

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ABSTRACT

This report presents the design process of the two stage amplifiers for UHF application. It is important to determine the design specifications before designing power amplifier. The procedure in designing two stage power amplifiers is selecting the correct transistor, DC biasing analysis, stability checking and designing of a good matching network. The challenge of the two stage amplifiers is to choose the suitable transistor at operating frequency range 460MHz up to 530MHz. Others challenge, it is too difficult to make the performance optimization of the power amplifier. Three different topologies of the two stage amplifier, which are feedback amplifier, balanced amplifier and conventional amplifier are designed and analyze in term of their performance. The simulation work is done by using Advance Design System (ADS) software. The optimization function of the software can help in getting the best result.

ABSTRAK

Laporan ini membentangkan prosess rekaan dua peringkat penguat untuk kegunaan aplikasi UHF. Spesifikasi reka bentuk perlulah ditentukan terlebih dahulu sebelum memulakan proses reka bentuk. Prosedur dalam mereka bentuk dua peringkat penguat adalah dengan memilih jenis transistor yang benar-benar bersesuaian dengan aplikasi yang digunakan, analisis DC pincangan, memeriksa kestabilan transistor dan juga reka bentuk rangkaian padanan. Cabaran dalam mereka bentuk dua peringkat penguat adalah dalam melilih transistor yang benar-benar sesuai pada frekuensi yang beroperasi dalam julat 460MHz sehingga 530MHz. Cabaran yang lain, ianya sangat sukar untuk membuat pengoptimum bagi mendapat prestasi penguat yang baik. Tiga topologi yang berbeza iaitu penguat maklum balas, penguat seimbang dan juga penguat biasa direka and dianalisis dari segi prestasi ketiga-tiga penguat tersebut. Kerja-kerja simulasi dilakukan menggunakan perisian Advance Design System (ADS). Fungsi pengoptimum perisian dapat sedikit sebanyak dapat membantu dalam mendapatkan hasil yang bagus.

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ADS – Advance Design System

BJT – Bipolar Junction Transistor

FET – Field-Effect Transistor

MAG – Maximum Available Gain

NF – Noise Figure

RF – Radio frequency

VSWR – Voltage Standing Wave Ratio

UHF – Ultra High Frequency

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CHAPTER I

INTRODUCTION

1.1 Project background

A Radio Frequency (RF) power amplifier is a type of electronic amplifier used to convert a low-power radio-frequency signal into a larger signal of significant power. There are used in a wide variety of applications including wireless communication, TV transmissions, Radar and RF heating. The most important parameters in RF power amplifier are need to define such as output power, high gain, noise figure, linearity, stability, DC supply voltage, efficiency and ruggedness. One of the types of the RF power amplifier is two stage amplifiers. The most important thing in designing two stage amplifiers is to define which types of transistor will be used. The function of this device is allows a small current or voltage to control the flow of a much larger current from a dc power source. There are two general types of transistors which is bipolar and field-effect. Very roughly, the difference between these two types is that for bipolar devices is an input current are controls the large current to flow through the device, while for field-effect transistors an input voltage will provides the control. Moreover, Ultra High Frequency (UHF) are designates the ITU radio frequency range of electromagnetic waves between 300MHz up until 3GHz. UHF radio waves propagate mainly by line of sight where they are blocked by hills and large buildings although the transmission through building walls is high enough for indoor reception. It used for television broadcasting, cordless phone, walkie-talkie, satellite communication, and other applications.

1.2 Problem statement

RF power amplifiers play an important role in modern telecommunications, where opposite design goals make the performance optimization of amplifier very difficult. Two stage amplifiers design is challenging as it required simultaneously to achieve the high gain, low noise figure and also good matching. However it is very hard for the conventional amplifier to meet these specifications. So it has many solutions to solve that problem and one of the solutions is by using multistage design.

1.3 Objective

In this project, different topologies of the two stage amplifiers design are proposed to solve the problem faced by the conventional amplifier and also to further improve on the performance of the amplifier. Balanced, and feedback of the two stage amplifiers are designed and compared. This design also can be operate over frequency range of 460MHz-530MHz

1.4 Scope of work

The scope for this project can be divided into two parts which are:

a) Literature review

The study of the RF fundamental and characteristics of the two stage amplifiers especially on the high gain, noise figure, stability which must be taken into consideration in two stage amplifiers

b) Design and simulation

Two stage amplifiers is designed and simulated at frequency range 460MHz-530MHz using Advanced Design System (ADS) and optimization will be performed to get the best result.

1.5 Thesis outline

The thesis is divided into five chapters which covers the complete design process of the two stage amplifiers design. Chapter 1 includes the brief introduction of the project where the problem statement, objective and scope of works are mentioned clearly in this chapter.

Chapter 2 is the literature review which discusses the topic on the RF fundamental such as scattering parameter, stability, high gain, noise figure and others that related on to the two stage amplifiers. There also discuss about the information on the different two stage amplifiers topologies namely balanced and feedback amplifier.

Chapter 3 is about on the design methodology which describe the design process of the two stage amplifiers which is include the selection transistor, checking the stability, design the input and output matching and others steps.

Chapter 4 is mainly on the result and analysis. This chapter will includes the manual calculation and also simulation result by different types of topologies of the two stage amplifiers. The simulation results are compared and analyzed by each topologies.

Chapter 5 is on conclusion and the future work. This chapter will be summarizes the result of the two stage amplifiers design. It also concluded the types of the two stage amplifiers that give the best performance.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Two stage amplifiers is one type of the multistage amplifier. In multistage amplifiers, the low noise stage should be first and the highest intercept stage should be last. If the overall gain control is required, the gain of the first stage is usually controlled to avoid overload under strong signal conditions [2]. It frequently used in transmitter driver circuit. In many applications, the control of the stage gain by changing its bias current is unacceptable, because to obtain lower gain so a lower bias current is required. The action by lower the intercept point is undesirable because of the lower gain is required exactly when the input signal levels are high. With the high input signal levels, it could to operate at a higher bias condition to avoid distortion. The total amount of the gain that is achievable with the multistage is ultimately limited by the isolation between the output and input. When the overall gain is greater than the isolation, the oscillation may result.

2.2 Design consideration

In power amplifier design, there must be have DC biasing circuit in order to bias the transistor, input and output matching network to ensure the maximum power transfer in the circuit. Different biasing technique can be employed to the transistor such as active or passive biasing. The main design parameter such as gain, noise and IP3 need to be firstly considered in order to determine the biasing point of the V_{CE} and I_C that will produce optimal performance.

Another important parameter that needs to be considered in designing power amplifier is stability checking. Unconditional stability of the circuit has to be achieved at the operating frequency so that the amplifier will not oscillate and become unstable. The scattering coefficients of the transistor were determined. The input circuit should match to the source while the output circuit should match to the load in order to deliver maximum power to the load. The input and output matching is the last step in designing two stage amplifiers.

2.3 Two stage amplifier topologies

The importance goal in designing two stage amplifiers is to achieve a high gain of the amplifier, minimize the noise figure and also producing a stability of 50Ω input impedance.

2.3.1 Feedback amplifier

Feedback amplifier is a system that process of signals. The processing part of a feedback system may be electrical or electronic, ranging from a very simple to complex circuits. Simple analogue feedback control circuits can be constructed using individual or discrete components, such as transistors, resistors and capacitors. A feedback system is one in which the output signal is sampled and then feedback to the input to form an error signal that drives the system. Feedback Systems are very useful and widely used in amplifier circuits, oscillators, process control systems as well as other types of electronic systems. There are two types of feedback amplifier such as positive and negative feedback.

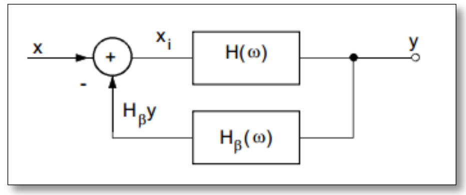

Figure 2.1 Block diagram model of feedback amplifier

Feedback amplifier gives the better performance including increase the stability, reduces distortion in the amplifier, increase the bandwidth of the amplifier and it is easier to achieve the desired input and output impedances.

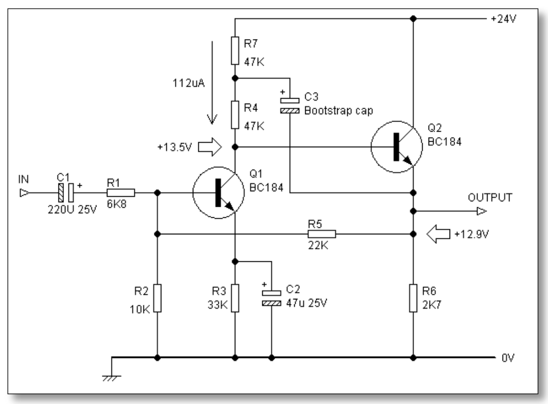

Figure 2.2 Two stage circuit of feedback amplifier

This circuits use a shunt feedback amplifier. There is a bootstrapped collector at the first stage that load to R4 in order to increase the loop gain, while at the second stage, there uses an emitter follower which will provides no voltage gain but buffers the high impedance at Q1 collector from the feedback network and external loads.

2.3.2 Balanced amplifier

Balanced amplifier is very important in many high frequency system because it is exhibits high bandwidth, have flat gain, and also good standing wave ratio at the input and at the output. A balanced amplifier provides a 3dB higher linearity as compared to a single power amplifier by employing 3dB Quadrature Hybrid coupler. Most of the power amplifier designs are based on non-linear large signal models.

Balanced amplifier has two amplifying devices that are run in quadrature. That is, they are operating 90 degrees apart in transmission phase. A quadrature coupler or splitter on the input phase-shifts the two signals 90 degrees at the amplifier inputs, then a second quadrature coupler on the output "un-phase-shifts" the signals at the amplifier outputs so they combine in phase.

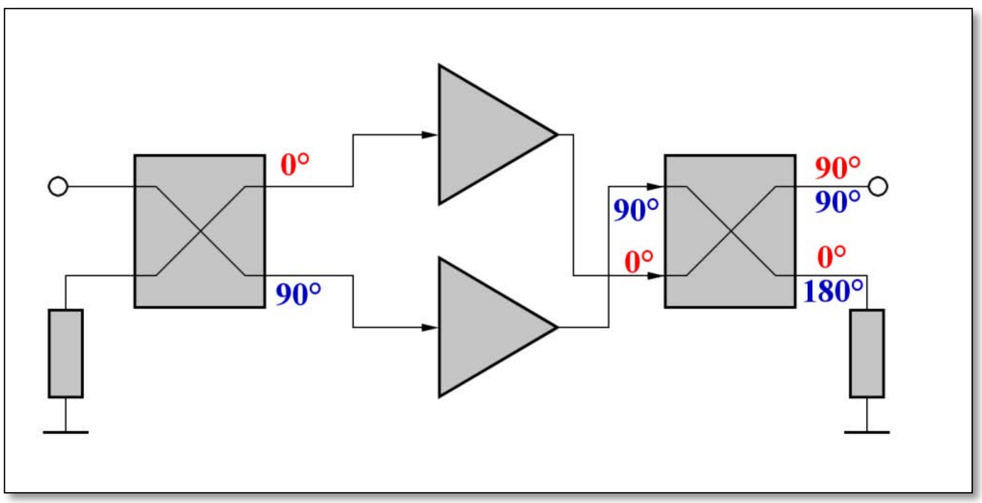

Figure 2.3 Principle of the balanced amplifier

The reflection coefficient external to a balanced amplifier is passed on to the individual amplifiers in all its glory, albeit at 180 degrees out of phase. Balanced amplifiers are more immune to load pull effects than in-phase power combining schemes, because the two reflection coefficients are seen 180 degrees out of phase. When the input signals are phase shifted by 90 degrees, the signals that reflect from the amplifying devices undergo a 180 degree phase shift and combine out of phase at the RF input. For near-identical devices they subtract from each other when they combine, so they combine to zero volts, and ultimately a great input match. A similar thing happens at the output. The bottom line is this: you can combine stuff with poor reflection coefficients and the amplifier end up matched closely to fifty ohms, so long as the devices are nearly matched in reflection coefficients.

Usually balanced amplifier has excellent input and output return loss. If they are presented with a bad match on the output, the bad match is seen by both amplifiers, but at phase angles differencing by 180 degrees. The load that terminates the isolated port on the output can see sizable heat dissipation if the phases of the two amplifiers (or their amplitudes) are not exactly the same. The use of balanced amplifiers at millimeter wave is quite common.

2.4 Scattering parameter

Scattering parameter or S-parameters describe as the electrical behavior of linear network when undergoing various steady state stimuli by electrical signal. It is very useful for electrical engineering, electronics engineering and especially for microwave engineering.

S-parameters are important in microwave design as they are relatively easy to obtain at high frequencies. It can be measured directly using vector network analysis. It is usually related to familiar measurements like gain, return loss, reflection coefficient and so on [1]. In addition, S-parameter file also easily can be import by using electronic simulation tools like ADS. In two stage amplifier design, S parameters will provide necessary values to do analysis on the stability and gain

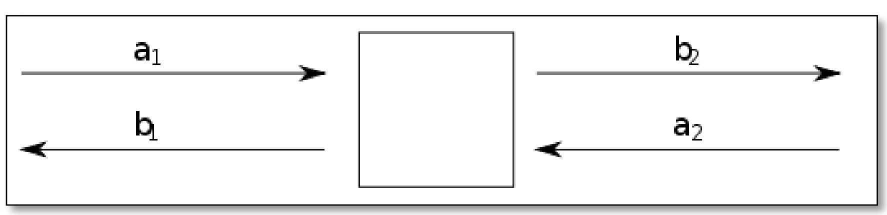

Figure 2.4 Two port S-parameters