DESIGN OF WIDEBAND LOW NOISE AMPLIFIER

YONG KOK SHENG

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Faculty of Electronic and Computer Engineering
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This project is dedicated to my mum and dad

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ABSTRACT

Today, wideband amplifier design remains one of the most challenging portions in the communication system. The conventional low noise amplifier operates on a single band, in which it is easier to design the amplifier to meet the entire specified goal. However, MOTOROLA wideband low noise amplifier which operate from 100 MHz to 1 GHz, making it harder to design as to operate at wider spectrum while maintaining low noise < 1.5 dB, great input and output return loss <-10dB, good gain > 15 dB with reverse isolation of < -20 dB with restriction of low power consumption < 1.8 V and < 10 mA, thus presenting a tougher challenge for the designer to achieve the goals for the extended frequency range. Traditional methods of tuning and tweaking will require more tedious and time consuming effort to cover the wider frequency range, thus rendering the methods to be impractical. Therefore, a more specific technical approach must be utilized to help the designers to better design the broadband amplifier. This research paper represents the amplifier requirements in wideband application and proposed a structured practical design approach which utilizes the feedback topology by using Advanced Design System (ADS) simulations in optimizing the amplifier to meet all the required specs. The best performance design is fabricated on a FR4 strip board and the performance of designed amplifier was verified using network analyzer. The fabricated LNA exhibits a signal gain of more than 17 dB, NF of less than 1 dB, IIP3 of more than 10 dBm and has been maintained unconditional stable throughout the frequency of interest.

ABSTRAK

Masa kini, rekaan penguat hinggar rendah kekal satu bahagian yang paling mencabar dalam bidang telekomunikasi. Penguat hinggar rendah konvensional beroperasi dalam satu jalur sempit sahaja, di mana ia lebih mudah untuk direka untuk mencapai semua gol yang ditentukan. Walau bagaimanapun, penguat hinggar rendah jalur lebar Motorola yang beroperasi dari 100 MHz hingga 1 GHz, membuatnya lebih sukar dalam mereka proses kerana ia perlu beroperasi pada spectrum yang lebih luas pada masa yang sama ia perlu mengekalkan hinggar yang rendah < 1.5 dB, S_{11} dan S_{22} < -10 dB, penguatan > 15 dB dengan pengasingan < -20 dB dengan sekatan penggunaan kuasa yang rendah < 1.8 V and < 10 mA. Kaedah tradisional penalaan akan memerlukan banyak usaha dan memakan masa untuk meliputi julat frekuensi yang lebih luas, maka menyebabkan kaedah tradisional untuk menjadi tidak praktikal. Oleh itu, pendekatan teknikal yang lebih khusus mesti digunakan untuk membantu pereka untuk mereka penguat hinggar rendah jalur lebar yang baik. Kertas kajian ini menbentangkan keperluan dalam perekaan penguat hinggar rendah jalur lebar dan mencadangkan pendekatan perekaan praktikal dengan menggunakan topologi penguat suap balik dengan menggunakan *Advance Design System* (ADS) simulasi dalam mengoptimumkan penguat untuk memenuhi semua spesifikasi yang ditentukan. Rekaan yang memberi prestasi terbaik akan difabrikasikan menggunakan papan FR4 dan ukuran praktikal reka bentuk diuji dengan menggunakan penganalisa vektor rangkaian untuk mengesahkan prestasi LNA. LNA yang difabrikasikan mempamer penguatan lebih daripada 17 dB, hinggar kurang daripada 1 dB, IIP3 lebih daripada 10 dBm dan kekal stabil sepanjang frekuensi operasi.

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LIST OF ABBREVIATIONS

LNA	-	Low Noise Amplifier
RF	-	Radio Frequency
IF	-	Intermediate Frequency
BJT	-	Bipolar Junction Transistor
E-PHEMT	-	Enhancement Mode Pseudomorphic HEMT
PHEMT	-	Pseudomorphic HEMT
WLAN	-	Wireless Local Area Network
DC	-	Direct current
VSWR	-	Voltage Standing Wave Ratio
ADS	-	Advanced Design System
FET	-	Field-Effect Transistor
Si	-	Silicon
GaAs FET	-	Gallium arsenide Field-Effect Transistor
CMOS	-	Complementary Metal–Oxide–Semiconductor
MMIC	-	Monolithic Microwave Integrated Circuit
MESFET	-	Mmetal Semiconductor Field Effect Transistor
HEMT	-	High Electron Mobility Transistor
SNR	-	Signal Noise Ratio

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The receiver can be divided into Front-End and Back-End. The front-end converts RF (radio frequency) to IF (intermediate frequency). The back-end converts IF to baseband. For digital radios, the back-end will also provide analog to digital conversion. This allows the microprocessor to perform digital signal processing on the received signal and convert it to useful information.

The LNA is a key component in the front-end of receiver section. The main function of LNA is to amplify possibly very weak signal without picking up excessive noise, which will enhance the receiver signal-to-noise ratio (SNR).

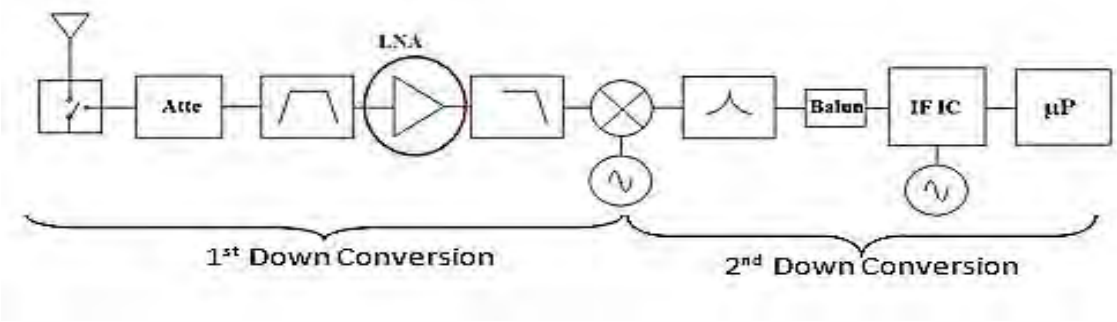

Figure 1.1: Block diagram of the superheterodyne receiver

Another important attributes of the LNA includes low noise figure, reasonable gain and stability over the designated frequency band without oscillating while operating at very low power levels. For large signal, the LNA amplifies the signal without introducing any distortions. Hence, the sensitivity of the receiver is highly dependent on the LNA as it defines the smallest signal that a receiver can detect. [9]

In this project, a high performance wideband low noise amplifier which operates from 100 MHz to 1 GHz is presented. This wideband requirement means that it will be harder for the designer to build the individual receiver section. The receiver subsection needs to be able to receive signals from every critical band across radio frequency while allowing the user to selectively choose the desired frequency band and convert it to baseband. To achieve that, the LNA needs to provide a constant gain, low noise high linearity and unconditionally stable to ensure the whole receiver chain to meet the standard specification. The technical requirements of the wideband LNA design is shown in Table 1.1 below.

Table 1.1: Wideband LNA Design Specification

Parameter	**Specs**
Operating Frequency (MHz)	100 – 1000
Noise figure (dB)	< 1.5
Gain (dB)	> 15
Input Third Order Inception, IIP3 (dBm)	> 5
Stability Factor (K)	> 1
Current (mA)	< 10
Voltage (V)	< 1.8
Input and Output Return Loss (dB)	< -10

1.2 Problem Statement

Portable two ways radio size has been shrinking over time, the employ of multiband radios which consist of several narrow band discrete circuits are larger because inside of housing must contain two or three separate transceivers. Besides, driving a slightly larger housing is the additional filtering and shielding between the transceivers in order to avoid the interfering effect between different transceivers.[1] To solve this problem, the combination of several narrow bands LNA circuit into single wideband LNA circuit is proposed. Wideband LNA design presents a considerable challenge, as we know conjugate matching will give maximum gain only over relatively narrow bandwidth, while designing for less max gain will improve the gain bandwidth, but the input and output part of the amplifier will be poorly matched.[2] For these reason feedback technique is proposed to simultaneously achieve improvement in bandwidth and also on its gain, noise figure and return loss. The conventional LNA suffer from the problem that the input matching network can be tuned for low noise figure or low VSWR (conjugate match) but not both parameter simultaneously.[3] The negative feedback technique can be used in wideband amplifier to provide a flat gain response and to reduce the input and output VSWR. It also controls the amplifier performance due to variations in the S parameters from transistor to transistor and furthermore, in-band stability is also improved by employing negative feedback. [4]

1.3 Objective

The objective of this project is to design low noise amplifiers for MOTOROLA application by using feedback and cascaded technique, then analysed on their noise figure, matching and gain at the operating frequency. Finally the best performance low noise amplifier will be fabricated as final result.

1.4 Scope of work

Scope of this project can be divided into four parts which are:

a) Literature review
   Include the study of the characteristics of the LNA especially on the gain, noise figure, stability which must be taken into consideration in LNA design.

b) Design and simulation
   LNA which operated at frequency band start from 100 MHz to 1 GHz is designed and simulated using Advanced Design System (ADS) and optimization will be performed to get the best result.

c) Fabrication
   The fabrication of the low noise amplifier will be done using microstrip FR4 will be used to fabricate the low noise amplifier.

d) Test analysis and measurement
   The performance of the designated amplifier circuit is measured using the vector network analyzer and will be compared with the simulation result.

1.5 Thesis Outline

The thesis is separate into five chapters. Chapter 1 is 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 where the basic of RF Fundamental, Introduction of LNA and LNA architecture are explained.

Chapter 3 involve the LNA design process include the transistor selection, stability checking, DC biasing, matching networks, simulation and layout design.

In chapter 4, this chapter will analysis the simulation results and fabrication process and lastly testing important parameter of the circuit.

Finally in chapter 5, the conclusion and future work will summarizes the result of the LNA designed. It also conclude the type of LNA that gives the best performance and most suitable to be used in Motorola product's application.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Recently, the growing demand in high performance wireless technology had boosted the development of LNA. The low noise amplifier is key block in any receiving system due to the receiver sensitivity is generally determined by its gain and noise figure. Besides, the noise figure for the follow amplifier stages in receiver system are reduced by providing a LNA with low noise figure and high gain, thus it is vital for LNA to amplify the received signal without introducing internal noise.

Most of the LNA are designed using BJT, GaAs FET, CMOS, PHMET and MESFET type of transistors. These are widely used in RF communication applications such as wireless communication, radar communication and also mobile communication. A low voltage, low power consumption, ability to operate at a wide range of temperatures and better performance are always being an advantage for a good LNA design for RF applications.

A lot of research is done before going through the project. This is definitely very important since some basic knowledge must be known before starting a project. Internet sources and books on RF were used to search for information on LNA design. Apart from good understanding on RF theory, knowledge on the wideband LNA methodology is also needed in order to design a broadband LNA

Basically, the research is done on the steps for a good design and what are the trade-offs involved. Datasheets for transistors are also reviewed from various sources to understand the characteristics of a good transistor. The S-parameter characteristic and the biasing information given by the manufacturer in the form of s2p file for various transistors are collected and simulated by using the Advance Design System (ADS). This will give a better understanding on the performance of the transistor for a certain operating frequency.

A BJT is a good choice for the LNA designers, because it gives higher gain with acceptable low noise figure, even though a GaAs FET gives extremely low noise compared to BJT. The problems with GaAs FET are that the designers will face significantly stability problem. This is because FET will oscillate at frequencies where bypassing and grounding becomes a challenge of its own. Hence, the trade-off involve between the choosing of both type of transistor must give prior consideration.

2.2 Design Consideration

The most important design considerations in a low noise amplifier design are stability, noise, power gain, bandwidth and DC requirements. As show in Figure 2.1, a LNA must have DC biasing circuit to biasing the selected transistor, input and output matching network for maximum power transfer in the circuit.

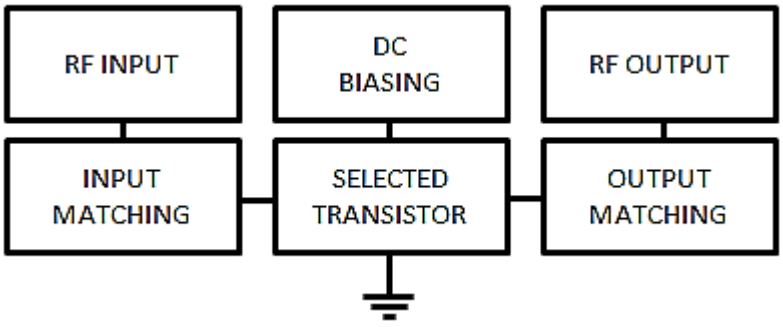

Figure 2.1 Block Diagram of basic LNA

LNA operate in class A mode, characterized by a bias point that is about at the center of maximum voltage and current of the bias supply for the transistor. By referring to data sheet, the biasing point for the LNA should have high gain, low noise figure, linear, good input and output matching and unconditionally stable at the lowest current drain from the supply. In this project, the current drain and voltage supply for the design are restricted to maximum of 10mA and 1.8V respectively.

Unconditional stability of the circuit is another important parameter in designing of LNA, this characteristic means that the device does not oscillate over a range of frequencies with any combination of source and load impedance.

The next step would be the input and output matching. For input matching, two main criteria can be match for, either match for best noise match or great Input Return Loss (IRL) where IRL defines how well the circuit is matched to 50 Ω of the source. A typical approach in designing a LNA is to develop a input matching network terminates the transistor with conjugate of Gamma optimum (Γ_{opt}), which imply the matching the impedance of the transistor for the greatest noise match. In most cases, this means that the input return loss (IRL) of the Low Noise Amplifier will be sacrificed. The optimal IRL only can be achieved when the input-matching circuit terminates the device with a conjugate of S_{11}, which is different from the conjugate of Γ_{opt}. Hence, there must always be a trade-off between both criteria. For output matching, conjugate matching has been exclusively used to maximize the gain of the circuit.

S_{11} and S_{22} are measures of the input and the output match. A value of -10 dB means matching to within 20 %. Therefore the target value for S_{11} and S_{22} is set to be below -10 dB over the entire bandwidth.

For the Third-Order-Intercept-Point (IIP3 and OIP3) and the gain is controlled by some external factors such as the linearizing inductor, and bypassing component which also play a significant role in the performance of the LNA itself.