San Jose State University
EE 198A

Project Report

LOW NOISE AMPLIFIER

Advisor: **Pro. George Venderlin**

Team Members: **Phuong Nham**
Thinh Nguyen
Ha Le
Tansy Le

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CONTENTS

1. ABSTRACT:

The purpose of this project is to design, build, and test a single state Pseudomorphic High Electron Mobility Transistor (PHEMT) Low-Noise-Amplifier (LNA) at 2GHz having a

gain of 16 dB and noise figure of less than or equal to 0.4 dB. The transistor used in this design is FHX35X. Impedance matching networks at the input and output are designed to give low-figure and desired gain respectively. The low-noise amplifier is designed in the hybrid Microwave Integrated Circuit form on a 50 Ohms substrate.

2. INTODUCTION:

This application note describes a low noise amplifier for use in the 2.0 GHz wireless local loop, wireless broadband access, and digital microwave radio markets. The amplifier makes use of low cost, miniature, multiplayer chip inductors for small size. When biased at a V_{DS} of 3 volts and I_{DS} of 10 mA, the Fujitsu FHX35X amplifier will provide 16 dB gain, and 0.4 dB noise figure.

LNAs find application in communication systems and instrumentation equipment. Sine the LNA is the first circuit block in a receiver chain, its noise performance dominates the system sensitivity. The primary objective of this work is to achieve low noise figure and flat gain over the wide frequency range of operation. Other considerations are low input voltage standing wave ratio (VSWR), and large range of source and load impedances for which the amplifier remains stable.

While minimum noise figure in narrow band amplifiers can be obtained with a single-frequency impedance matching network, achieving close-to-minimum noise figure across a wide frequency band is significantly more complicated. For this purpose, a resonance matching network is employed at this input, to track with frequency the optimal course impedance which results in the minimum noise figure.

3. SPECIFICATIONS:

At biasing point of V_{DS} = 3.0V and of I_{DS} = 10mA, the amplifier provides the following specifications:

Frequency range	1.8 – 2.2 GHz
Noise figure (NF)	0.4 dB
Gain	16 dB

Output power @1dB gain compression (P1dB)	+11.5 dBm
Third order output intercept point (OIP3)	+22.5 dBm
Input return loss	-15.5 dB
Output return loss	-10.0 dB
DC voltage supply (V_{DD})	+5 V

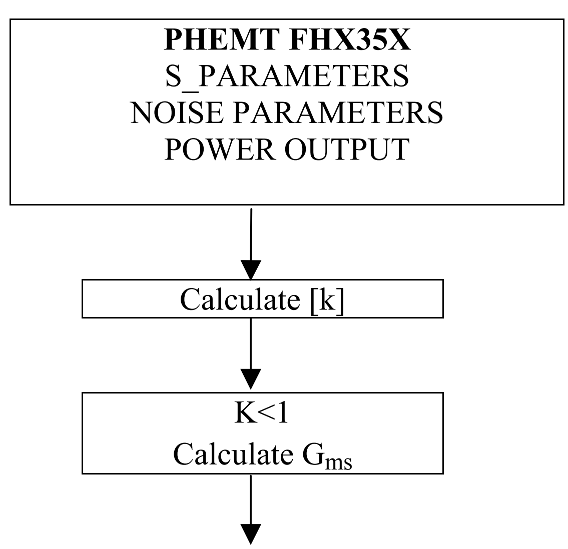
Frequency	S parameters			
	S(1,1)	**S(2,1)**	**S(1,2)**	**S(2,2)**
2.0 GHz	0.973/-26.3	4.097/159.2	0.033/77.5	0.493/-13.1

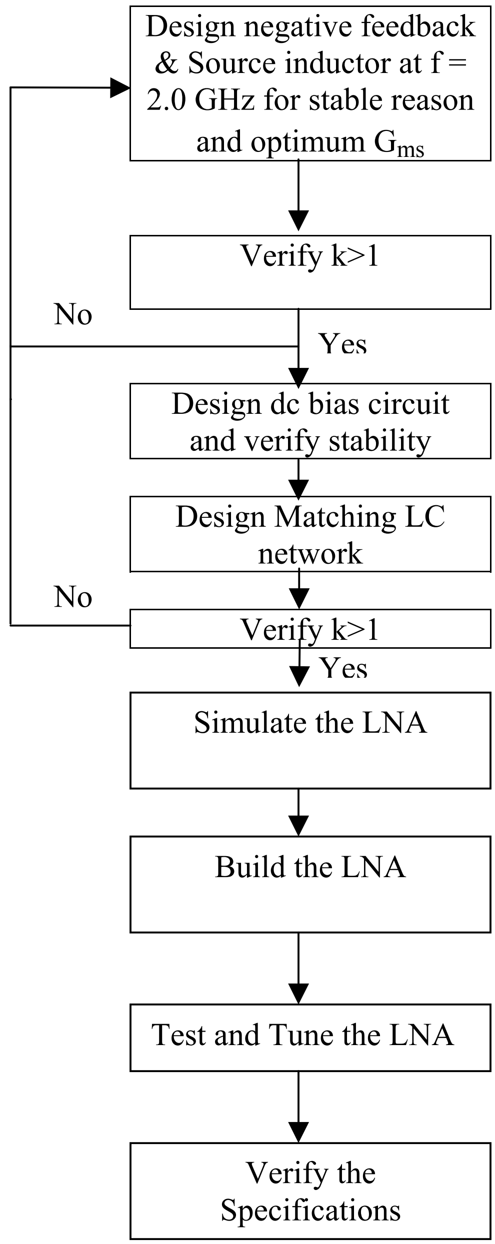
FHX35X noise figure parameters: V_{DS} = 3.0V and I_{DS} = 10mA

Frequency	**Max gain**	**Nfmin (dB)**	**Rn/50**	**Γ_{opt}**
2.0GHz	16 dB	0.40	0.67	0.81/20

4. <u>METHODOLOGY</u>:

a. ***Design flowchart:***





Design negative feedback & Source inductor at f = 2.0 GHz for stable reason and optimum G_{ms}
Verify k>1
No
Yes
Design dc bias circuit and verify stability
Design Matching LC network
No
Verify k>1
Yes
Simulate the LNA
Build the LNA
Test and Tune the LNA
Verify the Specifications

Figure 1. Design flowchart

b. Matching Circuit

Once a bias point is selected, s-parameters are measured and used to analyze the stability of the transistor. Stability is the most important issue in amplifier design. The amplifier must be stable at all frequencies: below the band, in the band, and above the band; moreover, it must be stable for all terminations that will be connected. The s-parameters of the device, the matching networks, and the terminations are all used to determine the stability of the amplifier. Figure 2 shows a block diagram of an amplifier circuit:

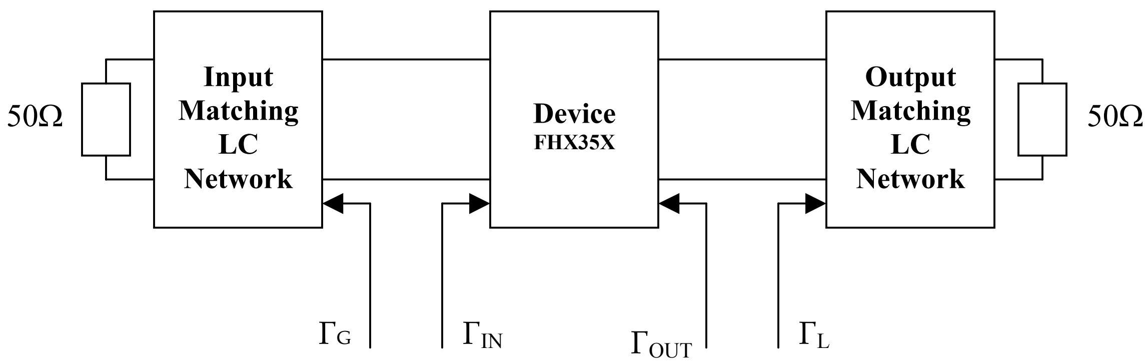


Figure 2. Amplifier Block Schematic

Where

$$\Gamma_{IN} = S_{11}$$

$$\Gamma_{OUT} = S_{22}'$$

$$\Gamma_{OUT} = S_{22} + \frac{S_{12}S_{21}\Gamma_{opt}}{1 - S_{11}\Gamma_{opt}}$$

c. Stability

In a two-port network, oscillations are possible when either port presents a negative resistance. This occurs when:

$$|\Gamma_{IN}| > 1$$

or $|\Gamma_{OUT}| > 1$

Therefore, a two-port network is considered to be unconditional stable at a given frequency if the real parts of Z_{IN} and Z_{OUT} are greater than zero for all passive load and source impedance. In terms of reflection coefficients, unconditional guaranteed if

$$|\Gamma_G| < 1$$

$$|\Gamma_L| < 1$$

$$|\Gamma_{IN}| = \left| S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \right| < 1$$

$$|\Gamma_{OUT}| = \left| S_{22} + \frac{S_{12}S_{21}\Gamma_G}{1 - S_{11}\Gamma_G} \right| < 1$$

In order to have the transistor unconditionally stable, all of the above expressions must be satisfied.

d.Graphical Method

A graphical method is also used to analyze the stability of the transistor. In a potentially unstable transistor, there may be values of Γ_S and Γ_L that produce a positive real part of Z_{IN} and Z_{OUT}. These values of Γ_S and Γ_L lie in circles known as stability circles. The circles are defined by their radius and center, which are found to be

Γ_L values for $|\Gamma_{IN}| = 1$ (Output Stability Circle)

$$\Gamma L = \left| \frac{S_{12}S_{21}}{|S_{22}|^2 - |D|^2} \right| \qquad \text{(Radius)}$$

$$C_L = \frac{\left(S_{22} - DS_{11}^*\right)^*}{\left|S_{22}\right|^2 - \left|D\right|^2} \qquad \text{(Center)}$$

Γ_G values for $|\Gamma_{OUT}| = 1$ (Input Stability Circle)

$$\Gamma_G = \left|\frac{S_{12}S_{21}}{\left|S_{11}\right|^2 - \left|D\right|^2}\right| \qquad \text{(Radius)}$$

$$C_G = \frac{\left(S_{11} - DS_{22}^*\right)^*}{\left|S_{11}\right|^2 - \left|D\right|^2} \qquad \text{(Center)}$$

Where $D = S_{11}.S_{22} - S_{12}.S_{21}$

The s-parameters of the device are used to determine which area of the Smith Chart produces a stable operation. The load reflection coefficient is described as following expression:

$$\Gamma_L = \frac{Z_L - Z_O}{Z_L + Z_O}$$

where Zo is 50Ω. It is apparent that $\Gamma_L = 0$ whenever $Z_L = Z_0$. From definition, if $\Gamma_L = 0$, then $|\Gamma_{IN}| = |S_{11}|$.

- If the magnitude of S_{11} is less than one, then $|\Gamma_{IN}| < 1$ when $\Gamma_L = 0$ (center of the Smith Chart.) The center of the Smith Chart represents a stable region and the portion of the chart that falls inside the stability circle represents the unstable region.
- If S_{11} is greater than one, then the center of the Smith Chart represents an unstable region and the area inside the stability circle represents the stable, operating region. Similar reason is applied for the input stability circle (interchanging Γ_L with Γ_G and S_{11} with S_{22})

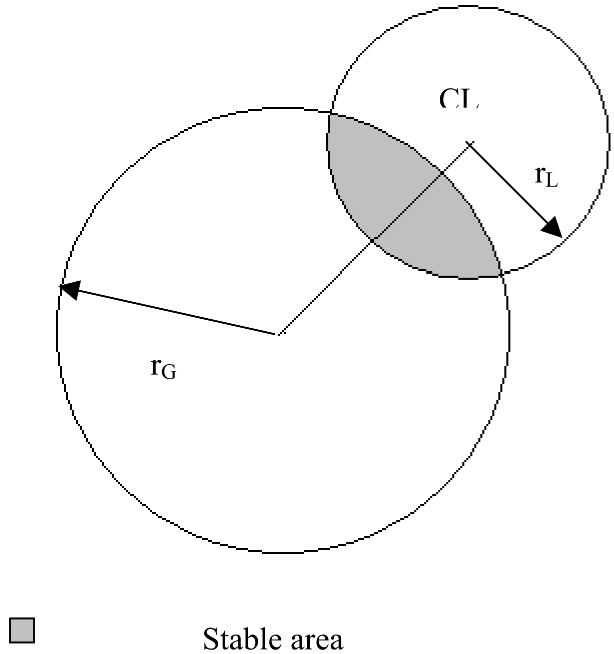


Figure 3. Output Stability Circle

For unconditionally stability, any passive load or source at either port must produce a stable condition. From the graphic, the stability circles must completely enclose or fall completely outside the Smith Chart for $|S_{11}| < 1$.

e. Mathematical Method

$$k = \frac{1 - (|S11|)^2 - (|S_{22}|)^2 + (|D|)^2}{2 \times |S_{12}||S_{21}|}$$

Unconditional stability at a particular frequency

$$k > 1$$
$$|D| < 1$$

If a transistor is unstable at the design frequency, resistive loading or the use of negative feedback may be used to make it stable.

f. Circuit

The schematic for the entire amplifier is given in Fig. 4 below, where all elements are realizable:

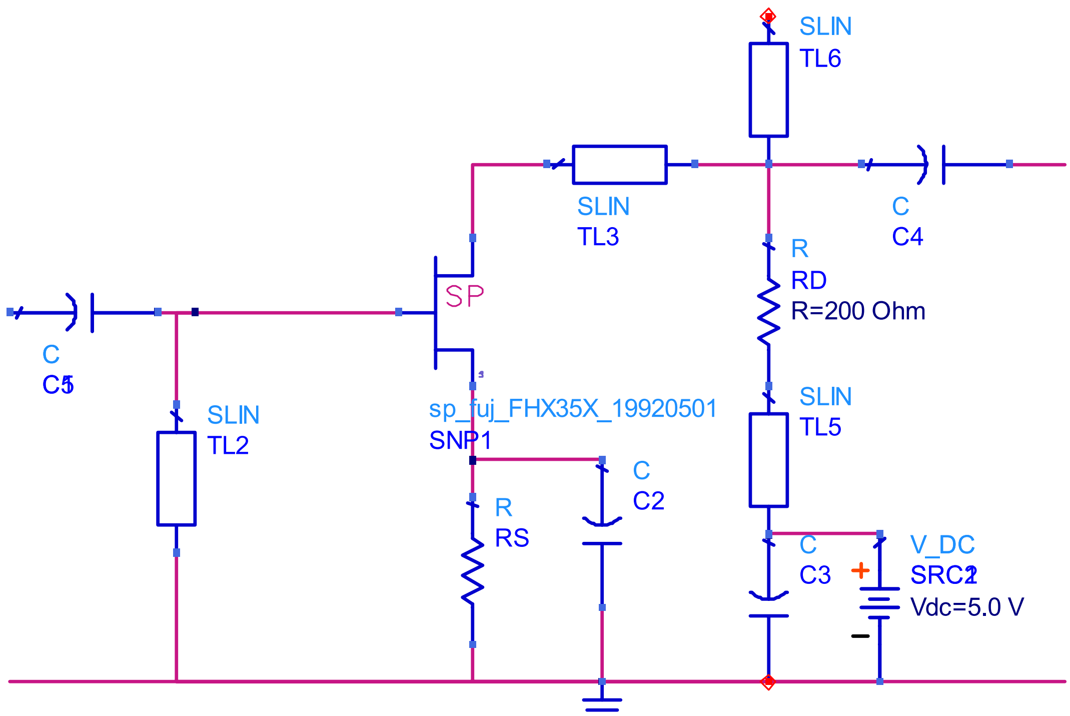


Figure 4.1 dc schematic

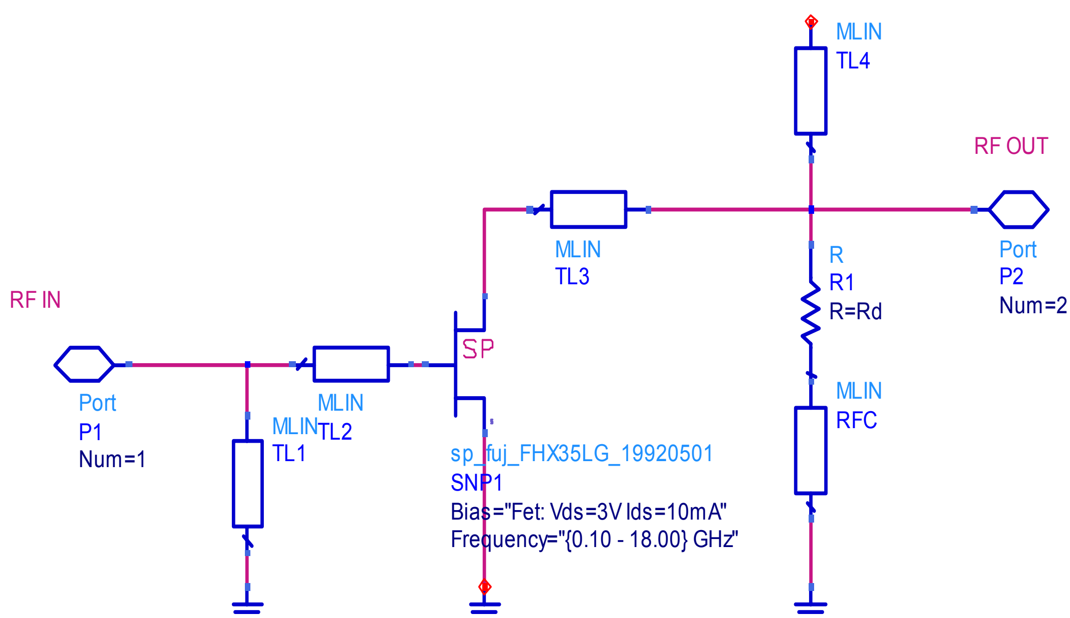


Figure 4.2 RF schematic

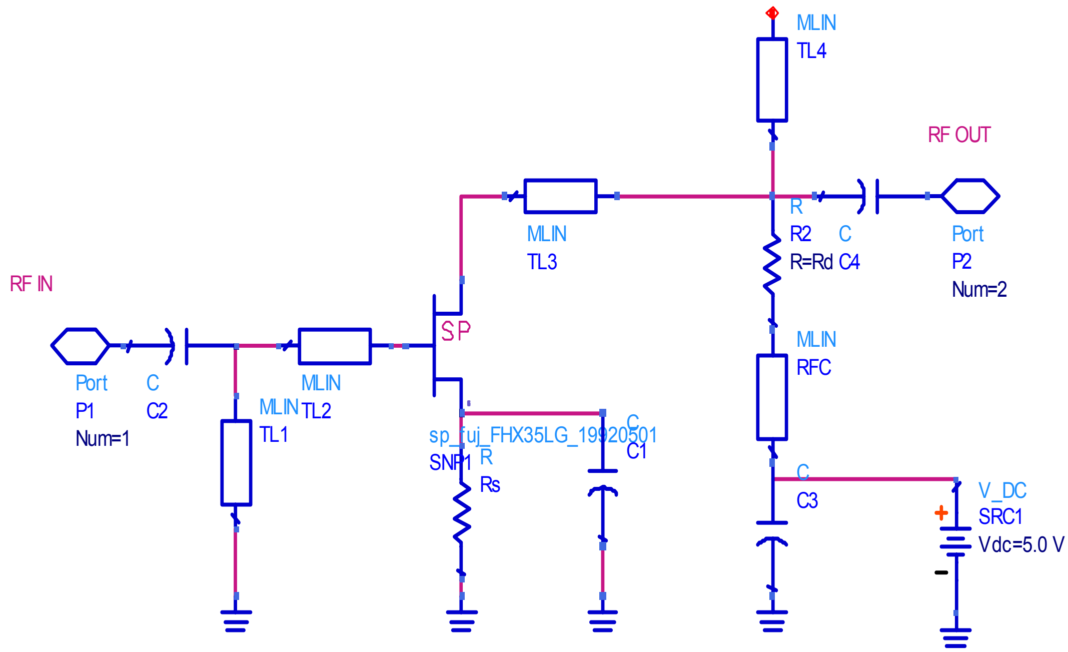


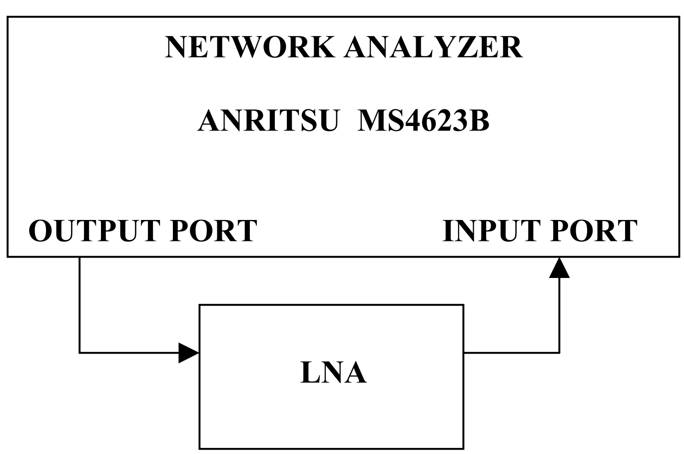
Figure 4.3 complete amplifier schematic

Test method:

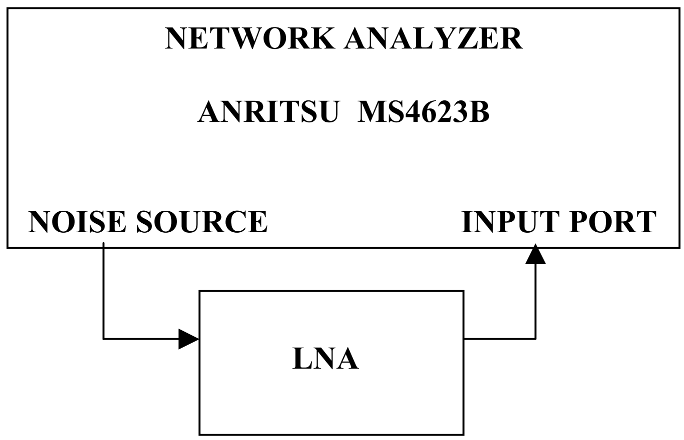
Using Agilent Advanced Design System (ADS) software to simulate the circuit before building the LNA. The following test procedures will be applied when the LNA is built.

g.Test setup

a. S-parameters test setup



b. Noise figure test setup



8. SUMMARY:

This project should be a fun challenge to see to completion. It deals with Microwave Technology, which has a lot of unexplored applications. To make it happen, the project needs to select the right package transistor, substrate, and other components. The design is also important part because the circuit has to calculate accuracy. After layout completely the schematic that needs to combine DC bias circuit with input and output matching impedance networks. When the layout is approved, the next step will start to fabricate and assemble the circuit into housing. In the final step is to test and evaluated. The final product will be done by the end of this semester.

SPECIFICATIONS:

GaAs MESFET MwT-770
At biasing point of $V_{DS} = 3.0V$ and of $I_{DS} = 10mA$, the amplifier provides the following specifications:

Frequency Range	1.8 – 2.2 GHz
Noise Figure (NF)	0.326 dB
Gain	16 dB
Output Power @1dB Compression (P1dB)	20 dBm
IDSS Range for Optimum P1dB	50-80 mA

Frequency	**S parameters**			
	S(1,1)	**S(2,1)**	**S(1,2)**	**S(2,2)**
2.0 GHz	0.92/-45.1	3.10/137.3	0.02/60.1	0.76/-30.6

MwT-770 noise figure parameters: $V_{DS} = 5.0V$ and $I_{DS} = 10mA$

Frequency	**Max gain**	**NFmin (dB)**	**Rn/50**	Γ_{opt}
2.0GHz	16 dB	0.326	0.484	0.858/19.11