ECE 432: Project 1

LNA design

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Contents

List of Figures

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1 Objective

The objective of this project is to use the information we've learned from the previous labs towards building a low noise amplifier. Low noise amplifiers are created by taking into account Gain, Noise Figure, Stability and signal reflection. By these four powers combined, we can initialize the low noise amplifier into a working product. Gain is measured by the increase of power coming out of an amplifier compared to the power coming into the amplifier, this is measured by the transfer coefficient S12. The noise figure is much more complicated and is determined by a significant series of equations, however we want it as low as possible. Stability is more simple and is measured by comparing the input and output reflection coefficients. If these coefficients end up becoming greater than 1, ever, this means that the amplifier is oscillating at that frequency. Signal reflection lastly is the degree of which the highest power transfer occurs. This happens when we match the complex conjugate, which allows the signal to flow unobstructed to the device.

Its very common that once a transistor is translated from ideal components, non ideal capacitors, inductors and transmission lines will cause the overall circuit to become unstable. Because of this, we implement feedback and optimization for the sake of minimaxing stability, gain and noise. Additional feedback is added by adding some inductance on the source. This simulates the added inductance from the via to ground for the source terminal. By implementing these methods, we can increase stability, maximize gain and minimize noise figure.

2 Theory and Background

S parameters measure the frequency response of a given circuit or device, showing the rate of transmission across a given sweep. We are often provided S parameters of transistors from the manufacturer. For the project, we first optimized a default circuit given by Keysite towards the s-parameters for the SAV541 at a given voltage of 3.3V and 60mA of current.

From the data in the s2p files, the input and output reflection coefficients could be plotted and solutions for simultaneously matching the input and output could be found as well. Our first and primary focus for LNA circuit design is stability. The device needs to be unconditionally stable in order to perform to the simulated specifications. We see how this works initially in figure **??**. Stability is found through a variety of methods. First and foremost is to simply add connections to ground from the input and the output. Another method is feedback. Adding feedback will lower gain and raise stability.

Next is to determine gain. When we look for gain, normally a transistor has a natural gain that is listed on the datasheet depending on the frequency. Because of this, we have a lot of the work already finished. The only thing needed is to match the input and out impedance with the load (Usually 50Ω).

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3 Design

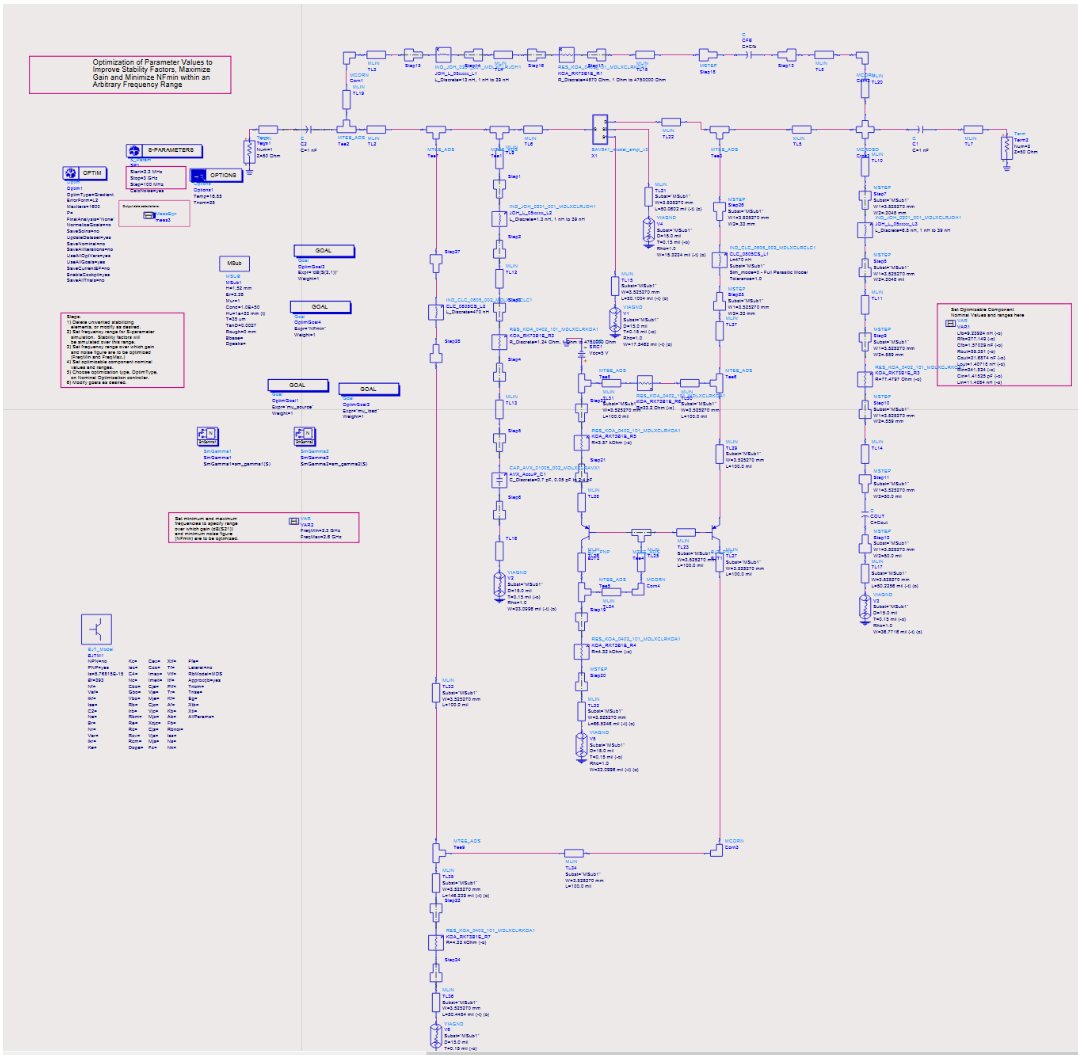


Figure 1: Final circuit schematic

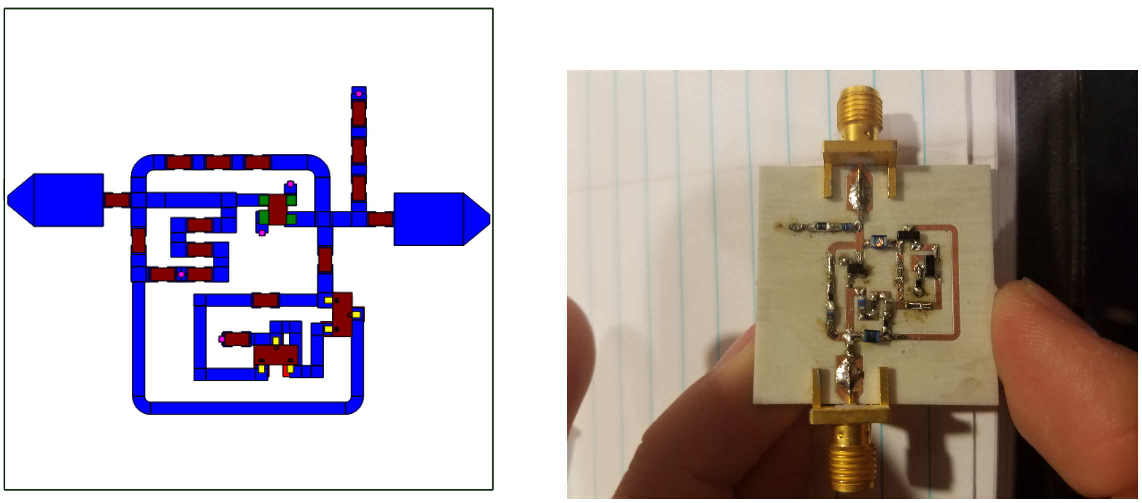
We started off with the original ADS layout given through their tools function. Using the S-parameters given by the manufacturer, we were able to directly tune our circuit using the ADS optimization function. We implemented this layout because its the initial stage for stability control. We also added feedback for similar reasons. Next on our list was to optimize for stability as the primary intention.

Next on the list was gain and similarly, we optimized. By the end we were optimizing for Gain, Stability, and Noise. We followed the design process of

- Optimize
- Implement more realistic components
- Optimize

until the entire circuit was finished.

This wasn't the last hurdle we had to face however, and during the layout process encountered several problems. Our first lay out appeared correct with respect to our circuit and once printed even looked like it should have worked.

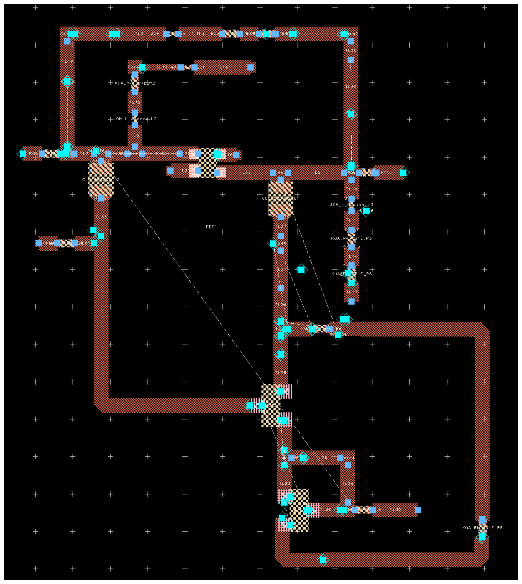


(a) Initial Layout

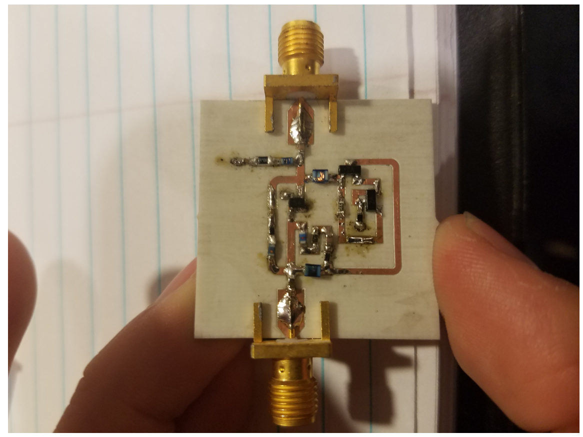
(b) Initial circuit

Figure 2: Original circuit and layout

But there was a problem with the way ADS described the SOT23 packaging, the base and emitter were switched in locations. This bug caused our entire circuit to have improper biasing and the circuit needed to be redone.



(a) New schematic



(b) Initial circuit

Figure 3: New circuit and layout

4 Results

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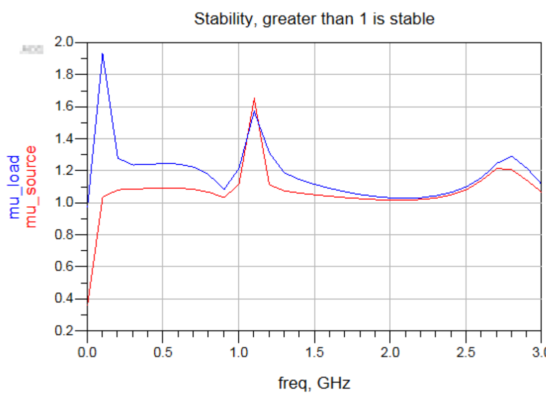
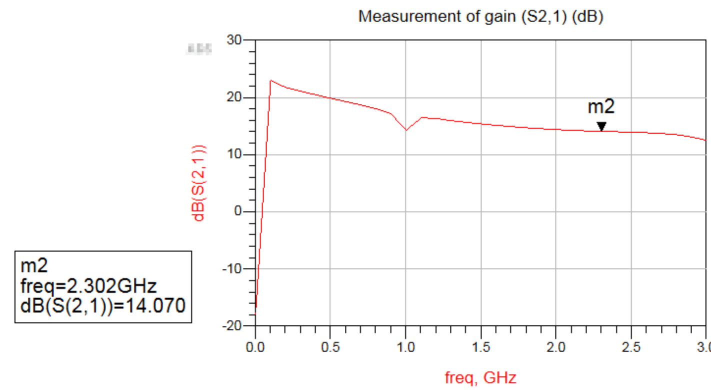
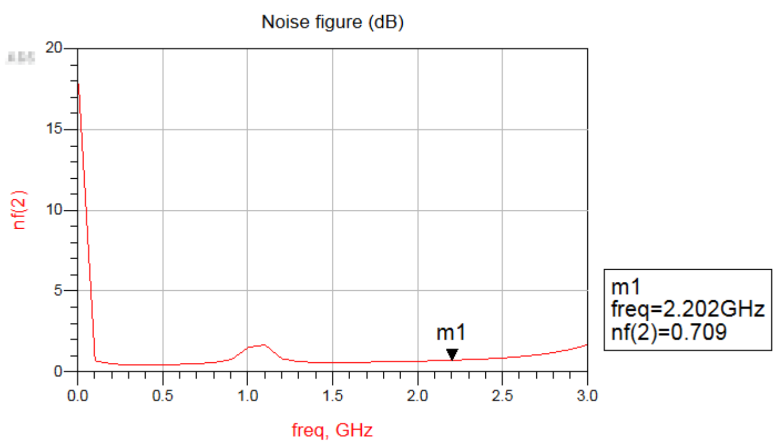


(a) Mu stability measurement



(b) Gain measurement



(c) Noise figure measurements

Figure 4: Amplifier measurements for unconditional stability, Gain and Noise Figure measurements.

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4.1 Part 3

pics/Part3_Sstabilitycircles.PNG	pics/Part3_Sstabilitycircles.PNG
(a) L Stability Circle measurement	**(b)** S Stability Circle measurement

Figure 5: Stability after implementation of SMD components

4.2 Part 4

pics/Part4Gain_IND_SWP.PNG

(a) Gain from inductor sweep

pics/Part4NF_IND_SWP.PNG

(b) Noise figure from inductor sweep

pics/Part4Stability_IND_SWP.PNG

(c) Stability from inductor sweep

Figure 6: Gain and noise measurements after inductor sweep

4.3 Part 5

pics/unconditionally_stable_MU_goals2GHz4_2GHz7.png

(a) Stability Mu_{source} and Mu_{load}

pics/unconditionally_stable_GAIN_goals2GHz4_2GHz7

(b) Gain resulting from stabilizing circuit

pics/final_schem.png

(c) Circuit schematic with stabilization.

Figure 7: Gain and noise measurements after inductor sweep

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5 Conclusion

In conclusion it is an iterative process to handle the tradeoffs between gain, stability and minimum noise figure. When something is optimized for gain, then the noise and the stability need to be checked and accounted for if they are in an unacceptable range. Likewise if an optimization for noise is made then gain and stability need to be re-evaluated in order to determine if it is acceptable. It is very useful to set up optimization goals for all three of these, as well as other important specifications such and input and output reflection coefficient. If the device ends up not being unconditionally stable after adding all the parasitic components and circuit and layout elements then it must be verified that the input and output loads won't produce impedances inside the potentially unstable regions.

6 Questions

Using ADS design guide for amplifiers, reproduce figure 13 from [1]. In your report comment on the amount of gain and stability. Limit your frequency range to 0.1 6 GHz. Do you anticipate any problems based on these results?

We anticipated instability after implementing modelithics components and transmission lines, luckily this was counteracted with the optimization function. The gain was anticipated to decrease with this implementation as well.

Add ground inductance into source lead of SAV 541+. Start with 0.4 nH and increase it to 1 nH. What effect does it have on noise, gain and stability?

The inductor added to the source had the effect of destabilizing our circuit and decreasing the gain by about 4 - 8 dB, see figure 6.

Final step involves designing either for maximum gain or some smaller value. Now that you have unconditionally stable device you can do simultaneous conjugate match. What gain do your simulations predict?

Our simulation predicts 13.169dB gain, under ideal matching conditions our gain was then lowered. Due to this, we decided against matching.

Write a short paragraph about the two most interesting new things that you learned this week

The most primary interesting thing we learned this last week was the implementation of feedback for the sake of stability while optimizing for the highest gain. Secondly we learned how to bias a circuit while using the S parameters for a given transistor. By empirically measuring the S parameters for a transistor in real life, we can optimize a circuit perfectly for stability and gain.

All of the students listed at the top of this report have read it and agree with its content.

7 References

Bowick, Chris, John Blyler, and Cheryl J. Ajluni. RF Circuit Design. Amsterdam: Newnes/Elsevier, 2008. Print.

Gonzalez, Guillermo. Microwave Transistor Amplifiers. Pearson, 1996. Print.

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