1 Laboratory 3

Low Noise Amplifiers

Summary: Students will design, assemble, and test their own low-noise amplifier, optimizing noise, gain, and output match at 4 GHz. The LNA will then be cascaded with a low-pass filter and the end-to-end performance evaluated.

1.1 Useful resources

`https://awrcorp.com/download/faq/english/docs/getting_started/ch05.html`

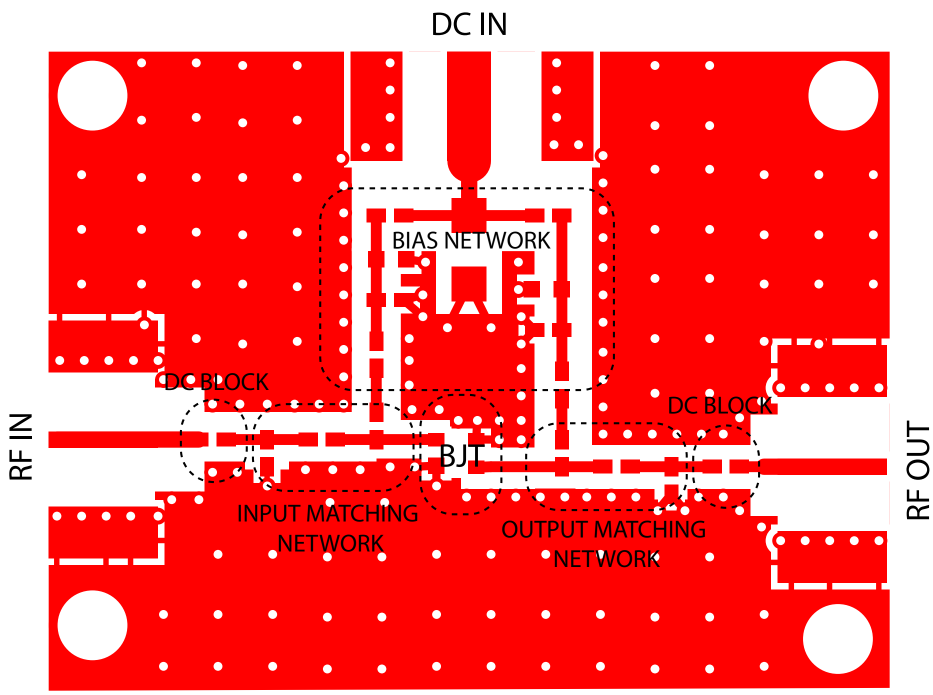

Figure 1: LNA board connector definition and location of circuit functions.

1.2 LNA Preparation

1. Open MWO template file for week 3.

2. There are three circuits associated with the LNA.

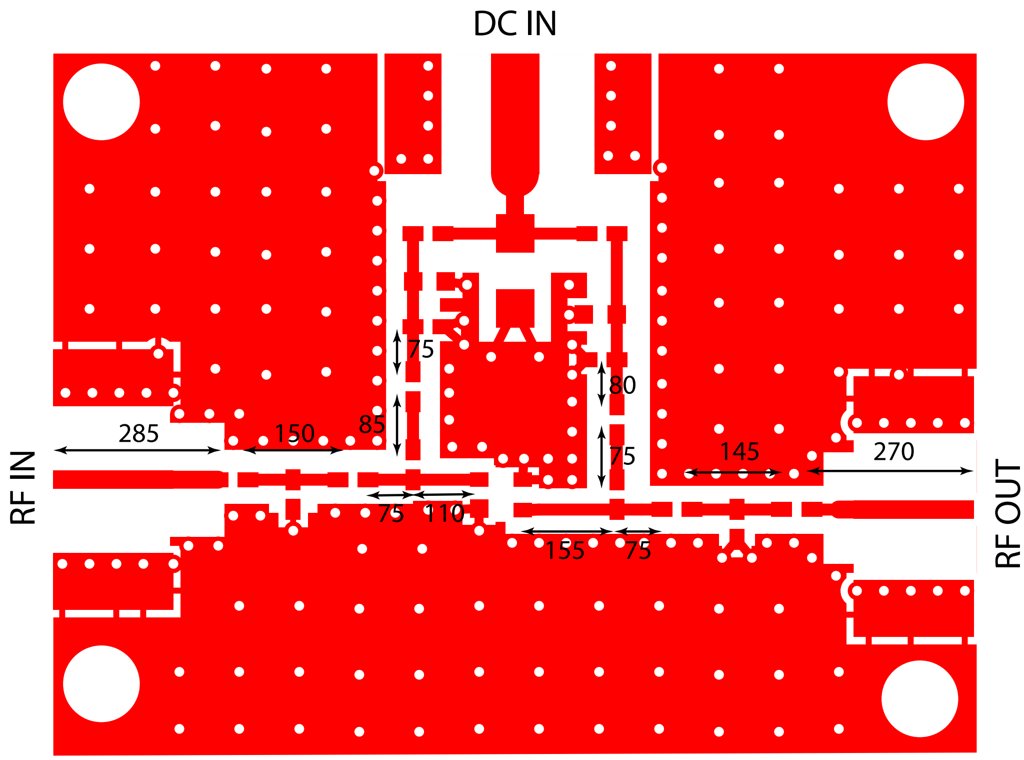

Figure 2: LNA board trace lengths. The width of the traces can be assumed to be 21 mils, above 12 mils of FR-4 ($\epsilon_r = 4.6 \pm 0.2$).

3. The **TestBench**, allows you to analyze the noise peformance of the SiGe HBT (BFU730). Alternate through the various .s2p files until you find the lowest T_{min} at 4 GHz, as shown in graph **NoiseStudy**. The equation for T_{min} has already been created for you.

4. The schematic **AmpBiasOnly** contains only those circuit elements associated with biasing up the transistor. Using your class notes determine the resistor values for the bias you selected. Place these in the schematic along with the appropriate .s2p file for the device you determined earlier.

5. You will need to change the associated microstrip widths and lengths to those shown in Figure 2.

6. Add in inductors at the base and collector to provide a high impedance to the device at the design frequency. Use the **Stability** plot to check the stability of your device. You can add a small amount of resistance in series with the output to aid stability. It is not essential that the device be unconditionally stable across the full frequency range, but trying to maximize stability will ease implementation.

7. Values of inductance between 1 and 5 nH are appropriate. Make sure to check the self resonance frequencies of the components you select (using the same kit as in Laboratory 2), ensuring that they are well outside your design frequency. Substituting in the vendors .s2p files for the inductors will correctly model self resonance effects.

8. Once you are satisfied, it is time to design the input matching network. You can use graph **NoiseMatch** to view the optimum generator impedance for you circuit, which minimizes the noise.

9. Design the input matching network and add it to the **AmpBiasOnly** schematic.

10. Make sure to add the correct line widths and lengths between components, as shown in Figure 2.

11. Now design your output matching network, using the simulation of your **AmpBiasOnly** schematic with the input noise matching network in place.

12. Once completed, your design should look similar to **SingleStageAmpFull** with your component and trace widths and lengths substituted therein. Substitute in your values and use graph **SingleStageAmplifier** to view the final circuit performance.

13. Bring your final design values with you for the laboratory on Friday. Do not attempt to the design during the lab session, **there is not enough time**.

1.3 Required Equipment

The required equipment for Laboratory 3 is listed in Table 1.

Descrition	Model	Quantity	Notes
FFox	N9917A or N9918A	1	-
Calibration Kit	85052D	1	-
Cables	TM26-3131-36	2	-
Noise Source	346A	1	Agilent
Noise Figure Analyzer	N8975A	1	Agilent
5 GHz Low Pass Filter	VLF-5000+	1	MiniCircuits
SMA Connectors	J658-ND	2	Cinch
SMA Connectors	J502-ND	1	Cinch
LNA PCB	NA	1	Custom
Resistor Design Kit	754-RG1005PD-KIT	1	Susumu
Capacitor/Inductor Design Kit	L/C-402DS	1	Johanson

Table 1: Required Equipment

1.4 Circuit Assembly

1. Locate the necessary connectors, inductors, capacitors, and resistors and populate your LNA board.

2. Note that there are two different types of SMA connector. The J502-ND connector is used at the DC port only.

3. Use solder paste and the hot air gun to mount all 0402 components. You may need to reflow the solder paste with a soldering iron for those terminals connected to the ground plane.

1.5 S-Parameter Measurements

1. Using the methods from the previous laboratories, calibrate the FFox in preparation for measurement of your amplifier and filters S-parameters. Set the input power to -30 dBm.

2. Set up a power supply with the necessary OVP and OCP.
3. Take the S-parameters of your amplifier and save the data to .s2p file for your report.
4. Repeat your calibration, this time with the maximum input power setting for the FFox. This will allow you to better measure the skirts of the low-pass filter.
5. Take the S-parameters of the VLF-5000+ filter and save the data to .s2p file for your report.
6. Remember to take photos of your setup.

1.6 Noise Temperature Measurements

1. The Noise Figure Analyzer (NFA) has already been calibrated. Calibration involves hooking the Noise Source (NS) directly to the cable feeding the NFA and using it to measure the noise of the analyzer itself. The measurement is used to correct for the noise temperature contribution of the LNA + analyzer.
2. There are two types of NS, traditional and so called *SMART* noise sources. SMART sources have the ENR table of the NS stored in memory. They also have an integrated temperature sensor. Both the device temperature and ENR data is read by the NFA. For traditional NS this information must be manually entered into the analyzer.
3. The NFA is setup to average 16 points per frequency point, resulting in a 4x decrease in measurement uncertainty per point.
4. Hook the NS to the input of your LNA. Hook up the output of your LNA to the input of the NFA.
5. Power up your circuit using the same OVP and OCP settings for the DC supply as earlier.
6. Let the analyzer sweep twice before saving the data to the HD floppy disk.
7. Use the USB HD drive to transfer the data to your computer.
8. Hook the VLF-5000+ filter to the input of your LNA and repeat the noise temperature measurements.

9. Hook the VLF-5000+ filter to the output of your LNA and repeat the noise temperature measurement.

10. If you were optimizing your system for noise where would you put the filter?

1.7 Data Analysis and Report

Reports are due by noon October 17th, emailed to drussell@caltech.edu and to dwinker@caltech.edu

Use the guidelines for the report from Laboratory 1.

Additionally, for this and future reports, you should include the following:

1. Response to any questions that were asked in the preparation section. Circuit derivations/-calculations should be included.

2. Circuit diagrams (schematics) taken from MWO, formatted so that they are legible when pasted into your report.

3. Photos of both your test setups and your completed circuits.

Note: It is likely that your measured circuit performance will not exactly match that of your simulations. That is ok, these will be explored during the analysis and explained in your report.

- Present the noise temperature measurements of your LNA, with the amplifier bias (current and voltage) in the title. How well did it compare to your simulation? Comment on any differences. If you had additional time, what would you have done to further optimize the circuit and why?

- Present your noise temperature measurements with the filter ahead of and behind your LNA. What was the change in noise temperature between the filter in-front of and behind the LNA? What would you expect? Note that the noise temperature contribution of the filter in its passband can be approximated by it loss. A 3 dB loss translating into a 3 dB noise figure. Use this fact, and your class notes to calculate what the increase in noise temperature should have been with the filter ahead of your LNA. Remember the Friss noise temperature cascading formula.

- Simulate your LNA with the filter ahead of it and compare it to your measurements. Comment on any differences, you will likely notice several. Comment on the effect of the amplifiers noise parameters and impedance of the filter (remember that you designed a matching network to transform Γ_{opt} to 50 Ω. The filter's match in and out of band should be considered).
- Plot out the S-parameters of your LNA, measured and simulated. Comment on any differences and changes to your simulation that would better reflect your measurements. Remember to include bias parameters in your title.