# EE133 - Lab 3
# Low Noise Amplifier

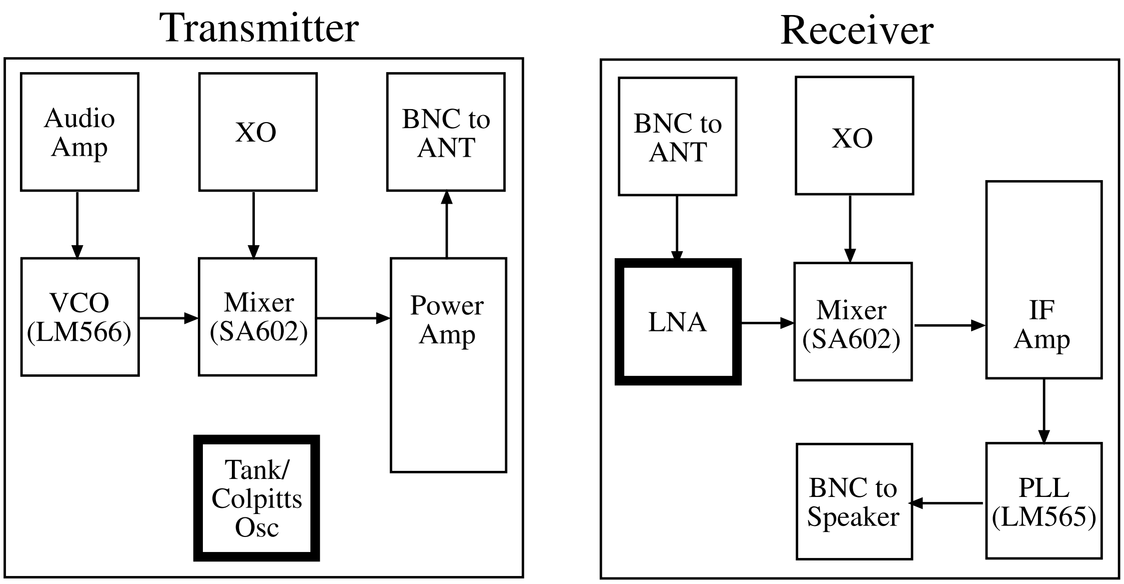


Figure 1: Lab 1 Roadmap

## 1 Introduction

In this lab we will focus on building the LNA and obtaining a good match with the input of the multiplier. This will be crucial in optimizing the range of the receiver. We will also take a look at some antenna characteristics to get a feel for the variability involved with using an antenna as a signal source. Toward the end of the quarter we will do some additional filtering at the input of the LNA, and perhaps additional impedance matching to the antenna.

## 2 The Low-Noise Amplifier

Build the amplifier designed in the prelab on your receiver solder board. The amplifier will receive signals from the antenna and feed them to the multiplier (with some matching in between).

### 2.1 Measuring DC Bias Points

Using the DVM (Digital Voltmeter), check the voltages at the collector, base and emitter of your circuit.

1. How close are these values to the computed ones?
2. What are the collector and bias currents?
3. What is the power dissipation of this circuit?
4. Calculate the percent error of these values from your prelab results and include this data in your lab writeup.

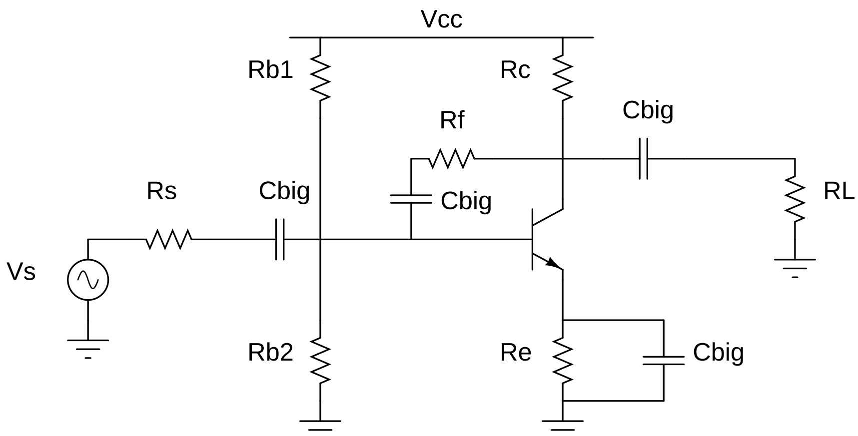


Figure 2: The Shunt-Shunt Low-Noise Amplifier

## 2.2 High Frequency Analysis

To perform a high frequency analysis on your circuit, you will need two BNC connectors, one for the input and one for the output. You should solder two leads to each BNC. Be sure to use bypass capacitors and short twisted pair connections to the BNC connectors. Long connections could throw off your measurements or allow unwanted noise to couple in.

**Analysis with the Network Analyzer - Agilent8712E:** Take your circuit and move over to one of the 8712E Network Analyzers. These machines should already be calibrated to the cables that are connected to them, so just hook your circuit up to the existing cables. Port 1 should go to the input of your amplifier, and Port 2 should go to the output.

1. **Measuring $S_{11}$ and $S_{22}$:** We'll start by measuring the input and output S-parameters. Set the frequency range to a reasonable value (10-30MHz should be fine). Set the format to Linear Magnitude, and record $S_{11}$ at 24.3MHz and a few frequencies near that. Do the same for $S_{22}$. Do these results match your simulations?

2. **Matching Impedances:** Now, switch the format to Smith Chart display. Notice that the display now shows impedance values in the upper right hand corner. For the same frequency values as above, record the impedance values. Move your marker over various frequencies and watch where it goes on the Smith Chart. Is the input impedance at our operating frequency near what you expect? Does it have a reactive component?

3. **Adjusting Impedances:** At this point, you may want to adjust your feedback resistor to get close to the desired input impedance. Because the antenna impedance is not exactly 50Ω and will fluctuate, it is not crucial to get exactly 50Ω. Remember that ultimately we would like these impedances to be purely real. How can you get rid of the reactive component? Try to obtain real input and output impedances.

4. **$S_{21}$ and gain:** In addition to giving information about input and output impedance, S-parameters also give information about gain. Change the display to show $S_{21}$ in Log Magnitude format. $S_{21}$ gives information about the transmission of a circuit from Port 1 to Port 2 (hence the gain) for matched input and output impedances.

5. $S_{12}$ **and Unilateral Amplifiers:** Finally, switch the display to show $S_{12}$ over the same frequency range. How does it compare to the values for $S_{21}$? Ideally, we wish $S_{12}$ to be zero, so that we have no transmission in the reverse direction. An amplifier that has this characteristic is called a 'unilateral' amplifier. Usually, amplifiers have $S_{12}$ much smaller than $S_{21}$ and can be approximated as unilateral amplifiers.

# 3 Match to Multiplier Input

Another benefit to designing circuit blocks with certain input and output impedances is that you can attach and detach blocks without worrying about impedance matching issues (this is useful in putting together systems from discrete blocks). Now we will put this concept into practice and match the input of the multiplier to 50Ω, so that we can connect it directly to the output of the LNA.

1. **Build the Match:** Build your multiplier input match with a $1.5k\Omega$ resistor as the multiplier input impedance (we will want to replace this resistor with a connection to the actual input of the multiplier, so place the components accordingly.) You may want to use an adjustable capacitor. Tune your circuit and measure the input impedance and Q at a resonant frequency of 24.3MHz. How does this compare to your prelab predictions?

2. **Actual Multiplier Impedance:** Now remove the $1.5k\Omega$ resistor and connect the output of your match to the input of the multiplier. Remember to use a bypass capacitor. Note that you might see feedthrough from the crystal oscillator of the multiplier (this will look like a spike at 24MHz). You may need to disconnect the oscillator if it interferes with your measurements. Retune your circuit and measure the input impedance and Q. How has it changed? What does this say about the input impedance of the multiplier? Can you get rid of the reactive component?

3. **Connect the blocks:** Now, connect the output of your LNA to the input of the impedance match to the multiplier and measure $S_{11}$ and the input impedance. The full circuit should look something like Figure 3. Do you still have a good match?

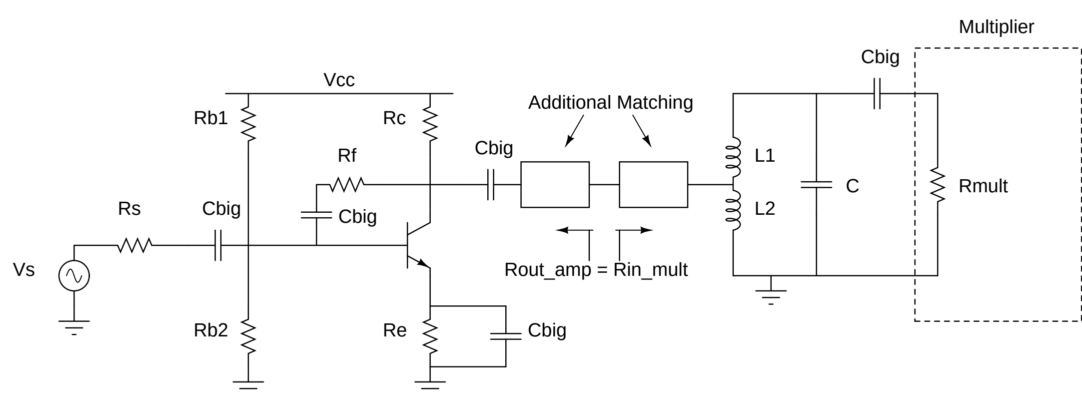


Figure 3: LNA and multiplier with impedance matching

4. **Test the Performance:** Connect a signal generator to the input of your LNA with a -50dBm signal at 24.3MHz. Measure the output of the multiplier with an active probe and adjust your impedance match away from a good match. What is the range of signal levels you can obtain? Can you see why a good match is important?

# 4 Antenna Measurements

Eventually, we will want to connect the input of the LNA to an actual antenna. Here we will make some measurements to get an idea of what impedance values we can expect for our antennas.

1. **Measurements with the Network Analyzer:** Choose an antenna from those available in the lab and connect it to Port 1 of the network analyzer. Be sure that the network analyzer is calibrated correctly. You should try this with the network analyzer calibrated with and without cables to observe the effect that holding the antenna has on its response.

   (a) With the antenna in a relatively stationary position, observe the log magnitude response vs. frequency and note how different orientations affect the response.

   (b) Switch to Smith Chart mode and obtain a reading of the impedance at our operating frequency. How much does it fluctuate and under what conditions?

2. **Measurements with the SWR Meter:** We will do one last measurement using a hand-held SWR meter. This device is good for getting a quick look at the impedance characteristics of a given device. Unfortunately, we cannot use this meter to characterize the LNA, because the output signal is about 10dBm, which will likely saturate your amplifier and throw off the impedance characteristics. Instead, we will use it to characterize the antennas in lab.

   (a) Tune the output of the SWR to 24.3MHz and connect an antenna to the output. Roughly what is the SWR at this frequency? What happens to the SWR when you adjust the frequency?

   (b) Notice that the meter does not give a sign for the imaginary part of the impedance. This could be potentially troublesome, but circuits generally look capacitive, so we can guess at a sign. What is the impedance measured? How does it change as you touch different parts of the antenna? This fluctuation in impedance is just one way in which RF design is made rather tricky, especially for portable applications. How do these measurements compare to those on the network analyzer? Why do you think they agree or disagree?