ECE145a / 218A lab project #3

Reactively Tuned Amplifier .
Mark Rodwell, Sunday, September 24, 2023

Assignment

Your assignment is to design and construct a reactively tuned amplifier. The transistor is to be an MRF 901 or MRF951 Bipolar Transistor. Please bias this at 5 mA collector current and at a V_{CE} of 10 volts. The goal is to obtain the maximum feasible gain at a target frequency, with different values to be announced in class for ece145a and for 218b. You should design to maintaining S11 and S22 below -10 dB at the target frequency. For both 145A and 218A the design must be unconditionally stable at the design frequency; for 218A we add the additional real-world design requirement that the circuit must be unconditionally stable at ***all frequencies*** from DC to 5 GHz (~the highest frequency at which we can reliably measure).

With the only restriction that you must not apply DC to the test ports of the network analyzer, you may design this amplifier in any way you desire. The following comments are simply suggestions.

Network analyzers, sampling oscilloscopes, and spectrum analyzers all cost well above $20k, and all have easily-damaged Schottky-diode mixer/sampler inputs. To project these, you *must* use the input and output DC blocking capacitors, with a maximum value of 100 pF for each.

Recall the safety considerations discussed earlier: do not use lead-based solder or solder-suckers. Use eye protection when cutting wires. Use normal electrical safety precautions: no bare feet, no liquids nearby, and do not touch bare conductors on circuits when biased, even if low-voltage.

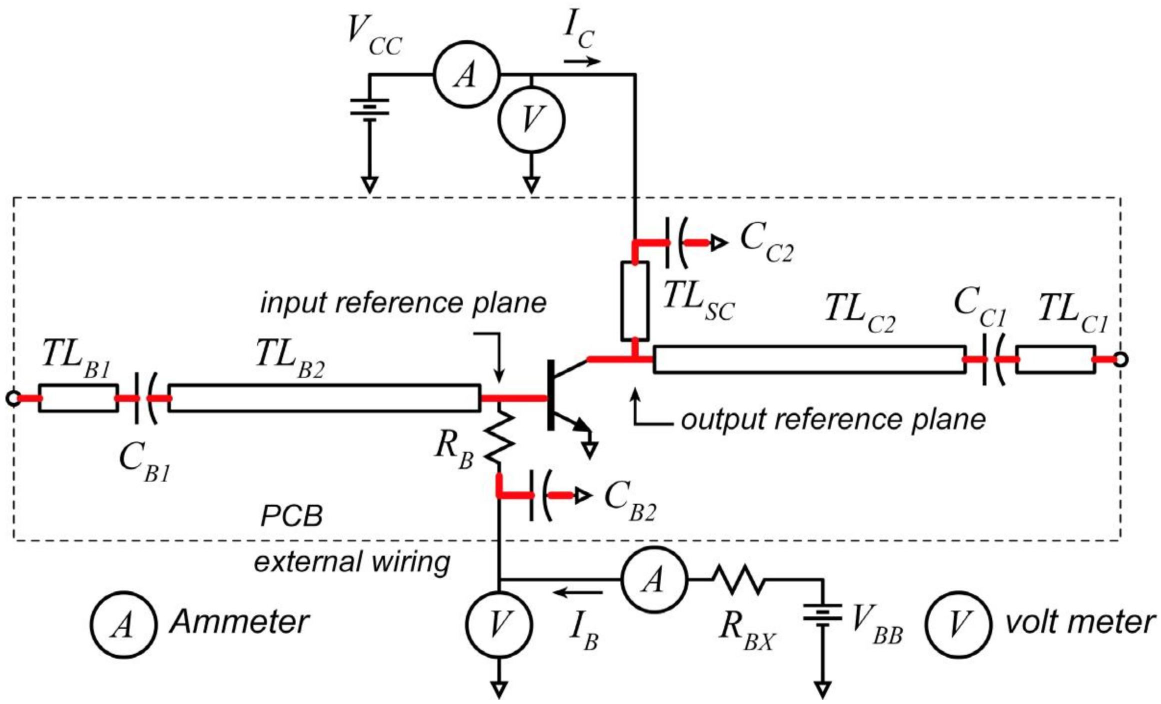

Figure 1: Bipolar transistor bias circuit.

Procedure

Your work on this project should build on the test structure you earlier made in lab project 1b. For your reference, the bias circuit is repeated in Figure 1, and the details of physical construction in Figure 2, both shown below. In lab 1b, you had measured the transistor S-parameters. If these turned out to differ greatly from the data sheet values, and the values in the ADS model, it would be wise to re-build the test structure and re-take the measurements. ***Above all, great care in construction and measurement is needed if your design is to work as simulations predicts.***

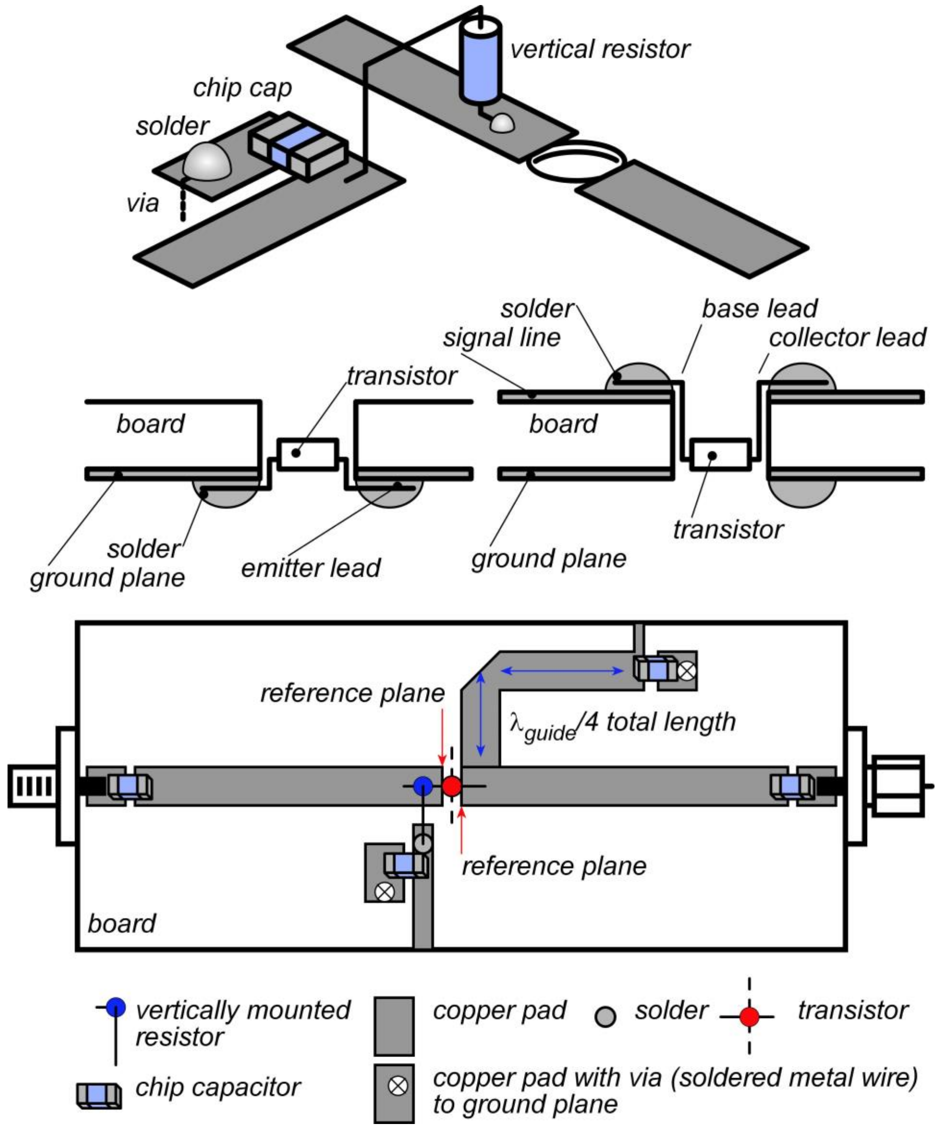

Figure 2: Details of fixture construction. The reference planes for S-parameter measurement are indicated by the red arrows.

I suggest the procedure below for amplifier design and construction. Each experimental step should be accompanied by measurement, so that you know when your design has gone wrong. You should first perform the simulations for all steps as soon as you have transistor S-parameter data.

1) Measure or re-measure the transistor S-parameters using the procedure of lab 1b, and using the fixture of Figure 2. This is repeated as Figure 3a.

2) In ADS, simulate the transistor stability circles. If the device is potentially unstable, or close, you must stabilize it. Decide whether to use series or shunt stabilization on the input or on the output. I have illustrated (Figure 3b and Figure 3c) series input stabilization. I cannot cover all possibilities here: you will have to think this through.

In Figure 3b, the line is cut to accommodate a series input resistor. One needs to know the new reference plane location, so S11 of board is measured in the condition shown in

Figure 3b to determine the new location of the input reference plane. We then solder in place the series input stabilization resistor (Figure 3c).

4) With the transistor now stabilized (Figure 3c), re-measure the S-parameters, with the reference planes moved to the indicated locations. Examine and plot the stability circles at the design frequency. What is the MAG/MSG at the design frequency now ? What is K ?

5) Now, using ADS, and with the aid of the Ga and Gp circles, determine the optimum source and load impedances. Design microstrip matching networks. Construct the matching networks (Figure 3d). Note that your reference planes have again moved. To determine the correct location of the reference planes, please disconnect the matching networks (Figure 3e) and measure the S-parameters. You should measure an open on both ports if the extensions are correctly set.

6) Then-reconnect the matching networks (Figure 3d) and measure the transistor S-parameters at the design frequency and as a function of frequency.

If results fit simulations well, ECE145a students have now completed their design.

7) ECE218A students should then proceed to make the transistor unconditionally stable at all frequencies. The goal here is to do so without significantly reducing gain at the design frequency. There are many ways to do this. One method is to add a parallel RC combination in series with the amplifier input; this will provide a moderate series resistance at lower frequencies, and only a small series resistance at high frequencies. This may or may not work given your S-parameters: you may well have to use a different stabilization method. The 50 Ohm input microstrip line is cut at some convenient point, and The network analyzer is used to determine the reference plane. The cut-line is ***temporarily*** re-connected so that you can measure the S-parameters with the reference plane located at the new location indicated. From these S-parameters, examine the stability parameters (K and B1) and the stability circles. Determine if an RC parallel combination, at the indicated location, can stabilize the amplifier over a broad bandwidth (DC-4 GHz or so), and can do so without a large loss of in-band gain. If so, design in ADS, construct and measure. This is shown in Figure 3f.

Note that a parallel resistance to ground might possibly be a better method of stabilization (Figure 4, left). It may be necessary to place a DC blocking capacitor in series with such a stabilization resistor, so as to avoid disturbing the circuit DC bias. Series or parallel networks on the amplifier output are also possible.

Another possibility, if a parallel resistance will stabilize the circuit out-of-band, is to place that parallel resistance in series with a stub (Figure 4, right) whose length is a quarter-wave length at the amplifier center frequency. As a result, the resistor provides no shunt loading at the design frequency, but does at other frequencies. A capacitor can be added to block DC, again so that you do not upset the DC bias. g

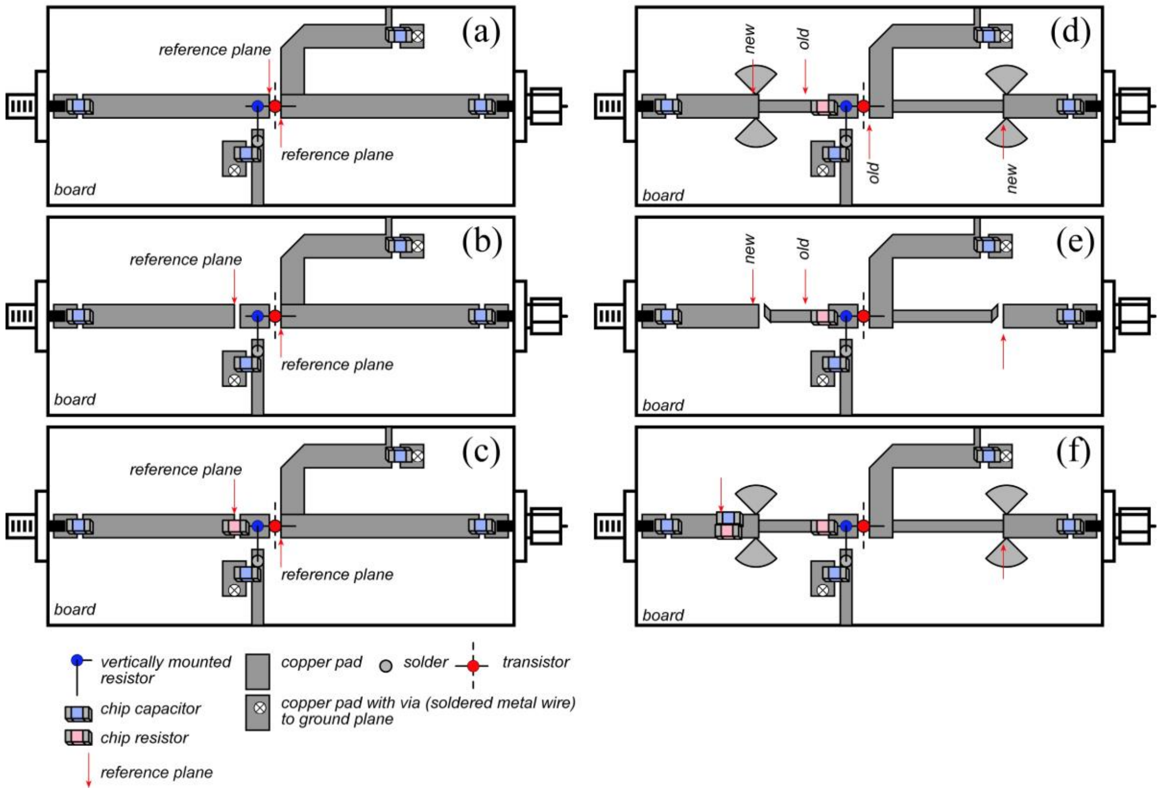

Figure 3: Example procedure for amplifier design, construction, and test.

Report

As always, the goal in engineering is to obtain a design which (a) works to specification and (b) agrees with design analysis. If you cannot attain (b), you will have no confidence in the robustness or reproducibility of your work. Work to obtain precise measurements. Construct your circuit carefully. Seek to obtain good agreement between simulation and measurement.

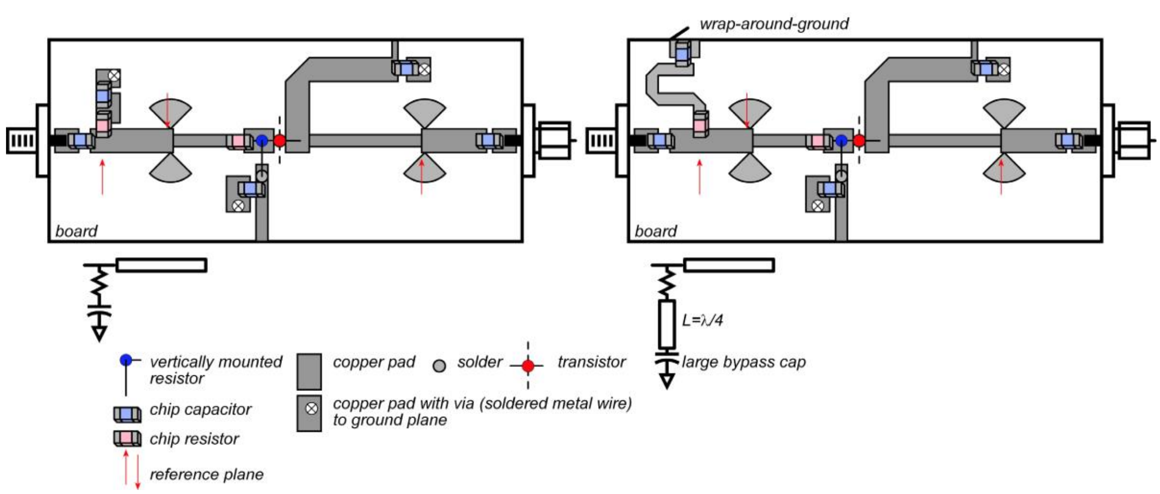

Figure 4: Out-of-band stabilization by an RC series network placed in parallel with the amplifier input (left), or with resistor and quarter-wave line section (right) to ground.