EE133 - Final Project
Guidelines and Specifications

1 The Finish Line

Congratulations, you're almost to the finish line. In a nutshell, here are the most important dates for you to keep in mind:

- **March 8, 2001** - Recommended Basic Functionality Done (See below)
- **March 12, 2001** - Recommended Freeze Date (See Below). Begin Characterizing.
- **March 14, 2001** - Finish Characterizing.
- **March 15, 2001** - Present projects to Professor Dutton.
- **March 16, 2001** - Demo Day!
- **March 21, 2001** - Final Report Due

Basic functionality is defined as a fully portable set of circuits that run off batteries. It doesn't have to transmit too far, but it has to transmit and receive. Every section must be functional, although not necessarily optimized. Note that this *does include* the Power Amp, IF Amp and LNA. This is not a hard deadline in that we will not be checking your circuits on that day, but we strongly recommend that you hit it. We realize that this might be tight for some of you, but it is a good guideline and gives a feel of where you should be at this time.

The *recommended freeze date* is the day we recommend that you stop making major changes to your circuit and concentrate on characterizing your overall system performance. Experience has shown that groups that try to make too many changes too close to the demo day can result in a sudden problem that cannot be fixed by demo day.

2 Characterizing your Circuit

As a requirement of the final report, you will need to characterize your radios. You should be familiar with what this means since we asked you to characterize each circuit module in your labs. If you have correctly characterized those circuits, you may take the measurements and graphs straight into your final report. If you've made significant changes to a block, you should remeasure these values. You can then use these measurements to describe in your final report how your changes have improved your circuit.

When preparing to characterizing your circuit, please keep in mind that it takes some time to complete. It can take as much as eight hours to fully characterize a circuit, depending on how organized that circuit is. This is where your forethought on modularizing your circuit blocks will pay off. Please plan to have this done before Demo Day. There may be one lab session after Demo Day for some last minute characterization, but it will be limited, and will probably be during finals week. (Also, you will be certainly be tired of being in lab, and so will the TA's.)

The last section of this handout lists the major characterizations we want for your circuit. It also includes a few helpful tips for measuring the requisite values.

3 Breakdown of Final Project Grade

As of this point, 50% of your overall grade has been determined through your lab reports, prelabs, and quizzes. The remaining 50% is still to be determined by your final project.

The grading for the final project will be as follows:

- Presentation to Professor Dutton(25%)
- Field Testing on Demo Day (15%)
- Final Write-Up (60%)

4 Presentation to Professor Dutton

During Friday of Dead Week you will arrange for a 15-20 minute presentation to Professor Dutton and your TA. It is an opportunity to highlight the best parts of your circuit, and to describe some of the challenges that you have overcome over the course of the quarter. Moreover, it provides a means of demonstrating your overall understanding of the system. Keep in mind that this is a low-key, informal discussion. You might wish to spend a few minutes beforehand to organize your thoughts and jot down a list of the most important points you want to cover. However, there's no need to spend a huge amount of time, ideas of preparing powerpoint slides (or anything like that),are going way too far. After spending a whole quarter on these circuits, most students find that they can easily talk about their radios for the entire presentation.

At the same time we will be taking a look at your overall quality of physical construction. This includes your soldering job and your packaging.

You should package your radios in some sort of a metal container. While many choose to buy metal boxes from HSC or Fry's, some creative people have used other metal containers like pots and pans or cans to hold their circuit. You should hook your circuit's ground to the metal container, as this can greatly improve the system performance. We're not looking for heroic efforts here, but we do want your packaging to be stable and functional. Packaging which is creative and humorous while still technically sound is encouraged but not a requirement.

Sign-ups for the presentation time will be posted Monday of Dead Week. Please plan on coming at least 15 minutes before your presentation time to hook up your circuit. In addition, plan to give yourself some leeway before your next class, since sometimes presentations run over.

Demo Day

It is our tradition to have Demo Day the Saturday of Dead Week. In the morning, we set up a large antenna and then cycle through all the transmitters. We then set up the strongest one to transmit and then ask students to test their receivers to see who can go the farthest and still detect a signal. For this part, it is to your benefit to concentrate on making sure you have a good receiver, since we end up using the best transmitter out of the entire class. Ross has vouched that he will personally pay the owners of the furthest receiver 1 million dollars ($20,000/year for 50 years minus taxes).

Generally, it is a picnic-like atmosphere, where we walk/bike around to test our radios. Small prizes are awarded for best receiver distance, maximum transmitter power, best packaging and most original/creative improvement. Afterwards, lunch is provided and we celebrate a job well done.

Currently Demo Day is scheduled to run from 10AM-1PM. These times may vary, especially in the case of rain. You will be notified via e-mail if any scheduling changes occur.

Final Report

You will turn in your own unique final report. It is due on Thursday of Finals Week (March 21) at 5 pm at CISX Rm 333 (Or 332 with Miho Nishi).

It is a concise summary of your circuit and its functionality. In general, most students prefer to first give a system overview of their radios covering major system integration issues. They then break down the radio into blocks to talk about each section in greater detail. Design considerations, major experimental results and key issues and problems are all topics which should be covered for each module. You may choose to append circuit information on the IF Amp and Power Amp as separate appendices, or you may choose to report on them in your main report.

In addition to you final report, you will turn in your well-organized lab notebook and all graded labs.

You will be graded on your ability to describe and analyze (in a clear organized fashion), the functionality and performance of your radio. If you've been getting 16's on your lab reports, this should be no problem for you.

5 Minimum List of Values Required for the Final Report

At the end of this handout is a list of quantities we would like to see summarized in your final report. Just before it, we describe a few ways of performing measurements. If you are at all confused about how you should go about measuring a parameter, please consult your TA.

Note that many of these values should have been recorded in your lab reports. You may reuse these values so long as there have been no major changes to that block since you measured them.

Here are some helpful tips for measuring these values:

- **DC Power** - Please stick your multimeter in series with the circuit and the power supply. Remember that the multimeter requires one of the wires to be in a different plug-in to measure current. Also remember to check that you are not current limiting your circuit with the power supply.

- **Gain** - In general, the circuits we have are not matched to 50 Ω. Use the following procedure to measure values. First, use a BNC cable through a BNC connector directly to the input of interest. Then use this cable to direct your signal from one of the signal generators appropriate for your frequency and amplitude requirements. Record the settings of the machine, but use the active probes to measure the input and the output. For consistency, we are defining the output as the signal just *after* the DC blocking cap of any block. Also please remember to ground your active probes properly.

  In the cases where you have designed for a 50 Ω load, you may use the spectrum analyzer or oscilliscopes. Please avoid using the passive probes that come with the Infinium unless all else has failed.

- **Power** - This measurement requires that you know two of three parameters: voltage, current, load resistance. Please keep in mind that you need to load your system in order to figure out how much power it is delivering. For these cases, the active probe is a requirement whenever your block requires a non-standard (not 50 Ω) load.

- **Frequency Response** - We recommend that you take at least 7-10 data points to chacterize the frequency response: Center frequency, 3dB points, and 4-7 other points to describe the slope to either side. However, if your block has multiple peaks, you should add additional points to describe their peaks and bandwidths. These measurements are gain measurements of some type, so please keep mind the same rules apply (See the bullet on measuring gain).

- **Linearity** - The Third-Order Intermodulation Point (IIP3) and 1dB Gain Compression Point (CP1) measuremnts have been specified in lecture. In lab 6 we tell you how to measure IIP3, which is a measure of how easily higher order harmonics can interfere with your signal. CP1 is a measure of your amplifier's gain limitations. To measure this value, please input a signal with a low amplitude value. Measure the input and then measure the output. Under normal circumstances you would expect that for every 1 dB increase in the input, you should get a 1dB increase in your output. To find CP1, simple increase the amplitude until the gain of the system is 1dB lower than what you would expect if there was no gain limitation. Note that a way to speed up this measurement is to quickly confirm by eye that your input changes porportionally with your voltage source,and then concentrate on measuring the output and when it falls off.
- **Signal to Noise Ratios** - On the spectrum analyzer, when you measure a signal, there ideally should be a distinct peak that represents your signal. Your noise should look like a "floor" with random peaks appears all over the frequency band. Put your marker on the noise floor and measure that value. You may want to take a few measurements to average. Alternatively, it might be easier for you to measure this signal in the time domain. Send in a DC signal, and measure on the oscilliscope how large your noise is. In either case, if your circuit has a noise composed of a particular set of frequencies, please make additional measurements to note them. Please only note the most significant peaks and the noise floor. Calculate your SNR from your signal to the noise floor, and note the other signals as a footnote. Remember that dB subtract from each other, while raw magnitudes divide.
- **Measuring in Spite of Noise** On some measurements, especially with the IF Amp, your noise will be on the same order of magnitude as your signal. First try to find the largest signal that will not rail your system. Then use a logarithmic scale to measure the differences. On a log scale, the noise doesn't affect your measurement as much (since you're crunching the linear scale down).
- **Battery Life** - This is a very rough estimate, but we would like you to look up how much energy your battery stores. With this information you should be able to calculate how long your battery will last with your circuit's power drain.

Receiver

- Overall DC Power Drain(mW)
- System Gain (Pre-PLL)
- System Bandwidth (kHz)
- System THD (dB or %)
- 9V Battery Lifetime (minutes)
- Minimum Detectable Signal (dBm)

1. **LNA**
   - DC Power (mW)
   - Power Gain (mW/mW) or (dBm)
   - Frequency Response (dBuV vs. Freq.)
   - Linearity (1dB Compression Pt)
   - Linearity (Third Intermodulation Pt)
   - Output Signal to Noise Ratio
   - Input Resistance (Ω)
2. **Mixer**
   - DC Power (mW)
   - Conversion Gain (V/V)
   - Frequnecy Response (dBuV vs. Freq.)
   - Linearity (1dB Compression Pt)
   - Linearity (Third Intermodulation Pt)
   - Output Signal to Noise Ratio
   - LO Input Voltage (mV)
3. **IF Amplifier**
   - DC Power (mW)
   - Voltage Gain (V/V or dBuV)
   - Filter Frequency Response (dBuV vs. Freq.)
   - Linearity (1dB Compression Pt)
   - Output Signal to Noise Ratio
4. **PLL**
   - DC power (mW)
   - Minimum Input Signal (mV)
   - Lock/Hold Frequency Range (Hz)
   - Center Frequency (Hz)
   - Sensitivity Parameter k_{PLL} (V/Hz)
   - Linearity (THD)
5. **Audio Amp (Optional)**
   - DC Power (mW)
   - Voltage Gain (V/V)
   - Frequency Response (dBuV vs. Freq.)
   - Linearity (THD)

Transmitter

- Overall DC Power (mW)
- Output Power (mW)
- Transmittable Audio Range (Hz-kHz)
- Signal Bandwidth (kHz)
- 9V Battery Lifetime (min)
- Maxmium Receivable Distance (ft) or (m)

1. **Mic/Audio Input**
   - DC Power (mW)
   - Gain (V/V)
   - Linearity (THD)
2. **VCO**
   - DC Power (mW)
   - Output Power (mW)
   - Tuning Range (kHz)
   - Sensitivity Parameter k_{vco} (Hz/V)
   - Bandwidth (kHz)
   - Stability (kHz/min)
3. **Power Amp**
   - DC Power (mW)
   - Power Gain
   - Freq. Response (dBm vs. Freq.)
   - Efficiency (Output Power/Power Consumed)
   - Output Match (Ω)