EE152
Final Project Guidelines

Abstract

This document describes the final project for EE152, Fall 2017. It includes guidelines on design, implementation, and performance requirements, as well as expectations for the final report.

I. Radar Project Guidelines

Students are required, at a minimum, to implement 2 active and 2 passive RF elements within their radar projects, the remaining may be Minicircuits components from the EE152 inventory list. Active elements posses a semiconductor device in their design and include the VCO, LNA, power amplifier, and mixer. Passive elements include, as you might guess, filters, antennas, splitters, and attenuators. By far the most difficult active items will be the VCO and mixer. You can choose the easy road and work on the amplifiers, but I encourage you to try your hand at the more difficult items.

Why are the VCO and mixer so difficult? The VCO requires you to obtain a certain chirp bandwidth from the oscillator. Your oscillator must be able to tune across this range, using the varactor diodes from the class inventory. There are many elements at play, as there are several non-linear elements involved. You will likely need a voltage translator, to allow you to marry the output range of the Radar analog board's chirp output to that of your varactor bias profile.

The mixer presents different challenges. To limit unwanted, in-band mixing products from reaching our ADC, we want a mixer with very high RF and LO isolation. Our single balanced mixers from Laboratory 4 were decent, but not great in terms of isolation, typically achieving about 20 dB. Potentially problematic are the multiple feedback paths opened up within the system by the isolation not being infinite. Sneak paths are created for the LO to circulate between receiver and transmitter, enhanced by the limited isolation of the splitter and cross-talk between cantennas. A double balanced mixer would greatly aide in isolation, but these are challenging to design given the available time, and are difficult to fabricate.[1]. You will have to pay close attention to LO isolation within your single balanced mixer design if you choose to incorporate it.

Students will also be responsible for the design and fabrication of their own cantennas. Your laboratory 6 measurements are based on two cantennas with about a 2.6 inch aperature. You can increase the gain of your antenna by moving to a larger diameter can, with the danger of having the 2.4 GHz ISM band now within the bandwidth of your receiver. This may or may not be a problem for you, depending on how you configure the bandwidth of your receiver. You may also choose to put in a band-pass filter within your receiver to remove 2.4 GHz ISM and other out-of-band interference.

The radar project includes a low-frequency analog board that provides the radar chirp and gating output, as well as low frequency amplification of the phase detector output. The processed signal is fed into the sound card of your computer. The digitized recordings will be processed with previously scripted Matlab routines. While you won't be required to design the low-frequency PCB, you will be required to populate and test it.

[1] They require machining of both the top and bottom copper layers of our Rodgers boards

Your completed design will be placed on a 12 x 12 inch panel of 1/4 inch aluminum plate. Teams will drill and tap mounting locations for the components within their chains, as well as the antenna mounting. They will be powered by battery packs, for easy deployment in the field.
Grading criteria will be based, at a minimum, on your ability to accurately measure the velocity of a car traveling between 20 and 45 mph down a road adjacent to Caltech. Your instructor will provide the test vehicle. Teams that are able to get within 10% of the true velocity will receive full points. You are encouraged to go beyond this and try your hand at the range and SAR capabilities of your radar.

II. Ideas for Alternative Projects

- 5.8-6.0 GHz Radiometer. To first order, radiometers are well calibrated gain stages, amplifying blackbody emission up to the μW level where they can be detected with zero-bias schottky detectors. A well built radiometer will have a sharply defined bandpass filter before the detector (also called a noise definition filter) that will set the system pre-detection bandwidth. Bandwidths of several hundred MHz are appropriate for your radiometer. To gain sensivity, you will likely need to make a Dicke radiometer, where the input of your radiometer switches rapidly between the antenna and a termination. Several components are within the class inventory to facilitate the build:

    1. ZX60-83LN+, A commerial low noise amplifier (you could likely do better with your own design).
    2. ZX47-60-S+, A microwave power detector with post amplification.
    3. ZFSWA2R-63DR+, A microwave single pole, double throw switch, which you can use for your Dicke switch.
    4. RTDs, the resistance of these devices change linearly with physical temperature, you can attach them to the termination of your Dicke switch to monitor its physical temperature.
    5. LabJack U6. This is a data acquisition module that is easily programmed with Matlab. It can be used to read your detected output voltage, control the Dicke switch, as well as read in the temperature of the Dicke termination. Grading criteria will be based on the sensitivity and power consumption of your radiometer. For example, could you resolve a 1 K shift in the physical temperature of a (nominally) 300 K blackbody target. You should explore using a mixer in your signal chain after the noise temperature has been fixed by the first two amplifiers. Creating gain at IF will take much less power and the filtering requirements will likely also be easier.

- 5.8-6.0 GHz Microwave Synthesizer. We have two Linear Technology PLL boards just waiting to be used in the EE152 inventory. These could be interfaced with your own, varactor based, voltage controlled oscillator to make a frequency synthesizer between 5.8 and 6.0 GHz. Oscillators can suffer from load-pull issues, where, depending on the details of your design, varying the output impedances can kill or pull the oscillation frequency out of range. This can be aleviated by placing a buffer amplifier after your oscillator, the amplifiers reverse isolation (S_{12}) desensitizing your oscillator from load-pull effects. Grading criteria would be the phase noise of your synthesizer, frequency-range, and output power.

- 5.8 GHz Radio. This is a challenging, but a really fun project[2]. It would require students to make a one way radio, by mixing up (in two stages) the audio band to 5.8-6.0 GHz,

[2] One of the teams from the 2016 term successfully built a radio link

transmitting it via cantenna or patch, and then receiving and down-converting back to the audio. Your smart-phone or laptop could provide the audio source and read(hear)-out. You would likely want to use the two laboratory signal sources for your RF local oscillators at transmitter and receiver. Alternatively, you could use the PLL boards within the class inventory. They have on-board VCO's that can be jumpered in. Grading criteria would be the range of your radio link, deployed on the lawn in front of Beckman.

III. Project Concept Plans

Your project concept plans, one per team, are due **November 19th at 5 p.m.** In it, you should describe in sufficient detail the system you will be building, including with it a block diagram where you indicate the components you will design vs purchase. For purchased material, you need to ensure that the cost of your project will be no greater than $150 for any specialized components, and that these components are readily available so that there is adequate time for you to use them in your system. You will also include the performance metrics by which your system will be judged, if you are building something other than a radar. These should be discussed and agreed upon with the instructor in advance.

IV. Project Material

The inventory for the EE152 lab has been uploaded to the moodle site. You are encouraged to use as much of this material as possible, along with material in the student stockroom. Material will be granted on a first justified first granted (by the instructor) basis. At the end of the project you will own any circuits you designed specifically for your project. Common hardware and microwave components (such as Minicircuits amplifiers, oscillators, attenuators, etc) must be returned to the lab inventory.

V. Resources

1. ExpressPCB. You may want to layout your own custom 2 or 4 layer PCB, for analog/digital circuitry that supports your RF/Microwave signal chain . You can use ExpressPCB for these layouts, the free software is available at `https://www.expresspcb.com/`. You will need to coordinate with other teams who may be laying out a board, so we can combine the projects for a single order.

2. Amplifiers. Additional single stage amplifier PCBs have been ordered, the same as those used in Laboratories 3 and 5. You are free to use a couple of these boards within your projects.

3. Radar Project Material. If you are building a radar, make sure you start by reading through the MIT and Purdue references posted on our Moodle site. Also included within the folder is the Matlab source code you will need for analyzing your radar's data.

VI. Project Grading

Projects that meet their project plan design and performance criteria will receive full points.

VII. Report Guidelines

Reports (to be submitted individually) should follow much of the same structure as your weekly laboratory reports. The general format should include:

- Abstract
- Introduction, which would include general background on your system. If you are constructing a radar this would include general principles of radar operation and system configurations/trade-offs.
- Design strategy and description. How did you attack your design? What drove the design of your components? How were things such as gain and output power distributed across your system? What performance trades did you consider? What was the general design strategy for individual elements?
- Circuit fabrication details. Including pictures of individual elements such as filters, splitters, amplifiers, etc.
- Sub-component performance including comparison to simulation. How did the components you designed measure against simulated performance? If you are using purchased components in your design, you should also include how these circuits performed against their datasheet values (similar to how you compared measurements of Minicircuits amplifiers to their datasheet values in Laboratory 1).
- System level testing. Description of system level testing and data-products, compared against simulation where applicable. It is highly unlikely that you will bolt everything together, flip the switch, and get the performance out that you suspect. Being engineers, you will likely go through a methodical procedure of bringing up the system, connecting one piece to another and testing the performance of the growing ensemble against your predictions. This section should describe this process, including photos.
- Presentation and analysis of final results. In this section you should document the performance of your system against proposed requirements. Any large deviations should be thoroughly explained, in either direction (better or worse).
- Summary, including areas for further improvement and study.

You should be thorough, without being overly verbose. Use as much of the material from your laboratory reports as possible.

Reports are due no later than 5:00 p.m. on Friday, December 8!

Good Luck!