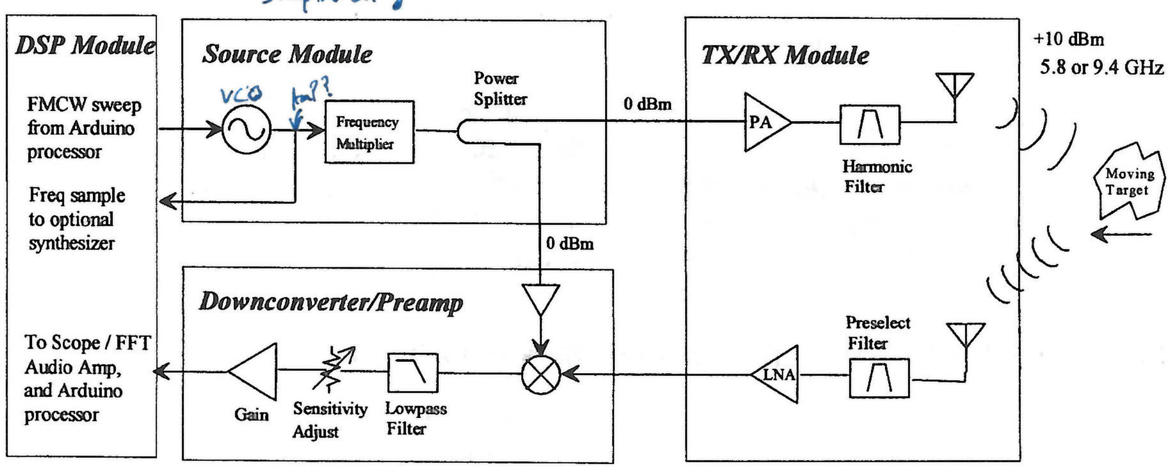
ECE 764 Fall 2017

Project Assignment - Automotive Doppler/FMCW Short-Range Radar

Due Dates and Grading:

Prelim Layouts Ready for Fab, Firmware testing:	*TBD*- Nov 8 Max - Nov 10
Prelim Design Review (PDR) Report	TBD- Nov 10
Second-Spin Layouts Ready for Fab,Firmware testing	TBD- Dec 3
Performance Test / Demo of Radar	Exam week or before
Final Critical Design Review (CDR) Report	***Friday Dec 15***

Simplified !



Product Development and Deliverables

During the remainder of the semester, we will be designing, building, testing, and refining a microwave system - a doppler and CWFM radar operating in C-Band at 5.8 Ghz or X-Band at 9.4 GHz. These are the same types of radars being installed in modern automobiles to improve drivability and safety. To keep our workload manageable, we will operate in 4 person companies, and our radars will use lower frequencies than their commercial counterparts. **Your company must decide as a group what frequency band your radar product will use[1] (from the above choices) and details of its block diagram, software, and packaging.**

To help spread the workload as evenly as possible, each student will be responsible for different components of the project. The major components are identified in the block diagram above and include:

1. Microwave Source Module
2. TX / RX Module - Nathan
3. Downconverter/Baseband Preamp Module
4. Digital Signal Processing and Control Software - Thomas
5. QA - Damian

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[1] It is recommended that you operate at 5.8 GHz, since 9.4 Ghz will be difficult with our construction methods. Attempting X-band operation will NOT buy you any extra points, or sympathy if it causes you to not meet performance goals or deadlines. If you do decide to try it, we will need to discuss the alternative VCO and mixer parts you will need.

System Architecture

The circuits and control/display software to be designed are outlined in the block diagram on page 1. For a successful project, you must work together especially at the interfaces and the software functional specifications. The DSP module will be implemented using a daughterboard board (Arduino-compatible Teensy LC). This board has dual 12-bit ADCs and DACs, and sufficient processing power and memory for all the basic functions if you write efficient code.

As noted in the schedule and in the course syllabus, we will build this in two steps, a prelim design for prototyping, and a final prototype in a "second spin". For the hardware designers, these correspond to two PC board revisions. You should aim to produce as complete and working a board as possible for the first-spin so that your second spin can correct and refine any issues so your company's success is maximized. For the DSP module engineer, a DAC output to set the VCO frequency and algorithms to immplement a user-interface/display with a ***velocity readout*** should be written ***and tested*** by the preliminary design review (PDR) due date.

In the "second-spin", your team should have ***all*** parts designed and built, and the DSP engineer should have their code interfaced and working with the boards, including FMCW sweeping. Your company as a whole must then demo a working product ***before*** the scheduled exam time (ideally ***before*** exam week), leaving enough time to submit the project report before 5pm on the last exam day. Your demo and report will be considered the critical design review (CDR) for your company's product development cycle.

Performance Specifications (Preliminary Marketing Data)

Mode	Doppler (FMCW ranging added in second spin)
Frequency of operation	5.8 or 9.4 GHz
Frequency accuracy/stability (after cal)	Better than +/- 10 MHz
Bandwidth (FMCW mode)	150 MHz
RF Output power	10 dBm +- 3 dB
Harmonic and spurious emissions	< -40 dBc
Target Velocity	0.5 to 50 m/s (1.8 km/hr to 180 km/hr)
Velocity Resolution (Doppler mode)	+/- 5% +/- 1 km/hr
Range (10 dB-m^2 RCS)	1 to 100 meters
Range Resolution (FMCW mode)	< 0.5 meter
Range/Velocity Update Rate	Better than 5 per second
DC Power	9V at < 500 mA
Operating Temperature range	0 to 50C for initial prototype development
Standards	ROHS compliant, FCC compliant

Design Procedure

There is no detailed step-by-step procedure for this project. You should use the knowledge you've gained in this course and previous courses to design your circuits as you would in the workplace. However, we will have class discussions as needed to help you get started and keep you going. Some important technical issues for you to consider (beyond the specs above) are outlined below.

Data Sheets

For this project, available active components have been pre-selected and included in your kit to help keep the scope reasonable for a (half) semester project. You should begin by studying the datasheets for these (they are on the class KSOL website), and reviewing your amplifier prototyping results from Lab 3 to down-select from this set. Pay particular attention to signal power levels, gains, and compression points and their behavior versus frequency.

Signal Level and Gain Distribution

In an analog/RF design, a key issue is what signal levels will exist at different points in the circuit and how gains should be allocated. Use what you have learned about gains, compression points, and insertion losses, together with appropriate specs from the datasheets to determine what amps you will use and where. Since gains of the amplifiers are not adjustable and insertion losses may not be accurately known in some areas, consider designing-in moderate excess gain and using pads to adjust as needed in key locations.

Software/Firmware Design

The individuals responsible for the downconverter/preamp and DSP modules and associated software/firmware will be using an Arduino Teensy LC for development, and should work closely with each other, as well as with the designers of the source and tx/rx modules. This DSP engineer should begin early by determining how to use the ADC and DSP functions of the Arduino and by designing, writing, and testing code for the velocity determination and display. User interfaces should also be considered. To do this, they will have to review the doppler radar operation equations and begin testing their code early using a waveform generator in the lab (what audio frequencies and what voltage-levels and offsets should be expected and tested ?). This individual should also contribute to the board design by helping to define suitable hardware DAC and ADC interfaces needed for setting the center frequency and digitizing the audio output waveform (and for later FMCW modulation of the VCO). FMCW should be implemented and tested with the full company during the second-spin board builds.

Design For Test

Experience in previous years has indicated that we should partition individual subsystems into sections and verify these independently. This will help in troubleshooting and achieving the performane specifications. To facilite this, you may may want to use U.FL connectors like cell-phone manufacturers do (but be careful of creating impedance bumps !). In addition, we have some decent 5+ GHz RF probes. More information on this will be supplied in class discussions. *100 mil header pins are recommended for connections to the Arduino, and for audio and power connections connections.*

EMC Considerations

Previous year experience ("corporate history") has pointed to the need for careful consideration of electromagnetic compatibility (EMC). In particular, we should strive to achieve good signal integrity (SI) and power integrity (PI). The former involves making good choices of signal routing and line-types where as the latter generally implies good supply bypassing - especially in cascade amplifiers. It is easy for RF (and even high-gain audio) signals to find themselves on the supply line, or simply coupling between lines on the board, creating feedback through injection into earlier stages in a cascade, or degradation of performane by excessive transmit/receive crosstalk on the board. Guard against this with careful *supply bypassing, bandpass filtering in your RF amp chains, providing "pads" at amplifier outputs, shielding, etc.*

Electronic Design Automation (EDA) Tools

You should plan to use Express PCB for the layouts and the Arduino development environment for the code, especially if you are not experienced with other tools. ***If you plan to use other tools, you must develop a written plan, documenting the approach that your full company agrees to, and certifying your company as a whole agrees to the schedule risks involved.***

You may also use ADS in your microwave circuit designs. In particular, you may wish to draw your power-divider, filters, and antennas in the ADS schematic editor and possibly auto-generate layouts which you can simulate/refine. This is especially valuable for the filters and antennas. While you will have to redraw them in the Express PCB layout tool, <u>*you should use the ADS-generated layout to check your design dimensions.*</u>

For other circuits and Ics (e.g. baseband amps, VCO, DAC/ADC), you may not have models needed for simulation and will have to do a good design by simply being careful and thorough, 'simulating' in your head.

For layouts, you should locate or create the needed "footprints". For standard packages, these are available in the Express PCB layout tool. However, for some RF parts, you will have to create your own. You may want to decide who will do what footprints in your company and then share these to help reduce workload.

<u>*When done with either a single footprint or your full board, print out your design at a 1:1 scale and verify your IC's will fit by placing them on the printout*</u>! Re-verify proper pinout at this stage too, and compare once again with your schematic to be sure all is correct. **(Failure to finish due to the need to refabricate a board is not an acceptable excuse for missing a deadline. That's why we are taking a two-spin prototyping approach and have two possible board-submission dates for each !)**

Layout Submissions

Layouts of PC boards must use the ExpressPCB standard 2.5" x 3.8" "Miniboard" form-factor. When doing your layout, remember to adhere to good design practices (e.g. vias directly below ground-pins of RF amps, using bypass caps on all ICs, etc.). Layouts must be submitted to your instructor in a .pcb file that passes the DRC checks run by the software in the pricing step. Your instructor will check and submit your layout for fabrication if they pass this design-rule check as well as a visual sanity check. Else he will return it shortly after you submit it with any problems identified, and with a grade deduction recorded. In the end, *it is up to you to do a careful design and resolve questions if you have any prior to fabrication.*

Two-Layer vs Four-Layer Boards

Two layer boards have been successfully done at 5.8 Ghz by previous company engineers. 4-layer boards provide more options, but also more pitfalls, and higher cost (both monetary and schedule-wise). Your kit cost has built in the monies needed for each company to fab two 2-layer boards for each deliverable - for a total of four 2-layer boards for the project development. If you choose 4-layer design, the kit cost covers only two boards total, so you will need to fund the second fab yourself, or fit everything on a single 2.5 x 3.8 inch board.

Deliverables and Grading

Each of the two layout deliverables is worth 10 % (DSP engineer should submit a software design document at the same time). Following construction and test of your first-spin circuits and first-rev code, your company should provide a writeup on the design and the testing results, which will be worth 15% of your grade. ***<u>As in the projects, carefully indicate which student did which part(s) of the design / writeup.</u>***

An additional 30% of your grade will be allocated to the second-spin design, layout, to the demo, and documentation that constitute the CDR and your final exam.