ECOSat Communications Subsystem: RF Division Progress Report 2

by

Tao Lu, Kris Dolberg, and Jarrah Bergeron
Supervisor: Peter Driessen
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Table of Contents

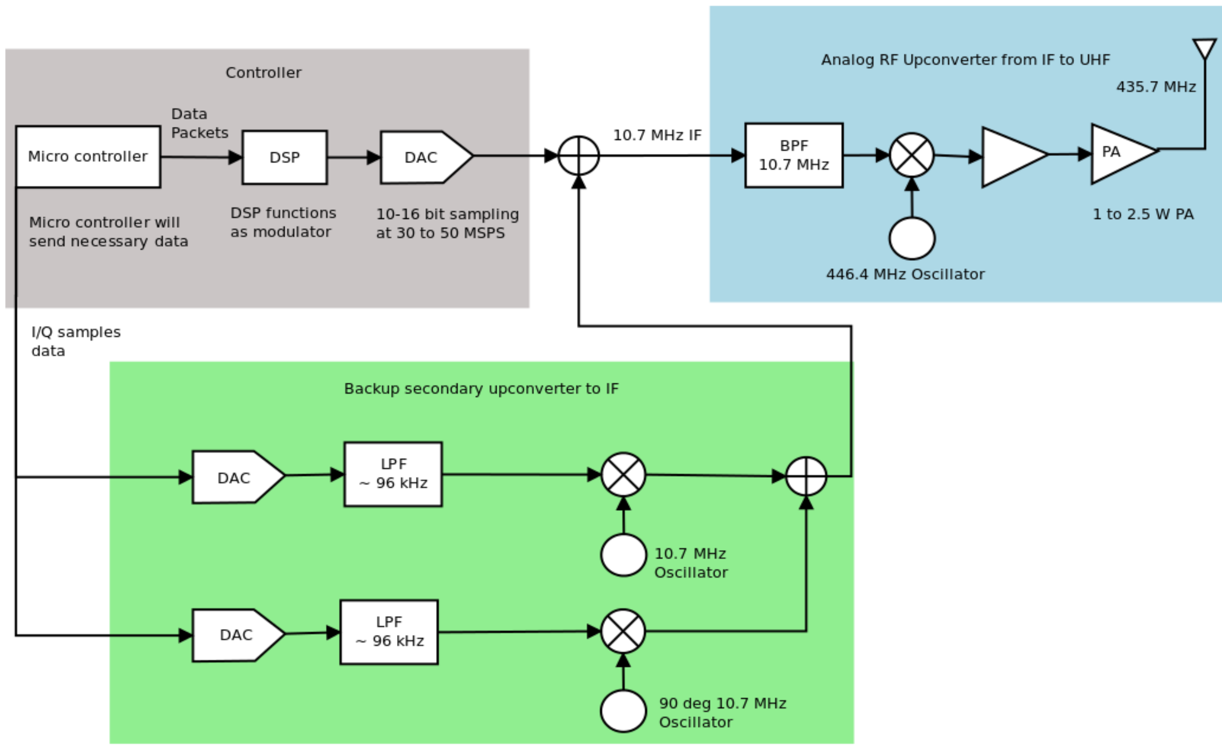
Chapter 1 ECOSat Communications Subsystem: RF Division

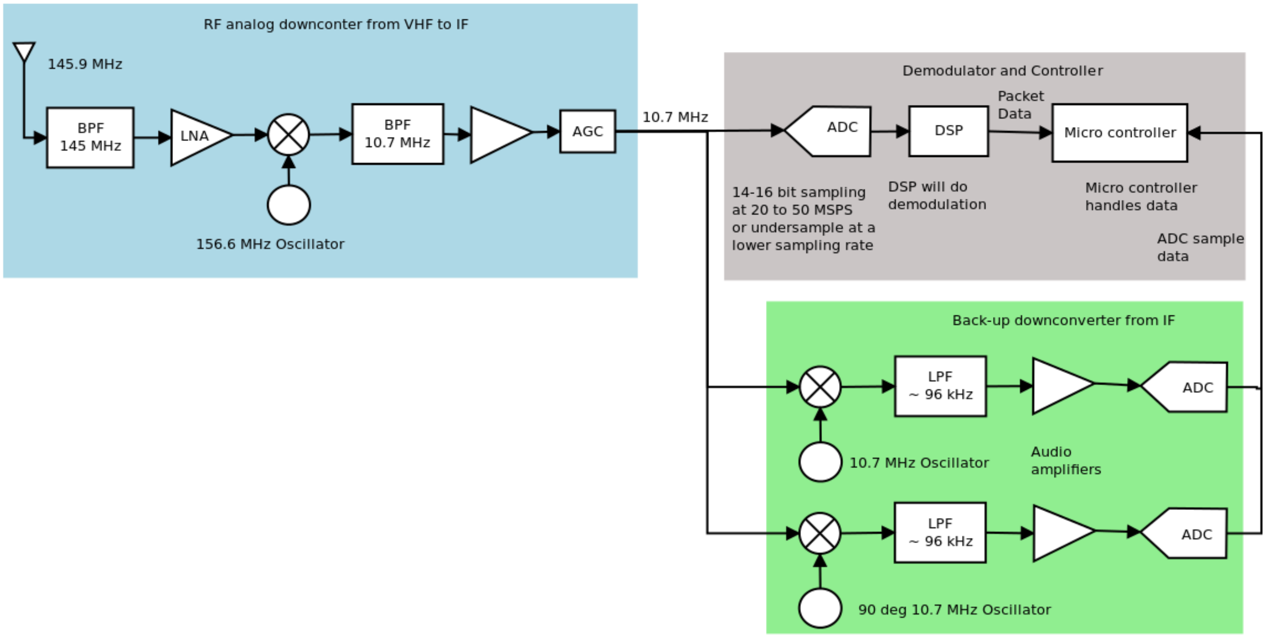
Project title: ECOSat Communications Subsystem: RF Division

Supervisor: Peter Drissen

The University of Victoria ECOSat team is competing with 11 other Canadian universities in Geocentrix's Canadian Satellite Design Competition. The nanosatellite to be designed is 3U in size (approximately 10 by 10 by 30 cm) and must execute two missions, one of which must be scientific in nature. One of ECOSat satellite's missions will be to measure diamagnetic properties of pyrolytic graphite which will help with materials research for future space applications such as propulsion mechanisms. The second mission will be an OSCAR (Orbiting Satellite Carrying Amateur Radio) which will relay amateur operator messages around the world. The competition has been going for almost two years and is currently in its last stage with the final hardware delivery deadline in mid-September. Each of the satellite's subsystems is in the process of being built which includes the communications subsystem.

The communications subsystem is a large part of the satellite as it not only must receive commands from the ground and send back telemetry and status data but is also at the heart of the OSCAR which the satellite will be carrying. The communications system will be based on software-defined radio (SDR) which allows the flexibility of modulating and demodulation of signals in software. However, the very-high (VHF) and ultra-high frequency (UHF) signals cannot be synthesized directly from the processor as such tasks would be too computationally hungry. Instead, as with the vast majority of radios, the signals are first synthesized in baseband at low frequencies and then up-converted to the final transmit frequency or down-converted received signals back down to baseband. To accomplish this task, radio frequency grade analog circuits are used. A block diagram of the current communications design is shown below, first the transmitter and then receiver.



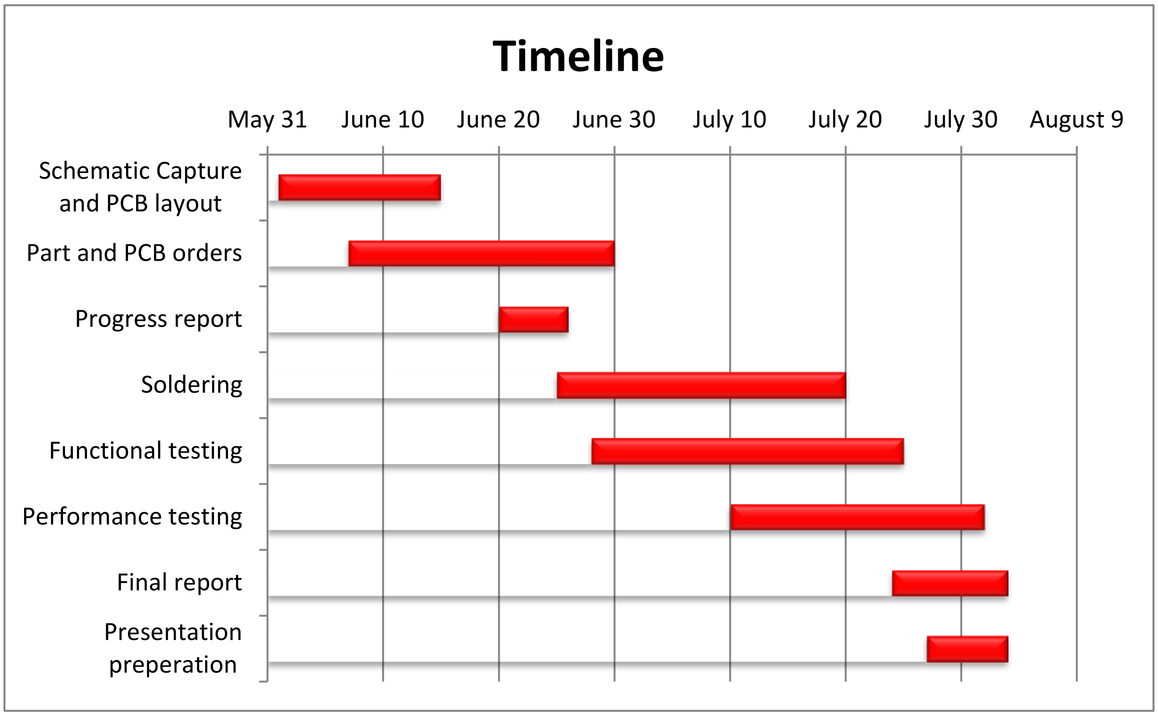


The proposed project is to complete both the up-converter and down-converter RF analog boards shown above in blue in the transmitter and receiver block diagram, respectively. Completion includes finishing the design, building and then testing the boards.

As this project is an ongoing venture, a preliminary schematic and board layout has already been produced for both the up-converter and down-converter boards. The tasks to be completed include:

- Finishing up the schematic capture, board layout and part selection
- Ordering the parts and the PCB boards
- Soldering components on to boards
- Functional and performance testing

A Gantt chart is shown below of the tasks and associated timeline for the project. Major milestones will include final circuit and PCB design completion, component soldering completion and board and design testing completion.



All of these tasks will be done in cooperation with other members of the communications team and the satellite team as a whole. Synchronization between teams is crucial to complete satellite integration.

By the end of the term, functional RF up-converter and down-converter boards are to be delivered. Also, key performance parameters such as power consumption will be measured to make sure the design will integrate well with the rest of the satellite design. Project progress and final results will be documented as well in the form of a final report and presentation.

Biography

Jarrah is currently a fourth year electrical engineering student. Originally from northern British Columbia, he moved to Victoria for post-secondary education. He is currently taking courses in the communications, digital signal processing and microwave and optics and will likely specialize in microwaves and photonics. Also, past co-op work include various board-level verification and debugging, digital logic and analog design and validation, extensive documentation and photonics research. Jarrah has experience in many schematic capture and PCB layout packages, circuit simulators and software and firmware development environments. However, his experience in electrical and electronics spans far before university, having broad knowledge in a variety of domains and done numerous projects namely in embedded development. This includes microcontrollers, digital logic and analog audio design both in theory and on PCB. Many types of test equipment have also been used including power supplies, power analysers, oscilloscopes and spectrum analysers. Interests mainly lie in high frequency analog and digital hardware and system design.

For this project, he has been part of and has contributed to the ECOsat project for many months and knows how the satellite team is organized and how the project is progressing, including most subsystems. Along with the breath on knowledge already acquired prior involvement in ECOSat makes Jarrah particularly well suited for this project. This will allow our project to start with little delay and help meet the project deadlines.

Kris Dolberg is a fourth year electrical engineering student planning to specialize in digital signal processing and mechatronics. Kris was born in Ottawa, and grew up in Victoria. After finishing high school in 2006, Kris attended Camosun College where he took two years of general studies. He enrolled in the University of Victoria's engineering program in 2008. Originally planning study mechanical engineering, he chose to study electrical after completing first year do its better fit for his interests.

Kris has previously completed two co-op work terms. The first was in the IT department of Odlum Brown Limited, a Vancouver-based investment firm. The second was working for UVic's own VENUS project.

He has been involved with ECOSat since 2011. Aside from the work for ELEC 399, Kris is currently designing the drive circuitry and redesigning the coils for the satellites magnetic torquers.

Upon graduating, he plans to move to Germany and pursue a career in control system design. In his spare time, he enjoys playing guitar, philosophizing, swing dancing, biking, cooking, and indoor rock climbing.

Chapter 2 Progress review

Currently, the circuitry has been fully designed and the schematic capture and printed circuit board layouts of both the up-converter and down-converter boards are completed. The parts have been selected as well as making sure that they are available and in stock from component distributers. The boards and part orders are in progress. However, overall, the project has been slower than anticipated due to certain complications.

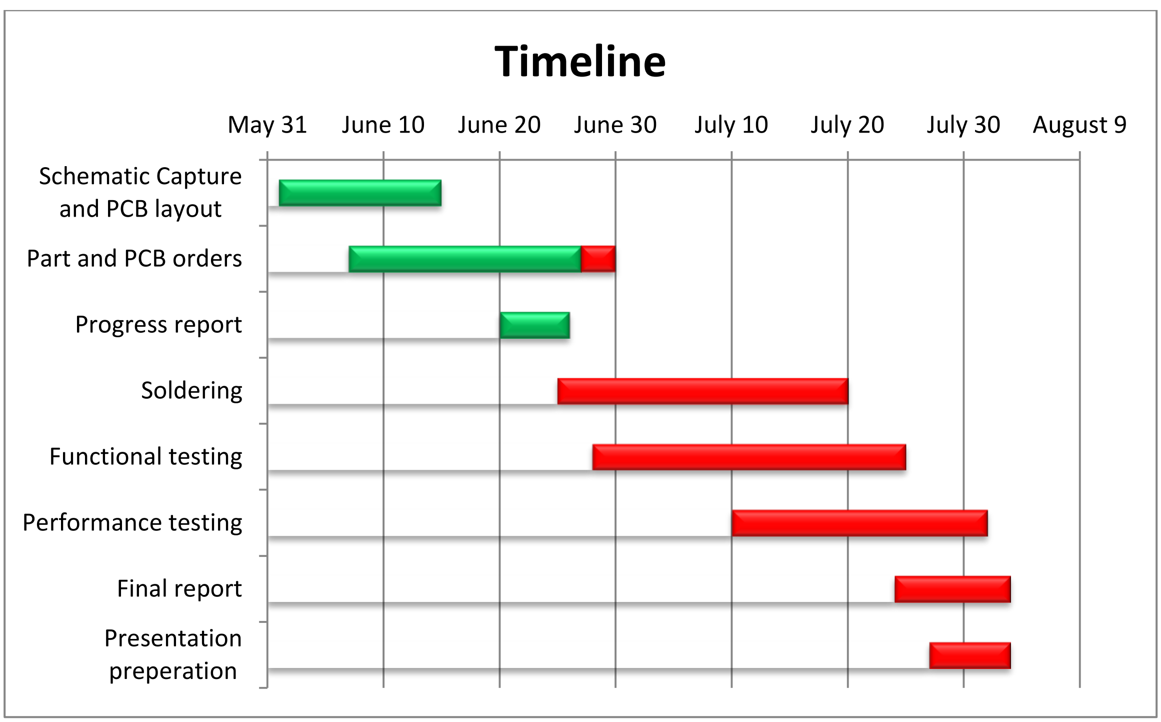
The part selection for both boards was much longer to complete than expected. Radio-frequency (RF) design often requires specialty components which are expensive and difficult to find especially in RF bands which are not highly utilized commercially, such as our 145 MHz uplink frequency. These components can also be challenging to design into circuits. Off-the-shelf and highly integrated components where sought after to minimize lengthy performance optimization during the board builds, including impedance matching and frequency response tuning, but more time had to be spent up front during part selection.

In addition, the complications associated with the space environment add more constraints on the design. The main concern was the operating temperature range. The satellite will be subject to high temperatures namely due to the lack of paths for heat to escape. The heat coming from the sun and generated by the satellite's systems can only leave the craft by radiation as it will be in a vacuum. Commercial operating temperatures only go up to 85 °C which is not high enough according to the thermal models which predict up to 100 °C when the satellite is in the sun. Automotive parts are rated up to 125

°C which is adequate for our purposes but this severely constrains part selection, especially from major component distributers. In addition, off-gassing requirements must be met which limits the use of certain types of passive components, especially capacitors. However, because our boards contain no digital logic (except the clock generator), the use of radiation-hardened parts is not a necessity. Analog circuitry is less prone to radiation damage in the short term then their digital counterparts.

Additional delays were due to consultants on the project who reviewed the design. Multiple people, with varying degrees of expertise, did review our boards. Some minor changes to the boards where done as a result. Although highly appreciated, some delays were incurred by this as well; however, it may help in the long run to avoid problems during board bring-up and performance testing.

The timeline is shown below. The green bars indicate progress so far and red bars indicate work to be completed.



It is evident that the soldering and functional testing are behind schedule. These tasks cannot be started until the PCB boards come back from the board manufacturer and most of the components have arrived. However, the boards are anticipated to be completed on time, even though thorough testing of the boards may be cut short at the end.

Chapter 3 Textbook Review

A requirement is a statement of a characteristic that a system must have or an action that the system must do. For example, on UVic's ECOSat, one requirement specified by the Canadian Satellite Design Challenge is that the satellite's Attitude Determination and Control System must be able to continue to operate (possibly at reduced performance) if one of the actuators fails.

In the systems development life cycle (SDLC), requirements will typically be listed in a document called the requirements definition. It would list both the functional and nonfunctional requirements. Functional requirements specify requirements directly relating to the purpose of the system. An example proposed by the book is "The system will enable salespersons to create a customer offer." Whereas a nonfunctional requirement is a requirement that does not relate directly to the purpose of the system, it does describe a characteristic that the system must have nonetheless. An example used by the book is "The system should run on tablet PCs to be used by salespeople." In our project, an example of this type of requirement includes the use of components which do not off-gas in a hard vacuum. While the essential functionality of the communications system is not dependent on the use of these components, this requirement is added to avoid reliability issues in the satellite once it is in space.

Use case analysis is an important tool used by analysts in process modeling. When creating a use case. An analyst would typically consider an action triggered by an event. The analyst must also consider the input that would produce the desired output or output, and the steps in between that lead from the former to the latter.

A process model is a graphical representation of a system. Although many process modeling techniques exist, the book focuses on the process modeling technique known as data flow diagramming. Data flow diagrams show the movement and processing of data, but do not specify implementation methods or what forms the data will take. For instance, one would not be able to tell from a data flow diagram if a process that processed data was automated by a computer or worked out by hand by a person.

Data flow diagrams have four basic components: processes, data flows, data stores and external entities. Processes are essentially activities. They often manipulate data in some way. A data flow represents a movement data from one source to another. An external entity is a person or thing that is not involved with the company.

The last topic of Part 2 of the book is data modeling. The most common graphical representation of a data model is the entity relationship diagram. Entities, attributes and relationships are the three building blocks used to create entity relationship diagrams. Their meanings are mostly self-explanatory. An entity is a person or organization. An attribute is information about an entity, and a relationship is how two entities are connected (for instance, a parent-child relationship could exist between two entities).

During the design phase of a system, important decisions must be made. The three main application architectures that are used are server-based architectures, client-based architectures and server-client architectures. Server-client architectures come in both thick and thin client varieties. Hardware and software specifications are used to describe the hardware and software needed for the system. It also specifies which software runs on which hardware.

The next topic the book discusses is user interface design. The basic principles of user interface design are introduced: allow user to become aware of content, make the interface aesthetically pleasing, keep aspects of the interface consistent with other aspects of the interface, and minimize user effort. The book moves on to discuss how these principles apply to navigation, input, and output design.

Program design is a critical part of the system design process. Structure charts are a high-level illustration of different components of a program broken down into modules. Each module must perform only one function. Anything that performs two functions needs two modules to describe it. A process called program specification is used to give more detail about each module such to the extent that programmers can write code that will make the module do exactly what it needs to do. Pseudocode (“code” written in English in the form of programming structures such as loops and if statements) is used to help programmers translate specifications into actual working code.

The last chapter of Part 3 discusses data storage design. There are different types of data storage that are best suited to the storage of different types of data. Files and databases are the two basic types. There are five types of files: master, look-up, transaction, audit, and history. There are four types of databases: legacy, relational, object, and multidimensional. The appropriate data storage format depends on the complexity and nature of the data to be stored. Physical entity relationship diagrams must be used in the data storage design process to show precisely how data will be stored in the data storage (whether the format is a file or database). Lastly, data storage must be optimized for access speed and storage efficiency. There are many factors to be considered in optimization. For instance, clustering (the process by which certain similar pieces of data are stored together) can be used to speed retrieval. Hardware selection also affects speed. In order to optimize a data storage for storage efficiency, it should ideally have no redundant (however redundancy is sometimes intentionally added to improve speed) data and a minimal number of data entries with null values.

As these chapters mostly focus on programming and software development, very little of it is applicable to our project. Our project is completely hardware based which demands very little programming so no data modeling or programming interfaces are required.

Conclusion

This report outlines the ECOSat Communications Subsystem: RF Division ELEC 399 project. It entails the designing, builting and testing of the radio-frequency analog front-end for the ECOSat communications subsystem. Progress so far has been slower than anticipated because of the lengthy part selection and design review process; however, the boards and parts are in the process of being ordered and the next step in the build is anticipated to be soon.

Also, a brief textbook review of “Systems Analysis and Design” is included. This book was also related back to our project but the subject matter are too distant for the book to be relevant: the book focuses on software system while our project is distinctly hardware based.

References

G. Shelly, H. Rosenblatt, *Systems Analysis and Design*, 9th ed., Boston: Course Technology, 2012.

ELEC/CENG 399 Design Project I Progress Report II Evaluation Form

<u>To be filled by students:</u>
Project title: ECOSat Communications Subsystem: RF Division
Group members: Kris Dolberg, and Jarrah Bergeron
Supervisor(s): Peter Driessen

To be filled by the supervisor(s):		
Progress report distributed to the supervisors for grading: **Friday, July 6, 2012.**		
Please complete the progress report grading by: **Monday, July 23, 2012.**		
Please refer to the rubric for grading.		
Topics	**Subtopics**	**Grade [%]**
[10%]Overall presentation	[3%]Table of contents is presented according to the sample report attached;	
	[3%]Citations are properly used;	
	[4%]Conclusion is written in a clear professional technical language;	
	subtotal [10%]:	**0.0**
[10%]Chapter 1, Project Proposal	[10%] Proposal revised according to the feedback from the supervisor(s);	
	subtotal [10%]:	**0.0**
[60%]Chapter 2, Progress Review	[20%] This chapter is written in a clear professional technical language;	
	[20%] Milestones/Deadlines described in Chapter 1 are met in timely fashion;	
	[20%] Overall progress is satisfactory;	
	subtotal [60%]:	**0.0**
subtotal [80%]:		**0.0**
To be filled by the instructor:		
[20%]Chapter 3 Textbook Review	[10%]Write the textbook review in a clear professional technical language;	
	[10%]Meet minimum page requirement (2 pages).	
	subtotal [20%]:	**0.0**
Total [100%]:		**0.0**

Comments by the supervisor: