

6.S965

Digital Systems Laboratory II

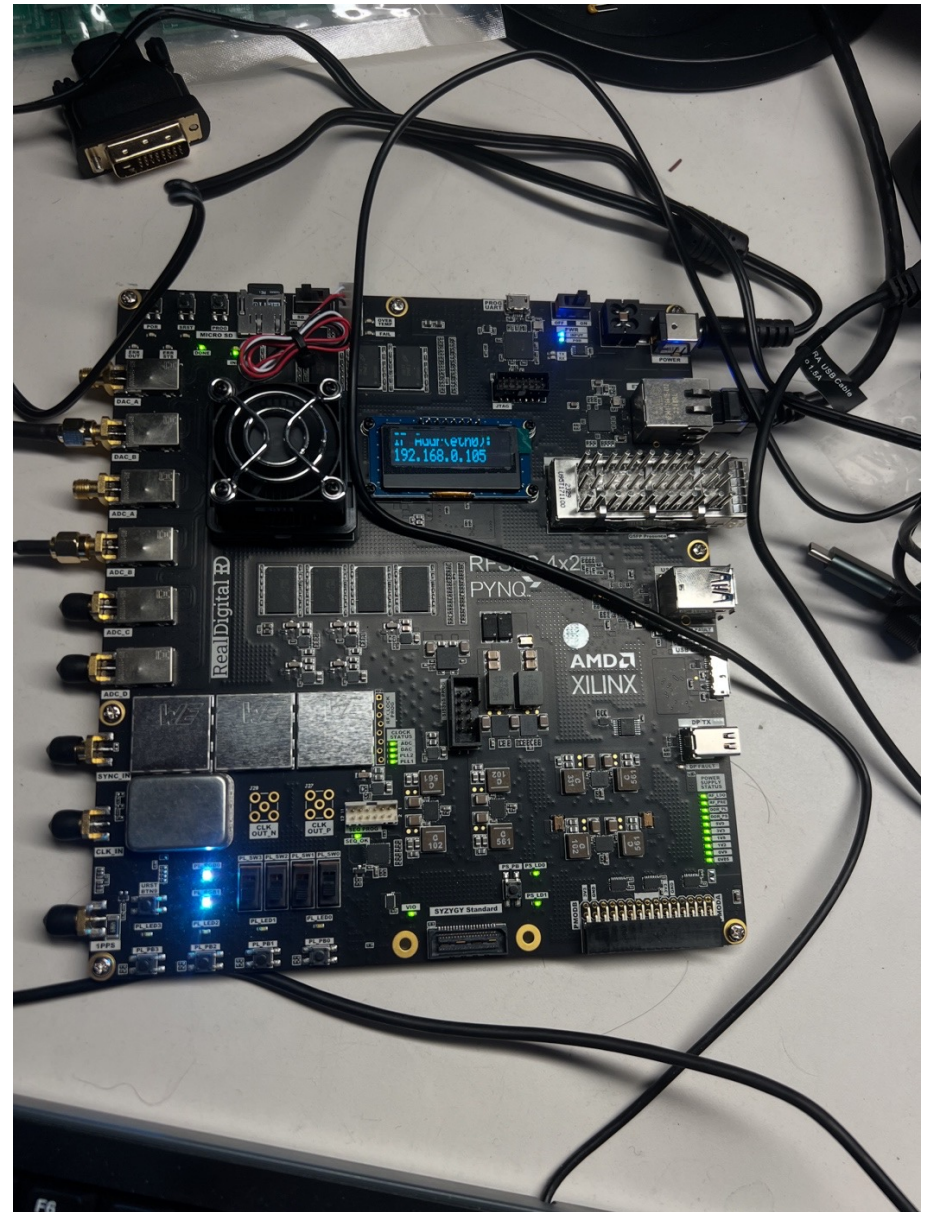
Lecture 10

Administrative Stuff

- I need us to figure out final projects and teams in the next day.
- In the next day or so, I'll put on the site a RFSoc lab. I'll set up (for starters) six RFSoc boards in the lab and we'll need to try to time-share them if possible (I have more)
- Next week I'd like to cover the idea of coverage with Cocotb and our verification framework
- Then we'll just roll into final projects

Lab This Week:

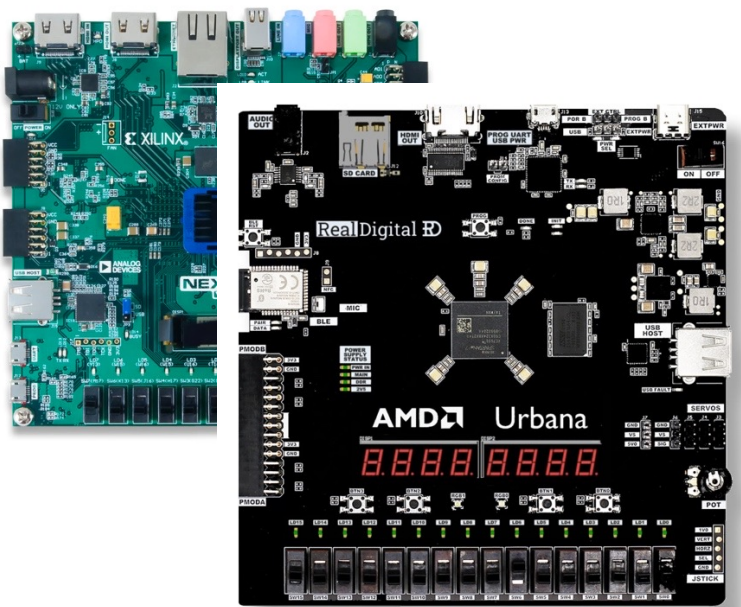
- We'll work with the RFSoc Board
- For starters we'll just configure and run the ADC and LO and dump some data into memory to analyze



Final Project Environment

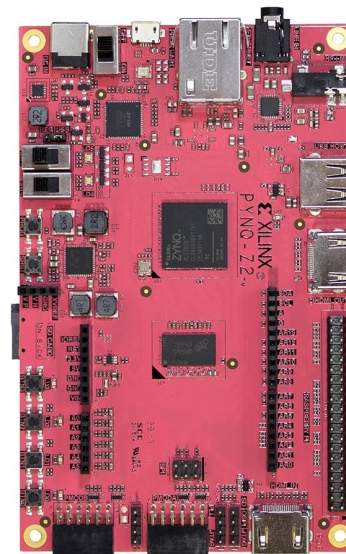
- Board Choice...don't really care, specifically...just pick one

Regular FPGAs



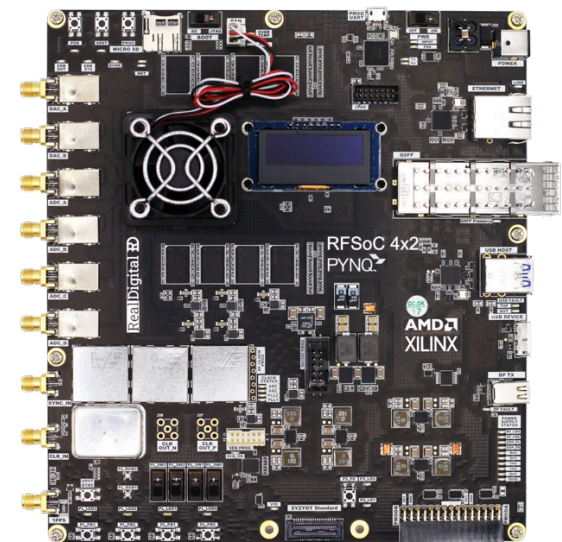
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Standard SoCs



6.S965 Fall 2024

RFSoc

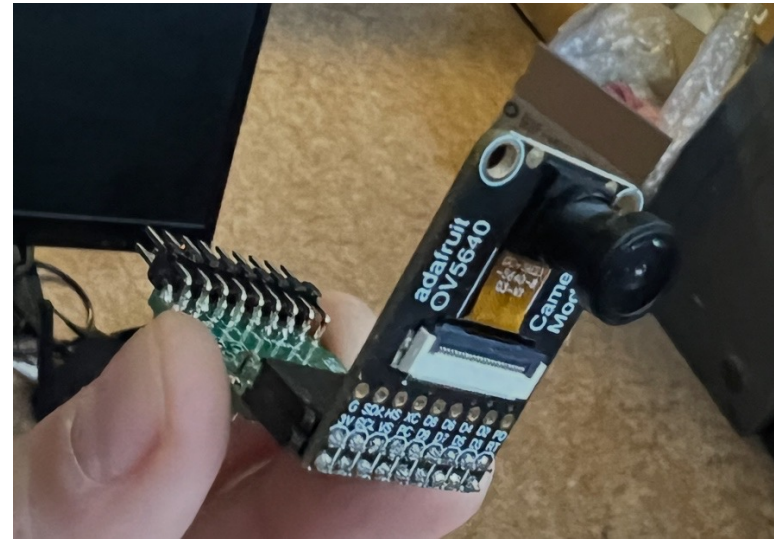


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Regular FPGAs

- We have extra Urbana boards (and we have pretty well-functioning DDR interface logic this year!)
- Also a bunch of Nexys 4 DDR boards (about 2X resources of Urbana)
- Also have several Nexys Video boards (about 8X resources of Urbana)

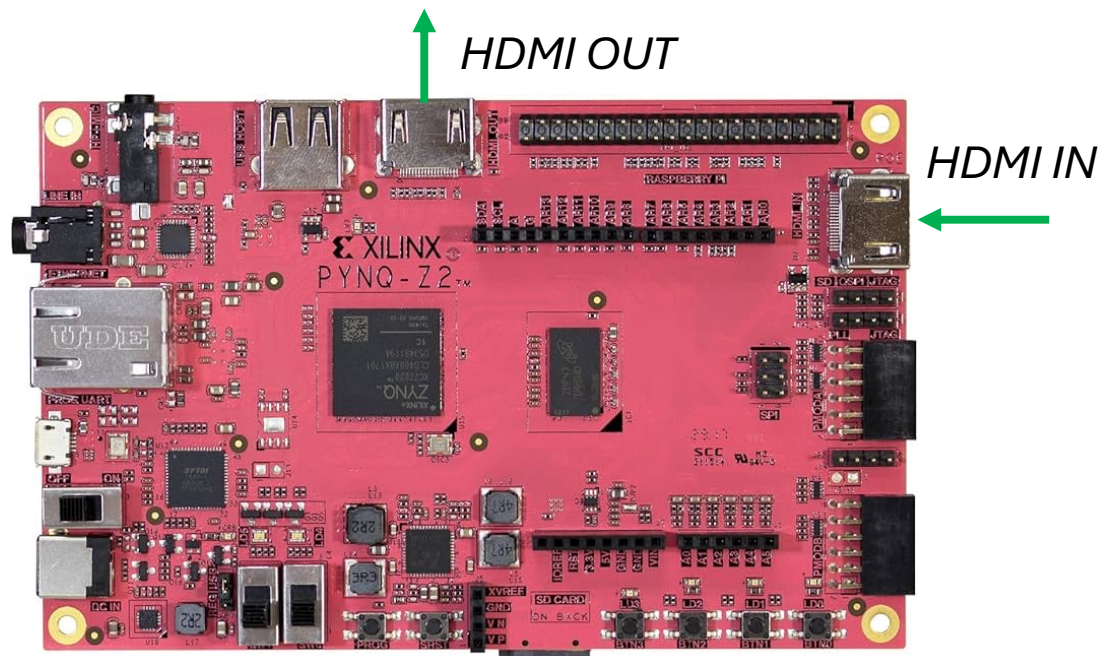
Additional Equipment



- 6.205 has a *much* better camera this year (720p 30fps) so if you want to do something with image-processing/anything, we have some you can use.
- Need a slightly different adapter for Pynq but just need to make more of those

The Pynq Z2 Board

- Does have HDMI in and out, so it is possible to incorporate this into some interesting video-processing pipelines.

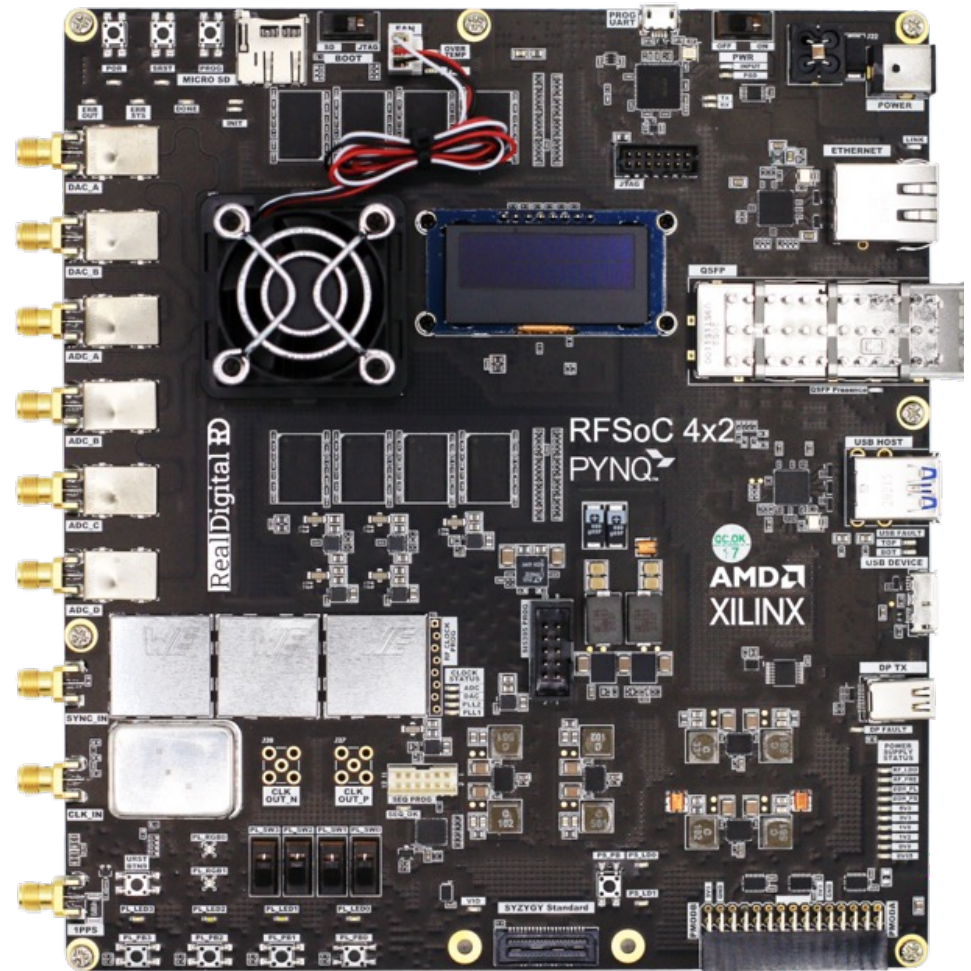


Anything with Computer Vision, this could be a good environment

- <https://www.youtube.com/watch?v=QPshQ9PsuFs>
- Sources of data could be computer feed (passthrough to monitor using HDMI in and out)
- Or camera input (@ 30 fps)

RFSoc

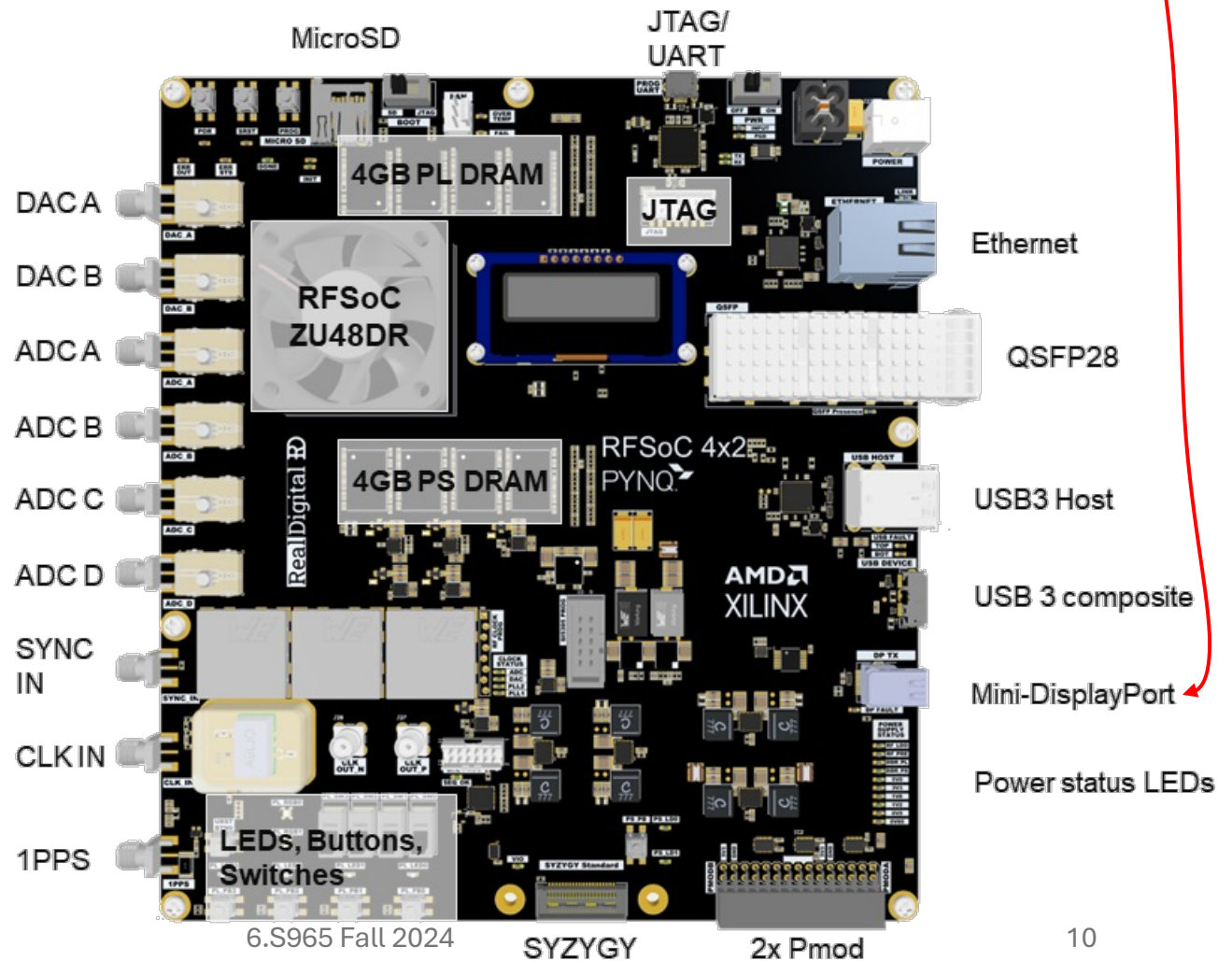
- It is basically the Pynq Z2 but with a lot more resources, the ADC, DAC and a lot less “fun” breakout parts like HDMI
- Chances are, outside of the ADC and DAC, most other peripherals have minimal codebase support



I've tested the...

Oh there's a display port

- ADC
- DAC
- LEDs
- Switches
- Buttons
- Pmod pins
- DMA



rfsoc.pynq.io

- Reference one:

The screenshot shows the website rfsoc.pynq.io with a dark sidebar menu on the left. The main content area features a large banner for a new free eBook titled "Software Defined Radio Systems with Zynq® UltraScale+ RFSoc". Below the banner, there is a paragraph of text describing the eBook and a link to the book website. A second section titled "New RFSoc-PYNQ release" provides information about the latest 3.0 release and a link to board images. At the bottom, there is a section for "RFSoc-PYNQ" with a description of the technology and a link to the GitHub repository. The AMD Xilinx Zynq RFSoc logo is visible in the bottom right corner of the page.

RFSoc-PYNQ
Main Menu
Home
RFSoc 4x2
Overview
Getting started guide
Resources
Overlays
Educational Resources
Tutorials
RFSoc Accessories
Support
Purchase
PYNQ support forum
FAQs
Legacy
RFSoc 2x2

New free eBook: SDR with Zynq UltraScale+ RFSoc

Software Defined Radio Systems with Zynq® UltraScale+ RFSoc

This book introduces Zynq UltraScale+ RFSoc, a technology that brings real, single-chip, Software Defined Radio (SDR) to the marketplace. The book is accompanied by Jupyter Notebooks that can be run on your RFSoc-PYNQ enabled board, illustrating key concepts including *sampling and quantisation, filter design, Fourier's theorem and FFTs, pulse shaping, QAM, frequency planning, Forward-Error-Correction, and OFDM.*

See the book website www.rfsocbook.com to download your **free** copy of the eBook and details on how to purchase hard copies.

New RFSoc-PYNQ release

The latest RFSoc-PYNQ 3.0 release adds supports for the [ZCU208](#) alongside the existing support for the [RFSoc 4x2](#), [RFSoc 2x2](#), and [ZCU111](#).
To download the latest PYNQ image for your board, see [PYNQ.io board images](#).

RFSoc-PYNQ

RFSOC-PYNQ is an extension to [PYNQ](#) bringing support for the AMD-Xilinx Zynq **RFSoc** family of devices. RFSoc created a new class of integrated circuit architecture for the communications and instrumentation markets. RFSoc combines high-accuracy ADCs and DACs operating at Giga samples per second (GSPS), with programmable heterogeneous compute engines.

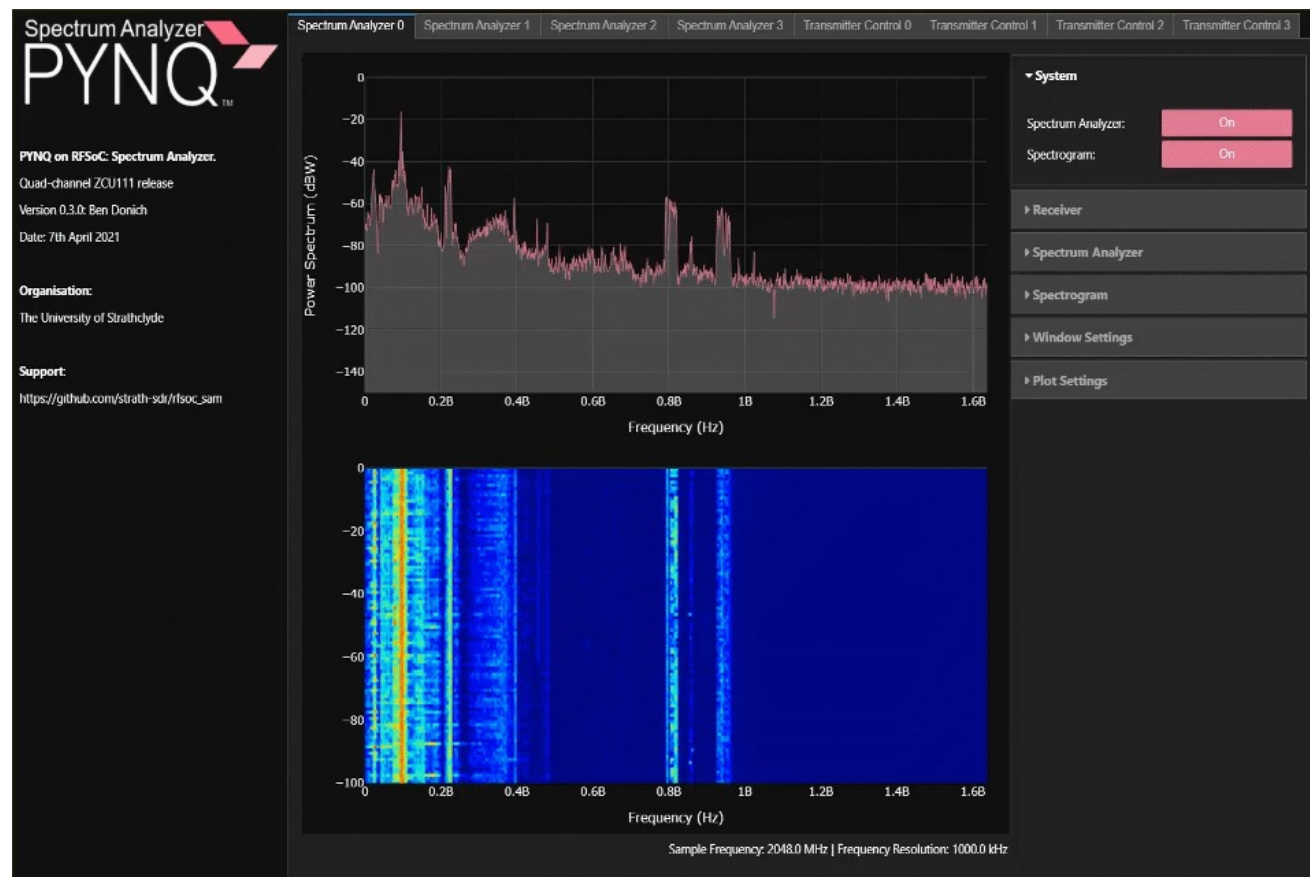
RFSoc-PYNQ provides Python APIs, libraries and drivers for the RFSoc, example overlays and designs, tutorials and other resources for RFSoc users.

[View on GitHub](#)

AMD XILINX ZYNQ RFSoc

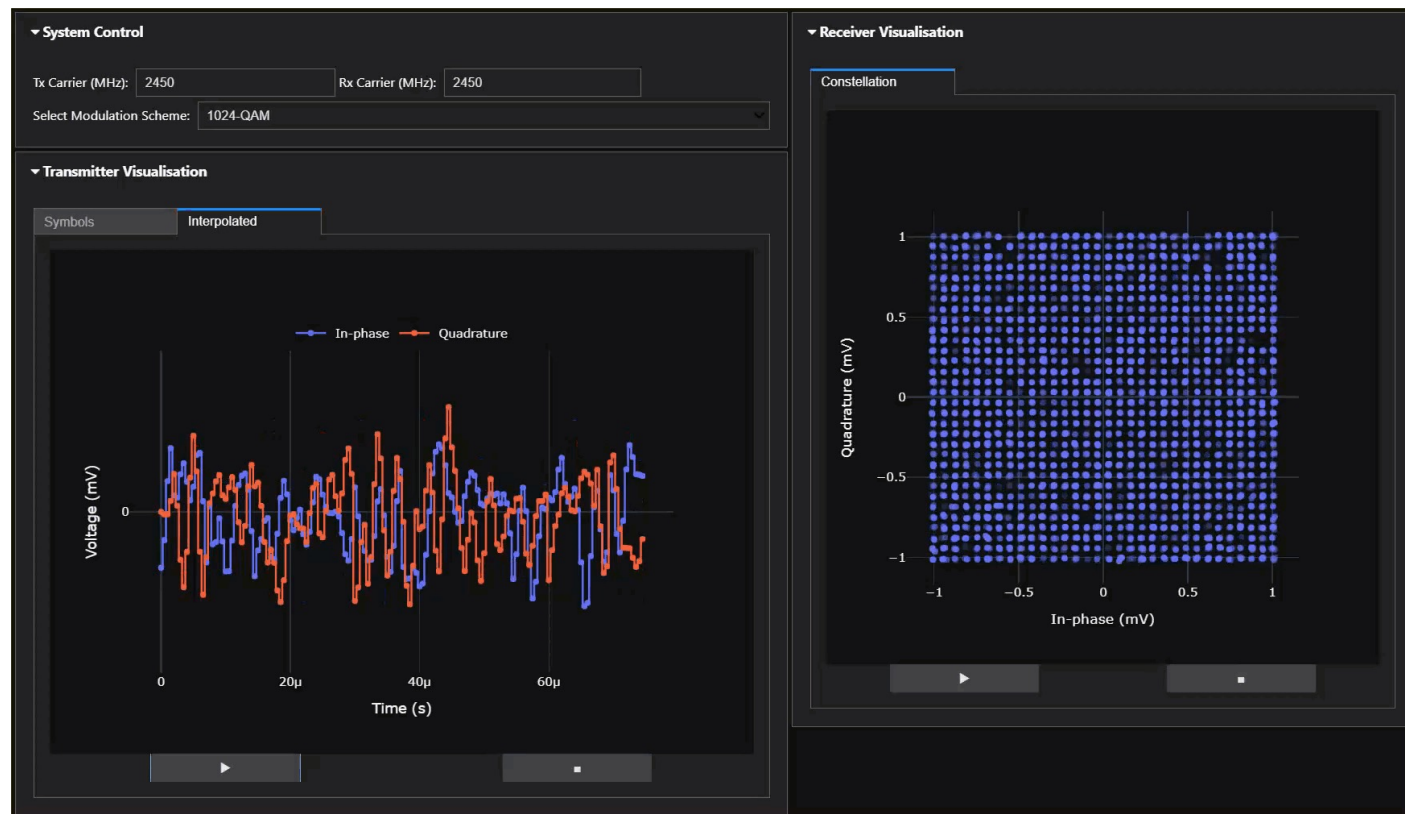
Has some interesting overlays

- Regular Old Spectrum Analysis



Has some interesting overlays

- 1024-QAM demo



Downsides

- All the code and widgets are found here:
 - https://github.com/strath-sdr/rfsoc_studio/tree/master
- All of their stuff was built with old Vivado (2022 or before). It does not build on 2023 or 2024, and they don't seem in any hurry to do anything about that.

The logo for RFSoc-PYNQ features the text "RFSoc-PYNQ" in a sans-serif font, followed by a stylized graphic of three overlapping pink and red shapes that resemble a bird or a flame.

This repository contains the source code and build scripts for the RFSoc-PYNQ base design and SD card images. The design files in this repository are compatible with Xilinx Vivado 2022.1, and PYNQ v3.0.0 and later.

Currently, the ZCU111, ZCU208, RFSoc4x2 and RFSoc2x2 platforms are supported.

You can run their notebooks and there's some interesting demos

- Most of which are built off of this “base.bit” overlay they wrote which has a lot of functionality in it.
- But you can't open it or rebuild it in vivado 23 or 24 (and even when I tried early on with vivado 22.2 it broke)

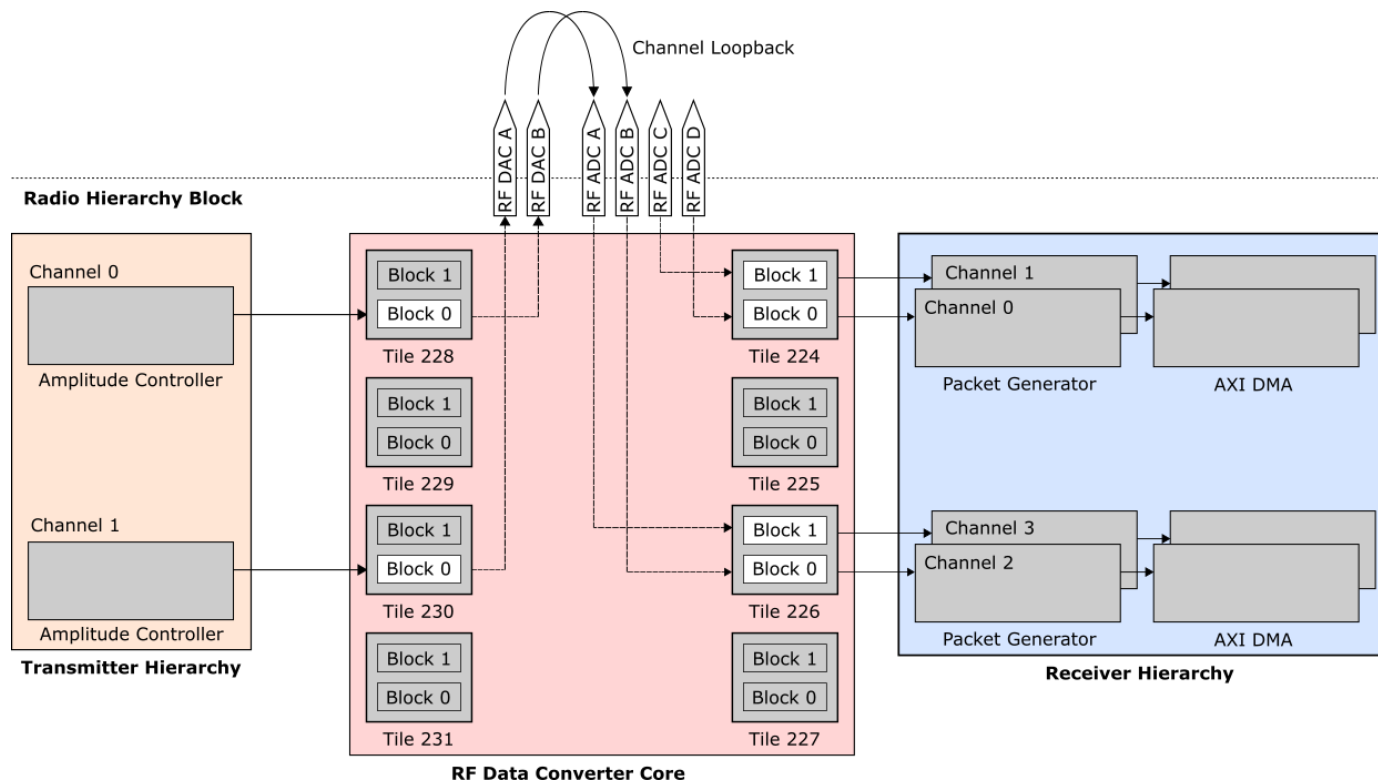
Good News

- Everything we've done on the cheaper Pynq board, including DMA ports right over in my experience.
- Things do seem to work with the Pynq...it isn't that it is unsupported in my experience, it is just there is nothing out there to show you how for specific things.
- There just aren't many walkthroughs about how to actually build something on the RFSoc out there.

There's two “new” devices

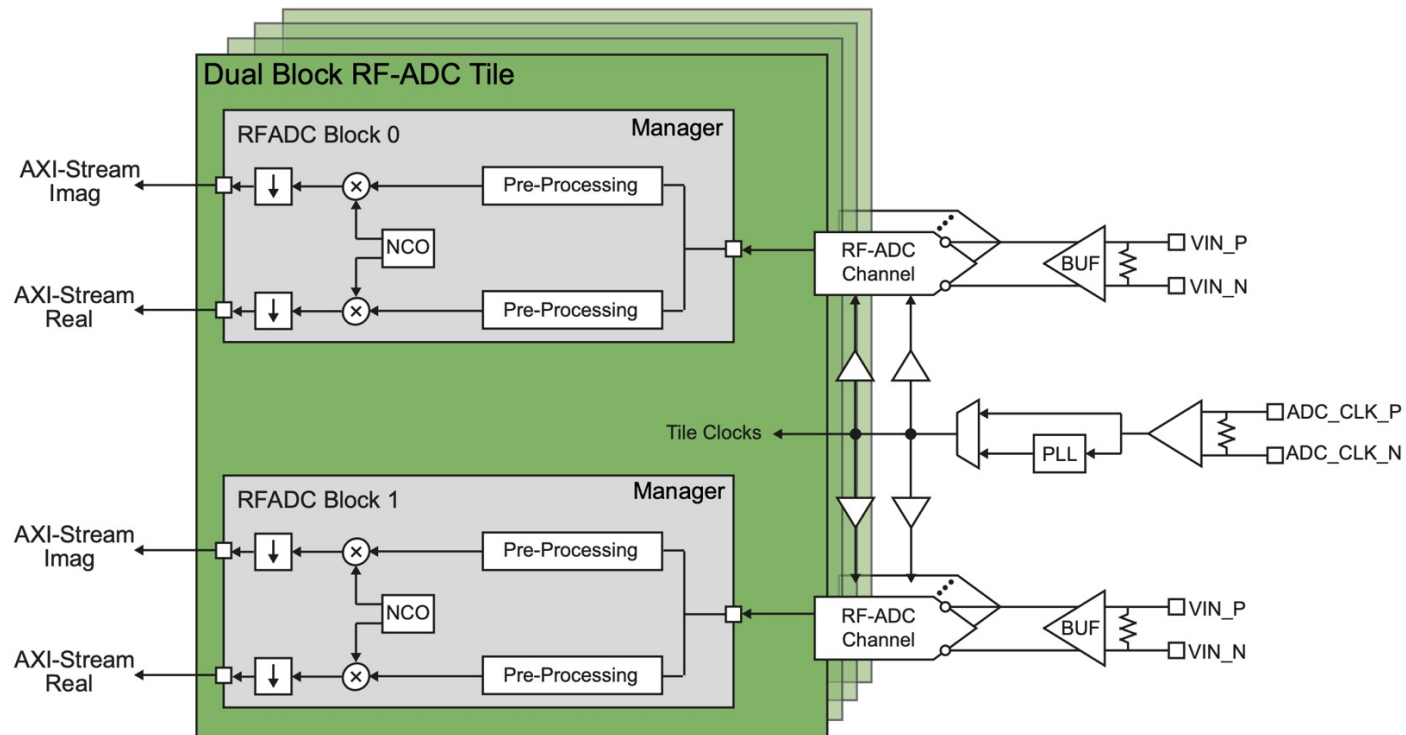
- The ADC and the DAC
- Week 6/Lab 6 will focus on the ADC since I think most of you will be using that (if you do use the RFSoc)

The RFSoc Board has DACs and ADCs in two blocks



ADCs

- You pretty much need to use these in I/Q format to get most functionality



DACs

- Basically work the opposite

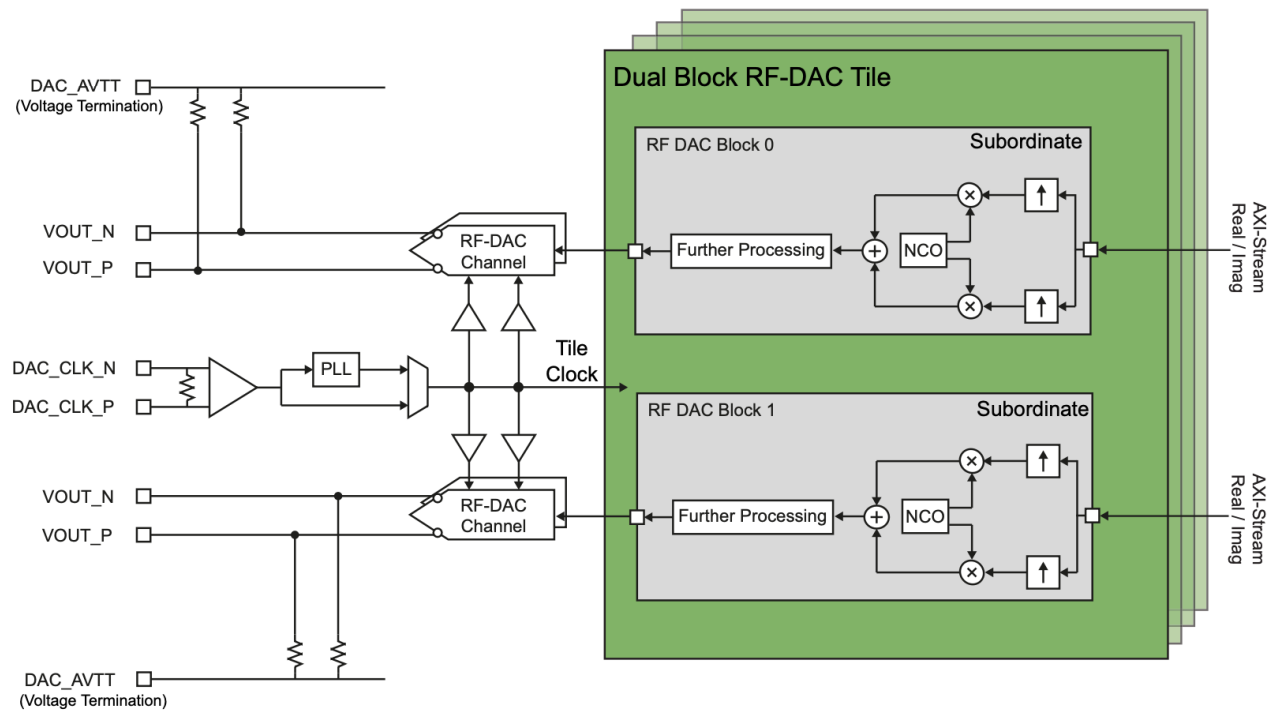
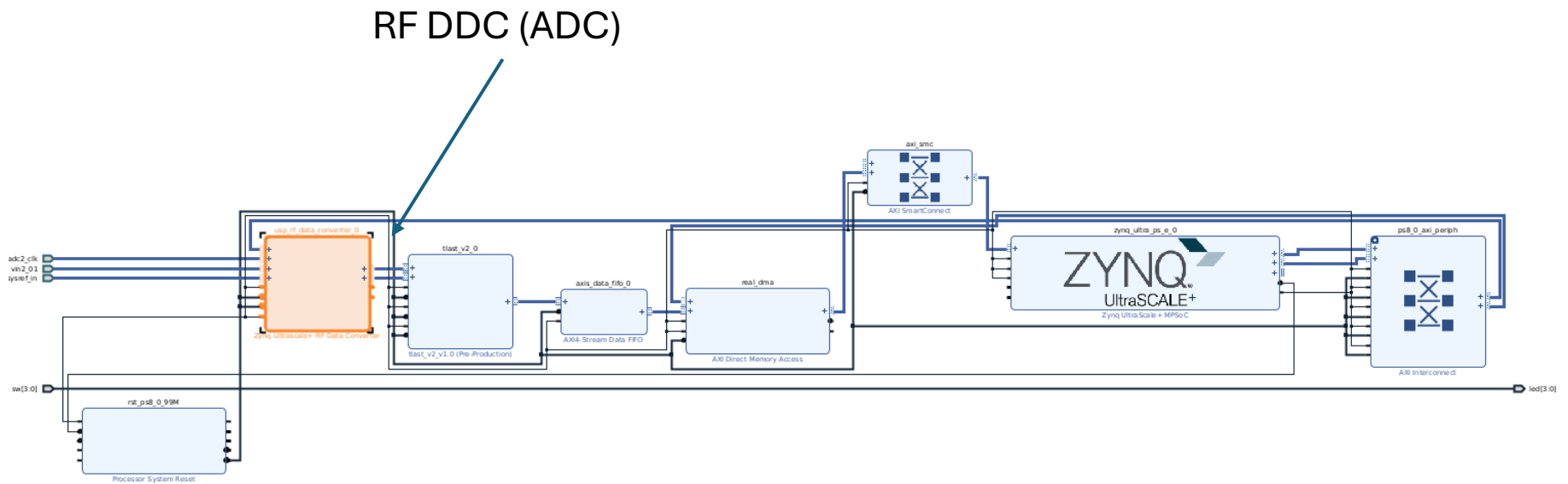


Figure 3.11: RF-DAC hierarchy for the ZU48DR RFSoc device [90].

Week 6

- Build an ADC pipeline and look at some signals in python



Project Ideas for RFSoc

- I wanted to list out some things that we could use the RFSoc for for ideas

Project Idea: QICK

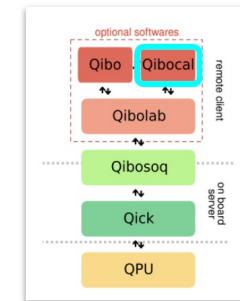
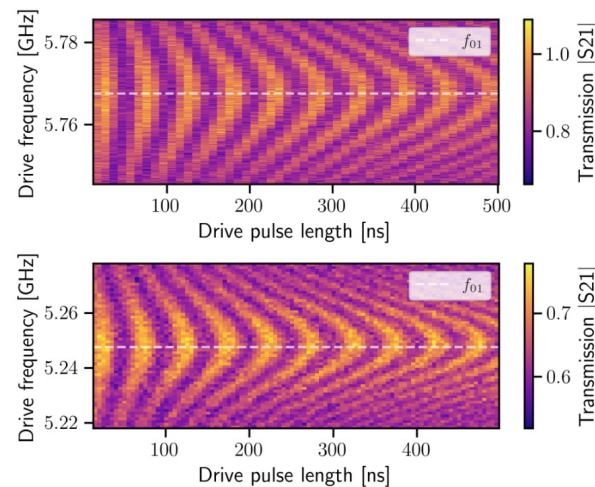
- I think quantum stuff is made up, but the RFSOCs are getting a lot of use in qubit analysis.
- Slides here:
 - https://docs.google.com/presentation/d/1rrgFXOn-ZROhKadeiPFLhmJAO-Ze_ezWnpoj1usnw/edit#slide=id.g30110b82c28_0_31
- I think there might be some interesting projects here involved in measuring these fake phenomena

QICK on a RFSoc

- Look at those Rabi oscillations (!) Very cool

Multi-qubit control with the Qibo/QICK stack

Simultaneous Rabi oscillations in neighboring qubits

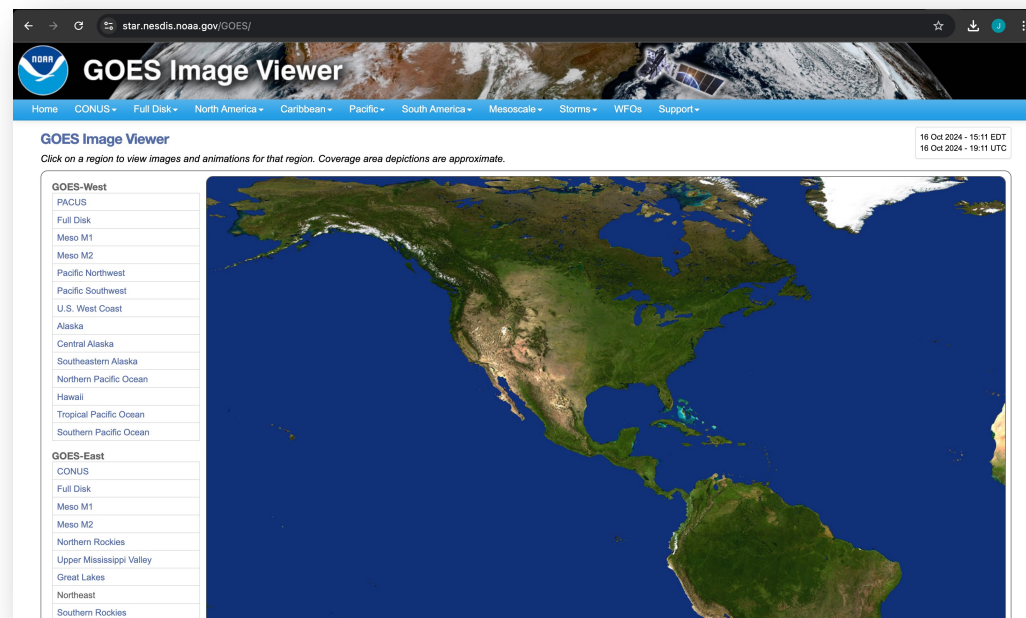


More by Qibo team:

- ❖ Characterization of 2 pairs of CZ interactions between 3 qubits
- ❖ Work-in-progress to use two synchronized ZCU216 QICK boards to control 8 qubits

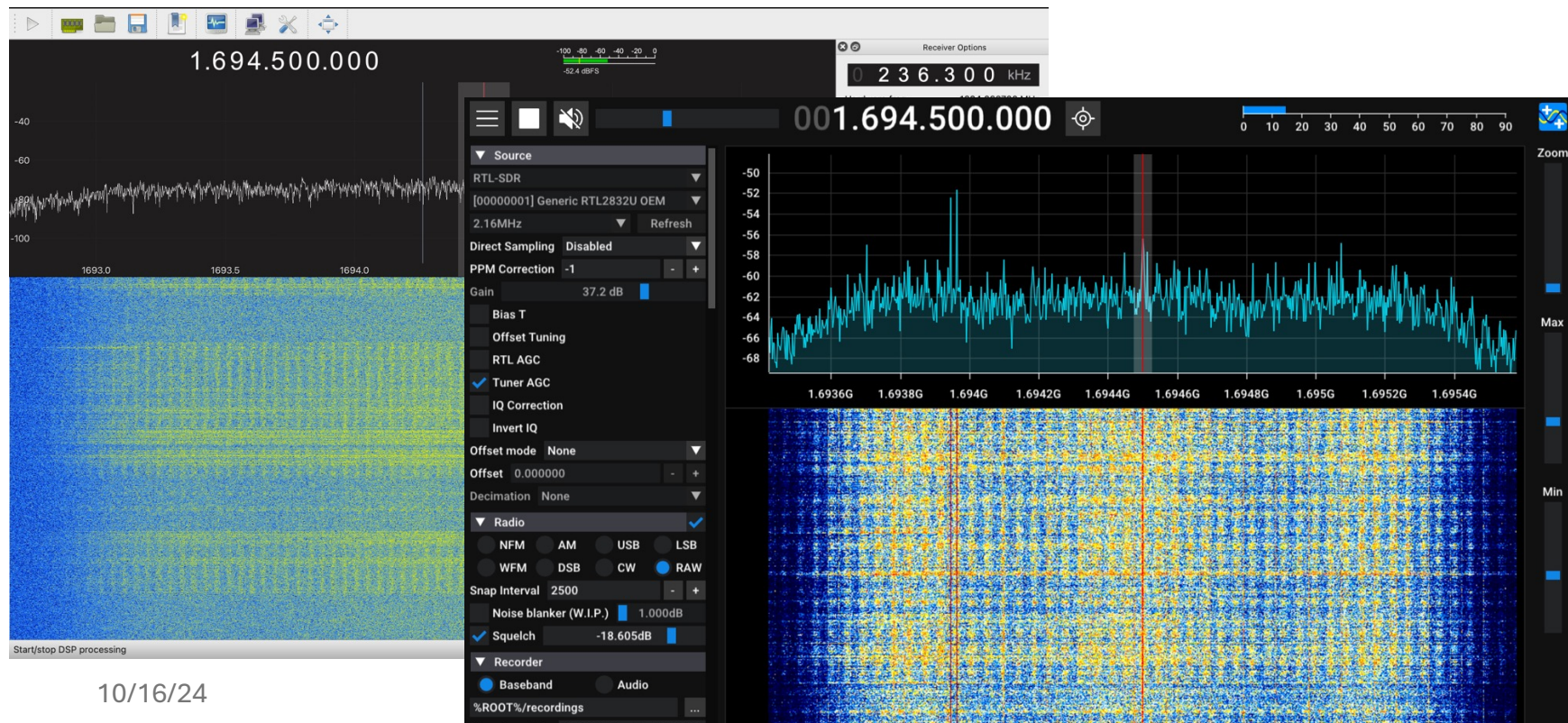
Satellites

- GOES (Geostationary Operational Environmental Satellites) send down really cool images with a complicated protocol
- Signals around 1.7 GHz



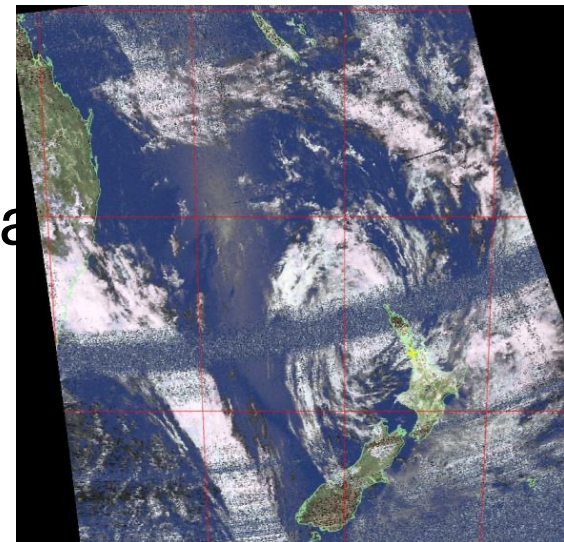
Satellites

- That dish I have on the 6th floor is meant for GOES...pointed it and with a front-end filter and LNA we were able to see some signal



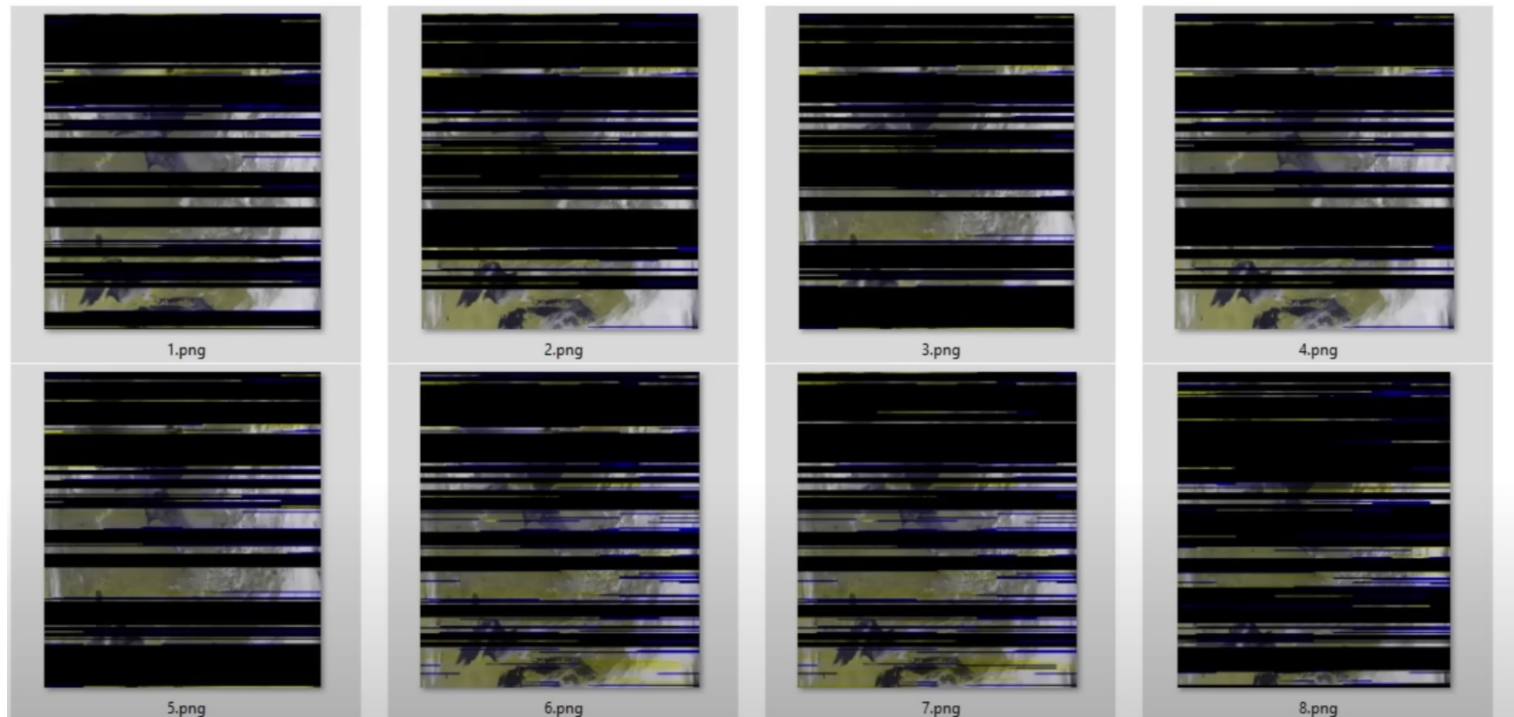
NOAA APT Satellites

- APT= Automatic Picture Transmission Satellites
- Not geostationary so will have to track...but should be possible...
- Send down
- Signals on/around 137 MHz
- Use circularly polarized antennas



Meteor Satellites (Russian)

- Russian weather satellites are also not geostationary but can give good images



International Space Station

- Periodically sends down SST (Slow-Scan Television) as well as other signals
- <https://www.youtube.com/watch?v=HaAprfh9ZtM>

Use some of these...parts

- Antennas
- Low Noise Amplifiers
- Some Front-end filters



Commercial FM radio



On that topic...Budget

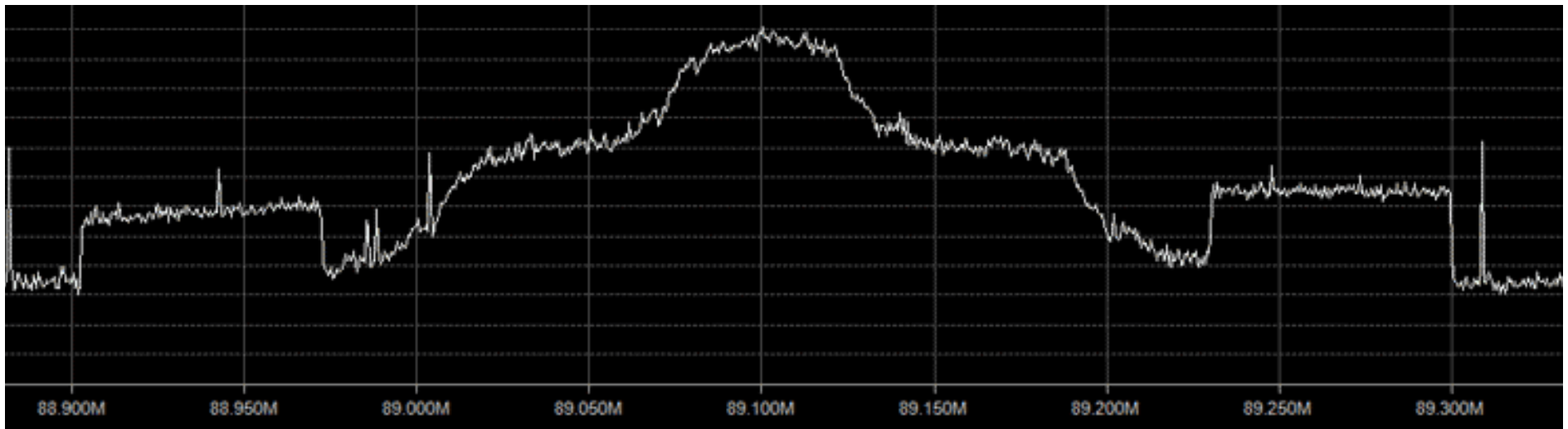
- I have ~3K cash dollars or so to spend if we need to (for full class) so any antennas, amps, filters, we can get.

Traditional FM radio

- Just do regular FM demodulation (which you can do using IQ data). It isn't that easy.
- Make it tunable to listen to all the stations

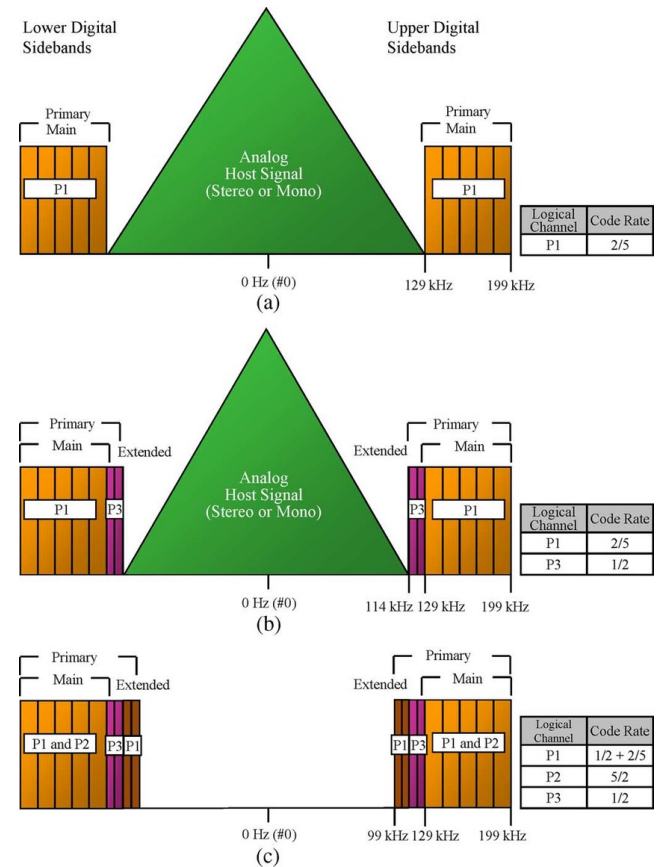
Digital Terrestrial Radio

- <https://www.rtl-sdr.com/decoding-and-listening-to-hd-radio>
- <https://github.com/theori-io/nrsc5-nrsc-5-with-an-rtl-sdr/>



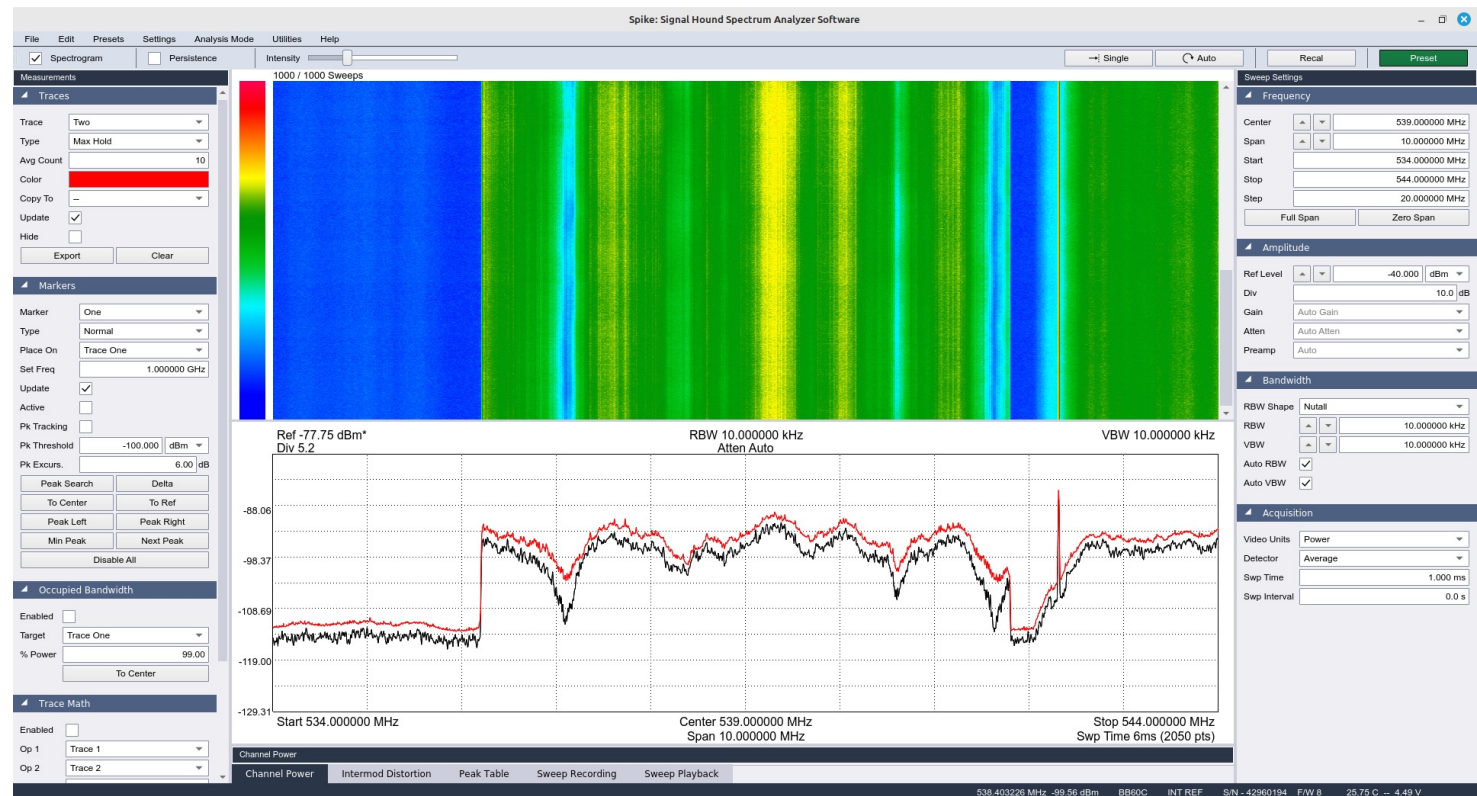
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Digital Television

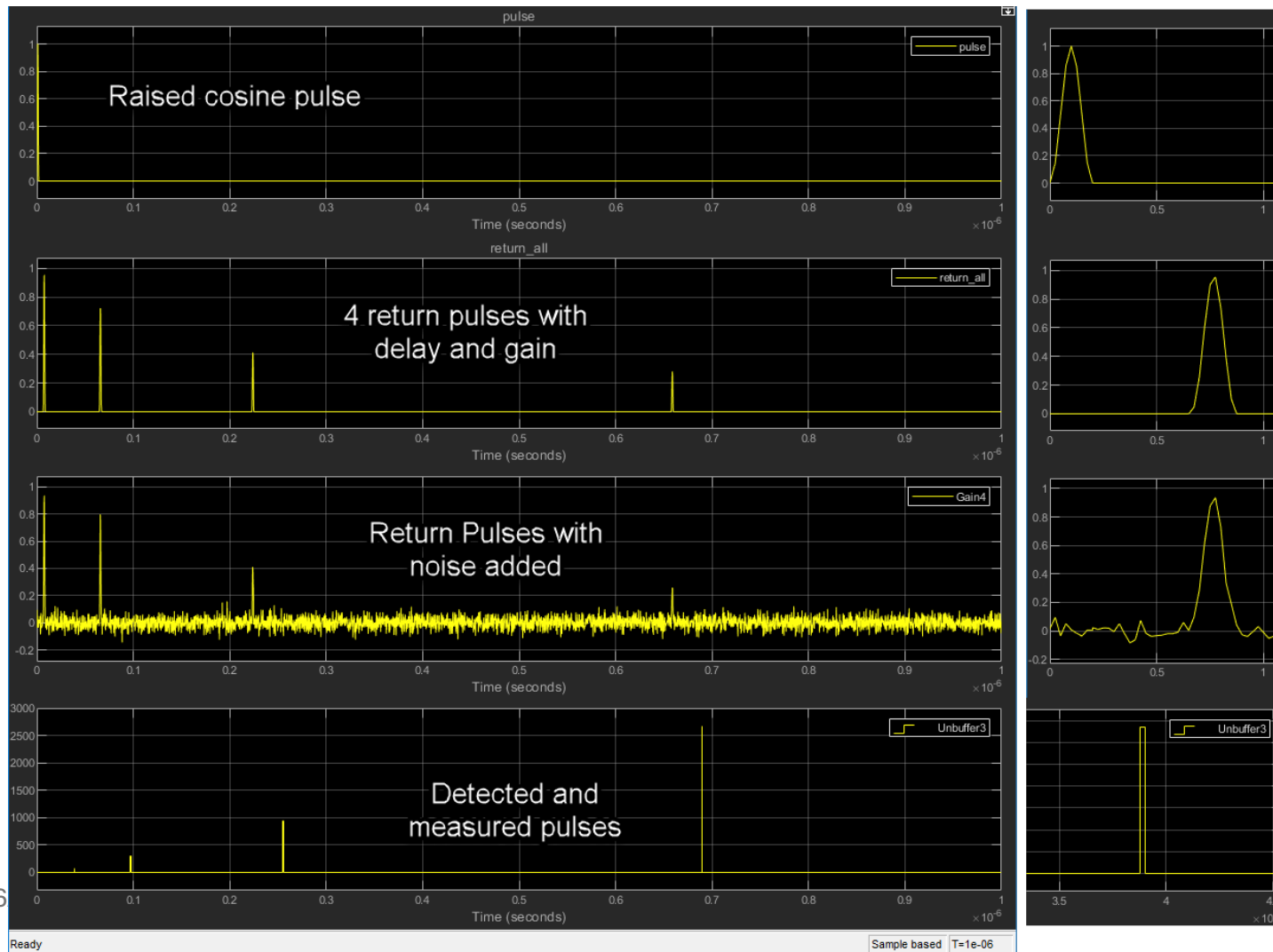
- Modern over-the air TV is digital. USA uses ATSC (Advanced Television Systems Committee)



LIDAR (use DAC)

- Some sort of continuous wave LIDAR:
 - <https://www.bridgerphotonics.com/blog/frequency-modulated-continuous-wave-fmcw-lidar>
- AMD/Xilinx have this project here:
 - <https://www.xilinx.com/developer/articles/lidar-pulse-detection-accelerator-model-based-design-targeting-vitis-and-rfsoc.html>

Pulse-based LIDAR?



So...

- I will post a teaming form and a project idea submission thing tonight.
- I'll talk about final project ideas in any depth you want.
- I'm not doing Wed evening office hours tonight since I need to finish the final 6.205 lab. I'll do a bit tomorrow and then Friday afternoon like usual