V2X Motorcycle HUD Weekly Updates

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Jacob Nguyen, Ryan Hiser, Jorge Pacheco
UCSD MAS WES
14 May 2022

V2X Motorcycle HUD

HUD DISPLAY
- Directions
- Fuel Warning Indicator
- Speed
- Range/Speed of Rider 1

HUD DISPLAY
- Directions
- Fuel Warning Indicator
- Speed
- Range/Speed of Rider 2

Communications with Range Estimation

Data: Name, Lat/Long, Speed, Nav, Fuel

Rider 2

Rider 1

Motivation and Goal

- Our goal intends to improve the motorcycle group riding experience, by safely providing more information to the riders.

- Final Demonstration:
  - We intend to implement a 2-Node system capable of transmitting various information (range, fuel level, ...) and audio. The audio could eventually be used as a intercom or to stream music from one rider to other (a DJ).
  - The system will be able to display that information via a heads-up display.

Overall Progress

- Waveform Description defined (data defined, QPSK modulated)
- Simulink Model of Waveform (full TX/RX, all code gen except demod)
- RX Demod fully designed in HLS/IP Cores (MATLAB -> HLS workflow)
- OLED and wireless link using arduino (WiFi msg integrated with zed)
- FMComms4 + Zedboard integration with PYNQ

Current Progress

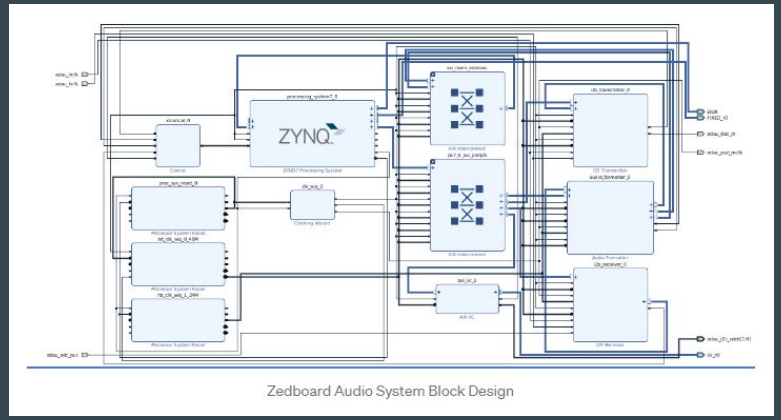
Previous Sprint

- Integration
  - ~~Integrate audio files with TX modulator SW~~
  - ~~Loopback test with TX/RX~~
- RX
  - ~~Hard decision and store to FIFO~~
  - ~~Finish verification via Verilog testbench~~
  - ~~Package RX IP module and integrate to design~~
  - ~~Integration with PL and RX Baseband software~~
- HUD
  - ~~Update kernel on Pynq for USB~~ (kernel module created and alternative approach)
  - Verification and Validation (V&V)

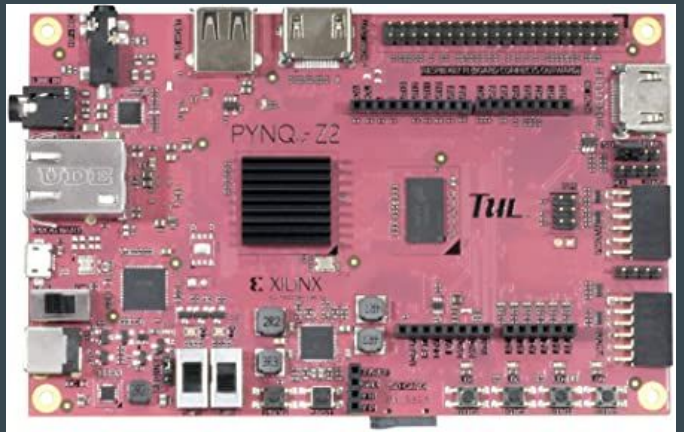
The fun continues...

Integration (audio)

- Audio file (in binary format) being read by the TX baseband code
  - 60 seconds of audio sample
  - 6000 frames of 0.01s audio samples
- Investigation on how to play audio on zedboard
  - https://yuhei1-horibe.medium.com/zedboard-audio-hardware-design-b19c3a1bf453
  - Requires zedboard IP core updates in vivado and kernel updates
- Alternatively play audio on the Pynq Z2 board (stream audio from zedboard to Z2)
  - Z2 has some audio support and libraries built in



Zedboard Audio System Block Design



Integration (loopback SW setup)

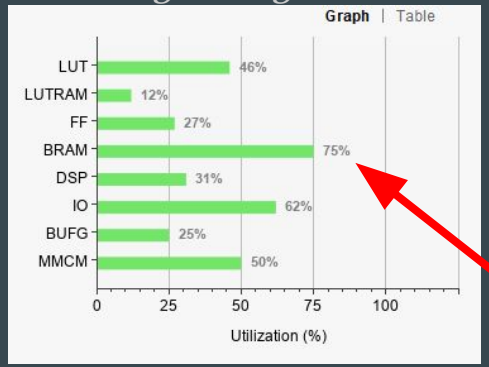
- Created UIO Kernel Module and modified device tree.
- Added TX/RX threads that interface with AD9361 and UIO
- TX thread periodically sends data to AD9361:
  - HUD data read from config.txt
  - Audio data read from sample_audio.bin
- RX thread periodically checks for data in UIO
  - UIO used instead of DMA to speed up development.

v2x_sdr_xcvr.c

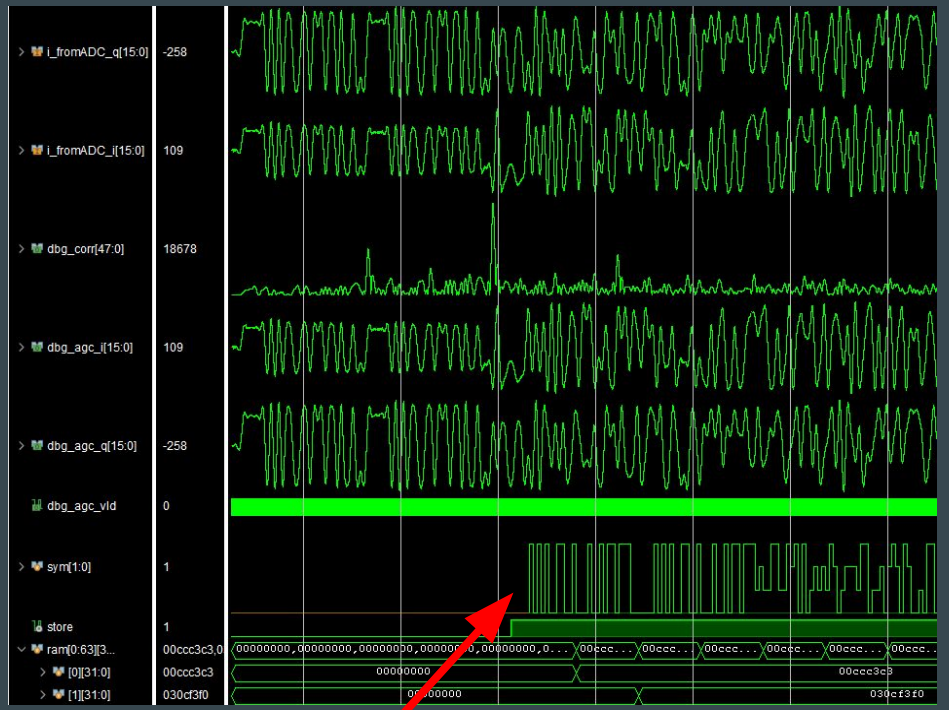
```
504  static void tx_thread_fn(void* args)
505  {
506      // Loop init
507      printf("TX thread started\n");
508      uint32_t loop_num = 0;
509
510      // Only run if shorts are used
511      int datasize = ((sdr_data*) args)->ini->datasize;
512      if (datasize == 2)
513      {
514          int16_t tx_mod_out[TX_MOD_OUT_SYMS * 2];
515          ssize_t nbytes_tx;
516          char *p_start;
517
518          // Run loop
519          while (!stop)
520          {
521              // WRITE: Get pointers to TX buf and write IQ to TX buf port 0
522              p_start = iio_buffer_first(txbuf, tx0_i);
523              load_frame_txmod(tx_mod_out);
524              memmove(p_start, tx_mod_out, TX_MOD_OUT_SYMS * 2);
525
526              // Schecule TX Buffer
527              nbytes_tx = iio_buffer_push(txbuf);
```

RX

- Hard decision was implemented in Verilog.
- The symbols are then converted to bits and stored in a RAM.
- The RAM module was implemented in Vivado HLS with an AXI-lite interface for the ARM (PS) to read.
- All of this was verified using a Verilog Simulation (right image):



Bram usage mostly ILA.

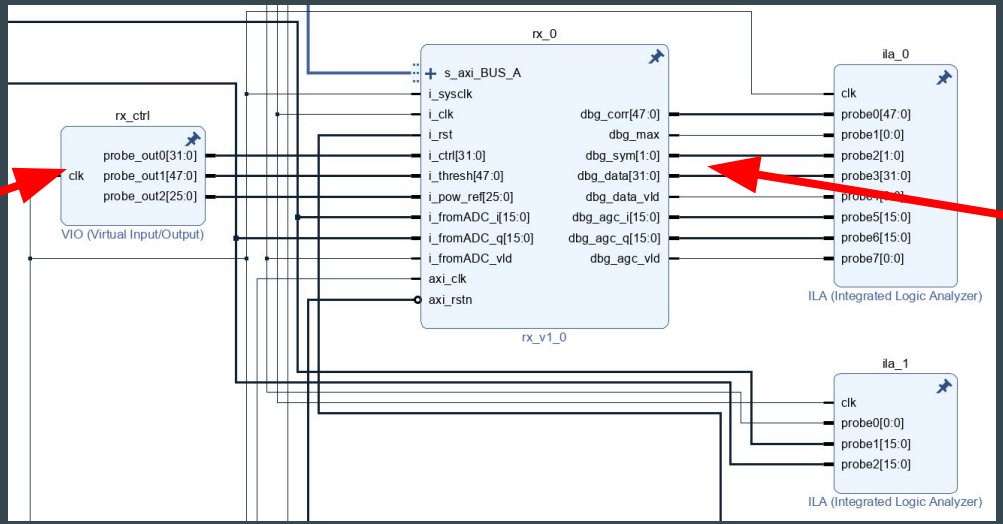


Received data matched sent data!

RX

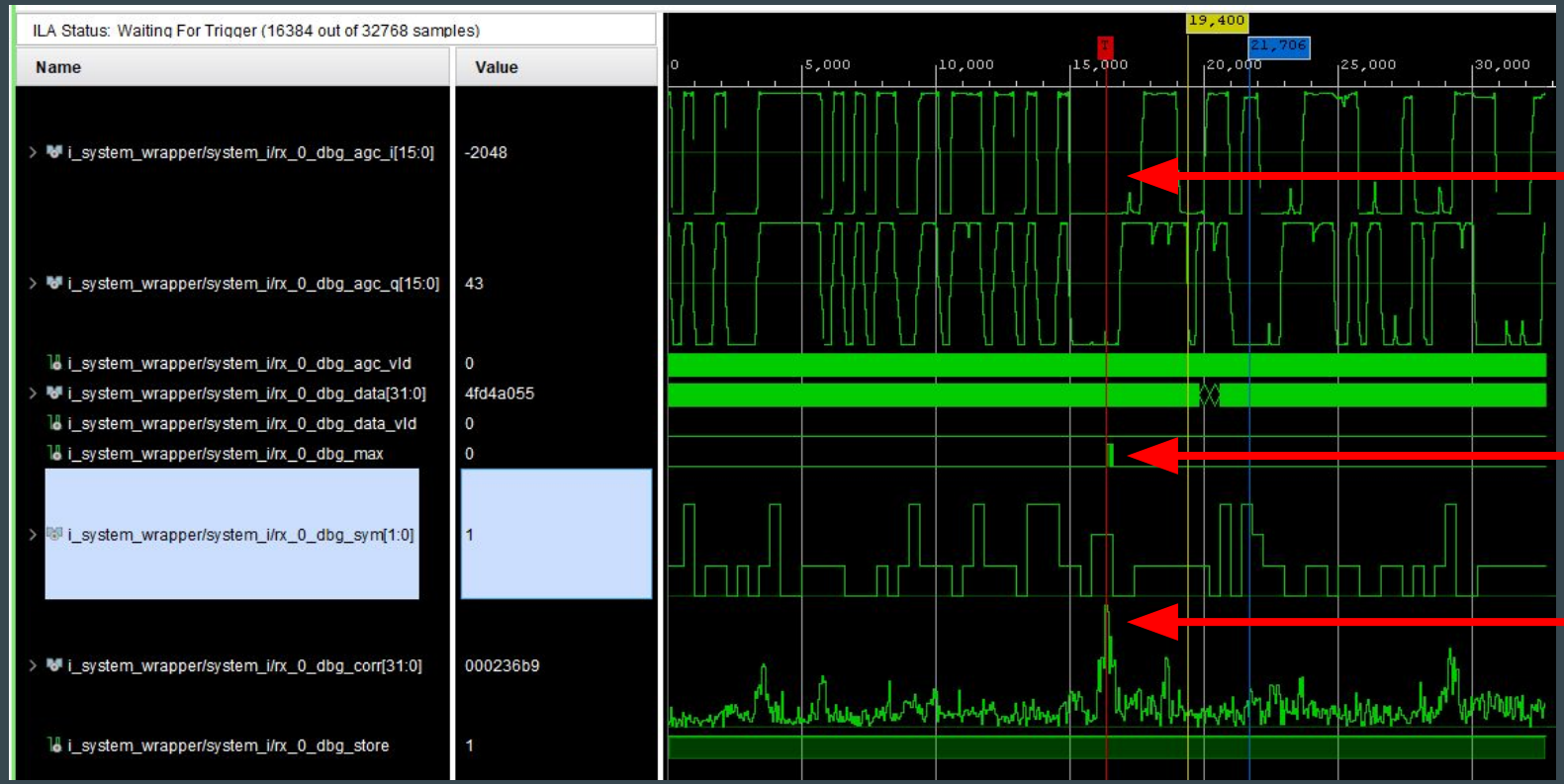
- Packaged RX IP module and integrated to Analog Devices HDL Project.
  - Currently using a Virtual Input/Output (VIO) to control.
  - Internal Logic Analyzer (ILA) was used to verify DAC input data, AGC, and correlation..

Will replace with a custom Axi-lite Interface



Our custom Demodulator

TX to RX Loopback (Internal Logic Analyzer Output)



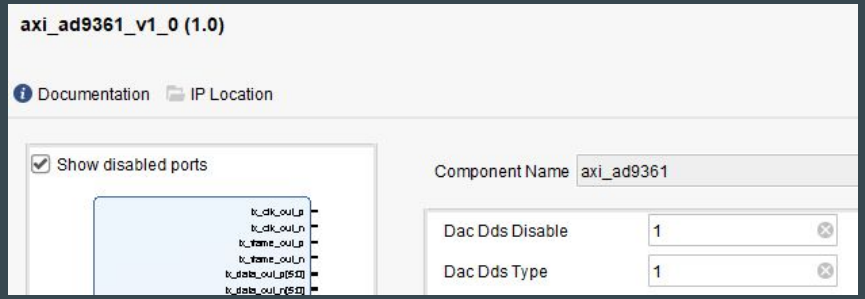
Output of AGC

Peak detection

Received Preamble Detected

TX to RX Loopback V&V (On-going)

- We had to disable the DDS of the axi_ad9361. When you stop filling the DMA it defaults to a DDS tone.

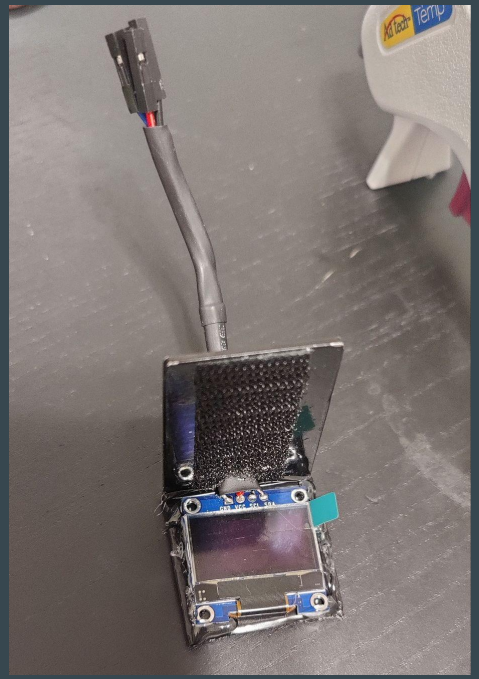


- More debugging required:
  - AD9361 fast-attack AGC seemed to work well for our system.
  - Bad SMA cable or attenuator (stops working if cable gets bumped).
  - TX gain adjustment error needs to be solved to use antennas.

```
* Hardware gain to be set: 15.000000 dB
Failed to set in_voltage0_hardwaregain: -95
--- END OF FMCOMMS4 RX CONFIGURATION ---
```

HUD - Progress since last time

- Created “L” bracket out of metal for robust mounting
- Attached OLED to helmet’s sun visor using velcro
- Ran connections through cable sleeve
- Measured clearance so that helmet’s visor still clears



HUD - Progress since last time (Cont.)

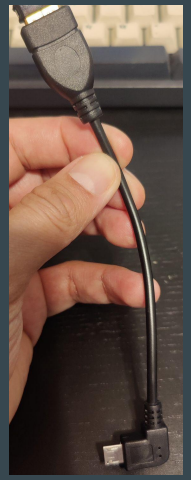
- Mounted ESP8266 WiFi module to helmet
- Ran longer jumper cables through cable sleeve
- Attached OLED to WiFI module

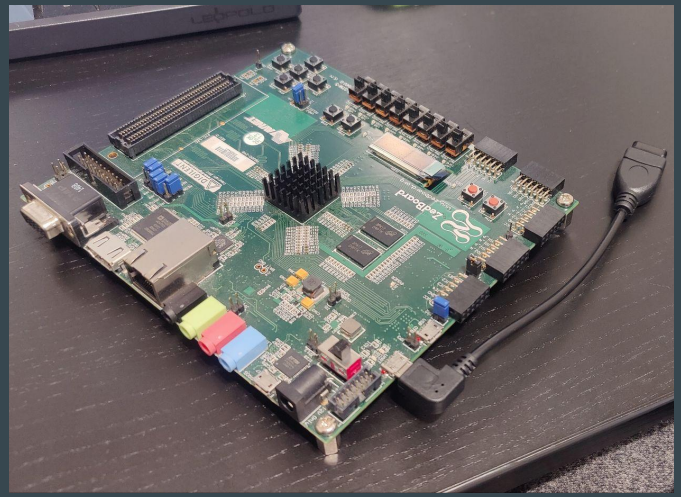
HUD Cont.

- Final Setup

RX Baseband and HUD - Ran into problems!

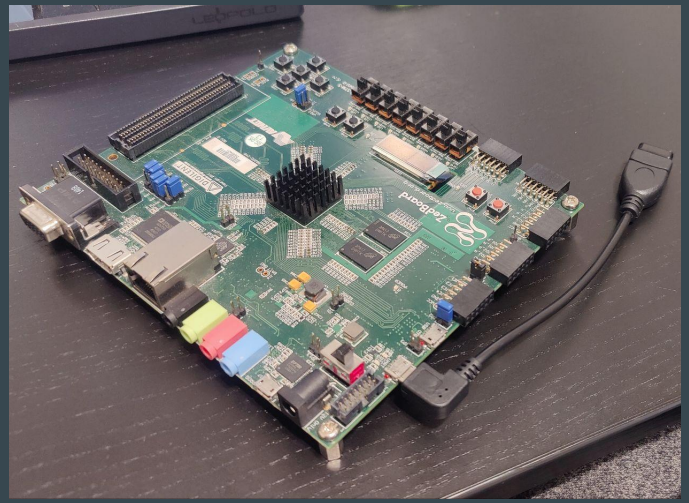
- Sourced USB WiFi adapter for Zedboard
- Could not get Kernel modules to recognize USB WiFi controller....





RX Baseband and HUD - Ran into problems!

Desired Setup:

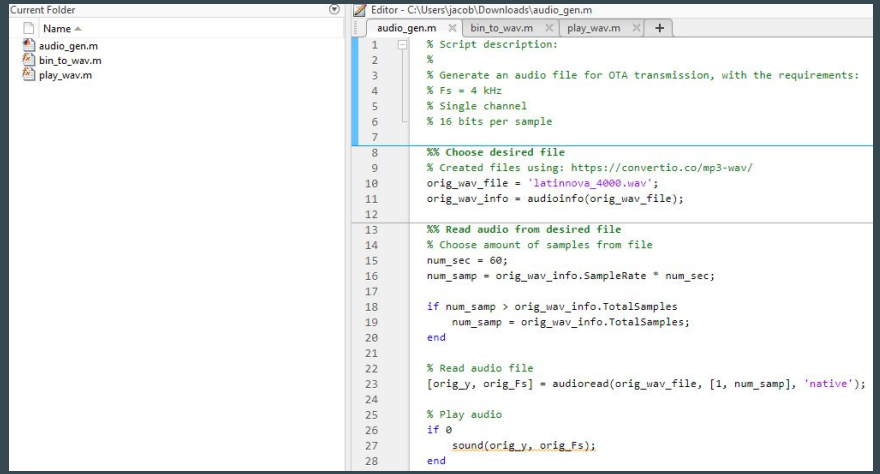


Demo

- Data generated from reading Config.txt
  - Loaded on zedboards for easy data configuration
  - On the fly updates to data bits transmitted
- Audio bits generated from 60 second audio binary file
  - Audio binary file generated from MATLAB reading 4 kHz .wav file
  - Final demo will save received audio data into binary file, and will be converted to .wav format in MATLAB
- Confirmed that Zedboard compiles with HUD code (libcurl/libev libraries)

Config.txt

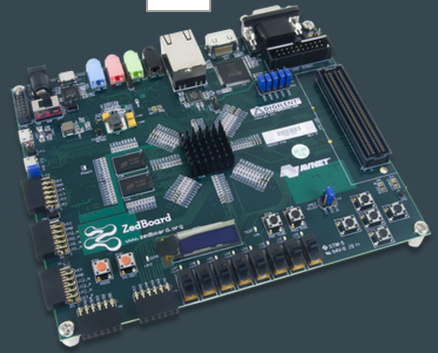
```
1  V2X!
2  32.880100
3  -117.234000
4  60
5  3
6  5.3
```



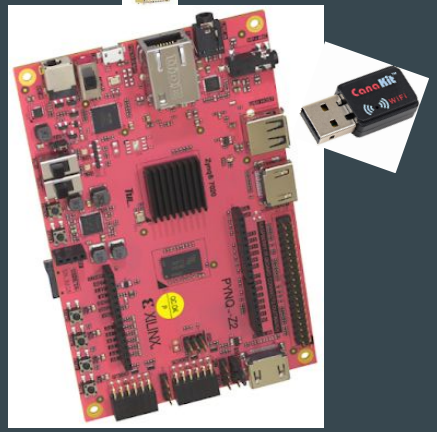
Engineering trickery!

Current Setup (while we sort out kernel drivers...):

2. Frames get sent over Ethernet to Pynq-Z2 using UDP packets



1. Zedboard produces data



3. Pynq-Z2 acts as a forward link to grab audio and data packets and send over WiFi to HUD

4. HUD packets are displayed in real time!

Future Plans

Gantt (timeline)

Next Sprint

- Debug/V&V RX post correlator.
- V&V with antennas.
- Merge all code TX and RX onto one SD Card
  - UIO Kernel Module
  - WIFI/Ethernet code
  - TX
  - RX
- Two-way link
- TDMA protocol investigation and planning
- (Aspirational Tasks) Improve WIFI and Audio approach