Physical Layer Prototyping using WARPLab

Patrick Murphy & Melissa Duarte
Rice University

WARP Workshop
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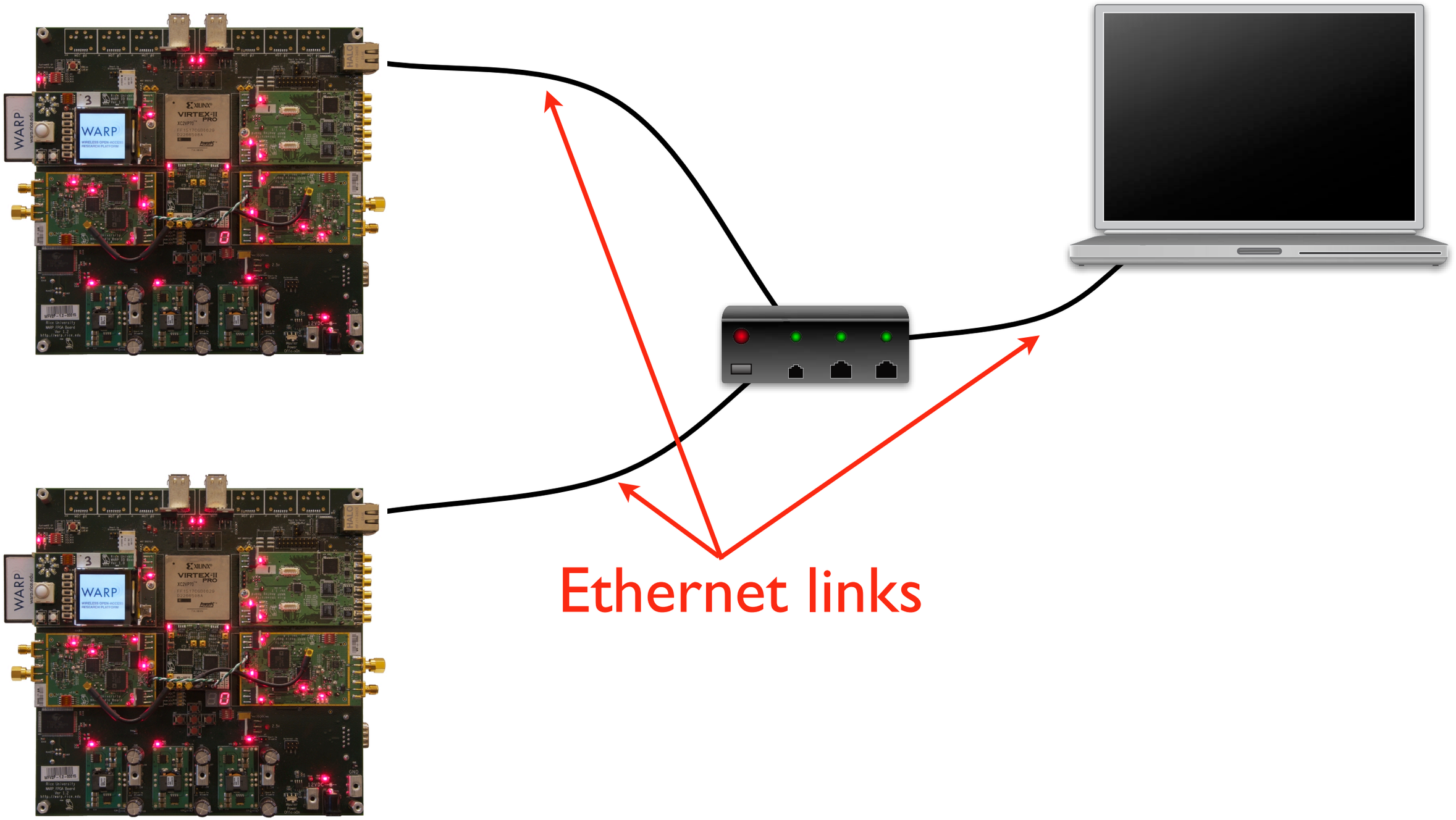
warp.rice.edu

WARPLab Overview

- MATLAB ⟷ WARP Link
  - Interact with WARP nodes directly from the MATLAB workspace
- Very rapid prototyping of PHY algorithms
- Real-time Tx-Rx and offline processing

WARPLab Overview



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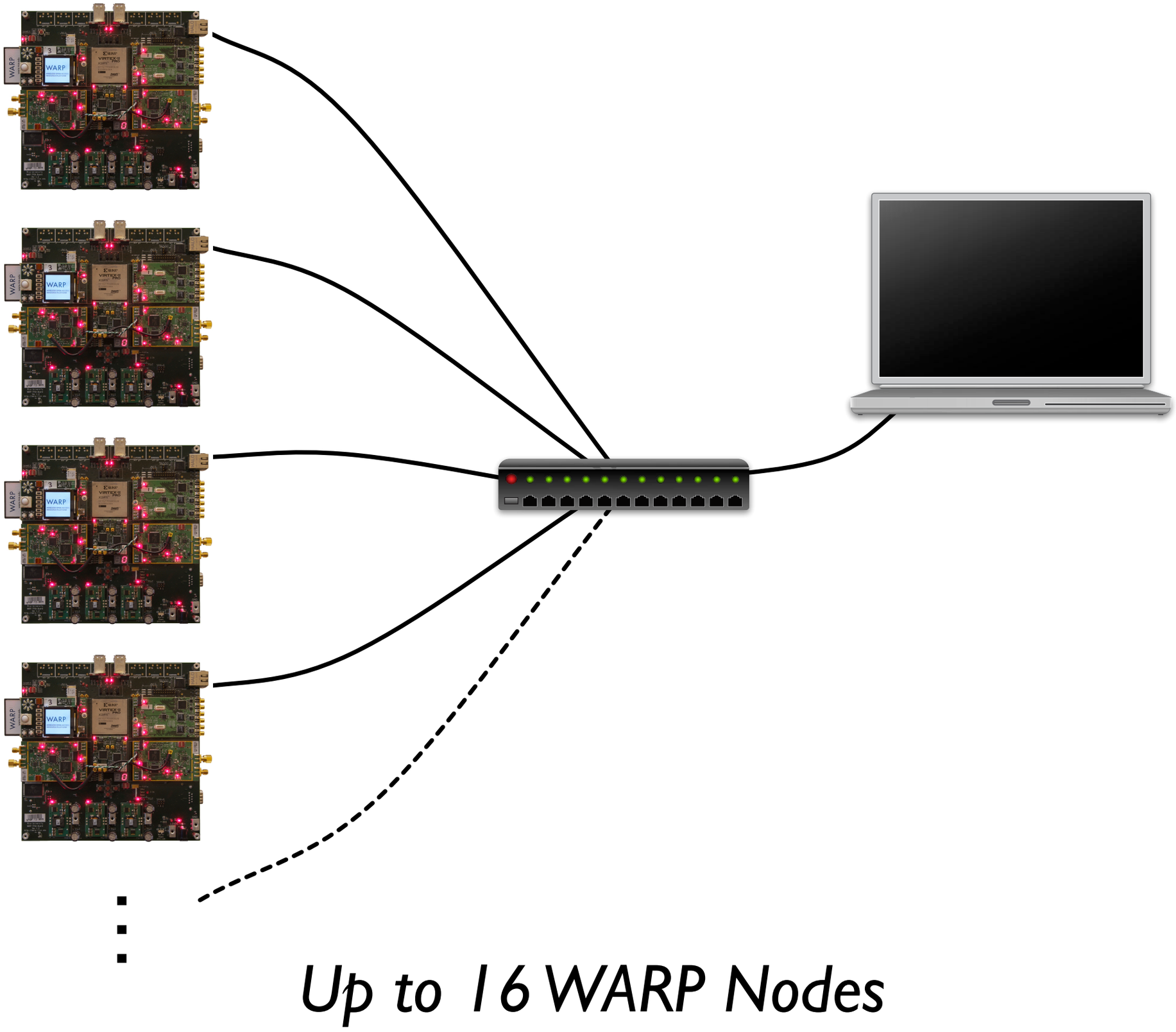
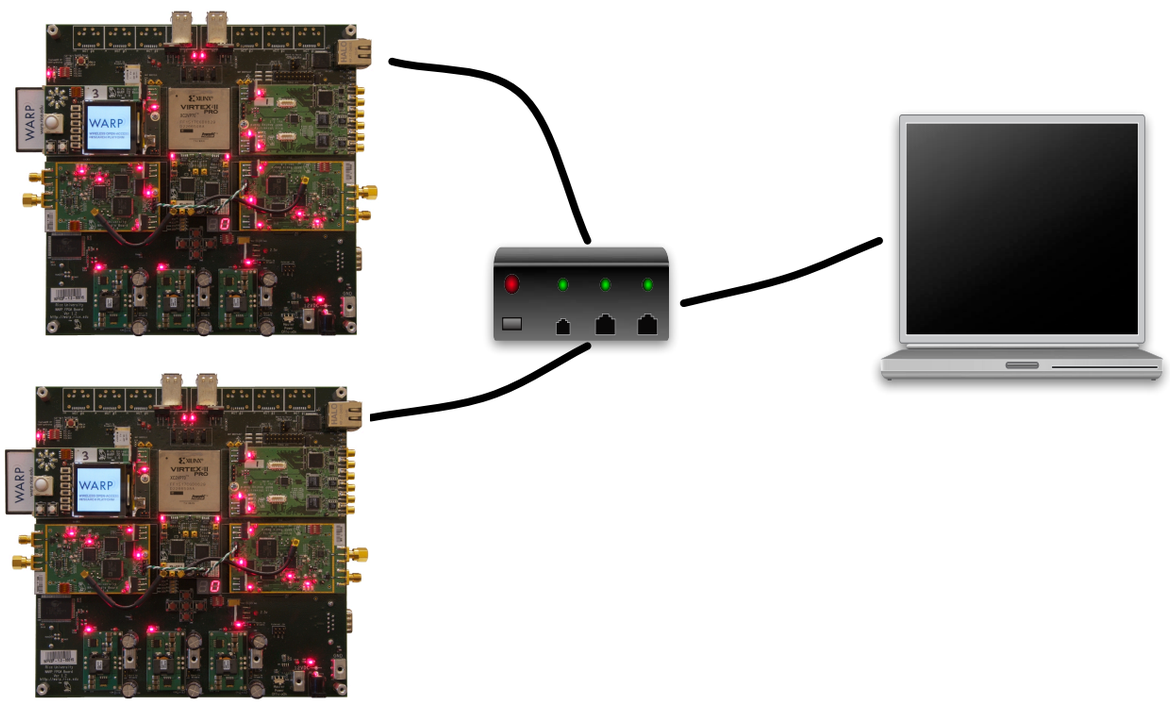


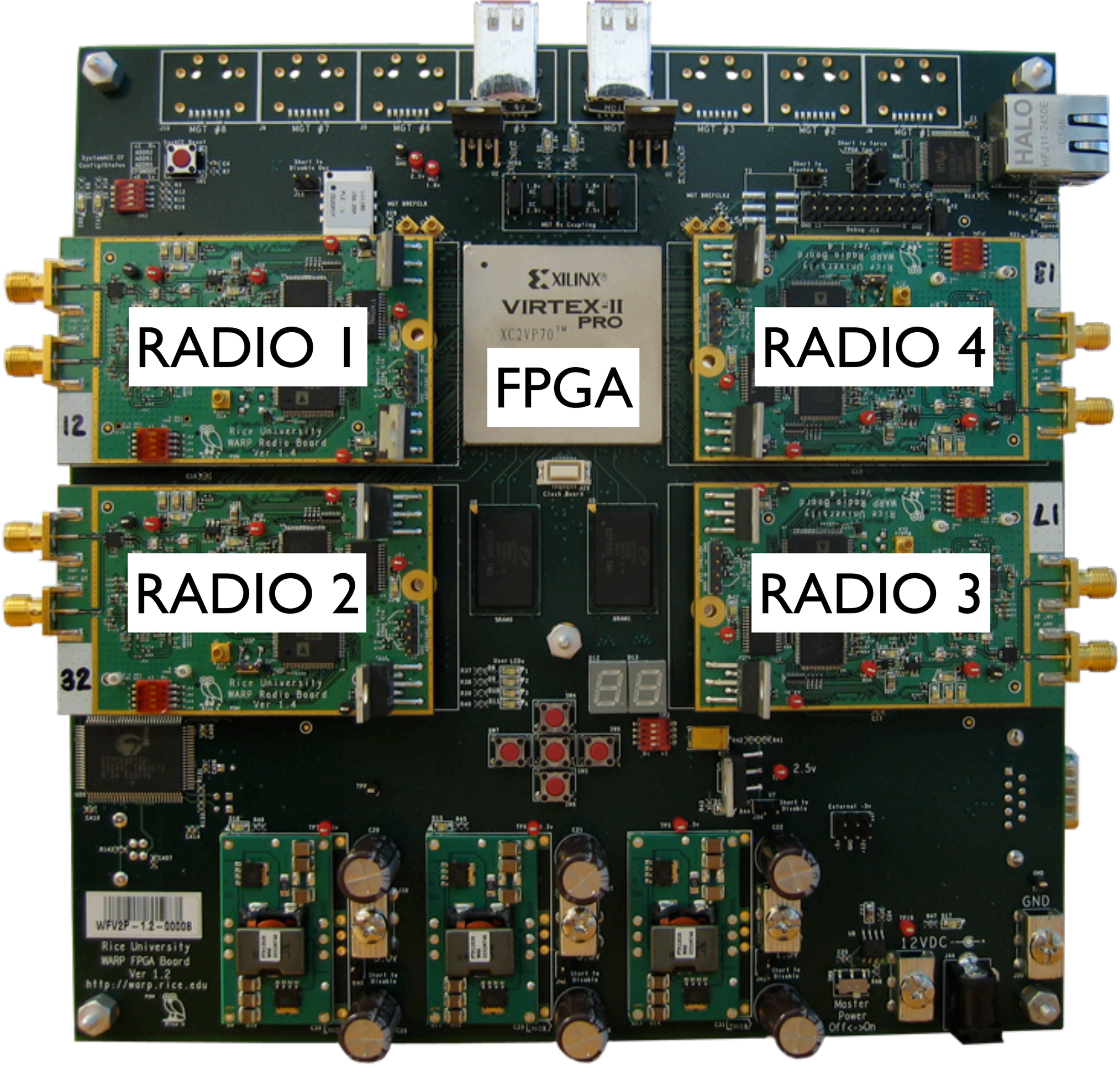
Up to 16 WARP Nodes

WARPLab Overview



- One PC controls many WARP nodes
- MATLAB for signal processing
- Non-real-time processing

- WARP for wireless interfaces
- Real-time channel use


RADIO 1
FPGA
RADIO 4
RADIO 2
RADIO 3
XILINX
VIRTEX-II PRO
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Rice University
WARP Radio Board
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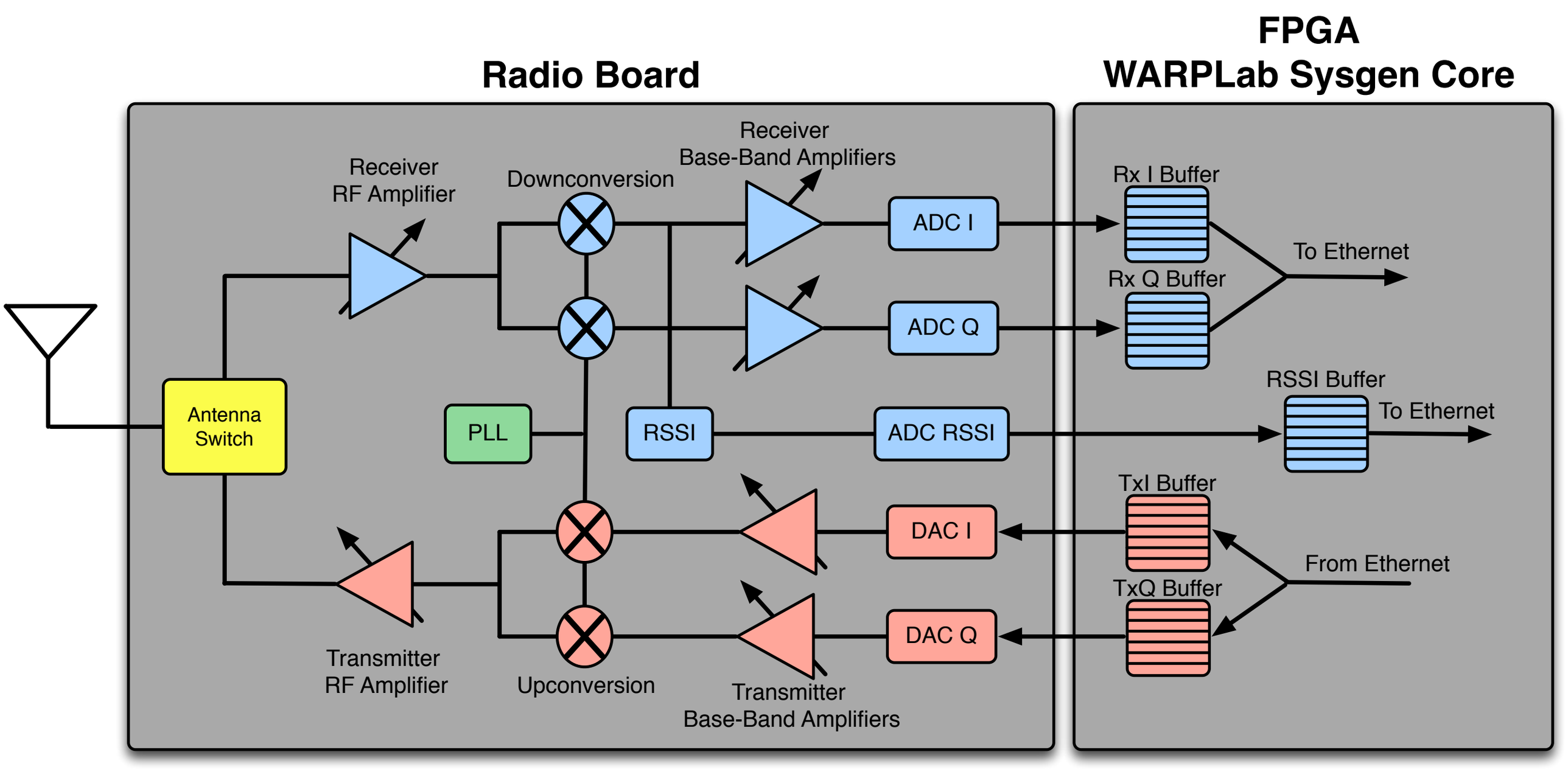
http://warp.rice.edu
WFV2P-1.2-00008
2.5v
12VDC
GND
Master Power Off<->On

WARPLab Architecture



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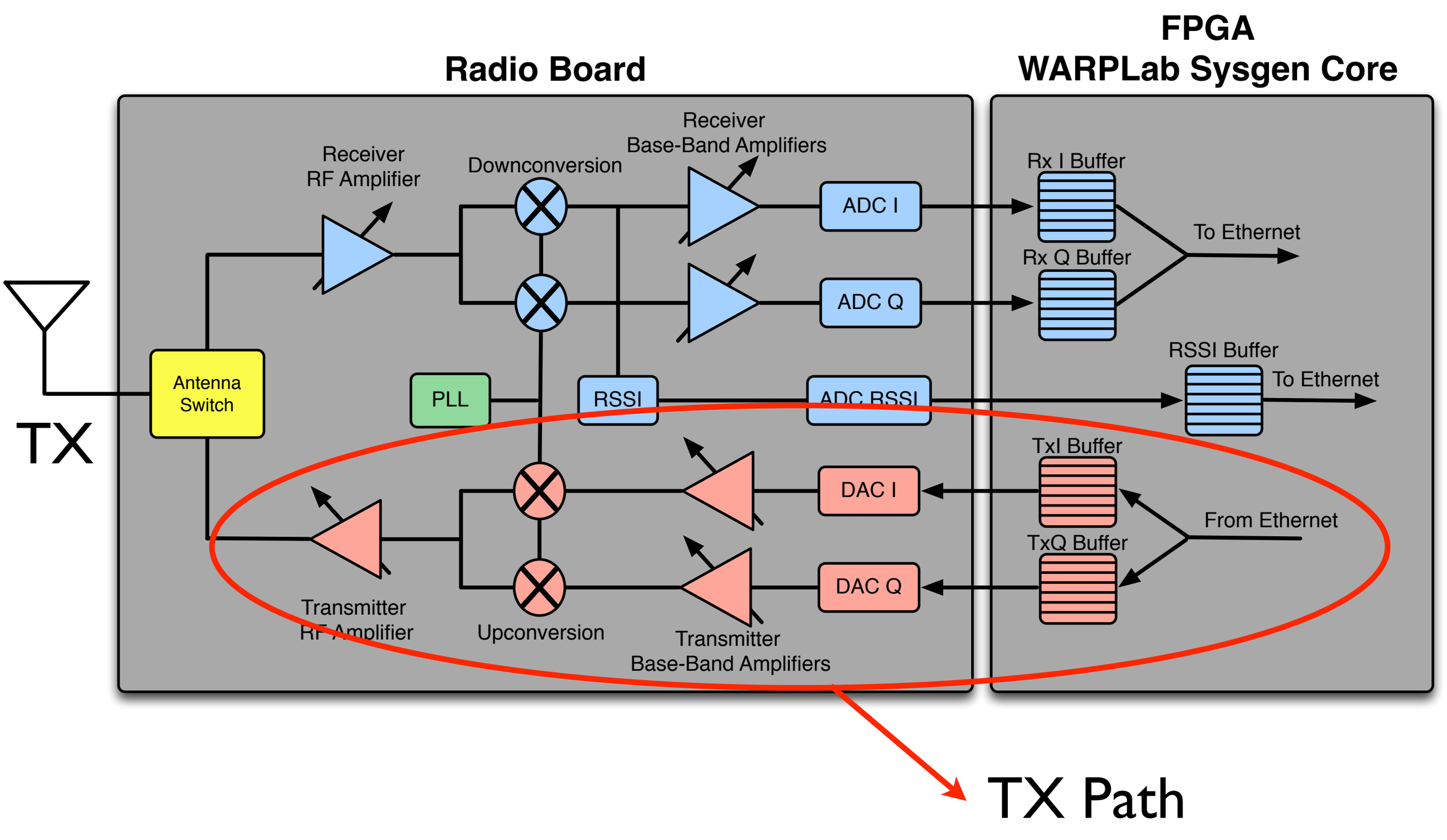

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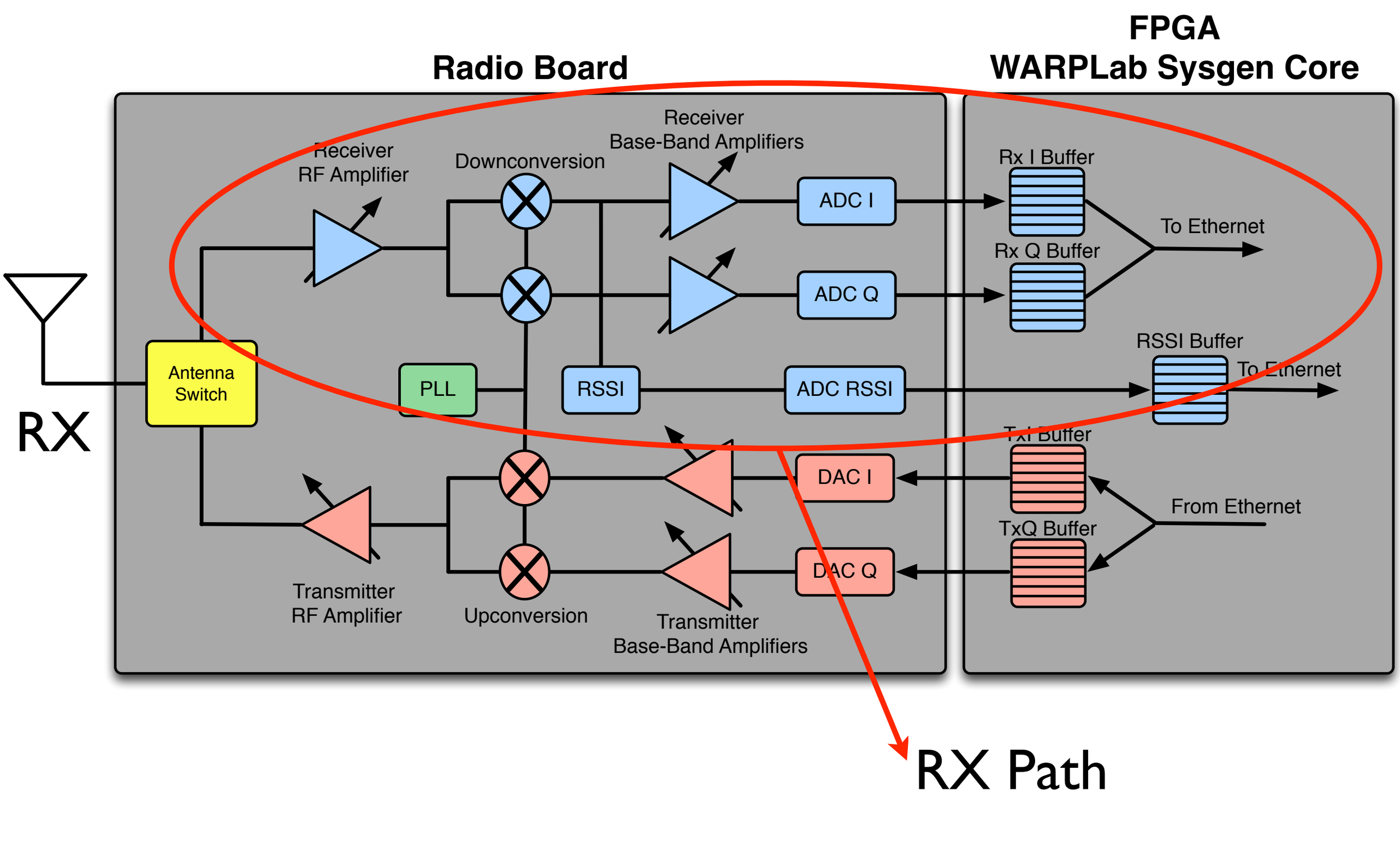

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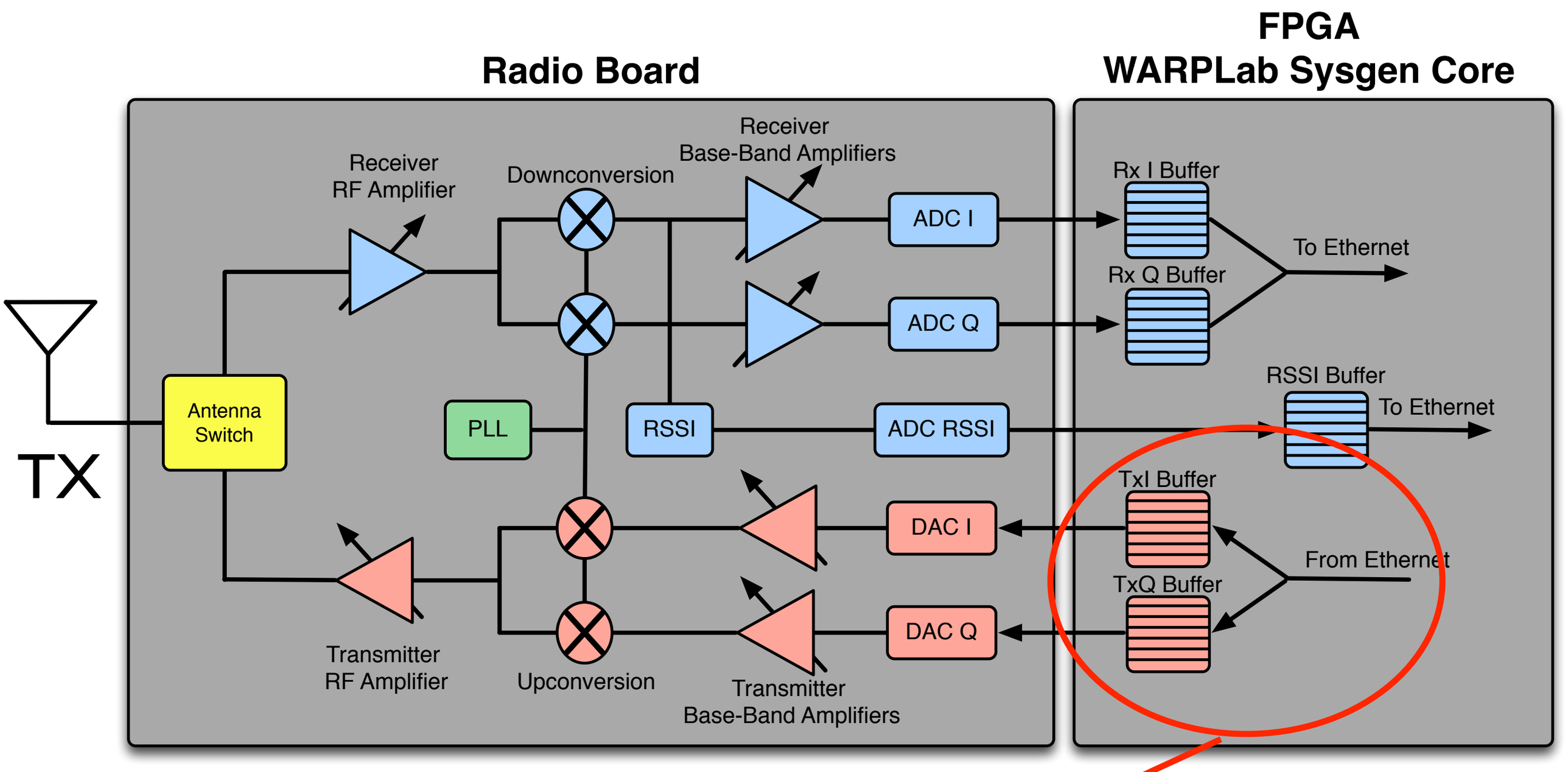
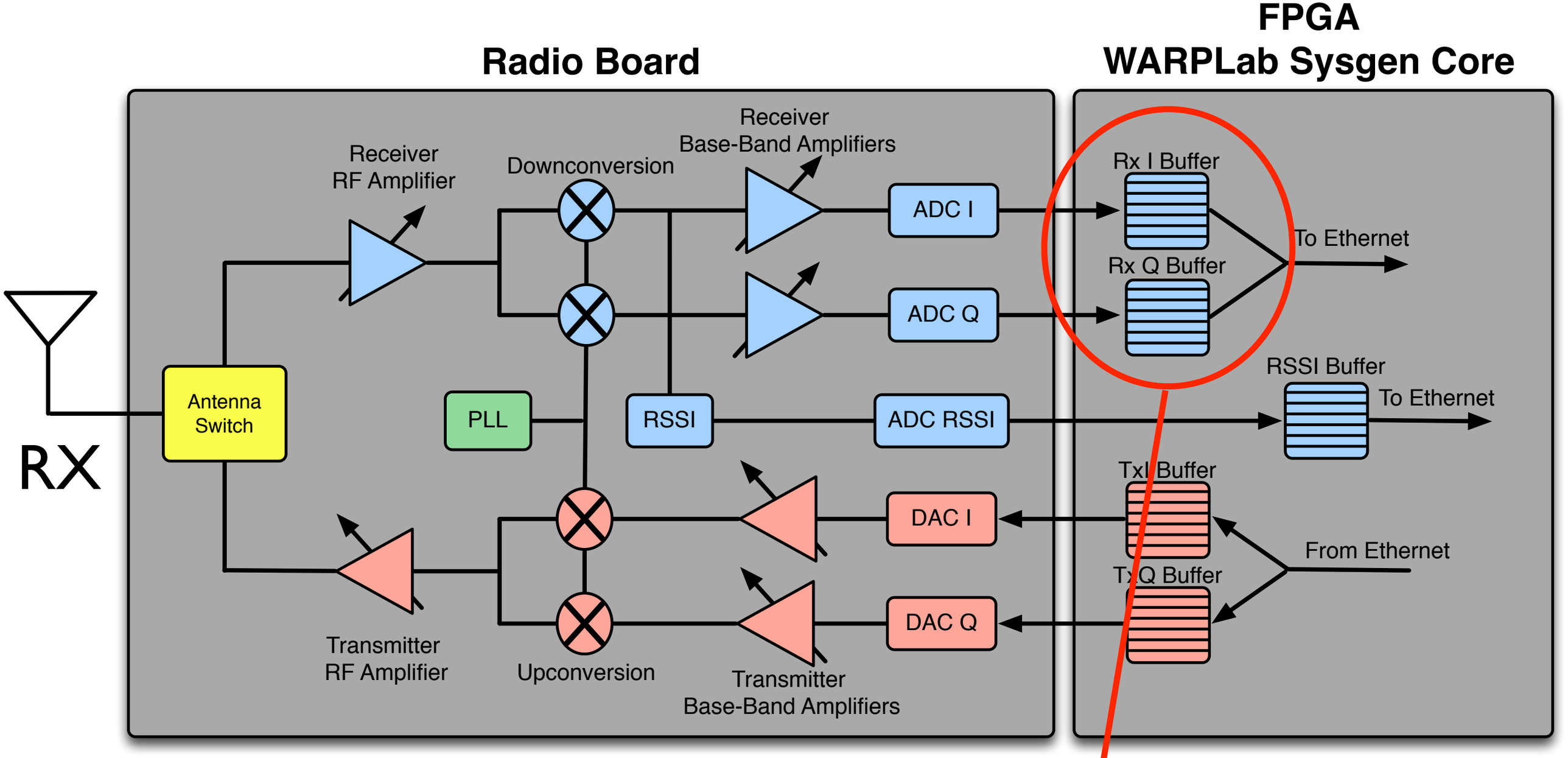


TX I/Q buffers
16384 (2^{14}) samples each

WARPLab Architecture



RX I/Q buffers

16384 (2^{14}) samples each

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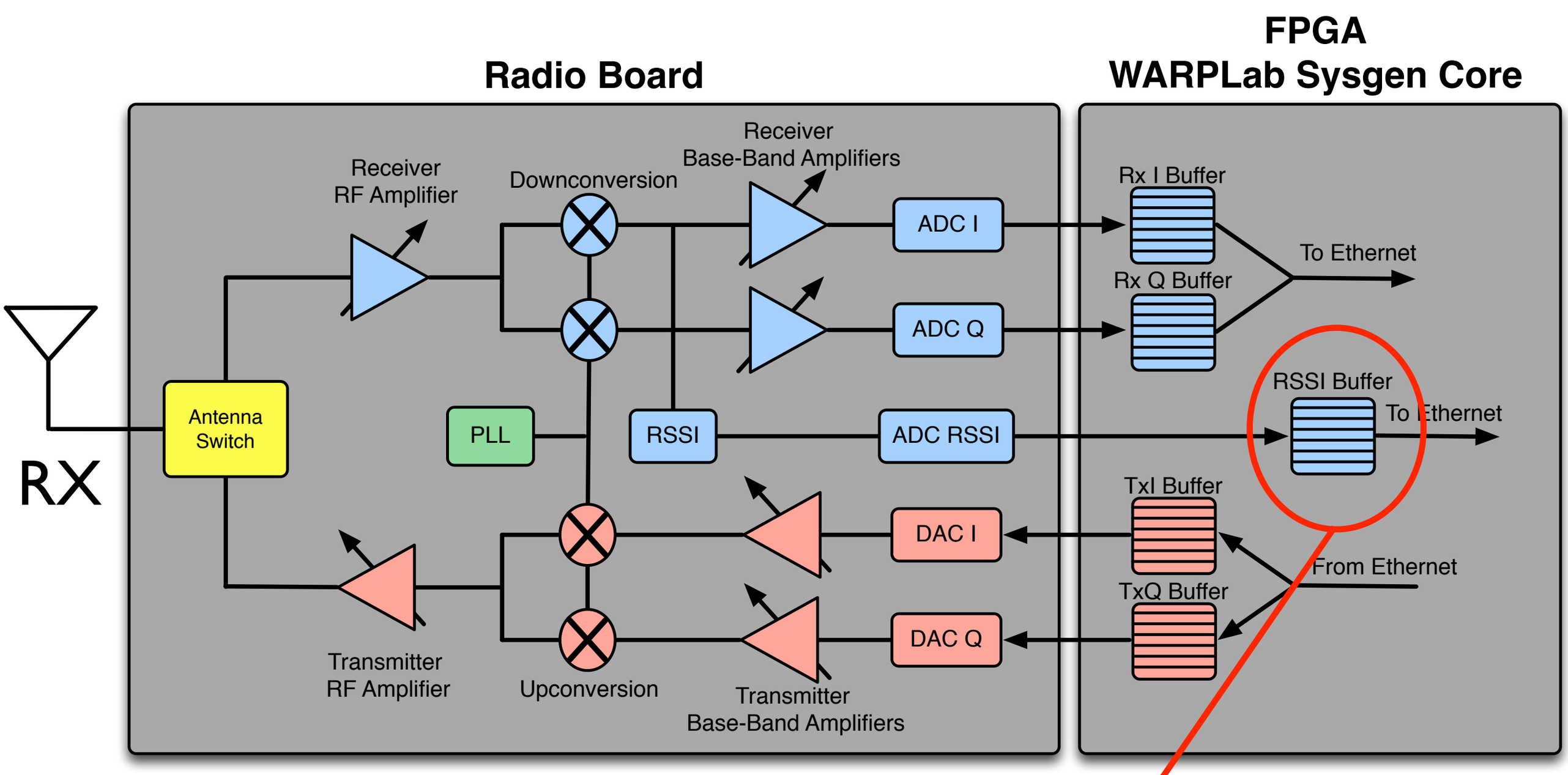
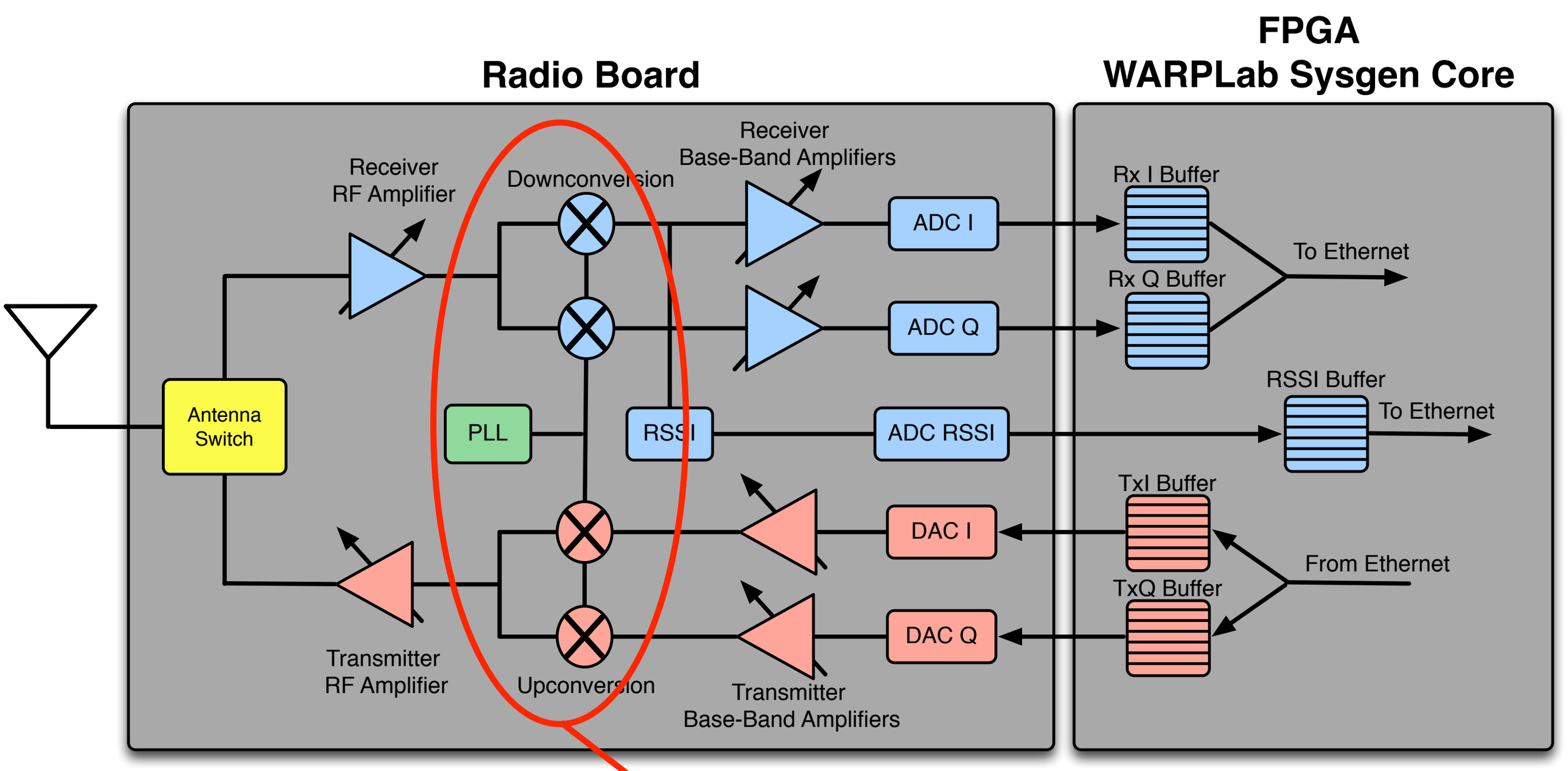


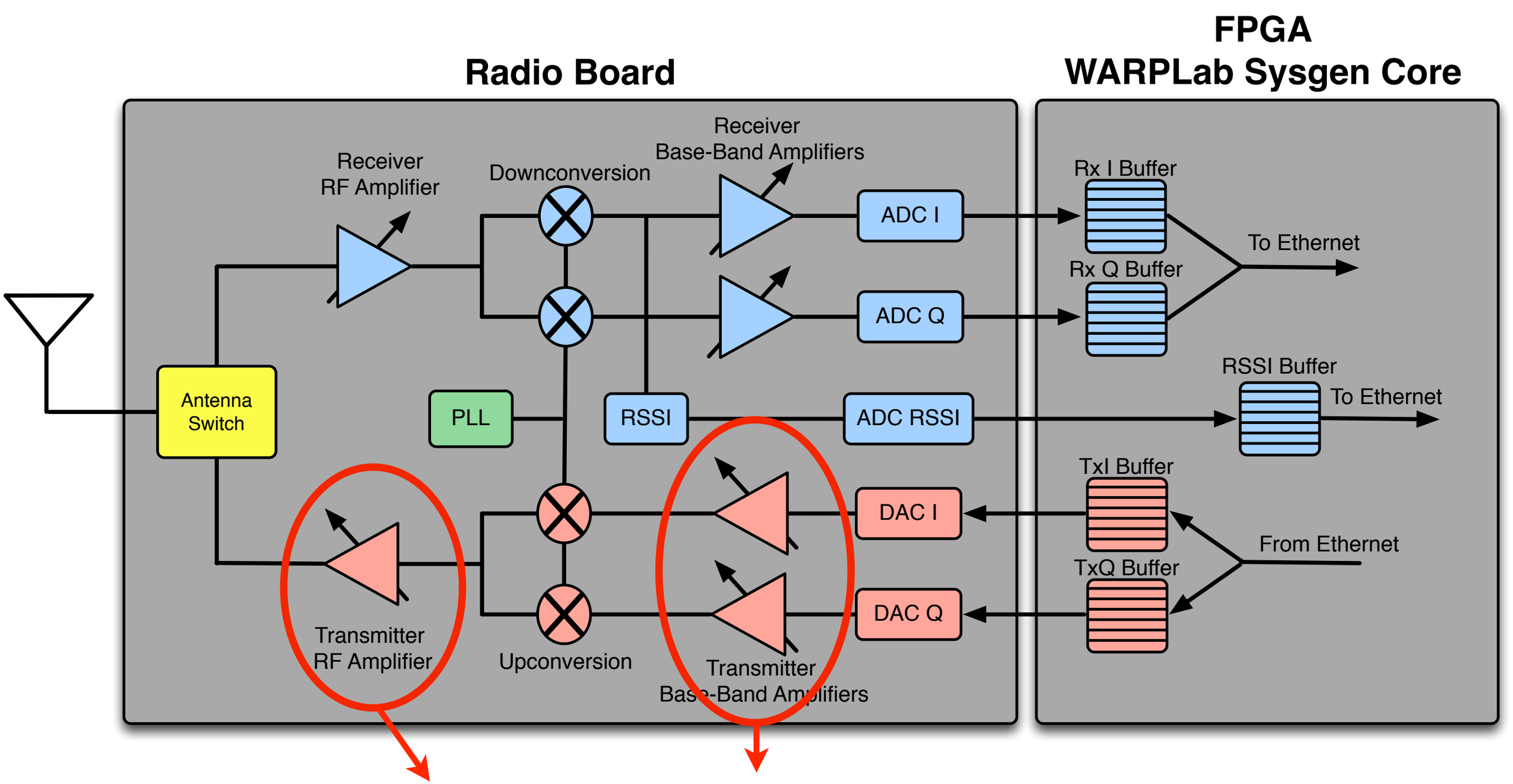
RSSI buffer
4096 (2^{12}) samples

WARPLab Architecture



Variable upconversion/downconversion carrier frequency
Value input from MATLAB

WARPLab Architecture



Variable gain Tx BB and RF amplifiers

Gain value input from MATLAB

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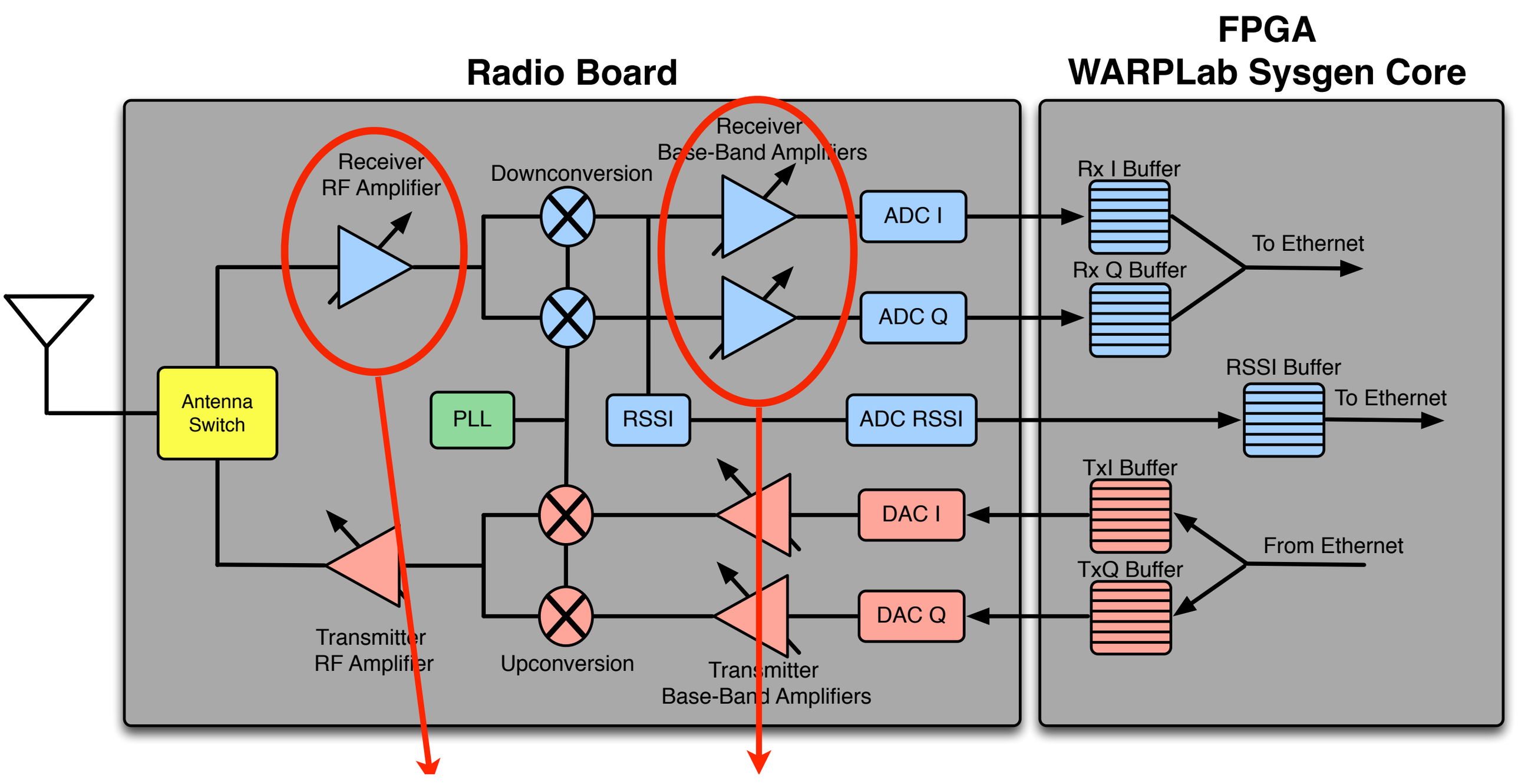

Variable gain Rx BB and RF amplifiers

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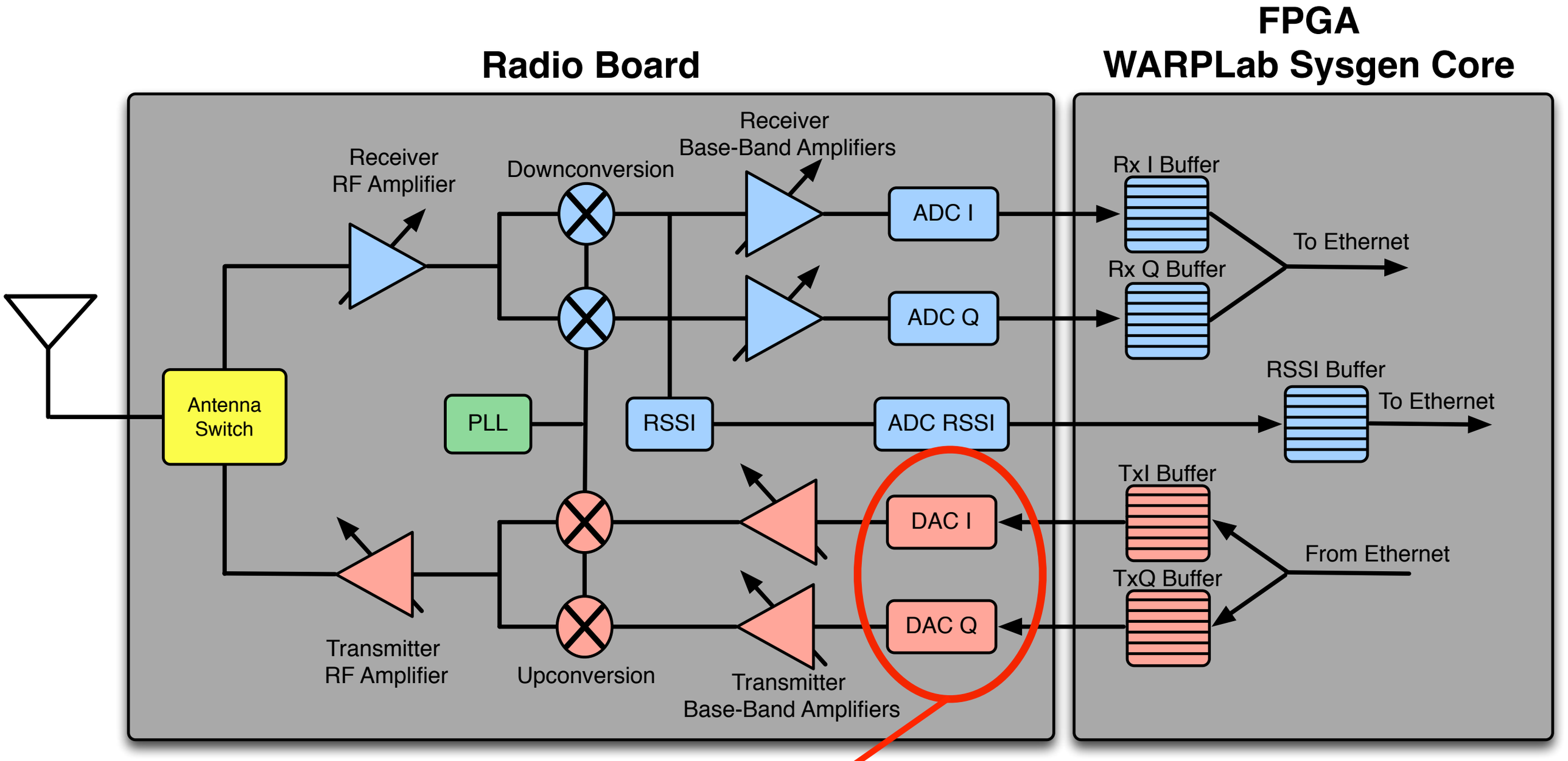
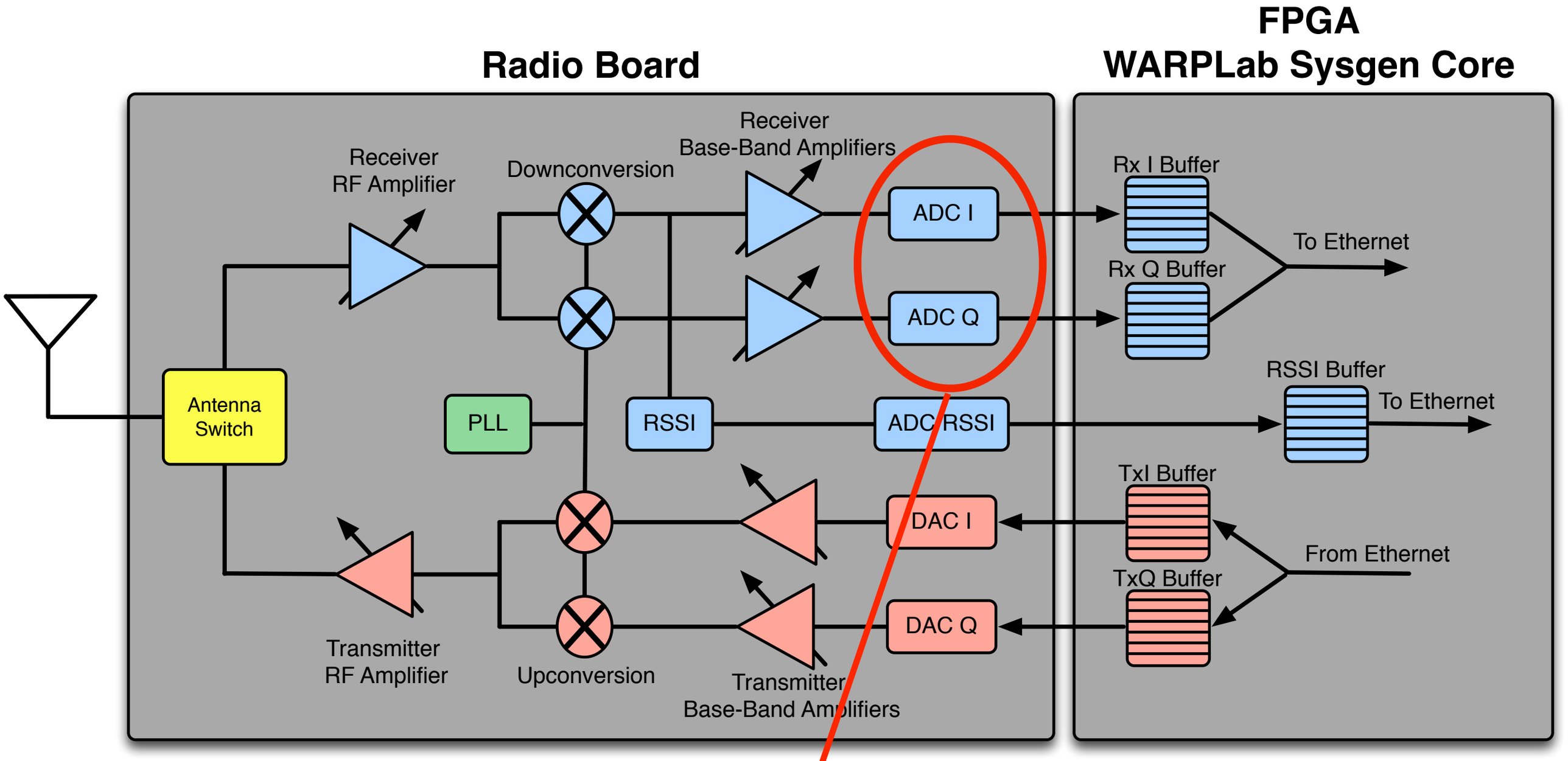


Fixed Point 16_15 I/Q DACs

Always clocked at 40 MHz

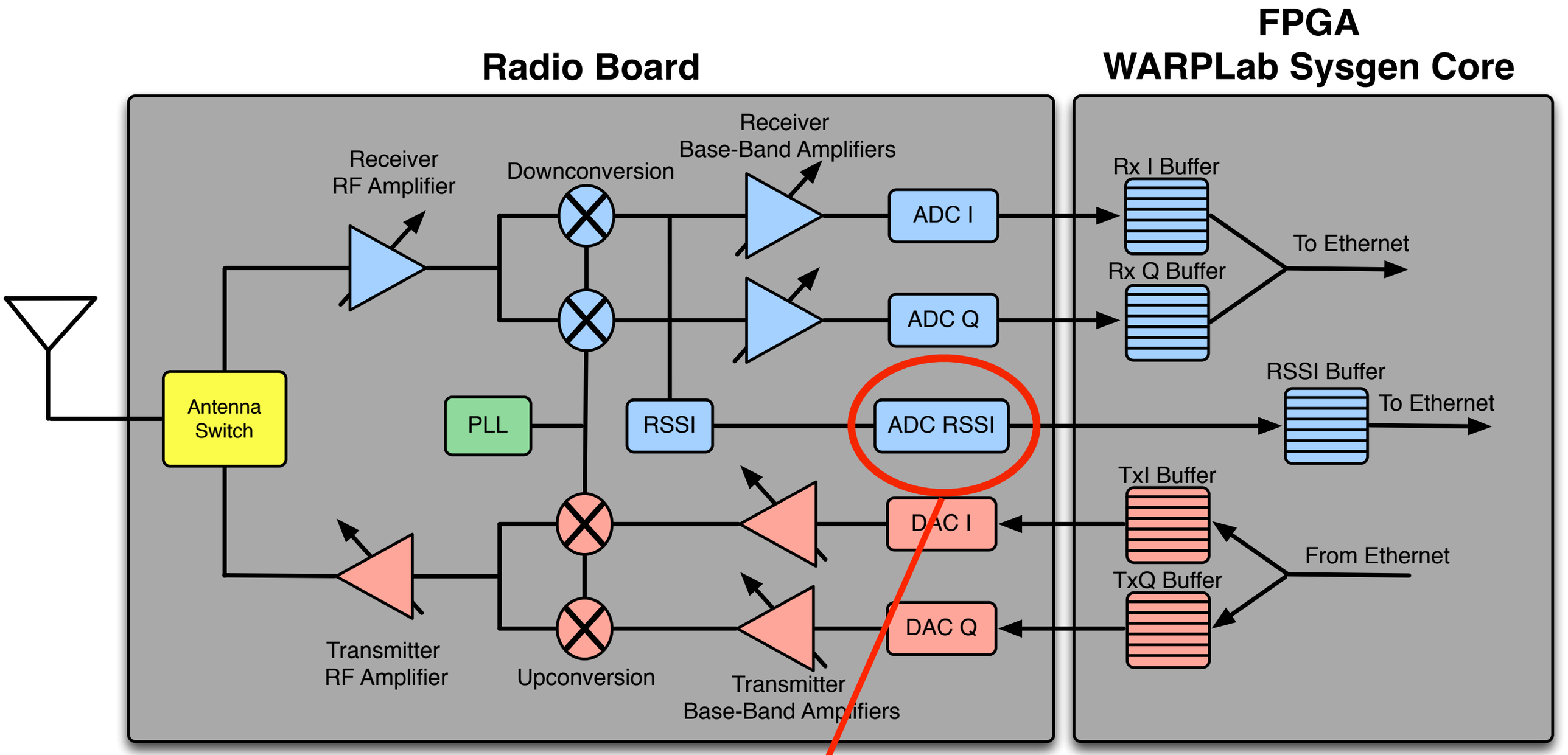
WARPLab Architecture



Fixed Point 14_13 I/Q ADCs

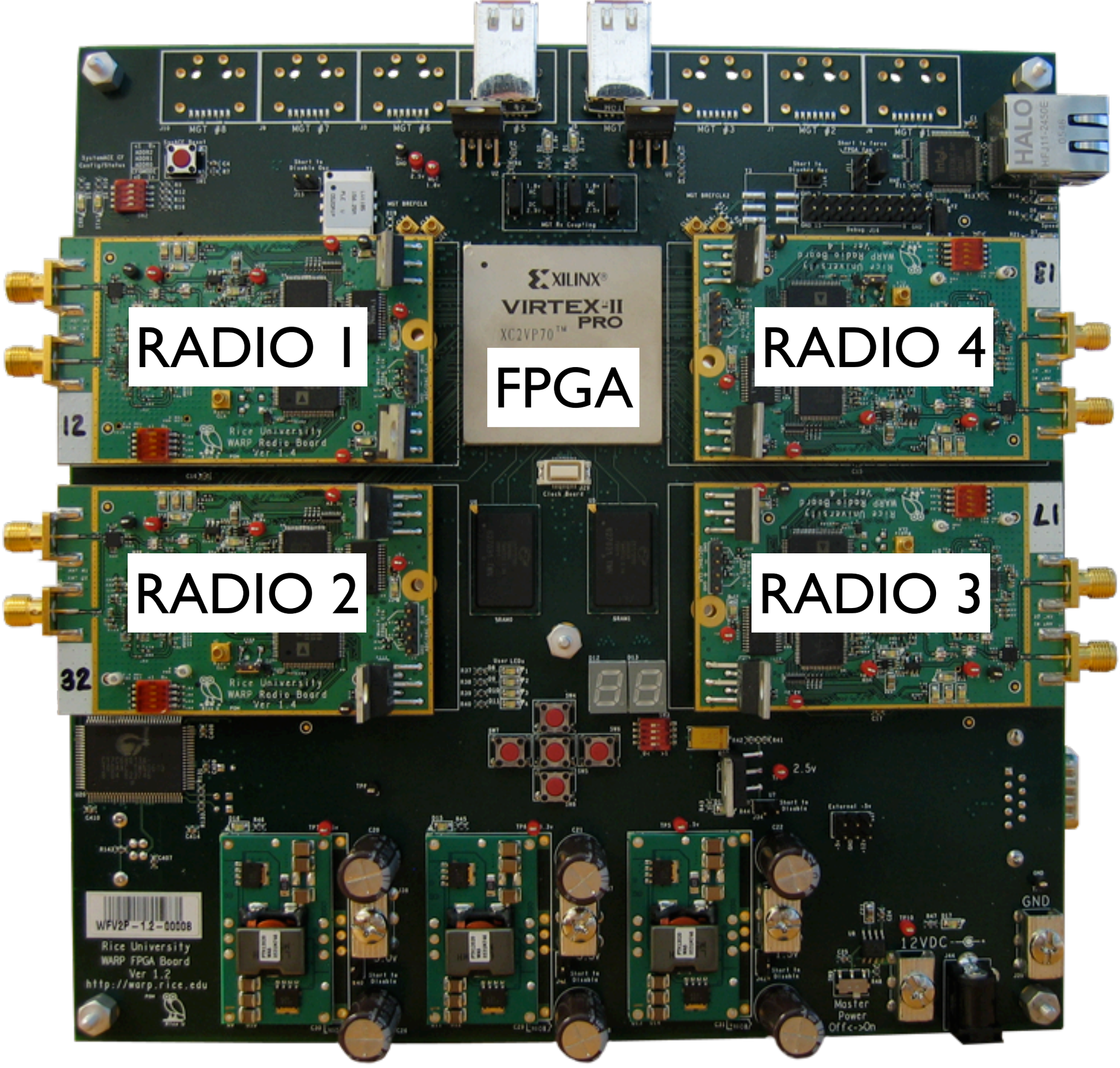
Always clocked at 40 MHz

WARPLab Architecture



RSSI ADC always clocked at 10 MHz

10 bit number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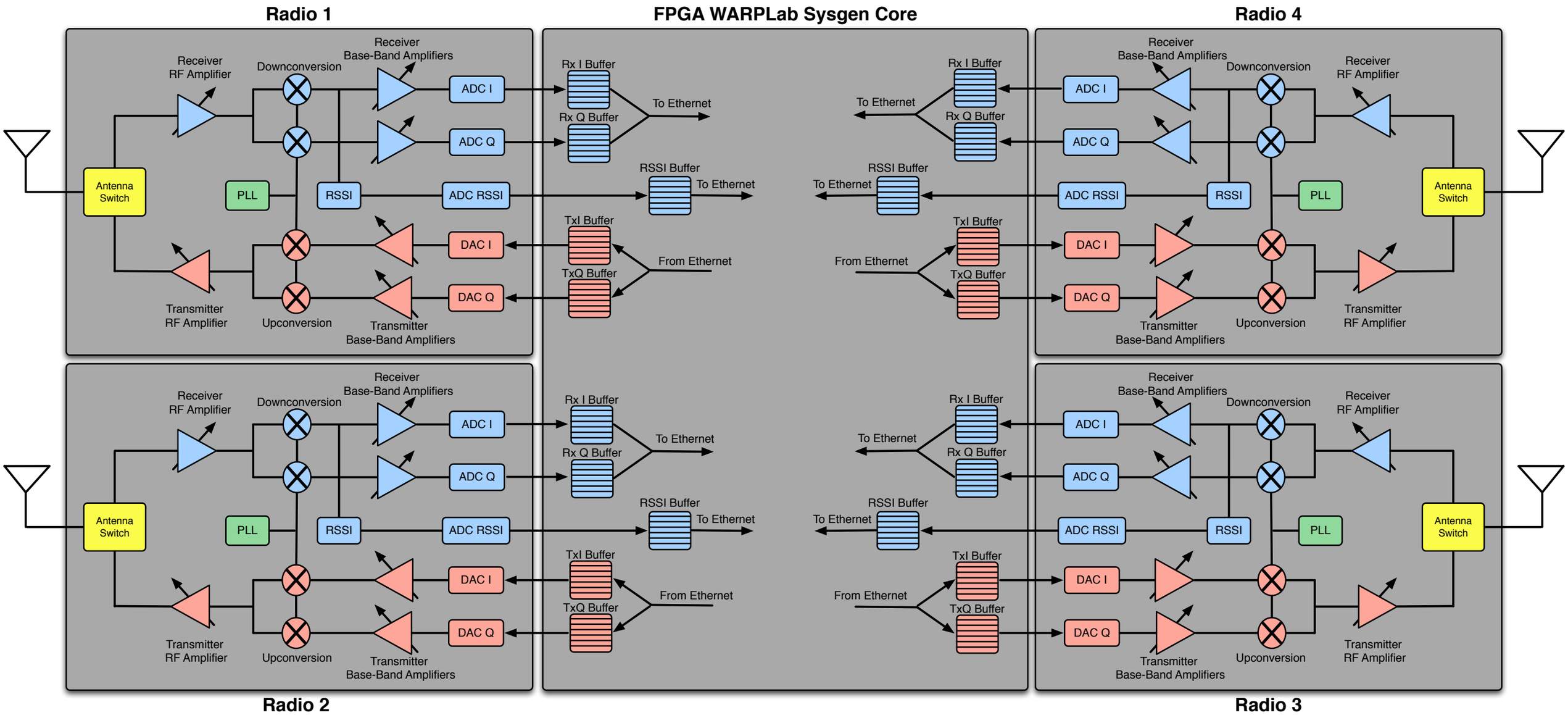

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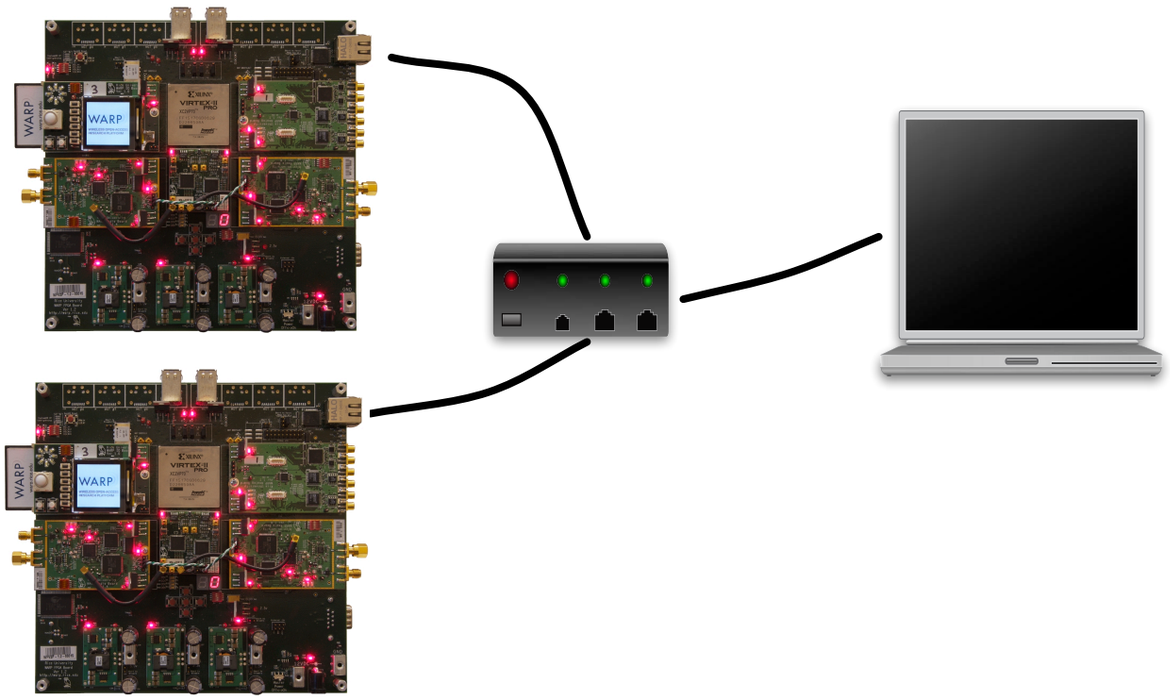

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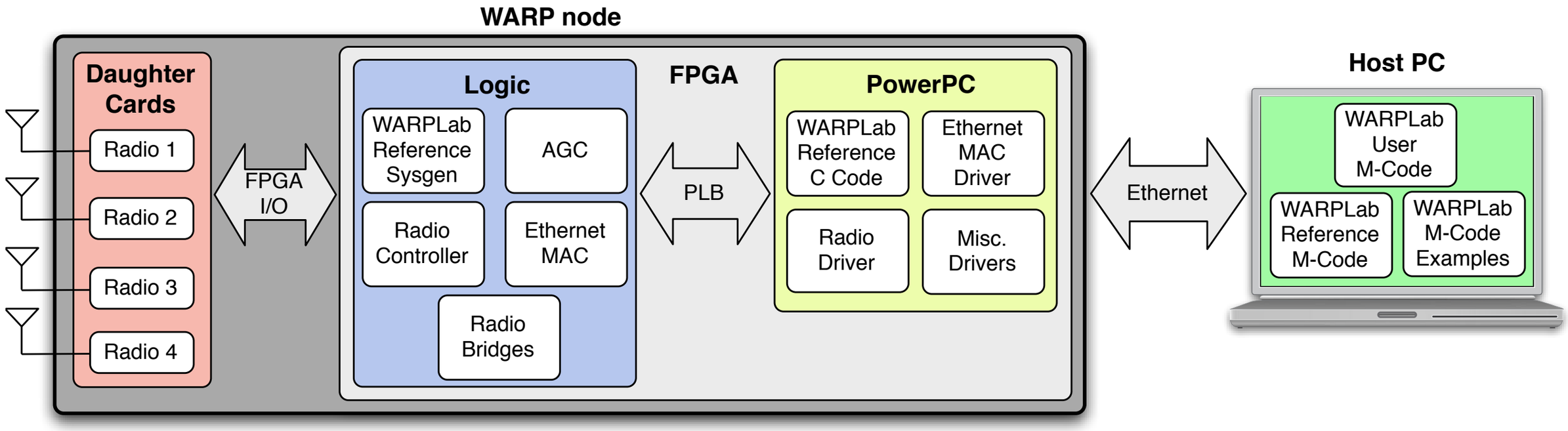

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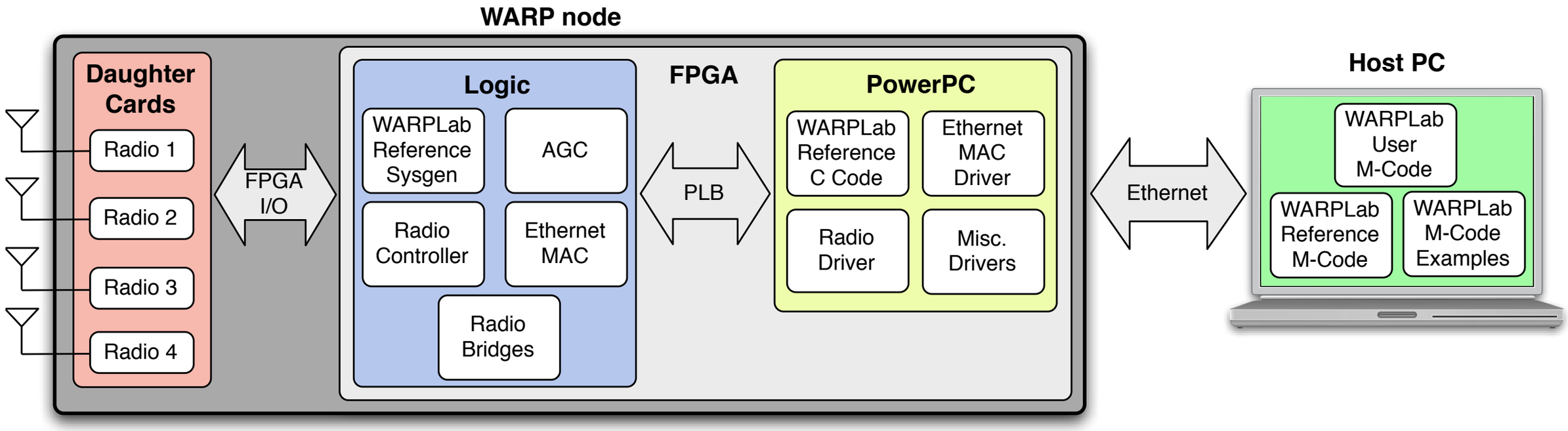

- The WARPLab framework provides the following
  - Reference design
  - Reference M-Code
  - M-Code Examples

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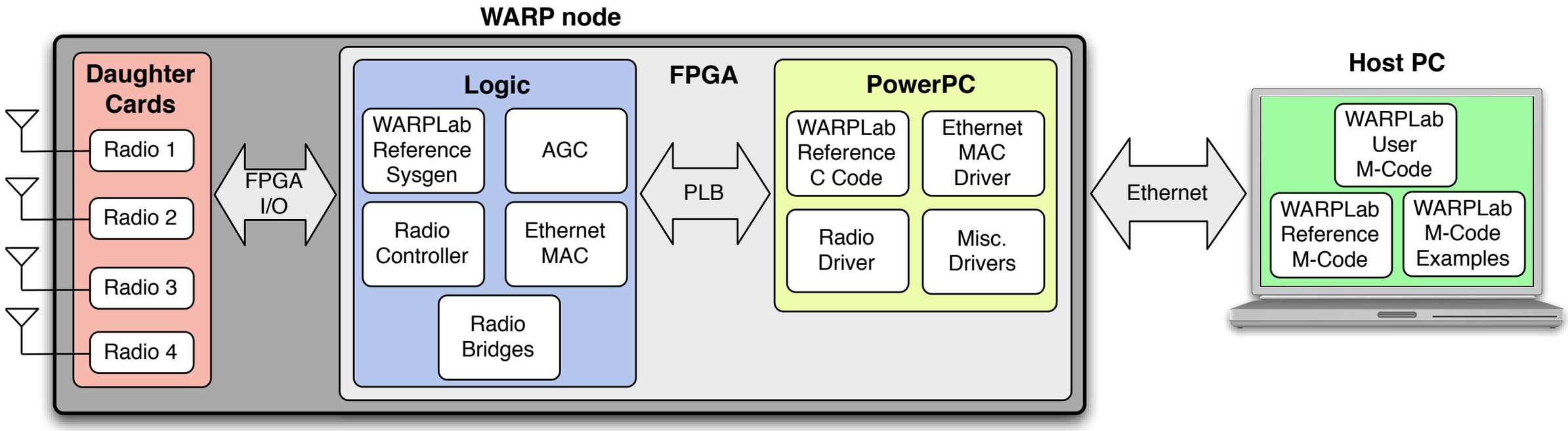

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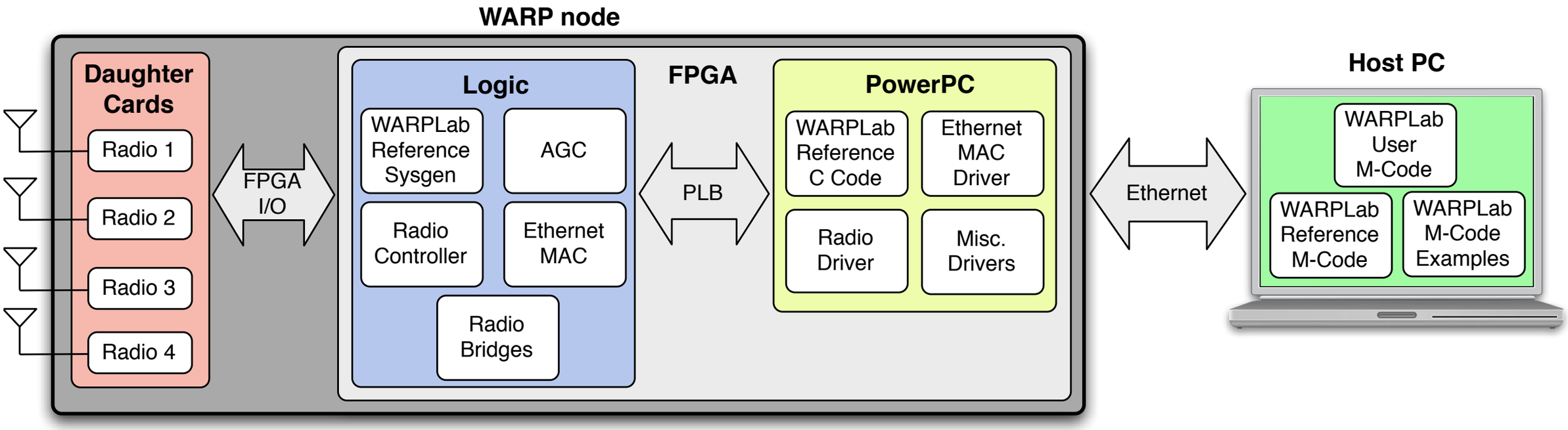

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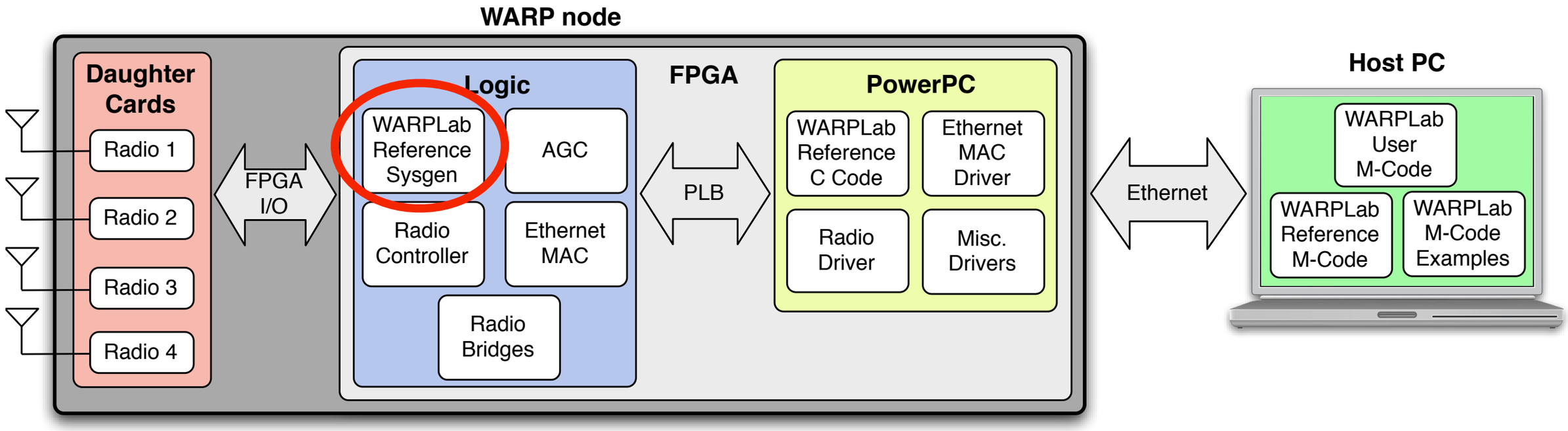

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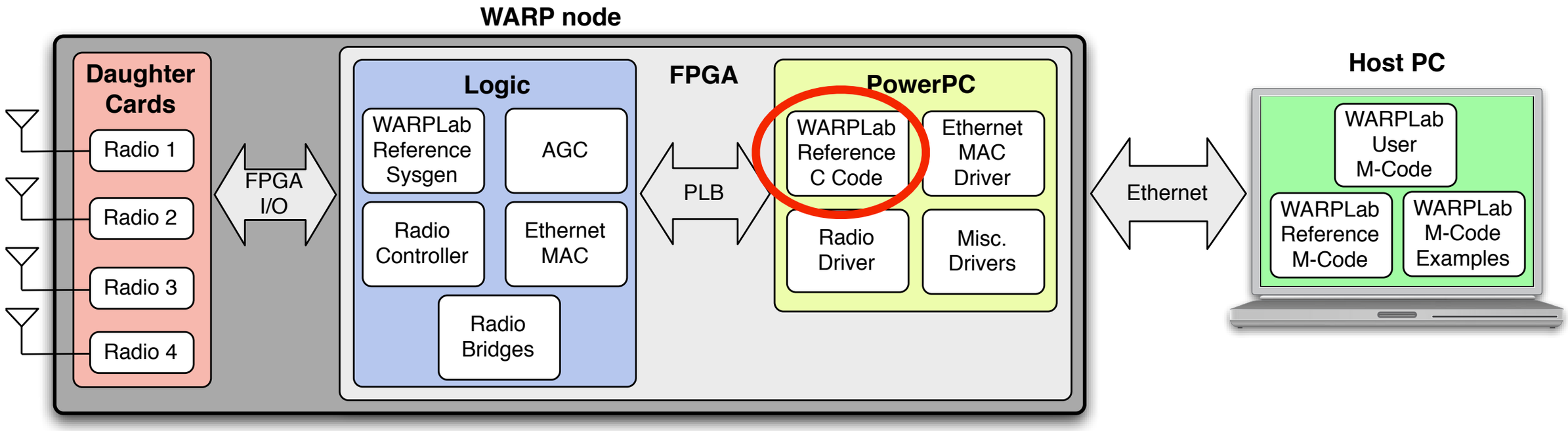
  - WARPLab Reference Sysgen - Ex: Buffers

WARPLab Architecture

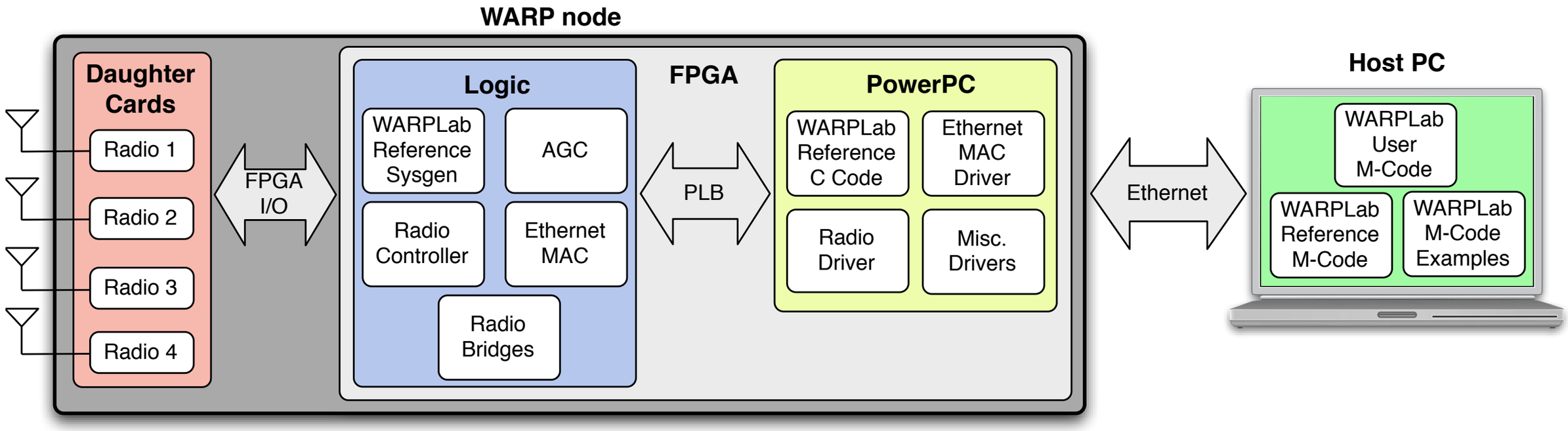


- Reference design
  - XPS project that contains all the FPGA code required to program the WARP nodes
  - WARPLab Reference Sysgen - Ex: Buffers
  - WARPLab Reference C Code - Ex: Ethernet

WARPLab Architecture

- Reference design
    - Bitsream (.bit) file to program the WARP nodes is provided
    - Same bitstream for all nodes.
        - Any node can be Tx or Rx
- All open source
    - All code required to generate bitstream is available online

WARPLab Architecture



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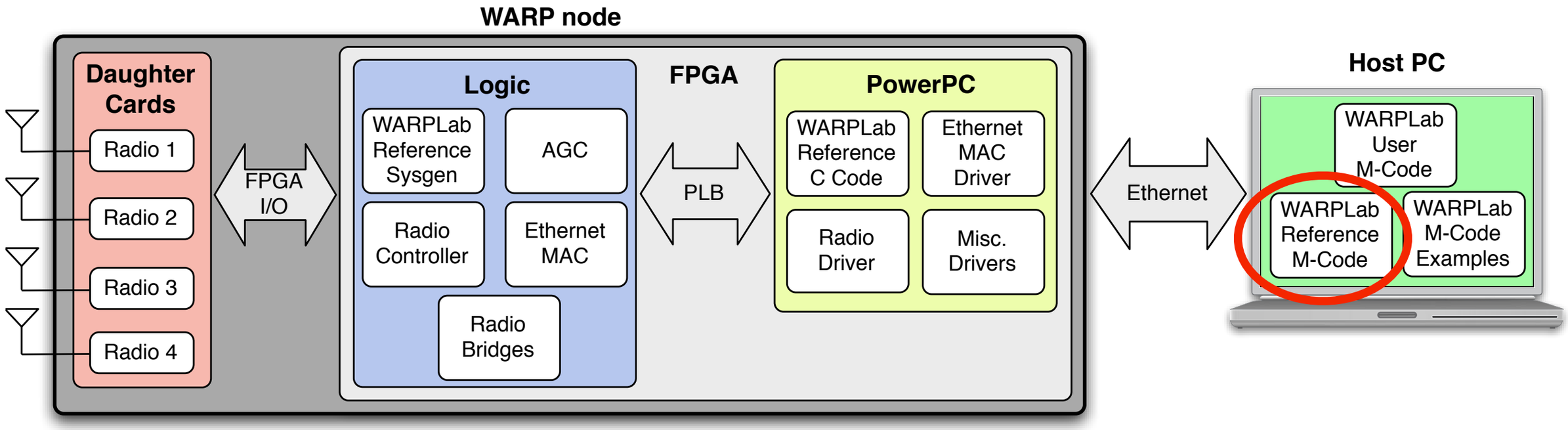
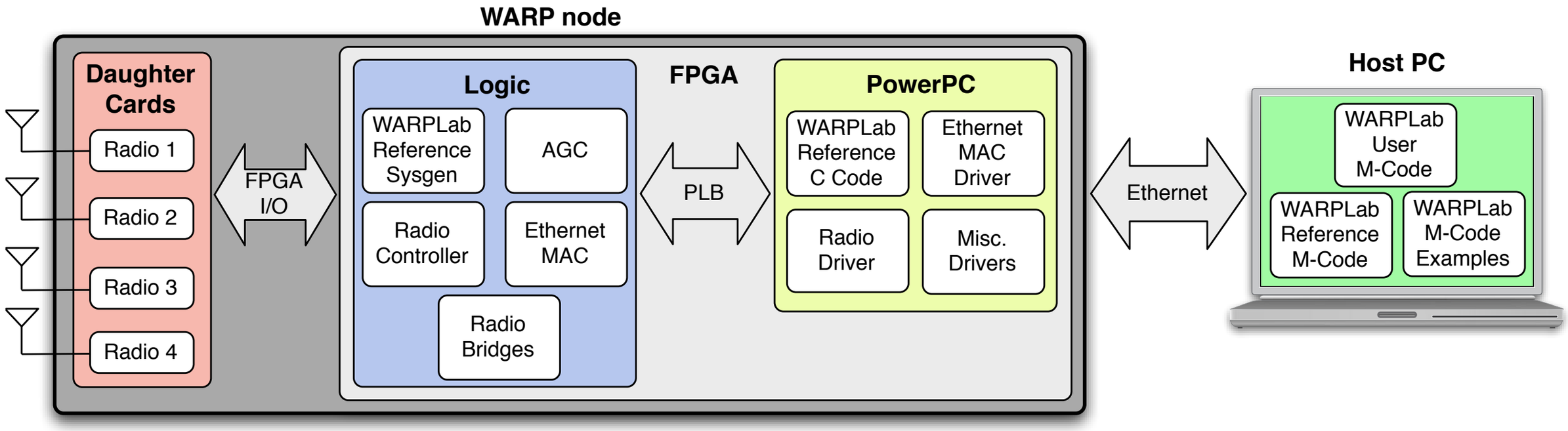


- Reference M-Code
  - MATLAB Code (M-Code) functions that allow interaction with WARP nodes
  - Ex:
    - warplab_writeSMWO(Node_ID,Buffer_ID,M_Vector)

WARPLab Architecture



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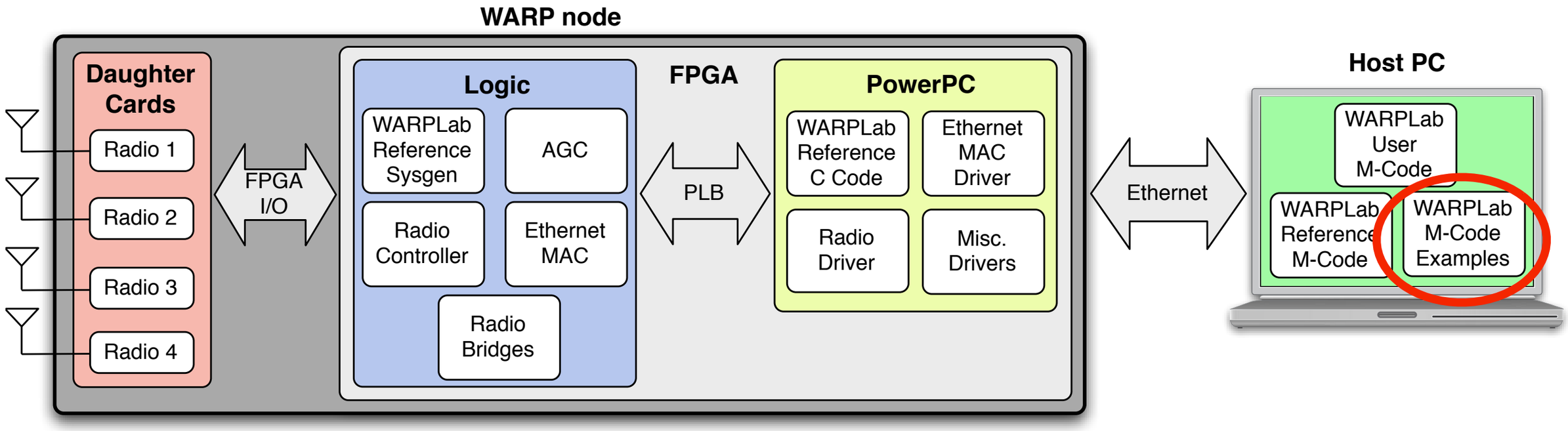
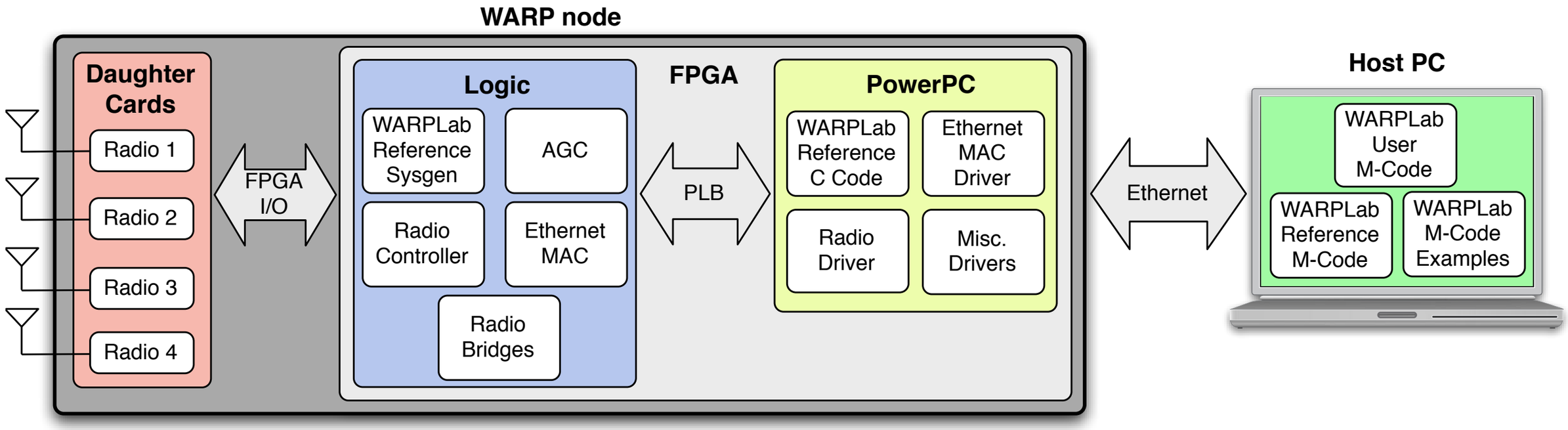


- M-Code Examples
  - Illustrate how to use the functions in the WARPLab Reference M-Code
  - Today's Lab 1

WARPLab Architecture



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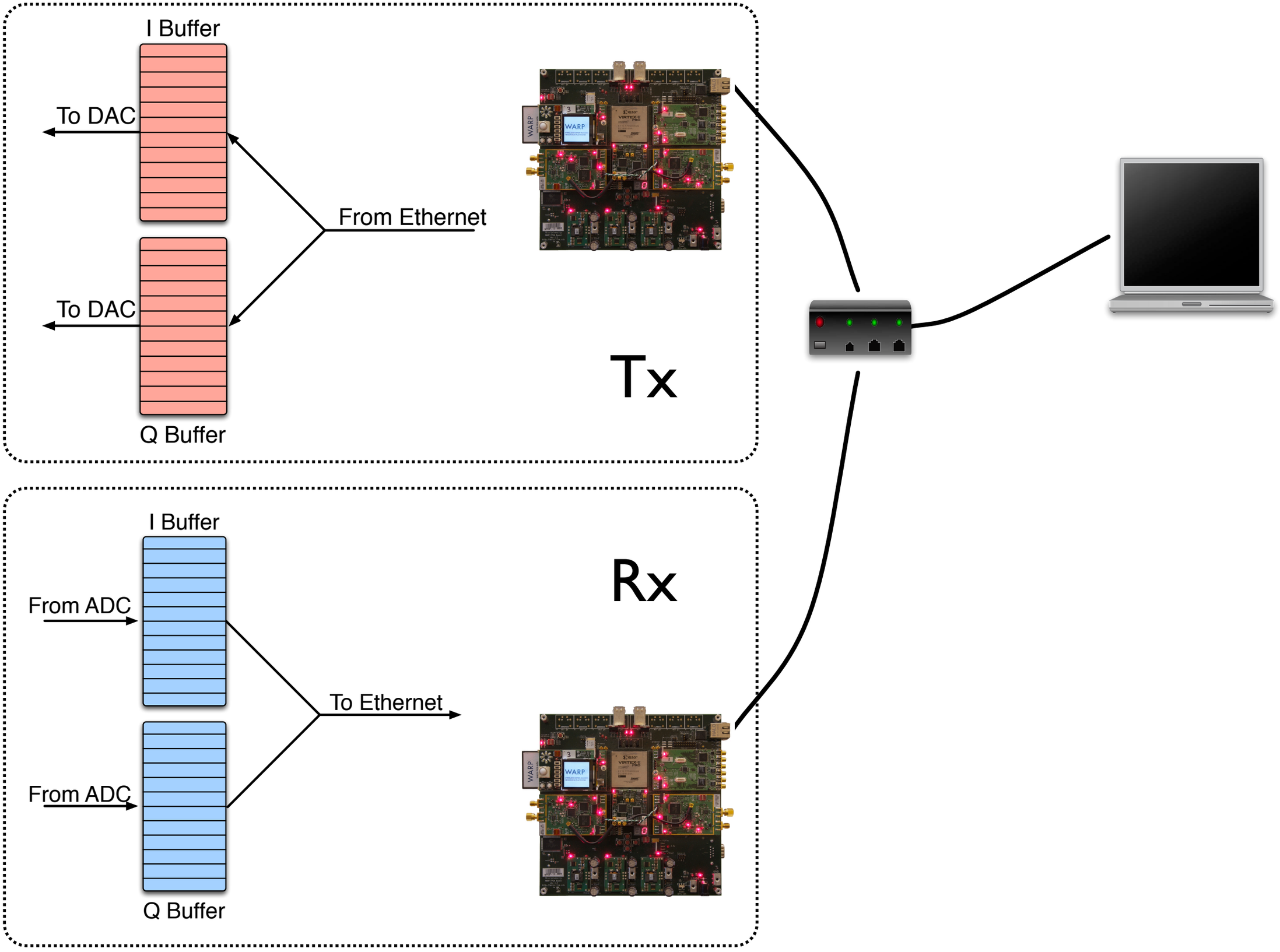
All open source

WARPLab Flow



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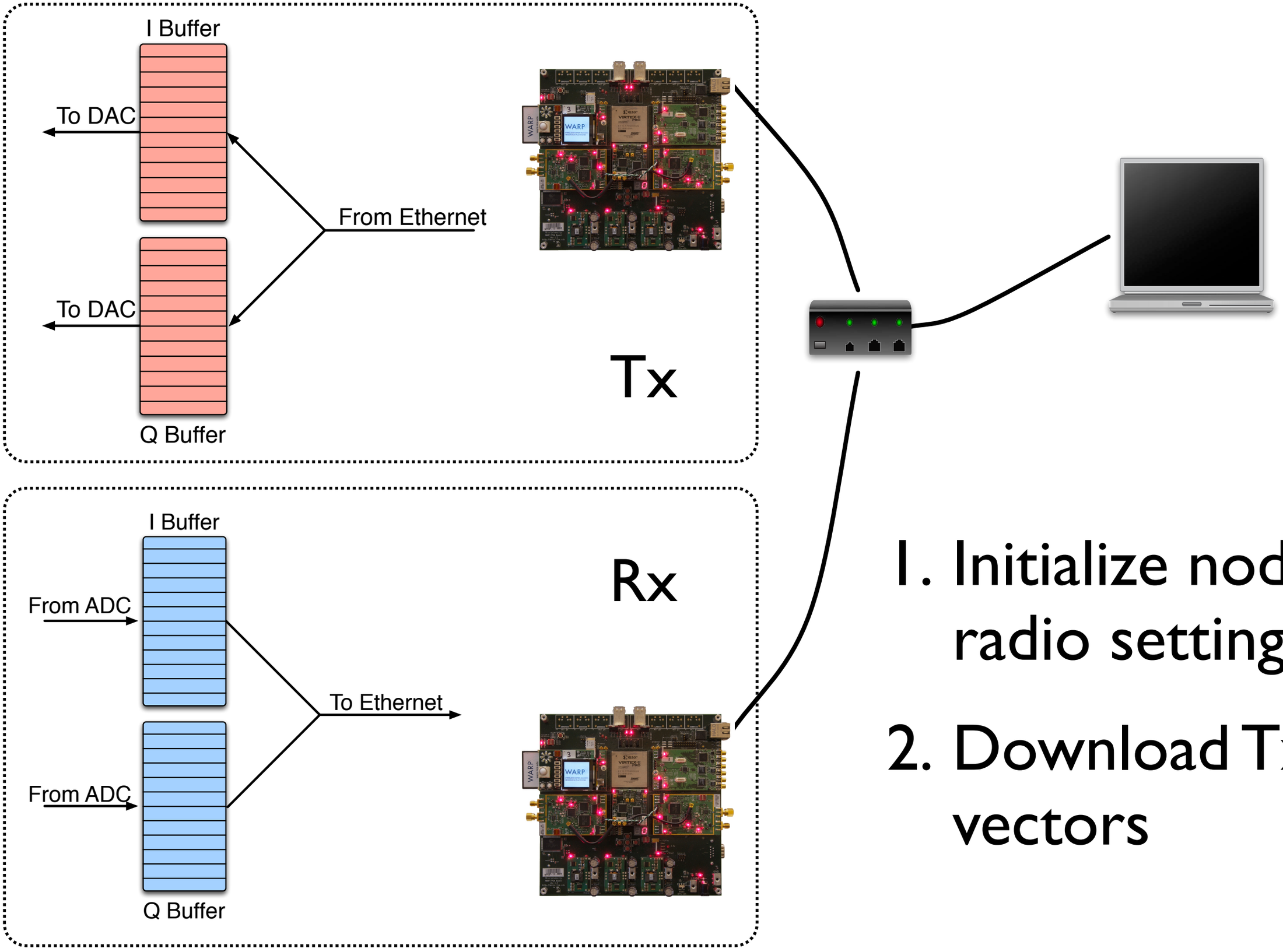
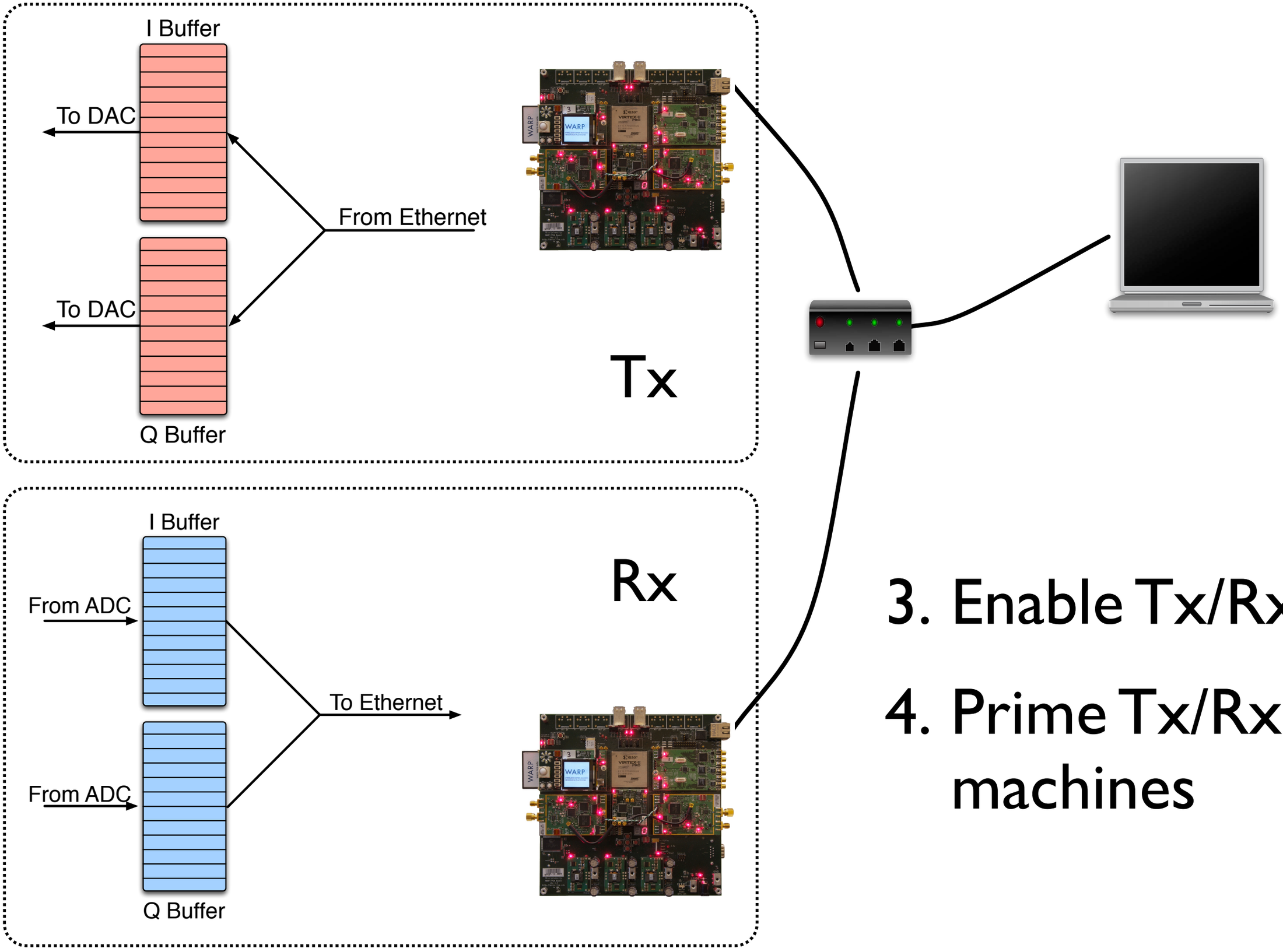


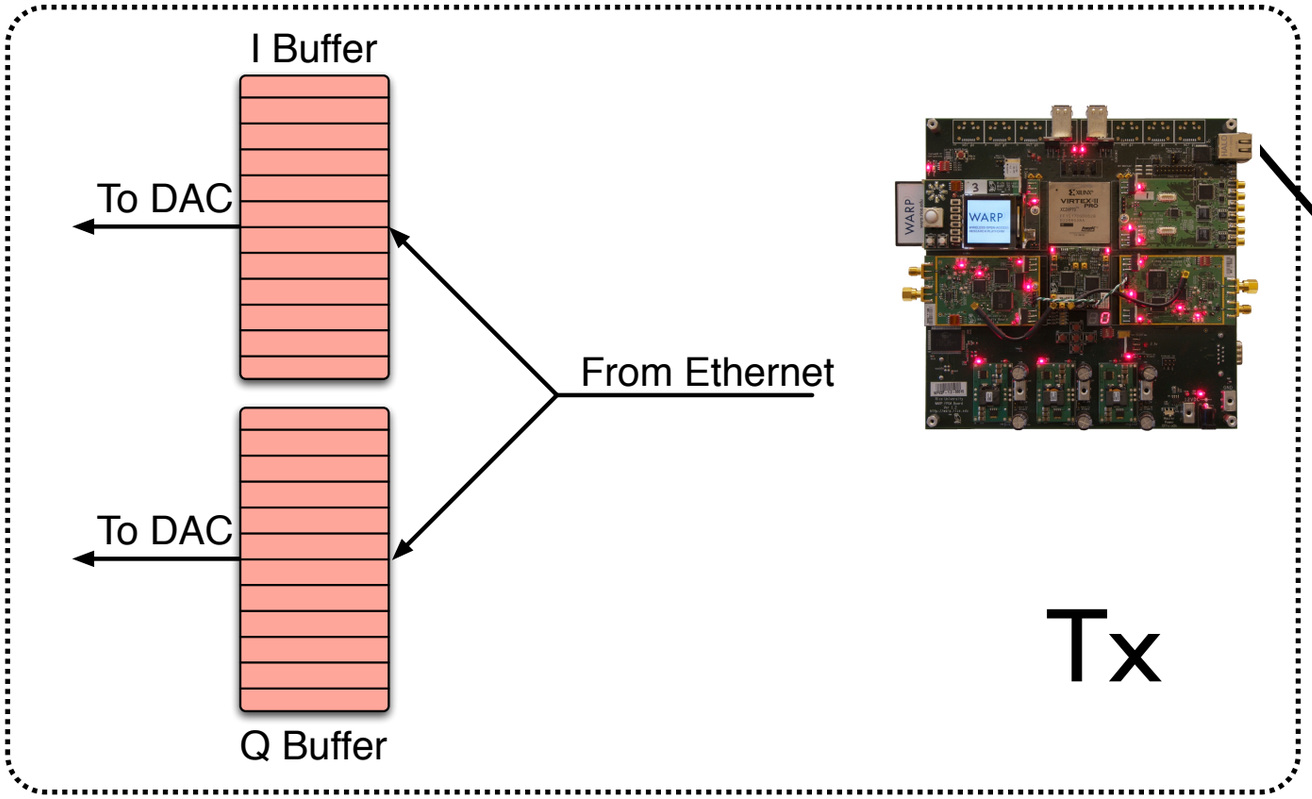
1. Initialize nodes & radio settings
2. Download Tx vectors

WARPLab Flow



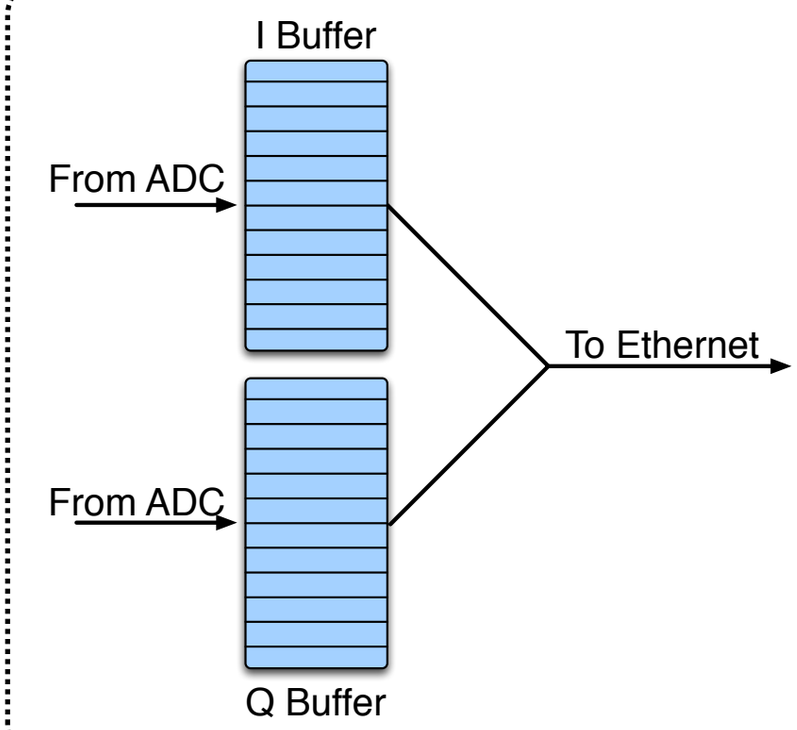
3. Enable Tx/Rx paths
4. Prime Tx/Rx state machines

WARPLab Flow

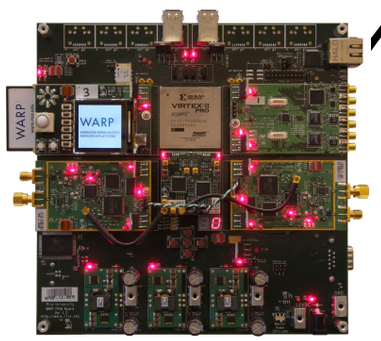


Tx

SYNC



Rx

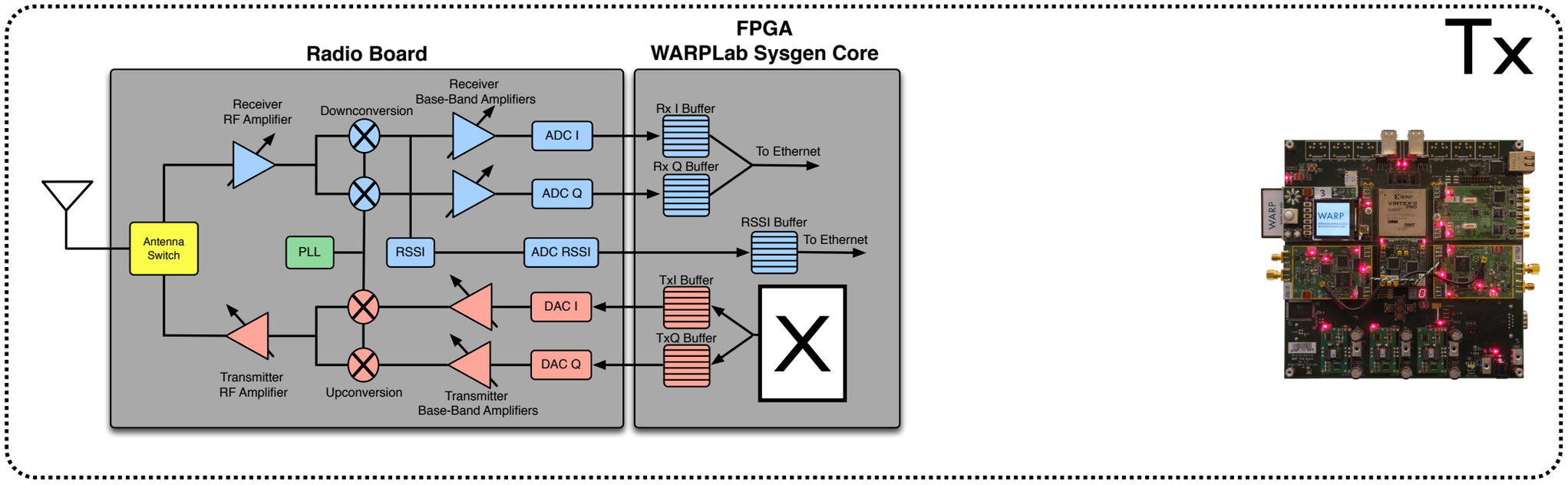


5. Trigger the transmission and capture
6. Retrieve Rx vectors

Tx BB Signal Requirements

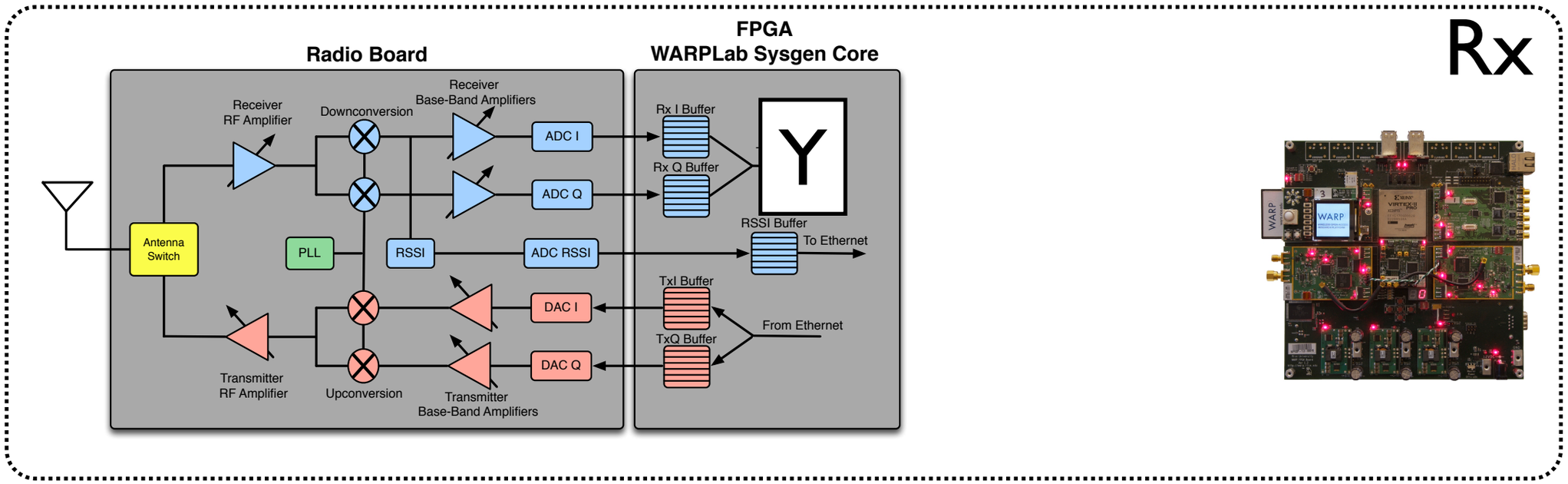
- Amplitude of real part in [-1,1]
- Amplitude of imaginary part in [-1,1]
- Highest frequency 9.5 MHz (19 MHz BW)
- Lowest frequency 30 KHz
- 40 MHz sampling
- Note: Buffers persist between triggers

Tx to Rx path



$|Y| = |H| G_{RXBB} G_{RXRF} G_{TXPA} G_{TXRF} G_{TXBB} |X|$

$|H|$:Wireless channel magnitude



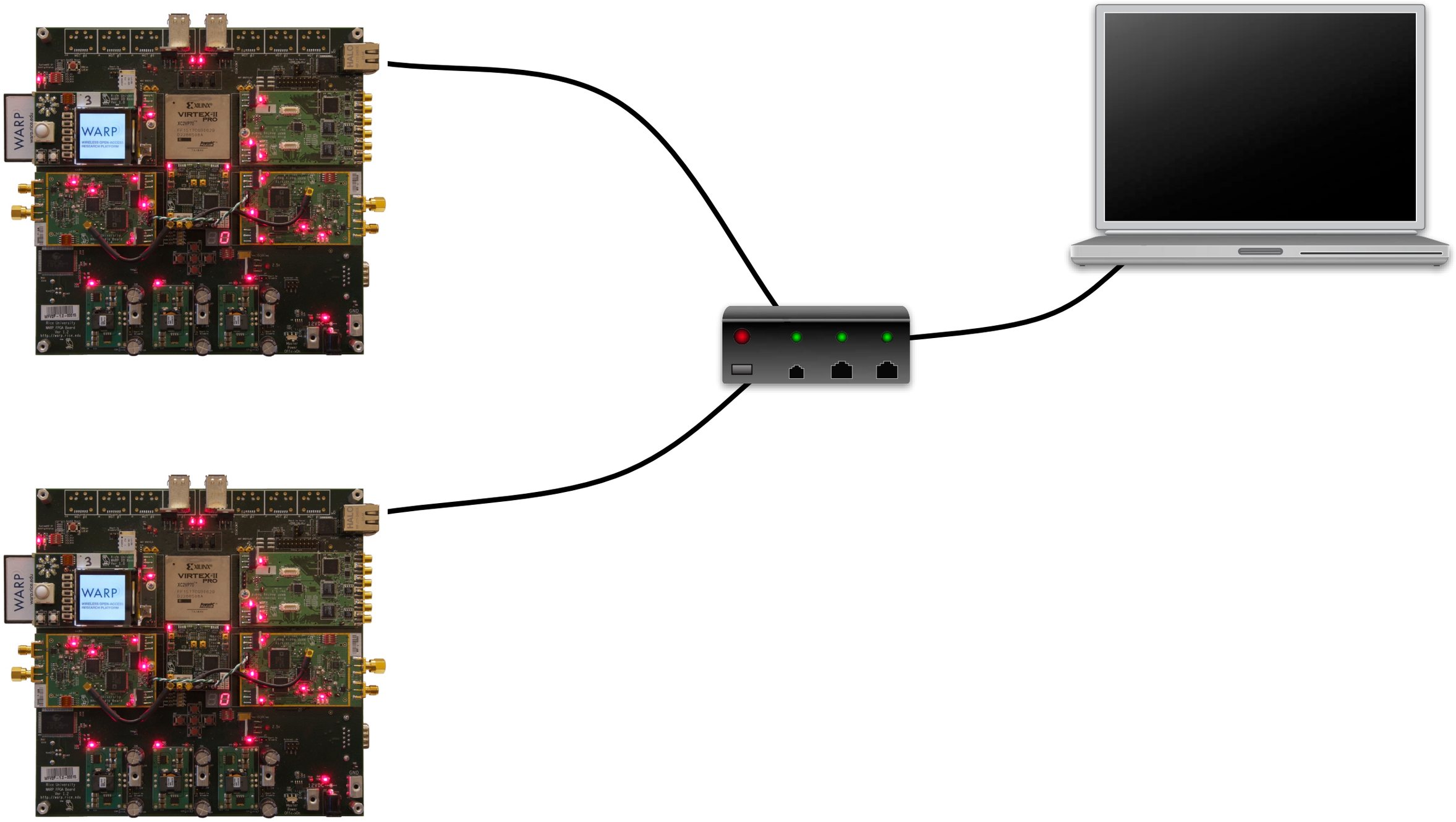
WARPLab Examples

- Hardware characterization
- Channel measurement
- Sphere detection
- Cooperative communications
- Beamforming

Lab 1: WARPLab

- WARPLab graphical interface
- SISO communication
- Measuring the wireless channel
- Building a real bits-to-RF transmitter
- Continuous transmitter mode
- Two-way communication
- 2x2 MIMO communication

WARPLab Overview



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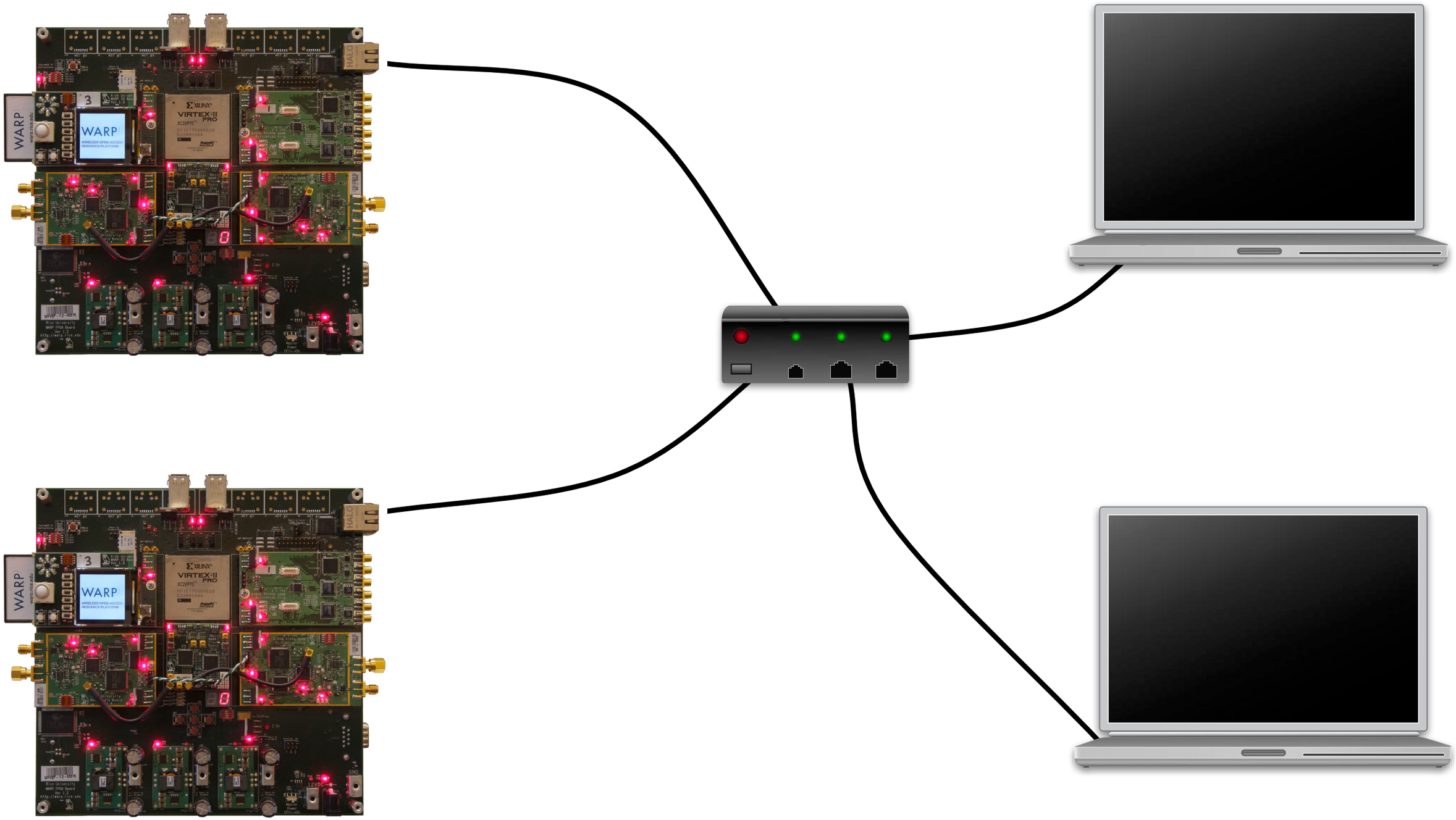

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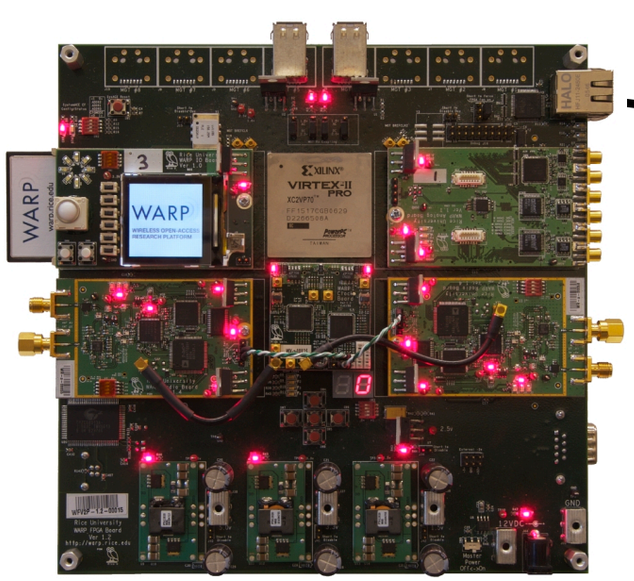

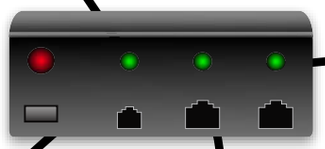

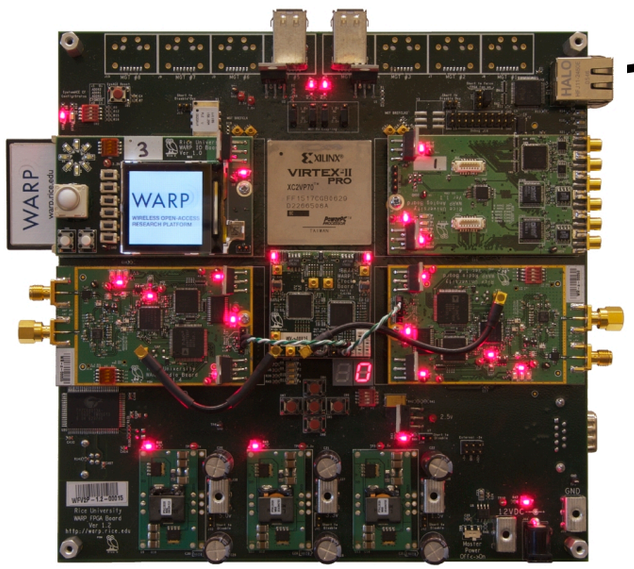

(2,3) (4,5) (7,8) (9,10)

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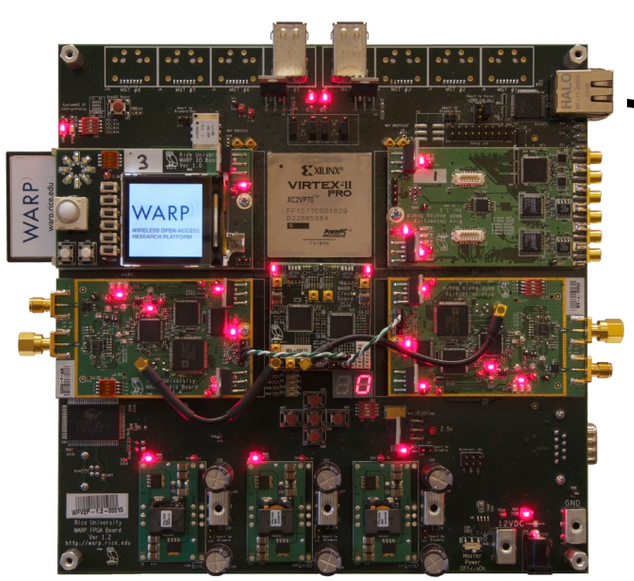

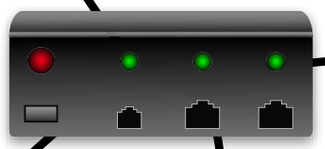

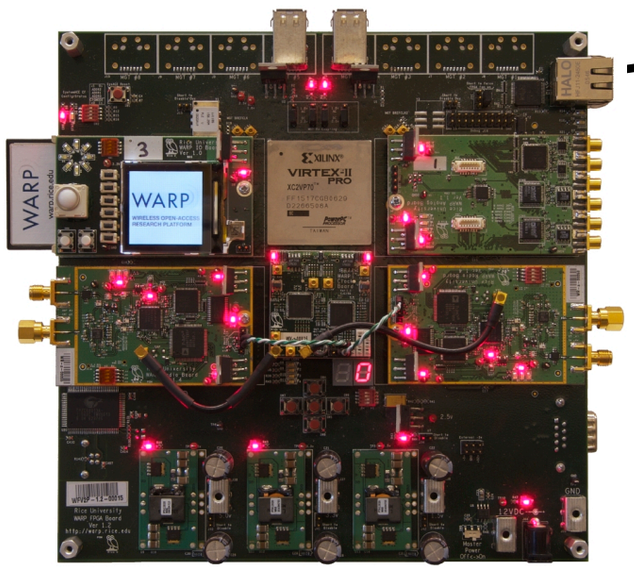

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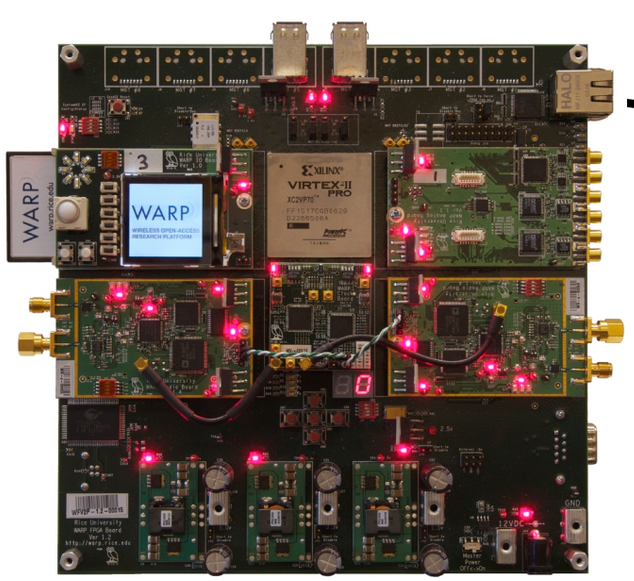

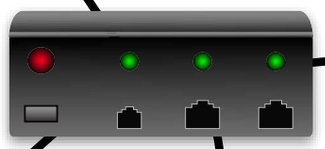

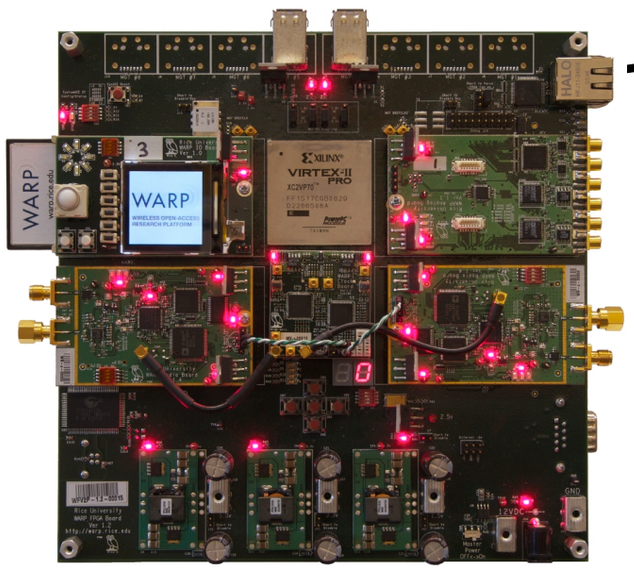

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