Z-Goggles

Multi-function Vision System

Group 1
C.J. Silver
Geoff Jean
Will Petty
Cody Baxley

What are Z-Goggles?

- Vision Modification System
- Image change functions – Flip, Color-inversion, Heat Map
- Function control via UI controller
- Portable, helmet-mounted screen
- Battery-powered

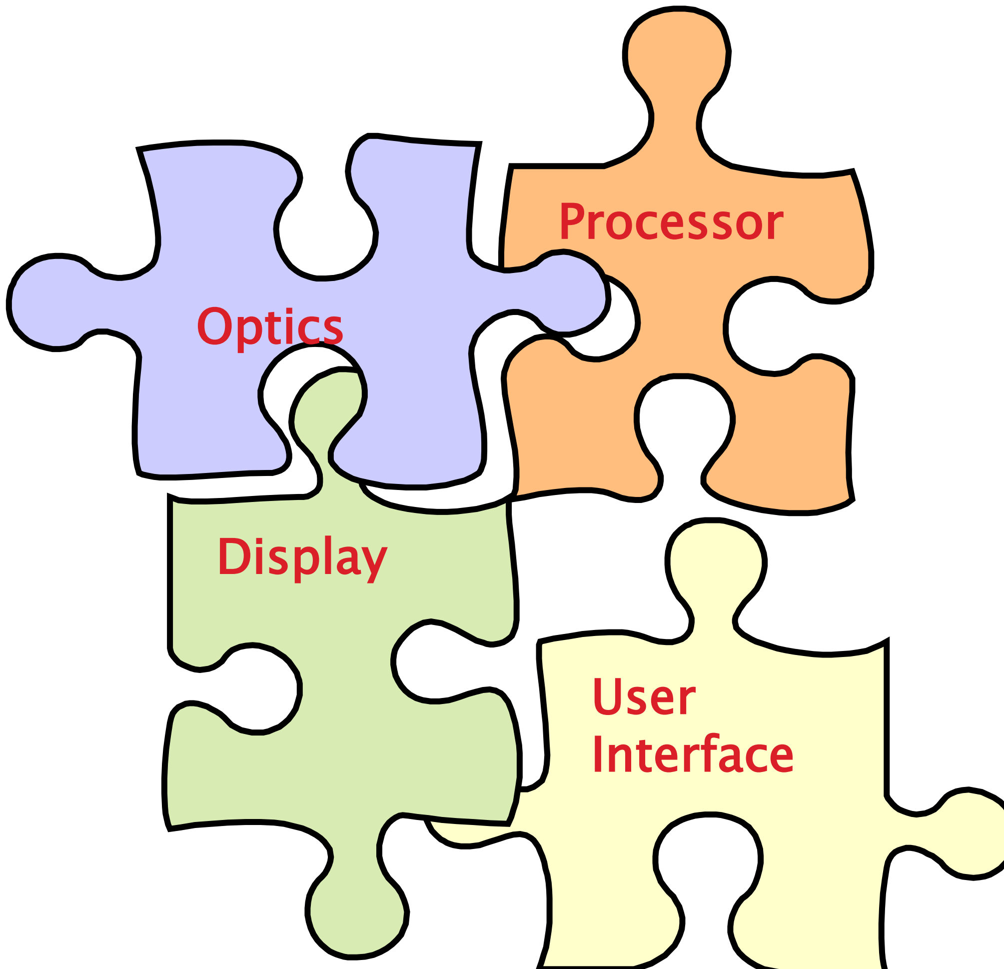
Goals and Objectives

- Cost-effective engineering
  - Low cost components requiring more work
- Portability
  - Battery and backpack/helmet system allows movement
- Simple to use
  - Simple UI controller for video mode and functions
- Effective video processing and display
  - Minimize choppiness by maximizing processing speed via parallel logic implementation

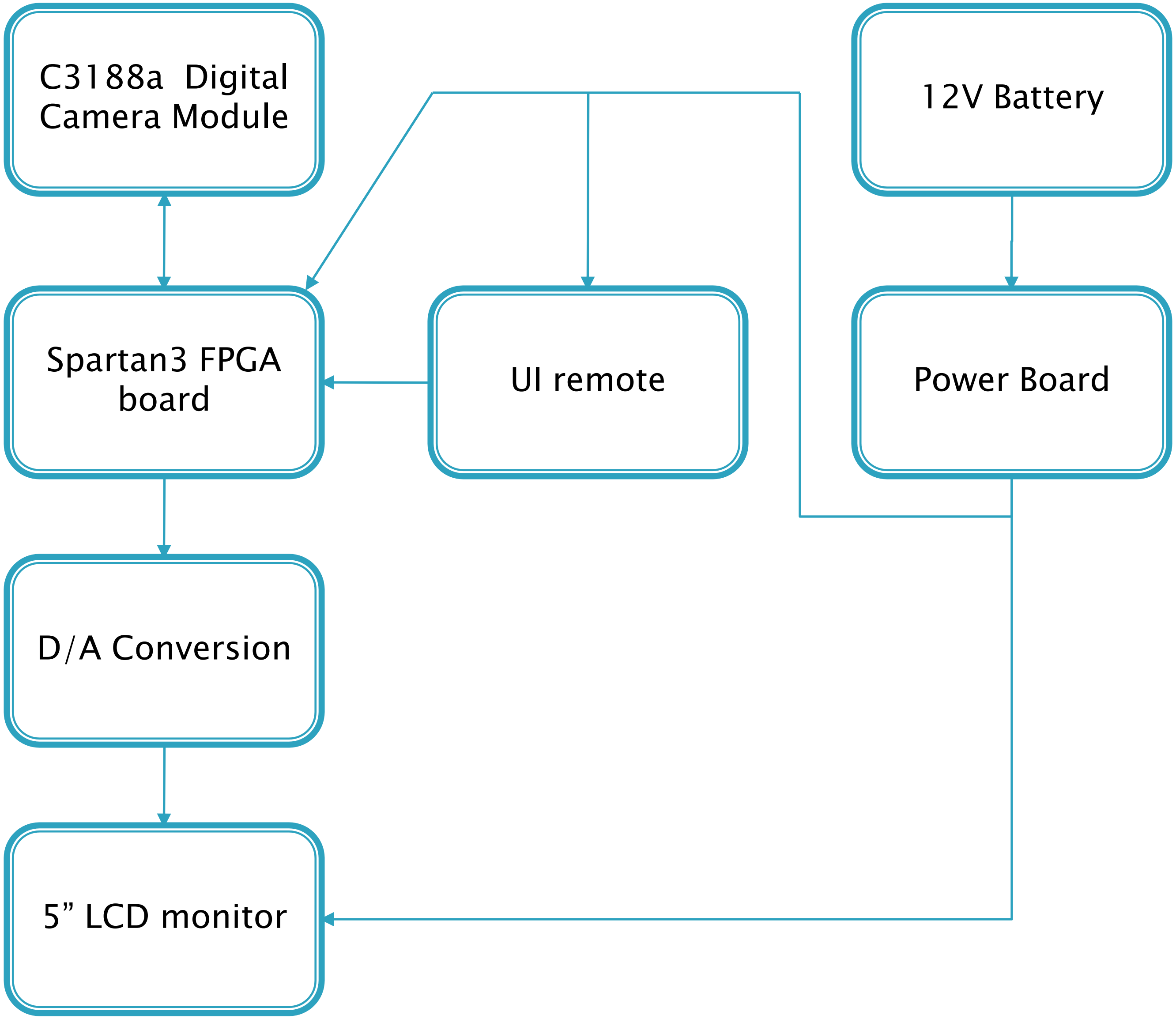
Design Approach

Separate systems – Integrated at later stages

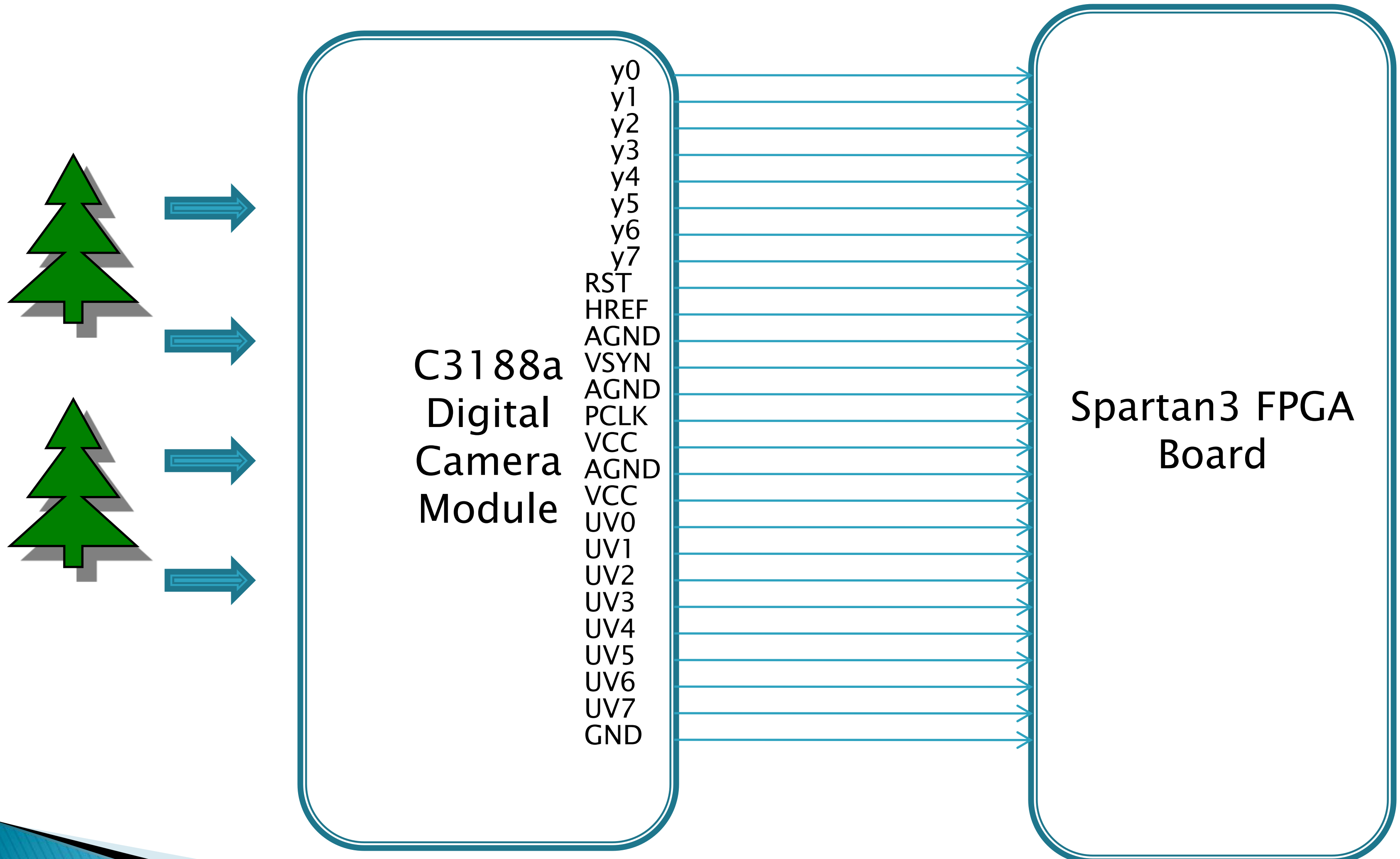
- Optical System
- Video Processor
- Display
- User Interface
- Power supply



Overall Project Diagram



Optical System overview



Optical System Specs and Reqs

- The camera will be designed for color video.
- Cameras resolution will be at least 320 x 240, up to 640 x 480.
- The Optical System will output RGB or YUV data in a usable or convertible size (8bit is the target for the Video Processor).
- The system shall be capable of output of at least 15 fps (30 preferred).

Camera Decisions

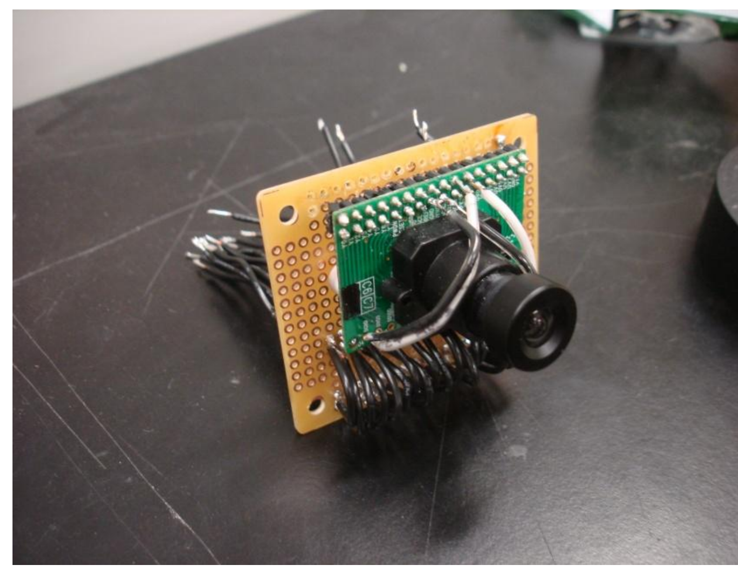
- Logitech C200 Webcam

- CM-26N NTSC Camera with the AL242 Video decoder and AL251 Video Scan Doubler

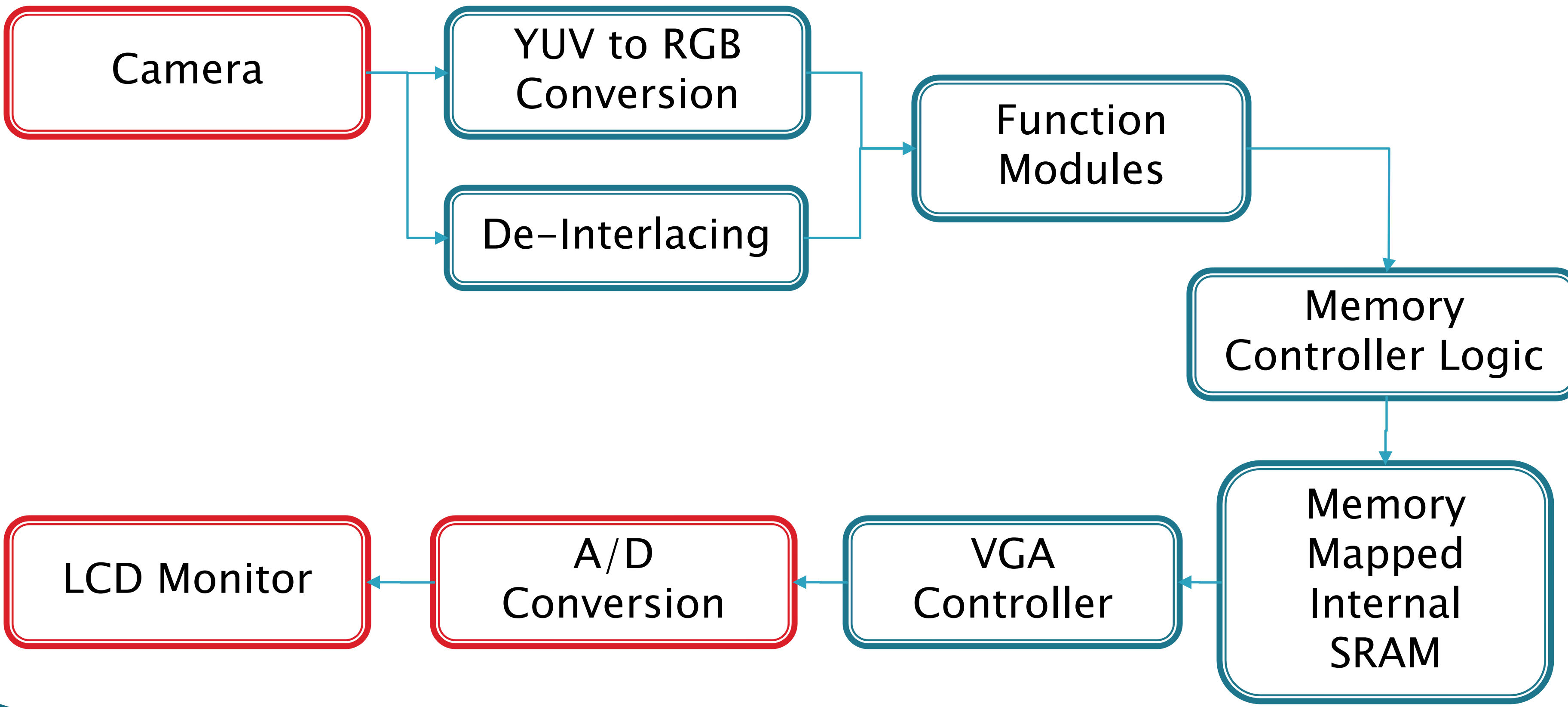
- C3188A Digital Camera with OV7620 image sensor

The C3188A Camera

- Direct connection to FPGA via group created header board, so no external driving circuitry needed.
- Default 16 bit YUV 4:2:2; Interlaced digital output
- 640x480 data output resolution
- Low power consumption



Video Processor overview



Design Decision – Platform (DSP vs. FPGA)

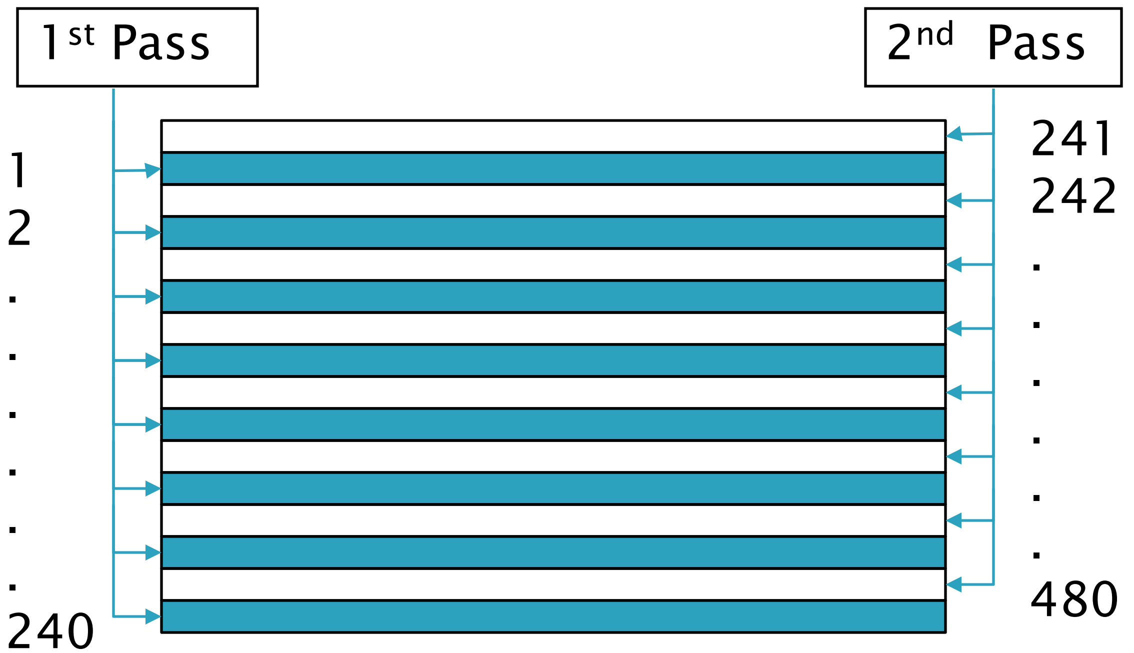
- FPGA
  - Scattered support of operations
  - Time-consuming implementation
  - Timing guarantees
  - Cheap development environments
- DSP
  - Strong compiler and tool-chain support
  - Fast linear multiply/add
  - Greatly simplify implementations of 2D transforms
  - No guarantee of timing/throughput

Video Processor Specs and Reqs

- Total process time will be designed for 30 fps of video output
- Pixel process time: <108ns
- Multiply/Add time <20ns
- Capable of Memory-mapping data (enough RAM for a frame of data)
- Capable of implementing Flip, Color Inversion, and Heat Map functions, as well as others

De-Interlacing

- To deal with the camera's interlaced output, we must allocate data to memory in an alternating fashion.



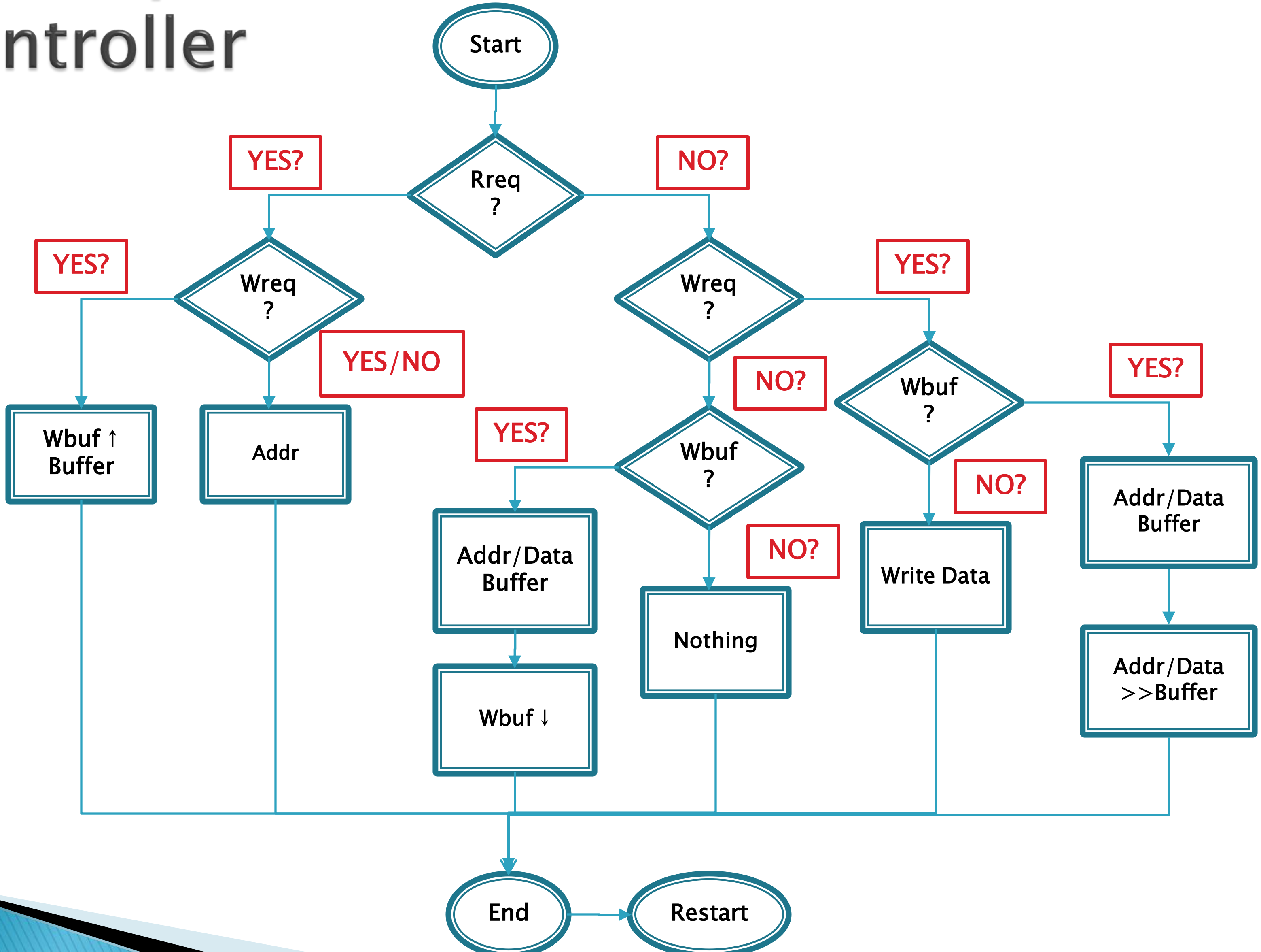
YUV to RGB conversion

- Standard we use for conversion is based on the following equations:
  - R = Y + 1.398*V
  - B = Y + 2.032*U
  - G = Y – 0.395*U – 0.561*V
- Due to technical constraints, our actual system implements these three equations instead:
  - R = Y + 1.5*V
  - B = Y + 2.0*U
  - G = Y – 0.5*U – 0.5*V

Functions

- Flipped Video Output
  - Vertical or Horizontal Flip
- Inverted Color Output
  - For both YUV or RGB
- YUV Heatmap Output
- Standard RGB Output

Memory Controller



Memory Mapping

- Addressing is done with 18 bits
  - X –> [0:640] which can be represented in 10 bits
  - Y –> [0:480] which can be represented in 9 bits
- Two memory chips, A and B, which chip enables CEA and CEB, respectively
- Addressing is implemented as a straight pipeline into memory, as such:

  ADDR[9:0] = X[9:0]

  ADDR[17:10] = Y[7:0]

  CEA = !CEB = Y[8]

VGA Controller

Sync Pulse Information for 640x480 VGA

Format	Pixel Clock (MHz)	Horizontal (in Pixels)				Vertical (in Lines)			
		Active Video	Front Porch	Sync Pulse	Back Porch	Active Video	Front Porch	Sync Pulse	Back Porch
640x480, 60Hz	25.175	640	16	96	48	480	11	2	31

- Given the memory address of the start of the frame
- Creates blanking pulses around the active video frame and creates Hsync and Vsync signals
- Outputs 4:4:4 RGB, Hsync, and Vsync to the Resistor ladder board

Digital to Analog Conversion

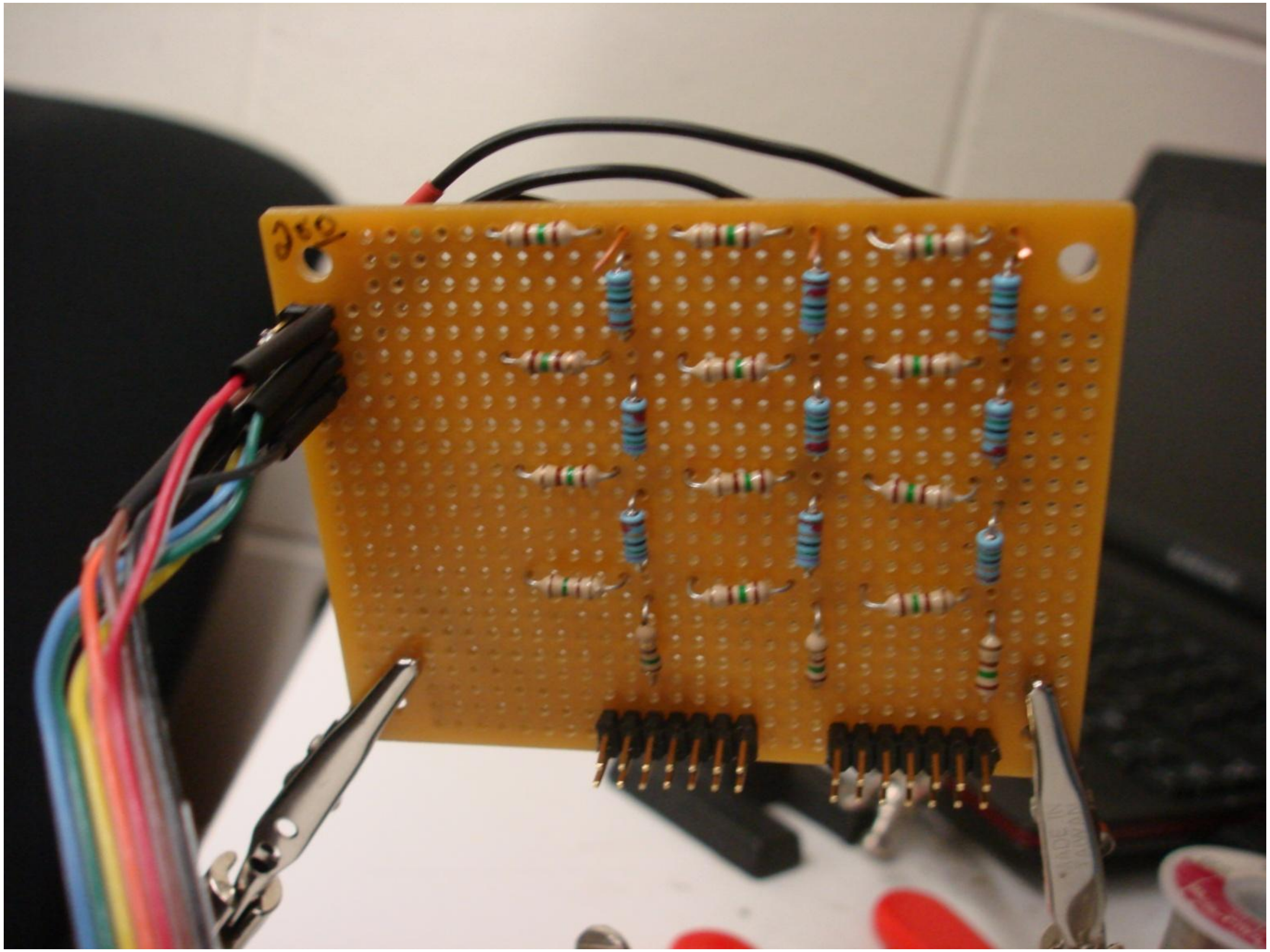
Problem

- Chosen FPGA has 3-bit VGA output, or 8 colors
- Need a VGA output capable of more color depth

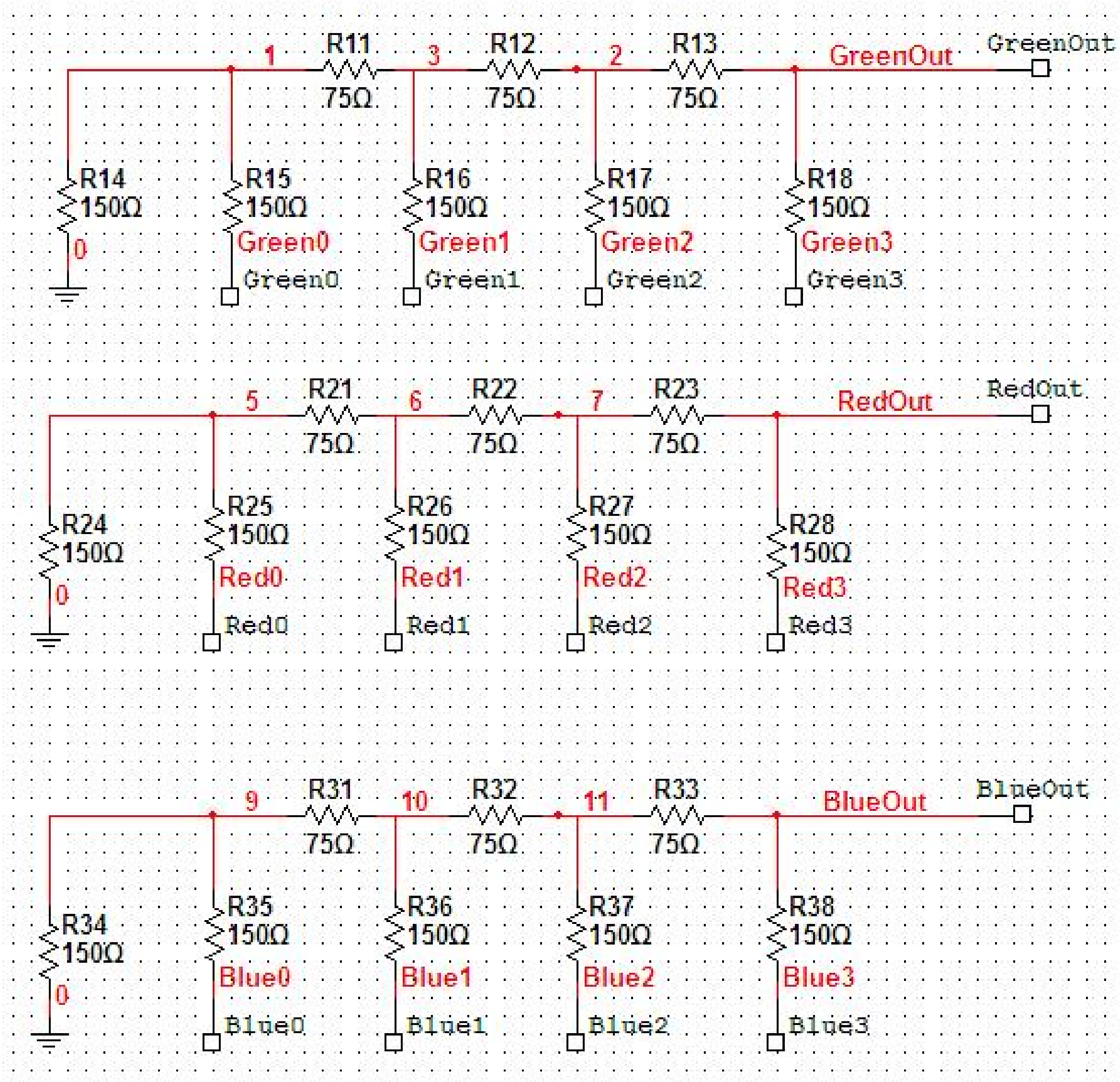
Solution

- Chose to build a three-tier resistor ladder to implement D/A conversion and a VGA port
- Each tier is a 4-bit ladder for each color channel that the Video Processor outputs: R, G, and B
- 4096 possible colors, tunable with potentiometers

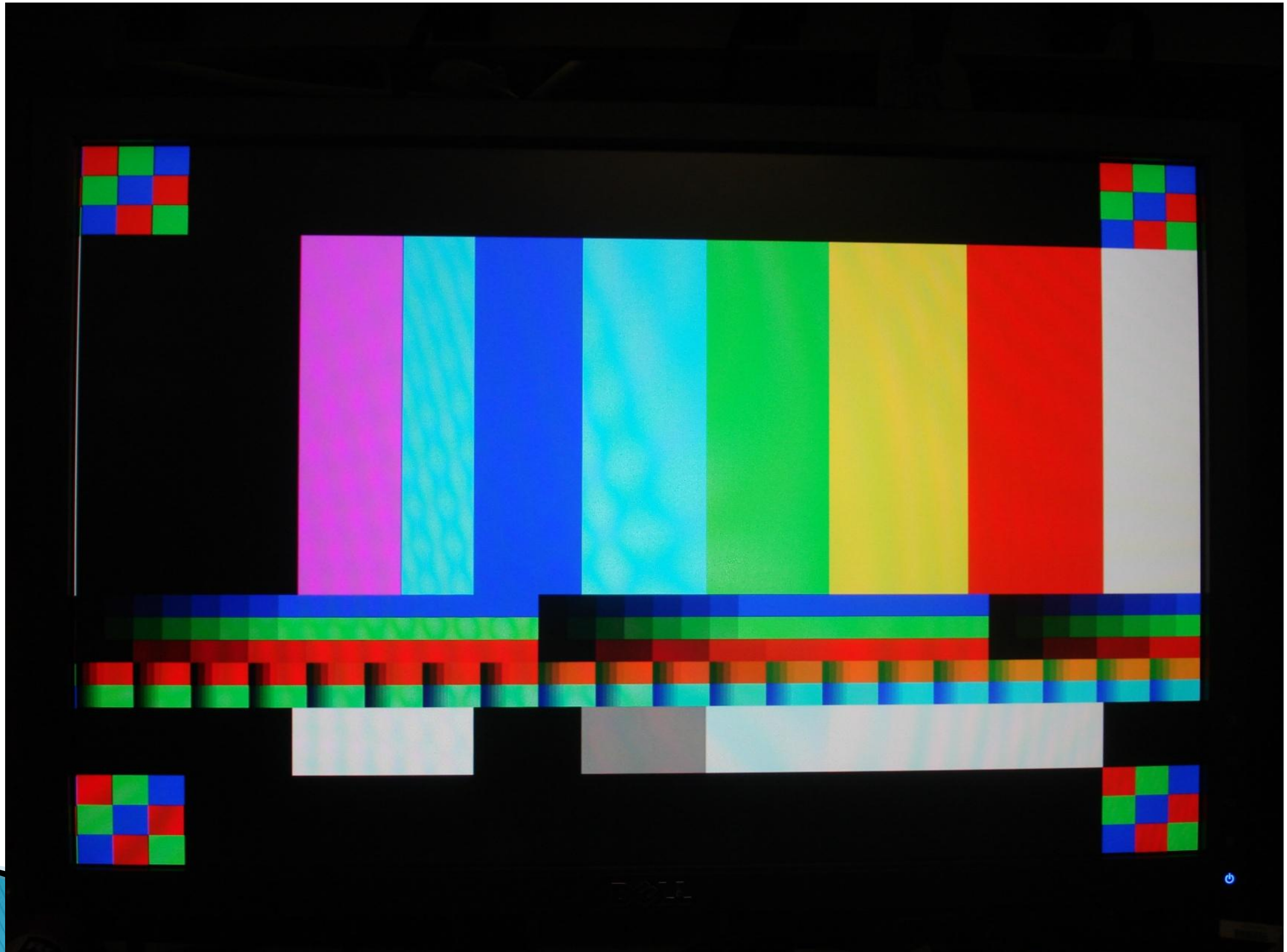
Resistor Ladder board



Output Resistance Ladder diagram



Output from Resistor Ladder



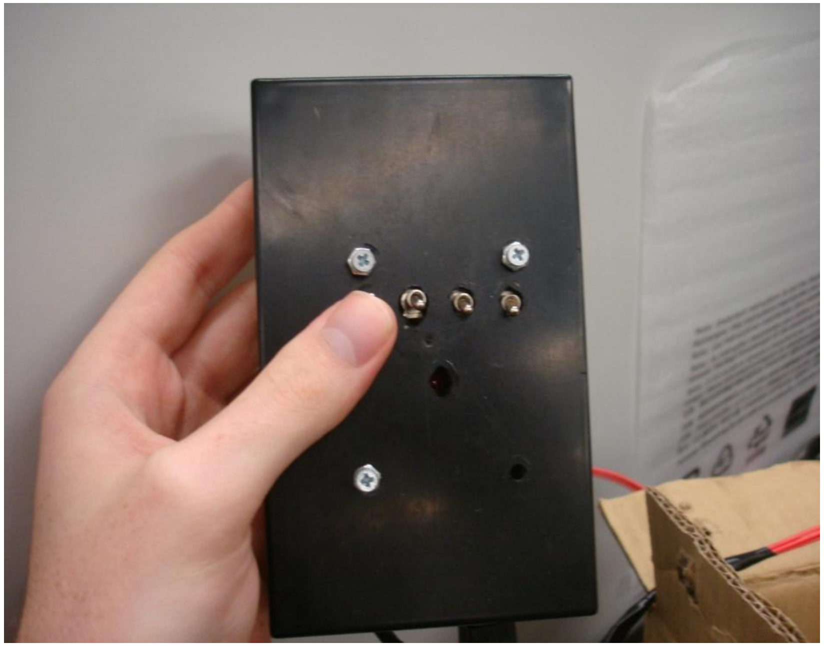
Display Specs and Reqs

- The unit's display system shall be capable of displaying at least 15 fps (30 preferred).
- The unit's display system shall be VGA compatible for easy interfacing.
- The unit's display system shall be mounted approx 6" from the user's face, and enclosed in a manner that allows the user to focus on the screen.
- The unit's display system will be capable of outputting a resolution of 640x480.

Design decision – Display Unit

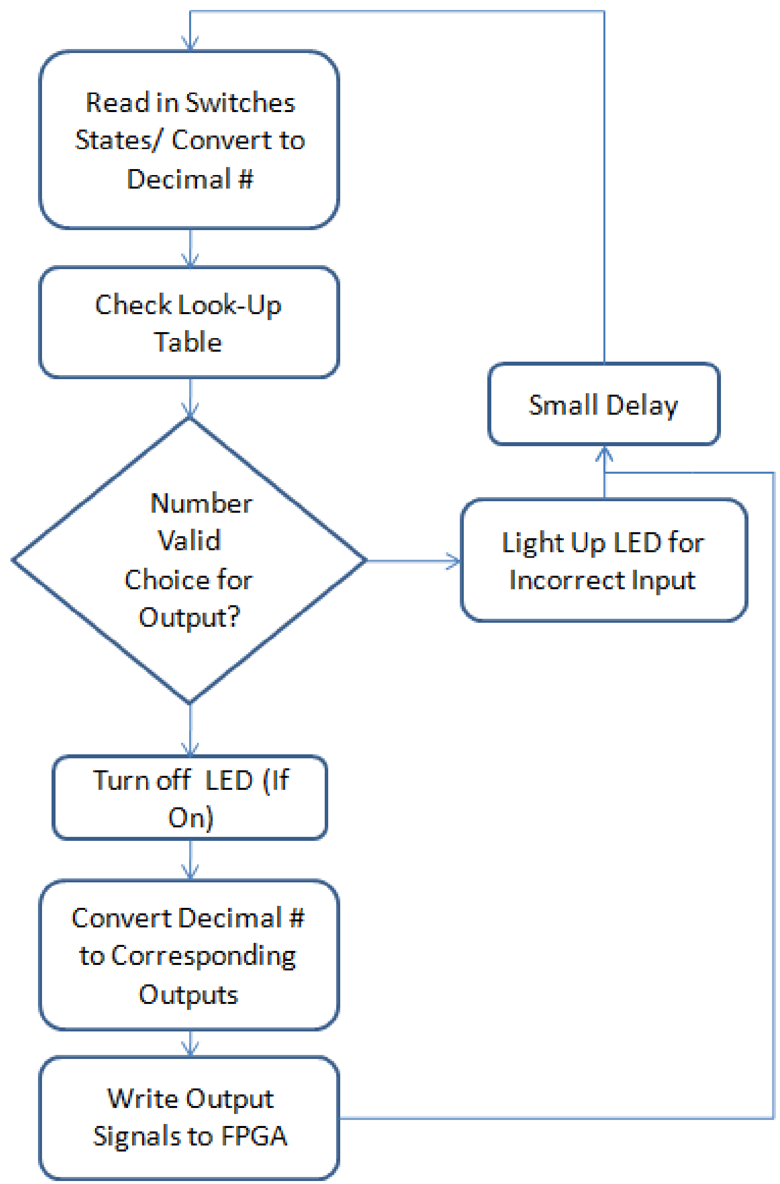
LCD Screen	Resolution	Connection	Price
Crystalfontz CFAF320240F-T	320x240	QVGA	$51.16
Sharp Microelectronics LS037V7Dw01	640x480	VGA/QVGA	$150+
SCPH-131 Sony Playstation	640x480	AV in	$55
Accelevision LCDP5VGA 5 Inch LCD Universal Monitor	640x480	VGA in	$160

UI Remote overview

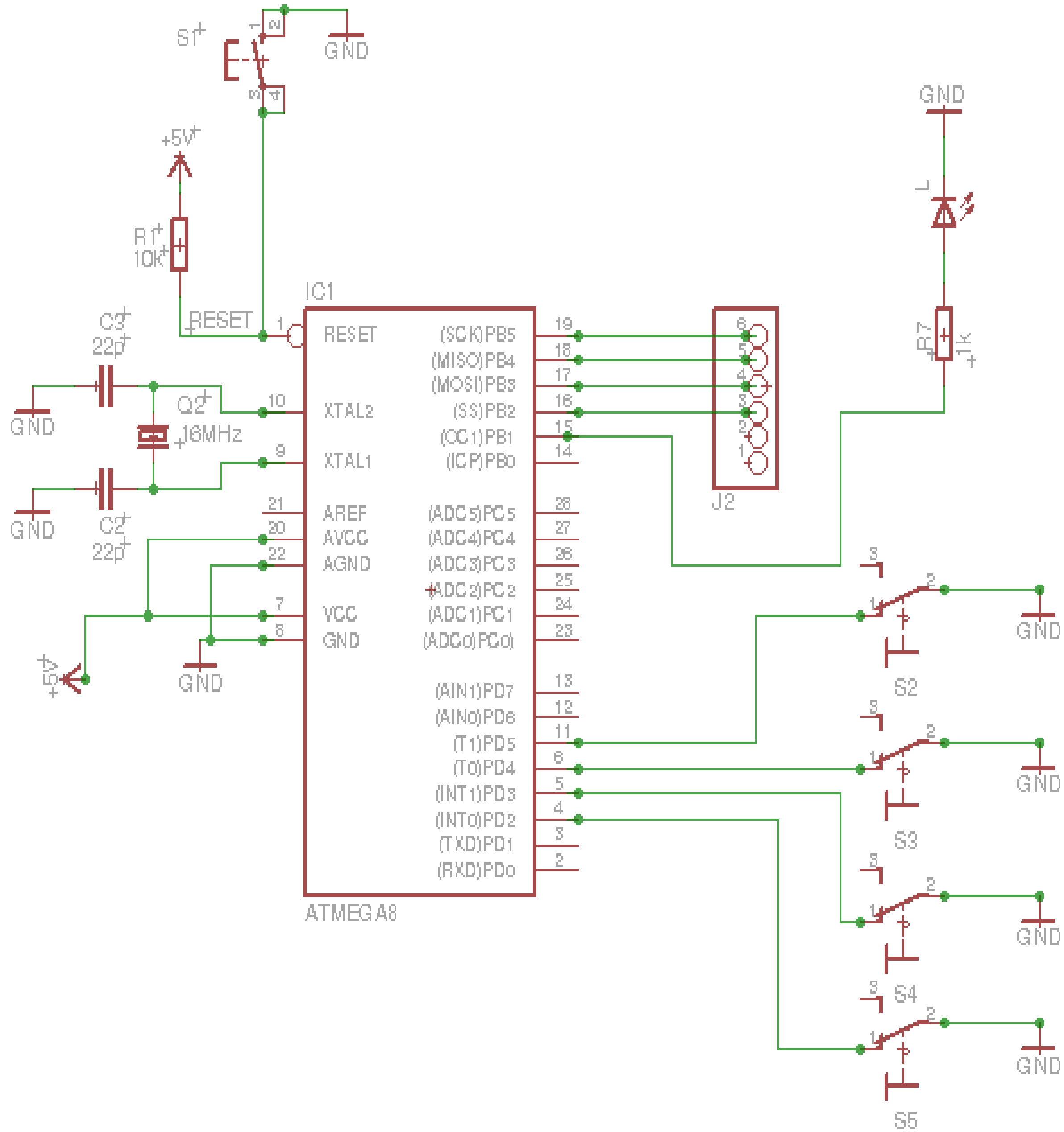


- Based on Arduino Duemilanove board
- Allows user to choose functions via 4 switches connected to the Video Processor.
- Disallowed function combinations show a red LED to the user.

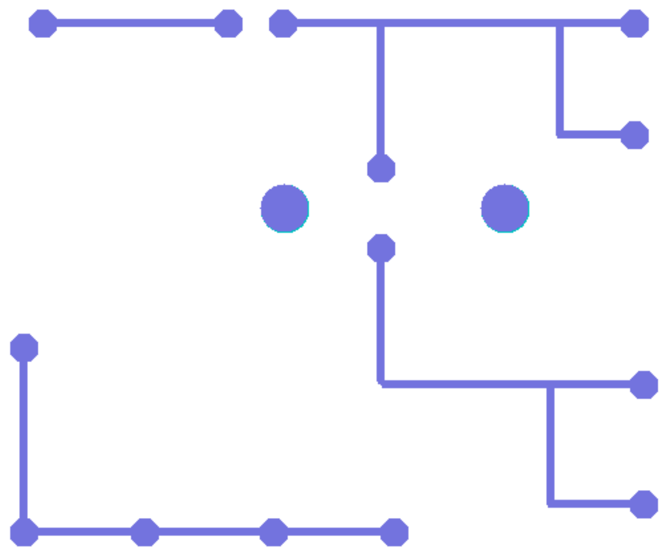
UI Remote Flow Diagram



UI Remote Schematic

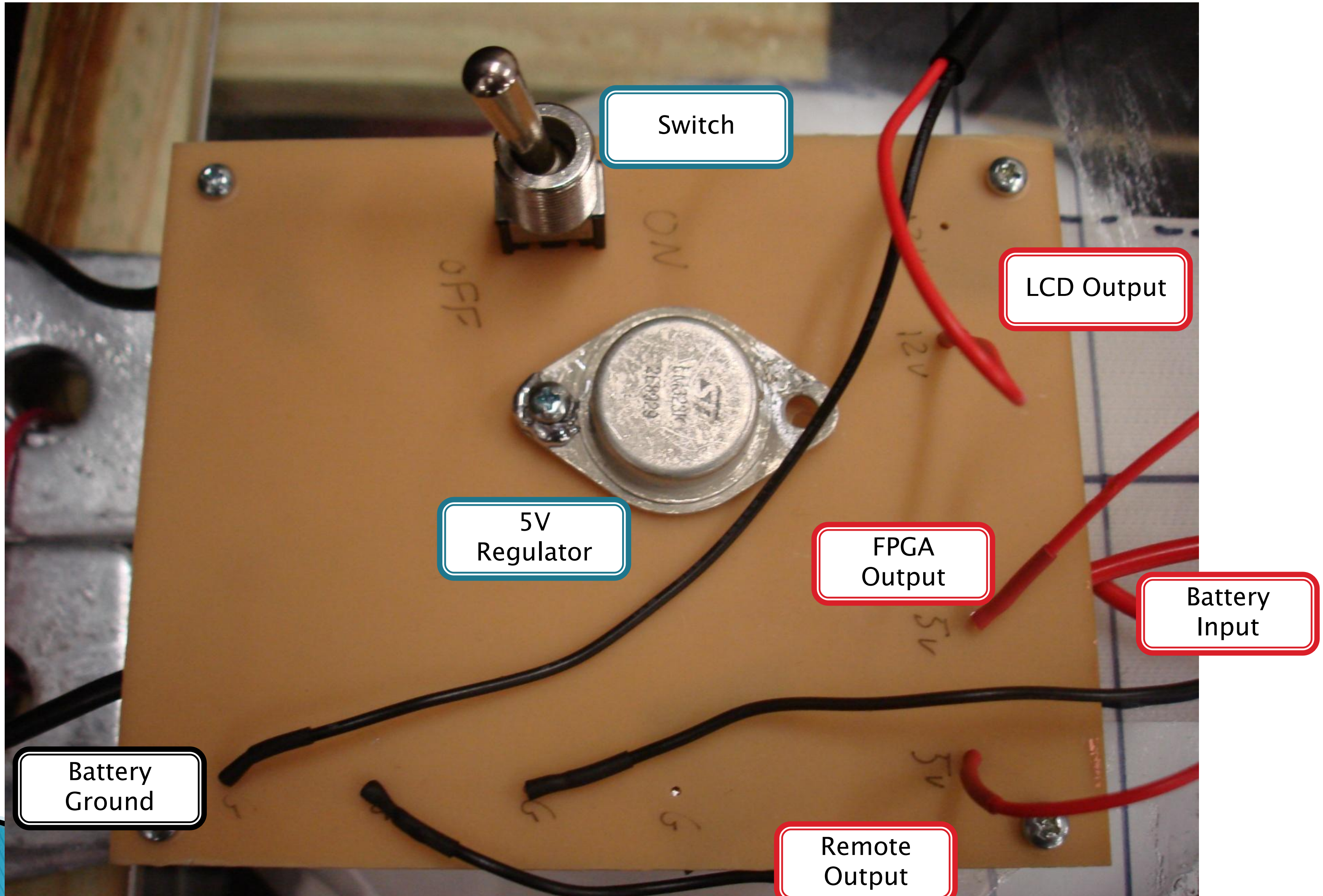


Power Board PCB design



- The board is used to route the various power inputs and outputs and hold the regulator and On/Off Switch
- Acid-etched the PCB with hydrochloric acid and hydrogen peroxide

Power Board front



Design Decision – Regulators

LMZ12003 evaluation board

- Surface mount
- Lower power consumption
- Replacement of surface resistors required

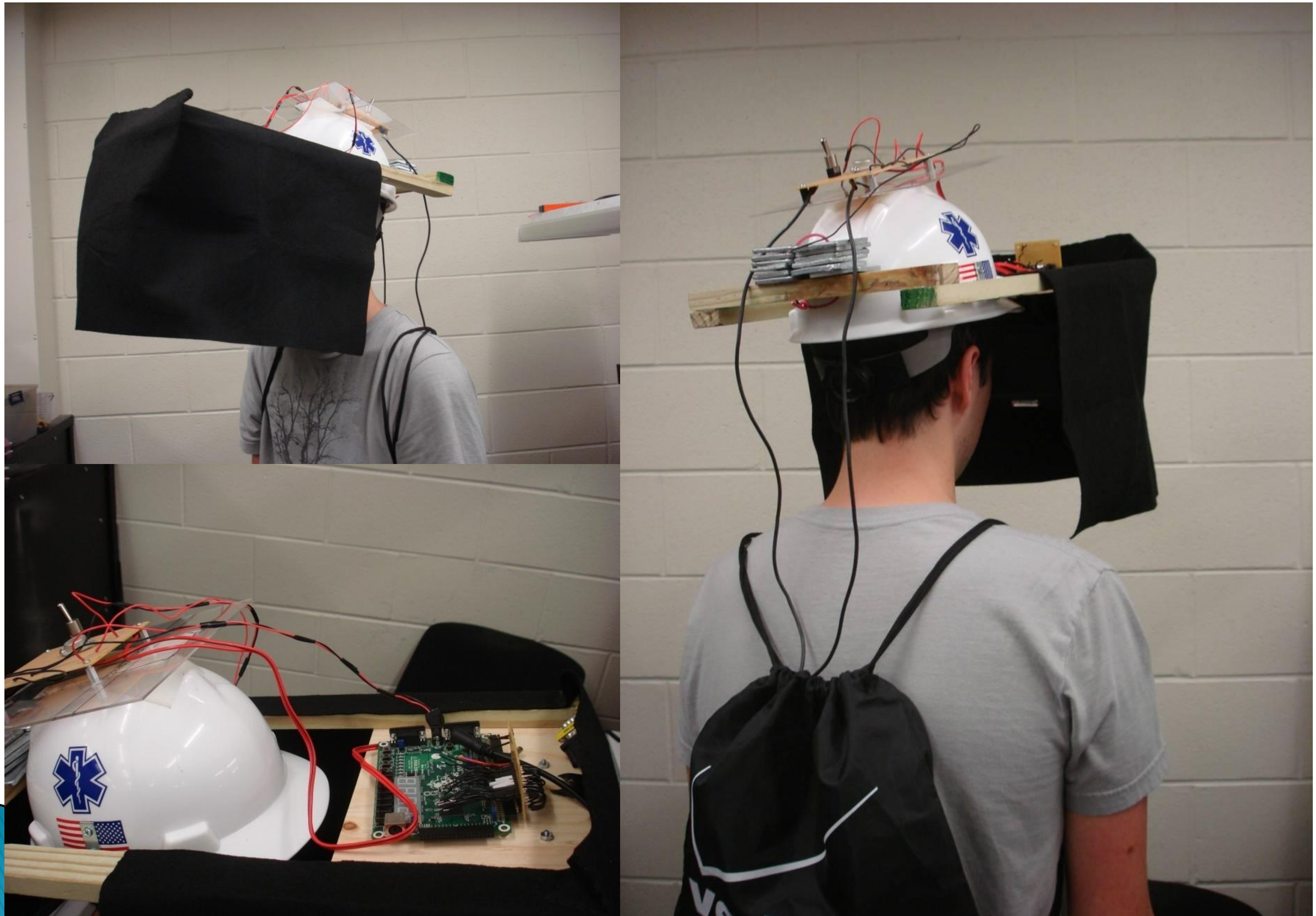
LM323K 5V regulator

- Through-hole mount
- Durable
- Easy to use
- Awkward ground on the case

Physical Distribution

- Battery in a small pack held on the user's back during use
- All electronics are routed through the helmet
- Camera stares ahead of the user
- Display is shown to user under the helmet shroud
- UI Remote is connected to Power Board and Video Processor

Complete System pictures



Final budget

Component	Cost
C3188A Camera	$57.00
Spartan 3 FPGA	$200.00
LCDP5VGA Monitor	$160.00
PS1270 Battery	$19.00
Power Board creation	$30.00
Helmet/Backpack creation	$20.00
Arduino Duemilanove	$30.00
Project Box (Remote)	$5.00
Battery Charger	$40.00
Resistor Ladder components	$12.00
Total Cost of Project:	$573.00

Major Challenges Faced

- Quite a few changes from SD1 design, including original cameras and FPGA.
- <u>Recent challenges include:</u>
  - Camera I2C functionality unusable due to unforeseen automatic register resetting.
  - Solution: Took camera data as-is, and reworked in Video Processor
  - Image Framing was very difficult to accomplish, due to lack of camera information and difficulties with I2C.
    - Solution: Added De-Interlacing, and performed lots of trial and error to get proper framing.

Major Challenges (Continued)

- Triple Channel 10-bit DAC working well for regular monitors, but pulls massive current out of the FPGA when using portable LCD.
  - Solution: Switched to resistor ladder for D/A conversion

- Camera burnout on the night of Wednesday, December 1, due to ground fault.
  - Solution: Ordered another C3188A camera overnight priority shipping

Conclusion

- Our group has learned the nature of design work, via several triumphs and many challenges and changes.
- Unforeseen issues near the end of the project has delayed further completion.
- The Z-Goggles project is still a work in progress, though many requirements set at the beginning were met.
- Future work would include: Better function operations, further error correction, infrared testing