Invisible Curtain

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1 Motivation

- Implement Chroma-keying on video stream relayed through a composite camera
- A red color foreground cloth is chosen
- When held before the camera, it gets masked to display the background
### Video Processing Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>SW [9:0]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invisible Cloak</td>
<td>0</td>
</tr>
<tr>
<td>Video OFF (for privacy)</td>
<td>1</td>
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<tr>
<td>Captured Background</td>
<td>2</td>
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<tr>
<td>Red Filter Video</td>
<td>3</td>
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<tr>
<td>Green Filter Video</td>
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<td>Blue Filter Video</td>
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<td>Grayscale Video</td>
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<td>Low Brightness Video</td>
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<td>High Brightness Video</td>
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</tbody>
</table>

KEY[0] → RST
2 Systems Architecture
3 NTSC

- Low resolution
- Auto-gain to adjust saturation
- Output data in YCbCr format
- Access from FPGA through ADV 7180

Color Format Used

- 16 bit YCbCr 4:2:2
- 24 bit YCbCr 4:4:4
- 10 bit RGB
Chromakey

SRAM → YCbCr(4:2:2 to 4:4:4) → YCbCrtoRGB

SDRAM

R_10bit[9:0], G_10bit[9:0], B_10bit[9:0]

R_3bit[2:0], G_3bit[2:0], B_3bit[2:0]

VGA Display

Input Colors in RED mask range?
Memory Management -I

Video Stream Buffer

→ YCbCr - 16 bit per pixel

→ 1 Frame = 16 x 640 x 480 = 4915200 bits ⇒ 600 KB but available only 512 KB in SRAM

SDRAM (4 - port)

→ Buffered each frame

→ Interlaced Write, Deinterlaced Read
Memory Management -II

Background Image

→ RGB - 3 bit per pixel, 3 channels

→ 1 Frame = 3 x 3 x 640 x 480 = 2764800 bits ⇒ 337.5 KB

→ Cannot use DRAM due to 2 port deinterlace logic ⇒ SRAM

SRAM

→ Store frame on RST

→ Read when Mask Enabled
Challenges

- Color Detection
  - Perfecting the threshold for detecting real-world red shades - varied lighting
- Memory Constraints in SRAM
  - Moved to SDRAM
- Handling aliasing artefacts
  - Accessing only Active Frame region using corrected HCount, VCount information to address pixel frame from memory
- SDRAM Synchronization
  - 3ns lead - PLL
  - Handling reads from 2 different memory areas – Background & Video Stream
What Could have been better? – Future Ideas

- Wider use of SDRAM ⇒ More bits for Background
- Connect to HPS – Software image processing + 1GB SDRAM
- Send video over network - Video Call (Ethernet camera)
Testing & Debugging

● Test Cases
  ○ Check Color Mask with different shades of Red
    ■ Expanded Color Range incrementally
  ○ Check if system works after reset - aliasing after reset
    ■ Resolved VGA → SRAM addressing issue
  ○ Background Storage - Isolating issue between camera & memory
    ■ Generated image in python and copied to SRAM
  ○ Test all
    ■ Covered possible video processing modes toggled through HW switches

Current_X = HCont-HBlank
Current_Y = VCont-VBlank
Addr = Current_Y*H_Active+Current_X
XBlank = XFront+XSync+Xback
Invisibility in action
Other features
Thank you for listening!
Open to Questions & Suggestions