Experiences Teaching an FPGA-based Embedded Systems Class

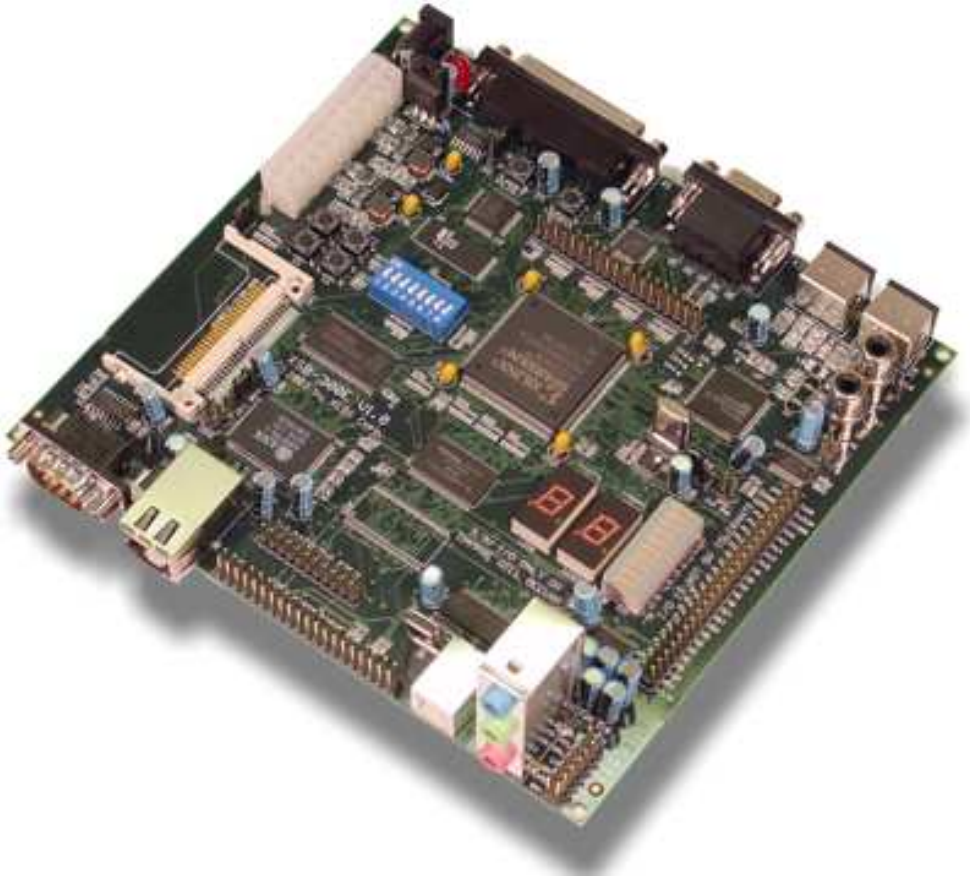
Stephen A. Edwards

Department of Computer Science,
Columbia University

www.cs.columbia.edu/~sedwards

sedwards@cs.columbia.edu

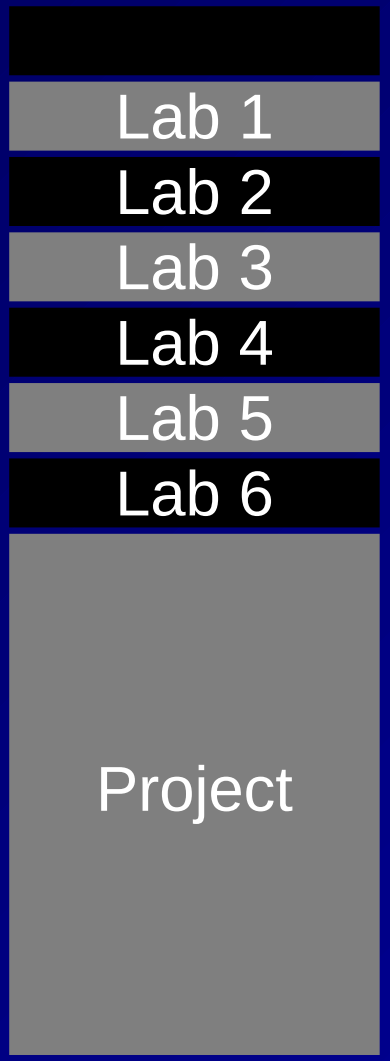
The Boards



XESS XSB–300E

Spartan IIE Starter

Course Structure



- Length: 14-week semester
- Goal: Hardware/software codesign in C and VHDL
- Tools: Xilinx ISE and EDK (Microblaze soft processor, OPB)
- Labs: teach the tools and how to code VHDL
- Projects: Design-your-own, groups of four

2004 Lab Assignments

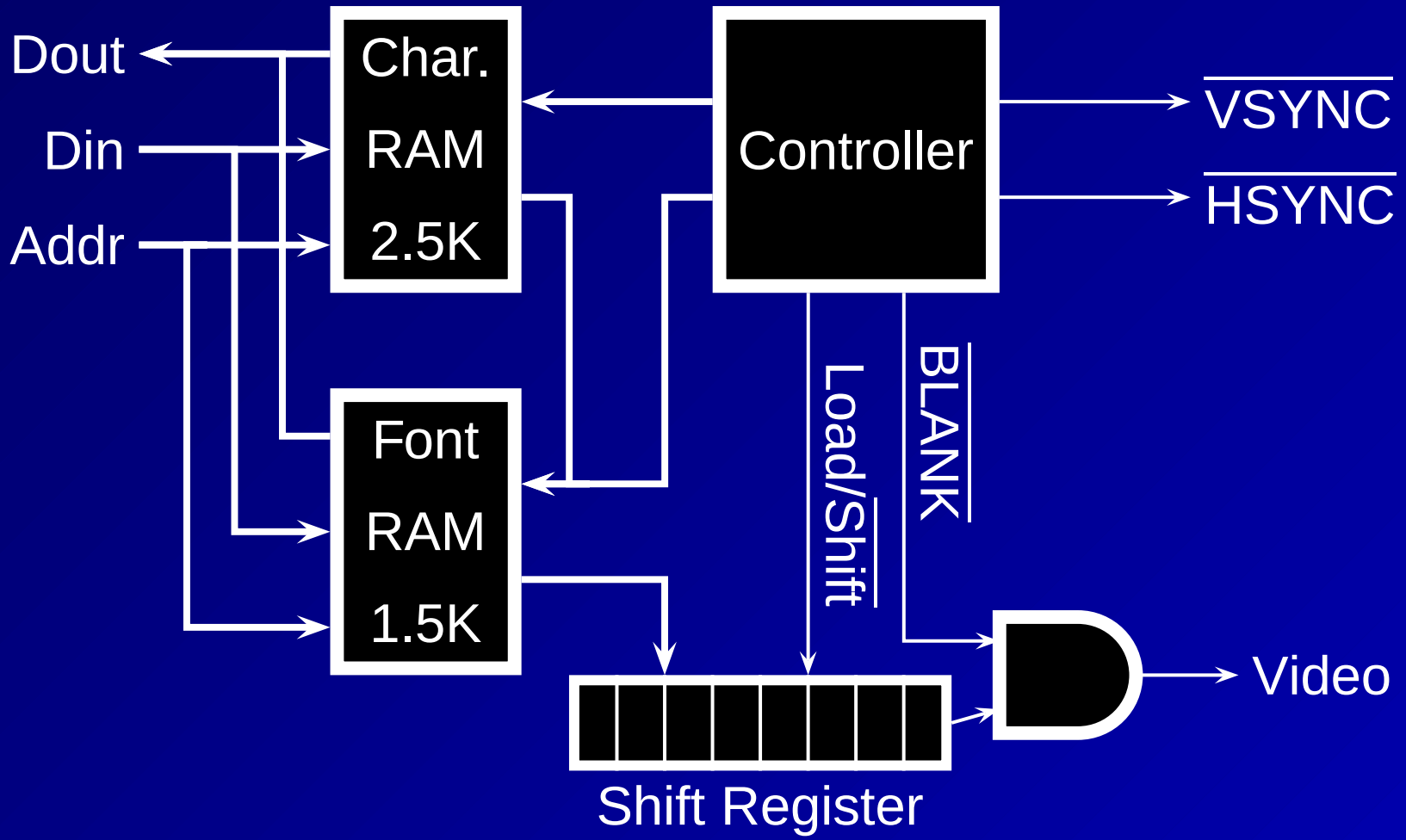
Assignment	Language
Count in decimal on 7-segment LEDs	C
Display “Hello world” using framebuffer	C
TV typewriter	C
Count in hex on 7-segment LEDs	VHDL
Make framebuffer display characters	VHDL
TV typewriter using character display	C & VHDL

2005 Lab Assignments

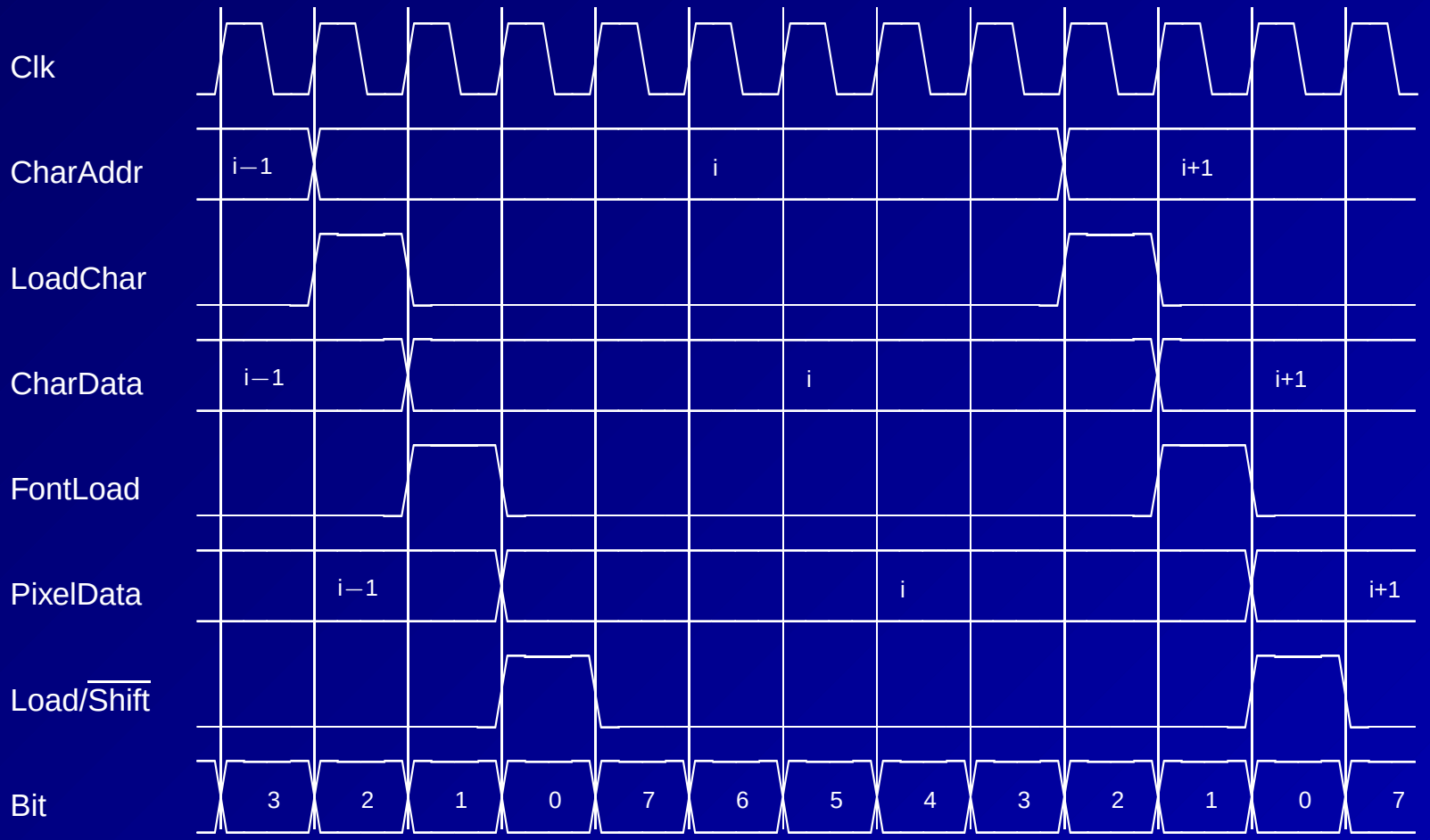
Assignment	Language
Count in decimal on 7-segment LEDs	C
Terminal emulator (video controller supplied)	C
Reverse-engineer some VHDL	drawings
Sum the contents of a memory	VHDL
Complex multiplier as OPB peripheral	VHDL
SRAM controller for OPB	C & VHDL

Disciplined Hardware Design

First: Block Diagrams



Second: Timing Diagram



Third: Code in VHDL

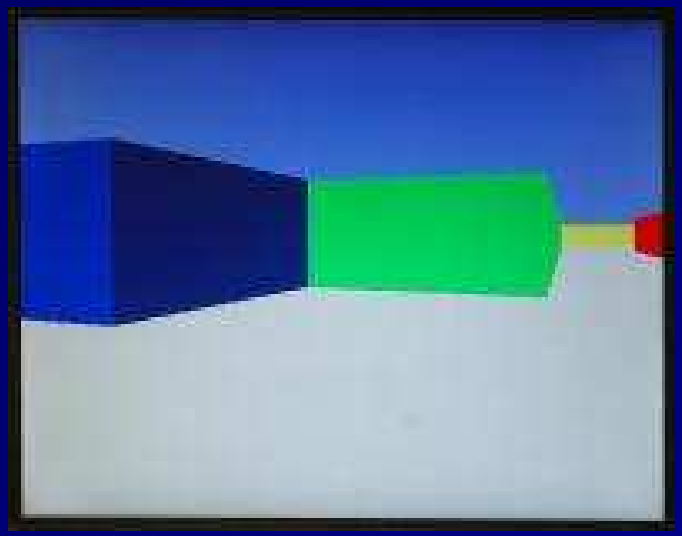
```
MemCycleFSM : process(OPB_Clk, OPB_Rst)
begin
  if OPB_Rst = '1' then
    MemCycle1 <= '0';
    MemCycle2 <= '0';
  elsif OPB_Clk'event and OPB_Clk = '1' then
    MemCycle2 <= MemCycle1;
    MemCycle1 <= ChipSelect;
  end if;
end process MemCycleFSM;

VGA_xferAck <= MemCycle2; -- OPB output

WE <= RamSelect when ChipSelect = '1' and
      RNW = '0' and OPB_Rst = '0'
      else "00000000";

RST <= not RamSelect when ChipSelect = '1' and
      RNW = '1' and OPB_Rst = '0'
      else "11111111";
```

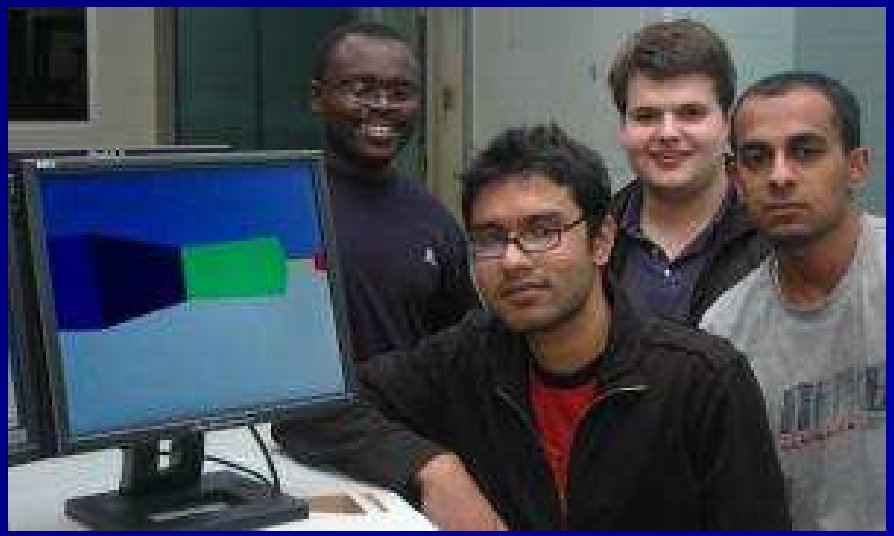
Nifty Projects

Project: Scorched Earth

Based on 1990s DOS game. Custom video hardware (terrain + sprites + text). Very popular.

Project: MAYD



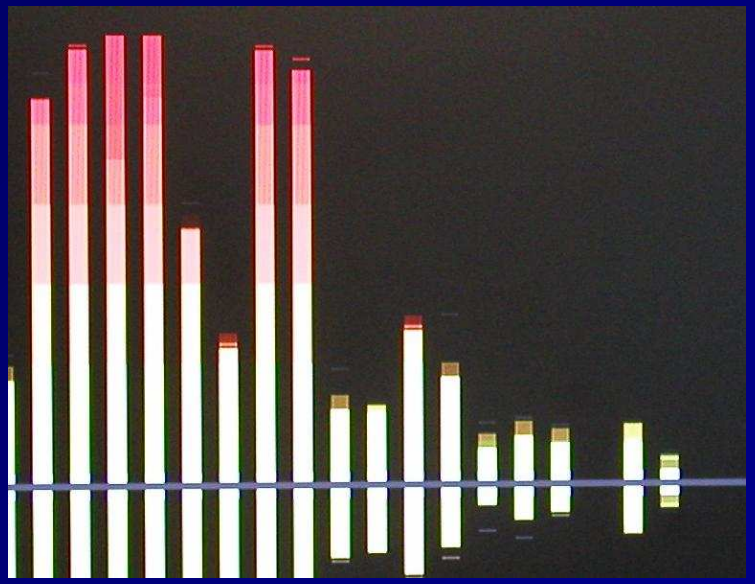


Simple raycasting-based game. Custom video hardware (sky + wall + floor). 20+ fps.

Project: JAYcam

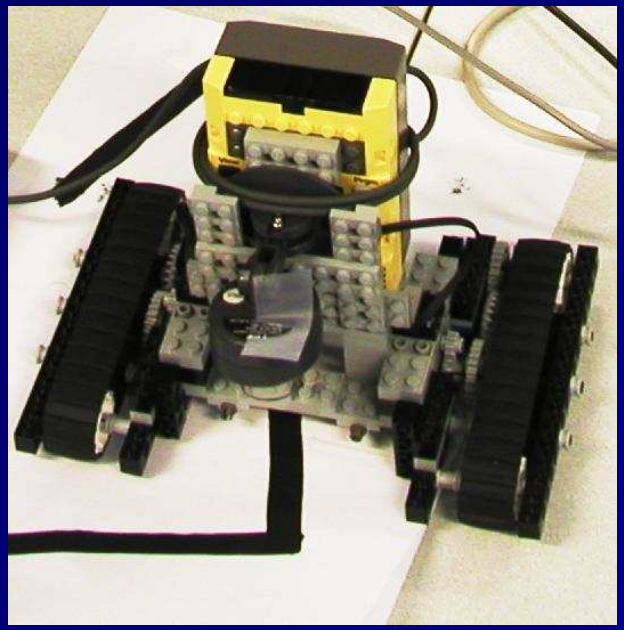
Internet video camera. NTSC video in, digitized, packetized, sent over UDP, displayed by Java program.

Project: Nortsam



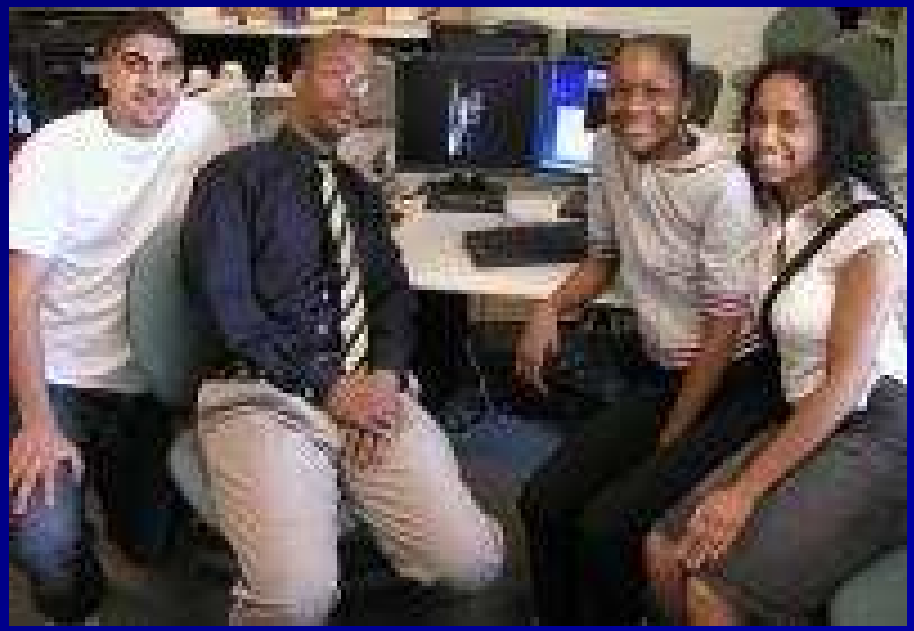
2048-point real-time FFT on 48 KHz stereo audio samples.

Project: Muddrover



Line-following Mindstorms robot with video vision.

Project: TAMF



Real-time video effects generator. Dynamically distorted still image.

Evaluation

“Experimental Results”

Columbia Course Evaluations

Question	2004	2005
Amount Learned	3.72	4.04
Appropriateness of Workload	3.33	3.64
Overall Quality	3.74	3.89

Numbers are averages, with 0=poor and 5=excellent.

Selected Comments from 2005

“Tough class but learned a great deal. Recommended.”

“I’d like to see a lecture that goes into more detail about the way that the various files definitions and programs are used to create the hardware. We end up learning it in pieces but a more detailed overview would be useful since the tools are a key component of understanding this class.”

“The lectures didn’t seem to serve as much help for the assignments and project.”

Conclusions

Definitely a work-in-progress

Steep learning curve on tools. Should they be the focus of the lectures?

Students accustomed to quick recompile & run times; leads to “jungle programming.”

One digital design course not enough preparation

Software vastly easier to create than hardware

Should we make it easier for them?

The Class Website

All slides, lab assignments, lab files, etc.

http://www1.cs.columbia.edu/~sedwards/