FPGA Music Project

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Biographic Info

- 2006 PhD, University of Michigan in Electrical Engineering
- 2003-2005 Statistical Physical Synthesis (EinsStat+PDS) at IBM TJ Watson
- 2000-2001 ASIC Consultant for National Semiconductor

Research in VLSI
- Physical Design
- Thermal-Aware Design
- Variation Tolerant Circuits

http://vlsida.soe.ucsc.edu/
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Hardware: The good and the bad

Why is hardware bad?
- Bugs are disastrous! Lots of time spent on verification.
- No upgrading, just replacing.
- It is expensive to make a (first) chip ($10k for old technology, $>1MM for new technology)

Why is hardware good?
- Fast (Several gigahertz, no software overhead)
- Parallel (Compute many pixels in parallel on a GPU)
- Low power (for example, video playback on PC versus iPod)
- Cheap (if you make a lot of them)

Processors
- Programmable through Instruction Set Architecture
- Can upgrade software, but not hardware.
- Expensive ($50 Core 2 Duo vs $0.50 Actel FPGA)
- Inefficient for power
Reconfigurable Logic

- Configurable Logic Block
  - FF memory
  - Small Truth Table

- FPGA (Field Programmable Gate Array)
  - Many, many CLBs
  - Configurable wires
  - Extra efficient memories (Block RAM)
Example FPGAs

Xilinx Virtex-4 FPGA
up to 200,000 Logic Cells

Actel ProASIC FPGA
15 k - 3 M Logic Gates
Acceleration

- **In-Socket FPGAs**
  - Hardware “on demand”
  - Replace 1 CPU in multi-CPU system
  - Uses
    - Medical imaging
    - Video/audio processing
    - Financial (e.g. Hedge Funds)
    - Security (Encryption/Decryption)

- **Peripheral FPGAs**
  - Accelerate certain functions
    - Could change the codec!
  - Plugs into any USB port
  - Uses
    - Video encoding
    - Others?

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XtremeData XD2000i
In-Socket Accelerator
http://www.xtremedatainc.com/

Elgato turbo.264,
USB stick H.264 encoder
http://www.elgato.com
Pure Data (PD)

- Simple GUI for audio (and video) processing
  - http://puredata.info
#include "m_pd.h"

static t_class *helloworld_class;

typedef struct _helloworld {
    t_object x_obj;
} t_helloworld;

void helloworld_bang(t_helloworld *x) {
    post("Hello world !!");
}

void *helloworld_new(void) {
    t_helloworld *x = (t_helloworld *)pd_new (helloworld_class);
    return (void *)x;
}

void helloworld_setup(void) {
    helloworld_class = class_new(gensym ("helloworld"),
        (t_newmethod)helloworld_new, 0, sizeof(t_helloworld),
        CLASS_DEFAULT, 0);
    class_addbang(helloworld_class, helloworld_bang);
}
Graphics Environment for Multimedia (GEM)

- External for PD for graphics
Interfaces

• Laser harp
  • Not velocity sensitive
• Monome
  • Not velocity sensitive
  • Restrictive digital interface
• Touch screen?
  • iPhone over network is out
CMPE 100 Basic System Board (BASYS)

- Xilinx Spartan 3E FPGA
  - 100k or 250k gates
  - Free software to program it (Xilinx Webpack ISE)
  - Only $59!
  - Probably not big or fast enough
• Xilinx Spartan-3E FPGA
  • 500K or 1200K gate, but only 50Mhz
  • VGA, external DAC
  • $99
- Xilinx Virtex®-5 XC5VLX110T
  - Stereo AC97 codec
  - Ethernet, VGA
  - Heat sink
  - $750
PD-FPGA Ideas

• Interface Device
  • Create MIDI interface with FPGA-decoding and HW level converters
    • Not too hard, in addition to acceleration below
  • Create a new input device (e.g. touch screen)
    • Virtual Mixer board & do digital mixing on FPGA
    • Control pitch & volume & do synthesis on FPGA

• PD External enhancements
  • High sampling rate audio output (24-bit @ >96k for recording)
  • High quality reverb, delay, chorus, etc.
  • Digital Equilizer/Mixer
  • Real-time lossless compression for recording
Idea 1: MIDI sound module
Idea 2: Multitouch Synth

Config Screen

- EQ
- Reverb
- Flange
- Distortion
- Attack
- Sustain
- OSC1
- OSC2
- OSC3
- OSC4

Instrument Screen

- Pitch
- Volume
- Inst1
- Inst2
- Inst3
- Inst4
- Record?

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What is involved

• Writing DSP algorithms in Verilog
  • Oscilate, FFT, Mix, Reverb, etc.

• Interfacing to touch display
  • To VGA
  • From touching

• Trading off hardware for DSP verses general CPU
  • Virtex-5 has embedded PowerPC cores
  • Writing graphics routines is non-trivial
  • Embedded Linux OS?
More Info

- **Spartan 3E Synth**
  - [http://www.fpga.synth.net/](http://www.fpga.synth.net/)
- **Opencores**
  - [http://www.opencores.org/](http://www.opencores.org/)
- **FPGA Boards**
Budget

- $1000
- I can get FPGA boards for free
  - Xilinx or Altera
  - Speed, size, etc.
- I have an old MIDI controller
  - Kawai K1
- Touch screen
  - 17” USB is ~$300 USB
  - 15” 5-wire proprietary is $81
- Digital-Analog Converters
  - 24-bit for CD quality