Fundamentals of Reconfigurable Computing

(ECGR6890)

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Course Outline

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Overview

Or, *What the heck is Reconfigurable Computing?*

What Is Reconfigurable Computing?

- ***reconfigurable computing*** — study of computing systems that incorporate user-programmable switches to determine functionality or architecture
- RC is seven less syllables
- in contrast, conventional computing systems use devices that
  - are fixed at manufacture
  - and have their function is pre-determined

Conventional Computing

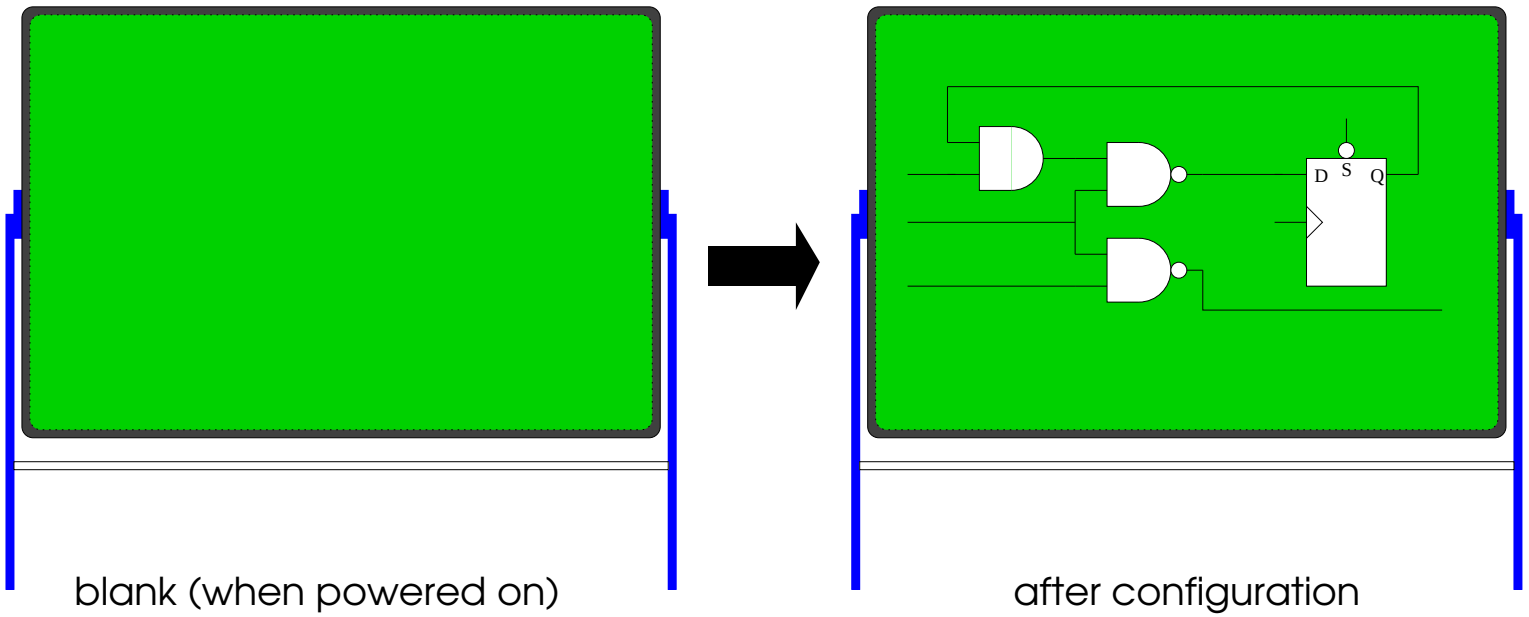
Contrast this with conventional computer architectures:

- von Neumann (EDVAC) introduced the first well-known computer architecture
  - stored program
  - sequential execution
- Harvard architecture
  - separated memory for code and data
  - (still) sequential execution

Most Common Technology for RC

- system composed of microprocessor(s) and Field-Programmable Gate Array(s) (FPGAs)
- ***FPGA*** — an Integrated Circuit (IC) that whose functionality can be configured in the field; i.e., its functionality can be determined after it has already been manufactured and soldered into a product
- many different ways to combine these components but for now envision the abstract picture

10,000-Meter View of An FPGA



FPGA is a blank slate that can be programmed to do almost any digital circuit

Other Configurable Technology

- FPGA-like technologies (CPLDs and other PLAs)
- Coarse-Grain Reconfigurable Arrays (CGRA)
- Polymorphic Computing Architectures (TRIPS, Raw, Monarch)
- Conventional Processor + Configuration Switches

RC Synonyms

- as with any new field (FPGAs are 20 years old) – different names emerge
- other names for the field:
  - custom computing machines (CCMs) (SRC)
  - configurable computing machines (VT)
  - Fixed+Variable (F+V) (Estrin)
  - Field-Programmable ...

What does the 'RE' in Reconfigurable Mean?

- two broad classes of Reconfigurable Computing machines based on when the switches are configured
  - ***Compile-Time Reconfiguration*** (CTR) — the architecture is defined before the application begins and remains fixed throughout the execution
  - ***Run-Time Reconfiguration*** (RTR) — the architecture is initially defined before the application begins but may change during execution

Conventional Computing Terms

- ***hardware*** — the electro/mechanical machine (the physical components of a computing system)
- ***software*** — the information that specifies the behavior of a computing system
- ***program*** (n) — the expression of software
- ***programming*** (v) — the act of creating a program

Reconfigurable Computing Terms

in programmable logic device, the behavior of the chip is specified like software but we use different terms:

- ***design*** — the information that specifies the behavior of a reconfigurable system
- ***configure*** (v) — transfer of a design to a reconfigurable device

Confusing Terms/Dual Meaning

- ‘program’ (v) is sometimes used a synonym for ‘configure’ as in...

  I am programming (configuring) the chip now.

- ‘design’ is short for *hardware design* and sometimes ‘hardware’ is subtituted for ‘design’ as in...

  Here’s the hardware part of my reconfigurable system.

RC Application Areas

- concisely: the very small and the very large
  - embedded computing systems
  - high-performance computing systems
- in other words: constrained systems

Embedded Computing Systems

- highly integrated: implement peripherals on chip plus customized operations
- replace traditional digital signal processing
- increasingly networked (support for different communication protocols)

Embedded Examples

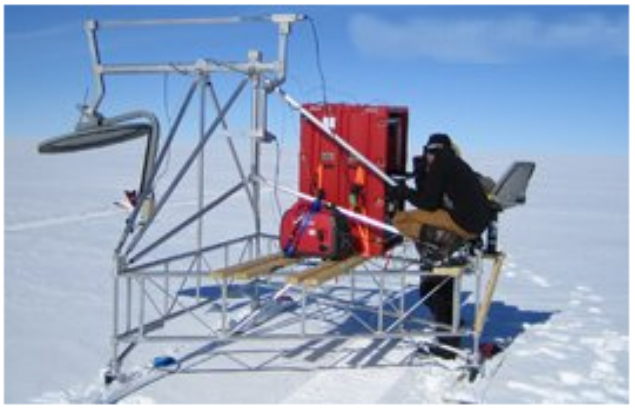
- soft radio

Embedded Examples

- soft radio
- Mars rover expeditions

Embedded Examples

- soft radio
- Mars rover expeditions
- measuring polar sheet ice depth



Embedded Examples

- soft radio
- Mars rover expeditions
- measuring polar sheet ice depth
- digital cameras

High-End Computing (HEC) Systems

- "hardware is faster than software" is a fallacy while it is not always true – a lot of times it is!
- processor-level parallelism
- power, space constrained systems

HEC Examples

- earliest machines
  - Splash-2
  - PAM
- contemporary supercomputing companies
  - Silicon Graphics (RASC)
  - Cray (XD-1)
  - SRC (SRC-6)
- research machines (Reconfigurable Computing Cluster)

Advantages of RC Technology

custom architectures have a number of big advantages:

- specialization produces more efficient (faster) circuits; especially if specialization occurs at run-time*
- less energy is spent on work that doesn't contribute to the solution
- trading space for time allows for lower clock rates and more energy efficient circuits
- smaller physical space; time-multiplexing offers greater gains*

*requires Run-Time Reconfiguration

Disadvantages of RC Technology

Sounds great, eh!? flexibility comes at a cost

- every circuit in an FPGA has a longer propagation delay
- automated tools are much less efficient that custom-designed CMOS
- Law of Diminishing Returns (Amdahl's Law) limitations
- I/O bandwidth can easily become the limiting factor

Summary

Net result:

- FPGA implementations incur a 10× to 100× penalty
- To get a performance improvement, one has first overcome this gap before we make gains on standard processor architectures

Outline for Today

- Introduction to Reconfigurable Computing (done :-)
- Mosaic Linux / Our Tools
- Review of Digital Systems