ELEC2041

Microprocessors and Interfacing

Lecture 1: Introduction

http://webct.edtec.unsw.edu.au/

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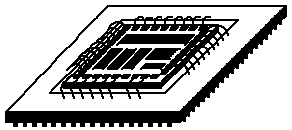
Integrated Circuits (2003 state-of-the-art)

Bare Die

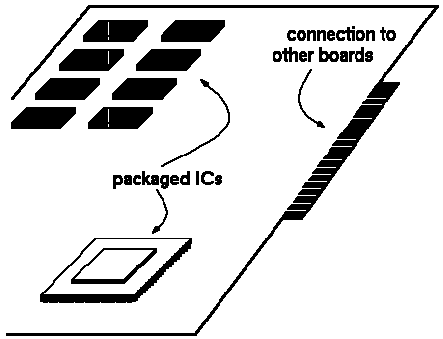
- Primarily Crystalline Silicon
- 1mm - 25mm on a side
- 2003 - feature size ~ 0.13μm = 0.13 x 10^{-6} m
- 100 - 400M transistors
- (25 - 100M "logic gates")
- 3 - 10 conductive layers
- "CMOS" (complementary metal oxide semiconductor) - most common.

Chip in Package



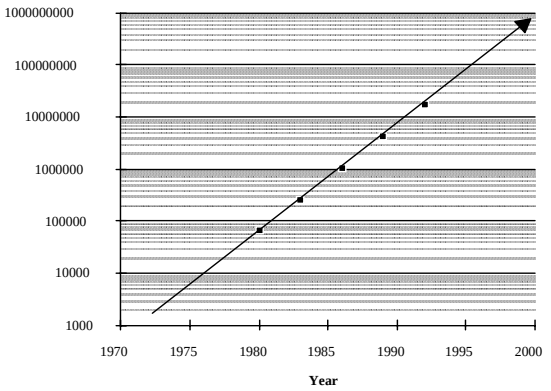
- Package provides:
  - spreading of chip-level signal paths to board-level
  - heat dissipation.
- Ceramic or plastic with gold wires.

Printed Circuit Boards



- fiberglass or ceramic
- 1-20 conductive layers
- 1-20in on a side
- IC packages are soldered down.

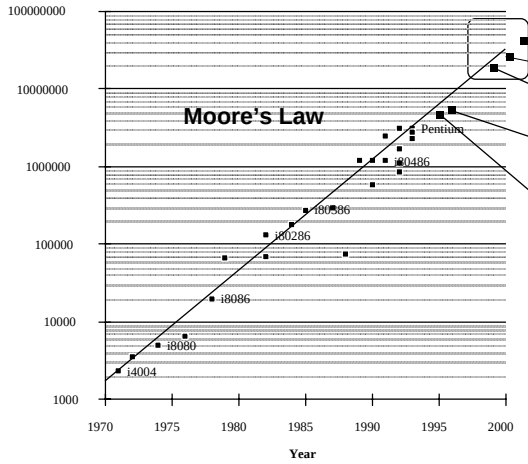
Technology Trends: Memory Capacity (Single-Chip DRAM)



year	size (Mbit)
1980	0.0625
1983	0.25
1986	1
1989	4
1992	16
1996	64
1998	128
2000	256
2002	512

- Now 1.4X/yr, or 2X every 2 years.
- 8000X since 1980!

Technology Trends: Microprocessor Complexity

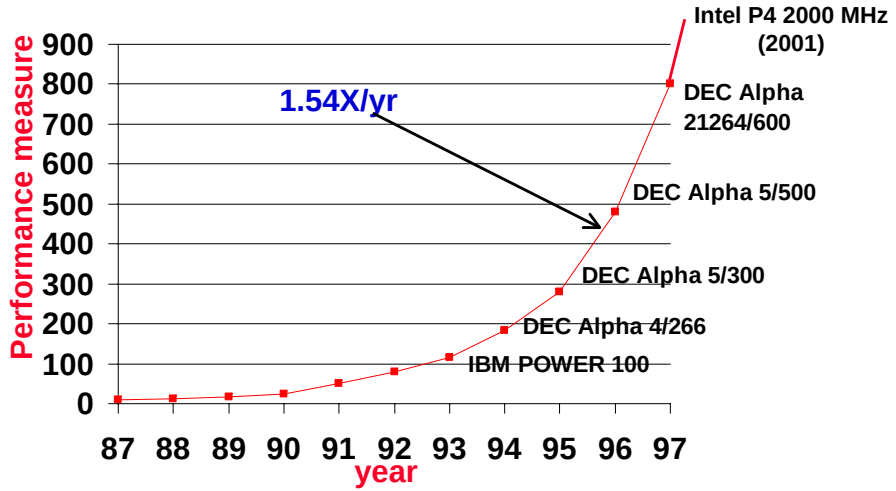


Itanium 2: 410 Million
Athlon (K7): 22 Million
Alpha 21264: 15 million
Pentium Pro: 5.5 million
PowerPC 620: 6.9 million
Alpha 21164: 9.3 million
Sparc Ultra: 5.2 million

2X transistors/Chip Every 1.5 years

Called "Moore's Law"

Technology Trends: Processor Performance



We'll talk about processor performance later on…

Computer Technology => Dramatic Change

- Processor
  - 2X in speed every 1.5 years; 100X performance in last decade
- Memory
  - DRAM capacity: 2X / 2 years; 64X size in last decade
  - Cost per bit: improves about 25% per year
- Disk
  - capacity: > 2X in size every 1.0 years
  - Cost per bit: improves about 100% per year
  - 250X size in last decade

Computer Technology - Dramatic Change!

- State-of-the-art PC when you graduate: (at least…)
  - Processor clock speed: 5000 MegaHertz (5.0 GigaHertz)
  - Memory capacity: 4000 MegaBytes (4.0 GigaBytes)
  - Disk capacity: 2000 GigaBytes (2.0 TeraBytes)
  - New units! Mega => Giga, Giga => Tera

(Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta = 10^{24})

Kilo, Mega, etc. are incorrect Terminologies!

Putting it all in perspective…

"If the automobile had followed the same development cycle as the computer, a Rolls-Royce would today cost $100, get a million miles per gallon, and explode once a year, killing everyone inside."

– Robert X. Cringely

Technical Writer, Broadcaster and Computer Guy

http://www.pbs.org/cringely/about/

Triumph of the Nerds

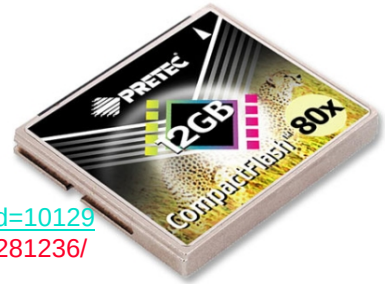
A history of the PC industry.

An ABC program a few years ago

Technology in the News

° BIG
- LaCie the first to offer consumer-level 1.6 Terabyte disk!
- ~$2,000
- Weighs 11 pounds!
- 5 1/4" form-factor

° SMALL
- Pretec is soon offering a 12GB CompactFlash card
- Size of a silver dollar
- Cost? > New Honda!



www.lacie.com/products/product.htm?id=10129

www.engadget.com/entry/4463693158281236/

Technology in the News

IBM Reclaims Supercomputer Lead

IEEE Spectrum Feb 2005

32,768 processors;

8 terabytes of memory;

28 terabytes of disk storage;

70.72 teraflops (trillion floating-point operations per second).

Linux and custom operating system

Challenges for 21st Century

° PostPC Era will be driven by 2 technologies:

1) Mobile Consumer Devices
- e.g., successor to cell phone, PDA, wearable computers

2) Massive I/O interfacing vs RAW computational power

Why Study Microprocessor Design?

- It's exciting!; It has never been more exciting!
- It impacts every other aspect of electrical engineering and computer science

Bionics:
Sensors in latex fingers instantly register hot and cold, and an electronic interface in his artificial limb stimulates the nerve endings in his upper arm, which then pass the information to his brain. The $3,000 system allows his hand to feel pressure and weight, so for the first time since losing his arms in a 1986 accident, he can pick up a can of soda without crushing it or having it slip through his fingers. *One Digital Day*

Only Sociology graduates help real people?

Why Study Microprocessor Design?

Sony Playstation 2000

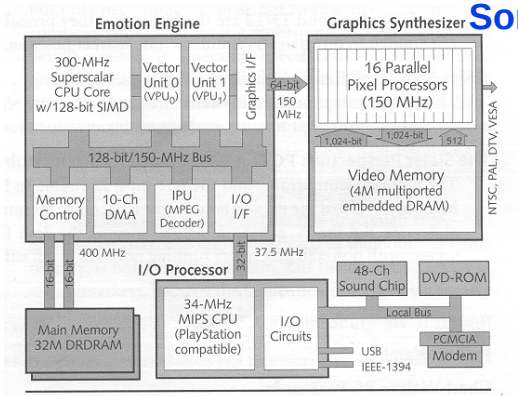


Figure 1. PlayStation 2000 employs an unprecedented level of parallelism to achieve workstation-class 3D performance.

Figure 2. PlayStation 2000 screenshot. (Source: Namco)

- (as reported in Microprocessor Report, Vol 13, No. 5)
  - Emotion Engine: 6.2 GFLOPS, 75 million polygons per second
  - Graphics Synthesizer: 2.4 Billion pixels per second
  - Claim: *Toy Story* realism brought to games!

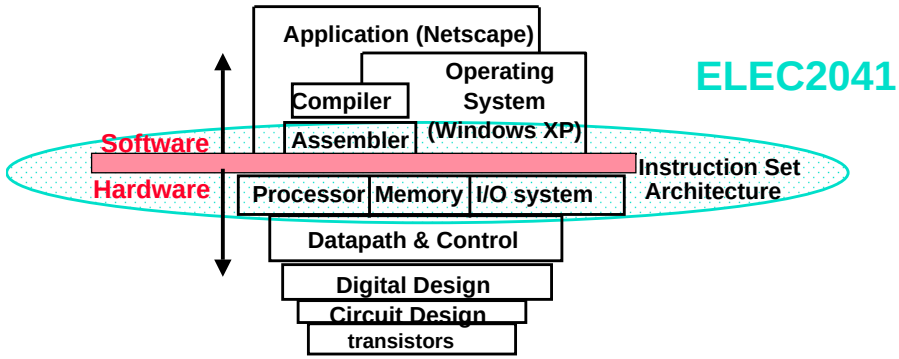
Why Study Microprocessor Design?

Putting Move back into Movies

- The ZVUE lets you walk around with a movie, TV show, or music video on its 2.5 inch display.
- Dazzling clarity
- Comes with SD card with up to 250 MB @ roughly 1 min/MegByte
- Uses a 100 to 1 compression scheme
- 75-gram unit plays up to 8 hrs on 4 AA batteries
- US $99

Ieee Spectrum oct. 2003 http://www.zvue.com

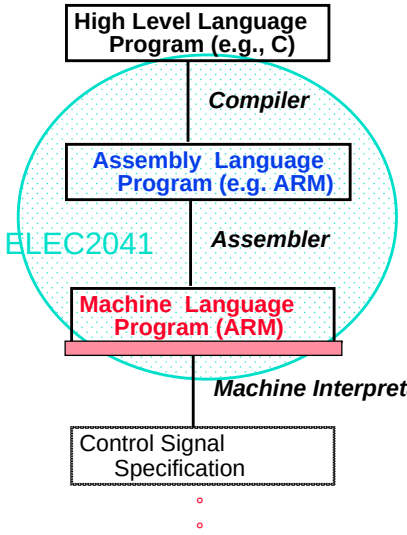
What is Subject about?



ELEC2041

- Coordination of many *levels of abstraction*

Programming Levels of Representation




```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
ldr  r0 , [r2, #0]
ldr  r1 , [r2, #4]
str  r1 , [r2, #0]
str  r0 , [r2, #4]
```

```
1110 0101 1001 0010 0000 0000 0000 0000
1110 0101 1001 0010 0000 0000 0000 0100
1110 0101 1000 0010 0001 0000 0000 0000
1110 0101 1000 0010 0001 0000 0000 0100
```

ALUOP[0:3] <= InstReg[9:11] & MASK

ELEC2041: An Overview

° **The Aims:**

- **Basics of Microprocessor-based systems**
- **Programmer's view of Computer Architecture**
- **Interaction between hardware and software, *i.e.* 'Interfacing'.**

° **What not covered:**

- **Designing Computer Hardware**
- **High level language programming**

What will You learn in ELEC2041?

° **Learn big ideas in Microprocessors & Interfacing**

- **5 Classic components of a Computer**
- **Principle of abstraction, used to build systems as layers**
- **Data can be anything (integers, floating point, characters): a program determines what it is**
- **Stored program concept: instructions just data**
- **Principle of stack and stack frames**
- **Compilation v. interpretation thru system layers**
- **Principle of Locality, exploited via a memory hierarchy (cache)**

Modern View of Microprocessor Design

° **Embedded VS Desktop PC:**

"Intel specializes in designing microprocessors for the desktop PC, which in five years may no longer be the most important type of computer. Its successor may be a personal mobile computer that integrates the portable computer with a cellular phone, digital camera, and video game player… Such devices require low-cost, energy-efficient microprocessors, and Intel is far from a leader in that area."

David Patterson

(Professor of Computer Science and Leading Computer Architect)

Where are the Microprocessors

"There were something like 2.9 billion microprocessors sold in 1997. Only 70 million of those went into PC's.

The 70 million (× $100) is nice for Microsoft and Bill Gates,

But the real action is with the 2.9 billion embedded systems"

Sun Microsystems chairman and chief executive Scott McNealy.

-*Australian* newspaper March 2, 1999

New Look ELEC2041!

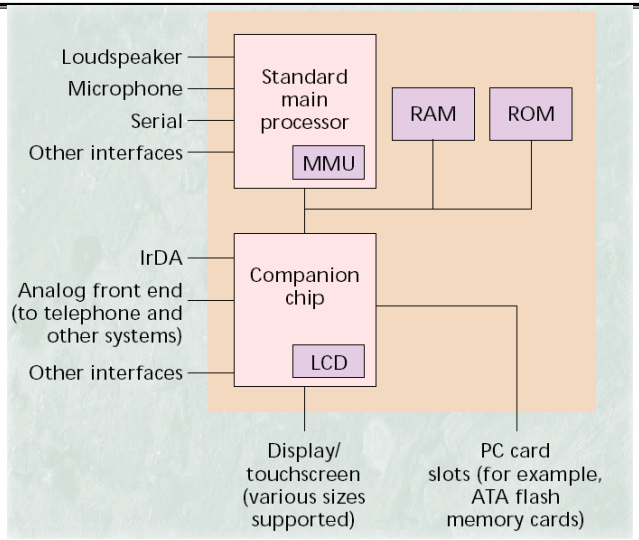
° Modern View of Microprocessor Based Design

- Embedded Systems (against desktop computing environment) with incredible processing power (1 GFLOPS Speed)
  - video games (PlayStation, XBox)
  - Handheld palmtop computers,
  - digital still cameras,
  - cellular phones, mobile personal communicators
  - Smart refrigerators (LG Life is Good!)
- System on Chip Design Concept
  - Integration of general purpose microprocessor core with flexible special purpose programmable peripheral devices to design large systems
  - Software/ Hardware Partitioning and Co-design

° Modern Development Hardware and Software

- We use the State-of-the-Art hardware and software in the laboratory
- With a view of the Microprocessor Design for 21st Century.

System on a Chip Example



° Hand Held PC

Syllabus

° Main Topics:

- Programmer model of computer organisation
- Assembly and machine language Programming.
- Process of translation from high level language to machine instructions.
- Number representation, computer arithmetic,
- Instruction Sets Architecture
- I/O interfacing,
- I/O interrupts
- Programming interrupts.

° Laboratory exercises:

- Programming and interfacing of an ARM based microprocessor hardware and software system.

Example Microprocessor

- Primary aim is to cover PRINCIPLES of microprocessor based systems
- In this class we mostly use ARM architecture as a vehicle for demonstrating the principle of microprocessor design & programming
- ARM:
  - An exciting 32 bit RISC architecture for high end embedded systems
  - Versatile instruction set architecture
  - Very compact code (High code density)
  - Very low power
  - Architecture is sold as core to semiconductor manufactures licensees.

ELEC2041 Administration (#1/2)

- Lecturer:

  Saeid Nooshabadi: saeid@unsw.edu.au

  241 EE Building
  - Consultation: Room EE241 Ext. 5663, Tues 12 – 13, (By email anytime)
- Lab Assessors:

  (See them for your lab time on the Class Website)

ELEC2041 Administration (#2/2)

- Home Page:

  http://webct.edtec.unsw.edu.au/

  http://subjects.ee.unsw.edu.au/elec2041

  Home Page will contain all information, so check it often:
  - Lecturer and lab Assessors info
  - All Lecture slides presented in the class
  - All documentation relating to the Laboratory Exercises
  - Pointer to Mirror image of the Companion CD-ROM
  - Announcements
  - It is your responsibility to check the homepage for all ELEC2041 related matters.

Pre-Requisite (#1/2)

- Digital Circuits (*e.g.* ELEC1041, COMP2021)
  - Number representation, coding, registers, state machines
  - Realisation of simple logic circuits
  - Integrated circuit technologies
  - Designing with MSI components
  - Flip-Flops &state machines
  - Counters and sequential MSI components
  - Register transfer logic
  - Bus systems

Pre-Requisite (#2/2)

° **Computers and Computing (*e.g.* COMP1011 & COMP1021)**

- The von Neumann model: memory/I-O/processing
- The instruction set and execution cycle;
- Registers and address spaces
- An instruction set: operations and addressing modes
- An expanded model of a computer: mass storage and I/O
- The layered model of a computer: from gate- to user-level
- C- Language Programming

ELEC2041 Reading Materials (#1/2)

° **Printed Laboratory booklets (Highly Recommended)**

- Buy from the EE Office for $10 (Available on-line for free as well)

° **Companion CD-ROM (Highly Recommended)**

- Buy from the EE Office for $5 (Available on-line for free as well)
- All Software tools and user manuals used in the lab
- All relevant documentation relating to hardware development board used in the lab
- Copies of all relevant data sheets for the processor and other devices on the hardware development board used in the lab
- Copy of ARM Processor Reference Manual
- All the Laboratory Exercises documentations
- Many programming examples
- And LOT MORE…

ELEC2041 Reading Materials (#2/2)

- **Textbooks:**
  - **Main references for lecture material:**
    - Steve Furber: ARM System on-chip 2nd Ed, Addison-Wesley, 2000, ISBN: 0-201-67519-6. We use chapters 2, 3, 5 and 6, 8, 9, 10, & 11
  - **Additional references for lectures and labs:**
    - David Patterson and John Hennessy: Computer Organisation & Design: The HW/SW Interface," 2nd Ed 1996. Relevant chapters are, 3, 4 & 8
    - Waldron, John: Introduction to RISC Assembly Language, Addison-Wesley Publishing, 1999, ISBN: 0201398281.
  - **C-Programming**
    - Brian Kernighan & Dennis Ritchie: The C Programming Language, 2nd Ed., Prentice Hall, 1988, ISBN:0-13-110362-8

ELEC2041 Lecture & Tutorial Schedule

° **Lecture & Tutorial:**

• Tuesday	09:00 – 10:00	Rex Vowels Theatre
• Wednesday	10:00 – 11:00	Science Theatre
• Friday	09:00 – 10:00	Biomed A Theatre

ELEC2041 Laboratory Schedule

- **Laboratory:**
  - Monday: 09:00 – 11:00 EE233
  - Monday: 12:00 – 14:00 EE233
  - Tuesday: 15:00 – 17:00 EE233
  - Thursday: 09:00 – 11:00 EE233
  - Thursday: 12:00 – 14:00 EE233
  - Thursday: 15:00 – 17:00 EE233
  - Friday: 12:00 – 14:00 EE233
  - Friday: 15:00 – 17:00 EE233
  - You will be only allowed into the lab class that you are enrolled in. No exception allowed.
  - Starts from week #2 for Friday Class and Week #3 for all other classes

Laboratory Format

- In group of two partners
- You choose your partner in Sign Up Class (Week #2 for Friday classes, Week #3 all other classes) . It CANNOT be changed later
- You will get a group Linux Account
- No formal report to hand in
- You are assessed based on a system of checkpoints

Assemble, link and run your program using the GNU Tools. Show your working program to the Laboratory Assessor.

Checkpoint 3: Signature:

- Assessors mark you check points
- Lab Demonstrators help you with the lab

Extra Credit Points for Lab Work

- Each lab has a set of extra credit points
  - You can do them for extra credit IF AND ONLY IF you have finished all the required checkpoints (~ 6% extra marks).
- Alternatively you can do a small project for up to 10% extra marks
  - You can do this IF AND ONLY IF you have a grade > 85%
  - Send me an email if you want to do a project.
- You are not eligible for both.

Extra Credit: EPA!

- **E**ffort
  - Attending tutorials and consultation time, completing all lab assignments, and doing all quizzes
- **P**articipation
  - Asking great questions in discussion on the WebCT, Tutorials and Lectures and making it more interactive
- **A**ltruism
  - Helping others in lab (no cheating) or on the WebCT
- EPA! extra credit points have the potential to bump students up to the next grade level! (but actual EPA! scores are internal)

ELEC2041 Software

- Edit Utility Tools
  - Enable creation of C or assembly source programs for ARM Processor on a Linux Platform
- GNU ARM Cross Compiler and Assembler Tools:
  - Enable Translation by Compilation, Assembly, and Linking of source programs into ARM object programs; Executable and Linking Format (ELF)

GNU ARM Source Level Debugger

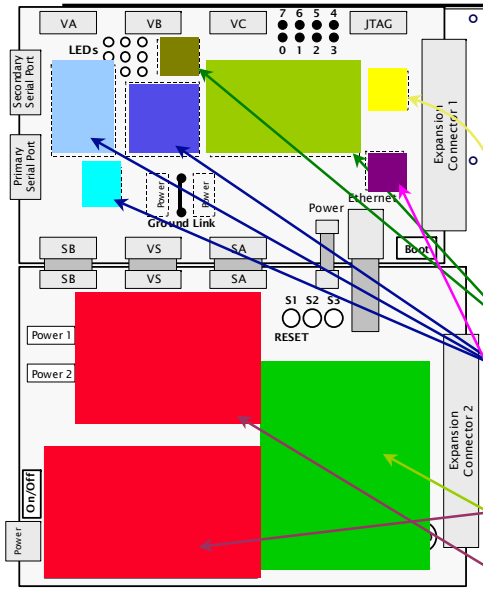
- Enables simulation of ARM ELF programs while referencing back to the source code.

Komodo Integrated Debugger

- Enables downloading of ARM ELF code into the target ARM Processor on DSLMU Development Board
- Enables Execution and debugging of the downloaded program on the target processor on DSLMU Development Board

All Tools included in the Companion CD-ROM

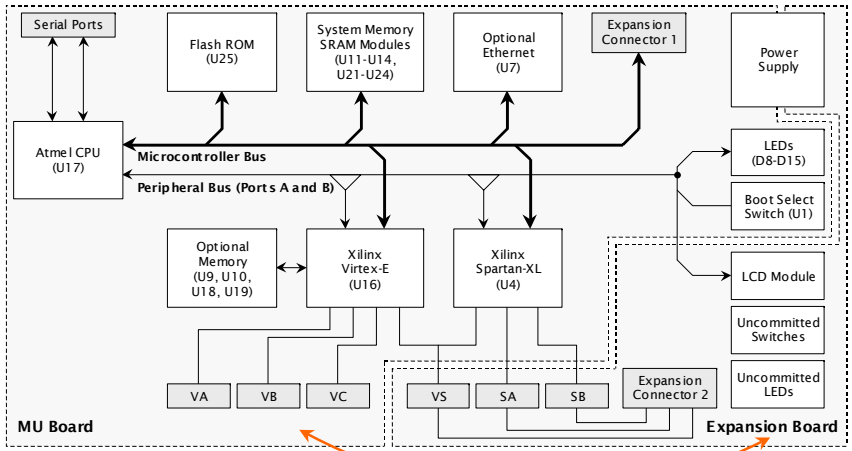
ELEC2041 DSLMU Hardware



- DSLMU is
  - A Board for 21st Century
  - The State-of-the-Art Development Board
- DSLMU Features:
  - Designed by the University of Manchester with lots of collaboration from UNSW
  - An ARM Microcontroller
  - With 2 MB of Flash and up to 4 MB of SRAM Memory
  - 2 Xilinx FPGAs for extended interfacing and specialised co-processors
  - Optional Ethernet chip
  - LCD Module
  - Lots of uncommitted Switches and LEDs
  - Terminal connector to FPGAs

Two PCBs

DSLMU Hardware Block Diagram



Two Printed circuit Boards

All Details and Circuit Diagrams included on the Companion CD-ROM

Laboratory Preparation & Catch Up

- You CAN finish the laboratory exercises in the allocated time, ONLY and ONLY, if you DO the preparation before hand.
- You need to prepare for the laboratory outside the laboratory by:
  - Carefully reading the Laboratory Documentation
  - Doing all the Pre-labs
  - Writing your program and possibly simulating them at home
- Leaving things for to the last minute or walking into the laboratory without preparation is invitation for DISASTOR

Laboratory Documentation Format

- Written Extensively
- They Server as:
  - Lecture Notes
  - Tutorials
  - AND Practical exercises
- Careful Reading Enables you to:
  - Understand the Subject material
  - Do tutorial practice
  - AND get practical experience

DO TAKE THEM VERY SERIOUS!

ELEC2041 Laboratory Experiments

- Lab Sign up Sign up to a lab group, and get group Linux account (starts week #2 [Fri] & 3 [others])
- Lab Exercise 1 An Introduction to the Laboratory (1 week) (starts week #2 [Fri] & 3 [others])
- Lab Exercise 2 Introduction to Assembly Language Programming (2 weeks)
- Lab Exercise 3 Data Types, Data Structures and Functions in ARM Assembly Language (3 weeks)
- Lab Exercise 4 I/O Interfacing (3 weeks)
- Lab Exercise 5 ARM Operating Modes, System Calls and Interrupts (2 weeks)

Course Grading Scheme

- Laboratory mark = 20%
- Regular Quizzes = 10 %
- Final Exam mark = 70 %

Quizzes

- Weekly on-line quizzes on Webct
- They are designed to help you stay up-to-date with the lectures
- They contain the lecture and lab materials
- You only get one chance at it for credit, but can make multiple attempts
- They are posted for a week only.
- You will spend the first 10 minutes in the lab to answer the question.
- It is your responsibility to check for the quizzes on Webct every week.

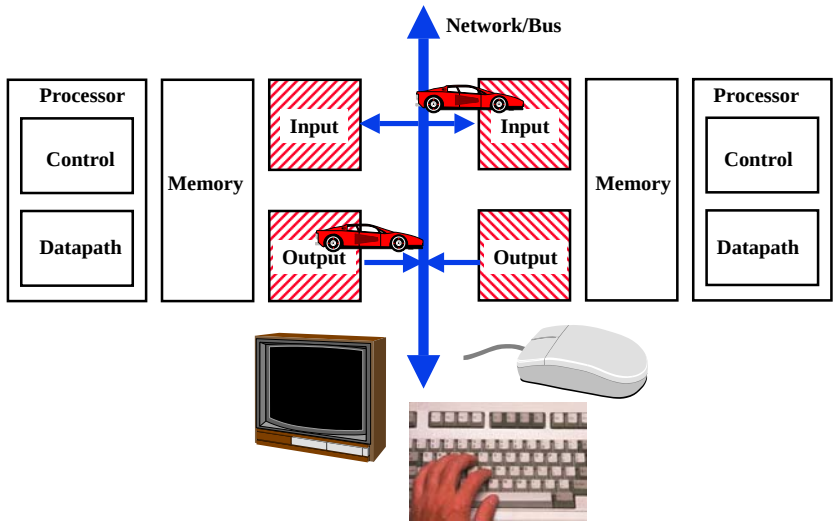
ELEC2041 6 Commandments

- Thou shall NOT talk in the class
- Thou shall PAY attention in the class
- Thou shall COME on-time to the class
- Thou shall REVIEW the published lecture slides before the next lecture to see what you don't understand
- Thou shall ASK Questions in the in the class
- Thou shall DO the reading assignments before the lab class, not while you are in the lab

Things to Remember

- Pay attention to Things to Remember!
- Do read the documentation on laboratory Exercises before coming to the laboratory
- Try doing as much as possible before coming to the laboratory
- Think Ahead!

5 Classic Components of a Computer



And in Conclusion...

- 14 weeks to learn big ideas in Microprocessors & Interfacing
  - Principle of abstraction, used to build systems as layers
  - Pliable Data: a program determines what it is
  - Stored program concept: instructions are just data
  - Principle of stack and stack frames
  - Principle of Locality, exploited via a memory hierarchy (cache)
  - Compilation v. interpretation to move down layers of system

And in Conclusion...

- Continued rapid improvement in Computing
  - 2X every 1.5 years in processor speed;
    every 2.0 years in memory size;
    every 1.0 year in disk capacity;
    Moore's Law enables processor, memory
    (2X transistors/chip/ ~1.5 yrs)
- 5 classic components of all computers

Control Datapath Memory Input Output

Processor

GOOD LUCK WITH THIS COURSE