

---

## COMP 3221

### Microprocessors and Embedded Systems

#### Lecture 1: Introduction

<http://www.cse.unsw.edu.au/~cs3221>

July, 2003

Saeid Nooshabadi

Saeid@unsw.edu.au

COMP3221 lec01-Intro.1

Saeid Nooshabadi

## 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
- 120X size in last decade

COMP3221 lec01-Intro.2

Saeid Nooshabadi

## Computer Technology => Dramatic Change

---

### ° State-of-the-art PC when you graduate:

- Processor clock speed: 4000 MegaHertz (4.0 GigaHertz)
- Memory capacity: 1000 MegaByte (1.0 GigaBytes)
- Disk capacity: 1000 GigaBytes (1.0 TeraBytes)
- New units! Mega => Giga, Giga => Tera

COMP3221 lec01-Intro.3

Saeid Nooshabadi

## Challenges for 21<sup>st</sup> 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

COMP3221 lec01-Intro.4

Saeid Nooshabadi

## Why Study Microprocessor Design?

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



COMP3221 lec01-intro.5

**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*

Saeid Nooshabadi

## Computers in the News: Sony Playstation 2

### "Scuffles Greet PlayStation 2's Launch"

- "If you're a gamer, you have to have one," one who preordered the \$US 299 console in February 2000
- Japan: 1 Million on 1st day



COMP3221 lec01-Intro.6

Saeid Nooshabadi

## μP in the News: Sony Playstation 2000

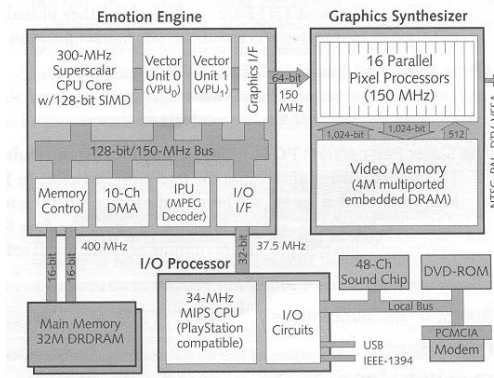


Figure 2. PlayStation 2000 screenshot. (Source: Namco)

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

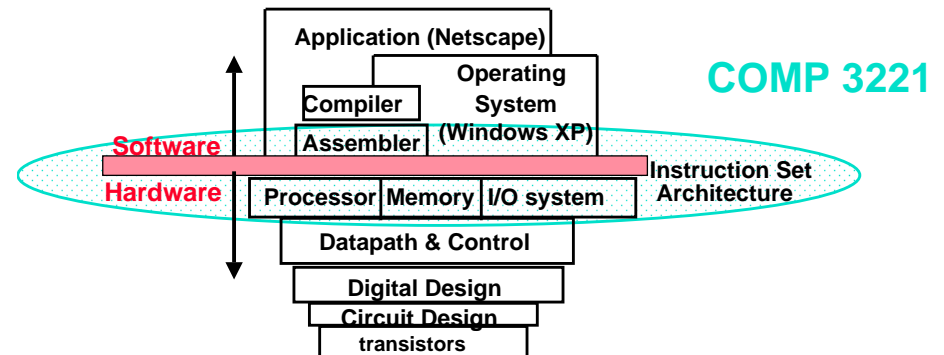
- (as reported in Microprocessor Report, Vol 13, No. 5)

- 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!

COMP3221 lec01-Intro.7

Saeid Nooshabadi

## What is Subject about?

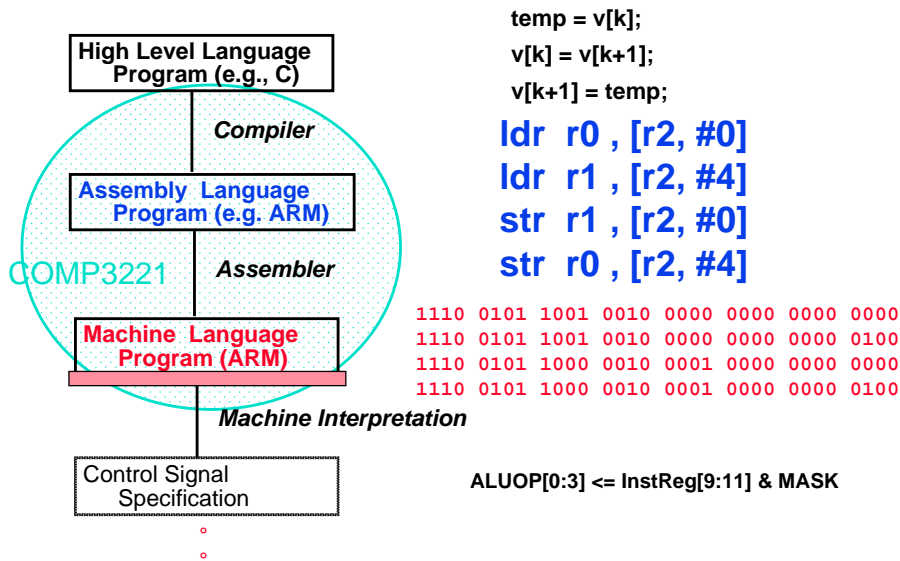


- Coordination of many **levels of abstraction**

COMP3221 lec01-Intro.8

Saeid Nooshabadi

## Programming Levels of Representation



COMP3221 lec01-Intro.9

Saeid Nooshabadi

## COMP 3221: 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

COMP3221 lec01-Intro.10

Saeid Nooshabadi

## What will You learn in COMP 3221?

### ◦ 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)

COMP3221 lec01-Intro.11

Saeid Nooshabadi

## 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)

COMP3221 lec01-Intro.12

Saeid Nooshabadi

## 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 chairman and chief executive Scott McNealy.*

*-Australian newspaper March 2, 1999*

## New Look COMP 3221!

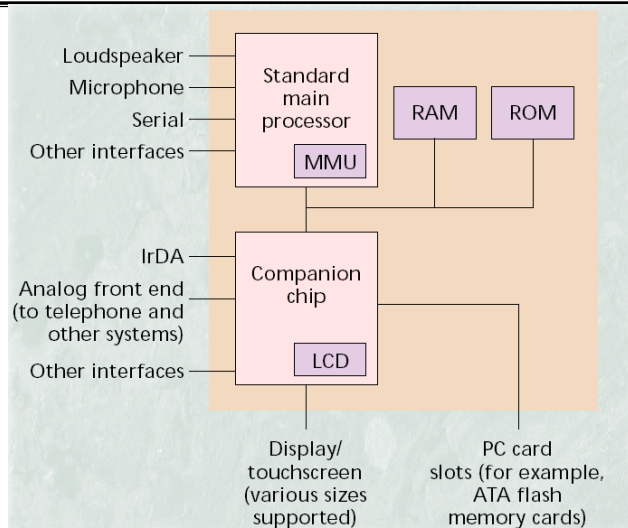
### ° Modern View of Microprocessor Based Design

- Embedded Systems (against desktop computing environment) with incredible processing power
  - 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 21<sup>st</sup> 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.

## COMP 3221 Administration (#1/2)

---

- **Lecturer:**  
**Saeid Nooshabadi:** [saeid@unsw.edu.au](mailto:saeid@unsw.edu.au)  
**241 EE Building**
  - Consultation: Room EE241 Ext. 5663, Tues 12 – 13, (By email anytime)
- **Lecturer In Charge of the Lab:**  
**Samir Omar:** [omar@cse.unsw.edu.au](mailto:omar@cse.unsw.edu.au)  
**233CSE K17 Building**  
For all issue regarding the lab contact Samir
- **Lab Assessors:**  
**(TBA)**

## COMP 3221 Administration (#2/2)

---

- **Home Page:**  
<http://www.cse.unsw.edu.au/~cs3221>
- **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 COMP 3221 related matters.**

## Pre-Requisite (#1/2)

---

- **Digital Circuits (e.g. ELEC 1041, COMP 2021)**
  - 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 & COMP 1021)

- 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

## COMP 3221 Reading Materials (#1/2)

---

### ◦ Printed Laboratory booklets (Highly Recommended)

- Buy from the Bookshop for \$10 (**Available from Week #2**)
- Available on-line as well

### ◦ Companion CD-ROM (Highly Recommended)

- Present your Lab booklet to CSE's store staff (in K17-B08) to be stamped and collect your CD. (**Available from Week #2**)
- 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...
- Available on-line as well

## COMP 3221 Reading Materials (#2/2)

---

### • Textbooks:

- **Main references for lecture material:**
  - Steve Furber: ARM System on-chip 2<sup>nd</sup> 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," 2<sup>nd</sup> 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, 2<sup>nd</sup> Ed., Prentice Hall, 1988, ISBN:0-13-110362-8

## COMP 3221 Lecture & Tutorial Schedule

---

### ◦ Lecture & Tutorial:

- |            |               |                   |
|------------|---------------|-------------------|
| • Thursday | 16:00 – 16:00 | Mathews Theatre A |
| • Friday   | 13:00 – 14:00 | Physics Theatre   |

## COMP 3221 Laboratory Schedule

### ◦ Laboratory:

- Monday: 14:00 – 16:00 EE233
- Monday: 17:00 – 19:00 EE233
- Tuesday: 11:00 – 13:00 EE233
- Wednesday: 13:00 – 15:00 EE233
- Thursday: 12:00 – 14:00 EE233
- Friday: 14:00 – 16:00 EE233
- You will be only allowed into the lab session that you are enrolled in. **No exception allowed.**
- **Starts from week #3**
- **Special Open Access labs**
- Wednesday : 16:00 – 18:00 EE233
- Friday: 16:00 – 18:00 EE233
- Not assessed
- It is only for those who need a bit of extra time

## Enrolling for the Lab Sessions

### ◦ Enrolment System in Lab Session:

- Run “sirius” booking system form any CSE lab machine.
  - Read <http://www.cse.unsw.edu.au/%7Ehelpdesk/documentation/SiriusGuideNew.ps> as how to run “sirius”
  - Any problem with “sirius”, contact Mei-Cheng Whale ([meicheng@cse](mailto:meicheng@cse))
  - If you want to work with a partner please make sure that both of you enrol for the same lab session.
  - You paired with a partner randomly if you don't have one.
- **Students who DO NOT select their Lab sessions will be not be allowed into the lab.**

## Laboratory Format

- In group of two partners
- You choose your partner in **Sign Up Session (Week #3)**. 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

## COMP 3221 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

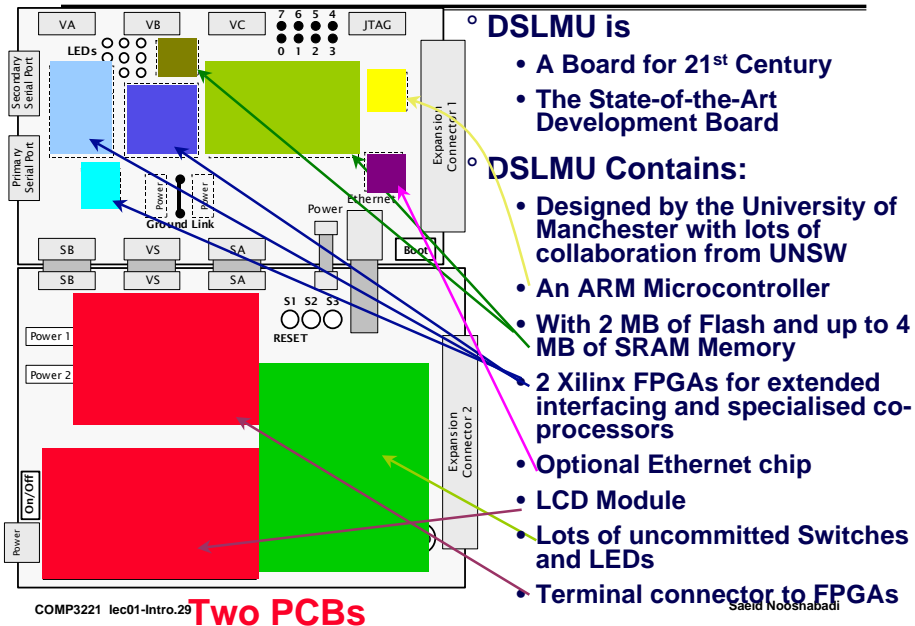
- Enables simulation of ARM ELF programs while referencing back to the source code.

### Komodo Integrated Debugger

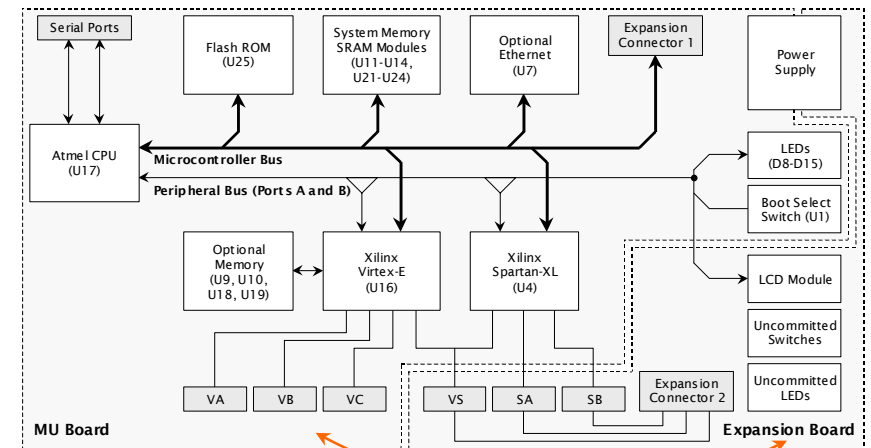
- Enables downloading of ARM ELF code into the target ARM Processor on DSLMU Development Board
- Enables Execution and debugging of the downloaded program on the target processor on DSLMU Development Board

**All Tools included in the Companion CD-ROM**

## COMP 3221 DSLMU Hardware



## DSLMU Hardware Block Diagram



## 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**
- Go to one of the **OPEN ACCESS** Sessions if you think you are falling behind.

## 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!**



## COMP 3221 Laboratory Experiments

---

- **Lab Sign up** Sign up to a lab group, and get group **Linux account** (starts week #3)
- **Lab Exercise 1** An Introduction to the Laboratory (2 weeks) (starts week #3)
- **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 (2 weeks)
- **Lab Exercise 5** ARM Operating Modes, System Calls and Interrupts (2 weeks)

## Course Grading Scheme

---

- **Laboratory mark = 25%**
- **Final Exam mark = 75%**

## COMP 3221 6 Commandments

---

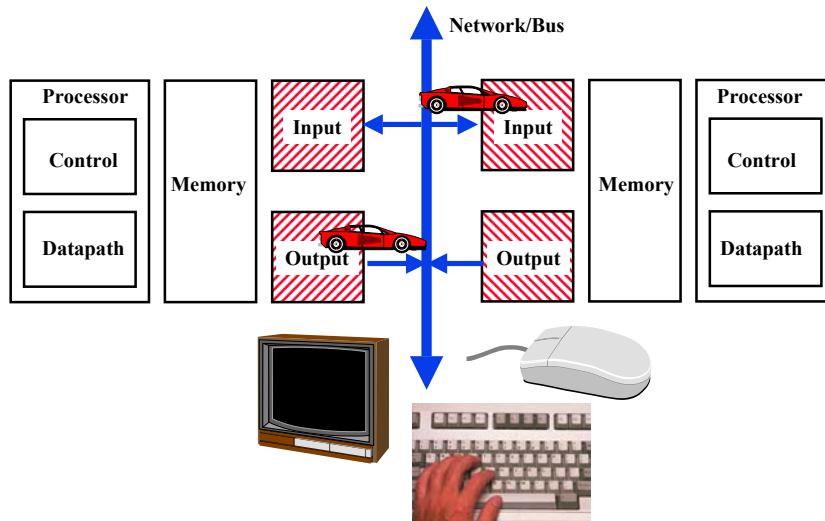
- **Thou shall NOT talk in the class**
- **Thou shall PAY attention in the class**
- **Thou shall COME on-time to the class**
- **Thou shall REVIEW the published lecture slides before the next lecture to see what you don't understand**
- **Thou shall ASK Questions in the in the class**
- **Thou shall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



COMP3221 lec01-Intro.37

Saeid Nooshabadi

## 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

COMP3221 lec01-Intro.38

Saeid Nooshabadi

## 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

COMP3221 lec01-Intro.39

Saeid Nooshabadi

◦ GOOD LUCK  
WITH THIS  
COURSE

COMP3221 lec01-Intro.40

Saeid Nooshabadi