Machine Organization and Assembly Language Programming

• Machine Organization
  – Hardware-centric view (in this class)
  – Not at the transistor (bit) level but at the building block level (registers, adders, memory words etc.)

• Assembly Language
  – A way to learn about the Instruction Set Architecture, the interface between the hardware and the software.
Hierarchical Layers

• Top Layer: Application programs
  – Written in high-level languages: C, C++, Java, html etc

• Basic Software Layer
  – Translates programs written in high-level languages into machine language made up of a sequence of instructions (assembly language is a symbolic rendering of machine language). The translators are programs called compilers.
  – A program, the Operating System, controls the execution of the translated application programs. The O.S. is responsible for functions such as I/O, allocating storage, scheduling etc.

• Hardware
  – Executes the instructions
Layered View

- Application Programs
- Compilers
- Operating System
- Machine Language
- Computer Structure

ISA
Programmatic view

\[ a = b + c; \]

HLL

\[
\begin{align*}
\text{lw} & \quad $2, 0($15) \quad \# \text{load } b \\
\text{lw} & \quad $3, 4($15) \quad \# \text{load } c \\
\text{add} & \quad $4, $2, $3 \quad \# \text{compute } b + c \\
\text{sw} & \quad $4, 8($15) \quad \# \text{store in } a
\end{align*}
\]

Assembly language

Machine language
What is Machine Organization (aka Computer Organization, aka Computer Architecture)?

- **Structure**: static arrangement of the parts of a computer system
- **Organization**: dynamic interaction of the parts and their control
- **Implementation**: design of specific building blocks
- **Performance**: behavioral study of the system or of some of its components
Alternate definition: Instruction Set Architecture (ISA) (subset of previous def.)

- ISA is the **interface** between hardware and software
- ISA is what is visible to the programmer (and ISA might be different for O.S. and applications)
- ISA consists of:
  - instructions (operations and how they are encoded)
  - information units (size, how they are addressed etc.)
  - registers (or more generally processor state)
  - input-output control
Computer structure: Von Neumann model
Computer Organization/Architecture

• Organization and architecture often used as synonyms

• **Organization** (in this course) refers to:
  – what are the basic blocks of a computer system, more specifically
    • basic blocks of the CPU
    • basic blocks of the memory hierarchy
  – how are the basic blocks designed, controlled, connected?

• Organization used to be transparent to the ISA.

• Today more and more of the ISA is “*exposed*” to the user/compiler in order to improve *performance*. 
## Advances in technology

<table>
<thead>
<tr>
<th>Processor technology</th>
<th>Vacuum tubes</th>
<th>Transistors</th>
<th>Integrated circuits</th>
<th>VLSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory technology</td>
<td>Vacuum tubes</td>
<td>Ferrite core</td>
<td>Semi-conductor</td>
<td>Semi-conductor</td>
</tr>
<tr>
<td>Processor structure</td>
<td>Single processor</td>
<td>Main frames</td>
<td>Micros and minis</td>
<td>PC’s 64-bit arch Super scalar Multithreaded</td>
</tr>
</tbody>
</table>
Evolution of Intel Microprocessor Speeds
Illustration of Moore’s Law
Power Dissipation

![Graph showing power dissipation over time](image)
Some Computer families

- Computers that have the same (or very similar) ISA
  - Compatibility of software between various implementations
- IBM
  - 704, 709, 70xx etc.. From 1955 till 1965
  - 360, 370, 43xx, 33xx From 1965 to the present
  - Power PC
- DEC
  - PDP-11, VAX From 1970 till 1985
  - Alpha (now Compaq, now HP) in 1990’s
More computer families

- **Intel**
  - Early micros 40xx in early 70’s
  - x86 (086,…,486, Pentium, Pentium Pro, Pentium 3, Pentium 4) from 1980 on
  - IA-64 (Itanium) in 2001

- **SUN**
  - Sparc, Ultra Sparc 1985 on

- **MIPS-SGI**
  - Mips 2000, 3000, 4400, 10000 from 1985 on