# Introduction to Computer Engineering

CS/ECE 252, Spring 2008
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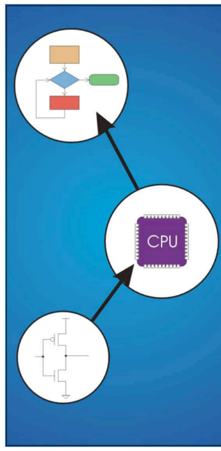
*Adapted from Prof. Hill's notes*

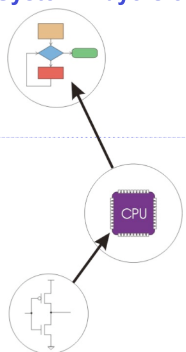



# Chapter 1
## Welcome Aboard

Slides based on set prepared by
Gregory T. Byrd, North Carolina State University



## Computer System: Layers of Abstraction




*Software*

*Hardware*

Problem
Application Program
Algorithms
Language

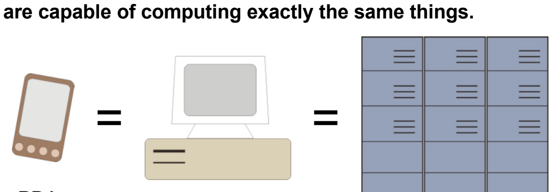
Instruction Set Architecture
(and I/O Interfaces)
Microarchitecture
Circuits
Devices





## Big Idea #1: Universal Computing Device

**All computers, given enough time and memory, are capable of computing exactly the same things.**




PDA

Workstation

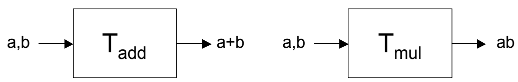
Supercomputer

## Turing Machine

**Mathematical model of a device that can perform any computation – Alan Turing (1937)**

- **ability to read/write symbols on an infinite "tape"**
- **state transitions, based on current state and symbol**

**Every computation can be performed by some Turing machine.** ***(Turing's thesis)***




*Turing machine that adds* *Turing machine that multiplies*

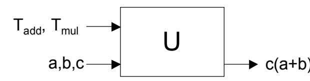




## Universal Turing Machine

**Turing described a Turing machine that could implement all other Turing machines.**

- **inputs: data, plus a description of computation (Turing machine)**




*Universal Turing Machine*

**U is programmable – so is a computer!**

- **instructions are part of the input data**
- **a computer can emulate a Universal Turing Machine, and vice versa**

***Therefore, a computer is a universal computing device!***



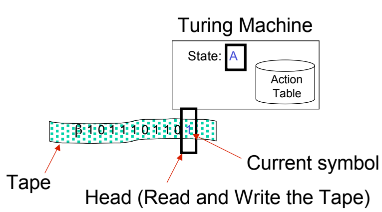


## Turing Machine Example

**Goal: Find a sequence '111' on the input tape.**

**Input: Tape with sequence of 0s and 1s, terminated by a blank character β**

**Output: Tape contains all 0s, except a single 1 indicating position of first sequence (if any).**








## TM Example Action Table

| State | Symbol | Tape | | Next State |
|---|---|---|---|---|
| A | β | - | - | Halt |
| A | 0 | Print 0 | Move Right | A |
| A | 1 | Print 0 | Move Right | B |
| B | β | - | - | Halt |
| B | 0 | Print 0 | Move Right | A |
| B | 1 | Print 0 | Move Right | C |
| C | β | - | - | Halt |
| C | 0 | Print 0 | Move Right | A |
| C | 1 | Print 1 | Move Right | D |
| D | β | - | - | Halt |
| D | 0 | Print 0 | Move Right | D |
| D | 1 | Print 0 | Move Right | D |

## From Theory to Practice

**In theory, computer can *compute* anything that's possible to compute**

- **given enough *memory* and *time***

**In practice, *solving problems* involves computing under constraints.**

- **time**
  - **weather forecast, next frame of animation, ...**
- **cost**
  - **cell phone, automotive engine controller, ...**
- **power**
  - **cell phone, handheld video game, ...**

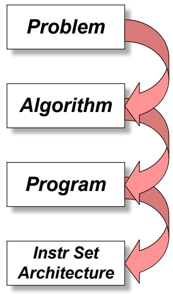




## Big Idea #2: Transformations Between Layers

**How do we solve a problem using a computer?**

**A systematic sequence of transformations between layers of abstraction.**




***Software Design:***
choose algorithms and data structures

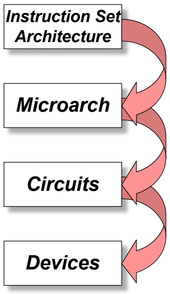
***Programming:***
use language to express design

***Compiling/Interpreting:***
convert language to
machine instructions





## Deeper and Deeper…




***Processor Design:***
choose structures to implement ISA

***Logic/Circuit Design:***
gates and low-level circuits to
implement components

***Process Engineering & Fabrication:***
develop and manufacture
lowest-level components





## Descriptions of Each Level

### Problem Statement
- **stated using "natural language"**
- **may be ambiguous, imprecise**

### Algorithm
- **step-by-step procedure, guaranteed to finish, deterministic**
- **definiteness, effective computability, finiteness**

### Program
- **express the algorithm using a computer language**
- **high-level language, low-level language**

### Instruction Set Architecture (ISA)
- **specifies the set of instructions the computer can perform**
- **data types, addressing mode**

## Descriptions of Each Level (cont.)

### Microarchitecture

- **detailed organization of a processor implementation**
- **different implementations of a single ISA**

### Logic Circuits

- **combine basic operations to realize microarchitecture**
- **many different ways to implement a single function (e.g., addition)**

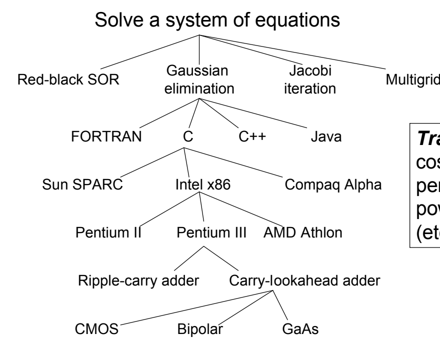
### Devices

- **properties of materials, manufacturability**





## Many Choices at Each Level




***Tradeoffs:***
cost
performance
power
(etc.)





## What's Next

### Bits and Bytes

- **How do we represent information using electrical signals?**

### Digital Logic

- **How do we build circuits to process information?**

### Processor and Instruction Set

- **How do we build a processor out of logic elements?**
- **What operations (instructions) will we implement?**

### Assembly Language Programming

- **How do we use processor instructions to implement algorithms?**
- **How do we write modular, reusable code? (subroutines)**

### I/O, Traps, and Interrupts

- **How does processor communicate with outside world?**