Digital Logic and Computer Organization

Introduction

Logistics

- Lectures & Labs
- Assessment
- Resources
- Academic Integrity

Overview

- Number Systems and Codes
- Boolean Algebra
- Combinational Circuits
- Sequential Circuits
- CPU, Memory, etc
- Verilog

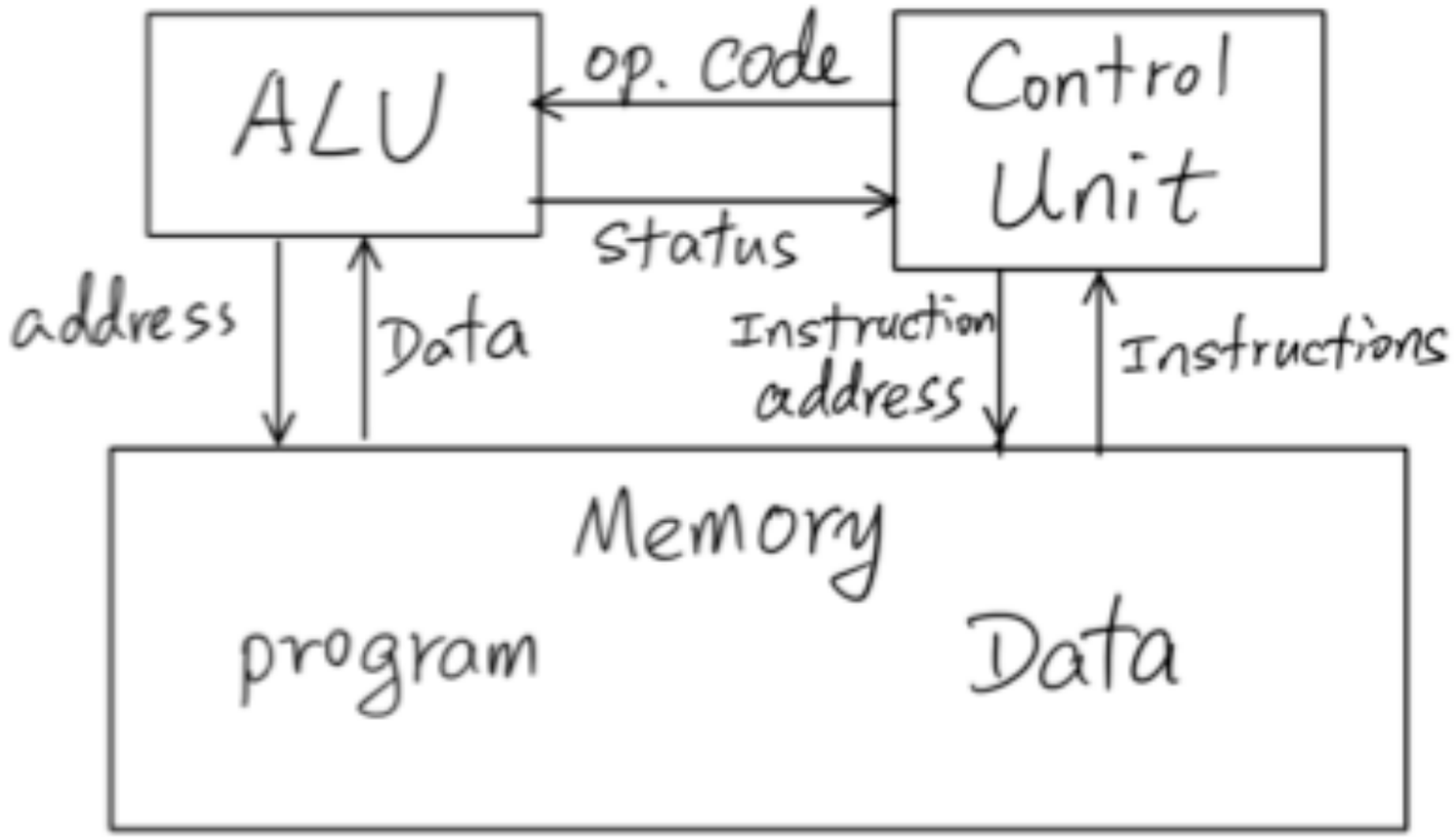
Learning Outcomes

- master the standard number and code systems;
- analyze and design combinational circuits per specification;
- analyze and design some typical sequential circuits per specification;
- simulate and test designed combinational and sequential circuits using Verilog
- enumerate typical challenges and common solution ideas in microcomputer system design.

Computer Organization

- CPU (microprocessor)
    - ALU (consists gates to perform arithmetic and logical operations)
    - register
    - control unit
- memory: address, little/big endian
    - RAM
    - ROM
    - flash memory: EPROM
- bus
- I/O (parallel and/or serial)
- chip (integrated circuit package)

Von Neumann Structure

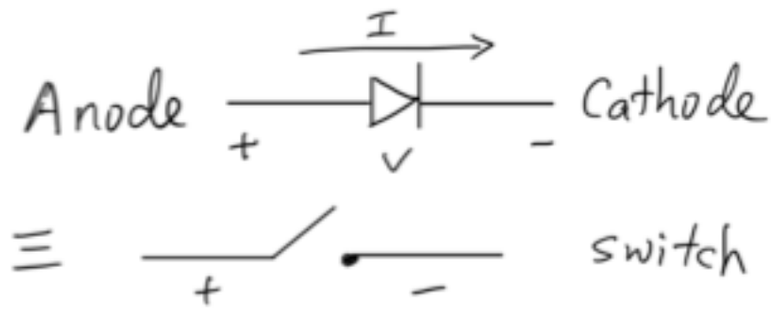


Digital Circuits

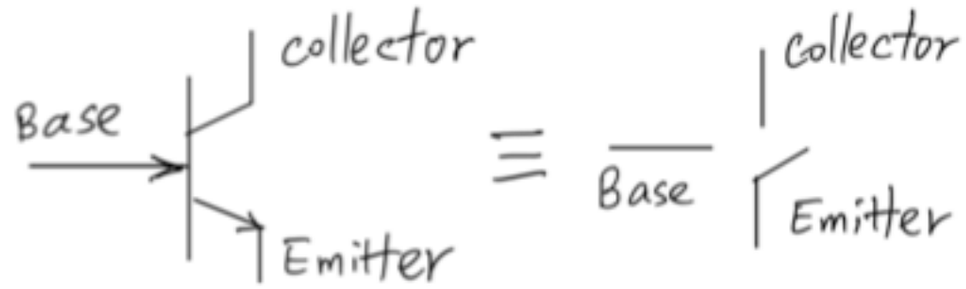
- Two types on logical level
  - combinational circuits — stateless
  - sequential circuits — with memory of present states

Circuit Elements/Switches

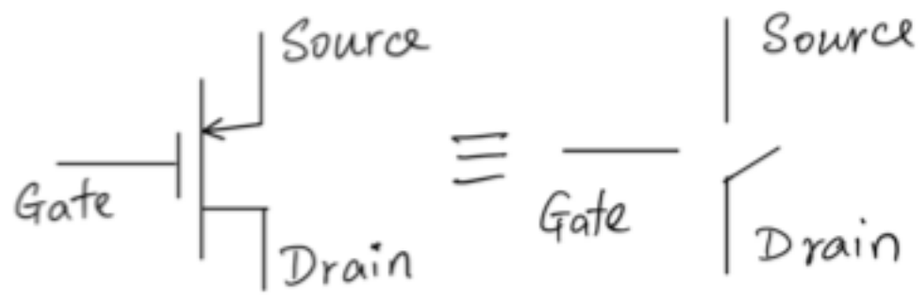
- diodes



- bipolar junction transistors



- MOS transistors



Design

- Three levels of design
    - System level design: build a computer by interfacing CPU, memory, and I/O, peripheral chips
    - Logic level design: build a digital component using logical gates
        - Device level design: build gates using transistors
- Design techniques (algorithms and analysis)
- Computer Aided Design (CAD) Tools
    - Verilog (IEEE 1364 in 1995)
    - VHDL (IEEE 1076 in 1987)

Integrated Circuits

- One or many gates are fabricated on a single silicon chip and packaged in a package
- ICs are typically classified as
    - Small Scale Integration (SSI)
        - less than 10 gates, e.g. multiple NAND gates
    - Large Scale Integration (LSI)
        - up to 1000 gates, e.g. memory chips, or an 8-bit microprocessor
    - Very Large Scale Integration (VLSI)
        - more than 5,000 gates (or 500,000 transistors) , e.g. microprocessor

IC Technology

- Full Custom: design from scratch and manufacture
- Semi Custom: design from pre-existing components (gates) and assemble
- Field Programmable Gate Array: reconfigure the manufactured hardware sold off-the-shelf to meet specific requirements

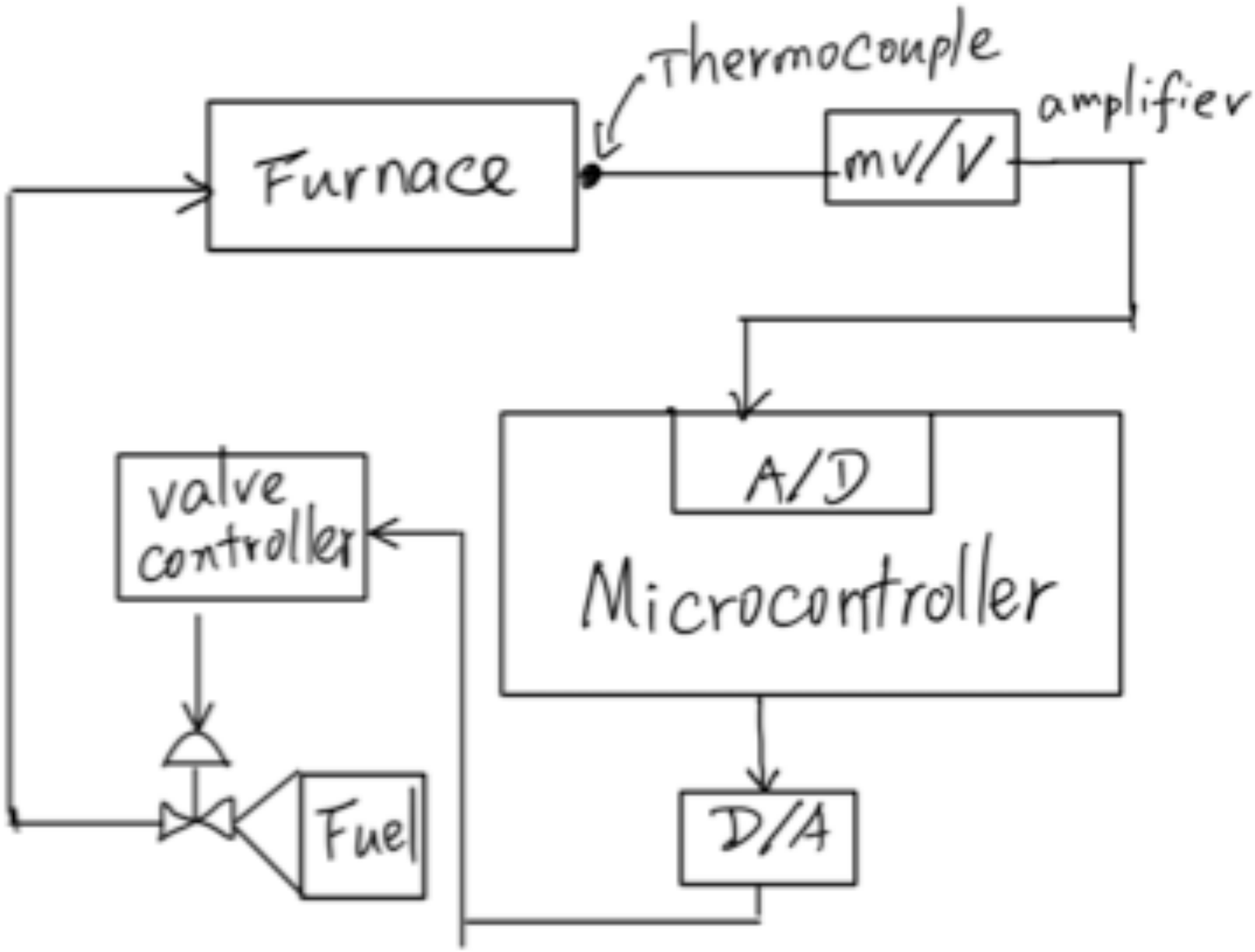
Microcomputer & Microcontroller

- Microcomputer: consists microprocessor (CPU) chip, I/O chips, and memory chips where programs (instructions and data) are stored.

- Microcontroller: a single chip containing CPU, memory, Input/ Output and peripherals which typically contains I/O, timers, A/D converter, serial I/O, etc. Some of its applications:

  - Automotive
  - Barcode readers
  - Card key readers
  - Robotics

Microcontroller Application Example



Design Process

- Product description
- Define specification
- Circle of (re)design, simulation, evaluation
    - Capture: schematic
    - Minimization and synthesis
    - Testing: behaviour, timing
- Circle of prototype implementation, testing, evaluation, debugging (even go back to redesign)
    - Testing: behaviour, timing, manufacture
- Deliver a finished product

Rules of Thumb

- Advances in design technology lags advances in processor and IC technologies
- Product success is influenced by time-to-market
  - first to market will success
  - second to market will survive
  - third to market will fail