Memory Technology
MCU Systems
Applications
Memory - Overview

• Memory = Data Storage
  – HDD, Optical, Electronic (on-chip)

• Many Variants:
  – Non-Volatile vs Volatile
  – Read-Only vs Write-Once vs Write-Many
  – Random Access vs Sequential Access

• Two Critical properties:
  – Capacity
  – Speed
Memory – Historical Magnetics

• Drum Memory
  – Precursor to modern HDD

• Magnetic Core
  – Fast-Access Non-Volatile
Memory – Historical Electrics

- CRT-based Memory
  - Williams Tube

- Delay-Based Memory
  - Electrical or Acoustic
Memory - ROM

• Read Only Memory
• ROM used for storing programs and constant tables

• Conflicting requirements
  – non-volatility
  – (re)-programability

• ROM is also RAM...
ROM Types

- **(UV) EPROM**
  - charge on a “floating gate”
  - erased by UV light
- **OTP PROM**
  - fusible nichrome/polysilicon links
  - programmed by blowing fuses
- **ROM**
  - mask-programmed
- **Emulated ROM ≡ NVRAM ≡ RAM-with-a-battery**
ROM

• Three inputs:
  – up to 16+ address bits
  – chip select
  – output enable

• One output:
  – typically 8 bits of tristate data output

• Access time (time from stable address to stable data)
  450 ns - 70 ns
EPROM

- EPROM’s may be written to many times
- Erased by using UV light – there is typically a small quartz window in the chip
- Each EPROM cell contains two transistors controlled by the ‘floating gate’ and the ‘control gate’
- Charge is stored in a thin oxide layer between the gates
- The charge (and therefore the logic value) is normally logic 1 and is changed to 0 by applying voltage to the ‘floating gate’
2716 EPROM
(2k x 8bits)
EEPROM

- Electrically Erasable Programmable Read-Only Memory
- Two main types:
  - Serial programmable and
  - Parallel programmable
- The chip does not have to be removed to be rewritten.
- The entire chip does not have to be completely erased to change a specific portion of it.
- Changing the contents does not require additional dedicated equipment
EEPROM

- Instead of using UV light to erase the data, a localised electrical field is applied to the gate.
- Data is erased (and programmed) 1 byte at a time = Slow!
FLASH Memory

• Very similar to EEPROM

• Currently very popular in consumer applications

• Typically, data is written in blocks (usually 512 bytes) making it faster than EEPROM (at least 512x?)

• Limited Re-Write Cycles (~100000)
Memory - RAM

- “Random Access” (Read-Write) Memory
- RAM used for storage of transient objects
  - global and static variables in C
  - the stack (auto variables)
  - the heap (unallocated memory)
- RAM types:
  - SRAM (Static RAM)
  - DRAM (Dynamic RAM)
SRAM

- bit stored as the state of a flip-flop
- selected by AND-ed inputs: address+CS+OE+R/W
- retains contents as long as power applied - no refresh
- access time 12 ns to 200 ns
- faster, but less dense than DRAM

- NVRAM: usually battery backed CMOS SRAM
6264 SRAM
(8k x 8bits)
DRAM

- each bit stored as a charge on a storage capacitor
- must be “refreshed” (write accessed) periodically - at intervals typically less than 8 ms
- many µPs, all SIMMS have built-in refresh

- less power, denser, but slower than SRAM

- PC RAM = SDRAM(?!?)
  = Synchronous Dynamic Random Access Memory
Sample Applications

- **ROM** - Storage of Program on deployed system
- **EEPROM** - Storage of calibration constants
- **FLASH** - Storage of Data (SSD’s)
- **SRAM** - Caching, low-capacity fast-access
- **DRAM** - Generic Storage