Memory Basics

- **RAM**: Random Access Memory
  - historically defined as memory array with individual bit access
  - refers to memory with both Read and Write capabilities
- **ROM**: Read Only Memory
  - no capabilities for “online” memory Write operations
  - Write typically requires high voltages or erasing by UV light
- **Volatility of Memory**
  - volatile memory loses data over time or when power is removed
    - RAM is volatile
  - non-volatile memory stores data even when power is removed
    - ROM is non-volatile
- **Static vs. Dynamic Memory**
  - Static: holds data as long as power is applied (SRAM)
  - Dynamic: will lose data unless refreshed periodically (DRAM)

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SRAM/DRAM Basics

- **SRAM**: Static Random Access Memory
  - Static: holds data as long as power is applied
  - Volatile: can not hold data if power is removed
  - 3 Operation States: hold, write, read
  - Basic 6T (6 transistor) SRAM Cell
    - bistable (cross-coupled) INVs for storage
    - access transistors MAL & MAR
    - word line, WL, controls access
      - WL = 0 (hold) = 1 (read/write)
- **DRAM**: Dynamic Random Access Memory
  - Dynamic: must be refreshed periodically
  - Volatile: loses data when power is removed
  - 1T DRAM Cell
    - single access transistor; storage capacitor
    - control input: word line (WL); data I/O: bit line
- **DRAM to SRAM Comparison**
  - DRAM is smaller & less expensive per bit
  - SRAM is faster
  - DRAM requires more peripheral circuitry
**ROM/PROM Basics**

- **ROM**: Read Only Memory
  - no capabilities for "online" memory Write operations
  - data programmed
    - during fabrication: ROM
    - with high voltages: PROM
    - by control logic: PLA
  - Non-volatile: data stored even when power is removed

- **PROM**: Programmable Read Only Memory
  - programmable by user -using special program tools/modes
  - read only memory -during normal use
  - non-volatile
  - Read Operation
    - like any ROM: address bits select output bit combinations
  - Write Operation
    - typically requires high voltage (~15V) control inputs to set data
      - stores charge to floating gate (see figure) to set to Hi or Low
  - Erase Operation
    - to change data
    - EPROM: erasable PROM: uses UV light to reset all bits
    - EEPROM: electrically-erasable PROM, erase with control voltage

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**Comparison of Memory Types**

- **DRAM**
  - very high density → cheap data cache in computers
  - must be periodically refreshed → slower than SRAM
  - volatile; no good for program (long term) storage

- **SRAM** (basically a Latch)
  - fastest type of memory
  - low density → more expensive
    - generally used in small amounts (L2 cache) or expensive servers

- **EEPROM**
  - slow/complex to write → not good for fast cache
  - non-volatile; best choice for program memory

- **ROM**
  - hardware coded data; rarely used except for bootup code

- **Register (flip flop)**
  - functionally similar to SRAM but less dense (and thus more expensive)
  - reserved for data manipulation applications
Memory Overview

- **N x n** array of 1-bit cells
  - n = byte "width": 8, 16, 32, etc.
  - N = number of bytes = "length"
  - m = number of address bits
    - max N = 2^m
- **Array I/O**
  - data (in and out)
    - D_{n-1} - D_0
  - address
    - A_{m-1} - A_0
  - control
    - varies with design
    - WE = write enable (assert low)
      - WE=1 = read, WE=0 = write
    - En = block enable (assert low)
      - used as chip enable (CE) for an SRAM chip

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Memory Array Addressing

- **Standard Memory Addressing Scheme**
  - m address bits are divided into x row bits and y column bits (x+y=m)
    - address bits are encoded so that 2^m = N
    - array physically organized with both vertical and horizontal stacks of bytes

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Memory "size":
- # bytes = N, # bits = N x n

Example:
1k x 8 RAM → 10 addr lines, 8-bit bytes
2^{10} = 1k (1024) mem locations = length
width = 8-bit, size = 1k-byte, 8k-bits
Typical Memory Chip

- **Data**
  - x-bits in parallel, typically x = 8, 16

- **Address signals**
  - m address signals → M = 2^m addresses

- **Control signals**
  - /WE: write enable - when activated, values on data lines are written to specified address
  - /OE: output enable - data at specified location placed on data pins of memory chip, data lines connected to data bus using tristate outputs
  - /CS: chip select - selects a specific chip in an array of memory chips

- **Connection to HC12**

Memory Expansion

expanding memory length
Memory Expansion
expanding memory width

Memory Expansion
expanding memory length and width