

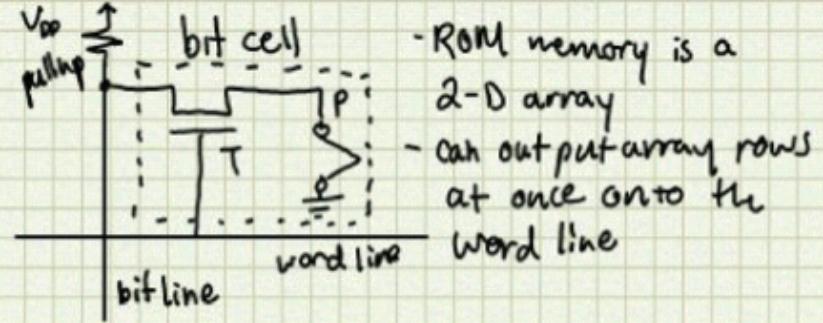
# Memory

## 1) Non-volatile (8.3)

- retains data on power-off

### 1.1) Read-Only Memory (ROM)

- bit cell is one bit of ROM memory



- ROM memory is a 2-D array

- can output array rows at once onto the word line

- T: transistor - a "1" on the word line closes the connection
- P: closed = 0, open = 1 (is permanently open or close)
- contents are programmed at foundry with mask
- mask cost is high  $\Rightarrow$  large production runs to be cost effective
  - method of creating integrated circuits

### 1.2) Programmable ROM (PROM)

- P is a fuse
- blow fuse with a high V to write a "1"  $\leftarrow$  permanently blown
- can only write once

### 1.3) Erasable PROM (EPROM)

- P is a special transistor that traps charge (for decades)
- erased by ultraviolet light (through quartz window)
- can erase & re-write multiple times (the whole chip)

### 1.4) Electrically Erasable PROM (EEPROM) or (NVRAM) non-volatile

- different voltages for writing, reading, and erasing
- any byte can be erased and re-written and supports multiple writes

### 1.5) Flash

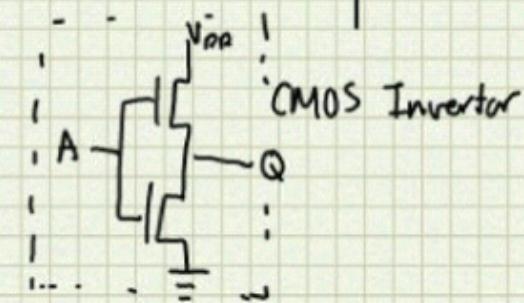
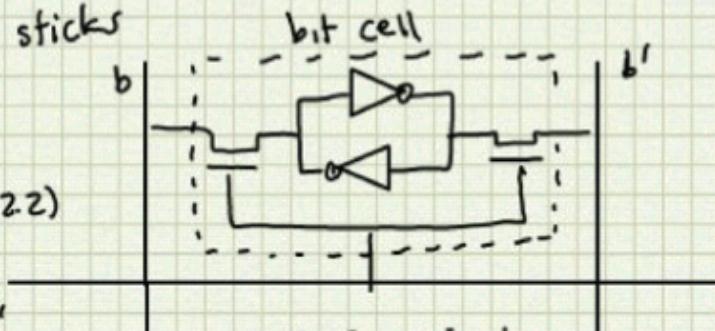
- like an EEPROM but erased/rewritten in blocks
- cheaper than EPROM
- used for BIOS, USB memory sticks

## 2) Volatile

- loses data on power-off

### 2.1) Static RAM (SRAM) (8.2.2)

- write by driving bit line b and its complement b'
- fast (invertors actively drive bit lines)
- large area (6 transistors)  $\Rightarrow$  expensive
- used for cache memory



## 2.2) Dynamic RAM (DRAM) (8.2.3)

- C: capacitor charged = 1 discharged = 0
- write by connecting b to  $V_{PP}$
- read:

- ① pre-charge b to  $V < V < V_{DD}$
- ② sense the signal
- ③ write-back

- about 4x slower than SRAM
- needs periodic refresh ( $T = \sim 10\text{ms}$ )
- smaller than SRAM  $\Rightarrow$  cheaper
- used for main memory

## 3) Classification

Type	Volatile?	Writable?	Erase Size
ROM	x	x	-
PROM	x	once	-
EPROM	x	yes	the whole chip
EEPROM	x	✓	byte
Flash	x	✓	block
SRAM	✓	✓	byte
DRAM	✓	✓	byte

