

Memory Technology

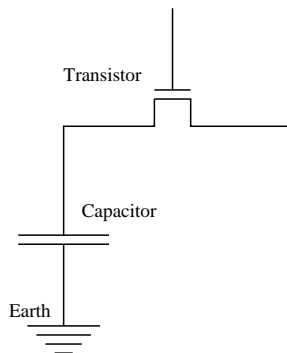
- ▶ All memory today is based on semi-conductor technology
- ▶ Previously magnetic core memory was used but replaced in 70s except for devices for use in nuclear facilities or space craft that needed to be resistant to ionization.
- ▶ Comes in two flavours
 - ▶ Dynamic random access memory (DRAM)
 - ▶ Static random access memory (SRAM)
- ▶ Random in this case means you can access locations in memory in any order. Compare with say magnetic tape

DRAM

- ▶ DRAM devices are charge based
- ▶ Each bit is represented by a charge in a capacitor
- ▶ This charge can leak away in a short time so the system needs to be refreshed to prevent data loss
- ▶ Reading a bit in DRAM discharges the capacitor so it needs to be refreshed
- ▶ Bits being refreshed are not available for reading

DRAM

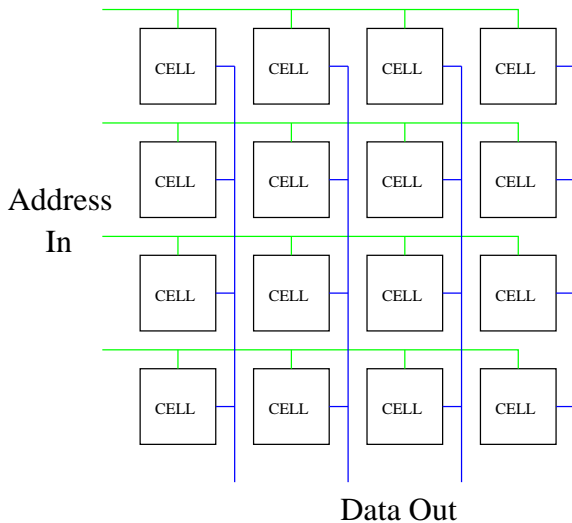
- Structure of DRAM cell shown below



DRAM

- ▶ DRAM cells are organised as arrays
- ▶ Green lines are the Row Address Strobe (RAS)
- ▶ They determine which set of cells are being accessed
- ▶ Blue lines are Column Lines
- ▶ They are used to read off the values of the cells or to write new values back

DRAM Array



DRAM Types

- ▶ Asynchronous DRAM
 - ▶ No explicit clocking of the chip
 - ▶ Responds to changes of the RAS
 - ▶ Small number of data lines
 - ▶ Improvements such as Paged DRAM and EDO DRAM
- ▶ Synchronous DRAM
 - ▶ Move to an explicit clocking with signals read on rising or falling clock edge
 - ▶ Double Data Rate (DDR) clocks on both edges
 - ▶ Currently DDR4 is current standard

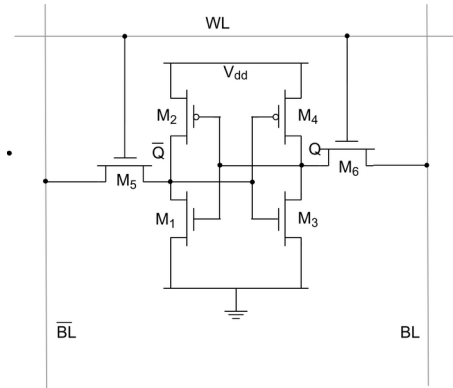
Future of DRAM

- ▶ DDR5 specs due by end of 2016
- ▶ Very little public information yet
- ▶ Alternatives to capacitance based storage
 - ▶ Resistive RAM - fast switching, led by RAMBUS
 - ▶ Magnetoresistive RAM - uses magnetism rather than electric charge to store data
 - ▶ Phase Change Memory - data based on the changes of crystal structure of a material

SRAM

- ▶ Instead of using the charge in a capacitor, static RAM (SRAM) uses the state of a set of transistors to store a bit
- ▶ Static means the value stays in the memory as long as there is power.
- ▶ There is no leakage and no need to refresh the memory
- ▶ SRAM is used to provide processor registers and caches
- ▶ SRAM also found in hard disks, DVD drives etc. to buffer track data before writing

SRAM Cell



SRAM v DRAM

- ▶ SRAM is faster than DRAM
- ▶ SRAM uses less power than DRAM (at low clock speeds)
- ▶ SRAM takes up more space than DRAM
- ▶ SRAM costs more than DRAM
- ▶ SRAM is used if low power or high performance is required
 - embedded devices, caches
- ▶ DRAM is used for main memory mainly due to cost

Effective memory access rate

- ▶ The effective memory access rate is the average time it takes to load some data
- ▶ Suppose 90% of data is found in L1 cache, 4% in L2 cache and the remainder in main memory
- ▶ $0.9 \times 2ns + 0.04 \times 4ns + 0.06 \times 50ns = 4.96ns$
- ▶ You want to organise your code to achieve good hit rates
- ▶ Exploit locality of reference
- ▶ Use the same data locations
- ▶ Amortize the cost of the cache miss over many accesses over and over since they are in the cache