Sequential Logic

CSCI 2050U - Computer Architecture

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Outline

- Flip flops
- Registers
  - Counters
- RAM
- The memory hierarchy

Flip Flops

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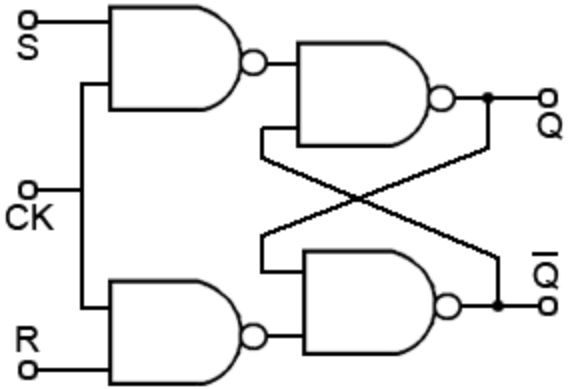
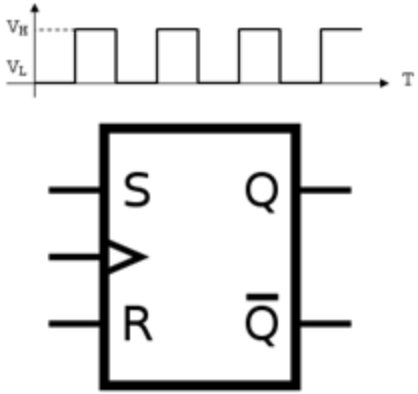
SR Flip Flops

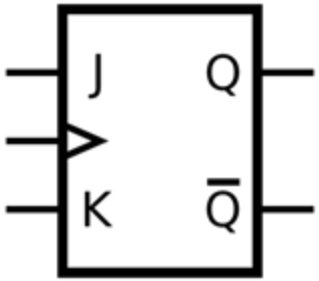
- The main issue with latches is that changes to the inputs start changing the value instantly
- To control when values update, we use an SR *flip flop*
  - Flip flops are (clock) *edge triggered*





JK Flip Flops

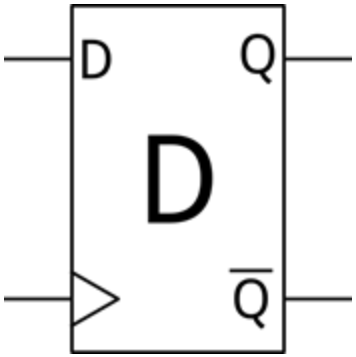
- A JK flip flop is identical to an SR flip flop, except:
  - It uses the S=1, R=1 input combination
  - S and R are called J and K, since they don't strictly mean set and reset, anymore
  - When J = 1 and K = 1, the bit is flipped/complemented (0 → 1, 1 → 0)

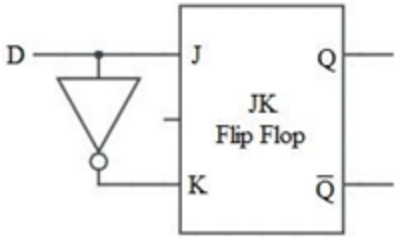


J	K	Q_{i+1}
0	0	Q_i
0	1	1
1	0	0
1	1	Q_i'

D Flip Flops

- A D flip flop a much simpler concept:
  - It has one input, D
  - When D = 1, the value is set to 1
  - When D = 0, the value is set to 0





D	Q_{i+1}
0	0
1	1

Registers

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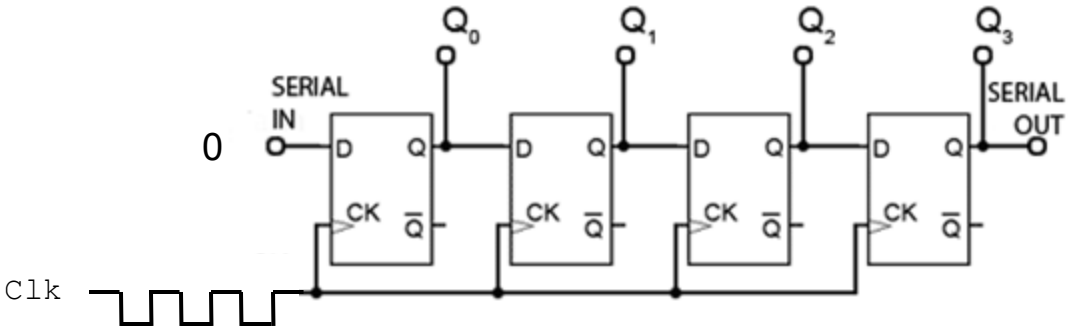
Registers

- A register is a high-speed memory component accessible to the CPU
  - Special-purpose registers:
    - Program counter: Address of the next instruction to be executed
    - Memory address register: Address for memory storage/retrieval
    - Memory buffer register: Value to be stored to/the value retrieved from memory
    - Status register: A set of flags used for signalling (e.g. carry, overflow)
  - General-purpose registers:
    - Registers used as operands in arithmetic operations

Registers

- This is a 4-bit register with serial loading:



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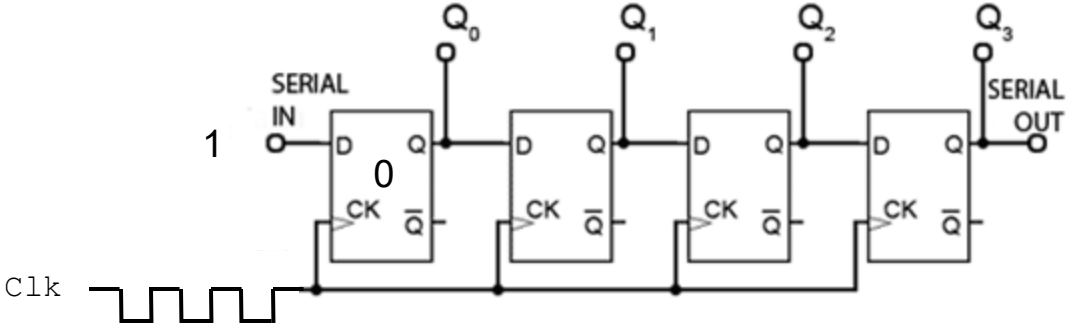

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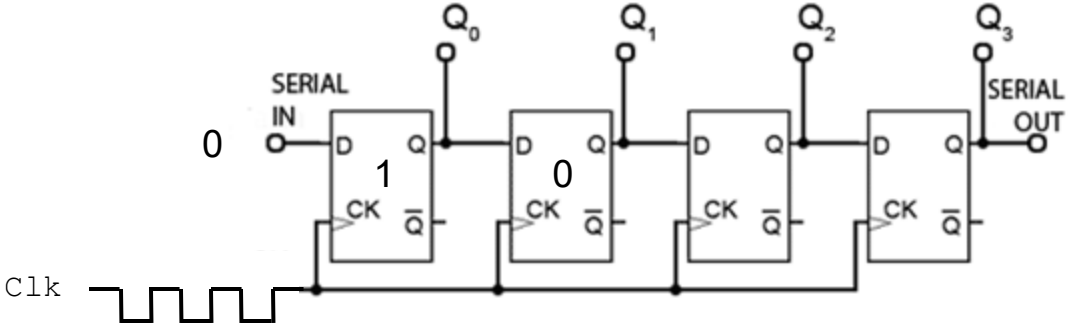

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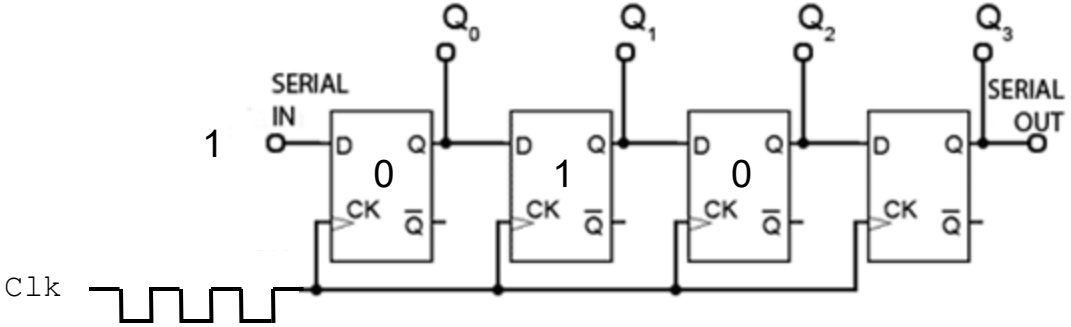

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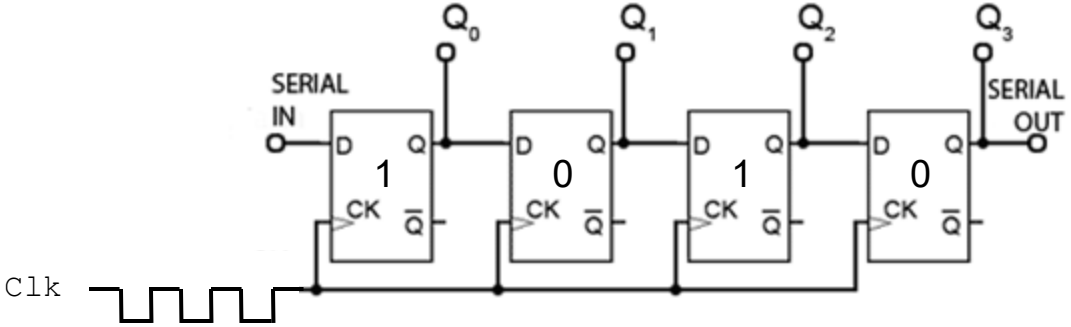

Registers

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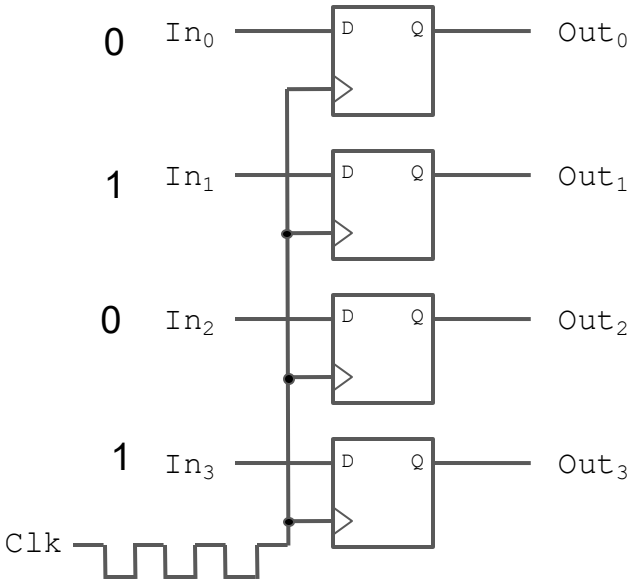

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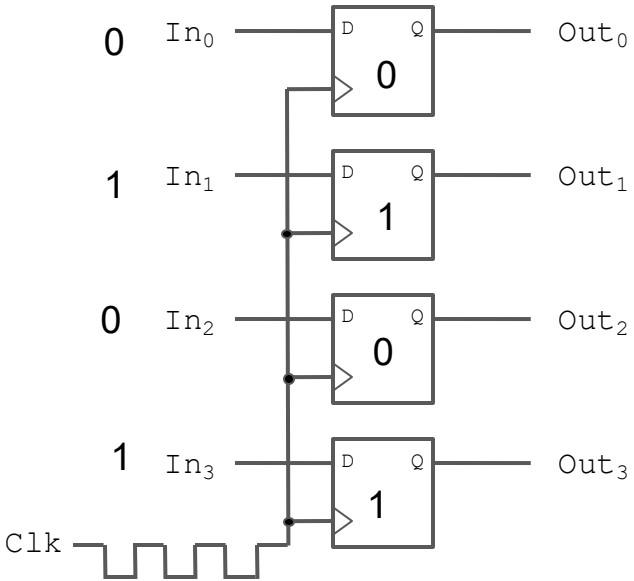
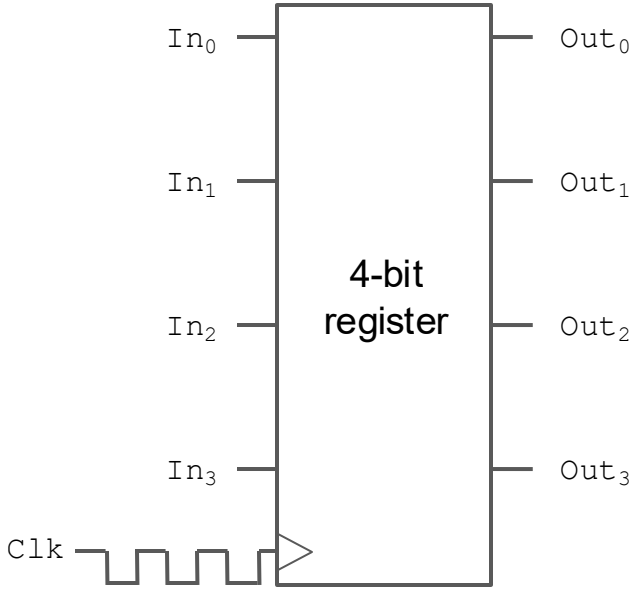


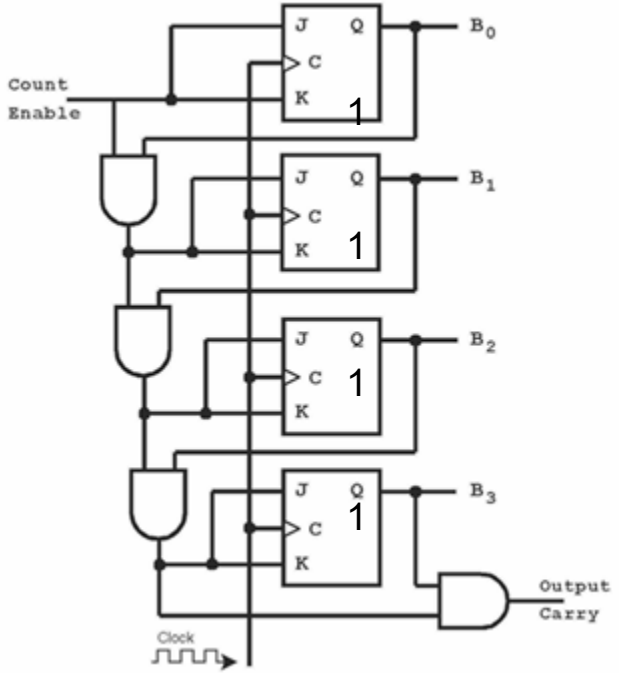
Registers

- This is the same 4-bit register shown in block notation:



Counters

- This is a 4-bit counter register:
  - Useful for the program counter and general-purpose registers



RAM

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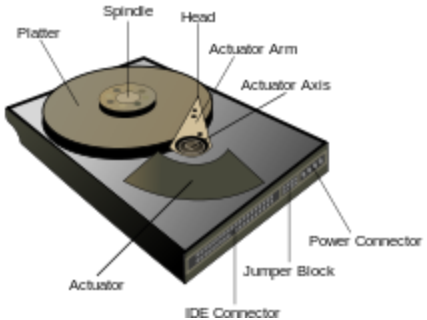
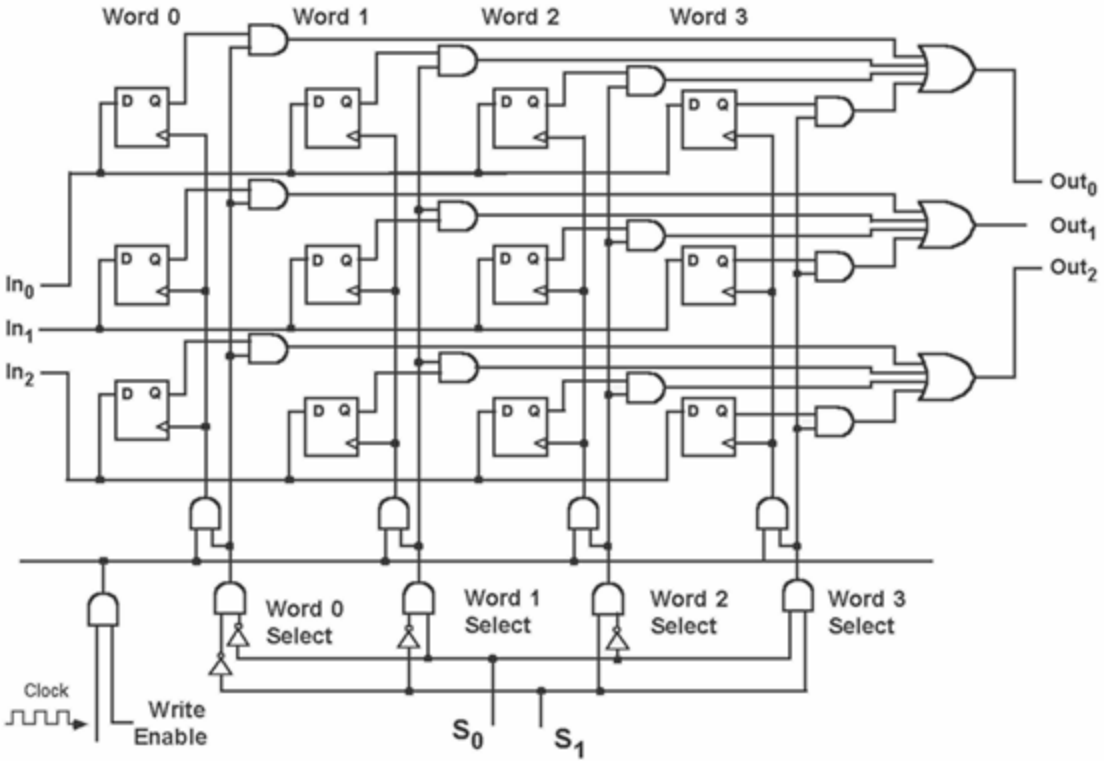
Memory

- Memory is implemented in several different ways:
  - Magnetic - permanent, high-density, low-cost (HDD)
  - Flash - permanent, high-density, low-cost (SSD)
  - Capacitors - volatile, medium-density, medium-cost (DRAM)
  - Flip flops - volatile, low-density, high-cost (SRAM, cache)
    - Let’s look at how we can implement this type of memory
- Other kinds of memory are discussed later:



Memory Arrays

- This is a 4x3-bit memory array



The Memory Hierarchy

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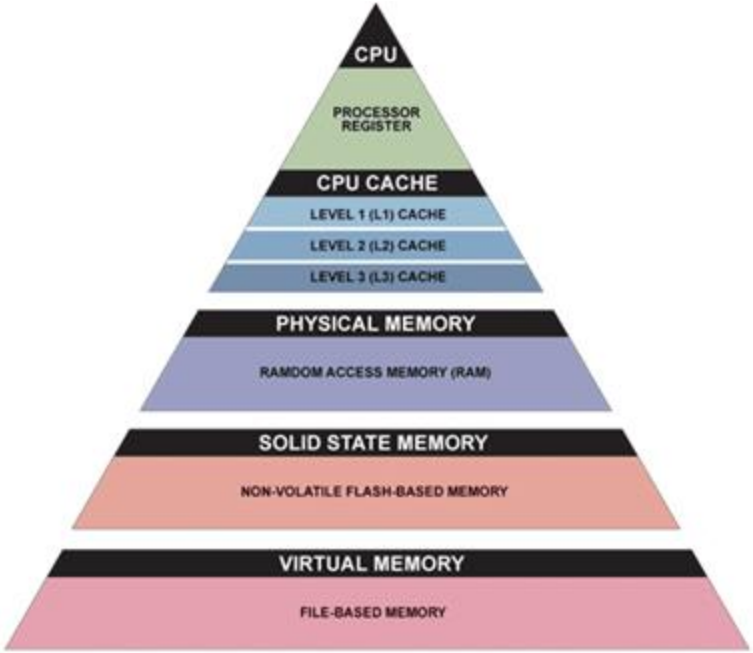
The Memory Hierarchy

- All forms of memory can be organized into the following hierarchy:



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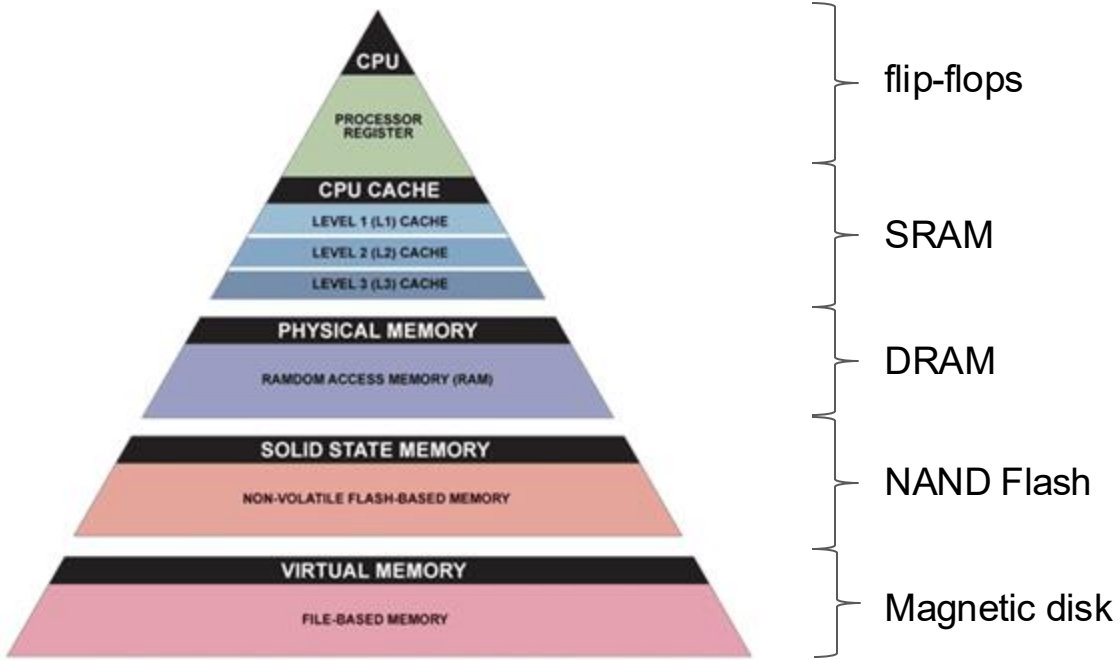

Wrap-up

- Flip flops
- Registers
  - Counters
- RAM
- The memory hierarchy

What is next?

- Caching
- Virtual memory