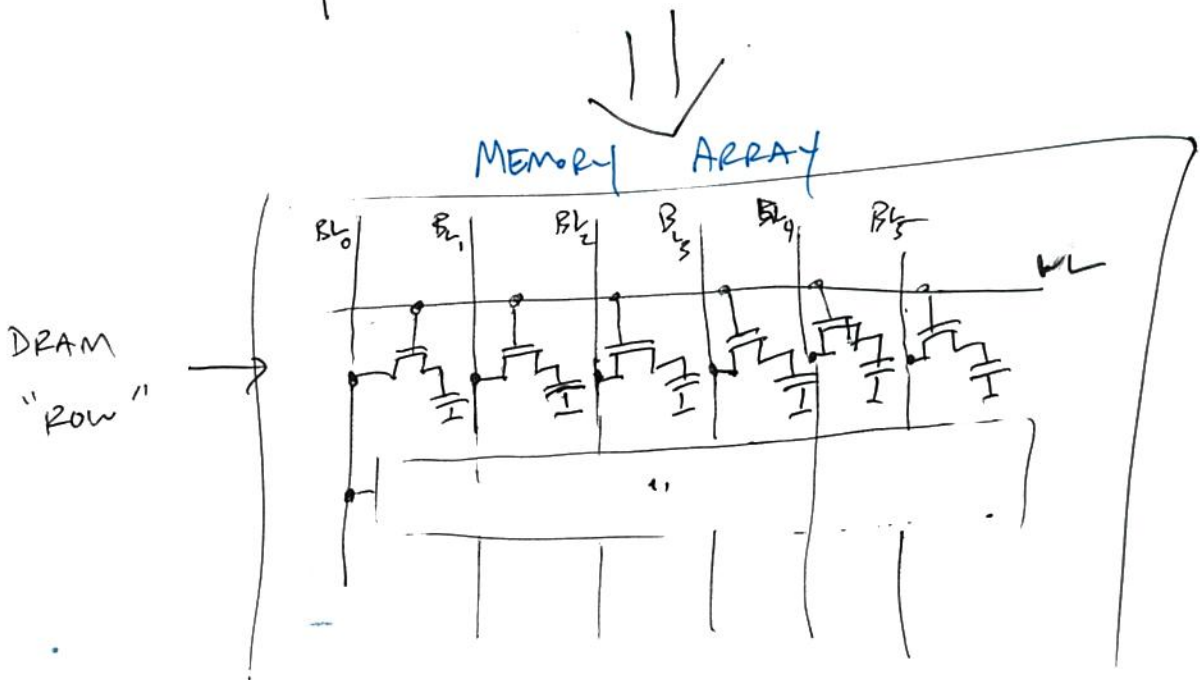
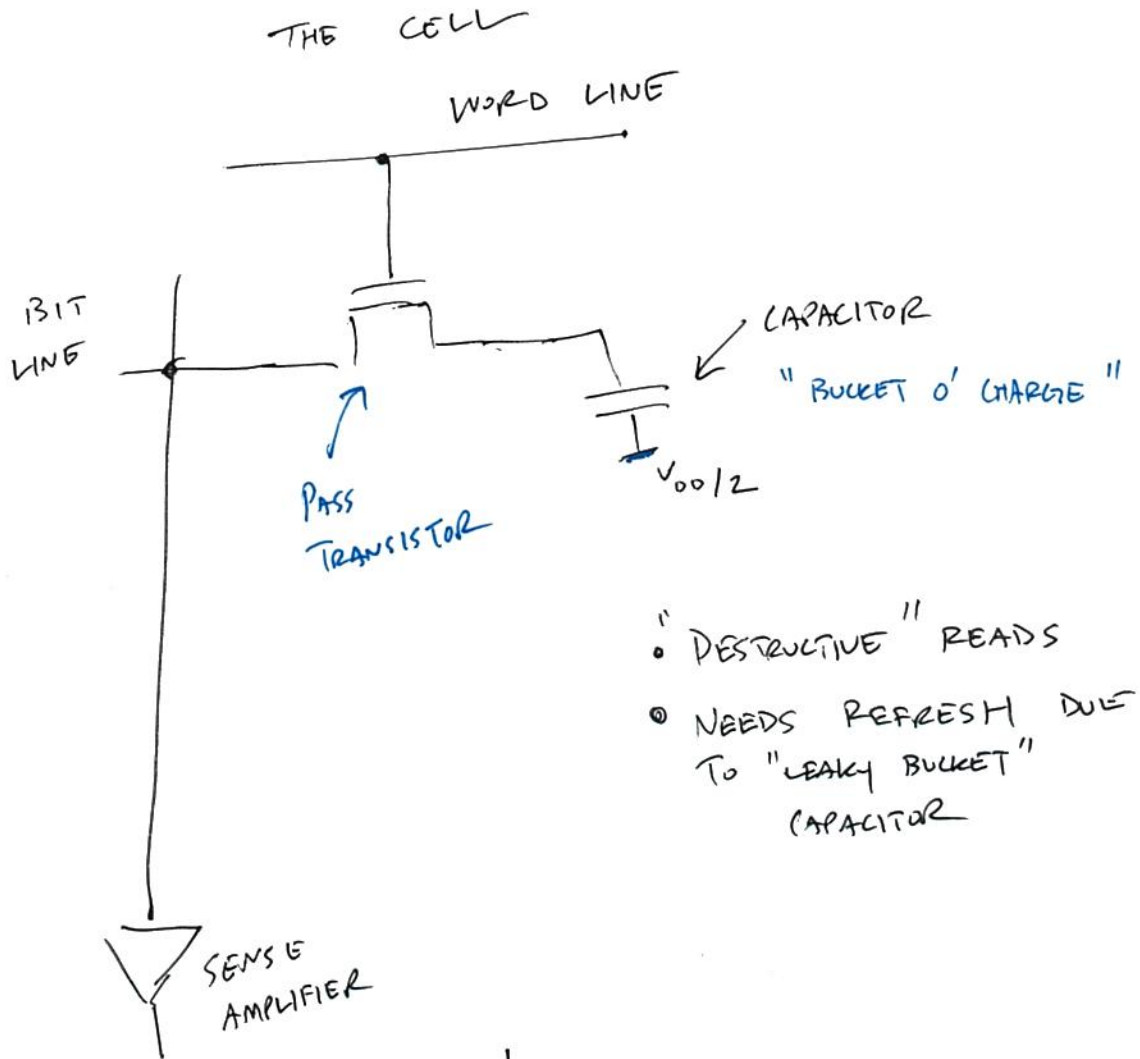


Sequential Circuits

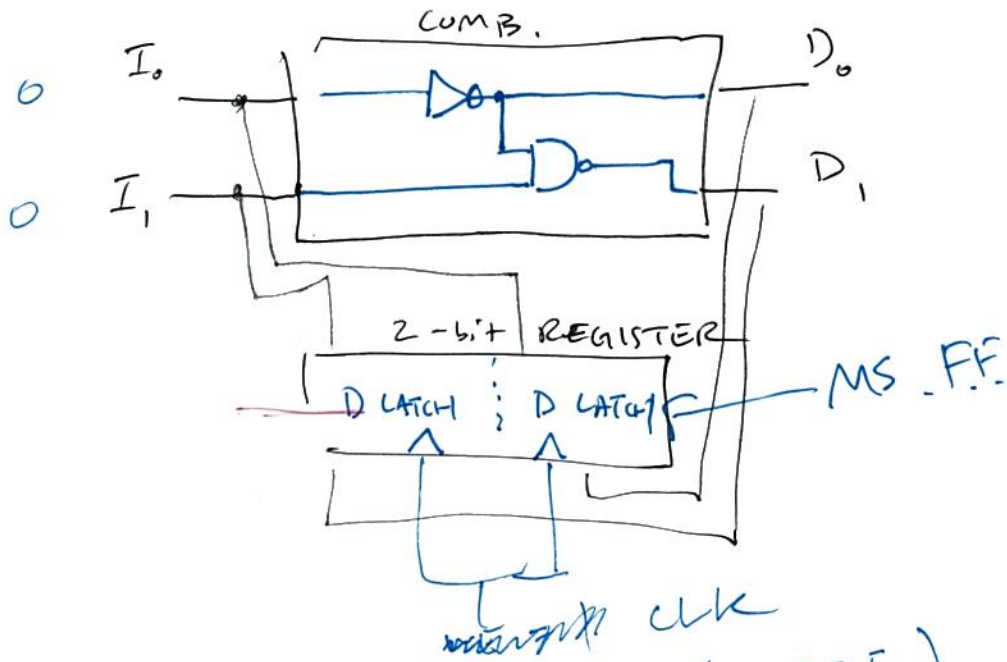
- A **Sequential circuit** is one that combines combinational logic and storage elements. The combinational circuit component takes in input values and stored values, and produces output values and new stored values (see drawing)
- When the combinational logic depends on the storage, we must have a way to make sure that things happen in a series of discrete steps. We'd like to have something like lockstep operation
- The solution turns out to be a **clock**. This allows us to make the circuit operate in a series of atomic steps in sequence (in lockstep).
- Another way to put this is that the clock **synchronizes** the operation of the storage logic and the combinational logic
- We *interleave* computation in the combinational circuit and storage circuit, having one happen after the other, but not at the same time
- You can think of a clock as a square wave. It goes between 0 and 1 at regular intervals. In actual devices, it is **not** an ideal square wave however
- What we'd like to have is that when the clock is *low*, we allow computation to happen in the combinational circuit, but changes are not accepted into the storage elements.
- When the clock is *high*, we accept inputs into storage
- A clock does not solve the problem, however, of races between the storage elements and the combinational circuit.
- The solution there is a flip flop. We're only going to look at the **master-slave** flip-flop, which is really just two clocked D latches connected in a series, one with an inverted clock signal
- This flip flop allows us to *stage* our writes to the storage in one flip flop, and they are finalized in the second on the next clock pulse

DRAM

" DYNAMIC
RANDOM
ACCESS
MEMORY "



EXAMPLE



SEQUENCE: $(I_0 = 0 = I_1)$

D_0 : 1 0 1 0 1 0 - - -

D_1 : 1 1 0 1 0 1

D_0 : 1 →

D_1 : → 11

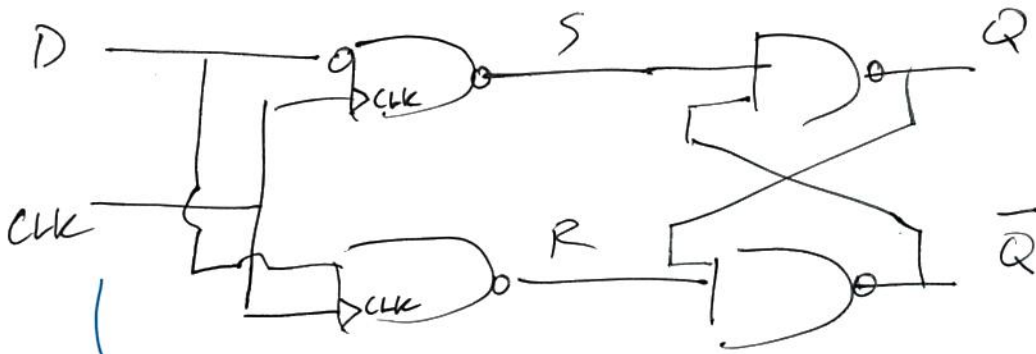


TRANSPARENT

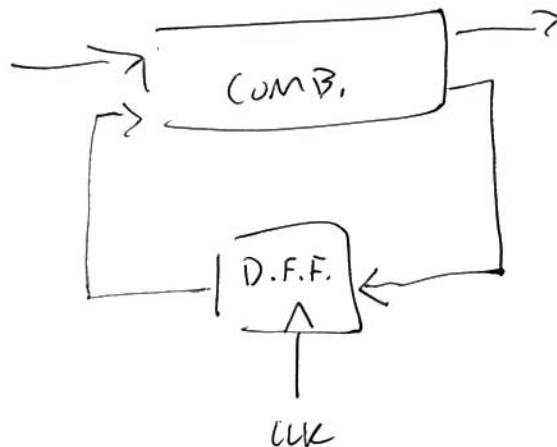
~~D-LATCH~~

D-FLIP FLOP!

(we now HAVE A CLOCK)

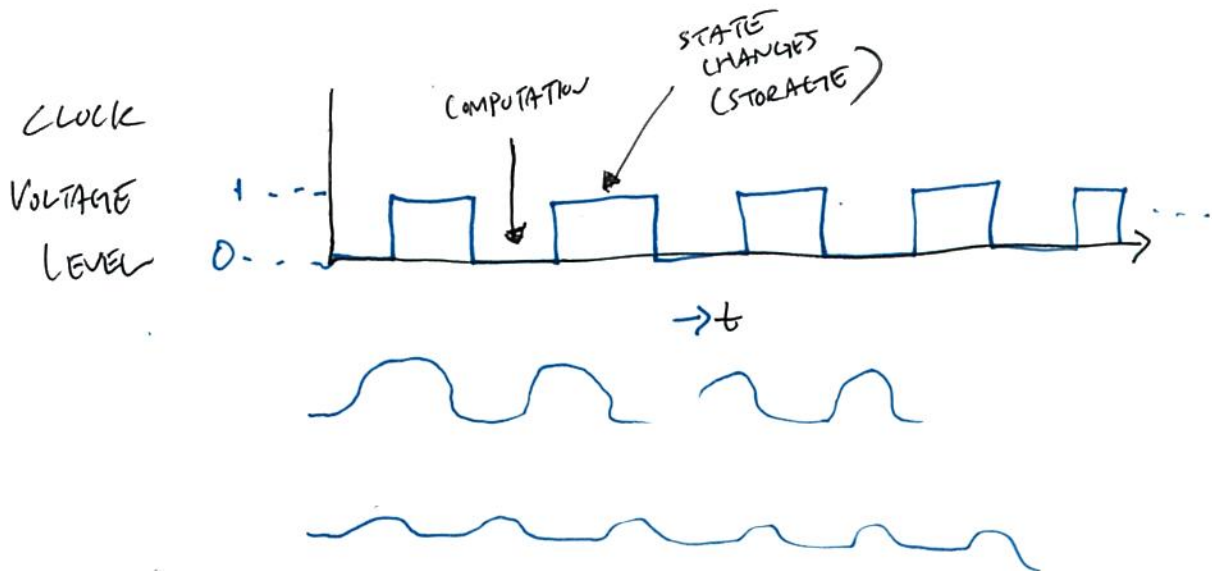
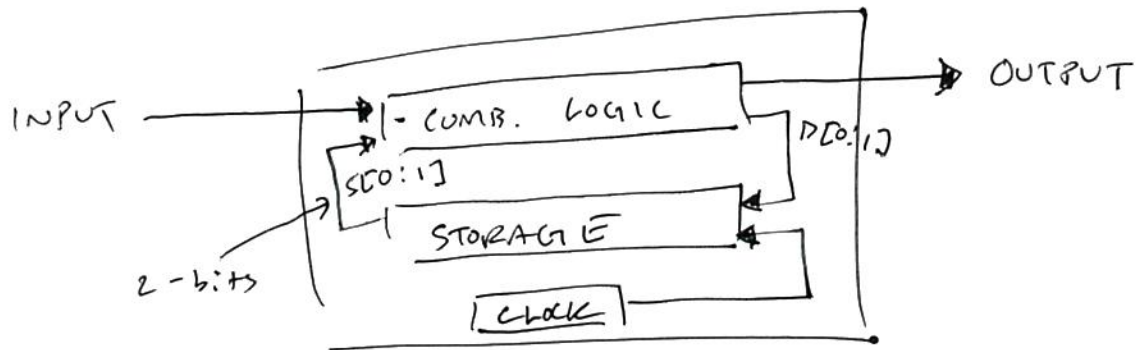


→ WRITE ENABLE IS NOW DRIVEN BY THE CLOCK!

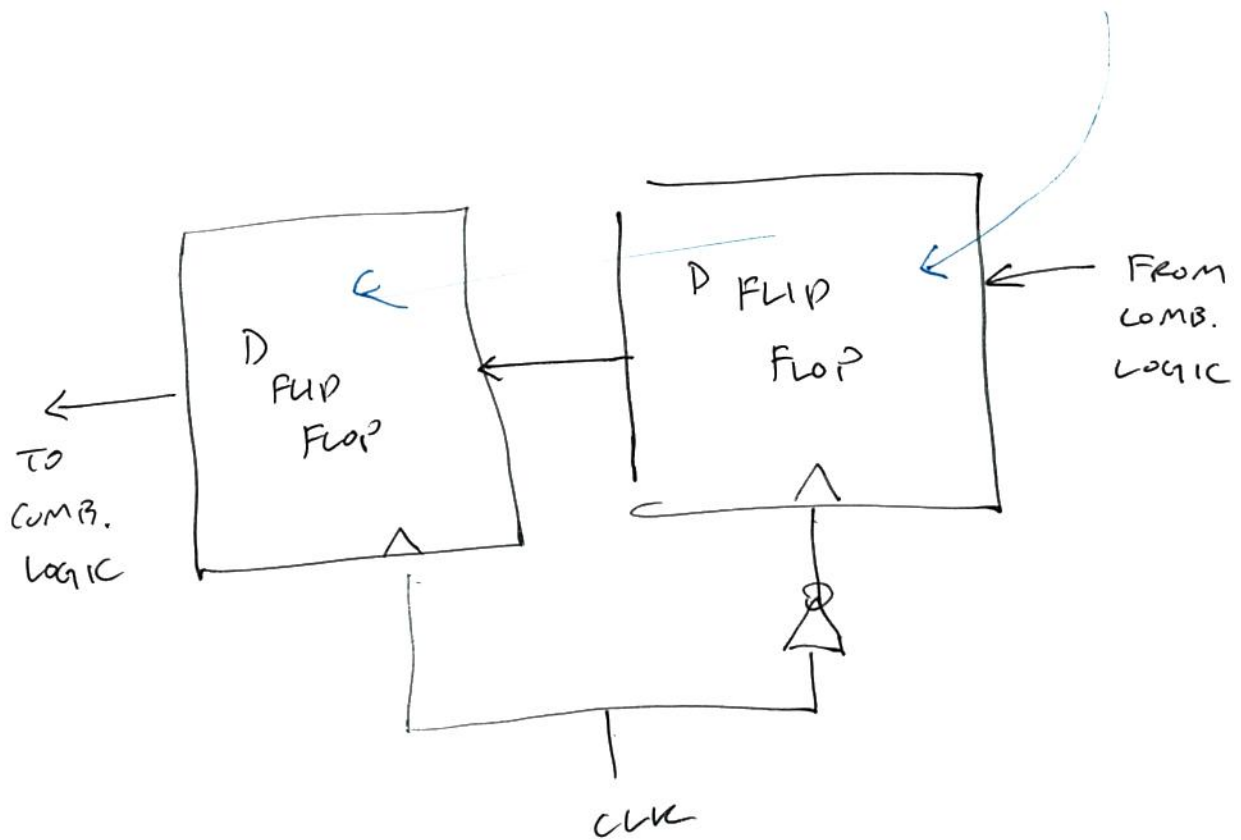


???

SEQUENTIAL CIRCUIT



MASTER - SLAVE FLIP-FLOP



" STAGED WRITING "