Introduction to Sequential Logic

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- In combinational circuits, boolean equations are used to generate a logical circuit

- Sequential circuits contain external inputs and outputs, as well as combinational logic, and, most importantly, memory (internal inputs and outputs)

- Combinational Circuits

    - Always gives the same output for a given set of inputs

        * Ex. An adder always generates sum and carry, regardless of previous inputs

- Sequential Circuits

    - Stores information

    - Output depends on stored information (state) plus input

        * So a given input might produce different outputs, depending on the stored information

    - Useful for building "memory" elements

    - Two kinds of sequential circuits

        * Asynchronous
        * Synchronous

- Storage Elements

    - Latches and flip-flops

        * Very fast, parallel access
        * Very expensive (one bit costs tens of transistors)

    - Static RAM (SRAM)

        * Relatively fast, only one data word at a time
        * Expensive (one bit costs 6+ transistors)

    - Dynamic RAM (DRAM)

        * Slower, one data word at a time, reading destroys content (refresh), needs special process for manufacturing
        * Cheap (one bit costs only one transistor plus one capacitor)

    - Other storage technology (flash memory, hard disk, tape)

        * Much slower, access takes a long time, non-volatile
        * Very cheap

- Asynchronous Sequential Circuit

– The output changes whenever the input changes. Sometimes, however, they do have an enable input. If this enable input is low, they maintain the previous output regardless of the changes in the inputs. If the enable is high, the output changes as the input changes.

– Implemented with latches

* SR latch
  · R is used to "reset" or "clear" the element — set it to zero
  · S is used to "set" the element — set it to one
  · If both R and S are one, out could be either zero or one
  · "Quiescent" state — holds its previous value

* D latch
  · Prevents downfall of SR latch
  · Multiple D latches may be used to store more data
  · A single write enable signal for all latches may be used for simultaneous writes
  · This makes a register, or a structure that stores more than one bit and can be read from and written to

• Synchronous Sequential Circuits

– Synchronous devices are triggered on the rising edge or the falling edge of an external clock. Any change in inputs has to wait until the next rising (or falling) edge of the clock to affect the output.

– Implemented with flip-flops:

* SR flip-flop
* D flip-flop
* JK flip-flop
* T flip-flop

– Currently, we cannot simply wire a clock to WE of a latch

– Whenever the clock is high, the latch propagates D to Q

– The latch is transparent