Memory Circuits

CS22

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Combinatorial circuits consisting of AND, OR, and NOT gates are very useful in modeling conditions or boolean expressions. For example, the above circuit's output is 1 if and only if $x_2 = 1$ and $x_1 = 0$.

However, we can also make more complex circuits by allowing feedback. That is, outputs from a gate may be inputs to that same gate. What additional properties might such circuits have?

In this circuit with an AND and an OR gate, we see that:
If $x_2 = 1$, the output will be 1 because of the OR gate.
If $x_2 = 0$ and $x_1 = 0$, the output will be 0.
If $x_2 = 0$ and $x_1 = 1$, the output will hold whatever value it has.

Once we introduce the notion of time, this ability to either hold or switch allows us to represent *memory*. In other words, the output may be 0 or 1 at some time, but the circuit may then cause it to change or remain the same, depending on the inputs.
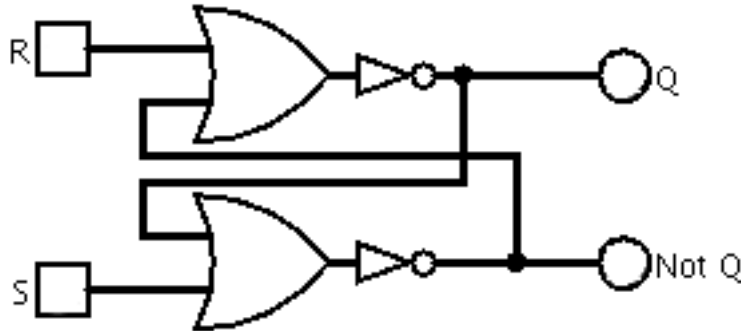
S-R Latch
This is a traditional basic memory component, which allows us to either store and hold Q or change its value by flipping an input, a very useful ability.
If $S = 0, R = 0$, then Q holds.
If $S = 1, R = 0$, then Q becomes 1.
If $S = 0, R = 1$, then Q becomes 0.
$S = 1, R = 1 \to Q$ is BAD because Q and not Q have the same value (try it).

The Clock:
An input to use (represented by C), that oscillates between 1 and 0 at some fixed rate. Clocks are often used by a computer to provide input in the absence of or in addition to user input. For example, when playing a video on your laptop, the image may be updated every few ticks to produce what appears like continuous motion.

D-Latch
Using the clock, we can allow D to change output Q only when the clock C is on (when $C = 1$). As long as the clock is on, changes to D will be immediately reflected in changes to Q. Notice that the D-latch is made up of 2 AND gates and an S-R latch.
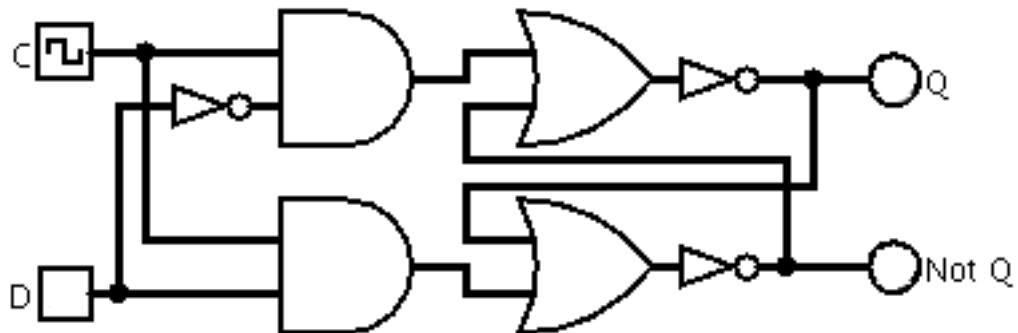
Flip-Flop
Rather than allowing D to change Q as long as $C = 1$, we often would like updates only at certain points in time. Flip-flops give us this ability to only update Q to D when the clock changes. In the following flip-flop containing 2 D-latches (as shown above), Q is updated when the clock changes from 0 to 1.
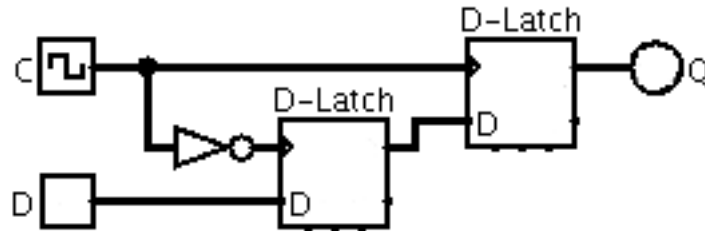
Note: Use Logisim to create and simulate these circuits and others!