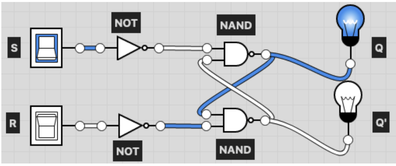
MATH 8 [2023 NOV 12]
HANDOUT 8 : LOGIC 3: SR FLIP-FLOPS. CONDITIONALS

SR Flip-Flop

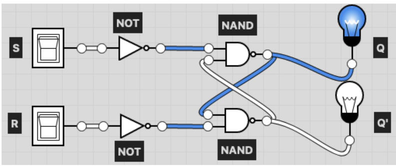
Today we played a little more with circuits, and especially with SR-Flip Flop. Consider the following circuit, which is called SP-Flip Flop. Interestingly, the output of NAND-gates is also an input to other NAND-gates. Let us look at how it works.

Let's imagine that we turn S on to 1. NOT-gate changes it to 0, and when it is fed to the NAND gate, the output of it would be 1, since $0\ \text{NAND}\ X = 1$ for any X (make sure you understand why it is so!). As a result, Q bulb will turn on.

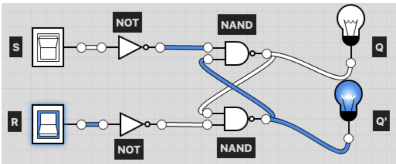
At the same time, R is off (is 0), and it is changed to 1 by the NOT-gate, and fed to NAND along with the output of the top NAND-gate, so the output of the bottom NAND-gate is 0 (since $1\ \text{NAND}\ 1 = 0$).



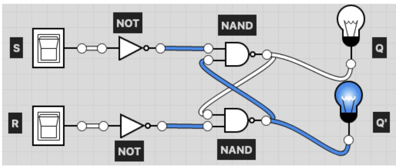
Interestingly, if we now flip S off, the lightbulbs will not change their state: lightbulb Q will stay on, and Q' will stay off: one of the inputs to the top NAND will always stay off, regardless of what S is.



Now if we switch S to off, and turn R on, the lightbulbs will flip: Q' will be lit up, and Q will be off.



We will also observe a similar situation: now switching R to off will not change the state of lightbulbs:



The state when the top lightbulb is lit up is called S-state, that is the flip-flop is in SET position. When the lower lightbulb is on, the flip-flop is in RESET (R) position.

The interesting thing about this circuit is that it has **memory**: once it's in SET-state, the top lightbulb indicates it, and switching S-switch off won't change anything – the top lightbulb will still be on. Similarly, once we're in R-state, we can switch R-switch off, but the lightbulbs will still indicate that we are in the R-state (the 2nd light bulb is on)

REVIEW: IMPLICATION AND EQUIVALENCE

In addition to all previous logic operations, there is one more which we have not yet fully discussed: **implication**, also known as **conditional** and denoted by $A \implies B$ (reads *A implies B*, or *"If A, then B"*). It is defined by the following truth table:

A	B	$A \implies B$
T	T	T
T	F	F
F	T	T
F	F	T

Note that in particular, in all situations where A is false, $A \implies B$ is automatically true. E.g., a statement "if $2 \times 2 = 5$, then..." is automatically true, no matter what conclusion one puts in place of dots.

Another logic operation is called **equivalence** and defined as $(A \iff B)$ is true if A, B always have the same value (both true or both false).

One can easily see that $(A \iff B)$ is equivalent to $(A \implies B)\text{ AND}(B \implies A)$.

PROBLEMS

1. Show that $A \implies B$ is not equivalent tp $B \implies A$, i.e. they have different truth tables and one of them can be true while the other is false.

2. Prove the contrapositive law: $A \implies B$ is equivalent to $(\neg B) \implies (\neg A)$

3. Show that $(A \implies B)$ is equivalent to $B \vee \neg A$. Can you rewrite $\neg(A \implies B)$ without using implication operation?

4. Consider the following statement (from a parent to his son):

"If you do not clean your room, you can't go to the movies"

Is it the same as:

(a) Clean your room, or you can't go to the movies
(b) You must clean your room to go to the movies
(c) If you clean your room, you can go to the movies

5. English language (and in particular, mathematical English) has a number of ways to say the same thing. Can you rewrite each of the verbal statements below using basic logic operation (including implications), and variables

- A: you get score of 90 or above on the final exam
- B: you get an A grade for the class

(As you will realize, many of these statements are in fact equivalent)

(a) To get A for the class, it is required that you get 90 or higher on the midterm
(b) To get A for the class, it is sufficient that you get 90 or higher on the midterm
(c) You can't get A for the class unless you got 90 or above on the final exam
(d) To get A for the class, it is necessary and sufficient that you get 90 or higher on the midterm

6. Show that in all situations where A is true and $A \implies B$ is true, B must also be true. [This simple rule has a name: it is called *Modus Ponens*.]

7. Show that if $A \implies B$ is true, and B is false, then A must be false. [This is called *Modus Tollens*.]