Logic Gates and Flip Flops

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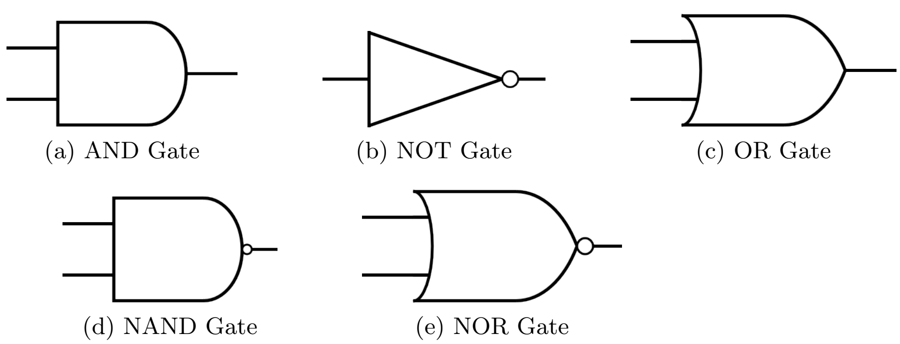
Abstract

Using NAND gates and inverters to construct logic gates, the action of the NAND, AND, OR, NOR, XOR and XNOR gates could be found. The results were found to be the same as the results predicted. A flip flop was then examined and it was found what the effects the inputs had on it. Finally, using flip flops, asynchronous and synchronous counters of scale 16 and 10 were constructed and examined.

⋆ Introduction

A logic gate is a device that takes one or more electrical signals, performs an operation on them and outputs a signal. There are two types of signals. When the signal is present, we refer to it as a 1 and when no signal is present, it is a 0. There are several logic gates and it is possible to put together logic gates to create even more complex logic gates.



(a) AND Gate (b) NOT Gate (c) OR Gate

(d) NAND Gate (e) NOR Gate

Figure 1: Graphical Notation for Various Logic Gates

AND Gate

The AND gate will produce a logical 1 if and only if all the inputs are 1s. Otherwise, it will output a 0.

NOT Gate

Also known as an inverter, this gate accepts an input and outputs the opposite result.

NAND Gate

The NAND gate is the opposite of the AND gate and will produce a 0 if and only if all the inputs are 1 and 1 otherwise. With the NAND gate and the NOT gate, a variety of logic gates can be produced.

OR Gate

The OR Gate produces a 1 if at least one of the inputs is 1 and 0 otherwise. The NOR gate does the opposite. There is also the XOR Gate which will only produce a 1 if one of the inputs is 1 and the other is 0.

Boolean Algebra

These operations can be expressed mathematically in terms of Boolean algebra. This is an algebra with two operations $\cdot$(AND) and $+$(OR). We also define negation as $\bar{A}$. One well known statement is De Morgan's Law whch says,

$$\overline{A \cdot B} = \bar{A} + \bar{B}$$

This can be proved by brute force by listing all the possibilities. As an example, taking $A = 1$, $B = 0$, then for the LHS,

$$\overline{1 \cdot 0} = \bar{0} = 1$$

and on the RHS,

$$\bar{1} + \bar{0} = 0 + 1 = 1$$

which are equal.

Flip Flops

The flip flop is a device that has four inputs; Ck(clock), J, K, Cr(clear) and Pr(set); and two outputs; Q and $\bar{Q}$. The flip flop will be in a particular state and can be changed by the clock pulses but how it changes depends on the inputs at J and K. If both are 0, then the outputs do not change. If they are of opposite value, then the output will change only once. If they are both 1, then the output will change for each pulse.

⋆ Experimental Method

The apparatus consisted of a board with five switches, a button switch and a clock to serve as inputs. There were several SN7400, SN7404, SN7410 and SN7476 logic gates and 10 indicator lamps to detect a signal. The signals used were all of five volts and it was ensured that each gate was powered and grounded correctly.

NAND and AND Gates

Using a SN7410 circuit, the logic of a 3 input NAND gate was found. With an inverter from the SN7404 circuit, an AND gate was produced and the truth table was found. An inverter was then put on the one of the inputs of the AND gate and the effect on the other two inputs was found.

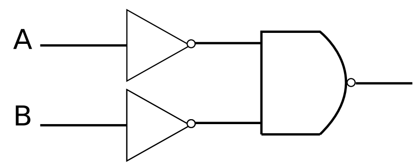


Figure 2: OR Gate Circuit

OR and NOR Circuits

The circuits in figure 2 were set up and the results were tabulated. An inverter was then added to the output to produce a NOR gate and the results were also tabulated.

XOR and XNOR Circuits

The circuits in figure 3 were set up and the results were tabulated. A XNOR gate was then created by putting an inverter on the XOR gate and the action was found.

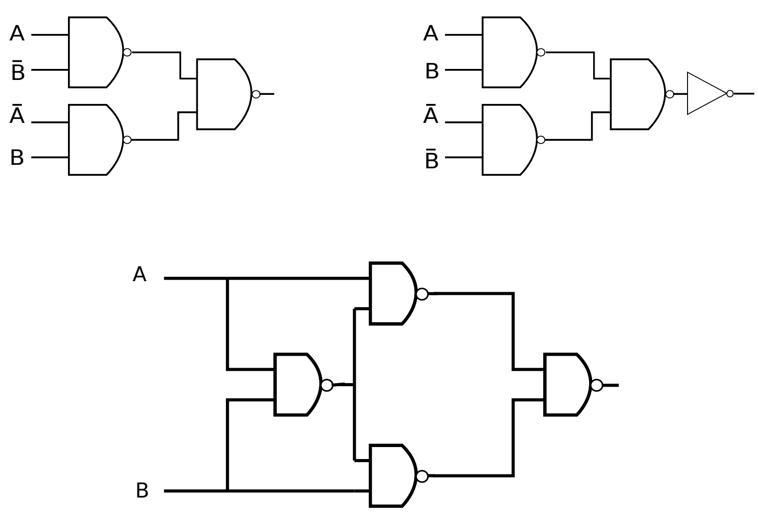


Figure 3: 3 different XOR Gate Circuits

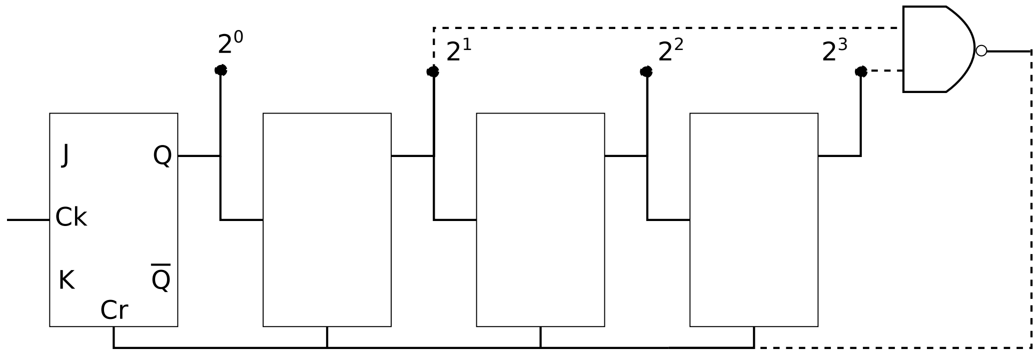


Figure 4: Asynchronous Scale of 16(conversion to scale 10 in dashes)

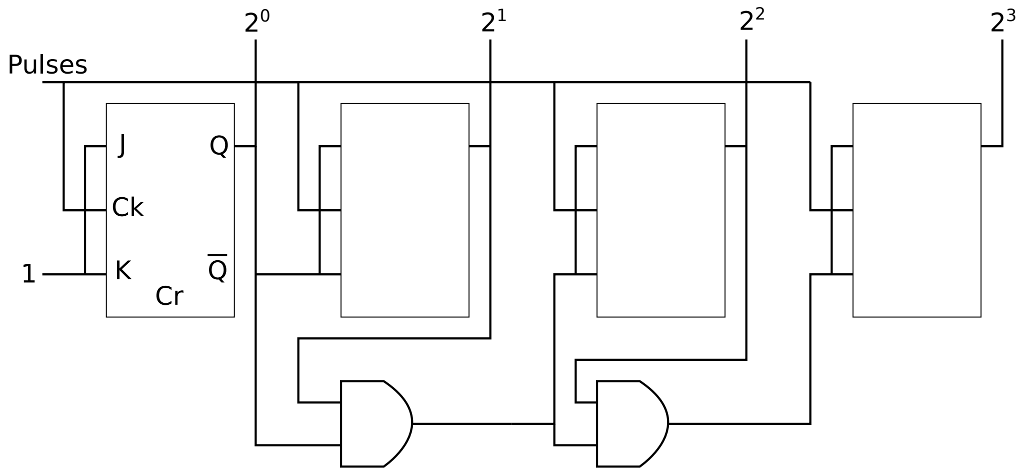


Figure 5: Synchronous Scale of 16

Flip-Flops

Using the SN7476, the clock is connected to the clock input and J, K, Cr, Pr are wired up to separate switches and the outputs were wired to the lamps. It was then observed what the action of the clock had with different values of J,K. The effects of the clear and set inputs were found.

Counter

The circuits in figures 4 and 5 are set up. The action of 16 pulses is found for both cases and the action of the dashed circuit is found.

⋆ Results and Analysis

NAND and AND Gates

These were the results for the NAND gate as expected. Disconnecting one of the inputs gave the same results as a two input gate.

A	B	C	Output
0	0	0	1
1	0	0	1
0	1	0	1
0	0	1	1
1	1	0	1
1	0	1	1
0	1	1	1
1	1	1	0

The AND gate was produced with an inverter and the following results were found,

A	B	C	Output
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
1	0	1	0
0	1	1	0
1	1	1	1

An inverter was then put on the outputs of one of the inputs and the following results were found,

Inhibit	B	C	Output
0	0	0	0
0	1	0	0
0	0	1	0
0	1	1	1
1	0	0	0
1	1	0	0
1	0	1	0
1	1	1	0

The inhibit input acts as an inhibitor on A and it only outputs a signal when the inhibitor is off.

OR and NOR Circuits

The following results were found for the OR gate,

A	B	Output
0	0	0
1	0	1
0	1	1
1	1	1

The NOR gate produced the following results,

A	B	Output
0	0	1
1	0	0
0	1	0
1	1	0

XOR and XNOR Circuits

The XOR gate produced the following results,

A	B	Output
0	0	0
1	0	1
0	1	1
1	1	0

The XNOR gate produced the following results,

A	B	Output
0	0	1
1	0	0
0	1	0
1	1	1

Flip-Flops

It was found that for $J = K = 0$, the clock pulse did not change the ouputs. For $J = 1$, $K = 0$, the output changed once upon clearing. Similar results were found for $J = 0$, $K = 1$. For $J = K = 1$, the outputs would alternate with each pulse. It was found that the clear input would reset how the input would change the output. So for example, for $J = 1$, $K = 0$, after one pulse, nothing would happen. Upon clearing, one pulse would change the output followed by nothing, thus "clearing" the flip flop. The set input would set Q to 1.

Counter

For both the asynchronous and synchronous counters of scale 16, the following results were found for each pulse,

Pulse	2^3	2^2	2^1	2^0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1
16	0	0	0	0

This corresponds in counting to 15 in binary. Using the asynchronous scale of 10 circuit, the following results were found,

Pulse	2^3	2^2	2^1	2^0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	0	0	0	0

It was found that other scales could be produced by hooking up the required inputs to the NAND gate which would produce an ouput when the number is reached thus clearing the flip flops.

⋆ Conclusion

All the logic gates produced the results that were predicted mathematically. It was found that any logic gate could be produced from NAND gates and inverters. Although it wasn't done, it was also possible to rely only on NAND gates since an inverter can be produced from NAND gates.

After examining flip flops, it was found that they could be used to produce simple counters. It was also possible to change the scale of the counters. This shows one of the applications of flip flops.

While this experiment was somewhat tricky at first, of the 10 types of people who understand logic, we feel that were are the ones who do understand it.