Digi-Course II

Chapter - 2

In the last chapter of Digi-Course II we have seen how two NAND gates can be connected to make a simple R-S Flipflop.

The circuit and its truth table is again reproduced here for reference.

1

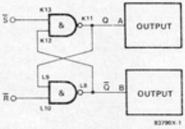


Table 1

$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$
0	0	1	1
0	1	1	0
1	0	0	1
1	1	0/1	1/0

As we have already seen, the last line of the truth table is ambiguous. Its relation is not defined in isolation, but the previous history of the outputs is involved in deciding which of the outputs will be 1 and which will be 0. The gate which had a "0" input prior to going on "1" retains a "1" at the output. By placing a "0" on the $\overline{S}$ input (set input) the Q output LED is turned on. By placing a "0" on the $\overline{R}$ input (Reset input) the Q output LED is turned Off. A practical application of this simple Flip flop circuit is the game of skill called "Old Shatterhand". this game tests how steadily you can move your hand?

Our R-S Flipflop works as an impartial judge of this game. The basic idea is very simple. A metalic ring is passed over a complexly bent wire such that the ring surrounds the wire but does not touch the wire at any place. If the ring touches the bent wire at any moment, that player has to drop out. Whether the ring touches the wire or not, is faithfully recorded by the R-S Flipflop.

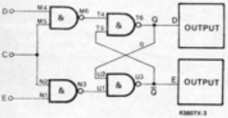
The bent wire is connected to the ground terminal on the Digilex board and the ring is connected to the input $\overline{S}$ (Pin K13) At the beginning of every round, the $\overline{R}$ input (Pin L 10) is momentarily shorted to the ground terminal. This gives "0" input to $\overline{R}$, thus resetting the Flipflop, and turning off the Q output LED. Now the player engages the ring aound the bent wire at one end and starts moving it towards the other end, without touching the wire with the ring. Even if the ring touches the wire just for a fraction of a second, the Flipflop is immediately set and the Q output LED glows, announcing the player to be an "Old Shatter hand".

The simple Flipflop circuit that we have just used can be said to have stored the information that the particular player has touched the wire with the ring. In short, the Flipflop is a memory device which stores the information last received. The information stored is always in form of zeroes and ones.

For complex memory applications like data storage, data processing, calculations which require large quantities of data to be handled, we require extremely large quantities of storage cells like Flipflops. Each Flipflop contains one bit-which is either zero or one. Integrated Circuits which serve this purpose are commercially available. One such IC is the popular 6116 memory IC, called a Static RAM. This Chip contains more than 16 thousand Flipflops. These Flipflops are internally arranged in such a way that they can be accessed externally using just a few pins. (16 thousand pins are not required!)

Nowlet us see another variation of our basic Flipflop. Connect two more NAND gates as shown in figure 3.

3



This arrangement is called a controlled or clocked R-S Flipflop. The Flipflop of this circuit can change its state only when a "1" appears on the control or clock input C.

Table 2.

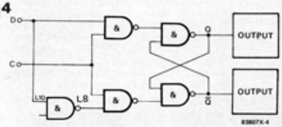
D	E	C	Q	$\overline{Q}$
0	0	0	0/1	1/0
0	1	0	0/1	1/0
1	0	0	0/1	1/0
1	1	0	0/1	1/0
0	0	1	0/1	1/0
0	1	1	0	1
1	0	1	1	0
1	1	1	1	1

The last condition which was present when C changed to "1" is retained, depending on which input had a "0" at that moment.

The C input thus behaves like a "Store" command input. The input conditions present when this input gets the "Store" command (logical "1" on C) are allowed to set or reset the Flipflop and this condition at the output is retained till a new "Store" command appears at pin C.

One disadvantage that still remains in this circuit can be removed by modifying it as shown in figure 4. Now we have only one input D for Set/Reset and one input for the control command "Store".

4



The restriction of having to use a zero as an input on $\overline{R}$ and $\overline{S}$ is now removed. The pin D can accept either zero or one.

Table 3

D	C	Q	$\overline{Q}$
1	1	1	0
0	1	0	1
1	0	0/1	1/0
0	0	0/1	1/0

Depending on the last condition when a "1" appeared on C

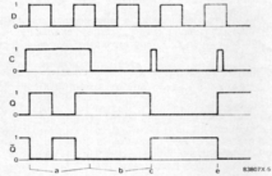
The functioning of this circuit can be summed up briefly as follows.

"1" appearing on D sets the Q output to "1"

"O" appearing on D resets the Q output to "O" provided a '71" was present on C. When a "O" is present on C, input D becomes ineffective.

As we have already seen, truth tables in case of Flipflops have ambiguous entires due to the time dependent nature of Flipflop operation. A better way to understand Flipflop operation is the use of timing diagrams.

5



These timing diagrams clearly illustrate the following properties of the Flipflop.

1. When C=1 (section a), whatever appears on D also appears on output Q.

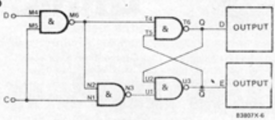
2. When C-O (section b), output retains its last level when C changed from 1 to 0 which means that the condition of output Q which was present at the moment when C changed from 1 to 0, is stored in the Flipflop. This is called the falling edge of the input on C.

3. Now that we have seen that only the following edge of input on C is effective as a "Store" command, we can easily understand the significance of points C and in the timing diagrams.

How long the level at c remains "1" is not important, what is important is only the moment it falls to "O" whatever state Q has at this moment is then retained.

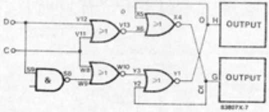
The circuit of figure 4 can be further simplified as shown in figure 6.

6



And using the counterpart of the NAND gate, namely the NOR gate, we can construct a Flipflop as shown in figure 7 below.

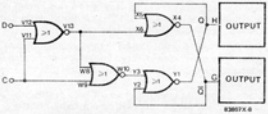
7

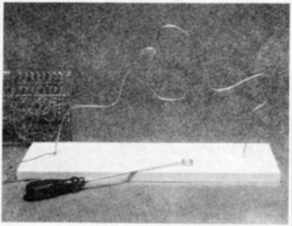


The NOR-Flipflop functions a bit differently from the NAND-Flipflop. Now that you have studied the NAND Flipflop in detail, it will not be difficult for you to prepare the truth table for the NOR-Flipflop as well, alongwith the timing diagrams!

A simplification of the circuit of figure 7 is also possible, and it is given below for reference.

8





"......... do you know different word for resistors?"

"No."

"Semiconductors!"

"Why do you say that? Resistors are not semiconductors"

Semiconductors

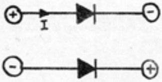
"Why not? If something has almost no resistance, we call it a conductor. If something has such a high resistance that it does not allow any flow of current, we call it a non-conductor. So if something has a resistance in between these two we must call it a semi-conductor!"

"No, it is not so. The resistors are not semi-conductors. The word semiconductor has a different meaning.

"Semiconductors are materials which sometimes conduct and sometimes don't. When they conduct and how much they conduct depends on various other factors."

"Then these semi conductors must be some sort of switches!

"No, these are not switches either. you are somewhere near the truth. We shall see a semiconductor with an example. You have seen a diode this is a semiconductor. It has two leads, and its symbol is like an arrow head and a bar. A current can flow through the diode if it has a direction which coincides with that of the arrow. In the other direction, no current can flow.



For simplicity let us say that when the plus pole of the applied voltage is behind the arrow, a current can flow, however when the plus pole is in front of the arrow, the bar between the plus pole and the arrow head can be imagined as blocking the current flow,"

"In that case, we can call the diode as an electrical 'One Way street!"

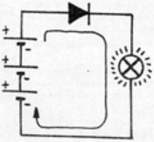
"Exactly that is what a diode is!

It acts as a conductor for current trying to flow in the direction of the arrow and it acts as a non-conductor for current trying to flow in the opposite direction.

This is the reason why it is called a semi conductor. We can also compare the diode with a unidirectional valve which opends only in one direction".

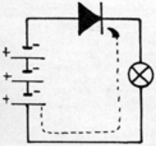
"But how do you cmpare this with a switch?"

"Let us again take the example of a diode.



This illustration shows a diode connected in series with a lamp and a battery. As we have already seen, the diode will allow the flow of current because the plus pole is behind the arrow head. The current will flow through the lamp and the lamp will glow. This diode is acting as a closed switch between the battery and the lamp.

Let us see now, what happends when the battery polarity is reversed



This time the plus ple is in front of the arrowhead and the bar comes between them. The current flow will be blocked by the bar and the lamp will not glow. The diode now behaves as an open switch."

"Then this circuit can be used as a polarity tester?"

"Right! The diode can certainly be used to check the polarity, because it behaves as a closed switch with the correct polarity and as a open switch with the wrong polarity"

"Is that all a diode can do?"

"Of course not! The diode is a very versatile device. Haven't you seen these diodes in a battery eliminator? There they work even four at a time."

"What are these diodes doing in a battery eliminator?"

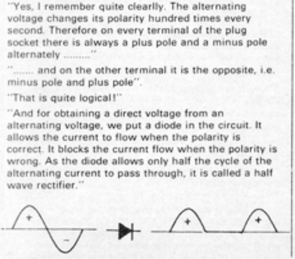
"Diodes are used to rectify the alternating voltage. We have already seen how alternating voltage behaves, haven't we?"

"Yes, I remember quite clearlly. The alternating voltage changes its polarity hundred times every second. Therefore on every terminal of the plug socket there is always a plus pole and a minus pole alternately ...."

"....... and on the other terminal it is the opposite, i.e. minus pole and plus pole".

"That is quite logical!"

"And for obtaining a direct voltage from an alternating voltage, we put a diode in the circuit. It allows the current to flow when the polarity is correct. It blocks the current flow when the polarity is wrong. As the diode allows only half the cycle of the alternating current to pass through, it is called a half wave rectifier."



Transistors

"....... What are transistors ?"

"Transistors are also semiconductor devices like diodes. We have seen how diodes function like one way valves. Transistors also behave like valves, but with a difference. Transistors are valves for electrical currents which can be regulated. With transistors, we can make currents flow with greater or lesser intensity."

"They are the water taps of electronics"

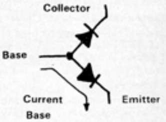
"Right!"

"But then the current can also be regulated with a potentiometer."

"A potentiometer has to be turned mechanically. It has a rotating spindle and a knob. The transistor has no such mechanical parts, it functions fully electronically. Most of the transistors are quite small and they have three leads coming out at the bottom."

"Three terminals? Then certainly it has some kind of a potentiometer inside?"

"No, transistors and potentiometers have absolutely nothing in common. The transistors have two very intelligently designed diodes inside them. as you can see in the illustration given here."



"How can you control current with two diodes?"

"No, it is not at all possible just with two diodes. But it can be done with a transistor. The illustration we just saw is nothing but a simplified view and not an physical combination of two ordinary diodes"

"I don't understand!"

"This is how it happens: When a positive voltage is applied to the base, a cuttent flows through the diode between the Base and the Emitter."

(Illustration)

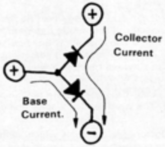
"Now, if we apply a negative voltage to the Collector current is also allowed to flow through the diode between the Base and Collector".

(Illustration)

"That is right, and with a plus pole connected to the collector......"

"...... the upper diode will block the current! What is the use of all this?"

"Just wait. It is certainly true that the upper diode will block. But as I have already said, these are just ordinary diodes. These diodes are designed in such a way, that the upper diode becomes conductive due to the current flowing through the lower diode. To simplify the matters we can say that the current flowing into the Base terminal, takes along a current from the collector and comes out through the Emitter terminal."



"Unbelievable! Do you mean to say that a current flowing into the Base can make the upper diode conduct a current from Collector to Emitter even with a plus pole connected to the collector?"

"That is exactly what happens inside a transistor. However when there is no Base current, the upper diode can block the current and no current can flow from Collector to Emitter."

"This means that the transistor is woking like a remote control switch, which is switched ON and OFF by the current flowing through the Base."

"Yes, it can be used as a switch controlled by the Base current. Incidentaly, as the transistor is not just two diodes connected together, it has been given a different symbol"

"Does the transistor work only like a switch? Then what does it do in an amplifier?"

"The Collector current is not only switched ON and OFF by the Base current. It can also be regulated by the base current. As in case of our water tap, the quantity that can flow through is adjustable. The Collector current can be as strong as 500 times the Base current. A Base current of just two microamperes can cause a Collector current of about one milliampere, which is quite a substantial amount in electronic circuits".

"This means that a transistors can also be called an amplifier?"

"Yes, and the ratio of the Collector current and the Base current can be said to be the amplification factor of that transistor"

"Do the Hi-Fi Stereos also function in the same manner?"

"You are right! However, a large number of transistors and many other components are necessary to obtain the Hi-Fi quality Stereo amplification."

"Has nobody ever thought of building an amplifier from water taps? We could call it an Under-water Hi-Fi".