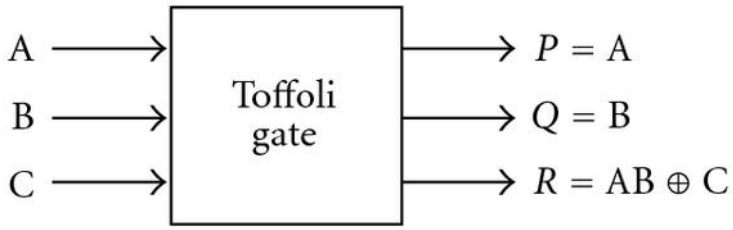
Circuit Simulation Project

https://esim.fossee.in/circuit-simulation-project

Name of the participant : Arpit Sharma

Title of the circuit : "Design of Toffoli CCNOT Quantum Gate using Sky130"

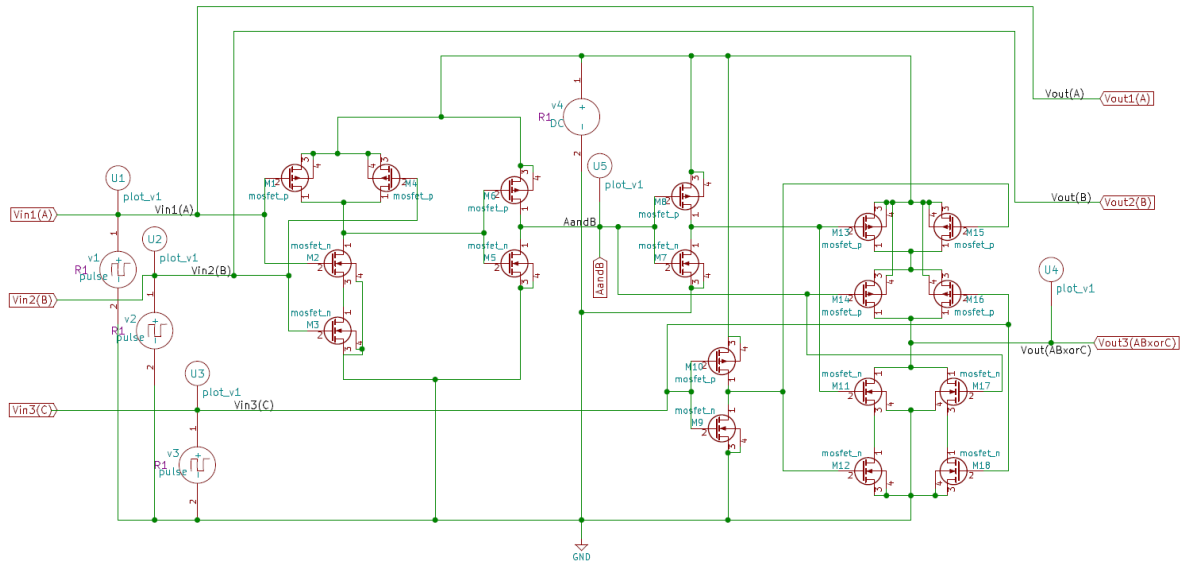
Description : This circuit simulation project presents the design and simulation of Toffoli Gate using open-source tool eSim and Sky130 PDK library. Toffoli gate is a 3 input, 3 output reversible logic gate. It is a universal logic gate i.e. it can be used to construct any classical reversible logic circuit. It is also called as CCNOT gate where CCNOT stands for Controlled Controlled NOT. For Toffoli gate if the first two input bits are high, then the third output bit becomes zero due to XOR operation, otherwise all bits remain the same.



A circuit is called reversible only when its inputs can be determined from its outputs and the input-output possess one to one mapping. Fredkin gate, Toffoli gate, interaction gate, and switch gate are other such examples of reversible logic gates. In a reversible logic gate, the number of outputs is always equal to the number of inputs. Reversible logic gates are memoryless logic units and the function realised by a reversible circuit is a mathematically Injective logic function. A function is called Injective function when its each input element is mapped to only one & unique output element. That's how it has one to one mapping.

The major advantage such kind of reversible circuits provide includes better input traceability, low computation time i.e. high speed computations and reduced information loss.Also, Reversible circuits make reversible computations possible in which the loss of information is drastically reduced which, according to the Landauer's Research leads to reduced loss of energy in the circuit. Major applications of reversable computing includes low-power VLSI design, quantum computation, DNA computing and nanotechnology etc.

Circuit Diagram :



Results :

The results are obtained by transient analysis for 90s with the following input parameters:

Vdc	1.8V

Vin1(V_A) : Vpulse

V1	0 V
V2	1.8 V
Period	50s
Pulse Width	25s

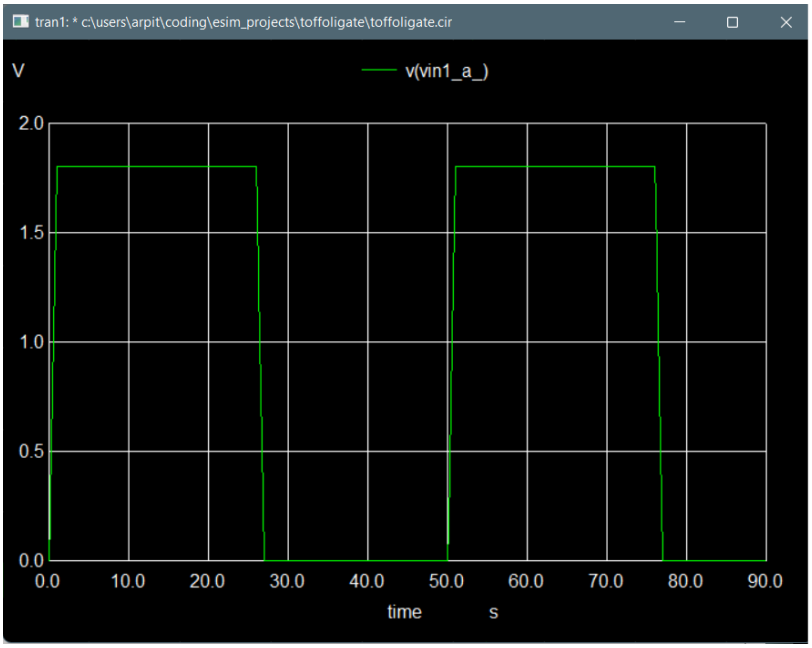
Vin2(V_B) : Vpulse

V1	0 V
V2	1.8 V
Period	15s
Pulse Width	7.5s

Vin3(V_C) : Vpulse

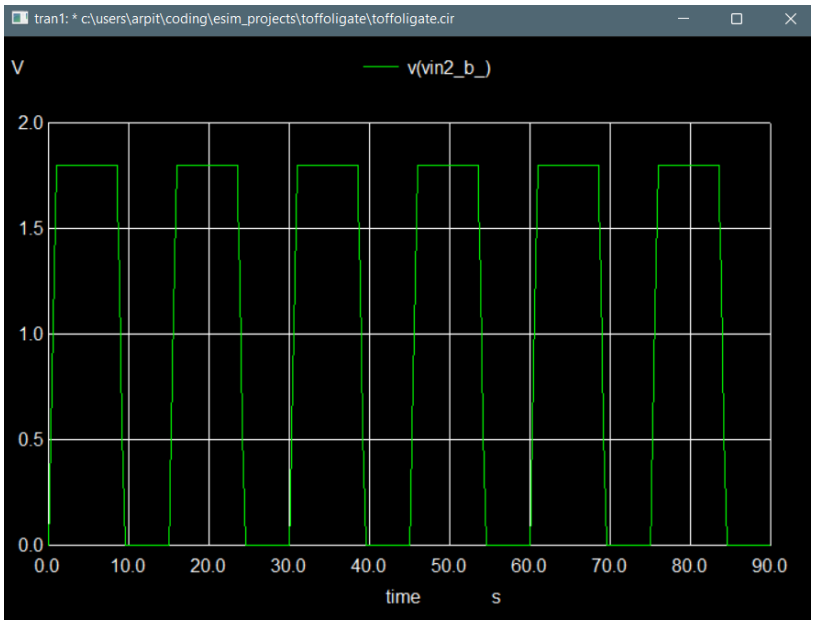
V1	0 V
V2	1.8 V
Period	30s
Pulse Width	15s

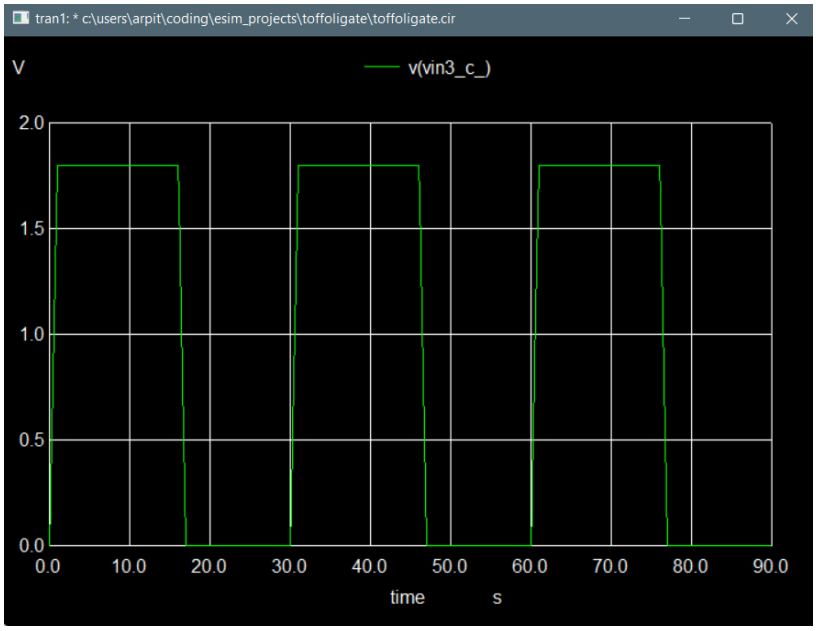
The input-output plots are shown below:



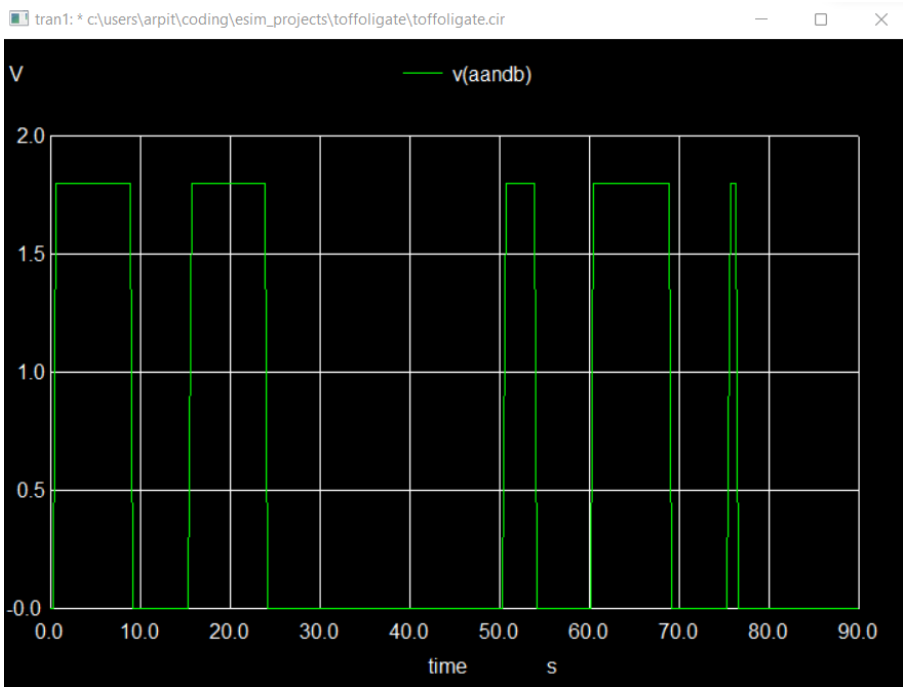
$V_{in1}(V_A)$

$V_{in2}(V_B)$

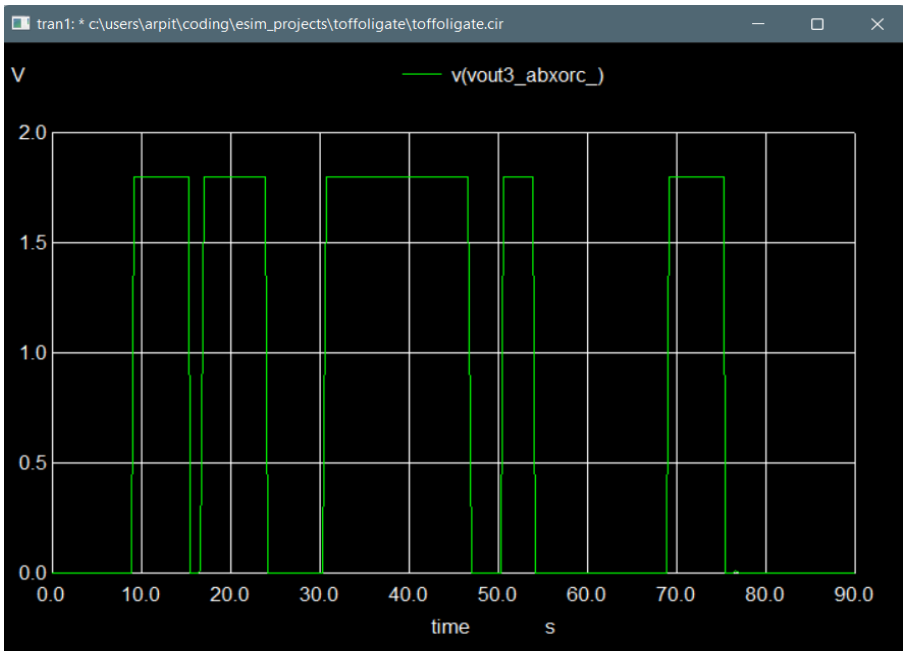




$V_{in3}(V_C)$



V_A AND V_B



V_{out} ((V_A AND V_B) XOR V_C)

The operation for Toffoli CCNOT gate is verified.

References :

[1.] “Design and Implementation of New Feynman and Toffoli (NFT) Gates in Quantum-dot Cellular Automata (QCA)” by Sajjad Waheed, Md. Golam Rasel.

[2.] “Cost Efficient Design of Reversible Adder Circuits for Low Power Applications” by Neeraj Kumar Misra, Mukesh Kumar Kushwaha, Subodh Wairya, Amit Kumar