Designing of 8-bit Barrel Shifter using CNT FET MUX

Deepika Bhadoriya[1] and Shweta Agrawal[2]

1. M.tech Sochalor 2.Assistant Professor
SRCEM Banmore, Gwalior

Abstract

As the technology is changing very fast from micro to nano, its applications are also changes according to requirement. Barrel shifter is a device which is used for shifting and rotating the data according to the need of system, or it is a combinational logic, that shifts a data by a specified number of bits in a clock cycle. A barrel shifter can be implemented as a tree of multiplexers (mux), and in such an implementation the output of one mux is connected to the input of the next mux just like cascading. This paper presents 8-bit barrel shifter using CNT FET using 2:1 mux. From the simulation results it is clear that the results of 2:1 is best hence tree of mux is used to reduce the power consumption.

Keywords: Mux, barrel shifter, rotation, shifting, CNT FET

1. Introduction:

In digital system design shifters are used for shifting the data by 1-bit position in right direction or left direction, which may be either arithmetic shifting or logical shifting. But when there is a requirement of 2 or 3 bit shifting in a single clock, in that case barrel shifter is used.

A barrel shifter is a device that permits its input to be shifted or rotated by any number of bit positions in either direction. For example, a 3-bit rotating barrel shifter can shift its inputs I2, I1 and I0 by zero, one, two bit positions to the right or left by using the shift control inputs S1, S0. Control signal controls the direction of shifting. Barrel shifter can be implemented as a purely combinational logic circuit, using conventional multiplexers (MUX), decoders, and logic gates. For designing of the sequential barrel shifter finite state machine (FSM) are used and a simpler data-path.

Barrel shifter performs 3 type of shifting operations which are circular shifting, logical shifting and arithmetic shifting which allow the shifting of typically 1 to n-1 bits. In logical shifting, the bit is shifted in either left or right direction while the empty places are filled by zeros. In Arithmetic shifter the procedure for left shifting is same as logical but in case of right shifting the empty place is filled by signed bit. Barrel shifter carries out the rotation of bits in left or right direction; in this the empty place is filled by the shifted bit. Circuit diagram of 4-bit barrel shifter is shown in fig.1, which can shift up to 4-bits places in one clock cycle.

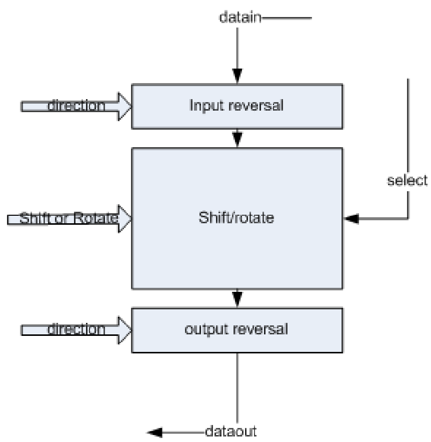

Fig. 1. Block Diagram of barrel shifter.

2. Baisc Architecture of barrel Shifter

Barrel shifter can be classified in two types:
(1) Mask based
(2) Multiplexer based.

3. FINFET

The term FinFET was coined by University of California, Berkeley researchers to describe non-planar, double gate transistor built on a SOl substrate. A Fin Field-effect transistor (**FinFET**) is a multigate device, a MOSFET built on a substrate where the gate is placed on two, three, or four sides of the channel or wrapped around the channel, forming a double gate structure. The main principle behind both the structures is a thin body, so the gate capacitance is closer to whole channel. The body is very thin, around 10nm or less. So, there is no leakage path which is far from the gate. The gate can effectively control the leakage.Fig.1 shows the structure of Fin FET.

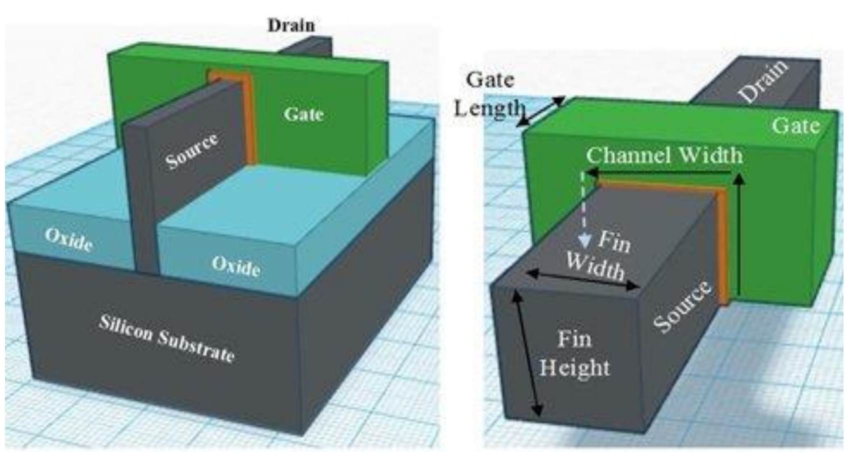

Fig.2. FINFET structure

4. CNT FET

The structural view of carbon nanotube-FET (CNFET) is similar to MOSFET except for a single CNT or an array of CNTs as the channel material instead of silicon in the MOSFET. The CNFET has several advantages over the conventional MOSFET such as reduction in carrier tunneling and short channel effects, better control over the channel, higher current density, enhanced carrier velocity and reduced leakage currents .The top view of CNFET is shown in Fig. 3. The design parameters of carbon nanotube-FET are: the number of CNTs in transistor channel (N), inter-nanotube space called Pitch (S) and diameter of carbon nanotube (DCNT). The gate length and width are illustrated as Lgate and Wgate respectively .A carbon nano tube field-effect transistor (CNTFET) refers to a field-effect transistor that utilizes a single carbon nano tube or an array of carbon nanotubes as the channel material instead of bulk silicon in the traditional MOSFET structure. The exceptional electrical properties of carbon nano tubes arise from the unique electronic structure of graphene itself that can roll up and form a hollow cylinder. The main difference between a CNTFET and a MOSFET is the channel, in CNTFET the channel comprises of one or more carbon nanotubes depending on the channel current requirements whereas in the MOSFET the channel is made of bulk silicon.

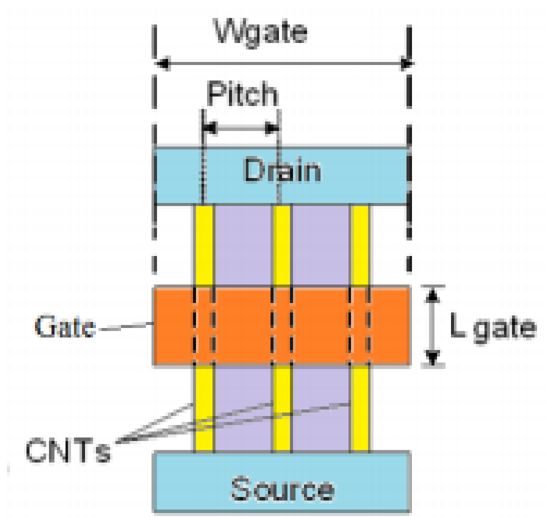

Fig.3. Top view of a carbon nanotube-FET with three CNT's

5. Proposed Work

5.1 8-bit Barrel Shifter

Here 8-bit barrel shifter is designed with the help of 2:1CNT FET mux. The behavior of 4-bit MUX based barrel shifter is shown in table 1 which has the five control signals. Likewise D for controlling the direction either left or right , S/R for shift/rotate operation, L/A for logical/arithmetic shift and S_1, S_0 for number of bits to be shifted or rotated.Y0,Y1, Y2 and Y3 are input bits and Z0, Z 1, Z2, Z3 represents the output bits. The circuit can be used to rotate or shift a 4-bit word in both right and left direction by 0, 1, 2, 3 bits.

D= '0' denotes the direction of shift/rotate operation is towards right and D= ' 1 ' denotes it is towards left. The control signal S/R='0' represents shift operation and S/R=' l' represents rotate operation. When L/A='0' it denotes logical shift, L/A=' 1 , it denotes arithmetic shift and when L/ A= 'x' it denotes rotate operation. The bits S_1, S_O are bit position, where S_1, S_O= ' 1 1 ' denotes the length is 3 bits.

Table 1 explains the different operations performed by 4-bit barrel shifter. As there are five control signals, there will be a need of 32xl MUX for each output bit. Thus for 4 output bits, we need four 32xl MUX in the design of a 4-bit barrel shifter. The same procedure is followed for 8-bit Barrel Shifter Each column of truth table can be implemented with a dedicated 32x 1 MUX circuit, which is designed using 2x 1 MUX cells, to obtain final output. Logical shift is a bitwise operation that shifts all the bits of its operand. The two logical shift operations are the logical left shift and the logical right shift. Logical shifts are equivalent to performing multiplication or division of unsigned integers by powers of two. Logical right shift by 'n' bits have the same effect of multiplying it by '2n' and logical left shift by 'n' bits will have the same effect of dividing it by ‘2n’.

5.2 2:1 MUX

Here 2:1 MUX is designed using CNT FET .Transmission gates are used to implement 2:1 MUX, using this 32:1 MUX tree structure will be implemented .Fig.4 and Fig.5 shows the 2:1 and 4:1 MUX using CNT FET respectively.

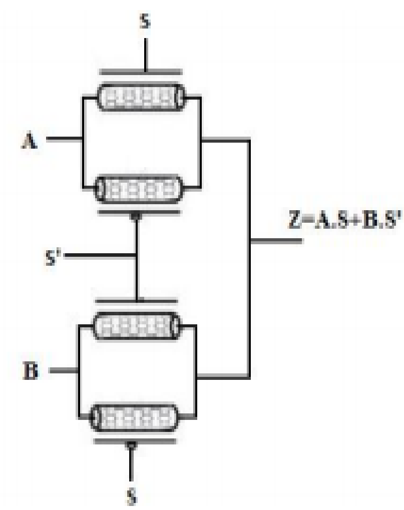

Fig.4 .2:1 MUX using CNT FET

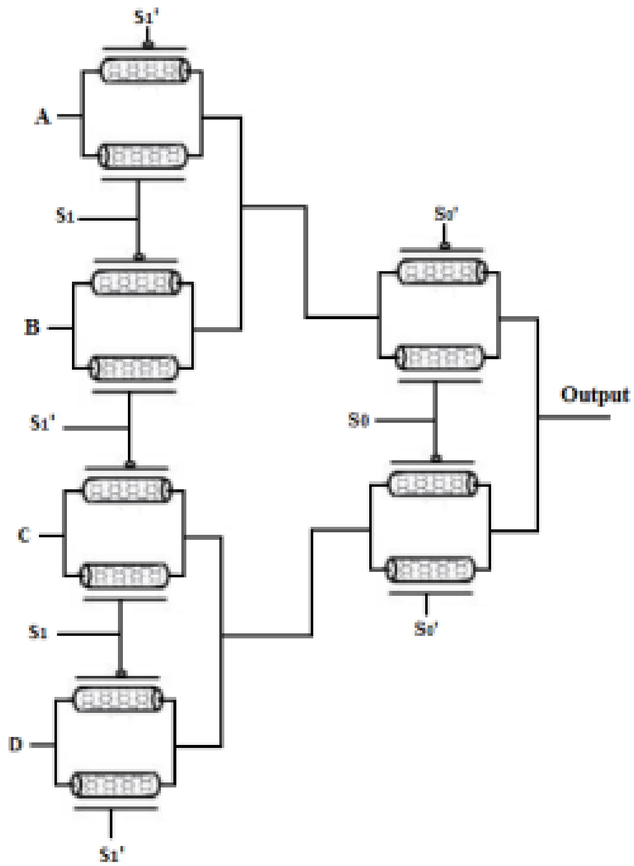

Fig.5 .4:1 MUX using CNT FET

Table 1. Different Operation Performed by 4-bit Barrel Shifter

Operation	**D**	**S/R**	**L/A**	**S_1**	**S_0**	**Z3**	**Z2**	**Z1**	**Z0**
Shift	0	0	0	0	0	Y3	Y2	Y1	Y0
Right	0	0	0	0	1	0	Y3	Y2	Y1
Logical	0	0	0	1	0	0	0	Y3	Y2
	0	0	0	1	1	0	0	0	Y3
Shift	0	0	1	0	0	Y3	Y2	Y1	Y0
Right	0	0	1	0	1	Y3	Y3	Y2	Y1
Arithmetic	0	0	1	1	0	Y3	Y3	Y3	Y2
	0	0	1	1	1	Y3	Y3	Y3	Y2
Rotate	0	1	X	0	0	Y3	Y2	Y1	Y0
Right	0	1	X	0	1	Y0	Y3	Y2	Y1
	0	1	X	1	0	Y1	Y0	Y3	Y2
	0	1	X	1	1	Y2	Y1	Y0	Y3
Shift Left	1	0	0	0	0	Y3	Y2	Y1	Y0

Logical	1	0	0	0	1	Y2	Y1	Y0	0
	1	0	0	1	0	Y1	Y0	0	0
	1	0	0	1	1	Y0	0	0	0
Shift Left Arithmetic	1	0	1	0	0	Y3	Y2	Y1	Y0
	1	0	1	0	1	Y3	Y1	Y0	0
	1	0	1	1	0	Y3	Y0	0	0
	1	0	1	1	1	Y3	0	0	0
Rotate Left	1	1	X	0	0	Y3	Y2	Y1	Y0
	1	1	X	0	1	Y2	Y1	Y0	Y3
	1	1	X	1	0	Y1	Y0	Y3	Y2
	1	1	X	1	1	Y0	Y3	Y2	Y1

6. Simulation Results and Discussion

The proposed architectures are designed & simulated in HSPICE using 32nm CNTFET technology. Table 2 shows the performance analysis of 2xl, 4xl, 16xl & 32xl MUX architectures. From which it can be seen that 2xl MUX has low power and delay, hence used in designing the proposed MUX tree architecture.

Table 2. Performance analysis of different MUX

MUX architecture in CNT FET in 32nm	**Delay in 'ns'**	**Average Power in nW'**	**Power delay Product (PDP)in'J'**
CNT FET 2:1 MUX	1.23	312	3.8376
CNT FET 4:1 MUX	2.12	411	8.7132
CNT FET 16:1 MUX	4.06	634	25.7404
CNT FET 32:1 MUX	4.09	978	40.0002

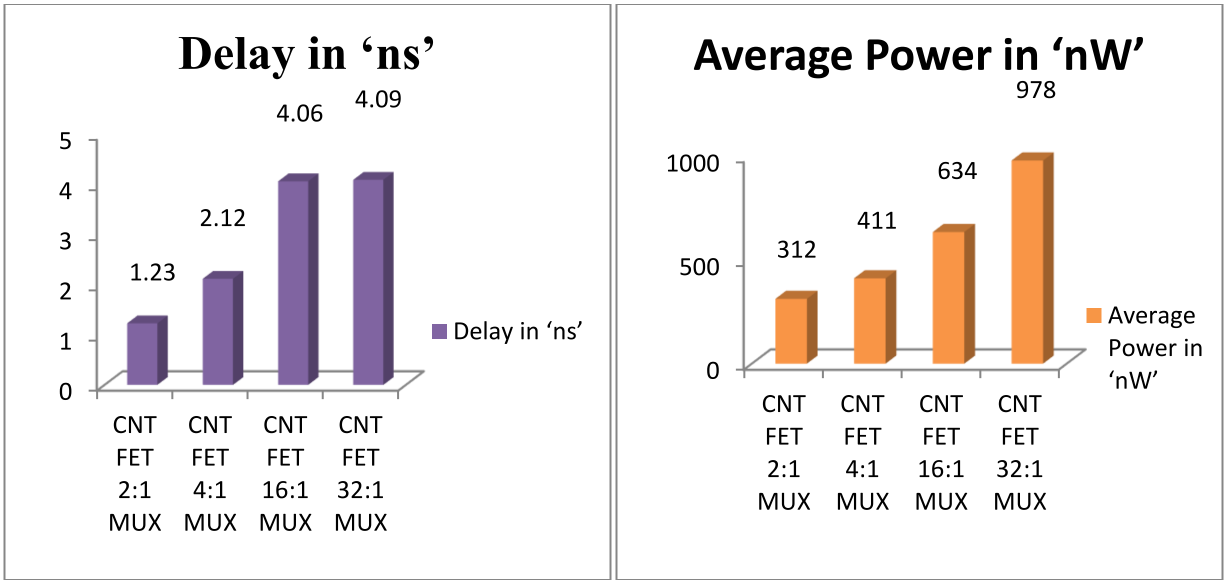

Fig .6. Delays and Average Power of different MUX using CNT FET

From Fig .6.it is clear that 2:1 CNT FET MUX has very less delay and average power consumption in comparison to other MUX, to reduce the power consumption and to improve the overall performance of Barrel Shifter 2:1 MUX is used for tree structure of MUX.

Table 2 shows the performance analysis of 8-bit Barrel shifter using conventional CMOS, conventional Fin FET and proposed CNTFET architectures.

Table 2. Performance analysis of different architecture of 8-bit Barrel shifter

Architecture Design	**Average power in "μ w"**	**Propagation delays in 'ps'**	**Power delay Product (PDP)in'J'**
Existing 8x8 barrel Shifter Using CMOS	16.451	81.02	1.332a
Conventional 8x8 barrel Shifter Using Fin FET	4.81	3.45	16.594f
Proposed 8x8 Barrel Shifter using CNT FET	3.135	1.45	4.545f

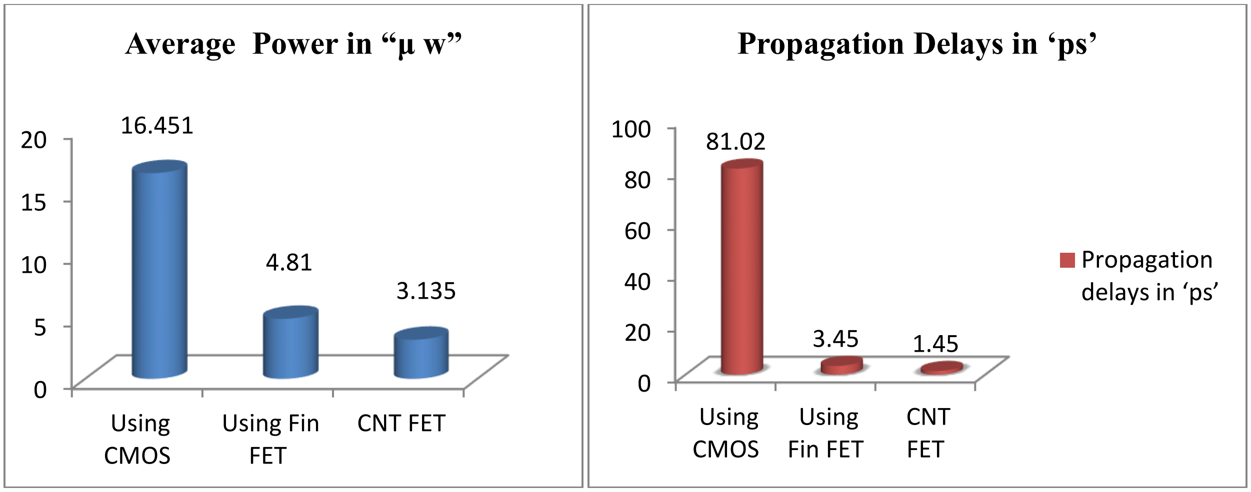

Fig .7. Average Power and Propagation Delays of different architecture design of Barrel Shifter

From Fig.7 it is very clear that proposed 8-bit barrel shifter is much more efficient than CMOS and Fin FET based 8-bit barrel shifter. It can be seen from the fig.7 that the Barrel shifter designed using CNTFET shows 34% reduction in power consumption, 57 % reduction in delay.

CONCLUSION

Purely MUX based Barrel shifter will have less power dissipation and propagation delays as compared to designed using combinational logic circuits such as multiplexers, decoders and logic gates .The Barrel shifter is designed using the proposed CNT FET MUX based architecture, will results best among other in terms of power and delay. It is evident from table 2 and 3 that the power consumed, propagation delay and Power Delay Product (PDP), are reduced compared to conventional CMOS and Fin FET architectures. Thus proposed CNT FET MUX based Barrel shifters are more eminent than conventional MOSFET Barrel shifters.

References

[1] White paper- "FinFET Technology - Understanding and Productizing a New Transistor from TSMC and Synopsys"Jan2013.

[2] S. Jim Hawkinson, International Journal of Emerging Technology and Advanced Engineering- Volume 3, Issue 2, February 2013, "Analysis and Performance Comparison of CMOS and FinFET for VLSI-Applications".

[3] R. Raj alakshmi , P. Aruna Priya, Design and Analysis of A 4-Bit Low Power Universal Barrel-Shifter In 16nm FINFET Technology, 2014 IEEE International Conference on Advanced Communication Control and Computing Technologies (ICACCCT),527-532.