

DESIGN AND IMPLEMENTATION OF OPTIMIZED 4:1 MUX USING ADIABATIC TECHNIQUE

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ABSTRACT

A multiplexer is the integral part of the any digital circuit and one of the most utilized circuits. A variety of applications a multiplexer has, where a multiplexer can be implemented for e.g. in Full Adder, Arithmetic Logic Unit (ALU), Digital Compressor etc. In this paper authors have proposed a 4:1 multiplexer using PFAL and ECRL adiabatic logic design technique and compared with the Conventional CMOS Multiplexer. The power dissipation of the proposed circuits, is compared to a Conventional CMOS Multiplexer with respect to the operating frequency, Load Capacitance and Supply Voltage. The schematic design and simulation has been carried out in the Tanner V.13 in 180nm CMOS Technology. The result shows the great improvement in the power dissipation result. The result also shows the considerable reduction in the area of the proposed 4:1 Multiplexer.

Keywords: Adiabatic, Multiplexer, PFAL, ECRL, Low Power, CMOS

I INTRODUCTION

Electronic device sizes are getting reduced day by day. As the size of the battery operated device like PDAs, Laptop, Mobile phones etc become quite small. As a result, size the battery also reduced in the same proportion making the device lighter. But on the other hand, the efficiency of the battery decreased and drained quickly. Battery efficiency can be enhanced either by making the size of the battery bigger, but it makes the device bulkier or by designing the circuit which consumes low power. The CMOS circuit has very low power consumption, but a major power dissipating component of the CMOS circuit is the dynamic power. In the CMOS circuit, during the one of the Supply voltage, during the transition 0 to V_{dd} , $C V_{dd}^2$ energy has been drawn up from the DC power supply. The half of the power get dissipated across the Pull-Up network and only $\frac{1}{2} C V_{dd}^2$ energy stored at the output load. During the power supply transition from V_{dd} to 0, the stored energy at the output load gets dissipated to ground through pull-down network. So in the CMOS circuit, the total power dissipation is $C V_{dd}^2$ for one cycle of operation. This is the

lower limit of power dissipation for the CMOS circuit. But there is another approach through which the power dissipation can be reduced from the theoretical lower limit. The technique is called Adiabatic Technique.[1]

Adiabatic Technique: The word Adiabatic is a Greek term which means “No exchange of heat”. The adiabatic circuit is also called the energy reversible circuit. Unlike the CMOS, the adiabatic circuit has lower dynamic power dissipation. The two key rule by which adiabatic circuits tries to conserve the energy are

- Never turn on a transistor when there is a voltage potential between source and drain.
- Never turn off a transistor when current is flowing through it. [1][2]

The basic concept behind the adiabatic circuit is, instead of using the constant voltage as in case of CMOS, It uses the constant current source. From fig (1) a CMOS inverter equivalent RC model has been shown, where R is the resistance of the Pull-up network and C is the output load capacitance and S is the switch. The expression for the energy in case of the adiabatic circuit is given by $\frac{RC}{T} C V_{dd}^2$. From the equation, Energy can be reduced by (a) increasing the charging time and (b) by reducing the resistance of the PMOS network.

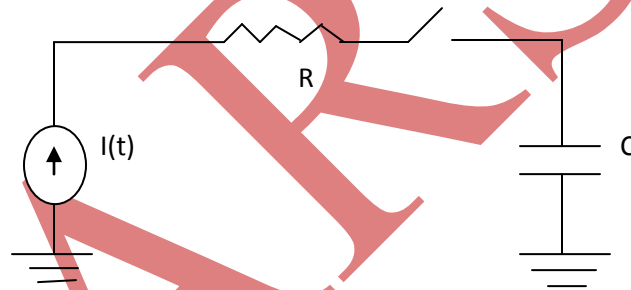


Fig. 1: RC Model

Voltage across the switch is $V = IR$

Power $P(t)$ in the switch given by: $P(t) = I^2 R$

Energy = $(I^2 R)T$

We know, $Q = CV$ and Current $I = \frac{Q}{T} = CV/T$.

Putting the Value of Current I in the above equation of Energy, We get

$$\text{Energy } E = \frac{C^2 V^2 R}{T}$$

Rearranging the terms an

$$\text{Energy } E_{diss} = \frac{RC}{T} C V^2 = \frac{2RC}{T} \left(\frac{1}{2} C V^2 \right) \quad (1)$$

From the above equation of energy dissipation, the number of conclusion can be made

- a. The Energy dissipation is small as compare to the conventional CMOS, by increasing the $T \gg RC$. In other words, Energy dissipation make small by increasing the charging time.
- b. From the equation, the energy dissipation is proportional to the resistance R. On reducing the internal on resistance of the PMOS network Power can be scale down from the lower limit prescribe in case of conventional CMOS.[1, 2].

II ADIABATIC LOGIC FAMILY ECRL & PFAL

2.1 Phases in Adiabatic Power Supply

In the adiabatic logic circuit power supply has a dual function i.e. act as power clock. [3] The supply clock has four phases as shown in Fig.2.

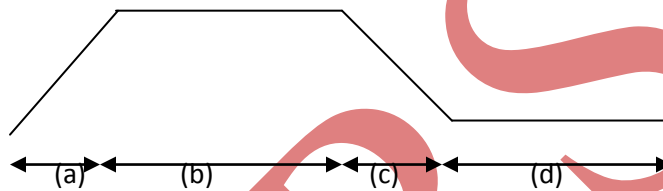


Fig. 2: Phase in adiabatic Power clock

As shown in Fig.2. Phase (a) is called *Precharge & Evaluation* phase. In this phase the load capacitance is charged and logic is evaluated. Next phase (b) is called *Hold* phase. In this phase the evaluated logic is kept on hold to be used as input of next stage. Phase (c) is called *Recover* Phase. In recover phase the charge drawn from the power supply, flown back to supply. And last phase is *idle* phase as circuit waits for the logic to be evaluated by the previous stages. [3]

2.2 Efficient Charge Recovery Logic (ECRL)

This adiabatic logic family falls under the partial adiabatic logic family as in this the complete charge doesn't recover. Efficient charge recovery logic (ECRL) is similar to CMOS family called Differential Cascode Voltage Switch (DCVSL). The structure of the ECRL is shown in Fig.3. ECRL has two cross coupled PMOS and two NMOS tree structure. An A.C power supply P_{wr} is used to recover the charge. [4] The terminal *Out* and *Out'* is generated so that power clock generator always drive a constant load independent to the input signal. The Logic is to be implemented, realized using NMOS, in both true and complementary form. The full output swing can be obtained in precharge and recovery phase. The disadvantage of the ECRL circuit is, due to the threshold voltage the PMOS the circuit suffer from the adiabatic losses in both precharge and recovery phase. So when the P_{wr} reaches the $|V_{tp}|$ the PMOS is cut off and circuit cannot give the output for full swing. Another disadvantage of this ECRL logic is that the circuit has the coupling effect.

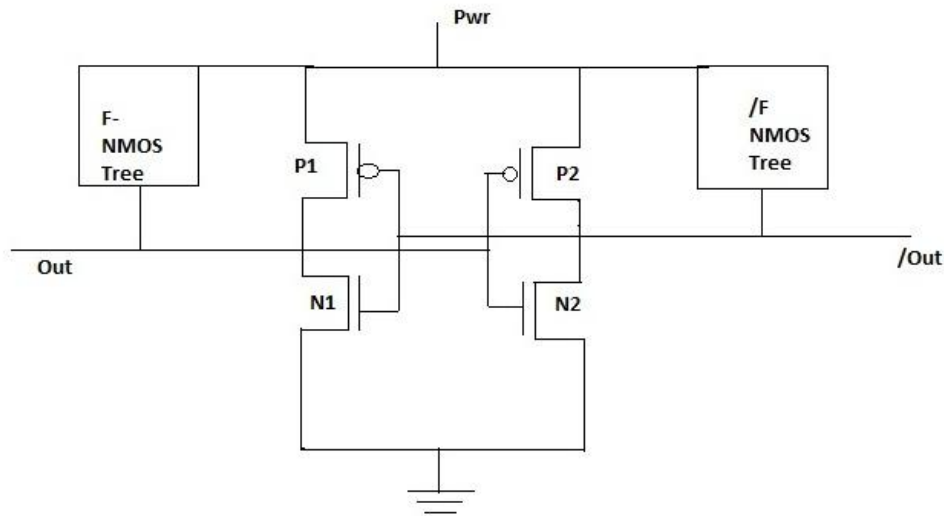


Fig.3: ECRL Basic Structure

To understand the circuit operation,

- Assume the *in* is high then *in/* will be at low level. When the *pwr* rises from 0 to V_{dd} , *in* turns on the F- NMOS tree functional box and *Out* remain at the zero level. */Out* follows the power clock through P1 and rises to V_{dd} . As value reaches to V_{dd} , the *Out* holds the valid logic level and. The value is maintained during HOLD phase and can be used as the input of the next stage.
- During the transition from V_{dd} to 0, the energy is recovered through the path */out* and charge recovered back to *Pwr*. From this, it can be observed that *Pwr* is used as power clock and power supply.[5]

2.3 Positive Feedback Adiabatic Logic Circuit (PFAL)

The Positive adiabatic logic family shows low power dissipation and robustness against the technology parameter variation. The general schematic of the circuit is shown in Fig. 4. As in figure shows that two latches made by the PMOS P1 & P2 and NMOS N1 & N2. The logic function that is to be implemented, realize using the NMOS functional box.[6] The two major differences with respect to ECRL are that the latch is made by two PMOSFETs and two NMOSFETS, rather than by only two PMOSFETs as in ECRL logic, and that the functional blocks are in parallel with the transmission PMOSFETs. Thus the equivalent resistance is smaller when the capacitance needs to be charged.[8] The advantage of the PFAL over the ECRL is, PFAL doesn't have the coupling effect and better power efficiency at higher frequency.

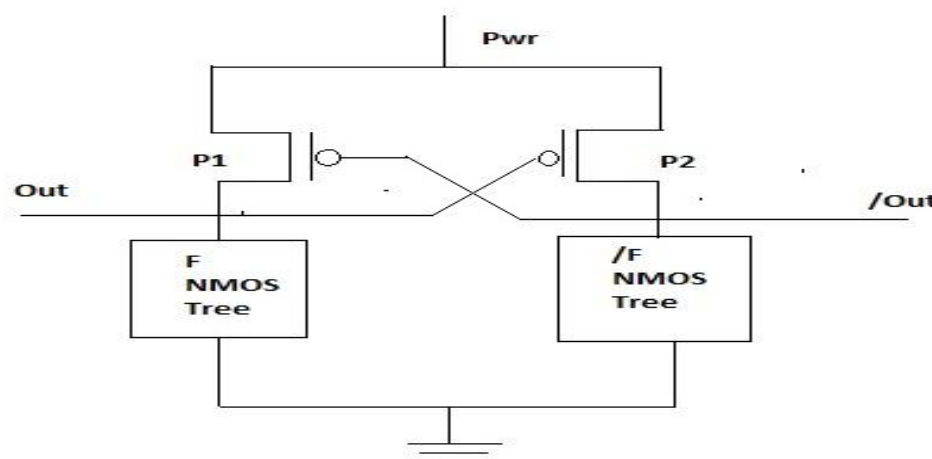
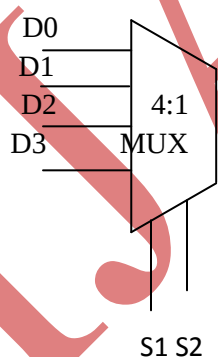


Fig.4: PFAL Basic Structure

III DESIGN AND SIMULATION OF THE CIRCUIT

3.1 Multiplexer

Multiplexer is the one of the basic and essential component of the VLSI digital system. Quite often it is required to transfer many signal over a single line one at a time. Multiplexers provide that required flexibility to transfer the signal over the single line. Multiplexer reduces the circuitry of the system that leads to reduction in cost and area of the device. The Fig.5 shows the block diagram and truth table of the 4:1 multiplexer. [7]



(a)

S1	S2	Out
0	0	D1
0	1	D2
1	0	D3
1	1	D4

(b)

Fig. 5: (a) Graphical Symbol of Mux (b) Truth table

The D0, D1, D2&D3 are the Data Lines and S1&S2 are the select lines. Here is equation of multiplexer.

$$Out = D0.\overline{S1}.\overline{S2} + D1.\overline{S1}.S2 + D2.S1.\overline{S2} + D3.S1.S2 \quad (2)$$

3.2 Conventional CMOS 4:1 Multiplexer

The transistor level architecture of the Conventional 4:1 Multiplexer is shown in Fig.6. The multiplexer contain 44 transistors. As the transistor counts are high, it leads to increase in the area and power dissipation

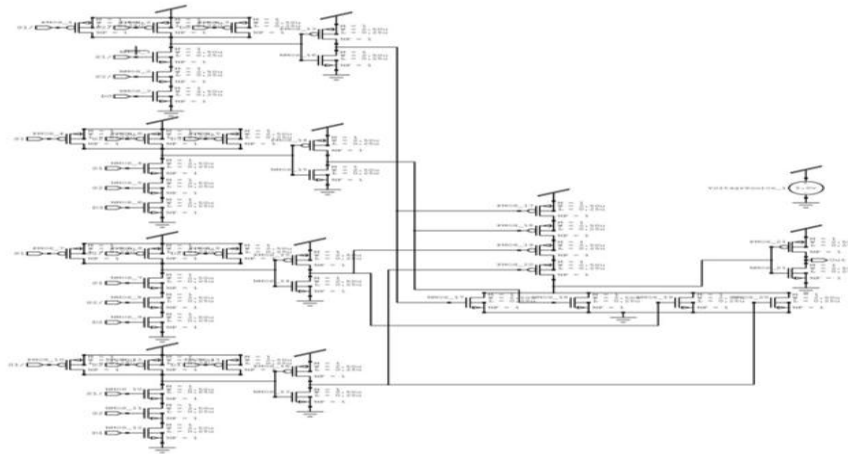


Fig.6: Transistor level 4:1 Mux Circuit

3.3 Low Power ECRL and PFAL Multiplexer

The proposed design using adiabatic technique ECRL and PFAL have considerable low power consumption and area as compared to the conventional CMOS multiplexer

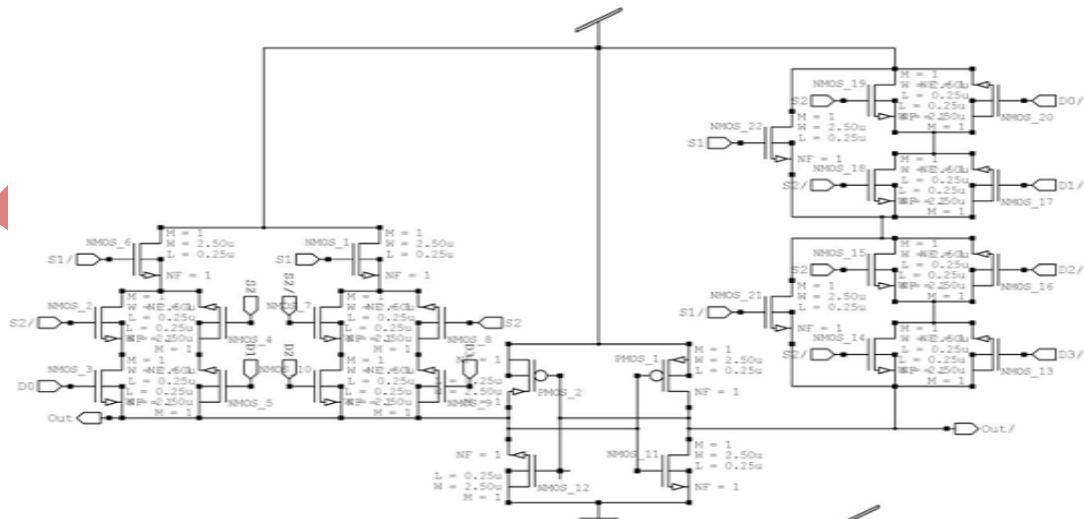


Fig.7: The 4:1 MUX Using PFAL

The Output Waveform of the 4:1 PFAL multiplexer

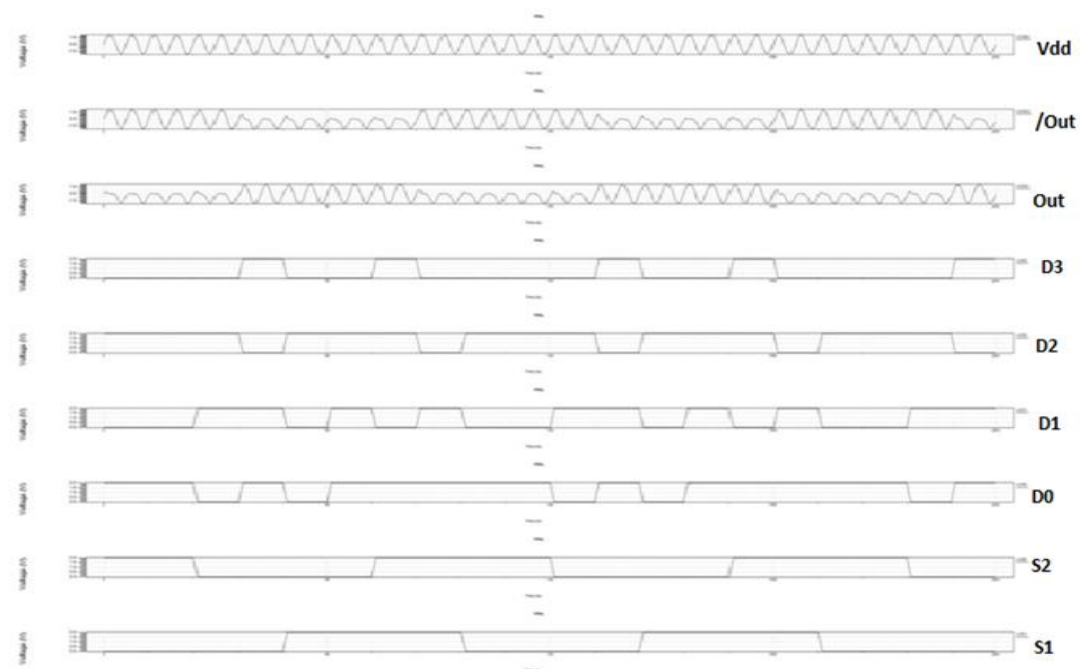


Fig.8: The PFAL 4:1 MUX Simulation Waveform

The 4:1 MUX using ECRL adiabatic, the proposed circuit is shown in Fig. 9

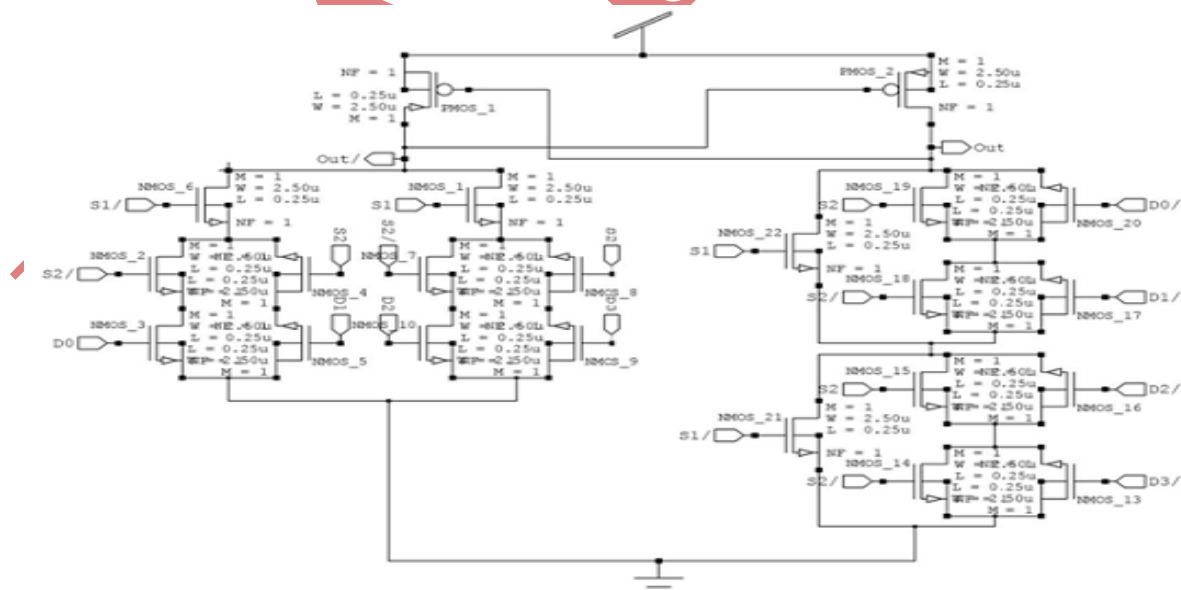


Fig.9: The 4:1 MUX using ECRL

The simulation result of the 4:1 Multiplexer using ECRL is shown in Fig.10

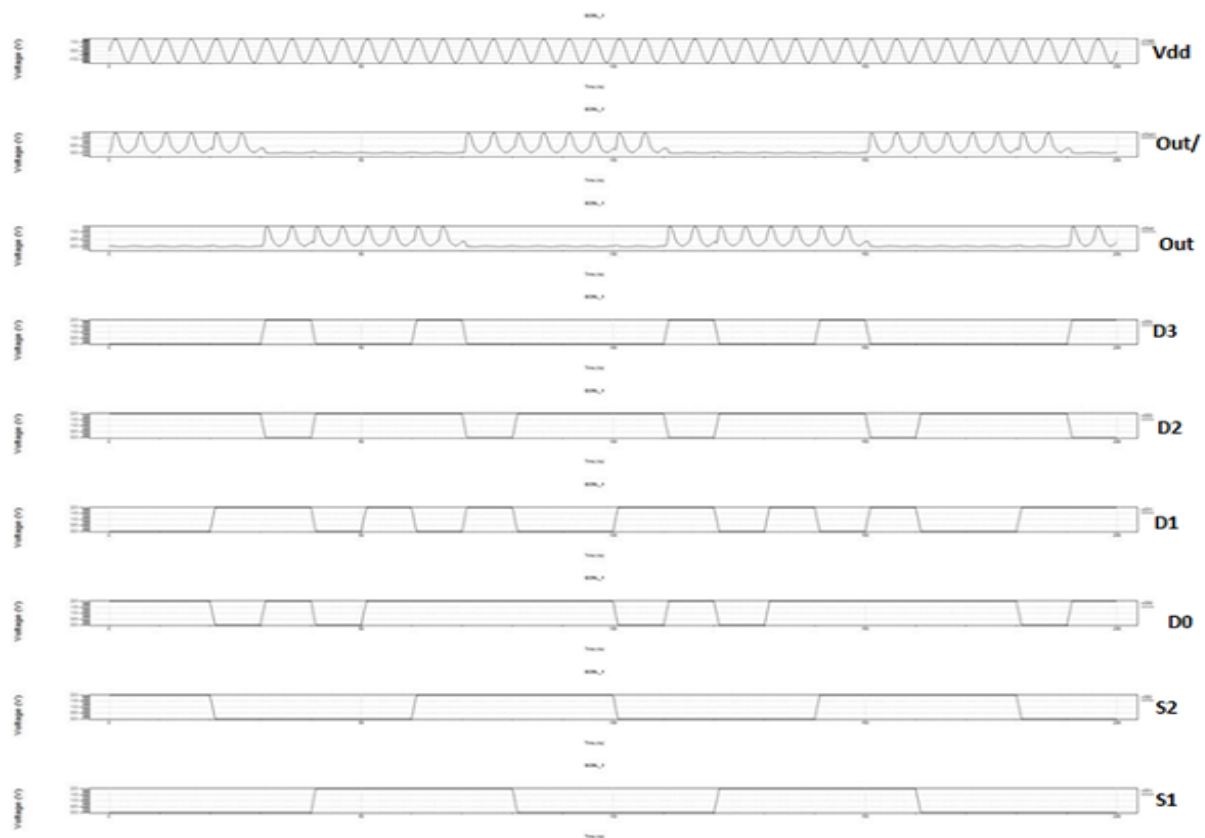


Fig.10: Simulation waveform of 4:1 ECRL Mux

IV IMPACT OF PARAMETRIC VARIATION ON POWER CONSUMPTION

The power consumption in adiabatic circuit depends upon the parameter variation. The analysis of the impact in variation in parameter on the power consumption carried out of two logic family with respect to CMOS logic circuit. The design and Simulation of the circuit has been done using TANNER EDA tool by using the 180nm TSMC CMOS technology. The W/L ratio for the PMOS and NMOS are 810/180 and 360/180 respectively.

4.1 Power Vs Frequency

The Fig. 11 shows the power dissipation versus frequency of the supply voltage. From the result analysis, the power dissipation of the CMOS circuit is higher than the two proposed ECRL and PFAL 4:1 MUX

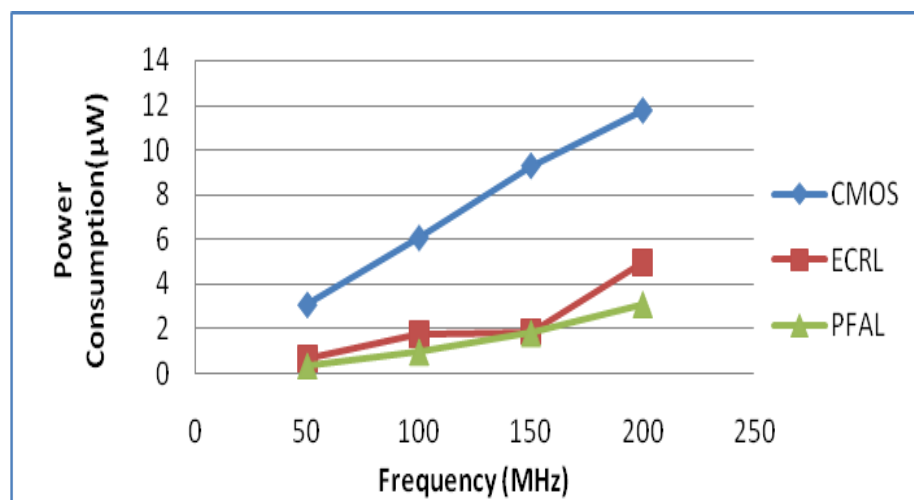


Fig. 11 Average Power Vs Frequency at Supply Voltage 1.4v and Load Capacitance 10fF

4.2 Load Capacitance Vs Power

The power dissipation with respect to the variation in load capacitance is shown in Fig 12. The two adiabatic logic families show the better power consumption as compare to the CMOS logic circuit.

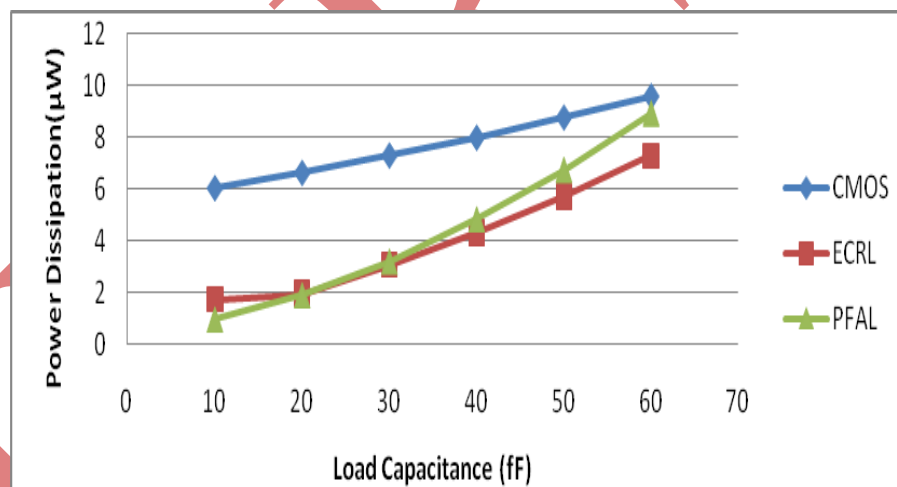


Fig.12 Average Power versus Load Capacitance at Supply Voltage1.4V and Frequency 100MHz

4.3 Supply Voltage Vs Power

The variation in Supply voltage and corresponding power dissipation is shown in the 13. The CMOS 4:1 Multiplexer dissipates more power as compare to the other two logic family.

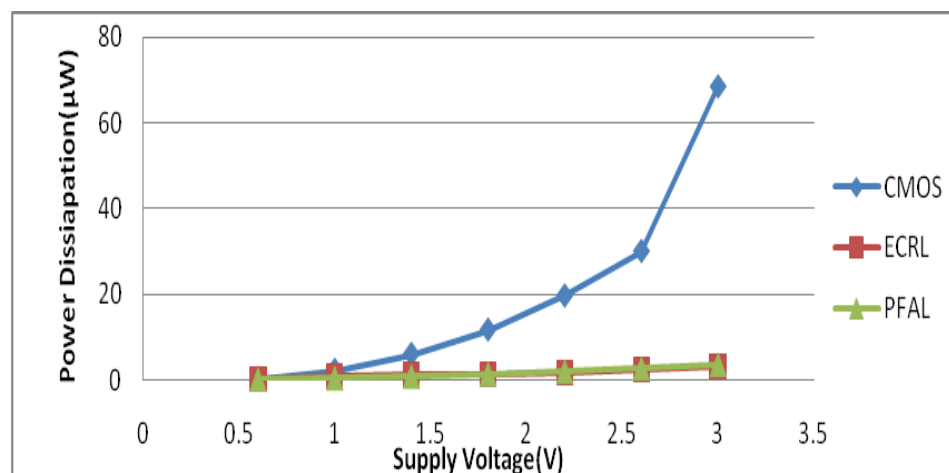
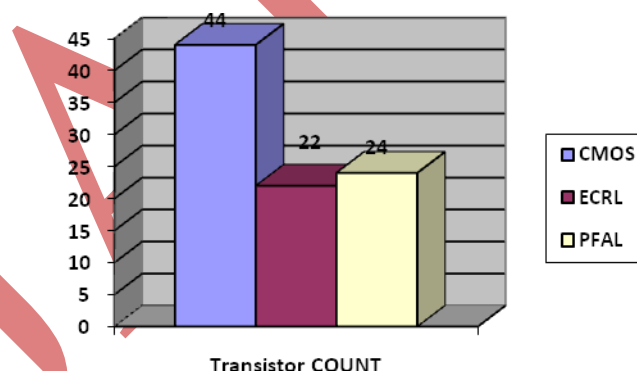


Fig. 13 The Average Power Dissipation with respect to the Supply Voltage at load Capacitance 10 fF and Frequency 100 MHz

4.4 Transistor Count

The design circuit of 4:1 multiplexer using PFAL, ECRL and CMOS has been shown above. The conventional CMOS uses the 44 transistor, due to that increase in the area of the multiplexer. The graph in Fig. 14 shows the comparison between the CMOS multiplexer and MUX designed using PFAL and ECRL.



V CONCLUSION

The 4:1 Mux using adiabatic logic such as ECRL and PFAL compared with the Conventional CMOS 4:1 Mux against the parameter variation. The result shows the adiabatic multiplexer shows the better power result against all the parametric variation as compare to CMOS multiplexer. At high frequency the PFAL Mux shows better power saving as compare to ECRL. The multiplexer has wide range of application like ALU, DSPs etc; Adiabatic multiplexer can be used in any application.

REFERENCES

- [1] William C. Athas, Lars "J." Svensson, J G Koller, Nestoras Tzartzanis and E. Chou "Low Power Digital system based on Adiabatic-Switching Principles." *IEEE Trans VLSI systems*, Vol. 2, pp. 398-407, Dec 1994
- [2] A.P. CHANDRAKASAN AND R. W. BRODERSEN, *Low-power CMOS digital design*, Kluwer Academic, Norwell, Ma, 1995.
- [3] B.VOSS AND M.GLESNER, "A Low Power Sinusoidal Clock," In Proc. of the International Symposium on Circuits and Systems, ISCAS 2001.
- [4] Y. MOON AND D. K. JEONG, "An Efficient Charge Recovery Logic Circuit," *IEEE JSSC*, Vol. 31, No. 04, pp. 514-522, April 1996.
- [5] Arun Kumar, Manoj Sharma. "Design and analysis of Mux using Adiabatic ECRL and PFAL" *ICCAI*, pp. 1341-1345, 2013
- [6] A.BLOTTI AND R. SALETTI, "Ultralow- Power Adiabatic Circuit Semi-Custom Design," *IEEE Transactions on VLSI Systems*, vol.12, no. 11, pp. 1248-1253, November 2004.
- [7] Meenakshi Mishra, Shyam Akashe, "High Performance, Low power 200Gb/s 4:1 MUX with TGL in 45nm Technology" Springer, 2013
- [8] J. Fischer et.al, "Improving the Positive feedback adiabatic logic family" *Adv. Radio Sci.*, Vol.2, 221-225, 2004