For A Power Constraint 32 bit adder Find the Voltage that will allow the Highest Performance

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***Abstract—*In this report, I will try to find the voltage that gives the fastest clock speed for a 32 bit adder under a certain power constraint. I design a 32 bit ripple carry adder with registers to give input vectors and sample outputs. The power consumption, delay of critical path, and voltage supply of the circuit are complicatedly connected. I want to give a clear pattern for these. I use Hspice to run simulation to get data. Then I draw a graph so that for any power constraint I can give the optimum voltage.**

***Index Terms—*32 bit adder, performance, power, supply,**

1. INTRODUCTION

In the world of high-end technology, circuits begins to consume more and more power. So power consumption problem becomes a hot topic for both the industry and academic field. There are unavoidable relationship among power, voltage supply and delay of critical path. So if we want to study one of the factors, we want to consider all these three factors.

First let us do some theoretical analysis. For a cmos technology there are dynamic and static power consumption.

1. *Dynamic Power*

CMOS circuits dissipate power by charging the various load capacitances (mostly gate and wire capacitance, but also drain and some source capacitances) whenever they are switched. In one complete cycle of CMOS logic, current flows from VDD to the load capacitance to charge it and then flows from the charged load capacitance (CL) to ground during discharge. Therefore in one complete charge/discharge cycle, a total of Q=CLVDD is thus transferred from VDDto ground. Multiply by the switching frequency on the load capacitances to get the current used, and multiply by the average voltage again to get the characteristic switching power dissipated by a

CMOS device:

 P = 0.5 C V^2 f .

Since most gates do not operate/switch at every clock cycle, they are often accompanied by a factor \alpha, called the activity factor. Now, the dynamic power dissipation may be re-written as

 P = \alpha C V^2 f .

A clock in a system has an activity factor α=1, since it rises and falls every cycle. Most data has an activity factor of 0.1.[[6]](http://en.wikipedia.org/wiki/CMOS#cite_note-6) If correct load capacitance is estimated on a node together with its activity factor, the dynamic power dissipation at that node can be calculated effectively.

Since there is a finite rise/fall time for both pMOS and nMOS, during transition, for example, from off to on, both the transistors will be on for a small period of time in which current will find a path directly from VDD to ground, hence creating a [short-circuit current](http://en.wikipedia.org/wiki/Short-circuit_current). Short-circuit power dissipation increases with rise and fall time of the transistors.

An additional form of power consumption became significant in the 1990s as wires on chip became narrower and the long wires became more resistive. CMOS gates at the end of those resistive wires see slow input transitions. During the middle of these transitions, both the NMOS and PMOS logic networks are partially conductive, and current flows directly from VDD to VSS. The power thus used is called crowbar power. Careful design which avoids weakly driven long skinny wires ameliorates this effect, but crowbar power can be a substantial part of dynamic CMOS power.

To speed up designs, manufacturers have switched to constructions that have lower voltage thresholds but because of this a modern NMOS transistor with a Vth of 200 mV has a significant subthreshold leakage current. Designs (e.g. desktop processors) which include vast numbers of circuits which are not actively switching still consume power because of this leakage current. Leakage power is a significant portion of the total power consumed by such designs. Multi-threshold CMOS (MTCMOS), now available from foundries, is one approach to managing leakage power. With MTCMOS, high Vth transistors are used when switching speed is very important, while low Vth transistors are used in speed sensitive paths. Further technology advances that use even thinner gate dielectrics have an additional leakage component because of current [tunnelling](http://en.wikipedia.org/wiki/Quantum_tunnelling" \o "Quantum tunnelling) through the extremely thin gate dielectric. Using [high-k dielectrics](http://en.wikipedia.org/wiki/High-k_dielectric) instead of [silicon dioxide](http://en.wikipedia.org/wiki/Silicon_dioxide) that is the conventional gate dielectric allows similar device performance, but with a thicker gate insulator, thus avoiding this current. Leakage power reduction using new material and system designs is critical to sustaining scaling of CMOS.

1. *Static Power*

Both NMOS and PMOS transistors have a gate–source threshold voltage, below which the current (called sub threshold current) through the device drops exponentially. Historically, CMOS designs operated at supply voltages much larger than their threshold voltages (Vdd might have been 5 V, and Vth for both NMOS and PMOS might have been 700 mV). A special type of the CMOS transistor with near zero threshold voltage is the native transistor.

1. DESIGN

The design is a 32 bit ripple carry adder. A full adder adds binary numbers and accounts for values carried in as well as out. A one-bit full adder adds three one-bit numbers, often written as A, B, and Cin; A and B are the operands, and Cin is a bit carried in from the previous less significant stage. I use 32 1 bit full adder to form a 32 bit ripple carry adder. Each carry bit "ripples" to the next full adder.

For giving clocks to the circuit, I add registers before and after the input and output of the adder.

The technology I use is 45 nm low power technology.

1. SIMULATION

I use Hspice to make the simulation. I assume that here “best performance” means fastest speed. I will first specify some voltage and under that voltage I use some tests to find the fastest clock and then find power consumption under this condition.

But the question is that is this voltage the best one under this power, or is there any other voltage could give me faster clock but less power?

The answer is no. If there really exists such a voltage, and if it is higher than the current voltage we have found, the faster clock and higher voltage will not satisfy power constraint. And if that another voltage is lower than the voltage we have found, it will not give me faster clock.

Here is the complete data table.

|  |  |  |
| --- | --- | --- |
| voltage(v) | power(w) | Minumun clock cycle(ns) |
| 0.7 | 3.52E-04 | 17.8 |
| 0.8 | 6.84E-04 | 8.2 |
| 0.9 | 9.92E-04 | 5.14 |
| 1 | 1.46E-03 | 3.78 |
| 1.1 | 2.07E-03 | 3.04 |
| 1.2 | 2.89E-03 | 2.6 |
| 1.3 | 3.41E-03 | 2.28 |
| 1.4 | 4.63E-03 | 2.06 |
| 1.5 | 5.73E-03 | 1.92 |
| 1.6 | 6.80E-03 | 1.76 |
| 1.7 | 8.18E-03 | 1.66 |
| 1.8 | 9.51E-03d | 1.58 |

Table 1. voltage, power and min clock cycle

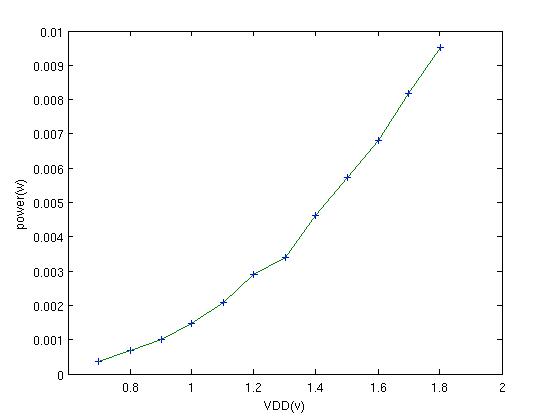
From this table, we can see that as the voltage increase, power consumption increase and minimum clock cycle drops. So here is the diagram for power and voltage relationship.

Figure 1. Power and voltage

From this graph, we can see that power increases as voltage increases. So if our customer requires some power constraint, we can draw a horizontal line with that power value, then draw a vertical line at the crossing point. The voltage at the vertical line is the most optimum voltage under that power constraint. In a word, I can give all the best voltage that allow highest performance if the power constraint is given in the range of Table 1.

1. Conclusions and expectations

From this project, I get a clear pattern of power, delay and voltage supply relationship. With these data, I can do more work. If I can get critical path delay, I can calculate the power-delay product, so I can set the most optimum voltage for this circuit. What is more, with alpha-power law, I can even estimate what value of alpha is. These are what I am going to do in future.

References

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