Low Static Power and High Throughput Wave-Pipelined Global Interconnect Circuits

Mark Youngblood
School of Electrical and Computer Engineering
Trends in the Semiconductor Industry: Moore’s Law

Each generation of Technology is getting progressively smaller according to Moore’s Law, which predicts that the number of elements on a microprocessor will double every 12-18 months.
How small can we go?

As of 2006, The semi-conductor industry has miniaturized transistors to the size of 65nm! However power dissipation has become a major impediment to future reductions in size.

With the amount of power dissipation increasing exponentially with each new generation, new techniques will need to be developed to continue to adhere to Moore’s Law.

Over 500 Million transistors can fit on this single chip.
Proposed Research

“This project will investigate a low power, high throughput design for global interconnect circuits.”

Reductions in power consumption will come from raising the transistor’s “turn-on” voltage, and thus reducing static power dissipation.

High throughput will be achieved through a “wave-pipelining” implementation.

Global Interconnect Circuits are circuits containing large, cross Chip wires.
Causes of Static Power

Static Power loss occurs during the non-conducting, “off” state of a transistor and is caused by three components:

1. Gate Leakage Current
2. Bulk Leakage Current
3. Channel Leakage Current

When these undesired currents flow in a transistor, they dissipate power according to the equation: \( P = I^2R \)

Static Power as a percentage of Total Power is quickly increasing as transistors shrink.

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Increasing the Threshold Voltage

A transistor’s “Threshold Voltage” is the voltage that separates a conducting “on” state from a non-conducting “off” state. This voltage can also regulate the amount of current flowing through a transistor. With a higher threshold voltage, there will be less current running through the transistor during “off” states, leading to less static power dissipation.
Increasing the Threshold Voltage

Simulations were performed using HSPICE software to verify that a higher threshold voltage will reduce static power consumption over a wide variety of transistor sizes.

These simulations measured the percentage of total power consumption that is static power. The low threshold voltage circuits clearly dissipate more static power.

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Increasing the Threshold Voltage

However as an unintended side-effect of an increased threshold voltage, the circuit’s throughput (or speed) will be reduced. This is due to a weaker drive current and thus, longer charge-up periods for each transistor.
Increasing Throughput

The loss in throughput can be overcome through a technique known as “wave-pipelining,” which allows multiple signals to propagate down a wire at the same time. The number of signals able to be contained on one line (and thus the increase in throughput) is related to the number of repeaters in the circuit.
Increasing Throughput

Throughput was measured for varying amounts of repeaters in each transistor size, eventually saturating around 25 repeaters.
Simulation Methods

Simulations were run using technology models obtained from the Berkley Predictive Technology Model (BPTM) website.

This basic inverter circuit was used to measure the amount of static power loss in each technology generation. With this number recorded, the Static power can be measured in any circuit by multiplying the power loss by the number of transistors in the circuit.
Simulation Methods

Throughput was measured in a global interconnect circuit. RLC segments were used to simulate the wiring between each repeater.
Summary of Findings

This research demonstrates that a low-power, high throughput global interconnect circuit can be constructed using high threshold voltage transistors and wave-pipelining.

In particular, a threshold voltage that is 30% of the supply voltage will have a smaller amount of static power dissipation than one that is 15%.
Future Work

Future work could investigate other methods of reducing power loss such as better construction materials and design techniques.

There are also several methods being developed to increase through-put in microprocessors, such as duel-core.

As Moore’s law continues to progress, further work will need to be done in this area.
Questions???