

Transistor Sizing for High Performance and Low Power

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Abstract

Tuning a circuit by adjusting individual transistor sizes offers higher performance and lower power, for circuits with up to hundreds of thousands of transistors, than the best that can be achieved with standard cells. Typically, at the same clock rate, power can be cut in half. At the same power, clock rate can be increased 25%.

1 Introduction

In recent years, the joint optimization of performance and power consumption in VLSI circuits has taken on increased importance, fueled by two market trends. First is the great expansion in portable products that must rely on battery power. Second is the large increase in power consumption of high-end microprocessors, due to increasing clock rates and scale of integration. The product that exemplifies both these trends is the laptop PC, which with current technology suffers from a combination of poor performance, heavy batteries, and limited charge lifetime. An improved delay-vs.-power tradeoff curve is an important asset in today's VLSI markets, and will increase in importance as line widths continue to decrease.

Both the power and maximum clock rate of a sequential circuit can be controlled by varying the sizes (channel widths) of the transistors. The sum of transistor sizes gives a rough estimate of power consumption, but delay depends nonlinearly on transistor sizes: Doubling a transistor's size halves the time for it to drive a load, but slows down its input. The problem can be formalized fairly simply: Given a synchronous circuit with N transistors of sizes $x_1, x_2, \dots, x_N$, find values for the x_i that jointly minimize the power consumption and the smallest clock period at which the circuit will operate correctly.

TILOS (Timed LOGic Synthesizer, pronounced tee-los) [4] [6], is a program that accepts a transistor-level connectivity file and a performance-specification file, and adjusts transistor sizes and permutes series-connected networks within complex logic gates to meet the user's performance specification while simultaneously minimizing power consumption. This paper relates experiences applying TILOS to various commercial circuits, and the enhancements necessary to accommodate these circuits.

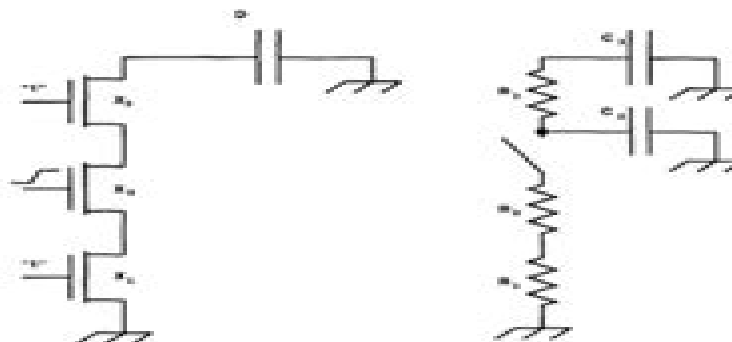


Figure 1: A pulldown network is modeled by an equivalent RC network.

2 Timing Model

TILOS models a transistor as a perfect switch in series with a linear resistor. The gate, source, and drain capacitances are proportional to transistor size X , and the transistor resistance is inversely proportional to X .

Figure 1 illustrates the modeling of a pulldown network by an equivalent RC network. The delay is modeled by Elmore delay [9], which in this case is

$$(R_1 + R_2)C_2 + (R_1 + R_2 + R_3)C_3. \quad (1)$$

Given that each terminal capacitance is proportional to transistor size, and resistance is inversely proportional to transistor size, (1) can be rewritten in terms of the transistor sizes X_1 , X_2 , and X_3 . Each R_i is proportional to $1/X_i$, and each C_i is some constant (for wire capacitance) plus one term for each transistor terminal incident on the node. Each of these terms is proportional to transistor size. (1) can then be rewritten as

$$(A/X_1 + A/X_2) \cdot (B \cdot X_2 + B \cdot X_3 + C) + (A/X_1 + A/X_2 + A/X_3) \cdot (B \cdot X_3 + D) \quad (2)$$

27.3.1

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Table of Contents Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference

1. Understanding the eBook Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - The Rise of Digital Reading Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Advantages of eBooks Over Traditional Books
2. Identifying Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - User-Friendly Interface
4. Exploring eBook Recommendations from Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference

- Personalized Recommendations
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference User Reviews and Ratings
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference and Bestseller Lists
5. Accessing Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference Free and Paid eBooks
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference Public Domain eBooks
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference eBook Subscription Services
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference Budget-Friendly Options
 6. Navigating Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference eBook Formats
 - ePub, PDF, MOBI, and More
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference Compatibility with Devices
 - Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference Enhanced eBook Features
 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Highlighting and Note-Taking Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Interactive Elements Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 8. Staying Engaged with Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 9. Balancing eBooks and Physical Books Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Setting Reading Goals Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference

- Fact-Checking eBook Content of Proceedings Of The Ieee 1997 Custom Integrated Circuits Conference
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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