Toward Design Technology in 2020: Trends, Issues, and Challenges

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Abstract

VLSI design does not stand alone. The challenges and opportunities for the design community are driven and shaped by larger forces, from semiconductor technology evolution through product trends, and ultimately to large scale societal forces which are far beyond the control of designers. To understand the requirements for design, then, we first need to examine the larger environment in which we will operate. Predictions are notoriously inaccurate[1], but I will attempt to outline the global issues and technological trends that will shape what designers must do. In my presentation, I will risk some prognostications about the specific trends and challenges in the VLSI design field over the next 20 years, in hopes that I will be retired long before anyone thinks to check my predictions.

1. Global Trends

At the top of the hierarchy that ultimately defines our task as designers, are global-scale demographic and social trends. In my talk, I will discuss some of the forces that will shape our profession:

1.1 Energy

It is well known that the world economy runs largely on a finite, exhaustible supply of fossil fuels. What is often not widely recognized is that even batteries, fuel cells, and the like ultimately depend on fossil fuels in their manufacture, distribution, and ultimate disposal. We cannot consider ourselves exempt from dealing with issues of energy supply and conservation, and will increasingly find ourselves held responsible for the complete life-cycle energy costs of our products.

[1] "It's tough to make predictions, especially about the future." Yogi Berra.

1.2 Global Economy

At the political level, individual countries will continue to maintain their historical identities and conflicts, but at the economic level it will truly be "one world." Successful products will need to be culture-neutral, or highly customizable, in order to serve global markets.

1.3 Connectivity

Computing and communications will complete their trend toward merger, and will be a totally pervasive component of everyone's life at all levels of society. Every home will be "wired," distributed sensors will be everywhere, and workforces will be globally distributed. All VLSI products will be designed as extensions of this global infrastructure.

2. Design trends

Large scale trends in society drive the kinds of products that will be designed, and thus shape the designer's task. The major forces in this arena will be:

2.1 Mission Critical Products

The ubiquity of computing and communications implies that VLSI will be embedded in medical, financial, transportation, security, and military systems to a degree nearly unimaginable today. This implies that the products we design must be free of "bugs," highly reliable, and tolerant of random failures. Product liability may be the hidden Achilles Heel of our industry.

2.2 Competitive Pressure

The global economy and worldwide connectivity will bring intense competition. Products which are not designed rapidly, which are not correct the first time, and which do not have practically zero marginal cost will quickly fail in the marketplace, along with the companies that design them. There will be no time for yield learning.

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The survivors will be those who consistently differentiate their products on innovation and are consistently first to market.

2.3 Everything will be Integrated

The trend toward single-chip solutions will continue indefinitely. No matter how hard it is to do, no matter how technologically "better" it may seem to develop multichip systems, economics will drive us toward single chip solutions for all kinds of systems.

3. Implications for Design

3.1 Design at the Application Level

Time-to-market pressure will dictate that all design must be done at the application level in the future. Unlike today's system-level tools, estimates of the technological and performance impact of high level decisions must be highly accurate, and their error bounds well-known. Designers must be able to roam the design space at a pace set by their imagination, not by tool performance and limitations. The entire chain of tools from the application level to manufacturing must be integrated and transparent to the designer.

3.2 Get it Right the First Time

Because of both time and cost pressure, there will be no second chances in the marketplace; NRE costs and market windows will not permit spins. Correctness to all specifications must be guaranteed by design at each transformation or refinement in the tool chain. Every tool must include its own quality assurance and guarantee the correctness of all its results. The tool infrastructure must also guarantee that all tool results, in addition to being locally correct, preserve global correctness in the overall system being designed.

3.3 Tools and Methodologies Must Evolve

Because of the complexity of the design tool chain, it will not be feasible to replace entire methodologies with each new technology innovation. Instead, the tool chain must be engineered to evolve, to learn from experience, and to adapt to a continually changing set of component tools. Individual tools must become truly "plug 'n play" and the infrastructure must accommodate regular tool changes without compromising the correctness of any design.

3.4 Products Must Evolve

Manufacturing technologies and the underlying devices with which we build systems are evolving perhaps faster than VLSI systems themselves. Not only must the tool chains evolve, but the products themselves must change as well. First, configurable designs will be necessary to support globalization and localization; second, since manufacturing processes cannot continue to produce perfect devices at a sustainable cost, products must be designed to be error-tolerant and function despite imperfections; and third, random failures and quantum uncertainty will rapidly increase as bulk silicon devices give way to radically new technologies, necessitating designs that diagnose and repair failures dynamically.

4. So How Do We Get There From Here?

Nothing I have said here should be a surprise to anyone at this symposium. But even though we all recognize the challenges ahead, it is not at all clear how we will be able to address them. It is tempting to tell ourselves that we will, somehow, just muddle through as we have often done in the past, but part of my job in a major funding agency is to try to catalyze the needed changes. Our analyses of the scale of the research challenges are not encouraging; a recent study[2] has identified a worldwide "research gap" (the difference between current research spending and what we believe to be necessary) of about US$132 million annually in design technology. In my presentation, I will present some details and offer some suggestions on how the worldwide community must respond to the challenges.

[2] Charles J. Nuese. *Research Needs vs. Funding*. Semiconductor Research Corporation, 2001.