Systems on Chips: The Microelectronics Challenge of the Next 20 Years

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Summary: Even if the present pace of progress continues, the prospects for microelectronics beyond the year 2000 will not be limited by technological constraints.

Equally positive statements can be made about future developments in applications. Thus, the computational power of a chip can be boosted by about four orders of magnitude to $10^8 - 10^6$ MIPS on the basis of verified structures. However, this implies that heed be paid to the various recommendations given in this paper as regards technology, circuit design, layout and architecture.

Conventional stand-alone markets for memory and logic ICs are predicted to grow by 10-15% annually for the next decade. But user-specific memory as well as logic with on-chip memory (volatile and non-volatile) will become increasingly important. These novel “systems on chips” will eliminate the bottleneck represented by the on-chip/off-chip metallization. Consequently, the technical approximation to “biological systems” will become feasible and lead to an increase in system performance of several orders of magnitude. These on-chip systems contain today’s system know-how and will become the modules of the hypersystems of tomorrow.

1 Introduction

The historical groundwork for microelectronics, which has now changed our lives so dramatically, was laid down in the recent past. Shockley, Bardeen and Brattain [1;2] discovered transistor action at Bell Laboratories in 1948. About 12 years later, Kilby [3] and Noyce [4], from Texas Instruments and Intel respectively, devised planar technology and the simultaneous manufacture of transistors and wiring systems and thus invented integrated circuits. This then triggered the ensuing rapid development in microelectronics. In 1970, bipolar circuits with around $10^3$ components (transistors, diodes, capacitors, and resistors) and switching times of some hundreds of nanoseconds could be produced. At the same time, the problem of interface charges at the oxide-silicon boundary was solved by suitable annealing treatment and the first MOS transistors could be successfully produced. Then in 1980, bipolar circuits with $10^4$ transistors and 200 nanosecond delay time, and MOS circuits with $10^5$ devices were
obtained on an industrial scale. Today (1992), this technique makes available bipolar circuits with more than $10^5$ devices and MOS circuits with almost 50 million components for applications in communications, data processing, automation, traffic technology, medicine and many other sectors of great importance in our lives [5].

Since about 1960, the semiconductor components market has been growing at a compound annual growth rate of approximately 15%. Forecasts assume that future growth rates will be the same. The result will be that the IC world market, amounting to DM 250-300 billion in the year 2000, will be about as large as the market of the automobile industry worldwide at the same time. It should be noted that this IC market is a pure components market whose technology push has a multiple effect on the systems business sector because without these key components, many systems cannot be realized at all or at least not in this form. The predictions made by the Club of Rome have therefore been vindicated, namely calling integrated circuits “the modern raw material of the industrial nations” whose importance for the future can hardly be overestimated [5].

To assess the development potential of microelectronics, we must look at possible “show-stoppers” in the physical, technological or business sectors that could well put the brakes onto the extrapolated development (Fig. 1).

![Figure 1 Development of chip complexity for memory (Moore curve) and logic devices](image-url)