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Why Are Low-Voltage and Low-Energy Devices Desired?

The original scaling rule [1] indicated that the dissipation power density (W/cm^2) of an integrated circuit is not changed by scaling [1, 2]. However, this guideline is only really applicable to DRAM devices. In most integrated circuits, the supply voltage is not scaled according to the designer's intent, and devices have faced negative impacts, such as hot-carrier phenomena [3] and negative bias temperature instability (NBTI) phenomena [4], due to high supply voltages [5]. In the twentieth century, central processing unit (CPU) revealed dramatic advances in device performance (high-speed signal processing with increases in data bit length), and the guideline seemed to be ignored (see http://www.depi.itch.edu.mx/apacheco/asm/Intel_cpus.htm, accessed May 18, 2016).

However, in the 1990s, CPU designers noticed the limitations of CPU cooling efficiency, which triggered an urgent and ongoing discussion of low-power device technology. The following possible solutions have been proposed:

- the introduction of a silicon-on-insulator integrated circuit (SOI IC) strategy based on advanced substrate technology [6];
- a multicore strategy [7];
- a low-voltage strategy [8].

These major strategic proposals have led the worldwide electronics industry to the Internet of Things.

Business opportunities based on information technology have increased in the real world without taking account of the issues raised by technologies such as cloud computing [9] and datacenter construction (see http://www.datacenterknowledge.com/,

MOS Devices for Low-Voltage and Low-Energy Applications, First Edition.
Yasuhisa Omura, Abhijit Mallik, and Naoto Matsuo.

accessed May 18, 2016), which have rapidly increased global energy consumption [10]. We must propose viable and innovative ideas on semiconductor device technologies to suppress such global-warming factors.

Information technology has widened perspectives on improving the quality of our future social life. Many companies are creating highly desirable products in the field of sensing technology, such as house monitoring (temperature, humidity, air pollution, fire, human health, security), office monitoring (temperature, humidity, air pollution, fire, security), traffic monitoring (for aspects such as car speed, traffic jams, and accidents), agriculture monitoring (for temperature, humidity, air pollution, rain, wind, lighting, storms), space monitoring (moon, sun, stars, meteorites, and other astronomical phenomena), defense monitoring, and so on. Many of these products use dry batteries or solar power/batteries for 24-hour monitoring. In the case of portable equipment, large batteries are impractical, which has triggered the development of small batteries with high energy density. This is also applicable to cellular phones and smart phones [11].

In battery-powered sensing devices, the battery volume must be small. This may be achieved by lowering the supply voltage, which in turn reduces the battery energy as it is proportional to the square of the voltage. Hence, it is more important to reduce the dissipation energy than the dissipation power for sensing devices. This will be addressed again later. We must, therefore, contribute to the solution of urgent social problems by proposing low-energy devices and integrated circuits.

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