A-26～A-31

LSI Logic Circuit Design

Switching Circuit Theory

Relay Circuit Theory

VLSI Design Automation Method

Action Description and Higher Order Logic Synthesis

Clock Wiring Method

System LSI Architecture Design Technology

Semiconductors are said to be “rice for industry,” and consequently, since the integrated circuit was invented by Jack Kilby in 1958, massive complications have been continuously advancing along with rapid improvement of manufacturing technology. Such advancements have been supported by a wide variety of technologies. Above all, design technology, especially, computer-aided design automation technology, played an important role. At our institute, this research agenda was actively discussed at the expert study committee for circuit network theory (currently the study group on circuits and systems) and at the expert study committee on computers (currently study group on computer systems). In 1987, the study group on VLSI design technology was set up.

The origins of logic design go back to the 1930s. In 1936 and 1937, A, Nakajima and M. Hanzawa proposed switching circuit theory, the basis of current logic design, before the rest of the world. In the 1940s, M. Ohashi advanced switching circuit theory further into relay circuit theory considering time-delay.

After the 1970s, the design technology of large-scale integrated circuits made progress, e.g., from manual design input to automated design for reasons of rationalization, process streaming went from lower and upper processes to more abstract levels. T. Ohtsuki, S. Goto and I. Shirakawa established automated circuit simulation, layout design and logical design ahead of the pack using approaches such as graph theory, network theory, and combination logic.

LSI design which involves a large amount of circuit data and constraint conditions often including difficult problems – theoretically hard to get the optimal solution. N. Harada constructed a new theory to find layout designs for master-slice-mode LSI from the standpoint of the statistical-mechanical approach.

In the 1990s, automatic circuit synthesis technology at the register transfer level or from the hardware description at higher levels of abstraction was developed. Y. Nakamura, K. Oguri and A. Nagoya developed the hardware description method and high-level logic synthesis technology which made it possible to perform movement simulation and automatic

synthesis and the optimization of logic circuits at higher levels of abstraction.

M. Edahiro advanced comprehensive research and development on the clock wiring method which was particularly important for LSI wiring design, and developed the minimization of variations in wiring lengths and the calculation of theoretically optimal values for wiring widths ahead of the pack.

In the 2000s, the research and development of system LSI technology which could realize systems with highly developed functions in one LSI were promoted. H. Yasuura and K. Murakami proposed new concepts, e.g., parallel processing system LSI architecture mix-loaded with the DRAM/logic and a soft/core processer and also developed the low-power-consumption method at the system level.

Recent years, studies about designs coping with variations and dependable LSI to operate appropriately under wide-ranging usage environments have been carried out.

A-32～A-33

Elastic Wave Filter Technology

Energy Confinement Filters

Surface Acoustic Wave Filters

The study of piezoelectric devices started with the discovery of the piezoelectric phenomenon of crystals by the Pierre brothers, Pierre Curie and Paul-Jacques Currie, in 1880. In 1949, a study group of ultrasonic waves was set up in our institution to provide a place to exchange research on science and technology concerning a wide spectrum of ultrasonic waves including the piezoelectric element.

Because the filter element with the use of mechanical resonance has excellent frequency discrimination characteristics, various methods have been researched and developed. Among others, the energy confinement filter published by M. Onoe, et al., in 1965 was a research finding ahead of the pack in terms of high-performance monolithic filters, and it consequently holds a monopolistic position in the world market even today.

As for filter technology with the use of surface acoustic waves, this started at the publication of the excitation of surface acoustic waves with reed-shaped electrodes in 1965 by K. Yamanouchi, et al. In the same year, White, et al., in the United States also reported excitation with reed-shaped electrodes. These findings became pioneers in this research field, and consequently, the practical implementation of surface acoustic wave filters progressed from the 1970s. Currently, 6 to 19 units of surface acoustic wave filters are mounted on the front-end of one mobile phone/smartphone, for example, and thus annually as many as 13 billion (estimation) devices have been manufactured. Accordingly, it has become an

important circuit element technology in communications system. In recent years, efforts to apply surface acoustic wave device technology to IoT, sensors, and actuators have been spreading as well.