The Hot Decade of Field Programmable Technologies

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Abstract

A historical review of the chip industry will be provided with the emphasis on the cyclical nature between standardization direction and customization direction. The basic mechanisms of the cycle will be discussed including technology factors and marketing factors. It is concluded that the field programmable technology will play the vital role in the emerging digital consumer market by providing features that are "standardized in manufacturing but customized in application".

1. Introduction

In recent years, we are observing strong trends toward field programmable technologies in the chip industry either in R&D phase or in business phase. For example, FPGA market has already surpassed that of conventional GA market and various types of reconfigurable devices are emerging to the market. This trend is enhanced by the paradigm shift of market, namely from PC centric market to consumer centric market where the "time to market" is of vital importance. The field programmable technologies provide unique features that are "standardized in manufacturing but customized in application". The author predicted in 1987 that the field programmability will become the hot subject in the decade starting around 1997 to 2007. The prediction was made after the careful review of the cyclical nature of the chip industry which changes direction between standardization and customization roughly every ten years. This cycle was later named as "Makimoto's Wave" by Electronics Weekly (UK) in January 1991.

2. Cyclical Changes of Chip Industry

After the incubation period of about ten years after the invention of transistors in 1947, the commercialization of semiconductor devices started in late 1950's. There have been various new technologies and devices in the course of semiconductor evolution in the past few decades either toward standardization direction or toward customization direction. Brief review of each decade will be described.

1947 to 1957 : Dawn of Semiconductor Age
This decade could be described as the incubation period of the semiconductor industry. Although the point contact transistor invented in 1947 was not suitable for the mass production, more manufacturable alloy junction transistor was invented in 1950 and mesa transistor in 1955.

1957 to 1967 : Era of Transistor
The transistor market took off in this decade and created the cycle of "standardization" since most of the discrete devices were standardized and interchangeable.

1967 to 1977 : Era of IC/LSI
The IC chip was invented in 1958 by Jack Kilby of Texas Instruments. The actual take-off of the chips industry began after several years of incubation, around 1967. Circuits were customized for specific applications like electronic calculators, so this decade was a cycle of "customization".

1977 to 1987 : Era of MPU/Memory
The "customization" cycle tends to lower the operating efficiency and the previous cycle led to the microprocessor being invented and introduced to the market in 1971 by Intel. Combined performance of MPU and memory provided the flexibility of system design leading to the clear take-off of the "standardization" cycle around 1977

1987 to 1997 : Era of ASIC
One of the problems with product standardization is that such products tend to create a market imbalance between demand and supply, resulting in the so-called "silicon cycle". Such a situation occurred in 1986 and led to another cycle of "customization". Thanks to the development of design automation technology,

application specific products became more feasible and the ASIC created a new cycle of "customization".

1997 to 2007 : Era of Field Programmability

In this decade, the market structure shifted from PC to digital consumer product and hence there was a strong requirement for shortening TTM or Time To Market. Field programmable devices such as FPGA's, after about ten years of incubation period, took over GA in market size indicating that the new cycle of "standardization" started around 1997. We are now in the hot decade of field programmable technology which will contribute for enriching electronic products for the betterment of our future society.

3. Makimoto's Wave and Semiconductor Pendulum

Fig.1 shows "Makimoto's Wave" which shows the cyclical nature of the semiconductor industry.

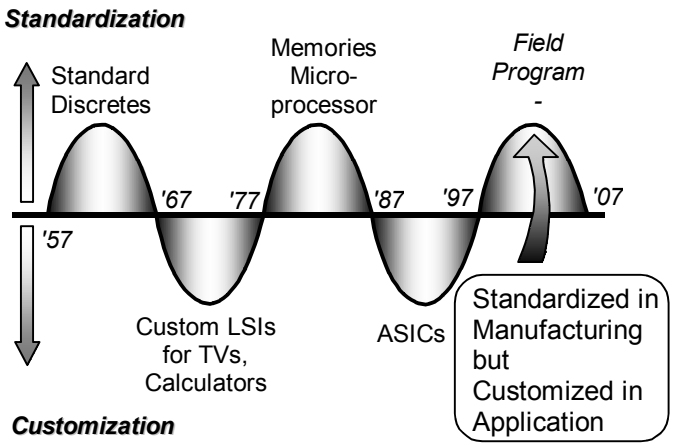

Fig.1 Makimoto's Wave

There are some basic mechanisms which create the cycles of the chip industry. Fig.2 shows a "Semiconductor Pendulum" which is intended to provide interpretations for the above mechanisms.

Imagine a long pendulum swinging back and forth between standardization and customization. There are various forces acting on and reacting to the pendulum, as shown in the figure. When the pendulum swings too far toward standardization, there will be such reacting forces as

- Need for differentiation
- Need for value addition
- Market confusion due to supply-demand imbalance

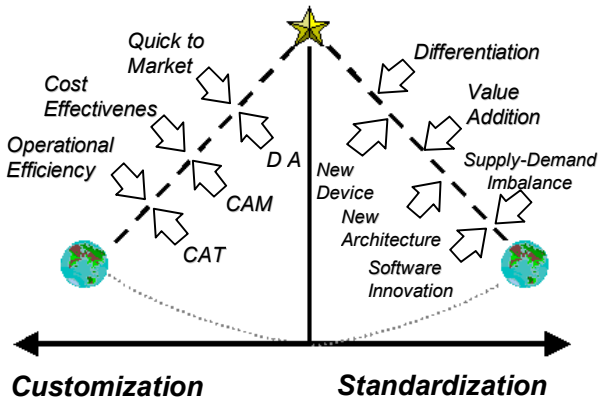

Fig.2 Semiconductor Pendulum

On the other hand, when the pendulum swings too far toward customization, there will be such reacting forces as

- Better operational efficiency
- Improved cost effectiveness
- Faster time to market

Various kinds of semiconductor technologies act on the pendulum. For example, the invention of the microprocessor pushed the pendulum towards standardization around 1977. That was based on innovations in architecture and software. Another example is the progress of design automation technology around 1987, which pushed the pendulum back towards customization.

Today's rising trend of standardization (1997-) depends on innovations in device structures as well as in architectures toward the field programmable technologies.

We are certainly in the hot decade of field programmable technologies today.

4. Shift in Market Structure

Fig.3 shows changes in semiconductor market structure from 1990 to 2010. As is seen from the figure, PCs have been the major driving force of the chip industry for the past two decades. However, we are observing a new trend driven by "Digital Consumer (DC)" products, such as digital cellular phones, digital still cameras, digital TV's, game machines, and so on.

One of the characteristics of the DC market is very dynamic change in the product life cycle and the "quick time to market" is of vital importance.

Technology	Volatility	Re-programmability	Area	Resistance(kΩ)	Capacitance(fF)	Example
SRAM Cell	Yes	OK	Large	0.2 ~ 2	10~20	Altera, Xilinx
EEPROM	No	OK	2 x EPROM	2~4	10~20	Lattice
Anti-fuse	No	NG	Small	~0.5	3~5	Actel, Quick Logic
EPROM	No	OK	Small	2~4	10~20	Altera

Table 1. Programming Technology of FPGA

At the same time, the consumer market requires products that are fine-tuned for specific segments. The development of field programmability will provide a solution for these contradictory requirements by making it possible to develop products that are “standardized in manufacturing” but “customized in application”.

Source: SG Cowen

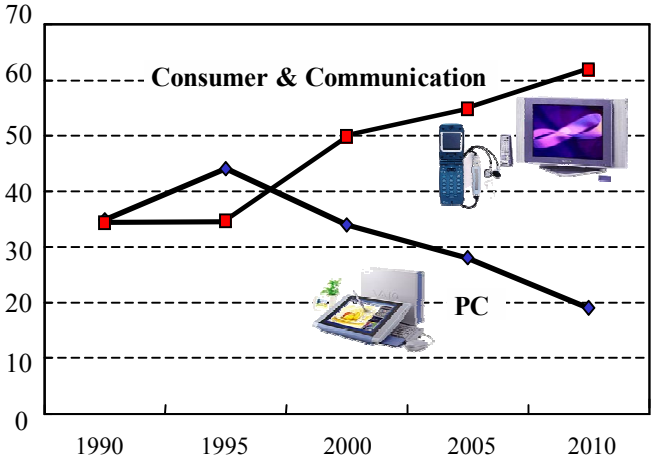

Fig. 3 Changes in Semiconductor Market Structure

5. Field Programmable Technologies

There are various different kinds of field programmable devices, some already on the market and others in the laboratory. Table 1 summarizes the programming technology of FPGA where various kinds of devices are used. Today, SRAM based FPGAs have the largest market share because of its flexible architecture, well balanced performance and compatibility with standard CMOS process.

It seems that non-volatile RAM will play the important role in the future and its development is accelerating. FRAM technology is intended for the low power applications such as smart cards and MRAM technology will be able to cover higher speed applications.

Innovation in architectures is also a hot area in the field of programmable technology. The concept of re-configurability of SoC, or System on Chip, will create a new category of semiconductor products which are called Application-Specific Programmable Products (ASPP).

The idea was presented by Jordan Selburn at the 1998 Dataquest Conference. Simply stated, ASPPs are Application-Specific Standard Products (ASSP) with embedded programmable logic that provide hardware flexibility.

As the integration density of SoC increases, total life time quantity tends to decrease as shown in Fig.4. On the other hand, tooling cost tends to rise, resulting in the prohibitively expensive tooling cost per chip. ASPPs will provide solution for this problem by increasing the total life time quantity.

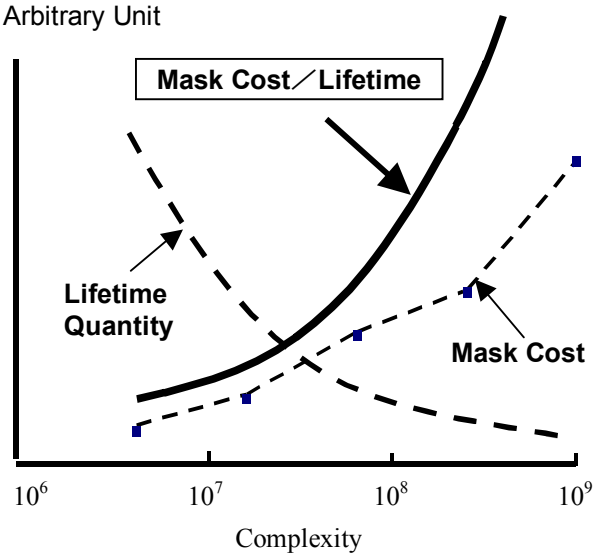

Fig. 4 Rising Cost of Tooling

6. Future Outlook

After the PC was introduced to the market in early 1980's, the "digital revolution" took place with a big impact to our society. We are now observing, however, a new digital wave propelled by the digital consumer products and network. Fig.5 shows three big waves which drove electronics industry since 1970. Since the digital consumer products require high degree of segmentation and personalization, the field programmable technologies will make the vital contributions for the rising second digital wave.

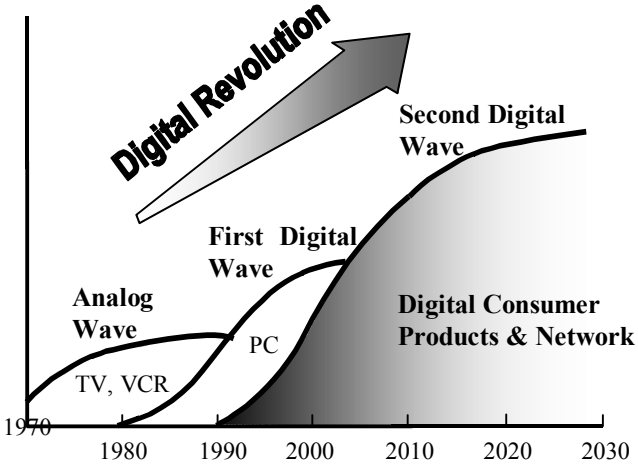

Fig.5 Rising Second Digital Wave