Chapter 11

F-ZTAT Becoming Mainstream MPU

Breakthrough from Hitachi

The F-ZTAT microprocessor is a successor to the ZTAT microprocessor as described in detail in Chapter 7.

“F” meaning flexibility was put at the top of the part number, because the OTP (One Time Programmable) ROM was replaced by flash memory, thus greatly enhancing the re-write flexibility. Also, “F” at the head indicates “F” for flash memory, as well as “F” for field programmability.

When looking back at Hitachi’s microprocessor business, there were three breakthrough technologies or concepts leading the new way in the global industry with major impact as described below. One of them is the F-ZTAT microprocessor.

Following are three major “breakthrough from Hitachi” in the field of microprocessor.

1) Hitachi led the move to CMOS in device technology. The device technology of 8-bit microprocessors from both Intel and Motorola in the 1970’s was NMOS, and it was an industry consensus that “NMOS is the mainstream of semiconductor devices”.
   Hitachi’s CMOS microprocessor “6301” introduced to the market in 1981 was the product which broke this conventional idea and clearly showed the advantage of CMOS. As a result of this, the global industry trend gradually shifted to CMOS, as was discussed in detail in Chapter 6.

2) Hitachi developed high performance / low power microprocessors based on the new RISC architecture, and developed new market through these products.
   The SH microprocessor which was introduced in 1992 played a leading role in opening up a new field of digital consumer products, such as digital cameras, car navigation systems and games.
   In addition, as a main engine in the nomadic era, it had a great influence on the change of our life style, as was introduced in Chapter 10.

3) Hitachi led the move to field programmability of on-chip ROMs of the microprocessors. Traditionally, mask-programmable ROMs had been used for mass-production microprocessors, but by adopting OTP (one time programmable) ROM in the ZTAT microprocessor introduced in 1985, we succeeded in mass production ahead of the world, as I mentioned in Chapter 7. The next field-programmable microprocessor that was commercialized was the F-ZTAT microprocessor, and this is the theme of this chapter

Development of microprocessor with flash memory

The first academic paper on Flash memory was presented at IEDM (The IEEE International Electron Devices Meeting) in 1984 by Fujio Masuoka, then with Toshiba.

Until then, EPROM which was representative of nonvolatile memory at the time had to be erased

by ultraviolet light. In case of flash memory, electrical batch-erase was made possible, making it much more convenient.
Initially, memory products were commercialized and megabit class products were made in the 90's. Under such circumstances, Hitachi also proceeded with studying to install flash memory in the microprocessor.
The year of 1990 was a turning point to make a big leap of Hitachi's microprocessor business. In this year all patent related disputes with Motorola settled, and execution of the new microprocessor development plan was started for "post war reconstruction" after the "microprocessor independence war". One of them was the SH microprocessor and the other was the flash-microprocessor (F-ZTAT).

As mentioned in Chapter 7, the previous generation ZTAT was mainly applied to the 63-series microprocessor (CMOS version of the 68-series microprocessor of Motorola architecture), but as the relationship with Motorola deadlocked, it was unexpectedly forced to "wind down "and it did not reach the full bloom. In that sense, the commercialization of F-ZTAT was also a revenge of ZTAT.

As shown in Fig. 11.1, microprocessor (MCU) is composed of a central processor unit (CPU), a memory unit (RAM and ROM), peripheral circuits, and the like. The ROM part contains user programs, and how to easily and quickly rewrite its content is the most important appealing point of the product.
The figure shows how the ROM part changed from mask-programmable ROM to OTP (One Time Programmable) ROM (ZTAT), and to flash memory (F-ZTAT).

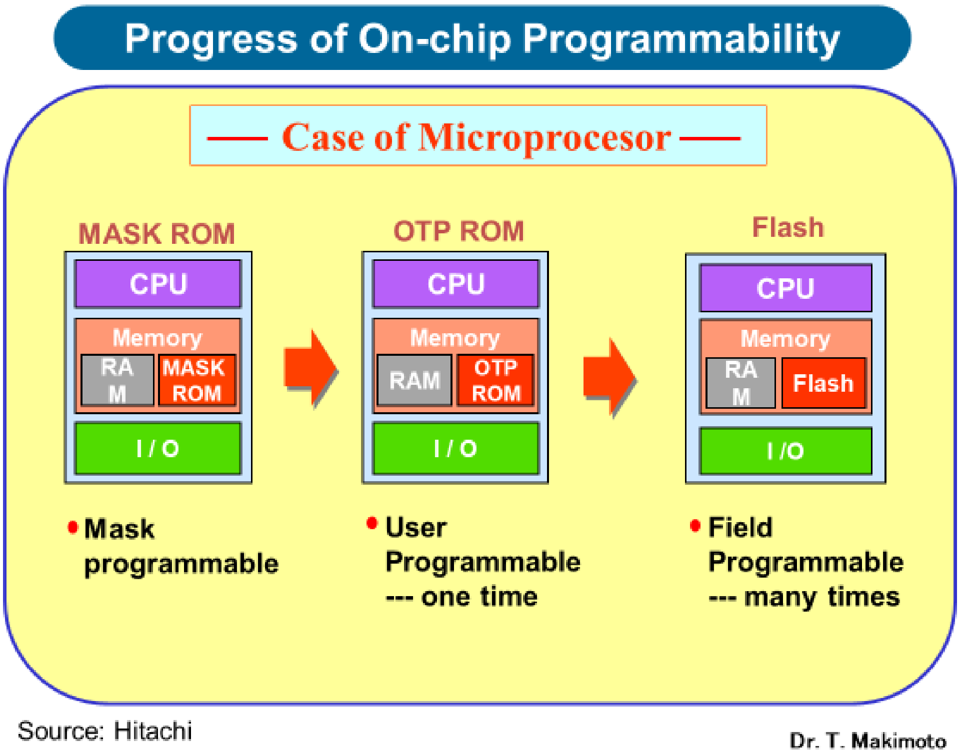

Fig. 11.1 Transition of ROM portion in microprocessor (MCU)

In the case of ZTAT microprocessors with OTP ROM, users can program only once, but in case of

F-ZTAT microprocessors with Flash ROM, they can change program many times. Therefore, the programs can be changed even after the end-product shipment, which makes it much more beneficial for the users.

Market introduction of F-ZTAT microprocessor

The development of flash-on-chip FZTAT microprocessor in Hitachi was promoted mainly by the microprocessor design department (Dept. Mgr. Toshimasa Kihara), and the first product was H8-538F. Its market introduction was in July 1993.

Technical details on the product are reported in the paper entitled "F-ZTAT Microprocessor with Built-in Flash memory" in July 1994 issue of Hitachi Review.

Key members of the development of H8-538F are Hirofumi Mukai, Kiyoshi Matsubara, Miyuki Uemura, Takashi Ito and Eiichi Ishikawa etc. who are also the authors of the above paper. In addition, Kenichi Ishibashi, Fumio Tsuchiya, Tsuneo Sato, Hiroshi Shinagawa, who were members of ZTAT, also shifted their focus to the development of the F-ZTAT version sequentially.

The first F-ZTAT microprocessor was a 16-bit product targeted at industrial and office equipment fields, and it had 60 KB flash memory on chip. Fig.11. 2 shows a chip photograph.

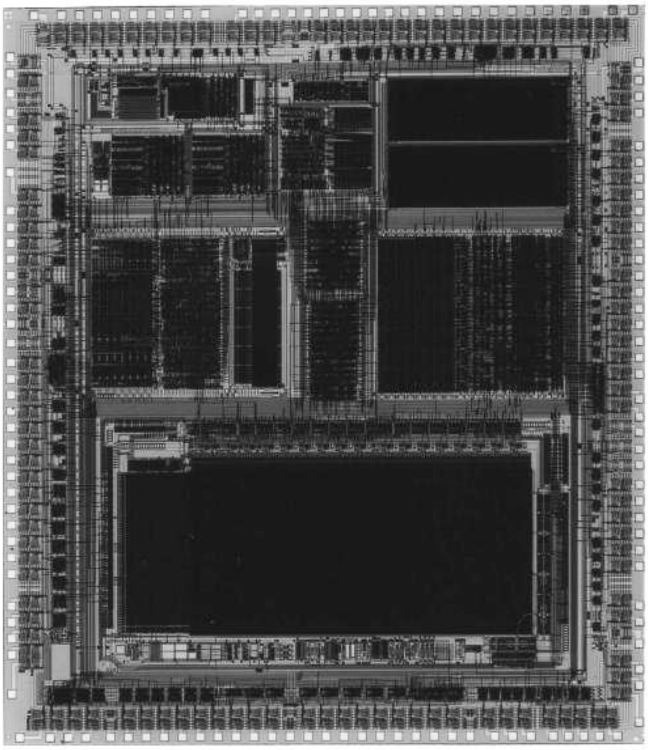

Fig. 11.2 The first F-ZTAT (with on-chip flash memory) microprocessor H8-538F
(0.8μm CMOS process, RAM: 2 KB, ROM: 60 KB, 16 MHz)

The following three points were major technical issues in the mass-production of flash-on-chip microprocessors.

① Ingenuity of memory cell structure and high yield technology to enhance cost competitiveness
② Number of read/write, or endurance
③ Data retention to keep the written data as long as possible

In order to overcome these technical problems, engineers from Memory Design Dept. (flash

memory unit), Process Engineering Dept., Manufacturing Engineering Dept., and Quality Assurance Dept. gathered under the leadership of Microprocessor Design Dept. and they finally succeeded in the mass production ahead of the world.
Meanwhile, as one of the means of strong marketing promotion, we decided to formalize “trademark registration”, and the PR group worked on this matter. Since the OTP version trademark was ZTAT (Zero Turn Around Time), it was named based on this as F-ZTAT. Since it can be rewritten multiple number of times, and it is rewritable even after the shipment, F for “Flexible” was put at the top. The trade-mark application was made in 1993, and the formal registration was completed in 1996 without major problems in the consultation with the authorities.

We succeeded in the development of various new markets with F-ZTAT microprocessor, which could not be covered before.
For example;

- ★ Products of small sized production for test markets
- ★ Products at the stage where industry standard has not been completely fixed; for example, communication, home appliances, etc.
- ★ Areas where program changes may be needed at the customer’s site such as automobile engine control use.
- ★ Products with frequent ROM-change potential such as home appliances
- ★ Fields requiring periodic calibration such as measurement and control equipment, etc.
- ★ Differentiation of products by region or by customer, etc.

As the applicable market fields expanded, demand for various kinds of product development came in. In response to such needs, Hitachi worked on expanding the product line substantially. In addition to the 8-bit microprocessor series (H8/300, 300 L) and the 16-bit series (H8/300H and 500), it was also expanded to the 32-bit SH microprocessor to enhance the lineup.
As of 1998, it was expanded to 33 products, and the applicable fields expanded to cover consumer equipment, information equipment, automobile field and others, as well as industrial and office automation equipment.

<u>The arrival of field programmable era</u>
For me, commercialization of F-ZTAT microprocessor had special significance. It was because the product was on the line of “Makimoto’s Wave” prediction.
Here I would like to briefly touch on “Makimoto’s Wave”. As shown in Fig. 11. 3, it refers to a phenomenon that the trend of the semiconductor industry swings between the “standard-oriented era” and the “custom-oriented era” every ten years.
I got this idea in 1987 when I was transferred to Takasaki Works. Four years later, in 1991, it was named “Makimoto’s Wave” by David Manners of Electronics Weekly (UK) and it became open to the public.

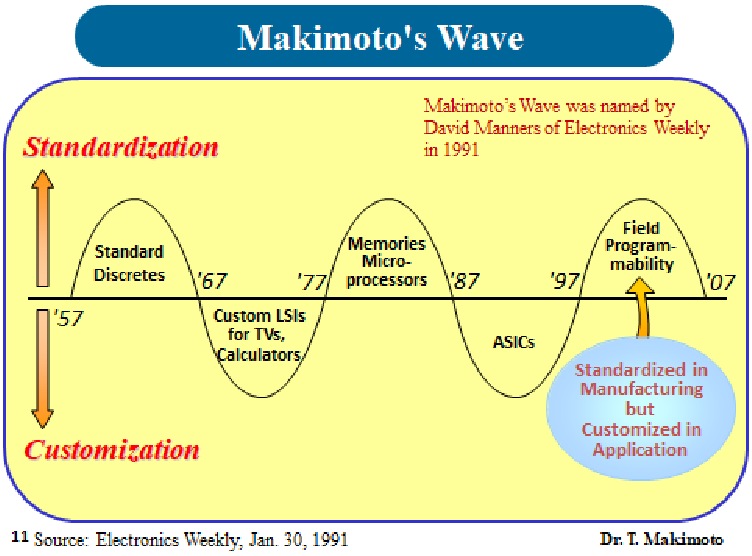

Fig. 11.3

Makimoto's Wave which predicted that the "field programmable era" would start from the latter half of the 1990's

Key phrase: Standardized in manufacturing but customized in application

What was predicted in this wave was that the decade from 1987 to 1997 was "the era of customization led by ASIC", and the cycle from 1997 to 2007 would be "standardization era led by field programmability".

Therefore, while feeling that "By all means, we have to make F-ZTAT successful as an actual example of a programmable device", I also had a firm belief that "F-ZTAT will surely become successful," based on the Wave's prediction.

Fig. 11.4 shows the trend of the annual shipment volume of flash-on-chip microprocessors in Hitachi. 100,000 units shipped in 1995 increased to 4 million units in 1996, to nearly 40 million units in 1997, and it reached the level of 100 million units in 2000.

It was accepted by the market at astonishing speed. The biggest factor was that the features of the product matched the market needs, and in addition, a major strategy of sales expansion promotion "MGO" (Microprocessor Grand Operation) played a major role. This point will be described later.

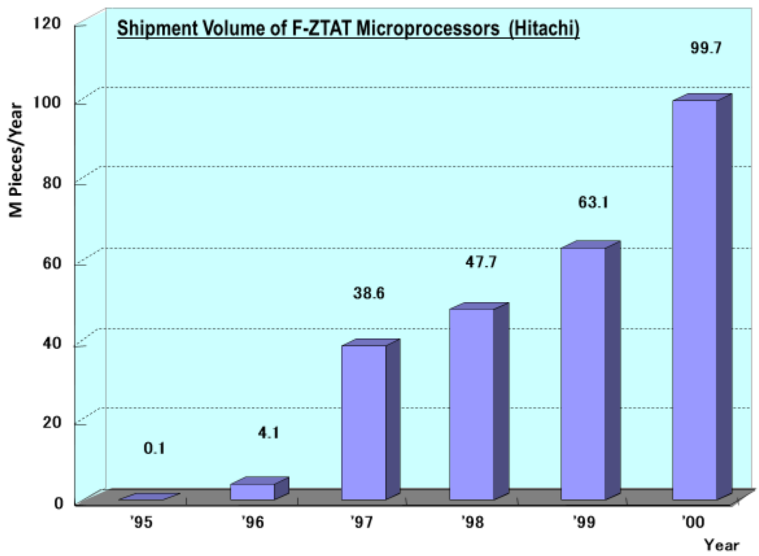

Fig. 11.4 Shipment volume of flash-on-chip (F-ZTAT) microprocessors (Hitachi)

The fact that the rising speed of F- ZTAT microprocessor shipment was extremely rapid towards the latter half of the 1990's was completely consistent with the prediction of the aforementioned "Makimoto's Wave", and it is one verification case showing that the prediction hit the mark.
At the same time FPGAs (Field Programmable Gate Arrays) were starting to rise in the market, and between F-ZTAT and FPGA, they clearly indicated "the arrival of the field programmable era".

Under such circumstances, the interest in "Makimoto's Wave" rapidly grew in the industry from the latter half of the 1990's to the first half of the 2000's, and I had many opportunities to receive invitations to give lectures at various industry meetings and academic societies.
In addition, this trend was not limited to the semiconductor field alone, but it was also in sync with the trend of "reconfigurable computing" in the computer field.
Due to such circumstances, I received unexpected invitations to talk at the major academic societies such as Computer Innovation 6016 in Beijing hosted by the Chinese government, Supercomputer Conference in the USA (SC 2006, Tampa), International Supercomputer Conference in Europe (ISC 2007, Dresden). And also in the field of communication, I received a lecture invitation from the "Reconfigurable Radio" meeting (WTP 2008, Yokosuka).
In any industrial field, it is the basis of business that, "How can customer satisfaction be realized?" and the selection of "standard or custom?" as a means for that purpose seems to be an eternal subject.

Microcomputer Car Rally (MCR)

Thanks to the flexibility of the F-ZTAT microprocessor, we now can do what we have not been able to do. New possibilities in the field of school education are one of them.
I was thinking for some time that F-ZTAT microprocessor might be suitable as a teaching material for semiconductors at high schools and universities.
The semiconductor education in our country was far behind compared with the United States and some other countries, but we had no good solution because of the high cost for the semiconductor education. When I was wondering about such things, teachers from technical high schools in Hokkaido gave us an unexpected proposal. "We would like to hold Microcontroller (MCU) Car Rally (MCR) of model cars using F-ZTAT MCUs".
This was an opportunity inspired by a proposal to a technical high school by Haruichi Terashita, a MCU engineer at Hokkaido branch office of Hitachi. In response to that proposal, the teachers, Mitsuhisa Ishimura at Kotoni Technical High School and Masahisa Sasagawa at Sapporo International Information High School, started enthusiastic activities. The passion and dedicated efforts of both teachers led to the realization of MCR.

I keenly felt "This is wonderful!" when I got the proposal from Kazuo Minorikawa, Mgr. of Application Dept. Although it would cost considerable amount of money (tens of millions of yen), I promised to fully support it. We decided to offer F- ZTAT version of H8 MCUs free of charge to participants, and to support the staff work including instructors as well.
The first MCR event was held on Sunday, January 13, 1996 in freezing Sapporo. Fig. 11.5 is a picture when I greeted in the opening ceremony at this time. I cheered them up, "Do your best,

aiming at Koshien in winter!" ("Koshien" is a baseball stadium where a very popular high school national tournament is held every year. The event is a dream for all the high school baseball players.)

Fig. 11.5 Greeting at the opening ceremony of the 1st MCR (Sapporo, January, 1996).

This event was very successful, and the number of participating schools increased year after year. From the third competition, it became a national tournament, developing into an event in which technical high school students from all over Japan participated; from Hokkaido in the north to Okinawa in the south.

By the way, 99 MCU cars participated in the high school section of the first event in 1996. The number continued to increase over the years; 159 in 1997, 202 in 1998, 352 in 1999, and it reached 974 in 2000. And finally in 2001 it came over 1,000 mark and reached 1413 cars.
At the 5th Tournament in 2000, I was unexpectedly given a commendation as one of contributors to MCR. The testimonial was to "honor the contribution to the establishment of MCR and to the development of its activities." Fig. 11.6 is a medal that I received at that time, and I have kept it as a memorable memento.

Fig. 11.6 Medal which I was awarded at 5th MCR Games

In 2007, a book compiled by high school teacher Masahisa Sasagawa in commemoration of the 12th anniversary of MCR was published. The title is "Really awesome! 12 years of Japan MCR". In this book the development process of MCR from the beginning to that time is written by various authors and a lot of moving stories are gathered. I would like to encourage you to read it.

I wrote the postscript of the book, and I would like to convey my thought by quoting some portion of it.
“First of all, I would like to briefly introduce the MCU Car Rally (MCR). The rule of MCR is very simple. It is “to run the cars along the prefixed course in the shortest time without getting off the course.”
Here, if you try to avoid getting off the course, the speed gets slow (the case of low risk/low return), and conversely if you try to increase the speed, the probability of getting off becomes higher (the case of high risk/high return). This kind of decision-making or choice is encountered in various aspects of real life and it is inevitable in human life. Challenging high goals with minimal risks is also an epitome of life. This is exactly the fascination of MCR and the profoundness of its technology behind it, and this kind of activity is also real “live education”.
One of the technological factors for which this event succeeded was the incorporation of microprocessor technological innovation in an extremely timely manner. The F-ZTAT microprocessor introduced by Hitachi in 1993 was already in mass production stage in 1995.
Its main feature is that “you can modify programs anytime, anywhere.” Even in the actual races, we see the participants modifying the programs right before the start, and it is only made possible by the F-ZTAT technology. It is extremely meaningful that technology which has been commercialized first in the world serves to actual high school education through the MCR. It can be said that the origin of industry-academia collaboration is right here.
It is a great pleasure for us engaging in business that students can feel from their experiences that “advanced technology is interesting”.”

<u>Someday, all microprocessors will be made this way: ZTAT</u>
The F-ZTAT microprocessor with which Hitachi led the industry made a great progress, becoming a synonym for field programmable microprocessors, and is now positioned as the mainstream of microprocessors.
It was in the mid-1980’s when we introduced the ZTAT microprocessor to the market as the first field programmable microprocessor. I still cannot forget the phrase I used at that time regarding its future potential. I slightly modified the advertisement of Seiko’s quartz watch and replaced it with the ZTAT microprocessor.
“Someday, all microprocessors will be made this way: ZTAT”

Even though it was changed from the first introduced ZTAT to F-ZTAT, it took about twenty years until the field programmable microprocessor established the mainstream position. And I feel deeply moved that “Someday” has finally become “Today”

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