R&D Spirits

Development of HDTV Codec LSIs: Bringing High-definition Video into Our Lives

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As the sole hardware manufacturer in the NTT Group, NTT Electronics Corporation markets products based on technology developed by NTT Laboratories to supply the world with optical components, LSIs, and other advanced electronic products. At present, much attention is being focused on video-compression LSIs as a vital element of NTT's broadband strategy. We talked to General Manager Ryota Kasai about the current state of these LSIs and future development plans.

Efficient LSI Development through Extensive Know-how

—Dr. Kasai, could you first give us a brief description of your current activities?

I am now involved in the development and application of LSIs at NTT Electronics (NEL), which develops and manufactures products such as optical components, LSIs, and subsystems as the only hardware manufacturer in the NTT Group. I came to NEL from NTT Laboratories in 2000.

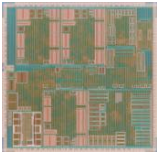
—What R&D area is your group particularly engaged in?

We are working on two types of MPEG-compatible HDTV codec LSIs in parallel—one for the professional market and the other for consumer use. The VASA chip, for example, is a codec for professional use (**Fig. 1**). It features an HDTV encoder and decoder on a single chip and supports digital terrestrial broadcasting, which recently began in Japan. The Super ENC-III* chip, on the other hand, is a typical codec for consumer use especially in digital home electronics (**Fig. 2**). The basic technology for these products comes from NTT Laboratories, which means that my role here is more on the management side than the technical side. To be more specific, I work on creating markets for our codec products by forming partnerships with major set makers and collaborating with them from an early stage so that product specifications reflect functions and performance demanded by the market.

—What benefits can these codec products provide?

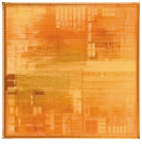
First, with regard to codecs for professional use, the users of these products are makers of broadcasting equipment while the end users are broadcasting stations. As I just mentioned, digital terrestrial broadcasting recently began in Japan, and if NHK (Japan Broadcasting Corporation) were to consequently upgrade their codecs to high-definition products, they would need several thousand new units throughout the company. This would be a major facility investment considering that the cost of current codec products is more than 10 million yen ($90,000) per unit. It would not be impossible, however, for this cost to suddenly drop by one order of magnitude if the equip-

* Super ENC-III: the product name of ISIL, a video codec LSI developed by NTT and marketed by NEL. [see NTT Technical Review, Vol. 1, No. 1, pp. 97-98, 2003.]



- Multi-processor system including parallel encoding processing
- Built-in three-encoder core, three-decoder core
- 128bit@200-MHz system bus
- Two connection paths for external 400-MHz DDR-SDRAM

Fig. 1. Professional HDTV codec LSI–VASA.



- Integrates MPEG2 audio, video, & system
- High performance
  - SDTV full-duplex codec
  - HDTV(720/30p) half-duplex codec
- Embedded 64b RISC core to run consumer application software
- Two connection paths for external 144-MHz SDRAM

Fig. 2. Consumer HDTV codec LSI: Super ENC-III.

ment were to use our VASA chip. Current high-definition codecs are too large to be easily carried around, but the VASA chip could lead to a compact codec about the size of a postcard. A small codec can be integrated with a camera so that captured video can be compressed and transmitted immediately by wireless means. This capability would make it possible to relay high-definition video from a motorcycle assigned to follow a pack of runners in a marathon.

Now, as for codecs for consumer use, the main market here is digital home electronics like video recorders and players and various audio-visual devices. We feel that the spread of these products and their interconnection with broadband communication services should make high-definition video a big part of all of our lives.

—What are some of the technical issues surrounding the development of HDTV codecs at NEL?

One issue is the algorithm used for calculating the interframe difference in MPEG video compression, which is a topic that I myself researched in the past. In this regard, digital video employs between 30 and 60 frames per second. At the same time, the system adopted by MPEG transmits only the interframe difference (i.e., the differences between one frame and the next) to achieve a higher compression rate. This means that the movement of various objects in a frame must be detected in a short time period of about 30 ms. Detecting the movement would normally require a huge amount of computation, but we use an algorithm that reduces the computational load significantly while finding the true motion vectors of the objects.

Another important technical issue is the compression-rate-control algorithm. In video, the amount of information can change dynamically from one frame to the next. For example, a picture with intricate patterns will have considerably more information than a "flat" picture showing only a wall. Now, if these two types of pictures are compressed in the same manner,

it will take a lot longer to transmit the information-heavy picture, which can create problems on the viewing side. It is therefore necessary to raise the compression rate of complex pictures while maintaining picture quality so that the amount of transmitted information is made as uniform as possible. This is compression rate control. How to go about achieving compression rate control without degrading quality has tested the resourcefulness of individual codec-LSI makers, and NEL has acquired know-how in this regard together with NTT Laboratories through a process of trial and error. Users consider the picture quality produced by our high-definition codec to be the best.

Finally, it is also important to use development tools skillfully in this field. Both the Super ENC-III and VASA codecs are system LSIs having a very large number of circuits. Traditionally, removing bugs one by one using a prototype product could be a very costly process for complex LSIs, which meant that failure to remove all bugs at the design stage would later create problems. Taking this into account, we have focused our attention on field programmable gate arrays (FPGAs), which are LSIs that allow circuits to be prepared by programming and operations to be checked. We were the first in Japan to introduce a circuit emulation system using FPGA for codec LSIs. This approach is extremely effective. It allows reliability checks to be performed several thousand times faster than software simulation, and it enables the Super ENC-III design to move into mass production without bugs. FPGA-base circuit emulator have since been introduced here and there, but I am confident that our technology is superior given the time that we have spent and the experience gained in applying the circuit emulators.

Increasing NEL Brand Recognition by Dominating the High-end Market

—Could you bring us up-to-date on international and domestic trends in the HDTV codec market?

Well, from the beginning, the market for professional-use codecs in Japan has not been very large and we have not had many competitors as a result. We have also been forming partnerships with major set makers as I mentioned with the result that 70–80% of digital terrestrial broadcasting facilities in Japan employ the VASA chip. The NEL brand is acquiring definite recognition, and our job at this point, I believe, is to establish a position that cannot be duplicated by other companies. I must admit, however, that our overseas competitors are strong. Our share overseas is still no more than a few percent. But as the high praise that our products have received in the Japanese digital-terrestrial-broadcasting market comes to be known overseas, I think our overseas share will start to grow gradually.

In contrast, the market for consumer-use codecs is experiencing fierce competition both in Japan and overseas. Devices that incorporate codec LSIs are many and varied ranging from high-end HDTV sets to low-end standard televisions and even cellular phones such as NTT DoCoMo's FOMA handsets. Within this competitive environment, we have again entered the high-end area making best use of our high standing in the market for professional-use codecs. Consequently, there is no competition for us in this area, at least for now. This part of the consumer market could suddenly heat up, however, if high-definition content begins to spread to digital home electronics and broadband services. Signs of this happening can already be seen, and we know we must continue to form partnerships with set makers both in Japan and overseas making best use of our technological expertise to penetrate markets even further.

—In these areas, how are NEL products actually used?

Our professional-use codecs are employed by most digital terrestrial broadcasting facilities in Japan, and our module products for cameras are used by almost all of the top camera manufacturers in Japan and overseas. Our chips have been used for processing the video taken by on-vehicle cameras in Formula One auto races and the video in the first high-definition hookup from Antarctica. I like to think that our products will make it possible to see high-definition video from space sometime in the near future.

As for the consumer market, the Super ENC-III codec LSI has been incorporated in the world's first high-definition camera for home use put on sale this year by a Japanese maker. With picture quality approaching that of a professional camera and a price tag of about 300,000 yen, this camera enables high-definition video to be handled at the personal level. Certainly our Super ENC-III codec has paved the way for this new era in personal high-definition video.

—Could you tell us about any current issues surrounding HDTV codec LSIs and what you see for their future?

For the professional market, I believe we have achieved our goals at least for the present. While some improvements and upgrades may be in order, I don't think they will represent any dramatic evolution in our codec LSIs for professional use. For the consumer market, on the other hand, I can envision many changes taking place. In particular, I can see the market expanding rapidly as high-definition content spreads to digital home electronics and broadband communication services and also as compression-and-coding technology itself continues to evolve. The professional market will no doubt be dominated by MPEG2 since frequent changes to technical standards are not conducive to good business. But the consumer market, which is known for its short product cycles, should see rapid adoption of new technical standards. For example, the H264 video-compression system that has recently become an international standard can encode video using half the bit rate required by past systems. This system will no doubt be adopted by high-definition DVD recorders and high-definition streaming over broadband networks. To keep up with these changes, we must, of course, develop new chips. The successor to the Super ENC-III will have to provide enhanced picture quality at the VASA level as well as low power consumption and an economical configuration.

Continuous Involvement with LSI Development since Days at NTT Laboratories

—Dr. Kasai, how did you first become interested in LSIs?

During my university days, I was somewhat of an audiophile, and my hobby was constructing vacuum-tube amplifiers. As an extension of this, I thought I would enjoy constructing electronic circuits for some of the key devices used in popular electronic products, and it was then that I entered NTT Laboratories. Perhaps the motivation that I feel in my current work stems from that sense of joy and accomplishment that I felt on hearing those first sounds emanating from an amplifier that I constructed myself with a soldering iron clutched in my hand.

—What kinds of R&D have you been involved with up to the present?

I have been exclusively engaged in the research and development of LSIs. My first assignment after entering NTT Laboratories in 1974 involved the development of a simulator to improve the characteristics of MOS transistors, the basic devices of an LSI. I have also worked on the design of LSIs used in receivers of touch-tone phones and on the development of various VLSIs. I worked, in particular, on LSIs used in the DIPS and DEX operating systems. The large number of bipolar ICs that originally made up the CPUs of those systems came to be replaced by CMOS-LSIs, which for that time were advanced devices. I then moved on to LSIs for signal processing systems and finally, through my current work, to the development of image-processing LSIs.

—Could you give us some specifics on image-processing LSIs that you have had a hand in developing?

Well, first on the list would be Very Long Instruction Word, or VLIW, processors, for which I prepared about six or seven chips. This kind of processor features extremely long instruction words that are especially conducive to parallel processing. For its time, VLIW was a revolutionary architecture. By applying it to image processing, we were able to improve throughput significantly.

Since 1998, our processing target has been MPEG video, and the first chip that we developed in this area was the Super ENC, the forerunner to the Super ENC-II and Super ENC-III chips. The Super ENC was the world's first encoder that could perform SDTV (standard definition TV) compression processing in a single-chip format, and it could also perform HDTV video processing in a multi-chip format. To tell the truth, the Super ENC was originally developed for consumer use. The plan at that time was to deploy it in DVD recorders of a home-electronics maker in the United States. Unfortunately, the project on the maker's side was toned down during the development process and this plan was never realized. We therefore decided that it was still too early for consumer codecs of this type, and we went on to develop the Super ENC-II for professional use. It was with the Super ENC-III chip that we finally entered the consumer market in earnest (**Fig. 3**).

—Looking back, what are some of your thoughts?

Well, as I have worked on LSI research and development for my entire career, I would say that I have accomplished my original personal goal. On the other hand, I believe our goal at NEL is to acquire a large share of the total market, and I think we are only

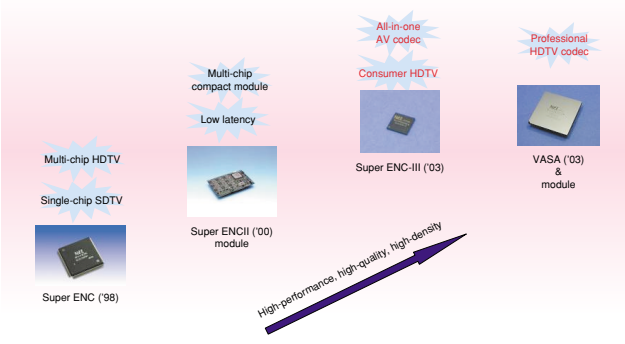


Fig. 3. MPEG2 encoder LSI product history.

about halfway there. I do feel a sense of accomplishment with regard to the Japanese professional market for HDTV codec LSIs, but there are still many things that I would like to do in other markets around the world.

Contributing to NTT's Broadband Strategy through Image Processing

—What direction does NEL plan to take from here on?

At present, R&D at NEL can be characterized by three keywords: light, broadband, and imaging. Among these, I think particular attention is being paid to imaging. The field of codecs for consumer use is fiercely competitive, and I cannot overstate that advanced LSI technology holds the key to victory here. Having established a solid position in the field of codec LSIs for professional use, this situation in the consumer market appears to us as the beginning of a very interesting era. In this regard, the NTT Group is currently steering a course toward broadband communication services. In the years to come, imaging will become an extremely important part of these services, and I hope that our codec products will help accelerate this trend.

—What kind of relationship does NEL have with NTT Laboratories?

NTT Laboratories provides NEL with basic technology that we attempt to put to practical use. For this reason, development projects can only proceed on the basis of close communication. The Super ENC-III and VASA projects, for example, involved interfacing mainly with the NTT Yokosuka R&D Center, and even today I hold discussions with researchers there about once or twice a week.

—Dr. Kasai, could you please give us some personal comments on NTT Laboratories.

Looking at NTT Laboratories today, I can see that much effort is being focused on the research and development of networks and services carried by those networks. But shouldn't hardware, the basis of networks and services, be one object of these efforts? Without hardware there can be no networks and services, and I cannot help but think that that critical element is being entrusted to electrical equipment manufacturers. Of course, there is a place for collaboration based on a division of roles, but considering that NTT Laboratories is proud of its worldwide renown as a comprehensive R&D center, wouldn't it be ben-

eficial to pay a bit more attention to the importance of hardware?

Once new technology is given a concrete form, software becomes the number one issue. The platform on which software runs, however, is the LSI, and that LSI becomes a single system as the level of integration increases. To bring about even greater achievements, I think it is important to consider what kind of technology should be embedded in system LSIs. In this regard, I would like NTT Laboratories to demonstrate their comprehensive research abilities, and once they develop the basic technology, I would ask them to let us at NEL give it actual form. If that kind of division of roles can be established, I think our relationship will become even more meaningful.

Interviewee profile

Ryota Kasai received the B.S., M.S., and Ph.D. degrees in electrical engineering from Osaka University, Osaka, Japan, in 1972, 1974, and 1992. In 1974 he joined the Electrical Communications Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT). Since then he has been working on the research and development of device modeling and circuit design for high-performance CMOS LSIs. From 1974 to 1980 he was with a research group working on electronic circuits, where he was engaged in the development of two- and three-dimensional device simulators for short-channel MOSFETs. From 1980 to 1986, he was part of an application group working on a CMOS VLSI processor family for NTT's data processing system (DIPS) and switching system (DEX). From 1988 to 1996 he was the leader of a signal processor research group that developed two original image compression processors: a 300-MOPS 1-W 0.8-µm CMOS video signal processor with a VLIW architecture and a realtime low-delay, 0.5-µm CMOS two-chip MPEG2 SP@ML video encoder. In 1998, he developed a 0.25-µm CMOS single-chip MPEG2 MP@ML video encoder with multi-chip scalability for HDTV as the project manager. He is currently the general manager of the 1st product group, digital video business group, NTT Electronics Corporation. His current interests are in the market exploitation of high-performance video codec VLSIs with advanced chip architecture. He chaired the technical group on integrated circuits and devices in the Institute of Electronics, Information and Communication Engineers (IEICE). He is a member of IEEE and IEICE.