Semiconductor Technology for Internet Appliances

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OVERVIEW: Advances in the Internet technology have brought about new services utilizing the Internet. Changes are also seen in the appliances used to enjoy these services. Specialized "Internet appliances" for Internet services are being increasingly used today in place of PCs. To this end, the importance of appliance architecture and system technology for these new services is increasing along with the demand for technologies needed to obtain low-power, high-performance system LSI chips for mobile applications. In an attempt to meet the demand for new Internet-based services, Hitachi has developed its "System Solutions" that comprise a system technology, an architecture for individual appliances, and a system LSI chip technology to support these solutions.

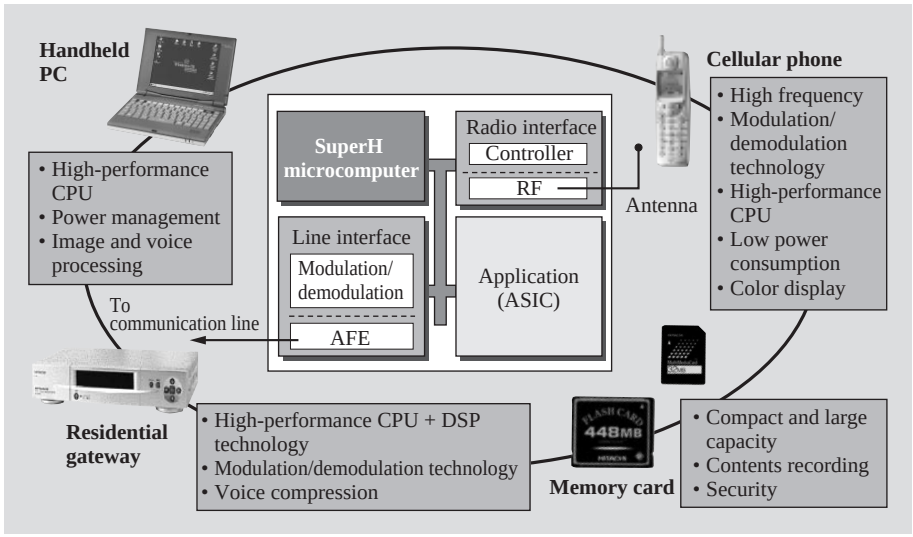
INTRODUCTION

THE types and the scope of new Internet-based services are increasing more rapidly than ever. In the world of cellular phones, ticket reservation services and contents (e.g., music) distribution services are being introduced in addition to the current available Internet access and electronic settlement services. In the near future, white goods, will also be connected via a network, enabling services such as the remote control and the energy saving through coordinated use of individual appliances. These services will require, in addition to current PCs, "Internet appliances" that can provide specialized services.

Service information will be delivered to homes via phones, PHSs, CATVs, and optical fiber. Home appliances will be connected via networks including Bluetooth and power lines, IEEE1394 and Ethernet*[1]. A home-use interface device (residential gateway) will be needed to enable communication via different types of networks inside and outside the home. With regard to appliances for receiving services, consumers today require "mobile appliances" that are smaller than notebook PCs and that can be used both inside and outside the home. Responding to this demand, Hitachi has developed the handheld PC.

Semiconductor parts used in these appliances, in addition to having such characteristics as low-voltage operation, low power consumption, high density, and high functionality, must also have a system technology supporting available services (see Fig. 1).

*1: Ethernet is a registered trademark of Xerox Corp.



RF: radio frequency
AFE: analog front end
ASIC: application-specific IC
DSP: digital signal processor

Fig. 1— Semiconductor Technology for Internet Appliances. Semiconductors in Internet appliances typically represented by handheld PCs are needed for high-performance, low-power CPUs, enhanced modulation/demodulation technologies, and diverse middleware. The role of memory cards is changing from that of a storage medium to that of a key security device.

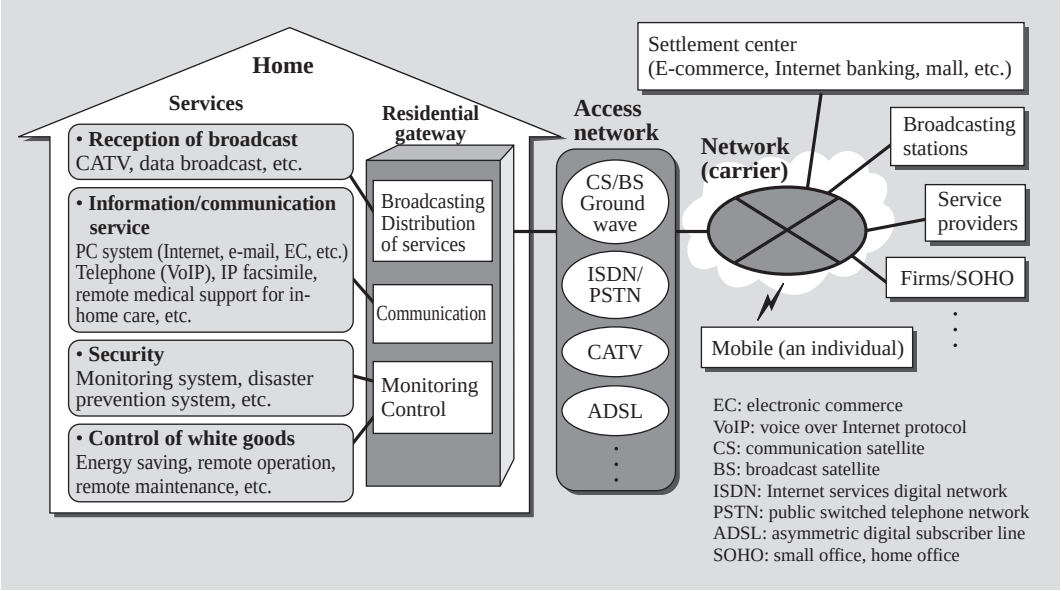


Fig. 2— Conceptual Drawing of Residential Gateway. Residential gateway is equipment installed in the home network to enable receiving services sent via various networks outside the home.

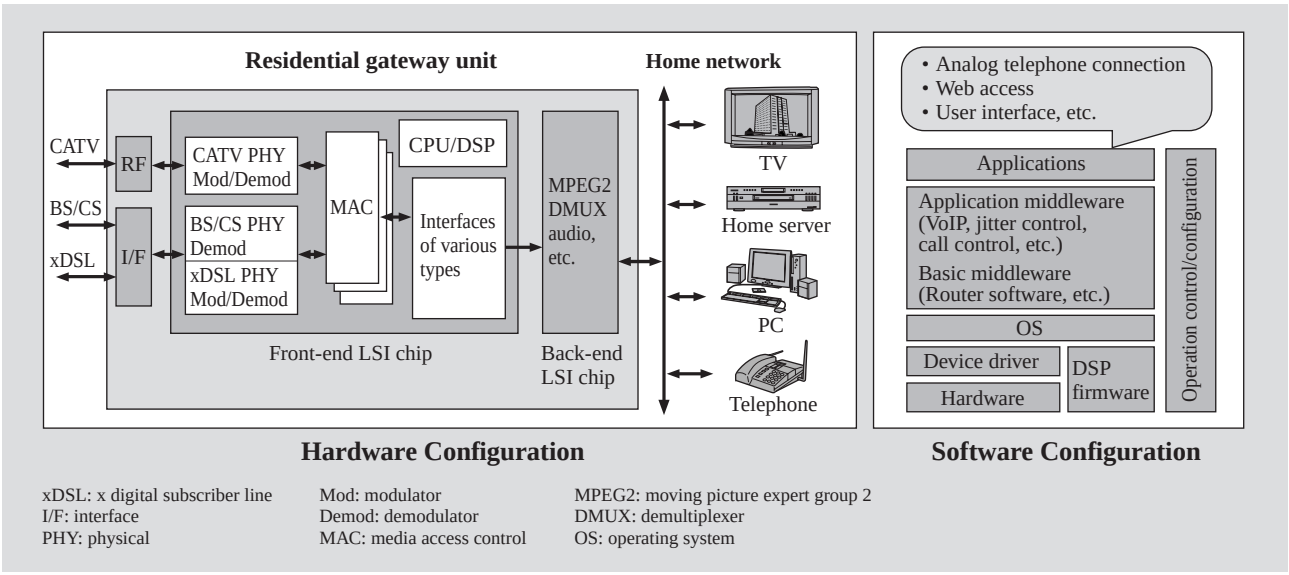


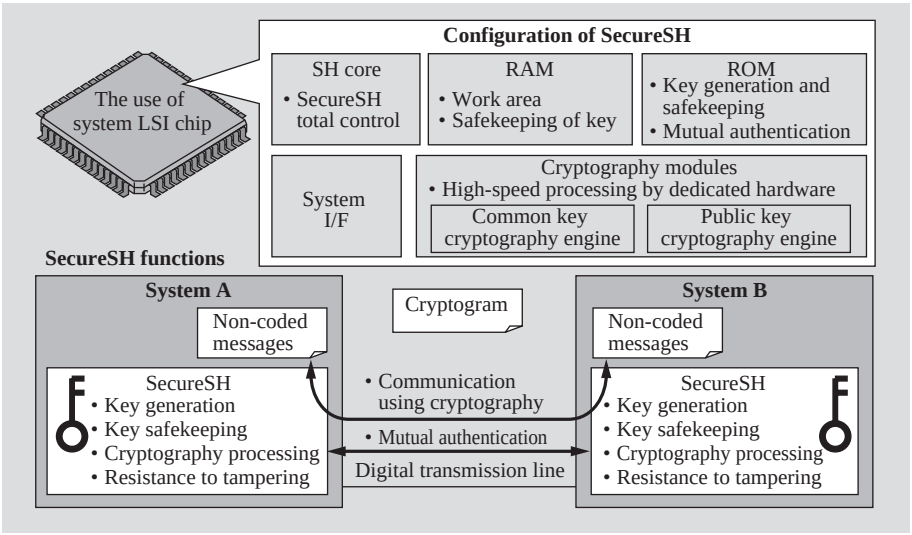
Fig. 3— Internal Configuration of Residential Gateway.
This figure shows the expected basic hardware and software configuration of a residential gateway.

The following describes a residential gateway technology and handheld PCs being developed by Hitachi along with their element technologies. We also describe semiconductor parts for cellular phones and memory cards that enjoy increasing demand today for the contents storing.

RESIDENTIAL GATEWAY

General Description

A residential gateway is equipment installed in a home network for receiving services sent via various networks outside the home. Fig. 2 shows the overall concept of the system. White goods in the home receive services (such as contents) from a network outside the home via the residential gateway. Responses can also be made via the residential gateway. It is also possible for white goods to send a request for services. The data handled by the residential gateway can be broadly classified into two types: the information system data (high-speed) such as the data for AV (audio-visual) equipment and PCs and white-goods control data (low-speed) including the data for lighting, air conditioners, and refrigerators. Although two residential gateway units may be necessary at the initial stage — one for the information system and the other for the control system, their functions will be combined into a single unit in the future.



RAM: random access memory
ROM: read-only memory

Fig. 4— Basic Concept of SecureSH. This system enables high-speed cryptography processing and enhanced resistance to tampering by integrating the CPU core, memory, and cryptography engine on a single chip.

Basic RG Functions

Fig. 3 shows the internal residential gateway configuration. The first basic function is "protocol conversion" that provides an interface between different networks inside and outside the home. Outside the home, networks include telephone lines (xDSL: x digital subscriber line), optical fibers (FTTH: fiber to the home), and a CATV. Inside the home, networks include HomePNA, Bluetooth, IEEE1394, and Ethernet, all of which require interface support.

To support address mapping between locations outside and inside the home, IP (Internet protocol)-based routing is needed. The problem here is how to prevent illegal access from outside the home. A router with a firewall function is needed to restrict illegal access. If the residential gateway is to handle the distribution of broadcasting system contents, a charging system and a de-scrambling function must also be developed. This means that in a network era, the residential gateway will change with changes in the home environment.

Element Technologies of Residential Gateway

Hitachi is now developing the following element technologies for residential gateways that are expected to become the key components in home networks.

The first task is to provide support for various types of network interfaces. Since home LANs are not well organized at present, a radio LAN such as Bluetooth will be useful at the initial stage. In this case, not only a communication protocol but also a support of its higher layer is required, too. For example, middleware will be necessary to provide ECHONET (energy conservation and homecare network) services via Bluetooth. ECHONET, which is now being formulated by the ECHONET Consortium, is a network standard that enables the control of white goods through the use of power lines and radio communication.

Assuming that services are distributed via networks, an environment for executing the program description language Java*2 will be needed in the future, too, in order to distribute and update control programs.

Every part of the residential gateway requires a security technology. For instance, in conditional access related to the charging system of broadcasting services, a real-time cryptographic processing is indispensable. To ensure high-speed cryptographic processing, Hitachi is now developing "SecureSH" that integrates a SuperH microcomputer and hardware for the cryptographic processing. Fig. 4 shows the basic concept of SecureSH.

This architecture provides an enhanced resistance to tamper by integrating the CPU, the memory, and all cryptographic processing logic circuits on a single chip. Logic circuits for cryptographic processing allow customization depending on applications.

VoIP used as an application program enables voice to be sent in IP packets and provides a telephone function using the Internet. Hitachi intends to provide system LSI chips that optimally match customer needs by developing the entire VoIP technology. This technology will cover not only the voice CODEC but also the jitter control for the smooth correction of voice

*2: Java and all Java-related trademarks and logo marks are trademarks or registered trademarks of Sun Microsystems, Inc. operating in the U.S. and other countries.

Fig. 5— Handheld HPW-600JC PC. VGA (video graphics array) screen and keyboard-type handheld PC equipped with an SH7500 SuperH RISC engine. First introduced in 1999 along with tablet-type PCs.

interruptions or delays as well as call controls for processing calling sequences using IP addresses. The VoIP technology will bring together the Internet and telephone functions and will enable voice communication in conjunction with web access.

HITACHI'S HANDHELD PC

The SuperH RISC family of microcomputers from Hitachi includes a high-performance, low-power RISC (reduced instruction set computer) engine and a chip set designed to enable the peripheral functions of handheld PCs. They are designed for highly functional portable information appliances.

Following a significant increase in the data communication rate, cellular phones with a built-in data communication function, as well as information appliances that enable Bluetooth-based wireless access to networks, will appear in the near future. At the same time, the semiconductor parts used in such equipment must be smaller and must offer higher performance and more functions at a lower current. Hitachi's handheld PC is an example of applying semiconductors having these features to a highly functional portable information terminal. The following describes the development and configuration of this product.

Development

Trends toward the higher data communication speeds and the lower communication costs make such communication functions as electronic mail and WWW (world wide web) browsing more important for cellular phones and PHSs, in addition to the currently available PIM (personal information manager) functions such as those of an address book and a schedule control.

More than 10 million cellular phones with Internet access have been sold thanks to the development of more compact, less expensive units with expanded information services. Although these network appliances are currently very popular, further market penetration by these products is restricted by the limited size of their displays and keyboards. Consequently, the above-mentioned communication functions are important for removing these shortcomings.

In April, 1998, Hitachi successfully introduced a half VGA (video graphics array)-type handheld PC equipped with an SH7709 microcomputer. A VGA/keyboard-type PC (see Fig. 5) and a tablet-type PC featuring an SH7750 chip were marketed as network appliances in June, 1999.

Configuration of Handheld PC

The handheld PC has a SuperH RISC engine consisting of a high-performance, a low-power RISC engine and a chip set designed to enable the peripheral functions of handheld PCs. This configuration was used, because portable information terminals must offer more functions and the greater performance than those offered by cellular phones as well as have a longer battery life. Fig. 6 shows the hardware configuration of a handheld PC equipped with an SH7750 SuperH RISC engine. The SH7750 engine has a superscalar design consisting of two numerical data processing units to enable 230 MIPS (million instructions per second) at 128 MHz. HD6445 is a companion LSI chip integrated with peripheral functions required for handheld PCs. It incorporates peripheral functions such as those of a PCMCIA (Personal Memory Card International Association)-compliant controller to support PC- and CF- card connection and a USB (universal serial bus) host controller. HD64464 is a graphic controller that displays 65,336 colors using a 128-bit graphics engine. The use of ASICs (application-specific ICs) in the handheld PC enables a communication interface that supports CDMA (code division multiple access)-type cellular phones.

Handheld PC as Network Appliance

The handheld PC Pro, equipped with Windows*3 CE and H/PC Professional Edition V3.0, features an e-mail client and a WWW browser each having functions equivalent to those of PC software. In

*3: Windows is a registered trademark of Microsoft Corp. in the U.S. and other countries.

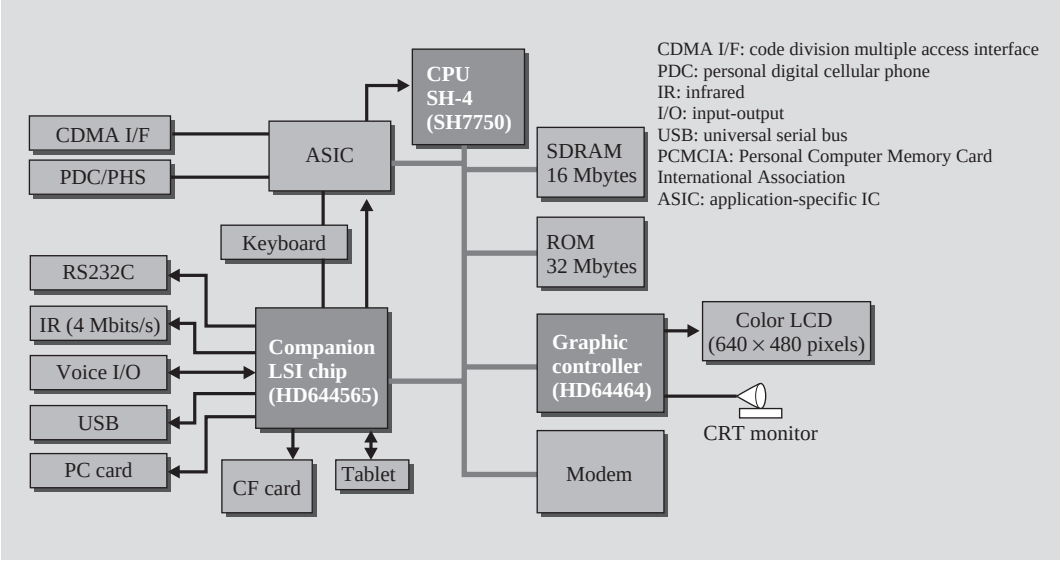


Fig. 6— Hardware Configuration of Handheld PC. Block diagram of HPW-600JC handheld PC. The PC has an SH7750 SuperH RISC engine, a companion LSI chip (HD64465) with peripheral functions, and a built-in graphic controller (HD64464).

addition, this handheld PC allows the use of ICA (independent computing architecture) client software. The ICA client software functions with MetaFrame of Citrix System, Inc., and enables server-based computing with the handheld PC. An application program, which runs on Windows NT*4 Terminal Server Edition, sends terminal-keyboard or pointing-device operation instructions to the server, and the results are sent back and displayed on the terminal. Due to this technology, users can enjoy PC applications from the server in a mobile environment as if they were directly operating a PC.

MEMORY CARD

Flashcards are being increasingly used today as large-capacity storage media for various types of portable and information equipment. Rapid growth of the digital camera, portable music player, and handheld PC markets due to a wider use of the Internet is generating strong demand for various types of flashcards.

The capacity of flash memory products is growing, too. Thus, 32- to 640-Mbyte hard disk drives widely used in current communication and industrial equipment are rapidly being replaced by flashcards that require less system maintenance and offer such advantages as compactness, low-power operation, and superb impact resistance. Flashcards are now supporting a wide variety of network equipment.

*4: Windows NT is a registered trademark of Microsoft Corp. in the U.S. and other countries.

Fig. 7— Large-Capacity CF and PC-ATA Cards. These flashcards are equipped with 256-Mbit 0.25-µm-thick AND-type flash-memory chips developed using Hitachi's multi-valued cell technology. They use a multi-layer package and our newly developed CF-type-2 package.

Increased Capacity of Flashcards

In response to the increasing demand for flashcards, Hitachi has developed CF type-1 cards (3.3-mm thick) for the 8- to 192-Mbyte range and PC-ATA-type cards (5.0-mm thick) for the 8- to 640-Mbyte range. In May, 2000, CF type-2 448-, 320-, and 256-Mbyte flashcards as well as a PC-ATA type-2 1-Gbyte card were introduced in response to the market demand for larger-capacity flashcards (see Fig. 7).

These flashcards have HN29W25611 256-Mbit, 0.25-µm thick AND-type flash memory chips based on Hitachi's multi-valued cell technology. They have a capacity of 512 Mbytes and employ a DDP (double density package) in which two flash memory chips are integrated into a single package. Hitachi has also succeeded in achieving a 1-Gbyte capacity by installing 16 such packages.

To expand the capacity of CF-types cards, Hitachi has developed a 5.0-mm thick type-2 package based on the CFA (Compact Flash Association) standard to

Fig. 8— Large-Capacity Multimedia Cards. These are equipped with 256-Mbit AND-type flash memory and a controller using a SuperH processor as the CPU core. The 64-Mbyte product has the largest capacity in the industry, due to the use of multi-layered chips.

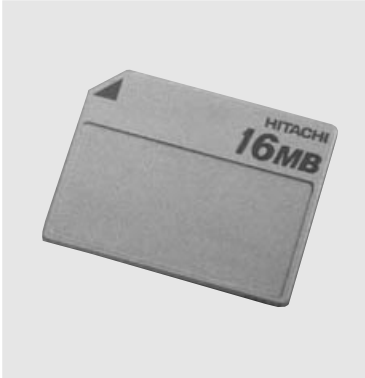


Fig. 9— Secure Multimedia Card (16 Mbytes). The card itself has encryption/decryption functions. A contents-protection-related instruction set has been added to it. This card meets security requirements of music distribution systems.

replace the current 3.3-mm-thick type-1 package. This enabled to develope a 448-Mbyte CF-type card — a card with the largest capacity in the industry, by installing seven multi-layer packages each having a 512-Mbit capacity.

Hitachi has also succeeded in achieving interleave operation of multiple chips using a conventional dedicated controller for the AND-type flash memory, which enable to rewrite at 2 Mbytes per second. This significantly reduces the time required to rewrite large amounts of data.

Hitachi's flash multimedia card is the smallest and lightest card available today, and it is used in a wide range of applications such as the recording of still images from digital video cameras, data from cellular phones (smart phone), and music from portable music players. The demand for large-capacity multimedia cards with even longer recording time is particularly strong in the field of portable music players.

In June, 2000, in response to the market needs, Hitachi commercialized its 64- and 32-Mbyte multimedia cards in addition to its 16-Mbyte product (see Fig. 8).

These products are configured with flash memory and a controller IC. The flash memory is 256-bit AND-type memory, and the controller IC has a SuperH RISC microcomputer. Multi-layer packages developed using Hitachi's assembly technology have enabled the development of 64-Mbyte products — the largest-capacity multimedia cards in the industry.

These products enable reading and writing operations at the speed of 14 Mbits per second and 3 Mbits per second, respectively, which makes these operations the fastest in the industry. In addition, these cards operate at low voltages in the 2.7- to 3.6-V range. For the card interface, both the multimedia card method and the currently used SPI (single program initiator) method can be used, which allows the users to choose the method that best suits their system design needs.

Support of Contents Distribution

The proliferation of the Internet as well as wider use of PCs and cellular phones have triggered attempts to distribute various types of digital information by using different approaches. In particular, in addition to being distributed from retail stores in the form of CDs, music will be increasingly distributed via the Internet and cellular phone carriers. At present, however, the distribution of information using these means is not widely spread because of the copyright violation problem due to illegal copying. To prevent illegal copying in the process of downloading and distributing music via the Internet, the SDMI (Secure Digital Music Initiative) is now formulating the specifications for the contents protection technology.

To this end, Sanyo, Fujitsu, and Hitachi in December, 1999, jointly developed and marketed a contents distribution system called "Keitai de Music" intended for the cellular phone market, which is currently experiencing rapid growth, and in which high-speed data distribution services are gradually becoming a reality. This system is designed to optimize the distribution network and characteristics of cellular phones. In May, 2000, a 16-Mbyte flashcard called "Security Multimedia Card" that was developed based on this standard was introduced into the market (see Fig. 9).

This product features a single chip that has built-in flash memory and a controller. The 128-Mbit AND-type flash memory used in the flash memory block has enabled reducing the size of the block, and the SuperH microcomputer used as the CPU in the controller block has enabled sophisticated cryptography processing. The following describes the main features of this product.

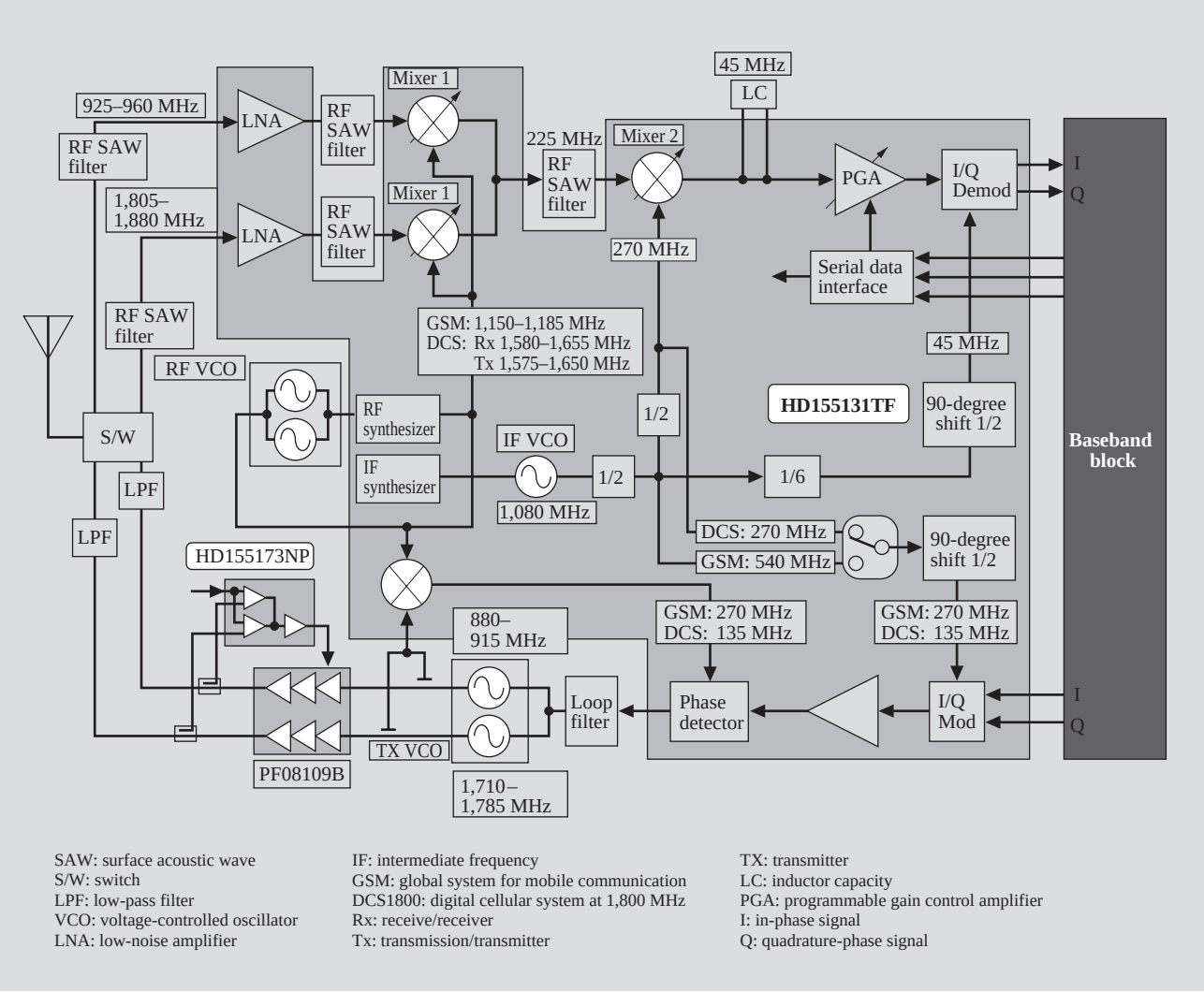


Fig. 10— Configuration of GSM/DCS1800 Dual-Band RF System.
A typical configuration of a GSM/DCS1800 dual-band RF system featuring Hitachi's new products.

High-security function

This card has a high degree of security based on UDAC-MB (universal distribution with access control — media base). In addition to the encryption/decryption function provided by the card itself, a secret key used for encryption/decryption is stored in a safe area on the card. By adding a contents protection-related instruction set, we can have a card that meets the security standards of music distribution systems.

Compatibility with current multimedia cards

To maintain the upward compatibility of this card with other multimedia cards, we used the same design for this card as that used for other multimedia cards not only in terms of the functions but also in terms of the appearance, including the thickness. This feature enables this card to be used not only with equipment that requires the new contents protection function but also with equipment designed for current multimedia cards.

In the future, in addition to introducing products with a capacity exceeding 32 and 64 Mbytes, we will strive to achieve higher writing speeds as well.

CELLULAR PHONES AND MAJOR SEMICONDUCTOR PRODUCTS

The use of cellular phones is rapidly expanding worldwide. Since GSM (global system for mobile communication) — a digital cellular phone method developed in Europe — was developed in 1992, more than 130 countries in Europe, Africa, the Middle East, and Asia have adopted this method, making it a de facto global standard. A wider use of cellular phones has been triggered by the international roaming

function, one of the features of GSM, and the number of subscribers is further increasing as the services become even more diverse.

In the cellular phone market, efforts have been focused more on developing smaller and lighter receivers, increasing the talking and waiting time, and designing a dual-band system (900- and 1,800-MHz bands) to support a larger number of subscribers. European countries have recently been stimulated by the success in accessing Internet services via cellular phones in Japan and are working to expand such systems as GPRS (general packet radio services) and EDGE (enhanced data rates for GMS evolution). This trend requires semiconductors for cellular phones that are capable of operating at lower voltages, lower power consumption, and higher density making it more suitable for data communications.

Hitachi's Products That Meet GRPS Requirements

Hitachi has been beefing up its lineup of high-frequency semiconductor products for GSM dual-band cellular phones by introducing new products including RF modules, communication signal processing ICs, transmission power control ICs, PLL (phase locked loop) frequency synthesizers, variable-capacity diodes for VCOs (voltage controlled oscillators), pin diodes for antennas, and high-frequency transistors.

Fig. 10 shows a typical GSM dual-band RF system featuring Hitachi's new products.

HD155131TF is a communication signal processing IC for GSM dual-band systems that is equipped with a built-in LNA (low noise amplifier) and a dual-PLL frequency synthesizer. A high-speed lockup function of this IC enables it to work with GPRS. PF08109B is a highly efficient (50% standard) RF module for GSM dual-band systems that is contained in a small package ($13.75 \times 11 \times 1.8$ mm). HD155173NP is a low-current transmission power control IC for RF modules that features a newly developed 16-pin QFN (quad flat non-leader) and is contained in a small package ($3.2 \times 3.2 \times 0.8$ mm).

Evaluation Board for RF Systems for GPRS Use

When Hitachi introduced these new products, it also developed an RF system evaluation board to enhance resolution as well as to offer semiconductor users an environment in which they can easily evaluate their semiconductor products.

Hitachi has developed this semiconductor-based GSM dual-band RF system evaluation board for GPRS use in collaboration with TTP Communications (TTPCom), an English GSM-system consulting firm.

The evaluation system is configured with an RF system evaluation board and an interface control board.

In addition to being equipped with such major semiconductors as a communication signal processing IC, an RF module, and a transmission power control IC, the RF block of this board is equipped with all the necessary high-frequency block devices including a TCXO (temperature compensated crystal oscillator), a VCO, and a SAW filter. Thus, connecting this evaluation board to a baseband block enables to evaluate the functions of GSM appliances. Six-layered printed circuit boards on the evaluation board allow not only the entire system but also the individual blocks to be evaluated.

This RF system evaluation board was combined with a performance-proven baseband platform from TTPCom, and its receiver sensitivity, modulation accuracy, and transmitting spurious, among other characteristics, were tested using a GSM tester to determine its overall performance. The test showed that the board meets the GSM standards and can thus be used in Hitachi's GMS semiconductor kit for GSM systems.

The interface control board is equipped with (1) a timing generation circuit for TDMA operation of the high-frequency system evaluation board in a state closely resembling actual operation, (2) a generating control signal function for the communication signal control IC, and (3) a generating control data function for the transmission power control IC, as well as with various other functions. By connecting to the RF system evaluation board and controlling it via a PC, we can evaluate the system in a state closely resembling actual operation.

Future Work

The development of high-speed and large-capacity mobile data communication systems is now actively being promoted in many countries.

In Europe, the GSM-standard-based GPRS service was introduced in 2000 and the development of an EDGE system that will enable faster data communication than that of GPRS has begun. The development of third-generation mobile communication systems has also begun.

Hitachi will continue promoting the development of high-frequency signal processing ICs with more functions and cost-reducing capabilities along with

high-frequency products designed for the EDGE system and third-generation mobile communication systems.

CONCLUSIONS

This paper described on Hitachi's achievements in the field of Internet appliance technology, semiconductor products, and technologies supporting Internet appliances.

We believe that combining the system technologies described here with element technologies will help greatly in configuring systems that are better suited for new Internet-based services in the future.

Hitachi will continue its efforts to integrate these technologies into system LSI chips and reinforce the "Solution Offering" concept to enable services required by users.

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