(1) Single-chip LSI for Mobile Terminal Processors

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A single-chip LSI integrating a mobile terminal's baseband processor and application processor and supporting dual-mode W-CDMA and GSM/GPRS has been developed. It is expected to reduce the cost of FOMA terminals and make development more efficient while providing global support for mobile communications.

1. Introduction

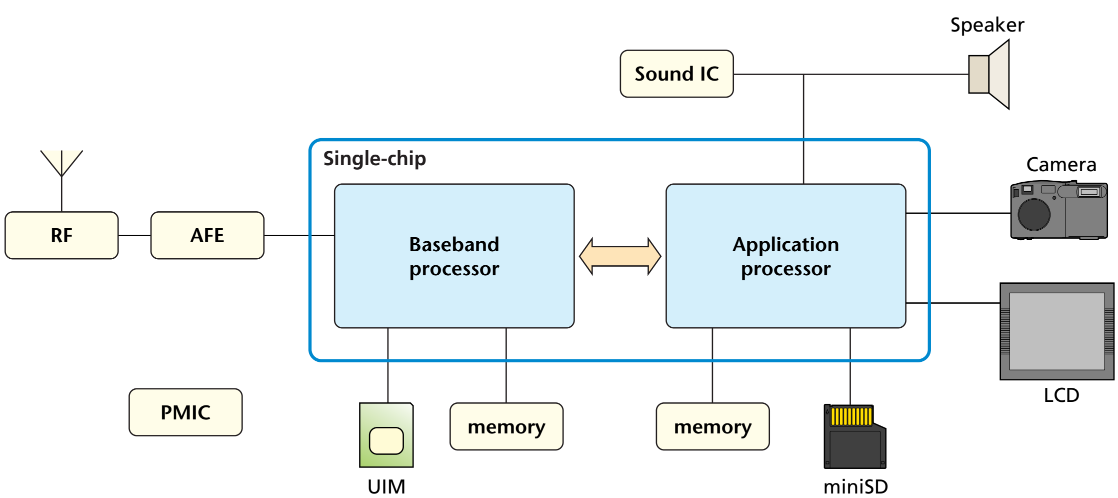
Since the launch of DoCoMo's Third-Generation FOMA mobile service in 2001, the demand for multi-function and multimedia-compatible mobile terminals has been increasing steadily. To meet this demand, existing FOMA terminals generally adopt a dual-chip configuration consisting of a baseband processor and application processor, but this has been one factor behind the high cost of mobile terminals.

In response to this problem, DoCoMo started joint development projects with semiconductor manufacturers, Renasas Technology Corp. and Texas Instruments Inc. in July 2004. The aim of these projects was to develop a single-chip LSI integrating the mobile terminal's built-in baseband processor and application processor and supporting a W-CDMA and Global System for Mobile communications (GSM)*1/General Packet Radio Service (GPRS)*2 dual-mode.

This article describes the development of this single-chip LSI, which began sample shipments in 2005.

2. Development Background and Benefits

Existing FOMA terminals adopt a two-processor configuration consisting of a baseband processor that handles communications and an application processor in charge of application processing (**Figure 1**). This type of hardware configuration that separates communication functions and application functions is beneficial from the viewpoint of software development. It also, however, increases the number of components, which makes it



RF (Radio Frequency): Radio circuits
AFE (Analog Front End): Analog/digital and digital/analog converter
PMIC (Power Management IC): IC that manages power for system circuits
UIM (User Identity Module): A smart card that stores subscriber information such as a telephone number. It is inserted into the mobile terminal to identify the user.

Figure 1 Basic block diagram of mobile terminal

*1 GSM: A Second-Generation mobile communications system used widely around the world, especially in Europe and Asia.
*2 GPRS: A packet-switching service available on GSM and W-CDMA networks.

undesirable from the viewpoint of lowering material cost and reducing circuit-board area.

The existing development method is also inefficient as each mobile-terminal manufacturer develops a baseband processor for use in FOMA terminals duplicating each other's efforts.

To solve these problems, the development of a single-chip LSI was conducted with the objectives described below.

2.1 Reduction of Material Cost and Circuit-board Area by a Single-chip Design

Making use of advanced semiconductor manufacturing processes, the baseband processor and application processor in the conventional dual-chip format have been integrated into a single chip thereby reducing total chip area (Fig. 1).

Considering that the cost of an LSI is greatly dependent on chip area in a mass-production environment, material cost can be lowered by reducing chip area. Our goal in this development was to a 30–40% reduction in cost compared to the conventional method. A reduction in chip area and decrease in number of components made possible by this single-chip design also help to reduce circuit-board area.

Moreover, while integrating components, it keeps the independence between communication processing and application processing as found in the conventional format. This maintains efficiency in software development and enables the reuse of existing software.

2.2 Efficient Development and Mass-production Effect in Cooperation with Semiconductor Manufacturers

Having semiconductor manufacturers provide a general-purpose LSI that has already completed operability tests with the FOMA network has the following two advantages.

First, it promotes common baseband processors in FOMA terminals. This reduces the number of test items in terminal development for mobile-terminal manufacturers and DoCoMo and simplifies the handling of non-common features making for more efficient development overall.

Second, it allows the semiconductor manufacturers to sell the LSI even overseas thereby expanding its market and lowering its price through a mass-production effect.

In this development, each of the companies involved brought tried-and-true technology making for early completion. This included DoCoMo's W-CDMA technology obtained from FOMA terminal development and the semiconductor manufacturers' high-performance application processors and GSM/GPRS technologies.

2.3 Inter-operability Improvement

The equipping of this LSI in mobile terminals targeted for overseas operators improves inter-operability with the networks of those operators. In this regard, W-CDMA, while conforming to 3rd Generation Partnership Project (3GPP) standards, may operate differently at the implementation level due to differences in interpreting specifications. Accordingly, the adoption of an LSI with proven results on the FOMA network in the mobile terminals of overseas operators will help to simplify interoperability tests.

To enable the advantages described above and in the previous section to be enjoyed to the fullest, this single-chip LSI must support not only the W-CDMA system used widely in European and American cities but also the GSM/GPRS systems used throughout the world.

3. Single-chip LSI

The developed single-chip LSI consists of independent baseband-processing and application-processing sections interconnected by an internal bus (**Figure 2**). The following describes the configuration and functions of each of these sections.

3.1 Baseband-processing Section

This section consists mainly of a Communication Central Processing Unit (C-CPU)[*3], W-CDMA circuits, and GSM/GPRS circuits interconnected by an internal bus. It performs baseband processing for W-CDMA and GSM/GPRS dual-mode communications.

The C-CPU incorporates a Real-Time Operating System

*3 C-CPU: Generic name for the CPU in charge of communications and call control processing in a mobile terminal.

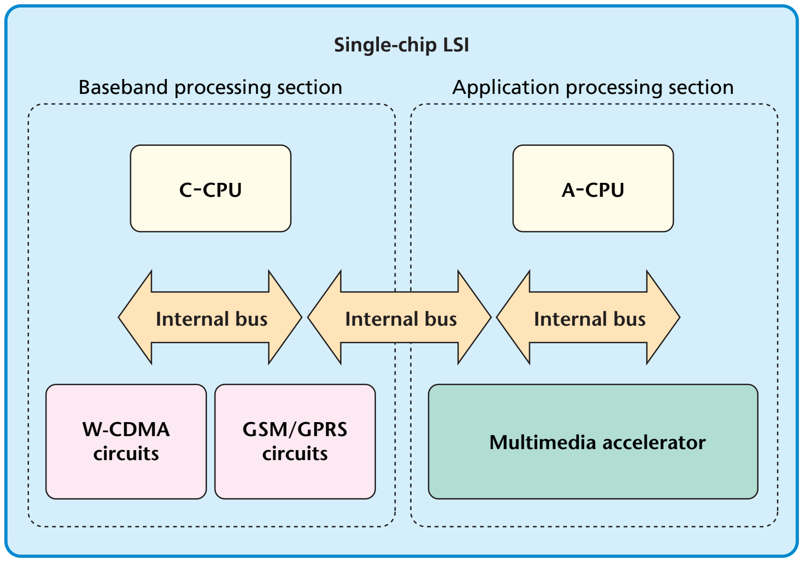


Figure 2 Single-chip LSI

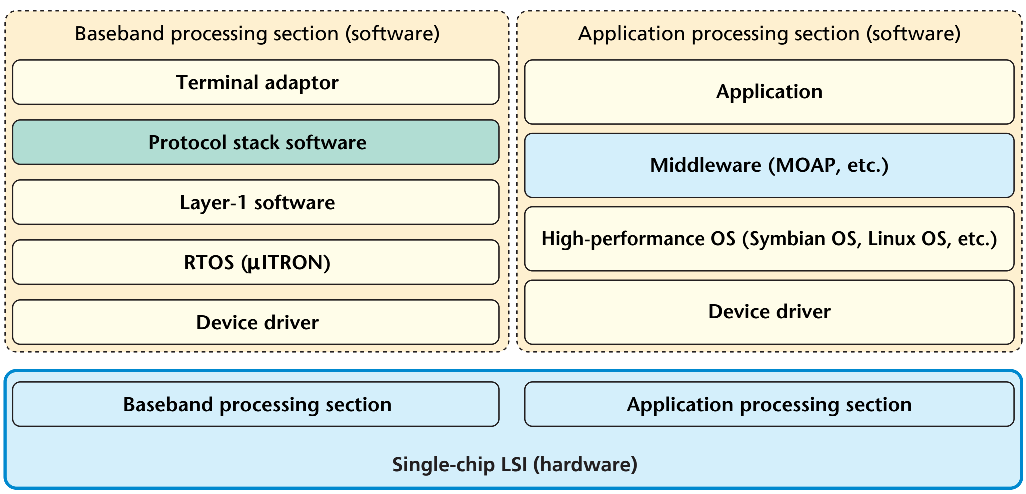


Figure 3 Configuration of entire platform

(RTOS)[*4] called Micro Industrial-The Real-time Operating system Nucleus (μITRON)[*5]. It performs communication-control protocol-stack (layer-2/layer-3 control) processing (**Figure 3**).

The W-CDMA and GSM/GPRS circuits provide layer-1 functions.

3.2 Application-processing Section

This section consists mainly of an Application Central Processing Unit (A-CPU)[*6] and multimedia accelerator. Its role is to run the OS, middleware, and video and audio multimedia applications.

The A-CPU controls the entire mobile-terminal system. It incorporates a high-performance real-time OS such as Linux OS[*7] or Symbian OS™[*8].

The multimedia accelerator consists of hardware and a Digital Signal Processor (DSP)[*9] specializing in computation-heavy multimedia processing. Its role is to reduce power consumption by easing the load on the A-CPU and to provide high-

*4 RTOS: An OS equipped with functions for performing real-time processing. It is used in embedded equipment such as Personal Digital Assistant (PDA) and home appliances that incorporate a CPU and software for specific applications.

*5 μITRON: An RTOS provided by the TRON Association and used widely such as in mobile terminals. Its compact configuration makes for easy loading onto various types of processors.

*6 A-CPU: Generic name for the CPU in charge of application processing in a mobile terminal. Demands for high-performance applications in FOMA and other Third-Generation mobile terminals increases the terminals that have built-in CPUs dedicated for application processing.

*7 Linux OS: An open-source Unix-type OS that can be freely redistributed under GNU Public License (GPL).

speed processing of multimedia applications.

The developed single-chip LSI is equipped with a multimedia accelerator that performs moving-picture processing through Moving Picture Experts Group phase 4 (MPEG-4)[*10] and H.264[*11] and 2D/3D graphic processing.

4. Conclusion

This article described the development of a single-chip LSI that integrates the baseband processor and application processor in a mobile terminal. Sample shipments of this LSI to mobile-terminal manufacturers have already begun. Incorporating this LSI in mobile terminals both in Japan and other countries is expected to help lower the cost of FOMA terminals.

As a future research issue, the single-chip LSI must support the High Speed Downlink Packet Access (HSDPA)[*12] system that will be introduced in 2006. We are also studying to support peripheral devices for services such as wireless LAN and Global Positioning System (GPS)[*13] which will be basically legislated for adopting in mobile terminal from April 2007.

*8 Symbian OS™: An OS for mobile terminals developed and licensed by Symbian Ltd. (UK). Symbian OS and other Symbian-related marks and logos are trademarks or registered trademarks of Symbian Ltd.

*9 DSP: A processor specializing in digital signal processing of audio and video signals.

*10 MPEG-4: A coding system for moving-picture data used for delivering video over relatively slow communication circuits as in mobile terminals.

*11 H.264: A coding system for moving-picture data capable of high rates of compression compared to MPEG-4. It can support a wide range of applications such as high-definition broadcasting.

*12 HSDPA: A high-speed downlink packet transmission system based on W-CDMA. Maximum downlink transmission speed under the 3GPP standard is about 14 Mbit/s. HSDPA optimizes the modulation method and coding rate according to the reception conditions of the mobile terminal.

*13 GPS: A system for measuring location in terms of latitude, longitude, and altitude with high accuracy using information transmitted from orbiting satellites.