# Fujitsu's New Direction for Image Processing LSIs: Integration into a Visual Application Platform

● Tom Miyake ● Yukio Otobe

**Under the catchphrase of "Fujitsu for Image Processing," Fujitsu has developed image-processing technologies that engage human emotions and has developed LSIs that apply those technologies. Many of these technologies have been adopted in imaging-related devices and systems in a wide variety of fields, and they have been highly praised for their proven track record in image quality and expressiveness. Today, digital images are finding widespread use in society, and the demands placed on imaging devices by the market are changing. In addition to the demand for high-performance, compact, and low-power devices, the mutual dependency between device performance and content and associated services is growing. This trend is driving a change from imaging devices of the single-function, standalone type to those of a multi-function, networked type. In the face of these market changes, Fujitsu is constructing a visual (visually appealing) application platform that integrates LSIs incorporating Fujitsu's proprietary image-processing technologies with a development support environment that has a proven track record in system development projects with customers. This paper introduces visual solutions based on this platform.**

## 1. Introduction

Digital image-processing technology has evolved dramatically in recent years in parallel with the rise of the broadband network as a social infrastructure. It has spread far and wide throughout society, raising the performance of televisions, digital cameras, mobile phones and other electronic devices and improving the quality of video, music, and game content. By doing away with time and place limitations and enabling people to enjoy a wide range of content in all sorts of environments, digital image-processing has become a prime technology for supporting diverse lifestyles in modern society.

At the same time, the market needs of such imaging-related devices have come to change. Of course, the pursuit of high-performance, compact, and low-power-consuming devices continues, but at the same time, the mutual dependency between device performance and content and associated services is growing. As a result, imaging-related devices are undergoing a transformation from a single-function, standalone type to a multi-function, networked type.

Under the catchphrase of "Fujitsu for Image Processing," Fujitsu has developed high-quality, low-power image-processing LSIs that have come to be adopted in imaging-related devices and terminals in a variety of fields.

In this paper, we first introduce Fujitsu image-processing technologies and the LSIs that apply them. We then describe visual solutions based on a visual (visually appealing) application platform that Fujitsu intends to make into a pillar of its image-processing-LSI business.

## 2. Requirements of image-processing LSIs

Most of the functional and performance requirements of an imaging device or information terminal are usually met through LSIs, which consolidate processors, memory, dedicated hardware for image processing, and other elements as well as the software running on those LSIs. This means that the system performance of a device or terminal—where higher performance means faster processing, higher image quality, more functions, and lower power consumption—greatly depends on the performance of such LSIs.

Algorithms and an architecture that can secure both high image quality and low power consumption are particularly important for image-processing LSIs. Achieving this involves function, performance, and cost design taking into account the complementary metal oxide semiconductor (CMOS) technology applied to the LSIs.

Image processing basically consists of numerical operations performed on pixel data. Taking video content for example, a large quantity of pixel data must be processed at high speed within a fixed amount of time, and pixel operations must often be performed on the basis of the correlation between consecutive images. This requires frequent data transfers between an image-processing LSI and external memory that stores image data. Such high-speed pixel operations and transferring of data between an image-processing LSI and external memory are not limited to video content—it is a feature that can be observed in all types of image processing including high-speed continuous shooting in digital cameras and graphic drawing. This is why it is important that algorithms and architecture achieve a balance between image quality and power consumption.

To improve image quality, it is particularly important to understand the characteristics of all related systems including those of input/output devices such as image sensors and displays and even human visual and cognition systems when applying image processing technologies to LSIs.

Nowadays, moreover, developers of imaging devices tend to be especially concerned about functions and performance that engage human emotions, as in advanced picture rendering, high expressive ability, and quick response. For this reason, it is also important to provide a system-development support environment that includes development tools and libraries.

## 3. Development technologies and their application to LSIs

In this section, we introduce image-processing technologies developed by Fujitsu and the LSIs that apply them in accordance with the basic process flow of capture, record, send, and view in an imaging system (**Figure 1**).

### 3.1 Capture: Milbeaut

Since its birth in 2000, Fujitsu's Milbeaut series[1), 2)] of image-signal-processing LSIs for cameras has come to be used in a variety of digital-imaging devices from digital single-lens reflex cameras to compact cameras and camera phones. These LSIs have a good reputation for image quality and expressiveness and have a proven track record in actual applications.

At the core of Milbeaut image-signal-processing technology are pixel generation engines that perform demosaicing and resolution conversion. Fujitsu has developed proprietary algorithms that aim for the "ultimate reproduction of colors and resolution," and it has applied these algorithms to these pixel-generation processes, which determine camera picture quality.

Output data from many types of charge coupled device (CCD)/CMOS image sensors consist of an array of pixels each of which contains information on only a single color. To generate a full-color image from this input, demosaic processing must be performed. This process generates color information from a pixel's neighboring pixels through inference and interpolation. "Reproduction of memory color" is also an important aspect of this color-generation process. Memory color is different from actual color. It is the color that many people form as an image in their minds and find most beautiful and agreeable. Incorporating a mechanism that enables the color space to be freely manipulated accommodates user preferences with respect to picture expression, as in adjusting the blueness of the sky and reproducing a person's natural skin color.

In recent years, moreover, the data output from many-pixel, high-speed image sensors have come to include considerable noise due to device miniaturization and complexity. The optical lens unit in the stage prior to the image sensor is also affecting noise levels as it becomes increasingly smaller and thinner. The net effect is that the signal-to-noise (S/N) ratio for data from image sensors is on a downward trend. Applying some means to eliminate this noise usually means that resolution must be sacrificed, but Fujitsu's proprietary adaptive noise filter can effectively eliminate noise components without degrading resolution.

In addition to these advanced, complex processes, Milbeaut pixel generation engines also minimize image disturbances and noise peculiar to image sensors such as false colors, jaggedness, and moiré all

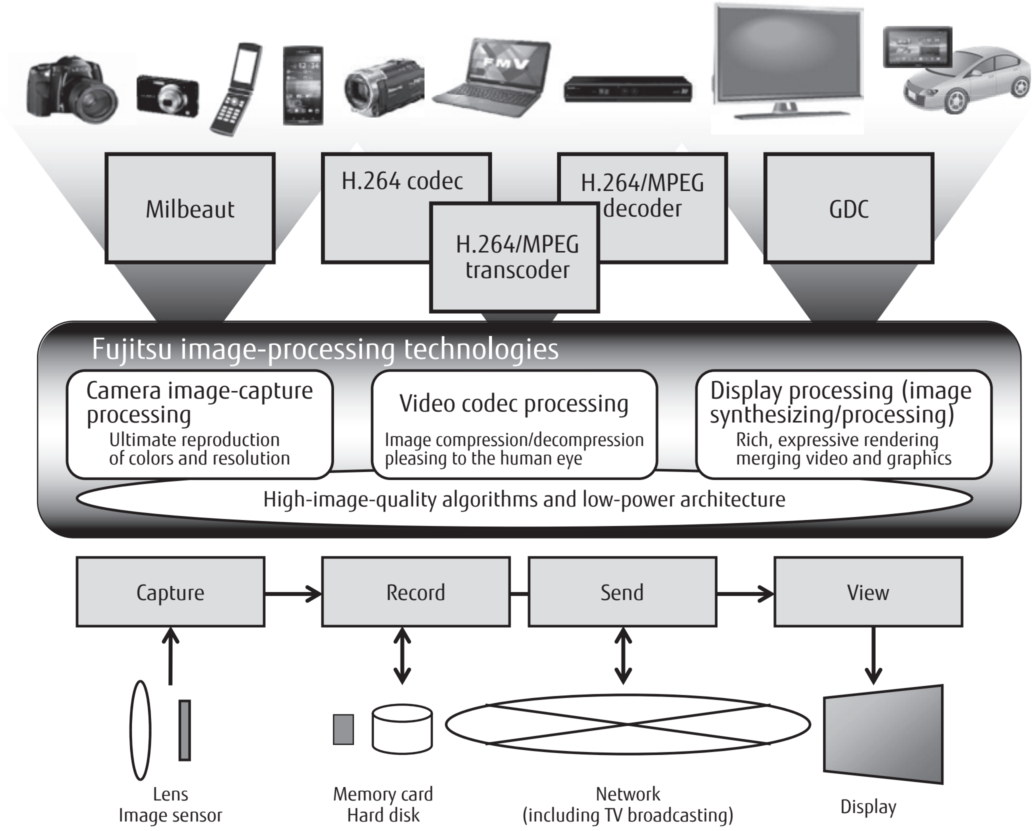


**Figure 1**
**Fujitsu image-processing technologies and their application to LSIs.**

through dedicated hardware circuits. This approach achieves high-speed, high-performance, and low-power operation and provides a level of image quality that satisfies even users of high-end digital single-lens reflex cameras.

Fujitsu also provides an extensive development environment in conjunction with the Milbeaut series of LSIs. This environment includes an automatic exposure and automatic white balance (AE/AWB) library essential for digital camera development and applications such as face detection, image stabilization (camera-shaking compensation), and wide dynamic range (WDR). The end result of this development environment is a shorter turnaround time (TAT) for customers in system development.

The Milbeaut series of LSIs has progressed in step with the evolution of digital cameras from their early days. The major strengths of this series have been to quickly provide the diverse camera functions and levels of performance demanded by the market and Fujitsu customers, to include technology and product development, and to provide an advanced development environment.

### 3.2 Record and send: video codec

Research and development of video codecs (where *codec* signifies *coder-decoder*) has a long history at Fujitsu.[3] As a technology for transmitting images over the network, Fujitsu has been developing codecs to preserve image quality, compress the transmission band, and achieve stability in image processing. Fujitsu has participated via Fujitsu Laboratories in international standardization conferences related to video encoding such as MPEG encoding and has proposed a number of encoding methods that have been selected as standards.

Fujitsu began to implement codecs as LSIs from early on and began developing video codec LSIs in the MPEG-2 era. These LSIs came to be used in professional video cameras, video editing equipment, and recorders and personal computers for making digital recordings of analog TV broadcasts. Fujitsu was also quick to investigate ways to improve encoding performance using the H.264 standard and, in 2007, was the first in the industry to commercialize an H.264 codec LSI supporting Full HD (1920 × 1080 pixels). As an LSI that used Fujitsu's proprietary high-image-quality algorithms and low-power architecture, this product received high marks from many users.

The strength of Fujitsu codecs is their "image quality." However, when talking about image quality in codecs (as opposed to that in Milbeaut image processors), the key question is how to preserve the quality of the original image under encoding (data compression), or in other words, how to decrease the amount of information in such a way that any picture degradation goes unnoticed. We can take as an example the encoding of Full HD video into a 10-Mb/s stream using H.264. Since one Full HD image consists of 1920 × 1080 pixels or more than 2 M (2 000 000) pixels, video display at 30 frames per second would consist of more than 60 M pixels per second. To convert this amount of information into 10 Mb of data, the luminance and color information of one pixel would have to be expressed on average with less than 0.2 bits of data. Achieving such highly efficient image encoding requires that data be culled in a way that makes any picture degradation unnoticeable, but this, in turn, requires a familiarity with human visual characteristics.

A key feature of Fujitsu's video-encoding algorithms[4), 5)] is encoding control based on feature and statistical analysis with respect to the original image. This means acquiring information on the complexity and movement of local patterns and calculating the distribution of this information on the screen ahead of encoding. By doing so, portions of the image for which humans can easily notice any degradation in image quality—such as human faces and slow-moving objects—can be controlled at the time of encoding, such as by prioritized encoding. Additionally, any camera panning or zooming, scene changes, fade-in or fade-out operations, etc. can be identified beforehand by such preprocessing, making it possible to perform adaptive encoding control for particular scenes.

The encoding process, moreover, adopts an original method to incrementally narrow down the search for motion—a load-intensive process—with the aim of greatly reducing the amount of calculation and amount of data transferred to and from memory (which lowers power consumption) while maintaining search performance.

Fujitsu has developed a variety of LSI products centered about these H.264 and MPEG-2 video codec technologies. The Full HD H.264 codec LSI mentioned above has been praised for its high image quality and has come to be used in video equipment in a wide range of fields, from consumer video cameras to commercial surveillance systems and video transmission equipment for broadcast studios.

Similarly, Fujitsu's transcoder LSI providing bidirectional conversion between the MPEG-2 and H.264 systems has found extensive use in televisions, recorders, and personal computers in applications like long-time recording of digital broadcasts and band compression for sending and receiving video over the network.

Additionally, by having its MPEG-2/H.264 dual-support decoder LSI conform to the European digital video broadcast (DVB) standard, Fujitsu is expanding the market for its LSI products to the European and Asian television and set-top-box markets.

### 3.3 View: graphics display controller

Fujitsu's series of graphic display controller (GDC) LSIs[6)] has evolved in parallel with the development of high-performance, multi-function on-vehicle information devices and displays. These LSIs have come to be used in many on-vehicle products as a high-level graphics solution for achieving a variety of display functions such as digital dashboards and center consoles for car navigation and driving support.

A distinguishing feature of the functional requirements for on-vehicle display terminals is that high graphics performance is not enough—also required is good display performance, that is, the ability to display various types of images such as video and maps in a manner that is easily understood by the user. What is needed is rich expressive ability, as in displaying video from a camera installed on the automobile in a way that is easy for the driver to view, superimposing multiple images and graphics assuming backseat viewing of television or DVD content, and displaying deformed or synthesized images. Another feature concerns graphics for embedded applications not limited to car navigation. In contrast to games and personal computers centered about 3D graphics, on-vehicle display terminals make extensive use of bit-map or vector 2D graphics for efficiency's sake.

Fujitsu's GDC LSI, which was commercialized in 2010, integrates a variety of image processing and display functions required of modern on-vehicle displays. First, in terms of graphic performance, this product is equipped with a high-speed 2D/3D graphics engine with a built-in programmable shader, enabling rich graphics expression with texture including reflected light and shadows. As an image-processing LSI for vehicles, this GDC product boasts top-class performance. Second, this product features an eight-layer superimposed display function and an inter-layer blending function as display controller functions. These functions enable the contour parts of camera video superimposed on a map screen to be obscured so that the video can meld with the background map. This GDC LSI can also perform simultaneous parallel processing of video from four video inputs. It can deform and synthesize these video inputs and display them as a single video output in real time.

The parallel-processing function is used in the OMNIVIEW system,[7] which uses technology developed by Fujitsu Laboratories to synthesize, on a three-dimensional model, video data from four automobile cameras pointing in four different directions. While past technology synthesized video data on a two-dimensional model and was consequently limited to video display from a specific viewpoint, the OMNIVIEW system is capable of displaying video from any viewpoint, thereby providing a 360° field of view. This greatly improves the level of visual assistance provided to the driver.

Fujitsu provides system-development support for the customer by preparing and integrating authoring tools, libraries, and middleware for the creation of a human-machine interface (HMI) that uses graphics, including those described above.

Fujitsu's GDC LSI series has been well received as an advanced solution for "video and graphics convergence." There are plans to expand the use of these LSIs beyond on-vehicle equipment to other kinds of display systems such as digital signage.

## 4. New direction for image-processing LSIs

Here we describe a visual application platform that is to become a pillar of Fujitsu's image-processing-LSI business. The basic configuration of this platform is shown in **Figure 2**.

### 4.1 Changing market needs

The transmission of video and music over the network is becoming commonplace, and imaging-related devices are being increasingly transformed by "digital convergence," in which functions combine and merge beyond traditional product fields, thanks to digital technology. Most noticeable in this regard is no doubt the dramatic growth of smartphones in the mobile/portable device market. The smartphone incorporates a variety of functions such as camera, television, audio player, gaming, and car navigation on top of the basic information-communication functions of voice calling and data communications. As such, it has the power to break down the traditional boundaries between product categories and make other types of portable devices redundant. In addition, smartphone terminals that run on an open OS such as Android and Linux feature a mechanism that simplifies the implementation of applications to accommodate inter-device linking and new services.

Looking forward, we can expect this move toward a concentration of market needs in open terminals with

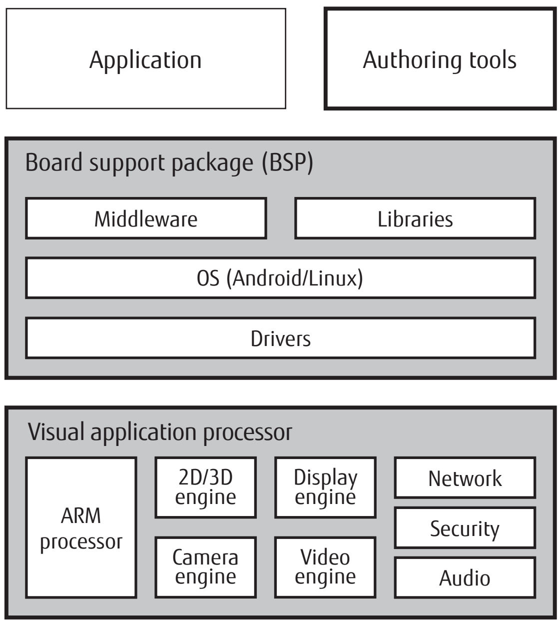


**Figure 2**
**Basic configuration of visual application platform.**

composite functions to expand beyond the mobile/portable device market to home-entertainment equipment, on-vehicle devices, and office equipment.

## 4.2 Visual application platform

Recognizing the importance of this movement, Fujitsu has set its sights on constructing a visual application platform toward next-generation imaging systems and has begun development of a visual application processor as the core element of this platform. This processor will be a single-chip LSI that consolidates and integrates engines (dedicated hardware) centered about Fujitsu's image-processing technologies on top of an advanced ARM processor platform.

The visual application platform will target the intelligent image- and information-processing terminals that are expected to play a central role in the homes, automobiles, and offices of the future, that is, open-OS terminals equipped with a continuous network connection and a 4K2K-class display (4096 × 2160 or 3840 × 2160 pixels). In short, Fujitsu envisions this platform to be applied to the development of systems that will provide users with all sorts of entertainment and enable them to enjoy cloud-based services.

## 4.3 Visual application processor

The main features of the visual application processor at the core of this platform lie in its architecture, which is oriented towards high performance and low power consumption.

The aim with this processor is to make operations more efficient and thereby raise performance and reduce power needs by significantly reducing the processing load on the main processor during execution of an image-processing application and by simplifying data flow throughout the LSI, including data transfers to and from external memory.

The processor also incorporates local processors within the various image-processing engines so that advanced and complex processing—such as image feature analysis and local modification of image texture—can be executed within an engine. The software running on the local processors can be used to support picture expression and image-quality adjustment as demanded by users. This approach is intended to reduce the load on the main processor and to simplify the data flow in image processing. Against the background of display resolutions increasing to 4K2K and 8K4K (7680 × 4320) and image-sensor pixel counts increasing to more than several tens of megapixels, we can view the architecture of this processor as being highly power efficient with enough processing performance to handle such ever increasing image-processing loads.

The architecture for the visual application processor was designed to facilitate the addition of new hardware to support specific applications. This will simplify functional and performance enhancements in future LSIs as the series expands while providing flexible support for customer-defined logic (CDL: logic circuits that incorporate customer-defined specifications) as demanded by customers. In other words, this architecture will enable expansion toward various types of business by enabling the development of custom LSIs based on this visual application platform.

## 4.4 System development support environment

In parallel with the development of this visual application processor LSI, we have begun preparation of a board support package (BSP) for Android and Linux OSes with the aim of integrating in this platform a system development support environment including middleware, libraries, and authoring tools.

Using Fujitsu's visual application platform as a base, our aim is to construct an environment in which customers can centralize resources for developing system functions that stand out from those of their competitors.

# 5. Conclusion

The last ten years or so have seen expanded use of digital images throughout society. Looking back at this period, it can be said that digital appliances in the form of digital cameras, televisions, video recorders, and game consoles have consistently led the global consumer electronics market, with Japanese enterprises taking a leading role. The reason for this is simply that these enterprises have taken the lead in developing devices that enable individuals and homes to process and enjoy digital images (photos, video, and graphics) and in developing technologies to support those devices.

We can look upon beautiful and highly expressive images as universal criteria for product evaluation (including sentiments such as like/dislike) that surmount the limitations of culture and language. In a market that is becoming increasingly dominated by open and general-purpose technologies, image-processing technology looks to become increasingly important as a means of distinguishing consumer electronics and information terminals.

At Fujitsu, we seek to create new visual solutions in collaboration with our customers on the basis of a visual application platform that supports a wide range of image-processing applications.

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**Tom Miyake**
*Fujitsu Semiconductor Ltd.*

Mr. Miyake is overseeing the development of advanced LSIs as the head of the Advanced Products Business Unit.


**Yukio Otobe**
*Fujitsu Semiconductor Ltd.*

Mr. Otobe is engaged in the development of LSIs and platforms related to image processing.