Graphics Display Controller for Automotive Applications

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Fujitsu has had graphics display controller (GDC) products on the market for years as system chips for use in in-vehicle information devices. More automobile instrument cluster and center display systems are now using full-color liquid crystal displays, and there are often multiple displays in a single vehicle. Keeping pace with this evolution of devices, Fujitsu developed the MB86R1x series of systems-on-a-chip (SoCs), which integrate a high-performance microprocessor with a proprietary graphics processing unit (GPU) and various in-vehicle network functions. Here, we briefly describe the latest trends in automobile information devices and systems and present an overview of the MB86R1x series of SoCs, our most recent automotive GDC product line. We also explain the technologies developed for these systems, including the GPU, image processor, and in-vehicle network.

1. Introduction

An automobile instrument cluster conveys to the driver information on vehicle operation, such as vehicle speed and fuel level. The main instrument is traditionally a needle-type speedometer. Light emitting diodes (LEDs) and small monochrome liquid crystal displays (LCDs) display various types of information using character patterns or text. Needle-type instruments are increasingly being replaced with relatively large monochrome or color LCDs that use graphics to provide more information in a way that is more readily understood. Large LCD screens are also used, and some products feature even the speedometer and other instruments implemented as drawn graphics.

Electronic information systems that provide driving support functions such as car navigation systems that use color map displays and video monitoring systems are growing in popularity, and we are beginning to see multiple color display devices in a single vehicle. Such systems are generally installed as independent electronic control units (ECUs). Integration of these systems would make them easier to use. Including the car navigation display, the video display, and the other displays in the instrument cluster would minimize movement of the driver's line of sight and provide a comprehensive and integrated electronic information system. Future development is expected to extend the provision of services and information to use of the Internet and the cloud.

Fujitsu offers a commercial graphics display controller (GDC) that is well suited to such an integrated electronic information system. In this article, we describe the latest trends in automobile information devices and systems, present an overview of the MB86R1x series of systems-on-a-chip (SoCs) designed for integrating ECUs, and explain the technologies developed for these systems.

2. Trends in automobile information devices

An example configuration of a current-generation automobile dashboard is shown in **Figure 1**. The instrument cluster displays the vehicle speed, fuel level, gear position, and other information needed for operating the vehicle. The head-up display shows the speed numerically, turn signal indicator, night vision images, and other information needed for quick decision making. It is projected as video onto the windshield. The center display presents map-based navigation information and in-vehicle entertainment using audio-video

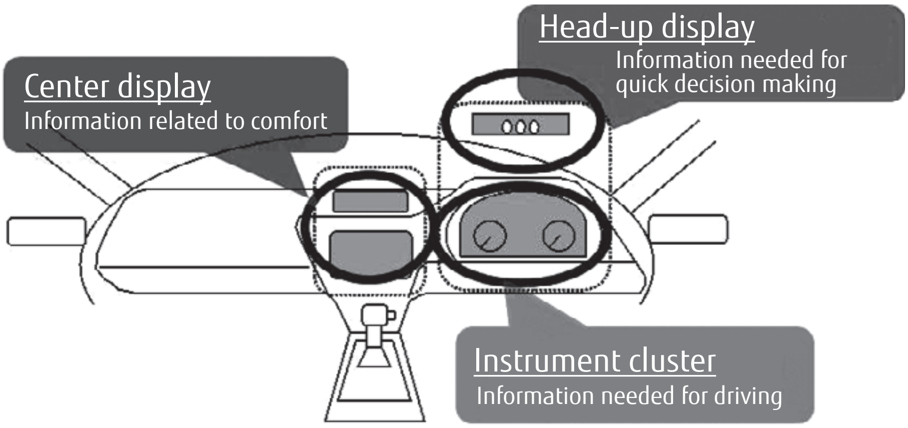

Figure 1
Example automobile dashboard configuration.

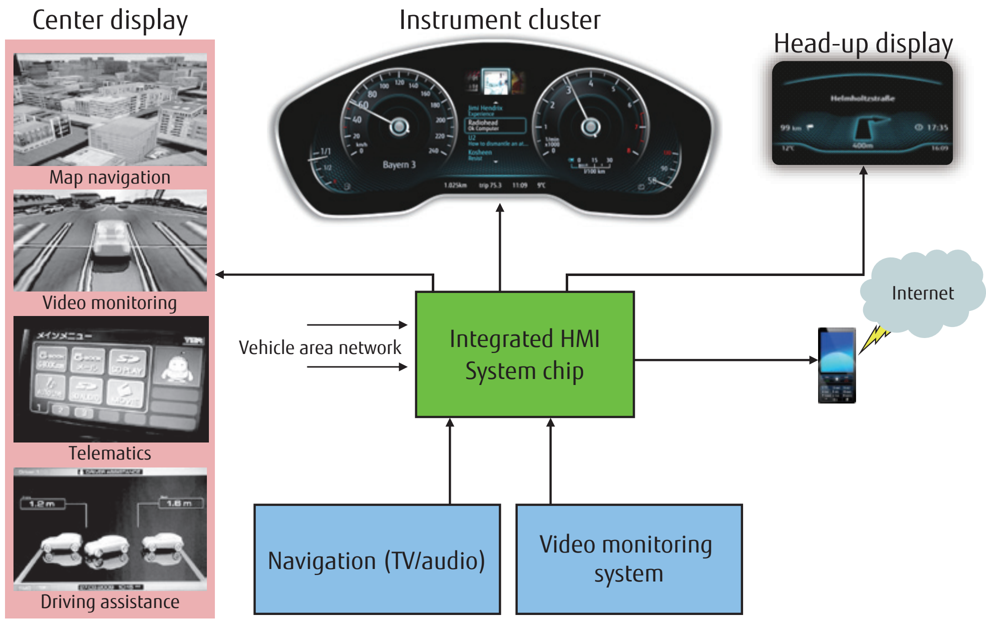

Figure 2
Integrated HMI system.

equipment for comfortable driving. This arrangement was designed in consideration of the needs of and ease of use by the driver and passengers.

An example configuration of a next-generation integrated system as described above is shown in **Figure 2**. In this human machine interface (HMI) system, the instrument cluster, head-up display, and center display are implemented as an integrated system rather than as independent ECUs. In addition to lowering system cost, this integration unifies the management of driver operations and control of the vehicle equipment, enables various types of information processing to be efficiently performed, and enables the results to be displayed using a single interface. It also enables flexible presentation of navigation information not only on the center display but also on the instrument cluster or head-up display when appropriate.

Such an integrated system requires a system chip with multiple input interfaces for vehicle information, navigation information, camera images, etc. It must also have multiple display outputs and be capable of high-performance graphics drawing and image processing as well as display control.

Future development will enable this integrated HMI system to provide a graphical interface for driver input operations using devices equipped with touch panels and haptic feedback instead of the many types of switches that are currently used.

3. MB86R1x series of SoCs

A block diagram of the MB86R1x series SoC developed by Fujitsu for the instrument cluster, car navigation, and integrated HMI system described above is shown in **Figure 3**. An ARM Cortex™-A9 CPU serves as the high-performance core. The graphics unit consists of a Fujitsu graphics processing unit (GPU) and an independent dedicated 2D graphics engine.

The graphic unit includes a four-channel video input function and a display output function that can drive up to five screens. It supports the high-speed video processing needed for the inputs and outputs. For example, a 360° video system composes and transforms the image data from four video cameras mounted on the front, back, left, and right sides of the vehicle into a single image in real time and displays this image on a monitor. This video processing can be implemented on a single chip. (See "Automotive Graphics SoC for 360° Wraparound View System" in this issue.)

The integrated HMI system is easy to implement along with other automobile information systems due to the provision of an APIX2 high-speed image transfer interface, a controller area network (CAN) in-vehicle network, and a media local bus (MLB) that complies with the Media Oriented Systems Transport (MOST) bus standard for in-vehicle multimedia networks, as well as USB, secure digital (SD), and Ethernet general-purpose peripheral device interfaces.

4. Developed technologies

This section presents a broad explanation of the technologies we developed for the MB86R1x series of

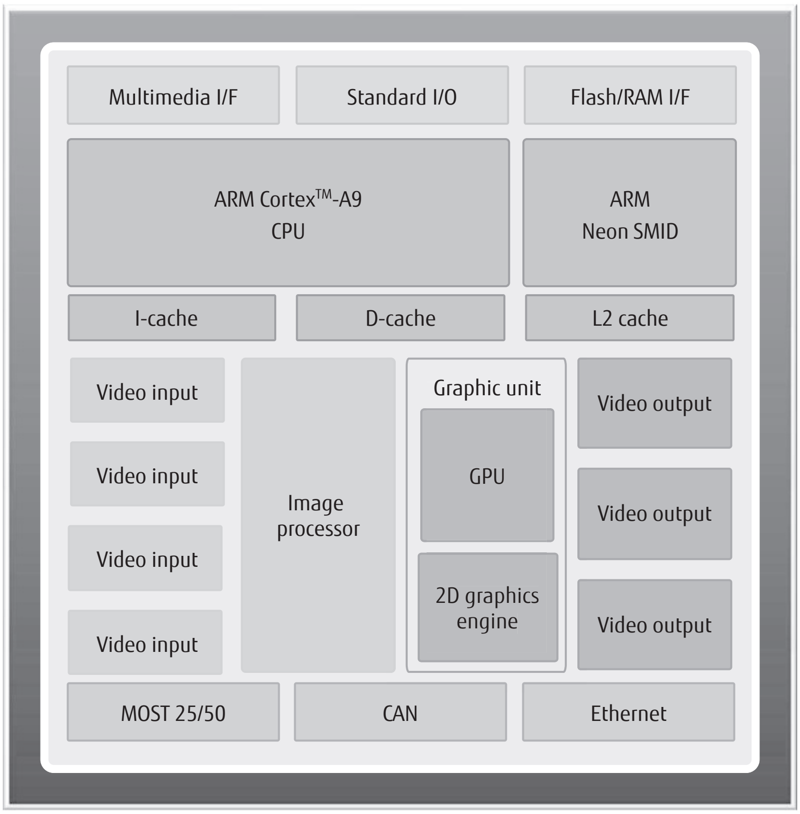

Figure 3
MB86R1x block diagram.

SoCs and other GDC products.

4.1 GPU

The GPU technology we developed supports the OpenGL ES 2.0 industrial standard for graphics application programming interfaces (APIs). The GPU can draw 10 million polygons containing 400 million pixels per second, so it can produce high-quality graphics at high speed.

This GPU has a unified programmable shader architecture. The 3D graphics processing includes a vertex shader, which computes shading in units of vertices, and a fragment shader, which computes color in units of pixels. This architecture describes hardware that supports both a vertex shader and a fragment shader and shading algorithms that are programmable. This enables a high degree of freedom for user-written shader programs, facilitating the attainment of the desired drawing results. The programmable shaders can also be used for numerical operations with a computational performance of up to 17 GFLOPS.

The GPU also supports two other functions.

1) Multi-sample anti-aliasing (MSAA)

This function achieves an image smoothness beyond the resolution of the display by reducing 'jaggies' (a zigzag pattern at the edges of an image).

2) Polygon drawing

This function supports high-speed drawing using simple commands for producing the polygons used, for example, in navigation maps.

4.2 Sprite engine

The sprite engine technology we developed is used to implement the graphics engine at low cost. The engine uses the sprite drawing method, which does not require a frame buffer. It can display up to 512 sprites, each of which can be a pattern of up to 512 × 512 pixels. There are functions for vertical and horizontal sprite reversal and rotation by 90°. There is also an animation function for automatically updating the pattern and an anti-aliasing function that is specialized for drawing fonts.

4.3 2D graphics engine

The 2D bit-map graphics engine technology we developed provides image transformation functions for image rotation, enlargement, and reduction for any angle or size. It also provides, for example, a function for head-up display. Advanced image filtering functions work together with the transformation functions to maintain high quality in the transformed images. The 2D graphics engine can operate independently of the GPU, enabling high-speed hybrid HMI system processing in which 2D graphics functions are used, for example, for drawing a speedometer and 3D graphics functions are used for drawing the outside view of the automobile, as shown in **Figure 4**.

4.4 Visibility enhancement unit

The MB86R1x series is also equipped with a visibility enhancement unit (VEU), a specialized image processing engine that was developed by applying visibility enhancement processing technology for video shot by vehicle-mounted cameras.[1] It is the result of research by Fujitsu Laboratories.

Figure 4
2D/3D hybrid HMI drawing example.

1) Motion-adaptive IP conversion

Interlace progressive (IP) conversion is a technique for converting images obtained by interlaced scanning of the analog video signal from a camera into the progressive scanning signal needed for output to digital processing devices and LCDs. It detects movement in an image and selects the image interpolation method that will maximize the quality of the converted image.

2) Visibility enhancement processing

Back lighting and headlight illumination can create a strong contrast in the images from the cameras in the video monitoring system. That is, the illuminated areas are white, and the unilluminated areas are black. This can make it difficult to distinguish objects and people in the images.

The visibility enhancement processing technology that we developed identifies the illuminated and unilluminated areas of the input image and corrects the gradation in those areas to improve their visibility. (See "Automotive Graphics SoC for 360° Wraparound View System" in this issue.)

3) Edge and color correction

The edge and color correction technology we developed analyzes the input image signal and performs edge processing in which the image processing method is selected on the basis of the image content and chrominance correction is performed by setting the gradation on the basis of the image content.

4) Back-lighting control

The back-lighting control technology we developed controls the back lighting of the LCDs on the basis of the content of the input video. This reduces power consumption and improves image contrast.

4.5 Input and display control

The image input and display control technology we developed coordinates the inputs from the cameras in the video monitoring system and displays the inputs (video) on display devices inside the vehicle.

There are four video input ports, and all of the input video data can be processed simultaneously. The generated video is of high quality and can be easily viewed due to the enlargement and reduction of images up to 1920 × 1080 pixels interlaced and up to 1280 × 720 pixels non-interlaced and the application of the VEU image processing described above.

The interface for output to the display devices has three independent channels, two of which can be used for multiplexed output to two screens to enable up to five display outputs. Each output image can be a composite of up to eight layers of video and images drawn by the GPU. Furthermore, the degree of transparency in the composite image can be controlled pixel-by-pixel, which facilitates the implementation of a high-definition, refined screen display and graphics user interface that is easy to use.

4.6 APIX interface[2)]

We adopted APIX as the image transfer interface and developed APIX (1 Gb/s) and APIX2 (3 Gb/s) high-speed I/O units (including the physical layer). The APIX is used on the MB86F332 and MB86R02 SoCs, and APIX2 is used on the MB86R12 SoC.

APIX uses current-mode logic (CML), in which changes in current are used to transfer data. It therefore features an excellent electromagnetic interference (EMI) characteristic and is rated highly as a high-speed interface for automobiles in particular.[2)]

The APIX uses sideband carrier waves for bi-directional transfer of commands and other control information, so it is possible to construct an inexpensive and highly reliable in-vehicle network with a simple configuration of twisted-pair signal line connections between ECUs.

APIX2 is compatible with APIX and is designed for high data transfer rates of 3 Gb/s down and 187.5 Mb/s up, thus enabling simultaneous transfer of two-channel uncompressed high-definition video streams, multiple-channel audio streams, and commands or other control data.

5. Conclusion

More and more automobiles are being equipped with instrument clusters, navigation systems, and other information systems, so the need for an HMI system that facilitates the understanding and operation of these systems is increasing.

In this article, we have outlined the latest trends in automobile information devices and systems, introduced our MB86R1x series of systems-on-a-chip designed for integrating them, and described the technologies developed for these systems. We will continue to develop networks for connecting vehicles to the Internet and for communication between vehicles to provide new systems and services for automobiles. Our goal at Fujitsu is the continuous development and offering of integrated products for automobile information systems.

References

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