



Selecting the Right Graphics Display Controller

Key Factors in Designing Embedded Graphics Architecture

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Introduction

From 3D rendering to image warping, the capabilities of today's graphics display controllers (GDCs) appeal to the eye across a broad range of applications. High-end GDCs help define a product's style and value with dynamic graphics that dazzle consumers. At the other end of the spectrum, modest GDCs display information clearly and simply, giving users what they want with a minimum of fuss.

Whether simply functional or absolutely dazzling, graphics deserve careful attention and reward good design in highly visible ways. The first step toward crafting good graphics is to choose a GDC that supports the application's goals with the right functionality at a suitable price point. GDC price/performance can be divided into three categories:

- Basic level – QVGA display, pre-rendered graphics, may include video input
- Mid level – WVGA display, primarily 2D dynamic graphics, 3D also possible, video input
- High level – SXGA or higher display resolution, dynamic 3D graphics, multiple video inputs

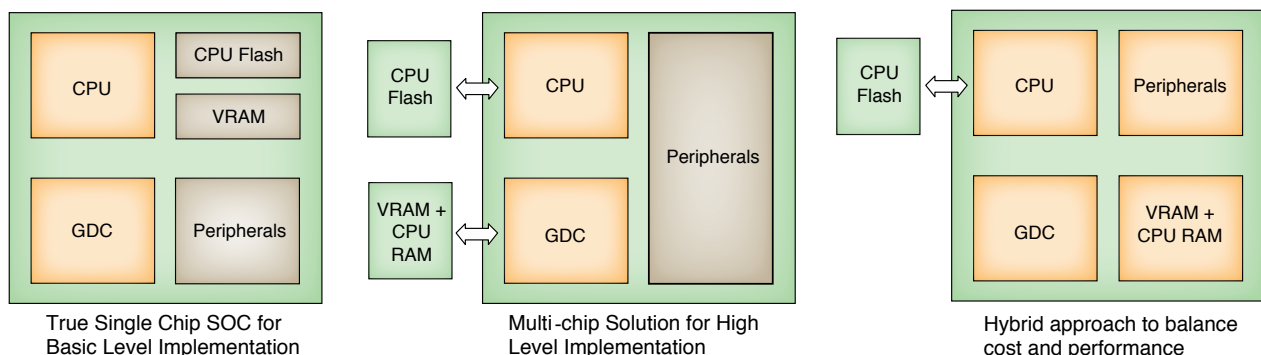
This white paper outlines the wide range of GDC features available in these three categories and describes how they

help meet applications' goals. Information at the end of the paper gives a snapshot of Fujitsu's extensive GDC family as well as a look at the company's 360° Wrap-Around Video Imaging Technology. Taking maximum advantage of GDC features is one of the most vital design tasks for today's product developers, for products ranging from treadmills and refrigerators to smart phones and automobiles.

Factors Determining Embedded Graphics Architecture

1. Cost Pressure

The automotive industry serves as a good example of a cost-sensitive application area, where one of the top priorities for system designers is to minimize the bill of materials (BOM). In basic to mid-level applications, designers can address this need by using system-on-a-chip (SoC) graphics controllers as a true single-chip solution. These GDCs can communicate with other automobile systems via the CAN bus and can go into shutdown power modes to preserve battery power. Due to the limitations of internal VRAM capacity and inherent system bottlenecks (e.g. bus speed), however, the level of graphic functionality supported, flexibility, pixel fill rate, and maximum display size of such devices is limited.



When cost considerations are less important than performance, applications can utilize high-end SoCs that are based on a multi-chip architecture. These GDCs rely on an external vehicle MCU to handle CAN traffic, power management, and peripherals such as stepper motor controllers. Additionally, because these GDCs do not have built-in VRAM and program flash memory, they have high-speed VRAM interfaces to support high performance. In the future, the use of built-in VRAM may further reduce the cost of high-end automotive GDCs.

In contrast to the automotive industry, applications such as medical, consumer white goods, and avionics have lower cost pressures. System designers may have the option of using discrete high-end SoCs where customers spend more to get better performance. If the system is not being designed from the ground up for the sake of legacy hardware or software reuse, just inserting a standalone GDC into the system can be a nice workaround.

Using a discrete CPU such as the Intel Atom, which runs at a clock speed around 1GHz, allows reuse of some hardware and software across the manufacturer's product line. Some products can use a standalone GDC that is bolted to the CPU. More price-sensitive products that require somewhat lower performance may be able to use high-end SoC products that integrate a powerful CPU with a high-end GDC core.

2. End Customers Expectation

Some application segments have to keep up with the high-end graphics common in smart phones. Examples range from automobiles to white goods.

In these applications, system designers must ensure that the GDC can create fluid, crisp graphics and that the system responds quickly to user inputs. Thus, the GDC must not impose bottlenecks in the system that create a lag in delivering the desired experience to the end user.

For basic to mid-level applications, a true single chip SoC may be suitable. For high-end applications, such devices will not provide sufficient performance, and a high-end (multi-chip architecture) SoC with external VRAM and flash memory will be needed.

If the product's display accommodates 24-bit RGB input, a GDC with 24-bit RGB output helps avoid the banding effect – abrupt changes between shades of the same color. The use of 24-bit color ensures smooth-looking graphics. Otherwise, the application may need a dithering function in the GDC for neutralizing the banding effect. Dithering applies randomized noise to the frame buffer to prevent the banding effect due to limited color depth.

While smooth, flashy graphics always have an appeal, applications such as industrial electronics equipment that prioritize rugged design and ease of use can get by just as well with more basic graphics functionality. Lower-end GDCs offer surprising performance for many uses without inflating the BOM.

3. Nature of Graphics Content – Static or Dynamic

The choice of GDC also depends on the nature of the graphics content. If the content is static and can be pre-determined, a low-cost GDC such as a sprite engine may suffice. Pre-rendered graphic bitmaps can be stored in the Sprite GDC's external flash memory. Such GDCs are very good at handling different color formats (those using a color lookup table or those having actual pixel values in the frame buffer) and can also handle transparency and alpha blending. Use of a low-overhead compression scheme, such as RLD (Run Length Decoder), can greatly reduce storage requirements for pre-rendered graphics, thus reducing cost.

Other applications need dynamic graphics content that is determined on the fly, such as maps or random animation. These applications require a GDC that has a fully functional pipeline capable of rendering 2D or 3D models with texture maps. The application may also benefit from the use of functions such as hardware lighting and fogging. For more complicated tasks, a graphics engine with shaders provides greater flexibility.

Use of a capable and flexible display controller simplifies the work of graphics implementation as well as supporting better graphics. Specifically, graphics development is significantly easier with controller features such as a flexible layering scheme and support for multiple layers and alpha planes, as well as a variety of color depths.



HMI Menu – Static Graphics Example



Dynamic Graphics Example

4. 2D or 3D Graphics

The use of 3D graphics has a major impact on the performance and features required from a GDC. For example, 3D applications demand much higher rates of vertex processing than 2D applications, along with functions such as perspective correction for texture maps and mip mapping that are needed for 3D graphics. (Mipmaps are optimized and resized version of the main texture map that are stored along with the main texture map. They are very useful in enhancing performance by helping avoid the need to resize the main texture map on the fly.)

Just adding the z coordinate for 3D graphics significantly increases processing requirements. 2D graphics rendering is much simpler, and if the content is static, it can be pre-rendered, as discussed earlier. In the cases of dynamic 2D or 3D content, a graphics engine with a full pipeline will be needed.

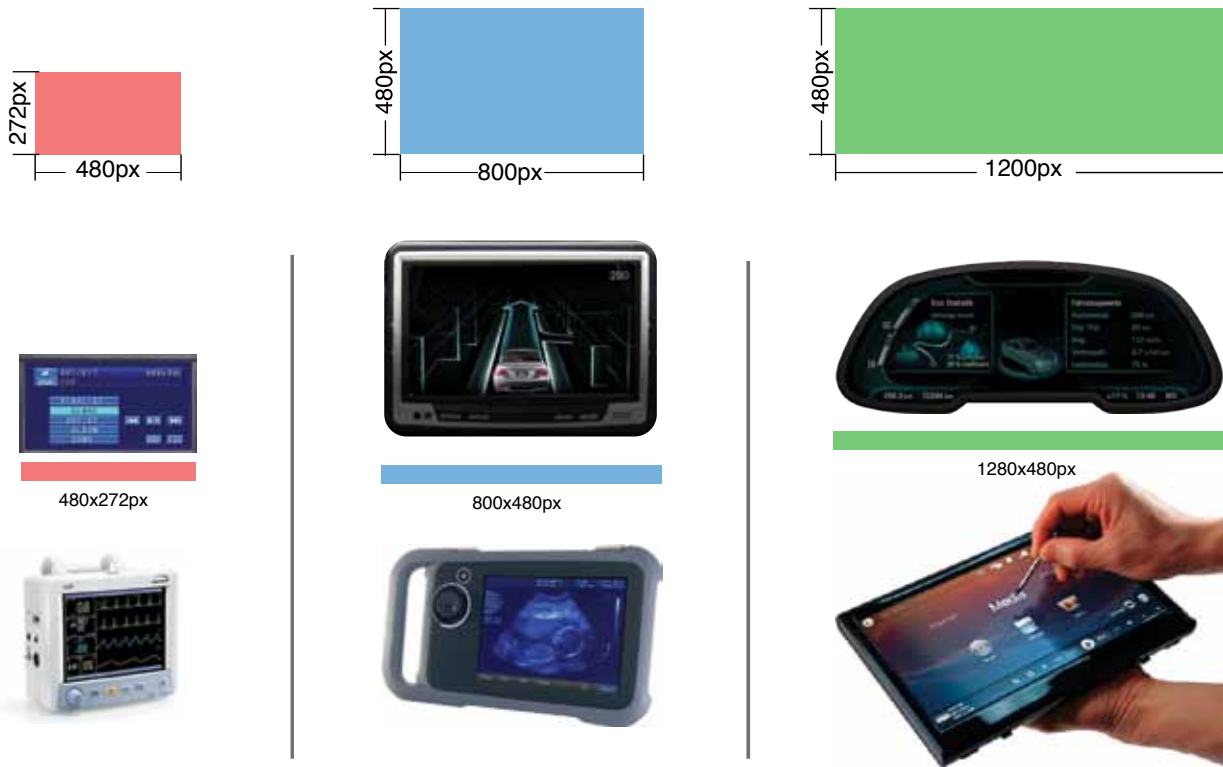
5. Display Resolution

Since larger, higher-resolution displays have more pixels to process, applications that use bigger displays need a faster, more powerful GDC. Avionics and medical applications generally require a 640x480-pixel display on the lower end and may go upwards of 1280x1024 pixels on the high end. In the automotive market, display sizes are typically 480x272 pixels for low-end clusters and center stacks, 800x480 pixels for mid-range applications, and 1280x480 pixels or higher for high-end applications.

6. Number of Displays

Whether you increase the resolution of a single display or add multiple displays, you multiply the number of pixels involved and thus increase the GDC processing requirement. You can handle that requirement with multiple GDCs, but some GDCs have display controllers that can support multiple displays using a single controller. These GDCs multiplex video output information, using twice the display or pixel clock frequency as for a single display. The dual displays must have the same timing characteristics and display resolution. This type of GDC is quite useful for automotive instrument clusters that have dual displays with identical resolution.

On the other hand, some GDCs integrate more than one display controller and can drive multiple displays that have different timing and resolution. This type of controller costs less than two independent GDCs and simplifies the design. A typical example is an automotive heads-up display (HUD), where the HUD has a lower resolution than that of the main display, such as in the instrument cluster area. Another automotive application is to use the a single GDC to control both the instrument cluster and center stack displays.



Screen Size Comparison – Popular Sizes

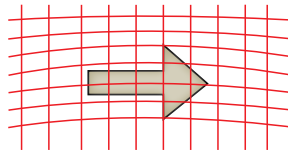
7. Video Capture Requirement

GDCs provide a range of features for displaying video input from a camera or some other source. Some GDCs integrate the analog circuitry needed to support analog NTSC/PAL video input, and these controllers can be useful in basic-level video capture applications. Other GDCs work with digital YUV/RGB video formats or require an analog converter.

Applications that require multiple video captures can take advantage of a higher-end GDC that integrates multiple video capture units. The display controller must also be more powerful to handle the multiple inputs and overlay the video stream(s) onto the rest of the graphics.



Original Camera Picture: Control the picture as texture data, by transforming YUV camera picture to RGB format



After Adjustment

Image Warping

Another application of this feature is in automotive heads-up displays. Since the image is projected on the windshield, a process similar to the fish-eye correction is needed to adapt the graphics to the windshield curvature.

Image warping requires a GDC with 3D capability. It is also useful if the GDC can scale the resolution of video images up and down.

Multi-camera Advanced Driver Assistance Systems

Another special application that could become important for automobiles in the future is the use of multiple video cameras around the vehicle perimeter whose inputs are combined into a single image. This application demands the ability to handle high-resolution video and special image processing functions to stitch together the images.

The ideal solution is a GDC with multiple video inputs and high-speed image processing capabilities, which eliminate the need for an external FPGA to implement these functions at the necessary performance level. Including 3D rendering capability in the GDC allows mapping of the stitched image onto a bowl-like surface, which enables the display of a realistic, distortion-free 360° view around the vehicle.

8. Special Requirements

Specialized requirements can drive the choice of GDCs in many cases. Some of these requirements are described in this section.

Image Warping

Video cameras have inherent fish-eye distortion that deforms the image. If the camera does not have a built-in function to correct the issue, as is often the case, the GDC needs to correct the distortion using a process called image warping. This process maps the video input to a 3D surface characterized to cancel out the fish-eye distortion. The surface is generated from a mesh that consists of a set of (x, y, z) points, as shown in the figure below.



Fujitsu 360° Wrap-Around Video Imaging Technology

Safety Applications

In the automotive industry, features such as image enhancement and object detection can help avoid accidents and save lives. Implementing such features requires special image processing blocks in the GDC.

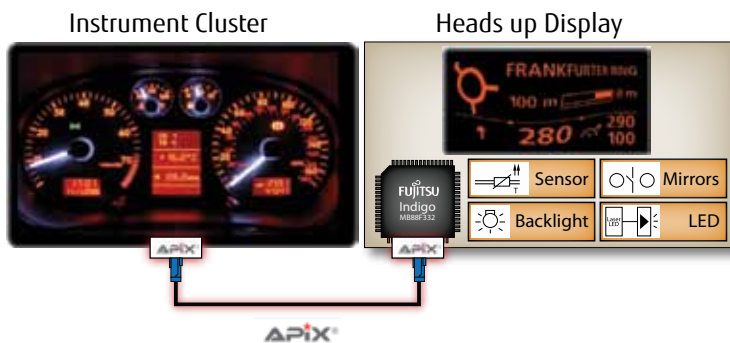
Some regions of the world mandate safety functions such as a signature unit – a checksum function that ensures that the graphics content is shown at the correct location on the display panel. Having this capability built-in saves cost and CPU overhead.

Legacy Hardware/Software Support and Standalone GDC Requirement

Some applications must reuse the CPU from previous designs to support legacy requirements and cannot just be designed from the ground up. These applications can often make good use of standalone GDCs that do not have built-in CPUs and can communicate with the legacy CPU via a memory, PCI, or PCI Express bus. This approach enables a scalable design with a variety of performance levels and feature sets.

Serial Link Connection with a Remote Display

Some applications require the display to be located remotely from the GDC. A high-speed serial bus such as APIX is needed in such cases to transmit the video to the display. This configuration allows use of a client/server architecture, in which the GDC acts as the server and the display as the client. Developing client and server systems independently helps reduce software and qualification costs on the server side because one PCB can be scaled for use across an entire product line. Such an implementation is highly effective if the high-speed serial output functionality is integrated in the GDC.



Automobile Remote Display with High-Speed Serial Link

High Quality Display/ UXGA	Carmine OpenGL ES 1.1, PCI, Dual Video in and out	Ruby OpenGL ES 2.0 OpenVG 1.1 support IRIS, PCIe	ARM Cortex Emerald-P Faster Cortex-A9 OpenGL ES 2.0 IRIS, APIX	ARM Cortex Emerald-L	HIGH LEVEL
Middle Quality Display/ WVGA	Coral-Q, -B, -PA	Jade Family 3" Gen. GDC + ARM9 APIX, T-CON	ARM Cortex Emerald-L OpenGL ES 2.0 OpenVG 1.1 support IRIS + CortexA9		MID LEVEL
Meter & Display/ QVGA	Lime, Mint	Indigo Sprite, APIX, T-CON	Indigo-L Sprite, APIX, T-CON Optimized peripherals and package	Sapphire Sprite/Draw/NTSC + FR81S 90nm Flash APIX, T-CON	BASIC LEVEL

Fujitsu GDC Product Lineup

Fujitsu's GDC Offerings

As shown in the figure below, Fujitsu offers a wide range of GDCs that span the spectrum of application categories from high to basic. In each category, Fujitsu offers an SoC that integrates a CPU, GDC, and peripherals; these devices are described separately below. The Fujitsu line of standalone GDCs are an attractive option if the system is not being put together from the ground up and there is some legacy component in the system that needs to be preserved.

The following products are ideal for cost-sensitive applications requiring basic standalone GDCs:

- MB86291 "Scarlet" is a second-generation GDC, capable of 3D rendering with a geometry processor, and the device supports both video output and input. A 2MB built-in VRAM saves board space and cost.
- MB86276 "Lime" and MB86277 "Mint" are GDCs that do not include a geometry processor, but still support a z-buffer. Lime can drive two multiplexed displays simultaneously. Lime and Mint (as well as Scarlet) have an SRAM interface for connecting to an external CPU.
- MB88F332 "Indigo" is a specialized device for APIX applications. It has all the necessary MCU peripherals for automotive use, including pulse-width modulators (PWMs), stepper motor controllers, analog-to-digital converters (ADCs), etc.
- MB88F333 "Indigo-L" is a low cost version of Indigo. It is based on the same architecture, but has an optimized peripheral set and a smaller package to reduce cost.

Fujitsu mid-level applications that balance cost, features and performance:

- GDCs in the MB8629x “Coral” family are fully capable, standalone 3D products. These GDCs operate at clock speeds as high as 166MHz.

Fujitsu’s high-end standalone GDCs offer outstanding performance and/or suit specialized applications. All of these standalone products enable scalable GDC implementation with an external CPU:

- MB86297 “Carmine” is a very powerful OpenGL ES 1.1 product that supports dual independent video inputs and outputs.
- MB86298 “Ruby” is the latest standalone GDC based on the OpenGL ES 2.0 core with shader engines. This product supports four independent video inputs and two video outputs.

Fujitsu’s SoC GDC products combine the CPU, GDC, and peripherals in a single device to provide a high level of integration at an attractive cost:

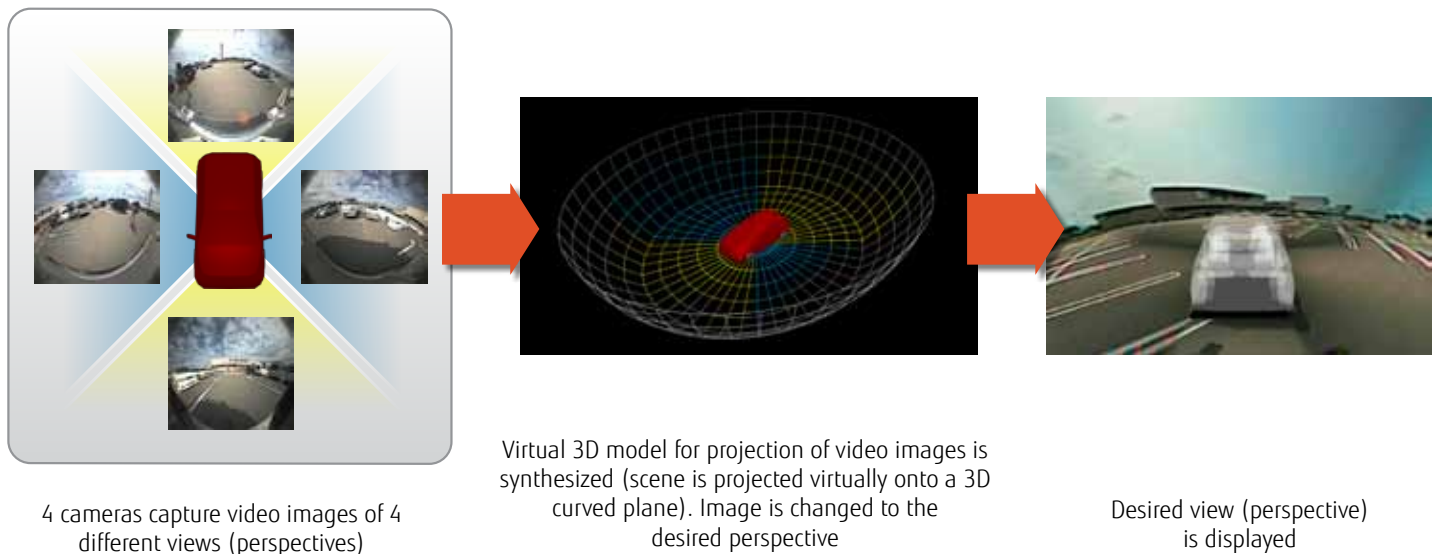
- MB91590 “Sapphire” is based on Fujitsu’s proprietary 32-bit RISC MCU and includes a dual-core GDC consisting of Bit Block Transfer (BitBLT or BLT) and Sprite engines. The SoC integrates 1MB CPU Flash and up to 800KB VRAM and also provides an external interface for parallel or serial Flash. Sapphire has proven useful for basic-level products that allow use of pre-rendered graphics and drive a relatively small screen. Because Sapphire also supports analog and digital video inputs, it can be useful for simple camera applications.
- For mid-range applications, the MB86R0x “Jade” Series offers feature-rich, cost-effective SoC solutions. Devices in this family boast a powerful ARM926EJ-S CPU at 333MHz and include a full 3D graphics engine. The Jade series

supports independent dual video inputs and outputs. One member of this family, MB86R02 “Jade-D”, supports APiX and another, MB86R03 “Jade-L”, implements a reduced feature set that suits low-cost systems. Otherwise, the Jade series is well suited for mid-range applications that may have dynamic content and need a 3D pipeline, but the display resolution is in the 800x480-pixel class. Series members can also support higher display resolutions – as high as 1280x768 pixels. The combination of video capture and 3D capability in these devices enables image warping for correction of camera or screen distortion.

- MB86R1x “Emerald family” are the most recent Fujitsu 2D/3D graphics SoCs with an integrated GDC and GPU. This state-of-the-art device comprises a power ARM Cortex-A9 processor up to 533MHz and contains an OpenGL ES 2.0 implementation with shader engines. Emerald has four independent video inputs, as well as three independent video outputs. It also offers a rich peripheral set. These features make Emerald a highly attractive device to support dynamic and rich 3D content for display at high resolutions. With multiple video inputs and built-in image-processing functions, Emerald is also well suited for multi-camera driver assistance and safety applications. The main differences between Emerald-L and Emerald-P are that Emerald-P runs faster (533MHz CPU clock versus 400MHz) and has APiX interface for high speed serial pixel link implementation.

Fujitsu 360° Wrap-Around Video Imaging Technology – A Toolset for Multi-camera Advanced Driver Assistance Systems

Fujitsu also offers 360° Wrap-Around Video Imaging Technology as a multi-camera driver assistance and safety application. Available as a toolset for use with Fujitsu graphics SoCs, the Fujitsu technology uses advanced 3D algorithms to smoothly combine images from four cameras to provide a 360 degree



Overview of 3D Virtual Image Projection Conversion Technology

omnidirectional view of a vehicle's surroundings. A key additional innovation of the Fujitsu technology is the ability to provide a dynamically definable perspective or a "free eye point." System designers and drivers can take advantage of the "free eye point" to select the optimal perspective for any given driving situation – including a virtual three-dimensional "third person" view of the vehicle and its surroundings.

The Fujitsu 360° Wrap-Around Video Imaging Technology is available with a full set of authoring tools and library and device drivers for ready integration with the Fujitsu line of 3D

graphics display controllers. System designers can combine the technology with the MB86R11 "Emerald-L" graphics SoC, with integrated GDC and GPU for a powerful single-chip omnidirectional viewing solution.

In conclusion, the enormous range of today's GDC capabilities makes device selection a crucial part of application development. Fujitsu helps make this selection easier by offering a variety of GDC options tailored to meet various application segments. These GDC choices are feature rich, proven in the industry, competitive, and cost effective.

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