Development of High Quality Image Processing Technology for vehicles "Vivid View Processor"

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Abstract

FUJITSU TEN LIMITED has been developing High Quality Image Processing Technology, which analyzes vividness and color of the images for on-board displays and achieves higher quality images with most appropriate and real-time compensations, collaborating with FUJITSU LIMITED and FUJITSU LABORATORIES LIMITED.

This report describes a new LSI, "Vivid View Processor", which we have developed with the technology mentioned above.

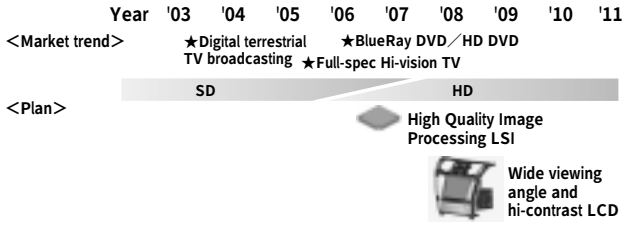
In accordance with the spread of DVD videos and digital terrestrial televisions, the time for enjoying videos in a vehicle is increasing. The LSI compensates for the best "contour", "contrast" and "color", analyzing the contour characteristic, color, gradation distribution by each image scene, in addition to the conventional image quality compensation. The textures of the subjects, the expressions of luster and the vividness look are greatly improved, and "sharp / clear / vivid" videos are displayed. Besides, this LSI achieves image quality compensation appropriate for on-board displays, slim-downed circuit, downsized packaging, and lower power consumption, and those enable the LSI to be installed in the AVN display unit.

This LSI is installed in the new Wide VGA*-type AVN products released in June 2007 of "ECLIPSE": FUJITSU TEN car AV products.

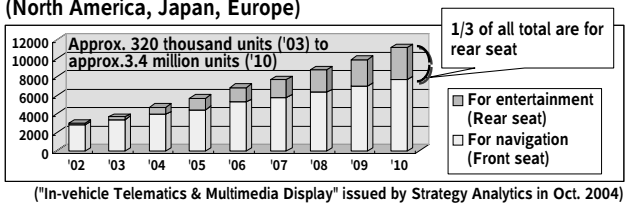
*Wide VGA: Wide Video Graphics Array (800x400 pixels)

1 Introduction

Matching the trend towards digital terrestrial TV broadcasting, it's becoming possible to enjoy high quality images on displays in vehicles, like images on displays at home. Especially, with the spread of rear seat entertainment and Hi-vision images such as by Blu-ray Disc and HD DVD, bigger size and higher quality of images for on-vehicle displays will be required. Fig.1 shows the trend towards Hi-vision and of on-vehicle display market.



Forecast of On-vehicle Display Market (North America, Japan, Europe)



("In-vehicle Telematics & Multimedia Display" issued by Strategy Analytics in Oct. 2004)

In accordance with the on-vehicle displays bigger in size (8 to 11 inch for rear seat) and trend towards HD (digital broadcasting and DVD), on-vehicle displays tend to be required for higher quality images similar to displays at home.

Fig.1 Trend towards Hi-Vision and of on-vehicle display market

FUJITSU TEN LIMITED has been aiming at higher quality images by processing image signals appropriate for on-vehicle displays, collaborating with FUJITSU LIMITED and FUJITSU LABORATORIES LIMITED, and finally we have co-developed the High Quality Image Processing LSI: "Vivid View Processor".

This LSI is installed in the new Wide VGA (1) type AVN (Audio Visual Navigation) products released in June 2007 of "ECLIPSE": FUJITSU TEN car AV products. This technology can show a higher image quality than wide VGA, which already achieved for an outstanding high-resolution.

This report describes the image-processing algorithms developed for on-vehicle products, approaches towards designing hardware (LSI), and comparison results to conventional products.

2 Overview of High Quality Image Processing LSI

2.1 Overview

The LSI we have developed, can analyze contour characteristics, color and gradation sequence distribution of each image scene, and compensate to optimize "contour", "contrast" and "color" in addition to the conventional image quality compensations. With this processing, texture of subjects, expression of luster and vividness on face are greatly improved, and "sharp / clear / vivid" images are displayed.

2.2 Characteristics

Fig.2 shows the schematic of High Quality Image Processing LSI. This LSI broadly consists of two kinds of image signal processing circuits.

①Contour compensation part

Aiming at displaying sharp images even on a compact size display, this LSI automatically adjusts contour compensations and strength of noise removal.

②Color Compensation Part

Aiming at displaying colors appropriate for an on-vehicle display, this LSI controls colors optimally (static color compensation) such as for skin or blue sky, and simultaneously controls gradation sequences such as for sharpness by each scene.

The on-vehicle displays are for multimedia, not only for TV. Therefore, this LSI enables a fine setting for each video source (such as analog TV, digital TV, DVD Video and navigation unit).

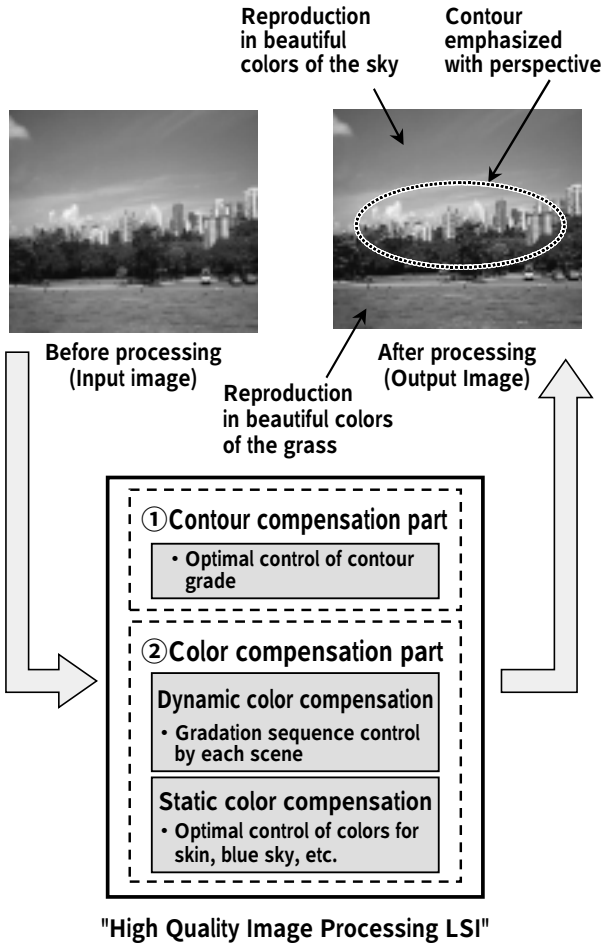


Fig.2 Schematic of High Quality Image Processing

*(1) Video Graphics Array

3 System Configuration and Issues

3.1 System Configuration

In order to make the configuration capable of high quality image processing for all images displayed on the AVN screen, we developed this LSI on the premise of its being installed on front display panel boards. Fig. 3 shows the system configuration diagram.

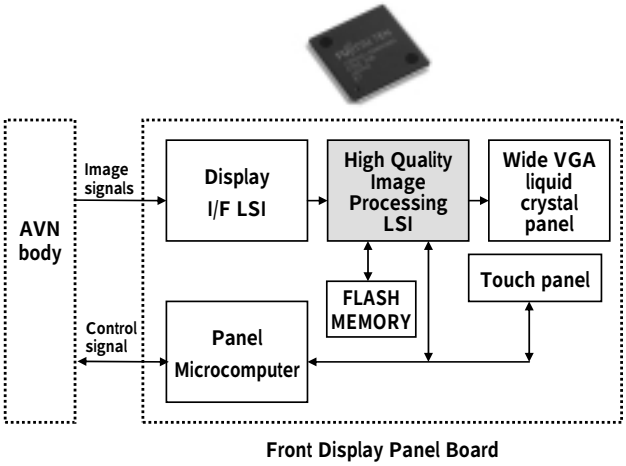


Fig.3 System Configuration Diagram

3.2 Issues for Commercialization

The issues for commercialization are as follows.

1. Downsizing to the mountable size for the free space on a display panel board and lower power consumption
2. Respective parameters setting function by each image source, and the corresponding time crunch in switching the image sources (fast boot function)
3. Processing at dual screen display (Range setting function for high quality image processing)
4. User adjustable function (simple operation on a touch panel)
5. Reduction of clock types to reduce noises

We commercialized this technology by solving the 5 issues above. The approach is set out in 5.1 to 5.5

3.3 Issues for High Quality Image Processing

The issues for high quality image processing are as follows.

In this development, we aimed for expressing powerful and alive quality of images with processing original images of DVD videos or TV. For these purposes, input images need to be controlled respectively regarding noise rejection, contour emphasis and color control that were conventionally controlled with fixed values. Besides, the automatic adjusting function is needed for advanced image composing appropriate for the environment on a vehicle.

4 Algorithms for On-vehicle Products

The high quality image processing consists of two kinds of technologies, contour compensation and color compensation, and the color compensation also consists of 2 kinds of processing, static processing and dynamic processing. The respective technologies are described as follows.

4.1 Contour Compensation

Fig. 4 shows the block diagram of contour compensation processing. Analyzing the input images, the contour is adjusted automatically using noise removal filter and emphasis filter separately depending on the image character. Fig. 6 and 7 show the respective images, before and after the application of contour compensation. The noises standing out against the plain part such as the sky are reduced, and the contour is emphasized to the appropriate level such as for flowers and branches. These enable composing nontextured and sharp images, and the on-vehicle panels can display images with real depth.

Besides, signal analyzing processing and filter processing can be customized with parameter setting. This enables contour compensation processing most appropriate for the characteristics of various image sources applied to on-vehicle devices.

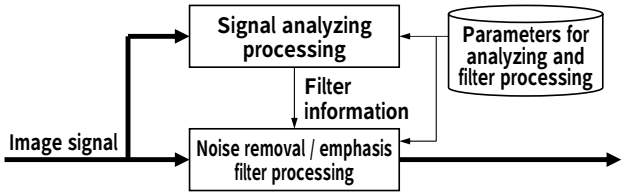


Fig.4 Block Diagram of Contour Compensation Part

4.2 Color Compensation

Fig. 5 shows the block diagram of color compensation processing. Broadly classified, there are dynamic color compensation processing described in the first block, and static color compensation processing described in the succeeding block.

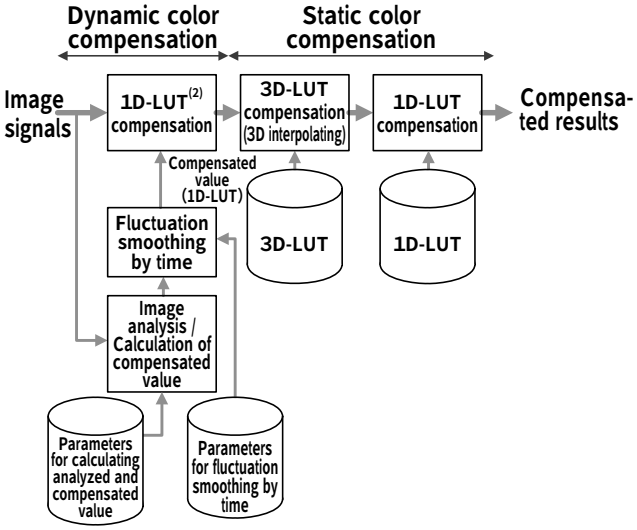


Fig.5 Block Diagram of Color Compensation Part

∗(2) LUT: Look Up Table (color compensation value)

Fig.6 Original Image

Fig.7 Contour Compensated Image

Notable points

- The contours such as of cherry blossoms and branches are made clear.
- The image captures spacial effects.

Fig.8 Contour and Color Compensated Image

Notable points

- The blue sky and cherry blossoms are clearly colored.
- The leaves shaded by cherry blossoms are clear.

As for dynamic color compensation, judging characters of a scene, the appropriate gradation sequence characteristics shall be set depending on the character. For example, sharpness shall be added selectively only for the scene lacking sharpness.

As for static color compensation, colors shall be compensated based on the compensation values previously set (Look Up Table). The Look Up Table shows cross-references in color values between before and after the compensation. This table is used for adjusting subtle colors, for example, when set for skin colors in accordance with the characteristics of a liquid crystal panel used.

4.2.1 Dynamic Color Compensation

The dynamic color compensation consists of 2 kinds of processing, one is to decide compensation values by frame with analyzing images, and the other is to smooth the fluctuation of compensation values by time.

Regarding the processing of the compensation value calculation by frame, analyzing histograms of the image data, etc. to be compensated, the compensation values for dynamic range (sharpness with black and white) and for the gradation sequence such as of brightness shall be calculated. The compensation values should be in the 1D Look Up Table (1D-LUT) style, capable of at will gradation sequence designation.

In the environment of a vehicle, stronger compensation in visibility tends to be preferred. Our technology automatically divides scenes looking unnatural (simple scene, etc.) with the stronger compensation, and controls the compensation values. Besides, this processing consists of parameters detailing the relationship between the histogram characteristics and the compensation values, and enabled a calculation of the stable compensation values.

Regarding the smoothing the fluctuation of compensation values by time, so as to control "flickering" visible when the fluctuation of compensation values by time is large, interpolating some compensation values to the just before compensation, the process smoothes fluctuation of compensation values by time. However, if the fluctuation by time is made too smooth, the changes of compensation values can't follow scene changes. Our new technology is in the configuration possible to set fine time constants of compensation value fluctuation, adjustable most appropriate for the environment of a vehicle.

4.2.2 Static Color Compensation

In the static color compensation processing, in addition to the conventional compensation with 1D-LUT, the compensation with 3D Look Up Table (3D-LUT) is possible.

The advantage of the compensation with 3D-LUT is that the fine compensation values can be set individually for various colors. For example, the setting for skin is to control chroma saturation and to eliminate redness, and the setting for blue of the sky is to emphasize chroma saturation and to compensate hue to bluish colors. Fig. 8 shows an example of a compensated result.

The color adjustment function with 3D-LUT requires a huge memory, if keeping all colors in 3-D as a table. Therefore, the function was implemented in the style of the memory with some separate tables and the interpolating calculations between their tables.

5 Specialized LSI Development Towards Commercialization

Based on the algorithms for contour and color compensation processing explained in the previous section, the specialized LSI has been developed. In this section, the main efforts responding to the issues for commercialization stated in section 3.2 are discussed.

5.1 Downsizing and Lower Power Consumption

The development target was narrowed down to displaying on the approx. 7-inch panels of wide VGA and wide EGA, aiming to simplify internal processing and optimize circuits. These efforts achieved mounting on QFP144 pin package in the size of 20 mm in length and width and lower power consumption, and enabled installation to the boards of AVN front display panel.

5.2 Individual Parameter and Fast Boot Function

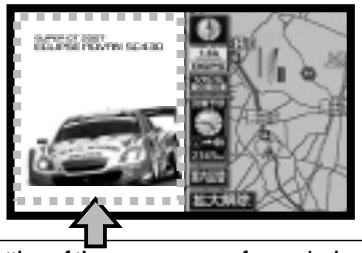
In this LSI, all kinds of image sources possible to be displayed on-vehicle models are input. So, the most appropriate compensation for each image source, every time the image sources are changed, requires updating compensation parameters, and similarly requires updating them whenever users adjust image quality. In this case, the LUT shown in Fig. 5 needs to be updated. But, there was a problem that it takes too long for a CPU directly to update values in LUT, which is because the size of 3D-LUT is too big.

To update the LUT at high speed, this LSI has the function of transferring data from FLASH memory to RAM data, and updating LUT with the command issued by CPU. Therefore, updating within the time for switching sources became possible.

5.3 Dual screen Display Processing

The characteristics for on-vehicle models are to have a function of dual screen display (such as displaying navigation and TV screens simultaneously). The dynamic compensation processing analyzes images and produces LUT compensating gradation sequence in accordance with image characteristics. Therefore when there are 2 different images such as at dual screen display, it's impossible to analyze images correctly. Also there is a risk that the compensation processing for one image with the produced LUT may have a bad effect on the other.

For this reason, the setting of screen range for analyzing and compensating was made possible. Now, even at dual screen display, it's possible to compensate colors appropriate only for TV.



The setting of the screen range for analyzing and compensating is adjustable. This makes it possible to compensate colors appropriate only for TV.

Fig.9 Dual-screen Display Processing

5.4 Display Adjustment Screen

On this LSI, the touch-switch with which users can switch the strength of high quality image processing within 4 levels, "Off-Low-Mid-Hi", has been set. Using this function, users can select simply their favorite image quality. Fig. 10 shows the GUI operation screen.

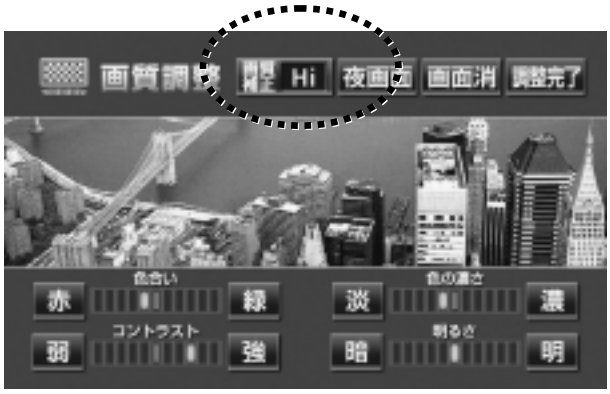


Fig.10 Display Adjustment Screen (Image Quality at Hi-mode Compensation)

5.5 Noise Reduction Method

If there are multiple clocks on one board, beat noises tend to be generated due to mutual interference. This LSI enables noise reduction, using dot-clock for input images as a system clock, instead of having crystal oscillator outside.

6 Effect Confirmation

Here, the effect confirmation regarding the developed High Quality Image Processing LSI is explained. Adjusting parameters such as for color processing, effects of the High Quality Image Technology were confirmed on an actual model.

6.1 Parameter Adjusting

The parameter adjusting for color and contour compensation was confirmed visually with displayed quality of natural images. However, regarding color compensation, as it is difficult to adjust multiple parameters most-appropriately only by eye, measuring instruments were also used for adjusting.

In particular, the measuring instruments are used for adjusting basic brightness (color temperature [3], maximum luminance, grey balance, gradation sequence characteristics) on panels. Setting gains to RGB color compositions is for the color temperature of white point and maximum luminance, and setting gradation sequence characteristics of RGB color compositions is for the grey balance and gradation sequence characteristics. All of them respond to parameters of static color compensation.

The adjustments by eye were used mainly as follows: Reproduction of highlights or shadows (luster or sharpness), Expressions of overall clearness, colors that people remember as ideal colors (memory colors), such as skin color, sky blue or plant's green, Strength of contour compensation.

Reproductions of highlights or shadows were adjusted so as to show enough sharpness within the visible change of the gradation sequence, mainly responding to parameters of dynamic color compensation. On the other hand, expressions of clearness or memory colors respond to parameters of static color compensation. The clearness was adjusted so as to show enough clearness within the ranges as follows: No unnatural color on the neighbor colors of an achromatic color, Smooth change of gradation sequence in clear colors, No unnaturally deep colors for skin, No impression of noise growth. The expressions of the memory colors were adjusted mainly in each color hue so as to give natural impression by eye. The strength of the contour compensation was adjusted so as to express the sharpness of contour edges, while controlling noises.

6.2 Subjective Evaluation

In order to confirm effects of High Quality Image Processing technology for on-vehicle products, the subjective evaluation was implemented.

6.2.1 Purpose

- Comparing models having High Quality Image Processing LSI with conventional models
- Confirming evaluations to luminance-based and color-temperature-based parameters (reflection into adjusting products)

6.2.2 Evaluation Method

Evaluated Models

- Conventional models: 3 models (A / B / C)
- Developed models: 2 patterns (parameters equivalent to 07 model D (luminance-based parameters: color temperature adjustment is controlled and luminance is set at high) / parameters equivalent to 07 model E (Color-temperature-based parameters: luminance lowering is allowed and color temperature is adjusted higher)

Image contents for evaluation

①Cat: Scene with a white cat on a black chair against the white background
②Sea: Scene at the blue bottom of the sea
③Flowers: Scene with colorful flowers
④Sumo: Scene of Sumo covered live
⑤Baseball: Scene of baseball game (with scores)

Evaluation method

①Rating in 5 Different Images

Displaying the same 5 kinds of images (Cat, Sea, Flowers, Sumo, Baseball) on the 5 different AVN models (conventional 3 models and developed 2 patterns), favorite AVN units shall be ranked for each image (ranking method). At this ranking, giving 4 points for the 1st, 3 points for the 2nd, a graph was made to show the results that the sums were divided by 31, total number of raters, with the point on the vertical axis.

②Best Choice in 5 Models

Displaying 5 types of images in a row, 1 model that one wants to buy was selected among 5 AVN models.

The evaluation conditions were based on ISO6658 and 31 nonspecialists evaluated models.

*(3) Refers to the light radiated by black body, and expresses a light color (It is indicated by black-body temperature). In principle, it is used for expressing a white color on displays. The hotter it is, the more bluish the color is in, and the cooler it is, the more reddish the color is in.

6.2.3 Evaluation Results

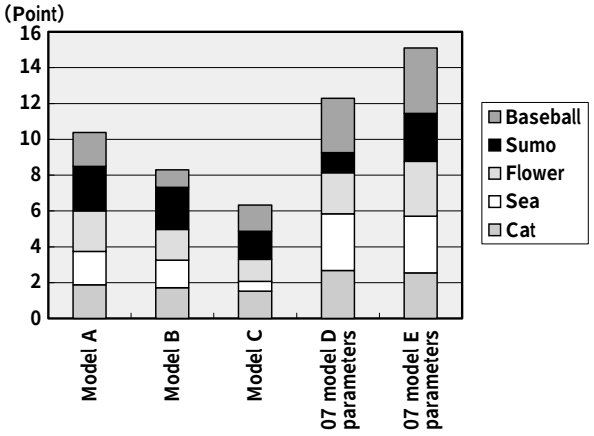


Fig.11 Subjective Quality Evaluation Rating in 5 Different Images

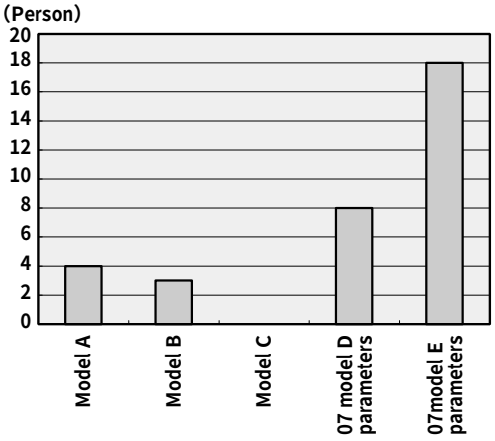


Fig.12 Subjective Quality Evaluation Best Choice in 5 Models

Fig. 11 shows the result of Evaluation ① (Rating in 5 Different Images). The result in this favorite ranking was: 07 model E parameters → 07 model D parameters → Model A → Model B → Model C.

Fig. 12 shows the result of Evaluation ② (Best Choice in 5 Models). The result was: 07 model E parameter → 07 model D parameter → Model A → Model B → Model C.

The model C and the units equivalent to 07 models have the same LCD panels and touch panels. With these results, we can judge that the High Quality Image Processing LSI had effects. Also, we recognized that 07 models are popular among many people, compared to conventional models.

Comparing parameter D to parameter E, the color-temperature-based parameter E was more popular than the luminance-based parameter D. We found that the color temperature shall be considered thoroughly in addition to the luminance so as to achieve a popular image quality. The new products have the parameters set based on these results.

7 Conclusion

As above, we have explained the development of High Quality Image Processing LSI that enables sharp / clear / vivid image composing.

The models with this LSI installed allowed us to enjoy images of digital TV or DVD videos at a high quality level on a vehicle. Considering that this need for higher image quality on a vehicle will be spreading to other applications, we continue to develop this technology.

<Trademarks>
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