

Design of an Image Processor for UXGA Class LCD

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Abstract

We propose a universal image processor for a-Si TFT LCD of UXGA class that can display the full screen on the LCD panel with low resolution of video sources such as NTSC, VGA, SVGA, XGA, and SXGA by using the proposed interpolation filter. In addition, we propose a real-time contrast controller for image improvement of multi-gray scale image.

The operation of the proposed methods has been verified using Synopsys VHDL and computer simulation. Results show that the proposed methods might be suitable for a UXGA LCD controller for real-time image improvement.

Keywords : LCD controller, contrast controller, interpolation filter

1. Introduction

With rapid progress in the information industry, multimedia electronic systems is continously changing The role of display systems that connect human with variable electronic devices is getting more important. LCD(Liquid Crystal Display) is a device that can replace existing CRT(Cathode Ray Tube) monitor, which is bulky and dissipates greate amount power than the LCD. The main advantage of LCD includes lightweight, thinness, high-resolution, and low-power operation.

Generally, the means of image enhancement are utilized to contrast control, edge enhancement, and noise reduction. However, it is true that these methods do not increase the inherent information contents image data [1-2].

In this paper, we describe the proposed interpolation algorithms and contrast control method for improving image quality of an LCD and show how it is applied to the proposed algorithm. The interpolation algorithm is described in Section 2. We describe the proposed contrast control video processing techniques in Section 3. Finally, we explain the architecture of the proposed method in Section 4.

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2. Image Scaler

There are three interpolation filter blocks for R, G and B color in the universal LCD controller, respectively. The proposed interpolation filter consists of an FOI (First Order Interpolation) filter for the horizontal interpolation and an adaptive window filter for the vertical interpolation. The FOI filter is suitable for real-time processing. The proposed adaptive window interpolation algorithm is a modified method of the median filter [3-5]. The proposed algorithm can easily be implemented by CMOS VLSI technology and provides almost similar level of performance as median filter.

2.1 The proposed adptive window algorithm

The adaptive window algorithm performs interpolation by converting a settlement of sub-window as correlationship among neighbored pixels of an arbitrary pixel in existing H-shaped method [4]. Generally, it was known that H-PMED method shows a superior performance in part of vertical edge, e.g, in the case where correlation of horizontal pixels is larger. We have used original sub-window of H-PMED in vertical

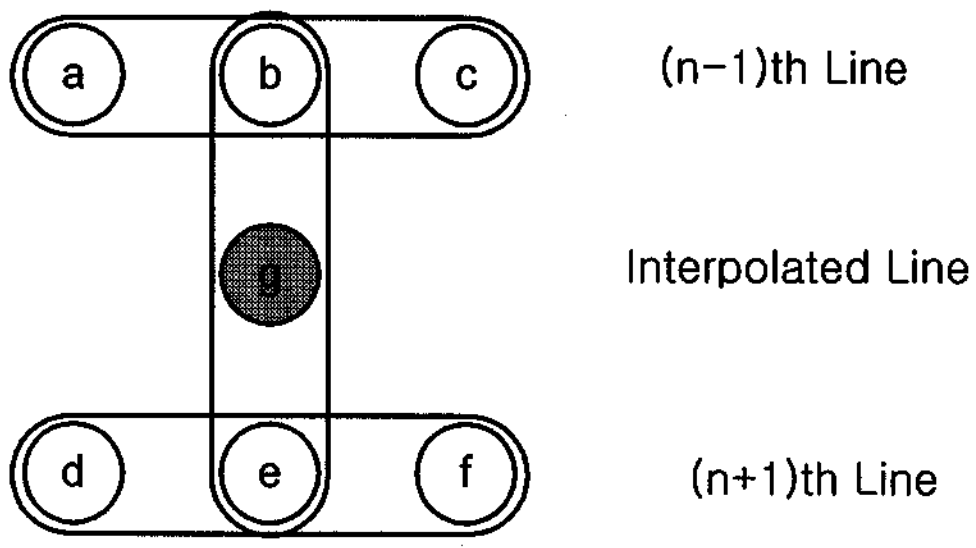


Fig. 1. H-shaped PMED filter.

edge and newly proposed sub-window in horizontal edge.

The interpolated pixel g is given by Eq. (1), which includes a linear and nonlinear operation of spatially neighbored pixel through horizontal and vertical direction[5].

$$\begin{aligned} g &= \text{PMED}\{a,b,c,d,e,f\} \\ &= 0.5\times\max[\min\{a,b,c\},\min\{d,e,f\},\min\{b,e\}] \\ &\quad +0.5\times\min[\max\{a,b,c\},\max\{d,e,f\},\max\{b,e\}] \end{aligned} \quad (1)$$

Eq. (2) is the equation to determine the correlation among neighbored pixels, where SH and SV represent the correlation in horizontal and vertical direction, respectively.

$$\begin{aligned} SH &= |a-c|+|d-f| \\ SV &= |a-d|+|c-f| \end{aligned} \quad (2)$$

In Eq. (2), the smaller one between these two values has a stronger correlation. That is, if SH is larger than SV, the correlation is stronger through vertical direction, otherwise, through horizontal direction. Figure 2 shows the pixel group that is used for determining the correlation.

If the correlation of vertical direction is stronger, sub-window is transposed as in Figure 3. Then, the interpolated pixel g is given by Eq. (3).

$$\begin{aligned} g &= \text{PMED}\{a,b,c,d,e,f\} \\ &= 0.5\times\max[\min\{a,b,d\},\min\{c,e,f\},\min\{b,e\}] \\ &\quad +0.5\times\min[\max\{a,b,d\},\max\{c,e,f\},\max\{b,e\}] \end{aligned} \quad (3)$$

The proposed adaptive window algorithm is performed as in Figure 4. First, the algorithm determines the correlation of pixels and then, executes interpolation with selected sub-window.

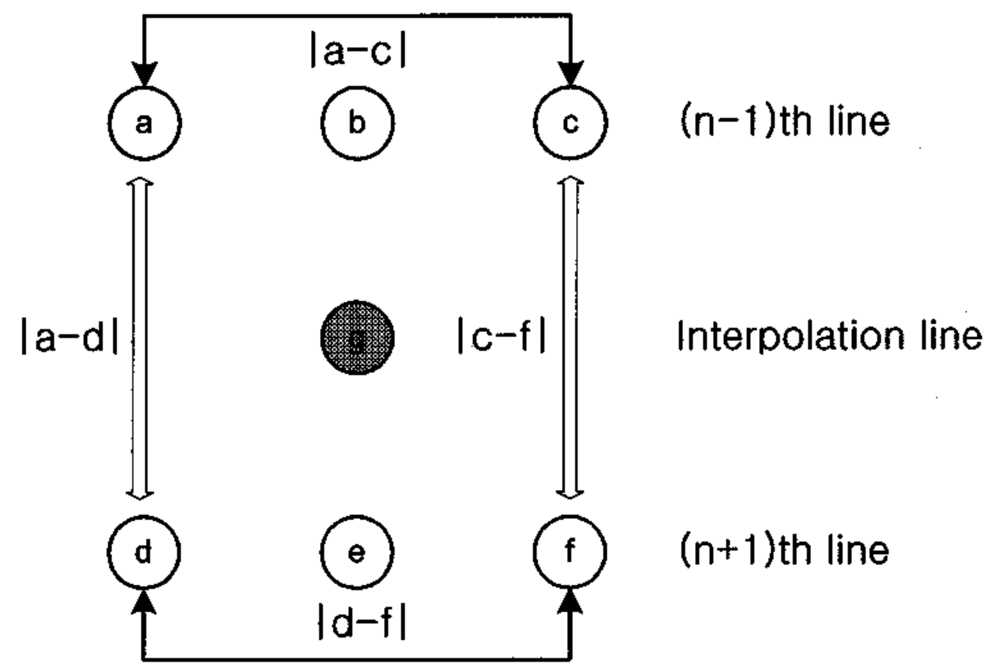


Fig. 2. group of pixels for determing correlation.

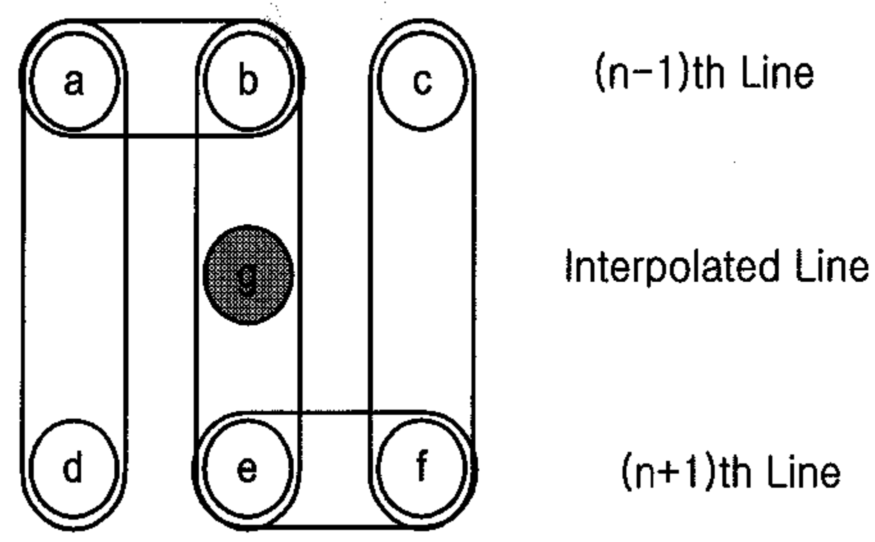


Fig. 3. ettlement of vertical direction sub-window.

SH=abs(a-c)+abs(d-f)
SV=abs(a-d)+abs(c-f)

If(SH<SV) then
new pixel=0.5×max[min{a,b,c},min{d,e,f},min{b,e}]
+0.5×min[max{a,b,c},max{d,e,f},max{b,e}]
else
new pixel=0.5×max[min{a,b,d},min{c,e,f},min{b,e}]
+0.5×min[max{a,b,d},max{c,e,f},max{b,e}]

2.2 Simulation results

The simulation for the proposed interpolation algorithms is by the following procedures. After eliminating the even rows of sample images that are semi-moving the image "salesman (512×480)" and still image "lena (512×480)" by C language, the eliminated lines are interpolated by existing interpolation algorithms (FOI, ZOI, H-PMED) and the proposed algorithm. Then, we compare and analyze the interpolated image and the original image by placing the focus on PSNR(peak signal noise ratio), which is the objective method of image comparison and the subjective assessment of the image quality.

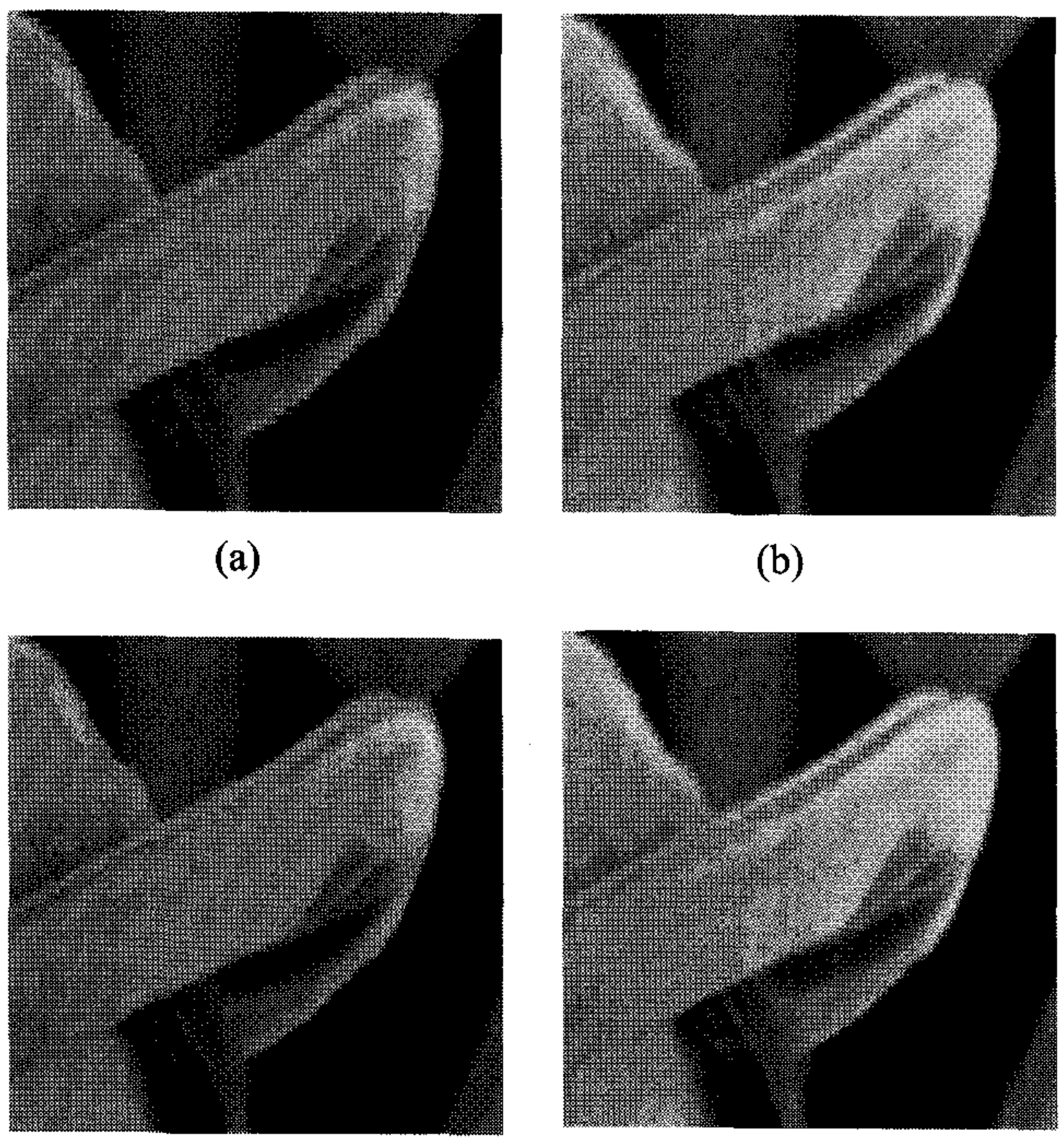
TABLE 1. Comparison of PSNR(Lena image).

	Proposed	H-MED	FOI	ZOI
LENA	37.387707	37.388317	37.591469	32.42594

TABLE 2. Comparison of PSNR(several frames of salesman).

	Salesman (Frame1)	Salesman (Frame9)	Salesman (Frame13)	Salesman (Frame20)
Proposed	39.977730	40.089432	40.049458	39.793667
H-PMED	39.83322	39.833221	39.902935	39.658085
FOI	41.166840	41.306297	41.238968	40.882095
ZOI	34.040150	34.261944	34.185131	33.917812

Table 1 and Table 2 show the PSNR results of each sample image(Lena and Salesman) for each interpolation method. The results show that the proposed algorithm achieves close results as the H-PMED in the case of lena (still image), and the proposed algorithm is better than the H-PMED in the case of salesman(semi-moving image).



(a) (b) (c) (d)

Fig. 4. Processed result (a) ZOI (b) FOI (c) HPMED (d) The proposed algorithm.

FOI results in high PSNR, but represent staircase phenomenon in edge image. It is more apparent in lena. However, the proposed algorithm shows excellent results in the subjective assessment as well as in PSNR. Figure. 4 shows the results of enlarged lena images that are interpolated by each algorithm.

2.3 Vertical scaler

The vertical scaler consists of four parallel filter blocks. In addition, the vertical scaler processes simultaneously four pixel data with only clock(DCLK2), as shown in Figure 5. Selector3 block chooses current or previous line data for interpolation. MUX3 block selects a path between bypass and interpolation. In addition, for real-time processing, the vertical scaler employs four-stage pipeline structure[6].

2.4 Display methods

In order to display the full screen of LCD panel, it is necessary to convert the timing of lower resolution source into that of UXGA class. For example, Figure 6 shows the horizontal and vertical display method in SVGA(800x600) case. Horizontally, the number of pixel at UXGA (1600x1200) mode simply doubles that of pixel at SVGA mode. So, one full-line(1600 pixels) can be obtained by FOI interpolation. Vertically, new (UXGA class) 2 lines are generated using original(SVGA class) 1 line. We can achieve 1200 lines of UXGA class using original 600 lines of SVGA mode.

3. Video Processing

3.1 Conventional methods

3.1.1 Look-up table method

The lookup table is used to contrast control. The present pixel value becomes the corresponding address of the look-up table and its content becomes a new pixel. This method is represented by Eq. 4.

$$\text{new pixel}=\text{DATA}[\text{add}(\text{input pixel})] \quad (4)$$

Here, Add(*) is the address of *. The additional circuits and memory are needed for the computation of LUT(Look-Up Table) and storage of the computed values.

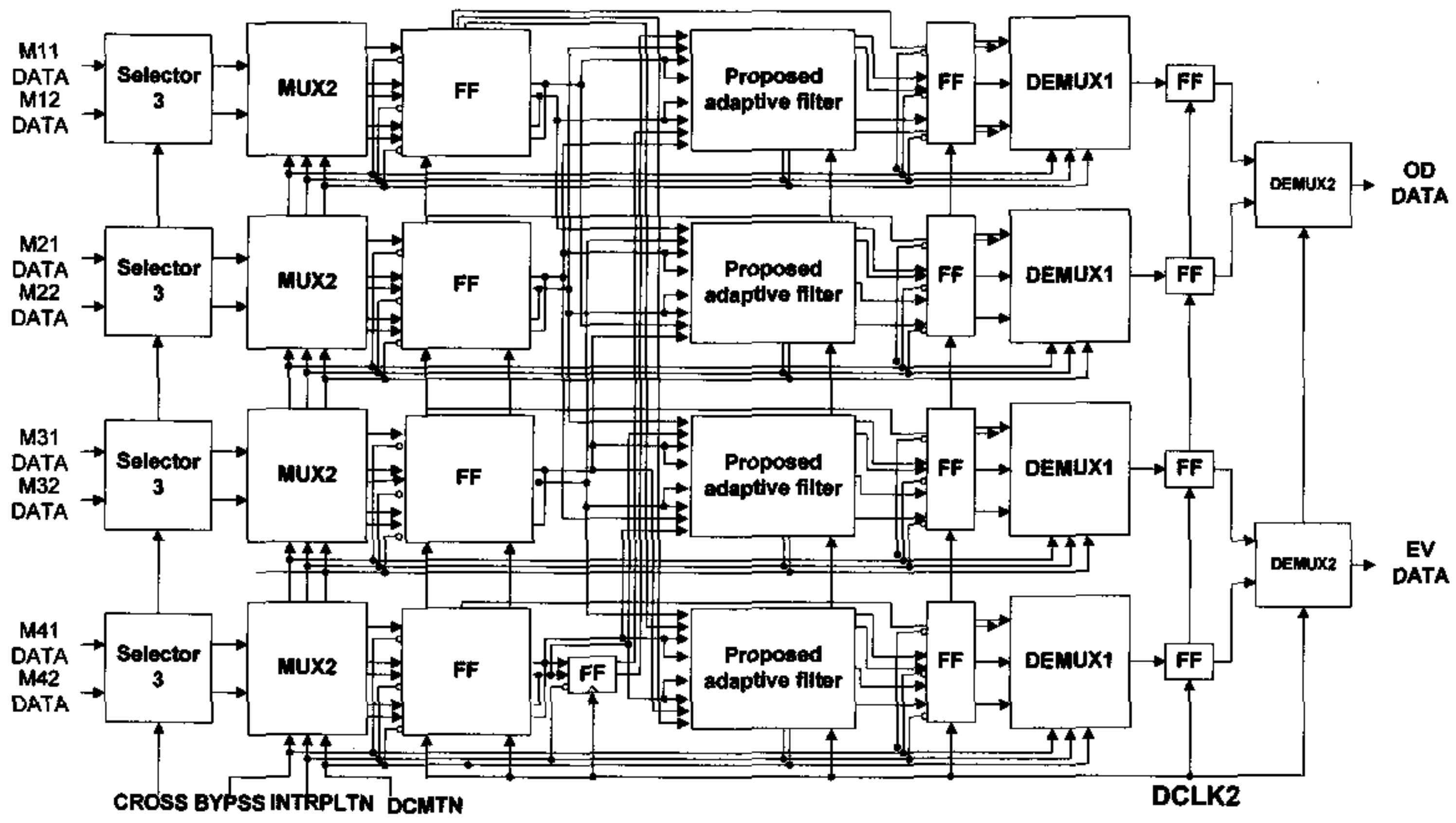
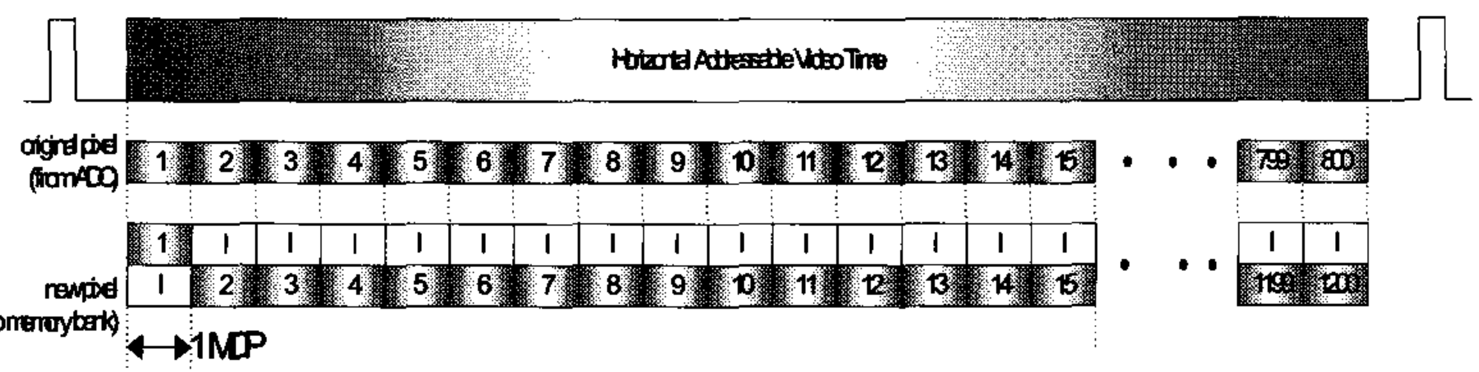
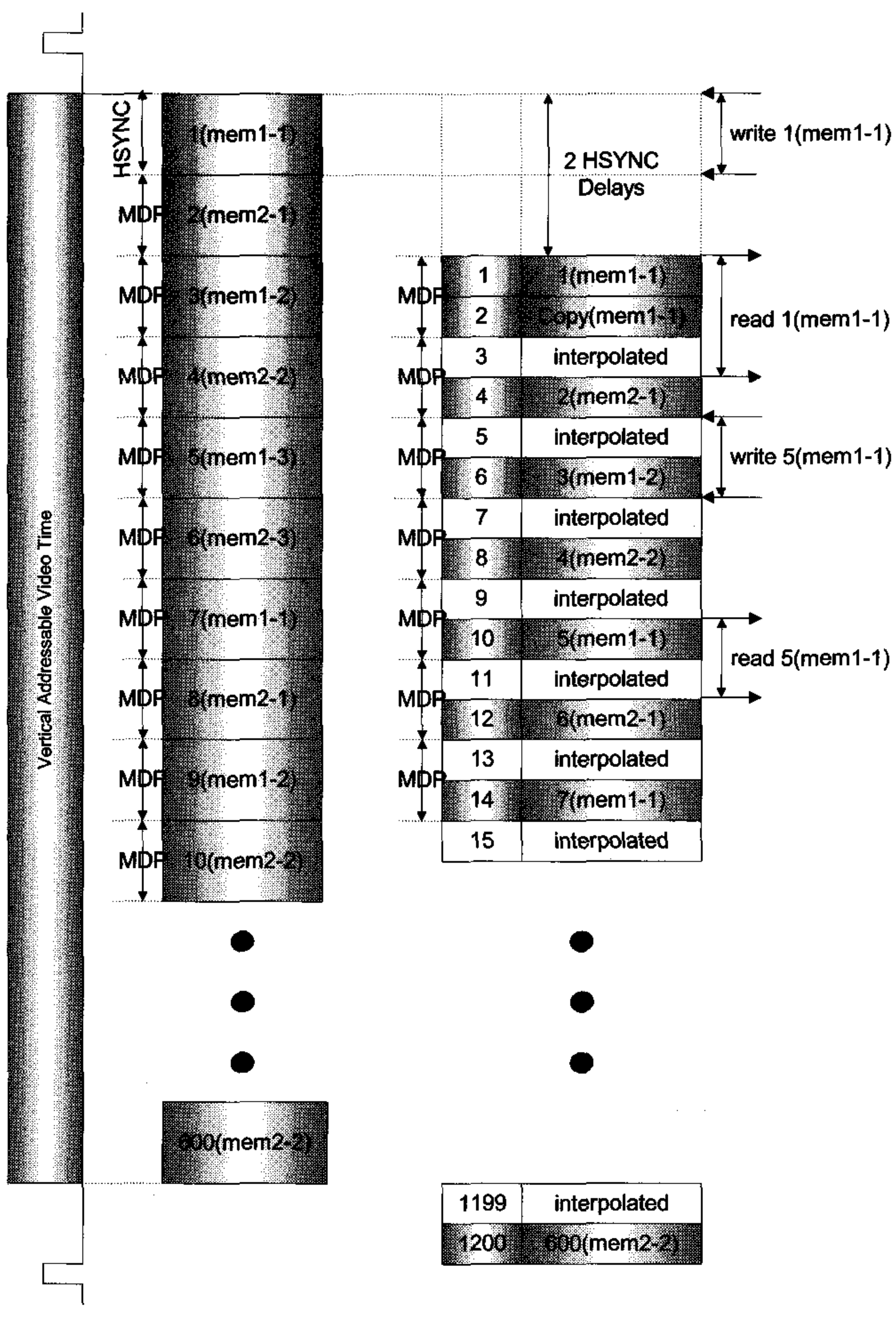


Fig. 5. The vertical scaler.



(a)



(b)

The horizontal and vertical display method in SVGA mode case. (a) Horizontal display, (b) Vertica

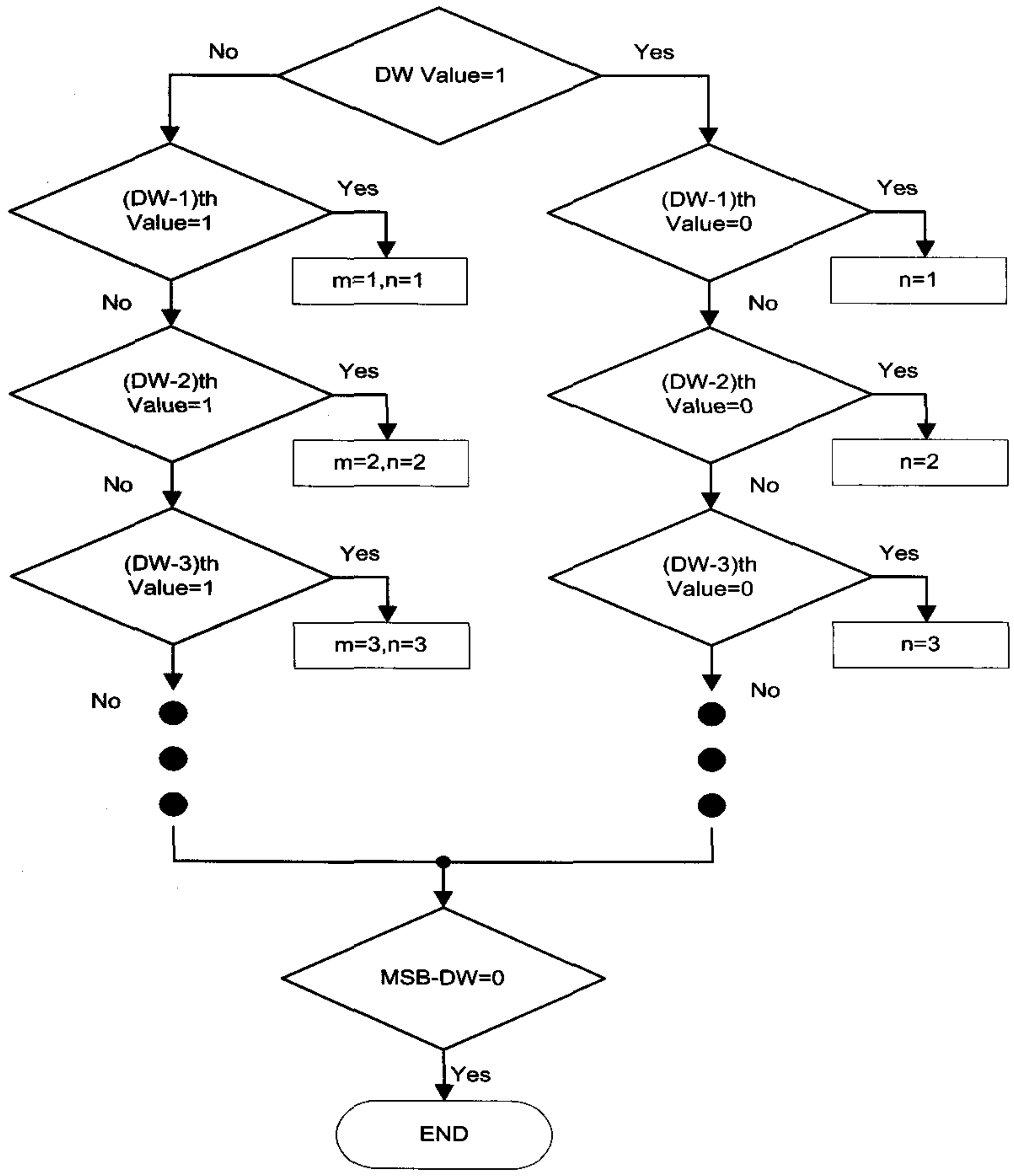


Fig. 7. The decision algorithm for index m,n.

3.1.2 Histogram sliding method

The histogram sliding method uses the relationship between the input pixel and the output pixel. Since this method requires extra circuits to calculate weight values, its circuit size is larger [2,7]. The new pixel is calculated by Eq. 5.

$$\text{new pixel} = \text{input pixel} \times \text{weight} \qquad (5)$$

3.1.3 Histogram stretching method

This method is a typical method to improve contrast. It is particularly suitable for images where the contrast is centralized toward the middle. The new pixel is obtained by Eq. 6.

$$\text{new pixel} = \frac{\text{Input pixel} - \text{Low pixel}}{\text{High pixel} - \text{Low pixel}} \times 255 \qquad (6)$$

This method can occur with some under or overflow and it isn't suitable for real-time processing like LCD driving systems.

3.2 Proposed contrast control method

The proposed Contrast Control method can provide image improvement regardless of input gray level. In addition, we propose that a contrast control can easily be applied to the LCD for real-time processing because of its lower hardware complexity than that of the conventional methods. The proposed method is given by Eq. 7.

$$\text{new pixel} = (\text{input pixel} - \text{low pixel}) \times \text{weight} \qquad (7)$$

In Eq. (7), if we subtract an input pixel from its lowest pixel value in the image, the histogram is shifted to the left. In order to prevent overflow and expand the range of histogram including the overall histogram, the proposed algorithm calculates weight value(M+US). A user can control the contrast of an image using the US(user select). The values of M(multiple) and US in

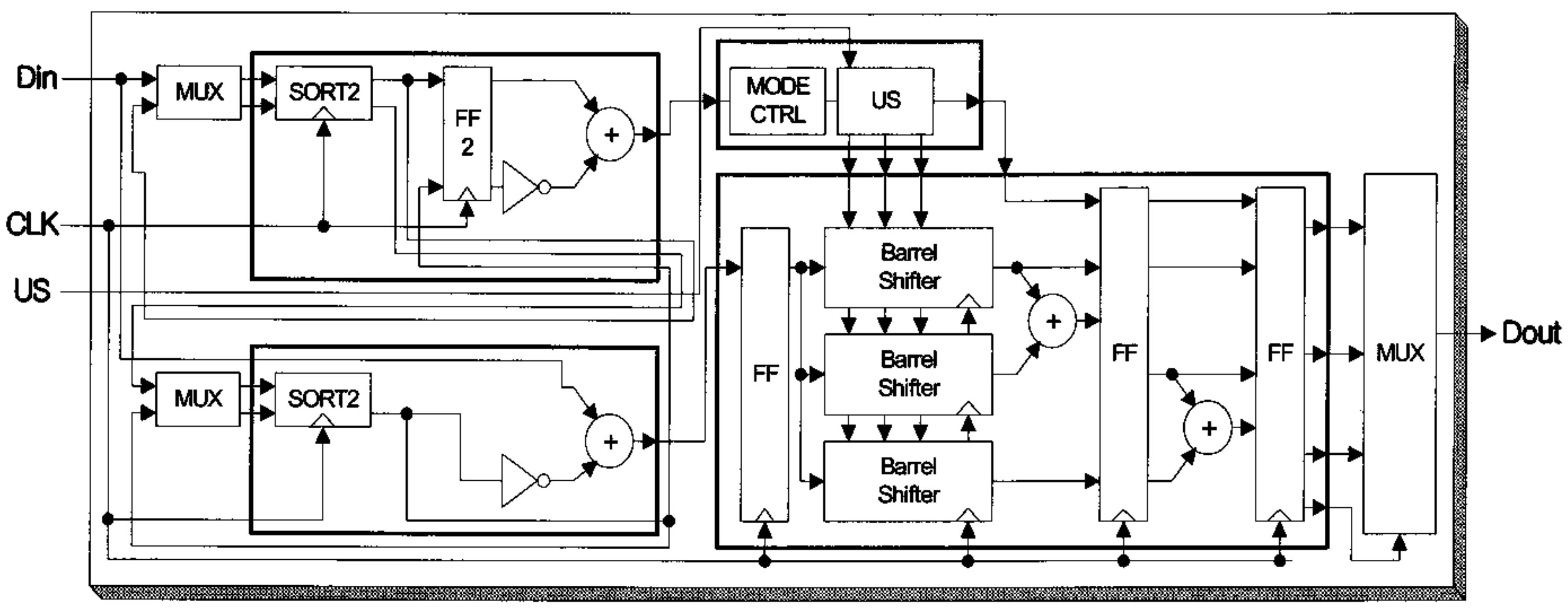


Fig. 8. Block Diagram of the proposed contrast controller.

weight value are given by Eq. (8).

If(MSB value=1)then (8)
M=input pixel+2^{-n}×input pixel
else
M=2^{m}×input pixel+2-n×input pixel

For decision of index(m ,n), where index value is an integer, the integer value is determined by the decision algorithm in Figure 7. The value of M is the MSB(most significant bit) in the difference of maximum and minimum pixel value. Therefore, this can easily be implemented by using priority encoder.

The US(user select), which acts as an optional function, can control the range of contrast.

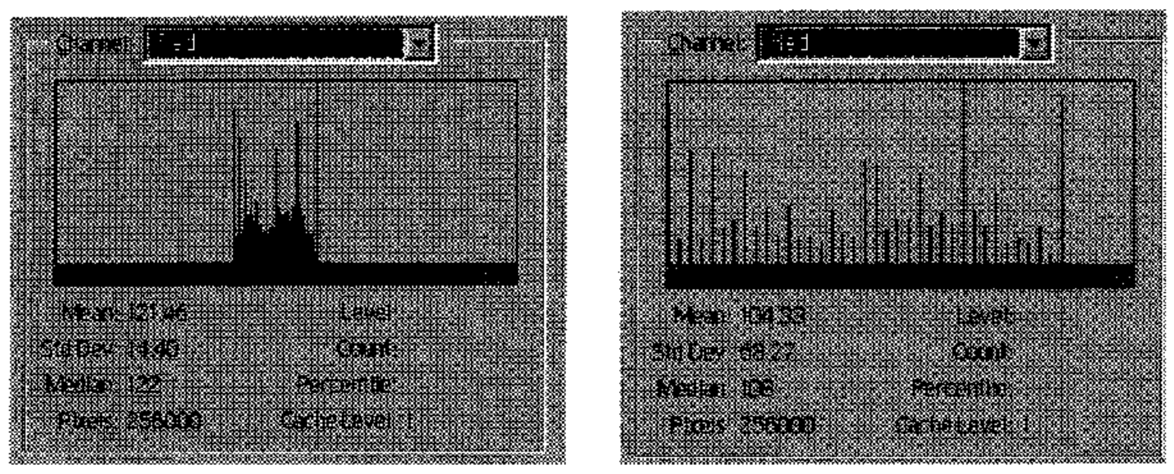
If(0≤DR≤MED) then (9)
US={n}
else
US={2^{-n}}

3.2 Architecture of the proposed contrast controller

The architecture of proposed contrast controller is shown in Figure 8. The contrast controller consists of MM(max min) Block, WD(weight determine) Block, WE(weight expansion) Block, and four pipeline stages. MM block subtracts an input pixel from its lowest pixel value in the image. WD block determines the weight value of an image. Finally, WE block expands a range of histogram including the overall histogram by using barrel shifter and adder circuits.

3.3 Simulation results

In order to compare the processed image using the proposed method with the original image, we have examined SD(standard deviation) of their histograms [7]. Figure 9 shows two histogram distributions according to each weight in the case where the histogram range of the maximum and the minimum pixel value is from 104 to 140. In Figure 10, we can find that its histogram distribution has equal interval as weight value increases. Figure 10 shows an original image and its processed image.

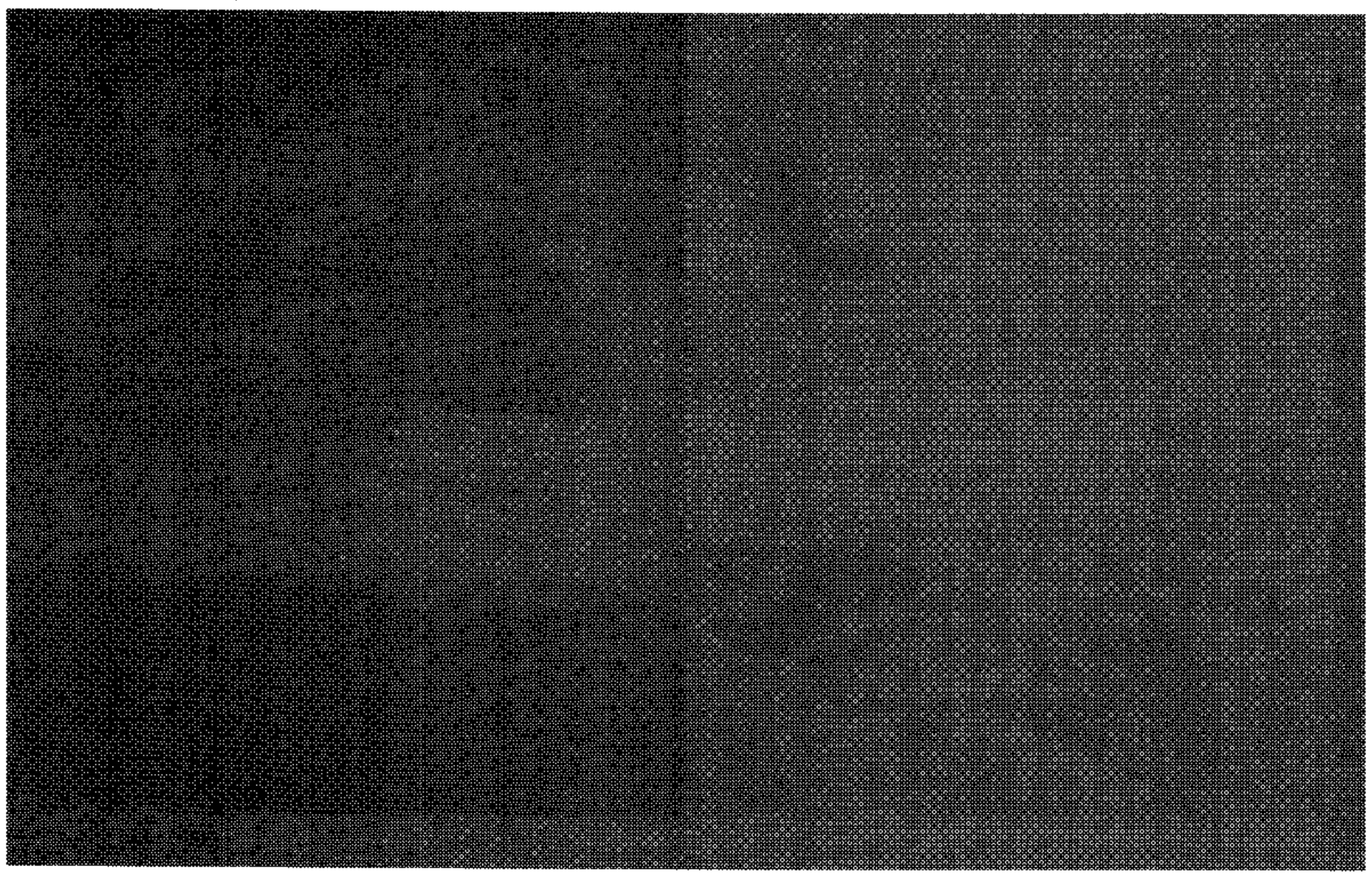


(a) (b)

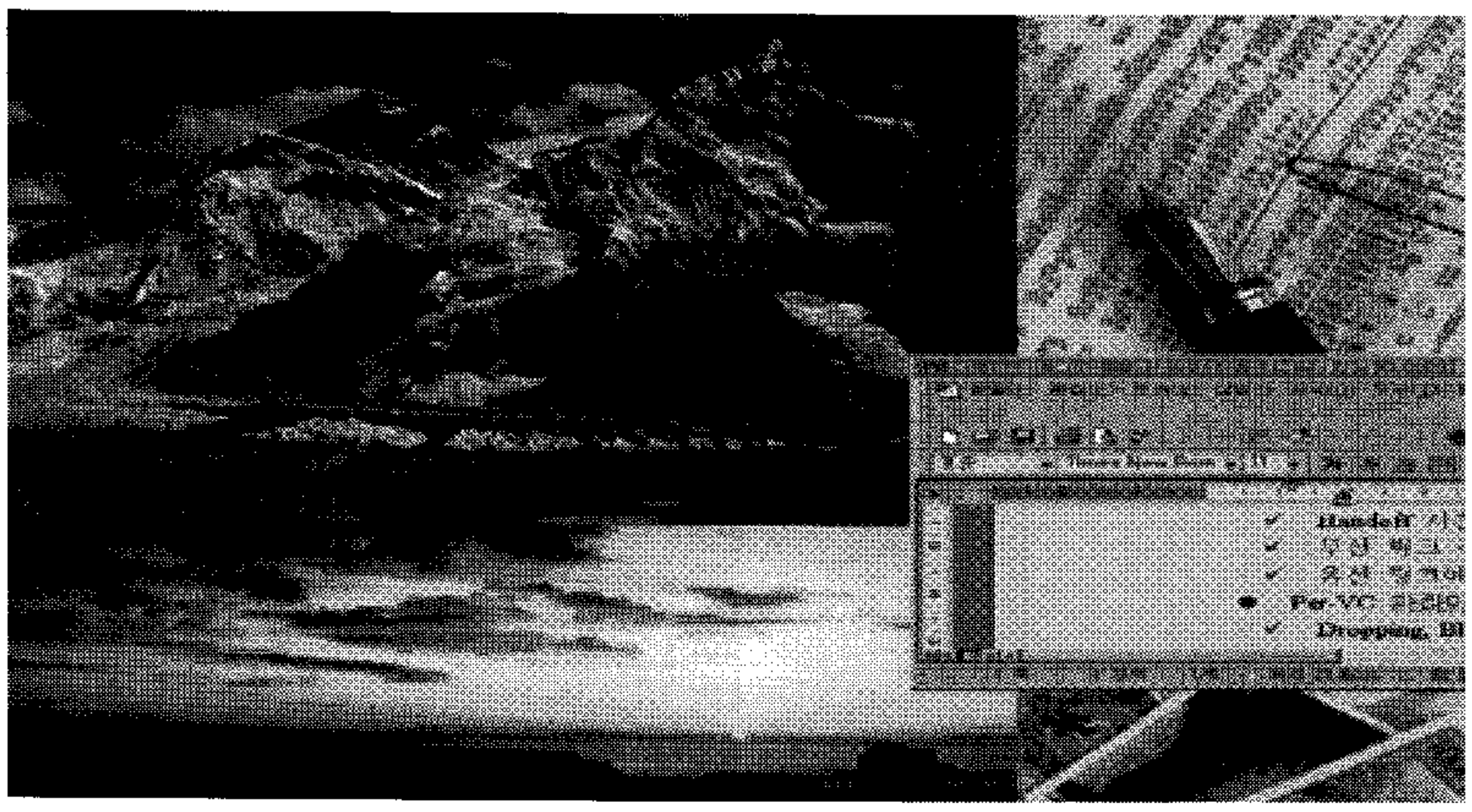
Fig. 9. Histogram distribution in the case where the difference of the maximum pixel value is from 140 to 104. (a) Original histogram (b) Processed histogram.

4. Architecture of The Proposed LCD Controller

Figure 11 shows the proposed LCD controller. The image processor consists of ADCs, memory banks, interpolation scaler blocks, video processing blocks, and a timing control block. The processor has a block diagram of the proposed driving control. It is possible to reduce the clock speed to quarter of the main clock. The required input signals are R, G, B, MODE, HSYNC, and VSYNC. The controller employs dual-port memory for the purpose of reading and writing data simultaneously. The controller can detect automatically variable video modes such as NTSC, VGA, SVGA, XGA, SXGA, and



(a)



(b)

Fig. 10. Comparison between original image and processed image.(a) Original image, (b) Processed image.

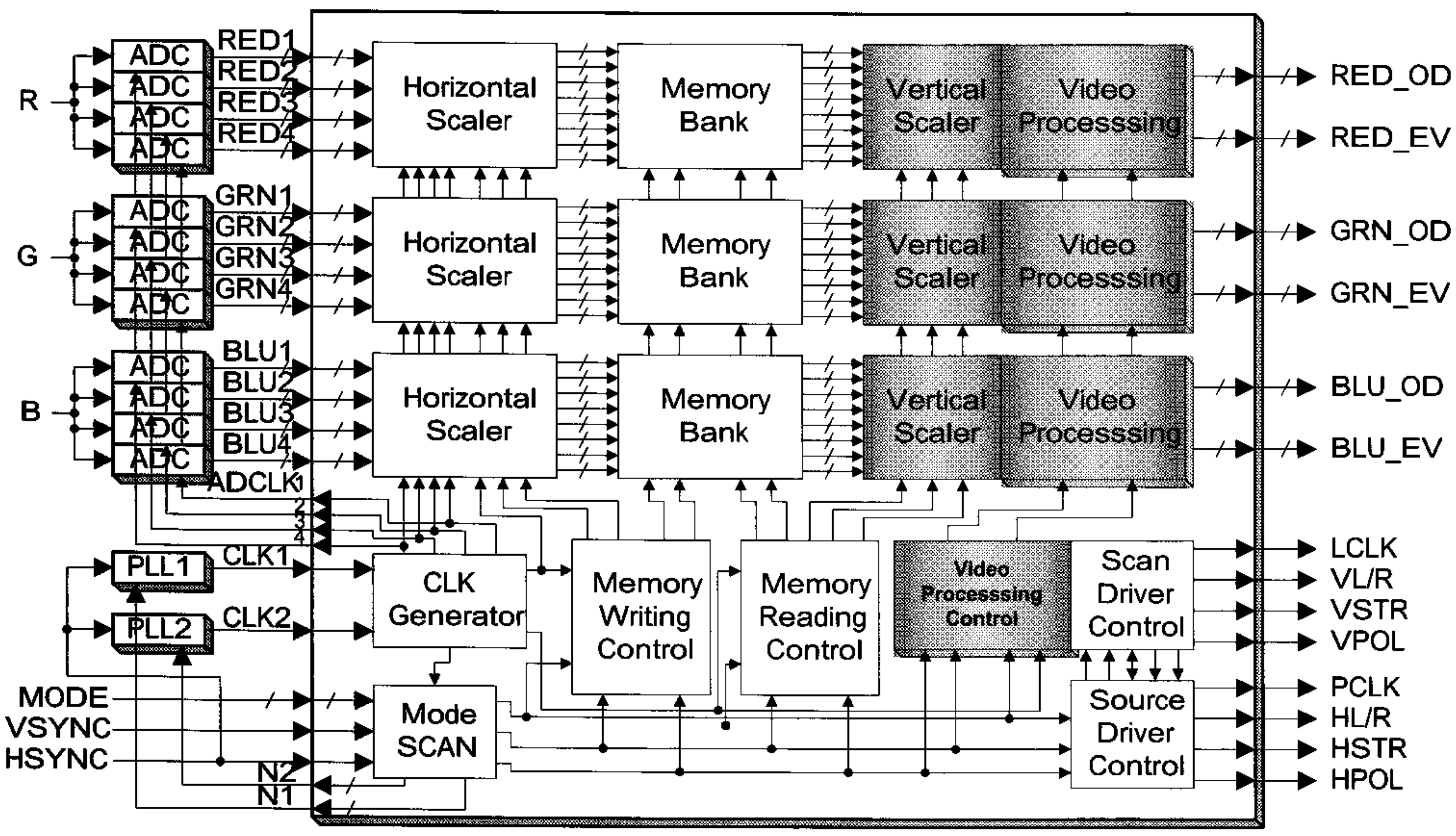


Fig. 11. The top level block

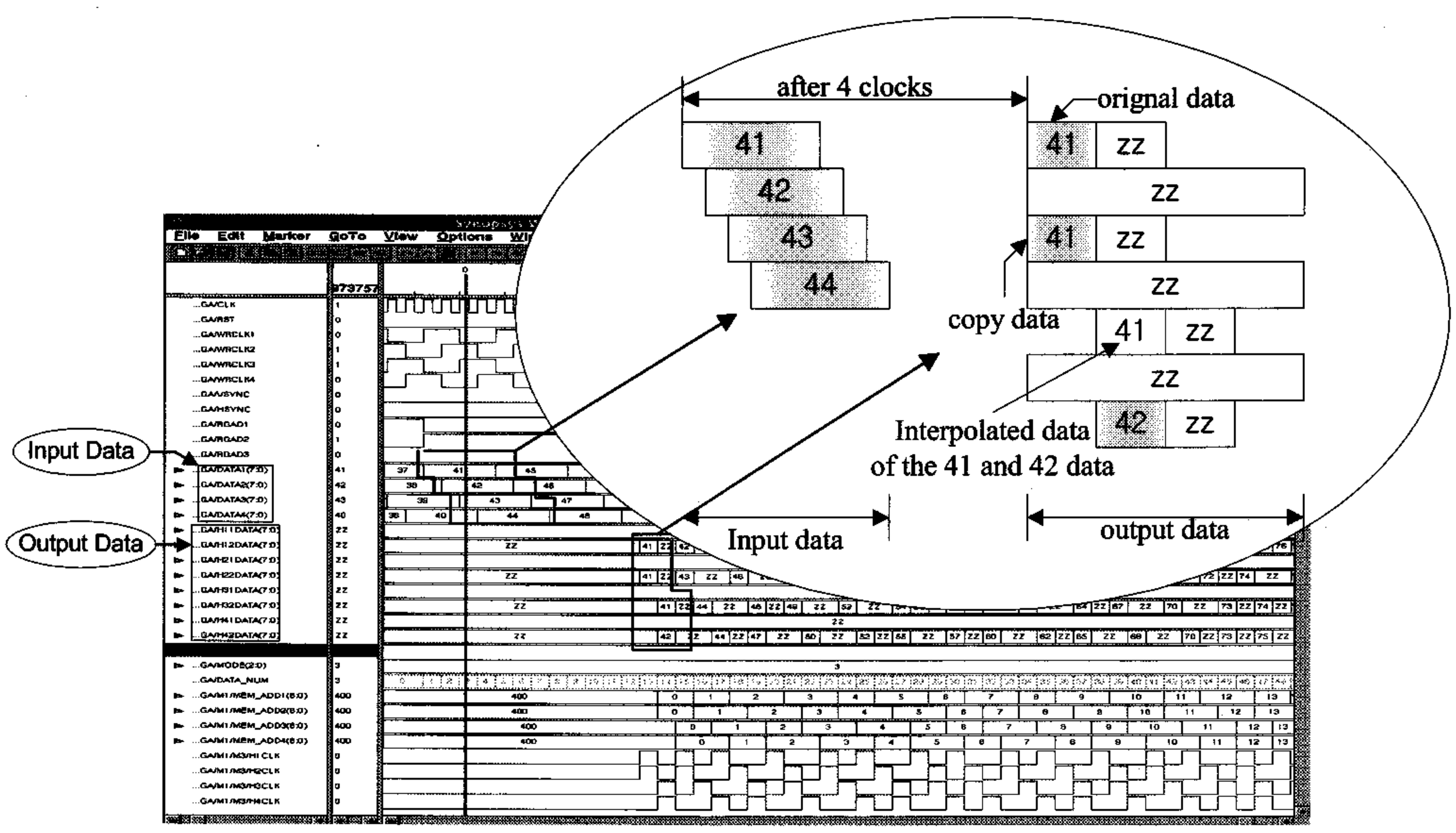


Fig. 12. Functional simulation results of LCD controller.

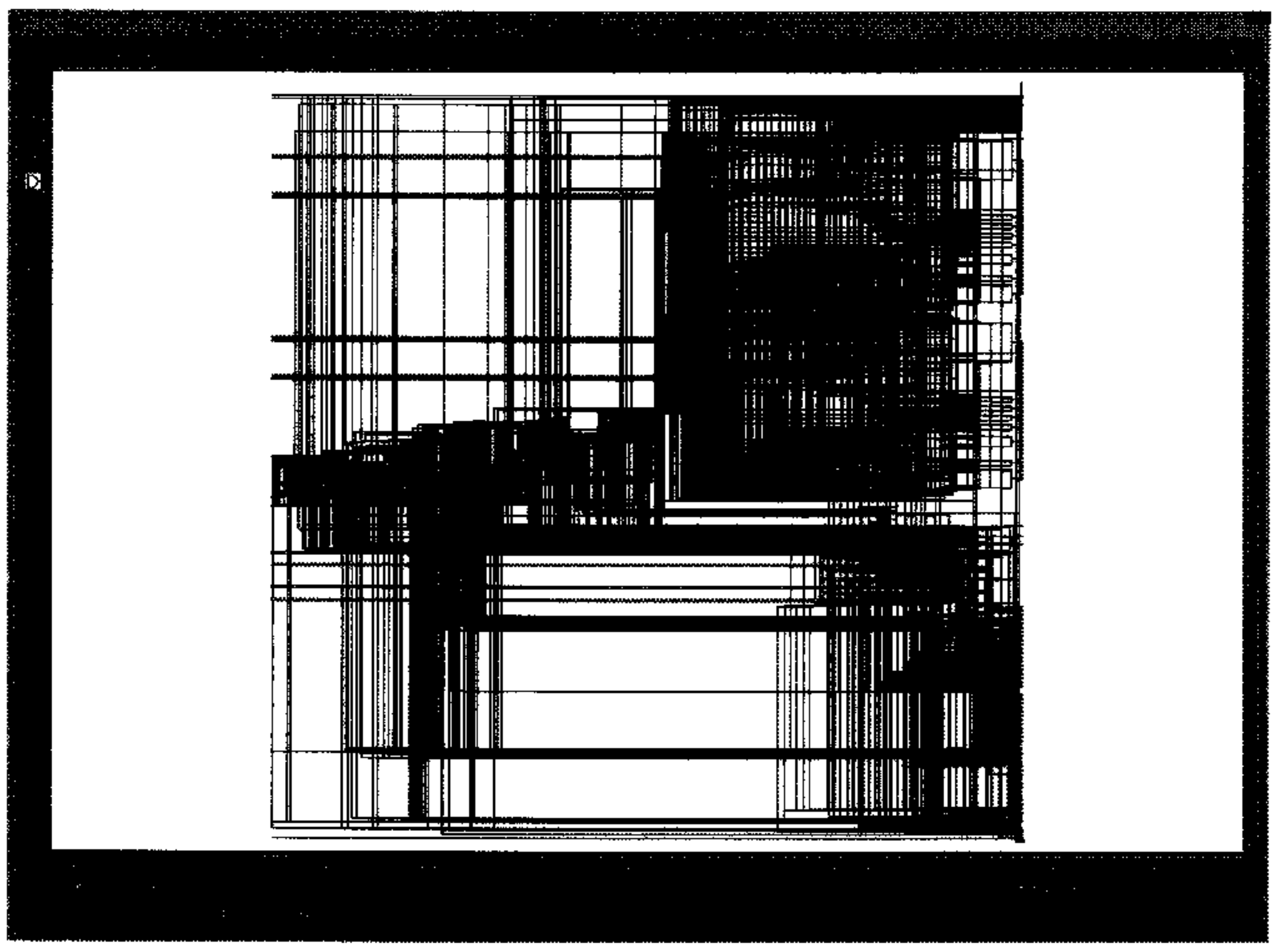


Fig. 13. The synthesis of LCD controller.

UXGA. In addition, it includes the video processing techniques for real-time improvement of image quality [3].

5. VHDL Simulation Results

We have designed the proposed LCD controller using Synopsys VHDL tool and verified it through functional simulation, which is shown in Figure 12. Figure 13 shows the synthesized results of the proposed LCD controller using a ANAM 0.25μm CMOS process. The results show that the contrast controller consists of 67,910 gates.

6. Conclusion

We presented a universal LCD controller that allows multi-function capability, high performance, and the full screen display of a LCD with lower or higher resolution of video sources such as NTSC, VGA, SVGA, XGA, and SXGA by applying new interpolation filters. In order to compare the picture quality of the proposed interpolation methods with that of the conventional methods, their PSNR values have been checked. The results shows that proposed interpolation methods is better than others from the point of view on the edge characteristic of the images.

In addition, we proposed a contrast control method for image improvement of multi-gray scale image. Visual test and histogram method have been employed to evaluate the results of the proposed contrast control method. The results show that the proposed contrast control method can improve image quality.

We have designed the proposed LCD controller by VHDL and verified it through functional and timing simulations. The proposed UXGA controller might be used for many LCD applications such as LCD monitor, internet LCD TV, notebook PC, etc

References

[1] M. A. Sid-Ahmed, Image Processing, McGrawHill, pp. 83 -98, 1995.
[2] William K. Pratt, Digital Image Processing, A Wiley -Interscience Publication, pp. 261-316, 1991.
[3] R. S. Prodan, "Multidimensional Digital Signal Processing for Television Scan Conversion," Philips J. Res. 41, pp. 576-603, 1986.
[4] H. B. Kwon, K. B Kim and B. W. Hwang, "Pseudomedian character for de-Interlacing Scan conversion," Journal of korea telecommunication society, vol. 21, no. 1, pp. 1151- 1171, 1996.
[5] Y. Koo, W. Kim, "An Image Resolution Enhancing Technique Using Adaptive Sub-Pixel Interpolation for Digital Still Camera System," IEEE Transaction on Consumer Electronics, pp. 118 -122, 1999.
[6] M. R. Choi, C. H. Choi and H. H. Cho, "An Image Processor for SXGA/UXGA FPD," AP-ASIC'99, pp. 250-253, 1999.
[7] Ran dy Crane, A Simple Approach to Image Processing, Prentice - Hall, pp. 55-83. 1997.