비선형 감마 커브 구현을 위한 작은 크기와 4bit(LSB) 오차를 가진 10비트 감마 라인 시스템의 설계

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Design of 10bit gamma line system with small size of gate count and 4bit error(LSB) to implement non-linear gamma curve

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요 약

이 논문에서, 제시된 감마(γ) 라인 시스템은 해당 공식에 의해 만들어진 비선형 감마 곡선과 하드웨어로 구현된 결과 사이의 오차를 최소화하기 위해 만들어 졌다. 제시된 알고리즘과 시스템은 특정 감마값이 2.2, 즉 $\{0,1\}^{2.2}$ 에 의해 생성되는 공식과 입, 출력 데이터 크기가 10bit를 기반으로 한다.

오차를 최소화하기 위해, 시스템은 데이터 점들 사이를 지나 적합한 다항식을 만드는 수치해석 방법, 최소 자승 다항식을 사용하였다. 제한된 감마 라인은, 정밀도를 높이기 위해, 서로 각각의 중첩된 범위를 가지는 2차 다항식 9개로 구성되어 있다.

MATLAB™ 7.0으로 검증된 알고리즘을 바탕으로, 제한된 시스템은 Verilog-HDL으로 구현되었다. 시스템은 2 클럭 지연을 가지며 1 클럭마다 결과가 생성된다. 오차 범위(LSB)는 -4에서 +3이다. 표준편차는 1.287956238을 가진다. 시스템의 전체 게이트 값은 2,083이며, 최대 타이밍은 15.56[ns] 이다.

Abstract

In this paper, the proposed gamma(γ) line system is developed for reducing the error between non-linear gamma curve produced by a formula and result produced by hardware implementation. The proposed algorithm and system is based on the specific gamma value 2.2, namely the formula is represented by $\{0,1\}^{2.2}$ and the bit width of input and out data is 10bit.

In order to reduce the error, the system is using least squares polynomial of the numerical method which is calculating the best fitting polynomial through a set of points. The proposed gamma line is consisting of nine kinds of quadratic equations, each with their own overlap sections to get more precise.

Based on the algorithm verified by MATLAB™ 7.0, the proposed system is implemented by using Verilog-HDL. The proposed system has 2 clock latency; 1 result per clock. The error range (LSB) is -4 and +3. Its standard deviation is 1.287956238. The total gate count of system is 2,083 gates and the maximum timing is 15.56[ns].

Key words : gamma(γ), the numerical method

Ⅰ. Introduction

The non-linear luminance produced by display devices can be described with gamma correction of the form, $f(x) = x^{\gamma}$, namely the formula is represented by $[0,1]^{\gamma}$. The value of γ is determined experimentally by display characteristic [1]. Figure 1 shows Effect of Gamma. When an orderly sequence of floating between 0 and 1, the green line, is entered into the display device, we get the distorted result, the red line, which is not an linear sequence but an non-linear sequence. It is because of the display's character that it take place. In order to get the exact result on the display device, it is the solution to correct an orderly sequence of floating, the green line, to an linear sequence of floating, the blue line.

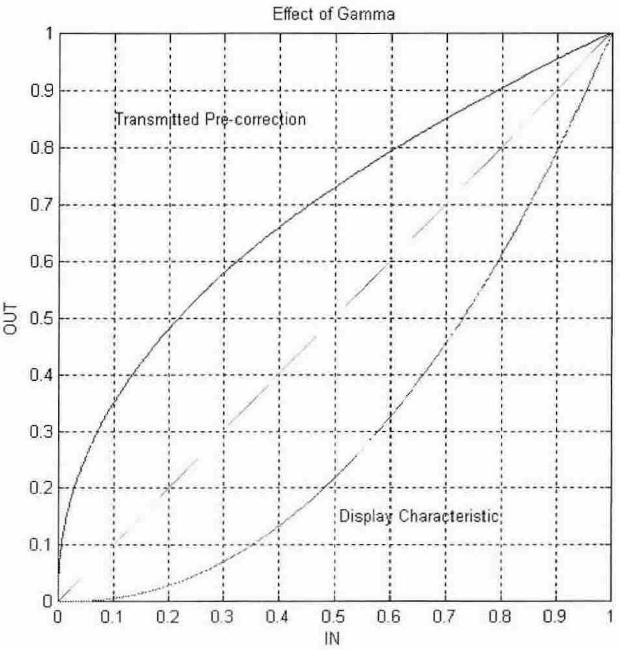

Figure 1. Effect of Gamma

Gamma correction controls the overall brightness of an image. Images which are not properly corrected can look either bleached out, or too dark. Varying the amount of gamma correction changes not only the brightness, but also the ratios of red to green to blue.

It is impossible that A^B (exponential form) should be implemented to algorithm of hardware unless A is an exponential power of B which always has positive integer values. Also, the error between the exponential function and the alternative function must be generated due to non-linear character of gamma curve. Thus, a "curve-fitting" which is found by minimizing can be detected to use least squares polynomial of the numerical method [2].

In this paper, we describe the algorithm, design and performance of the implemented system, block of gamma10.v.

II. The proposed algorithm of Gamma Block

The proposed algorithm shows that the proposed function consists of nine kinds of quadratic equations. The Eq. 1 is the form of proposed function form.

$$p(x) = p(x_1)\Big|_{x_1=A}^{x_1=B} + p(x_2)\Big|_{x_2=B+1}^{x_2=C} + \dots + p(x_9)\Big|_{x_9=I+1}^{x_9=J} \quad (1)$$

Suppose that $[(x_k, y_k)]_{k=1}^{N}$ are N points in which the abscissas $[x_k]_{k=1}^{N}$ are distinct. Using the least squares, we find $p(x_i)$ to minimize the sum of the squares of $(p(x_i) - y_i)$. The partial derivatives of the form [3]

$$S = \sum_{i=1}^{n}[p(x_i) - y_i]^2,\ (p(x_i) = a_0 + a_1 x_i + a_2 x_i^2) \quad (2)$$

In this method, we can detect coefficients a_k of quadratic equations. Table 1 shows coefficients of the quadratic equations.

Table 1. Coefficients a_k of the quadratic equations

Section	Coefficients (a_0, a_1, a_2)		
1st	0.0000,	44.0000,	0
2nd	0.03125,	13.5,	-448
3rd	0.0546875,	8,	-128
4th	0.078125,	5.25,	-36
5th	0.109375,	3.5625,	-12
6th	0.1484375,	2.4375,	-4
7th	0.203125,	1.65625,	-1.375
8th	0.2734375,	1.1640625,	-0.5
9th	0.359375,	0.84375,	-0.203125

Because the coefficients of floating digit points generated by MATLAB are infinite, we should convert original equations into RTL (Register Transfer Level description) equations. That is, the available digit points of calculated coefficients are determined. The Eq. 3 shows this process. (a_k is the floating formation and b_k is the integer formation.)[4].

$$\begin{aligned} f(x) &= [a_0 + (a_1 \times x/1024) + (a_2 \times x^2/1024^2)] \times 1024 \\ &= [b_0 \times 2^{-n} + (b_1 \times 2^{-n} \times x \times 2^{-10}) + (b_2 \times 2^{-n} \times x^2 \times 2^{-20})] \times 2^{10} \\ &= b_0 \times 2^{-n+10} + (b_1 \times x) \times 2^{-n} + (b_2 \times x^2) \times 2^{-n-10} \end{aligned} \quad (3)$$

Ⅲ. Design and Performance

Figure 2 shows the block diagram of gamma10.v. The proposed system is consisting of four major parts, such as Control (left and lower), X^2 (upper), X^1 (middle) and Constant (center and lower).The bit width of input and output signals used in the hardware is the 10bit.

In a way that agrees with the size of input data, the part of Control generates the signals which are choosing coefficients of the quadratic equations. The other parts, including X^2 (b_2x^2), X^1 (b_1x) and Constant (b_0), are composed of the quadratic equations, the Eq. 3. Because implementation of multiplication is required for the big gate count, we transform the multiplication operator into the adder operator. To minimize the size of adder device and system hardware, we implement the multiplexes which are selecting the components for the bit shift operators. The system has 2 clock latency; 1 result per clock.

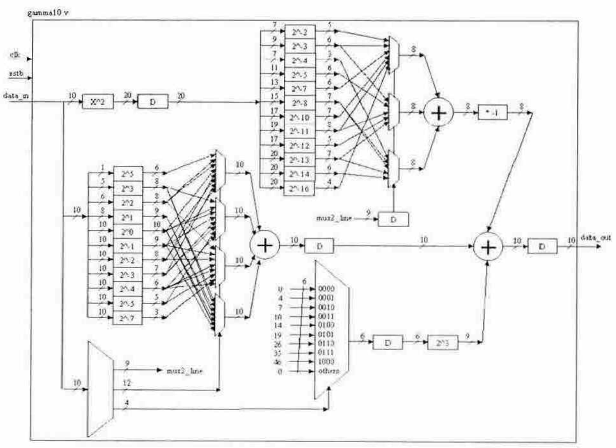

Figure 2. Block diagram of gamma10.v

Figure 3 shows results of gamma line generated when the input is an orderly sequence of integers, 0 and 1023. The red line, plus sign:+, indicates that the part of X^2 calculates a sequence of output based on b_2x^2 . The green line, asterisk:*, shows that the part of X^1 products a sequence of output based on b_1x. The blue line, circle:○, presents that the part of Constant generates a sequence of output based on b_0. The cyan line, diamond:◇, indicates a sequence of output produced by this method that the system subtracts blue one from green one which is added to red one, $(b_0+b_1x+b_2x^2)$. The black line, cross:x, presents a sequence of output, f(x)=x$^\gamma$, multiplied by 1023, gamma value 2.2.

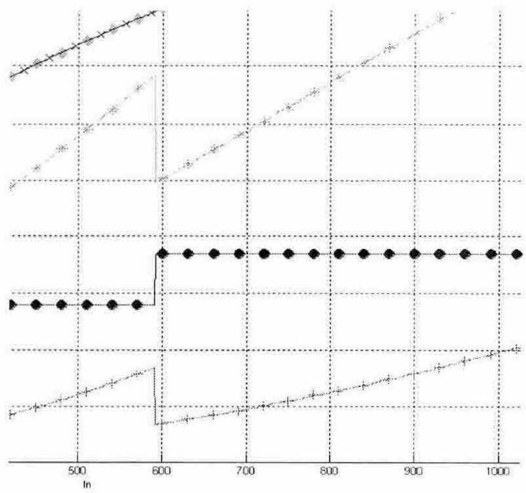

Figure 3. Results of gamma line

Figure 3 shows difference between the results produced by proposed system and the results of a formula multiplied by 1023, gamma value 2.2 when the input is an orderly sequence of integers, 0 and 1023. The error range (LSB) is -4 and +3.

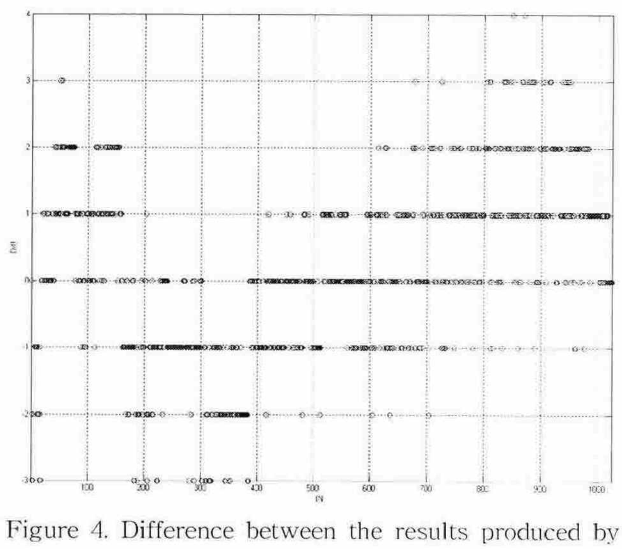

Figure 4. Difference between the results produced by Proposed system and the results of a formula

Figure 5 shows difference between the results produced by existing system which is having offset_system and four kinds of quadratic equations and the results of a formula multiplied by 1023, gamma value 2.2 when the input is an orderly sequence of integers, 0 and 1023. The error range (LSB) is -2 and +2[5].

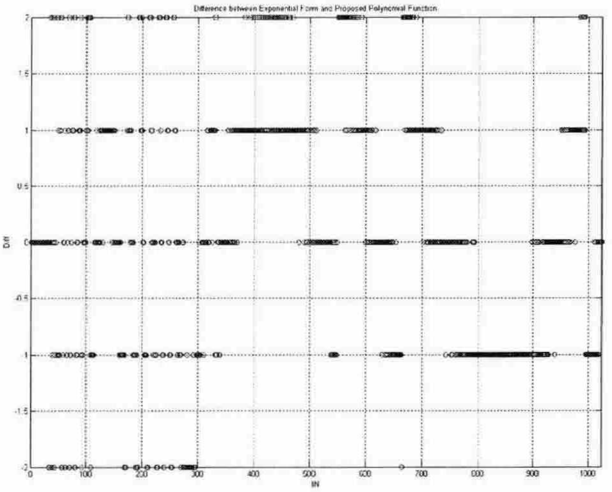

Figure 5. Difference between the results produced by Existing System and the results of a formula

Table 2 compares difference, standard deviation, maxtiming and gate count of the proposed system with those of the existing system.

Although the proposed system and the existing system are alike in that they both have maxtiming and standard deviation, we know that gate counts of the former is at least four times smaller than those of the latter.

Table 2. Comparison for Proposed system an Existing system

	Proposed System	Existing System
Difference(LSB)	-4 ~ +3	-2 ~ +2
Standard devi.(LSB)	1.287956238	1.7295417785645
Maxtiming [ns]	15.56	11.99
Gate Count	2,083	7,218

Ⅳ. Conclusions

In this paper, we have proposed the gamma (ϒ) line system reducing the error between non-linear gamma curve and result produced by hardware implementation.

We have divided the non-linear gamma curve into nine sections, each with their own overlap sections to get more precise. All quadratic equations are gotten by using least squares. They are changed into RTL (Register Transfer Level description) equations which can be applied to hardware implementation.

The proposed system designed by using Verilog-HDL models, and the Verilog-HDL models are verified by using the Synopsys simulator. After the verification are conducted, the models are synthesized into gates to see the hardware complexity by using the Synopsys synthesizer with the SAMSUNG STD90 0.35-um library. The total gate count of system is 2,083 gates and the maximum timing is 15.56[ns].

Due to implementation of gamma line, we can expect that the proposed system has more advanced performance than the existing system. Finally, display devices can produce more efficient non-linear luminance by using the less gate count of the system

AcKnowledgements

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