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모바일 TFT-LCD 응용을 위한 새로운 형태의 자동화질 최적화 시스템 개발

(Development of a New Automatic Image Quality Optimization System for Mobile TFT-LCD Applications)

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요 약

본 논문은 DSP를 이용한 새로운 형태의 TFT-LCD 자동 화질 최적화 시스템을 제안한다. 실제 산업 현장에서 이와 같은 화질 최적화 과정은 시행착오를 반복하는 형식으로 진행되어 많은 시간이 소요되고 있으며 LCD 개발 엔지니어들의 성향 및 숙련도에 따라 조정 결과에도 편차가 큰 문제점이 있다. 이러한 시스템은 평균 감마 오차, 감마 조정 시간 및 플리커 등을 줄이기 위해 모바일 LCD 구동 IC 내의 감마 조정 레지스터들과 전압 설정 레지스터들을 자동적으로 제어한다. 제안된 최적 화질 향상 시스템은 측정 대상이 되는 모듈 (MUT, LCD 모듈), 제어 프로그램, 휘도 측정용 멀티미디어 디스플레이 측정기 및 인터페이스용 제어 보드로 구성되어 있다. 개발된 시스템에는 참조 감마 곡선과의 6-점 프로그램 정합 기술을 이용한 새로운 알고리즘 및 자동 전압 설정 알고리즘이 내장되어 있다. 개발된 알고리즘과 프로그램은 범용 LCD 모듈에 적용가능하다. 또한 1.8, 2.0, 2.2 및 3.0 감마를 조정할 뿐만 아니라 플리커 수준을 자동으로 조절한다. 제어 보드는 DSP와 FPGA로 구성되어 있고, RGB 및 CPU와 같은 다양한 인터페이스들을 지원한다. 개발된 자동 감마 시스템은 기존의 시스템에 비해 현저히 짧은 감마 조정 시간 및 아주 작은 평균 감마 오차를 보였다. 또한 본 논문에서 제안하는 시스템은 최적화된 감마 곡선 설정을 이용한 개발 공정을 향상시키고, 고화질의 LCD를 제공하는데 아주 유용하다.

Abstract

This paper presents a new automatic TFT-LCD image quality optimization system using DSP for the first time. Since conventional manual method depends on experiences of LCD module developers, it is highly labor-intensive and requires several correction steps providing large gamma correction error. The proposed system optimizes automatically gamma adjustment and power setting registers in mobile TFT-LCD driver IC to reduce gamma correction error, adjusting time, and flicker. It contains module-under-test (MUT, TFT-LCD module), PC installed with program, multimedia display tester for measuring luminance and flicker, and control board for interface between PC and TFT-LCD module. We have developed a new algorithm using 6-point programmable matching technique with reference gamma curve and applying automatic power setting sequence. Developed algorithm and program are generally applicable for most of the TFT-LCD modules. It is realized to calibrate gamma values of 1.8, 2.0, 2.2 and 3.0, and reduce flicker level. The control board is designed with DSP and FPGA, and it supports various interfaces such as RGB and CPU. Developed automatic image quality optimization system showed significantly reduced gamma adjusting time, reduced flicker, and much less average gamma error than conventional manual method. We believe that the proposed system is very useful to provide high-quality TFT-LCD and to improve developing process using optimized gamma-curve setting and automatic power setting.

Keywords : Automatic image quality optimization system, gamma curve optimization, 6-point programmable matching technique, flicker, automatic power setting

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I. Introduction

In this work, we present automatic TFT-LCD image quality optimization system using gamma curve optimization and programmable power setting sequence far the first time. It adjusts gamma curve and flicker level automatically by controlling grayscale voltages and power in the TFT-LCD modules using developed algorithms. The gamma correction error, gamma adjusting time, and flicker adjusting time are significantly reduced by controlling automatically gamma adjustment and power setting registers in mobile TFT-LCD driver IC as compared to traditional manual way. The proposed system consists of module-under-test (MUT, TFT-LCD module), PC installed with program, multimedia display tester for measuring luminance and flicker, and control board for interface between PC and TFT-LCD module. New algorithms and programs using 6-point programmable matching technique with reference gamma curve, and automatic power setting are developed. Developed algorithms and programs are generally applicable for most of the TFT-LCD modules. It is realized to calibrate gamma values of 1.8, 2.0, 2.2 and 3.0 and reduce flicker level. The control board is designed with DSP (Digital Signal Processor), and it supports different interfaces such as RGB and CPU.

II. Interconnects Analysis and Optimization

The LCD driver IC used in mobile TFT-LCD displays has various registers to control image quality. Optimized image quality is adjusted by setting these registers. Image quality control registers are classified by flicker adjustment, gamma adjustment and power control.

2.1. Overview of TFT-LCD

Every TFT-LCD panel requires several power supplies to turn on TFT (Thin Film Transistor) arrays and be capable of supplying enough current to charge and discharge all of the pixels within the display very quickly. Fig. 1 shows equivalent circuit of a TFT-LCD pixel. The C_{sc} and C_{lc} depict storage capacitor to hold charges during one frame period and equivalent capacitance of LC, respectively. The Cgd shows parasitic capacitance between gate and drain of a TFT. To turn on or off TFT arrays, gate voltage providing a high V_{on} voltage and a negative V_{off} voltage is used to power the row driver (or gate driver) within the display. When gate voltage, V_{on} is high, the difference of source voltage and common voltage is charged in C_{sc} and C_{lc} of a TFT-LCD pixel.

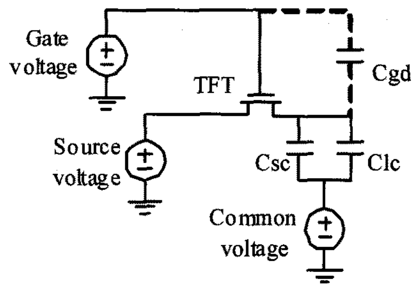


그림 1. TFT-LCD 픽셀 등가회로
Fig. 1. Equivalent circuit of a TFT-LCD pixel.

2.2. Flicker Adjustment

Due to offset within the LCD panel, the required common voltage can differ slightly from the ideal voltage of one-half main supply voltage (AVDD). Fig.2 shows voltage wave form applied in TFT-LCD pixel. The kick-back voltages ($\triangle V_p$, $\triangle V_n$) as shown in Fig. 2 are generated by the capacitance, Cgd shown in Fig.1. The negative kick-back voltage ($\triangle V_n$) is not equal to the positive kick-back voltage ($\triangle V_p$). The $\triangle V_p$ is expressed by Equation (2.1). The difference of these voltages generates the difference of brightness as well as flicker of a TFT-LCD. Thus, this in turn can cause the appearance of flicker within the display. This inherent flicker can be eliminated in production by accurate adjustment of common voltage around the midpoint of the main supply voltage. To eliminate this effect, the common

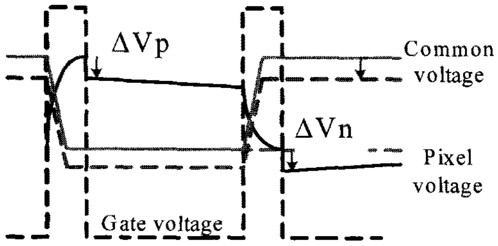


그림 2. TFT-LCD 픽셀에 인가되는 전압 파형
Fig. 2. Voltage waveform applied in TFT-LCD pixel.

voltage is usually adjusted on a panel-by-panel basis until the appearance of flicker is removed. However, since mobile TFT-LCD displays use line inversion driving or frame inversion driving, it is very difficult to eliminate flicker due to asymmetry between negative polarity and positive polarity as shown in Fig. 2. The flicker can be reduced by controlling common voltage so that the negative kick-back voltage ($\triangle V_n$) is almost equal to the positive kick-back voltage ($\triangle V_p$), but it is very time-sensitive.

$$\Delta V_p = \frac{C_{gd}}{C_{lc} + C_{sc} + C_{gd}} \cdot (V_{on} - V_{off}) \tag{2.1}$$

where, V_{on} and V_{off} represent high gate voltage and negative gate voltage, respectively.

The proposed system with automatic flicker adjustment algorithm adjusts automatically desired common voltage to minimize flicker. It gives LCD engineers the flexibility and time savings to reduce flicker of the display panel as many times as the production process requires.

2.3. Gamma Adjustment

A gamma characteristic is a non-linear relationship that approximates the relationship between the encoded luminance in a LCD system and the actual desired image brightness. Fig.3 shows gamma characteristic curve. The relationship between the light emitted from a pixel and the voltage applied to it is a non-linear. This so called 'Gamma Curve' as shown in Fig. 3 is actually an S-curve in nature and can be either positive or negative referenced to common voltage.

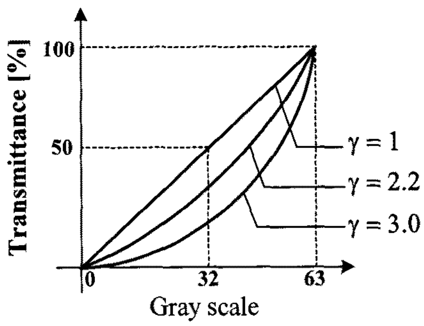


그림 3. 감마 특성 곡선
Fig. 3. Gamma characteristic curve.

The gamma correction is a step which controls luminance of images to express graded grayscale, and it matches perceptual difference between TFT-LCDs and human eyes. Human eyes with non-linear characteristics are sensitive to the dark region as compared to the bright region. Therefore, the linearly-encoded scale that has a nonlinearly-increased intensity will show much more even steps in perceived brightness. Considering detail grayscale in the dark region, the transmittance is defined using gamma (γ) value as described in equation (2.2).

$$\text{Transmittance}(\%) = \left(\frac{\text{Gray\_Number}}{\text{Max\_Gray\_Number}}\right)^{\gamma} \cdot 100 \tag{2.2}$$

When gamma value is increased, dark gray has much minute transmittance. The LCD usually uses a standard gamma of 2.2. In fact, most panels switch alternating pixels between one polarity and the other. As each panel has a different gamma curve response, the column drivers need a reference curve so that they can drive the right voltage to each pixel to get the brightness required. These curves are typically supplied using the gamma buffers and a string of resistors which can be used to mimic the curve. However, gamma adjustment also takes a lot of time to match a standard gamma of 2.2. The proposed system with automatic gamma adjustment algorithm adjusts automatically desired common voltage and source voltage to match gamma curve of 2.2.

2.4. Register Setting

Fig. 4 shows a setting sequence of LCD driver IC for mobile LCDs. The gamma adjustment registers of the mobile LCD driver IC depend on panel characteristics. This sequence consists of three steps such as contrast adjustment, flicker adjustment, and gamma adjustment. These steps are sequentially set. At first, the contrast adjustment step adjusts brightness of a black image and white image. The higher contrast ratio, the better image quality because it delicately expresses images of dark region, and clearly expresses images of bright region. It is important to set optimum contrast ratio to solve trade-off between power consumption and degradation of grayscale images[1-2]. As depicted, this contrast adjustment step controls white image and black image, and sets voltages applied in LC. The next step is flicker adjustment. The flicker can be reduced by controlling common voltage so that the negative kick-back voltage ($\triangle V_n$) is almost equal to the positive kick-back voltage ($\triangle V_p$). After flicker adjustment, the gamma adjustment step controls grayscale voltages. It is known that the gamma curve of an LCD is affected by the liquid crystal material, the cell gap and pixel structure, reference voltages, and other factors[1-3]. Even if these factors should be fixed from a design step, gamma values of mass-produced LCD panels have a very wide distribution from the target gamma due to process variations. Therefore, it is very important to control gamma curve according to the various TFT-LCD panels. After gamma setting, flicker can be generated by adjusting of grayscale voltages, so these two steps repeatedly perform to minimize flicker and match a standard gamma of 2.2. The driver IC for mobile LCD include gamma and flicker adjustment registers of more than 10 sets to optimize gamma curve. Traditional way of mobile LCD gamma adjustments involves manually correction steps by trial and error to adjust these 10-set registers. Since this depends on skills and experiences of LCD module developers, it is highly labor intensive and requires several correction steps providing large gamma correction error and large flicker level. Thus, programmable gamma and flicker adjustments are needed to compensate for the wide spread error in panel-to-panel gamma variation and flicker, respectively. For this purpose, we have developed a new automatic image quality optimization system for gamma and flicker.

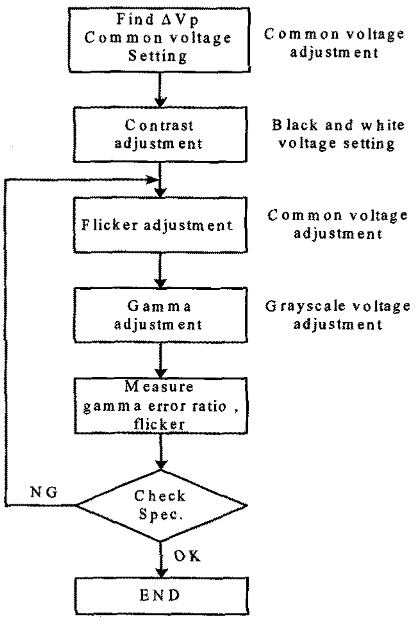


그림 4. 자동 LDI 레지스터 설정 과정

Fig. 4. Register setting sequence for LCD driver IC.

2.4.1. Automatic Flicker Adjustment Algorithm

Fig. 5 shows brightness for flicker waveform of LCD. It has periodical characteristics with DC level of V_{dc} and peak-to-peak value of V_{pp}. The flicker level is defined by Equation (2.3).

$$\text{Flicker level [\%]} = 100\times(\text{Vpp/Vdc}) \qquad (2.3)$$

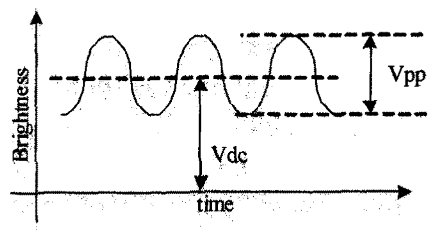


그림 5. LCD 플리커 특성

Fig. 5. Brightness for flicker waveform of LCD.

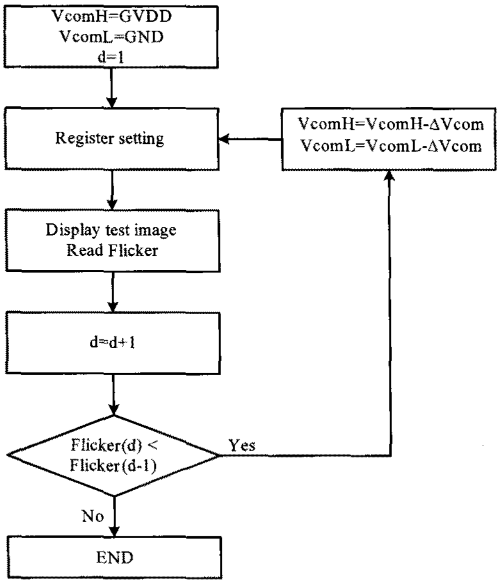


그림 6. 플리커 자동 조정 알고리즘

Fig. 6. Automatic flicker adjustment algorithm.

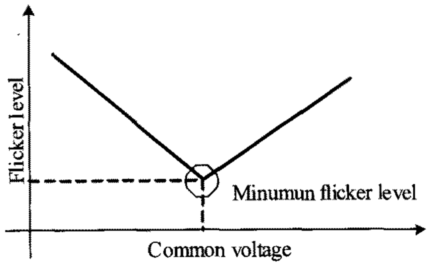


그림 7. 공통전압과 플리커의 관계

Fig. 7. Common voltage vs. flicker level.

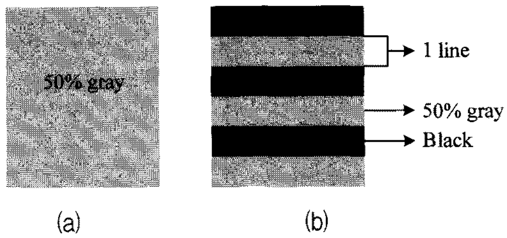


그림 8. 반전 방법에 따른 플리커 테스트 화면

Fig. 8. Flicker test image according to inversion method.

Fig. 6 shows the flowchart for proposed automatic flicker adjustment algorithm. In this figure, VcomH and VcomL represent maximum and minimum of common voltage, respectively. ΔV_{com} is the difference of common voltage, and GVDD means maximum voltage applied in the gamma adjustment block of a LCD driver IC. Without considering ΔV_p (or ΔV_n), register setting values for VcomH and VcomL are initially set by GVDD and GND, respectively. As shown in Fig. 6, the algorithm finds minimum flicker level step-by-step. In this case, if flicker level of current step is more than flicker level of previous step, Vcom adjustment follows stop step, but if not, the loop continues.

The common voltage versus flicker level is described in Fig. 7. This flicker level can be minimized by accurate adjustment of common voltage around the midpoint of the main supply voltage as shown in Fig. 2. This relationship generally shows minimum flicker level at the optimum common voltage.

The flicker measurement depends on display test patterns according to inversion driving method as shown in Fig. 8. Since the ΔV_p is related to capacitances C_{sc} and C_{lc} of a TFT-LCD pixel as described in Equation (2.1), and has different values in each grayscale level, it is impossible to minimize flicker in all grayscale levels. Thus, when line inversion and frame inversion modes drive a LCD, Figs. 8(a) and 8(b) are used to investigate flicker level, respectively.

2.4.2. Automatic Gamma Adjustment Algorithm

The structure of gamma adjustment block of a LCD driver IC is shown in Fig. 9. The grayscale voltages are generated by using ADC (Analog-to-Digital Converter) consisting of resistor strings. The gamma adjustments are performed by the variable resistors and selectors as shown in Fig. 9. In this block, the variable resistors control reference, gradient and amplitude adjustments, and the selectors provide micro adjustment.

Fig. 10 shows the function of gamma adjustment registers. The g-correction registers consist of gradient-adjustment, amplitude-adjustment, reference-adjustment, and micro-adjustment registers as shown in Fig. 9 to correct grayscale voltage level according to the gamma characteristics of the LCD panel. These register settings make adjustments to the relationship between grayscale number and grayscale

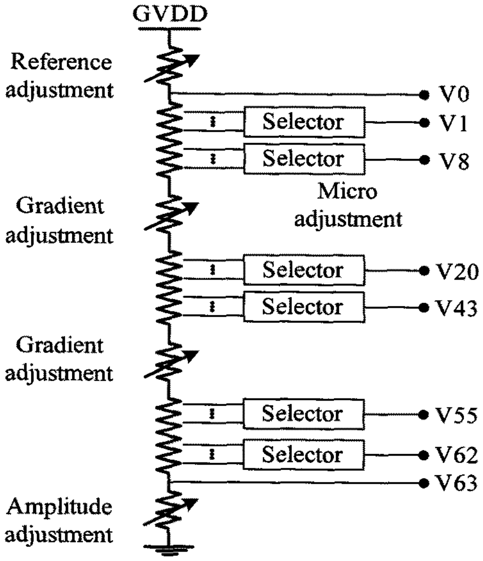


그림 9. LCD 구동 IC의 감마조정 블록 구조

Fig. 9. Structure of gamma adjustment block of a LCD driver IC.

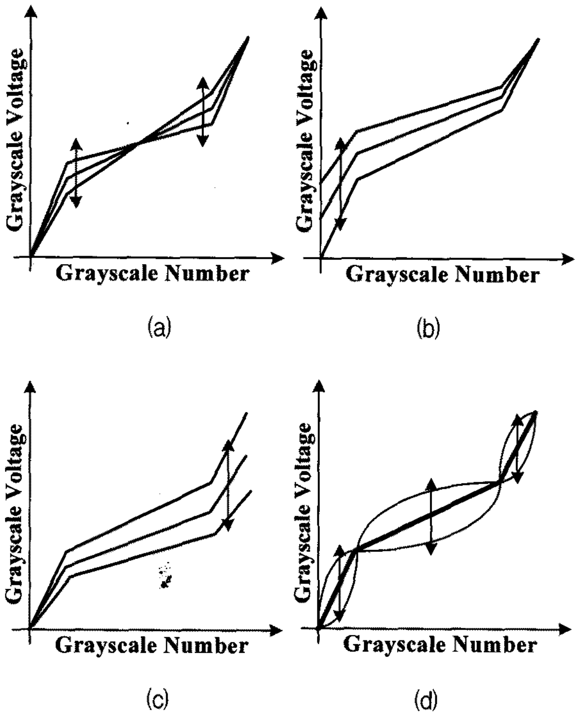


그림 10. 감마 조정 레지스터들의 동작: (a) 기울기 조정, (b) 진폭 조정, (c) 참조 조정, (d) 마이크로 조정

Fig. 10. Operation of gamma adjusting registers: (a) gradient adjustment, (b) amplitude adjustment, (c) reference adjustment, (d) micro adjustment.

voltage, and the setting can be made differently for positive and negative polarities. The gradient adjustment registers are used to adjust the gradient without changing the dynamic range, namely initial point and end point of grayscale voltage. The grayscale voltages for middle grayscale number can be adjusted by this register setting. The amplitude and reference adjustment registers are used to adjust the amplitude and reference of the grayscale voltages, respectively. The micro adjustment registers are used for minute adjustment of grayscale voltage levels.

The driver ICs for mobile LCDs include gamma adjustment registers of more than 10-set to optimize gamma curve. Traditional way of mobile LCD gamma adjustments involves manually correction steps by trial and error to adjust these 10-set registers. Since this depends on experiences of LCD module developers, it is highly labor intensive and requires several correction steps providing large gamma correction error. Thus, programmable gamma reference values are needed to compensate for the wide spread error in panel-to-panel gamma variation. For this purpose, we have developed a new automatic gamma control system.

The proposed g-correction follows a sequential step that adjusts amplitude/reference, gradient and micro registers as shown in Fig. 11. First, the algorithm adjusts offset of overall gamma curve, and then it adjusts luminance slope for middle grayscale using gradient adjustment. Finally, the algorithm adjusts minutely each grayscale using micro adjustment. After completing g-correction, gamma error rate is calculated as defined in equation (2.4).

$$\text{Gamma error rate}(\%) = \left(\sum \frac{\left| L_{ref(k)} - L_{meas(k)} \right|}{L_{ref(k)}} \right) \times 100 \quad (2.4)$$

where k is the number of grayscale, $L_{ref(k)}$ is reference brightness in each grayscale, and $L_{meas(k)}$ is brightness measured in each grayscale.

The gamma error rate is calculated by the difference between reference brightness and brightness measured in each grayscale as defined in equation (2.4). Our proposed system looked at the accuracy of gamma adjustments using the value.

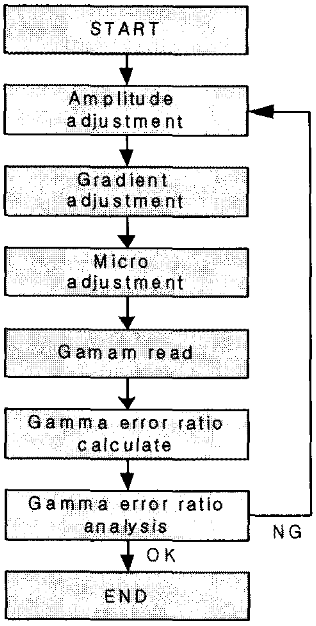


그림 11. 감마 조정 레지스터 설정 순서도
Fig. 11. Gamma register setting flowchart.

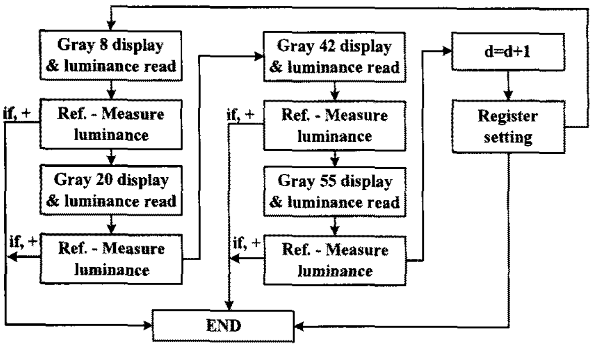


그림 12. Amplitude 조정 알고리즘의 순서도
Fig. 12. Flowchart for amplitude adjustment algorithm.

Fig. 12 shows the flowchart for amplitude/reference adjustment algorithm. To accomplish the adjustment, register values are controlled by variable resistors in IC as shown in Fig. 9. The proposed algorithm follows a sequential step that reads and displays each luminance for the voltages of grayscale numbers of 8, 20, 43 and 55 shown in Fig. 12. As shown in Fig. 9, amplitude and reference registers in driver IC are designed to choose these four grayscale numbers.

When each luminance value measured at any one of grayscale numbers of 8, 20, 43 and 55 is located in lower or higher point than that of reference value, the algorithm employs the gradient adjustment. Let's

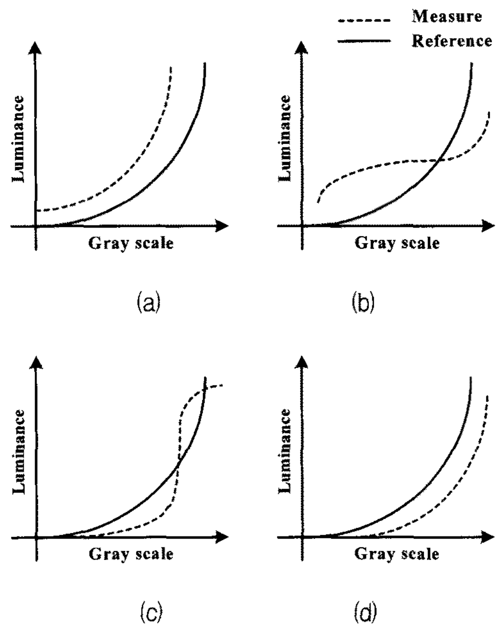


그림 13. Gradient 조정 유형:
(a) 유형 1, (b) 유형 2, (c) 유형 3, (d) 유형 4
Fig. 13. Possible measured modes: (a) mode 1, (b) mode 2, (c) mode 3, (d) mode 4.

consider four modes shown in Fig. 13. It can be assumed that the measured luminance at least represents one of these modes. In this case, we can use the gradient adjustment register, since it can be used to adjust the upper and lower sides of the luminance slope for middle grayscale. These possible modes can be controlled by the developed algorithm.

Fig. 14 shows the flowchart for gradient adjustment algorithm employing four different modes shown in Fig. 13. To accomplish the adjustment, register values are also controlled by variable resistors in driver IC. The proposed algorithm follows a sequential step that reads and compares each luminance for the voltages of grayscale numbers of 8 and 55 for each mode as shown in Fig. 14. When the specific mode in the initial step is determined, the algorithm compares measured luminance with reference luminance by changing assigned register value. At this time, the register value is continuously increased until gamma curve modes are changed.

The micro adjustment algorithm adjusts minutely luminance at grayscale levels of 1, 8, 20, 43, 55 and 62. Fig. 15 shows the flowchart for micro adjustment

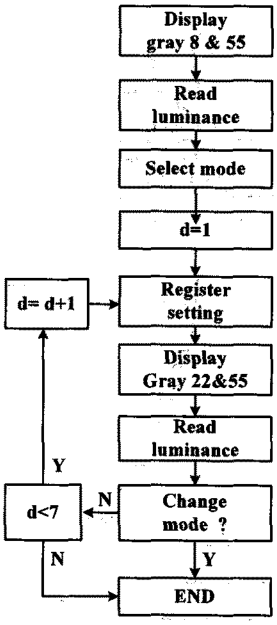


그림 14. Gradient 조정 알고리즘 순서도
Fig. 14. Flowchart for gradient adjustment algorithm.

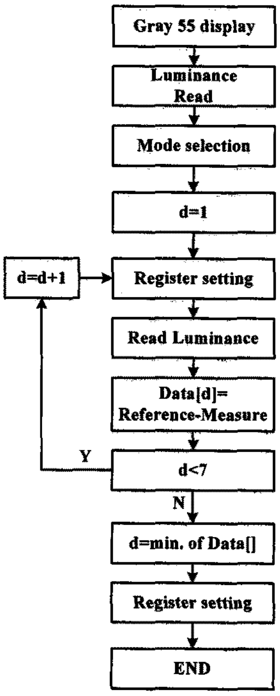


그림 15. Micro 조정 알고리즘 순서도
Fig. 15. Flowchart for micro adjustment algorithm.

algorithm to adjust luminance at grayscale level 55. The developed algorithm uses 6-point programmable matching technique with reference gamma curve. To accomplish the adjustment, register values are also controlled by variable resistors in driver IC. Each micro register is selected by comparing reference value with initially measured luminance value by changing each grayscale level.

Ⅲ. Development of System and Software

3.1. Development of Hardware

The proposed system consists of module-under-test (MUT, LCD module), PC installed with algorithm and program, multimedia display tester for measuring luminance, and control board for interface between PC and LCD module as shown in Fig. 16. It is realized to calibrate gamma values of 1.8, 2.0, 2.2 and 3.0. The control board is basically constructed with TMS320F2812 DSP chip of Texas Instruments. The board is also designed with FPGA, and it supports different interfaces such as RGB and CPU. It plays a role in RS232 interface between PC and luminance meter controlling luminance meter, reading LCD luminance data, setting LDI register, and providing grayscale images in LCD. The PC part has GUI program, gamma adjustment algorithm and system monitoring function.

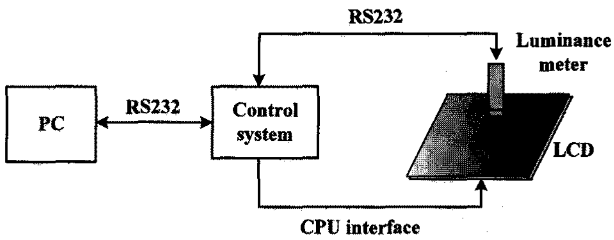


그림 16. 자동감마조정시스템 구성도
Fig. 16. Block diagram of automatic gamma adjustment system.

3.2. Development of Control Program

Fig. 17 shows captured screen of PC control program developed to control automatic image quality adjustment system. This program is developed using LabCVI of National Instruments. This PC program contains automatic image quality adjustment algorithm, luminance meter control, and LCD control function. When [AUTO] button in program is

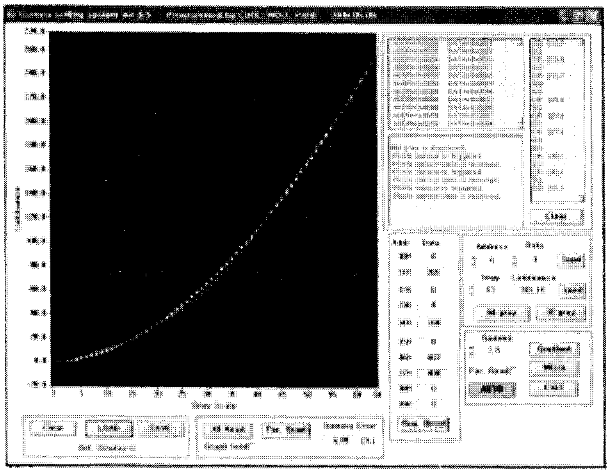


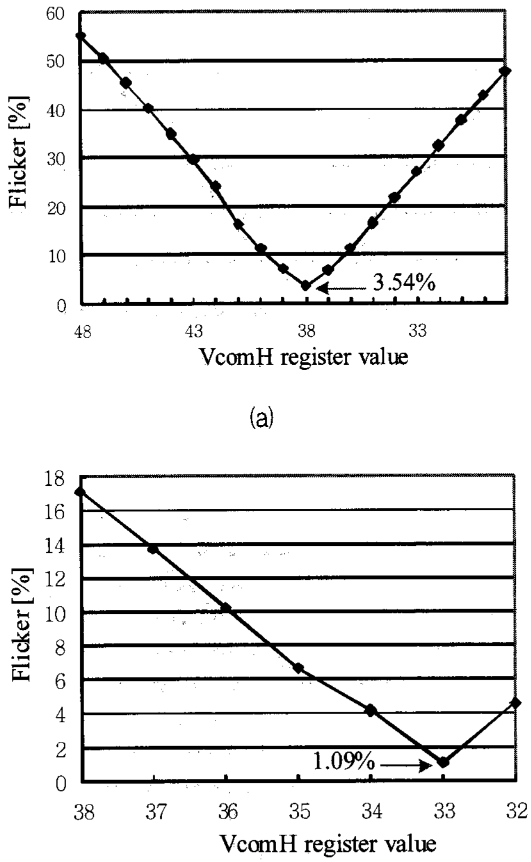
그림 17. 자동감마조정시스템을 구현한 소프트웨어
Fig. 17. Software of automatic gamma adjustment.

click-on, the steps that adjust amplitude/reference, gradient and micro registers are sequentially processed. After completing g-correction, the result is displayed as [Gamma Error] term, and adjusted register data is extracted using [save] button.

Ⅳ. Experimental Results and Discussion

In this work, panels with different sizes and different liquid crystal modes, and driver ICs with different resolutions and different interfaces are performed to verify performance of proposed automatic image quality system. We used ECB (Electrically Controlled Briefringence) mode and TN (Twisted Nematic) mode QVGA TFT-LCDs with line inversion driving method for module-under-test (MUT).

The results are shown in Figs. 18 and 19. The proposed system is set with target values of flicker level of 3% and gamma error ratio of less than 15%. The x-axis in Fig. 18 shows VcomH register setting value, and the values of 38 and 33 indicate VcomH voltage of 4.21V and 4.05V, respectively. The reference gamma curve shown in Fig. 19 depicts a standard gamma value of 2.2. Using algorithms shown in Figs. 6, 12, 14 and 15, the target values are convergent. After 1st adjustment, the system showed flicker level of 3.54% and gamma error ratio of 35.2%

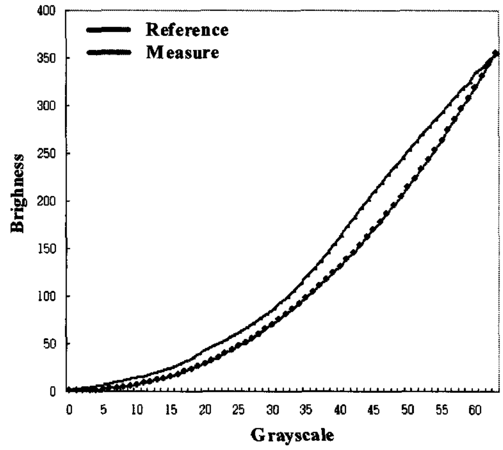


(a)

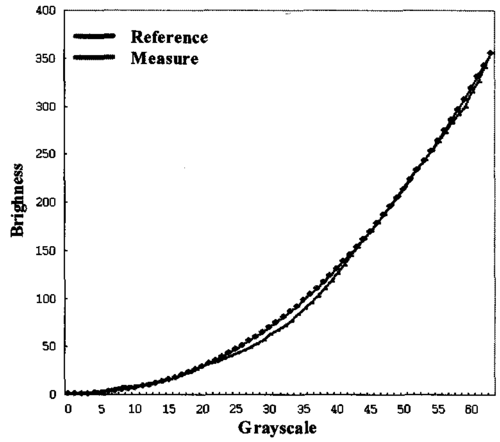
(b)

그림 18. VCOM 조정에 의한 플리커 조정:
(a) 첫 번째 조정, (b) 두 번째 조정
Fig. 18. Flicker changes by VCOM adjustment:
(a) 1st adjustment, (b) 2nd adjustment.

as shown in Figs.18(a) and 19(a). These results don't satisfy target values of flicker level of 3% and gamma error ratio of less than 15%, so 2nd adjustment was performed. The proposed system showed target values with flicker level of 1.09% and gamma error ratio of 4.85% from 2nd adjustment as shown in Figs.18(b) and 19(b). For twice loop iterations, it spent adjustment time of approximately 10 minutes. Since traditional manual method depends on experiences of LCD module developers, it requires very long adjustment time of approximately 40 hours with large gamma error ratio of over 20%. As shown in these results, proposed system showed excellent image quality adjustment including less gamma error ratio and less flicker level with fast adjustment time compared to conventional method.



(a)



(b)

그림 19. 감마 조정 결과:
(a) 첫 번째 조정, (b) 두 번째 조정

Fig. 19. The adjusted results of gamma:
(a) 1st adjustment, (b) 2nd adjustment.

표 1. 자동 화질 최적화 시스템의 적용 결과

Table 1. Summary of the adjusted results for the proposed system.

LC Mode	Driver IC	Resolution	Flicker level (%) Before adjustment	Flicker level (%) After adjustment	Gamma error rate (%) Before adjustment	Gamma error rate (%) After adjustment	adjusting time (min.)
TN	A type	QCIF	35.2	1.9	21.97	9.95	8
TN	B type	QCIF	26.4	2.3	20.97	7.00	8
TN	B type	QCIF	19.5	1.7	21.89	6.81	8
ECB	C type	QVGA	29.5	2.4	41.50	12.83	8
ECB	C type	QVGA	21.9	2.52	37.48	13.27	8
ECB	D type	QVGA	17.3	1.1	32.52	4.85	12

Table 1 summarizes the adjusted results of the proposed system for a standard gamma value of 2.2. Although several ECB modes provide average gamma error rate of more than 10%, this meets specification of less than 15% with significantly reduced adjusting time. However, as listed in Table 1, proposed system has much longer adjusting time to get much enhanced image quality with flicker level of less than 2% and gamma error rate of less than 5%. Proposed system showed flicker level of 1.1% and gamma error rate of 4.85% with the adjusting time of 12 minutes.

(a) (b)

그림 20. 화질 최적화 결과 비교: (a) 기존의 수작업 결과, (b) 자동 화질 최적화 시스템 결과

Fig. 20. The adjusted results for each method:
(a) Conventional manual adjustment,
(b) Proposed adjustment.

Fig. 20 shows comparison results for the traditional method and proposed method. Conventional result shown in Fig. 20(a) provides flicker level of 20% and gamma error rate of 30% with the adjusting time of 48 hours. However, proposed system showed excellent image quality with the flicker level of 2.52%, gamma error rate of 13.27%, and adjusting time of 8 minutes. As shown in Fig. 20, proposed system showed much excellent image quality with significantly reduced adjusting time compared to conventional manual adjustment approach.

Table 2 shows comparison results for the traditional method and proposed method. Traditional way of mobile LCD gamma adjustments involves manually correction steps by trial and error to adjust these 10-set registers. Since this depends on experiences of LCD module developers, it is highly labor intensive and requires several correction steps providing large gamma correction error. As listed in Table 2, proposed method showed very low flicker level, low gamma error rate and fast adjusting time. This result reveals that the proposed system can

표 2. 기존 방법과 자동 화질 최적화 방법 비교
Table 2. Comparison results for the traditional and proposed methods.

LC Mode	Driver IC	Resolution	Flicker level		Gamma error rate		adjusting time	
			Traditional	Proposed	Traditional	Proposed	Traditional	Proposed
TN	A type	QCIF	30%	1.9%	25%	9.95%	36hr	8min
ECB	C type	QVGA	20%	2.52%	30%	13.27%	48hr	8min

remarkably reduce test overhead in mass production line of the mobile TFT-LCD. We believe that proposed system will be used in flat panel display applications including TVs and monitors.

V. Conclusions

We presented automatic TFT-LCD image quality system. It could adjust gamma curve and flicker level automatically by controlling analog supply voltage and gamma voltages of the LCDs. The flicker level, gamma correction error and adjusting time were significantly reduced by automatic image quality adjustment approach. The system contained module-under-test (MUT, LCD module), PC installed with program and algorithm, luminance tester, and control board. We have developed a new algorithm that provides 6-point programmable matching technique with reference gamma curve. Developed algorithm and program were generally applicable for most of the LCD modules. The system was realized to calibrate gamma values of 1.8, 2.0, 2.2 and 3.0. We believe that the proposed system is very useful to develop high-quality LCD and to reduce test overhead in mass production line of the mobile TFT-LCD. We hope that proposed system will be used in flat panel display applications including TVs and monitors.

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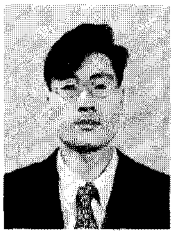

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