Automated System for Response Time and Flicker Optimization in LCDs

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Abstract
One of representative techniques for compensation of LC's slow response characteristic is the Response Time Acceleration (RTA) technique. The conventional data definition for the RTA is based on the manual measurement and thus it takes long time. Therefore it is almost impossible to use panel specific compensation data in MP line. We have developed a new automated measurement system and flicker minimization for this purpose, which could achieve dramatic measurement time reduction, consistency over different operator, and optimized values as well. This system laid the groundwork for the application of image quality enhancement technologies to panels individually, and using this system, we can expect very uniform image quality for all LCD panels.

1. Introduction
In order to compensate the slow response characteristic of liquid crystal, the well-known RTA (Response Time Acceleration) technique has been widely used. This RTA is implemented by LUT (Look-Up Table) in memory, the conventional measurement for LUTs is based on the manual method and LCD products share typical LUTs model by model, not panel by panel. Additionally, all LCD panels need to adjust V_{com} level for minimizing flicker amount, but this process is also manual work by operators. So these measurement processes to define LUT and flicker amount have been time-consuming, subjective, and inconsistent. What is worse, there are panel-to-panel variations of operation characteristics from mass production lines. Therefore we need panel-specific values for the enhancement of image quality of LCD products. This paper reports a development of automated measurement system based on our LUT optimization algorithm presented at IMID 2004, including a new flicker minimization algorithm.

2. Algorithm

2.1 RTA LUT Optimization
Conventional LCD response time has been defined by measuring the time interval from 10% to 90% of the target luminance. But this 10/90 metric disregards some information such as A and B in Figure 1. Even if an overshoot transition occurs as in circle B, 10/90 response time can't identify this effect. Additionally, excessive overshoot creates a moving picture artifact. Therefore we have proposed a new metric, frame luminance, which represents the actual luminance from the liquid crystal after one frame time. This concept was introduced in our IMID'04 paper[1].

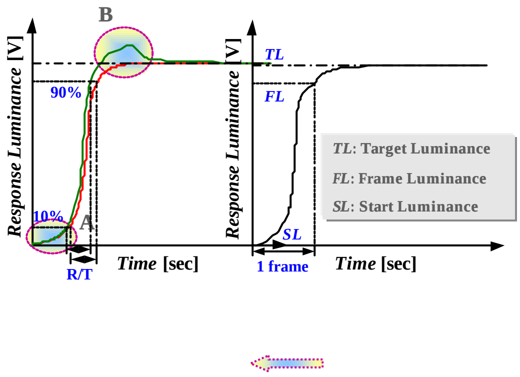

Figure 1. Response Time vs. Frame Luminance

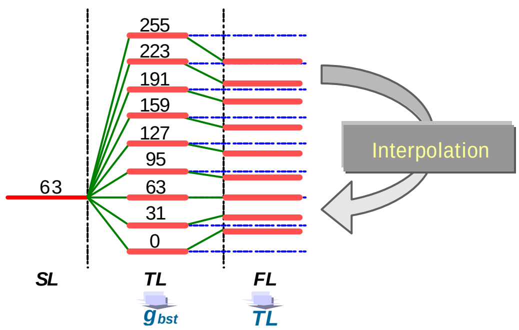

Figure 2. Interpolation Algorithm

The frame luminance concept allows easy calculation of the optimum LUT with minimal resulting luminance overshoot. As shown in Figure 2, the entire gray range from black to white is divided into 8 sub-sections, and the FL values are measured for all possible combinations of gray levels (9x9-9=72). In the figure example, Start Level (SL), Target Level (TL), and Final Level (FL) values are represented for the 9 transitions starting from gray level 63. Since FL levels are induced by inherent LC characteristics, the distribution will be arbitrary. Using an interpolation technique, we rearrange the FL levels into a uniform distribution, such that the TL values will be changed accordingly to achieve optimum boost levels. In the above figure for example, with prior frame at gray level 63 and target luminance at gray level 159, interpolation yields the result that gray level 190 should be applied for one frame.

2.2 Flicker Optimization

We describe our automated flicker minimization method. 'DVR' stands for Digital Variable Resistor. DVR uses a 7-bit word as a control register. Figure 3 shows the relationship between flicker level and DVR value. A quadratic approximation is used to solve for the minimum flicker level. The quadratic approximation is as follows:

$$Flicker\_Level_{n-1} = px_{n-1}^2 + qx_{n-1} + r$$

$$Flicker\_Level_{n} = px_{n}^2 + qx_{n} + r$$

$$Flicker\_Level_{n+1} = px_{n+1}^2 + qx_{n+1} + r$$

Where x_n indicates n_{th} DVR index value, and p, q, and r are coefficients of the quadratic equation. The coefficients can be solved by using Cramer's rule. Once the DVR index value is written into the DVR register through the I^2C interface, the flicker level will be minimized.

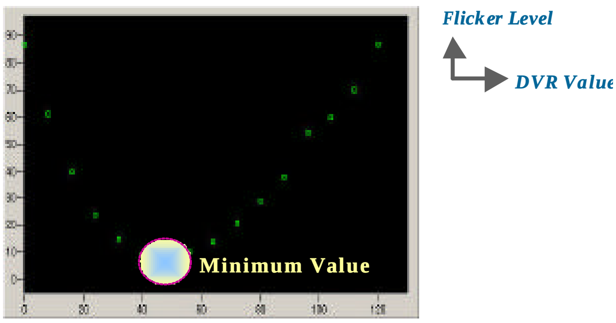

Figure 3. Flicker Level vs. DVR Index

3 Automated System

Figure 4 shows the functional block diagram of the proposed system. The system consists of a data acquisition board connected to a luminance meter, and a data processing section implemented on a PC. The luminance meter measures the Device Under Test (DUT), which in turn can be programmed by the PC. The system incorporates many useful features, not only LUT measurement capability, but also various manual features for R&D work. The LUT can be applied instantly to the panel for immediate response time performance visual feedback. Conventional trial-and-error methods and the frame luminance value interpolation method can be compared, as both techniques are supported by the system. The interpolation method requires less than one hundredth of the time required for conventional methods, with even better results. Major features of the system include:

- Multiple waveforms can be repeatedly measured and accumulated, enabling noise reduction by signal averaging
- Several low pass filter options are supported, including Butterworth, Chebyshev, and Elliptical filters
- Arbitrary reference levels (not just 10/90) can be set for more measurement flexibility
- Measure and Apply: Derived LUT can be directly applied and evaluated right after the calculation
- Linear and cubic SPLINE interpolation algorithms are supported
- Measured "before" and "after" waveforms can be overlapped for comparison
- LUT editing: LUT entries can be modified, applied, and measured within the same window

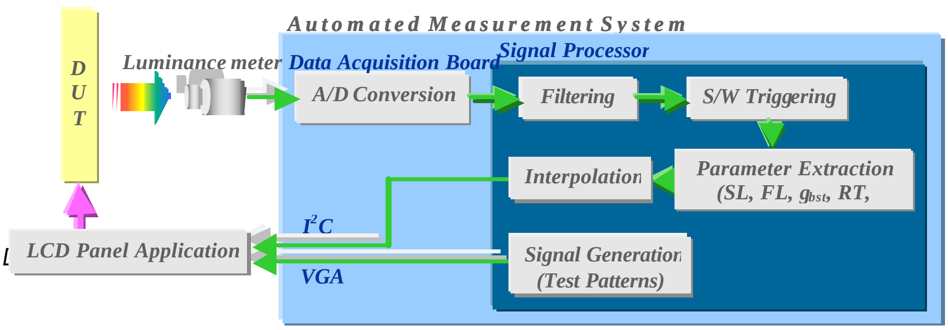

Figure 4. Functional Block Diagram of the Proposed System

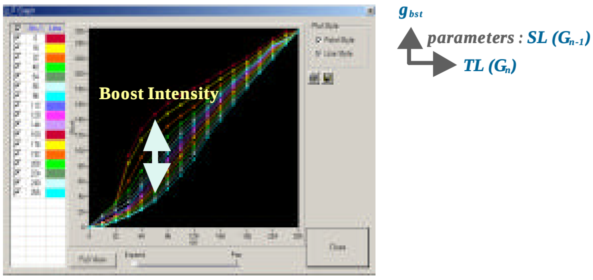

Figure 5. Measured LUT

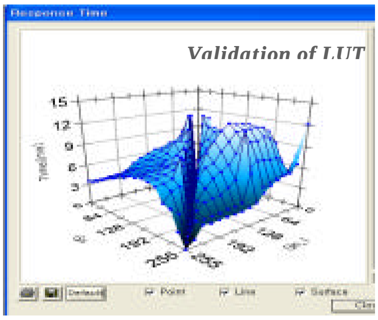

Figure 6. Measured Response Time

Figure 5 shows the graphical representation of measured LUT. Each curve represents one column of the LUT so that the three dimensional table can be represented by a two-dimensional graph. The wider the curves are spread, the greater the boost intensity will be. Figure 6 shows the window for measured response time. All graphs and tables can be exported into bitmap images or spreadsheet data to support different applications. Also, an externally generated LUT can be loaded and applied to the DUT so that such LUT performance can be evaluated on the panel.

4. Conclusions

We have developed a new automated measurement system incorporating a very efficient measurement algorithm, which includes LUT and flicker optimization. To characterize and program the LUT and flicker amount, the system requires less than one hundredth of the time of conventional methods while delivering greater accuracy. This approach makes use of the frame luminance concept to capture basic temporal parameters of the liquid crystal panel for LUT, and then applies an interpolation algorithm to calculate the optimized panel-specific boost table. The procedure is fully automated and the resultant values can be programmed into panel on the fly. This system enables compensation of all LCD characteristics which naturally vary due to process differences in panel manufacturing. Using the new system, flicker characteristics of LCD panels can be easily measured and adjusted on the production line.

5. References

[1] Taesung Kim, Bongim Park, “Novel LUT Measurement Method for Response Time Compensation,” IMID’04 DIGEST, pp.331~334

[2] Hao Pan, Xiaofan Feng, Scott Daly, “A new metric for LCD temporal response: Dynamic gamma,” IMID’04 DIGEST, pp.419~422.