A New Approach to the Response Time Measurement Method of OLED TVs

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ABSTRACT

This study suggests a problem in the existing response time evaluation method focusing on the traditional LCD in the evaluation method for a display with a very fast response time such as OLED. In addition, for a new display with better performance than LCD, we understand the display driving behavior, including pixel addressing time and pixel response time, and reconsider the response time evaluation method.

1 Introduction

In the past, the purpose of the display was clear, but now it is ambiguous. Due to social issues such as Covid-19, TV products are expanding not only to movies and TV shows, but also to home entertainment equipment that allows people to enjoy games. As a result, the demand for the quality of the moving picture is increasing and the response time of the display is being used as a representative quality indicator of moving picture.

Among the many indicators of display performance, response time has become a very important indicator of display performance in managing and improving LCD weaknesses; The physical properties of LCD's slow liquid crystals lead to the slow response time performance of the display. [1], [2] Therefore, the current response time measurement method focuses on the mainstream display, LCD with slow response time.

However, as technology advances and new displays are developed improving the disadvantages of LCDs, it is necessary to re-check whether existing response time evaluation methods can evaluate all kinds of displays

In this paper we suggest a problem with exiting evaluation and reconsider the measurement method through the understanding of the display behavior about the response time.

2 Display Response Time Measurement

2.1 General Method from IDMS

For the moving image performance evaluation of the display, MPRT and response time are typical methods. The MPRT represents the overall moving image quality of the display as a measurement from scrolled images including refresh rate, response time, image quality improvement skills, human visual factors, etc.[3] On the other side, the response time of a display is a measurement of how fast the display can switch from black to white and white to black again.[4] The purpose of this assessment is to acquire the transition time from activation to deactivation of a pixel. It is just a performance close to display's hardware.

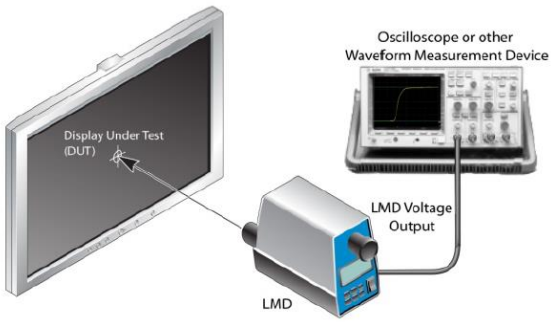


Fig. 1 The response time measurement system (IDMS, 2012, p.170)

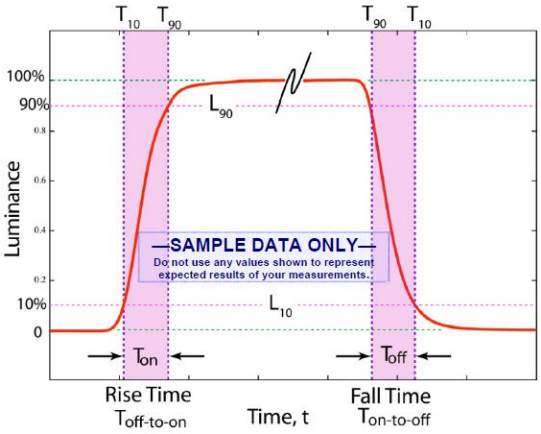


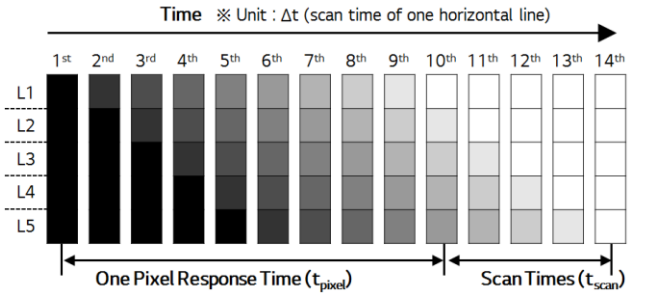
Fig. 2 A response time's waveform with rise and fall times (IDMS, 2012, p.169)

The basic procedure for response time measurement is to apply a time blinking test pattern to the DUT while measuring the relative luminance of the display with a high speed LMD. Fig.1 shows the response time measurement system. The response time is generally referred to as the time that it takes for the display to transition from 10% to 90% of the initial and ending

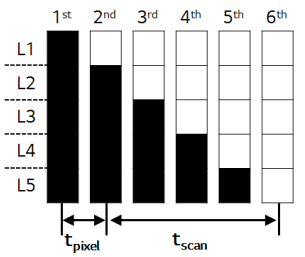
relative luminance levels. (see Fig. 2) We can call the response time the sum of the rise and fall times, or the average of them.

2.2 Relationship between response time and measurement area

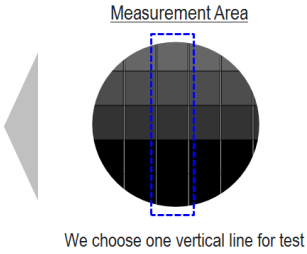
Usually, to measure the response time the LMD has an aperture of a certain size including multiple pixels; typically under the conditions of aperture 2 degree and working distance 500 mm, the aperture diameter is approximately 17.6 mm, but the IMDS does not fix the size. Fig. 3(c) shows an aperture including pixels in a particular size. It consists of several horizontal lines. Here we can see that one vertical line in the measurement area changes over time in Fig. 3 (a), (b). We can think of two cases in which one pixel's response time is significantly greater than the scan time of one horizontal line and is similar or smaller than that scan time.



(a) At slow pixel response time



(b) At high speed pixel response time



(c) A measurement area of response time

Fig. 3 Display's pixel movements in response time measurement area

The first is for LCD to be in this case, it takes several scan times 10th Δt for one pixel of L1 line to transition from black to white in Fig. 3 (a). It will be one pixel response time t_{pixel}. And the pixels of each line are changed to saturated white sequentially. It will be also scan times t_{scan}.

In the second case, if One Pixel's Response Time is significantly faster, it is saturated within one horizontal line scan time Δt, as shown in Fig. 3 (b). And it takes t_{scan} as much scan time as the number of vertical lines. OLED will be a similar case.

In this simple modeling, the response time of the display can be expressed with the following formula. The display response time $t_{R/T}$ is the sum of one pixel response time t_{pixel} and scan times t_{scan} in measurement area.

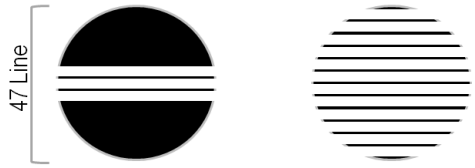
$$t_{R/T} = t_{pixel} + t_{scan} \quad (1)$$

For conventional LCDs, because one pixel response time is very slow compared to one line scan time, LCD's response time is highly influenced by one pixel response time, but very little with the scan time of lines in measurement area. So measurement area is not a big problem in measuring response time.

However, OLED has one pixel response time in microseconds. So we cannot ignore the impact of scan time of lines. ; The scan times for UHD 60Hz and UHD 120Hz are approximately 6 to 8 us and 3 to 4 us respectively. Eventually, response time has a value that is changed depending on the scan time of lines in measurement area. We can check how the measurement area affects the response time of the display through the following experiment.

3 Experiment and Result

To determine the change in response time according to the measurement area, the aperture diameter of the LMD is fixed to about 17.6mm and it is measured by reducing the number of blinking lines in the aperture. For the convenience of measurement, the aperture is fixed, but the decrease in the number of lines is the same as the decrease in the measurement area. It would be like measuring the response time by decreasing the measurement area. The number of lines decreases from 60 to 10, and the aperture of the LMD is completely filled at 47 lines. Fig. 4 (a) is an aperture image under the 47 lines, and (b) shows an aperture overflowing with 47 to 60 lines. The Lines switch from white to black and from black to white again at 1 cycle per second.

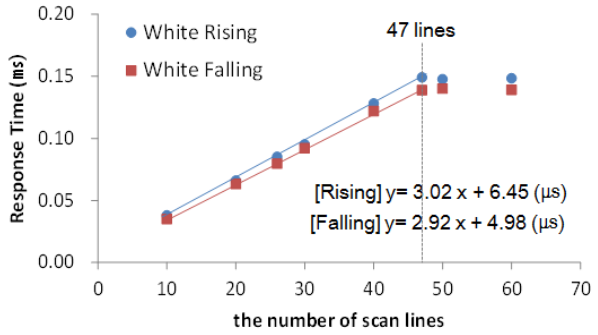


(a)10 ~ 46 line in aperture (b) 47 ~ 60 line in aperture

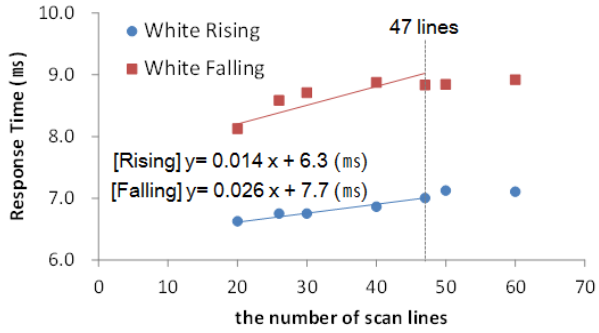
Fig. 4 Measurement lines in aperture of LMD

We evaluated two models, a 65" UHD 120Hz OLED TV and a 65" UHD 60Hz LCD TV. Fig.5 shows the results. In the OLED TV both rise and fall times linearly decrease as the number of lines decrease from 47 lines. As a matter of course, it results similar response times in all conditions above 47 lines. We figure out that the response time of OLED decreases as measurement area decrease. On the other hand, LCD TV shows only a slight decrease under 47 lines and in other conditions

similar results are also shown. The slopes of each regression formula at the rising and falling of OLED TV is 3.02, 2.92 μs per line, which means the one line scan time of display. It's similar to the scan time 3~4 μs of UHD 120 Hz models; The values of the LCD TV are 14, 26 μs per line, which are very larger than one line scan time, so It can have a big measurement distortion compared to scan time 6 to 8 μs of UHD 60 Hz models. The constant of a regression formula is estimated to be a response time of one pixel, OLED TV has about 5 ~ 6 μs and LCD TV has about 6 ~ 8 ms. The same results can be seen in Fig. 5 for each color of red, green, and blue in the OLED TV. One pixel response times of OLED TV at each color can be also estimated at 3.1 to 4.6 μs, which are very fast compared to LCD TV.



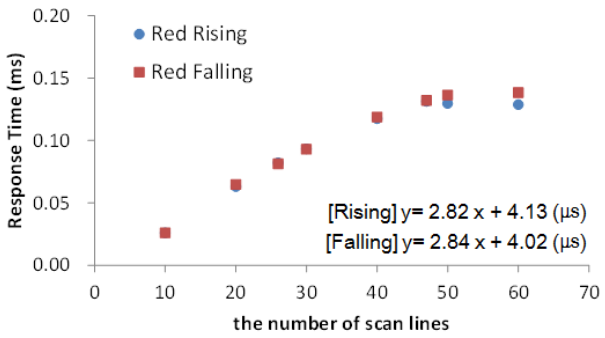
(a) 65” UHD 120Hz OLED TV



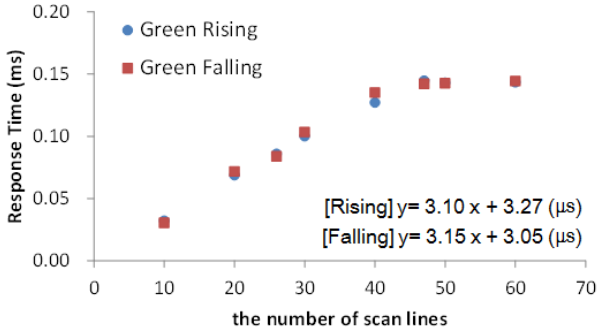
(b) 65” UHD 60Hz LCD TV

Fig. 5 Results of response times depending on scan lines

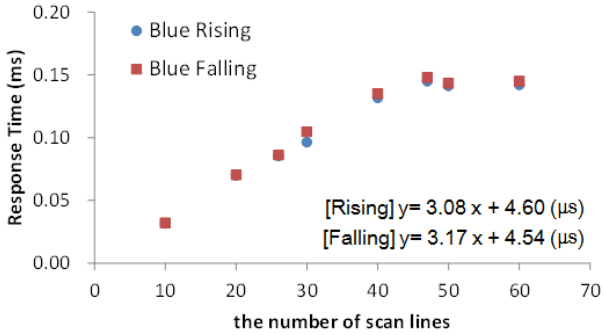
In order to verify this, using a high-sensitivity LMD and a high-speed amplifier we can measure one line response time of OLED TV, it results 5.8 μs on the average of each white, red, green and blue one line response time at rise and fall times, as shown in Table 1. Similar to the tested experiment with changes in the number of lines above, we find out that OLED TV has fast pixel response time under 10 μs and measurement area have a significant impact on OLED.



(a) Red pixel response time



(b) Green pixel response time



(c) Blue pixel response time

Fig. 6 Results of response times at color patterns

Color	Rise Time (μs)	Fall Time (μs)
White	8.5	6.8
Red	6.9	5.8
Green	5.0	4.9
Blue	5.8	2.9
Average	5.8	

Table 1 Response times of each color on one horizontal line

4 Conclusions and Discussions

We know a response time of the OLED varies depending on the area of evaluation as shown in previous experiments when measured by current evaluation method. The reason is that a response time can be expressed as the sum of one pixel response time

and the scan times within the measurement area. Here, the OLED has very fast pixel response time as below 10 μs, the scan times make large influence on the response time. So OLED has different values of response time depending on the measurement area.

Therefore, we need a new evaluation method that can solve this problem. Typically, the scan time within the measurement area can be calculated using the resolution and refresh rate of the display and the pixel response time eventually can determine the response time of the display. So the measurement response time of one line or one pixel not including scan time can be an objective indicator from hardware's performance perspective.

The response time is a very important performance on the display. But its method is focused on managing and improving the weakness of LCD. Now we think some changes are needed for the new display not LCD.

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