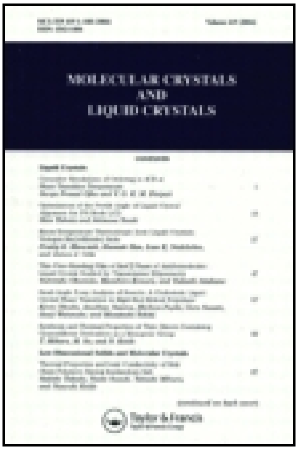


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Application of an Interlaced Scan Driving Method to TFT-LCD

T. Terazawa [a] & F. Matsukawa [a]

[a] Advanced Technology R&D Center, Mitsubishi Electric Corp., 997 Miyoshi, Nishikoushi-machi, Kumamoto, 861-1197, JAPAN

Version of record first published: 24 Sep 2006

To cite this article: T. Terazawa & F. Matsukawa (2001): Application of an Interlaced Scan Driving Method to TFT-LCD, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 367:1, 833-847

To link to this article: http://dx.doi.org/10.1080/10587250108028707

Mol. Cryst. and Liq. Cryst., 2001, Vol. 367, pp. 833-847
Reprints available directly from the publisher
Photocopying permitted by license only

Application of an Interlaced Scan Driving Method to TFT-LCD

T. TERAZAWA and F. MATSUKAWA

Advanced Technology R&D Center, Mitsubishi Electric Corp. 997 Miyoshi, Nishikoushi-machi, Kumamoto 861-1197, JAPAN

The optical response of a TFT-LCD has a hold-type characteristic. Therefore, the luminous intensity after scanning lines is kept almost constant. A TFT-LCD has an advantage over a CRT in that a luminous intensity does not reduce when an interlaced scan driving method is used.

This paper describes the quality of interlaced motion pictures by using the parameters of optical transition width and frequency response. Those parameters are related to edge blur and dynamic contrast ratio, respectively. The degradation caused by an interlaced scan was compared with other intrinsic factors that degrade TFT-LCD picture quality. It was found that the interlaced scan driving method has a relatively little influence on the widening of edge blur, but causes a relatively large loss in dynamic contrast ratio.

Keywords: motion picture; interlaced scan; TFT-LCD; optical transition width; optical frequency response; transfer function

1. INTRODUCTION

The pixel-selection time in a high-resolution TFT-LCD is so short that picture quality suffers because there is not enough time for charging the pixel capacitance.

An interlaced scan diving method that compensates this insufficiency by skipping some scanning lines has therefore been proposed.[1]

The luminous intensity of a TFT-LCD varies with the electric field in the pixel and its intensity after scanning is kept almost constant. The pixel works as a capacitive device. Its optical response is a hold-type response.[2] A CRT, in contrast, has an impulse response. An advantage of the TFT-LCD over the CRT is that a luminous intensity does not reduce when an interlaced scan driving method is used.

This paper describes a theoretical study of the interlaced motion picture quality. The quality is assumed to be degraded by intrinsic factors such as the slow optical response of the liquid crystal and the hold-type characteristic of the responses as well as by the use of the interlaced scan driving method.

We classified motion pictures into moving images and blinking images and used two parameters to evaluate the contributions of these factors. One is the optical transition width, which is related to edge blur in moving images. And the other is the optical frequency response of the transfer function, which is related to dynamic contrast ratio in blinking images.

2. OPTICAL TRANSITION WIDTH OF A MOVING IMAGE

2.1 Simulation model

The moving image is assumed here to be a rectangle that has a luminous intensity between 1 and 0, and that object moves in the positive x direction at a velocity of V (pixel/s).

2.2 Optical transition width by a liquid crystal

In this estimation, the relation between luminous intensity and applied voltage is assumed to be linear. When a step pulse voltage is applied to a pixel, the luminous intensity Ls(t) is expressed as follows:

$$Ls(t)=1-\exp(-t/T_{lc}) \qquad (2.2.1)$$

where t is time and T_{lc} is the time constant of the liquid crystal.

The picture quality is evaluated by using T_{lc90} in general. As T_{lc} is the time needed for the response to be 63% complete, the transition time T_{lc90} that needs for the response to be 90% complete can be calculated from the following equation.

$$T_{lc90} = 2.3 \times T_{lc} \qquad (2.2.2)$$

The optical transition width ΔX_l is defined as the product of the velocity V and the transition time T_{lc90}:

$$\Delta X_l = V \times T_{lc90} \qquad (2.2.3)$$

Figure 2.2.1 illustrates the displayed moving images. The optical transition width is the width of gray area and this appears when the response of the liquid crystal lags behind the input signal.

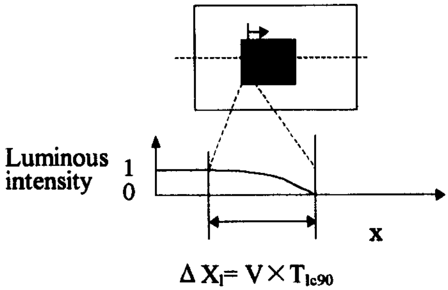


FIGURE 2.2.1 Optical transition width caused by slow response of liquid crystal.

2.3 Optical transition width caused by hold-type characteristics

The luminous intensity of a hold-type display is kept almost constant, and this too causes a transition width when image moves. Figure 2.3.1 shows the luminous intensity of displayed moving images, sampled along the temporal axis. If eye movement tracks an image moving at the average velocity, the average luminous intensity at the boundary has the gradient shown in Figure 2.3.2.

The width of the gradient is defined as the optical transition width ΔX_h and is given by[3]

$$\Delta X_h = V \times T_{fr} \qquad (2.3.1)$$

where T_{fr} is the frame period.

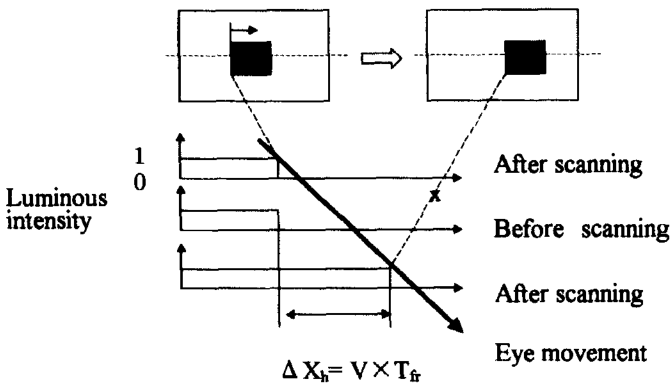


FIGURE 2.3.1 Boundary movement in horizontal(x)-temporal(t) domain.

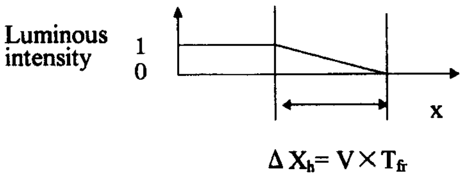


FIGURE 2.3.2 Optical transition width caused by hold-type characteristic.

2.4 Optical transition width caused by interlaced scan driving method

Interlaced scan is a driving method that skips some scanning lines. One frame image is thus formed from some sub-field images. In this paper it is assumed that the decrease in luminous intensity after scanning lines is negligible and that the skipped space is narrower than can be perceived by the eye.

The luminous intensity of the boundary thus becomes the average of skipped and selected line. Figure 2.4.1 illustrates one of the interlaced moving images, where 1 frame is formed from 2 sub-fields (this means that the interlaced ratio is 2:1).

The optical transition width ΔX_i of the interlaced ratio n:1 is expressed as follows:

$$\Delta X_i = (n-1) \times V \times T_{sf} \qquad (2.4.1)$$

where T_{sf} is the sub-field period.

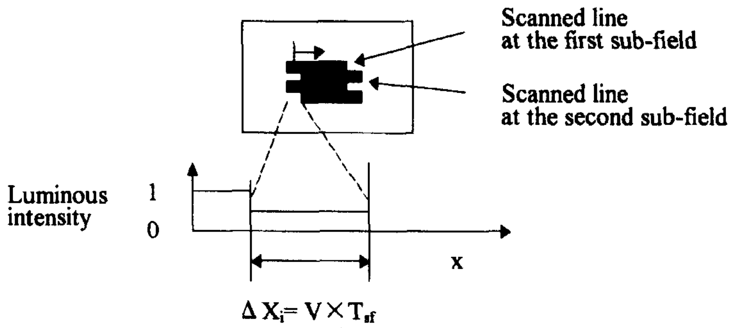


FIGURE 2.4.1 Optical transition width caused by interlaced scan

When the interlaced scan driving method is used, the transition width caused by hold-type characteristic is given by equation (2.4.2), which uses the sub-field period T_{sf} instead of the frame period T_{fr} used in equation (2.3.1).

$$\Delta X_h = V \times T_{sf} \qquad (2.4.2)$$

The equation (2.4.1) and (2.4.2) show that the transition width caused by hold-type characteristics is equal to that caused by interlaced scan of 2:1 ratio.

3. OPTICAL FREQUENCY RESPONSE TO BLINKING IMAGES

3.1 Simulation model

When the image blinks, the decreased optical frequency response reduces the contrast ratio of the image. This characteristic can be expressed by the amplitude of transfer function. Figure 3.1.1 shows a model in which the luminous intensity of images varies as a sinusoidal wave, where the response without reduction and that with reduction are drawn by solid and dashed curves, respectively. The response without reduction is assumed to be expressed as follows:

$$La(t)=1/2+1/2 \times \sin(w \times t) \qquad (3.1.1)$$

where $w=2 \times \pi \times f$, f is blinking frequency.

Then, the response with reduction can be expressed by the following equation.

$$Lb(t)=1/2+\alpha/2 \times \sin(w \times t) \qquad (3.1.2)$$

We defined the dynamic contrast ratio α that is calculated as the product of each amplitude of the transfer function.

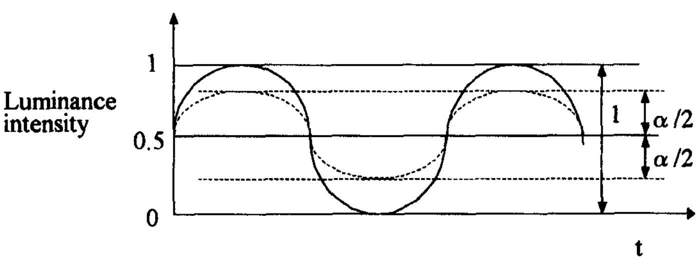


FIGURE 3.1.1 Model for calculating the optical frequency response to blinking images.

3.2 Optical frequency response of liquid crystal

The optical frequency response of liquid crystal has the first-order delay element in equation (2.2.1). The transfer function can be expressed as follows:

$$G_l(s)= (1+T_{lc}\times s)^{-1} \qquad (3.2.1)$$

The frequency response can be calculated by substituting jw for s in this equation. The amplitude of luminous intensity is expressed by following equation:

$$|G_l(jw)|= (1+(T_{lc}\times w)^2)^{-1/2} \qquad (3.2.2)$$

where $w=2\times\pi\times f$, f is blinking frequency.

Figure 3.2.1 shows the amplitude of the transfer function calculated for various values of the time constant of the liquid crystal: T_{lc}=0.0043 s (T_{lc90}=10 ms), T_{lc}=0.0087 s (T_{lc90}=20 ms), and T_{lc}=0.0174 s (T_{lc90}=40 ms). Those curves show that liquid crystal has a low-pass characteristic.

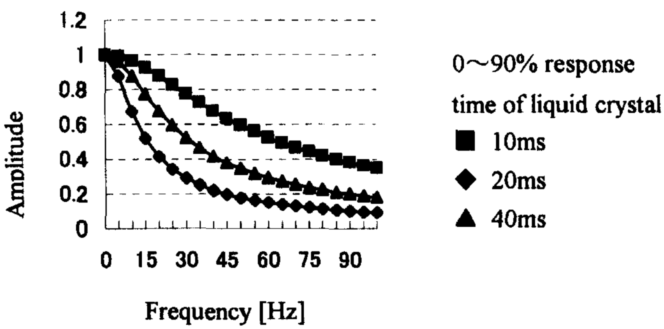


FIGURE 3.2.1 Optical frequency response of liquid crystal.

3.3 Optical frequency response of a hold-type display

The optical frequency response of a hold-type display can be simulated by using a sample-and-hold circuit. Thus, its transfer function is expressed as follows:

$$G_h(s)=(1-\exp(-T_{fr}\times s))/(T_{fr}\times s) \qquad (3.3.1)$$

where T_{fr} is the frame period.

By substituting jw for s, we can calculate the frequency response. The amplitude of the transfer function is expressed as follows:

$$|G_h(jw)|=|\sin(w\times T_{fr}/2)/(w\times T_{fr}/2)| \qquad (3.3.2)$$

where $w=2\times \pi \times f$.

Figure 3.3.1 shows the optical frequency response at the frame rate of 60Hz. This curve shows that hold-type display also has a low-pass characteristic. For example, when the signal is sampled at the rate of 60Hz, the response of the signal of 30 Hz is reduced to 63%.

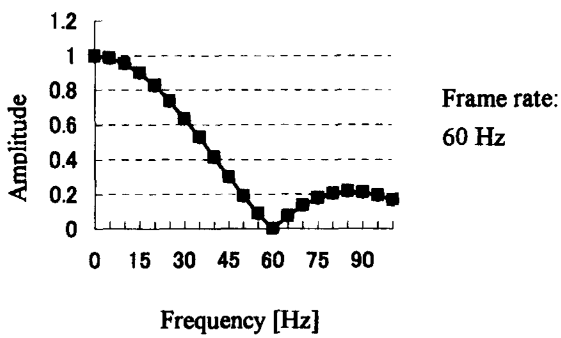


FIGURE 3.3.1 Optical frequency response of a hold-type display

3.4 Optical frequency response to an interlaced scan

The transfer function of interlaced scan is equivalent to that of a low-pass filter circuit with delay elements. When the interlaced ratio is 2:1, for example, the transfer function is expressed by using z transformation:

$$G_i(z)=(1+z^{-1})/2 \qquad (3.4.1)$$

Its amplitude is expressed as follows:

$$|G_i(jw)|= |\cos(w\times T_{sf}/2)| \qquad (3.4.2)$$

where T_{sf} is sub-field period.

Figure 3.4.1 shows the frequency response to interlaced scan when the interlaced ratio is 2:1, the frame rate is 30 Hz and the sub-field rate is 60 Hz. This curve shows that interlaced scan has a low-pass characteristic too. The response of 30 Hz blinking pattern, for example, becomes 0.

When an interlaced scan is used, the optical response of a display with a hold-type characteristic has to be calculated with equation (3.4.3) instead of equation (3.3.2) because the whole image changes in a period of T_{sf} while each picture element is rewritten in a period of $2\times T_{sf}$:

$$|G_h(jw)|= |\sin(w\times T_{sf}/2)/(w\times T_{sf}/2)| \qquad (3.4.3)$$

where $w=2\times \pi \times f$.

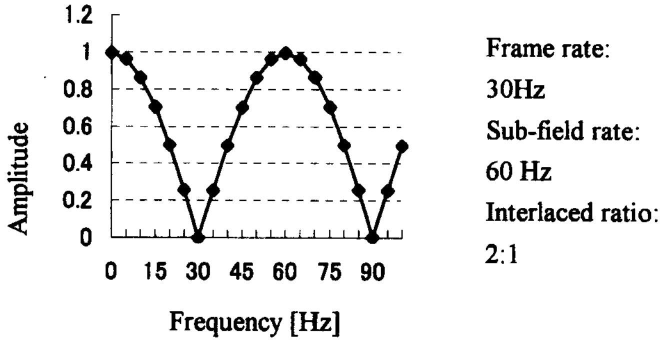


FIGURE 3.4.1 Optical frequency response to interlaced scan

4. DISCUSSION

The previous sections described the estimation of three factors: the slow response of liquid crystal, the hold-type characteristic, and the interlaced scan. In this section those three factors are compared and the degradation by interlaced scan is estimated. In this discussion, frame rate is assumed to be 60 Hz when interlaced scan is not used.

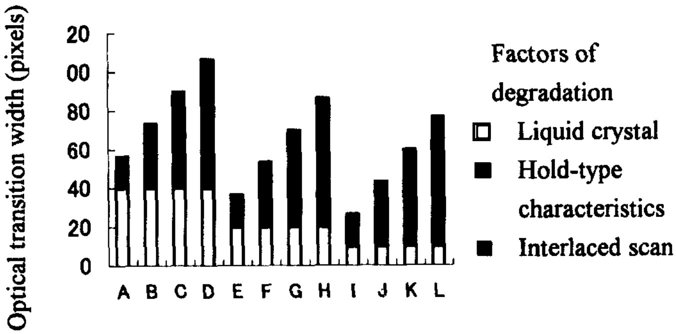
4.1 Evaluation on the optical transition widths

Each optical transition width is independent, and the total optical transition width can be obtained by adding the each component width. Figure 4.1.1 shows the total transition width and each component width when the velocity V of the images is 1000 pixel/s, the interlaced ratio is either 2:1(frame rate = 30 Hz), 3:1(20Hz) to 4:1(15Hz), and the response time of the liquid crystal varies from T_{lc90}=10ms (T_{lc}=0.0043s), T_{lc90}=20ms (T_{lc}=0.0087s) to T_{lc90}=40ms (T_{lc}=0.0174s).

In this figure, the ratio of each width is constant because each width is proportional to V as shown in equation (2.2.3), (2.3.1), and (2.4.1).

When liquid crystal with a T_{lc90} of 20ms and an interlaced scan of 2:1 ratio is used, the transition width increases from 36(20+16) pixels to 52(20+16+16) pixels. This width is about 1.4 times of that obtained when the interlaced scan is not used. The width is caused by the slow response of liquid crystal and the hold-type characteristic as well as by the interlaced scan. Thus, the width is not proportional to the interlaced ratio when interlaced scan is used. This means that an interlaced scan has a relatively weak influence on degrading moving picture quality.

When liquid crystal with a T_{lc90} of 10ms and an interlaced scan of 2:1 ratio is used, the transition width increases from 26(10+16) pixels to 42(10+16+16) pixels. This width is about 1.6 times of that obtained when the interlaced scan is not used. This means that an interlaced scan is more influential on degrading moving picture quality when the response of a liquid crystal is faster.



T_{lc90}	Interlace
A: 40ms	No-interlace
B: 40ms	2:1 Interlace
C: 40ms	3:1 Interlace
D: 40ms	4:1 Interlace
E: 20ms	No-interlace
F: 20ms	2:1 Interlace
G: 20ms	3:1 Interlace
H: 20ms	4:1 Interlace
I: 10ms	No-interlace
J: 10ms	2:1 Interlace
K: 10ms	3:1 Interlace
L: 10ms	4:1 Interlace

Moving speed = 1000 pixel/s

Driving condition
No-interlace
  Frame rate 60Hz
2:1 Interlace
  Frame rate 30Hz
  Sub-field rate 60Hz
3:1 Interlace
  Frame rate 20Hz
  Sub-field rate 60Hz
4:1 Interlace
  Frame rate 15Hz
  Sub-field rate 60Hz

FIGURE 4.1.1 Optical transition widths

4.2 Evaluation on the optical frequency response

The typical frame rate of motion picture is 25 or 30 frame/sec in TV and 24 frame/sec in movies. According to the sampling theorem, the maximum reproduced frequency component is half of the frame rate when those motion pictures are displayed. Thus, the frequency response was evaluated at 15 Hz.

Figure 4.2.1 shows each frequency response and the dynamic contrast ratio α. The amplitude of liquid crystal of T_{lc90}=20ms becomes 0.77. The amplitude of a display with hold-type characteristic becomes 0.9. The amplitude of interlaced scan of 2:1 rate becomes 0.71.

The dynamic contrast ratio α is the product of each amplitude, α therefore becomes 0.5 at 15 Hz.

This result means that the interlaced scan is most influential on degrading blinking picture quality.

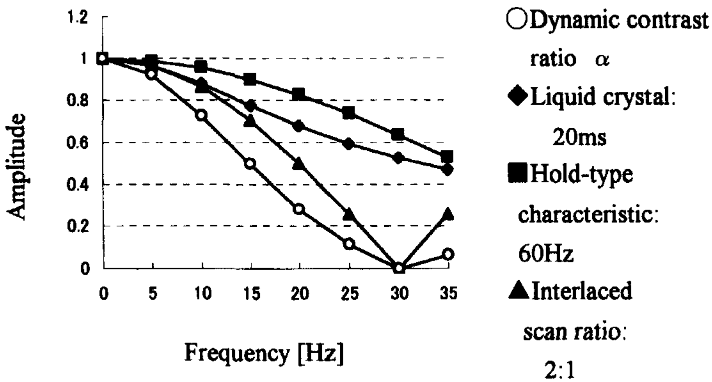


FIGURE 4.2.1 Frequency response and dynamic contrast ratio

5. CONCLUSION

The quality of motion pictures obtained when an interlaced scan driving method is applied to a TFT-LCD was discussed. It was shown that the interlaced scan driving method has a relatively little influence on the widening of edge blur but causes a relatively large loss in dynamic contrast ratio.

References

[1] T. Nose, N. Ikeda, H. Kanoh, H. Ikeno, H. Hayama, and S. Kaneko, "A 28-cm-Diagonal UXGA TFT-LCD for Legible A4-Size Document Viewers", 1999SID Int. Symp. Digest of Technical Papers, pp. 180-183, (1999).
[2] T. Kurita, A. Saito and I. Yuyama, "Consideration on Perceived MTF of Hold Type Display for Moving Images", Proc. the 5th. Int. Display Workshops(IDW'98), pp. 823-826, (1998).
[3] Y. Noyori, H. Washio, Y. Shimodaira, T. Muraoka, K. Yamamoto, and Y. Ishii, "Subjective Evaluation of Quality of Moving Pictures on a TFT-Liquid Crystal Display", Proc. the 14th. Int. Disp. Res. Conf., pp. 329-332, (1994).