…a voice of reason in the kingdom of silence

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Image sticking and burn-in in flat panel displays

Abstract

We live in a time of proliferation of flat panel display (FPD) technologies. LCDs and plasmas are becoming more and more mainstream and taking over the CRT market share. They are also becoming bigger which means that their range of application broadens from desktop computers to control rooms, personal walls, digital signage etc. But often we have our doubts where it comes to the longevity of the FPDs and their ability to resist long-term, 24/7 usage. Do LCD's suffer from permanent burn-in or not? And what about plasmas? Thumbs up for LCDs and thumbs down for plasmas? The truth is probably somewhere in between. All flat panel displays, like your teeth, hair, shoes, house or car need maintenance. Otherwise they well eventually deteriorate. Indeed, some FPDs are worse off than others. Barco has decided to speak openly about these issues that bother the whole industry, but yet nobody dares to speak about. This white paper demystifies the myths associated with the terms 'image retention', 'image sticking', and 'burn-in'.

What we are talking about

WHILE LCDS SUFFER FROM REVERSIBLE IMAGE STICKING, PLASMAS SUFFER FROM PERMANENT BURN-IN

First, let us distinguish the terms we use. We are all probably familiar with the notion of "*image sticking"*, or at least with the phenomenon this term describes. Say you have a Windows desktop on your brand-new LCD screen. Let this on for some time (days or even weeks) without using a screen saver and without using your computer (don't try this at home, this is just a though experiment, or a bad memory for some of you!). Eventually you will probably end up with your icons and the start logo 'burned' in the background. You can see this by eg. creating a Power Point gray slide and showing it full screen. The area below your logo, text or icon will have a different color than the gray background. We say the original image sticks, and hence the name of this phenomenon. Another term is "*image retention*" which means pretty much the same. We also refer to this as 'ghost images', not only because these artifacts are as scary as ghosts when they occur on your multi-thousand dollar large LCD.

Another effect that you might see are dark lines that follow the original edges of your logo, icon, or text. This is something different than the "normal" image sticking and we call it "*lateral or boundary image retention*", to accentuate the fact that it occurs at the edges.

Now, will this image sticking go away or not? Probably yes, but you have to wait a very long time, at least as long as the original 'stress' time. Of course, you have to completely switch your screen (not just the backlights) and let it rest. After some days (if of course you turn the screen back on) you will see the image sticking blurring away. How fast it will disappear, depends on how serious it was in the first place (how long you waited for it to occur without performing preemptive measures).

If you used your LCD like for a year while some logos or graphics remained on the same position all that time, the chances are that you will never get rid of the image sticking. The physical structure of your ***L**iquid* ***C**rystal* ***D**isplay* might change below that logo, and the image will remain burned in forever.

Now, beware that every single LCD on this planet will sooner or later suffer from image retention if you use still images! So don't be mislead by 'no burn-in' highlights on LCD brochures. The next time a salesman tries to convince you his LCD is better than all the rest and completely free of image sticking, tell him that you know better (or show him this white paper). They probably tested their LCD for 3 days (72 hours) without noticing any effect…

Now, what will happen if you use a plasma screen instead? The named logos, text or icons will burn in, and will not go away. This burn in happens very fast (a few days) and is permanent. The burn-in in plasma screens happens because of physical damage on the layers in the display and is cumulative. Preemptive measures may postpone it, but if you show everyday the same image again, eventually it will be stuck.

Now compare this few days (or even a couple of weeks) needed for permanent burn-in in a plasma screen with the weeks or months needed for reversible image sticking in LCDs…

Terrible! How can I prevent this?

Know what to expect

First of all, set your expectations right. If you want to buy a mission-critical display, or something you want to use 24/7 for a long, long time, the only feasible solution for you is a DLP rear projector. We know, they might be large and thick and so on, but they are the best there is. They don't suffer from any image retention whatsoever and are a perfect choice for 24/7 applications. And they can be tiled seamlessly unlike the present flat panel display technologies.

Take precaution

Brush your teeth! Go to the hairdresser! Run screensavers and switch off the LCD when you don't need it!

We don't want to sound like your parents, but taking the preemptive measures described below is the only way to prolong the life of your LCD and postpone image retention.

Re-Layout

In control room applications, a display is often used to show a layout of several video sources with borders. Whereas the video content in these windows changes continuously, the borders are static images and may cause boundary image retention. The layout of the windows (size, number of videos shown etc) should be changed on a regular basis, say once per month. One should take care that most of the borders of the old layout are covered with video in the new layout. In the picture below, the striped layout is the old one, and the layout with the full lines is the new one. Notice that the striped lines now fall in the windows with video content, so any possible image retention can be cured.

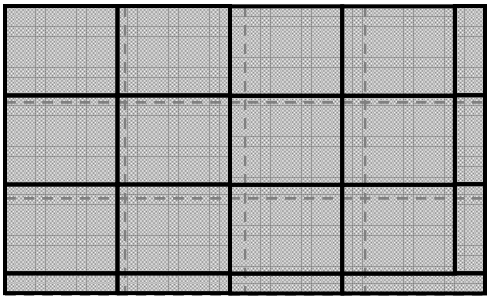


Fig.1 Change the layout of your video windows occasionally

Making such new layouts of course means sacrificing some usable display space, like the narrow bands to the right and at the bottom in the picture, but these bands don't have to be much wider than the borders between the video windows (so maybe 10-20 pixels at most).

Power off, power save mode, screen saver

A second way is to use screen savers and power saving modes as much as possible. You don't need the display during the lunch hour? Switch it off. You only need to look at it when you actually do something on the screen? Use a screen saver. The amount of "relaxation" time should be considerable, the more you do it the better. "Flashing" the screen for a few seconds with a screen saver will not help a slightest bit. Image retention is a slow process to build up, but it also disappears slowly.

Panel brightness and contrast

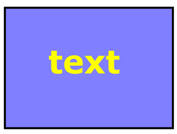
The brightness and contrast levels of your screen should not be used at their maximum values. The heat and light from the backlight makes image retention more serious. Also, driving the display at full power (full white at 100% contrast value) has the same effect. The voltages over the LCD (white areas) are then higher, and that enforces boundary image retention. Use maximum 80% of both brightness and contrast (the screen can still be adjusted properly for the whole range of gray scales). Finally, as you might have learned from our other white papers, a 20% lower luminance is perceived as only 8% less brightness by the human eye.

Optimize the color usage

If the LCD screen is to be used to show graphics (lines, symbols, text etc.), the worst thing to do from the point of image retention is graphics with high contrast (white graphics on a black background or vice versa). Use colors in a creative way. Your display has 16.8 million colors, not just black and white! White text on a black background is just begging for image sticking.

The colors on a display are made by combining red green and blue, each of which takes a level from 0 to 255. These are called "DAC levels". You can adjust these levels by e.g. going to "font color", "more colors", "custom", and set the "red", "green" and "blue" boxes to any value from 0 to 255. Colors that have the same DAC sum (sum of the DAC levels of their R, G and B components) will not cause image retention when combined on top or next to each other.

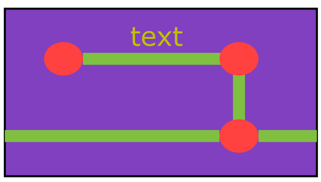
So the idea is to use colors with a same or similar DAC sum. Everything is better than using white (DAC sum 255+255+255=765) over black (DAC sum 0+0+0=0). Use red on purple, yellow on blue, or a combination of colors whose sum yields similar DAC values. Of course, the higher the DAC sum, the higher the brightness of your symbols, but also the lower the number of color combinations you can make. It's a trade-off. Examples are given below.



Text: R=255, G=255, B=0

Background: R=128,G=127, B=255

DAC sum: R+G+B=510



Text: R=192, G=192, B=0

Background: R=128, G=64, B=192

Circles: R=255, G=65, B=64

Lines: R=128, G=192, B= 64

DAC sum: R+G+B=384

Fig.2 Examples of layouts that help against image retention

Run grey-level checkups

Waiting until the display develops serious image retention before you start curing it may be too late. The best way to see what the status of the display is, is to run periodic check-ups with a uniform grey shade shown on the whole screen (a procedure we refer to as 'evaluation'). Make a uniformly gray Power Point slide and show it full screen. When a 50% gray shade is applied, one can clearly see if boundary lines develop near the borders of the original layout. If this is the case (even if the border lines are very thin), it is a sign to change the layout, and to start "refreshing" the display (power off, screen saver) more frequently. Otherwise, the image retention will become even more serious.

Yes, but what's really happening in my display?

You want to get technical? You want to know more about the underlying processes so you can come with a creative solution? No problem, we can quench your thirst for knowledge.

PDP – What it is and how it works

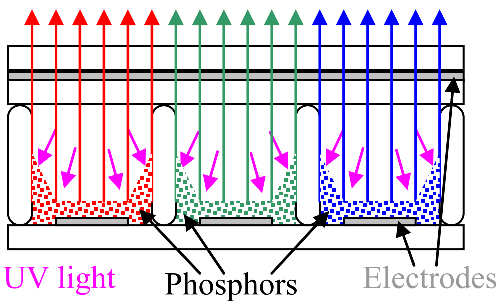


Fig.3 Working principle of an PDP cell

PDP is short for *Plasma Display Panel*. It consists of small cells filled with a special gas. On top and bottom of the cells there are electrodes that are used to apply a voltage over the gas. At the bottom of the cell there is a red, green or blue phosphor (material that emits light). When voltage is applied over the cell, the gas starts emitting UV light that hits the phosphor. The phosphor starts glowing, and according to its color, produces R, G, or B light. These three subpixels are mixed to make one pixel with a given color.

Why does my plasma burn in?

The UV light is merciless when it hits the phosphor. It chunks phosphor pieces away. The longer one pixel is used, the more it ages in comparison to the neighboring pieces and the more this difference becomes visible. A still image (logo, graphics, text) thus permanently damages the phosphors (more than the rest of the panel), and when you change the content, remnants of these images are still visible. It is clear that this burn-in doesn't go away.

LCD – What it is and how it works

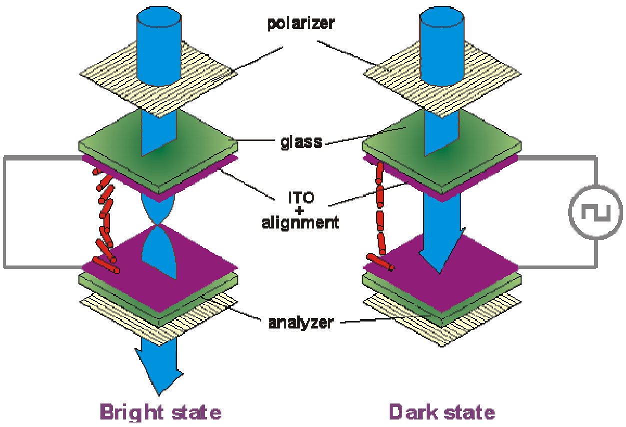


Fig.4 Working principle of an LCD cell

LCD is short for *Liquid Crystal Display*. A liquid crystal is a fluid with crystalline properties. The LCD is build from two parallel glass plates, coated with electrode patterns (rows and columns) from the inner side and polarizers from the outer side (see figure 4[†]). The liquid crystal is sandwiched between the two glass substrates. In addition, the electrodes on the inner side have an insulating polymer layer (alignment layer) that makes the liquid crystal orient in a given direction.

The principle of operation of an LCD pixel is the following: when there is no voltage over the pixel electrodes, the liquid crystal is undisturbed. The light from the backlights passes through the back polarizer, but the crossed front polarizer stops the light and thus the pixel is black. When voltage is applied over the liquid crystal layer, it is disturbed and changes orientation, thus changing the properties of the light. The light then can pass through the front polarizer and we see a bright pixel. Depending on the 'strength' of the voltage, the transmission through the pixel can be changed in steps from black to white, resulting in a given number of grey levels.

In order to maintain an image (a given transmission value), the applied voltage over the pixel is not steady, but its polarity changes very fast. For the liquid crystal it doesn't matter what is the polarity of the voltage, but as we will see below, for the ions it does.

[†] Figure 4 is courtesy of the LC&P group, Ghent University, Belgium

Ions – the evildoers

Image retention in LCDs is caused by ion impurities in the liquid crystal layer. The ions are charged particles and can move under influence of the electric field that is applied over the LCD. Not only can they move, but they also modify this electric field. There are three ion effects that occur when a static image is shown for a long time, which leads to various sorts of image retention.

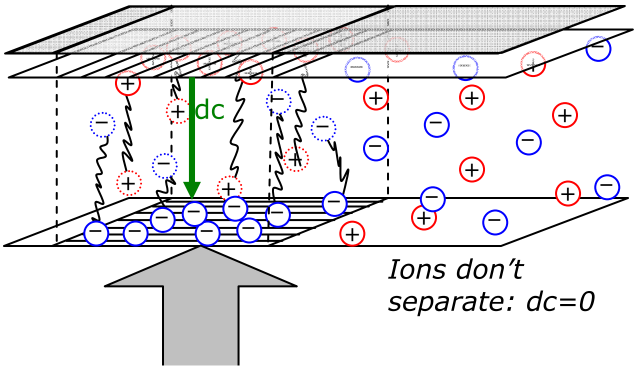


Fig.5 Illustration of image sticking

1) As said above, the driving voltage of LCD screens changes the polarity. Because the used voltage forms are complicated, it might be possible that there is a small dc component left on top of the alternating voltage. During a longer time, this dc component will separate the ions in the liquid crystal layer (see figure 5). The amount of ion separation depends on the dc voltage component, thus also on the displayed image. Furthermore, the separated ions can stick to the alignment layers. When the steady image is removed and a grey background is shown on the whole screen, the separated ions will remain in their position for some time. Now they form a small dc field that interferes with the applied voltage. The regions of the display where these ions are present will have a different transmission that the rest, and this is the reason that ghost images appear. Present day LCDs are almost free of this sort of image retention, because the driving voltage waveforms are dc-free.

2) When electric field with a certain voltage is applied over the LCD, the corresponding response of the liquid crystal leads to a given light transmission (a grey level). Because of the ions, the electric field in the cell is modified, and thus the light transmission through the LCD also changes. This results in a different grey level depending on the number of ions in the cell, even if the voltage over the cell is the same. This explains an uneven display. When a gray shade is displayed on the whole screen, some regions will be darker or brighter than the rest of the screen, because they contain more or less ions then elsewhere.

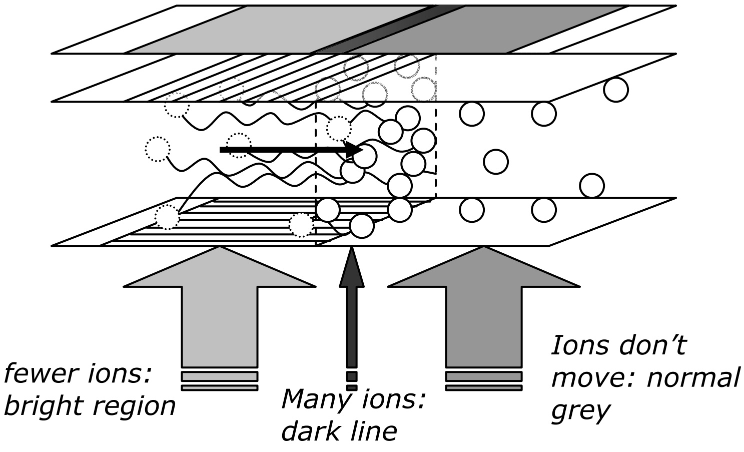


Fig.6 Illustration of boundary image retention

3) When a static image is displayed, the voltage over the cell changes its polarity continuously. That means that the ions in the liquid crystal layer move up and down all the time. But the ions can also move sideways. They will move as long as they are in the region of a displayed image, but when they come to the border of the image, they will stop and concentrate in a small region. Because the ion concentration at the borders of the image becomes high, it influences the applied voltage and this border turns dark. When the static image is removed, these border lines still remain visible. The region of the image becomes lighter than the rest of the display because there are now fewer ions (they have moved out).

This kind of image retention is the most persistent one. It takes a long time to develop, but also a long time to cure. The ions have traveled a long distance sideways and need a lot of time to diffuse back to their original position. This is why one should change the layout of the screen: where there have been borders, now video should be played, which allows the concentrated ions to diffuse away.

Summary

Image retention has always accompanied the LCDs and caused headaches to the industry. It is only during the latest years when the consumers lifted their expectations from LCDs that they started being annoyed by these artifacts. No doubt that the LCD producers are spending money and resources to make purer liquid crystals and to devise driving schemes that inhibit ion motion. However this is not enough and till the present day the image retention problem has not been solved. This is why we felt the need to speak openly about it, explain it and give a few tips to postpone it or completely remove it.

References and further reading

[1] Goran Stojmenovik, "Ion transport and boundary image retention in nematic liquid crystal displays", PhD thesis, Ghent University, 2005, ISBN 90-8578-005-5

http://escher.elis.ugent.be/publ/Edocs/DOC/D105_138.pdf

[2] Ernst Lueder, "Liquid Crystal Displays : Addressing Schemes and Electro-Optical Effects", ISBN: 0471490296, John Wiley & Sons, 2001