White Paper

Missing Pixels in Medical Grayscale Flat Panel Displays

What's inside?

- What are missing pixels?
- International Standards to characterize LCD quality
- Missing Pixels, overview for different LCD displays

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ABSTRACT

Without any doubt, the transition to the current state–of-the-art medical grayscale displays brought a major improvement in image quality compared to CRT technology. However, LCD also brought some new issues such as missing or “stuck pixels”.

This paper will explain the missing pixel situation with current LCD technology.

TABLE OF CONTENTS

1. INTRODUCTION

In recent years, we have witnessed a major shift from the traditional CRT display technology toward LCD technology. Starting from low resolution and low quality displays, LCD technology has matured and taken a substantial share in the consumer and professional display markets. The continuous technological innovation has even resulted in affordable state of the art high-resolution displays that provide the quality required for high-end applications such as Medical Imaging.

Although LCD displays offer a number of substantial advantages over CRT displays (such as increased sharpness, high brightness, small physical size, and less power consumption) there are still a number of issues where the CRT outperforms the LCD display.
One of these issues is the "dead" or "stuck" pixel. Even current state of the art LCD manufacturing processes cannot guarantee that a panel is completely free of panel defects. Although the manufacturers continuously seek to improve the process, the maximum allowed number of pixel defects on a panel actually defines the yield, hence the cost of the panel.
To keep flat panel costs affordable, we have to strike a balance between image quality (partially reflected by the number of dead pixels) and cost.

For medical applications, missing pixels have become more and more of a concern for the radiologist, even when current state of the art medical applications offer features (such as zoom and panning), which can easily identify a dead or stuck pixel.

2. LCD TECHNOLOGY

The image generation in an LCD display is quite different compared to the way an image is generated on a CRT.

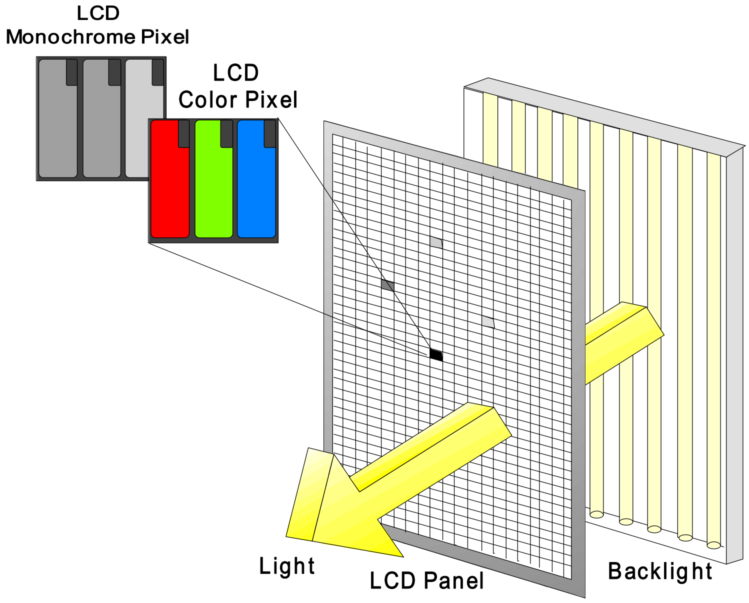
A flat panel display has a backlight, composed of a number of tiny fluorescent lamps, which are all permanently lit when powered on.

In front of this backlight is the liquid crystal panel. One can think of this panel being composed of small cells (pixels) organized in a perfect matrix structure, having a number of rows and columns. The number of rows and columns defines the resolution of the flat panel display.
For example: A flat panel with a resolution of 1280 * 1024 will contain 1280 cells in the horizontal direction and 1024 such rows in vertical direction.

Each individual cell acts as a small dimmable light-switch. If you turn the switch of each cell completely on, the light of the backlight will pass through that cell and a WHITE dot will appear on the screen.
If the switch is completely off, no light can pass through the cell and one sees the cell as BLACK. By dimming the switch a proper amount, one can obtain any (gray) value between black and white.

By splitting each cell into sub-cells (sub-pixels), and covering each sub-pixel with a certain colored (red, green, blue) filter, one can build a color display. Due to the fact that a color filter will dim the light substantially, color displays will reduce the potential brightness (luminance) of a medical display by about one third.

To manufacture a medical grayscale display one has to remove the color filters, hence obtaining a monochrome pixel. As there are no color filters, each pixel is much brighter than its color counterpart.



2.1. Definition of a dead or stuck pixel

As presented in (2), the intensity of the individual pixels on a flat panel display is formed by switching individual cells on, off or somewhere in between. This is achieved by placing an individual transistor to control each LCD cell. In the event that sub-pixels are present, there are individual transistors for each sub-pixel.
During the manufacturing process of the display there is a small chance that this transistor is defective, resulting in a continuous open or closed switch. The result is that this pixel is either always lit or dark (stuck or dead).
Given a certain chance to create a defective transistor, it is clear that the more pixels a panel contains, the larger the number of dead or stuck pixels will be.

In a dark environment, lit pixels can be readily observed as they look like stars in the night sky. Dead, dark pixels on a white background are less easy to observe as the eye receives too much light from the surrounding pixels.

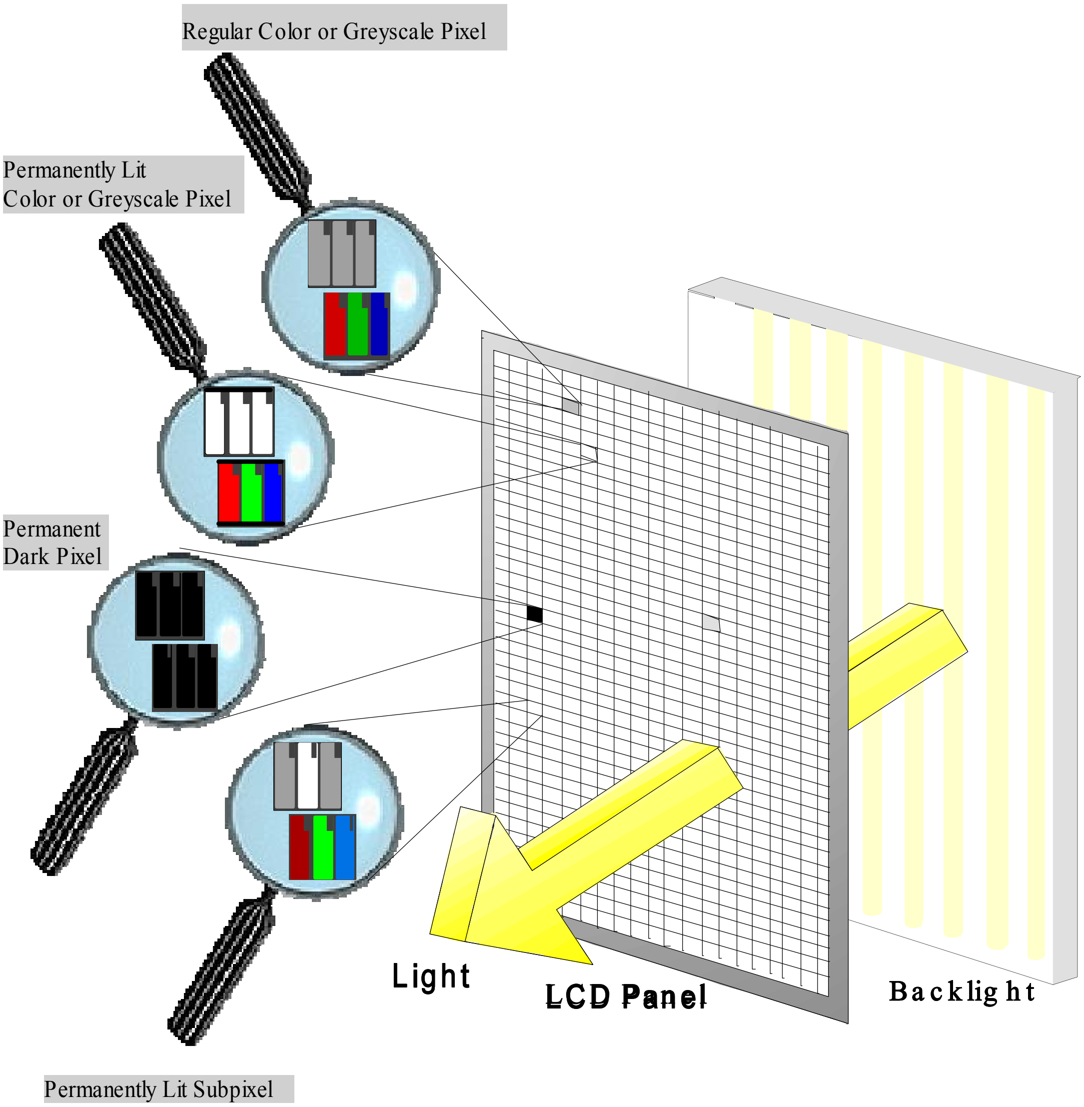
Some LCD manufacturers, using advanced manufacturing processes, can take advantage of this property of the human eye as they can destroy a transistor by targeting it with a laser beam. However, this will just turn bright-lit pixels into continuously dark pixels.

In spite of the current state of the art technology, it is impossible to manufacture LCD panels without defective transistors. Given a certain number of stuck pixels per display, lowering the number of allowed missing pixels will result in more panels being classified as scrap and the cost of the panel will increase.

2.2 Dead pixel defect rate

Continuously lit and dark pixels are a fairly common problem during the LCD manufacturing process and therefore manufacturers of LCD panels have defined some limits for pixel defects based on customer feedback and cost trade-off.
The picture below illustrates some of the most common pixel defects that can occur on both color and grayscale medical displays.

Missing (Sub) - Pixels on Greyscale and Color LCD Displays



Suppose that the illustration contains a state of the art 5 MegaPixel display.
This 5-megapixel flat panel with a resolution of 2048 * 2560 contains 15.728.640 sub-pixels (2048 * 2560 * 3).
Typically about 15-30 sub-pixels will fail, giving a defect rate of 0.000095 % to 0.000190 %.

As this specification can vary widely among panel manufacturers and among panels of a specific batch, the International Standard Organization has made an attempt to define a standard for missing pixel defects.

This standard is outlined in detail in the ISO 13406-2 specification.

In practice this standard defines 4 different classes of LCD displays where the maximum allowed number of pixel defects per million pixels characterizes each class. (See detailed overview in the table below)

Class I LCD displays are considered to be "perfect" as they allow no pixel or sub-pixel defects. However, even with the current state of the art technology this level of display quality is impossible to achieve in a mass production process. For Class I displays, the overall yield of such a manufacturing process approaches 0 percent, resulting in unaffordable display prices.

Class II displays, which allows for 2 pixel or 5 sub-pixel defects per million, has been an extremely difficult standard for manufacturers to achieve in mass production, but a few manufacturers have achieved this goal.

Pixel Defects per million pixels Class	Defect Type 1 (Continuously Lit Pixel)	Defect Type 2 (Continuously Dark Pixel)	Defect Type 3 (Sub-pixel defect) (Lit or Dark)
I	0	0	0
II	2	2	5
III	5	15	50
IV	50	150	500

From this table it is obvious that the more pixels a panel has, the more pixel defects it will show.

The Table below lists the maximum number of tolerated defects for each quality class on some of the more popular resolutions of medical displays.

Panel Type	Defect Type 1	Defect Type 2	Defect Type 3	Display Class	Horizontal Resolution	Vertical Resolution
1 MP	0	0	0	Class I	1024	1280
	3	3	7	Class II	1024	1280
	7	20	66	Class III	1024	1280
	66	197	655	Class IV	1024	1280
2 MP	0	0	0	Class I	1200	1600
	4	4	10	Class II	1200	1600
	10	29	96	Class III	1200	1600
	96	288	960	Class IV	1200	1600
3 MP	0	0	0	Class I	1536	2048
	6	6	16	Class II	1536	2048
	16	47	157	Class III	1536	2048
	157	472	1573	Class IV	1536	2048
5 MP	0	0	0	Class I	2048	2560
	10	10	26	Class II	2048	2560
	26	79	262	Class III	2048	2560
	262	786	2621	Class IV	2048	2560

3. Conclusion

Until panel yields increase, basic component costs come down or new LCD manufacturing processes are developed to eliminate defective pixels, these defects we see today will continue to be present.
Consequently, replacing one display with another one will not result in an improved situation.

Many users will never notice most LCD sub-pixel defects. For those applications where tiny image details could be confused with defective pixels, roaming of the image will immediately clarify if a detail is a pixel defect or a true part of the image.

One should not forget that, despite the occasional lit pixel or dark pixel, LCD technology continues to offer significant benefits over CRT based displays. CRT displays have other issues such as inferior MTF characteristics, lower brightness, more susceptibility to ambient light, geometric distortion, convergence problems (color), higher power consumption and larger size.