DEFECTIVE PIXELS IN LIQUID CRYSTAL DISPLAYS

INTRODUCTION

LCD technology has taken off in the past several years, with expanded availability of increasingly cost-effective product alternatives to the traditional CRT display. LCD manufacturing yields have improved, lowering costs. Technology innovations have enabled the production of ever-larger screen sizes, and today's LCD monitors are brighter than comparable CRT monitors, with viewing angles that rival the CRTs they are being groomed to replace. With their slim profile and small footprint, LCDs require about 60% of the desk space and consume approximately one-third the power of a comparably sized CRT. However, while LCDs offer many advantages over CRTs, and the price gap is continually narrowing, they are still more expensive to produce than their cathode-ray tube cousins, due to the required clean room manufacturing process and lower-than-CRT yields. A concern for some manufacturers and consumers regarding LCDs has been the issue of dead pixels.

DETECTING & DEFINING DEAD PIXELS

Visible pixel malfunction is occasionally noted in both types of displays, however, the higher cost of LCDs is one reason this issue seems to be more prominent with LCDs than it has been with CRTs. Pixel outage is difficult to assess during the manufacturing process of both CRTs and LCDs. Only upon completed assembly can an individual display be assessed for defective pixels. The more units classified as defective due to pixel malfunction, the lower the overall yield. This results in scrapped materials and, therefore, higher production costs. With higher volume production and lower material costs for CRT displays, this decrease in yield has a minimal effect. Because of the lower production runs and higher material costs associated with LCDs, however, every attempt is made to reduce the number of scrapped displays.

Active matrix TFT LCD panels achieve their beautiful images, in part, because of the individual transistor placed at each pixel, which controls the backlight shining through a given pixel (see Figure 1). In actuality, each pixel or dot is made up of 3 sub-pixels (one red, one green and one blue) with each having its own transistor. Occasionally, these individual transistors will short, or remain open, resulting in a defective pixel. There are two phenomenon which define a defective LCD pixel: A "lit" pixel, which appears as one of several randomly placed red, blue and/or green pixel elements on an all-black background; or a "missing" or "dead" pixel, which appears as a black dot on all-white backgrounds. (By comparison, CRT defective pixels exhibit themselves as black holes in an all-white raster. This is due to missing phosphor material or an obstruction in the shadow mask.)

The "lit" pixel phenomenon, more common than "missing/dead" pixels, results when a transistor occasionally shorts on and results in a permanently "turned-on" (red, green or blue) sub-pixel. There are some possible corrective measures, such as "killing" a transistor using a laser, however, this just creates black dots which would appear on a white background. Fixing the transistor itself is not possible after assembly. Additionally, it is not possible to turn a "lit" pixel off, except for the aforementioned laser method, which essentially just makes the transistor inoperative, thus resulting in a black dot.

DEALING WITH DEAD PIXELS

Turned on or "lit" pixels are a fairly common occurrence in LCD manufacturing. Like their CRT counterparts, LCD manufacturers have set limits as to how many defective pixels are acceptable for a given LCD panel, based on user feedback and manufacturing cost data. The goal in setting these limits is to maintain reasonable product pricing while minimizing distraction from defective pixels for maximum user comfort. Considering the number of pixels contained in an LCD panel, this defective rate is quite minute. For example, a panel with a native resolution of 1024 x 768 pixels contains a total of 2,359,296 red, green and blue pixels per panel (1024 x 768 x 3 = 2,359,296). Therefore, a panel with 20 lit pixels would have a sub-pixel defect rate of: (20/2,359,296)*100 = 0.0008%.

Liquid Crystal Display Basics

Viewing Angle — Front Glass Substrate / Polarizer

Liquid Crystal Material — Rear Glass Substrate / Polarizer / Backlight / TFT (Transistors)
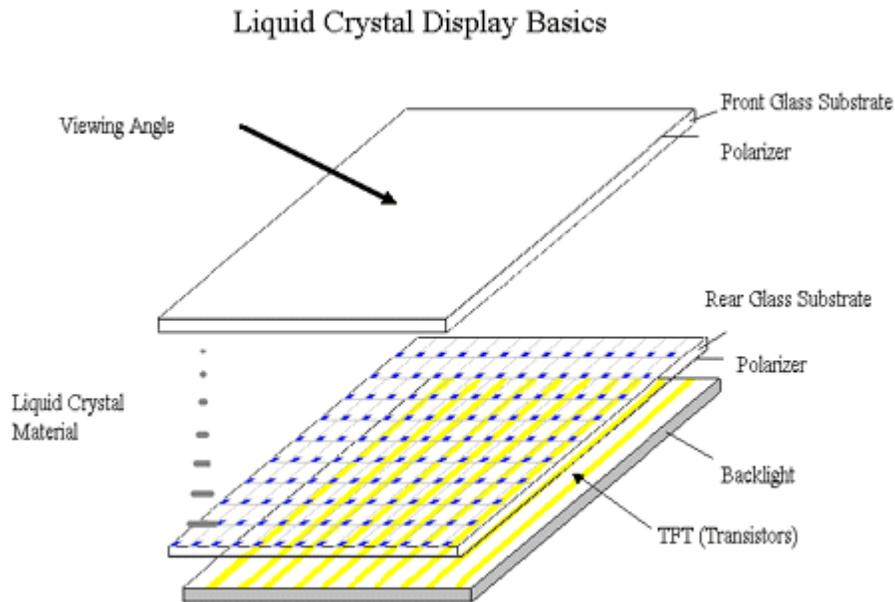
Note: The rear glass substrate contains both the LCD material and each pixel's transistor.

Figure 1: Cross-Section View of an LCD Panel

Fortunately, the most widely-used operating system, Windows (3.xx/95/98/NT/2000), and Windows-based applications tend to mask, or hide, the phenomenon of turned-on pixels due to their reverse video of black characters on a white background. Older DOS/text-based applications will suffer by comparison when the graphics mode calls for white characters on a black background. Using these DOS-based applications will "highlight" the occasional red, green or blue turned-on pixel, causing possible concentration problems for some users.

SETTING A STANDARD

In the interest of setting a standard for allowable pixel faults in a display for manufacturers, an ISO specification (ISO 13406-2) was established. The specification determined four fault classes of LCD displays, with each having a certain number of pixel faults allowed (see Table 1). Class 1 LCD displays are considered "perfect," allowing zero pixel or sub-pixel faults. However, this standard has been viewed as virtually impossible or much too costly for LCD display manufacturers to consider for mass production. Class 2, which allows for five pixel or sub-pixel faults, has been an extremely difficult standard for manufacturers to achieve in mass production but a select few have managed to be certified. This groundbreaking achievement is a major breakthrough in the visual display industry and has set the bar for others to follow. Consumers should be aware, though, that Class 2

displays have been certified according to manufacturing standards and do not reveal pixel faults to the untrained human eye. Remember that each pixel, or dot, on a color LCD is actually made up of 3 sub-pixels—one for red, one for green and one for blue. On an 18" VIS LCD display, the typical resolution is 1280 pixels by 1024 pixels (often referred to as 1280 x 1024 or SXGA), so there are 1280 x 1024 x 3 sub-pixels, or 3.9 million sub-pixels—each of which measures less than 0.28 mm in height and 0.09 mm in width. For comparison purposes, the finest tip of a mechanical pencil designed for precision drafting work is often 0.3 mm, so a sub-pixel at 0.09 mm is less than 1/3 of this width and barely perceptible to the naked eye in most working environments.

Class	Number of sub-pixel faults
I	0
II	1-5
III	6-50
IV	51-500

Table 1. Maximum number of faults per type per million pixels.

SUMMARY

Until yields increase, material costs come down or new technology is developed to address the issue of defective pixels in LCDs, this phenomenon will occasionally present itself to some users under some circumstances. Most users, however, will never notice LCD pixel defects within the acceptable range. In addition, despite the occasional lit pixel to contend with, LCD technology continues to offer significant benefits over CRTs. These older-technology displays have other annoying artifacts, such as geometric distortion and misconvergence, which are nonexistent in LCDs. In addition, CRTs' greater size, weight and power consumption make LCDs all the more attractive, even with the occasional defective pixel. Finally, some more good news for LCD users: transistors do not generally "go bad" over time, so if there are no noticeable dead or lit pixels upon initial purchase, then chances are none will become defective over time.

For more information on dead pixels, refer to:

• "Dealing with Dead Pixels in TFT Displays," Charles W. Moore, *Low End Mac.*
http://www.lowendmac.com/misc/2k0323pf.htm
• "New EU Standard Targets Flat Panel Visual Displays: ISO 13406-2 Picks Up Where ISO 9241 Leaves Off," *TUV Rheinland World News, The International Journal of Safety and Standards, Trends & Information*.
http://www.us.tuv.com/news/newslett/nl0699/item3.html

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