Introduction

Liquid crystal display (LCD) technology was first developed over four decades ago and has been improving ever since—to the point that today’s high-quality flat panel displays rival and often surpass their CRT counterparts in delivering crisp, clear visual quality at a reasonable price. Even so, some LCD monitors may harbor tiny defects due to the extreme complexity of the manufacturing process. To deal with these inevitable minor flaws, HP has developed a set of policies and detection methods to help ensure that each customer receives the highest quality product available.

Executive summary

Flat panel LCD technology is a complex subject. To help you understand how pixel and sub-pixel defects occur, and what HP does about them, this white paper explains:

• **How do LCDs work? What are sub-pixels?** A detailed look will show that millions of tiny sub-pixels cover the typical flat panel screen, producing the sharp, vibrant images flat panel users have come to expect.

• **How do pixel and sub-pixel defects occur?** The HP specification does not allow for any full or complete pixel defects. It does however allow for some minimal sub-pixel defects. This is because the current state-of-the-art in manufacturing processes still results, on average, in very few sub-pixel defects per screen. These defects can be extremely hard to see unless they are viewed under special conditions, or unless they happen to be clustered in groups. Nevertheless, special practices and policies have been devised to reject any complete pixel defects and minimize sub-pixel defects.

• **What is HP doing about it?** HP adopted a stringent unified standard for all models, which is discussed in greater detail later in this paper. This new policy applies to all new flat panel models introduced in 2003 and later, and is not retroactive.

• **Why is this important to me?** Doing business with HP gives you the advantage of dealing with a distributor that strives to consistently deliver a higher standard of quality to its customers. In this case, no full or complete pixel defects, and fewer sub-pixel defects than many competitors. This means better quality for the customer and ultimately greater satisfaction for the end user because the user is viewing a cleaner image without the distraction of pixel defects.

Understanding TFT-LCD technology

Thin-film transistors (TFTs) are the basis of the type of liquid crystal display (LCD) used in all HP flat panel monitors as well as iPAQ and notebook displays. To understand how pixel defects occur, it helps to first understand the technology behind these displays.

How LCDs work

A liquid crystal is exactly what it sounds like: a substance which, although still a fluid, shows some crystal-like order in its internal structure. In 1963, an RCA researcher showed how some liquid crystal materials’ effects on light could be used as the basis for an electronic display. Before long, the technology was being applied to everything from calculator to computer displays.

Liquid crystal molecules tend to have long, rod-like shapes, and in the type used in liquid crystal displays (LCDs) tend to align with one another in a helical arrangement which can rotate the polarization of light. Light entering through a polarizer—and so, in the diagram below, polarized in the vertical direction—will be rotated to horizontal polarization as it passes through the LC (liquid crystal), and so will pass through the horizontal polarizer at the front. This effect can be switched on and off through the application of an electric field across the material. With the field on, the molecules align as shown in the second diagram, and the polarization change no longer occurs—and
light cannot pass through the display. Conductive electrodes built onto the glass of the display are used to produce this field, and the arrangement of these electrodes defines individual small areas which can be independently controlled. This makes the LCD essentially an array of tiny shutters, each of which can be set either to pass light or to block it, arranged in rows and columns across the screen.

By themselves, though, these individual shutters (or pixels, a term which derives from “picture element”) do nothing to affect the color of the light passing through them. If such an LCD panel were to be used with a plain white backlight behind it, someone viewing the panel from the front would see the "open" shutters as white, and the "closed" shutters as black. Creating a color display requires that we add an array of color filters over these individual shutters, so that we can control red, green, and blue light separately. (Combining red, green, and blue light gives the appearance of white, and by using different amounts of these three colors we can generate all of the colors required for a “full color” display). Since it does take all three colors to give us this capability, the individual red, green, and blue areas are generally referred to as sub-pixels, and a set of three of these (one of each color) then defines a complete pixel.

Figure 1. (Top) With no voltage across the LC material, polarized light passing through is "rotated" 90 degrees so that it can pass through the second polarizer. Applying a voltage across the material (bottom) changes the orientation of the LC molecules, so this rotation does not occur and the light no longer can pass through.
The TFT-LCD advantage

Many simple LCDs are made with just the structure described so far: pixels and sub-pixels defined by the row and column electrodes, and controlled by voltages applied to these rows and columns. The intersection of a given row with a given column defines a pixel (or in color displays, a subpixel) which can be individually addressed and controlled.

However, this simple structure doesn’t provide very good contrast or speed. A great improvement can be obtained by placing a switch at each pixel or subpixel location, something that can turn a voltage at that location on or off and leave it in that state until it is changed. In modern LCDs, these switches are created from thin-film transistors (TFTs), tiny devices built into a thin film of silicon which is produced on the surface of the glass.

![Diagram of TFT-LCD structure](image)

Figure 2. Making the LCD into a full-color display is achieved by placing red, green, and blue color filters over the individual “light valves” or “shutters” of the LC panel; each independently-controlled colored area is a sub-pixel. Each set of three sub-pixels (one each of red, green, and blue) is considered to be one full pixel.

Today’s color TFT-LCD displays actually have at least one transistor for each of the primary colors in each pixel, or in other words one transistor per sub-pixel. This makes for an enormous number of transistors in the entire panel, and makes the average TFT-LCD an enormously complex device. For example, producing one of today’s ultra high-resolution UXGA displays with 1600 x 1200 pixels requires embedding nearly six million transistors in the screen (1600 x 1200 x 3), which is nearly double the number of transistors found in the original Intel® Pentium® processor.

To match the richness and color depth of CRTs, today’s TFT-LCD displays support eight bits of color control per pixel (256 different voltage levels for each color), which yields $2^{24}$ or $2^{24}$ (16.7 million) colors. This control is provided by the column drivers, which are integrated circuits at the edge of the display panel that drive each individual column (one for each color in each pixel) on the display. There are also other integrated circuits, called the row drivers, which select the row or line of pixels to which data is currently being written. Together, these drivers, plus the thin-film transistors located within each pixel of the display, permit a modern TFT-LCD to provide highly detailed images with full, rich color.

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Figure 3. In a “TFT-LCD” (also known as an active-matrix LCD), thin-film transistors (TFTs) at each sub-pixel location are used to control the switching of the LC material.

Other components of the LCD

As noted above, LCDs work through the effect the liquid crystal material has on polarized light. These types of display panels, then, require polarizing films placed on either side of the panel to polarize incoming light and to make sure that only light of the proper polarization is passed through the panel to the viewer. Other films may also be applied to either the top or bottom glass to protect the surfaces, reduce reflected glare, or to improve the contrast or viewing angle of the display.

LCD panels used in notebook PCs, desktop monitors, or televisions are almost always backlit—the display module itself includes a source of the light controlled by the LC panel to produce the image. The most common type of backlight in these displays uses cold-cathode fluorescent (or "CCFL") tubes, which are just miniature versions of the fluorescent lighting common in many offices. A layer of translucent plastic material, the diffuser, is added between these tubes and the panel itself to produce more even, uniform lighting. Smaller panels, especially those used in notebook PCs, may have only one or two such tubes, located at the edge of the panel to reduce the overall thickness. Larger monitor or TV LCDs may have several tubes (as many as six or eight, or even more, in the largest displays) spaced across the back of the module.

The operation of the LCD also depends on the proper alignment of the LC molecules in the "off" (no field applied) state, and this is ensured by the intentional production of microscopic physical structures on the inner surface of the substrate glass, with which the molecules will align. These structures are produced by depositing a thin film of a relatively soft material (specifically, a polyimide) on the glass surface, and then carefully buffing or "rubbing" it with a special roller. This "rubbing" process is critical, and problems with this process will result in a very distinctive flaw in the appearance of the finished display panel.

Finally, there are components of the LC display which are very, very small and yet are extremely important—the spacers placed between the sheets of glass, in the area filled by the liquid-crystal material itself. For a uniform appearance and performance of the display, it is important that the thickness of the liquid crystal layer—referred to as the cell gap or cell thickness—be precisely maintained across the panel. To ensure this, tiny glass spheres whose diameter equals the desired gap are spread between the inner surfaces of the glass panels. They are much smaller than the sub-pixel size (the cell gap is generally less than ten microns, or ten millionths of a meter) and so are invisible to the viewer. However, if the distribution of these spacers is not uniform (which can result from shock or pressure applied to the panel), visible problems in the displayed image can result.
Understanding pixel defects

Defects in LCDs and how they occur

LCD displays provide a number of advantages over the older CRT technology, especially in terms of the types of visible problems within the image which can occur with the two types. LCDs, because of their discrete-pixel structure, never suffer from problems with image geometry or linearity, poor focus, color misconvergence or impurity, and so forth. However, no technology is ever completely perfect, of course, and the LCD can still suffer from some defects in the displayed image. In this technology, though, most defects in the basic electronics, such as failure of the backlight or the row or column drivers, result in a completely unusable display, and so when such occur in production they are easily detected and corrected. It is extremely rare for a product to ship with any such problems.

There are, though, some defects which are very difficult to completely avoid but which do not have a serious impact on the usability of the display. The thin-film transistors are produced in a process very much like that used to create silicon integrated circuits—the "backplane" of a TFT-LCD (the glass on which the transistors are created) is, in effect, a very large integrated circuit. Like an IC, these devices are made in a clean room, and very tiny particles of dirt or debris, or microscopic defects in the glass or the silicon film, can result in transistors which do not operate properly. Since these transistors control the individual color sub-pixels of the display, the failure of any one can result in a sub-pixel which does not light at all, or which is stuck in the bright state.
When you look at the total number of pixels—and the even larger number of transistors—in a UXGA display, it is easy to understand that the failure of one sub-pixel out of 5.76 million is a very low error rate indeed—only 17 millionths of one percent (0.000017%). For lower-resolution SXGA displays, a single sub-pixel defect still represents a failure rate of only 25 millionths of one percent. To look at it another way, having 10 sub-pixel defects on a 1280 x 1024 color panel means that the panel is still 99.9999% defect free!

Other defects in the LCD structure can result in defects which may appear very similar to a failed sub-pixel. A small piece of debris trapped within the panel during the assembly process can block light and appear to be a "stuck off" pixel or subpixel. It is also possible that bubbles or other defects may appear within the glass from which the panel is made, or there may be defects in the polarizing films or color filters which also make up the display.

While the rate of any of these defects is extremely low, it must be recognized that the limit can never in practice be held to zero. The maximum number of defects permitted in the final product determines the *yield* of those products (the number of acceptable panels that are produced vs. the number of "starts"—the panel count at the start of the production process), and so the cost of the panels. Requiring that all panels produced be completely defect-free would force the panel manufacturers to set the price of those products unreasonably high. Fortunately, the vast majority of panels produced have a very low number of defects, and those which are accepted are strictly limited to those which are unlikely to cause a significant problem for display users.

HP has established strict limits on the type and number of defects which are acceptable in our display products. As noted, setting these limits to zero is impractical, and would result in very expensive displays for no good reason—very few customers will detect these permitted defects, or will find them objectionable. We are constantly working with display manufacturers around the world to continue to improve the quality and performance of these products, and so to be able to continue to reduce the number of defects that will be accepted in HP displays. If, however, you encounter any situation in which you believe an unacceptable panel has been shipped in an HP product, the following will help you make a final determination.

**How to spot and identify defects**

Due to their tiny size relative to the screen, defective sub-pixels and other flaws can be extremely hard to see. A defect in a sub-pixel covers an area that is so small, it may be visible only when viewed against a background that contrasts with the defective pixel hue. It is generally preferable, therefore, to check the panel using full white and full black screens, plus solid red, green, and blue.

Because they appear brighter to the human eye, defective green sub-pixels may be easier to spot than defective red or blue ones. Sub-pixel defects are also easier to spot when they are clustered together in a single area. If all three sub-pixels fail simultaneously you are more likely to detect the resulting light or dark pixel. However, since HP display specifications require that TFT panels not have any complete pixel defects (i.e., all three sub-pixels defective), HP customers are not likely to encounter this situation.

To locate defective sub-pixels, the monitor should be viewed under normal operating conditions, in normal operating mode at a supported resolution and refresh rate, from a distance of approximately 20 inches (51 cm). The following are the typical conditions under which HP scans for pixel defects:

- Viewing distance of approximately 14 inches (36 cm)
- Ambient illumination of 300 to 500 lux (average room lighting can vary from 60 to 600 lux; typical museum lighting is 50 lux).
- Viewing angle of 70 to 110 degrees horizontal and 80 to 100 degrees vertical
HP pixel-defect standards

Since some degree of sub-pixel defects are inevitable, all manufacturers find it necessary to tolerate a minimal number of sub-pixel defects in their products. Replacing a panel with just a few minor sub-pixel defects is not recommended, since the replacement unit may also have a similar number of defects.

Historically, HP has maintained stringent manufacturing specifications for pixel defects, and it has been tightening those specifications over time—most recently adopting a single set of specifications for all its units, beginning with all newly introduced 2003 models.

HP specifications

In early 2003, HP pixel defect specifications were tightened considerably and standardized across our entire line of new 2003 and later models. In a simplified format, the new pixel defect specifications are as follows (see next section for more detailed pixel defect specifications):

<table>
<thead>
<tr>
<th>Bright sub-pixel defects:</th>
<th>3 maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark sub-pixel defects:</td>
<td>5 maximum</td>
</tr>
<tr>
<td>Total sub-pixel defects:</td>
<td>5 maximum</td>
</tr>
<tr>
<td>Full pixel defects:</td>
<td>0 allowed</td>
</tr>
</tbody>
</table>

As a result of these tighter specifications, an estimated 60 to 70 percent of all units are shipping with no pixel defects at all (per HP’s internal audits), and another 10 to 20 percent are shipping with only a single sub-pixel defect. Most remaining units are shipping with only a handful of pixel defects that fall within the above listed range of acceptable pixel defects.

International standards (ISO13406)

The International Standards Organization (ISO) has published its own set of specifications for pixel defects, called ISO13406-2. This standard identifies three classes for measuring pixel defects in flat panel monitors:

- **Class 1** panels are completely defect-free, including no full pixel or sub-pixel defects.
- **Class 2** panels permit any or all of the following:
  - 2 full bright or dark pixels
  - 5 single or double bright or dark sub-pixels
  - 2 sub-pixel defects within 5 pixels (about 2 mm for 15” and 17” panels)
- **Class 3** panels permit any or all of the following:
  - 5 full bright pixels
  - 15 full dark pixels
  - 50 single or double sub-pixels stuck on or off
  - 5 sub-pixel defects within 5-pixel distance of each other (about 2 mm on most average-sized panels)
The new HP specification meets or exceeds Class 2 requirements. As mentioned earlier, the HP specifications dictate no full pixel defects, no double sub-pixel defects, and no single sub-pixel defects closer than 15 mm, with a maximum of five total sub-pixel defects.

Detailed specifications

The following table provides more detail specifications listing the countable and rejectable sizes for each common defect. Defects within the countable size are allowed; however, the total number of countable defects shall not exceed the maximum number of all countable defects noted in the table. Any single defect with dimensions greater than the countable defect is also sufficient cause for rejecting the display. The symbols used are: $d =$ diameter, $l =$ length, $w =$ width, $n =$ number, $s =$ separation from edge to edge, $\text{dot} =$ sub-pixel stuck on/off (electrical). Note that these specifications also cover defects other than "stuck on" or "stuck off" subpixels—i.e., those defects resulting from problems elsewhere in the LCD structure. Defect types are illustrated and defined in more detail on the next page.

**Figure 6.** Visual defects (non-electrical).

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
<th>Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark/white spot</td>
<td>$0.25 &lt; d \leq 0.40, n \leq 3$</td>
<td>$d &gt; 0.40$ or $n &gt; 3$</td>
</tr>
<tr>
<td>Bright line (light lint)</td>
<td>$0.03 &lt; w \leq 0.152, l \leq 2.03, n \leq 4$</td>
<td>$w &gt; 0.152$ or $l &gt; 2.03$ or $n &gt; 4$</td>
</tr>
<tr>
<td>Dark line (contamination)</td>
<td>$0.03 &lt; w \leq 0.10, 0.3 &lt; l \leq 1.0, n \leq 4$</td>
<td>$w &gt; 0.10$ or $l &gt; 1.0$ or $n &gt; 4$</td>
</tr>
<tr>
<td>Polarizer scratch</td>
<td>$0.01 &lt; w \leq 0.07, 1.0 &lt; l \leq 10.0, n \leq 3$</td>
<td>$w &gt; 0.07$ or $l &gt; 10.0$ or $n &gt; 3$</td>
</tr>
<tr>
<td>Polarizer dents</td>
<td>$0.15 &lt; d \leq 0.4, n \leq 3$</td>
<td>$d &gt; 0.4$ or $n &gt; 3$</td>
</tr>
<tr>
<td>Polarizer bubble</td>
<td>$0.254 &lt; d \leq 0.40, n \leq 3$</td>
<td>$d &gt; 0.40$ or $n &gt; 3$</td>
</tr>
<tr>
<td>Rubbing defects</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Newton rings</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Mottling</td>
<td>Not allowed</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7.** Electrical defects.

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
<th>Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright dot (electrical):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High and low level (total)</td>
<td>$n \leq 3$</td>
<td>$n &gt; 3$</td>
</tr>
<tr>
<td>Dark dot (electrical)</td>
<td>$n \leq 5$</td>
<td>$n &gt; 5$</td>
</tr>
</tbody>
</table>
**Figure 8.** Minimum distance between defects (mm).

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
<th>Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>High level green to high level green</td>
<td>s ≥ 25.4</td>
<td>s &lt; 25.4</td>
</tr>
<tr>
<td>Bright dots: high level to high level</td>
<td>s ≥ 15</td>
<td>s &lt; 15</td>
</tr>
<tr>
<td>Bright dots: high to low level; low to low level</td>
<td>s ≥ 5</td>
<td>s &lt; 5</td>
</tr>
<tr>
<td>Bright dots: two adj. Low level and low level (any plane)</td>
<td>n ≤ 2</td>
<td>n &gt; 2</td>
</tr>
<tr>
<td>Bright dots</td>
<td>3+ adj. high/low level (horiz. plane)</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Dark dots</td>
<td>s ≥ 15</td>
<td>s &lt; 15</td>
</tr>
<tr>
<td>Dark dots: two adjacent (horizontal plane only)</td>
<td>n ≤ 2</td>
<td>n &gt; 2</td>
</tr>
<tr>
<td>Dim lines</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Cross line(s) on/off</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Horizontal line(s) on/off</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Vertical lines(s) on/off</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Min. distance between allowable defects</td>
<td>s ≥ 25 (unless otherwise specified)</td>
<td>s &lt; 25</td>
</tr>
<tr>
<td>Maximum no. of allowable defects</td>
<td>n ≤ 5 (all types)</td>
<td>n &gt; 5</td>
</tr>
</tbody>
</table>
Defect type definitions

**Bright/dark dot**: A sub-pixel stuck on or off. “Stuck on” sub-pixels almost always result from a failure of an associated transistor or other component within the TFT array. Dark or “stuck off” sub-pixels may also result from such failures, but may also be caused by contamination—a speck of dirt or debris trapped within the LCD panel’s structure. It may be difficult to distinguish these, but in the case of trapped debris the dark area will generally be irregularly shaped (rather than just the rectangular area of the sub-pixel), and may let small pinpoints of light through at the edges of the debris.

**Bright spots/lines**: Spots or lines that appear light in the display. Defects do not vary in size or intensity (contrast) when the “gray level” of the pixel is varied. This variation can be achieved through the use of varying gray shade patterns. A bright line, extending from the top edge of the display to the bottom (or from either edge to the center), generally indicates a failed column driver or connection; a similar failure causing a horizontal line generally indicates a failed row driver or connection. A completely failed row or column driver IC will result in a large number of adjacent lines appearing dim, dark, or stuck on.

**Cluster**: A group of defective sub-pixels which are in close proximity to each other.

**Cross lines off**: When the unit lights, lines in both the minor and major axis do not appear.

**Dark spots/lines (not limited to a specific sub-pixel)**: Spots or lines that appear dark in the display patterns and are usually the result of contamination or failed drivers (see **Bright spots/lines**, above). Defects do not vary in size or intensity when the gray level is varied. (Identification of this can be achieved through the use of varying gray shade patterns.) Contamination-related defects may not completely block the light emitted by some pixels. A dark vertical line, extending from the top edge of the display to the bottom (or from either edge to the center), generally indicates a failed column driver or connection; a similar failure causing a dark horizontal line generally indicates a failed row driver or connection. A completely failed row or column driver integrated circuit (IC) will result in a large number of adjacent lines appearing dim, dark, or stuck on.

**Dim line**: When the unit lights, line(s) in the vertical or horizontal axis appear dim, but not completely on or off. These defects are generally the result of a failure in the row (horizontal) or column (vertical) drivers or their connections. A completely failed row or column driver will result in a large number of adjacent lines appearing dim, dark, or stuck on.

**Mottling**: Variation/non-uniformity (“splotchiness”) appears in what should be a uniform area (i.e., an area which is supposed to be all white, all black, or a single color or gray level). The affected area can vary in size. This type of problem can result from non-uniform cell thickness in the LC panels, or defects in the polarizers or other films used in the display or in their attachment to the substrate glass.

**Mura**: Japanese for “blemish,” the term “mura” (pronounced “moo-rah”) has come to mean a spot or region of non-uniformity within an LC display resulting from improper cell thickness in that region. Mura defects result from missing, insufficient, or excessive spacers or foreign material in the affected region, or some other defect which has disturbed the cell thickness, and can in some cases appear after the panel has been manufactured, if it has been subjected to excessive pressure on the glass or extreme mechanical shock. The appearance of the affected region may also change with viewing angle.

**Newton’s rings**: A circular “rainbow” effect (actually, an interference pattern) which may be caused by non-uniform cell thickness or other defects resulting in a flat surface in contact with a slightly curved one.

**Polarizer dent**: Physical damage to the polarizer that does not damage the glass. When the unit lights, spots appear bright (white) with display patterns dark and do not vary in size. This defect may not completely block the light emitted by any pixels.
**Polarizer scratch**: Physical damage to the polarizer that does not damage the glass. When the unit lights, lines appear bright (white) with dark patterns and do not vary in size. This defect may not completely block the light emitted by any pixels.

**Rubbing lines/defects**: Horizontal or diagonal lines that appear gray when the display is dark and may have resulted from a problem in the "rubbing process," which is part of the preparation of glass panels used in the LCD.

**Defect illustrations**

![Defect illustrations](image)

*Figure 9. "Stuck off" and "stuck on" sub-pixel defects and a contamination defect.*

In the top image above, a dark spot on a white background results from a green sub-pixel which is stuck in the "off" or dark state. Bright spots on a black background, as shown in the middle image, are often caused by sub-pixels (in this case, a red sub-pixel) stuck in the "on" state. Finally, debris trapped within the LCD structure can also result in dark spots, but under magnification these can be distinguished from a "stuck off" subpixel, as the shape of the contaminating particle will often be visible.
Clustered defects, as shown in the top two images, may be stuck “on” sub-pixels, stuck “off” sub-pixels, or a combination of these. Even if the total number of defects is within the specification limit, the panel may still be unacceptable if the limits on the minimum spacing between defects is not met. In the bottom two images, defects resulting from other causes are illustrated. On the left, "mura" (moo-rah) defects appear as regions of brightness non-uniformity (grayish patches appearing on a white or black background, for example), and are caused by cell thickness problems which may result from mechanical pressure on or shock to the panel. The right image shows two different types of defects. Rubbing layer defects will also appear as regions of brightness non-uniformity, but are generally better defined as lines or rectangles as compared with the mura type defect. Finally, failed row or column drivers will appear as entire lines of pixels, either vertical or horizontal, which are stuck "on" or "off." These visible defects may also be caused by failures in the driver connections to the panel, or break in the electrodes which cross the surface of the panel’s glass substrate.
The HP advantage

HP’s pixel defect specifications are part of HP’s ongoing effort to provide high quality products. When it comes to flat panel displays, fewer pixel defects means better quality.

HP quality and reliability

HP prides itself on a reputation for industry-standard best-of-breed products—and our line of flat panel monitors is a testament to that reputation. HP quality and reliability helps reduce maintenance, repair, and support costs throughout the monitor lifecycle and result in a high residual value for HP products. The HP strong market share reflects a global awareness and strong customer loyalty to the HP full line of innovative and competitively priced products. Here’s how HP builds quality into every product.

- **Customer feedback**: HP products are a result of extensive customer feedback, including focus groups, trade shows, customer visits, support calls, human factors studies and surveys of thousands of desktop users.
- **Testing**: HP internal product teams help ensure reliability and long life by testing every model with hundreds of third-party devices in a variety of networked environments to simulate years of real-world stress. HP systematically tests its products to certify that they will perform in the toughest workplace conditions.
- **Factory audits**: Before leaving the factory, each unit passes a rigorous examination to help minimize defects and increase likelihood of operation out of the box.
- **Engineering excellence**: HP quality does not stop at the factory door. Our service and engineering teams continue to support each unit throughout its lifecycle. The award-winning HP call center quickly resolves most issues on the first call.

Environmentally sound

HP environmental policies are designed to help integrate sound environmental practices into every aspect of product design, including the following features:

- **Low emissions**: HP and Compaq monitor products meet the exacting Swedish low emissions guidelines known as TCO ’99 and/or ’03.
- **Energy savings**: HP and Compaq monitor products include advanced power management features that comply with the U.S. Environmental Protection Agency’s Energy Star requirements.
- **Recycleability**: Commonly recycled materials are easily identified, making it easier to find a market for discarded components.
- **Packaging**: Packaging consists of recyclable materials, no heavy metal inks, and minimal packaging material.
- **Disassembly**: Products are easily disassembled at the end of the product life to aid in recovery of recyclable components.
- **CFC-free**: Both HP and its suppliers use only CFC-free processes to protect the ozone layer from further damage.
HP service and support

HP and Compaq flat panel monitors are protected under the HP support umbrella, which includes 65,000 sales and service professionals in 160 countries around the world who provide an impressive depth of service and support at the local level.

All HP and Compaq flat panel monitors come with a three-year limited warranty\(^2\) on parts and labor, including the backlight. Global coverage ensures that any product purchased in one country and transferred to another, non-restricted country\(^3\), remains covered under the original warranty. In the United States, HP offers toll-free, round-the-clock telephone hotline support (terms and conditions may vary by region). Additional support is available 24 hours a day on the Web at www.hp.com.

For more information

For the HP sales office nearest you, please refer to your local phone directory, or call the HP regional office listed below.

**Corporate and North American headquarters**

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Europe, Africa, Middle East
Hewlett-Packard
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Phone: (41 22) 780-8111

\(^2\) Terms and conditions may vary by country. Restrictions and exclusions may apply.

\(^3\) Restricted countries are countries that a government has restricted HP from selling tech products into.