More and more Dell customers are using portable computers as primary computing devices, in and out of the office. Because of this trend, higher demands are being placed on the liquid crystal displays (LCDs) used in portables. LCD technology improvements have increased display resolutions, introduced a 16:10 wide-aspect ratio, improved image quality, and expanded limited viewing angles.

The current generation of high-density, high-resolution Dell portable computer LCDs offers sharp and vivid display quality on 14.1-, 15-, and wide-aspect 15.4-inch LCDs. The appearance of documents, maps, and images approaches paper-like quality when viewed at optimal resolutions. Dell also offers wide-viewing technology on some of its high-end portable computers. This technology offers even richer colors and allows users to view the screen from a much wider viewing angle.

This white paper discusses the advantages of high-resolution and wide-aspect LCDs, explains the concept of “native resolution,” and compares the way that LCD and cathode ray tube (CRT) displays scale between different resolutions. We also discuss the wide-viewing technology—UltraSharp™—featured on Dell’s high-end Latitude™, Inspiron™, and Dell Precision™ Mobile Workstation portable computers.

### High-Resolution LCDs

To achieve higher resolutions on current 14.1- and 15-inch portable computer LCDs, the pixel size is reduced, thus increasing the number of pixels that can be displayed on the screen. This pixel density is measured in pixels per inch (ppi). The higher the ppi of an LCD (or CRT), the higher the resolution that can be displayed on the screen. For example, a 15-inch extended graphics array (XGA) panel has a pixel density of 85 ppi; an ultra XGA (UXGA) panel, 133 ppi. For the purposes of this paper, a high-density LCD is defined as an LCD with a minimum pixel density of 117 ppi. This is the density required to display super XGA+ (SXGA+) resolution on a 15-inch screen.

PPi is directly related to “pixel pitch” (or “dot pitch”), which is the size in millimeters (mm) of each screen pixel. An LCD is composed of a grid of pixels, each composed of a red, green, and blue (RGB) component. The pixel pitch is the distance in mm between a red (or green or blue) component and the next closest red (or green or blue) component. Table 1 shows the ppi and, thus, pixel pitches required to display resolutions currently available on Dell LCD panels ranging from 12.1 to 15.4 inches.

### Advantages of High-Resolution LCDs

Current high-resolution LCDs available on Dell notebook computers can display resolutions as high as 1600 x 1200 on a 14.1- or 15-inch screen and 1920 x 1200 on a 15.4-inch screen. These higher resolutions result in the

<table>
<thead>
<tr>
<th>LCD Size</th>
<th>XGA 1024 x 768</th>
<th>Wide XGA (WXGA) 1280 x 720</th>
<th>SXGA+ 1400 x 1050</th>
<th>Wide SXGA+ (WSXGA+) 1680 x 1050</th>
<th>UXGA 1600 x 1200</th>
<th>Wide UXGA (WUXGA) 1920 x 1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.1 inches</td>
<td>106 ppi 0.240-mm pixel pitch</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>14.1 inches</td>
<td>91 ppi 0.280-mm pixel pitch</td>
<td>Not available</td>
<td>124 ppi 0.205-mm pixel pitch</td>
<td>Not available</td>
<td>142 ppi 0.179-mm pixel pitch</td>
<td>Not available</td>
</tr>
<tr>
<td>15 inches</td>
<td>85 ppi 0.298-mm pixel pitch</td>
<td>Not available</td>
<td>117 ppi 0.218-mm pixel pitch</td>
<td>Not available</td>
<td>133 ppi 0.191-mm pixel pitch</td>
<td>Not available</td>
</tr>
<tr>
<td>15.4 inches</td>
<td>Not available</td>
<td>98 ppi 0.259-mm pixel pitch</td>
<td>Not available</td>
<td>129 ppi 0.197-mm pixel pitch</td>
<td>Not available</td>
<td>147 ppi 0.173-mm pixel pitch</td>
</tr>
</tbody>
</table>

Table 1. LCD Pixel Densities and Pixel Pitches on Dell Portable Computers

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sharp, clear, and photo-like screen images required for applications such as digital imaging, multimedia presentations, and mapping programs. They also allow more digital information to be displayed on the screen. For example, a UXGA panel can display 96 percent of the digital detail in a photo taken with a 2-megapixel digital camera at its highest quality setting. Figure 1 compares a sample photo displayed on XGA, SXGA+, and UXGA panels. For productivity applications such as the spreadsheet shown in Figure 2, the higher resolution of a high-density display allows more viewable content so that the user does not have to scroll as much to view the entire spreadsheet. Also, as notebooks are increasingly used as desktop replacement computers, financial applications and computer-aided design (CAD)/computer-aided manufacturing (CAM) applications benefit from higher resolutions. Finally, there are ergonomic advantages to high-density displays, because improved image quality and text legibility tend to reduce eye strain.

**Wide-Aspect Ratios**

Recently, high-resolution LCDs with wide aspect ratios have become available. These LCDs can display even more information than standard high-resolution LCDs. Aspect ratio refers to the ratio of width to height of a display. New high-end Dell portable computers feature a 15.4-inch LCD with an aspect ratio of 16:10, instead of the standard CRT and LCD ratio of 4:3. Figure 3 compares the two aspect ratios. Wide-aspect LCDs...
accommodate special wide display resolutions: WXGA, WSXGA+, and WUXGA. The resulting wide-screen format displays more information from left to right. For example, a wide-aspect 15.4-inch WXGA screen can display 30 percent more information than a standard aspect ratio 15-inch XGA screen. Similarly, a 15.4-inch WUXGA screen can display 20 percent more information than a standard 15-inch UXGA screen.

**Choosing an LCD Resolution**

While the overall appearance of documents and photos is greatly improved as the ppi increases, fonts, icons, and graphic elements that make up the user interface become smaller. Text that is readable on a 15-inch XGA panel can be more difficult to read on a 15-inch UXGA panel. When faced with this issue on a UXGA panel, a user's first instinct is to enlarge the text by changing the resolution from UXGA to a lower resolution such as XGA. However, lowering the resolution of a UXGA panel reduces the crispness and clarity of displayed text. This is because each LCD has an optimal “native resolution” and LCDs do not scale between resolutions as cleanly as CRTs.

Unlike a CRT display, an LCD has a fixed number of pixels and, thus, a fixed or “native” resolution. Each pixel on an LCD corresponds to three transistors (RGB), so that an XGA display is “hard-wired” to display 1024 x 768 resolution most accurately. To display a lower resolution, such as 640 x 480, on an XGA display, the monitor must scale the image up 1.6x using sophisticated algorithms. This scaling process can degrade the display quality noticeably. For example, screen text will appear less clear and sharp than at the display’s native resolution and graphics will appear more grainy. Scaling is most accurate when switching between two resolutions with the same aspect ratio in whole-number increments. For example, scaling from UXGA to super video graphics array (SVGA) is very accurate. Both have a 4:3 aspect ratio and the image is scaled up 2x.

In contrast, a CRT has an architecture of scalable pixels that allows it to effectively display many different screen resolutions up to the maximum resolution possible for the particular display. A CRT display is made up of a dense matrix of thousands of tiny phosphor dots arranged in trios of red, green, and blue. Phosphors are chemicals that emit colored light when struck by electrons. In a CRT, an electron gun shoots a stream of electrons back and forth across the back of the screen, illuminating selected phosphor dots on each pass. In this way, the image is drawn, line by line, on the screen. Unlike the LCD panel, the graphics controller alone governs the pixel resolution that is displayed. The CRT simply renders the image to the display.

Because of the scaling issues associated with LCDs, an LCD panel should normally be run at its native resolution. Dell recommends that customers running Microsoft® Windows® operating systems choose the “large fonts” option in the advanced display settings. This enlarges the icons and fonts in the Windows user interface, making them readable at high resolutions. Dell Quickset software is included on most of Dell’s latest portable computers. This software allows the user to resize desktop fonts and icons. Advanced options allow the user to resize the text in some applications.

Finally, there is also third-party software that adjusts the Windows user interface (such as desktop icons and...
toolbar) for high-resolution LCDs. Like Dell Quickset, these products typically do not alter the native resolution of the screen, but scale up key screen components of the user interface. Documents and photos, which look best at higher resolutions, are not scaled.

The long-term solution is built-in operating system and application support for high-resolution LCDs. Today, the operating system and most applications assume that they are running on a 96-ppi display. The user interfaces must be rewritten to be resolution-independent, so that they display correctly at any resolution. Support in Microsoft operating systems is expected in a future Windows operating system release. To help software vendors, Microsoft has published a white paper, “How to Write High-DPI Applications,” on its website at msdn.microsoft.com.

**Dell UltraSharp Wide-Viewing LCD Technology**

Portable computer LCDs have historically suffered from limited viewing angles, particularly when viewing the screen from the top or bottom. Unless the screen is viewed straight-on, with the LCD panel position adjusted to its optimal angle, the color can vary significantly from the top to the bottom and from one side to the other of the screen. This problem, referred to as "color inversion," is particularly problematic for graphics and multimedia applications.

Wide-viewing technology minimizes color inversion by increasing the horizontal and vertical viewing angles, referred to as the "viewing cone." Available on flat-panel monitors for several years, wide-viewing technology has migrated to LCDs and is included on Dell's high-end notebook computers equipped with 15- and 15.4-inch LCDs. The wide-viewing solutions implemented by Dell also increase the contrast ratio, providing brighter and more vivid colors.

**Viewing Angles on Portable Computer LCDs**

The viewing angle is expressed as a vertical angle and a horizontal angle from the center point of the display, as shown in Figure 4. The vertical viewing angle is more restricted than the horizontal viewing angle. The range of the viewing angle is defined by a minimum contrast ratio (or ratio of white-to-black luminance). Viewing angles

![Figure 4. Comparison of Horizontal and Vertical Viewing Angles](image-url)
assume the viewer is at a typical distance of 18 inches from the portable computer display.

LCD specifications describe the maximum viewing angle at a contrast ratio of 10:1. Figure 4 compares the viewing angles of an LCD with and without wide-viewing technology at a 4:3 aspect ratio. This figure shows that the technology improves the horizontal viewing angle by over 50 percent. The vertical viewing angle improvement is even more pronounced, increasing by over 150 percent.

The viewing angles at a 10:1 contrast ratio are useful to compare vendor LCD specifications. Because of technology trends in the past few years, it is more useful to compare the viewing angles at 100:1. This contrast ratio provides a better indicator of the usable viewing angles for most viewers. At a contrast ratio of 100:1, the typical LCD screen without wide-viewing technology has viewing angles of approximately +20/-20 degrees horizontal and +5/-15 degrees vertical. Wide-viewing technology enlarges these viewing angles by over 100 percent to approximately +45/-45 degrees horizontal and +20/-20 degrees vertical.

There are a number of approaches to widening the viewing angle. Some wide-viewing systems change the alignment of the liquid crystal material within the display and some use wide-viewing film. Some approaches are more efficient than others. While viewing angles are improved, the light-transmission efficiency is reduced, which results in lower luminance in white, but darker blacks. In this way, a higher contrast ratio is achieved, even though the white luminance may be reduced.

Dell's current portable computer solutions use either wide-viewing film technology or a combination approach that uses film and internal alignment adjustments.

**Conclusion**

Dell continues to enhance the LCD panels on its portable computers to improve the display quality and user experience. Dell offers high-resolution, wide-viewing 15-inch LCD panels on high-end Precision Mobile Workstation, Latitude, and Inspiron portable computers. Wide-aspect 15.4-inch panels are also available on the latest high-end models. A 14.1-inch high-resolution LCD is also available on some Latitude and Inspiron models. Native resolutions range from XGA+ to WUXGA. For more information on the features and technologies discussed in this white paper, see:

- Display Search: [www.displaysearch.com](http://www.displaysearch.com)
- Society for Information Display (SID): [www.sid.org](http://www.sid.org)
- Microsoft white paper, “How to Write High-DPI Applications”: [msdn.microsoft.com](http://msdn.microsoft.com)