

Dots per inch

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Dots per inch (DPI) is a measure of spatial printing or video dot density, in particular the number of individual dots that can be placed in a line within the span of 1 in (2.54 cm). The DPI value tends to correlate with image resolution, but is related only indirectly.

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A close-up of the dots produced by an inkjet printer at draft quality. Actual size is approximately 0.25 inches square (0.635 centimetres square). Individual coloured droplets of ink are visible; this sample is about 150 DPI.

DPI measurement in video resolution

Because color display units use three coloured sub-pixels (red, green and blue) per pixel, the DPI measurement is frequently misused, especially in the automotive market. An example of misuse would be if an LCD monitor manufacturer claimed that a 320 × 240 pixel 3 in (76 mm) monitor (2.4 in × 1.8 in/61 mm × 46 mm) actually had a resolution of 400 DPI, (three times the pixels per inch). Technically this would be correct (as each sub-pixel could be considered a dot), but compared to the standard accepted practice of using pixels as a means of measuring resolution, it could mislead customers into thinking the relabeled monitor had a greater resolution and therefore better picture quality than identical but normally labeled monitors. Such misuse is commonly found in advertising for in-car LCD displays.

A less misleading term, therefore, is pixels per inch. Video displays are almost universally rated in dot pitch, which refers to the spacing between the sub-pixel red, green and blue dots which make up the pixels themselves. Very often, DPI is confused with image size, leading to expressions such as *1,024 × 768 DPI XGA*.

DPI measurement in printing

Up to a point, printers with higher DPI produce clearer and more detailed output. A printer does not necessarily have a single DPI measurement; it is dependent on print mode, which is usually influenced by driver settings. The range of DPI supported by a printer is most dependent on the print head technology it uses. A dot matrix printer, for example, applies ink via tiny rods striking an ink ribbon, and has a relatively low resolution, typically in the range of 60 to 90 DPI. An inkjet printer sprays ink through tiny nozzles, and is typically capable of 300–600 DPI.^[1] A laser printer applies toner through a controlled electrostatic charge, and may be in the range of 600 to 1,800 DPI.

The DPI measurement of a printer often needs to be considerably higher than the pixels per inch (PPI) measurement of a video display in order to produce similar-quality output. This is due to the limited range of colours for each dot typically available on a printer. At each dot position, the simplest type of colour printer can print no dot, or a dot consisting of a fixed volume of ink in each of four colour channels (typically CMYK with cyan, magenta, yellow and black ink). Contrast this to a standard sRGB monitor where each pixel produces 256 intensities of light in each of three channels (RGB) to additively create $256^3 = 16,777,216$ colours. The number of unique colours for a printed CMYK dot from this simplest type of inkjet printer is only 8 since no coloured ink is visible when printed on black and black is used instead of CMY:

- White (no ink)
- Cyan
- Magenta
- Yellow
- Blue = cyan + magenta
- Green = cyan + yellow
- Red = magenta + yellow
- Dark brown (not used) = cyan + magenta + yellow
- Black

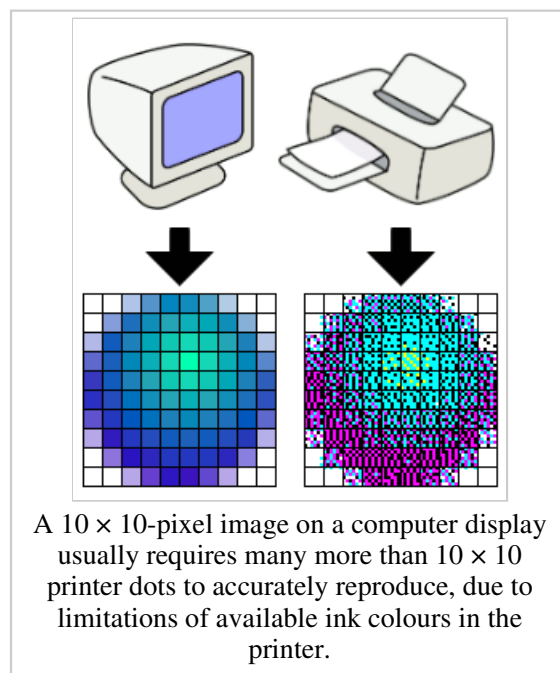
While some colour printers can produce variable drop volumes at each dot position, and may use additional ink colour channels, the number of colours is still typically less than on a monitor. Most printers must therefore produce additional colours through a halftone or dithering process. The exception to this rule is a dye-sublimation printer that utilizes a printing method more akin to pixels per inch.

The printing process could require a region from four to six dots (measured across each side) in order to faithfully reproduce the colour contained in a single pixel. An image that is 100 pixels wide may need to be 400 to 600 dots in width in the printed output; if a 100×100-pixel image is to be printed inside a one-inch square, the printer must be capable of 400 to 600 dots per inch in order to accurately reproduce the image.

DPI or PPI in digital image files

DPI refers to the physical dot density of an image when it is reproduced as a real physical entity, for example printed onto paper, or displayed on a monitor. A digitally stored image has no inherent physical dimensions, measured in inches or centimetres. Some digital file formats record a DPI value, or more commonly a PPI (pixels per inch) value, which is to be used when printing the image. This number lets the printer know the intended size of the image, or in the case of scanned images, the size of the original scanned object. For example, a bitmap image may measure 1,000 × 1,000 pixels, a resolution of one megapixel. If it is labeled as 250 PPI, that is an instruction to the printer to print it at a size of 4 × 4 inches. Changing the PPI to 100 in an image editing program would tell the printer to print it at a size of 10×10 inches. However, changing the PPI value would not change the size of the image in pixels which would still be 1,000 × 1,000. An image may also be resampled to change the number of pixels and therefore the size or resolution of the image, but this is quite different from simply setting a new PPI for the file.

For vector images, there is no equivalent of resampling an image when it is resized, and there is no PPI in the file because it is resolution independent (prints equally well at all sizes). However there is still a target printing size. Some image formats, such as Photoshop format, can contain both bitmap and vector data in the same file. Adjusting the PPI in a Photoshop file will change the intended printing size of the bitmap portion of the data and also change the intended printing size of the vector data to match. This way the vector and bitmap data maintain a consistent size relationship when the target printing size is changed. Text stored as outline fonts in bitmap image formats is handled in the same way. Other formats, such as PDF, are primarily vector formats which can have bitmaps pasted into them. In these formats the target PPI of the bitmaps is adjusted to match when the target print size of the file is changed. This is the converse of how it works in a primarily bitmap format like Photoshop, but has exactly the same result of maintaining the relationship between the vector and bitmap portions of the data.



Computer monitor DPI standards

Since the 1980s, the Microsoft Windows operating system has set the default display "DPI" to 96 PPI, while Apple/Macintosh computers used a default resolution of 72 PPI until approximately 2000^[2]. These default specifications arose out of problems rendering standard fonts in the early display systems of the 1980s, including the IBM-based CGA, EGA, VGA and 8514 displays as well as the Macintosh displays featured in the 128K computer and its successors. The

choice of 72 PPI by Macintosh for their displays arose from the convenient fact that the official *72 points-per-inch* mirrored the *72 pixels-per-inch* that actually appeared on their display screens. (Points are a physical unit-of-measure in typography dating to the days of printing presses, where 1 point by the modern definition is 1/72 of the international inch (25.4 mm), which therefore makes 1 point approximately 0.0139 in or 352.8 μm). Thus, a 72 pixels-per-inch seen on the display was the exact same physical dimensions as the 72 points-per-inch later seen on a printout, with 1 pt in printed text equal to 1 px on the display screen. As it is, the Macintosh 128K featured a screen measuring 512 pixels in width by 342 pixels in height, and this corresponded to the width of standard office paper (512 px ÷ 72 px/in = 7.1 in, with a 0.75 in margin down each side when assuming 8.5 in × 11 in North American paper size).

Though the Apple's decision to use this standard was logical and convenient, the consequence was that the widely-used 10 point fonts from the typewriter era had to be allotted 10 display pixels in em height, and 5 display pixels in x-height. This is technically described as 10 *pixels per em* (*PPEm*). This made 10-point fonts crudely rendered and difficult to read on the display screen, particularly for lowercase characters. Furthermore, there was the consideration that computer screens are typically viewed (at a desk) at a distance 1/3 or 133% greater than printed materials, causing a mismatch between the perceived sizes seen on the computer screen versus those on the printouts. Microsoft's inelegant solution to both related problems was to scale 72 PPI upwards by 1/3 to 96 PPI ($72 \times 4 \div 3 = 96$). This increased the display pixels allotted to text by 1/3, (1) making them (a) 1/3 larger on the display screen, (b) making rendering more detailed, and (c) therefore making them more readable, and (2) making perceived screen sizes similar to perceived printout size (assuming the screen was still seen at a distance 1/3 greater than the printouts). Thus, for example, 10 point font on a Macintosh (at 72 PPI) was represented with 10 pixels (i.e., 10 PPEm) whereas 10 point font on a Windows platform (at 96 PPI) using the same display monitor is represented with 13 pixels (i.e., Microsoft rounded 13.3333 to 13 pixels, or 13 PPEm). Likewise, 12 point font was represented with 12 pixels on a Macintosh, and 16 pixels on a Windows platform, and so on. [3] The negative consequence of this standard is that with 96 PPI displays, there is no longer a 1-to-1 relationship between the display size in pixels and the printout size in points. This difference is accentuated on more recent displays that feature higher pixel densities. Many Windows software programs have been written since the 1980s making the assumption of 96 PPI, and accordingly, these programs do not display properly at common alternative resolutions such as 72 PPI or 120 PPI. Since the release of Mac OS X in 2000-2001, Apple computers have also been set to a default resolution of 96 PPI. [4]

Proposed metrification

There are some ongoing efforts to abandon *DPI* in favour of metrification, giving the inter-dot spacing in micrometres (μm). A resolution of 72 DPI for example equals an inter-dot spacing of about 350 μm, 96 DPI → 265 μm, 160 DPI → 160 μm, 300 DPI → 85 μm, 4,000 DPI → 6. μm. Going the other way, 1 μm → 25,400 DPI, 30 μm → 850 DPI, 200 μm → 127 DPI. Note that 25,400 = 1 DPI·μm, so dividing 25,400 by a measurement in one of these units gives the measurement in the other unit.

Some have also proposed using *dots per centimeter* (dpcm). [5]

See also

- Pixels per inch
- Samples per inch
- Lines per inch
- Metric typographic units
- Display resolution
- Mouse DPI
- Twip

References

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External links

- All About Digital Photos - The Myth of DPI (<http://www.rideau-info.com/photos/mythdpi.html>)
- Monitor DPI detector (<http://www.infobyip.com/detectmonitordpi.php>)

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