

PPI, DPI, LPI and Color

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Tips and Techniques for

Many *Photoshop* users are good with their software tools, but relatively few truly understand the meaning and application of “dpi”, “ppi” and “lpi”. Even fewer dig past the idea of 1-bit color depth. We all know that 300 ppi scans are called “high-res” and 150 ppi scans are called “low-res”. But what are the real world differences between them in your workflow?

This article will discuss the fundamentals for scanning lean and mean. The difference between being able to complete a project on time—or not—using your present hardware may hinge on whether you create monster files too large to manage. So here’s how to avoid them.

WHAT DETERMINES BITMAP FILE SIZES?

Bitmapped images are composed of square elements called pixels, which require color information to be assigned to each and every one. The greater the number of pixels and color information, the bigger the file size. To be precise, bitmap file sizes are affected by three factors: image dimensions, image resolution, and image color depth (also known as ‘tonal’ depth).

We don’t usually have a lot of flexibility in choosing image dimensions or color depth, but we can certainly control file sizes by

scanning images with the correct resolution for output. To understand how to scan for printing, we first have to tackle the subjects of ppi, dpi, lpi and tonal depth of images.

HALFTONES: PPI, DPI, AND LPI

First, the basic definitions:

PPI or Pixels Per (linear) Inch—is the number of square samples of the same size, per horizontal and vertical linear inch in a scanned image (Figure 1). Image resolution is measured in ppi. Yes, there is plenty of confusion around the term “resolution”. Desktop scanners often incorrectly show image resolution as dpi.

DPI or Dots Per (linear) Inch—is the number of square laser dots of the same size that an imaging device can print per inch. Resolution of desktop printers and imagesetters is measured in DPI (Figure 2).

Bitmaps

Also called: raster images, scans

Resolution: dependent

Resizing: affects quality

File size: potentially large; size affected by resolution, dimensions and color depth (mode).

Art category: continuous tone art: photographs, paintings, wash drawings, generally composed of random coverage and changes of color.

Control: per pixel

File formats: EPS and TIFF for printing; GIF, JPEG and PNG for electronic publications only. Only EPS, GIF and PNG fully support transparent backgrounds.

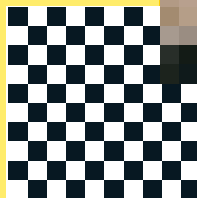


Figure 1
BITMAP
10 ppi resolution

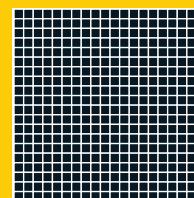
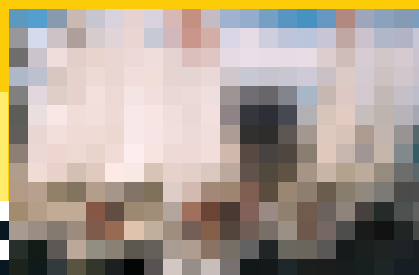


Figure 2
LASER SPOTS
20 dpi resolution

Depth Unravelled

Scanning Lean and Mean

LPI or Lines Per (linear) Inch—is the number of lines of variable size halftone dots needed to break continuous color into a series of printable dots (Figure 3).

The term resolution should not be used to describe a halftone dot since it is variable in size (resolution means that the unit must always be the same size). The number of lines of halftone dots per linear inch is referred to as “screen frequency”.

In the old days, a continuous tone image was photographed through a mesh screen; today it is just a matter of typing the correct number of lines per inch into the Page Setup or Print dialog window. In some page layout programs (e.g. *QuarkXPress*) you can even override global lpi settings picture by picture.

Of course, as the halftone dot becomes smaller, the paper must be finer and the press has to be better. Here are some guidelines for screens on different paper stocks: newsprint (uncoated)—65-100 lpi; magazines (coated stock)—133-150 lpi; art books—175-200 lpi. Before we scan, we should know the kind of paper (and therefore the halftone screen value). So the only unknown factor will be the image input resolution (recognized more commonly as “What ppi should I scan this image at?”).

Figure 3
HALFTONE DOTS
15 lpi screen
frequency

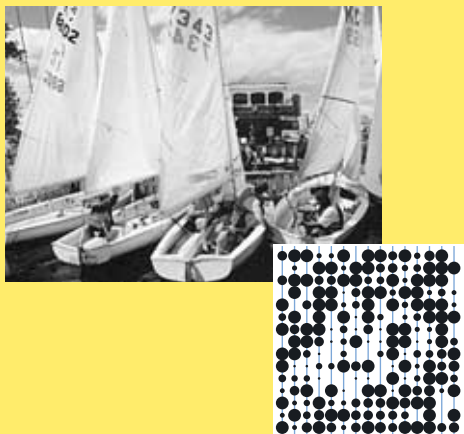


Figure 4
200 PPI, 133 LPI
21 MB/91 MB with layers



Figure 5
300 PPI, 133 LPI
9.2 MB/40 MB with layers

HOW TO SCAN CONTINUOUS TONE IMAGES

The input resolution (ppi) of continuous tone art should be based on (a) the frequency of the halftone screen (or lpi) used for printing the image and (b) the output image dimensions (although resizing factors can usually be calculated automatically by the scanner). This can be summarized by the following formula:

$$\text{ppi} = 1.5 \times \text{lpi to } 2.5 \times \text{lpi}$$

In other words, we should always use at least 1.5 pixels to build each halftone dot, or up to 2.5 pixels for maximum detail. Below 1.5 and above 2.5 the image gets softer—we lose detail in highlight and shadow areas. A halftone factoring range of 1.5 to 2.5 allows us, if necessary, to resize the image by adjusting its resolution slightly rather than allowing *Photoshop* to resample the pixels.

So where did the 300 ppi standard for “high-res” resolution originate? It simply covers all possibilities



Figure 6
LINE ART
900 ppi

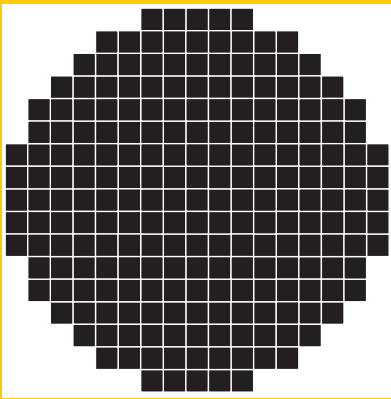


Figure 7
HALFTONING DOTS are built from laser spots which may be square, round or oval.



Figure 8
Standard dpi/lpi ratio for *IMAGESETTER* OUTPUT:
2400 dpi/133 lpi (ppi range 200-333 ppi)
 $2400/133 = 18 \times 18 = 324 + 1 = 325$ tones

Settings for *DESKTOP LASER PRINTER* OUTPUT:
600 dpi/75 lpi (150 ppi)
 $600/75 = 8 \times 8 = 64 + 1 = 65$ tones
This is the best quality tradeoff between screen frequency and the number of tones for a 600 dpi printer (the lower the frequency, the larger the maximum size of halftone dot). Default resolution on many 600 dpi laser printers is usually set even lower at 71 lpi.

1200 dpi/75 lpi (ppi range 150-200 ppi)
 $1200/75 = 16 \times 16 = 256 + 1 = 257$ tones
For quality output on 1200 dpi desktop laser printers, use screens between 75 and 100 lpi.

Figure 9
BLACK & WHITE IMAGE
1-bit color depth



Figure 10
GREYSCALE IMAGE
8-bit color depth



Figure 11
CMYK IMAGE
32-bit color depth



up to 200 lpi screens ($1.5 \times 200 = 300$), but in almost all cases, it's not needed at all.

Let's see what we have saved on a file size by using the proper formula—for example, an image in RGB (24-bit), $8 \times 10''$ in size, to be printed on coated paper at 133 lpi.

At a resolution of 300 ppi, the $8 \times 10''$ RGB image opened in *Photoshop* is about 21 MB. Each *Photoshop* layer you add also adds about 7 MB to your file size. Now let's say that you have ten layers; your file size will increase by about 70 MB. Added to the original 21 MB, it will grow to about 91 MB in total (Figure 4).

The same $8'' \times 10''$ image, scanned at a resolution of 200 ppi (1.5×133 lpi) is only 9.2 MB. Add ten *Photoshop* layers at around 3 MB each and you end up with an image that's only 40 MB—less than half the size of the 300 ppi file (Figure 5)—and with no visible difference in image quality.

Because the resolution of desktop output devices is generally lower (usually no more than 1200 dpi), we do not recommend that you use halftone screens higher than 100 lpi when printing to laser or inkjet desktop printers. Thus, applying our input image resolution formula of 1.5×100 lpi, a resolution of 150 ppi will be enough to print continuous tone images with good quality to any desktop printer.

LINE ART: PPI AND DPI

The input resolution (ppi) for scanning line art (line illustrations, type, etc.) should be based on the output device's imaging resolution. In other words, unless you're converting it to vector format by tracing, the formula for line art is:

$$\text{Input ppi} = \text{Output dpi}$$

The eye can't distinguish differences in image quality past 900 ppi. Thus for output at 100% sizing, 900 ppi is the highest input resolution required (Figure 6) for line art—unless it includes tints (screen percentages), in which case we should scan at 1200 ppi.

HOW A HALFTONE DOT IS BUILT FROM 256 POSTSCRIPT TONES

Variable size halftone dots are built from square laser spots (Figure 7), whether round, oval, or any other shape. The more laser spots per inch (called imaging device resolution and measured in dpi), the more halftone dot sizes we can build, and the more tones we can produce.

PostScript Level 1 is capable of printing 256 tones per color. That's a lot, considering that the human eye is hard-pressed to dis-

tinguish tonal changes in increments of even 1% (1/100 of the full tonal range)—never mind a unit as small as 1/256. However, we need a minimum of 256 laser spots in a halftone dot to be able to produce a full tonal range (although PostScript Level 2 and PostScript 3 introduced supercell screening with 4096 or more levels of gray).

The number of tones we can actually print (Figure 8) depends on (a) the frequency of the halftone screen (lpi) and (b) the output resolution of the imaging device (dpi):

$$\text{No. of Tones} = \left(\frac{\text{dpi}}{\text{lpi}}\right)^2 + 1^*$$

*one extra tone is simply an empty cell (no color)

This is the reason we cannot apply high frequency halftone screens when printing to desktop printers, even at 1200 dpi—they simply don't have enough laser spots to build all 256 sizes of nice,

smooth, round halftone dots which are needed for quality printing with all the available tones of colors.

TONAL DEPTH: B&W, GRAYSCALE AND PROCESS COLOR

Since computer language is based on binary numbers, each bit (switch) can be either zero or one (on or off). When we talk about single color images (in printing, black is an ink color), it is easy to understand that only one bit of information per pixel is required to describe its color: 'off', or zero, for color and 'on', or one, for no color. But what about grayscale or color images?

To describe a grayscale image with quality, we need eight bits of information per pixel (eight switches with two positions each). This will give us:

$$2^8 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 256 \text{ tones}$$

So eight bits will give us 256 different tones of gray.

We can also use the same eight bits to describe 256 different colors, as for Indexed color on the Internet or 8-bit EPS previews.

To describe a full color RGB (red, green, blue) image with the best quality, we need three times the number of bits of information per pixel (eight bits red, eight bits green and eight bits blue), which produces 24-bit color (3 x 8 = 24). And since every eight bits can describe 256 tones of color, 24-bit RGB color mode really means that there are 16.7 million colors (256 x 256 x 256) in an RGB image.

The full spectrum of light is much bigger than the 16.7 million colors in RGB but since the average eye can only see 10 million colors, this is more than enough for anyone (and, by the way, all of us don't see the same colors).

The sensitivity of a scanner's CCD array (how many bits of information per pixel it can read) is called tonal depth (or tonal res-



Figure 12
RGB to CMYK
COLOR
CONVERSION
without merging
layers

Figure 13
RGB to CMYK
COLOR
CONVERSION with
merging layers



Vectors

Also called: Object-oriented art

Resolution: Independent

Resizing: Doesn't affect quality

File size: Relatively small; size is affected by the number of anchor points and effects or filters applied to objects.

Art category: Line art — images composed of definite shapes and few solid colors.

Control: Shapes and fills of objects

File formats: EPS for print, SVG for electronic publications, and PDF for either

9 tips on scanning for print

Use the ppi formula

to scan at the proper resolution:

$$\text{ppi} = 1.5\text{-}2.5 \times \text{lpi} \times \text{sizing \%}$$

(sizing can be controlled through scanner software)

This can save you many megs of unnecessary information—the larger the image dimensions, the bigger the file size. Follow this handy rule: for images intended for output at less than 133 lpi, scan at a halftone factor of 2 x lpi; for images which will be output at 133 lpi or higher, use 1.5 x lpi.

Scan line art

to 800-900 ppi maximum, using the formula:

$$\text{ppi} = \text{dpi}$$

(times sizing factor, if not calculated by a scanner)

16-bit (per channel)

color is a waste of RAM and hard disk space—don't use it. Stick to 24-bit color (8-bit per channel). Unless you're scanning from high-density transparencies, you won't be able to see the difference.

Good descreening control

is a must, so be sure you're using a scanner with descreening software. When you scan from offset print originals, you superimpose a grid of pixels on top of halftone dots, producing a crosshatch effect (called moiré) which is particularly visible on flat color areas (e.g. human skin) and is very difficult to eliminate.

Resize originals

to the final output dimensions using scanner software.

Change color mode to CMYK only once

after you've finished editing the image. Not only does each color mode change cause color information to degrade, but you will also have a larger 32-bit image (instead of 24-bit) to deal with. On top of that, many photo editing programs only work partially (if at all) in CMYK.

If you must resize a scan

adjust its resolution within the 1.5 to 2.5 ppi:lpi ratio. Don't check the resampling box. Remember that every time you resample, the software must either discard information ('downsampling' or reducing the dimensions of an image), or "guesstimate" the color of inserted pixels (when you enlarge). Neither is true to the original color information. If used excessively, both produce blurred and out-of-focus images.

On low-end desktop scanners

with low quality optics, don't bother using the "millions of colors" mode. It will only increase the file size with bad color information.

Let Photoshop merge layers

when changing the color mode from RGB to CMYK. Photoshop performs color space conversions much better when it deals with only a single layer.

olution). When talking about images, we call this measurement 'color depth'. For example, black and white images have a color depth of 1-bit (Figure 9). Grayscale images (Figure 10) and images built out of 256 colors (such as EPS previews) have an 8-bit color depth; RGB is 24-bit, CMYK is 32-bit (Figure 11).

Most current scanner technologies can capture images at 10 to 16 bits per pixel per color channel (or twenty-five to 100 percent more than 8-bit), called "supersampling". This captures better detail in the shadow areas of a scanned image, but this extra data is rarely used by output devices. The enormous file sizes of supersampled images are only a worthwhile trade-off for high-density transparency scans.

And be warned: even though many low end desktop scanners have a mode called "millions of colors", their optics don't generally read color values correctly, so you end up with lots of false data.

COLOR MODES

Changing color modes will always degrade color information. This is because RGB and CMYK have different color gamuts (and RGB is much bigger than CMYK). They are made from different components (RGB is made from red, green and blue light, CMYK from cyan, magenta and black inks). Switch the color mode of an image between RGB and CMYK and you sacrifice color integrity—and with subsequent changes, even more so.

So here is the rule: Scan and edit in RGB; change the color mode to grayscale, duotone or CMYK only once; and always do so after editing the image.

And one more tip—allowing *Photoshop* to merge layers will produce much a better result (Figure 12 and 13). Just don't forget to save the flattened file with a different name and hold onto your original RGB image with layers. 🍷

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