Introduction to Digital Halftones, Scanning & Image Capture

A few things you should know about scanning & image capture

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Introduction to Halftones and Scanning

Halftoning is the process of breaking down a continuous tone image into solid spots of differing sizes to create the illusion of transitioning grays or colors in a printed image. This process has been used since the 19th century in traditional printing. Now with digital technology, traditional techniques have been adapted to the desktop.

Most print publication done today uses digital images, which are usually acquired by scanning. Adobe Photoshop can work wonders in enhancing your images, but getting the best result on your printed page depends on starting with a correct scan.

These pages offer a few guidelines for getting the best results in scanning and printing continuous tone images, whether grayscale or color.

Digital Halftones

Desktop publishing and PostScript technology have opened a way to reproduce images digitally. Digital images are normally created using a scanner (though they may also originate with a digital camera).

Two main factors that come into play when producing a digital halftone are the quality of the scan, and the capabilities of the printer used for the final output. These will determine the size of the halftone cell and the number of gray levels that can be created.

Halftone Cells

Creating a halftone cell is the basic foundation for digital halftoning. Like photographic halftoning, digital halftoning takes into account line screen frequency (lpi), but it must also take into account the printer’s output resolution, which is measured in dots per inch (dpi). Halftone cells are created by superimposing the screen frequency grid over the output resolution grid. A single halftone cell is any square on the line screen grid subdivided into a number of output resolution grid squares:
The divisions within the halftone cell represent the smallest marks the printer can make; these are also known as device pixels. The quality of the halftone dot increases as the number of printer marks per halftone cell increases. This number can be determined using a simple formula based on the line screen frequency and the output resolution:

\[(\text{output resolution} \div \text{screen frequency})^2\]

The halftone cell must be uniform and fit precisely with other halftone cells, which means it must be even on four sides. The values may have to be rounded, since the result of this formula may be fractional. The printer can't make a mark smaller than one device pixel and will have to round up or down — which is done by the PostScript interpreter in the printer — to create the halftone cell. For example, printing 75 lpi on a 600 dpi imagesetter produces a halftone cell that is exactly 8 by 8 pixels (64).

This is easy to determine, because there are no fractions involved. But what of a 106 lpi screen at 600 dpi? The quotient of 600 ÷ 106 is 5.66, but you can’t have a halftone cell that is 5.66 by 5.66, it must be rounded to 5 by 5 or 6 by 6. Whether the fractions round up or down largely depends on the printer's RIP.

So far, the halftone cells we’ve shown are not angled but black halftone screens are always rotated at 45° and, as we’ll show later, four-color process separation also uses screens that are angled at 75° and 105°. When halftone cells are angled, they must fit the fixed square resolution grid:
This will usually cause some variance in the exact screen frequency as well as the exact angle. For example, an exact 75% or 105% angle can’t be created on a square grid. The actual angle and screen ruling will differ depending on the desired screen frequency and output resolution.

Gray Levels

Another factor in digital halftoning is the number of gray levels that can be represented by the halftone cell.

The human eye can discern up to about 200 different levels, or shades, of gray. PostScript can create 256 gray levels: 0 (black) through 255 (white). The number of gray levels that can be reproduced in a digital halftone will vary and is closely connected to the number of device pixels within the halftone cells. In fact, the formula for determining gray levels is nearly identical:

\[(\text{output resolution} \div \text{screen frequency})^2 + 1\]

The importance of determining gray levels is to avoid posterization. This problem occurs when there are insufficient gray levels to adequately represent the whole range of shade or tone in an image. This problem affects color and grayscale images equally.

Compare the right and left halves of the images below, to see the effect of posterization in an image:
Scanned Images

Scanned images are composed of a layout, or bitmap, of pixels and have four basic characteristics:

- resolution
- bit depth
- color model
- size

Image Resolution

Image resolution refers to the number of pixels per unit of measure in the digital image. This is commonly expressed in pixels per inch (ppi), though samples per inch (spi) is also common. Both terms refer to the same thing and should not be confused with dots per inch (dpi) which is a measurement of output resolution on a laser printer or imagesetter. Another, less common, measurement is pixels per millimeter which is expressed as res \( x \), where \( x \) is the number of pixels per millimeter (e.g., res 4 is four pixels per millimeter, or, roughly, 102 ppi/spi).

Pixels are small square picture elements that contain color, grayscale, or black and white information about each sampling of the scanned image. Pixels vary in size depending on the resolution. At 150 spi, the scanner takes a sampling of the image every 150th of an inch; at 72 spi, samplings are taken every 72nd of an inch. The higher the scanning resolution, the greater the amount of detail that can be captured. Notice the change in detail and pixel size from 144 spi to 72 spi to 36 spi:
Scanning Resolutions

When an image is scanned at a low resolution the pixels are larger and must represent larger pieces of the original, resulting in less picture detail, less color information, and an obvious degradation in the quality of reproduction. On the other hand, scanning at too high a resolution will be counterproductive; the file size of the scanned image will be unnecessarily large causing longer process time at the RIP, with no gain in the quality of the printed halftone.

To get the best scans, follow the guidelines below:

Halftones

The key to getting the right resolution for halftones is to scan in relation to the desired line screen frequency. (You'll need to get this from your printer). Once you know this, use one of the following formulas:

a) For halftones with a line screen 133 lpi or higher
   line screen x 2 x scaling of original

b) For halftones with a line screen less than 133 lpi:
   line screen x 1.5 x scaling of original

For example, if you're scanning a 3 by 5 photo that will be reproduced at 3 1/2 by 6 inches (120% of original) using an 85 lpi line screen, you would scan at 153 spi (85 x 1.5 = 127.5 x 1.2).

Line Art

The guidelines for scanning line art is differ from those for scanning halftones. To get the best resolution, scan as close as possible to your final output resolution. Otherwise, you risk a “jaggy” appearance in the printed image:

[Images: LOW-RESOLUTION (low-resolution image) and HIGH-RESOLUTION (high-resolution image)]
When it comes to capturing images for reproduction, you have a number of options at your disposal. You’ll want to carefully select the process that works best for your job. If you don’t have the resources you need in house, you can purchase these services from a printer or prepress service provider. That, of course, adds to the cost of your job and must be factored into your budget.

What you will need:
As you consider the equipment you will need for image capture, weigh these options:

Scanners

Today, you will find a wide range of color scanners available, ranging from handheld scanners and flatbed scanners to transparency scanners and drum scanners. Each has a specialized role in the image capturing cycle. Before using your own equipment or a prepress service provider’s, it is important to analyze the type of originals to be handled and the end use of the captured images. Many scanners in use today are low-end to midrange desktop flatbed scanners that capture light reflected from an original print or piece of artwork. A majority of prepress service providers and printers, however, invest in high-end scanners (that can operate in either reflection or transmission mode) which provide a level of quality and speed unattainable by low-end scanners. The important factors to consider when choosing a scanner are dynamic range, resolution, image size, scanning software and the ability to scan transparent materials.

If you plan to do a lot of color scanning, you should also be aware that scanned images can consume megabytes of storage space with astonishing speed. In addition, color scans can eat up computer memory and slow down screen redraw. It pays to invest in as much memory as your computer can use.

Digital Cameras

These tools allow photographers to supply customers with digital images ready for electronic manipulation. Similar in operation to desktop scanners, digital cameras are image grabbers that record RGB (red, green, blue) values in digital form instead of on film. Digital cameras, however, take time to record image information and may be best used in studio and tabletop work than live action photography. Resolution may also be a problem in some kinds of high-end work, much the way small, inexpensive scanners have their resolution limitations. As a general rule, use the highest quality setting (usually TIFF) on your 2 megapixel digital camera without JPG compression.

**NOTE:** The quality for printing photos on a home printer and what is needed for commercial print reproduction are dramatically different. If these guidelines are followed before photos are taken, most times your images will give us the best results.
If you plan to use digital photographs in your project, don’t forget to convert them from RGB to CMYK (for a full color project) or RGB to Greyscale or Line Art (for single color project).

**Color management system**

A color management system (CMS) coordinates color between the monitor, scanner, scanning software, digital proofing device, image (film or plate) recorder, contract proof, and the final press sheet. A CMS helps ensure consistency during the color reproduction process by correcting for differences in color introduced by each device.

**File formats**

We ask you to provide digital images in CMYK or greyscale TIF format with the resolution of 300 DPI and line art at 600 dpi in TIF format. (See our File Format Supplement for more guidelines about file formats and standards.)

**Storage devices**

Once you’ve captured your images, you’ll need to store them for use in your design. If you’re handling the images yourself, the simplest way to store them is on your hard drive. If you are sending your images to a prepress service, however, you will need a removable storage device. Among the removable storage options available to you are:

- Floppy disks
- Zip Disks
- CD-ROM’s
- Via email
  *(using compression software such as Stuff It for Mac and WinZip for the PC)*
What you can expect:

Having decided on how to capture and store your images, you are ready to consider the quality of the images you capture. Whether you capture your own images or have a prepress service provider do it for you, ask these questions:

How are images converted from RGB to CMYK?

While you may choose to archive your images in the RGB format, they all must be converted to CMYK prior to final film output or plate imaging. Some service providers prefer to perform the RGB-to-CMYK conversion on their prepress systems. If, however, you convert your images from RGB to CMYK on your desktop either during scanning or by using image-editing software, be sure to consult your printer about the values required to perform this conversion correctly.

Is the scanning resolution appropriate?

When scanning images, a higher pixels per inch (ppi) setting does not necessarily improve final output quality. Higher ppi readings do, however, take up more storage space. For jobs that will be printed, you'll obtain the best results if you scan at twice as many ppi as there are lpi (lines per inch, or line screen) in the final output. That relationship will guarantee that you capture enough color information to make a reasonably accurate halftone dot. To get the best possible images at the lowest cost in file size and output processing time, plan your page and image sizes before scanning.

Example: If you are planning to resample (enlarge) an image for another use, you'll need to scan it at a higher ppi by multiplying your normal input (usually twice the lpi) by the percentage of the enlargement. For example, an image to be printed at 133 lpi and with a 150% enlargement works out like this.

$$133 \times 2 \times 1.5 = 399 \text{ ppi scanner resolution}$$

It is easier to reduce than to enlarge scanned images. Pixels can always be thrown away when image size is reduced, but true image pixels cannot be added to maintain resolution when an image is enlarged. Also, to prevent aliasing, type and linework need higher input resolutions than continuous-tone photographic images.

NOTE:

Color Keys are usually required by your service bureau or printer to simulate the results of the press, giving an accurate proof to view. So remember that what you see on an uncalibrated computer screen and printer will usually not match the final output at your service provider or printer.
What are ppi, lpi and dpi? And why should you care?

Together ppi, lpi and dpi represent a confusing trio of acronyms used throughout our industry. Defined below, each actually refers to a distinct measure of a separate step in the process of capturing and printing images.

ppi, or pixels per inch (or samples per inch (spi), is a measure of the amount of information scanned in, or sampled, from an image. The finer the optics of a scanner, the higher the scan resolution (degree of detail), which is critical to image quality.

lpi, or lines per inch or line screen is a measure of the frequency of the halftone screen used late in the process to print an image. A specific lpi is recommended for the paper stock being used. Working backward, the lpi that you select in consultation with your printer determines what ppi is best to use early in the process, when an image is scanned.

dpi, or dots per inch, is a measure of resolution of input devices such as scanners and digital cameras and output devices such as laser printers, copiers, digital proofing devices, imagesetters and platesetters.

As an example, you may be scanning in a transparency at 300 ppi because it will print on paper at 150 lpi and you are previewing it on a monitor at 72 dpi.

What are duotones?

Duotones are used to increase the tonal range of a grayscale image and has been manipulated in a photo editing program to include two channels. Usually a greyscale channel and a color channel. This process is used most commonly when trying to reproduce a sepia tone image. To minimize printing problems, save duotones using default values for screen ruling and screen angles, unless you are familiar with screen frequency and its results. Colors should be defined as either CMYK or spot colors, not RGB. To avoid unnecessary film output and the associated costs, define color properly and consistently between layout and image editing applications.

Are your images the right size?

Be sure to crop and size your images during scanning or in an image editing program. If you wait to crop them in your page layout program, the cropped portion remains part of your document and creates an unnecessarily large-harder to manage file. If you resize an image in the page layout file, this function must be calculated every time the file is printed. This can add significant processing time and may result in printing errors.
Do your images need to be altered?

As a general rule, always edit your images (e.g. resize, crop, rotate, flip, composite) in an image editing software program before adding the image to your page layout file. For example, rotating or flipping your images during scanning saves your page layout program from calculating the rotation every time you print the file. That calculation is very time-consuming and memory-intensive.

Should you compress your image files?

Compressing image files affects the processing and quality of the printed piece. Consequently, many prepress service providers recommend that you do not compress your image files. Always check with your prepress service before you supply compressed image files.

How is a continuous tone image reproduced?

Photographs and transparencies are examples of continuous tone images. To be printed, they must be saved as greyscale images to be converted to halftones of various sized dots at a postscript device. This will create the illusion of a continuous tone image. The quality of the copy that you input will determine the quality of the reproduction that you output. Remember the old adage: GIGO, garbage in, garbage out.

How does the line art look?

If you are aiming for a high-contrast image, whether pictorials, graphics, or type, among the things to look for are:
Copy quality: You want high density and sharp focus.
Scan resolution: Continuous tone images may require only 300 dpi, whereas pictorials, graphics, and type require at least 600 dpi.

Are the images sharp and clear?

All scanned images look a little soft and fuzzy compared to their originals. Sharp and unsharp filters on your graphics software or scanning program can help correct the problem by increasing detail.

Some scanners have automatic sharpening routines built in. In addition, most scanners and image editing software programs provide sharpening filters that are menu-selected. Sharpen, Sharpen More, and Unsharp Masking functions apply increasing amounts of sharpening. Despite its name, the unsharp filter sharpens rather than blurs the image.
IMAGE CAPTURE TIPS

Dynamic range - the range of tones from lightest to darkest a scanner can see and resolve - affects the quality of scanned image more than resolution. The higher the dynamic range of a scanner, the more likely it can record the differences between two closely matched colors or greyscale areas.

The quality of the images captured with scanners, digital cameras, and copiers varies with the technical sophistication of these devices. For best results, use current technology and associated software, or send your images to a prepress service provider that has the appropriate equipment.

If you are not completely comfortable with image capture technology or if you lack the proper equipment, don’t attempt to do it yourself. Turn the job over to a prepress service provider or your printer. They’ll work with you to give you predictable color images on press.

It is common to apply a “sharpness” tool or apply “unsharp masking” in an image editing application to image files captured by a digital camera.

Make sure that your storage device is compatible with the computer system that you and your prepress service provider will use to produce the actual design, color correction, pagination and output.

Calibrate your scanning devices, monitors and proofing devices on a regular basis. Most manufacturers provide calibration instructions and provide the IT8.7/1 (transparency) and IT8.7/2 (reflection) calibration targets for their devices.

Do not try to pre-screen images in a photo retouching program. You will end up with a moiré pattern when your greyscale image is sent to a postscript device, like a printer or imagesetter.
Glossary

Bit
A binary pair. This is the smallest unit of data on a computer. Each bit can define itself as on or off (1 or 0). Eight bits make a byte, 1024 bytes make a kilobyte (1K) and 1024K makes a megabyte (1 MB).

Device Pixel
The smallest mark that can be made by a printer. For most desktop laser printers this will be a 1/300" square dot for 300 dpi and a 1/600" square dot for 600 dpi. Imagesetters, which are capable of much higher resolutions, can make a mark as small as a 1/3300" square dot. By comparison, most video monitors display with device pixels that are 1/72" square.

Moiré
A pattern that may form when screens of differing angles or frequency are overlayed. This is a common consideration in four color process printing. It is also a problem when scanning images that are already halftoned.

Offset Printing
Any form of printing in which the ink transfer is not made directly from the plate to the paper. The offset is supplied by the use of a blanket (a large rubber roller). The plate transfers the ink to the blanket which, in turn, transfers the ink to the paper. The most common form is offset lithography (also the most common method of commercial printing overall). Letterpress and gravure are two other printing methods that can be offset. Offset lithography is distinguished from these two by the fact that there is no etched or raised surface on the plate; the separation of printing and non-printing areas is made chemically, rather than physically.

Output Resolution
The resolution of the device used for the final output of a digital file expressed as dots per inch (dpi). When printing halftones, the output device is normally a PostScript laser printer or imagesetter. Resolution varies between 300 dpi and 3300 dpi.

Paper Quality
This is a big factor in determining screen frequency. If the paper is porous, dot gain will obviate any detail that could be gained from using a high screen frequency. Papers come in a large variety of types and are intended for many different purposes. The basic types of paper and how they affect dot gain are as follows:

Newsprint
A coarser paper made mostly from wood pulp and highly porous. It is manufactured almost exclusively for printing newspapers. The dot gain for newsprint is 20% or more.

Uncoated Paper
Any number of different paper types that are unvarnished. Dot gain for uncoated paper is roughly 12%.
Coated Paper
Paper that has been given a varnish coat. This helps to seal the paper and reduce dot gain (which runs at about 8% on average). High quality grayscale and four-color images are printed on coated stock.

PostScript
A print technology developed by Adobe Systems, Inc. This is the standard technology for printed output from computers.

Plate
A (usually) metal plate for the printing press on which the image is held. The image on the plate picks up ink and transfers it to the paper or, in offset lithography, to a blanket. Plates used for offset lithography are photosensitive. The image area is created by exposure to ultraviolet light. On the press, the exposed image area picks up the ink by chemical attraction. Other types of plates can have a raised surface area (letterpress) or an incised area (photogravure).

RIP
Raster Image Processor. This is built into all PostScript desktop printers and is a separate component for imagesetters. (Some RIPs are also software-based.) The RIP performs the function of interpreting the PostScript code sent from an application and translating it to instructions for the marking engine that marks the pixels on the paper or film that is output.

TIF
The Tagged-Image File Format (TIFF) is used to exchange files between applications and computer platforms.