
Scanners and How to Use Them

Written by Jonathan Sachs
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Introduction

A scanner is a device that converts images to a digital file you can use with your computer. There are many different types of scanners: film scanners, flatbed scanners, video capture devices, and drum scanners.

Film Scanners

This type of scanner is sometimes called a slide or transparency scanner. They are specifically designed for scanning film, usually 35mm slides or negatives, but some of the more expensive ones can also scan medium and large format film. These scanners work by passing a highly focused beam of light through the film and reading the intensity and color of the light that emerges. The Photo CD scanning process works with a high quality film scanner.

Flatbed Scanners

This type of scanner is sometimes called a reflective scanner. They are designed for scanning prints or other flat, opaque materials. These scanners work by shining white light onto the object and reading the intensity and color of the light that is reflected from it. Some flatbed scanners have available transparency scanning adapters, but in most cases these are not as well suited to scanning film as a dedicated film scanner.

Video Frame Grabbers

This type of scanner uses a video camera to capture a scene or object and then converts the video signal that comes out of the camera to a digital image in your computer memory. A video camera can be used to digitize scenes containing 3-dimensional objects, but they usually have much lower image quality than film or flatbed scanners.

Drum Scanners

These professional devices are pretty much out of the reach of the individual photographer. To use a drum scanner, the original is taped to a rotating clear plastic drum and scanned as the drum rotates. Drum scans have the highest quality but are labor intensive and very expensive.

CCDs vs. Photomultipliers

Most film scanners, flatbed scanners, and video cameras use light sensing elements called CCDs (Charge Coupled Devices) to measure light. CCDs are relatively inexpensive, compact, and efficient. Most high end drum scanners use photomultiplier tubes to measure light. Photomultipliers, while larger and more expensive to design around, do offer superior dynamic range. Thus a scanner that uses photomultiplier tubes can extract more detail from very dark shadow areas of a transparency. CCD scanners, while steadily improving in this area, are still prone to losing detail in deep shadow areas.

Scanner Characteristics

Just as there are many different types of scanners, each one has its own characteristics. The quality of the digital images you can obtain from a scanner depend on many factors:

Color vs. Grayscale

While some scanners, especially those designed for scanning printed documents, only scan in black in white, most modern scanners work in color. This means they really make three independent scans, one for each primary color (red, green, and blue) and then combine them into a single image. Sometimes each scan is performed in a separate passe over the image and sometimes they are done in a single pass -- neither technique is inherently superior.

Number of Bits

Most digital images are made up of pixels which have 8 bits of brightness information for each color component. This corresponds to 256 different brightness levels (per color) -- more than the human eye can distinguish under most conditions. However, the response of the human visual system is more or less logarithmic. This means that the eye is much more sensitive to small variations in dark areas than in light areas. To account for this nonlinearity, digital images are usually displayed using what is called a gamma curve. The gamma curve relates the actual brightness of the image to the numeric value that is stored in the image file. Since most image sensors have a linear response, this means that to capture 256 visibly different gray levels, the scanner must start out by capturing more than this number and then applying a gamma curve to the captured data to match the response of the human visual system. In addition, the scanner needs to allow for some amount of operator intervention in adjusting brightness, contrast, etc. For this reason, better scanners capture between 10 bits (1,024 brightness levels) to 14 bits (16,384 brightness levels) of information for each color component and then reduce this internally to 8 bits (256 brightness levels) in the final image transmitted to the computer. Some of the newer scanners can transmit more than 8 bits per color to the computer. Using Picture Window Pro, you can manipulate these extended dynamic range images directly.

Optical and Interpolated Resolution

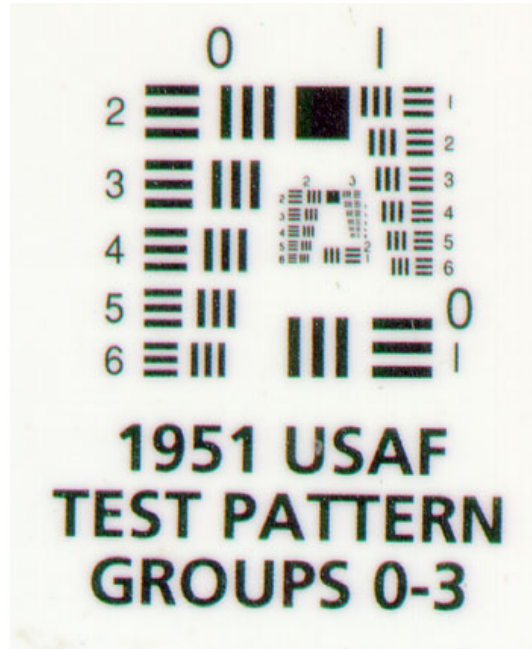
The amount of detail captured in the scanning process is determined primarily by the resolution of the scanner. Transparency scanners normally require much higher resolution than reflective scanners because film is so much smaller than a print. The more pixels the scanner captures, the finer the detail it can reproduce. Scanner resolution is usually reported in dots per inch (dpi)—this is the same as pixels per inch. For example, a 2,000 dpi film scanner can generate an image file consisting of about 2,000 by 3,000 pixels when scanning a 35mm frame. (A 35mm frame is about 1 inch by 1.5 inches, and $1 \times 2,000 = 2,000$ and $1.5 \times 2,000 = 3,000$).

Most film and flatbed scanners operate at a specific resolution called their *optical resolution*. This resolution is determined by the mechanical and optical characteristics of the scanner (such as the spacing between its individual CCD elements). Scanning at the optical resolution of the scanner ensures that you extract all the information from the image that the scanner is capable of generating. The scanning software that comes with the scanner usually can create higher resolution scans by interpolating between the actual scanned pixels. This higher number is usually referred to as *interpolated resolution*. This technique (which is basically the same as that used in Picture Window's Resize transformation) does not actually add any

new image detail. And, to make matters worse, the resulting files are much larger and thus more difficult to work with. Therefore, it is almost never worthwhile to scan at a resolution higher than the optical resolution of your scanner. Similarly, the scanning software can simulate a lower resolution scan, but again Picture Window probably does a better job of this than the scanning software.

Resolving Power

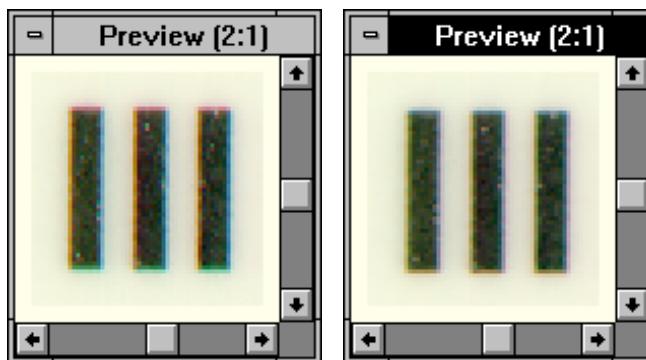
Although a scanner may have an optical resolution of 600 dots per inch, this does not necessarily mean that it can resolve detail at that level. The actual resolving power is determined by scanning a resolution test chart and then examining the resulting digital image to see the finest detail the scanner can actually resolve. The resolving power is a function not only of the optical resolution, but also the quality of the scanner's optical system, the stability of the transport mechanism, the type of sensing elements used, and other factors related to the design of the scanner. A high quality scanner may have significantly more resolving power than a lower quality scanner of the same optical resolution. Here's what an scan of part of the standard airforce resolution test chart looks like from an HP II-CX flatbed scanner:



Color Registration

A color scanner really makes three separate scans of your image; one for the red channel, one for the green channel, and one for the blue channel. This is usually accomplished either by making three passes over the image with different color filters or by making a single pass with a light that can change colors very rapidly. In any case, it is very important that the three scans be precisely aligned with each other. Registration errors lead to visible color fringes that parallel prominent edges in the image. This is most easily seen by zooming in on a scan of a target such as crisp black and white text. Registration is not an issue when scanning black and white images as there is only one channel. Low quality color scanners often have color registration problems. If the registration errors are consistent across the entire image, you can use Picture Window's Color Registration transformation to correct or reduce the problem. If the registration errors vary significantly from one part of the image to another, fixing the problem is much more difficult.

Here's what a magnified section of a slightly misregistered image looks like:



Before Correction

After Correction

Notice the green/magenta fringes on the top and bottom edges of the bars and the blue/yellow fringes on the sides of the bars. These indicate slight vertical misregistration of the green channel and horizontal misregistration of the blue channel. After correcting the problem using the Color Registration transformation, the color fringes are considerably reduced.

Dynamic Range

For a scanner to capture the full dynamic range of an image on the film or print, the range of its light sensors must exceed that of the image data. The CCD sensors used in less expensive scanners have a smaller dynamic range than the photomultiplier tubes used in the high-end drum scanners used for commercial prepress work. This can lead to loss of shadow detail, especially when scanning very dense transparency film. Where scanners have the most problem is usually extracting detail from the darkest parts of transparencies. Scanner vendors frequently report a DMAX number with is the maximum optical density the scanner is capable of distinguishing from solid black. Density is a logarithmic scale, so a density of 4.0 means that only 0.0001 of the light (or 0.01%) passes through the film. Transparency film typically has a DMAX of around 4.0, so a scanner with a DMAX of 3.4 will lose some deep shadow detail.

Color Accuracy

Different color scanners may measure the same color differently due to the spectral response of their sensing elements, the nature of the light source they use and the corrections applied by the scanning software.

What type of film scans best?

Debates over what film type is best for scanning are endless, but whatever you use, scanning the original film is always preferable to scanning a print made from the film.

Film Grain

The finer the film grain, the higher resolution image you will be able to scan. Scanning coarse grained film at high resolution imparts a disagreeable, lumpy texture to the image which is difficult to remove.

One technique for removing graininess from a scanned image is to use Picture Window's Blur transformation (or Blur tool) with a radius about the size of the grain and a relatively low threshold value. This will help to blur out most of the low level noise from the film grain without sacrificing too much of the detail in the underlying image.

Slides or Negatives?

If you are using a film scanner, you can scan either transparency film or color negative film—each film type has its unique advantages and is capable of producing high quality results.

As a rule, color slide film is contrastier than color negative film so if you are photographing a subject with a wide dynamic range, you can easily exceed the exposure latitude of the film. On the other hand, color negative film compresses the contrast range of the scene which makes it a better choice for capturing a wide range of brightness levels. But, if you are photographing a low contrast subject with color negative film, the resulting contrast range may be reduced so far that the scanning process cannot recover subtle tonal variations. Thus for very high contrast subjects, color negative film is usually better and for very low contrast subjects color positive film may be the best choice.

The biggest difficulty when scanning slide film is loss of shadow detail. Very dense slides let so little light pass through that only the most expensive drum and slide scanners can measure it accurately. When shooting slide film for scanning, avoid deliberately underexposing the film to heighten colors as this will aggravate the loss of shadow detail and you can easily increase the saturation digitally after scanning the image.

Color negative film has a different set of problems. Because color negative film compresses the dynamic range of the scene into a smaller range of film densities and also because of its orange masking layer, large parts of the scanner sensitivity range goes unused and the image data must be expanded considerably to recover a properly color balanced image with rich blacks and pure whites. The necessary amplification of the image data makes the resulting scans significantly noisier than scans of equivalent color slide films, showing up as increased graininess in areas of solid color such as clear blue skies and a certain lack of smoothness in the overall tonal range. Color fidelity from color negative films is also harder to achieve due to the lack of a visual reference.

As a rule, fine grained transparency films such as Fuji Velvia or Provia 100F yield the highest quality results if you can live with their limited contrast range, if you don't underexpose it, and if you have a good enough scanner to extract acceptable shadow detail.

Scanning Tips and Techniques

Keep your scanner free of dust and dirt and clean your originals

If you have a flatbed scanner, clean the glass frequently with a commercial glass cleaner and a lint free cloth. If you have a transparency scanner, use compressed air to blow dust out of the scanner and to clean off your film before scanning. A little effort in keeping the scanner and originals clean can save a lot of retouching work later.

If you are using a film scanner, carefully clean your film before scanning. Always handle film by its edges as it is very easy to scratch the film or get finger prints on it. Use a cleaning solution such as PEC-12 and lint free pads such as PEC Pads to carefully clean your film before scanning (for more information on PEC products, see <http://www.photosol.com>). Moisten the pad with a small amount of solution, place the film on a clean sheet of paper and gently wipe it with the pad once on each side. Use an anti-static brush and compressed air to remove any residual specks of dust.

PEC-12 and PEC Pads can also be used to clean photographic prints before scanning.

Selecting the right number of colors

Many scanners can operate in different modes that are designed to let you get the best results depending on the nature of the material you are scanning. For example when using a flatbed scanner to digitize black and white printed documents, you can reduce the file sizes greatly by scanning at one bit per pixel. This means each pixel is either totally black or totally white. For photographic images, there are usually only two useful choices: 8 bits per pixel (256 grays) for black and white images or 24 bits per pixel (16.7 million colors) for color images.

Some scanners can both capture and transmit to the computer more than 8 bits per pixel. With the Pro version of Picture Window, you can capture and manipulate these extended dynamic range images.

Selecting the right image resolution

The best way to determine what resolution you need is to work backwards from the size of the print you want to produce. For most purposes, you will need between 100 and 300 pixels per inch to make a photographic quality print. This assumes a normal viewing distance of about 10 inches and a high quality scan and original. Below about 150 dpi, the results become noticeably soft; between 200 and 300 dpi the improvement is quite small. Thus to make an excellent quality 4x5 print, assuming a resolution of 200 dpi, requires an image that contains roughly 800x1000 pixels. Working with a file much smaller than this will not yield the highest possible print quality; working with much larger files requires a computer with more RAM and each operation you perform takes longer due to the larger number of pixels. If the expected viewing distance is greater than 10 inches, you can get by with a proportionally lower resolution for the same apparent sharpness.

When scanning to make a print of a particular size, you should thus adjust the scanner resolution accordingly, although scanning above the optical resolution of your scanner is not recommended (see above). The actual resolution in dots per inch depends on the size of the original you are scanning. For example, if you are using a flatbed scanner and scanning a 4x5" original to make a 4x5" print, then you would scan at roughly 200 dpi; if the original was smaller or if you want a larger print, you would need to scan at a higher dpi to get an image of the same print resolution. If the original was larger or the desired print size was smaller, you could safely scan at a lower resolution. The important thing is the final image resolution in pixels per inch. Alternatively, you can always scan at the scanner's optical resolution and then use Picture Window's Resize transformation to adjust the file size to the optimum size.

Sharpening the scanned image

Most scans benefit to some degree from sharpening. Some scanner drivers incorporate sharpening internally while others depend on image editing software for this function. In most cases, sharpening is best done in Picture Window after transferring the scanned image to the computer since you have the benefit of a high resolution preview of the result and more control over the sharpening parameters. Some experimentation is required to determine the best sharpening techniques and settings. The Unsharp Mask option in the Sharpen transformation is often the best choice since it has a variable radius setting and allows for a threshold to prevent oversharpening smooth areas of the image. The best choices for the radius and threshold will depend on the scanning resolution, scan quality, and subject matter.

Scanning printed material

If you are using a flatbed scanner, sooner or later you will probably scan a photograph from a magazine or other printed material. Photographic images are printed on printing presses using a technique called halftoning whereby the image is reproduced by printing clusters of dots in various patterns. The halftone dots vary in size, but are each made up of one of the solid colors of the printing inks being used. For black and white images, just black ink is used; for color images, cyan, magenta, yellow, and black dots are used. This contrasts with so-called continuous tone printing technologies such as dye sublimation technology in which different colors and gray levels are reproduced directly.

There are several issues involved in scanning printed material. First, depending on what you intend to do with the images, you need to be concerned about copyright violation as most printed images cannot be reproduced legally without the permission of the copyright holder. Second, there is an annoying effect called a moiré pattern that is caused by the interaction of the repeating pattern of halftone dots in the image and the grid of sensors used in the scanner.



This interference pattern usually manifests itself as a pattern of regular variations in the brightness and color of the scanned image. Some scanners come with software

that claims to be able to reduce or eliminate these moiré patterns, but for the most part these techniques do not work very well as this is not an easy problem. Most so-called descreening techniques result in a somewhat blurred image. Applying a Gaussian blur of a radius of 1 pixel to the above image does a fairly good job of removing the moiré pattern without blurring the image too much:



Another trick that sometimes helps reduce moiré patterns is to rotate the original on the scanner bed by various angles.

Using a flatbed scanner to scan objects directly

If you have a flatbed scanner, you can use it as a “lensless camera” to photograph flat objects directly. For example, you can place leaves, flowers, grass, newsprint, paper, coins, stamps, etc. right on the glass and scan them in—but be careful not to scratch the glass on the scanner.



For a dramatic effect, try placing black velvet or black flocked paper over the objects you are scanning to create a black background.