

# Digital Negatives for Contact Printing

## Analog and digital combined to hybrid halftone printing

For the most part, I favor the distinctive attributes of analog photography and, hence, prefer to work in the darkroom. But, there are some advantages to digital imaging that cannot be ignored by even the most diehard of film enthusiasts. The option and flexibility to take a digital image and easily make the necessary tonal corrections, or dramatically manipulate its composition and contents, does either not exist or is only difficult to achieve in a purely analog environment. Still, some photographers just do not want to give up on the unique qualities of an analog, fiber-base print. The reasons are mostly subjective in nature, because a well-made fiber-base print is clearly in a class of its own and truly 'beautiful'. But sometimes, the reasons to opt for a fiber-base print may be based on a specific customer request, or they simply serve as a trademark to be clearly distinguished from competing photographers. Nevertheless, there is no longer a compelling reason to make an either-or decision between analog photography and digital imaging, based on the desire to have a fiber-base print as the final output, because analog and digital techniques are easily combined. Through use of hybrid halftone printing, time-proven materials and digital image manipulation are successfully incorporated, and the final product is a fiber-base print, which is impossible to distinguish from its analog counterpart.

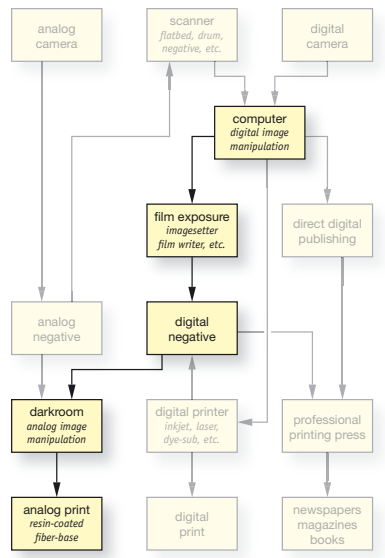
### Process Overview

Hybrid halftone printing starts with digital image data, which is first transformed into a 'digital negative' by using image manipulation software and then printed onto clear film. The digital negative is contact printed onto photographic paper and chemically processed in a conventional darkroom.

The origin of the digital image data is of no consequence to the process. The image data might come



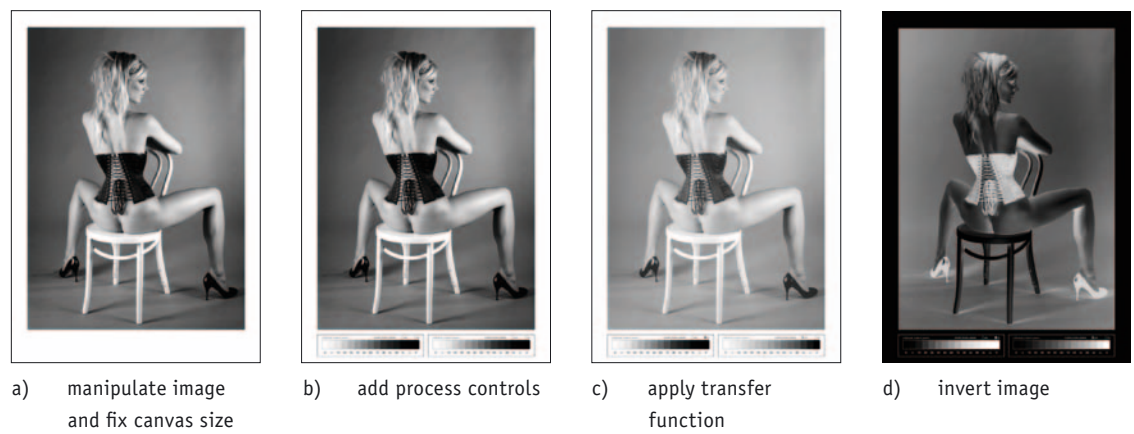
fig.1 Before a digital negative can be produced, the image has to be prepared for it through several process steps.



The imaging path of the digital-negative process bridges the gap between digital manipulation and analog processing.

### Digital Image Preparation in Brief

1. Adjust Tonal Values
2. Set Image Resolution  
Set Image Size
3. Correct Image Sharpness
4. Fix Canvas Size
5. Add Process Controls
6. Apply Transfer Function
7. Invert Image and Save Data



directly from a digital camera, or indirectly from a scanned analog negative or print. However, with the aim of contact printing, the digital negative must be of the same dimensions as the final print. In order to prepare the image data and turn it into a digital negative, image manipulation software, such as Photoshop, is used to adjust, customize and invert the image. The actual digital negative is then produced by a professional service bureau, which will use a high-resolution imagesetter to expose the image data onto clear photographic film. These machines are still used for analog printing processes, and a good offset printer in your area will help you find a local source. A digital negative differs from an analog negative only through the fact that not all image tones are continuous but are simulated through a sophisticated and imperceptible halftone pattern (see fig.10). The hybrid halftone printing process is completed in the darkroom, where the digital negative is contact printed onto light-sensitive photographic paper, after which, all remaining process steps are identical to conventional, analog photographic processing.

The cost of a digital negative depends on its size and is approximately \$10-15 for an 8.5x11-inch (DIN A4) or \$15-25 for a 12x16-inch (DIN A3) print. These are average prices for 'films', as they are referred to in offset printing, but unfortunately, some service bureaus charge much more, as soon as they discover the photographic intent. In that case, just make sure to simply ask for a film and not a digital negative. Store your digital negatives in traditional large-format sleeves, in a cool and dry place, alongside your other analog negatives.

### Digital Image Preparation in Detail

After opening the data file in Photoshop, the image is first improved for its pictorial impact. This includes giving emphasis to essential image content, all burn-in exposures and retouching of image flaws. In other words, in hybrid halftone printing, typical photographic improvements are transferred from the darkroom to the software and carried out only once for each negative, and not again and again for each print. Afterwards, the image is prepared for output to an imagesetter. Since the required process steps are the same for every negative, it is straightforward to list and explain them by means of an example (fig.1).

#### 1. Adjust the Tonal Values

Digital negatives are always monochrome, which is why the image data is immediately converted into this mode (Image > Mode > Grayscale). This reduces the amount of data to a minimum without losing any image detail. On the other hand, special care needs to be taken that subtle highlights and shadows do not become too light or too dark, respectively. There is a risk that extreme tonal values are otherwise lost in the image transfer process from digital image, through digital negative to fiber-base print. To prevent this from happening, the image data is adjusted up to a point where the brightest highlights are not brighter than 4% and the darkest shadows are not darker than 96% (Image > Adjustments > Curves...). At this point, all tonal manipulations are completed, and if the image is still in 16-bit mode, it can be safely reduced to 8 bit now, since this is sufficient to represent up to 256 different shades of gray (Image > Mode > 8 bits/channel).

## 2. Set Image Resolution and Size

To produce quality halftone negatives, digital images of relatively high resolution are required. Consequently, I recommend an image resolution of 450 ppi. Since the final negative size is known, in this example DIN A3, we can specify the image resolution and size together in one operation (Image > Image Size...). To have the benefit of a border around the image, make sure that the image dimensions are about 40-60 mm smaller than the DIN-A3 canvas (297 x 420 mm) itself, and resample the image data, using the bicubic option in Photoshop, which will minimize the side effects of extrapolating image data (fig.2a).

## 3. Correct Image Sharpness

After the image is set to the final dimensions, it may be necessary to correct the overall image sharpness. Photoshop's unsharp filter is an excellent tool to do so (Filter > Sharpen > Unsharp Mask...). Acceptable image sharpness depends heavily on personal preference, but with this powerful filter, it is easily overdone. To maintain a realistic-looking image, the settings in fig.2b are recommended as a starting point for digital negatives.

## 4. Fix the Canvas Size

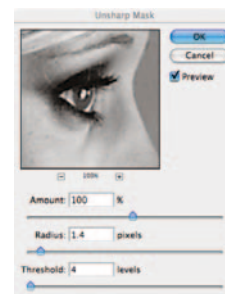
We need to expand the canvas now in order to match the DIN-A3 format (Image > Canvas Size...). This is done symmetrically on the horizontal axis, but in the vertical direction, it is to our advantage if we leave a wider border below the image than above it. This provides the necessary space to add two process controls in the next step. Nevertheless, final image placement on the canvas is not overly important and also depends on image size (fig.2c). At this point, our new canvas should look very similar to the example in fig.1a.

## 5. Add Process Controls

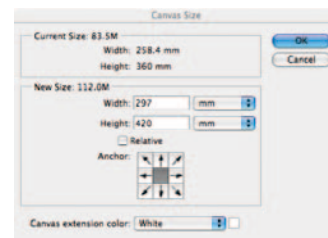
This is an optional but highly recommended step when preparing a digital negative. Add two process controls, by opening a reference file and placing it twice, side by side, below the image. This reference file is called 'ProcessCheck.tif' and is available from my website at no cost (fig.3). It is designed as a step tablet and is used to easily verify significant process parameters. With the aid of a densitometer, the step tablet on the left is used to confirm correct exposure and development of the film at the service bureau.



a) Image resolution and size are specified together with 'Image Size'.



b) Image sharpness is corrected with 'Unsharp Mask'.



c) The final digital negative dimensions are defined with 'Canvas Size'.

The step tablet on the right is a useful guide to determine the best exposure and contrast in the darkroom. Depending on image size, it may be necessary to adjust the scale of the step tablet in order to fit it in twice below the image. While doing so, be sure to keep the tablets and image resolution identical. After placing both step tablets, reduce all layers to one (Layer > Flatten Image). Following that, the canvas should look like the example in fig.1b.

fig.2 Subsequent to artistic image manipulations and adjustment of tonal values, it takes three more steps to specify image resolution and size, to correct image sharpness and to define the final digital negative dimensions.

## 6. Apply the Transfer Function

Most photographic processes are nonlinear, or in other words, the relationship between their input and output is not proportional. As an example, doubling the film exposure does not necessarily double the transmission density of the negative. During hybrid halftone printing, all image tones are transferred from the digital image, through the digital negative to the fiber-base print. Through careful selection of exposure and contrast, it is not difficult to control the highlight and shadow endpoints to prevent a loss of detail at the extremes of tonality. However, all remaining tonal values are forced to follow material characteristics alone and fall predictably somewhere in between the endpoints of tonality. In order to achieve a close match between on-screen image and final print, it is important that the influence of these material characteristics are compensated through the use of a transfer function. Applying such a function is easy, and creating a transfer function only needs to be done once, but it does involve a few additional steps. That is why we added a chapter with detailed instruction to the appendix and called it 'Make Your Own Transfer Function'.

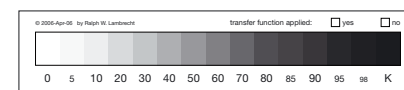


fig.3 'ProcessCheck.tif' is an optional process control to monitor exposure and development at the service bureau and in the darkroom.

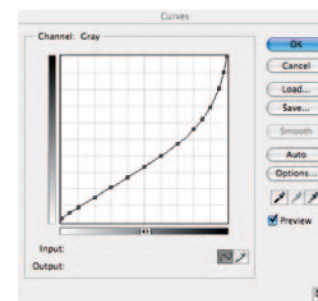


fig.4 Nonlinear photographic processes are controlled through a compensating transfer function.



### Transfer Function Example

(monitor  $\gamma=2.2$  > **imagesetter** > MGIV-FB)

Input	target density	Output at
0 %	0.05	2 %
5 %	0.11	5 %
10 %	0.16	9 %
20 %	0.27	15 %
30 %	0.38	21 %
40 %	0.51	27 %
50 %	0.66	33 %
60 %	0.83	40 %
70 %	1.04	47 %
80 %	1.30	56 %
85 %	1.45	62 %
90 %	1.63	69 %
95 %	1.84	81 %
98 %	1.99	90 %
100 %	2.10	100 %

### Overview of Work Instructions for the Service Bureau

1. Order a typical 'film' as it is used in analog pre-press work for offset printing.
2. Ask for an imagesetter resolution of at least 3,600 dpi.
3. Demand a halftone screen ruling of 225-300 lpi.
4. Request the film to be made emulsion-side up but imaged right-read, which means no image flipping or mirroring.

The transfer function is not applied to the entire canvas. The step tablet on the left serves only to verify the service bureau's film quality, and must, therefore, be excluded from the transfer function. This is done by first selecting the left step tablet, and immediately inverting this selection again (Select > Inverse). As a result, everything but the left step tablet is now selected. The appropriate transfer function is activated through the curve menu (Image > Adjustments > Curves... > Load...). For this example, I have chosen a transfer function that was specifically developed for Ilford's Multigrade IV FB (see fig.4 and text box on the left). Once the transfer function has been applied, the entire selection is turned off (Select > Deselect). At this point, our canvas should look similar to fig.1c, which in many cases may not look right at first sight. But, that is no reason for concern, because it just illustrates how much image tonality needs to be skewed in order to compensate for the subsequent nonlinear reproduction of tonal values.

### 7. Invert the Image and Saving the Data

So far, we have worked exclusively with the image positive, but obviously, contact printing requires a negative. Photoshop makes this conversion as simple as possible (Image > Adjustments > Invert). This concludes the digital image preparation, and the only step left is to select an appropriate data storage format and medium for storing the digital negative.

Many image data formats, including jpg, are good options for storing digital negatives, but I recommend using the lossless Tagged Image File Format (tif). Don't compress the file, and don't attach a color profile to it. Professional service bureaus are most accustomed to tif data, and color-management features are often incompatible with their imagesetter software. High-resolution negatives, for DIN-A3 or 11x14-inch print formats, easily require 40-60 MB of memory, which makes a compact disk (CD) an economical and convenient choice for transferring and storing several negative files.

### Digital Negatives from Imagesetters

We leave the exposure and actual production of the physical digital negative to a professional service bureau. They use a raster image processor (RIP) to convert the digital image to a half-tone bitmap and send the data to an ultra-high resolution printing

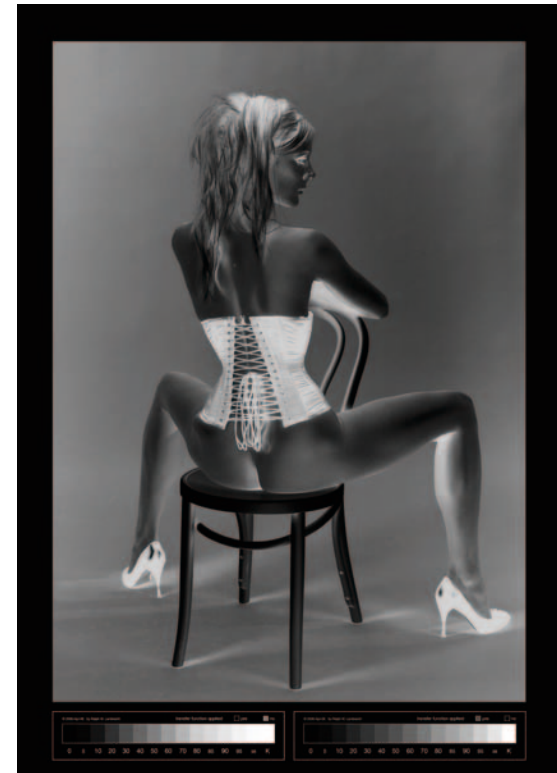


fig.5 There is no physical difference between analog and digital negatives. Both have a transparent base that is coated with a silver-gelatin emulsion. However, the formation of continuous image tones is very different between the two.

device, called an imagesetter, where a piece of high-contrast film is exposed by a laser. This film is then developed, fixed, washed and dried to produce a digital negative for contact printing.

There is little physical difference between analog and digital negatives. Both have a transparent base that is coated with a silver-gelatin emulsion. However, the formation of continuous image tones is very different between the two. In an analog negative, image tones depend on negative density, which in turn is directly related to how many microscopically small silver particles have randomly accumulated in a specific area. This allows for almost perfect continuous image tones. In a digital negative, on the other hand, continuous tones are only simulated through a complex bitmap halftone pattern, which mimics the equally spaced

## Glossary of Abbreviations

**dpi** (dots per inch)

Printers reproduce text and images by marking film or paper with numerous dots of ink or light. Printer resolution is measured in dpi.

**lpi** (lines per inch)

Grouping several dots into a halftone cell provides the potential of simulating many different shades of gray. Halftone cells are organized in line screens, and their resolution is measured in lpi.

**ppi** (pixels per inch)

Monitors display text and images through tiny pixels. Monitor resolution is measured in ppi.

**spi** (samples per inch)

Scanners, scanning backs and digital cameras detect image and print detail in fine increments and record them as image samples. The resolution of image-capturing devices is measured in spi.

*To use the processing steps of hybrid halftone printing as an example, one would say:*

*An image was recorded by a scanner or digital camera with 300 spi, then displayed on a monitor with 300 ppi, extrapolated by Photoshop to 450 ppi in order to rasterize it with a 225-lpi halftone screen and print it on film with a 3,600-dpi imagesetter.*

dots of varying sizes, used for conventional halftone printing. This does not allow for a truly continuous-tone image, because only a limited number of gray tones can be created this way, but the increments can be kept so small that tonality boundaries become imperceptible to the human eye.

The resolution of a halftone pattern, also called ‘halftone screen ruling’ or simply ‘halftone screen’, is measured in lines per inch (lpi). Newspapers, which use halftone patterns to simulate photographs, use a rather coarse halftone screen of about 85 lpi, which is easily detectable by the naked eye. High-quality magazines make use of much finer halftone screens of up to 133 lpi, which makes it much harder to detect the pattern. For digital negatives, an extremely fine halftone screen of 225-300 lpi is used to simulate continuous tones, approaching the quality and fine graduation of analog photographic prints. This is

roughly equivalent to 6-9 lp/mm, and even with perfect eyesight, such a fine halftone pattern cannot be detected without the aid of a loupe.

## Contact Printing

In the darkroom, the digital negative is positioned, emulsion-side up, onto photographic paper and both are securely and tightly held together in a contact frame. If such a frame is not available, the weight of a thick sheet of glass (1/4 inch or 6 mm) is usually sufficient to press negative and paper gently together (fig.6). For larger prints, light clamping around the edges may be necessary to ensure that they are in contact across the entire surface.

Subsequent exposure and paper processing are identical to analog contact printing, because the same fiber-base materials are used for hybrid halftone printing. This also means that the halftone print can be chemically toned to add to its life expectancy; it can be retouched, dry-mounted, presented and stored like any other analog fiber-base print.

Contact printing the digital negative with the emulsion-side up brings the film emulsion in direct contact with the glass, and separates emulsion and paper by the film thickness. This minimizes the formation of Newton’s rings and causes some light scattering in the film base during the print exposure, which has advantageous consequences. The scatter is strong enough to diffuse the halftone pattern somewhat, but it’s too small to produce a detectable loss of image sharpness (fig.7). In other words, if the digital negative is printed emulsion-side up, the simulation of continuous tones is improved without a detrimental effect on overall image quality. Also, a diffused halftone pattern is more responsive to paper-contrast manipulations, which the halftone image is largely resistant to, if printed emulsion-side down.

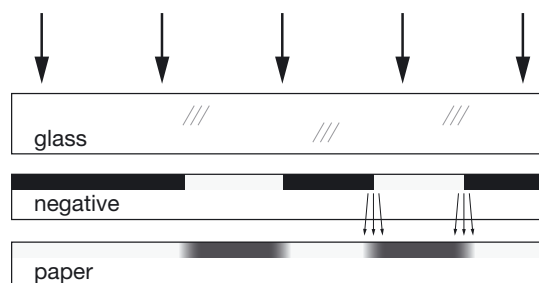


fig.6 In the darkroom, the digital negative is positioned, emulsion-side up, onto the paper and both are tightly held together by the weight of a thick sheet of glass. Subsequent exposure and paper processing are identical to analog contact printing.

fig.7 Contact printing the digital negative emulsion-side up causes some light scattering and a welcome loss of clarity in the halftone pattern, without a loss of image sharpness. It also makes the halftone image more sensitive to skillful paper-contrast manipulations.

### Exposure

Determining the ideal exposure for the hybrid print is greatly simplified by utilizing the right step tablet as an aid and process control. This step tablet was customized through the transfer function, and hence, it contains all required tonal values in smooth increments.

First, the enlarger light filters are set to a normal paper contrast of grade 2. Then, while making test strips of the step tablet, an exposure time is established at which step oK still maintains paper white, but step 5K clearly shows the first signs of density.

Once the ideal exposure is found, record all enlarger settings and refer to them for other hybrid printing sessions. This can be done, because digital negatives have a very consistent density due to tightly controlled processes at the service bureau. This process stability can be alternatively checked, measuring the left step tablet with a densitometer before printing a digital negative for the first time.

### Contrast

Well-designed transfer functions allow creation of digital negatives that easily print on normal-grade paper without the need for further manipulation. Nevertheless, there are always small process-dependent deviations while working in the darkroom, and to compensate for them, moderate contrast adjustments are sometimes necessary. Remember that halftone images are not very susceptible to paper-contrast changes. It will often take modest increments to see minute affects. Nevertheless, the ideal paper contrast is determined

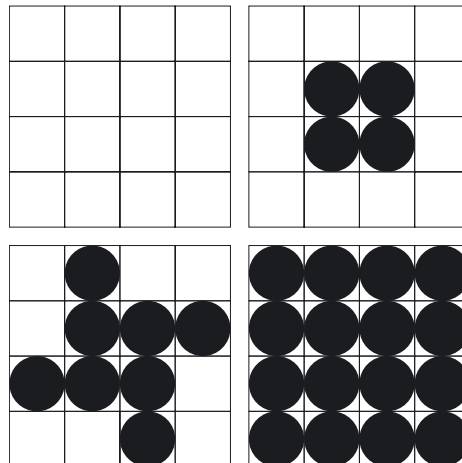
through a second test strip, using the ideal exposure found above, but altering the contrast until steps 95, 98 and 100K are still distinguishable from each other. Optimizing print exposure and contrast ensures that all tonal values, captured in the digital negative, are fully represented in the final hybrid print.

### About Halftones

The history of halftone printing dates back to 1850, when William Fox Talbot suggested using 'screens' in connection with a photographic process. Several screen designs were proposed, but it took until 1880 for the first reproduction of a photograph to be published in the *New York Daily Graphic* by Stephen H. Horgan. Shortly after, in 1881, the first successful commercial implementation was patented by Frederick Ives. Prior to his invention, newspapers and magazines could not be easily illustrated with photographs, because publishers were limited to woodcuts, engravings or etchings, in order to include images into the printing process. Ives's method, still in use today, was the first not limited to printing just black or white, but made it possible to reproduce all shades of gray. In 1992, Dan Burkholder rediscovered halftone printing for B&W photography, by using offset printing films as contact negatives. In 1995, he published his technique in a book called *Making Digital Negatives*.

Analog halftone printing is a reprographic technique that simulates continuous-tone images through equally spaced dots of varying sizes. In digital halftone printing, this is accomplished by

fig.8 Grouping several dots to a cell provides the potential of reproducing many different shades of gray. By printing none, all, or only specific dots of a 4x4 halftone cell, 16 shades of gray plus white can be simulated. A 12x12 matrix can represent 144 shades of gray, and using a 16x16 matrix allows for 256 different grays, which are more than the human eye can possibly differentiate in a photograph.



$$\text{shades of gray} = \left( \frac{\text{printer resolution}}{\text{halftone screen}} \right)^2$$

$$\text{halftone screen} = \frac{\text{printer resolution}}{\sqrt{\text{shades of gray}}}$$

$$\text{printer resolution} = \text{halftone screen} \cdot \sqrt{\text{shades of gray}}$$

$$\text{image resolution} = \text{halftone screen} \cdot \text{quality factor}$$

$$\text{quality factor} = 1,5 - 2,0 \quad (\text{good} - \text{better})$$

fig.9 halftone mathematics

creating varying bitmap patterns through equally spaced halftone cells. A single dot only represents one of two conditions; it either exists (black), or it does not (white). However, grouping several dots to a cell, organized as a matrix in rows and columns, provides the possibility of reproducing many different shades of gray. Fig.8 shows four halftone cells, all of which consist of the same 4x4 matrix of printing dots. By printing none, all, or only specific dots, a halftone cell of these dimensions can simulate 16 shades of gray plus white. A 12x12 matrix can represent 144 shades of gray, and using a 16x16 matrix allows for 256 different grays, which are more than the human eye can possibly differentiate in a photograph.

Unfortunately, combining several small printing dots, in order to form larger halftone cells, reduces the available image output resolution. To make things worse, the technique can only be successful if the cells are small enough, or seen from a sufficient distance, for the halftone pattern not to be resolved. Halftone screen rulings of 225-300 lpi satisfy this requirement, but this calls for relatively high digital image and printer resolutions. The image resolution depends on individual quality requirements and must be 1.5-2x higher than the halftone screen. The

printer resolution, on the other hand, depends on the required shades of gray and must be 12-16x finer than the halftone screen. Fig.9 shows the mathematical relationships involved, which can be easily illustrated through the following examples.

Let's assume that our service bureau is using an imagesetter with a maximum printer resolution of 3,600 dpi. If we prefer a very fine halftone screen of 300 lpi, we will be limited to 144 shades of gray. However, if we require 256 shades of gray, we are forced to reduce the halftone screen to 225 lpi. If we demand both, we need an imagesetter with a printer resolution of 4,800 dpi. And, using a 225-lpi screen, we can expect to get the best halftone print possible, if our digital image has a resolution of 450 ppi.

The development of the ideal halftone pattern for each cell is a rather complex mathematical task. We gladly leave this chore to the service bureau and their Raster Image Processor (RIP). It's our job as photographers to make sure that we maintain the correct digital image resolution, and that we provide the service bureau with all the data they require to produce a high-quality digital negative for us. Then, we will finish our hybrid halftone prints in our dark-rooms, just as we do with our analog prints.

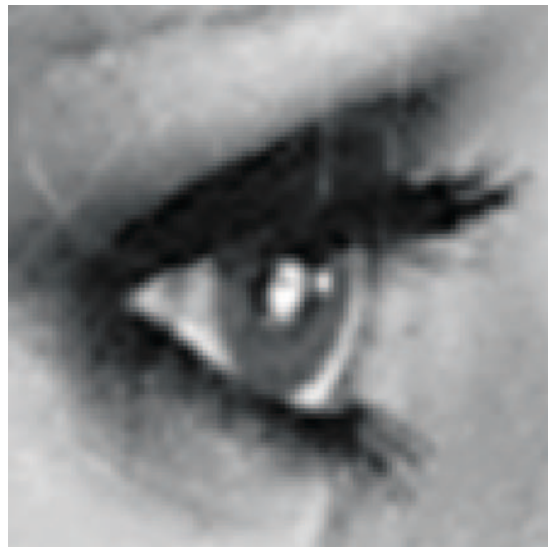


fig.10 These close-ups represent roughly 12x magnifications of their original images. Individual pixels can easily be detected in the monitor representation on the left, and the halftone pattern is clearly visible in the hybrid halftone print on the right. Nevertheless, one can get as close as 250 mm to the original hybrid print without detecting the halftone pattern with the naked eye. In relation to these magnifications, this is equivalent to a 3-meter (12-foot) viewing distance. Try to view this page from such a distance, and see if you can detect a difference between the two images.