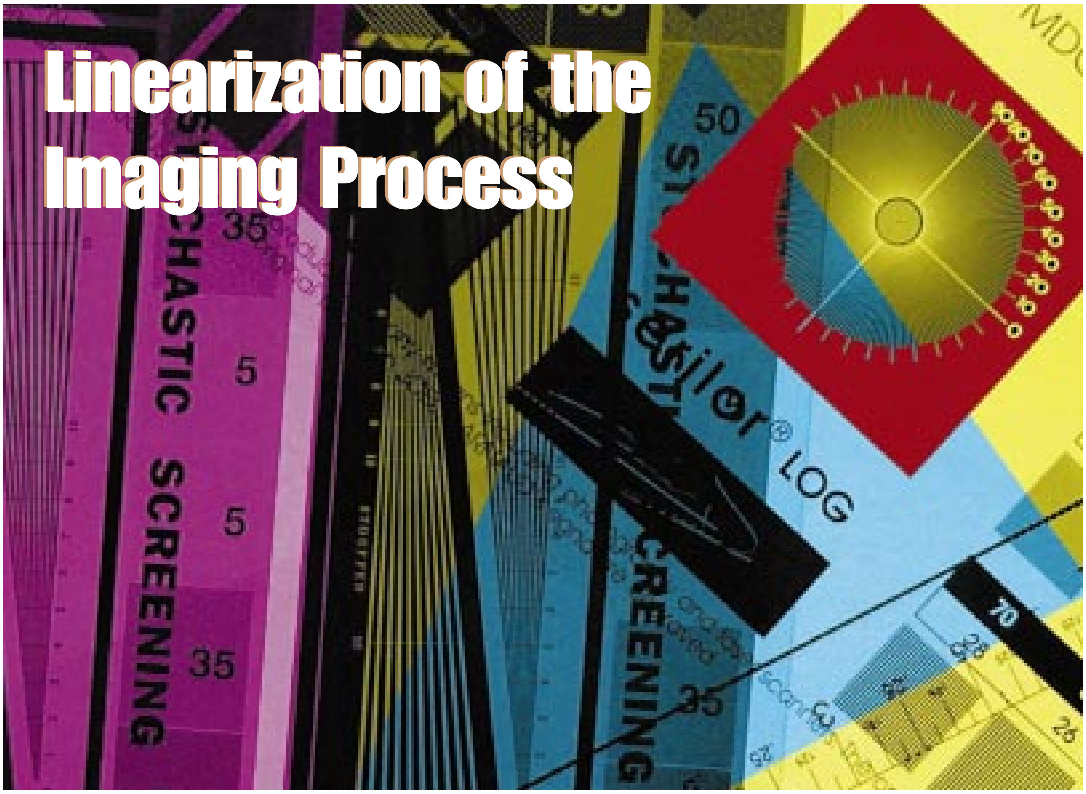
Linearization of the Imaging Process



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The client wants you to print a tonal-based image. Some type of halftone dot structure is necessary.

This halftone structure may be a conventional center dot array type of screening, diffusion dither, or higher order stochastic/random dot. Regardless of the type screening, you — the expert — must be able to predict and control the size and shape of the halftone structure to successfully reproduce the tone and color in the image.

Part of achieving and maintaining predictability and control is managing dot gain. All printing processes have dot gain — the tendency of the printed halftone dot to change in size at the moment of ink imprinting, thus changing the overall visual quality of the print. The dot gain profile is unique to each printing process. In order to compensate for the inevitable gain on press, you must alter the prepress, film and screen making.

Prepress compensation for the known gain profile depends on printing stability and the ability to duplicate conditions on press. Without this control, you can't make meaningful prepress adjustments that will improve tone and color reproduction in the final image. The relationship between the two is interdependent. What happens on press is a function of the film, screen, press set-up, squeegee, ink and environment. These factors cause the halftone to reproduce as a variation of the original intent, resulting in color and tone variation.

The subject here is not printing procedures necessary to maintain the gain profile, but rather the steps necessary to ensure that the halftone information is correct and accurate on the film and stencil/screen.

The process of ensuring that the image setter, film positive, and stencil are reproducing the original color data is known as dot predictability, or linearization.

Dot predictability means that you are confident that the digital information you wish to reproduce is being faithfully moved along at each step of the prepress journey. You may gain and lose at each step, but the gain and loss is consistent, predictable and repeatable.

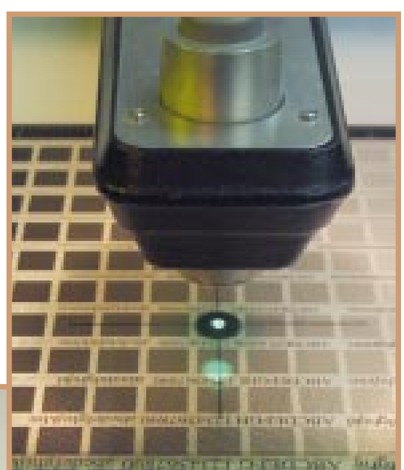
Dot for dot, your job is to ensure that the image setter, film positive and stencil are reproducing original color data. That's linearization, and it's just a measure away.

TAKING THE LINEAR PATH

Linearization is another way of saying that the production process follows a linear, predictable flow from start to finish. The process involves identifying variance at each step, and correcting the variance to bring it back into a linear progression. The corrections involve changing the size of the dot on film to correct for different types of dot gain or loss.

In other words, linearization is the process of translating input data into output data. In this case, the input data are tonal measurements that increase from zero percent dot in the spectral highlight to 100 percent in the solid area. Our objective is to reproduce the input information identically as output printed dot. For example, a 10 percent dot will reproduce as a 10 percent dot on the final print, a 15 percent dot as a 15 percent dot, and so on.

In order for identical reproduction to happen you must make a series of measurements and adjustments to the file data, image setter, mesh, stencil and exposure. These measurements are fundamental in achieving good color reproduction with halftones. As time consuming and tedious as this is, the final compensations will be of no value to you if you can't reproduce our printing conditions. This repeatability on press is the stability that determines how consistent your reproductions will be. One set of corrections acts upon another, which acts upon another, and on and on.



Two parameters act as our foundation. The first is: never assume that the information on the film or screen is accurate. Secondly, measure the process. No matter how expensive the imaging device is, it must be measured and calibrated. Once this is done, the daily output must be routinely monitored and corrected for drift. This is a normal and expected part of any prepress operation. Even if you are receiving film from a service bureau or other provider, you still need some way of measuring to determine if you are accepting film that falls within expected parameters.

DOTS GAINED, LOST

The measurement of halftone dot gain or loss is accomplished with two different instruments. The first is a transmission densitometer. This device measures the amount of transmitted light that comes through your negatives or positives. It is most often used in "dot area" mode so that the reading you see will be the actual percentage of area covered by the halftone dot.

You also use the transmission densitometer to measure the maximum density of the black area of the film. This is done to assure that the film is dark enough to avoid burn-through during screen exposure. The reading is a logarithm of how much light is transmitted. A reading of 4.0 means that 1/10,000 (0.00010%) of the light hitting the film is being transmitted through the film. Typical Dmax values will be in excess of 4.0 for most silver-based image set films. Values below 3.0 run the risk of burn-through during screen exposure, therefore changing the size of the halftone dot and the value it represents.

Our second instrument is a reflection densitometer. This device measures the reflected light from the surface of the printed image. It also measures direct dot area, can calculate absolute dot gain, and the Dmax of the ink you are printing. Unlike the transmission densitometer, the reflection densitometer is filtered to give direct readings of yellow, magenta, cyan and black ink. This helps you to control the dot area, and how the dot is viewed due to ink density — or darkness — of the ink film.

TWO STEPS BACK, ONE STEP FORWARD

You want the printed dot to visually represent its position between white and solid. In other words, you want a 50 percent black dot to represent a 50 percent gray between white and black. As simple as this sounds, there are many things that can keep it from happening. If the ink you print is too light, a dot with exactly 50 percent area may only represent 30 percent visual tonal value. Likewise, if the ink is too dark, that same 50 percent dot will look like 70 percent. These are hypothetical values, and in actuality, could represent almost anything.

To linearize the process you must work backward from our printed substrate. The press and printing conditions must be repeatable. If you change anything, the results will be different and any changes you have made to the file, film or screens will not be apparent.

Limit changes to a single variable so that you can measure the impact of what is happening. An example would be changing the substrate between brands. This one situation could affect the surface characteristics, ink absorption, surface color or ink-wetting of the substrate. All of these potential variations will have an effect on how the tone reproduces without changing anything on the film or screen.

In working backward you can test the stability of your printing conditions by burning two or three screens with exactly the same positive on it. Print 25 to 50 sheets of your stock and change the screen out. Repeat the process again and complete the test by setting up and printing the third screen. Pick different parts of the image to measure. Each test area should represent information from across the tone range. This means that you should sample highlight, quartertone, midtone, three quartertone, and shadow information in the image. Make a table and sample every fifth sheet in each run. This will give you an idea of where you started and how you progressed until you were finished with each test run. Compare the results between the three runs. You should not see more than plus or minus two percent variation.

SCREEN MAKING

Besides the consistency of your printing, you should also determine what is the finest dot that you can consistently hold without a moiré appearing. This will vary by line count and mesh count. For ultraviolet light (UV) printers using 355-380 plain weave mesh with 34 micron thread, the typical values are as follows:

Line Count	Highlight	Shadow	Range
55 lpi	2-3%	97-98%	94-96%
65 lpi	3-4%	96-97%	92-94%
85 lpi	6-7%	93-94%	87-88%
100 lpi	8-9%	91-92%	82-84%

Here is a typical screen print profile:

- **Final print:** Dot loss in highlight and quartertone, gain at midtone, three quartertone and shadow.
- **Screen making:** Dot loss in highlight, less dot loss across the remaining tone range; loss is due to thread eclipsing, vacuum and exposure.
- **Film:** Can be loss or gain depending on a number of factors. Usually consistent across the tone range with the exception of the extreme ends of the range where highlights drop and shadows plug entirely.
- **Monitor:** Can be loss or gain depending gamma, white point, black point, color temperature, ambient light levels and other factors.
- **Digital file:** Can be loss or gain depending on how the original was acquired, setting of black point, white point and gamma.

In prepress, make sure what you are doing is stable and predictable. If it is not, the next step will either cancel or add to the error. More importantly, you will have no confidence in the accuracy of the tone reproduction at any step of the process. It is difficult enough trying to get it right at the screen making and printing stages. If the other steps in the process are unpredictable, your chances of success are very low.

At the screen making stage, dot loss or gain is influenced by:

- Thread diameter
- Mesh tension
- Percentage of open area
- Moiré
- Halftone angle
- Halftone line count
- Dot percent value at any given line count
- Stencil profile
- Coating technique
- Emulsion sensitivity and resolution
- Vacuum
- UV exposure level
- Exposure measurement
- Washout practices

Any variation in any of these variables will cause the halftone information to become distorted and drift from its desired value. By far the most common situation is for the dot to close up. This happens across the entire tone range, with the most extreme impact in the highlight and shadow areas. Here the dots are either blocked by the thread, or the dot is too small to hold onto the thread. The finer the halftone, the more of an impact.

Producing an accurate stencil could easily be the basis for another article. Nevertheless, if you keep your parameters constant, it is quite easy to achieve repeatability in this area. But to get to that point, you must be willing to maintain the discipline of following your procedures exactly each time.

STENCIL MAKING

Stencil making is one of the most difficult areas to actually measure. Neither the reflection or transmission densitometers will do a good job. Unless you are willing to inspect your halftone dots with a microscope each time, you will have to settle for the best possible processing methods instead of physical verification. The troubling fact is, no matter how good the stencil maker is, there is still no way of checking to see if the material or equipment is working properly to give you the kind of stencil you need to print good halftone work.

About the best you can do is to image the most extreme ends of the tone range and verify at what point the dots either block or fall off the mesh. If you also include a Stouffer type continuous tone gray scale along with the halftone image, you should be able to have reasonable assurance that the stencils you are producing are accurate.

IMAGE SETTING

To measure dot gain or loss at the image setting stage, make a simple test image in a drawing program like Adobe Illustrator, Macromedia Freehand, or CorelDraw. Start with the first six steps being in one percent increments, from zero to five. Continue in five percent increments until you get to 95 percent, then step down in one-percent increments until the image is 100 percent solid (Figure 1).

Send the test image to the image setter and then measure the resulting film with a transmission densitometer. Make sure you have a Dmax in the range of 4.0 to 4.2 at the 100 percent solid step. Do this by measuring the solid area of the film. Then conduct dot area measurements of each target level.

If the values are close, but drift a percent or two, the correction can be made using a "transfer curve function" attached to the EPS file. If you own your image setter, the transfer curve can reside at the RIP level and it will be applied to every job that is sent out for imaging. If the percentage varies more than plus or minus two percent from the target values, you will need to make adjustments to the image setter, chemistry or development time.

Image setter correction is exposure related, development related, or both. Items that cause exposure to vary include:

- Laser voltage level too high or too low
- Laser tube or diode age
- Dust on the imaging mirror
- Developer of the wrong concentration
- Replenishment level incorrect
- Old or exhausted developer
- Developer temperature too high or too low
- Development cycle too long or too short
- Film incompatible with developer chemistry

If you are using an imaging system other than conventional silver, the basic principles still apply. The imaging level on the film surface is the area of interest. Each situation is slightly different, but the amount of area imaged onto the film must be controlled precisely. It must be opaque to UV light (high Dmax) and it must have halftone information that is accurate to the file that it was imaging. You will still need to use a transmission densitometer to check the values.

Most service bureaus follow established testing and monitoring procedures to make sure that the film they are delivering is correct. It is not uncommon for them to run a test image file where the minimum and maximum values are .5, 1 and 1.5 percent at 200 lines per inch (lpi) for the highlights and 98.5, 99 and 99.5 percent for the shadows.

Whenever possible, make your tests at a resolution that is, at minimum, twice as fine as what you will be printing. For instance, if you are generating film with 65-line halftones, do your linearization tests at 133 lines. Testing at this resolution narrows the parameters, giving you even better end results.

Screen printers have a nasty habit of assuming that the film that they are imaging is correct. This is particularly bad if they are making their own film. No matter how sophisticated the imaging device is, unless you calibrate it and periodically test it, the film coming off is suspect. Since you are making complicated, compound dot gain corrections, the film must be completely predictable for you to make the proper decisions and corrections.

CALIBRATING THE MONITOR

Stepping back from the image setter, you must now consider the viewing conditions under which you make color choices. This relates to the ambient environment in the art department and how you view our computer monitors. There is a quick check that you can perform to determine if the monitor is within reasonable calibration. Make sure that no direct light falls on the monitor face. Working in subdued daylight is the best. Work areas with high levels of ambient light will cause the monitor to have an inaccurate appearance. Wear neutral to black clothing to minimize reflected color onto the screen. For general color work this is usually not an issue. For critical work involving fleshtones, cosmetics, food or product shots it can be.

Figure 1

0%	1%	2%	3%	4%	5%
10%	15%	20%	25%	30%	35%
40%	45%	50%	55%	60%	65%
70%	75%	80%	85%	90%	95%
95%	96%	97%	98%	99%	100%

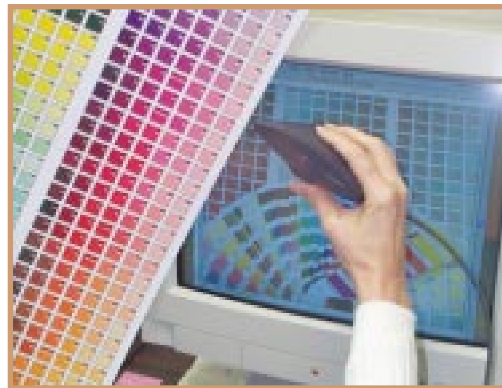
To evaluate the light level and the monitor, make a tone ramp starting with pure white and blend it to pure black. On your screen, move the cursor to the point where you can first see a tonal change in the image. In your file, use Adobe Photoshop's Info Pallet to find the digital value for the first light and dark areas that you can perceive. They should be very, very close to the end of the scale. If they are not, it is a good bet that your monitor will need to be recalibrated. Another way to check this is to pick a pure white and pure black area in the image. There should be no information in the black area (values 0, 0, 0) and the white should be 255, 255, 255. If the values are anything but this, you need to do some work.

Besides ambient environment, monitor calibration centers around five key areas. These are phosphor balance, white point, black point, gamma, color temperature and ambient environment.

The phosphor balance assures the monitor is balanced to a neutral position. Neutral means that all guns fire at the same intensity.

The white and black points are the settings at which you have all data (white) or no data (black) established and set. If the guns are not balanced it will be impossible to obtain a neutral balance and the white point will have an unnatural cast. This can cause the designer or separator to compensate by adding more of the complementary color to the image that is being processed. The result on press is a strong cast in the direction of the compensation. For example, cyan is added to balance an image that is too red on the screen. When the job is printed, there is an excessive shift toward cyan that cannot be compensated for during the press set-up or run. The only solution is to remake the films.

Gamma is the rate of change between input and output information. The flatter the slope (below 1.00) the darker the image will appear on screen. The normal gamma range for viewing graphic arts images is 1.4 to 1.8. The higher the gamma, the lighter the image will look. This can result in an over compensation (making the image darker to look natural on the screen). This excessive correction will then compound with the dot gain on press to make the final printed image look very dark.



Color temperature for monitors should be set at 6500° K (D65), the established value for emissive color viewing. Most graphic arts grade monitors have natural color temperature ranging from 9100° to more than 12,000° K. Color temperatures above 6500° will shift noticeably toward the cyan, necessitating an overcompensation of red to balance. Temperatures below 6500° move toward the red, resulting in over compensation toward the cyan and blue.

There are many commercial programs and hardware devices to establish monitor calibration. They can range from freeware (Knoll Gamma) that is distributed with Adobe Photoshop to much more sophisticated colorimeters, spectrophotometers, and other calibration devices costing thousands of dollars. Before you invest in one solution, determine exactly how the software functions and to what it is calibrating. You work in a Postscript environment for the most part. The solutions that I have found to be the most successful calibrate by setting white and black points and the color temperature of the monitor. Then the programs establish 255 steps from white to solid RGB and 255 steps from Solid RGB to black. The monitor then has the capability of displaying a total of 16.7 million colors (24 bit). This type of calibration software and hardware is usually in the $600 to $1000 range.

BLOCK BY BLOCK

Linearization of the halftone process is a basic building block of color reproduction. Without understanding how dot size can be affected by the various viewing, imaging and printing processes, you cannot achieve constancy in image reproduction. You can have some success with noncritical images, but as soon as memory or reference colors enter the equation, the entire process begins to collapse. Screen printers who are printing process color on an occasional basis have little chance of ongoing success. It is the printer who makes it a practice to seek out and print process color that will be the achiever. Like any worthwhile activity, true proficiency comes from diligent practice, education and review of performance.