Print Grain Index

AN ASSESSMENT OF PRINT GRAININESS FROM COLOR NEGATIVE FILMS

Print Grain Index refers to a method of defining graininess in a photographic color print, typically made from a color negative. The Print Grain Index method replaces rms (root-mean-square) granularity and has a different scale which cannot be compared with rms granularity. This method is designed to be more meaningful to viewers who are accustomed to looking at prints as the end product (see "THE PRINT GRAIN INDEX METHOD"). Currently, the method applies only to color negative films.

The Print Grain Index (PGI) method uses a uniform perceptual scale, with a change of two units equaling a jnd (just-noticeable difference) in graininess. A PGI rating of 25 on the scale represents the approximate visual threshold for graininess, with higher numbers indicating an increase in the amount of graininess observed.

The method uses a diffusion enlarger to make prints, so Print Grain Index numbers may not represent graininess observed from more specular printing illuminants such as condenser enlargers.

DEFINITIONS

Grain	A particle of metallic silver or a cloud of dye in a photographic emulsion. Exposed silver halide crystals in raw emulsion that become grains in the photographic process.
Granularity	The *objective* measurement of the local-density variations in an area of overall uniform density.
Graininess	The *subjective* perception of a mottled random pattern apparent to a viewer who sees small local-density variations in an area of overall uniform density
KODAK Grain Ruler	A standard for graininess; a sequence of images of grain reproduced with their corresponding Print Grain Index numbers.
jnd	Just-noticeable difference. Refers to increments of the scale on the KODAK Grain Ruler.
PGI	Print Grain Index
rms	Root-mean-square. A mathematical term used to express deviations from a mean value. You find it by taking the square root of the mean of the squares of the deviations from the mean.

GRAININESS AND GRANULARITY

Granularity *describes the physical measurement of density variation.*

Graininess *describes an observer's subjective sensation to non-uniform grain.*

Graininess is the visual sensation of small, local-density variations in what you would expect to be a uniform-density field. In photographic systems based on silver halide, these density variations result from the size, number, and random distribution of the light-sensitive elements in film or paper.

The more you magnify the original image, the more apparent the graininess. High-speed films usually produce prints with higher graininess than low-speed films because higher sensitivity to light requires larger silver halide crystals. With low-speed films or with small prints, graininess can be so low that it is visually insignificant.

THE RMS-GRANULARITY METHOD

The characteristics that cause graininess in a photographic image can be measured using a micro-densitometer to scan density fluctuations in a uniformly exposed and processed piece of film. In practice, a single microdensitometer reading aperture of 48 micrometres in diameter is used. The 48 micrometre aperture corresponds to about a 12X magnification. You could vary the size of the aperture to represent changes in film magnification, but it's not necessary. For most films, the relative differences in granularity will also apply to other magnifications.

The rms deviations of the microdensitometer scan are then calculated using statistical formulas for standard deviation. This is the source of the term "rms granularity" which is generally used to express granularity measurement. You record the standard deviation of density as a decimal number, which is multiplied by 1,000 to make comparisons easier. The resulting number is usually between 5 and 50.

Recent tests done with large numbers of observers have demonstrated a correlation between relative granularity and relative graininess.

THE PRINT GRAIN INDEX METHOD

The Method

The problem with applying standard rms-granularity techniques to color negative film involves the way we view the recorded image. We rarely view the negatives as the final image, as we do with positive images produced on reversal films. Rather, the negatives are usually printed by enlargement onto color negative paper. To properly characterize the granularity of negative films, we must consider the effects of the printing step and the print material.

A thorough analysis of the effects of printing on granularity would require several complex measurements of the film, printing lens, and print material. Instead, if we make some assumptions about the "standard" characteristics of these components, we can simplify the analysis. This simplification lets us predict print graininess from a single measurement of the film with the Print Grain Index method.

Other features of this method include—

- The ability to predict print graininess for various negative film formats and print sizes.
- A uniform perceptual scale with increments that can be related to jnd (just-noticeable differences).
- Linkage to a physical standard known as the KODAK Grain Ruler—a series of visual representations of graininess with corresponding index numbers.
- A mathematical framework that can readily accommodate any changes in future negative/positive system parameters.

Summary of Basic Steps

For color negative films, the Print Grain Index method involves three basic steps:

1. Conversion of measured red, green, and blue *negative film granularity* to red green and blue *print granularity*.
2. Conversion of red, green, and blue print granularity to *visual granularity*.
3. Conversion of *visual granularity* to perceived graininess intervals linked to the KODAK Grain Ruler.

We will not describe the mathematical details involved in each of these steps. Instead, we will discuss the factors in the color negative/positive system that affect each step and their relationships.

Step1: Conversion from Negative Granularities to Print Granularities

This is the most complicated transformation because it depends on so many factors:

Microdensitometer spectral sensitivity
Negative film granularity and noise frequent content
Negative film surface characteristics, including matte
Negative film dye spectral sensitivity
Print material spectral sensitivity
Print material contrast
Print material granularity
Print material modulation transfer function (MTF)
Printing system MTF
Magnification

With so many factors involved, it might seem difficult to describe a simple, stable relationship between negative and print granularities. However, when considering modern color films and papers, most of these factors do not vary enough to affect the method. In addition, for most color negative films, there is a linear relationship between film granularity and resulting print granularity.

Film and paper users generally have little control over the factors listed above. Graininess is mostly determined by the choice of film, exposure, and—to a lesser extent—color paper. But there are a few exceptions:

Film Surface Characteristics. Color negative films have microscopic, irregular, matte surfaces to keep the film from sticking to itself. This surface is also useful for retouching, which makes it more prominent on films intended for professional applications. In a spectral illumination condition typical of microdensitomers, these surface conditions record as density fluctuations similar to granularity.

With diffuse illumination typical in most printers, these variations do not appear in the final print. For this reason, we have chosen to calculate Print Grain Index based on printing systems. However, in some very specular printing systems, such as condenser enlargers or some high-speed printers, the matte surface of the film can add graininess to the prints.

Printing System Modulation Transfer Function. Variations in both printer lens quality and focus precision can affect print graininess. The poorer the lens and focus, the less graininess will be observed in prints. This improvement in graininess, however, comes at the expense of image sharpness. For the Print Grain Index method, an average-quality lens is used at optimum focus.

Print Material Contrast. Print material contrast can also affect the appearance of graininess if the contrast differs from its nominal value. In this case, the variation usually comes from poor process control. The Print Grain Index method uses the average contrast of a variety of print materials* in a standard process.

* F-surface paper.

Step 2: Conversion from Print Granularity to Visual Granularity

This step combines the separate red, green, and blue print granularities into a single number which represents the visual granularity. Calculation is based on the spectral characteristics of the print material image dyes* and the spectral luminous efficiency curve for the human visual system. Your eyes are most sensitive to green followed by red and then blue. Differences in image dyes among various color print materials do not significantly affect the result.

Step 3: Conversion from Visual Granularity to Perceived Granularity

Psychophysical tests on observers have shown that intervals of perceived graininess correlate well with the logarithm of the visual granularity. We perceive graininess based on relative or percent changes in the granularity rather than absolute changes. For example, a change in granularity from 5 to 6, or 20%, is more visually significant than a change from 10 to 11 (10%).

The KODAK Grain Ruler. Using computer simulation, Kodak has generated a physical standard for graininess known as the KODAK Grain Ruler. It consists of a sequential series of grain images reproduced with their corresponding Print Grain Index numbers.

The Grain Ruler was scaled for graininess by several observers following the behavior described above. Although there is some flexibility in setting a numerical scale to describe the graininess intervals on the Grain Ruler, two constants in the relationship prevail: One relates to the absolute level of the scale; and the other to the direction and magnitude of the differences between intervals. For the PGI method, these constants were chosen to meet the following conditions:

1. Higher print graininess produces higher PGI numbers. A difference of two units on the scale produce a 50% jnd (just-noticeable difference). A 50% jnd means that in a side-by-side comparison, half of the observers can distinguish patches that differ by two units. Approximately 90% of the observers can distinguish patches that differ by four units.
2. On the Grain Ruler, the value of 25 produces that approximate visual threshold for graininess. At or below the visual threshold, observers see no graininess in prints. As PGI numbers below 25 have no meaning when assessing prints, any number calculated by the PGI method to be below 25 is simply recorded as “Less than 25.”

* The Print Grain Index method assumes the dyes of KODAK EKTACOLOR Papers.

Applying the Method

Using the Grain Ruler, the PGI method can represent graininess from different combinations of films, film formats, and print sizes. It allows a photographer to access whether a given color negative film will yield acceptable graininess at the intended print size or judge whether it is better to use a larger negative size or slower-speed film to achieve the desired graininess level for a particular application.

Assessing Graininess

To assess the graininess of a print, inspection is usually made at a closer distance than that used to view the entire image. Therefore by choosing a common viewing distance, we avoid the complication of trying to identify a “typical” viewing distance for each print size.

Note: The PGI method specifies a common viewing distance of 14 inches (36 cm) for all print sizes.

The distance at which small (4 x 6-inch) prints are typically viewed is 14 inches. This is also the approximate distance at which larger prints are usually inspected for graininess. For meaningful comparisons, you should relate PGI numbers to each other only at the specified, common print sizes of 4 x 6, 8 x 10, and 16 x 20 inches.

Cropping Images

When comparing the graininess of color negative films, the PGI method assumes that the full negative area is considered for each film format. But you can also use PGI numbers to predict the effect that cropping will have on the print graininess and whether a negative will be suitable for cropping.

Cropping increases film magnification without increasing print size, so graininess increases as the area used from the negative decreases. The best way to illustrate this effect is to consider three different situations:

1. A 4 x 6-inch print from a full-frame 35 mm negative with, for example, a PGI number of 42 at 4.4X magnification.
2. An 8 x 10-inch print from the same 35 mm negative.The PGI number is 63 at 8.8X magnification.
3. A 4 x 6-inch print cut from the center of the 8 x10-inch print mentioned in No. 2 above, the PGI number is still 63.

The least grainy print will be the standard 4 x 6-inch print from the full-frame 35 mm negative (PGI number of 42).

When viewed at the standard 14-inch distance specified by the PGI method, the difference in graininess is obvious between the 4 x 6-inch print from the full-frame negative and the 4 x 6-inch cropped print (PGI numbers 42 vs 63).

The 8 x 10-inch print and 4 x 6-inch area cropped from it will have the same graininess if you view both at the standard 14-inch distance. But the cropped 4 x 6-inch print will appear more grainy if you move the 8 x 10-inch print farther away to a viewing distance more appropriate for viewing large prints.

THE *KODAK* GRAIN RULER

Illustrated below is a reproduction of the KODAK Grain Ruler to acquaint you with the appearance of graininess at various Print Grain Index numbers. The graininess you see here is based on the Kodak reference standard. We used a 300-dots-per-inch screen so that the dots of ink would be too small to influence the grain images. You should view the KODAK Grain Ruler at a distance of 14 inches.

Note: The Print Grain Ruler is produced photographically, and cannot be reproduced for on-line or fax documents.

PRINT GRAIN INDEX NUMBERS FOR SELECTED *KODAK PROFESSIONAL* FILMS

Negative Size: 24 x 36 mm (Size 135)

Print Size (inches)	4 x 6	8 x 10	16 x 20
Magnification	4.4X	8.8X	17.8X
KODAK Professional Film	**Print Grain Index No.**		
PROFESSIONAL PORTRA 160NC	30	52	81
PROFESSIONAL PORTRA 160VC	33	55	84
PROFESSIONAL PORTRA 400NC	41	62	92
PROFESSIONAL PORTRA 400VC	43	64	94
PROFESSIONAL PORTRA 800	50	72	101
PROFESSIONAL PORTRA 100T	33	55	84
PROFESSIONAL SUPRA 100	27	49	78
PROFESSIONAL SUPRA 400	36	58	87
PROFESSIONAL SUPRA 800	50	72	101

Negative Size: 6 X 6 cm (Size 120/220)

Print Size (inches)	4 x 6	8 x 10	16 x 20
Magnification	2.6X	4.4X	8.8X
KODAK Professional Film	**Print Grain Index No.**		
PROFESSIONAL PORTRA 160NC	Less than 25	30	52
PROFESSIONAL PORTRA 160VC	Less than 25	33	55
PROFESSIONAL PORTRA 400NC	29	41	62
PROFESSIONAL PORTRA 400VC	31	43	64
PROFESSIONAL PORTRA 800	38	50	72
PROFESSIONAL PORTRA 100T	Less than 25	33	55

Negative Size: 4 X 5 inches (Sheets)

Print Size (inches)	4 x 6	8 x 10	16 x 20
Magnification	1.2X	2.1X	4.2X
KODAK Professional Film	**Print Grain Index No.**		
PROFESSIONAL PORTRA 160NC	Less than 25	Less than 25	26
PROFESSIONAL PORTRA 160VC	Less than 25	Less than 25	31
PROFESSIONAL PORTRA 400NC	Less than 25	26	39
PROFESSIONAL PORTRA 100T	Less than 25	Less than 25	31

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