The following paper has been submitted to the SMPTE Working Group on Digital Pictures This group is charged with the task of developing a recommended practice to enable conversion of film, video, and computer-generated images. Since the work is not presently complete, this paper represents work in progress. It is being offered for its tutorial value in presenting consideration and relationships involved with multimedia digital image exchange.

Gray-Scale Transformations of Digital Film Data for Display, Conversion, and Film Recording

By Glenn Kennel and David Snider

The conversion of image data from film to video and video to film has created challenges in the design and calibration of telecines and film recorders. The use of high-resolution film scanners and recorders for digital film production also opens up a new world of computer-based imagery. The exchange of digital image data between film, television, and computer systems requires the conversion of the basic image data representations. Although complete color matching requires rigorous characterization and calibration of all capture and display devices in the chain, a reasonable image representation can be achieved by implementing the gray-scale transformations described herein.

The Film System

In order to understand how to transform Cineon Digital Film data for display or conversion to linear or video representation, it is necessary to review some basics about the motion-picture negative/positive film system. A color negative film is used for original photography. This film is printed onto a color print film that is used for projection display. The basic characteristics of the color negative film and the color print film and the placement of image information on those films will be reviewed.

Color Negative Film

The characteristic curves for a typical motion-picture color negative film are shown in Fig. 1. The three curves represent the red, green, and blue color records, which are reproduced by cyan, magenta, and yellow dyes, respectively. The three curves are offset vertically because the base density of the negative film is orange in color (it contains more yellow and magenta dye than cyan dye).

Film characteristic curves are produced by plotting density versus relative log exposure. Density is defined as the negative logarithm of film transmittance, so this is a log/log plot. The 90% white card is used as the reference for 0 relative log exposure.

In order to simplify the following illustrations, the typical negative film will be represented by the single curve shown in Fig. 2. The placement of image information and data transformations apply to all three records in the color film. The color offset between the three records is removed in the process of printing the color negative film to reproduce neutral grays on the color print, as well as in the scanning of the color negative film on the Cineon Digital Film scanner.

The characteristic curve of a typical negative film has five regions: D_{min} (minimum density), the toe, the straight-line portion, the shoulder, and D_{max} (maximum density). Exposures of less than -2.0 relative log exposure will be recorded as D_{min}. The toe is the portion of the curve where the slope increases gradually with increasing exposure.

The straight line is the portion of the characteristic curve with constant slope. For optimum reproduction, the camera exposure should be adjusted to place all significant image informa-

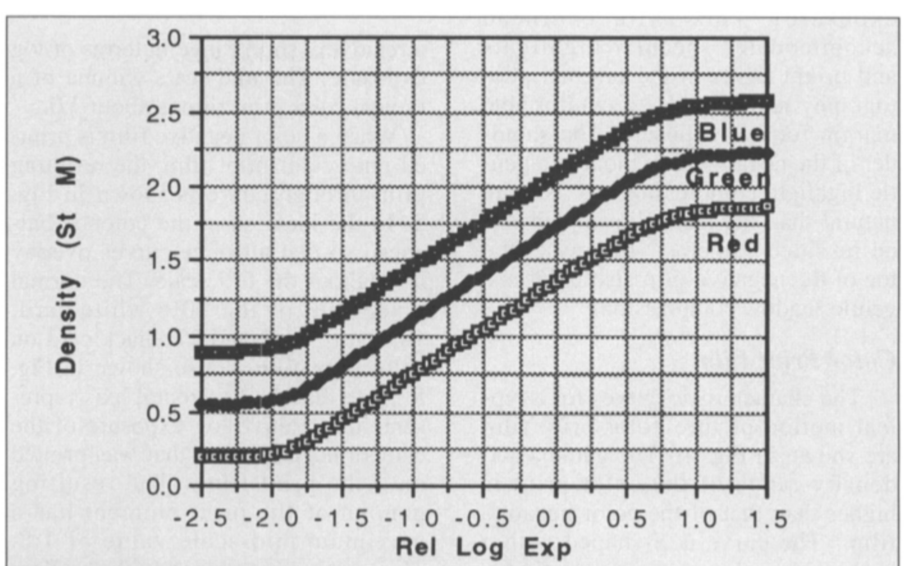

Figure 1. Characteristic curves for color negative film.

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tion on the straight-line portion. The slope of the straight-line portion is known as the gamma of the film. The gamma of a typical motion-picture color negative film is 0.6.

The shoulder is the portion of the curve where the slope decreases with increasing exposure. Film introduces a "soft clip," with exposures in excess of 1.0 relative log exposure recorded as D_{max}.

The nominal placement of a 90% white card, 18% gray card, and 2% black card for a normal camera exposure are shown in Fig. 3. The 18% gray card is a commonly used test object in film photography. A 90% white card is typically used to set the white level of television cameras. The 2% black is shown for additional reference. Interior scenes often have a contrast range of 50:1 or less. Exterior scenes with shadows may have a contrast range of 100:1 or more.

The latitude of the film is defined as the total range of exposure that results in a recorded density change. The latitude of a typical motion-picture negative film is 3.0 log exposure, or a scene contrast range of 1000 to 1. This corresponds to approximately ten camera stops (each stop represents a factor of 2 in exposure).

Several other important observations can be made from the characteristic curve for a typical negative film. The range above 90% white is the overexposure latitude of the film, and is about 1.0 log exposure (10:1 in exposure). This extra overhead accommodates specular highlights and bright lights in the original photography and provides a comfortable margin for overexposure. The shoulder of the negative film induces a gentle highlight compression that is more natural than the hard clip implemented in video cameras. Likewise, the toe of the negative film also induces a gentle shadow compression.

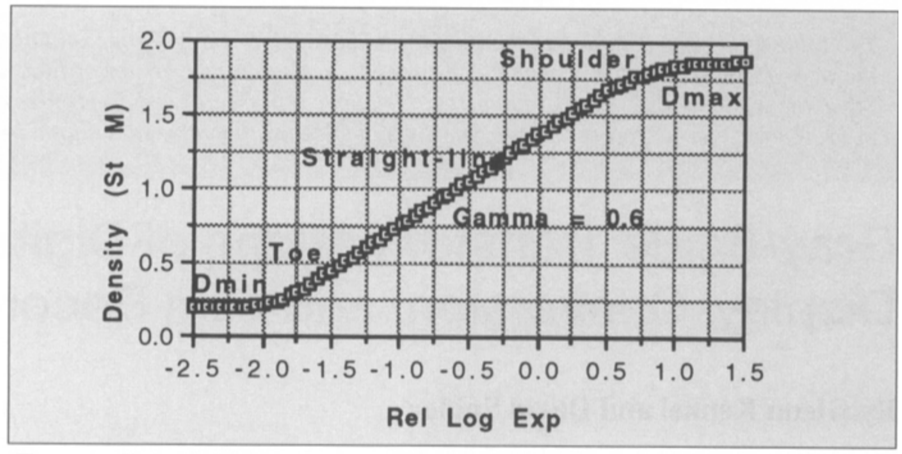

Figure 2. Characteristic curve for a typical negative film.

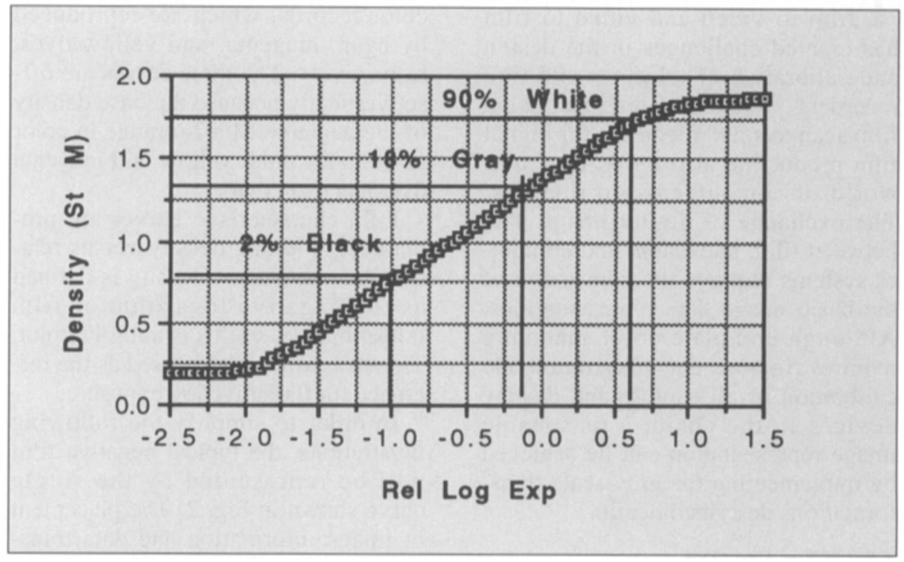

Figure 3. Characteristic curve for a typical negative film, showing nominal placement of 90% white card, 18% gray card,and 2% black card for normal camera exposure.

Color Print Film

The characteristic curves for a typical motion-picture color print film are shown in Fig. 4. The gamma and density range of the color print is higher than that of the color negative film. The curve is S-shaped with a high mid-scale contrast, creating a long straight-line density portion, but a relatively short range in terms of log exposure. The mid-scale gamma of a typical color print film is about 3.0.

When a color negative film is printed onto color print film, the resulting print-through curve is shown in Fig. 5. In the ideal case, the color is balanced so that all three curves overlay throughout the full scale. The normal placement of the 90% white card, 18% gray card, and 2% black card on color print film is also shown in Fig. 5. Note that the horizontal axis represents the relative log exposure of the camera negative film that was printed onto the print film. The resulting gamma of the print element has a maximum mid-scale value of 1.8. This gamma, combined with the flare of cameras and projectors, produces a visually pleasing gray scale when the print film is projected in a darkened theater.

In addition to the highlight compression induced by the shoulder of the negative film, the toe of the print film also induces further highlight compression.

Printing Heavy Negatives

It is common practice to overexpose negative films when light levels permit to reduce graininess, saturate colors, or for other creative reasons. When a negative film is overexposed, the result is a "heavy" negative, or one in which the densities are heavier (higher) than those on a normally exposed negative film. The placement of the 90% white, 18% gray, and 2%

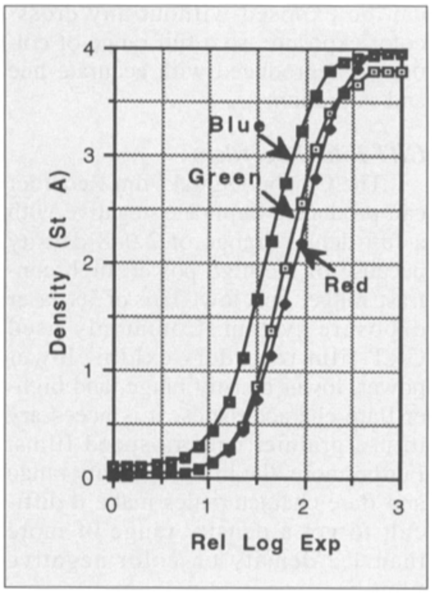

Figure 4. Characteristic curves for a typical color print film.

black cards all shift up the scale, as illustrated in Fig. 6, for an over-exposure of two stops. If a print were made using the standard printer exposure settings, the resulting print-through curve would look like Fig. 7. The whites would appear compressed, blacks would be washed out, and the overall scene would appear flat.

The heavy negative film can be "printed down" by increasing the printer exposure to compensate. When this is done, the resulting print-through curve (Fig. 8) looks much like that of the normally exposed negative film, except that the shoulder of the curve is extended. Overexposing the negative and then printing it down can extend the blacks, darkening deep shadows if the scene has a wide contrast range.

The Cineon Digital Negative

The digital negative produced by the Cineon Digital Film Scanner is a digital representation of the typical negative film shown in Fig. 2.

Full Latitude

The Cineon scanner is calibrated for a 2.048 density range: this allows it to capture the full latitude (density range) of the negative film with some margin at top and bottom. The scanner light source is balanced on film D_{min}, so that the resulting digital image will have a neutral color balance if the film was exposed at the correct color temperature. The digital negative includes significant headroom above the nominal white point to handle over-exposed negative films and scenes with wide contract range.

10 Bits

With 10 bits per color over a 2.048 density range, the resulting quantization step size is 0.002 D per code value. This exceeds the threshold for contour visibility, which insures that no contour artifacts will be visible in images. Furthermore, having 10 bits rather than 8 bits allows the Cineon scanner to capture the extended headroom of the negative film.

Printing Density

The Cineon digital negative is represented in printing density, which is to say, the density that is "seen" by the print film when the negative is printed with a standard illuminant. The illumination and color filters in the Cineon scanner were designed so that the effective spectral response of the scanner matches that of print film.

Normal Digital Negative

The characteristic curve for the Cineon digital negative is shown in Fig. 9. For a normally exposed negative film, the 90% white card has a code value of 685, the 18% gray card has a code value of 470, and the 2% black card has a code value of 180.

Heavy Digital Negative

For a heavy negative, the code values of the 90% white, 18% gray, and 2% black cards are shifted higher. The digital negative resulting from a heavy negative that was overexposed by 2 stops is shown in Fig. 10. This results in 90% white at 860 code value, 18% gray at 650 code value, and 2% black at 360 code value. In order to compensate for the overexposure, the digital negative can be "printed down" by subtracting a code value offset of 180. With a typical negative film gamma of 0.6, each stop in exposure offsets the digital negative by 90 code values.

Producing a Duplicate Negative

To make a film recording of the digital negative, it is necessary to understand the characteristics of the film recorder and to calibrate it accordingly.

Cineon Digital Film Recorder

The Cineon Digital Film Recorder produces a film duplicate negative from the digital negative data that

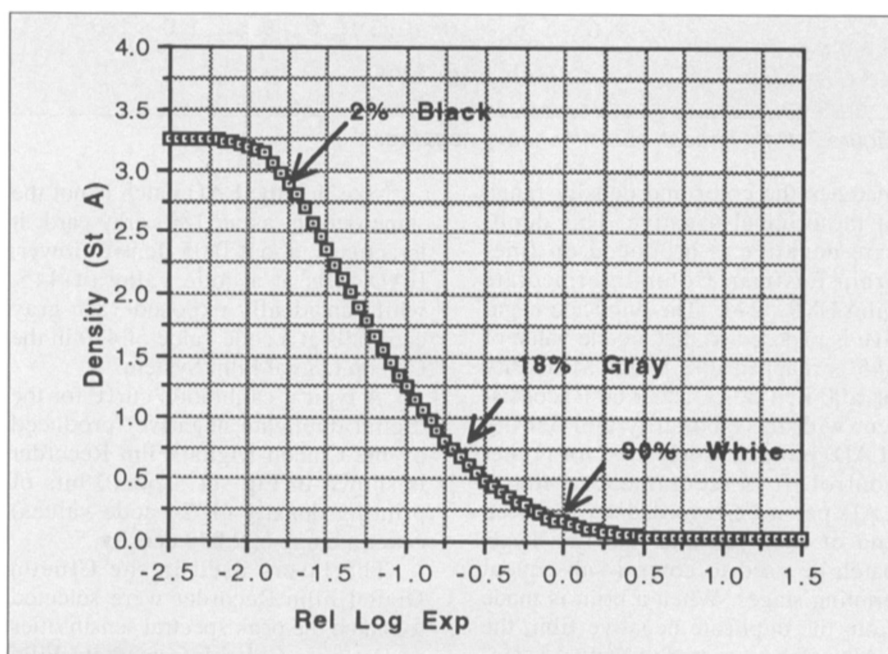

Figure 5. Typical print-through curve.

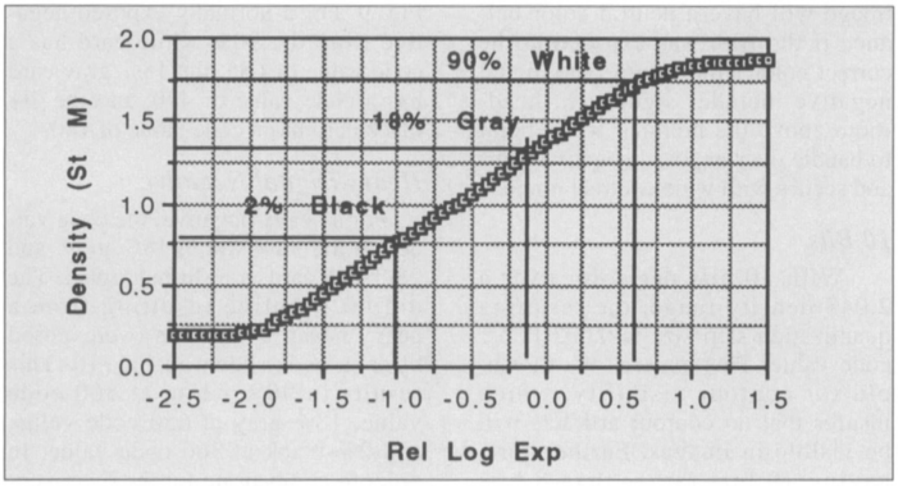

Figure 6. Heavy negative film with 2 stops overexposure.

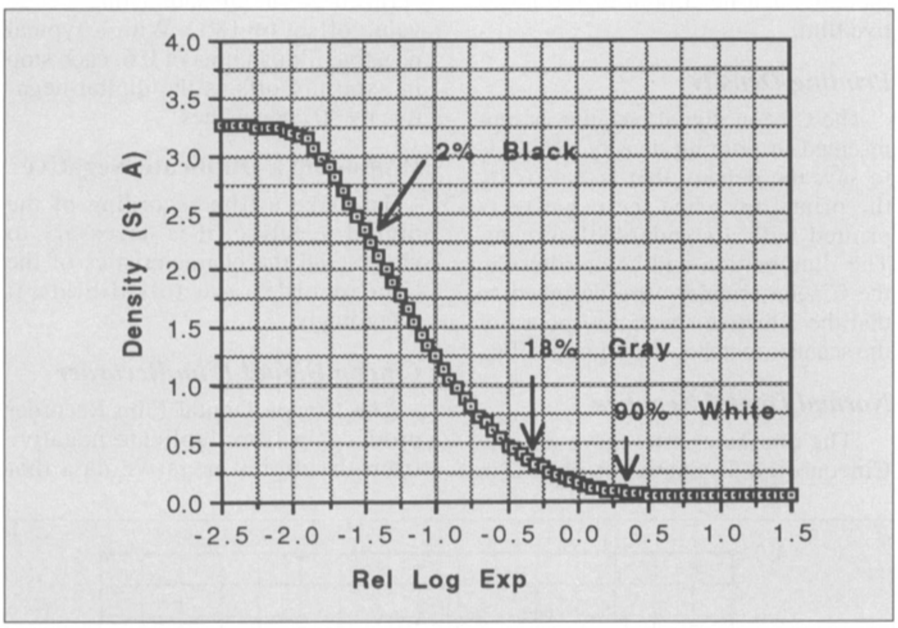

Figure 7. Print-through curve for heavy negative.

matches the color and density range of the original negative. This duplicate negative is produced on fine-grain Eastman Color Intermediate Film EXR 5244. The duplicate negative is exposed so that a code value of 445 is mapped to a Status-M density of 1.00 R, 1.50 G, and 1.60 B, consistent with the laboratory aim density (LAD) process widely used for printer control. It is recommended that a LAD patch be recorded on the head end of each job and that this LAD patch be used to control subsequent printing stages. When a print is made from the duplicate negative film, the LAD patch is printed to Status-A densities of 1.09 R 1.06 G 1.03 B.

Note that the LAD patch is not the same density as an 18% gray card; it is actually about 0.05 density lower. LAD falls at a code value of 445, while an ideally exposed 18% gray card falls at a code value of 470 in the Cineon Digital Film System.

A typical calibration curve for the digital duplicate negative produced by the Cineon Digital Film Recorder is shown in Fig. 11. The 10 bits of printing density (1024 code values) cover a range of 2.048 density.

The lasers used in the Cineon Digital Film Recorder were selected to match the peak spectral sensitivities of Eastman Color Intermediate Film EXR 5244. The full density range can be exposed without any cross-color exposure, so a full range of colors are reproduced with accurate hue and saturation.

CRT Film Recorders

The Cineon Digital Film Recorder can produce a duplicate negative with a full density range of 2.048 density because of the high power, high contrast range, and low flare of its laser exposure system. Commonly used CRT film recorders exhibit lower power, lower density range, and higher flare characteristics. It is necessary to use grainier camera-speed films. Furthermore, the limited density range and flare characteristics make it difficult to get a density range of more than 1.2 density on color negative films.

For CRT film recorders, it is necessary to reduce the calibration range to accommodate the reduced density range. This should not be a problem with normally exposed negative films, or with digital negatives that have been "printed down" by subtracting a code value offset. The calibration curve, shown in Fig. 11, can be used over the range of 95 to 685 code values, with the appropriate adjustment for the D_{min} of the filmstock. An example calibration curve is shown in Fig. 12. Note that the densities shown are densities above the D_{min} of the output filmstock.

Displaying 10-Bit Printing Density

Displaying 10-bit per color printing density on an 8-bit per color graphics display requires some compromises. With appropriate clipping of the printing density data, subsequent scaling for display, and adjustment of the display gamma, reasonable results can be obtained.

Characteristics of Typical Graphics Display Monitor

A typical graphics display monitor is not calibrated for color imaging applications. The color temperature is generally around 9000 K, which is substantially bluer than the television standard of 6500 K or the film projection standard of 5400 K. The contrast ratio (with lights off) is limited to about 100:1. The frame buffer usually

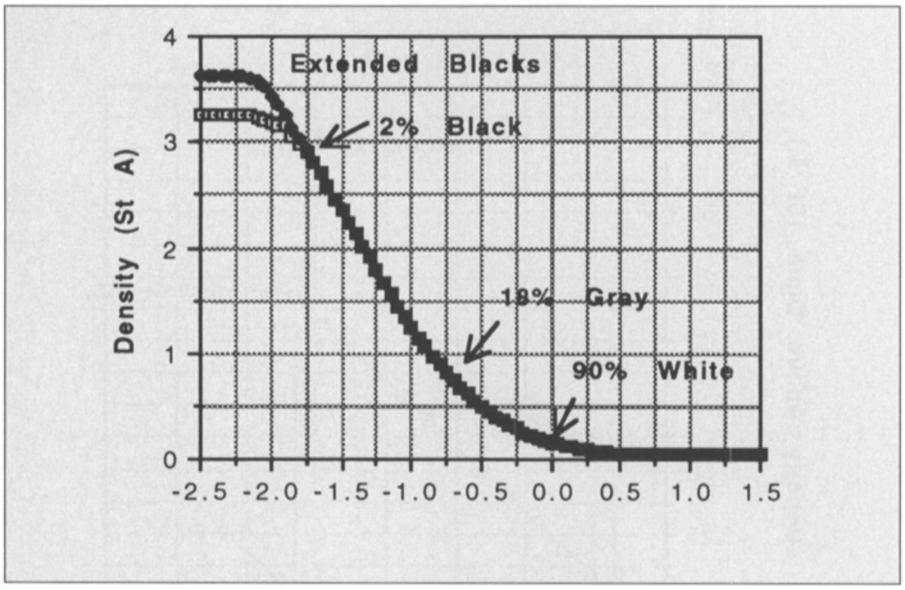

Figure 8. Print-through of heavy negative printed down.

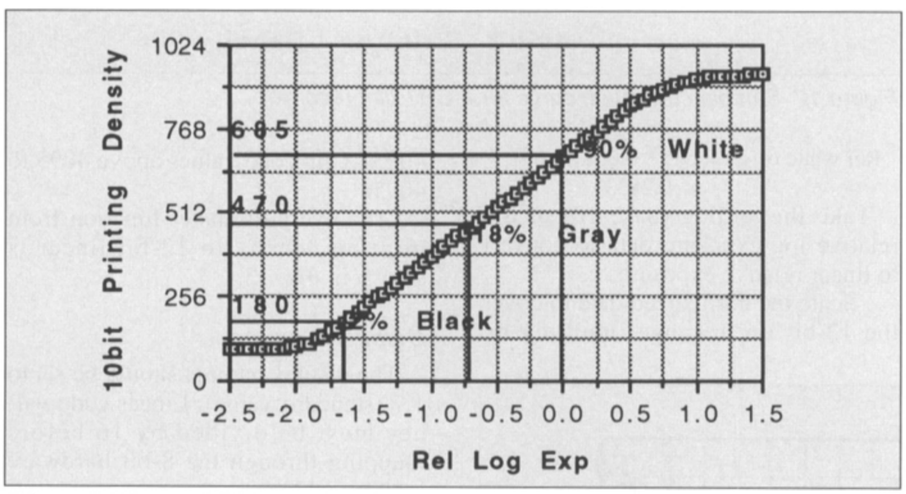

Figure 9. Cineon digital negative (normal exposure).

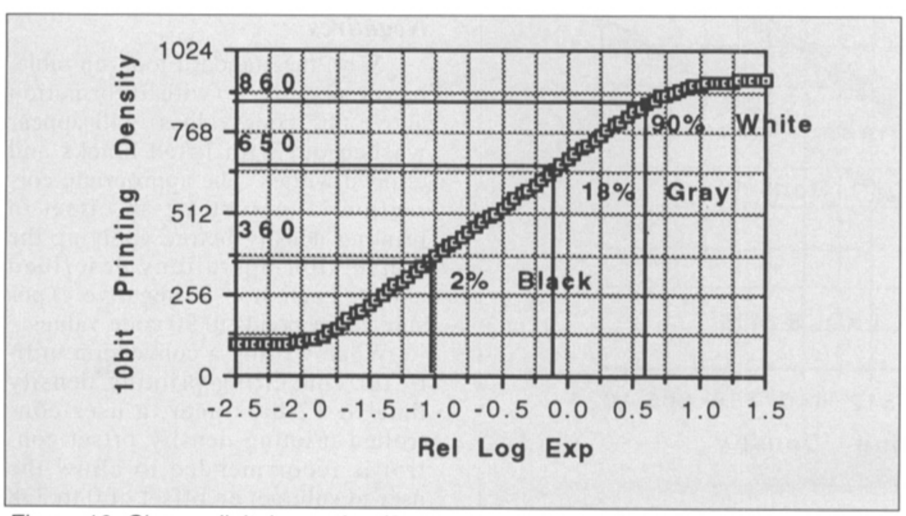

Figure 10. Cineon digital negative (2 stops overexposure).

includes an 8-bit to 8-bit look-up table to implement gamma correction. The standard gamma is set to 1.7.

Clip to Reference White

The first step is to set the white point based on the nominal code value for the 90% white card. Code values above 685 are clipped to 685.

Scale for 8 Bits

The next step is to scale the data to fill the 8-bit range from 0 to 255 code values. This is accomplished by multiplying the clipped 10-bit code values by 255/685.

Display Gamma

The display gamma should be set to 0.6 to match the apparent contrast of the image to a projected print film.

Adjusting an Offset for Heavy Negatives

With the standard look-up table, heavy negatives (with information above 685 code values) will appear washed out with lifted blacks and clipped whites. The appropriate correction is to subtract an offset in printing density before applying the clipping, scaling, and gamma operations described above. Each stop in negative exposure corresponds to 90 code values.

If you are writing a display utility for directly displaying printing density data, a user-controlled printing density offset control is recommended to allow the user to subtract an offset of 0 to 338 code values.

Display on Cineon Workstations

The Cineon workstations include a calibrated monitor for film display. At the factory, the monitor is stripped down to set the color temperature to 5400 K to match the film projection standard. The contrast range is set to 1000:1, to match print film (Fig. 5).

A custom look-up table is loaded to emulate a projected film print. This look-up table is built from the print film characteristic curve and compensates for the monitor gamma.

Using the Cineon workstations, critical color-correction decisions can be made with the confidence that these decisions will be translated to film.

Conversion of Printing Density to 12-Bit Linear

Conversion of logarithmic printing density to a linear representation requires both a scaling and an antilog operation. To maintain the same precision over the full scale, a 10-bit logarithmic representation requires 14-bits linear. When working with 12-bits linear, it is necessary to restrict the printing density range.

Reference White

The 90% white card at code value 685 is mapped to peak white at 4095 code value.

Converting from Printing Density to Relative Exposure

The first step is to convert the printing density code values to a floating point representation. This is accomplished by multiplying by 0.002. The next step is to divide the printing density data by the gamma of the negative film (0.6) to convert to relative log exposure (see Fig. 2).

Adjust the reference white log exposure to 0.0 by subtracting 2.28333. This number is computed by multiplying the reference white code value by 0.002 and dividing by the gamma of the film (0.6).

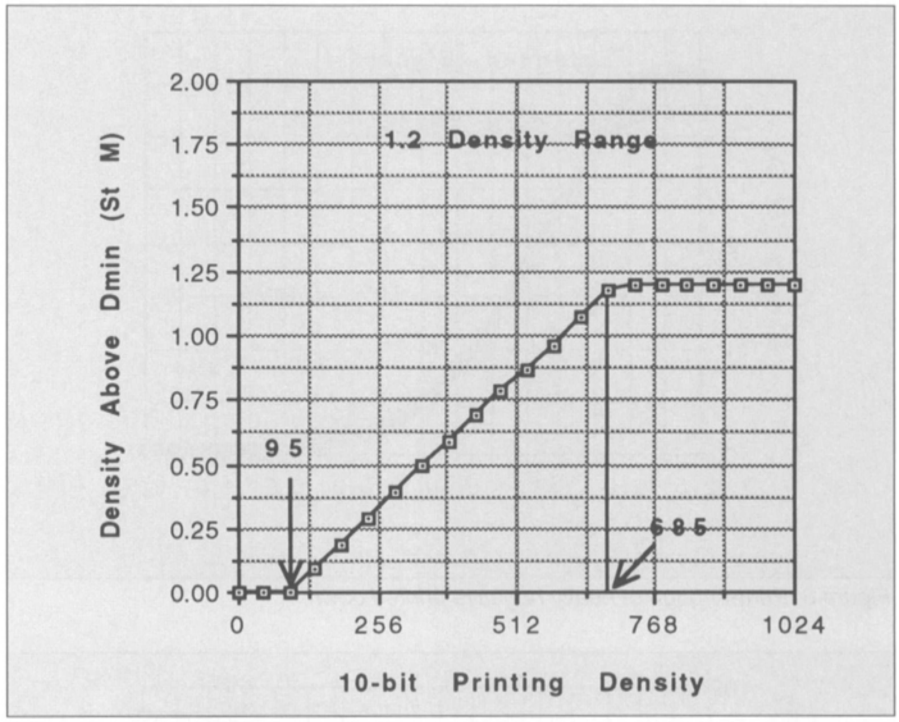

Figure 12. Sample calibration curve for a CRT film recorder.

Ref white offset = 685 * 0.002 / 0.6
=> 2.28333

Take the antilog (base 10) of the relative log exposure data to convert to linear relative exposure.

Scale the normalized data to cover the 12-bit linear range (multiply by 4095). Clip code values above 4095 to 4095.

The overall transfer function from printing density to 12-bit linear is shown in Fig. 13.

Display Gamma

The display gamma should be set to 1.7 (standard value). Linear code values must be divided by 16 before mapping through the 8-bit hardware look-up table.

Adjusting an Offset for Heavy Negatives

With the standard look-up table, heavy negatives (with information above 685 code values) will appear washed out with lifted blacks and clipped whites. The appropriate correction is to subtract an offset in printing density before applying the conversion operations described above. Each stop in negative exposure corresponds to 90 code values.

When writing a conversion utility for converting printing density data to 12-bit linear, a user-controlled printing density offset control is recommended to allow the user to subtract an offset of 0 to 338 code values.

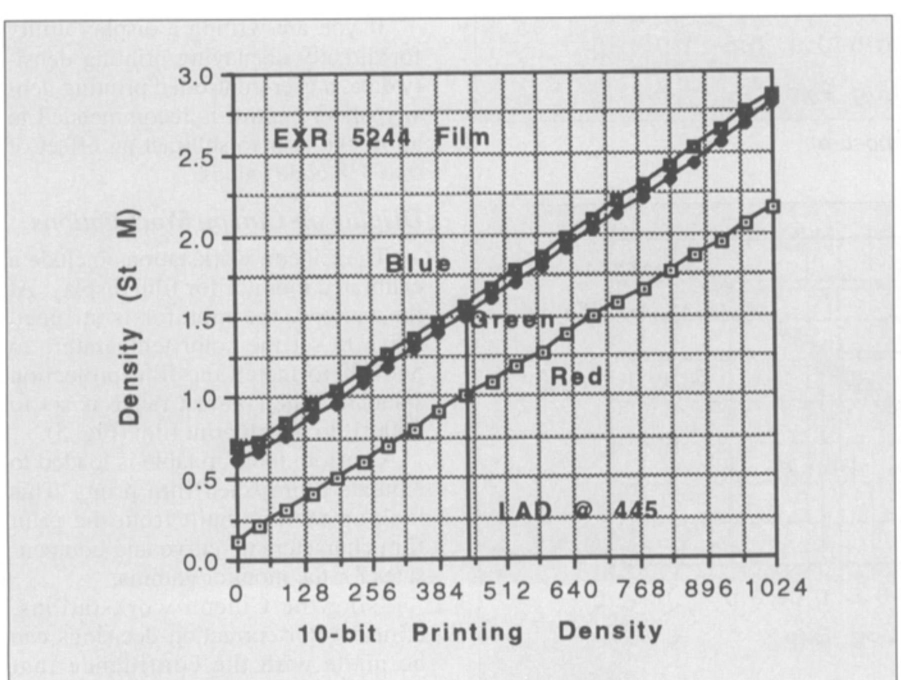

Figure 11. Calibration curves for Cineon recorder.

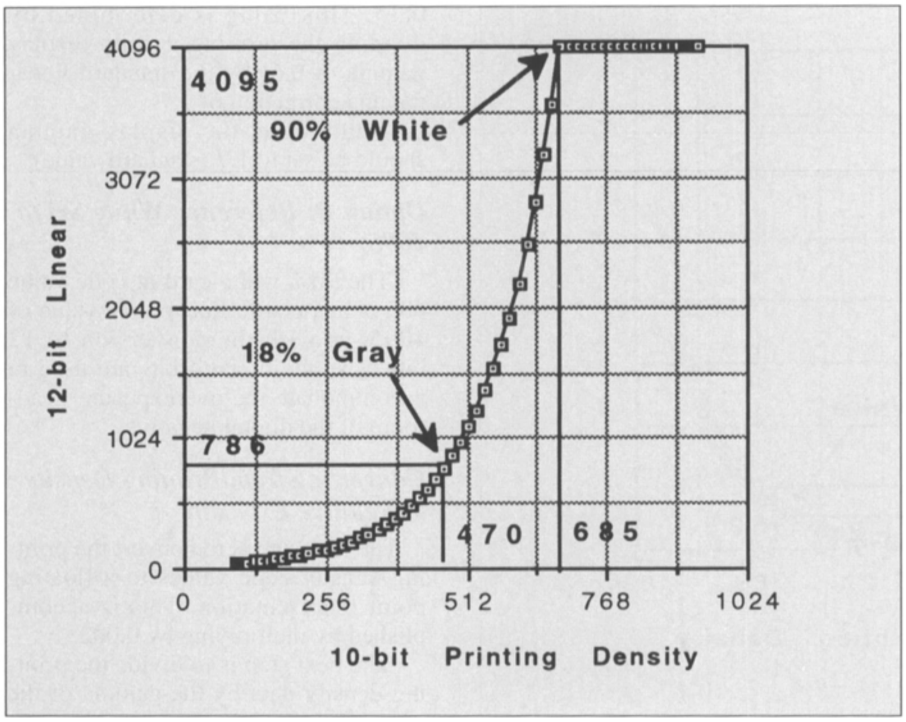

Figure 13. Printing density to 12-bit linear.

Quick Method for "Linearizing" Printing Density Data

A reasonable approximation for the transformation described above can be implemented simply by applying a gamma precorrection of 0.35 to the clipped and scaled printing density data.

The first step is to set the white point to 685 and to clip higher code values. Then, scale the data to fill the 12-bit range from 0 to 4095. Multiply the clipped 10-bit code values by 4095/685.

Apply a gamma precorrection of 0.35. This value is determined by dividing the printing density display gamma of 0.6 by the standard linear gamma correction of 1.7.

In this case, the display gamma should be set to 1.7 (standard value).

Conversion of Printing Density to 16-Bit Linear

Conversion of logarithmic printing density to a linear representation requires both a scaling and an anti-log operation. To maintain the same precision over the full scale, a 10-bit logarithmic representation requires 14-bits linear. When working with 16-bits linear, it is possible to maintain the full printing density range, although the common practice is to put reference white at the maximum code value of 65535. Therefore, two options will be described.

Option A: Reference White Set to Max Code Value

The 90% white card at code value 685 is mapped to maximum code value of 65535.

Converting from Printing Density to Relative Exposure

The first step is to convert the printing density code values to a floating point representation. This is accomplished by multiplying by 0.002.

The next step is to divide the printing density data by the gamma of the negative film (0.6) to convert to relative log exposure (Fig. 2).

Adjust the reference white log exposure to 0.0 by subtracting 2.28333. This number is computed by multiplying the reference white code value by 0.002 and dividing by the gamma of the film (0.6).

Ref white offset = 685 * 0.002 / 0.6
=> 2.28333

Take the antilog (base 10) of the relative log exposure data to convert to linear relative exposure.

Scale the normalized data to cover the 16-bit linear range (multiply by 65535).

Clip code values above 65535 to 65535.

The transfer function from printing density to 16-bit linear with the white point at 65535 code value is shown in Fig. 14.

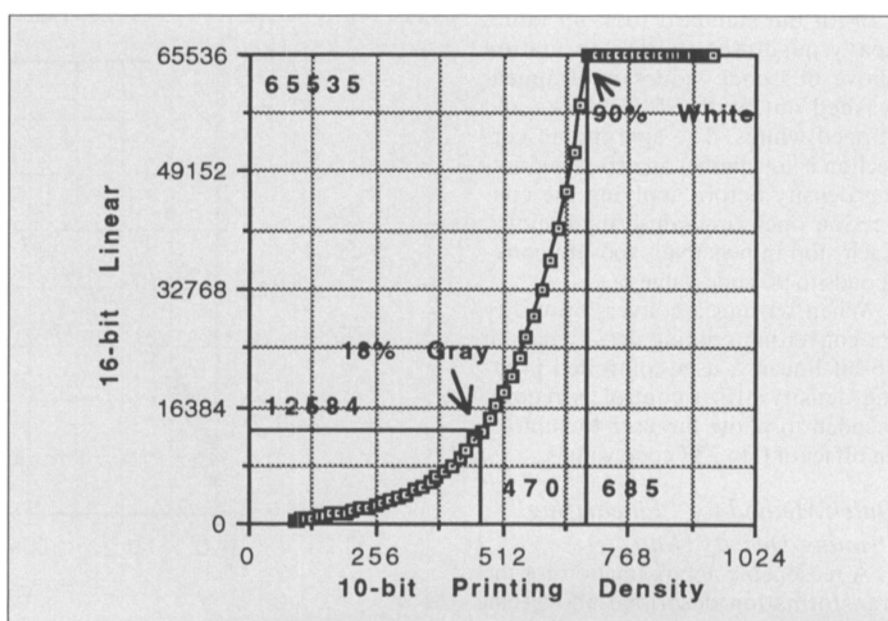

Figure 14. Printing density to 16-bit linear (white @ 65535).

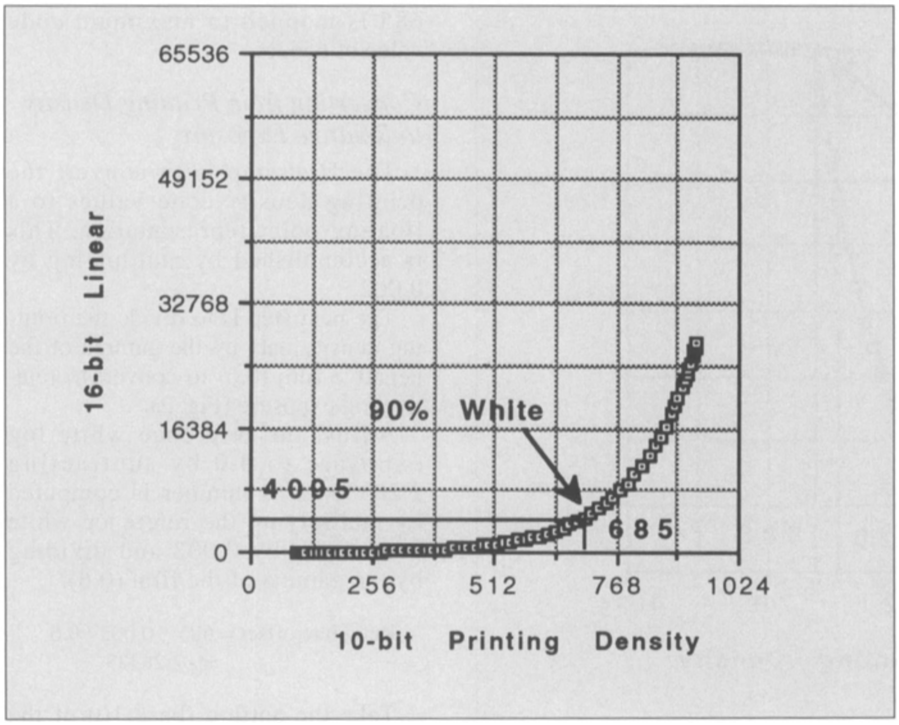

Figure 15. Printing density to 16-bit linear (white @ 4095).

Display Gamma

The display gamma should be set to 1.7 (standard value). Linear code values must be divided by 256 before mapping through the 8-bit hardware look-up table.

Adjusting Offset for Heavy Negatives

With the standard look-up table, heavy negatives (with information above 685 code values) will appear washed out, with lifted blacks and clipped whites. The appropriate correction is to subtract an offset in printing density before applying the conversion operations described above. Each stop in negative exposure corresponds to 90 code values.

When writing a conversion utility for converting printing density data to 16-bit linear, a user-controlled printing density offset control is recommended to allow the user to subtract an offset of 0 to 338 code values.

Quick Method for "Linearizing" Printing Density Data

A reasonable approximation for the transformation described above can be implemented simply by applying a gamma precorrection of 0.35 to the clipped and scaled printing density data.

The first step is to set the white point to 685 and to clip higher code values. Then, scale the data to fill the 16-bit range from 0 to 65535. Multiply the clipped 10-bit code values by 65535/685.

Apply a gamma precorrection of 0.35. This value is determined by dividing the printing density display gamma of 0.6 by the standard linear gamma correction of 1.7.

In this case, the display gamma should be set to 1.7 (standard value).

Option B: Reference White Set to 4095

The 90% white card at code value 685 is mapped to linear code value of 4095, as with the conversion to 12 bits. The additional 4 bits are used to accommodate the overexposure headroom of the digital negative.

Converting from Printing Density to Relative Exposure

The first step is to convert the printing density code values to a floating point representation. This is accomplished by multiplying by 0.002.

The next step is to divide the printing density data by the gamma of the negative film (0.6) to convert to relative log exposure (Fig. 2).

Adjust the reference white log exposure to 0.0 by subtracting 2.28333. This number is computed by multiplying the reference white code value by 0.002 and dividing by the gamma of the film (0.6).

Ref white offset = 685 * 0.002 / 0.6
=> 2.28333

Take the antilog (base 10) of the relative log exposure data to convert

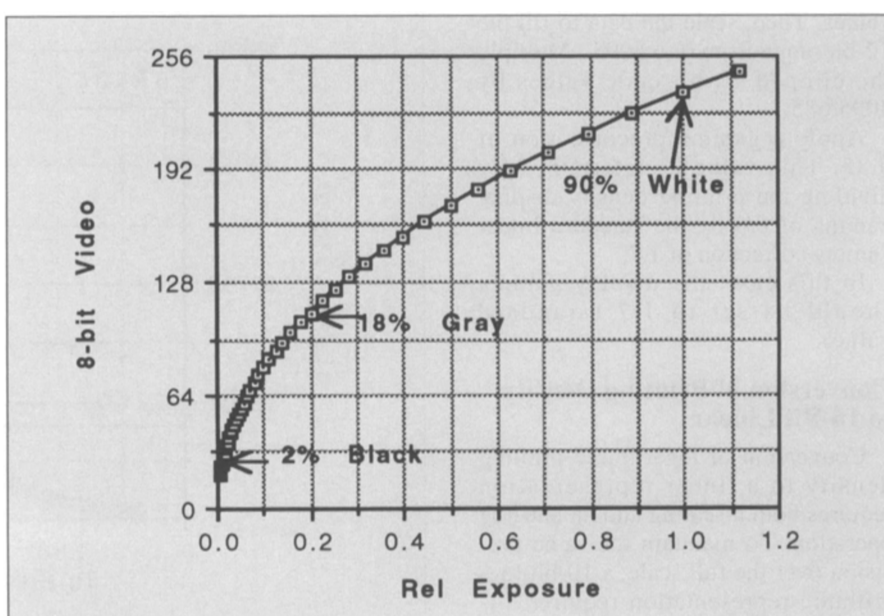

Figure 16. Video transfer function.

to linear relative exposure.

Scale the normalized data to set the white point at the maximum code value for the 12-bit linear range (multiply by 4095).

Clip code values above 65535 to 65535. Code values between 4096 and 65535 represent the over-exposure image information above reference white.

The transfer function from printing density to 16-bit linear with the white point at 4095 code value is shown in Fig. 15. This transformation provides an extra factor of two headroom for the 16-bit linear data that can be used for extended computational accuracy.

Display Gamma

The display gamma should be set to 1.7 (standard value). Linear code values must be divided by 16 and clipped to 255 before mapping through the 8-bit hardware look-up table.

Adjusting Offset for Heavy Negatives

With the standard look-up table, heavy negatives (with information above 685 code values) will appear washed out with lifted blacks and clipped whites. The appropriate correction is to subtract an offset in printing density before applying the conversion operations described above. Each stop in negative exposure corresponds to 90 code values.

When you are writing a conversion utility for converting printing density data to 16-bit linear, a user-controlled printing density offset control is recommended to allow the user to subtract an offset of 0 to 338 code values.

Quick Method for "Linearizing" Printing Density Data

A reasonable approximation for the transformation described above can be implemented simply by applying a gamma precorrection of 0.35 to the clipped and scaled printing density data.

The first step is to scale the data to put the white point at 4095. Multiply the clipped 10-bit code values by 4095/685. Clip all values above 65535 to 65535.

Apply a gamma precorrection of 0.35. This value is determined by dividing the printing density display gamma of 0.6 by the standard linear gamma correction of 1.7.

In this case, the display gamma should be set to 1.7 (standard value).

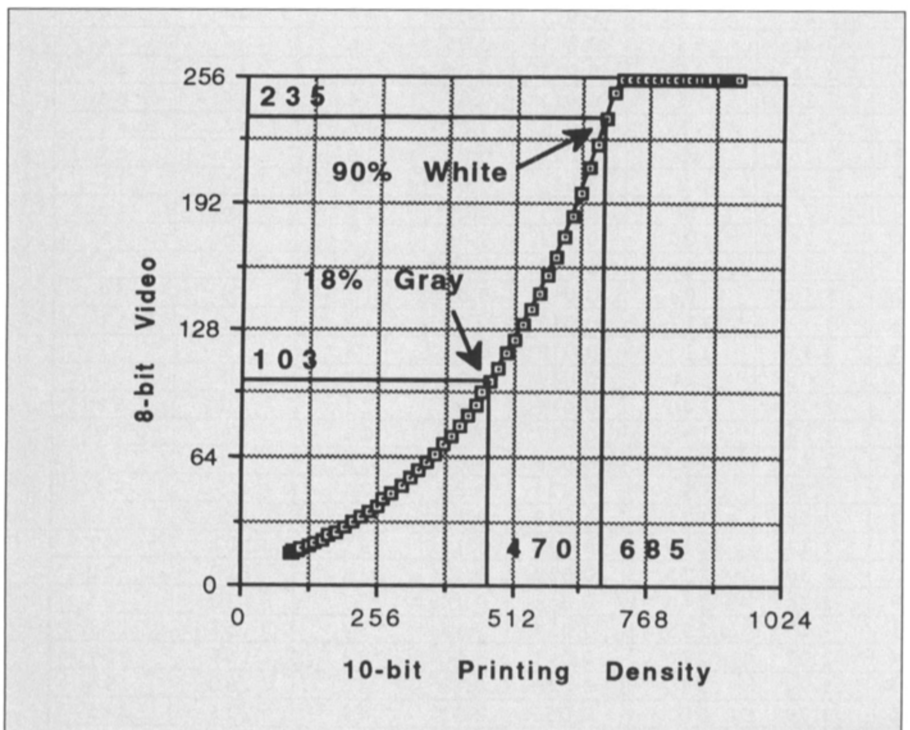

Figure 17. Printing density to digital video.

Conversion of 10-Bit Printing Density to CCIR 601 Video

CCIR 601 digital video representation requires an anti-log operation, followed by implementation of the video transfer function.

Reference White

The 90% white card at code value 685 is mapped to video reference white at 235.

Converting from Printing Density to Digital Video

The first step is to convert the printing density code values to a floating point representation. This is accomplished by multiplying by 0.002.

The next step is to divide the printing density data by the gamma of the negative film (0.6) to convert to relative log exposure (Fig. 2).

Adjust the reference white log exposure to 0.0 by subtracting 2.28333. This number is computed by multiplying the reference white code value by 0.002 and dividing by the gamma of the film (0.6).

Ref. white offset = 685 * 0.002 / 0.6 => 2.28333

Take the antilog (base 10) of the relative log exposure data to convert to linear relative exposure.

Build in the video transfer function specified by CCIR 709, and illustrated in Fig. 16:

$$V' = 1.099 * V^{0.45} - 0.099 \quad \text{for } 1 \geq V \geq 0.018$$

$$V' = 4.50 * V \quad \text{for } 0.018 \geq V \geq 0$$

Scale the video level (V') to put reference white at 235 and reference black at 16 code values, per CCIR 601. To do this, multiply the video level by 230 and add 5.

Clip code values above 255 to 255.

The transfer function from printing density to 8-bit video is shown in Fig. 17.

Display Gamma

If displayed on a graphics monitor, the display gamma should be set to 1.0.

Adjusting Offset for Heavy Negatives

With the standard look-up table, heavy negatives (with information above 685 code values) will appear washed out with lifted blacks and clipped whites. The appropriate correction is to subtract an offset in printing density before applying the conversion operations described above. Each stop in negative exposure corresponds to 90 code values.

When writing a conversion utility for converting printing density data to 8-bit video, a user-controlled printing density offset control is recommended to allow the user to subtract an offset of 0 to 338 code values.

Conversion to YC_bC_r

The RGB data must be converted to YC_bC_r for D-1 recording. This can be implemented in software or can be handled in external hardware in the Abekas Digital Disk Recorder and some video interface cards.

Appendix A: What Does "Linear" Really Mean?

In the strictest sense, linear data representation in imaging systems refers to the representation of original scene luminance values in a linear scale. A linear data representation is widely used for computer-generated imagery (CGI) because models of illumination, diffusion, and other physical phenomena are defined linearly.

The human visual system responds logarithmically at threshold illumination and can be characterized by a power law at higher intensities. Digital imaging systems with a limited number of bits (by definition) must be designed so that there is enough precision in the low levels (shadow information) to avoid visible contouring. This can be achieved by applying a logarithmic or gamma law pre-correction to the linear data prior to digitization. With this pre-correction, the number of bits required to eliminate contouring in a video display can be reduced from 12 bits for linear data to 8 bits for logarithmic or gamma-corrected data.

The response of color negative film is optimized to make good prints. Film response curves have traditionally been measured on a logarithmic scale to compress the dynamic range (Fig. 1). In color photography, dyes add logarithmically (known as Beers law). When digitizing film, it is most efficient to capture and store the data in a logarithmic (density) representation.

Most digital imaging processing operations are linear mathematical operations applied to the whole image. These operations can be applied to any data representation: linear, film density, gamma-corrected video, or other. In theory, operations involving spatial resampling or filtering are best done in linear space rather than density or gamma-corrected space. In practice, many video and digital film systems have been implemented which process the density or gamma-corrected data directly without linearization.

Appendix B

Gray-Scale Conversions

	A	B	C	D	E	F	G	H	I	J	K
1		Log E	R Log E	Neg D	Print D	10b P.D.	Rel Exp	Video	8b Video	12b Lin	16b Lin
2		0.00	-2.50	0.19	3.26	95	0.011	0.05	16	44	44
3		0.05	-2.45	0.19	3.26	95	0.011	0.05	16	44	44
4		0.10	-2.40	0.19	3.26	95	0.011	0.05	16	44	44
5		0.15	-2.35	0.19	3.26	95	0.011	0.05	16	44	44
6		0.20	-2.30	0.19	3.26	95	0.011	0.05	16	44	44
7		0.25	-2.25	0.19	3.26	96	0.011	0.05	16	45	45
8		0.30	-2.20	0.20	3.25	98	0.011	0.05	16	45	45
9		0.35	-2.15	0.20	3.24	99	0.011	0.05	17	46	46
10		0.40	-2.10	0.20	3.24	100	0.011	0.05	17	46	46
11		0.45	-2.05	0.21	3.21	104	0.012	0.05	17	47	47
12		0.50	-2.00	0.22	3.19	108	0.012	0.05	17	49	49
13		0.55	-1.95	0.23	3.17	113	0.012	0.06	18	51	51
14		0.60	-1.90	0.23	3.15	115	0.013	0.06	18	52	52
15		0.65	-1.85	0.26	3.06	128	0.014	0.06	19	57	57
16		0.70	-1.80	0.28	2.98	140	0.015	0.07	21	62	62
17		0.75	-1.75	0.31	2.89	153	0.017	0.08	22	69	69
18		0.80	-1.70	0.33	2.81	165	0.018	0.08	24	76	76
19	**2% Blk**	**0.85**	**-1.65**	**0.36**	**2.70**	**180**	**0.021**	**0.09**	**26**	**85**	**85**
20		0.90	-1.60	0.39	2.58	195	0.023	0.10	29	95	95
21		0.95	-1.55	0.42	2.47	210	0.026	0.11	31	107	107
22		1.00	-1.50	0.45	2.36	225	0.029	0.13	34	120	120
23		1.05	-1.45	0.48	2.24	240	0.033	0.14	37	135	135
24		1.10	-1.40	0.51	2.13	255	0.037	0.15	39	151	151
25		1.15	-1.35	0.54	2.02	270	0.041	0.16	43	169	169
26		1.20	-1.30	0.57	1.90	285	0.046	0.18	46	190	190
27		1.25	-1.25	0.60	1.79	301	0.053	0.19	49	215	215
28		1.30	-1.20	0.64	1.67	318	0.060	0.21	53	244	244

Gray-Scale Conversions

	A	B	C	D	E	F	G	H	I	J	K
1		Log E	R Log E	Neg D	Print D	10b P.D.	Rel Exp	Video	8b Video	12b Lin	16b Lin
29		1.35	-1.15	0.67	1.55	334	0.067	0.23	57	276	276
30		1.40	-1.10	0.70	1.44	350	0.076	0.25	62	313	313
31		1.45	-1.05	0.73	1.34	365	0.086	0.26	66	351	351
32		1.50	-1.00	0.76	1.25	380	0.096	0.28	70	394	394
33		1.55	-0.95	0.79	1.15	395	0.108	0.30	75	442	442
34		1.60	-0.90	0.82	1.06	410	0.121	0.33	80	496	496
35		1.65	-0.85	0.85	0.98	425	0.136	0.35	85	557	557
36		1.70	-0.80	0.88	0.90	440	0.153	0.37	91	625	625
37		1.75	-0.75	0.91	0.82	455	0.171	0.40	96	701	701
38	**18% Gr**	**1.80**	**-0.70**	**0.94**	**0.74**	**470**	**0.192**	**0.42**	**103**	**786**	**786**
39		1.85	-0.65	0.97	0.68	485	0.215	0.45	109	882	882
40		1.90	-0.60	1.00	0.62	500	0.242	0.48	116	990	990
41		1.95	-0.55	1.03	0.55	515	0.271	0.51	123	1111	1111
42		2.00	-0.50	1.06	0.49	530	0.304	0.54	130	1246	1246
43		2.05	-0.45	1.09	0.45	545	0.341	0.58	138	1398	1398
44		2.10	-0.40	1.12	0.41	560	0.383	0.61	146	1569	1569
45		2.15	-0.35	1.15	0.36	575	0.430	0.65	155	1760	1760
46		2.20	-0.30	1.18	0.32	590	0.482	0.69	164	1975	1975
47		2.25	-0.25	1.21	0.29	606	0.546	0.74	175	2237	2237
48		2.30	-0.20	1.25	0.26	623	0.619	0.79	186	2535	2535
49		2.35	-0.15	1.28	0.23	639	0.701	0.84	198	2871	2871
50		2.40	-0.10	1.31	0.20	655	0.794	0.89	210	3253	3253
51		2.45	-0.05	1.34	0.18	670	0.891	0.94	222	3650	3650
52	**90% W**	**2.50**	**0.00**	**1.37**	**0.16**	**685**	**1.000**	**1.00**	**235**	**4095**	**4095**
53		2.55	0.05	1.40	0.14	700	1.122	1.06	248	4095	4595
54		2.60	0.10	1.43	0.12	715	1.259	1.12	255	4095	5155
55		2.65	0.15	1.46	0.11	730	1.413	1.18	255	4095	5784
56		2.70	0.20	1.49	0.10	745	1.585	1.25	255	4095	6490
57		2.75	0.25	1.52	0.09	760	1.778	1.32	255	4095	7282
58		2.80	0.30	1.55	0.08	775	1.995	1.40	255	4095	8171
59		2.85	0.35	1.58	0.07	790	2.239	1.48	255	4095	9168
60		2.90	0.40	1.61	0.07	805	2.512	1.56	255	4095	10286
61		2.95	0.45	1.64	0.06	820	2.818	1.65	255	4095	11541
62		3.00	0.50	1.67	0.05	835	3.162	1.75	255	4095	12950
63		3.05	0.55	1.69	0.05	846	3.447	1.82	255	4095	14117
64		3.10	0.60	1.72	0.05	858	3.758	1.90	255	4095	15391
65		3.15	0.65	1.74	0.05	869	4.097	1.97	255	4095	16779
66		3.20	0.70	1.76	0.04	880	4.467	2.06	255	4095	18292
67		3.25	0.75	1.78	0.04	888	4.732	2.11	255	4095	19376
68		3.30	0.80	1.79	0.04	895	5.012	2.17	255	4095	20524
69		3.35	0.85	1.81	0.04	903	5.309	2.23	255	4095	21740
70		3.40	0.90	1.82	0.04	910	5.623	2.29	255	4095	23028
71		3.45	0.95	1.83	0.04	914	5.788	2.32	255	4095	23700
72		3.50	1.00	1.84	0.04	918	5.957	2.35	255	4095	24393
73		3.55	1.05	1.84	0.04	921	6.131	2.39	255	4095	25105
74		3.60	1.10	1.85	0.04	925	6.310	2.42	255	4095	25838
75		3.65	1.15	1.85	0.04	926	6.370	2.43	255	4095	26087
76		3.70	1.20	1.86	0.04	928	6.432	2.44	255	4095	26338
77		3.75	1.25	1.86	0.04	929	6.494	2.45	255	4095	26592
78		3.80	1.30	1.86	0.04	930	6.556	2.46	255	4095	26849
79		3.85	1.35	1.86	0.04	931	6.620	2.47	255	4095	27108
80		3.90	1.40	1.87	0.04	933	6.683	2.48	255	4095	27369
81		3.95	1.45	1.87	0.04	934	6.748	2.50	255	4095	27633
82		4.00	1.50	1.87	0.04	935	6.813	2.51	255	4095	27899