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Hardware Monitor Calibration

PDF version / Settings for Acrobat

Edit / Preferences / General / Page Display
(since version 6)

Use Custom Resolution 72 dpi
Do not use 2D GPU acceleration
(which would smooth test patterns on p.4–11)

Edit / Preferences / General /Color Management
(full version only)

Color Management Off
RGB: your System Monitor Profile

The PDF document is pixel synchronized for
zoom 100% / 200% / 72 dpi

HTML version

In any case of doubt use the HTML version [8]

Table of Contents

Use page number for jump to Table of Contents and zoom 100%

1. Introduction

The next page shows a simple procedure for the Hardware Monitor Calibration.

This is a reasonable method for all users who do not intend to apply Adobe Gamma.

It is also recommended in advance to the application of Adobe Gamma.
Do not use the Hardware Calibration after Adobe Gamma has been already executed.

The Gamma test patterns are valid only for not smoothed images and zoom 100% or 200%.

Settings for Acrobat:
Smooth text and line art, do not smooth images.

Page 5 shows the influence of the adaptation to a black background.

Altogether this works for modern CRT monitors with individual settings for RGB.

Use square and circle for geometry calibration.

1. Einführung

Auf der nächsten Seite findet man ein einfaches Verfahren für die Hardware-Kalibrierung.

Dies ist eine sinnvolle Methode für alle Benutzer, die Adobe Gamma nicht verwenden wollen.

Hardware-Kalibrierung ist auch vor der Ausführung von Adobe Gamma zu empfehlen.
Auf keinen Fall soll die Hardware-Kalibrierung nach Adobe Gamma vorgenommen werden.

Die Gamma Test Muster sind nur für nicht geglättete Bilder und Zoom 100% oder 200% gültig.
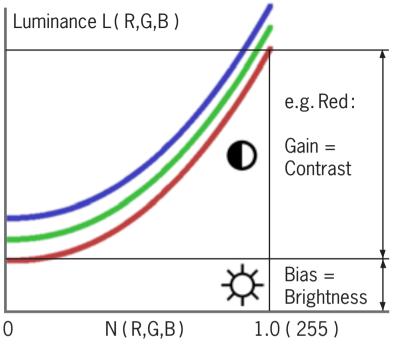
Einstellungen für Acrobat:
Text glätten, Grafik glätten, Bilder nicht glätten.

Seite 5 zeigt den Einfluß der Adaption an einen dunklen Hintergrund.

Das Verfahren funktioniert für moderne Röhrenmonitore mit Einzeleinstellungen für RGB.
Quadrat und Kreis helfen bei der geometrischen Kalibrierung.
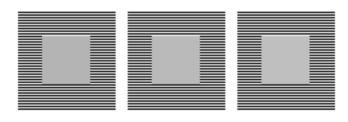
2. Hardware Monitor Calibration

Luminance L (R,G,B)

e.g. Red :

Gain = Contrast

Bias = Brightness

0   N (R,G,B)   1.0 (255)

$$\text{Luminance} = (\text{Brightness} + \text{Contrast} \cdot N)^{\text{Gamma}}$$

1 Let your monitor warm up one hour

2 Adjust Contrast (Gain) to maximum

3 Adjust Brightness (Bias) for Black
   Brightness is not used for White
   A black rectangle should be visible (arrow)

4 Adjust Contrast for White luminance

5 Try to balance all colors until the Grayscale
   shows no tint of any color

6 Shift to red gray: Standard D65   6500 K
   Shift to blue gray: Standard Monitor 9300K

This image should show vibrant colors

Gamma Test Patterns
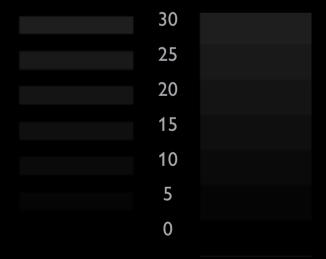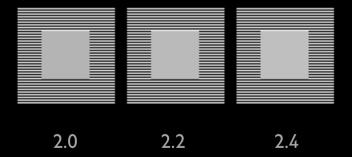
2.0   2.2   2.4

Equal Gray for inner and outer square
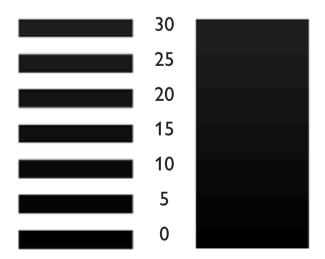Adjust Gamma = 2.2

Use Zoom 100%

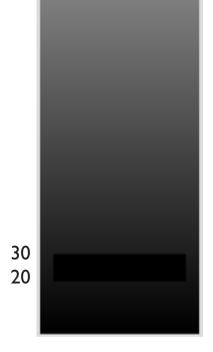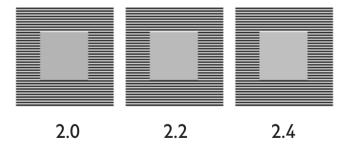Browsers are not accurate
Please download and view by Acrobat

4

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25

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0

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20

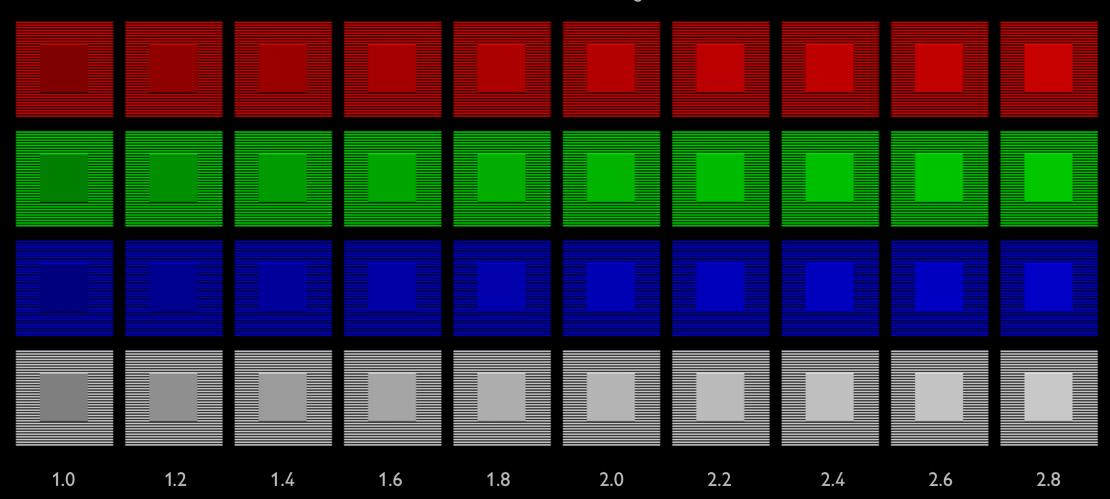2.0   2.2   2.4

30
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2.0   2.2   2.4
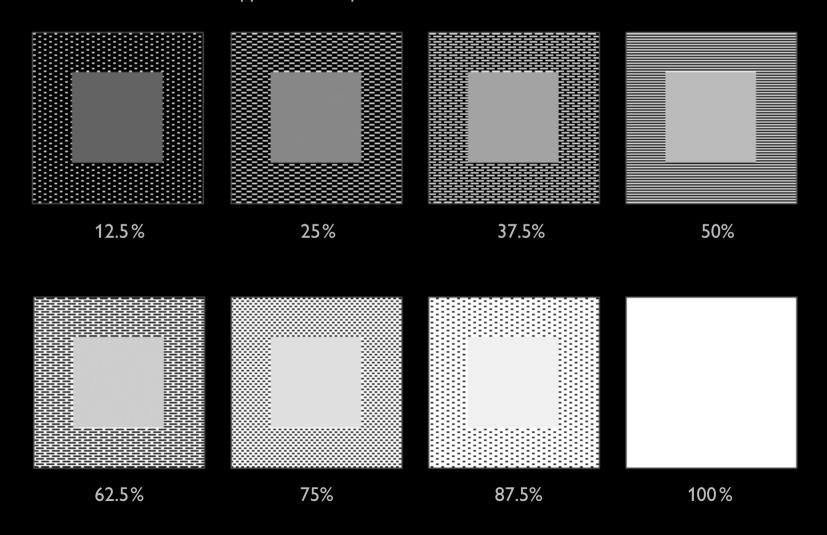
5. Color Gamma Test Patterns
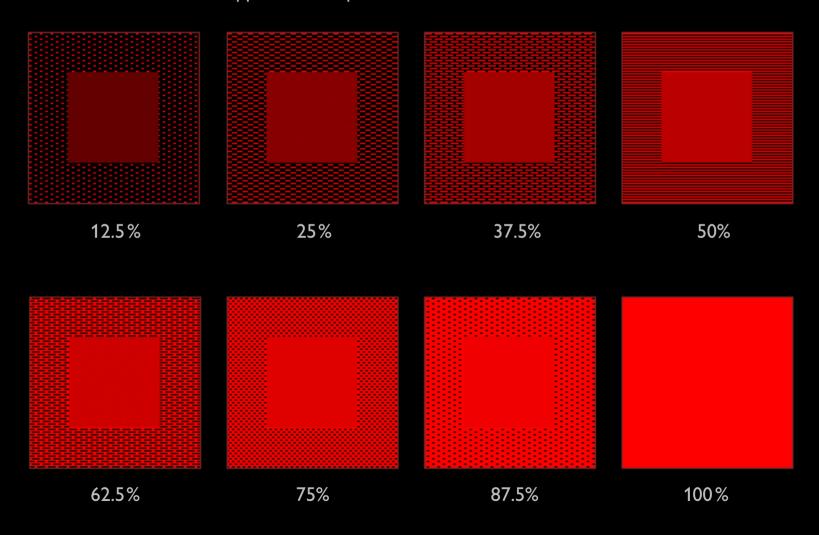
Zoom 100%. Browsers are not accurate
Please download and view by Acrobat

| 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 |

6. Gray Test Patterns for Gamma=2.2

Zoom 100%. Please use large viewing distance
Zoom 200% avoids minor deviations in the dot patterns
These happen on cheap monitors because of low bandwidth

12.5%   25%   37.5%   50%

62.5%   75%   87.5%   100%

7. Red Test Patterns for Gamma=2.2

Zoom 100%. Please use large viewing distance
Zoom 200% avoids minor deviations in the dot patterns
These happen on cheap monitors because of low bandwidth

12.5%	25%	37.5%	50%
62.5%	75%	87.5%	100%
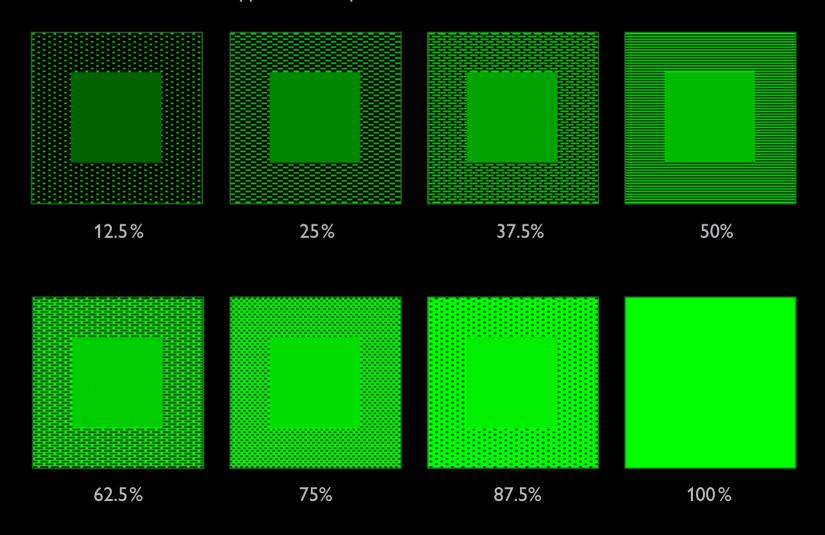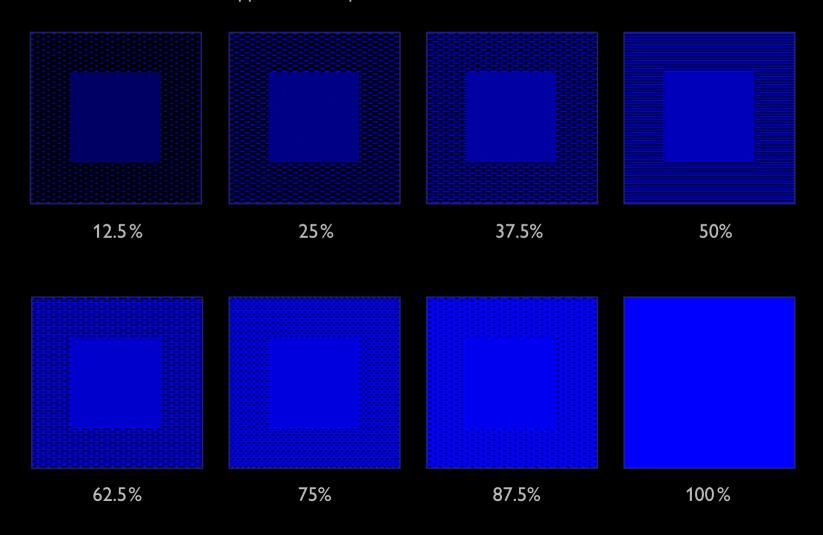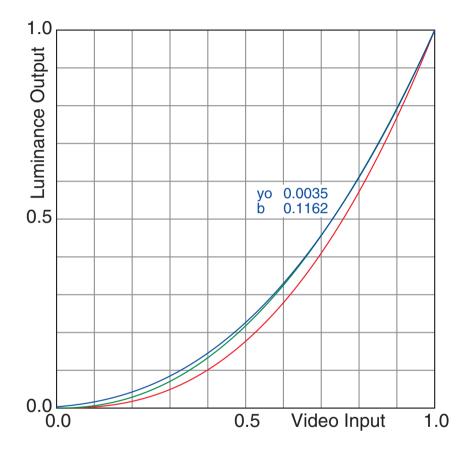
8. Green Test Patterns for Gamma=2.2

Zoom 100%. Please use large viewing distance
Zoom 200% avoids minor deviations in the dot patterns
These happen on cheap monitors because of low bandwidth

12.5%	25%	37.5%	50%

62.5%	75%	87.5%	100%

9. Blue Test Patterns for Gamma=2.2

Zoom 100%. Please use large viewing distance
Zoom 200% avoids minor deviations in the dot patterns
These happen on cheap monitors because of low bandwidth

12.5%	25%	37.5%	50%
62.5%	75%	87.5%	100%

yo	0.0035
b	0.1162

Red   G=2.5
Green   G=2.2
Blue   Effective tone reproduction curve

This diagram shows tone reproduction curves for one channel of a CRT monitor. The video input x is normalized for 0...1 for any channel R,G,B=0...255. The luminance output y(x) is normalized for 0...1.

We assign 0 to black and 1 to the brightest available value.

A typical CRT monitor delivers the not normalized luminance $L(x)=K(b+cx)^G$, according to [9], but somewhat simplified.

The input offset b represents the brightness. c means contrast.

For varying brightness and contrast, the function can be written normalized by $y(x)=(b+cx)^G/(b+c)^G$.

For generic uncalibrated monitors we have about G=2.5. This is the red curve for b=0.

The green curve shows the intended or desired tone reproduction curve $y_1(x)=x^{2.2}$.

The maximal luminance is typically $L_m=100cd/m^2$. The minimal luminance L_o is not zero but about $0.5cd/m^2$, here $0.35cd/m^2$.

b is calculated by $y(0)=y_o=L_o/L_m=b^G/(b+c)^G$, which delivers

$b=c/(y_o^{-1/G}-1)$.

The blue curve is valid for $y_o=0.0035$ and c=1. The effective Gamma is near to 2.2.

This shows that the effective tone reproduction curve is much affected by the black point settings.

Once the monitor is adjusted like here, then a further calibration by graphics card look-up tables (LUTs) does not require strong corrections.

11. Visual Effects of Wrong Gamma

Images are on PCs mostly optimized for Gamma=2.2. If the actual monitor is already calibrated, then the middle image should look correct.
Mac users have Gamma=1.8. They would see the image lighter, like the left image.
Users of uncalibrated monitors Gamma=2.6 would see the image darker, like the right image.

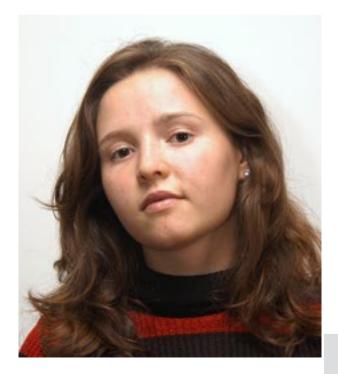Best view zoom 100% / all backgrounds should be visible as rectangles

Gamma=1.8	Gamma=2.2	Gamma=2.6

12. Visual Effects of Color Temperature
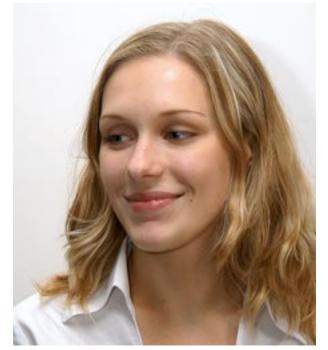
Test patterns for the color temperature are not available. If the monitor is already properly calibrated for D65 (6500K), which is widely accepted as a standard, then we can simulate the effect of other color temperatures.

The middle image should look as expected in D65. The left simulates D50 (5000K), the right D93 (9300K). In order to preserve the lightness, only the highlights were downscaled for maxima at 255 for Red (left) and Blue (right).

The effects look exaggerated, but measurements of the background, which is almost neutrally gray in D65, show left 5055K, middle 6573K and right 9157K (measured by X-Rite Monitor Calibrator). For a full size image one would adapt to expected colors (memory colors) and to the uniform background. The image would not look as red-ish or blue-ish, but still different. Blow up the right image by zoom 600% and wait.

Best view zoom 100% / all backgrounds should be visible as rectangles

13. Calibration by Instruments

These remarks refer especially to X - Rite Monitor Calibrator (former name Optimizer).
This instrument can apply Software Calibration by LUTs and measure a Profile for the transfer function between Video RAM and Monitor Luminance.
Software Calibration defines very precisely the shape of the curves L(N) and therefore the Effective Gamma values for R, G and B.

In the measurement diagrams the curves L(N) are always shown like curve C .

Pure Hardware Calibration is a tedious process of trial and error, until the perceptual correctness, equal curves R(N), G(N), B(N), a common Gamma value and an intended color temperature are achieved.
Lower Effective Gamma values will result if the Brightness is increased and the Contrast is decreased for the same visual lightness.
A higher color temperature results from increased Contrast for Blue and decreased Contrast for Red.

For any adjustment, the monitor should be warmed up for one hour. The instrument has to be calibrated actually.

Starting with 'native' monitor settings, which are in the region of 9300K and Gamma=2.5..2.6, can result in a poor calibration by instruments.
The calibration for D65 produces always a darker monitor, this cannot be avoided. The monitor is analyzed for bright settings, but the characteristics are a little different for darker settings. A simple forward calculation for the corrections is not safe.
An adjustment by hardware towards the desired appearance improves the accuracy dramatically:
Reduce Contrast for RGB equally, increase Contrast for R and decrease for B then, until the uncalibrated monitor looks nearly like the calibrated.
Achieved accuracies are in the region 50K and 0.01 for Gamma.

14. CIELab Graypatterns

The CIELab Graypatterns can be used for the final test if an instrument is available. The grays are numbered by L* values and packed into the PDF as LAB colors. For tests by Photoshop use mode Lab. For small values L*<9 we have L*=9 Y (L*, Y=0...100). Single Graypatterns are in chapter 19. The HTML version is converted into sRGB.

0	1	2	3	4	5	6	7	8	9	10

0	10	20	30	40	50	60	70	80	90	100

Software Calibration does not work
As mentioned above, any Software Calibration needs programmable TrueColor Lookup-Tables (three channels) on the graphics card and appropriate drivers.
Software Calibration does not work in some situations:

DOS
Windows NT
Old graphics cards

Matrox G400AGP , G450AGP
It depends on the Hardware Acceleration (HA)
HA =   0%   No calibration
HA = 100%   All functions
HA = 66%   May work

No calibration means
Adobe Gamma and other tools can measure a profile, but they cannot calibrate. It´s obvious because the color of the screen does not change. One may get a profile for a badly adjusted monitor.
In this case one should use Hardware Calibration.

Low bandwidth, page 8:
The large dot patterns consist of black and white pixels, independent of Gamma. The appearance of the inner gray squares depends on Gamma.
Video signal amplifiers cannot reproduce signal jumps from 0.0V to 0.7V in infinite short time.
The transisition time is shorter for a larger bandwidth.
The bandwidth itself is the difference of the upper and the lower cut-off frequencies.
Simplified: the upper cut-off frequency. Here we have the signal attenuation 0.707 instead of 1.0 .
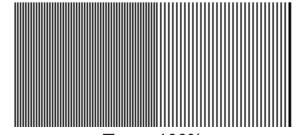
For zoom 200% at least 4 coherent black or white pixels are shown in a row, therefore the transition time is less relevant.

The bandwidth is also affected by Moiré reduction: low-pass filters may reduce the bandwidth further.

1 line   1 line
1 gap   2 gaps

Zoom 100%

17. Nomenclature

Luminance
Luminous intensity per area, a measurable quantity

Brightness
Attribute of a visual sensation, according to which an area appears to exhibit more or less light
Also the adjustment input for a monitor

Lightness
The brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting

Color Temperature
Represents a typical white
5000 K   More red, less blue, daylight for prints
6500 K   Normal impression, daylight
          Standard for monitor image processing
9300 K   Less red, more blue, cold impression
          Standard for uncalibrated monitors
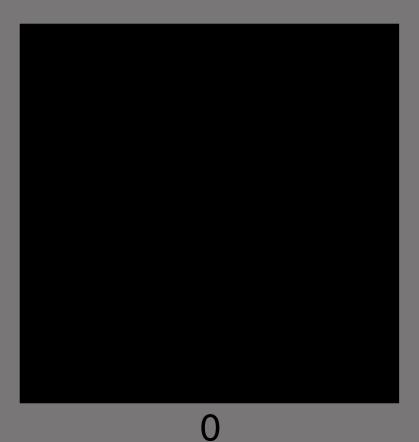
18. References
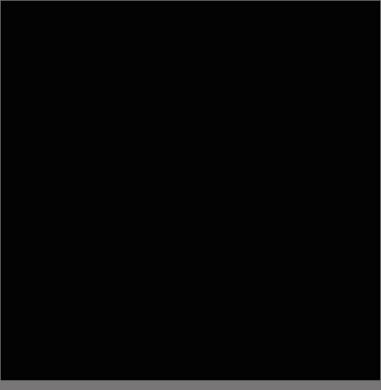
[1]   R.W.G.Hunt
       Measuring Colour
       Fountain Press England, 1998

[2]   Everything about Color and Computers
       http://www.efg2.com

[3]   M.Nielsen + M.Stokes
       The Creation of the sRGB ICC Profile
       http://www.srgb.com/c55.pdf
       Year unknown, after 1998

[4]   International Color Consortium
       http://www.color.org

[5]   T.Autiokari
       Accurate Image Processing
       http://www.aim-dtp.net
       2001

[6]   G.Hoffmann
       CIELab Color Space
       http://docs-hoffmann.de/cielab03022003.pdf

[7]   G.Hoffmann
       CIE (1931) Color Space
       http://docs-hoffmann.de/ciexyz290800.pdf

[8]   This doc by HTML
       http://docs-hoffmann.de/caltutor.html

[9]   R.S.Berns + N.Katoh
       Methods for characterizing displays
       in P.Green + L.MacDonald (Editors)
       Color Engineering
       John Wiley& Sons, 2003

       This doc
       http://docs-hoffmann.de/caltutor270900.pdf
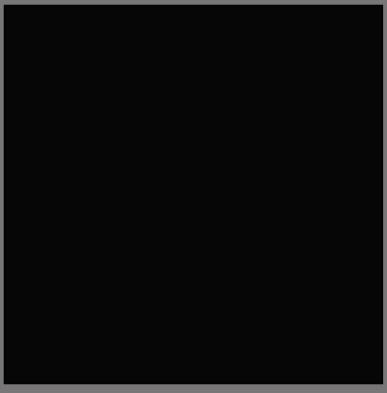
19.000 CIELab Single Graypatterns

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