Curves and Histograms

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Contents

Introduction

The concepts of curves and histograms are basic to working with digital images. This document explains what they are, how to interpret them and how to use them to get the effect you want. Once you understand histograms and curves you will be able to:

- Lighten images without losing highlight detail.
- Darken images without losing shadow detail.
- Adjust mid-tones without altering shadows or highlights
- Control brightness and contrast precisely for each part of the tonal range.
- Evaluate image quality.
- Create special effects.

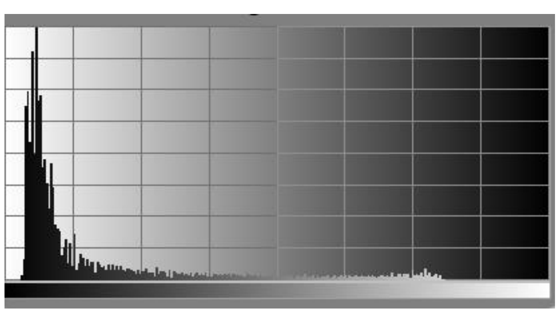
What is a Histogram?

Thanks to digital cameras, most photographers have at least a passing acquaintance with histograms. The term histogram has several meanings. Originally a graphical tool developed by statisticians to visualize frequency distributions, it has come to have a very specific meaning when used to characterize digital images.

To keep it simple, we'll start with black and white images—later we'll see how the same concepts work in color. In 8-bit black and white images, each pixel has a brightness level between 0 and 255. Pure black corresponds to 0 and pure white corresponds to 255. Most observers, even under ideal conditions, can barely distinguish 200 different gray levels, so the 256 available gray levels in a digital image, if properly used, are usually more than adequate to represent even the most subtle variations in a black and white image.

How histograms are computed

Imagine a row of 256 buckets, the first one labeled 0, the next one labeled 1, and so on up to 255. The histogram of an image such as the one shown below is computed by examining each of its pixels in turn and tossing it into the bucket that corresponds to its brightness level. When we're done, we count how many pixels are in each bucket. Picture Window displays histograms as a graph that looks like this:



The gray scale along the bottom of the histogram indicates the brightness level of each bucket, starting with 0 at the left (black) and progressing up to 255 on the right (white). For each brightness level, there is a vertical white line who height is proportional to how many pixels in the image have the corresponding brightness level. To make the display fit the available space, pixel counts are scaled vertically so the tallest line runs all the way from the bottom to the top of the graph. This means you cannot directly compare the heights of peaks in two different histograms.

How to Interpret Histograms

The basic idea is simple: where you see a tall line in a histogram display, it means there are a lot of pixels of the corresponding brightness level in the image. Where you see a short line or no line there are very few or no pixels of that brightness level.

The histogram says nothing about where the pixels are located within the image, just how many of them have a given brightness level. You get exactly the same histogram if you rearrange all the pixels in the image as long as you don't change their brightness.

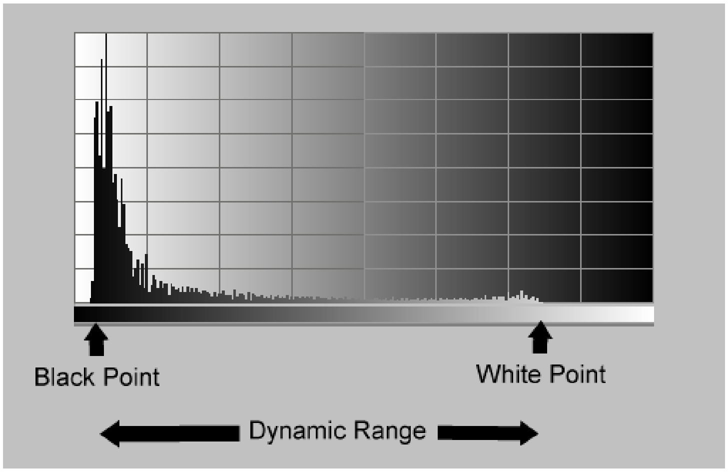
Determining Overall brightness

The first thing we can tell about the example image above based on its histogram is that most of it is dark since most of its pixels have relatively low brightness levels as indicated by the lines at the left of the histogram being much taller than those at the right.

Each image has its own unique distribution of light and dark tones—there is no right or wrong histogram. If an image is made up of all one shade of gray, then the histogram of that image consists of a single line corresponding to that gray level. If it is part one gray and part another, then it would have two lines, one for each gray level, and their relative heights would reflect how much area of the image is covered by each gray. If the image is a smooth gradient going all the way from black to white, each of the lines in the histogram would be the same height since there would be equal numbers of pixels of each brightness level.

Dynamic Range

The next thing we can tell about an image from its histogram is its darkest shadow and lightest highlight, sometimes called the black point and the white point.

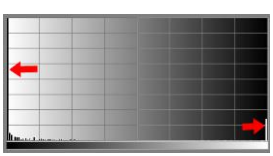


If the histogram is 0 there are no pixels of the corresponding brightness, so we can see that where the histogram drops to 0 on the left (marked Black Point), there are no pixels in the image darker than this. Similarly, where the histogram falls to zero on the right (marked White Point), there are no brighter pixels in the image. These two points define the dynamic range of the image—the range between its darkest and lightest parts.

We can see from looking at the histogram of this image that its shadows do not go all the way to pure black and that its highlights fall short of pure white. The greater the dynamic range of an image, the more contrast it has. If all the lines in the histogram fall in a narrow range, the image has only a small variation of gray levels and will consequently have very low contrast. Whether this is good or bad depends on the effect you want to achieve.

Shadow and Highlight Clipping

A spike in the histogram at the black or white end is an indication that shadows or highlights have been clipped. This can be a legitimate creative choice, but usually it indicates underexposure or overexposure with an associated loss of shadow or highlight detail.



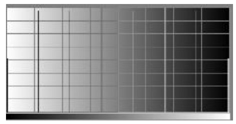
The best way to avoid this is by adjusting the brightness of the image during raw file conversion when you have access of the full exposure range of the sensor.

Posterization -- How smooth is the histogram

Posterization occurs when an image is rendered using a limited set of colors or gray levels. The smoothness of a histogram can tell you how well the image represents subtle tonal variations.

Smooth

Posterized



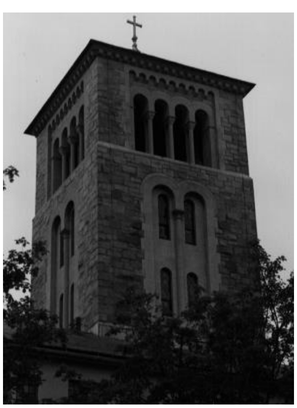
Histograms

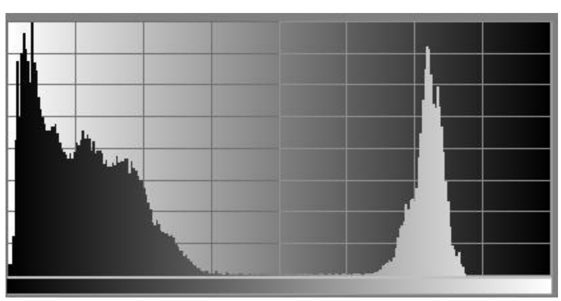
The more the histogram consists of isolated spikes separated by empty spaces, the more the image is posterized. While intentional posterization can be a striking special effect, in normal images excessive posterization of an image indicates a loss of subtle tonal detail which in turn can mean lower image quality. Posterization can be caused by starting with a posterized original or by excessive or extreme image manipulation.

Even if you start with a digital image that has a nice smooth histogram that covers the entire tonal range, each time you perform operations on the image that change its brightness curve such as trying to bring out shadow, mid-tone, or highlight detail, you will unavoidably lose some brightness levels. The best way to keep this loss of tonal variation from becoming visible in the image is to start with 16-bit images derived from raw files. This gives you enough extra brightness levels that even after you lose some, the effects will usually be negligible. The more radical the changes you make, the more likely you are to introduce visible artifacts. For example, if you heavily brighten a severely under-exposed image to bring out shadow detail, in addition to amplifying image noise, you will also likely introduce some posterization.

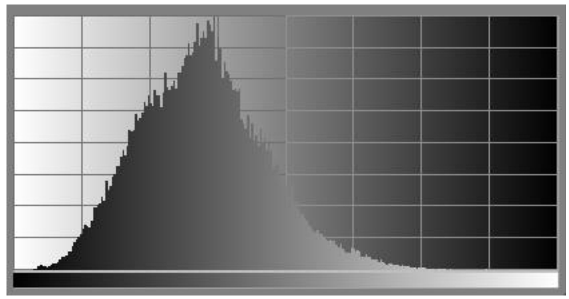
Two Images and Their Histograms

To help you understand the relationship between an image and its histogram, here are some examples:



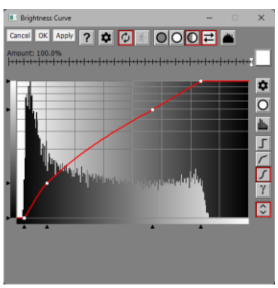


The histogram of this image has two peaks, a broad one in the shadow area and a narrower one in the light gray area. These correspond to the foreground and building which are large and dark and the background sky which is a fairly uniform gray. The area under a peak is proportional to the percentage of the pixels in the input image that have a particular brightness range; the width of the peak indicates the brightness range it covers. As you can see, while this image has plenty of dark tones, it does not go all the way to white which makes it somewhat dingy. Also, there are essentially no mid-tones, which is typical of images that silhouette a dark subject against a light background or vice versa.



This image has a fairly smooth histogram. Note that it does not go all the way down to black or all the way to white, but that is normal for this type of image because the original scene lacked contrast.

The Brightness Curve Transformation



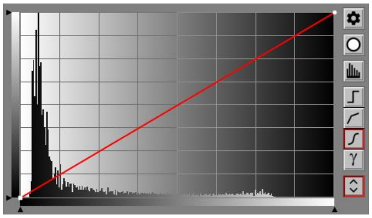
While curves can be used to adjust any channel of an image, by far the most common use is to adjust brightness. Picture Window’s Brightness Curve transformation lets you work with curves and histograms to adjust the brightness and contrast of your images.

Within the Brightness Curve transformation, curves and histograms are adjusted using a Curve control. This same control is also incorporated into many other transformations, so once you master it you will also know how to use it in other contexts.

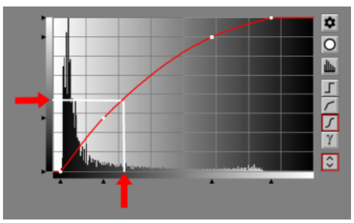
The Brightness Curve transformation is based on a very simple principle. Each pixel in the output image is computed by applying a curve to the corresponding value in the input image. The curve is just a table of 256 values, each corresponding to a brightness level from 0 to 255.

For each input pixel, its brightness is changed to the value found in the corresponding table entry and the result is stored in the output image.

For example, suppose the table simply contains the sequence of numbers from 0 to 255. Then the output image will be an exact copy of the input image because brightness level 0 is set to 0 and so on up to 255. If we draw a graph of this table, we get a curve like this—a straight line running diagonally from the lower left corner (0,0) to the upper right corner (255,255):



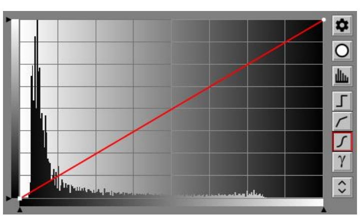
To see what the curve will do to a pixel of a given brightness, locate its gray level along the horizontal axis, run a vertical up from that point to the curve and then run a horizontal from the intersection point over to the vertical axis and read off the corresponding brightness value in the output image.



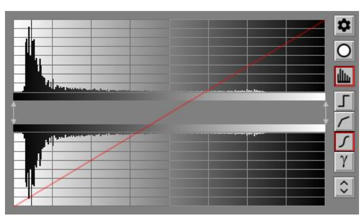
Switching between Curve and Histogram

The Curve control lets you work with curves and histograms at the same time. You can view the curve in the foreground with the input image histogram displayed in the background, or you can view the input and output image histograms with the curve displayed in the background.

To switch from one view to the other, use the  button to the right of the curve display.



Curve Display



Histogram Display

When you click the  button, the display switches over to show you two histograms, one above the other. The top histogram is for the input image and remains unchanged unless the input image changes. The bottom histogram is displayed upside down and shows you what the histogram of the output image will be after applying the curve to it. This histogram changes as you experiment with different curves. For each control point (see below) on the curve, Picture Window displays a pair of arrow heads connected by a line. The top arrow head defines a brightness level in the input image and the bottom arrow head the brightness level it will be changed to in the output image.

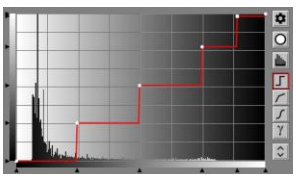
Control points

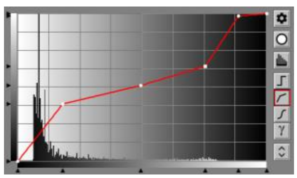
There are several ways to alter a curve. The simplest is to click and drag one of the little circles that indicate control points on the curve. Initially, there are just two of these, one at either end. To create additional control points, shift-click on the curve where you want the new control point to appear. To remove a control point, position the cursor over it and ctrl-click. Neither the first nor the last control point can be removed.

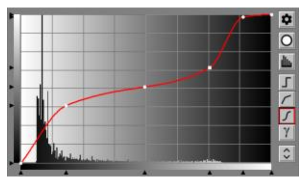
The current control point (usually the one you most recently added or moved) is displayed as a small square. The other control points are displayed as small circles.

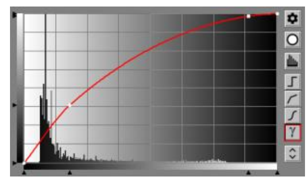
The curve always passes through all the control points, no matter how many you create. The more points you add, the more control you have over the shape of the curve. In practice, however, only a small number of control points are required for most operations. There are many different shapes of curves that can be passed through the control points.

Here are some examples of the four different types of curves:


Stair Step


Broken Line


Smooth


Gamma

Gamma only applies if there are exactly three control points. If there are more than three, it switches to Smooth; if there are less than three, it switches to Broken Line.

For the most part, control points can be moved freely, but you cannot move one control point past another horizontally. To move a control point, simply position the cursor over it until the cursor changes to a crosshair and then click and drag it to the desired location. In the curve display, for each control point there are a pair of arrowheads displayed one along the bottom edge of the graph and one along the left edge. These arrowheads track the motion of the corresponding control point. You can move a control point in a single direction, either horizontally or vertically, by clicking and dragging the corresponding arrowhead.

Adjusting control points from the histogram display is even simpler. All you need to do is click and drag one of the upper or lower arrow heads. To insert a new control point, shift-click anywhere along the base of the upper histogram; to remove a control point, position the cursor over the upper arrowhead and ctrl-click.

Adjusting dynamic range

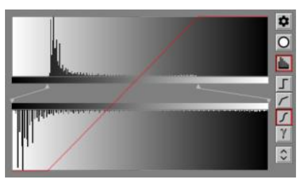
You can either increase of decrease the dynamic range of an image very easily using the double histogram display.

Start by positioning the upper arrow heads to the black and white points of the image. These correspond to the darkest and lightest points in the input image. Then move the bottom arrow heads to where you want the black and white points to be in the final image. In changing the histogram control points, you are simultaneously changing the control points of the curve. For reference, the curve is displayed in the background along with the histograms.

Moving the bottom arrowhead for the black point lightens or darkens the shadow areas. Moving the bottom arrowhead for the white point lightens or darkens the shadow areas. The farther apart you move the two arrowheads, the greater the spread of tonal values in the resulting image and hence the greater the contrast. The closer you move them to each other, the narrower the range and the less the contrast.

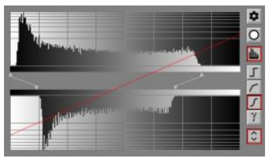
Using the full dynamic range

To make the image use the entire available tonal range from black to white without losing highlight or shadow detail, position the top arrow heads at the black and white points and the bottom arrow heads at the far left and far right of the brightness scale. Notice that the slope of the corresponding curve gets steeper the more the contrast is increased. Picture Window expands the dynamic range automatically when you select Autorange from the curve settings menu.

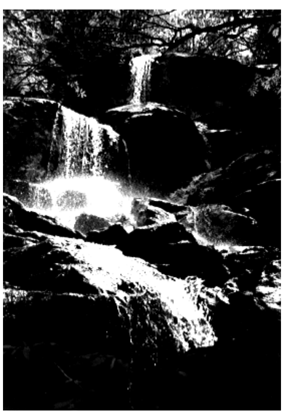

Reducing dynamic range

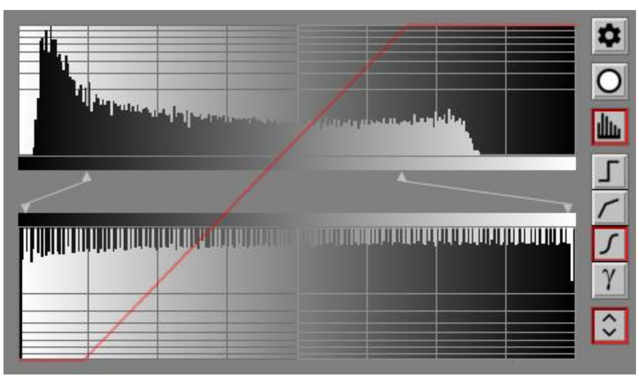
To reduce dynamic range, move the bottom arrow heads closer together. Moving the lower left arrowhead to the right lightens the shadows; moving the lower right arrowhead to the left darkens the highlights. The closer together you move the bottom arrow heads, the lower the contrast. Notice that the slope of the corresponding curve gets more horizontal the more the contrast is reduced.



Creating extreme contrast

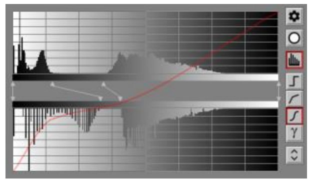
If you move the upper left arrowhead right past the black point, you will continue to increase the contrast of the image but you will start to lose shadow detail; if you move the upper right arrowhead left past the white point, you will continue to increase the contrast of the image but you will start to lose highlight detail. You can tell this is happening because the bottom histogram will start to show a sharp spike at black or white. If you see an image with this kind of histogram it is a sign that it was either over- or under-exposed or that somewhere in the manipulation of the image it was lightened or darkened too much. Of course, if you want to create a dramatic high contrast image, this effect may be exactly what you want.





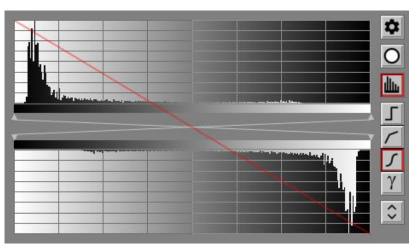
Other ways to use the full range

In this example, the original image has a bright sky and a dark foreground. There are two parts of the histogram that indicate parts of the tonal range that are unused—the gap between the shadows and highlights and another gap above the highlights. To take advantage of the unused brightness levels, you can stretch to shadows and highlights in the image to fill the whole range as illustrated below:


Creating a negative image

If you reverse the positions of the bottom arrow heads, you get a negative image. The bottom arrow heads correspond to the brightness levels you want in the final image. If you move the lower left arrow head all the way to the right, you are telling Picture Window to make the dark parts of the image light; if you move the lower right arrow head all the way to the left, you are making the light areas dark. Changing dark to light and light to dark gives you a negative. Notice that the corresponding curve slopes downward instead of upward.

Using Curves to adjust brightness and contrast

While histograms are a powerful tool for adjusting the dynamic range of an image, curves are often better for adjusting its brightness and contrast. You can switch back and forth between the two methods at any time.

Here are a few very important things to keep in mind about curves:

- Where the curve lies above the diagonal line connecting the lower left corner to the upper right corner, it will lighten the image; where it lies below the main diagonal it will darken the image. The closer the curve lies to the main diagonal, the more subtle its effect on the image; the farther away, the stronger the effect.
- Where the curve rises steeply, it will increase the contrast of the image; where it rises slowly, it will decrease the contrast. Increasing the local contrast in one part of the tonal range always decreases it in another part.
- Where the curve is flat, the image will be posterized.
- Where the curve slopes downward, the image will be a negative or solarized.
- Kinks in the curve usually produce some kind of artifact in the image. Unless you are trying to create special effects deliberately, try to keep your curves smooth.

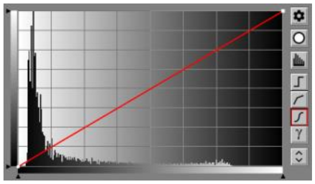
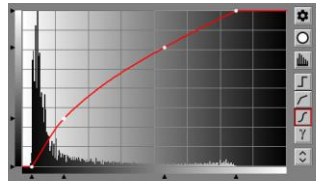
To fully control brightness and contrast, you will usually need to add control points to the curve. Additional control points give you more control over the shape of the curve since the curve always passes through each control point. To add a new control point, first position the cursor over the curve display where you want the new point to be and then shift-click. To remove control points (except for the first and last point which cannot be removed), position the cursor over the control point and ctrl-click.

Lightening or darkening an image

Let's continue using the same image and assume that we have just used the histogram to increase its dynamic range to go all the way from black to white, but we still want to lighten it up to help bring out some of the shadow detail.

The first way you might think of to brighten an image is to add a fixed amount to each of its brightness values. This corresponds to shifting the entire curve upward or shifting the entire histogram to the right. The problem with this approach is that it can lighten the darkest shadow areas, but it can cause loss of highlight detail and weaken the blacks. This shows up in the histogram as a blank space at the left end of the histogram and spike at the right end indicating that multiple brightness levels at the lighter end of the scale have all been changed to the same maximum level. A similar problem occurs when attempting to darken an image by shifting its histogram to the left. To avoid this difficultly, we need to lighten or darken intermediate brightness levels while leaving the black and the white points unchanged. Here's one way to do it:

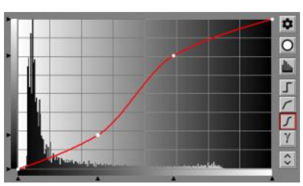
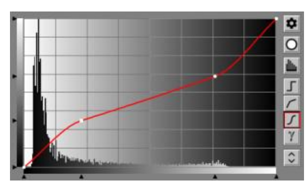
First add two intermediate control points in the middle of the curve and then position them as illustrated below on the right. Make sure you leave the first and last control points fixed as these determine the dynamic range.

Since the curve lies above the main diagonal, it is lightening the image. Because it slopes steeply on the left, it is increasing the contrast in the shadows; since the slope is flattened in the highlight area, we are reducing the highlight contrast. The result is a brighter image with a lot more shadow detail. To darken an image, arc the curve downward (below the main diagonal) instead of upward.

Increasing or decreasing mid-tone contrast

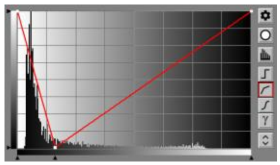
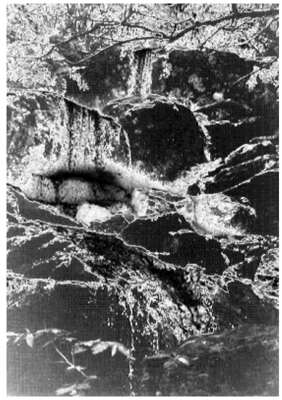
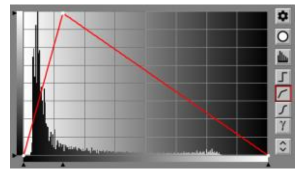
When people talk about increasing or decreasing the contrast of an image, they are usually talking about increasing or decreasing its mid-tone contrast. Bear in mind however that you cannot increase contrast in the mid-tones without decreasing either the shadow or highlight contrast or both. Increasing the mid-tone contrast involves lightening the highlights and darkening the shadows. Reducing the mid-tone contrast means lightening the shadows and darkening the highlights. The curves look like this:

Special effects -- solarization

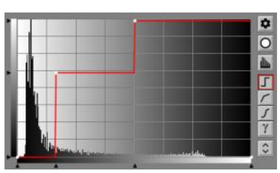
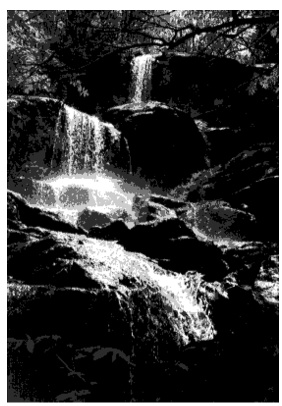
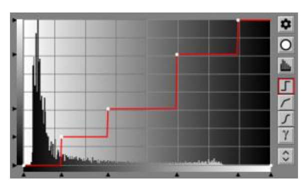
Solarization is a special effect where part of the tonal range is inverted. This creates an image which is part positive and part negative. To solarize, you need to make part of the curve slope upward and part slope downward.

For solarizing, a broken line curve often gives the best results. The following examples illustrate different types of solarization and the curves that produce them.

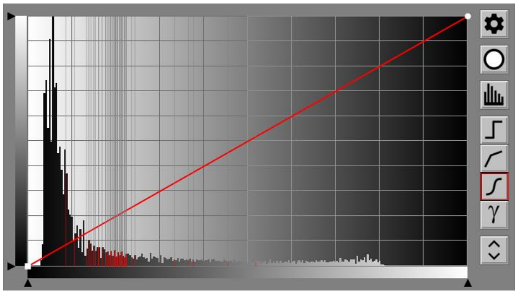
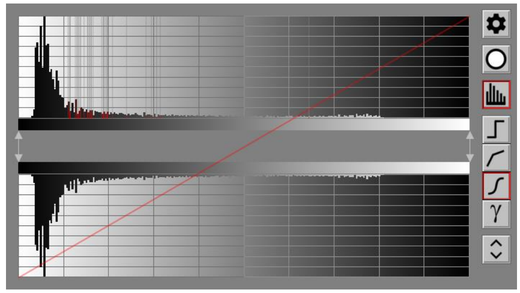
Special effects -- posterization

Posterization is the result of rendering an image using a limited number of gray levels. This creates an image made up of areas of solid color, something like a silk-screened poster. To posterize, you need to make a curve that has a series of stair steps . To create more gray levels, add more control points; the more levels you use, the more subtle the effect. If the stair step curve runs primarily above the main diagonal, the posterized image will be brighter than the original; if it runs below the diagonal, the result will be darker. You can combine posterization with solarization for additional effects. The following examples illustrate two different posterization curves and the effects they produce. The first example uses only three gray levels (black, white and a fairly light gray); the second uses five (black, white, and three intermediate grays).

Using the probe

When the brightness curve transformation is active, its probe is enabled. This means that as you drag the cursor over the input image, a red marker line appears in the curve or histogram display to show you the brightness value of that part of the image. The marker line highlights the input histogram display as illustrated below. The point where the vertical red line intersects the gray scale at the bottom of the curve or histogram is an indication of the brightness of the input image at the probe's location.

The brightness probe is a very useful tool. For example, suppose there is one specific part of an image that you want to lighten or darken. You can start by activating the probe and clicking and dragging the cursor over the region in the input image you want to alter. By noting where the marker shows up on the curve or histogram display, this will show you what part of the tonal range needs to be changed. To lighten or darken that part of the tone scale, you can use either the curve or the histogram.

Either way, the first step is to create a new control point at the brightness level of the region you want to change. There are two ways to create a new control point:

- Shift-clicking over a part of the input image representative of the brightness level you want to modify automatically inserts a new control point at the corresponding point in the curve or histogram. You can tell which new control point you added since it becomes the current control point and is therefore displayed as a small square instead of a small circle.
- Shift-clicking over the curve or upper (input) histogram where you want the new control point to appear inserts a new control point at the cursor location. You can base the location on the results of previous probing of the image.

The next step is to apply brightness corrections using the curve or histogram.

If you are using the curve, then drag the new control point up to lighten or down to darken -- the farther you move it, the brighter or darker that part of the tonal range will become.

If you are using the histogram, then drag the control point's bottom arrowhead to the right to brighten or to the left to darken.

To increase or decrease the contrast for the part of the image corresponding to the new control point, adjust the curve to increase or decrease its slope as it passes through the control point.

If you start changing other parts of the image that you don't want to modify, you can probe them and create additional control points to control their brightness independently. If you end up creating a curve that is not smooth, it will probably result in some kind of visual artifact in the result image since the local contrast will either be very low or very high in some parts of the brightness scale. If this happens, switch to the curve view and adjust the control points to make the curve smoother. If you can't get the effect you want on one region without adversely affecting other parts of the image, you will need to create a mask that isolates the region you want to adjust. This lets you restrict the transformation to a specific part of the input image.

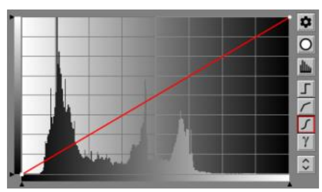
Histogram Expansion

When Picture Window displays a histogram, it automatically sets the vertical scale so the largest value just fills the available space between the top and the bottom of the graph. If a histogram happens to contain one very tall spike, this can create a situation where the rest of the information in the histogram is reduced so much that it disappears or becomes too small to interpret.

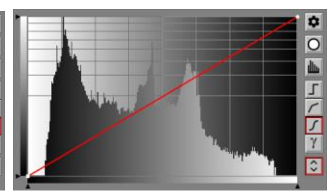
If this happens, you can use the  button to magnify small values and reduce large values. This expanded scaling lets you see both the small histogram values and the large ones at the same time even if the large ones are huge and the small ones are tiny. However, when using histogram expansion, you must bear in mind that large values are actually much larger than they appear, and small values are much smaller.

Histogram expansion helps you identify the true white and black points of an image when adjusting its dynamic range as shown in the following example:

Input image



Histogram



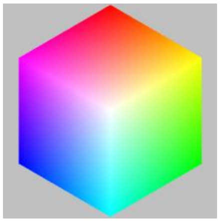
Expanded Histogram

Here, the darker tones cover so much more area of the input image than the white snow that the bright end of the histogram is scaled way down. Once the histogram is expanded however, these smaller values are exaggerated and become easily visible. Had you adjusted the dynamic range of the image based on the unexpanded histogram, you would have clipped all the highlight detail.

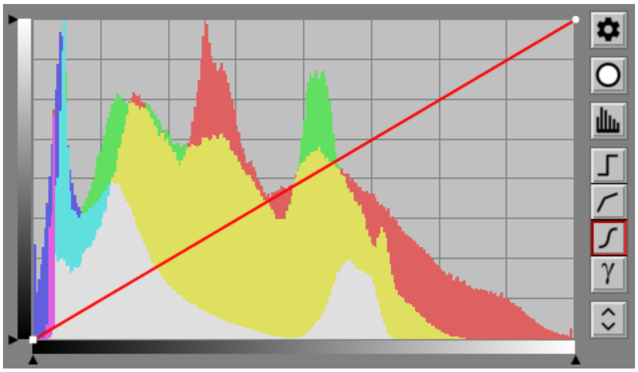
Working with color images

Everything so far has dealt with black and white images, but what about color? For color images there are many different ways to compute histograms. We could compute separate histograms for the red, green, and blue components of the image or, what is often more useful, we can use the HSV or HSL color space and just histogram the brightness component, ignoring the hue and saturation. This lets us work with the brightness of the image without worrying about changing its color.

Interpreting a color brightness histogram requires some understanding of the underlying color model. In the HSL model, a brightness level of zero corresponds to black and a maximum brightness value corresponds to white. In the HSV model, zero brightness still corresponds to black, but the maximum brightness value corresponds to any color whose red, green, or blue component is maxed out at 255. This includes all the colors in the color hexagon.



When you select the RGB color model, Picture Window displays superimposed histograms of each channel.



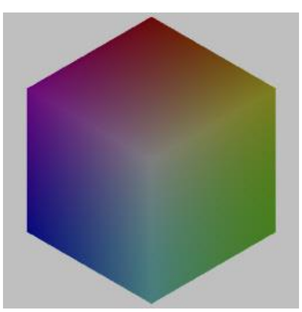
The main thing to remember about the difference between HSV and HSL color spaces is that when you lighten an image using HSV, the colors get brighter while remaining fully saturated, but they never reach pure white. As you lighten using HSL, colors all approach pure white but become progressively more washed out. Choose the color space according to the effect you want to achieve.

Examples – HSV vs HSL

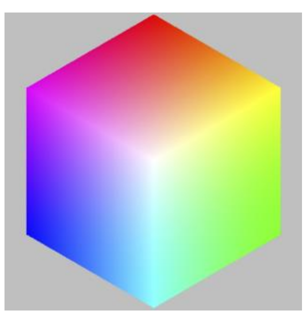
Both HSV and HSL work similarly when lightening or darkening dark pixels, but their effect on light pixels is somewhat different. Here is a summary of the differences and some examples.

HSV

Lightening bright pixels in HSV makes colors brighter since 100% HSV V contains all the brightest colors. Conversely, darkening highlights in HSV makes them duller.

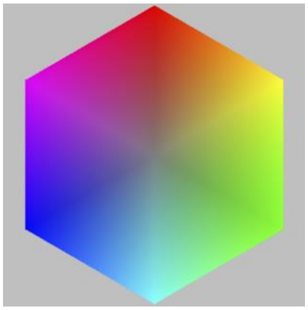


50% HSV V

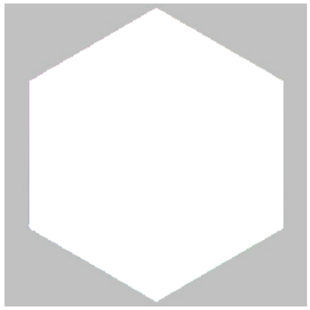


100% HSV V

HSL



50% HSL L



100% HSL L

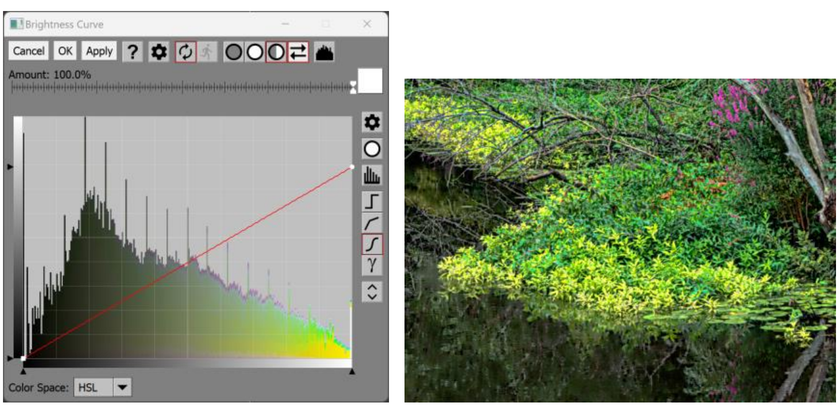
Lightening bright pixels in HSL makes them washed out since 100% HSL L is pure white. This can be used to create the effect of very bright light.

Darkening highlights in HSL makes them more colorful since 50% HSL L contains the brightest colors. This can be a good way to restore color to washed out highlights.

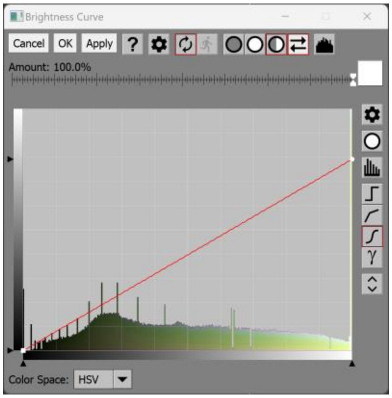
Examples

Darkening highlights:

Original Image



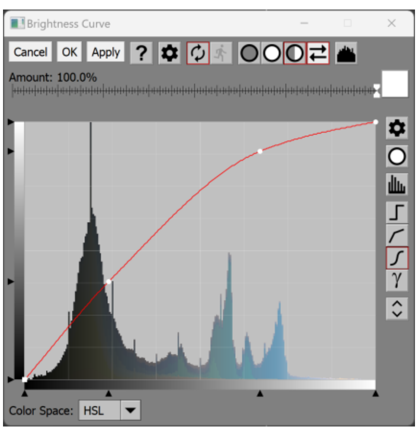
Darkened using HSL



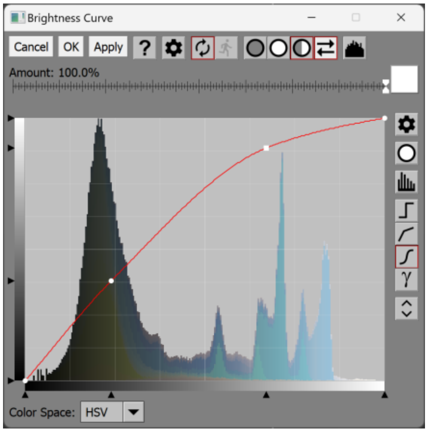
Darkened using HSV

Lightening highlights:

Original Image



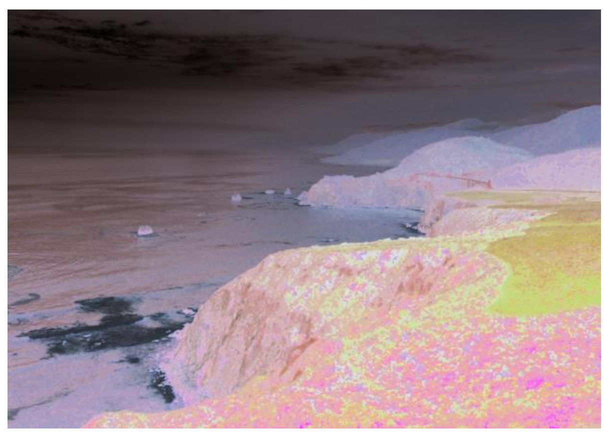
Lightened using HSL



Lightened using HSV

RGB is not recommended for lightening or darkening images. When you use this color space, the same curve is applied to each of the three components of the image which can result in hue and saturation shifts in different parts of the image. Working in HSV or HSL avoids this problem. On the other hand, when using the Brightness Curve transformation to produce special effects like solarization and especially posterization of color images, sometimes the best results are obtained using the RGB color space instead of HSV or HSL. For example, creating a negative image using RGB yields an image where each color is replaced by its complement and light colors become dark and vice versa. The same effect applied in the HSV or HSL color space leaves the hue and saturation of each pixel the same and just inverts the brightness—the effect is very different:

Negative using RGB

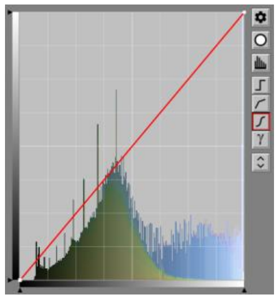


Negative using HSV

Color Histograms

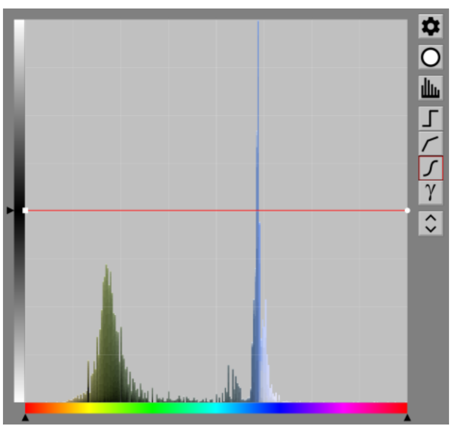
Histograms of black and white images are displayed in a black and white. For color images, the vertical histogram bars are colored instead. For example, a histogram of the HSV-V or HSL-L channel of a color image is colored according to the hue and saturation of the colors in the image for each brightness level. This makes it easier to see the relationship between a color image and its histogram by identifying how colors are distributed in the image according to their brightness as in the following example:

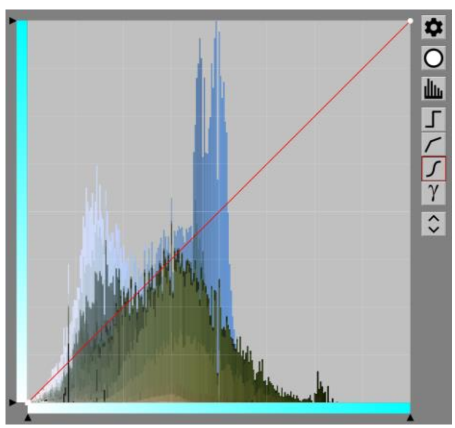

Input Image


Histogram

From the histogram you can see how the central peak corresponds mostly to the green foliage and the area to the right of the peak corresponds mostly to the sky. If you want to adjust the brightness or contrast of the sky or foliage, you can see what part of the curve you need to work on. Similarly, hue histograms are colored by saturation and brightness, and saturation histograms are colored by hue and brightness.

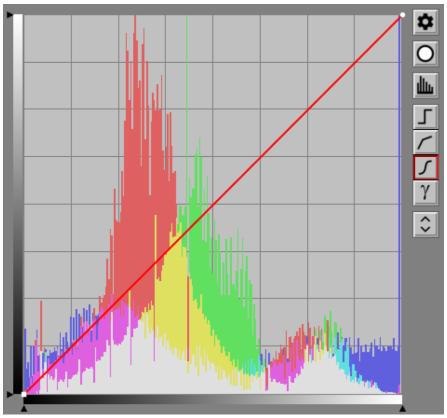
Here is what the hue and saturation histograms of this same image look like:


Hue Histogram

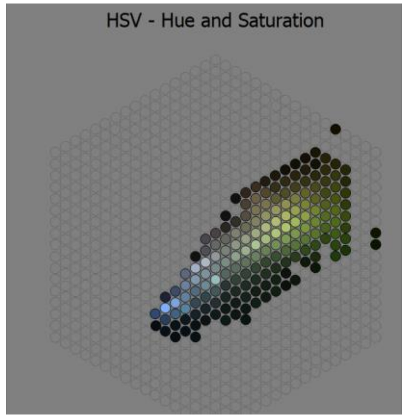

Saturation Histogram

RGB histograms simply display red, green and blue histograms superimposed.

Certain tools and transformations make use of a 2-dimensional hue-saturation histogram. The hue saturation histogram subdivides the normal color hexagon into a number of color samples. The brightness of each one is proportional to the number of pixels in the image having the corresponding hue and saturation, regardless of their brightness.



RGB Histogram



Hue-Saturation Histogram

From the RGB histogram, you can see the blue channel of this image is clipped.

From the hue-saturation histogram you can see the colors in the image occupy a relatively small part of the color space and which ones are the most common.

Color Curves

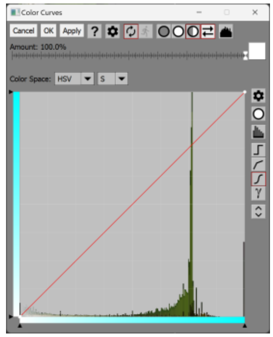
So far, we have seen how curves and histograms work to adjust image brightness as this applies to both black and white and color images and is the most common type of curve adjustment. However, curves can also be used to adjust hue and saturation, primarily using the Color Curves or Conditional Curves transformations:

Saturation Curves

You can use curves to adjust saturation the same way you use them to adjust brightness. The main difference is that instead of using the Brightness Curve transformation you use the Color Curves transformation. This transformation lets you work in HSV, HSL or RGB and adjust hue, saturation, brightness or the red, green or blue channels.

If you select saturation, then the histogram you see is based on the saturation of the image going from pure white (fully unsaturated) to pure cyan (fully saturated).

Input image



Color Curves

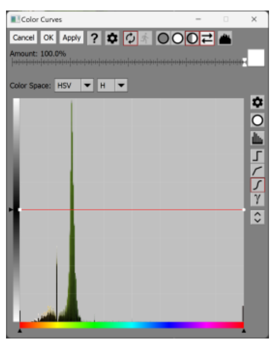
Everything works the same as adjusting brightness including the double histogram display, the probe, and the procedure for adding or removing control points to the curve.

Hue Curves

You can also adjust hue using the Color Curves transformation, but it works a little differently because hue is an angle, so 0 degrees is the same as 360 degrees. This means the left edge of the hue curve, which is by convention red, is also the same hue at the right edge and therefore the curves must match up at the ends. Changing hue is done not by setting the desired value, but by specifying a clockwise or counter-clockwise hue shift.

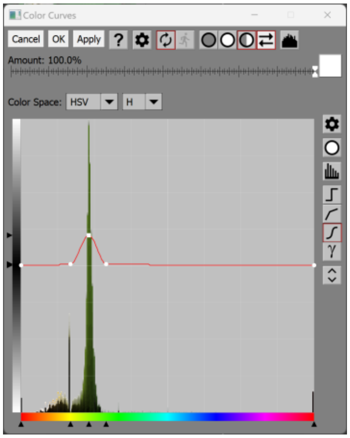
When you start out, the initial curve is a straight line that runs horizontally, cutting the graph in half. The hue histogram is shown in the background.

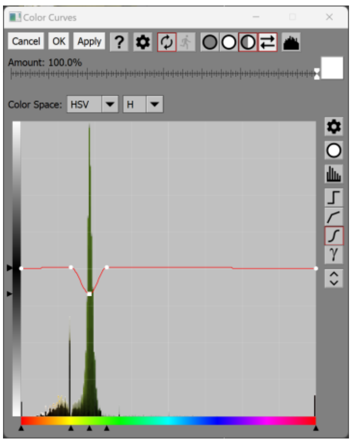
Input image



Color Curves

The histogram shows a peak in the yellow-green that corresponds to the green leaves in the input image. If you drag that part of the curve upward, you shift the hue clockwise (towards cyan). If you drag it downward, you shift the hue counter-clockwise (towards yellow).

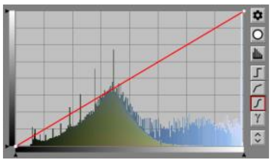


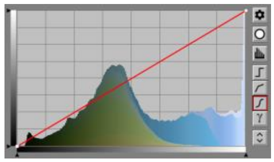


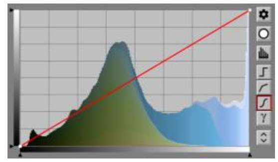
The first and last control points for hue curves cannot be moved horizontally, and adjusting one changes the other to match.

Histogram Smoothing

Curve controls have their own settings menu which you can access via the  button displayed just to the right of the curve area. The last group of three items in the menu lets you select how much histogram smoothing (none, moderate, heavy).


No Smoothing


Moderate Smoothing

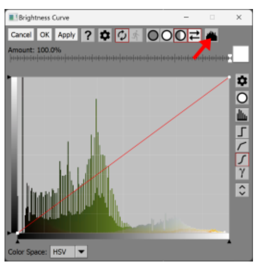

Heavy Smoothing

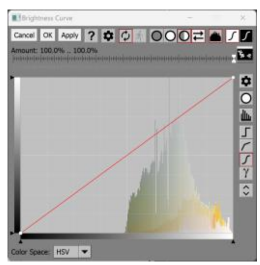
Smoothing noisy histograms can make them easier to interpret since fluctuations from one brightness level to the next do not make much of a difference in the image. Turning histogram smoothing off makes it easier to evaluate how noisy the histogram is – a noisy histogram can be a sign of reduced image quality.

Using Curves with Masks

When you are applying a curve to an image and using a mask to change just part of the image, the histogram can be misleading since it includes pixels from the entire input image. All the transformations that apply curves to image have an extra button in the upper right corner of their dialog boxes to deal with this.


Image with Mask


Histogram of Entire Image


Histogram of Masked Area Only

If  is depressed, the histogram in the curve control is based just on the parts of the input image where the mask is white. Parts of the input image where the mask is gray, make a partial contribution to the histogram. Parts of the input image where the mask is black make no contribution.

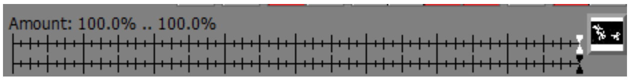
If the button is not depressed, the histogram is based on the entire input image.

White/Black Curves

When using the Brightness Curve transformation with a mask, this two-button tool bar is displayed in the upper right corner of the dialog box. The transformation actually supports two complete groups of settings – one for where the mask is white and one for where it is black.

Clicking the White Curve button displays the white settings and clicking the Black Curve button displays the black settings. This lets you apply one curve to the masked parts of the input image and a different curve to the un-masked areas, so for example you could lighten one part of the image and darken the rest at the same time. The default black curve has no effect on the output image, so you don't need to do anything special if you don't want to use it.

When you use a mask, in addition to the White/Black Curve buttons, the Amount slider is replaced by two sliders – one that lets you scale back the effects of the white curve and the other that scales back the effects of the black curve.



The black slider remains hidden until you define a black curve.

Composing Curves

The idea behind composing two curves is to create a new curve whose effect is like applying the first curve to produce a temporary image and then applying the second curve to that temporary image.

Assume you have two curves: A and B, and that each one has been saved in its own curve file. To create a curve C that combines the effects of applying curve A followed by curve B:

- Click the button in the curve control and select Load… from the settings menu. Then select curve B to load it.
- Click the button in the curve control and select Exact Compose With… or Approximate Compose With… from the settings menu. Then select curve A to compose the two curves.
- This adjusts all the control points in the curve B according to curve A to produce curve C.

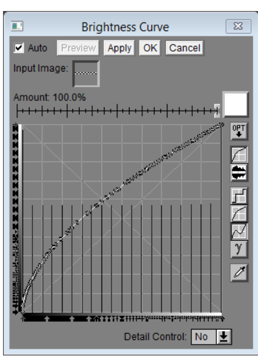
If you do an Exact Compose, the final curve C will have 256 control, regardless of the number of points in the first curve or its style. Since a curve with this many control points is difficult to edit, you can use Approximate Compose instead which creates a final curve C with fewer control points but which may be very slightly inaccurate.

To compose the A and B in the other order, simply start by loading the curve A and then compose with the curve B.

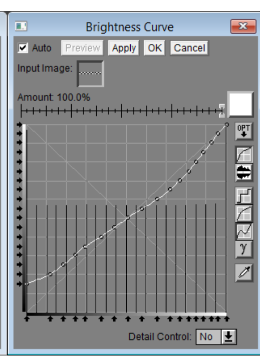
An example of composing two curves might be if you have two curves—one that lightens shadow detail and one that increases contrast. You can compose them to create a single curve that first lightens the image and then increases its contrast. Note that the composition order can make a big difference.

Example

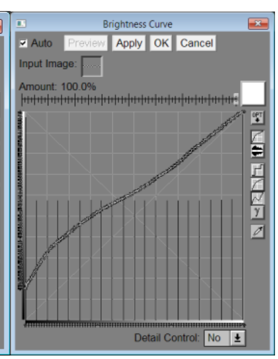
In the example below, the first curve lightens the image, particularly in the shadow areas. The second curve applies a calibration for an alternative printing process. The composed curve lightens the image and then applies the calibration in a single step.



Curve A



Curve B



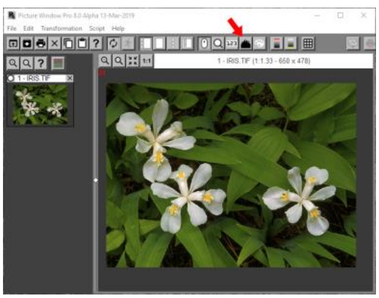
Curve C

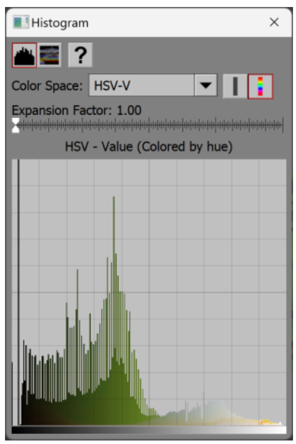
Histogram Mode

Picture Window's Histogram Mode gives you the option of viewing either the histogram or the waveform of the current image. To access it, click the histogram button on the main tool bar.

When Histogram Mode is turned on, the Histogram window is displayed (see below). This window automatically displays the histogram or waveform of the current image or, if a transformation is in progress, the current output image. This gives you an easy way to compare the histograms or waveforms of two or more images or to track how changes in the transformation affect the histogram of the result.

When the Histogram Mode window is active, clicking and dragging on the current image in the main image area displays a series of red markers in the histogram at the brightness level corresponding to the image where you drag. This lets you see what parts of the image correspond to what parts of the histogram. The markers are cleared when you release the mouse button.





Histogram/Waveform

This tool bar selects histogram or waveform display. See below for more on waveforms.

Color Space

The Color Space control lets you select which channel(s) you want to histogram and what type of histogram to display. For black and white images, this control is ignored, and the brightness of the image is always selected.

HSV-H, HSV-S, HSV-V – displays a histogram of the HSV hue, saturation or value.

HSL-H, HSL-S, HSL-V – displays a histogram of the HSL hue, saturation or value.

HSV-HS, HSL-HS – displays a 2-dimensionsal hue-saturation histogram (see below).

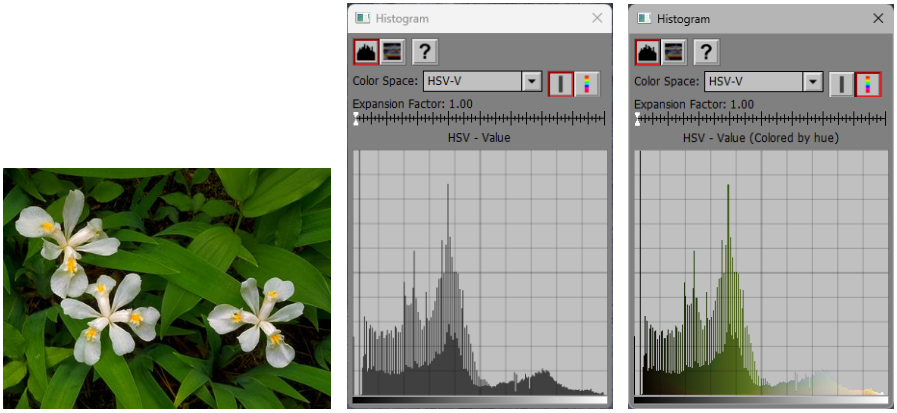
R, G, B – displays a histogram of the red, green or blue channel.

RGB – displays a combined red/green/blue histogram.

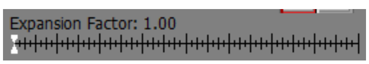
Luminance – displays a histogram of the luminance channel.

Colored Bars

This tool bar lets you select whether to display solid or colored bars when the input image is color and the color space is HSV-V or HSL-L. Selecting this option displays the relative amounts of different hues in the image at each brightness level.



Expansion Factor



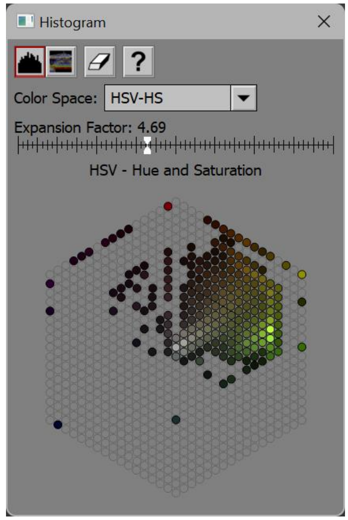
Histograms are scaled vertically so that their largest value just fits on the vertical axis. If there are one or more large spikes in the histogram, this can cause smaller values to disappear or be difficult to see.

The Expansion Factor slider controls the amount of range expansion applied to the histogram. At 1.0, no expansion is applied and the lengths of the bars in the histogram are proportional to the number of pixels of the corresponding brightness level. Increasing the expansion exaggerates smaller histogram values making them easier to see.

For Hue-Saturation histograms and waveforms, the expansion factor is applied to the brightness instead of the height of the histogram.

Hue-Saturation Histograms

Hue-Saturation histograms give you a way to see the distribution of colors in an image, based on the color wheel. A 2-dimensional histogram is displayed when you select HSV-HS or HSL-HS as the Color Space.

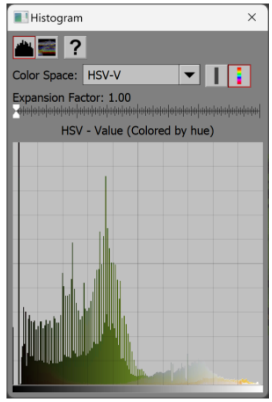


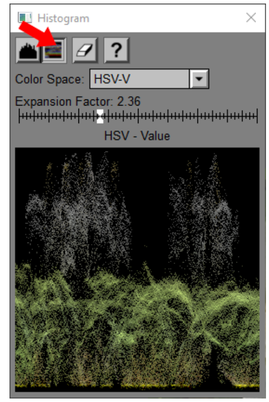
This shows a color wheel with dots at various combinations of hue and saturation. The color displayed in each dot has its corresponding hue and saturation, but with brightness proportional to the number of pixels of that hue and saturation in the image. You will generally need to increase the Expansion Factor to see details in the histogram.

Waveforms

Waveforms are an alternative way of presenting the distribution of brightness levels in an image.

How to Display the Waveform of an Image





To switch from histogram to waveform, click the waveform button at the top of the dialog box. To make the waveform easier to see, you usually need to increase the Expansion Factor as shown above.

Like histograms, for black and white images, the color space option is ignored. For color images, you can compute the waveform based on any of the channels listed in the Color Space control.

If you select HSV-V or HSL-L, the waveform is colored to reflect the colors in the image. If you select RGB, the individual red, green and blue waveforms are superimposed, each in its own color. Otherwise, the waveform is black and white.

What is a Waveform

Waveforms are an extension of histograms that capture not only the distribution of brightness levels in an input image, but also retain some information about where in the image they occur.

The horizontal axis of the waveform corresponds to the horizontal axis of the input image, so the left edge of the waveform corresponds to the left edge of the image and the right edge of the waveform corresponds to the right edge of the image, even though their proportions may differ. Each vertical line in the waveform is computed from just the corresponding vertical line in the input image.

The vertical axis of the waveform corresponds to brightness levels in the input image. The bottom edge of the waveform corresponds to black and the top edge to white. For each point along a vertical line there is a corresponding brightness level between 0 at the bottom and 255 at the top.

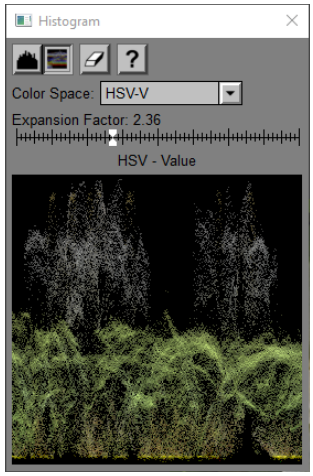
For each point in the waveform, the x coordinate tells you which vertical line of the input image is being sampled, and the y coordinate tells you a brightness level in the input image.

The brightness of the waveform at a point (x,y) is proportional to the number of pixels in the vertical line of the image corresponding to x with brightness corresponding to y.

You can think of the waveform as a series of vertical histograms where the frequency is shown by a brightness level instead of the length of the line.

How to Interpret Waveforms

The advantage of waveforms over histograms is that they give you not just an idea of the distribution of brightness levels but also what parts of the image are bright or dark.



Looking again at the example above, the greens in the waveform are generated by the dark green leaves. You can tell they are dark because they are clustered toward the bottom half of the waveform. The whites in the upper part of the waveform represent the bright white petals as you can see both by their color and their location. The yellow at the bottom comes from the very dark brown background behind the leaves.

Highlight clipping in the input image shows up in the waveform as a bright area up against the top edge and shadow clipping shows up as bright areas up against the bottom edge. Using the color and location of the clipped areas gives you a good idea what parts of the input image are clipped.

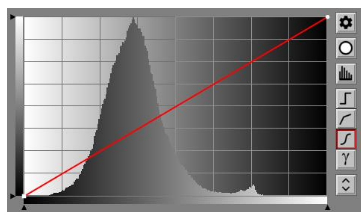
Tonal Adjustment Examples

A common processing goal is to enhance contrast and detail in specific parts of an image. Picture Window has two powerful transformations to accomplish this: Brightness Curve and Multipass Sharpen. Brightness curve is generally better for adjusting large areas of the image while Multipass Sharpen is better at bringing out texture and fine detail.

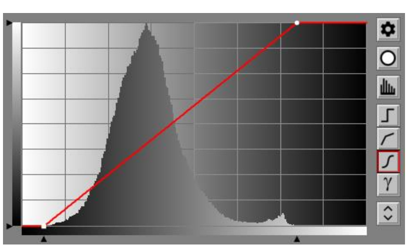
When you examine the histogram of an image, commonly it has one or more peaks indicating the image contains a lot of pixels of roughly the same brightness. One way to increase contrast is to spread out one these peaks over a wider tonal range by applying an S-shaped curve that sweeps upward across the histogram peak. The steeper the curve, the greater the contrast enhancement of the corresponding pixels. However, increasing contrast in one part of the tone curve always decreases it somewhere else, so it may be necessary to use a mask to restrict the changes to just the parts of the image that correspond to the histogram peak to avoid reducing the contrast for the rest of the image.

Example 1

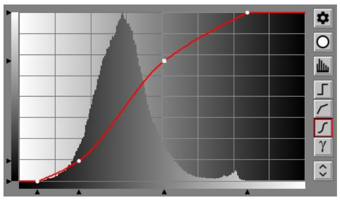
Here is an infrared black and white image that has typically low contrast and its histogram.

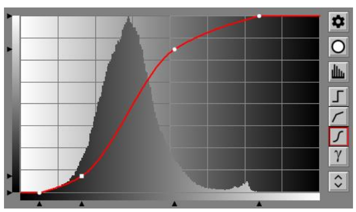


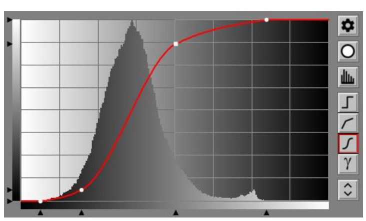
The small peak to the right represents the sky peeking through the foliage and the main peak represents everything else in the image. Also notice that the image does not use the full dynamic range from pure black to pure white. The first thing you might do to increase the contrast is expand the dynamic range:



While a step in the right direction, to get even more contrast we need to spread out the main histogram peak by creating an S-shaped curve between the black and white points. Here are several possible curves and their results. Notice that this can be combined with the dynamic range expansion using a single curve:

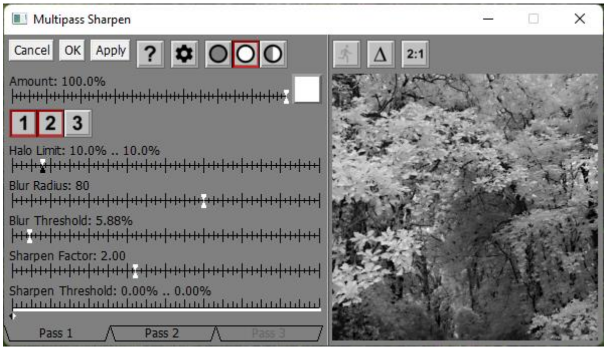


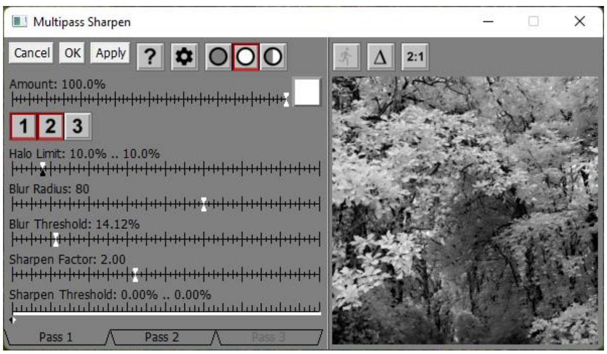



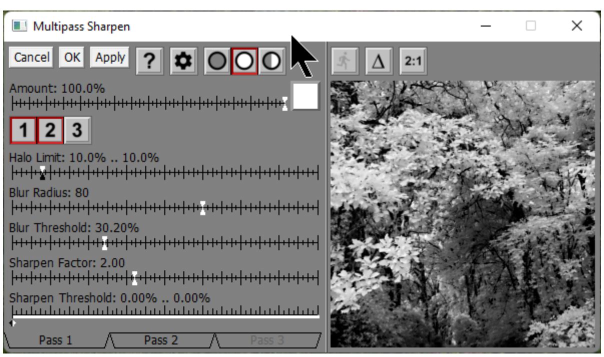




As you can see, the steeper and narrower the S-curve, the stronger the effect. In the last curve, you can see a definite loss of both highlight and shadow detail. There is no right or wrong curve – it all depends on the effect you are trying to create.

To increase contrast further, you can use Multipass Sharpen with a large Blur Radius which will bring out additional detail and texture. To make the effect stronger, try increasing the Blur Threshold.



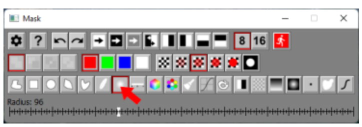




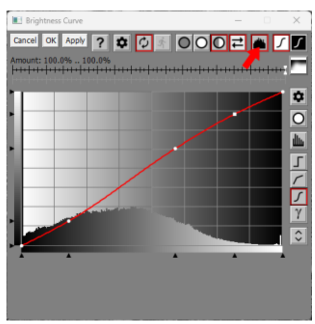
Finally, you can make local brightness and contrast adjustments to emphasize or de-emphasize different parts of the image. Here is an example illustrating how to lighten the foreground and darken the background.

The first step is to bring up Brightness Curve and click the small white button just to the right of the Amount control and select New Mask from the popup menu. This brings up the Mask dialog box with the Freehand Outline tool already selected. Draw a crude outline on the input image of the area you want to alter.

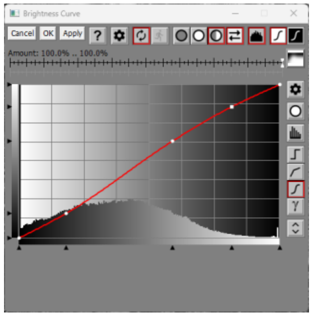
Then click on the Mask Blur tool button and select a Blur Radius that gives the selected region a soft edge.



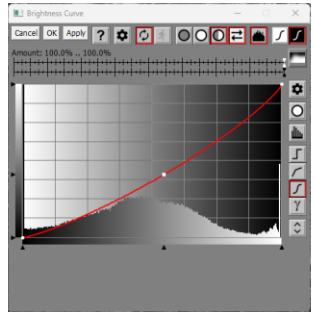
At this point you can close the Mask dialog box to make the red overlay go away. If you need to edit the mask later, you can click the Amount button again and select Re-Open Mask Dialog Box from the menu. Returning to the Brightness Curve dialog box, click the Histogram button at the top right to change the histogram to show just the areas selected by the mask.



Notice the white and black curve buttons just to the right of the Histogram button. These are used to flip back and forth between two independent curves – one is applied to the areas where the mask is white and the other where the mask is black. This lets you, for example, lighten one area and darken the rest of the image.



White Curve



Black Curve


Input Image


Output Image

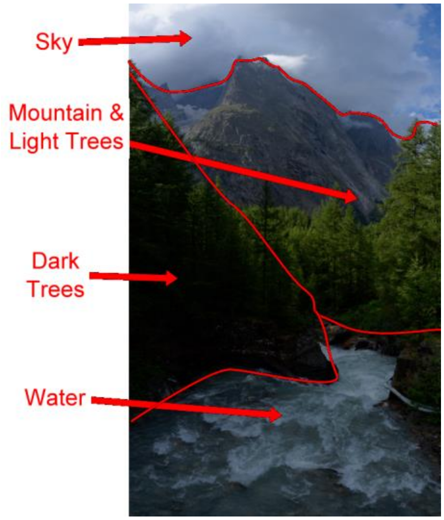
This has the subtle effect of darkening the background and lightening the foreground slightly, adding depth to the image. The dual Amount sliders (one white and one black) let you scale back the effects of the white and black curves independently so you can fine tune the result.

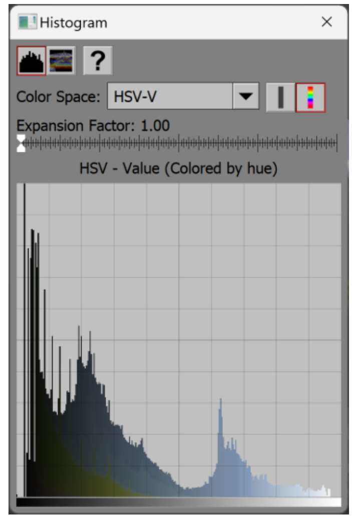
Noise

Any contrast enhancement technique tends to amplify noise in the input image since noise is just a form low contrast detail. If you boost contrast aggressively, you may want to apply noise reduction to the end result. Picture Window's Denoise transformation works well if the image is not too noisy. For more extreme cases, the DxO PhotoLab or Topaz Denoise program can sometimes work wonders although it may also create artifacts. Your mileage may vary.

Example 2

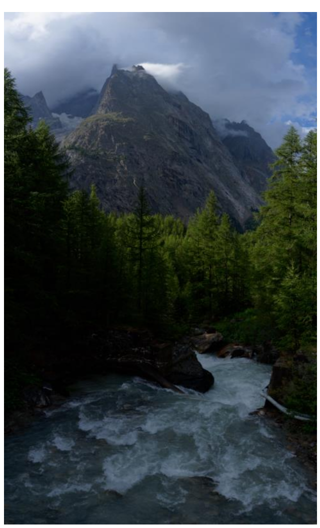
Here is an example of a landscape image that, somewhat arbitrarily, can be divided into four regions, mostly corresponding to the peaks in its histogram.

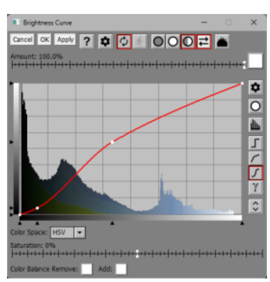




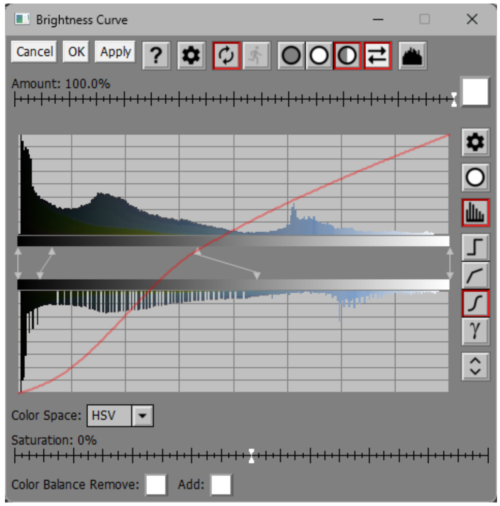
This image was exposed to avoid clipping the highlights in the sky and water, so the rest of the image is relatively dark and lifeless. From left to right, three histogram peaks correspond roughly to the dark trees that dominate the left side of the image, the lighter trees and mountain in the midground, and the white water and sky. To get an idea where different parts of the image fall within the histogram, you can click and drag on the input image which marks the corresponding values in the histogram with a red line.

Widening the central peak with an S-curve increases the contrast of the corresponding areas in the input image (the lighter trees and the mountain). However, the curve also makes the shadows darker and the highlights lighter, resulting in loss of both shadow and highlight detail.

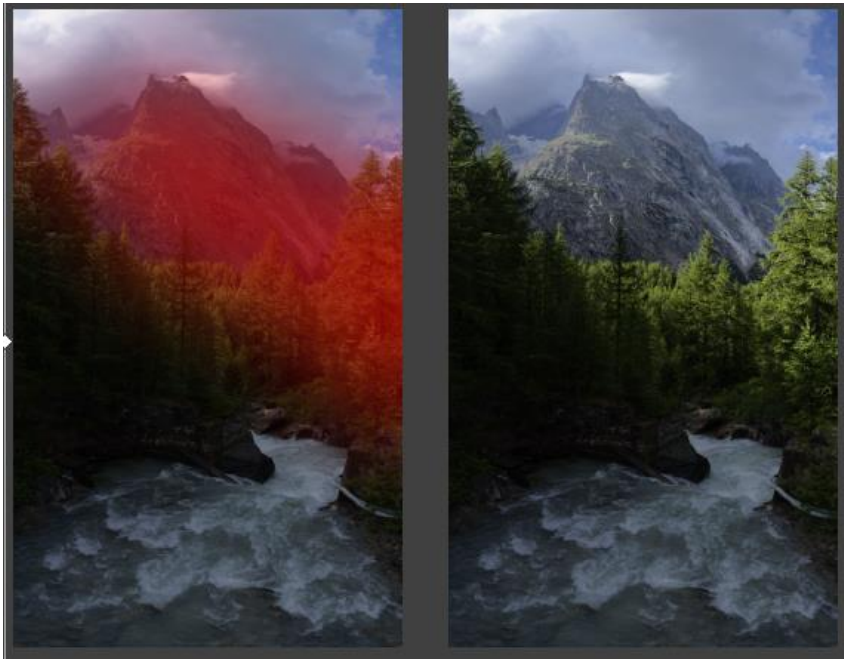




The location and steepness of the S-curve determine which brightness levels are affected and by how much, so it is worth experimenting a little with the location of the control points to get just the effect you want. By switching to the histogram view, you can see how this curve has widened the central histogram peak and narrowed the other two peaks and pushed them towards the ends of the tone curve:

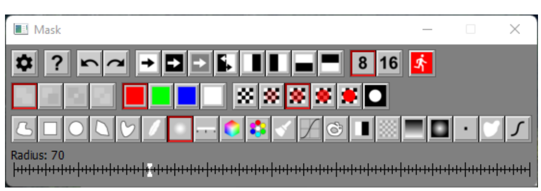


To avoid disturbing the shadows and highlights, you need to use a soft-edged mask to restrict the transformation to just the areas you want to affect. You can create such a mask either by specifying a region of the image to modify or by specifying a range of brightness values. While this second method sounds like a good idea, it often does not work as well as the first method since it tends to select bits of the image you don't want to modify.

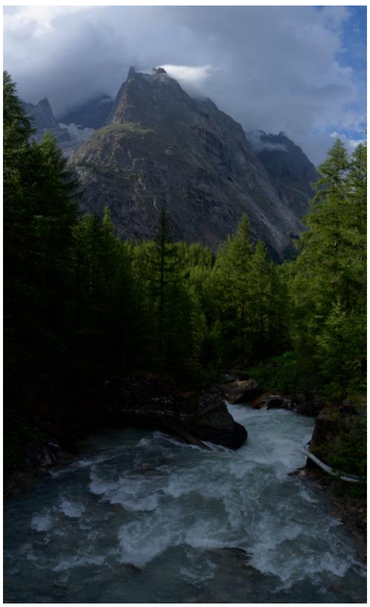


Mask Curve Applied Using Mask

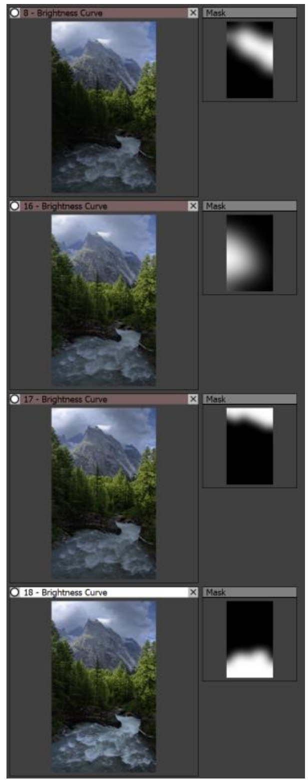
As with the previous example, the mask was created by roughly outlining the mountain and lighter trees using the Freehand Mask tool and then blurring it using the Mask Blur tool.



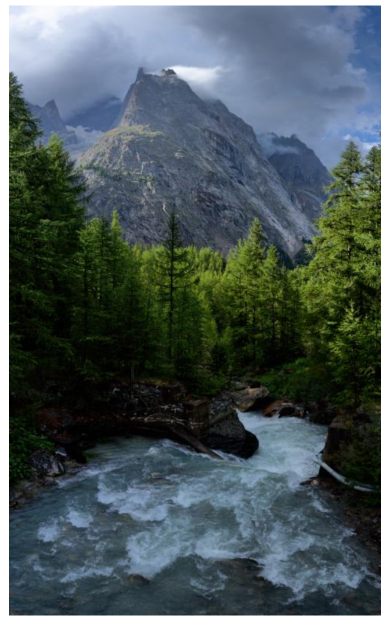
Repeating this same process for the three other parts of the image (the dark trees, the sky and the water) yields a final result with improved overall tonal balance and contrast. Notice how the sky and the water become more dramatic and the light on the mountain and trees gets more intense.



Input Image

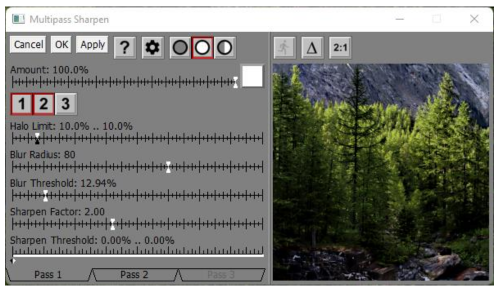


Transformations



Result

Another way to enhance contrast is to use the Multipass Sharpen transformation with a large Blur Radius. Rather than apply a single curve to the entire image (or to the part selected by a mask), this transformation effectively selects a different curve for each pixel based on the pixels surrounding it, bringing out detail across shadows, highlights and midtones in a single operation. Applying Multipass Sharpen to the results of the previous sequence of Brightness Curve transformations can enhance the local contrast of the image.



To vary the strength of Multipass Sharpen, increase or decrease the Blur Threshold and possibly also experiment with the Blur Radius. Too much local contrast and the image starts to break up – not enough and it has little effect. If the effect is too strong in some areas you can use a mask to limit its application.

Finally, you might want to lighten the bottom half of the image a little to bring it more in line with the top half: