Exposure – A Comprehensive Overview

From the dawn of photography, the common denominator in creating photographs has been exposure. However, digital imaging has changed how this is accomplished. Over the years, film was improved to emulate what the human eye perceives. Both film and the eye are logarithmic which means that doubling of light intensity is perceived as equal amounts of change. Digital sensors capture light in a much different way and need to be understood in order to produce the best possible results. Exposure, the total amount of light captured by the camera's sensor, is a function of three settings aperture, shutter speed and ISO.

The aperture is an adjustable opening calibrated in f/stops through which all light must pass. Each f/stop allows either twice or one half the light to pass depending on which direction it is adjusted. Higher numbered f/stops allow less light through while lower numbered f/stops allow more light through. The aperture also increases the depth of field (focus) as the f/stop number is increased and reduces the depth of field (focus) as the f/stop number is decreased.

Shutter speed is typically set in 100ths of a second and is the amount of time the shutter mechanism allows light to pass to the sensor. By varying the shutter speed the amount of blur from fast moving objects can be controlled.

ISO is an electronic adjustment, which sets the sensitivity of the sensor. It is the same as the ISO of film. The higher the ISO setting the more sensitive the sensor is to light. On the down side, if the ISO is set to high values, the amount of noise caused by the sensor amplification increases. This is similar to grain found in fast films.

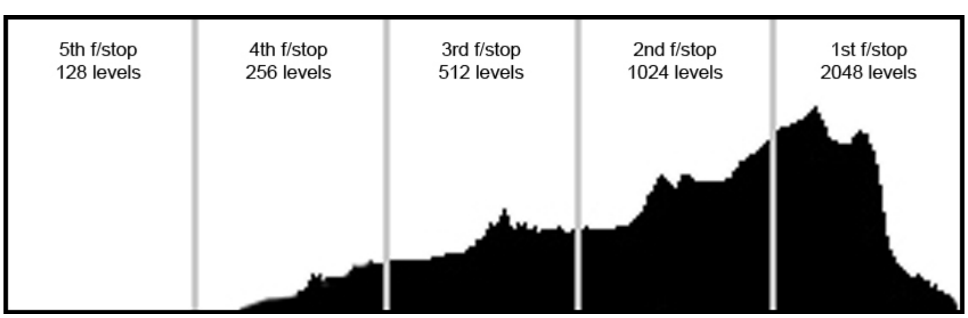
Most photographers are also aware that overexposure on a digital camera should be avoided in order to prevent clipping of the highlights. When an image is clipped due to overexposure, the detail in the highlights is lost forever! To protect the highlights photographers may tend to underexpose. This practice has its own set of detrimental effects. Let's examine this a little closer.

The CCD or CMOS sensor is a linear device, which means that the voltage output from the sensor is directly proportional to the number of photons of light that strikes it. Let's say, on average, the sensor has a dynamic range of five stops. A 12 bit RAW file can capture up to 4096 tonal values per color. These tonal values when split up in f/stops, which are logarithmic, end up with the following distribution:

Brightest Tones	1st f/stop	2048 levels
	2nd f/stop	1024 levels
Mid-Tones	3rd f/stop	512 levels
	4th f/stop	256 levels
Darkest Tones	5th f/stop	128 levels

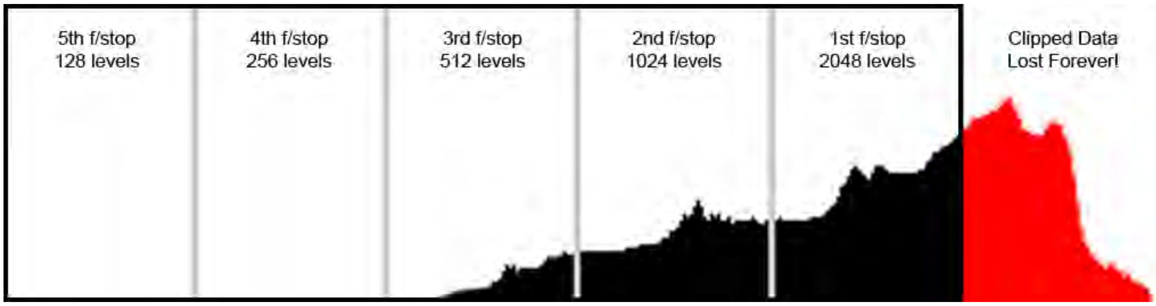
The end result is that a full 50% of all the tones are captured in the 1st f/stop of exposure. This is equivalent to the right 1/5 of the histogram on your camera.

Optimal image quality is produced when the greatest numbers of tonal levels are preserved after conversion to a JPEG. This can be achieved by adjusting the exposure so the majority of data is situated in the right 1/5th of the histogram without clipping the highlights. Again, the reason this occurs is that the CCD or CMOS sensor is a linear device, but exposure is logarithmic. Sensors have low highlight latitude and high shadow latitude, just the opposite of film.



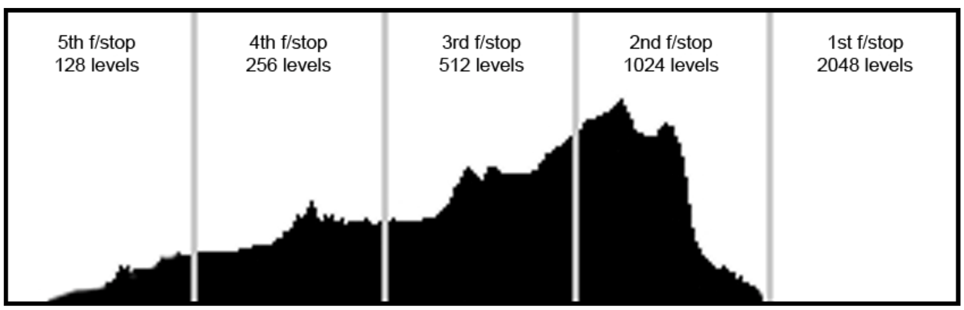
Optimized Normal Exposure

What happens when the camera is set to overexpose by one stop? The data moves 1/5 of the way to the right (1 f/stop) on the histogram, which clips the highlights and throws them away forever!



1 Stop Overexposure

What happens when the camera is set to underexpose by one stop? The data moves 1/5 of the way to the left (1 f/stop) on the histogram, which throws away literally half the available RAW data.



1 Stop Underexposed

JPEGs are created from the RAW data by applying various algorithms. One such algorithm is the Gamma Correction Curve. This fairly high contrast algorithm is designed to modify the linear data to create an image that the human eye perceives as normal. The Gamma Correction Curve does this by shifting some of the tonal levels from the higher f/stops to the lower f/stops. Along with algorithms for things like white balance, sharpening and noise reduction, compression is applied which converts the 12 bit 4096 tonal levels down to an 8 bit image with 256 tonal levels per color. The effect of these mathematical manipulations is to redistribute the tonal layers as follows:

Brightest Tones	1^{st} f/stop	69 levels
	2^{nd} f/stop	50 levels
Mid-Tones	3^{rd} f/stop	37 levels
	4^{th} f/stop	27 levels
Darkest Tones	5^{th} f/stop	20 levels

The remaining 53 tonal levels are lost beyond the five f/stop dynamic range. Since underexposure requires adjustments to the lower half of the dynamic range the number of tonal levels left to work with has been substantially reduced by at least a factor of eight! Enhancing these lower tonal levels causes noise (grain), to become more apparent as well as visibly stepped tones, this is referred to as posterization.

Exposure is the most important setting on the camera. It can make or break the final outcome. Sometimes it is appropriate to under or over expose in order to achieve a certain artistic result but, in most situations, optimal exposure is the ultimate goal and therefore should not be taken for granted.