The Zone System and the Digital Image

Revised October, 2019

Print Zones (JPEG Zones)

The zones described by Adams and Archer for the Zone System specifically refer to print zones.

Zone	Description
0	Pure black
I	Near black, with slight tonality but no texture
II	Textured black; the darkest part of the image in which slight detail is recorded
III	Average dark materials and low values showing adequate texture
IV	Average dark foliage, dark stone, or landscape shadows
V	Middle gray: clear north sky; dark skin, average weathered wood
VI	Average Caucasian skin; light stone; shadows on snow in sunlit landscapes
VII	Very light skin; shadows in snow with acute side lighting
VIII	Lightest tone with texture: textured snow
IX	Slight tone without texture; glaring snow
X	Pure white: light sources and specular reflections

From the [Wikipedia article on the Zone System](#)

Values in an 8-bit JPEG range from 0 (pure black) to 255 (pure white). Middle gray is in the middle of Zone V. Zones I through IX represent a range of gray tones.

Although the Zone System was defined for black and white images, the descriptions work for color images. Colors become gradually less apparent as you move away from Zone V towards black or white.

Exposure Zones

Exposure zones are one stop increments on either side of what the camera sees as middle gray. For a scene with a wide dynamic range that can easily extend above zone 8 or below zone 0.

The objective of the original film version of the Zone System is to place one of the exposure zones in a specific print zone. How you develop the film then determines where the other exposure zones fall. You can then move portions of the image relative to each other up or down during printing by dodging and burning, etc.

With digital images the situation is similar. You can place the brightness of a portion of the scene in a print zone and all other parts of the scene will move up or down together. You can still edit the result to move portions of the image up or down as you could to when printing. If you are converting your image directly from raw data it is easy to move highlights and shadows up or down. This is harder to do if you are working with the camera's JPEG.
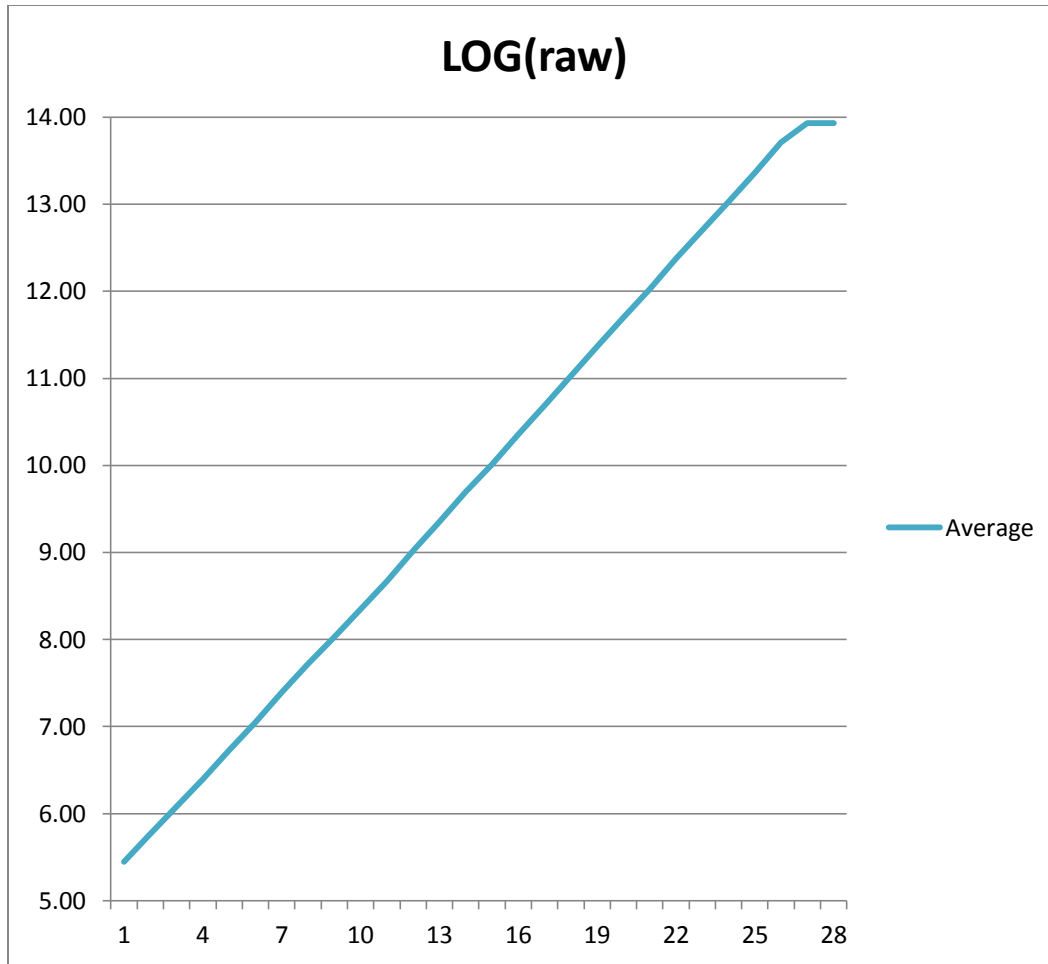
The raw file values are an arithmetic progression that gets turned into a logarithmic progression during raw conversion. They may be:

EC[1]	Exposure Zone	14-bit raw value range	Base 2 logarithm raw value range
-5	0	32-63	5-5.999
-4	1	64-127	6-6.999
-3	2	128-255	7-7.999
-2	3	256-511	8-8.999
-1	4	512-1023	9-9.999
0[2]	5[3]	1024-2047	10-10.999
+1	6	2048-4095	11-11.999
+2	7	4096-8191	12-12.999
+3	8	8192-16383[4]	13-13.999

1. Exposure compensation applies to exposure zones.
2. Exposure zone 5 ranges about +/-½ stop above and below middle gray
3. Exposure zone 5 corresponds with print Zone V
4. The raw file at base ISO never gets this high in the green channel

A sensor can capture about three full stops above the exposure zone that contains middle gray. Nikon, Canon, Sony and Fujifilm place middle gray within exposure zone 5 close to 1311 (base 2 log 10.36). This places the upper limit of the raw file about 3½ steps above middle gray.

The following chart shows the average of four different cameras – Sony A7 II, Nikon D610, Nikon Df and Fujifilm X100T. The sensor responds in a directly proportional manner. The measurements taken for each camera are each nearly identical. Point 16 is middle gray.
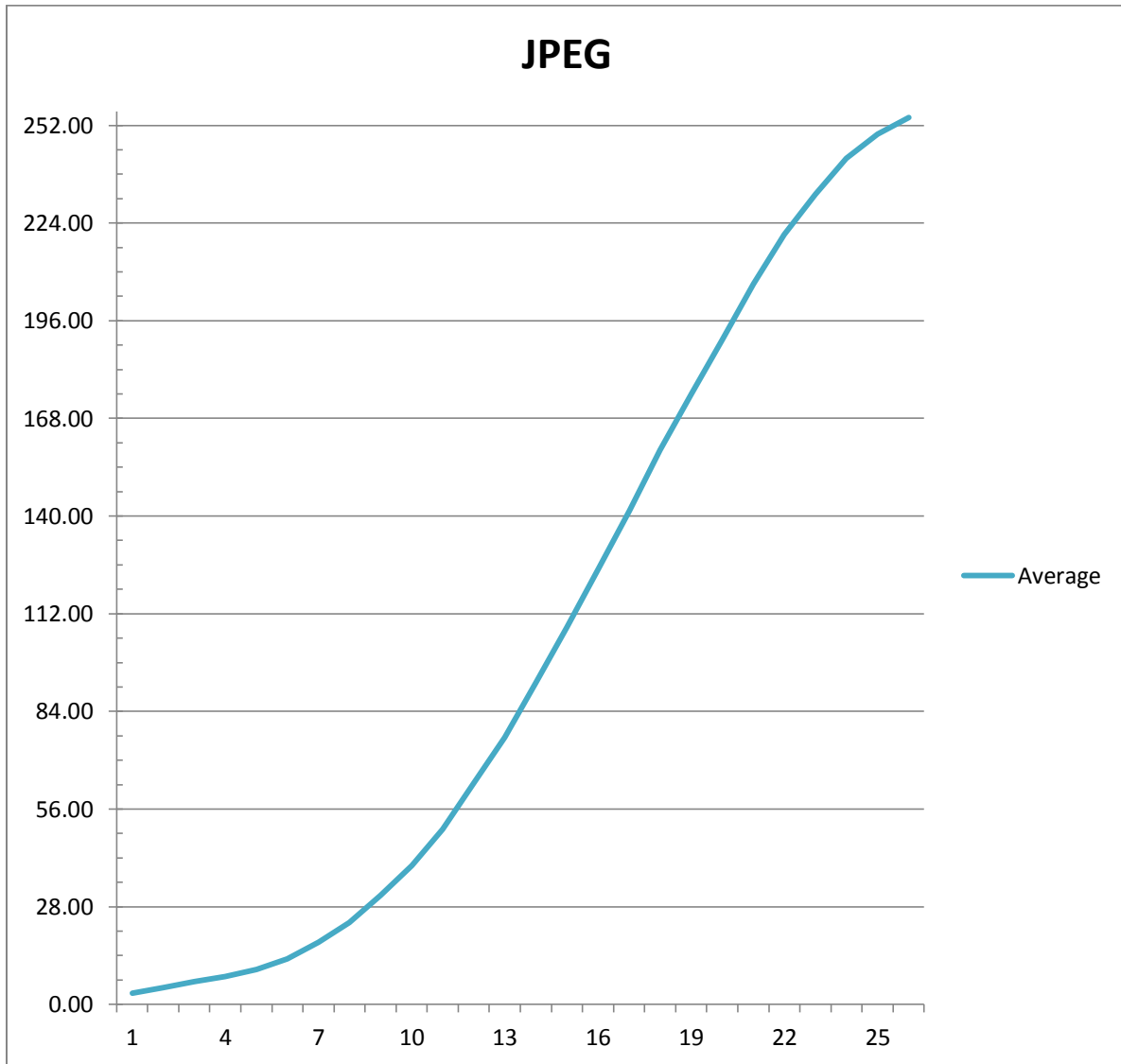
LOG(raw)

The measurements were taken at base ISO from the green channel for each camera in 28 increments separated by 1/3 stop starting from 5 stops below middle gray (point 16 is at about 10.36) through 4 stops above middle gray. The line is straight to about 3.3 steps above middle gray and it never reaches 14.

If you change from ISO 100 to ISO 400 the exposure for middle gray must be reduced by two stops but the signal is then amplified 4x to get point 16 back to about 10.36. The maximum value recorded in the raw file is the same as before. The amount of noise that could be seen 5 steps below middle gray will now become visible 3 steps below middle gray. In other words, the sensor loses two stops of noiseless dynamic range at the dark end.

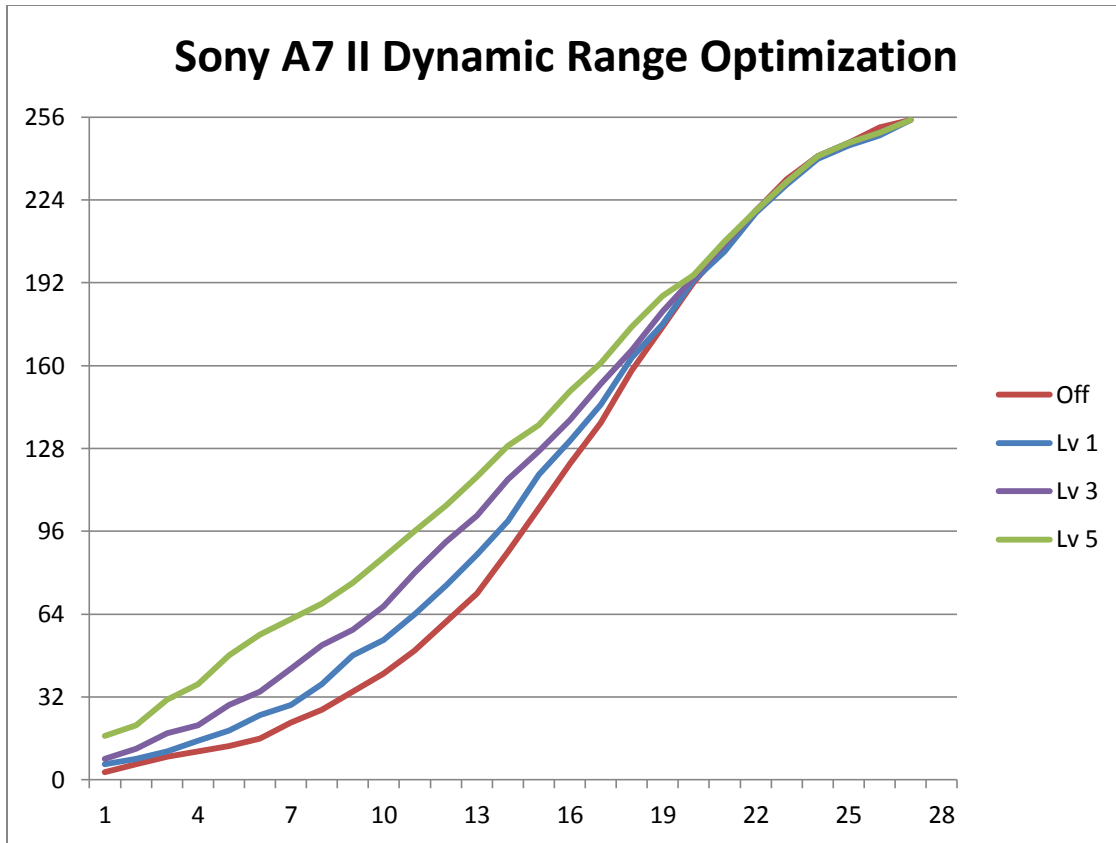**Mapping Digital Exposure Zones to Print Zones**

The JPEG image created in the camera covers all nine zones. If it did this in a straight line there would not be enough contrast in the middle zones. So the camera bends that line into an "S" shaped curve.

This basic mapping is applied under all lighting conditions. If the scene has a moderate or narrow dynamic range the image contrast is uniform from dark to light for everything close to middle gray, point 16. But if the scene has a very wide dynamic range, the JPEG will have less contrast in the highlights and a lot less contrast in the deep shadows.
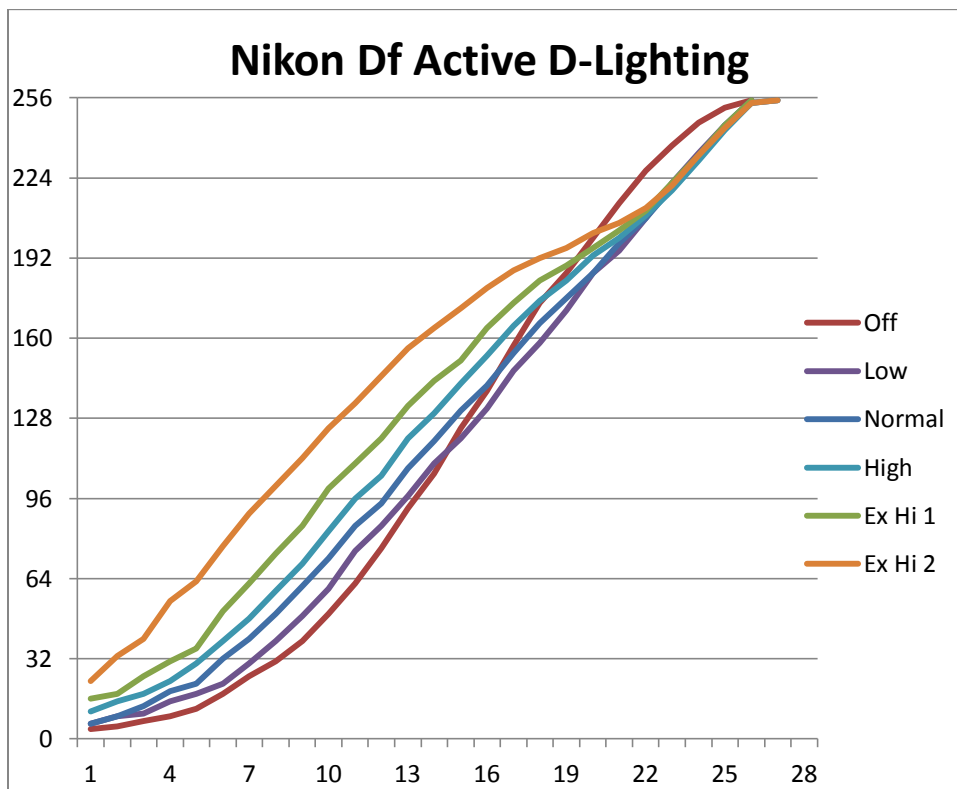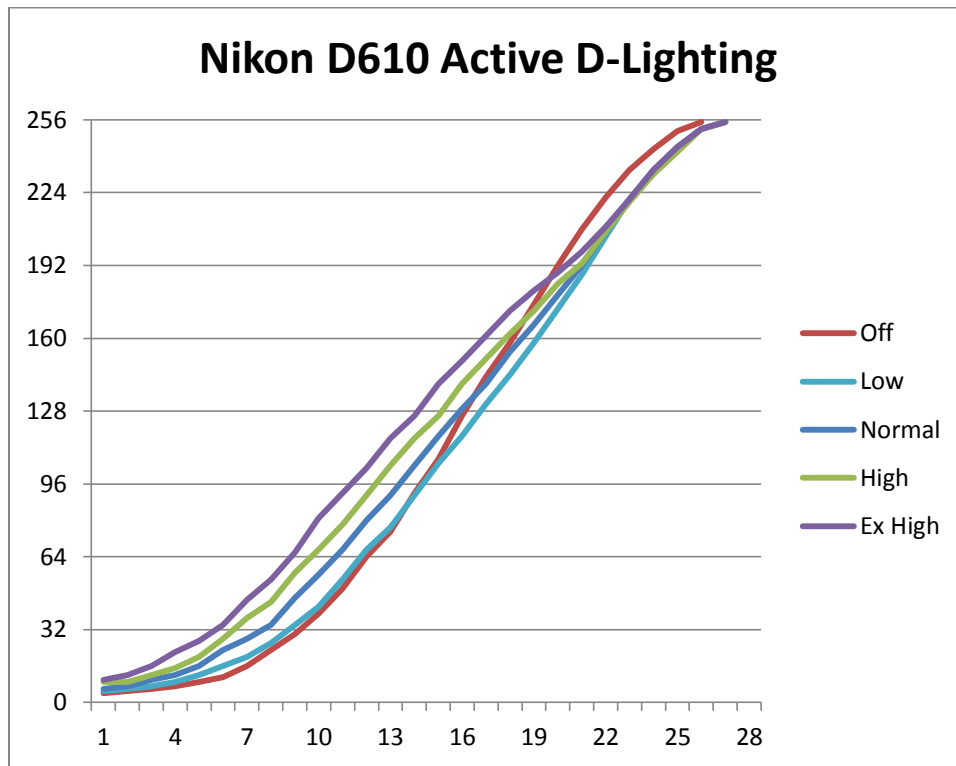
The critical brightness values are at the high end of the range. If the raw file's upper limit is exceeded the highlights stop recording – they are "blown" – and with them the JPEG highlights. Nothing we can do in the camera or later on the computer will get them back. But we can always recover a lot of shadow information, even though it might mean making the noise more visible.

Shadow recovery can even be done in the camera. Sony uses Dynamic Range Optimization:

Sony A7 II Dynamic Range Optimization

Off	
Lv 1	
Lv 3	
Lv 5	

Shadow recovery is accomplished by straightening out the "S" curve. The shadow contrast is increased at the expense of the mid-tone contrast. Other makes offer similar in-camera settings.

Nikon's Active D-Lighting is similar but it also alters the curve slightly at the high end.

Nikon D610 Active D-Lighting

Nikon Df Active D-Lighting

How to avoid blowing the highlights

All four cameras were remarkably consistent. The raw highlights get blown at the top of exposure zone 8, about 3½ stops above middle gray. The default JPEG is capable of using all of the raw information from about 1/3 stop below where the raw file blows out.

The camera's histogram shows the distribution of brightness levels in the JPEG for the entire image. It is not a reliable indication of where the raw file blows out.

But the highlight warnings (blinkies) consistently indicate where there will be a problem with the raw file. They also show where in the image the highlights might blow out.

With the A7 II, the blinkies or zebra warnings appear about one stop before the raw file reaches the limit regardless of whether the cameras settings are altering the shape of the curve for the JPEG.

With the two Nikons the blinkies show up about 1/3 stop before the raw file blows out. In the X100T they show up at the point where the raw file limit is exceeded.

Exposing to the right (ETTR)

A technique was published in 2003 by Michael Reichmann to cope with the camera he was using at the time. His camera used a 12-bit raw file so the raw values ranged from 0 through 4095. Modern cameras have much more capable sensors and primarily use 14-bit raw files. ETTR is no longer routinely needed but it's a good idea to understand what it does.

The meaning of "right" in ETTR refers to the location of the histogram. When the histogram is close to the right in the display it is an indication that the image is recorded using the higher range of raw values. Increasing exposure moves it more to the right and less exposure will move it to the left.

If the scene itself has a narrow dynamic range and you are using the camera's base ISO, you may not need to move the histogram at all. Small errors in exposure can be easily corrected on the computer.

But if the scene has a wide dynamic range and you are using an ISO higher than the base, it is possible that the histogram is already beyond the right limit – there may be a spike at the right end of the histogram and the image may be showing blinkies. To get a proper image you would need to reduce the exposure or the ISO.

But if you are not already at base ISO, ETTR serves little purpose.

Testing Procedure

Unless you happen to own one of the four cameras used in these tests you can follow these steps to generate our own numbers:

1. You need a reliable target like a white screen displayed on a computer monitor. An empty folder or white page will work.
2. Turn off the camera's autofocus.
3. Set your camera to its base ISO.
4. Set your white balance to Daylight.
5. Turn off Active D-Lighting or your camera's equivalent JPEG curve adjustment.
6. Set your camera to spot metering at the center of the frame.
7. Select an aperture that will require no exposure compensation at 1/125s.
8. To get the 28 exposure sequence, aim your camera at the screen:
   a. If your camera can set the exposure compensation from EC-5 through EC+4 in 1/3 stop increments, use Aperture priority and exposure compensation. Start at EC-5 and adjust the EC in 1/3 step increments until you reach EC+4. Exposure #16 will be at EC+0 and #28 at EC+4.
   b. If your EC range is not that wide, start the series of 28 exposures at 1/4000s and adjust the shutter speed in 1/3 stop increments until you reach 1/8s. Exposure #16 will be at 1/125s and #28 at 1/8s.
   c. If you can only set your shutter speed in full stop increments, start at 1/4000s and open the aperture by 1/3 stop for each of the next two shots. Then set the shutter speed to 1/2000 and return to the starting aperture and take the next three shots the same way. Exposure #16 will be at the starting aperture and 1/125s and #28 at 1/8s.
9. Use RawDigger to measure the maximum the raw value for the green channel for a small spot in the center of the frame. Record the raw value for each frame in a spreadsheet.
10. To get the base 2 logarithm for the raw value use the function: =LOG(*raw value*,2)
11. If you also captured recorded the JPEG, use any program to get the readout of the JPEG green channel value (0-255) at the center of each image.

The reason we are looking at the green channel is green is primarily responsible for the overall luminance value. Of the three colors, it will also be the one furthest to the right and the first channel to blow out when the raw file reaches its limit.