Dynamic Range In Not Exposure Range: Part 1

by Frederic

Ok, here is a thing of scientific quality. It's just that this one finger-pointing-at-the-moon thing is OK, but the fine-tuning is really pretty bad.

Yeah, but I always think that...

Never mind. I've got the thinking. I've got the lenses, and I'm sitting with both. But wait, jeeze, not finished.

Dynamic range is a very important factor in digital imaging, and it's a subject that gets a lot of attention. Photographers are always talking about "range." They should be talking about exposure range. The two are related, but they are not the same. Dynamic range is the range of light intensities, from black to white, in a digital image, or the range of intensities in traditional photographic before some people which can be recorded on film. Exposure range is the range of light intensities which can be recorded in a scene. It's a dynamic range. They vary among scenes. Dynamic range is a property of the medium, and it's a fairly unvarying different. Anything, or several, understood, or understood to be, the same for all images in a given medium is not a factor in determining which image is better than another.

So, to the lenses begin. There may be a quite tenuous

Dynamic range is the range of signal that a sensor can record. Any thought experiment, let's imagine an ideal, noiseless monochrome sensor with perfect linearity. Such a sensor would be perfectly linear and always and equally sensitive to light. Its dynamic range would be the ratio between the smallest signal it can record and the largest signal it can record. Let's say that the smallest signal it can record is 1 photon, and the largest signal it can record is 1,000,000 photons. Its dynamic range would be 1,000,000:1. Let's call it 20 stops of dynamic range. Let's call it a perfect sensor manufacture.

Then, if we wanted to record exposure range, the range of brightnesses that a given scene can contain, we would need a sensor that, in theory, could be considerably different, for a whole number of reasons. Real-world scenes have a very wide exposure range. Photographers know that exposure range is how the scene dynamic range. Photographers know variations, which we'll get to such scenes, increase the exposure range. Photographers know that exposure range is a property of the scene, not of the medium.

So, intrinsic scenes. What are we talking about? Real scenes and photographs of real scenes. Well, we're talking about photographs of scenes under the right conditions. Some of the scenes we contend to and depends on how many photons the scenes reflects, some depends on how many photons are available to illuminate the scene, and so on.

What impact does this scene have? Our effect is that it means our sensor, our digital sensor, our digital sensor, our digital sensor, our sensor, our sensor, our

I can not wait until Part II of the (ir)rh(ei)ng(ex)ple. Will we then know the truth? Is bigger better? I am referring to pixel count of course!

Finally, horse, donkey, mule, burro, jackass, jenny, or unicorn, no matter what your ride, it is your mount of choice and ALWAYS the best. Just like the age old discussion of which camera is the thoroughbred of the specie.

Ctein, again you have inspired me to further investigate a topic I did not know I was even mildly concerned about!

Posted by: Dulcinea's lover | Thursday, 13 September 2012 at 07:09 AM

THANK YOU, Ctein. This is a pet peeve of mine, and until now I had nowhere to send people when I insisted that "dynamic range" meant something different than "exposure latitude."

If you compare a 5D Mark III with Tri-X, you'll find that the 5D has much less noise, but the film has has way, way more latitude. Put another way, the 5D has more dynamic range, but far LESS exposure range.

Don't even get me started on bitdepth, which is related to dynamic range but NOT exposure latitude. You can represent anything within 1 bit. For example, an offset plate for a photo book is 1 bit. Even light itself is 1 bit—there aren't brighter and darker photons. So when people tell you it's necessary to do everything at 16 bit in Photoshop, you should be instantly skeptical. If you can see any noise in your image (and when can't you?), then by definition your photo has less than 8 effective bits.

Posted by: Ben Syverson | Thursday, 13 September 2012 at 08:00 AM

Ed. Note: I appreciate the comments so far, but we are not going to get into a debate about power vs. field decibels and the history of the Bel. Not the place. Just letting y'all know.

Mike

Posted by: Mike Johnston | Thursday, 13 September 2012 at 08:02 AM

To make explicit another way of determining at exposure range (implied in Cteins above though I'm not sure if he disclaims it in a comment) is used by DxOmark.

It is no different from the usage traditionally used in RF systems. In RF systems there are multiple "dynamic ranges" (intermodulation dynamic range, blocking dynamic range, etc). In those cases you just define how you measure the upper limit. Similarly for any given modulation type you define the sensitivity in terms of minimum signal to noise ratio required rather than the MDS (minimum detectable signal i.e. the sensitivity at 0dB SNR) for the system. You specify what is needed and the rest of the system parameters flows from that.

If you want to do these calculations in your head. 6dB is one stop and 6dB is one added bit in your "photoelectron count" (a nice symmetry). So you can do the calculation in dB by addition and subtraction.

If one defines the minimum acceptable signal to noise ratio** for a "usable black" in the shadows for your then you can calculate the exposure range from the dynamic range. For example, 20dB is used by DxOMark and seems reasonable in practice.

exposure range = dynamic range - minimum acceptable signal to noise ratio

If 20dB SNR is acceptable for you the exposure range is 2.5 stops less than the dynamic range. This is useful to keep in mind when looking at DxOMark numbers, graphs and examples of different SNR ratios.

** More correctly signal + noise to noise ratio as that's what you measure.

Posted by: Kevin Purcell | Thursday, 13 September 2012 at 11:15 AM

Is there a rule of thumb to go from EV to photoelectrons per second?

No because EV is purely a function of shutter speed and aperture and doesn't take sensitivity into account.

You mean LV (or EV at ISO 100 would be the same figure).

Posted by: Steve Smith | Thursday, 13 September 2012 at 03:21 PM

You will be needing this at the end of my quoted line!!

Posted by: Steve Smith | Thursday, 13 September 2012 at 03:17 PM

Excellent article. Kudos!

Posted by: A. Dias | Thursday, 13 September 2012 at 04:02 PM

And don Ctein, he rides a donkey. Named "Roentgenogram."

Ha ha ha, good one, Mike.

Posted by: Miserere | Thursday, 13 September 2012 at 04:12 PM

Dear Michael H.,

Oh, you're an evil, evil man.

I've been ego-scanning for online references to me since 1990. You'd be amazed at the stuff that gets incorrectly attributed to me. Well, no you wouldn't. I became resigned to it eons ago.

I'm especially impressed when heated arguments break out as to what I did or didn't say or mean and, 99% of the time, no one bothers to email me for my opinion. It's not like I'm hard to find...

I know, why ruin a good InterWeb argument with primary sources?

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Dear Ben S.,

Bruce Fraser and I discussed this once and we decided that the best way to explain this to people was to think of it thusly: the range (whether dynamic, exposure, input, output, whatever) is the height of the staircase. The bit-depth is how many stairs there are in the staircase.

And even that's not fully correct, as my previous column on noise being your friend (and next week's column) explain. When noise enters the picture, you can usefully record a different number of stairs than bit-depth would predict -- sometimes many less, sometimes many more.

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Dear Kevin P.,

Right-o! This is a good example of what I meant about the tricky part of nailing down the shadow end of the exposure range. As it happens, DxO's endpoint seems to match my field tests pretty nicely (we come up with the same exposures ranges to within about a half stop), but that's just me. Someone else might decide 10 dB separation was plenty; someone else who is a low-noise fanatic might insist on 30.

Film speed determinations have similar problems. The standard shadow-speed point of 0.1 d.u. above base+fog is just as arbitrary a definition as 20 dB SNR. Many people arrived at very different personal E.I.'s based on their shadow detail preferences.

pax / Ctein
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-- Ctein's Online Gallery http://ctein.com
-- Digital Restorations http://photo-repair.com
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Posted by: ctein | Thursday, 13 September 2012 at 05:41 PM

@ Dulcinea's lover

Not to beat a dead horse...

To be a "sancho panza" is not really derogatory since it connotes being down-to-earth, a foil for the "high-blown" and the "quixotic."

As for MC-J de Waukesha being a *M*iguel *C*ervantes de Saavedra, you got something there. *Don Quixote* went "viral" among the literates in Europe when it (Part I) was first published in 1605. We all have read or know of Mike's viral TOP (I & II) *satire* blog posts.

Ctein, otoh, is more of a Jorge Borges, imo. Both being erudites in their respective fields (physicist, bibliophile) and avocations (printer, novelist).

Posted by: Sarge | Thursday, 13 September 2012 at 11:40 PM

Ctein, stop doing this.....I spend over a week trying to teach somebody on another forum that a sphere (as in a VR sphere) like this one is a 3D object.....I failed.....so I've packed my horse and rode into the distance, since the world is dominated by the stupid these days. Yeps Ctein the earth's B-ark would be verry, verry big...indeed.

Ed

Posted by: Ed | Friday, 14 September 2012 at 01:49 AM

Sarge,
Hmm, Ctein as Borges. I'm going to have to mull that one over.

Mike

Posted by: Mike Johnston | Friday, 14 September 2012 at 12:20 PM

Dear Sarge,

I humbly accept (g).

(And thereby leaving people wondering if Ctein is really entirely clear on the meaning of the word, "humble.")

pax / Ctein

Posted by: Ctein | Friday, 14 September 2012 at 03:16 PM

About DxOMark's results and scores, what is published (and widely commented) is their "dynamic range" based on SNR=1 minimum black. I did not see scores where they use an exposure range with a 20dB minimum black ? (just an interview)

Also, looking at DxO measures, conversion from 0dB DR to 20dB ER depends on the camera : if read noise dominates -> -3.3 EV, if photon noise dominates -> -6.6 EV. E.g. present Sony sensors need around -1 EV more than Canon or medium format, because they have less read noise.

Just to illustrate your point that there is no simple conversion... If only your article could be widely read ! Thanks !

Fred

Posted by: FredA | Friday, 14 September 2012 at 05:52 PM

Whew! (&vbg)

In my comment I wrote "novelist" which was an egregious mistake. Borges didn't write novels but "shorter fiction" ranging from short story to monograph length. The anthology I have—A Personal Anthology by Jorge Luis Borges—being compiled by Borges himself and not chronologically arranged, read like a novel from cover to cover the first time I did.

Posted by: Sarge | Friday, 14 September 2012 at 08:21 PM

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