Photographic Exposure Metering and the Infamous "18% Calibration"

Douglas A. Kerr, P.E.

Issue 1
July 19, 2007

ABSTRACT AND SUMMARY

We often hear it said that photographic exposure meters (including those forming part of camera automatic exposure systems) are "calibrated to 18% reflectance" (or maybe 12.8% or thereabouts). What does this mean? In this article, we discuss what this actually means in digital photography. We also discuss the closely-related matter of "18% gray card metering".

INTRODUCTION

Caveat

In this paper, I will give a fairly simplistic (though hopefully correct) discussion of the issues. The entire matter of exposure meter calibration is a very complex one. But here we are trying to explain a simplistic statement, and a simplistic explanation seems most fitting.

Digital *vs* film worlds

The specific discussions in this article pertain strictly to digital photography. While the same concepts apply to film photography, many of the details are different there.

The term "exposure"

In this area of photography, there are two legitimate but quite different quantitative meanings of the word "exposure" (as well as its narrative meaning: "I took the exposure at about 4:30 pm"). We will be using both in this article. To avoid any ambiguity, I have taken the step of coining the two terms "exposure1" and "exposure2" for these two quantitative meanings, as follows:

- Exposure1: the joint effect on the photographic exposure process of the *exposure time* (shutter speed) and the *effective relative aperture* (effective f/number).

- Exposure2: the *time integral of illuminance* on some spot on the photographic film or digital sensor over the course of the exposure. (Note that for any given spot on the image, this is affected both by the exposure1 in effect in the camera and the *luminance* of the corresponding spot on the scene.)

Exposure metering

A common form of exposure metering is *scene-average reflected light metering*. Here, the metering instrument measures the average luminance ("brightness") of the entire scene and from this, plus knowledge of the ISO sensitivity of the film or digital sensor system, sets (or advises us to set) an "appropriate" value of exposure1.

The objective is to secure a desirable distribution of exposure2 for all the values of luminance actually found in the scene, within the range of exposure2 which the sensor can distinguish.

Calibration

The simple formula used by the exposure metering system to develop its choice of exposure1 is not uniform among camera or exposure meter manufacturers. Nevertheless, there is guidance given in this regard by various international standards (although it is tricky to figure out what is actually meant), and as a result, there is a certain degree of uniformity in practice. The relationship in a particular metering system, for a particular ISO sensitivity, between the measured average luminance and set (or recommended) exposure1 is often called the *calibration* of the exposure metering system.

A classical calibration

One widely-used calibration in the field of digital cameras[1] has the following properties. Once the meter has determined the average scene luminance, and set (or led us to set) a certain exposure1 (that is, a shutter speed and f/number that will together give that exposure1), an area on the scene whose luminance is 7.8 times the average luminance of the scene will receive an exposure2 on the sensor that is the maximum that can be distinguished (the so-called "saturation limit" of the sensor system). [2]

In terms of reflectance, if the scene is uniformly illuminated, this means that an area on the scene whose reflectance is 7.8 times the average reflectance of the scene will receive exactly the "saturation" exposure2.

---

[1] It is in fact the one prescribed by the international standard for automatic exposure control systems. Appendix A discusses this.

[2] In the digital realm, the ISO sensitivity ("speed") of a digital sensor system in fact tells us the actual numerical value of the saturation value of exposure2.

Describing this calibration

We could describe this calibration situation by saying that, if the average reflectance of the scene were 12.8%, then a scene element with a reflectance of 100% would receive exactly the saturation value of exposure2. (Again, as in all that follows, uniform illumination of the scene is assumed.)

Or we can say that the brightest element of the scene will receive exactly the saturation value of exposure2 if the average scene reflectance were 12.8% of the maximum reflectance.

But we can also say (arbitrarily) that if the average reflectance of the scene were 18% of the maximum reflectance, the highest-reflectance area will receive an exposure2 that is 0.71 of the saturation exposure2 (which, in photographer’s terms, is “one-half stop from saturation”).

So, if we want, we can choose to say that this classical calibration is based on:

- An assumed maximum possible reflectance of 100%.
- An assumed average scene reflectance of 18%.
- One-half stop of “cushion” against overexposure of the brightest possible scene elements in the case of a real scene whose average reflectance is not 18% of the maximum reflectance but rather somewhat less.

It is this outlook that is responsible for the common statement about exposure meters being “calibrated to 18% reflectance”.

But we could equally-validly say that this very same calibration is based on:

- An assumed maximum possible reflectance of 100%.
- An assumed average scene reflectance never less than 12.8%.
- The brightest scene element never receiving above the saturation exposure2.

It is this outlook that is responsible for the sometimes-heard statement about exposure meters being “calibrated to 12.8% reflectance” (or some nearby number).

THE 18% GRAY CARD

Most times, we would really like to use an exposure1 such that a 100% reflectance element in the scene would (if present) always receive exactly the saturation exposure2. By doing this, we make the "tonal scale" of the camera output represent object reflectance in an absolute way. This can lead to realistic portrayal of the reflectance of scene objects, regardless of average scene reflectance.

Assuming that the exposure meter calibration is the one we have been discussing, then if the scene happens to have an average reflectance of 12.8%, we get that desirable result. But for average scene reflectances away from that value, a different (and generally less desirable) result will occur. For example, a shot of a white cat on a snow pile (a very high average reflectance) will end up on the print or onscreen display looking like a gray cat on a dustpile.

But we can predictably attain the desirable result mentioned above with a clever metering technique.

If we place in the scene an object whose reflectance is known to be 12.8% (perhaps a "gray card" of 12.8% reflectance), and can arrange during metering for the metering system to only regard that "metering target", we have made the metering system regard a scene of average reflectance 12.8% (12.8% everywhere, as a matter of fact).

This will cause the metering system to recommend (or set) an exposure1 that will produce the result mentioned above. Then we somehow arrange for this value of exposure1 to be retained for the actual shot, remove the gray card, compose the scene, and shoot.

The relationship between the luminance of elements of the scene and the resulting exposure2 values will be such that any 100% luminance element (if any are present in the scene) will receive exactly the saturation exposure2.

Now, where can we get such a gray card of 12.8% reflectance? It isn't easy. But we can easily acquire a gray card whose reflectance is 18%—all photo supply houses sell them. If we follow the scenario above with such a card as our "metering target", the exposure1 recommended or set by the metering system will be 1/2 stop less than needed to produce the effect we seek. (The greater illuminance seen from the 18% card will cause the metering system to feel that a lesser exposure1 is required than we need, by 1/2 stop.)

So, after we see the exposure1 that the metering system recommends (or actually sets) when the meter is regarding the 18% gray card, we manually force the camera to use a 1/2 stop greater exposure1 and use that for the shot.

Why are gray cards of 18% reflectance readily available, and those of 12.8% reflectance almost non-existent? The answer lies in decades of evolution and folklore, and in part from the fact that things work differently in the film world (in which the use of the 18% reflectance card arose) than the digital world.

For one thing, film doesn’t really have a clear saturation value of exposure2. Accordingly, the matter of a “cushion against overexposure” is not so compelling.

#

APPENDIX A

Basis For The “Standard Calibration” in International Standards

In this appendix we describe how the specific exposure metering calibration described in the body of this article is in fact the one prescribed by the international standard for camera automatic exposure control systems, working in concert with the international standard for the determination of the “ISO Speed” (sensitivity) of a digital camera sensor system, and is also consistent with the international standard for the calibration of free-standing exposure meters.

In what follows, the symbol H is used for the quantity I call exposure2 (as is customary in modern scientific work).

Automatic exposure systems

International standard ISO 2721, ***Photography—Cameras—Automatic controls of exposure***, gives the following definition of the recommended calibration for automatic exposure control systems:

$$H = \frac{10}{S} \text{ lux-sec} \qquad (1)$$

where H is the average exposure2 at the image plane and S is the ISO sensitivity of the sensor system.

This means that when the camera, with its automatic exposure control metering system, regards a scene with a certain average luminance, the camera should set exposure1 such that the average exposure2 on the film or digital sensor will be $10/S$ lux-sec.

To interpret this in terms of the saturation value of exposure2, we will need to know more about S. That is covered in a different standard.

International standard ISO 12232, ***Photography—Electronic still picture cameras—Determination of ISO speed***, gives the following definition of the ISO sensitivity of a digital camera sensor system (following the option under which this is determined based on the saturation value of exposure2):

$$S = \frac{78}{H_{sat}} \qquad (2)$$

where S is the ISO speed (sensitivity) and H_{sat} is the saturation value of exposure2 (in lux-sec) for the camera’s sensor system.

Combining the two gives us:

$$H_{avg} = \frac{H_{sat}}{7.8} \qquad (3)$$

This implies that a specific area on the scene whose luminance is 7.8 times the average luminance of the scene will receive an exposure2 (H) of H_{sat}. This is in fact exactly the calibration we discuss in the body of the article.

Free-standing exposure meters

The matter of the properties (including calibration) of free-standing photographic exposure meters is covered by international standard ISO 2720, ***Photography—General purpose photographic exposure meters (photoelectric type)—Guide to product specification***.

This standard does not prescribe a single calibration, but defines a calibration involving a "metering constant", K, for which a modest range of values is permitted. This formulation is intended to allow manufacturers to choose an exact calibration they feel will be most beneficial to their users. The range of values of K permitted by the standard is from 10.6 to 13.4.

A further complication is that a free standing exposure meter gives the user a value of exposure1; however for a given luminance of a spot on the scene, a given exposure1 will not produce a certain exposure2, but rather one that varies (slightly) based on lens transmission loss and other related matters. One reason a meter manufacturer might wish to choose a certain value of K is to take account of some assumed typical value of lens transmission loss.

Ignoring that subtlety for now, and assuming 100% transmission, the calibration prescribed by ISO 2721, for K = 12.7, is the same as that prescribed by ISO 2720, the one discussed in the body of this article.

I'll spare you the proof.

#