



Application Note #1

How to use a target for white balancing in RAW file import

1. Introduction

1.1. What is a RAW file?

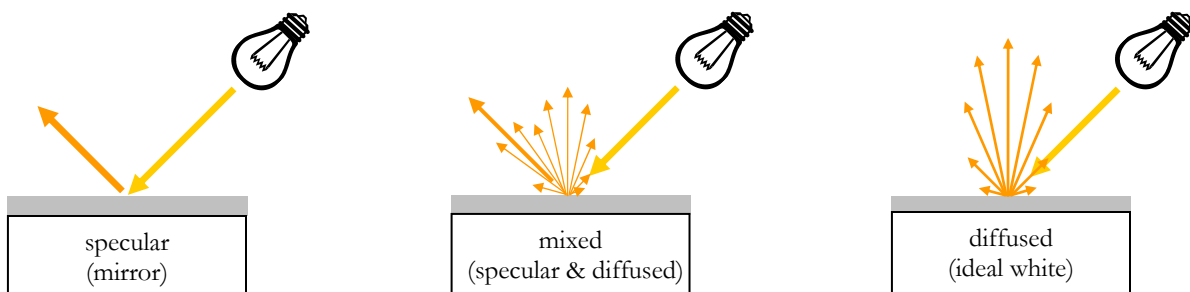
A RAW file stores non-gamma-corrected, non-color-corrected, and high-resolution (much more than 3 x 8-bit RGB) data taken directly from a digital camera's imaging sensor. In addition, its RGB information is not in a directly useable format since the sensor is made of a "mosaic" of detectors where the individual R, G, and B detectors are non-uniformly dispersed and vary in number (there are more G detectors than R and B ones). RAW data is the least "manipulated" or the "purest" information you can get from your camera, and, in principle, will enable you to get the maximum results out of an image. But this capability comes at a cost: the file sizes can be extremely large, and extracting images from them requires making "educated" choices in order to obtain quality results.

Supplementary information (called EXIF tags) is usually enclosed in the file; this information may include the camera model, the lens aperture, the shutter speed, the white balance setting, etc. In particular, the recorded white balance value is used, often by default, to "automatically" correct the RAW file colors when the file is imported (opened) in an image editing software such as Photoshop, CorelDRAW, Paint Shop Pro, etc. The overall color balance obtained by default can go from acceptable to horrific, and is rarely close to perfect. However, all of these programs, as well as stand-alone programs dedicated to RAW file processing, like Bibble (www.bibblelabs.com), Capture One (www.phaseone.com), RawShooter (www.pixmantec.com), and others, have specific tools to correct white balance based on manual or pre-assigned user-selected settings. This application note is a simple introduction in the use of dedicated targets for white balancing RAW color images when they are first opened.

1.2. What is white?

An object can be called "white" when, for all the colors (wavelengths) of the visible spectrum, 100% of the light shining on the object is reflectively diffused. By reflectively diffused, we mean reflected back uniformly in all directions, not reflected in a mirror-like fashion, the latter technically called specular reflection. In comparison, a flat mirror will reflect the received light in an angle opposite to the incoming angle; the reflected light from a mirror is thus not the color of the mirror but (mostly) the color of the light source.

A shiny white surface is mainly white, the color perceived when looking at the diffused reflection, with a percentage of its color coming from the light source when looking directly into the specular reflection. As a consequence, the shiny white surface will exhibit variations of color depending on the source location relative to the observation point. Thus, the ideal white reference surface would be totally diffusing, and subject to no specular reflection.



The fact that an object is white does not mean it will look white when viewed under all light sources. If you shine a red lamp on a white object, and this lamp is the only light source where you are, the object will look red. On the other hand, this white object will look “white” under many illuminating conditions. For example, a typical white sheet of paper will look white under the noon sun (a bluish white), as well as when illuminated by a late afternoon sun (the so-called “golden hour”), or illuminated by a halogen bulb (a yellowish white) and other whitish light sources (see the *Color Temperature* box below). This uniformity of white perception has its roots in the human brain which “knows” what a white paper color looks like and modifies, i.e. adapts, our perception to correct for it. This adaptation process takes a few seconds to happen and is done without much conscious control on our part. One way to see its effects is to look at two similar sheets of paper placed near one another, with one of them directly illuminated with outside sunlight (around noon) and the other illuminated with a common halogen lamp. Moving your sight rapidly from one to the other, you will see that the paper illuminated with the halogen lamp is definitely yellowish and one illuminated from the outside lightly bluish.

Is one white “whiter” than the other? When compared side by side, many observers looking at the two sheets of paper of the preceding example may select the sun-illuminated sample as the whiter one, but the same observers will not see a difference if adapted to each light in a separate room. This tendency of the human brain to assign a whiter white to a bluish white compared to a yellowish white is used by laundry detergents and paper manufacturers which add Ultra-Violet (UV) fluorescent compounds in their products to add some blue in the reflected light. The UV light, invisible to the human eye, is converted to blue light which is added to the normal blue light reflected by the sample. This enhanced blue reflection makes other white objects yellower by comparison; however, if you let your eyes adapt to the non-UV-enhanced paper for a few seconds, you may clearly see a bluish tint coming out of the UV-enhanced sample. In addition, UV enhancement varies with each material (various UV emitting chemicals) and light source (various UV content), and can be difficult to manage and control.

So what is the best white? The simple answer is that it is the one that “looks good” for the application. Artistic considerations may favor a golden hour look to convey a warm feeling, or a colder bluish dominant for dramatic effect, and technical applications will call for a numerically defined white (i.e. precise color temperature and known spectrum). Fashion shots will often require a more “mid-range” D50 illumination with images checked in D50 light booths. In all cases, being able to rely on a stable, well characterized white reference will help in obtaining the desired image.

Color Temperature

White illuminants are often described by their Color Temperature. This temperature is expressed using the kelvin scale, with zero kelvin, the absolute zero temperature, equal to about -273 Celsius (within fractions!). The kelvin and Celsius scales are simply shifted relative to one another, and a one kelvin temperature difference is the same as a one Celsius difference. For example, zero Celsius is 273 kelvin (which can also be written 273 K) and a room temperature of 22 Celsius is $273 + 22 = 295$ kelvin.

When a blackbody, often a “chunk” of metal, is heated, it emits light with a non-uniform wavelength distribution, and thus a perceived color, which changes according to its temperature. Sunlight has an apparent Color Temperature of 5 500 K, which is affected by clouds, atmospheric diffusion and pollution, and time of day (i.e. by its relative position in the sky).

Artificial lamps based on heated filaments have properties similar to blackbodies, and we can easily associate them with a Color Temperature. We can also find equivalent blackbodies temperature to associate with fluorescent lamps, even if they emit a significant amount of light at discrete wavelengths, quite far from the smooth spectrums of blackbodies.

Lights with Color Temperatures below 5 000 K can have a yellowish appearance while light with temperatures over 6 500 K can have a bluish appearance. These appearances are more pronounced, i.e. yellower and bluer, as we go to lower and higher temperatures respectively.

1.3. What is white balance?

With the knowledge that white lights can come in different “hues”, we can better understand the requirement of an adjustment mechanism to make sure that the imaged white corresponds to the required white. This is the purpose of the white balance settings seen in all digital cameras. Usually identified by the letters WB (for White Balance), the available settings are (these settings are not available in all camera models; the first four can be found on most cameras):

	White Balance setting	Approximate color temperature (Kelvin)
1	Automatic White Balance (AWB)	3 500 to 8 000 K
2	Incandescent (Tungsten/Halogen) lights	3 000 K
3	Fluorescent lights	4 200 K
4	Direct sunlight	5 200 K
5	Flash	5 400 K
6	Sun with clouds	6 000 K
7	Shade	8 000 K
8	Select color temperature	2 500 to 10 000 K
9	Preset/Custom	See note 1

Note 1: Usually requires an additional white or grey card of suitable size which needs to be placed in front of the camera and illuminated by the scene light.

The automatic (AWB) setting is usually selected by default. This setting is appropriate for general snapshots with scenes where objects and subjects cover a large color gamut, which would result in an average grey if all scene colors were mixed together, and where the illumination is principally from a single type (either all tungsten, or all sunlight, etc.). However, as soon as a color is dominant in the photographed scene, leaves in a forest, a brightly colored dress in a fashion shot, or floor/walls/ceiling/furniture/etc. colors in a room, the AWB settings will likely be fooled and introduce significant color errors.

You can minimize the damage by selecting the closest white balance setting your camera offers. For instance, in the leaves in the forest shot, selecting “Sunlight” white balance would ensure more realistic results. Similarly, for pictures inside a fluorescent lighted room, the fluorescent settings would be indicated. However, one could argue on the accuracy of the built-in “Sunlight” setting. Is it morning sun, noon sun, cloudy sun, overcast sun or late afternoon sun (each having a particular tint)? As well, there are many fluorescent tube types, with quite different spectrums resulting in very different perceived colors, not to mention mixed-lighting conditions, such as fluorescents combined with tungsten. This simply points to the limitation of fixed AWB settings; they can improve the general color accuracy, but accurate results require more precise control.

As this application note title says, we are concerned about RAW files here, and, as we mentioned in the introduction, the WB setting is independent of the RAW data. So why be concerned with the white balance setting? Firstly, this is the info that will be used by your camera and processing software if you automatically generate non-RAW images (i.e. BMP, JPEG, TIF, etc.), and the more accurate you get, the less post-processing will be required. Secondly, your camera display will use this setting to show the image preview so, there also, the more accurate, the better. This being said, you may elect to choose fully automatic WB, if only to see what your camera’s processor has selected as the most appropriate setting. In all of the above cases, when you open your file in RAW compliant software, you can discard the automatic or manual WB setting and replace it with one based on the measurement of a known white target. This is what we will look at in the next section.

In a nutshell:

- a- White balance corrects the scene colors in regards to the ambient illumination.
- b- Manually selecting the WB setting is recommended for better preview accuracy, and when saving files in non-RAW file formats.
- c- Best results often require additional WB adjustments.

2. Correcting the White Balance of your images

2.1. Positioning the white balance target

The two main guidelines for target positioning are:

Place the target at such a distance that its white surface image is at least 10 pixels in diameter

Making sure that your target image is of sufficient size will ensure that your target pixels are not affected by neighboring pixels and that you can use the average features of the color sampling tools (i.e. eyedroppers).

Place the target facing towards the camera while being illuminated by the main ambient light


The intent here is to sample the light used for your shot main subject, both in intensity and in color quality. If you position the target in a shadow, you may still be able to achieve white balance, but the light in the shadow zone may have a different spectral content than the main illumination. Even when placed under the main lighting, you should take care that the target is not placed towards a large colored surface or object; such colored zones will affect the illumination falling on the target and will affect any correction based on the target image. On the other hand, you may want to use the target in this manner to compensate for the color imbalance resulting from such a situation.

2.2. Importing a RAW file

We present two examples, one using *Bibble* V-4.5d (www.bibblelabs.com), a stand-alone RAW file importer, and the other using *Adobe Camera Raw* (ACR) V-3.0, part of Photoshop CS2 (www.adobe.com).

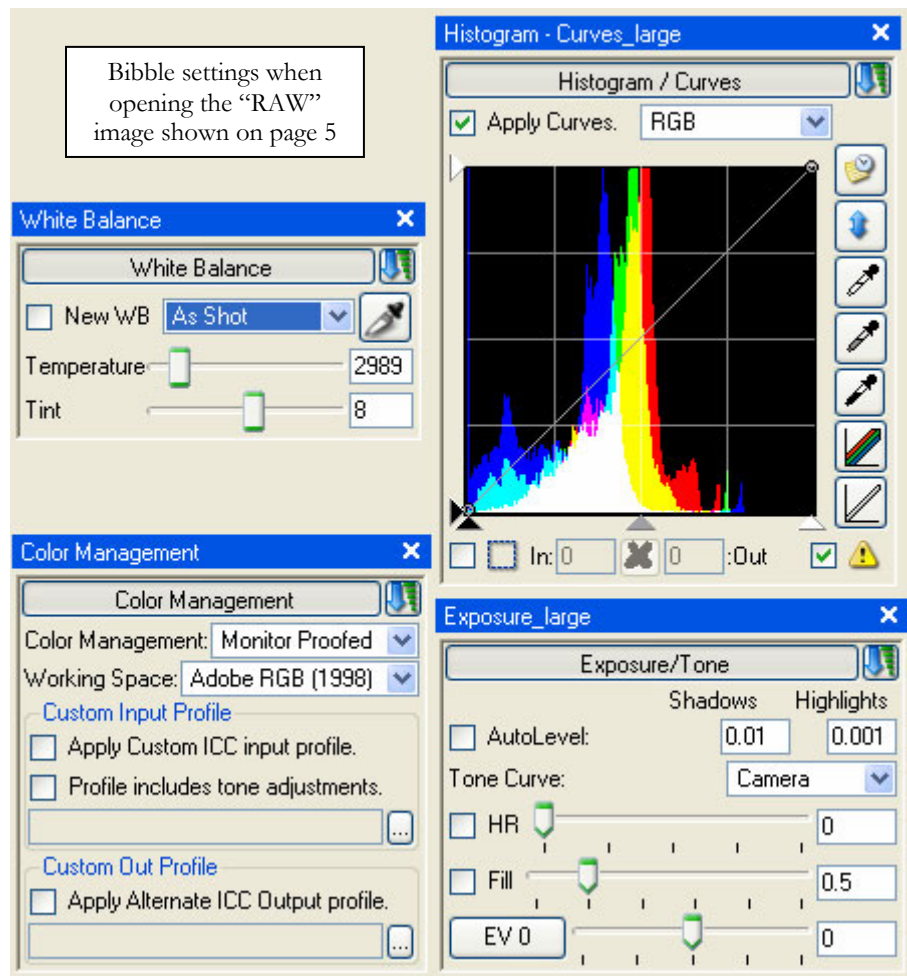
Example 1: Bibble

Hint: A very nice feature of Bibble is that it can also open JPEG files, and thus give access to its import tools, with its “Click White Cursor” being of special interest here. This is useful for those without a camera that supports RAW files, and for those who have many legacy JPEG images.

The image on the right shows the various program settings we used for our example. As you see, most of automated processing features are unselected, except the “Overexposure Warning”, which is checked. 

The picture is shown on the next page. It was taken in a room predominantly lit with halogen lamps, but non-negligible daylight came through a neighboring window.

The camera, a Nikon D100, was set to “Tungsten” WB.





Note: All images have been further converted and saved in sRGB before being pasted in this document. This pdf is tagged for color management.

White balance: As Shot (Tungsten)
 Target (Adobe RGB): 188-194-203

White balance: Click White (target)
 Target (Adobe RGB): 196-194-195

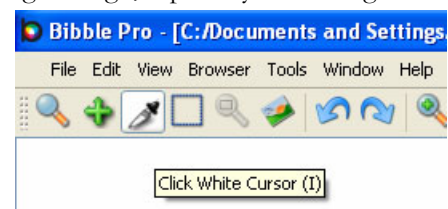


The “RAW” (i.e. “As Shot”) image is dull. Apart from a lack of brightness, which we will adjust shortly, it exhibits a blue cast due to the “spilled” daylight. This can be confirmed by moving the cursor over the white target (within Bible), which shows Adobe-RGB values of 188-194-203, a bluish light grey.

Hint: In Bible’s “General preferences”, set the “Click-tool sample size” to “Large”. The larger this setting, the better the average (as long as your target image is large enough!).

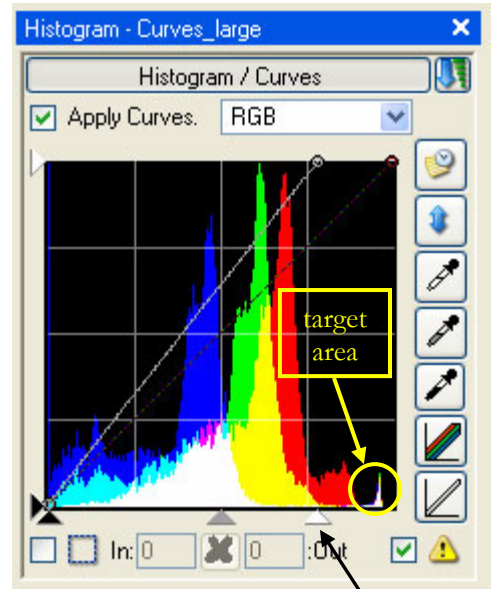
Because we had checked the “Overexposure Warning” box, all saturated pixels, i.e. pixels with one or more RGB value of 255, would have been highlighted. The absence of any highlight is a good sign, especially in the target area since any correction based on a saturated color will give skewed results.

To correct the WB, select the “Click White Cursor” tool, represented by an eyedropper icon, and click the white target in the image. The result is shown on the “WB” image, where the target white is 196-194-195, an almost neutral light grey.



From there, we adjust the exposure by moving the “Histogram’s” white cursor to the left until the target white is around 250-250-250. If you go too far, you will see highlighted areas with overexposure popping up. We stopped just before any highlights could be seen; the white target value is about 249-246-247 (Note: this value changes slightly depending on the cursor position). The corrected image, “WB + EXP”, is shown below. In its histogram, shown at right, we can see, on the extreme right, a little white peak corresponding to the target area. If you look at the right of the first histogram shown on page 4, you will see that there are three little peaks instead of one, corresponding to the red, green and blue primaries. The white balance tool “simply” corrected the three channels in such a way that the histograms of the primaries are matched.

In the “WB + EXP” image, apart from a neutral white target, the fruits, the straw basket, as well as the stone table, all have very realistic colors.



histogram
“white”
cursor



White balance: Click White (target)
 Target (Adobe RGB): 249-246-247
Exposure: Corrected

Once these simple corrections are done, nothing prevents you of further working on your images using the other tools offered by Bible, or transfer them to your favorite image editor. In any case, when you are satisfied with the adjustments within Bible, you should save the settings using the

Edit/Settings/Save Image Settings

menu command.

You can then apply the same corrections to any picture taken in the same illumination conditions by using the

Edit/Settings/Load Image Settings

menu command. Of course, the target does not need to be in these other pictures.

Note: Bible white balance tool gave us a touch less neutral correction than Adobe Camera Raw (i.e. equal R, G and B). This has nothing to do with the target since these programs always assume it is perfectly neutral to start with.

Note: Contrary to our expectations, we obtained slightly different results in Bibble, when using its WB tool, depending on the WB setting used when taking the picture (all pictures were taken using both a custom WB and AWB, even if the AWB results are not shown here). In principle, the camera WB setting should have no effect on RAW file processing. Such a difference was seen with images of the two examples presented in this document; best results were obtained when using a custom WB setting, not AWB. Such an effect was not detected when using Adobe Camera Raw on the same files.

Example 2: Adobe Camera Raw (ACR)

The image below shows the various ACR settings we used to process our RAW image. Like with the Bibble example, most of the automated processing features are unselected. The settings of the other tabs (“Detail”, “Lens”, etc.) are the default values obtained when selecting the “Camera Raw Default” setting.

Here again, we selected Adobe RGB as the target space, and 8 bits per channel. In addition, for viewing purposes, we checked the following boxes:



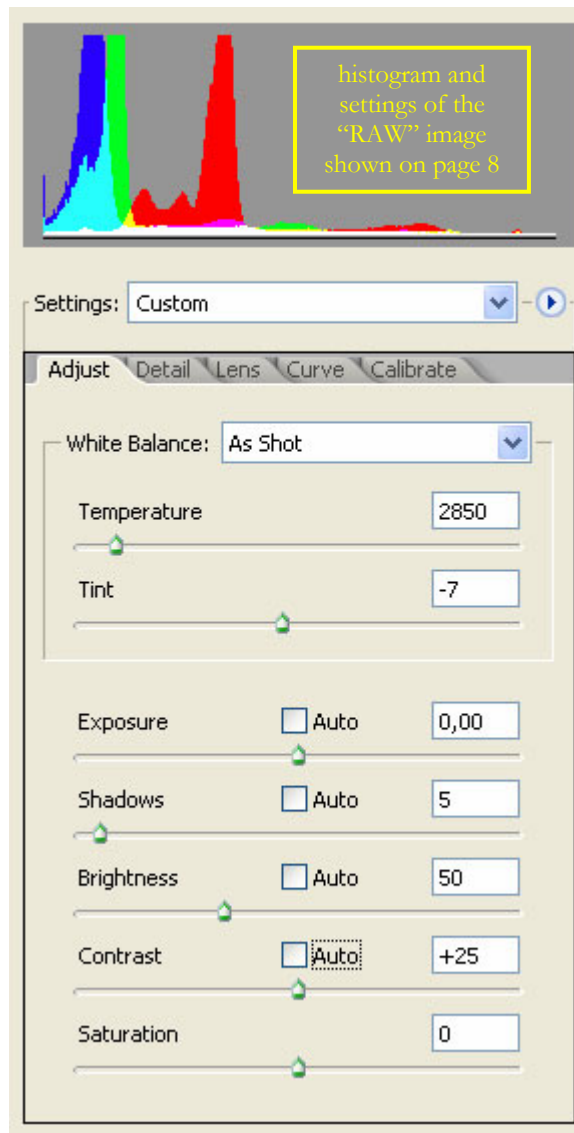
The “Highlights” checkbox is equivalent to the “Overexposure Warning” checkbox of the Bibble histogram interface.

The picture is shown on the next page. The hand is solely lit with five small halogen lamps (50 W, PAR20 type, 110 VAC) attached to a rail on a 4 m (13 ft) ceiling. Some of the lamps are directed towards a “light cream” wall facing the burgundy wall in front of which the hand is positioned.

The light falling on the top of the arm is not too influenced by the burgundy wall color, but the light under the arm has a definite reddish tint. Spot metering on a grey card was done to insure proper exposure; spot metering on the hand could also be acceptable but bracketing would then be recommended.

The Nikon D100 camera was set to “Tungsten” WB, which is not “yellow” enough to compensate the ambient illumination, but which is a good start. You should definitely not select “Auto” WB (i.e. AWB) in such a picture because of the dominant and strongly chromatic wall color. As we mentioned before, the camera setting is the one used when you preview and first import your picture, and you may also decide to take and save a non-RAW image, which will be color corrected based on this setting.

The images on the next page are presented in the same order as in Example 1; additional information is shown beside each one.





White balance: As Shot (Tungsten)
Target (Adobe RGB): 236-203-180
Other settings: as shown on page 7

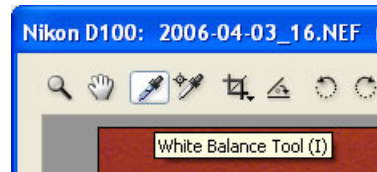


White balance: Custom (on target)
Target (Adobe RGB): 203-203-204
Other settings: as shown on page 7

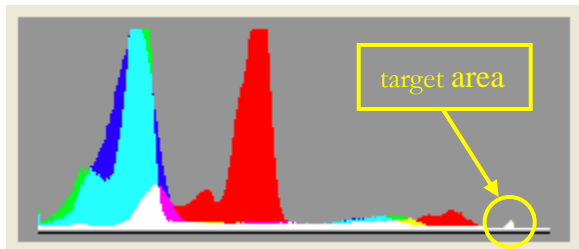


White balance: Custom (on target)
Target (Adobe RGB): 236-236-236
Exposure: +1,00 (instead of 0,00)
Contrast: +36 (instead of +25)

The uncorrected RAW image made with the Tungsten WB setting is much too orange. The silver chains holding the colored glass beads almost look like gold and the “white” target is imaged as being light peach. The second image, “WB”, was obtained by clicking on the white target using the “White Balance Tool”. Tweaking the “Exposure” and “Contrast” settings resulted in the third image, “WB + EXP”. Apart from a more accurate skin tone, we now see silvery reflections from the chains, neutral white on the target, neutral dark tones on the target holder, and realistic blue-colored “tiger-eye” stones on the bracelet.



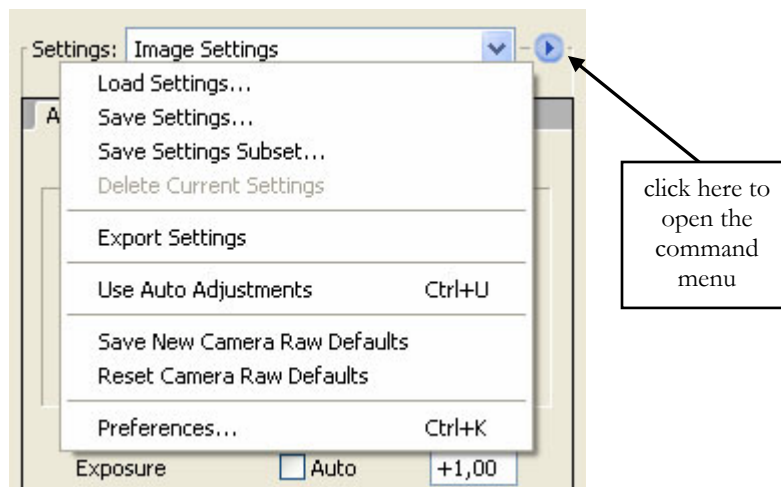
Note: According to very reliable sources (thanks guys!), at 100% or lower magnification, all ACR sampler tools read 5x5 **screen** pixels. For magnifications larger than 100%, they read 5x5 **image** pixels. The sampling size is not affected by any “Sample Size” selection you may have made for Photoshop’s “Eyedropper Tool”.



Looking at the histogram of the “WB + EXP” image, we see, as we did in Example 1, a tiny white peak at the extreme right, which corresponds to the target area. The small size of this peak in comparison with the rest of the histogram is simply due to the small target area relative to the entire picture, which is cropped significantly for the images of the preceding page. You will also notice that the three peaks of the RAW image are not even visible in its histogram shown on page 7. Please

note that not all images will result in a histogram with such a well defined peak, as it may be combined with the data of other white zones.

To save your settings and apply them to other images, use the menu commands accessible by clicking on the small arrow at the right of the control panel:



3. Conclusion

Getting to understand and control white balance can improve the quality of the pictures we take. The potential improvement can be dramatic or subtle, depending on the lighting, the scene, and the camera settings, but there is, more than likely, always room for improvement. The technique of using a near perfect white target is a simple way of achieving that goal.

The additional advantage of using a target with 99% plus reflectance is that you can also better control the image highlights. Firstly, you know there is a highlight if a pixel value on a scene object is higher than the value of the pixels representing the white target (assuming that the target is subjected to the maximum scene illumination). Secondly, you can adjust the image exposure by monitoring the target pixel values. It is then up to you to select the amount of highlight clipping you desire, but at least you know that ALL color tones will be within the image gamut.



The BabelColor Company

Founded in 2003, *The BabelColor Company* is dedicated to the development and sale of specialized color translation software and color tools. It also provides color consulting services for the professional and industrial markets.

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