tutorial

Improving Video Color Quality

By S. Scott Grizzle

Over the past 10-plus years, many customers and colleagues have asked me how to improve the quality of their web videos. The first thing I tell them is to get out of the it's-only-for-the-web mentality. Web viewership is growing faster than anyone thought possible, and its acceptance has surpassed TV's adoption over the same time span. So think quality first, and remember that a shoot for the web is the same as a shoot for HDTV.

Once you're in that mind-set, there are three more ways to improve quality. First, know your equipment and how to adjust for optimal output. Second, adjust your white-and-black balances during acquisition. Finally, raise your contrast and complexity during encoding. By doing these things, you can make your video look great and differentiate yourself from everyone else.

A major element of great-looking webcasts or streaming media is content acquisition. Without a decent camera and knowledge of its characteristics, the video will look unimpressive. The first step is getting to know your camera. There isn't one brand that is best—that's totally subjective and up to personal preference—but simply knowing your camera's brand will tell you quite a bit about its characteristics. It doesn't matter if you are doing a single-camera or a multicamera shoot. Just knowing the brand and how each one differs allows you to set up the camera properly. These differences affect the white balance and color saturation.

You might notice how one camera's reds look brighter and appear to "pop," while another brand's reds are dull but the blues appear to pop. This can be true whether the camera is professional or prosumer. One brand's camera might use complementary metal oxide semiconductors (CMOS) while another brand uses charge-coupled devices (CCD) sensors.

Making the CMOS/CCD Decision

The difference between CMOS and CCD isn't something most people need to know. However, understanding how each one works and the differences between them can tell you which filters you should be using and how light is affected. One good question to ask is, "What is CMOS, and why is it good for a camera and my production?" CMOS sensors use multiple transistors to amplify and move the charge provided by incoming photons of light, enabling the pixels to be read individually.

One of the advantages of CMOS is its low power consumption. CMOS sensors consume up to 100 times less power than CCDs. Because CCDs are essentially capacitive devices, they need external control signals and large clock swings to achieve acceptable charge transfer efficiencies.

Another advantage of CMOS is that it is adaptable for high frame rates and resolutions. Most CMOS sensors are set at HD resolutions, but since their resolutions are so high and their sensors can access just the pixels of a region, they allow high frame rate. Basically, reducing the resolution allows the higher frame rates. This is a real advantage of CMOS. Now, you can set your camera up right and use it in high frame rate applications.

One last thing that is good about CMOS is that the sensors don't have artifacts, smear, or blooming. They have a clean, high-quality image.

However, like everything else in life, CMOS sensors have their drawbacks. First, they aren't as sensitive to light as your typical CCD sensors. So if you're in a low-light setting, you might run into problems.

Another issue is that these sensors usually don't have infrared (IR) filters installed on them. In industrial applications, this is more common. But without an IR filter, your colors will be skewed. Basically, your spectrum will be adjusted so that your greens will be brown. But this is an easy fix—simply add a filter. Many CMOS sensors use a Bayer filter that passes red, green, or blue light to selected pixels. Lastly, CMOS is considered to be noisier than CCDs, but, in most cases, this is only noticeable on test equipment.

The alternative to CMOS is the older standard, CCD, and three-CCD solutions. Many people know the term CCD, but what is it? Well, again, it's not a know-or-fail thing, but it helps to understand the complete workflow. The CCD is a solid-state chip that turns light into electric signals. In a full-frame device, all of the image area is active, and there is no electronic shutter. A mechanical shutter must be added to this type of sensor or the image will smear as the device is clocked or read out. The sensors respond to 70% of the incident light, making them far more efficient than photographic film, which captures only about 2% of the incident light.

Most common types of CCDs are sensitive to infrared light, which allows zero lux (or near-zero lux) video recording. Many CCDs, like CMOS sensors, use a Bayer mask over the CCD. Each square of four pixels has one filtered red, one blue, and two green. The result of this is that luminance information is collected at every pixel, but the color resolution is lower than the luminance resolution.

Better color separation can be reached by three-CCD devices (3CCD). Each of the three CCDs in these devices is arranged to respond to a particular color. Another advantage of 3CCD over a Bayer-mask device is higher efficiency (and, therefore, higher light sensitivity for a given aperture size). This is because, in a 3CCD device, most of the light entering the aperture is captured by a sensor, while a Bayer mask absorbs a high proportion of the light falling on each pixel.

CMOS is allowing a cheaper entry into the HD and HDV realm. This is why technologies that enable the HDV movement are available at an affordable price, unlike those that enable the HD CCD movement. Neither technology has a clear advantage in quality. CMOS can potentially be implemented with fewer components; they use less power and provide data faster than CCDs. However, CCD is a more mature technology and is, in most respects, the equal of CMOS.

Choosing the Right Camera

All cameras have their advantages and disadvantages. It doesn't matter if they are a camcorder, dockable, or box (industrial) camera. The typical camcorder is the video professional's bread and butter. Camcorders are used in probably 90% of the industry because you can go to tape instantly or to a hard drive in some cases. Along with going to tape, they provide FireWire and analog outputs. As mentioned earlier, with the emergence of new technology, we are seeing prices drop, allowing an easier movement into the HD world.

Another trend in the camera movement is to go away from camcorders to dockable cameras. Dockables offer the advantage of changeable recording formats. Maybe you have an event that requires a videotape recorder (VTR) back or camera control units. Obviously, dockables offer greater flexibility in these situations. They aren't the cheapest route to go up front, but one camera can do the job of three or more camera formats. So in the long run, if you can afford this solution, it can pay for itself relatively quickly.

If the dockable price is too high or you want to go for a smaller-sized camera, the box (industrial) camera is a great option. You can set these up to be controlled remotely or in a studio configuration. Their prices, in most cases, are affordable, and you can more than likely use the lenses you already have. The major drawback is that there is no camera back or VTR that is already on board or that can be attached. But then again, you're not format-dependent. You can use a VTR of any format, and you can also hook up a CCU to give you more control over the black levels and color saturation.

With so many camera options, what format should you use and what is best for the web? Well, you can use the three main formats: DV, HDV, and AVCHD. It really depends on what your shoots are now and how you want to position yourself for the future.

Now, HD streaming is still small but growing. With more people getting cable modems that can handle higher bitstreams, HD is becoming more attractive. Granted, we are a long way from the days of postage-stamp-sized video, but wouldn't you love to see a great-looking 1080 video stream at full frame rate? It's coming, but who are the first players going to be?

If the cost of HD still scares you and you don't do enough other projects that can justify a full-blown HD camera, then the HDV route is probably the best way to go—just go progressive and skip the interlaced route. Keep in mind, however, that a progressive HDV camera like the JVC HD200 shoots the same resolution (1280x720) as a non-HDV HD camera like the Panasonic HVX200. Most TV and computer monitors are going away from cathode ray tubes (CRT). If you need to do interlaced video, go ahead and change from progressive to interlaced in postproduction. You will be happier in the long run.

If you have never used a CCU before, it allows you to control almost every aspect of the camera. So when should you use a CCU and when should you go straight to tape? Most people associate CCUs with broadcast or multicamera shoots. The truth is that it's up to your standards. If you're satisfied with the default white balance, black balance, and filters, then go straight to tape. If you are not and want more, then look into CCUs.

That said, not all cameras can use CCUs. The trend over the last few years has been to allow professional camcorders to be attached to CCUs. Most use them with dockable cameras, where you can put on a studio back and connect it with 26-pin cable or Triax.

However, if you can't afford a dockable with a CCU solution, a box camera may be right for you. You can find them with bayonet mounts and 2/3" CCDs along with many of the same features that the dockable cameras have. Almost all of the box cameras can be hooked up to some form of CCU.

Some box cameras are better than others, and the price will reflect that. But you can't beat their size for travel, and their cost is usually lower than the dockables. However, you can't attach a VTR to the back of them. You can set them up in studio configurations with viewfinders and lens-control systems. But since you might want to use CCUs, the video will then go to your real VTR, where it will be processed by your personal settings. Yes, you can set filters and the pedestal. Some box cameras even have options to control remotely with pan and zoom. This is great, except then you need to do multiple multicamera shoots, and you may not have the staffing to do them all.

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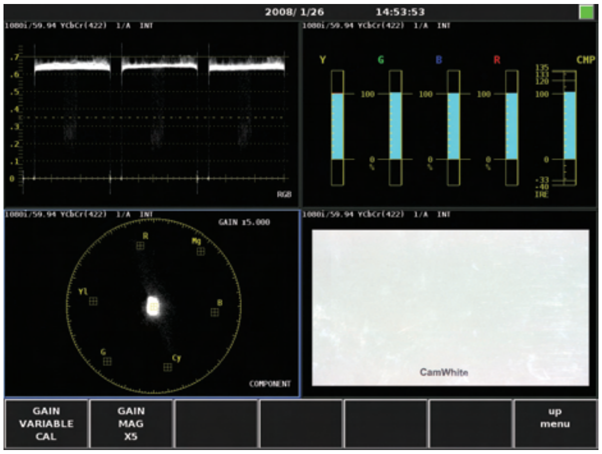


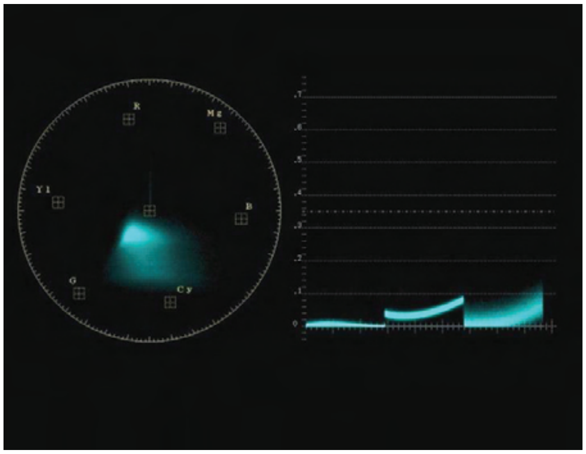


Figure 1 *(far left). Leader Instruments LV5800 with white balance set to 100 IRE*

Figure 2 *(near left). Leader Instruments LV5800 with black balance set to zero*

Getting Your Settings Straight

When it comes to balancing your whites and blacks, some of you may already be thinking, "I just use the on-board white balance. I flip the toggle and wait for the screen to tell me it is complete." However, there is a real value to doing a more detailed white balance and black balance. The defaults on most cameras are fine, but if your camera or equipment allows it, tweaking the white and black balances allows your colors to pop and makes your picture appear warmer or cooler, depending on how you set them up. Most people do a quick white balance, which allows skin tone to look OK. The camera's colors are going to be close to the right range, but there is no guarantee that they will be exactly where they should be.

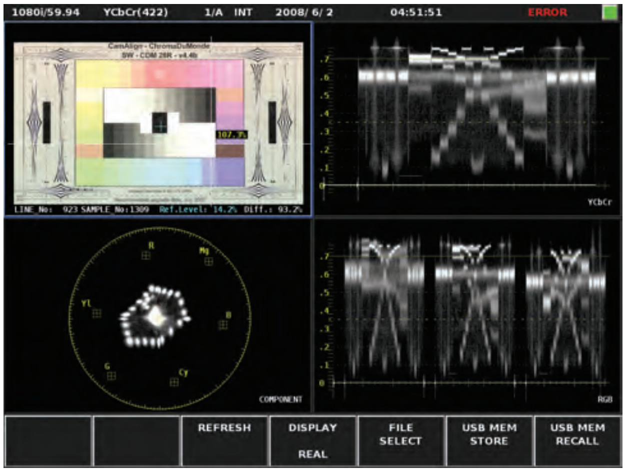
When adjusting the color range, most people forget to adjust the black balance, but this is just as important as the white balance. Without setting your black levels, it's difficult to truly set your white balance. The black level is the base. In most cases, the white level is set to 100 IRE, while the black level is set to 7.5 IRE (see **Figure 1**). The reason black is set to 7.5 IRE is because blanking is set to zero. (Blanking is the NTSC interlaced scan line.) This is done so no one will constantly see the line constantly in the video. With LCD and digital displays (computer monitors and now home television), there is no blanking, so black can be set to zero (see **Figure 2**). The tools you can use to set your blacks and whites are called waveform monitors and vectorscopes. It is key to know about these tools, IRE, illegal blacks and whites, and how to make your videos appear cold and warm.

Using waveform monitors and vectorscopes seems to be a dying trend. I guess it's more of the way the analog guys used to do it. I'm not calling them old, I'm just saying that, in the digital world, the analog ways of doing things aren't exactly being transferred. They're not wrong, they're just not being taught anymore. That said, it may be a digital world, but it's an analog workflow. Waveform monitors and vectorscopes allow a person to see where whites, blacks, and the full-color spectrum fit. I bet you would be surprised where your default settings are and where your colors are with each day-to-day use. You may even have software versions of waveform monitors and vectorscopes on your nonlinear editing system. You use them and probably don't know it.

Basically, waveform monitors and vectorscopes are oscilloscopes that are designed to be used in the video environment. Waveform monitors are used to see where black levels and white levels are, while vectorscopes work with chrominance information. The vectorscope shows where the colors should be. Typically, this is where you would use your color bar chart. On the scope are red, magenta, blue, cyan, green, and yellow. So you can see that by using these two devices, with proper adjustment, your colors can be dead-on and give you the extra pop that most companies' videos just don't have.

IRE, named for the Institute of Radio Engineers, is a unit of measurement in the video world that was developed to measure the amplitude of video signals. For standard NTSC—the analog television system used in the U.S. and named for the National Television System Committee—these settings are as follows: White is 100 IRE and black is 7.5. However, with computer monitors and digital displays, the blanking frequency has been

Figure 3 (near right). Leader Instruments LV5800 with white balance set too high



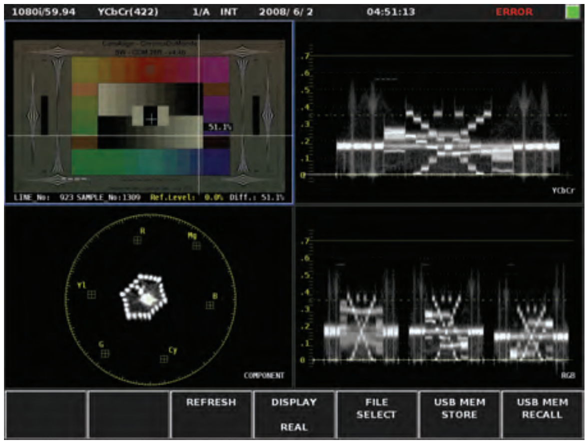


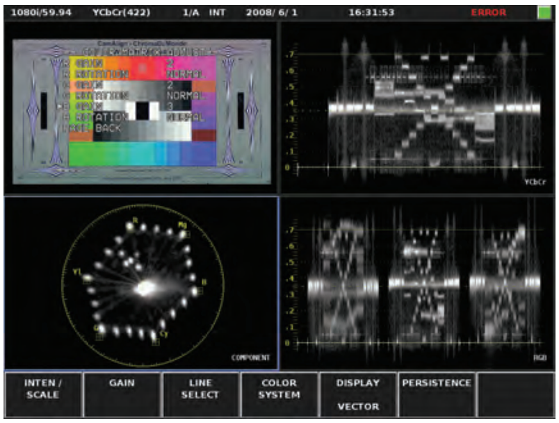
Figure 4 (far right). Leader Instruments LV5800 with illegal blacks and over-saturation

removed, and now, black can be set to zero. But doing this can cause your videos, when played on nondigital devices, to have issues. For example, if switching, you might hear a pop in the audio with each dissolve or cut. Also, your colors' brightness may be different on the two settings. Setting the black to zero is known as super black or enhanced black.

Illegal whites and blacks, which cannot be reproduced by traditional CMYK printing, are a bad thing. Whenever you hear the term illegal, it's never good. What the term means is that your color settings are out of the norm. With illegal whites and blacks, or even just one or the other, all of your colors become illegal. Your colors will be either blooming or crushed, so your skin tone and other colors just won't look good. This is why you should take control of your camera's settings. When you use the automatic setting on your camera, the settings are approximations and not true settings. So your black settings may be at 3 IRE or even 15 IRE, while your whites may be at 70 to 80 IRE or even above 100. Both are bad. **Figure 3** shows a white balance set too high, while **Figure 4** shows illegal blacks and oversaturation. **Figure 5** shows correct settings.

Some great tools you can use to prepare your settings are a Society of Motion Picture and Television Engineers (SMPTE) color chart and a warm card. The SMPTE color chart is considered the broadcast standard for setting colors and has multiple shades inside of it. When you look on a vectorscope, you will be considerably more accurate. The warm cards are a nice tool that very few people use. They are white balance cards, but they are not pure white and are set for different levels of lighting and filaments. If you use them, you can shoot in fluorescent lighting and your whites will look white and not green. So with these cards, you can make your video warmer or colder as you see fit.

Figure 5. Leader Instruments LV5800 with correct settings



Warm and cold videos are easy to define. Warm has a tendency to be on the red side, while cold is on the blue side. Again, choosing which way to go is really up to personal preference. However, you need to know your audience before you make the choice. Do you think your audience is on CRTs or on LCD and plasma displays? Since CRTs are tube-based and tend to run warm, you might want to make your videos on the cooler side. If your audience is more web-based or even HD-based, they are on the cooler side, so you will probably want to work on the warmer side. There are some exceptions. Again, this is where you need to know your equipment. Are your cameras on the warm or cold side? What looks better to you? How is your contrast?

Encoding for Maximum Quality

Now that acquisition and color correction have been covered, the final element for great-looking video on the web is complexity and contrast. Since the original days of streaming media, we have been looking for ways to make videos look better. In the early days, there were only a couple of codecs, and live and real-time encoding was difficult. We could add filters, but more importantly, they gave us control of contrast. As mentioned earlier, televisions and computer monitors used different technology, and as such, the contrast would be different. So using the aforementioned programs, you can tweak web videos by adding more contrast than you would for normal videos. What this will do is give colors more saturation, which will make them seem fuller and brighter. If your contrast is too low, your video will look washed out, dull, and a little more gray. If you look at most web videos, this is the case. So in many cases, adding extra contrast will cause your videos to have some pop.

Another option to help make your video look better is encoding it in high complexity. High complexity can be used in both live and transcoding workflows. Using high complexity is basically giving the encoder more information to work with. It's like shooting the same content at the same angle with both HD and SD cameras. It's the same information, but the user has more to work with (not to mention a completely different frame shape!).

Now, that is an extreme example. From doing my own lab tests, there isn't any noticeable file size difference. But there is a definite image quality difference. I know it can be hard to tell at first glance, especially if your largest video size is 320x240. But when you start doing 640x480 and above, it's much more noticeable. I'm not saying that if you do a side-by-side of smaller-sized images, you won't see the difference. You will. So now you're saying, "If this is such a great thing, why isn't everyone doing it?" The answer is time. As such, you must choose between speed and quality.

So which is more important? There is an old saying that time is money. That is true. The faster you get things done, the more you can get done and the more money you can make.

But I come from the school of doing the highest quality work possible. Why invest all this time and creative ability only to kill your work in the encoding process? Again, this is a personal judgment. Back in 2000, my crew and I did about 160-plus hours of footage per week. We then had to edit it and get it up on the web with Synchronized Multimedia (SYMM) technology. We always went for the highest quality and the largest-sized videos. Most of our competitors were doing videos that were 240x180 or smaller. Our smallest was 240x180, and our average was 320x240. Some customers requested even larger videos, such as 640x480. We always did high-contrast and high-complexity work. This gave us a competitive advantage over our competitors. We never lost a show or lost a bid because of quality.

But this had a drawback. We had a good-sized encoding farm, and the machines were going 24/7. Back then, there was no hardware that would assist with this. Now, there are accelerators. I'm familiar, obviously, with the LSI Tarari Encoder Accelerator (see Jan Ozer's review, p. 70–72). This is a hardware accelerator that speeds up the software encoders such as Windows Media Encoder, and it accelerates at higher complexity. So it basically offers hardware speed with software quality and high complexity.

Summary

To improve your quality and give yourself a competitive advantage over the other guys, you should know your equipment and how it operates. You don't need to be an engineer and know every facet, but be familiar with how your equipment works and the tweaks needed to make your video stand out. After you know your equipment, remember to make sure you adjust your white and black levels during acquisition. By doing this, your color saturation will be where it should be and not an approximation. Lastly, take advantage of adding to your contrast and encoding in high complexity. Encoding with high contrast will allow your colors to have a deeper saturation that will make your video seem to have more pop. Using high complexity will make your video appear to be clearer and encoded at a higher bitrate than it actually was.

S. Scott Grizzle is the senior systems applications engineer at LSI Corp., working with digital media. He is a certified broadcast engineer but has been working in streaming media and encoding since 1998.

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