PRIMARY COLOR ADJUSTMENTS

In this chapter we’ll examine the common methods you can use to make primary color adjustments to affect an overall image.

As discussed at the beginning of Chapter 3, the human visual system processes color signals separately from luminance, and as a result, color conveys a completely different set of information. Color is used by what Margaret Livingstone refers to as the “what” system of the brain to identify objects and faces. Other studies support the idea that color plays an important part in speeding object identification and in enhancing memory recall.

For example, in their article “Revisiting Snodgrass and Vanderwart’s Object Databank: Color and Texture Improve Object Recognition” (Perception Volume 33, 2004), Bruno Rossion and Gilles Pourtois used a set of standardized images first assembled by J.G. Snodgrass and M. Vanderwart to determine whether the presence of color sped subjects’ reaction times for object identification. The study sorted 240 students into separate groups and asked them to identify one of three sets of test images: black and white, grayscale, and color (such as those images shown in Figure 4.1). The resulting data showed a clear increase in the speed of object recognition by nearly 100 milliseconds with the addition of color.

Similarly, in “The Contributions of Color to Recognition Memory for Natural Scenes” (Wichmann, Sharpe, and Gegenfurtner, Journal of Experimental Psychology: Learning Memory and Cognition, 2002), subjects were reported to have performed 5–10 percent better at memory retention tests that used colored images than they did with grayscale images.

NOTE
In an interesting aside, this research dovetails with other research on so-called memory colors (a topic covered in more detail in Chapter 8), in that the memory-enhancing effect is dependent on a subject’s conceptual knowledge of the object being remembered (in other words, knowing in advance that bananas are yellow). Memory retention improvements diminished when subjects were tested with false-color versions of the same images.
Beyond these purely functional benefits to color, artists, critics, and researchers over the centuries have called attention to the emotional signifiers of various colors and the importance that color exerts on our creative interpretation of visual scenes. For example, not many people would dispute that orange/red tones are high-energy colors and that an abundance of warmth in the art direction of a scene will lend a certain intensity to what’s happening, as shown in Figure 4.2.

Similarly, blue has an innate coolness, and bluish lighting will give an entirely different impression to an audience (Figure 4.3).

In her book, *If It’s Purple, Someone’s Gonna Die* (Elsevier, 2005), designer, author, and professor Patti Bellantoni cites numerous color experiments with her art students, whom she separated into groups, asking each to create an environment based on a specific color. The resulting color-dominated rooms not only drew a clear emotional response from the students, but over a number of years, successive classes of students exhibited strikingly similar interpretations for identical colors.

In the “backstory” chapter of her book, Bellantoni says, “My research suggests it is not we who decide what color can be. After two decades of investigation into how color affects behavior, I am convinced, whether we want it to or not, that it is color that can determine how we think and what we feel.”
COLOR TEMPERATURE

Simple primary corrections won’t unrecognizably alter the art direction and costumes within a scene. However, by correcting, shifting, and deliberately controlling the overall color tone of the lighting, you can create distinct audience impressions about the emotional atmosphere of a scene, the health and attractiveness of your characters, the tastiness of food, the time of day, and the kind of weather, no matter what the lighting of the shot originally was. Figure 4.4 shows two contrasting versions of the same scene.

To master these kinds of adjustments, we’ll examine the role that color temperature, manipulation of the chroma component, additive color math, and an understanding of color contrast all play in the use of the color balance and RGB Curve controls present in nearly every professional color correction application.

NOTE
This chapter is not concerned with specific color changes to isolated objects, which is the purpose of the secondary color corrections covered in Chapters 5 and 6.

Figure 4.4 Which room would you rather wake up in?

COLOR TEMPERATURE

All color in a scene interacts with the dominant light source, or illuminant, of that location. Each type of illuminant, whether it’s the sun, practical tungsten or halogen light fixtures, or stage and cinema lighting instruments, has a particular color temperature that dictates the color quality of the light and how it interacts with subjects in a scene.

Nearly every lighting effect dealt with in this book is a result of differing color temperature, or color of light, in various circumstances. Every time you correct or introduce a color cast in an image, you’re effectively manipulating the color temperature of the light source.

Color temperature is one of the most important concepts for a colorist to understand because the color temperature of the lighting in any scene changes the viewer’s perception of the colors and highlights found within. Despite the human eye’s adaptive nature, when the color temperature of the dominant lighting is not taken into account through the use of film stocks, filtration, or white balance, a color cast will be recorded. Sometimes a color cast is desirable, as in the case of “magic hour” lighting or sunset photography. Sometimes it’s not desirable, such as when you’re shooting interior scenes with incorrectly balanced or spectrally varied light sources.
Each type of light source used to illuminate subjects recorded by film or digitally has its own particular color temperature, which in many cases corresponds to how hot that light source must be to emit light. Light emitters can be modeled in physics as black-body radiators, which are idealized light sources that output pure color corresponding to their temperature. For example, the heating elements in some toaster ovens are approximate black-body radiators. The hotter they get, the brighter they glow: first dark orange and then progressively lighter. The carbon rods used for arc welding are so hot that they glow a bright blue-white.

Candles, light bulbs, and sunlight operate at very different temperatures, and as a result, they emit more or less radiation at different wavelengths of the visible spectrum. Thus, comparing two different light sources (such as a household lamp next to a window on a clear morning) reveals differently colored light. Consider Figure 4.5, color-balanced for tungsten, which accounts for the white quality of the interior lighting. This reveals how cool the sunlight coming in through the window is, which by comparison is a vivid blue.

The color temperature of a light source is measured in Kelvin (Figure 4.6), named after William Thompson (aka Lord Kelvin), a Scottish physicist who first proposed a scale for absolute temperature measurement. While named for Kelvin, Max Planck was the physicist who developed the principle (called Planck’s law) that, as Wikipedia explains, “describes the spectral radiance of electromagnetic radiation at all wavelengths emitted in the normal direction from a black body in a cavity in thermodynamic equilibrium.”

The math is complex, but for our purposes the general idea is that the hotter an emission source, the “bluer” the light. The cooler the emission source, the “redder” the light. Consider how the scale in Figure 4.6 matches to light sources and other illuminant standards.
It’s not a coincidence that the color gradient from 1600K to 10000K matches the progression in the quality of sunlight from sunrise to bright, noon sunlight.

**“D” ILLUMINANTS AND D65**

A second color temperature standard you may hear mentioned describes the so-called “D” illuminants (also listed in Figure 4.6), which are defined by the Commission Internationale de l’Eclairage (CIE). The CIE defined standard illuminant graphs to describe the spectral distribution of different types of lighting. The “D” illuminants are all intended to describe daylight color temperatures so that manufacturers of lighting fixtures can standardize their products.

Each of the CIE illuminants was developed for a specific purpose. Some illuminants are intended for use as lighting for critical color evaluation; others are meant for use in commercial lighting fixtures.

One illuminant you should memorize is D65 (corresponding to 6500K), which is the North American and European standard for noon daylight. This is also the standard setting for white that broadcast video monitors use in the United States and in Europe, and it is the type of ambient lighting you should employ in your

**NOTE**

The native white point used by computer displays typically defaults to D65.
color correction suite. Inconsistent lighting in your environment will cause your eyes to adapt incorrectly to the colors on your monitor, resulting in bad color decisions.

Broadcast monitors in China, Japan, and Korea are balanced to D93, or 9300K, which is a significantly bluer white. This should ideally be paired with matching D93 ambient lighting.

**SPECTRALLY VARIED LIGHT SOURCES**

The simple color temperature measurements shown in Figure 4.6 are good for describing light quality in general terms, as well as for standardizing film stocks, optical filters, and HDSLR, camcorder, and digital cinema camera white balance controls. However, the spectral distribution of real-world light sources isn’t always so perfect. Different light sources have unique spectral distributions that may include numerous spikes and dips at specific wavelengths of light.

A good example of a spectrally varied light source is fluorescent lighting, which has spikes in its spectral distribution that can illuminate other colors differently than you might expect. An average office fluorescent tube has small but significant spikes in the green and indigo-blue portions of the spectrum that, while appearing perfectly white to the human eye, may lend a greenish/blue cast to unfiltered film and improperly white-balanced video. For example, the image on the left in Figure 4.7 is incorrectly balanced for tungsten, and the fluorescent lighting lends a greenish cast to the image (especially visible in the gray doors). The image on the right is properly white balanced.

![Figure 4.7](image)

The image to the left exhibits the greenish tint of fluorescent lighting shot with an incorrect white balance. The image to the right is shot using the correct white balance.

Generalizing about the light given off by fluorescent tubes is difficult because there are many different designs, all of which have been formulated to give off different qualities of light. Some fluorescent tubes have been specially designed to eliminate these spectral inconsistencies and produce light with nearly equal amounts of radiation at all frequencies of the visible spectrum.

Other spectrally varied light sources are the sodium vapor lamps used in municipal street lights, which give a severe yellow/orange cast to an image, as shown in Figure 4.8.

![Figure 4.8](image)
Other spectrally varied light sources include mercury vapor lamps, which lend an intense off-red tint to shots, and metal halide lamps, which can give off either magenta or blue/green casts.

With a shot that has one of these intensely red/orange light sources as the primary source of illumination, you’ll be surprised at how much of a correction you can make, assuming that the main subjects of the shot are people. Because these light sources have a strong red component, you can generally bring back relatively normal-looking skin tones. Unfortunately, other colors won’t fare as well, so cars, buildings, and other colorful exterior objects may prove troublesome.

**WHAT IS CHROMA?**

Once the illuminant within a scene has bounced off a subject and has been captured by the optical/digital components of a camera, the reflected color information is stored via the chroma component of video. *Chroma* is that portion of an analog or digital video signal that carries color information, and in many video applications it can be adjusted independently of the luma of the image. In component Y′C_bC_r- encoded video, the chroma is carried in the C_b and C_r color difference channels of the video signal.

This scheme was originally devised to ensure backward compatibility between color and monochrome television sets (back when there were such things as monochrome television sets). Monochrome TVs were able to filter out the chroma component, displaying the luma component by itself. However, this scheme of color encoding also proved valuable for video signal compression, since the chroma component can be subsampled for consumer video formats, lowering the quality in a virtually imperceptible way, while shrinking the bandwidth necessary for storing initially analog, and later digital files, allowing more video to be recorded using less storage media.

The color of any recorded subject with an encoded chroma component has two characteristics: **hue** and **saturation**.

---

**NOTE**

The notation for composite video varies depending on whether it’s digital or analog. Y′C_bC_r denotes digital component video, whereas Y′P_bP_r denotes analog component video.
WHAT IS HUE?

Hue simply describes the wavelength of the color, whether it’s red (a long wavelength), green (a medium wavelength that’s shorter than red), or blue (the shortest visible wavelength of all). Each color we consider to be unique from any other (orange, cyan, purple) is a different hue.

Hue is represented on any color wheel as an angle about the center (Figure 4.9).

When hue is assigned a control in a color correction application, it’s typically as a slider or parameter in degrees. Increasing or decreasing the degree of hue shifts the colors of the entire image in the direction of adjustment.

WHAT IS SATURATION?

Saturation describes the intensity of a color, such as whether it’s a vivid or deep blue or a pale and pastel blue. A desaturated image has no color at all—it’s a grayscale, monochrome image.

Saturation is also represented on the color wheel used in onscreen color correction interfaces in some applications, seen as completely desaturated (0 percent) at the center of the wheel and completely saturated (100 percent) at the wheel’s edge (Figure 4.10).

---

**Figure 4.9** How hue is represented by a color wheel.

**Figure 4.10** This shows 100 percent and 0 percent saturation on a standard color wheel, corresponding to the saturated and desaturated regions of a vectorscope.
Increasing saturation intensifies the colors of an image. Decreasing saturation reduces the vividness of colors in an image, making it paler and paler until all color disappears, leaving only the monochrome luma component.

**PRIMARY COLORS**

Video uses an additive color system, wherein red, green, and blue are the three primary colors that, added together in different proportions, are able to produce any other color that’s reproducible on a particular display (Figure 4.11).

![Figure 4.11](image)

Red, green, and blue are the three purest colors that a display can represent, by setting a single color channel to 100 percent and the other two color channels to 0 percent. Adding 100 percent of red, green, and blue results in white, while 0 percent of red, green, and blue results in black.

Interestingly, this scheme matches our visual system’s sensitivities. As mentioned previously, our sensitivity to color comes from approximately 5 million cone cells found within our retinas, distributed into three types of cells:

- Red-sensitive (long-wavelength, also called L cells)
- Green-sensitive (medium-wavelength, or M cells)
- Blue-sensitive (short-wavelength, or S cells)

The relative distribution of these is 40:20:1, with our lowest sensitivity corresponding to blue (the chief penalty of which is limited sharpness perception for predominantly blue scenes).

These are arranged in various combinations that, as we’ll see later, convey different color encodings to the image-processing part of our brains, depending on what proportions of each type of cone receive stimulus.

You may have noticed that some stage lighting fixtures (and increasingly, LED-based lighting panels for the film and video industry) consist of clusters of red, green, and blue lights. When all three lights are turned on, our naked eyes see a bright, clear
white. Similarly, the red, green, and blue components within each physical pixel of a video or computer display combine as white to our eyes when all three channels are at 100 percent.

**RGB CHANNEL LEVELS FOR MONOCHROME IMAGES**

Another important ramification of the additive color model is that identical levels in all three color channels, no matter what the actual amounts are, result in a neutral gray image. For example, the monochrome image in Figure 4.12 is shown side by side with an RGB parade scope displaying each color channel. Because there’s no color, every channel is exactly equal to the others.

Because of this, spotting improper color using an RGB or YRGB parade scope is easy, assuming you’re able to spot a feature that’s supposed to be completely desaturated or gray. If the gray feature does not have three perfectly equal waveforms in the RGB parade scope, then there’s a tint to the image.

For example, the white pillar in the image corresponds to the leftmost high spikes in the red, green, and blue waveforms of the parade scope (Figure 4.13). Since they’re nearly equal (actually, there’s a bit of a blue cast, but that makes sense since they’re outside in daylight), we can conclude that the highlights of the image are fairly neutral.
WHAT ABOUT FILM?

Color negative film uses a subtractive model. Three sets of layers that contain light-sensitive silver halide crystals are separated by a color filtering layer to restrict what colors are exposed by each layer record color information and absorb different dyes when developed:

- Blue-sensitive layers on top absorb yellow dye when they are developed.
- Green-sensitive layers in the middle absorb magenta dye when they are developed.
- Red-sensitive layers at the bottom absorb cyan dye when they are developed.

Since cyan absorbs red, magenta absorbs green, and yellow absorbs blue, all three layers added together at their maximum result in black, while all three layers at their minimum pass all light, creating white.

This book discusses digital color correction procedures that require film to be either telecine’d or scanned into a digital medium, to be operated upon within the additive color system of the computer. Even if you’re working on a digital intermediate, you’ll be using the additive color principles described in this section to perform your work.

SECONDARY COLORS

Secondary colors are the combination of any two color channels at 100 percent, with the third at 0 percent:

- Red + green = yellow
- Green + blue = cyan
- Blue + red = magenta

Because the primary and secondary colors are the easiest colors to mathematically create using the RGB additive color model, they are used to comprise the different bars of the standard color bars test pattern used to calibrate different video equipment (Figure 4.14).

As discussed later in “Using the Vectorscope,” each bar corresponds to a color target on the vectorscope graticule. These color targets provide a much-needed frame of reference, showing which traces of a vectorscope graph correspond to which colors.
HOW COLOR BARS ARE GENERATED

Colorist Joe Owens pointed out that color bars are extremely easy to create digitally using a divide-by-two counter to create the color-channel square waves that form the bars. The method is as follows:

- The green channel of the first four bars is enabled with a logical 1, while the green channel of the last four bars are disabled with a logical 0. In other words, the green channel is “on” for four bars and then “off” for the next four bars.
- For the red channel, the first and second bars toggle it “on,” while the third and fourth toggle it “off.” This pattern is repeated for the last four bars.
- For the blue channel, the odd bars are toggled “on,” while the even bars are toggled “off.”

And that’s how you make color bars (or colour bars, depending on where you live). It’s an extremely simple wavetrain.

COMPLEMENTARY COLORS

There’s one more aspect of the additive color model that’s crucial to understanding how nearly every color adjustment we make works: the way that complementary colors neutralize one another.

Simply put, complementary colors are any two colors that sit directly opposite one another on the color wheel.

Figure 4.15 Two complementary colors sit directly opposite one another on the color wheel.

Whenever two perfectly complementary colors are combined, the result is complete desaturation. As the hues fall off to either angle of being complementary, this cancelling effect also falls off, until the hues are far enough apart for the colors to simply combine in another additive way (Figure 4.16).
To understand why this works, it’s useful to delve deeper into the mechanics of human vision. As discussed in Margaret Livingstone’s *Vision and Art: The Biology of Seeing* (Harry N. Abrams, 2008), the dominant theory for how bipolar and M retinal ganglion nerve cells encode color information for processing in the thalamus of the brain is the color-opponent model.

The cones described earlier connect in groups to bipolar cells that compare the cone inputs to one another. For example, in one type of bipolar cell, (L)ong-wavelength (red-sensitive) cone inputs inhibit the nerve, while (M)edium-wavelength (green-sensitive) and (S)hort-wavelength (blue-sensitive) cone inputs excite it (Figure 4.17). In other words, for that cell, each red input is a positive influence, and each green or blue input is a negative influence.

![Diagram of color-opponent model](image)

**Figure 4.16** Where the hues are perfectly complementary to one another, the colors are completely cancelled out. As the angle of hue falls off from being complementary, so does this desaturating effect.

![Diagram of opponent model cell organization](image)

**Figure 4.17** This is an approximation of opponent model cell organization. Groups of cone cells are organized so that multiple cell inputs influence the retinal ganglion cells, which encode cell stimulus for further processing by the brain. Some cells excite (+) the ganglion, while other cells inhibit (−) the ganglion. Thus, all color signals are based on a comparison of colors within the scene.
In Maureen C. Stone’s *A Field Guide to Digital Color* (A K Peters, 2003), the first level of encoding for this color-opponent model is described as conveying three signals corresponding to three different cone combinations:

- **Luminance** = L-cones + M-cones + S-cones  
- **Red – Green** = L-cones – M-cones + S-cones  
- **Yellow – Blue** = L-cones + M-cones – S-cones

Color-opponent cells, in turn, connect to double-opponent cells, which further refine the comparative color encoding that’s used to pass information on to the thalamus, the vision-processing region of our brains.

Two important byproducts of double-opponency are the cancellation of complementary colors discussed previously and the effect of simultaneous color contrast, where gray patches are seen to assume the complementary hue of a dominant surround color (Figure 4.18).

Perhaps the simplest way of summing up the opponent model of vision is that cone cells don’t output specific wavelength information—they simply indicate whether long-, medium-, or short-wavelength light is present, according to each cell’s sensitivities. It’s the *comparison* of multiple combinations of triggered and untriggered cone cells that our visual system and brain interpret as various colors in a scene.

In short, we evaluate the color of a subject relative to the other colors surrounding it. The benefit of this method of seeing is that it makes us capable of distinguishing the unique color of an object regardless of the color temperature of the dominant light source. An orange still looks orange whether we’re holding it outside in daylight or inside by the light of a 40-watt bulb, even though both light sources output dramatically different wavelengths of light that interact with the pigments of the orange’s skin.

We’ll see later how to use complementary color to adjust images and neutralize unwanted color casts in a scene.
COLOR MODELS AND COLOR SPACES

A color model is a specific mathematical method of defining colors using a specific set of variables. A color space is effectively a predefined range of colors (or gamut) that exists within a particular color model. For example, RGB is a color model. sRGB is a color space that defines a gamut within the RGB color model.

The print standard of CMYK is a color model, as is the CIE XYZ method of representing color in three dimensions that’s often used to represent the overall gamut of colors that can be reproduced on a particular display.

There are even more esoteric color models, such as the IPT color model, a perceptually weighted color model designed to represent a more uniform distribution of values that accounts for our eyes’ diminished sensitivity to various hues.

COLOR MODELS IN 3D

Another interesting thing about color models is that you can use them to visualize a range of color via a three-dimensional shape. Each color model, when extruded into three dimensions, assumes a different shape. For example, a good pair of color model extrusions to compare is RGB and HSL:

- The RGB color model appears as a cube, with black and white at two opposite diagonal corners of the cube (the center of the diagonal being the desaturated range of neutral black to white). The three primary colors—red, green, and blue—lie at the three corners that are connected to black, while the three secondary colors—yellow, cyan, and magenta—lie at the three corners connected to white (Figure 4.19, left).

- The HSL color model appears as a two-pointed cone, with black and white at the top and bottom opposite points. The 100 percent saturated primary and secondary colors are distributed around the outside of the middle, fattest part of this shape. The center line of the shape connecting the black and white points is the desaturated range of gray (Figure 4.19, right).

Figure 4.19 Three-dimensional RGB and HSL color space models compared.
These color models sometimes appear as the representation of a range of color in a video analysis tool, such as the 3D Histogram in Autodesk Smoke (Figure 4.20). Three-dimensional color space representations also appear in the onscreen interfaces of applications that use 3D keyers.

Outside of the practical use of 3D color space shapes in application interfaces, these representations also are useful in giving us a framework for visualizing ranges of color and contrast in different ways.

**RGB VS. Y’C₇C₉ COLOR MODELS**

In general, the digital media you’ll be color correcting will be delivered as either RGB- or Y’C₇C₉-encoded files. Consequently, color correction applications all work with both RGB and Y’C₇C₉ color models. Components of each can be mathematically converted into those corresponding to the other, which is why even though you may be working with Y’C₇C₉ source media shot using video equipment, you can examine the data using RGB parade scopes and make adjustments using RGB curves and RGB lift/gamma/gain parameters.

Similarly, RGB source media ingested via a film scanner or captured using a digital cinema camera can be examined using the Y’C₇C₉ analysis of Waveform Monitors and vectorscopes and adjusted using the same luma and color balance controls that have been traditionally used for video color correction.

Converting one color space into the other is a mathematical exercise. For example, to convert RGB components into Y’C₇C₉ components, you’d use the following general math:

- \[ Y' \text{ (for BT.709 video)} = (0.2126 \times R') + (0.7152 \times G') + (0.0722 \times B') \]
- \[ Cb = B' - L' \]
- \[ Cr = R' - L' \]
THE HSL (HSB) COLOR MODEL

HSL stands for Hue, Saturation, and Luminance. It’s also referred to sometimes as HSB (Hue, Saturation, and Black). HSL is a color model, a way of representing and describing color using discrete values.

Even though digital media is not actually encoded using HSL, it’s an important color model to understand because it appears within the onscreen interfaces of numerous color correction and compositing applications. HSL is convenient because the three parameters—hue, saturation, and luminance—are easily understood and manipulated without the need for mind-bending math.

For example, if you had the R, G, and B controls shown in Figure 4.21, how would you change a color from greenish to bluish?

If you instead examined a set of H, S, and L sliders, it’s probably a lot more obvious that the thing to do is manipulate the H(ue) dial. To provide a more concrete example, Figure 4.22 shows the HSL qualification controls used to isolate a range of color and contrast for targeted correction.

Once you understand the HSL color model, the purpose of each control in Figure 4.22 should at least suggest itself to you, even if you don’t immediately understand the details.
ANALYZING COLOR BALANCE

Most of the time, you’ll be able to spot inaccurate color balance visually, simply by looking at your calibrated display. For example, a tungsten-lit scene will look orange when you’re using film stock that is balanced for daylight or a video camera with its white balance set to daylight.

Aside from the obvious color cast, orange light from incandescent fixtures may lend an inadvertently theatrical look because of the viewer’s association with artificial lighting. For example, the image on the left in Figure 4.23 is incorrectly balanced for daylight, and the tungsten lighting lends a warm, orange cast to it. The image on the right is properly white balanced, with whiter highlights and truer colors throughout the scene (note the blue sunlight spill in the foreground).

Similarly, a daylight scene shot using tungsten-balanced film stock or a video camera with its white balance set to tungsten/indoors will look bluish (Figure 4.24).

If the filmmaker was not intending to portray a cold winter day, this is clearly a shot that would benefit from correction. Compare the image on the left in Figure 4.24, which is incorrectly balanced for tungsten, to the properly white-balanced image on the right.
USING THE VECTORSCOPE

The vectorscope measures the overall range of hue and saturation within an image. Measurements are relative to a graticule that’s overlaid on the scope, which provides a frame of reference via crosshairs, diagonal I and Q bars, and labeled color targets corresponding to 75 percent saturated primary and secondary hues. Figure 4.25 shows all of these indicators relative to the color wheel that represents the reproducible range of color and saturation.

Figure 4.25 should clearly illustrate that hue is indicated by the location of a graph trace’s angle around the center, and saturation is indicated by a trace’s distance from the center.

In reality, the graticules of most software vectorscopes are considerably simpler. At the least, a vectorscope should have the following graticule elements:

- Primary and secondary color targets that correspond to the top row of bars on the SMPTE color bars test pattern (Figure 4.26).

- Crosshairs that indicate the desaturated center of the vectorscope graph.

- I and Q diagonal crosshairs (and their –I and –Q counterparts). These stand for In-phase and Quadrature (an amplitude modulated phase 90 degrees relative to In-phase), which correspond to the purple and cyan/blue patches at the bottom of the color bars signal.

- Tic marks along the I- and Q-bars correspond to the voltage waveform that would be traced by the discrete I and Q components, while tic marks running along the outside border note 10-degree increments.
When it comes to graticules, most vectorscopes have some manner of centered crosshairs at the center, which are critical for providing a reference of neutral black, gray, and white in the signal. The “I-bar” (as I’ve come to call it) is optional, and opinions vary as to whether it truly belongs on an HD scope. I happen to think it’s still a useful reference, as I discuss in Chapter 8.

Different software scopes display different graticule elements and also draw the vectorscope graphs differently. Some software scopes represent the analyzed data as a discrete point of data on the graph, while others emulate the CRT method of drawing traces corresponding to each line of video that connect these points together. These traces aren’t necessarily adding any actual data to the graph, but they make it easier to see the different points, and so they can be easier to read. Figure 4.27 illustrates the differences in three commonly used vectorscopes.

DaVinci Resolve has a traditional vectorscope, the graph of which emulates a trace-drawn graph, with 75 percent color bar targets and an In-phase reference line. Autodesk Smoke has a unique vectorscope graph option that averages analyzed color as a scatter graph that consists of differently sized dots representing the amount of color at that position, which makes it really easy to read and calls attention to the outer boundary of signal that light traces might not make apparent. Smoke draws both crosshairs and 75 percent targets.

The third vectorscope shown, Divergent Media’s ScopeBox, has a more traditional graticule available, with a trace-drawn graph, but it’s also a forward-looking application that was the first software scope to incorporate the Hue Vector graticule I designed, which presents lines that are aligned with each of the primary and secondary colors to help give colorists reference points for comparison, a center crosshair that’s aligned with the warm/cool axis of naturalistic color temperature for lighting, an In-phase positioned reference line, a user-customizable reference line, and both 75 percent and 100 percent tic marks for color intensity. ScopeBox also has a peak option for the vectorscope, which shows an absolute representation of the outer boundaries of the signal, making it easy to spot signal excursions that can be hard to see with faint traces. In fact, you may notice that the peak outline shape matches the scatter graph of the Smoke vectorscope.
TRACES VS. SCATTER GRAPHS

Older CRT-based hardware scopes used an electron beam to sweep over the phosphorescent coating on the screen from one point of data to the next in order to draw an analysis of each sequential line of video in the image, thus creating the overall graph. The resulting series of overlapping traces served to “connect the dots” and produce the graph that’s characteristic of CRT video scopes.

Software scopes, on the other hand, don’t need to draw this trace from point to point and sometimes draw a more direct plot of all the values in the image, similar to a scatter graph. This plot bears more resemblance to a series of individual points than overlapping lines. This is most apparent in the optional Smoke 2D vectorscope.

As a result, individual points of data represented by software scopes won’t necessarily look the same as they do on older video scopes. However, some dedicated outboard digital scopes from such companies as Videotek and Tektronix have hybrid displays that integrate both types of graphs: plot and vector.

JUDGING COLOR BALANCE USING A VECTORSCOPE

Since the center of the vectorscope graph represents all desaturated, neutral values, it follows that if a graph is uncentered and the image is supposed to have neutral tones in it, a color cast is present.

In Figure 4.28, the vectorscope graph to the left is suspiciously lopsided, leaning heavily toward yellow-green. This may not necessarily be wrong, but it should at least cause you to look at the source image a bit more closely to make sure this makes sense.

The vectorscope graph to the right corresponds to a neutral version of the same image. Notice how this graph is much more evenly balanced relative to the center crosshairs of the graticule, with arms stretching more prominently toward several different hues. Again, this is no guarantee that the color balance is correct, but it’s a pretty good indication that you’re in the right ballpark if the image on your broadcast display looks right.
Tektronix’ video scope models feature a luma-qualified vector display that can make it easier to judge color balance within specific tonal zones. Essentially, it’s a regular vectorscope with additional controls to limit its analysis to a specific range of luma. The range of tonality that’s analyzed is customizable, and if you like, you can display multiple vectorscopes, each set to analyze chroma within a different range of video luma.

For more information, see the Tektronix How-To Guide, LQV (Luminance Qualified Vector) Measurements with the WFM8200/8300, available from www.tek.com.

**JUDGING SATURATION USING THE VECTORSCOPE**

Judging the relative amount of saturation of an image is easy, since more saturated values extend farther away from the center of the scope than do less saturated values. In the following low-saturation image, the vectorscope graph is small, hugging the very center of the vectorscope graticule (Figure 4.29).

![Figure 4.29](image1.png) A low-saturation image with a correspondingly small vectorscope graph.

Take a close look at the graph. There are in fact excursions (parts of the graph that extend in various directions) that stretch toward the R(ed) and B(lue) targets, but they’re small, indicating that while there is color within the image, there’s not very much.

Most vectorscopes have the option to zoom into the graph, allowing you to see the shape of the graph with more clarity, even if the image is relatively desaturated (Figure 4.30).

![Figure 4.30](image2.png) Zooming into the vectorscope graph from Figure 4.29 makes it easier to see more detail in the graph of an image with low saturation.

The high-saturation image in Figure 4.31 yields a much larger vectorscope graph, with arms stretching out toward the various color targets that correspond to each hue.

In the more highly saturated image in Figure 4.31, notice how the abundance of red reads as an arm of the graph that extends toward the R(ed) target, while the blues in the man’s clothing appear as another arm of the graph that extends toward the B(lue) target. An abundance of yellow and orange creates a cloud in the vectorscope...
graph stretching toward the Yl (yellow) target. Finally, two conspicuous gaps in the graph, in the direction of the G(reen) and Mg (magenta) targets, tell us that there’s very little of either of these two hues present in the image.

**USING THE RGB PARADE SCOPE**

The parade scope shows separate waveforms analyzing the strength of the R, G, and B components of the video signal. This is a composite representation, even if the original video is Y'CbCr-encoded. By showing a comparison of the intensity of the red, green, and blue components of the image, the parade scope makes it so you can detect and compare imbalances in the highlights (the top of the graph), shadows (the bottom of the graph), and midtones for the purposes of identifying color casts and performing scene-by-scene correction.

Recall that the whitest highlights and darkest blacks of an image are nearly always desaturated. With that in mind, red, green, and blue waveforms with tops at or near 100 percent/IRE and bottoms at or near 0 percent/IRE should typically align very closely.

In **Figure 4.32**, we can see that the lighting outside the window is a cool blue, the lighting on the wall behind the woman is fairly neutral, and the shadows are deep and black.

**Figure 4.31** A highly saturated image with a correspondingly large vectorscope graph stretching farther out toward the edge of the graticule.

**Figure 4.32** An evening scene for analysis.
Each feature can be seen within the parade scope, and the relative height of the corresponding graphs indicates the color balance within that zone of image tonality. For example, the blue window can be seen in the elevated spike at the left of the blue waveform (Figure 4.33). The woman’s face corresponds to the elevated spike in the middle of the red waveform. And the neutral wall can be confirmed by the equally level shape of all three color channels at the right of all three waveforms.

By learning to identify features within the parade scope graphs, you can quickly spot where unwanted color casts appear and get guidance as to where within the image you need to make corrections.

**LEARNING TO READ PARADE SCOPE GRAPHS**

The RGB parade scope is essentially a Waveform Monitor that displays separate graphs for the red, green, and blue channels of an image. To understand the parade scope’s analysis, you need to learn how to compare the shape and height of the three Waveform graphs to one another.

Similar to the Waveform Monitor, each of the parade scope’s graphs presents a left-to-right analysis of the tonality in the scene. The difference is that while the Waveform Monitor measures the luma component, each graph in the parade scope represents the individual strengths of the red, green, and blue color channels.

In Figure 4.34, the generally accurate and neutral color balance of the scene is evidenced by the relative equality of the heights of the red, green, and blue channels, especially at the top and bottom of each waveform.
Even though the graphs look similar, closer inspection reveals that the peaks and valleys of the parade scope’s three graphs correspond to various features in the picture. While strong highlights, shadows, and desaturated elements often have components of equal height in each graph, saturated subjects will certainly vary.

For example, splitting apart the red, green, and blue channels of the image in Figure 4.35 and superimposing the red, green, and blue parade scope waveforms shows the correspondence between individual features within the image and the strength of each parade scope waveform. Keep in mind that each individual color channel is merely a grayscale image and that the corresponding waveform is simply an amplitude measurement of that channel.

Looking closely at each waveform reveals that, while the highlights corresponding to the pillar and window sill are of equal height, the portion of the red waveform corresponding to the faces is stronger than in the green and blue channels, which we’d expect. There’s also a spike in the red channel that lines up with the brick wall, which we’d also expect.

By identifying a particular feature within the graph, you can check its color balance. Generally speaking, color casts are the result of one or two of the color channels being either too strong or too weak. Whatever the problem, it’s easy to see which color channels are at fault using the parade scope. In Figure 4.36, a bit of detective work might reveal that the white balance setting of the video camera was incorrectly set relative to the lighting of the environment. If you’re dealing with a film image, a film stock may have been used that was inappropriate for the lighting.
PRIMARY COLOR ADJUSTMENTS

Figure 4.36 In this image, the red channel is significantly stronger (elevated) all the way through the graph, while the green channel is the next strongest. This indicates a strong yellow/orange (the secondary combination of red and green) color cast throughout the shadows, midtones, and highlights of the image.

Whatever the reason for the color cast, simply knowing that one of the channels is inappropriately strong is a starting point. A closer examination of the parade scope’s graph will also tell you exactly what you can do about it.

In Figure 4.37, the bottom of the blue channel’s graph is significantly lower than those of the red and green, even though the top of the blue channel is higher (providing the strong bluish highlights for this night scene). This is your cue that the deepest shadows (blacks) of the image are imbalanced, which lends an odd, washed-out look to the image.

Figure 4.37 A low-light image with a color imbalance in the shadows.

Keep in mind that balancing shadows using the Lift control can be a tricky operation that, if not done precisely, can cause more problems than it solves if you inadvertently add a different color imbalance to the blackest parts of your image.

Most scopes have an option to zoom into the graph so you can get a closer look at how closely the shadows of the parade scope waveforms are aligned, making it a lot easier to do this critical black balancing.

In Figure 4.38, we can clearly see after zooming into the parade scope that the blue channel is weaker in the shadows than the red and green channels.
RGB PARADE VS. RGB OVERLAY

An RGB parade scope and an RGB overlay scope both display the same information, but they differ in their presentation. As we’ve seen previously, parade scopes display discrete waveforms of information side by side so that you can see each waveform independently and in its entirety. Overlay scopes, on the other hand, superimpose all three waveforms over one another so that you can see how they align more interactively.

Which is better is completely a matter of preference, but here’s a hint on how to spot where the red, green, and blue waveforms line up, and where they don’t, on an overlay scope: Modern overlay scopes usually have the option of displaying each of the three color-channel waveforms with the color they represent and the three graphs combined additively (Figure 4.39). This means that, where the three waveforms align perfectly, the resulting traces in the graph turn white (since equal red + green + blue = white).

Many software scopes provide the option to turn color on and off, on the premise that the colors can be a distraction in a darkened suite. While parade scopes can still be read with the graph colors turned off, color is essential to being able to make sense of an RGB overlay scope, so make sure it’s turned on.
Where the waveforms don’t line up, the discrete colors of each waveform are more or less clearly visible in the region of image tonality where the incongruity occurs, making offsets more visible.

**RGB HISTOGRAMS**

Different applications also present individual histograms for the red, green, and blue channels. Similar to a luma histogram, each color channel histogram shows a statistical analysis of the number of pixels at each level of image tonality. The results are somewhat similar to the RGB parade scope in terms of seeing the comparative strength of each color channel in the highlights, midtones, and shadows of an image.

Unlike the RGB parade scope, there is no way to correlate an individual feature or subject within the frame to the rises or dips on any of the color channel histograms. Large rises indicate a lot of color channel pixels at that range of image tonality, while dips indicate fewer color channel pixels.

Depending on the application, RGB histograms can be either presented in parade mode or overlaid over one another. Sometimes histograms are oriented vertically, as in FilmLight Baselight (Figure 4.40, left), while other applications present them horizontally (Figure 4.40, right).

RGB histograms are very good, however, at allowing you to compare the overall strengths of each color channel within each zone of image tonality.

**USING COLOR BALANCE CONTROLS**

Whatever your intention, there are two ways you can manipulate the overall color within an image using the primary color correction interface of most applications. You can use color balance controls, or you can use curves (covered later in this chapter).
Color balance controls are a vital means of making adjustments. Once you master how they work, you can quickly solve a wide range of common issues relating to color temperature, white balance, and unexpected hues within your images.

As you’ll see in the following sections, color balance operations rely on the fact that complementary colors cancel one another out. This phenomenon is what makes it possible to selectively eliminate an unwanted color cast from an image by dragging or rolling a color balance control toward the color that’s complementary to it. It also allows us to introduce warmth or coldness that wasn’t in the shot to begin with, for creative purposes.

Depending on the application you’re using, color balance controls can be manipulated in several ways. The more you understand how color balance controls affect the image, the better you’ll be able to control your corrections, targeting them to the specific areas of the image that need adjustment.

ONSCREEN INTERFACES FOR COLOR BALANCE

Nearly every color correction application prominently features a set of color balance controls (you can see four of them in Figure 4.41). Most feature three or four controls, usually presented as a set of onscreen color wheels, that provide a graphical interface for rebalancing the red, green, and blue color components of a video clip to remove or introduce color casts in specific portions of the image.

**Figure 4.41** Color balance controls for different applications, compared. Top to bottom: FilmLight Baselight, Assimilate Scratch, DaVinci Resolve, Adobe SpeedGrade.
Other grading applications may feature five onscreen color wheels (Figure 4.42), or they may allow you to assign the three onscreen color wheels to three different ranges of image lightness or tonality, for a total of nine color wheel assignments.

The procedure for making an adjustment using a color balance control is pretty much the same no matter what application you’re using: Click anywhere inside the color wheel that is the outer boundary of each control (you usually don’t have to click right on the handle or indicator that shows what the balance is) and drag.

The color balance handle or indicator moves from the center détente position that indicates no correction is taking place, into the direction you drag, toward one color and away from its complement on the outside of the color wheel. Professional color correction applications let you see the correction while you’re making it on your broadcast display and within the video scopes.

Interestingly, most current color correction applications feature color balance controls that distribute the angle of hue correction in the same way as the vectorscope. With time, this distribution of hues will become second nature to you as you grade more and more shots so that your ability to both read the vectorscope and manipulate the color balance controls will become a matter of instinct and muscle memory.

**OTHER ONSCREEN COLOR BALANCE CONTROLS**

There are usually other ways of manipulating color balance besides the color wheels. Many, but not all, onscreen interfaces provide numeric controls for making specific adjustments. Keep in mind that many color correction interfaces express numeric controls as floating-point numbers to many decimal places of precision.

If you’re making a creative adjustment, you’re probably better off using an onscreen slider while watching your broadcast display. However, if you’re trying to match one parameter of an adjustment specifically to another parameter, numeric entry can be a benefit for copying and pasting values from one correction to another.
Another method for making specific color balance adjustments is to use either keyboard modifiers (press a key while dragging a color balance control) or dedicated onscreen sliders to alter only a single parameter of color balance. Common options include the following:

- **Hue Balance Only**: Lets you keep the current distance of the handle/indicator locked while you rotate the handle/indicator around the center of the control to change the hue of the correction

- **Color Temperature**: Locks the angle of hue to the orange/cyan vector while allowing you to drag the handle/indicator closer to or farther from the center détente position

- **Adjustment Amount**: Locks the angle of hue to whatever the current angle happens to be, while allowing you to drag the handle/indicator closer to or farther from the center détente position

Methods for making these adjustments vary by application, so be sure to check your documentation for how to perform these operations.
ADJUSTING COLOR BALANCE USING A CONTROL SURFACE

It’s mentioned frequently in this book, but the advantages control surfaces provide for color balance cannot be overstated. The ability to quickly adjust one control relative to another lets you implement many of the interactions covered later in this chapter to make very detailed corrections.

Also, the ergonomic benefits, in terms of operator comfort, are a big deal. It’s not that you can’t work using a mouse-based interface alone, but the “mouse-claw” you’ll develop after hundreds of click-and-drag adjustments will make the price of a dedicated control surface seem pretty reasonable after a while.

The three color balance controls typically correspond to the three trackballs found on most control surfaces. For example, the JLCooper Eclipse at the left of Figure 4.44 has three trackballs that correspond to the Shadow, Midtone, and Highlight controls.

Some control surfaces have more trackballs. The DaVinci Resolve control surface, shown on the right in Figure 4.44, has a fourth trackball that can be used for Log grading controls, moving windows, adjusting control points on curves, and other things.

AUTOMATIC COLOR BALANCING

Before going into manual color balancing, it’s worth mentioning that most color correction applications provide one of two methods for performing automatic color balancing. Automatic color balancing can be quick to use in instances where you’re having a difficult time identifying the exact nature of a color cast, and auto color balance controls are usually designed to give you a solid neutral starting point for further manual adjustments to a particular color balance control.

AN AUTO-BALANCE BUTTON

The first method usually involves nothing more than clicking an appropriately named button. With this method of automatic color correction, the application automatically samples the three darkest and lightest parts of each color channel, on the premise...
that these correspond to black and white in the image. If they’re misaligned, an automatic calculation is made using the equivalent of the Shadows and Highlights color balance controls, and the correction is applied to the image.

In many cases, the contrast of the image is also stretched or compressed automatically to fit into the maximum and minimum allowable range from reference black at 0 percent/IRE/mV to reference white at 100 percent/IRE (700 mV). The results are usually fine, but you can sometimes run into problems if the sampled parts of the waveform don’t actually correspond to true black and white values, in which case you’ll get unexpected results.

**MANUAL SAMPLING FOR AUTOMATIC CORRECTION**

The second method of automatic balancing is more hands-on, but the results are usually more predictable. Once you have identified which part of the image’s tonal range a color cast belongs to, you usually click the equivalent of an eyedropper for the Shadows, Midtones, or Highlights controls and then click a feature that’s supposed to be a clean, neutral white, black, or gray in your picture to make an automatic adjustment to that tonal region of the image.

**THERE’S NO SUBSTITUTE FOR MANUAL COLOR BALANCING**

The manual method, which is ultimately more flexible (especially if you’re not planning on making a completely neutral correction), is to adjust the color balance controls for the Gain, Lift, and Gamma by hand, usually by dragging the color balance control in the direction of the color that’s complementary to that of the unwanted color cast.

This book focuses mainly on the manual method of making adjustments. The beauty of manual color balancing is that you can correct an overzealous color cast as aggressively or as gently as possible, making a deliberate choice about whether to neutralize it completely, preserve part of it, or introduce a completely different color balance of your own.

Also, as we’ve seen in numerous examples, our perception of color within a scene is often at odds with the strict numerical hue and saturation of the image components. Computer applications generally can’t take such perceptual quirks into account, which makes your eyeball the best judge of what “looks right.”

**COLOR BALANCE EXPLAINED**

When you manipulate a color balance control, you’re simultaneously raising or lowering all three color channels. Every time you adjust a color balance control, you’re either boosting one color channel at the expense of lowering the other two channels or raising two channels while lowering the third. It’s simply not possible to boost all three color channels, nor would you want to, because simultaneously boosting all three channels is the same as brightening the image with a Master Offset control.
To see this effect in action, try this exercise:

1. Examine the parade scope. You see a trio of flat graphs at 50 percent/IRE (Figure 4.45). Any time you see three equal graphs in the parade scope, you know the image is completely desaturated.

   Figure 4.45 The original gray test image, with three equal color channels.

2. Drag the Gamma color balance control away from the center détente position toward red, which causes the reds graph to shoot up toward the top and the green and blue graphs to move down together (Figure 4.46).

   Figure 4.46 The adjustment described in step 2.

The gray field turns red (Figure 4.47).

   Figure 4.47 The results of the adjustment in step 2.
3 Now, drag the color balance control toward a hue that’s between cyan and blue to lower the red channel while boosting both the green and blue channels simultaneously, if unevenly (Figure 4.48).

As you move the control, the three color channels redistribute themselves based on this new direction, turning the field bluish (Figure 4.49).

As you can see, dragging a color balance control into a particular direction simultaneously rebalances all three color channels based on the direction of hue in which you move the control.

COLOR BALANCE CONTROL OVERLAP

The power of three-way color balance controls is that they let you make individual adjustments to the portions of an image that fall into the shadows, midtones, and highlights tonal zones.
These tonal zones are based on the luma component of the image. In other words:

- The Lift color balance control affects all portions of the image that correspond to a specific range of the lowest luma values in that image.

- The Gamma control affects all portions of the image that correspond to a range of middle luma values in the image.

- The Gain color balance control affects all portions of the image corresponding to high luma values above a specific range in the image.

Figure 4.50 shows this relationship visually using a false color representation to show how the luma channel corresponds to the lightest highlights (blue), the darkest shadows (green), and the range of midtones (red).

**Figure 4.50** It can be difficult to discern the three zones of image tonality that correspond to shadows, midtones, and highlights with the color still in the image. Stripping away the color reveals the lightness of everything within the frame, and a false color representation shows the extremes of each tonal zone.

The regions of the image that each of the three color balance controls affect are so dependent on the luma channel that any adjustments to the luma channel correspondingly affect how the color balance controls work. For this reason, it’s a good idea to make any dramatic contrast adjustments that are necessary first, before moving on to the color of your image.

Naturally, there will be a certain amount of interactivity between color and contrast adjustments, with one set of adjustments affecting the other. This is yet another reason why control surfaces are a time-saver, as they allow rapid and often simultaneous adjustment of multiple color and contrast parameters.

**NOTE**

Color balance controls in RGB processing operations will have an effect on image saturation as well. For example, eliminating an extreme color cast in an image typically results in lower average levels in all three color channels, which reduces saturation. This is easily fixed by boosting overall saturation, covered later in this chapter.
Figure 4.51 is an oversimplification, however. In most professional color correction applications, the three tonal zones overlap broadly and fall off very smoothly, so you can make large adjustments without incurring artifacts such as aliased edges or solarized color that can be the result of a hard transition (or shelf) at the boundaries of affected tonality.

Furthermore, these broad overlapping zones guarantee interactions among adjustments made with each of the three color balance controls. While at first these interactions may seem like an inconvenience, they’re actually essential to exercising fine color control.

Exactly how the color balance of each control overlaps differs from application to application (Figure 4.52 shows how the overlaps look in FilmLight Baselight’s Region Graph). Some applications even allow you to customize these overlaps, setting them to whatever your working preferences happen to be.

These differences in tonal overlap often account for the differences in “feel” between different color correction applications and plug-ins. If you’re used to working using one application’s approach, switching to another may throw you off a bit until you get used to the new default overlaps.

THE OFFSET CONTROL AND PRINTER POINTS

The Offset color balance control (sometimes called Master or Global) is so named because it rebalances color by offsetting each color channel up or down, basically adding or subtracting an adjustment value to move each channel. In the following example, an Offset adjustment is used to correct a color cast due to incorrect white balance (Figure 4.53).
All of the techniques described later for balancing colors apply equally to the Offset control. Keep in mind that Offset rebalances the entire range of image tonality all at once. Because Offset adjusts the entirety of each color channel, it’s a time-saving and useful control for images where there’s a huge color cast running from the shadows all the way through the highlights. Furthermore, with color casts that are this severe, the linear way in which this technique rebalances the signal may give you a more natural-looking result than separate adjustments to lift, gamma, and gain, depending on the image and on what you’re trying to achieve.

Offset is related to printer points controls because both do the same thing: offset each color component of the image (Figure 4.54). However, the Offset color balance control adjusts all three color channels at once, allowing you to rebalance the color throughout an image with a single control or track ball. By contrast, printer points provide either sliders or plus and minus buttons (a more classic configuration) that let you adjust each color channel independently, one at a time.

Printer points controls are valuable for colorists and cinematographers who are used to working with the printer points system employed for color timing film (described in more detail in Chapter 9). As originally used by color analyzers such as the Hazeltine, the printer points dials of a color analyzer adjust the individual levels of the Red, Green, and Blue channels in discrete increments called printer points. Each point is a fraction of one f-stop (a doubling of light in the scale used to measure and adjust exposure).

Figure 4.53 The RGB channels before and after a simple Offset adjustment, which raises and lowers each channel in its entirety to correct the image.

Figure 4.54 Offset controls in DaVinci Resolve provide functionality similar to printer points controls.
Various applications use different fractions, and each printer point can be anywhere from 1/7 to 1/12 of an f-stop, depending on how the analyzer is configured. Most systems use a range of 50 printer points for each color component and for density, with 25 being the neutral détente for each control.

Working digitally, printer points controls make a uniform adjustment to the entire color channel, irrespective of image tonality, by adding or subtracting the adjustment value. Some applications even emulate the nature of the optical filtration used by color analyzers so that raising the Red printer points control doesn’t actually boost the red; instead, it removes red, causing the image to shift to cyan (which is the secondary of green and blue). In this case, to increase red you actually need to decrease the Red printer points control.

FIVE-WAY AND NINE-WAY COLOR CONTROL OVERLAP

Some applications go beyond the lift/gamma/gain model of color balance control to provide five and even nine sets of controls, for even greater specificity in the adjustments you make.

For example, SGO Mistka provides an option for five-way color balance controls, with separate adjustments for Black, Shadows, Midtones, Highlights, and White.

These five color balance controls work together to enable targeted adjustments to the image in various zones of exposure, just like other variations on these controls. However, they overlap in a very different way.

Other applications, such as Lustre and SpeedGrade, use the same set of three-way controls provided for lift, gamma, and gain adjustments, but give you an additional three sets of controls over shadows, midtones, and highlights so you can divide each of the main tonal regions of an image into three subregions, allowing you to make very fine color balance and contrast adjustments to nine different tonal regions. In other words, you can adjust the offset, gamma, and gain of lift independently of the offset, gamma, and gain of gamma and gain, as shown in Figure 4.55.

![Figure 4.55](image-url) An approximation of the specific control that lift/gamma/gain for each zone of lift, gamma, and gain image tonality gives you. Different programs employ differing tonal zone overlaps, so this illustration is not specific to any application.
These types of overlapping multizone controls let you bend the video signal in ways that are similar to the kinds of adjustments you can make using curves but have the advantage of being operated by the rings and trackballs of a conventional control surface.

For example, using the Midtone color balance control to add a bit of blue to the shadows results in a wide portion of image tonality being affected (Figure 4.56).

Using SpeedGrade’s ability to adjust the Gain color balance control of the Shadows zone, on the other hand, lets you make a much more subtle change. This control targets a much narrower zone of image tonality, such that you can add a bit of blue just to the lighter shadows (Figure 4.57).

If you’re making large adjustments for bolder changes, you may find that a few control points on a curve control work faster. Also, if you want to insert color or make a correction to a narrow zone of image tonality, you can also use the Luma qualifier of a secondary operation (covered in Chapters 5 and 11) to isolate a custom tonal zone for correction using the nearest corresponding Lift/Gamma/Gain color balance control.
COLOR DECISION LISTS (CDLs)

In an effort to rein in the operational differences between various color correction applications, the American Society of Cinematographers (ASC) has spearheaded an effort to standardize primary color and contrast adjustments. The ASC Technology Committee responsible for drafting the Color Decision List (CDL) combines the expertise of leading cinematographers and film/video engineers in an effort to define and extend the CDL for use by the production and postproduction communities alike.

The reason this is important to know is that some applications provide a “CDL-compliant” mode that sets the color and contrast controls to act as the CDL specification dictates. Understanding this specification helps you to understand how to work in this mode.

The dual purposes of the CDL are to encourage predictability of operation from application to application and to facilitate project exchange among different color correction applications.

Currently, the CDL governs the following grading parameters, assuming an RGB rendering application:

- **Slope** (for contrast this is similar to gain; for color this is a multiply operation)
- **Offset** (for contrast this is similar to lift; for color this is an add operation)
- **Power** (for contrast this is similar to gamma; for color this is an equal power operation)

Using these three parameters (sometimes referred to as SOP), a contrast and color balancing operation applied to a particular shot is governed by the following equation:

\[
\text{Output} = (\text{Input} \times \text{Slope} + \text{Offset})
\]

If this seems limited, it is. The CDL doesn’t account for customizable color balance zones, or more exotic controls like RGB or luma curves, contrast or color temperature sliders, or highlight and shadow saturation controls. Nor does the CDL have a means for describing secondary color correction operations such as hue curves, HSL qualification, power windows or vignettes, or blending modes.

However, the current purpose of the CDL is to govern primary corrections, for which it is well suited. Furthermore, the CDL is a work in progress and will certainly evolve over time to take more parameters into consideration. For example, additional math has also been defined as of version 1.2 of the CDL specification to account for control over SAT, or a commonly agreed upon definition of RGB saturation (SOPS).
COLOR BALANCE OVERLAP IN ACTION

Despite the overlap described in the previous section, you’d be surprised at how targeted your changes can be. To examine how these controls overlap, we’ll make adjustments using a simple grayscale ramp test pattern.

The following example demonstrates how the Lift, Gamma, and Gain controls’ areas of influence overlap while you make corrections.

1 Adjust the Gain color balance control to push it toward blue and then adjust the Lift control to push it toward red; you’ll get something like the result shown in Figure 4.58.

![Figure 4.58](image)

When adjusting a grayscale ramp using any one of the color balance controls, you’ll see the corresponding region become tinted.

2 Next, adjust the Gamma color balance control, pushing it toward green, in order to examine the resulting overlap in Figure 4.59.

![Figure 4.59](image)

This new green adjustment smoothly blends into the red and blue zones, pushing them back to the extremes of shadow and highlight within the image (Figure 4.60).
If you look carefully at the area of overlap, you may start to notice a stripe of cyan falling between the green and blue adjustments. This stripe makes sense when you remember that cyan is an additive mix of green and blue.

This is clearly an artificial example; with real-world images and subtle corrections, you won’t often notice this effect. However, when you make large adjustments involving two color balance controls, you may see some unexpected interactions of this sort, so keep a sharp eye out.

**MAKING A SIMPLE COLOR BALANCE CORRECTION**

Now that we’ve gone over how color balance controls work, let’s look at a simple example of how you would use these controls to make a relatively simple correction.

The shot in the following example exhibits a clear warm/orange color cast. This could be because of an incorrect white balance of the camera or simply a creative decision made during the shoot. The client has expressed a desire to ease off the warmth, so that’s the correction you’ll be making.

1. Take a look at the Waveform Monitor. Your first order of business is to adjust the contrast to fit within the acceptable limits of 0–100 percent/IRE (Figure 4.61).
2 Additionally, look at the vectorscope in Figure 4.61. You’ll see the truly monochromatic nature of the image. The overly warm lighting of the room serves to exaggerate the already orange tones of the brown jacket and the flesh tone of the actor. There are no spikes of color stretching toward any other hue in the vectorscope.

That’s not necessarily a problem, but what does look a bit odd is the extent to which the entire graph is off center. Judging from the amount of white in the frame (the lampshade and lamp base), there ought to be at least some part of the vectorscope graph that sits directly on the center of the crosshairs, but the graph is almost entirely to the upper left of the crosshairs, as shown in Figure 4.62.

Figure 4.62 The lopsided nature of the vectorscope graph confirms that the color cast is fairly severe. Very little of the graph touches the center, and the entire waveform stretches toward orange (the additive combination of red and yellow).

3 Examine the RGB parade scope. It’s easy to see that the top of each waveform (corresponding to the blown-out window) is clipped off and thus relatively equal. The bottoms of the waveform are fairly level with one another (at least, level enough).

The biggest visible inequality here is right within the middle. The segments of the waveforms that are called out in Figure 4.63 correspond to the wall.

Figure 4.63 The circled waveform sections correspond to the color of the wall.
Even though the wall isn't pure white (a question put to the client revealed that the wall is actually a warmish/yellowish “antique” white), this is a fairly extreme inequality of nearly 30 percent, far more than at either the top or the bottom of the parade scope waveforms.

Having spotted the changes you need to make, it’s time to do the correction. The fact that the color channel inequality lies in the middle of the RGB parade scope graph is a good clue that the best way to correct for it is to adjust the Gamma color balance control. The fact that you can see the imbalance in the vectorscope as being toward orange tells you that the best correction to make is to pull the midtones away from orange—or toward the complementary color to orange, which is a hue between cyan and blue.

4 Correct the contrast by lowering the Gain control until the top of the luma waveform touches 100 percent, while raising the Gamma control to keep the lightness of the midtones where it was to begin with. Lightening the midtones makes it necessary to lower the Lift control to restore some density to the shadows, thus keeping the appearance of a high contrast ratio even though you’ve compressed the highlights a bit.

5 Next, act upon the analysis you made in step 3, and drag the Gamma color balance control toward a cyan/blue split (in other words, between these two hues), as shown in Figure 4.64.

While you drag the Gamma color balance control toward cyan/blue, keep one eye on the RGB parade scope. What you’re trying to do is to balance the middle of the red, green, and blue channels so that they’re closer together.

Also pay close attention to the image; you want to make sure you don’t overcompensate. Keep in mind that although the lamp base and trim around the window are white, the wall color is not. So if you try to overcompensate, the image will start to look odd. In this case, the correction the client likes the
best brings the middle of the red, green, and blue waveforms much closer to one another (Figure 4.65).

6 Examine the results of these corrections. The image is generally improved; however, there’s something funny about it, particularly in the shadows and in the dark regions of the man’s beard and hair. Look at the bottom of the waveforms in the parade scope; you can see that the extreme correction you made to the midtones has affected the shadows, and the bottoms of the three waveforms are now very unequal, with exaggerated blue shadows that you don’t want.

You can also see that making this adjustment to balance the midtones has reduced the lightness of the image. This is because the correction dropped the levels of red channel to closer match that of the green and blue channels, and the results lowered the luma component, darkening the image.

7 To compensate, you need to raise the Gamma contrast control until the image is as light as it was before and then push the Lift color balance control back toward orange (since you’re eliminating a blue/cyan cast in the shadows), as shown in Figure 4.66.
As you make this last adjustment to the color balance of the shadows, keep an eye on the bottoms of the RGB parade scope graphs. You’ll know you made a successful adjustment when the bottoms of the red, green, and blue waveforms align as evenly as possible (Figure 4.67).

Lastly, the process of neutralizing the excessive color cast from the image resulted in a loss of saturation (you dropped the level of all three color channels when you leveled the highlights out), so turn up the overall saturation to compensate for this effect.

When making changes like this, it’s easy for you (and the client) to forget what the original “problem” image looked like, since the eye is constantly adapting to the updated state of the image. This is the reason why most color correction applications have some sort of “disable grade” command, so you can get a before and after look at the image, to demonstrate that your correction is a tangible improvement over the original.

The image is still warm, but it no longer has all that orange in it. Take a look at the vectorscope in the final correction; you can see that it’s much more centered than before, and the overall level of orange saturation has decreased,
creating a finer distinction between the colors in the wall, the actor’s jacket, and the skin tone of his face and hands (Figure 4.68).

This example showed several common strategies of using the video scopes in conjunction with color adjustment controls, not just for spotting a color cast but to help you figure out where a particular color cast is most pronounced in order to quickly use the most appropriate control for making a specific correction.

**REDUCING THE OVERLAP OF HIGHLIGHT, MIDTONE, AND SHADOW COLOR CORRECTIONS**

The previous example demonstrated quite clearly that a correction made in one tonal zone can inadvertently affect portions of the image you’d rather leave alone. In these cases, you will often find yourself making an opposite adjustment to an adjacent color balance control. This may seem counterintuitive, so if you’re wondering how this works, take a look at Figure 4.69, which uses a simple ramp gradient, so that you can see this effect clearly.

1 Make a bold correction by dragging the Gain color balance control toward blue (Figure 4.70).

Figure 4.68 The vectorscope analysis of the final image. The graph is now more centered and isn’t as widely stretched toward orange as it was originally.

Figure 4.69 The original test image, a ramp gradient with values from 0 to 100 percent.
As you can see, the blue correction extends well past the midtones and a bit into the shadows (Figure 4.71).

There will be plenty of times when you’d want to ease off this correction in the lower midtones of a real-world image.

2 To compensate for this overly wide correction, adjust the Gamma color balance control, dragging it toward yellow, which is the complement of blue, to reduce the blue cast at the lower midtones (Figure 4.72).
As you make this adjustment, you’ll see more and more of the darker midtones become a neutral gray once again, while the upper range of the highlights continues to exhibit the original blue correction (Figure 4.73).

While the typical overlap of color balance controls may initially seem a bit overenthusiastic when it comes to affecting the image, this type of interaction is part of what makes these controls so powerful and quick to use. These kinds of opposing corrections are actually an extremely common way of further targeting corrections in exactly the tonal portion of the image where you need them.

**CREATING A DELIBERATE COLOR CAST FOR EFFECT**

You’re not always going to want to create corrections to eliminate color casts. Deliberate color temperature adjustments can be also added as an audience cue for conveying the time of day or the environment in which the subjects find themselves. For example, audiences fully expect a candlelit scene to be extremely warm, like the image in Figure 4.74.

You can play off the audience’s expectation of color temperature and change the perceived time of day, or the type of location, by throwing off the white balance and introducing a deliberate color cast.