Implementing Display Standards in Modern Video Display Technologies

BACKGROUND

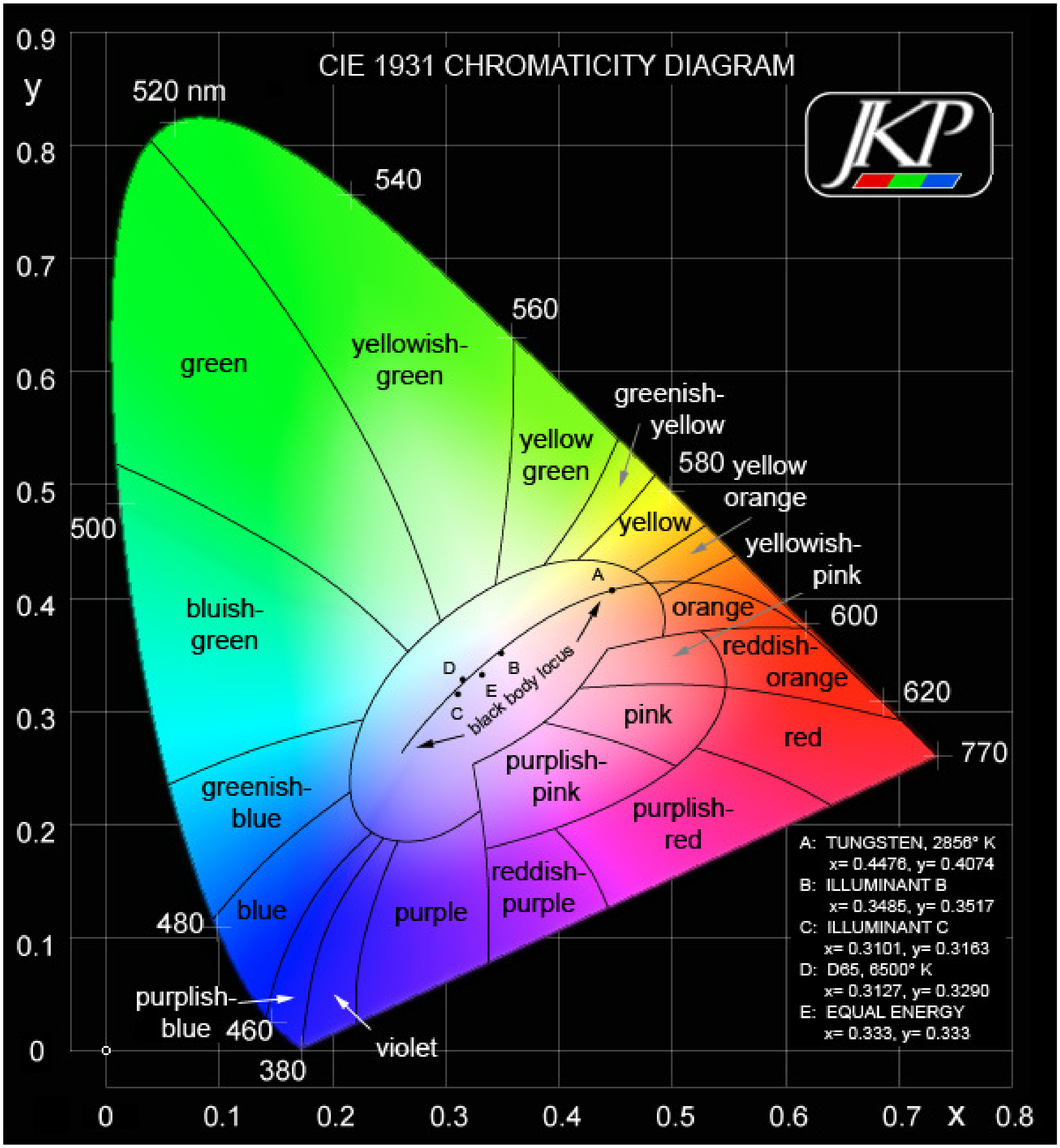
The first commercially available device for the electronic display of moving images came about in the late 1930's. The technology is called the Cathode Ray Tube, or CRT.

1950 Zenith Black and White TV set

Put simply, the CRT is a small linear accelerator; the electron gun in the neck of the tube, shooting electrons at a glass screen covered in phosphor. When the electron beam hits an area of the phosphor, it gives off photons (light), and continues to give off light some time after the beam has moved on to other parts of the tube. The color of the light emitted from the phosphors is "white" in a black and white picture tube. The amount of light produced is proportional to the amount of energy hitting the phosphor. For the CRT, this is not a linear relationship of voltage in versus light out, but more properly described as a Gaussian curve. The response curve of voltage in versus light output is known as the gamma of the display.

When color came to our black and white system in December 1953, three different types of phosphors were used in the CRT that emitted colors of light, red, green, and blue (RGB) when struck by the electron beam. (Phosphors only show their "colors" when being driven by an electron beam. You don't see the colors unless the set is on.)

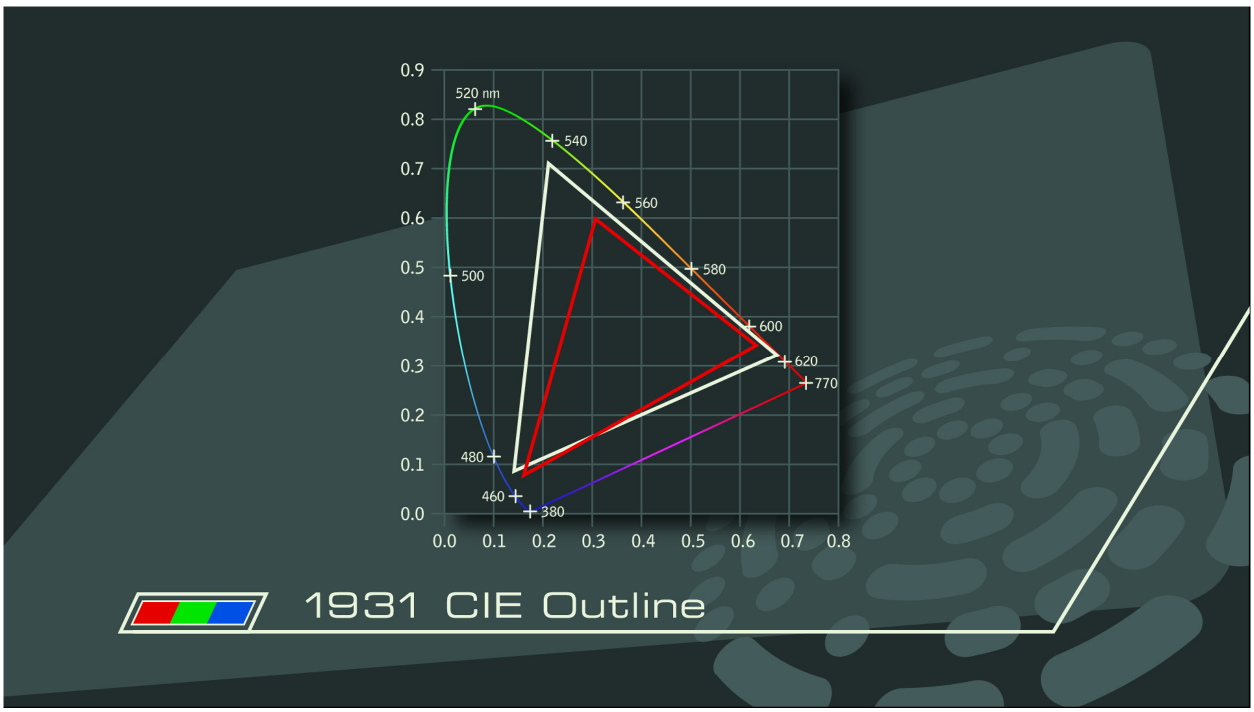
The work of 1931 International Commission on Illumination[1] (CIE) was used as the basis for the specifications in the color system.



The 1931 CIE Diagram

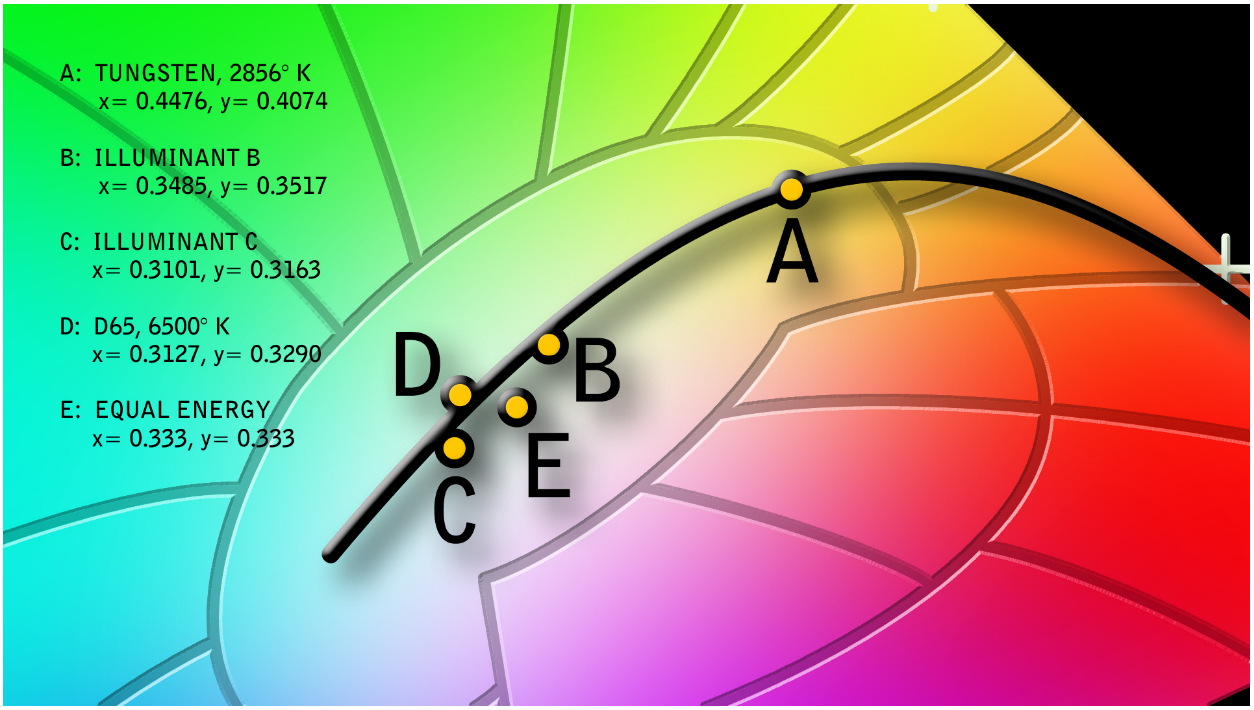
In the United States, the colors chosen for red, green and blue were called NTSC[2]. The choice of the individual colors was partially based on the color quality already being presented in a mechanical color filter wheel system. http://www.novia.net/~ereitan/ The mechanical spinning color filter wheel had been officially sanctioned around 1951 as our color system before the all electronic system of 1953. The phosphor colors chosen for our first all electronic system didn't work as anticipated in the picture tube. An official change to our specifications to something that would work didn't come about until 1979 when we established the SMPTE-C color space as the substitute for NTSC colors.

With the exception of one model of a TV set that was on the market for a couple of years, consumer product manufacturers never adopted the industry standard for color in their sets.



The original NTSC color space is in White, the SMPTE-C color space in Red

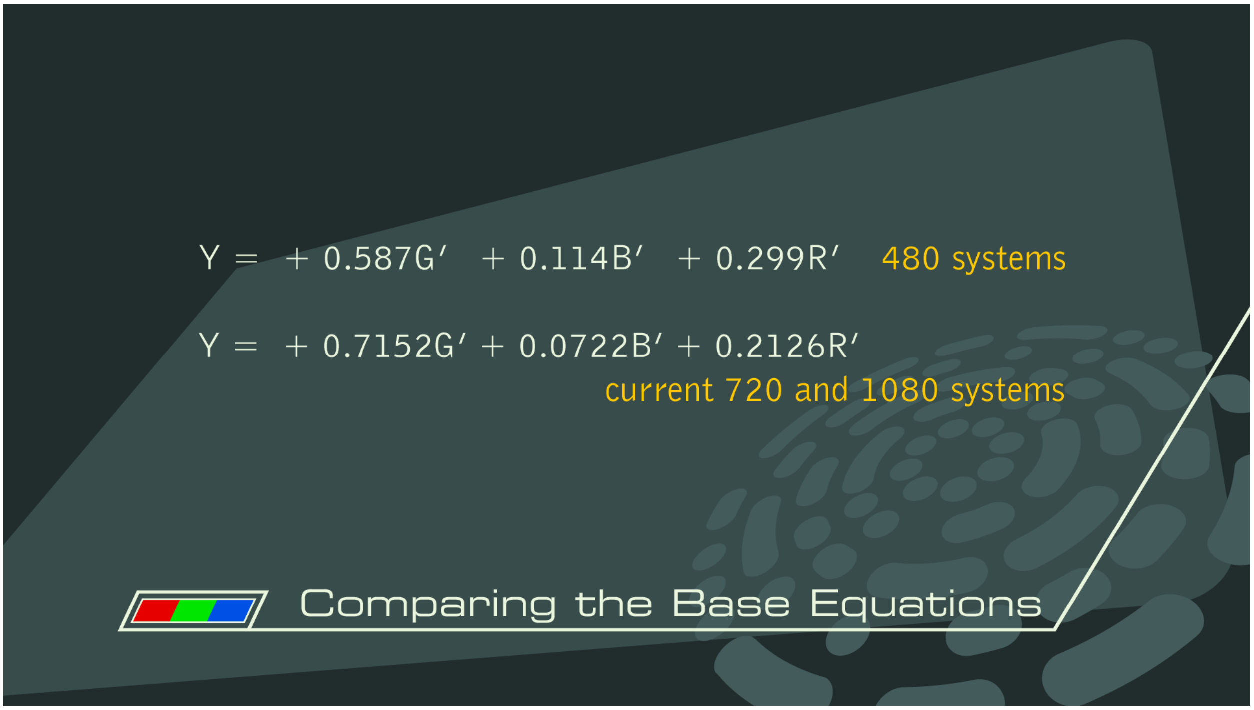
The color of white in the system was originally defined as being near the equal energy point in the CIE diagram. Sometime prior to all three networks going to color in 1964 the color of gray, what you get when you add red, green and blue together, drifted up in color temperature to the D point in the 1931 CIE diagram. We know it today as D65, or D6500 or sometimes as 6500 Kelvin, although 6500 Kelvin is not specific enough to be considered a real definition of the color of gray.



The D Point is just above the Black Body Curve in the 1931 CIE Diagram

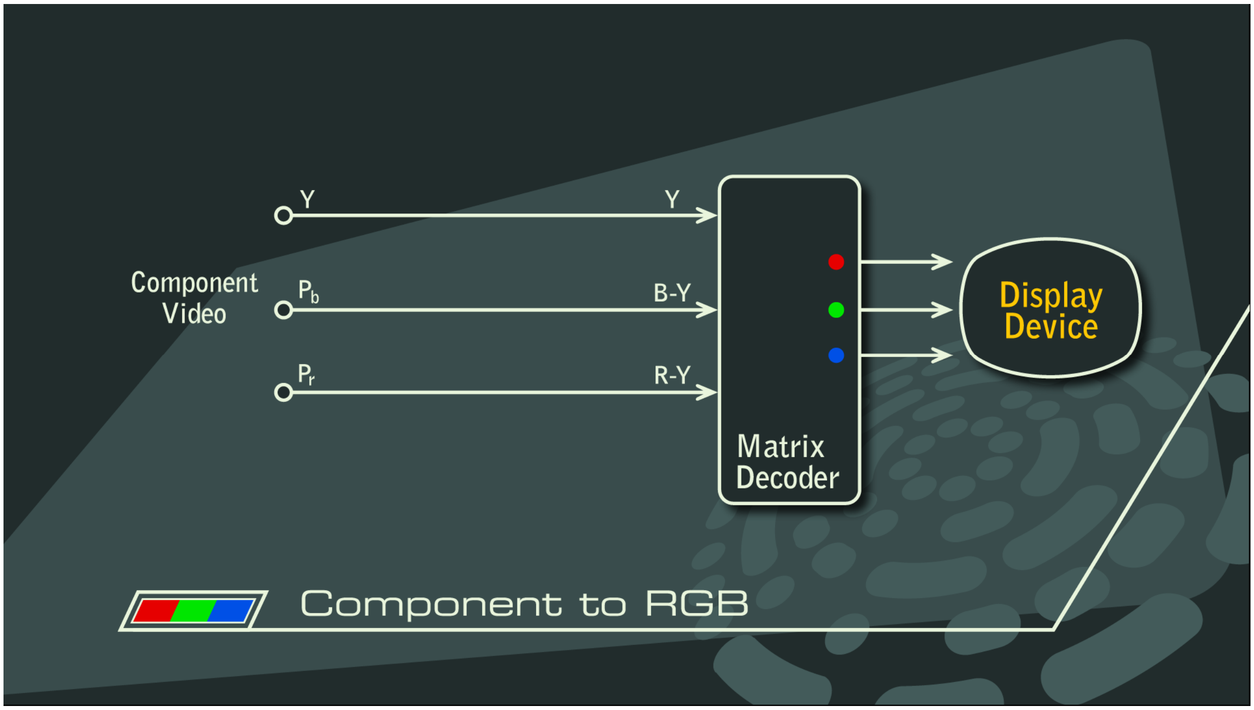
In the process of defining our color television system it was recognized that the bandwidth required to broadcast three full bandwidth channels of information, RGB, would be three times that of a black and white channel. In writing the rules of the system there was an additional requirement for a full bandwidth black and white signal. This was necessary so the color television system would be fully backwards compatible with existing black and white TV sets, something that did not exist in the mechanical color filter wheel system.

It was also desirable to have both black and white and color signals occupying no more space than the single TV channel already being used for black and white TV. The ultimate solution offered by the NTSC color system was to derive a black and white signal from the red, green and blue signals by adding them together. The information necessary for color sets to derive color would be carried along with the black and white signal on color subcarriers.



Adding Red, Green and Blue together to get Black & White or Y

Once you had the black and white signal two more pieces of information were needed for a color set to figure out the right proportions of red, green and blue to display. This is the birth of what we now know as component video. The black and white signal was called Y and the two additional pieces of information were the color difference signals, which eventually became known as Pb and Pr. In the NTSC days of color television the Pb and Pr signals were amplitude and bandwidth reduced, modulated onto two color subcarriers and added back into the black and white signal.



Analog Component (Y Pb Pr) to RGB Decoding

The ability to put reduced bandwidth color in the signal and have it be acceptable to viewers was possible because all of the detail in the picture was contained in the black and white signal.

It's almost as if we have a paint by the numbers system. The black and white provides the boarders and the color is just filled in.

On the display side of things, even in color displays, the black and white signal or the Y signal is the foundation of what we see. It provides al of the detail as well as the brightness of the picture. Basically if a color display won't do a good job of reproducing black and white it won't be good in color.

When digital video was introduced it was a digital copy of the analog signal, with all of the benefits of processing in the digital domain. The analog Y Pb Pr became known in the digital world as Y Cr Cb. (The reversal of the written order of the two color difference signals is a topic for another discussion.) In both cases, it is up to the display to decode the component signals into the three full bandwidth signals needed to drive an RGB display. How this is done differs between standard definition component and high definition component video.

We changed the rules slightly for deriving Y Cr and Cb when we went to high definitions. The standard definition video system uses a Y Cr Cb that is defined by rules set out in the ITU[4] –R BT.601 document, while our high definition system uses a Y Cr Cb that is defined by ITU-R BT.709. Many manufactures of display devices somehow missed the fact that we changed the rules for deriving Y Cr Cb when we made the transition to high definition, not to mention they were always playing with the rules set out in the ITU 601 document for standard definition sets.

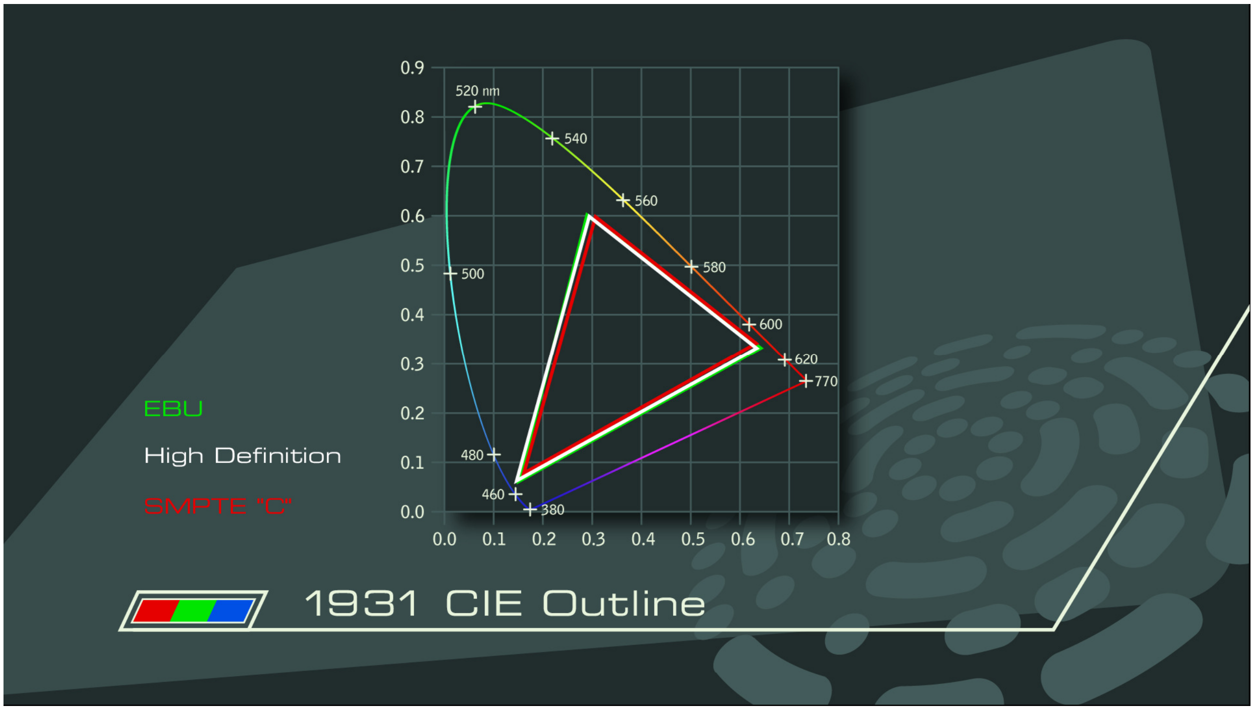
That playing with standards was part of making their sets look different from others on the show floor, hopefully (in their minds) drawing your attention to their set rather than any of the others. Bottom line, they essentially ignored the system rules on how a component signal should be converted back to RGB. They essentially lost sight of their responsibility to the video communications system. For the most part they don't even include the option of an ability to properly reproduce the video signal.

THE CHALANGE

The majority of video production you see on television and distributed video content today is created using studio-grade CRT monitors to set and judge the color quality of the program. In the standard definition days the well calibrated professional grade sets adhered to the rules set out in the ITU 601 document and related color practices for the NTSC and PAL video systems.

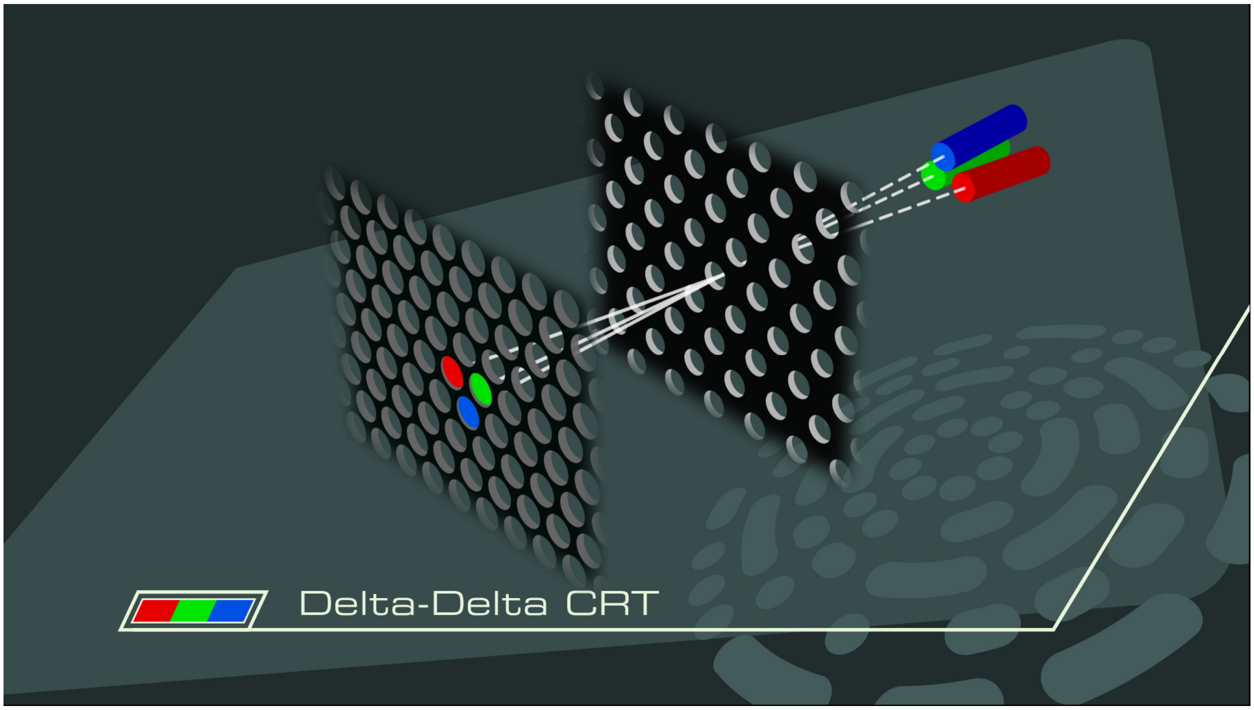
The colors of red, green and blue are different in the NTSC and PAL systems. The colors used in the PAL world encompassed a slightly larger color gamut than the SMPTE-C colors did for our NTSC system. This is related to the persistence of the green phosphors. Highly saturated greens take longer to decay, but that time is available in the PAL system with fewer pictures per second. The fact that the PAL system had fewer frames per second allowed it to have a slightly larger color space. Those colors didn't work well in a picture tube that was required to display the 60 pictures per second found in the NTSC system.

When we wrote the rules for high definition television we picked colors of red, green and blue that were much closer to PAL, partially because they looked better. The idea was to make HD color look better than NTSC standard definition color. Due to limitations of phosphors in CRT based displays, the colors of red, green and blue stayed at SMPTE-C despite what was written in the ITU 709 document.



SMPTE-C, HD and EBU colors

To be a true HD display, according to the rules set out in the ITU 709 document, the display must have the colors of red, green and blue that are defined in the 709 document. That set of colors differs from PAL only in the color of green. The color of green in HD is slightly less saturated than the PAL green. You might think that would put European high definition well ahead of North America in color quality. It isn't happening that way. Since the majority of high definition monitors are being produced for the North American and Asian markets, SMPTE-C is what is available in HD CRT based monitors, even in Europe.



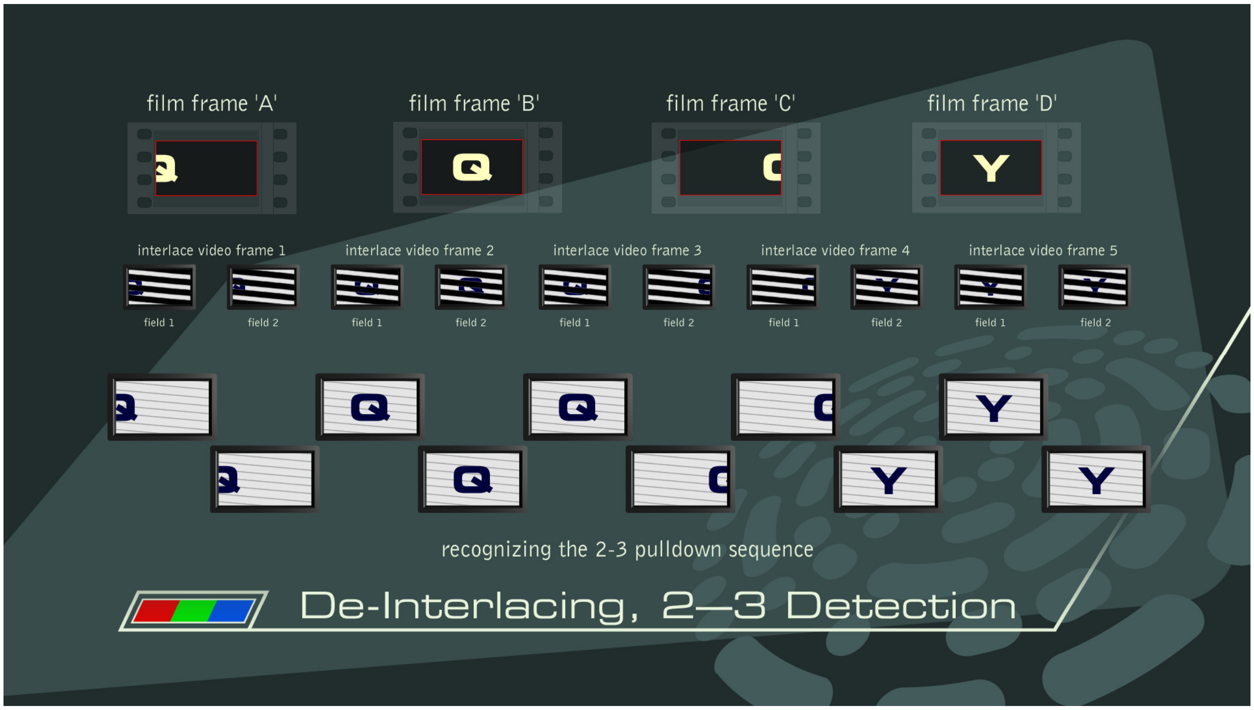
Electron beam going through the shadow mask to the phosphors on the inside surface of the glass CRT

In building a good high definition display we need to start with a technology that will allow us to produce a great black and white picture. Ideally the display would also have perfect color, being able to match system standards, any one of the three, SMPTE-C, HD and EBU.

Then comes the ability to display all of the scan rate options in our standard definition and high definition systems. As much as you probably know about the 50 and 60 Hz rates, we've added a new rate, that of motion picture film. The display also needs to function properly for a signal coming into it at 24 frames per second.

In the analog world the display had to move at 50 or 60 Hz rates in order to avoid an excessive amount of flicker in the image. In the digital world we only need to transmit what is in the source. We can let the display figure out what to do with it. In film there are usually only 24 pictures per second. In analog we would add a 2 – 3 count to the 24 frames to step it up to 60 Hz. In the PAL world the film is sped up to 25 Hz then doubled to be sent out at their 50Hz rate.

The world of digital video has allowed us the flexibility of conveying what's in the source and letting the display do the rest. In doing so it puts some new design requirements on digital displays.



24 frame film rate being transferred to a 60 Hz picture rate, then detecting the presence of the 2 – 3 count to create real film frames in a 60 Hz progressive image.

It may be worth mentioning marketing strategy for the new display we are building. Once we have a display that conforms to the three basic world standards for television, and all of their variations, we then have to address the topic of letting consumer know we have something they have probably never seen before, but need in order to see the program content as intended.

The idea of a display that conforms to communications system standards is a totally new concept and goes against claims being promoted for super colors being a good thing. They aren't.

JKP is starting that campaign with a Blu-ray and HD DVD program called *DVE: HD Basics* that provides consumers with an overview of the design intent behind our television systems and what is required to make display function properly. Along the way the viewer learns that the majority of what manufacturers build into sets is designed to set them apart from everyone else on the show floor, not to conform to any video system standard. The idea of "more brilliant colors" or a "wider color gamut" or a larger on-off contrast ratio is at best misleading, but in most cases is just completely wrong.

In gaining acceptance for a display that conforms to systems standards we need to help viewers understand that the best possible picture can only be obtained when the display they are watching precisely matches the standard being used to create the program. Any deviation away from the standard, in any direction, will produce a picture that is something other than what was intended by those creating the program.

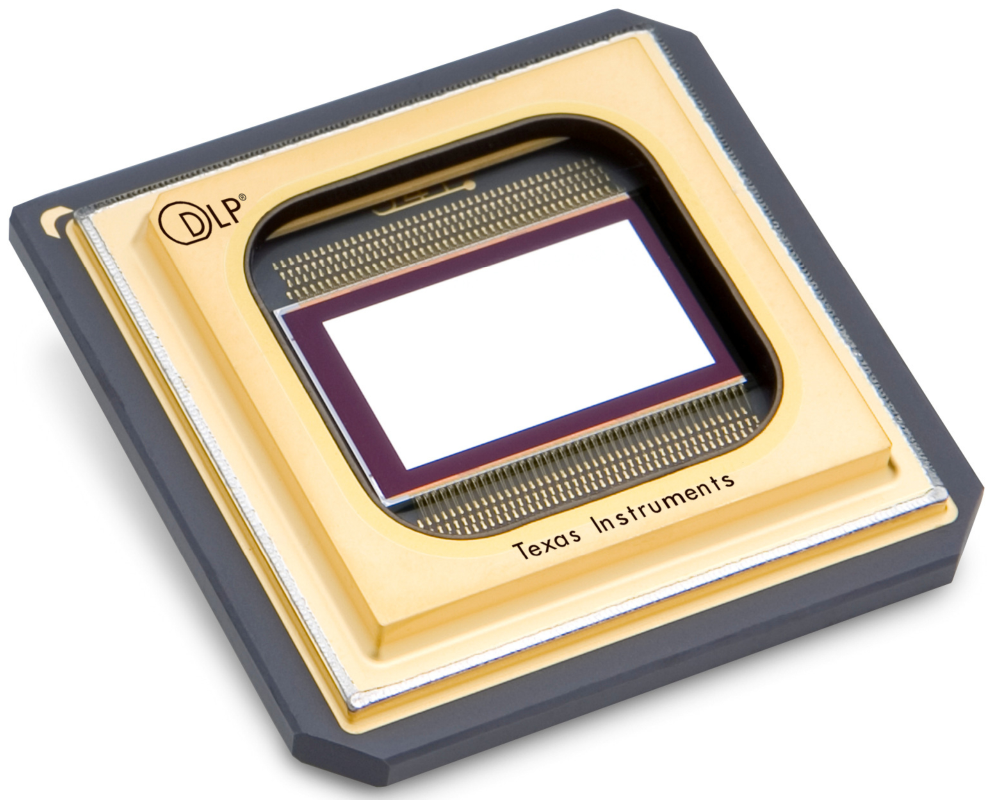
THE SOLUTION

Among current display technologies in the market place are CRT, (well almost) LCOS[6] (D-ILA®[7] SXRD®[8]), DLP®[9], plasma, and LCD[10]. The long standing CRT technology, the foundation of our standard and high definition video systems, suffers from limitations in providing consumers with the correct color quality, limitations in display size and light output. Even in the professional world, where CRT displays are the dominant technology used to monitor program content, that monitoring has to be done in a dimly lit room.

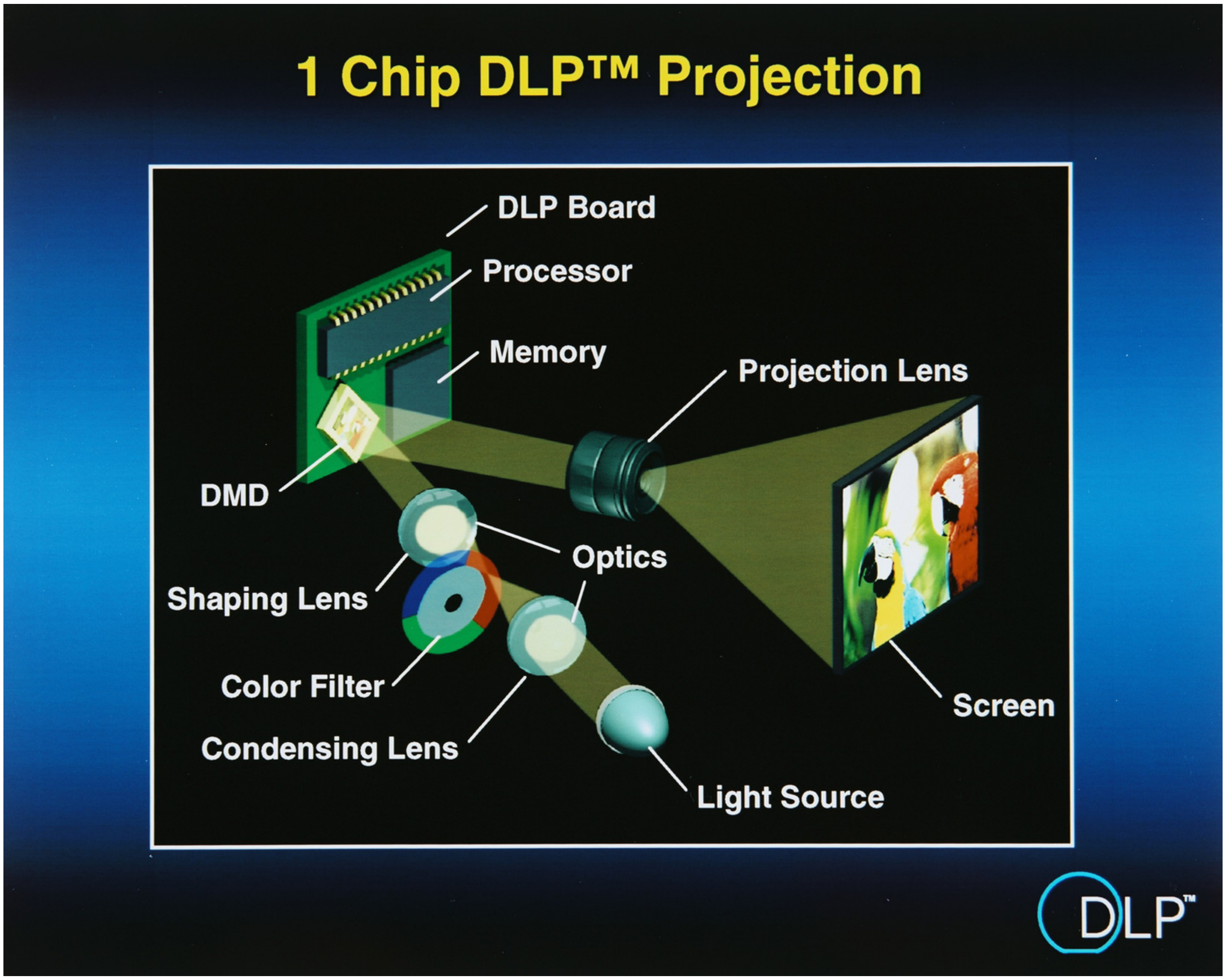
Telecine Bay where the lights have been turned up so you can see the equipment in the room

Other technologies have their own limitations. Among them are uniformity of picture quality over the entire area of the picture, limited viewing angle for a potentially accurate picture, inability to display high speed motion without blur, lack of real resolution meeting system specifications, an ability to track a gray scale from black to white, an inability to display light to dark transitions in fine detail even if the display has the pixel count of a high definition signal, correct video signal in versus light output characteristics; gamma, and an ability to produce the correct colors of red, green and blue. Circuits driving these display often don't have separate decoders for high definition and standard definition signals, let alone decoders that accurately convert the Y Cr Cb signals to RGB, even if they have two separate decoders.

Of the current technologies that are affordable in the mass communications system we call video or television, Texas Instruments' DLP® technology currently holds the most promise in being able to easily meet the majority of all of our system standards in a single box.



DLP is a projection technology. You see it packaged in rear screen sets and in front projectors. In the front screen application it is possible to produce a flat field uniformity that far exceeds any of our system standards. High quality screen technology assists in making the picture quality essentially the same at any viewing angle in front of the screen. Since the DLP engines are driven with light bulbs it is possible to create a color space that can be switched among all three of the system standards. The image refresh time is much faster than any motion rate used in video, allowing it to display low frame rates, such as the 24 frame film rate without the associated flicker of CRT displays.



A good implementation of DLP technology will allow field calibration of the display to meet system stands from a high quality screen.

Equally important to all of the capabilities of DLP technology is the lens in front of it. Among the things we look for is an ability to display the light on the screen without chromatic aberrations, white lines being displayed as white lines instead of having colored edges, sharp focus over the entire image area, and single pixel light to dark transitions without light scatter to cover them up.

Not all 1080p displays are created equal. Many displays claiming a 1080p resolution can't actually display a full 1080p resolution. As you'll discover using the Pixel Phase test pattern in DVE: HD Basics some part of the high frequency content is missing altogether and or is reproduced as a color rather than the black and white content of the test signal.

THE RESULT

Samsung Electronics, in cooperation with Joe Kane Productions, has put these ideas into what is nothing short of one of the best single chip DLP® projectors available at *any* price. The SP-A800 and the SP-A900 do not get in the way of the video signal. Within the limitation of the 1920 by 1080 resolution of the imager the resulting picture is essentially a transparent representation of the video signal driving the display. What is in the video signal is what you see – nothing more, nothing less. As testament to this remarkable property of the SP-A800 and A900, is that it is now being used as a reference monitor for creating program content. It has become the choice of display for several content creators who are critical about display quality. It has become the display of choice for several motion picture studios in QC'ing there content prior to distribution in the consumer market. In the broadcast and post production environments it has become a significant step up in picture quality when compared to any other technology available.
We respectively challenge any single chip projector manufacturer to take advantage of Joe Kane Productions *DVE: HD Basics* program and display the Pixel Phase (for depth of modulation and MTF,) 601 / 709 Color Bars (color decoding accuracy) and Overscan (flat field uniformity and video circuitry performance) test patterns. Some may argue a static test pattern says nothing about how well a projector may look. We say: *it goes a long way to defining a good display*.

One final though is the irony of being correct is that the majority of people seeing the picture have declared it one of the best pictures they have ever seen. They often comment that they had no idea picture quality could be this good.

Samsung Electronics America and Joe Kane Productions proudly invite you to view the SP-A800 and SP-A900.

"Come See What the Cinematographer Sees™"

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1 More properly, *Commission Internationale de l'éclairage,*
2. National Television System Committee. Responsible for the standard definition standards as used in the United States.
3. Society of Motion Picture and Television Engineers
4. International Telecommunications Union
5. Advanced Television Systems Committee. Responsible for the high-definition standards as used in the United States.
6. LCOS - Liquid Crystal On Silicon a reflective technology using polarized light
7. DILA - Digital Direct Drive Image Light Amplifier® From Japan Victor Corporation (JVC®)
8. SXRD (Silicon X-tal Reflective Display) Sony's proprietary variant of liquid crystal on silicon
9. DLP - Digital Light Processing The chip is also known as DMD device for Digital Micromirror Device
10. Liquid Crystal Display