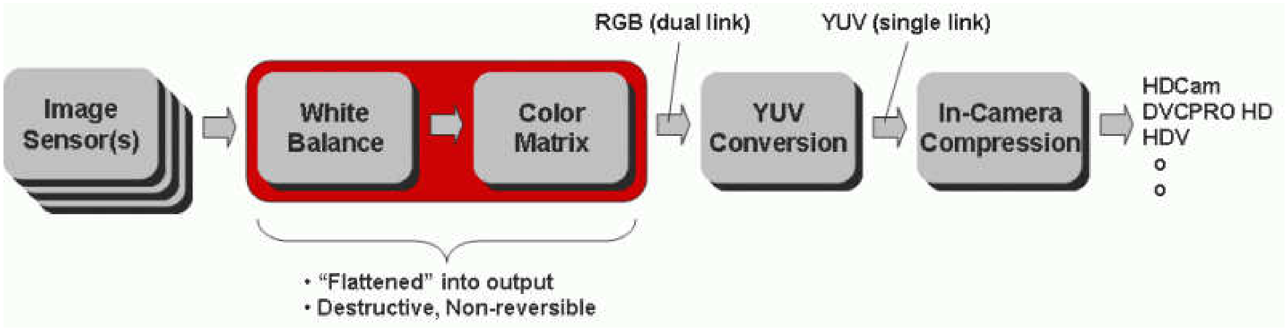
CineForm RAW™ Technology Overview

Background
Digital cinema camera designs based on single-chip "Bayer"-pattern sensors are emerging as likely replacements for 35mm and 16mm film cameras. Such Bayer-pattern designs have been used in digital still photography for many years, while traditional SD and HD video cameras have used three-chip designs. In a three-chip camera design each sensor acquires one of the red, green, or blue color primaries. In a single-chip design, the sensor contains separate R, G, and B sensor sites as shown in the diagram below. There are numerous books and articles that discuss the technology and characteristics of Bayer pattern sensors that we don't intend to repeat in this text other than in summary form. In this primer we'll instead focus on CineForm RAW and will discuss the applied technology of working with digital raw (in our case CineForm RAW) material plus the workflow and visual fidelity benefits gained by filmmakers.

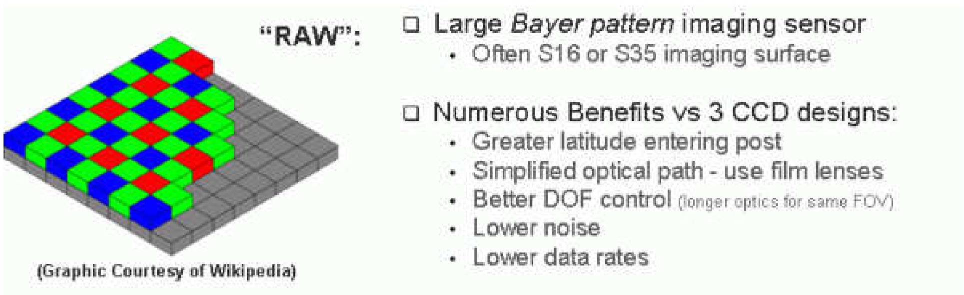
In-Camera Signal Processing for a Traditional HD Camera



Traditional In-Camera Signal Processing
In-camera signal processing for traditional HD cameras is similar to the diagram above. After image acquisition, white balance is applied, followed by color and saturation parameters, defined collectively as Color Matrix. All in-camera processing modifies data captured by the image sensor(s) to produce a final "flattened" stream representing the uncompressed RGB "look" of the camera. The remainder of the signal processing chain reformats data from RGB (dual-link HD-SDI) to YUV (single-link HD-SDI) after which camera compression is applied.

Each of the signal processing steps are "destructive" - they cannot be undone. When correction to the camera's "look" is desired in post, corrections are applied on top of those already applied in-camera.

Bayer-Pattern Imaging Sensor



Bayer-Pattern Imagers
In the diagram above, a Bayer-pattern image sensor is shown with its organization of R, G, and B cells. Individual color cells are created by application of a color filter to each cell site during the manufacturing process. A typical 2K image sensor such as used in the Silicon Imaging SI-2K camera has 2048x1152 available cell sites of which half are green (1024x1152), and one-quarter each are red and blue (1024x576).

Before we discuss characteristics of Bayer images we should note that Bayer-pattern sensors have some unique characteristics compared to 3-chip camera designs.

1. The direct optical path for a single-sensor design is relatively simpler, and also reduces optical distortion compared to the prism design used in 3-chip cameras. Difficulties with optical alignment in 3-chip camera designs practically limits the upper size of image sensors whereas the simpler optical path in single-sensor designs avoid these problems.
2. The simple optical path in single-sensor designs is similar to film cameras allowing use of many existing 16mm and 35mm film lenses.
3. Because most in-camera signal processing is avoided and is instead performed in post (more on this in the next section) images from Bayer pattern designs enter post with better latitude than images from 3-chip designs. Current Bayer camera designs are claiming over 11 stops of light, whereas most 3-chip cameras typically deliver under 10 stops of light.
4. As Bayer sensors increase in size per cell site versus 3-chip sensor sizes, noise characteristics fall resulting in better noise performance.
5. Larger sensors allow better control over shallow depth of field.

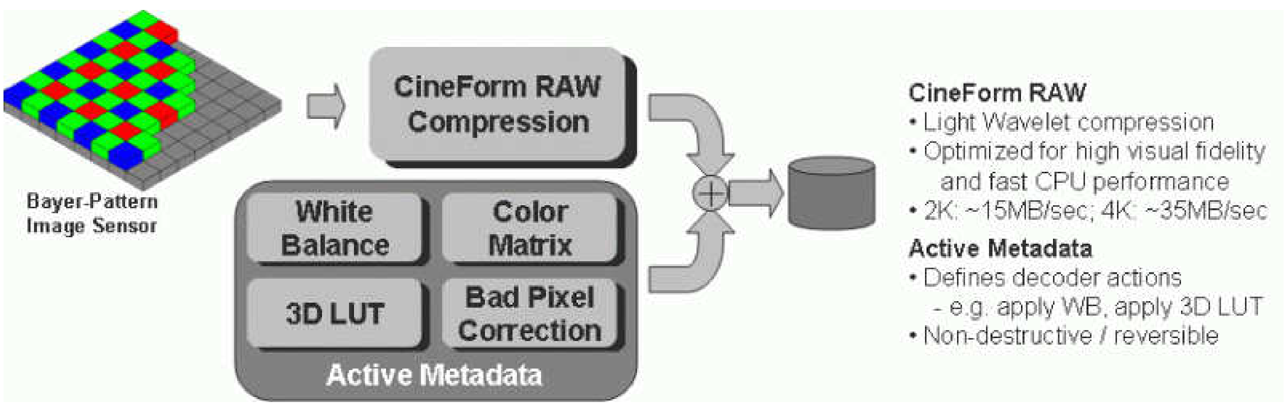
Bayer Pattern Image Characteristics
There are some interesting characteristics about images resulting from Bayer sensors. First of all, each color site is not "pure" because the color filters themselves are not pure. The visual result of this is that images observed from a Bayer sensor in an RGB color space exhibit a flat de-saturated look and sometimes contain a green-ish cast (anybody seen Viper images in Filmstream mode?). Also, the format of data from Bayer sensors does not obey expected norms, so no NLE, compositing, or effects applications understands Bayer data.

Traditionally, to use images from a Bayer camera (Dalsa Origin and others) in post production the image data must first be "digitally developed", akin to chemically developing 35mm or 16mm film. The digital development process is also known as "demosaicing" or deBayering. (You'll likely find we use all of the terms at different times, but they all mean the same thing.) Traditional digital developing for still camera raw images is performed using the Adobe Camera Raw converter utility or Photoshop Lightroom prior to applications such as Photoshop can process the raw format. The deBayering algorithm does a few things:

1. Extracts color purity from each image cell site
2. Extracts full spatial resolution from the image
3. Yields a traditional RGB image at the spatial resolution of the sensor (e.g. 2048 x 1152 for the SI-2K)

DeBayering is an extremely compute intensive algorithm that may take as much as much a 1 - 2 seconds per frame (24x to 48x) for a 4K image. Fortunately computers are getting faster, but deBayering algorithms are getting more sophisticated too. And there isn't just one choice of deBayer algorithm - there are many different deBayer algorithm choices. Regardless, if you have to deBayer your material at the front-end of your project - before post begins - a lot of compute resources are required!

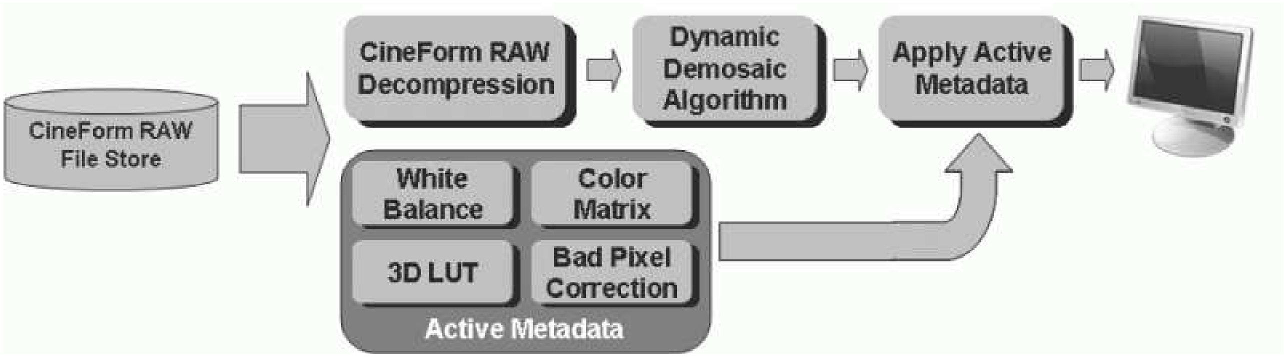
In-Camera CineForm RAW Signal Processing



CineForm RAW Camera Processing
Recognizing the importance of new Bayer-Pattern camera designs, CineForm developed new patent-pending technology called CineForm RAW™ to support in-camera coding of Bayer data directly, plus the associated real-time workflow to enhance Bayer image processing throughout post-production. These developments include dynamic deBayering of CineForm RAW images for real-time playback, and also allow the deferral of final deBayer processing until much later in post-production, ensuring both highest visual quality, the most creative flexibility, and most efficient post workflow.

As shown in the diagram above, and In comparison to traditional in-camera processing, digital raw images are acquired from the sensor with little or no in-camera processing. White balance and color matrix processing remain necessary, but instead of flattening this information into the digital stream, it is instead carried as non-destructive metadata within the digital file. This allows it to be applied to the decoded CineForm RAW images at presentation time without changing the originally acquired data. This technique allows metadata to be changed non-destructively later - in post for example - and replaced with different white balance or color matrix parameters if those parameters had originally been set inside the camera at the time the material was shot.

In the case of CineForm RAW, a light visually lossless Wavelet compression is applied to the acquired sensor data in real time to reduce its size. Files are converted from linear (sensor output) to log space (for optimum visual fidelity), then encoded at either 10- or 12-bit precision based on camera design parameters. White balance and color matrix parameters defined in the camera are inserted into the recorded stream as active metadata. Further, CineForm's active metadata construct allows inclusion of "bad pixel" coordinates and 3D LUT data. Of these latter two, inclusion of 3D LUT information allows the DP to define a "look", much like the selection of a film stock in the days of shooting film, that is included in the recorded data file. As with white balance and color matrix data, 3D LUT information is non-destructive and may be changed in post.



CineForm RAW Playback
During playback, the CineForm RAW decoder subsystem first separates the CineForm RAW compressed stream from active metadata. After CineForm RAW decompression, a real-time demosaic algorithm is applied, followed by application of active metadata. When played within an editing environment that includes CineForm's RAW playback controls (such as Prospect 2K), a number of parameter controls may be selected:

1. Demosaic algorithm selection:
   - "Quadlet" decode displayed at half-horizontal and half-vertical resolution of the image sensor (fastest), or
   - Bilinear demosaic which produces a full-resolution output (fastest at full resolution)
2. Selection of which metadata to apply on playback. Apply all active metadata, or only portions of the included metadata.

During shot review, or playback within a video player such as Windows Media Player or QuickTime player, the demosaic algorithm used is a Quadlet decode, and all active metadata is applied.

A final note about active metadata: Active metadata stored in the file at record time is non-erasable - it will always remain in the stream. CineForm RAW controls within an editing environment allow an alternative set of active metadata to be applied, but it is always possible to return to the metadata defined at record time.