Film Scanning for all Disciplines: Video and Film Resolutions Merge

By P. R. Swinson

Film and video co-exist in the television environment. With the transition to digital widescreen, high definition, and digital film resolution, the importance of film becomes even more significant. It has many advantages as an image capture medium, with resolution well beyond high definition; a colorimetric capture range that greatly exceeds any video capture device; and a 50-year archive for digital television and high definition. Film scanning at high resolutions is a precise science, so it is no longer acceptable to invest in a scanner that only samples standard or high definition and generates all other resolutions by interpolation. An available film scanner must sample the film at many resolutions rather than one fixed convenient one, and it has become clear that compromises in resolution and bit depth will be apparent in today's imaging media. This paper describes a film scanner designed to meet the demands for the high-quality imagery from all 35mm and 16mm film content.

The debate regarding film scanning technologies will probably continue forever. However, with specific regard to resolution, CRTs have some undeniable advantages over CCD technology. While CCDs segment the image at the detection stage, a CRT scanning beam illuminates the image in a linear analog fashion from instant to instant.

CCD photosites are a fixed size, with a fixed number on each chip, which determines a CCD system's resolution. Conversely, a CRT beam is a continuous linear sampling device that can sample all or part of the film image by CRT raster resizing. Filtering is added only after sampling and prior to A/D clock sampling. The A/D clock and filtering are changed to suit the particular transfer standard.

The CRT's physical spot size can be adjusted and shaped and has a true gaussian distribution of illumination once afterglow correction has been applied (Fig. 1). This offers at least two advantages: first, the gaussian spot illumination acts as a good anti-alias filter at very high resolutions. Second, the system's maximum resolution can be varied in an optical sense and is set by the CRT spot size and the objective lens reduction ratio, which reduces the spot size at the film plane (Fig. 2). As the spot effectively forms part of an "instantaneous" sampling system there is no loss of vertical resolution due to the film's vertical motion through the gate. It is also worth noting that as the scan geometry is digitally controlled, the CRT scans compensate for line tilt as the film transverses the scan raster. This allows very accurate image geometry for video and data output.

CRT technology, as utilized in Cintel's C-Reality, offers spot sizes that encompass resolutions well beyond 2K; and being of a gaussian nature, the roll-off in resolution is similar in characteristic to that of the film image itself, rather than the "brick wall" segmenting structure of CCDs. This is especially true when comparing a CRT zoomed image to the DVE zoom applied to CCD scanners. While a CRT zoomed image maintains a full set of clocked samples across the wanted image area, a CCD generated zoomed image must resize the reduced number of fixed samples determined by the degree of zoom.

Evolvable Resolution

Flying spot technology relies solely on the CRT and objective lens for front end resolution. It is therefore safe to assume that higher resolutions than those currently chosen can be achieved without any replacement of the detector system.

Spreading the Light Load

Very bright sharp CRT rasters put high loading on the CRT phosphor. If the CRT beam is concentrated over a small area of the face-plate, it would be reasonable to assume that the phosphor would quickly deteriorate. To avoid high phosphor loading it is desirable that the CRT raster be spread over a large surface area. This is straightforward while scanning a still frame as the raster shape is that of the output format, either 4:3 or 16:9. However, when the film is running there is little vertical raster scan, as the film motion itself generates the vertical scan. This causes the scan raster to occupy only a small vertical area of the CRT and would be undesirable with very high brightness designs.

C-Reality overcomes this dilemma by scanning in reverse and flipping the image within the scanner's store. Scanning with the moving film image rather than against it, forces the raster to chase the film, creating a vertical raster that is approximately twice the height of a still raster. This distributes a powerful, sharp beam energy over a large area of the phosphor and offers very long life to the CRT (Fig. 3).

Illumination + Detection—The Question of Signal to Noise

The world of telecine often seems at odds with all other technological advances in the industry. Probably the best example is the belief that only by increasing the amount of light directed at the film image can signal to noise be improved. However, it is known that too much light on the image can actually fade the film dye in seconds. Such fading is most prevalent with negative material in the magenta layer. Modest illumination from 250-W light sources on line array CCD scanners has been observed to start fading the magenta layer in tens of seconds and xenon-

Presented at IBC99 in Amsterdam, The Netherlands, Sept. 10-14, 1999. Peter Swinson is with Cintel International Ltd., Ware, Hertfordshire, U.K. Published by permission of the IBC.

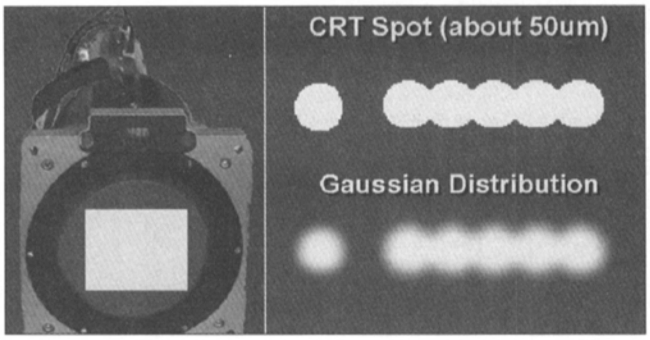


Figure 1. CRT gaussian spot.

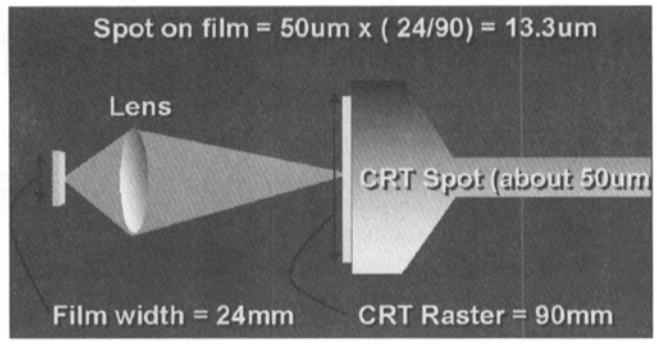


Figure 2. CRT spot imaged on film.

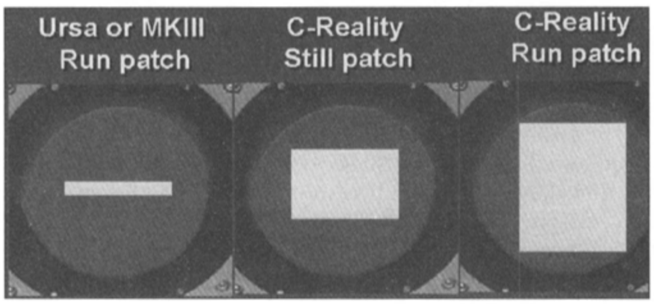


Figure 3. Large CRT scan raster in run.

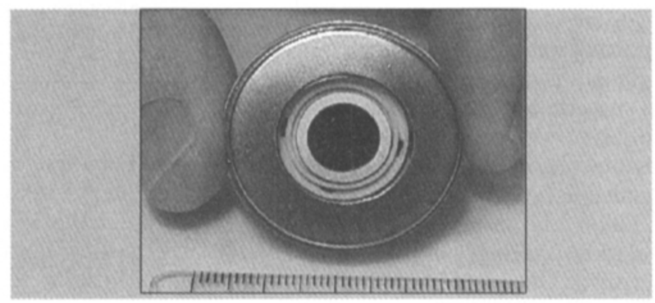


Figure 4. Large area avalanche photodiode.

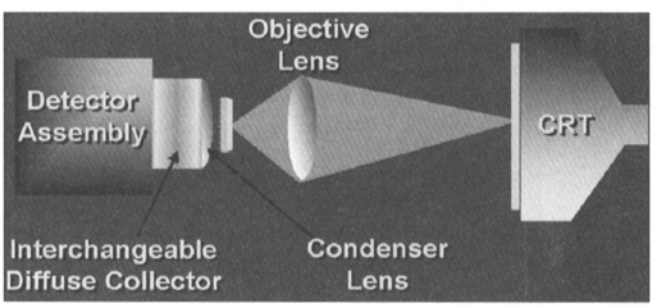


Figure 5. Location of diffuse detection filter.

Figure 6. Image without diffuse detection.

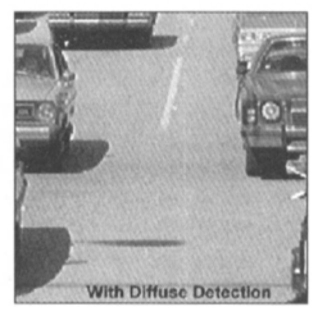


Figure 7. Image with diffuse detection.

based scanner light sources need capping whenever the film is stopped in the gate. Camera sensitivities have been dramatically enhanced to improve signal to noise, and film emulsions are now extremely sensitive with very low grain levels. In both instances it is the capture device sensitivity, be it a video camera or film, that has led to improvements in signal to noise.

Devices known as large area avalanche photo diodes (LAAPDs) offer efficient means of converting photons to electrons with quantum efficiencies of greater than 80% (Fig. 4). Their sensitivity and dynamic range are significantly higher than CCDs or photomultipliers. These detector sensitivities more than compensate for the fact that CRTs are not as bright as xenon lamps. Additionally, CRT phosphor compensation removes any modulation of the light source. It is the combination of brighter CRTs and these avalanche photodiodes that really dispel the concern of noise from film transfers.

It should also be remembered that with flying spot telecines the detectors have effectively infinite resolution. They are only converting photons into electrons and have no part in generating the image's spatial structure.

Diffusion

While CCD systems can use diffuse light sources to mask scratches and dirt, diffusing a flying spot would not work. Cintel offers an alternate solution in the form of special interchangeable optical diffusion filters (Fig. 5). These filters, unlike diffuse illuminators, are placed after the scanned film plane, where the

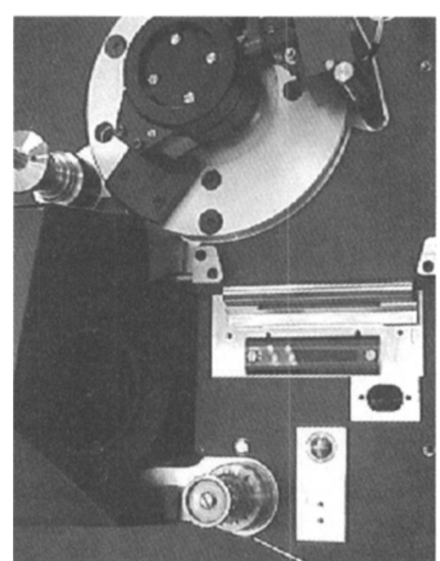


Figure 8. Gate location area, gate removed.

interest is only in instantaneous light levels. They have no effect on resolution, yet significantly reduce scratches and dust. Since the filters do attenuate the available light source to a certain degree, they are user selectable. For example, a powerful filter that is very efficient at minimizing vertical scratches can be selected or a general filter with good overall performance may be substituted (Figs. 6 and 7).

Positional Stability

High resolutions and large dynamic ranges are of no use if the image is not physically stable. Stability in all transfer disciplines is desired, however, it is critical in certain areas of operation. For multilayer edits at standard definition, previous telecine stabilities have been regarded as mostly adequate. For high definition and, more importantly, film-resolution layering, positional stability is critical. Outside of layering operations, with today's compression systems, in standard and high definition, interframe instability can wreck the compression ratios.

C-Reality's film guidance and transport criteria had to improve over previous designs. To achieve such improvements the transport servo has at least a thousand-fold increase in positional resolution compared to earlier telecines, and the horizontal guidance has been totally redesigned to avoid weave artifacts. Feed and take-up servos must handle large masses of film, however, they are designed so that, despite these large masses, the film fed through the critical imaging path is undisturbed. If so desired, being a two-dimensional raster scanned system, the scanner could be adapted to pin registered gates, as the gate area is sufficiently large to accommodate such mechanisms, however to date the need has not arisen for such devices (Fig. 8).

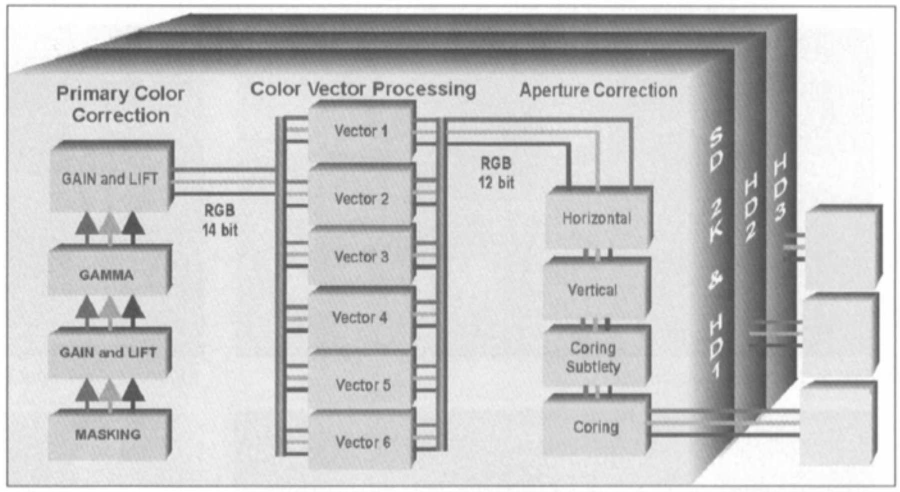


Figure 9. CVIP color channel.

Scanning

All scanning and image processing is progressive and any interlacing is performed at the output store. In all instances each color channel operates at full resolution, full bandwidth, and at 14-bit depth. The gate and lens dimensions allow the full area of 35mm and 16mm material to be scanned, including 35mm VistaVision. Compromises cannot be afforded when scanning for film resolution or high definition, where layering is to be performed.

Standard Definition

At all frame rates up to 25 frames/sec the CRT raster scans at twice the vertical line count, i.e., 1250 lines for 625 and 1050 lines for 525. Together with precision control of the spot this allows C-Reality to capture all the film's verti-

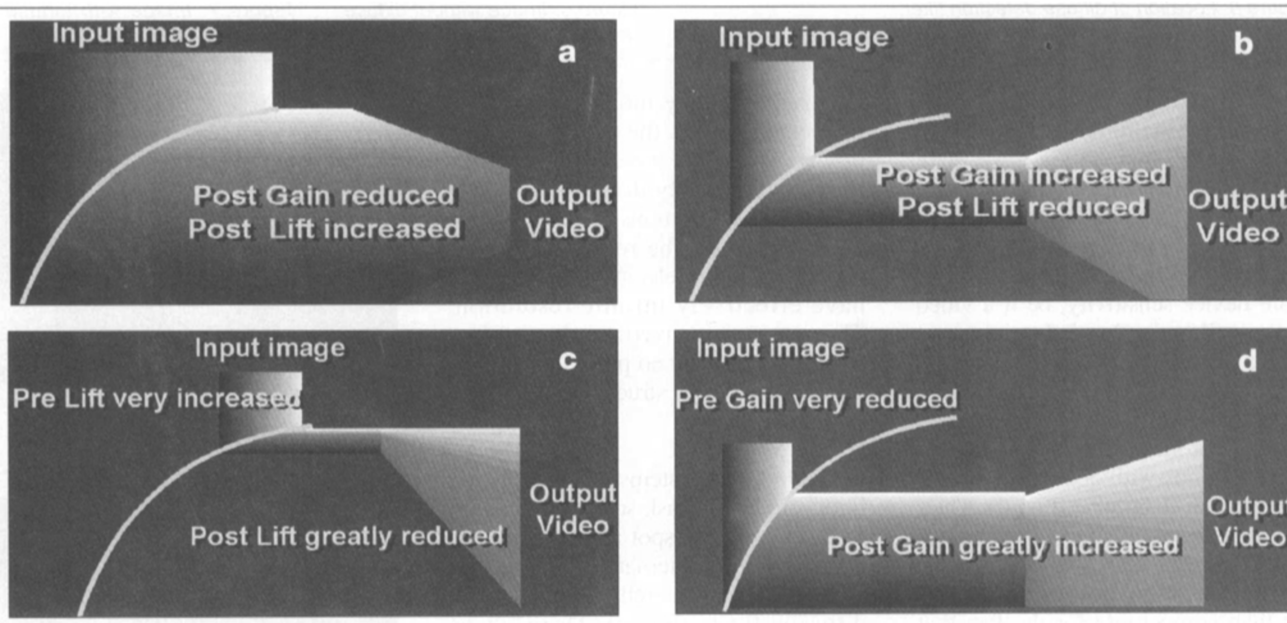


Figure 10. Manipulated image signals using CVIP. (a) Image density compressed; (b) image density stretched; (c) image black stretched; (d) image white stretched.

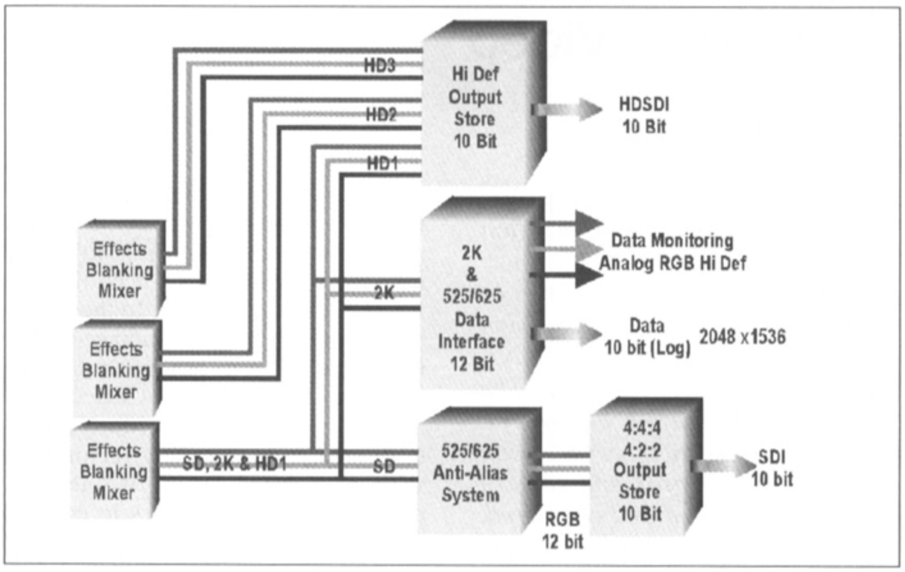


Figure 11. C-Reality output configurations.

cal information. The result is interpolated and filtered to minimize interlace aliasing. Due to the natural filtering of switchable analog filters prior to the A/D sampling, little if anything is gained in oversampling horizontally. Therefore, horizontal sampling is presently carried out at standard rates.

High Definition and 2K Data

For present 1920 x 1080 standards the CRT raster scans 1080 active lines, each line is converted at the A/D into 1920 samples, and the spot shape and size is optimized for such scans. The spot shape is also optimized for the 2K format. In this mode 1556 lines are scanned and each line at the A/D is sampled as 2048 horizontal pixels.

CRT Scanning Benefits

As a flying spot system, other scan formats are easily catered for by changes in vertical line count and horizontal sampling after the detector. This is an important point because it is not reliant on a fixed number of CCD segmented samples, it is therefore a simple matter to change the sampling rate for each line scanned. This not only optimizes the sampling but avoids aliasing and other undesirable losses where fixed sampling sizes need to be interpolated.

A simple example is a zoom. To zoom into the image the CRT raster size is simply reduced. The line count and scan time for each line do not change. Therefore, the output signal contains the full set of lines and the A/D samples a full set of horizontal pixels, regardless of the degree of zoom, without the need for interpolation.

Signal Processing

Signal processing is common across all scan standards from 525 to 2K data. The image signal can be user manipulated with C-Reality's CVIP and any downstream color correction system (Fig. 9). CVIP includes powerful processing such as pre- and post- gamma gain and offset control, allowing dramatic nonlinear stretch and/or compression of the film image while still in the 14-bit dynamic range of the signal. Figure 10 illustrates the principle; in reality the transfer characteristics are more complex and can only be appreciated by actually observing real scenes. Six fully variable color vector channels are also available with hue saturation, and luminance on each. Again, these operate at 14-bit color depth and full resolution. Such a color control system enables decisions made in one resolution to be equally applied at any other resolution.

Aperture Correction

Aperture correction is not a means of artificially boosting resolution. Any sampling system, flying spot, CCD, etc., has a known sampling aperture. The corrector will allow the size of the sampling system to be corrected, when used correctly. Therefore, the scanner's aperture corrector has correction bands that come into effect relative to the scan and sampling rate being used, ensuring a flat resolution response within the scanners required modes of operation.

Video and Data Outputs

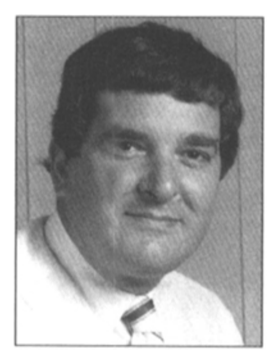
For standard definition and high definition the image signal is converted to interlace, unless the output requirement happens to be progressive (Fig.11). The structure of the scanner data option is dependent upon the user's requirement. In all instances, however, monitoring of the data output is always available.

Conclusion

The scanner or telecine for the 21st century must be capable of the finest video and data transfers. Such scanners must offer flexibility to scan at the optimum resolution for present and future standards, whether video or data.

Film formats in the main remain as 35mm and 16mm, however larger formats are now finding favor in some cinematographic arenas. Likewise, S8mm is still often used in various parts of the industry.

THE AUTHOR



Peter R. Swinson joined Rank Cintel Ltd. in 1982 as telecine products manager, where he the introduced Ursa, Ursa Gold, and Klone high-resolution film scanners. In 1998, he became market development director at Cintel International Ltd. and is currently responsible for all of the company's products, including the introduction of C-Reality, Rascal Digital, and Ursa Callisto.

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