SONY

SONY HDCAM: EXPOSURE INDEX - Issues of Camera Operational Sensitivity

24P TECHNICAL SEMINAR #1

by Laurence J. Thorpe

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ABSTRACT

The advent of 24P offers an important new acquisition tool to the cinematographer. Video cinematographers, however, are trying to adapt to a lingua franca of the film community and to operational practices long-honed in the film world. The film cinematographer, on the other hand, is trying to decipher published performance specs that are still in "video" language. It is useful, therefore, to begin our Technical Seminar series with an expose on the most fundamental aspect of any camera – namely, its sensitivity. Called Exposure Index by the film community, the sensitivity of the camera relates to its ability to capture quality pictures under a wide variety of scene lighting conditions.

The good news for all cinematographers is that the 24P camcorder is very sensitive. In film terms, it will be shown to have an effective Exposure Index (EI) range that endows a single 24P camera with the combined equivalency of very slow speed, medium speed, and high speed 35mm motion picture film.

TEN YEARS AGO, THE *SMPTE JOURNAL* PUBLISHED AN EASTMAN KODAK TECHNICAL PAPER ENTITLED:

"A COMPARISON OF COLOR NEGATIVE FILMS AND HDTV CAMERAS FOR TELEVISION PROGRAM PRODUCTION" [1]

In that paper, the authors outlined a comprehensive comparison between the performance of Sony's analog HD camera model HDC-300 and their contemporary 35mm motion picture film. The paper focused on many of the controversial parameters that are debated in traditional comparisons between HD video and motion picture film. In doing so, it shed valuable light on an approach that would be more useful in comparing video and film.

THE PAPER MADE A KEY POINT IN THE FOLLOWING STATEMENT:

"Film speed is specified by a recommended Exposure Index (EI) which the cinematographer can modify to achieve his artistic aims. The sensitivity of video cameras is specified by a minimum illumination (in Lux) required to produce a peak white signal from a 89.9% reflectance white card at a particular lens aperture."

This statement spoke directly to the video community's traditional tendency to favor signal-to-noise evaluation, compared with the far more flexible approach to camera exposure long-favored by film DPs.

The Kodak paper compared HD camera Video Sensitivity (as then published by Sony) with the Exposure Index of their films. The authors made a useful contribution to a convergence in thinking about these seemingly disparate definitions of camera operational sensitivity.

Most important, their paper also compared the electronic signal-to-noise performance of the HD camera with the Equivalent Noise for their films (scaled by Kodak from the published Granularity specifications of these same films). This facilitated an "apples to apples" comparison of the level of "grain" in the two media.

The authors then made the key point that any comparison of film and HD cameras must include the comparison of BOTH sensitivity AND noise. Taken together, the comparison of sensitivity and noise establishes the boundaries of operational sensitivity for both film cameras and electronic cinematography cameras.

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THE SENSITIVITY AND EXPOSURE INDEX COMPARISON IS REPRODUCED AS FOLLOWS [2]:

SENSITIVITY AND EXPOSURE INDEX

Image Format	Illumination* (Lux)	Exposure Index (EI)
EXR-5245 (35mm)	4300 (D)	50
EXR-5296 (35mm)	430 (T)	500
EXR-7245 (16mm)	4300 (D)	50
ECN-7292 (16mm)	690 (T)	320
HDC-300 (1-Inch)	1600 (T)	160

* Minimum Illumination @ F-4

THE NOISE COMPARISON TABLE IS REPRODUCED AS FOLLOWS:

EQUIVALENT NOISE (DB)

Image Format	EXR-5245	EXR-5296
16mm	-42	-37
Super-16	-44	-39
35mm	-49	-44
Super 35	-50	-45
HDC-300	**-46**	

As we can see, the analog HD camera of 1991 was modest in its performance when compared to film -- lying somewhere between slow and high speed 35mm film in exposure index, and between slow-speed Super16mm and 35mm in its level of "grain". The next ten years, however, would witness striking advances in High Definition CCD imager technology [2]. These advances would be further augmented by the advent of 12-bit DSP digital processing in the camera. The consequences of these technological improvements will be illustrated below.

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SENSITIVITY OF THE DIGITAL 24P CAMCORDER - A VIDEO PERSPECTIVE

In deference to those who are familiar with the sensitivity specifications of a traditional interlaced video camera operating at 59.94Hz - (hereafter rounded out to 60Hz - or 60 fields per second - for simplicity), the sensitivity of Sony's new HDW-F900 digital camcorder is as follows:

With 2000 Lux of incident illumination on an 89.9% reflectance Reference White card imaged by the camera operating in a 60i interlaced mode (a Lens aperture of F-10 producing a nominal 100 IRE video level) at the nominal 0 dB Master Gain setting. Under this camera setting, the video signal-to-noise ratio is specified as 54 dB.

A key point that needs to be made is that the long march to develop and improve video cameras has involved two parallel struggles: to lower the electronic noise level to the minimum physically possible, and to elevate the operational sensitivity. The specification quoted above is remarkable in showing what has been achieved in the HD camera over the past decade.

The sensitivity of the 1080/60i camera is identical to its sensitivity when operating in a progressive 30-frame mode, described as 1080/30P. The sensitivity of the camera when operating at the slower capture rate of 24-frame per second -- or 1080/24P (with no shuttering) -- is 1.25 times higher than 30P because of its proportionally longer exposure time. With the 180-degree shutter operation invoked, the sensitivity of the camera in the 1080/24P mode is reduced to one-half of 1.25 times that of 1080/60i.

THUS:

SENSITIVITY OF 24P OPERATION = 62.5% OF 60i OPERATION (WITH 180-DEGREE SHUTTER)

EXPOSURE INDEX OF THE 24P CAMCORDER - A FILM PERSPECTIVE

The Sony HDW-F900 digital 24P camcorder was designed according to today's international standard for HD Production: the ITU 709 standard. As such, it conforms to this standard by embodying five picture capture rates. These include three progressive scan modes of operation: 24P, 25P, and 30P -- as well as two interlaced modes: 60i and 50i.

When the camera is set up to image an 89.9% reflectance Reference white card (with 2000 Lux of incident illumination) and is operating in 24P mode with no shutter at the nominal 0 dB gain setting, then a calibrated light meter will show an EI reading of 640. This has been carefully verified with a range of lightmeters. When operating with a 180-degree shutter in the 24P mode, the nominal exposure index (as defined for the Nominal 0 dB gain setting) becomes, in round numbers: 640/2 = 320.

The most impressive aspect of the 24P camcorder, however, only emerges when its operating speed is combined with its signal-to-noise specification of 54 dB at that specific camera setting. Bearing in mind that a slow-speed low-grain 35mm EXR-5245 film has a rating of 50 ASA, with an attendant equivalent noise (film grain level) of 49 dB, the performance of the 24P camera (combining an Exposure Index of 320 with a signal-to-noise ratio of 54 dB) makes for superb low-speed operation.

It must be emphasized that this comparison based on equivalent signal-to-noise numbers does not address the subjective appearance of film grain and electronic noise. It merely speaks to the equivalent levels of "grain". In this context, Eastman Kodak pointed out [1] a general rule-of-thumb: a difference of 1 dB is just noticeable, and a difference of 3 dB is easily visible.

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THE KEY ISSUE WHEN SPECIFYING THE EXPOSURE INDEX OF THE 24P CAMERA

Eastman Kodak made the important observation that a cinematographer traditionally modifies the EI when actually operating the film camera with a given film stock. In video, on the other hand, we have traditionally specified a single number for sensitivity based upon a long-standing fixation with maximizing signal-to-noise performance.

We need to depart from that fixation when we consider the 24P camcorder in the hands of a film cinematographer -- because the cinematographer will, for creative reasons, purposefully seek to modify the effective Exposure Index. Having long experience in skillfully accommodating film grain, the film DP will be much less intimidated by the presence of a modest amount of electronic "grain." It should be kept in mind that the cinematographer chooses a particular film stock speed based upon his familiarity with the exposure index range that can be achieved and the associated levels of film grain that accompany that choice. While DP's don't think in terms of any "dB" spec for that grain level, they are still sharply attuned to its subjective visual effect.

Accordingly, it is useful to look at the HDW-F900 from the perspective that it is outfitted with an all-important operational control over its GAIN setting. To the film DP, this endows the camera with an innovative real-time control over the operational "speed" of the camera.

Again, the Nominal Exposure Index (EI) for that setting is 320 -- with an attendant "grain" level of a very low 54 dB. With that as our starting point, let us consider what the cinematographer is now free to do simply by altering Master Gain.

EQUIVALENT EXPOSURE INDEX AND EQUIVALENT GRAIN FOR THE 24P CAMERA

The following table refers to the HDW-F900 24P camcorder's performance when operating with a 180-degree shutter. It makes the simplistic assumption that there is a direct dB correspondence between the gain alterations and the attendant change in signal-to-noise performance. In practice, this assumption is reasonably accurate.

The table tracks the combined alteration of Exposure Index and Noise when the camera Master Gain control is switched over a range of settings above and below the nominal 0dB. The reference values of two film stocks specified by Eastman Kodak have been inserted in the table on the basis of their ranking in terms of equivalent signal-to-noise (equivalent grain).

GAIN SETTING (dB)	EXPOSURE INDEX (ASA)	SIGNAL/ NOISE (dB)	REFERENCE FILM STOCK
- 6	156	60	
- 3	220	57	
0	312	54	(Nominal setting)
+3	440	51	49 dB EXR-5245 (50 ASA)
+6	624	48	
+9	880	45	44 dB EXR-5296 (500 ASA)
+12	1148	42	

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THE ISSUE OF RECORDING NOISE AND DYNAMIC FILM GRANULARITY

The above discussion centered on the specification of Sony's HD digital 24P camera. Any true equivalence with film capture must, of course, factor in the performance of the associated digital recorder. While the latter has no effect on the exposure index (EI) performance of the camera, it does add a further degree of electronic noise which, in turn, modifies the "grain" level of the final 24P capture.

This noise level is difficult to quantify because of the nature of the real-time dynamic performance of the digital compression engine used in the HDCAM recorder. Depending on the content of each scene, the system is continually making real-time adjustments to the quantization and to the deployment of digital bits between the luminance and color difference video channels.

A reasonably accurate accounting of this VTR noise factor, based upon technical assessments of recorded pictures having a wide range of scene content, can be made by reducing all of the digital signal-to-noise figures above by 1.5dB.

It should be pointed out that motion picture film has a similar anomaly: the level of film granularity is also dynamically changing over the range of the recorded signal as it varies from black regions to overexposed highlight levels. Eastman Kodak publishes this variation in the technical data sheets for their various film stocks. To accommodate these variations in the discussions above would be mathematically daunting and Kodak made no attempt to do so in their paper.

SUMMARY

SETTING APART ISSUES OF 24P RECORDING NOISE AND DYNAMIC FILM GRANULARITY, THE ABOVE TABLE PRESENTS THE BASIC CAPABILITY OF THE 24P CAMCORDER IN RELATION TO REFERENCE 35MM FILM STOCKS.

THE 24P CAMCORDER IS SENSITIVE. THE VERY GOOD NEWS FOR THE DP IS THAT THE CAMERA IN EFFECT COMBINES THE CAPABILITIES OF SLOW-SPEED 35MM FILM, MEDIUM-SPEED FILM, AND HIGH-SPEED FILM.

- The nominal 24P camera setting -- at 0 dB gain -- yields an exposure index (EI) of 320, which is equivalent to medium-speed 35mm film but with a considerably lower grain level.
- At a lower Master Gain setting of -6 dB, the 24P camera has a slower speed, equivalent to an Exposure Index (EI) of about 150 - but it still has a higher speed than EXR-5245 slow-speed film and a grain level far lower than this 50 ASA 35mm film.
- At a Master Gain of only +9dB, the 24P camera has an exposure index of almost 900 and a grain level in the vicinity of that of 500 ASA EXR-5296 high-speed 35mm film.

  This wide range of control over Exposure Index greatly empowers a cinematographer. It eliminates the need to change film stocks of different speeds and assures constancy of tonal and color reproduction - and, of course, picture sharpness.

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