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Harry Mathias
San Jose State University, harry.mathias@sjsu.edu

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A Proven Method of Establishing Exposure Indexes for Video Cameras

By Harry Mathias

This article discusses a production-tested method for determining exposure indexes for video cameras. Also discussed are exposure control methods, camera sensitivity, waveform monitors, lighting, and other factors. The importance of this procedure in practical production situations is described.

Video cameras are becoming more deeply involved in the creative areas previously occupied only by film cameras and film production methods. Single-camera video production is becoming more common as a production style than multiple camera live-switched production; as a result, many of our old video image control methods are being questioned. As we begin to explore the suitability of high-definition television (HDTV) technology for feature-length dramatic production, we must admit that even the current generation of video production cameras is being used increasingly to tape dramatic subjects for broadcasting.

Exposure Control Methods

Problems faced and solved in film production years ago are only now being addressed in video, and one of these problems is creative exposure control. Most current video cameras contain auto-iris with a sophistication that film technology never dreamed of, but that is precisely the point. In determining exposure, cinematographers take factors into account which the designers of auto-iris never dreamed of.

One method of video exposure control is to let the auto-iris do the exposing. The other traditional method is to have a video engineer remotely controlling the camera iris while observing a waveform monitor and carefully keeping the whites at 100 IRE units as light levels in the scene vary. This is perhaps closer to the ideal method—at least a human is involved. However, it is impractical in a single-camera film-style shoot, although the method is frequently used in this type of situation.

There is a third video exposure control method, which I adapted from standard film practices twelve years ago. I have taught this method to film and video camerapersons all over the country, and by now it has become part of the daily production repertory for myself and many others.

If the optimum exposure for a scene were always one which resulted in a peak white level of 100 units, it would be a relatively simple matter to automate exposure control so that neither the cinematographer nor the video engineer would ever have to be concerned with it. The problem with such an approach, of course, is that it totally ignores the content of the scene. Suppose the scene being shot contained a skier going over a hill. The brightness range of such a scene would probably exceed the latitude of any photographic medium, so a compromise must be made in exposure. In a long shot, a cinematographer would set the exposure to hold detail in the snow-covered hill and silhouette the skier, but for a closeup, the cinematographer would expose for an appropriate rendering of the skin tone and let the highlights in the background burn out.

Even when the brightness range of a scene can be encompassed by the latitude of the system, it may be necessary to compromise in tone reproduction to achieve consistency from scene to scene. In cinematography, it is usually considered important to maintain consistency of skin tone. Because of the way in which scenes are cut together, it can be very distracting if the leading lady's skin seems dark in one shot and light in the next. An incident light meter with a photosphere is designed to enable a cinematographer to determine the exposure setting which will make an 18% gray card appear as a mid-gray regardless of the content of the rest of the scene. This is very helpful in maintaining consistency of skin tone.

No matter how sophisticated the automatic exposure control system in a video camera, it can never understand the content and context of the scene being shot. Even a tone capture exposure control which keys the exposure to flesh tones in the scene cannot determine the difference between a high key scene and a somber dramatic scene in which faces are deliberately placed in shadow.

Exposure Control System for Video

What is required is an accurate system for determining exposure which takes all the elements of the scene into consideration and specifies a setting for the iris which can be left constant throughout the shot. Such a system was developed for motion-picture photography over 40 years ago, and there is no reason not to use it in video production. It contains three elements: a light meter, a sensitivity reading for the film or camera, and the creative judgment of the cinematographer.

The first step in the process is to establish a direct relationship between incident illumination and f-stop independent of the reflectances of the objects comprising the scene. The second step is the judgment of the cinematographer in adjusting the exposure level or f-stop based on considerations of the content and context of the shot. The second step is possible only on the basis of the first, and it is the first step which is missing in the traditional approach to exposure in video.

Incident Illumination

The type of exposure meter most commonly used in cinematography measures incident light and has a scale which reads in f-stops. It is designed to accept slides which alter the amount of light striking the photosensitive cell according to the ASA or
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exposure index of the film. There is an individual slide for each common film speed, and the whole system is based on the idea that the specified f-stop would cause a gray card with a reflectance of 18% to produce a mid-density on the negative. The f-stop must be set so that the 18% gray card will be consistently reproduced as a mid-density on the negative regardless of how much light is falling on it.

Obviously such a system for determining exposure depends on a consistent method for rating the speed of the film. While there have been some revisions made in recent years regarding the method for measuring the speed of a particular film, on the whole the manufacturer's specified exposure index is a reliable basis for calculating exposure.

Camera Sensitivity

Video camera specifications generally include some kind of figures for the sensitivity of the camera, but there are no widely accepted standards for measuring this. Also, the specified sensitivity ratings apply to one camera of a given type that was tested and may not apply to the particular camera being used. Just as with automobile EPA mileage ratings, it is expected that the manufacturer will select an exceptional camera for its test specimen, and will test it under ideal conditions.

The sensitivity of a video camera is generally specified in terms of the amount of incident illumination required on a specified reflectance to produce a fully modulated video signal at a given f-stop. This is tied to the signal-to-noise ratio (SNR) which is specified for the camera. Just as there is a trade-off between speed and grain in a film emulsion, there is a trade-off between sensitivity and noise in a video camera.

A typical sensitivity rating for a video camera might be 200 fc of 3200K light on a 60% reflectance at f/4 with a 58-dB SNR. Such a rating assumes that the camera will be set up so that the 60% chip on the EIA 9-step chip chart (the "white" chip) will register at the peak white level, and the cross-over chip, which has a reflectance of 13.4%, will be at the mid-gray level. This would place an 18% reflectance about one-third stop above the middle gray, but we can assume that this is a reasonable compromise given the limited latitude of video in comparison to film. It is also assumed that extreme highlight detail is more expendable than shadow detail. Often the opposite is true, but in practice, this difference in video and film gray card standards can either be compensated for with an exposure index adjustment or ignored. Accuracy to one-third of a stop is generally considered within professional photographic tolerances.

There are also specifications involving gain boosts of up to 12 or 18 dB, which increase noise levels as well as sensitivity. Even worse, many specifications for camera sensitivity do not spell out all the factors, and there is no way of knowing what reflectance or gamma setting or gain boost is involved. In addition, the manufacturer's specifications may not be sufficiently accurate for the particular camera which is being used.

The practical solution to this problem is a simple procedure for rating the sensitivity of a video camera at the beginning of a shoot. It will enable the cinematographer to use an incident light meter exactly as it is used with film.

Determining the Exposure Index

The method used to determine an exposure index for a video camera is...
The sensitivity of a video camera is generally specified in terms of the amount of incident illumination required on a specified reflectance to produce a fully modulated video signal at a given f-stop. This is tied to the signal-to-noise ratio (SNR) which is specified for the camera.

uncomplicated. When a video camera is being set up at the beginning of a shoot, it is possible to establish an effective exposure index by means of a simple procedure which takes only a few minutes.

First, a chart is set up and lit evenly, which is now the practice for color balancing a camera. Then the camera is focused on the chart; the iris is opened until the crossover chip is at 55 units on the waveform monitor or the peak white chip is at 100. Normally, this will already have been done in order to set video levels.

The f-stop on the lens is noted, and then a reading with an incident meter is taken at the chart. The photosphere on the meter should be pointed at the camera. The slide in the meter is then changed until the f-stop reading on the meter coincides with the f-stop at which the lens was set. When the slide is found that results in the closest approximation to the f-stop on the lens, the effective exposure index of the camera has been determined. The light meter will then predict the sensitivity response of that video camera just as it would predict the response of a film with an equivalent emulsion speed.

This method of setting up the meter to coincide with the camera has an added advantage in that it compensates for any light loss due to the camera optics. It is the equivalent of establishing T-stops for the lens, since it matches the meter to the amount of light that is actually reaching the pickup tubes. The f-stop on the lens then becomes an accurate indication both of exposure and of depth of field.

The exposure index determined in this manner may not be an absolute measurement of the camera’s sensitivity, but it is a reliable, practical basis for setting the f-stop during production. It enables the cinematographer or videographer to expose every scene so that mid-tones will be consistently reproduced or to adjust the exposure so that the reproduction of the mid-tones will be altered in a controllable manner.

Waveform Monitors

Perhaps it may be helpful to explain how using an exposure index of this sort differs from setting exposure simply by means of a waveform monitor. A waveform monitor can tell you how to expose a scene so that as much as possible of it can be encompassed by the latitude of the camera, but it cannot easily ensure that a given object will be reproduced with consistency.

Normally, a waveform monitor is used by a video engineer to set an f-stop which will place the brightest object in the scene at peak white in the signal. If he knows that the brightest object is something like a window where detail is not important, he may adjust the exposure and let the brightest area exceed the normal peak white level to bring out more detail in the shadow areas. However, the waveform monitor is not practical for determining how much to adjust the exposure or the lighting for correct tone reproduction control. Similarly, there is no guarantee that the brightest object in a given scene should necessarily be at peak white. Depending on the content of the scene, the brightest object may be a skin tone or some other object which really looks better at a much lower level.

The waveform monitor also cannot easily ensure that an object will be reproduced consistently from one shot to the next. As an example, let us consider a scene involving two different angles in a room containing dark paneling on the walls and dark furniture. One angle includes a white marble bust of Napoleon next to the bookcase. The other angle does not show the bust, but includes a table and part of a wall visible in the first. Suppose that the brightest area in the second angle is a portion of the polished tabletop which is reflecting light from an off-screen window. The same tabletop is visible in the first angle, but it would obviously not be as bright as the white marble bust.

If the f-stop for each angle were set so that the brightest area was at peak white, then the paneled wall would appear much darker in the first angle than in the second.

This might be all right for each shot taken out of context, but if the two were cut together in one scene, the result would be distracting and confusing. The solution is obviously to set the exposure so that the tabletop or the wall is more or less at the same level in both angles. Accomplishing this without an incident light meter would require analyzing the display on the waveform monitor to determine which portion of the signal represented the wall or the tabletop, and matching that level for both shots. While this may be possible, it is not very practical, since the use of an incident light meter will give identical results. With an incident light meter it is only necessary to take a reading with the photosphere pointed at the camera for each angle and to set the f-stop according to the meter.

The need for video exposure indexes may still seem esoteric and subtle, but a practical need for this standard exists for the following reasons:

1. To predict a camera’s sensitivity and compare it with other cameras’ performances in an actual production situation, as well as to compare video cameras with equivalent film stocks. Establishing and publishing video camera exposure indexes may encourage the production of high-sensitivity, low-SNR video cameras, but publishing film Els has not led to this practice in film. On the contrary, it has made it easier for users to see the relationships between film speed and grain and to make intelligent choices as to sensitivity needed for a given project. Published Els would allow cinematographers and lighting directors to separate facts from assumptions about video in production lighting situations, as they now do with film.

2. Predetermined video Els are necessary to pre-light a set for video and accurately predict lens stop needed, depth of field to be expected, and camera proc amp gain boost needed (if any). This information becomes more essential for dramatic single-camera video production than it has been for traditional studio video production. Future HDTV production, if
it is to acquire any of the production values of film lighting methods, will require this technique.

3. If video can be compared directly to film (not only in the area of sensitivity), but in other areas, such as gamma, as well, all the existing production knowledge and literature of the motion-picture industry can be applied to video with ease.

Lighting

The video camera and picture or waveform monitor, when used to evaluate and facilitate lighting, are in fact, the world's most expensive light meter. The major flaw in using the video camera to light is that it may not always be available for that purpose. Often, when the camera is being registered or color balanced, lighting must be done at the same time. If the camera is being powered by batteries and the batteries must be conserved, than it cannot be used to evaluate lighting. Lighting for video must be possible without using a video camera as a lighting tool, but this is not the case with current methods.

Conclusion

Much remains to be considered before video exposure indexes can actually be an industry-wide standard, if this ever occurs. Questions of gamma differences between film and video would have some bearing on this subject (although study has not shown as much as one might have imagined). But these questions of comparative gammad must be addressed anyway for the purpose of selecting a durable worldwide HDTV production standard.

The method described in this article has by now become an informal production exposure standard that is growing in popularity every day. For this to become a truly functional standard, it remains only for the manufacturers of video cameras to become aware of it, and for the SMPTE to recognize it.

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Discussion

Bob Zahn, Broadcast Video Rentals, New York. My question is really much more of a statement. It seems to me that because of the immediacy of television and videotape, the ability to see a picture on a color monitor, and the time constraints that apply to television productions, that people aren't taking the time in conceiving a scene to think about lighting in advance and the exposure indexes you've indicated. I think one of the basic problems is that film producers will take the time because they have the luxury of it, or the sensitivity, to appreciate the quality that goes in when you prethink a situation. I think that is the major problem in applying the research in your results to television.

Mathias: Thank you. You made several comments that were very interesting. I do agree that working both in video and film production there is a real tendency to say, "Well, speed is what we're here for." The major argument I hear for using an automatic iris, for example, on a video camera, is that in breaking news situations you can't stop to take a light-meter reading. Well, I'm a former film news cameraman, and I can tell you that the turnaround time in taking a camera out of the car and running to a fire or accident was always quicker in film than it is in video. Any news cameraman who worked in film had no trouble either beginning with a guessed exposure and sneaking a quick meter reading as he was filming, or having an assistant do exposure meter reading as he was running to a scene.

I'll give you an example of the problem with auto irises — and auto irises, I think, are the biggest bane of video production quality. The coverage of the Sadat assassination was obtained with a video ENG camera. The only camera on the scene was an ENG camera on auto iris, because the cameraman was ducking and hiding behind something. He panned up into the sky, and as a result the auto iris completely stopped down the lens and obliterated the coverage of the event.

Now, without getting into the ramifications of whether assassinations should be covered, the shooting of an international figure is of major importance to history. When we were exposing film by guessed exposure and by light-meter readings, we were not losing major footage because of the vagaries of an auto iris that might see, for example, the glint off of chrome from a car turning the corner two blocks away, and as a result stop down and lose the major area of interest. But more to the point, the video people are always laboring under the condemnation of their work being quick and dirty, and of its being of poorer quality. As the technology gets better and better, video can never escape the "quick and dirty" label. It's becoming more and more obvious that technology is no longer the limiting factor. We are now able or soon will be able to get equal, or slightly worse, but in any case, equivalent production quality on video with the high-definition capabilities of film.

Now the time has come to address whether the production quality of video will be done along the lines of this "knee-jerk" auto iris, which has resulted in the basically news and field quality of video production. Now, I realize that I may be saying something that might antagonize some people, but I also hasten to add that much of the production that is actually going on in video today is not that kind of poor quality. In other words, more and more people are applying light meters and film production techniques to video cameras. Video equipment manufacturers still are pretending that they are building cameras for auto-iris and remote video-van applications, and they don't concern themselves with the needs of people in the field who are actually using film production techniques with video cameras, and have been for some years. This is going to be more and more the case, of course, as we go to high-definition TV and to the application of video for dramatic productions.

Ulrich Reimers: I'm from Bosch, and, as a matter of fact, a camera manufacturer. I have two remarks and one question. One remark is that there may be cameras on the market right now which give you the possibility to spot meter within the camera. That means you have a manual iris, if not an auto iris control. You point to the spot you want to have 60% video level at, you press a button, and the iris automatically adjusts to have 60% video value there and then it remains manual. This is something which probably helps you to use the camera as if it had the metering equipment you were accustomed to from film.

The second remark is that I think that
things have become more complicated because cameras nowadays tend to become more film-like, they don't have the flat transmission curve that they were used to, which means 10% light gives 10% video, and 100% light should give 100% video, but now they are compressing and decompressing the parts in the darks and in the whites. For example, the "knee function" is something which is used to give you an approximate film look between say 80% and 200% video level, or 300% video level.

The paper was so interesting that something really bothers me. You had a formula; this formula was to give exposure control for a given specification of a manufacturer. I am afraid that this formula does not include changes in picture formats which are standard in video equipment. For example, if you do the same thing for a 1-in., a 3/4-in., and 1/2-in. camera, although they have the same sensitivity, you come out with different exposure indexes. Thank you.

Mathias: You've raised a lot of interesting points. Let me start on the first and try to work my way down. First of all, I definitely applaud flexibility in the design of video cameras in giving more exposure level and signal level information to the cameraman. This takes the approach that the cameraman is a cinematographer, not simply a camera operator. I especially applaud the use of a manual rather than an automatic iris configuration that allows input on the part of the cinematographer. The trouble is that any such equipment in the camera still does not solve the problem that the camera becomes a lighting instrument, and the camera is still the world's most expensive light meter. A good light meter is $150; that option undoubtedly costs more than $150 (if it is available as an option). In a practical production situation, the camera is being registered and color balanced while the lighting is going on. That means you cannot begin to light until the camera is available to use as a light meter. Also, the advantage of a light meter is that if I walk into a set to light it, I have my light meter there. If I were to bring the camera into the set, you can imagine the difficulty of dollying a fairly large camera around the set to check various angles and key to fill ratios and so on. For quality lighting, but for dramatic lighting, it is absolutely ridiculous to pan a camera to check the fill, the back light, and the key, bring it around the person, and use it to check the back light. Obviously this is easy to do with a light meter.

There is another point that you made that is very interesting, and that is about non-linear film-like compression curves being used on the gamma circuits of cameras. I am aware of them. Both as a cinematographer and as a consultant, I worked on the design of non-linear film simulating compression circuits. But as a cinematographer, they are very important to me because you have to realize that the motion-picture film also has a non-linear compression curve, and we expose with light meters for the non-linear compression curve of film. In other words, we've been doing that longer on film because we have had the non-linear compression curve for 90 years or more. We didn't know that's what it was called until video defined it.

But in any case, when working with a non-linear compression curve, that is all the more reason to have a linear standard available and then extrapolate from that for the application of non-linear information. For example, when working with the Panacamera, the EC-35, I based my exposure without the gamma compression. I calculated what the exposure situation was without the gamma compression and then put it in. The problem you get into in using gamma compression in a practical production situation is, if you use it and then expose for 100 IRE units, you are essentially defeating the gamma compression. So, essentially you have to ignore the gamma compression when lighting and use it when photographing. This is all the reason why it's important to establish exposure indexes.

The third point concerns the formula. The formula was put in as a concession to film-established techniques. I prefer to use the light meter rather than the formula to calculate because the meter does T-stop the optics. The formula is essentially equivalent to an f-stop method.

It is true, as you pointed out, that in video cameras the target area is a factor in camera sensitivity, and this is not the case with film. No allowance for tube format needs to be made in the formula, however, because the f-stop variable in the formula is specified as the f-stop required for correct exposure (as determined by a waveform monitor). This cancels out the effects of format variations on camera sensitivity.

In the absence of a standard, the reason this informal standard has been so successful (it has spread throughout the U.S. and several countries in Europe) is that it works. It's the kind of a thing where whether you believe the paper or not, you should get a light meter and try it. If you are exposing video regularly, you'll be using the system in two weeks. People come back to me after many years and say, "I've been doing this for years and it gives me control over video." It seems more cumbersome because it's non-electronic and because it's non-microprocessor, but using the criterion that simplicity is elegant, it's a simpler, more straightforward system.

Session Chairman: We're getting some serious signals about wrapping this up from the back. We were supposed to have been out by 5:00, but this is such a fascinating presentation, it's very difficult to interrupt. Let me limit this to one more question. I think you have one, and hopefully, a reasonably short answer.

Don McCroskey, ABC: Time for a broadcaster to make some comments. I applaud your studies, Harry, and I always look forward to hearing your talks and ideas. However, and I must have completely different circles of friends when it comes to video operators and television lighting directors, because the practices you refer to are not at all common among the people I know. Even 30 years ago, when I was a black-and-white video operator, we never went for peak whites — we always went for faces, and matching. Lighting television directors have always used light meters to set up lighting on stages, and I really think you're doing a disservice to many of the good television lighting directors and video operators.

Mathias: Thank you. I can accept that criticism. All good video control engineers do not follow the practices I outlined. Where I would disagree with you is that many, many video control engineers do. I would not say, and I did not attempt to say, that all video control engineers follow this practice, but in addressing large groups of people who work in video production, I hear this complaint time and time again. It's not only a question of where live camera switch remotes set their signal levels. I can't tell you how many producers have been told by the networks' Standards and Practices Committees not only that they cannot exceed 100 IRE units, but that the FCC requires them to have 100 IRE units. The FCC has definitely stayed out of the area of legislating picture content and picture levels.

We agree to good video practice (and any competent video engineer will agree to the practices you and I are talking about). I was at a presentation where an independent producer providing programming material for your network told me that that exact thing was told to him about video levels — about 100 IRE units — and his programming was rejected. I talk to cinematographers every day who were fired for not maintaining what are very flat and very unimaginative signal levels on network television production.

One of the most common discussions among film cinematographers and video producers alike is about basically inflexible and unimaginative signal standards and the requirements of local stations for their commercials and programming. Obviously, you share my concern about this, and I did not mean to imply that all video control engineers produce signals in this way. But the problem is very prevalent and it is, I'm sorry to say, not as rare as you may imagine, even if it's not as common as I think.

Session Chairman: I sense there may be some other questions. Harry, would you be willing to meet outside for a few minutes just outside this room, since we have to close it up, for those who have a few more questions?

Mathias: Absolutely.

Session Chairman: Thank you very much. You've been a great audience.