Infrared Illumination

The Case for IR Illuminators in Video Security
Introduction

The overall effectiveness of most video security systems is limited by how well it performs in adverse lighting conditions. Since much of the activity that requires surveillance happens during the vulnerable hours of darkness, most security systems need to be equipped for round-the-clock operation. This paper provides a brief overview of why and how infrared illuminators can play a key role in these systems.

Factors Affecting Camera Performance

Clearly the camera plays the most important role in any video security system. Virtually all video security cameras can capture good, useable images in bright daytime conditions. But how well do they perform in low-light conditions? Several security camera characteristics directly affect its performance. We will examine each of these.

Camera Sensitivity

The quality of the video image in low light conditions is strongly dependent on the sensitivity of the camera. There are several camera components that affect its sensitivity. The sensor itself is a key contributor. The size of the sensor has decreased over time, which decreases sensitivity simply because it gathers less light. At the same time, technological advantages have made these smaller devices more sensitive. The end result is that modern cameras are significantly better despite their smaller format.

The lens is the other main contributor to camera sensitivity. Clearly a lens with a larger aperture will gather more light. In general, larger lenses are more expensive, but result in greater sensitivity.

Camera Brightness Control

Video security cameras are designed to operate in a wide range of lighting conditions. The brightness range from bright sunlight to a dark overcast day spans more than three decades (1000 to 1). The sensor itself is not capable of operating over this range with optimal image quality.

The camera has several mechanisms to compensate for scene brightness in order to maximize the quality of the image. First, there is a variable iris, which can be opened or closed to let more or less light through the lens.

Second, the camera can adjust the exposure time. At a 60Hz frame rate, the exposure time can vary from less than one thousandth (1/1000) of a second to one sixtieth (1/60) of a second. Longer exposures can only be used at lower frame rates. Longer exposures also mean that motion in the scene will be blurred.

The control of the lens iris size in combination with frame exposure time is very effective at maintaining good images under the full multi-decade range of normal daytime conditions. What happens as it gets darker, and the iris and exposure time are at their maxima? The image becomes darker and darker as the scene gets darker, if it weren’t for another mechanism that the camera can use to compensate – Automatic Gain Control (AGC).

AGC and Image Noise

Simply put, AGC amplifies the signal coming from the sensor. Of course, this raises the level of the image information, making it brighter. Unfortunately, it also raises the level of noise along with the image signal. Figure 1 below illustrates the effect of AGC on a typical nighttime security camera image.
Noise is an unavoidable fact of the image sensing process. There are several sources of noise, including shot noise, thermal noise, readout noise, and fixed pattern noise. Shot noise, for example, is caused by statistical variability of the light hitting each pixel due to the quantum nature of light (photons).

Further discussion of noise sources in imaging systems is beyond the scope of this paper. Suffice it to say that noise manifests itself as graininess in the image. We all have seen examples of grainy, poor quality video. While there are post-processing filter techniques that can reduce the perception of the noise, there are fundamental limits to how much improvement can be made.

Day/Night Cameras

Some video security cameras designed for round-the-clock surveillance have one more mechanism to increase their sensitivity. All silicon sensors happen to be sensitive to light somewhat beyond the visible spectrum. Specifically, they can “see” near infrared (IR) light – light that has a wavelength longer than red light (above 780nm). Figure 2 shows the spectral sensitivity of a typical CMOS camera sensor versus the human eye.
In addition, the color filter array on the sensor is essentially transparent to infrared light. This is a disadvantage under normal conditions, because natural lighting contains significant IR content which interferes with the accurate color rendition of the scene. For this reason, all cameras insert an infrared blocking filter between the lens and the sensor.

However in low-light conditions, it is more important to get a high quality black and white image than it is to get a very grainy color image. So-called true day/night cameras have a mechanism to insert or remove the infrared-blocking (or IR-cut) filter, depending on how much light is available. This capability substantially improves the camera sensitivity and extends the range of lighting conditions that can be covered with good image quality. Figure 3 represents the image from a day/night camera with the IR-cut filter removed and the image converted to black and white.

Figure 3 - Effect of Day/Night Mode

<table>
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<tr>
<th>Color Mode</th>
<th>Day/Night Mode</th>
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Required Image Quality

Given the camera has done all it can to generate the best possible image, the question becomes, is it good enough? It largely depends on the mission of the security system. The goal may be merely to determine if and when there is activity. On the other hand, the goal may be to identify the people or objects of interest. Assuming that the image of the observed target is large enough to resolve its features, it is the noise in the image that becomes the limiting factor. An image good enough for detection may be far too grainy for identifying the target.

Some video security systems already have sufficient scene illumination and camera sensitivity to get good images around the clock; a brightly lit parking lot is a good example. But often, nighttime illumination is not sufficient to accomplish the objectives of the system.

Consider this scenario: A parking lot is lit with overhead lights bright enough for people to find their way to and from their vehicles. This level of illumination may allow a security operator to monitor the general activity in the lot, or for video recording to capture the activity. It may even be sufficient for analytics software to monitor the video and, as a result of detecting activity, trigger an alarm and/or start recording the triggering event.

But in this same scenario, the quality of the image may not be sufficient for identification. If an assault or vehicle break-in were to take place, the video evidence would be useless for identifying or convicting the perpetrator.
Infrared Illuminators

Even with the added sensitivity of day/night cameras, many situations still don’t have enough normal illumination for good quality video; the partially-lit parking lot described above is a case in point. Of course, one alternative is to install additional conventional lighting. This may not be feasible or desirable. In some areas, there may be limits to the brightness of outdoor lighting to control light pollution. In other cases, it may not be desirable to “announce” that an area is under surveillance by having bright overhead lighting burning all night long.

Infrared illuminators are designed to address exactly these situations, and more. They provide additional illumination that the camera can see but humans cannot, taking advantage of a day/night camera’s sensitivity to near infrared light. They are efficient and cost-effective, since they can add just enough light over the camera’s field of view to produce the desired image quality. Figure 4 illustrates the benefit of adding IR illumination to our already partially-lit scene.

**Figure 4 - Effect of IR Illumination**

| Ambient Lighting | With Illuminator |

IR illuminators can be easily added to any security system that utilizes day/night cameras. They can operate completely automatically and autonomously. NuOptic illuminators contain a photo-sensor that will turn the illuminator on at dusk and off at dawn. In addition, they can be synchronized to the camera, such that the illuminator comes on exactly when the camera switches from day to night mode.

Please note that IR illuminators are not useful with standard color video cameras, because their IR-blocking filters are fixed in place. Only color cameras with specific day/night functionality benefit from IR illumination. On the other hand, black and white (monochrome) cameras do not use IR-blocking filters. They are therefore very effective with IR illuminators.

**850nm vs. 940nm**

It was stated above that infrared light beyond 780nm is invisible to humans but that day/night cameras are sensitive to this light. This is not totally accurate and requires more examination. In reality, there isn’t a sharp threshold between the red light we can see and the infrared light we cannot. Our eyes simply become less sensitive as the wavelength gets longer – i.e. light of the same power level just appears dimmer.
Most illuminators are designed to operate at 850nm. This wavelength is almost invisible to humans. We do not see the infrared light flooding the target area at all. Looking up directly at the illuminator, we only see a dull red glow. For this reason, 850nm illuminators are considered “semi-covert.”

Some illuminators operate at or around 940nm. This wavelength is for all practical purposes invisible to us. Since we cannot even tell whether the illuminator is on or off, we consider it to be fully “covert.” Why not always use 940nm illuminators? While the camera’s sensor is sensitive to infrared light, it is not uniformly sensitive to all wavelengths. In fact, it is roughly twice as efficient at 850nm as it is at 940nm. So by using 940nm wavelength light, we either get significantly lower image quality, or we need an illuminator of twice the power.

Digital Benefits

Improving image quality and usability are the obvious benefits of adding infrared illuminators to a security system. However, there is another key benefit for modern digital systems that is often overlooked.

Digital video is compressed, either in the camera for transmission across a network, or for storage at the DVR (Digital Video Recorder). Image compression relies on the fact that all images have structure or redundancy, such as areas of the same color or texture. The compression algorithm employs encoding “shorthand” for these areas, rather than encoding all of the pixel information directly. Unfortunately, noise is random and therefore has no redundancy or regularity at all. It cannot be compressed without substantial loss of information.

This would not be an issue if our compression algorithm could be set for “constant image quality.” Good, clean video would then just compress more than noisy video. But in most systems, it would be inconvenient or impractical to consume the network bandwidth or the DVR storage space at a variable rate depending on the quality of the camera’s video. As a result, the compression algorithm usually is set for “constant bit rate” or “constrained bit rate.” Good quality video compresses well and that image quality is preserved at a nominal maximum bit rate. Noisy video does not compress well, but is now forced to the same maximum bit rate. The unavoidable loss of detail and addition of “compression artifacts” further degrades the already poor image quality.

One obvious solution is to increase the bit rate to the point that the compression artifacts are reduced to an acceptable level. The cost of additional network infrastructure and video storage is substantial, if not prohibitive. And at best, we simply avoid making a poor quality image any worse.

Adding infrared illumination is by far the better solution. Reducing the noise in the video from the camera mitigates or even eliminates the additional degradation caused by image compression. And of course, both generating and preserving a better quality image maximizes the effectiveness of the entire system.

Summary

Infrared illuminators can play a key role in modern full-time video security systems. They work synergistically with day/night cameras that are sensitive to near-infrared light. They often are the simplest and most cost-effective way to maximize image quality in low-light conditions.
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References


