

# In the best of light

## The challenges of minimum illumination

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## 1. Introduction

Light is fundamental to the quality of an image. As a rule, provided it is not overexposed, the image will be better the more light that is available in the scene. If the amount of light is insufficient, the image will be noisy or dark. The amount of light that is required to produce a good-quality image depends on the camera and how sensitive to light it is. In other words, the darker the scene, the more sensitive to light the camera has to be.

Light sensitivity, or minimum illumination, refers to the smallest amount of light needed for the camera to produce an image of useable quality. Minimum illumination is presented in lux (lx), which is a measure of illuminance, often inappropriately referred to as light intensity. Thus, one might argue that the lower the lux rating indicated by the vendor, the more sensitive the camera. However, it is not quite that simple. There is a paradox to the minimum illumination issue. While light sensitivity is often a key deciding factor when deciding between products and vendors, it is a challenging aspect of camera technology and one of the most difficult to depict.

This paper aims to bring some nuance to the discussion on light sensitivity, to highlight the traps and explain why in-the-field testing is preferred over datasheet comparisons and necessary to make an informed purchase decision.

## 2. The puzzle of light sensitivity

The process of measuring light sensitivity is complicated and inconclusive. There are several reasons for this.

First, illuminance is measured using a lux meter. Although the measuring method in itself is accurate, lux readings are deceptive in regards to describing a camera's light sensitivity because lux meters and cameras do not collect the same light information. So when we talk about illuminance or lux, we refer to how a scene is lit, not how the light is collected by the camera.

Whereas a lux meter records the amount of visible light that hits, or illuminates, a given area (incident light), a camera records the amount of light reflected from the objects in the covered area (reflected light). Thus, the lux readings of two people occupying the same space, where one is dressed in white and the other in black, would turn out identical. However, the amount of light captured by a camera covering the same scene may be lower or higher, partly because the person dressed in black reflects less light than the person dressed in white. Also, glossy objects reflect more light than dull objects and weather conditions affect lighting and reflection as well. While snow will intensify the reflected light, rain will absorb much of the reflected light.

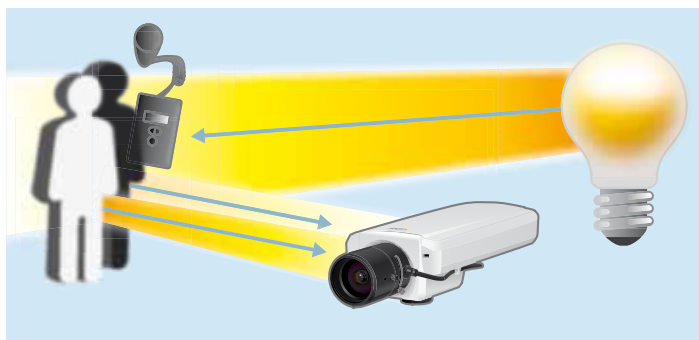


Figure 1. The difference between incident light measured by a lux meter and reflected light captured by a camera.

Second, many natural scenes have fairly complex illumination, with backlit situations, shadows and highlights that affect how the camera interprets the scene. Backlight, for instance, will put your object in darkness, restricting your chances of positive identification. In outdoor surveillance, the sunlight shifts in both intensity and direction during the day. Therefore, you need to consider that one lux reading does not indicate the light condition for a scene as a whole, nor does it say anything about the direction of the light.



*Figure 2. At left, an example of how 5 lux appear in reality, in the middle 80 lux, and at right 4000 lux.*

Keep in mind that when a lux value is measured in a scene, it only represents the illuminance at the object in focus. In the images above, for example, the lux value represents the illuminance at the point of the tree or in front of the building. The brighter sky and the darker ground are not taken into account.

Third, there are a number of factors that influence the light sensitivity of a camera. These include exposure time, f-stop, the size and quality of the sensor, the quality of the lens and color temperature. The IRE level is also brought into the mix, although it is an analog value that persists in the digital world through interpretation and despite the fact that it is not applicable.

Many of these factors can be manipulated so that the camera will collect more light. In fact, some vendors are not shy about manipulating values to make their products seem better. For example, an increase of the exposure time (slowing down the shutter speed) will allow for more light to reach the sensor. It is a convenient way of improving image quality and achieving good values with still images. However, if there is motion in the scene, the video image will be blurry and the object unidentifiable. This does not stop vendors from using this trick when providing test images and data. Always be aware of vendors claiming still images as evidence of their camera's motion video performance in low-light conditions.

Gain does not influence the camera's light sensitivity, but it is an amplifier of the video signal. Increasing the gain level boosts the video signal and makes the image brighter. As a trade-off, the noise in the image is increased as well. It would be similar to turning up the volume on a radio with poor reception; you would not only hear more music but also more static and interference.



*Figure 3. At left, a scene taken at 500 lux with low gain. At right, a similar scene also taken at 500 lux but with high gain. The images illustrate how an increase of the gain will amplify the video signal and make the image brighter at the sacrifice of increased noise in the image.*

Last, but perhaps most importantly, there is currently no global standard for measuring minimum illumination on the market, which means that not even the market leaders share the same method, making it a challenge for any vendor to achieve fair values and for customers to trust them.

### 3. Do not be fooled!

The consequence of the challenges described above is that a comparison between products from different vendors based on their lux ratings, f-numbers or sensor sizes is flawed by default. A camera purchase established on such an inadequate review is prone to be a bad one. A camera with a minimum illumination rating specified as 5 lx, F10, can have the same performance in low-light conditions as a camera specified as 0.05 lx, F1.0. The same properties can be expressed in many different ways and different vendors use different benchmarks. As a result, the job of reviewing products from competing vendors is much more complicated than comparing their technical data.

Some will even optimize performance during testing by using optional lenses or expensive, high-end lenses that the average customer would be resistant to purchase. Do not forget to compare the provided minimum illumination value and f-number with the actual f-number of the standard lens, if one is delivered with the camera. Axis' camera offerings are all-inclusive; the cameras are always delivered with a lens and our tests are consistently completed with the standard lens alternative and the default settings.

As an experiment, we used the Axis method<sup>1</sup> of measuring minimum illumination to compare a few of our products with similar products from other vendors. All the images below are captured using the cameras' default settings and the differences between the lux ratings specified in the product datasheets and the test results speak for themselves.

#### Fixed network cameras

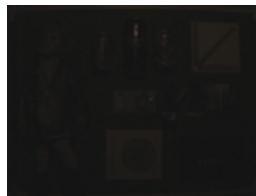
*AXIS P1346 Network Camera*



*Test image<sup>2</sup>*  
0.5 lx

*Datasheet<sup>3</sup>*  
0.6 lx (color)

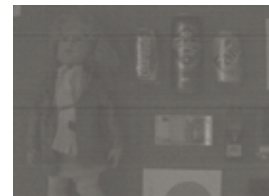
*Competitor product 1*



*Test image<sup>2</sup>*  
0.5 lx

*Datasheet<sup>3</sup>*  
0.3 lx (color)

*Competitor product 2*



*Test image<sup>2</sup>*  
0.1 lx

*Datasheet<sup>3</sup>*  
0.2 lx (color)

*AXIS M1031-W Network Camera*



*Test image<sup>2</sup>*  
1 lx

*Datasheet<sup>3</sup>*  
1 lx (color)

*Competitor product 1*



*Test image<sup>2</sup>*  
1 lx

*Datasheet<sup>3</sup>*  
1 lx (color)

*Competitor product 2*



*Test image<sup>2</sup>*  
1 lx

*Datasheet<sup>3</sup>*  
0.5 lx (color)

1 A technical note on Measurement of Minimum Illumination (MMI)  
The Axis Method can be found at [www.axis.com/corporate/corp/tech\\_papers.htm](http://www.axis.com/corporate/corp/tech_papers.htm)  
2 Illumination during testing  
3 Minimum illumination specified in product's datasheet

Fixed dome network cameras  
AXIS M3114-R Network Camera



Test image<sup>2</sup>  
0.5 lx

Datasheet<sup>3</sup>  
1 lx (color)

Competitor product 1



Test image<sup>2</sup>  
0.5 lx

Datasheet<sup>3</sup>  
0.5 lx (color)

Competitor product 2



Test image<sup>2</sup>  
0.5 lx

Datasheet<sup>3</sup>  
0.4 lx (color)

If the requirements for the installation are such that the minimum illumination value is a key deciding factor, it is well invested time to really do your homework and test the cameras rather than blindly trust the presented value.

#### 4. Making the smarter choice

In conclusion, there are two options when making a confident and successful camera choice. The best way is to compare the cameras in the field with moving objects since it is only then the cameras can truly be tested according to the requirements of the specific application. If an in-the-field comparison is not possible, make sure you turn to a vendor that uses a documented, repeatable process since this ensures that

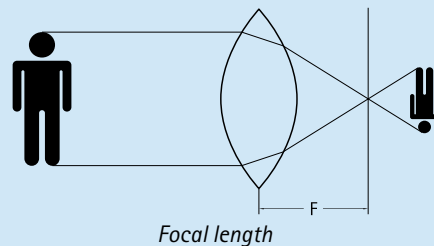
- > products from that particular vendor can be compared with each other.
- > the ratings are not manipulated to oversell a particular product.

## Exposure time

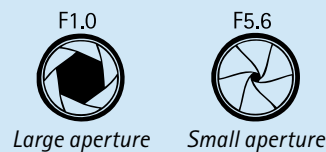
The length of time the image sensor is exposed to light is defined as the exposure time. The longer the exposure time, the more light an image sensor receives. Increasing the exposure will improve image quality in poor lighting conditions, but it will also increase motion blur and lower the total frame rate since a longer time is required to expose each frame.

## F-stop

F-stop, or f-number, is a measure of the capacity of lenses to collect light. It is the ratio of focal length (the distance between the centre of the lens and its focus point) to the



diameter of the aperture (the iris opening that lets light through the lens to the sensor).



The smaller the f-number, the better is the light collecting capacity of the lens. F-stops are often written as  $F_x$  or as  $f/x$  (focal length/aperture). An f-stop of  $F_4$  means that the iris diameter is equal to the focal length divided by 4. If a camera has an 8 mm lens, light must pass through an iris opening that is 2 mm in diameter.

## Quality of the lens

The quality of the lens material and how the lens assembly is designed influence the kind of resolution a lens can provide. No lens is perfect, and all create some form of aberration or image defects as a result of the limitations. Lenses are manufactured to match the sensor and it is important to select a lens suitable for the camera.

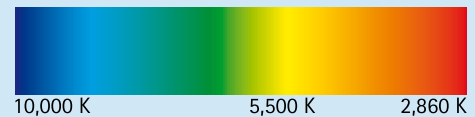
## Quality of the sensor

The light that passes through the lens is focused on the network camera's image sensor. The pixels of the sensor register the amount of light they are exposed to and convert them into a corresponding number of electrons, or electrical signals. The brighter the light, the more electrons.

The general rule used to be that a large sensor collects more light than a small one and also that the electron storing capacity of each pixel increases with the size of the pixel. But nowadays there are technologies and designs that improve and concentrate the light and increase the sensitivity of a sensor. Thus, small sensors and pixels may very well be better than large ones. The only way to know for sure is to look beyond the pixel size and test the sensor.

## Color temperature

Color temperature is measured in degrees Kelvin (K). The scale is based on the fact that all heated objects radiate. The first visible light radiating from a heated object is red and as the temperature of the heated object rises, the radiating color becomes bluer. Just like



the daylight color temperature shifts during the day, indoor light comes in an array of color temperatures. The human eye will compensate for the differences in color that different light sources produce so that objects appear to maintain their color. Cameras, however, must be adjusted for the local illumination. Usually, they have an automatic mode, where the white balance is calculated automatically, rather than manual referencing to a neutral surface such as a gray card. There are also camera settings for optimizing color representation.

## About Axis Communications

Axis is an IT company offering network video solutions for professional installations. The company is the global market leader in network video, driving the ongoing shift from analog to digital video surveillance. Axis products and solutions focus on security surveillance and remote monitoring, and are based on innovative, open technology platforms.

Axis is a Swedish-based company, operating worldwide with offices in more than 20 countries and cooperating with partners in more than 70 countries. Founded in 1984, Axis is listed on the NASDAQ OMX Stockholm under the ticker AXIS. For more information about Axis, please visit our website at [www.axis.com](http://www.axis.com).