Measurement of Minimum Illumination (MMI) - The Axis Method

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1. Introduction

This paper details the method by which Axis measures the minimum amount of illumination required by Axis network video products to produce images of a specified quality. The **MMI (Measurement of Minimum Illumination)** method described here applies solely to camera blocks developed by Axis Communications AB. The Axis MMI method is based on the CEA-639 standard, "Consumer Camcorder or Video Camera Low Light Performance."

The Axis MMI method measures the performance of a camera in four dimensions:

- Luminance
- Black level
- Signal-to-noise level
- Resolution

For each dimension an illumination level is defined at which the camera fails. The highest of these (i.e. the worst performance dimension) is defined as the minimum illumination required by the camera. This value represents the lowest illumination that the camera can operate under with acceptable image quality, as defined by this method.

2. Light sensitivity

The light sensitivity of a camera is affected by many factors. These include the aperture, the quality of the lens, the size and quality of the sensor, the gain, the exposure time, and image processing.

When using several criteria, as in the Axis MMI method (see the following page), it is difficult to compensate for the quality of the camera with gain and image processing. For example, increasing the gain level may provide better luminance, but it may also increase the noise in the image.

Light sensitivity can be quantified by various different methods, several of which are listed below.

- For TV cameras this is usually measured at a fixed level of illumination, 2 kilolux (studio lighting), and by adjusting the f-stop until it no longer becomes possible to resolve a given number of TV lines with a given signal-to-noise ratio.
- Still image film cameras are rated by their ISO speed.
- The light sensitivity of a sensor (CCD or CMOS) is essentially a measure of how many photons are needed to register light in a sensor pixel.
- For surveillance purposes, the level of *minimum illumination* is usually required. This is the illumination needed to obtain images of a specified quality, which can be done by specifying an f-stop, or an IRE (a luminance level, typically 30, 50 or 70).
  For a full specification, the f-stop, color temperature, exposure time, acceptable IRE level for white, applied gain and the signal-to-noise ratio are all required.

3. Physical concepts

- The most important concept is ***illumination,*** which is measured in lux (lx). Illumination measures the visible light falling per unit area in a given position. It is important to note that illumination concerns the spectral sensitivity of the human eye, so that electromagnetic energy in the infrared and ultraviolet ranges contributes *nothing* to illumination. Illumination can also be measured in foot-candles (fcd): 1 lx = 10.76 fcd. (Note that 1 lx can be interpreted as 1 “meter-candle”).

- This type of measurement uses ***incandescent light***, i.e. light with the same type of spectral profile as sunlight or the filaments in light bulbs and halogen lamps.

- The ***color temperature*** of the incandescent light must also be specified. This should correspond to an ideal temperature at which the filament burns.

4. The Axis MMI method: a summary

1. The camera uses the default video settings, unless otherwise specified. If using other settings to make measurements, these must be specified and the default measurements must be given first.
2. The various test charts (TE 153, logarithmic grey-scale reflectance; TE 182 18 % reflectance; TE 170 Resolution Chart) are illuminated with incandescent light with a color temperature of 3100 +/-200 K, with a maximum variation in illumination flatness of +/-10% from the centre of the charts. The spectral profile of the illumination must not vary with the level. Illumination is measured in the centre of the charts as close as possible to and parallel to the chart plane. Adjust the camera so that the charts fill the image.
3. The total exposure time shall not exceed 200 ms, for any type of exposure or frame integration.
4. Ensure the focus on the charts is kept stable.
5. If used, infrared filters should be enabled throughout the measurement process. Make a note of any false colours, for example on the TE 153 infrared reflectant patches.
6. The 4 criteria listed below are measured, for color mode (non-infrared, non-monochrome). The illumination level where each fails is noted, the highest of which will be the level of minimum illumination.
    a) Luminance: The luminance criterion fails when the bright white in TE 153 is no longer at least 50% of the level at full brightness.
    b) Black level: This criterion fails when the 2% reflectance black patch in TE 153 increases by more than 5% of the nominal luminance signal amplitude relative to the black level at full brightness. Alternatively, this fails when the camera no longer correctly separates the grey scale steps.
    c) Signal-to-noise ratio: The ratio of luminance signal to the noise (the RMS of the variance of the luminance) is measured in TE 182 and should be higher than 17 db (a 50:1 power ratio).
    d) Resolution: The resolution should be more than 70 % of the level at full brightness, measured in TE 170.

5. Concepts in detail

5.1. Aperture and focal number

The *focal ratio*, or *f-number* (also known as *f-stop*) is the ratio between the diameter of the aperture and the focal length. So f-stop f/2 means that the diameter of the aperture is half the focal length. Lowering the f-number to 1.4 means doubling the aperture area (the square root of 2 ~1.4), and thus also doubling the amount of light reaching the sensor.

5.2. Infrared

For infrared it is appropriate to quote the minimum *irradiance* (incident power per area) at a certain wavelength, or for a given infrared source.

5.3. IRE

In analog TV systems, IRE is a normalized scale for video signal voltage levels. 100 IRE corresponds to bright white. In NTSC video systems black is 7.5 IRE, but in PAL this is set at 0 IRE.
Note that for analog video it is possible to have IRE values greater than 100 and less than 0, e.g. the sync signal can be a negative IRE. In the digital world, 0 IRE corresponds to digital black, i.e. an encoded zero luminance signal.

5.4. ISO rating

The linear ISO speed of a given film is a measure of the *exposure* (the product of illumination and time) needed to get an appropriate exposure for the film (neither under- nor overexposed).

5.5. Sensor sensitivity

For sensors (and films) it is more usual to give the *quantum efficiency*, which essentially measures (at a given wavelength) how many quanta of light (photons) that must hit the sensor in order to detect one electronic quantum.