WHITE PAPER

Some like it hot

Thermal cameras in surveillance

AXIS COMMUNICATIONS

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Introduction

All network cameras have a basic physical limitation: they need light to work.

At least up to now.

Sure, some network cameras have night and day functionality that allows them to operate in very poor lighting conditions, down to fractions of a lux. And of course, if natural light is not available it can be substituted by electrical light, either visible to the human eye or infrared. But in some instances these solutions have serious drawbacks – they can be expensive, and energy consuming; and illumination creates shadows where an intruder can hide – to mention a few.

The first true thermal network camera is a perfect complement to any professional IP-Surveillance system; it can be seamlessly combined with existing equipment, and it is possible to secure an area or a perimeter that lies in complete darkness.

1. Thermal imaging – the heat is on

Thermal imaging is nothing new. But until recently, costs have usually been prohibitive, making practical applications outside the military rare. This has started to change as new sensors, new materials and other improvements are driving the volumes and making prices more reasonable. Thermal cameras can now be found in various lines of business such as the aircraft industry, shipping industry, and security and surveillance. The technology is also used in public services like fire fighting and law enforcement. Lately it has even appeared in consumer products, albeit often expensive ones like luxury cars.

Complete darkness, haze, smoke, rain, snow, even bright and blinding lights – a thermal network camera will still be able to detect people and objects.

Like any other camera, a thermal or thermographic camera collects electromagnetic radiation which is formed into an image. But while a conventional camera works in the range of visible light, i.e. with wavelengths between approximately 400 and 700 nanometers (0.4–0.7 µm), a thermal camera is designed to detect radiation with greater wavelengths, up to around 14,000 nanometers (14 µm). Radiation in this part of the electromagnetic spectrum is referred to as infrared, or commonly IR, which in turn can be divided into several sub-groups.

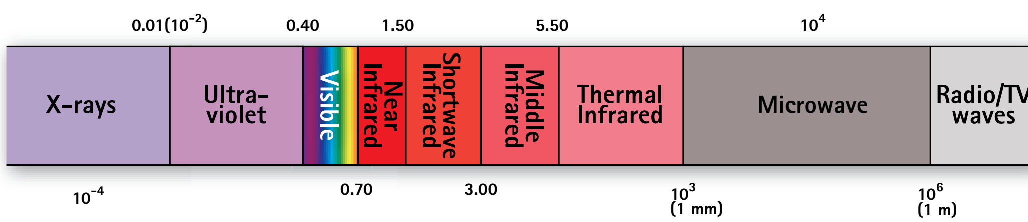
Near-infrared light has a wavelength of about 0.7–1.5 µm, which is just beyond what the human eye can see. Camera sensors, on the other hand, can be built to detect and make use of this type of radiation. A so-called day-and-night camera uses an IR-cut filter during daytime to filter out IR-light so it will not distort the colors of images as perceived by the human eye. When the camera is in night mode, the IR-cut filter is removed. Since the human eye is unable to see infrared light the camera displays the image in black and white. Near-infrared light also requires some kind of light source – either natural, such as moonlight, or man-made, such as street lights or a dedicated IR-lamp.

Moving further away from visible light, the rest of the IR-spectrum is usually divided into the following categories:

> Short-Wave Infrared (SWIR), approx. 1 – 3 µm
> Mid-Wave Infrared (MWIR), approx. 3 – 5 µm
> Long-Wave Infrared (LWIR), approx. 8 – 12 µm
> Very Long-Wave Infrared (VLWIR), approx. 12 – 25 µm
> Far-Wave Infrared (FWIR), approx. 25 µm – 1 000 µm or 1 mm

Note that there is a gap between 5 µm (MWIR) and 8 µm (LWIR). This part of the waveband is virtually unusable for thermal imaging purposes because of the high spectral absorption of the atmosphere in this range.

Microwaves have a wavelength exceeding 1 mm. At the far end of the spectrum are radio waves, with a wavelength of 1 meter and more. In the other end of the spectrum, wavelengths shorter than those of visible light are successively referred to as ultraviolet, x-rays, and gamma rays.



Conventional cameras work in the range of visible light, i.e. with wavelengths between approximately 0.4–0.7 µm. Thermal cameras, on the other hand, are designed to detect radiation in the much broader infrared spectrum, up to around 14 µm (the distances in the spectrum above are not according to scale).

2. What makes it work?

Images, as they are perceived by the human eye, can be described as light reflected by different objects. No light means no reflection and thus the eye is "blind" under such circumstances. Thermal images on the other hand, are not dependent on visible light. Instead, images are created by operating in the infrared spectrum. It works perfectly well even in total darkness since the ambient light level does not matter.

What makes this possible is the fact that all objects – organic or inorganic – emit a certain amount of infrared radiation as a function of their temperature. This is true for all objects that have a temperature that is above absolute zero, i.e. 0 degrees Kelvin (-273° C or -459° F). That means that even very cold objects, such as ice or an outdoor steel post in winter, emit thermal radiation.

The ability to emit absorbed energy is termed emissivity. All materials have more or less emissivity (e). Their respective value ranges, depending on their different properties, from 0 to 1. The latter value only applies for a theoretical object called a Black-body. In general it could be said that the duller and blacker a material is, the closer its emissivity is to 1. Conversely, a more reflective material has a lower e value. For example highly polished silver and brass have an emissivity of about 0.02 and 0.03 respectively. Iron has an emissivity of 0.14 – 0.035 if polished, but 0.61 if it has rusted red. Regular glass, which effectively blocks thermal radiation, has an emissivity of 0.92.

All objects emit thermal radiation which can be detected with a thermal network camera. Images are generally produced in black and white but can be artificially colored to make it easier to distinguish different shades.

An object's thermal radiation is also dependent on its temperature – the hotter it is the more thermal radiation it emits. Humans cannot see this, but we can sense it, for example, when we approach a camp fire or enter a sauna. The greater the temperature difference in a scene, the clearer will the thermal images will be.

Furthermore, some materials will have a different emissivity in the mid-wave infrared spectrum than in the long-wave span. For imaging purposes these differences in emissivity are, for the most part, of secondary importance since the camera's sensitivity can be defined as its capability to distinguish between temperature differentials.

Thermal images are sometimes associated with bright, intense colors – which may seem a bit odd considering that the camera works outside the spectrum of visible light. The answer is that the colors are created digitally, so-called pseudo-colors. Each color or nuance represents a different temperature, usually white and red for higher temperatures, over green, blue and violet for colder ones. The reason is foremost practical since the human eye is better at distinguishing different shades of color than different shades of grey.

Detectors used for thermal imaging can be broadly divided into two types: Cooled thermal imagers that typically operate in the mid-wave infrared (MWIR) band and uncooled thermal imagers that operate in the long-wave infrared (LWIR) range.

3. As cold as it gets – cooled detectors

Cooled infrared detectors are usually contained in a vacuum-sealed case and cooled to temperatures as low as 60 to 100° K (circa -210° to -170° C or -346° to -274° F), depending on the type and level of performance desired. These extremely low temperatures are accomplished with so-called cryogenic coolers. Cooling is needed to reduce thermally induced noise – at higher temperatures the sensors risk being flooded or "blinded" by their own thermal radiation. The equipment not only makes the detectors relatively bulky and expensive, but also rather energy-consuming.

Although this technology is both expensive and demanding in maintenance, it has benefits. These detectors work in the mid-wave spectral band, which provides better spatial resolution because the wavelengths are much shorter and provide higher thermal contrast than in the long-wave band. Hence, cooled detectors can distinguish smaller temperature differences and produce crisp, high resolution images.

Another advantage is that greater sensitivity also allows the use of higher F-number lenses. Consequently, cooled detectors are a better choice for long range detection, i.e. 5 km – 16 km (3 – 10 mi).

4. Cool but uncooled

The sensor in an uncooled thermal camera is not dependent on cryogenic cooling. In this case the sensor is stabilized at or close to the ambient temperature, using less complicated temperature control elements. Sensors of this kind operate in the long-wave infrared band.

A widespread design is based on microbolometer technology. This is typically a tiny resistor with high temperature-dependent properties on a silicon element, which is thermally insulated and read electronically. Changes in scene temperature will cause changes in the bolometer which are then converted into electrical signals and processed into an image. The camera's sensitivity to infrared radiation, i.e. its capability to distinguish different temperature differences in a scene, can be expressed as its NETD-value (Noise Equivalent Temperature Difference). Later generations of bolometers have reached NETD as low as 20 mK.

Uncooled thermal image sensors are smaller and built with fewer moving parts. Not only does this make them less expensive than their cooled counterparts but also allows for much longer service intervals. Whereas the cooled cameras typically need a rebuild for the cryocooler every 8,000 to 10,000 hours, an uncooled camera can run continuously for years.

5. Come rain or shine

Thermal cameras do not only perform well in total darkness, they also perform well under difficult climatic circumstances such as haze, dust, rain, snow and smoke. All the same, there are physical limitations to the performance of thermal cameras.

Deep shadows or other difficult lightings situations – thermal network cameras are an excellent complement to regular surveillance cameras.

Water droplets or small dust particles in the air will naturally hinder the transmittance of thermal radiation from a single object, making it harder to detect from a great distance. Consequently, haze, snow and rain will hamper camera performance. Water limits thermal radiation and the moisture in the air evens out temperature differences between different objects in the picture. Therefore, a thermal camera will produce better and clearer images during winter time with clear skies and good weather conditions than under comparable atmospheric conditions during summer when humidity is usually higher.

But even with these limitations considered, when it comes to detection, thermal cameras are superior to conventional cameras under a wide range of difficult weather conditions.

6. A well guarded technology

The integration of thermal cameras into the conventional video surveillance market is not free from challenges – technical as well as legal and other.

A number of products and technologies that can be used both for military purposes and in commercial applications are called dual-use goods. Exports of such items are regulated in the international Wassenaar Arrangement from 1996, which aims to promote transparency and greater responsibility in transfers of conventional arms as well as dual-use goods and technologies.

Not surprisingly, thermal imaging technologies, which often have been originally developed for military use, fall under this category. Thermal sensors may therefore only be freely exported if the maximum frame rate is 9 fps or below. Most cameras for surveillance purposes fall under this category. Cameras with a maximum of 111,000 pixels and a frame rate of up to 60 fps can be sold in the US, the EU, and a handful of other friendly nations, on the condition that the buyer is registered and can be traced.

Regardless of these restrictions, resolutions are generally much lower for thermal cameras than for conventional network cameras. This is primarily due to the more expensive sensor technology involved in thermal imaging. However, lower frame rate is less of a problem in most surveillance applications since thermal cameras are first and foremost used for detection and not for identification.

No lurking in the shadows! Thermal network cameras can also be used indoors to improve building security and emergency management. They can verify that people are not hiding in a building after closing time, and prevent vandalism and institutional riots.

7. Blocked by glass

More troublesome, at least from an economic point of view, is that there are no standard optics for thermal cameras. Any adaptation of focal length or a special required field of view must be done at the factory. The reason why regular optics and lenses, such as a standard CS-mount or C-mount, cannot be used is that ordinary glass efficiently blocks thermal radiation. Manufacturers therefore have to rely on other materials. Presently, Germanium is most used for thermal camera optics. This very expensive metalloid, chemically similar to tin and silicon, blocks visible light while letting thermal radiation through.

Naturally, the same requirements apply for housings, making it impossible to use standard housings for outdoor installations. Like lenses, housings must thus be specially adapted for thermal cameras.

8. New ground for thermal cameras

Although the investment costs are high, thermal cameras are not unknown within security and surveillance; on the contrary. They are primarily used in high security buildings and areas, such as, for example, nuclear power plants, prisons, airports, pipelines, and sensitive railway sections.

So far, however, incorporating thermal cameras into a conventional video surveillance system has not been a straightforward operation. With the development of thermal network cameras, compatibility will of course, be far less of an issue. New devices will more easily integrate with, for example, existing video management systems.

Among other benefits that IP-Surveillance brings are Power over Internet (PoE), distributed intelligent video, standardized video compression techniques and audio support.

PoE is a technology for safe and simultaneous transfer of electrical power and data in Ethernet networks, thus eliminating the need for power cables and reducing installation costs. Intelligent video is a comprehensive term for any solution where the video surveillance system automatically performs an analysis of the captured video, such as motion detection, audio detection, and virtual fences, or sets off an alarm when cameras are vandalized or tampered with. With thermal network cameras, this analysis can be distributed out to the cameras leading to improved efficiency and scalability.

9. An excellent complement

With thermal imaging becoming relatively cheaper and an integral part of IP-Surveillance systems, a whole range of uses becomes both possible and economically viable. Thermal cameras can be an excellent complement in many situations where conventional cameras are inadequate or insufficient.

They are, of course, unparalleled in a situation of total darkness. They can also be an option in areas that are very difficult to illuminate effectively, for example a sea front, a harbor, or any other vast expanse of open water. Similarly, artificial light not only runs the risk of revealing where the cameras are placed, enabling parties to avoid or vandalize them, but can also create projected shadows in which an intruder can avoid detection.

Furthermore, spotlights can blind as well as illuminate. So cameras that do not rely on light can be the preferred solution in many different traffic situations, whether it is in railway tunnels, on air strips or on regular streets. Thermal cameras, on the other hand, cannot be blinded by bright lights or laser beams.

All in all, thermal network cameras perfectly complement and complete a network video system, making sure that objects, people, and incidents are detected 24 hours a day, seven days a week.


The first true thermal network cameras, AXIS Q1910, for indoor applications, and the AXIS Q1910-E, with tailor-made protective housing for outdoor installations.

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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.

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