

TECHNICAL NOTE



HIGH-SPEED THERMAL IMAGING FOR AUTOMATION APPLICATIONS

For many years, thermal imaging cameras have found their way onto the factory floor. Manufacturing and process engineering specialists have used thermal imaging cameras with great success for practically any automation application, including automated inspection, process control, condition monitoring, fire prevention & detection, and continuous optical gas imaging. However, not all automation cameras are created equal and for some high-speed automation applications dedicated, advanced thermal cameras are required.

Frequently, manufacturing and process engineers use automation techniques to improve throughput and product quality. Automated thermal imaging offers the potential for improving a host of industrial production applications, including process monitoring and control, quality assurance, asset management, and machine condition monitoring.

Thermal imaging in an automation environment

Thermal imaging cameras use thermal radiation, which is not detectable by the human eye, but can be converted into a visual image that depicts thermal variations across an object or scene. Covering a part of the electromagnetic spectrum, thermal energy is emitted by all objects at

temperatures above absolute zero, and the amount of radiation increases with temperature. A thermal imaging or infrared (IR) camera can capture thermal images of target objects and provide accurate non-contact temperature measurements. These quantitative measurements can be used in a variety of monitoring and control applications.

In some cases, a thermal camera is referred to as a smart sensor. In these cases the thermal camera has built-in logic and analytics that allows the comparison of measured temperatures with user-supplied temperature data. It also has a digital I/O interface so that a differential temperature can be used for alarm and control functions.



FLIR A66xx: Compact, thermal imaging camera with cooled InSb detector

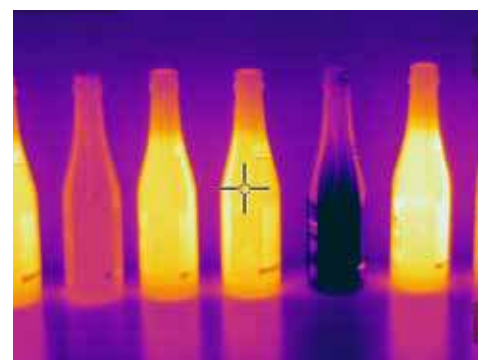


Figure 1: Process monitoring of a production line: different areas on a bottle can be defined and used to trigger an alarm and remove bottles that are over- or under-filled



Figure 2: Cooled automation cameras can be interesting for monitoring high-speed conveyor belt applications, like this screw capping machine.

Cooled and uncooled cameras

There is plenty of choice when it comes to thermal imaging camera systems for automation applications. An often asked question is therefore: "Should I use a cooled or an uncooled thermal imaging system and which one is the most cost effective?"

In fact, there are two classes of thermal imaging camera systems available on the market today: cooled and uncooled systems. The component costs for these two classes of systems can be quite different, making it extremely important to decide which way to go.

Cooled thermal imaging cameras

A modern cooled thermal imaging camera has an imaging sensor that is integrated with a cryocooler. This is a device that lowers the sensor temperature to cryogenic temperatures. This reduction in sensor temperature is necessary to reduce thermally-induced noise to a level below that of the signal from

the scene being imaged. Cryocoolers have moving parts made to extremely close mechanical tolerances that wear out over time, as well as helium gas that slowly works its way past gas seals.

Cooled thermal imaging cameras are the most sensitive type of cameras and can detect the smallest of temperature differences between objects. They can be produced to image in the mid-wave infrared or MWIR band of the spectrum where the thermal contrast is high due to blackbody physics. Thermal contrast is the change in signal for a change in target temperature. The higher the thermal contrast, the easier it is to detect objects against a background that may not be much colder or hotter than the object.

Uncooled thermal imaging cameras

An uncooled infrared camera is one in which the imaging sensor does not require cryogenic cooling. A common detector design is based on the microbolometer, a tiny vanadium oxide resistor with a large temperature coefficient on a silicon element with large surface area, low heat capacity and good thermal isolation. Changes in scene temperature cause changes in the bolometer temperature which are converted to electrical signals and processed into an image. Uncooled sensors are designed to work in the Longwave infrared or LWIR band, where terrestrial temperature targets emit most of their infrared energy.

Uncooled cameras are generally much less expensive than cooled infrared cameras. The sensors can be manufactured in fewer steps with higher yields relative to cooled sensors, less expensive vacuum packaging, and uncooled cameras do not require cryocoolers, which are very costly devices. Uncooled cameras have fewer moving parts and tend to have much longer service lives than cooled cameras under similar operating conditions.

Cooled cameras for automation applications

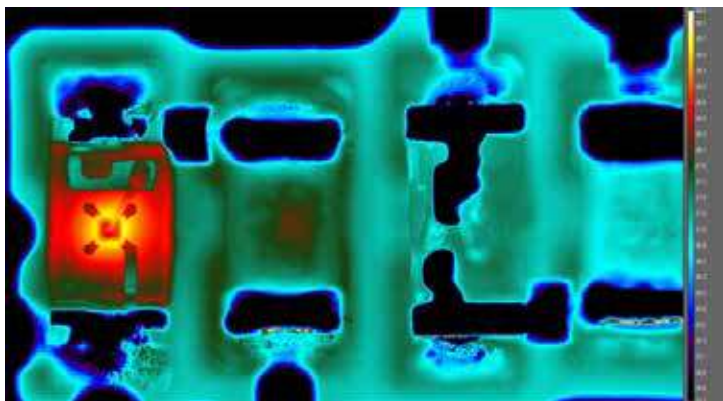
Advantages of uncooled cameras beg the question: When is it better to use cooled thermal imaging cameras for automation applications? The answer is: it depends on the application.

If you want to see the minute temperature differences, need the best image quality, have fast / high speed applications, if you need to see the thermal profile or measure the temperature of a very small target, if you want to visualize thermal objects in a very specific part of the electromagnetic spectrum, or if you want to synchronize your thermal imaging camera with other measuring devices, then a cooled thermal imaging camera is the instrument of choice.

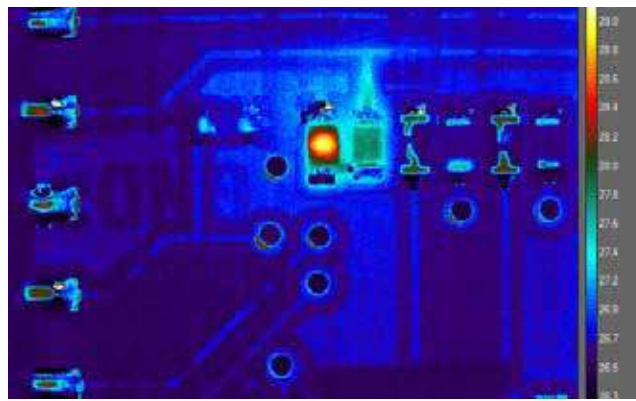
Speed

Cooled cameras have much higher imaging speeds than uncooled ones. Automation cameras like FLIR's A66xx series can have image speeds up to 480 frames per second and therefore

Figure 3

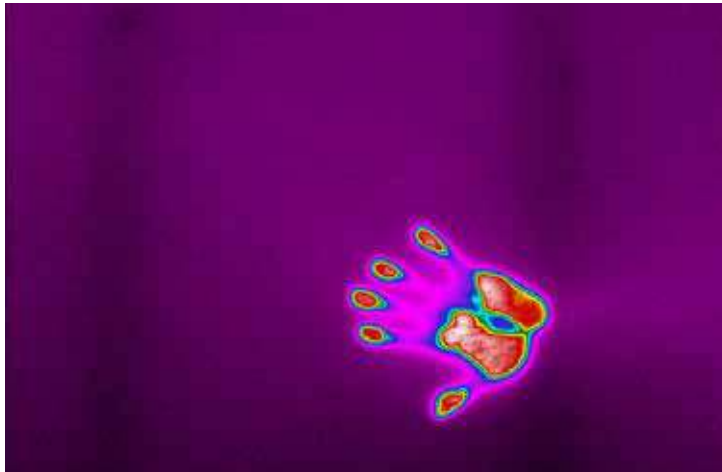


Cooled thermal camera image of electronics board

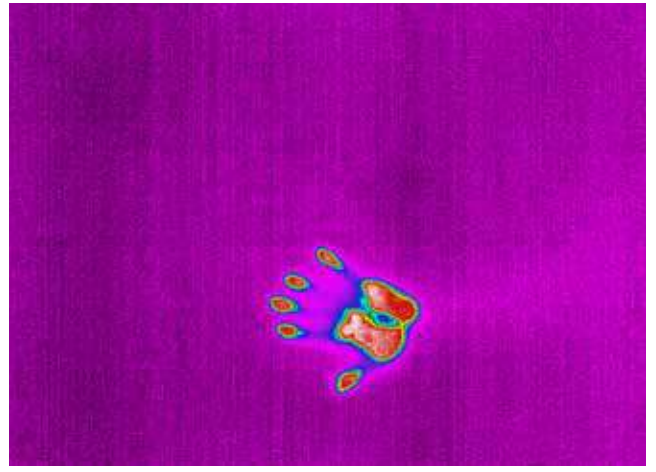


Uncooled thermal camera image of electronics board

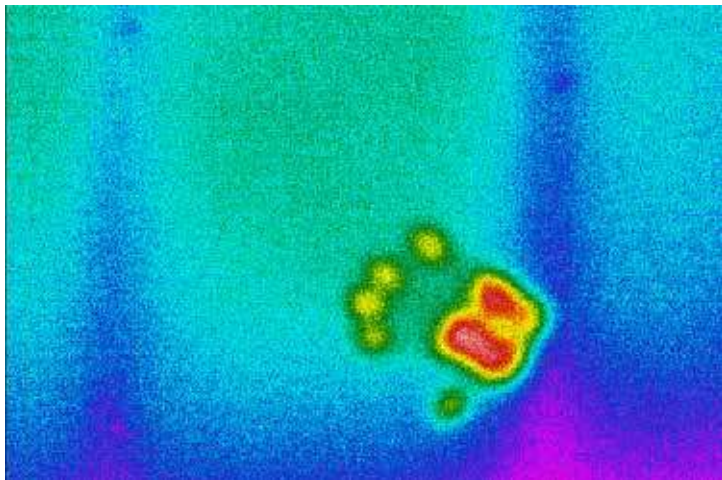
Figure 4



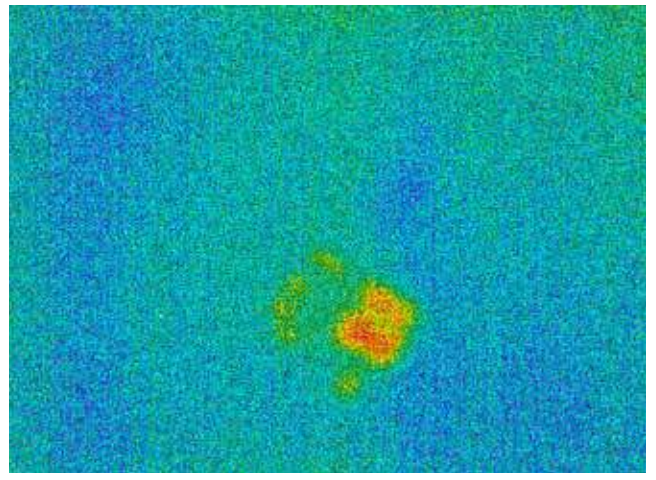
Cooled thermal camera image of handprint on wall initial image



Uncooled thermal camera image of handprint on wall initial image



Cooled thermal camera image of handprint on wall after 2 minutes



Uncooled thermal camera image of handprint on wall after 2 minutes

they are ideal for capturing high-speed thermal events and moving targets. This can be interesting for example when manufacturing quality of high-speed conveyor belt applications needs to be monitored (Figure 2). The capture rate of uncooled thermal imaging cameras is simply too slow to capture the speed of some conveyor belt applications.

Cooled cameras have very fast response times and they make use of a global shutter. This means that they will read out all pixels at the same time, as opposed to reading them out line by line, which is the case with uncooled cameras. This allows cooled cameras to handle moving objects much better. This is especially important in the process industry like paper processing,

or in high-volume manufacturing, where things move fast and cannot be slowed down. Cooled cameras will also accurately monitor fast changes in heat-up processes.

Spatial resolution

Cooled cameras typically have greater magnification capabilities than uncooled cameras, because they sense shorter infrared wavelengths. Because cooled cameras have greater sensitivity characteristics, lenses with more optical elements or thicker elements can be used without degrading the signal to noise ratio allowing for better magnification performance.

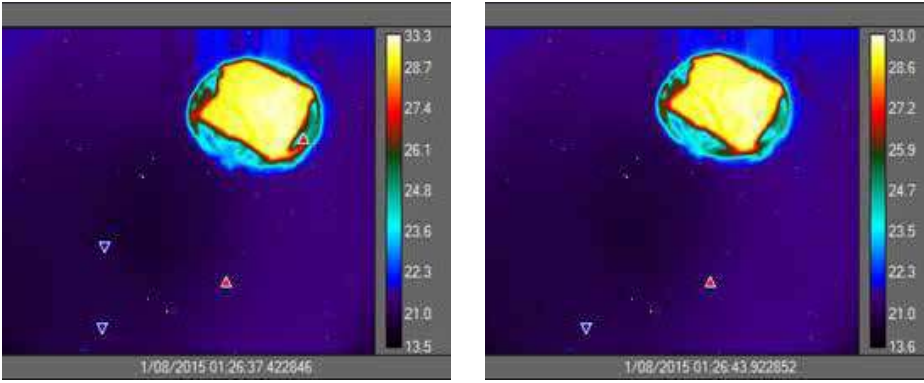
The thermal images in figure 3 compare the best close-up magnification that

can be achieved with a cooled and uncooled camera system. The image on the left was taken with a 4× close-up lens and 13µm pitch cooled camera combination resulting in a 3.5µm spot size. The image on the right was taken with a 1× close-up lens and 25µm pitch uncooled sensor resulting in a 25µm spot size.

Sensitivity

How do you get a feeling of the benefit from a 50mK sensitivity uncooled thermal camera in comparison to a 20mK sensitivity cooled thermal camera? Let's illustrate this with a quick sensitivity experiment (see figure 4). For this comparison we put our hand on a wall for a brief few seconds to create a thermal handprint. The first two images show the

Figure 5



Two drops of the same coin will trigger the camera at the same time giving you the object in the same position every time.

handprint immediately after the hand was removed. And the second set of images shows the thermal handprint's signature after two minutes. The cooled camera can still see most of the thermal signature of the handprint, whereas the uncooled camera only shows the partial remains of the handprint. The cooled camera clearly can detect smaller temperature differences and for longer durations than the uncooled camera. This means the cooled camera will provide better detail on your target and help you detect even the faintest of thermal anomalies.

Spectral filtering

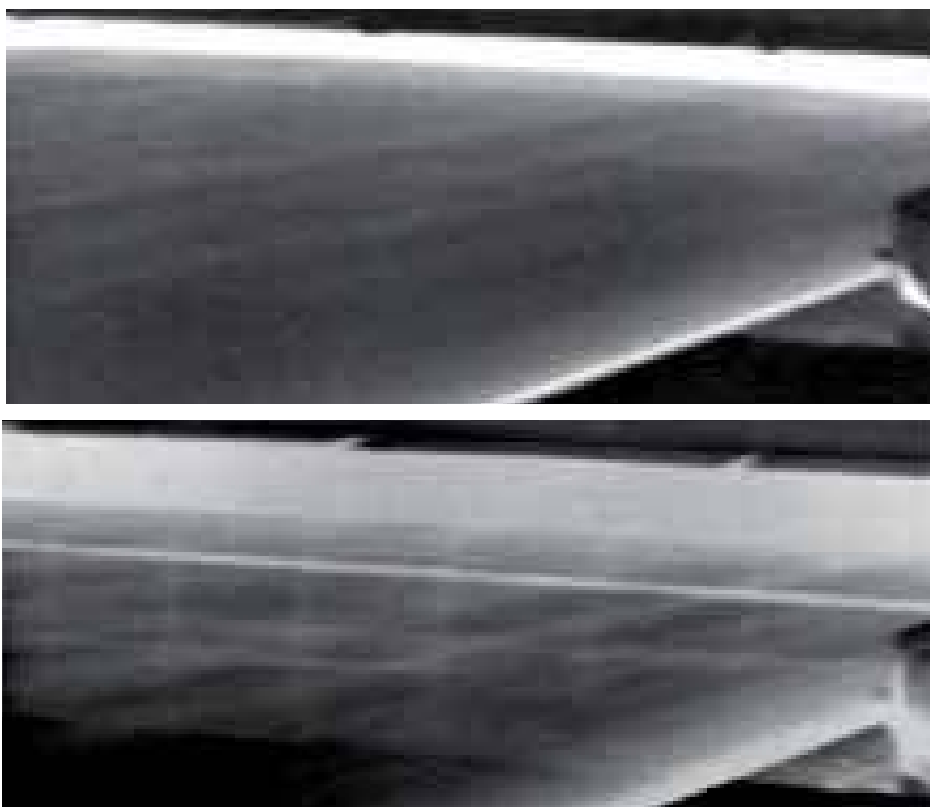
One of the great advantages of cooled

thermal cameras is the ability to easily perform spectral filtering in order to uncover details and take measurements that otherwise would be unachievable with uncooled thermal cameras. You could use cooled cameras to look through glass or to spot dangerous gases like Benzene, Ethanol, Methanol and Octane in gas installations that are in remote areas or in zones that are difficult to access. Another application is the quality monitoring of a plastic calendaring process (Figure 6).

Synchronization

Precise camera synchronization and triggering makes the cameras ideal for high-speed, high sensitivity applications.

Figure 6



Top: Plastic calendaring process seen without a spectral filter. No surface temperature differences can be seen. Bottom: Plastic calendaring process seen with a spectral filter: temperature differences help to detect, measure and classify defects in the calendaring process

Working in snapshot mode the FLIR A66xx is able to register all pixels from a thermal event simultaneously. This is particularly important when monitoring fast moving objects where a standard IR camera would suffer from image blur.

The images in figure 5 are a good example. You drop a coin and have a sensor trigger the camera to take an image. Two drops of the same coin will trigger the camera at the same time giving you the object in the same position every time. With a microbolometer you would not catch the coin at all and if you did by luck it would be blurry, positioned anywhere in the image.

FLIR A66xx: Compact, thermal imaging camera with cooled InSb detector

FLIR offers a solution for practically any automation application: from uncooled, low-cost cameras to high-end thermal cameras like the FLIR A66xx. The FLIR A66xx is ideal for high-speed thermal events and moving targets and incorporates a cooled Indium Antimonide (InSb) detector. The camera produces crisp thermal images of 640 x 512 and achieves a high thermal sensitivity of <20 mK. The FLIR A66xx is able to capture the finest image details and temperature difference information. The camera supports image frame rates up to 480 frames per second when operating in windowing mode. Custom cold filtering options for specific spectral detection and measurement are available. Perfect for imaging through glass, measuring temperature of thin film plastics, filtering different wavebands for laser profiling and detection, or optical gas imaging.



FLIR A66xx

For more information about thermal imaging cameras or about this application, please visit:

www.flir.com

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