DIAS Infrared Systems

How to find the right ...

Thermal imaging camera

Make the right decision for optimal measurement results

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Introduction

Thermal imaging cameras for non-contact temperature measurement are used today in a wide range of applications in industry, science and other fields. Many different portable and stationary thermal imaging cameras are available.

Frequently, users underestimate the process that precedes the acquisition of such a camera. In addition to the fundamental measurement range required by the application, there are numerous additional criteria to consider. If this is not properly done, the consequences range from faulty measurement results to the necessary purchase of a new suitable camera.

What is the best way to proceed and what do you have to pay attention to if you want to acquire a thermal imaging camera?

The following is a summary of important features and selection criteria for thermal imaging cameras. Here, we focus on the example of a stationary thermal imaging camera with uncooled infrared detectors for industrial process measurement technology, because there are particularly high requirements for stability, reliability and robustness as well as many years of low-maintenance operation.

The following six chapters of our whitepaper are designed to help you choose a thermal imaging camera, with three signs to provide you with a simple reading aid:

Special **tips** that are good for you to know

Important **basic knowledge**

Questions that you should ask yourself specifically before you buy a thermal imaging camera

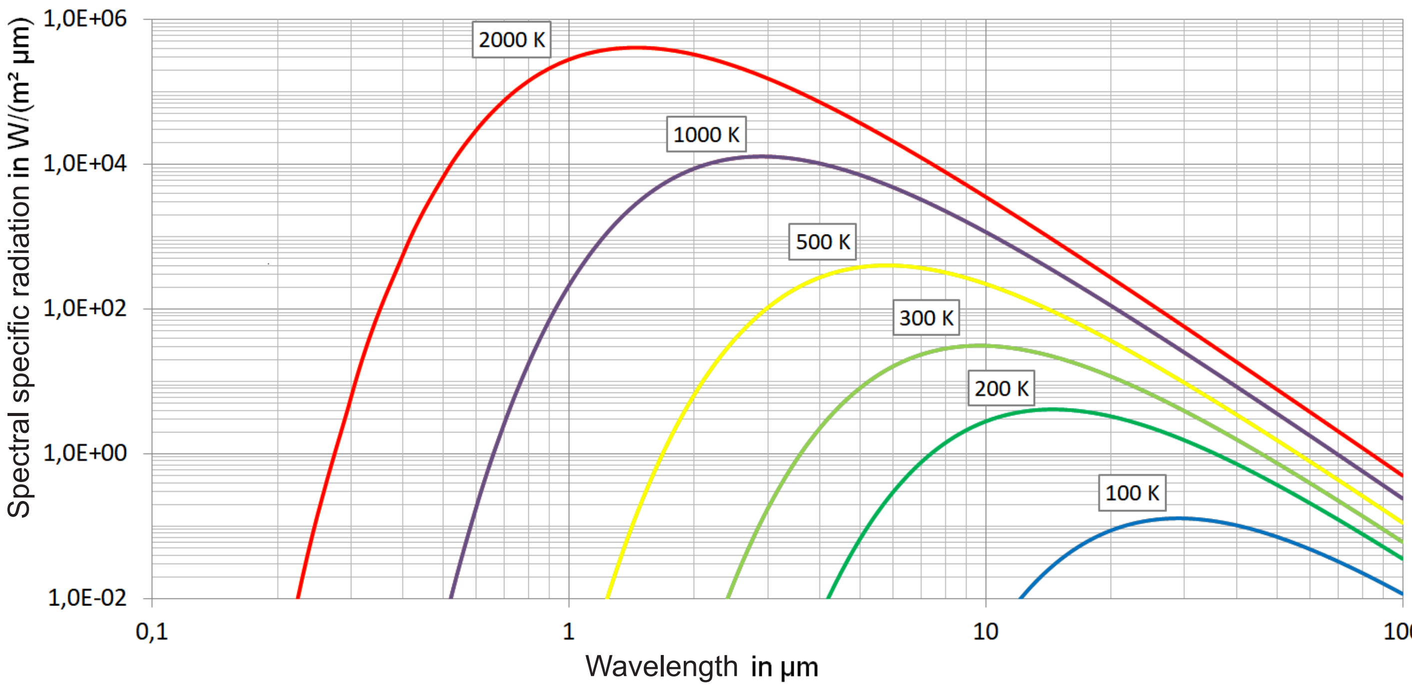


Figure 1: Wavelength dependence of radiation (parameter: temperature of a black body)

Measuring temperature range, spectral range and emissivity

Every object emits a natural electromagnetic dependent radiation on its surface temperature, wavelength and emissivity. By measuring the emitted radiation within a known spectral range, the temperature of the body can be measured without contact.

For typical industrial process measurements, temperatures to be measured usually are within –20 °C to 2500 °C.

In accordance with Planck's radiation law (Fig. 1), the maximum of the emitted radiation at room temperature is about 10 µm wavelength. At higher **measurement temperatures**, the radiation maximum shifts to lower wavelengths, for example to about 1.3 µm at 2000 °C. The primary spectral components of surface radiation from typical industrial measurement target materials lie within the infrared **wavelength range** between about 0.8 µm and 14 µm, longer wavelengths than are visible to the human eye.

The spectral range from 8 µm to 14 µm (long-wave infrared **LWIR**) is of particular interest for materials around room temperature, because here the radiated energy is maximized, while the surrounding air has a high transparency largely independent of the measurement distance and humidity. For measurement of higher temperature objects, the wavelength ranges between 3 µm and 5 µm (mid-infrared **MWIR**) and 0.8 µm to 1.1 µm or 1.4 µm to 1.8 µm (near infrared **NIR** or **SWIR**) are preferred, following spectrally the peak of radiated energy, for highest measurement accuracy, where in addition, the atmosphere is highly transparent (Figure 2).

The following important wavelength ranges are distinguished:

Long wave infrared (**LWIR**):	8 µm to 14 µm
Medium infrared (**MWIR**):	3 µm to 5 µm
Near infrared (**NIR** or **SWIR**):	0.8 µm to 1.1 µm or 1.4 µm to 1.8 µm

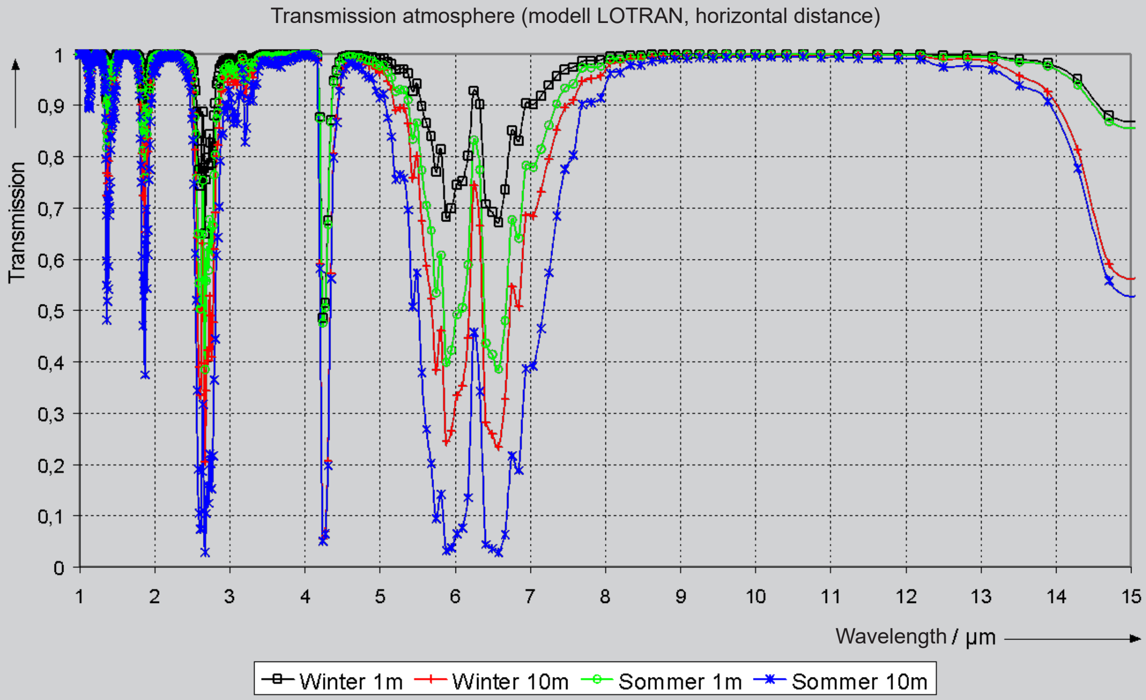


Figure 2: Wavelength dependence of the transmission of the atmosphere at different seasons and distances between the measuring object and the measuring device (source: Hofmann, G.: Uncooled infrared arrays, thermal infrared sensors. In: Carl Cranz Society, Lecture Materials 2018)

For correct non-contact temperature measurements it is essential to consider the **emissivity**. The emissivity of a surface indicates the relative amount of radiation it emits, within a particular wavelength range, compared to an ideal radiator (black body). Emissivity must be properly adjusted on the thermal imaging camera. In process measurement technology, different settings are often required for different surfaces within the image areas. Not all thermal imaging cameras offer this possibility. The **maximum value** of the emissivity is 1. The minimum selectable value is often 0.1. The actual value to be set can be taken from tables, but is always best determined, for example, by a contact comparison temperature measurement.

It should be noted that non-transparent or low-transparent measurement objects with a low emissivity always have a high **radiation reflection**. This can lead to measurement errors caused by ambient or background radiation being reflected. The thermal imaging camera should allow ambient temperature corrections to be made where physically possible.

Independent of the camera, in some cases measures can be taken to reduce or avoid ambient interference radiation.

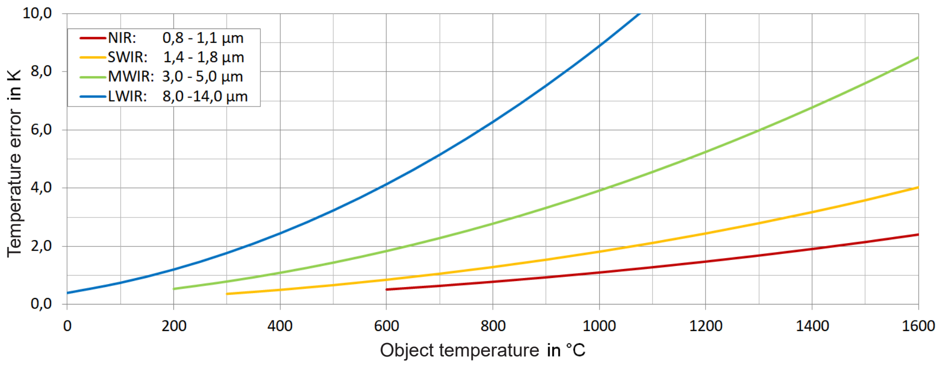


Figure 3: Resulting temperature measurement error at an emissivity error of 1

Based on these principles, Table 1 summarizes typical **spectral ranges**, recommended **measuring temperature ranges** and sample applications. When selecting a suitable thermal imaging camera, special attention should be paid to the spectral range required for measurement.

As a general rule temperature measurement errors become significantly higher for higher temperature objects measured at long wavelengths. Therefore, in order to minimize measurement errors one should always use as short wavelength as practical for the application.

If, for example, a temperature of 1000 °C is to be measured, then if the emissivity is incorrectly adjusted by only 1 %, the temperature measurement error for a thermal imaging camera operating between 8 µm and 14 µm (LWIR) is already about 9 K, whereas when using a spectral range of 0.8 µm to 1.1 µm (near infrared NIR), the error is only about 1 K (Fig. 3).

What **measurement temperature** range do I need for my application?

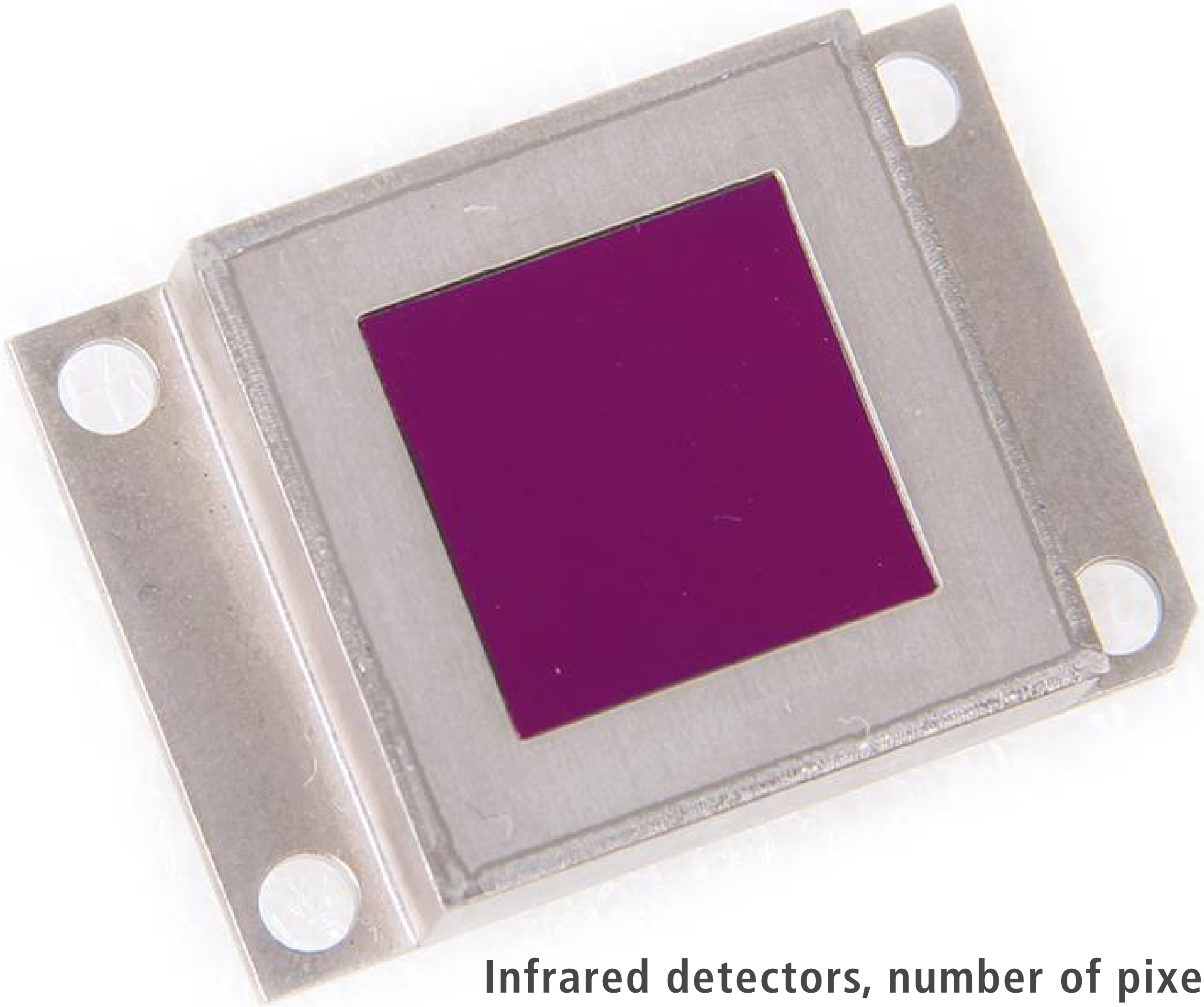
Which **spectral range** should I use?

What **emissivity** does my target have in the selected spectral range?

Measuring temperature range	Spectral range	Application examples
–20 °C to 500 °C	8 µm to 14 µm	Non-metals, coated metals
200 °C to 1250 °C	4.8 µm to 5.2 µm	Glass surfaces
600 °C to 1250 °C	around 3.9 µm	Measurement through flames and combustion gases
100 °C to 500 °C	3 µm to 5 µm	Ceramics, metals
300 °C to 1200 °C	1.4 µm to 1.8 µm	Metals, ceramics, graphite
600 °C to 3000 °C	0.8 µm to 1.1 µm	Metals, glass melts

Table 1: Typical temperature measuring ranges, spectral ranges and application examples for thermal imaging cameras

When **specifying the temperature measurement range in data sheets**, it should be noted that thermal imaging cameras often have several switchable, individually specified temperature ranges. Sometimes, however, only **one overall measurement range** is specified. In these cases, it is often important to double check that the overall range is not subdivided into **several individual ranges** within the camera. In that case the range of measurement within any captured image becomes limited.



Infrared detectors, number of pixels, NETD and measurement uncertainty

A core component of most thermal imaging cameras is an **infrared 2D detector**. There are various types of 2D array detectors available, including **uncooled** detectors, uncooled quantum detectors for the near infrared and cooled quantum detectors for mid to long wavelength infrared.

Cooled detectors show excellent characteristics regarding highest measuring frequencies and best signal-to-noise ratios. However, they require regular maintenance and periodic replacement of coolers and therefore are associated with **high costs**.

Uncooled microbolometer arrays for the LWIR and MWIR range or **uncooled quantum detectors** based on SI or InGaAs arrays for the near infrared are widely used for **industrial process measurements**. It must be noted that thermal imaging cameras with the sensor arrays mentioned above often are subject to **export restrictions**.

Today, **2D microbolometer arrays** with 320 × 240, 384 × 288 or 640 × 480 pixels are used to most applications in industrial process measurement. The infrared sensor used determines the **noise-equivalent temperature difference NETD** – a measure of the minimum resolvable temperature change above noise in the image.

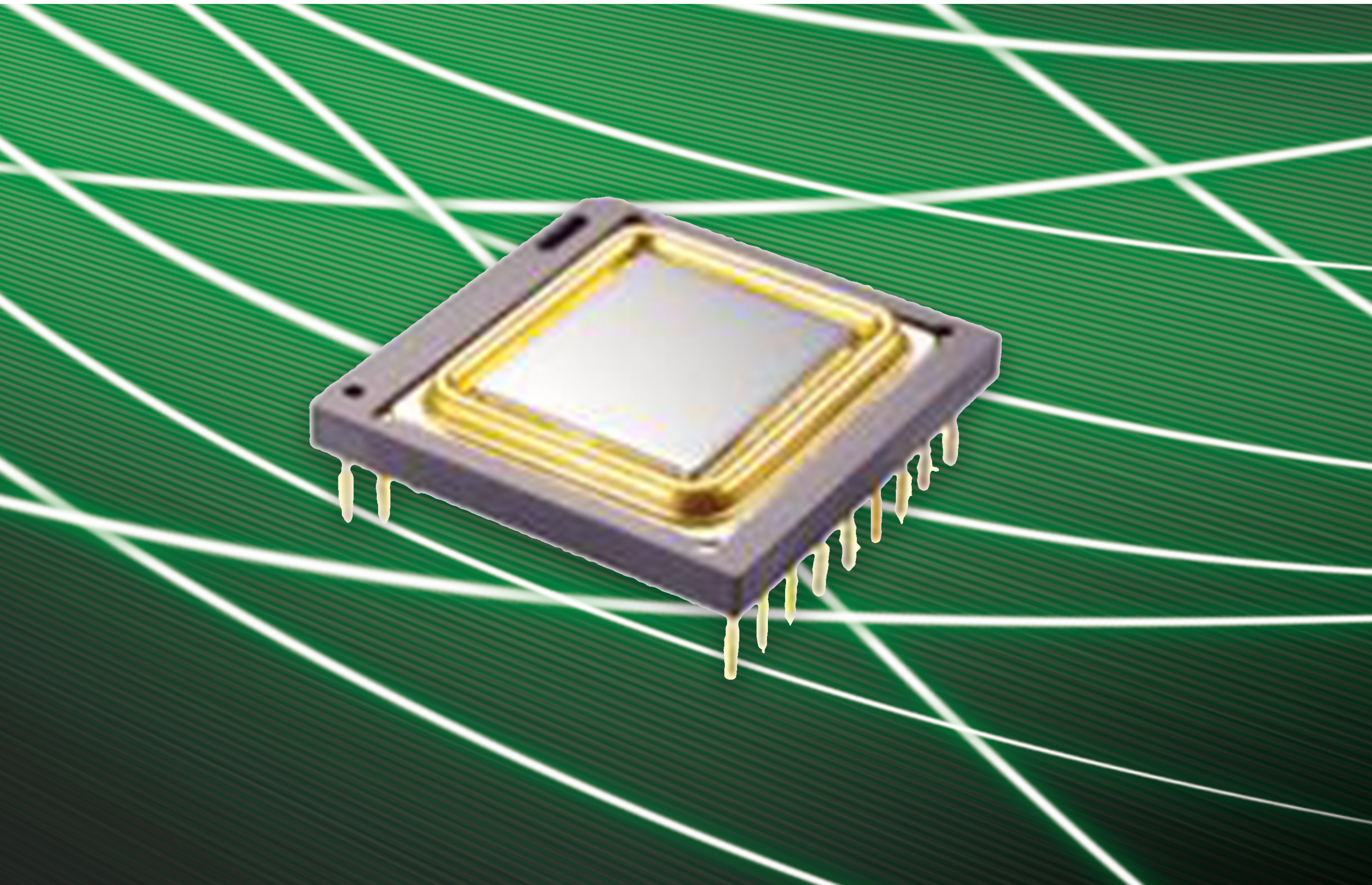
Modern thermal imaging cameras with microbolometer array detectors have NETD values of about **30 mK to 100 mK** in the LWIR spectral range for targets at room temperature. The actual value in this range is not important for most practical applications. The NETD is a contribution to the **measurement uncertainty**, which is much greater (see right). The same applies to microbolometer-based cameras in the MWIR range, where the NETD values at the beginning of the measuring range are in the order of 1 K.

In the NIR/SWIR spectral range, higher pixel numbers dominate, for example 512 × 384 and 768 × 576 for **Si-2D arrays**. Because of the still very high costs, 320 × 240 (256) pixels are preferred for **InGaAs arrays**. For both Si and InGaAs arrays, **high dynamic range sensors** are preferred, because they allow "long" temperature measurement ranges without range switching. The NETD values at the beginning of the measurement ranges are also about 1 K.

The measurement uncertainty of current thermal imaging cameras with microbolometers is about 2 K for measurement temperatures below 100 °C and 2 % of the measured value in °C for measurement temperatures above 100 °C. For thermal imaging cameras with semiconductor sensor arrays the measurement uncertainties are 1 % to 2 % of the measured value in °C.

What **number of pixels** is required for my measuring task?

How accurate must my measurement be?



Measurement frequency and response time

When measuring moving objects, measurement frequency and response time are important for detecting rapid temperature changes. In microbolometer-based devices, the maximum measurement frequency of the thermal imaging camera is determined by the thermal time constant of sensor elements.

The so-called thermal **time constant** of current microbolometers is in the range around 10 ms, therefore from a metrological point of view, maximum frame rates of about 50 Hz are reasonable. The response time is then about 40 ms.

Is the **sensor type** used fast enough at the selected measuring frequency?

Which **measuring frequency** do I need for my application?

Semiconductor sensor arrays have significantly lower time constants. Here the sensor signal processing and transmission determines the maximum measuring frequency. Measurement or image frequencies up to 100 Hz are used. If only smaller image sections of the semiconductor sensor array are used (subframes), measuring frequencies of up to several 1000 Hz can be achieved.

Infrared optics and FOV

In order to optimally adapt the thermal imaging cameras to the **target size** and **distance**, modern thermal imaging devices can be equipped with different **optics** (standard, wide angle and telephoto lenses, but also special lenses such as macro, zoom, borescope or endoscope optics). This results in different FOV (**Field Of View**) angles.

In industrial process measurements, it is important that the thermal imaging cameras can be **focused** conveniently even already mounted. A **motorized focus** is often preferred especially of course at unfavorable mounting locations. Motor focus devices that have no **external moving parts** are best. This facilitates the integration into special housings as well as existing plants and machines.

Which **image area** does my thermal imaging camera have to cover?
How large should the **aperture angles** be?
Do I have to or should I use optics with **motor focus**?

Environmental conditions, housing and power supply

In industrial environments, the **standard housings** (usually **IP54** protection class) of stationary thermal imaging cameras are often insufficient. They must then be housed in protected and, if necessary, **water- or air-cooled housings**. This ensures **long-term functionality**. Some manufacturers therefore offer cameras in special industrial protective housings. Examples are the mounting of standard housing thermal imaging cameras in separate **weatherproof** or **ATEX housings.** Particularly cost-effective solutions are solutions where the thermal imaging camera assemblies are mounted directly into a protective housing. Examples are **IP65 stainless steel housings with protective window** and integrated air purge for dusty environments as well as optional water cooling for high ambient temperatures.

For the use of a thermal imaging camera, the **ambient temperature** is an important consideration. Modern thermal imaging cameras have an operating temperature range from **–10 °C to 50 °C**. if this range is to be fully exploited in a specific application, tests and detailed enquiries should be made to the manufacturer.

It should also be possible to supply power to the cameras with strongly fluctuating and disturbed industrial power supplies in a wide voltage range (12 V to 36 V). A PoE (Power over Ethernet) power supply as well as a dual operating voltage supply (PoE/direct) to increase reliability is sometimes useful.

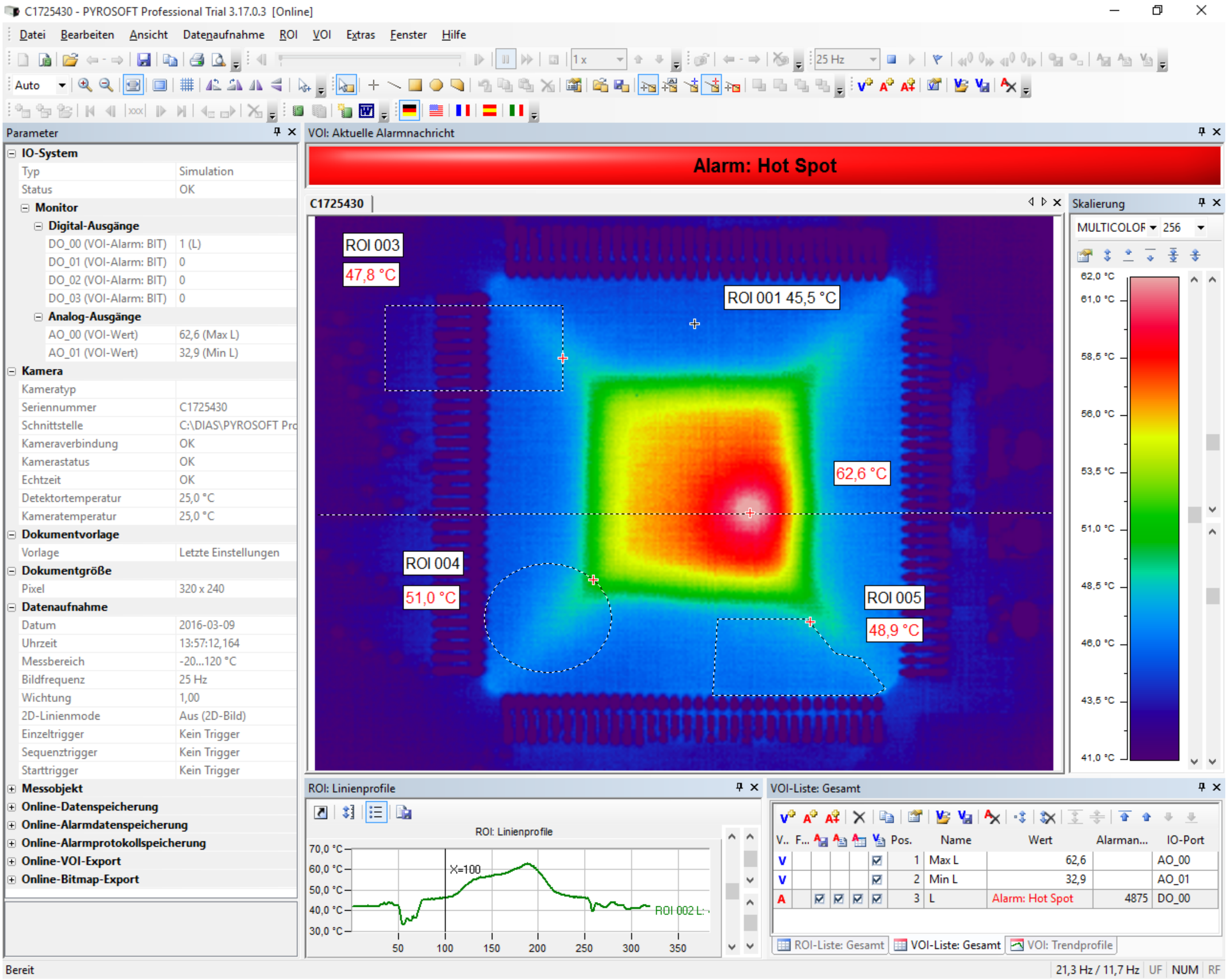
What does my **measurement environment** look like?
What is the **ambient temperature**?
Do I need **industrial housings**?
How should the **power supply** of my thermal imaging camera be provided?

Electrical interfaces and software

High-performance stationary thermal imaging cameras have a wide **dynamic range** and **16-bit A/D conversion**. For industrial process measurement today, an **Ethernet** interface with loss-free compression and low delay times is preferred. It uses the **Internet Protocol (IP)** for the transmission of measurement data, but also for camera control, service and maintenance. For applications with short distances of up to 5 m between the host computer and thermal imaging camera, e.g. in the laboratory, USB interfaces can also be used. For measurement tasks in harsh industrial environments over **long distances up to 100 m**, an Ethernet interface is the better choice.

Data transmission and storage should be fully dynamic and independent of the visualization. This allows **subsequent optimum visualization** and image evaluation from various points of view. The measured values are recorded and transmitted in **real time** (**„online functionality“**).

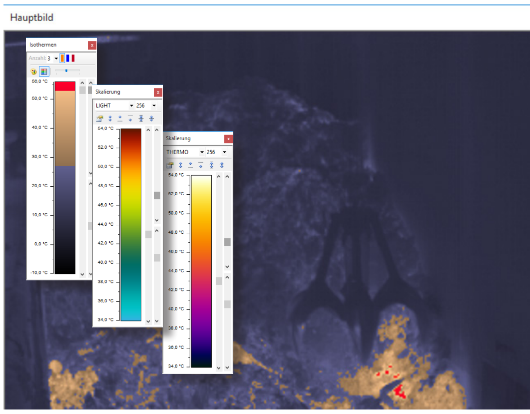
Alarm and limit value monitoring as well as **triggered measurements** are realized by **galvanically isolated** inputs and outputs. Some thermal imaging cameras have a **stand-alone** functionality and can be operated without PC coupling for simple measurement tasks such as hot spot detection using the alarm outputs and trigger inputs.

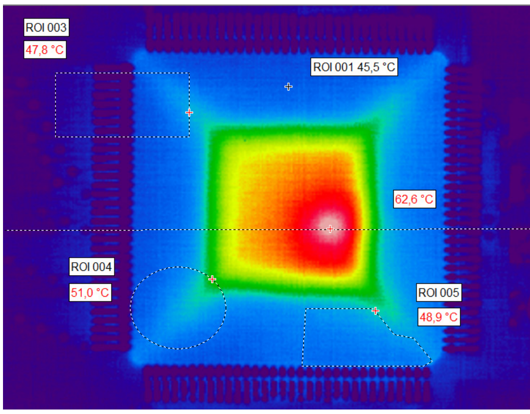


When the cameras are connected to a computer or local networks, extensive and powerful software packages are available. With this software, thermographic data can be recorded and **displayed**, **analyzed** and **controlled** as well as **evaluated** and **documented**.

Powerful universal software solutions offer a choice of **color palettes** and **scales** including auto-scaling and zoom functions with auto zoom, full screen view, rotation and tilting. Analysis functions are designed to facilitate image evaluation, for example:

– Correction of emissivity, transmittance and ambient temperature
– Difference image display with selectable reference image
– Filter image (minimum, maximum, average, image size)
– Display of isotherms





ROI (Region of Interest) functions are an important point. An ROI is the image section whose measured values are to be used for further evaluation. This can be a single point, a line or a partial area (rectangle, circle, polygon) of the camera image. Each ROI has corresponding parameters assigned to it, for example:

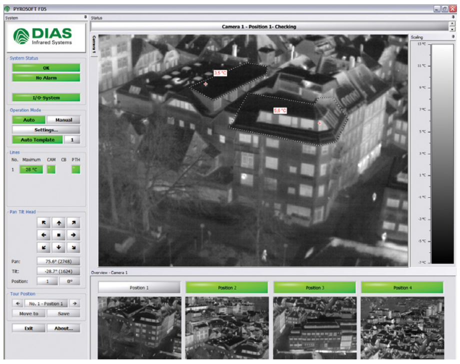
– Position and dimensions,
– Temperature minimum, maximum, average, standard deviation,
– Points, lines, areas (rectangle, ellipse/circle, polygon),
– Marking of minimum/maximum (hot/cold spot) for lines and areas,
– Specific correction of emissivity, transmittance and ambient temperature within the ROI,
– Histogram calculation,
– Spot calculation.

Data generated by ROI can be further processed and analyzed as **VOI**, as „**Value of Interest**“. This can be a single value, for example only the average value of an ROI. However, various combinations (difference, minimum, etc) of several different ROI parameters are also possible.

The calculated value of the VOI can then be used for further analysis for:

– Output on the screen,
– Output via an IO system,
– Trend display over time,
– Generation of an alarm.

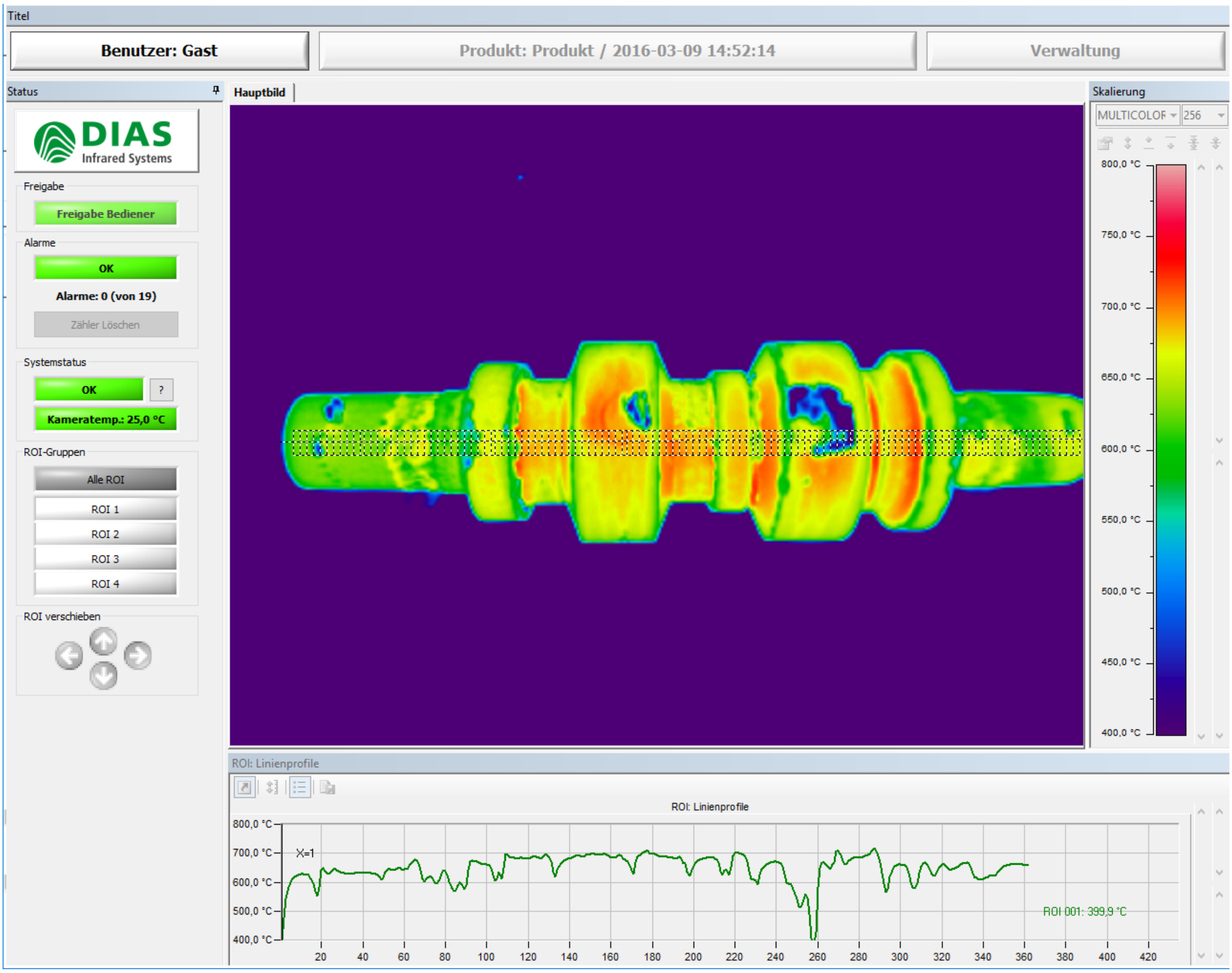
Which **interfaces** do I need for my application?
Is **stand-alone operation** important for me?
Which **software functionalities** do I need?
Is an **integrated web server** available?



Additional functions for operating the software with an optionally connected **IO system** are desirable:

– Support of numerous IO systems, for example network-based IO System WAGO®, PROFIBUS® with PC master or slave card, PROFINET® with PC card, TCP socket (client), MODBUS and file-based IO system Text-IO,
– Analog and digital value output (measured values, alarms),
– Control of online data recording (start, stop, trigger),
– Triggering of reference and difference image acquisition,
– Control of online export functions,
– Possibility to connect **external reference pyrometers** for correction and calculation functions.

In addition, there are special solutions, for example for the integration of thermal imaging cameras in automation processes. For users who want to integrate the cameras themselves into their software environment, appropriate **DLL interfaces** should also be available. Especially for setup, service and maintenance, there are also web servers integrated into the thermal imaging camera, which can be accessed by any web browser in parallel to the measurement data acquisition. The web server displays the IR image of the current process and information about the technical data and the current operating status of the camera.



Conclusion

Selection of modern stationary thermal imaging cameras for industrial process measurements requires consideration of multitude of properties and selection criteria. Thorough planning is necessary. Appropriate advice and test measurements are useful in many cases in order to avoid undesired measurement errors and mistakes in advance.

The **questionnaire for non-contact temperature measurement** under www.dias-infrared.de summarizes important details that are relevant to your application and device requirements:

https://www.dias-infrared.com/contact/questionnaire

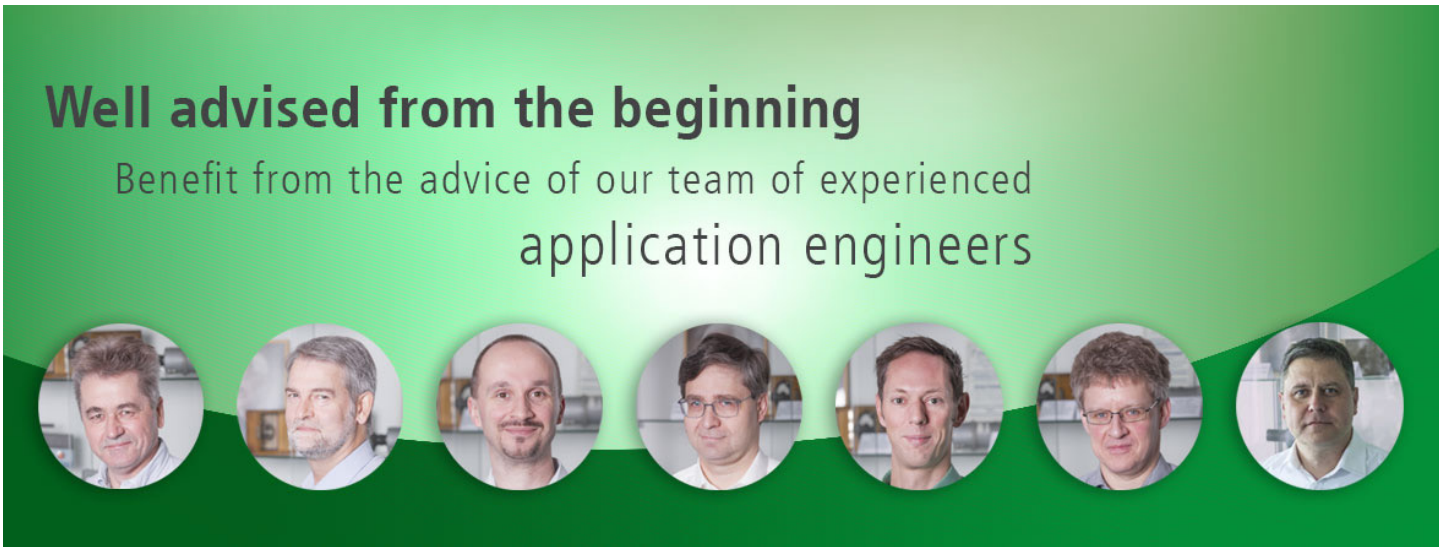
Fill out this questionnaire online and we can help you with a professionally qualified answer without obligation and free of charge.

Do you have any more questions?
What measurement task do you currently have to solve?

You can talk to one of our engineers **without obligation** and, if necessary, take a test measurement.

Please contact us:

Phone: **+49 351 896 74-10** or
Email: **sales@dias-infrared.de**



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