We measure it. testo

Test to compare various thermal imagers

Heat reveals all

Thermal imagers are used more and more frequently in industrial maintenance – both for identifying damage to electrical installations and also for diagnosing mechanical drive elements. The Fraunhofer Institute of Optronics, System Technologies and Image Exploitation has now tested six imagers which are suitable for this use. The test focuses on these questions: How do the manufacturers' imagers perform in direct comparison? Does "SuperResolution" Technology provide demonstrable improvements in the practice of preventive maintenance – and, if so, which ones?

Thermography is wide-spread in industry and above all here in maintenance. Thermal imagers enable the detection of "hot spots" which are caused by defective components or faulty connections.
In addition, heat is an indicator of whether electrical and electronic assemblies are working reliably and safely, or are correctly connected. There are also often limit values in this area which must be adhered to, for instance for electrical insulation.

Another important field of application in terms of industry is monitoring mechanical drive components. For example, bearing zones which are overheating, that is faulty, can be detected at an early stage. This means operators avoid larger losses if they act quickly and replace the bearings.

An established preventive maintenance tool

However, the measurements do not just serve to detect irregularities and damage on machines and systems and – in terms of preventive maintenance – to enable these to be dealt with before there are any breakdowns. Since temperatures of the mechanical and electrical components are used as indicators of their function, the instruments also take on an important function as far as fire prevention is concerned.

Because thermography enables early detection of the superheating of components which might cause a fire.

Non-contact measurement, which also allows the recording of objects at greater distances, along with the thermal imager's simplicity of use and compact design are advantageous. In addition, the way the imager works – non-contact measurement also possible at greater distances – is a prerequisite for the system not having to be shut down or switched off during the examination, but being able to be examined while in operation.

Figure 1

Manufacturer	Type	Detector elements	Field of view	IFOV
NEC Avio	R300W2	320 × 240	21.9° × 16.5°	1.20 mrad
FLIR Systems	T440	320 × 240	25.0° × 18.7°	1.36 mrad
Testo	t885	320 × 240	29.5° × 22.4°	1.62 mrad
NEC Avio	G120EX	320 × 240	32.1° × 24.1°	1.75 mrad
FLIR Systems	E30	160 × 120	24.4° × 18.3°	2.66 mrad
Testo	t875i	160 × 120	32.4° × 23.8°	3.50 mrad

Measured fields of vision and IFOV calculated on the basis of these for the thermal imagers under examination. When searching for thermal irregularities on large systems, a large field of view is an advantage

These features mean that they have become widely established in industry, especially in maintenance departments.

Important factors: the geometric resolution – and the price

As far as users are concerned, geometric resolution is not an insignificant parameter when it comes to thermal imagers. Maintenance staff would also like to detect the smallest thermal anomalies, such as "hot spots", as early as possible, even in large systems. This means that locating irregularities precisely is also important for them. This requires a sensor unit with a high resolution.

The interesting measurement parameter is the spatial resolution here, which can be given as IFOV ("Instantaneous Field of View") in milliradians (mrad). The smaller this number is, the higher the spatial resolution. As a rule, this number correlates to the detector's pixel data: a high-resolution detector with a high number of pixels achieves a good IFOV.

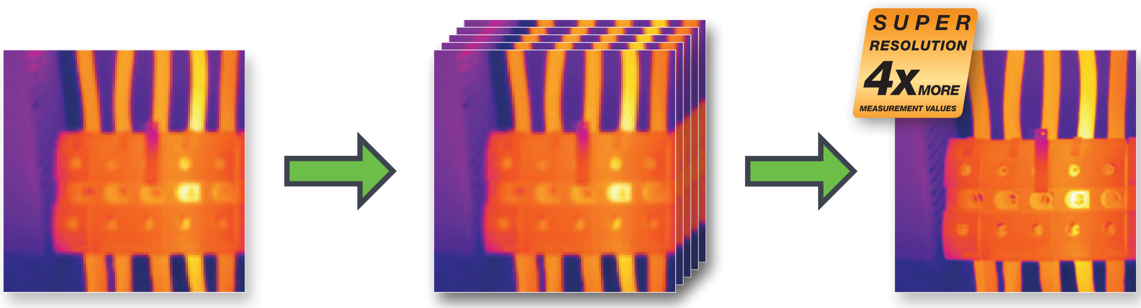
However, the interplay between the largest possible field of view (FOV), enabling users to detect a large amount in the image, and the smallest possible IFOV, for the detection of all the details, is even more crucial than simply having a good IFOV.

The price of the sensor unit certainly rises with the resolution and, because the sensor is the most expensive individual component of a thermal imager, this has a direct impact on the price of the imager. Developers from several leading manufacturers have therefore looked for possible ways of increasing a thermal imager's resolution without using a higher-resolution sensor which is therefore correspondingly more expensive. A large field of view or measurement field also still needed to be achieved, so that users could retain the overview **(Figure 1)**.

Two different measuring technologies – which is better?

The design of "SuperResolution Technology" managed to achieve what sounds like squaring the circle. Imagers with this technology take

Figure 2



Standard infrared image

SuperResolution Technology: overlaying of several images

Infrared image with SuperResolution Technology

The way SuperResolution Technology works: images recorded in a sequence are combined into a single high-resolution image

a sequence of images which are converted into a single high-resolution image in the imager or subsequently **(Figure 2)**.
In this way, the number of measuring points can for instance be increased by a factor of four and the geometric resolution can be improved accordingly. This enables more accurate measurement or also accurate measurement from a greater distance.

This means that users of thermal imagers have instruments available for industrial uses which work according to two different principles. Instruments that work using SuperResolution Technology are significantly cheaper than imagers that use conventional technology with the same resolution. However, are their results just as easy to use in practice?

A neutral test, carried out by the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation in Ettingen (IOSB) and commissioned by the specialist media company Vogel Business Media, compared six different thermal imagers. The results are now available (note) and are summarised in brief below.

Six instruments in the test

Six instruments were tested **(see Figure 3)**. All the imagers work with uncooled microbolometer detectors with a detector resolution of 320 × 240 or 160 × 120. This information corresponds to the resolution in pixels. Three of the six instruments use SuperResolution Technology.

Figure 3

The six thermal imagers which were examined with their technical data

Manufacturer	Flir	Flir	NEC Avio	NEC Avio	Testo	Testo
Type	E30	T440	G120EX-NNU	R300W2-NNU	t875-2i	t885
SN	49000139	62100150	1051429	1070388	2359038	2337099
Detector	FPA microbolometer	FPA microbolometer	FPA microbolometer	FPA microbolometer	FPA aSi microbolometer	FPA aSi microbolometer
Spectral range	7.5 – 13 µm	7.5 – 13 µm	8 – 14 µm	8 – 14 µm	7.5 – 14 µm	7.5 – 14 µm
Elements	160 × 120	320 × 240	320 × 240	320 × 240	160 × 120	320 × 240
Image rate	60 Hz	60 Hz	60 Hz	60 Hz	33 Hz	33 Hz
Focal length	18 mm	18 mm	14 mm	19.5 mm	7.5 mm	15 mm
Aperture	–	–	–	–	0.84	0.9
Min. focal distance	0.4 m	0.4 m	0.1 m	0.1 m	0.1	0.1
Temperature range	-20 to 120 °C	-20 to 120 °C	-20 to 60 °C	-20 to 60 °C	-20 to 100 °C	-20 to 100 °C
Accuracy	± 2 °C	± 2 °C	± 2 °C	± 1 °C	± 2 °C	± 2 °C
Considered for temperature calculation	Emission, refl. temp., ambient temp., distance, rel. humidity	Emission, refl. temp., ambient temp., distance, rel. humidity	Emission, ambient temp., distance, rel. humidity	Emission, ambient temp., distance, rel. humidity	Emission, refl. temp.	Emission, refl. temp., ambient temp., distance, rel. humidity
SuperResolution	No	No	No	Yes	Yes	Yes
Monitor	3.5" LCD, 320 × 240	3.5" LCD, 320 × 240	3.5" LCD, 320 × 240	3.5" LCD, 320 × 240	3.5" LCD, 320 × 240	4.3" LCD, 480 × 272
Data	SD card, *.jpg	SD card, *.jpg	SD card, *.jpg	SD card, *.jbmt	SD card, *.bmt	SD card, *.bmt

Four functions or parameters were examined on the imagers:

- Field of view
- Total noise
- Line spread function and modulation transfer function
- Accuracy of the temperature measurement depending on the object size with and without SuperResolution.

Four parameters examined

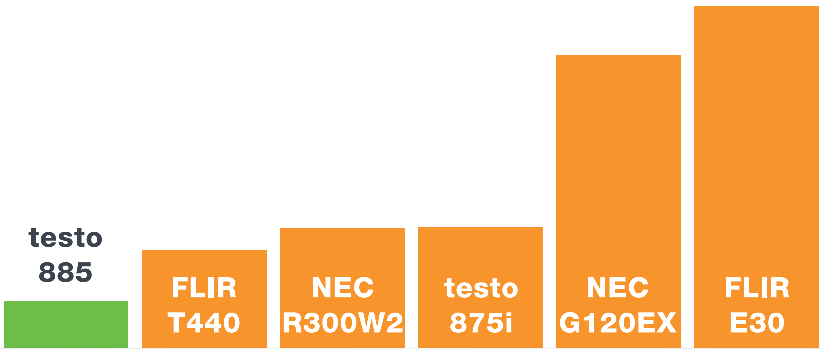
The field of view (FOV) is the field of vision or measurement field of a thermal imager. The test recorded the size of the field of view along with the resolution of the imager. The core questions here are: How accurately does the imager also “detect” smaller hot spots? And is the field of view big enough for users to be able to find their way around larger systems too?

Inherent inaccuracies are recorded in the measurement with **total noise**. It is logical that the lowest possible noise level is judged to be the best.

It becomes more complicated when testing the imager’s electro-optical resolution, measured via the line spread function and modulation transfer function (LSF and MTF). This involves descriptors for the electro-optical quality of the imagers.

On the other hand, it is clear what is at issue with **temperature accuracy**. The IOSB engineers determined here how accurately thermal imagers measure temperatures on objects of different sizes. In this process, the focus of the measurements was on the question of how SuperResolution Technology impacted on the accuracy of the measurement results.

Figure 4



Manufacturer	Type	Total noise		Difference
		Without HPF	With HPF	
Testo	t885	33.9 mK	20.7 mK	38.9%
FLIR	T440	50.1 mK	42.7 mK	14.7%
NEC	R300W2	73.8 mK	51.9 mK	29.7%
Testo	t875i	66.9 mK	52.6 mK	21.4%
NEC	G120EX	145.5 mK	126.4 mK	13.1%
FLIR	E30	151.6 mK	147.3 mK	2.8%

Comparison of thermal imagers commissioned by the specialist media company Vogel Business Media; Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB; April 2013

Results: improved spatial display through SuperResolution

In terms of the display of the measurement parameters, which the Fraunhofer IOSB recorded in minute detail and under defined conditions. What results emerge from the examinations of the independent institute? They show that there is a clear lead for imagers with SuperResolution with respect to the measurement parameters of geometric resolution. Very small zones with increased temperature are also very reliably detected. This can for instance be advantageous when searching for defective plug-in connections, as well as troubleshooting in switching cabinets.

The “Instantaneous Field of View” (IFOVgeo for short) is an important parameter here; see page 2. By this we mean the field of vision of every detector element which is determined by the focal length and the centre to centre distance and which describes the nominal geometric resolution of an imager. The smaller the IFOV is, the finer the granulation of the image which users see. The IFOV value of the instruments under examination varied by around a factor of three. As expected, the imagers with the higher number of detector elements performed better here, e.g. the testo 885.

Efficient noise suppression

As a matter of principle, all thermal imagers exhibit a certain amount of noise. There were also significant differences between the instruments here. The total noise (without a high-pass filter) varies by almost a factor of 5 and the instruments with a 160 × 120 detector also performed worse here than those with a 320 × 240 detector. As shown by the test results, this is at its lowest with the testo 885. The reason for this is the Testo imager’s extremely low noise level, due to intelligent noise suppression. **(Figure 4)**.

Everyday use gives good reasons for choosing the version with HPF: the human eye filters low-frequency structures out of the image when there are moving images. Because the test set-up did not take this behaviour of the human eye into consideration, a high-pass filter was used, in order to include the behaviour of the human eye in the test.

Electro-optical quality

In the third series of measurements (“line spread function and modulation transfer function”) it was apparent that SuperResolution Technology shows a certain “overstating” of the temperatures in the peripheral areas. From the point of view of the researcher who wants to determine exact temperatures, this may be unsatisfactory. However, for maintenance staff who are interested in precisely these temperature differences because they indicate irregularities, this kind of display, which is a result of overlaying several “snapshots”, is an advantage, because they can very quickly locate temperature increases in often confusing industrial systems and look into their causes.

Practice-oriented temperature display via SuperResolution

The comparison of the temperature values measured by the IOSB showed that the temperature resolution (NETD: Noise Equivalent Temperature Difference) is not improved by SuperResolution Technology, to the extent that the accuracy is recorded with a reference range of +/- 1 K.

The NETD gives the temperature resolution of the imager in millikelvins (mK). The smaller the value, the better the temperature resolution.

On this subject it should be noted from a manufacturer's viewpoint that there is no scientific or measuring technology standard for the precise evaluation of SuperResolution Technology in terms of improving measuring accuracy. From a manufacturer's viewpoint a tolerance range of +/- 2 K for industrial thermography is a more practice-oriented value than the one of +/- 1 K which is taken as a basis here: in the final analysis, for users it is not a case of knowing the most accurate possible temperature value of a hot spot in the switching cabinet or of a overheated bearing. They would prefer to detect temperature changes and hot spots at an early stage. And it is precisely this requirement that is met through SuperResolution. If a tolerance value of +/- 2 K is assumed, a clear improvement in temperature resolution emerges for SuperResolution Technology.

Conclusion: SuperResolution provides benefits in practice

The test series carried out by the Fraunhofer IOSB Institute show: instruments with SuperResolution provide clear advantages for applications in industrial maintenance. Their resolution is significantly higher and the overstatement in terms of the temperature display established in the tests is very much in line with the aims of maintenance staff.

The cost aspect must not be forgotten: a thermal imager with 320 × 240 detection elements and SuperResolution achieves around the same resolution as an imager with 640 × 480 pixels without SuperResolution. However, it is less than half the cost. This means the benefits of SuperResolution Technology should be seen as proven, both from technical and commercial viewpoints.

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