

Professional article – background article

Testo SuperResolution – the patent-pending technology for high-resolution thermal images

Abstract

In many industrial or trade applications, it is necessary to reliably thermograph even the smallest or extremely distant measuring objects. In such cases, the better the image resolution and the more readings in the thermal image, the more detailed and clearer the representation of the measuring object. The Testo SuperResolution technology improves the usable, geometric resolution of the thermal image by a factor of 1.6 and provides four times more readings – comparable with a higher detector resolution. These thermal images with SuperResolution quality, which can be conveniently viewed in the PC-based analysis software, are achieved by combining the two technologies super-sampling and deconvolution, which can be used by Testo thermal imagers thanks to a complex algorithm. The SuperResolution technology takes real thermal readings – without using a large detector and in a form that can be simply evidenced, e.g. using a slit diaphragm structure.

1. Introduction

Thermographers in the building industry, industrial maintenance, the electrical trade or in development teams continually face similar problems: thermal analyses are required of very small or extremely distant objects. The structure of thermal imagers restricts their image resolution due to the detector technology available on the market. The SuperResolution technology adds a new dimension that clearly improves the image quality for thermal imagers. Thermal images taken using SuperResolution have a far higher resolution: four times more readings and a 1.6 times better geometric resolution offer far more details on every thermal image and thus greater reliability during every thermographic measurement.

The SuperResolution technology uses the natural hand movement to take multiple slightly offset photos in rapid succession. Thanks to the precise knowledge of the lens properties and use of the individual images in the sequence, an algorithm can be used to convert these individual photos into a high-resolution image. The key factor here is that real readings are taken, which are comparable to the result obtained by a higher detector resolution. This is not an interpolation process.

2. Technological challenges of creating images of infrared radiation

In comparison to digital cameras, infrared detectors only have a low resolution. This situation is due to both physical and technological reasons and can particularly cause problems if a user wishes to detect and measure extremely small objects. These measuring objects are even often smaller than a single pixel. In the worst cases, the small measuring object only makes up a fraction of the entire radiation measured, which means that it may disappear into the background and no longer be recognisable. If it is large enough to make up a significant portion of the radiation, the influence from the background can still tend to cause the measurement value to be between the temperature of the measuring object and that of the background. For the measurement, this means that it is usually only possible to record a distorted value. This problem is particularly well-known in the field of microelectronics where thermographic images are taken of objects for which a particularly small and fine resolution is required. This challenge is also common in the field of building thermography where objects can be positioned many metres away, for example roof ridges or upper floors.

3. Testo SuperResolution – the solution for high-resolution thermal images

The Testo SuperResolution technology makes it possible to depict more real temperature measurements without using a large detector, and thus to correctly measure smaller measuring objects. This is not a simple interpolation procedure, such as bilinear or bicubic interpolation, in which artificial intermediate values are generated without obtaining additional information. Such artificially generated values can never exceed the neighbouring values – which would be particularly necessary in the case of small objects, for example to detect hot spots. In contrast, SuperResolution increases the measurement resolution and the level of detail. The original signal behaviour can be reconstructed (see figure 1).

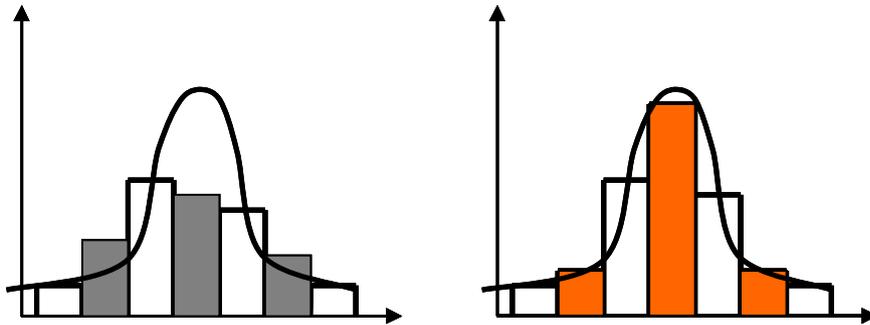


Figure 1: The black line represents the original signal. The white bars are original pixel values. The grey bars on the left are artificially generated interpolation values – these cannot reconstruct the original signal. The orange bars on the right are SuperResolution values – these can reconstruct the original signal.

Real readings are therefore calculated, which are comparable with the photo taken by an imager with a higher detector resolution. The geometric resolution of the SuperResolution thermal image is clearly improved. In practice, this means that even the ‘smallest measurable object’ can be far smaller while retaining the same distance between the thermographer and the measuring object. This means that the thermographer does not need to get closer to the measuring object yet can still view far more details when analysing the thermal image on the PC (see figures 2 and 3).

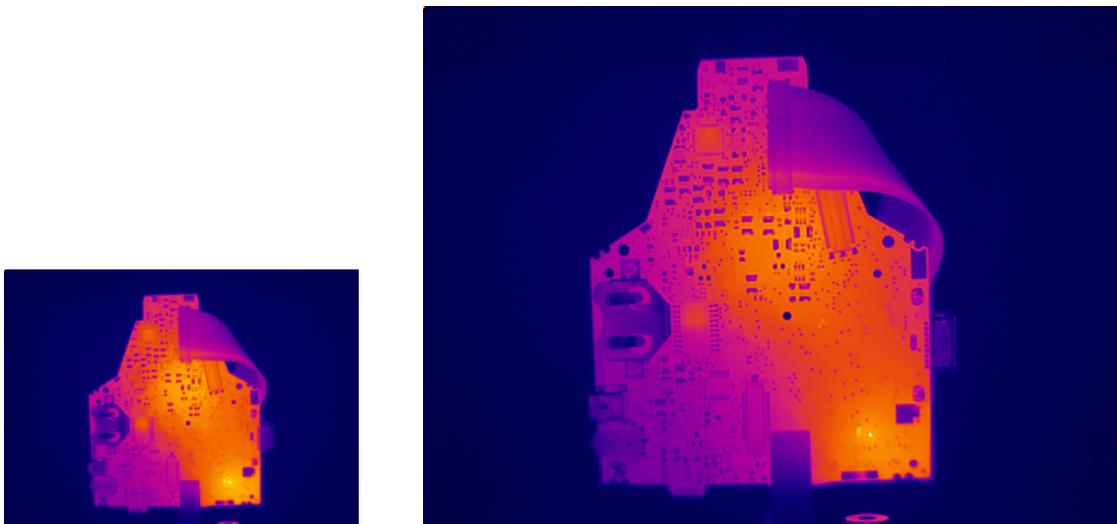


Figure 2: The image on the left shows a thermal image with 320 x 240 pixels; the image on the right shows a SuperResolution thermal image with 320 x 240 pixels (corresponds to 640 x 480 pixels).

SuperResolution offers the following advantages:

- Four times as many readings in the thermal image
- Geometric resolution (IFOV_{geo}) of the thermal image improved by a factor of 1.6
- Measurable objects are 1.6 times smaller ($\text{IFOV}_{\text{meas}}$)
- Far more details for PC-based analyses and thus qualitatively and quantitatively improved evaluation options in the thermography report

Testo's SuperResolution technology, for which a patent is pending, combines two well-known, recognised methods:

- 1) Super-sampling
- 2) Deconvolution

'Super-sampling' involves each photo storing a sequence of multiple, slightly offset images. This sequence of images is then used to conduct calculations and create a higher-resolution image. The process makes use of the natural tremor (from the Latin: tremere) apparent in all humans, which results in minute movements while the thermal image is being taken. This creates a sequence of images that are minimally offset from each other at random. Testo's special algorithm uses the additional information and readings to create a higher-resolution image of the thermographed object.

The 'deconvolution' process improves the image quality through the detailed knowledge of the infrared lens properties. This occurs through the calculation of the imaging properties of the lens with the thermal image.

3.1 Physical principles of the SuperResolution technology

3.1.1 Super-Sampling

Bolometer detectors for infrared imagers comprise a matrix arrangement of individual pixels, which absorb the radiation and convert it into an electrically evaluable signal. The pixel matrix is stored in vacuum housing for thermal insulation purposes. In turn, each pixel is made up of a thin bolometer membrane attached to fine pins over a substrate. There are small gaps between the pixels – also for thermal insulation purposes. This insulation should prevent any crosstalk, i.e. the flow of heat from one pixel to the next. However, this insulation also creates a gap between the individual pixels in which no radiation can be detected. Furthermore, the entire pixel area is not sensitive to radiation. The radiation is only absorbed in the inner section of the pixel membrane.

This means that there are 'blind spots' between the pixels in which no infrared radiation is detected. If an object is extremely small, it is possible for the signal emitted to hit such a 'blind spot' and thus be practically lost. The classic super sampling principle resolves this problem by moving the entire detector matrix half a pixel width each way so that the image sequence created is stitched to for a single image. The gaps between the pixels are therefore filled with additional information and the limit frequency of the detector is improved.

3.1.2 Deconvolution

The illustration of an object is mathematically described through the convolution (folding) of the object radiation with the transmission function of the imager. Deconvolution is the reversal of a folding of two functions. It is therefore a mathematical algorithm which uses solely the information about the result of the folding – here, the output signal – and the transmission function to determine the input signal. In our case, this means that with the output signal of the bolometer and the knowledge of the lens properties of the thermal imager, the input signal, i.e. the actual radiation of the thermographed object, is reconstructed. The result is a far sharper thermal image. Incidentally, deconvolution also works without super-sampling. For thermographers, this means that their thermal images are sharper even when they are not using super-sampling, i.e. without using the natural tremor.

3.1.3 SuperResolution: super-sampling and deconvolution in one

SuperResolution is the technological combination of super-sampling and deconvolution in an algorithm and gives rise to a far higher geometric resolution of the thermal image. The SuperResolution technology can be used to take sharper thermal images with more details and conveniently view these on a PC using the analysis software. This makes it possible to detect even the smallest or most distant measuring objects without using a higher-cost detector.

3.2 Evidence of SuperResolution technology

In thermography, there are several factors that play an important role in relation to the quality of the thermal image. Two factors of particular importance are the geometric resolution and the sharpness of the object. The improved resolution and sharpness can be seen by looking at several narrow slit diaphragms. In this setup, a slit diaphragm mask with vertical apertures that gradually become smaller and closer together, is placed in front of a black panel radiator at a constant temperature.

Image without SuperResolution technology

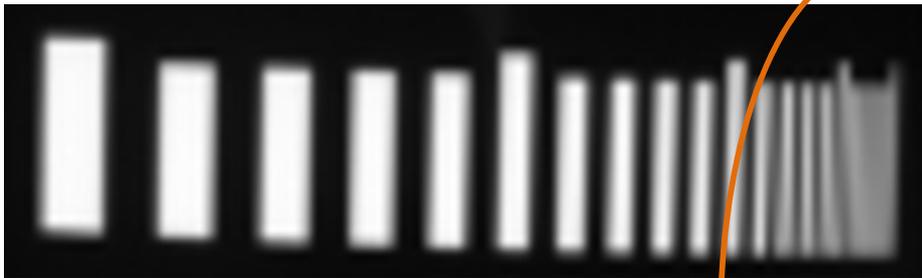


Image with SuperResolution technology



Figure 3: trial setup with slit diaphragm

Without SuperResolution technology, you can see that the image becomes blurred as the slits become more compact and closer together. The same process with SuperResolution technology results in an overall sharper image, in which far more details are clearly visible despite the slits becoming smaller and closer together.

The more precise analysis shows just how problematic too low a detector resolution is: artefacts are created through aliasing and the measured temperature strongly deviates.

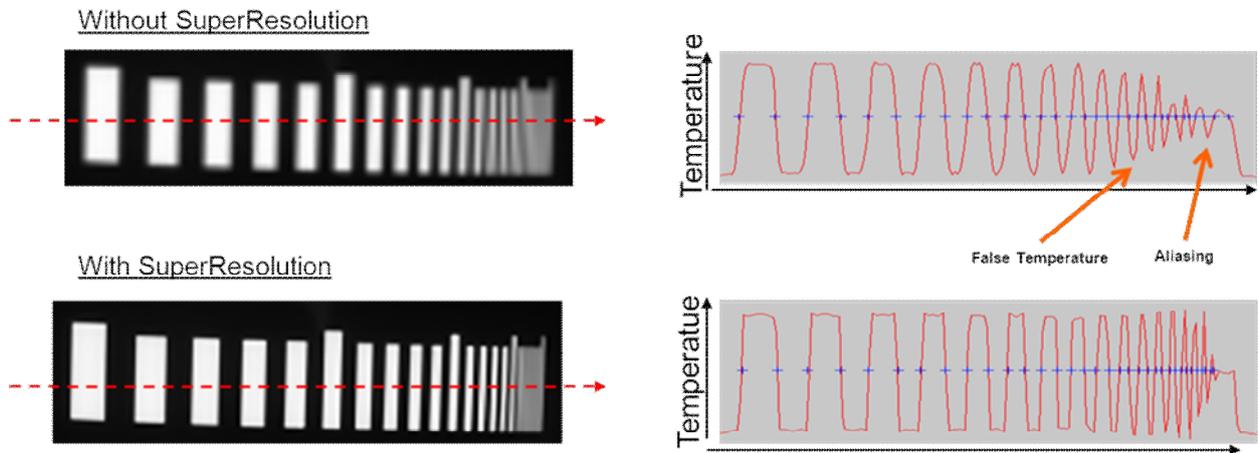


Figure 4: Trial setup with slit diaphragm

3.3 Availability of the SuperResolution technology

The Testo SuperResolution technology is available in all imager models in the series testo 875, testo 876, testo 881, testo 882, testo 885 and testo 890. Even thermal imagers that have already been supplied can be equipped with this technology by upgrading the imager software.

3.4 Applications of the SuperResolution technology

3.4.1 Building thermography

In building thermography, SuperResolution technology is ideal for quickly and effectively detecting construction damage and analysing energy losses in buildings' heating or air conditioning systems. The high level of detail in the thermal image makes inadequate insulation, thermal bridges or construction defects clearly visible. SuperResolution thermal images are therefore ideal for comprehensive error diagnosis and maintenance in interior areas or building envelopes – especially for energy consultation purposes.

3.4.2 Electrical trade and industrial maintenance

The SuperResolution technology makes detailed thermography easier in low, medium and high-voltage systems. High resolution thermographic images during maintenance work lead to the early detection of defective components or connections so that the necessary preventive measures can be introduced in a targeted manner. This minimises the dangerous risk of fire and avoids costly production downtime. SuperResolution also enables detailed early detection of potential damage to production-related system components. In the case of mechanical components in particular, the discovery of thermal irregularities (e.g. due to friction or incorrect alignment) can indicate an elevated level of stress.

3.4.3 Research and development

In the field of research and development, high-resolution thermal images are required for the targeted analysis of heat distribution and heat development, e.g. on printed circuit boards. The often tiny components can be quickly inspected in a contactless process and the smallest details can be thermographically depicted. All the temperature readings can then be analysed on a PC and the components thermally optimised.

4. Summary

The Testo SuperResolution technology provides four times more readings and a geometric resolution that has been improved by a factor of 1.6 for significantly more details and thus more reliability during every thermographic measurement. From a technical perspective, this is achieved by combining two technologies: super-sampling and deconvolution. A special algorithm combines these technologies and displays additional real readings. The higher resolution of the thermal images can be evidenced using a slit diaphragm trial setup. These far more detailed thermal images are used in many building and industrial thermography applications, both for the early detection of damage and for more detailed analyses of thermal discrepancies.

Company profile

Testo AG, with its headquarters in the Upper Black Forest, is a globally leading manufacturer of portable and stationary measurement technology. The high-tech company offers measurement solutions for climate and environmental technology, industrial applications, emission measurement, the monitoring of food quality and the building trade, among other areas. Every year, the company invests approximately 15 percent of its turnover in research and development and thus has an above-average expenditure on future-oriented technologies.

With 30 subsidiary companies and over 80 distribution partners, the company is represented all over the world, and has a worldwide staff of roughly 2200.