

TECHNICAL NOTE

How Far Can You Measure?

Considering Spot Size Ratio is Key

If you recently bought a thermal camera, you might be wondering how far you can measure with it. Or maybe you're interested in purchasing one, but you aren't sure which one will both accurately measure your target and fit within your budget. The answer to "how far can you measure?" depends on factors such as resolution, Instantaneous Field of View (IFOV), lenses, the size of the object, and more.

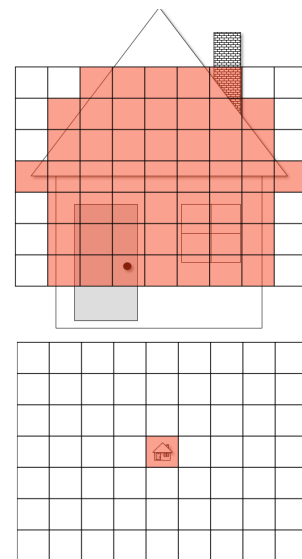
You can compare it to a visual exam at the doctor's office. When you look at the eye chart from the exam room chair, you may be able to see that there are letters on the smallest line – but at what distance can you still read the letters (i.e. "measure" them)? If you have 20/20 vision, you can define the smallest letters at greater distances. In this case, 20/20 vision would be equivalent to a high-resolution thermal imager. If your vision isn't perfect, you can improve it with glasses (i.e. adding a magnifying glass to the camera) or getting closer to the eye chart (i.e. reduce the distance to your target).

Understanding spot-size ratio is important. Spot-size ratio is a number that tells you how far you can be from a target of a given size and still get an accurate temperature measurement.

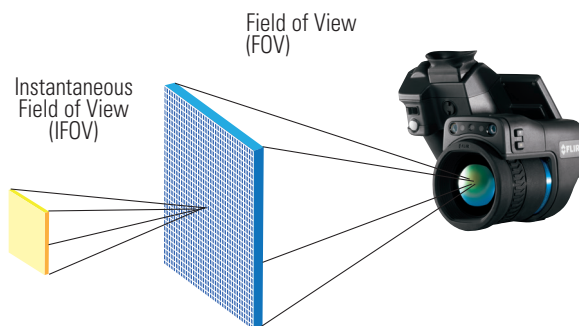
For the most accurate temperature measurement, you want to get as many pixels from your camera's detector as possible onto your target.

This will give you more detail in your thermal image. As you move farther and farther away from the object you want to measure, you lose the ability to measure temperature accurately. The higher the resolution your camera has, the more likely you are to get more pixels on a target from farther away with accurate results. Digital zoom doesn't improve accuracy, so higher resolution or narrow field of view is key here.

Let's say you're looking to get an accurate temperature measurement of a one-inch target from 20 feet away with your thermal camera. How do you figure out whether your camera can do this? You'll need to check the specs of your camera and know both the field of view and the resolution. For this example, let's say your camera's resolution is 320 x 240, and your lens has a 24-degree horizontal field of view.



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IFOV is an angular projection of just one of the detector's pixels in the IR image. The area each pixel can see depends on your target distance for a given lens.

You first need to calculate IFOV in milliradians (mrad) with this formula:

$$\text{IFOV} = (\text{FOV}/\text{number of pixels}) \times [(3.14/180)(1000)]$$

***Use the number of pixels that matches the direction (horizontal/vertical) of your FOV**

Since your lens has a 24-degree horizontal FOV, you'll divide 24 by the camera's horizontal pixel resolution — in this case, 320. Then you'll multiply that number by 17.44, which is the result of $(3.14/180)(1000)$ in the equation above.

$$(24/320) \times 17.44 = 1.308 \text{ mrad}$$

Knowing that the IFOV is 1.308 mrad, you then must find your IFOV in inches with this formula:

$$\text{IFOV (inches): } (1.308/1000) \times 240^* \\ \text{inches} = 0.31392 \text{ inches}$$

***The distance from your target**

So what does this number mean? The spot size ratio is 0.31:240 (or 0.31 to 240). This number is the measurable size of one single pixel (1 x 1). To put it in more simple terms, 0.31392 is about 1/3 of an inch, so this calculation tells you that your camera can measure a 1/3-inch spot from 20 feet away.

This single-pixel measurement is called "theoretical spot size ratio." Some manufacturers list theoretical spot size ratio in their product specifications. While this may be considered the true spot size ratio, it is misleading because it is not necessarily the most accurate. This can be because it only gives you the temperature of a very small area within a single pixel. As previously mentioned, you want to get as many pixels as possible on your target for the greatest accuracy. One or two pixels may be enough to qualitatively determine that a temperature

difference exists, but it may not be enough to provide an accurate representation of the average temperature of an area.

A single pixel measurement may be inaccurate for various reasons:

- Thermal cameras can develop bad pixels
- Objects reflect — a scratch or solar reflection would cause a false positive and a false high reading
- The object that is hot — say a bolt head — might be close to the same width as a pixel but those are square whereas a bolt head is hexagonal
- No optics are absolutely perfect — there are always some distortions in optical systems which impact measurements

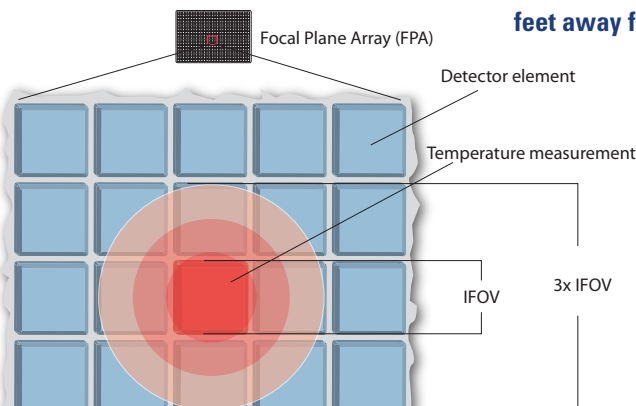
Due to a phenomenon called optical dispersion, radiation from a very small area will not give one detector element enough energy for correct value. We recommend making sure that the hot area where the spot value requested is at least 3 x 3 pixels. Just multiply your theoretical spot size ratio in inches by three, which gives you a spot size ratio of 3 x 3 pixels instead of 1 x 1. This number is going to be more accurate.

**So if you multiply IFOV in inches
0.31392 by 3, you get: 0.94176**

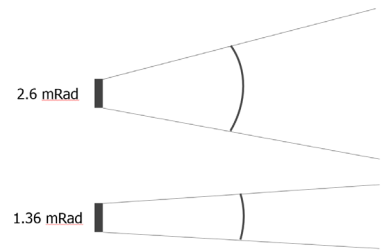
This means you can measure nearly a one-inch sized spot from 20 feet away. If you want to know exactly how far you can accurately measure a one-inch spot, you need to use a little cross-multiplication:

$$\begin{aligned} \text{IFOV in inches: Distance in inches} \\ (20 \text{ feet} = 240 \text{ inches}) \\ 0.94176 : 240 \\ 1 \text{ inch} : x \\ 240 * 1 = 0.94176 * x \\ 240 / 0.94176 = x \\ x = 254 \text{ inches or } 21.16 \text{ feet} \end{aligned}$$

You can measure a 1-inch spot from 21.16 feet away from your target



In the ideal situation the projected target should cover at least one pixel. To ensure accurate readings it is advisable to cover a wider area to account for the optical dispersion of the projection.



An illustration of field of view at 2.6 mrad vs. 1.36 mrad. Courtesy of the Infrared Training Center.

Other manufacturers may not use this number when they discuss IFOV or SSR; but in truth, this number will give you a more accurate temperature reading on an anomaly.

Ultimately, spot size ratio matters because it will help you understand whether your thermal camera is capable of accurately measuring temperature at the distance that you need it to. If you need to measure small targets from long distances, knowing the spot size ratio of the camera and whether you are standing within accurate measurement range is crucial.

If you are planning a thermography survey, think about whether you can get close enough to a target to get an accurate reading. Accurate should be taken as "good enough for proper interpretation." This does not necessarily even mean within the accuracy specification of your camera. You can make the mistake of being off by several — even hundreds — of degrees if you don't consider the spot size ratio.

To make the calculations quicker, FLIR has a FOV calculator for each of our cameras on <http://flir.custhelp.com>. Just click on the FLIR camera series you are using, which will take you to a list of all the cameras in that series. Click on "FOV Calc." next to the correct camera, and it will show you your camera's spot size ratio.



Learn about calculating spot size ratio and much more with professional certification training from the thermography experts at ITC. **Call 1-866-TRAIN-IR** or visit ITC online at www.infraredtraining.com

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

www.flir.com/instruments

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