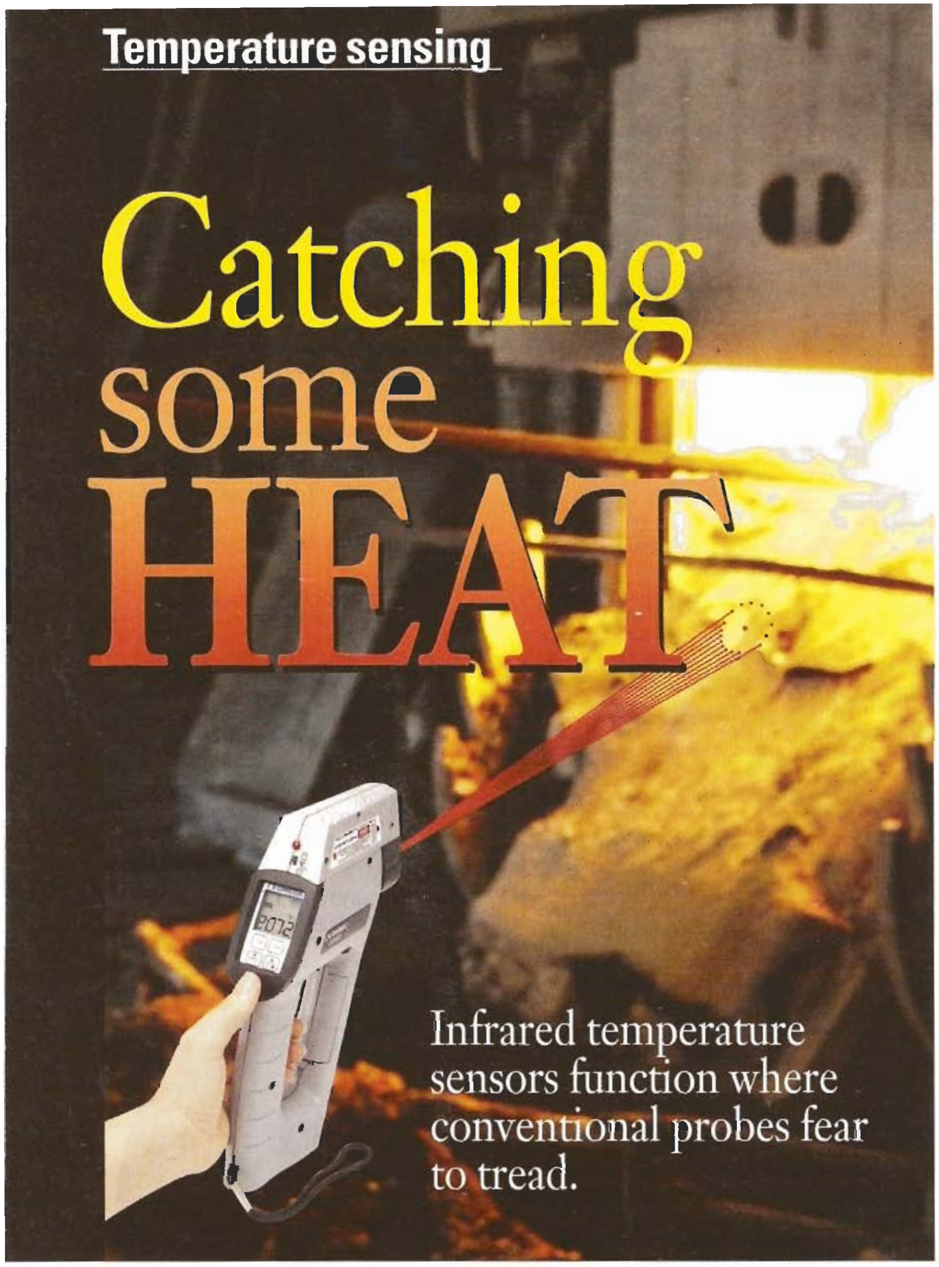


Catching some HEAT

Infrared temperature sensors function where conventional probes fear to tread.

Kathleen Kwiat
Omega Engineering, Inc.
Stamford, Conn.

Few industrial tools in recent years have generated more interest than non-contact infrared temperature sensors. These devices can reliably measure temperatures to 800°F in areas where surface probes tend to fail. Besides temperature extremes, infrared sensors can also handle moving or otherwise irregular surfaces, electromagnetic fields, and vacuum environments, all of which are hazardous to conventional thermometers.

If there is a catch, it's the complexity of the measuring method itself. Non-contact sensors measure temperature precisely by collecting an object's infrared energy from a distance, and then using integrated equations to factor in the effects of ambient temperature, object surface texture, and material.

Infrared history

It was in 1800, 200 years after Galileo invented the thermometer, that English astronomer John Frederick William Herschel hypothesized the existence of infrared light. Over 100 years later (in 1931) total radiation sensors were finally put into production. The first *modern* infrared quantum sensors (lead sulfide photodetectors originally developed for the military) became available after World War II.

Since then, infrared sensing has had an impact on a host of industries. On the research front, infrared (IR) thermometry is used to study faults in metals, composites, and coatings. In meteorology, satellite-borne infrared imaging devices map clouds and feed pictures to weather reports. Non-contact infrared sensors also improve the casting, rolling, forging and heat treating of metals; extrusion, lamination, and drying of plastics, paper, and rubber; and quality control in food processing.

Benefits and applications

Certain conditions make (contact-free) infrared temperature measurement preferable to contact thermometry. In some systems, direct contact is impractical or impossible. Other times, objects are hard to reach or in motion. On some equipment, extremes of temperature can quickly degrade the very contact sensors attached to read the phenomenon. Finally, where contact might contaminate, scratch, tear or otherwise damage surface equipment or products, infrared technology is also more suitable.

Many handheld models have a gun design, in which a laser beam targets a part or area of an object to be measured. Electro-optic circuits inside the gun adjust for the object's emissivity and ambient temperature, collect infrared waves through a lens, filter out atmospheric interference such as moisture, convert the radiation to an electrical signal, calculating target-object temperature almost instantly.

Other technologies

Temperature can be measured in several ways, but all sense some change in a physical characteristic of the sensor itself.

Thermocouples consist of two strips or wires of different metals, joined at one end. Changes in temperature at their junction induce a change in electromotive force (emf) measurable across the leads. As temperature goes up, this thermocouple emf rises. Sometimes an array of thermocouples (aptly called a *thermopile*) is used.

Resistive temperature devices (RTDs) capitalize on the fact that a material's electrical resistance changes with temperature. Metallic units rely on resistance change in a metal, with the resistance rising more or less linearly with temperature. In contrast, thermistors are based on the resistance change of a ceramic semiconductor; this resistance drops nonlinearly with temperature rise.

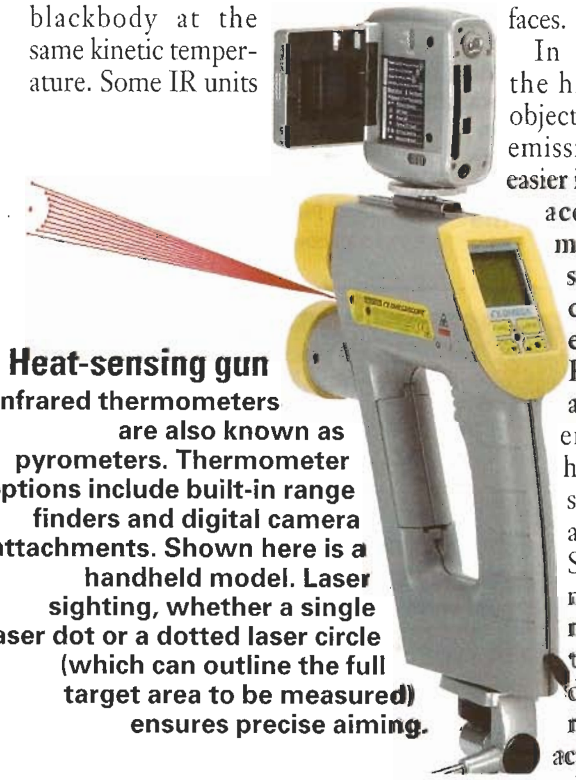
Bimetallic devices take advantage of differences in rate of thermal expansion between different metals. Strips of two metals are bonded together. When heated, one side expands more than the other, and the resulting bending is translated into a temperature reading by mechanical linkage to a pointer. These devices are portable and they do not require a power supply, but they are usually not as accurate as thermocouples or RTDs. They also do not lend themselves to temperature recording.

Fluid-expansion devices, typified by the household thermometer, do not require electric power, do not pose explosion hazards, and are stable even after repeated cycling. On the other hand, they do not generate data that is easily recorded or transmitted, and cannot make spot or point measurements.

Change-of-state temperature sensors consist of labels, pellets, crayons, lacquers, or liquid crystals that change appearance once a certain temperature is reached. Response time typically takes minutes, so they don't report transient changes. Accuracy is low, and the change in state is irreversible, except in the case of liquid-crystal displays. Even so, change-of-state sensors can be handy for confirming that the temperature of something has not exceeded a certain level — for instance, during product shipment.

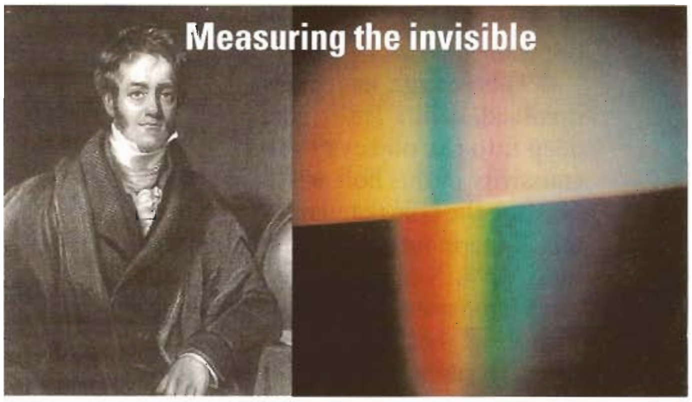
Infrared sensors record temperature from afar by measuring thermal radiation via photons emitted by objects. Units with thermal detectors are blackened for maximum radiation absorption, and are heated by it to register temperature much like traditional thermocouples. Photon detectors release electric charges when exposed to photons. Similarly, pyroelectric detectors (which we focus on here) respond to radiation by generating *surface* charge.

As mentioned, a target object's emissivity must be taken into account, as it can affect heat readings. Emissivity, remember, characterizes a material's tendency to radiate energy. It's a ratio of radiant energy from a material to that from a blackbody at the same kinetic temperature. Some IR units can recognize emissivity values from 0.10 to 1.00 (in 0.01 increments) to accurately measure the temperature of almost all surfaces.



Heat-sensing gun

Infrared thermometers are also known as pyrometers. Thermometer options include built-in range finders and digital camera attachments. Shown here is a handheld model. Laser sighting, whether a single laser dot or a dotted laser circle (which can outline the full target area to be measured) ensures precise aiming.



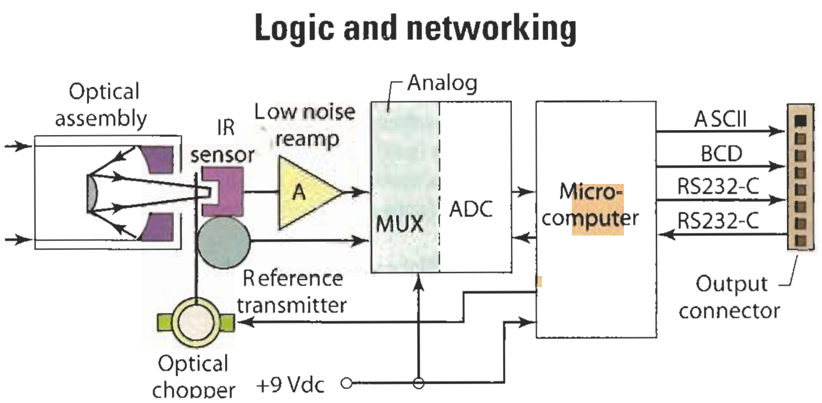
Measuring the invisible

Studying electromagnetic energy, John Herschel split sunlight with a glass prism, laid thermometers in the rainbow, and found that energy increased toward the red. He then measured the temperature just beyond the spectrum's red portion — and found that this region had the highest temperature of all.

In general, the higher an object's surface emissivity, the easier it is to get accurate IR temperature measurements. Organic substances such as wood, cloth, and plastic have an emissivity of about 0.95. Rough or painted surfaces also typically have high emissivity. On the other hand, objects with very low surface emissivity (below about 0.2) are problematic. Some polished, shiny metal surfaces such as aluminum are so reflective in the infrared range that reduced IR energy and spurious reflections preclude accurate measurements.

In both situations, a designer can account for material emissivity in several ways:

❶ Using a precise temperature sensor, heat a sample of the material to a known temperature, then read the sample with an IR thermometer. Adjust the emissivity value in the IR



Some infrared transducers include microprocessors that run linearization and compensation alrorithms in real-time, calculating temperature almost instantly. Some models can also interface with chart recorders, data loggers, or computers — useful for troubleshooting hot spots and scheduling preventive maintenance.

thermometer to match the correct reading.

❷ Where lower temperatures (under 500°F) are involved, cover the part of the object to be measured with masking tape, which has a known emissivity of 0.95. Adjust the IR thermometer's emissivity to correspond.

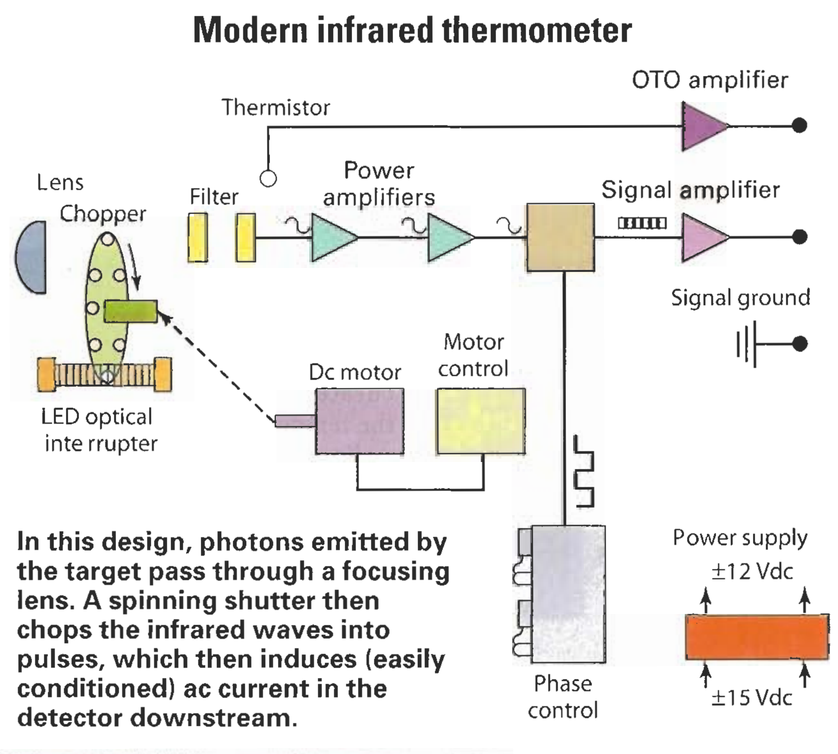
❸ Where high temperatures are involved, drill a 1.5-in. hole 5 in. deep into the object surface. The emissivity of this hole will be 0.98. Measure the hole temperature using the IR thermometer with emissivity set to 0.98. Next, measure the object's temperature next to the hole with an IR thermometer, adjusting emissivity until the thermometer displays the correct temperature.

❹ Paint the object with dull black paint, which has an emissivity of about 1.0. Set the IR thermometer's emissivity accordingly.

❺ Consult an emissivity table, which provides emissivity values for many common materials. Note that this is a last resort because such values are approximations at best.

❻ Consider using an IR thermometer that senses two separate wavelength ranges. Such *two-color* thermometers calculate temperature from the ratio of energies measured at the two wavelength bandwidths.

Information courtesy Omega Engineering. For more information, e-mail the editor at eeitel@penton.com or visit omega.com.



In this design, photons emitted by the target pass through a focusing lens. A spinning shutter then chops the infrared waves into pulses, which then induces (easily conditioned) ac current in the detector downstream.

Contact vs. non-contact measurement

Use infrared measurement when a surface is:

- Too hot to measure with thermocouples
- Too large to measure without several thermocouples
- Moving in a way that could break thermocouple lead wires
- Too high in electrical potential for safe thermocouple use
- So low in mass that the thermocouple itself would influence temperature
- Too fragile or wet to accommodate thermocouple contact
- Too chemically active to accept a thermocouple
- In a particularly hostile atmosphere
- Inaccessible to a thermocouple or its instrumentation
- Close to noise-producing electric or magnetic fields