TECHNICAL NOTE

Precautions for measuring terminal part temperature

§0 Abstract

When using a derating curve based on the terminal part temperature, it is necessary to measure the terminal part temperature of surface-mount resistors (SMD resistors) in a correct procedure. Failure in this measurement will lead to accidents and damages of devices caused by the excessive temperature rise. This Technical Note explains the precautions for measuring the terminal part temperature of SMD resistors.

§1 Temperature measurement by thermography

In recent years, thermography for its easy handling has been put to widespread use for monitoring the temperature of electronic devices. This chapter presents essential points when using thermography.

1.1 Environment for measurement

A thermography is a method which detects infrared-rays (IR) radiated from an object and determines the temperature of the object based on the detected infrared energy. The IR measured by thermography includes not only those radiated from the measuring object but also reflection from the measuring object (Fig. 1). In order to measure the temperature of the object accurately, it is recommended to measure in a room without other infrared sources such as lighting, soldering iron and human body, or without infrared reflections from surrounding objects.

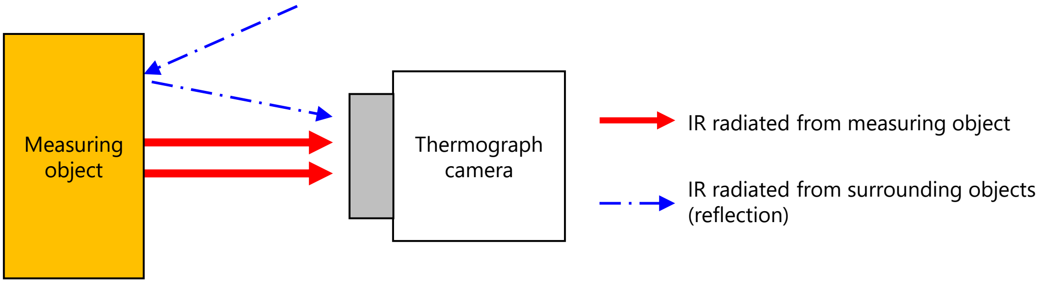


Fig. 1 IR measurement by thermography

1.2 Emissivity of materials

The energy of IR radiated from the measuring object varies with the temperature and emissivity of the material. That is, for the same temperature, a thermograph may show different temperatures depending on the material or surface condition. Therefore, in thermographic measurements, it is necessary to correct the thermograph according to the emissivity of the object to be measured. The emissivity is defined as the ratio of the energy radiated from the surface of a material. It is a dimensionless number between 0 for a perfect reflector and 1 for a perfect emitter. When the object to be measured consists of multiple materials as in the case of a mounted PWB, it is difficult to set a uniform emissivity for the object. In this case, it is advised to apply blackbody (*) paint on the object to be measured in order to bring the emissivity close to 1.

* Blackbody: An ideal body radiating theoretically maximum energy of IR according to the temperature of the body. This body does not reflect any spectrum of light and looks black at room temperature.

Figure 2 shows a thermal image of a mounted PWB with blackbody paint partially applied. The SMD resistors and surrounding PWB with blackbody paint looks uniformly white in the thermal image, indicating that the temperatures is above 100 °C. However, the terminal parts of SMD resistors without blackbody paint are observed to be around 50 °C. This is because the metallic terminal parts have low emissivity and the temperature is observed lower by thermography. It is essential to unify the emissivity of the object with blackbody paint in order to measure the accurate temperature.

blackbody
paint applied

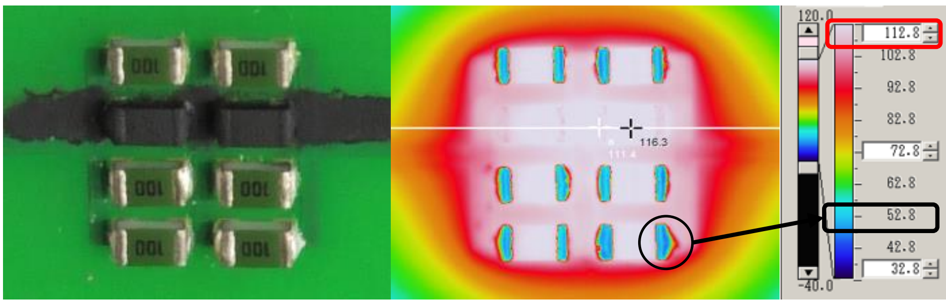
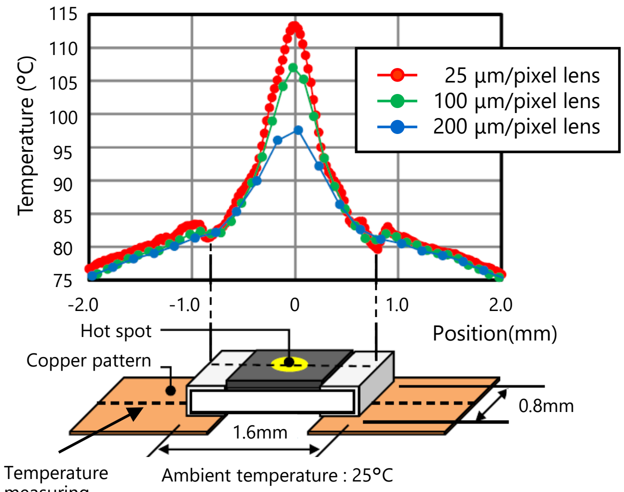


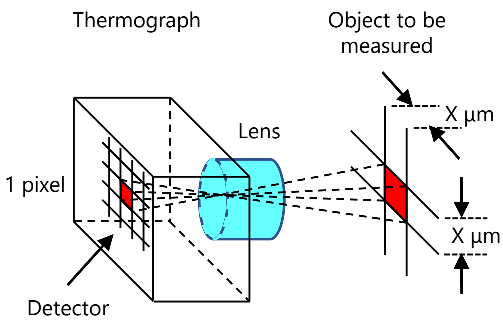
Fig. 2 Thermal image captured by thermography

1.3 Effects of resolution of a thermograph

To accurately measure the temperature of tiny components, such as SMD resistors, it is necessary to take the resolution of the thermograph into consideration. The resolution of a thermograph changes not only with the number of pixels of the detector but also with the magnification of the lens. Explained below is an example of temperature measurement of the SMD resistor(inch size code : 0603) using lenses of different magnification. Figure 3(a) shows the temperature distributions when 0.25 W is applied to the resistor mounted on a PWB. The X µm/pixel lens means that the performance of the lens is capable of enlarging the measured area of X µm square to one pixel of a light receiving element of the detector as shown in Fig. 3(b).



(a) Measurement result



(b) Magnification of lens

Fig. 3 Measurement by lenses having different magnification

As shown in Fig. 3(a), the temperature of the hot spot is observed as 113 °C with the 25 µm/pixel lens, but it is 107 °C with the 100 µm/pixel lens and 98 °C with the 200 µm/pixel lens. This means that the result of measuring the same temperature can vary with the magnification of the lens. The influence of magnification is large in locations with very small area and sharp temperature gradient such as a hot spot on a SMD resistor. So the magnification of the lens is critical when measuring the hot spot. On the other hand, the observed temperatures of the terminal part are much the same regardless of the magnification. Therefore the terminal part is a better location for measurement.

§2 Temperature measurement with thermocouple

Thermocouples are widely used in the temperature measurement of electronic devices. Unlike the use of thermography, temperature measurement using a thermocouple can be done in actual operating environments, in which a PWB is incorporated in a housing. Hence, it is recommended to employ a thermocouple when measuring the terminal part temperature of SMD resistors. This chapter presents precautions for the temperature measurement with a thermocouple.

2.1 Fixation of thermocouple to measurement position

When measuring temperatures with a thermocouple, the junction needs to have a secure contact with the measurement point. KOA recommends soldering for the fixation of thermocouples.
Since the thermocouple conducts electricity, caution is required in malfunction when measuring during operation. Also, the withstand voltage in between the channels and between the channel and the ground of the device to which the thermocouple is connected can be critical depending on the voltage applied to the resistor. Therefore, it is safer to fix the thermocouple to the terminal part on the GND side (Fig. 4). In addition, when measuring multiple points with a measuring instrument, one with insulated channels is required.

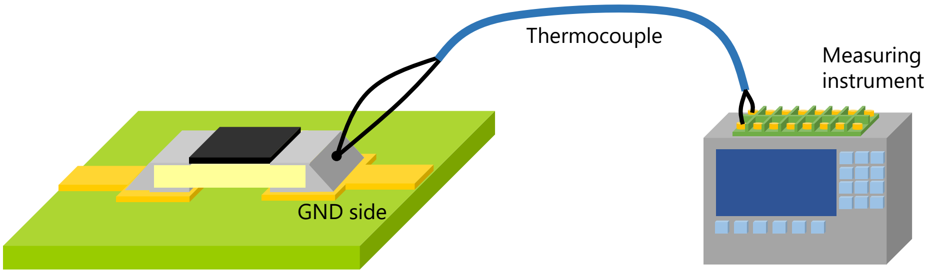


Fig. 4 Connection of thermocouple

A thermocouple fixed with a tape or adhesive may cause erroneous measurement of temperatures. If the thermocouple is fixed with tape, the resilience of the tape may make the junction of the thermocouple to become loose contact with the measurement point (Fig. 5(a)). The tape can also be loosened by aging of the tape or heating of the measuring point, which may cause separation of the measuring point and the junction (Fig. 5(b)). Accurate measurements of temperature can only be expected when the measuring point and the junction have a secure contact. Even when they look in contact, they may in fact be separate from each other. This is why fixing thermocouples with tape is not recommended for measuring terminal part temperature of resistors.
Meanwhile, fixation with an adhesive may cause a gap by intrusion of the adhesive in between the measuring point and the junction during the curing process. This can also result in erroneous measurement of temperatures, because the measurement is done via the adhesive (Fig. 6).

(a) Initial state of fixation (b) Separation due to aging or heating

Fig. 5 Faulty fixation with tape

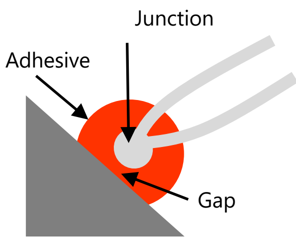


Fig. 6 Faulty fixation with adhesive

2.2 Treatment of the junction

Thermocouples are delivered with the tip already welded or loose. If the end of thermocouples are twisted instead of welding, the measuring junction of the temperature will be at the beginning of the twist, not at the tip of the thermocouple. This will result in measurement of temperature taking place away from the intended measuring point (Fig. 7(a)). Forming the junction by soldering the wires together will also require caution. Separation of wires may occur during soldering process, which will result in erroneous temperature measurement (Fig. 7(b)).
Hence, it is advisable to weld the end of the thermocouple for temperature measurement (Fig. 7(c)).

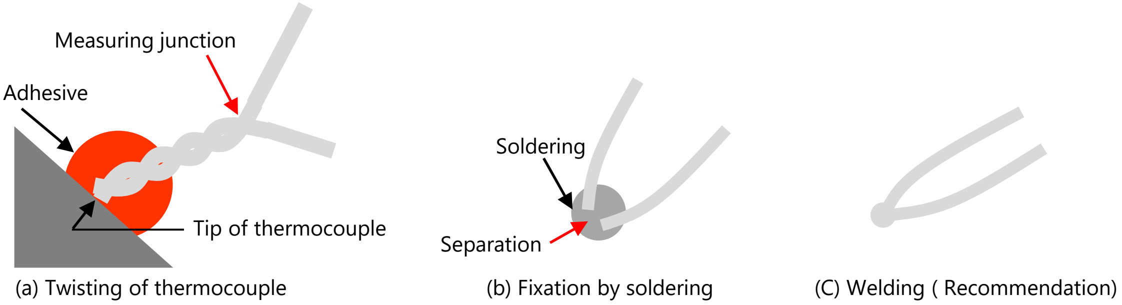


Fig. 7 Forming of the junction

2.3 Heat dissipation via thermocouple

To measure the temperature with a thermocouple, it is necessary to fix it to the terminal part of the resistor. At the same time, this thermocouple also acts as a new heat dissipation path. This new path from the thermocouple into the ambient air causes temperature drop as shown in Fig. 8. This temperature drop is shown as ΔT. For accurate temperature measurement, it is essential that ΔT is held to a minimum.

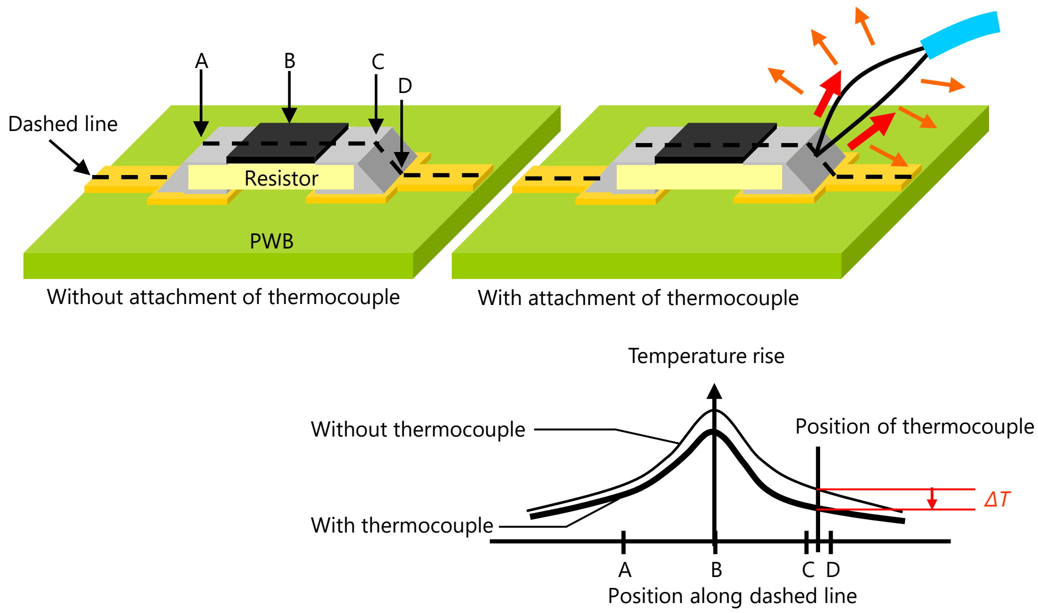


Fig. 8 Temperature drop caused by thermocouple

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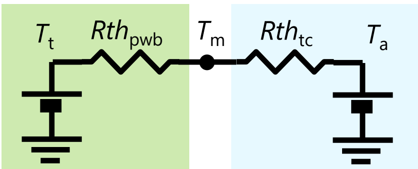
Precautions for measuring terminal part temperature

In this part, type-T and type-K thermocouples are compared. The type-T thermocouple with a diameter of 0.2 mm is widely used. It is made of a combination of copper wire and constantan wire. Copper has high thermal conductivity and dissipates much heat. This causes large Δ*T*, making type-T unsuitable for measuring terminal part temperature of resistors.
KOA recommends the use of type-K thermocouple with a diameter of 0.1 mm. The type-K thermocouple is made of a combination of alumel wire and chromel wire. Their low thermal conductivity curb the heat dissipation. Table 1 shows the results of Δ*T* calculated using a simplified thermal network shown in Fig. 9. *Rth* represents the thermal resistance, which is the objects' ability to resist the heat flow.

* Thermal network method: A technique for analysis of thermal characteristics by use of a circuit of thermal behavior analogous to electricity in an electric circuit. Please contact us for any inquiry about details.



T_m : Temperature measured by thermocouple
T_a : Ambient temperature
T_t : Terminal part temperature
Rth_{pwb} : Thermal resistance of PWB
Rth_{tc} : Thermal resistance of thermocouple

Fig. 9 Thermal network when thermocouple is attached

Table 1 Calculated Δ*T* using the thermal network

Thermo -couple type	Wire diameter (mm)	*Thermal resistance* (°CW^{-1})		*Terminal part temperature* T_t (°C)	*Measured temperature* T_m (°C)	*Temperature drop* ΔT (°C)
		Rth_{pwb}	Rth_{tc}			
K	0.1	300	5500	**100**	**96.1**	**3.9**
T	0.2	300	1000	**100**	**82.7**	**17.3**

The temperature difference Δ*T* is 3.9 °C for type-K with a diameter of 0.1 mm, whereas it is 17.3 °C for type-T with a diameter of 0.2 mm. In addition to the difference of the material, the small diameter increases the thermal resistance and curbs the heat dissipation. KOA recommends the use of type-K thermocouple with a diameter of 0.1 mm featuring small Δ*T*.

* Note that soldering of the type-K can be done by using high active flux for stainless steel.

§3 Conclusion

For power derating based on the terminal part temperature, it is of prime importance to measure the terminal part temperature accurately. When measuring by thermography, a proper measuring environment must be prepared, the emissivity must be adjusted, and a lens with an appropriate magnification for the object to be measured must be used. When measuring with a thermocouple, it is important to take into account the way of attaching the thermocouple, the treatment of the wire end, and the temperature drop; Δ*T* due to the heat dissipation via the thermocouple. The Δ*T* may be lessened by use of a type K thermocouple with a diameter of 0.1 mm.
KOA offers various supports, such as guidelines on the procedure of measuring the terminal part temperature. Feel free to contact us for inquiries.