Pyroelectric IR Sensor with Surface Mount Capability

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Abstract

Pyroelectric IR sensors have been used as human detection sensors in security applications because of their low power consumption, non-requirement of peripherals, possibility of human/object differentiation, and simplicity of wiring and signal processing circuitry. They are recently being applied as power conservation measures and for improving comfort and convenience by switching equipment operations based on the detection of human presence/absence. At the present time sensors incorporated in electronic equipment are subject to needs that were not previously relevant, such as compatibility with surface mounting as well as reflow soldering optimized for mass-production, a low sensor profile and resistance to the effects of vibrations and signals generated by other devices in the equipment. This paper introduces the pyroelectric sensor as a device that meets these requirements.

Keywords

human detection sensor, power saving, reflow compatibility, pyroelectric effect, sensitivity

1. Introduction

The pyroelectric IR sensor (hereafter “pyroelectric sensor”) has traditionally been used in human detection sensors for security applications because of its low power consumption, non requirement of peripherals such as lighting equipment, capability of human/object differentiation, and the simplicity of wiring the signal processing circuitry of the subsequent stage.

Furthermore, the recent worldwide trend in innovative power saving devices has begun to include pyroelectric sensors in electronic equipment including in home appliances. These devices are contributing to the reduction of power consumption of the applications that switch the equipment operation mode upon the absence of humans being detected in range of the sensor. The equipment operation switching based on detection of human presence/absence is also being applied in fields for improving the comfort and convenience of our everyday lives.

At present, the sensors incorporated in electronic equipment are subject to previously non-existing requirements, such as compatibility with surface mounting as well as reflow soldering optimized for mass-production, low sensor heights for enabling equipment thickness reduction and resistance to the effects of vibrations and signals generated by other devices in the equipment. This paper introduces a low profile pyroelectric sensor that features high sensitivity and resistance to the reflow soldering temperature for enabling surface mounting.

2. Principles of the Pyroelectric Sensor

2.1 Pyroelectric Effect

Fig. 1 and **Fig. 2** explain the operating principles of the pyroelectric sensor.

Fig. 1 is a schematic diagram of a pyroelectric sensor. The electrical operations of the pyroelectric sensor are determined by the pyroelectric element and the junction field effect transistor (JFET). The JFET is used to convert the very high impedance of the pyroelectric element. Its drain (D) terminal is connected to the power supply and the gate (G) terminal to the pyroelectric element. When IR rays are activated, the pyroelectric element discharges electric charges and causes the

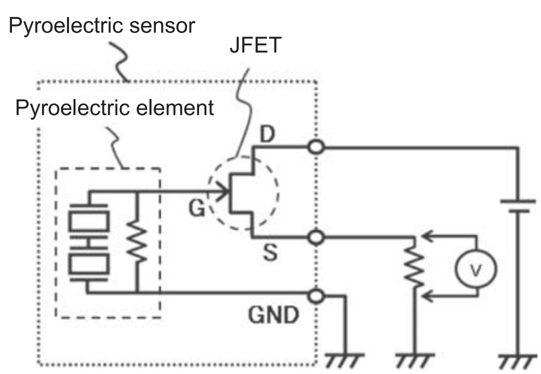

Fig. 1 Schematic diagram of a pyroelectric sensor.

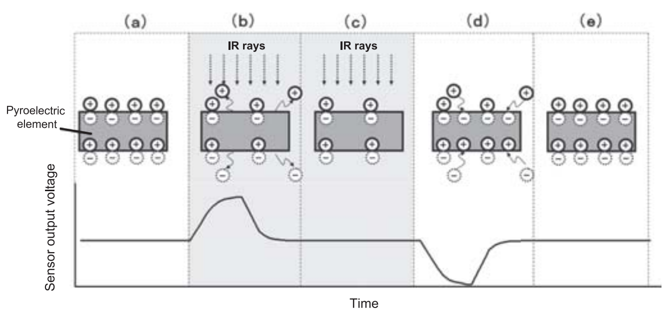

Fig. 2 Pyroelectric effect and sensor output voltage.

gate voltage to vary. As a result the variation in the current drained from the source (S) terminal and the subsequent variation in the potential difference across an externally attached resistor causes the change in the IR rays to be detected. If the IR rays are not irradiated onto the pyroelectric element, the current leaked from the Drain terminal to the Gate terminal and the resistance of the pyroelectric element apply a voltage to the gate terminal and a DC voltage is generated across the resistance connected to the Source terminal (this DC voltage will hereafter be referred to as the offset voltage).

Fig. 2 shows the relationship between the presence/absence of IR radiation and the pyroelectric sensor output voltage. Period (a) shows the status in which IR rays are not present. Electrical deviation called spontaneous polarization is generated inside the pyroelectric element, but it is neutralized by atmospheric ions. As the pyroelectric element is apparently without charge, the sensor output is equal to the offset voltage.

At the moment IR rays are irradiated in (b), the rise in the pyroelectric element temperature alters the spontaneous polarization status and the gate voltage of the JFET changes instantaneously. This phenomenon results in variation of the sensor output voltage.

Thereafter, even when the IR rays continue to be irradiated, the temperature of the pyroelectric element does not change from status (b) so the sensor output voltage is kept at the offset voltage as shown in (c).

When the IR rays are interrupted in (d), a change occurs in the pyroelectric element to return the temperature and the spontaneous polarization to the status in (a). As a result, the sensor output voltage at this time presents a reverse potential to (b) with respect to the offset voltage.

Subsequently, if the IR rays continue to be interrupted, the temperature of the pyroelectric element does not change from status (d) so the sensor output voltage remains at the offset voltage as shown in (e).

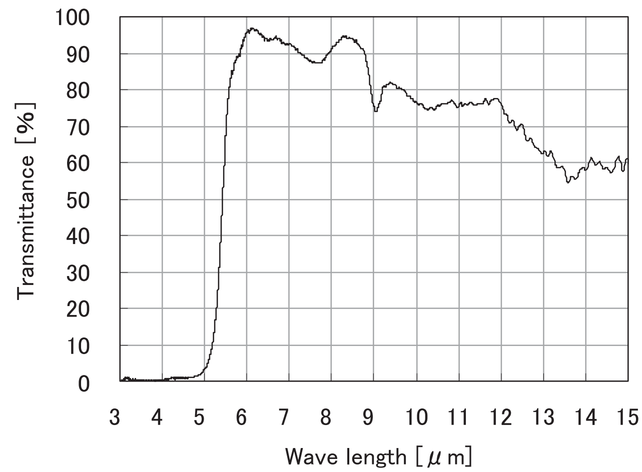

Fig. 3 General characteristic of the long-pass filter.

As seen above, the pyroelectric sensor generates output only at the moment the IR rays start to be irradiated or are interrupted.

2.2 Application as a Human Detection Sensor

The pyroelectric effect described above has low wavelength dependency with IR rays. Therefore, when using a pyroelectric sensor as a human detection sensor, a frequency filter is attached at the light receptor of the sensor. Although a band-pass filter transmitting only the wavelengths around 9 and 10 μm that correspond to the IR rays emitted by the human body is ideal, a long-pass filter is used generally due to cost considerations etc. **Fig. 3** shows the general transmittance characteristics of a long-pass filter for use as a pyroelectric human detection sensor. In this example, too, a filter with which the transmittance of short wavelengths is reduced is used to prevent malfunction due to external disturbance, etc.

As discussed above, a human detection sensor that outputs a signal when a human being comes into or goes out of the detection range can be fabricated by combining a pyroelectric sensor and a frequency filter.

3. Basic Characteristics of a Pyroelectric Sensor

In general, a pyroelectric sensor is easier to use when the electrical power of the detection signal is larger compared to the input of the same physical quantity, just like other sensors.

At NEC TOKIN, we started development of a pyroelectric sensor from the stage of choosing the pyroclastic material to be used. The rest of this section describes the relationship between the material evaluation index (referred to as Fv - valuation factor - in the formula below), which is the index of the performance of each pyroelectric material, and the pyroelectric sensor output voltage.

3.1 Material Evaluation Index

When the material is in the block condition before being divided into the shapes of individual pyroelectric elements, the material evaluation index (Fv) that can be used to judge the performance of the pyroelectric material, can be expressed by formula (1).

$$Fv = \frac{\lambda}{Cp \cdot \varepsilon r} \qquad (1)$$

λ: Pyroelectric coefficient.
Cp: Constant pressure specific heat.
ε r: Relative permittivity

where the pyroelectric coefficient λ can be expressed by formula (2).

$$\lambda = \frac{1}{S}\frac{I}{\varDelta T} \qquad (2)$$

S: Surface area.
I: Pyroelectric current.
$\varDelta$T: Temperature change.

As shown above, the material evaluation index (Fv) can be calculated by measuring the current I produced when a sudden temperature change ΔT is applied to the material.

3.2 Material Evaluation Indices and the Pyroelectric Sensor Output Voltage

We prepared several levels of pyroelectric materials with variable material evaluation indices (Fv), processed them into pyroelectric elements of the same shape and arranged them in packages of the same structure to fabricate the pyroelectric sensors. We then measured the output voltages of these pyroelectric sensors according to the measurement system shown in **Fig. 4** .

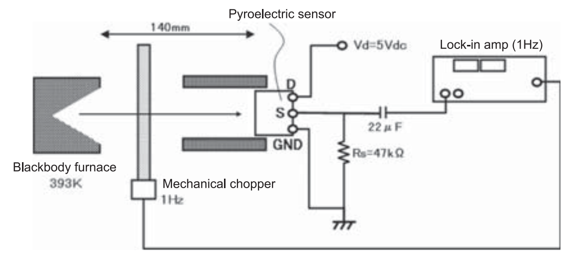

Fig. 4 Measurement system.

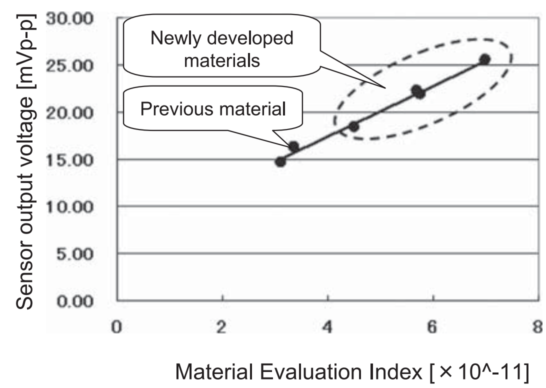

Fig. 5 Material evaluation index and sensor output voltage.

As shown in Fig. 4, the blackbody furnace irradiates the IR rays, which are divided by 1 Hz time division of the mechanical chopper before being received by the pyroelectric sensor. We eliminated the DC component from the pyroelectric sensor output and then measured it with a Lock-in amplifier. The results were as shown in **Fig. 5** , which indicated that there is a linear relationship between the material valuation index and the sensor output voltage. This means that the output voltage of a pyroelectric sensor can be estimated by measuring/calculating the material evaluation index of the pyroelectric material when it is in the block status. This information enabled efficient development of new materials and actually allowed us to develop pyroelectric materials that can improve the sensor output voltage considerably compared to our previous pyroelectric material as shown in Fig. 5.

4. Improvement of Sensor Performance

4.1 Reflow Compatibility

The assembly of mass-produced equipment often involves

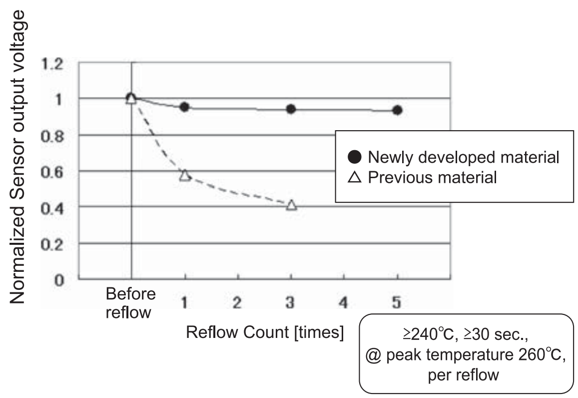

Fig. 6 Reflow count and drop in sensor output voltage.

the technique of mounting parts using a surface mounting tool and by then soldering them using a reflow furnace. Consequently, the pyroelectric sensor should withstand the reflow temperature so that it can be used in surface mounting. In general, reflow soldering is performed for a few seconds at temperatures near 260 degrees C. This process is sometimes repeated twice or more.

However, the material transition point of our previous pyroelectric material, called the Curie point was not high enough for the reflow temperature. Its material evaluation tended to degrade after having been processed by the reflow furnace.

NEC TOKIN has also succeeded in raising the Curie point of the developed pyroelectric materials. **Fig. 6** shows the change in the sensor output voltage when one of the developed materials is incorporated in a sensor device and is subjected to repeated reflow. With the previous pyroelectric material that was from our inventory, the output drops below 60% after single reflow, but the newly developed material presents little drop in output voltage even after five times of repeated reflow.

4.2 External Disturbance Resistance

When a pyroelectric sensor is embedded in electronic equipment the potential risk of disturbance from other devices in the same equipment will increase. We adopted various structural improvements to deal with the associated problems. In the following we review the results obtained from a structure that is resistant to the influence of vibration of the magnetic wave-source devices that are often used in electronic equipment.

Fig. 7 shows the measurements of the sensor output voltage when a pyroelectric sensor is soldered onto a PC board and

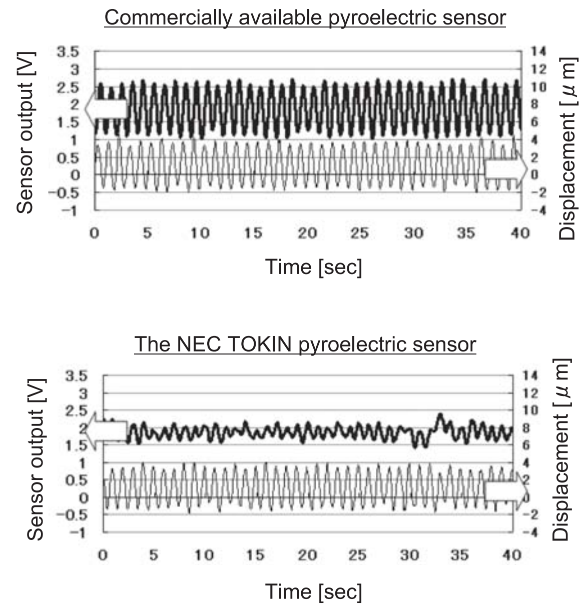

Fig. 7 Comparison of output voltage under vibration.

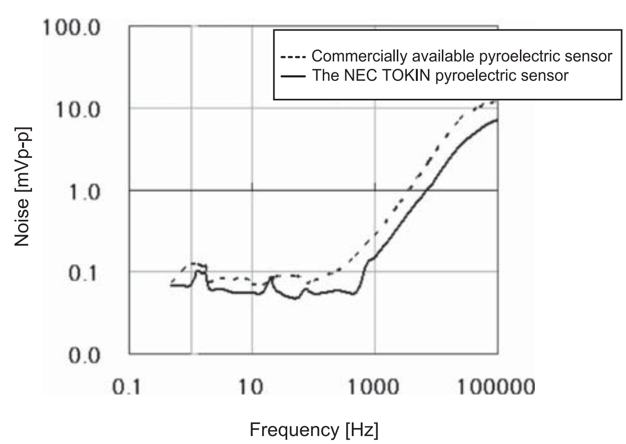

Fig. 8 Comparison of noise characteristic in the electrical field.

vibrations are applied to the board. The vibrations applied to the PC board had amplitude of 5 μm and a frequency of 1 Hz. As the IR rays were not irradiated during the measurements, the output voltage should desirably be free of charge. However, the pyroelectric sensor output voltage actually varied due to the vibrations. Nevertheless, when the same vibrations are applied to PC boards on which different pyroelectric sensors are mounted, the output voltage variation of our present pyroelectric sensor was about 1/3rd that of the commercially available pyro sensors.

Fig. 8 shows the measurements of the output noise of pyroelectric sensors when an electrical field is generated in the proximity of each sensor. Even when the frequency of the electrical field is varied, the noise output of our present pyroelectric sensor was lower than that of the commercially available pyroelectric sensors.

5. Device Implementation

The incorporation of various measures including the above improvements has led us to the successful development of a pyroelectric sensor with a surface mounting compatibility. **Photo** shows the external view of the completed pyroelectric sensor and **Table** shows its basic specifications.

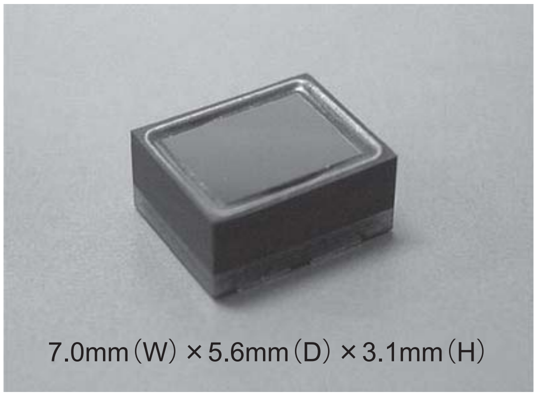

Photo External view of developed pyroelectric sensor.

Table Basic specifications of the developed pyroelectric sensor.

Parameters	Units	Criteria	Condition
Output Voltage	mVp-p	24(MIN)	Heat source：393K(Φ10),1Hz
Output Balance	%	±10%(MAX)	｜Va-Vb｜/ (Va＋Vb)×100
Offset Voltage	V	0.2 ～ 2.0	Vd＝5V,Rs＝47kΩ
White Noise	mVp-p	250(MAX)	Amp：72dB,Rs＝47kΩ
Field of View	deg	θ1(V)：±50° θ2(H)：±75°	Angles between element end and opening end
Supply Voltage	V	2.0 ～ 15.0(DC)	-
Operating Temp.	℃	-40 ～＋70	-
Storage Temp.	℃	-40 ～＋85	-

6. Conclusion

This paper introduced the basic principles of the pyroelectric sensor device and described a pyroelectric sensor featuring ease of equipment embedding and reflow compatibility developed by NEC TOKIN for use in new kinds of applications.

It is expected that the requirements for power saving, size reduction and comfort/convenience improvements will be expanded via various equipment developments, and we also believe that the scope of the applications of pyroelectric sensors in such equipment will increase in the future. NEC TOKIN intends to advance the development of pyroelectric sensors by targeting further improvements of their characteristics and size reductions.

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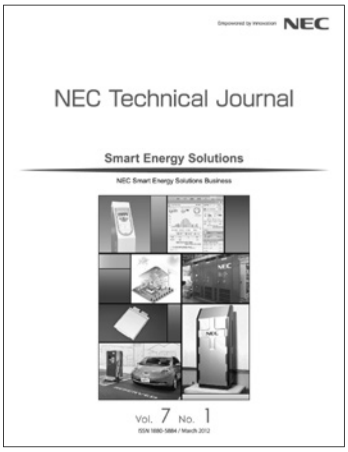

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