Thermal Diode Infrared Sensor "MelDIR" and User Support Tools

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1. Introduction

IoT is essential in our lives and accompanying this we are surrounded by a variety of sensors. Among those are infrared sensors whose characteristics include the ability to detect people and objects while securing privacy. In this paper, we introduce the features of the thermal diode infrared sensor MelDIR which uses Mitsubishi Electric unique technology and we introduce the development of user support tools which support customers from product planning to commercialization.

2. Thermal Diode Infrared Sensor

The infrared sensor has a function which detects and enables visualization of the heat from objects without contact by converting the infrared radiation received into an electric signal. Figure 1 shows those features. (1) Because the sensor can acquire the heat information from the heat source without contact, it is excellent from the view of hygiene and safety. (2) It can determine a person's motion or posture from the silhouette of the heat source. This is particularly effective in scenarios where privacy protection is required, so the sensor can be used even in toilets or bathrooms where cameras cannot be installed. (3) The heat source can be detected even in darkness or where there is no visibility due to smoke, so the sensor can be used with peace of mind even indoors at night.

Mitsubishi Electric developed new resolution and price range product MelDIR compared to conventional thermopiles and bolometers using its unique thermal diode sensor technology.

The thermal diode Technology features the use of a PN junction diode formed in the general silicon semiconductor manufacturing process for the temperature detection area. This technology has good compatibility with semiconductor processes as well as for bolometers, so it's suitable for multi-pixelization. The thermal diode performs thermoelectric conversion by detecting the temperature dependence of the forward voltage drop of the diode.

The forward voltage of the diode changes approximately linearly with temperature, and its characteristics are determined by the process conditions of the semiconductor, so it can be manufactured with high uniformity.

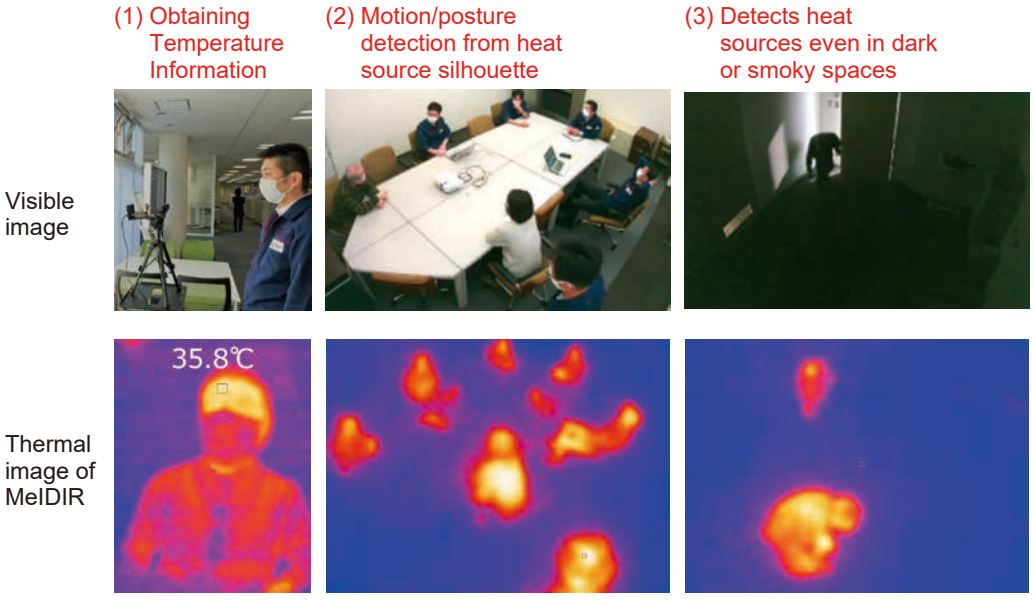


Fig. 1 Features of infrared sensor

*High Frequency & Optical Device Works

3. MelDIR Thermal Diode Infrared Sensor

The conventional infrared sensor market has polarized into low pixel, low cost products for heat detection uses, and high pixel, high price infrared cameras for infrared imaging uses. Using unique technology, Mitsubishi Electric developed infrared sensor module MelDIR with a high pixel count at an unprecedented low cost. Table 1 shows our product lineup. In 2019, we released the MIR8032B1, and it was used mainly in Japan for monitoring in elderly people's facilities and was also installed in air conditioners. In 2023, we released the MIR8060B3, targeting markets such as factory equipment surveillance and kitchen temperature management which require object detection at higher temperatures. This product increased the maximum measurable object temperature from +60°C to +200°C by optimizing the signal processing and the lens.

Because the thermal infrared sensor thermoelectrically converts the temperature rise part, the detection sensitivity falls if the heat conductance is high between the temperature detection area and the surrounding environment. In addition, if the heat conductance is high between the surrounding pixels, the resolution decreases because the heat detected by the pixels is transmitted to the surrounding pixels. Therefore, the space between the diode and the silicon substrate is hollowed out to form a structure in which the diode is held by supporting legs. By placing the electric line in these support legs, the thermal conductance between the diode and the silicon substrate is lowered while maintaining the structure and electrical connection. This supporting leg structure is formed by carrying out dry etching of the thin film Silicon On Insulator (SOI) substrate which enables low cost manufacture. Figure 2 shows a SEM image of thermal diode area. It can be confirmed that the hollowed out structure, in which the 25 um pitch temperature detection area is maintained by the supporting leg structure, is formed uniformly.

4. User Support Tools

Figure 3 shows the series of user support tools. We have prepared a proposal paper to support the customer's product concept making stage. It provides a wealth of thermal image examples to show them ideas of how to use MelDIR, it indicates the benefits, etc. of adopting MelDIR, and provides a stepping stone for starting their evaluation.

We provide a dedicated demo kit for customers to evaluate MelDIR. In 2022, We released the EVA series of demo kits, that integrate MelDIR, shutters, and substrates and further reduce the substrate area to about 45% of the conventional size. Figure 4 shows a photograph of the demo kit. It's available and ready to use, it does not require any additional time for evaluation preparation.

In order to provide design information for the required hardware and software at the customer's product development stage, we developed a reference design. The reference design summarizes the design information of the EVA series demo kit, and the design information for hardware such as BOM and Gerber, and

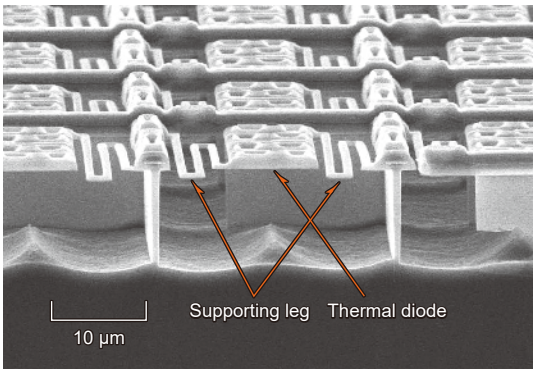
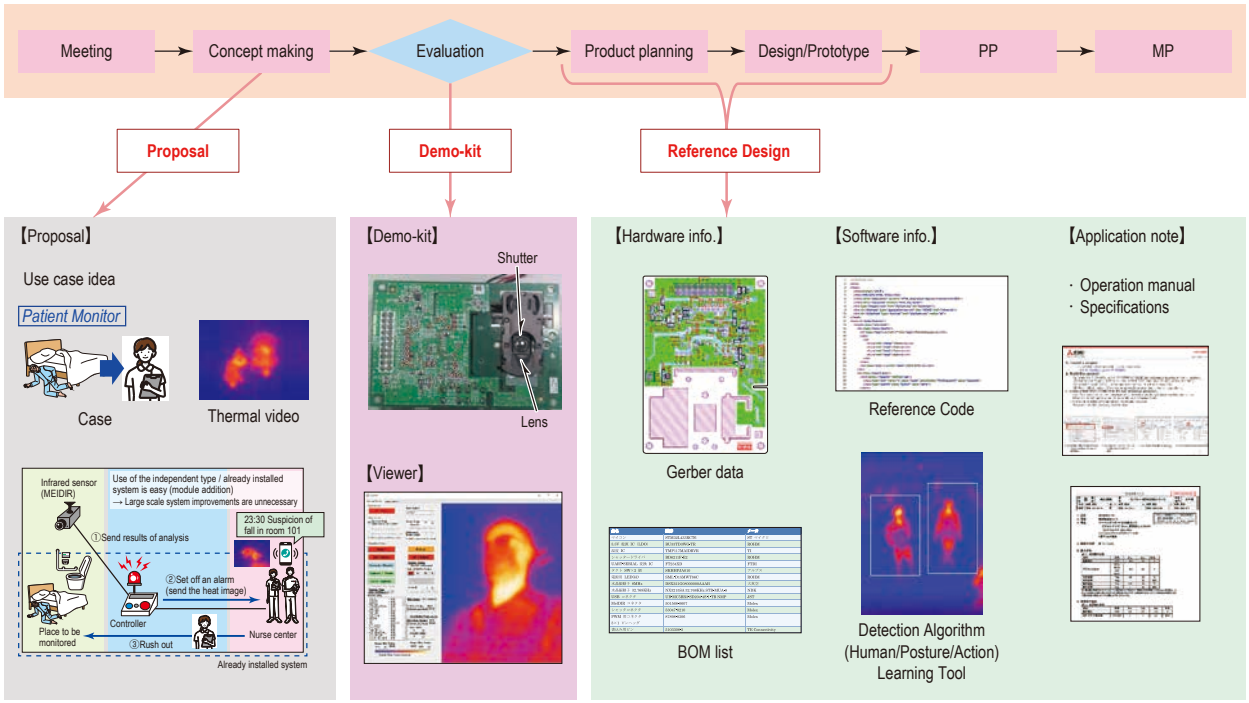


Fig. 2 SEM image of thermal diode

Table 1 MelDIR product lineup

Type No.	MIR8060B3	MIR8060B1	MIR8032B1
Launch date	Mar. 2023	Jul. 2021	Nov. 2019
Detectable temperature range	-5℃ ~ +200℃	-5℃ ~ +60℃	-5℃ ~ +60℃
Number of Pixels	80×60	80×60	80×32
Field of View	78°×53° (Typ.)	78°×53° (Typ.)	78°×29° (Typ.)
Frame Rate	4 / 8 fps Selectable	4 / 8 fps Selectable	4 fps Fixed
NETD	250 mK (Typ.)	100 mK (Typ.)	100 mK (Typ.)
Power consumption	50 mA or less		
Module Size	19.5×13.5×9.5 mm		
Communication interface	Serial Peripheral Interface (SPI)		



All stage in development would be supported by each tool

Fig. 3 MelDIR User Support Tools

Fig. 4 Demo kit "EVA-MIR8060B1-MC02V1-01"

Table 2 Heat source detection algorithm and hardware specifications

Item	Specification
Type No.	MIR8060B1-01
Type No. of Demo kit	EVB-8060B1-MN****
Type No. of reference code	SAPM-MD**V*
Target MCU	STM32H723_G (Cortex-M7 1177 DMIPS@530MHz)
Deep learning algorithm	MobileNetV2-YOLOv3-Nano
Rom size	<1Mbyte
Ram size	<512Kbyte
Frame rate	7fps(=142ms/frame)

the software design such as object detection by deep learning and reference code, and application notes such as several kind of manuals. These tools contribute to reducing product development period.

We provide heat source detection algorithm using the deep learning in reference designs. The detection algorithm based on You Only Look Once (YOLO) is optimized for use with MelDIR, and it has the characteristic that it is developed as an edge AI to target a general-purpose Micro Controller Unit (MCU) for embedded use. Table 2 shows the heat source detection algorithm and the hardware specifications.

Since November 2022, we have been offering two algorithms: a human detection algorithm which detects people in a living room, and a posture detection algorithm which detects the posture in a toilet stall and judges whether or not there is any abnormality.

The detection algorithms provided may not achieve sufficient detection accuracy depending on the customer's usage conditions. For this reason, we developed and have been offering a model training tool (MTT-V001) with the purpose of creating an AI model to match the respective usage environments. Furthermore, we have been also offering a manual to summarize the series of work procedures of extraction of gray scale images, annotations, AI model creation, and embedding

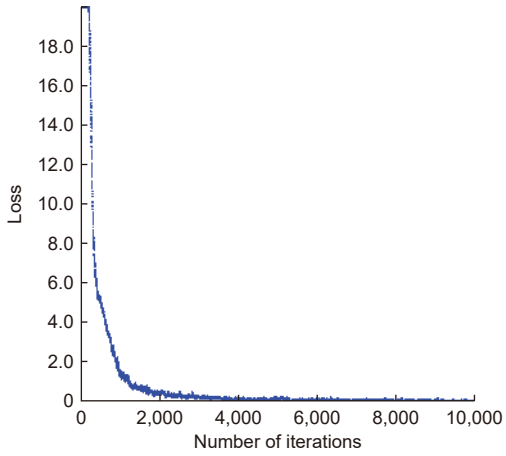


Fig. 5 Example of a training result

in a MCU, and are arranging an environment in which the customer themselves can optimize for their own products.

Figure 5 shows an example of the training result. It shows that as the number of iterations increases, the loss is decreased and the calculation is converged. In this example, for 10,000 iterations, mean Average Precision (mAP), which is the detection rate index, achieves 80% or more.

5. Conclusion

We released MIR8060B3 as a new product of MelDIR in 2023. By expanding the upper limit of the detection temperature range from the conventional +60°C to +200°C, we have made it possible to meet the growing needs of monitoring factory equipment and temperature control in kitchens. Furthermore, we have enhanced our user support tools to assist in customer evaluation and product development, contributing to a reduction in time to market. We released the EVA series of demo kits, that integrate MelDIR, shutters, and substrates and further reduce the substrate area to about 45% of the conventional size. Furthermore, in order to provide the hardware and software design information necessary for the customer's product development, we prepared a reference design.

We aim to expand the application of these product lineup and support tools to a wide variety of fields, and contribute to the realization of secure, safe, and healthy society.