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CaliPile™: Wide Angle Lens-less Motion- and Presence Detection

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Abstract:

We have developed a sensor that consists of a single-pixel thermopile and a signal-processing unit in a single package, which is able to detect people in a range of up to 3 meters. The device can work without any optical system such as a multifocal Fresnel lens. In order to suppress unwanted false triggers an internal background subtraction algorithm is applied. Besides motion and presence detection, also temperature measurement and monitoring features were implemented in the compact SMD package. The combination of an interrupt feature and a very low power consumption of only 50 µW make this device ideal for space-constraint consumer devices.

Key words: Smart Thermopile, Presence and Motion Detection, Remote Temperature Measurement

People Detection of Today

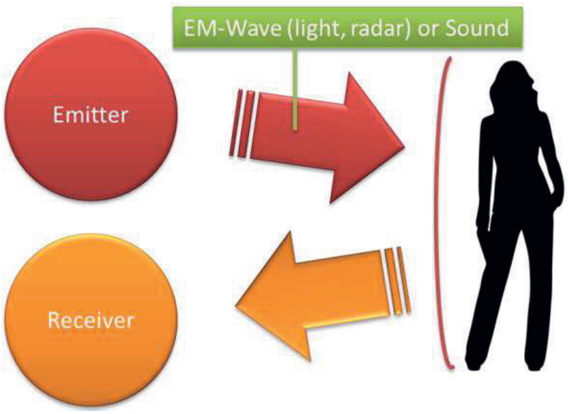

Fig. 1. People detection through an active emission and reception of waves.

The remote detection of persons can be sub-divided into mainly two categories: active and passive systems. Active systems consist of an emitter which sends out electromagnetic or sonic waves to be reflected by the surface of the object to be detected into a receiver. This lock-in principle is very reliable and often even allows for the measurement of a distance. Typical examples are LiDAR, Ultra-sonic sensors and Proximity Sensors.

However, to achieve a large field of view (> 10°) and long distances (> 50 cm) the emission power has to be scaled accordingly and/or the sensitivity of the receiver needs to be increased. Moreover, the distinction between (cold) objects and persons is difficult without larger efforts on the software side. In the end low power (< 100µW) and low profile (< 5mm z-height) solutions for battery operated systems are hard to find.

Passive systems use naturally emitted waves and those can be therefore much lower in power consumption.

The obvious approach is to measure the visible light through CMOS or CCD cameras and to process the data to detect features and to search for motion patterns. But again, challenges are low-light conditions which in turn require a light source as well as the low-power condition since sensors still require a back-end feature analysis running on the host system.

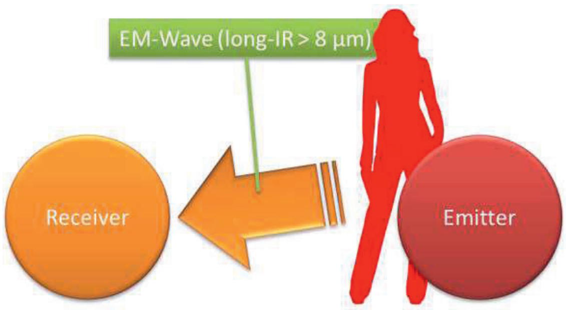

Fig. 2. People detection through passive detection of (infra-red) waves.

One of the most successful passive systems on the market is based on the detection of infrared light which is being emitted from warm objects. As long as the temperature of the person is different from the background, a person itself can be distinguished at wavelengths above

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5 µm which is regarded as the far-infrared (FIR) region. As receiver, commonly a pyroelectric material is being employed which is sensitive to temperature changes. This system is typically referred to as Passive Infrared (PIR) Sensor.

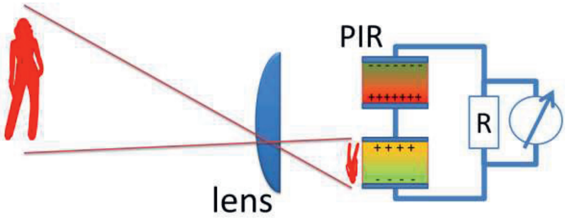

Fig.3. Functional principle of a pyroelectric sensor with a lens.

Any variation of the PIR's temperature alters the field-strength inside the polarized material which can be sensed as a current flow through a resistor. Once the PIR has discharged, no further signal is generated as long as the temperature stays constant. To compensate for ambient temperature changes, pairs of PIRs are arranged oppositely to each other. To distinguish a person from the ambient, a lens is used to project the radiation onto one of both elements only. A wider field of view is achieved by arranging several lenses looking into different directions in the room (not illustrated). As long as the person is not moving, no signal is generated. Those motion detectors are very cost effective and reliable, but the major drawback is the necessity for the lens which adds a certain z-height to the total component size.

We are here presenting a solution for the near and medium distance detection of people which are approaching a sensor, without the need for additional lenses. Under certain conditions, even no movement is necessary to sense the presence of a person.

CaliPile™: The Smart Thermopile

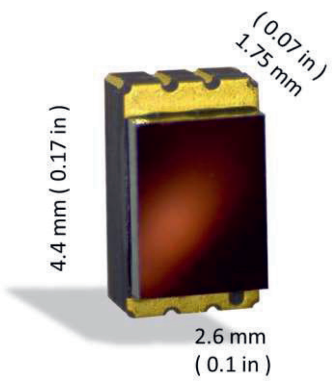

Fig.4. The CaliPile™ in the SMD ceramic package.

We have developed a sensor that consists of a single-pixel thermopile and a signal processing unit in a single LCC package. The sensor is able to detect people in a distance of up to 3 meters without any further optical system. Detection can be achieved within the sensor's very large field of view of 120°. The thermopile's advantage over a pyroelectric PIR is the voltage output which is proportional to the net radiation onto the sensor. Even a resting person is creating a constant signal for further analysis.

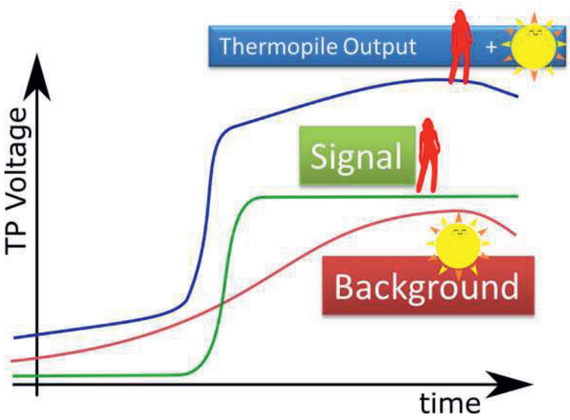

Fig.5. Contribution to the IR light generating the thermopile voltage.

The signal analysis is being performed as depicted in figure 6. The raw thermopile detector data consists of 3 major components and may look like sketched in figure 5: The signal from the object itself (person approaching), a background contribution from the ambient (sun, air-conditioning, etc.) and the noise from the thermopile and the electronics.

The data is being passed through two independent transformation and filtering stages which are in fact low pass filters with different cut-on values. One low pass filter possesses a long time constant and thus eliminates fast changes in the raw data. What remains is the major component of the slowly changing background.

In contrast to the slow temperature changes of the ambient forming the background, a person is moving significantly faster. The second filtering stage has therefore a faster response and removes only the high frequency contribution of the noise. This leaves us the background and the signal of the person. The decision, if a person is sensed or not is done by subtracting both filtered data and assigning a threshold on that background subtracted signal. If the result exceeds the preset threshold, the CaliPile™ sends an interrupt to the host system to wake it up for further actions.

Once a person is detected, it is possible to set a threshold on the absolute raw thermopile data. As long as the person is the dominating

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contribution to the data, presence can be sensed and an interrupt will be generated once the person leaves the field of view.

The small SMD package measures only 4.4 x 2.6 x 1.7 mm³ featuring a wide 120° field of view and a very low power consumption of only 50 µW @ 3.3 V power supply. In addition, a fully configurable interrupt feature, I²C communication and addressing for up to 4 devices on one BUS. The EEPROM contains moreover calibration data which allows the measurement of the ambient as well as the object temperature in the same application. For the application of remote temperature measurement also versions with lenses in the established (iso-thermal) TO-packages are available, providing a well-defined distance to spot ratio of up to 11:1.

Applications

The cost-effective CaliPile™ solution allows for completely new approaches in the system design. In Internet-of-things (IOT) applications for example, it is possible now to build up grids consisting of very compact battery operated wireless devices, monitoring the occupancy of a room. Thin battery operated human interfaces can be waked up upon the arrival of a person and put to sleep when the person is leaving. The limitations in size are not given any more by optical restrictions.

Comparison to PIR Sensors

Thermopiles are able to sense a DC IR-radiation. The voltage output is proportional to the net IR-radiation on the thermopile. While slowly moving persons will be not recognized by a pyro-electric sensor, the voltage of a thermopile will follow the total received IR-power, allowing for the recognition of motion without a lens.

Many pyro-electric ceramics are not able to with-stand high soldering temperatures without depolarization. Pyro-electric devices in SMD packages can therefore be only produced with very special type of material. Thermopiles are resistant to reflow processes.

Pyro-electric sensors are very susceptible to electro-magnetic distortions due to the very strong electric fields inside. A metal-can TO-package is thus the best choice for the optimal performance. Thermopiles are much less influenced by electromagnetic components of to-days high frequency wireless devices and can be generally used in SMD packages.

While pyro-electric sensors are mainly sensitive to motion parallel to the sensor plane, thermopiles can also evaluate if a person is approaching or leaving since the signal will raise or fall depending on the fill factor of the field-of-view.

Still, to reach long sensing distances of more than 3 m, the customer must apply a lens in front of the sensor. This is due to the fact that even when the CaliPile™ contains one of the most sensitive thermopile chips available on the market, it is still up to 10 times less sensitive than a standard dual PIR at a frequency of 1Hz. So even when opening new markets and giving a completely new freedom in the device design, the classical domain of motion detection with PIR remains untouched. The CaliPile™ is the ultimate solution where the PIR sensor reaches its limitations: in today’s space restricted consumer devices, i.e. IoT.

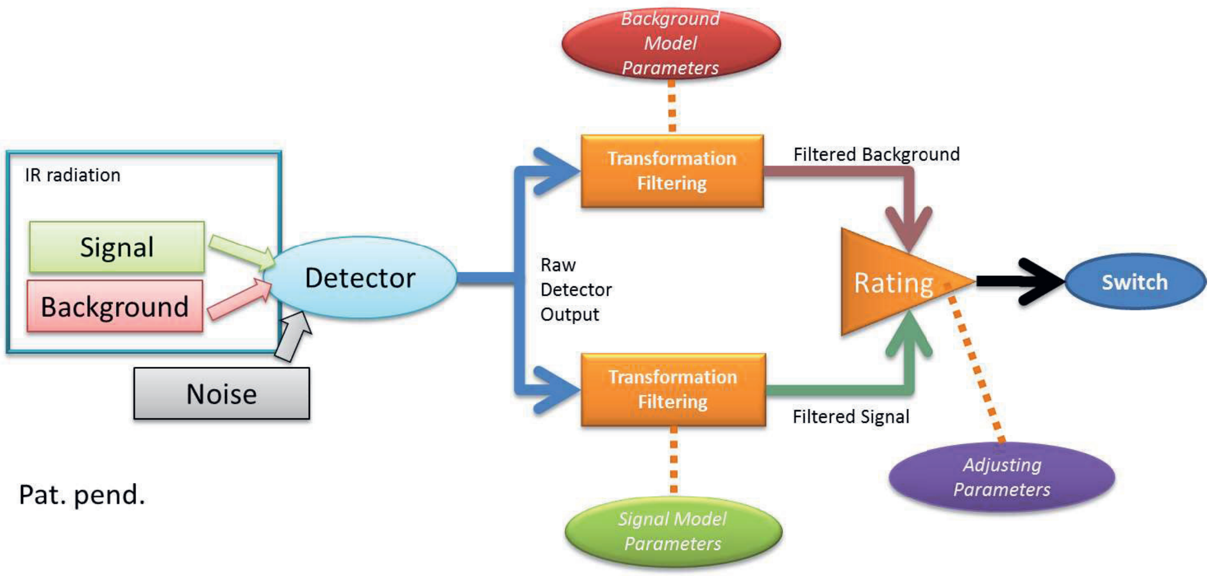

Fig.6.Analysis scheme for presence detection on the CaliPile