APPLICATION NOTE

C o n t e n t s

1. INTRODUCTION

A thermopile is serially-interconnected array of thermocouples, each of which consists of two dissimilar materials with a large thermoelectric power and opposite polarities. The thermocouples are placed across the hot and cold regions of a structure and the hot junctions are thermally isolated from the cold junctions. The cold junctions are typically placed on the silicon substrate to provide effective heat sink. In the hot regions, there is a black body for absorbing the infrared, which raises the temperature according to the intensity of the incident infrared. These thermopiles employ two different thermoelectric materials which are placed on a thin diaphragm having a low thermal conductance and capacitance. Since this creates a large temperature difference between the hot and cold regions, this structure enables improved detector performance. The thermopile has some unique properties which cannot be duplicated by other detectors. It shows an inherently stable response to DC radiation and is not sensitive to ambient temperature variations.

It responds to a broad infrared spectrum, does not require a source of bias voltage or current.
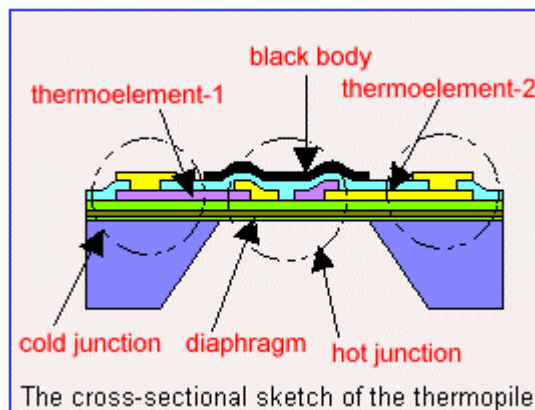

The cross-sectional sketch of the thermopile

Figure 1.

2. APPLICATION CONSIDERATIONS

2-1. Specific Detectivity

The NEP is convenient for predicting the maximum power a given system can detect, but it has some undesirable features:

  - A good thermopile detector will have a small NEP
  - The thermopile detectors of different sizes will have different NEPs

So we cannot say in general what a good NEP should be unless we specify the size of thermopile detector.

Detectivity has been introduced to include device noise and sensitivity simultaneously. It is usually normalized with respect to detector size and noise bandwidth, and the resulting specific detectivity, D*, is defined by

$$D^* = \frac{\text{Resposnsivity} \times \sqrt{\text{Area}}}{\text{Noise}/\sqrt{\Delta f}} = \frac{\text{Signal} \times \sqrt{\Delta f}}{\text{Noise} \times \text{Incidance} \times \sqrt{\text{Area}}} [cm \cdot Hz^{1/2}/W] \quad (2.1)$$

A large D* is good, and for a given environment all good detectors should have almost the same D*.

2-2. Noise

The thermopile detector noise is another important factor determining the detector performance. There are many noise sources in a thermopile detector. A fundamental noise is caused by actual temperature fluctuations. A theoretical limit of thermopile sensitivity will be determined when this noise is at its minimum.

In this thermopile detector, Johnson noise of these many noise sources is a predoment electrical noise source. Since the device impedance for a typical thermopile detector is mainly resistive, the Johnson noise for a detector having a device resistance R is

$$v_J = \sqrt{4k\text{TRB}} \quad (2.2)$$

where B is the noise bandwidth. At low frequency, flicker noise originating from contacts or other sources may be dominants, and, depending upon the sensing materials, shot noise may also be involved. Typically Johnson noise is the most important of these electrical noise sources for most thermopile detectors.

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2-3. Package

Our thermopile detector is packaged with silicon filter and thermistor as shown in Figure 2. We are supplying TO-5 package and TO-46 package as the standard type , but on request, other package types are also available.
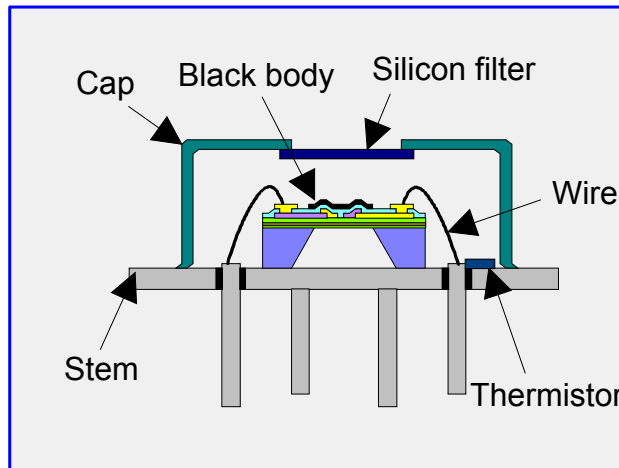

Figure 2.

(1) Thermistor for the compensation of an environment temperature

According to the variation of an environment temperature, the output of thermopile detector is also varying. It is therefore need to compensate this temperature performance of thermopile detector. Our thermopile detectors are using a thermistor for the compensation of an environment temperature, and we have also a variety of thermistors enough for pursuing customer`s need.

(2) Windows Filter

In order to improve the thermopile detector performance, it is also a very important factor to select suitable filter for a given application. We are basically using a broadband-silicon filter of which the transmittance is 6-13um.

But when there is an application for an optical system, the preparation of proper filter specifications is also of prime importance for the optimum performance. Therefore we are available for many typical infrared filters -not only a broad band pass filters(BBP) but also a narrow band pass filters(NBP).

The following specifications will assist an engineer who designs the optical system.
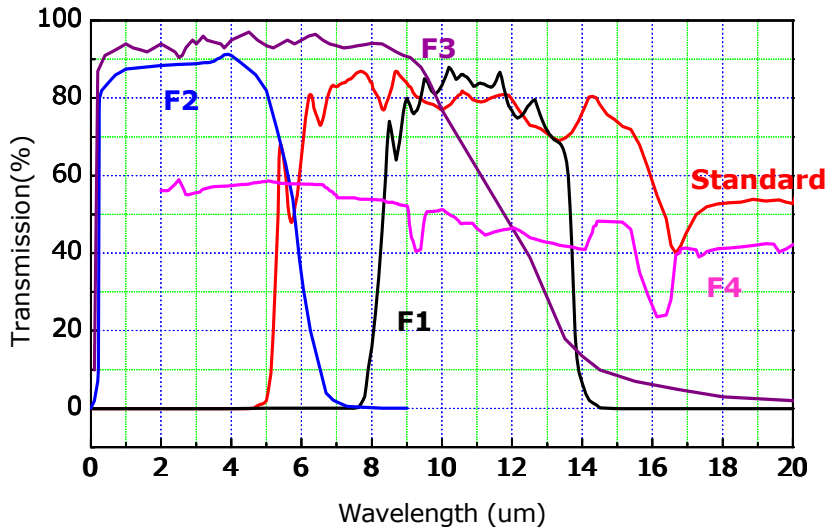
* Filters

Figure 3.

Type	Material	Transmission Range(um)
Standard	Si	6 ~ 13um
F1	Si	8 ~ 14um
F2	Sapphire	0.2 ~ 5um
F3	CaF$_2$	1 ~ 10um
F4	Si	refer to Figure 3.

Narrow band pass filters are also available for special application.

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3. Typical Applications of IR detector

It is very important to select a suitable type of thermopile detector for the desired device and performance. The following typical applications will help you when selecting the type of thermopile sensor.

3-1. Energy/Water/Gas
- Monitoring of power station
- Search for fluid leaks
- Control of storage reservoirs

3-2. Materials
- Control of chimney stacks, shafts and pipes
- Monitoring of high temperature kilns and furnaces
- Control of casting of fusion metal

3-3. Automotive industry
- Temperature reliability test of electric parts
- Control of heating and thermal isolation of the passenger compartment
- Control of windscreen deicing

3-4. Household electricals
- Control of ovens, cooking appliances, heating elements, electrical iron
- Control of refrigerators, freezers and air-conditioner

3-5. Transport/Navigation
- Detection of obstacles
- Driving at night or in difficult conditions (fog, mist et al.)

3-6. Farming
- Detection of plant and farmland diseases
- Transfer of heat in plants

3-7. Medical
- Measurement of surface temperatures of the human body
- Control of blood flow (varicose veins, obstruction)
- Monitoring of thermotherapy treatments
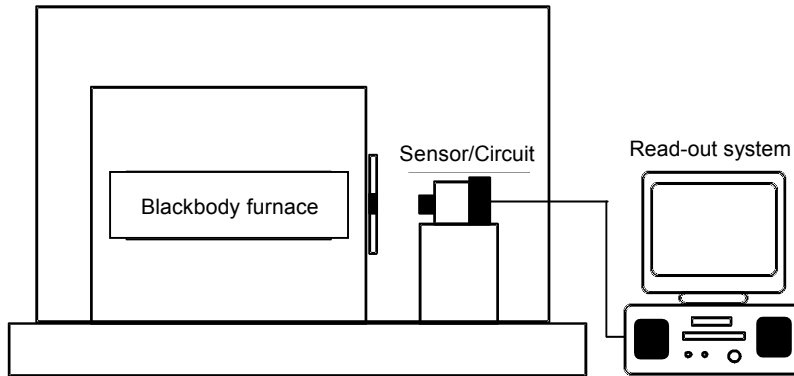- Monitoring of physical training

A. APPENDICES

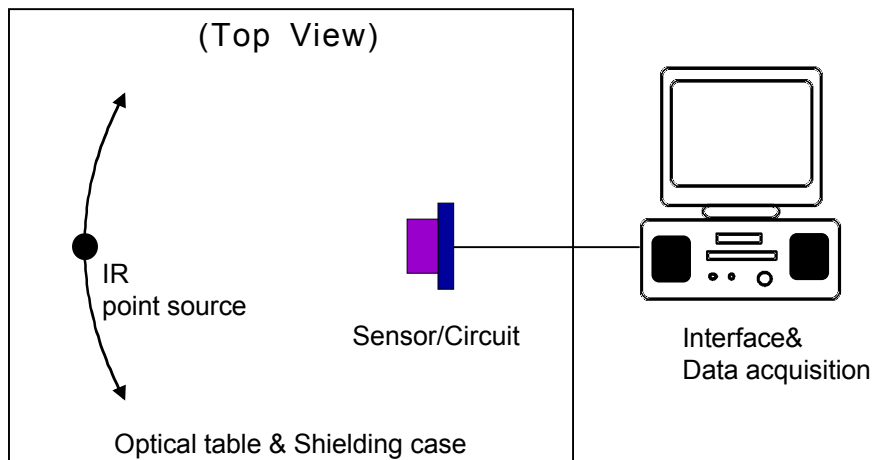A-1. Example circuitry for thermopile IR sensor
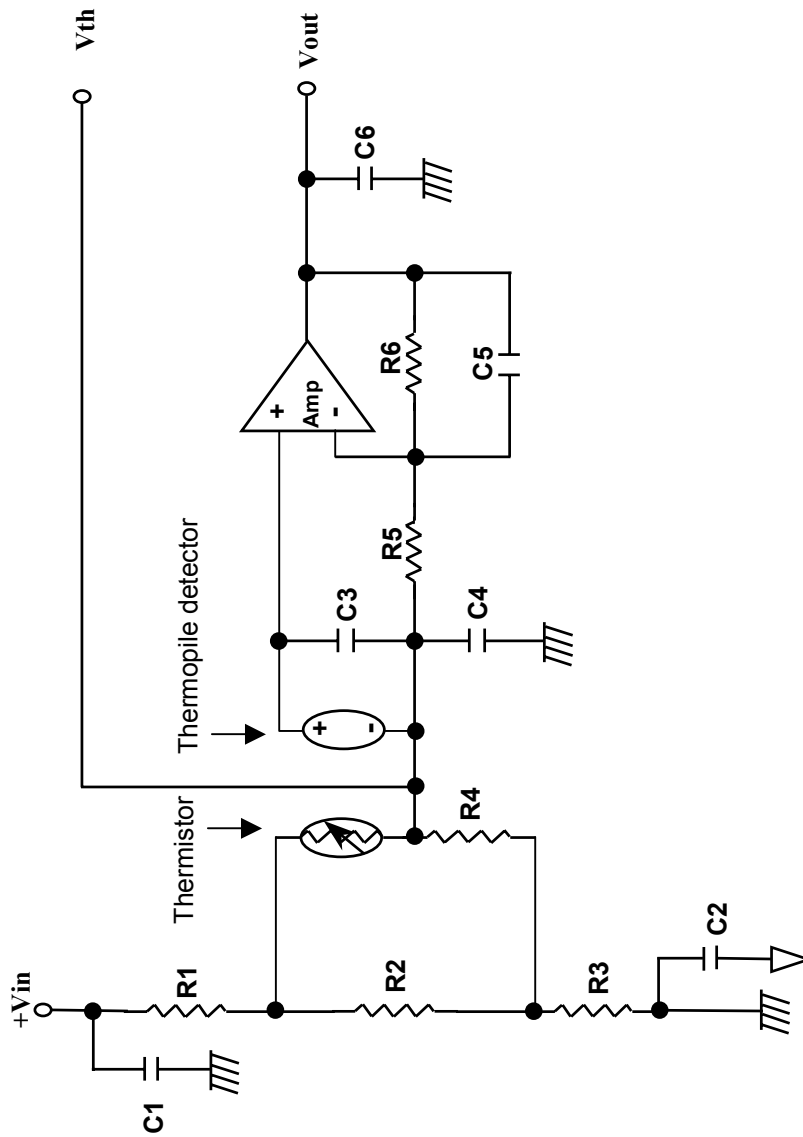
A-2. Measurement Block Diagrams

(1) Sensitivity measurement

Blackbody furnace
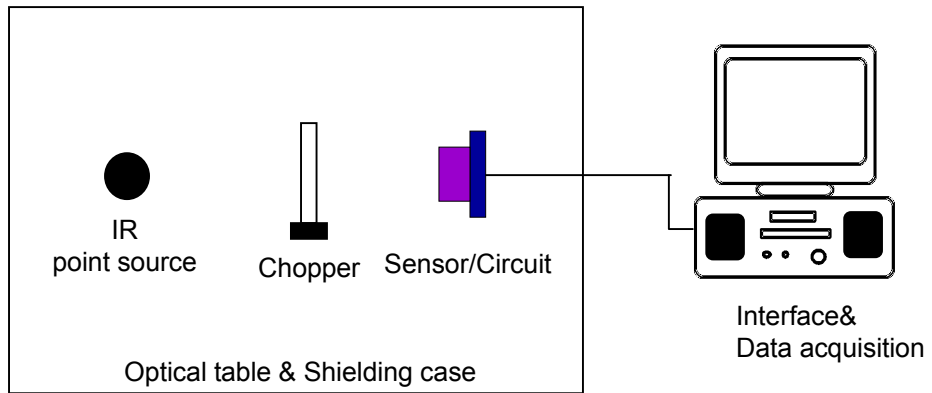
Sensor/Circuit

Read-out system

- The heat source is the standard blackbody furnace to be set at a desired temperature
- There should be no other heat source within F.O.V of the detector
- The opening aperture size of the standard blackbody furnace is always same
- The ambient temperature is always same

(2) Field of View (FOV) measurement

(Top View)

IR point source

Sensor/Circuit

Interface&
Data acquisition

Optical table & Shielding case

- The heat source is a movable IR point source
- There should be no other heat source within F.O.V of the detector
- The ambient temperature is always same

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(3) Time constant measurement

IR point source — Chopper — Sensor/Circuit — Interface& Data acquisition

Optical table & Shielding case

- The heat source is a IR point source
- The time constant shall be decided by the time required 63%

 of the detector output voltage

- The ambient temperature is always same

A-3. Glossary of terms

The followings are basic terms and symbols used to define the characteristics of a thermopile IR detector.

Bias Voltage[V]

Application of an electrical voltage to make operate a thermopile detector in a desired way.

 - Maximum bias : A bias voltage which yields maximum signal output
 - Optimum bias : A bias voltage which yields maximum S/N ratio output

Black Body

A source of infrared whose output can be predicted accurately by Planck`s law.

Cutoff Wavelength[um]

The wavelength at which the specific detectivity(D*) has decreased to one half of its peak value.

Field of View[FOV, SR]

The solid angles through which the detector can see given object.

Linearity

How well the output signal tracks the infrared power.

Noise Equivalent Power[NEP, W]

A minimum signal power the detector can detectable. This is a function of source temperature, chopping frequency, noise equivalent bandwidth, field of view and ambient temperature.

Responsivity[Rv, V/W]

A thermopile detector sensitivity defined as the ratio of the thermopile detector output signal generated in response to a unit input radiant power.

Specific Detectivity[D, cm(Hz)$^{1/2}$/W]*

The detectivity normalized by detector responsive area and noise bandwidth, so it is a convenient way to specify and compare detector performance.

Spectral Response

How the responsivity varies with the wavelength of the infrared power.

Time Constant[ms]

A term to describe the detector response speed. This depends on the thermal resistance and the thermal capacitance of the thermopile IR detector.