Amphenol Advanced Sensors

Thermometrics
Infrared Thermopile Sensors
Infrared Thermopile Sensors
Non-contact Temperature Measurement
Infrared Thermopile Sensors

What is Infrared?

- Form of electromagnetic wave
- Extends from 0.7 $\mu$m - 1000 $\mu$m
  - Near infrared: 0.7 $\mu$m - 2.5 $\mu$m
  - Intermediate infrared: 2.50 $\mu$m - 25.0 $\mu$m
  - Far infrared: over 25.0 $\mu$m
- Most IR sensors based on two regions … 3 - 5$\mu$m and 8 - 12 $\mu$m
Infrared Thermopile Sensors

Infrared Radiation

- Electromagnetic emission and absorption
- Occurs at the speed of light
- Travels in a straight line
- Takes place across a vacuum
- Passes through many crystalline, plastic, gaseous materials
- Does not penetrate metals
Infrared Thermopile Sensors
Radiated Infrared Energy

The warmer the source, the more energy it emits

<table>
<thead>
<tr>
<th>$W = \delta \varepsilon T^4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W =$ Radiant flux emitted per unit area (W/cm$^2$)</td>
</tr>
<tr>
<td>$\delta =$ Stefan-Boltzmann constant</td>
</tr>
<tr>
<td>$\varepsilon =$ Emissivity</td>
</tr>
<tr>
<td>$T =$ Absolute temperature of target (K)</td>
</tr>
</tbody>
</table>

As the temperature of the source increases, the wavelength at which most of the energy is radiated decreases

<table>
<thead>
<tr>
<th>$\lambda_{\text{max}} = b/T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b =$ Wien’s displacement constant</td>
</tr>
</tbody>
</table>

Infrared Sensing

- Hot objects emit infrared (IR) and visible radiation as a function of surface temperature
- As an object gets hotter, not only does it radiate more, but the peak wavelengths it emits get shorter
- Objects have different wavelengths of radiation

\[ \varepsilon + R + T = 1 \]

- \( \varepsilon \) = emissivity
- \( R \) = Reflectance
- \( T \) = Transmittance
Infrared Thermopile Sensors
Approximate Emissivity Figures

<table>
<thead>
<tr>
<th>Material</th>
<th>Radiation</th>
<th>Material</th>
<th>Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>0.92~0.94</td>
<td>Aluminum (luster)</td>
<td>0.095</td>
</tr>
<tr>
<td>Plastic</td>
<td>0.95</td>
<td>Aluminum oxide</td>
<td>0.26~0.42</td>
</tr>
<tr>
<td>Ceramic</td>
<td>0.90</td>
<td>Copper (luster)</td>
<td>0.05</td>
</tr>
<tr>
<td>Water</td>
<td>0.95~0.963</td>
<td>Copper oxide</td>
<td>0.78</td>
</tr>
<tr>
<td>Human skin</td>
<td>0.985</td>
<td>Cast Iron (luster)</td>
<td>0.21</td>
</tr>
<tr>
<td>Paint (lusterless)</td>
<td>0.95</td>
<td>Nickel (luster)</td>
<td>0.045</td>
</tr>
<tr>
<td>Paint (luster)</td>
<td>0.9</td>
<td>Nickel oxide</td>
<td>0.37</td>
</tr>
<tr>
<td>Epoxy/Glass</td>
<td>0.86</td>
<td>Stainless steel</td>
<td>0.16~0.44</td>
</tr>
</tbody>
</table>
Infrared Thermopile Sensors

Thermopile Construction

- Seebeck effect

\[ V = \alpha \Delta T = (\alpha_A - \alpha_B)(T_h - T_c) \]

- To increase the sensitivity (high Seebeck coefficient):
  - Higher \( T_h \), lower \( T \)
  - More thermocouples
  - Heavier inert gas filling
  - Thin diaphragm with lower thermal conductance
  - Highly transmitted IR filter
  - High efficient IR absorber

Sensing Mechanism

Thermopile Detector Packaging
Infrared Thermopile Sensors

What is a Thermopile?

- Serially-interconnected array of thermocouples
- Each thermocouple formed by the junction of two dissimilar materials
- Thermocouple array placed across hot and cold regions of structure
- Hot junctions thermally isolated from the cold junctions
- Cold junctions placed on silicon substrate for effective heat sinking
- Hot junctions formed over thin diaphragm that thermally isolates hot and cold junctions
- In hot regions, a black body absorbs the infrared energy, raising temperature according to the intensity of incident energy
Infrared Thermopile Sensors
Unique Features

Thermopile sensors have unique properties not offered by other detectors:

- Response to broad infrared spectrum
- No source of bias voltage or current needed
- Inherently stable response to DC radiation
## Infrared Thermopile Sensors
### Features of Thermometrics Thermopile IR Sensors

### PRODUCT COMPARISON TABLE OF ZTP SERIES

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package type</th>
<th>Sensitivity (Vircal) @Tobj=40°C</th>
<th>Thermopile resistance (kΩ) @Tamb=25°C</th>
<th>Thermistor Resistance &amp; B-Value @Tamb=25°C</th>
<th>Filter transmittance range (um)</th>
<th>Field of View</th>
<th>Lead length (mm)</th>
<th>Window size (mm)</th>
<th>Main Application</th>
<th>Mass Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZTP-101T</td>
<td>TO-39(TO-5)</td>
<td>1.0mV</td>
<td>200</td>
<td>30kΩ_3811</td>
<td>6~13</td>
<td>50 degree</td>
<td>6.7</td>
<td>Dia 2.5</td>
<td>Non-contact Temperature Measurement Thermometry, Medical, General Industrial, Occupancy Detection, HVAC, etc.</td>
<td>Yes</td>
</tr>
<tr>
<td>ZTP-115</td>
<td></td>
<td>0.6mV</td>
<td>50</td>
<td>10kΩ_3970</td>
<td>6~13</td>
<td>55 degree</td>
<td>5</td>
<td>Dia 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZTP-135SR</td>
<td>TO-46(TO-18)</td>
<td>1.3mV</td>
<td>60</td>
<td>10kΩ_3960</td>
<td>6~13</td>
<td>85 degree</td>
<td>13.5</td>
<td>Dia 2.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Sensor type</th>
<th>Main Application</th>
<th>Output type</th>
<th>Communication protocol</th>
<th>Pixel Q’ty</th>
<th>Range of Measuring Temperature (°C)</th>
<th>Ambient Temperature Range (°C)</th>
<th>Input supply voltage</th>
<th>Module Size (mm)</th>
<th>Mass production</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZTP-115M</td>
<td>Single module</td>
<td>General Industrial, Microwave Oven, Appliances, etc.</td>
<td>Analog</td>
<td>Voltage</td>
<td>Single</td>
<td>-40 ~ 145</td>
<td>-20 ~ 120</td>
<td>+5V</td>
<td>17 X 33</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Infrared Thermopile Sensors

Thermopile Characteristics

\[ V = S \cdot (T_O^B - T_A^B) \]

\( V \) = Output voltage from thermopile
\( T_O \) = Object temperature in K
\( T_A \) = Ambient temperature in K
\( S \) = Sensitivity coefficient
\( B \) = Coefficient (~4)

S and B are determined by measurement
Infrared Thermopile Sensors

Temperature Compensation

- Output from thermopile varies with both ambient and object temperature
- Need to know the ambient temperature to calculate the object temperature
- Thermometrics standard thermopiles supplied with integrated thermistor for compensation
- Options include customer-specified thermistor or external temperature compensation (no internal thermistor)
# Infrared Thermopile Sensors

## Various Filter Options

<table>
<thead>
<tr>
<th>Filter</th>
<th>Material</th>
<th>Transmission Range</th>
<th>Application</th>
</tr>
</thead>
</table>
| Standard | Silicon | 6~13um | Appliances, Microwave Oven  
Medical, Ear Thermometer  
Automotive, Tire Temperature  
HVAC, Human Body Detection |
| F1 | Silicon | 8~14um | Occupancy Detection, Intruder alarms |
| F2 | Sapphire | 2~5um | Flame Detection, Analysis equipment |
| F3 | CaF2 | 1~10um | |
| NDIR | Silicon | 3.99±1%  
4.65±1%  
4.26±1%  
3.45±1% | reference  
CO gas detection  
CO₂ gas detection  
HC gas detection |
Infrared Thermopile Sensors
Standard ZTP Series

ZTP-101T
ZTP-115
ZTP-135SR

The ZTP series of IR thermopile sensors are used for non-contact surface temperature measurement. The product consists of thermoelements, flat IR filter, a thermistor for temperature compensation in a hermetically-sealed TO package. There are also a variety of filters available to help maximize performance in specific applications.
Infrared Thermopile Modules
Standard ZTP Series

ZTP-115M

The ZTP-115M is a single IR module. It consists of a thermopile, IR sensor, signal conditioning and voltage output.
Infrared Thermopile Modules
ZTP-115M Signal Conditioning & Amplification
Infrared Thermopile Modules
ZTP-115M Compensated Output

Temperature Deviation (°C)

Ambient Temperature (°C)

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Infrared Thermopile Modules
ZTP-115M Field of View

(3) Spot Size of Normalized Output (above 10%)

100 mm 200 mm 300 mm
Φ50  Φ90  Φ130

H(+/-) : Horizontal Direction
V(+/-) : Vertical Direction
Infrared Thermopile Sensors
Example Interface Circuit

NTC Thermistor used for compensation of the ambient factors.

Op Amp used to amplify the output voltage signal from the thermopile.
Infrared Thermopile Sensors

Typical Applications

- Ear, Forehead Thermometry
- Non-contact Temperature Measurement Thermometry
- Microwave Ovens
- Induction Heater Cookers
- Air Conditioners
- Occupancy Detection
- Lighting
- Underfloor Heating Control
- HVAC / Automotive