SOLID STATE DIVISION

COMPOUND SEMICONDUCTOR PHOTOSENSOR

HAMAMATSU

Selection guide

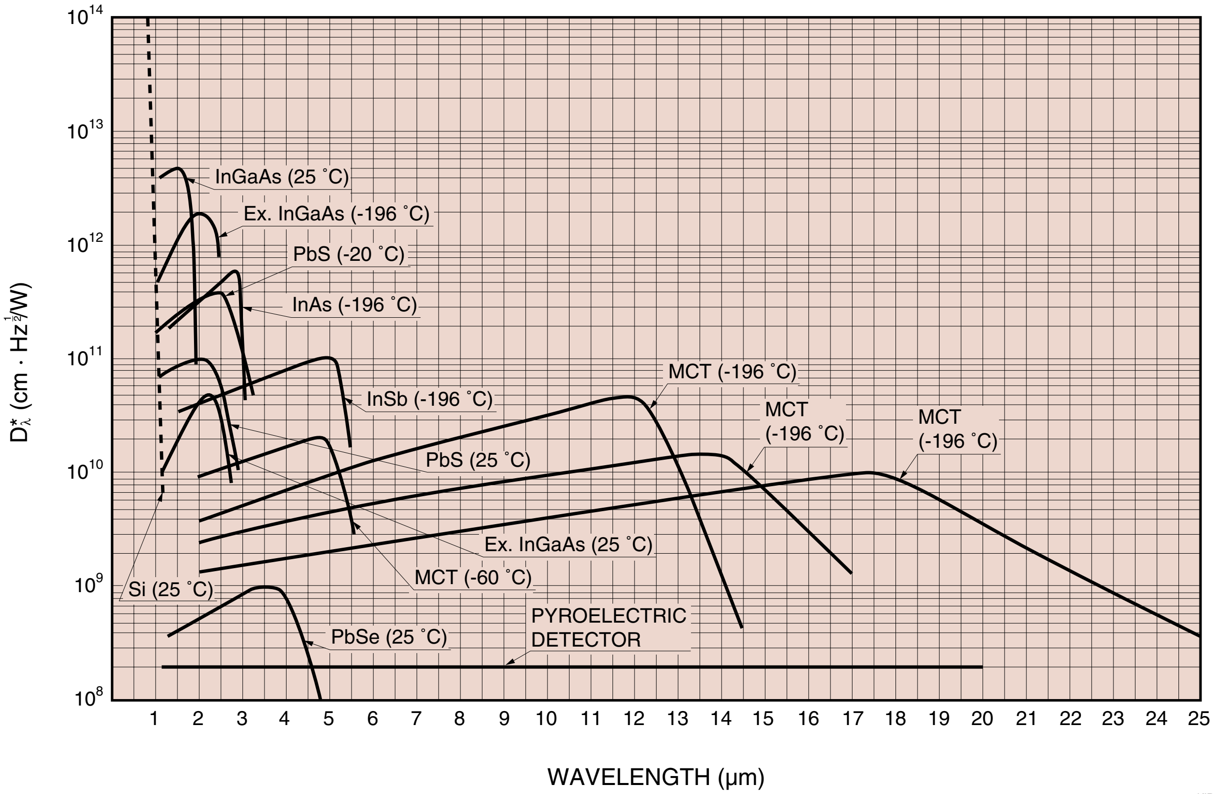
Product name		Spectral response range (μm) 0 5 10 15 20 25	Feature	Page
Infrared detector				
PbS photoconductive detector		1 3.2	· Photoconductive detectors whose resistance decreases with the input of infrared light. · Can be used at room temperatures in a wide range of applications such as radiation thermometers and flame monitors.	1
PbSe photoconductive detector		1.5 5.2	· Detects wavelengths up to 5.2 μm. · Offers higher sensitivity at room temperatures compared to other detectors used in the same wavelength range. Suitable for a wide range of applications such as gas analyzers.	
InSb photoconductive detector		1 6.7	· Detects wavelengths up to around 6.5 μm, with high sensitivity over long periods by thermoelectric cooling.	2
InSb photovoltaic detector		1 5.5	· High speed and high sensitivity in so-called atmospheric window (3 to 5 μm).	
InAs photovoltaic detector		1 3.8	· Covers a spectral response range close to PbS but offers higher response speed.	
MCT (HgCdTe) photoconductive detector		2 25	· Various types with different spectral response are provided by changing the HgTe and CdTe composition ratio. · Photoconductive detectors whose resistance decreases with the input of infrared light. · Available with thermoelectric coolers, cryogenic dewars and starling coolers.	4
Pyroelectric detector		2 20	· Ideal for human body detection such as intruder alarm and chemical analysis.	5
Two-color detector	Si + PbS	0.2 3.1	· Wide spectral response range from UV to IR. · Two-color detectors incorporate an infrared-transmitting Si photodiode mounted over a PbS detector, PbSe detector or InGaAs PIN photodiode along the same optical axis.	7
	Si + PbSe	0.2 5.1		
	Si + InGaAs	0.25 1.7		
Photon drag detector		10	· High-speed detector with high sensitivity in 10 μm band (for CO_2 laser detection). · Room temperature operation with high-speed response.	8

Product name		Spectral response range (μm) 0 0.5 1	Feature	Page
UV to visible photosensor				
GaAsP photodiode	Diffusion type	0.3 0.68	· For visible range, low dark current and high stability.	9
		0.4 0.76	· Red enhanced type, low dark current and high stability.	
		0.26 0.4	· Short wavelength type, low dark current and narrow spectral response range.	
	Schottky type	0.19 0.68	· For UV to visible range, low dark current and high UV sensitivity.	
		0.19 0.76	· Red enhanced type, low dark current and high UV sensitivity.	
GaP photodiode		0.19 0.55	· High UV sensitivity and low dark current.	

Product name	Spectral response range (μm) 0 0.5 1	Feature	Page
Visible photosensor			
CdS photoconductive cell	0.4 0.7	· Spectral response close to human eyes.	11

For InGaAs PIN photodiodes and InGaAs linear image sensors, see our separate catalogs titled “InGaAs PIN photodiode” and “Image sensor”.

● Typical spectral response characteristics of Hamamatsu compound semiconductor photosensors



KIRDB0259EA

When using compound semiconductor photosensors, the following points should be taken into consideration for making a correct choice.

Spectral response

As can be seen from the figure above, Hamamatsu Photonics provides a variety of compound semiconductor photosensors with different spectral response characteristics. It should be noted that cooling a detector element may affect its spectral response. For InGaAs, InAs and InSb detectors, the spectral response shifts to the shorter wavelength side; in contrast, for PbS, PbSe and MCT detectors it shifts to the longer wavelength side.

Response speed

Various detectors are available with different response speeds. It should be noted that the response speeds of the PbS and PbSe detectors become worse with cooling.

Active area and number of elements

Hamamatsu photosensors are available in a wide range of active areas and configurations. Also available are multi-element detector arrays optimized for high-speed multichannel spectrophotometry.

Cooling

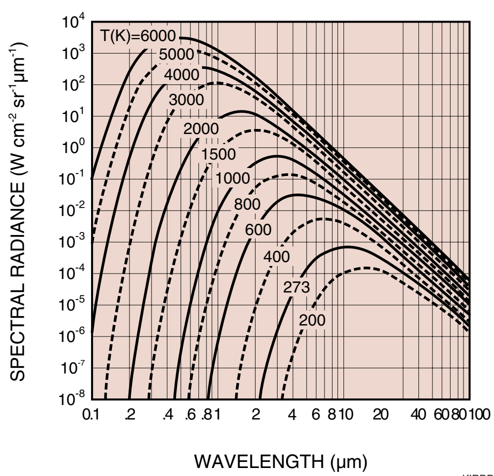
Besides easy-to-use photosensors designed for room temperature, Hamamatsu Photonics provides various types of cooled sensors using thermoelectric coolers not requiring liquid cryogen, cryogenic dewars (liquid nitrogen cooling) having minimal noise and starling coolers.

Object temperature

When selecting a detector in accordance with the temperature of an object, it is necessary to consider the distribution of the energy (the wavelength dependency of the energy) radiated from the object. When the temperature of the object is known, the distribution of the radiating energy is given by the law of black body radiation (Planck's law), as shown in the figure at the right-hand side. The following relationship is established by the peak sensitivity wavelength λp (μm) and the absolute temperature T (K).

$$\lambda p \cdot T = 2897.9$$

● Planck's law



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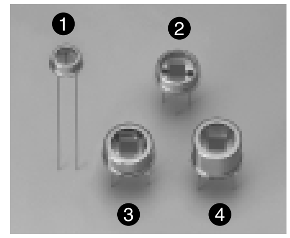
PbS, PbSe photoconductive detector

PbS and PbSe detectors are photoconductive sensors whose resistance decreases with the input of infrared light. These sensors can be used at room temperatures and detect infrared light with high sensitivity. Large active area type is also available.

PbS photoconductive detector

PbS photoconductive detectors are infrared sensors having a spectral response range from 1 to 3.2 µm. These sensors can be used at room temperatures in a wide range of applications such as radiation thermometers and flame monitors.

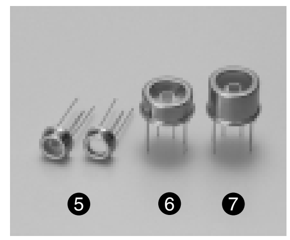


(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P394	❶	TO-5	Non-cooled	1 × 5	2.9	2.2
P394-22	❷	TO-8	Non-cooled	4 × 5	2.9	2.2
P2532-01	❸	TO-8	One-stage TE-cooled	4 × 5	3.1	2.4
P2682-01	❹		Two-stage TE-cooled		3.2	2.5

PbSe photoconductive detector

PbSe photoconductive detectors are infrared sensors having a spectral response range from 1.5 to 5.2 µm. These sensors deliver high sensitivity and high-speed response at room temperatures. Cooled types are also available with a higher S/N, making them widely used in analytical equipment, radiation thermometers and other precision photometry.



(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P791-11	❺	TO-5	Non-cooled	2 × 2	4.8	4.0
P791-13				3 × 3		
P3207-05 *				2 × 2		4.3
P2038-02	❻	TO-8	One-stage TE-cooled	2 × 2	5.1	4.1
P2038-03				3 × 3		
P2680-02	❼		Two-stage TE-cooled	2 × 2	5.2	4.2
P2680-03				3 × 3		

* Incorporates a bandpass filter that transmits infrared light of 4 to 4.8 µm.

Infrared detector module with preamp

These modules consist of an infrared detector assembled with matched preamplifier, and operate just by connecting a DC power supply.

Accessories (Supplied)

- P4245: 4-conductor cable (2 m)
  (For connection to DC power supply; connector installed on one end) A4372-02
- P4683, P4639: 6-conductor cable (2 m)
  (For connection to DC power supply; connectors installed on both ends) A4372-03

Accessories (Optional)

- Power supply for P4245 (±15 V) : C3871
- Power supply for P4638, P4639 (±15 V, +2.5 V): C3871-03

(Typ.)

Type No.	Photo	Detector element	Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P4638	❽	PbS	TE-cooled	4 × 5	3.2	2.5
P4245	❾	PbSe	Non-cooled	3 × 3	4.8	4.0
P4639	❽		TE-cooled	3 × 3	5.2	4.2

InSb photoconductive detector, InSb, InAs photovoltaic detector

InSb and InAs photovoltaic detectors are photovoltaic photosensors having a PN junction, covering a spectral response range equivalent to PbSe and PbS photoconductive detectors. InSb and InAs photovoltaic detectors, however, offer a higher response speed and better S/N, and can be used in applications impossible for PbSe and PbS photoconductive detectors. InSb photoconductive detectors can also be used with a sensitivity up to around 6.5 µm.

InSb photoconductive detector

Thermoelectrically cooled InSb photoconductive detectors are capable of detecting infrared light up to around 6.5 µm with high sensitivity and high speeds. No liquid cryogen is required.

(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P6606-110	❶	TO-8	One-stage TE-cooled	1 × 1	6.7	5.5
P6606-210			Two-stage TE-cooled		6.5	
P6606-310	❷	TO-3	Three-stage TE-cooled	1 × 1	6.3	
P6606-305				0.5 × 0.5		
P6606-320				2 × 2		

InSb photovoltaic detector

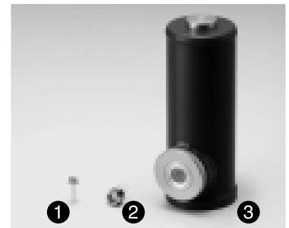
InSb photovoltaic detectors are high-speed, low-noise infrared detectors that deliver high sensitivity in the so-called atmospheric window between 3 and 5 µm. Infrared light in the 5 µm band can be detected with peak responsivity and highest response speed. There are two cooling types: a metal dewar type cooled with liquid nitrogen and a starling cooler type requiring no liquid nitrogen.

(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P5968-060	❸	Metal dewar	Liquid nitrogen	ϕ0.6	5.5	5.3
P5968-100				ϕ1		
P5968-200				ϕ2		
P5968-300				ϕ3		
P5968-105	❹	Metal	Starling	ϕ1		
P4247-16	❺	Metal dewar	Liquid nitrogen	0.25 × 1.4 (16 elements)		
P4247-44				0.45 × 0.45 (4×4 elements)		

InAs photovoltaic detector

InAs photovoltaic detectors are high-speed, low-noise infrared detectors capable of detecting infrared light up to around 3.8 μm. Hamamatsu InAs detectors are available in a non-cooled type, thermoelectrically cooled type and metal dewar type cooled with liquid nitrogen.

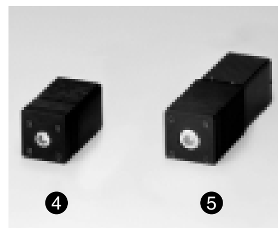


(Typ.)

Type No.	Photo	Package	Cooling	Active area (mm)	Cut-off wavelength (μm)	Peak sensitivity wavelength (μm)
P8079-01	❶	TO-5	Non-cooled	ϕ1	3.8	3.45
P8079-11	❷	TO-8	One-stage TE-cooled		3.6	3.3
P8079-21			Two-stage TE-cooled		3.5	3.25
P7163	❸	Metal dewar	Liquid nitrogen		3.1	3

Infrared detector module with preamp

These modules consist of an InAs or InSb photovoltaic infrared detector assembled with the matched preamplifier, and operate just by connecting a DC power supply. In addition to compact thermoelectrically cooled modules, metal dewar modules cooled with liquid nitrogen are also provided.



Accessories (Supplied)

- P4631-01/-03: 6-conductor cable (2 m) (for connection to DC power supply, connector installed on both sides) A4372-03
- P7751-01/-02: 4-conductor cable 2 m (for connection to DC power supply, connector installed on one end) A4372-02

Accessories (Optional)

- Power supply for P4631-01 (±15 V, +2.5 V): C3871-03
- Power supply for P4631-03 (±15 V, +4.5 V): C3871-04
- Power supply for P7751-01/-02 (±15 V) : C3871

(Typ.)

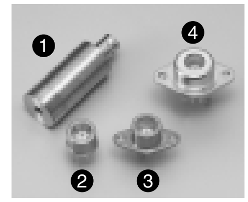
Type No.	Photo	Detector element	Type	Active area (mm)	Cut-off wavelength (μm)	Peak sensitivity wavelength (μm)
P4631-01	❹	InAs	TE-cooled	ϕ1	3.5	3.25
P4631-03	❺	InSb	TE-cooled	1 × 1	6.3	5.5
P7751-01	❻		Metal dewar type	ϕ0.6	5.5	5.3
P7751-02				ϕ2		

MCT (HgCdTe) photoconductive detector

MCT (HgCdTe) photoconductive detectors have decreasing resistance as infrared light is input. Various types with different spectral response are provided by changing the HgTe and CdTe composition ratio. In addition to the standard types listed in this catalog, custom devices are available with different active areas and number of elements.

Metal package

Non-cooled types and one-stage thermoelectrically cooled types have sensitivity up to 10 µm, making them suitable for CO_2 laser detection. Two or three-stage thermoelectrically cooled types deliver high sensitivity and high-speed response in detecting wavelengths up to 5.5 µm.

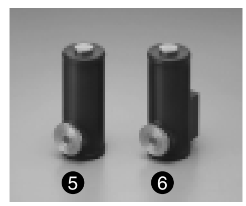


(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P3257-30	❶	With BNC connector	Non-cooled	1 × 1	11.0	6.0
P3257-31	❷	TO-8	One-stage TE-cooled		11.5	6.5
P3981	❷	TO-8	Two-stage TE-cooled		3.7	3.6
P3981-01	❸	TO-66			3.7	3.6
P2750-08	❷	TO-8			5.4	4.8
P2750	❹	TO-3	Three-stage TE-cooled	1 × 1	5.5	4.8
P2750-06				0.25 × 0.25		

Metal dewar, Starling type

Metal dewar MCT detectors with peak sensitivity at 10 µm are suitable for measuring the infrared radiation emitted from an object at room temperatures. MCT detectors with a narrow, medium and wide spectral response bands are also provided for use in spectroscopy. Starling cooler type requiring no liquid nitrogen and array type MCT detectors are also available.

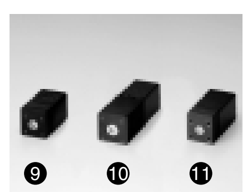


(Typ.)

Type No.	Package		Cooling	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P3257-25	❺	Side-on type metal dewar	Liquid nitrogen	0.025 × 0.025	12	10
P3257-01				0.1 × 0.1		
P3257-10				1 × 1		
P4249-08	❻			0.5 × 0.5/8 elements		
P2748-40	❺			1 × 1	14	12
P2748-42				0.25 × 0.25		
P5274				1 × 1	17	14
P5274-01				1 × 1	22	17
P2748-41	❼	Head-on type metal dewar		1 × 1	14	12
P3257-50	❽	Starling type metal	Starling	1 × 1	14	12

Infrared detector module with preamp

These modules consist of an MCT detector assembled with the matched preamplifier, and operate just by connecting a DC power supply. In addition to compact thermoelectrically cooled modules, metal dewar modules cooled with liquid nitrogen are also provided.



Accessories (Supplied)

- P4631/-04/-10: 6-conductor cable 2 m (for connection to DC power supply, connector installed on both sides) A4372-03
- P7752-10: 4-conductor cable 2 m (for connection to DC power supply, connector installed on one end) A4372-02

Accessories (Optional)

- Power supply for P4631/-10 (±15, +2.5 V): C3871-03
- Power supply for P4631-04 (±15, +4.5 V) : C3871-04
- Power supply for P7752-10 (±15 V) : C3871

(Typ.)

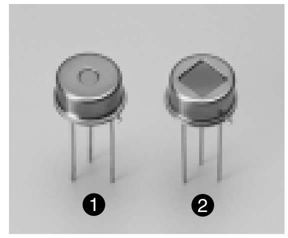
Type No.	Photo	Type	Active area (mm)	Cut-off wavelength (µm)	Peak sensitivity wavelength (µm)
P4631	❾	TE-cooled	1 × 1	3.7	3.6
P4631-04	❿			5.5	4.8
P4631-10	⓫			11.5	6.5
P7752-10	⓬	Metal dewar	1 × 1	14	12

Pyroelectric detector

Pyroelectric detectors are widely used for human body sensing and portable analytical instruments.

Thermally compensated type

This type of pyroelectric detectors contains a thermally compensated element in the same package to minimize noise fluctuation caused by changes in ambient temperature. Ideal for portable analytical instruments.

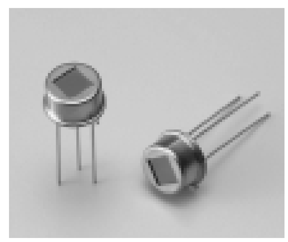


(Typ.)

Type No.	Photo	Window material	Active area (mm)	Spectral response range (μm)	Sensitivity (500, 1) (V/W)
P3782	❶	Silicon	ϕ2	2 to 20	1000
P3782-01	❶	7 μm long-pass filter	ϕ2	7 to 20	840
P3782-02	❶	4.3 μm band-pass filter	ϕ2	4.3 (HW=90 nm)	1800
P3782-03	❶	8-14 μm band-pass filter	ϕ2	8 to 14	640
P3782-05	❶	5 μm long-pass filter	ϕ2	5 to 20	1200
P3782-12	❶	4.4 μm band-pass filter	ϕ2	4.4 (HW=600 nm)	2000
P4736	❷	Silicon	ϕ2	2 to 20	940
P4736-01	❷	7 μm long-pass filter	ϕ2	7 to 20	670
P4736-05	❷	5 μm long-pass filter	ϕ2	5 to 20	880
P4736-12	❷	4.4 μm band-pass filter	ϕ2	4.4 (HW=600 nm)	1400

Single element type

This type of pyroelectric detector uses a single pyroelectric element and is inexpensive.

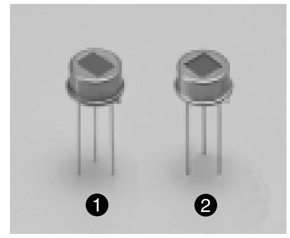


(Typ.)

Type No.	Window material	Active area (mm)	Spectral response range (μm)	Sensitivity (500,1) (V/W)
P2613	Silicon	ϕ2	2 to 20	1200
P2613-01	7 μm long-pass filter	ϕ2	7 to 20	940
P2613-02	4.3 μm band-pass filter	ϕ2	4.3 (HW=90 nm)	1500
P2613-03	8-14 μm band-pass filter	ϕ2	8 to 14	670
P2613-12	4.4 μm band-pass filter	ϕ2	4.4 (HW=600 nm)	2000

Dual-element/four-element type

These dual-element and four-element pyroelectric detectors are optimized for human body sensing.

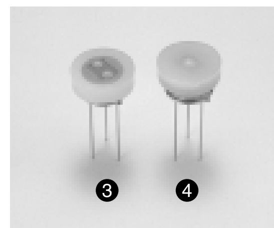


(Typ.)

Type No.	Photo	Window material	Active area (mm)	Spectral response range (μm)	Sensitivity (500, 1) (V/W)
P7176	❶	6.5 μm long-pass filter	2 × 1 (× 2)	7 to 20	1300
P7176-02		5 μm long-pass filter		5 to 20	1500
P7178		6.5 μm long-pass filter		7 to 20	1300
P7178-02		5 μm long-pass filter		5 to 20	1500
P7108	❷	6.5 μm long-pass filter	1 × 1 (× 4)	7 to 20	2200
P7108-02		5 μm long-pass filter		5 to 20	2800

Dual-element type with lens

These pyroelectric detectors are designed for human body sensing. The lens cap provides limited fields of view.

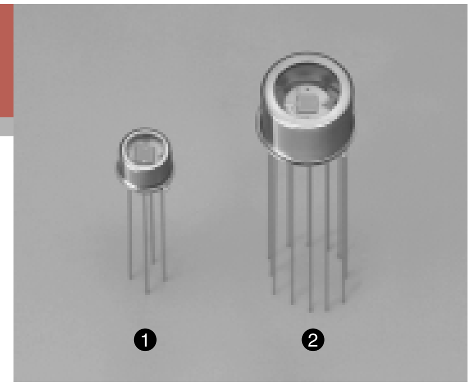


(Typ.)

Type No.	Photo	Window material	Active area (mm)	Spectral response range (μm)	Sensitivity (500, 1) (V/W)
P3514	❸	6.5 μm long-pass filter	2 × 1 (× 2)	7 to 20	450
P3514-01	❹				
P3514-02	❸	5 μm long-pass filter		5 to 20	500
P3514-03	❹				

Two-color detector

Two-color detectors incorporate an infrared-transmitting Si photodiode mounted over a PbS detector, PbSe detector or InGaAs PIN photodiode along the same optical axis. This structure delivers a broad spectral response range. Thermoelectric cooled types maintain a constant temperature during operation allowing precision measurement with an improved S/N.

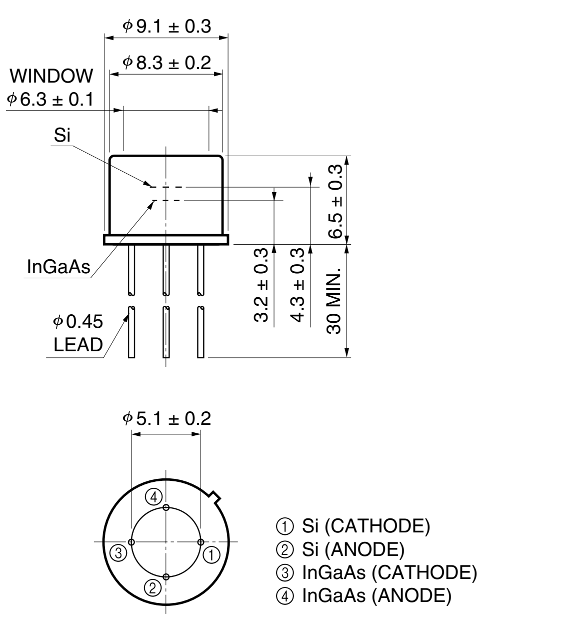


(Typ.)

Type No.	Package		Cooling	Detector element	Active area (mm)	Spectral response range (µm)	Peak sensitivity wavelength (µm)	Photo sensitivity (A/W)
K1713-01	❶	TO-5	Non-cooled	Si	2.4 × 2.4	0.2 to 2.9	0.94	0.45
				PbS	1.8 × 1.8		2.2	6×10^4 (V/W)
K1713-02				Si	2.4 × 2.4	0.2 to 4.8	0.94	0.45
				PbSe	1.8 × 1.8		4.0	5×10^2 (V/W)
K1713-05				Si	2.4 × 2.4	0.25 to 1.7	0.94	0.45
				InGaAs	ϕ0.5		1.55	0.55
K1713-08				Si	2.4 × 2.4	0.25 to 2.6	0.94	0.45
				InGaAs	ϕ1		2.3	0.60
K1713-09				Si	2.4 × 2.4	0.25 to 1.7	0.94	0.45
				InGaAs	ϕ1		1.55	0.55
K3413-01	❷	TO-8	One-stage TE-cooled	Si	2.4 × 2.4	0.2 to 3.1	0.94	0.45
				PbS	1.8 × 1.8		2.4	3×10^5 (V/W)
K3413-02				Si	2.4 × 2.4	0.2 to 5.1	0.94	0.45
				PbSe	1.8 × 1.8		4.1	1.5×10^3 (V/W)
K3413-05				Si	2.4 × 2.4	0.25 to 1.7	0.94	0.45
				InGaAs	ϕ0.5		1.55	0.55
K3413-08				Si	2.4 × 2.4	0.25 to 2.6	0.94	0.45
				InGaAs	ϕ1		2.3	0.60
K3413-09				Si	2.4 × 2.4	0.25 to 1.7	0.94	0.45
				InGaAs	ϕ1		1.55	0.55

■ Example of two-color detector (K1713-05/-08/-09)

The drawing below shows a two-color detector consisting of a Si photodiode and an InGaAs PIN photodiode assembled on the same optical axis. The Si photodiode detects infrared light at shorter wavelengths and serves as a short-wavelength cut-off filter for the InGaAs PIN photodiode.



Photon drag detector

The photon drag detector makes use of the photon drag effect in which holes created in a semiconductor by incident photons are dragged along in the direction of the photons, generating an electromotive force. Because of its high-speed response and high sensitivity at 10.6 µm, this detector is ideally suited for detection of CO_2 lasers. The surface of the detector element is coated with a non-reflective material.

Non-cooled type

Accessories (Optional)

- Magnet stand: A1447

(Typ.)

Type No.	Cooling	Active area (mm)	Peak sensitivity wavelength (µm)
B749	Non-cooled	ϕ5	10.6

Infrared detector module with preamp

Accessories (Supplied)

- 4-conductor cable 2 m (for connection to DC power supply, connector installed on one end): A4372-02

Accessories (Optional)

- Power supply for B7506-01 (±15 V): C3871

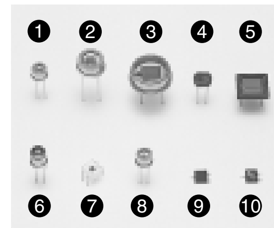
(Typ.)

Type No.	Cooling	Active area (mm)	Peak sensitivity wavelength (µm)
B7506-01	Non-cooled	ϕ4.6	10.6

GaAsP, GaP photodiode

GaAsP, GaP photodiodes have a spectral response range close to that of the human eyes, with suppressed sensitivity at longer wavelengths which are covered by Si photodiode spectral response. Typical applications include UV detection, spectrophotometry and color sensing.

■ Diffusion type GaAsP photodiode



For visible range

(Typ.)

Type No.	Package		Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current Max. V_R=10 mV (pA)
G1115	1	TO-18	1.3 × 1.3	300 to 680	640	1
G1116	2	TO-5	2.7 × 2.7			2.5
G1117	3	TO-8	5.6 × 5.6			5
G1118	4	Ceramic	1.3 × 1.3			1
G1120	5	Ceramic	5.6 × 5.6			5
G3067	6	TO-18	1.3 × 1.3			1
G2711-01	7	Plastic	1.3 × 1.3			1

Red sensitivity extended type

(Typ.)

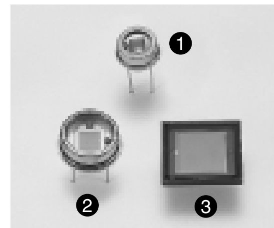
Type No.	Package		Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current Max. V_R=10 mV (pA)
G1735	1	TO-18	1.3 × 1.3	400 to 760	710	2
G1736	2	TO-5	2.7 × 2.7			5
G1737	3	TO-8	5.6 × 5.6			10
G1738	4	Ceramic	1.3 × 1.3			2
G1740	5	Ceramic	5.6 × 5.6			10
G3297	6	TO-18	1.3 × 1.3			2

Short-wavelength type

(Typ.)

Type No.	Package		Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current V_R= 5 V Max. (pA)
G5645	8	TO-18	0.8 × 0.8	300 to 580	470	50
G5842	9	Plastic		260 to 400	370	
G6262	10	Plastic		280 to 580	470	
G7189	7	Plastic		300 to 580	470	

■ Schottky type GaAsP photodiode



For UV to visible range

(Typ.)

Type No.		Package	Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current Max. VR=10 mV (pA)
G1126-02	❶	TO-5	2.3 × 2.3	190 to 680	610	5
G1127-02	❷	TO-8	4.6 × 4.6			10
G2119	❸	Ceramic	10.1 × 10.1			100

Red sensitivity extended type

(Typ.)

Type No.		Package	Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current Max. VR=10 mV (pA)
G1746	❶	TO-5	2.3 × 2.3	190 to 760	710	10
G1747	❷	TO-8	4.6 × 4.6			20

■ Schottky type GaP photodiode

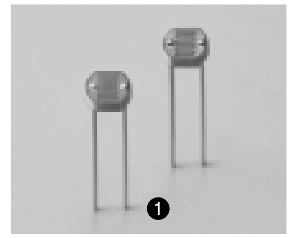
(Typ.)

Type No.		Package	Active area (mm)	Spectral response range (nm)	Peak sensitivity wavelength (nm)	Dark current Max. VR=10 mV (pA)
G1961	❹	TO-18	1.1 × 1.1	190 to 550	440	2.5
G1962	❺	TO-5	2.3 × 2.3			5
G1963	❻	TO-8	4.6 × 4.6			10

CdS photoconductive cell

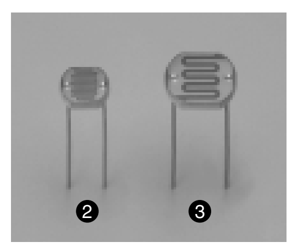
These photoconductive sensors decrease their resistance with input of visible light.

Resin coating type



(Typ.)

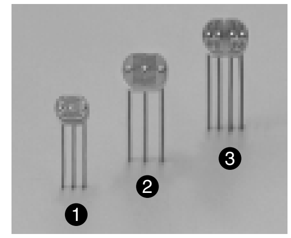
Type No.	Package		Peak sensitivity wavelength λp (nm)	Resistance 10 *lx*, 2856 K Min. (kΩ)	Resistance 10 *lx*, 2856 K Max. (kΩ)	Resistance 0 *lx* Min. (MΩ)	γ^{100}_{10} 100 to 10 *lx*
5R type							
P201D-5R	❶	5.1 × 4.3	520	48	140	20	0.90
P380-5R			620	12	36	20	0.85
P722-5R			560	5.3	15	0.5	0.70
P1082-03				13	39	0.2	0.55
P1201			540	20	60	5.0	0.75
P1201-01				30	90		
P687-02			620	5	20	5.0	0.70
P1201-04			540	50	200	20	0.90
P1201-06				50	100		
P1241-04			560	3	9	0.2	0.70
P1241-05				8	24	0.5	0.70
P1241-06				5	20	0.5	0.75
P1444			620	10	50	5.0	0.85
P1445				48	140	20	



(Typ.)

Type No.	Package		Peak sensitivity wavelength λp (nm)	Resistance 10 *lx*, 2856 K Min. (kΩ)	Resistance 10 *lx*, 2856 K Max. (kΩ)	Resistance 0 *lx* Min. (MΩ)	γ^{100}_{10} 100 to 10 *lx*
7R type							
P380-7R	❷	7.0 × 5.9	620	4.4	13	20	0.85
P722-7R			560	2.5	7.5	0.5	0.70
P1195			550	50	150	20	0.90
P1202-12			560	3.5	14	0.5	0.70
P1202-16			550	23	67	20	0.90
10R type							
P722-10R	❸	10.1 × 8.5	560	12	36	0.5	0.70
P1096-06			550	2.8	8.4		0.75

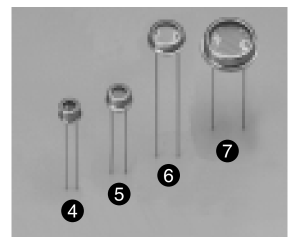
Resin coating · dual type



(Typ.)

Type No.	Package		Peak sensitivity wavelength λp (nm)	Resistance 10 lx, 2856 K Min. (kΩ)	Resistance 10 lx, 2856 K Max. (kΩ)	Resistance 0 lx Min. (MΩ)	γ^{100}_{10} 100 to 10 lx
5R type							
P1395-01	❶	5.1 × 4.3	550	5	15	0.1	0.60
7R type							
P2405	❷	7.0 × 5.9	520	45	135	20	0.90
P2478-01	❸	7.0 × 5.9	530	25	75	1	0.70

Metal package type



(Typ.)

Type No.	Package		Peak sensitivity wavelength λp (nm)	Resistance 10 lx, 2856 K Min. (kΩ)	Resistance 10 lx, 2856 K Max. (kΩ)	Resistance 0 lx Min. (MΩ)	γ^{100}_{10} 100 to 10 lx
5M type							
P1114-01	❹	(TO-18)	630	13	39	1	0.80
P1114-04			570	15	45	10	
6M type							
P930	❺	(ϕ5.5)	560	7	23	0.5	0.68
8M type							
P201B	❻	(TO-5)	560	21	63	20	0.85
P201D			520	20	60	10	0.90
P368			620	14	43	20	0.85
P380				4.4	13		
P467			520	8	24	5	0.90
P534			560	1.3	3.7	0.05	0.55
12M type							
P621	❼	(TO-8)	570	1.3	3.7	0.3	0.75
P3872			540	5	15	1.0	0.80

Application example

Compound semiconductor photosensors are utilized in a wide range of technical and scientific fields, including industry, agriculture, medicine, astronomy, communications and remote sensing from space. Hamamatsu compound semiconductor photosensors are used in many applications as listed in the table below. Type numbers herein are main products we recommend for each application.

● Hamamatsu compound semiconductor photosensors and major applications

Application \ Detector	PbS	PbSe	InSb	InAs	MCT	Pyroelectric detector	Two-color detector	Photon drag detector	GaAsP	GaP
Thermometers	P394	P791-11	P6606-310		P2750 P3981 P3982	P2613-03 P3782-03				
HMD (Hot Metal Detectors)	P394									
Flame monitors	P394						K1713-01			
Fire detectors		P791-11				P2613-12 P3782-12 P4736-12	K1713-02			
Moisture analyzers	P394 P394-22 P2532-01 P2682-01				P3982					
Gas analyzers		P791-11 P2038-03 P2680-03	P5968 series P6606-310		P3981 P3982 P2750	P2613 series P3782 series P4736 series				
Spectrophotometers			P5968 series	P7163	P3257 series P5274	P2613 P3782 P4736	K1713-05 K1713-08 K1713-09			
Film thickness gauges		P791-11 P2038-03			P3257 series P3981					
Laser monitors				P8079 series			K1713-05 K3413-05	B749		
Optical power meters						P2613 series P3782 series P4736 series				
Laser diode life test										
O/E converters										
FTIR					P3257/P5274 series	P2613 P3782 P4736				
Thermal imaging			P5968-060		P3257-01/-25 P2750					
Remote sensing			P5968 series		P3257 series					
Human body detection						P3514/P7178 series				
Chromaticity meter									G1115 G1116 G1117 G1120	
DPE									G1126-02 G1746	
UV monitors										G1962 G1963 G5842

Description of terms

1. Dark resistance: Rd

This is the resistance of a photoconductive device (PbS, PbSe, MCT, etc.) in the dark state.

2. Dark current: ID

The dark current is the small current which flows when a reverse voltage is applied to a photovoltaic detector (InGaAs, InAs, InSb, etc.) under dark conditions. This is a factor determining the lower limit of light detection.

3. NEP (Noise Equivalent Power)

This is the radiant power that produces S/N of 1 at the detector output. In this data sheet, the NEP value at the peak wavelength and bandwidth of 1 Hz is listed. The NEP is given by

$$\text{NEP} = \frac{\text{Noise current [A/Hz}^{1/2}]}{\text{Photo sensitivity at } \lambda p \text{ [A/W]}} \text{ [W/Hz}^{1/2}]$$

In actual detector operation, the detection limit must be taken into account along with other factors such as the supply voltage, noise frequency bandwidth and signal processing. This means that the minimum detection limit in the actual operation will be higher than the NEP obtained from the noise current under dark conditions.

4. FOV (Field Of View)

The field of view is the angular measure of the volume of space within which the systems can respond to the presence of a target. It is related to the background radiation noise and greatly influences the value of D*.

5. Offset voltage

This is DC output voltage of an amplifier when the input is zero.

6. Responsivity

1) Photo sensitivity: S

This is the detector output divided by the incident radiant power at a given wavelength. It is usually expressed in V/W for photoconductive or pyroelectric detectors and in A/W for photovoltaic detectors. For photon drag detectors, this is represented as the output voltage with respect to incident pulsed energy of 1 kW radiated from a CO_2 laser.

2) Sensitivity

This term also expresses the output voltage from a pyroelectric detector when operated under certain conditions using blackbody, etc. light source.

7. Photoconductive detector

This is a semiconductor detector whose resistance decreases with increase in light intensity. Photoconductive detectors include PbS, PbSe and MCT detectors.

8. Photovoltaic detector: Photodiode

This is a semiconductor detector that convers radiant energy into current or voltage when radiant flux enters its PN junction. InGaAs, InAs and InSb detectors are photovoltaic.

9. Peak sensitivity wavelength: λp

This is the wavelength at which the sensitivity of the detector is at maximum.

10. Reverse voltage (Max.): VR (Max.), Supply voltage (Max.)

Applying reverse voltage to photodiodes (or applying voltage to photoconductive detectors) at a certain level can cause breakdown and severe deterioration of detector performance. The maximum reverse voltage (or maximum supply voltage) is the limit that can be applied to the detector.

11. Allowable current (Max.)

Photoconductive detectors are operated using a constant-current power supply. When the supply current is higher than the maximum allowable current, the detector performance may deteriorate, therefore, excessive current must be avoided.

12. Cut-off frequency: fc

This is a measure of a detector response to sine-wave incident light and defined as the frequency at which the output voltage drops by 3 dB from the response level at low frequencies.

13. Rise time: tr

This is the measure of a detector time response to a stepped light input, and defined as the time required for transition from 10 % to 90 % (or 0 to 63 %) of the output level. The light sources used are GaAs LED (0.92 µm), laser diode (1.3 µm), etc.

14. Terminal capacitance: Ct

In a photovoltaic detector, an effective capacitor is formed at the P-N junction. This capacitance is termed the junction capacitance and is a major factor in determining the response speed of the detector. In data sheets, this capacitance is measured between the lead terminals of the package including the package stray capacitance.

15. Short circuit current: Isc

This is an indication of the responsivity of a photovoltaic detector. It refers to current which flows when a detector with zero load resistance is illuminated by a tungsten lamp (2856 K, 100 *lx*). The Isc value varies in proportional to the active area.

16. Cut-off wavelength: λc

This represents the long wavelength limit of spectral response and in data sheets is listed as the wavelength at which the sensitivity becomes 10 % of the value at the peak wavelength.

17. Chopping frequency

In the measurement of infrared detector responsivity, an optical chopper is often used to perform on-off operation of incident light. This is the frequency of the chopper.

18. D* (D-star)

D* is the detectivity of a detector that indicates the S/N when radiant energy of 1 W is incident on the detector. Since D* is normalized by an active area of 1 cm^2 and noise bandwidth of 1 Hz, it is independent of the size and shape of the active element. D* is defined with respect to the following three parameters: A) infrared source temperature (K) or wavelength (µm), B) chopping frequency, and C) noise bandwidth, as represented in D* (A, B, C). D* is expressed by cm · $Hz^{1/2}$/W, and the higher D* value, the better the detector. D* is given by

$$D^* = \frac{S/N \cdot \Delta f^{\frac{1}{2}}}{P \cdot A^{\frac{1}{2}}}$$

where S is the signal, N is the noise, P is the incident energy in W/cm^2, A is the active area in cm^2 and Δf is the noise bandwidth in Hz. The following relation is established by D* and NEP.

$$D^* = \frac{A^{\frac{1}{2}}}{\text{NEP}}$$

19. Noise: N

The noise is the output voltage from a photoconductive detector operated under specified conditions and 300 K background radiations.

20. Shunt resistance: Rsh

This indicates the dark current characteristics of a photovoltaic detector (InGaAs, InAs, InSb, etc.). It is the voltage/current ratio of a detector operated in the 0 V region (10 mV in data sheets) in a dark state.

21. Quantum efficiency: η

This is the ratio of the number of incident photons to resulting photoelectrons in the output current. Quantum efficiency, and photo sensitivity have the following relation at a given wavelength λ.

$$\eta = 1.24 \; S/\lambda$$

Characteristic and use

1. PbS, PbSe photoconductive detector

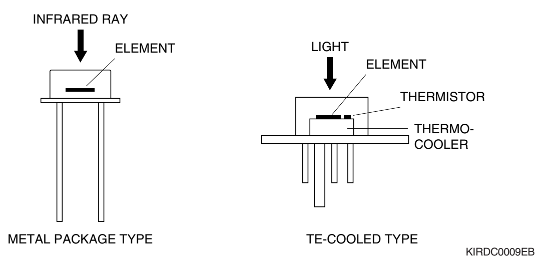
PbS, PbSe detectors are photoconductive semiconductors that detect infrared radiation utilizing the fact that their resistance drops upon input of incident infrared radiation. Compared to other types of detectors used in the same wavelength range, they have higher detectivity and can be used at a room temperature, making them useful in a wide range of applications.

■ Construction

PbS, PbSe detectors are manufactured by using a chemical deposition technique in which a granular thin film is formed onto a glass substrate. For this reason, the active area and shape of the photoconductive surface can be changed relatively easily. Two types of packages are available.

· Metal package type
The detector is hermetically sealed in a metallic package and is used chiefly at a room temperature.
· TE-cooled type
The detector, a thermistor and a thermoelectric cooler are in vacuum (or nitrogen) atmosphere and sealed by a metal case. Cooling and temperature regulation are performed by the combination of the thermoelectric cooler and the thermistor.

Figure 1-1 Configuration of PbS and PbSe detectors



■ Theory of operation

It is known that there are two models of photoconductive mechanisms observed in PbS, PbSe detectors. One is the effect observed when infrared energy strikes the p-n-p-n structure that has been formed by oxidation of the surface of n-type granular thin film. The incident infrared energy is thought to lower the potential barrier of the p-n-p-n structure and promote the flow of minority carriers. The other mechanism consists of the formation of minority carrier traps by oxidation of the granular surface. The electrons that are released resulting from the absorption of infrared energy are thus captured. It is thought that this increases the lifetime of majority carriers and increases the number of free positive holes.

■ Spectral response

At room temperature operation, PbS detectors have peak sensitivity at 2.2 μm, while that of PbSe is at 3.8 μm. For both types, temperature characteristics of the band-gap differ from those of other semiconductors. Thus, by cooling the detector, the cut-off wavelength will be shifted in the direction of longer wavelength.

Figure 1-2 Spectral response (PbS)

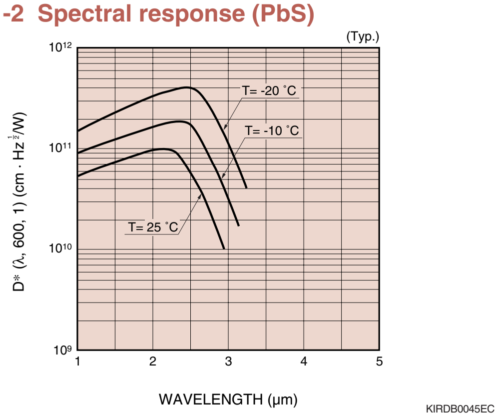
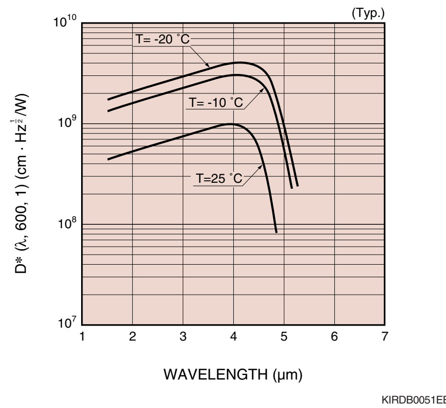


Figure 1-3 Spectral response (PbSe)



■ Temperature characteristic

For PbS, PbSe detectors, changes in ambient temperature result in shifts in spectral response, dark resistance, and time constant.
As described above, the spectral response at longer wavelengths increases as the temperature decreases. This is accompanied by increase in dark resistance. The change in dark resistance at near room temperature is approximately 3 %/˚C. The time constant for both PbS, PbSe detectors increases by 5.3 %/˚C approx. With a decrease in temperature. When such cells are cooled with dry ice (-77 ˚C), detectivity increases in one order of magnitude, the dark resistance is in the range of several MΩ to several tens of MΩ, and the time constant is in the order of several milliseconds. High ambient temperature not only reduces detectivity but is a cause of accelerating detector deterioration and should therefore be avoided.

Figure 1-4 Dark resistance, rise time vs. element temperature (PbS)

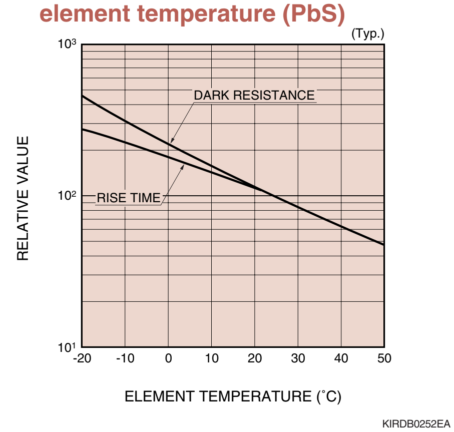
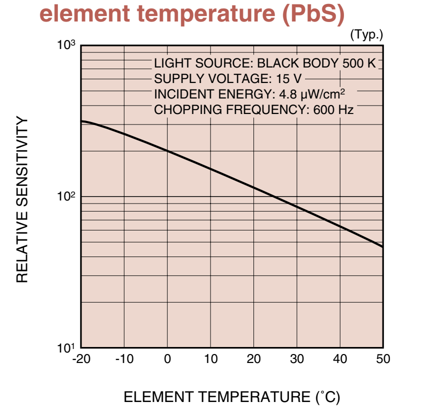


Figure 1-5 Photo sensitivity vs. element temperature (PbS)



■ Frequency response

The frequency sensitivity for sensitivity is given by the following formula.

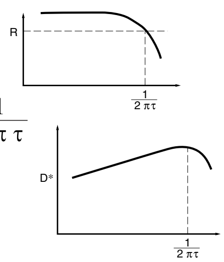
$$R\,(f) = \frac{R_0}{(1 + 4\pi^2 \cdot f^2 \cdot \tau^2)^{1/2}}$$

In this relationship, R (f) is the frequency response, Ro is the response at frequency 0 Hz, and τ is the time constant. PbS and PbSe detectors exhibit typical 1/f noise spectra. The measure of this, D*, is given by the following formula:

$$D^*\,(f) = \frac{Kf^{1/2}}{(1 + 4\pi^2 \cdot f^2 \cdot \tau^2)^{1/2}}$$

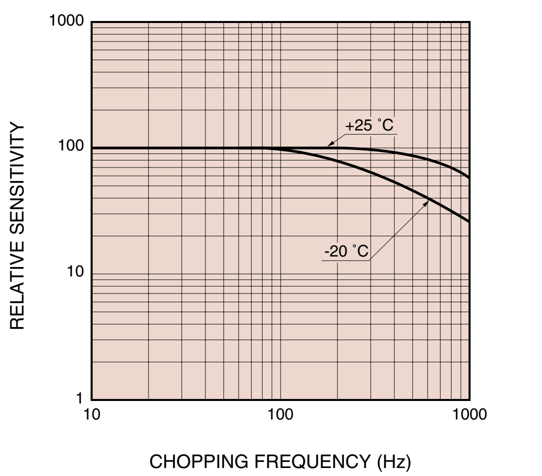
The maximum D* occurs when $f = \dfrac{1}{2\,\pi\,\tau}$

For PbS detectors, the frequency response characteristics will be shown as below.



KIRDC0010EA

Figure 1-6 Photo sensitivity vs. chopping frequency (PbS)



KIRDB0083EC

■ Voltage dependence

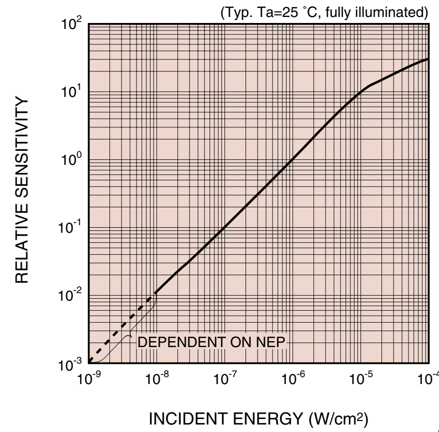
In general, noise is not a significant factor at low supply voltages, but increases linearly after a certain voltage is exceeded and rises sharply as the voltage increases further. The output signal also increases in proportion to the supply voltage. During actual use the supply voltage must be below the absolute maximum rating specified in data sheets, and should be kept as low as possible.

■ Linearity and power dissipation

The relationship between incident energy and output is shown in Figures 1-7 and 1-8. The lower limits are determined by the NEP (Noise Equivalent Power) values for PbS and PbSe detectors. The NEP is given by

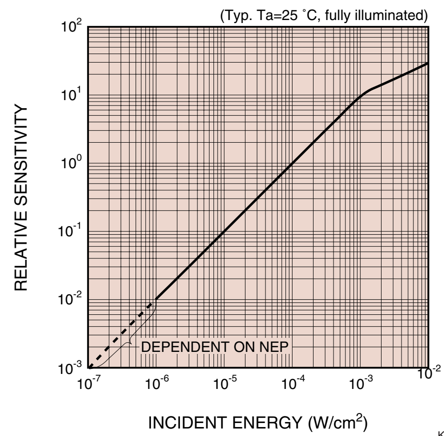
$$NEP = \frac{\sqrt{A}}{D^*}$$ Where A is the active area

Figure 1-7 Photo sensitivity linearity (PbS)



KIRDB0050EA

Figure 1-8 Photo sensitivity linearity (PbSe)



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■ Operating circuit examples

Figure 1-9 Basic operating circuit

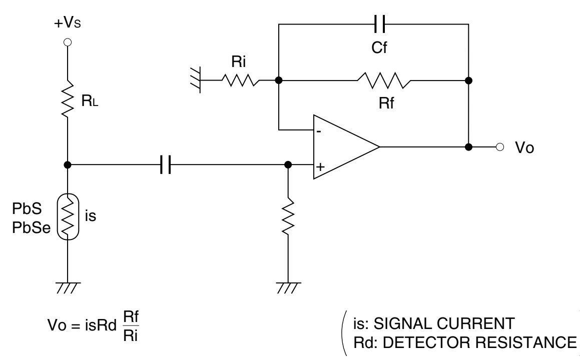

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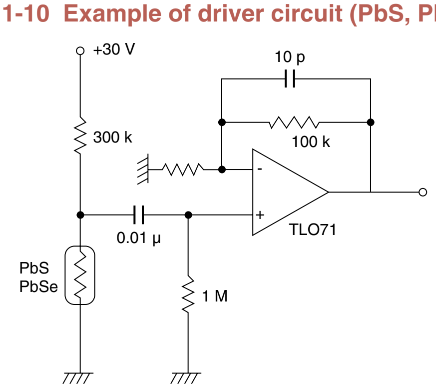
Figure 1-10 Example of driver circuit (PbS, PbSe)



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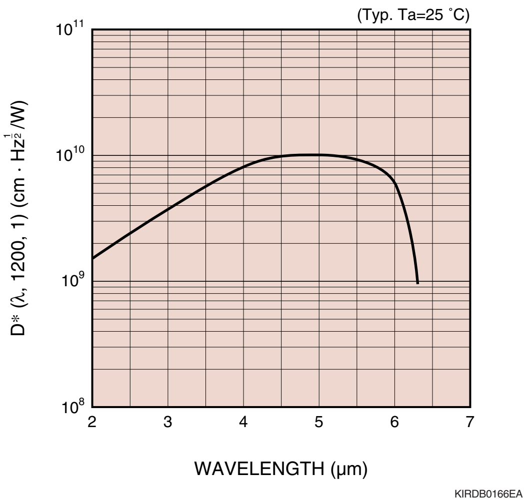
2. InSb photoconductive detector

Like PbS and PbSe photoconductive detectors, InSb photoconductive detectors detect infrared light by utilizing the photoconductive effect by which resistance lowers as infrared light is input.

■ Spectral response

InSb photoconductive detectors spectral response curve is shown in figure 2-1.

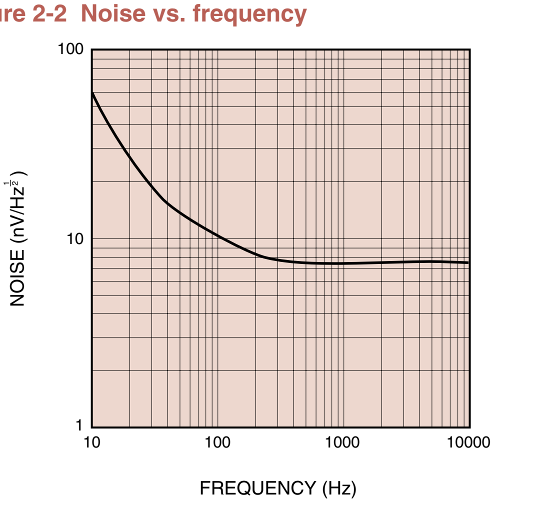
Figure 2-1 Spectral response



■ Noise characteristic

Noise generated in InSb photoconductive detectors is composed of 1/f noise, g-r noise due to electron-hole recombination, and Johnson noise (thermal noise). The 1/f noise is predominant at lower frequencies and the g-r noise becomes dominant at higher frequencies. The relation between noise and frequency is shown in Figure 2-2.

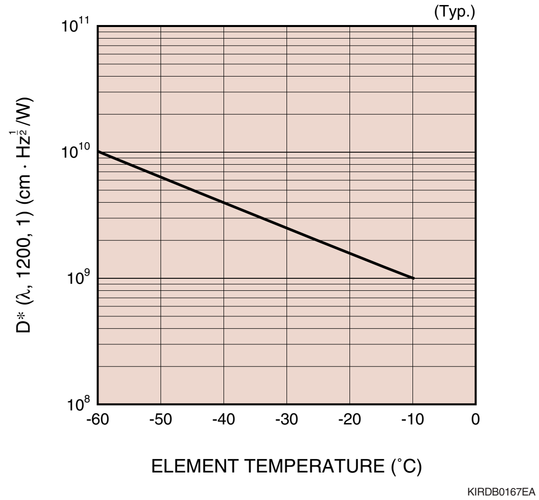
Figure 2-2 Noise vs. frequency



■ Temperature characteristic

D∗ and spectral response characteristics of InSb photoconductive detectors vary with the detector element temperature. As the temperature increases, D∗ decreases and the spectral response range shifts towards the short wavelengths.

Figure 2-3 D∗ vs. element temperature



3. InSb, InAs photovoltaic detector

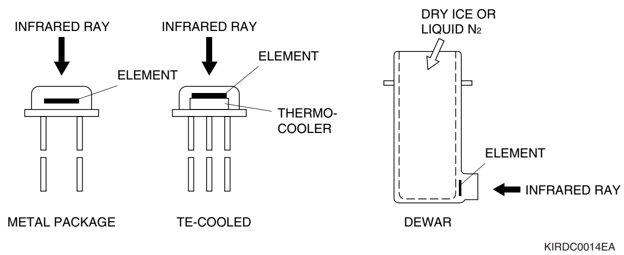
InAs, InSb photovoltaic detectors are semiconductors that make use of the photovoltaic effect in that a voltage is generated upon input of infrared energy.

■ Construction

The detector element itself consists of a mesa type or planer type diode structure. Metal dewars are used when cooling the detector with dry ice or liquid nitrogen.

· Metal package type
 The detector element is hermetically sealed in a metal package. Used mainly at room temperatures.
· Dewar type
 The detector element is housed in an evacuated metal dewar. Used at low temperatures by cooling with dry ice, etc.
· Thermoelectrically cooled type
 The detector element is hermetically sealed in a metal package filled with inert gas, together with a thermoelectric cooler and thermistor. A one-stage or two-stage thermoelectric cooler is used.

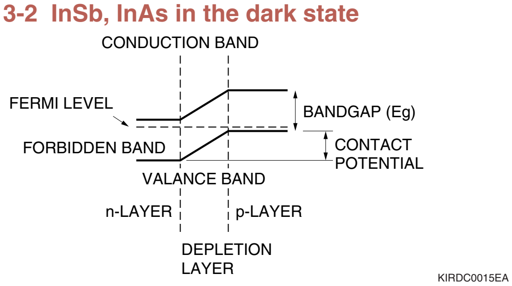
Figure 3-1 Constructions of InSb and InAs detectors



■ Theory of operation

When no infrared energy is applied to the detector, it is in thermal equilibrium with uniform p- and n-layer Fermi levels. Internally, a contact potential develops, forming a potential barrier and a resultant potential gradient in the depletion layer.

Figure 3-2 InSb, InAs in the dark state



When infrared energy is allowed to strike the detector, the electrons in the detector are excited. When the energy of the excited electrons exceeds the band gap Eg, the electrons are pulled into the conduction band and become free electrons, leaving behind positive holes. As this is happening, in the depletion layer positive holes drift towards the p-layer and negative electrons towards the n-layer by virtue of the potential barrier in that layer. In addition, the electrons in the p-layer within the electron diffusion length and holes in the n-layer within the hole diffusion length are diffused into the depletion layer resulting in drift caused by the potential difference and the stored charges in the p- and n-layers (see Figure 3-3).
These stored charges lower the potential barrier formed at the p-n junction and thus promotes movement of electrons from the n- to p-layer and of holes from the p- to n-layer, causing a reduction in the stored charges. This provides a natural limit on the amount of charges that are stored; in effect, the potential barrier lowers to a certain level when the movement of charges ceases. The detector output is taken as either the open circuit voltage (Voc) or the current that flows when the output is shorted, (Isc), either of which can be used to represent the change in potential barrier.

Figure 3-3 InSb, InAs with incident IR radiation

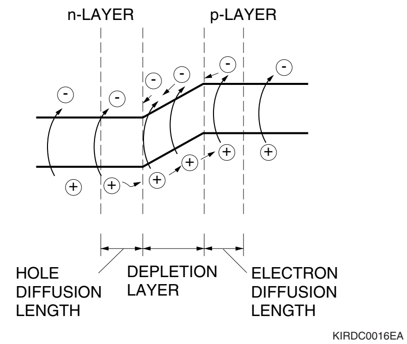
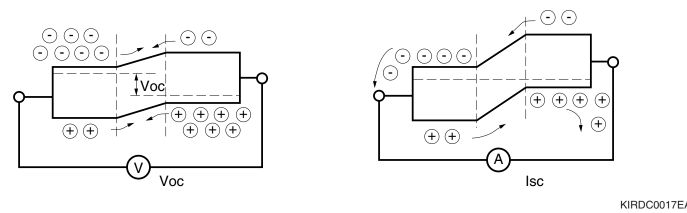


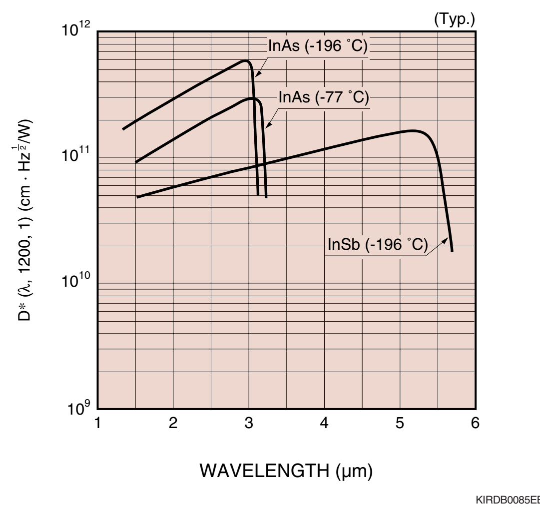
Figure 3-4 InSb, InAs outputs



■ Spectral response and temperature

The spectral response of photovoltaic detectors shifts as the temperature changes. As shown in Figures 3-5, as the temperature decreases, the overall detectivity increases, with the detectivity to longer wavelengths, however, decreasing.

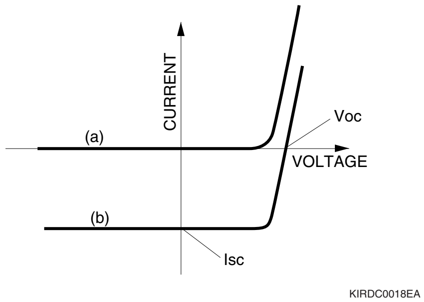
Figure 3-5 Spectral response of InSb, InAs detectors



■ V-I characteristic

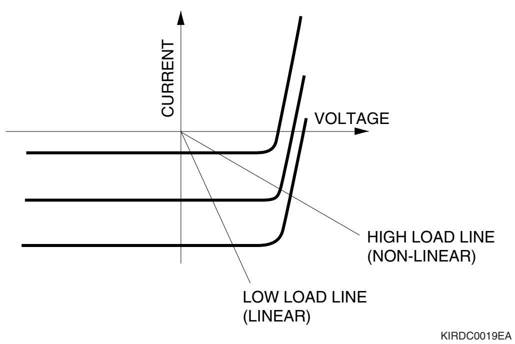
Curve (a) in Figure 3-6 shows the V-I characteristic of a detector in the dark state. When infrared radiation is applied, the curve shifts to that shown as (b). When the detector's terminals are left open, the forward voltage Voc appears and when shorted, the current Isc flows in the reverse direction.

Figure 3-6 Current vs. voltage



Voc changes logarithmically with respect to the amount of incident infrared light, while Isc changes linearly. The effect of applying a load is shown in Figure 3-7. Note that the applying a load lowers the upper limit of linearity, so that the load should be kept as small as possible to maintain high linearity.

Figure 3-7 Effect of applied load on linearity



■ Noise characteristic

Like other types of detectors, the lower limits of light detection for a photovoltaic detector are determined by its noise characteristics. The noise in of a photovoltaic infrared detector is expressed in the sum of Johnson noise ij caused by the internal shunt resistance Rsh and the shot noise resulting from the photocurrent and the dark current. Thus the noise in is given by

$$in = \sqrt{(ij^2 + is^2)}$$

In general, because photovoltaic infrared detectors have a large dark current, they are usually used at 0 V bias. In this case, the noise is determined only by Johnson noise ij, as follows:

$$in = ij = \sqrt{\frac{4\,kTB}{Rsh}}$$

k : Boltzman constant
T : Absolute temperature of the element
B : Noise bandwidth

In contrast, when used with a bias voltage applied, the shot noise is added, as follows

$$is = \sqrt{2qIB}$$

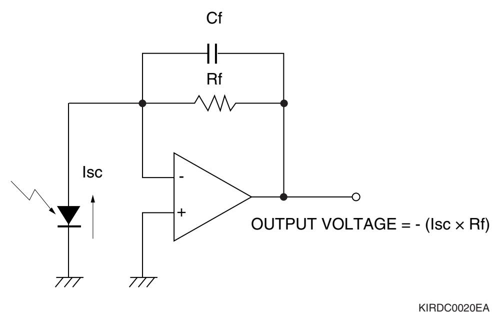
q : Elementary charge
I : Photocurrent + dark current
B : Noise bandwidth

The noise current represents flat frequency characteristics and are proportional to the square root of the noise bandwidth, so that they are expressed in units of $A/Hz^{1/2}$, normalized by the bandwidth. NEP becomes large due to flicker noise, etc. To approximate the lower detection limit or NEP, use of a synchronous measurement technique is effective. It is also necessary to narrow the bandwidth using a lock-in amplifier, etc.

■ Basic circuit connection

It can be seen from the description of the V-I characteristic of the detector that the most common form of output is not the voltage appearing across an applied load, but rather the output current. This is particularly true in precision measurement applications for which the use of an operational amplifier circuit having an equivalent input resistance near zero is recommended.
Figure 3-8 shows the basic circuit connection for use of such an amplifier. The output is simply the product of Isc and the feedback resistance Rf, with the output signal being converted from a current to voltage by this circuit. From the stand point of noise performance, the feedback resistance Rf should be made smaller than the detector's parallel resistance. The feedback capacitance Cf is used mainly to prevent oscillation or ringing and should have a value of more than several picofarads.

Figure 3-8 Basic circuit connection



While the circuit of Figure 3-8 makes use of the time constant of Cf × Rf to provide noise filtering, it also limits the rise time. The circuit constants should, therefore, be chosen in consideration of the possible application. For applications in which extremely small amounts of infrared energy are to be measured, Rf can be made larger to increase the output voltage as its parallel resistance. Care is required however, the operational amplifier noise, offset as well as detector noise will increase by a factor of [1 + (Rf/Rsh)].

4. MCT (HgCdTe) photoconductive detector

MCT (HgCdTe) photoconductive detectors make use of the photoconductive effect in which conductivity increases with incident infrared radiation. The energy band-gap of an HgCdTe crystal can be varied by the composition ratio of HgTe and CdTe. Thus, various spectral response characteristics are available.

■ Construction

MCT photoconductive detectors are manufactured by forming a single HgCdTe crystal on a sapphire substrate. Therefore, the active area, shape and number of elements can be changed relatively easily. In an ordinary operation, since MCT detectors for long wavelength detection are cooled at a liquid nitrogen temperature, they are contained in a metal dewar. Easy-to-use thermoelectrically-cooled type and starling type are also available.

■ Operating principle (photoconductive effect)

When infrared light enters an MCT detector, the electrons within the valence band absorb the incident light energy. They are thus excited and pulled into the conduction band, resulting in an increase in conductivity. This photoconductive effect takes place when the incident light energy is greater than the band gap energy of the MCT so that the carriers are excited.

■ Temperature characteristic

The D∗ and spectral response characteristic of MCT detectors vary with temperature. When an MCT detector is operated at higher than -196 ˚C, the D∗ value decreases and the peak sensitivity wavelength shifts to the shorter wavelength side. It is recommended that dewar type MCT detectors be cooled by liquid nitrogen during operation.

■ Spectral response

As stated above, the energy band gap of an MCT (HgCdTe) crystal can be varied by the composition ratio of HgTe and CdTe. Figure 4-1 shows this relation. For example, the Hamamatsu P3257 MCT detector uses a composition ratio of $Hg_{0.8}Cd_{0.2}Te$ having an energy gap of 0.1 eV that offers high sensitivity in the 8 to 14 μm wavelength region. Typical spectral response curves for different composition ratios are shown in Figure 4-2.

Figure 4-1 Energy gap vs. HgCdTe composition ratio

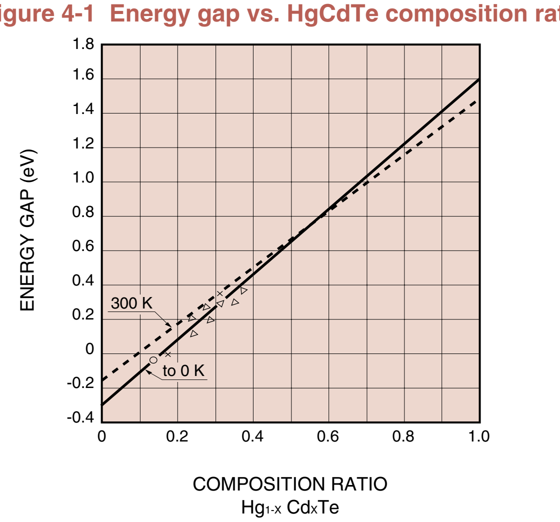


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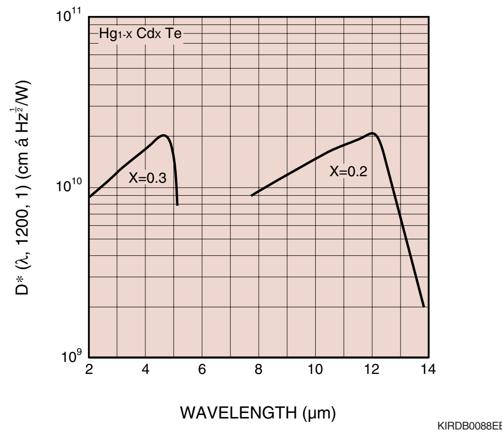
Figure 4-2 Spectral response



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■ Frequency response

Figures 4-3 and 4-4 show the characteristics of noise vs. frequency and D∗ vs. frequency respectively. At 400 Hz or below, it is clear that 1/f noise is dominant. When making measurements, it is recommended to operate the detector within the frequency range where D∗ is flat.

Figure 4-3 Noise vs. frequency

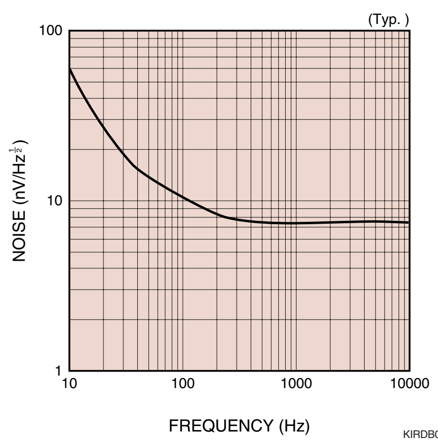

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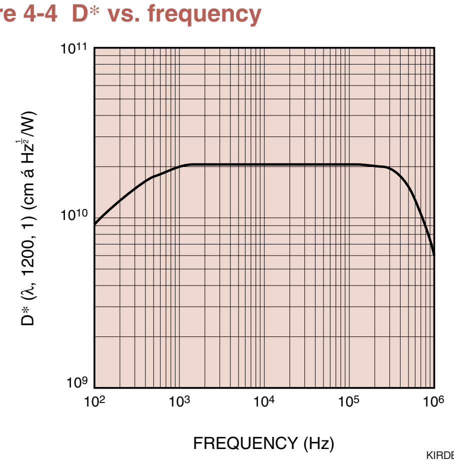
Figure 4-4 D∗ vs. frequency



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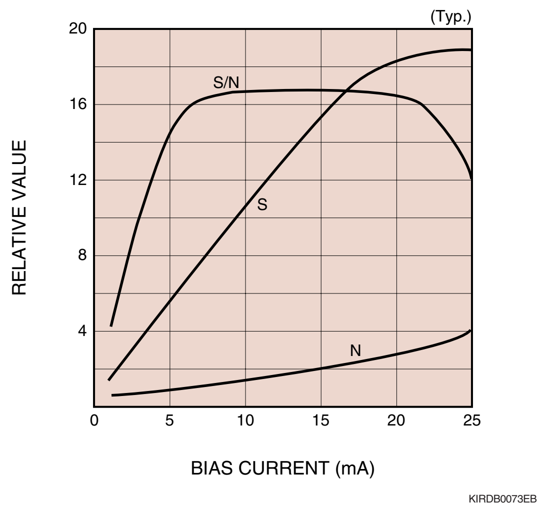
Sensitivity, D∗ and noise of MCT photoconductive detectors vary with the bias current, as shown in Figure 4-5. D∗ improves gradually as the bias current increases, but deteriorates when the bias current exceeds a certain value.

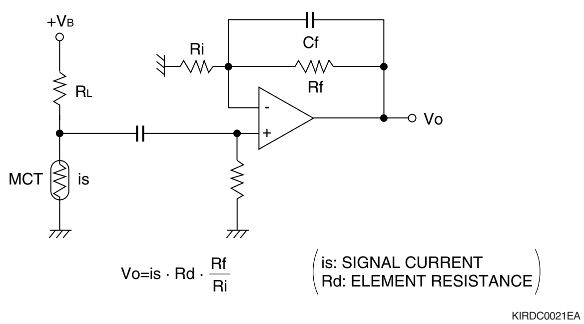
Figure 4-5 S/N vs. bias current



A bias current larger than necessary may damage the detector element and must be avoided. Never apply a bias current to the detector element before it has cooled.

■ Operating circuit

Figure 4-6 Example of basic operating circuit



■ Noise characteristic

As explained above, at 400 Hz or less, the 1/f noise becomes the major factor in the noise of MCT photoconductive detectors. For infrared detectors like MCT detectors having high sensitivity in the long wavelength region, D* is given by the following equation, assuming that background radiation at 300 K is the only source of noise.

$$D^*\lambda = \frac{\lambda}{2hc}\left(\frac{\eta}{Q}\right)^{1/2}$$

η: Quantum efficiency   c : Velocity of light
h: Planck's constant   Q: Background radiation flux

To reduce the background radiation noise, it is necessary to use a cold shield which limits the FOV (Field Of View) or a cold bandpass filter that transmits only a selected wavelength band.

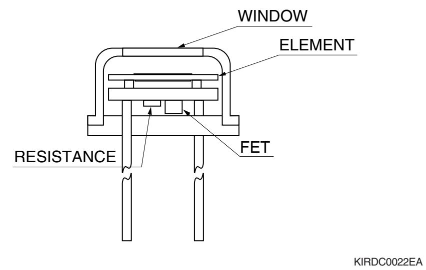
5. Pyroelectric detector

Pyroelectric detectors are thermal type infrared detectors featuring stable operation at room temperatures and their sensitivity is independent of wavelength.

■ Construction

The pyroelectric detector is made of PZT that has very high impedance. Therefore, an FET for impedance conversion is built into the same TO-5 package, as shown in Figure 5-1.
The spectral response is determined by the window material used, so various spectral response characteristics (2 to 20 µm, 7 to 20 µm, 4.3 µm, etc.) are available.

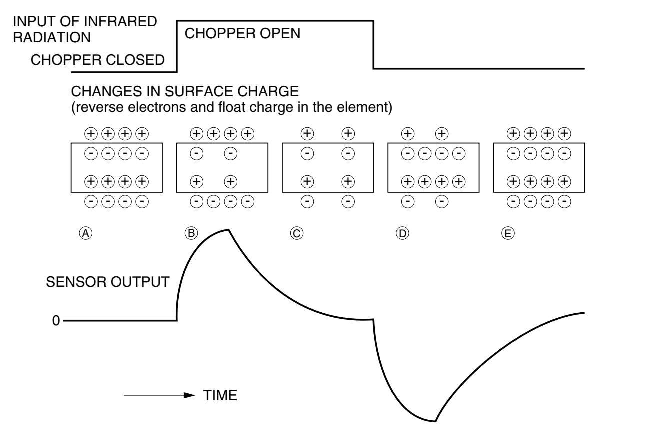
Figure 5-1 Construction of pyroelectric detector



■ Theory of operation

The PZT is spontaneously polarized in the dark state. The element surface is always electrified, but it is neutralized by ions in the air. When light enters the element and is absorbed, the element temperature increases, resulting in a change in the state of spontaneous polarization. These changes are outputted as a voltage change. Since the pyroelectric detector detects light only when a temperature change in the element occurs, it is necessary to use an optical chopper for measurement of still objects. Figure 5-2 shows a schematic presentation of the pyroelectric effect.

Figure 5-2 Pyroelectric effect



There are two ways to obtain the surface charge output from a pyroelectric element. One is voltage output, and the other is current output. The most common way is the voltage output type using a source follower circuit as a trans-impedance circuit. In this case, the responsivity Rv of the pyroelectric detector is expressed by in the following formula.

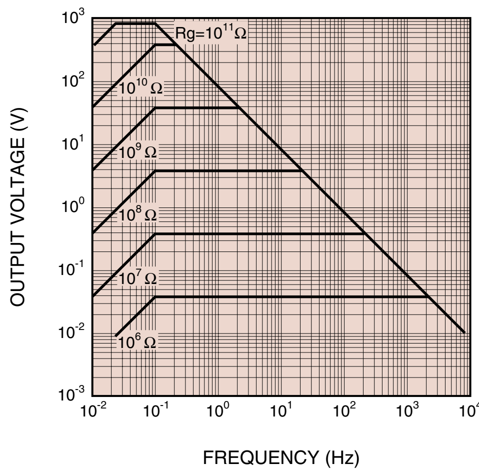
$$Rv = \frac{\eta\omega A_O\lambda R}{G\,(1+\omega^2\,\tau t^2)^{1/2}\,(1+\omega^2\,\tau e^2)^{1/2}}$$

η : Efficiency   λ : Pyroelectric factor   AO: Sensitive area
R : Combined resistance   G: Thermal radiation level   τt : Thermal time constant
τe: Electric time constant   ω: Angular velocity

■ Frequency characteristic

Voltage sensitivity versus frequency characteristics appear as trapezoidal patterns that increase and decrease at both ends of the frequency range determined by the time constant τt and electrical time constant τe, as shown in Figure 5-3. The frequency range where the sensitivity is flat can be widened by choosing the resistance Rg placed in parallel to the pyroelectric element.

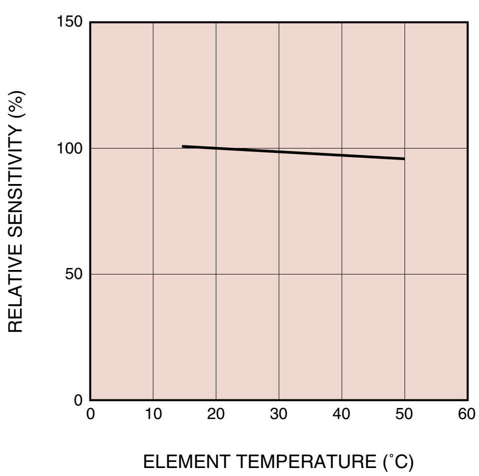
Figure 5-3 Output voltage vs. frequency



■ Temperature characteristic

The typical temperature coefficient of Hamamatsu pyroelectric detectors is 0.2 %/˚C to maintain stable operation. Figure 5-4 shows the relation between the detector sensitivity and temperature.

Figure 5-4 Sensitivity vs. element temperature (P7178 series)



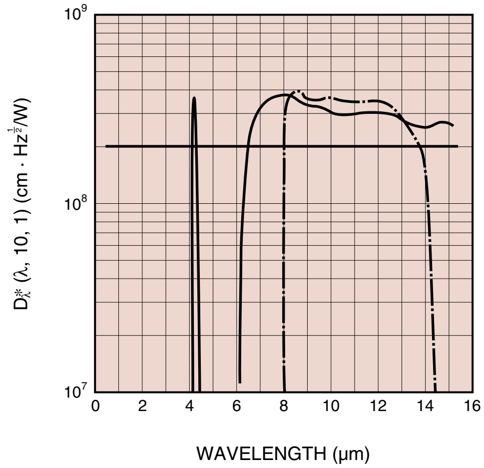
■ Directivity

A light acceptable angle at which the output becomes 50 % of the maximum responsivity is defined as the field of view (FOV). This is 100 degrees for single element types and 120 degrees for dual element types.

■ Spectral response

Since the pyroelectric detector is a thermal type detector, there is no wavelength dependence. The spectral response range is determined only by the window material used. Figure 5-5 shows typical spectral response characteristics of Hamamatsu pyroelectric detectors.

Figure 5-5 Spectral response

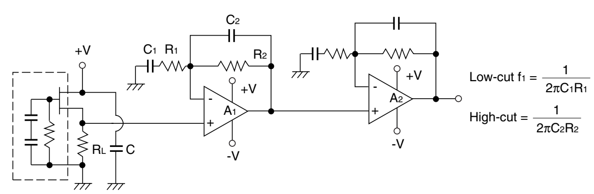


■ Basic operating circuit

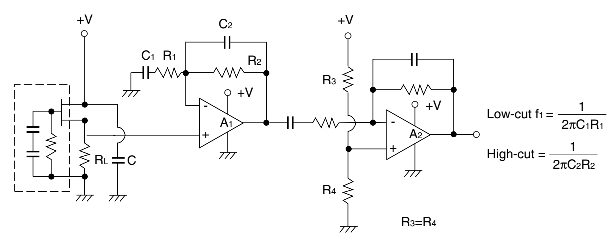
Basic operating circuits are shown in Figure 5-6, (a) with preamplifiers using two power supplies and (b) with preamplifiers using a single power supply.

Figure 5-6 Basic operating circuits

(a) Using two power supplies



(b) Using single power supply



When using circuit (b), care should be taken regarding the following:

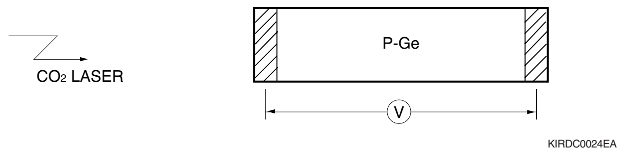
- Set the operating potential of A_2 so that it is centered at the supply voltage.
- In the case A_1 is not AC-coupled, its operating potential is determined by the offset voltage of the pyroelectric detector.

6. Photon drag detector

Photon drag detectors are infrared radiation detectors that make use of the photon drag effect, and are used chiefly as monitors for CO_2 lasers (10.6 μm)

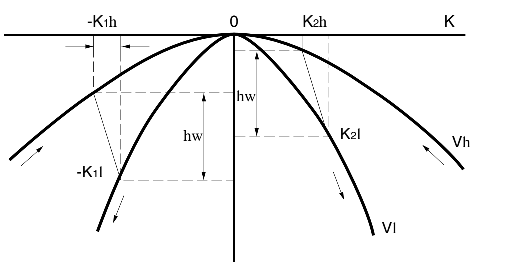
Theory of operation

Figure 6-1 Photon drag detector operation



When the output radiation of a CO_2 laser (10.6 μm) strikes the optically polished germanium surface of the photon drag detector, a voltage is generated. This effect is known as the photon drag effect because it consists of holes in the semiconductor material to be dragged along in the direction of travel of incident photons.
When light is absorbed into the semiconductor material, the photon energy and momentum are imparted to the electrons and holes in the semiconductor. In the range from visible light to infrared, the photon momentum can be neglected. When the number of incident photons becomes large, the overall amount of momentum is great enough to create a detectable current or voltage. Consider this effect as it occurs in p-type germanium. The valence band of germanium is divided into two bands, as shown in Figure 6-2. When photons strike the material, holes absorb the photons' energy and move from the heavy mass band (Vh) to the light mass band (Vl). This movement upsets the hole distribution in both the Vh and the Vl bands in the region K. Movement of holes thus occurs in a direction that restores equilibrium. This movement is known as the photon drag current.

Figure 6-2 Germanium valence electron band structure



High-level input characteristic

When incident laser radiation reaches a level of approximately 10 MW/cm^2, the photon drag voltage is no longer linearly proportional to the incident radiation and exhibits a non-linear characteristic. This is due to a saturation effect in the material absorbing the incident energy. Care is required as the nonreflecting coating of germanium can be damaged by levels of light approximately 10 MW/cm^2.

Precaution for use

Infrared detector

1) Storage

Always store the infrared detector in dark places at a room temperature and humidity. Avoid leaving the detector in locations where it would be exposed to sunlight, strong UV or visible light, as this may result in degradation of the detector characteristics.

2) Handling

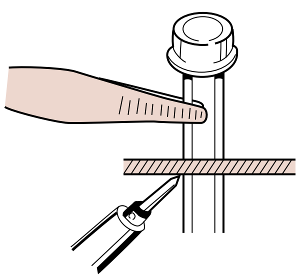
Avoid touching the detector with bare hands as much as possible. And wearing rubber fingertips or teflon gloves is recommended. Some detectors employ such soft materials as ZnS for their windows. When using tweezers or other hard tools, pay attention so as not to allow the tip or any sharp objects to touch the window surface. If the window is scratched or damaged, accurate measurement cannot be expected. In addition, when mounting the detector in place, avoid applying mechanical stress on the package and fixing it with the package decentered, because these unwanted conditions may result in leakage or damage of the package.

3) Lead forming

When forming leads, observe the following recommended mechanical stress limits: For metal package devices, a 0.5 kg pull for 5 seconds maximum, two 90 degree bends and three twists of the device leads at 6 mm minimum away from the package base.
For glass dewar devices, never carry out lead forming as it may cause cracks.

4) Soldering

Since detectors are subject to damage by excessive heat, particular care should be taken when soldering. (Some form of heatsink such as a pair of tweezers should be provided.) As a guide, metal package devices should be soldered at 260 ˚C or below within 10 seconds.



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5) Cleaning

Avoid cleaning the detector in chloric-based vapor or soaking it in alcohol for cleaning, as this may obliterate package marking.

6) Cleaning of window

Be careful to keep the window as clean as possible. If the window needs to be cleaned, use ethyl alcohol and wipe off the window gently. Avoid using any other organic solvents than ethyl alcohol.

Clean away grime by wiping gently with ethyl alcohol.

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InSb photovoltaic detector

InSb photovoltaic detector may be damaged or its performance may be deteriorated by such factors as static electricity charges from the human body, surge voltages from measurement equipment, leakage voltages from soldering irons, and packing materials. As a countermeasure against static electricity, the device, operator, work place and measuring jigs must all be set at the same potential. In using, observe the following precautions:

1) To protect the device from static electricity charges that accumulate on the operator or the operator's clothes, use a wrist strap, etc. to ground the operator's body via a high impedance resistor (1 MΩ). Wearing antistatic clothes is recommended when handling the detector. If not available, wear cotton clothes. Avoid wearing clothes of wool or chemical fiber.
2) A semiconductive sheet (1 MΩ to 100 MΩ) should be laid on both the work table and the floor in the work area.
When soldering, use an electrically grounded soldering iron with an isolation resistance of more than 10 MΩ.
3) For containers for transportation and packing, use of a conductive material or aluminum foil is effective. When using an antistatic material, use one with a resistance of 0.1 MΩ/cm^2 to 1 GΩ/cm^2.

TE-cooled detector

The built-in thermoelectric cooler requires supply current much higher than the maximum allowable current used for the thermistor and detector element incorporated in the same package. If the supply current for the thermoelectric cooler is applied to the thermistor or detector element even momentarily, the thermistor and detector element may be damaged. Sufficient care must be taken when dealing with supply current.

1) Always use a heatsink having the specified thermal resistance (2 ˚C/W or less for three-stage TE-cooled MCT; 3 ˚C/W or less for two-stage TE-cooled MCT and other one or two-stage TE-cooled detectors). The detector's metal package should be securely attached to the heatsink. If heat radiation is inadequate, the detector element may be deteriorated by high temperature, eventually leading to permanent damage.

2) Thermal resistance between the metal package and the heatsink should be as low as possible. To improve thermal coupling, apply heat conductive grease such as silicone grease between them. If the thermal resistance is large, heat dissipation will be poor causing damage to the detector element.

3) Be careful not to misconnect the plus and minus leads of the thermoelectric cooler. If these connections are reversed, this increases the detector temperature and possibly leads to permanent damage to the detector element.

4) Never supply the thermoelectric cooler with higher current than the maximum rating. Excessively high current will result in significant damage to the cooler. The cooler must be operated within the maximum ratings listed in this catalog. For long-term stable operation, it is recommended that the cooler be operated at 1.0 A or less for the two or three-stage TE-cooled MCT and other one-stage TE-cooled detectors, and at 0.8 A for the two-stage TE-cooled detectors other than the MCT.

5) Always operate the built-in thermistor within the rated conditions (0.2 mW). It should preferably be operated at less than 0.03 mW.

6) In temperature control, the thermoelectric cooler capacity must be taken into consideration in order to set optimum supply current. Never apply higher current than the maximum rating for the thermoelectric cooler.

7) Excessive shocks, drop impacts or vibrations may lead to significant damage to the detector.

8) When the detector is installed onto the heatsink, be sure not to apply any excessive stress to the package. This may cause cracks or leakage in the package.

9) Do not apply any strong stress to the leads (especially to the base of each lead) during handling of the detector. The glass located around the leads on the bottom of the metal package may crack and cause air leakage. The detector performances are deteriorated in this instance.

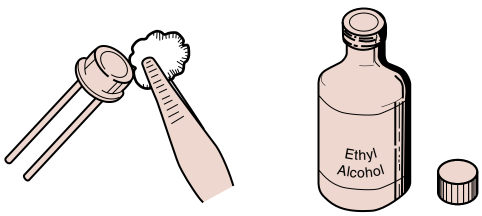
Dewar type detector

Before pouring liquid nitrogen into the dewar, be sure to check that no water or moisture remains inside the dewar, as it may cause cracks in the glass dewar when frozen.
When filling the dewar with liquid nitrogen, use the following procedure: First pour 20 to 30 cc into the dewar, and wait for a while until the whitish vapor (made by the ebullient liquid nitrogen) settles.
Then pour another 20 to 30 cc into the dewar and wait for a while again. The remainder of filling may be made in one step. (Sudden filling from the beginning can cause the liquid nitrogen to overflow or splash. When using dry ice, first put it into another vessel. Then slowly pour ethyl alcohol into the vessel. Mix the two until they have the consistency of sherbet and then pour the mixture into the dewar.

GaAsP, GaP photodiode

1) Window

Care should be taken not to touch the window with bare hands, especially in the case of ultraviolet detection since foreign materials on the window can seriously affect transmittance in the ultraviolet range. (There have been occasions where contamination of the window by oil from hands reduced sensitivity at 250 nm by as much as 30 %.)
If the window needs to be cleaned, use ethyl alcohol and wipe off the window gently. Avoid using any other organic solvents than ethyl alcohol as they may cause deterioration of the device's resin coating or filter.
When using tweezers or other hard tools, be careful not to allow the tip or any sharp objects to touch the window surface. If the window is scratched or damaged, accurate measurement cannot be expected when detecting a small light spot. In particular, use sufficient care when handling resin-coated or resin-molded devices.



Lightly wipe dirt off the window using ethyl alcohol.

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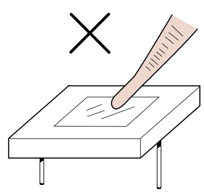

Avoid scratching the light input window with pointed objects (tweezers tip, etc.) or rubbing it with a hard flat surface.

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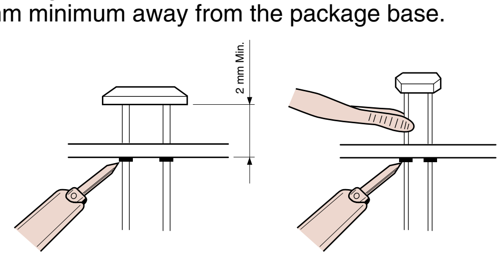
2) Lead forming

When forming leads, care should be taken to keep the recommended mechanical stress limits: 5 kg pull for 5 seconds maximum, two 90 degrees bends and two twists of the leads at 6 mm minimum away from the package base.
To form the leads of plastic-molded package devices, use long-nose pliers to hold near by the root of the leads securely.

3) Soldering

Since photodiodes are subject to damage by excessive heat, sufficient care must be given to soldering temperature and dwell time. As a guide, metal package devices should be soldered at 260 ˚C or below within 10 seconds, ceramic package devices at 260 ˚C within 5 seconds at 2 mm minimum away from the package base, and plastic package devices at 230 ˚C or below within 5 seconds at 1 mm minimum away from the package base.



Mount ceramic package types 2 mm minimum away from any surface and solder at 260 ˚C maximum for 5 seconds maximum time.

Use tweezers, etc. as a heatsink when soldering small photodiodes.

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4) Recommended soldering conditions

Package	Soldering temperature Max. (˚C)	Soldering time Max. (s)	Remark
Metal	260	10	
Ceramic	260	5	2 mm or more away from package
Plastic	230	5	1 mm or more away from package

5) Cleaning

Use alcohol to remove solder flux. Never use other type of solvent because, in particular, plastic packages may be damaged. It is recommended that the device be dipped into alcohol for cleaning. Ultrasonic cleaning and vapor cleaning may cause fatal damage to some types of devices (especially, hollow packages and devices with filters). Confirm in advance that there is no problem with such cleaning methods, then perform cleaning.

CdS photoconductive cell

1) Usage precautions

- Even within the absolute maximum ratings, try to stay in the low region for power dissipation, applied voltage, and ambient temperature.
  (Since this allowable power dissipation applies to total illumination of the photosensitive surface, when only part of the photosensitive surface is used, the allowable power consumption should be reduced in proportion to the surface that is being used.)
- Use at high temperature and high humidity shortens the cell life, and should be avoided.
- Avoid usage that exposes the CdS photoconductive cell to strong ultraviolet light.
- For low-light detection (1 *lx* or less for general CdS photoconductive cells), characteristics are less stable.
- If the CdS photoconductive cell is subject to strong vibration or shock, reinforce the cell itself and its leads.

2) Handling precautions

- Since the window is made of glass and plastic coating, avoid touching it, pressing it, and causing friction with it with hard objects and hot objects. In particular, this can cause deterioration of the optical and electrical characteristics of plastic-coated CdS photoconductive cells. However, there is no problem with normal handling by hand.
- Since extreme bending or twisting of the lead at the root places stress on the lead root, avoid this. When forming the lead near the root, provide support for the lead root before bending the lead.
- Do not solder the leads with stress applied. Do not pull, twist, or compress the leads right after they have been soldered. Allow them to cool before changing the position or direction of the leads.
- When soldering, be careful about the soldering temperature and duration. In general, CdS photoconductive cells should be soldered at least 5 mm down the lead from the cell package itself, with a solder iron no hotter than 260 ˚C, for no longer than 5 seconds.
  (Check the temperature of the tip of the soldering iron and use a soldering iron temperature controller if necessary.)
  If these conditions cannot be observed, prevent the temperature rise from reaching the CdS photoconductive cell (by using heatsink) or increase the distance of the soldering from the CdS photoconductive cell itself.
- Avoid any chemicals that can corrode metal or cause deterioration of plastic. If there is a possibility of metal corrosion or deterioration of plastic, experiment ahead of time and carry out the operation in question only after confirming that it will not harm the CdS photoconductive cell.
- When washing or cleaning with solvents, use an alcohol solvent (isopropyl alcohol, ethyl alcohol, or a similar agent). Ultrasound wave cleaning with these solvents depends greatly on the usage conditions, but the cleaning time should be no longer than 30 minutes. Avoid chloro-hydrocarbon and ketone solvents. They can cloud and dissolve the plastic parts of the CdS photoconductive cell.

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