Photodiode Technical Guide
- Construction
- Description of terms
- Reliability
- Precaution for use
- Technical Guide in PDF format

Silicon Photodiodes
Parametric Search
Product list
Selection Guide
Request Info

Description of terms

1. Spectral response

The photocurrent produced by a given level of incident light varies with the wavelength. This relation between the photoelectric sensitivity and wavelength is referred to as the spectral response characteristic and is expressed in terms of photo sensitivity, quantum efficiency, etc.

2. Photo sensitivity: S

This measure of sensitivity is the ratio of radiant energy expressed in watts (W) incident on the device, to the resulting photocurrent expressed in amperes (A). It may be represented as either an absolute sensitivity (A/W) or as a relative sensitivity normalized for the sensitivity at the peak wavelength, usually expressed in percent (%) with respect to the peak value. For the purpose of this catalog, the photo sensitivity is represented as the absolute sensitivity, and the spectral response range is defined as the region in which the relative sensitivity is higher than 5 % of the peak value.

3. Quantum efficiency: QE

The quantum efficiency is the number of electrons or holes that can be detected as a photocurrent divided by the number of the incident photons. This is commonly expressed in percent (%). The quantum efficiency and photo sensitivity S have the following relationship at a given wavelength (nm):

$$QE = \frac{S \times 1240}{\lambda} \times 100\ [\%] \quad \text{............} \ (1)$$

where S is the photo sensitivity in A/W at a given wavelength and λ is the wavelength in nm (nanometers).

4. Short circuit current: Isc, open circuit voltage: Voc

The short circuit current is the output current which flows when the load resistance is 0 and is nearly proportional to the device active area. This is often called “white light sensitivity” with regards to the spectral response. This value is measured with light from a tungsten lamp of 2856 K distribution temperature (color temperature), providing 100 time illuminance. The open circuit voltage is a photovoltaic voltage developed when the load resistance is infinite and exhibits a constant value independent of the device active area.

5. Infrared sensitivity ratio

This is the ratio of the output current IR measured with a light flux (2856 K, 100 time) passing through an R-70 (t=2.5 mm) infrared filter to the short circuit current Isc measured without the filter. It is commonly expressed in percent, as follows:

$$\text{Infrared sensitivity ratio} = \frac{I_R}{Isc} \times 100\ [\%] \quad \text{............} \ (2)$$

6. Dark current: ID, shunt resistance: Rsh

The dark current is a small current which flows when a reverse voltage is applied to a photodiode even in dark state. This is a major source of noise for applications in which a reverse voltage is applied to photodiodes (PIN photodiode, etc.). In contrast, for applications where no reverse voltage is applied, noise resulting from the shunt resistance becomes predominant. This shunt resistance is the voltage-to-current ratio in the vicinity of 0 V and defined as follows:

$$Rsh = \frac{10\ [mV]}{I_D}\ [\Omega] \quad \text{............} \ (3)$$

where ID is the dark current at VR=10 mV.

7. Terminal capacitance: Ct

An effective capacitor is formed at the PN junction of a photodiode. Its capacitance is termed the junction capacitance and is the major factor in determining the response speed of the photodiode. And it probably causes a phenomenon of gain peaking in I-V conversion circuit using operational amplifier. In Hamamatsu, the terminal capacitance including this junction capacitance plus package stray capacitance is listed.

8. Rise time: tr

This is the measure of the time response of a photodiode to a stepped light input, and is defined as the time required for the output to change from 10 % to 90 % of the steady output level. The rise time depends on the incident light wavelength and load resistance. For the purpose of data sheets, it is measured with a light source of GaAsP LED (655 nm) or GaP LED (560 nm) and load resistance of 1 κ Ω.

9. Cut-off frequency: fc

This is the measure used to evaluate the time response of high-speed APD (avalanche photodiodes) and PIN photodiodes to a sinewave-modulated light input. It is defined as the frequency at which the photodiode output decreases by 3 dB from the output at 100 kHz. The light source used is a laser diode (830 nm) and the load resistance is 50 Ω. The rise time tr has a relation with the cut-off frequency fc as follows:

$$tr = \frac{0.35}{fc} \quad \text{............} \ (4)$$

10. NEP (Noise Equivalent Power)

The NEP is the amount of light equivalent to the noise level of a device. Stated differently, it is the light level required to obtain a signal-to-noise ratio of unity. In data sheets lists the NEP values at the peak wavelength λp. Since the noise level is proportional to the square root of the frequency bandwidth, the NEP is measured at a bandwidth of 1 Hz.

$$NEP\ [W/Hz^{1/2}] = \frac{\text{Noise current } [A/Hz^{1/2}]}{\text{Photo sensitivity at } \lambda p\ [A/W]} \quad \text{............} \ (5)$$

11. Maximum reverse voltage: VR Max.

Applying a reverse voltage to a photodiode triggers a breakdown at a certain voltage and causes severe deterioration of the device performance. Therefore the absolute maximum rating is specified for reverse voltage at the voltage somewhat lower than this breakdown voltage. The reverse voltage shall not exceed the maximum rating, even instantaneously.

Reference

- **Physical constant**

Constant	Symbol	Value	Unit

Constant	Symbol	Value	Unit
Electron charge	e or q	1.602×10^{-19}	c
Speed of light in vacuum	c	2.998×10^{8}	m/s
Planck's constant	h	6.626×10^{-34}	Js
Boltzmann's constant	k	1.381×10^{-23}	J/K
Room temperature thermal energy	KT (T=300 K)	0.0259	eV
1 eV energy	eV	1.602×10^{-19}	J
Wavelength in vacuum corresponding to 1 eV	-	1240	nm
Dielectric constant of vacuum	ε o	8.854×10^{-12}	F/m
Dielectric constant of silicon	ε si	Approx. 12	-
Dielectric constant of silicon oxide	ε ox	Approx. 4	-
Energy gap of silicon	Eg	Approx. 1.12 (T=25 °C)	eV

12. D* (Detectivity: detection capacity)

D, which is the reciprocal of NEP, is the value used to indicate detectivity, or detection capacity. However, because the noise level is normally proportional to the square root of the sensitive area, NEP and D characteristics have improved, enabling detection of even small photo-sensitive elements. This makes it possible to observe the characteristics of materials by multiplying the square root of the sensitive area and D, with the result being used as D*. The peak wavelength is recorded in units expresseed as cm Hz½ /W, as it is for the NEP.

$$D^* = \frac{[\text{Effective Sensitive Area (cm}^2)]^{1/2}}{\text{NEP}}$$