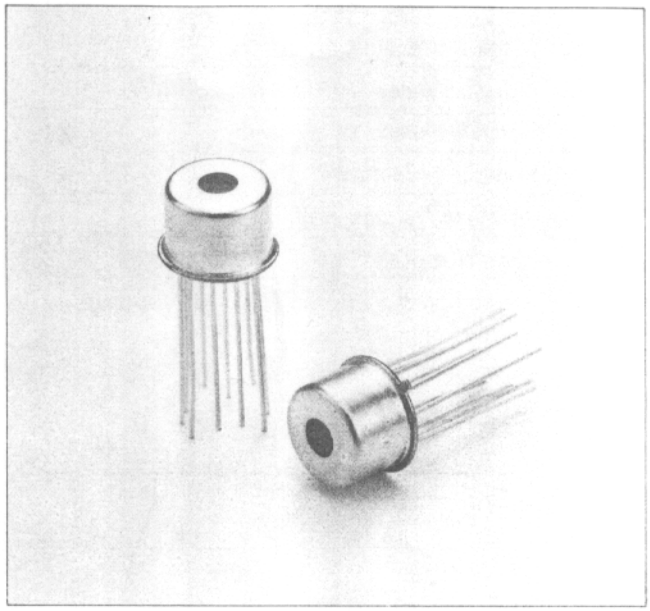
HAMAMATSU

TECHNICAL DATA

SILICON PHOTODIODES WITH BUILT-IN OP AMP S1406 SERIES

FEATURES

- Uses UV enhanced silicon photodiodes (S1226, S1336 series)
- FET input operational amplifier (I_B = 30pA)
- Hermetically sealed in the TO-5 package
  - S1406-03/05 : Synthetic silica window
  - S1406-04/06 : Borosilicate glass window
- Highly linear output over a wide input light range
- Long term stability and highly reliable reproducibility
- Low noise (0.15 $\mu V/Hz^{1/2}$, at 20 Hz, Rf = 1MΩ)
- Low NEP (1 x 10^{-14} $W/Hz^{1/2}$, at 340nm, 20 Hz, Rf = 1MΩ)
- Selectable output polarity
- Output short circuit protection included



The S1406 series is a photodiode/amplifier combination device. It incorporates, within the TO-5 package, a silicon photodiode chip and an operational amplifier. This combination allows direct conversion from light to voltage and easy mounting on PC boards. The silicon photodiodes used are highly stable, UV enhanced types and the operational amplifier is of the FET input type, thus providing a low-noise, miniature light detection circuit.

■ ABSOLUTE MAXIMUM RATINGS

Parameters		Symbols	Ratings	Units
Supply Voltage		Vs	±18	V
Power Dissipation		P	500	mW
Photocurrent		I_P Max.	10	mA
Photodiode Reverse Voltage		V_R Max.	5	V
Operating Temperature	Synthetic silica	T_{opr}	0 to + 60	°C
	Borosilicate glass		0 to + 70	
Storage Temperature	Synthetic silica	T_{stg}	–30 to + 80	°C
	Borosilicate glass		–30 to + 100	

■ GENERAL CHARACTERISTICS (Typ. Ta = 25°C)

Parameters	Symbols	Conditions	S1406-03/04	S1406-05/06	Units
Photodiode Type No.	—		S1336	S1226	—
Active Area	—		5.7		mm^2
Spectral Response Range	λ		190 to 1100 (S1406-03①)	190 to 1000 (S1406-05①)	nm
			320 to 1100 (S1406-04②)	320 to 1000 (S1406-06②)	
Photo Sensitivity ③	S	λ = 340nm	1.5 x 10^5		V/W
		λ = 900nm	5 x 10^5	2 x 10^5	
Noise Equivalent Power ③④	NEP	λ = 340nm	1 x 10^{-12}		$W/Hz^{1/2}$
		λ = 900nm	3 x 10^{-13}	8 x 10^{-13}	
Noise Voltage ③④	—	Dark	1.5 x 10^{-7}		$V/Hz^{1/2}$

① Synthetic silica window, ② Borosilicate glass window, ③ External feedback resistance : 1MΩ, ④ f = 20 Hz

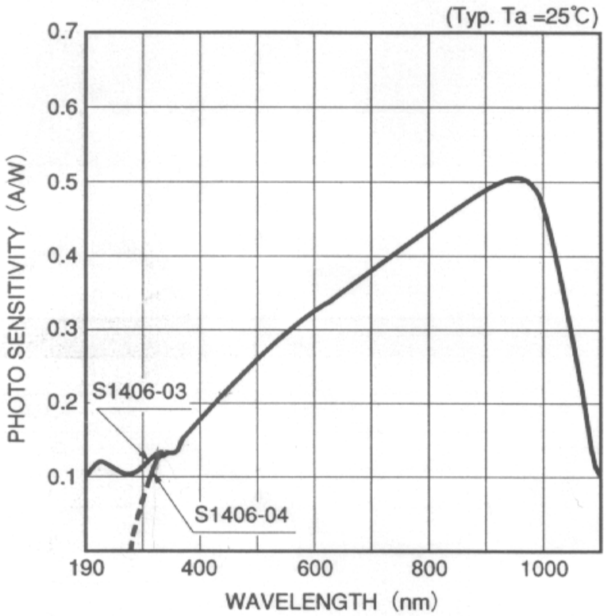
■ PHOTODIODE CHARACTERISTICS (at 25°C, Vs = ±15V)

Parameters	S1406-03,-04			S1406-05,-06			Units
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Photo Sensitivity, S :340nm	—	0.15	—	—	0.15	—	A/W
(Photodiode) :900nm	—	0.5	—	—	0.2	—	A/W
Peak Sensitivity Wavelength, λp	—	960	—	—	720	—	nm
Terminal Capacitance, C_t (f = 10kHz, V_R = 0V)	—	65	—	—	200	—	pF
Shunt Resistance, R_{sh}	0.4	1	—	0.5	10	—	GΩ
Dark Current, I_D (V_R = 10mV)	—	10	25	—	1	20	pA
Reverse Voltage, V_R Max.	—	—	5	—	—	5	V
Temperature Rise ①, ΔT	—	12	—	—	12	—	°C

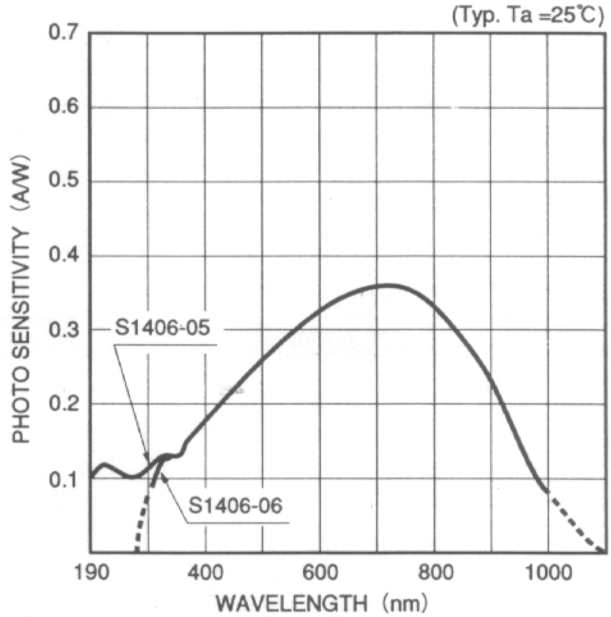
①: Temperature rise of a element when ±15V is biased. (Refer ● Power Supply Voltage of the last Page)

Figure 1 : Spectral Response of Photodiode

a) S1406–03, –04



b) S1406–05, –06



■ OPERATIONAL AMPLIFIER ELECTRICAL CHARACTERISTICS (Ta = 25°C, Vs = ±15V)

Parameters		Min.	Typ.	Max.	Units
Bias Current, I_B (T_j = 25°C)②		—	30	100	pA
Offset Current, I_{OS} (T_j = 25°C)		—	3	—	pA
Offset Voltage, V_{OS} (R_S = 50Ω)		—	3	10	mV
Offset Drift, $\Delta V_{OS}/\Delta T$		—	5×10^{-6}	—	V/°C
Output Impedance, Ro		—	—	50	Ω
Slew Rate, SR (A_V = +5)		—	40	—	V/µs
Output Voltage Swing, (R_L = 2kΩ)		± 10	± 12	—	V
Gain Bandwidth Product, GBW		—	25	—	MHz
Input Noise	:f = 20Hz	—	4×10^{-8}	—	$V/Hz^{1/2}$
	:f = 1kHz	—	2×10^{-8}	—	
	:f = 10kHz	—	1.5×10^{-8}	—	

②: The bias current doubles for every 10°C rise in junction temperature (T_j).

Figure 2: Dimensional Outline and Pin Connections

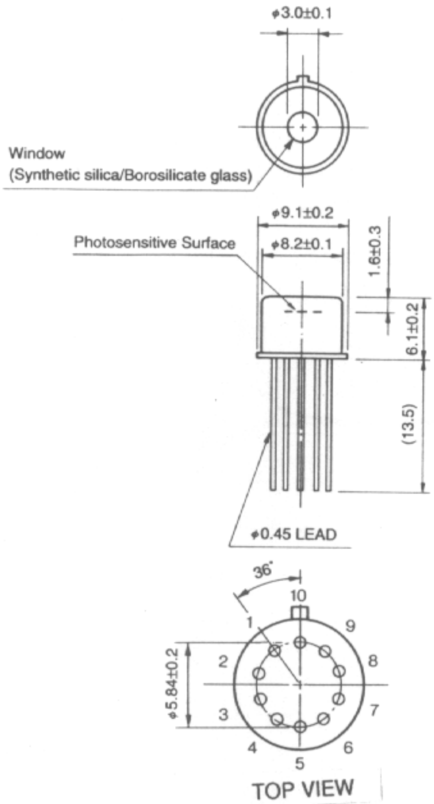
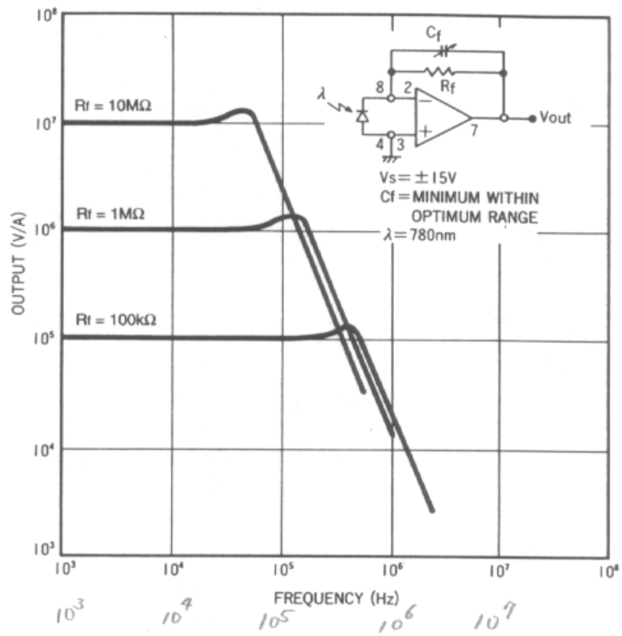


Figure 3: Frequency Response

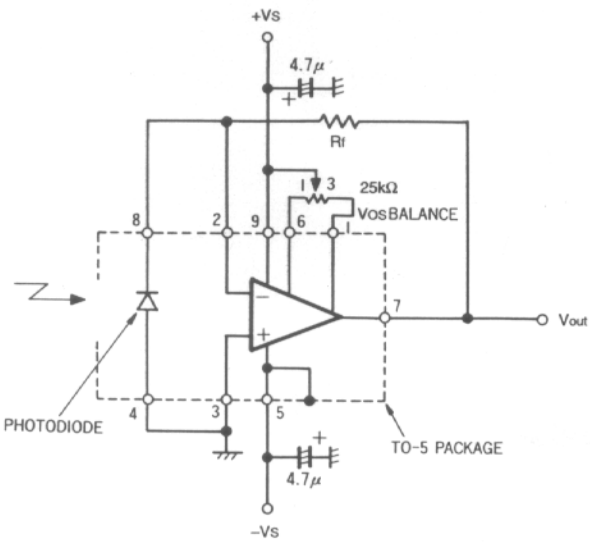


EXAMPLE OF CIRCUIT CONNECTION

• Pin Connection

Figure 4 shows pins connection. Pin 5 (–Vs) is internally connected to the case. The isolation must be taken. V_{out} outputs plus polarity. When altering polarity of the output, connect pins 4 and 2, and pins 8 and 3 respectively. Output offset is adjusted with a 25kΩ variable resistor after completely blocking off the incident light. R_f can be built into the package. Resistance values of 100kΩ, 1MΩ and 10MΩ are available. Please specify when ordering.

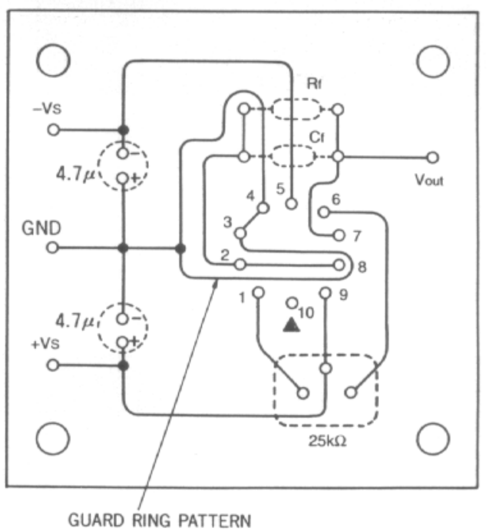
Figure 4: Pin Connection



• Printed Circuit Board Layout

When making a detection circuit for low level light, it is recommended to wire the operational amplifier input terminal and feedback resistor on standoff terminals made of teflon or similar high-insulation materials in order to avoid errors due to current leakage flowing through the circuit board. When soldering S1406 directly onto a circuit board, it is recommended to surround the photocurrent path (Pin 2 and 8) with a guard ring pattern as shown in Figure 5.

Figure 5: PC Board Layout (Pattern Side)



INSTRUCTIONS FOR OPERATING S1406 SERIES

• Power Supply Voltage

When operating with ±15V, the temperature inside the metal case rises by about 12°C as compared to the external temperature due to the power dissipation of the operational amplifier. This rise in temperature would cause the shunt resistance of the internal silicon photodiodes to drop to approximately 1/3. In order to minimize this, we recommend either that the supply voltage be kept as low as possible within the specified limits of S1406 output dynamic range, or that a heat sink be installed on the metal case.

With S1406, an output swing of ±1V (typ.) can be achieved even with a supply voltage of ±3V.

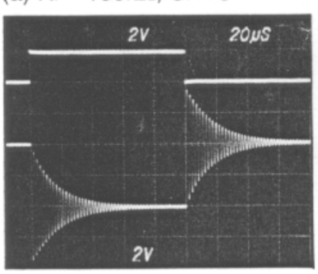
• Feedback Capacitance

The typical terminal capacitance of the S1406 photodiodes is 65pF for the –03, –04 and 200pF for the –05, –06. For this reason, if there is no feedback capacitance in parallel with the feedback resistance, the optical pulse response may become unstable. In particular, if the feedback resistance is smaller than approximately 100kΩ, this effect becomes significant, requiring a parallel connected capacitance of several picofarads or greater. The photograph in Figure 6 shows the response waveform for such a condition.

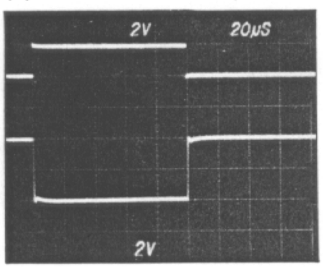
In the case of $C_f = 0$, picture (a), a ringing is seen on the S1406's output, while smooth response waveform shown in picture (b) is obtained with $C_f = 4pF$. From the standpoint of stability, when R_f is changed, a resistance of 1MΩ or greater should be paralleled by approximately 1pF and a resistance of 10kΩ should be paralleled by approximately 10pF, although a slightly larger capacitance value is recommended for higher stability.

Figure 6: Output Waveforms

(a) $R_f = 100k\Omega$, $C_f = 0$



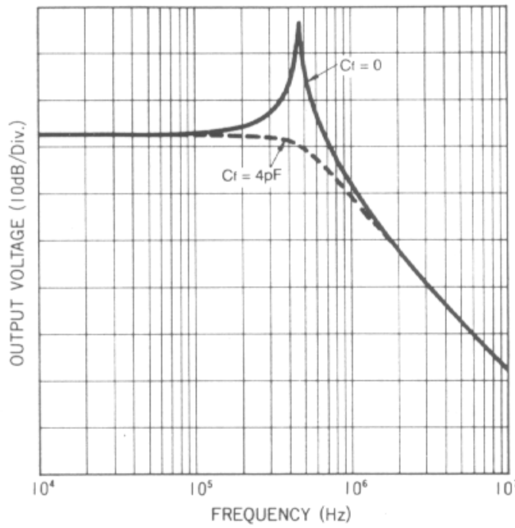
(b) $R_f = 100k\Omega$, $C_f = 4pF$



• Gain Peaking

In the case of the response waveform shown in Figure 6 (a), there is a prominent peak in the frequency response. This is shown in Figure 7. A sharp peak exists in the region of 460 kHz and this corresponds to the ringing period in the Figure 6 photograph. By connecting a feedback capacitance of 4pF, it is possible to suppress this peaking.

Figure 7: Gain Peaking Spectrum

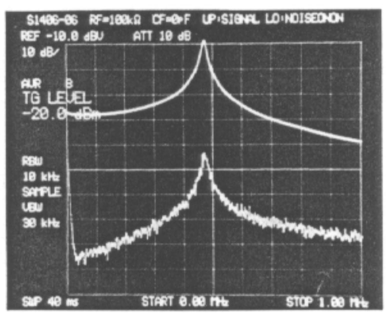


• Gain Peaking and Noise

When the above described peak phenomena occurs, this peaking is evident with respect to noise characteristics as well when no light is being input. This will prevent the expected S/N ratio from being achieved for light measurements.

Figure 8 shows the frequency response for the signal and noise of a circuit with such peaking and indicates that the sharp peaking exists for noise as well. This can be corrected by the connection of a parallel capacitance.

Figure 8: Gain Peaking and Noise ($R_f = 100k\Omega$, $C_f = 0$)



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