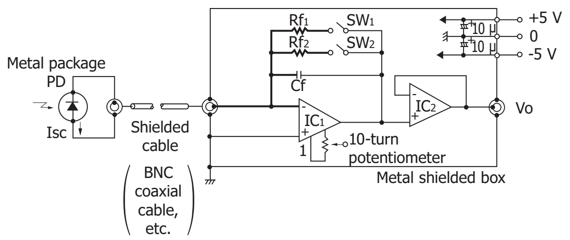
Application circuit examples

Low-light-level detection circuit

Low-light-level detection circuits require measures for reducing electromagnetic noise in the surrounding area, AC noise from the power supply, and internal op amp noise, etc.
Figure 4 shows one measure for reducing electromagnetic noise in the surrounding area.

Figure 4 Low-light-level sensor head

(a) Example using shielded cable to connect to photodiode



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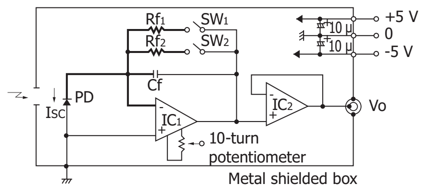
(b) Example using metal shielded box that contains entire circuit



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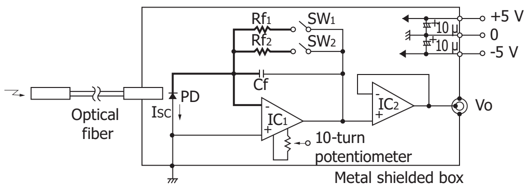
(c) Example using optical fiber



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Bold lines should be within guarded pattern or on teflon terminals.
IC_1 : AD549, OPA124, etc.
IC_2 : OP07, etc.
Cf : 10 pF to 100 pF, polystyrene capacitor
Rf : 10 GΩ max.
SW: Low-leakage reed relay, switch
PD : S1226/S1336/S2386 series, S2281, etc.

$Vo = Isc \times Rf$ [V]

Extracting the photodiode signal from the cathode terminal is another effective means. An effective countermeasure against AC noise from the power supply is inserting an RC filter or an LC filter in the power supply line. Using a dry cell battery as the power supply also proves effective way. Op amp noise can be reduced by selecting an op amp having a low 1/f noise and low equivalent input noise current. Moreover, high-frequency noise can be reduced by using a feedback capacitor (Cf) to limit the circuit frequency range to match the signal frequency bandwidth.
Output errors (due to the op amp input bias current and input offset voltage, routing of the circuit wiring, circuit board surface leak current, etc.) should be reduced, next. A FET input op amp with input bias currents below a few hundred fA or CMOS input op amp with low 1/f noise are selected. Using an op amp with input offset voltages below several millivolts and an offset adjustment terminal will prove effective. Also try using a circuit board made from material having high insulation resistance. As countermeasures against current leakage from the surface of the circuit board, try using a guard pattern or elevated wiring with teflon terminals for the wiring from the photodiode to op amp input terminals and also for the feedback resistor (Rf) and feedback capacitor (Cf) in the input wiring.
Hamamatsu offers the C6386-01, C9051 and C9329 photosensor amplifiers optimized for use with photodiodes for low-light-level detection.

Figure 5 Photosensor amplifiers

(a) C6386-01

(b) C9051

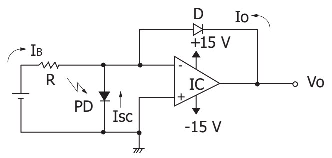
(c) C9329

The photodiodes, and coaxial cables with BNC-to-BNC plugs are sold separately.

Light-to-logarithmic-voltage conversion circuit

The voltage output from a light-to-logarithmic voltage conversion circuit (Figure 6) is proportional to the logarithmic change in the detected light level. The log diode D for logarithmic conversion should have low dark current and low series resistance. A Base-Emitter junction of small signal transistors or Gate-Source junction of connection type of FETs can also be used as the diode. I_B is the current source that supplies bias current to the log diode D and sets the circuit operating point. Unless this I_B current is supplied, the circuit will latch up when the photodiode short circuit current Isc becomes zero.

Figure 6 Light-to-logarithmic-voltage conversion circuit



D : Diode of low dark current and low series resistance
I_B : Current source for setting circuit operation point, $I_B << Isc$
R : 1 GΩ to 10 GΩ
Io: D saturation current, 10^{-15} to 10^{-12} A
IC: FET-input Op amp, etc.

$$Vo \approx -0.06 \log \left(\frac{Isc + I_B}{Io} + 1 \right) \text{ [V]}$$

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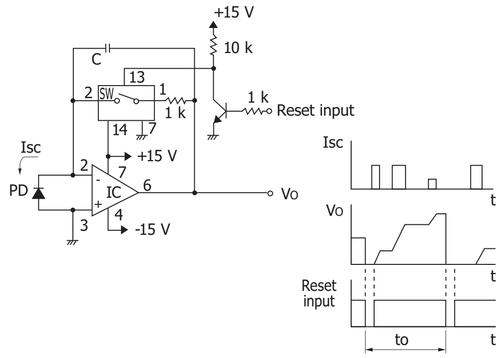
Light integration circuit

This is a light integration circuit using integration circuits of photodiode and op amp and is used to measure the integrated power or average power of a light pulse train with an erratic pulse height, cycle and width.
The integrator IC in the figure 7 accumulates short circuit current Isc generated by each light pulse in the integration capaci-

tance C. By measuring the output voltage Vo immediately before reset, the average short circuit current can be obtained from the integration time (to) and the capacitance C. A low dielectric absorption type capacitor should be used as the capacitance C to eliminate reset errors. The switch SW is a CMOS analog switch.

Figure 7 Light integration circuit



Reset input: Use TTL "L" to reset.
IC : LF356, etc.
SW: CMOS 4066
PD : S1226/S1336/S2386 series, etc.
C : Polycarbonate capacitor, etc.

$$Vo = Isc \times to \times \frac{1}{C} \text{ [V]}$$

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Basic illuminometer (1)

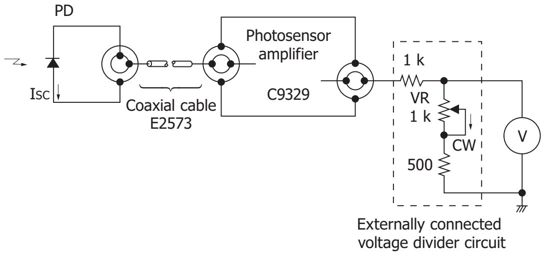
A basic illuminometer circuit can be configured by using Hamamatsu C9329 photosensor amplifier and S9219 Si photodiode with sensitivity corrected to match human eye response. As shown in Figure 8, this circuit can measure illuminance up to a maximum of 1000 *lx* by connecting the output of the C9329 to a voltmeter in the 1 V range via an external resistive voltage divider.

A standard light source is normally used to calibrate this circuit, but if not available, then a simple calibration can be performed with a 100 W white light source.

To calibrate this circuit, first select the L range on the C9329 and then turn the variable resistor VR clockwise until it stops. Block the light to the S9219 while in this state, and rotate the zero adjusting volume control on the C9329 so that the voltmeter reads 0 mV. Next turn on the white light source, and adjust the distance between the white light source and the S9219 so that the voltmeter display shows 0.225 V. (The illuminance on the S9219 surface at this time is approximately 100 *lx*.) Then turn the VR counterclockwise until the voltmeter display shows 0.1 V. The calibration is now complete.

After calibration, the output should be 1 mV/*lx* in the L range, and 100 mV/*lx* in the M range on the C9329.

Figure 8 Basic illuminometer (1)



PD: S9219 (4.5 µA/100 *lx*)

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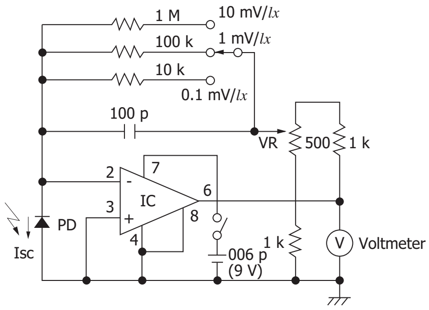
Basic illuminometer (2)

This is an basic illuminometer circuit using a visual-compensated Si photodiode S7686 and an op amp. A maximum of 10000 *lx* can be measured with a voltmeter having a 1 V range. It is necessary to use a low consumption current type op amp which can operate from a single voltage supply with a low input bias current.

An incandescent lamp of 100 W can be used for approximate calibrations in the same way as shown above "Basic illuminometer (1)". To make calibrations, first select the 10 mV/*lx* range and short the wiper terminal of the variable resistor VR and the output terminal of the op amp. Adjust the distance between the photodiode S7686 and the incandescent lamp so that the voltmeter reads 0.45 V. (At this point, illuminance on S7686 surface is about 100 *lx*.) Then adjust VR so that the voltmeter reads 1.0 V. Calibration has now been completed.

Figure 9 Basic illuminometer (2)



VR: Meter calibration trimmer potentiometer
IC : TLC271, etc.
PD: S7686 (0.45 µA/100 *lx*)

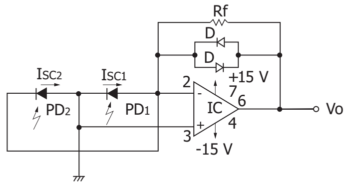
KPDC0018ED

Light balance detection circuit

Figure 10 shows a light balance detector circuit utilizing two Si photodiodes PD_1 and PD_2 connected in reverse-parallel and an op amp current-voltage converter circuit.

The photoelectric sensitivity is determined by the feedback resistance Rf. The output voltage Vo of this circuit is zero if the amount of light entering the two photodiodes PD_1 and PD_2 is equal. By placing two diodes D in reverse parallel with each other, Vo will be limited range to about ±0.5 V in an unbalanced state, so that the region around a balanced state can be detected with high sensitivity. This circuit can be used for light balance detection between two specific wavelengths using optical filters.

Figure 10 Light balance detection circuit



PD: S1226/S1336/S2386 series, etc.
IC : LF356, etc.
D : ISS226, etc.

$$Vo = Rf \times (Isc2 - Isc1) \text{ [V]}$$
$$(Vo < \pm 0.5 \text{ V})$$

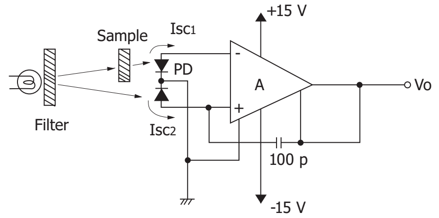
KPDC0017EB

Light absorption meter

This is a light absorption meter using a dedicated IC and two photodiodes which provides a logarithmic ratio of two current inputs (See Figure 11). By measuring and comparing the light intensity from a light source and the light intensity after transmitting through a sample with two photodiodes, light absorbance by the sample can be measured.

To make measurements, optical system such as the incident aperture should first be adjusted to become the output voltage Vo to 0 V so that the short circuit current from the two Si photodiodes is equal. Next, the sample is placed on the light path of one photodiode. At this point, the output voltage value means the absorbance by the sample. The relationship between the absorbance A and the output voltage Vo can be directly read as A=-Vo [V]. If a filter is interposed before the light source as shown in the figure 11, the absorbance of specific light spectrum or monochromatic light can be measured.

Figure 11 Light absorption meter



A : Log amp
PD: S5870, etc.

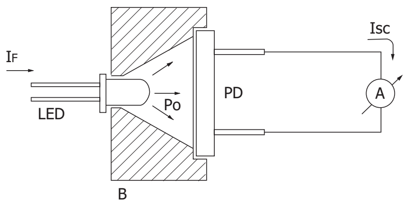
$Vo = \log (Isc_1/Isc_2)$ [V]

KPDC0025EC

Total emission measurement of LED

Since the emitting spectral width of LEDs is usually as narrow as about several-ten nanometers, the amount of the LED emission can be calculated from the Si photodiode photosensitivity at a peak emission wavelength of the LED. In Figure 12, the inner surface of the reflector block B is mirror-processed so that it reflects the light emitted from the side of the LED towards the Si photodiode. Therefore, the total amount of the LED emission can be detected by the Si photodiode.

Figure 12 Total emission measurement of LED



A : Ammeter, 1 mA to 10 mA
PD: S2387-1010R
B : Aluminum block, inner Au plating
S : Photosensitivity of Si photodiode
Refer to the spectral response chart in the datasheets.
S2387-1010R: S ≈ 0.58 A/W (λ=930 nm)
Po: Total emission

$Po \approx \frac{Isc}{S}$ [W]

KPDC0026EA

High-speed photodetector circuit (1)

The high-speed photodetector circuit shown in Figure 13 utilizes a low-capacitance Si PIN photodiode (with a reverse voltage applied) and a high-speed op amp current-voltage converter circuit. The frequency band of this circuit is limited by the op amp device characteristics to less than about 100 MHz.

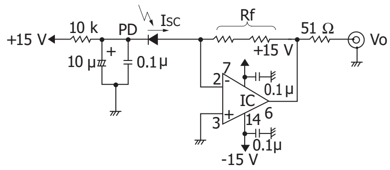
When the frequency band exceeds 1 MHz, the lead inductance of each component and stray capacitance from feedback resistance Rf exert drastic effects on device response speed. That effect can be minimized by using chip components to reduce the component lead inductance, and connecting multiple resistors in series to reduce stray capacitance.

The photodiode leads should be kept as short as possible and the pattern wiring to the op amp should be made as short and thick as possible. This will lower effects from the stray capacitance and inductance occurring on the circuit board pattern of the op amp inputs and also alleviate effects from photodiode lead inductance. Moreover, a ground plane structure utilizing copper plating at ground potential across the entire board surface will prove effective in boosting device performance.

A ceramic capacitor should be used as the 0.1 μF capacitor connected to the op amp power line, and the connection to ground should be the minimum direct distance.

Hamamatsu offers C8366 photosensor amplifier for PIN photodiodes with a frequency bandwidth up to 100 MHz.

Figure 13 High-speed photodetector circuit (1)



PD: High-speed PIN photodiode (S5971, S5972, S5973, etc.)
Rf : Two or more resistors are connected in series to eliminate parallel capacitance.
IC : AD745, LT1360, HA2525, etc.

$Vo = -Isc \times Rf$ [V]

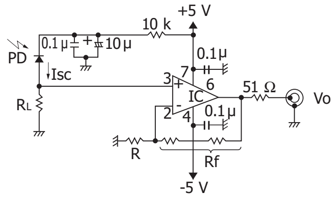
KPDC0020ED

Figure 14 Photosensor amplifier C8366

High-speed photodetector circuit (2)

The high-speed photodetector circuit in Figure 15 uses load resistance R_L to convert the short circuit current from a low-capacitance Si PIN photodiode (with a reverse voltage applied) to a voltage, and amplifies the voltage with a high-speed op amp. There is no problem with gain peaking based due to phase shifts in the op amp. A circuit with a frequency bandwidth higher than 100 MHz can be attained by selecting the correct op amp. Points for caution in the components, pattern and structure are the same as those listed for the "High-speed photodetector circuit (1)".

Figure 15 High-speed photodetector circuit (2)



PD : High-speed PIN photodiode (S5971, S5972, S5973, S9055, S9055-01, etc.)
RL, R, Rf : Determined by recommended conditions of the op amp
IC : AD8001, etc.

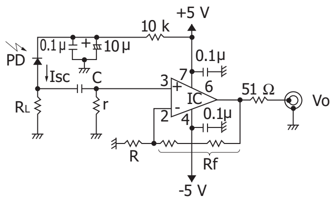
$$Vo = Isc \times R_L \times (1 + \frac{Rf}{R}) \text{ [V]}$$

KPDC0015EE

AC photodetector circuit (1)

The AC photodetector circuit in Figure 16 uses load resistance RL to convert the photocurrent from a low-capacitance Si PIN photodiode (with a reverse voltage applied) to a voltage, and amplifies the voltage with a high-speed op amp. There is no problem with gain peaking based due to phase shifts in the op amp. A circuit with a frequency bandwidth higher than 100 MHz can be attained by selecting the correct op amp.
Points for caution in the components, pattern and structure are the same as those listed for the "High-speed photodetector circuit (1)".

Figure 16 AC photodetector circuit (1)



PD : High-speed PIN photodiode (S5971, S5972, S5973, S9055, S9055-01, etc.)
RL, R, Rf, r : Determined by recommended conditions of the op amp
IC : AD8001, etc.

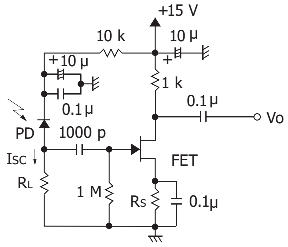
$$Vo = Isc \times R_L \times (1 + \frac{Rf}{R}) \text{ [V]}$$

KPDC0034EA

AC photodetector circuit (2)

This AC photodetector circuit utilizes a low capacitance PIN photodiode (with a reverse voltage applied) and a FET serving as a voltage amplifier. Using a low-noise FET allows producing a small yet inexpensive low-noise circuit, which can be used in light sensors for FSO (free space optics) and optical remote controls, etc. In Figure 17 the signal output is taken from the FET drain. However, for interface to a next stage circuit having low input resistance, the signal output can also be taken from the source or a voltage-follower should be added.

Figure 17 AC photodetector circuit (2)



PD : High-speed PIN photodiode (S2506-02, S5971, S5972, S5973, etc.)
RL : Determined by sensitivity and "time constant of Ct" of photodiode
Rs : Determined by operation point of FET
FET: 2SK362, etc.

KPDC0034EA