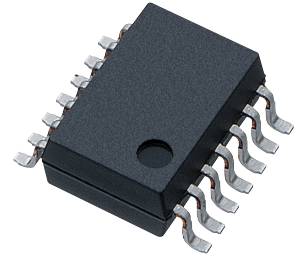


PC928 Series

**Built-in Short Protection Circuit,
Gate Drive SMD 14 pin *OPIC
Photocoupler**



■ Description

PC928 Series contains an IRED optically coupled to an OPIC chip.

It is packaged in a Mini-flat, Half pitch type (14 pin).
Input-output isolation voltage(rms) is 4.0kV.

■ Features

1. 14 pin Half lead pin pitch (Lead pitch=1.27 mm) package type
2. Double transfer mold package
(Ideal for Flow Soldering)
3. Built-in IGBT shortcircuit protector circuit
4. Built-in direct drive circuit for IGBT drive
(Peak output current : I_{O1P} , I_{O2P} : MAX. 0.4 A)
5. High isolation voltage ($V_{iso(rms)}$: 4.0 kV)

■ Agency approvals/Compliance

1. Recognized by UL1577, file No. E64380 (as model No. **PC928**)
2. Approved by VDE (VDE0884) (as an option) file No. 94626 (as model No. **PC928**)
3. Package resin : UL flammability grade (94V-0)

■ Applications

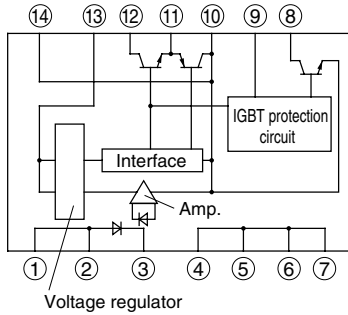
1. Inverter

* "OPIC"(Optical IC) is a trademark of the SHARP Corporation. An OPIC consists of a light-detecting element and a signal-processing circuit integrated onto a single chip.

Notice The content of data sheet is subject to change without prior notice.

In the absence of confirmation by device specification sheets, SHARP takes no responsibility for any defects that may occur in equipment using any SHARP devices shown in catalogs, data books, etc. Contact SHARP in order to obtain the latest device specification sheets before using any SHARP device.

Internal Connection Diagram



- ① Anode
- ② Anode
- ③ Cathode
- ④ NC*
- ⑤ NC*
- ⑥ NC*
- ⑦ NC*
- ⑧ FS
- ⑨ C
- ⑩ GND
- ⑪ O₂
- ⑫ O₁
- ⑬ V_{CC}
- ⑭ GND

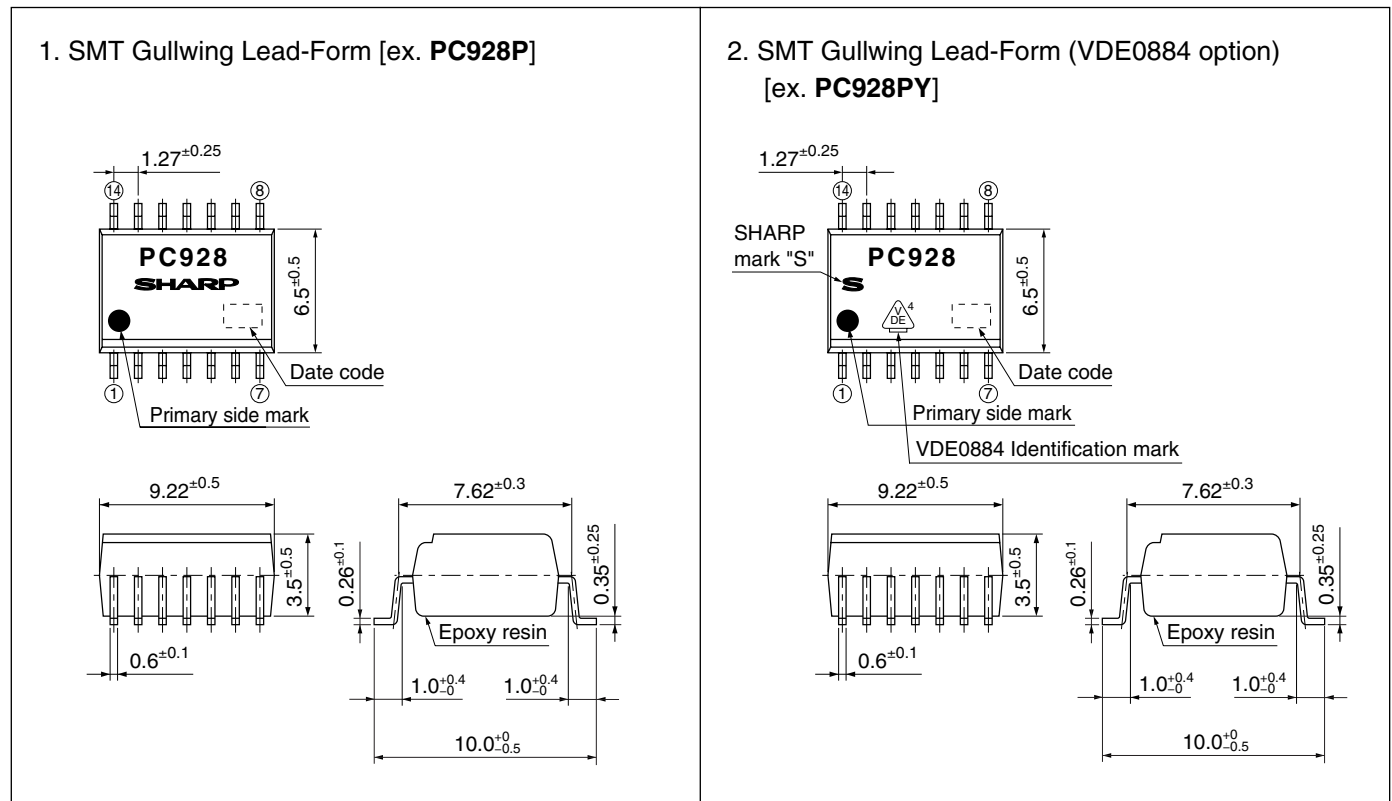
* No. ④ to ⑦ pin shall be shorted in the device.

Truth table

| Input | C input-output | O ₂ output | FS output | |
|-------|----------------|-----------------------|------------|----------------------------------|
| ON | Low level | High level | High level | |
| | High level | Low level | Low level | At operating protection function |
| OFF | Low level | Low level | High level | |
| | High level | Low level | High level | |

Outline Dimensions

(Unit : mm)



Product mass : approx. 0.47g

Date code (2 digit)

| 1st digit | | | | 2nd digit | |
|--------------------|------|------|------|---------------------|------|
| Year of production | | | | Month of production | |
| A.D. | Mark | A.D | Mark | Month | Mark |
| 1990 | A | 2002 | P | January | 1 |
| 1991 | B | 2003 | R | February | 2 |
| 1992 | C | 2004 | S | March | 3 |
| 1993 | D | 2005 | T | April | 4 |
| 1994 | E | 2006 | U | May | 5 |
| 1995 | F | 2007 | V | June | 6 |
| 1996 | H | 2008 | W | July | 7 |
| 1997 | J | 2009 | X | August | 8 |
| 1998 | K | 2010 | A | September | 9 |
| 1999 | L | 2011 | B | October | O |
| 2000 | M | 2012 | C | November | N |
| 2001 | N | ∴ | ∴ | December | D |

repeats in a 20 year cycle

Country of origin

Japan

■ Absolute Maximum Ratings

(unless otherwise specified $T_a=T_{opr}$)

| | Parameter | Symbol | Rating | Unit |
|----------------------------|---------------------------------------|-------------|----------|------|
| Input | *1 Forward current | I_F | 25 | mA |
| | *2 Reverse voltage | V_R | 6 | V |
| Output | Supply voltage | V_{CC} | 35 | V |
| | O ₁ output current | I_{O1} | 0.1 | A |
| | *3 O ₁ peak output current | I_{O1P} | 0.4 | A |
| | O ₂ output current | I_{O2} | 0.1 | A |
| | *3 O ₂ peak output current | I_{O2P} | 0.4 | A |
| | O ₁ output voltage | V_{O1} | 35 | V |
| | *4 Power dissipation | P_O | 500 | mW |
| | Overcurrent detection voltage | V_C | V_{CC} | V |
| | Overcurrent detection current | I_C | 30 | mA |
| | Error signal output voltage | V_{FS} | V_{CC} | V |
| | Error signal output current | I_{FS} | 20 | mA |
| *5 Total power dissipation | P_{tot} | 550 | mW | |
| *6 Isolation voltage | $V_{iso (rms)}$ | 4.0 | kV | |
| Operating temperature | T_{opr} | -25 to +80 | °C | |
| Storage temperature | T_{stg} | -55 to +125 | °C | |
| *7 Soldering temperature | T_{sol} | 260 | °C | |

*1 The derating factors of a absolute maximum ratings due to ambient temperature are shown in Fig.15

*2 $T_a=25^\circ\text{C}$

*3 Pulse width $\leq 0.15\mu\text{s}$, Duty ratio : 0.01

*4.5 The derating factors of a absolute maximum ratings due to ambient temperature are shown in Fig.16

*6 AC for 1 minute, 40 to 60%RH, $T_a=25^\circ\text{C}$, $f=60\text{Hz}$

*7 For 10s

■ Electro-optical Characteristics

(unless otherwise specified $T_a=T_{opr}$)

| | Parameter | Symbol | Conditions *8 | MIN. | TYP. | MAX. | Unit |
|--------------------------|--|--|--|------|------|------|---------------|
| Input | Forward voltage | V_{F1} | $T_a=25^\circ\text{C}$, $I_F=20\text{mA}$ | - | 1.2 | 1.4 | V |
| | | V_{F2} | $T_a=25^\circ\text{C}$, $I_F=0.2\text{mA}$ | 0.6 | 0.9 | - | V |
| | Reverse current | I_R | $T_a=25^\circ\text{C}$, $V_R=4\text{V}$ | - | - | 10 | μA |
| | Terminal capacitance | C_t | $T_a=25^\circ\text{C}$, $V=0$, $f=1\text{kHz}$ | - | 30 | 250 | pF |
| Output | Supply voltage | V_{CC} | $T_a=-10$ to $+60^\circ\text{C}$ | 15 | - | 30 | V |
| | | | - | 15 | - | 24 | V |
| | O ₁ Low level output voltage | V_{O1L} | $V_{CC1}=12\text{V}$, $V_{CC2}=-12\text{V}$, $I_{O1}=0.1\text{A}$, $I_F=10\text{mA}$ *9 | - | 0.2 | 0.4 | V |
| | O ₂ High level output voltage | V_{O2H} | $V_{CC}=V_{O1}=24\text{V}$, $I_{O2}=-0.1\text{A}$, $I_F=10\text{mA}$ *9 | 20 | 22 | - | V |
| | O ₂ Low level output voltage | V_{O2L} | $V_{CC}=24\text{V}$, $I_{O2}=0.1\text{A}$, $I_F=0$ *9 | - | 1.2 | 2.0 | V |
| | O ₁ leak current | I_{O1L} | $T_a=25^\circ\text{C}$, $V_{CC}=V_{O1}=35\text{V}$, $I_F=0$ *9 | - | - | 500 | μA |
| | High level supply current | I_{CCH} | $T_a=25^\circ\text{C}$, $V_{CC}=24\text{V}$, $I_F=10\text{mA}$ *9 | - | 10 | 17 | mA |
| | | | $V_{CC}=V_{O1}=24\text{V}$, $I_F=10\text{mA}$ *9 | - | - | 19 | mA |
| Low level supply current | I_{CCL} | $T_a=25^\circ\text{C}$, $V_{CC}=V_{O1}=24\text{V}$, $I_F=0$ *9 | - | 11 | 18 | mA | |
| | | $V_{CC}=V_{O1}=24\text{V}$, $I_F=0$ *9 | - | - | 20 | mA | |

*8 It shall connect a by-pass capacitor of 0.01 μF or more between V_{CC} (pin ③) and GND (pin, ⑩, ④) near the device, when it measures the transfer characteristics and the output side characteristics.

*9 FS=OPEN, $V_C=0$

(unless otherwise specified $T_a=T_{opr}$)

| Parameter | | Symbol | Conditions *10 | MIN. | TYP. | MAX. | Unit | |
|--|--|-----------------------------------|---|--|--------------|------------|-------------------|---------------|
| Transfer characteristics | *11 "Low→High" input threshold current | I_{FLH} | $T_a=25^\circ\text{C}$, $V_{CC}=V_{O1}=24\text{V}$, $FS=OPEN$, $V_C=0$ | 1.0 | 4.0 | 7.0 | mA | |
| | | | $V_{CC}=V_{O1}=24\text{V}$, $FS=OPEN$, $V_C=0$ | 0.6 | - | 10 | mA | |
| | Isolation resistance | R_{ISO} | $T_a=25^\circ\text{C}$, $DC=500\text{V}$, 40 to 60%RH | 5×10^{10} | 10^{11} | - | Ω | |
| | Response time | "Low→High" propagation delay time | t_{PLH} | $T_a=25^\circ\text{C}$, $V_{CC}=V_{O1}=24\text{V}$, $I_F=10\text{mA}$, $R_G=47\Omega$, $C_G=3\ 000\text{pF}$ $FS=OPEN$, $V_C=0$ | - | 1.0 | 2.0 | μs |
| | | "High→Low" propagation delay time | t_{PHL} | | - | 1.0 | 2.0 | μs |
| | | Rise time | t_r | | - | 0.2 | 0.5 | μs |
| | | Fall time | t_f | | - | 0.2 | 0.5 | μs |
| | Instantaneous common mode rejection voltage (High level output) | CM_H | $T_a=25^\circ\text{C}$, $V_{CM}=600\text{V(p-p)}$ $I_F=10\text{mA}$, $V_{CC}=V_{O1}=24\text{V}$, $\Delta V_{O2H}=2.0\text{V}$, $FS=OPEN$, $V_C=0$ | -1.5 | - | - | kV/ μs | |
| | Instantaneous common mode rejection voltage (Low level output) | CM_L | $T_a=25^\circ\text{C}$, $V_{CM}=600\text{V(p-p)}$ $I_F=0$, $V_{CC}=V_{O1}=24\text{V}$, $\Delta V_{O2L}=2.0\text{V}$, $FS=OPEN$, $V_C=0$ | 1.5 | - | - | kV/ μs | |
| | Overcurrent detection | *12 Overcurrent detection voltage | V_{CTH} | $T_a=25^\circ\text{C}$ $V_{CC}=V_{O1}=24\text{V}$ $I_F=10\text{mA}$, $R_G=47\Omega$ $C_G=3\ 000\text{pF}$, $FS=OPEN$ | $V_{CC}-6.5$ | $V_{CC}-6$ | $V_{CC}-5.5$ | V |
| Overcurrent detection voltage hysteresis width | | V_{CHIS} | 1 | | 2 | 3 | V | |
| Protection output | O ₂ "High→Low" propagation delay time at overcurrent protection | t_{PCOHL} | $T_a=25^\circ\text{C}$ $V_{CC}=V_{O1}=24\text{V}$ $I_F=10\text{mA}$, $R_G=47\Omega$, $C_G=3\ 000\text{pF}$, $R_C=1\text{k}\Omega$, $C_P=1\ 000\text{pF}$ $FS=OPEN$ | - | 4 | 10 | μs | |
| | O ₂ Fall time at overcurrent protection | t_{PCOf} | | 2 | 5 | - | μs | |
| | O ₂ "High→Low" output voltage at overcurrent protection | V_{OE} | | - | - | 2 | V | |
| Error signal output | Low level error signal voltage | V_{FSL} | $T_a=25^\circ\text{C}$, $I_F=10\text{mA}$ $V_{CC}=V_{O1}=24\text{V}$ $I_{FS}=10\text{mA}$, $R_G=47\Omega$ $C_G=3\ 000\text{pF}$, $C=OPEN$ | - | 0.2 | 0.4 | V | |
| | High level error signal current | I_{FSH} | | - | - | 100 | μA | |
| | Error signal "High→Low" propagation delay time | t_{PCFHL} | | $T_a=25^\circ\text{C}$, $V_{CC}=V_{O1}=24\text{V}$ $I_F=10\text{mA}$, $R_{FS}=1.8\text{k}\Omega$ $R_G=47\Omega$, $R_C=1\text{k}\Omega$ $C_G=3\ 000\text{pF}$, $C_P=1\ 000\text{pF}$ | - | 1 | 5 | μs |
| | Error signal output pulse width | Δt_{FS} | | | 20 | 35 | - | μs |

*10 It shall connect a by-pass capacitor of 0.01 μF or more between V_{CC} (pin ⑬) and GND (pin ⑩, ⑭) near the device, when it measures the device, when it measures the overcurrent characteristics, Protection output characteristics, and Error signal output characteristics.

*11 I_{FLH} represents forward current when output goes from "Low" to "High"

*12 V_{CTH} is the value of C (pin ⑨) voltage when output becomes from "High" to "Low"

■ Model Line-up

| Lead Form | SMT Gullwing | | | |
|-----------|--------------|---------------|---------------|----------------|
| | Sleeve | | Taping | |
| Package | 50pcs/sleeve | | 1 000pcs/reel | |
| VDE0884 | —— | Approved | —— | Approved |
| Model No. | PC928 | PC928Y | PC928P | PC928PY |

Please contact a local SHARP sales representative to inquire about production status and Lead-Free options.

Fig.1 Test Circuit for O₁ Low Level Output Voltage

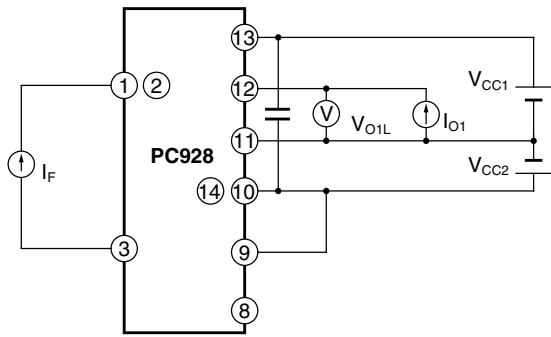


Fig.2 Test Circuit for O₂ High Level Output Voltage

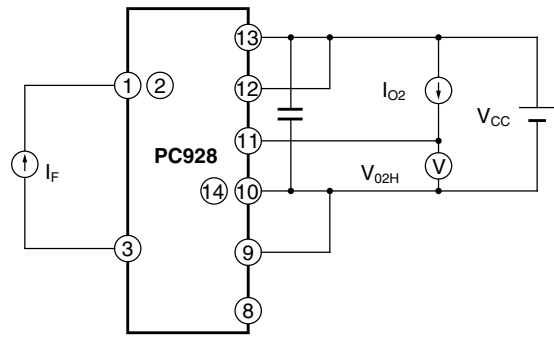


Fig.3 Test Circuit for O₂ Low Level Output Voltage

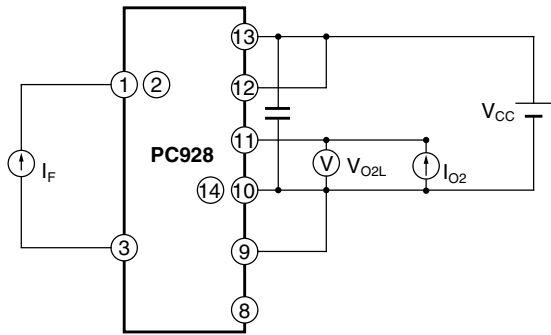


Fig.4 Test Circuit for O₁ Leak Current

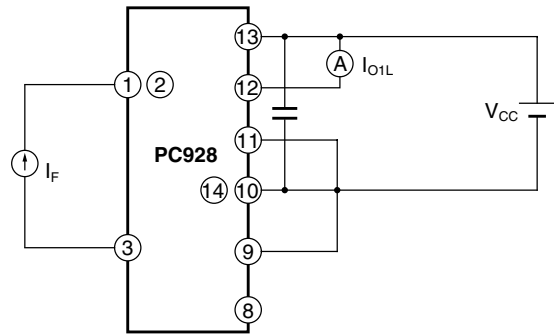


Fig.5 Test Circuit for "Low→High" Input Threshold Current

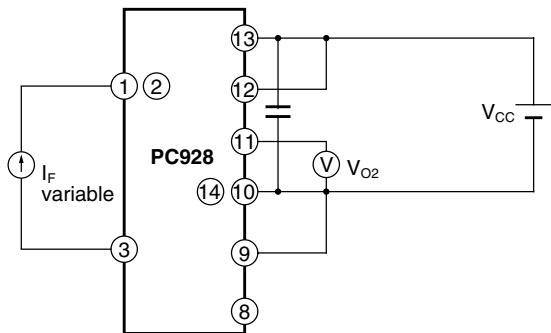


Fig.6 Test Circuit for High Level / Low Level Supply Current

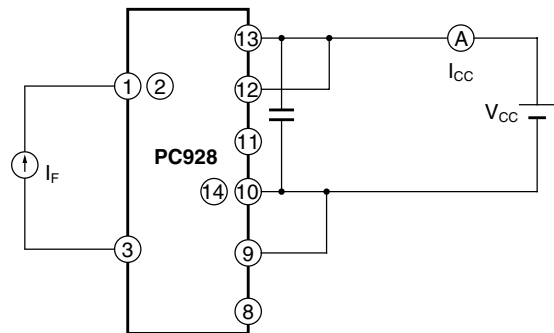


Fig.7 Test Circuit for Instantaneous Common Mode Rejection Voltage

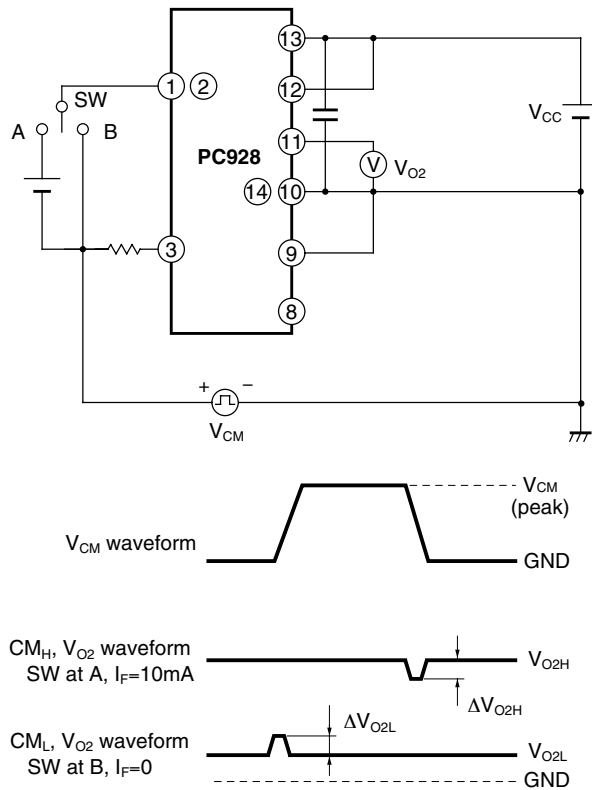


Fig.8 Test Circuit for Response Time

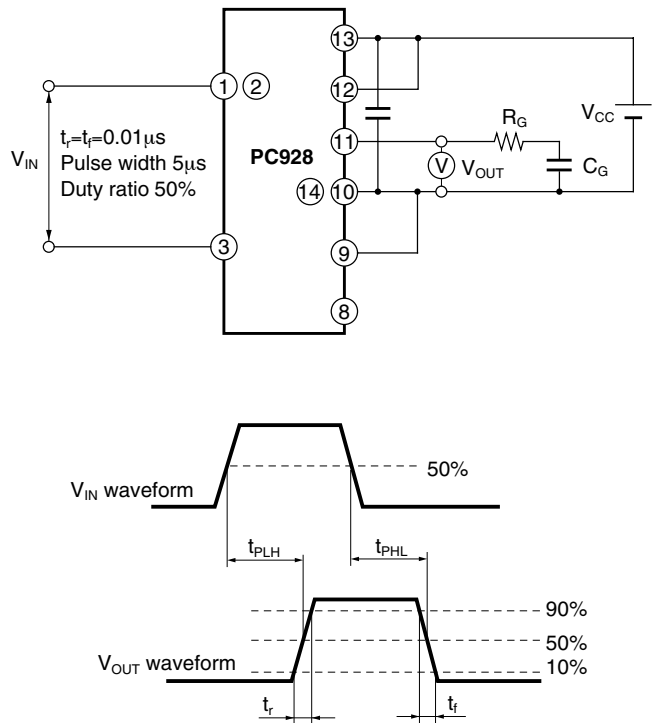


Fig.9 Test Circuit for Overcurrent Detection Voltage, Overcurrent Detection Voltage Hysteresis

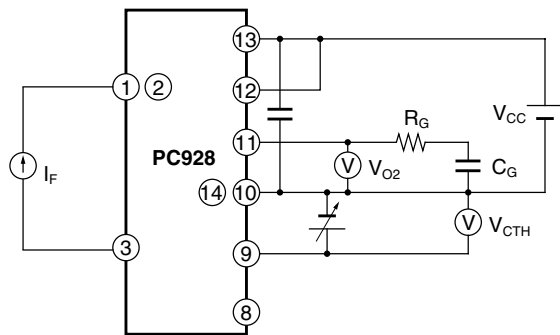


Fig.10 Test Circuit for O₂ Output Voltage at Overcurrent Protection

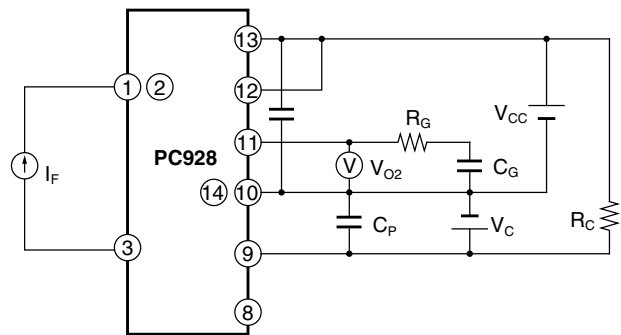


Fig.11 Test Circuit for O₁ Low Level Error Signal Voltage

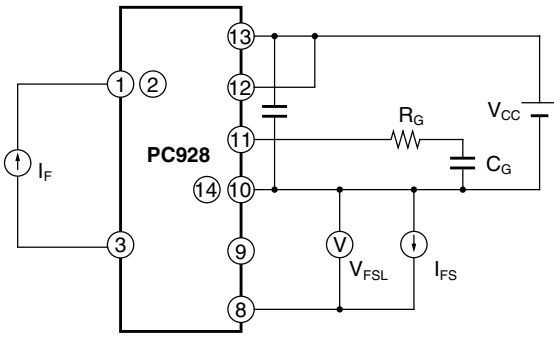


Fig.12 Test Circuit for High Level Error Signal Current

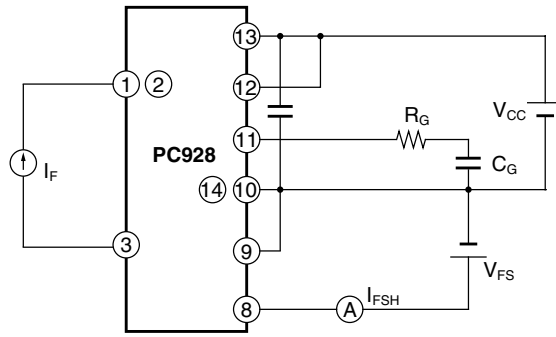


Fig.13 Test Circuit for O₂ "High→Low" Propagation Delay Time at Overcurrent Protection, O₂ Fall Time at Overcurrent Protection

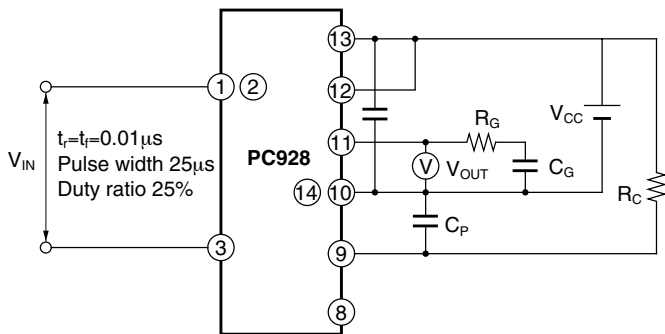


Fig.14 Error Signal "High→Low" propagation Delay Time, Error Signal Output Pulse Width

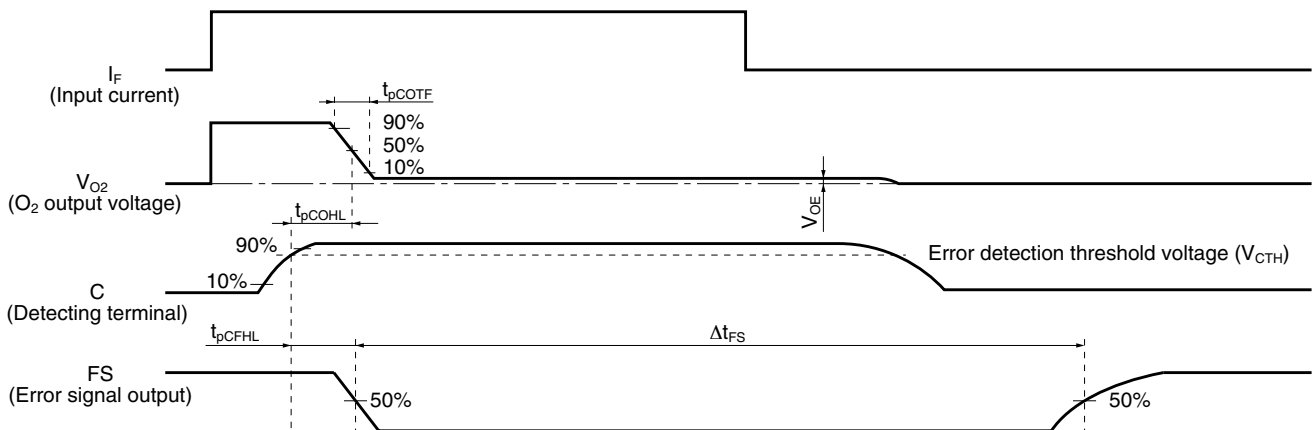
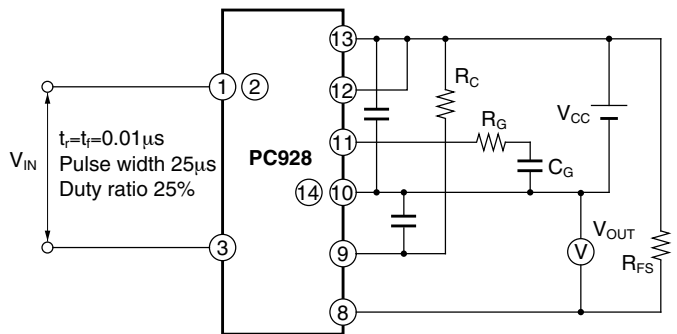


Fig.15 Forward Current vs. Ambient Temperature

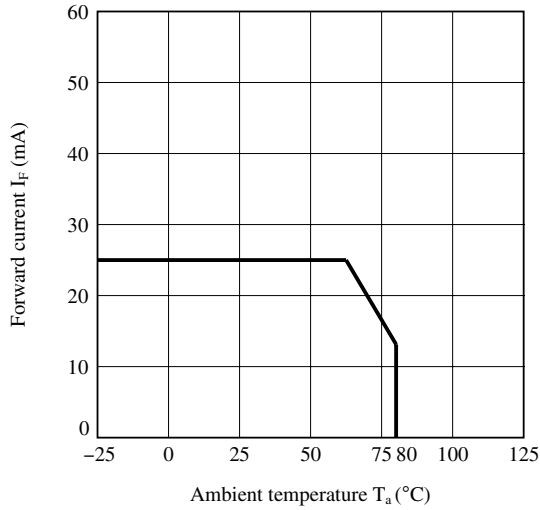


Fig.16 Power Dissipation vs. Ambient Temperature

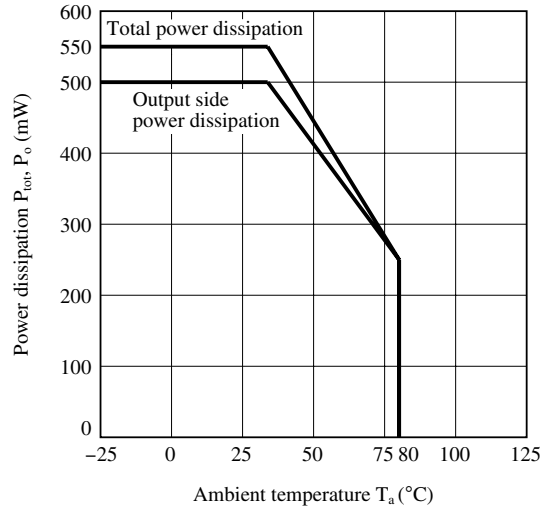


Fig.17 Forward Current vs. Forward Voltage

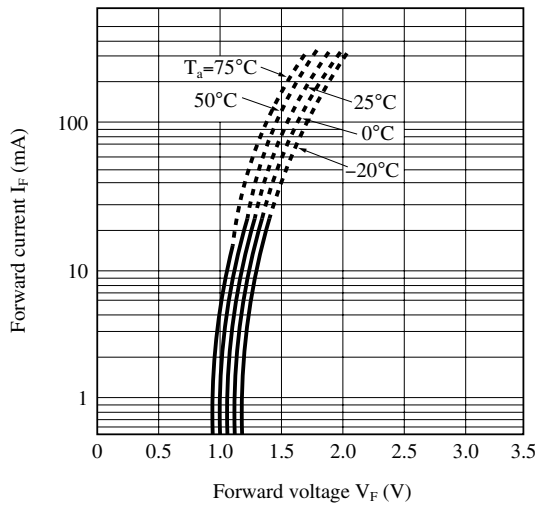


Fig.18 "Low→High" Relative Input Threshold Current vs. Supply Voltage

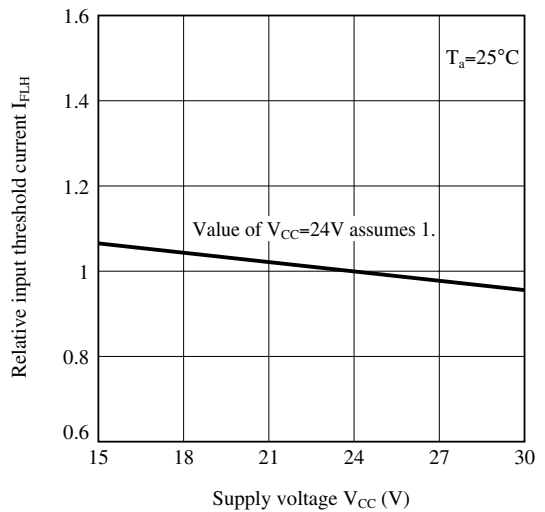


Fig.19 "Low→High" Relative Input Threshold Current vs. Ambient Temperature

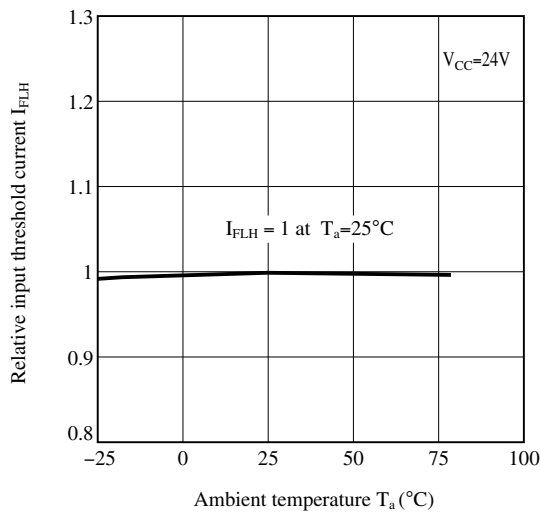


Fig.20 O₁ Low Level Output Voltage vs. O₁ Output Current

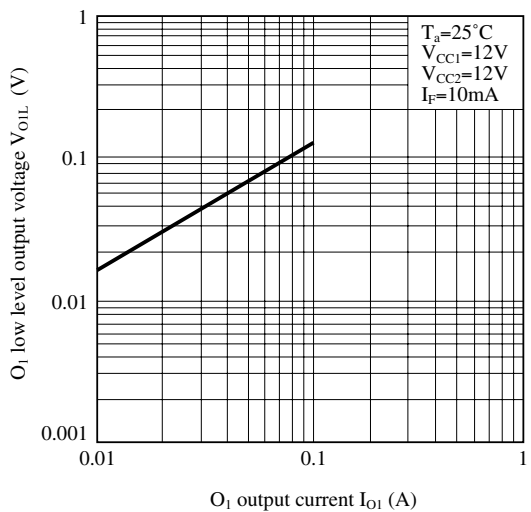


Fig.21 O₁ Low Level Output Voltage vs. Ambient Temperature

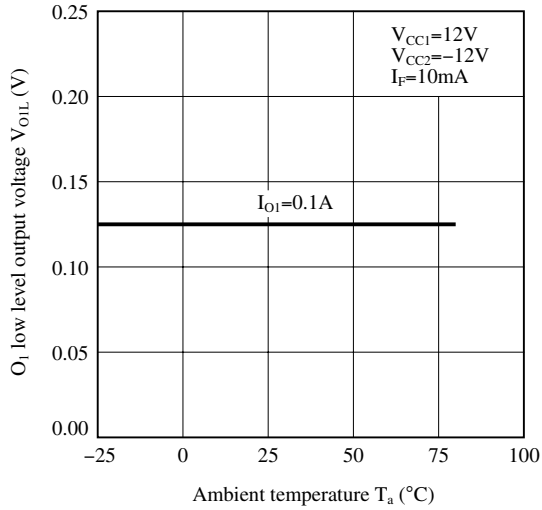


Fig.22 O₁ Leak Current vs. Ambient Temperature

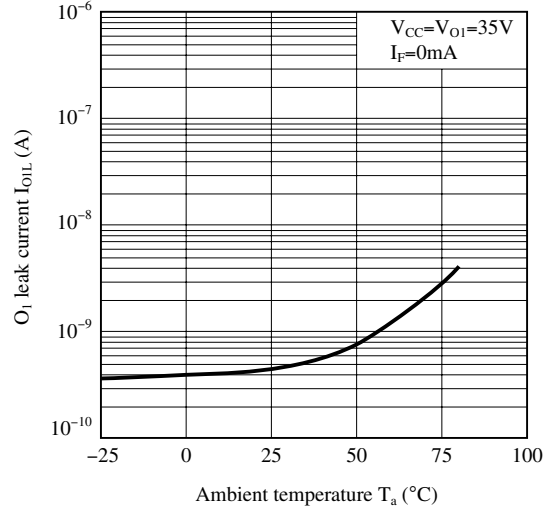


Fig.23 O₂ High Level Output Voltage vs. Supply Voltage

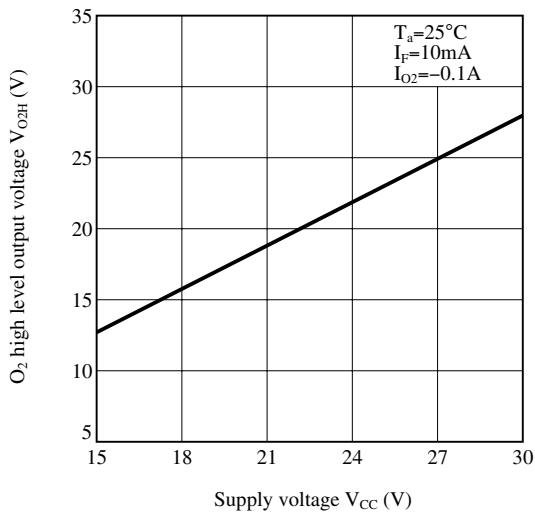


Fig.24 O₂ High Level Output Voltage vs. Ambient Temperature

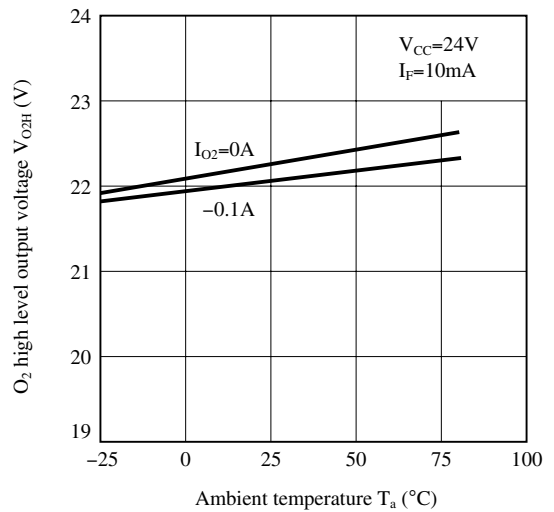


Fig.25 O₂ Low Level Output Voltage vs. Output Current

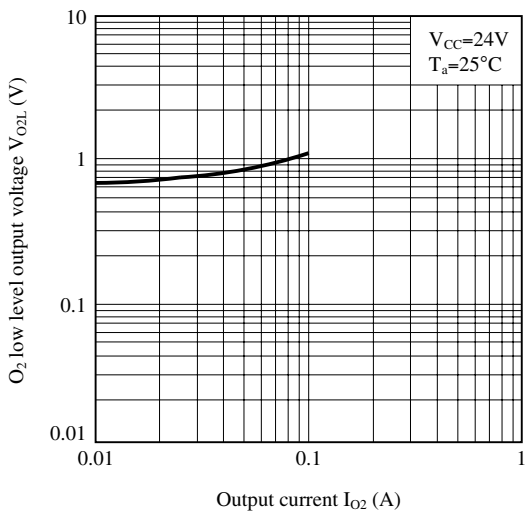


Fig.26 O₂ Low Level Output Voltage vs. Ambient Temperature

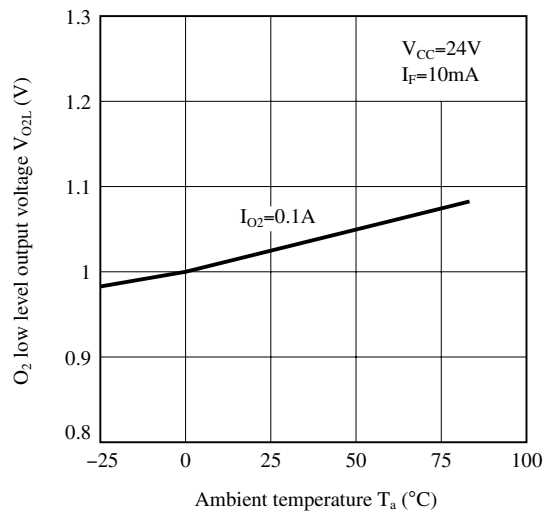


Fig.27 High Level Supply Current vs. Supply Voltage

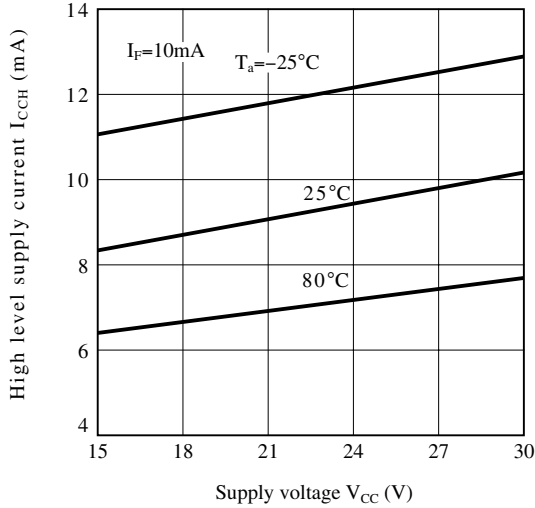


Fig.28 Low Level Supply Current vs. Supply Voltage

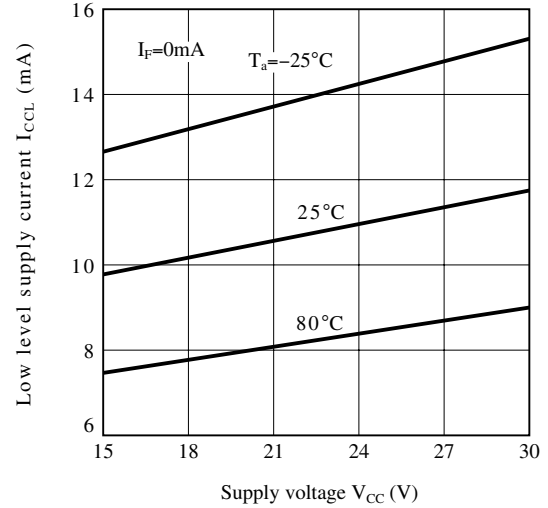


Fig.29 Propagation Delay Time vs. Forward Current

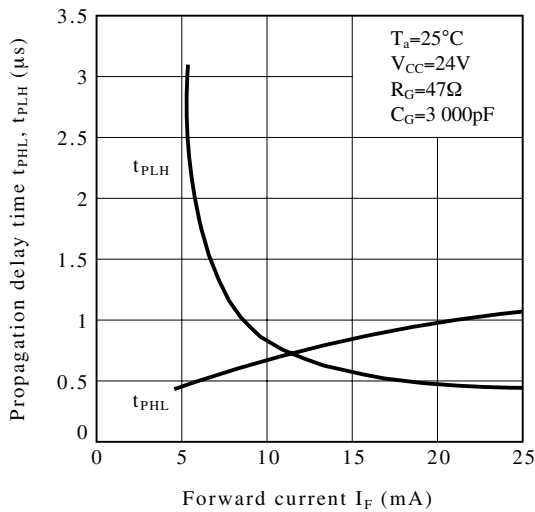


Fig.30 Propagation Delay Time vs. Ambient Temperature

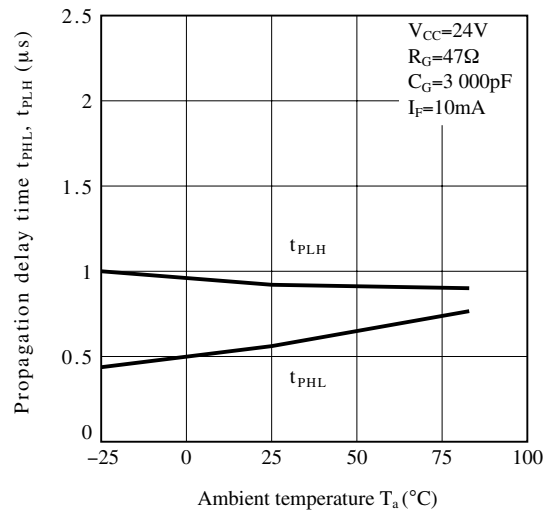


Fig.31 Overcurrent Detecting Voltage vs. Ambient Temperature

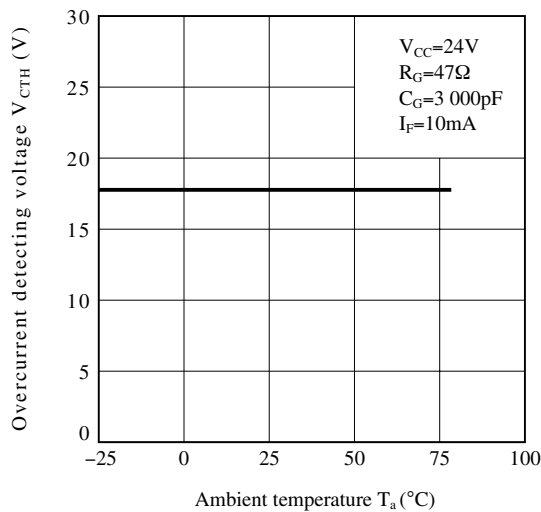


Fig.32 O₂ Output Fall Time at Protection from Overcurrent/O₂ "High-Low" Propagation Delay Time at Protection from Overcurrent vs. Ambient Temperature

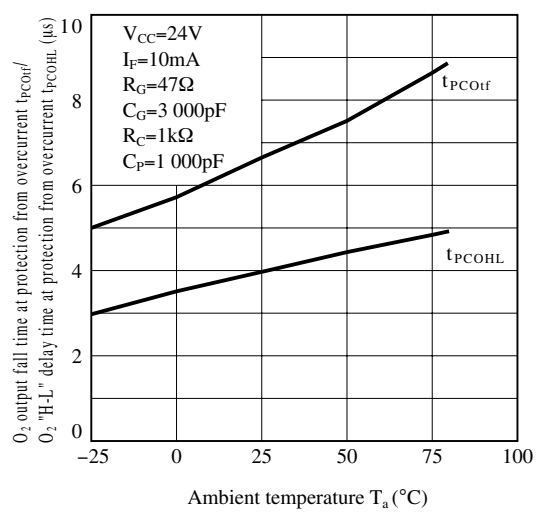


Fig.33 Error Signal "High-Low" Propagation Delay Time vs. Ambient Temperature

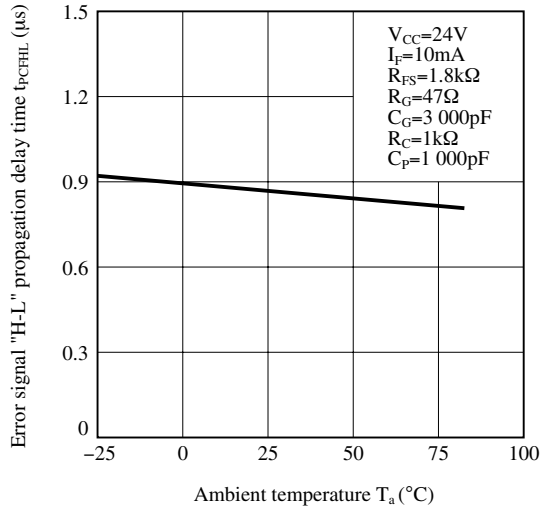


Fig.34 O₂ Output Voltage at Protection from Overcurrent vs. Ambient Temperature

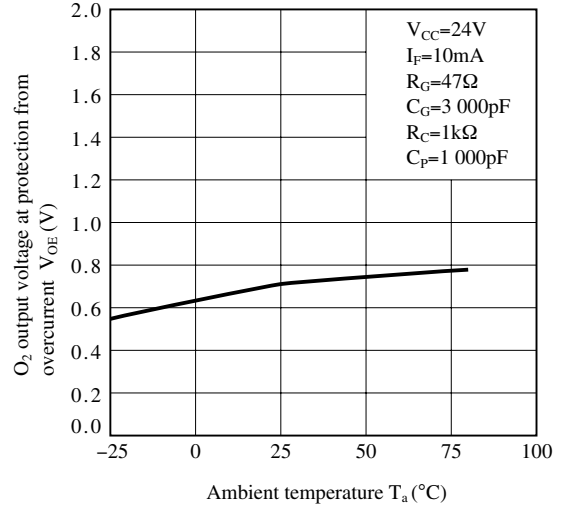


Fig.35 Low Level Error Signal Voltage vs. Ambient Temperature

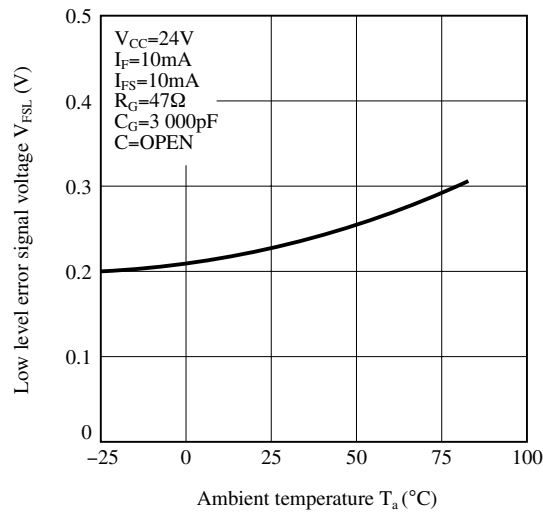


Fig.36 High Level Error Signal Current vs. Ambient Temperature

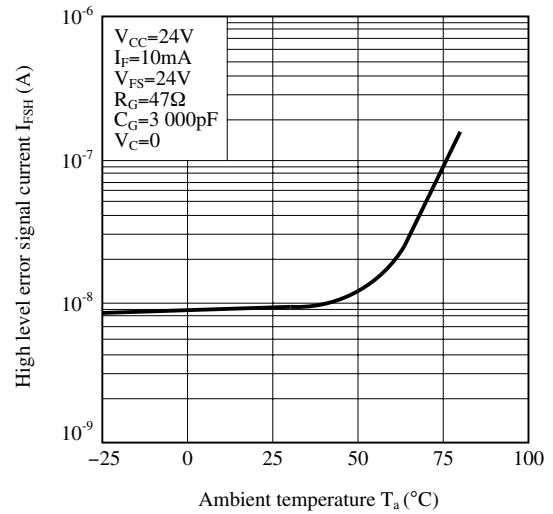


Fig.37 Error Signal Output Pulse Width vs. Ambient Temperature

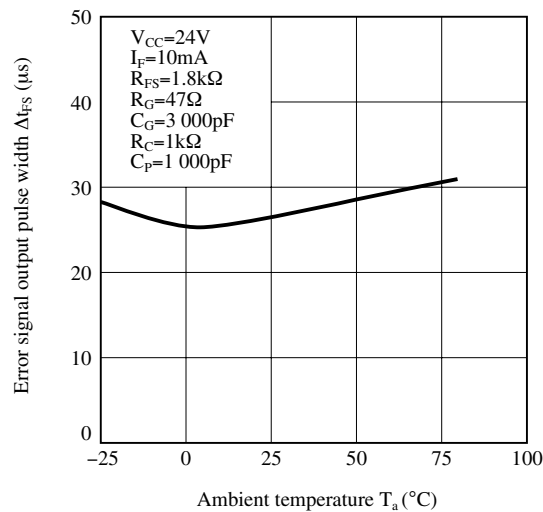


Fig.38 Overcurrent Detecting Voltage vs. Supply Voltage

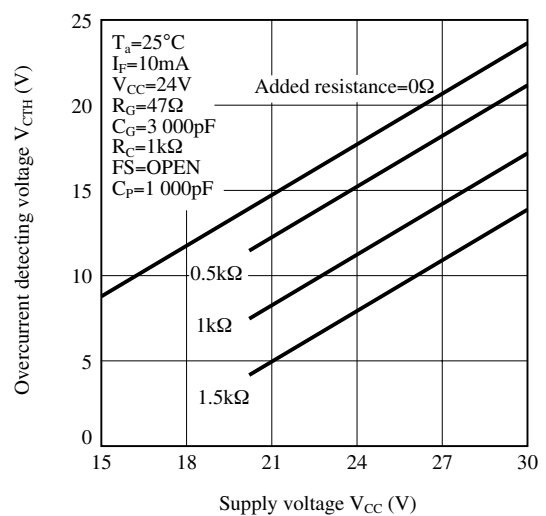


Fig.39 Overcurrent Detecting Voltage - Supply Voltage Characteristics Test Circuit

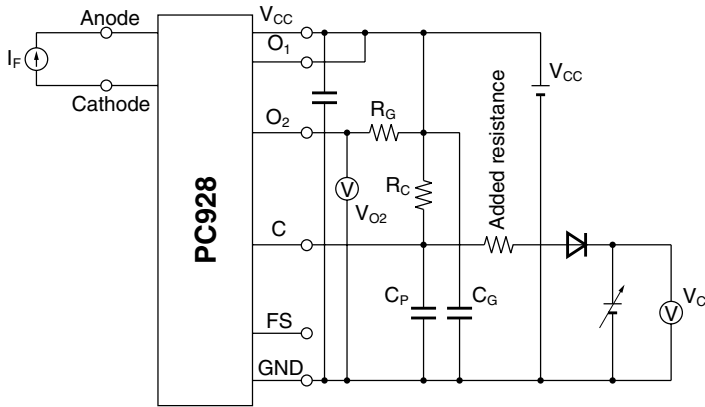
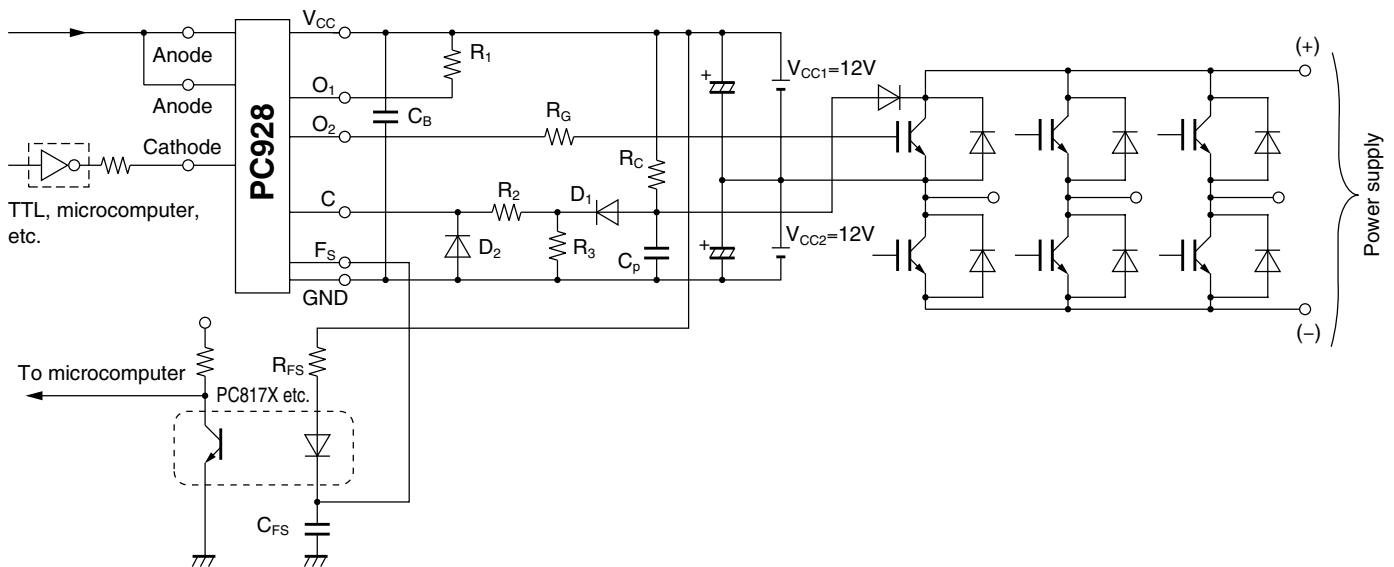


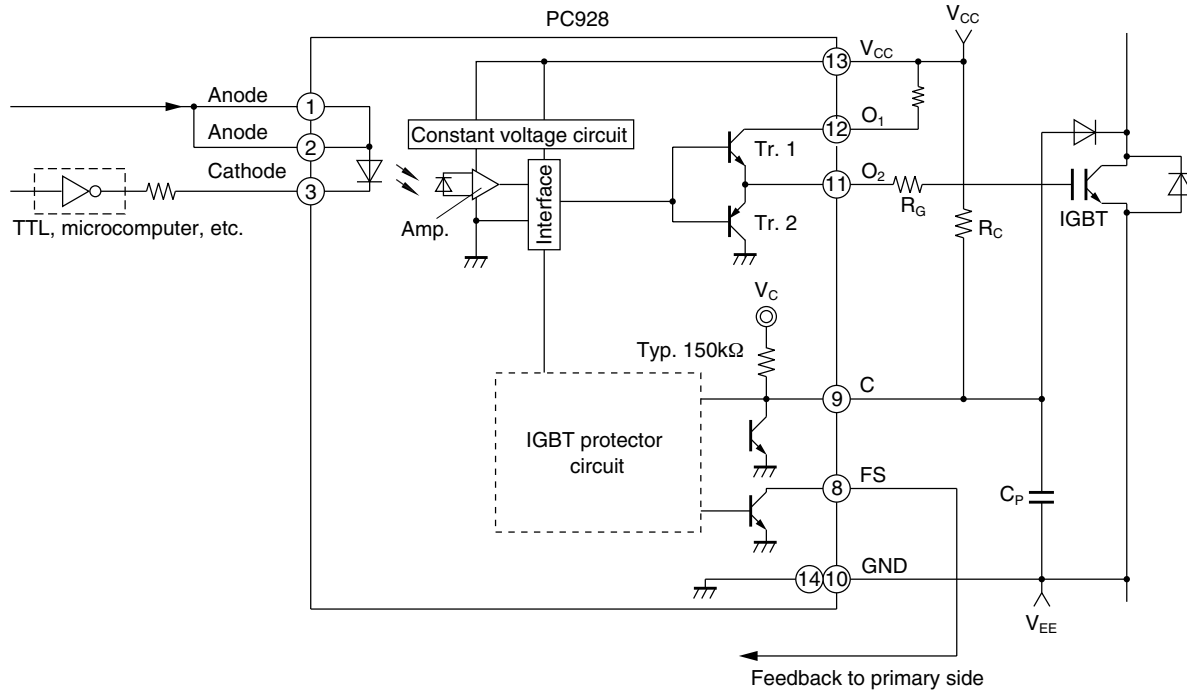
Fig.40 Example of The Application Circuit (IGBT Drive for Inverter)



- In order to stabilize the power supply line, we recommend to locate a bypass capacitor C_B (0.01 μ F or more) between V_{CC} and GND near photocoupler.
- In order to stabilize the detecting voltage of pin-C, we recommend to locate a capacitor C_P (approximately 1 000pF) between pin-C and GND, and a resistor R_C (approximately 1.0k Ω) between V_{CC} and pin-C. However, the rise time of the detection voltage at Pin-C varies along with the time constants of C_P and R_C . So, please make sure the device works properly in actual conditions.
- For the diode D, which is located between pin-C and collector of IGBT, we recommend to use a diode that has the withstand voltage characteristic equivalent to IGBT and also has little leak current.
- In order to prevent the failure mode or breakdown of pin-C from V_{CE} variation of IGBT, we recommend to locate a resistor R_2 (approximately 10k Ω) and a diode D1 at near pin-C, and a resistor R_3 (approximately 50k Ω) and a diode D2 at between pin-C and GND.

This application circuit shows the general example of a circuit, and is not a design guarantee for right operation.

Fig.41 Operations of Shortcircuit Protector Circuit



1. Detection of increase in $V_{CE(sat)}$ of IGBT due to overcurrent by means of C terminal (pin ⑨)
2. Reduction of the IGBT gate voltage, and suppression of the collector current
3. Simultaneous output of signals to indicate the shortcircuit condition (FS signal) from FS terminal (pin ⑧) to the microcomputer
4. Judgement and processing by the microcomputer
 - In the case of instantaneous shortcircuit, run continues.
 - At fault, input to the photocoupler is cut off, and IGBT is turned OFF.

Remarks : Please be aware that all data in the graph are just for reference and not for guarantee.

■ Design Considerations

● Notes about static electricity

Transistor of detector side in bipolar configuration may be damaged by static electricity due to its minute design.

When handling these devices, general countermeasure against static electricity should be taken to avoid breakdown of devices or degradation of characteristics.

● Design guide

In order to stabilize power supply line, we should certainly recommend to connect a by-pass capacitor of 0.01 μ F or more between V_{CC} and GND near the device.

We recommend to use approximately 1 000pF of capacitor between C-pin and GND in order to prevent miss operation by noise.

In the case that capacitor is used approximately 1k Ω of resistance shall be recommended to use between V_{CC} and C-pin. However, the rise time of C-pin shall be changed by time constant of added CR, so that please use this device after confirmation.

In case that some sudden big noise caused by voltage variation is provided between primary and secondary terminals of photocoupler some current caused by it is floating capacitance may be generated and result in false operation since current may go through IRED or current may change.

If the photocoupler may be used under the circumstances where noise will be generated we recommend to use the bypass capacitors at the both ends of IRED.

The detector which is used in this device, has parasitic diode between each pins and GND.

There are cases that miss operation or destruction possibly may be occurred if electric potential of any pin becomes below GND level even for instant.

Therefore it shall be recommended to design the circuit that electric potential of any pin does not become below GND level.

This product is not designed against irradiation and incorporates non-coherent IRED.

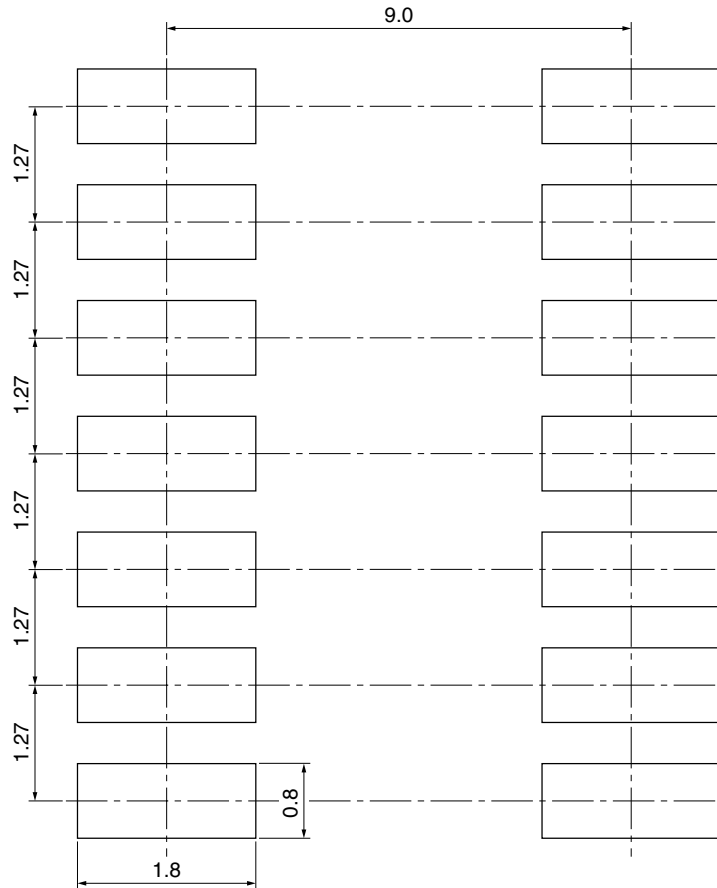
● **Degradation**

In general, the emission of the IRED used in photocouplers will degrade over time.

In the case of long term operation, please take the general IRED degradation (50% degradation over 5years) into the design consideration.

Please decide the input current which become 2times of MAX. I_{FLH} .

● **Recommended Foot Print (reference)**



(Unit : mm)

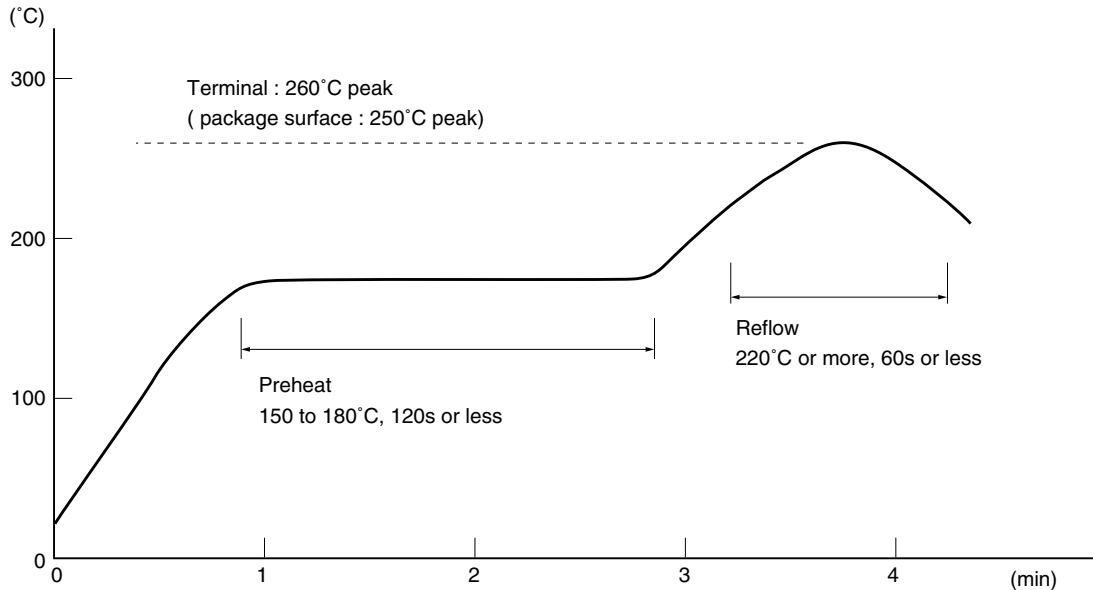
☆ For additional design assistance, please review our corresponding Optoelectronic Application Notes.

■ Manufacturing Guidelines

● Soldering Method

Reflow Soldering:

Reflow soldering should follow the temperature profile shown below.
Soldering should not exceed the curve of temperature profile and time.
Please don't solder more than twice.



Flow Soldering :

Due to SHARP's double transfer mold construction submersion in flow solder bath is allowed under the below listed guidelines.

Flow soldering should be completed below 260°C and within 10s.
Preheating is within the bounds of 100 to 150°C and 30 to 80s.
Please don't solder more than twice.

Hand soldering

Hand soldering should be completed within 3s when the point of solder iron is below 400°C.
Please don't solder more than twice.

Other notices

Please test the soldering method in actual condition and make sure the soldering works fine, since the impact on the junction between the device and PCB varies depending on the tooling and soldering conditions.

● Cleaning instructions**Solvent cleaning:**

Solvent temperature should be 45°C or below Immersion time should be 3minutes or less

Ultrasonic cleaning:

The impact on the device varies depending on the size of the cleaning bath, ultrasonic output, cleaning time, size of PCB and mounting method of the device.

Therefore, please make sure the device withstands the ultrasonic cleaning in actual conditions in advance of mass production.

Recommended solvent materials:

Ethyl alcohol, Methyl alcohol and Isopropyl alcohol

In case the other type of solvent materials are intended to be used, please make sure they work fine in actual using conditions since some materials may erode the packaging resin.

● Presence of ODC

This product shall not contain the following materials.

And they are not used in the production process for this device.

Regulation substances : CFCs, Halon, Carbon tetrachloride, 1.1.1-Trichloroethane (Methylchloroform)

Specific brominated flame retardants such as the PBBOs and PBBs are not used in this product at all.

■ **Package specification**

● **Sleeve package**

Package materials

Sleeve : HIPS (with anti-static material)

Stopper : Styrene-Elastomer

Package method

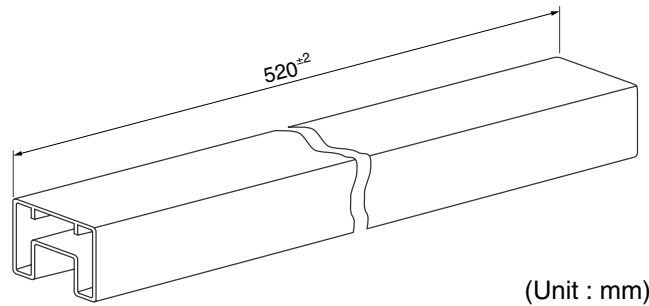
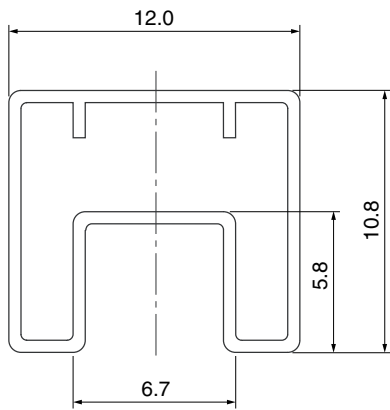
MAX. 50 pcs. of products shall be packaged in a sleeve.

Both ends shall be closed by tabbed and tabless stoppers.

The product shall be arranged in the sleeve with its primary side mark on the tabless stopper side.

MAX. 20 sleeves in one case.

Sleeve outline dimensions



(Unit : mm)

● **Tape and Reel package**

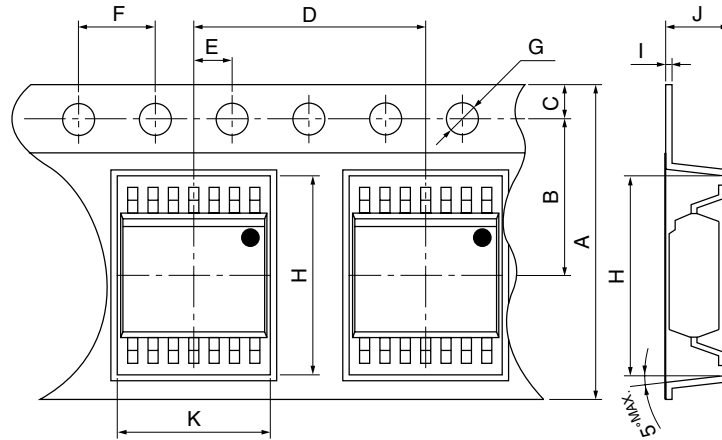
Package materials

Carrier tape : A-PET (with anti-static material)

Cover tape : PET (three layer system)

Reel : PS

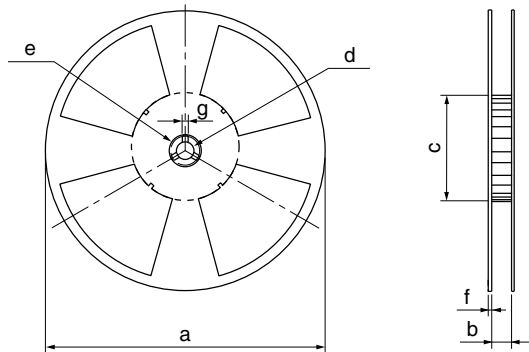
Carrier tape structure and Dimensions



Dimensions List (Unit : mm)

| A | B | C | D | E | F | G |
|----------|----------|----------|----------|---------|---------|----------|
| 16.0±0.3 | 7.5±0.1 | 1.75±0.1 | 12.0±0.1 | 2.0±0.1 | 4.0±0.1 | φ1.5±0.1 |
| H | I | J | K | | | |
| 10.4±0.1 | 0.4±0.05 | 4.2±0.1 | 9.7±0.1 | | | |

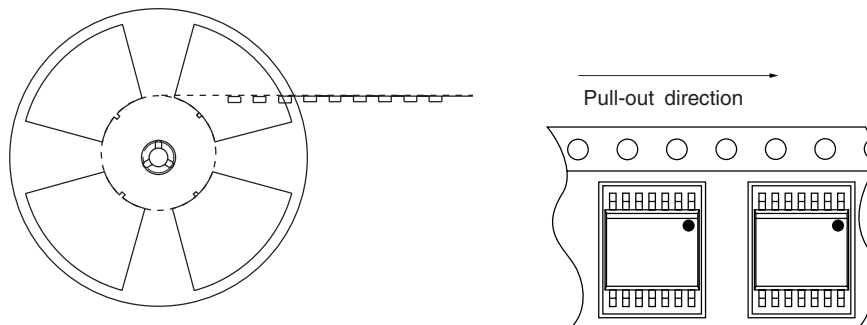
Reel structure and Dimensions



Dimensions List (Unit : mm)

| a | b | c | d |
|--------|----------|---------|--------|
| 330 | 17.5±1.5 | 100±1.0 | 13±0.5 |
| e | f | g | |
| 23±1.0 | 2.0±0.5 | 2.0±0.5 | |

Direction of product insertion



[Packing : 1 000pcs/reel]

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(i) The devices in this publication are designed for use in general electronic equipment designs such as:

- Personal computers
- Office automation equipment
- Telecommunication equipment [terminal]
- Test and measurement equipment
- Industrial control
- Audio visual equipment
- Consumer electronics

(ii) Measures such as fail-safe function and redundant design should be taken to ensure reliability and safety when SHARP devices are used for or in connection

with equipment that requires higher reliability such as:

- Transportation control and safety equipment (i.e., aircraft, trains, automobiles, etc.)
- Traffic signals
- Gas leakage sensor breakers
- Alarm equipment
- Various safety devices, etc.

(iii) SHARP devices shall not be used for or in connection with equipment that requires an extremely high level of reliability and safety such as:

- Space applications
- Telecommunication equipment [trunk lines]
- Nuclear power control equipment
- Medical and other life support equipment (e.g., scuba).

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