Photorelay Specifications

June 2018

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WHAT ARE PHOTORELAYS?

Classification of Relays

Group	Sub-Group	Notes
Contact (Mechanical Relay)	Signal Relay	• low current switching mechanical relays, often below 2A, for applications such as signal, circuit, high frequency control etc. • includes high frequency relays
	Power Relay	• high current switching mechanical relays, above 2A • includes general purpose relays for control panel, high DC current control power relays etc.
Contactless (Semiconductor Relay)	Photorelay (MOSFET output)	• uses MOSFET as the output device • mainly used as signal relay replacement • able to handle both AC and DC loads Products with ION>1A are referred to as high capacity (current) photorelays
	SSR (Solid State Relay)	• uses semiconductor photo traic, photo transistor or photo thyristor as the output device • photo traic, photo thyristor output devices are limited to AC loads

Note: This classification may differ from the actual classification in a catalog distributor (eg Digikey / Mouser etc.).
We recommend searching with the product name directly.

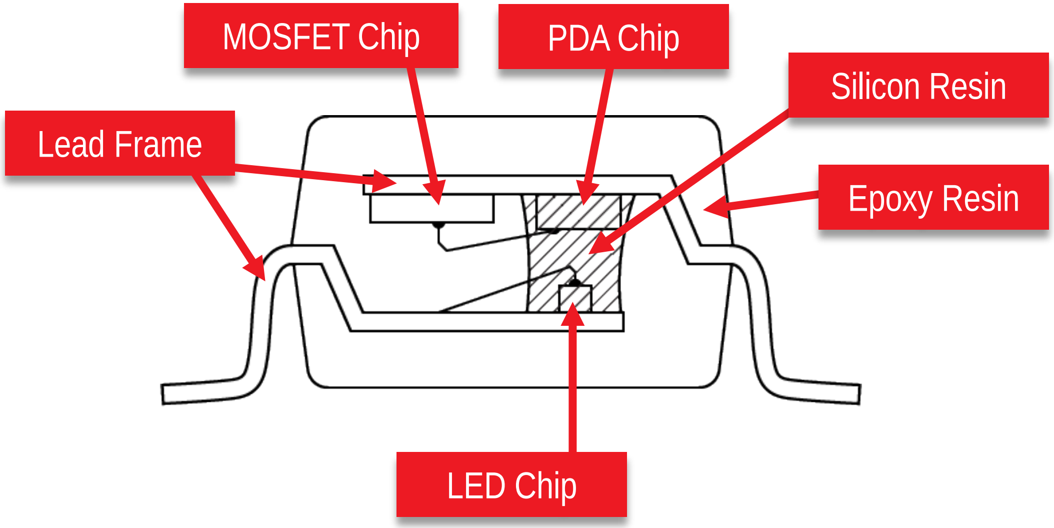
Structure of Photorelays

NEW !

SO6 Package

3.7 × 7.0 x 2.1mm

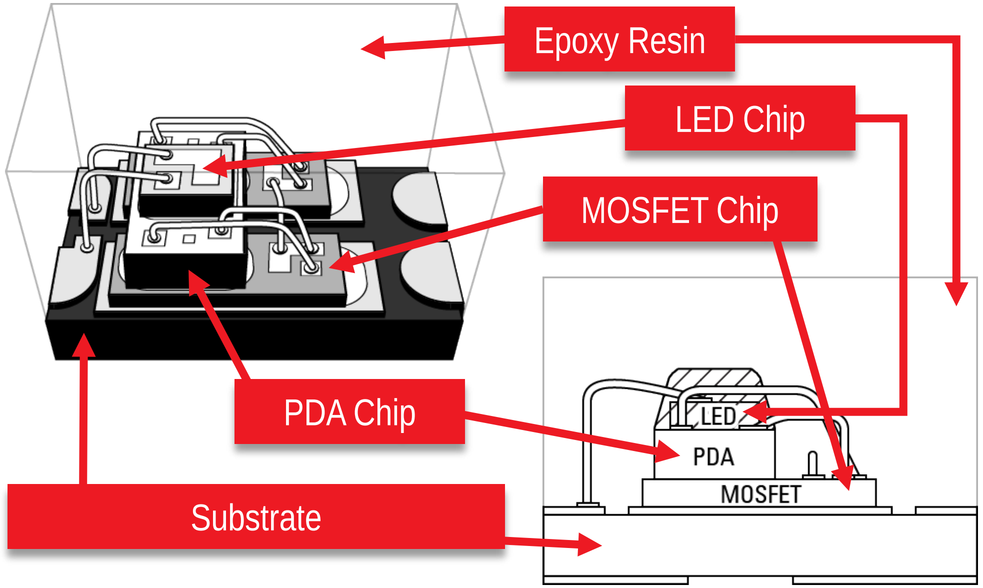
Frame Type



S-VSON4 Package

2.0 × 1.45 x 1.65mm

Substrate Type

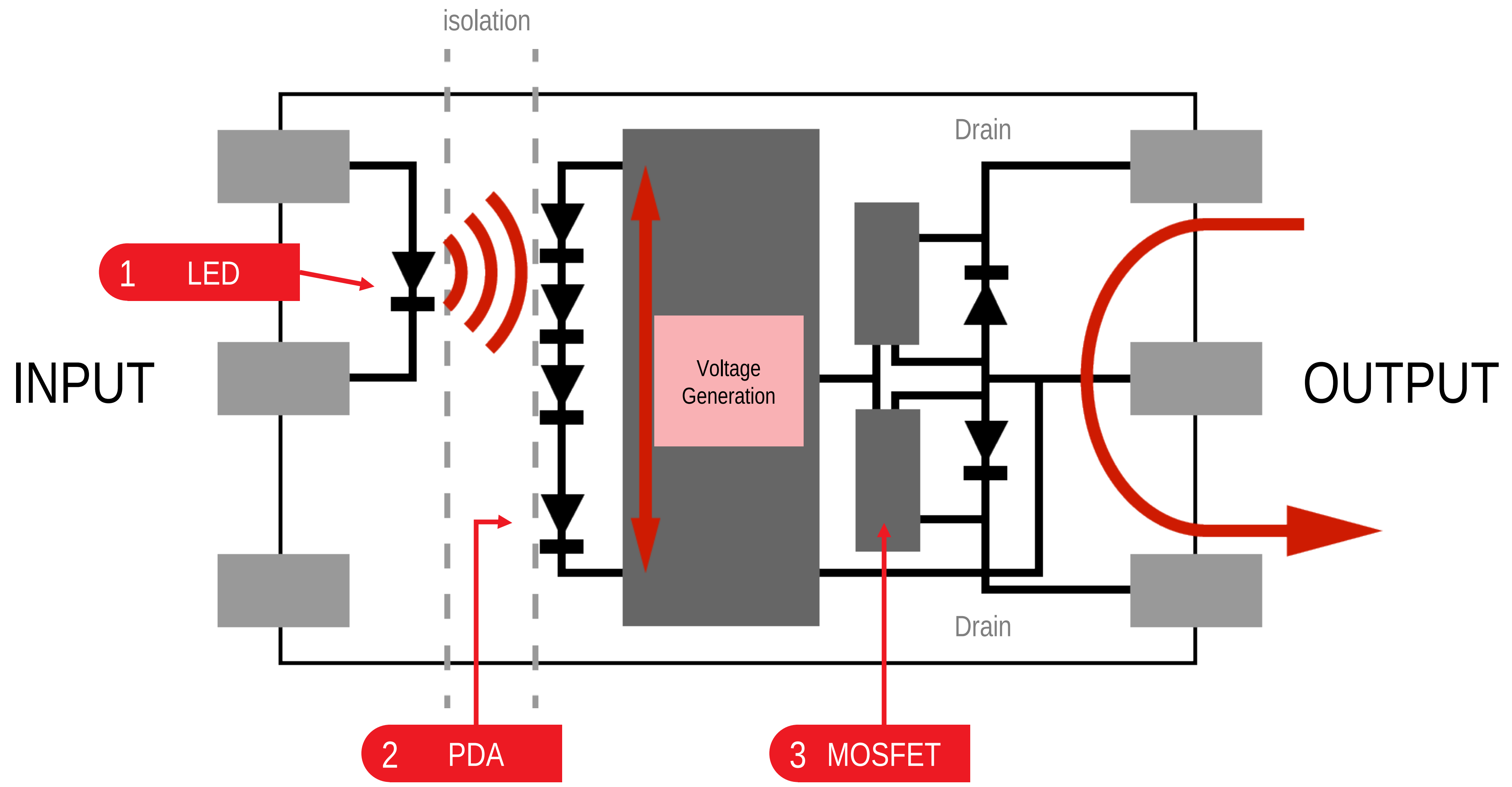


Semiconductor relay

MOSFET : (Metal Oxide Semiconductor Field Effect Transistor) PDA : (Photo Diode Array)

How Photorelays operate

The relay function is made up of LED / PDA / MOSFET × 2 pcs



1 A current is passed through the LED to cause it to emit light,

2 The PDA powers and drives the gate of the MOSFET

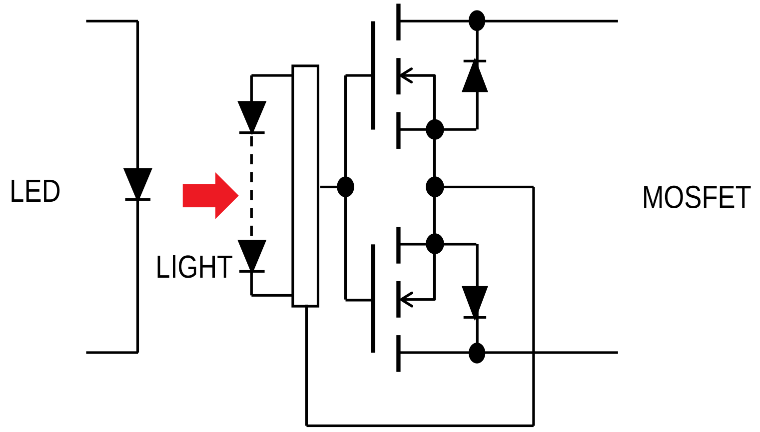
3 MOSFET turns on.

2

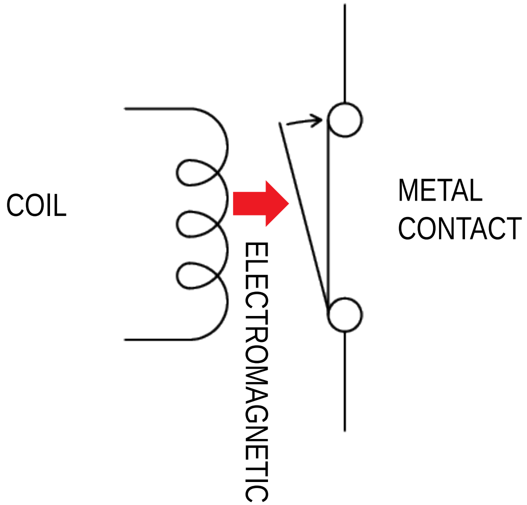
ADVANTAGES

Photorelays feature vs Mechanical relays

Photorelays
(MOSFET output photocouplers)



Mechanical Relays



Comparison with Mechanical relays

1. Miniaturization of mounting area
2. High reliability (long life)
3. Low input current / low voltage drive
4. Excellent switching characteristics (high speed, low noise)
5. Hot switch support

Miniaturization of mounting area

Toshiba Photo Relay package trend

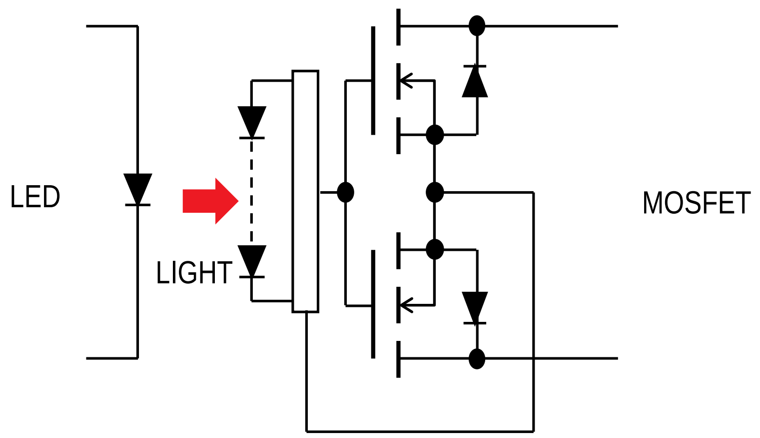
Package Trend

We have a line-up of small package products such as those in the SO6 and VSON packages.
Replacing with photorelays greatly contribute to miniaturization of the set

High reliability (long life)

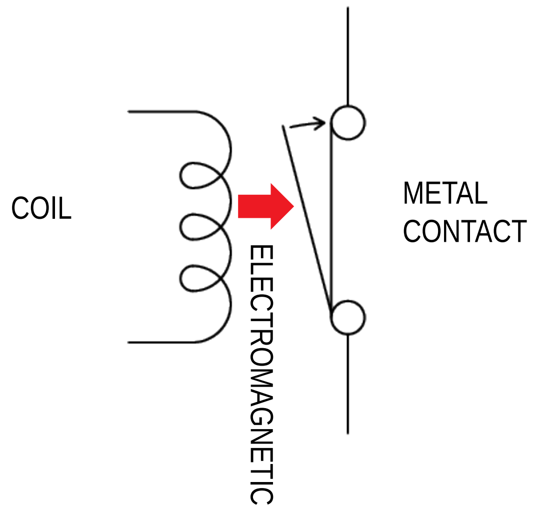
Photorelays

(MOSFET output photocouplers)



No wear and tear induced degradation

Mechanical Relays



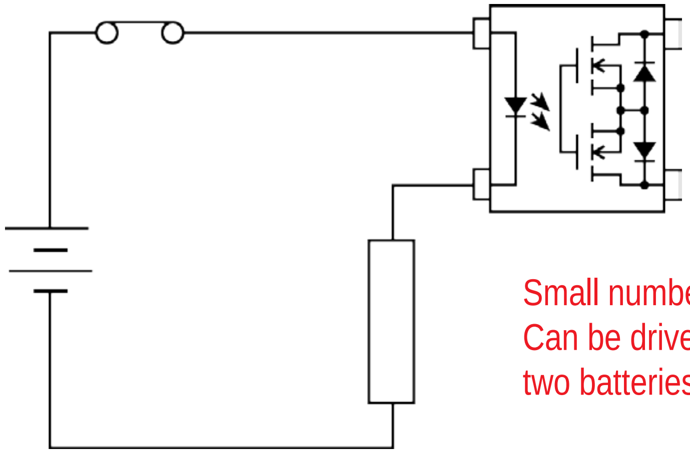
Wear and tear, periodic maintenance required

The photo relay operates by receiving the LED light with the photodiode array, converting it into voltage that drives the MOSFET. Since there are no mechanical contacts, there is no wear and tear induced degradation like a mechanical relay (no limit on number of contacts, maintenance free)

Low input current / low voltage drive

Photorelays

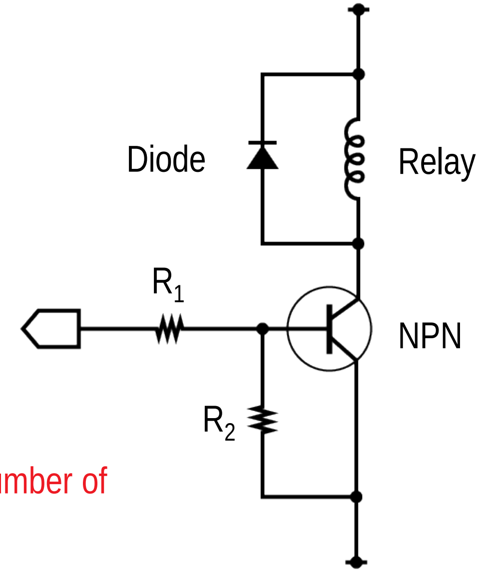
(MOSFET output photocouplers)



Small number of parts
Can be driven with just two batteries

The drive circuit of the photo relay is simple. Low input type can also be battery driven or driven directly from the microcomputer

Mechanical Relays



Large number of parts.

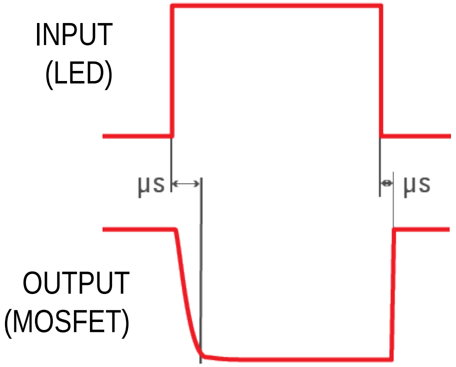
Since the driving current is large, buffer transistor is required to boost the Microcomputer output

Since the LED is used on the input side which is driven by current, and necessary input current (trigger LED current; IFT) for turning on the output is as low as 3 to 5 mA (Max.), the photorelay can be driven even by a small battery.
It is necessary to consider the LED lifetime when designing the IF spec.

Excellent switching characteristics (high speed, low noise)

Photorelays

(MOSFET output photocouplers)



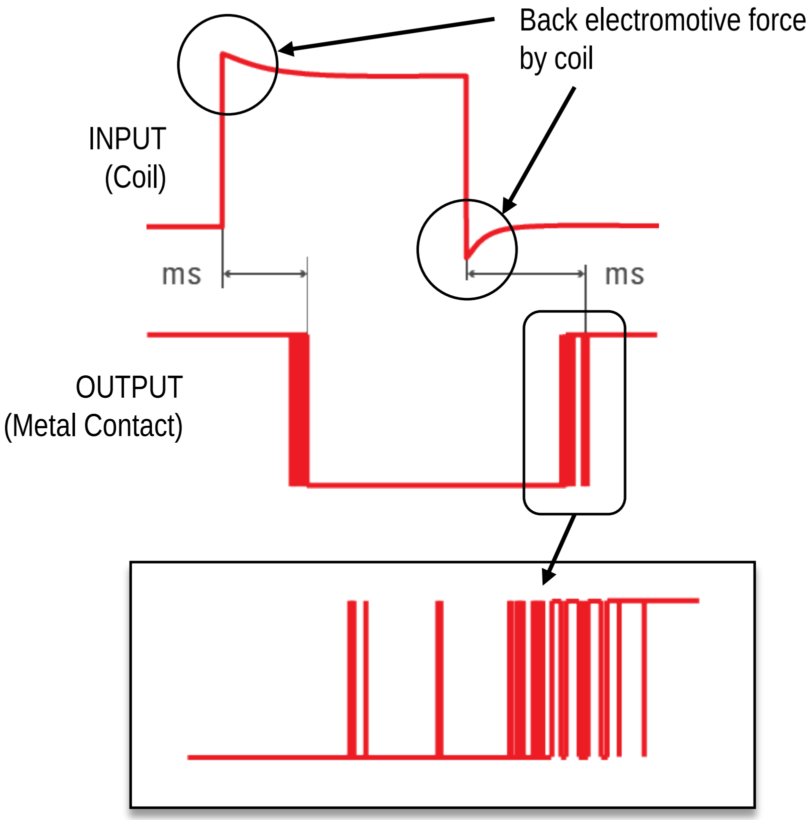
Benefits of replacing mechanical relays to photo relays

Reduction of noise

- input: no back electromotive force
- output: no bounce

Switching speed is 1/10～1/100

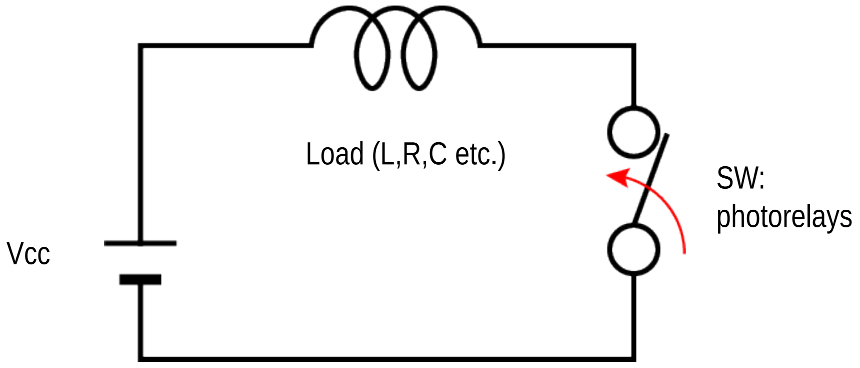
Mechanical Relays



Since the photo relay uses an LED on the input side and a MOSFET on the output side, noise caused by back electromotive force or bounce is non-existent. It also does not produce contact sounds like mechanical relays.

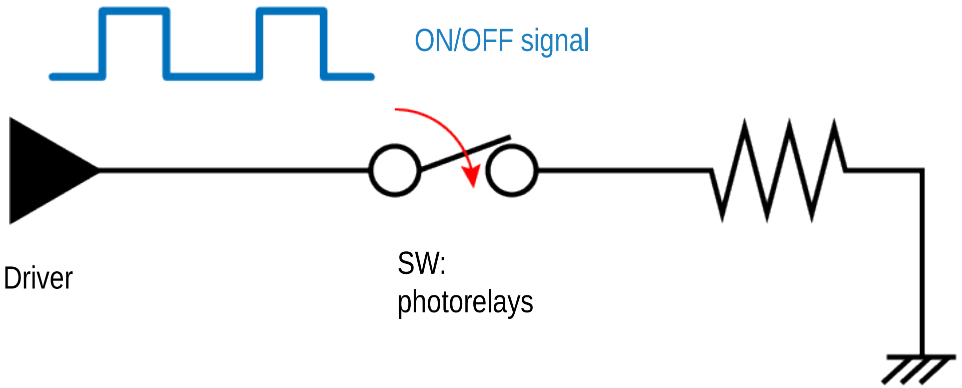
Hot switch support

Case of HOT switch



This means that the switch (SW) operates with voltage applied. Current flows to the load at the moment SW is closed.

Case of COLD switch



This means that the switch(SW) operates without voltage applied. Therefore no current flows when SW is closed, then output the signal from power supply.

Mechanical relays have shorter lifespan when used with the HOT switch.
The photo relay can be used with either the HOT switch or the COLD switch as long as the maximum rating is maintained.
＊In the case of a mechanical relay, since the voltage is applied by the HOT switch, current flows at the moment the contact is closed, and the contacts are likely to be worn out. Also, when the switch opens, the current is interrupted, an arc is generated, and the life is shortened.

Comparison with mechanical relay

	Mechanical relay (Signal relay)	Photorelay	Remarks (Feature of Photorelay)
Lifetime	△ (With contact limit)	◎ (No contact limit)	Long life
Contact Capacity	◎ (2A) ※Ta 85℃/AC・DC applicable	○ (~5A) ※Ta 25℃/VOFF=60V basis	
Contact Resistance (ON Resistance)	About 0.1Ω (Degraded by On/Off)	About 0.02~25Ω (Stable)	High reliability
Contact Voltage (OFF Voltage)	◎ (ex：AC 250V, DC 30V)	○ (ex：line up with 20V～600V)	
Isolation Voltage	○ (ex：1KVrms)	◎ (max:5KVrms)	
Operation / Release Time	△ About 5ms	○ About 0.1ms	High speed
Operation Sound	△(exist)	◎(No sound)	No noise
Miniaturization	○ (ex : 60mm^2)	◎ (S-VSON: 2.9mm^2 - 1.45 × 2.0 mm)	Smaller size
Input Power Consumption	× (coil) 100mW～	◎ (LED) (ex: 0.5mW～)	Less power consumption
Contact Form	1c、2c	1a、1b、2a、1a1b	
Leakage Current	◎(not exist)	○(20pA～)	

In recent years, replacement from mechanical relays and reed relays is accelerating.

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TERMINOLOGY

Electrical Characteristics Comparison Mechanical relay vs Photorelay

Mechanical Relay Characteristic	Explanation	Photorelay Characteristic Equivalent
Rated Coil Voltage and (Coil) Nominal Operating Current	Voltage, intended by design, applied to the coil for operation and the resulting value of current flow in the coil	Input Current (IF) , Input Voltage (VF) Recommended Input Current (IF)
Contact Form	Contact mechanism and the number of contacts in the circuit Eg: Normally Open × 1 Contact (1a) Normally Close × 1 Contact (1b) Change-over contacts × 1 Contact (1c)	Contact Form Eg: Normally ON × 1 Contact (1a) Normally OFF × 1 Contact (1b)
Contact Resistance	Total resistance when the contacts meet	ON Resistance (RON)
Contact Capacity	Voltage and current that the part can handle in the ON state	OFF-State Output Terminal Voltage (VOFF), ON-State Current (ION , IONP)
Maximum Allowable Contact Power	Upper limit of power within which the part can be turned on and off properly	Output power dissipation (PO)
Maximum Allowable Contact Voltage	Maximum open circuit voltage Requires derating according to operation load and current	OFF-State Output Terminal Voltage (VOFF)
Maximum Allowable Contact Current	Maximum current that the contacts can handle Requires derating according to operation load and voltage	ON-State Current (ION , IONP)

Electrical Characteristics Comparison Mechanical relay vs Photorelay (cont'd)

Mechanical Relay Characteristic		Explanation	Photorelay Characteristic Equivalent
Maximum Allowable Contact Current		Maximum current that the contacts can handle Requires derating according to operation load and voltage	ON-State Current (ION , IONP)
Switching (Time) Characteristics	Operation Time	Time from which power is applied to the coil until the closure of the contact. (Bounce time not included)	Turn ON Time (tON)
	Release Time	Time from which power is removed from the coil until the return of the contact to it's initial position. (Bounce time not included)	Turn OFF Time (tOFF)
Lifetime	Mechanical Life	Minimum number of operation cycles the relay can undergo with no load on the contacts.	LED Lifetime Data
	Electrical Life	Minimum number of operation cycles the relay can undergo with a specified load on the contacts.	LED Lifetime Data
Operating Temperature		Ambient temperature of the environment at which the relay is operated.	Operating Temperature (Topr)

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Terminology 1

Term		Symbol	Description
Absolute Maximum Rating		---	Maximum value which can never be exceeded during operation, even for an instant. When temperature conditions are unspecified, T_a=25℃.
Input	LED Forward Current	I_F	Rated current which can flow continuously in the forward direction of the LED
	LED Peak Forward Current	I_{FP}	Rated current which can flow momentarily in the forward direction of the LED
	Input Forward Current Derating	$\Delta I_F/\Delta Ta$	Rate of change of maximum allowable Input forward current with the ambient temperature
	LED Reverse Voltage	V_R	Rated reverse voltage which can be applied between the cathode and anode
	Junction Temperature	T_j	Temperature which can be allowed in the junction section of the LED
Output	OFF-state Output Terminal Voltage	V_{OFF}	Rated voltage which can be applied between the MOSFET's output pins in the OFF-state. In the case of alternating current, this is known as Vpeak.
	ON-State Current	I_{ON}	Rated current which can flow between the MOSFET's output pins in the ON-State (For AC, this is the peak current)
	ON-Current Derating	$\Delta I_{ON}/\Delta Ta$	Rate of change of maximum ON-Current with the ambient temperature
	Pulse ON-State Current	I_{ONP}	Rated current which can flow instantaneously between the MOSFET's output pins in the ON-State （100ms,DUTY ＝1/10)
	Junction Temperature	T_j	Temperature which can be allowed in the junction section of the photodetector

Absolute Maximum Rating: Maximum value which can never be exceeded during operation, even for an instant

Terminology 1 (cont'd)

Term	Symbol	Description
Isolation Voltage	BV_S	Isolation voltage between input and output at the specified voltage value （High POT)
Ambient Temperature	T_a	Ambient temperature of the environment at which the photorelay is used
Storage Temperature	T_{stg}	Ambient temperature range at which the device can be stored at while not in operation
Lead Soldering Temperature	---	Rated temperature at which the pins of the device can be soldered without loss of functionality

Absolute Maximum Rating: Maximum value which can never be exceeded during operation, even for an instant

Terminology 2

Electrical Characteristics

	Term	Symbol	Description
Input	LED Forward Voltage	V_F	Voltage drop between the LED's anode and cathode at certain forward current ratings
	Reverse Current	I_R	Leakage current flowing in the LED's reverse direction (from cathode to anode)
	Capacitance (LED)	C_T	Electrostatic capacitance between the anode and cathode pins of the LED
	Trigger LED Current	---	Minimum value of the input current IF necessary to change the original state of the output terminal IF larger than maximum IFT is required in the design to ensure that the relay operates.
		I_{FT}	Contact a: Minimum LED input current IF required to put the output MOSFET into the ON-State
		I_{FC}	Contact b: Minimum LED input current IF required to put the output MOSFET into the OFF-State
	Return LED Current	---	Maximum value of the input current required for the output terminal to return to its original state. IF smaller than minimum IFC is required in the design to ensure that the relay operates.
		I_{FC}	Contact a: Maximum LED input current IF required to return the output MOSFET into the OFF-State
		I_{FT}	Contact b: Maximum LED input current IF required to return the output MOSFET into the ON-State
Output	ON-State Resistance	R_{ON}	Resistance between the MOSFET's output pins at a specified ON-State rating
	OFF-State Current	I_{OFF}	Leakage current flowing between the MOSFET's output pins in the OFF-State
	Capacitance	C_{OFF}	Electrostatic capacitance between the MOSFET's output pins (between the two drains)

Terminology 2 (cont'd)

Electrical Characteristics

Term	Symbol	Description
Current Limit	I_{LIM}	Current at which the load current is maintained at when the current limit function kicks in
Input-Output Capacitance	C_{I-O}	Electrostatic capacitance between the input and output pins
Isolation Voltage	Bvs	Maximum allowable voltage between the input and output pins
Operation Time	t_{ON}	Time taken for the output waveform to change from the original state upon input of a specified current into the LED
		Contact a: Time taken for the output waveform to change from 100% to 10% upon turning on the LED
		Contact b: Time taken for the output waveform to change from 100% to 90% upon turning off the LED
Return (Release) Time	t_{OFF}	Time taken for the output waveform to change upon turning off the specified current to the LED
		Contact a: Time taken for the output waveform to change from 0% to 90% upon turning off the LED
		Contact b: Time taken for the output waveform to change from 0% to 10% upon turning on the LED
Equivalent Rise Time	ERT	An indicator of the output transition characteristics for applications with high frequency or high speed signals . ERT is expressed with the formula $ERT=\sqrt{(tr_{out}2-tr_{in}2)}$, where tr_{in} is the input waveform rise time and tr_{out} is the output waveform rise time after relay transition The lower the ERT value, the closer the output signal is compared to the original input waveform.

Terminology 3

Term		Symbol	Description
Recommended Operating Conditions	Recommended Operating Conditions	---	Design guideline, taking into consideration derating of the absolute maximum specifications, in order to achieve the intended performance of the device. Each recommendation was considered independently and does not take into account multiple usage conditions.
	Supply Voltage	V_{DD}	Recommended supply voltage taking into consideration derating of maximum specifications. In the case of alternating current, this is the peak voltage
	LED Input Forward Current	I_F	Recommended LED forward current taking into consideration derating of maximum specifications.
	ON-State Current	I_O	Recommended load current taking into consideration derating of maximum specifications. In the case of alternating current, this is the peak current
	Operating Temperature	T_{opr}	Recommended operating temperature taking into consideration derating of maximum specifications.

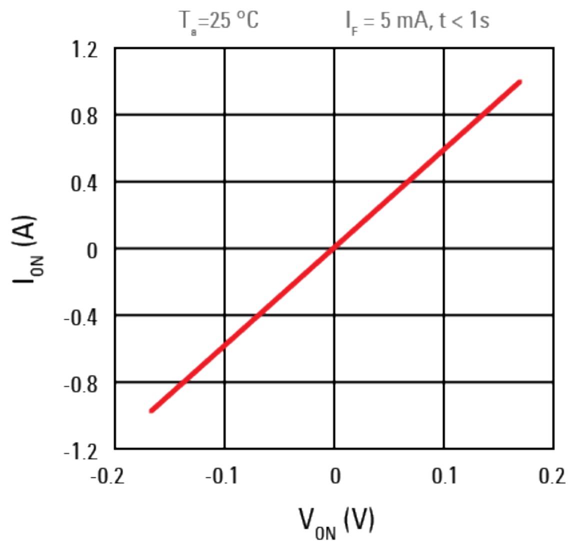
Recommended Operating Conditions: Design guideline to achieve the intended performance of the device. It is necessary to design in detail according to the customers usage conditions.

Terminology 3 (cont'd)

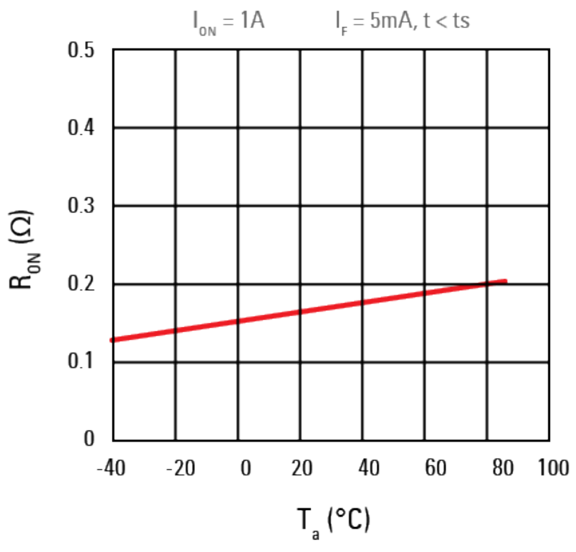
Term		Symbol	Description
Reference Data	MOSFET ON-Voltage	V_{ON}	Voltage level between the output pins when the MOSFET is turned on
	Relative Output Capacitance	$C_{OFF}/C_{OFF}(0V)$	Capacitance of the output pins relative to the capacitance between the output pins at zero volts
Others	Current Limit Function	---	Function whereby the load current is maintained at a certain value between the current limit specification when an overcurrent is detected. This helps to protect the photorelay and the related electronic parts in the circuit from damage.
	Low C×R	---	An indicator for photorelay output characteristics in applications with high frequency or high speed signals. C refers to C_{OFF} – Electrostatic capacitance between the MOSFET's output pins . R refers to R_{ON} - Resistance between the MOSFET's output pins at a specified ON-State rating Large COFF may cause the following phenomena: ・Signal transition may occur even when the relay is OFF (signal leak or lower isolation level) ・Longer output signal rise time (waveform distortion) Large RON contributes to signal transition loss (voltage drop and insertion loss reduction). Therefore in such applications, small COFF and RON, i.e., a low C x R characteristic, is important.

Recommended Operating Conditions: Design guideline to achieve the intended performance of the device. It is necessary to design in detail according to the customers usage conditions.

Key Characteristic: ON Resistance (RON)



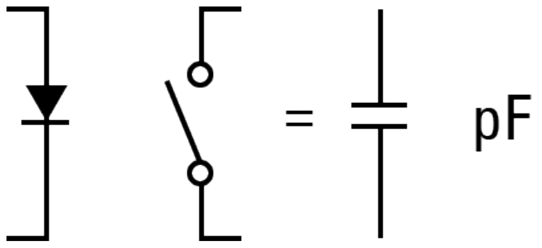
$I_{ON} – V_{ON}$
Diagram 1



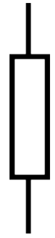
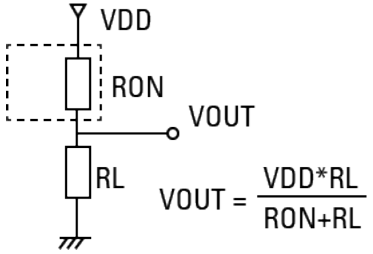
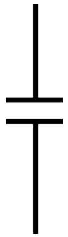
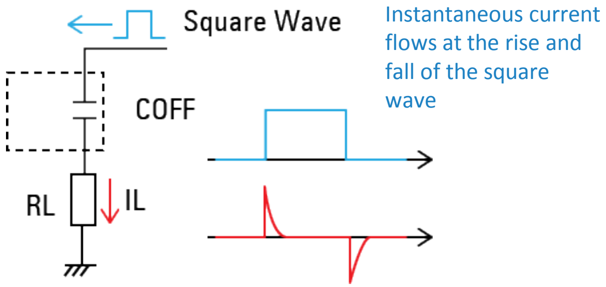
$R_{ON} – T_a$
Diagram 2

- Equivalent to contact resistance of mechanical relays
- I-V characteristic of photorelay output side is *shown*. The steeper the I-V curve, the smaller the RON (Diagram 1)
- RON and VOFF are trade-offs: RON and power consumption increases with higher VOFF and vice versa
- RON changes with ambient temperature (Diagram 2)
- Please take into account sufficient VOFF margin in your design. It is desirable to choose a photorelay with the smallest RON in this VOFF range.
- RON increases with ambient temperature, bringing about increased power consumption
- Heat from the increased power consumption is a cause of chip destruction. Make sure to keep within the maximum current ratings when the photorelay is to be used at high temperatures

Key Characteristic: Output Capacitance (COFF)



Unlike mechanical relays, ON Resistance and OFF capacitance are inherent characteristics of photorelays (semiconductor relays), that requires consideration when designing with photorelays as mechanical relay replacements. The diagram on the right shows the operation example of the part due to on resistance and OFF capacitance.

Mode	Equivalent Circuit	Operation Example
LED : ON	Resistor 	
LED : OFF	Capacitor 	

・Output capacitance is the electrostatic capacitance between the MOSFET output pins when there is no current input to the LED (MOSFET is OFF). In a non conductive state, the AC signal leaks through this capacitance.

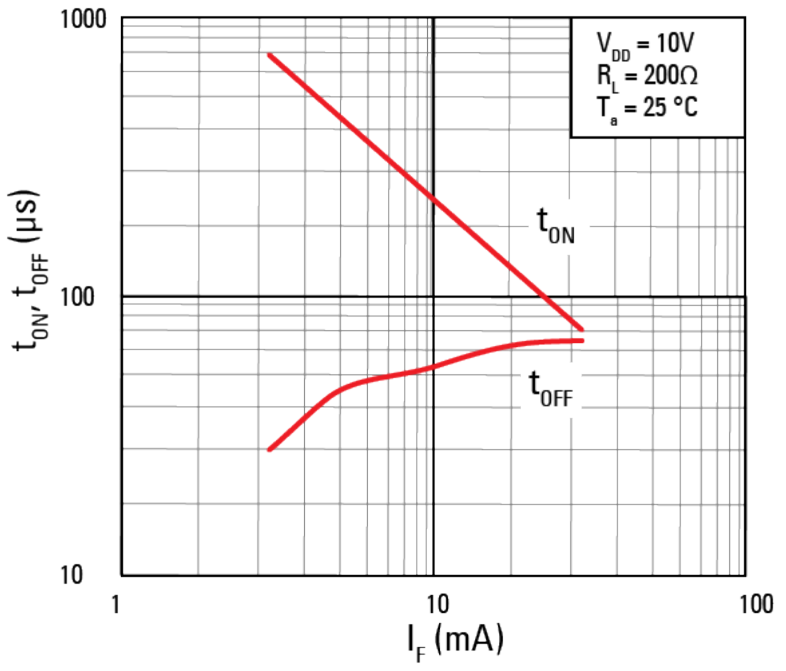
・The resistive flow of current in an AC circuit is known as impedance. In a DC circuit, this is known as resistance. The impedance of electrostatic capacitance becomes smaller with higher frequencies and larger electrostatic capacitance – also to say that current flows more easily.

・When the LED is OFF, it is desirable to have a smaller leak current on the output side. A lower electrostatic capacitance helps in limiting this leak current (especially at high frequencies).

Switching Time （tON/tOFF)

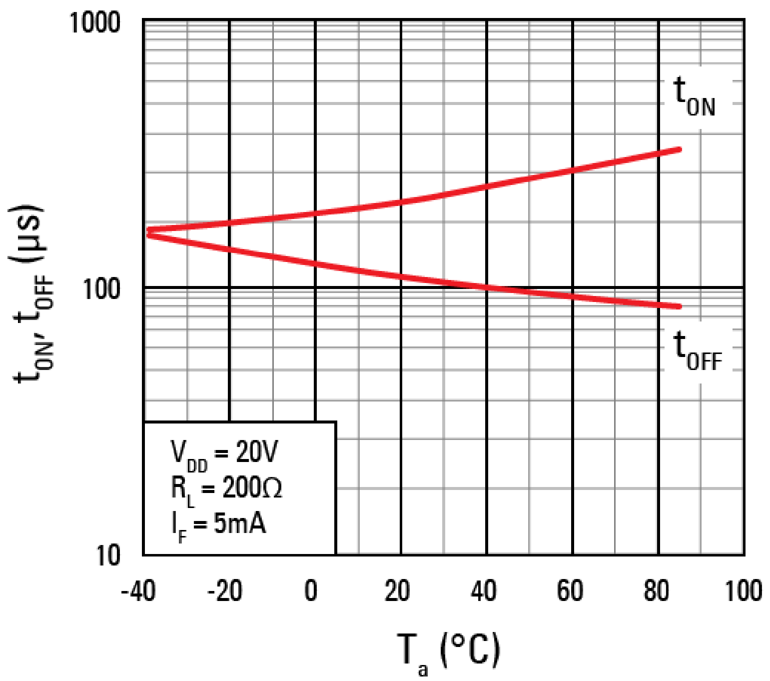
Switching time – LED Input current

Diagram 1



Switching time – Ambient temperature

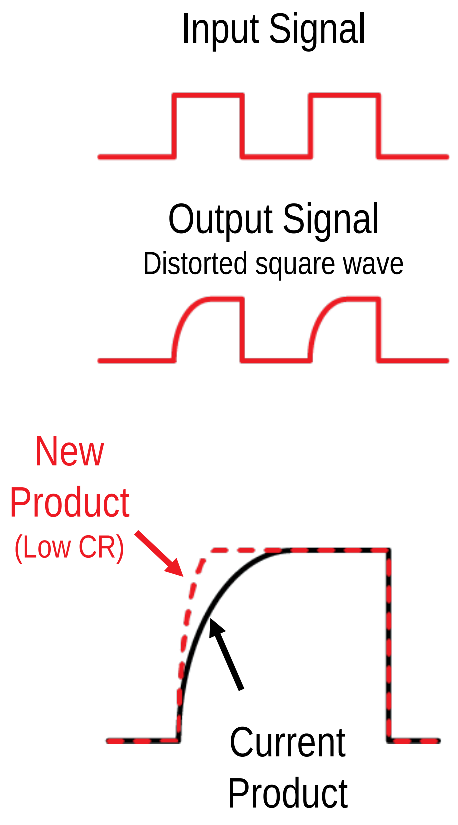
Diagram 2



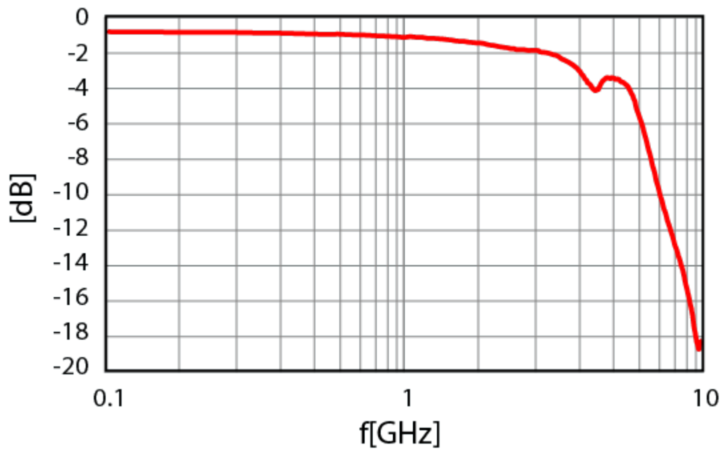
- Switching times for standard products range from 0.2ms ~ 2.0ms, although it may be differ with products.
- Larger input currents imply higher LED emission intensity which brings about faster switching times.
- With higher ambient temperatures, LED emission intensity drops together with PDA capabilities resulting in increased switching times

What is Low C×R?

When semiconductors are used to relay the original input high speed (> Several MHz) square waves, distortion of the wave is observed.

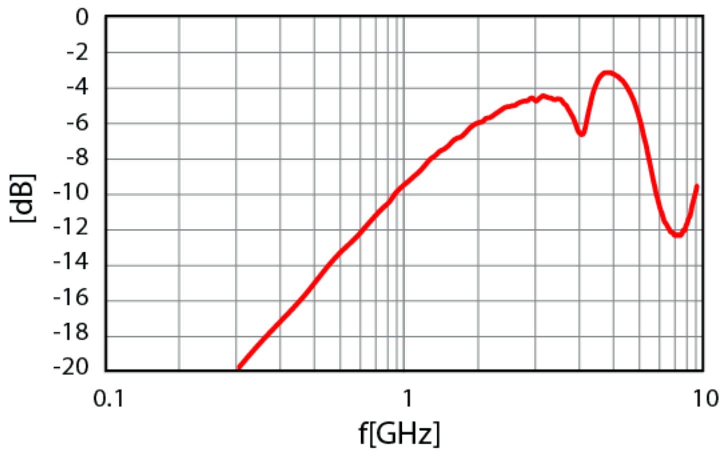


Insertion Loss: LED ON



At high frequencies, impedance from the frame and wires become significant, making it more difficult for the signal to pass

Insertion Loss: LED OFF



At high frequencies, impedance due to the off capacitance is lowered. The signal can be passed easily even in the off-state. Also, C and L also causes resonance

The lower the C×R value, the closer the output is to the original waveform (Better 50Ω matching characteristics） ＝＞ Reed relay replacement possible

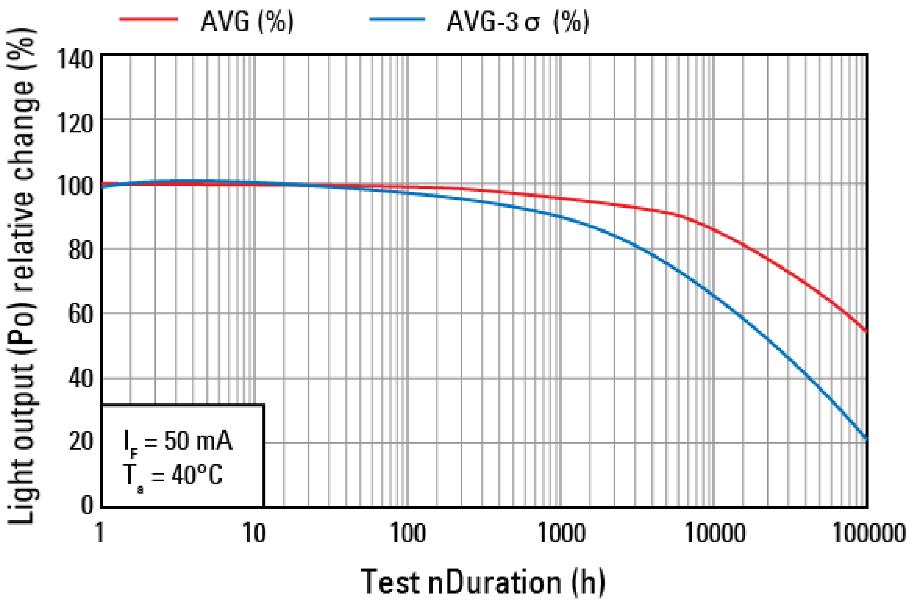
Better high frequency characteristic. More accurate reproduction of test waveforms

LED Life Estimation

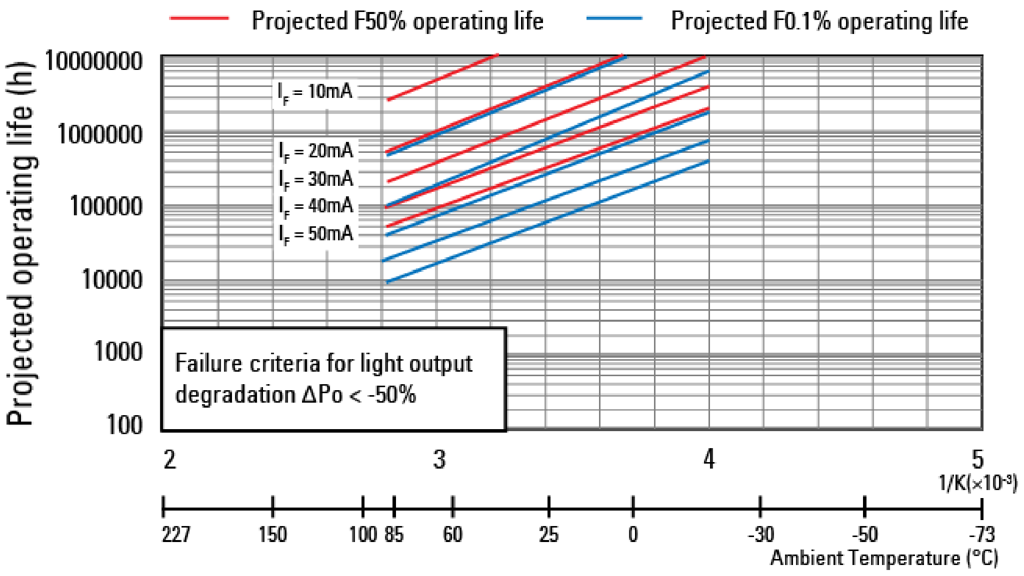
The LED degradation rate changes with the input current and time.
The LED life estimate is based on LED long term data taken from small lots and thus can only be used for reference purposes.

F50% Lifetime: Projected lifetime for 50% of cumulative failures. This is the time period up to where the projected long-term light output degradation curve of the average light output change (AVG) reaches the failure criteria.
F0.1% Lifetime: Projected lifetime for 0.1% of cumulative failures. This is the time period up to where the projected long-term light output degradation curve AVG-3σ reaches the failure criteria.

GaAs LED Projected Light Output Degradation Data
Diagram 1



GaAs LED Projected Operating Life Data
Diagram 2



Toshiba Photorelay Datasheet Example

Max LED Forward Current

Max allowable forward current at 25°C that can be input into the LED without damage.
Please note to design within this spec.

OFF-state output terminal voltage

Max voltage which can be applied between the MOSFETs output pins in the OFF-state. It provides an indication as to the power source used.

Absolute Maximum Ratings (Note) (Unless otherwise specified, T_a = 25 °C)

	Characteristics		Symbol	Note	Rating	Unit
LED	Input forward current		I_F		30	mA
	Input forward current derating	($T_a \geq$ 25 °C)	$\Delta I_F/\Delta T_a$		-0.3	mA/°C
	Input reverse voltage		V_R		5	V
	Junction temperature		T_j		125	°C
Detector	OFF-state output terminal voltage		V_{OFF}		40	V
	ON-state current		I_{ON}		120	mA
	ON-state current derating	($T_a \geq$ 25 °C)	$\Delta I_{ON}/\Delta T_a$		-1.2	mA/°C
	ON-state current (pulsed)	(t = 100 ms, Duty = 1/10)	I_{ONP}		360	mA
	Junction temperature		T_j		125	°C
Common	Storage temperature		T_{stg}		-40 to 125	°C
	Operating temperature		T_{opr}		-40 to 110	
	Lead soldering temperature	(10 s)	T_{sol}		260	
	Isolation voltage	AC, 60 s, R.H. ≤ 60 %	BV_S	(Note 1)	500	Vrms

ON-state current

Max current which can flow between the MOSFETs output pins in the ON-state.
Design for both DC and AC currents are to be kept within this value.
ION(max) changes with ambient temperature.

Isolation Voltage

Resistance between the input and output pins at the specified voltage.
The limit within which isolation breakdown does not occur.

Toshiba Photorelay Datasheet Example

Electrical Characteristics (Unless otherwise specified, T_a = 25 °C)

	Characteristics	Symbol	Note	Test Condition	Min	Typ.	Max	Unit
LED	Input forward voltage	V_F		I_F = 10 mA	1.1	1.27	1.4	V
	Input reverse current	I_R		V_R = 5 V	—	—	10	μA
	Input capacitance	C_t		V = 0 V, f = 1 MHz	—	30	—	pF
Detector	OFF-state current	I_{OFF}		V_{OFF} = 40 V	—	—	1	nA
	Output capacitance	C_{OFF}		V = 0 V, f = 100 MHz, t < 1 s	—	0.45	0.8	pF

Coupled Electrical Characteristics (Unless otherwise specified, T_a = 25 °C)

Characteristics	Symbol	Note	Test Condition	Min	Typ.	Max	Unit
Trigger LED current	I_{FT}		I_{ON} = 100 mA	—	—	3	mA
Return LED current	I_{FC}		I_{OFF} = 10 μA	0.1	—	—	
ON-state resistance	R_{ON}		I_{ON} = 100 mA, I_F = 5 mA, t < 1 s	—	12	14	Ω

Isolation Characteristics (Unless otherwise specified, T_a = 25 °C)

Characteristics	Symbol	Note	Test Condition	Min	Typ.	Max	Unit
Total capacitance (input to output)	C_S	(Note 1)	V_S = 0 V, f = 1 MHz	—	1	—	pF
Isolation resistance	R_S	(Note 1)	V_S = 500 V, R.H. ≤ 60 %	—	10^{14}	—	Ω
Isolation voltage	BV_S	(Note 1)	AC, 60 s	500	—	—	Vrms
			AC, 1 s in oil	—	1000	—	
			DC, 60 s, in oil	—	1000	—	Vdc

Note 1: This device is considered as a two-terminal device: Pins 1 and 2 are shorted together, and pins 3 and 4 are shorted together.

Switching Characteristics (Unless otherwise specified, T_a = 25 °C)

Characteristics	Symbol	Note	Test Condition	Min	Typ.	Max	Unit
Turn-on time	t_{ON}		See Fig. 11.1. R_L = 200 Ω, V_{DD} = 20 V, I_F = 5 mA	—	—	200	μs
Turn-off time	t_{OFF}			—	—	300	

Output Capacitance

Electrostatic capacitance between the MOSFET's output pins (capacitance of the PN junction between the two drains). There is leakage through this "capacitor" when LED is OFF.

Trigger LED Current

Min value of the input current IF necessary to turn the output MOSFET into the ON-state

ON-state Resistance

Resistance between the MOSFET output pins when the MOSFET turns on at a specified input LED current.

Turn-ON Time

Time required for output waveform to drop to 10% upon turning on the LED

Turn-OFF Time

Time required for output waveform to return to 90% upon turning off the LED

4

SELECTION GUIDE

PHOTORELAY AND MECHANICAL RELAY

Photorelay selection guide and points to note (1 of 3)

1

Voltage and Current Maximum Ratings

Unlike mechanical relays where exceeding the maximum ratings may not cause the part to break down immediately, photorelays are susceptible to break down when the rated limits are crossed. Care is to be taken for design within the specified maximum ratings.

2

Lifetime (Reliability)

Cycle lifetime is specified for mechanical relays due to contact wear and tear.
Conversely, since photorelays turn on and off with the respective MOSFET operation, there is no mechanical contact and therefore no need for maintenance unlike mechanical relays. When used within the specified ratings, photorelays provide long lifetimes.

3

Output ON-state - ON Resistance

While mechanical relays hardly have any ON resistance, photorelays have a range of high to low RON products. High capacitance photorelays with lower RON than that of mechanical relays also exist.

Photorelay selection guide and points to note (2 of 3)

4 Output OFF-state

OFF-state output terminal voltage

Complete isolation is achieved in mechanical relays when the connection is open. On the other hand, photorelays are not completely isolated due to the existence of the PN junction. Compared to mechanical relays, the OFF-state terminal voltage is weaker, and therefore it is recommended that a protection diode is added to the circuit.

OFF-state current (leakage)

There is hardly any leakage current in mechanical relays. In photorelays, leakage current flows when voltage is applied on the output side. For applications where leakage is a concern, please consider Toshiba's low leakage (pA order) products.

5 Switching time

Toshiba has photorelays with typical switching times less than 1ms and also high speed photorelays with that of 0.01ms. Unlike mechanical relays, which takes a few milliseconds for signal relay. Also photorelays have no bounce during at operation.

Photorelay selection guide and points to note (3 of 3)

6 Input power consumption

Mechanical relay power consumption, even for low power consumption signal relays, are typically from 100mW onwards. For photorelays trigger currents of about 3mA will operate the MOSFETs. Typically IF is set at around 5mA (below 10mW) is sufficient. There are also products with IFT=0.2mA(max) further lowering the power consumption.

7 Drive current

Mechanical relays cater to DC and AC specifications. Most of the photorelays are for DC drive.

8 Contact Form

Mechanical relays have a range of contact forms (Form a、Form b、Form c) to choose from. Photorelays are typically Form a. (Some products support Form b)

9 Size

Small sized mechanical signal relays takes up 60mm2 area.
Photorelays can achieve considerable space merits with the 2.9mm2（2.0mm × 1.45mm）area, making high density usage possible.

5

DESIGN CONSIDERATIONS

PHOTORELAY FAILURE MODES

IF DESIGN

INPUT SIDE (OVERVOLTAGE/OVERCURRENT)

POINTS TO NOTE FOR INPUT SIDE DESIGN

OUTPUT SIDE (OVERVOLTAGE/OVERCURRENT)

POINTS TO NOTE FOR OUTPUT SIDE DESIGN

Photorelay Failure Modes

Below are the causes for photorelay failures when used beyond the specified voltage and current limits. To prevent the risk of such failures, the section [Design Considerations] has been provided for your reference.

	Factor	Cause	Area of Defect	Phenomena	Cause of Defect	Counter-measure
Detection of defect	Electrical stress	Overvoltage or overcurrent on the input side	Melted wire	Open: IFT does not turn on	1. Load-induced noise in the circuit 2. Surge in the circuit	1. Redesign the protection circuit 2. Surge counter-measures
			LED chip burnout	Open IFT does not turn on	1. Load-induced noise in the circuit 2. Surge in the circuit 3. ESD damage	1. Redesign protection circuit 2. Surge counter-measures 3. ESD counter-measures
			LED chip junction	Short/Leak: IFT does not turn on	1. Load induced noise in the circuit 2. Surge in the circuit 3. ESD damage	1. Redesign protection circuit 2. Surge counter-measures 3. ESD counter-measures
			Package discoloration (from heat)	Short/Leak: IFT does not turn on	1. Overcurrent (higher than specification limit) 2. Overvoltage	Redesign circuit (Resistance/Voltage)
		Overvoltage or overcurrent on the output side	Melted wire	Open: IFT does not turn on	1. Load-induced noise in the circuit 2. Surge in the circuit	1. Redesign protection circuit 2. Surge counter-measure
			MOSFET chip burnout	Open: IFT does not turn on	1. Load induced noise in the circuit 2. Surge in the circuit 3. ESD damage	1. Redesign protection circuit 2. Surge counter-measure 3. ESD counter-measures
			MOSFET chip junction damage	Short/Leak: IFT does not turn on	1. Load induced noise in the circuit 2. Surge in the circuit 3. ESD damage	1. Redesign protection circuit 2. Surge counter-measure 3. ESD counter-measures
			Package discoloration (from heat)	Short/Leak: IFT does not turn on	1. Overcurrent (higher than specification limit) 2. Overvoltage	Redesign circuit (Resistance/Voltage)

IF Design Consideration

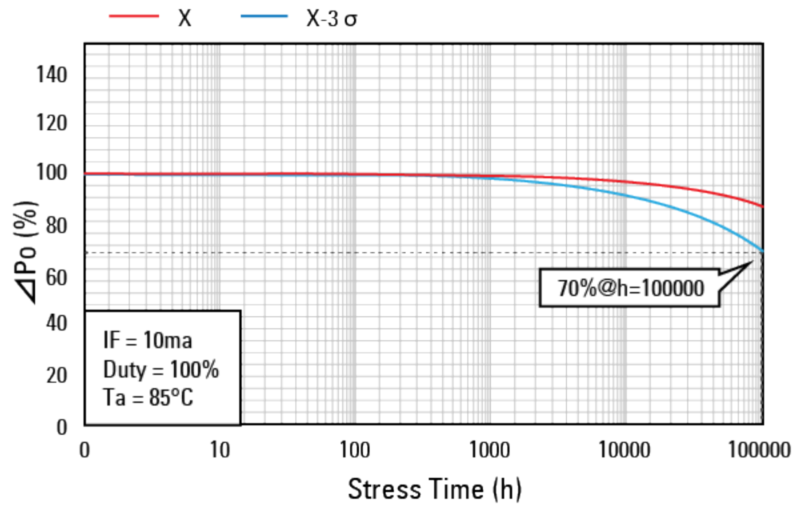
To turn the photorelay ON, the input current (IF) should be designed to be higher than the trigger current (IFT). Based on the maximum trigger current, the design IF should take into consideration factors like in the below reference equation.

Design IF(ON)＝IFT(max.） × α1 × α2 （ × α3)

α1: LED Degradation Rate (Multiplication factor)	Derive α1 from the related (X)―3σ curve (Eg: Diagram 1) The higher the ambient temperature and/or IF value, the greater the degradation rate. Note: LED used changes with product. If required, please contact us for more information.
α2: IFT-Ta Characteristic (Multiplication factor)	Refer to the datasheet for IFT-Ta. Derive α２ (Eg: Diagram 2)
α3: Drive Factor	Power supply fluctuations, tolerance levels

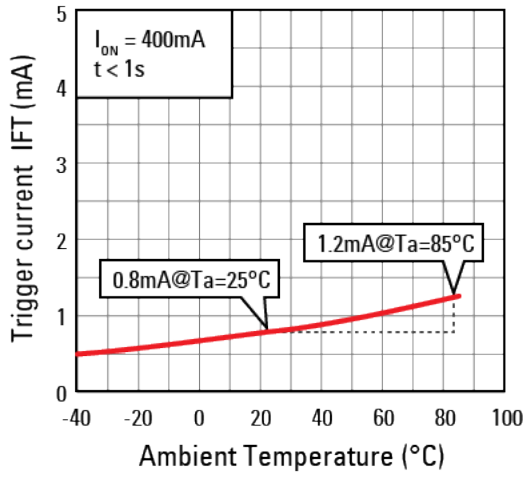
GaAs LED Projected Light Output Degradation Data

Diagram 1



IFT-Ta

Diagram 2

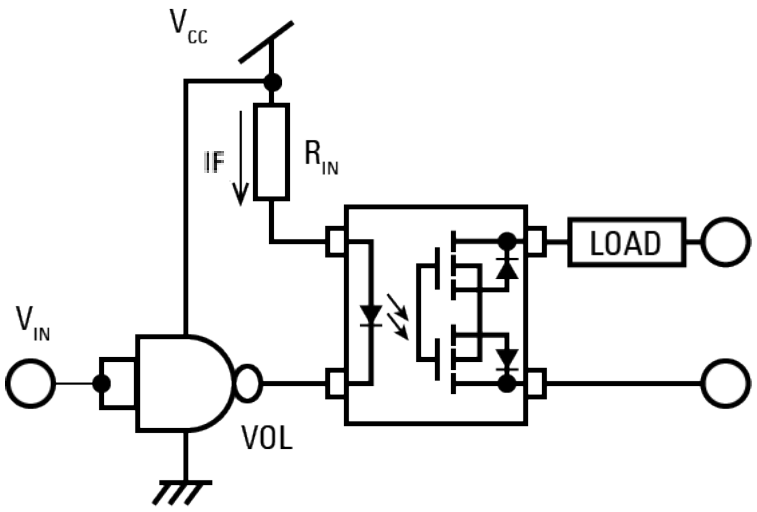


e.g. IFT(max)=3mA. When designing for use in Ta=85℃, with lifetime of 100khrs: DesignIF(ON)＝3mA×1.43×1.5＝6.53mA ← Set IF at above 6.53mA.

IF Design Consideration

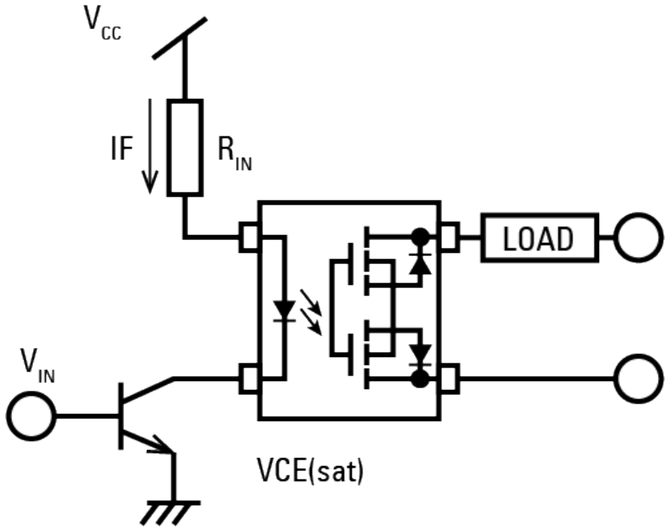
Points to note for Voltage Application (Determining LED limiting resistor value)

We will derive the value of the limiting resistor to be connected in series to the LED, based on the design IF(ON) calculated in the previous page. The voltage drop due to LED input current, temperature dependency (Lower temperature higher VF) and voltage drop of input signal are some of the factors to take into consideration. Please note to design with the respective maximum values in the datasheet, and make sure to design within the specified absolute maximum IF value. Also, check that the power supply (VCC) used is able to support input current larger than the design IF(on) value.



$$R_{IN} \leqq \frac{Vcc(MIN) - VF(MAX) - VOL(MAX)}{\text{Design } IF(ON)}$$

$$^{*}R_{IN} > \frac{Vcc(MAX) - VF(MIN) - VOL}{IF(max)}$$

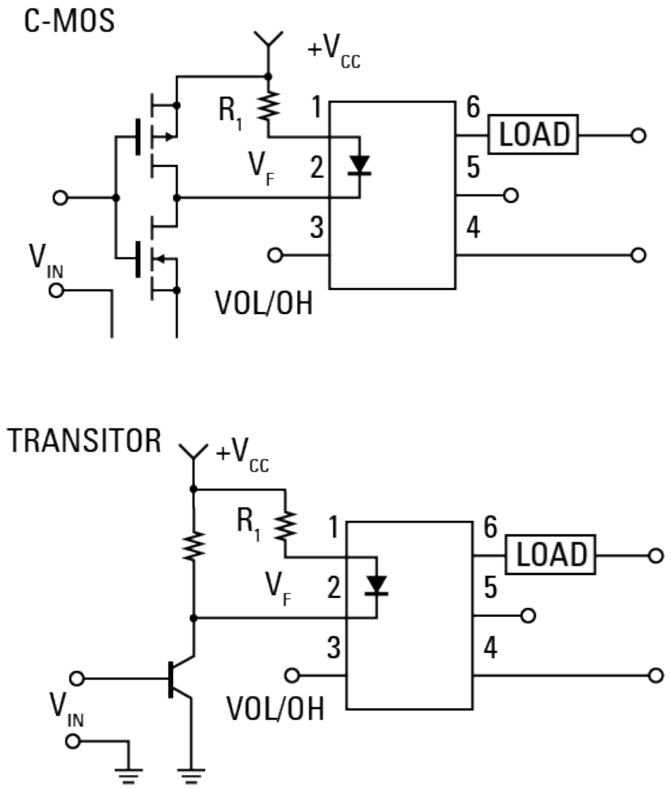


$$R_{IN} \leqq \frac{Vcc(Min) - VF(MAX) - VCE(sat)(MAX)}{\text{Design } IF(ON)}$$

$$^{*}R_{IN} > \frac{Vcc(MAX) - VF(MIN) - VCE(sat)}{IF(max)}$$

Recommended LED Drive Circuit Example

Representative photorelay drive circuit



Calculation of LED current limiting resistor required for proper operation of the photorelay

Current Limiting Resistor

$$R_1 = \frac{V_{CC} - V_{OL} - V_{F(ON)}}{5 - 20mA}$$

Calculation of LED forward voltage VF required for proper return operation of the photorelay

Return Voltage (LED forward direction)

$$V_{F(OFF)} = V_{CC} - I_F R_1 - V_{OH} < 0.8V$$

The above CMOS drive circuit has excellent resistance to noise (when LED is OFF, the top MOS is ON (shorted)). Should noise occur in the transistor drive circuit, connect in parallel to the LED a resistor in the order of several tens of kΩ.

Overvoltage/overcurrent on input side

Input side considerations

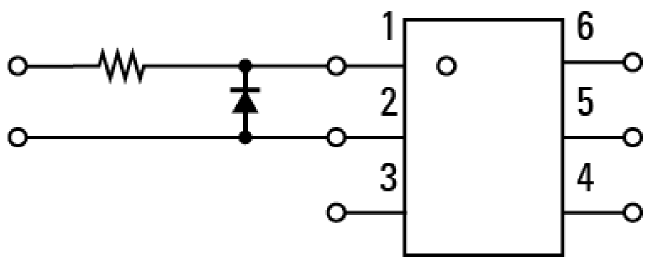
Output abnormality from external surge: Causes

When a reverse voltage greater than that of the rated maximum is applied to the LED

- Shorted input terminals ⇒ LED does not turn on
- Open input terminals ⇒ LED does not turn on

Output abnormality from external surge: Countermeasure

For applications that may have reverse voltage surges on the input side, connect a reverse diode to the input terminals to prevent excess reverse voltages on the LED diode. The representative circuit is shown below.



Surge voltage protection circuit example for input side

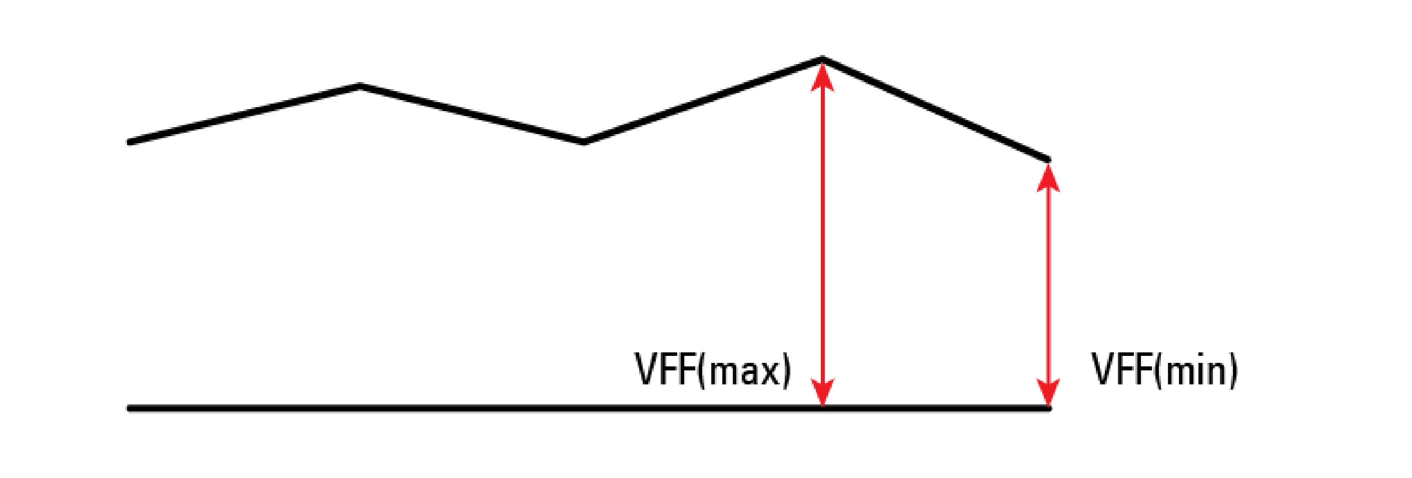
Overvoltage/overcurrent on input side

Input side considerations

Input power source ripple: Causes

When a current greater than that of the rated maximum is applied to the LED

- Shorted input terminals ⇒ LED does not turn on
- Open input terminals ⇒ LED does not turn on



Input power source ripple: Countermeasure

When there is a ripple in the input side power source, please note the following.

- Check and confirm the LED trigger input corresponding to VFF(min.) of LED.
- Do not exceed the max rated current for input current at VFF(max.).

Insufficient input side design consideration

Points to note for input side design

Insufficient input current to trigger on : Causes

The design input current did not take into sufficient consideration changes to the IFT therefore the photorelay ceased to turn on after a period of operation time. It is important to take into consideration changes to IFT with ambient temperature and also LED degradation over time in your design.

Insufficient input current to trigger on: Countermeasure

Please set the appropriate design IF according to the below recommendation (pg 37-38) at the early stages of circuit design.

Pg.37

Pg.38

Insufficient input side design consideration

Points to note for input side design

Design failure Example 1

LED trigger current in the datasheet is 1mA (typical) at ambient temperature T_a = 25°C

Mr. A set the design IF at 1mA. The prototype set worked fine when tested in the lab. (Ambient temperature at the lab is 25°C)

However, the set did not work properly at production..

Trigger LED current (max.) is designed as below.

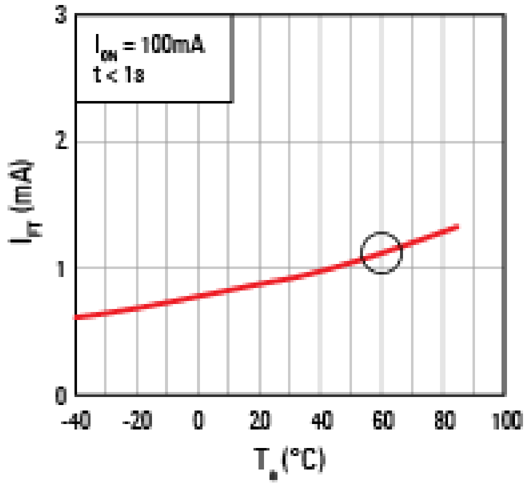
Coupled Electrical Characteristics (Unless otherwise specified, T_a = 25°C)

Characteristics	Symbol		Test Condition	Min	Typ.	Max	Unit
Trigger LED current	I_{FT}		I_{ON} = 500 mA	—	1	3	mA
Return LED current	I_{FC}		I_{OFF} = 100 μA	0.1	0.5	—	mA
ON-state resistance	R_{ON}		I_{ON} = 500 mA, I_F = 5 mA	—	1	2	Ω

Insufficient input side design consideration

Points to note for input side design

Causes 1



IFT increases with higher temperatures. According to the IFT temperature characteristic curve on the left, the design IF of 1mA is less than the IFT required to turn on the part at 60°C. Therefore the photorelay does not turn on at IF=1mA.

Coupled Electrical Characteristics (Unless otherwise specified, T_a = 25°C)

Characteristics	Symbol		Test Condition	Min	Typ.	Max	Unit
Trigger LED current	I_{FT}		I_{ON} = 500 mA	—	1	3	mA
Return LED current	I_{FC}		I_{OFF} = 100 μA	0.1	0.5	—	mA
ON-state resistance	R_{ON}		I_{ON} = 500 mA, I_F = 5 mA	—	1	2	Ω

Ambient temperature around the photorelay at production was at 60°C

Insufficient input side design consideration

Points to note for input side design

Design failure Example 2

LED trigger current in the datasheet is 3mA (max) at ambient temperature Ta=25°C
Mr. A set the design IF at 3mA. The prototype set worked fine when tested in the lab.
However the set did not turn on at the outgoing test after 1000h.

Design without considering LED degradation over time

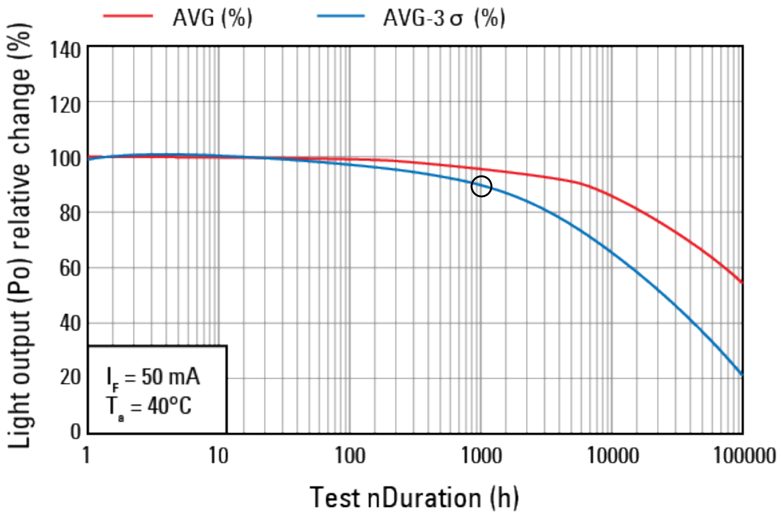
Coupled Electrical Characteristics (Unless otherwise specified, T_a = 25°C)

Characteristics	Symbol		Test Condition	Min	Typ.	Max	Unit
Trigger LED current	I_{FT}		I_{ON} = 500 mA	—	1	3	mA
Return LED current	I_{FC}		I_{OFF} = 100 μA	0.1	0.5	—	mA
ON-state resistance	R_{ON}		I_{ON} = 500 mA, I_F = 5 mA	—	1	2	Ω

Insufficient input side design consideration

Points to note for input side design

Cause 2



Crystal defects increase in the LED as current is being applied. Light output degrades (decreases) with LED operation time. LED light output has dropped by 10% at 1000h and therefore IFT has to be compensated by 10% for operation (IFT=3.3mA).
Since IF3mA＜IFT3.3mA, the set does not turn on.

Light output from LED has decreased with time.

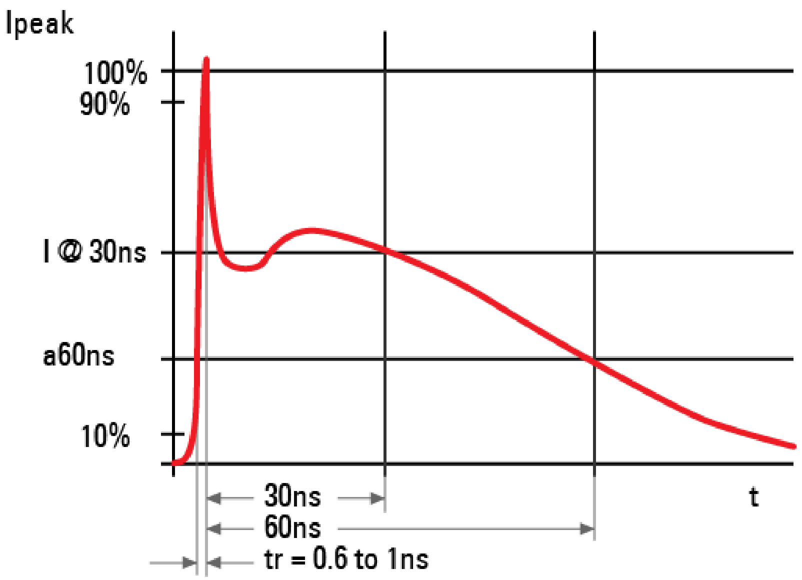
Overvoltage/overcurrent on output side

Output side considerations

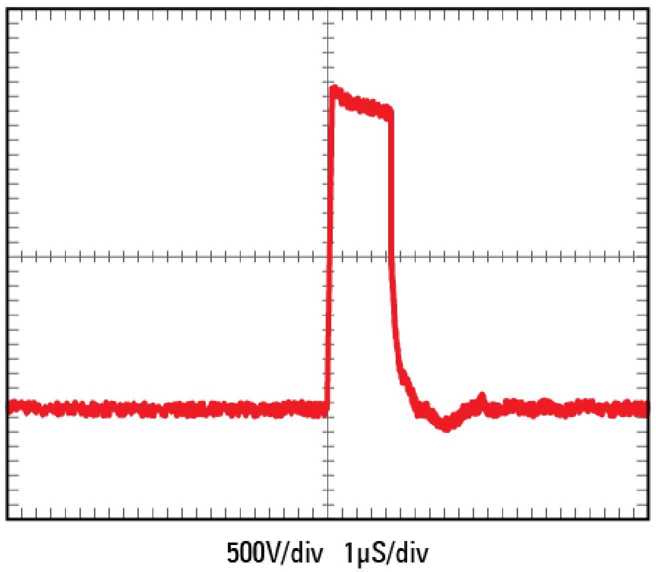
Output abnormality from external surge: Causes

There are cases in the load power supply whereby the induced impulse noise of the power line overlaps with ESD surge etc. causing damage to the photorelay output chip. (short or open)

- Output terminal is short ⇒ Photorelay is ON even when input LED is not.
- Output terminal is open ⇒ Photorelay does not turn ON.



ESD noise waveform example: ns order



Impulse noise waveform example: μs order

Overvoltage/overcurrent on output side

Output side considerations

Output abnormality from external surge: Countermeasure

Add a varistor (variable resistor)

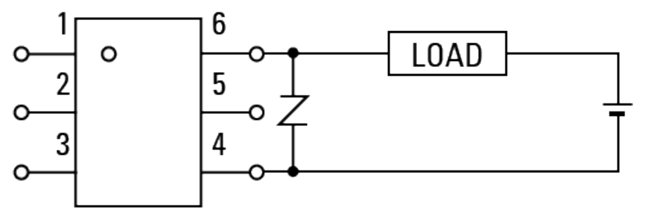
Varistor: Typically (small currents) acts like a condenser, but with high currents from overvoltage acts like a resistor to draw away the short circuit current, thereby protecting the circuit

Selection Guide

Choose a varistor with limiting voltage not more than that of the OFF-state terminal voltage of the photorelay. (Guideline:VOFF×0.7).

- ESD: Stacked type varistor for ESD protection is typically used.
- When used with commercial AC power supply

Power Supply Voltage	Recommended Varistor Rated Voltage	Photorelay V OFF	Surge current tolerance
AC100V line	220～270V	400-600V	Above 1000A
AC200V line	430～470V	600V	Above 1000A

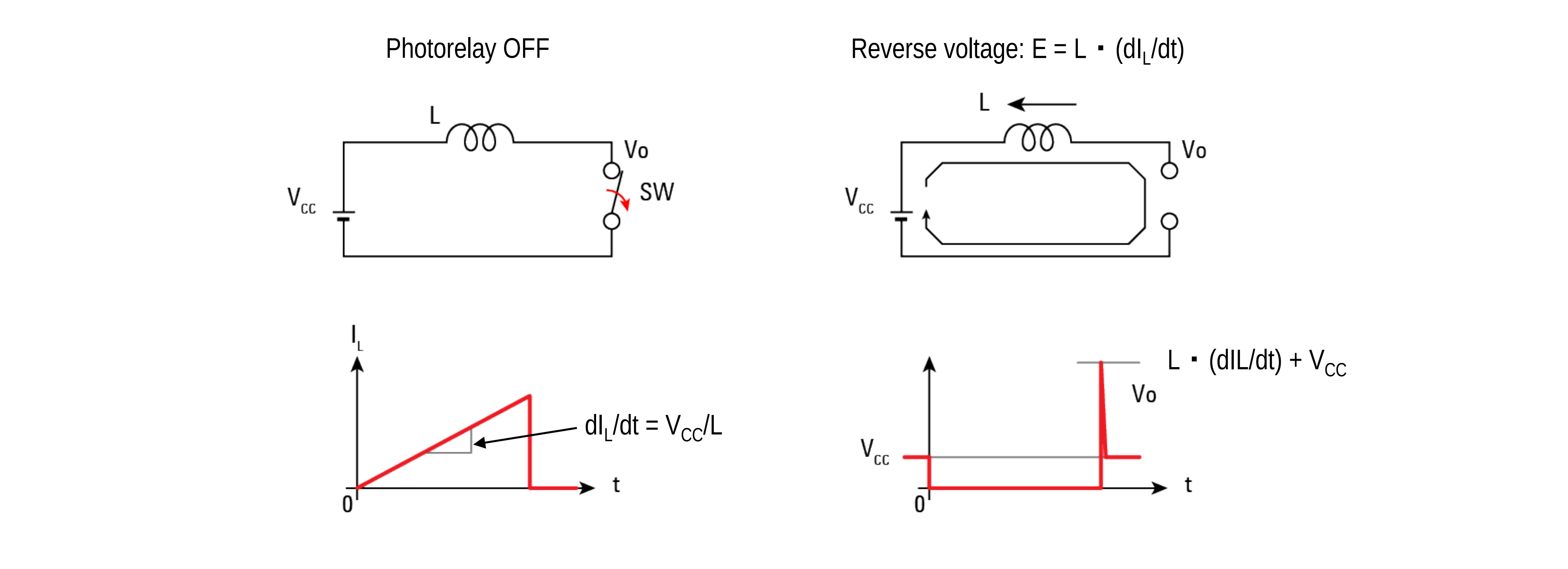


Overvoltage/overcurrent on output side

Output side considerations

Output chip damage from counter voltage : Causes

With inductive loads, impedance current, IL=(Vcc/L)･t1, quickly decreases to zero when the photorelay turns from ON to OFF, inducing high rate of change of current （-dIL/dt). As a result, high counter voltage is induced according to the relationship E=L･(-dIL/dt). When this voltage exceeds the OFF-state terminal voltage of the photorelay, it becomes a cause for output chip damage.

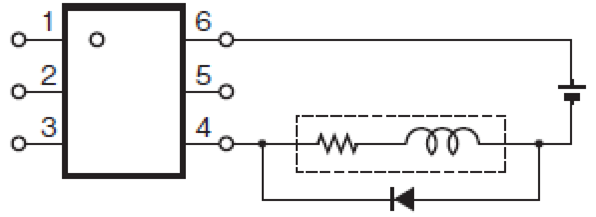


Overvoltage/overcurrent on output side

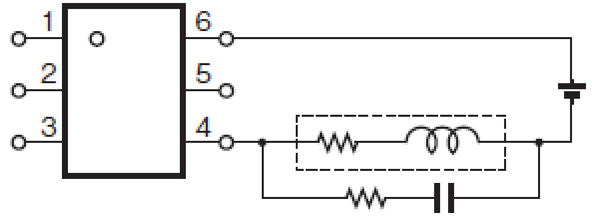
Output side considerations

Output chip damage from counter voltage : Countermeasure

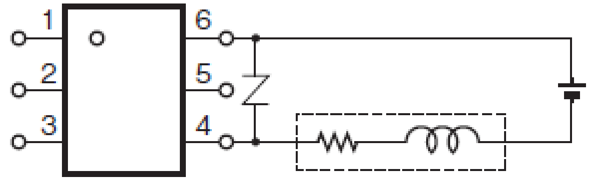
Addition of protection diodes to prevent overvoltages from inductive loads is recommended. The point is to keep overvoltage values within the rated VOFF.



Provide energy path through the diode.



Absorb the energy with a snubber circuit.



Prevent input of overvoltages with a varistor.

Note: When using protection elements such as diodes, snubbers (C-R), varistors etc., it is necessary to place them close to the load and/or photorelay or the effect will diminish. As a guideline, consider distances within 50cm.

Overvoltage/overcurrent on output side

Output side considerations

Output chip damage from inrush current : Causes

In-rush current occurs when power is supplied to the load controlled by the photorelay. Depending on the type of load, the magnitude of the in-rush current changes. The below explains the characteristics of the various types of loads.

1. Heater Loads (Resistive load)

   Typically no in-rush current. However, there are some heaters with changing resistance as temperature changes. For such heaters, in-rush current occurs due to the low resistance at room temperature. When this in-rush current exceeds the rated current for photorelay pulse ON, it may cause output chip damage.

   Heater types with in-rush currents

   - Pure metal type heater (3~5 times of rated current)
   - Ceramic type heater (3~5 times of rated current)
   - Lamp heater (10~15 times of rated current)

2. Lamp Loads

   Incandescent light bulb ・ halogen lamp (including lamp heater etc.) produces in-rush current of around 10~15 times that of rated current. It is a cause of output chip damage when this in-rush current exceeds the photorelay rated pulse current repeatedly.

Overvoltage/overcurrent on output side

Output side considerations

Output chip damage from inrush current : Causes

3. Motor Loads

When inductive loads from the motor starts, in-rush current of around 5~10 times of the rated current flows. It is a cause of output chip damage when this in-rush current exceeds the photorelay rated pulse current repeatedly.

4. Transformer Loads

When power is supplied on the input side of a transformer, excitation current about 10~20 times that of the photorelay rated current flows within a short duration of 10~500ms. When excitation current exceeds the photorelay rated ON current repeatedly, it is a cause for chip damage.

** Pulse ON current condition: t=100ms、 Duty=1/10*

Overvoltage/overcurrent on output side

Output side considerations

Output chip damage from inrush current : Countermeasure

When selecting photorelays, confirm the in-rush currents required in the application. Make sure to choose photorelays with pulse ON current ratings higher the required in-rush currents.

Detector	OFF-state output terminal voltage	V_{OFF}	60	V
	ON-state current (A connection)	I_{ON}	5	A
	ON-state current (B connection)		5	
	ON-state current (C connection)	I_{ON}	10	
	ON-state current derating (A connection)	$\Delta I_{ON}/\Delta T_a$	-50	mA/°C
	ON-state current derating (B connection)		-50	
	ON-state current derating (C connection)	ΔION/ΔTa	-100	
	ON-state current (pulsed)	I_{ONP}	15	A

Insufficient output side design consideration

Points to note for output side design

Design failure Example 1

From the datasheet, absolute max rating of ON Current is 500mA.
Mr. A took a 20% margin into account and designed the circuit at 400mA. The prototype worked in the lab (set at 25℃ ambient).
However the set did not work at production.

Not aware of the temperature dependency of ON Current (ION)

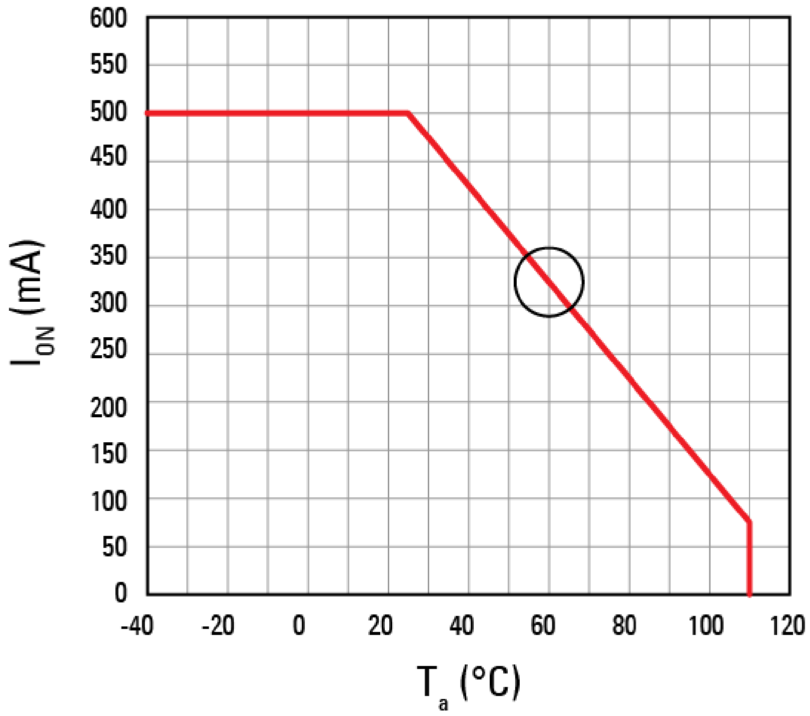
Absolute Maximum Ratings (Unless otherwise specified, T_a = 25°C)

	Characteristics		Symbol	Note	Rating	Unit
LED	Input forward current		I_F		30	mA
	Input forward current derating	($T_a \geq$ 25 °C)	$\Delta I_F/\Delta T_a$		-0.3	mA/°C
	Input forward current (pulsed)	(100 μs pulse, 100 pps)	I_{FP}		1	A
	Input reverse voltage		V_R		6	V
	Input power dissipation		P_D		50	mW
	Junction temperature		T_j		125	°C
Detector	OFF-state output terminal voltage		V_{OFF}		60	V
	ON-state current		I_{ON}		500	mA
	ON-state current derating	($T_a \geq$ 25 °C)	$\Delta I_{ON}/\Delta T_a$		-5.0	mA/°C
	ON-state current (pulsed)	(t = 100 ms, Duty = 1/10)	I_{ONP}		1.5	A
	Output power dissipation		P_O		300	mW
	Junction temperature		T_j		125	°C

Insufficient output side design consideration

Points to note for output side design

Cause 1



As a semiconductor, there is a need to derate the photorelay ON current according to the temperature conditions.

From the curve on the left, the difference in ON current at 60℃ and 25℃ is:

500mA-(5mA×(60℃-25℃)) = 325mA

Which is smaller than the specified ION maximum value on the datasheet.

The designed 400mA exceeds the allowable maximum ION for this application scenario. Overheating from the excess current caused the MOSFET to break down.

At production, the temperature around the area of the photorelay rose to 60℃

6

TOSHIBA PHOTORELAY LINE-UP

High Current Photorelay Line-up

For the full line up of photorelays, please refer to the photorelay webpage here.

A parametric search function is also available here.

Current Products

※New products

PKG	20V	30V/40V	60V	80V/100V	200V	400V/600V
S-VSON4		TLP3406S 30V/1.5A				
VSON4	TLP3403 20V/1A					
2.54SOP4		TLP3123 40V/1A	TLP3122/TLP3127 60V/1A/1.7A			
		TLP3146 30V/3.3A In production	**TLP3147** 60V/2.5A In production	**TLP3149** 100V/1.5A In production	**TLP3145** 200V/0.5A In production	
4pin SO6			**TLP3122A** 60V/1.4A In production			
2.54SOP6	TLP3100 20V/2.5A	TLP3102 40V/2.5A	TLP3103 60V/2.3A	TLP3105 100V/1.4A		
		TLP3106 30V/4A	TLP3107 60V/3.3A	TLP3109 100V/2A		
DIP4	TLP3553 20V/3A	TLP3554/TLP241A 40V/2.5A/2A	TLP3555 60V/2A	TLP3556 100V/1A		
	TLP3553A 30V/3.5A In production		**TLP3555A** 60V/2.5A In production	**TLP3556A** 100V/1.5A In production	**TLP3558A** 200V/0.7A In production	
DIP6	TLP3543 20V/4A	TLP3544 40V/3.5A	TLP3542/TLP3545 60V/2.5A/3A	TLP3546 100V/2A		
	TLP3543A 30V/5A In production		**TLP3545A** 60V/4A In production	**TLP3546A** 100V/2.5A In production		
DIP8			**TLP3547** 60V/5A	**TLP3823** 100V/3A In production	**TLP3825** 200V/1.5A In production	**TLP3548/TLP3549** 400V/0.4A 600V/0.6A

※Line up is as of June/2018. You can find the latest line-up from Toshiba webpage.

7

APPLICATION EXAMPLES

HVAC(Including thermostat)

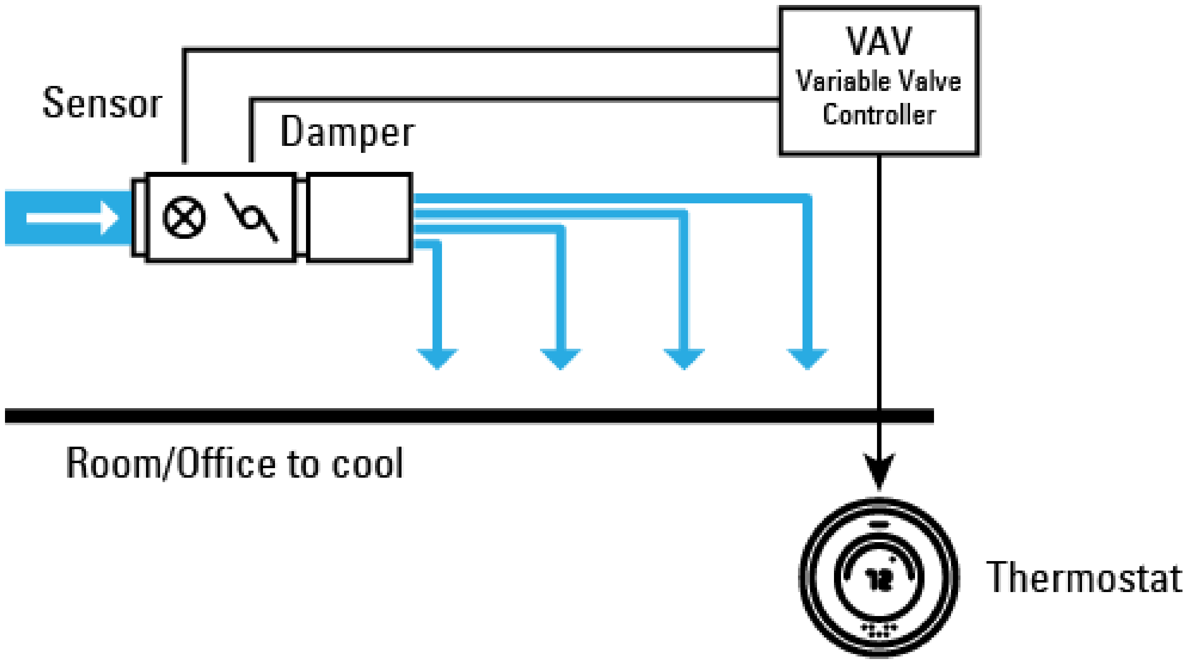
HVAC （Heating Ventilation and Air Conditioning)

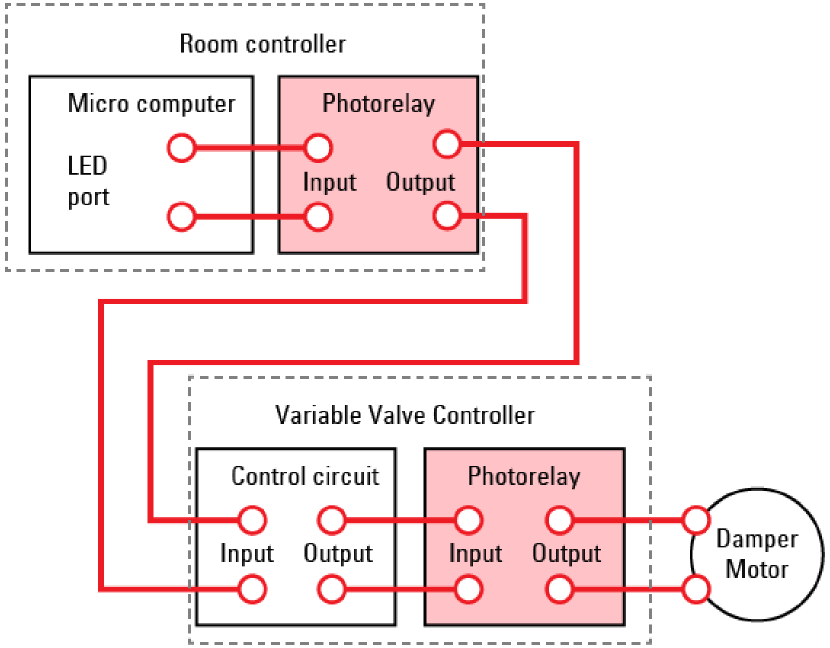
Function of relay

Photorelays are used for signal transmission from the thermostat to heating, ventilation (damper motor in VAV) and air conditioning control equipment in building automation. Conventionally, mechanical relays are used, but these can be replaced with high capacity photorelays.

Merits of Photorelays

- No noise
- Long life
- High capacity





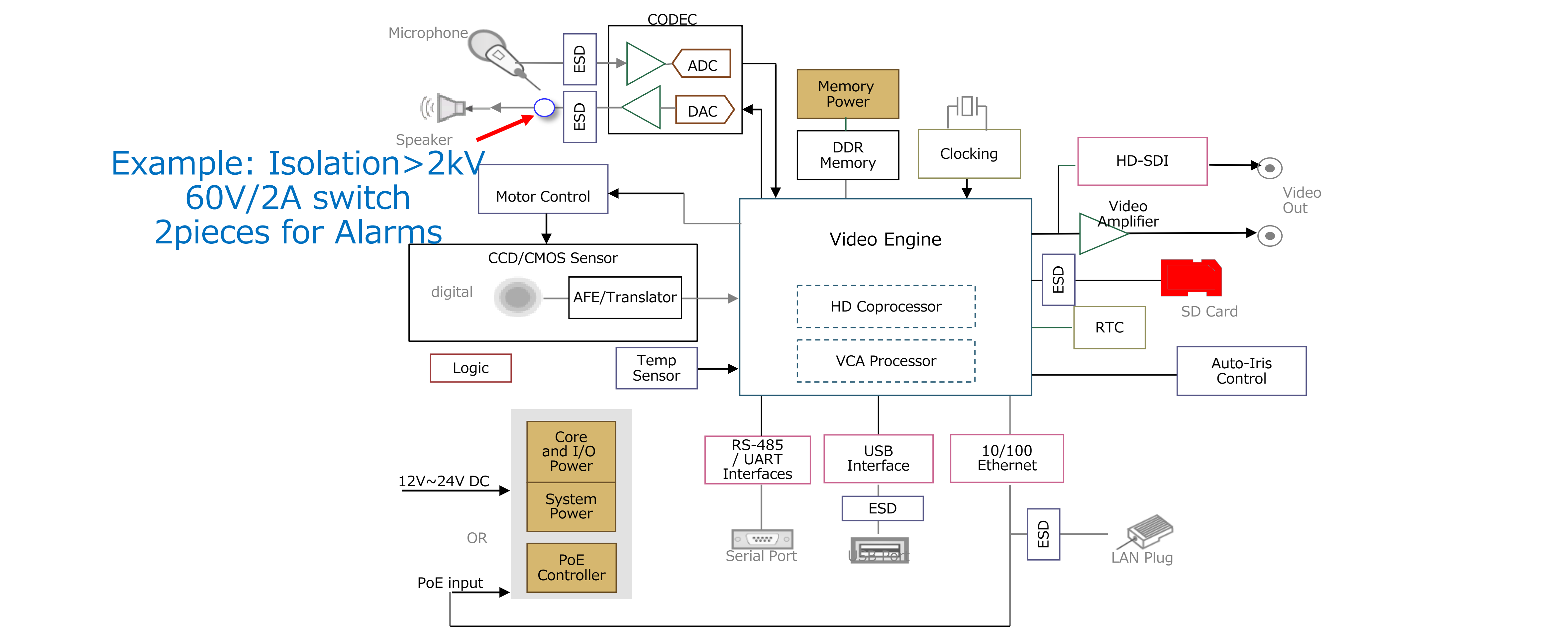
Surveillance camera application

Function of relay

Photorelay is used as a switch for the output of light and sound of the camera set

Merits of Photorelays

- No noise
- Long life
- Small size



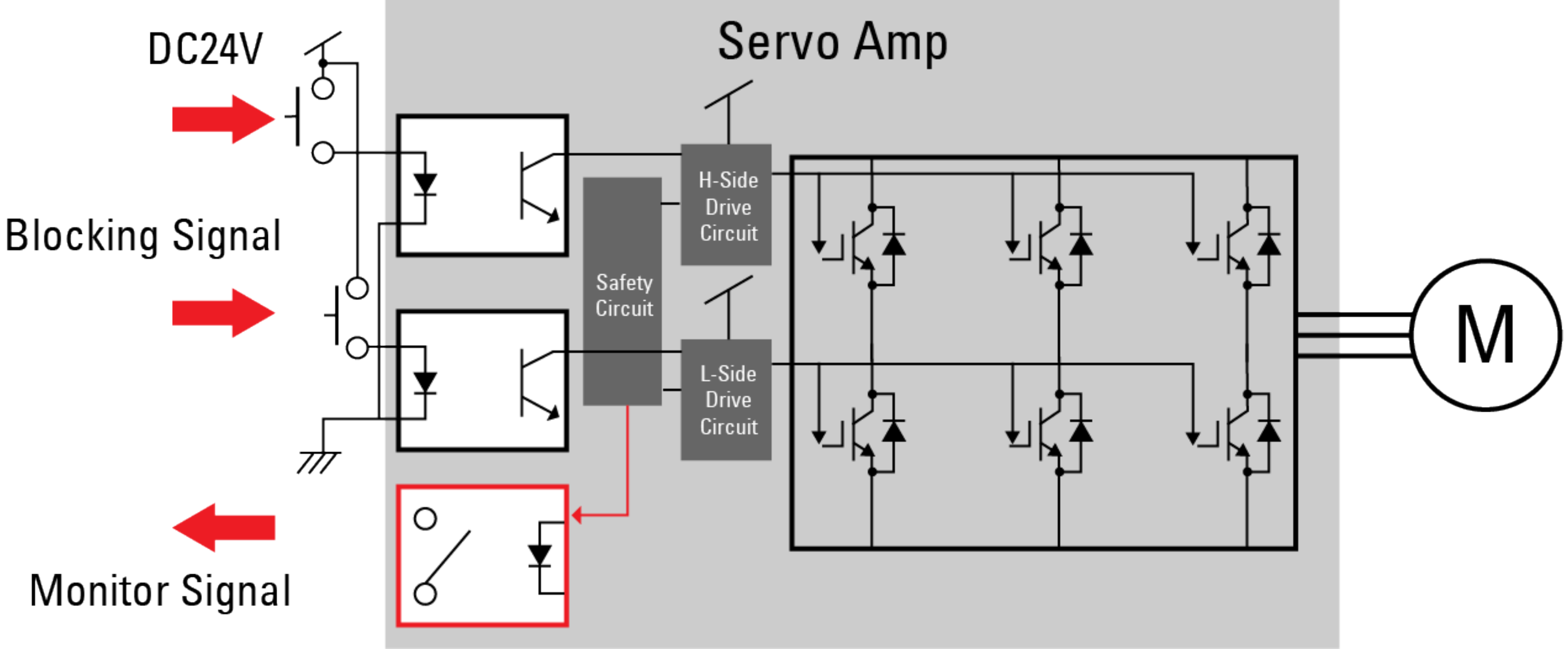
FA with STO function

Function of relay

The safe torque off function is a safety function. In the event of anomaly (indicated by a safety signal input), drive signal to the servo amplifier shuts down, which in turn stops the motor torque. Photorelays are used to transmit monitor signals to controls, such as PLCs, in the safety circuit of the servo amplifier.

Merits of Photorelays

- Small Size
- High Speed



Use servo amplifier, CNC, Robot etc.

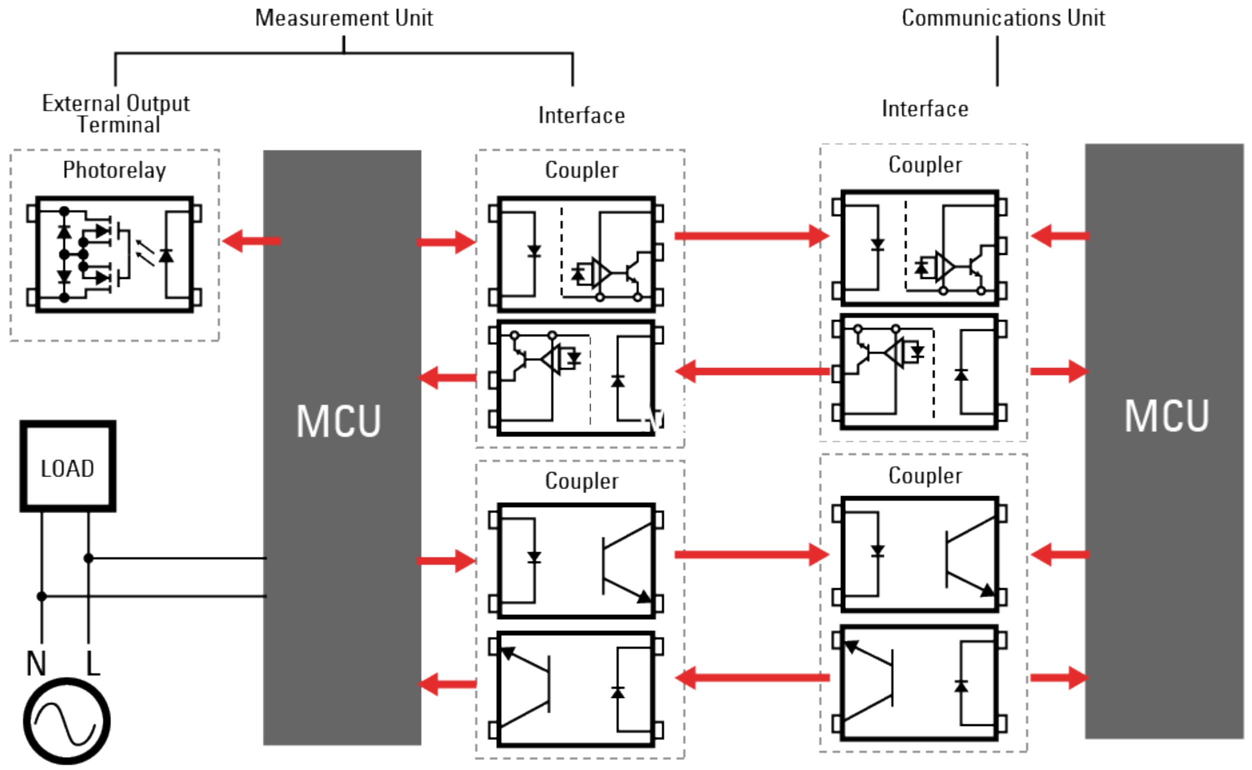
E-meter ・ Smart meter

Function of relay

Photorelays are used as contact output for external communication.

Merits of Photorelays

- High withstand voltage
- Reinforced insulation
- Long life



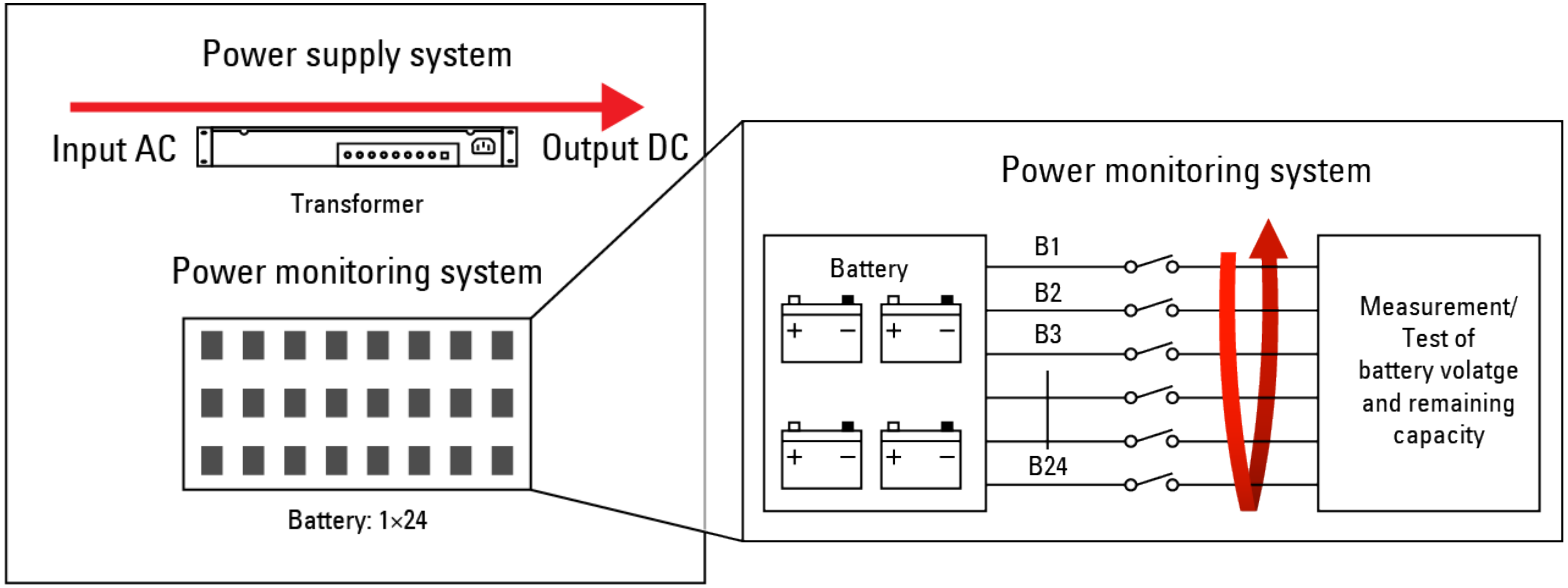
Power monitoring system(BMS etc.)

Function of relay

Photorelays are in the power monitoring circuit of battery cells. The relay is expected to make many contacts and photorelays are highly recommended as they have no contact life (long life).

Merits of Photorelays

- Small size
- Long life
- High withstand voltage



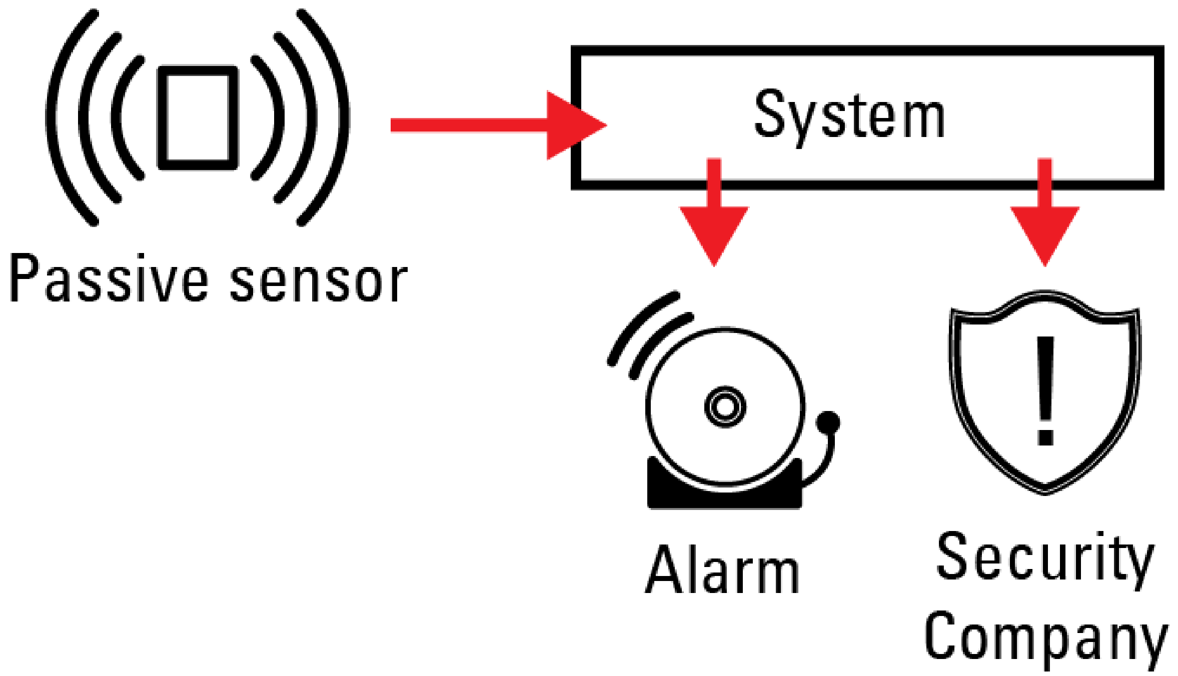
Security (e.g. Passive sensors)

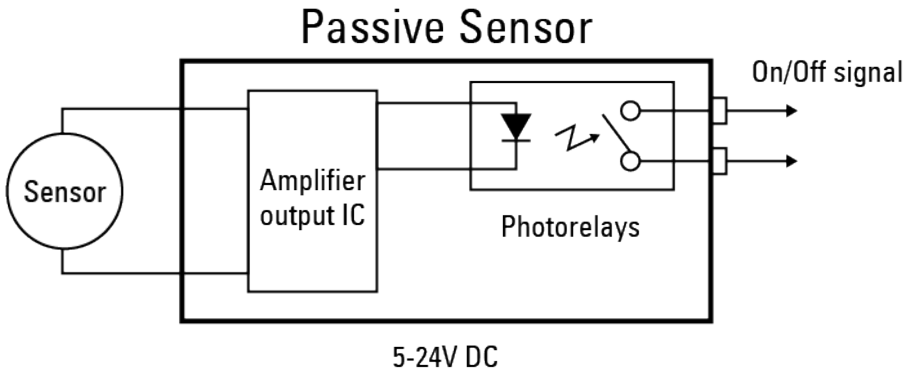
Function of relay

When a suspicious activity is detected by the passive security sensor, the photorelay transmits this information to the reporting terminal.

Merits of Photorelays

- Small size
- Low power consumption
- High capacity





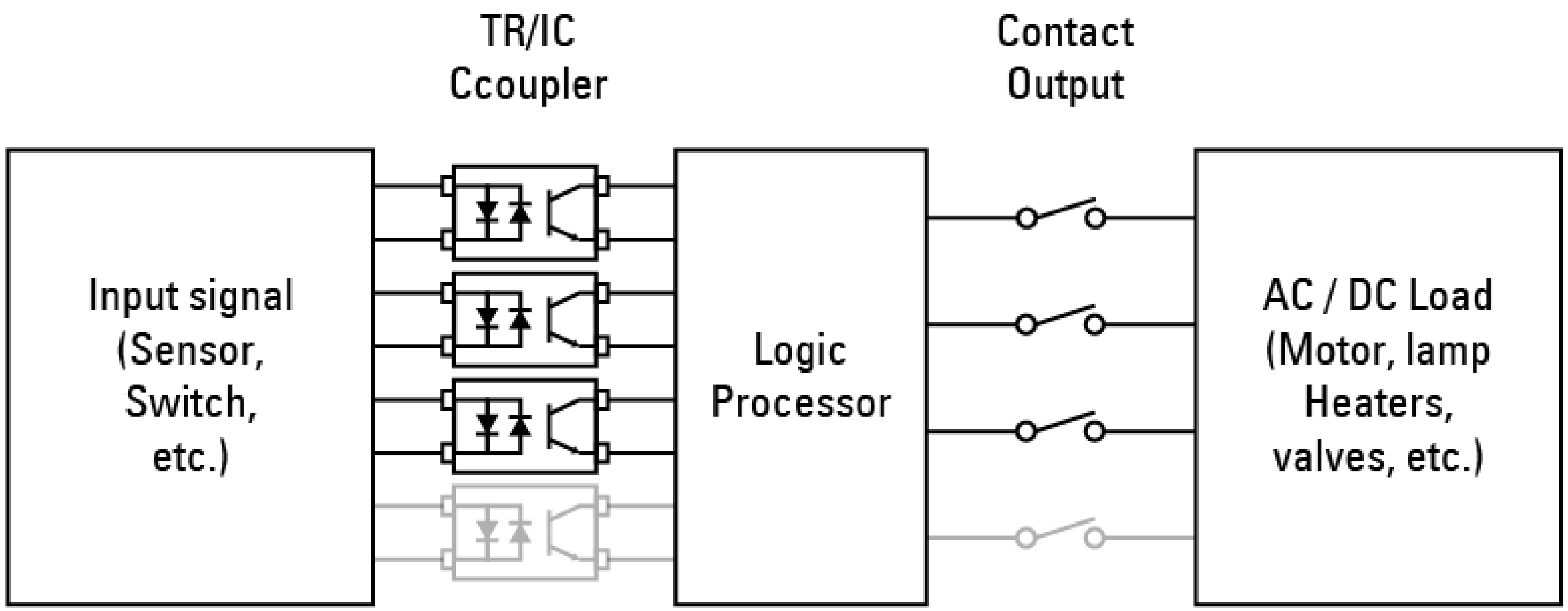
PLC (Programmable logic controller)

Function of relay

A mechanical relay is traditionally used as the contact output of the PLC output stage. However, semiconductor relays (photorelays, PDA couplers + MOSFETs) have become the common choice due to their superior reliability.

Merits of Photorelays

- High reliability
- Small size
- High capacity



Restrictions on Product Use