Applications of photorelays to FA equipment

Overview

Compared with mechanical relays, photorelays are superior in terms of long life, low current drive, and high-speed response of contacts, and are increasingly being installed in FA equipment.

This document introduces examples of photorelay applications in FA equipment and describes precautions when using photorelays.

Table of cntents

1. Introduction

FA equipment used in various production sites and processes is evolving to meet a variety of needs, including improved facility availability and production efficiency, higher precision, improved safety, and energy conservation.

Specifically, in order to rationalize preventative maintenance from monitoring and analysis of operating conditions, and to respond to predictive maintenance, we are improving functions such as strengthened coordination between instrumentation and control and equipment, and maintenance-free.

This application note introduces the case of output terminals for equipment I/O and the case of analog signal measurement functions as examples of photorelay applications that contribute to the improvement of these functions.

A brief introduction to the photorelay is given in front of this manual.
Photorelay is a type of solid-state relay that uses MOSFET for its contacts (switches). It is also known as a photo-MOS relay or a MOSFET relay.

A photorelay consists of an LED that converts an electrical signal for controlling a contact into an optical signal, a photodiode array (hereinafter referred to as PDA) that converts an optical signal into an electrical signal, and a MOSFET that performs a contact function.

The operation of the photorelay is as follows (Fig. 1):
(1) To drive the contacts, apply current to the LEDs. The LED emits light and an optical signal is generated.
(2) The optical signal is converted into an electric signal by the PDA on the contact side, and an electric signal is input to the control terminals (gates) of MOSFETs.
(3) When an electric signal is input to the gate, MOSFETs turns ON and the contact is connected.

Since the contact part is a semiconductor element, there is no mechanical wear, and even if it is opened and closed repeatedly, there is no deterioration of the contact.

In order to obtain the electromagnetic force to move the contact, the mechanical relay requires that a current of about tens of mA flow through the control coil.

In contrast, photorelays can operate MOSFETs with LED currents as small as a few milliamperes. Therefore, it has features of long life, low drive input and high-speed response compared with conventional mechanical relays.

Semiconductor relays use triacs with similar features, but photorelay with MOSFET has the advantage of being able to control not only alternating current signals but also direct current signals with lower leakage currents.

The basics of photorelays and precautions for their use are described in our application note "How to replace mechanical relays with photorelays". Please also refer to this.

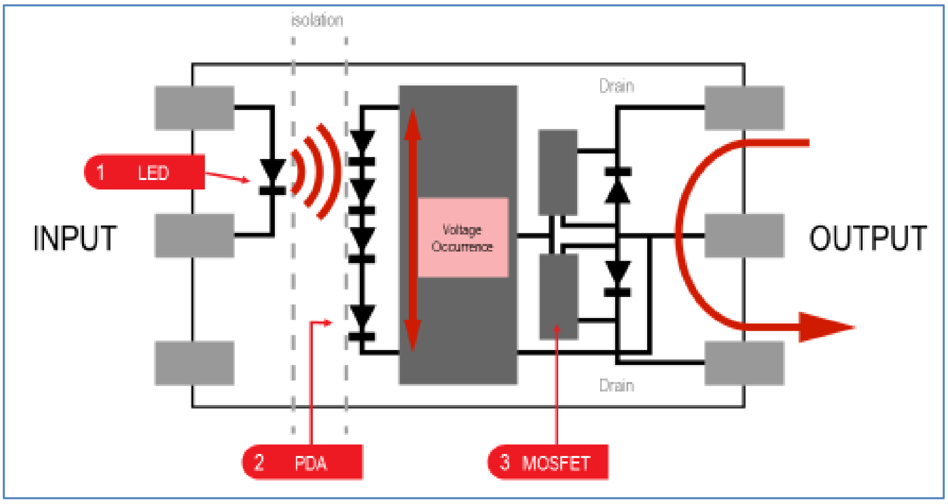

Fig. 1 Principle of photorelay operation

2. Output Terminals (I/O), Alarm output applications

In addition to the contact output units of programmable logic controllers (PLCs), general-purpose inverters, servo amplifiers, various sensors, measuring and weighing equipment are increasingly equipped with output terminals that control external devices and loads (Fig. 2(a), (b)).

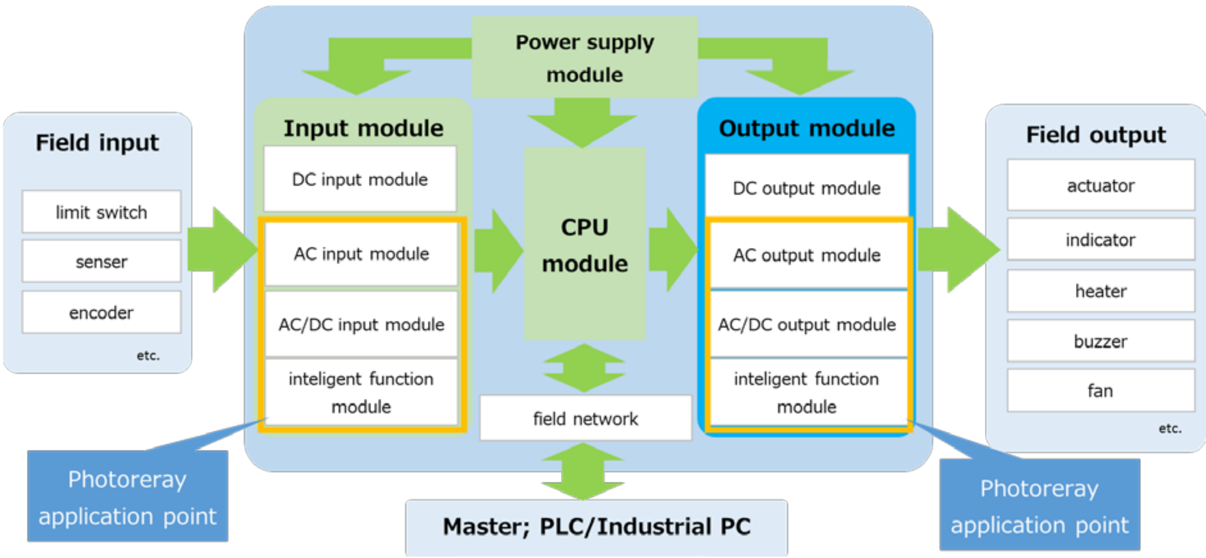

Fig. 2(a) PLC Function Block Diagram
(Photorelay Application Point Image)

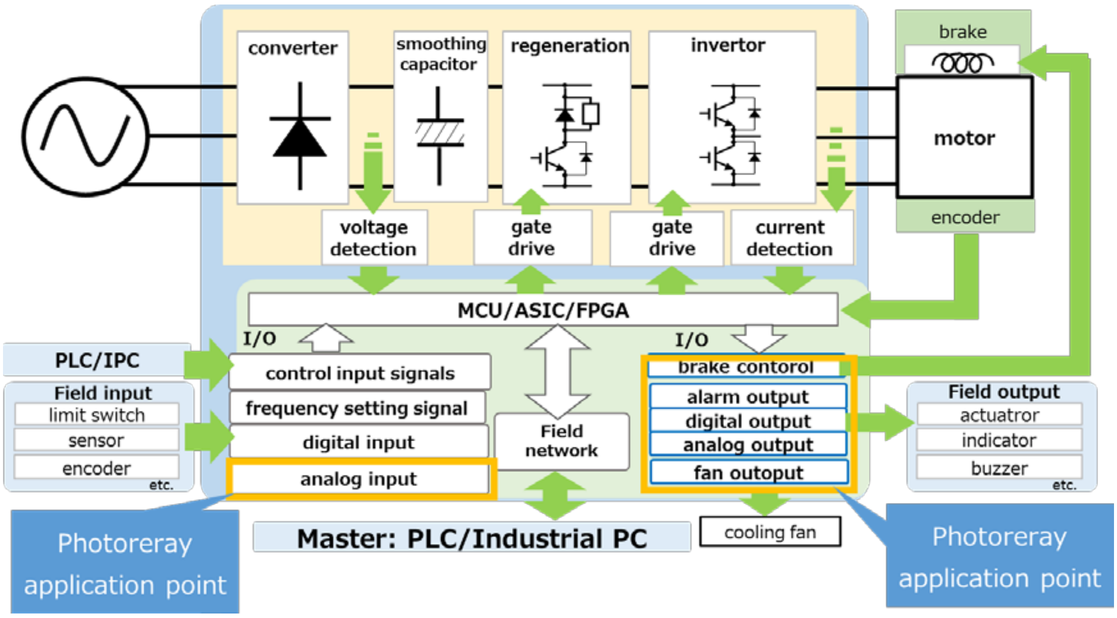

Fig. 2(b) Servo Amplifier Function Block Diagram
(Photo Relay Application Point Image)

2.1 Types of output terminals

Typical output pin types are shown below.

1) Transistor/MOSFET outputs (sink type, source type)... Control of DC-load, responsiveness of 1 ms or so
2) CMOS high-speed output... Equipment control signal (serial communication, analog (PWM) signal, etc.), response of 1 μs or so
3) Triac output: Control of AC (alternating current) load, response of about 10 ms
4) Contact output (mechanical relay)... Control of DC/AC load, response of about 5 to 10 ms
5) Contact output (photo relay)... Control of DC/AC load, response of about 0.5 to 5 ms

This section describes the advantages of replace 1) transistor/ MOSFET output, 4) contact output (mechanical relay) with 5) contact output (photorelay).

2.2 Application example of photorelay to transistor output terminal

Photorelays have mainly been used to solve mechanical relay problems, but in recent years, photorelays have also been applied to eliminate the disadvantages of transistor and MOSFET outputs.

The transistor and MOSFET outputs are used to output signals to weak electrical equipment ranging from 12 to 48 VDC.
There are two ways to connect the power supply and load: a sink type in which current flows from the load to the output terminal when the output transistor is turned on, and a source type in which current flows from the output terminal to the load (Fig. 2.2.1(a), (b)).

In sink type, if the wiring connected to the equipment output terminal is grounded, load current flows regardless of the status of the output terminal. In contrast, the source type is preferred in European countries because it is highly safe because it is open to ground fault accidents.

In this way, the sink type and source type can be used according to the user's design philosophy. However, since the wiring is different from each other, the assembly of the source type and sink type must be changed according to the destination, and the contact must be changed manually by attaching a switch on the board (Fig. 2.2.2(a) and (b)).

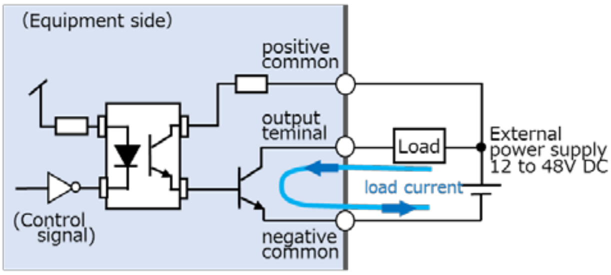

Fig. 2.2.1(a) Transistor output sink type

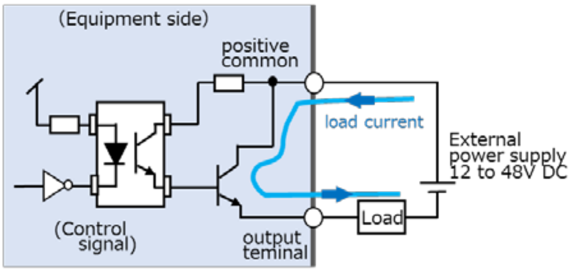

Fig. 2.2.1(b) Transistor output source type

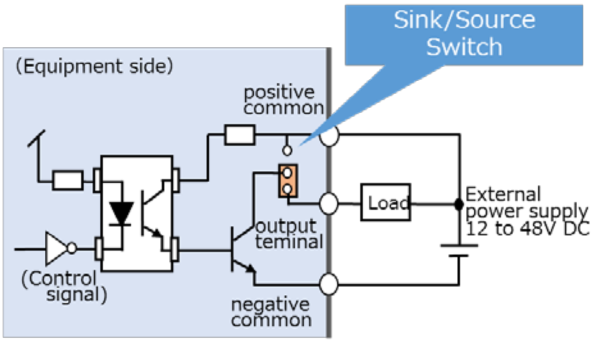

Fig. 2.2.2(a) Example of Transistor Output and Common Board Sink Type

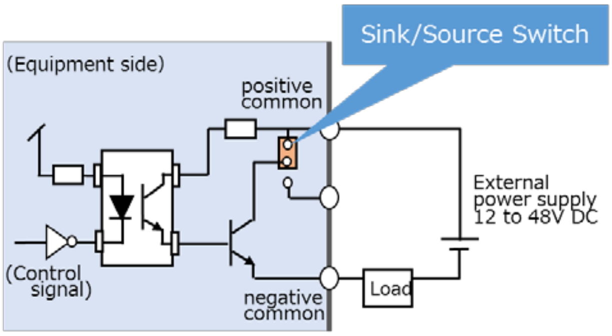

Fig. 2.2.2(b) Transistor output/common board source type example

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In addition, the output transistor has polarity, so the expected operation cannot be performed if the user makes a mistake in wiring. In the worst case, the equipment may be damaged (Fig. 2.2.2(c)).

These precautions can be resolved by using photorelays.

Photorelays usually consist of two MOSFET sources-common connections, so there is no polarity restriction on the contacts.

Therefore, it is possible to accommodate both sink-source connections.

It is possible to provide users with equipment that does not need to worry about the polarity during wiring (Fig. 2.2.2(d), (e)).

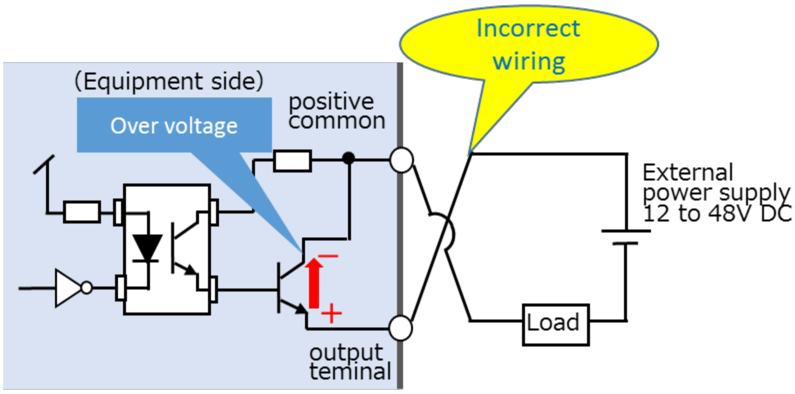

Fig. 2.2.2(c) Example of transistor output/incorrect wiring (reverse connection)

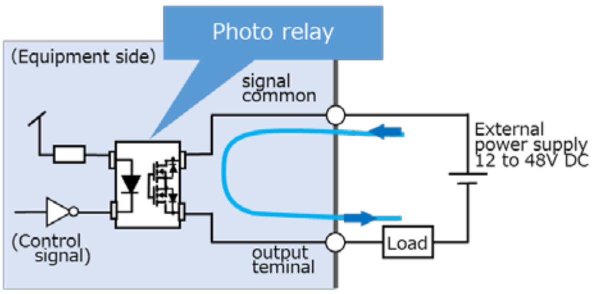

Fig. 2.2.2(d) Example of Photorelay output

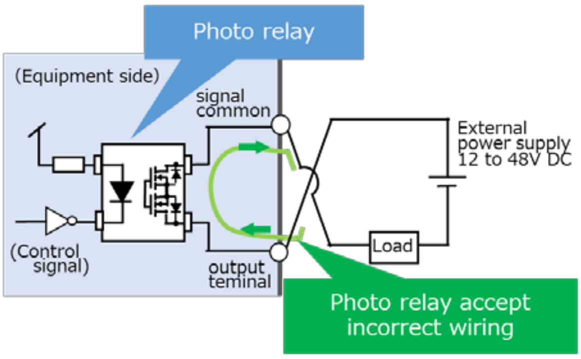

Fig. 2.2.2(e) Example of photorelay Output /reverse connection

2.3 Example of photorelay application to contact output (mechanical relay)

Mechanical relays are often used to control high-capacity loads (100V/240V AC, currents that exceed 1A, etc.).
Because the contact structure of the mechanical relay is mechanical, operation noise is generated when the contact is turned ON. In addition, not only the sound but also the contact instantaneously repeats ON/OFF (bouncing), during which the applied current will ON/OFF, causing electric noises. In contrast, the photorelay has no mechanical contacts, so no noise is generated when switching the contacts, contributing to quieter equipment. Electrical noise can also be suppressed because contact bounce does not occur.
Other advantages include no restrictions on the number of contacts, high-speed response, and low power supply circuits.

On the other hand, the area with high capacity of the mechanical relay may not be covered by the photorelay due to the electrical specifications.
In such cases, photocouplers (photocouplers consisting of LED and PDA, hereafter abbreviated as PV) with MOSFET standalone products and photo-couplers with photovoltaic outputs can be used to achieve the same effects as photorelays (Fig. 2.3(a)-(d)).

There are not only merits, but also cautions. Since the surge resistance of photorelays is lower than that of mechanical relays, it is necessary to select products and investigate countermeasure parts. A photorelay or MOSFET with an off-voltage rating that is sufficiently greater than the applied voltage must be used. When selecting the off-voltage rating, also check the parasitic inductance component from the contact output terminal to the load and the load voltage caused by the load current. Also, consider using a protective element such as a protective diode or varistor and verify the operation in the actual operating environment. In addition, the light intensity of the LEDs controlled by the contacts decreases depending on the ambient temperature and the magnitude of the forward current (I_F) to be energized (reduction of the light output). Therefore, when designing initially, determine I_F considering the loss of optical power.

Details on how to design are given in the application note "How to replace from a mechanical relay" and “Basic Characteristics and Applied Designs of Photovoltaic Couplers for MOSFET Drives for Relays”. Please refer to thse documents as well.

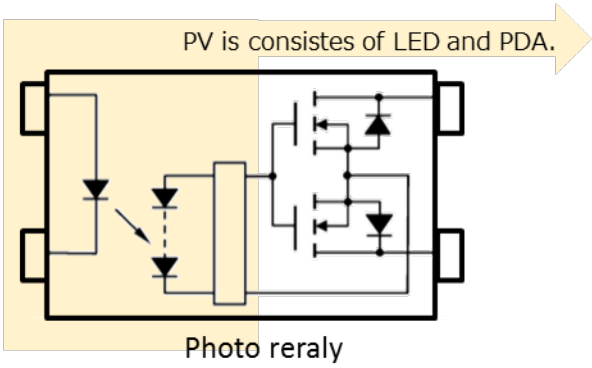

Fig. 2.3(a) Photorelay Internal circuit configuration

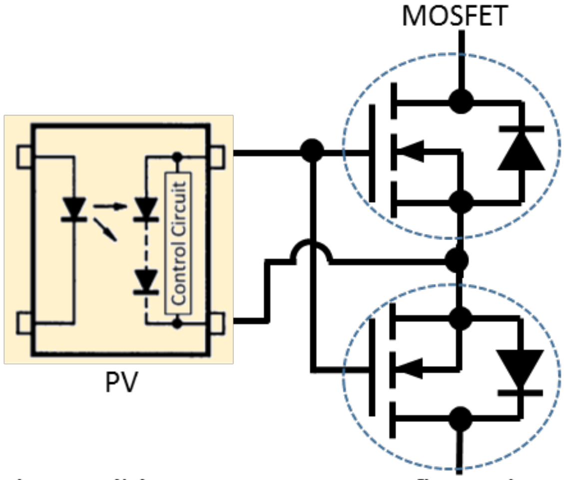

Fig. 2.3(b) PV+ MOSFET configuration

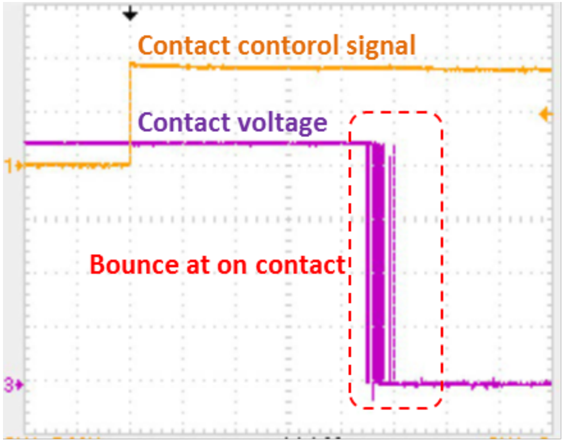

Fig. 2.3(c) Driving waveform of Mechanical relay by resistive Load

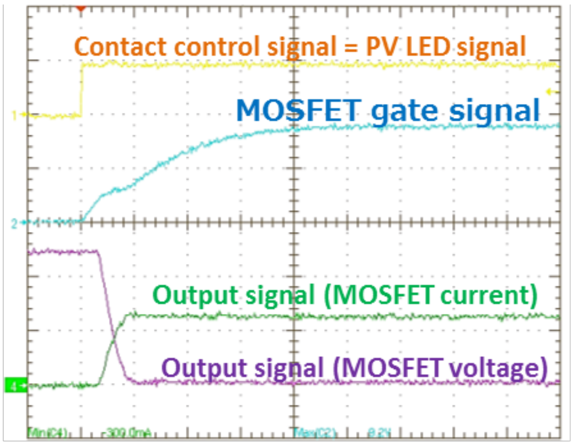

Fig. 2.3(d) PV+ MOSFET Drive waveforms by resistive Loads

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Table 1 summarizes the characteristics of the different types of contacts mentioned above. Please select photorelays that can meet the purpose of your design equipment, such as quietness, power consumption reduction, and miniaturization.

Table 1. Comparison by different contacts

	Mechanical relay	Photorelay (MOSFET output)	Transistor coupler	PV coupler+ Power MOSFET	SSR (triac)
Mounting area	☆	☆☆ (No. of parts: 1 pc.)	☆ (An isolated power supply is needed)	☆ (No. of parts: 2 to 4 pcs.)	☆ (No. of parts: 2 pcs.)
Contact endurance (No. of switching limitation)	× (Have a limitation)	☆☆ (Nothing)	☆☆ (Nothing)	☆☆ (Nothing)	☆☆ (Nothing)
Operation noise (sound)	☆ (Make a sounds when switching)	☆☆ (Nothing)	☆☆ (Nothing)	☆☆ (Nothing)	☆☆ (Nothing)
Input side power consumption	× (≤ 100 mW for coil activation)	☆☆	☆	☆☆	☆
Contact rating	☆☆☆ (2 A to 300A)	☆☆	☆☆ (Depends on transistor / MOSFET)	☆☆☆	☆
Polarity	☆☆	☆☆	× (DC only)	☆☆	☆☆
Leakage current	☆☆☆ (Zero)	☆☆	× (Dark current must be considered)	☆	×

(Recommend) ☆☆☆ > ☆☆ > ☆ > × (Not recommend)

Table 2 shows some of our photorelay recommendations. Photorelays with OFF-state output terminal voltage (V_{OFF}) of 60 V or higher are recommended for 24 V system. Select a product whose load current is within the ON-state current rating of the photorelay. Moreover, the ON-state current derating according to the ambient temperature should be considered.

Table 2. Example of Toshiba photorelays

(Unless otherwise specified, T_a = 25 ℃)

System voltage	Photorelay part number	Absolute maximum ratings			Maximum value
		OFF-state output terminal voltage V_{OFF} (V)	ON-state current I_{ON} (mA)	ON-state current @T_a = 50 ℃ I_{ON} (mA)	ON-state resistance R_{ON} (Ω)
24 V system	TLP170AM	60	700	492.5	0.3
	TLP3122A		1400	1050	0.25
	TLP3107A		4000	3000	0.04
	TLP240A		500	375	2
100 V system	TLP170GM	350	110	82.5	35
	TLP240G		100	75	50
200 V system	TLP172GAM	400	110	82.5	65
	TLP240GA		120	90	35

3. Analog measurement applications

Rationalization of preventive maintenance and predictive maintenance are required in production facilities and processes to achieve both improved facility performance, operating rate, and quality. In order to meet these requirements, instrumentation and control technology is being developed to grasp, predict, and control facility conditions from signals with various sensors.

For predictive maintenance, not only ON/OFF digital signals based on thresholds but also data on transition conditions (analog signals) are becoming more important for detection values of sensors such as temperature, flow rate, pressure, and vibration. In addition, in order to efficiently handle analog signals as a control system, there are increasing cases in which analog input functions are implemented in various devices, as well as the use of analog input modules of PLCs.

In order to utilize analog signals with high accuracy and efficiency, the following problems must be solved in analog input circuits.

1) Measurement mode (Voltage detection, Current detection) •••
   Switching of shunt resistance for detection
2) Output Signal Magnification (Gain) (Gain = Output Signal/Input Signal) •••
   Switching feedback resistance
3) Switching of various sensor signals, mutual influence (noise) elimination•••
   Separation of unnecessary sensor signals and separation of control power supplies

The resistance can be switched manually using the jumper pins at the initial setting of the device. This can be done by switching using a mechanical relay, etc. but by using a photorelay. It will contribute to solving these problems.

3.1 Switching between Current and Voltage Measurements (Shunt Resistor)

Depending on the type of output from the sensor, there are voltage or current outputs. As an analog input function, it is ideal to have input terminals dedicated to each of them, but there are problems such as the mounting area and the number of components mounted such as the AD converter (ADC).

One solution is the sharing of voltage and current detection circuits. Sharing is possible by providing a switch in the shunt resistor part of the current detection circuit (Fig. 3.1(a), (b)). There are methods such as configuring the switch part with jumper pins and manually switching at the time of initial setting of the equipment, using mechanical relays, etc. When jumper pins are used, they can only be detected in that mode after the initial setting. When mechanical relays are used, the life of the contacts, power consumption of the contact drive circuit increases. The mounting area of the drive circuit is required, making it difficult to downsize the equipment. The use of photorelays in this switch enables these issues to be solved (Fig. 3.1(c)).

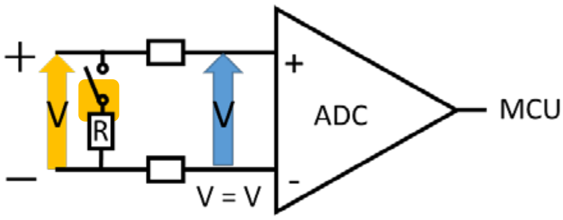

Fig. 3.1(a) Voltage/current detection circuit (voltage output state) Shunt resistor switch open status

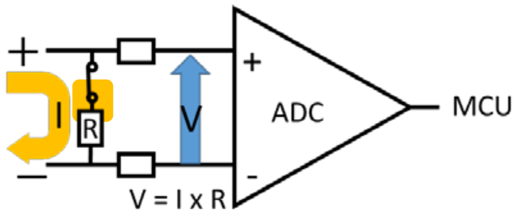

Fig. 3.1(b) Voltage/current detection circuit (current output state) Shunt resistor switch closed

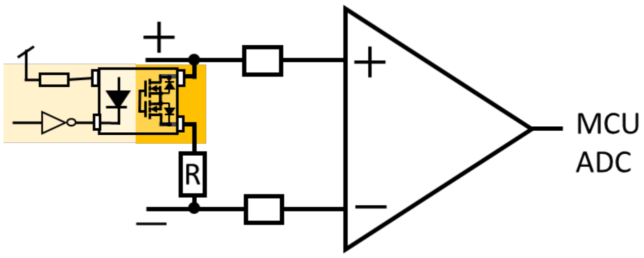

Fig. 3.1(c) Voltage/current detection circuit
(Use a photorelay for the shunt resistor switch.)

3.2 Gain control

Matching the maximum level of the sensor signal with the maximum input level of the AD converter will improve resolution. Depending on the level of the sensor signal, setting the feedback resistor value to a circuit that can be selected by the photorelay allows the setting to be made to be close to the input maximum level of the AD converter (Fig. 3.2).

3.3 Switching various sensor signals and eliminating mutual effects (noise)

When multiple analog signal inputs are provided to the equipment, it is preferable to connect an AD converter to each signal line in terms of accuracy, but the part mounting area and cost increase. One solution is to use a multiplexer that selects signal lines. However, unselected (unwanted) signals can become noisy and worsen accuracy. By using the photorelay as a switch for each wire, it is possible to suppress the mutual influence of each wire (Fig. 3.3).

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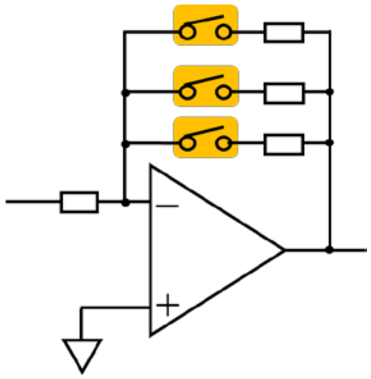

Fig. 3.2 Gain Control Circuit
(Use photorelay for feedback resistance value selection switch)

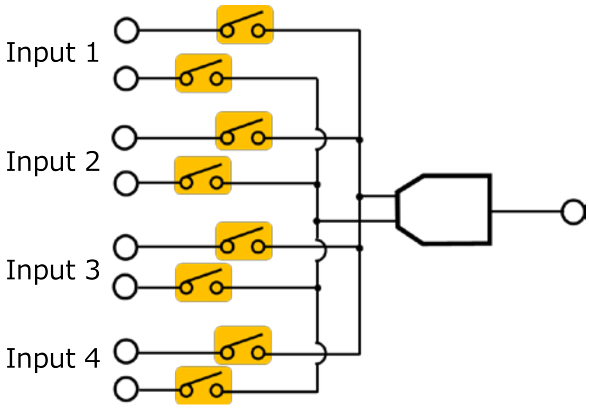

Fig. 3.3 Signal Switching Circuit

The photorelay has capacitance between the contact (MOSFETs) terminals, and leakage (minute) current flows through this capacitance when the contact (MOSFETs) is turned off. If the expected accuracy cannot be obtained due to this leakage current, a T-shaped switch configuration can improve this problem by adding a switch constituting the low impedance path from the photorelay contact of the signal path to the ground (Fig. 3.4).

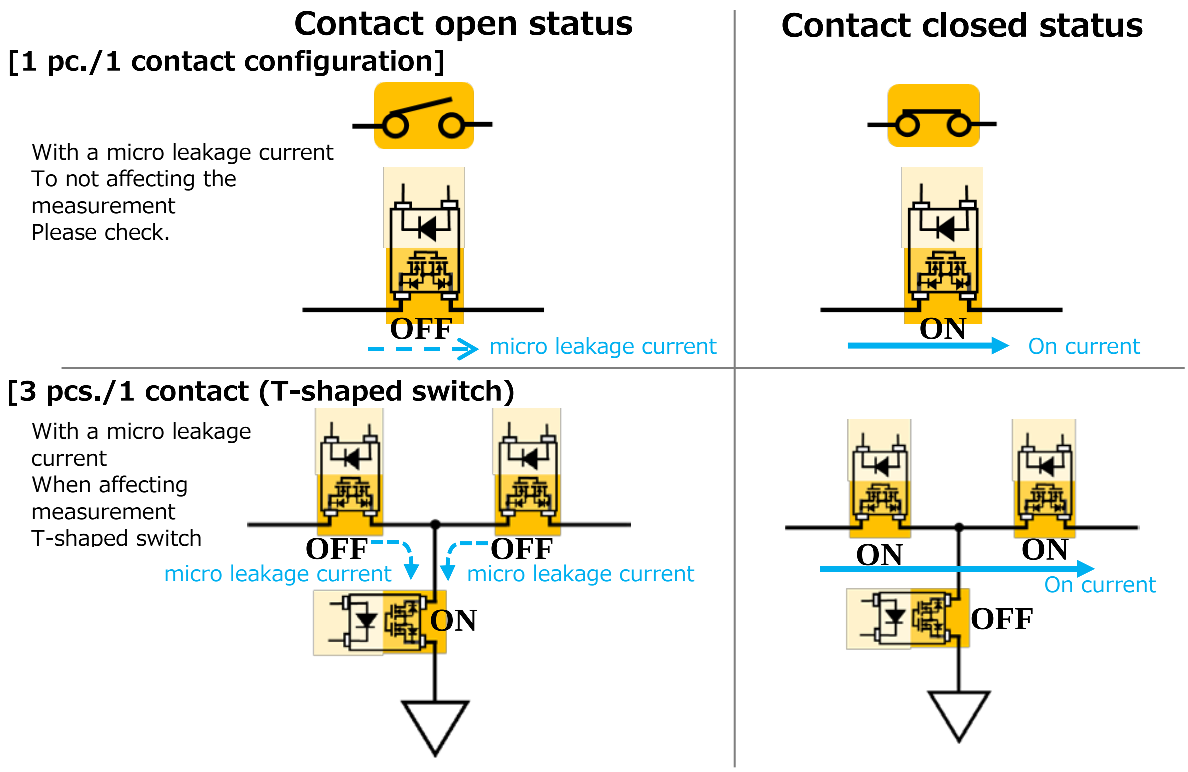

Fig. 3.4 Contact configuration method

These applications require ultra-small photorelays which can control a high signal quality (i.e. low attenuation and distortion of signal components).

To maintain signal quality, photorelays must have a low output capacitance component when the contact is off (C_{OFF}) and a low resistance component when the contact is on (R_{ON}). We offer a variety of ultra-small packages. Some of these products have the built-in LED forward current limiting resistor, eliminating the need for external resistors on the PCB and contributing to space saving. Table 3 shows the representative products. The products with an ★ mark are products with the built-in current limiting resistor.

In addition, please refer to the application note that summarizes points to keep in mind when using photorelays in high-frequency circuits; "Points for photorelays in high frequency circuit applications".

Table 3. VSON series photorelay for measuring instruments and analog signal switching (applications that do not require safety standards)

Part number	Package (Toshiba)	I_{FT} Max (mA)	V_{FON} Max (V)	V_{OFF} Max (V)	C_{OFF} typ. (pF)	R_{ON} Max (Ω)	I_{ON} Max (A)	t_{on} Max (ms)	t_{off} Max (ms)
TLP3403	VSON4	3	—	20	40	**0.22**	1.00	2.0	1.0
TLP3403R★	VSONR4	–	3	20	40	**0.22**	1.00	2.0	1.0
TLP3406S	S-VSON4	3	–	30	120	**0.20**	1.50	2.0	1.0
TLP3406SRH★	S-VSON4T	–	3	30	120	**0.20**	1.50	2.0	1.0
TLP3406SRL★	S-VSON4T	–	1.6	30	120	**0.20**	1.50	2.0	1.0
TLP3407S	S-VSON4	3	–	60	80	**0.30**	1.00	2.0	1.0
TLP3407SR★	S-VSON4T	–	3	60	80	**0.30**	1.00	20	1.0
TLP3407SRA★	S-VSON4T	–	3	60	80	**0.30**	1.00	20	1.0
TLP3407SRH★	S-VSON4T	–	3	60	80	**0.30**	1.00	2.0	1.0
TLP3407SRL★	S-VSON4T	–	1.6	60	80	**0.30**	1.00	2.0	1.0
TLP3409S	S-VSON4	3	–	100	50	**0.60**	0.65	2.0	1.0
TLP3412	VSON4	3	–	60	20	1.50	0.40	0.5	0.5
TLP3412R★	VSONR4	–	3	60	20	1.50	0.40	0.5	0.5
TLP3412SRH★	S-VSON4T	–	3	60	20	1.50	0.40	0.5	0.2
TLP3412SRHA★	S-VSON4T	–	3	60	20	1.50	0.40	0.5	0.2
TLP3414	VSON4	3	–	40	5	3.00	0.25	0.5	0.5
TLP3417	VSON4	3	–	80	5	12.00	0.12	0.5	0.2
TLP3419	VSON4	3	–	80	6	8.00	0.20	0.4	0.4
TLP3420	VSON4	3	–	100	6	14.00	0.10	0.3	0.3
TLP3431	VSON4	3	–	20	5	1.20	0.45	0.5	0.5
TLP3440S	S-VSON4T	3	–	40	**0.45**	14.00	0.12	0.2	0.3
TLP3441	VSON4	3	–	40	**0.70**	10.00	0.14	0.2	0.2
TLP3442	VSON4	3	–	40	**0.30**	20.00	0.10	0.2	0.2
TLP3450	VSON4	3	—	20	**0.80**	5.00	0.20	0.2	0.2
TLP3451	VSON4	3	–	60	**0.70**	15.00	0.12	0.2	0.2
TLP3475R★	VSONR4	–	3	50	12	1.50	0.30	0.5	0.4
TLP3475S	S-VSON4	3	–	60	12	1.50	0.40	0.5	0.25
TLP3475SRHA★	S-VSON4T	–	3	60	12	1.50	0.40	0.5	0.2

4. Conclusion

This document introduces typical applications of photorelay in FA equipment. Improvements in the performance and miniaturization of photorelays have increased the number of applications to parts not shown in this document.

We will continue to expand our lineup of photorelays, so we would like to consider various contacts.

When designing a new product, please check the latest product information on our website.

Revision History

Revision	Date	page	Description
Rev. 1.0	2020-04-10	-	1st edition
Rev. 2.0	2021-03-04	P.10, P.11, P.15	Add Table 1, 2 and 3

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