Basic Electrical Characteristics and Application Circuit Design of Photovoltaic Couplers for MOSFET Drive for Relays

Outline:

Photovoltaic-output photocouplers(photovoltaic couplers), which incorporate a photodiode array as an output device, are commonly used in combination with a discrete MOSFET(s) to form a semiconductor relay. This application note discusses the electrical characteristics and application circuits of photovoltaic-output photocouplers.

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Typically, photocouplers consist of a light emitting device optically coupled with a light detecting device via a transparent galvanic insulator. They are commonly used to transfer an electrical signal between two circuits with different ground potentials by means of light. In the past, electromagnetic relays, isolation transformers, and other devices were used to transfer electrical signals from an integrated circuit or between isolated primary and secondary sides. At present, photocouplers are generally used because they help resolve an impedance mismatch, provide higher isolation between input and output, suppress induced electromotive force, and simplify noise blocking. A photovoltaic-output photocoupler generates electricity on its own in response to light energy from the input light emitting diode (LED). Capable of driving a discrete MOSFET(s) without a power supply, photovoltaic-output photocouplers are expected to replace conventional mechanical relays. This application note provides a description of their electrical characteristics and application circuits for engineers who are unfamiliar with photovoltaic-output photocouplers.

1. What is a photovoltaic-output photocoupler?

1.1 Structure of a photovoltaic-output photocoupler

As is the case with other types of photocouplers, photovoltaic-output photocouplers consist of an input light emitting device optically coupled with an output light detecting device via a transparent galvanic insulator (Figure 1.1(a)). In the case of photovoltaic-output photocouplers, an infrared LED is used as a light emitting device whereas a photodiode array is used as a light detecting device (Figure 1.1(b)).

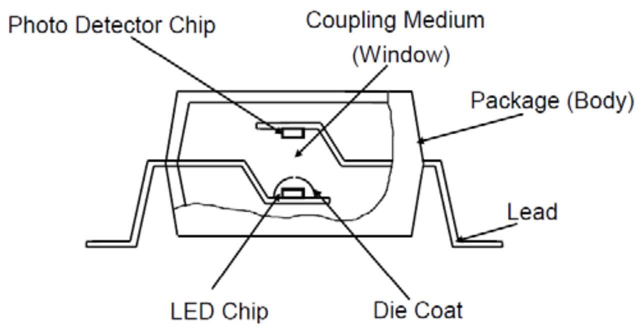


Figure 1.1(a) Internal structure example

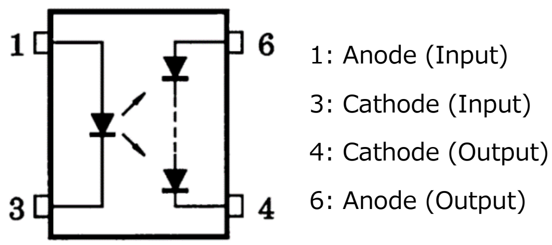


Figure 1.1(b) Pin assignment example

1.2 Principle of operation of a photovoltaic-output photocoupler

A photodiode that detects light in the photovoltaic-output photocoupler is a semiconductor device with a pn junction.

When a photodiode detects light with energy greater than its energy band gap (Eg), the excited electrons move to the n region (holes move to the p region), causing the number of electrons in the n region and the number of holes in the p region to increase. This creates a difference in potential between the n and p regions, with the n region being positive with respect to the p region. Consequently, a positive open voltage appears in the p region (anode) when both ends of the photodiode are open-circuited whereas short-circuit current flows from the p region (anode) to the n region (cathode) when they are short-circuited (Figure 1.2). The voltage that appears across a single photodiode is a fraction of a volt. An open voltage of a few volts can be obtained by using an array of photodiodes.

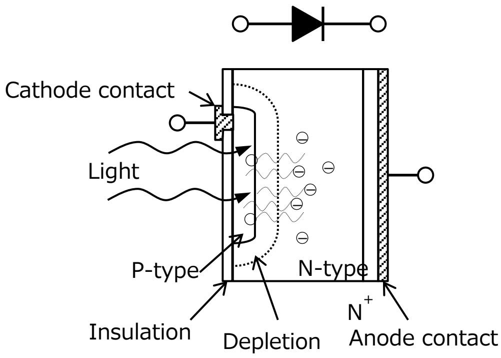


Figure 1.2 Principle of voltage generation in a photodiode

1.3 Basic usage of photovoltaic-output photocouplers

A photovoltaic-output photocoupler (PV) generates DC voltage that is used to drive the gate of the following MOSFET(s). Since the short-circuit current from a photovoltaic-output photocoupler is typically on the order of ten to a few tens of microamperes, it is unsuitable for switching power supply drive and other high-speed switching applications. Therefore, photovoltaic-output photocouplers are commonly used for relay applications that tolerate low-speed switching. Photovoltaic-output photocouplers provide an open voltage (V_{OC}) of about 7 to 9 V at a room temperature of 25°C. However, V_{OC} decreases as temperature increases. Therefore, multiple photovoltaic-output photocouplers might be necessary, depending on the environmental conditions under which they are used or the gate threshold voltage (V_{th}) of the driven MOSFETs (Figure 1.3(1b)). Discrete MOSFETs contain a parasitic body diode. Therefore, in the case of AC relay applications, it is necessary to connect the drain and source terminals of two MOSFETs as shown in Figure 1.3(1a) (i.e., the drain (source) terminal of a MOSFET and the source (drain) terminal of an adjacent MOSFET). In contrast, in the case of DC relay applications, a single MOSFET suffices as shown in Figure 1.3(2).

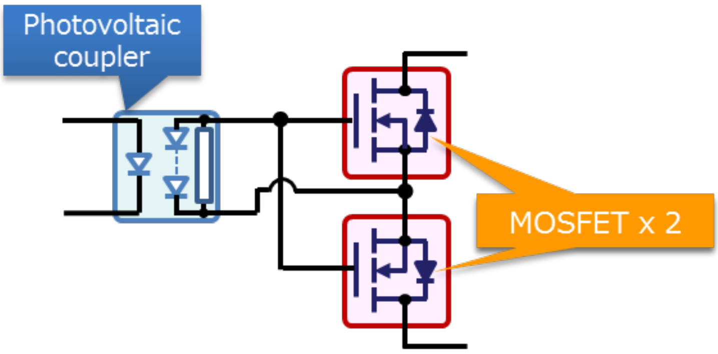


Figure 1.3(1a) AC relay consisting of one PV and two MOSFETs

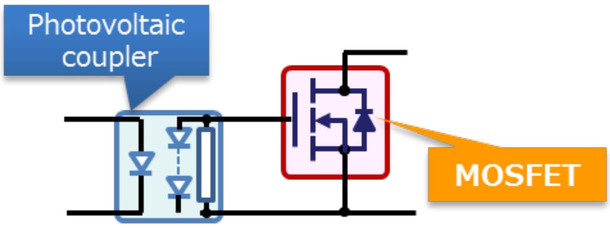


Figure 1.3(2) DC relay consisting of one PV and one MOSFET

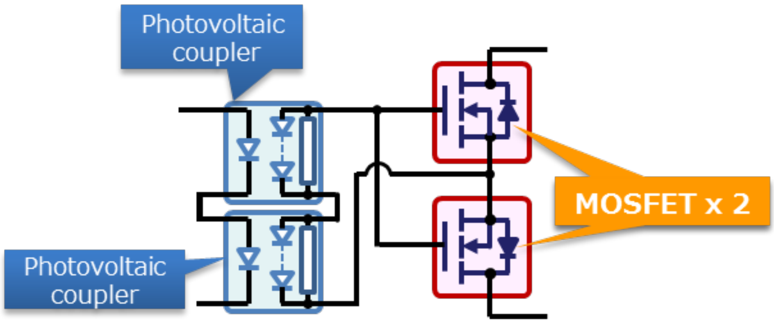


Figure 1.3(1b) AC relay consisting of two PVs and two MOSFETs

A photorelay integrates a photovoltaic-output photocoupler and MOSFETs in a single package. It requires much less board space than a combination of a photovoltaic-output photocoupler and discrete MOSFETs. A disadvantage of the photorelay is that its current rating is constrained by the size of the chips that can be integrated in one package.

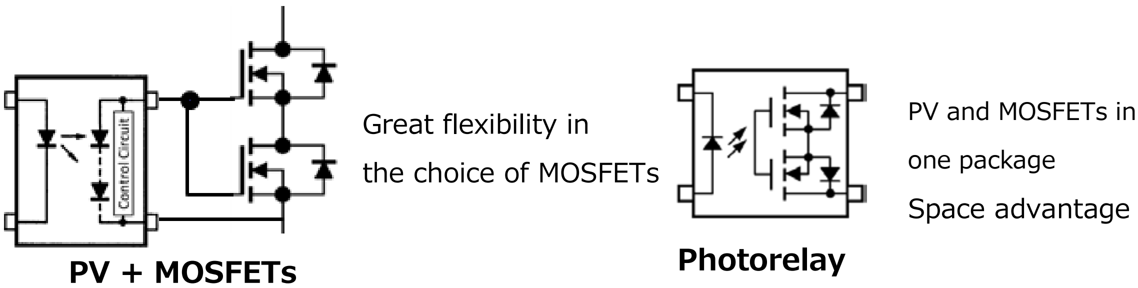


Figure 1.4 PV+MOSFETs vs. photorelay

1.4 Advantages of PV+MOSFET combinations

A PV+MOSFET combination compares unfavorably with a conventional mechanical relay in terms of price and has a limit on the maximum power that can be switched. Nonetheless, PV+MOSFET combinations have several advantages over mechanical relays.

(1) Bounceless switching

A mechanical relay has a physical contact. When the contact opens, it is susceptible to bounce noise, which might affect the correct operation of the neighboring devices (Figure 1.5 (a)).

In contrast, semiconductor relays including PV+MOSFET combinations are free from bounce noise because they have no mechanical parts (Figure 1.5(b)).

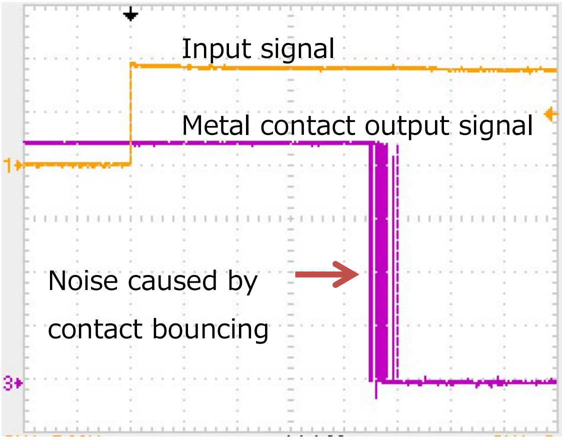


Figure 1.5(a) Operating waveforms of a mechanical relay with a resistive load

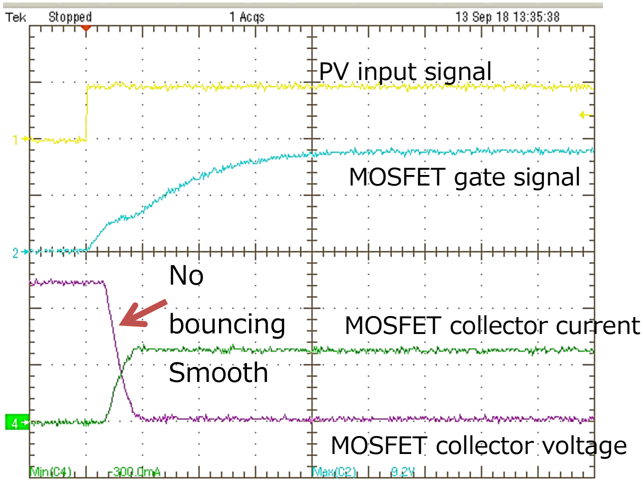


Figure 1.5(b) Operating waveforms of a PV+MOSFET relay with a resistive load

(2) No limit on the number of contact open/close cycles

Mechanical relays have a limit on the number of open/close cycles because of the use of a mechanical contact. In contrast, semiconductor relays such as PV+MOSFET combinations are free from mechanical aging and failure.

(3) High response speed

When response speed is a priority, PV+MOSFET relays can be configured to switch faster than mechanical relays although this advantage depends on the on-resistance and gate capacitance of the driven MOSFET. Therefore, PV+MOSFET relays can be used for phase control applications.

(4) Reduction in the power consumption of a power supply circuit

Because mechanical relays drive a solenoid coil, they require an input current as high as a few tens of milliamperes. In addition, a separate power supply might be needed for a drive circuit that supplies this input current. In contrast, semiconductor relays such as PV+MOSFET combinations require an input current of only a few to 10 or so milliamperes.

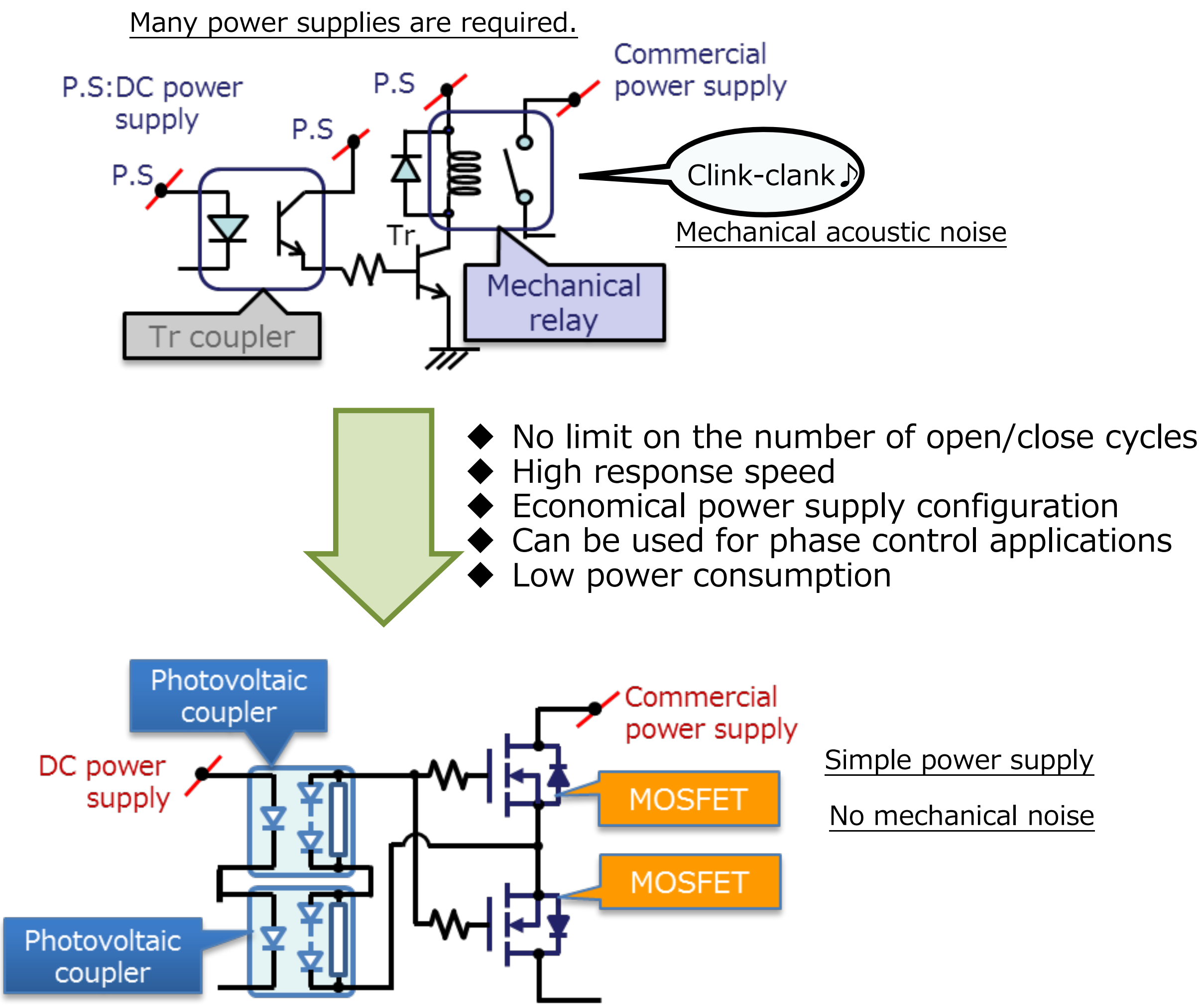


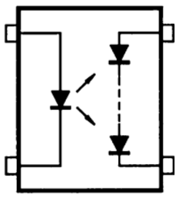
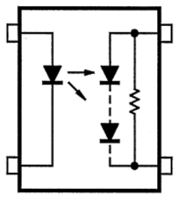
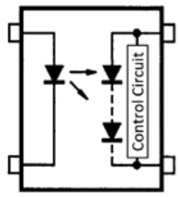
Figure 1.6 Advantages of PV+MOSFETs

1.5 Types of photovoltaic-output photocouplers

A photovoltaic-output photocoupler that drives a MOSFET requires a circuit to discharge the gate capacitance to turn it off. Some photovoltaic-output photocouplers incorporate a discharge circuit, and others do not. The simplest photovoltaic-output photocoupler requires an external discharge circuit. In the simplest case, it is a single resistor connected between the anode and cathode outputs of the photovoltaic-output photocoupler. A high-value resistor allows the photovoltaic-output photocoupler to provide an open voltage (V_{OC}) close to its V_{OC} rating. However, a high-value resistor slows the turn-off of a MOSFET because the discharge time is dependent on the product of the gate capacitance of the driven MOSFET and the resistor value (C x R). An advantage of using photovoltaic-output photocouplers without an internal discharge circuit such as the TLP3905 is the flexibility in adjusting open voltage and turn-off time within certain ranges. In contrast, photovoltaic-output photocouplers with an internal discharge circuit such as the TLP191B do not provide such design flexibility, but require fewer parts and less board space and design workload. Another type of photovoltaic-output photocouplers such as the TLP3906 incorporate a discharge clamp circuit instead of a resistor that operates only during the turn-off of a

MOSFET. These photovoltaic-output photocouplers provide the voltage generated by a photodiode array (i.e., open voltage) without attenuation when the LED is on and quickly discharges the MOSFET gate when it turns off. They simplify system design and provide outstanding electro-optical characteristics.

Table 1.1 Types of output circuits in photovoltaic-output photocouplers

Output circuit type	No discharge circuit	Built-in discharge resistor	Built-in discharge circuit
Equivalent circuit			
Product example	TLP3905	TLP191B	TLP3906
Characteristics	• Requires an external discharge circuit	• No need for an external discharge circuit • Limited MOSFET gate discharge performance because of the fixed internal resistor value	• No need for an external discharge circuit • Provides higher MOSFET gate discharge performance and thus shorter MOSFET turn-off time than a built-in resistor

2. Major electrical characteristics and behavior of photovoltaic-output photocouplers

This section describes major electrical performance characteristics shown in the datasheets of photovoltaic-output photocouplers and their behaviors that you need to understand to design a PV+MOSFET relay.

Table 2.1 Major terms used in the technical datasheets of photovoltaic-output photocouplers

Term	Symbol	Description
Input Forward Current	I_F	Rated current that can flow continuously in the forward direction of the LED
Input Power Dissipation	P_D	Rated power that can be dissipated in the LED
Open Voltage	V_{OC}	Output photovoltaic voltage generated at the specified input current, I_F
Short-Circuit current	I_{SC}	Output photo-current generated by the specified input current, I_F
Turn-ON time	t_{on}	Time taken for the output waveform to change from 100% to 10% after the LED current is turned on under the specified conditions
Turn-OFF time	t_{off}	Time taken for the output waveform to change from 0% to 90% after the LED current is turned off under the specified conditions

2.1 V_{OC}-I_F characteristics

The V_{OC}-I_F characteristics show the dependence of open voltage (V_{OC}) on input forward current (I_F). As I_F increases, V_{OC} increases. In the case of photovoltaic-output photocouplers that require an external discharge resistor such as the TLP3905, a high-value resistor helps maintain V_{OC} at high voltage as shown in Figure 2.1. However, a high-value resistor causes the MOSFET turn-off time to increase as indicated by the t_{off} -C_L characteristics of Figure 2.6 shown later. The TLP3906 incorporating a discharge circuit does not require an external resistor. Therefore, Figure 2.2 gives only one V_{OC} characteristic when its outputs are open-circuited. The TLP3906 incorporates a discharge circuit that provides the highest open voltage and efficiently turns off a MOSFET.

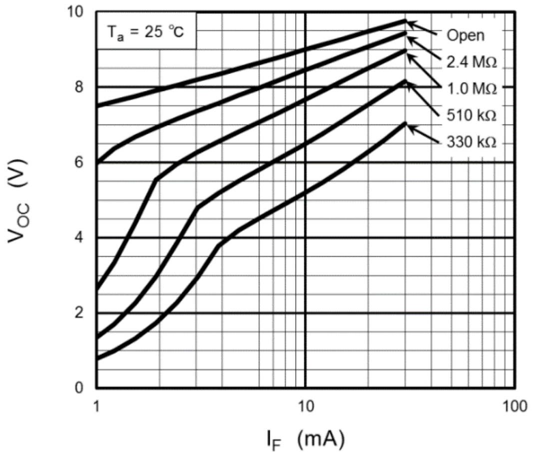


Figure 2.1 TLP3905 V_{OC}-I_F characteristics

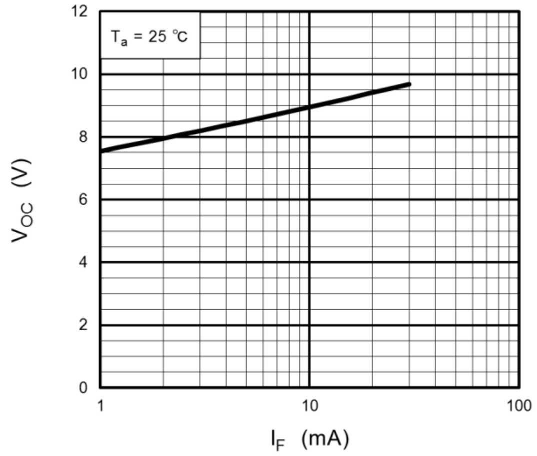


Figure 2.2 TLP3906 V_{OC}-I_F characteristic

2.2 V_{OC}-Ta characteristic

The V_{OC}-Ta characteristic shows the dependence of open voltage (V_{OC}) on the ambient temperature (Ta). V_{OC} decreases as the ambient temperature increases, as shown in Figure 2.3. Even at the highest ambient temperature, V_{OC} must be higher than the gate threshold voltage (V_{th}) of the driven MOSFET. If V_{OC} is lower than V_{th}, multiple photovoltaic-output photocouplers must be connected in series in order to obtain a higher open voltage. The V_{OC}-Ta characteristic is negatively sloped because both the light output of an LED and the open voltage of a photodiode array decrease as the ambient temperature increases.

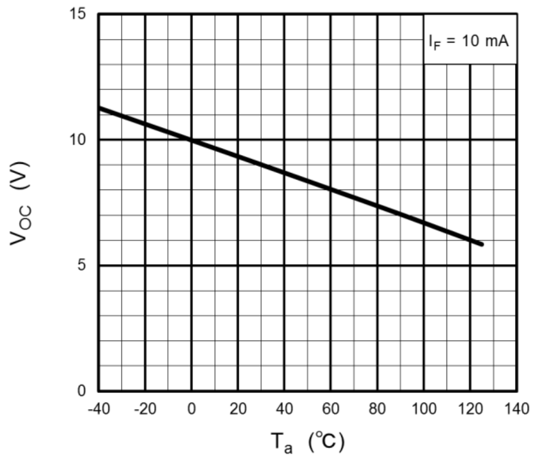


Figure 2.3 TLP3905 V_{OC}-Ta characteristic

2.3 I_{SC}-I_F characteristic

The I_{SC}-I_F characteristic shows the dependence of short-circuit current (I_{SC}) on input forward current (I_F). The output short-circuit current (I_{SC}) increases as I_F increases, as shown in Figure 2.4. I_{SC} charges the gate capacitance of the driven MOSFET. The higher the I_{SC} value, the shorter the charging time becomes. In other words, increasing I_{SC} helps reduce the MOSFET turn-on time.

Some photovoltaic-output photocouplers are available with some I_{SC} ranks. Table 2.2 shows the I_{SC} ranks for the TLP3905. The TLP3905 with Rank C20 provides an I_{SC} of minimum 20 μA whereas the TLP3905 without a rank option provides an I_{SC} of minimum 12 μA. Therefore, Rank C20 makes it possible to control a MOSFET with a high drive capability.

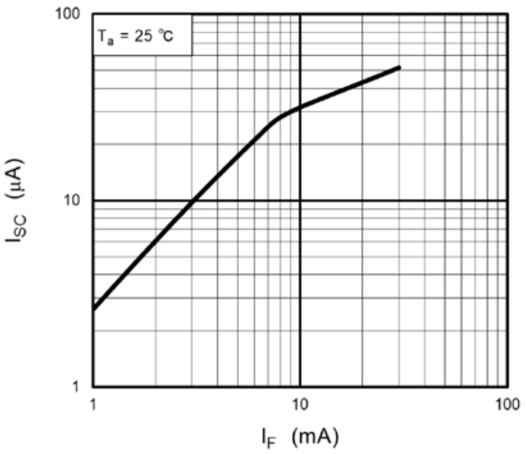


Figure 2.4 TLP3905 I_{SC}-I_F characteristic

Table 2.2 TLP3905 short-circuit current I_{SC} rank classification

(Ta = 25°C)

Rank	I_{SC} Rank Marking	Test Condition	Short-Circuit Current I_{SC} (min)	Unit
C20	C	I_F = 10 mA	20	μA
None	C, Blank	I_F = 10 mA	12	

2.4 I_{SC}-Ta characteristic

The I_{SC}-Ta characteristic shows the dependence of short-circuit current (I_{SC}) on the ambient temperature (Ta). I_{SC} decreases as the ambient temperature increases, as shown in Figure 2.5. The I_{SC}-Ta characteristic is negatively sloped because the light output of an LED decreases as the ambient temperature increases.

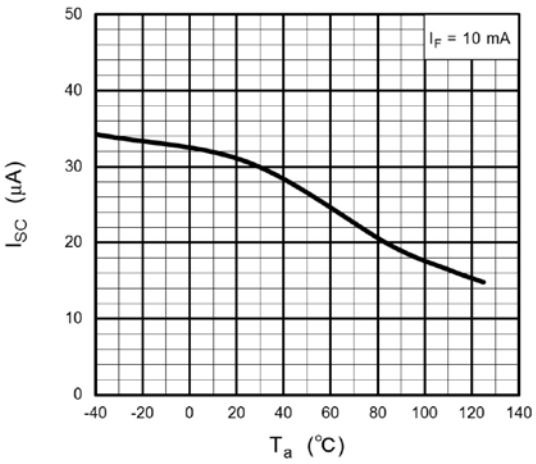


Figure 2.5 TLP3905 I_{SC}-Ta characteristic

2.5 t_{on}-C_L and t_{off} -C_L characteristics

The t_{on}-C_L and t_{off} -C_L characteristics show the dependence of turn-on and turn-off times (t_{on} and t_{off}) on load capacitance. In the case of a PV+MOSFET relay, C_L represents the gate capacitance of the driven MOSFET, C_g (=Q_g/V_{GE}). As the load (i.e., the MOSFET gate capacitance) increases, the time taken to charge and discharge the gate capacitance increases, causing t_{on} and t_{off} to increase. Figure 2.6 indicates that, in the case of the TLP3905, t_{off} can be reduced by using a low-value discharge resistor. However, using a low-value discharge resistor causes the output open voltage (V_{OC}) to decrease as indicated by the V_{OC}-I_F characteristics of Figure 2.1.

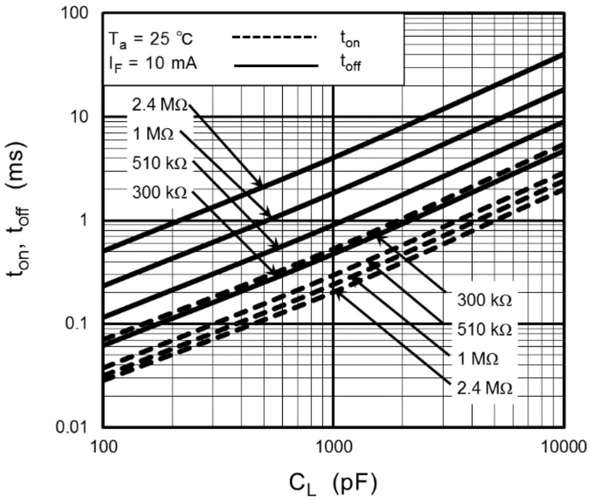


Figure 2.6 TLP3905 t_{on}-C_L and t_{off}-C_L characteristics

3. Considerations for configuring relays with PV+MOSFET combinations

PV+MOSFET relays have many advantages over conventional relays as described thus far. However, careful consideration is necessary because various factors affect their performance as discussed in this section.

PV+MOSFET relays are convenient particularly when you need to:

- Solve the service life and reliability problems of mechanical relays
- Eliminate contact bouncing during turn-off
- Reduce the turn-on and turn-off times
- Provide more intricate control than is achievable with triac- and thyristor-based solid-state relays (SSRs)
- Provide higher off-state output terminal voltage (V_{OFF}) and on-state current (I_{ON}) than those achievable with photorelays, a type of semiconductor relays. (Toshiba's photorelays are available with a V_{OFF} of up to 600 V and an I_{ON} of up to 5 A.)

Figure 3.1 is an example of a semiconductor switch for switching a 24-V/2-A load. The following subsections discuss the considerations for this DC switch.

Example of DC switch specifications:
Operating temperature: T_{opr} = -10 to 60°C
Switch speed: Interval > 1 second
On/Off < 5 ms
Control-side supply voltage: V_{CC1} = 5 VDC ± 5%
Load supply voltage: V_{CC2} = 24 VDC ± 5%
Load current: 2 A
Operating life: 10 years (88,000 hours)

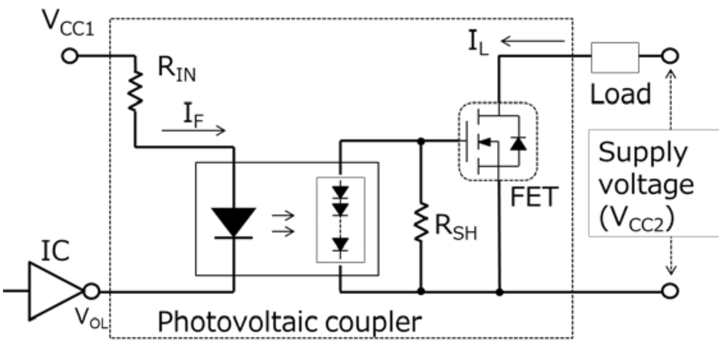


Figure 3.1 Example of a semiconductor switch with a 24-V/2-A load

3.1 Selecting a MOSFET and determining its gate drive conditions

For the DC switch of Figure 3.1, we should select a MOSFET with a drain-source voltage (V_{DSS}) of 60 V because the load supply voltage is specified to be 24 VDC. Of Toshiba's low-voltage MOSFETs with a V_{DSS} of 60 V, let's consider using the TPH9R506PL with the lowest drain-source on-resistance ($R_{DS(ON)}$). As an example, the TPH9R506PL is combined with the TLP3905 photovoltaic-output photocoupler with a basic configuration.

TPH9R506PL: V_{DSS} = 60 V, $R_{DS(ON)}$ = 15 mΩ (max) at V_{GS}= 4.5 V and I_D = 8 A
TLP3905: V_{OC} =7 V (min), I_{SC} = 12 μA (min) at I_F = 10 mA

When a photovoltaic-output photocoupler is used to drive a MOSFET, the open voltage (V_{OC}) of the photovoltaic-output photocoupler must be higher than the gate threshold voltage (V_{th}) of the MOSFET:

$$V_{OC} > V_{th}$$

As described in Section 2.2, the open voltage (V_{OC}) of the photovoltaic-output photocoupler is dependent on the ambient temperature. In some cases, it is necessary to connect multiple photovoltaic-output photocouplers in series, depending on the maximum ambient temperature at which a switch will be used as well as the requirement for the MOSFET gate voltage.

First, check the recommended gate threshold voltage (V_{th}) of the TPH9R506PL MOSFET. The recommended gate threshold voltage of a discrete MOSFET is indicated as a test condition for drain-source on-resistance. In the case of the TPH9R506PL, V_{GS} = 4.5 V will be appropriate (Figure 3.2).

(Ta = 25°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Drain-source on-resistance	$R_{DS(ON)}$	V_{GS} = 4.5 V, I_D = 8 A	—	10.2	15.0	mΩ
		V_{GS} = 10 V, I_D = 17 A	—	7.3	9.5	

Figure 3.2 TPH9R506PL $R_{DS(ON)}$ test conditions

3.2 Setting the input forward current (I_F) and discharge resistor (R_{SH}) of the photovoltaic-output photocoupler that satisfy the gate drive condition of the MOSFET

As described in Section 2.2, the V_{OC} of the photovoltaic-output photocoupler decreases as the ambient temperature increases. The PV+MOSFET relay needs to operate properly at an ambient temperature (Ta) of up to 60°C according to the specifications shown in Figure 3.1. In other words, it is necessary to maintain V_{OC} at a level that satisfies V_{GS} = 4.5 V even at a Ta of 60°C. From the slope of the V_{OC}-Ta characteristics shown in Figure 3.3, it is estimated that V_{OC} should be higher than 5.7 V at a Ta of 25°C.

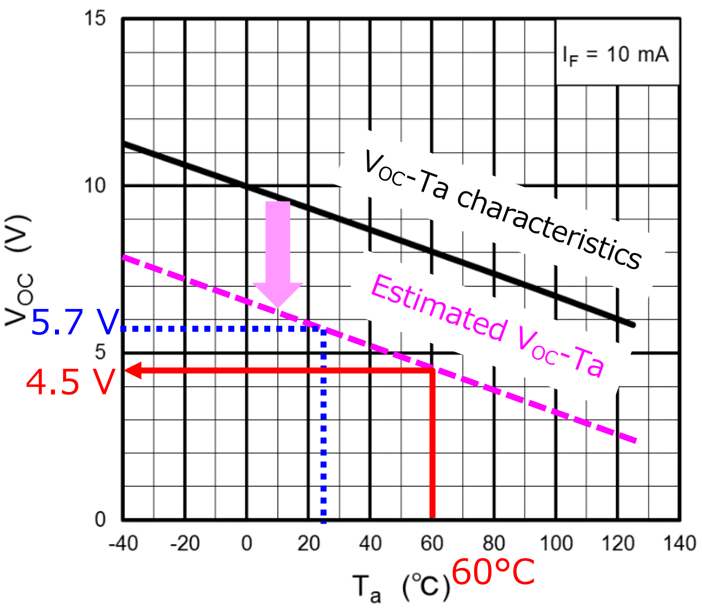


Figure 3.3 TLP3905 V_{OC} -Ta characteristics

Next, look at the V_{OC}-I_F characteristics of the TLP3905 shown in Figure 3.4.

To turn off a MOSFET, it is necessary to discharge the gate during turn-off. The external resistor (R_{SH}) in the circuit of Figure 3.1 serves this purpose. Figure 3.4 shows that its resistance is a parameter that affects the V_{OC}-I_F characteristics.

Figure 3.4 shows the V_{OC}-I_F characteristics of the TLP3905 with a typical V_{OC} of 9 V shown in Figure 3.5. Even if the TLP3905 has a minimum V_{OC} of 7 V, V_{OC} will be higher than 5.7 V when I_F is higher than 10 mA and R_{SH} is 1 MΩ or higher.

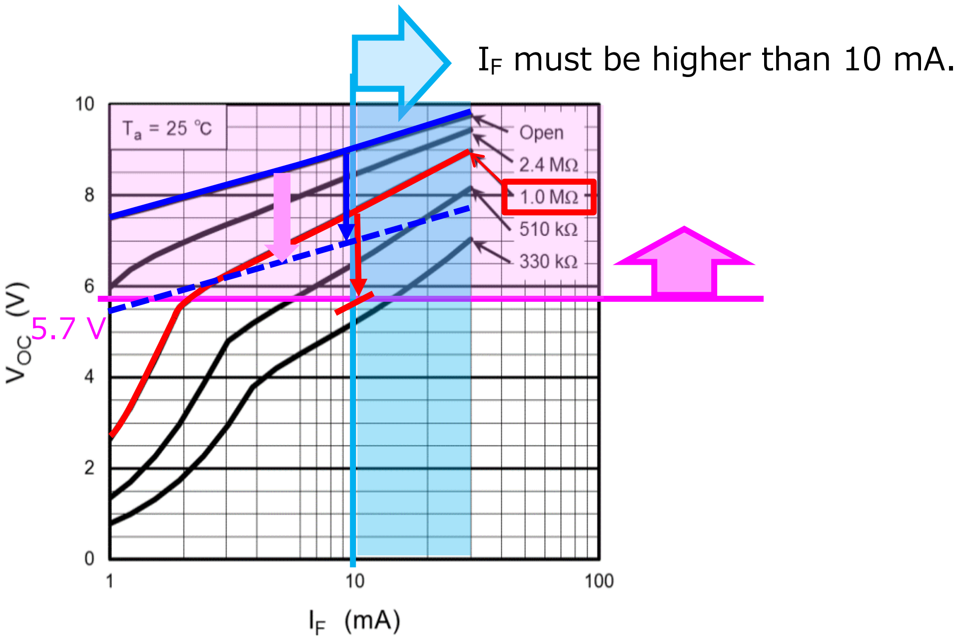


Figure 3.4 TLP3905 V_{OC} -I_F characteristics

(Ta = 25°C)

Characteristics	Symbol	Note	Test Condition	Min	Typ.	Max	Unit
Open voltage	V_{OC}		I_F = 10 mA	7	9	—	V
			I_F = 10 mA, T_a = 125 °C	—	5	—	

Figure 3.5 TLP3905 V_{OC} specification

The external discharge resistor (R_{SH}) affects both the turn-on and turn-off of the MOSFET. To select an appropriate discharge resistor that satisfies the switching speed requirement, it is necessary to calculate the MOSFET gate capacitance first. When the TPH9R506PL is driven at a V_{GS} of 4.5 V, its gate capacitance (C_g) can be estimated from the Q_g-V_{GE} characteristics. From the dynamic input/output characteristics of the TPH9R506PL shown in Figure 3.6, the gate charge (ΔQ_g) can be read as 11 nF at a V_{DS} of 24 V and a V_{GS} of 4.5 V.

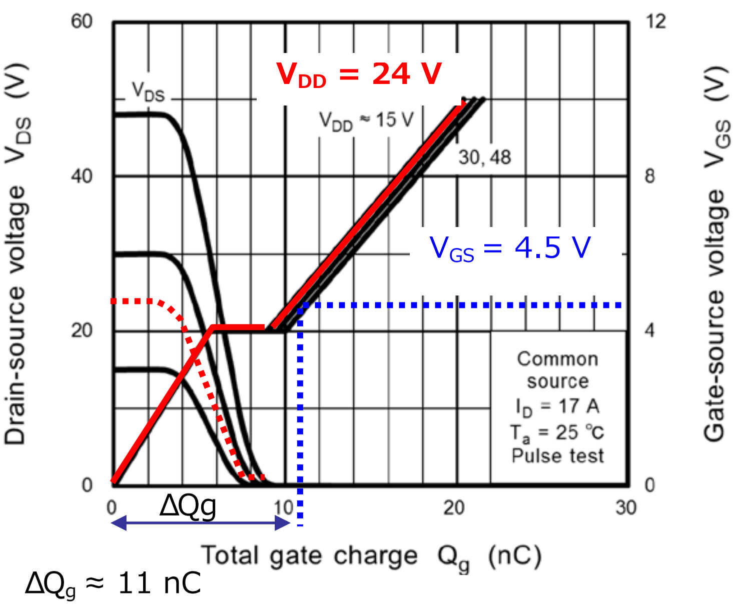


Figure 3.6 TPH9R506PL dynamic input/output characteristics

According to Coulomb's law, $C_g=Q_g/V_{GE}$. Hence, C_g is estimated to be 11/4.5 = 2.4 nF. The datasheet of the TLP3905 shows the t_{on}-load capacitance and t_{off}-load capacitance characteristics (Figure 3.7). In the case of photovoltaic-output photocouplers with a configuration like that of the TLP3905, t_{off} tends to be predominantly longer than t_{on}. Figure 3.1 shows that both the t_{on} and t_{off} requirements are less than 5 ms. When the load capacitance (C_g) is 2.4 nF or greater, the t_{on} requirement is satisfied regardless of the discharge resistor values shown in Figure 3.7. However, Figure 3.7 indicates that the discharge resistor must be 1 MΩ or lower to satisfy the t_{off} requirement.

Now, look at the t_{on}-load capacitance and t_{off}-load capacitance characteristics of Figure 3.7. Are they dependent on the V_{OC} and I_{SC} parameters of the photovoltaic-output photocoupler?

The turn-off time (t_{off}) is determined by the MOSFET gate capacitance (C_L) and the discharge resistor value (R_{SH}). It is hardly affected by the photovoltaic-output photocoupler. On the other hand, the MOSFET turn-on (t_{on}) is the process of charging the gate capacitance (C_L) with the output current (I_{SC}) from the photovoltaic-output photocoupler. Therefore, t_{on} increases as I_{SC} decreases.

Figure 3.7 shows the dynamic input/output characteristics of the TLP3905 with a standard rank (I_{SC} ≈ 30 μA) described in Sections 2.3 and 2.4. Assuming that I_{SC} is at the minimum, I_{SC} can be estimated as follows at an I_F of 10 mA:

In the case of the C20 I_{SC} rank, when T_a = 25°C, I_{SC}(typ) = 30 μA → I_{SC}(min) = 20 μA

When Ta increases from 25°C to 60°C, I_{SC} decreases by 20%. That is: I_{SC}(min) = 20 μA at T_a = 25°C → 16 μA at Ta = 60°C

Taking this into consideration, it is necessary to assume that the t_{on} values shown in Figure 3.7 can differ by roughly 1.9 times at the typical and minimum I_{SC} (30 μA / 16 μA). However, in the case of our DC switch, t_{on} will not exceed t_{off} even at the minimum I_{SC}.

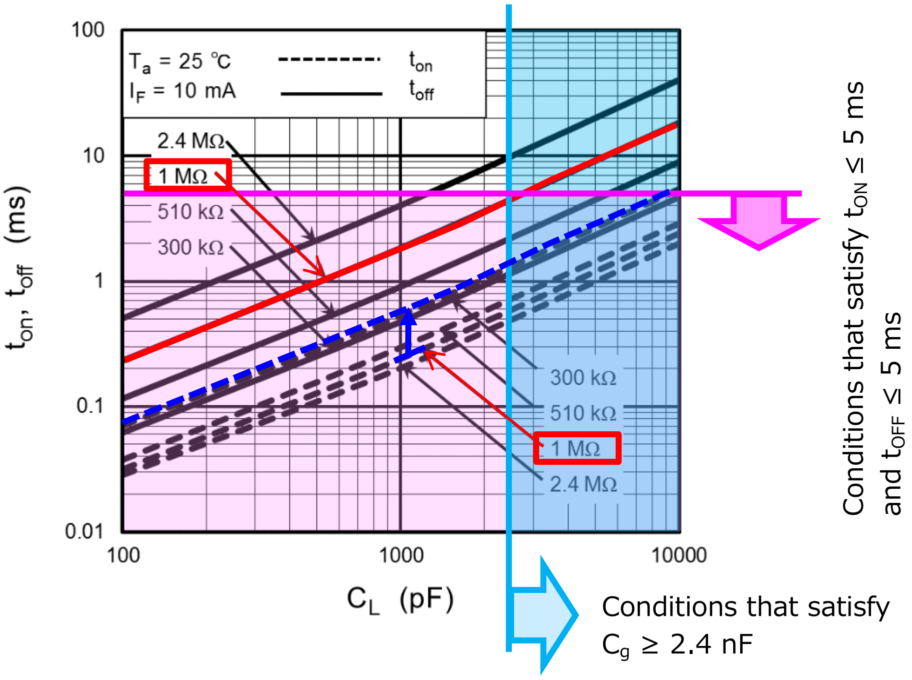


Figure 3.7 TLP3905 t_{on}, t_{off} –load capacitance (C_L) characteristics

3.3 Input forward current (I_F) of the photovoltaic-output photocoupler and selection of R_{IN} based on I_F

In Section 3.2, the conditions that satisfy $I_F > 10$ mA were estimated. Now, remember that the light output of the input LED decreases over time. The degradation of the LED depends on its input current and the number of hours of operation. A reduction in the output short-circuit current (I_{SC}) is highly dependent on a reduction in the LED's light output. Figure 3.8 shows the degradation of the light output of the LED incorporated in the TLP3905. Suppose that the expected service life is 10 years (roughly 88,000 hours). Figure 3.8 shows that the light output decreases to roughly 85% after 10 years of operation. Allowing for a margin, assume that the light output will decrease to 80% of the initial output after 10 years of use (i.e., a 20% decrease).

Taking the degradation in the light output into consideration, I_F should be set to 10 mA / 0.8 = 12.5 mA.

Let the low-level output voltage of the logic IC that drives the input LED be V_{OL}. Then, $I_{F\ (typ.)}$ is expressed as:

$$I_{F(typ.)} = \frac{V_{CC} - V_{F(typ.)} - V_{OL}}{R_{IN(typ.)}}$$

The datasheet of the TLP3905 shows:

$V_{F\ (typ.)} = 1.65$ V ($I_F = 10$ mA)

Hence:

$$R_{IN} = \frac{5V - 1.65V - 0.4V}{12.5mA}$$

$$= 236\ \Omega$$

Therefore, a resistor with 240 Ω ± 5% should be selected as R_{IN}.

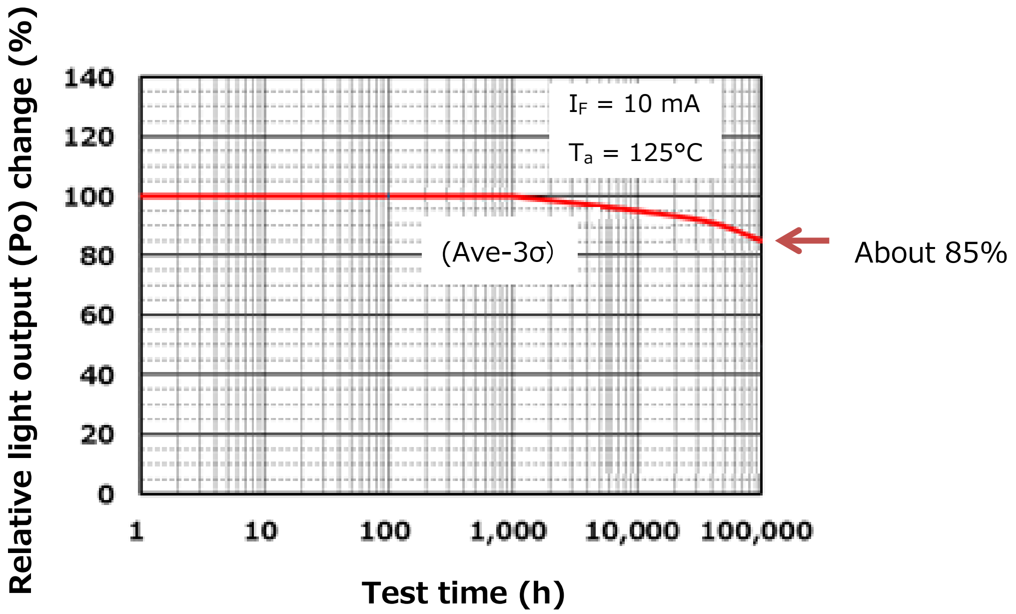
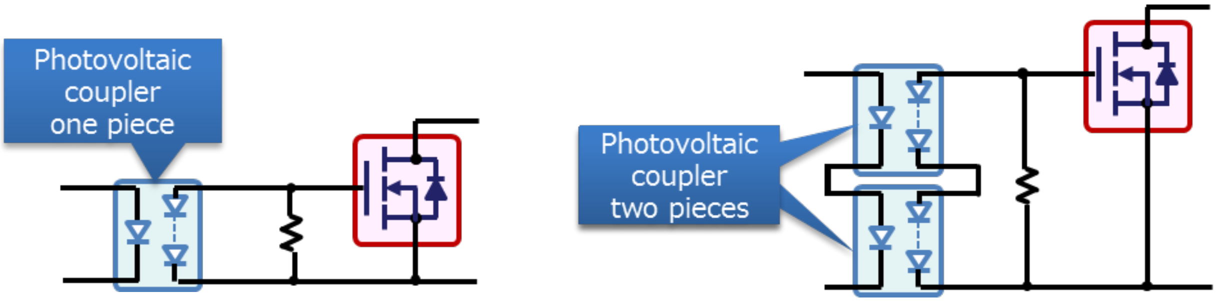


Figure 3.8 Example of LED light output degradation curve

(The above graph shows a typical LED light output degradation curve. When designing a circuit incorporating photocouplers such as the TLP3905, consult the reliability data of each photocoupler.)

In this example, V_{OC} is greater than V_{GS} = 4.5 V even at a Ta of 60°C. If the relationship V_{OC} > V_{GS} (V_{th}) cannot be satisfied, sufficient gate voltage can be obtained by connecting multiple photovoltaic-output photocouplers in series.



(1) When V_{OC} > V_{th}

(2) When V_{OC} < V_{th}

Figure 3.9 Study for the photovoltaic-output photocoupler configuration based on the MOSFET V_{th} requirement

4. Terms

(General terms)

Term	Symbol	Description
Absolute Maximum Rating		Maximum value that must not be exceeded even for an instant during operation
Isolation Voltage	BV_S	Isolating voltage between input and output under the specified conditions
Capacitance (Input to Output), Total Capacitance (Input to Output)	C_S	Electrostatic capacitance between the input and output pins
Capacitance (Input), Input Capacitance	C_T C_t	Electrostatic capacitance between the anode and cathode pins of the LED
Forward Current, Input Forward Current	I_F	Rated current that can flow continuously in the forward direction of the LED
Pulse Forward Current, Input Forward Current (Pulsed)	I_{FP}	Rated current that can flow momentarily in the forward direction of the LED
Peak Transient Forward Current	I_{FPT}	Rated current that can flow momentarily in the forward direction of the LED
Reverse Voltage, Input Reverse Voltage	V_R	Rated reverse voltage that can be applied across the LED's cathode and anode
Reverse Current, Input Reverse Current	I_R	Leakage current flowing in the reverse direction of the LED (from cathode to anode)
Forward Voltage, Input Forward Voltage	V_F	Voltage drop across the anode and cathode pins of the LED under the specified forward-current condition
LED Power Dissipation, Input Power Dissipation	P_D	Rated power that can be dissipated in the LED
Total Power Dissipation	P_T	Total rated power that can be dissipated in both the input and output devices
Isolation Resistance	R_S	Resistance between the input and output pins at the specified voltage
Junction Temperature	T_j	Permissible temperature of the junction of the photodetector or LED
Operating Temperature	T_{opr}	Ambient temperature range in which the device can operate without loss of functionality
Lead Soldering Temperature	T_{sol}	Rated temperature at which the device pins can be soldered without loss of functionality
Storage Temperature	T_{stg}	Ambient temperature range in which the device can be stored without operation
Creepage Distance		Shortest distance along the surface of insulation between the path of two conductive parts (input and output)
Clearance(Clearance Distance)		Shortest distance through air between the path of two conductive parts (input and output)
Internal Isolation Thickness, Insulation Thickness		Distance through insulation. Shortest thickness through internal insulation between the path of two conductive parts (input and output)

(Photovoltaic output)

Term	Symbol	Description
Forward Current, Output Forward Current	I_{FD}	Rated forward current that can be applied between anode and cathode of the output diode array
Reverse Voltage, Output Reverse Voltage	V_{RD}	Rated reverse voltage that can be applied across anode and cathode of the output diode array
Forward Voltage, Output Forward Voltage	V_{FD}	Forward voltage across the output's anode and cathode
Reverse Current, Output Reverse Current	I_{RD}	Reverse leakage current between the output's anode and cathode
Open Voltage	V_{OC}	Output photovoltaic voltage generated by the specified input current,I_F
Short-Circuit Current	I_{SC}	Output photo-current generated by the specified input current, I_F

(Photorelay (MOSFET output))

Term	Symbol	Description
Trigger LED Current	(Contact a) I_{FT}	Minimum input current, I_F, necessary to turn on the output MOSFET (*1)
	(Contact b) I_{FC}	Minimum input current, I_F, necessary to turn off the output MOSFET (*1)
Return LED Current	(Contact a) I_{FC}	Maximum input current, I_F, necessary to return the output MOSFET to the OFF state
	(Contact b) I_{FT}	Maximum input current, I_F, necessary to return the output MOSFET to the ON state
OFF-State Output Terminal Voltage	V_{OFF}	Rated voltage that can be applied across the MOSFET's output pins in the OFF state
ON-State Current	I_{ON}	Rated current that can flow between the MOSFET's output pins in the ON state
ON-State Resistance	R_{ON}	Resistance between the MOSFET's output pins under the specified ON-state conditions
OFF-State Current	I_{OFF}	Leakage current flowing between the MOSFET's output pins in the OFF state
Load Current Limiting	I_{LIM}	Output current range in which the current limiting function is tripped
Output Capacitance	C_{OFF}	Capacitance between the MOSFET's output pins (between the two drains)
Turn-ON Time	(Contact a) t_{ON}	Time taken for the output waveform to change from 100% to 10% after the LED current is turned on under the specified conditions
	(Contact b) t_{ON}	Time taken for the output waveform to change from 100% to 10% after the LED current is turned off under the specified conditions
Turn-OFF Time	(Contact a) t_{OFF}	Time taken for the output waveform to change from 0% to 90% after the LED current is turned off under the specified conditions
	(Contact b) t_{OFF}	Time taken for the output waveform to change from 0% to 90% after the LED current is turned on under the specified conditions

(*1) I_F greater than the maximum I_{FT} (I_{FC}) is required to ensure that the photorelay transitions from the OFF (ON) state to the ON (OFF) state.

Revision history

Version	Date	Page	Description
Rev. 1.0	2019-04-25	-	First edition

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