

# Self-protected Photorelay

## TLP241BP

### **Description**

This document explains about the self-protected photorelay, TLP241BP.

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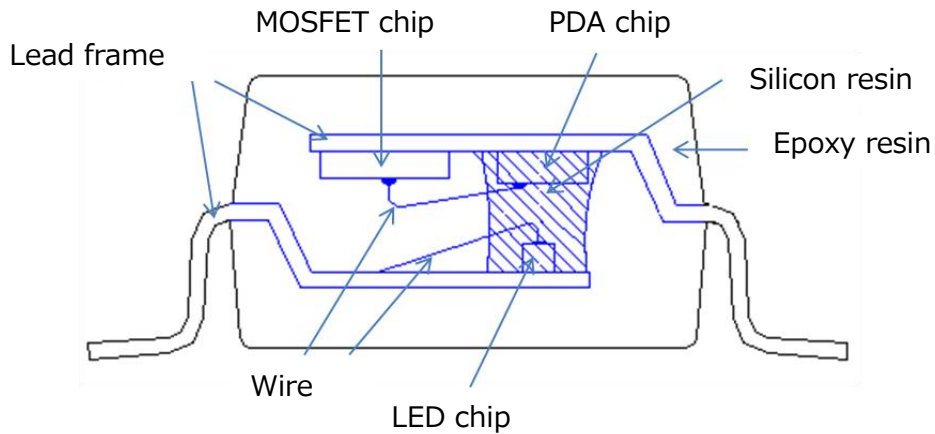
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## 1. What is Photorelay ?

### 1.1. Structure

Photorelay is a semiconductor-relay. In input side there is infrared LED and in output side there are Photo Diode Array (referred to as PDA) and MOSFETs. It is isolated electrically between input side and output side by resin.

Figure 1.1.1 shows an internal structure of photorelay. Input LED and Output PDA are facing and isolated by resin.



**Figure 1.1.1 Photorelay internal structure**

## 1.2. Operating principle

To turn on of the photorelay (normally open type), apply input LED current so that the LED emits infrared light. The infrared light is received by output PDA and the PDA has electromotive force. This electromotive force drives the gate of the output MOSFETs, turning on the output side.

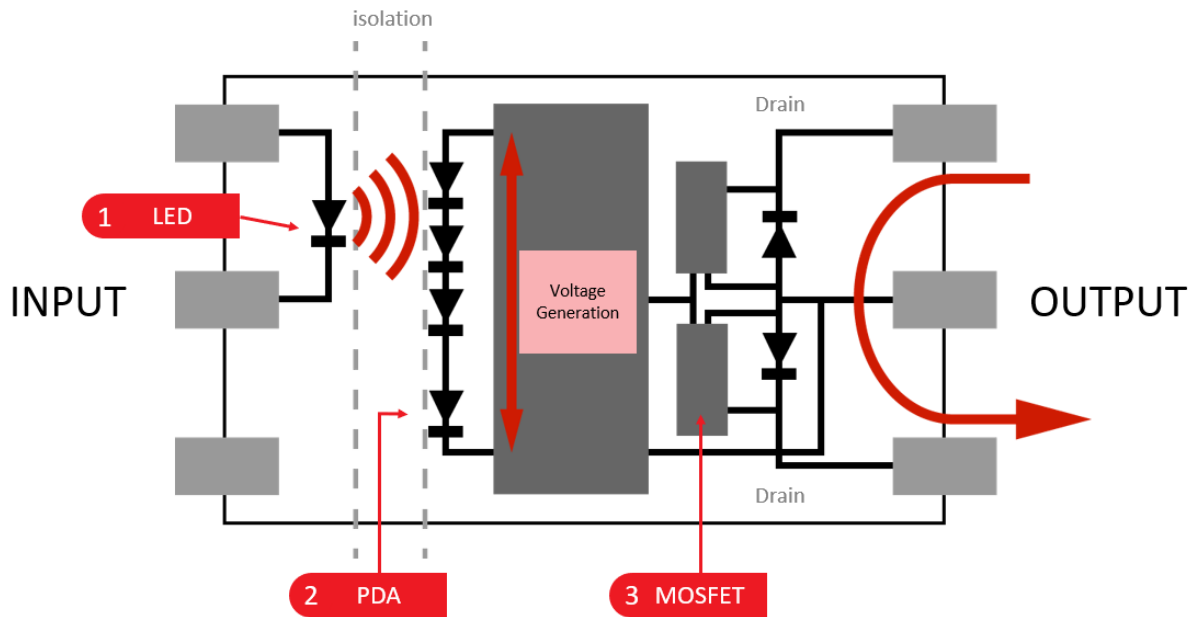


Figure 1.2.1 Operating principle of photorelay

### 1.3. Cause of failure and type of protection

Photorelay is highly reliable switch but there are some causes of failure. If over absolute maximum rating current is applied to output side, MOSFETs overheat and might be broken down with its heat. And when back electromotive force from inductance generates temporary over voltage, it might break down photorelay. So, Toshiba develop protection photorelay to make more reliable. As written table 1.3.1, over temperature protection is for overheating and over voltage protection is for over voltage surge. By these protections in the photorelay prevent failure and make more whole set reliable.

**Table 1.3.1 Cause of failure and type of protection**

Cause of failure	Reason (example)	Related Characteristics	Protection	TLP241BP
Over heat	Heating by over current Ambient temperature	$T_{opr}$ $T_a$	Over temperature protection	Supported
Over voltage	Back electromotive force	$V_{OFF}$	Over voltage protection	Supported
Over current	Short circuit	$I_{ON}$	Over current protection	No (note)

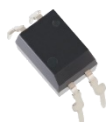
(note) It is possible to detect over current as an over temperature protection indirectly through over current heat-up.

## 2. Self-protected Photorelay

### 2.1. TLP241BP

The table 2.1.1 shows the self-protected photorelay TLP241BP main specification.

Symbols  $V_{OVC}$  and  $T_{SD}$  mean “Voltage Over Voltage Clamp” and “Thermal Shut-Down” respectively. Those are related with the over voltage protection and the over temperature protection. Definitions is explained in later chapter.

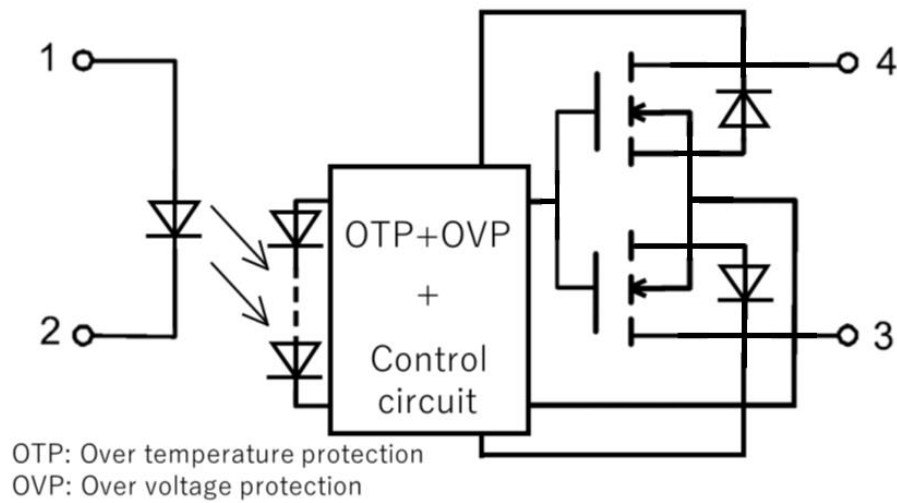


**Table 2.1.1 TLP241BP main specifications**

Item	Specification
Output	1-form-A
Package	DIP4
Over voltage clamp $V_{OVC}$ (max)	100 V
Over voltage clamp $V_{OVC}$ (min)	80 V
Thermal shutdown temperature $T_{SD}$ (typ.)	145°C
Isolation voltage $BV_s$ (min)	5,000 $V_{rms}$
OFF-state output terminal voltage $V_{OFF}$ (min)	80 V
OFF-state current $I_{OFF}$ (max) ( $V_{OFF}=40$ V)	1 $\mu$ A
OFF-state current $I_{OFF}$ (max) ( $V_{OFF}=60$ V)	10 $\mu$ A
OFF-state current $I_{OFF}$ (max) ( $V_{OFF}=80$ V)	1.4 A
Trigger LED current $I_{FT}$ (max)	3 mA
ON-state resistance $R_{ON}$ (max)	0.28 $\Omega$
Turn-on time $t_{ON}$ (max) ( $I_F=10$ mA)	1.4 ms
Turn-off time $t_{OFF}$ (max) ( $I_F=10$ mA)	0.5 ms
Operating temperature $T_{opr}$	-40 to 110°C

### 2.2. TLP241BP internal circuit

As mentioned in Chapter 1, the TLP241BP has protections in addition to conventional photorelay. The TLP241BP has OTP (Over Temperature Protection) and OVP (Over Voltage Protection). Figure 2.2.1 shows internal circuit of this photorelay.



**Figure 2.2.1 Internal circuit**

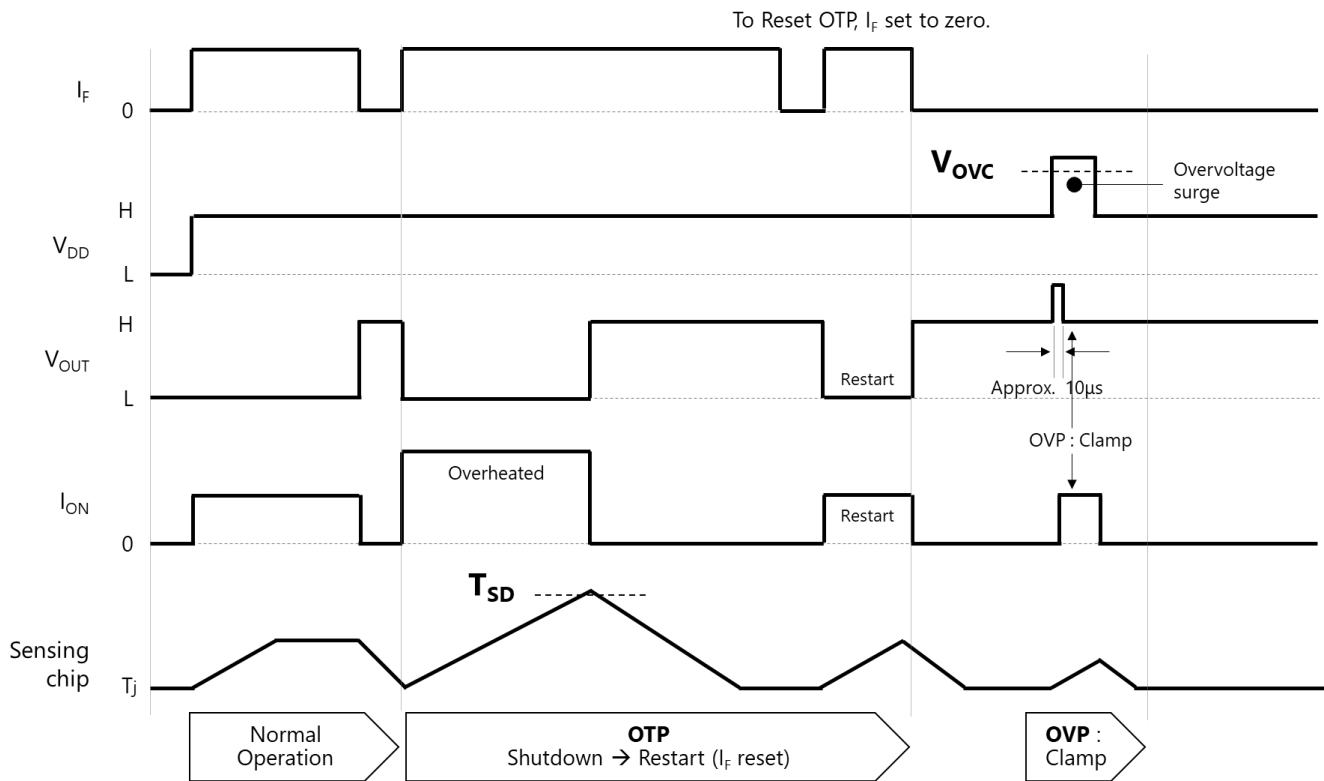
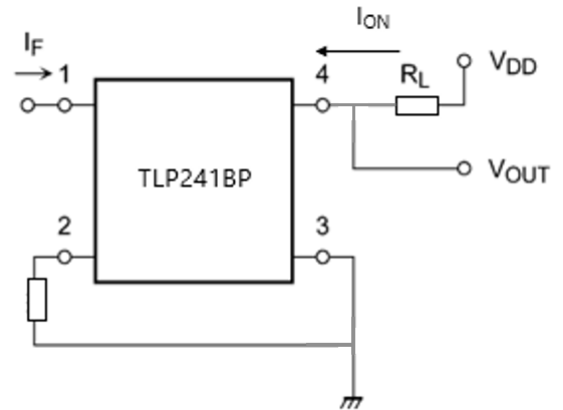


**2.3. TLP241BP operation timing diagrams**

Figure 2.3.1 shows timing diagrams of TLP241BP. Input (LED side) current is called  $I_F$  and output (MOSFET side) current is called  $I_{ON}$ .

In "Normal Operation" same as usual photorelay,  $I_{ON}$  turns on when applied  $I_F$ . In "OTP" over current (it means over absolute maximum rating current.) is applied and TLP241BP becomes over-heating. When sensing chip temperature  $T_j$  reaches  $T_{SD}$ , OTP activates and TLP241BP shuts down until  $I_F$  is reset. In "OVP" when output side is off and applied over voltage, OVP activates and clamps MOSFETs. And momentary current flows.

Detailed operation of OTP and OVP shows on later pages.



**Figure 2.3.1 TLP241BP timing diagram**

### 3. Over Temperature Protection

#### 3.1. What is OTP ?

An OTP is a function that stops photorelay operation when the temperature of the device becomes too high and there is a risk of failure. Temperature of photorelay  $T_j$  is detected as a voltage by a sensing circuit in control logic. This over temperature protection protects the photorelay from thermal destruction and contributes to avoiding the risk of failure of the entire set.

#### 3.2. OTP operating principle

Figure 3.2.1 shows relationship between voltage of OTP circuit in control logic and MOSFET threshold gate voltage. They are connected in parallel. In case of normal temperature, MOSFET gate is applied enough voltage to its turn on. When the  $T_j$  becomes high and OTP circuit voltage becomes lower than the MOSFET threshold gate voltage, current flows to OTP circuit and not enough voltage to turns on is applied to MOSFET gate. Then the MOSFET turns off.

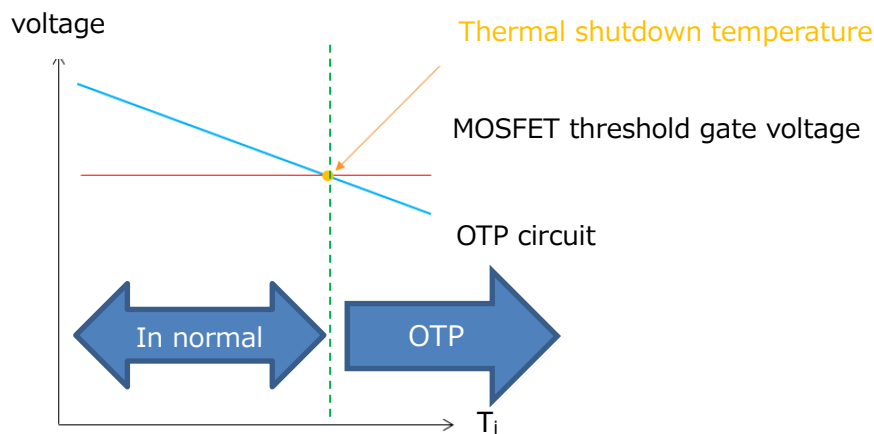


Figure 3.2.1 OTP operation principle

### 3.3. How to return from OTP

There are some methods how to return from protection mode. In case of shutdown type, it needs specific operation to resume. In case of auto-return type, it returns automatically after a lapse of time. The TLP241BP adopts shutdown method. To return from OTP mode, it is necessary to set  $I_F = 0$  mA once and then set to enough  $I_F$  to restart of the operation. Otherwise, the TLP241BP keeps shutdown mode even if the temperature is falling.

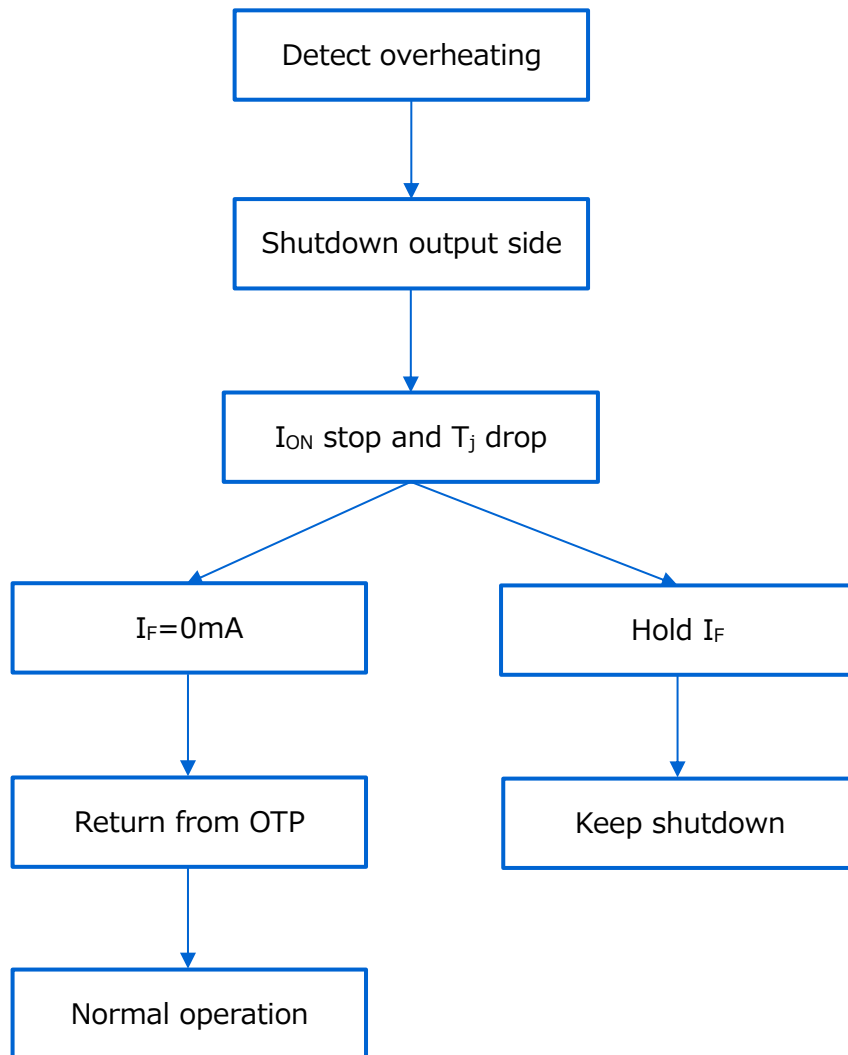


Figure 3.3.1 Method and operation of OTP

### 3.4. Operation example of OTP

Let's look how to operate the OTP using an oscilloscope. In the circuit shown in Figure 3.4.1 left, during normal operation at 25°C, the output side turns on when the LED current  $I_F$  is applied on the input side, resulting in the waveform shown in Figure 3.4.1 right. This operation is same as a typical 1-form-a (normally open) photorelay.

$I_F$  : 10 mA/div  
 $V_{OUT}$  : 10 V/div  
 $I_{ON}$  : 100 mA/div  
 X axis : 100 ms/div

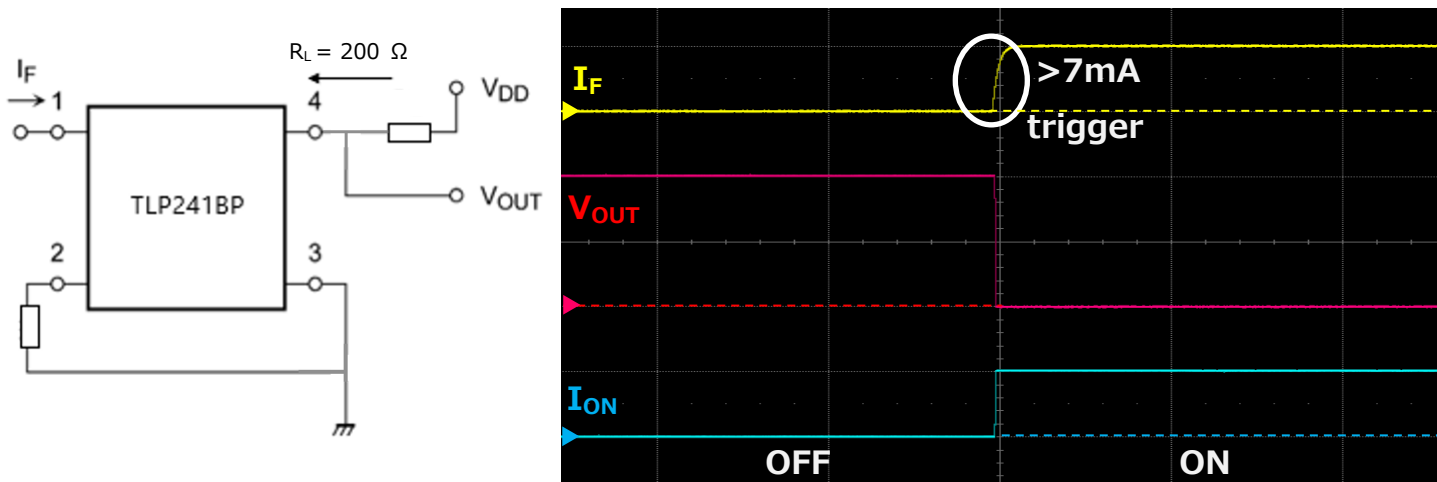


Figure 3.4.1 Measurement circuit and waveform of TLP241BP (normal operation)

Next, raise the ambient temperature  $T_a$  to 160°C using the same circuit as in Figure 3.4.1. While changing the temperature, we can see that the  $I_{ON}$  of the TLP241BP turns off, i.e., shuts down due to overheating, as shown in Figure 3.4.2.

This is because the TLP241BP temperature ( $T_j$ ) exceeds the thermal shutdown temperature  $T_{SD}$  while the temperature is changing.

$I_F$  : 10 mA/div  
 $V_{OUT}$  : 10 V/div  
 $I_{ON}$  : 100 mA/div  
 X axis : 100 ms/div

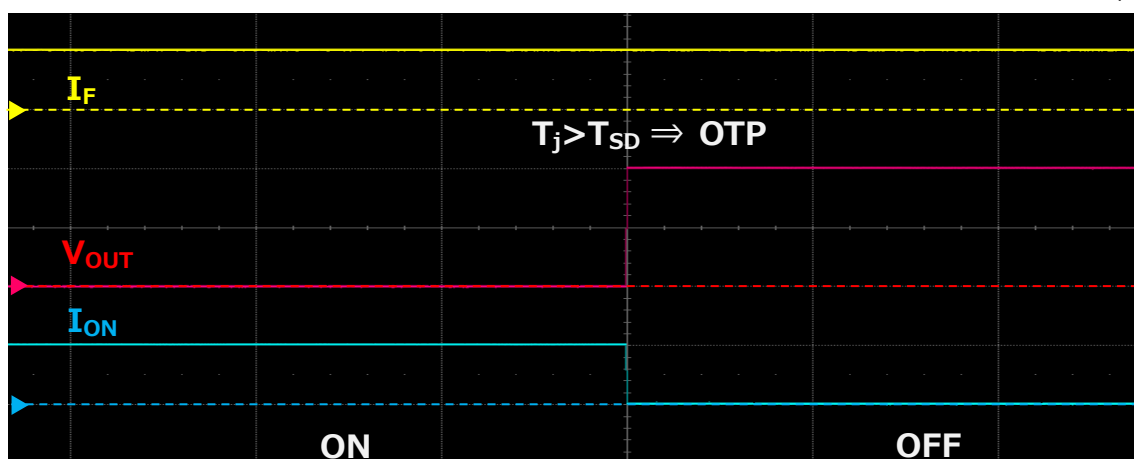
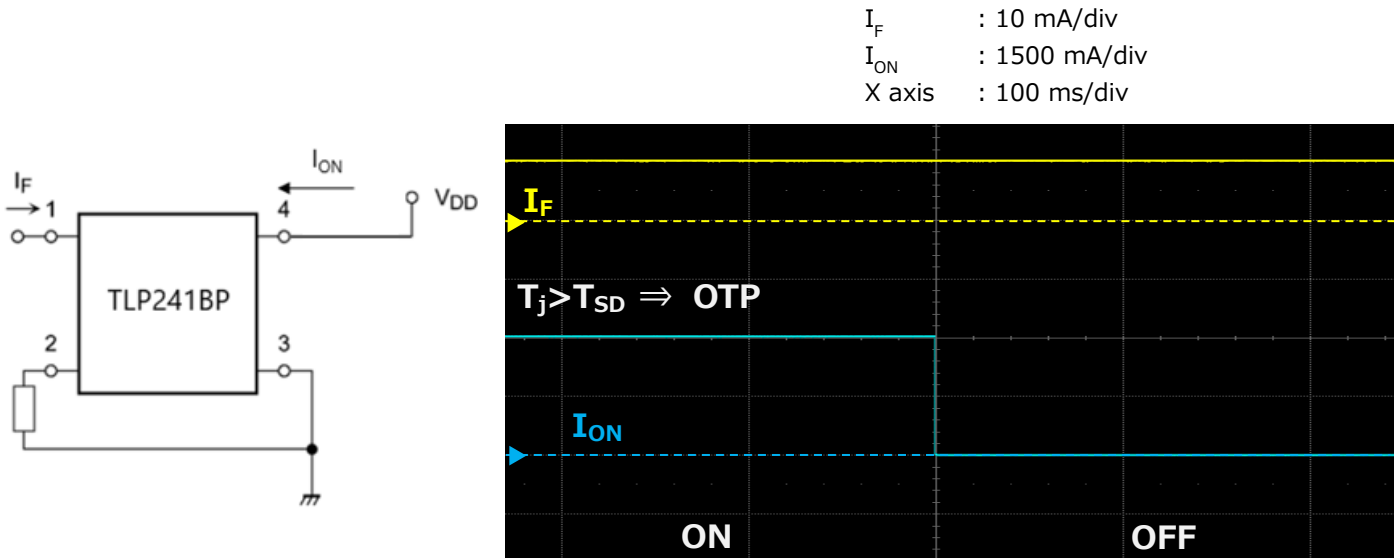


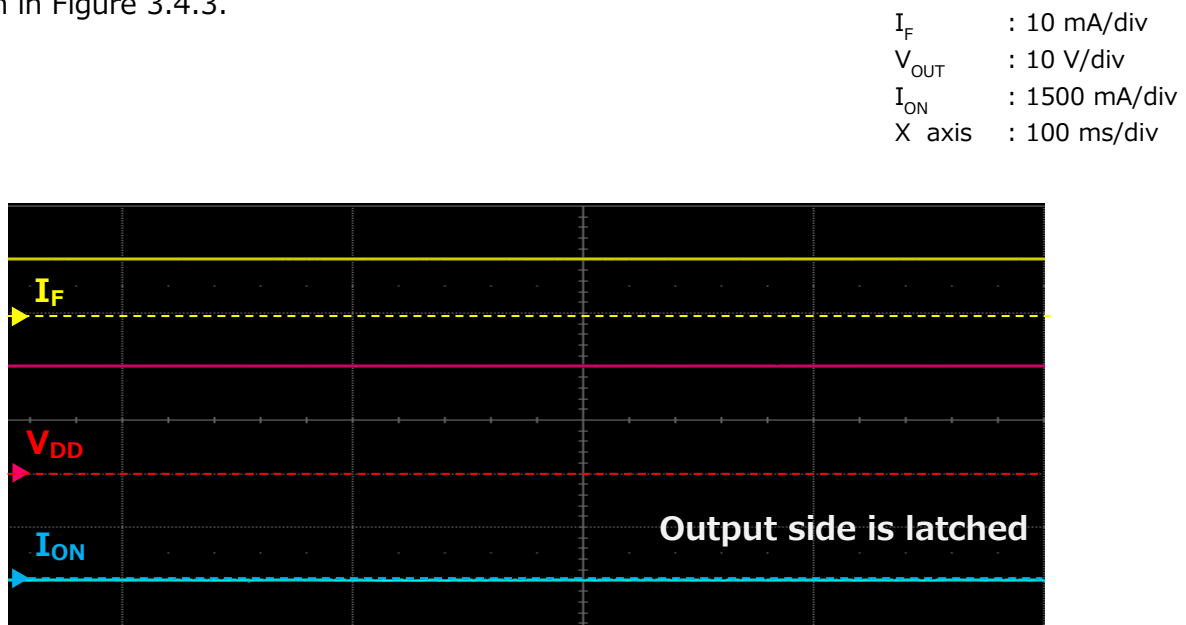
Figure 3.4.2 OTP operation by ambient temperature change

After returning the ambient temperature to room temperature, current is now applied to the output side to heat the TLP241BP by electric power. The rated current is 1.4 A, but 3 A is applied here to activate the protection function. A Figure 3.4.3 right shows the measured waveform.  $I_F$  is 10 mA, which is sufficient, but the output side current has stopped flowing. This is because the temperature of the product rose due to the large current flow, and as a result, the over temperature protection function was activated, and the output side turned off.



**Figure 3.4.3 OTP operation by over current**

With  $I_F$  input, the output side is de-energized ( $I_{ON} = 0$  A) to lower the temperature of the device. Even if the temperature of TLP241BP decreases and  $T_j < T_{SD}$ , the TLP241BP keeps in protection mode (shutdown), so no current flows at the output side even if  $V_{DD}$  is applied, as shown in Figure 3.4.3.



**Figure 3.4.4 Latch off status by OTP**

Resetting  $I_F$  once, resets the over temperature protection (unlatches off) and current flows to the output side again (See Figure 3.4.5).

$I_F$  : 10 mA/div  
 $I_{ON}$  : 1000 mA/div  
 X axis : 100 ms/div

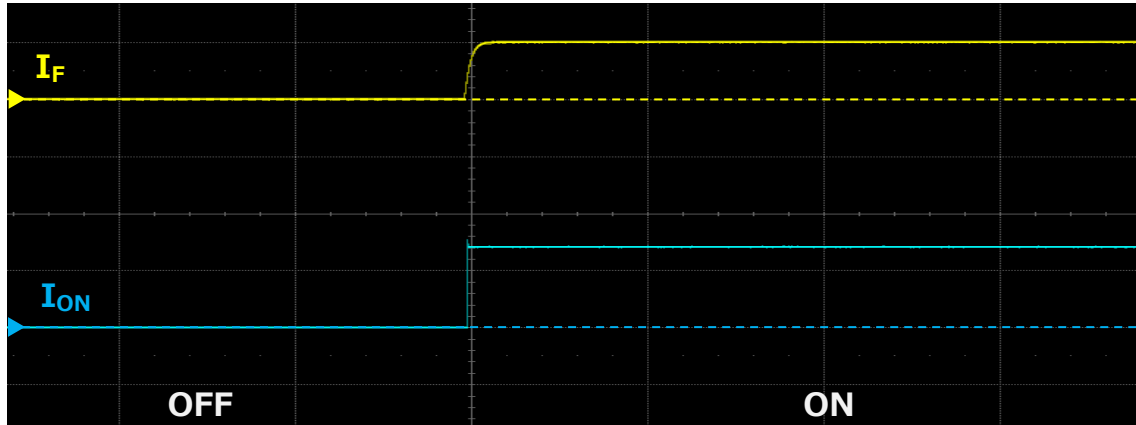
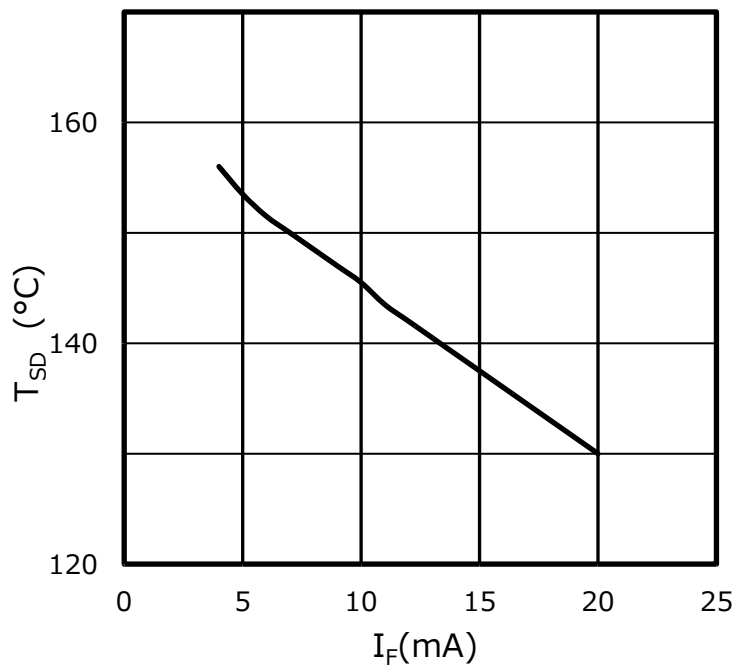


Figure 3.4.5 Latch off released by  $I_F$  reset

**3.5. Depending on  $I_F$  of shutdown temperature  $T_{SD}$**

The shutdown temperature ( $T_{SD}$ ) is change depending on  $I_F$ . Fig 3.5.1 shows the typical characteristic. Recommended operating  $I_F$  is designated as 7 to 14 mA. The recommended operating conditions are given as a design guide necessary to obtain the intended performance of the device.

If  $I_F$  is applied below the lower limit of the recommended operating condition, the over temperature protection function may not work and  $I_F$  is applied higher than the upper limit of the recommended condition,  $T_{SD}$  tends to decrease.



**Figure 3.5.1  $T_{SD}$ — $I_F$  characteristic**

## 4. Over Voltage Protection

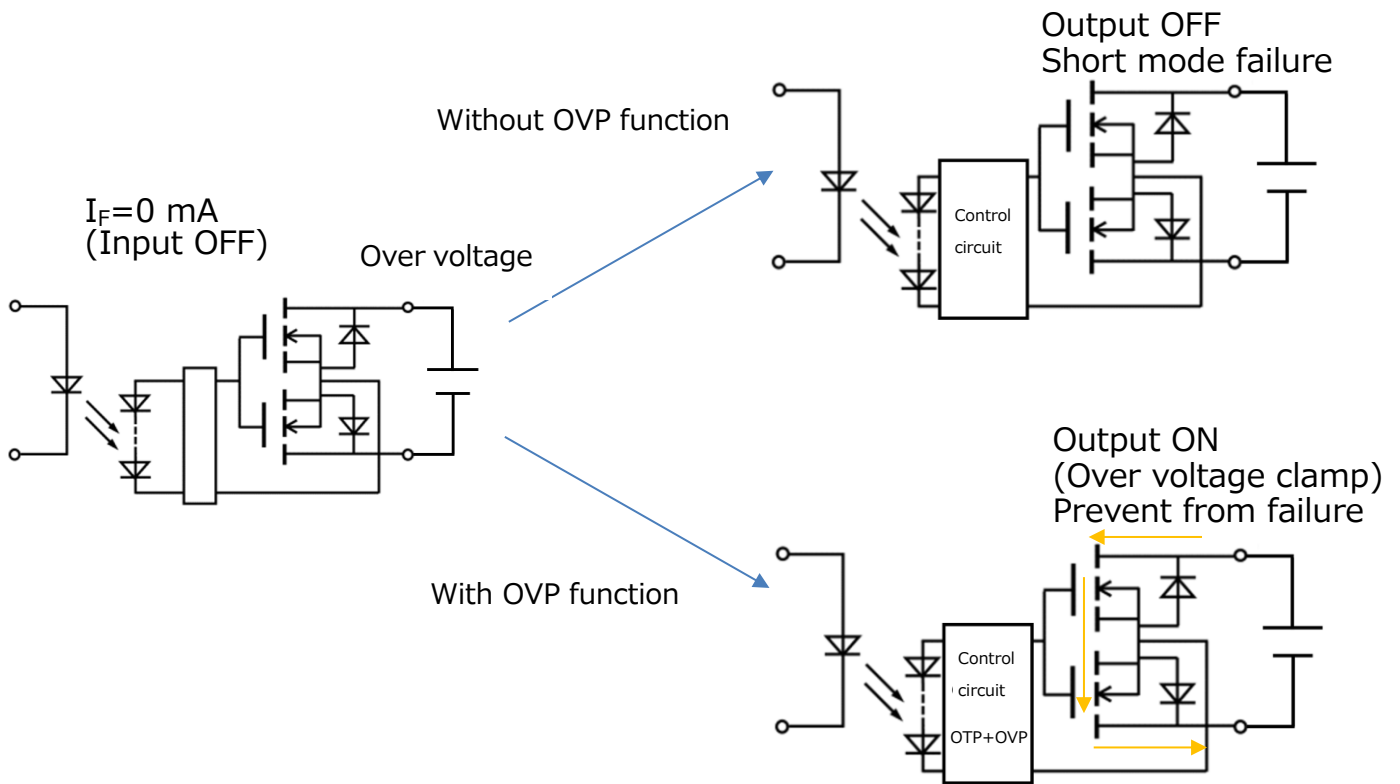
### 4.1. What is an OVP ?

The OVP is a protection function that clamps voltage applied to MOSFETs so that release energy to prevent failure when it is off state and applied over  $V_{OFF}$  voltage from surge and so on. The minimum clamp voltage is "Over Voltage Clamp  $V_{OVC}$ ", the TLP241BP prevents from failure with this protection and contributes to end set safety. This protection function is effective for momentary surge voltage such as generated from inductive loads. Applying high voltage between output terminals continuously may cause failure of the photorelay.

### 4.2. OVP operating principle

Leak current in output MOSFETs is small if applied voltage is lower than  $V_{OFF}$ . However, when applied voltage is higher than  $V_{OFF}$ , a large current flows due to the avalanche breakdown. In that case, if MOSFETs are off, the large current flows with high voltage, leading to the destruction of the MOSFETs.

The OVP function makes a path to MOSFETs gate through active clamp diodes to turning on of the MOSFETs. This mechanism releases energy and protects against overvoltage that destroy the photorelay.

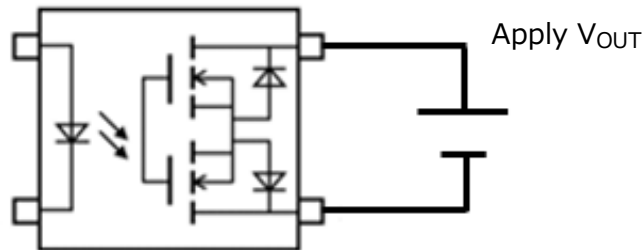


**Figure 4.2.1 Voltage clamp when OVP operates**



### 4.3. Operating waveform of OVP

Let's check actual OVP operation using an oscilloscope. As shown in Figure 4.3.1, input LED current  $I_F$  is not applied and voltage  $V_{OUT}$  is applied to the output side. The red waveform is the output voltage and the yellow one is the output current. Firstly,  $V_{OUT} = 79\text{ V}$  is applied. The clamping voltage of the TLP241BP is  $80 < V_{OVC} < 100\text{ V}$ , it will not clamp at this voltage. This is the same behavior as when  $V_{OFF}$  is applied to a typical photorelay.



V : 40 V/div  
 $I_{OFF}$  : 4 mA/div  
 X axis : 5  $\mu$ s/div

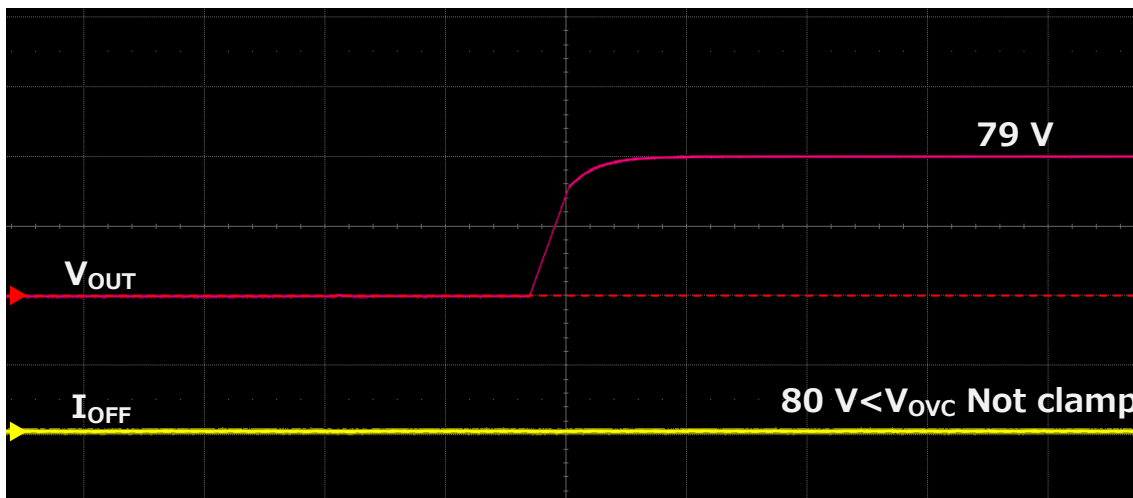


Figure 4.3.1 Applying  $V_{OFF}$  in normal operation

Next,  $V_{OUT} = 100\text{ V}$  is applied. Figure 4.3.2 shows the result. We can see that the voltage between the photorelay output terminals is clamped before reaching 100 V and the voltage is suppressed to 87 V ( $=V_{OVC}$ ). When applying  $V_{OUT}$  of 100 V to a typical photorelay without OVP, the device may fail due to the voltage. In case of the TLP241BP, it protects as shown in the figure. For example, when an inductive surge voltage of about 100  $\mu\text{s}$  is applied, the overvoltage protection activates about 10  $\mu\text{s}$  after the voltage apply, clamping and making a path to release energy to protect the MOSFET from overvoltage.

$V_{OUT}$  : 1 V/div  
 $I_{OFF}$  : 4 mA/div  
 X axis : 5  $\mu\text{s}$ /div

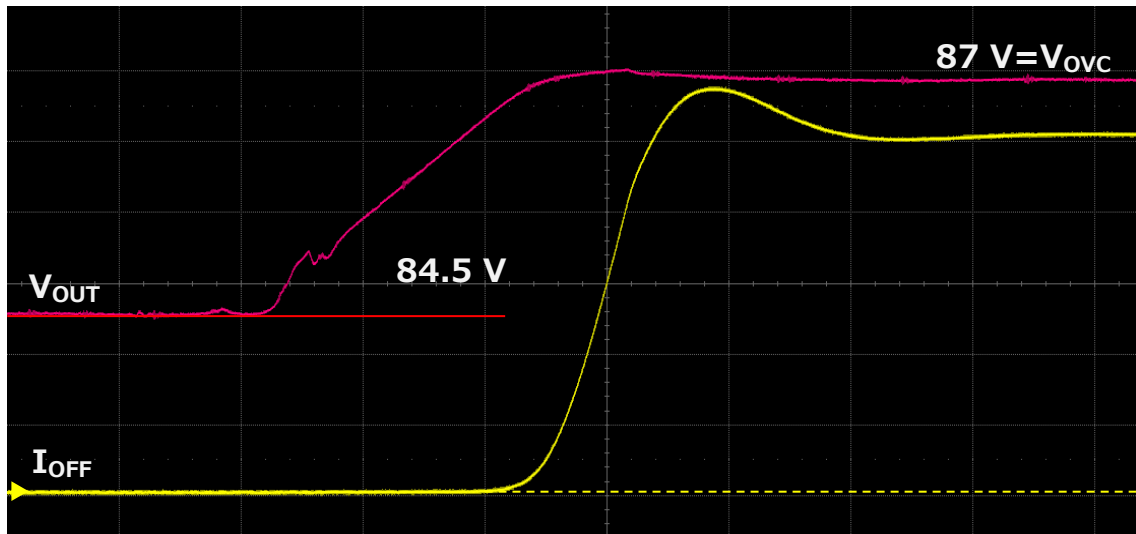


Figure 4.3.2 Waveform of operating OVP

## 5. Precautions for use

The over temperature protection of this device is a function to stop the output current at high temperature, not a function to prevent thermal destruction of the product itself. Therefore, it does not protect against heating from external sources other than current. In addition, the device may be destroyed due to inadequate over temperature protection against sudden heating is the event of a short circuit.

The overvoltage protection of this device is a function to protect against overvoltage for a short period of time. Never apply continuous overvoltage , as the voltage and current may cause of malfunction of the device.

## 6. Conclusion

This document explained about the self-protected photorelay. We will continue to develop products with variety of self-protection type photorelays. Please check the latest product information on our website.

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