Self-protected Photorelay
TLP241BP

Description

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

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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 thare are Photo Diode Aray (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.

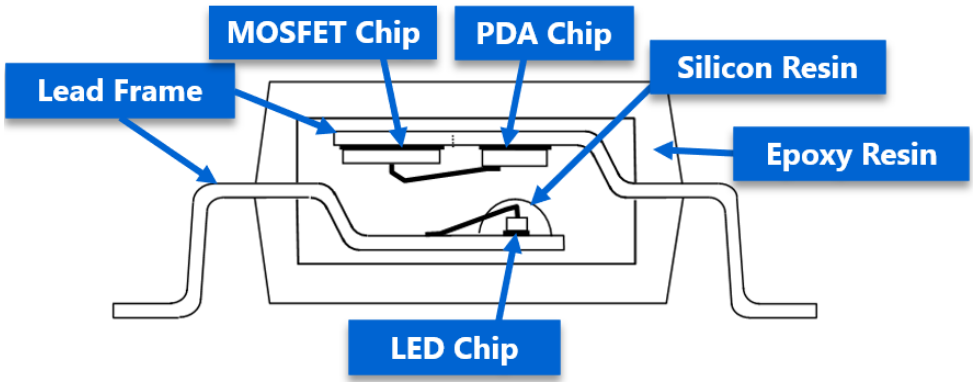

Figure 1.1.1 Photorelay internal structure

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.

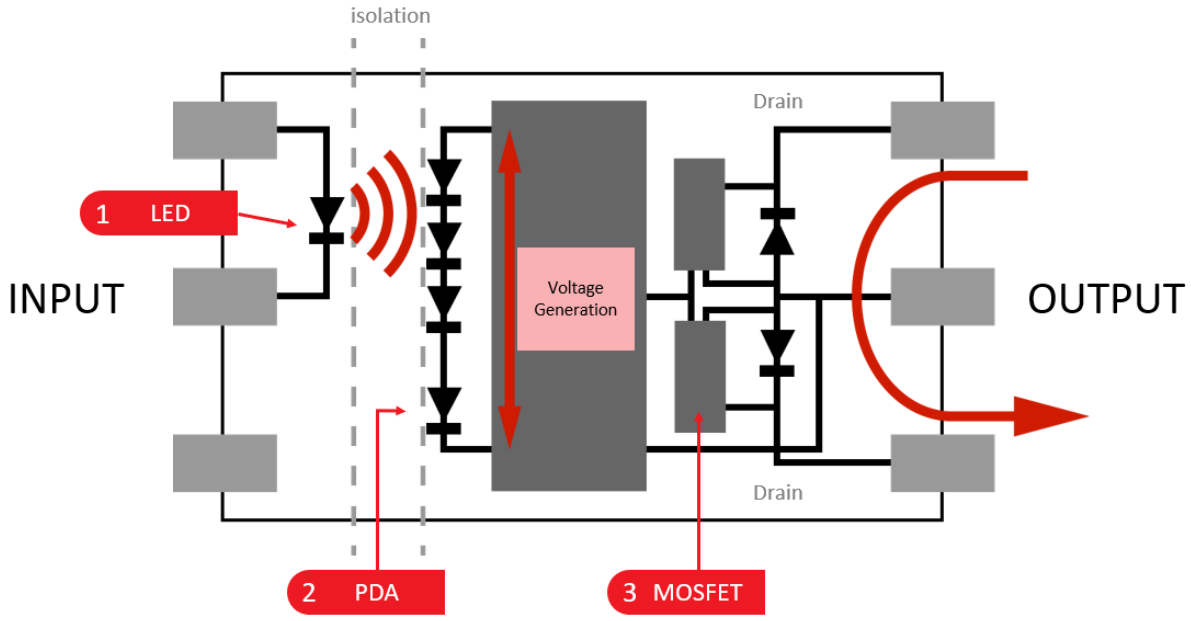

Figure 1.2.1 Operating principle of photorelay

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	Type of protection	TLP241BP
Overheat	Heating by over current Ambient temperature	T_a T_j T_{opr}	Over Temperature Protection (OTP)	Supported
Overvoltage	Back electromotive force	V_{OFF} V_{OVC}	Over Voltage Protection (OVP)	Supported
Overcurrent	Short circuit	I_{ON}	Over Current Protection (OCP)	No Supported (note)

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

<Meaning of above Symbols>

T_a : Ambient temperature
T_j : Junction temperature
T_{SD} : Thermal shutdown temperature
V_{OFF} : OFF-state output terminal voltage
V_{OVC} : Over voltage clamp
I_{ON} : ON-state current

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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 μA
OFF-state current I_{OFF} (max) (V_{OFF}=60 V)	10 μA
ON-state current I_{ON} (max) (V_{OFF}=80 V)	1.4 A
Trigger LED current I_{FT} (max)	3 mA
ON-state resistance R_{ON} (max)	0.28 Ω
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

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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.

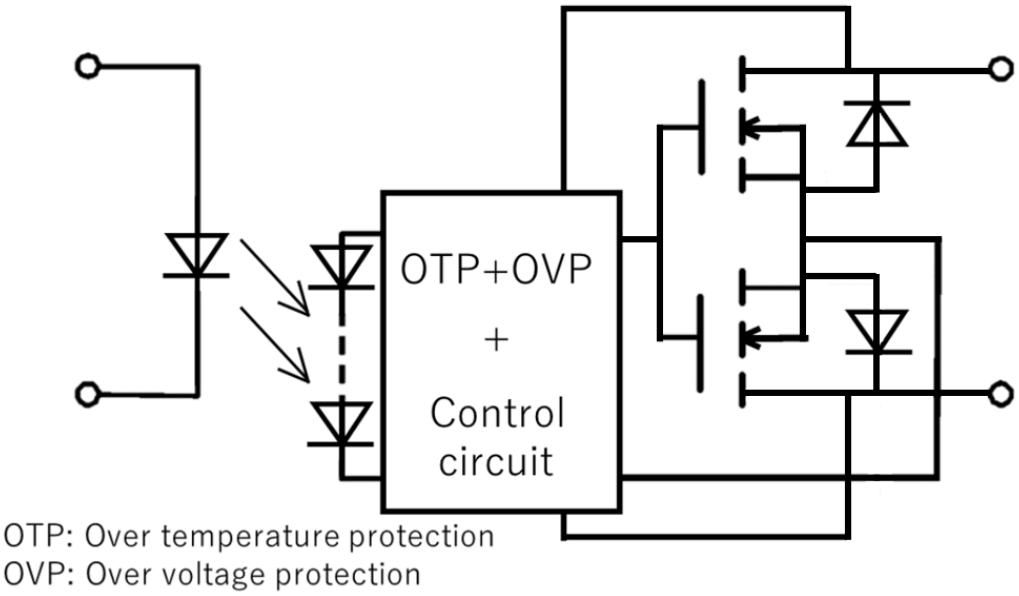


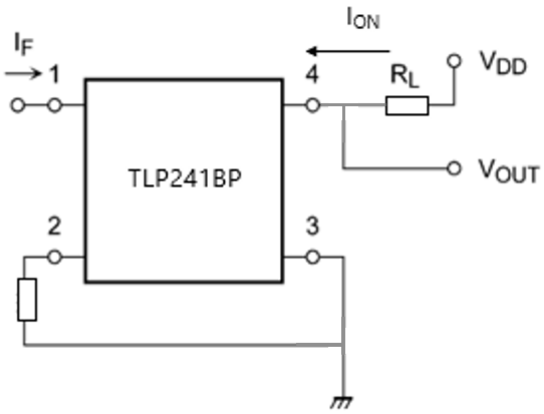
Figure 2.2.1 Internal circuit

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.



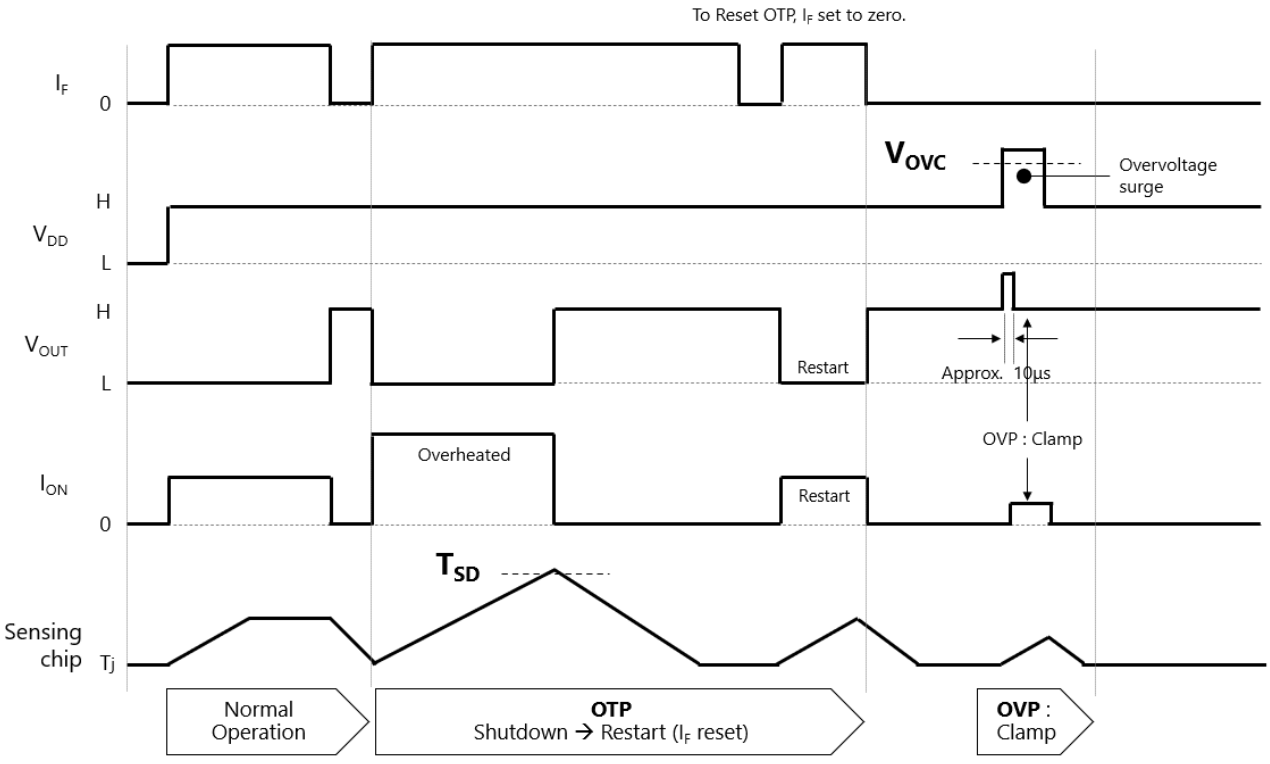


Figure 2.3.1 TLP241BP timing diagram

3. Over Temperture 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.

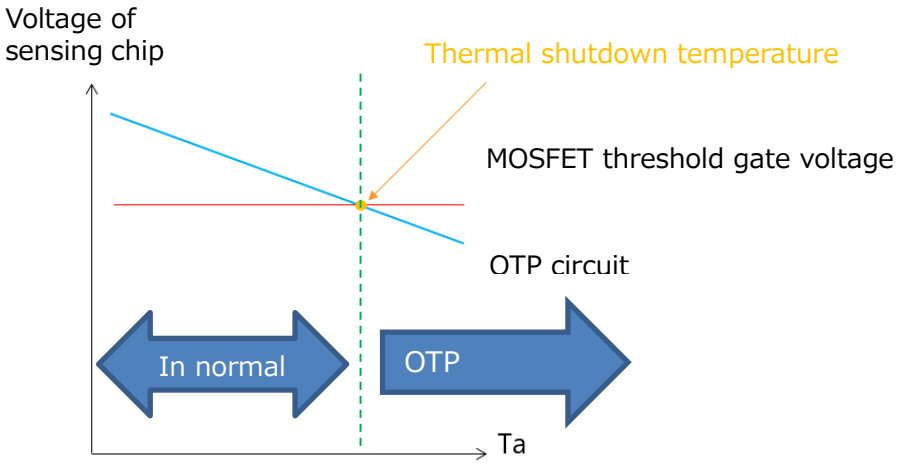


Figure 3.2.1 OTP operation principle

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.

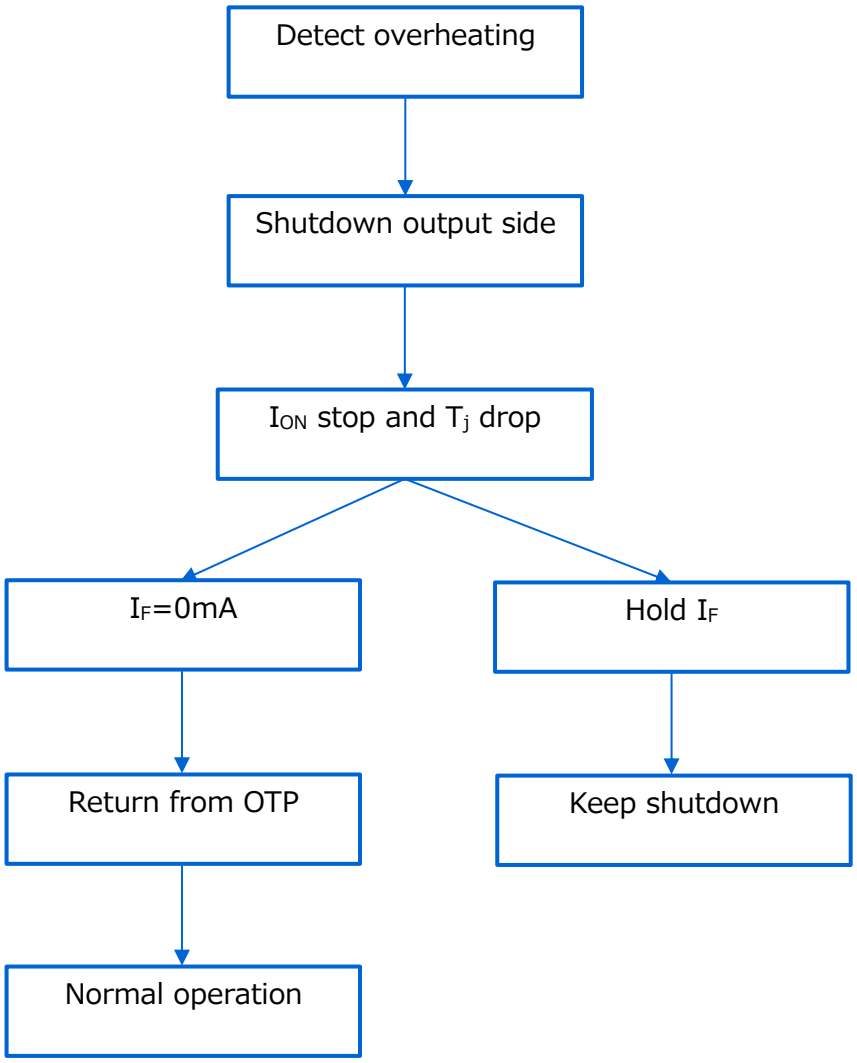


Figure 3.3.1 Method and operation of OTP

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

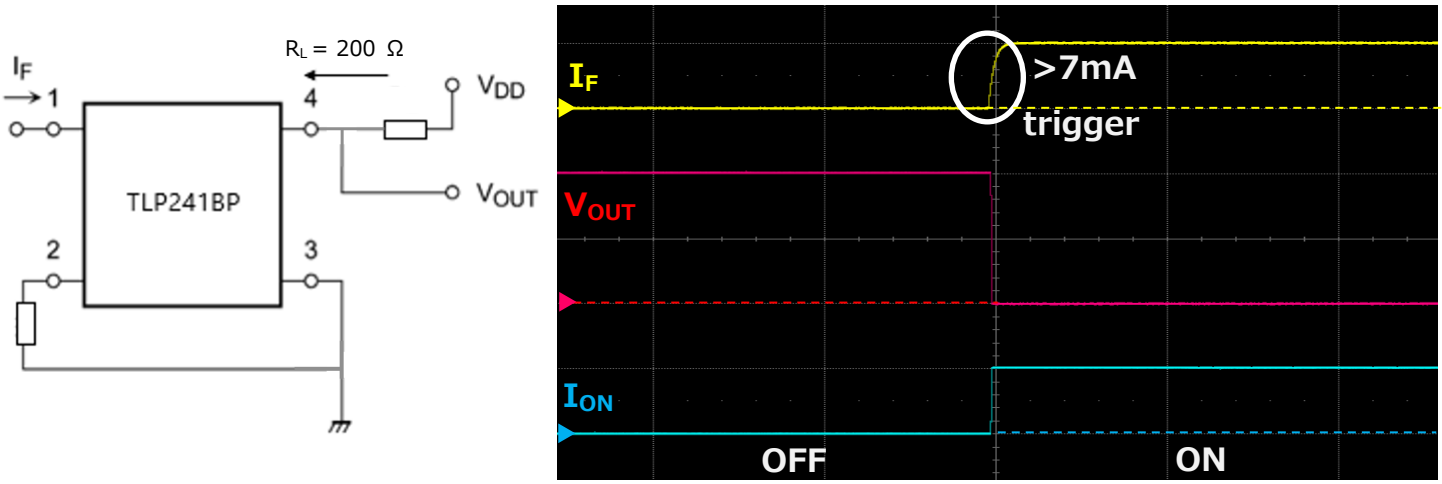


Figure 3.4.1 Measurement circuit and waveform of TLP241BP (normal operation)

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 (Tj) 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

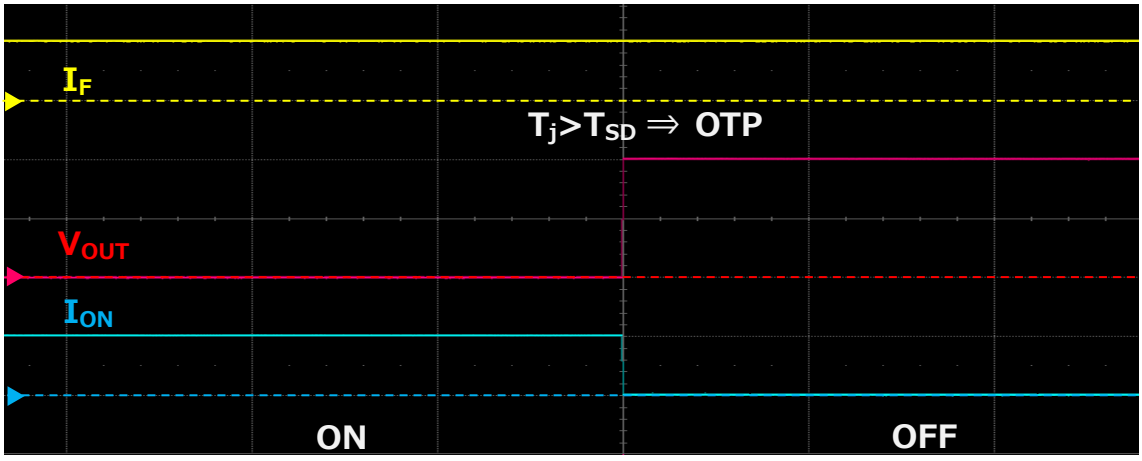


Figure 3.4.2 OTP operation by ambient temperature change

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.

I_F : 10 mA/div
I_{ON} : 1500 mA/div
X axis : 100 ms/div

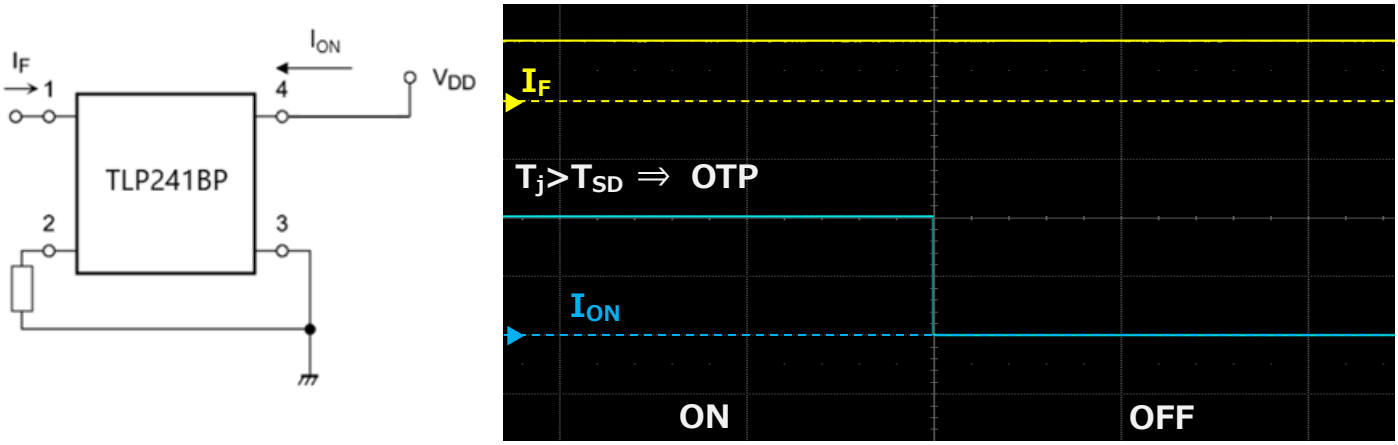


Figure 3.4.3 OTP operation by over current

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.

I_F : 10 mA/div
V_{OUT} : 10 V/div
I_{ON} : 1500 mA/div
X axis : 100 ms/div

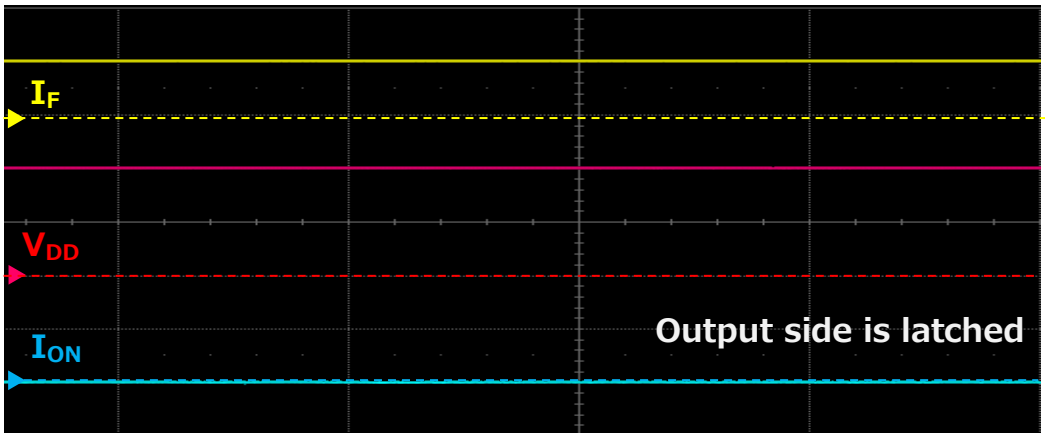


Figure 3.4.4 Latch off status by OTP

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

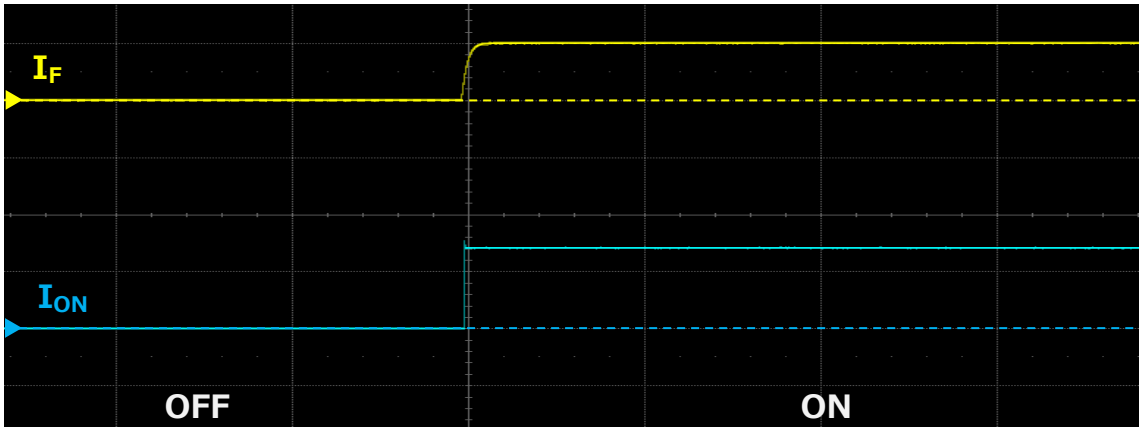


Figure 3.4.5 Latch off released by I_F reset

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.

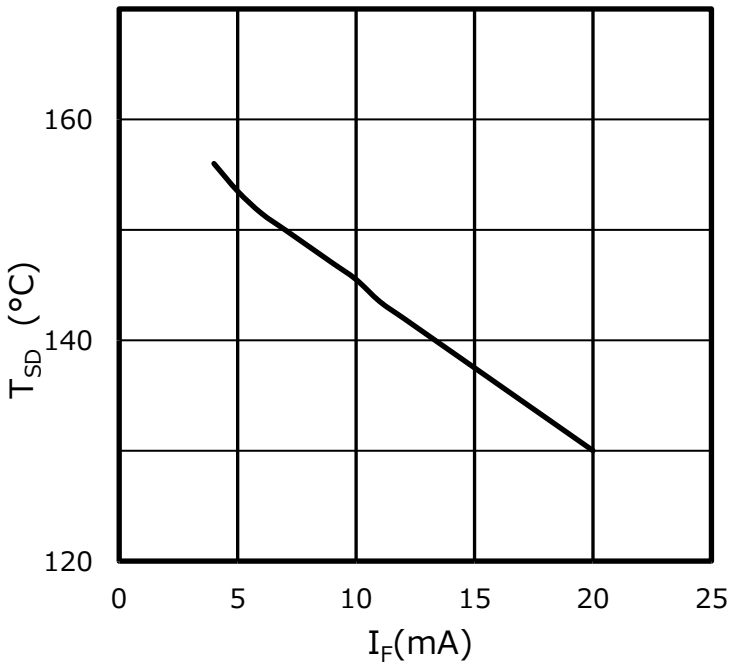


Figure 3.5.1 T_{SD}—I_F characteristic

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.

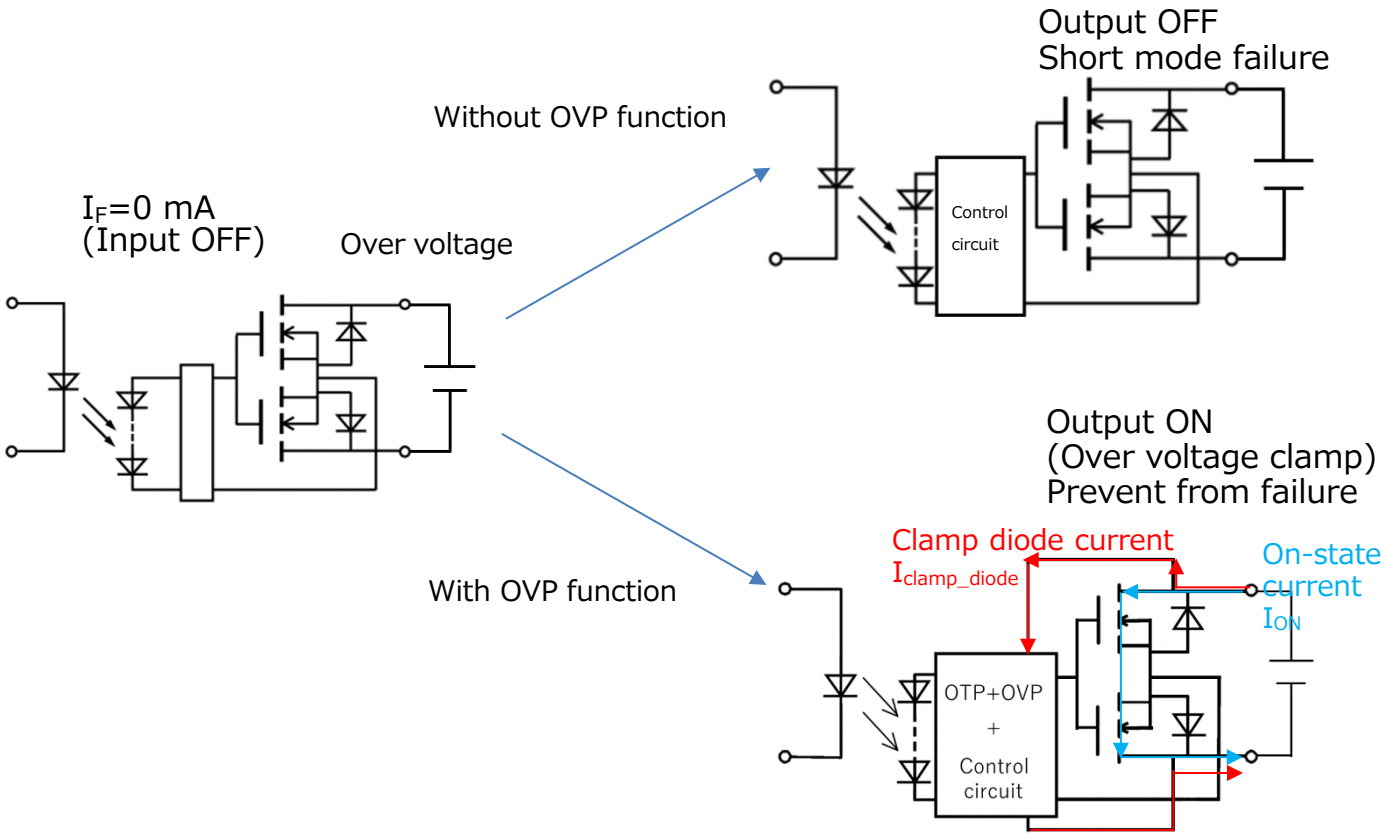


Figure 4.2.1 Voltage clamp operation when OVP occurs

4.3. Operating waveform of OVP

Let's check actual OVP operation according to the circuit from figure 4.3.1. V_{DD} = 85 V, which exceeds the OFF-state output terminal voltage (V_{OFF}) of TLP241BP, is applied for 10ms but LED on input side is OFF. That result is figure 4.3.2 in which yellow waveform, green waveform and blue waveform show V_{DD}, V_{OUT} and I_{ON} respectively. Because the clamping voltage (V_{OVC}) of the TLP241BP is approximately 89 V, it will not clamp when V_{DD} = 85 V; thus, I_{ON} is not flow. If it is a photorelay without OVP function, the overvoltage will cause avalanche breakdown that damages device.

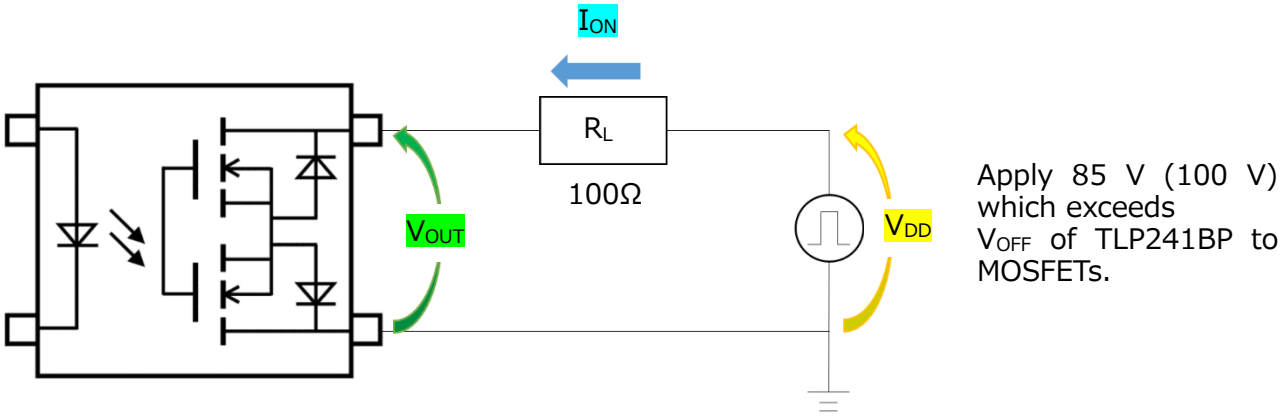


Figure 4.3.1 Circuit for verifying OVP operation

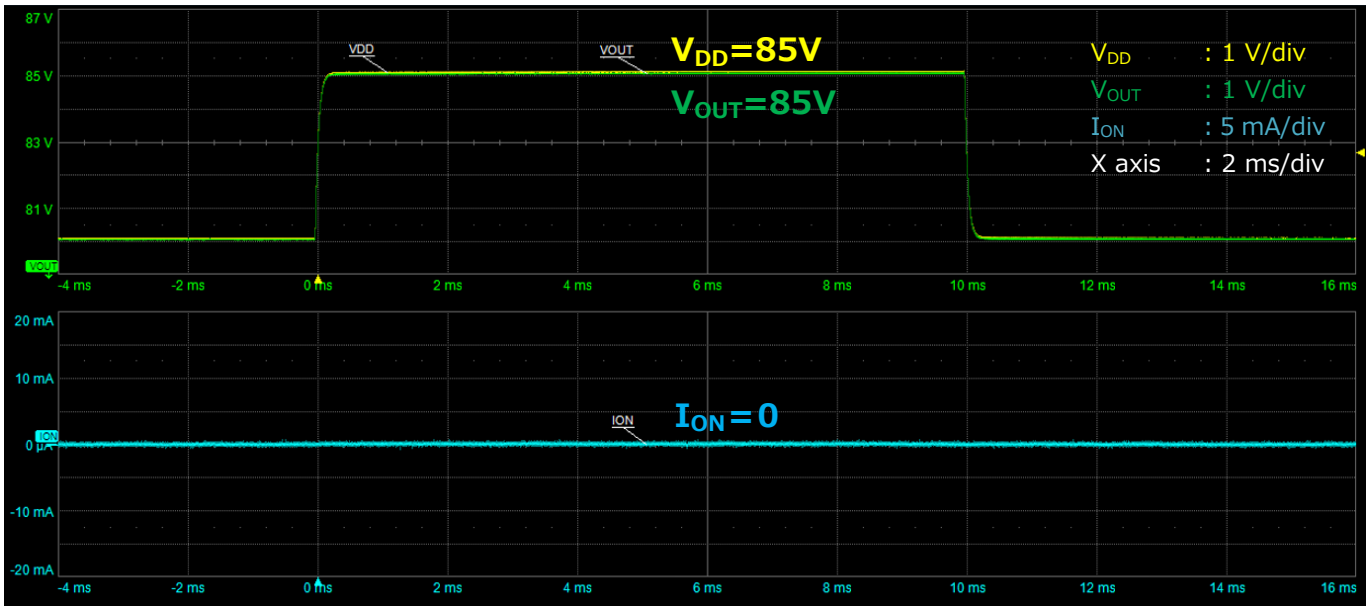


Figure 4.3.2 Waveform when V_{DD} = 85 V

Next, V_{DD} = 100 V (yellow waveform) is applied to MOSFETs of TLP241BP for 10 ms. It is obvious from figure 4.3.3 that V_{OUT} (green waveform) is suppressed to approximately 89V, the clamping voltage V_{OVC}, before it reaches 100V. Under such condition, there is a concern that overvoltage exceeds V_{OFF} of photorelay may damages device seriously. But TLP241BP will temporarily turn on MOSFETs by using clamp diodes, then dissipating energy through the current path to protect MOSFETs. This can also be seen that I_{ON} is flowing at 100 mA.

Figure 4.3.4 shows the rising edge of OVP. It takes about 3 μs that V_{OUT} reaching the clamp voltage for the OVP to start operating. For example, when an inductive surge voltage of about 100V for 50 μs is applied, the OVP function protects photorelay and circuit about 3 μs after applied.

V_{DD} : 5 V/div
V_{OUT} : 5 V/div
I_{ON} : 10 mA/div
X axis : 2 ms/div

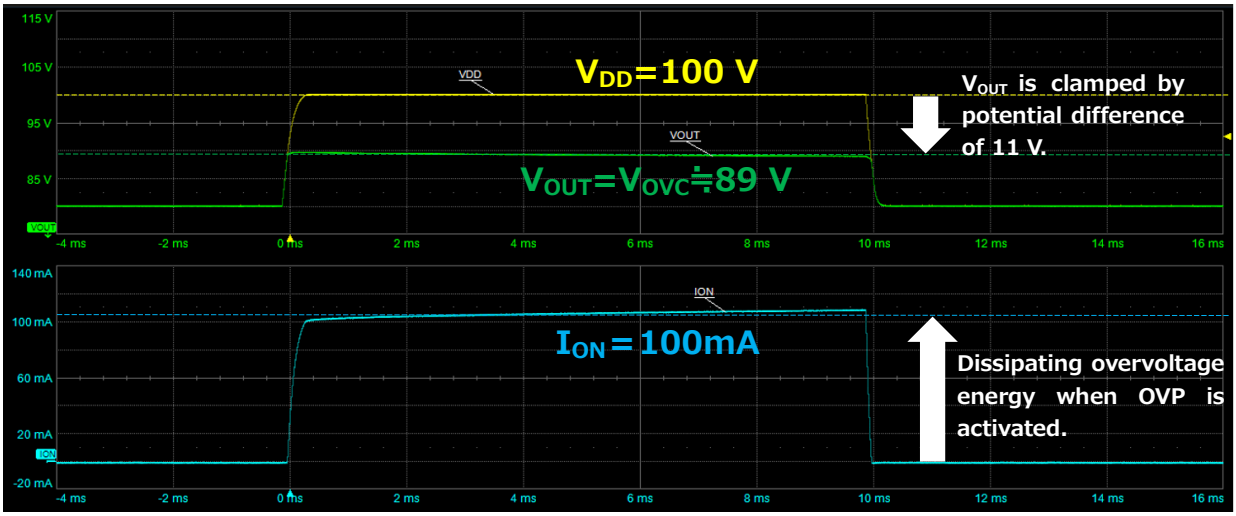


Figure 4.3.3 Waveform when V_{DD}=100V

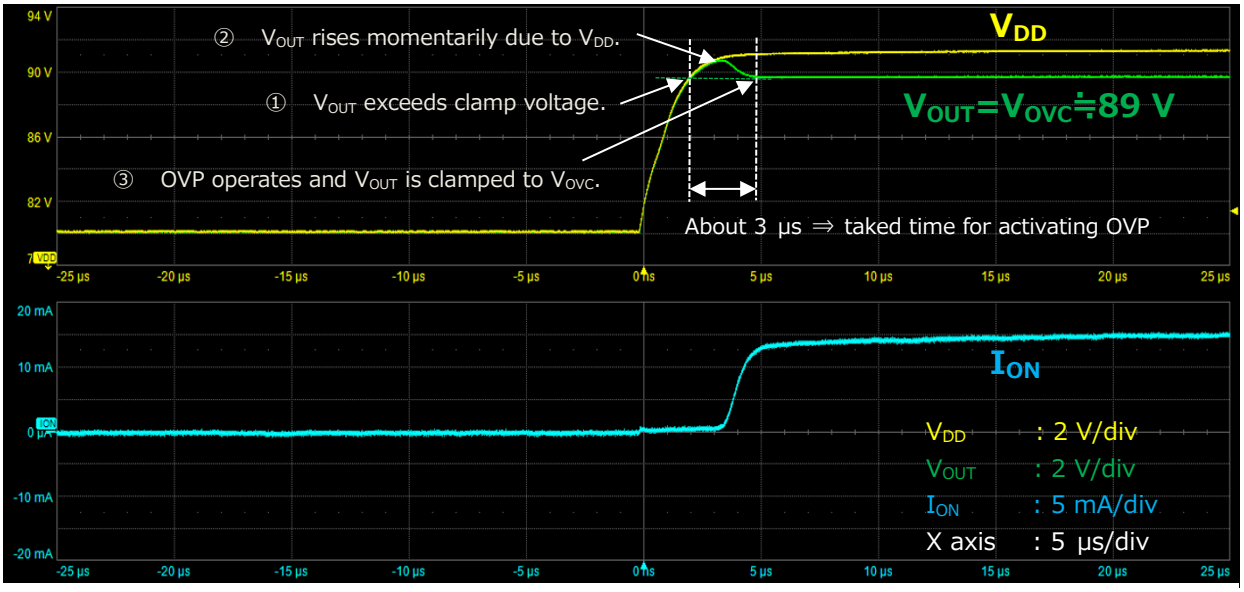


Figure 4.3.4 Rising edge of OVP

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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