Smart gate driver coupler TLP5214A/TLP5214/TLP5212/TLP5222 Application Note -Introduction-

Outline

This document provides an overview of the features of the Smart Gate Driver coupler TLP5214A/TLP5214/TLP5212/TLP5222 as an introduction.

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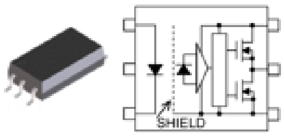
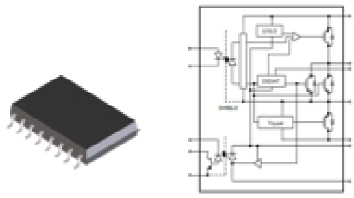
Introduction

TLP5214A/TLP5214/TLP5212/TLP5222 are smart gate driver (hereinafter SGD) couplers with a VCE(sat) detecting function, miller clamping function, FAULT outputting function in addition to a general-purpose gate driver coupler to protect IGBT from overcurrent generated in the inverter applications, etc.
To accommodate multi-functionality, 16-pin SO16L package is used for these products.

In this document, the functional outline of TLP5214A/TLP5214/TLP5212/TLP5222 will be explained.

Table 1. Comparison table of general-purpose gate driver couplers and SGD couplers

	General-purpose gate driver coupler	SGD coupler
Model	TLP5702, TLP5754など	TLP5214A/TLP5214/TLP5212/TLP5222
Package/Internal circuit diagram	SO6L 	SO16L 
Pin count	6pin	16pin
Direct driving of the IGBT gate	✔	✔
UVLO function	✔	✔
$V_{CE(sat)}$ detecting function	-	✔
Active miller clamp	-	✔
FAULT outputting function	-	✔

1. What is overcurrent protection?

Overcurrent protection is to detect abnormal current flowing in the circuit and prevent damage to the circuit.

In particular, if an overcurrent is applied to IGBT used in the inverter circuit, the collector-emitter voltage (V_{CE}) will rise, and destroy IGBT due to that excessive power is applied. Therefore, the overcurrent must be shut off in as short a time as possible. The time from when an overcurrent flows to IGBT until it is destroyed is called the short-circuit tolerance, and the overcurrent must be interrupted within the short-circuit tolerance. Although the short-circuit tolerance varies depending on the product, the design must be made so that the overcurrent is cut off within at least 10µs. In addition, for the safety of humans, many electrical equipment must be equipped with an overcurrent protection function according to safety standards.

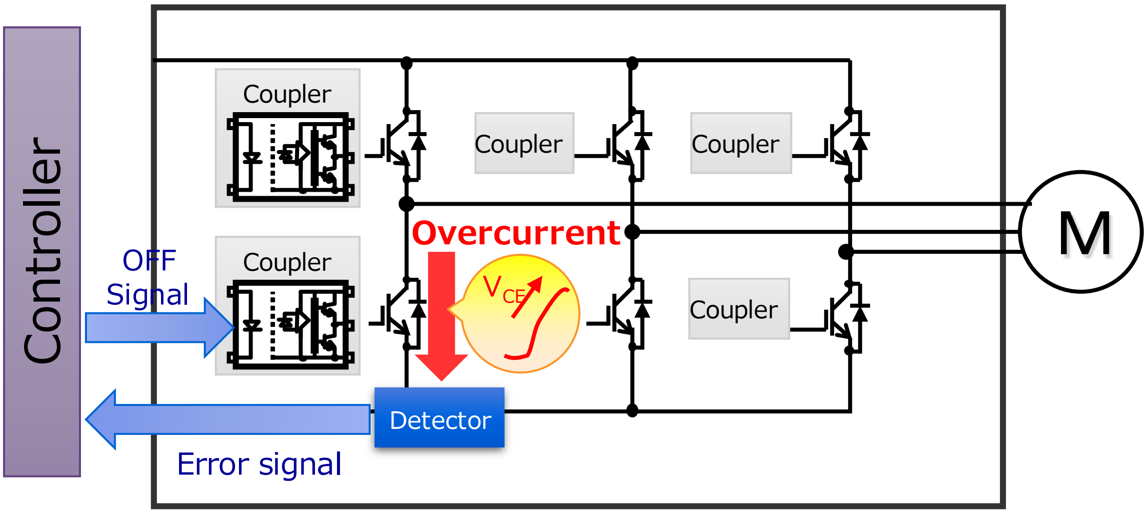


Figure 1. Example of inverter circuit

2. Cause of overcurrent

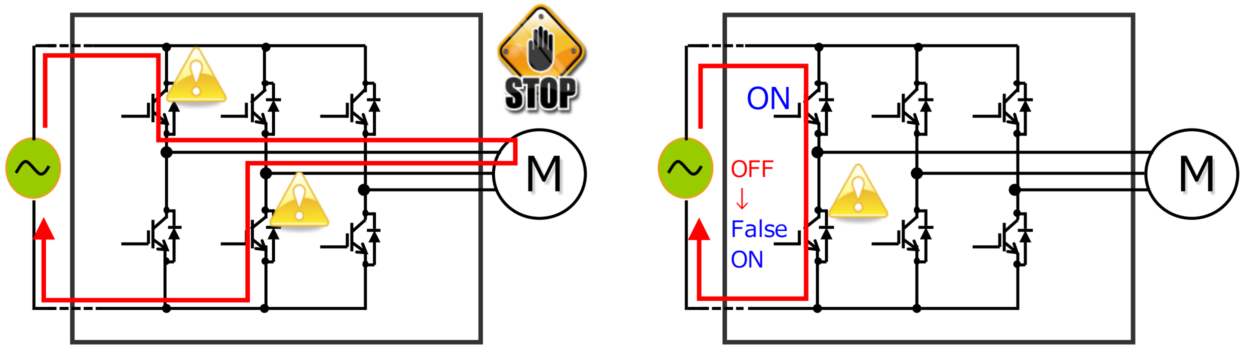
There are various causes of overcurrent, but some typical examples are given here.

2-1. Output short circuit

Excessive current flows between separate arms due to human-induced connection errors or load breakage. Overcurrent also flows when the motor is mechanically constrained by external factors.

2-2. Arm short circuit

The upper and lower arms are short-circuited and overcurrent flows, due to malfunction caused by noise or IGBT malfunction caused by miller current during switching.



(a) Output short circuit

(b) Arm short circuit

Figure 2. Examples of overcurrent generation causes

3. Type of overcurrent protection

There are several ways to prevent IGBT destruction caused by overcurrent. Each of them has different advantages, but especially, the method of monitoring the saturation voltage $V_{CE(sat)}$ shown in Fig. 3(c) have the merits of lower power dissipation and faster operation because the protective operations are performed in IGBT driving circuitry.
TLP5214A/TLP5214/TLP5212/TLP5222 are IGBT driver photocouplers with a built-in protective circuitry that monitors $V_{CE(sat)}$.

a) Current transformer

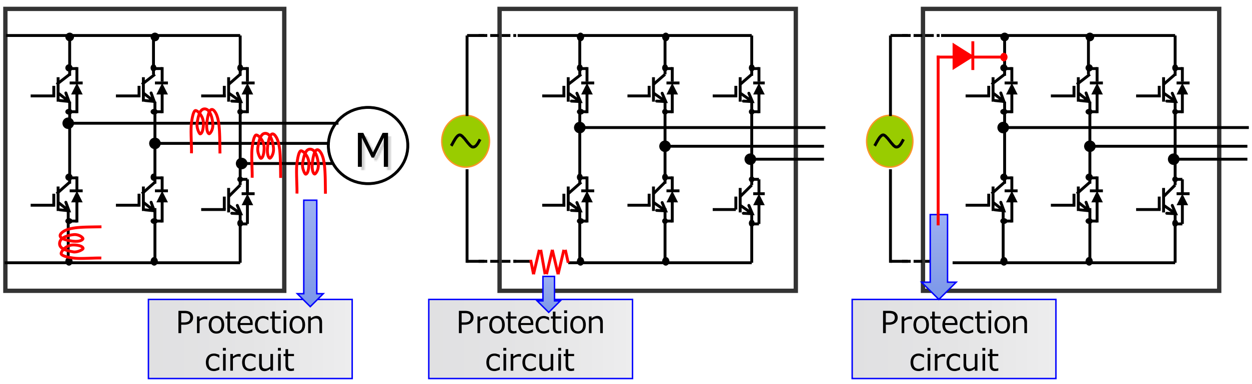
Current transformer is used to monitor the currents in inverter circuitry. Electrical isolation is not necessary, but it may be physically too large.

b) Current sense resistor

A metallic resistor for sensing the current is used to monitor the current. Insulation is needed. Although relatively small, it produces large power losses due to the load current.

c) $V_{CE(sat)}$ monitor

A high voltage diode is used to monitor the collector-emitter voltage. This method provides low power loss, relatively inexpensive, and fast operation.



a) Current transformer **b) current sense resistor** **c) $V_{CE(sat)}$ monitoring**

Figure 3. Type of overcurrent protection

4. Example of protection circuitry using general-purpose / SGD couplers

Fig. 4 shows an illustration of the example of protective circuitry by Fig. 3(c) $V_{CE(sat)}$ monitoring using a general-purpose driver-coupler TLP5702.

In the protective circuit, $V_{CE(sat)}$ is monitored through diode D_1, and when an overcurrent occurs, the gate signal of IGBT is softly turned OFF.

A 1Mbps high-speed coupler is used to transmit FAULT signals to the controller. External component in the protection circuits are complex and use much areas in the board, but SGD couplers are the photo couplers that integrate these functions into one package, and offers smart gate-drive and protection circuitry.

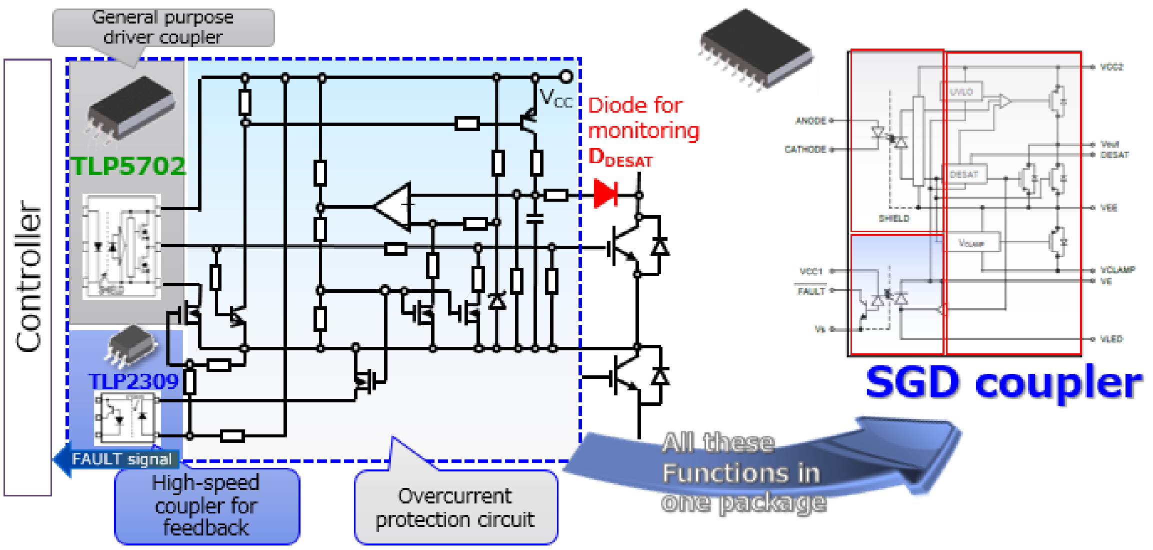


Figure 4. Example of protection circuitry using general-purpose / SGD couplers

5. Functional explanation of the SGD coupler

5-1. Outline of protection operation

TLP5214A/TLP5214/TLP5212/TLP5222 monitors IGBT collector-emitter voltage (V_{CE}) on DESAT pins. Normally, when IGBT is ON, $V_{CE(sat)}$ is about 2V. In the event of overcurrent, $V_{CE(sat)}$ increasing causes the DESAT – VE pin-to-pin voltage (V_{DESAT}) exceeds the threshold of 6.5 V (Typ.), and the following two-stage overcurrent protection sequence will be carried out by the SGD couplers.

① Soft shutdown of V_{OUT} (gradual transition to OFF status) to prevent IGBT breakdown due to the overcurrent;

② Fault signal transfer to controller.

While most driver couplers take several microseconds to generate the fault signal to the controller and shut down LED signal/coupler output, the TLP5214A/TLP5214/TLP5212/TLP5222 are able to initiate the V_{OUT} shutdown in less than 500 ns, and are therefore suitable for designing quick and safety circuits.

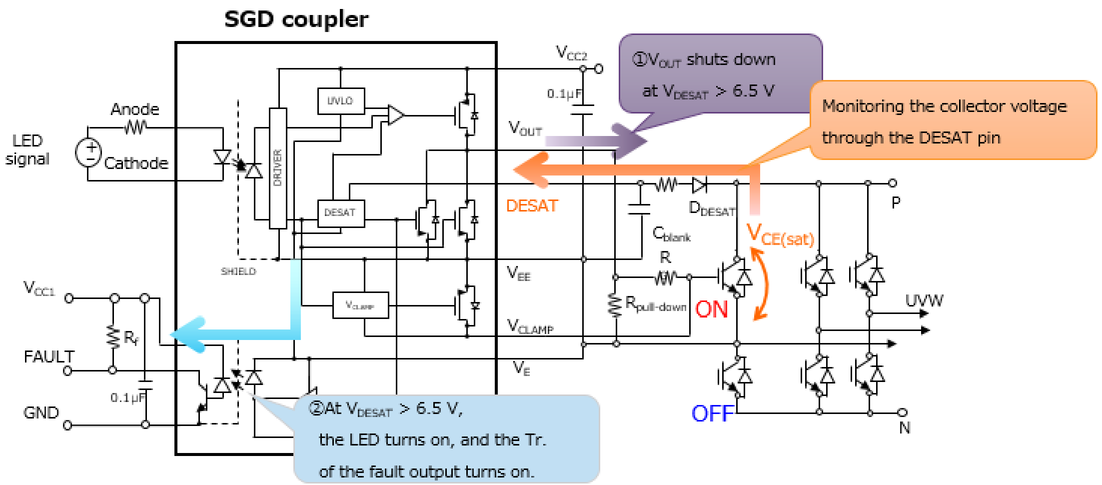


Figure 5. Outline of the protective function of SGD coupler

5-2. Fault signal reset method

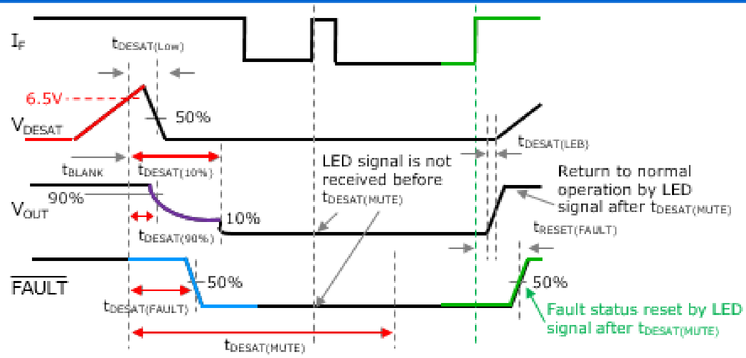
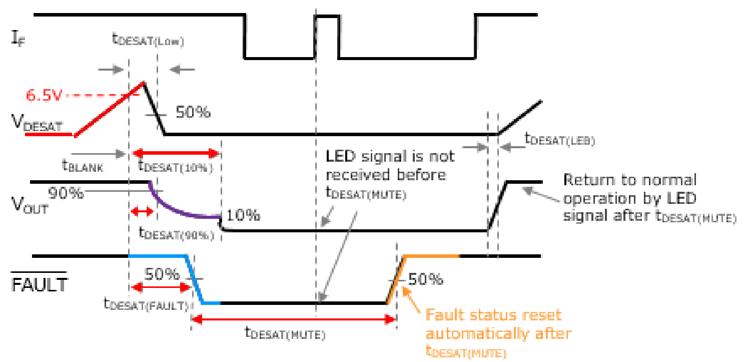
Once the protection operation is triggered, the LED signal is not received by SGD couplers for a preset period. This period is denoted $t_{DESAT(MUTE)}$. There are two types of resetting methods for Fault signal during protection operation.

① LED trigger: The New LED signal, arising after $t_{DESAT(MUTE)}$, initiates reset procedure.
TLP5214A/TLP5214/TLP5212 are applicable.

② Automatic: Automatically initiates reset procedure after $t_{DESAT(MUTE)}$.
TLP5222 is applicable.

The timing chart of Protection and fault signal reset are shown in Table 2

Table 2. Protection and Fault signal reset procedure timing chart

<table>
<tr><th>Reset type</th><th>Protection and reset procedure timing chart</th></tr>
<tr><td>LED trigger (TLP5214 / TLP5214A / TLP5212)</td><td>
</td></tr>
<tr><td>Automatic (TLP5222)</td><td>
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</table>

For the LED trigger reset type, resetting Fault signal is linked with LED signal. Therefore, a command from the controller is required. On the other hand, for the automatic reset type, Fault signal is automatically reset over time, which simplifies the sequencing setting in the controller.

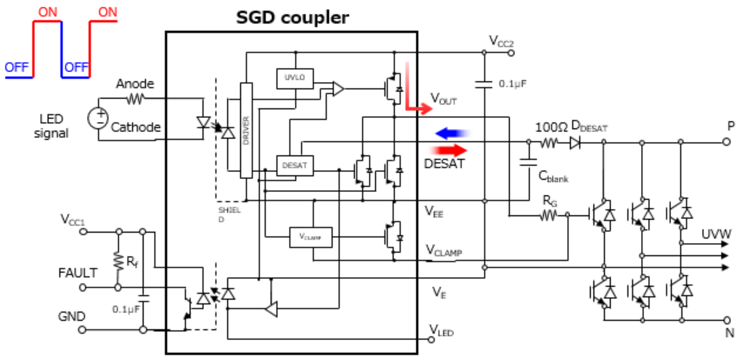
5-3. Normal operation

a) When the LED signal is OFF

VOUT is Low and DESAT pin is inactive. FAULT isn't sent even if more than the V_{DESAT} voltage is applied to the DESAT pin.

b) When the LED signal is ON

VOUT is High and the DESAT pin is active. The above protection operation is triggered when an overcurrent condition occurs.



LED	DESAT terminal	FAULT output	V_{OUT}
OFF	Inactive	High	Low
ON	Active Low (< V_{DESAT})	High	High
ON	Active High (> V_{DESAT})	Low (FAULT)	Low

Figure 7. List of DESAT Pin Operation in Normal Operation

5-4. Malfunction due to miller capacity, and the prevention

Malfunctions caused by a parasitic miller capacitance between the collector and gate of IGBT C_{CG}, should be mentioned as one of the malfunctions due to switching noise in the inverter circuitry. This malfunction mechanism and the active miller clamp function on the SGD coupler are explained here.

When IGBT of the upper arm in the inverter circuitry is turned on, the V_{CE} of the IGBT of the lower arm rises sharply.

At this time, the displacement current $I_S=C_{CG}$ x (dV_{CG}/dt) is generated via C_{CG} of IGBT of the lower arm and flows toward the output of the photocoupler, and the gate voltage of IGBT rises due to that I_S flows through R_G. Due to this voltage rising of gate, IGBT will be erroneously turned on, and this induces a short circuit in the upper and lower arms.

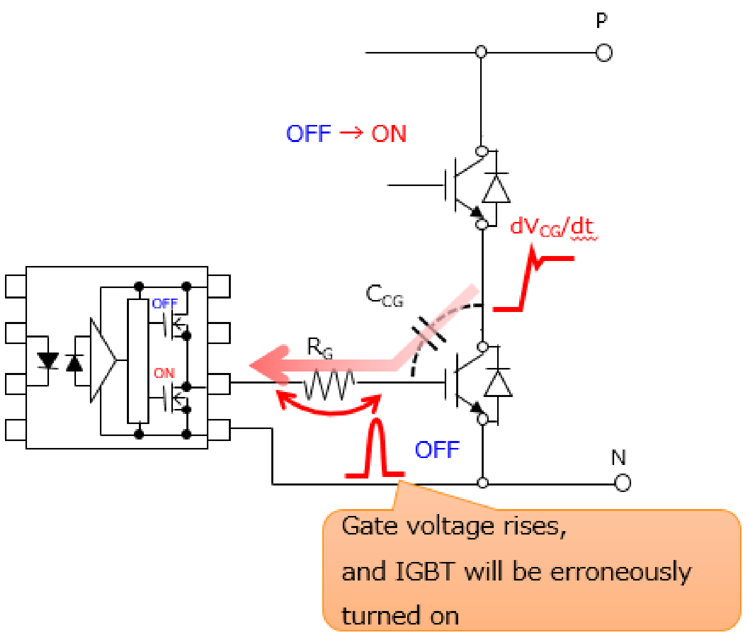


Figure 8. Illustration of malfunction due to miller capacity

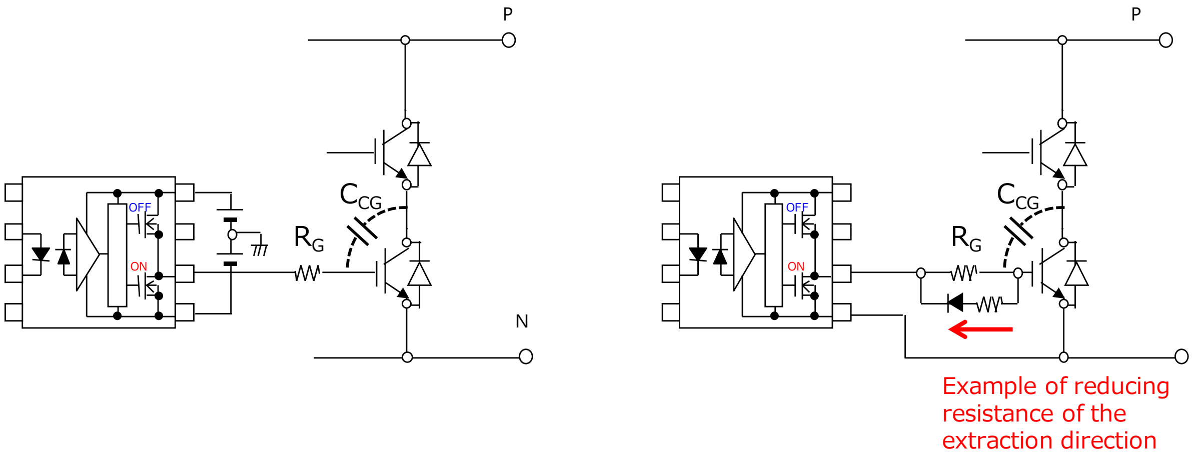
Below are two methods to prevent a malfunction due to miller capacitance. The 1st involves using a negative power source. The 2nd involves adjusting the gate resistance.

a) Use of negative power supply

Using a negative supply voltage for the photocoupler's power source prevents this malfunction because the gate has a negative voltage when the IGBT is off. Since this solution requires a negative power supply circuit, cost and size can be an issue.

b) Adjusting the gate resistance

The increasing in gate potential can be minimized by using a smaller gate resistance. Although this solution is less inexpensive than using a negative power supply, switching noise may increase.



a) Use of negative power supply **b) Adjusting the gate resistance**

Figure 9. Example of prevention of malfunction due to miller capacity

5-5. Active Miller Clamp Function

Another way to prevent malfunction due to miller capacitance C_{CG} is to short the gate-emitter of IGBT. Constructing a circuit that clamps the gate safely with external components becomes complicated and requires a large board area (see page 5). SGD couplers has a built-in function to connect the gate-emitter of IGBT called the active miller clamping function, so there is no need for clamping circuitry with external components. The miller clamp pin V_{CLAMP} is connected to the gate terminal of IGBT. When the output of the photocoupler switches from High to low and the gate voltage falls below approximately 3V, MOSFET between V_{CLAMP}-V_{EE} turns ON and the gate is clamped to the emitter (V_{EE}). By bypassing the miller current from V_{CLAMP} pin to the emitter, the rise of the gate voltage is suppressed and the short circuit of the upper and lower arms of inverter will be prevented.

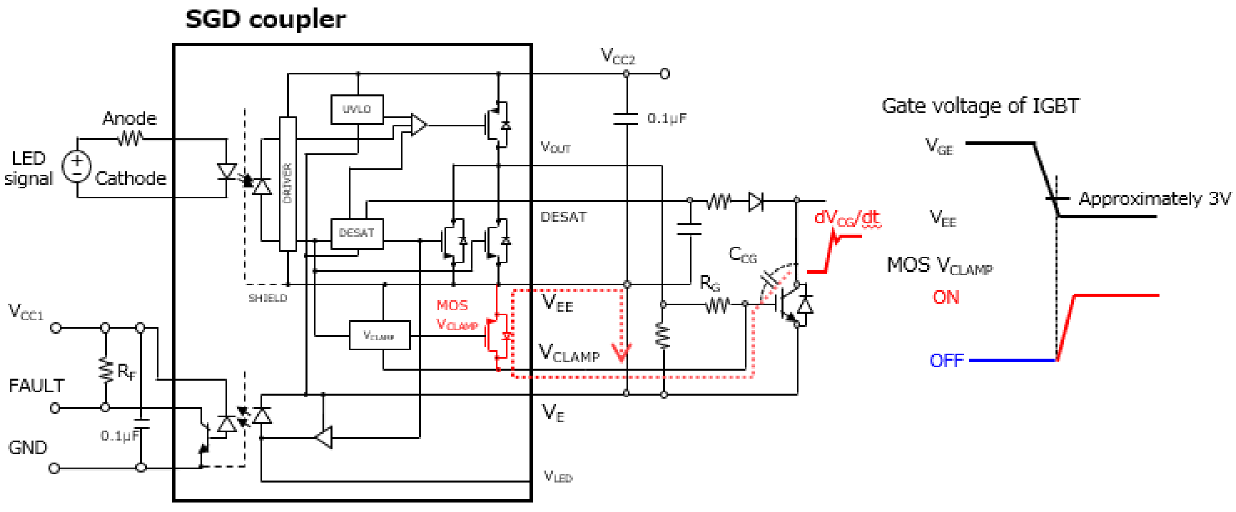


Figure 10. Illustration of Active Miller Clamp Operation

6. Application

TLP5214A/TLP5214/TLP5212/TLP5222 are suitable for applications which need inverter such as industrial inverters, PV inverters, UPSs, BMSs, etc.

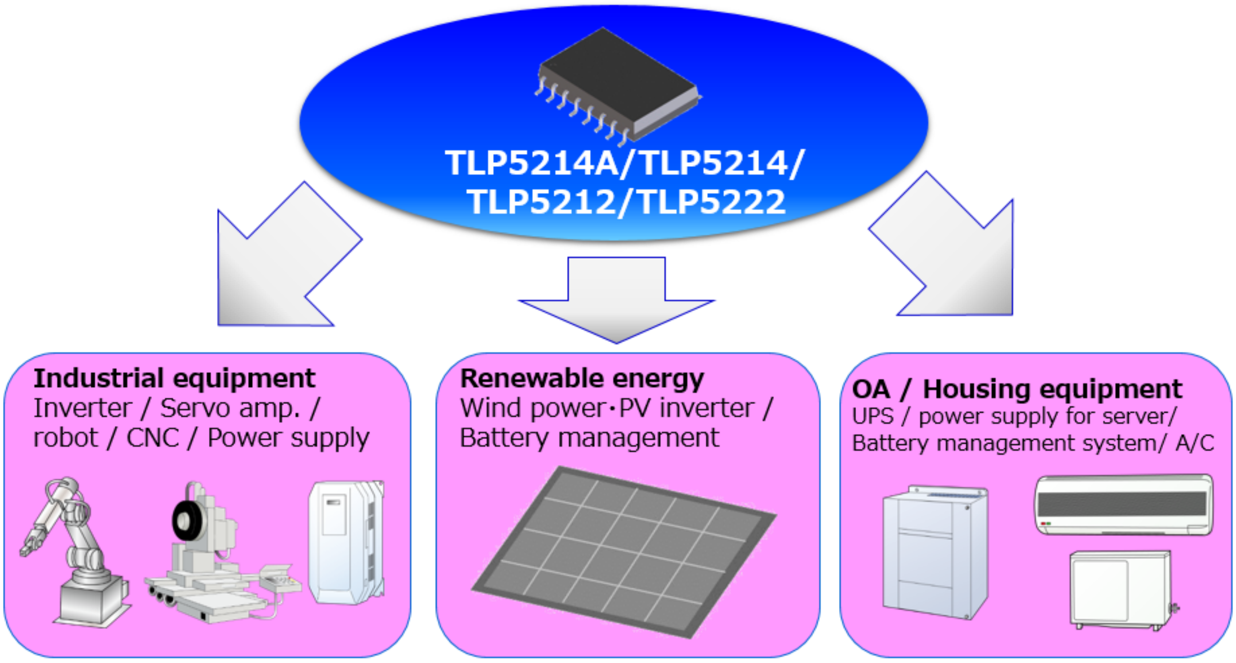


Figure 11. Application example of TLP5214A/TLP5214/TLP5212/TLP5222

Revision History

Revision	Date	Page	Description
Rev. 1.0	2014-8-12	-	1st edition
Rev. 1.1	2014-9-9	P2,9	Revision due to the correction of errors
Rev. 2.0	2021-3-2	All pages	Revision due to the format changes
Rev. 2.1	2021-5-19	P2, 4, 10, 11, 12	Revision due to the correction of errors
Rev. 3.0	2022-4-21	All pages	Postscript for TLP5212/TLP5222 and protection operation reset type

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