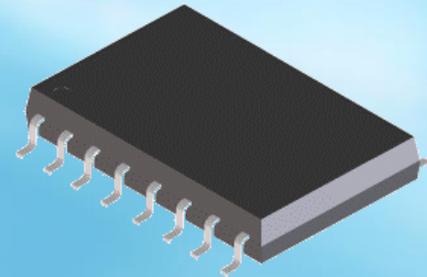


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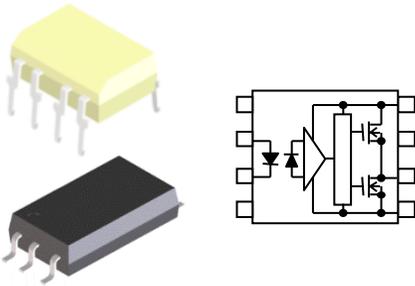
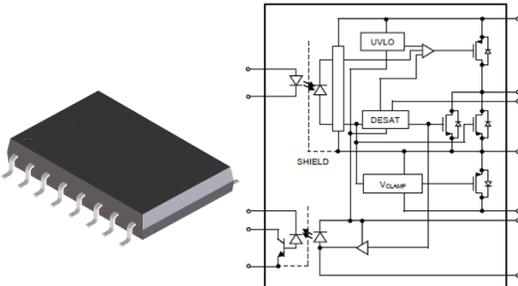
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Smart Gate Driver Coupler TLP5214 Application Note -Introduction-



Introduction

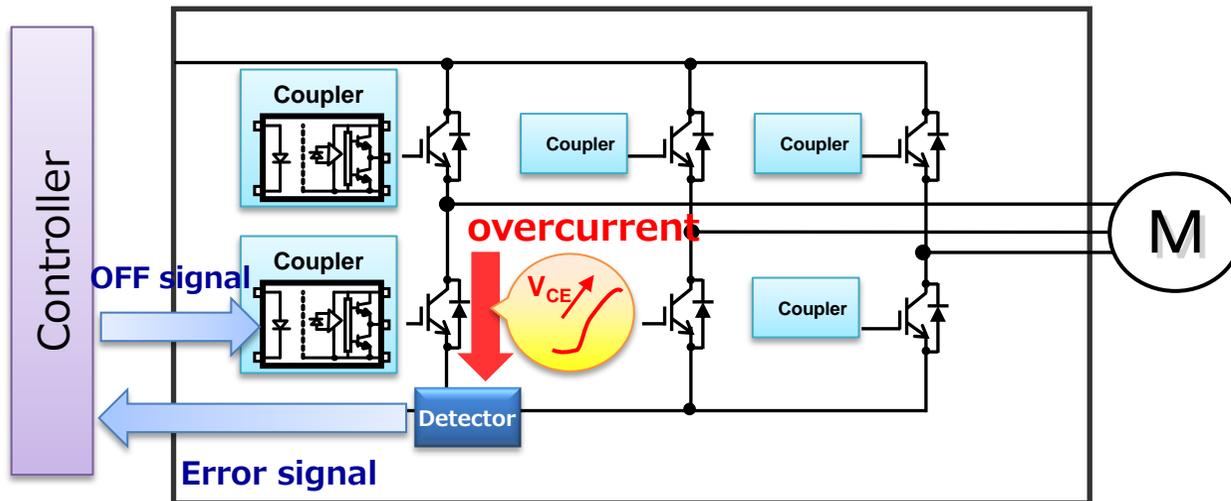
TLP5214 is a general purpose gate driver coupler to which we have added a $V_{CE(sat)}$ detection function, miller clamp function, FAULT detection function, and more, for a driver coupler equipped with functions to protect the IGBT from overcurrent (such as generated in inverter circuits). These photocouplers use the 16-pin SO16L package to handle multifunction expansion. This document describes these newly added functions.

	General purpose gate driver coupler	Smart gate driver coupler
Model	TLP352, TLP5701, etc.	TLP5214
Package/Internal circuit diagram	DIP8, SO6L etc. 	SO16L 
Pin count	8 pin or 6 pin	16 pin
IGBT gate direct drive	✓	✓
UVLO function	✓	✓
$V_{CE(sat)}$ detection function	-	✓
Active miller clamp	-	✓
FAULT feedback	-	✓

What is overcurrent protection?

Overcurrent protection detects abnormal currents in a circuit and prevents them from damaging the circuit. For overcurrents in IGBTs used in inverter circuits, stopping any overcurrent as fast as possible is necessary since there is a risk of the powerful load damaging the circuit when the voltage (V_{CE}) between collector and emitter rises. The time from the start of an overcurrent until the IGBT is damaged is called the short circuit capability. It is necessary to stop the overcurrent within the short circuit capability time period. The short circuit capability depends on the product or junction temperature, etc., but circuits must be designed such that the overcurrent is cut off within 10 μ s. Also, many electrical products are required by safety regulations to have features that protect humans from overcurrent conditions.

Example inverter circuit



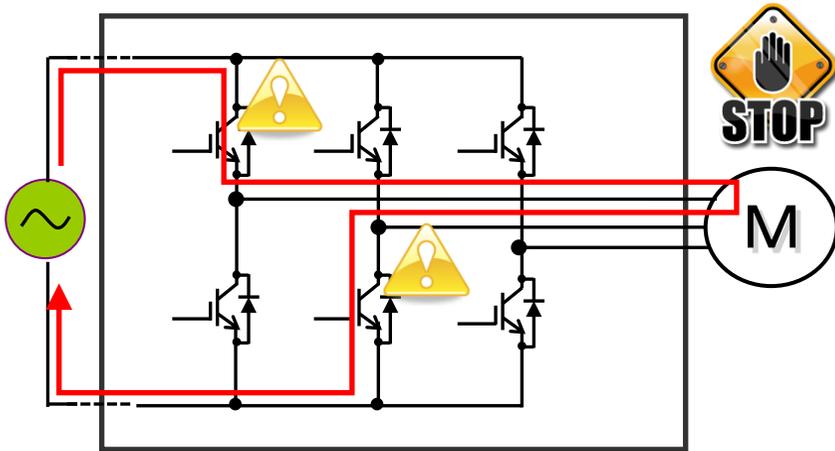
robot motor

Causes of overcurrent in inverter circuits

There are various reasons for overcurrent conditions - some typical examples are given here. When the overcurrent protector is activated, the inverter stops operating and can be restarted when the cause is removed.

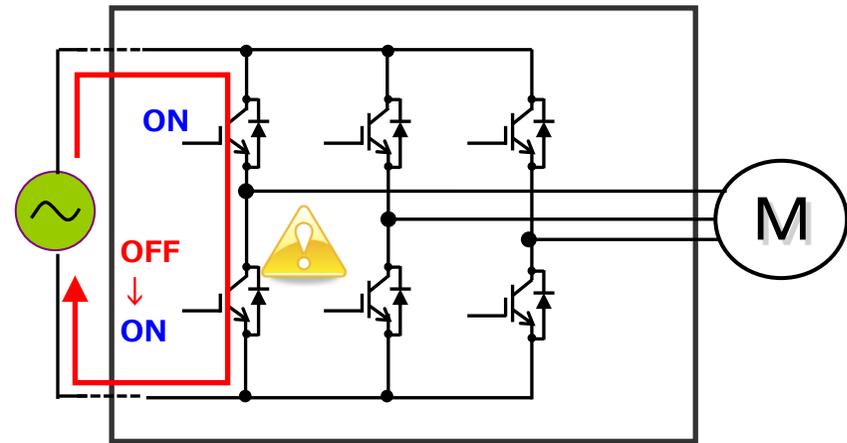
Output short circuit:

An overcurrent flows between two opposite arms due to a human error, causing a mis-connection or load that causes damage. Or, an overcurrent condition may be caused by the motor being mechanically impeded by some external factor.



Arm short circuit:

An overcurrent condition occurs when the upper and lower arms short circuit. Two examples are ...
(1) malfunction caused by the miller current during switching
(2) malfunction due to noise.

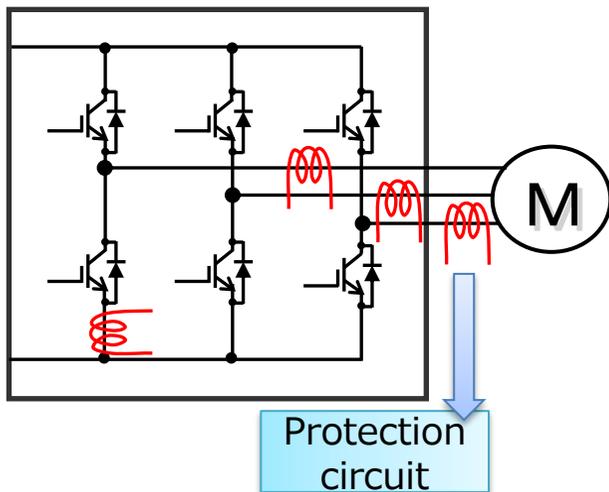


Types of overcurrent protection

There are several ways to prevent IGBT destruction caused by overcurrent. Each of them has different advantages. Number 3, monitoring the saturation voltage $V_{CE(sat)}$ of the IGBT, has the advantage of (1) low power loss, and, (2) the protection function can be done on the IGBT side, so it works quickly. The TLP5214 photocoupler monitors $V_{CE(sat)}$ while driving an IGBT in a protection circuit.

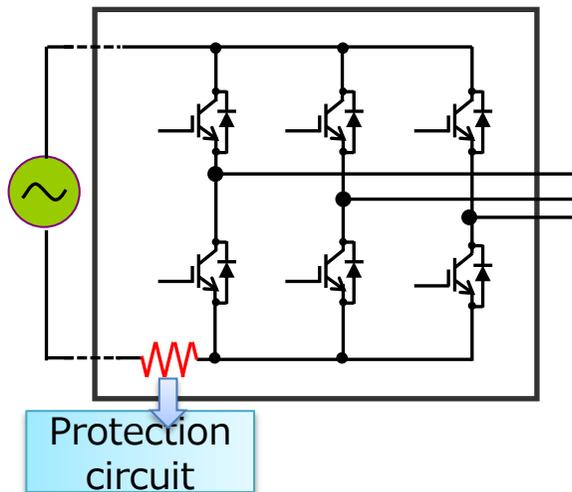
1. Current transformer(CT)

Current transformer for high frequency AC or DC currents are used to monitor currents. Electrical isolation is not necessary, but it may be physically too large for the latest compact inverters.



2. Current sense resistor

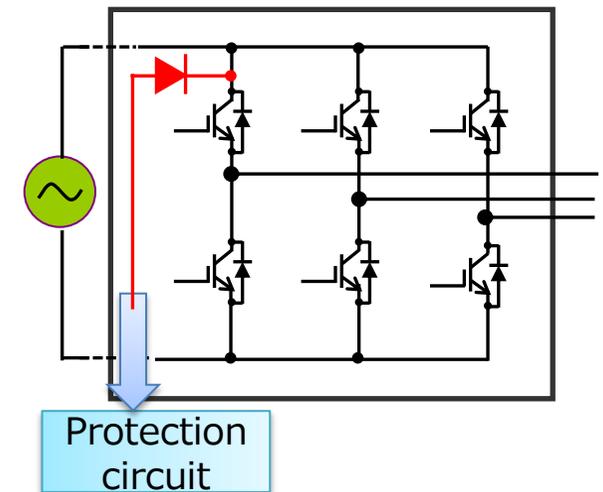
A metallic resistor for sensing the current is used to monitor the current (insulation is needed). Although relatively small, it produces large power losses due to the load current.



3. $V_{CE(sat)}$ monitor

A high voltage diode is used to monitor the collector-emitter voltage. This circuit has several advantages, including ...

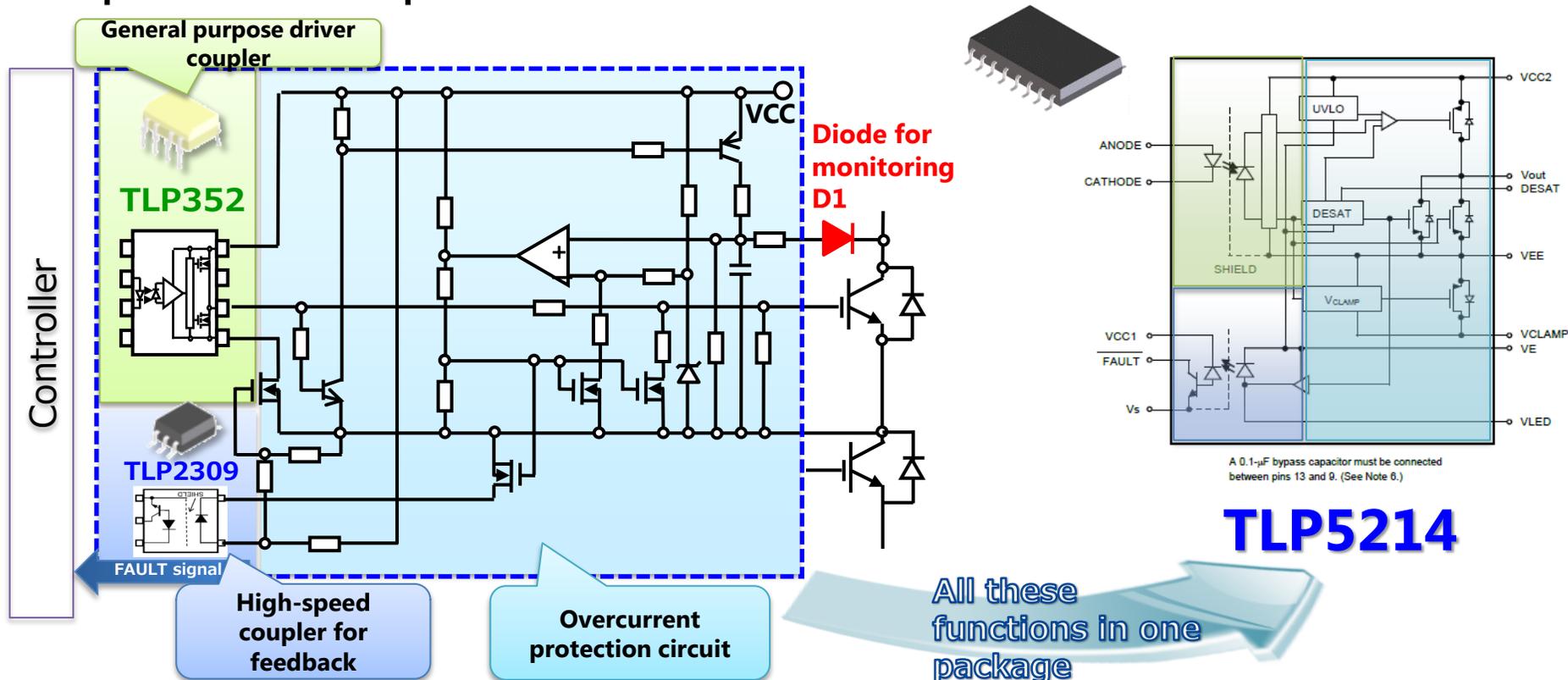
1. low power loss
2. relatively inexpensive
3. fast operation



Example of the TLP352 with a protection circuit, and the TLP5214

The diagram on the lower left shows an example of a protection circuit that uses the No.3 VCE(sat) monitor (from the previous page) in the TLP352 general-purpose driver coupler. In the protection circuit, the VCE(sat) voltage is monitored as it goes through diode D1, so the gate signal of the IGBT turns off softly when an overcurrent is detected. Also, a 1 Mbps-class high-speed coupler is used to transmit fault signals to the controller. The external components of the control circuit are complicated and use much of the PWB space, but the TLP5214 photocoupler provides a smart gate drive circuit and overcurrent protection with all these functions in a single package.

Example inverter circuit protection:



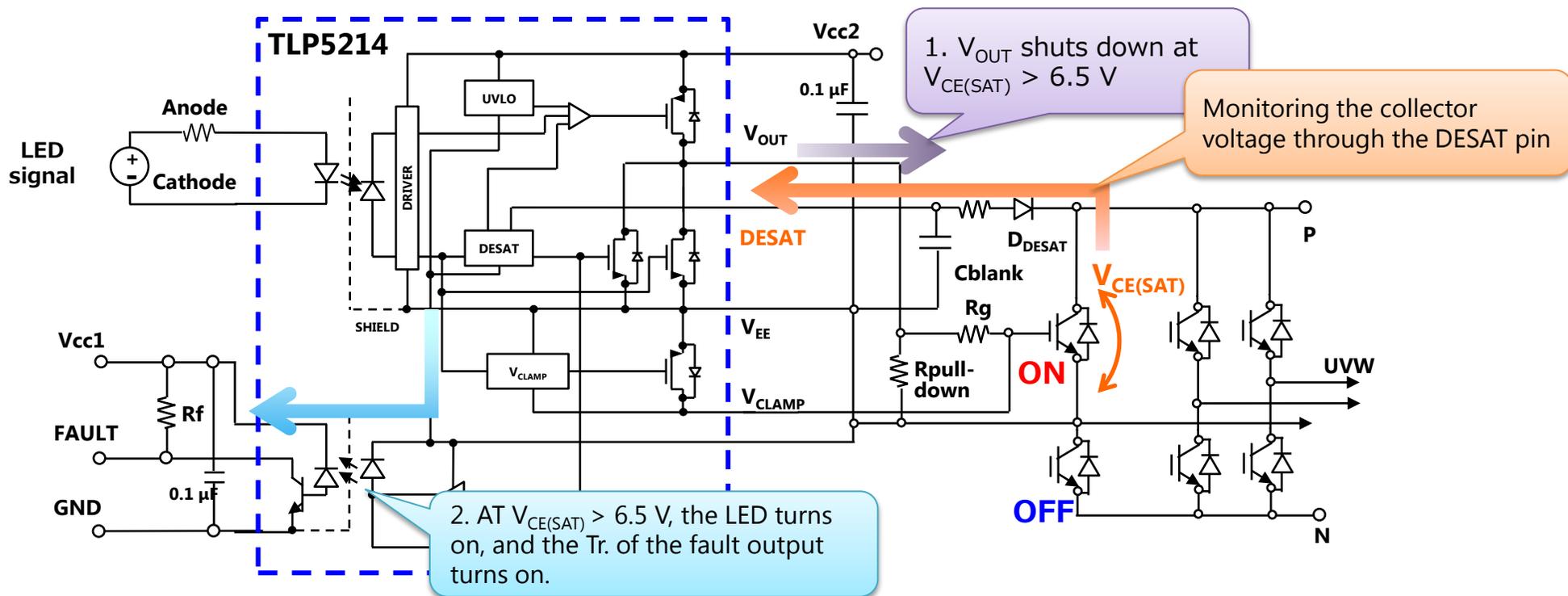
Overview of protection functions

With the TLP5214, the DESAT pin is used to monitor the voltage (V_{CE}) between the collector and the emitter of the IGBT through the external diode D_{DESAT} . Normally, when the IGBT is in an ON state, V_{CE} becomes the saturation voltage $V_{CE(sat)}$ (under about 2 V), but when an overcurrent occurs it enters a non-saturation state and $V_{CE(sat)}$ rises. The TLP5214 performs two operations when the $V_{CE(sat)}$ exceeds 6.5 V (standard).

1. V_{OUT} softly turns off and prevents the overcurrent from damaging the IGBT.

2. A fault signal is transmitted to the controller.

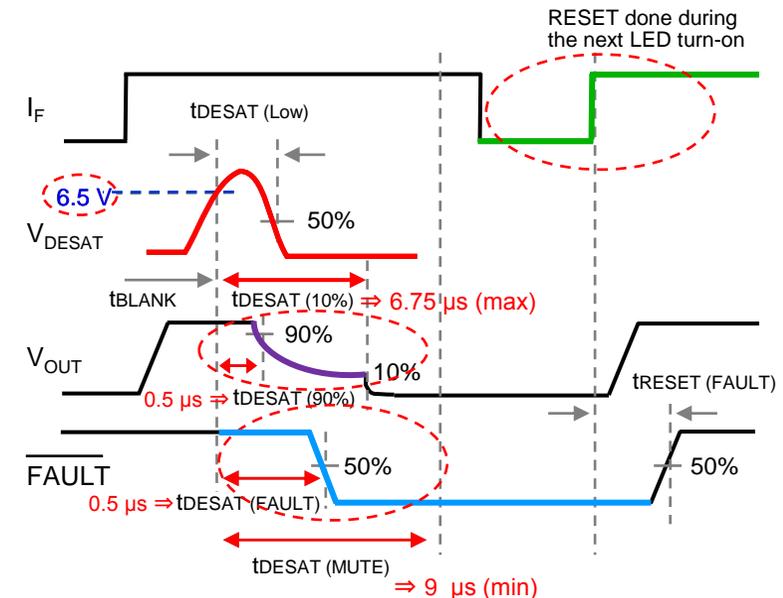
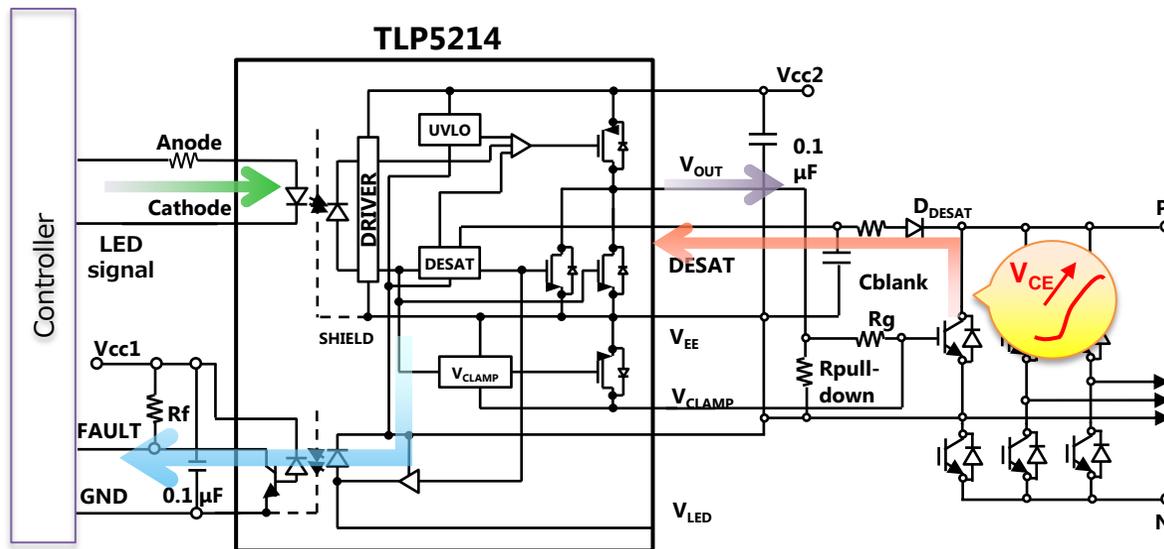
Normally, the fault signal is fed back to the controller, and a few μs pass before the LED signal/coupler output stops. The TLP5214, however, provides excellent circuit protection that is fast and reliable because the V_{OUT} shut down starts in less than 700 ns.



Protection operations and reset method

With the TLP5214, when the protection circuit operates, LED signals are not accepted until a set period of time elapses, $t_{DESAT(MUTE)}$. The reset of the protection operation is initiated by the LED signal after the $t_{DESAT(MUTE)}$ time period has elapsed. The flow of operations from start to reset of the protection operation is shown below.

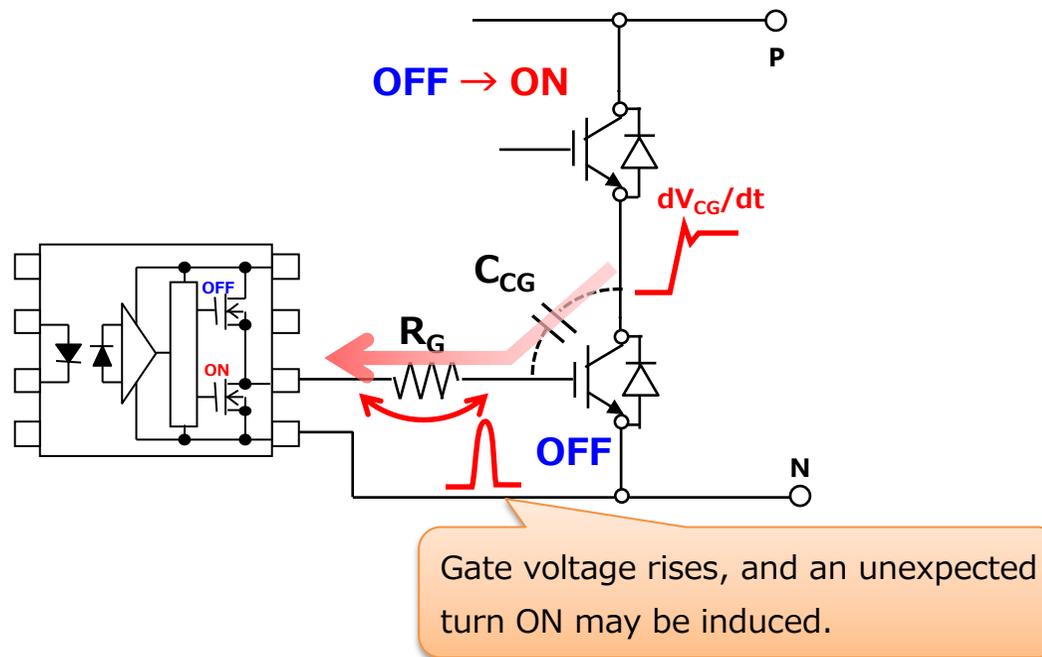
1. When an overcurrent occurs the V_{CE} of the IGBT rises, when it exceeds 6.5 V the protection operation starts
2. Coupler output does a soft shutdown (to protect the IGBT from secondary damage caused by wiring inductance)
3. The fault pin falls to the L level because the signal is fed back to the controller
4. The next LED signal following the occurrence of the protection operation resets the protection operation



Malfunction due to miller capacitance

Malfunctions include parasitic miller capacitance, C_{CG} , between the collector gates of the IGBT, caused by switching noise in the inverter. This malfunction mechanism and the miller clamp function on the TLP5214 are explained here.

When the IGBT of the upper arm in the inverter circuit turns on, the V_{CE} of the IGBT of the lower arm rises sharply.* At this time, the C_{CG} of the lower IGBT is introduced and the displacement current $I_S = C_{CG} \times (dV_{CG}/dt)$ is generated and flows in the direction of the photocoupler's output. As the current passes through the gate resistor R_G of the circuit, the voltage drops and the gate voltage rises, generating a false ON condition of the IGBT, which induces a short circuit in the upper/lower arms.



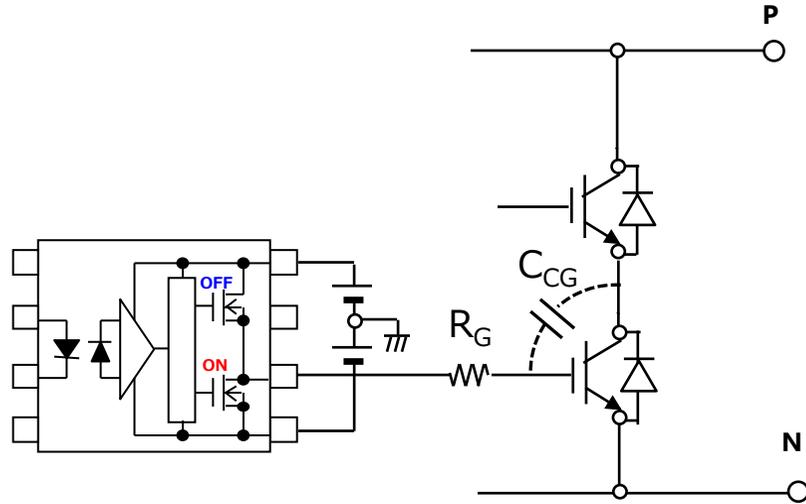
*Depending on the circuit, dV_{CG}/dt may be generated during the dead time when the lower arm IGBT goes from on to off.

Preventing a malfunction due to miller capacitance

Below are two measures to prevent a malfunction due to miller capacitance. The first involves using a negative power source. The 2nd involves adjusting the gate resistance. Using a negative supply voltage requires a power circuit, so cost and size can be an issue. The switching noise induced by adjusting the gate resistance also has an effect. In addition, there is a limit to lowering the gate resistance.

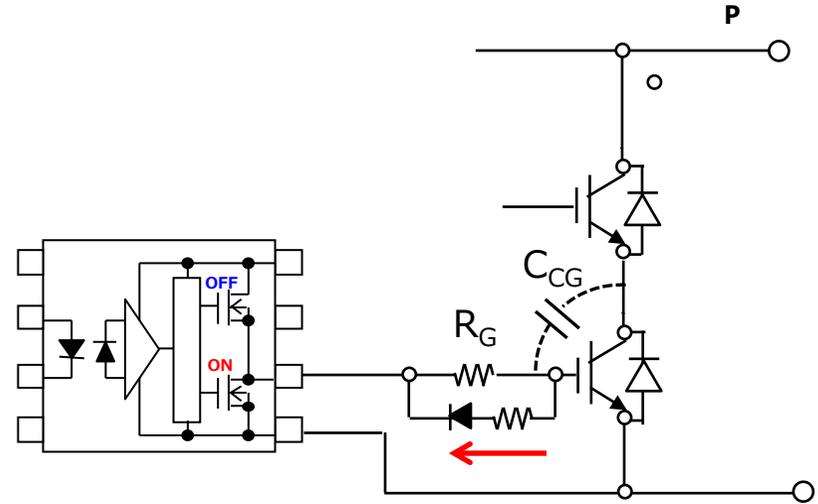
1. Using a negative supply voltage

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.



2. 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.



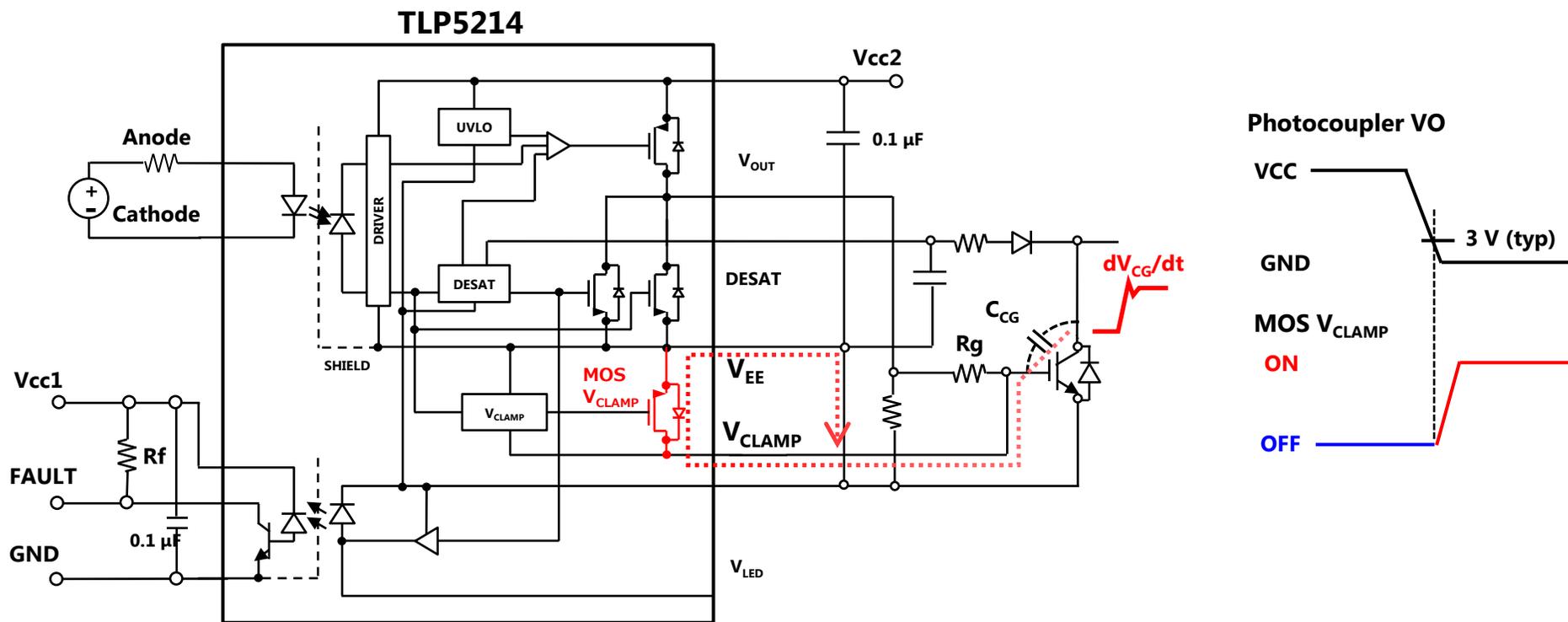
Example of reducing resistance of the extraction direction

Active miller clamp function

Another method to prevent a malfunction caused by miller capacitance includes making a short circuit between the gate emitters of the IGBT. Configuring a circuit to clamp the gate safely from an external component is complicated and requires additional PWB space (refer to page 5 and 6). The TLP5214 has an internal function, called the active miller clamp function, that connects the gate emitters of the IGBT – this eliminates the need for an external component in the clamp circuit.

The miller clamp pin V_{CLAMP} is connected to the gate of the IGBT.

The output of the photocoupler switches from high to low, the gate voltage goes under about 3 V, so the MOSFET between V_{CLAMP} - V_{EE} turns on and the gate clamps on the emitter (V_{EE}). This causes the miller current to bypass to the emitter from the V_{CLAMP} pin, which suppresses the rise in voltage at the gate, and prevents short circuits on the upper/lower arms.



Application

Inverter circuits are used in a wide range of applications, ranging mainly from general purpose inverters, power conditioners for solar power generation and other industrial equipment, to UPS, home use storage cells and other household equipment.



Factory Automation

Inverters, servo amps, robots, production machinery, high power supplies.



Green energy

Photovoltaic inverters, industrial storage batteries



Household equipment

Home use storage batteries, air conditioners



Office equipment

UPS, server power supplies



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Revision	Date	Page	Description
Rev.1.0	Aug/12/2014	-	First edition