Smart gate driver
TLP5214A/TLP5214
Application Note -Introduction-

Outline

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

Table of contents

Introduction ..................................................................................................................................2
1. What is overcurrent protection? ..........................................................................................3
2. Cause of overcurrent ..........................................................................................................4
  2-1. Output short circuit .......................................................................................................4
  2-2. Arm short circuit ..........................................................................................................4
3. Type of overcurrent protection ..........................................................................................5
4. Example of protection circuitry using TLP352, and TLP5214A/TLP5214 .........................6
5. Functional explanation of TLP5214A/5214 .......................................................................7
  5-1. Outline of protection operation ....................................................................................7
  5-2. Protective operation and reset method .......................................................................8
  5-3. Normal operation ..........................................................................................................9
  5-4. Malfunction due to miller capacity, and the prevention .........................................10
  5-5. Active Miller Clamp Function ....................................................................................12
6. Application .......................................................................................................................13
RESTRICIONS ON PRODUCT USE ..................................................................................15
Introduction

TLP5214A/TLP5214 are driver 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 will be explained.

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

<table>
<thead>
<tr>
<th></th>
<th>General-purpose Driver coupler</th>
<th>Smart gate driver coupler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>TLP352, TLP5701, etc.</td>
<td>TLP5214A/TLP5214</td>
</tr>
<tr>
<td>Package/Internal circuit diagram</td>
<td>DIP8, SO6L etc.</td>
<td>SO16L</td>
</tr>
<tr>
<td>Pin count</td>
<td>8pin, 6pin</td>
<td>16pin</td>
</tr>
<tr>
<td>Direct driving of the IGBT gate</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>UVLO function</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>V(_{CE(sat)}) detecting function</td>
<td>-</td>
<td>✔</td>
</tr>
<tr>
<td>Active miller clamp</td>
<td>-</td>
<td>✔</td>
</tr>
<tr>
<td>FAULT outputting function</td>
<td>-</td>
<td>✔</td>
</tr>
</tbody>
</table>
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.

![Diagram of overcurrent causes](image)

(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 and TLP5214 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.

![Diagram of overcurrent protection methods](image)

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

Figure 3. Type of overcurrent protection
4. Example of protection circuitry using TLP352, and TLP5214A/TLP5214

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 TLP352.

In the protective circuit, $V_{CE(sat)}$ is monitored through diode D1, 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 TLP5214A and TLP5214 are the photocouplers that integrate these functions into one package, and offers smart gate-drive and protection circuitry.

**Figure 4. Example of protection circuitry using TLP352, and TLP5214A/TLP5214**
5. Functional explanation of TLP5214A/5214

5-1. Outline of protection operation

TLP5214A/TLP5214 monitors IGBT collector-emitter voltage (V_{CE}) on DESAT pins. Normally, when IGBT is ON, saturated voltage V_{CE(sat)} is about 2V or less, however, when an overcurrent occurs, the V_{CE(sat)} increases. TLP5214A performs two operations when V_{CE(sat)} reaches or exceeds 6.5V (Typ.).

① VOUT is softly shut down (transitions to OFF-state softly) to prevent damage to IGBT due to overcurrent.

② Transmits FAULT signal to the controller.

Normally, it takes several microseconds to feedback FAULT signal to the controller and stop the LED input signal/coupler output, however, TLP5214A/TLP5214 provide high-speed and safe protective circuits by shutting down VOUT in 700ns or less.

![Figure 5. Outline of the protective function of TLP5214A/TLP5214](image-url)
5-2. Protective operation and reset method

With the TLP5214A and TLP5214, when the protection circuit operates, LED signals are not accepted until a set period of time elapses, $t_{\text{DESAT(MUTE)}}$. The reset of the protection operation is initiated by the LED signal after the $t_{\text{DESAT(MUTE)}}$ has elapsed. The flow of operations from start to reset of the protection operation is shown below.

<Flow of protection and reset operation>

① Protective operation starts when the $V_{CE}$ of IGBT rises to 6.5V or higher when an overcurrent occurs.
② The output of coupler is softly shut down (to prevent secondary breakdown of IGBT due to wire inductance)
③ FAULT pin is lowered to the L-level in order to return the signal to the controller-side.
④ The protection operation is reset by the next LED signal after the protection operation occurs.

Figure 6. Flow of protective operation of TLP5214A/TLP5214
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 $V_{\text{DESAT}}$ 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.

![Figure 7. List of DESAT Pin Operation in Normal Operation](image-url)
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 miller clamp function on the TLP5214A/TLP5214 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 $I_S = C_{CG} \times (dV_{CG}/dt)$ 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](image-url)
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). TLP5214A/TLP5214 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](image_url)
6. Application

TLP5214A/5214 are suitable for applications which need inverter such as industrial inverters, PV inverters, UPSs, BMSs, etc.

Figure 11. Application example of TLP5214A/TLP5214
## Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rev. 1.0</td>
<td>2014/8/12</td>
<td>-</td>
<td>1st edition</td>
</tr>
<tr>
<td>Rev. 1.1</td>
<td>2014/9/9</td>
<td>P2,9</td>
<td>Revision due to the correction of errors</td>
</tr>
<tr>
<td>Rev. 2.0</td>
<td>2021/3/2</td>
<td>All pages</td>
<td>Revision due to the format changes</td>
</tr>
<tr>
<td>Rev. 2.1</td>
<td>2021/5/19</td>
<td>P2, 4, 10, 11, 12</td>
<td>Revision due to the correction of errors</td>
</tr>
</tbody>
</table>
RESTRICTIONS ON PRODUCT USE

Toshiba Corporation and its subsidiaries and affiliates are collectively referred to as “TOSHIBA”.

Hardware, software and systems described in this document are collectively referred to as “Product”.

- TOSHIBA reserves the right to make changes to the information in this document and related Product without notice.

- This document and any information herein may not be reproduced without prior written permission from TOSHIBA. Even with TOSHIBA’s written permission, reproduction is permissible only if reproduction is without alteration/omission.

- Though TOSHIBA works continually to improve Product’s quality and reliability, Product can malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Before customers use the Product, create designs including the Product, or incorporate the Product into their own applications, customers must also refer to and comply with (a) the latest versions of all relevant TOSHIBA information, including without limitation, this document, the specifications, the data sheets and application notes for Product and the precautions and conditions set forth in the “TOSHIBA Semiconductor Reliability Handbook” and (b) the instructions for the application with which the Product will be used with or for. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this Product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. TOSHIBA ASSUMES NO LIABILITY FOR CUSTOMERS’ PRODUCT DESIGN OR APPLICATIONS.

- PRODUCT IS NEITHER INTENDED NOR WARRANTED FOR USE IN EQUIPMENTS OR SYSTEMS THAT REQUIRE EXTRAORDINARILY HIGH LEVELS OF QUALITY AND/OR RELIABILITY, AND/OR A MALFUNCTION OR FAILURE OF WHICH MAY CAUSE LOSS OF HUMAN LIFE, BODILY INJURY, SERIOUS PROPERTY DAMAGE AND/OR SERIOUS PUBLIC IMPACT (“UNINTENDED USE”). Except for specific applications as expressly stated in this document, Unintended Use includes, without limitation, equipment used in nuclear facilities, equipment used in the aerospace industry, lifesaving and/or life supporting medical equipment, equipment used for automobiles, trains, ships and other transportation, traffic signaling equipment, equipment used to control combustions or explosions, safety devices, elevators and escalators, and devices related to power plant. IF YOU USE PRODUCT FOR UNINTENDED USE, TOSHIBA ASSUMES NO LIABILITY FOR PRODUCT. For details, please contact your TOSHIBA sales representative or contact us via our website.

- Do not disassemble, analyze, reverse-engineer, alter, modify, translate or copy Product, whether in whole or in part.

- Product shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.

- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOSHIBA for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.

- ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS OF SALE FOR PRODUCT, AND TO THE MAXIMUM EXTENT ALLOWABLE BY LAW, TOSHIBA (1) ASSUMES NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (2) DISCLAIMS ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

- Do not use or otherwise make available Product or related software or technology for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). Product and related software and technology may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of Product or related software or technology are strictly prohibited except in compliance with all applicable export laws and regulations.

- Please contact your TOSHIBA sales representative for details as to environmental matters such as the RoHS compatibility of Product. Please use Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. TOSHIBA ASSUMES NO LIABILITY FOR DAMAGES OR LOSSES OCCURRING AS A RESULT OF NONCOMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS.