AND9285/D

Low Saturation Transistor for Gate Drive Application

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APPLICATION NOTE

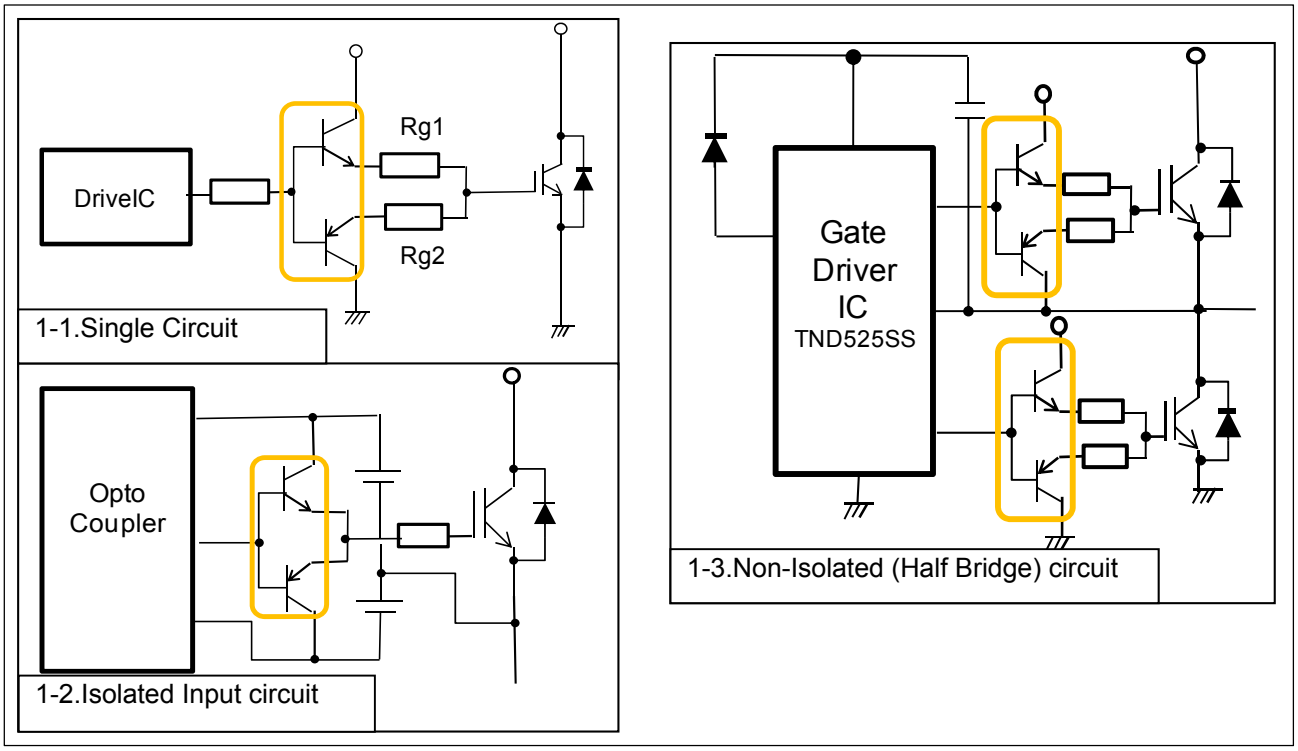
1. Overview

IGBTs or MOSFETs that control high current of more than 100A are used as power discrete device. Usually these devices have large size because they operate high current. Consequently, large gate capacitance is required for powering on these devices, so it is necessary to consider gate driving in order to achieve fast turn-on and off. Specifically, a gate drive circuit (current buffer circuit) is required as a driving device to instantaneously charge and discharge the large gate capacitance (Cies, Ciss). Therefore, low-saturation Bipolar Transistor with low operating voltage (approx.1V) and current operating ability is used for the gate drive circuit of the IGBT or MOSFET.

2. Drive Circuit Configuration

Below shows several methods of actual gate drive circuit. Typical example is shown as Table.1. PNP and NPN complementary device is used.

1-1 is a single circuit or bridge circuit's low-side circuit. When driving ability of the Drive IC is not sufficient, fast turn-on/off can be enabled by adding a PNP/NPN Bipolar transistor with totem-pole connected between the gate of the IGBT (MOSFET).
1-2 is an isolated input circuit where input is composed of insulated circuit. When the current driving ability of the Optocoupler is not sufficient, as is the case with 1-1, the driving ability can be improved by adding a Bipolar Transistor.
1-3 is a non-isolated circuit: fast switching operation is enabled by adding a PNP/NPN BipTR circuit to the high side of the half-bridge driver IC and such kind of BipTR circuit also to the low side (bridge circuit).



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3. How to select the gate drive transistor (1)

3-1) About VCEO

Because it is operated below the IGBT (or MOSFET)'s gate voltage (VGES or VGSS), this VCEO becomes an indicator. In case of IGBT, gate operating voltage is usually VGE=15~16V, so we recommend the gate drive TR's voltage to be VCEO=30V. However, as shown in 1-2, in case the drawing side is negative, the voltage of gate drive TR becomes VBB+|VEE|, when considering the margin, we recommend VCEO=50V.

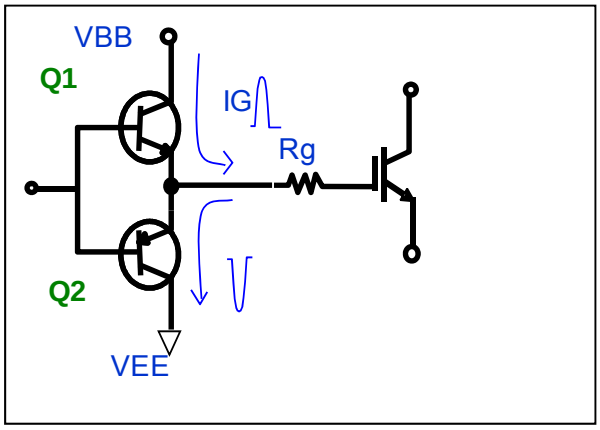

Fig.1 Gate Drive circuit

3-2) Current specification

The specifications shall meet the following requirements.

1) Gate drive current: IGp

IGp is determined by the difference between the applied voltage (+VBB) and VEE (typically minus) and the external resistance (Rg).

$IGp \approx (VBB - VEE) / Rg$

2) Specification of IGBT(or MOSFET) and IGp

Typically, Cies becomes larger as the current specification of IGBT becomes higher. Switching speed (tr or tf) is expressed as in Fig.2 when simply considering the circuit as RC circuit. When you want to keep tr constant, the larger the Cies becomes, the smaller the Rg becomes.

Therefore, in consideration of the TR's speedup, the higher the IGBT's current specification and Cies are, the more necessary to make the gate drive TR's current capacitance (Icp) larger.

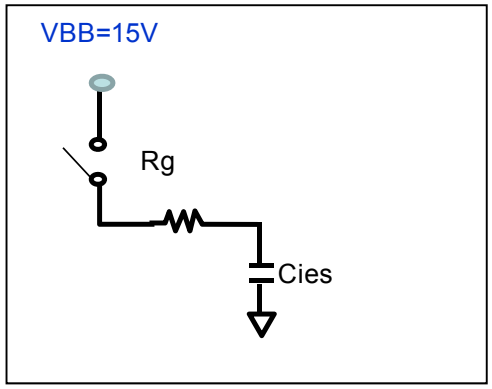

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Fig.2 Equivalent circuit of RC

As shown in Fig.2: when considering the current flowing the gate TR (IGp), taking the power supply VBB=15V, Rg=10Ω,

Gate charge current = IGp of the gate drive TR,

then, $IGp \approx VBB \div Rg = 15 \div 10 = 1.5$ [A]

So, a gate drive TR of Icp>1.5A is required.

Gate voltage rise time (tr) at this time is calculated as follows:

R: equivalent to external gate resistance Rg

C: Cies of the IGBT

Assuming VBB is constant, C's charge voltage's final value (=VBB), then, tr is equivalent to the time from the point of (VC=VBB x 10%) to the point of (VC=VBB x 90%). The calculation of tr period in RC circuit (t10% → t90%) is as below:

Tr=2.2CR(calculated from charge time of C).

For example,

When Cies=5000pF, Rg=10Ω,

Gate voltage rise time's theoretical value is calculated as tr=110ns.

3-3) How to select the gate drive transistor (2)

As shown in Fig.3: in case of changing the drive ability at ON side and OFF side of the IGBT.

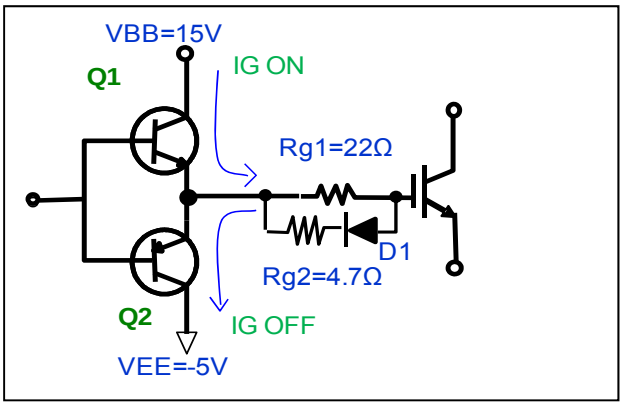


Fig.3 Gate Drive circuit (Rg1 ≠ Rg2)

In case of emitter-common (Fig.3), IGON and IGOFF are sometimes set as separate path, considering Rg as R1 and R2 in parallel, then,

$IGp = (VBB-VEE)/(R_{g1}\times R_{g2}\div(R_{g1}+R_{g2}))$

$IGp = (15+5) / (22\times 4.7\div(22+4.7)) = 5.17A$

For this circuit, devices of Icp > 5.2A are recommended.

If the device is s single item, current specification of Q1and Q2 can be different.

With respect to Icp:

Icp expresses the maximum absolute rating of pulse current, which is under the condition of Ton(ON time) < 1μs, pulse duty < 1% and Tc=25°C. In fact, because Ta > 25°C, you should take this into account when selecting device.

The same is true for the case when the operation's repetition frequency is high, sometimes you should take the temperature rise into account.

3-4) Comparison

When actually operating IGBT, we compared the characteristics of the 2 cases: without gate driver and with gate driver. Fig.4 is the case without gate driver; Fig.5 is the case with gate driver. We compared IGBT's output side (collector-emitter side) switching loss: Eon (loss at the time when Ic begins to flow) + Eoff (loss at the time of Ic cutoff). The smaller one [(the smaller value of (Eon + Eoff)] is considered to be able to reduce the loss of the circuit.

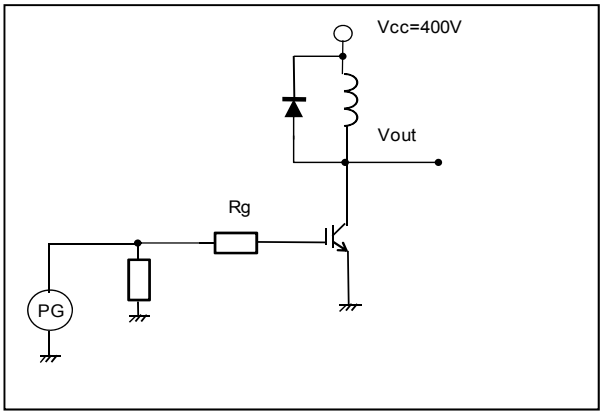


Fig.4 Test circuit without Gate driver

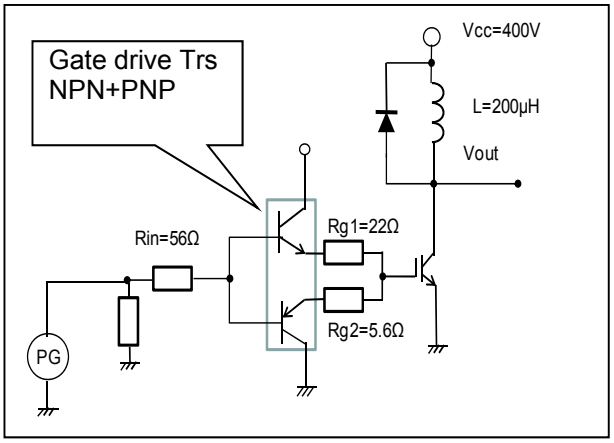


Fig.5 Test circuit with Gate driver

In case of without gate driver, the value is small, but (Eon + Eoff) did not decrease even when making Rg lower than 5.6Ω. However, when adding the gate driver circuit, the value of (Eon + Eoff) further decreased by 5%, which contributes greatly to the overall circuit efficiency. (Fig.6)

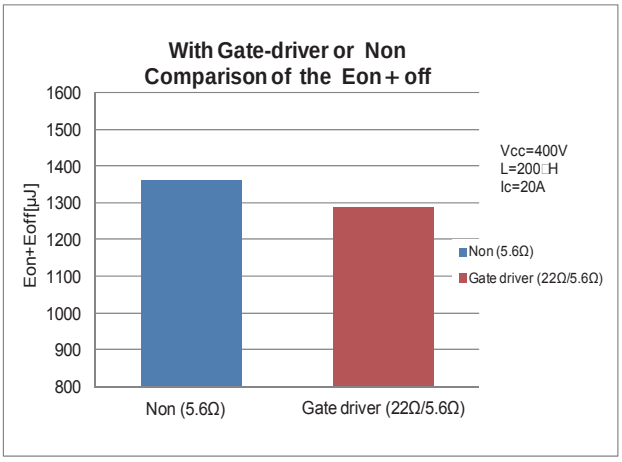


Fig.6 Comparison of (Eon + Eoff)

4. Lineup

We provide the following lineup of gate drive transistors according to input capacitance and voltage.

Table.2 and Table.3 are NPN and PNP single products separately.

Table 2. TR NPN for gate drive

VCEO (V)	IC (A)	MCPH3	CPH3	PCP
50	2	MCH3245	CPH3245	2SC5994
	3		CPH3223	2SC5964

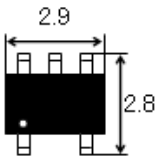
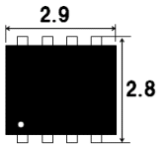
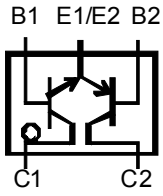
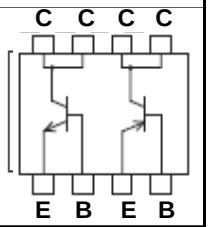
Table 3. TR PNP for gate drive

VCEO (V)	IC (A)	MCPH3	CPH3	PCP
50	2	MCH3145	CPH3145	2SA2153
	3		CPH3123	2SA2125

Complex type (NPN and PNP housed in 1 package) lineup is shown in Table 4.
Standard value in the table is an indicator of the gate capacitance of the IGBT (or MOSFET) that can deliver the performance of the gate drive transistor.

For example, when IGBT(or MOSFET) input capacitance Cies=5000pF, CPH5506 can be recommended.

Table.4: TR complex type for gate drive

		Package Name	CPH5	ECH8
Standerd value			SOT-23-5	2.9×2.8×0.9
IGBT'S (MOSFET) Cies (Ciss) [pF]	VCEO	ICP*1(IC)		
up to 3000	50V	3A(1A)	CPH5518	
up to 10000		5A(2A)	CPH5520	
up to 15000		6A(3A)	CPH5524	
up to 40000		30A*2(5A)		ECH8502
	Electrical connection		**E common** 	**E separate** 

*1 PW ≤ 10μs, Duty cycle ≤ 1%

*2 PW ≤ 1μs, Duty cycle ≤ 1%

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