Basics of Common-drain Type N-ch MOSFET Gate Driver IC (TCK42xG Series)

Overview

This IC drives N-ch MOSFET gate used for the load switch. A low Ron N-ch MOSFET is suitable for the load switch compared to P-ch MOSFET, but the suitable voltage must be applied to the gate.

This IC not only generates the suitable gate drive voltage by the charge pump circuit, but also supports protection functions such as over voltage lockout (OVLO), under voltage lockout (UVLO), and reverse current blocking (by external MOSFET). In addition, this IC also contributes to the miniaturization of circuit by using a common-drain type N-ch MOSFET.

This document explains the functions and precautions for use of TCK42xG series, which is ultra-compact and achieves various voltage operations.

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1. Introduction

TCK42xG series is a MOSFET gate driver IC for supplying power with large current and various voltages using an external N-ch MOSFET. It has a good drive performance capable of various low Ron MOSFETs, and by using a common drain type MOSFET with a reverse-current blocking, it is possible to realize a circuit configuration that minimizes power dissipation and heat generation reducing the mounting area.

One of the typical load switch application, USB–PD (Power Delivery) requires not only increasing the current to shorten the charging time, but also charging voltages. TCK42xG series supports a wide range of input voltages from 2.7 V to 28 V, and it is suitable for USB–PD and quick charge. To prevent inrush current when the switch is turned on, a built-in slew-rate control function protects the load side IC from unintentional inrush current. This document explains the operation and built-in functions of TCK42xG series.

2. TCK42xG series applications

TCK42xG series is suitable for use in load switch circuits and following applications:

- Power management, such as battery charging and discharging
- Power lines such as power delivery using USB Type-C® (Note) connectors
- Power multiplexer circuit with two inputs and one output

*USB Type-C® is registered trademarks of USB Implementers Forum.

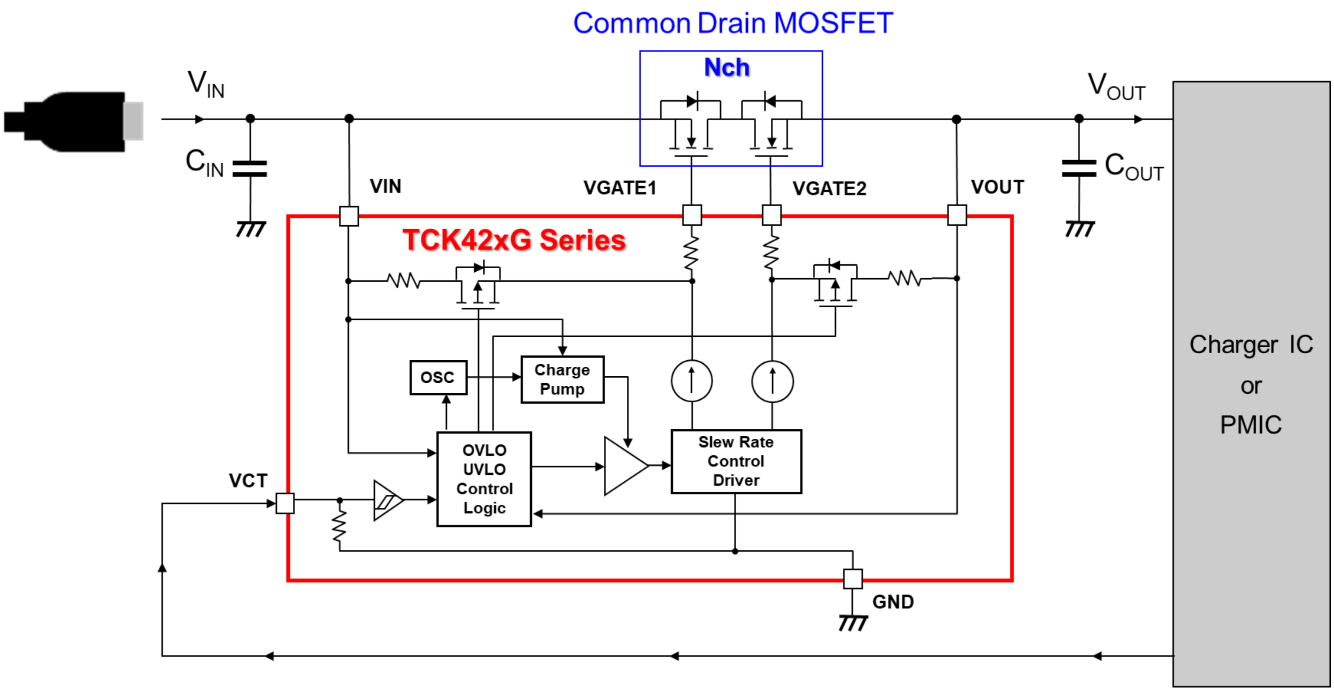


Fig 2.1 Example of Load Switch Circuit Using TCK42xG Series

This is a parametric search for external MOSFET suitable for as above applications.

☞ Click Here

This is a reference design for power multiplexer circuitry using TCK42xG.

☞ Click Here

3. Differences from Common source type Nch-MOSFET gate driver IC (TCK40xG Series)

We have already produced a TCK40xG which is the common source type Nch-MOSFET gate driver IC and we have a lineup of TCK401G for V_{CT} Active High and TCK402G for V_{CT} Active Low.

The functional differences between TCK42xG and TCK40xG are ① MOSFET connection method, ② Over voltage lockout (OVLO) lineup, ③ Gate drive voltage, and ④ Auto-discharge function.

3.1. How to connect MOSFET

Regarding external MOSFET, TCK42xG works for the common drain connection and TCK40xG works for the common source connection (Fig 3.1). These back-to-back connection prevents reverse current from the output side to the input side by commonly connecting the drains or sources of the two external MOSFET. Regarding two external MOSFET, TCK42xG controls it with two independent VGATE terminals. On the other hand, TCK40xG controls it with one VGATE terminal. TCK42xG and TCK40xG also support a single high-side connection (Fig 3.2).

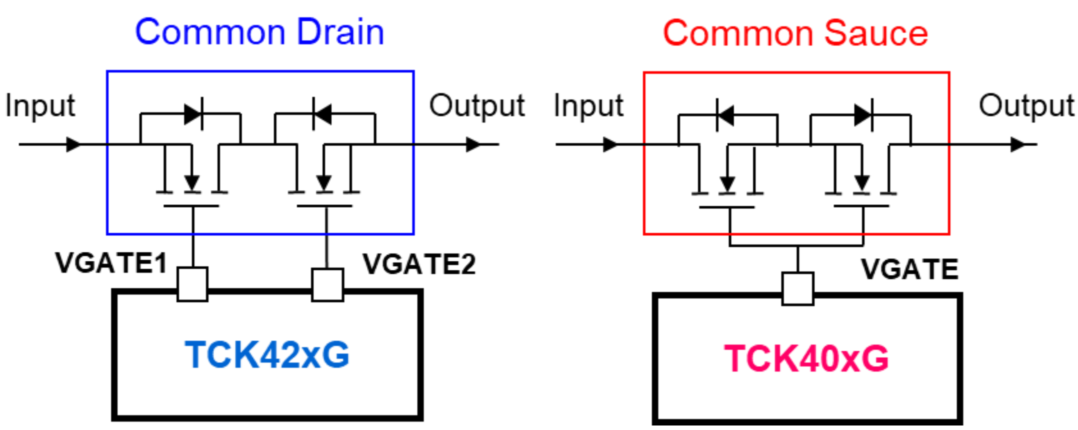


Fig 3.1 Back-to-back connection of external MOSFET

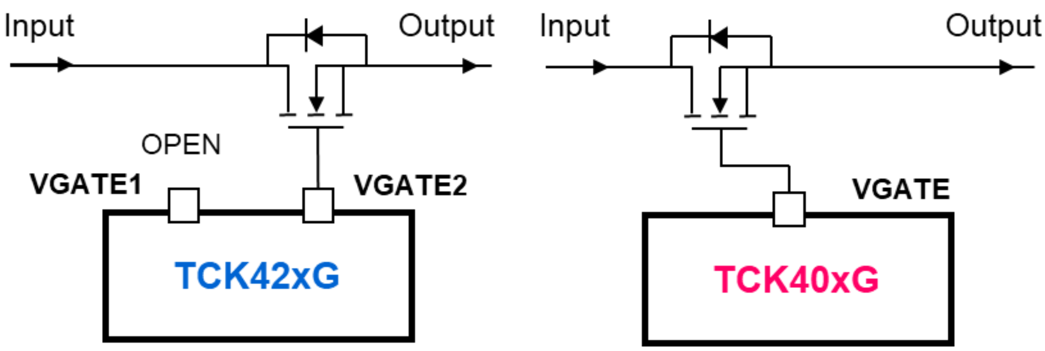


Fig 3.2 Single high-side connection of external MOSFET

3.2. Lineup of over voltage lockout

TCK42xG and TCK40xG have an over voltage lockout (OVLO) function. When V_{IN} rises above the over voltage lockout threshold voltage (V_{IN_OVLO}), this function turns off the output by shut down V_{GATE} to protect the external MOSFET and load side IC (Fig 3.3).

TCK42xG has several V_{IN_OVLO} lineup for various application and it is suitable for using from 5 V to 24 V power lines (Table 3.1).

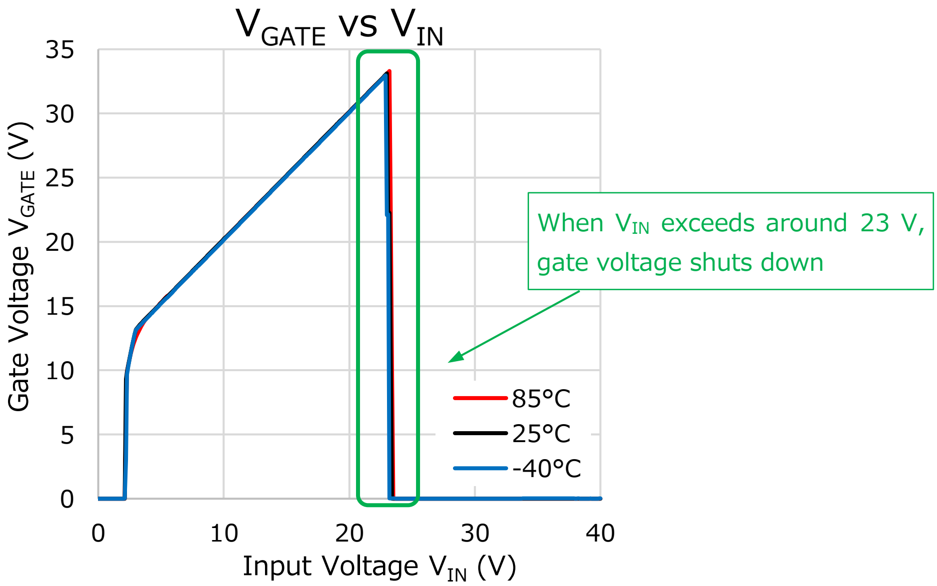


Fig 3.3 V_{GATE} vs V_{IN} curve of TCK42xG (TCK421G, GATE2)

Table 3.1 Over voltage lockout threshold voltage of Nch-MOSFET Gate Driver IC

Product		Over voltage lockout threshold voltage (V_{IN_OVLO})		
		min	typ.	max
TCK40xG		Over 28 V		
TCK42xG	TCK420G	26.50 V	27.73 V	28.50 V
	TCK421G	22.34 V	23.26 V	24.05 V
	TCK422G	13.61 V	14.29 V	14.91 V
	TCK423G	13.61 V	14.29 V	14.91 V
	TCK424G	10.35 V	10.83 V	11.47 V
	TCK425G	5.76 V	6.31 V	6.87 V

3.3. Gate drive voltage

TCK42xG and TCK40xG have a charge pump circuit that drives external MOSFET by generating a gate drive voltage (V_{GS}: V_{GATE}-V_{IN}) from the booster circuit. V_{GS} of TCK40xG depends on V_{IN}, but the V_{GS} of TCK42xG is internally controlled to be remains constant at V_{IN} = 5 V or higher (Table 3.2).

Table 3.2 Gate drive voltage of Nch-MOSFET Gate Driver IC

Product		Measurement conditions	Gate drive voltage (V_{GS}: V_{GATE} – V_{IN})				
			Ta = 25 °C			Ta = -40 to 85 °C	
			min	typ.	max	min	max
TCK40xG		V_{IN} = 3 V	-	4.0	-	2.8	5.1
		V_{IN} = 5 V	-	6.5	-	5.1	7.9
		V_{IN} = 9 V	-	6.5	-	5.1	7.9
		12 V ≤ V_{IN} ≤ 28 V	-	8.5	-	6.9	10
TCK42xG	TCK420G TCK421G TCK422G	V_{IN} = 2.7 V	-	9.2	-	8	10
		V_{IN} = 5 V	-	10	-	9	11
		V_{IN} = 9 V	-	10	-	9	11
		V_{IN} = 12 V	-	10	-	9	11
		V_{IN} = 20 V (TCK422G excluded)	-	10	-	9	11
		V_{IN} = 24 V (TCK420G only)	-	10	-	9	11
	TCK423G TCK424G TCK425G	V_{IN} = 2.7 V	-	5.6	-	4.9	6.3
		V_{IN} = 5 V	-	5.6	-	5.0	6.3
		V_{IN} = 9 V (TCK425G excluded)	-	5.6	-	5.0	6.3
		V_{IN} = 12 V (TCK423G only)	-	5.6	-	5.0	6.3

3.4. Auto-discharge function

TCK42xG does not have an auto-discharge function. This function quickly discharges the electric charge stored in the capacitive load. TCK40xG has an auto-discharge function. When IC is turned off, it makes it possible to shorten the discharge time even when a large capacitance output capacitor is connected by turning on the built-in MOSFET between DIS terminal and GND. It works for the setting of the power sequence of the system (Fig 3.4, Fig 3.5). If the power sequencing requires extreme care in a system with capacitive loads existing a number of load switch circuits, TCK40xG is a suitable device.

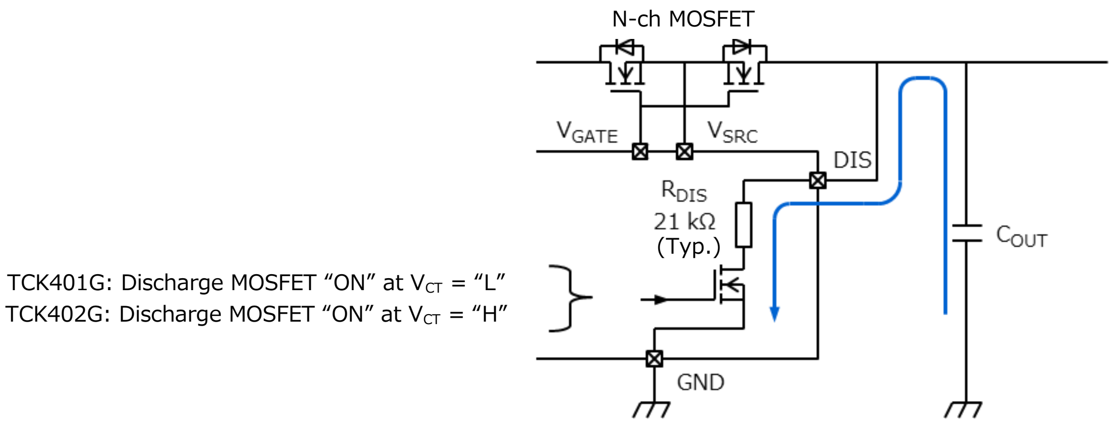
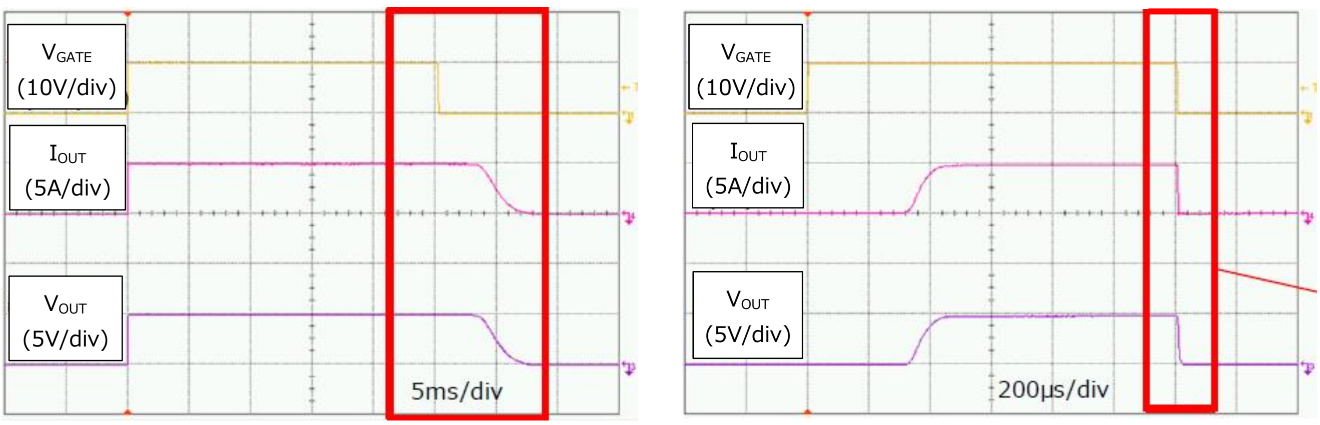


Fig 3.4 Auto-discharge function of TCK40xG

Measurement conditions : V_{IN} = 5 V, V_{CT} = 0 V → 5 V, I_{OUT} = 5 A, C_{OUT} = 4.7 μF, Ta = 25°C



Without auto-discharge function With auto-discharge function

Fig 3.5 Differences in waveform with or without auto-discharge function (TCK401G)

4. Block diagram and circuit description of TCK42xG

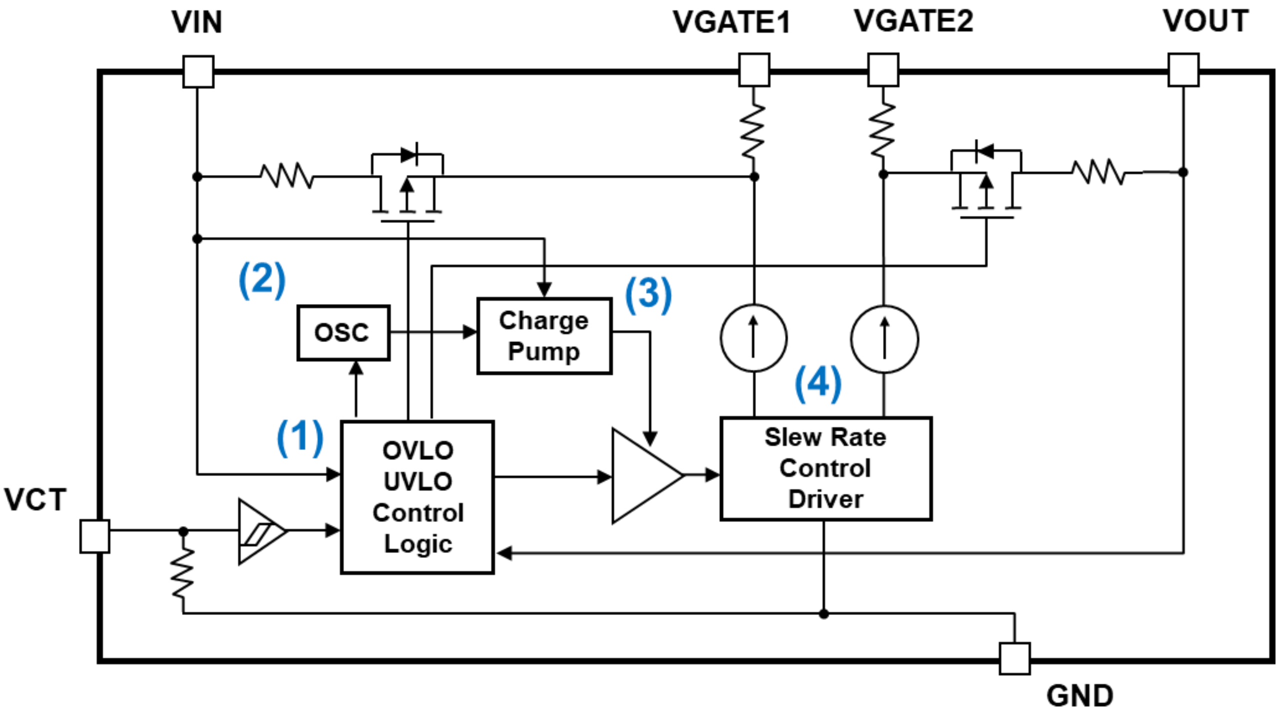


Fig 4.1 TCK42xG block diagram

(1) Over voltage lockout (OVLO)/ under voltage lockout (UVLO) circuit

This circuit detects a voltage that exceeds or falls the operating voltage range and turns off the output to the gate.

(2) Oscillation circuit

This circuit operates the charge pump circuit to drive an external MOSFET gate.

(3) Charge pump circuit

This circuit generates the gate drive voltage V_{GS} (= V_{IN}-V_{GATE}) of an external MOSFET. TCK42xG generates a constant V_{GS} with V_{IN} ≧ 5 V (Table 3.2). V_{GATE} also increases with V_{IN}, but IC turns off the output when V_{IN} exceeds the over voltage lockout threshold voltage to avoid exceeding the external MOSFET's V_{GSS} absolute maximum ratings (Tables 3.1 and Fig 3.3).

(4) Gate drive circuit with Slew rate control function

This circuit has a slew rate control function that suppress inrush current. If the external MOSFET on the output-side is turned on at a high speed with a large capacitive load connected, a large current flows to charge this capacitive load. At this time, V_{IN} may drop momentarily due to the wire impedance of the board on the power supply side of the load switch circuit resulting in unstable or malfunctioning of the system. The slew rate control function suppresses inrush current and enables stable system startup.

5. Built-in protection function

5.1. Reverse current blocking by the external common drain MOSFET

The reverse current blocking prevents current from the output side to the input side by back-to-back when TCK42xG operation stops. Back-to-back is a circuit that prevents reverse current by connecting two external MOSFET to the common drain and turning off the two MOSFET at the same time when the output is turned off (Fig 3.1).

5.2. Over voltage lockout and under voltage lockout

Fig 5.1 is V_{IN} vs V_{GATE} curve of TCK421G.

The over voltage lockout (OVLO) turns off the output by shut down V_{GATE} to protect external MOSFET and load side IC when V_{IN} rises above the over voltage lockout threshold Voltage (V_{IN_OVLO}).

The under voltage lockout (UVLO) turns off the output by shut down V_{GATE} when V_{IN} falls the under voltage lockout threshold voltage (V_{IN_UVLO}) so that the unexpected system operation by falling the minimum operating voltage of load side IC does not occur.

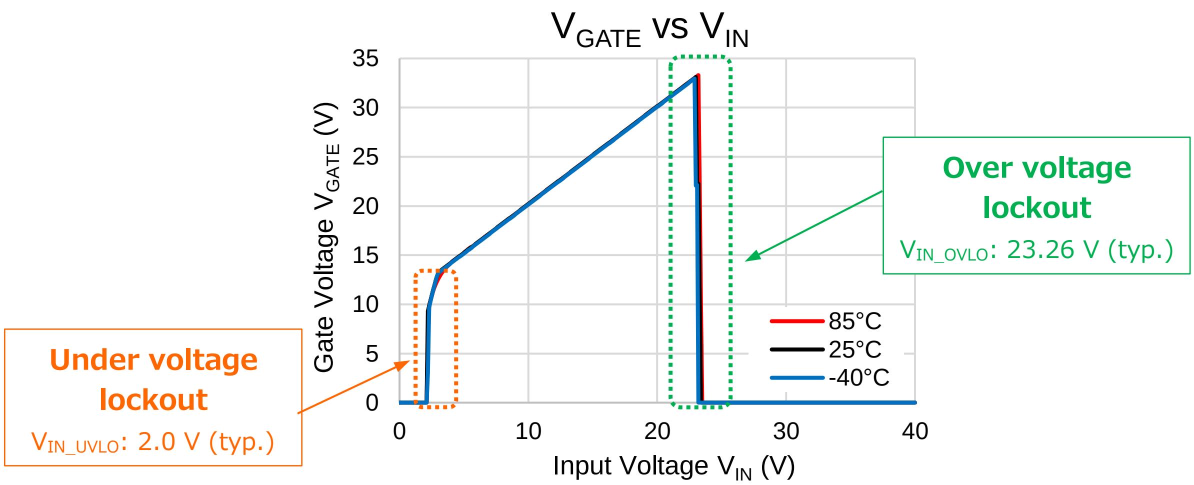


Fig 5.1 Over voltage lockout and under voltage lockout (TCK421G)

5.3. Input tolerant function

The input tolerant function prevents a current from VCT terminal to VIN terminal even when the VCT terminal voltage V_{CT} is higher than V_{IN} or when V_{IN} is 0 V (Fig 5.2).

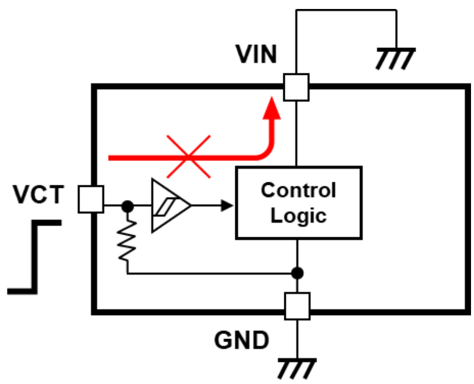


Fig 5.2 Input tolerant function

6. TCK42xG switching time

VGATE terminal is used to drive the gate of an external MOSFET. When TCK42xG becomes active mode by inputting a switch signal to VCT terminal, the voltage inputted VIN terminal is boosted by the built-in charge pump circuit and is outputted to VGATE terminal. This section explains the switching time specifications in the datasheet.

Fig 6.1 is a waveform diagram of TCK42xG switching operation at the output side VGATE terminal (V_{GATE2}). V_{GATE} ON time (t_{ON}) described in AC characteristics of the datasheet defines the time until V_{GATE2}-V_{OUT} is boosted from the voltage at ½ V_{CT} of VCT terminal control signal to 1 V. TCK42xG controls t_{ON} to remain constant when V_{IN} is greater than or equal to 5 V. V_{GATE} OFF time (t_{OFF}) defines the time until V_{GATE2}-V_{OUT} is downed from ½ V_{CT} of VCT terminal control signal to 1 V.

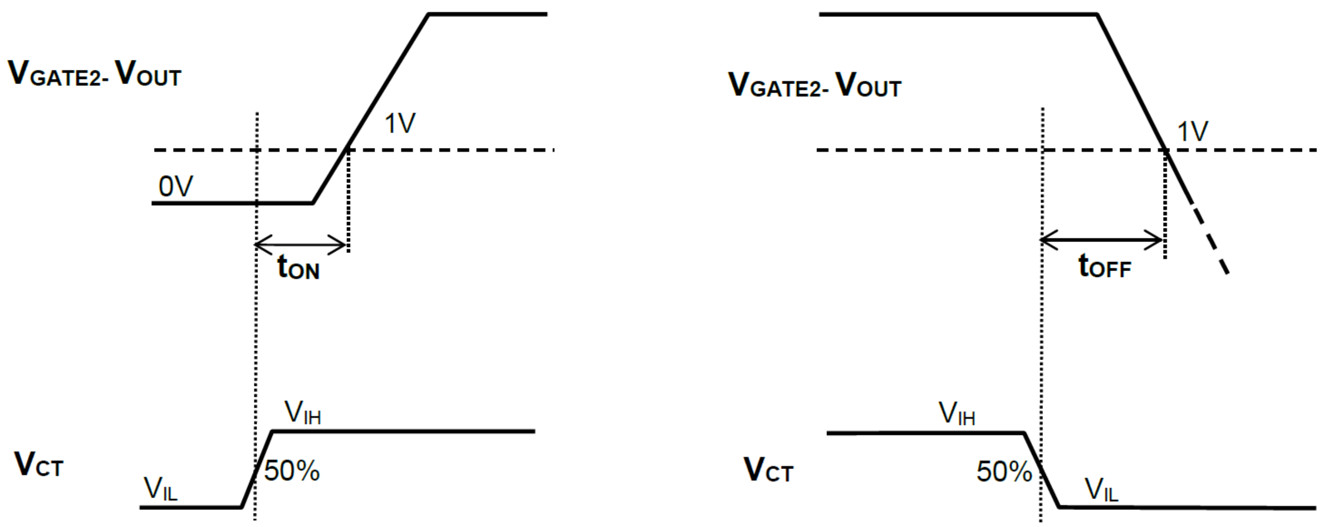


Fig 6.1 Switching operation waveform diagram of TCK42xG

7. Actual operation using TCK42xG and Toshiba MOSFET

This section explains the actual operation using TCK42xG and Toshiba MOSFET, referring to a circuit in which two TPHR6503PL1s with a common drain are connected to TCK421G (Table 7.1, Fig 7.1).

Table 7.1 Products used

Gate driver IC		MOSFET	
Product	Outline	Product	Outline*
TCK421G	V_{GS}: 10 V V_{IN_OVLO}: 23.16 V	TPHR6503PL1	Single N-channel MOSFET V_{DSS}: 30 V V_{GSS}: ± 20 V $R_{DS(ON)}$: 0.41 mΩ at V_{GS} = 10 V C_{iss}: 7700 pF Package: SOP Advance(N)

*V_{DSS}: Drain-Source voltage
V_{GSS}: Gate-Source voltage
$R_{DS(ON)}$: Drain-Source Ron
C_{iss}: Input capacitance

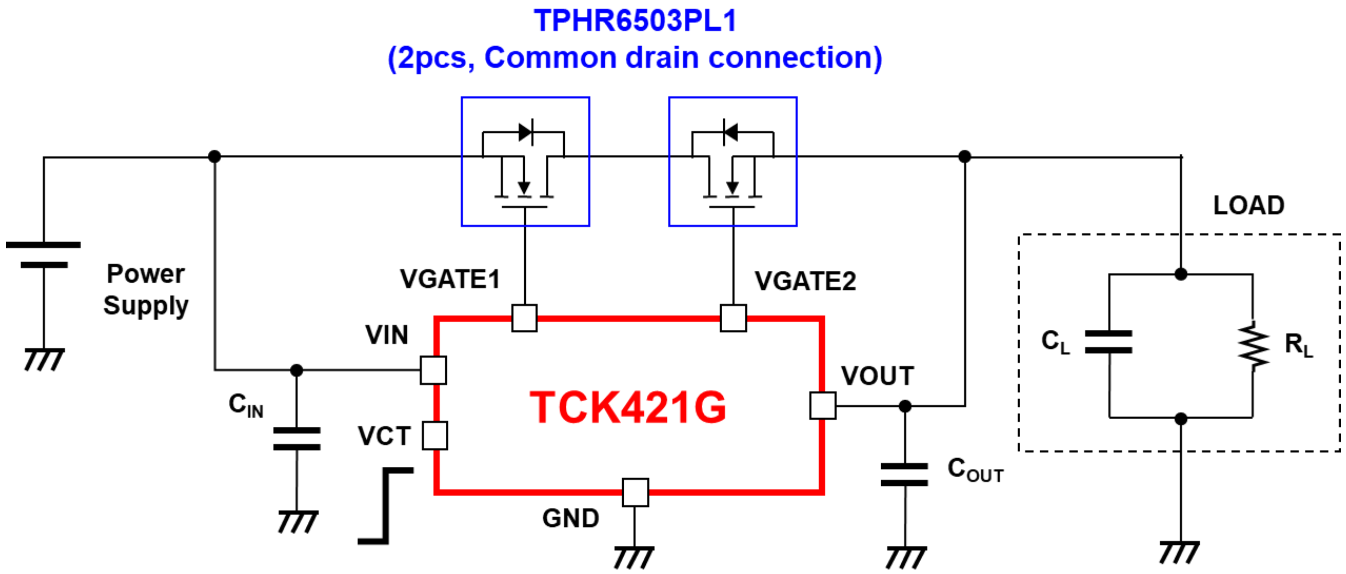


Fig 7.1 Application circuit

7.1. Switching operation

Fig 7.2 and Fig 7.3 are the turn-on operation of VGATE1 and VGATE2 terminals. If V_{CT} is turned on when a V_{IN} inputs, it is not output immediately, and a delay period t_{HD} (Hold time) occurs (①). After t_{HD}, V_{GATE1} and V_{GATE2} increase until V_{GS} (= V_{GATE}-V_{IN}) is 10 V (②). After increasing, intermittent operation is performed so that V_{GS} keeps 10 V (③).

Measurement conditions : V_{IN} = 20 V, V_{CT} = 0 V → 1.2 V, I_{OUT} = 1 A, C_{IN} = 1 μF, C_{OUT} = 1 μF, Ta = 25°C

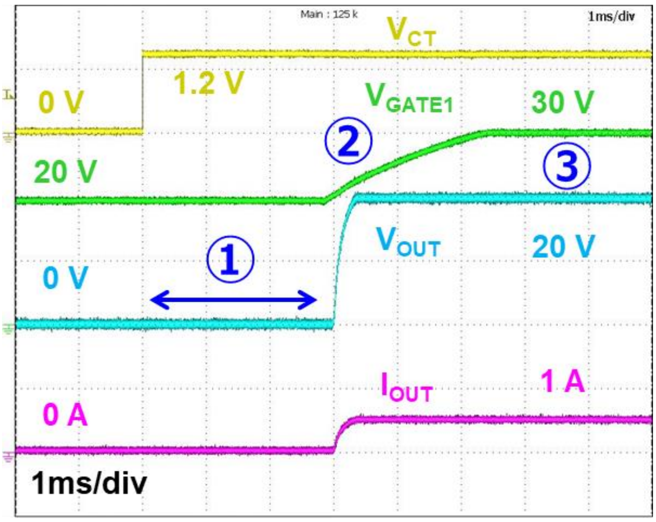


Fig 7.2 Turn-on operation (VGATE1)

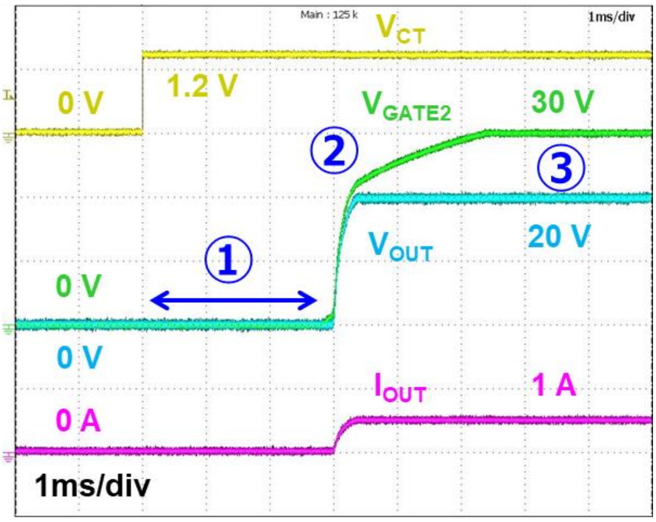


Fig 7.3 Turn-on operation (VGATE2)

Fig 7.4 is the turn-off operation of VGATE2 terminal. If V_{CT} is turned off (①), V_{GATE2} and V_{OUT} will shut down (②). When V_{GATE2}-V_{OUT} falls the gate threshold voltage V_{th} of the external MOSFET, V_{OUT} and I_{OUT} are turned off completely (③).

Measurement conditions : V_{IN} = 20 V, V_{CT} = 1.2 V → 0 V, I_{OUT} = 1 A, C_{IN} = 1 μF, C_{OUT} = 1 μF, Ta = 25°C

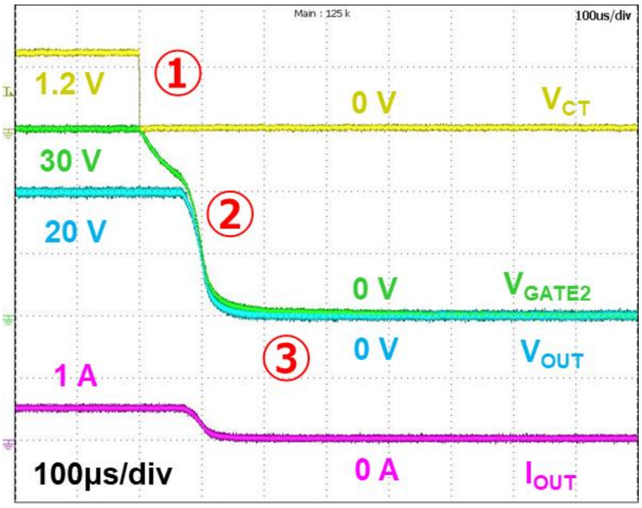


Fig 7.4 Turn-off operation (VGATE2)

(Note) About V_{GATE} ON time (t_{ON}) of TCK42xG

The rise of V_{GATE} that drives MOSFET's gate is specified on the datasheet as V_{GATE} ON time (t_{ON}), but note that it does not specify the switching times of external MOSFET in actual circuit. The turn on time in an actual application circuit depends on the gate capacitance and the gate threshold voltage V_{th} of external MOSFET (Table 7.2, Fig 7.5). t_{ON} is controlled so that it remains constant with V_{IN} ≧ 5 V regardless of V_{IN} at the same gate-capacitance.

t_{ON} defined in the data sheet is assumed at gate capacitance 4000 pF. If the gate capacitance value is less than 4000 pF, t_{ON} is shorter than the datasheet value, and if the gate capacitance value is greater than 4000 pF, t_{ON} is longer than the datasheet value. The data sheet specifications about the rise of V_{GATE} are described in "6. TCK42xG Switching Time". Please refer to them as well.

Table 7.2 V_{GATE} ON time (t_{ON}) simulation data

V_{IN}	GATE capacitance						Unit
	1000 pF	2000 pF	4000 pF	6000 pF	8000 pF	10000 pF	
2.7 V	2870	2890	2920	2960	3000	3040	μs
5 V	3450	3460	3490	3510	3540	3570	
9 V	3450	3460	3490	3510	3540	3570	
12 V	3450	3460	3490	3510	3540	3560	
20 V	3450	3460	3490	3510	3540	3570	
24 V	3450	3460	3490	3510	3540	3570	

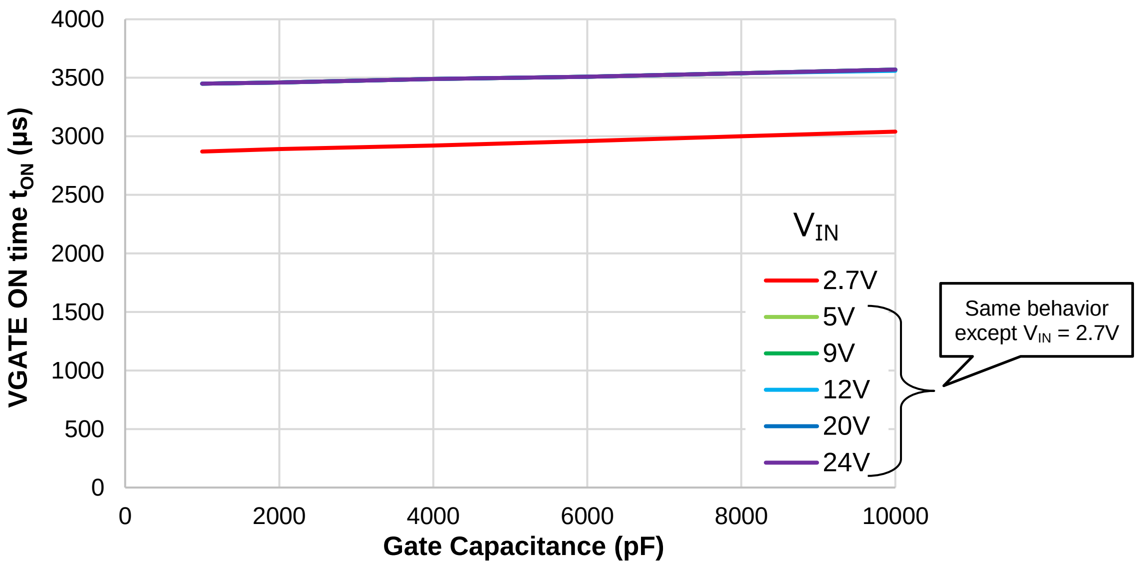


Fig 7.5 V_{GATE} ON time(t_{ON})-Gate capacitance (pF)

7.2. Over voltage lockout operation

Fig 7.6 is the over voltage lockout operation of VGATE2 terminal. Increasing V_{IN} will also raise V_{GATE2} and V_{OUT} (①). When V_{IN} exceeds V_{IN_OVLO} of TCK421G, the over voltage lockout function is activated and shuts down V_{GATE2} and V_{OUT} (②). When V_{GATE2}-V_{OUT} falls the gate threshold voltage V_{th} of the external MOSFET, V_{OUT} and I_{OUT} are turned off completely (③).

Measurement conditions : V_{IN} = 20 V → 25 V, V_{CT} = 1.2 V, I_{OUT} = 1 A, C_{IN} = 1 μF, C_{OUT} = 1 μF, Ta = 25°C

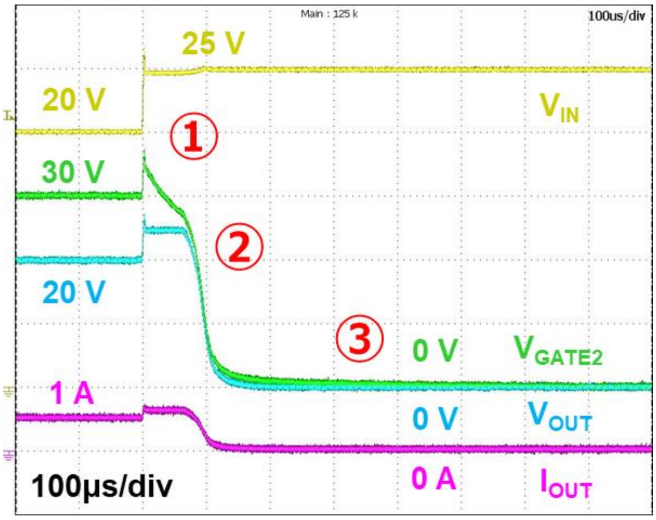


Fig 7.6 Over voltage lockout operation (TCK421G, VGATE2)

Fig 7.7 is the recovery operation from the over voltage lockout. When V_{IN} falls V_{IN_OVLO} and returns to the normal operating range (①), V_{GATE2} and V_{OUT} begin rising after a certain period (②), and the intermittent operation is performed so that V_{GS} keeps 10 V (③). In this series of recovery operations, the turn-on time from when V_{IN} returns to normal operating range until V_{GATE} increases is equivalent to t_{ON}.

Measurement conditions : V_{IN} = 25 V → 20 V, V_{CT} = 1.2 V, I_{OUT} = 1 A, C_{IN} = 1 μF, C_{OUT} = 1 μF, Ta = 25°C

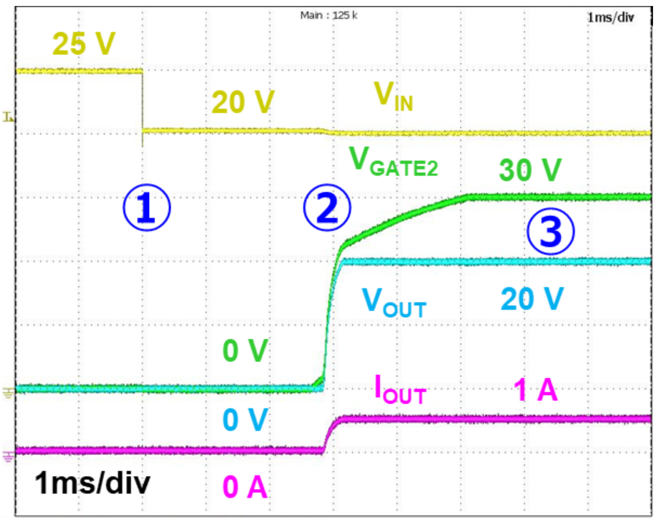


Fig 7.7 Over voltage lockout recovery operation (TCK421G, VGATE2)

8. Attention to use

8.1. Input/Output capacitor

For the stable operation, connect a 1 µF or higher input-capacitor C_{IN} and output-capacitor C_{OUT}. Place C_{IN} and C_{OUT} as close to the terminals as possible. The withstand voltage of the capacitor must have a margin with respect to the voltage used.

8.2. VCT terminal

A Schmitt trigger inverter is connected to VCT terminal of TCK42xG. The Schmitt trigger inverter has thresholds (V_P, V_N) that differs between the rising and falling of the input. Even if an unstable control signal with superimposed chattering and ringing due to the mechanical switch is input, the output is stable as shown in Fig 8.1 (b). Conversely, a normal inverter with one threshold for the input may cause the output to malfunction as shown in Figure 8.1 (a).

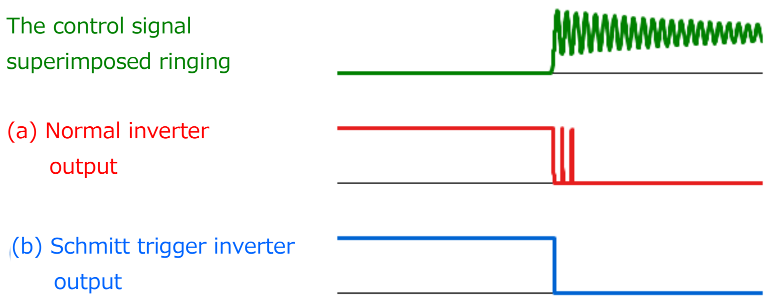


Fig 8.1 Normal inverter and Schmitt trigger inverter operation

9. Summary

This document explains the basic contents described in the datasheet such as the electric characteristics and protection functions of TCK42xG, which are the common-drain type N-ch MOSFET gate driver IC. In addition to the gate-driver IC, we also offer a variety lineup of low-loss load-switch IC with built-in MOSFET. The load switch IC is very useful for power management of mobile devices and other electronic devices. When using the Load Switch IC, please refer to this application note, etc. and be sure to consider our lineup.

10. Related Links

- Product Lineup (Catalogue) ☞ Click
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- Load Switch IC Lineup (Parametric Search) ☞ Click
- Online distributor purchase and inventory search Buy Online
- FAQ of power management IC ☞ Click
- Application Notes ☞ Click

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