TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

# **TCK42xG Series**

Over Voltage Protection MOSFET Gate Driver IC

# 1. Description

TCK42xG series is Over Voltage Protection Gate Driver IC for External N-channel MOSFET. This product support to MOSFET operating in wide voltage line from 2.7 V to 28 V with various Over Voltage Lock Out lineups. And this features low standby current, less than 1  $\mu$ A, built in charge pump circuit and MOSFET gate-source protection circuit. Package is very small and thin WCSP6G (1.2 mm x 0.8 mm (typ.), t: 0.35 mm (max)). Thus this is suitable for mobile, wearable system and power management circuit such as load switch application.



Weight: 0.61 mg (typ.)

## 2. Applications

Load switch circuit for mobile, wearable, and IoT equipment

## 3. Features

- Gate driver for N-channel Common Drain MOSFET
- Gate driver for N-channel Single High side MOSFET
- High maximum input voltage: V<sub>IN max</sub> = 40 V
- Wide input voltage operation: V<sub>IN</sub> = 2.7 to 28 V
- Gate-Source protection circuit
- Over Voltage Lock Out : VIN\_OVLO = 6.31 V, 10.83 V, 14.29 V, 23.26 V and 27.73 V typ
- Under Voltage Lock Out : VIN\_UVLO = 2.0 V typ
- Built in Charge pump circuit: Gate source voltage V<sub>GS</sub> = 5.6 V and 10 V typ
- Low standby current : I<sub>Q(OFF)</sub> = 0.9 μA max at V<sub>IN</sub> = 12 V (Except TCK424G, TCK425G)

# 4. Absolute Maximum Ratings (Note)

Characteristics	Symbol	Rating	Unit
Input voltage	VIN	-0.3 to 40	V
Output voltage	Vout	-0.3 to 40	V
Control voltage	Vст	-0.3 to 6	V
Output GATE voltage	VGATE1,2	-0.3 to 40	V
Power dissipation	PD	800 (Note 1)	mW
Operating temperature range	T <sub>opr</sub>	-40 to 85	°C
Junction temperature	Tj	150	°C
Storage temperature	T <sub>stg</sub>	-55 to 150	°C

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings. Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note1: Rating at mounting on a board: FR4 board. ( 40 mm × 40 mm × 1.6 mm, Cu 4 layer )

## 5. Top Marking, Pin Assignment (top view)



B1: VGATE2 C1: VOUT A2: VIN B2: GND C2: VCT YYWW: Lot No. 42x: Device name code 420: TCK420G 421: TCK421G 422: TCK422G 423: TCK423G 424: TCK424G 425: TCK425G

# 6. Operating Ranges

Characteristics	Symbol	Min.	Тур.	Max.	Unit
Input operation voltage	V <sub>IN_opr</sub> (Note 2)	2.7	—	28	V
CONTROL High-level input voltage	Vін	1.2	—	5.5	V
CONTROL Low-level input voltage	VIL	_	_	0.4	V

Note 2:  $V_{IN_{opr}} < V_{IN_{ovr}}$  of each product

# 7. List of Products Number, OVLO and VGS

	OVLO	External MOSFET Gate-
Product number	threshold, falling	Source voltage
	typ (V)	(Control ON) typ (V)
TCK420G	27.73	10
TCK421G	23.26	10
TCK422G	14.29	10
TCK423G	14.29	5.6
TCK424G	10.83	5.6
TCK425G	6.31	5.6

# 8. Block Diagram



## 9. PIN Description

PIN	Name	Description
A1	VGATE1	Gate Driver Output for Gate 1 Or OPEN state (Non connection) for Single MOSFET use case
B1	VGATE2	Gate Driver Output for Gate 2
C1	VOUT	Monitoring Output voltage Connecting Output (Source 2) of Common Drain MOSFET Or Connecting Output (Source) of single MOSFET use case
A2	VIN	Input power supply voltage Connecting Output (Source 1) of Common Drain MOSFET Or Connecting Output (Drain) of single MOSFET use case
B2	GND	Ground
C2	VCT	Mode control input terminal VCT=High turn the external MOSFETs OFF

# 10. Operation Table

 $2.7V \leq V_{\text{IN}} \leq 28$  V (Ta = -40 to 85°C)

VCT	VGATE1, VGATE2
High	Driver ON mode
Open	Driver OEE mode
Low	

# **11. Electrical Characteristics**

## 11.1. DC Characteristics (Ta = -40 to 85°C)

Characteristic	25	Symbol	Test Condition	-	Ta = 25°(	0	Ta = -40 to 85°C (Note 3)		Unit
Onaracteristic		Cymbol		Min.	Тур.	Max.	Min.	Max.	Onic
VIN UVLO threshold, VouT falling		VIN_UVLO	—		2.0		—	2.5	V
VIN UVLO hysteresis		VIN_UVhyst	_	_	0.2	_	_	_	V
	TCK420G		—	_	27.73	_	26.50	28.50	V
	TCK421G		—	—	23.26		22.34	24.05	V
VIN OVLO threshold, V <sub>OUT</sub> falling	TCK422G TCK423G	VIN_OVLO		_	14.29		13.61	14.91	V
Characteristic VIN UVLO threshold, Vou VIN UVLO hysteresis VIN OVLO threshold, Vout falling VIN OVLO hysteresis Input quiescent current (ON state) Standby current (OFF state)	TCK424G			_	10.83		10.35	11.47	V
	TCK425G		_	_	6.31		5.76	6.87	V
	TCK420G		—	—	0.17	—	—	—	V
VIN OVLO hysteresis	TCK421G TCK422G TCK423G TCK424G TCK425G	VIN_OVhyst	_		0.12	_	_		V
	TCK420G TCK421G		V <sub>CT</sub> : High, V <sub>IN</sub> = 2.7 V	_	140	—	—	200	μA
			V <sub>CT</sub> : High, V <sub>IN</sub> = 4 V	_	130	_	_	420	μA
			VCT: High, VIN = 5 V	—	140		—	300	μA
			VcT: High, VIN = 9 V	_	170	_	_	460	μA
	1004220		V <sub>CT</sub> : High, V <sub>IN</sub> = 12 V	_	185	_	_	490	μA
Input quiescent current		IQ(ON)	V <sub>CT</sub> : High, V <sub>IN</sub> = 20 V (Except TCK422G)	_	220		_	560	μA
			V <sub>CT</sub> : High, V <sub>IN</sub> = 2.7 V	_	75	_	_	130	μA
			V <sub>CT</sub> : High, V <sub>IN</sub> = 4 V	—	95		—	150	μA
	TCK423G		V <sub>CT</sub> : High, V <sub>IN</sub> = 5 V	_	100	_	—	160	μA
	TCK424G		V <sub>CT</sub> : High, V <sub>IN</sub> = 9 V (Except TCK425G)	—	125	_	—	200	μA
			V <sub>CT</sub> : High, V <sub>IN</sub> = 12 V (TCK423G only)	—	140	_		225	μA
			V <sub>CT</sub> : Low, V <sub>IN</sub> = 2.7 V	—	0.14	—	—	0.3	μA
			VCT: Low, VIN = 4 V		0.25		_	0.4	μA
			VCT: Low, VIN = 5 V	_	0.28		_	0.5	μA
Standby current (OFF state)		lq(off)	V <sub>CT</sub> : Low, V <sub>IN</sub> = 9 V (Except TCK425G)	_	0.42			0.7	μA
			V <sub>CT</sub> : Low, V <sub>IN</sub> = 12 V (Except TCK424G, TCK425G)	_	0.52			0.9	μA
			V <sub>CT</sub> : Low, V <sub>IN</sub> = 20 V (TCK420G and TCK421G)	—	0.80	_		1.3	μA

## 11.1. DC Characteristics (Ta = -40 to 85°C) (continued)

Characteria	tion	Symbol	Test Condition	7	Ta = 25°C			Ta = -40 to 85°C (Note 3)	
Characteristics		Symbol	Test Condition	Min.	Тур.	Max.	Min.	Max.	Unit
			V <sub>IN</sub> = 2.7 V		9.2	_	8	10	V
			VIN = 5 V	_	10	_	9	11	V
	TCK420G		VIN = 9 V	_	10	_	9	11	V
	TCK421G TCK422G		V <sub>IN</sub> = 12 V		10	_	9	11	V
GATE Drive voltage		V <sub>GS</sub>	V <sub>IN</sub> = 20 V (Except TCK422G)	_	10	_	9	11	V
(VGATE1-VIN) (VGATE2-VOUT)		(Note 4)	VIN = 24 V (TCK420G only)	_	10	_	9	11	V
			V <sub>IN</sub> = 2.7 V	_	5.6	_	4.9	6.3	V
T T T	TCK423G		V <sub>IN</sub> = 5 V	_	5.6	_	5.0	6.3	V
	TCK424G TCK425G		V <sub>IN</sub> = 9 V (Except TCK425G)	_	5.6	_	5.0	6.3	V
			V <sub>IN</sub> = 12 V (TCK423G only)	_	5.6		5.0	6.3	V
Control pull down resi	stance	RCT	V <sub>CT</sub> = 5 V		550		_	_	kΩ

Note 3: This parameter is warranted by design

Note 4:  $V_{IN}$  is stable power supply condition

## 11.2. AC Characteristics (Ta = 25°C, V<sub>IN</sub> = 5 V, C<sub>GATE1,2</sub> (Note 5) = 4000 pF)

Characte	ristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Тур.	Max.	Unit
V <sub>GS</sub> ON time		ton	Initial startup time V <sub>GATE2</sub> – V <sub>OUT</sub> = 1 V after V <sub>CT</sub> = High, I <sub>OUT</sub> = 0 mA	_	2.9	_	ms
	TCK420G TCK421G TCK422G	torr			52		μs
VGS OFF une	TCK423G TCK424G TCK425G	UOFF	VGATE2 - VOUT - 1 V, aller VCT - Low, IOUT - 0 IIIA		23	_	μs

## 11.3. AC Characteristics (Ta = 25°C, VIN = 12 V, CGATE1,2 (Note 5) = 4000 pF)

Characte	ristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Тур.	Max.	Unit
V <sub>GS</sub> ON time		ton	Initial startup time VGATE2 – V <sub>OUT</sub> = 1 V after V <sub>CT</sub> = High, I <sub>OUT</sub> = 0 mA	_	2.9	_	ms
V <sub>GS</sub> OFF time	TCK420G TCK421G TCK422G	tOFF	V <sub>GATE2</sub> - V <sub>OUT</sub> = 1 V, after V <sub>CT</sub> = Low, I <sub>OUT</sub> = 0 mA		44		μs
	TCK423G			_	16.4	_	μS

## TCK420G, TCK421G

## 11.4. AC Characteristics (Ta = 25°C, V<sub>IN</sub> = 20 V, C<sub>GATE1,2</sub> (Note 5) = 4000 pF)

Characteristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Тур.	Max.	Unit
V <sub>GS</sub> ON time	ton	Initial startup time VGATE2 – VOUT = 1 V after VCT = High, IOUT = 0 mA		2.9	_	ms
V <sub>GS</sub> OFF time	tOFF	$V_{GATE2} - V_{OUT} = 1 V$ , after $V_{CT} = Low$ , $I_{OUT} = 0 mA$		36	_	μs

### TCK420G

### 11.5. AC Characteristics (Ta = 25°C, VIN = 24 V, CGATE1,2 (Note 5) = 4000 pF)

Characteristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Тур.	Max.	Unit
V <sub>GS</sub> ON time	ton	Initial startup time VGATE2 – VOUT = 1 V after VCT = High, IOUT = 0 mA	_	2.9	_	ms
V <sub>GS</sub> OFF time	tOFF	$V_{GATE2} - V_{OUT} = 1 V$ , after $V_{CT} = Low$ , $I_{OUT} = 0 mA$		32		μS

# 11.6. AC Characteristics (Ta = 25°C, C<sub>GATE1,2</sub> (Note 5) = 4000 pF)

Characte	ristics	Symbol	Test Condition (Figure 5,6)	Min.	Тур.	Max.	Unit
	TCK420G		V <sub>IN</sub> = 24 to 29 V, V <sub>IN rising</sub> = 2 V/µs VGs typ to VGs (VGATE2-VIN) = 1 V I <sub>OUT</sub> = 0 mA	_	31		μs
	TCK421G		$V_{IN}$ = 20 to 25 V, $V_{IN rising}$ = 2 V/µs V <sub>GS</sub> typ to V <sub>GS</sub> (V <sub>GATE2</sub> -V <sub>IN</sub> ) = 1 V I <sub>OUT</sub> = 0 mA	_	34	_	μs
-	TCK422G	tour	$V_{IN}$ = 12 to 15 V, $V_{IN rising}$ = 2 V/µs V <sub>GS</sub> typ to V <sub>GS</sub> (V <sub>GATE2</sub> -V <sub>IN</sub> ) = 1 V I <sub>OUT</sub> = 0 mA	_	41	_	μs
VGS turn OFF time	TCK423G	UVP	V <sub>IN</sub> = 12 to 15 V, V <sub>IN rising</sub> = 2 V/µs VGS typ to VGS (VGATE2-VIN) = 1 V IOUT = 0 mA	_	16	_	μs
	TCK424G		V <sub>IN</sub> = 9 to 12 V, V <sub>IN rising</sub> = 2 V/µs VGS typ to VGS (VGATE2-VIN) = 1 V IOUT = 0 mA	_	18	_	μs
	TCK425G		V <sub>IN</sub> = 5 to 8 V, V <sub>IN rising</sub> = 2 V/µs V <sub>GS</sub> typ to V <sub>GS</sub> (V <sub>GATE2</sub> -V <sub>IN</sub> ) = 1 V I <sub>OUT</sub> = 0 mA	_	19		μs

Note 5: CGATE1 and CGATE2 are input capacitance connected to each VGATE1 and VGATE2 instead of external MOSFET

## 11.7. Timing Chart





## 11.8. Switching Waveform and Test circuit













Fig.4 V<sub>GS</sub> ON and OFF time test circuit









## 12. Application Note

#### 12.1. Common Drain Connection N-channel MOSFET circuit example



1. Input and Output capacitor

An input capacitor ( $C_{IN}$ ) and an output capacitor ( $C_{OUT}$ ) are recommended for the stable operation. And it is effective to reduce voltage overshoot or undershoot due to sharp changes in output current and also for improved stability of the power supply. When used, place  $C_{IN}$  and  $C_{OUT}$  as close to VIN pin and VOUT pin to improve stability of the power supply.

2. VCT pin

VCT pin is pull down connection to GND. VCT High level voltage must be under 5.5V  $V_{I\!H}$  max.

3. VGATE1,2 pin and VOUT pin

VGATE1 pin is connected to Gate of VIN side MOSFET. VGATE2 pin is connected to Gate of VOUT side MOSFET. VOUT pin is connected to Source of VOUT side MOSFET. When the gate driver IC turns off state, VGATE1 terminal voltage is close to VIN voltage dropped by parasitic diode forward voltage. This circuit works to protect over voltage for VIN side MOSFET Gate-Source terminal. VOUT terminal works to protect VOUT side MOSFET as same circuit.

 Turn on recovery time after Over Voltage Lock Out (OVLO) Once V<sub>IN</sub> is in normal voltage range after OVLO, the turn on recovery time is similar V<sub>GS</sub> ON time (t<sub>ON</sub>).

#### 5. Under Voltage Lock Out (UVLO) and Over Voltage Lock Out (OVLO)

UVLO and OVLO are designed in these products, but these are not designed to constantly ensure the suppression of the gate driver IC and external MOSFETs within operation limits. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. To select external MOSFETs, please consider enough electrical design margin. When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the above mention or our 'Semiconductor Reliability Handbook'. Then use these products under absolute maximum ratings in any condition. Furthermore, Toshiba recommends inserting failsafe system into the design.

#### Common Drain Connection N-channel MOSFET Switching Waveform

#### Typical switching waveforms with TOSHIBA MOSFETs

OVP Gate	MOSFET		Test conditions	
Driver IC	Part Number	Description	Turn ON and OFF	Over Voltage Lock Out
TCK423G (V <sub>GS</sub> = 5.6 V)	TPN1R603PL	Single N-channel MOSFET $V_{DSS}$ : 30 V, $V_{GSS}$ : ± 20 V $R_{DS(ON)}$ : 1.2 m $\Omega$ typ at $V_{GS}$ = 10 V Package: TSON Advance	$\begin{split} V_{IN} &= 12 \ V \ (TCK423G) \\ V_{IN} &= 20 \ V \ (TCK421G) \\ I_{OUT} &= 1 \ A, \ 3 \ A \\ C_{IN} &= 1 \ \mu F \\ C_{OUT} &= 1 \ \mu F \\ V_{CT} &= 0 \ V \ \Leftrightarrow \ 1.2 \ V \\ Ta &= 25 \ ^{\circ}C \end{split}$	$\begin{split} V_{\text{IN}} &= 12 \text{ V} \iff 15 \text{ V} (\text{TCK423G}) \\ V_{\text{IN}} &= 20 \text{ V} \iff 25 \text{ V} (\text{TCK421G}) \\ I_{\text{OUT}} &= 1 \text{ A} \\ C_{\text{IN}} &= 1  \mu\text{F} \\ C_{\text{OUT}} &= 1  \mu\text{F} \\ V_{\text{CT}} &= 1.2 \text{ V} \\ \text{Ta} &= 25 ^{\circ}\text{C} \end{split}$
TCK421G (V <sub>GS</sub> = 10 V)	TPHR6503PL1	Single N-channel MOSFET $V_{DSS}$ : 30 V, $V_{GSS}$ : ± 20 V $R_{DS(ON)}$ : 0.41 m $\Omega$ typ at $V_{GS}$ = 10 V Package: SOP Advance(N)		

#### TCK423G + TPN1R603PL x 2pcs

#### 1. Turn ON and OFF ( $I_{OUT} = 1 A$ )



2. Turn ON and OFF (I<sub>OUT</sub> = 3 A)





2.

#### TCK421G + TPHR6503PL1 x 2pcs

1. Turn ON and OFF (I<sub>OUT</sub> = 1 A)



- Turn ON and OFF (lour = 3 A)

   Mm: 25k
   Vcr: 1 V/div

   VGATE2: 10 V/div

   Vour: 10 V/div

   Vour: 10 V/div

   Ims/div
- 3. Over Voltage Lock Out Men: 325 V/div VIN: 5 V/div VGATE2: 10 V/div VGATE2: 10 V/div VOUT: 10 V/div IOUUS/div IOUUS/div

## 12.2. Single N-channel MOSFET circuit example

'OSHIBA



1. Input and Output capacitor

An input capacitor ( $C_{IN}$ ) and an output capacitor ( $C_{OUT}$ ) are recommended for the stable operation. And it is effective to reduce voltage overshoot or undershoot due to sharp changes in output current and also for improved stability of the power supply. When used, place  $C_{IN}$  and  $C_{OUT}$  as close to VIN pin and VOUT pin to improve stability of the power supply.

2. VCT pin

VCT pin is pull down connection to GND. VCT High level voltage must be under 5.5V VIH max.

3. VGATE1,2 pin and VOUT pin

VGATE1 pin is OPEN state/Non connection. VGATE2 pin is connected to Gate of MOSFET. VOUT pin is connected to Source of MOSFET. When the gate driver IC turns off state, VGATE2 terminal voltage is close to VOUT voltage dropped by parasitic diode forward voltage. This circuit works to protect over voltage for MOSFET Gate-Source terminal.

 Turn on recovery time after Over Voltage Lock Out Once V<sub>IN</sub> is in normal voltage range after OVLO, the turn on recovery time is similar V<sub>GS</sub> ON time (t<sub>ON</sub>).

#### 5. Under Voltage Lock Out (UVLO) and Over Voltage Lock Out (OVLO)

UVLO and OVLO are designed in these products, but these are not designed to constantly ensure the suppression of the gate driver IC and external MOSFETs within operation limits. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. To select external MOSFETs, please consider enough electrical design margin. When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the above mention or our 'Semiconductor Reliability Handbook'. Then use these products under absolute maximum ratings in any condition. Furthermore, Toshiba recommends inserting failsafe system into the design.

### Single N-channel MOSFET Switching Waveform

#### Typical switching waveforms with TOSHIBA MOSFETs

OVP Gate	MOSFET		Test conditions	
Driver IC	Part Number	Description	Turn ON and OFF	Over Voltage Lock Out
TCK423G (V <sub>GS</sub> = 5.6 V)	TPN1R603PL	Single N-channel MOSFET $V_{DSS}$ : 30 V, $V_{GSS}$ : ± 20 V $R_{DS(ON)}$ : 1.2 m $\Omega$ typ at $V_{GS}$ = 10 V Package: TSON Advance	$V_{IN} = 12 V (TCK423G)$ $V_{IN} = 20 V (TCK421G)$ $I_{OUT} = 1 A, 3 A$	$V_{IN} = 12 V \Leftrightarrow 15 V (TCK423G)$ $V_{IN} = 20 V \Leftrightarrow 25 V (TCK421G)$ $I_{OUT} = 1 A$
TCK421G (V <sub>GS</sub> = 10 V)	TPHR6503PL1	Single N-channel MOSFET $V_{DSS}$ : 30 V, $V_{GSS}$ : ± 20 V $R_{DS(ON)}$ : 0.41 m $\Omega$ typ at $V_{GS}$ = 10 V Package: SOP Advance(N)	$C_{IN} = 1 \ \mu F$ $C_{OUT} = 1 \ \mu F$ $V_{CT} = 0 \ V \Leftrightarrow 1.2 \ V$ $Ta = 25 \ ^{\circ}C$	$C_{IN} = 1 \ \mu F$ $C_{OUT} = 1 \ \mu F$ $V_{CT} = 1.2 \ V$ $Ta = 25 \ ^{\circ}C$

#### TCK423G + TPN1R603L



100µs/div

1ms/div

Vout: 10 V/div

lout: 2 A/div

VIN: 5 V/div

VGATE2: 10 V/div

VOUT: 10 V/div

IOUT: 2 A/div

**100µs/div** lo

1ms/div

**Over Voltage Lock Out** 

3.

100us/div

1ms/div

VGATE2: 10 V/div

Vout: 10 V/div

lout: 2 A/div

VIN: 5 V/div

VGATE2: 10 V/div

Vout: 10 V/div

lout: 2 A/div

#### TCK421G + TPHR6503PL1

6. Turn ON and OFF (I<sub>OUT</sub> = 1 A)



7. Turn ON and OFF ( $I_{OUT} = 3 A$ )



8. Over Voltage Lock Out



# **13. Representative Typical Characteristics**

## 13.1. Gate voltage vs. Input voltage



### 13.2. Gate voltage vs. Gate current

### 1. $V_{GS} = 10V (TCK421G)$



#### 2. $V_{GS} = 5.6 V (TCK423G)$



# 13.3. Quiescent current vs. Input voltage



## 13.4. Standby current vs. Input voltage (Note 6)



Note 6: Common characteristic of  $V_{\text{GS}}$  = 10 V and 5.6 V

## 14. Package Information

## WCSP6G

Unit: mm



Weight: 0.61 mg (Typ.)

# 15. Land pattern dimensions for reference only

WCSP6G

Unit: mm



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