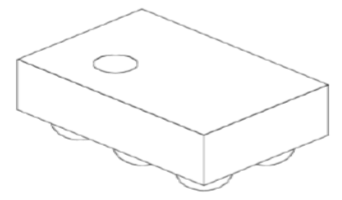
TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

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 μA, 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: $V_{IN\ max}$ = 40 V
- Wide input voltage operation: V_{IN} = 2.7 to 28 V
- Gate-Source protection circuit
- Over Voltage Lock Out : V_{IN_OVLO} = 6.31 V, 10.83 V, 14.29 V, 23.26 V and 27.73 V typ
- Under Voltage Lock Out : V_{IN_UVLO} = 2.0 V typ
- Built in Charge pump circuit: Gate source voltage V_{GS} = 5.6 V and 10 V typ
- Low standby current : $I_{Q(OFF)}$ = 0.9 μA max at V_{IN} = 12 V (Except TCK424G, TCK425G)

Start of commercial production
2021-11

2022-03-10

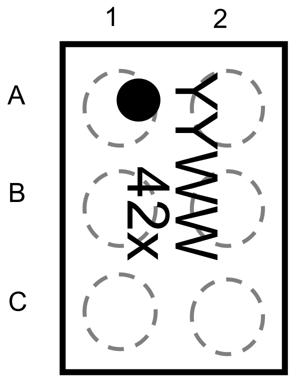
4. Absolute Maximum Ratings (Note)

Characteristics	Symbol	Rating	Unit
Input voltage	V_{IN}	-0.3 to 40	V
Output voltage	V_{OUT}	-0.3 to 40	V
Control voltage	V_{CT}	-0.3 to 6	V
Output GATE voltage	$V_{GATE1,2}$	-0.3 to 40	V
Power dissipation	P_D	800 (Note 1)	mW
Operating temperature range	T_{opr}	-40 to 85	°C
Junction temperature	Tj	150	°C
Storage temperature	T_{stg}	-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)



A1: VGATE1
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

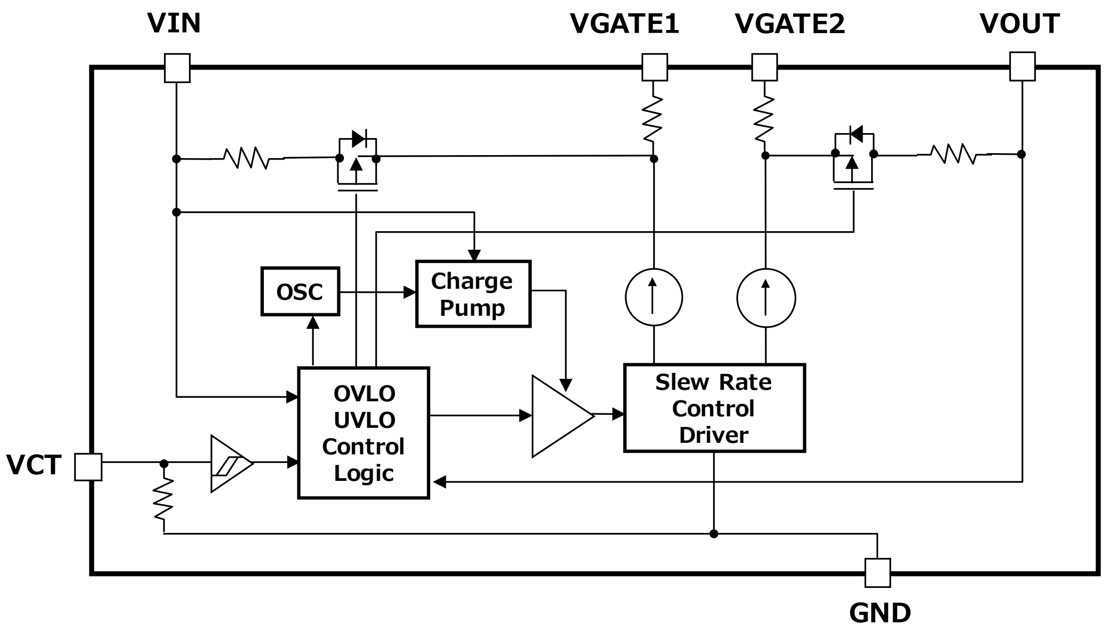
Characteristics	Symbol	Min.	Typ.	Max.	Unit
Input operation voltage	V_{IN_opr} (Note 2)	2.7	—	28	V
CONTROL High-level input voltage	V_{IH}	1.2	—	5.5	V
CONTROL Low-level input voltage	V_{IL}	—	—	0.4	V

Note 2: V_{IN_opr} < $V_{IN\_OVLO\ Max}$ of each product

7. List of Products Number, OVLO and VGS

Product number	OVLO threshold, falling typ (V)	External MOSFET Gate-Source voltage (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 ON, VCT=Low, turn the external MOSFETs OFF

10. Operation Table

2.7V ≤ V_{IN} ≤ 28 V (Ta = -40 to 85°C)

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

11. Electrical Characteristics

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

Characteristics		Symbol	Test Condition	Ta = 25°C			Ta = -40 to 85°C (Note 3)		Unit
				Min.	Typ.	Max.	Min.	Max.	
VIN UVLO threshold, VOUT falling		V_{IN_UVLO}	—	—	2.0	—	—	2.5	V
VIN UVLO hysteresis		V_{IN_UVhyst}	—	—	0.2	—	—	—	V
VIN OVLO threshold, VOUT falling	TCK420G	V_{IN_OVLO}	—	—	27.73	—	26.50	28.50	V
	TCK421G		—	—	23.26	—	22.34	24.05	V
	TCK422G TCK423G		—	—	14.29	—	13.61	14.91	V
	TCK424G		—	—	10.83	—	10.35	11.47	V
	TCK425G		—	—	6.31	—	5.76	6.87	V
VIN OVLO hysteresis	TCK420G	V_{IN_OVhyst}	—	—	0.17	—	—	—	V
	TCK421G TCK422G TCK423G TCK424G TCK425G		—	—	0.12	—	—	—	V
Input quiescent current (ON state)	TCK420G TCK421G TCK422G	$I_{Q(ON)}$	V_{CT}: High, V_{IN} = 2.7 V	—	140	—	—	200	μA
			V_{CT}: High, V_{IN} = 4 V	—	130	—	—	420	μA
			V_{CT}: High, V_{IN} = 5 V	—	140	—	—	300	μA
			V_{CT}: High, V_{IN} = 9 V	—	170	—	—	460	μA
			V_{CT}: High, V_{IN} = 12 V	—	185	—	—	490	μA
			V_{CT}: High, V_{IN} = 20 V (Except TCK422G)	—	220	—	—	560	μA
	TCK423G TCK424G TCK425G		V_{CT}: High, V_{IN} = 2.7 V	—	75	—	—	130	μA
			V_{CT}: High, V_{IN} = 4 V	—	95	—	—	150	μA
			V_{CT}: High, V_{IN} = 5 V	—	100	—	—	160	μA
			V_{CT}: High, V_{IN} = 9 V (Except TCK425G)	—	125	—	—	200	μA
			V_{CT}: High, V_{IN} = 12 V (TCK423G only)	—	140	—	—	225	μA
Standby current (OFF state)		$I_{Q(OFF)}$	V_{CT}: Low, V_{IN} = 2.7 V	—	0.14	—	—	0.3	μA
			V_{CT}: Low, V_{IN} = 4 V	—	0.25	—	—	0.4	μA
			V_{CT}: Low, V_{IN} = 5 V	—	0.28	—	—	0.5	μA
			V_{CT}: Low, V_{IN} = 9 V (Except TCK425G)	—	0.42	—	—	0.7	μA
			V_{CT}: Low, V_{IN} = 12 V (Except TCK424G, TCK425G)	—	0.52	—	—	0.9	μA
			V_{CT}: Low, V_{IN} = 20 V (TCK420G and TCK421G)	—	0.80	—	—	1.3	μA

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

Characteristics		Symbol	Test Condition	Ta = 25°C Min.	Ta = 25°C Typ.	Ta = 25°C Max.	Ta = -40 to 85°C (Note 3) Min.	Ta = -40 to 85°C (Note 3) Max.	Unit
GATE Drive voltage (V_{GATE1}-V_{IN}) (V_{GATE2}-V_{OUT})	TCK420G TCK421G TCK422G	V_{GS} (Note 4)	V_{IN} = 2.7 V	—	9.2	—	8	10	V
			V_{IN} = 5 V	—	10	—	9	11	V
			V_{IN} = 9 V	—	10	—	9	11	V
			V_{IN} = 12 V	—	10	—	9	11	V
			V_{IN} = 20 V (Except TCK422G)	—	10	—	9	11	V
			V_{IN} = 24 V (TCK420G only)	—	10	—	9	11	V
	TCK423G TCK424G TCK425G		V_{IN} = 2.7 V	—	5.6	—	4.9	6.3	V
			V_{IN} = 5 V	—	5.6	—	5.0	6.3	V
			V_{IN} = 9 V (Except TCK425G)	—	5.6	—	5.0	6.3	V
			V_{IN} = 12 V (TCK423G only)	—	5.6	—	5.0	6.3	V
Control pull down resistance		R_{CT}	V_{CT} = 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_{IN} = 5 V, $C_{GATE1,2}$ (Note 5) = 4000 pF)

Characteristics		Symbol	Test Condition (Figure 2,3,4)	Min.	Typ.	Max.	Unit
V_{GS} ON time		t_{ON}	Initial startup time V_{GATE2} – V_{OUT} = 1 V after V_{CT} = High, I_{OUT} = 0 mA	—	2.9	—	ms
V_{GS} OFF time	TCK420G TCK421G TCK422G	t_{OFF}	V_{GATE2} - V_{OUT} = 1 V, after V_{CT} = Low, I_{OUT} = 0 mA	—	52	—	μs
	TCK423G TCK424G TCK425G			—	23	—	μs

11.3. AC Characteristics (Ta = 25°C, V_{IN} = 12 V, $C_{GATE1,2}$ (Note 5) = 4000 pF)

Characteristics		Symbol	Test Condition (Figure 2,3,4)	Min.	Typ.	Max.	Unit
V_{GS} ON time		t_{ON}	Initial startup time V_{GATE2} – V_{OUT} = 1 V after V_{CT} = High, I_{OUT} = 0 mA	—	2.9	—	ms
V_{GS} OFF time	TCK420G TCK421G TCK422G	t_{OFF}	V_{GATE2} - V_{OUT} = 1 V, after V_{CT} = Low, I_{OUT} = 0 mA	—	44	—	μs
	TCK423G			—	16.4	—	μs

TCK420G, TCK421G
11.4. AC Characteristics (Ta = 25°C, V_{IN} = 20 V, $C_{GATE1,2}$ (Note 5) = 4000 pF)

Characteristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Typ.	Max.	Unit
V_{GS} ON time	t_{ON}	Initial startup time V_{GATE2} – V_{OUT} = 1 V after V_{CT} = High, I_{OUT} = 0 mA	—	2.9	—	ms
V_{GS} OFF time	t_{OFF}	V_{GATE2} - V_{OUT} = 1 V, after V_{CT} = Low, I_{OUT} = 0 mA	—	36	—	μs

TCK420G
11.5. AC Characteristics (Ta = 25°C, V_{IN} = 24 V, $C_{GATE1,2}$ (Note 5) = 4000 pF)

Characteristics	Symbol	Test Condition (Figure 2,3,4)	Min.	Typ.	Max.	Unit
V_{GS} ON time	t_{ON}	Initial startup time V_{GATE2} – V_{OUT} = 1 V after V_{CT} = High, I_{OUT} = 0 mA	—	2.9	—	ms
V_{GS} OFF time	t_{OFF}	V_{GATE2} - V_{OUT} = 1 V, after V_{CT} = Low, I_{OUT} = 0 mA	—	32	—	μs

11.6. AC Characteristics (Ta = 25°C, $C_{GATE1,2}$ (Note 5) = 4000 pF)

Characteristics		Symbol	Test Condition (Figure 5,6)	Min.	Typ.	Max.	Unit
OVLO V_{GS} turn OFF time	TCK420G	t_{OVP}	V_{IN} = 24 to 29 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	31	—	μs
	TCK421G		V_{IN} = 20 to 25 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	34	—	μs
	TCK422G		V_{IN} = 12 to 15 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	41	—	μs
	TCK423G		V_{IN} = 12 to 15 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	16	—	μs
	TCK424G		V_{IN} = 9 to 12 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	18	—	μs
	TCK425G		V_{IN} = 5 to 8 V, $V_{IN\ rising}$ = 2 V/μs V_{GS} typ to V_{GS} (V_{GATE2}-V_{IN}) = 1 V I_{OUT} = 0 mA	—	19	—	μs

Note 5: C_{GATE1} and C_{GATE2} are input capacitance connected to each VGATE1 and VGATE2 instead of external MOSFET

11.7. Timing Chart

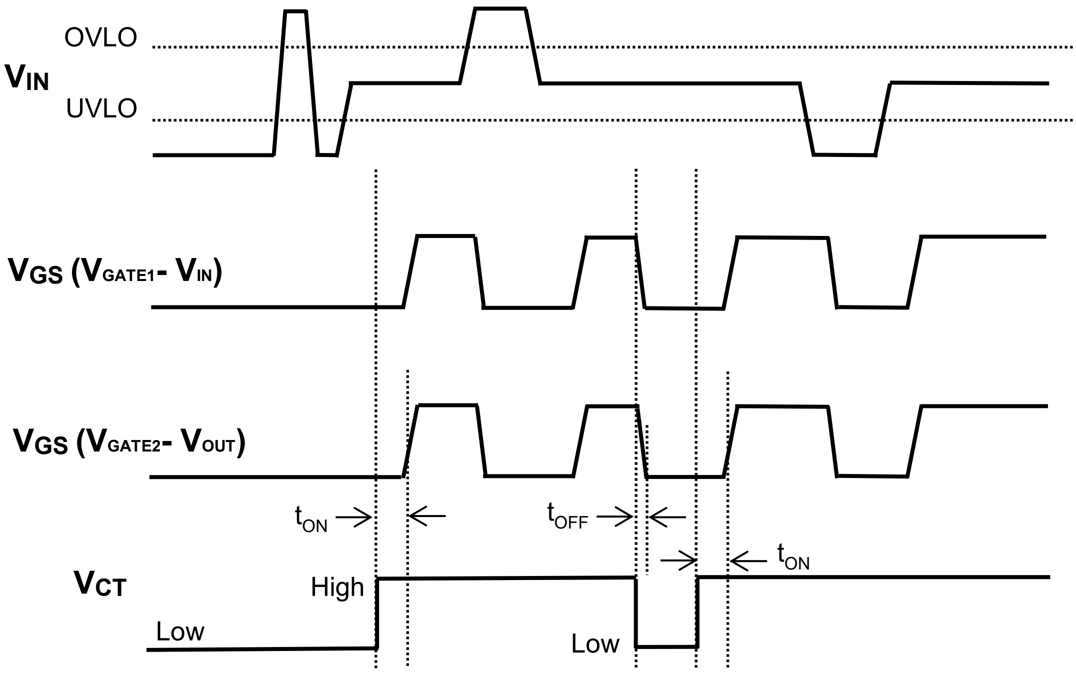


Fig.1 t_{ON}, t_{OFF}

11.8. Switching Waveform and Test circuit

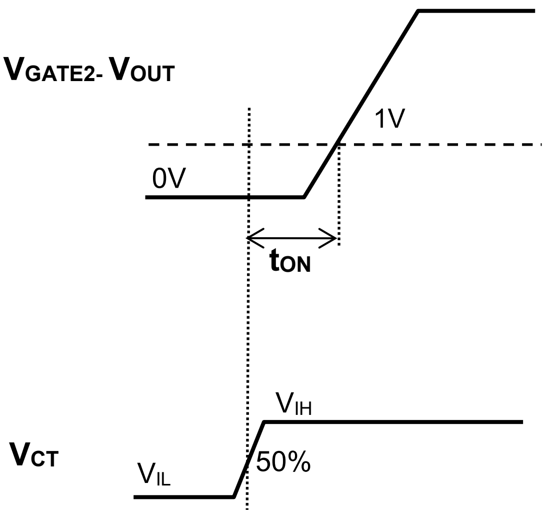


Fig.2 V_{GS} ON time Waveform

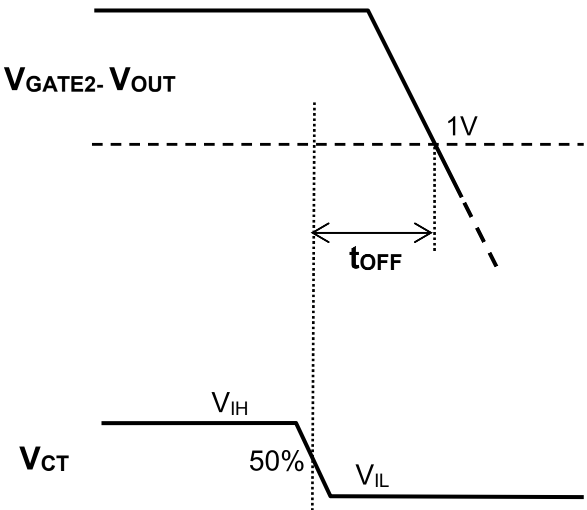


Fig.3 V_{GS} OFF time Waveform

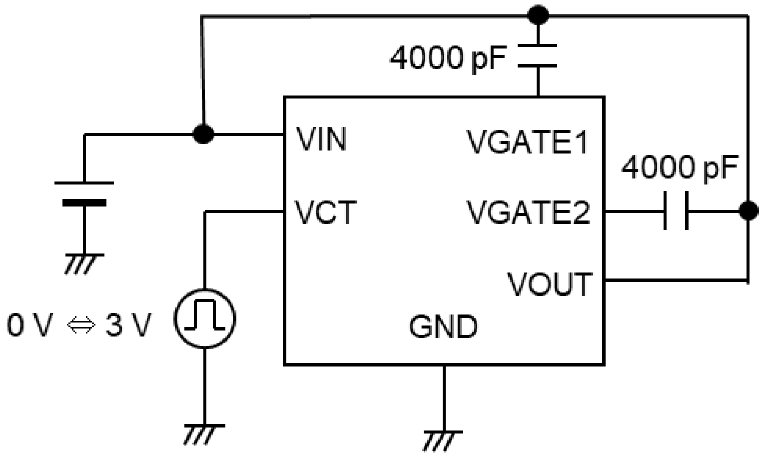


Fig.4 V_{GS} ON and OFF time test circuit

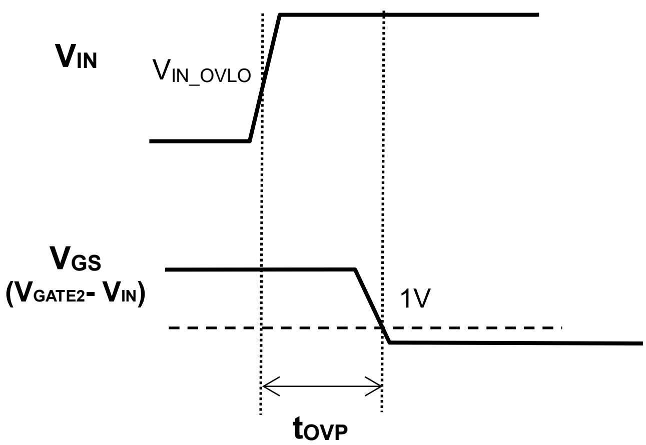


Fig.5 t_{OVP} Waveform

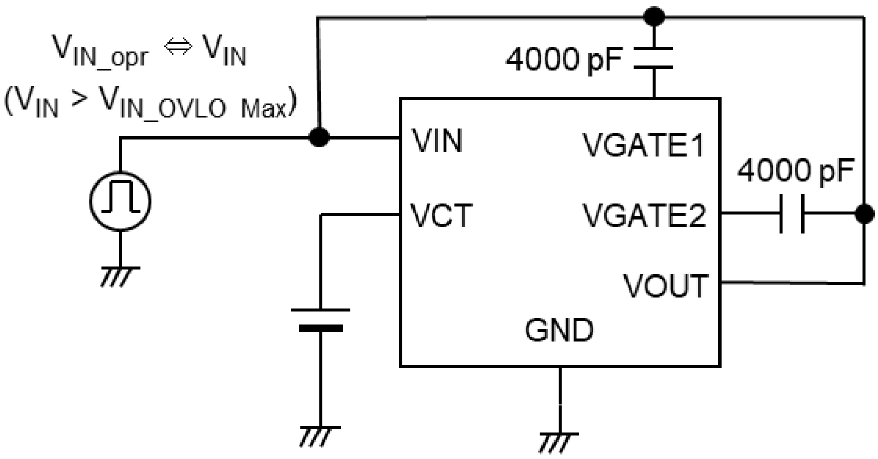
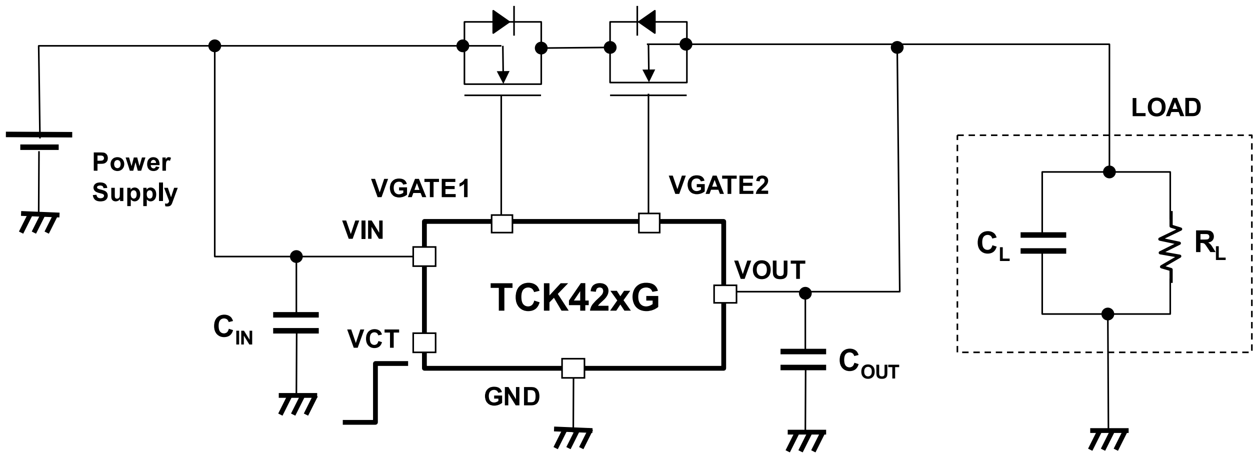


Fig.6 t_{OVP} test circuit

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_{IH} 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.

4. Turn on recovery time after Over Voltage Lock Out (OVLO)
   Once V_{IN} is in normal voltage range after OVLO, the turn on recovery time is similar V_{GS} ON time (t_{ON}).

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.

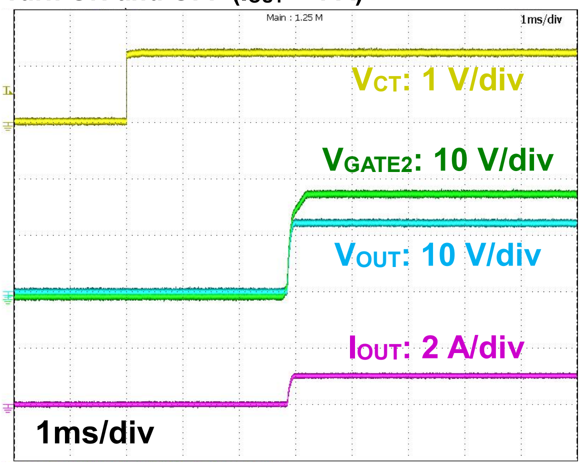
Common Drain Connection N-channel MOSFET Switching Waveform

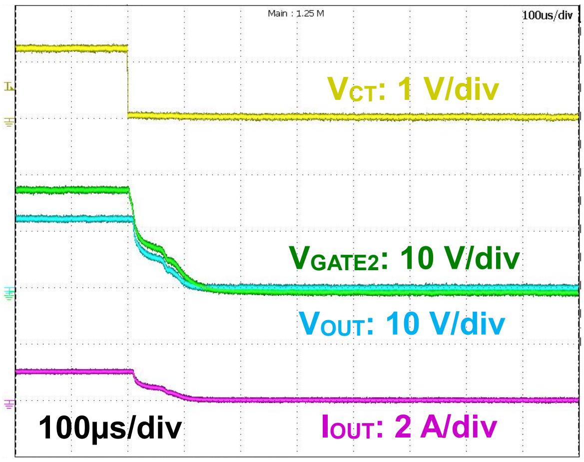
Typical switching waveforms with TOSHIBA MOSFETs

OVP Gate Driver IC	MOSFET		Test conditions	
	Part Number	Description	Turn ON and OFF	Over Voltage Lock Out
TCK423G (V_{GS} = 5.6 V)	TPN1R603PL	Single N-channel MOSFET V_{DSS}: 30 V, V_{GSS}: ± 20 V $R_{DS(ON)}$: 1.2 mΩ 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 C_{IN} = 1 μF C_{OUT} = 1 μF V_{CT} = 0 V ⇔ 1.2 V Ta = 25 °C	V_{IN} = 12 V ⇔ 15 V (TCK423G) V_{IN} = 20 V ⇔ 25 V (TCK421G) I_{OUT} = 1 A C_{IN} = 1 μF C_{OUT} = 1 μF V_{CT} = 1.2 V Ta = 25 °C
TCK421G (V_{GS} = 10 V)	TPHR6503PL1	Single N-channel MOSFET V_{DSS}: 30 V, V_{GSS}: ± 20 V $R_{DS(ON)}$: 0.41 mΩ typ at V_{GS} = 10 V Package: SOP Advance(N)		

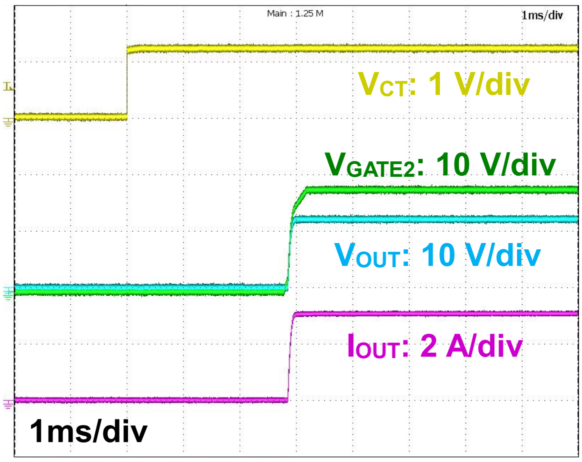
TCK423G + TPN1R603PL x 2pcs

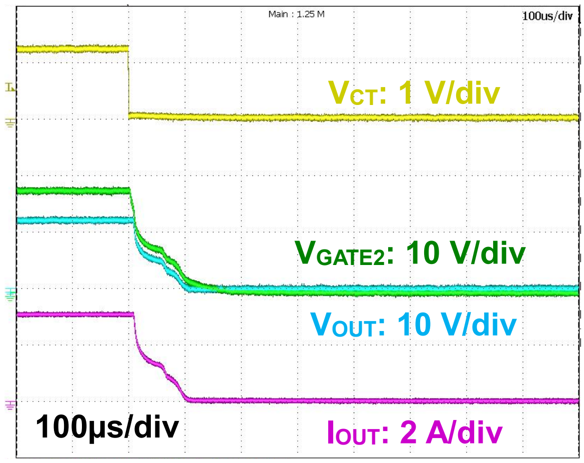
1. **Turn ON and OFF (I_{OUT} = 1 A)**



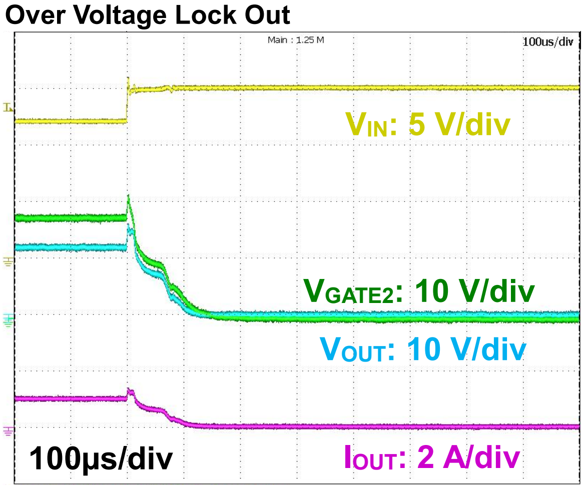


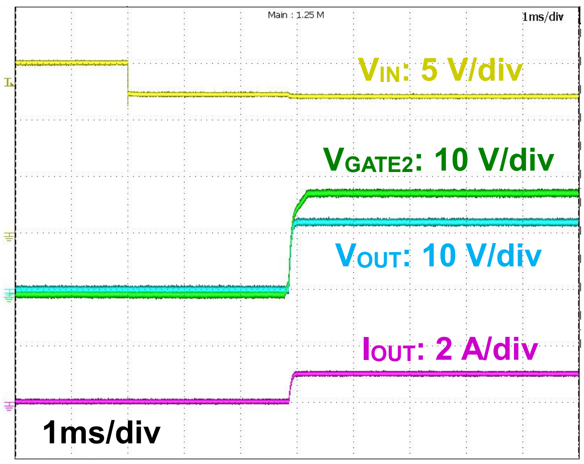
2. **Turn ON and OFF (I_{OUT} = 3 A)**





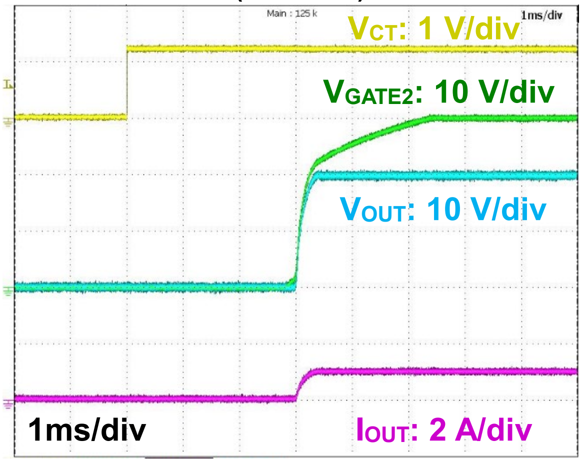
3. **Over Voltage Lock Out**

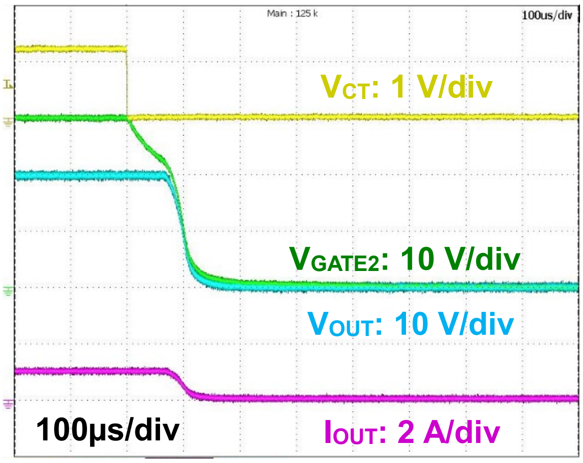




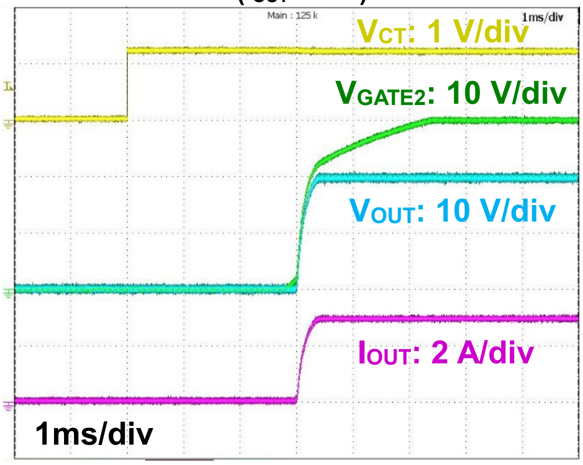
TCK421G + TPHR6503PL1 x 2pcs

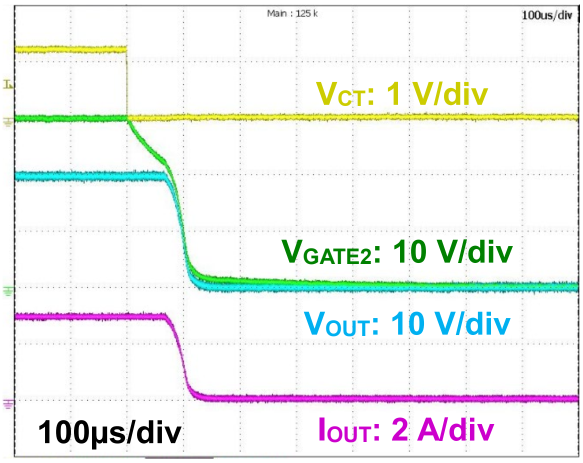
1. Turn ON and OFF (I_{OUT} = 1 A)



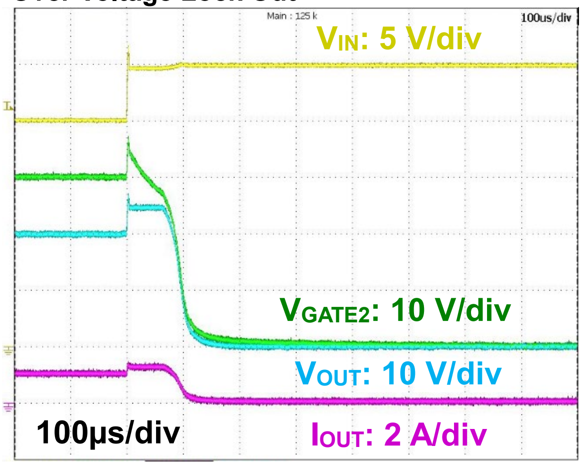


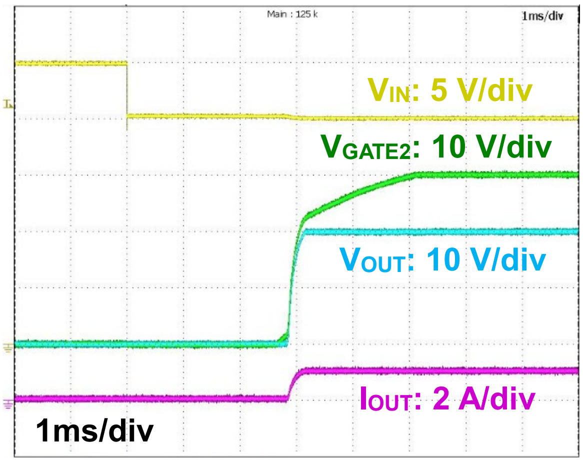
2. Turn ON and OFF (I_{OUT} = 3 A)



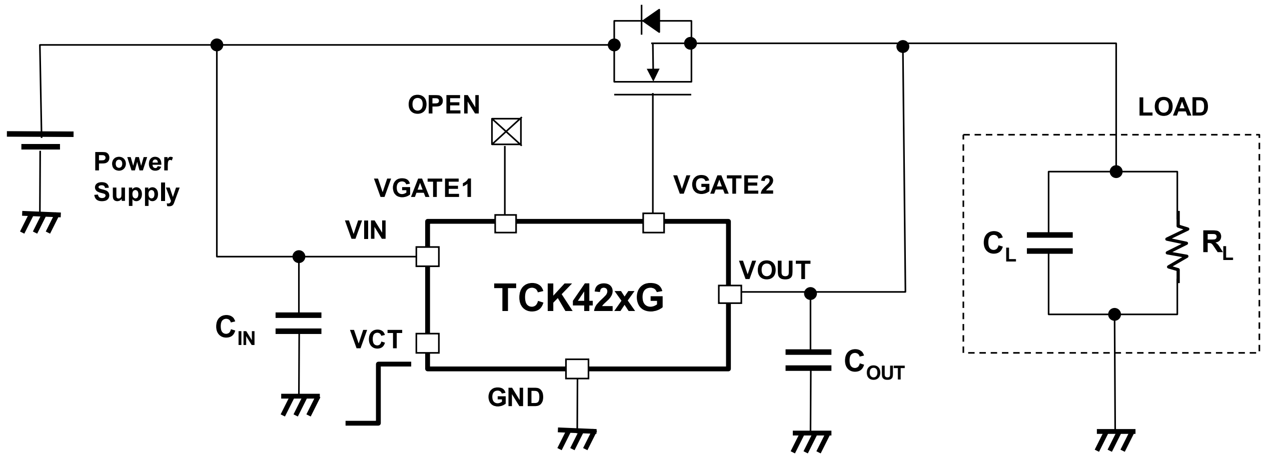


3. Over Voltage Lock Out





12.2. Single N-channel MOSFET circuit example



1. Input and Output capacitor
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2. VCT pin
   VCT pin is pull down connection to GND. VCT High level voltage must be under 5.5V V_{IH} 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.

4. Turn on recovery time after Over Voltage Lock Out
   Once V_{IN} is in normal voltage range after OVLO, the turn on recovery time is similar V_{GS} ON time (t_{ON}).

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.

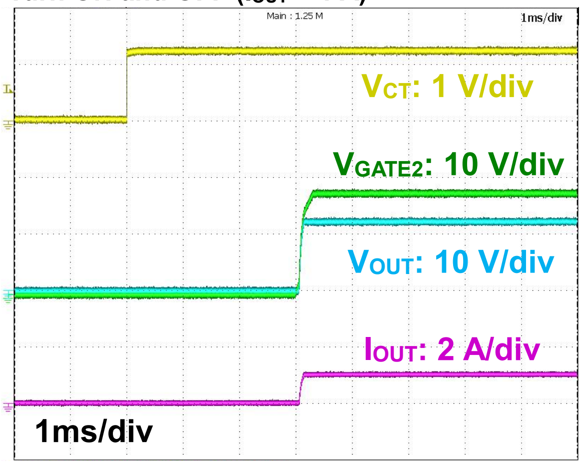
Single N-channel MOSFET Switching Waveform

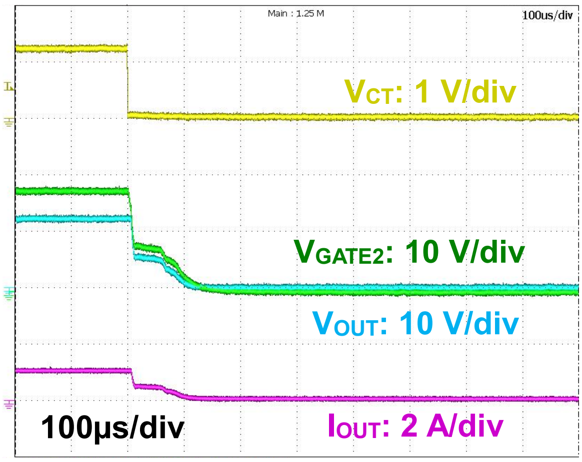
Typical switching waveforms with TOSHIBA MOSFETs

OVP Gate Driver IC	MOSFET		Test conditions	
	Part Number	Description	Turn ON and OFF	Over Voltage Lock Out
TCK423G (V_{GS} = 5.6 V)	TPN1R603PL	Single N-channel MOSFET V_{DSS}: 30 V, V_{GSS}: ± 20 V $R_{DS(ON)}$: 1.2 mΩ 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 C_{IN} = 1 μF C_{OUT} = 1 μF V_{CT} = 0 V ⇔ 1.2 V Ta = 25 °C	V_{IN} = 12 V ⇔ 15 V (TCK423G) V_{IN} = 20 V ⇔ 25 V (TCK421G) I_{OUT} = 1 A C_{IN} = 1 μF C_{OUT} = 1 μF V_{CT} = 1.2 V Ta = 25 °C
TCK421G (V_{GS} = 10 V)	TPHR6503PL1	Single N-channel MOSFET V_{DSS}: 30 V, V_{GSS}: ± 20 V $R_{DS(ON)}$: 0.41 mΩ typ at V_{GS} = 10 V Package: SOP Advance(N)		

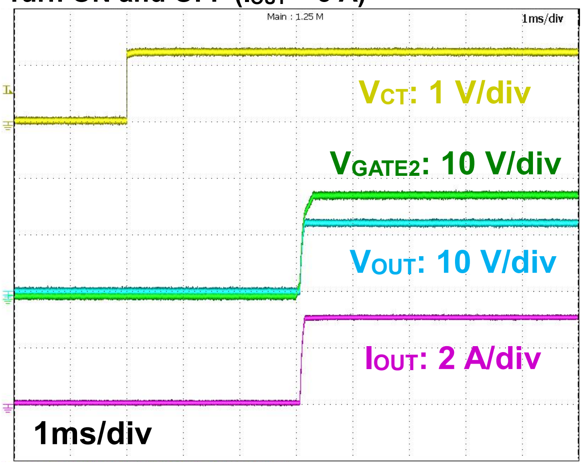
TCK423G + TPN1R603L

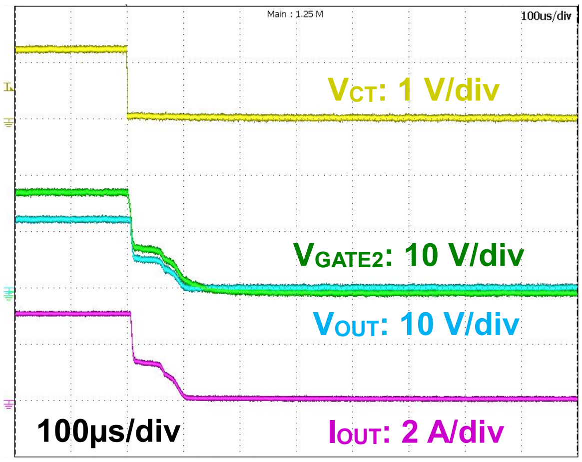
1. Turn ON and OFF (I_{OUT} = 1 A)



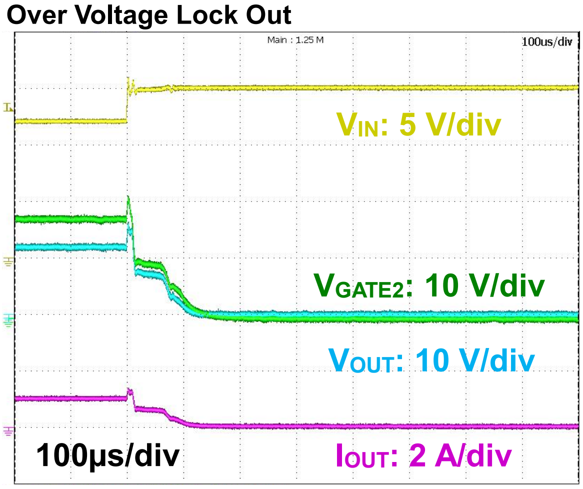


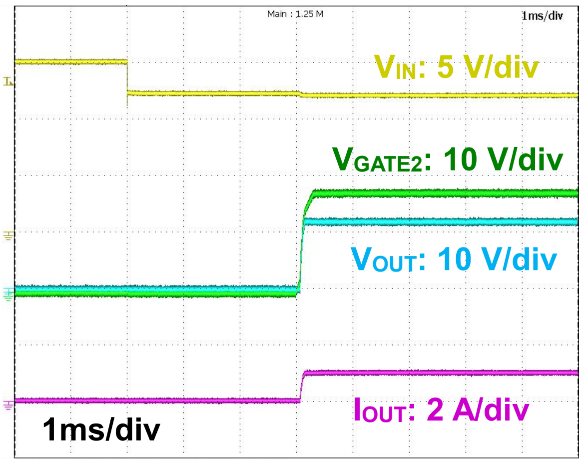
2. Turn ON and OFF (I_{OUT} = 3 A)





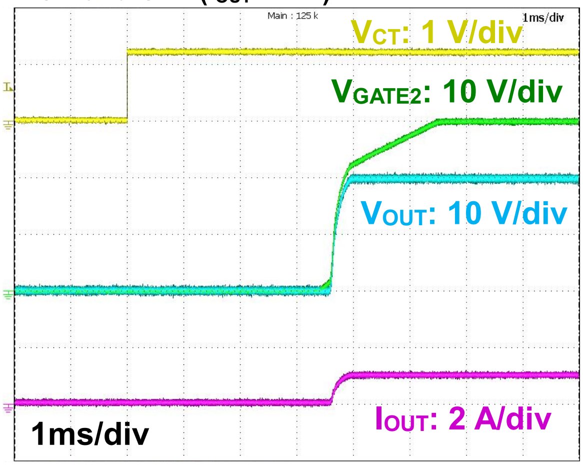
3. Over Voltage Lock Out

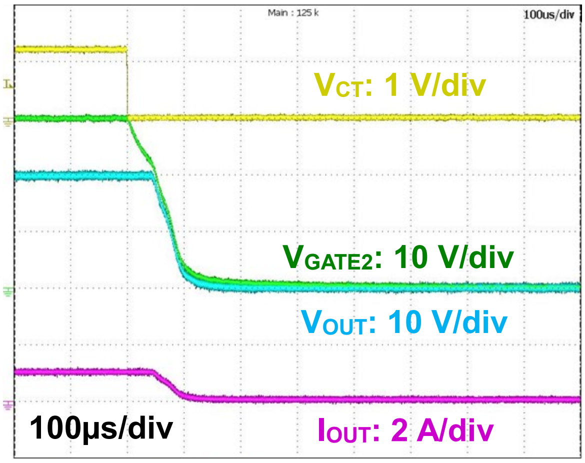




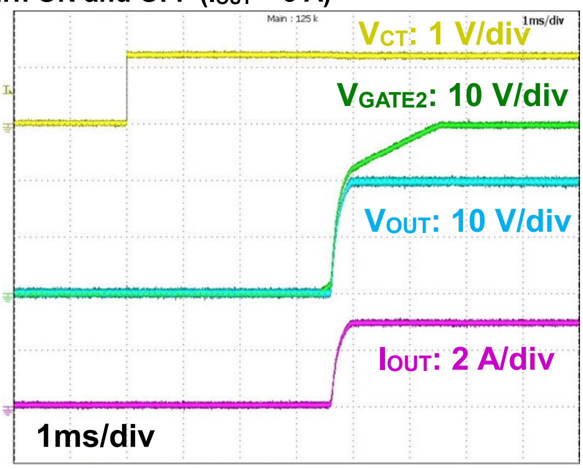
TCK421G + TPHR6503PL1

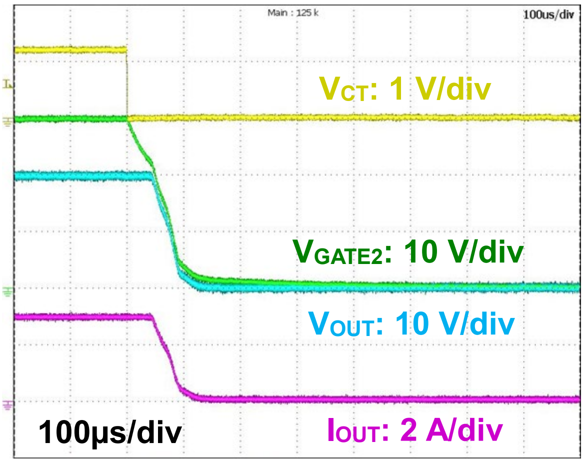
6. Turn ON and OFF (I_{OUT} = 1 A)



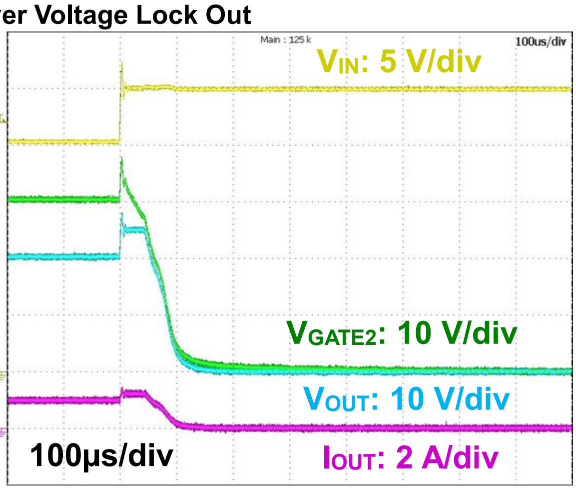


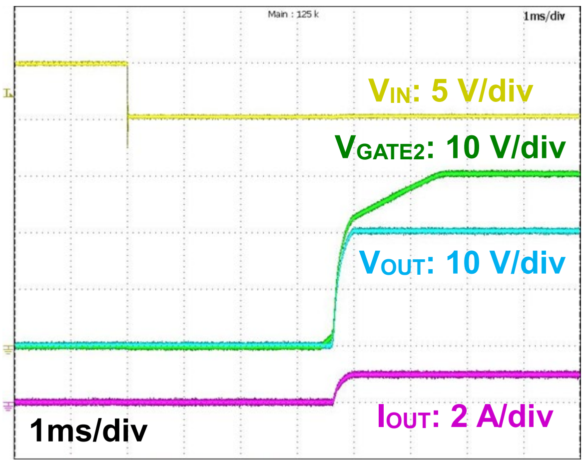
7. Turn ON and OFF (I_{OUT} = 3 A)





8. Over Voltage Lock Out

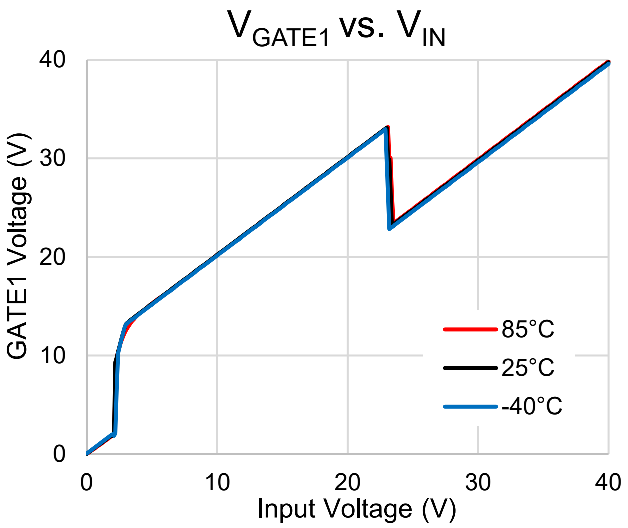


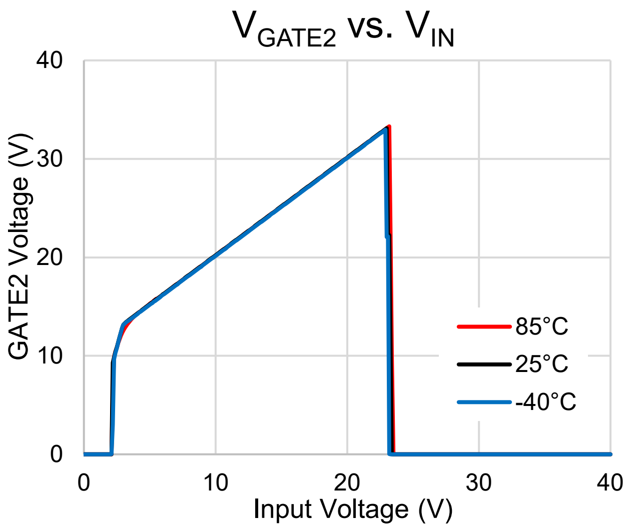


13. Representative Typical Characteristics

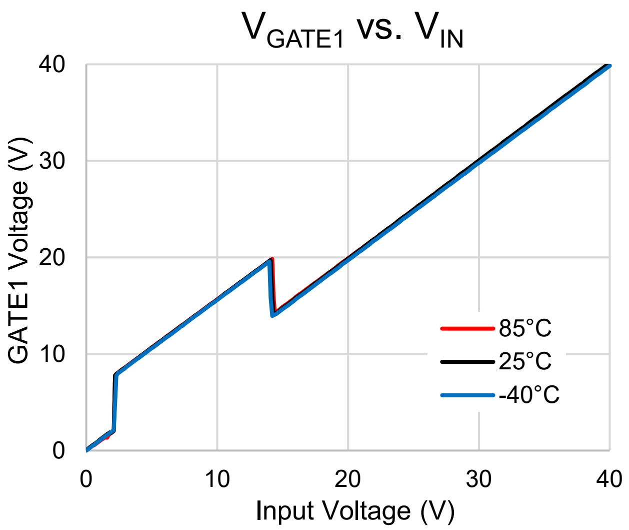
13.1. Gate voltage vs. Input voltage

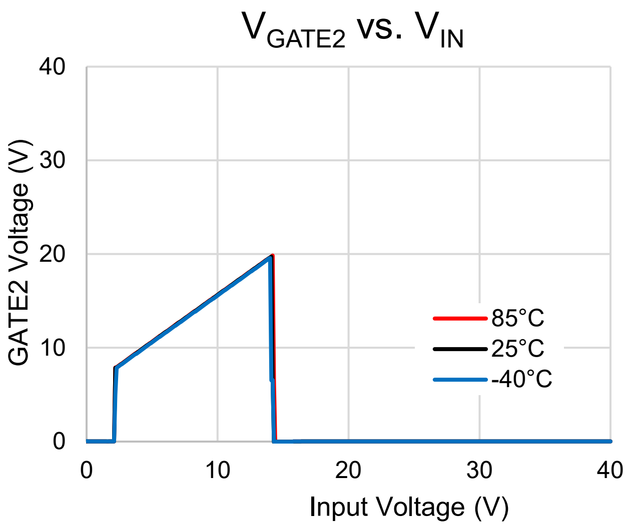
V_{GS} = 10 V (TCK421G)





V_{GS} = 5.6 V (TCK423G)

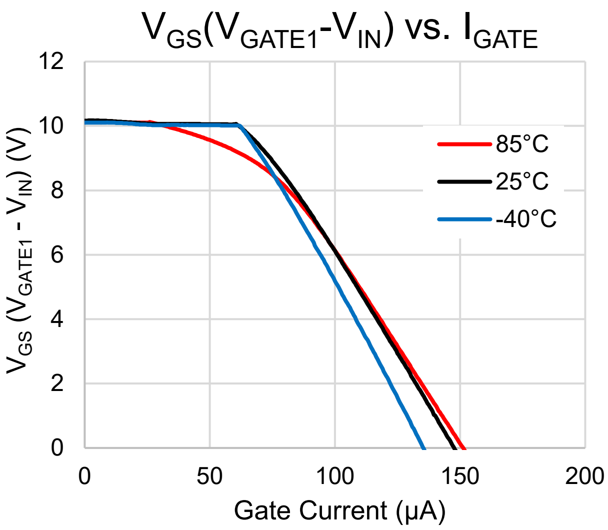


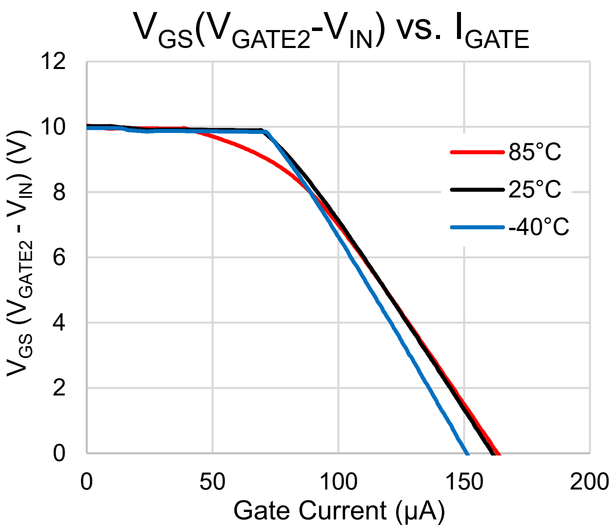


13.2. Gate voltage vs. Gate current

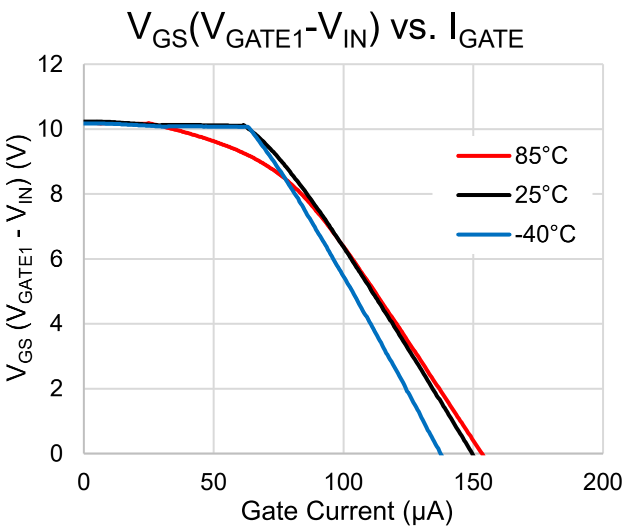
1. V_{GS} = 10V (TCK421G)

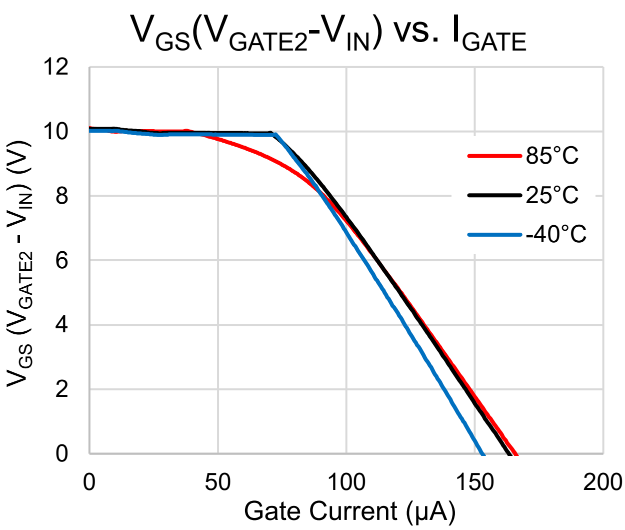
V_{IN} = 20 V





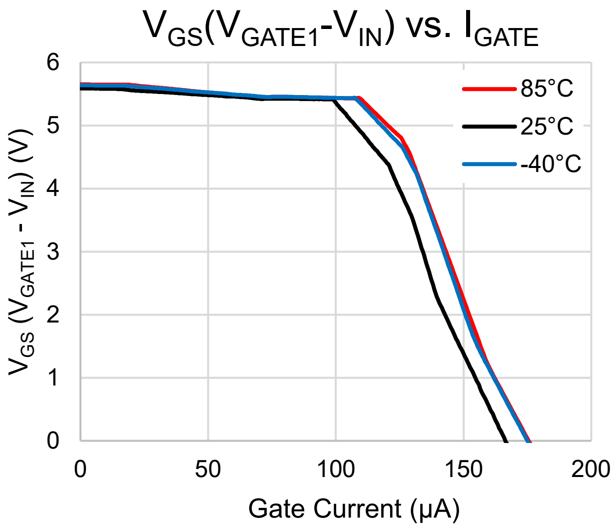
V_{IN} = 12 V

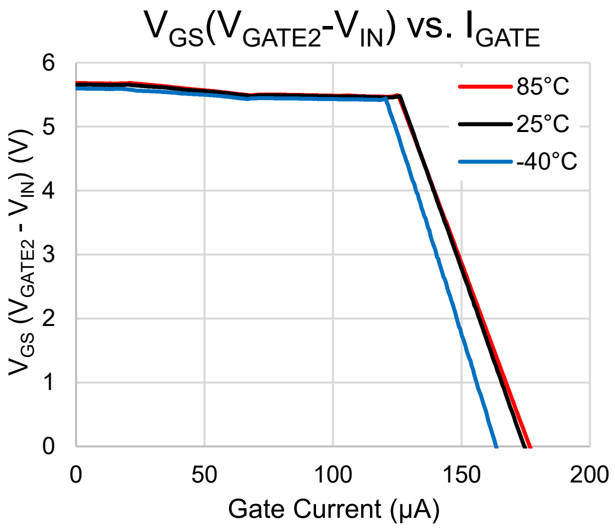




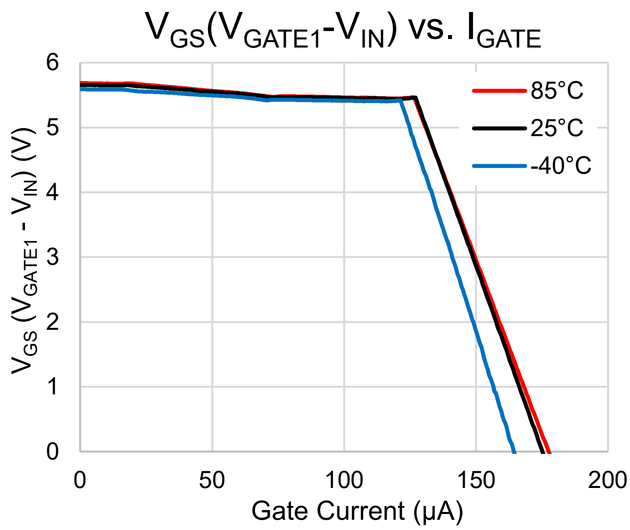
2. V_{GS} = 5.6 V (TCK423G)

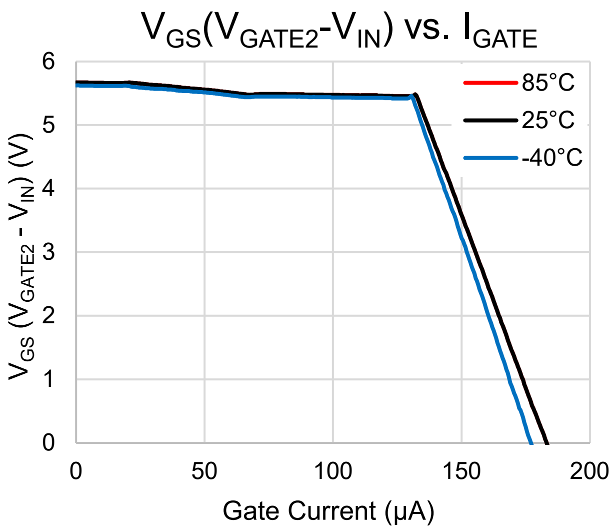
V_{IN} = 12 V





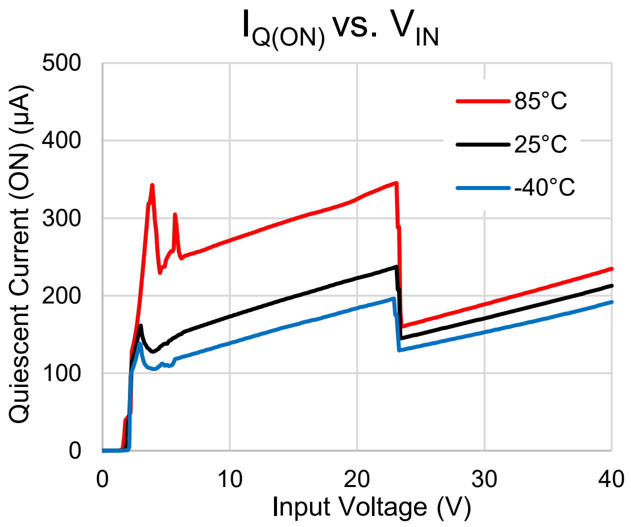
V_{IN} = 9 V



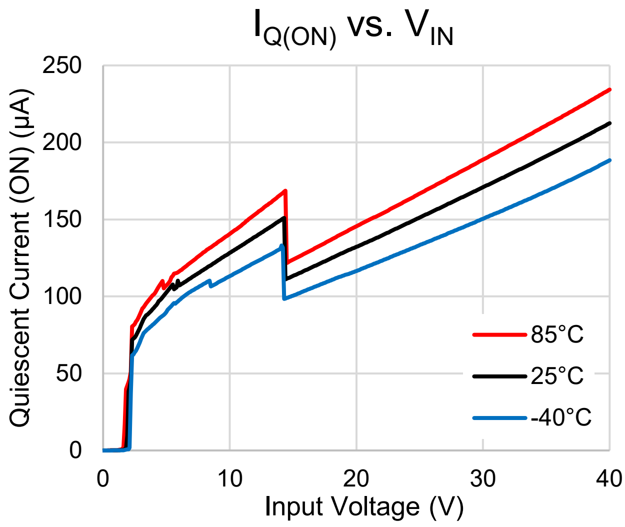


13.3. Quiescent current vs. Input voltage

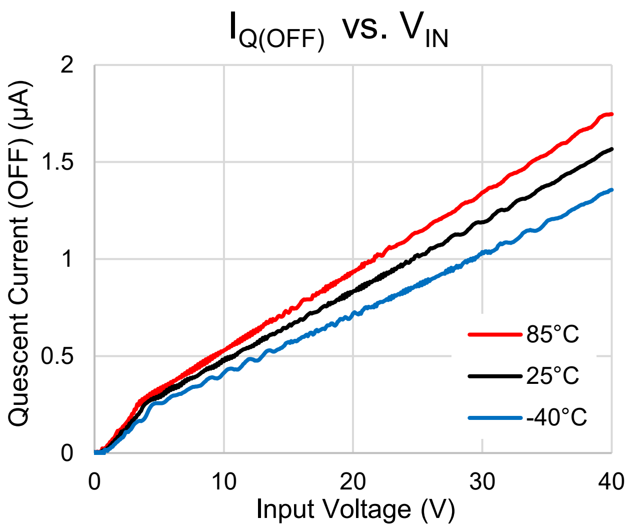
V_{GS} = 10 V (TCK421G)



V_{GS} = 5.6 V (TCK423G)



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

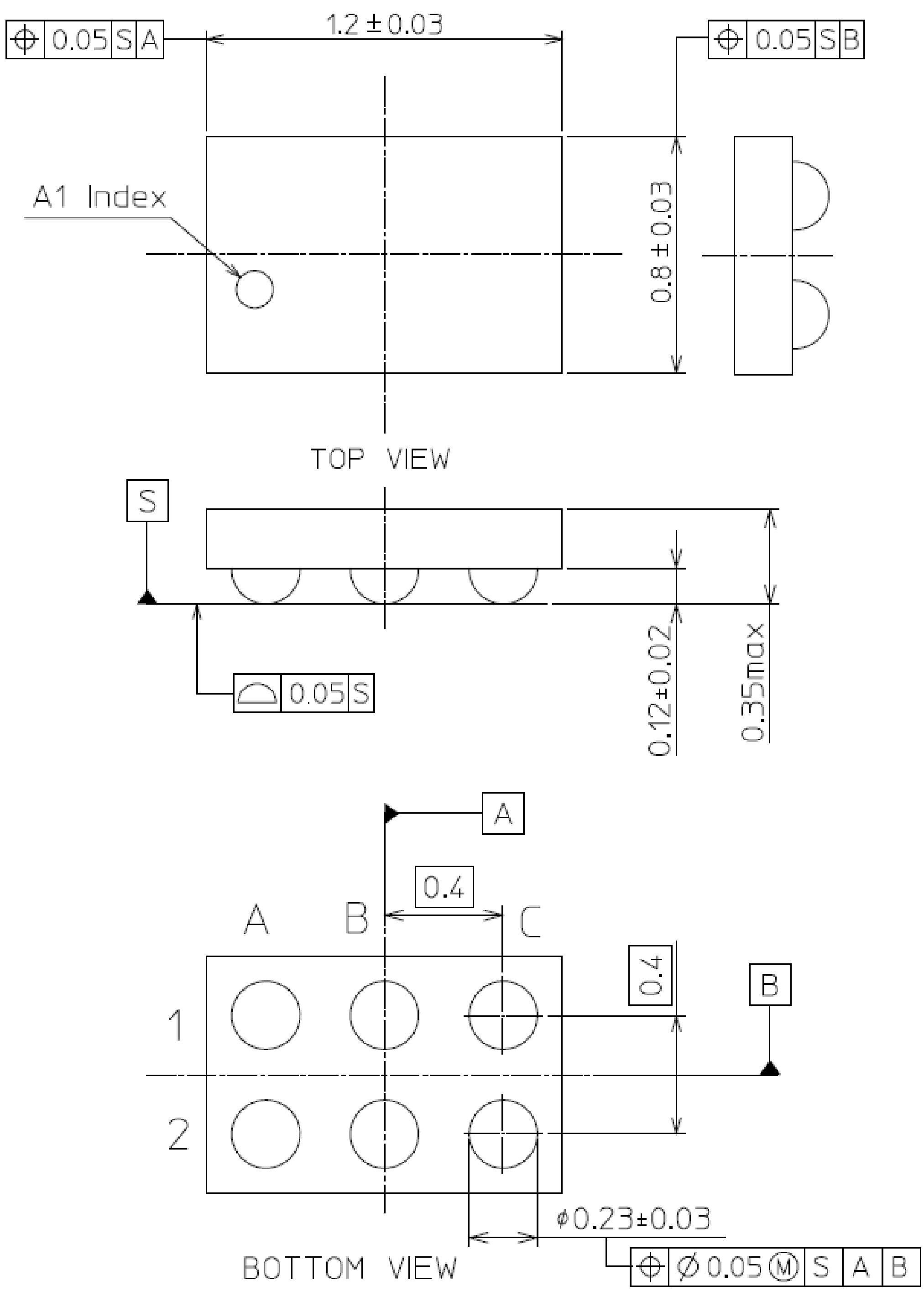


Note 6: Common characteristic of V_{GS} = 10 V and 5.6 V

14. Package Information

WCSP6G

Unit: mm

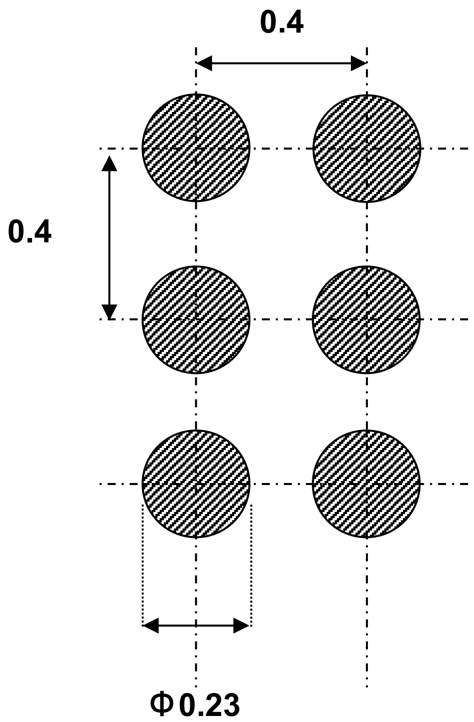


Weight: 0.61 mg (Typ.)

15. Land pattern dimensions for reference only

WCSP6G

Unit: mm



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