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Off-line Controllers for LED Lighting

■ GENERAL DESCRIPTION

The XC9401 series are off-line controller ICs for LED lighting. Through optimization of the external components, these ICs can be made to operate in a range from 85VAC to 270VAC, as well as by DC input, and a diversity of specifications can be achieved by selecting components appropriate for the circuit configuration. Fixed off-time control is used for the basic control method, and by detecting the current that flows to the external power MOSFET, the current that flows to the LED is monitored to provide a stable power supply for LED lighting. Three product series differing by function type are available, the XC9401A type, XC9401B type and the XC9401C type.

The circuit configuration of type A is designed for the power factor, achieving a high power factor by synchronizing the LED current to the input current (sine wave).

Type B and C holds the peak current due to switching that flows to the external power MOSFET constant, enabling the LED current to be kept constant.

With the type C, dimming is possible by inputting a PWM signal into the EN/DIM pin to set the LED current within a range of 1% to 100%.

■ APPLICATIONS

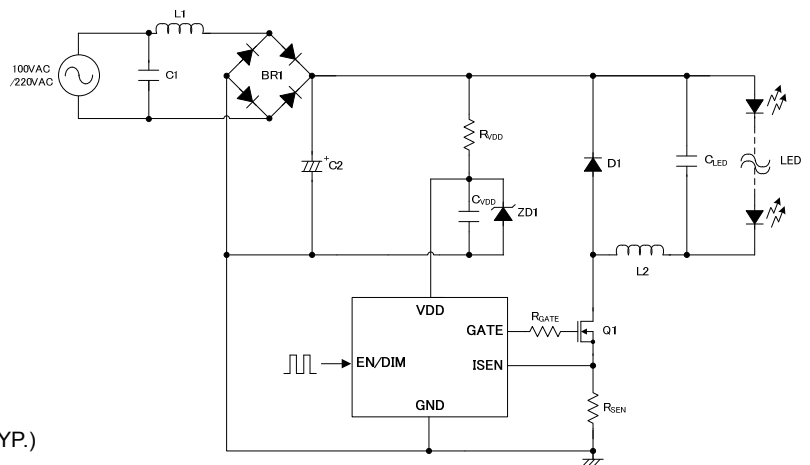
- LED bulb (GU-10, MR-16, Other)
- LED tube lights
- LED down lights
- LED spot lights
- LED stands

■ FEATURES

Operating Voltage	: 85VAC ~ 270VAC
	DC Input
I _{SEN} Voltage	: 0.34V ±2.5% (Type C)
Fixed Off-time	: 6.0μs
Protection Circuits	: Thermal Shutdown 150°C (TYP.)
	V _{DD} Over voltage protection, V _{DD} =18V (TYP.)
	UVLO, V _{DD} =6.5V (TYP.)
	Over current protection, V _{ISEN} =0.7V (TYP.)
Dimming	: PWM Dimming (LED Current:1%~100%@1kHz, Type C)
Packages	: SOT-26 (Type A, Type B) SOT-25 (Type C)
Operating Ambient Temperature	: -40°C ~ +85°C
Environmentally Friendly	: EU RoHS Compliant, Pb Free

■ TYPICAL APPLICATION CIRCUITS

(XC9401C60CSR-G Non-isolation buck Type)



■ SOLUTION EXAMPLES

Input Voltage	Product	Isolation/ Non-Isolation	Topology	Reference designs			
				Output Power	LED Voltage/ LED Current	Efficiency/ Power Factor	Option
100VAC/110VAC	XC9401C60CSR-G	Non-Isolation	Buck	7.2W	60V/120mA	91%/0.5~0.65	-
220VAC/240VAC	XC9401C60CSR-G	Non-Isolation	Buck	7.2W	60V/120mA	85%/0.5~0.65	-
	XC9401C60CSR-G	Isolation	Flyback	7.0W	19.2V/360mA	83%/0.5~0.65	-
	XC9401A605MR-G	Isolation	Flyback	7.2W	20V/360mA	82%/0.9~	-
400VDC	XC9401C60CSR-G	Non-Isolation	Buck	104W	200V/520mA	97%	With PFC circuit
15VDC	XC9401C60CSR-G	-	Buck	3.5W	9.6V/350mA	92%	-
12VAC	XC9401C60CSR-G	-	Buck	2.7W	9V/300mA	87%	For MR16

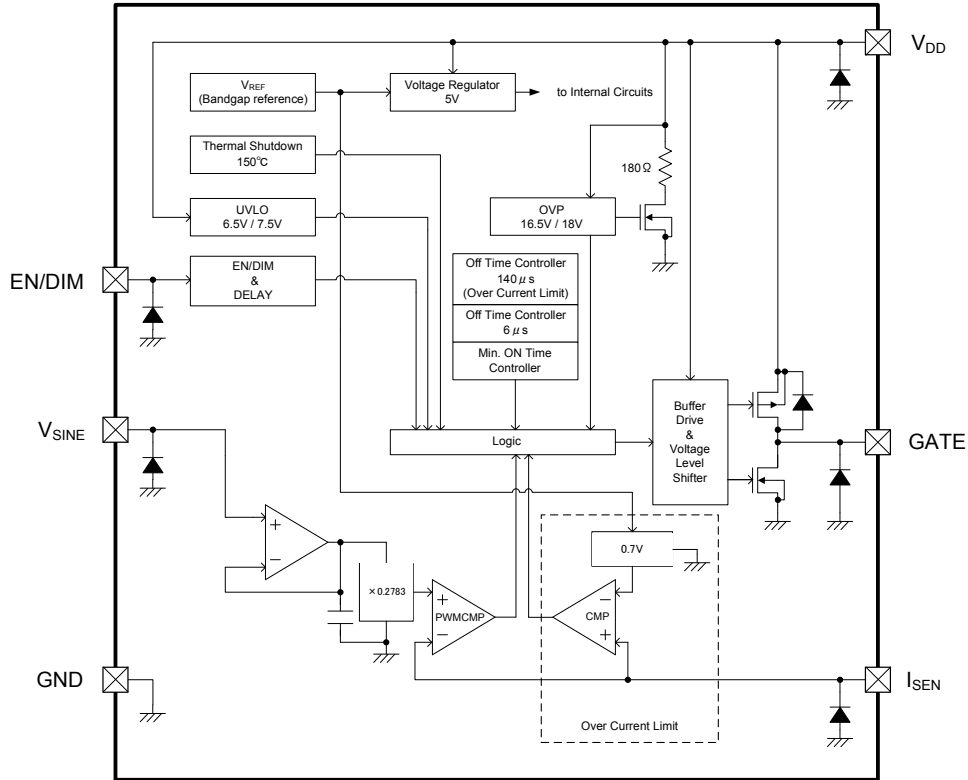
*Due to dispersion of constant values of external components, the above values may be deviated.

Please understand that the above are typical values. For details, refer to the XC9401 Series Application Notes.

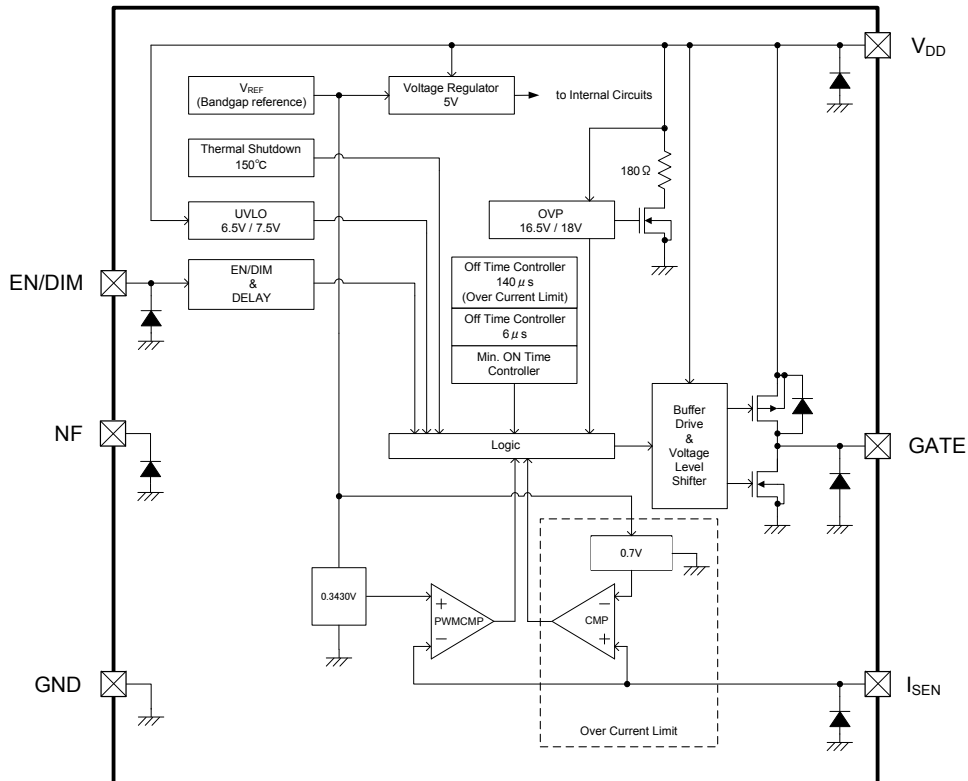
XC9401 Series

BLOCK DIAGRAM

1) XC9401 Series, Type A



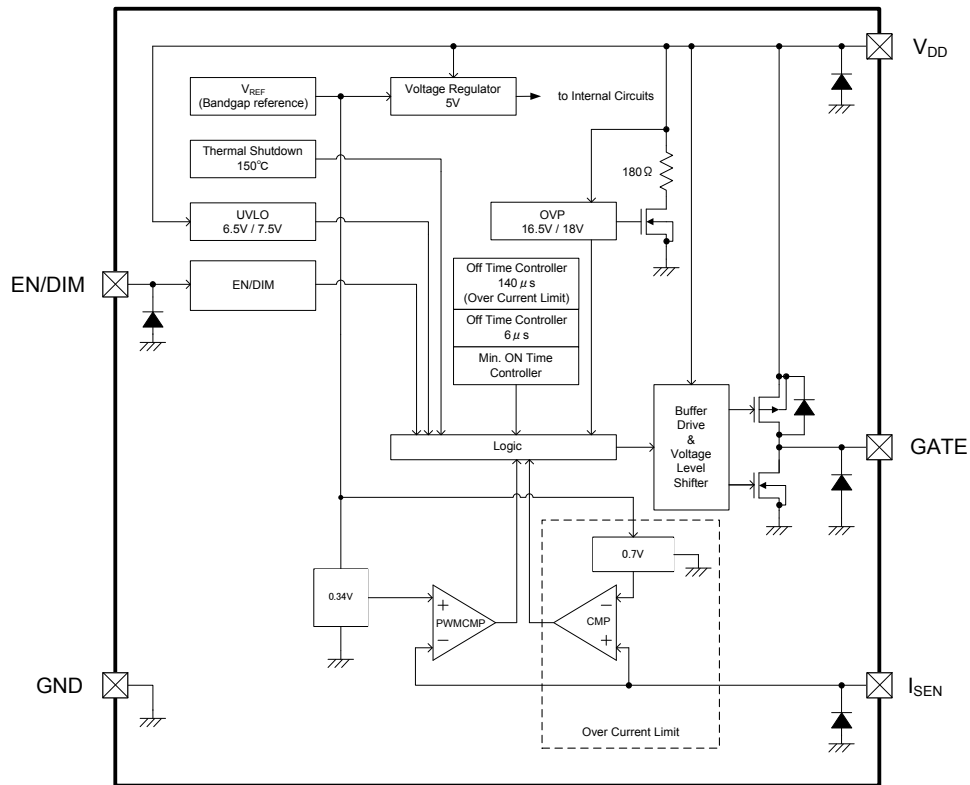
2) XC9401 Series, Type B



* Diodes inside the circuit are an ESD protection diode and a parasitic diode.

■ BLOCK DIAGRAM

3) XC9401 Series, Type C



* Diodes inside the circuit are an ESD protection diode and a parasitic diode.

PRODUCT CLASSIFICATION

Ordering Information

XC9401①②③④⑤⑥-⑦(*1)

DESIGNATOR	ITEM	SYMBOL	DESCRIPTION
①	Type	A	Refer to Selection Guide
		B	
		C	
②	OFF Time	6	OFF Time is fixed in 6μs
③④	Accuracy	05	Type A, Type B : I _{SEN} Voltage Accuracy is ±5%
		0C	Type C : I _{SEN} Voltage Accuracy is ±2.5%
⑤⑥-⑦	Packages (Order Unit)	MR-G	SOT-26 (Type A, Type B) (3,000pcs/Reel)
		SR-G	SOT-25 (Type C) (3,000pcs /Reel)

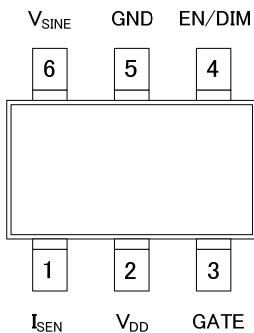
(*1) The "-G" suffix denotes Halogen and Antimony free as well as being fully EU RoHS compliant.

Selection Guide

TYPE	COMPARISON WITH ISEN	PWM DIMMING	DESCRIPTION
A	"V _{SINE} " × 0.2783	Yes	Type A is suitable for PFC circuit.
B	0.3430V	Yes	Type B is suitable for constant LED current circuit.
C	0.3400V	Yes	Type C is suitable for constant LED current circuit and for PWM DIMMING control.

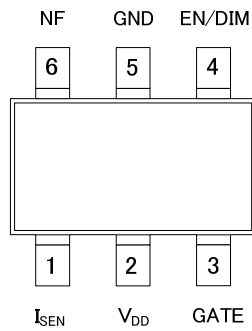
PIN CONFIGURATION

*Type A



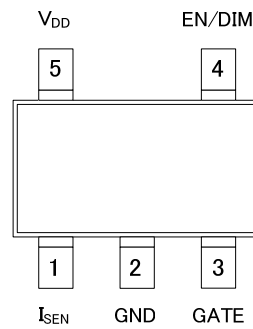
SOT-26
(TOP VIEW)

*Type B



SOT-26
(TOP VIEW)

*Type C



SOT-25
(TOP VIEW)

PIN ASSIGNMENT

PIN NUMBER		PIN NAME	FUNCTIONS
SOT-26	SOT-25		
1	1	I _{SEN}	Current Feedback
2	5	V _{DD}	Power Input
3	3	GATE	External Power MOSFET Drive
4	4	EN/DIM	ON/OFF / PWM Dimming
5	2	GND	Ground
6	-	Type A : V _{SINE}	V _{SINE} Pin : Current Feedback Reference Voltage Input.
		Type B : NF	NF Pin : No Function. Please connect to GND.

■ FUNCTION

PIN NAME	EN/DIM	STATUS
EN/DIM	L	Stand-by Mode
	H	Active Mode
	OPEN	Undefined State ^(*)

^(*) Prohibited in the XC9401 series due to undefined operation.

■ ABSOLUTE MAXIMUM RATINGS

Ta=25°C

PARAMETER	SYMBOL	RATINGS	UNITS	
V _{DD} Pin Voltage	V _{DD}	-0.3 ~ +19.4	V	
EN/DIM Pin Voltage	V _{EN/DIM}	-0.3 ~ +19.4	V	
GATE Pin Voltage	V _{GATE}	-0.3 ~ V _{DD} +0.3 or +19.4 ^(*)	V	
I _{SEN} Pin Voltage	V _{ISEN}	-0.3 ~ 5.5	V	
V _{SINE} Pin Voltage	V _{SINE}	-0.3 ~ 5.5	V	
NF Pin Voltage	V _{NF}			
Power Dissipation	SOT-26	Pd	250	mW
			600 (PCB mounted) ^(*)	
	SOT-25		250	
			600 (PCB mounted) ^(*)	
Operating Ambient Temperature	T _{opr}	-40 ~ +85	°C	
Storage Temperature	T _{stg}	-55 ~ +125	°C	

^(*) All voltages are described based on GND.

⁽²⁾ The maximum value should be either V_{DD}+0.3 or +19.4V in the lowest.

⁽³⁾ The power dissipation figure shown is PCB mounted. Please refer to pages 21 ~ 22 for details.

ELECTRICAL CHARACTERISTICS

XC9401 Series, Type A

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	CIRCUIT
V _{DD} Voltage Range	V _{DD}		9	-	15	V	①
I _{SEN} Voltage	V _{ISEN}	V _{ISEN} =SWEEP ^(*) , V _{SINE} =1V	0.2644	0.2783	0.2922	V	①
V _{SINE} Voltage Range ^(**)	V _{SINE}		GND	-	1.8	V	①
UVLO Detect Voltage	V _{UVLO}	V _{DD} =SWEEP ^(***)	5.5	6.5	7.5	V	①
UVLO Release Voltage	V _{UVLOR}	V _{DD} =SWEEP ^(****)	6.5	7.5	8.5	V	①
UVLO Hysteresis Width	V _{UVLOH}	V _{UVLOH} =V _{UVLOR} - V _{UVLO}	-	1.1	-	V	①
Supply Current ^(***)	I _{DD}	V _{DD} =V _{ENDIM} =15V	-	250	300	μA	①
Stand-by Current ^(****)	I _{STB}	V _{DD} =15V, V _{ENDIM} =GND, V _{SINE} =GND	-	225	280	μA	①
V _{DD} Overvoltage Protection Voltage	V _{OVPR}	V _{DD} =SWEEP ^(***) , V _{ENDIM} =V _{DD}	17	18	19	V	①
V _{DD} Overvoltage Protection Release Voltage	V _{OVPR}	V _{DD} =SWEEP ^(****) , V _{ENDIM} =V _{DD}	15.5	16.5	17.5	V	①
V _{DD} Overvoltage Protection Hysteresis Width	V _{OVPH}	V _{OVPH} =V _{OVPR} - V _{OVPR}	-	1.5	-	V	①
V _{DD} Overvoltage Protection Discharge Current ^(****)	I _{OVPR}	V _{DD} =19V	-	30	-	mA	①
GATE "H" ON Resistance	R _{GATEH}	I _{GATE} = -10mA R _{GATEH} = (V _{DD} -V _{GATE}) / I _{GATE}	2	5	8	Ω	③
GATE "L" ON Resistance	R _{GATEL}	V _{ISEN} =1V, R ₁ =300Ω R _{GATEL} = V _{GATE} / I _{R1} ^(***)	-	5	-	Ω	④
OFF Time ^(***)	t _{OFF}	V _{ISEN} =0.4V, V _{SINE} =1V	-	6	-	μs	①
Minimum ON Time	t _{ONMIN}	V _{ISEN} =1V	-	0.2	-	μs	①
Current Limit Voltage ^(****)	V _{LIM}	V _{ISEN} =SWEEP, V _{SINE} =1.4V	0.65	0.70	0.95	V	①
Thermal Shutdown Temperature ^(****)	T _{TSD}		-	150	-	°C	①
Thermal Shutdown Release Temperature	T _{TSDR}		-	130	-	°C	①
Thermal Shutdown Hysteresis Width	T _{HYS}		-	20	-	°C	①
PWM Dimmer Delay Time1 ^(****)	t _{PWMDIM1}	V _{ENDIM} =2.2V to GND	-	0.3	4.0	μs	②
PWM Dimmer Delay Time2 ^(****)	t _{PWMDIM2}	V _{ENDIM} =GND to 2.2V	100	140	200	μs	②
EN/DIM "H" Voltage	V _{ENDIMH}		2.2	-	15.0	V	①
EN/DIM "L" Voltage	V _{ENDIML}		GND	-	0.4	V	①
EN/DIM Bias Current	I _{ENDIMH}	V _{ENDIM} =15V	-	-	32	μA	①

Unless otherwise stated, GND standard, V_{DD}=13V, V_{ENDIM}=V_{DD}, V_{ISEN}=GND, V_{SINE}=5.5V

(*) I_{SEN} pin voltage measured at start of GATE pin switching.

(**) Indicates V_{SINE} pin voltage at which OFF TIME 6μs switching becomes possible.

(***) V_{DD} pin voltage measured when GATE pin=L occurs.

(****) V_{DD} pin voltage measured when GATE pin=H occurs.

(*) Indicates internal supply current when "H" level is input into EN/DIM pin and all circuits are activated. (When not switching.)

(**) Indicates internal supply current when "L" level is input into EN/DIM pin and the switching circuit is stopped.

(***) Indicates the current that discharges the capacitance between the V_{DD} and GND pins at V_{OVPR}.

(****) Please refer to P.7 "CIRCUIT④".

(*) May not be fixed at 6μs when UVLO is detected or during DIM signal control.

(**) When the current limit voltage V_{LIM} is exceeded, off time is extended to about 140μs to prevent element damage.

For details, refer to the operation description.

(***) To protect the IC from thermal destruction, thermal shutdown activates when the chip temperature reaches 150°C and forcibly sets the GATE pin voltage to "L". When the chip temperature falls to 130°C, operation resumes.

(****) Time from attainment of EN/DIM "L" voltage until GATE pin=L.

(****) Time from attainment of EN/DIM "H" voltage until GATE pin=H.

■ ELECTRICAL CHARACTERISTICS (Continued)

XC9401 Series, Type B

Ta=25 °C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	CIRCUIT
V _{DD} Voltage Range	V _{DD}		9	-	15	V	①
I _{SEN} Voltage	V _{ISEN}	V _{ISEN} =SWEEP ⁽¹⁾	0.3259	0.3430	0.3602	V	①
UVLO Detect Voltage	V _{UVLO}	V _{DD} =SWEEP ⁽²⁾	5.5	6.5	7.5	V	①
UVLO Release Voltage	V _{UVLOR}	V _{DD} =SWEEP ⁽³⁾	6.5	7.5	8.5	V	①
UVLO Hysteresis Width	V _{UVLOH}	V _{UVLOH} =V _{UVLOR} - V _{UVLO}	-	1.1	-	V	①
Supply Current ⁽⁴⁾	I _{DD}	V _{DD} =V _{EN/DIM} =15V	-	250	300	μA	①
Stand-by Current ⁽⁵⁾	I _{STB}	V _{DD} =15V, V _{EN/DIM} =GND	-	225	280	μA	①
V _{DD} Overvoltage Protection Voltage	V _{OV}	V _{DD} =SWEEP ⁽²⁾	17	18	19	V	①
V _{DD} Overvoltage Protection Release Voltage	V _{OVPR}	V _{DD} =SWEEP ⁽³⁾	15.5	16.5	17.5	V	①
V _{DD} Overvoltage Protection Hysteresis Width	V _{OVPH}	V _{OVPH} =V _{OV} - V _{OVPR}	-	1.5	-	V	①
V _{DD} Overvoltage Protection Discharge Current ⁽⁶⁾	I _{OV}	V _{DD} =19V	-	30	-	mA	①
GATE "H" ON Resistance	R _{GATEH}	I _{GATE} = -10mA R _{GATEH} = (V _{DD} - V _{GATE}) / I _{GATE}	2	5	8	Ω	③
GATE "L" ON Resistance	R _{GATEL}	V _{ISEN} =1V, R ₁ =300Ω R _{GATEL} = V _{GATE} / I _{R1} ⁽⁷⁾	-	5	-	Ω	④
OFF Time ⁽⁸⁾	t _{OFF}	V _{ISEN} =0.45V	-	6	-	μs	①
Minimum ON Time	t _{ONMIN}	V _{ISEN} =1V	-	0.2	-	μs	①
Current Limit Voltage ⁽⁹⁾	V _{LIM}	V _{ISEN} =SWEEP	0.65	0.70	0.95	V	①
Thermal Shutdown Temperature ⁽¹⁰⁾	T _{TSD}		-	150	-	°C	①
Thermal Shutdown Release Temperature	T _{TSDR}		-	130	-	°C	①
Thermal Shutdown Hysteresis Width	T _{HYS}		-	20	-	°C	①
PWM Dimmer Delay Time1 ⁽¹¹⁾	t _{PWMDIM1}	V _{EN/DIM} =2.2V to GND	-	0.3	4.0	μs	①
PWM Dimmer Delay Time2 ⁽¹²⁾	t _{PWMDIM2}	V _{EN/DIM} =GND to 2.2V	100	140	200	μs	②
EN/DIM "H" Voltage	V _{EN/DIMH}		2.2	-	15.0	V	②
EN/DIM "L" Voltage	V _{EN/DIML}		GND	-	0.4	V	①
EN/DIM Bias Current	I _{EN/DIMH}	V _{EN/DIM} =15V	-	-	32	μA	①

Unless otherwise stated, GND standard, V_{DD}=13V, V_{EN/DIM}=V_{DD}, V_{ISEN}=GND, V_{NF}=GND

⁽¹⁾ I_{SEN} pin voltage measured at start of GATE pin switching.

⁽²⁾ V_{DD} pin voltage measured when GATE pin=L occurs.

⁽³⁾ V_{DD} pin voltage measured when GATE pin=H occurs.

⁽⁴⁾ Indicates internal supply current when "H" level is input into EN/DIM pin and all circuits are activated. (When not switching.)

⁽⁵⁾ Indicates internal supply current when "L" level is input into EN/DIM pin and the switching circuit is stopped.

⁽⁶⁾ Indicates the current that discharges the capacitance between the V_{DD} and GND pins at V_{OV}.

⁽⁷⁾ Please refer to "CIRCUIT④".

⁽⁸⁾ May not be fixed at 6 μs when UVLO is detected or during DIM signal control.

⁽⁹⁾ When the current limit voltage V_{LIM} is exceeded, off time is extended to about 140 μs to prevent element damage.

For details, refer to the operation description.

⁽¹⁰⁾ To protect the IC from thermal destruction, thermal shutdown activates when the chip temperature reaches 150 °C and forcibly sets the GATE pin voltage to "L". When the chip temperature falls to 130 °C, operation resumes.

⁽¹¹⁾ Time from attainment of EN/DIM "L" voltage until GATE pin=L.

⁽¹²⁾ Time from attainment of EN/DIM "H" voltage until GATE pin=H.

ELECTRICAL CHARACTERISTICS (Continued)

XC9401 Series, Type C

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	CIRCUIT
V _{DD} Voltage Range	V _{DD}		9	-	15	V	①
I _{SEN} Voltage	V _{ISEN}	V _{ISEN} =SWEEP ⁽¹⁾	0.3315	0.3400	0.3485	V	①
UVLO Detect Voltage	V _{UVLO}	V _{DD} =SWEEP ⁽²⁾	5.5	6.5	7.5	V	①
UVLO Release Voltage	V _{UVLOR}	V _{DD} =SWEEP ⁽³⁾	6.5	7.5	8.5	V	①
UVLO Hysteresis Width	V _{UVLOH}	V _{UVLOH} =V _{UVLOR} - V _{UVLO}	-	1.1	-	V	①
Supply Current ⁽⁴⁾	I _{DD}	V _{DD} =V _{EN/DIM} =15V	-	250	300	μA	①
Stand-by Current ⁽⁵⁾	I _{STB}	V _{DD} =15V, V _{EN/DIM} =GND	-	225	280	μA	①
V _{DD} Overvoltage Protection Voltage	V _{OV}	V _{DD} =SWEEP ⁽²⁾	17	18	19	V	①
V _{DD} Overvoltage Protection Release Voltage	V _{OVPR}	V _{DD} =SWEEP ⁽³⁾	15.5	16.5	17.5	V	①
V _{DD} Overvoltage Protection Hysteresis Width	V _{OVPH}	V _{OVPH} =V _{OV} - V _{OVPR}	-	1.5	-	V	①
V _{DD} Overvoltage Protection Discharge Current ⁽⁶⁾	I _{OV}	V _{DD} =19V	-	30	-	mA	①
GATE "H" ON Resistance	R _{GATEH}	I _{GATE} = -10mA R _{GATEH} = (V _{DD} - V _{GATE}) / I _{GATE}	2	5	8	Ω	③
GATE "L" ON Resistance	R _{GATEL}	V _{ISEN} =1V, R ₁ =300Ω R _{GATEL} = V _{GATE} / I _{R1} ⁽⁷⁾	-	5	-	Ω	④
OFF Time ⁽⁸⁾	t _{OFF}	V _{ISEN} =0.45V	-	6	-	μs	①
Minimum ON Time	t _{ONMIN}	V _{ISEN} =1V	-	0.2	-	μs	①
Current Limit Voltage ⁽⁹⁾	V _{LIM}	V _{ISEN} =SWEEP	0.65	0.70	0.95	V	①
Thermal Shutdown Temperature ⁽¹⁰⁾	T _{TSD}		-	150	-	°C	①
Thermal Shutdown Release Temperature	T _{TSDR}		-	130	-	°C	①
Thermal Shutdown Hysteresis Width	T _{HYS}		-	20	-	°C	①
PWM Dimmer Delay Time1 ⁽¹¹⁾	t _{PWMDIM1}	V _{EN/DIM} =2.2V to GND	-	0.3	4.0	μs	①
PWM Dimmer Delay Time2 ⁽¹²⁾	t _{PWMDIM2}	V _{EN/DIM} =GND to 2.2V, V _{ISEN} =0.45V	-	6.0	10.0	μs	②
EN/DIM "H" Voltage	V _{EN/DIMH}		2.2	-	15.0	V	②
EN/DIM "L" Voltage	V _{EN/DIML}		GND	-	0.4	V	①
EN/DIM Bias Current	I _{EN/DIMH}	V _{EN/DIM} =15V	-	-	32	μA	①

Unless otherwise stated, GND standard, V_{DD}=13V, V_{EN/DIM}=V_{DD}, V_{ISEN}=GND

⁽¹⁾ I_{SEN} pin voltage measured at start of GATE pin switching.

⁽²⁾ V_{DD} pin voltage measured when GATE pin=L occurs.

⁽³⁾ V_{DD} pin voltage measured when GATE pin=H occurs.

⁽⁴⁾ Indicates internal supply current when "H" level is input into EN/DIM pin and all circuits are activated. (When not switching.)

⁽⁵⁾ Indicates internal supply current when "L" level is input into EN/DIM pin and the switching circuit is stopped.

⁽⁶⁾ Indicates the current that discharges the capacitance between the V_{DD} and GND pins at V_{OV}.

⁽⁷⁾ Please refer to "CIRCUIT ④".

⁽⁸⁾ May not be fixed at 6μs when UVLO is detected or during DIM signal control.

⁽⁹⁾ When the current limit voltage V_{LIM} is exceeded, off time is extended to about 140μs to prevent element damage.

For details, refer to the operation description.

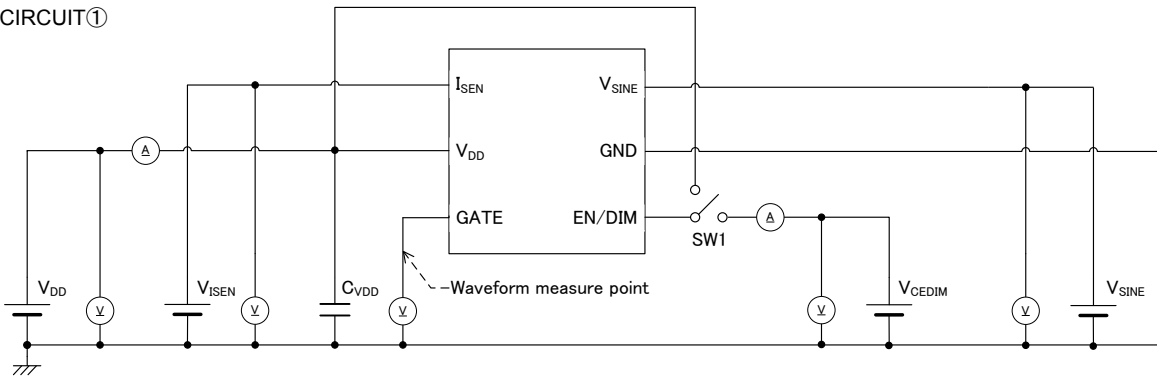
⁽¹⁰⁾ To protect the IC from thermal destruction, thermal shutdown activates when the chip temperature reaches 150°C and forcibly sets the GATE pin voltage to "L". When the chip temperature falls to 130°C, operation resumes.

⁽¹¹⁾ Time from attainment of EN/DIM "L" voltage until GATE pin=L.

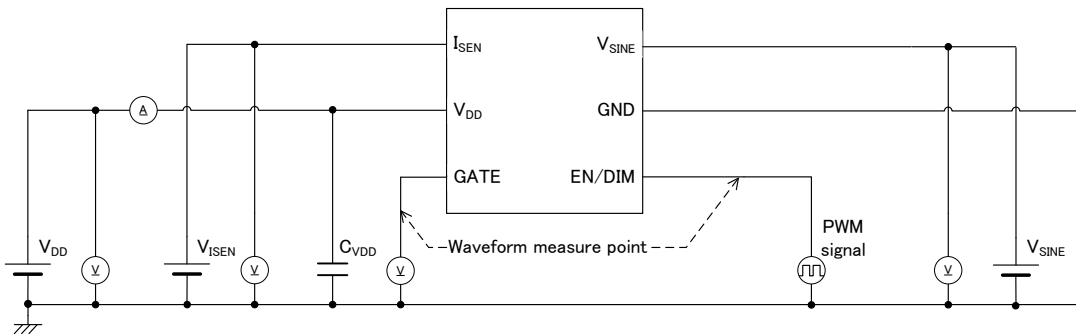
⁽¹²⁾ Time from attainment of EN/DIM "H" voltage until GATE pin=H.

■ TYPICAL APPLICATION CIRCUIT (Type A)

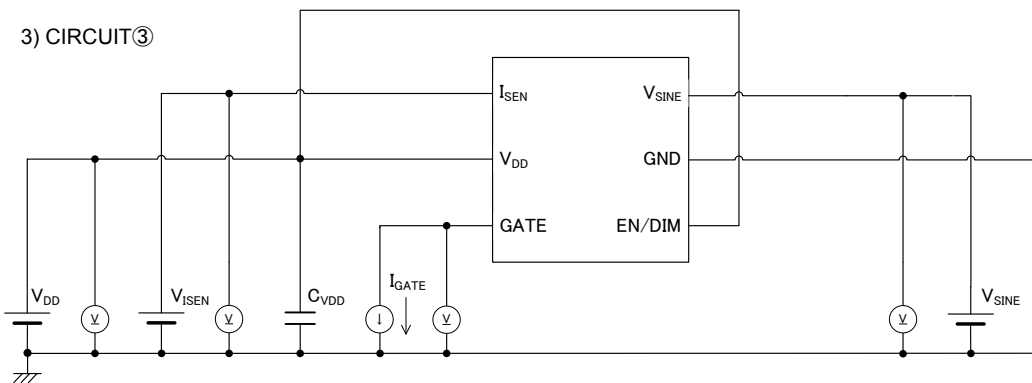
1) CIRCUIT①



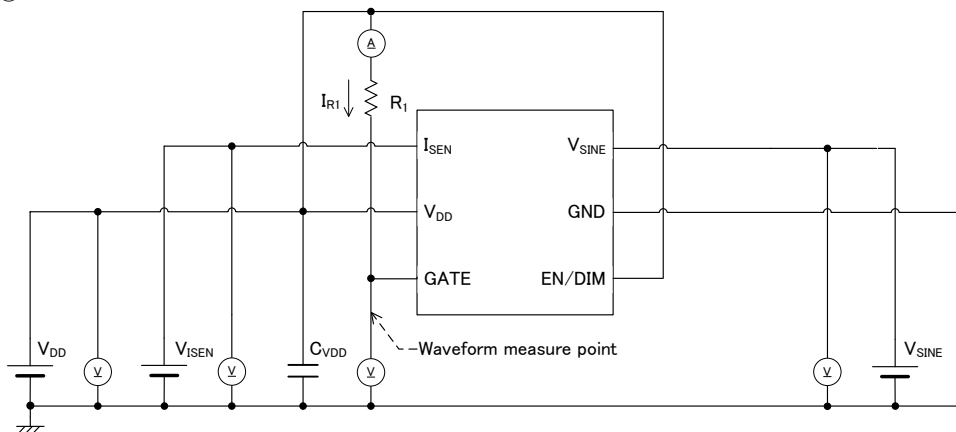
2) CIRCUIT②



3) CIRCUIT③

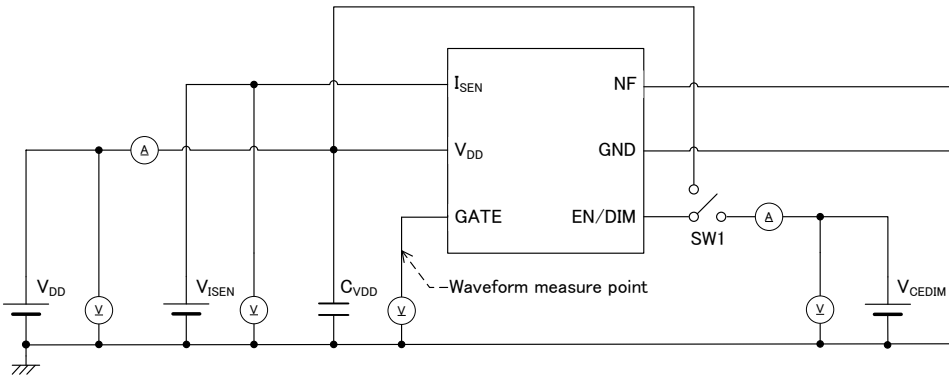


4) CIRCUIT④

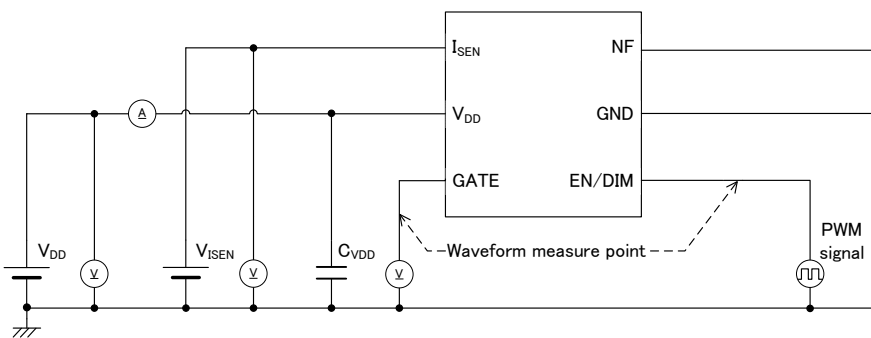


TYPICAL APPLICATION CIRCUIT (Continued) (Type B)

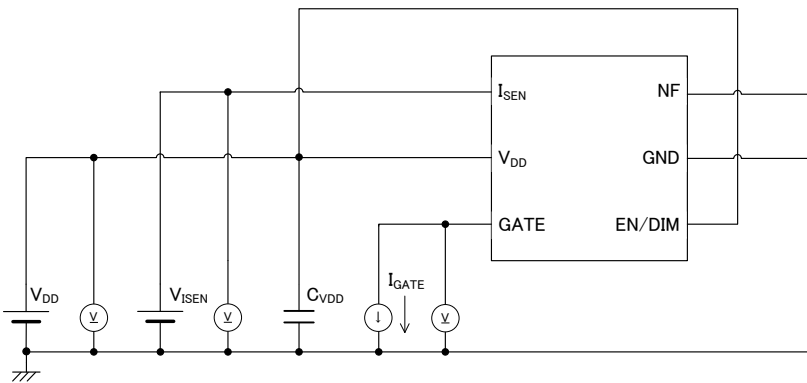
1) CIRCUIT①



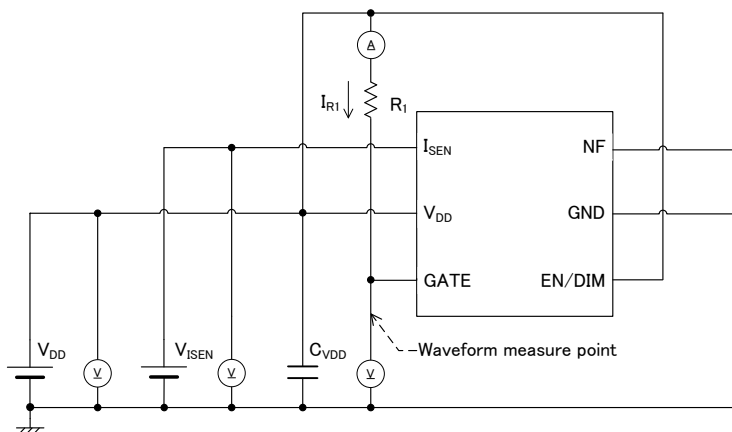
2) CIRCUIT②



3) CIRCUIT③

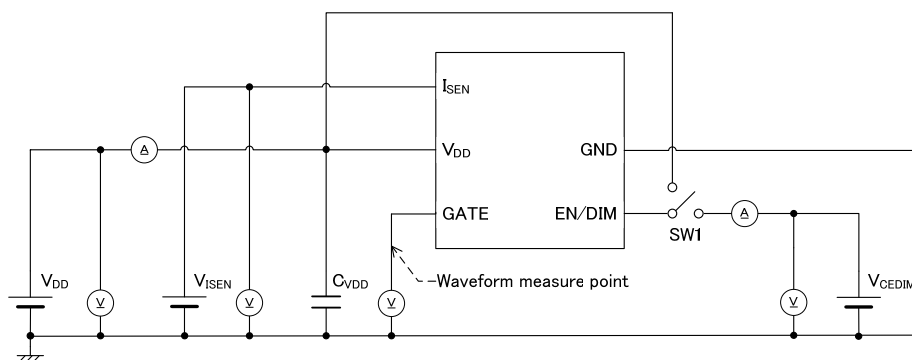


4) CIRCUIT④

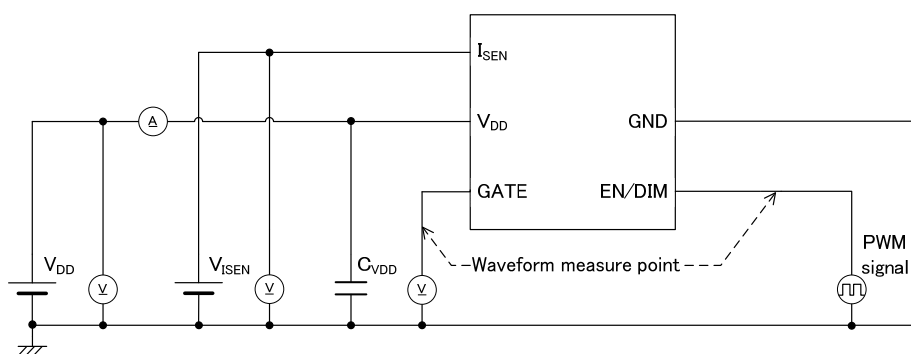


TYPICAL APPLICATION CIRCUIT (Continued) (Type C)

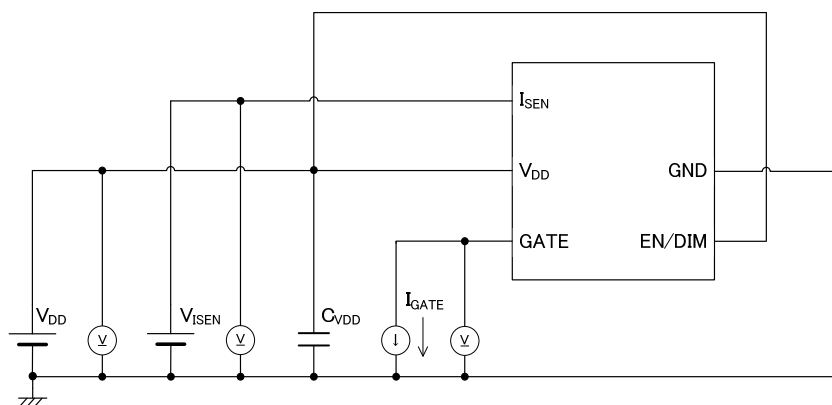
1) CIRCUIT①



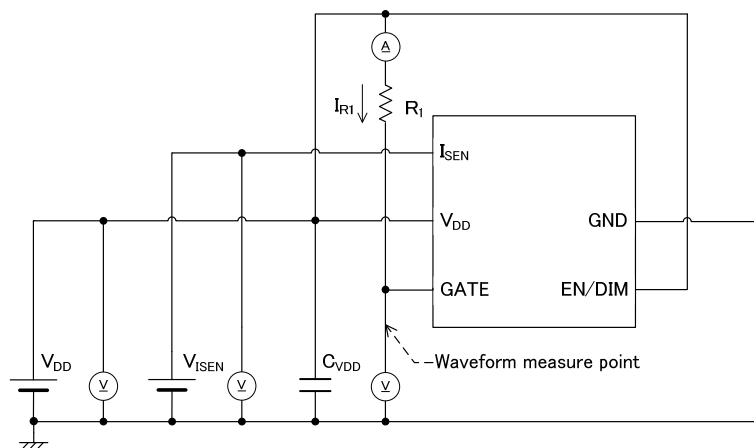
2) CIRCUIT②



3) CIRCUIT③



4) CIRCUIT④



OPERATIONAL EXPLANATION

The internal circuitry of the XC9401 series consists of a reference voltage source (V_{REF}), PWM comparator (PWMCOMP), buffer drive circuit (Buffer Drive), over-current protection circuit (Over Current Limit), under-voltage lockout circuit (UVLO), V_{DD} over voltage protection circuit (OVP), thermal shutdown circuit (Thermal Shutdown), and other circuits. (Refer to the block diagram.) The control method is fixed off-time control.

With type A, the PWM comparator compares the voltage at the I_{SEN} pin to that at the V_{SINE} pin $\times 0.2783$ (TYP.) The output of the PWM comparator is connected to the buffer drive circuit and an external Power MOS FET drive signal is output from the GATE pin. When the I_{SEN} pin voltage is 0.2783 times (TYP.) higher than the V_{SINE} pin voltage, the GATE pin switches to low. After a fixed off-time elapses, the GATE pin switches to high. This operation is repeated continuously.

With type B, the PWM comparator compares the 0.3430V (TYP.), which is 0.2783 times (TYP.) the reference voltage, to the I_{SEN} pin voltage.

With type C compares the 0.3400V to the I_{SEN} pin voltage.

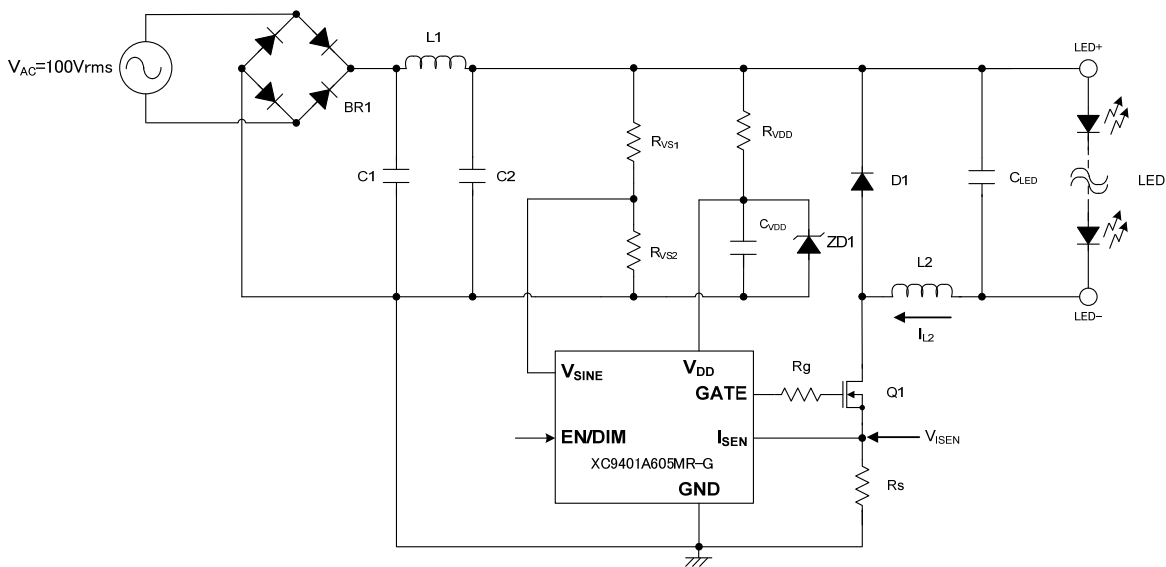


Fig.1. Reference Circuit (XC9401A605MR-G)

■ OPERATIONAL EXPLANATION (Continued)

Details of each circuit block are as follows.

<Reference voltage supply (V_{REF})>

Reference voltage that enables stable operation of the internal functions of the IC.

<PWM comparator (PWMCMP)>

With type A, the PWM comparator compares the voltage at the I_{SEN} pin to that at the V_{SINE} pin x 0.2783 (TYP.) When the I_{SEN} pin voltage is higher than V_{SINE} x 0.2783, the GATE pin switches to low.

With type B, the PWM comparator compares the 0.3430V (TYP.), which is 0.2783 times (TYP.) the reference voltage, to the I_{SEN} pin voltage.

With type C compares the 0.3400V to the I_{SEN} pin voltage.

<Buffer drive circuit (Buffer Drive)>

This outputs an H or L signal from the GATE pin that drives the external Power MOS FET. The H level is the V_{DD} pin voltage, and the L level is the GND pin voltage. The signal that is output is determined by the PWM comparator, as well as by the below described UVLO circuit, V_{DD} over-voltage protection circuit, over-current protection circuit, thermal shutdown, and EN/DIM pin voltage.

<Enable / PWM Dimming (EN/DIM)>

Inputting "L" to the EN/DIM pin voltage forcibly puts the GATE pin voltage in the "L" state. The stopped state when the EN/DIM pin voltage is "L" is not shutdown; rather, it is a Stand-by state wherein the switching pulse output is stopped by logic circuit and the internal circuitry continues to operate.

With type A and type B when the power is turned on, it takes about 200 μ s (MAX.) for the GATE pin to initially become "H" after the EN/DIM pin voltage is changed from "L" to "H".

The C type can do the dimming control between 1% and 100% more precisely by adjusting the duty width and following at high speed to the PWM signal (500Hz to 1kHz) because it is as fast as 10 μ sec that Gate terminal is tuned into "H" state at the beginning after changing EN/DIM terminal voltage into "H" from "L".

< Minimum on time controller circuit >

Noise occurs in the XC9401 series due to switching. To prevent malfunction of the internal circuit by such noises, a minimum on time is established. The GATE pin voltage is forcibly kept at "H" until the minimum on time elapses. (Refer to Fig. 2.)

During the minimum on time, if the below described UVLO, OVP or thermal shutdown is detected, or if the Stand-by state is set from the EN/DIM pin, the GATE pin voltage is immediately changed to "L".

<Off Time Controller>

This circuit controls the fixed off time. The off time is normally fixed at 6 μ s (TYP.), and the GATE pin voltage is kept at "L" during this time. After the fixed off time, the GATE pin voltage becomes "H". (Refer to Fig. 2.)

If the EN/DIM pin voltage is changed from "L" to "H" during the above PWM dimming, the off time is 140 μ s (TYP.) during the over-current protection and ULVO release described below.

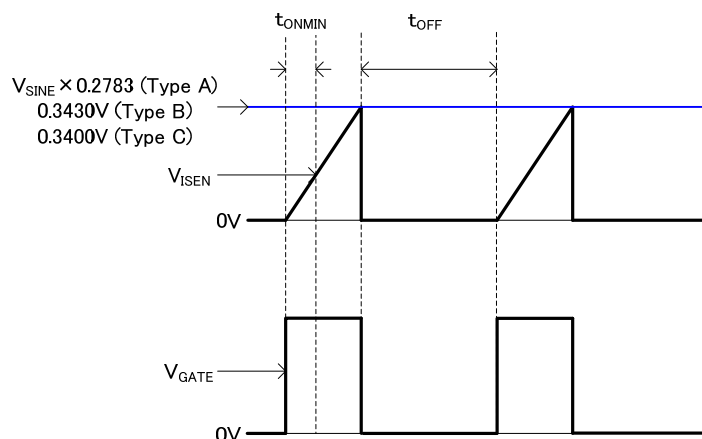


Fig.2. Off Time Controller, Min. On Time Controller

OPERATIONAL EXPLANATION (Continued)

<Over Current Limit>

When the switching current of the external power MOSFET is in the over-current state and the I_{SEN} pin voltage reaches 0.7V (TYP.), L level voltage is output to the GATE pin and the external power MOSFET is turned off. In addition, the off time is temporarily extended from the normal 6.0μs (TYP.) to 140μs (TYP.). When the I_{SEN} pin voltage falls to 0.7V (TYP.) or less after the extended off time, normal operation resumes.

When LED+ and LED- short circuit in the reference circuit shown in Fig.1, the current slope of the coil (L2) becomes smaller during the off time than the slope during normal switching, which prevents sufficient discharge during the 6.0μs (TYP.) off time. During the minimum on time, the external power MOSFET Q1 always turns on, and thus the coil current gradually increases. The I_{SEN} pin voltage becomes higher at the same time as the coil current increases, and when the I_{SEN} pin voltage reaches 0.7V (TYP.), the off time is extended to 140μs (TYP.). (Refer to Fig.3)

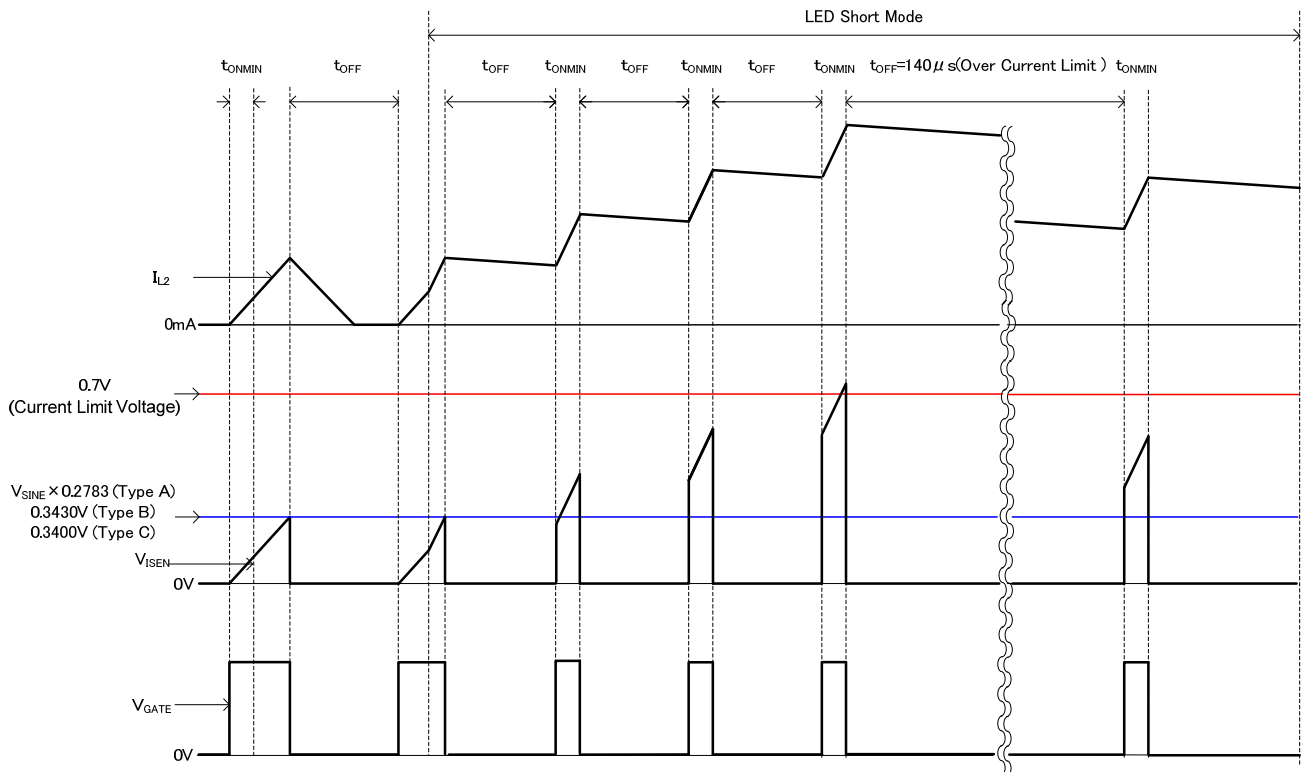


Fig.3. Over Current Limit (Fig.1. Operation when LED+ and LED- short-circuit in the reference circuit)

<Under-voltage lockout circuit>

When the V_{DD} pin voltage falls to the UVLO Detect Voltage (V_{UVLO}) or lower, the GATE pin voltage is forcibly set to “L” to prevent incorrect pulse output. When the V_{DD} pin voltage rises to the UVLO Release Voltage (V_{UVLOR}) or higher, switching resumes.

A UVLO stop simply stops pulse output; it is not a shutdown state and the internal circuitry continues to operate.

<V_{DD} over-voltage protection circuit>

When the V_{DD} pin voltage rises to the V_{DD} Overvoltage Protection Voltage (V_{OVP}) or higher, the charge of the capacitance between the V_{DD} pin and GND pin is discharged by the resistance and transistor connected between the V_{DD} pin and GND pin in order to prevent withstand voltage destruction in the internal circuitry. The GATE pin voltage at this time is forcibly set to “L”.

When the V_{DD} pin voltage falls to the V_{DD} Overvoltage Protection Release Voltage (V_{OVPR}) or lower, switching is resumed.

<Thermal shutdown>

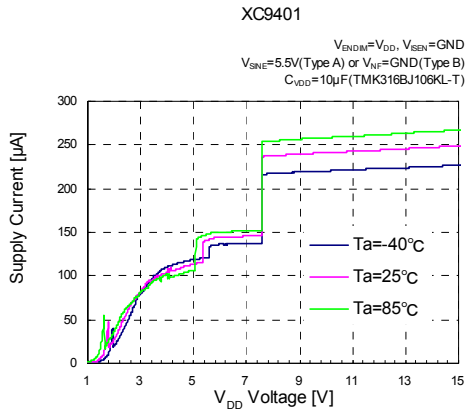
To protect the IC from thermal destruction, thermal shutdown activates when the chip temperature reaches 150 °C (TYP.) and forcibly sets the GATE pin voltage to “L”. When the chip temperature falls to 130 °C (TYP.), switching is resumed.

■ NOTE ON USE

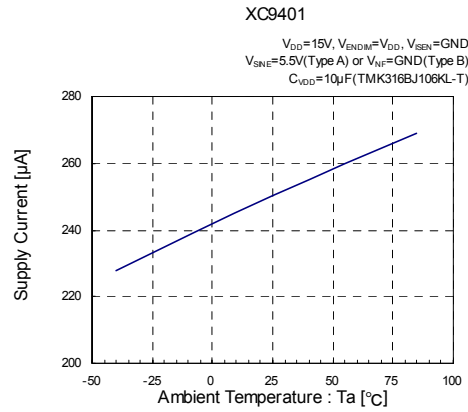
1. For the phenomenon of temporal and transitional voltage decrease or voltage increase, the IC may be damaged or deteriorated if IC is used beyond the absolute MAX. specifications.
2. In a switching controller such as the XC9401 series, and in a peripheral circuit controlled by a switching controller, spike voltage and ripple voltage occur. These are greatly affected by the peripheral components (inductance value of the coil, capacitors, peripheral component board layout).
Please select the appropriate external components with referring to the XC9401 series application note. During design, test sufficiently using the actual equipment.
3. With type A and type B, a delay time of 200 μ s (MAX.) after the UVLO release voltage, and after EN/DIM pin voltage "H", has been established in the IC.
With type C a delay time of 140 μ s(TYP.) after the UVLO release voltage, and a delay time of 10 μ s after EN/DIM pin voltage "H" , has been established in the IC. Keep these delay times in mind during sequence design.
4. The NF pin of the XC9401B605MR-G is connected to part of the internal circuitry, although not as a circuit function. When using this IC, connect this pin to GND.
5. Make sure to use this IC within specified electric characteristics.
6. Please pay attention not to exceed absolute maximum ratings of this IC and external components.
7. To reduce V_{DD} fluctuations as much as possible, connect a bypass capacitor (C_{VDD}) over the shortest path between V_{DD} and GND. If there is too much distance between the IC and C_{VDD} , operation may become unstable.
8. Please mount each external component as close to the IC as possible. Please also wire external components as close to the IC as possible and use thick, short connecting traces to reduce the circuit impedance.
9. Sufficiently reinforce the wiring between V_{DD} and GND. Noise that enters through V_{DD} and GND during switching may cause unstable IC operation.
10. Torex places an importance on improving our products and their reliability.
We request that users incorporate fail-safe designs and post-aging protection treatment when using Torex products in their systems.

TYPICAL PERFORMANCE CHARACTERISTICS

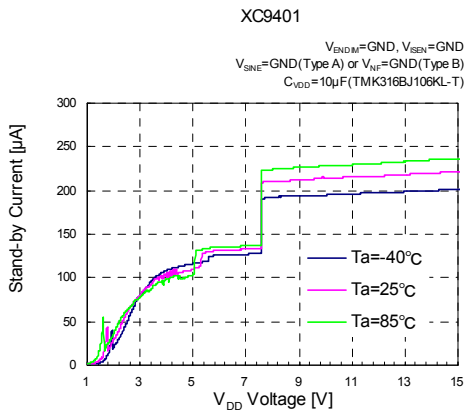
(1) Supply Current vs. V_{DD} Voltage



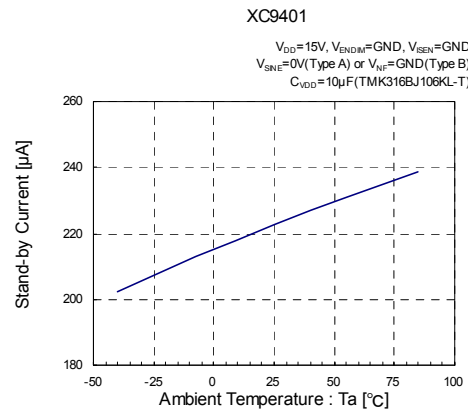
(2) Supply Current vs. Ambient Temperature



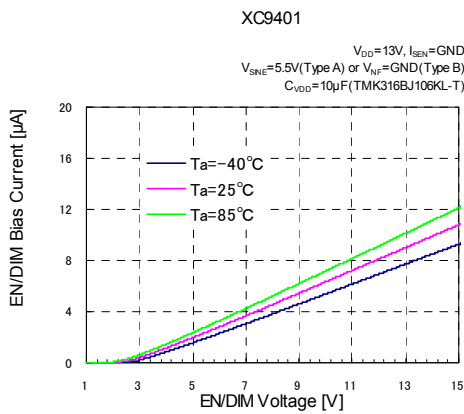
(3) Stand-by Current vs. V_{DD} Voltage



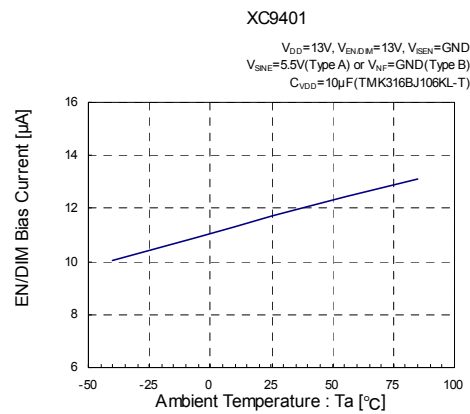
(4) Stand-by Current vs. Ambient Temperature



(5) EN/DIM Bias Current vs. EN/DIM Voltage



(6) EN/DIM Bias Current vs. Ambient Temperature

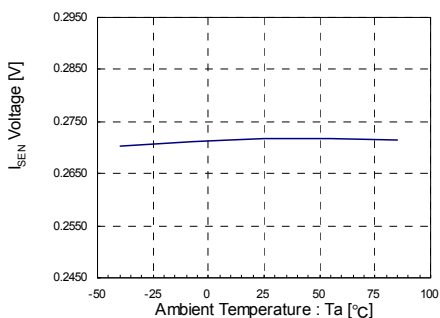


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(7) I_{SEN} Voltage vs. Ambient Temperature

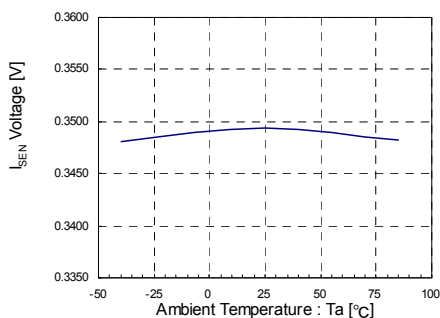
XC9401A605MR

$V_{DD}=13V, V_{ENDM}=V_{DD}$
 $V_{SNE}=1.0V$ (Type A)
 $C_{VDD}=10\mu F$ (TMK316BJ108KL-T)



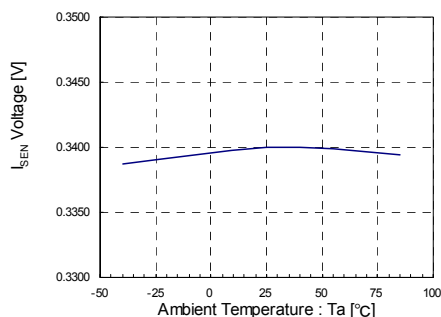
XC9401B605MR

$V_{DD}=13V, V_{ENDM}=V_{DD}$
 $V_{NF}=GND$ (Type B)
 $C_{VDD}=10\mu F$ (TMK316BJ108KL-T)



XC9401C60CSR

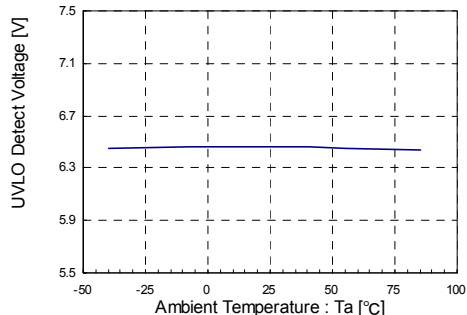
$V_{DD}=13V, V_{ENDM}=V_{DD}$
 $C_{VDD}=10\mu F$ (TMK316BJ106KL-T)



(8) UVLO Detect Voltage vs. Ambient Temperature

XC9401

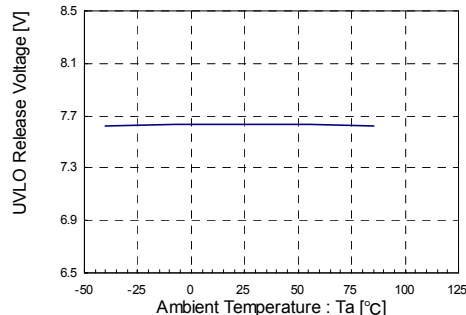
$V_{ENDM}=V_{DD}, V_{SEN}=GND$
 $V_{SNE}=5.5V$ (Type A) or $V_{NF}=GND$ (Type B)
 $C_{VDD}=10\mu F$ (TMK316BJ106KL-T)



(9) UVLO Release Voltage vs. Ambient Temperature

XC9401

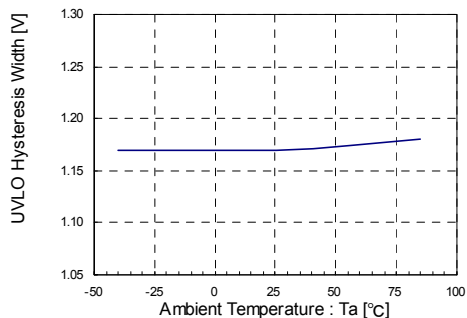
$V_{ENDM}=V_{DD}, V_{SEN}=GND$
 $V_{SNE}=5.5V$ (Type A) or $V_{NF}=GND$ (Type B)
 $C_{VDD}=10\mu F$ (TMK316BJ106KL-T)



(10) UVLO Hysteresis Width vs. Ambient Temperature

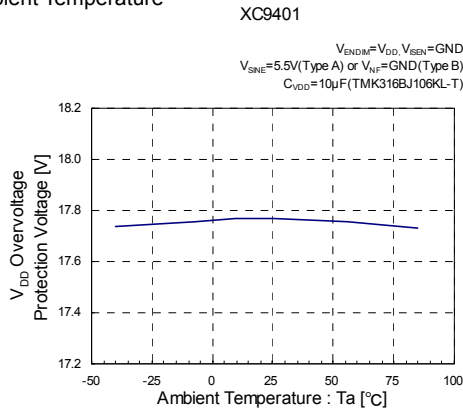
XC9401

$V_{ENDM}=V_{DD}, V_{SEN}=GND$
 $V_{SNE}=5.5V$ (Type A) or $V_{NF}=GND$ (Type B)
 $C_{VDD}=10\mu F$ (TMK316BJ106KL-T)

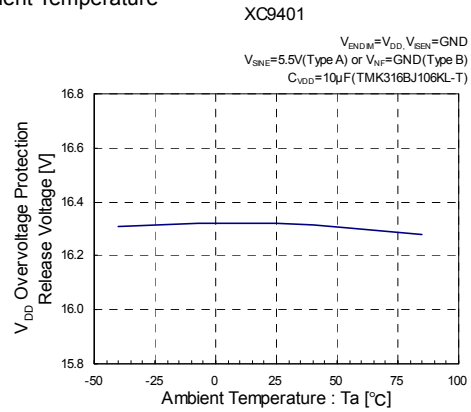


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

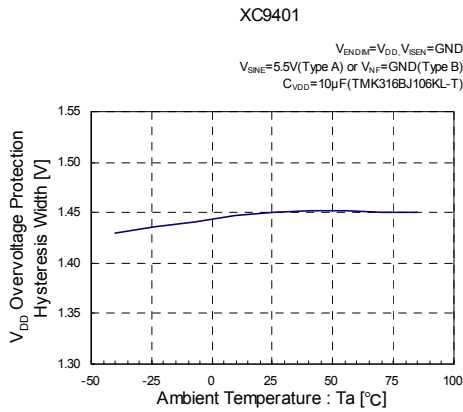
(11) V_{DD} Overvoltage Protection Voltage vs. Ambient Temperature



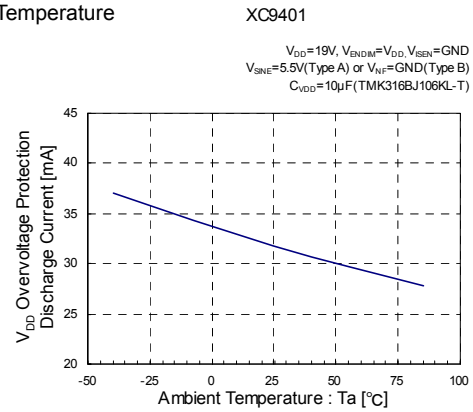
(12) V_{DD} Overvoltage Protection Release Voltage vs. Ambient Temperature



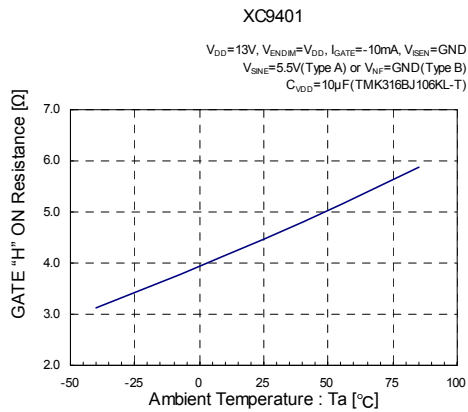
(13) V_{DD} Overvoltage Protection Hysteresis Width



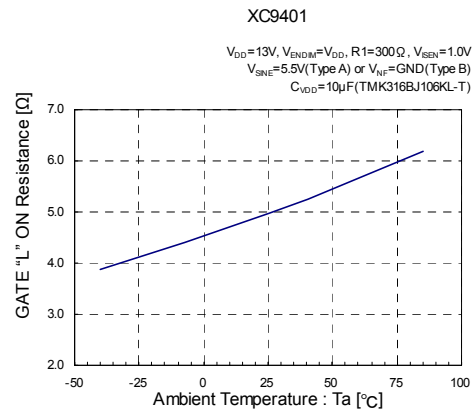
(14) V_{DD} Overvoltage Protection Discharge Current vs. Ambient Temperature



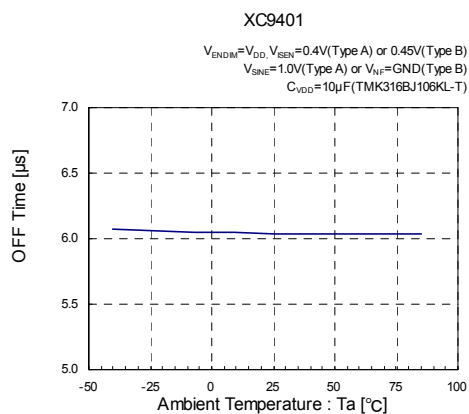
(15) GATE "H" ON Resistance vs. Ambient Temperature



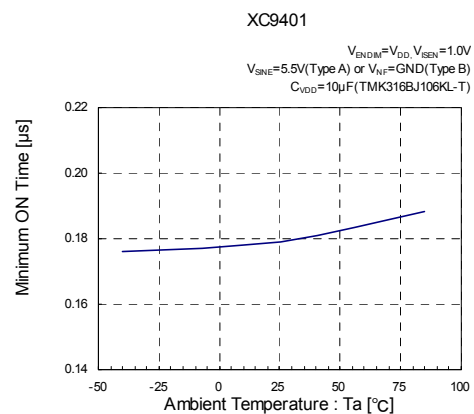
(16) GATE "L" ON Resistance vs. Ambient Temperature



(17) OFF Time vs. Ambient Temperature

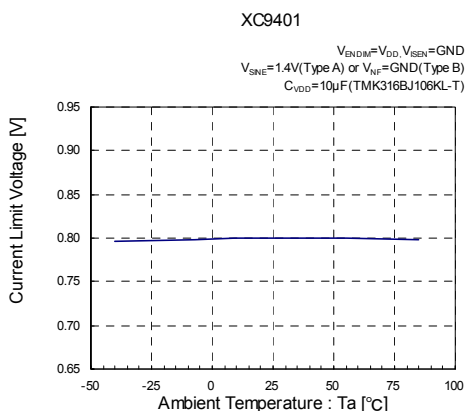


(18) Minimum ON Time vs. Ambient Temperature

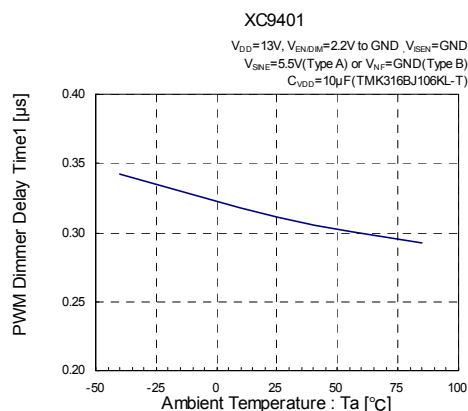


■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

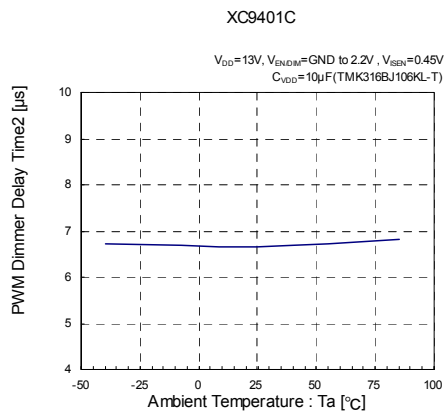
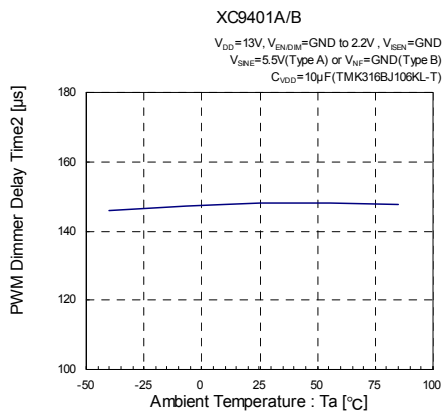
(19) Current Limit Voltage vs. Ambient Temperature



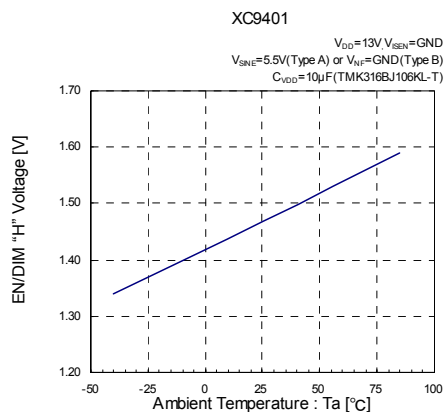
(20) PWM Dimmer Delay Time1 vs. Ambient Temperature



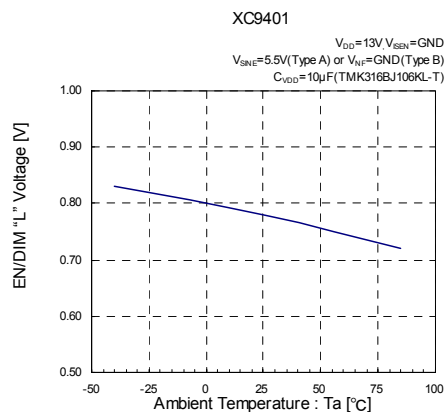
(21) PWM Dimmer Delay Time2 vs. Ambient Temperature



(22) EN/DIM "H" Voltage vs. Ambient Temperature

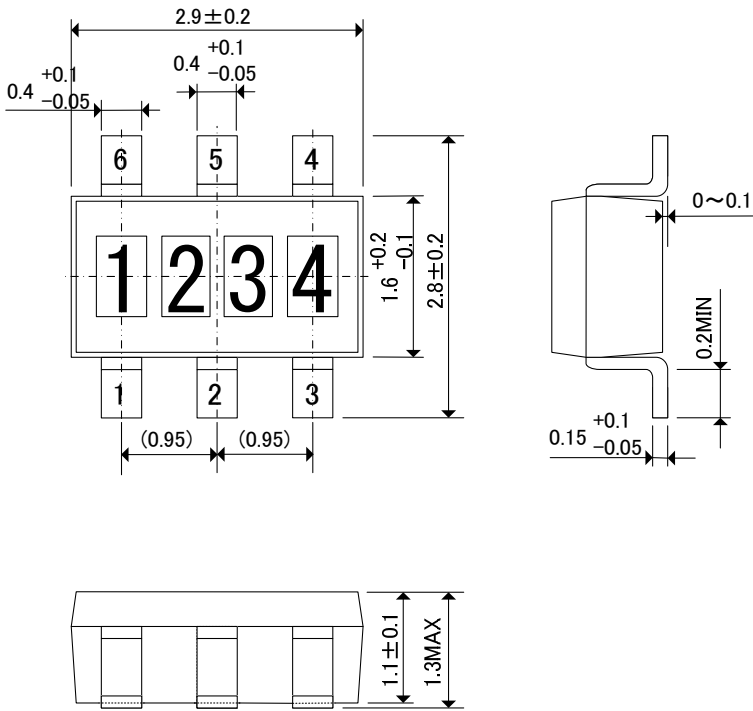


(23) EN/DIM "L" Voltage vs. Ambient Temperature

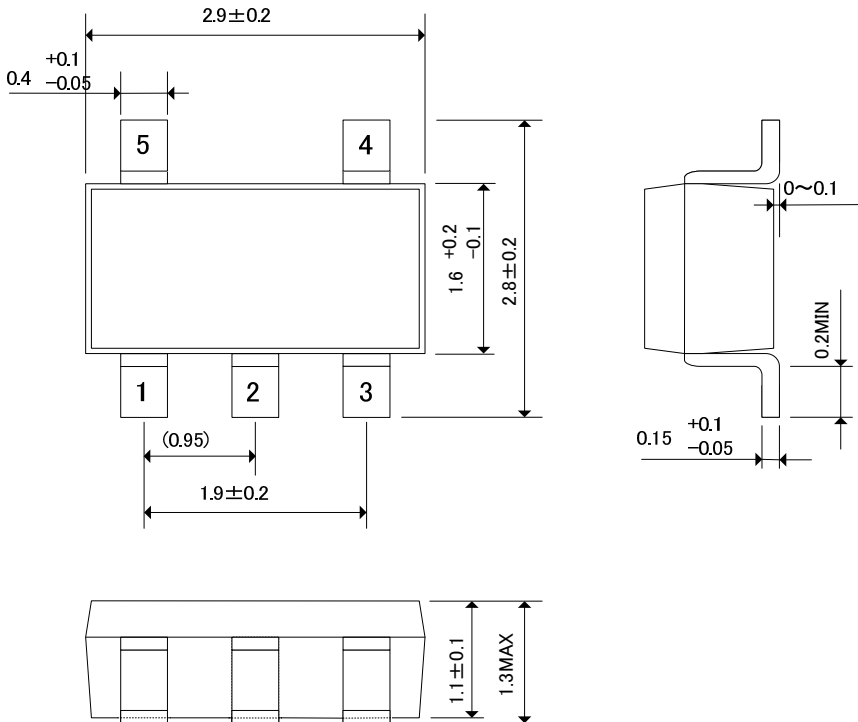


PACKAGING INFORMATION

● SOT-26 (unit: mm)



● SOT-25 (unit: mm)



■ PACKAGING INFORMATION (Continued)

● SOT-25 Power Dissipation

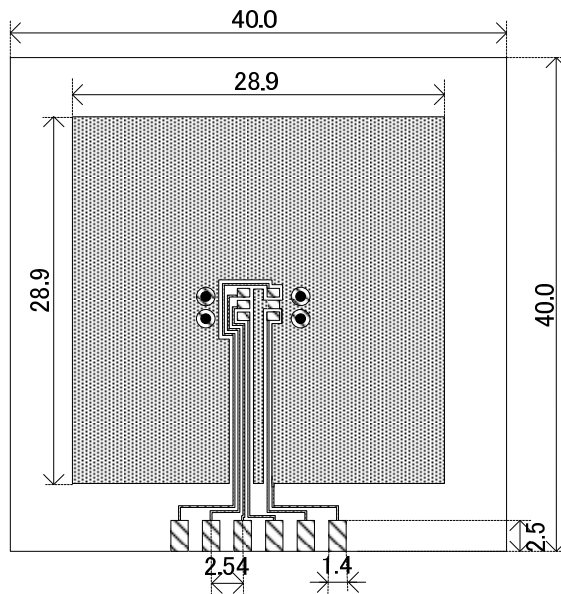
Power dissipation data for the SOT-25 is shown in this page.

The value of power dissipation varies with the mount board conditions.

Please use this data as one of reference data taken in the described condition.

1. Measurement Condition (Reference data)

- Condition: Mount on a board
- Ambient: Natural convection
- Soldering: Lead (Pb) free
- Board: Dimensions 40 x 40 mm (1600 mm² in one side)
Copper (Cu) traces occupy 50% of the board area
In top and back faces
Package heat-sink is tied to the copper traces
(Board of SOT-26 is used.)
- Material: Glass Epoxy (FR-4)
- Thickness: 1.6 mm
- Through-hole: 4 x 0.8 Diameter

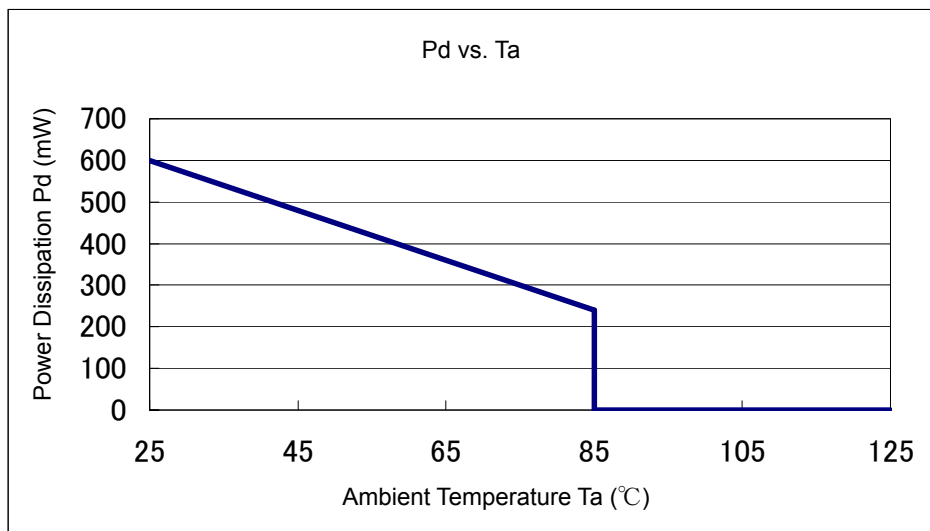


Evaluation Board (Unit: mm)

2. Power Dissipation vs. Ambient temperature

Board Mount ($T_j \text{ max} = 125^\circ\text{C}$)

Ambient Temperature ($^\circ\text{C}$)	Power Dissipation Pd (mW)	Thermal Resistance ($^\circ\text{C}/\text{W}$)
25	600	166.67
85	240	



PACKAGING INFORMATION (Continued)

- SOT-26 Power Dissipation

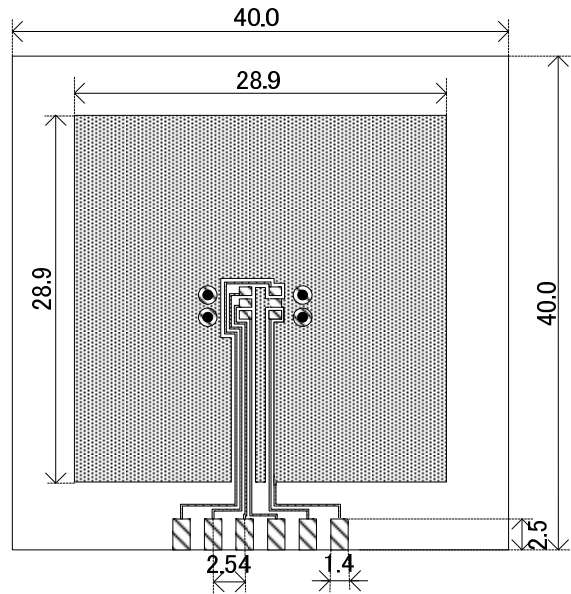
Power dissipation data for the SOT-26 is shown in this page.

The value of power dissipation varies with the mount board conditions.

Please use this data as one of reference data taken in the described condition.

1. Measurement Condition (Reference data)

- Condition: Mount on a board
- Ambient: Natural convection
- Soldering: Lead (Pb) free
- Board: Dimensions 40 x 40 mm (1600 mm² in one side)
Copper (Cu) traces occupy 50% of the board area
In top and back faces
Package heat-sink is tied to the copper traces
(Board of SOT-26 is used.)
- Material: Glass Epoxy (FR-4)
- Thickness: 1.6 mm
- Through-hole: 4 x 0.8 Diameter

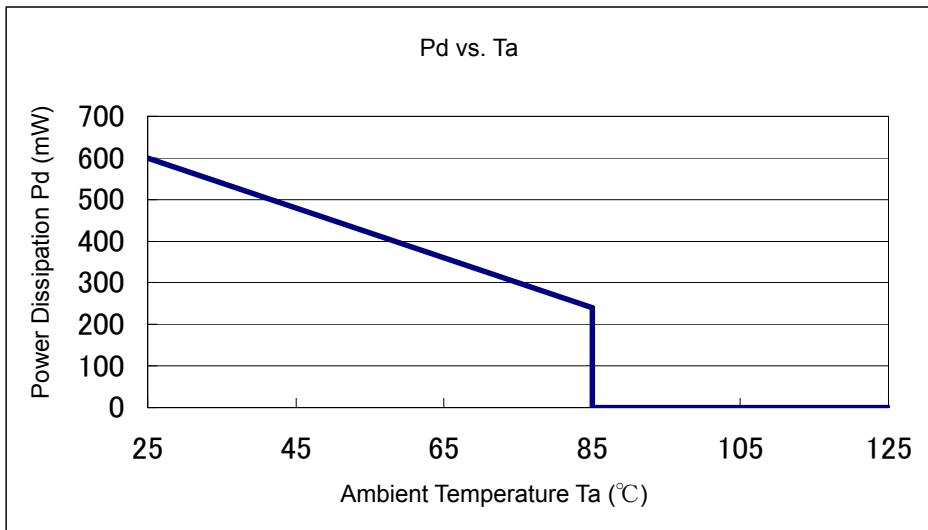


2. Power Dissipation vs. Ambient temperature

Evaluation Board (Unit: mm)

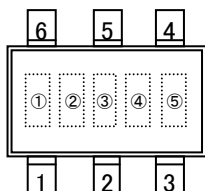
Board Mount (T_j max = 125°C)

Ambient Temperature (°C)	Power Dissipation Pd (mW)	Thermal Resistance (°C/W)
25	600	166.67
85	240	



MARKING RULE

●SOT-26



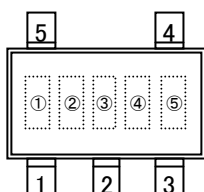
① represents product series

MARK	PRODUCT SERIES
3	XC9401*****-G

②③ represents product type

MARK		PRODUCT SERIES
②	③	
A	A	XC9401A605**-G
B	A	XC9401B605**-G
C	A	XC9401C60C**-G

●SOT-25



④⑤ represents production lot number
01~09, 0A~0Z, 11~9Z, A1~A9, AA~AZ, B1~ZZ in order.
(G, I, J, O, Q, W excluded)
*No character inversion used.

1. The product and product specifications contained herein are subject to change without notice to improve performance characteristics. Consult us, or our representatives before use, to confirm that the information in this datasheet is up to date.
2. The information in this datasheet is intended to illustrate the operation and characteristics of our products. We neither make warranties or representations with respect to the accuracy or completeness of the information contained in this datasheet nor grant any license to any intellectual property rights of ours or any third party concerning with the information in this datasheet.
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5. Although we make continuous efforts to improve the quality and reliability of our products; nevertheless Semiconductors are likely to fail with a certain probability. So in order to prevent personal injury and/or property damage resulting from such failure, customers are required to incorporate adequate safety measures in their designs, such as system fail safes, redundancy and fire prevention features.
6. Our products are not designed to be Radiation-resistant.
7. Please use the product listed in this datasheet within the specified ranges.
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