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LV5029MD

Bi-CMOS IC

LED Driver IC for LED Lighting

ON Semiconductor®

http://onsemi.com

Overview

LV5029MD is a High voltage LED drive controller which drives LED current with external MOSFET.
LV5029MD is realized very simple LED circuits with a few external parts. It corresponds to active power factor corrector control.
Note) This LV5029MD is designed or developed for general use or consumer appliance. Therefore, it is NOT permitted to use for automotive, communication, office equipment, and industrial equipment.

Functions

- High voltage LED controller
- Various Dimming Control
  -Analog Input & PWM Input
- Selectable Switching frequency
  [50 kHz or 70 kHz, open: 50 kHz]
- Built-in overvoltage detection of CS pin.
- Built-in active power factor corrector.
- Short protection circuit
- Selectable reference Voltage
  -Internal 0.605V & External Input Voltage
- Low noise switching system/skip frequency function
  - 5 stages skip mode Frequency
  - Soft driving

Specifications

Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum input voltage	V_{IN} max (Note1)		-0.3 to 42	V
REF_OUT, REF_IN, RT, CS, PWM_D			-0.3 to 7	V
OUT pin	V_{OUT}_abs		-0.3 to 42	V
Allowable power dissipation	Pd max	With specified board*	1.0	W
Junction temperature	Tj		150	°C
Operating junction temperature	Topj (Note2)		-30 to +125	°C
Storage temperature	Tstg		-40 to +150	°C

*1 Specified board: 58.0mm × 54.0mm × 1.6mm (glass epoxy board)
Note1) Absolute maximum ratings represent the values which cannot be exceeded for any length of time.
Note2) Even when the device is used within the range of absolute maximum ratings, as a result of continuous usage under high temperature, high current, high voltage, or drastic temperature change, the reliability of the IC may be degraded. Please contact us for the further details.

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

Recommended Operating Conditions at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Input voltage	V_{IN}		8.5 to 24	V

* Note : supply the stabilized voltage.

Electrical Characteristics at Ta = 25°C, V_{IN} = 12V, unless otherwise specified.

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Reference voltage block						
Built-in reference voltage	VREF		0.585	0.605	0.625	V
VREF V_{IN} line regulation	VREF_LN	V_{IN} = 8.5 to 24V		±0.5		%
Reference output voltage	REFOUT	I_{REFOUT} = 0.5mA		3.0		V
- Maximum load	REFOUT_MAX		0.5			mA
- equivalent output impedance	REFOUT_RO			10		Ω
Under voltage lockout						
Operation start Input voltage	UVLOON		8	9	10	V
Operation stop input voltage	UVLOOFF		6.3	7.3	8.3	V
Hysteresis voltage	UVLOH			1.7		V
Oscillation						
Frequency	FOSC1	RT =OPEN	40	50	60	kHz
	FOSC2	RT = REF_OUT	55	70	85	kHz
FOSC1 Switch voltage	$V_{OSC}1$		2		5	V
FOSC2 Switch voltage	$V_{OSC}2$				0.5	V
Maximum ON duty	MAXDuty			93		%
Comparator						
Input offset voltage (Between CS and VREF)	V_{IO}_VR			1	10	mV
Input offset voltage (Between CS and REFIN)	V_{IO}_RI			1	10	mV
Input current	$I_{IO}SC$			160		nA
	$I_{IO}REF$			80		nA
CS pin max voltage	VOM				1	V
malfunction prevention mask time	TMSK			150		ns
PWM_D circuit						
OFF voltage	V_{OFF}		2		5	V
ON voltage	V_{ON}		0		0.6	V
Thermal protection circuit						
Thermal shutdown temperature	TSD	*Design guarantee		165		°C
Thermal shutdown hysteresis	ΔTSD	*Design guarantee		30		°C
Drive Circuit						
OUT sink current	$I_{O}I$		500	1000		mA
OUT source current	$I_{O}O$			120		mA
Minimum On time	TMIN			200	300	ns

Continued on next page.

Continued from preceding page.

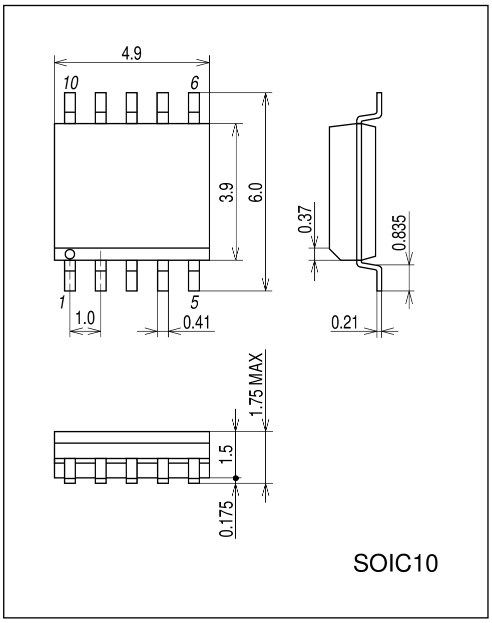
Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
V_{IN} current						
UVLO mode V_{IN} current	I_{IN}OFF	V_{IN} < UVLOON		80	120	μA
Normal mode V_{IN} current	I_{IN}ON	V_{IN} > UVLOON, OUT = OPEN		0.8		mA
V_{IN} over voltage protection circuit						
V_{IN} over voltage protection voltage	V_{IN}OVP		24	27	30	V
V_{IN} current at OVP	I_{IN}OVP	V_{IN} = 30V	0.7	1.0	1.5	mA
CS terminal abnormal sensing circuit						
Abnormal sensing voltage	CSOCP			1.9		V

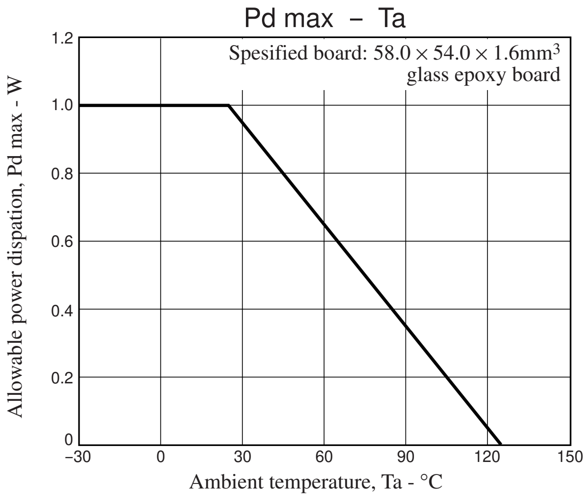
*: Design guarantee (value guaranteed by design and not tested before shipment)

Package Dimensions

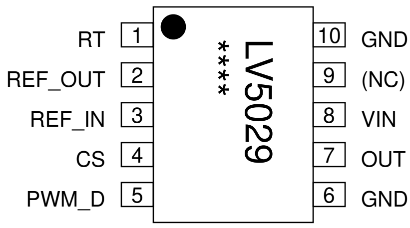
unit: mm (typ)

3426A

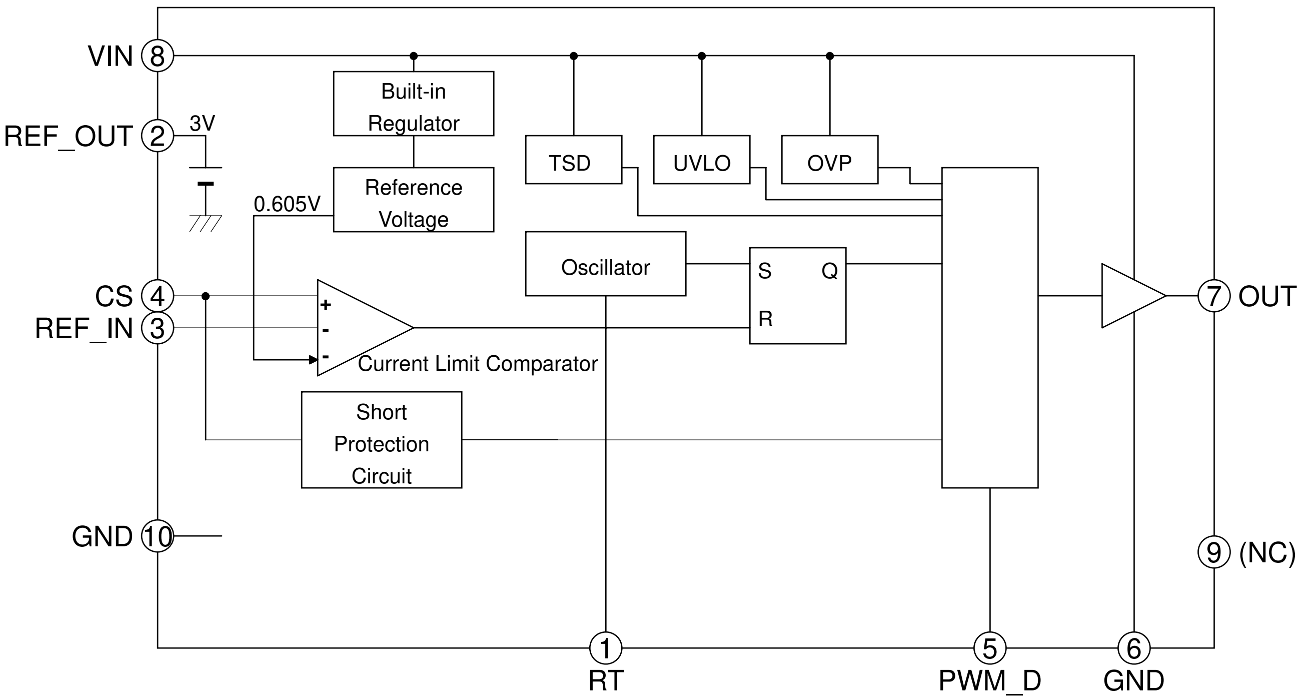




Pin Assignment

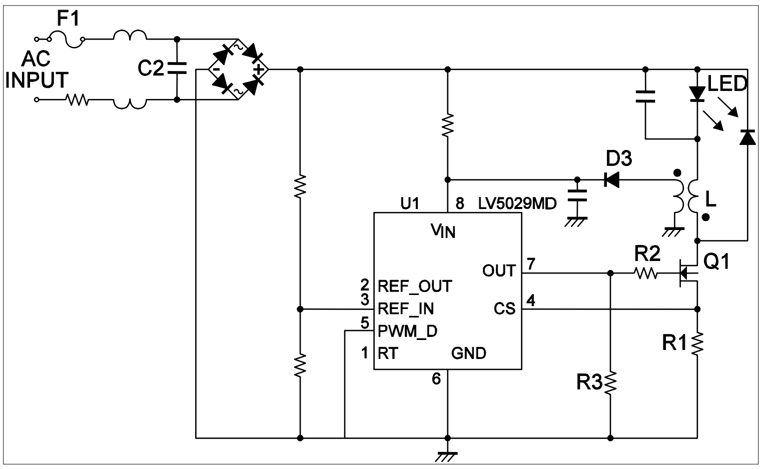


Block Diagram

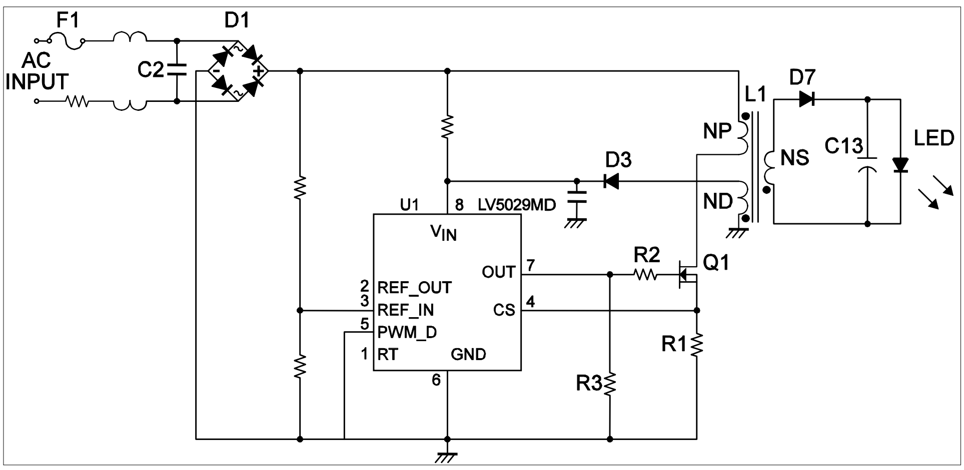


Sample Application Circuit

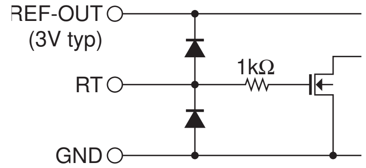
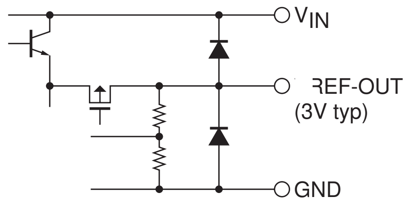
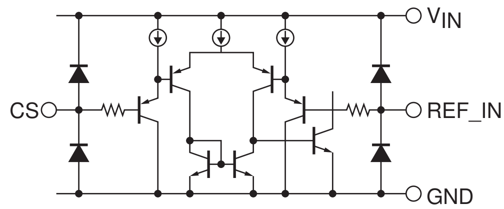
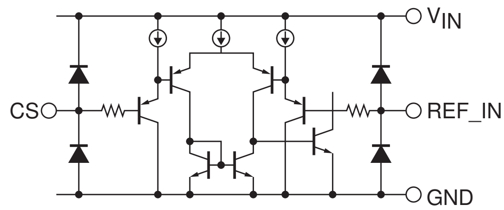
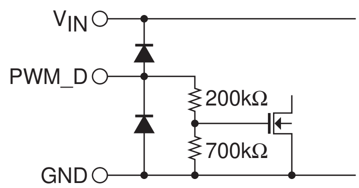
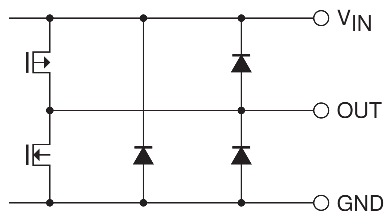
Non isolation



Isolation



Pin Functions

Pin No.	Pin name	Pin function	Equivalent circuit
1	RT	Switching frequency selection pin. L or Open : 50kHz switching, H: 70 kHz switching. In case of 70kHz, connect to RT pin to REFOUT pin. on time	
2	REF_OUT	Built-in 3V Regulate out Pin. If this function isn't used, please connect to nothing.	
3	REF_IN	External LED current Limit Setting pin. If less than VREF (0.61V) voltage is input, Peak current value is used at the input voltage. If more than REF_IN voltage is input, it is done at VREF voltage. If this function isn't used, please connect nothing.	
4	CS	LED current sensing in. If this terminal voltage exceeds VREF (Or REF_IN), external FET is OFF. And if the voltage of the terminal exceeds 1.9V, LV5029MD turns to latch-off mod	
5	PWM_D	PWM Dimming pin. L or open: normal operation, H: Stop operation.	
6	GND	GND pin.	
7	OUT	Driving the external FET Gate Pin.	
8	V_{IN}	Power supply pin. Operation : V_{IN} > UVLOON Stop: V_{IN} < UVLOOFF Switching Stop : V_{IN} > V_{IN}OVP	
9	NC	Connect to nothing	
10	GND	GND pin.	

LED current and inductance setting

• Relation ship between REF_IN and CS pin voltage (Power Factor Correction (PFC))

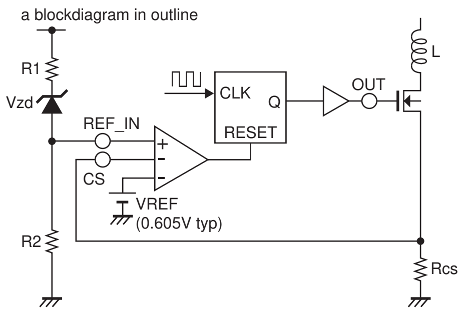
The output current value is the average of the current value that flows during one cycle. The current value that flows into coil is a triangular wave shown in the figure below. Make sure to set Ipk so that (average of current value at one cycle) is equal to (LED current value).Ipk is set by the relationship between REF_IN voltage and Rcs voltage.

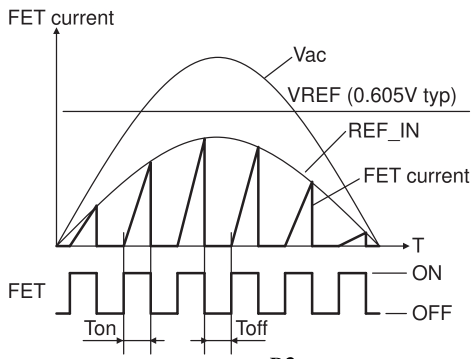
This relationship make Power Factor Correction (PFC).Therefore, it is available to make LED current a sine curve.

• Setting Zener voltage

Vzd depend on LED voltage (VF). Choose Zener diode around Vf (LED voltage).When VAC voltage is lower than Vf, LED operation is not normal. Using Zener diode prevents incorrect operating during VAC voltage lower than Vf. In detail, refer to [LED current and inductance setting]

In case of REF_IN pin open, this error amplifier negative input(-) is under control of internal VREF voltage (0.605Vtyp).





$$Ipk = \frac{(Vac\text{-}Vzd)\times \frac{R2}{R1+R2}}{Rcs}$$

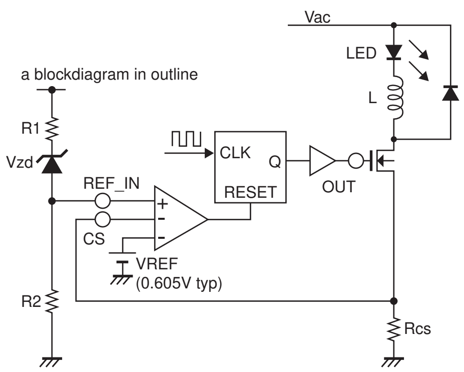
Ipk: peak inductor current Vf: LED forward voltage drop Vac: effective value, R.M.S value VREF: Built-in reference voltage (0.605V) VREF_IN: REF_IN voltage (6 pin) Rs: External sense resistor Vzd: Zener diode voltage (REF_IN pin)

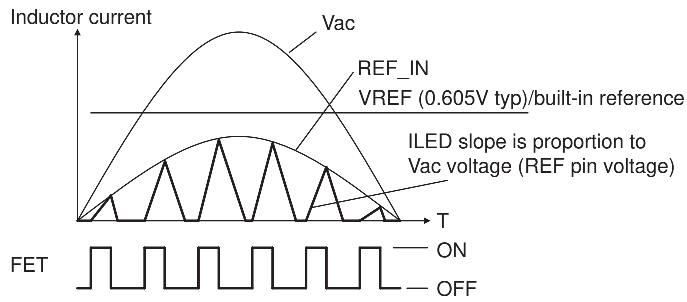
LED current and inductance setting

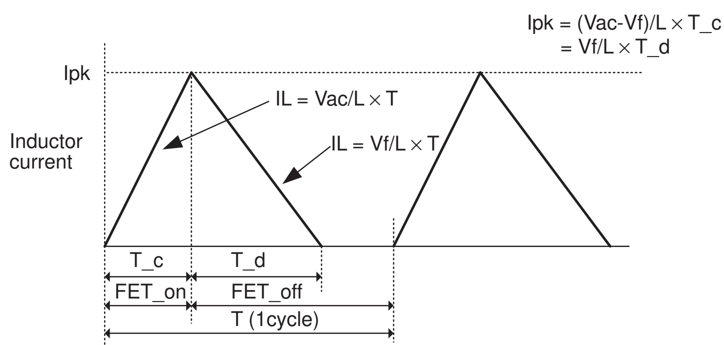
It is available to use both no-isolation and isolation applications.

(For non-isolation application)

The output current value is the average of the current value that flows during one cycle. The current value that flows into coil is a triangular wave shown in the figure below. Make sure to set IL_PK so that (average of current value at one cycle) is equal to (LED current value).







Given that the period when current flows into coil is

$$\text{DutyI} = \frac{T\_c+T\_d}{T}$$

$$Ipk \times \frac{1}{2} \times (Duty \times T)/T = ILED$$

$$Ipk \times \frac{2 \times ILED}{DutyI} \quad (1) \text{ since} \quad Ipk \times \frac{VREF\_IN}{Rcs}$$

$$Rcs \times \frac{VFEF\_IN}{Ipk} = \frac{DutyI \times VFEF\_IN}{2ILED} \quad (2)$$

Ipk: peak inductor current
Vf: LED forward voltage drop
Vac: effective value(R.M.S value)
VREF: Built-in reference voltage (0.605V)
VREF_IN: REF_IN voltage (6 pin)
Rs: External sense resistor
Vzd: Zener diode voltage (REF_IN pin)

Since formula for LED current is different between on period and off period as shown above,

$$Ipk \times \frac{Vac\text{-}Vf}{L} \times T\_c = \frac{Vf}{L} \times T\_d \quad (3)$$

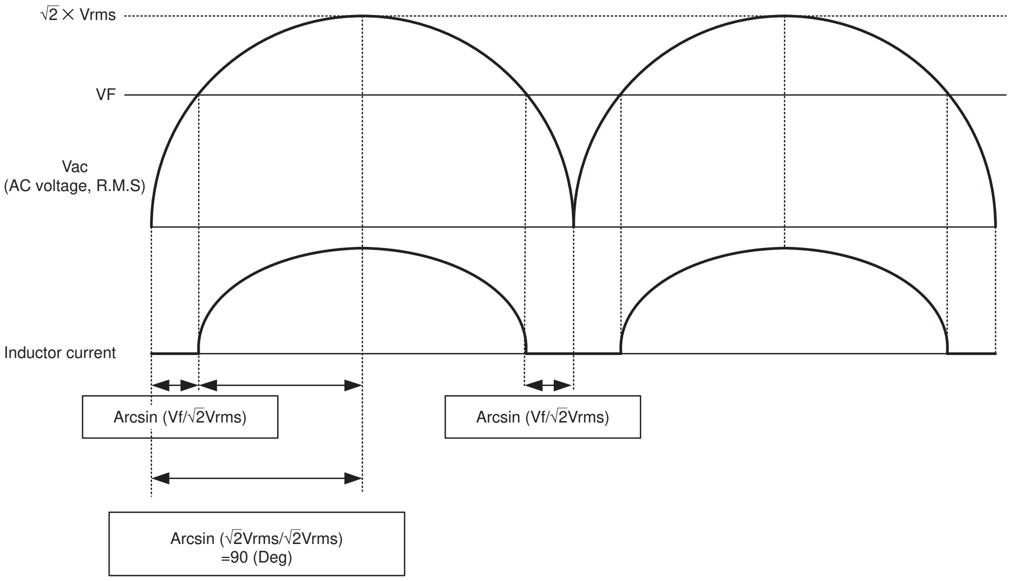
Since $T\_c + T\_d = DutyI \times T,\ T\_c = DutyI \times T - T\_d$ (4)

Based on the result of (3) and (4), $T\_d = DutyI \times T \times \frac{Vac\text{-}Vf}{Vac}$ (5)

To obtain L from the equation (1), (3), (5),

$$L \times \frac{Vf \times DutyI}{2 \times ILED} \times DutyI \times T = \frac{Vac - Vf}{Vac} = \frac{Vf}{2 \times ILED} \times \frac{1}{fosc} \times \frac{Vac - Vf}{Vac} \times (DutyI)^2 \quad (6)$$

Since LED and inductor are connected in serial in non-isolation mode, LED current flows only when AC voltage exceed VF.



Given that the ratio of inductor current to AC input is DutyAC.

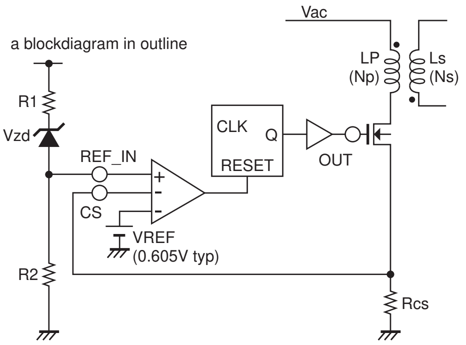
$$DutyAC = \frac{90 - \arcsin\left(\frac{Vf}{\sqrt{2}Vrms}\right)}{90}$$

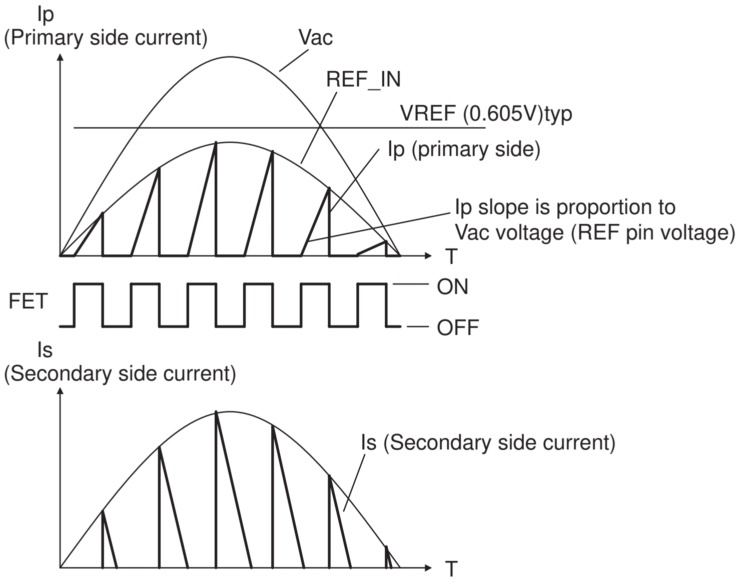
Since the period when the inductor current flows are limited by DutyAC, the formula (6) is represented as follows:

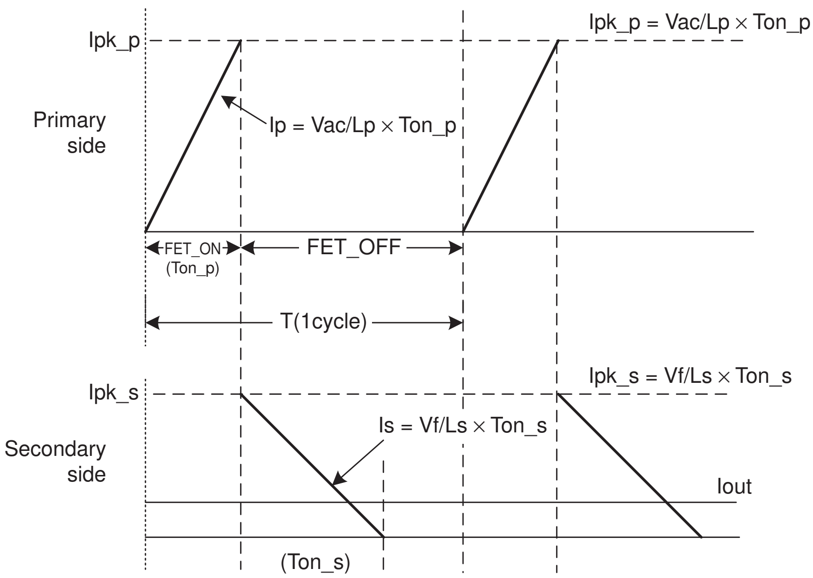
$$L = \frac{Vf}{2 \times ILED} \times \frac{1}{fosc} \times \frac{Vac - Vf}{Vac} \times (DutyI)^2 \times \left(\frac{90 - \arcsin\left(\frac{Vf}{\sqrt{2}Vrms}\right)}{90} \right)^2 \quad (7)$$

(for Isolation circuit)

Using the circuit diagram below, the wave form of the current that flows to Np and Ns is as follows.
Current waveform flows to primary side and secondary.







[Inductance Lp of primary side and sense resistor Rs]

If a peak current flow to transformer is represented as Ipk_p, the power (Pin) charged to the transformer on primary side can be represented as:

$$Pin = \frac{1}{2} \times Lp \times (Ipk\_p)^2 \times fosc \quad (11)$$

$$Ipk\_p = \frac{Vac}{Lp} \times Ton\_p \quad (12)$$

$$Lp = \frac{Vac^2 \times Ton\_p^2 \times fosc}{2 \times Pin} = \frac{Vac^2 \times Don\_p^2}{2 \times Pin \times fosc} \quad (13)$$

$$(Don\_p = \frac{Ton\_p}{T} = Ton\_p \times fosc),$$

To substitute the following to the formula below,

$$\because \eta = \frac{Pout}{Pin} \quad (14)$$

$$\therefore Lp = \frac{Vac^2 \times Ton\_p^2 \times fosc \times \eta}{2 \times Pout} = \frac{Vac^2 \times Don^2 \times \eta}{2 \times Pout \times fosc} \quad (15)$$

Sense resistor is obtained as follows.

$$Rs = \frac{VREF\_IN}{Ipk\_p} = \frac{VREF\_IN \times Lp}{Vac \times Ton\_p} = \frac{VREF\_IN \times Lp}{Vac \times Don\_p \times T} \quad (16)$$

[Inductance Ls of secondary side]

Since output current Iout is the average value of current flows to transformer of secondary side

$$Iout = Ipk\_s \times \frac{Ton\_s}{T} \times \frac{1}{2} = \frac{Ipk\_s \times Don\_s}{2} \; (Don\_s = \frac{Ton\_s}{T} = Ton\_s \times fosc) \quad (17)$$

$$Ipk\_s = \frac{Vout}{Ls} \times Ton\_s = \frac{Vout}{Ls} = \frac{Don\_s}{fosc} \quad (18)$$

$$Ls = \frac{Vout \times T \times Don\_s^2}{2 \times Iout} = \frac{Vout \times Don\_s^2}{2 \times Iout \times fosc} = \frac{Vout^2 \times Don\_s^2}{2 \times Pout \times fosc} \quad (19)$$

Calculation of the ratio of transformer coil on primary side and secondary side

Since ratio and inductance of transformer coil is

$$\frac{Ns}{Np} = \frac{\sqrt{Ls}}{\sqrt{Lp}} \quad (20)$$

substituted equations (15), (19) for (20)

$$\therefore \frac{Np}{Ns} = \frac{Vac}{Vout} \times \sqrt{\eta} \times \frac{Don\_p}{Don\_s} \quad (21)$$

Calculation of transformer coil on primary side and secondary side

$$N = \frac{Vac \times 10^8}{2 \times \Delta B \times Ae \times fosc} \quad (22)$$

ΔB: variation range of core flux density [Gauss]

Ae: core section area [cm^2]

To use Al (L value at 100T),

$$N = \sqrt{\frac{L}{Al}} \times 10^2 \quad (23)$$

L: inductance [μH]

Al: L value at 100T [uH/N^2]

lg (Air gap) is obtained as follows:

$$lg = \frac{\mu_r \, \mu_0 \, N^2 \, A_e \, 10^2}{L} \quad (24)$$

μr: relative magnetic permeability, μr = 1

μ0: vacuum magnetic permeability $\mu 0 = 4\pi * 10^{-7}$

N: turn count [T]

Ae: core section area [m^2]

L: inductance [H]

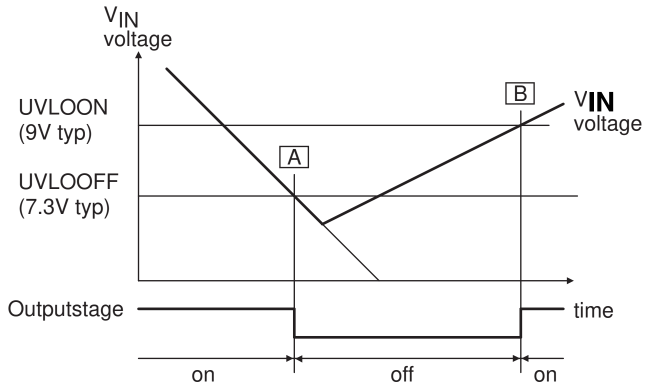
Description of operation

Protection function

	tilte	outline	monitor point	note
1	UVLO	Under voltage lock out	V_{IN} voltage	
2	OCP	Over current protection	CS voltage	available FET current
3	OVP	Over voltage protection	V_{IN} voltage	
4	OTP (TSD)	Over Temperature Protection (Thermal Shut Down)	PN Junction temperature	

1. UVLO (Under voltage lock out)

If V_{IN} voltage is 7.3V or lower, then UVLO operates and the IC stops. When UVLO operates, the power supply current of the IC is about 80μA or lower. If V_{IN} voltage is 9V or higher, then the IC starts switching operation.

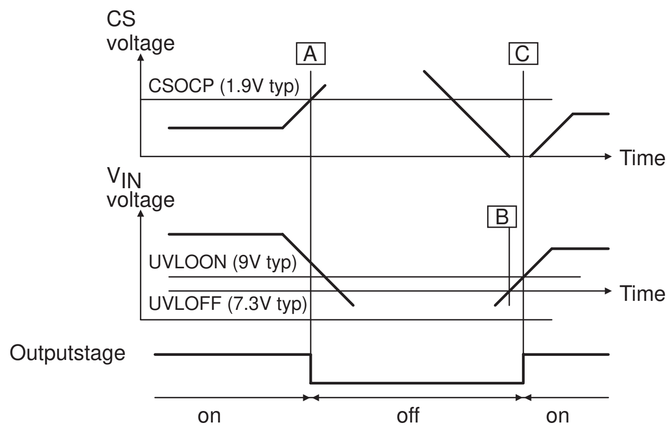


2. OCP (Over current protection)

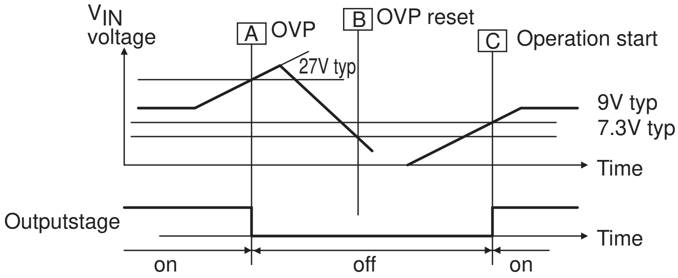
The CS pin senses the current through the MOS FET switch and the primary side of the transformer. This provides an additional level of protection in the event of a fault. If the voltage of the CS pin exceeds VCSOCP (1.9V typ) (A), the internal comparator will detect the event and turn off the MOSFET. The peak switch current is calculated

Io (peak) [A] = VSOCP [V]/Rsense [Ω]

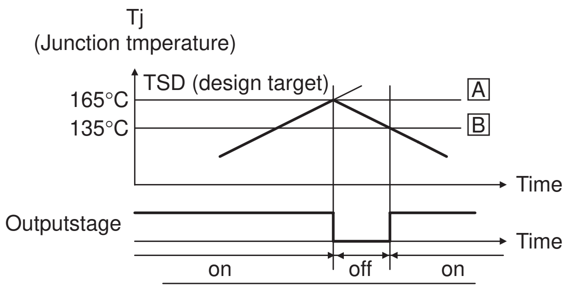
The V_{IN} pin is pulled down to fixed level, keeping the controller latched off. The latch reset occurs when the user disconnects LED from VAC and lets the V_{IN} falls below the V_{IN} reset voltage, UVLOOFF (7.3V typ)(B). Then V_{IN} rise UVLOON (9V typ) (C), restart the switching.



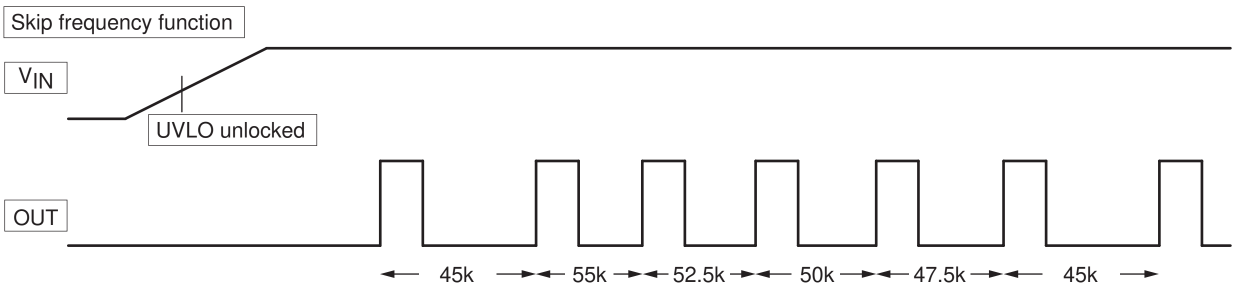
3. OVP (Over voltage protection)
   If the voltage of V_{IN} pin is higher than the internal reference voltage V_{IN}OVP (27V typ), switching operation is stopped.
   The stopping operation is kept until the voltage of V_{IN} is lower than 7.3V. If the voltage of V_{IN} pin is higher than 9V, the switching operation is restated.



4. OTP (Over temperature protection)
   The over temperature protection function works when the junction temperature of IC is 165°C (typ) (A), and the IC switching stops. The IC starts switching operation again when the junction temperature is 135°C typ (B) or lower.



Skip frequency function
   LV5029MD contains the skip frequency function for reduction of the peak value of conduction noise. This function changes the frequency as follows.



Switching frequency is changed as follows.
… ×0.9 → ×1.1 → ×1.05 → ×1 → ×0.95 → ×0.9 → ×1.1 …
It's repeated by this loop.

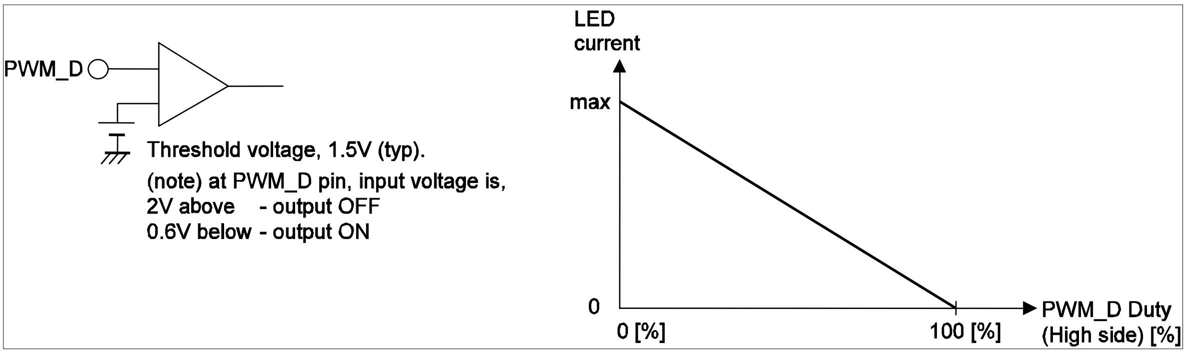
PWM dimming function

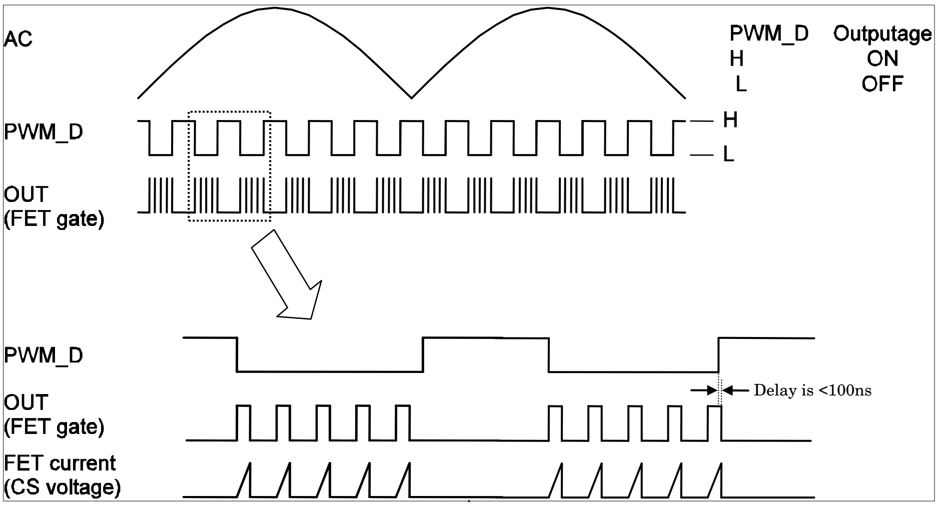
LED current can be adjusted according to Duty of PWM pulse input to PWM dimmer pin. PWM pulse is High (2V to 5V) then switching operation stops, and LED current stops flowing. PWM pulse is Low (under 0.6V), then switching operation stop is released, and it returns to normal operation. The OUTPUT FET is turned OFF within 100ns if PWM input turns into High when the OUTPUT FET is turned on.

The recommended frequency of PWM dimming input is 100Hz (twice the AC voltage frequency) to 5 kHz. When frequency of the PWM is less than twice the AC frequency, a flicker becomes easy to be observed. On the other hand, if PWM frequency rise to around 50 kHz that is driving frequency of the switching of the OUTPUT FET, the flicker is easy to occur.

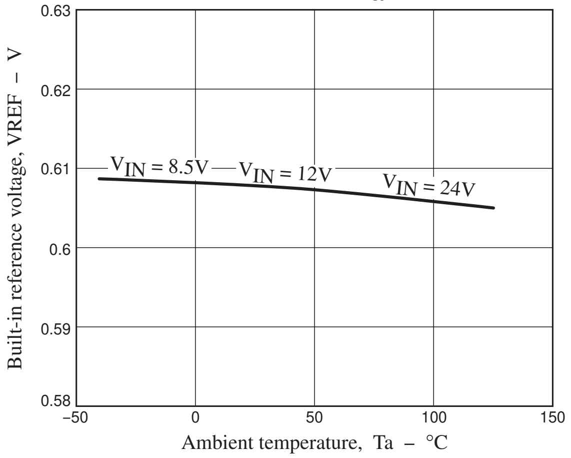
An outline of PWM_D pin

LED current vs PWM_D duty (outline)

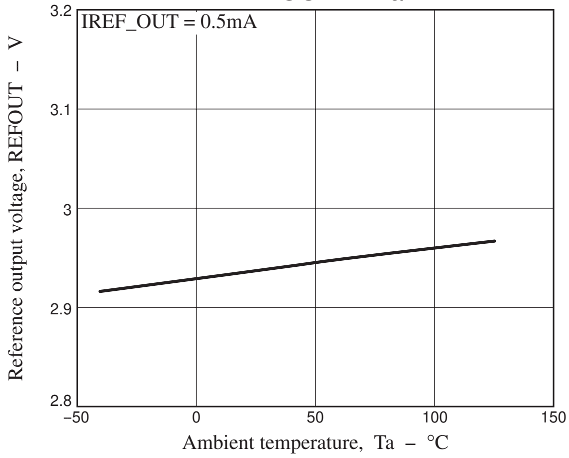




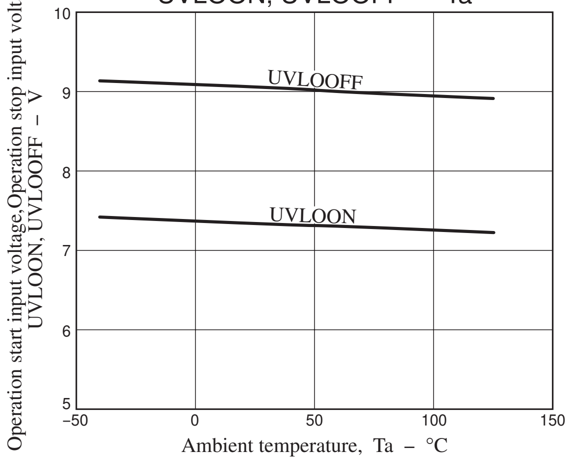
VREF – Ta



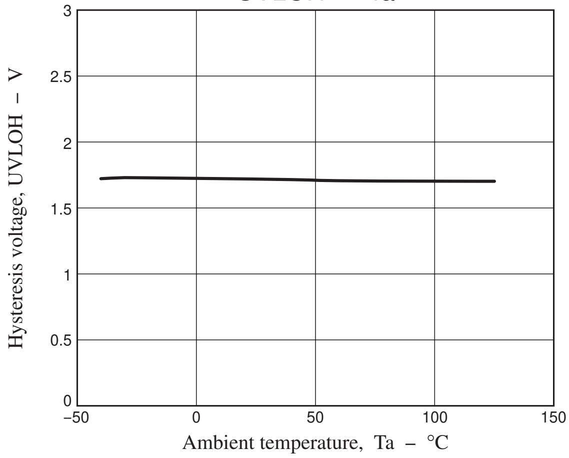
REFOUT – Ta



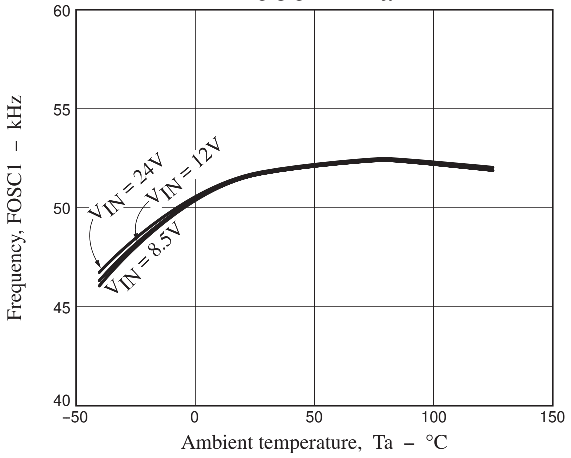
UVLOON, UVLOOFF – Ta



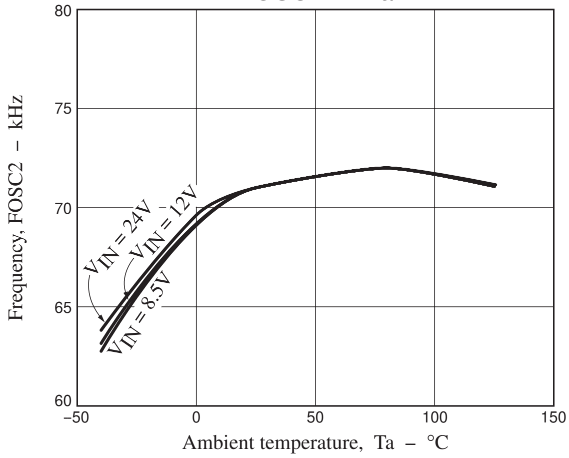
UVLOH – Ta



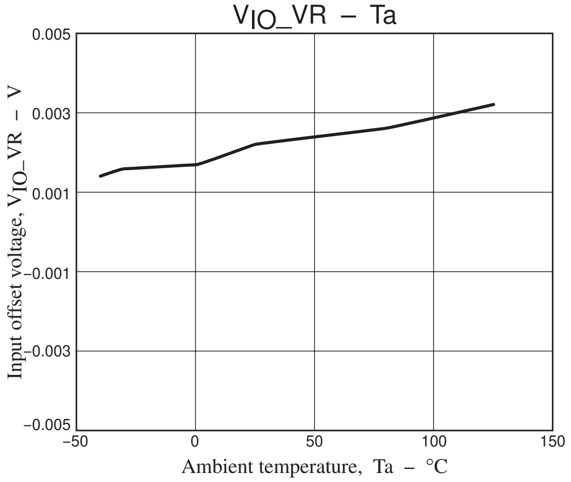
FOSC1 – Ta



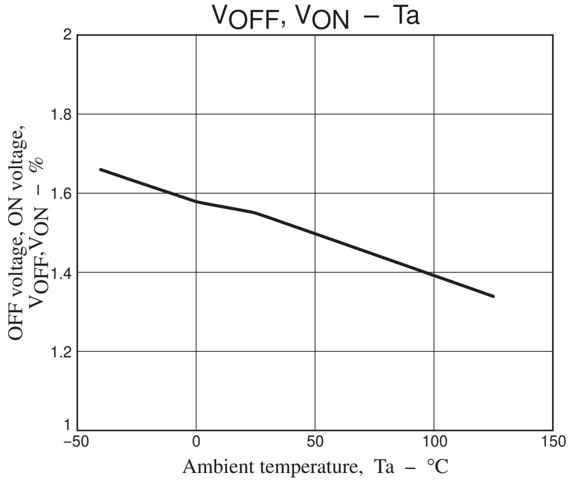
FOSC2 – Ta

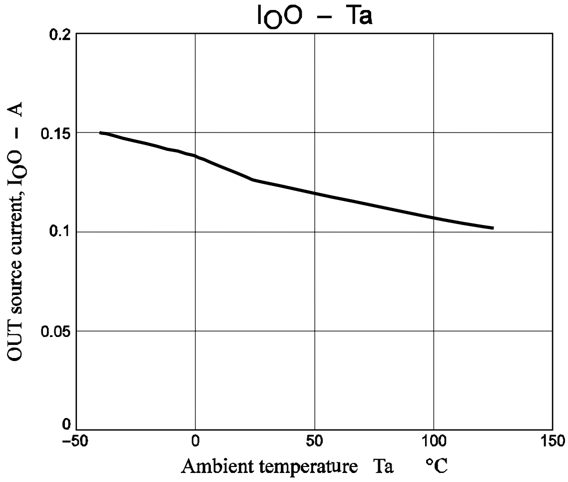


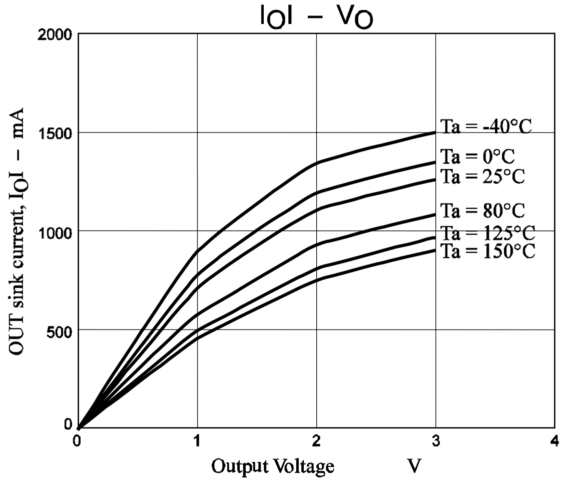
V_{IO}_VR – Ta

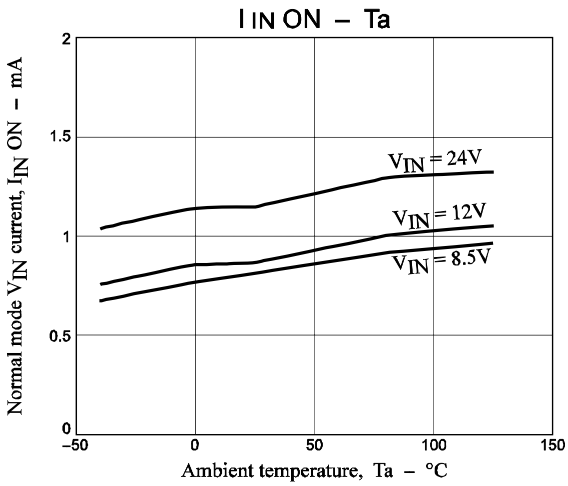


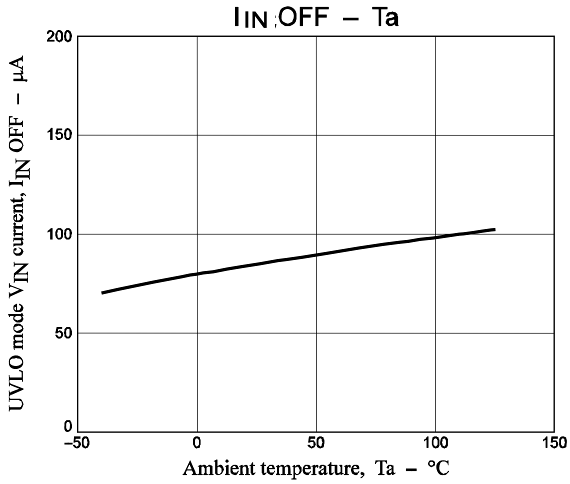
V_{OFF}, V_{ON} – Ta

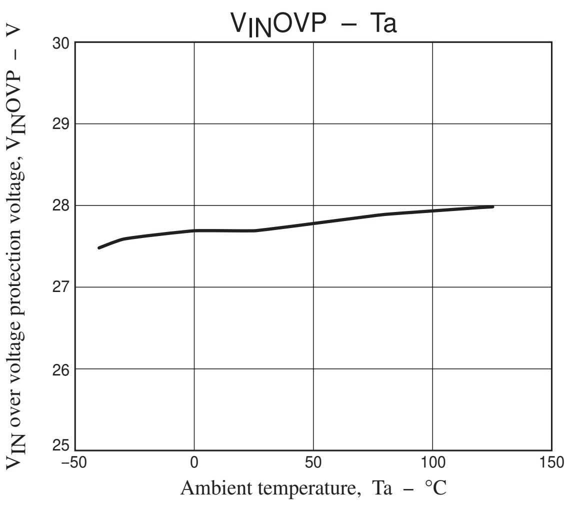


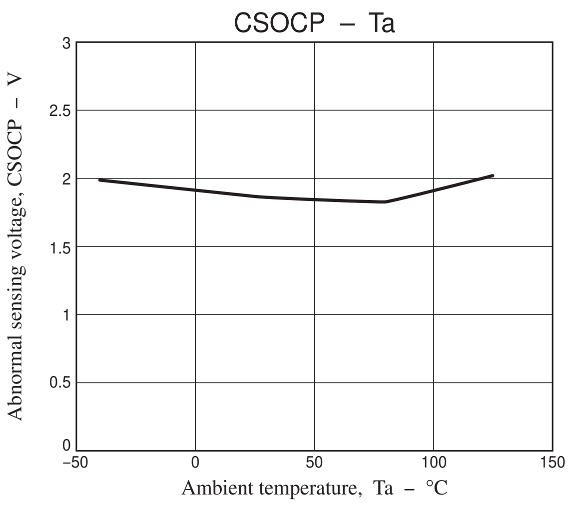

IOO – Ta
OUT source current, IOO – A
Ambient temperature Ta °C
0.2
0.15
0.1
0.05
0
–50
0
50
100
150


IOI – VO
OUT sink current, IOI – mA
Output Voltage V
Ta = -40°C
Ta = 0°C
Ta = 25°C
Ta = 80°C
Ta = 125°C
Ta = 150°C
2000
1500
1000
500
0
1
2
3
4


I IN ON – Ta
Normal mode VIN current, IIN ON – mA
Ambient temperature, Ta – °C
VIN = 24V
VIN = 12V
VIN = 8.5V
2
1.5
1
0.5
0
–50
50
100
150


I IN OFF – Ta
UVLO mode VIN current, IIN OFF – μA
Ambient temperature, Ta – °C
200
150
100
50
0
–50
150


VINOVP – Ta
VIN over voltage protection voltage, VINOVP – V
Ambient temperature, Ta – °C
30
29
28
27
26
25
–50
0
50
100
150


CSOCP – Ta
Abnormal sensing voltage, CSOCP – V
Ambient temperature, Ta – °C
3
2.5
2
1.5
1
0.5
0
–50
50
100
150