


**SANYO Semiconductors**

# DATA SHEET

An ON Semiconductor Company

## LV5028TT — Bi-CMOS IC LED Driver IC

### Overview

LV5028TT is a High voltage LED drive controller which drives LED current up to 3A with external MOSFET. LV5028TT is realized very simple LED circuits with a few external parts. It corresponds to various wide dimming controls including the TRIAC dimming control.

Note) This LV5028TT is designed or developed for general use or consumer appliance. Therefore, it is NOT permitted to use for automotive, communication, office equipment, industrial equipment.

### Functions

- High voltage LED controller
- Switching frequency: 50kHz
- Soft Start function
- Built-in TRIAC stabilized function
- Built-in circuit of detection of overvoltage of CS pin.
- Corresponds to TRIAC stabilized
- 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 <sub>IN</sub> max (Note1)		-0.3 to 42	V
REF_OUT, REF_IN, CS, PWM_D, ACS			-0.3 to 7	V
OUT1 pin	V <sub>OUT_abs</sub>		-0.3 to 42	V
OUT2 pin	V <sub>OUT2_abs</sub>		-0.3 to 42	V
Allowable power dissipation	Pd max	With specified board*	1.0	W

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Parameter	Symbol	Conditions	Ratings	Unit
Junction temperature	T <sub>j</sub>		150	°C
Operating junction temperature	Topj (Note2)		-30 to +125	°C
Storage temperature	Tstg		-40 to +150	°C

\*1 Specified board: 58.0mm x 54.0mm x 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.

## Recommended Operating Conditions at T<sub>a</sub> = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Input voltage	V <sub>IN</sub>		8.5 to 24	V

\* Note : supply the stabilized voltage.

## Electrical Characteristics at T<sub>a</sub> = 25°C, V<sub>CC</sub> = 5.0V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
<b>Reference voltage block</b>						
Built-in reference voltage	VREF		0.585	0.605	0.625	V
VREF V <sub>IN</sub> line regulation	VREF_LN	V <sub>IN</sub> = 8.5 to 24V		±0.5		%
Reference output voltage	REFOUT	I <sub>REFOUT</sub> = 0.5mA		3.0		V
- Maximum load	REFOUT_MAX		0.5			mA
- equivalent output impedance	REFOUT_RO			10		Ω
<b>Under voltage lockout</b>						
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
<b>Oscillation</b>						
Frequency	FOSC		40	50	60	kHz
Maximum ON duty	MAXDuty			93		%
<b>Comparator</b>						
Input offset voltage (Between CS and VREF)	V <sub>IO_VR</sub>			1	10	mV
Input offset voltage (Between CS and REFOUT)	V <sub>IO_RI</sub>			1	10	mV
Input current	I <sub>IO_SC</sub>			160		nA
	I <sub>IO_REF</sub>			80		nA
CS pin max voltage	VOM				1	V
malfunction prevention mask time	TMSK			150		ns
<b>Thermal protection circuit</b>						
Thermal shutdown temperature	TSD	*Design guarantee		165		°C
Thermal shutdown hysteresis	ΔTSD	*Design guarantee		30		°C
<b>Drive Circuit</b>						
OUT sink current	I <sub>O</sub> I		500	1000		mA
OUT source current	I <sub>O</sub> O			120		mA
Minimum On time	TMIN			200	300	ns
<b>TRIAC Stabilization circuit</b>						
Threshold of OUT2	V <sub>ACS</sub>	OUT2 = High [less than right record]	2.8	3.0	3.2	V
OUT2 sink current	I <sub>O2</sub> I	V <sub>IN</sub> = 12V, OUT2 = 6V		0.6		mA
OUT2 source current	I <sub>O2</sub> O	V <sub>IN</sub> = 12V, OUT2 = 6V		0.6		mA
<b>V<sub>CC</sub> current</b>						
UVLO mode V <sub>IN</sub> current	I <sub>CCOFF</sub>	V <sub>IN</sub> < UVLOON		80	120	μA
Normal mode V <sub>IN</sub> current	I <sub>CCON</sub>	V <sub>IN</sub> > UVLOON, OUT = OPEN		0.8		mA

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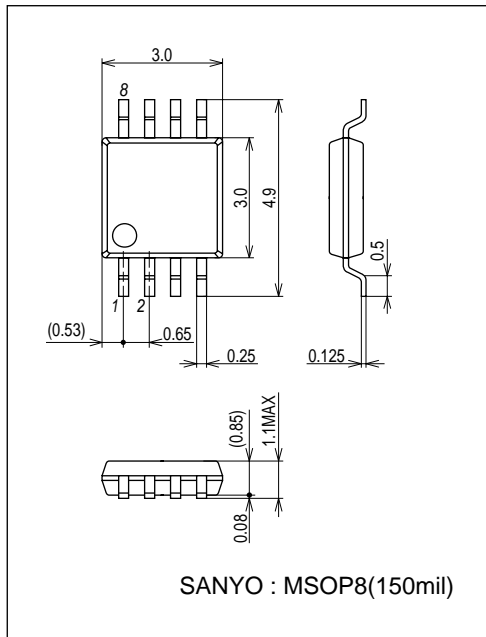
Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
<b>V<sub>IN</sub> over voltage protection circuit</b>						
V <sub>IN</sub> over voltage protection voltage	V <sub>INOVP</sub>		24	27	30	V
V <sub>IN</sub> current at OVP	I <sub>INOVP</sub>	V <sub>IN</sub> = 30V	0.7	1.0	1.5	mA
<b>CS terminal abnormal sensing circuit</b>						
Abnormal sensing voltage	CSOCP			1.9		V

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

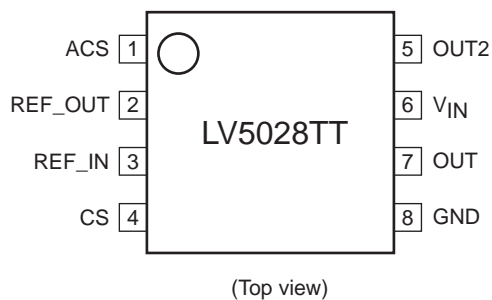
## Package Dimensions

unit : mm (typ)

3245B

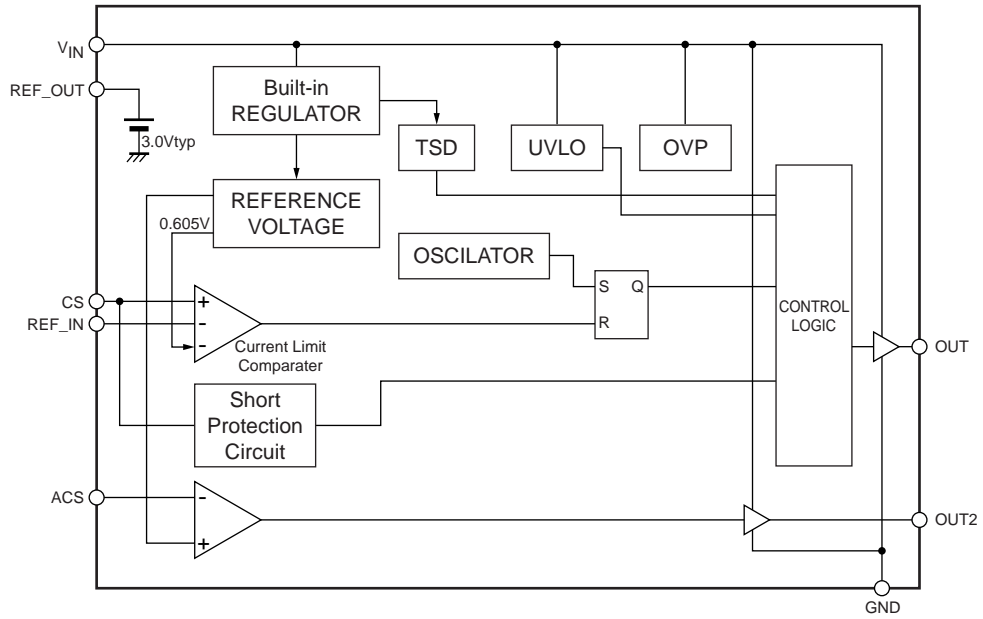


## Pin Assignment



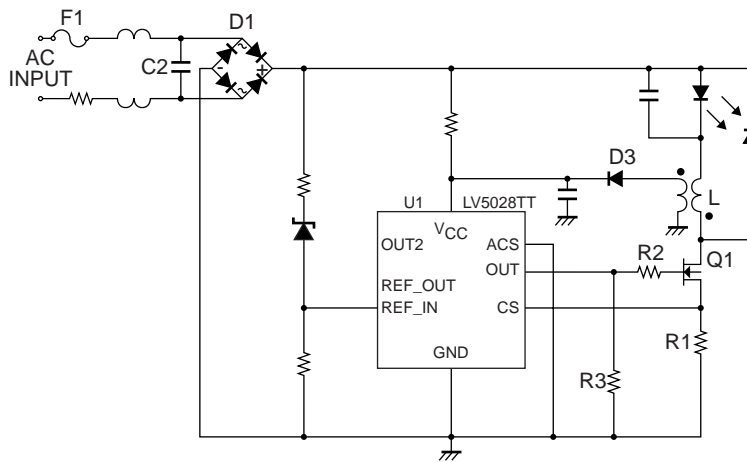
# LV5028TT

## Block Diagram

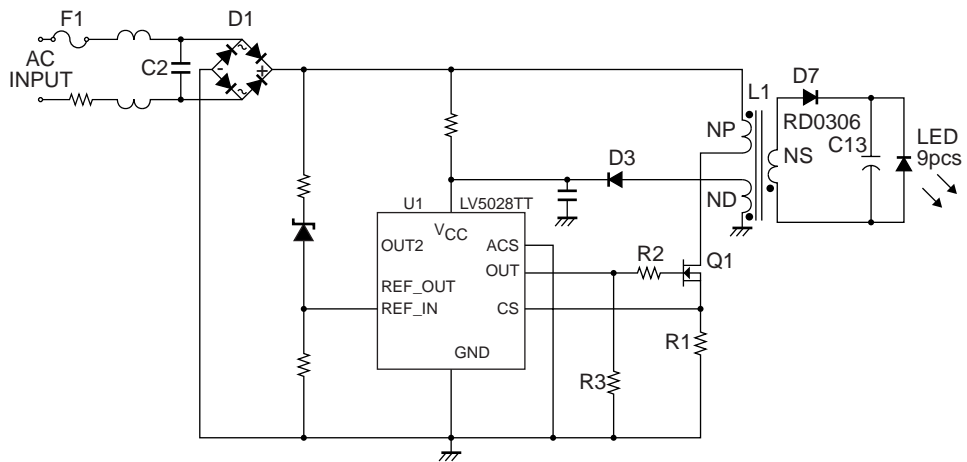


## Sample Application Circuit

Non isolation



Isolation



# LV5028TT

## Pin Functions

Pin No.	Pin name	Pin function	Equivalent circuit
1	ACS	ACS pin senses AC Voltage. If this function isn't used, please connect GND.	
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, LV5028TT turns to latch-off mod	
5	GND	GND pin.	
6	OUT	Driving the external FET Gate Pin.	
7	V <sub>IN</sub>	Power supply pin. Operation : $V_{IN} > UVLOON$ Stop: $V_{IN} < UVLOOFF$ Switching Stop : $V_{IN} > V_{IN}OVP$	
8	OUT2	This pin drive the FET which is stabilized the TRIAC dimming application. If ACS is less than 3V, OUT2 turn High voltage. If this function isn't used, please connect nothing.	

## LED current and inductance setting

- Relation ship between REF\_IN and CS pin voltage(Power Factor Crrction(PFC))

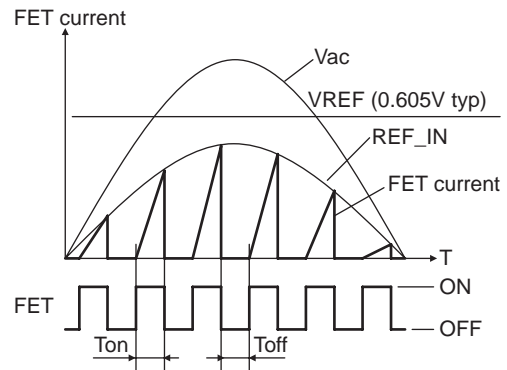
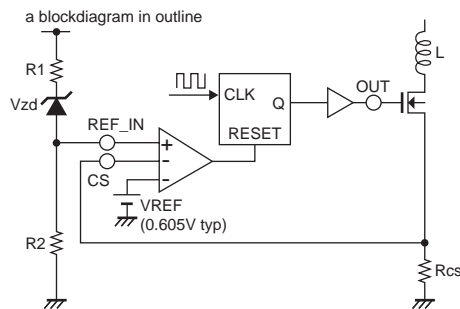
The output current value is the average of the current value that flows during one cycle. The current value that flows into coil is a triangular wave shown in the figure below. Make sure to set  $I_{pk}$  so that (average of current value at one cycle) is equal to (LED current value).  $I_{pk}$  is set by the relationship between REF\_IN voltage and  $R_{cs}$  voltage.

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

- Setting Zener voltage

$V_{zd}$  depend on LED voltage ( $V_f$ ). Choose Zener diode around  $V_f$  (LED voltage). When VAC voltage is lower than  $V_f$ , LED operation is not normal. Using Zener diode prevents incorrect operating during VAC voltage lower than  $V_f$ . 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 (0.605V typ).



$$I_{pk} = \frac{(V_{ac} - V_{zd}) \times \frac{R_2}{R_1 + R_2}}{R_{cs}}$$

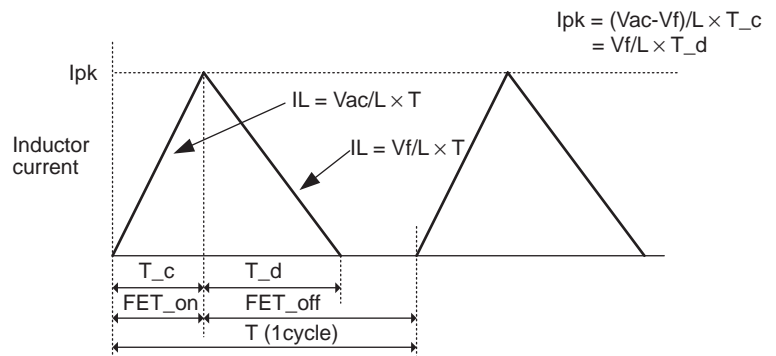
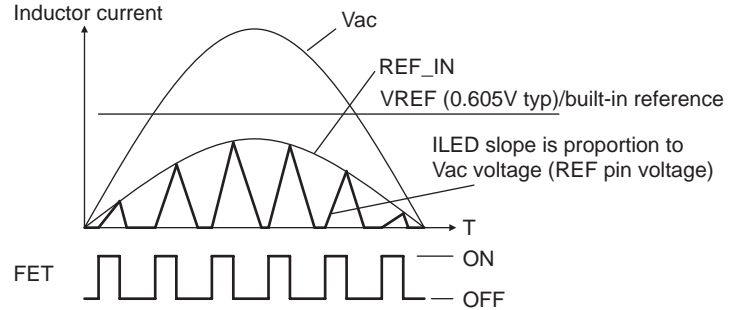
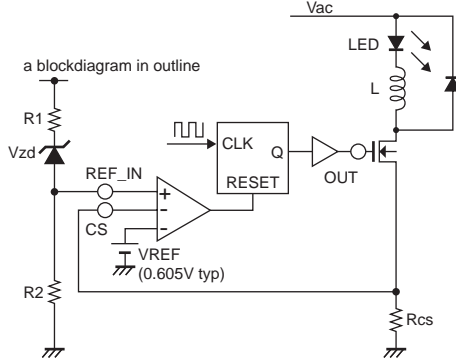
- $I_{pk}$ : peak inductor current
- $V_f$ : LED forward voltage drop
- $V_{ac}$ : effective value, R.M.S value
- $V_{REF}$ : Built-in reference voltage (0.605V)
- $V_{REF\_IN}$ : REF\_IN voltage (6 pin)
- $R_s$ : External sense resistor
- $V_{zd}$ : Zener diode voltage (REF\_IN pin)

## 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

$$\text{Duty}I = \frac{T_c + T_d}{T}$$

$$I_{pk} \times \frac{1}{2} \times (\text{Duty} \times T) / T = I_{LED}$$

$$I_{pk} \times \frac{2 \times I_{LED}}{\text{Duty}I} \quad (1) \text{ since } I_{pk} \times \frac{V_{REF\_IN}}{R_{cs}}$$

$$R_{cs} \times \frac{V_{FEF\_IN}}{I_{pk}} = \frac{\text{Duty}I \times V_{FEF\_IN}}{2I_{LED}} \quad (2)$$

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  
 Vzdz: Zener diode voltage (REF\_IN pin)

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

$$I_{pk} \times \frac{Vac - Vf}{L} \times T_c = \frac{Vf}{L} \times T_d \quad (3)$$

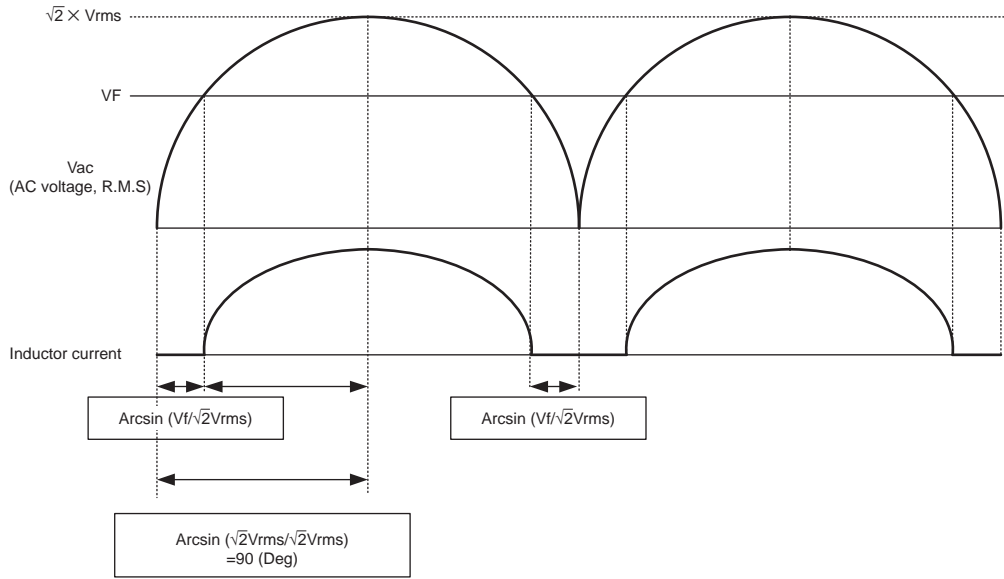
$$\text{Since } T_c + T_d = \text{Duty}I \times T, T_c = \text{Duty}I \times T - T_d \quad (4)$$

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

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

$$L \times \frac{Vf \times \text{Duty}I}{2 \times I_{LED}} \times \text{Duty}I \times T = \frac{Vac - Vf}{Vac} = \frac{Vf}{2 \times I_{LED}} \times \frac{1}{f_{osc}} \times \frac{Vac - Vf}{Vac} \times (\text{Duty}I)^2 \quad (6)$$

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.

$$DutyAC = \frac{90 - \arcsin\left(\frac{V_f}{\sqrt{2}V_{rms}}\right)}{90}$$

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

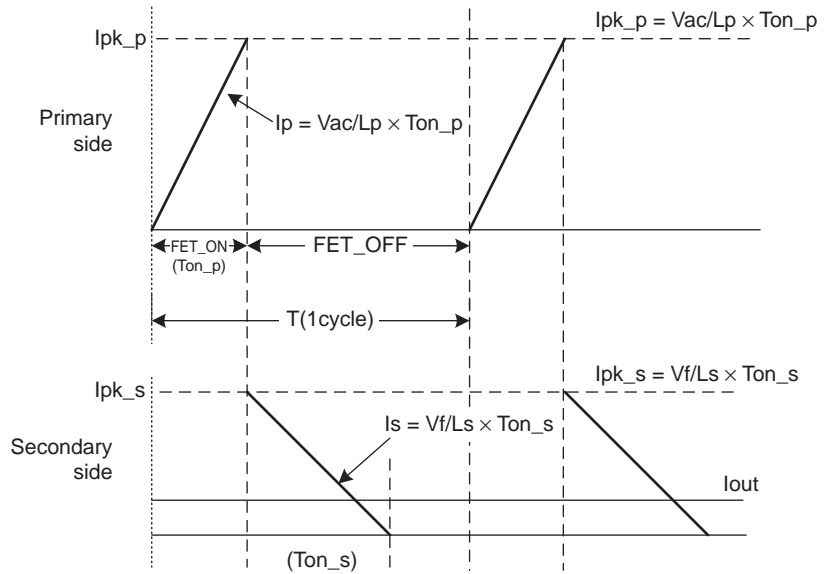
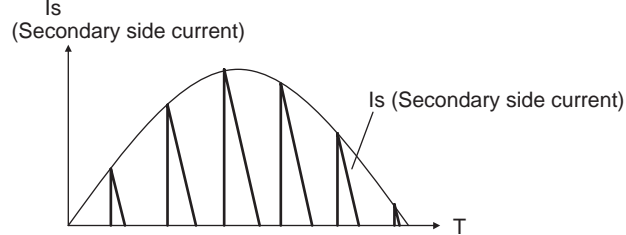
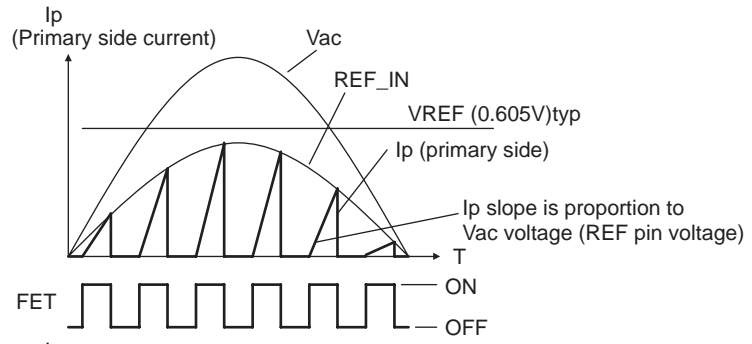
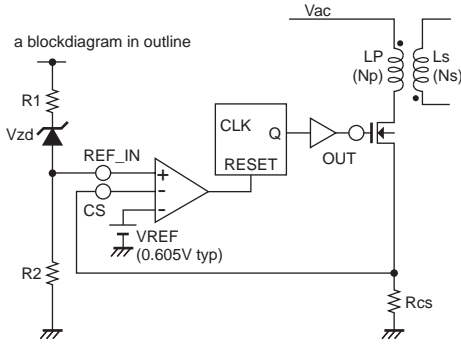
$$L = \frac{V_f}{2 \times I_{LED}} \times \frac{1}{f_{osc}} \times \frac{V_{ac} - V_f}{V_{IN}} \times (DutyI)^2 \times \left(\frac{90 - \arcsin\left(\frac{V_f}{\sqrt{2}V_{rms}}\right)}{90}\right)^2 \quad (7)$$



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(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 Ip\_k\_p, the power (Pin) charged to the transformer on primary side can be represented as:

$$P_{in} = \frac{1}{2} \times L_p \times (I_{pk\_p})^2 \times f_{osc} \quad (11)$$

$$I_{pk\_p} = \frac{V_{ac}}{L_p} \times T_{on\_p} \quad (12)$$

$$L_p = \frac{V_{ac}^2 \times T_{on\_p}^2 \times f_{osc}}{2 \times P_{in}} = \frac{V_{ac}^2 \times Don\_p^2}{2 \times P_{in} \times f_{osc}} \quad (13)$$

$$(Don\_p = \frac{T_{on\_p}}{T} = T_{on\_p} \times f_{osc}),$$

To substitute the following to the formula below,

$$\therefore \eta = \frac{P_{out}}{P_{in}} \quad (14)$$

$$\therefore L_p = \frac{V_{ac}^2 \times T_{on\_p}^2 \times f_{osc} \times \eta}{2 \times P_{out}} = \frac{V_{ac}^2 \times Don^2 \times \eta}{2 \times P_{out} \times f_{osc}} \quad (15)$$

Sense resistor is obtained as follows.

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

[Inductance Ls of secondary side]

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

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

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

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

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

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

$\Delta B$ : variation range of core flux density [Gauss]

$Ae$ : core section area [cm<sup>2</sup>]

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<sup>2</sup>]

lg (Air gap) is obtained as follows:

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

$\mu_r$ : relative magnetic permeability,  $\mu_r = 1$

$\mu_0$ : vacuum magnetic permeability  $\mu_0 = 4\pi \times 10^{-7}$

N: turn count [T]

$Ae$ : core section area [m<sup>2</sup>]

L: inductance [H]

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## Bleeder current circuit for TRIAC dimmer

### 1. Operating voltage setting

ACS pin voltage set operating voltage at OUT2. ACS pin threshold voltage is 3V typ.

OUT2 operating voltage is set by R1 and R2. R1 and R2 is determined below.

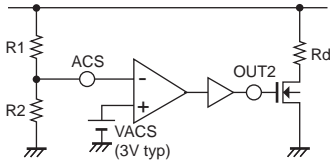
$$ACS = Vac \times \frac{R2}{R1+R2}$$

### 2. Bleeder current setting

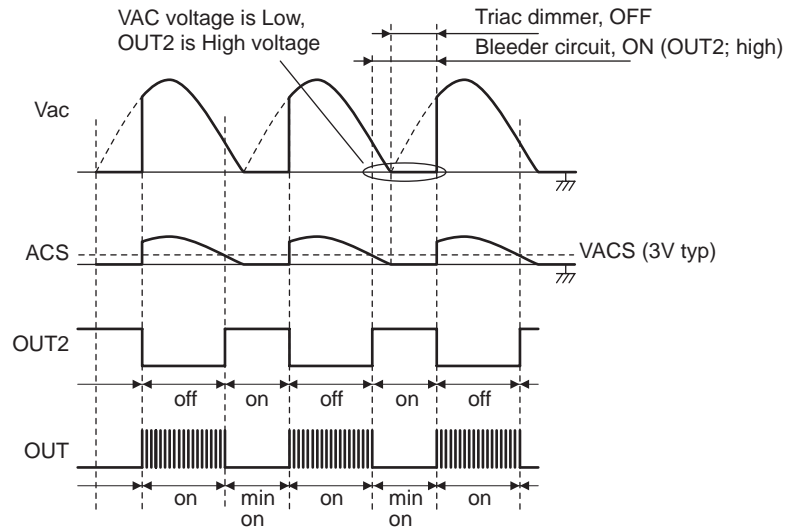
Rd set hold current at Triac dimmer.

Bleeder current is set at Rd depending on Triac dimmer.

a blockdiagram in outline



a blockdiagram in outline



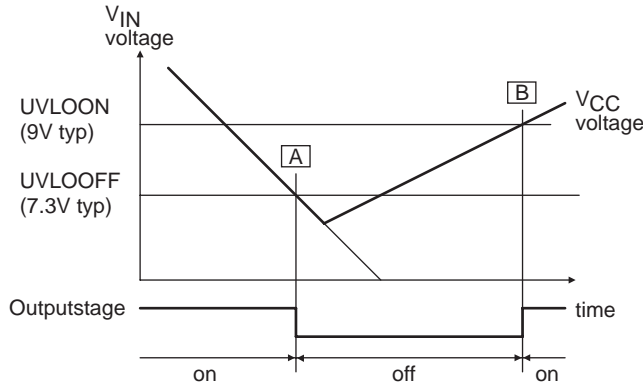
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## Description of operation protection function

	tilte	outline	monitor point	note
1	UVLO	Under voltage lock out	V <sub>CC</sub> voltage	
2	OCP	Over current protection	CS voltage	available FET current
3	OVP	Over voltage protection	V <sub>CC</sub> voltage	
4	OTP (TSD)	Over Temperature Protection (Thermal Shut Down)	PN Junction temperature	

### 1. UVLO (Under voltage lock out)

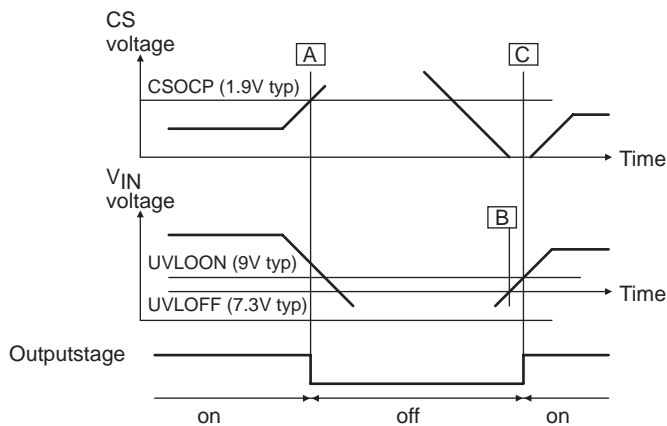
If V<sub>IN</sub> voltage is 7.3V or lower, then UVLO operates and the IC stops. When UVLO operates, the power supply current of the IC is about 80μA or lower. If V<sub>IN</sub> voltage is 9V or higher, then the IC starts switching operation.



### 2. UVLO (Under voltage lock out)

The CS pin sense 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  $I_o \text{ (peak) [A]} = V_{SOCP} [V] / R_{sense} [\Omega]$

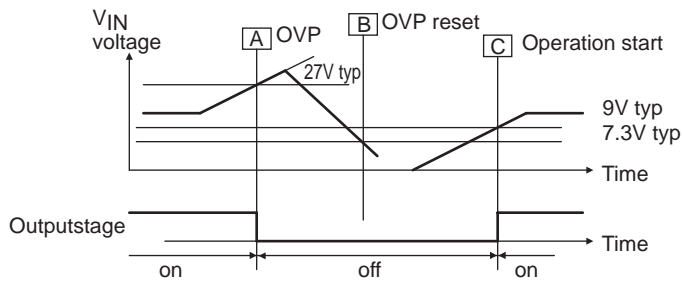
The V<sub>CC</sub> pin is pulled down to fixed level, keeping the controller latched off. The lach reset occurs when the user disconnects LED from V<sub>AC</sub> and lets the V<sub>CC</sub> falls below the V<sub>CC</sub> reset voltage, UVLOOFF (7.3V typ)(B). Then V<sub>CC</sub> rise UVLOON (9V typ) (C), restart the switching.



### 3. OVP (Over voltage protection)

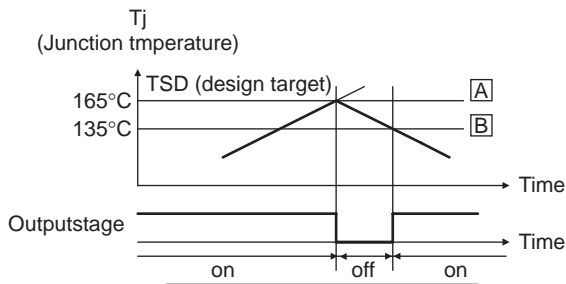
If the voltage of  $V_{IN}$  pin is higher than the internal reference voltage  $V_{INOVP}$  (27V typ), switching operation is stopped.

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.



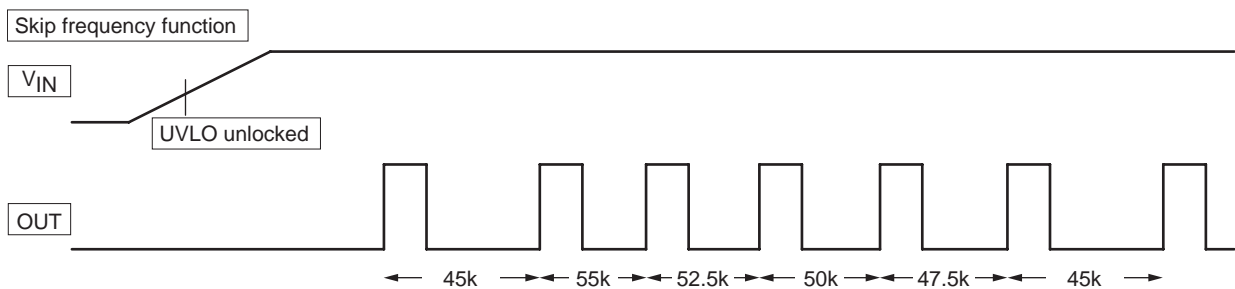
### 4. TSD (Thermal shut down protection)

The thermal shutdown 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

LV5028TT contains the skip frequency function for reduction of the peak value of conduction noise. This function changes the frequency as follows.

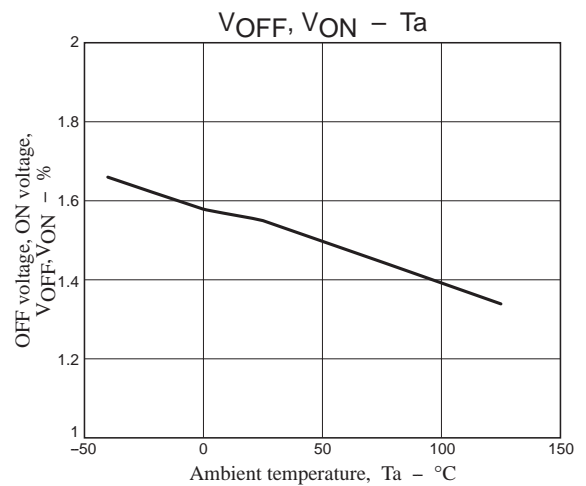
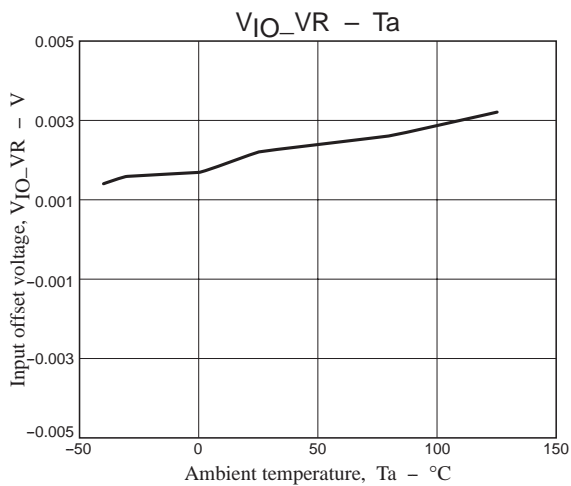
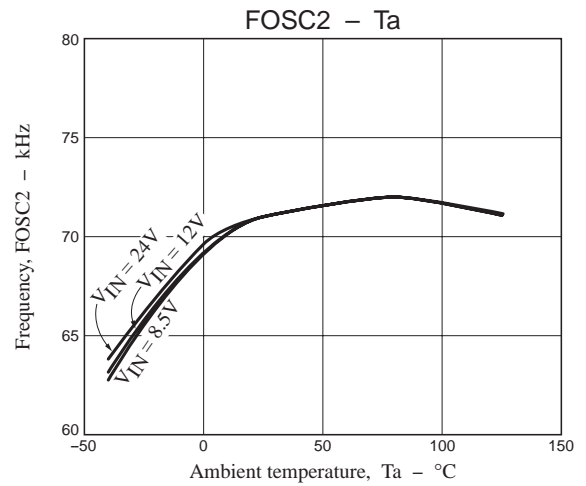
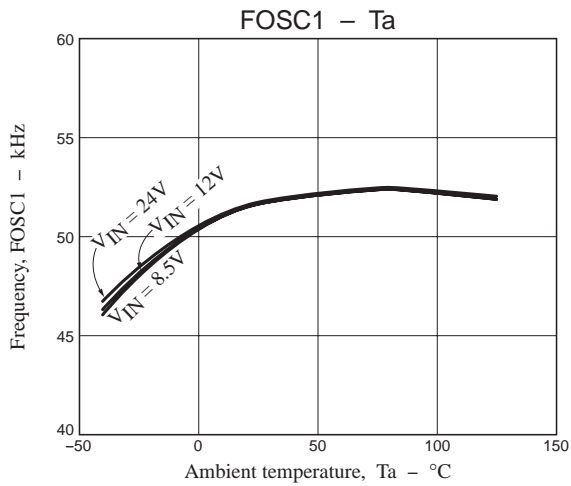
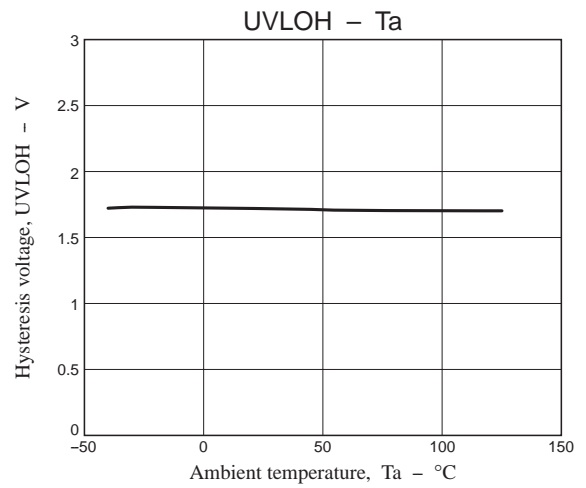
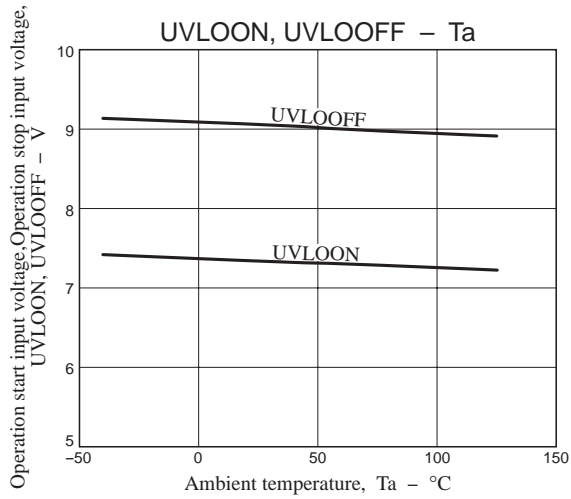
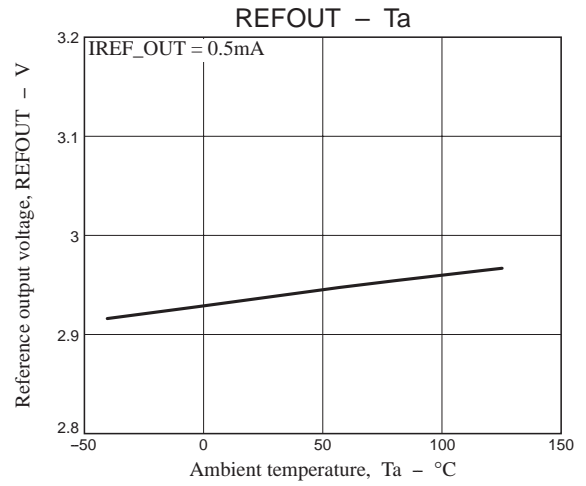
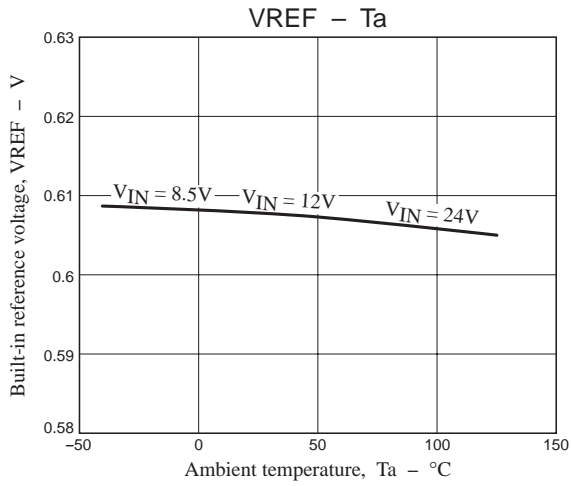


Switching frequency is changed as follows.

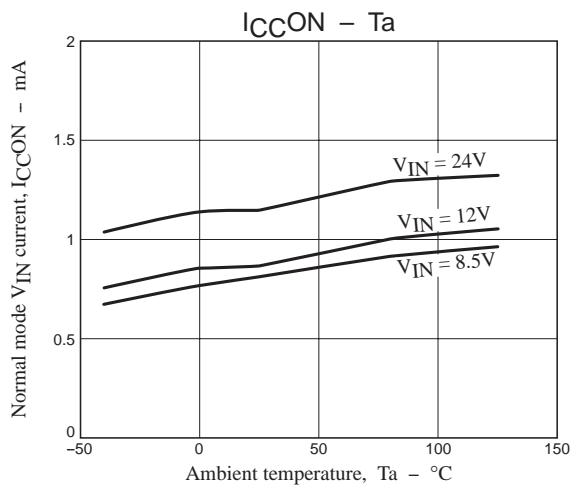
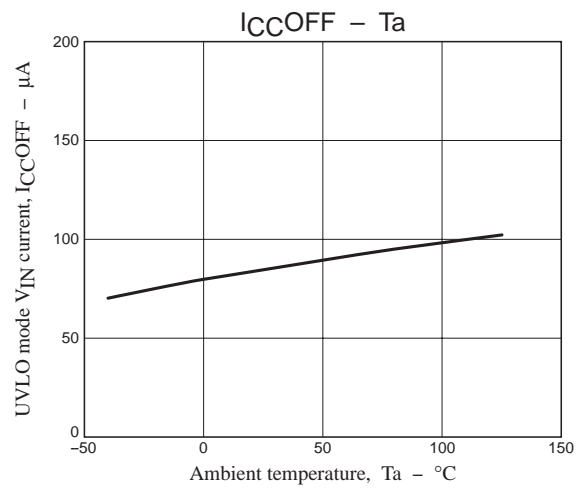
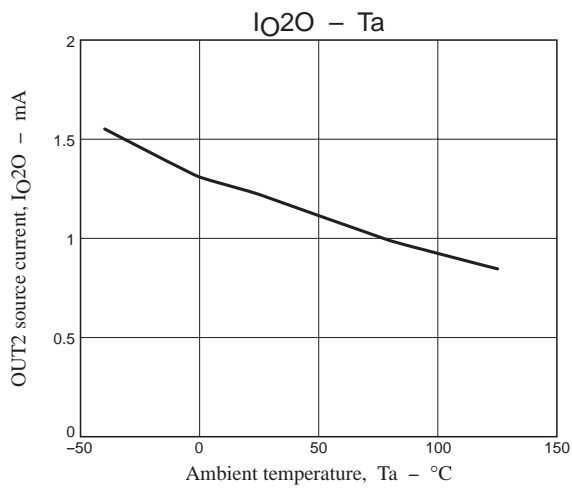
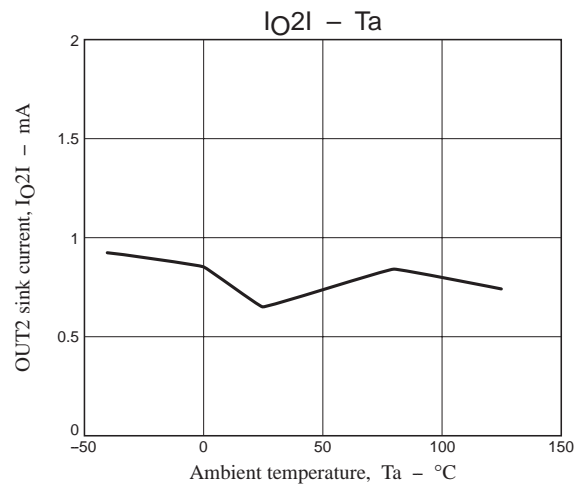
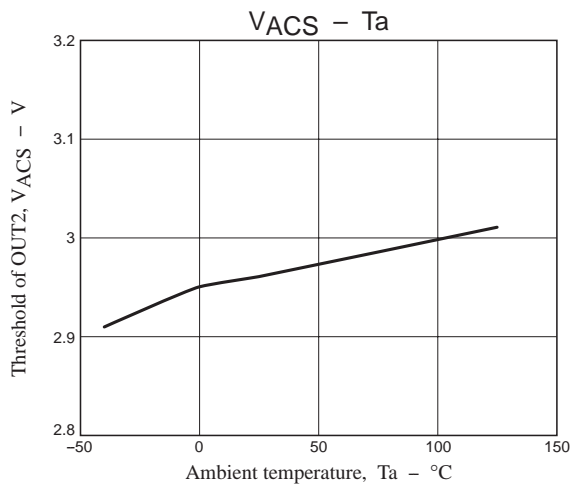
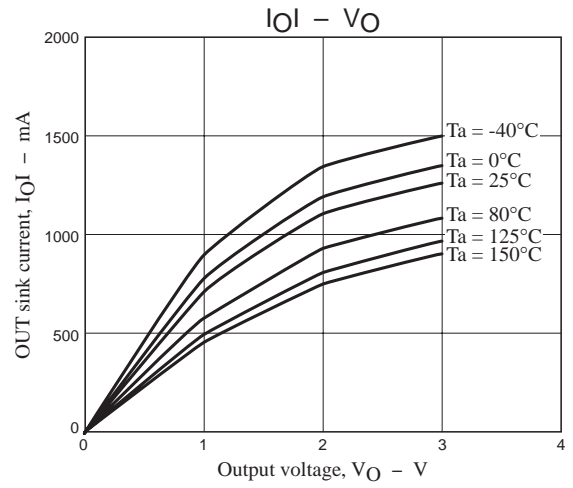
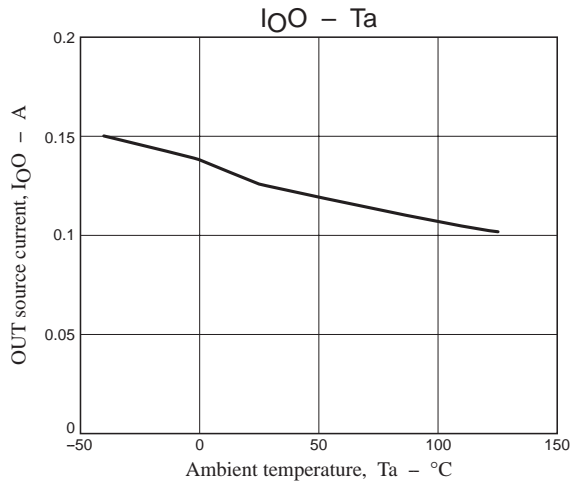
$\dots \times 0.9 \rightarrow$     $\times 1.1 \rightarrow$     $\times 1.05 \rightarrow$     $\times 1 \rightarrow$     $\times 0.95 \rightarrow$     $\times 0.9 \rightarrow$     $\times 1.1 \dots$   
 (45kHz)   (55kHz)   (52.5kHz)   (50kHz)   (47.5kHz)   (45kHz)   (55kHz)

It's repeated by this loop.

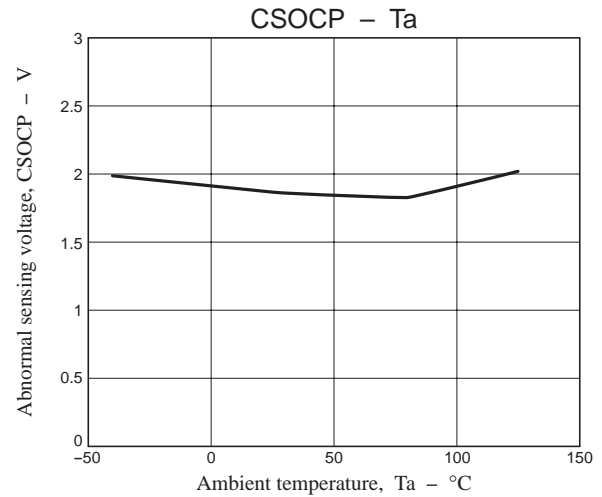
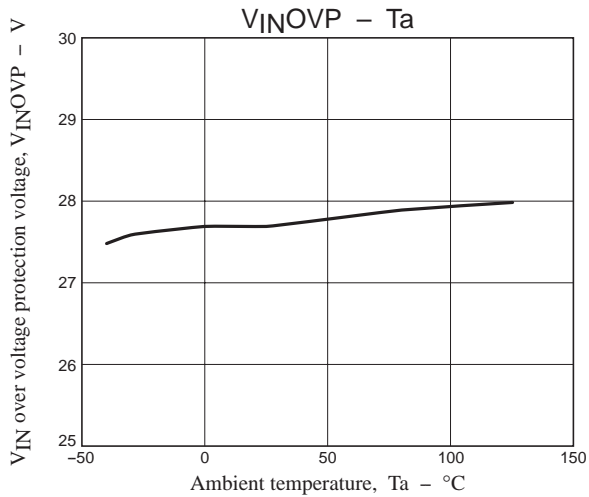
# LV5028TT



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