Ordering number : ENA****

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 various wide dimming controls including the TRIAC dimming control.

Functions

- High Voltage LED Controller
- Various Dimming Control
  - TRIAC & Analog input
- Switching frequency 50kHz
- Low noise switching system
  - 5 stages skip mode Frequency
  - Soft driving
- Selectable Reference voltage
  - Internal 0.605V & External input voltage
- Short Protection Circuit
- Built-in stabilized function

Specifications

Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum Input voltage	V_{IN} max		-0.3 to 42	V
REF_OUT,REF_IN,CS,ACS			-0.3 to 7	V
OUT	V_{OUT}_abs		-0.3 to 42	V
OUT2	V_{OUT2}_abs		-0.3 to 42	V
Allowable power dissipation	Pd max	With specified board*	1.0	W
Junction temperature	Tjmax		150	°C
Operating temperature	Topr		-30 to +125	°C
Storage temperature	Tstg		-40 to +150	°C

*Specified board: 58.0×54.0×1.6mm (glass epoxy board)

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Recommended Operating Conditions at Ta = 25°C

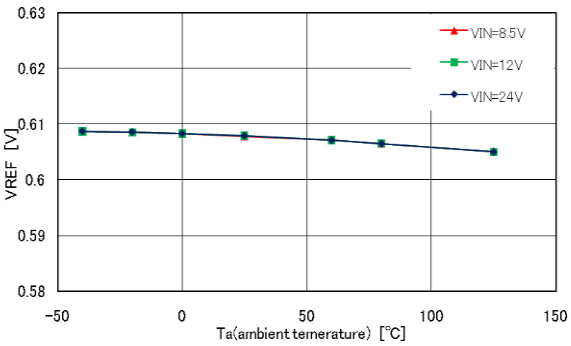
Parameter	Symbol	Conditions	Ratings	Unit
Input voltage	V_{IN}		8.5 to 24	V

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

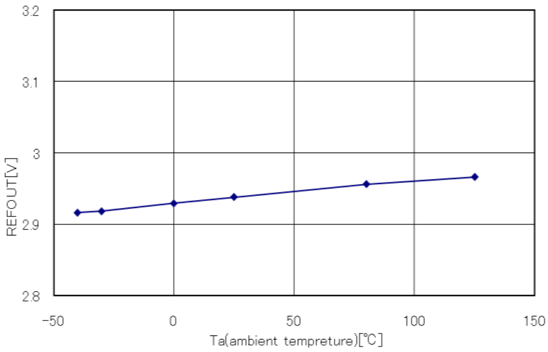
Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Reference Voltage block						
Built-in Reference Voltage	VREF		0.585	0.605	0.625	V
VREF V_{IN} line regulation	VREF_LN	V_{IN} = 8.5 to 24V		±0.5		%
Reference Output Voltage	REFOUT			3.0		V
-Maximum load	REFOUT_MAX		0.5			mA
-equivalent output impedance	REFOUT_RO			10		ohm
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	FOSC		40	50	60	kHz
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 REFOUT)	V_{IO}_RI			1	10	mV
Input current	IIOCS			160		nA
	IIOREF			80		nA
CS pin max voltage	VOM				1	V
malfunction prevention mask time	TMSK			150		ns
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_OI		500	1000		mA
OUT source current	I_OO			120		mA
Minimum On time	TMIN			200	300	ns
TRIAC Stabilization Circuit						
Threshold of OUT2	VACS	OUT2=High [less than right record]	2.8	3.0	3.2	V
OUT2 sink current	I_O2I	VIN=12V, OUT2=6V		0.6		mA
OUT2 source current	I_O2O	VIN=12V, OUT2=6V		0.6		mA
VIN current						
UVLO mode V_{IN} current	I_{CC}OFF	V_{IN}<UVLOON		80	120	μA
Normal mode V_{IN} current	I_{CC}ON	V_{IN}>UVLOON, OUT = OPEN		0.6		mA
V_{IN} Over Voltage Protection Circuit						
V_{IN} over voltage protection voltage	V_{IN}OVP		24	27	30	V
VIN Current at OVP	IINOVP	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)

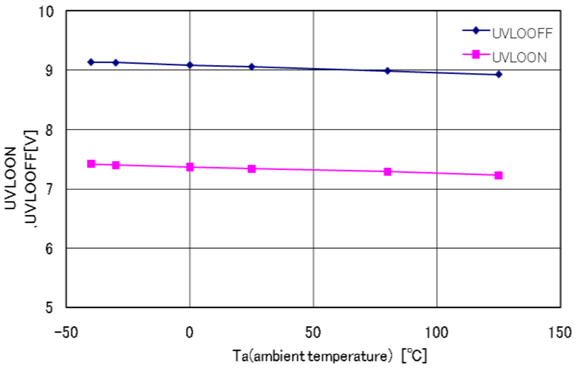
TYPICAL CHARACTARISTICS



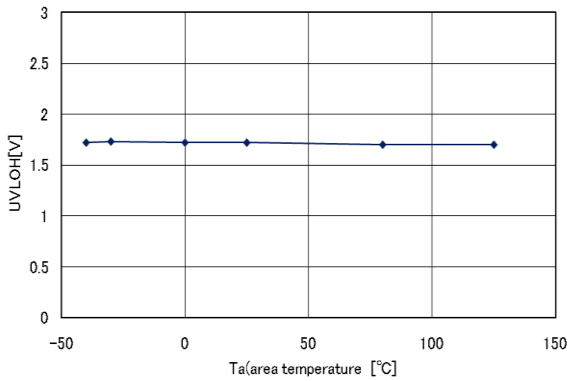
VREF(reference voltage) vs Ta(ambient temperature)



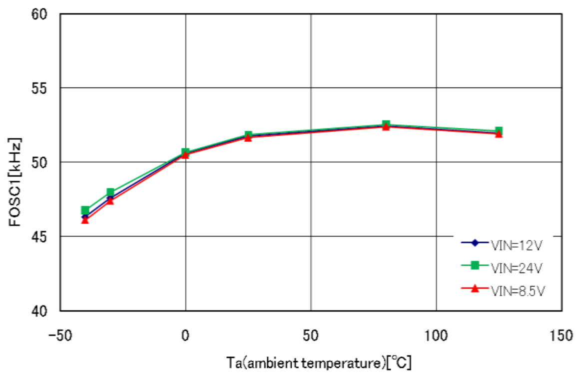
REF_OUT(internal reference viltage vs Ta(ambient temperature)
[IREF_OUT=0.5mA]



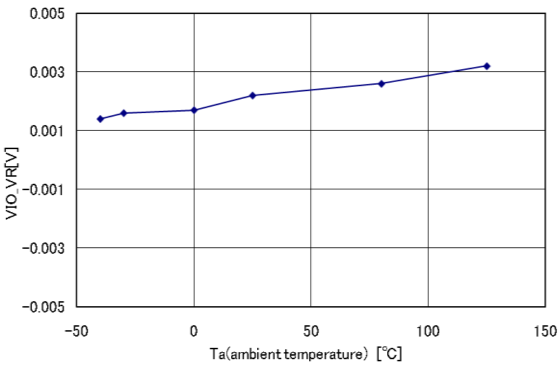
UVLOON, UVLOOFF(UVLOoperating voltage) vs Ta(ambient temperature)



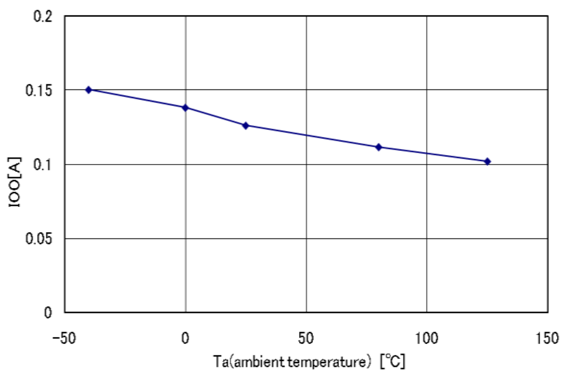
UVLO Hysteresis vs Ta(ambient temperature)



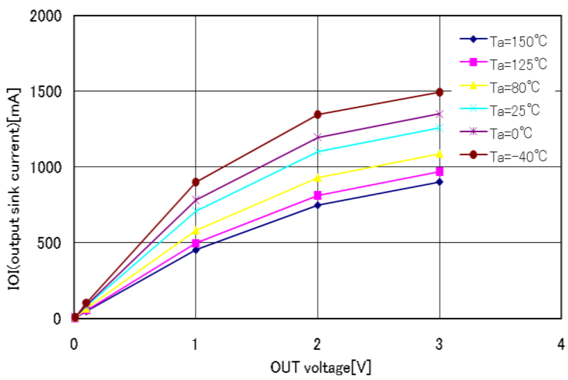
FOSC1(50kHz)(reference scillation freq vs Ta(ambient temperature)



VIO_VR(Input oddset viltage) vs Ta(ambient temperature)[REF_IN=0.3V]

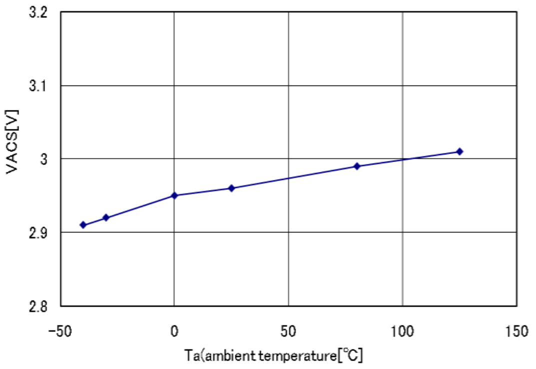


IOO(output source current) vs Ta(ambient temperature)

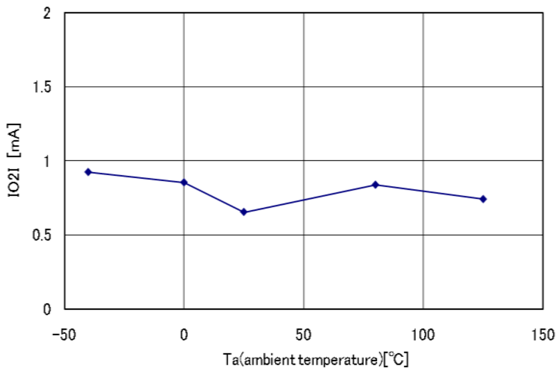


IOI(output current) vs OUT voltage

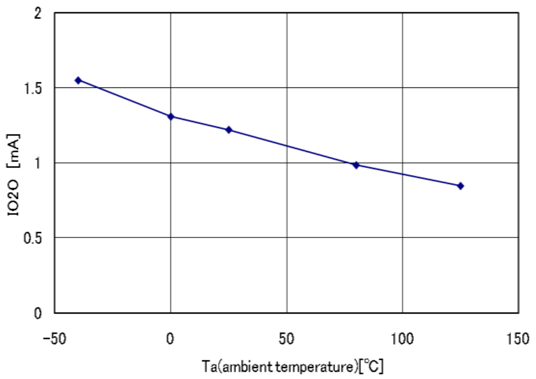
TYPICAL CHARACTARISTICS



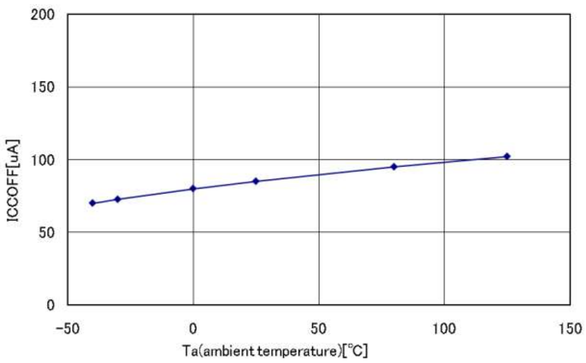
VACS(ACS changeover voltage) vs Ta(ambient temperature)



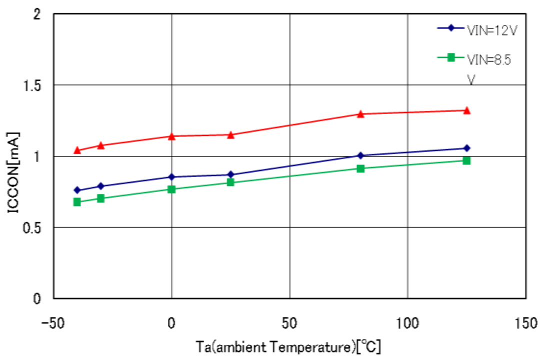
IO2I(OUT2 source current) vs Ta(ambient temperature)



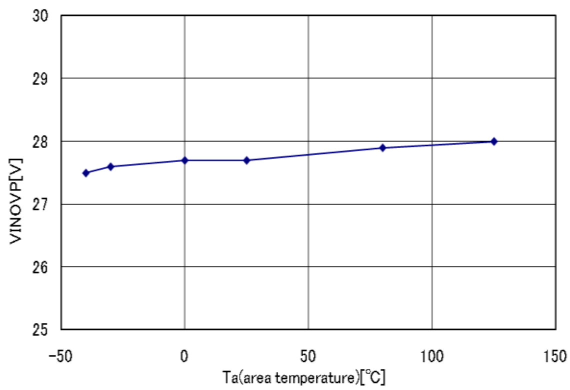
IO2O(OUT2 sink current) vs Ta(ambient temperature)



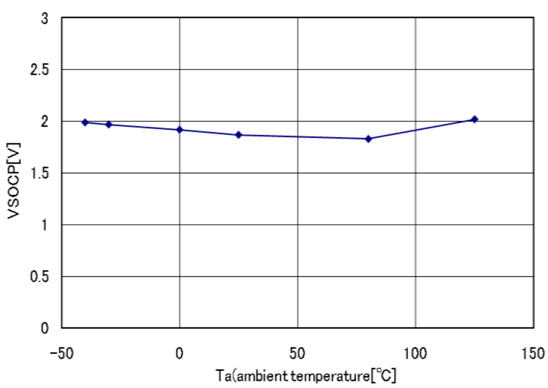
ICCOFF(static current consumption) vs Ta(ambient temperature)



ICCON(curreent consumption) vs Ta(ambient temperature)



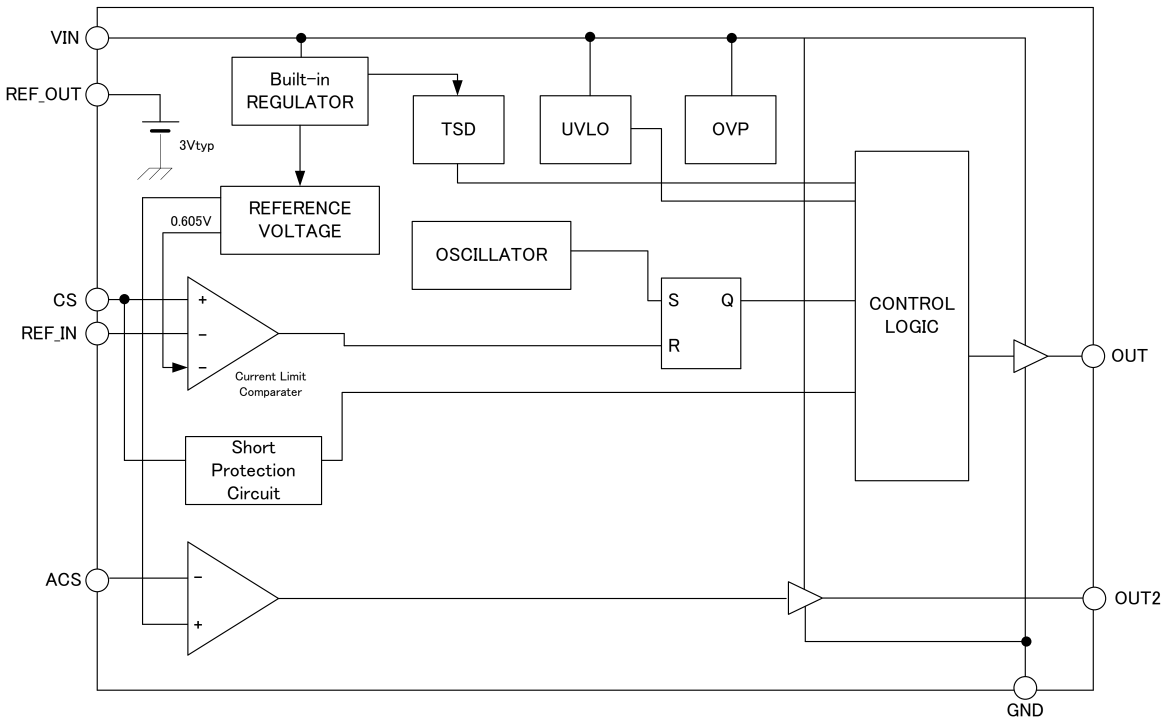
VINOVP vs Ta(ambient temperature)



CSOCP(CS error detection voltage) vs Ta(ambient temperature)

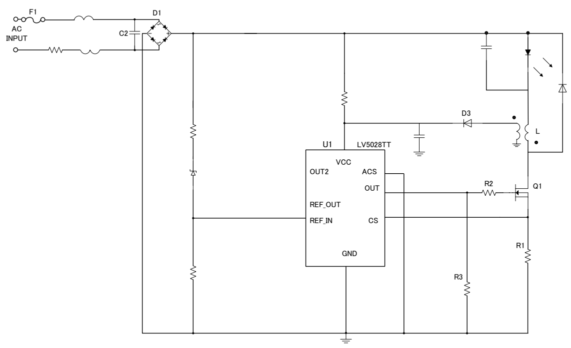
TYPICAL CHARACTARISTICS

Block Diagram

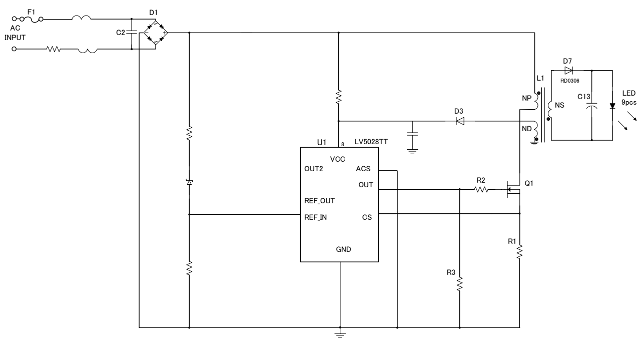


Sample Application Circuit

Non isolation

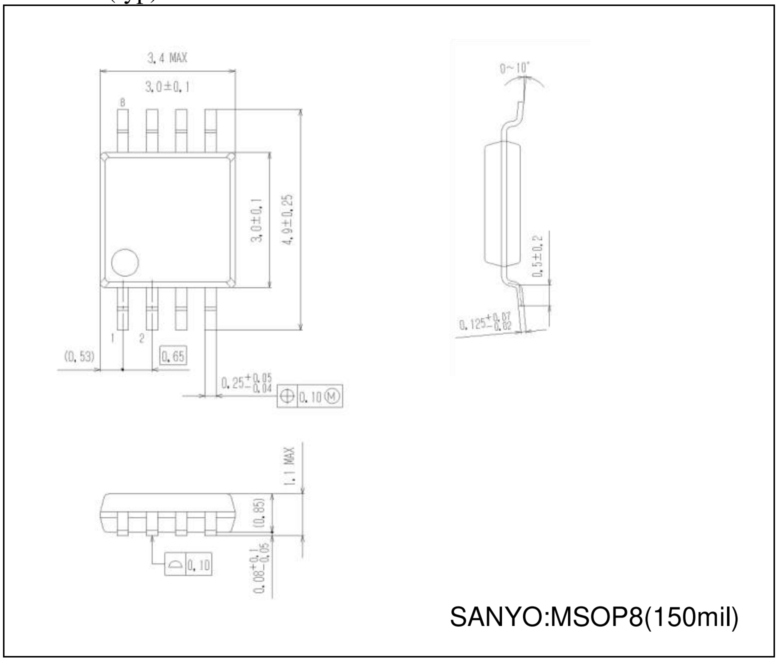


Isolation

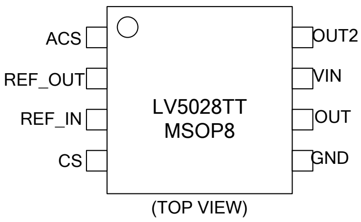


Package Dimensions

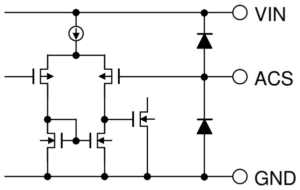
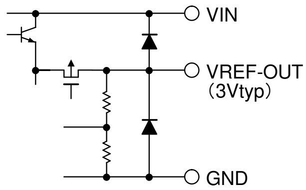
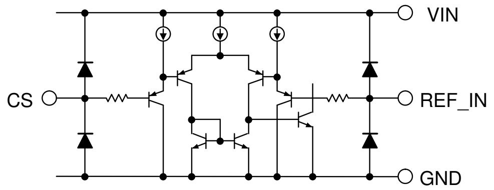
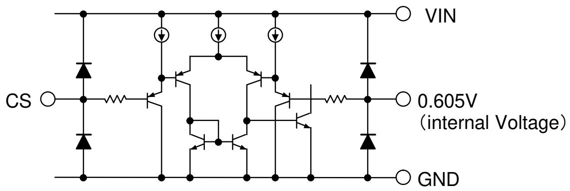
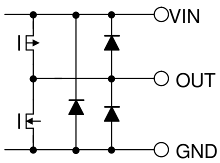
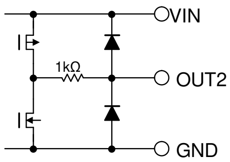
unit: mm (typ)



Pin Assignment



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, external FET is OFF. And if the voltage of the terminal exceeds 1.9V, LV5028TT turns to latch-off mode.	
5	GND	GND pin.	
6	OUT	Driving the external FET Gate Pin.	
7	VIN	Power supply pin. Operation : VIN＞UVLOON Stop: VIN＜UVLOOFF Switching Stop : VIN>VINOVP	
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.	

Relation ship beween VREF and CS pin voltage

Relation ship beween REF_IN and CS pin voltage(Power Factor Crrection(PFC))

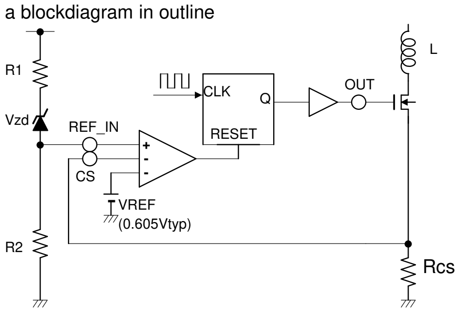
The output current value is the average of the current value that flows during one cycle. The current value that flows into coil is a triangular wave shown in the figure below. Make sure to set Ipk so that (average of current value at one cycle) is equal to (LED current value).Ipk is set by the relationship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

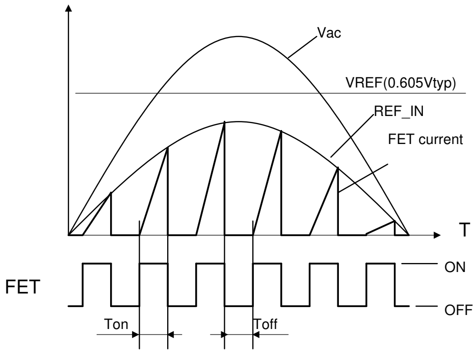
Setting Zener voltage

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).

a blockdiagram in outline





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

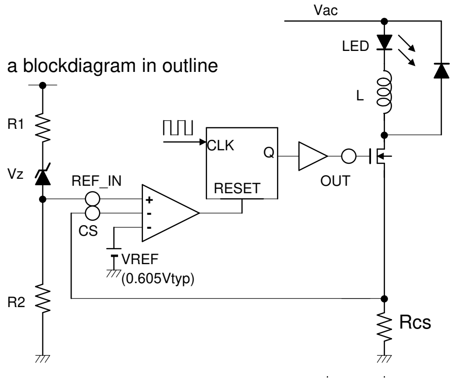
Ipk: peak inductor current
Vf: LED forward voltage drop
Vac: effective value,R.M.S value
VREF: Built-in reference voltage (0.605V)
VREF_IN:REF_IN voltage(6 pin)
Rs: External sense resistor
Vzd:Zener diode voltage(REF_IN pin)

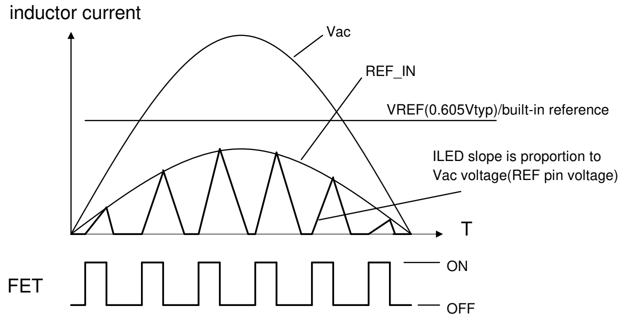
LED current and inductance setting

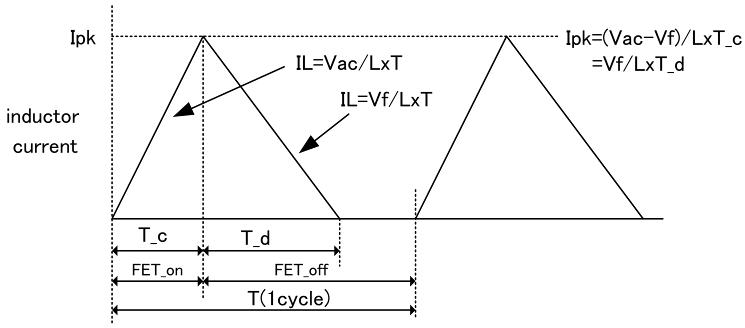
It is available to use both no-isolation and isolation applications.

（For non-isolation application）

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







Given that the period when current flows into coil is

$$\mathrm{DutyI} = \frac{T\_c + T\_d}{T},$$

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

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

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

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,

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

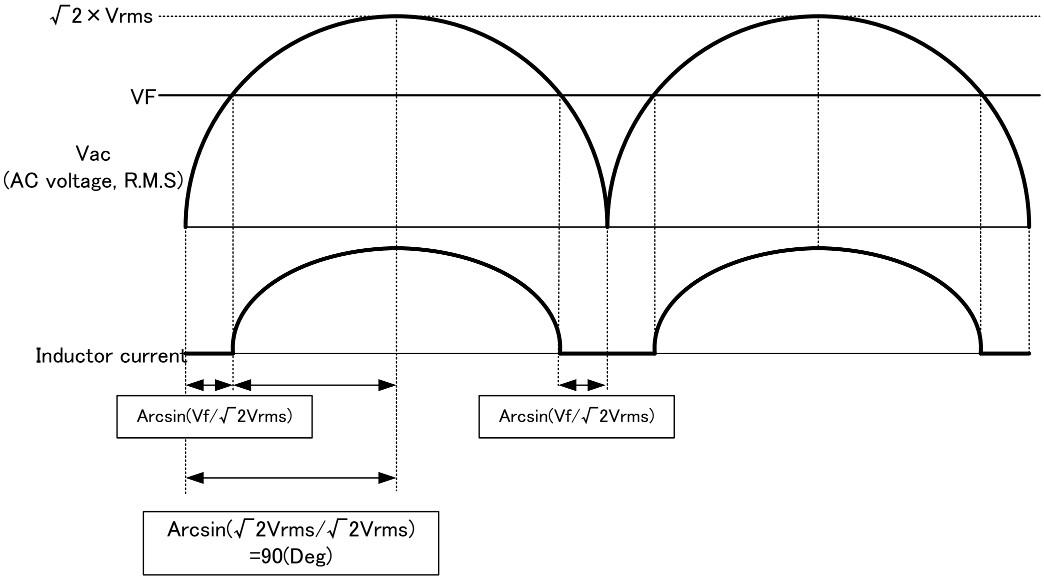
Since $T\_c + T\_d = DutyI \times T$, $T\_c = DutyI \times T - T\_d$ (4)

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

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

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

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.

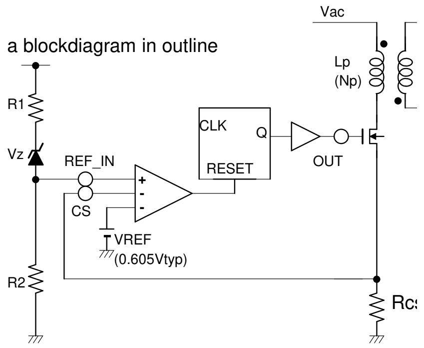
$$DutyAC = \frac{90 - \arcsin(\frac{Vf}{\sqrt{2}Vrms})}{90}$$

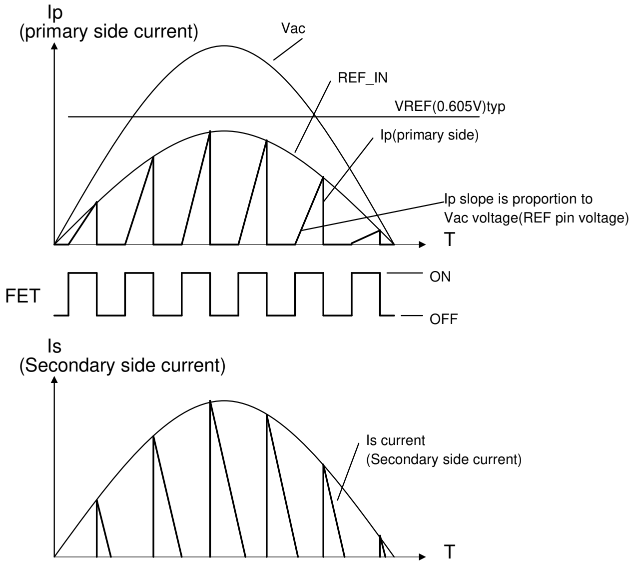
Since the period when the inductor current flows are limited by DutyAC, the formula (6) is represented as follows:

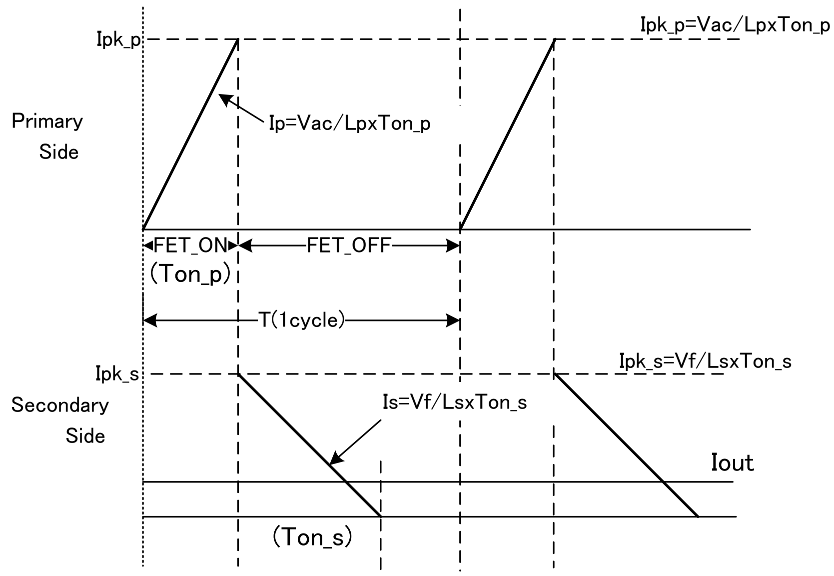
$$L = \frac{Vf}{2 \times ILED} \times \frac{1}{fosc} \times \frac{Vac - Vf}{VIN} \times (DutyI)^2 \times \left(\frac{90 - \arcsin(\frac{Vf}{\sqrt{2}Vrms})}{90} \right)^2 \qquad (7)$$

(for Isolation application)

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:

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

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

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

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

To substitute the following to the formula below,

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

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

Sense resistor is obtained as follows.

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

[Inductance Ls of secondary side]

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

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

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

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

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

Since ratio and inductance of transformer coil is

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

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

$$\therefore \frac{Np}{Ns} = \frac{Vdc \min}{Vout} \times \sqrt{\eta} \times \frac{Don\_p}{Don\_s} \qquad (21)$$

Calculation of transformer coil on primary side and secondary side

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

⊿B : variation range of core flux density [Gauss]

Ae : core section area [cm^2]

To use Al (L value at 100T),

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

L : inductance [uH]

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

lg (Air gap) is obtained as follows:

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

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

μ_0: vacuum magnetic permeability $\mu_0 = 4\pi * 10^{-7}$

N: turn count [T]

Ae: core section area [m^2]

L: inductance [H]

Bleeder current cuircuit for TRIAC dimmer

1. Operating voltage setting

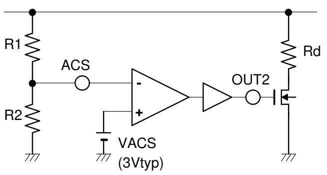
ACS pin voltage set operating voltage at OUT2. ACS pin threshold volage is 3Vtyp.
OUT2 operating voltage is set by R1 and R2. R1 and R2 is determined below.

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

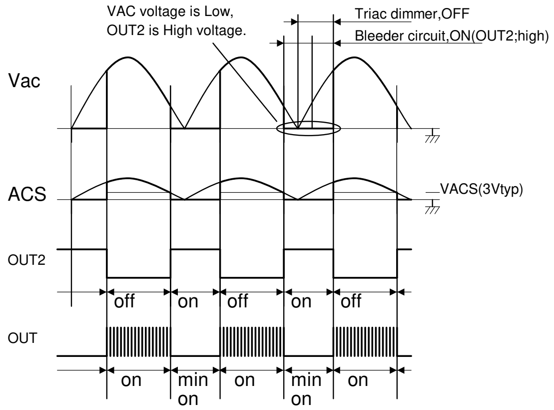
2. Bleeder current setting

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

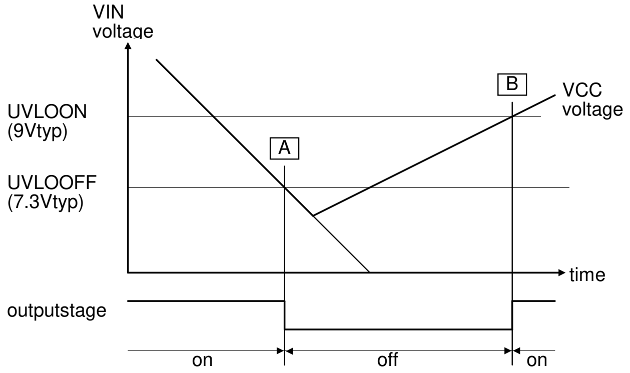


Description of operating protection function

	tilte	outline	monitor point	note
1	UVLO	Under Voltage Lock Out	VIN voltage	
2	OCP	Over Current Protection	CS voltage	equivalent FET current
3	OVP	Over Voltage Protection	VIN voltage	
4	OTP (TSD)	Over Temperature Protection (Thermal Shut Down))	PN Junction temperature	

1.UVLO(Under Voltage Lock Out)

If VIN 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 80uA or lower. If VIN voltage is 9V or higher, then the IC starts switching operation.

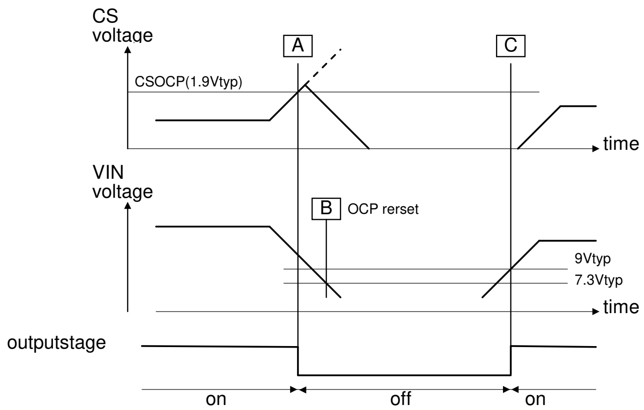


2.OCP(Over Current Protection)

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(1.9Vtyp)(A), the iternal comparator will detect the event and turn off the MOSFET. The peak switch current is calculated

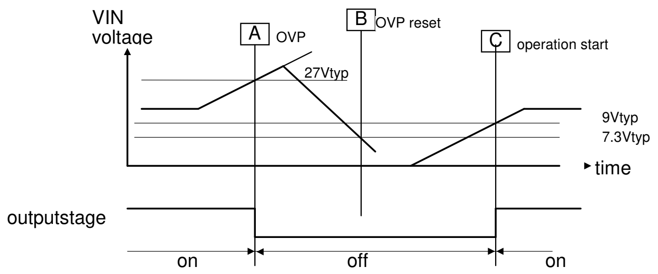
Io(peak) [A] = VSOCP[V]/Rsense[ohm]

The VIN pin is pulled down to fixed level, keeping the controller lached off.The lach reset occurs when the user disconnects LED from VAC and lets the VIN falls below the VIN reset voltage,UVLOOFF(7.3Vtyp)(B). Then VIN rise UVLOON(9Vtyp)(C),restart the switching.



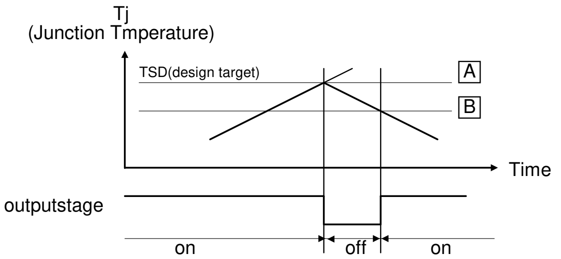
3.OVP(Over Voltage Protection)

If the voltage of VIN pin is higher than the internal reference voltage VINOVP(27Vtyp),switching operation is stopped. The stopping operation is kept until the voltage of VIN is lower than 7.3V. If the voltage of VIN pin is higher than 9V, the switching operation is restated.



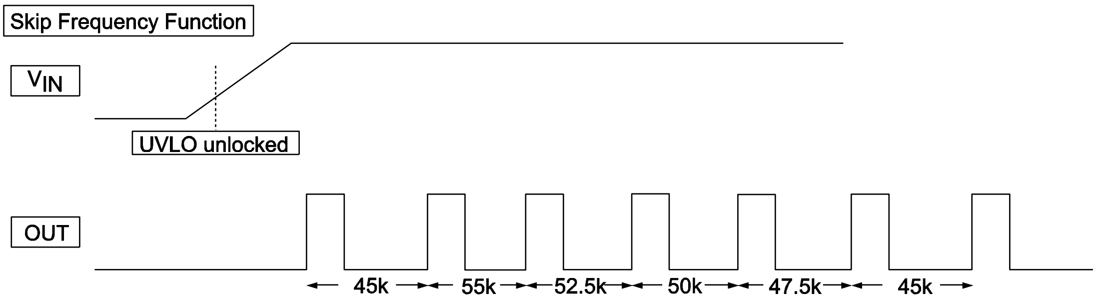
4.TSD(Thermal Shut Down protection)

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°Ctyp (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.

… ×0.9 → ×1.1 → ×1.05 → ×1 → ×0.95 → ×0.9 → ×1.1 …

It's repeated by this loop.

This catalog provides information as of March, 2011. Specifications and information herein are subject to change without notice.