LC5710S
DATA SHEET Rev.1.9

SANKEN ELECTRIC CO., LTD.

http://www.sanken-ele.co.jp

CONTENTS

General Descriptions

The LC5710S product is the power IC for LED driver which incorporates a power MOSFET and a controller IC in a package.
This product is a DC/DC converter which features are; wide input voltage range, 100kHz to 500kHz operating frequency, and Buck/ Boost/ Buck-Boost converter can be selected with external circuit configuration.
LED string current can be set with the external resistor, and LED dimming can be controlled by the digital input signal or DC-bias. The rich set of protection features helps to realize low component counts, and high performance-to-cost power supply.

Package

SOP8

Features

- Operation Types: The following converter types are applicable by the external circuit configuration
  ・Buck Converter
  ・Boost Converter
  ・Buck-Boost Converter
- High Efficienby: η > 90%(TYP)
- Operation Frequency:
  100kHz to 500kHz(adjustable)
- LED string current setting with an external resistor.
- Current Detection voltage of LED string:
  100mV±3%
  Thus, low power loss and high accuracy LED string current can be achieved by setting of an external resistor.
- PWM Dimming Frequency: available to 20000Hz(MAX)
- Analog Dimming by the DC-bias(0 to 2V)
- Package: HSOP8
  Heat slag in the back can increase heat dissipation effect by connecting it to GND pattern
- Protection Functions
  ・Overcuurent Protection Function (OCP) ------Pulse-by-pulse basis
  ・OvervoltageProtection Function (OVP) ------Auto restart
  ・Thermal Shutdown Protection Function (TSD) ------Auto restart
  ・LED cross protection

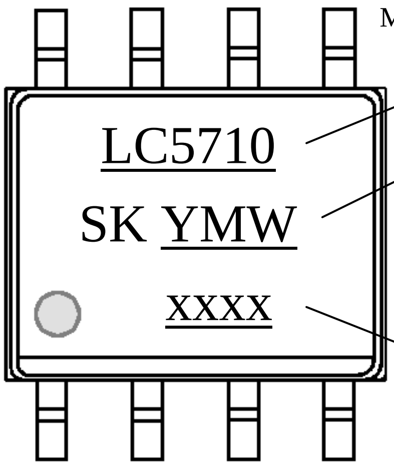
Characteristics

Input voltage range	5V (MIN)～58V(MAX)
$R_{DS(ON)}$	550mΩ(TYP)

Applications

- LED lighting fixtures
- LED light bulbs

Marking



Product number

Lot number
Y=The last digit of the year (0 to 9)
M=Month (Jan to Sep:1 to 9, O=”10”, N=”11”, D=”12”)
W=Week(1 to 3)
Date = 1 to 10:1
Date = 11 to 20:2
Date = 21 to 31:3

*Our control number (4 digit)

1.Absolute Maximum Ratings

- Certain details refer to the specification sheet of this product.
- The polarity value for current specifies a sink as “+”, and a source as “–”, referencing the IC.
- Unless specifically noted, Ta is 25°C

Table.1

Characteristic	Pins	Symbol	Rating	Unit	Notes
VIN Pin Voltage	5－3	V_{IN}	−0.3 to 60.0	V	
SW Pin Voltage	4—3	V_{SW}	−0.3 to 60.0	V	
CSP Pin Voltage	6—3	V_{CSP}	−0.3 to 60.0	V	
CSN Pin Voltage	7—3	V_{CSN}	−0.3 to 60.0	V	
Differential Voltage bwteen CSP and CSN Pins	6—7	$V_{CSP-CSN}$	−0.3 to 3.3	V	
COMP Pin Voltage	1—3	V_{COMP}	−0.3 to 3.3	V	
DIM Pin Voltage	8—3	V_{DIM}	−0.3 to 3.3	V	
RT Pin Voltage	2—3	V_{RT}	−0.3 to 3.3	V	
Allowable Power Dissipation of MOSFET (1) (2)	—	P_D	1.2	W	
Junction Temperature in Operation (3)	—	T_J	125	°C	
Thermal Resistance (junction-ambient air) (2)	—	θ j-a	82.8	℃/W	
Thermal Resistance (junction- Pin No. 3)	—	θ j-pin	59.0	℃/W	
Operating ambient temperature (1)	—	T_{op}	−40 to 125	°C	
Storage Temperature	—	T_{STG}	−40 to 150	°C	

(1) However, it is limited by Junction temperature.

(2) When mounted on a 40×40mm Glass-epoxy board (copper area in a 25×25mm).

(3)Thermal shutdown temperature is approximately 150°C

2.Recommended Operation Conditions

- Recommended Operation Conditions are the required operating conditions to maintain the normal circuit functions described in the electrical characteristics. In actual operation, it should be within these conditions.
- The polarity value for current specifies a sink as “+” and a source as “–” referencing the IC.
- Unless specifically noted, Ta is 25°C

Table.2

Characteristic	Pins	Symbol	MIN	MAX	Unit	Notes
VIN Pin Voltage	5 − 3	V_{IN}	5	58	V	
Output current (4)	—	Io	0	1	A	(5)Buck
			0	0.5		(5)Boost/Buckboost
DIM Terminal Voltage	8 − 3	V_{DIM}	$V_{DIM(OFF)}$	2.5	V	Analogue Dimming
DIM Terminal Dimming Frequency	8 − 3	f_{DIM}	100	20000	Hz	Digital Dimming
Peak to Peak Inductor Ripple current	—	⊿IL	0.1	0.4	A	
Operating ambient temperature (4)	—	T_{op}	-40	+85	℃	

(4) To be used within the allowable package power dissipation characteristics (fig. 1)
(5)Buck circuit：1A, Boost circuit／Buck-boost circuit：0.5A, Each condition is ⊿IL ≦0.4A.

3.Electrical Characteristics

- Certain details refer to the specification sheet of this product.
- The polarity value for current specifies a sink as “+” and a source as “–”, referencing the IC.

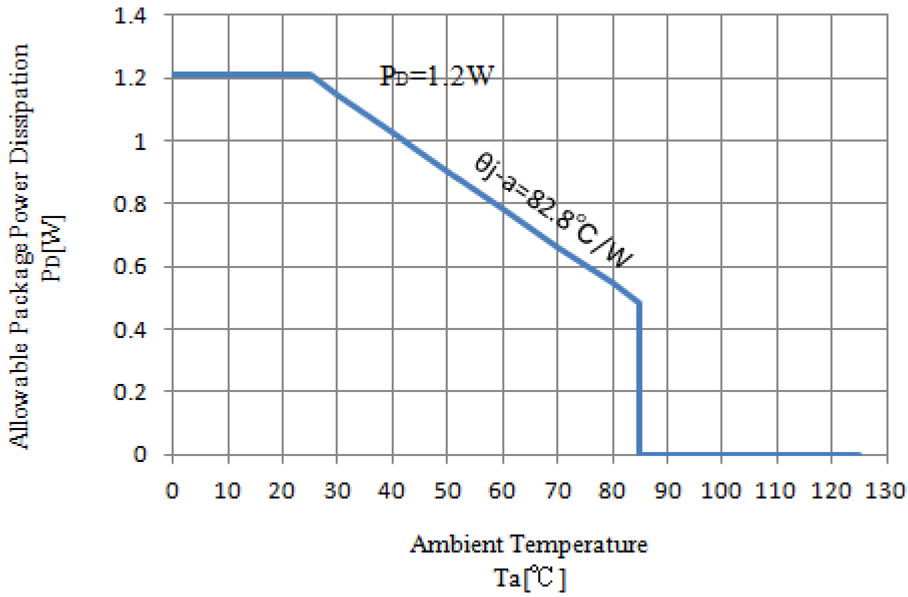
3.1 Electrical Characteristics of Control Part (MIC) Unless specifically noted, Ta is 25°C, V_{IN}=15V

Table.3

Parameter		Terminal	Symbol	Ratings			Units	Remarks
				MIN	TYP	MAX		
Operation Start Voltage		5−3	$V_{IN(ON)}$	3.8	4.1	4.5	V	
Operation Stop Voltage		5−3	$V_{IN(OFF)}$	3.4	3.7	4.2	V	
Operation Hysteresis Voltage		5−3	$V_{IN(HYS)}$	0.25	0.37	0.50	V	
Supply Current	(6)	5−3	$I_{IN(ON)}$	—	1.6	—	mA	
Supply Current in No Operation	(6)	5−3	$I_{IN(OFF)}$	—	0.24	—	mA	V_{IN}= 3V
Oscillator Frequency1		—	f_{OSC1}	80	100	135	kHz	R_{RT}=180kΩ
Oscillator Frequency2		—	f_{OSC2}	350	500	650	kHz	R_{RT}=18kΩ
Minimum On Time		—	$t_{ON(MIN)}$	100	200	300	ns	V_{COMP}= 0V
Maximum Duty Cycle		—	D_{MAX}	84	90	95	%	V_{COMP}= 2.8 V
Current Sense Voltage		6−7	V_{CS}	97	100	103	mV	
SW Current Limit		4−3	$I_{SW(LIM)}$	1.4	1.8	2.2	A	
CSP Input Current		6−3	I_{CSP}	22	35	50	µA	
CSN Input Current		7−3	I_{CSN}	5	9.5	18	µA	
COMP Terminal Source Current		1−3	$I_{COMP(SO)}$	-65	-50	-35	µA	V_{CS}=20mV V_{COMP}=2V
COMP Terminal Sink Current		1−3	$I_{COMP(SI)}$	35	50	65	µA	V_{CS}=180mV V_{COMP}=2V
Error Amplifier Conductance	(6)	—	G_M	—	4.2	—	mS	V_{CS}=70 ~130mV
Over Voltage Threshold		6−7	$V_{CS(OVP)}$	140	150	160	mV	
Setup time of Watch Dog Timer	(6)	—	T_{WDT}	—	30	—	mS	Vcomp=2.5V Vcs=short
DIM Voltage in LED On at Dimming mode		8−3	$V_{DIM(ON)}$	0.17	0.20	0.23	V	
DIM Voltage in LED Off at Dimming mode		8−3	$V_{DIM(OFF)}$	0.12	0.15	0.18	V	
DIM Hysteresis Voltage at Dimming mode		8−3	$V_{DIM(HYS)}$	10	50	100	mV	
Thermal Shutdown	(6)	—	TSD	—	165	—	°C	
Thermal Shutdown Hysteresis	(6)	—	$TSD_{(HYS)}$	—	22	—	°C	

(6) Guaranteed by design, not tested.

3.2 Allowable package power dissipation



When mounted on a 40×40mm Glass-epoxy board (copper area in a 25×25mm).

fig.1 Package power dissipation of LC5710S
(Thermal Derating Curve)

Note1 : The power dissipation in fig.1 is calculated at the junction temperature 125 ℃.

4. Functional Block Diagram

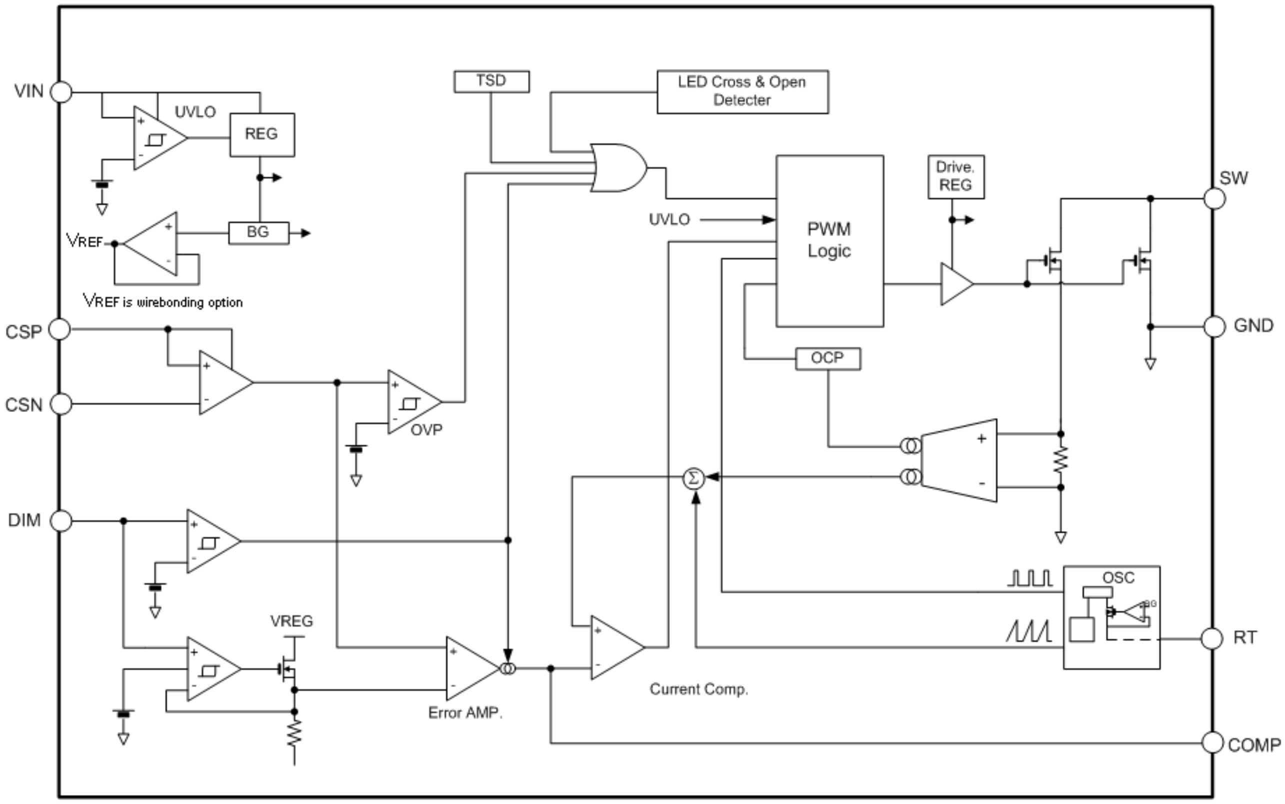


fig.2 Block diagram

5. Pin Assign & Functions

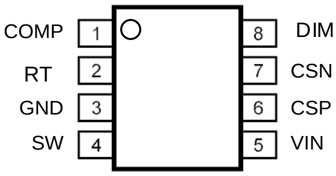


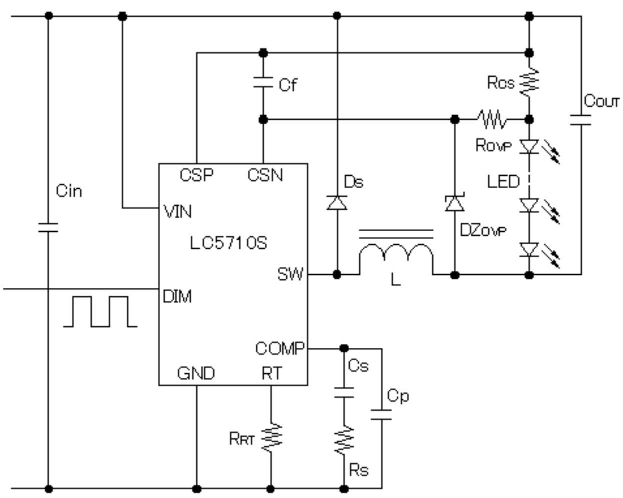
fig.3 Pin Assign

Table.4

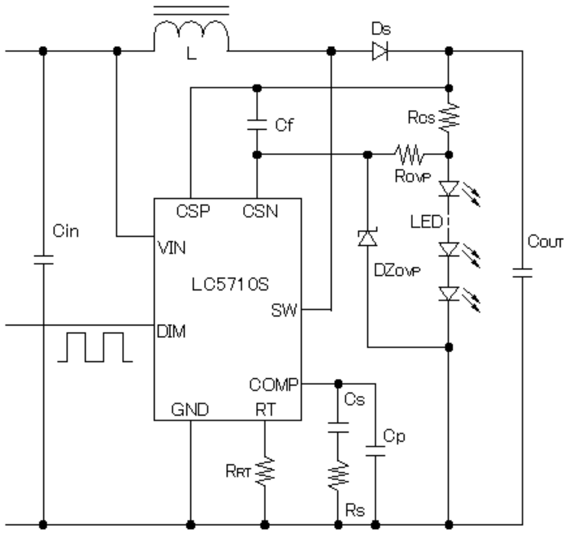
Pin No.	Symbol	Functions
1	COMP	External phase compensation terminal.
2	RT	For adjust switching frequency,Connect RRT resisitor to ground.
3	GND	Ground terminal.
4	SW	Switching Output. Switching node that drives the external inductor.
5	VIN	Supply Input. Input capacitor CIN is connected between VIN and GND.
6	CSP	Current Sense Input Positive. Reference potential for the current sense input.
7	CSN	Current Sense Input Negative. Connect current sense resistor to sense output current.
8	DIM	PWM Dimming Signal Input. And Analog Dimming is possible as to input of DC voltage that is : $V_{DIM\ (OFF)} < V_{DIM} < 2.5V$. LC5710S continues off-condition when this pin is held in the one under $V_{DIM\ (OFF)}$.

6. Typical Application Circuit

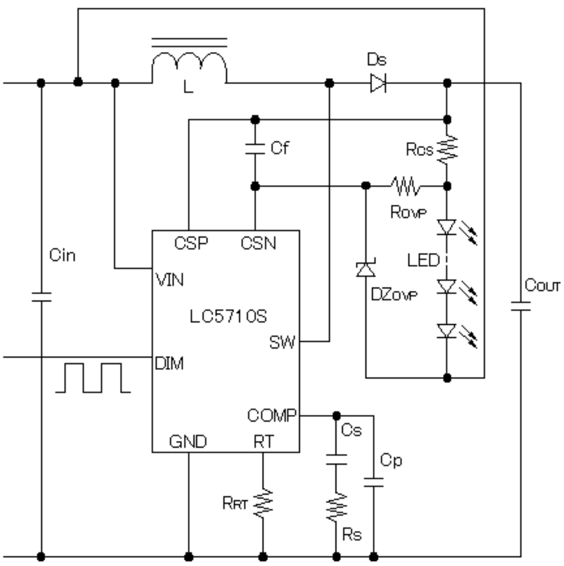
Examples for LED lighting power supply



A)Buck application



B)Boost application

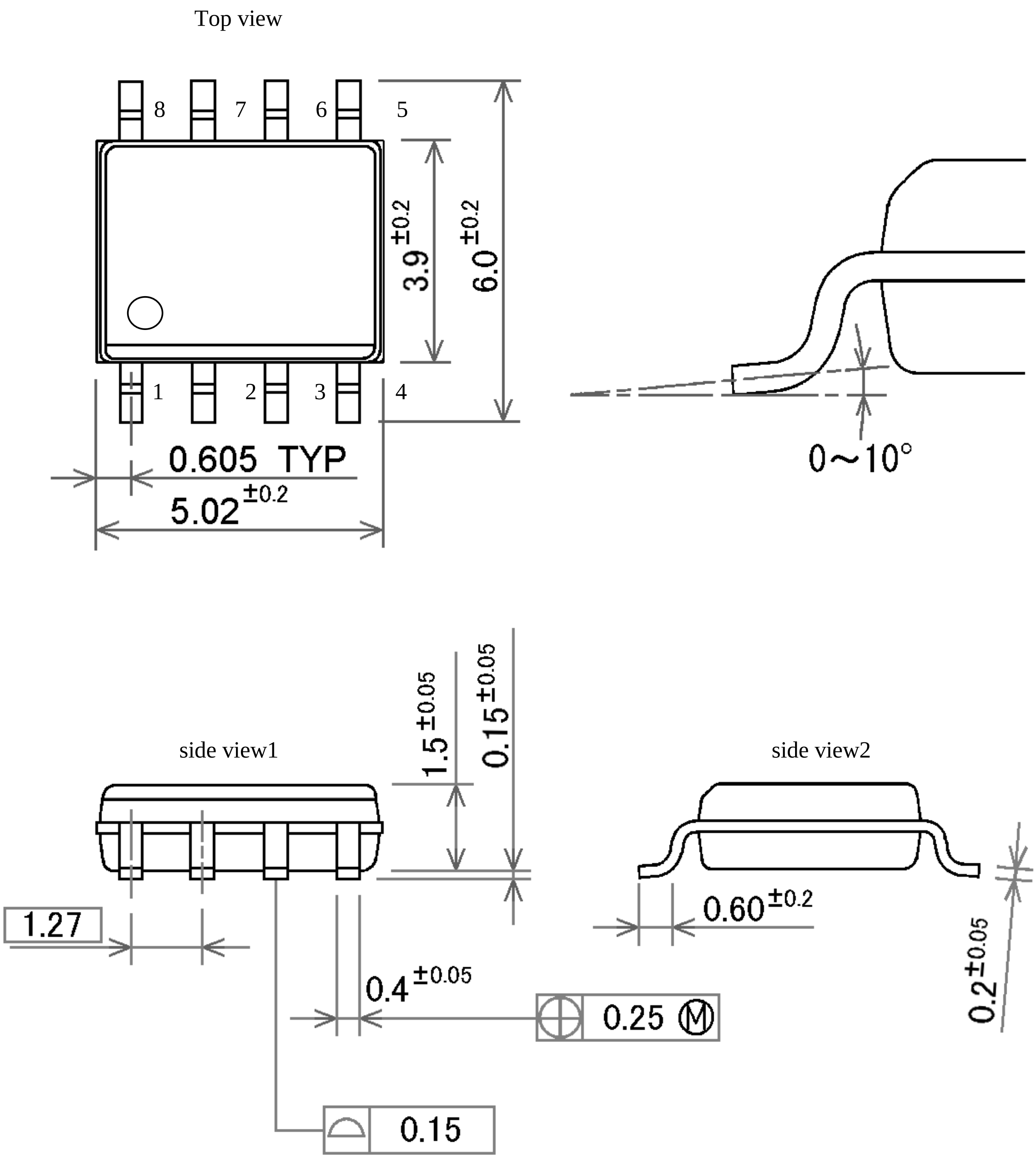


C)Buck-Boost application

fig.4 Typical Application Circuit of LC5710S

7. Package Information

SOP8 Package



NOTES2:

1) All dimensions are in Millimeter
2) Pb-free. Device composition compliant with the RoHS directive
3) Drawing is not to scale.

fig.5 SOP8 package outline

8. Functional Description

All of the parameter values used in these descriptions are typical values of the electrical characteristics, unless they are specified as minimum or maximum.
With regard to current direction, "+" indicates sink current (toward the IC) and "–" indicates source current (from the IC).

8.1 Settlement of the operating frequency

The operating frequency of the LC5710S is adjustable with the value of "setup resistor R_{RT}" that is connected between RT terminal (2 pin) and GND terminal (3 pin). This frequency Fosc can be calculated with an equation (1). The relations of the frequency to the resistance value of R_{RT} are shown in the fig. 6.

Fosc(Hz)={4.74／(24×R_{RT})＋0.365E-6}／21.5E-12 ･･･(1) *Unit of R_{RT}=(Ω)

LC5710S R_{RT} vs. Fosc characteristic

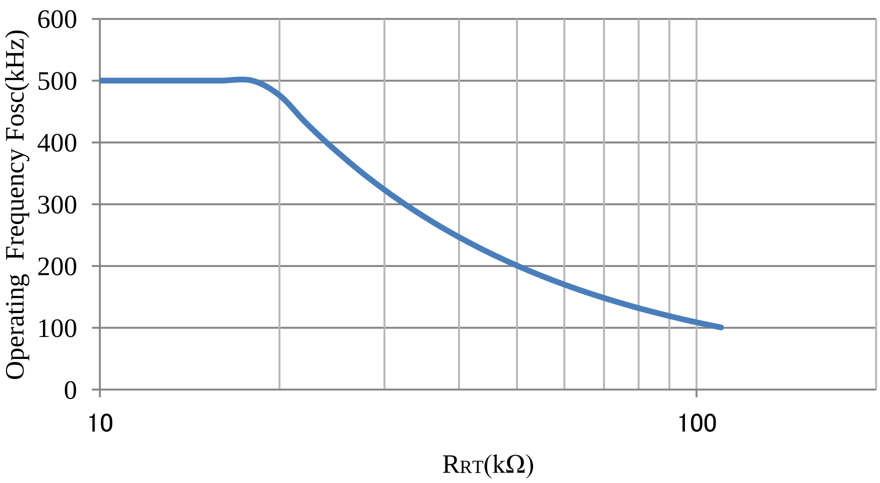


fig.6 R_{RT} vs. Fosc

8.2 PWM Current Control

The current control circuit is shown in fig.7.

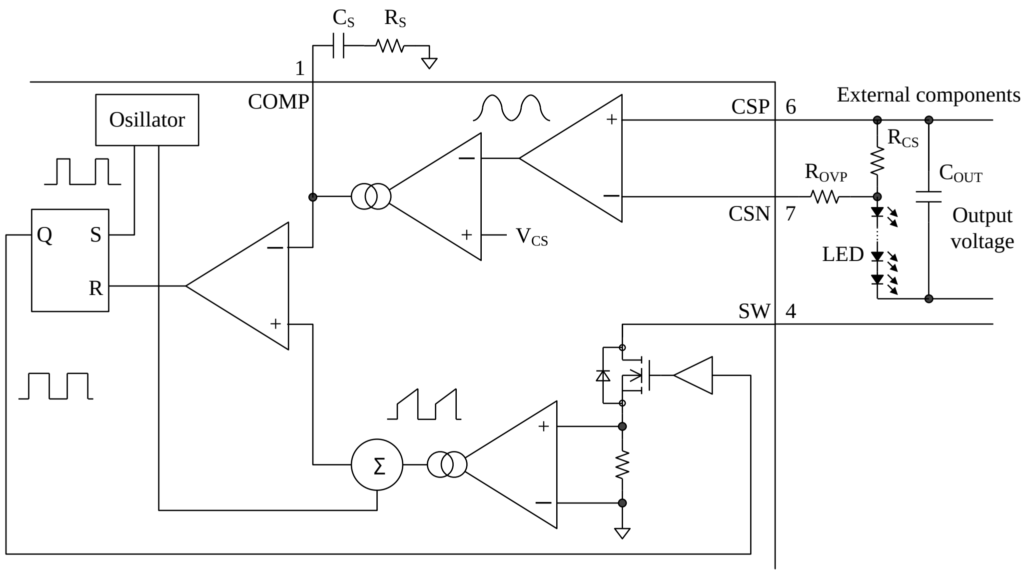


fig.7 Current control circuit

For enhanced response speed and stability, current mode control (peak current mode control) is used for constant current control of the output current. The operating frequency, F_{OSC} is adjustable between 100kHz and 500kHz by the setting resistor R_{RT}.

LED string current is detected by the current detection resistor, R_{CS}.
The voltage of R_{CS} is detected by both CSP and CSN pins. This IC compares this voltage with the Current Detection Voltage, V_{CS}, and makes a target value for current control.
The constant current is controlled so that the detection voltage of peak current of internal power MOSFET is close to the target value, and thus the LED string current is constant.

The constant current of LED string, I_{OUT}, is calculated by the following with R_{CS} as the current detection resistor and R_{OVP} as the resistor for overvoltage protection in the case that LED string is open.

$$I_{OUT} = \frac{V_{CS} - I_{CSN} \times (R_{CS} + R_{OVP})}{R_{CS}} \qquad \cdots(2)$$

where; I_{CSN} : the CSN Pin Sink Current, 9.5μA.
V_{CS} : the Current Detection Voltage, 100mV.

Also, I_{OUT} can be expressed by the following, if $I_{CSN} \times (R_{CS}+R_{OVP})$ is negligibly small against V_{CS}.

$$I_{OUT} = \frac{V_{CS}}{R_{CS}} \qquad \cdots(3)$$

R_{OVP} value should be chosen so that I_{OUT} is within the acceptable accuracy range referring to the calculation in “8.5 Overvoltage Protection Function (OVP)”.

8.3 LED Dimming

8.3.1 Analog dimming

The dimming of LC5710S copes with both of Analog (the input of a DC voltage) and PWM-digital-Dimming. Though it is Analog-dimming first, there are relations of the fig.8(A),(B) in the input DC voltage of the DIM pin and the dimming-ratio. Moreover,Dimming by the Pull-down resistor R_{DIM} is possible by using a internal current-source of the IC, too. The relations of the DIM pin voltage and R_{DIM} are shown by the figure 8 (B). Dimming ratio is 100% when the DIM pin voltage is more than DC 2V.

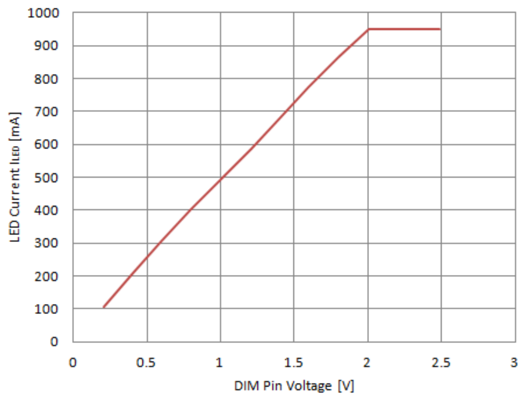


fig.8(A) DIM Pin voltage vs. LED Current

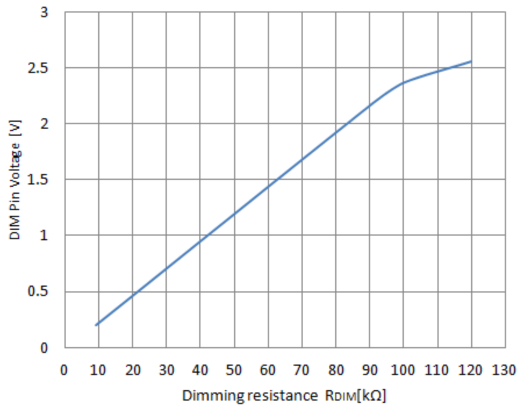
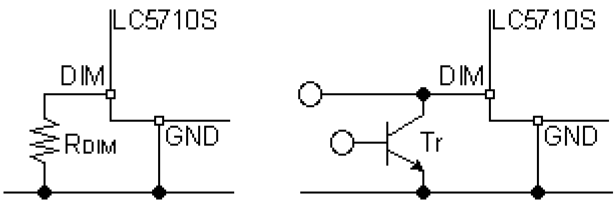


fig.8(B) Pull-down resistor R_{DIM} vs. DIM pin voltage



Though LC5710S doesn't have an exclusive "Remote ON/OFF pin",
But,"Remote ON/OFF function" is as well as possible by using a DIM pin.

fig.8I The connection of R_{DIM} and remote ON／OFF application

From the port of the microcomputer of the use and so on, and if the DIM pin of LC5710S is held continuously to the “Low” level,LC5710S continues suspension of a movement. The “Low level” voltage must be lower voltage than $V_{DIM\,(OFF)}$. For reverse logic, put one small signal Transistor as the fig8I.

8.3.2 PWM digital dimming

LED dimming is controlled by the duty cycle of PWM digital signal which is input to DIM terminal.
The constant current output turns ON/OFF by the following signal input voltage to DIM pin which is within the absolute maximum rating; −0.3V to 3.3V.

- When the DIM terminal Voltage is higher than "LED-ON-Threshold ($V_{DIM(ON)} \geqq 0.2V$)" , I_{OUT} flows.
- DIM terminal voltage hysteresis $V_{DIM(HYS)}$=50mV.

The Dimming-ratio depends on the duty ratio of the PWM-digital-dimming signal pulse (fig.9).

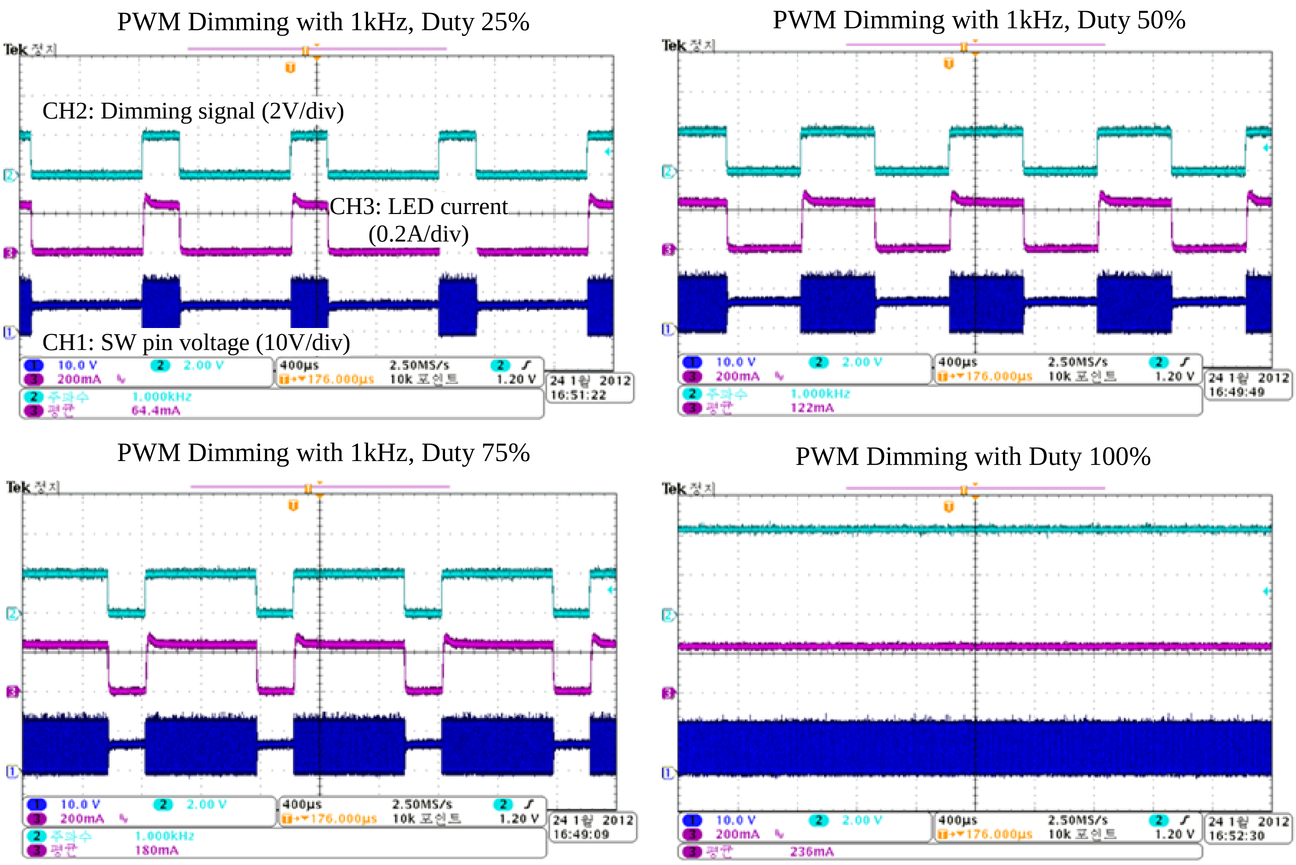


fig.9 Actual waveform in Dimming operation

As well as the case of the analog-dimming, if the signal of the "Low" level lower than VDIM (off) is inputted to DIM-pin continuously, the suspension of a movement is continued. As for the fig9 as well, when a Dimming signal (CH2:pale-blue) is a "Low" level, the switch-pin voltage waveform(CH1:blue) isn't switching.

8.4 Overcurrent Protection Function (OCP)

The IC incorporates Overcurrent Protection Function (OCP) limited the current flowing to SW terminal (fig.10). When the current to SW terminal reaches $I_{SW(LIM)}$= 1.8A, the internal power MOSFET turns off on pulse-by-pulse basis.This protection is activated in case of the constant current detection failure or the output end shorted.

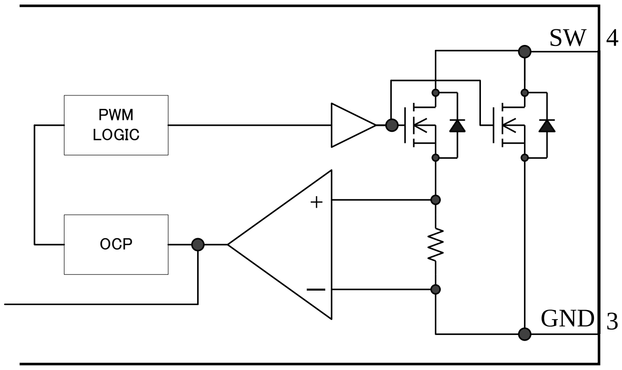
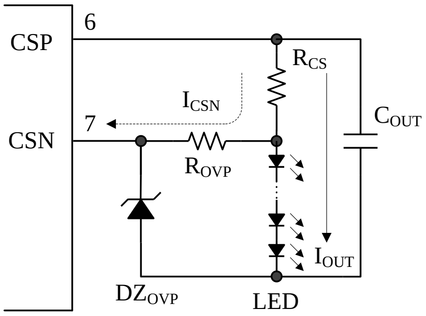


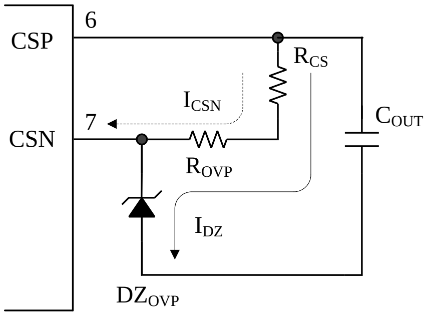
fig.10 Overcurrent protecton circuit

8.5 Overvoltage Protection Function (OVP)

If LED string is open and the constant current loop is cut, the output voltage increases more than the controlled voltage. As shown in fig.11, the OVP Function with the circuit connected R_{OVP} and a zener diode, DZ_{OVP}, is done OVP protection. After LED string is open, when DZ_{OVP} is conducted, the output voltage is limited to the sum voltage of the zener voltage of DZ_{OVP} and the Overvoltage Protection (OVP) Threshold Voltage, V_{CS}=150mV.



Normal operation



LED string is open

fig.11 Overvoltage protection circuit

The allowable current of DZ_{OVP}, I_{DZ}, can be expressed by the following with P_{DZ} as the allowable dissipation and V_{DZ} as the zener voltage of DZ_{OVP}.

$$I_{DZ} \leq \frac{P_{DZ}}{V_{DZ}} \qquad \cdots(4)$$

The R_{OVP} value, by which the loss of DZ_{OVP} is less than the allowable dissipation, is chosen by the following with I_{CSN} as the CSN Pin Sink Current and R_{CS} as the constant current detection resistor.

$$R_{OVP} \geq \frac{V_{CS\,(OVP)}}{I_{DZ} + I_{CSN}} - R_{CS} \qquad \cdots(5)$$

Also, when I_{CSN} is negligibly small against I_{DZ}, the approximate equation of Equation (4) becomes as follows.

$$R_{OVP} \geq \frac{V_{CS(OVP)}}{I_{DZ}} - R_{CS} \qquad \cdots(6)$$

R_{OVP} value should be chosen so that the loss of DZ_{OVP} is less than the allowable dissipation in OVP protection, and I_{OUT} is within the acceptable accuracy range.
DZ_{OVP} value, V_{DZ}, should be chosen to be higher than the maximum output voltage of LED string to avoid DZ_{OVP}

conduction during the normal operation.

For example,when these conditions are V_{CS}=150mV,I_{CSN}=9.5μA,I_{DZ}=5mA,R_{CS}=0.33Ω, Because of I_{CSN} << I_{DZ}, ROVP becomes 29.67Ω (≒ 30Ω) that is calculated following the equation(6).

8.6 Selection of application circuit

Select application circuit properly in the relations with the LED strings voltage and the input voltage VIN in the Table 5.

Table.5

Relations between the input voltage and the LED string voltage .	Circuit type
VIN＞(n × V_{FLED})＋Vcs	Buck
VIN＜(n × V_{FLED})＋Vcs	Boost
VIN(Low)＜(n × V_{FLED})＋Vcs＜VIN(High)	Buckboost

The number of LED which can be serial connection in LC5710S becomes as follows in the Table 6 in each circuit type. But, there are the following 1) – 4) as a factor which a movement condition is restricted to.

1) Settlement of the input voltage under $VIN_{(ON)}$ ･･･The setup that VIN is under 5V is impossible by the start condition of the IC.
2) $VIN_{(MAX)}$ or $Vsw_{(MAX)}$ ･･･As an example, the condition that VIN or Vsw voltage reaches 48V by 80%-derating against 60V which is the absolute maximum ratings.
3) A limitation (0.15<Duty<0.84) by the minimum or maximum ON-duty.
4) The input and output condition that “Inductor peak current ILp” reaches threshold of “SW current limit $Isw_{(LIM)}$ =1.4A $_{(Min)}$” .

Table.6 VIN(or Vsw)＜48V(60V×0.8), 0.15＜Duty＜0.84 are common condition.

Number of LED (pcs) (Serial connection)	Vout or LED strings voltage(V)	Range of the VIN(V)					
		Buck-type		Boost-type		Buckboost-type	
		ILED=1.0A, ⊿IL=0.4A		ILED=0.5A, ⊿IL=0.4A		ILED=0.5A, ⊿IL=0.4A	
		MIN(V)	MAX(V)	MIN(V)	MAX(V)	MIN(V)	MAX(V)
1	3.6	5.00	24.00			5	20.4
2	7.1	8.45	47.33	5.00	6.04	5.1	39.9
3	10.6	12.62	48.00	5.00	9.01	7.6	37.4
4	14.1	16.79	48.00	6.60	11.99	10.1	33.9
5	17.6	20.95	48.00	8.30	14.96	12.7	30.4
6	21.1	25.12	48.00	9.90	17.94	15.1	26.9
7	24.6	29.29	48.00	11.60	20.91	17.6	23.4
8	28.1	33.45	48.00	13.20	23.89		
9	31.6	37.62	48.00	14.90	26.86		
10	35.1	41.79	48.00	16.50	29.84		
11	38.6	45.95	48.00	18.20	32.81		
12	42.1			19.80	35.79		
13	45.6			21.50	38.76		

For non ･･･In case of following condition, VIN under $VIN_{(ON)}$, VIN or Vsw reaches 48V, and ILp reaches $Isw_{(LIM)}$, it is the setup which doesn’t become utility. When a table 6 is graphed, they are shown in the fig12 – the fig14.

Buck-type Number of LEDs serial connection vs. Range of VIN

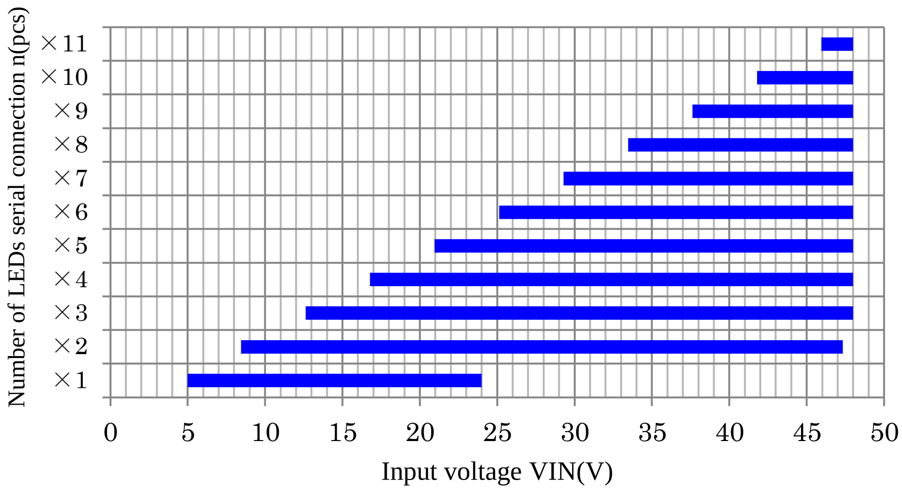


fig.12

Boost-type Number of LEDs serial connection vs. Range of VIN

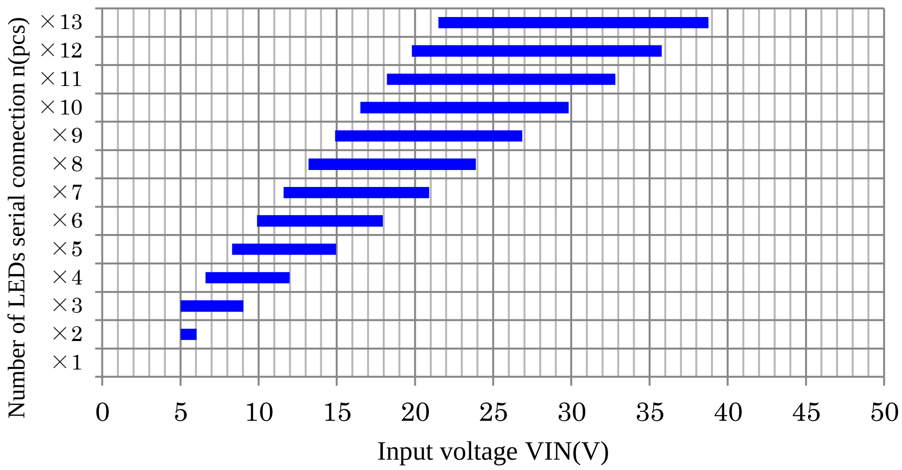


fig.13

Buckboost-type Number of LEDs serial connection vs. Range of VIN

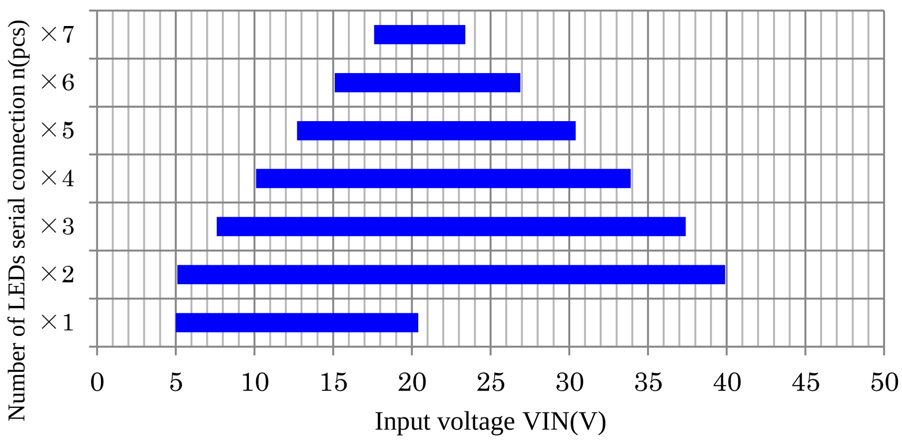


fig.14

The fig12 – the fig14 are based on the calculation. You must reduce ILED,frequency and Vout when surge voltage is big in the waveform of the SW terminal, and when the heat generation of the IC is high. And, you must use it within the range of “Thermal Derating Curve” of the fig1.

8.7 Setting of External Inductor

The each operation of Buck, Boost and Buck-Boost converter is explained as follows.
The inductance value is designed so that the operation becomes Continuous Conduction Mode (CCM) which the inductance current flows continuously, because the load current of LED lighting application is constant.
The duty, D, is set within the following range, based on “3. Electrical Characteristics”.

$t_{ON(MIN)} \times F_{OSC} < D < D_{MAX}$ ･･･(7)

Therefore, Duty-D is within the range of 0.84 from 0.15 (0.15< D <0.84).
The output voltage, V_{OUT}, can be calculated by the following with V_{OUT} as the output voltage, IL as the inductor current, and ΔIL as the ripple current of inductor current.

$Vout = n \times V_{FLED} + V_{CS}$ ･･･(8)

where; V_{FLED} : Forward voltage drop of a LED(･･･V_F=3.5V／1PCS)
n : The number of LED in series
V_{CS} : Current Detection Voltage, V_{CS}= 100mV

Table.7 Equations to calculate Necessary Inductance L

	Buck type	Boost type	Buckboost type
SW terminal voltage Vsw	VIN	Vout	VIN＋Vout
ON-duty “D”	$\frac{Vout}{VIN}$	$\frac{Vout - VIN}{Vout}$	$\frac{Vout}{VIN + Vout}$
Inductor average current IL_{AVE}	ILED	$\frac{ILED}{1 - D}$	$\frac{ILED}{1 - D}$
Inductor peak current ILp	$ILED + \frac{\Delta IL}{2}$	$\frac{ILED}{1 - D} + \frac{\Delta IL}{2}$	$\frac{ILED}{1 - D} + \frac{\Delta IL}{2}$
Necessary Inductance L	$\frac{Vout \times (1 - D)}{\Delta IL \times Fosc}$	$\frac{VIN \times D}{\Delta IL \times Fosc}$	$\frac{VIN \times D}{\Delta IL \times Fosc}$

In case of Buck-type, as for the Drain-current which flows into the SW terminal, Drain-current becomes equal to LED current. But, in case of Boost-type, or in case of Buckboost-type, for example when the Duty-D is 0.5, if it is same inductor-ripple current, Drain-current is doubled from Buck-type. Be careful to this point.
Inductor-ripple-current is the range of “⊿IL=0.1A to 0.4A”, it is based on a recommendation. And, by the condition of internal-over-current-protection, because it is required that Inductor-peak-current “ILp” doesn’t reach
“$I_{SW\ (LIM)}$ =1.4A (MIN)”. Substantially, the current which can be supplied to LED becomes as follows (you must satisfy together a temperature limitation referring to the fig.1).

*Buck- type ･･･ 1.0A
*Boost-type/Buckboost-type ･･･ 0.5A
A calculation example graph is shown as follows (Refer to the fig15－ the fig17).
And, a V_F of white-LED for the lighting is prescribed with 3.5V, and calculated with 5pcs series-connection (Vout=17.6V).

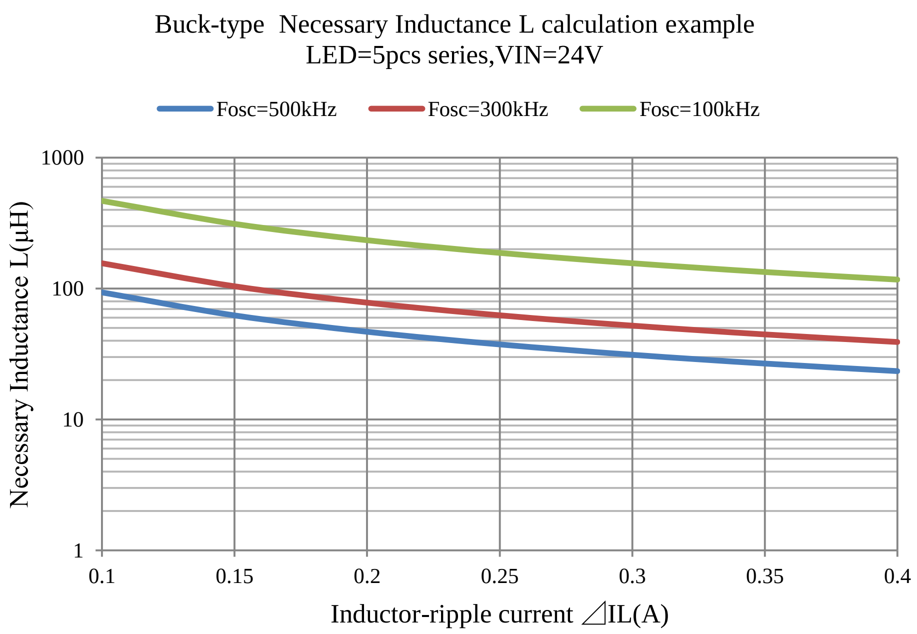

Buck-type Necessary Inductance L calculation example
LED=5pcs series,VIN=24V
Fosc=500kHz
Fosc=300kHz
Fosc=100kHz
1000
100
10
1
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Necessary Inductance L(μH)
Inductor-ripple current ⊿IL(A)

fig.15

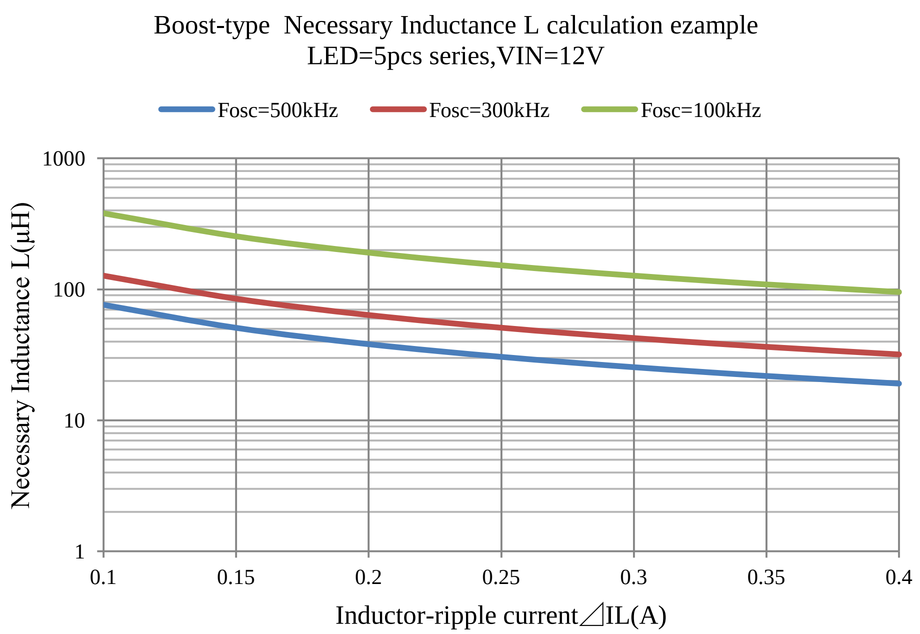

Boost-type Necessary Inductance L calculation ezample
LED=5pcs series,VIN=12V
Fosc=500kHz
Fosc=300kHz
Fosc=100kHz
1000
100
10
1
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Necessary Inductance L(μH)
Inductor-ripple current⊿IL(A)

fig.16

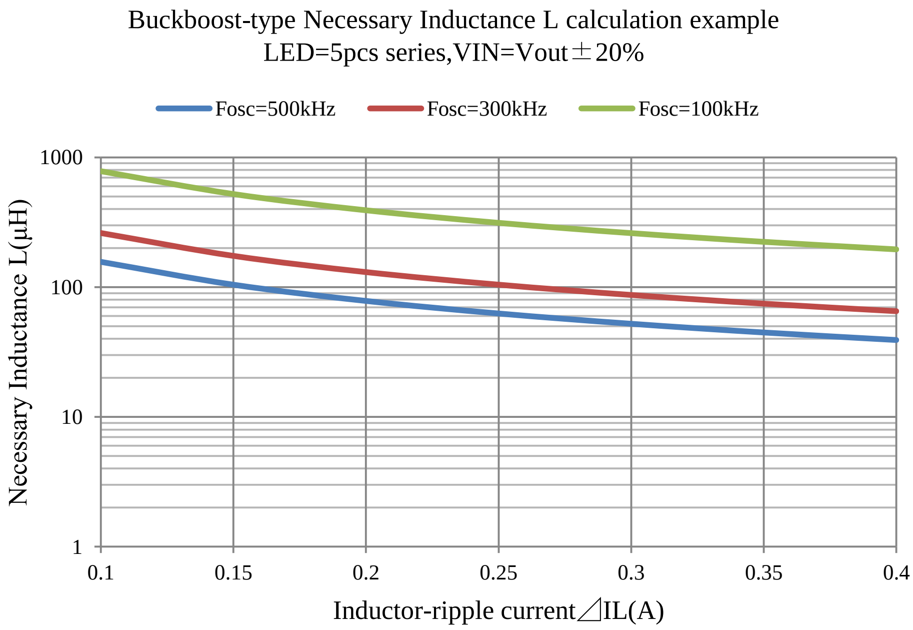


fig.17

fig15－fig17 Necessary Inductance L calculation example
*Fosc = 100kHz,300kHz,500kHz
*Number of LED = 5pcs series
The value of graph is calculated following the equation in the Table7

Note:

*Necessary inductance value grows big by the setup whose "⊿IL is small".
As a tendency of characteristics of the Inductor,
・In case of big Inductance value, allowable current limits decrease.
・The contour of Inductor becomes large with the core size when allowable current is satisfied and Inductance is kept.
As a circuit application of the LED driver, it has Buck-type, Boost-type and Buckboost-type as same as the DC/DC converter,
As a setup of ⊿IL, generally, it is said that the cost performance of 20%-30 % of the setups of output current is the best.
When it says easily,"⊿IL=Iout× α (α =0.2 to 0.3)" is best choice.

8.8 The Internal Power Dissipation Pd

8.8.1 The loss Pcont of the control circuit

The loss Pcont of the control circuit depends on the input voltage and frequency. (fig.18) .

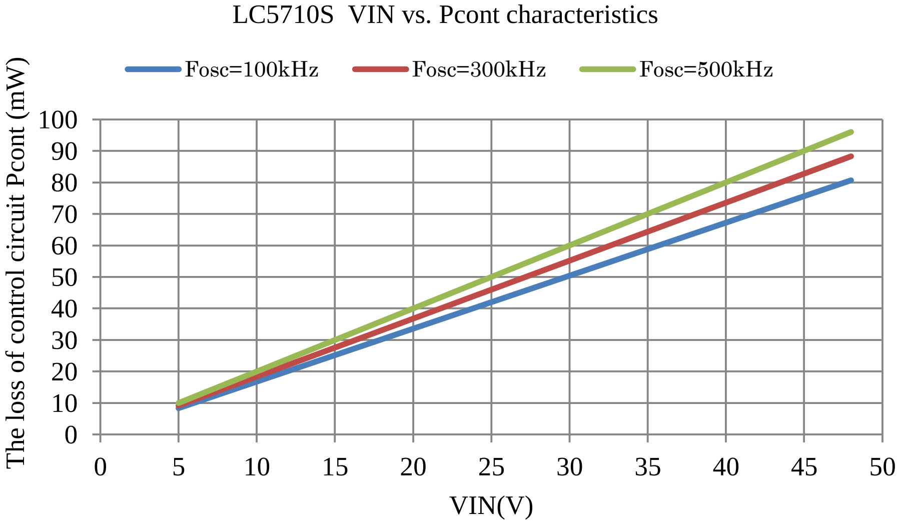


fig.18

The loss of the control circuit is prescribed with containing the steady loss by circuit static electric current Iq and the drive loss which drives internal PowerMOSFET. A fig.18 is the total of the loss of circuit electric current and the drive loss. Read near value in the fig.18, and substitute it when you calculate a loss.

8.8.2 The switching-speed of internal PowerMOSFET

As for the fig.19, in the calculation of the switching-time of internal PowerMOSFET, this is based on the assumption with no influence such as Prasitic-Inductance in main-circuit. It is prescribed with “turn-on time tr” and “turn-off time tf” being the same speeds.

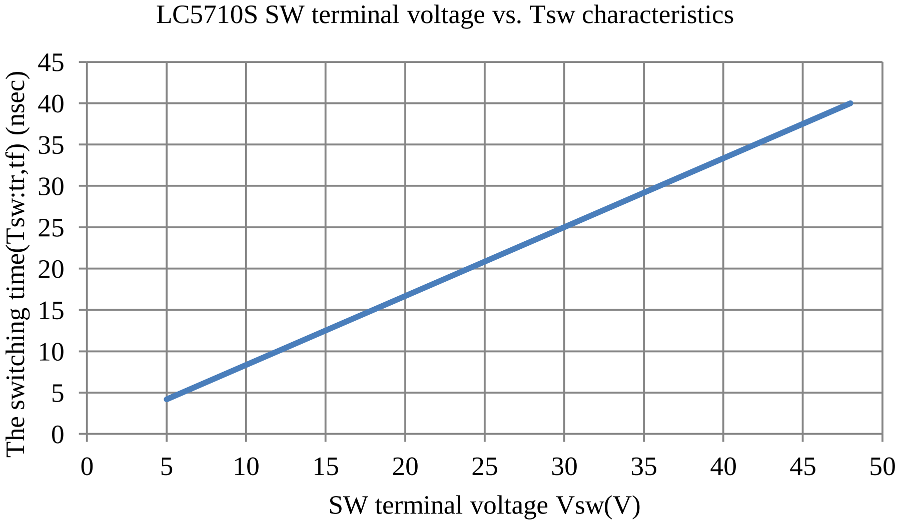


fig.19

However,actually,The internal PowerMOSFET is connected with the main-circuit of the voltage conversion part. By the condition of pattern wiring, the switching-speed becomes fast, or becomes slow.

・In case of the pattern which Parasitic-Inductance inheres in, probably it becomes fast.

・In case of the pattern which high-impedance inheres in, probably it becomes slow.

Approve it in advance.

There is no problem if actual measurement value is substituted when an actual movement wave form can be observed with oscilloscope and so on.

8.8.3 The loss of internal PowerMOSFET .

As the loss of internal-PowerMOSFET, there are the loss of “steady-ON” by the ON-resistance “Ron” between the “source” and “drain”, and the switching-loss by the switching-time in the fig.19.

Buck-type, Boost-type and Buckboost-type, the loss of PowerMOSFET of each type are shown the approximation in the Table8.

Table.8

	Loss of “Steady-ON” Pon	Switching loss Psw
Buck type	$Ron\times(ILED)^2\times Ton\times Fosc$	2×{VIN×(ILED／2)×Tsw×Fosc}
Boost type	$Ron\times(IL_{AVE})^2\times Ton\times Fosc$	2×{Vout×(ILAVE／2)×Tsw×Fosc}
Buckboost type	$Ron\times(IL_{AVE})^2\times Ton\times Fosc$	2×{(VIN＋Vout)×(ILAVE／2)×Tsw×Fosc}

*

･Ton=(1／Fosc)×D･･･D=Duty (Refer to Table7.)

･Tsw is prescribed by the value (sec) of the figure 19 with “turn-on time tr” and “turn-off time tf” being the same speeds. In the same period, switching occurs twice. There is no problem if actual measurement value is substituted when an actual movement wave form can be observed with oscilloscope and so on.

･Fosc= oscillating frequency (Hz)

･In case of the Buck-type, ILED(A)=ILAVE(A)

･Refer to a Table 7 for ILAVE (A).

･Ron is “ON-resistance(Ω)” of the internal PowerMOSFET, between drain and source.

8.8.4 Power dissipation in the IC, Pd

The internal loss is to follow a equation (9).

Pd=Pcont＋Pon＋Psw ･･･(9)

(Calculation example in the Buck-type)

Conditions:Fosc=300kHz､VIN=24V､LED strings voltage=17.6V(5LEDs)､ILED=1A､Ron=0.5Ω.

･Pcont=44mW (It was referred from fig.16.)

･Pon=0.5(Ω)×1(A)×1(A)×2.444E-6(sec)×300E+3(Hz) ≒0.367W

･Psw=2×{24(V)×(1(A)／2)×20E-9(sec)×300E+3(Hz)} ≒0.144W

∴Pd=0.044(W)＋0.367(W)＋0.144(W) =0.555W

(Calculation example in the Boost-type)

Conditions:Fosc=300kHz､VIN=12V､LED strings voltage=17.6V(5LEDs)､ILED=0.5A､Ron=0.5Ω.

･Pcont=22mW (It was referred from fig.16.)

･Pon=0.5(Ω)×0.73(A)×0.73(A)×1.061E-6(sec)×300E+3(Hz) ≒0.084W

･Psw=2×{17.6(V)×(0.73(A)／2)×15E-9(sec)×300E+3(Hz)} ≒0.057W

∴Pd=0.022(W)＋0.084(W)＋0.057(W) =0.163W

(Calculation example in the Buckboost-type)

Conditions:Fosc=300kHz､VIN=17V､LED strings voltage=17.6V(5LEDs)､ILED=0.5A､Ron=0.5Ω.

･Pcont=33mW (It was referred from fig.16.)

･Pon=0.5(Ω)×1.018(A)×1.018(A)×1.696E-6(sec)×300E+3(Hz) ≒0.264W

･Psw=2×{(17(V)＋17.6(V))×(1.018(A)／2)×28.8E-9(sec)×300E+3(Hz)} ≒0.305W

∴Pd=0.033(W)＋0.264(W)＋0.305(W) =0.602W

Notes:

The thermal resistance θj-a of the package is becomes 82.8(℃／W). Thermal shutdown(protection function:TSD) may activate by the condition of Pd.

When ambient temperature is defined as “Ta”, Junction temperature “Tj” is shown with a equation (10).

Tj=(Pd×θj-a)＋Ta ･･･(10)

The “ON-resistance” Ron of internal PowerMOSFET has a positive temperature coefficient.
When Tj is nearing 100(℃) , Ron has the possibility to increase about 1.5 times from condition of Tj=25(℃).
*Be careful.
When temperature of the IC is high, you must have the following item reduced.

- ・Oscillating frequency
- ・Value of the ILED
- ・The number of LED serial connection

Or, you must establish the input voltage condition again, you must put Pd within the area of “Thermal Derating Curve” in the fig.1.

8.9 PHASE COMPENSATION (COMP terminal)

8.9.1 The calculation of the Phase compensation “fixed-number” .

In the page8, the fig.4 of sixth clauses – Typcal application circuit example, as for the Phase-compensation fixed-number of the COMP terminal connection, “Rs, Cs, Cp”, they are calculated in accordance with the equation of the Table9.

Table.9

Rs	Cs
$Rs = \frac{2\pi \times Co \times Fc \times Vout}{K}$	$Cs \geqq \frac{4}{2\pi \times Rs \times Fc}$
Cp Requirement decision	(←When a left equation satisfies a condition.) Cp
$\frac{1}{2\pi \times Co \times ESR} < \frac{Fosc}{2}$	$Cp = \frac{Co \times ESR}{Rs}$
Rled	Fz2
$Rled = \frac{Vout}{ILED}$	$Fz2 = \frac{Rled \times (1-D)^2}{2\pi \times L}$
Fc of the Buck-type	Fc of the Boost-type
$Fc \leqq \frac{Fosc}{50}$	$Fc \leqq \frac{Fz2}{50}$

*Co : Capacitance of output capacitor (F), Vout : Output voltage (V), Fc : Crossover frequency (Hz), ESR : The equivalent serial resistance of the output capacitor (Ω), Rled : The resistance when LED was considered a resistance load (Ω), ILED : Average current of LED (A), Fz2 : The zero point frequency which is characteristic of Boost-type (Hz) ・・・ This does the function of the zero in the gain-characteristics, and this does the function of the pole in the phase-compensation. L : Inductance of the main inductor (H), D : Duty (On-period/period of a cycle), refer to Table5. *Cp is necessary because ESR is big when a output capacitor COUT is aluminum electrolytic capacitor.
The setup of crossover-frequency Fc is different in the Buck-type and the Boost-type.In this IC, at the case of Buck-type, Fc is set up in less than 1/50 of Fosc.
But, it has the condition of ‘a righthalf plane zero’ in case of Boost-type of the Current-Mode.
Therefore you must calculate Fz2 by the equation of Fz2 of the Table9, and you must set up Crossover-frequency Fc in less than 1/50 of Fz2.
*” K” is the multiplier which is characteristic of the feedback loop of LC5710S.
K=2.497E-4

8.9.2 Rs,Cs, calculation example (COUT: ceramics capacitor)

Table.10 Buck-type ,Fosc=500kHz, ILED=1A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μH)	Co total capacitance(μF)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(nF)
1	3.6	5	5.6	1	10	10	0.91	70.348
2	7.1	12	15	1	10	10	1.79	35.669
3	10.6	15	18	1	10	10	2.67	23.892
4	14.1	18	18	1	10	10	3.55	17.961
5	17.6	24	27	1	10	10	4.43	14.389
6	21.1	28	27	1	10	10	5.31	12.002
7	24.6	36	39	1	10	10	6.19	10.294
8	28.1	42	39	1	10	10	7.07	9.012
9	31.6	42	43	1	10	10	7.95	8.014
10	35.1	48	47	1	10	10	8.83	7.215

*The numerical value in the table shows value in calculation.
*Select a part from the near fixed-number , because numerical value doesn’t agree completely in the geometric progression such as E12 series and E24 series.
* Decide a fixed-number after you surely confirm a movement in the experiment.
*The capacity of Cout and ESR are the expressions of ‘the total’. When Ceramics capacitor of the little size more than one are connected in parallel , it is shown that it becomes the numerical value of the table in the total.
*Table13 and Table17 are the same situations,too.

Table.11 Buck-type, Fosc=300kHz, ILED=1A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μH)	Co total capacitance(μF)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(nF)
1	3.6	5	9.1	4.7	10	6	2.55	41.577
2	7.1	12	27	4.7	10	6	5.04	21.081
3	10.6	15	27	4.7	10	6	7.52	14.120
4	14.1	18	27	4.7	10	6	10.00	10.615
5	17.6	24	43	4.7	10	6	12.48	8.504
6	21.1	28	47	4.7	10	6	14.96	7.093
7	24.6	36	68	4.7	10	6	17.45	6.084
8	28.1	42	82	4.7	10	6	19.93	5.326
9	31.6	42	68	4.7	10	6	22.41	4.736
10	35.1	48	82	4.7	10	6	24.89	4.264

Table.12 Buck-type, Fosc=100kHz, ILED=1A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μH)	Co total capacitance(μF)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(nF)
1	3.6	5	27	10	10	2	1.81	175.872
2	7.1	12	75	10	10	2	3.57	89.174
3	10.6	15	82	10	10	2	5.33	59.730
4	14.1	18	82	10	10	2	7.09	44.903
5	17.6	24	120	10	10	2	8.85	35.973
6	21.1	28	150	10	10	2	10.61	30.006
7	24.6	36	200	10	10	2	12.37	25.737

8	28.1	42	270	10	10	2	14.13	22.531
9	31.6	42	200	10	10	2	15.89	20.036
10	35.1	48	270	10	10	2	17.66	18.038

Table.13 Boost-type, Fosc=500kHz, ILED=0.5A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μ H)	Co total capacitance(μ F)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(μ F)
2	7.1	5	7.5	1	10	2.990	0.53	0.398
3	10.6	5	15	1	10	1.001	0.27	2.382
3	10.6	7	12	1	10	2.454	0.65	0.396
4	14.1	7	18	1	10	1.230	0.44	1.187
4	14.1	9	18	1	10	2.033	0.72	0.434
5	17.6	12	20	1	10	2.606	1.15	0.211
6	21.1	12	27	1	10	1.610	0.85	0.463
6	21.1	15	22	1	10	3.087	1.64	0.125
7	24.6	12	33	1	10	1.130	0.70	0.806
7	24.6	15	33	1	10	1.765	1.09	0.330
7	24.6	18	27	1	10	3.107	1.92	0.106
8	28.1	15	36	1	10	1.417	1.00	0.449
8	28.1	18	33	1	10	2.225	1.57	0.181
9	31.6	18	39	1	10	1.675	1.33	0.285
10	35.1	24	39	1	10	2.680	2.37	0.100

Table.14 Boost-type, Fosc=300kHz, ILED=0.5A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μ H)	Co total capacitance(μ F)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(μ F)
2	7.1	5	15	4.7	10	1.495	1.25	0.339
3	10.6	5	22	4.7	10	0.683	0.86	1.090
3	10.6	7	20	4.7	10	1.472	1.84	0.234
4	14.1	7	33	4.7	10	0.671	1.12	0.849
4	14.1	9	27	4.7	10	1.355	2.26	0.208
5	17.6	12	33	4.7	10	1.579	3.29	0.122
6	21.1	12	43	4.7	10	1.011	2.52	0.249
6	21.1	15	36	4.7	10	1.887	4.71	0.071
7	24.6	12	51	4.7	10	0.731	2.13	0.409
7	24.6	15	51	4.7	10	1.142	3.32	0.167
7	24.6	18	43	4.7	10	1.951	5.67	0.057
8	28.1	15	62	4.7	10	0.823	2.73	0.283
8	28.1	18	56	4.7	10	1.311	4.36	0.111
9	31.6	18	68	4.7	10	0.96	3.59	0.184
10	35.1	24	68	4.7	10	1.537	6.38	0.064

Table.15 Boost-type, Fosc=100kHz, ILED=0.5A, ⊿IL=0.4A

Number of LED serial connection	Vout(V)	VIN(V)	Inductance L (μ H)	Co total capacitance(μ F)	Co total ESR (mΩ)	Fc(kHz)	Rs(kΩ)	Cs(μ F)
2	7.1	5	39	10	10	0.575	1.03	1.078
3	10.6	5	68	10	10	0.221	0.59	4.895

3	10.6	7	62	10	10	0.475	1.27	1.059
4	14.1	7	91	10	10	0.243	0.86	3.035
4	14.1	9	82	10	10	0.446	1.58	0.902
5	17.6	12	100	10	10	0.521	2.31	0.529
6	21.1	12	150	10	10	0.290	1.54	1.429
6	21.1	15	120	10	10	0.566	3.00	0.374
7	24.6	12	180	10	10	0.207	1.28	2.399
7	24.6	15	150	10	10	0.388	2.40	0.682
7	24.6	18	120	10	10	0.699	4.33	0.210
8	28.1	15	180	10	10	0.283	2.00	1.122
8	28.1	18	180	10	10	0.408	2.88	0.541
9	31.6	18	200	10	10	0.327	2.6	0.751
10	35.1	24	200	10	10	0.523	4.61	0.264

*In theBuckboost-type, Relations between “Duty D” and the movement mode are as the following.

D＞0.5：Boost mode

D＜0.5：Buck mode

Referring to the Table10 – the Table15, adjust compensation value in accordance with the condition of the use, under the actual movement .

8.10 LED Cross-Connection Protection Function

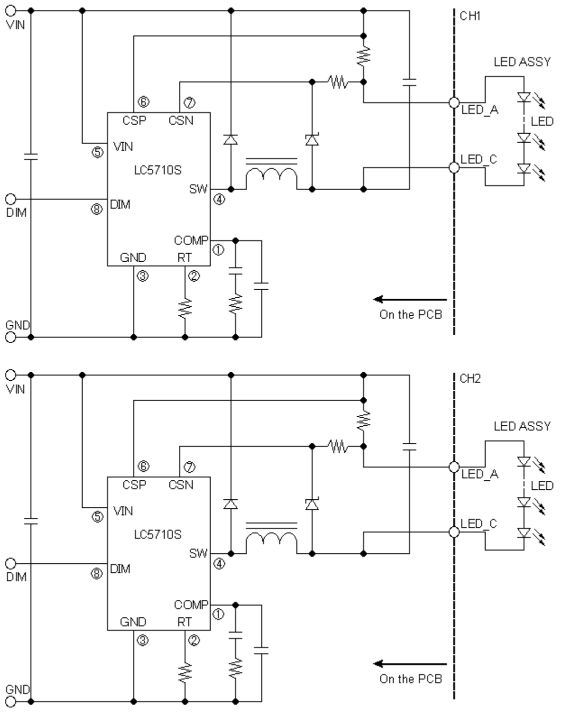


fig.20-1 The normal connection of LED

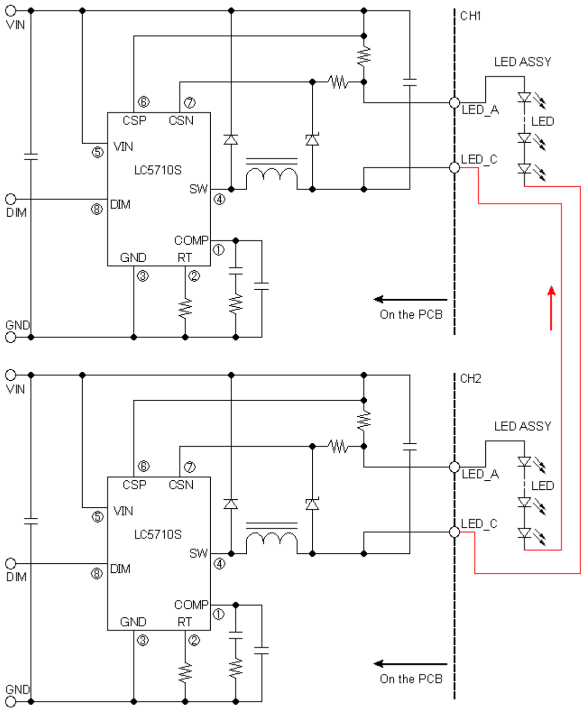


fig.20-2 Mis-wiring (Cross-connection)

With the application when each-string of LED-ASSY is driven by using LC5710S for the plural, against the normal connection of the fig20-1, by mis-wiring of the connector part which connects harness to LED-ASSY and so on, it may become a connection like a fig20-2. This is prescribed as “Cross-connection”.

“LED Cross-connection protection function” is built in the LC5710S to avoid the saturation of Inductor and the damage, by the heat-generation when the over-load condition with “Cross-connection”.

In the LC5710S, in case of the above-mentioned “Cross-connection”,the “watch-dog-timer (30msec : typ)” watches the decline of V_{CS} (CSP-CSN voltage) and rise in the COMP terminal voltage.

When the same condition goes on beyond 30msec, movement of LC5710S becomes the burst-mode, and it is possible that the heat-generation is restrained.

When it is seen from LC5710S, because “Cross-connection” is the persistently abnormal condition of the peripheral circuit.

Even if “Cross-connection protection” activates as well as the “thermal protection”, a stress may be given to the peripheral part and IC itself, and so on.

This condition isn’t assured for a long time because a user recognizes mis-wiring and it is the protection which is the simple target until wiring is amended.

Be careful.

8.11 Peripheral Parts Design

Take care to use properly rated and proper type of components.
The following circuit symbols refer to “6. Typical Application Circuit”. In page.9.

- Inductor L

This is a choke coil for smoothing LED current.
When the 26illimeter is larger, the output ripple current is smaller, and the current stability is improved.
In actual operation, it should be considered so that the coil is not saturated by the peak of ripple current.
If the coil is saturated, the surge current beyond expectations flows. Thus LED, IC and peripheral circuit will be damaged.

- Diode D_S

This is a free-wheel diode for Buck converter, and this is a boost diode for Boost and Buck-Boost converter.
For diode selection, the withstanding voltage and the recovery time (t_{rr}) are important. In case that diode with a long t_{rr} is used, the large surge current flows into power MOSFET when power MOSFET turns on. Thus, it may cause noise increasing, malfunction and efficiency decreasing.
It is recommended to choose from Schottky barrier diode and Ultra-fast diode according to the withstanding voltage.

- Current detection resistor R_{CS}

If the current detection resistor with high inductance is used, it may cause malfunctioning because of the high frequency current flowing through it.
It is recommended to choose a low equivalent series inductance and high surge tolerant type for the current detection resistor.

- Input capacitor C_{IN}

This is a smoothing capacitor for main power supply. When the capacitance is larger, the ripple voltage is smaller.
It is recommended to choose the capacitance according to the output power because the ripple voltage becomes bigger when the output power increases even if the same capacitance.

- Output capacitor C_{OUT}

By the ipple current specification of LED string, it is recommended to determine whether C_{OUT} is needed or not, or to determine the capacitance value.
If large ripple current can be set, the inductance of L can be smaller, the C_{OUT} capacitance can be smaller or the C_{OUT} can be removed. Thus, the power supply will be downsized and reduced the cost.
If the small ripple current is set, the inductance of L is increased or C_{OUT} is connected in parallel with LED string.
Thus, the heat generation of LED string, which is caused by ripple current variation, can be reduced.
In addition, if LED string is far from the output edge of power supply, C_{OUT} is connected close to LED string in parallel so that the ripple voltage and ripple current can be reduced.

- Phase compensation network C_P, C_S, R_S

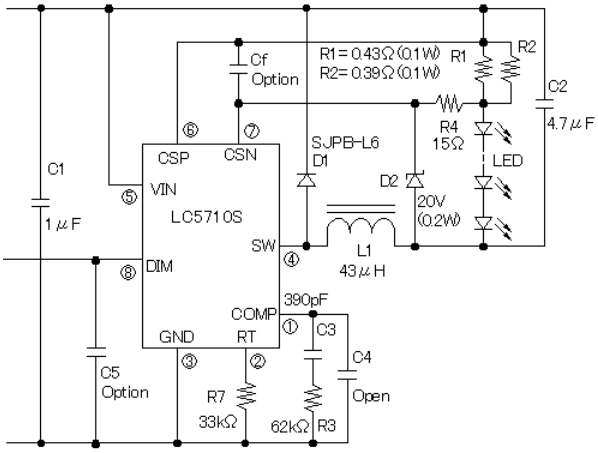
These are the “phase compensation parts” of a control-loop to connect to the COMP terminal. Connect the GND side of the “phase compensation parts” to GND Pin of the IC at shortest wiring. When it is far from GND of the IC,
noise appears in the COMP terminal by the influence such as parasitic-inductance of the pattern, and the faulty operation occurs often. Be careful.

- Setup resistor (R_{RT}) of oscillating frequency

The oscillating-frequency of LC5710S is possible to adjust between 100kHz and 500kHz by the connection of R_{RT}.
Connect the GND side of the frequency-setup-resistor R_{RT} to GND Pin of the IC at shortest wiring.
This is to avoid the unstable movement of the IC by the influence of the noise.

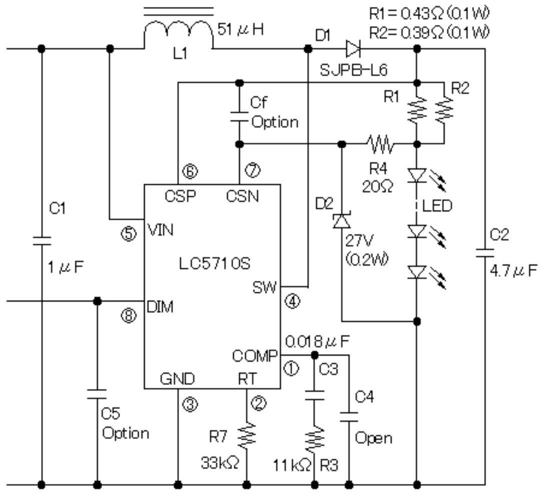
8.12 Reference Design Example

4) Buck-type



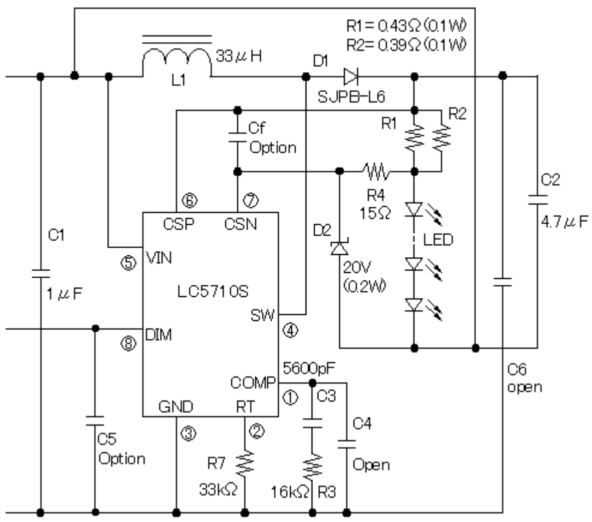
Fosc=300kHz
ILED=500mA
Inductor ripple current ⊿IL=0.4A
Number of LED=5LEDs(Vout=17.6V)
VIN=24V
Vsw=24V
Cout(ESR)=10mΩ/ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

(B)Boost-type



Fosc=300kHz
ILED=500mA
Inductor ripple current ⊿IL=0.4A
Number of LED=7LEDs(Vout=24.6V)
VIN=12V
Vsw=24.6V
Cout(ESR)=10mΩ/ ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

IBuckboost-type



Fosc=300kHz
ILED=500mA
Inductor ripple current ⊿IL=0.4A
Number of LED=5LEDs(Vout=17.6V)
VIN=12V～18V
Vsw=29.6V～35.6V
Cout(ESR)=10mΩ/ ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

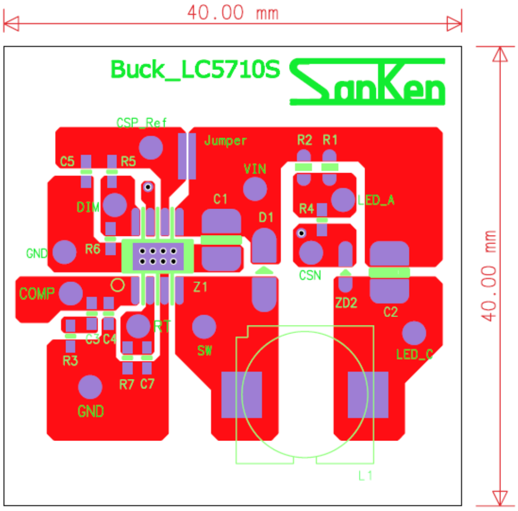
*The above reference design example is only a guide. Decide the fixed-number on your circuit board after you confirm a movement in the actual working,experiment adjustment.

Fig.21 (a) – (c)Reference design example

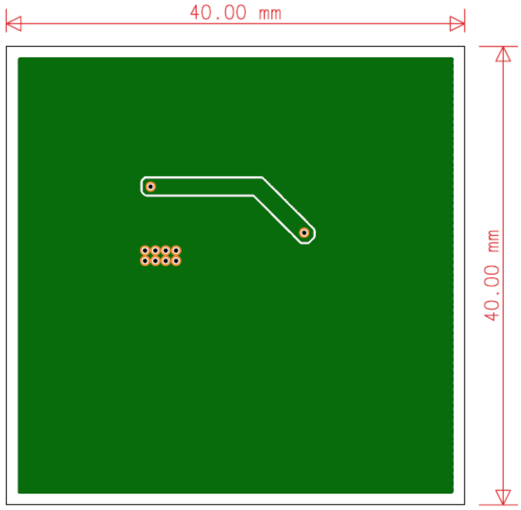
9. Example Pattern Layout

For the LC5710S,the LC5711S and the LC5720S, the circuit board pattern of demonstration-board manufactured by our company is shown in the following.

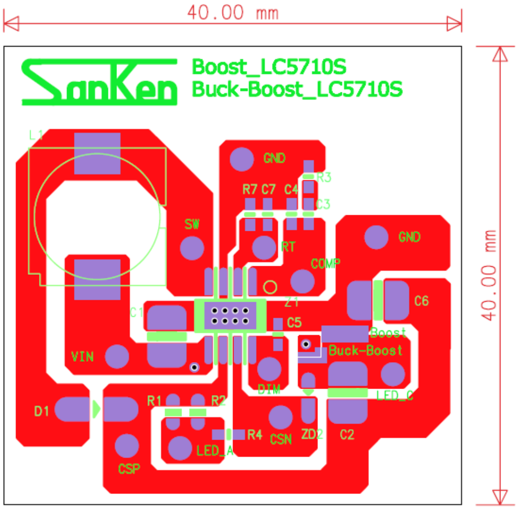
9.1 pattern layout



For Buck-type (parts mounting side)

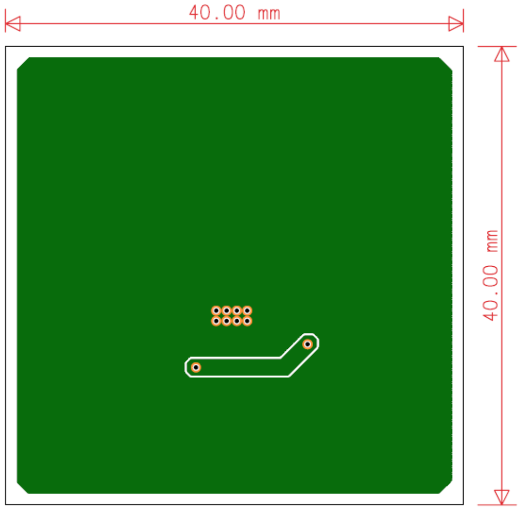


For Buck-type(back side)



For Boost-type/Buckboost-type

(parts mounting side)



For Boost-type/Buckboost-type(back side)

fig.22 Demo-board pattern layout

9.1.1 Foot print drawing

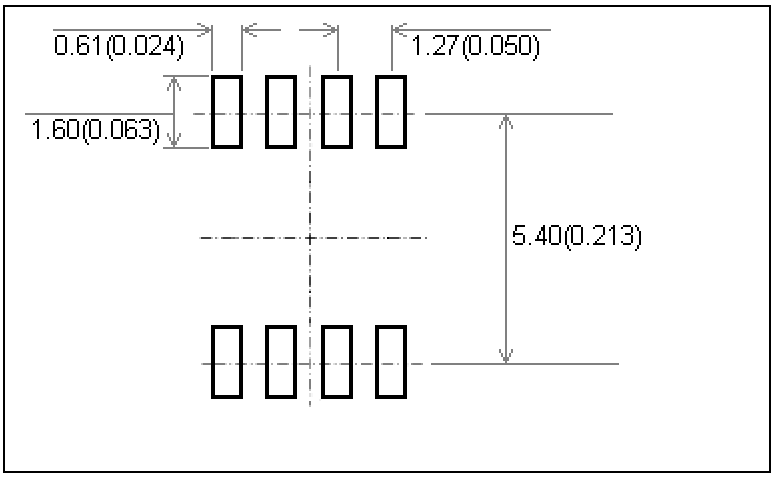


fig.23 Footprint drawing for LC5710S

9.2 Circuit diagram of Demonstration-Board

9.2.1 For Buck-type

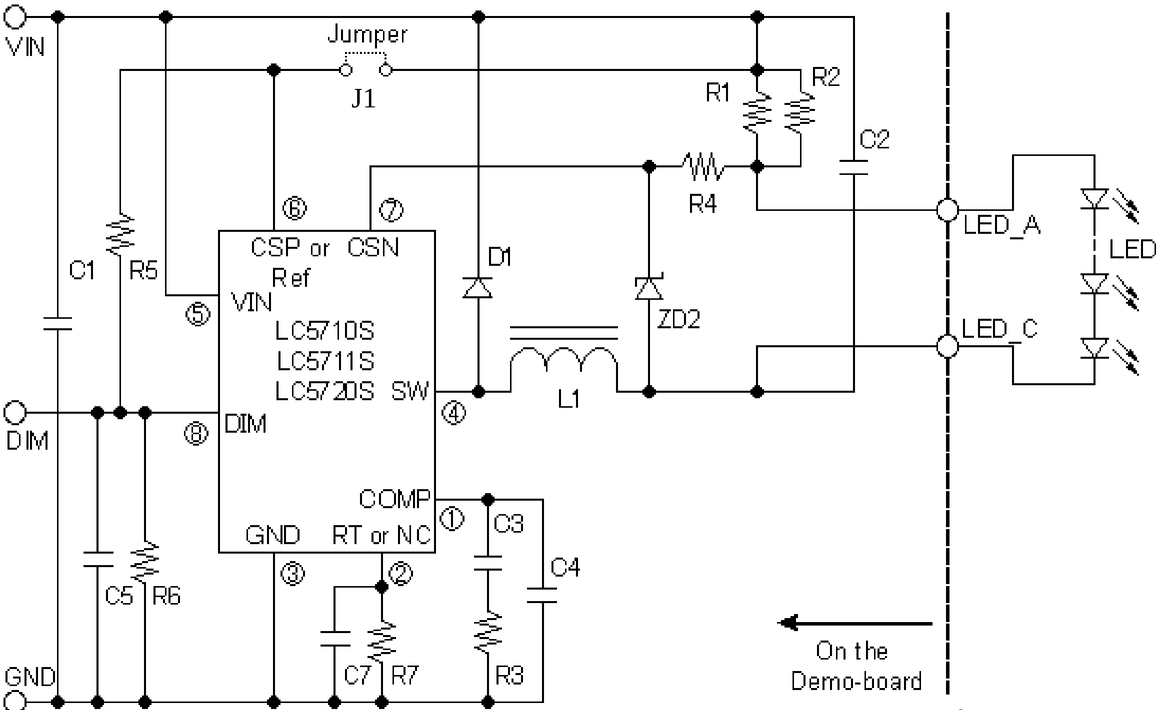


fig.24

*LC5710S/LC5720S : R5 and R6 must be open. Jumper-J1 must be inserted. C7 and R7 are used only with LC5710S.

9.2.2 For Boost-type and Buckboost-type

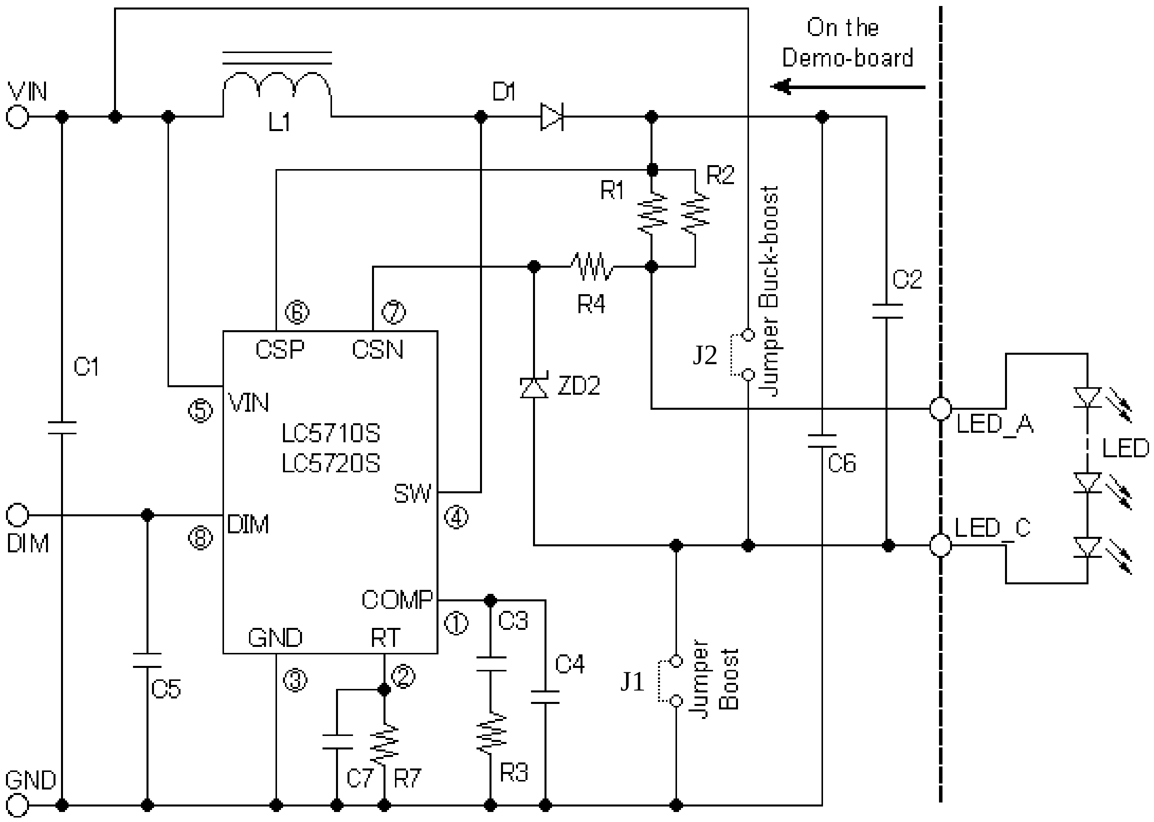


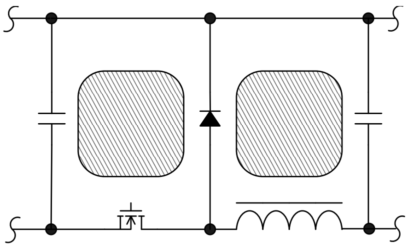
fig.25

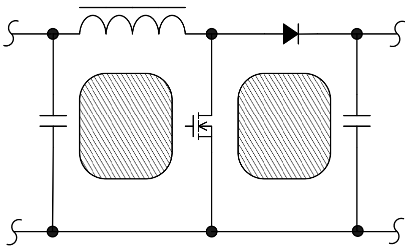
*The setup of Jumper
For Boost-type: J1= Insert, J2= Open
For Buckboost-type: J1= Open, J2= Insert
* C7 and R7 are used only with LC5710S.

10. Design Considerations

10.1Trace and Component Layout Design

PCB circuit trace design and component layout affect IC functioning during operation. Unless they are proper, malfunction, significant noise, and large power dissipation may occur.
Circuit loop traces flowing high frequency current, as shown in fig.26, should be designed as wide and short as possible to reduce trace impedance.
In addition, earth ground traces affect radiation noise, and thusshould be designed as wide and short as possible.
Switching mode power supplies consist of current traces with high frequency and high voltage, and thus trace design and component layout should be done in compliance with all safety guidelines.
Furthermore, because an integrated power MOSFET is being used as the switching device, take account of the positive thermal coefficient of $R_{DS(ON)}$ for thermal design.


(A)Buck-type


(B)Boost-type

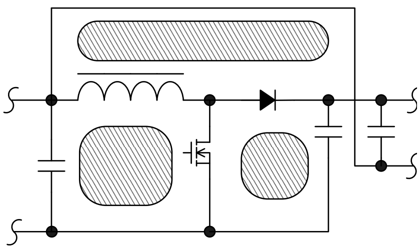

(C)Buckboost-type

fig.26 High frequency current loops（hatched portion）

Fig.26 shows practical trace design examples and considerations. In addition, observe the following:

IC peripheral circuit

(1) Main Circuit Traces

Main circuit traces carry the switching current; therefore, widen and shorten them as much as possible.
The loop formed with C_{IN}, VIN pin, and GND pin should be small in order to reduce the inductances of the traces against high frequency current.

1) Traces around GND pin

Main circuit GND and Control circuit GND should be connected to the vicinity of GND pin with dedicated traces respectively, in order to avoid interference of the switching current with the control circuit.

1) Traces around the current detection resistor, R_{CS}

The traces of R_{CS} should be connected to CSP pin and CSN pin with dedicated traces respectively, in order to reduce noises when the current is detected. When the noise between CSP and CSN is high, a filter capacitor Cf can be added like a “Page9, sixth clauses-application circuit example”,too.

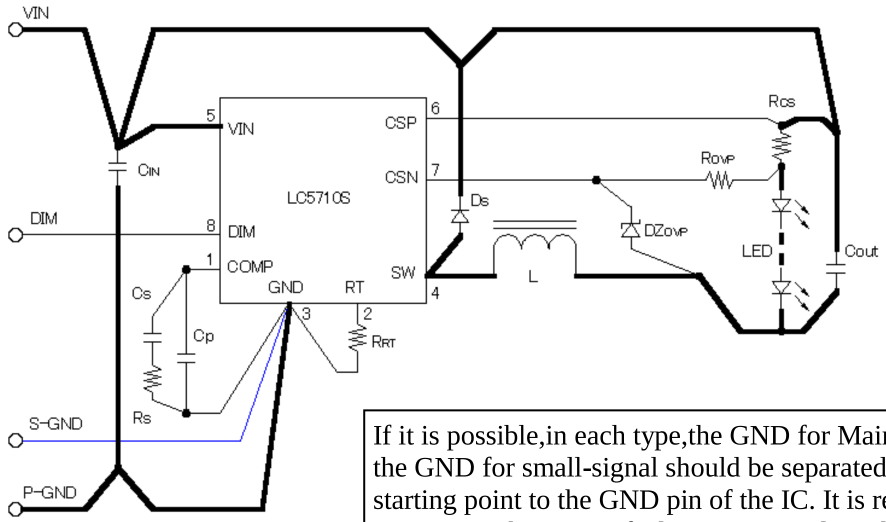
(4)Peripheral components

The components for phase compensation such as C_P, C_S, R_S should be connected close to COMP pin and GND pin. Also,frequency-setup-resistor R_{RT} should be connected close to RT pin and GND pin.

(5)When C_{OUT} is used, it should be connected close to LED string.

* As for the GND pattern, be careful that routes for the Main-circuit(switching current flows), and the routes for the small-signal don’t become common impedance.

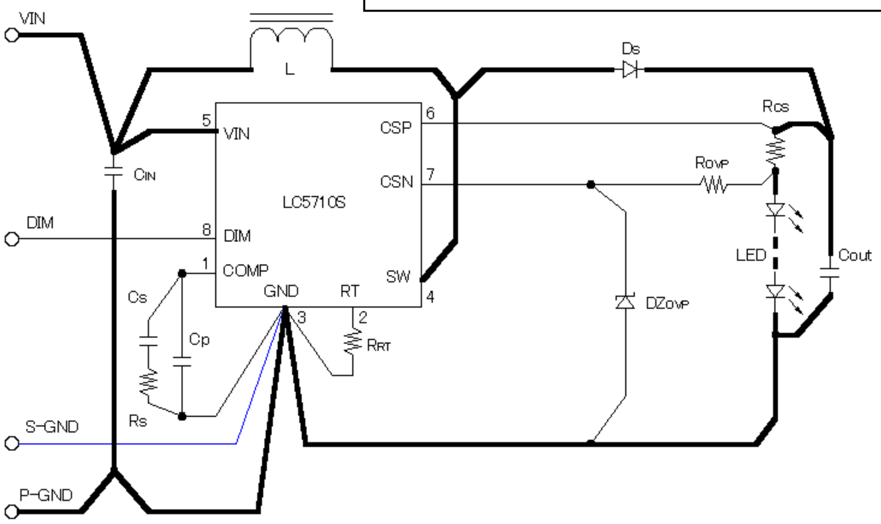
5) Buck-type



If it is possible,in each type,the GND for Main-circut and the GND for small-signal should be separated as the starting point to the GND pin of the IC. It is recommended to separate the GND of "dimming-signal" and GND of "Main-circuit",too.

*A Bold line is a main-circuit.**

(B)Boost-type



Ibuckboost-type

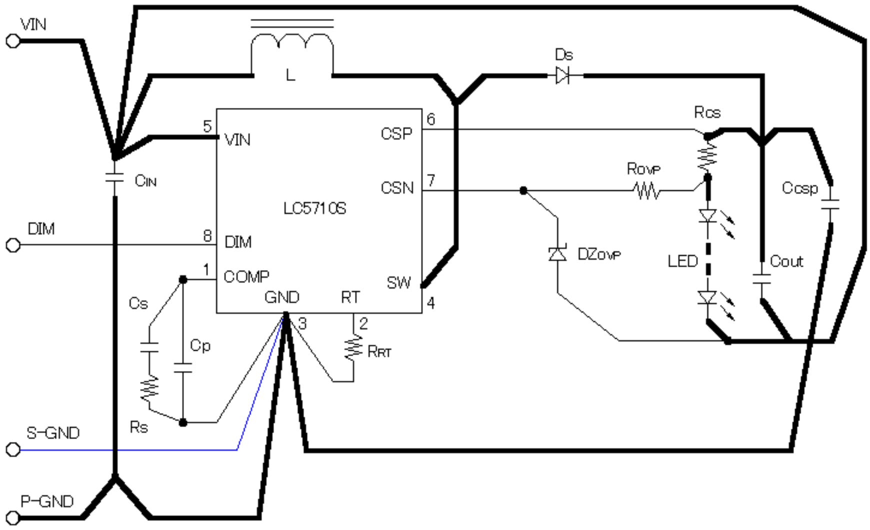


fig.27 The trace of the pattern

11. Typical characteristics (Ta=25℃)

11.1 Efficiency

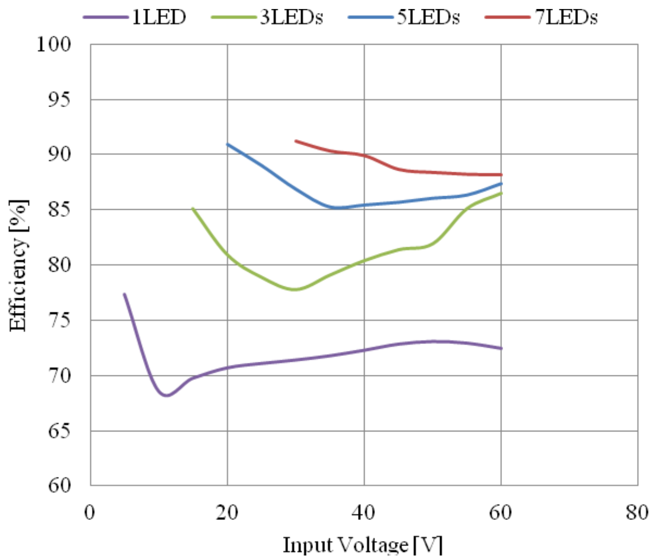


fig.28-1 Buck-mode
I_{LED}=1.0A L=220uH
F_{OSC}=100kHz

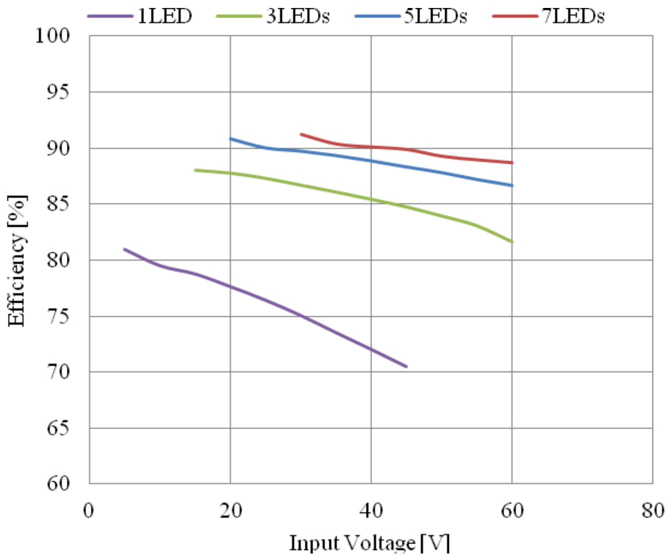


fig.28-2 Buck-mode
I_{LED}=1.0A L=47uH
F_{OSC}=500kHz

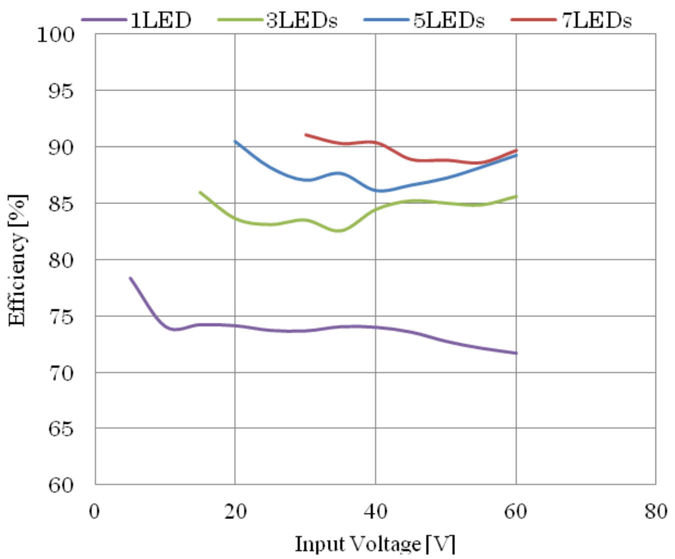


fig.28-3 Buck-mode
I_{LED}=0.5A L=220uH
F_{OSC}=100kHz

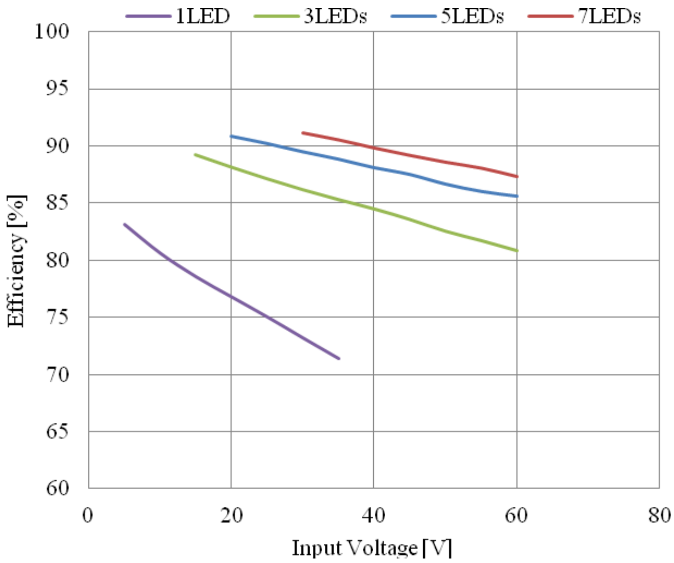


fig.28-4 Buck-mode
I_{LED}=0.5A L=47uH
F_{OSC}=500kHz

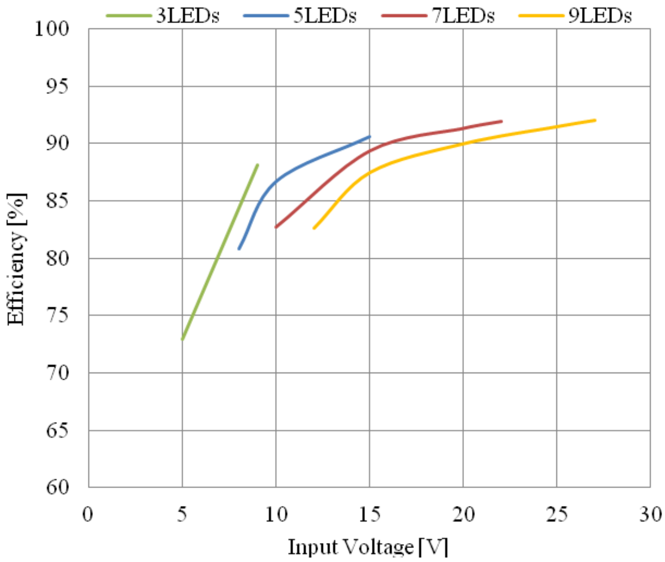


fig.28-5 Boost-mode
I_{LED}=0.5A L=100uH
F_{OSC}=100kHz

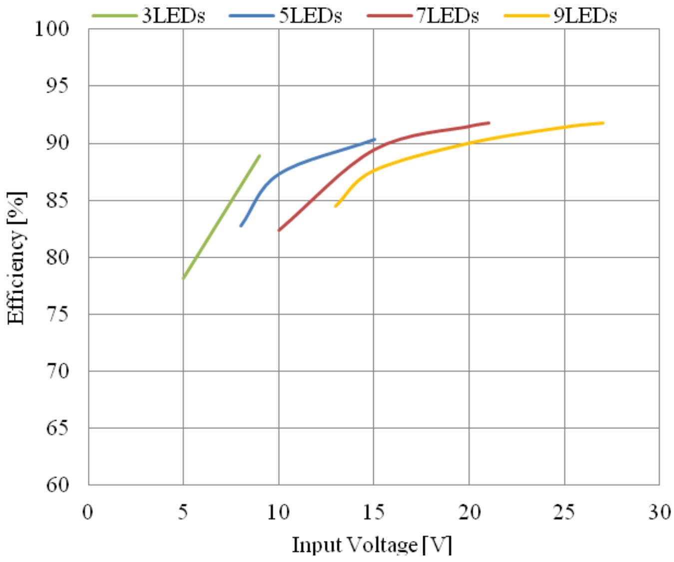


fig.28-6 Boost-mode
I_{LED}=0.5A L=22uH
F_{OSC}=500kHz

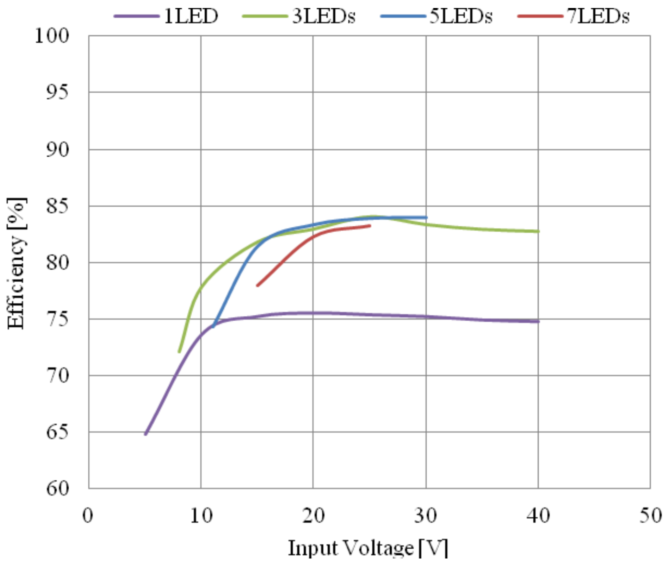


fig.28-7 Buckboost-mode
I_{LED}=0.5A L=100uH
F_{OSC}=100kHz

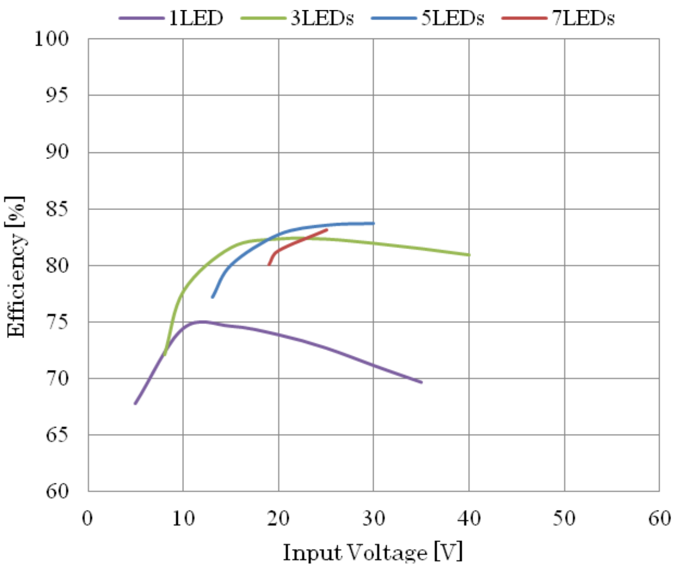


fig.28-8 Buckboost-mode
I_{LED}=0.5A L=22uH
F_{OSC}=500kHz

11.2 UVLO (Under Voltage Lock Out)

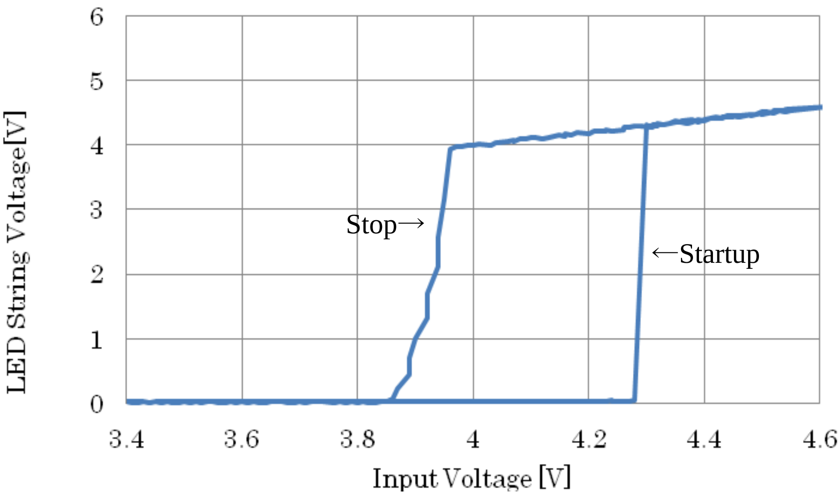


fig.28-9 Buck-mode
5LEDs I_{LED}=0.5A
UVLO

11.3 Switching Frequency Settings

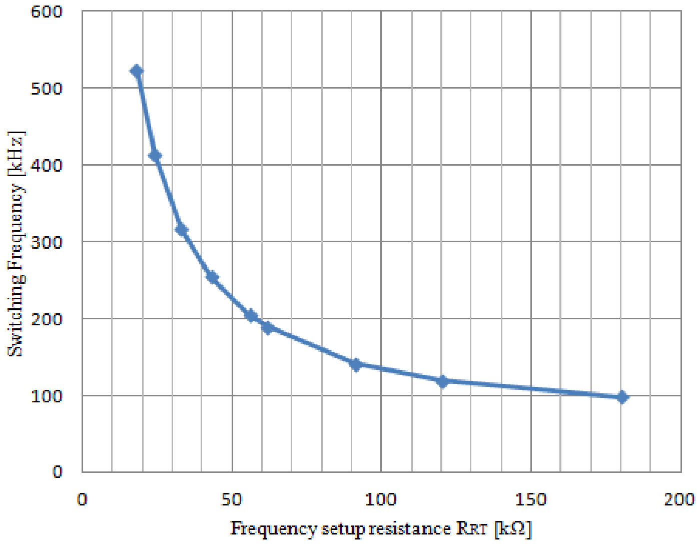


fig.28-10 R_{RT} Resistance vs. Switching Frequency

11.4 Digital Dimming characteristics

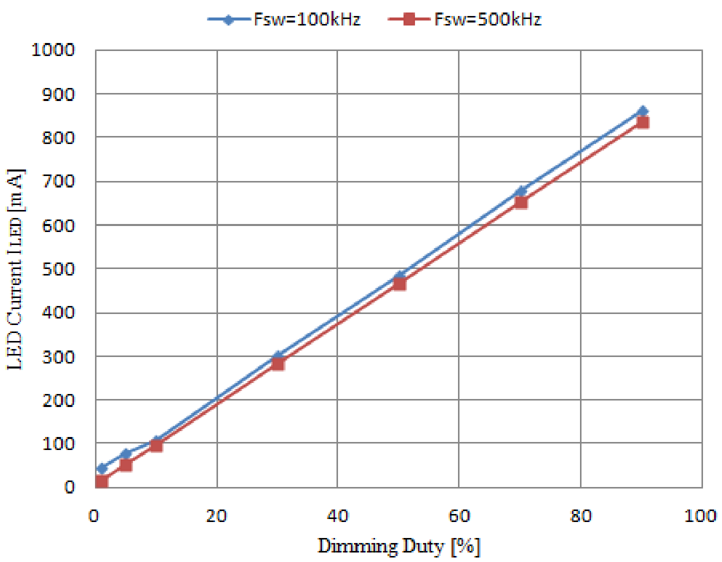


fig.28-11 Dimming Frequency=1kHz, Duty vs. I_{LED}

11.5 Analogue Dimming characteristics

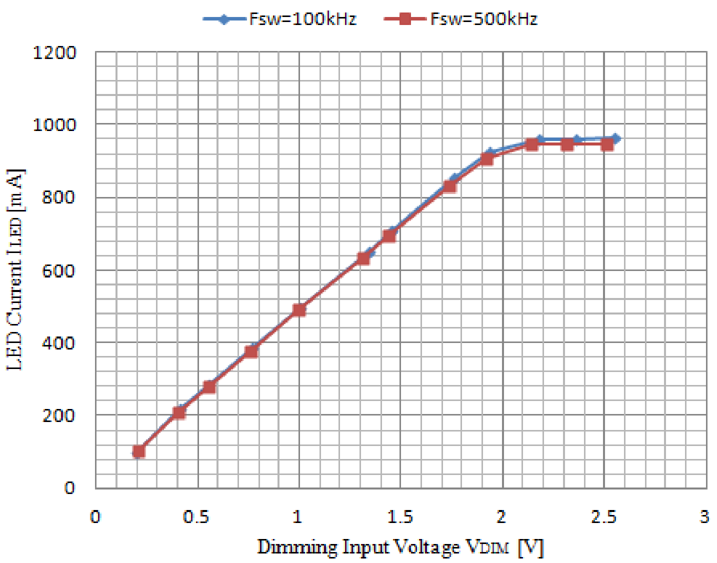


fig.28-12 DIM Voltage V_{DIM} vs. I_{LED}

11.6 CS Threshould voltage Temperature characteristics

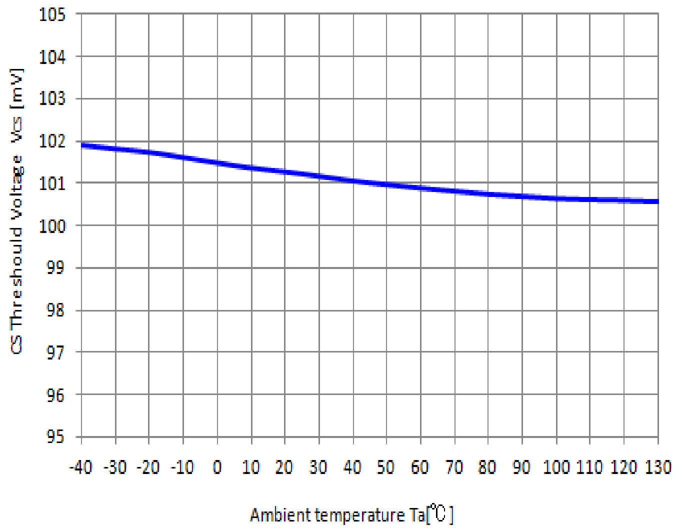


fig.28-13 V_{CS} vs. Ta

11.7 CS Threshould voltage V_{IN} Regulation (5LEDs)

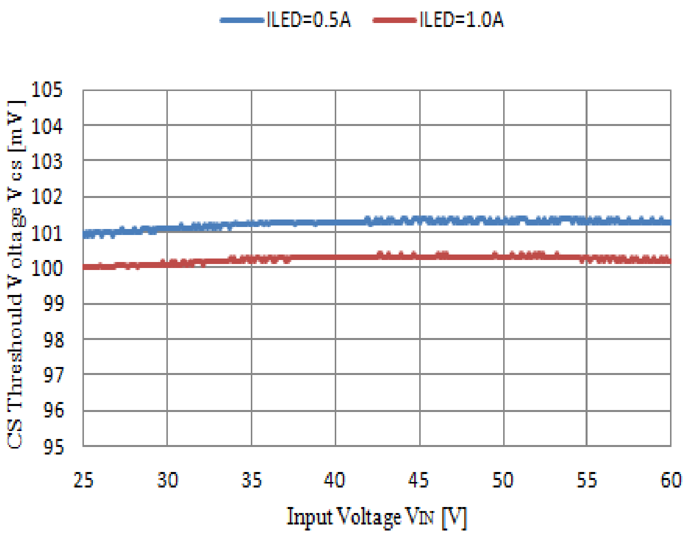


fig.28-14 V_{CS} vs. V_{IN}

11.8 TSD (Thermal Shut Down)

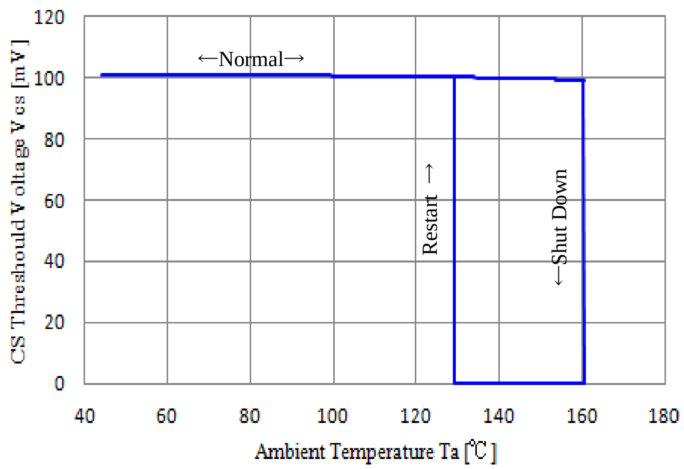


fig.28-15 V_{CS} vs. Ta at TSD(V_{IN}=24V,5LEDs, I_{LED}=10mA)

11.9 Supply Current $I_{IN(ON)}$

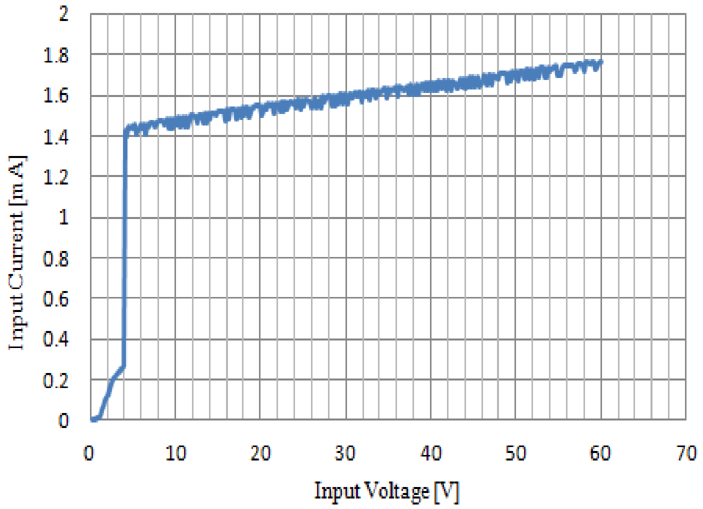


fig.28-16 $I_{IN(ON)}$ vs. V_{IN} (R_{DIM}=120kΩ)

11.10Supply Current $I_{IN(OFF)}$

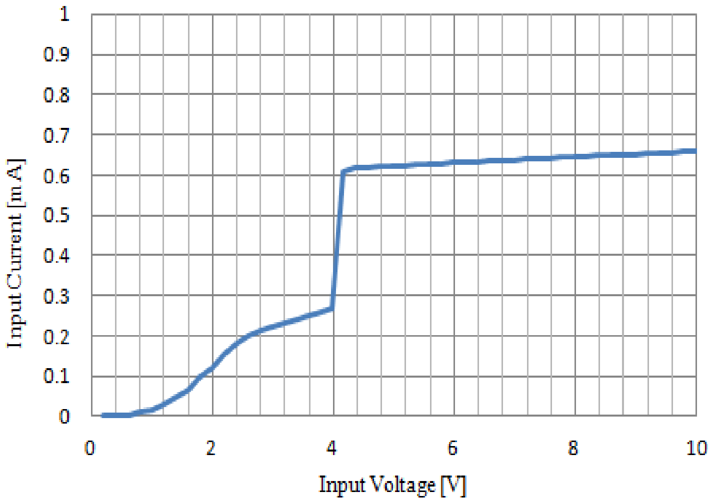


fig.28-17 Input Supply Current $I_{IN(OFF)}$ vs.V_{IN} (V_{DIM}=0V)

11.11 Waveform of Digital Dimming (1kHz／Duty=5%)

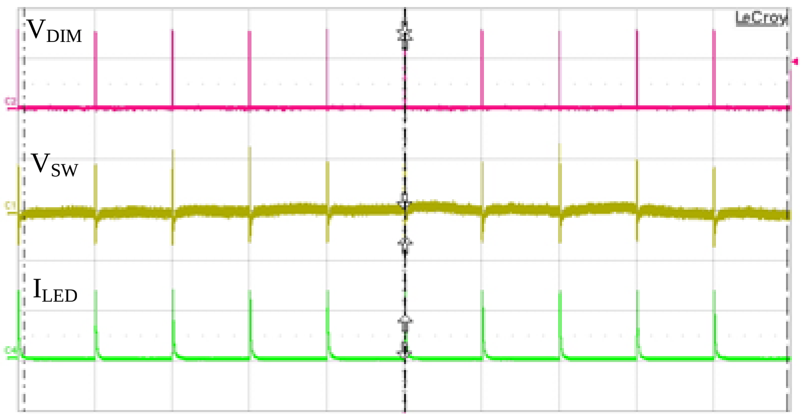


fig.28-18 PWM Dimming Duty=5%,V_{DIM},V_{SW},I_{LED} (1kHz)

V_{DIM} : 2V/Div
V_{SW} : 10V/Div
I_{LED} : 500mA/Div
Time : 1msec/Div

11.12 Waveform of Digital Dimming (1kHz／Duty=5%)

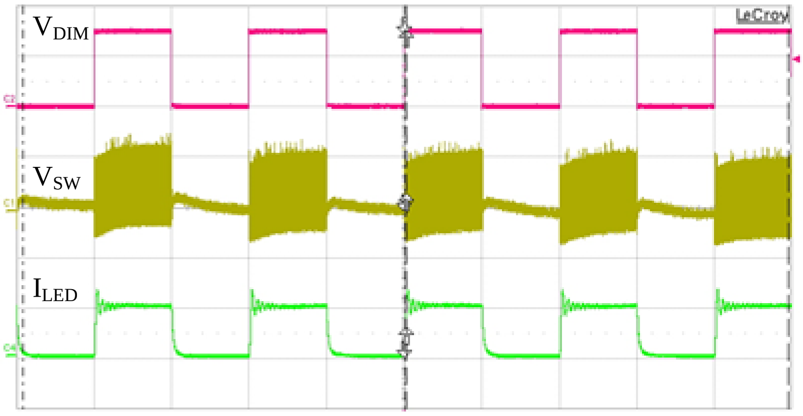


fig.28-19 PWM Dimming Duty=50%,V_{DIM},V_{SW},I_{LED} (1kHz)

V_{DIM} : 2V/Div
V_{SW} : 10V/Div
I_{LED} : 500mA/Div
Time : 1msec/Div

11.13 Steady state operation Buck-mode V_{IN}=30V,5LEDs,Fosc=100kHz

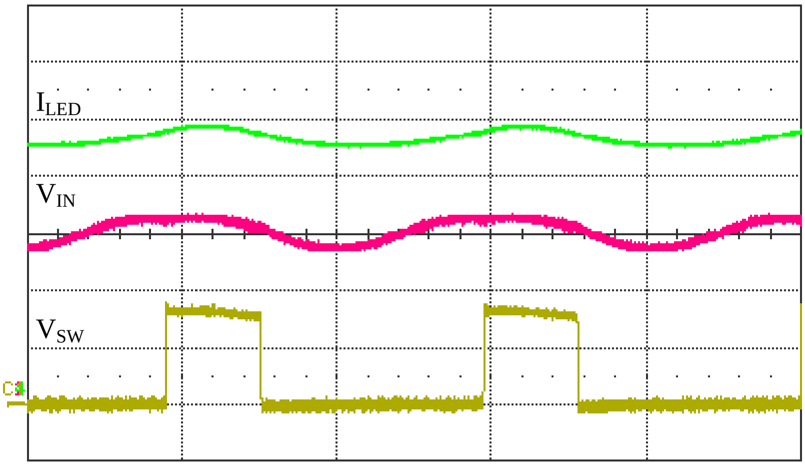


fig.28-20 Buck-mode

CH1 : V_{SW} : 20V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

11.14 Steady state operation Buck-mode V_{IN}=30V,5LEDs,Fosc=500kHz

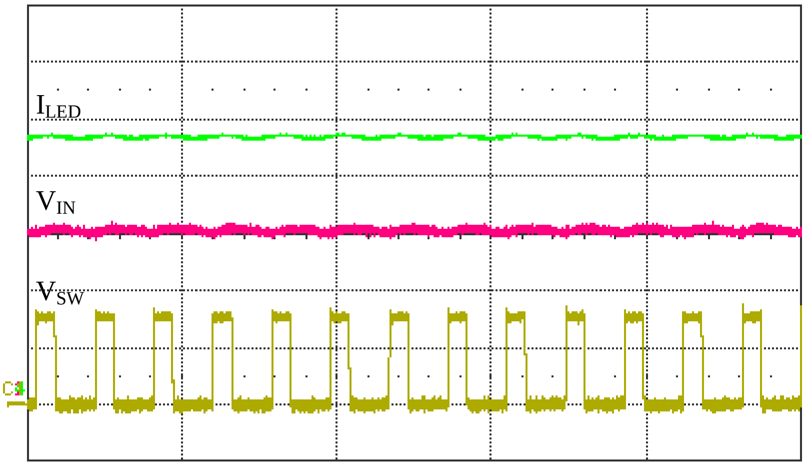


fig.28-21 Buck-mode

CH1 : V_{SW} : 20V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

11.15 Steady state Operation Boost-mode V_{IN}=15V,5LEDs,Fosc=100kHz

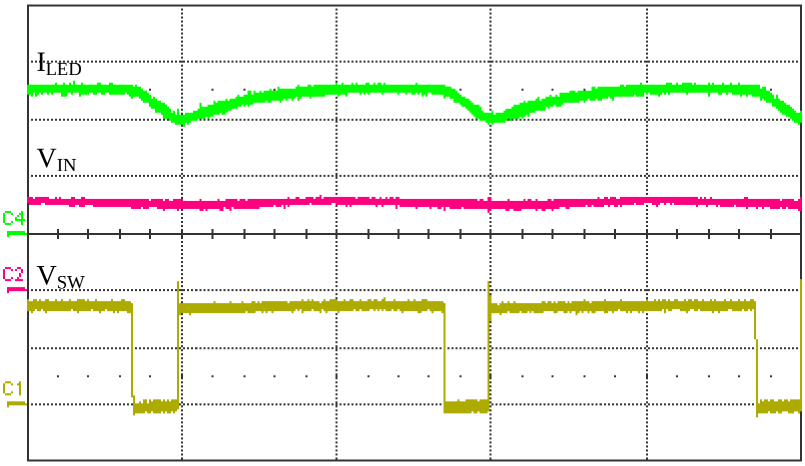


fig.28-22 Boost-mode

CH1 : V_{SW} : 10V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

11.16 Steady state operation Boost-mode V_{IN}=15V,5LEDs,Fosc=500kHz

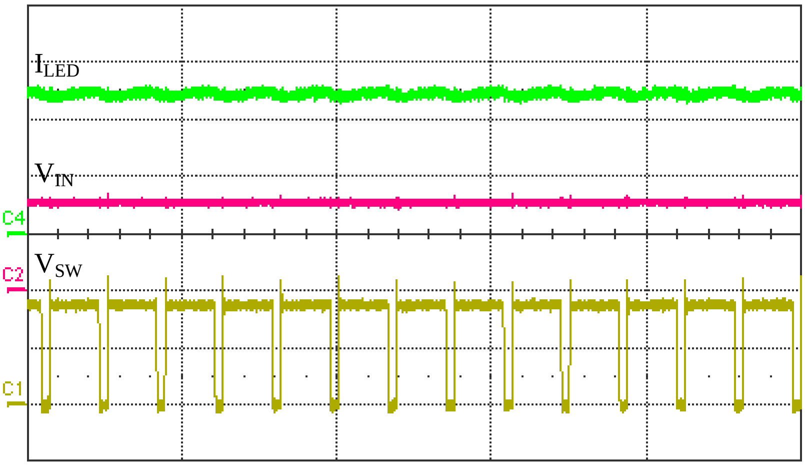


fig.28-23 Boost-mode

CH1 : V_{SW} : 10V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

11.17 Steady state operation Buck-boost-mode V_{IN}=20V,5LEDs,Fosc=100kHz

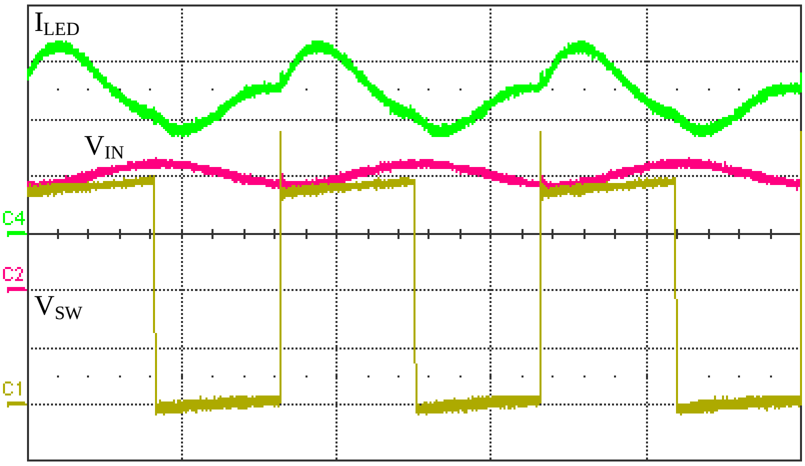


fig.28-24
Buck-boost-mode

CH1 : V_{SW} : 10V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

11.18 Steady state operation Buck-boost-mode V_{IN}=20V,5LEDs,Fosc=500kHz

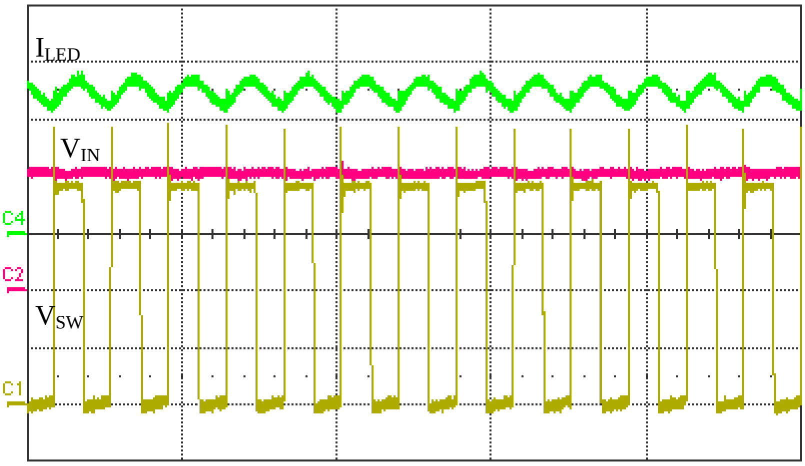


fig.28-25
Buck-boost-mode

CH1 : V_{SW} : 10V/Div
CH2 : V_{IN} : 10V/Div
CH4 : I_{LED} : 200mA/Div
Time : 5 μ S/Div

12. Packing specifications

12.1 Taping & Reel outline

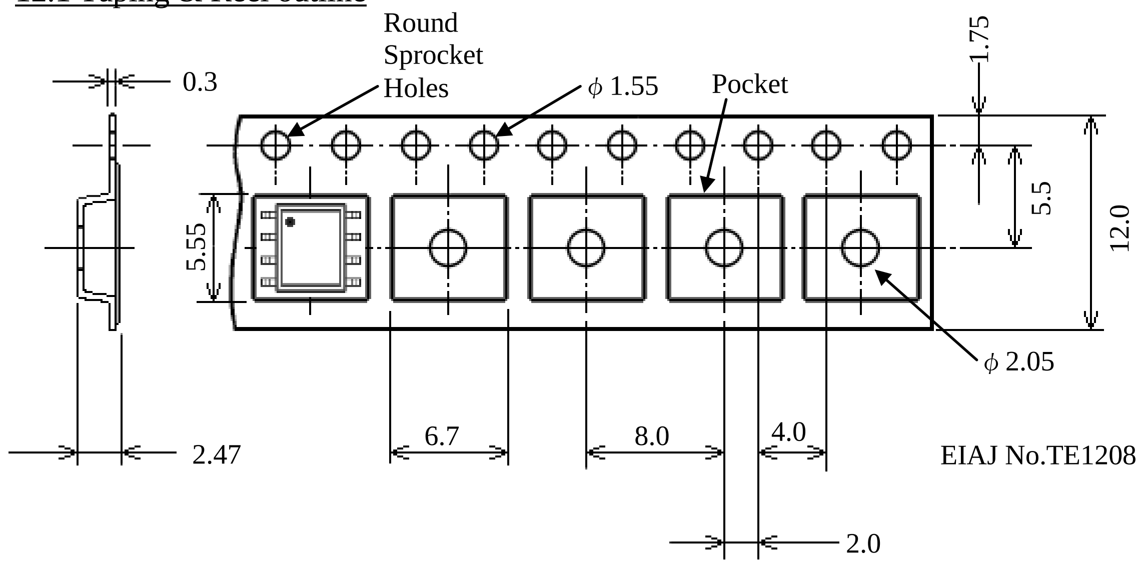


fig. 29 Taping outline

Notes:
1) All dimensions in 41illimeters
2) Surface resistance：under 10^9 Ω
3) Drawing is not to scale

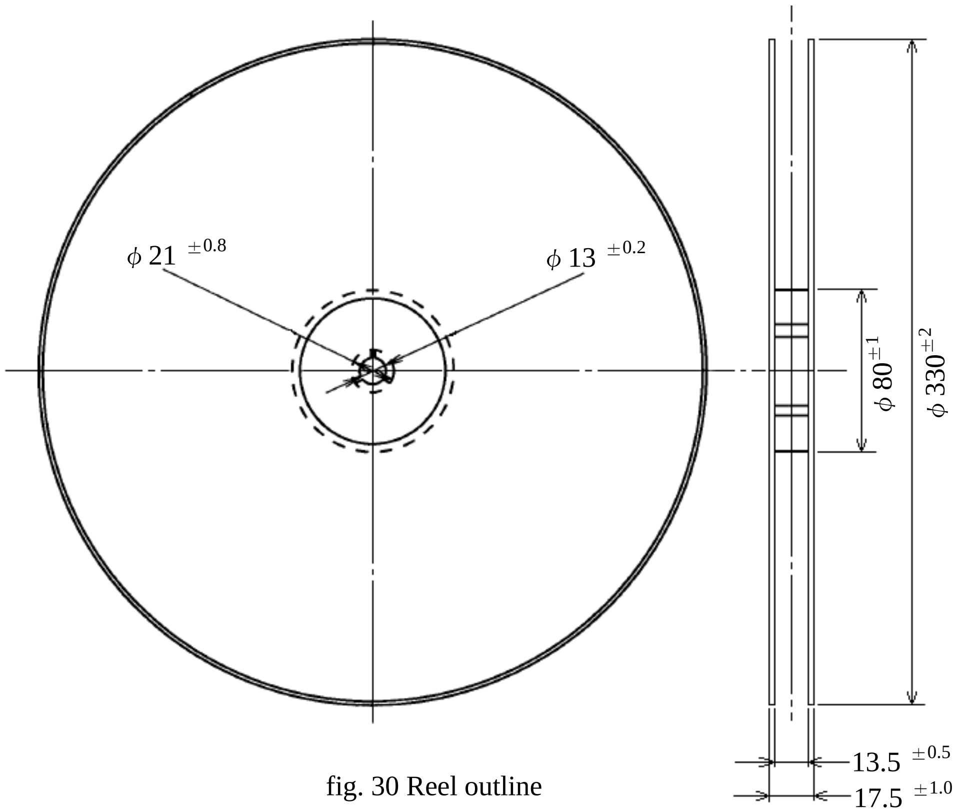


fig. 30 Reel outline

Notes:
1) All dimensions in millimeters
2) Drawing is not to scale.

EIAJ No.RRM-12DC

Quantity
4000pcs／reel

IMPORTANT NOTES

- All data, illustrations, graphs, tables and any other information included in this document as to Sanken's products listed herein (the "Sanken Products") are current as of the date this document is issued. All contents in this document are subject to any change without notice due to improvement, etc. Please make sure that the contents set forth in this document reflect the latest revisions before use.
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