LC5720S
Application Note Rev.1.1

SANKEN ELECTRIC CO., LTD.
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CONTENTS

General Descriptions

The LC5720S 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, 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. The rich set of protection features helps to realize low component counts, and high performance-to-cost power supply.

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: 500kHz(TYP)
- LED string current setting with an external resistor.
- Current Detection voltage of LED string: 100mV±5%
  Thus, low power loss and high accuracy LED string current can be achieved by setting of an external resistor.
- PWM Dimming Frequency: available to 20kHz(MAX)
- 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

Package

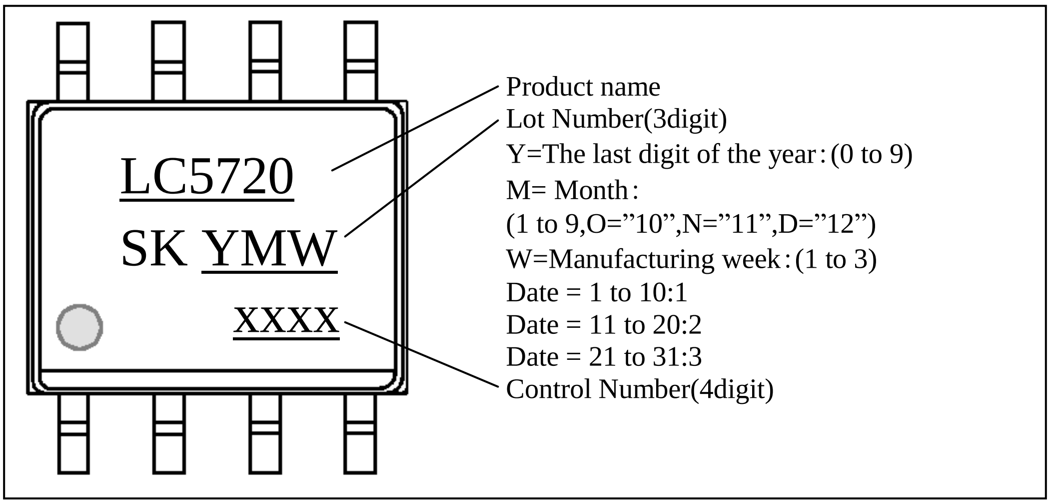
SOP8

Characteristics

Input voltage range	9.5V (MIN)～50V(MAX)
Output current	2A(MAX)
$R_{DS(ON)}$	215mΩ(TYP)

Applications

- LED lighting fixtures
- LED light bulbs



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 50.0	V	
SW Pin Voltage	4—3	V_{SW}	−0.3 to 50.0	V	
CSP Pin Voltage	6—3	V_{CSP}	−0.3 to 50.0	V	
CSN Pin Voltage	7—3	V_{CSN}	−0.3 to 50.0	V	
Differential Voltage bwteen CSP and CSN Pins	6—7	$V_{CSP-CSN}$	−0.3 to 5.5	V	
COMP Pin Voltage	1—3	V_{COMP}	−0.3 to 5.5	V	
DIM Pin Voltage	8—3	V_{DIM}	−0.3 to 5.5	V	
Allowable Power Dissipation of MOSFET (1) (2)	—	P_D	1.35	W	
Junction Temperature in Operation (3)	—	T_J	125	°C	
Thermal Resistance (junction-ambient air) (2)	—	θ j-a	74	℃/W	
Operating ambient temperature (1)	—	T_{op}	−40 to 125	°C	
Storage Temperature	—	T_{STG}	−40 to 150	°C	Non-movement

(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}	9.5	50	V	
CSP Pin Voltage	6 − 3	V_{CSP}	4.75	50	V	
Output current (4)	—	Io	0	2	A	(5)Buck
			0	1		(5)Boost/Buckboost
Peak to Peak Inductor Ripple current	—	ΔI_L	−	0.8	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：2A, Boost circuit／Buckboost circuit：1A, ⊿IL ≦0.8A.

3. Electrical Characteristics

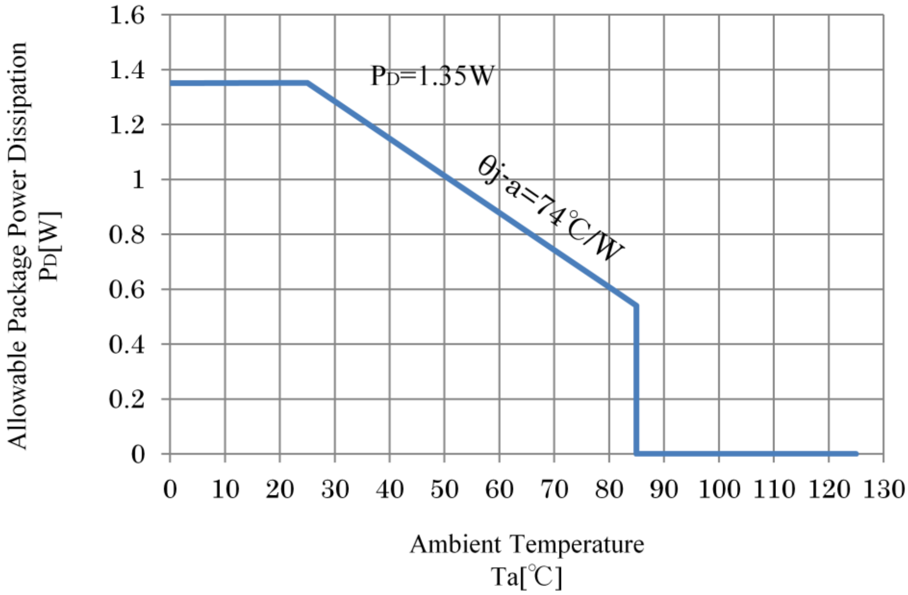
- Certain details refer to the specification sheet of this product.
- The polarity value for current specifies a sink as “+” and a source as “–”, referencing the IC.

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

Characteristic	Pins	Symbol	MIN	TYP	MAX	Unit	Notes
Operation Start Voltage	5 − 3	$V_{IN(ON)}$	7.7	8.5	9.4	V	
Operation Stop Voltage	5 − 3	$V_{IN(OFF)}$	7.2	8.0	8.9	V	
Operation Hysteresis Voltage	5 − 3	$V_{IN(HYS)}$	0.1	0.3	0.5	V	
Circuit Current in Operation	5 − 3	$I_{IN(ON)}$	3.0	4.5	7.0	mA	
Circuit Current in None-Operation	5 − 3	$I_{IN(OFF)}$	400	600	1000	µA	V_{IN}=6.5V
Operation Frequeny	4 − 3	f_{OSC}	420	500	570	kHz	
Minimum On-Duty Cycle	4 − 3	$t_{ON(MIN)}$	50	75	100	ns	V_{COMP}=0V
Maximum On-Duty Cycle	4 − 3	D_{MAX}	89	94	98	%	V_{COMP}=4V
On-Time1	4 − 3	$t_{ON(1)}$	300	600	800	ns	V_{COMP}=0.7V
On-Time2	4 − 3	$t_{ON(2)}$	0.85	1.4	1.8	µs	V_{COMP}=1.2V
On-Time for Current Contol (6)	4 − 3	t_{CON}	0.14	0.33	0.63	µs	V_{COMP}=0.7V, I_{SW}=2A
Current Detection Voltage	6 − 7	V_{CS}	95	100	105	mV	
CSP Pin Sink Current	6 − 3	I_{CSP}	85	130	175	µA	
CSN Pin Sink Current	7 − 3	I_{CSN}	40	65	95	µA	
CSP Pin Minimum Voltage	6 − 3	$V_{CSP(MIN)}$	4.75	—	—	V	
COMP Pin Source Current	1 − 3	$I_{COMP(SRC}$	−95	−60	−38	µA	V_{CS}=20mV, V_{COMP}=2V
COMP Pin Sink Current	1 − 3	$I_{COMP(SNK)}$	38	60	95	µA	V_{CS}=180mV, V_{COMP}=2V
Error Amplifier Conductance	—	g_M	—	750	—	µs	V_{CS}=50 to 150mV
Overvoltage Protection (OVP) Threshold Voltage	6 − 7	$V_{CS(OVP)}$	200	240	280	mV	
SW Pin Current Limit	4 − 3	$I_{SW(LIM)}$	2.5	3.5	4.7	A	
SW Pin On-Resistance (6)	4 − 3	$R_{SW(L)}$	—	200	—	mΩ	I_{SW}=1A
DIM Pin Voltage for LED On	8 − 3	$V_{DIM(ON)}$	1.2	1.4	1.7	V	
DIM Pin Voltage for LED Off	8 − 3	$V_{DIM(OFF)}$	0.75	1	1.2	V	
DIM Pin Hysteresis Voltage	8 − 3	$V_{DIM(HYS)}$	0.3	0.5	0.7	V	
DIM Pin Dimming Frequency (6)	8 − 3	FDIM	32	—	20000	Hz	
Thermal Shutdown Activating Temperature (6)	—	$T_{J(TSD)}$	150	160	—	°C	
Thermal Shutdown Hysteresis Temperature (6)	—	$T_{J(TSDHYS)}$	—	20	—	°C	

(6) Verified by design/characterization

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 LC5720S
(Thermal Derating Curve)

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

4. Functional Block Diagram

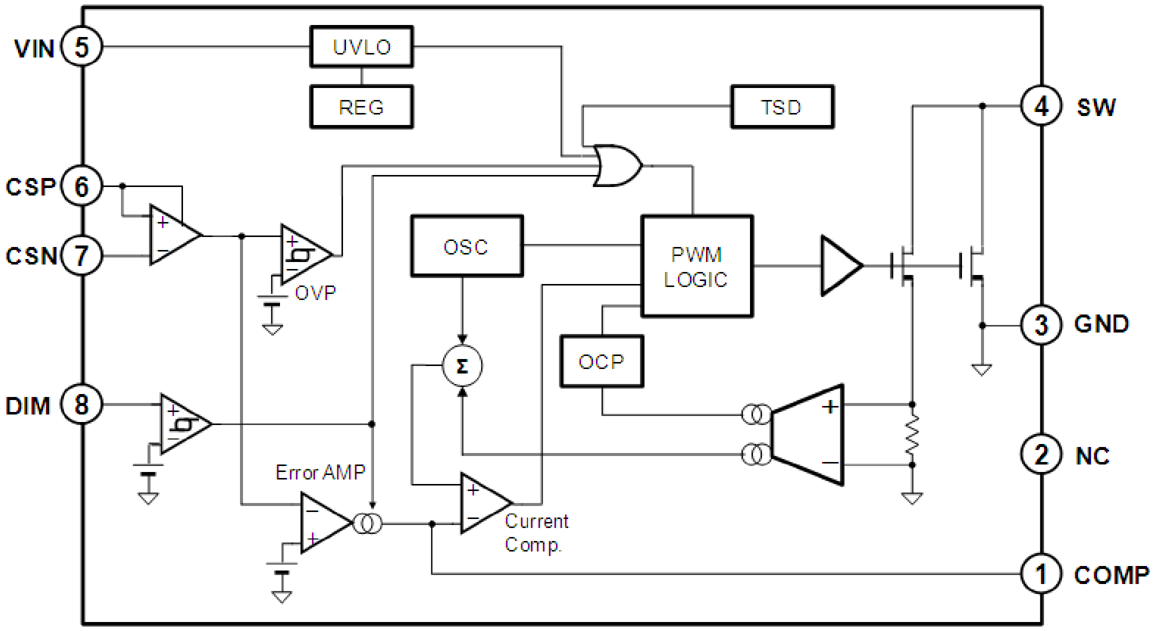


fig.2 Block diagram

5. Pin Assign & Functions

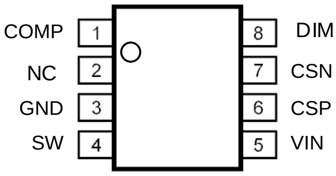


fig.3 Pin Assign

Table.4

Pin No.	Symbol	Functions
1	COMP	External phase compensation terminal.
2	NC	No-Connection
3	GND	Ground terminal.
4	SW	Switching Output. Switching node that drives the external inductor.
5	VIN	Supply Input. Input capacitor C_{IN} 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.

6. Typical Application Circuit

Examples for LED lighting power supply

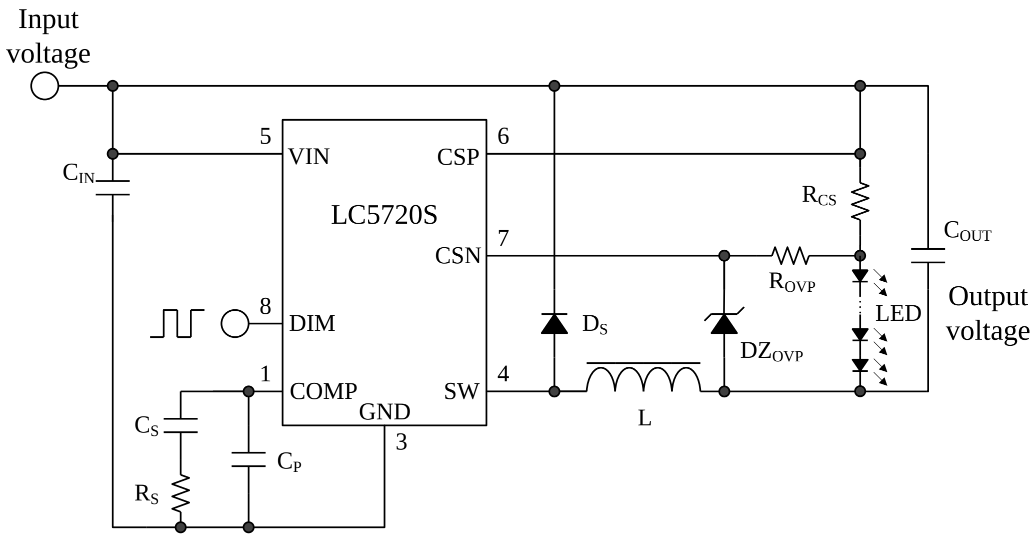


fig.4-1 Buck converter
(Input voltage ≥ Output voltage)

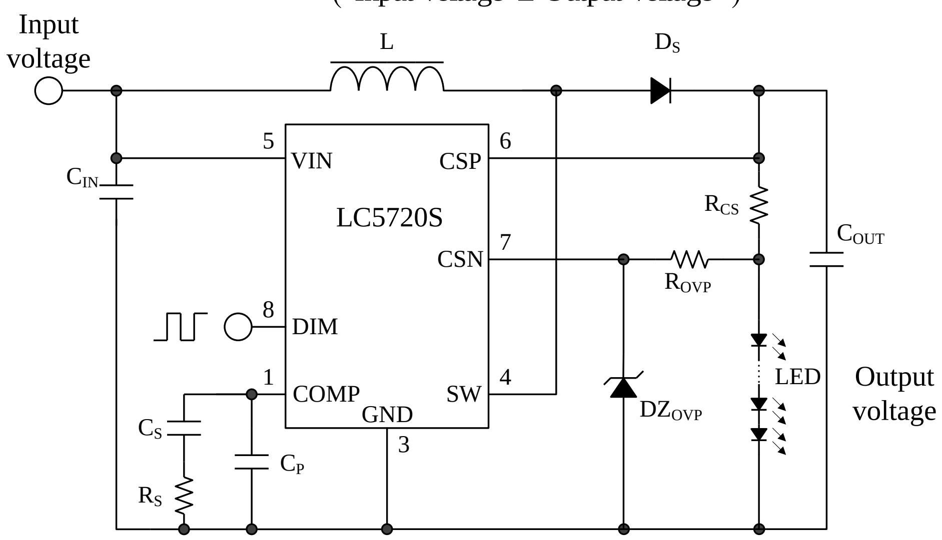


fig.4-2 Boost converter
(Input voltage ≤ Output voltage)

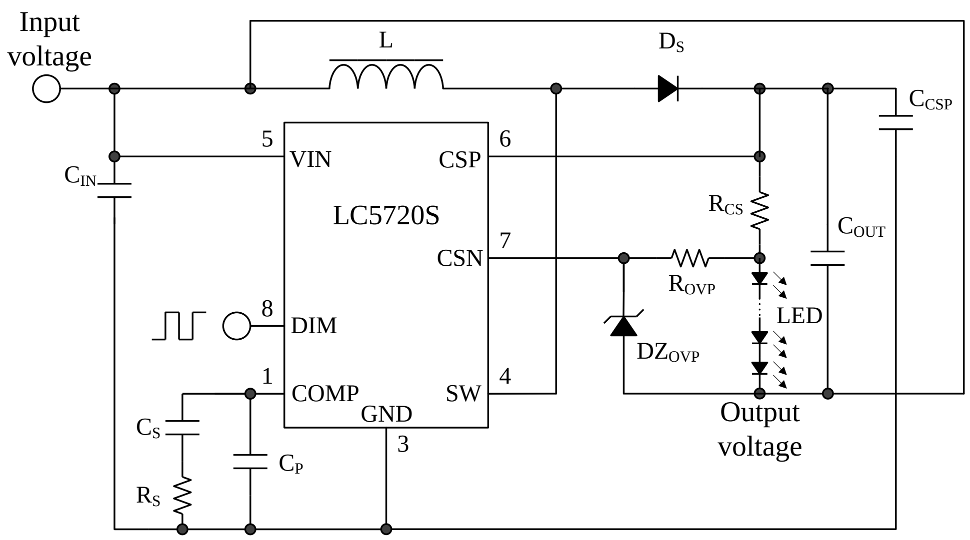
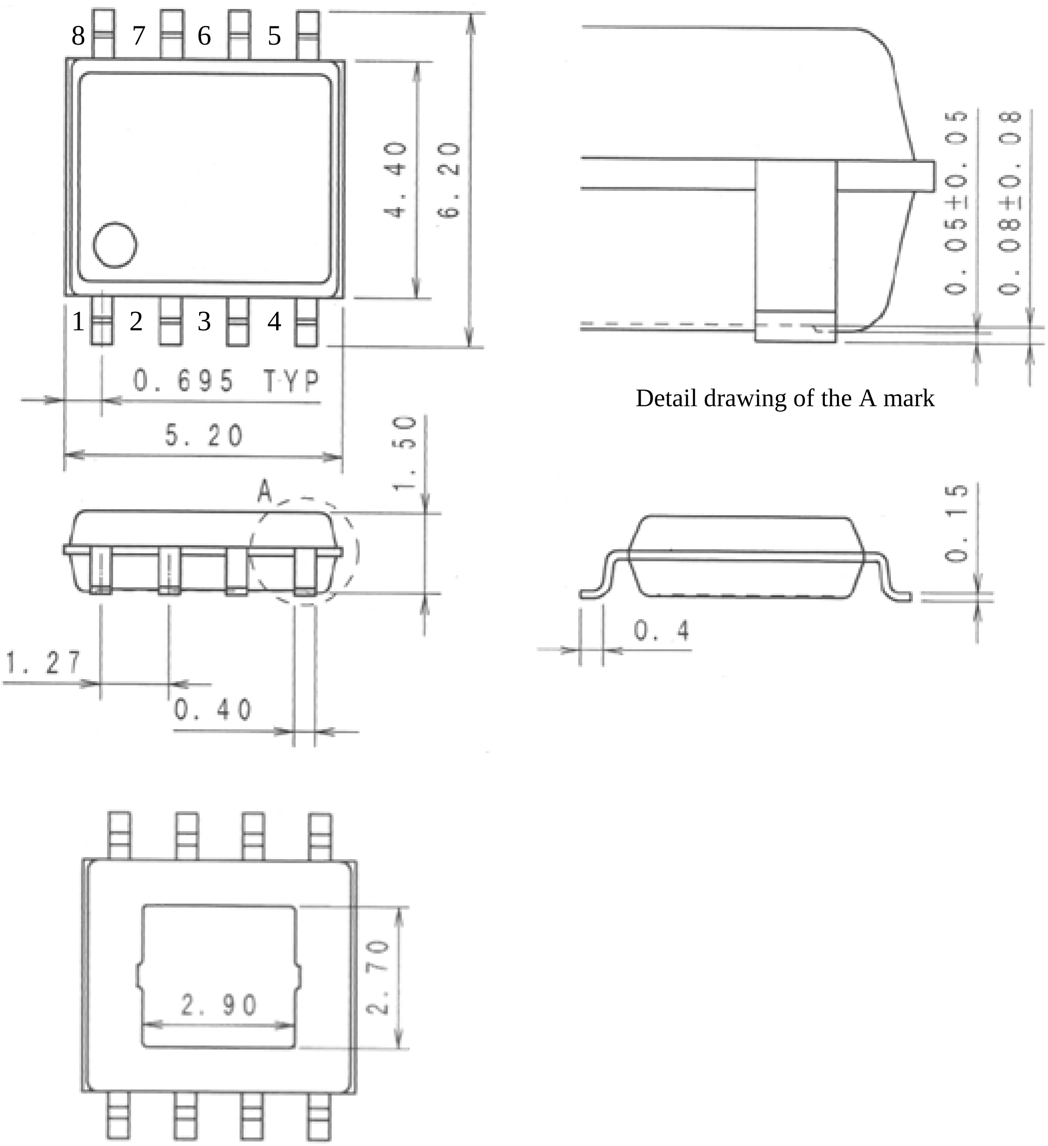


fig.4-3 Buck-Boost Converter
(Input voltage ≤ Output voltage ≤ Input voltage)

7. Package Information

HSOP8



NOTES:
1) All dimensions are in Millimeter
2) Pb-free. Device composition compliant with the RoHS directive

fig.5 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 PWM Current Control

The current control circuit is shown in fig.6.

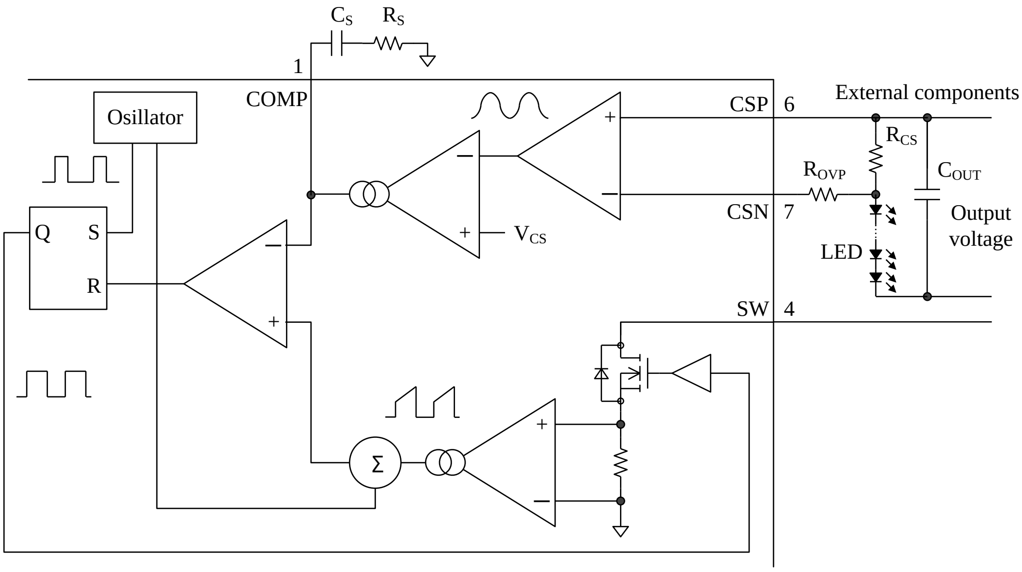


fig.6 Current control circuit

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 fixed to 500kHz.
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.

$$I_{OUT} = \frac{V_{CS} - I_{CSN} \times (R_{CS} + R_{OVP})}{R_{CS}} \qquad \cdots(1)$$

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}.

$$I_{OUT} = \frac{V_{CS}}{R_{CS}} \qquad \cdots(2)$$

R_{OVP} value should be chosen so that I_{OUT} is within the acceptable accuracy range referring to the calculation in “8.4 Overvoltage Protection Function (OVP)”.

8.2 LED Dimming

LED dimming is controlled by the duty cycle of PWM digital signal which is input to DIM pin.
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 5.5V.

- When DIM Pin Voltage for LED On, $V_{DIM(ON)}$= 1.4V or more is input, I_{OUT} flows.
- When DIM Pin Voltage for LED Off, $V_{DIM(OFF)}$= 1V or less is input, I_{OUT} stops.

The constant current value is controlled with the current detection resistor, R_{CS}, and the current detection voltage, V_{SC}. When DIM pin voltage is less than $V_{DIM(ON)}$, COMP pin voltage is held with the fixed voltage, and when DIM pin voltage is more than $V_{DIM(ON)}$, COMP pin voltage is increased from this hold voltage.
This makes the constant current startup speed fast at DIM dimming.
The Dimming-ratio depends on the duty ratio of the PWM-digital-dimming signal pulse (fig.7).

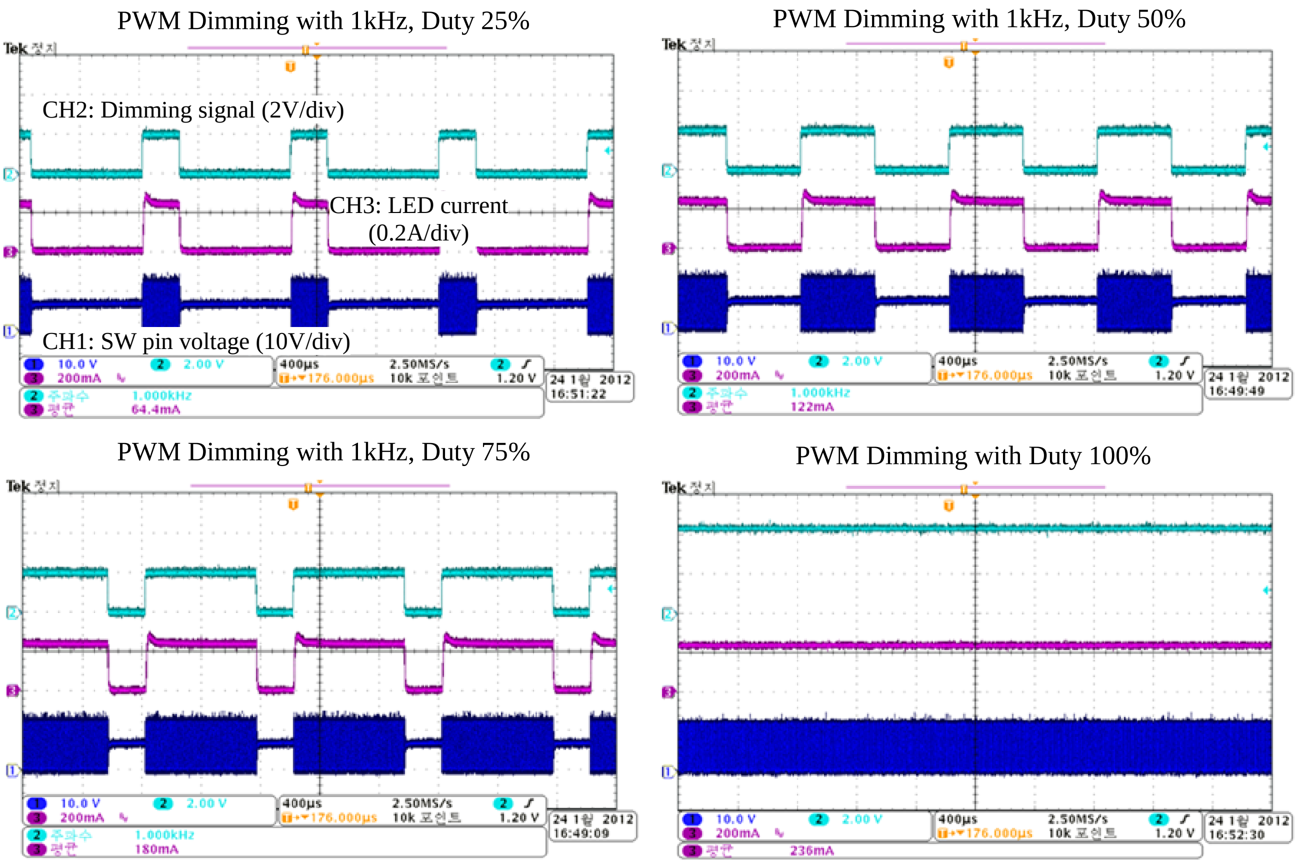


fig.7 Actual waveform in Dimming operation

8.3 Overcurrent Protection Function (OCP)

The IC incorporates Overcurrent Protection Function (OCP) limited the current flowing to SW terminal (fig.8).
When the current to SW terminal reaches $I_{SW(LIM)}$= 3.5A, 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.

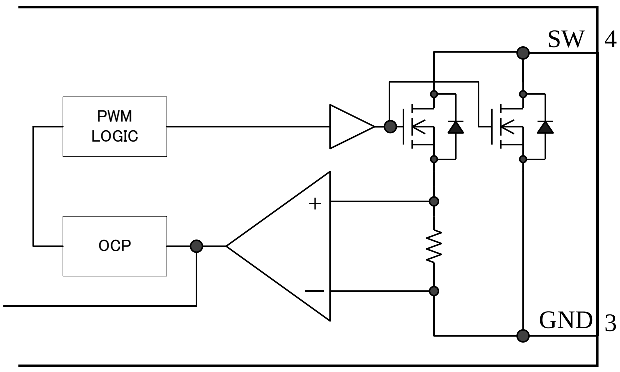


fig.8 Overcurrent protecton circuit

8.4 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.9, 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}=240mV.

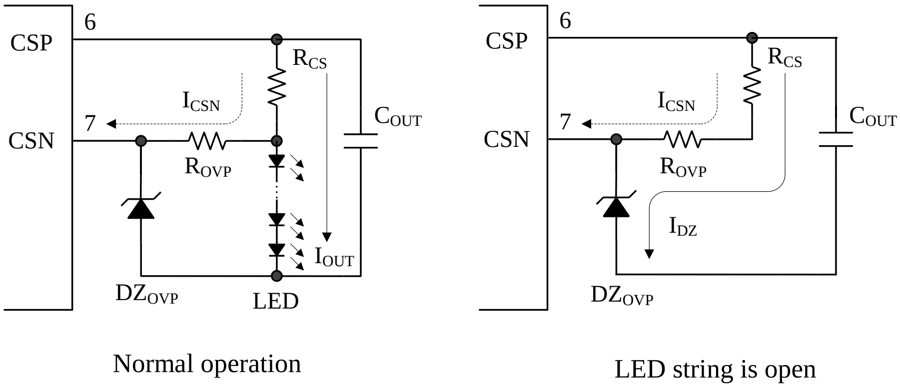


fig.9 Overvoltage protection circuit

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}.

$$I_{DZ} \leq \frac{P_{DZ}}{V_{DZ}} \qquad \cdots(3)$$

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.

$$R_{OVP} \geq \frac{V_{CS\,(OVP)}}{I_{DZ} + I_{CSN}} - R_{CS} \qquad \cdots(4)$$

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

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

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.

8.5 Selection of application circuit

Select application circuit properly in the relations with the LED strings voltage and the input voltage VIN in the Table 6.

Table.6

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 7 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 9.5V 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 40V by 80%-derating against 50V which is the absolute maximum ratings.
3) A limitation (0.05<Duty<0.89) 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) =2.5A (Min)" .

Table.7 VIN(or Vsw)＜40V(50V×0.8), 0.05＜Duty＜0.89 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=2.0A, ⊿IL=0.8A		ILED=1.0A, ⊿IL=0.4A		ILED=1.0A, ⊿IL=0.4A	
		MIN(V)	MAX(V)	MIN(V)	MAX(V)	MIN(V)	MAX(V)
1	3.6	9.50	40.00			9.5	36.4
2	7.1	9.50	40.00			9.5	32.9
3	10.6	11.91	40.00	9.50	10.07	9.5	29.4
4	14.1	15.84	40.00	9.50	13.40	10.9	25.9
5	17.6	19.78	40.00	9.50	16.72	13.6	22.4
6	21.1	23.71	40.00	10.30	20.05	16.3	18.9
7	24.6	27.64	40.00	11.80	23.37		
8	28.1	31.57	40.00	13.40	26.70		
9	31.6	35.51	40.00	15.20	30.02		
10	35.1	39.44	40.00	16.80	33.35		
11	38.6			18.40	36.67		

For non ･･･In case of following condition, VIN under VIN(ON), VIN or Vsw reaches 40V, and ILp reaches Isw(LIM), it is the setup which doesn't become utility. When a table 7 is graphed, they are shown in the fig10 – the fig12.

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

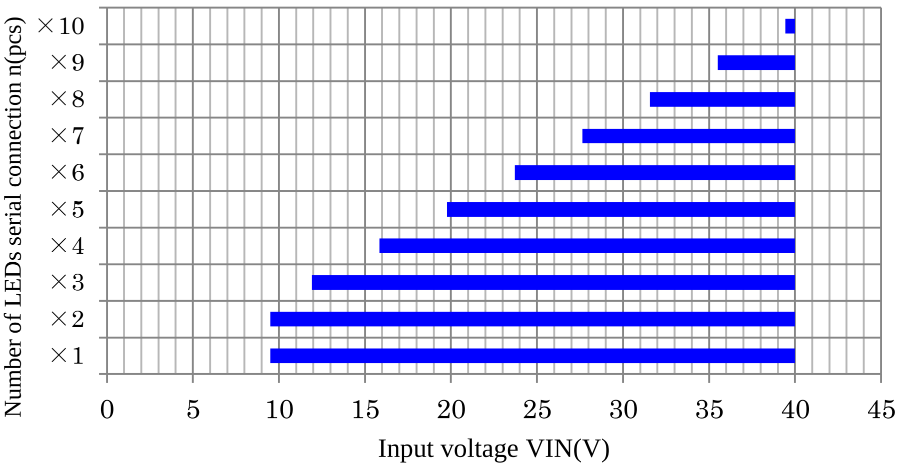


fig.10

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

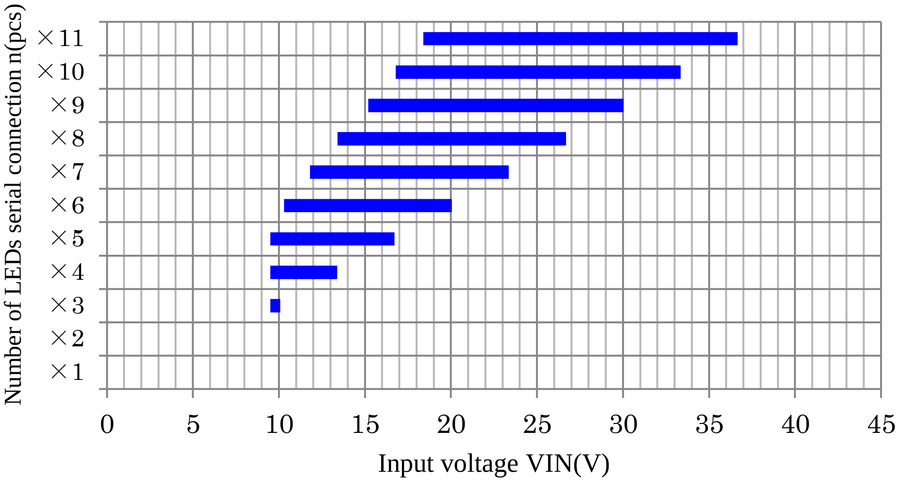


fig.11

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

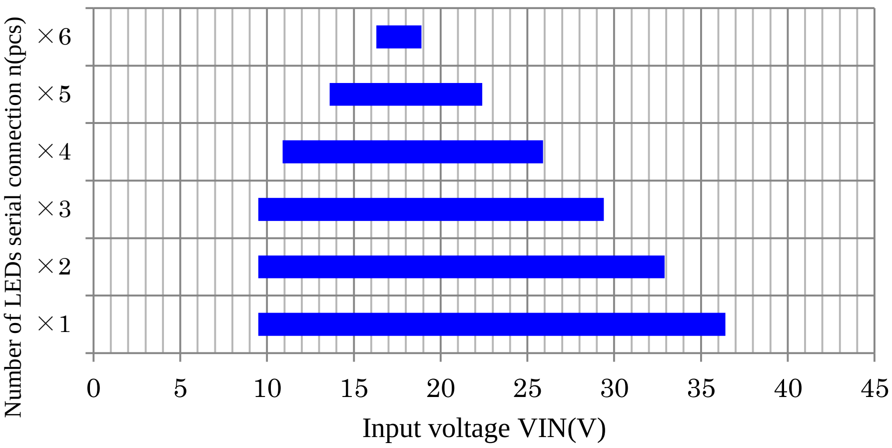


fig.12

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.

8.6 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”.

$$t_{ON(MIN)} \times F_{OSC} < D < D_{MAX} \quad \cdots(6)$$

Therefore, Duty-D is within the range of 0.89 from 0.05 (0.05< D <0.89).
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.

$$V_{out} = n \times V_{FLED} + V_{CS} \quad \cdots(7)$$

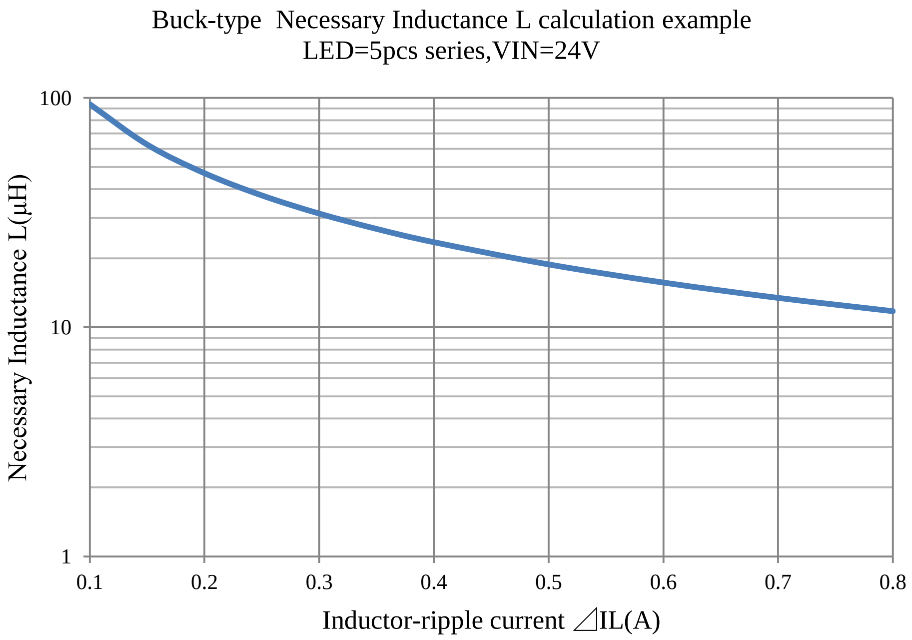
where; V_{FLED} : Forward voltage drop of a LED(・・・V_F=3.5V／1PCS)
n : The number of LED in series
V_{CS} : Current Detection Voltage, V_{CS}= 100mV

Table.8 Equations to calculate Necessary Inductance L

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

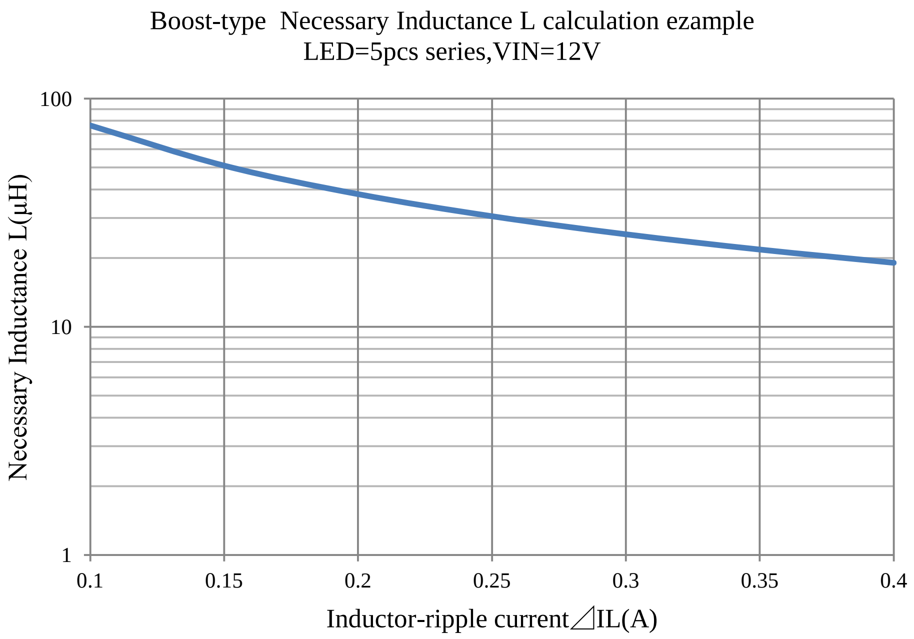
In case of Buck-type, as for the Drain-current which flows into the SW terminal, Drain-current becomes equal to LED current. But, in case of Boost-type, or in case of Buckboost-type, for example when the Duty-D is 0.5, if it is same inductor-ripple current, Drain-current is doubled from Buck-type. Be careful to this point.
Inductor-ripple-current is "⊿IL=0.8A(Max)", 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 "$I_{SW(LIM)}$ =2.5A (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 ・・・ 2.0A , ⊿IL=0.8A(Max)
*Boost-type/Buckboost-type ・・・ 1.0A , ⊿IL=0.4A(Max)
A calculation example graph is shown as follows (Refer to the fig13－ the fig15).
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
Necessary Inductance L(μH)
100
10
1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Inductor-ripple current ⊿IL(A)

fig.13



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

fig.14

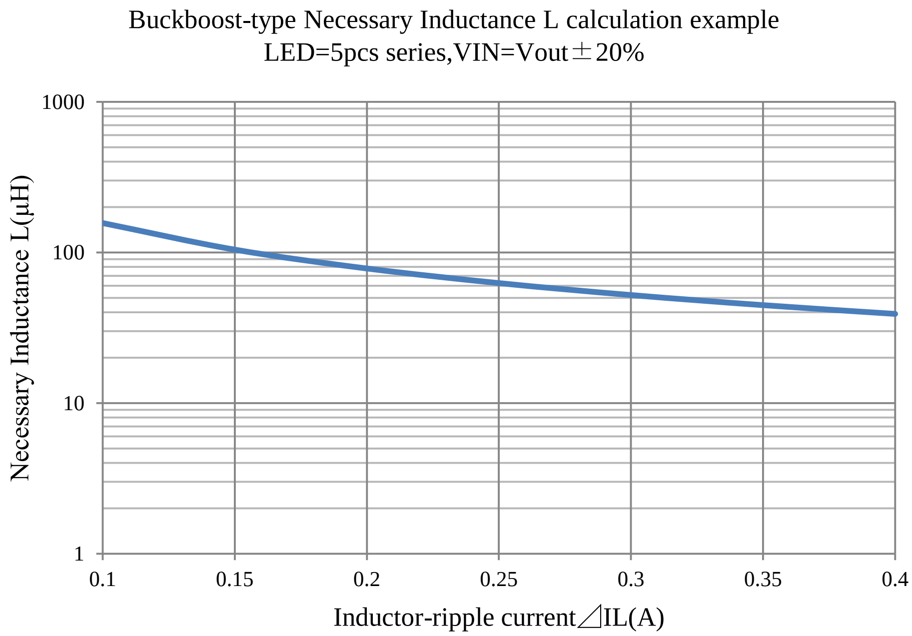


fig13－fig15 Necessary Inductance L calculation example
*FOSC = 500kHz
*Number of LED = 5pcs series
The value of graph is calculated following the equation in the Table8.

fig.15

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.

8.7 The Internal Power Dissipation Pd

8.7.1 The loss Pcont of the control circuit

The loss Pcont of the control circuit depends on the input voltage and frequency. (fig.16) .

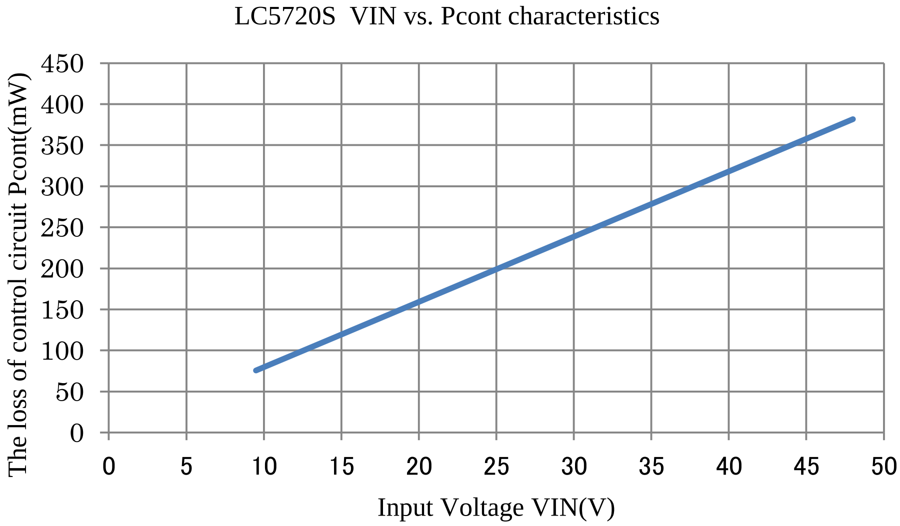


fig.16

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.16 is the total of the loss of circuit electric current and the drive loss. Read near value in the fig.16, and substitute it when you calculate a loss.

8.7.2 The switching-speed of internal PowerMOSFET

As for the fig.17, 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.

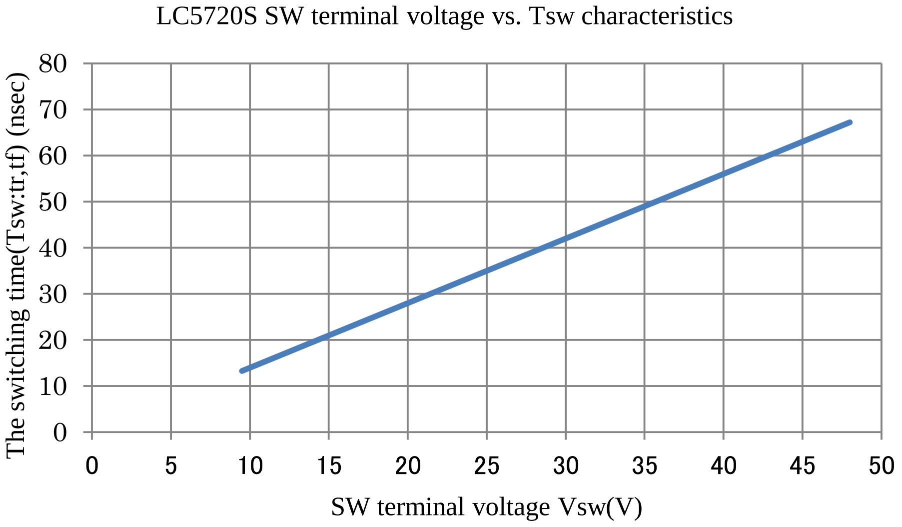


fig.17

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.

8.7.3 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.17.
Buck-type, Boost-type and Buckboost-type, the loss of PowerMOSFET of each type are shown the approximation in the Table9.

Table.9

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

*

・Ton=(1／Fosc)×D・・・D=Duty (Refer to Table7.)
・Tsw is prescribed by the value (sec) of the fig19 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)=IL_{AVE}(A)
・Refer to a Table 7 for IL_{AVE} (A).
・Ron is "ON-resistance(Ω)" of the internal PowerMOSFET, between drain and source.

8.7.4 Power dissipation in the IC, Pd

The internal loss is to follow a equation (8).

Pd=Pcont＋Pon＋Psw ・・・(8)

(Calculation example in the Buck-type)
Conditions:Fosc=500kHz、VIN=24V、LED strings voltage=17.6V(5LEDs)、ILED=2A、Ron=0.215Ω.
・Pcont=200mW (It was referred from fig.16.)
・Pon=0.215(Ω)×1(A)×1(A)×1.46E-6(sec)×500E+3(Hz) ≒0.157W
・Psw=2×{24(V)×(1(A)／2)×35E-9(sec)×500E+3(Hz)} ≒0.42W
∴Pd=0.2(W)＋0.157(W)＋0.42(W) =0.777W

(Calculation example in the Boost-type)
Conditions:Fosc=500kHz、VIN=12V、LED strings voltage=17.6V(5LEDs)、ILED=1A、Ron=0.215Ω.
・Pcont=100mW (It was referred from fig.16.)
・Pon=0.215(Ω)×1.467(A)×1.467(A)×0.636E-6(sec)×500E+3(Hz) ≒0.147W
・Psw=2×{17.6(V)×(1.467(A)／2)×25E-9(sec)×500E+3(Hz)} ≒0.322W
∴Pd=0.1(W)＋0.147(W)＋0.322(W) =0.567W

(Calculation example in the Buckboost-type)
Conditions:Fosc=500kHz、VIN=17V、LED strings voltage=17.6V(5LEDs)、ILED=0.5A、Ron=0.215Ω.
・Pcont=140mW (It was referred from fig.16.)
・Pon=0.215(Ω)×1.018(A)×1.018(A)×1.016E-6(sec)×500E+3(Hz) ≒0.113W
・Psw=2×{(17(V)＋17.6(V))×(1.018(A)／2)×48E-9(sec)×500E+3(Hz)} ≒0.422W
∴Pd=0.14(W)＋0.113(W)＋0.422(W) =0.675W

Notes:

The thermal resistance θj-a of the package is becomes 74(℃／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 (9).

Tj=(Pd×θj-a)＋Ta ・・・(9)

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.

8.8 PHASE COMPENSATION (COMP terminal)

8.8.1 The calculation of the Phase compensation "fixed-number" .

In 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 Table10.

Table.10

Rs	Cs
$Rs = \dfrac{2\pi \times Co \times Fc \times Vout}{K}$	$Cs \geqq \dfrac{4}{2\pi \times Rs \times Fc}$
Cp Requirement decision	(←When a left equation satisfies a condition.) Cp
$\dfrac{1}{2\pi \times Co \times ESR} < \dfrac{Fosc}{2}$	$Cp = \dfrac{Co \times ESR}{Rs}$
RLed	Fz2
$RLed = \dfrac{Vout}{ILED}$	$Fz2 = \dfrac{RLed \times (1-D)^2}{2\pi \times L}$
Fc of the Buck-type	Fc of the Boost-type
$Fc \leqq \dfrac{Fosc}{10}$	$Fc \leqq \dfrac{Fz2}{10}$

*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 Table7. *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.Usually, at the case of Buck-type, Fc is set up in less than 1/10 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 1/10 of Fz2.

*" K" is the multiplier which is characteristic of the feedback loop of LC5720S.

K=2.497E-4

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

Table.11 Buck-type ,Fosc=500kHz, ILED=2A, ⊿IL=0.8A

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(pF)
1	3.6	5	2.7	1	10	50	4.53	2814
2	7.1	12	7.5	1	10	50	8.93	1427
3	10.6	15	8.2	1	10	50	13.33	956
4	14.1	18	8.2	1	10	50	17.73	719
5	17.6	24	12	1	10	50	22.13	576
6	21.1	28	15	1	10	50	26.53	480
7	24.6	33	18	1	10	50	30.93	412
8	28.1	36	18	1	10	50	35.34	361
9	31.6	40	18	1	10	50	39.74	321

*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.
*Table12 is the same situations,too.

Table.12 Boost-type, Fosc=500kHz, ILED=1A, ⊿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(pF)
2	7.1	5	7.5	1	10	14.952	2.67	15956
3	10.6	5	15	1	10	5.007	1.33	95286
3	10.6	7	12	1	10	12.268	3.27	15874
4	14.1	7	18	1	10	6.149	2.18	47510
4	14.1	9	18	1	10	10.164	3.6	17387
5	17.6	12	20	1	10	13.028	5.77	8478
6	21.1	12	27	1	10	8.05	4.27	18523
6	21.1	15	22	1	10	15.436	8.19	5037
7	24.6	12	33	1	10	5.649	3.5	32259
7	24.6	15	33	1	10	8.827	5.46	13214
7	24.6	18	27	1	10	15.535	9.61	4266
8	28.1	15	36	1	10	7.083	5.01	17962
8	28.1	18	33	1	10	11.127	7.86	7279
9	31.6	18	39	1	10	8.373	6.65	11433
10	35.1	24	39	1	10	13.401	11.83	4018

*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 Table11 - the Table12, adjust compensation value in accordance with the condition of the use, under the actual movement .

8.9 Peripheral Parts Design

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

- Inductor L
  This is a choke coil for smoothing LED current.
  When the indactance 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.

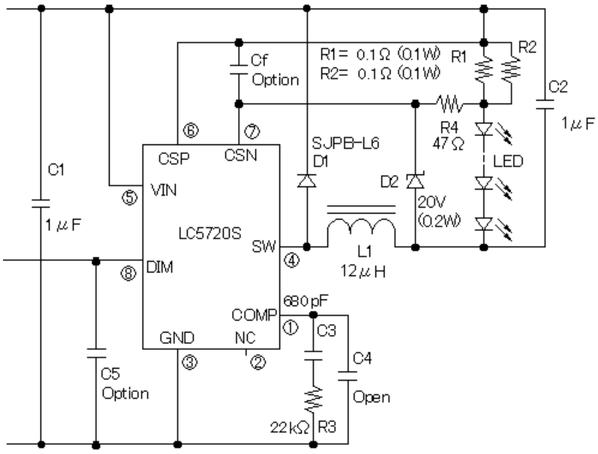
- Input capacitor C_{IN}
  This is a smoothing capacitor for main power supply. When the capacitance is larger, the ripple voltage is smaller.
  It is recommended to choose the capacitance according to the output power because the ripple voltage becomes bigger when the output power increases even if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

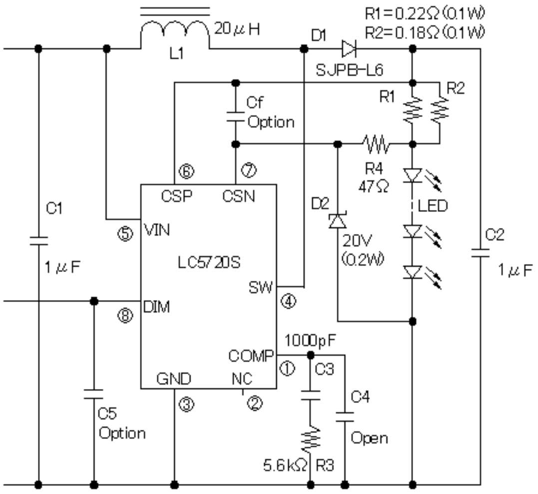
8.10 Reference Design Example

(A)Buck-type



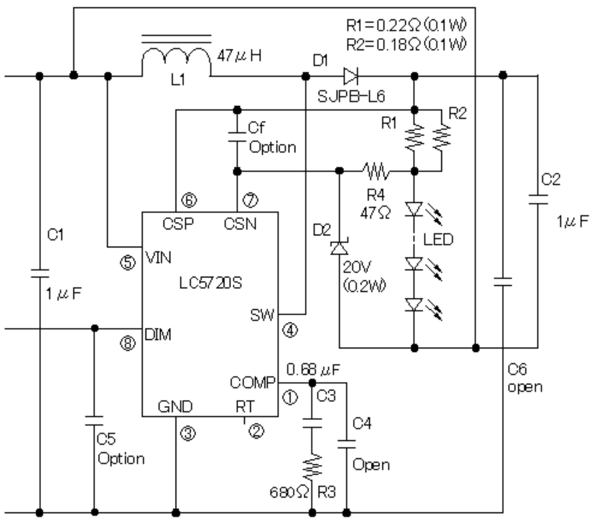
Fosc=500kHz
ILED=2A
Inductor ripple current ⊿IL=0.8A
Number of LED=5LEDs(Vout=17.6V)
VIN=24V
Vsw=24V
Cout(ESR)=10mΩ/ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

(B)Boost-type



Fosc=500kHz
ILED=1A
Inductor ripple current ⊿IL=0.4A
Number of LED=7LEDs(Vout=17.6V)
VIN=12V
Vsw=17.6V
Cout(ESR)=10mΩ/ ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

(C)Buckboost-type



Fosc=500kHz
ILED=1A
Inductor ripple current ⊿IL=0.4A
Number of LED=5LEDs(Vout=17.6V)
VIN=17V
Vsw=34.6V
Cout(ESR)=10mΩ/ ceramics capacitor
Cp(C4):Open
*SJPB-L6 being used as the D1 is manufactured by "Sanken-electric Co".

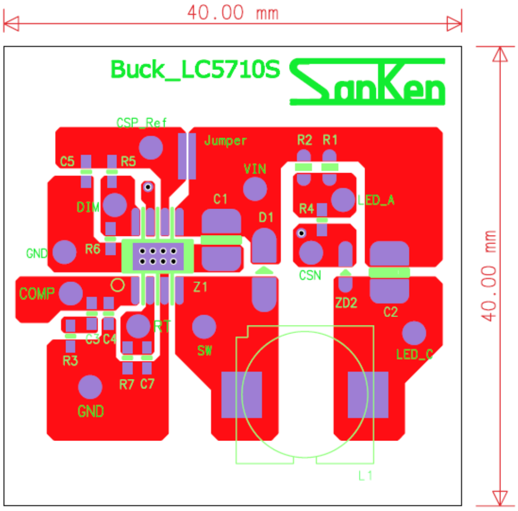
*The above reference design example is only a guide. Decide the fixed-number on your circuit board after you confirm a movement in the actual working,experiment adjustment.

fig.18 (a) - (c) Reference design example

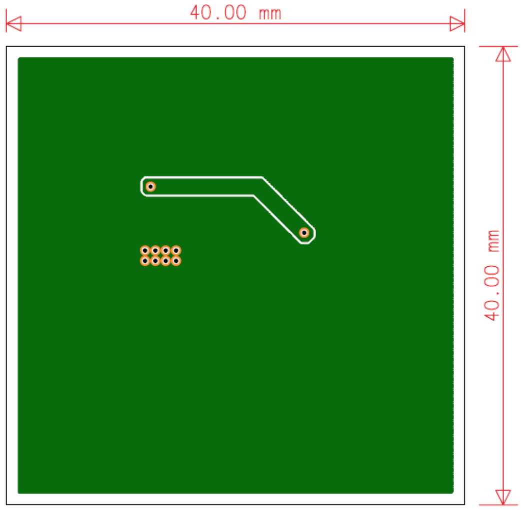
9. Example Pattern Layout

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

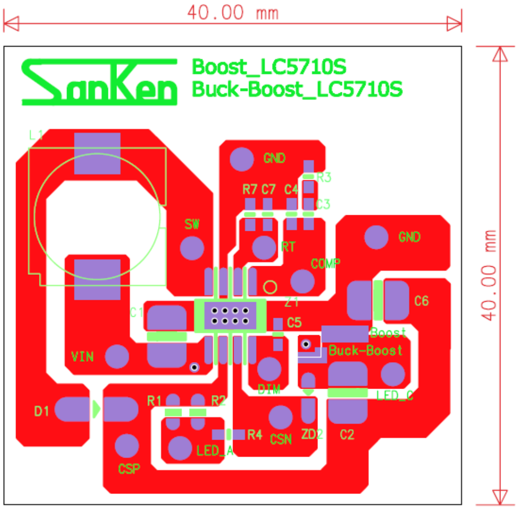
9.1 pattern layout



For Buck-type (parts mounting side)

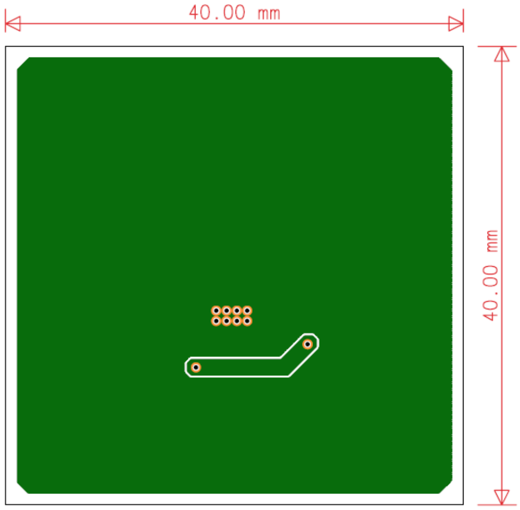


For Buck-type(back side)



For Boost-type/Buckboost-type

(parts mounting side)



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

fig.19 Demo-board pattern layout

*Foot print drawing

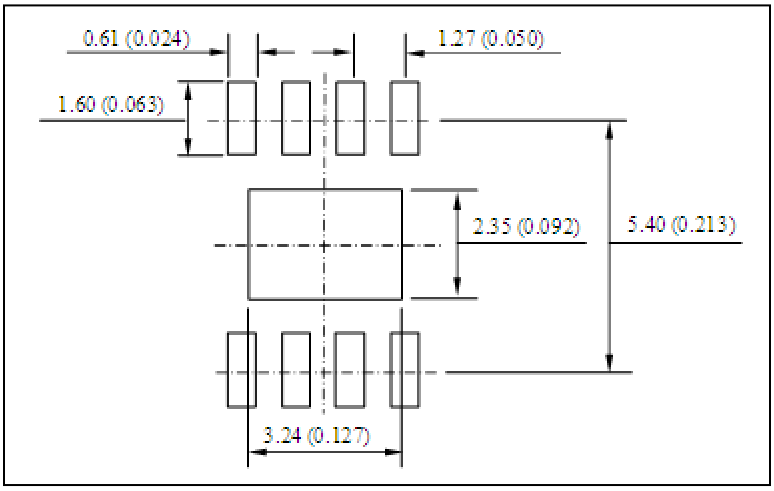


fig.20 Footprint drawing for LC5720S

9.2Circuit diagram of Demonstration-Board

9.2.1 For Buck-type

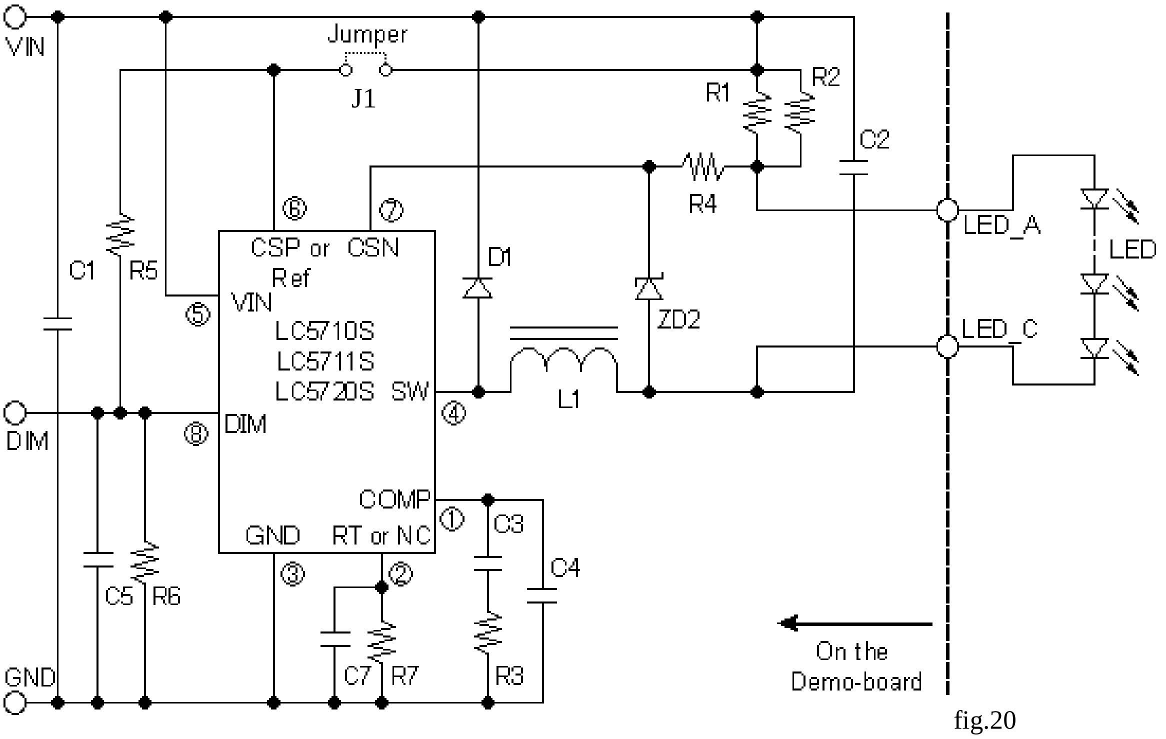


fig.20

*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

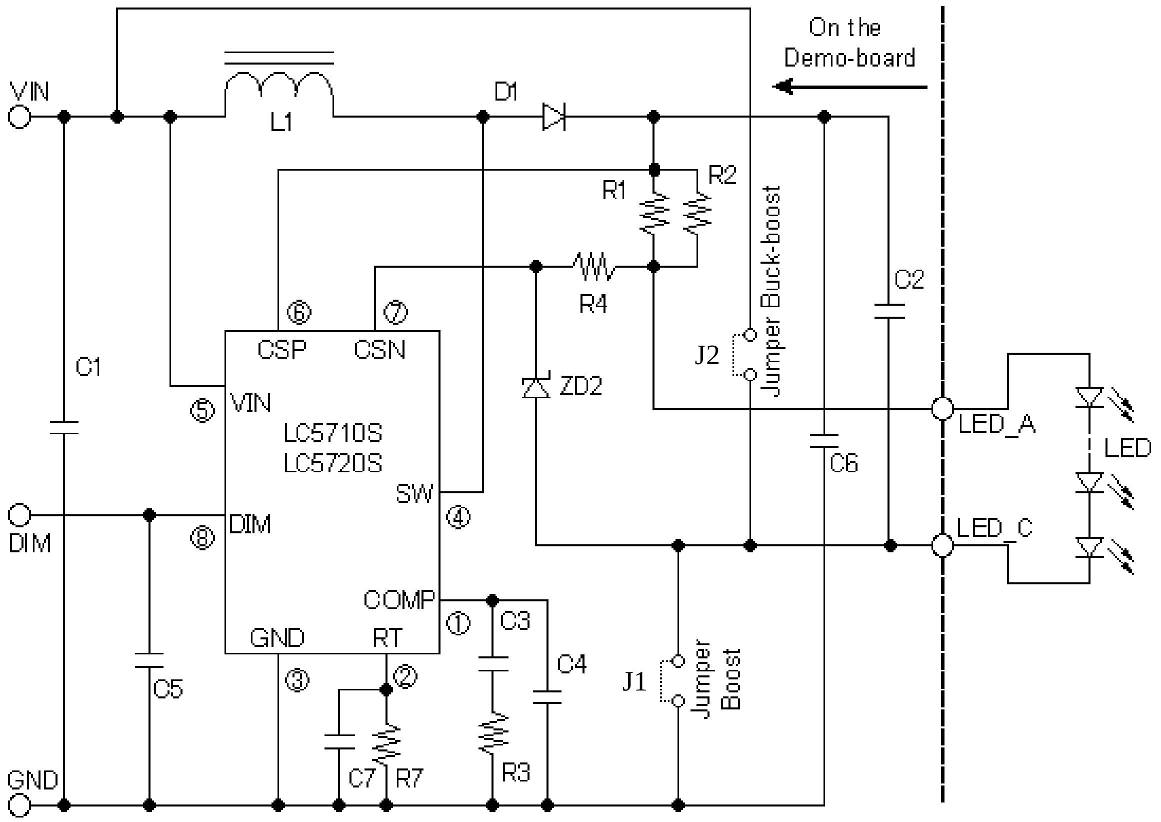


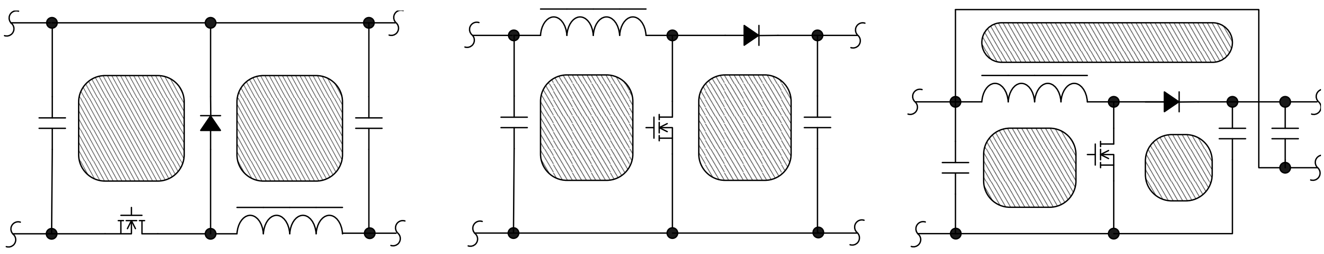
fig.21

*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

Trace 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.22, 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.22 High frequency current loops（hatched portion）

fig.23 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.

(2) 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.

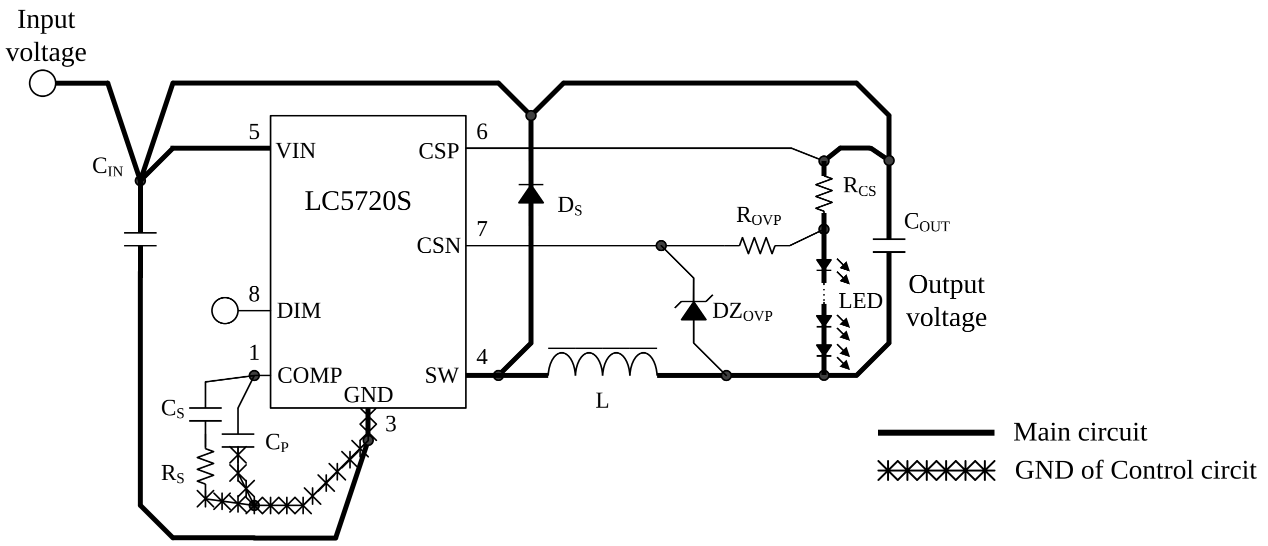
(3) Traces around the current detection resistor, R_{CS}
The traces of R_{CS} should be connected to CSP pin and CSN pin with dedicated traces respectively, in order to reduce noises when the current is detected. When the noise between CSP and CSN is high, a filter capacitor Cf can be added like a "Page8, 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.

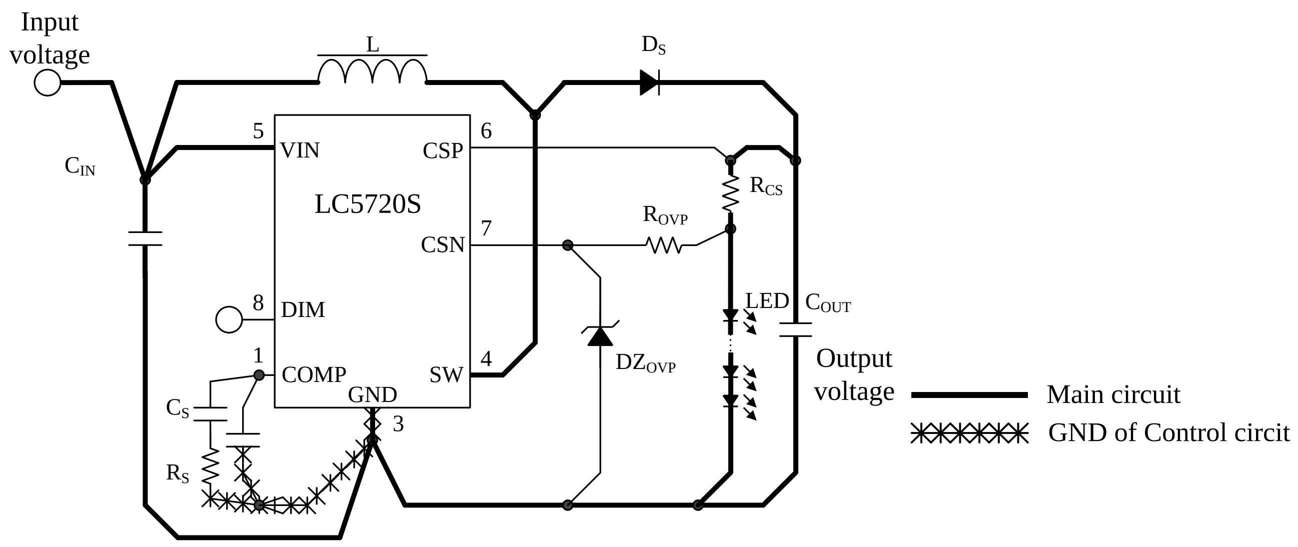
(5)When C_{OUT} is used, it should be connected close to LED string.

* 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.

(A)**Buck-type**



(B)Boost-type



(C)Buckboost-type

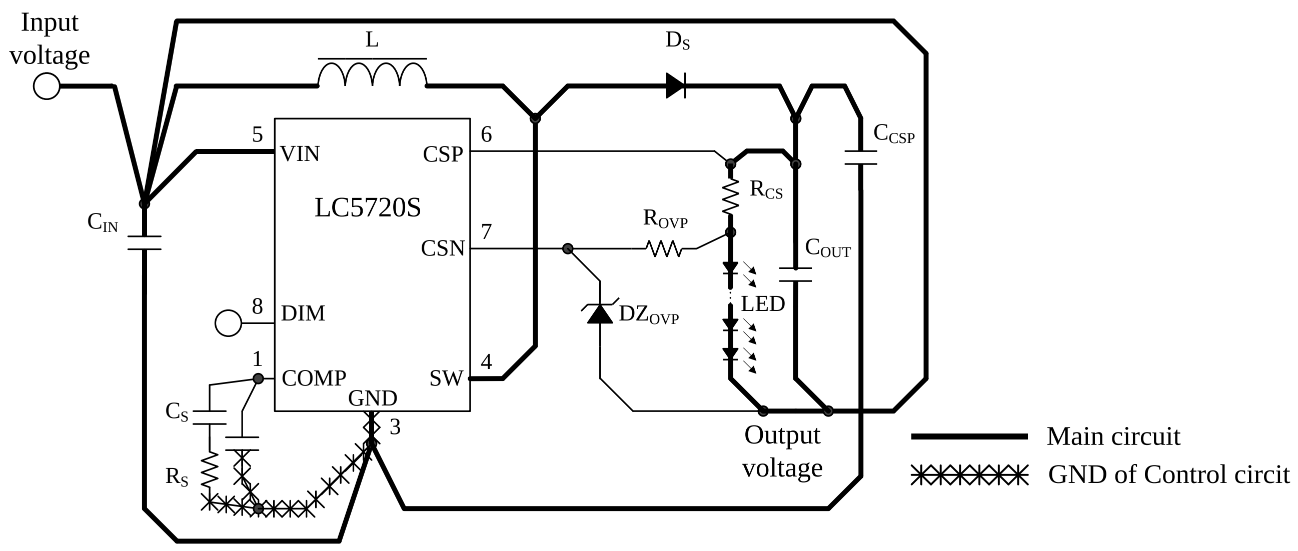


Fig.23 The trace of the pattern

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