DESCRIPTIONS

EKSD42511_01_V1.0 is the evaluation board for SD42511. When the supply voltage is 12V, the output is 350mA, 700mA, 1A constant current, it can drive six LEDs, the max. efficiency is up to 95%.

SD42511 is a step-down PWM control LED driver with a built-in internal power MOSFET. It achieves 1A continuous output current over a wide input supply range. It provides thermal shutdown circuit, current limiting circuit and PWM dimming.

SD42511 has high efficiency of up to more than 90%, and has excellent constant current characteristic when the input voltage changed, with average current characteristic in the whole voltage range within ±1%. With the high input voltage of up to 25V and built-in slope compensation, it can drive six LEDs or LED strings.

DEMO BOARD

Size: 31×27×1.5(mm^3)

Board name	IC no.
EKSD42511_01_V1.0	SD42511

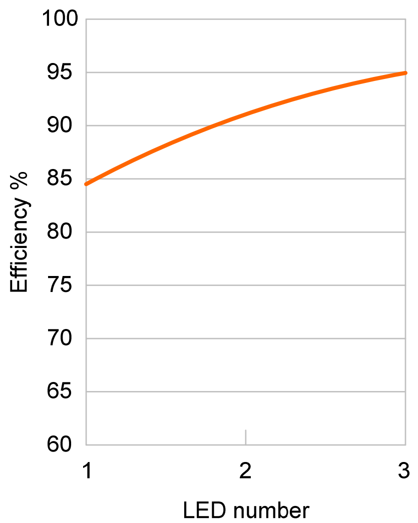
FEATURES

* Max. 1A output current
* 0.25Ω internal power MOSFET
* PWM dimming
* 280kHz fixed frequency
* Current accuracy ±1%
* High efficiency is up to 90% when drive multi-LEDs.
* Thermal shutdown
* Cycle-by-cycle over current protection
* 6-25V input voltage range

ELECTRICAL PARAMETERS

Parameter	Symbol	Rating	Unit
Input Voltage	V_{IN}	6~25	V
Output Current	I_{OUT}	0.35~1	A
Conversion Efficiency	Ev	95(Max.)	%

EFFICIENCY CURVE



Connect 1-3 LEDs under 12V voltage

TOPOLOGY

EKSD42511_01_V1.0 adopts step-down converter (Buck converter) topology to drive Power LED. The step-down converter is the basic power regulator which composed of a power MOSFET, diode, LC filter net and load, its average output voltage is less than input voltage ($V_{OUT}<V_{CC}$), and provides unipolar output voltage and single-phase output current. The step-down converter is mainly applied in the situation that needn't isolation between input and output port and input voltage is always higher than output voltage, this converter is seldom applied in the common circuit, mainly in the derive circuits such as return, forward, push-pull, half-bridge or complete bridge.

Buck converter structure refers to fig.1, includes power MOSFET M1, schottky diode D1, inductor L1 and LED. Power MOSFET M1 is controlled by IC through detecting the current of Rsense.

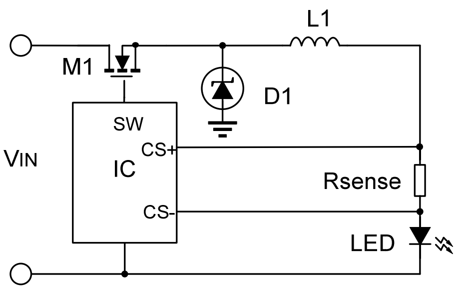


Fig. 1 the structure of buck converter drive to Power LED

BUCK circuit has three modes: continuous conduction mode, continuous-discontinuous conduction mode boundary and discontinuous-conduction mode. When the BUCK circuit runs in the continuous conduction mode, the voltage and current of inductor refers to fig.2. During charge and discharge, the current direction of inductor remains unchanged, and the current value is varying from ILmax to ILmin, it won't decrease to zero. On the other side, when BUCK circuit runs in the discontinuous-conduction mode, the current of inductor remains zero for some time, and then begins to next charge and discharge period, the current is in discontinuous state.

Continuous Conduction Mode

In the fig.2, tON is the M1 conduct period, tOFF is M1cut-off period, the detail operating will be discussed in the next content:

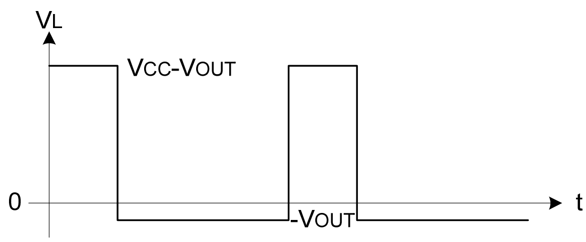


Fig.2(A) Inductance voltage of BUCK circuit in continuous conduction mode

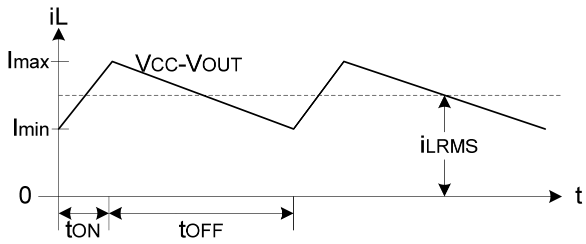


Fig. 2(B)Inductance circuit of BUCK circuit in continuous conduction mode

(1) Power MOSFET M1 conduct period (tON)

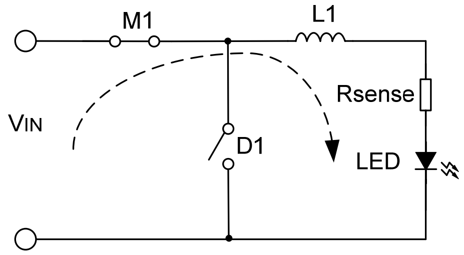


Fig. 3 In power MOSFET M1 conduction mode, LED is lighted through loop circuit

When power M1 is on, diode D1 is off, the circuit starts from power Vin, through MOSFET M1, inductor L1 and sense resistor Rsense and LED, the inductor charged and supply to load at the same time.

$$V_L = L * \frac{di_L}{dt} \Rightarrow \Delta I_L = \frac{V_L}{L} * \Delta T$$

$$\Delta I_L(+) = \frac{V_{IN} - V_{DS} - I_L * (R_L + Rsense) - V_{OUT}}{L} * t_{ON},$$

Where,

$\Delta I_L(+)$ is the added current in M1 on period;

V_{DS} is the conduction voltage in M1 on period;

R_L is inductor resistance;

t_{ON} is on time.

(2) The period when power MOSFET M1 is off (tOFF)

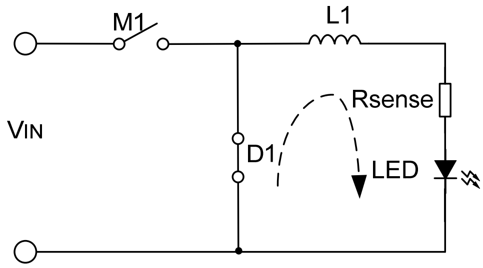


Fig.4 when Power MOSFET M1 off, inductor discharge to light the LED

When power MOSFET M1 is off, because the inductor current can not be abrupt change, the diode D1 is on, thus form the current loop via inductor L1, Rsense and LED. Now the power VIN can not feed the output load directly, so the storage energy of the inductor will discharge to light LED through this close loop. The inductance current is decreased to:

$$\Delta I_L(-)=\frac{V_{D1}+I_L*(R_L+Rsense)+V_{OUT}}{L}*t_{OFF}$$

Where, VD1 is conduction voltage of D1.

According to the energy conservation theorem, the energy stored in the inductor must equal to the energy that discharged from inductor to load, thus the discharge current cycled. So after a complete discharge period, the net current Itotal in the inductor is zero:

$$\Delta I_L(+)=\Delta I_L(-)\text{ ,therefore: }V_{OUT}=(V_{IN}-V_{DS})*\frac{t_{ON}}{t_{ON}+t_{OFF}}-V_{D1}*\frac{t_{OFF}}{t_{ON}+t_{OFF}}-I_L*(R_L+Rsense)$$

Because $D=\frac{t_{ON}}{t_{ON}+t_{OFF}}$, $1-D=\frac{t_{OFF}}{t_{ON}+t_{OFF}}$,so $V_{OUT}=(V_{IN}-V_{DS})*D-V_{D1}*(1-D)-I_L*(R_L+Rsense)$

Because the sample voltage caused by V_{DS}, V_{D1} and inductor resistance is smaller , it can be neglected, and the VDS,VD1, RL and Rsense are also can be neglected, so $V_{OUT}=V_{IN}*D$, which is the relation about input and output voltage.

Discontinuous Conduction Mode

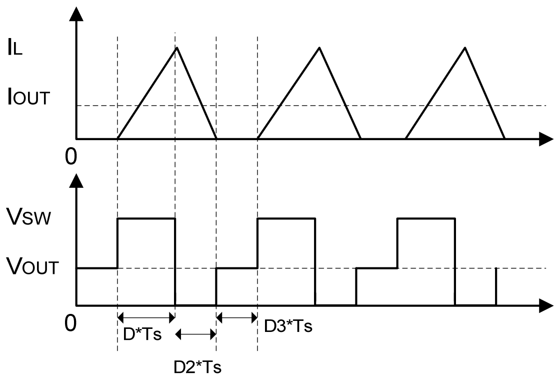


Fig.5 Inductor current and ON/OFF voltage waveform in discontinuous mode

Increased current: $\Delta I_L(+)=\frac{V_{IN}-V_{OUT}}{L}*t_{ON}$

Decreased current: $\Delta I_L(-)=\frac{V_{OUT}}{L}*t_{OFF}$

Because the above current is equation, so $V_{OUT}=V_{IN}*\frac{t_{ON}}{t_{ON}+t_{OFF}}=V_{IN}*(\frac{D}{D+D2})$

Output current: $I_{OUT}=\frac{V_{OUT}}{R}=\frac{Ipk}{2}*\frac{D*Ts+D2*Ts}{Ts}=\frac{(V_{IN}-V_{OUT})*D*Ts*(D+D2)}{2*L}$

So $V_{OUT}=\frac{(V_{IN}-V_{OUT})*D*Ts*(D+D2)}{2*L}*R$

Then $V_{OUT}=V_{IN}*\frac{2}{1+\sqrt{1+\frac{4*K}{D^2}}}$,where $K=\frac{2*L}{R*Ts}$, gain the relation about input and output voltage.

Continuous Mode And Discontinuous Mode Judgment

When $\Delta I_L = I_O$, it is in the boundary of continuous and discontinuous mode. That is $\frac{V_{OUT}}{2*L} * t_{OFF} = I_{OUT}$, so

$$L_{min} = \frac{V_{OUT} * (1 - \frac{V_{OUT}}{V_{INmax}})}{2 * I_{OUT}} * Ts$$

V_{INmax} is the max. voltage

When the inductor is larger than above value, system works in continuous mode, if the inductor is smaller than the value, system works in discontinuous mode.

To be brief, in the BUCK structure, input port only supply for output port in MOSFET on period, other time is supplied through inductor. The inductor store energy in MOSFET on period, and release energy at MOSFET off period. The charge and discharge of inductor generates sawtooth wave current that is current ripple, refers to fig.2(B) . the positive slope rate means charge, and the negative slope rate means discharge, the ripple(I_{max}-I_{min}) is affected by inductor:

$$V_L = L\frac{di_L}{dt} \longrightarrow \frac{di_L}{dt} = \frac{V_L}{L}$$

Where, VL is inductor voltage drop, L is inductor value, IL is the inductor current. From the above formula, the higher the inductor is, the smaller the slope of discharge current , the smaller the ripple is, and the LED output current is more stable.

IC OPERATION PRINCIPLE

Block Diagram

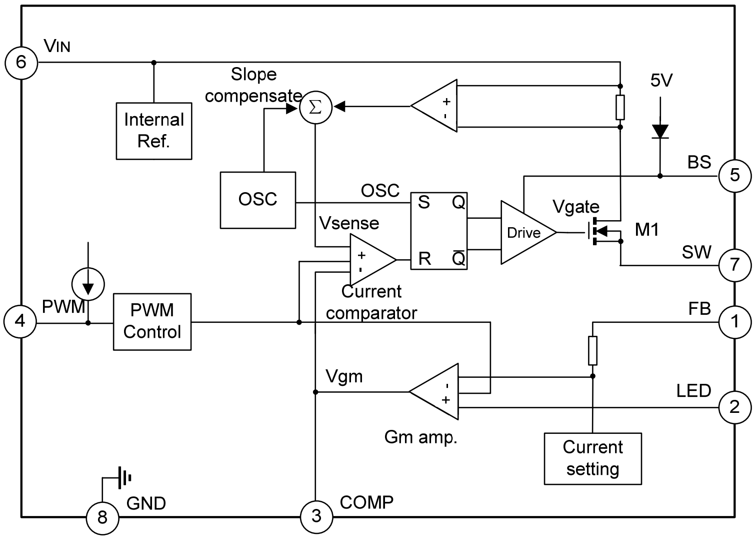


Fig.6 SD42511 block diagram

In the above fig, the beginning of a cycle: the upper transistor M1 is off; the COMP pin voltage is higher than the current sense amplifier output; and the current comparator's output is low. The rising edge of the 280KHz CLK signal sets the RS Flip-Flop. Its output turns on M1 thus connecting the SW pin and inductor to the input supply. The inductor current is sensed and amplified by the current sense amplifier. Ramp compensation is summed to current sense amplifier output and compared to the Gm amplifier output by the current comparator. When the current sense amplifier plus ramp compensation signal exceeds the comp pin voltage, the RS Flip-Flop is reset and the chip reverts to its initial M1 off state. If the current sense amplifier plus slope compensation signal does not exceed the comp voltage, then the falling edge of the CLK resets the RS Flip-Flop.

The trsanscondutance amplifier compares the output current to the threshold current (threshold current is set by internal). When the output current is higher than threshold current, the COMP pin's voltage is lower down. Since the COMP pin's voltage is proportional to the peak inductor current a decrease in its voltage decreases current delivered to the output. When the output current is lower than threshold current, the COMP pin's voltage is up while the output current increases. The output current is stable at the set value by the adjusting of the loop. Refers to the fig.7:

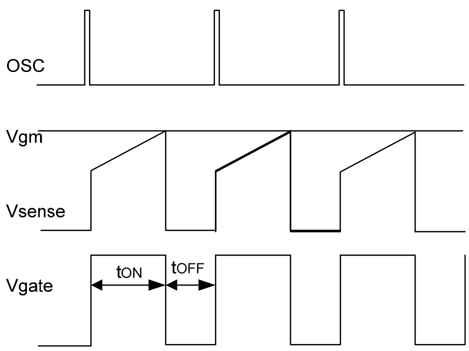


Fig.7 output waveform

PWM Dimming

PWM dimming is one important function of LED driver, the PWM dimming adjust the LED current through controlling the chip normal working and cutoff time with external PWM signal. The traditional analog dimming changes the LED peak current to shift the average current; while PWM dimming has no color difference compare to the analog dimming, and the dimming ratio is larger than the analog dimming. Now, most of LED driver adopt PWM dimming. There are two dimming modes: one is output current is sync with external PWM signal, and the LED current is controlled by external signal, the output peak current remains unchanged. When the external PWM control turns on, LED output current outputs normally; when the external PWM control turns off, LED won't output any current. Thus realize the PWM dimming through controlling the PWM duty. Another mode is PWM is converted to DC signal through filter, and then change the LED peak current, this mode has the same effect as analog dimming, so it is not PWM dimming in strict definition.

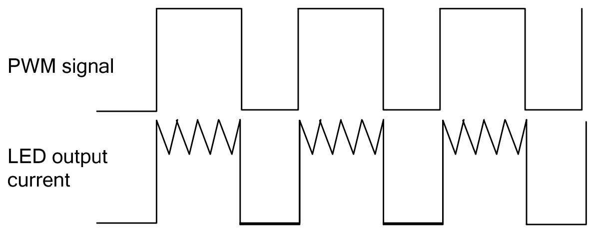


Fig.8 PWM dimming waveform

SD42511 has internal PWM dimming function. When PWM voltage is open or connects to high level, the chip is working normally; when PWM voltage connects to low level, COMP pin disconnects with the chip, the charge of the capacitor is in hold state, voltage level holds, and the output of current comparator is high, transistor is off without output current. When PWM signal is high, COMP pin is connected with the chip to improve the startup speed of the chip. Adjust the output current by control the duty of external PWM signal.

The minimum setup time of SD42511 PWM dimming is less than 20μS, and the maximum PWM dimming ratio is up to 500:1. When high dimming ratio is needed, the dimming frequency is recommended 500Hz below; or else the dimming frequency can be up to 2 KHz. When PWM pin is low, output is shutdown. In normal condition, LED pin holds above 2V, and if the LED or other components have electric leakage which makes the LED pin is low and caused change on PWM dimming, we recommend to increase the output capacitor, then the LED level will not be too low when shutdown to maintain the normal PWM dimming.

Output Current Setting

The output current is determined by the sampling resistor and setting voltage. The sampling voltage of $V_{FB}-V_{LED}$ is 88mV, and adjusts the output current by adjusting the sampling resistor Rs (refer to Typical Application Circuit).

$$I_{OUT} = \frac{V_{FB} - V_{LED}}{R_S}$$

Because the sample resistor is very small that ensures the chip efficiency.

DEMO DESIGN GUIDANCE

EKSD42511_01_V1.0 is the application board used to drive Power LED, the structure is as follows. In low voltage (6-25V) application, power MOSFET is embedded in IC which adopts BUCK step-down structure. The input voltage of 6-25V can drive one or more serial LEDs. All the components are selected according to the application; we will discuss it next:

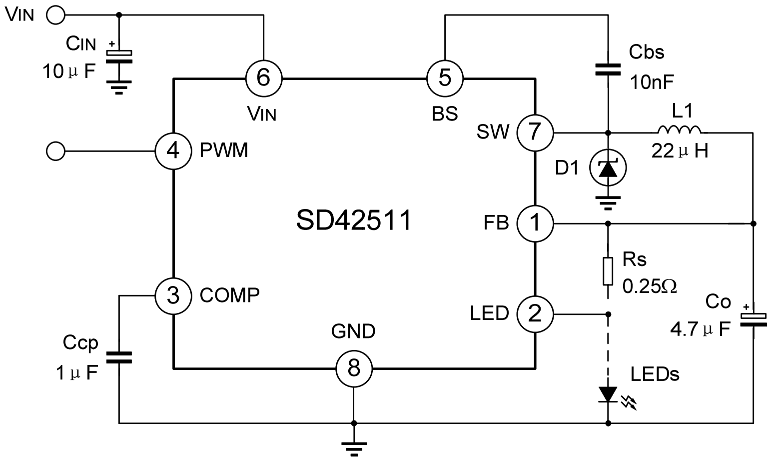


Fig.9 Typical application circuit

Power LED

The brightness of LED is direct proportion to the drive current, the higher the drive current, the greater the brightness, take the LumiLED for example, the relationship between brightness and drive current refers to fig.10:

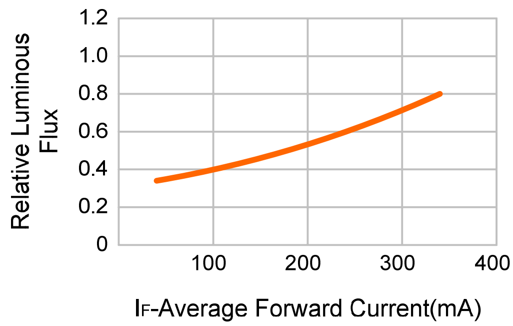


Fig.10 Power LED brightness and drive current

In the other side, when LED is forward conduction, the forward voltage V_F will increase with drive current increasing, refer to fig.11:

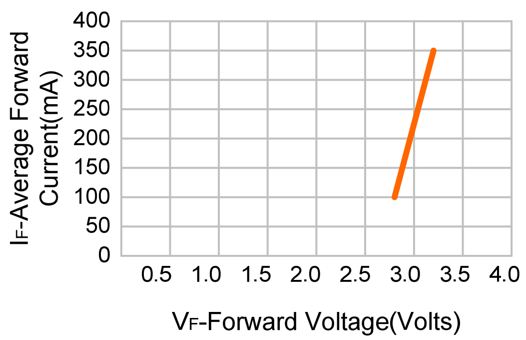


Fig. 11 LED forward voltage and drive current

Expect the drive current, LED forward voltage V_F will decrease with the junction temperature increasing. Take the LumiLED-DS47 series for example; when the drive current is 350mA, V_F decreased 2mA for junction temperature increased 1°C.

For the Quantum LED, in the 350mA drive current, input voltage of measuring one and more LEDs list as following table:

White LED no.	VIN(V)@ I=350mA	VIN(V)@ I=700mA
1	4.5	4.5
2	7.6	8
3	11.5	12
4	15	16
5	18.5	20
6	22.5	24

Conditions: 1. Rsense=0.25Ω(350mA);Rsense=0.125Ω(700mA)L=22μH;

2. LED forward voltage VF=3.3V(350mA); VF=3.4V(700mA);
3. Because the max. Voltage is 25V, so the max. Number of serial LEDs is 6.
4. additionally, because the V_F is different according to vary factories, general speaking, the V_F of 3W LED is larger than 1W. According to BUCK schematic, if the V_F is too large, SD42511 may not drive six serial 3W LEDs at 24V voltage.

Input Capacitor Selection

The input capacitor provides the pulse current when the power MOSFET is on, and charge the capacitor when the power MOSFET is off, thus to keep the stability of the input voltage. The input capacitor is recommended to be more than 10μF, which can reduce the peak current drawn from input source and the switch noise. The input capacitor should be near to the input pin when in real routing.

Output Capacitor Selection

Parallel connecting a capacitor between the two ends of LED can reduce the output voltage ripple accordingly reduce the ripple current of LED, while this capacitor will not effect the operating frequency and efficiency, but the start time will be longer by reducing the rising speed of the voltage on LED. The larger the output capacitor is, the smaller the current ripple on LED is. It is recommend to use the capacitor of 4.7μF or larger.

Inductor Selection

The inductance is used to keep the output current constant, the bigger the inductance is, the smaller the output current ripple is; while the bigger the physical size is, the bigger the series-wound resistor is. The selected effective current (RMS current rating)of inductance current should be bigger than the maximum output current, and the saturation current should be 30% bigger than maximum output current. In order to improve the efficiency, the series-wound resistor (DCR) of inductance should be smaller than 0.2Ω.

The relation between inductance and ripple:

$$L = V_{OUT} * \frac{V_{IN} - V_{OUT}}{V_{IN} * f * \Delta I}$$

Where: L: Inductance value

F: Oscillator frequency

ΔI is ripple current

When select inductance, you should consider the combination of various factors to select suitable inductance.

When output current is less than 700mA, you can use 22μH inductance; and the inductance value is recommended to increase with the increasing of the number of serial LEDs; when output current is 1A, 47μH inductance is recommended.

Diode Selection

SD42511 is a non-synchronous step-down adjuster, so the diode should provide continuous current when the power MOSFET is off. Because the forward voltage of Schottky diode is small, and the reverse continuous current time is short, so it is usually used for continuous current. During the power MOSFET is conducting, the diode will withstand high voltage, so the reverse voltage of selected diode should be bigger than the input voltage.

The average current through the diode is ID:

$I_D = (1-D) * I_{LED}$ ILED is the current of LED

When the input voltage is high with a small duty, ID increases, so the selected maximum continuous current diode should be bigger than the output current.

Sample Resistor Setting

Output current is determined through sample resistor and setting voltage. The sampling voltage of VFB-VLED is 88mV. and adjusts the output current by adjusting the sampling resistor Rs (refer to Typical Application Circuit).

$$Rs = \frac{V_{FB} - V_{LED}}{I_{OUT}}$$

VFB is the voltage of FB; VLED is the voltage of LED, IOUT is current flow through LED.

EVALUATION BOARD SCHEMATIC

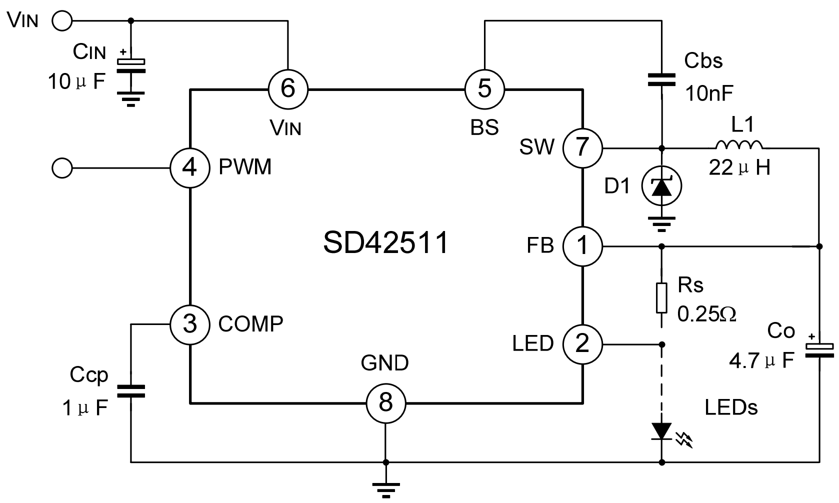
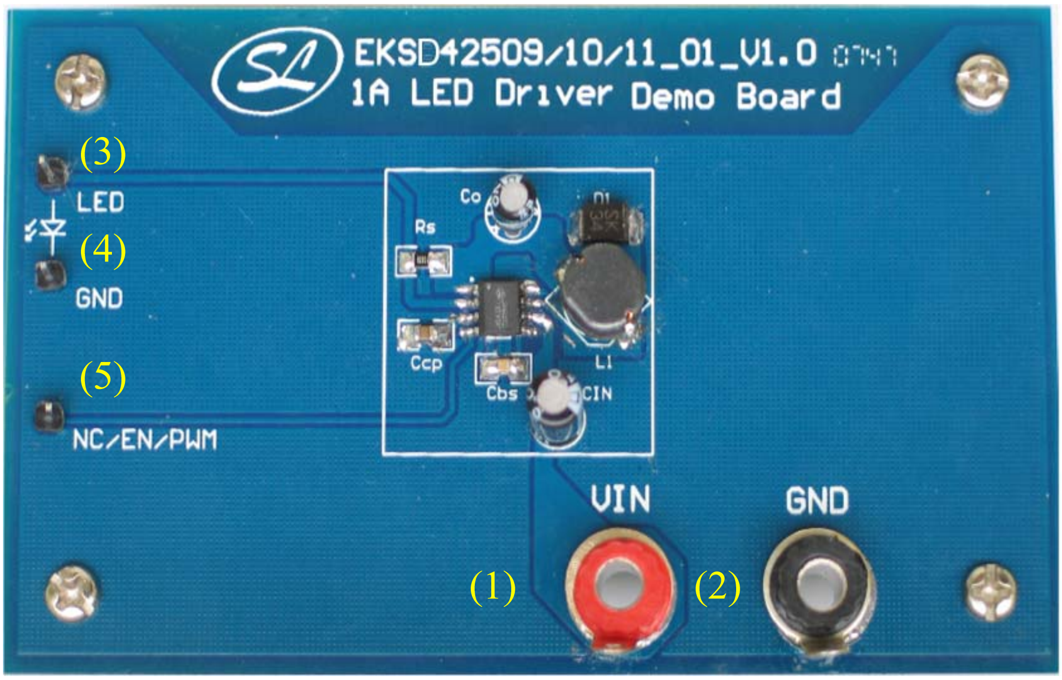


Fig.12 DEMO board schematic

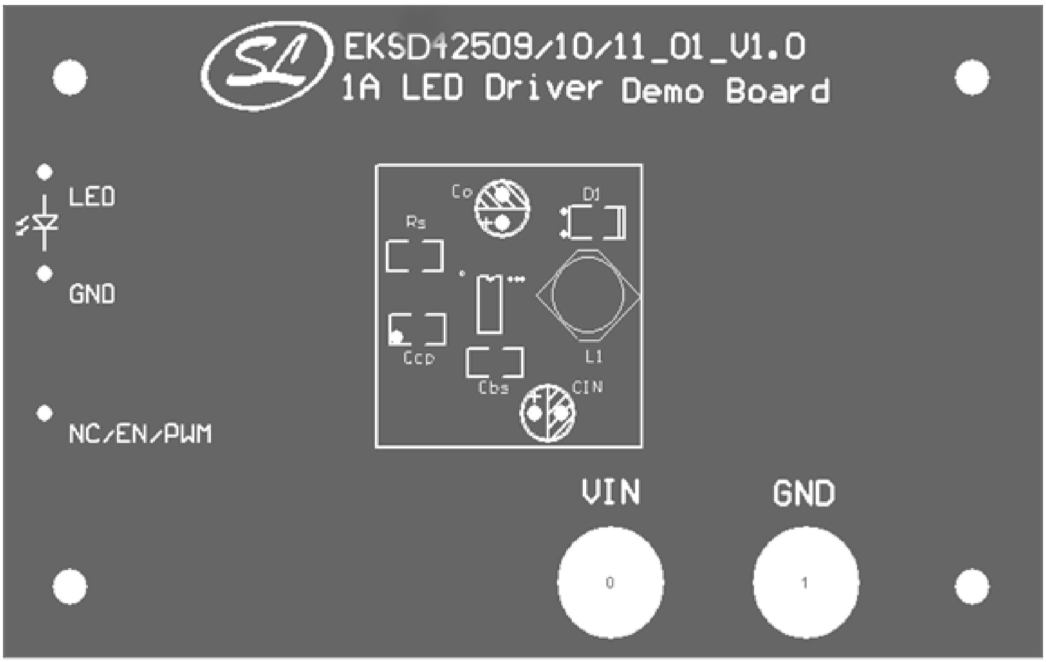
COMPONENTS LIST

Quantity	Name	Value	Package	Notes
1	Rs	0.25	0805	-
1	Ccp	1µF	0805	10V withstand voltage
1	Co	4.7µF	-	50V withstand voltage
1	CIN	10µF	-	50V withstand voltage
1	Cbs	10nF	0805	10V withstand voltage
1	L1	22µH/47µH	SMD	110mΩ resistance
1	D1	5819/5822	SMA	2A/3A
1	-	SD42511	SOP8	Main control IC

PCB LAYOUT

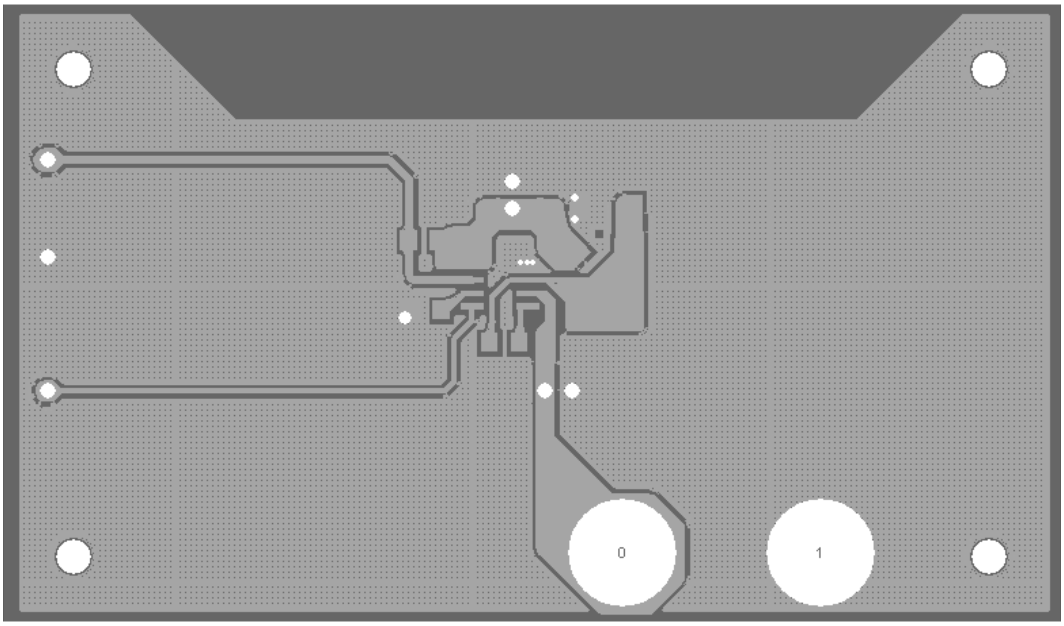


PCB Board



Top silk layer

PCB LAYOUT(continued)



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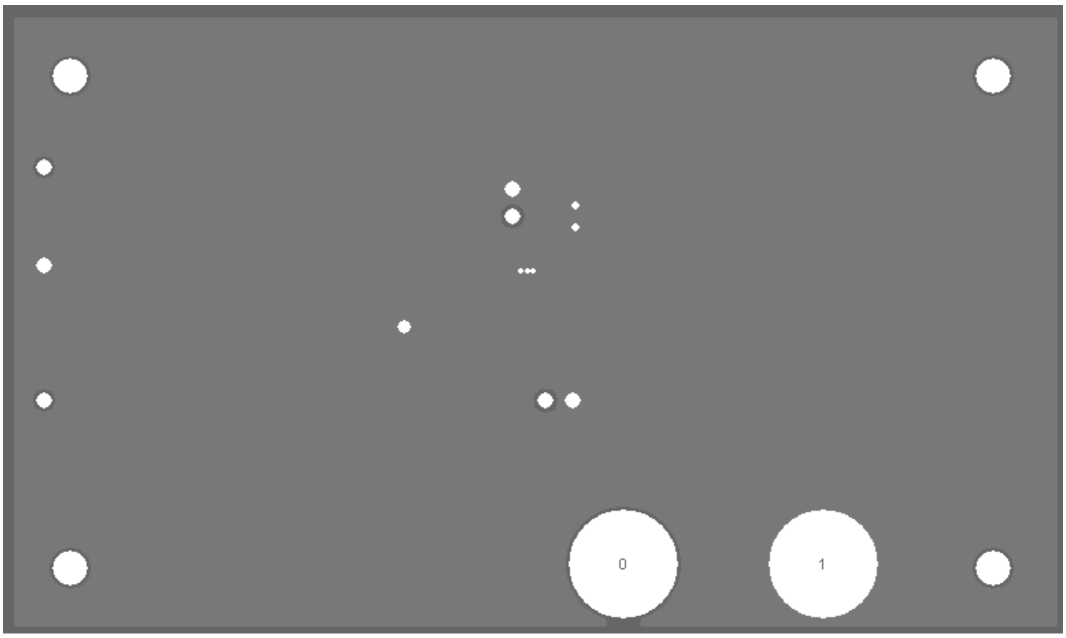

Bottom layer

APPLICATION EXPLANATION

- **Interface description**

1. VIN(1)/GND(2) connect with input power supply and ground respectively.
2. LED(3)/GND(4) connect with load LED positive and negative polar.
3. PWM(5) is PWM dimming input port.

- **Conditions**

1. The max. VIN is 25V, don't exceed the safety voltage in application.
2. The load can connect 1~6 LEDs.

- **Steps**

1. Select sample resistor according to the needed current;
2. Select proper external components according the load and output current;
3. Please pay attention to the positive or negative of LED in connection;
4. Supply to VIN after confirm;
5. Output current can be adjusted through PWM pin, the dimming frequency selected in the range of 100Hz~2KHz, PWM high level must be lower than 5.5V.

- **Caution**

1. The loop area of power loop is as small as possible, and the line is short and as thick as possible.
2. Input capacitor should be near to the input pin and the GND pin.
3. The GND line is better to be made as ground level.