4.5V to 32V Input High Current LED Driver IC

For Buck or Buck-Boost Topology

CN5816

General Description:

The CN5816 is a current mode fixed-frequency PWM controller for high current LED applications. The device operates from an input supply between 4.5V and 32V and provides to drive an external N-channel MOSFET. With the maximum operating input voltage of 32V, the CN5816 is ideal for buck or buck-boost LED driver operation.

The CN5816 contains all the necessary building blocks including a bandgap reference, a 330KHz oscillator, current-mode control circuitry, chip shutdown block, softstart block and gate driver, etc. Current mode control provides improved transient response and simplified loop compensation. On-chip soft start reduces the inrush current on power up. The other features include chip shutdown, over voltage protection, built-in 5V regulator and slope compensation, etc.

The CN5816 is available in 10-pin SSOP package.

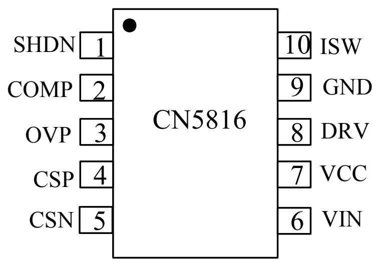
Applications:

- High Power LED Lighting
- Desk Lights and Room Lighting
- Building and Street Lighting
- Industrial Display Backlighting

Features:

- Peak Current Mode Controller
- 4.5V to 32V Input Range
- Buck or Buck-Boost Operation
- 330kHz Switching Frequency
- High Side Current Sense
- 120mV Current Sense Threshold
- Cycle-by-Cycle Peak Inductor Current Limit
- On-Chip Slope Compensation
- Programmable Over Voltage Protection
- Internal Soft-start to Avoid Inrush Current
- Built-in 5V Regulator
- Low Shutdown Current
- Operating Temperature Range:
  －40℃ to 85℃
- Available in 10-pin SSOP package.
- Lead-free, Rohs-compliant and Halogen free

Pin Assignment



Typical Application Circuit

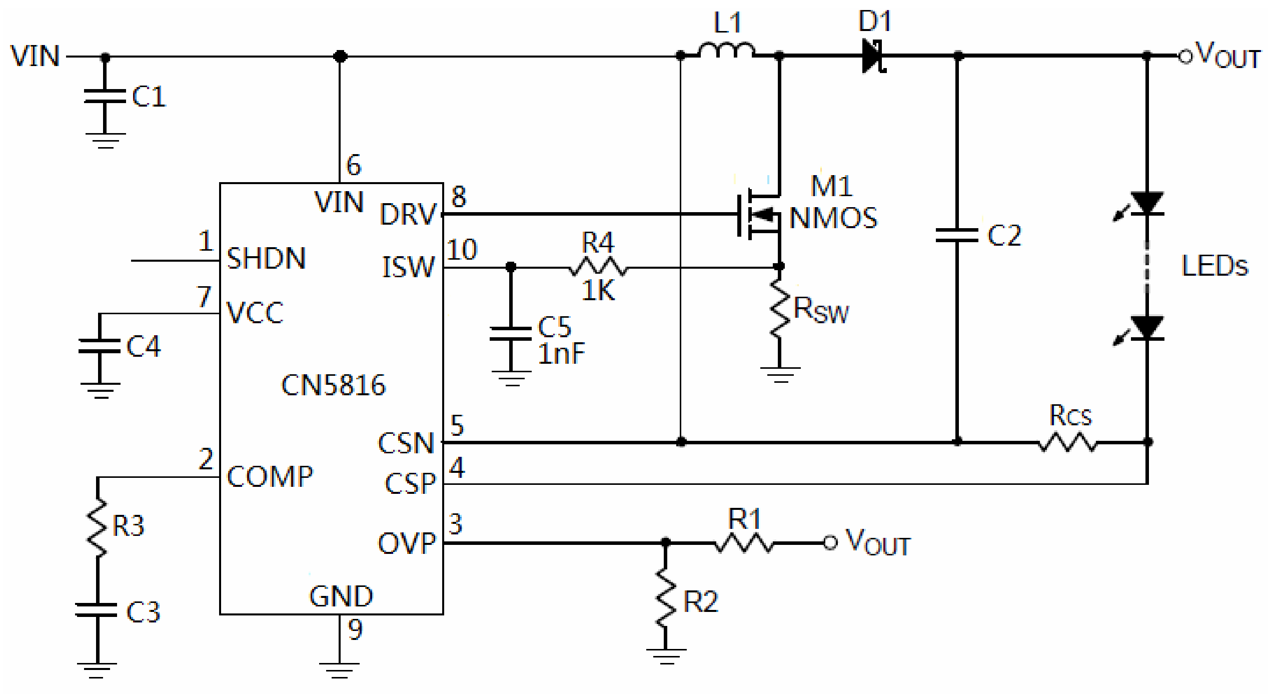


Figure 1 Typical Application Circuit of Buck-Boost Topology

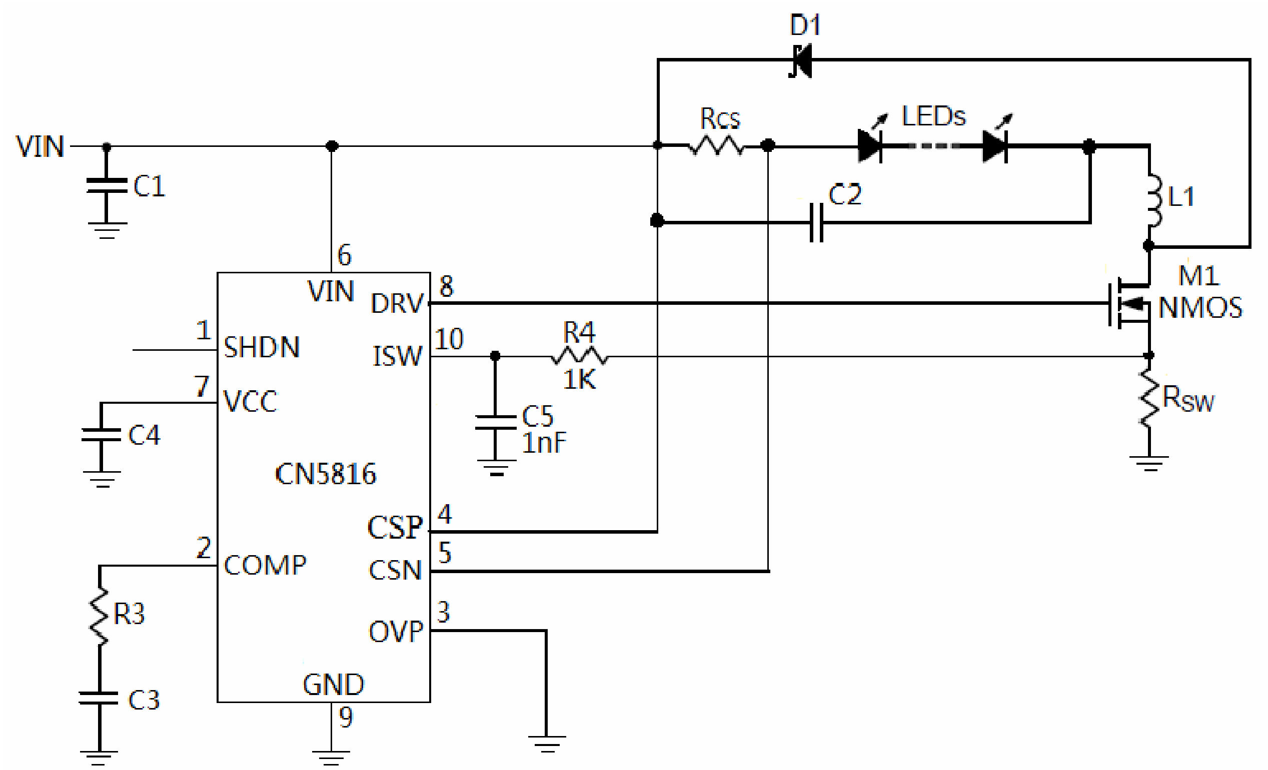


Figure 2 Typical Application Circuit of Buck Topology

Ordering Information

Part No.	Shipment	Operating Ambient Temperature
CN5816	Tape and Reel, 3000/Reel	－40℃ to ＋85℃

Pin Description

No.	Name	Description
1	SHDN	**Shutdown Input Pin.** Pulling this pin high, places the CN5816 into shutdown mode. Shutdown mode is characterized by a very low quiescent current. In shutdown mode, all the functionality of all blocks is disabled and the on-chip 5V regulator is also shutdown. Pulling this pin low places the part into normal operation mode.
2	COMP	**Compensation Pin.** Connect the compensation network between COMP pin and GND to stabilize the PWM control loop.
3	OVP	**Over Voltage Protection Input Pin.** The PWM converter turns off when the voltage of the pin goes to higher than 1.283V, and returns to normal operation if the voltage at OVP pin falls below 1.219V.
4	CSP	**Positive Terminal of Current Sense.** Connect CSP pin to one terminal of external current sense resistor for high side LED current sensing.
5	CSN	**Negative Terminal of Current Sense.** Connect CSN pin to one terminal of external current sense resistor for high side LED current sensing.
6	VIN	**Input Supply Voltage.** Positive terminal of input supply. The input voltage range is 4.5V to 32V. Connect a local bypass capacitor from this pin to GND.
7	VCC	**5V Regulator output.** A bypass capacitor of 4.7uF at least should be connected from this pin to GND. If the input voltage is less than 5.5V, the voltage at VCC pin may be less than 5V.
8	DRV	**Gate Drive Pin.** Gate drive for the external N-channel MOSFET. Connect this pin to the gate of external N-channel MOSFET.
9	GND	**Ground.** Negative terminal of input supply.
10	ISW	**Inductor Current Sense Pin.** The inductor current is sensed at ISW pin on the cycle-by-cycle basis for both the current mode control and overcurrent protection.

Absolute Maximum Ratings

VIN,CSP,CSN Terminal Voltage..…－0.3V to 36V
Other Terminals Voltage…………..－0.3V to 6.5V
Operating Temperature…...............－40℃ to 85℃
Thermal Resistance(Junction to Case) .....200℃/W

Maximum Junction Temperature……………150℃
Storage Temperature……….......－65℃ to 150℃
Lead Temperature(Soldering，10seconds)….260℃

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

(VIN = 12V, TA＝－40°C to +85°C, Typical values are at TA＝+25°C, unless otherwise noted)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Supply Voltage	VIN		4.5		32	V
Input Supply Current	I_{VIN}	V_{FB}＝1.3V, V_{SHDN}=0V	700	800	900	µA
Shutdown Current	I_{SD}	SHDN＝3V, VIN＝12V	3.6	5.2	6.8	µA
		SHDN＝3V, VIN＝30V	9	13	17	
Switching Frequency	f_{SW}	Normal operation	285	330	375	KHz
Maximum Duty Cycle	D_{MAX}			93		%
Minimum On Time	T_{MIN}			100		ns
Soft-Start Time	T_{SS}			9.5		ms
LED Current Sense	V_{CS}	Normal Operation, V_{CSP}－V_{CSN}	108	120	132	mV
Overcurrent Threshold	$V_{SW(OC)}$	Measured at ISW pin	162	180	198	mV
SHDN Pin						
Input Voltage High	V_{IH}		2.3			V
Input Voltage Low	V_{IL}				0.5	V
SHDN Bias Current	I_{SHDN}		－100	0	＋100	nA
OVP Pin						
OVP Rising Threshold	V_{OVPR}	OVP pin voltage rises	1.23	1.283	1.336	V
OVP Falling Threshold	V_{OVPF}	OVP pin voltage falls	1.166	1.219	1.272	V
OVP Pin Bias Current	I_{OVP}		－100	0	＋100	nA
DRV Pin						
Source Current		V_{DRV}＝4V		0.8		A
Sink Current		V_{DRV}＝1V		1.5		A
Fall Fime	t_f	C_{DRV}＝2nF		22		ns
Rise Time	t_r	C_{DRV}＝2nF		30		ns
VCC Pin						
Output Voltage	VCC	I_{VCC}＝0.1mA to 4mA, VIN＝5.5V to 32V	4.7		5.3	V
Load Regulation		I_{VCC}＝0.1mA to 4mA，		5		Ohm
Line Regulation		VIN＝6V to 32V, I_{VCC}＝3mA		6		mV
PSRR	PSRR	I_{VCC}＝3mA， f＝10kHz		-35		dB
Startup Time	t_{START}	VCC＝0 to 4.5V, C_{OUT}＝4.7uF		5		mS

Detailed Description

The CN5816 is a current mode fixed-frequency PWM controller for high current buck buck-boost LED applications. The device operates from an input supply between 4.5V and 32V and provides to drive an external N-channel MOSFET.

The CN5816 contains all the necessary building blocks including a bandgap reference, error amplifier, 330KHz oscillator, compensation slope generator, current-mode control circuitry, inductor overcurrent protection circuit, chip shutdown block, softstart block and gate driver, etc.

Current mode control provides improved transient response and simplified loop compensation. A dedicated COMP pin allows the optimization of loop response. Soft start reduces the inrush current on power up.

The internal over voltage comparator monitors the output voltage, if the voltage at OVP pin is higher than 1.283V(Typical), the DRV pin will be pulled low until the voltage at OVP pin falls below 1.219V(Typical).

Application Information

Input Voltage Range

The CN5816 is intended to implement buck or buck-boost LED drivers. The input voltage range is from 4.5V to 32V.

Shutdown Mode

The SHDN pin is active high shutdown input. Pulling this pin above 2.3V causes the CN5816 to completely shut down and enter a low current consumption state. In this state, the regulator connected to the VCC pin is turned off. Pulling SHDN pin below 0.5V brings the CN5816 back to normal operation.

+5V Regulator

The CN5816 includes a fixed +5V output regulator that delivers up to 4mA of load current for low-power applications throughout the +5.5V to +32V input voltage range. The regulator supplies power for the internal low voltage circuitry of the controller including the gate driver.

Connect a 4.7µF at least bypass capacitor from VCC pin to GND.

If the +5V regulator is used to power the external circuitry, cares must be taken not to overload the +5V regulator, otherwise the gate drive capability may be affected.

When SHDN pin is pulling high, the 5V regulator is also turned off.

Setting LED Current

The LED current is set by placing a current sense resistor between CSP pin and CSN pin. The LED current is decided by the following formula:

$$I_{LED} = \frac{120mV}{R_{CS}}$$

Where:

I_{LED} is the LED current

R_{CS} is the current sense resistor between the CSP pin and CSN pin

Setting the Over Voltage Protection Level

The CN5816 is equipped with Over Voltage Protection (OVP) function. When the voltage at OVP pin exceeds a threshold of 1.283V(Typical), the power switch is turned off. The power switch can be turned on again once the voltage at OVP pin drops below 1.219V(Typical). For the Buck-Boost application, the output voltage could be clamped at a certain voltage level. As shown in Figure 1 and 2, the OVP voltage can be set by the following equation:

$$V_{OUT} = 1.283 \times (1 + \frac{R1}{R2})$$

Where, R1 and R2 form the resistor divider at OVP pin.

LED Dimming

The CN5816 provides pulsed or chopped current dimming. Generally, high-brightness LEDs are binned to match at their full-rated current. However, LEDs from the same bin exhibit poor matching at currents other than full-rated current. To achieve uniformity, high brightness LED manufacturers recommend PWM pulsing of the LED current at their full-rated value. This can be achieved by pulsing the shutdown input (SHDN) while having a constant voltage at VIN.

The internal soft start circuit will be triggered every time SHDN pin goes low from high, the soft start time is 9.5ms(Typical). So the soft start time should be taken into consideration while choosing PWM pulse frequency and pulse width.

N-Channel MOSFET Gate Driver (DRV Pin)

The CN5816 offers a built-in gate driver for driving an external N-channel MOSFET. The DRV pin can source/sink currents in excess of 800mA/1500mA. The gate driver is powered by on-chip 5V regulator, so the voltage at DRV pin is 5V while output high.

Duty Cycle Estimation

As shown in Figure 1 and Figure 2, for a buck-boost or Buck LED driver operating in continuous conduction mode (CCM), the duty cycle is:

$$D = \frac{V_{LED}}{V_{LED} + V_D + VIN}$$

Where, VIN is the input voltage, V_{LED} is forward LED voltage, V_D is the forward voltage of freewheeling diode. So the maximum duty cycle occurs when VIN is minimum, namely:

$$Dmax = \frac{V_{LED}}{V_{LED} + V_D + VIN_{min}}$$

The minimum duty cycle occurs When VIN is maximum, namely:

$$Dmin = \frac{V_{LED}}{V_{LED} + V_D + VIN_{max}}$$

Maximum Inductor Current (Input Current)

CN5816 measures the inductor current (Input current) by sensing the voltage across the inductor current sense resistor (R_{SW} in Figure 1 and 2) between the source of external N-channel MOSFET and GND. So the LED current needs to be reflected back to the input in order to guarantee the correct LED current regulation. Based on the fact that, ideally, the output power is equal to the input power, the maximum average inductor current is:

$$I_{IN} = I_L = \frac{V_{LED}}{VIN} I_{LED}$$

The internal current mode control loop will not allow the inductor peak to exceed $0.18/R_{SW}$. In practice, one should allow some margin for variations in the CN5816 and external component values, and a good guide for selecting the peak inductor current (Input current) is:

$$I_{INpeak} = I_{Lpeak} = 1.8 \times \frac{V_{LED}}{VIN} I_{LED}$$

Inductor Selection

An inductor should be chosen that can carry the maximum input DC current which occurs at the minimum input voltage. The peak-to-peak ripple current is set by the inductance and a good starting point is to choose a ripple current of 30% of its maximum value:

$$\triangle I_L = 30\% \times \frac{V_{LED}}{VIN} I_{LED}$$

The inductor value should meet the requirement of the following equation:

$$L \geqslant \frac{VIN_{max} \times Dmin}{f_{SW} \times \triangle I_L}$$

Where, f_{SW} is the switching frequency in Hz, typical value is 330KHz.

Inductor Current Sense Resistor Selection

The CN5816 is current mode controller and use a resistor in series with the source terminal of external N-channel MOSFET to perform cycle-by-cycle inductor current sense for both the current mode control and overcurrent protection. The inductor current sense resistor is shown in Figure 1 and 2 as R_{SW}. The DRV pin will become low and turn off the external N-channel MOSFET if the voltage at the ISW pin exceeds the current limit threshold voltage $V_{SW}(oc)$ from the electrical specifications table.

So the value of R_{SW} should meet the requirement of the following equation:

$$R_{SW} \leqslant \frac{V_{CS(oc)}}{I_{Lpeak}} = \frac{VIN}{10 \times V_{LED} \times I_{LED}}$$

The CN5816 adopts peak current mode control to regulate LED current, which needs a compensation slope to prevent the device from sub-harmonic oscillation. In CN5816, the compensation slope is applied in a fixed amount. At ISW pin, the compensation slope is:

$$S_e = 4.49 \times 10^4 \text{ V/S}$$

To ensure that the converter does not enter into sub-harmonic oscillation, the compensation slope S_e must be at least half of the down slope of the current sense signal at ISW pin. Since the compensation slope is fixed in the CN5816, this places a constraint on the selection of the current sense resistor.

The down slope of the current sense signal at ISW pin for buck-boost or buck topology is:

$$m2 = \frac{R_{SW} \times (V_{LED} + V_D)}{L}$$

Where,

- S_e is the compensation slope applied to ISW pin in V/S
- m2 is the down slope of the inductor current sense waveform seen at ISW pin in V/s
- R_{SW} is the inductor current sense resistor at ISW pin in ohm(Ω)
- V_{LED} is the LED voltage in volt (V)
- V_D is the forward voltage of freewheeling diode in volt (V)
- VIN is the input voltage in volt(V)
- L is the inductor value in Henry(H)

Since the compensation slope must be at least half, and preferably equal to the down slope of the current sense waveform seen at ISW pin, namely,

$$Se \geqslant \frac{1}{2} m2$$

Hence, a maximum value is placed on the inductor current sense resistor R_{SW} when operating in continuous conduction mode at 50% duty cycle or greater.

For buck-boost topology or buck topology:

$$R_{SW} \leqslant \frac{2 \times 4.49 \times 10^4 \times L}{V_{LED} + V_D}$$

As a conclusion, R_{SW} should simultaneously meet the requirements of the following 2 equations for inductor overcurrent protection and current mode control purposes in buck-boost or buck topology:

$$R_{SW} \leq \frac{V_{CS(oc)}}{I_{Lpeak}} = \frac{V_{IN}}{10 \times V_{LED} \times I_{LED}}$$

and

$$R_{SW} \leq \frac{2 \times 4.49 \times 10^4 \times L}{V_{LED} + V_D}$$

For design purposes, some margin should be applied to the actual value of the inductor current sense resistor R_{SW}. As a starting point, the actual resistor chosen should be 80% or less that the value calculated in the above equations.

Inductor Current Sense Filtering

In most cases, a small filter placed on the ISW pin improves performance of the converter. These are the components R4 and C5 in Figure 1 and 2. The time constant of this filter should be approximately 100ns. R4 should be less than 2KΩ.

Freewheeling Diode Selection

For better efficiency and less power dissipation, a low forward voltage schottky diode should be used as the freewheeling diode (D1 in Figure 1and 2), the diode must have a breakdown voltage that is a few volts higher than the output voltage. The diode's average current should be higher than the maximum output current, the diode's peak current should be higher than the inductor's peak current estimated by the following equation:

$$I_{INpeak} = I_{Lpeak} = 1.8 \times \frac{V_{LED}}{V_{IN}} I_{LED}$$

MOSFET Selection

The CN5816 drives an external N-channel MOSFET. The voltage stress on the MOSFET ideally equals the sum of input voltage and LED voltage in buck-boost topology, or the sum of Input voltage and the forward drop of the freewheeling diode in buck topology. In practice, voltage overshoot and ringing occur due to action of circuit parasitic elements during the turn-off transition. The MOSFET voltage rating should be selected with the necessary margin to accommodate this extra voltage stress.

The MOSFET's power rating and on-resistance should be chosen based on the inductor current.

Output Capacitor Selection

The output capacitor should be sized to reduce the LED current ripple which is affected by the ESR, ESL and bulk capacitance. It should be carefully chosen to account for derating due to temperature and operating voltage. It must also have the necessary RMS current rating. Ceramic capacitors are the best choice due to their high ripple current rating, long lifetime, and good temperature performance. An X7R dieletric rating is suggested. Several capacitors may also be placed in parallel to meet size or height requirements in the design.

Input Capacitor Selection

The input capacitor supplies the transient input current for the inductor of the converter and must be placed and sized according to the transient current requirements. The output current, tolerable input voltage ripple, input voltage source impedance and cable length determine the size of the input capacitor, which is typically in the range of 10µF to 100µF. A low ESR capacitor or two type of capacitors in parallel is recommended.

Please note that the input capacitor can see a very high surge current when a input supply is suddenly connected to the input of the converter and solid tantalum capacitors can fail catastrophically under these conditions.

Frequency Compensation Network Design

Figure 3 shows the AC response-related circuit of CN5816.

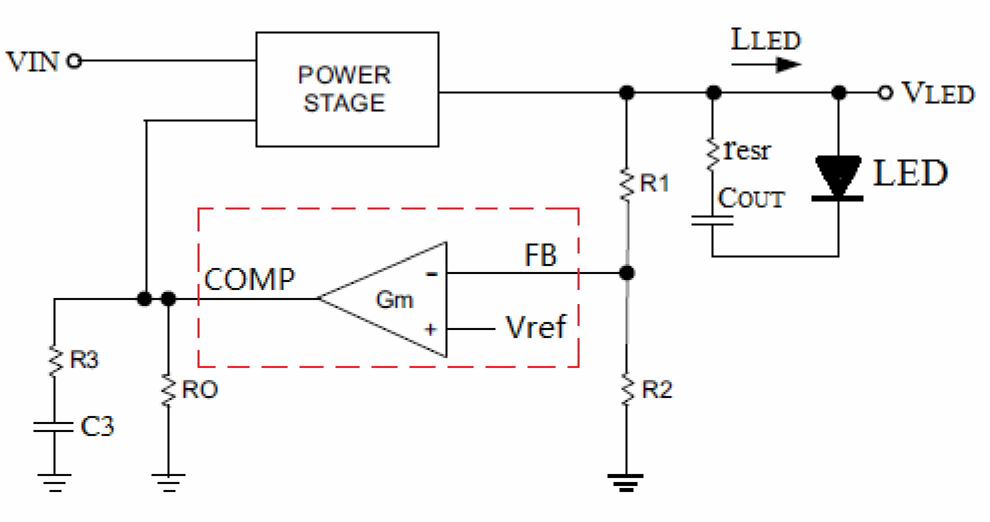


Figure 3 AC Response-Related Circuit

The inductor, output capacitor and LEDs form 1 pole and 2 zeros, they are:

- The pole formed by output capacitor and the load:

$$\omega_{p1} = \frac{2 I_{LED}}{V_{LED} C_{OUT}}$$

- The zero formed by the output capacitor and its equivalent series resistance(ESR)

$$\omega_{z1} = \frac{1}{r_{esr} C_{OUT}}$$

  This zero can be neglected if low ESR ceramic capacitor is used.

- A right half plane zero at the frequency:

  For buck-boost topology:

$$\omega_{Z2} = \frac{V_{LED}(1-D)^2}{L \times I_{LED} \times D}$$

  For buck topology, there is no right-half-plan zero.

In the above 3 equations, V_{LED} is the LED's forward voltage, I_{LED} is the LED current, C_{OUT} is the output capacitance across the LEDs, r_{esr} is the ESR of output capacitor, D is the duty cycle, and L is the inductance.

In Figure 3, C3 and R3 form the compensation network. The design procedure of the compensation network is:

Step 1: Calculate ω_{P1}, ω_{z1} and ω_{z2} based on the above 3 equations

Step 2: Determine the crossover frequency ω_c of the overall loop

For stable operation, the overall loop gain should cross 0dB with -20dB/decade slope.

For buck topology, the 0dB crossover frequency should be from 10KHz to 30KHz.

For buck-boost topology, due to the presence of the RHP zero, the 0dB crossover frequency should be from $0.3 \times \omega_{z2}$ to $0.4 \times \omega_{z2}$.

Step 3: Determine R3's value in ohm (Ω) and C3's value in Farad (F)

For buck topology, R3 and C3's values can be determined by the following 2 equations:

$$R3 = 3.333 \times 10^3 - \frac{1}{C3 \bullet \omega_c}$$

$$C3 = \frac{1}{R3 \bullet \omega_{p1}}$$

For buck-boost topology, R3 and C3's values can be determined by the following 2 equations:

$$R3 = 333 \bullet \sqrt{\frac{\omega_c^2}{\omega_{p1}^2} + 1} - \frac{1}{C3 \bullet \omega_c}$$

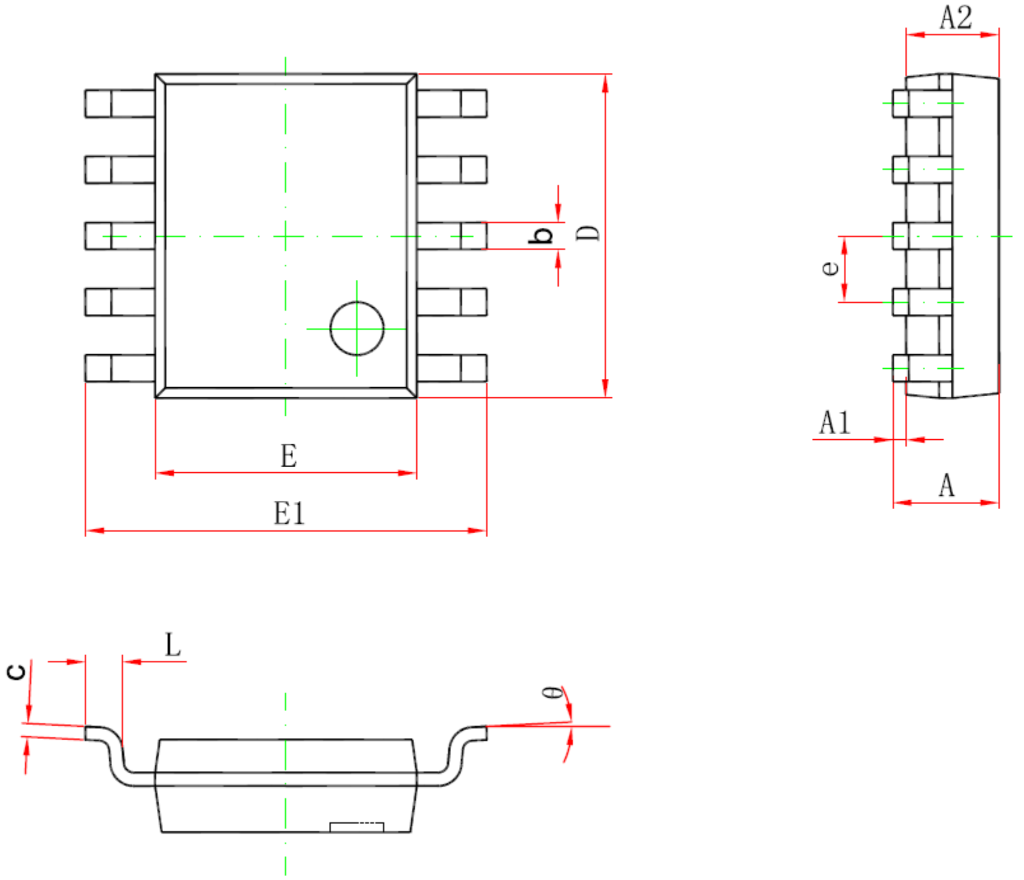
$$C3 = \frac{1}{R3 \bullet \omega_{p1}}$$

Board Layout Considerations

Careful PCB design is very important for correct function and good performance. For the application circuit shown in Figure 1 and 2, the following suggestions should be followed.

- All connections carrying large pulsed currents must be very short and as wide as possible. The inductance of these connections must be kept to an absolute minimum due to the high di/dt of the currents. This implies that the C1, inductor, MOSFET, diode and C2 should be placed in a compact area. Additionally, small current loop areas reduce radiated EMI.
- The copper plane of the MOSFET should be minimized as much as possible for less EMI.
- The ground plane for the power section of the converter should be kept separate from the analog ground plane. This implies that the negative terminal of C1 and switch current sense resistor R_{SW} must be close together.
- The CN5816's GND pin and the negative terminal of R2, C3, C4 and C5 should be connected together and return to the system ground separately.
- For higher LED current, multi-layer PCB is recommended.
- Place R1, R2, R3, C3 and C4 as close to the CN5816 as possible.
- The anode of D1 must be connected very close to the drain of the external N-channel MOSFET.
- The cathode of D1 must be connected very close to C2.

Package Information



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.300	0.450	0.012	0.018
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.000 (BSC)		0.039 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	1°	8°

Consonance does not assume any responsibility for use of any circuitry described. Consonance reserves the right to change the circuitry and specifications without notice at any time.