Universal High Brightness LED Driver

Features

- Constant current LED driver
- Applications from a few mA to more then 1A output
- LED string from one to hundreds of diodes
- 8.0 to 450V input range
- PWM Low-Frequency dimming via enable pin
- Input voltage surge ratings up to 500V
- >90% efficiency
- Epoxy: UL 94V-0 rate flame retardant

Applications

- DC/DC or AC/DC LED driver applications
- RGB backlighting LED driver
- Back lighting of flat panel displays
- General purpose constant current source
- Signage and decorative LED lighting
- Chargers

General Description

The FC9910B is a PWM high efficiency LED driver control IC. It allows efficient operation of High Brightness LEDs from voltage sources ranging from 8V DC up to 450V DC.
The FC9910B controls an internal MOSFET at fixed switching frequency up to 300kHz. The frequency can be programmed using a single resister.
The LED string is driven at constant current rather then constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between afew milliampares and up to more then 1.0A.

The FC9910B uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 450V. Output current to an LED string can be programmed to any value between zero and its maximum value by appling an external control voltage at linear dimming control input of the FC9910B. The FC9910B provides a low frequency PWM dimming input that can accept an external control signal with a duty ratio of 0~100% and a frequency of up to a few kHz.

Typical Application Circuit

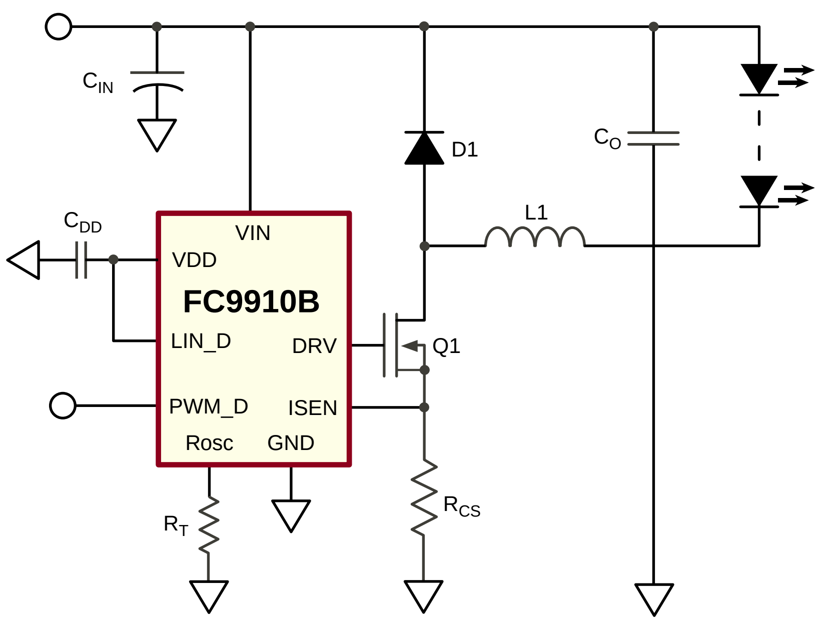


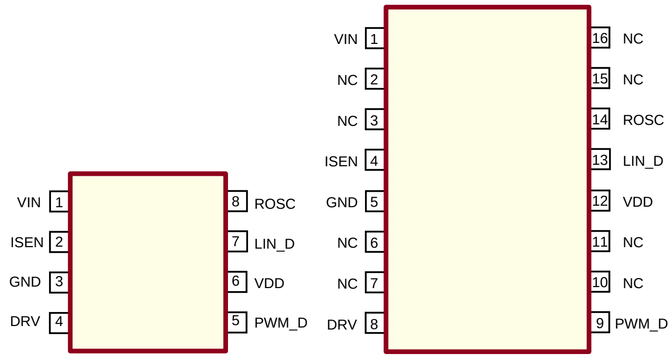
Figure 1. Typical Application Circuit of FC9910B

Absolute Maximum Ratings

Parameter	Value
V_{IN} to GND	-0.5V to +470V
V_{DD} to GND	13.5V
CS, LD, PWMD, GATE, RT to GND	-0.3V to (V_{DD} +0.3V)
Operating temperature range	-40°C to +125°C
Storage temperature range	-65°C to +150°C
Junction temperature range	-45°C to +150°C
Continuous power dissipation *(T_A = +70°C)*	
SOP-8	340mW
SOP-16	550mW
SOP-16(Exposed pad)	920mW

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.

Pin Description



SOP-8

SOP-16
SOP-16(Exposed pad)

Figure 2. Pin Assignment of FC9910B

Thermal Resistance

Name	Package	θ_{ja}
FC9910B	SOP-8	160°C/W
FC9910BX	SOP-16	100°C/W
FC9910BP	SOP-16(Exposed pad)	60°C/W

Electrical Characteristics *(The specifications are at T_A= 25°C. V_{IN} = 12V, unless otherwise noted.)*

Symbol	Description	Min	Typ	Max	Units	Conditions
V_{INDC}	Input DC supply voltage range	8.0		450	V	DC input voltage
I_{INSD}	Shut-Down mode supply current		0.5	1	mA	Pin PWM_D to GND
V_{DD}	Internally regulated voltage	7.25	7.5	7.75	V	V_{IN} = 8V, $I_{DD(ext)}$=0, 500pF at Gate; R_T=226kΩ, PWM_D = V_{DD}
$\Delta V_{DD,line}$	Line Regulation of V_{DD}	0	-	1	V	V_{IN} = 8 - 450V, $I_{DD(ext)}$ = 0, 500pF at GATE; R_T = 226kΩ, PWM_D = V_{DD}
$\Delta V_{DD,load}$	Load Regulation of V_{DD}	0	-	100	mV	$I_{DD(ext)}$ = 0 - 1mA, 500pF at GATE; R_T = 226kΩ, PWMD = V_{DD}
UVLO	V_{DD} undervoltage lockout threshold	6.45	6.7	6.95	V	V_{DD} rising
ΔUVLO	V_{DD} undervoltage lockout hysteresis		500		mV	V_{DD} falling
$I_{IN,MAX}$	Current that the regulator can supply before IC goes into UVLO	5	-	-	mA	V_{IN} = 8V
$V_{EN(lo)}$	Pin PWM_D input low voltage			0.8	V	V_{IN} = 8-450V
$V_{EN(hi)}$	Pin PWM_D input high voltage	2.0			V	V_{IN} = 8-450V
R_{EN}	Pin PWM_D pull-down resistance at PWM_D	50	100	150	kΩ	V_{EN} = 5V
$V_{CS,TH}$	Current sense pull-in threshold voltage	225	250	275	mV	-40°C < T_A < +85°C
		213	250	287		T_A < +125°C
V_{OFFSET}	Offset voltage for LD comparator	-12	-	12	mV	---
T_{BLANK}	Current sense blanking interval	150	215	280	ns	0< T_A < +85°C, V_{LD} = V_{DD}, V_{CS} = $V_{CS,TH}$ + 50mV after T_{BLANK}
		145	215	315		-40°C < T_A < +125°C, V_{LD} = V_{DD}, V_{CS} = $V_{CS,TH}$ + 50mV after T_{BLANK}
t_{DELAY}	Delay to output	-	80	150	ns	V_{LD} = V_{DD}, V_{CS} = $V_{CS,TH}$ + 50mV after T_{BLANK}
fosc	Oscillator frequency	20	25	30	kHz	R_T = 1.00 MΩ
		80	100	120		R_T = 226 kΩ
I_{SOURCE}	Gate sourcing current	0.165	-	-	A	V_{GATE} = 0V, V_{DD} = 7.5V
I_{SINK}	Gate sinking current	0.165	-	-	A	V_{GATE} = V_{DD}, V_{DD} = 7.5V
t_{RISE}	GATE output rise time	-	30	50	ns	C_{GATE} = 500pF, V_{DD} = 7.5V
t_{FALL}	GATE output fall time	-	30	50	ns	C_{GATE} = 500pF, V_{DD} = 7.5V

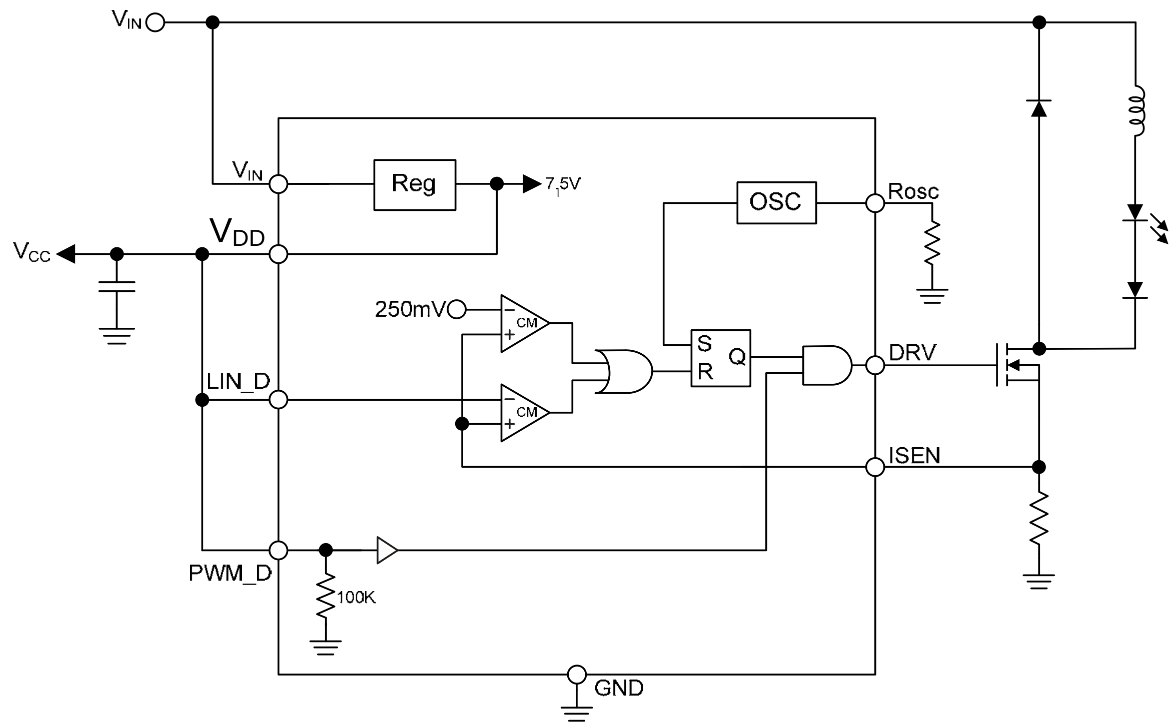


Figure 3. Block Diagram of FC9910B

Pin Description

Name	Description		
	SO-16	SO-8 DIP-8	
V_{IN}	1	1	Input voltage 8V to 450V DC
CS	4	2	Senses LED string current
GND	5	3	Device ground
GATE	8	4	Drives the gate of the external MOSFET
PWM_D	9	5	Low Frequency PWM Dimming pin, also Enable input. Internal 100kΩ pull-down to GND
V_{DD}	12	6	Internally regulated supply voltage. 7.5V nominal. Can supply up to 1mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings.
LD	13	7	Linear Dimming by changing the current limit threshold at current sense comparator
R_{OSC}	14	8	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency.

No Connects (NC) are not internally connected and may be used for pass-thru PCB traces.

Application Information

The FC9910B is a low cost off line buck boost or buck-boost converter control IC specifically designed for driving enables fairly accurate LED current control without the need multi-LED strings or arrays. It can be operated from either universal AC line o r any DC voltage between 8~450V. Optionally, passive power factor collection circuit can be used in order to pass the AC harmonic limits set by EN 61000-3-2 Class C for lighting equipment having input power less than 25W. The FC9910B can drive up to hundreds of high brightness LEDs or multiple strings of HB LEDs.
The LED arrays can be configured as a series or series/ parallel connection. The FC9910B regulates constant current that ensures controlled brightness and spectrum of the LEDs. and extends their life time. The FC9910B features an enable pin(PWM_D) that allows PWM control of brightness.
The FC9910B can also control brightness of LEDs by programming continuous output current of the LED driver (so called linear dimming) when a control voltage is applied to the LIN_D pin.

The FC9910B is offered in standard SOP-8. It is also available in a high voltage rated SOP-16 package for applications that require Vin greater than 250V.

The FC9910B includes an internal high voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage external circuitry.

1. LED Driver Operation

The FC9910B can control all basic types of converters, isolated or non-isolated operating in continuous or discontinuous conduction mode. When the gate signal enhances the internal power MOSFET, the LED driver stores the input energy in an inductor or in the primary inductance of a transformer and depending on the converter type may partially driver the energy directly to LEDs.
The energy stored in the magnetic component is further delivered to the output during the off cycle of the power MOSFET producing current through the string of LEDs. (Flyback mode of operation)

When the voltage at the Vcc pin e xceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the internal power MOSFET. A current sense resistor is connected in series with the source terminal of the MOSFET.

The voltage from the sense resister is applied to the ISEN pin of the FC9910B. When the voltage at ISEN pin exceeds a peak current sense voltage threshold, the gate drive signal terminates, and the power MOSFET turn off. The threshold is internally set to 250mV, or it can be programmed externally by applying voltage to the LIN_D pin. When soft start is required, a capacitor can be connected to the LIN_D pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

Optionally a simple passive power factor correction circuit consisting of 3 diodes and 2 capacitors, can be added as as shown in the application circuit diagram of figure 1.

2. Supply current

A current of 1mA is needed to start the FC9910B.
As shown in block diagram , this current is internally generated in FC9910B without using bulky start up resistors typically required in the off line applications. Moreover, in many applications the FC9910B can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

3. Setting Light output

When the buck converter topology of Figure 1 is selected.
The peak ISEN voltage is a good representation of the everage current in the LED. However there is a certain error associated with this current sensing methode that need to be accounted for. This error is i ntroduced by the difference between the peak and the everage current in the inductor is 150mA, to get a 500mA LED current, the sense resistor should be 250mV/(500mA+0.5*150mA) = 0.43 ohm.

4. Dimming

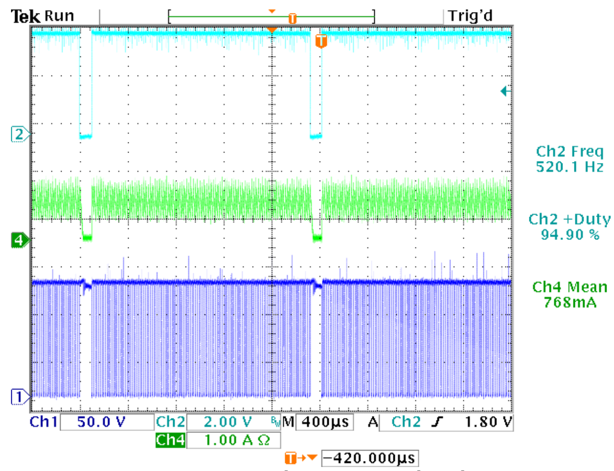
Dimming can be accomplished in two ways, seperately or combined, depending on the application.
Light output of the LED can be controlled either by linear change of its current, or by switching the current on and off while maintaining it constant.

The second dimming methode (so called PWM dimming) controls LED brightness by varying the duty ratio of the output current.

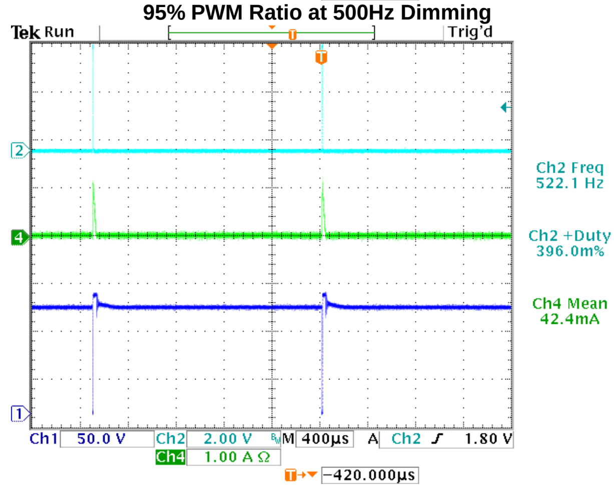
Application Information (Continued)

The linear dimming can be implemented by applying a control voltage from 0mV to the 250mV to the LIN_D pin. This control voltage overrides the internally set 250mV threshold level of the ISEN pin and programs the output current accordingly. For example, a potentiometer connected between Vcc and ground can program the control voltage at the ISEN pin. Applying a control voltage higher then 250mV will not change the output current setting. When higher current is desired, select a smaller sense resistor.

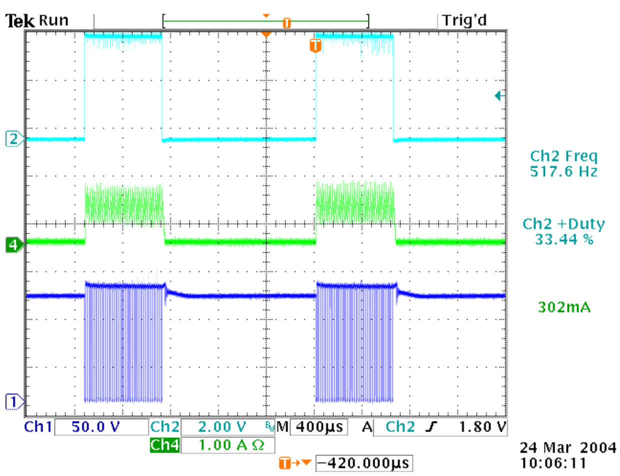
The PWM dimming scheme can be implemented by applying an external PWM signal to the PWM_D pin. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode LED current can be in one of the two states, zero or the nominal current set by the current sense resistor. It is not possible to use this methode to achive everage brightness levels higher then the one set by the current sense threshold level of the FC9910. By using the PWM control methode of the FC9910, the l ight output can be adjusted between zero and 100%. the accuracy of the PWM dimming methode is limited only by the minimum gate pulse width, which is a fraction of a percent of the low frequency duty cycle.



95% PWM Ratio at 500Hz Dimming



0.4% PWM Ratio at 500Hz Dimming



33% PWM Ratio at 500Hz Dimming

5. Programming Operating Frequency

The operating frequency of the oscillator is programmed between 25 and 300kHz using an external resistor connected to the connected to the Rosc pin.

Fosc = 25000/(Rosc[kΩ] +22) [kHz]

6. Power Factor Correction

When the input power to the LED driver does not exceed 25W, a simple passive power factor correction circuit can be added to the FC9910B application circuit of Figure 4 in order to pass the AC line harmonic limits of the EN61000-3-2 standard for Class C equipment. The typical application circuit diagram shows how this can be done without affecting the rest of the circuit significantly. A simple circuit consisting of 3 diodes and 2 capacitors is added across the rectified AC line input to improve the line current harmonic distortion and to achieve a power factor greater than 0.85.

7. Inductor Design

Reffering to t he typical application circuit below the value can be calculated from the desired peak to peak LED ripple current in the inductor.

Typically such ripple current is selected to be 30% of the nominal LED current. In the example given here, the nominal current I_{LED} is 350mA.

The next step is determining the total voltage drop across the LED string. For example, when the string consists of 10 High Brightness LEDs and each didode has a forward voltage drop of 3.0V at its nominal current , the total LED voltage V_{LED} is 30V.

Knowing the nominal rectified input voltage Vin = 120V*1.41 = 169V, the switching duty ratio can be determined as:

$D = V_{LED} / Vin = 30 / 169 = 0.177$

Then given the switching frequency , in the example $f_{OSC} = 50kHz$, the required on time of the MOSFET transistor can be calculated:

$T_{ON} = D / f_{OSC} = 3.5$ microsecond

The required value of the inductor is given by

$L = (V_{IN} - V_{LEDS}) * T_{ON} / (0.3 * I_{LED}) = 4.6mH$

8. Input Bulk Capacitor

An input filter capacitor should be designed to hold the rectified AC voltage above twice the LED string voltage throughout the AC line cycle.
Assuming 15% relative voltage ripple across the capacitor, a simplified formula for the minimum value of the bulk input capacitor is given by:

$C_{MIN} = I_{LED} * V_{LEDS} * 0.06 / V_{IN}^2$

C_{MIN} = 22uF, a value 22uF / 250V can be used.

A passive PFC circuit at the input requires using two series connected capacitors at the place of calculated C_{MIN} . Each of these identical capacitors should be rated for 1/2 of the input voltage and have twice as much capacitance.

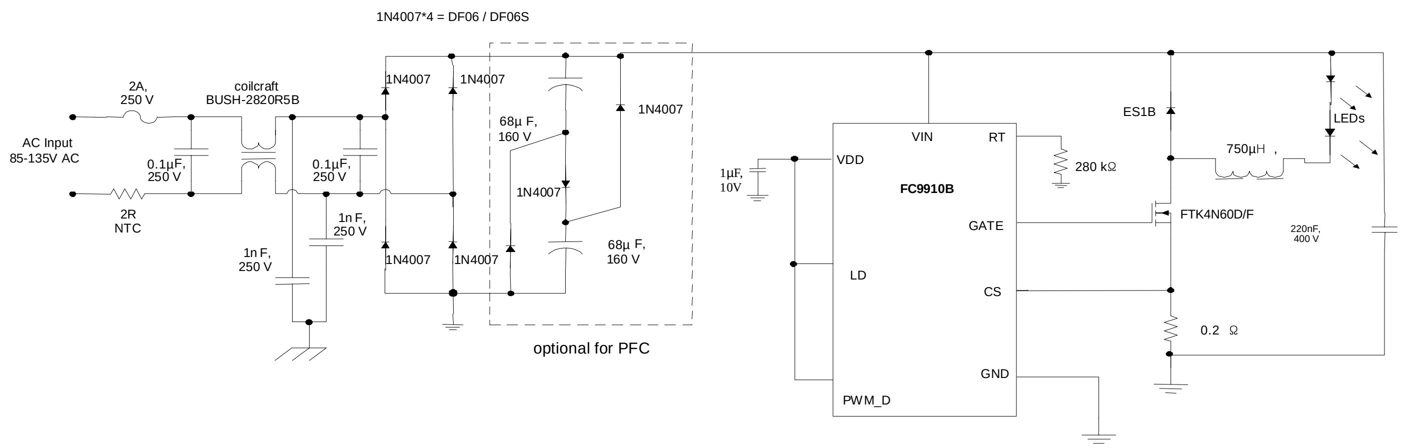
9. Enable

The FC9910B can be turned off by pulling the PWM_D pin to ground. When disabled, the FC9910B draws quiescent current of less then 1mA.

Application Information (Continued)

10. output Open Circuit Protection

When the buck topology is used, and the LED is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and can be continuous. However, in the case of the buck-booster or the flyback topology the FC9910B may cause excessive voltage stress of the switching transistor and the rectifier diode and potential failure.
In the case, the FC9910B can be disabled by pulling the PWM_D pin to ground when the over voltage condition is detected.



LED(s) – a string of HB LEDs , 16 diodes

Figure 4：Typical Application Circuit

Application Information (Continued)

DC DC Low Voltage Application

1. Buck Converter Operation

The buck power conversion topology can be used when the LED string voltage is needed to be lower then the input supply voltage. The design procedure for a buck LED driver outlined in the previous chapters can be applied to the low voltage LED drivers as well. However, the designer must keep in mind that the input voltage must be maintained higher than 2 times the forward voltage drop across the LEDs. This limitation is rated to the output current instability that may develop when the FC9910B buck converter operates at a duty cycle greater than 0.5. This instability reveals itself as an oscillation of the output current at a sub-harmonic of the switching frequency.

2. Flyback(Buck-Booster) Operation

The power conversion topology can be used when the forward voltage drop of the LED string is higher, equal or lower than the input supply voltage. For example, the buck-booster topology can be appropriate battery(12V) and output string consists of three to six HB LEDs, as the case ma be for fail and break signal lights.
In the buck-booster converter, the energy from the input source is first stored in the inductor or a flyback transformer when the switching transistor is ON. The energy is then delivered to the output during the OFF time of the transistor. When the energy stored in the flyback inductor is not fully depleted by the next switching cycle (continuous conduction mode) the DC conversion between input and output voltage is given by:

$$Vout = -Vin * D / (1-D)$$

The output voltage can be either higher or lower than the input voltage, depending on duty ratio.

Let us discuss the above exanple of an auto-motive LED driver that needs to drive three HB LEDs at 350mA. Knowing the nominal input voltage VIN=12V, the nominal duty ratio can be determined, as

$$D = V_{LEDs} / (Vin + V_{LEDs}) = 9 / (12+9) = 0.43$$

Then, given the switching frequency, in this example f_{OSC} = 50kHz, the required on-time of the MOSFET transistor can be calculated:

$$L = Vin * T_{ON} / (0.3 * I_{LED}) = 0.98mH, \text{ use 1mH}$$

3. Output Capacitor

Unlike the buck topology, the buck-booster converter requires an output filter capacitor to deliver power to the LED string during the ON time of switching the transistor, when the flyback inductor current is diverted from the output of the converter.

In the order to average the current in the LED, this capacitor must present impeadance to the switching output AC ripple current that is much lower than the dynamic impeadance Rout of the LED string.
If we assume Rout=3 Ohm in our example, in order to attenuate the switching ripple by a factor of 10, a capacitor with equivarent series resistance (ESR) of 0.3 Ohm is needed. A chip SMT tantalium capacitor can be selected for this purpose.

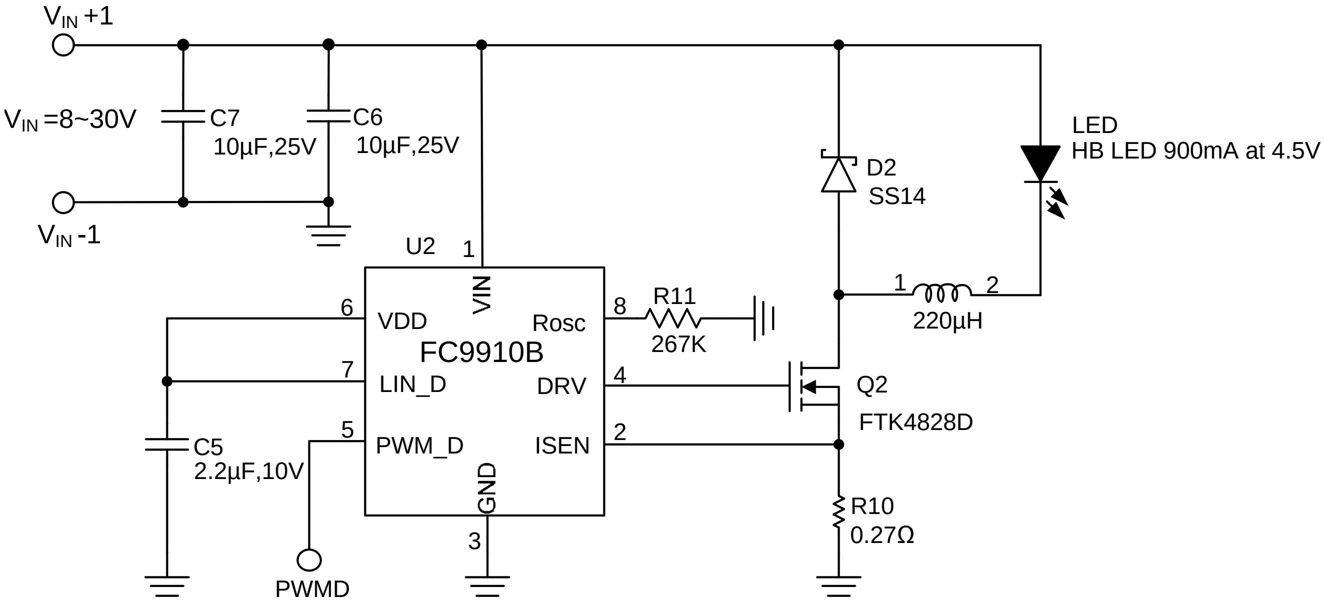


Figure 5: FC9910B Buck driver for a single 900mA HB LED

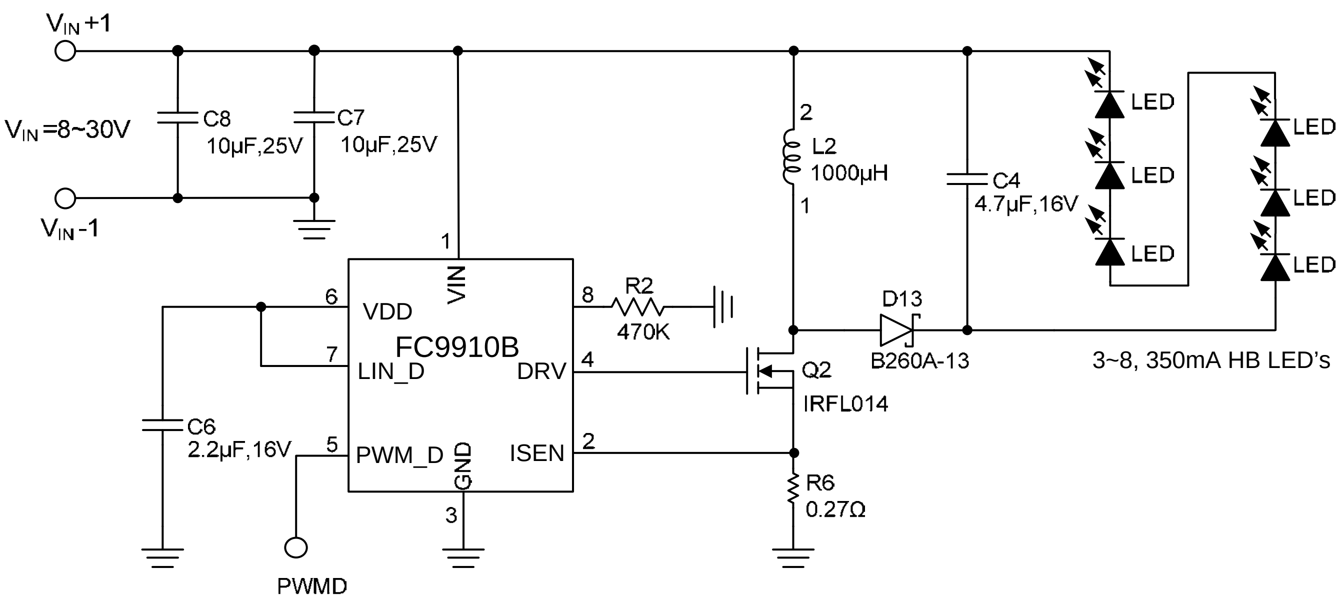


Figure 6: FC9910B Buck-boost driver string 3 to 8, 350mA HB LED