



ILD8150/E 80 V high side buck LED driver IC with hybrid dimming

Operation, design guide and performance

About this document

Scope and purpose

This application note introduces Infineon’s hysteretic high-side MOSFET buck DC-DC LED driver IC ILD8150 for general lighting applications. It describes the device operation, features and component value calculations and selection. An example of the reference design performance is shown. ILD8150 provides a highly efficient solution up to 97 percent with superior hybrid dimming performance, and various protections such as cycle-by-cycle current limitation and over-temperature protection.

Intended audience

This document is intended for engineers and students who design highly efficient LED drivers with a wide dimming range.

Table of contents

About this document.....	1
Table of contents.....	1
1 Introduction	3
1.1 Features.....	3
1.2 Applications.....	3
2 Circuit description.....	4
2.1 Operation.....	4
2.1.1 Current regulation.....	4
2.2 Cycle-by-cycle current limitation	5
2.2.1 OTP	5
2.2.2 UVLO	5
2.2.3 Dimming	6
2.2.4 Dim-to-off	7
2.2.5 Soft-start.....	7
2.2.6 Shut-down.....	8
2.2.7 Floating driver and bootstrap supply.....	8
2.2.8 V _{IN} pin ESD protection	9
2.2.9 OVP by CS pin	9
2.2.10 Microcontroller use	10
2.3 Component selection.....	11
2.3.1 Current Sense (CS) resistor	11
2.3.2 Inductor and switching frequency selection.....	11
2.3.3 Diode D selection	11
2.3.4 Input capacitor C _{IN} selection.....	12
2.3.5 Output capacitor C _{OUT} selection.....	12
2.3.6 Bootstrap capacitor C _{BOOT} selection	13

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Introduction

2.4	Layout consideration	13
2.5	Design example	13
2.5.1	Determine R_{CS}	14
2.5.2	Select switching frequency	14
2.5.1	Inductor value and its current calculation	14
2.5.2	Diode selection	14
2.5.3	C_{IN} capacitor selection	14
2.5.4	C_{OUT} capacitor selection	15
2.5.5	Bootstrap capacitor C_{BOOT} selection	15
2.5.6	V_{CC} capacitor C_{VCC} selection	15
3	Application circuit	16
3.1	Schematic layout	16
3.2	PCB layout	17
4	Measurement results with reference design	18
4.1	LED current vs supply voltage	18
4.2	Dimming	19
4.3	Soft-start	20
4.4	Cycle-by-cycle current limitation	20
4.5	Efficiency	21
4.6	Thermal behavior	21
4.7	Output current ripple	22
5	Application with flyback converter XDPL8219	24
6	Appendix A	25
7	References	27
	Revision history	28

Introduction

1 Introduction

This application note explains the operation of Infineon's high-side MOSFET buck LED driver IC ILD8150. ILD8150 provides a highly efficient solution, with multiple protection features, superior hybrid PWM dimming performance and high accuracy across all conditions – input/output voltage, dimming and temperature.

ILD8150 is a next-generation buck DC-DC LED driver recommended for general LED lighting. The target application is a secondary stage together with AC-DC such as Power Factor Correction (PFC) flyback or PFC + LLC. ILD8150 is flexible enough to use up to 1.5 A with a short duty cycle. The hysteretic current control is extremely fast and always stable without the need for any loop compensation. A maximum duty cycle of up to 99 percent enables use in applications where the input and output voltage are close to each other. It is suitable for applications with a wide range of supply voltages from 8 V to 80 V, which gives flexibility and a clear advantage over existing 60 V solutions.

ILD8150 operates in hybrid dimming mode, which helps to minimize LED color shift and audible noise. In the range 12.5 to 100 percent it operates in analog dimming mode, and from 0.5 to 12.5 percent in PWM mode with fixed output frequency f_{out} .

ILD8150 provides high accuracy across all conditions, as well AC 100 or 120 Hz input flicker rejection across the whole dimming range.

1.1 Features

- Wide input voltage range from 8 V to 80 V
- Capable of providing output current up to 1.5 A
- Up to 2 MHz switching frequency
- Digital soft-start
- PWM dimming input up to 20 kHz
- Hybrid output dimming
- Typical ± 3 percent output current accuracy
- Very low LED current drift over-temperature
- Under-Voltage Lockout (UVLO)
- Cycle-by-cycle current limitation
- Shut-down mode with low self-consumption
- PG-DSO-8 package with and without exposed pad
- Over-Temperature Protection (OTP)

1.2 Applications

- LED driver for general lighting
 - with single output channel
 - with two output channels for tuneable white light
- LED driver for horticultural lighting
 - with multiple output channels

Circuit description

2 Circuit description

2.1 Operation

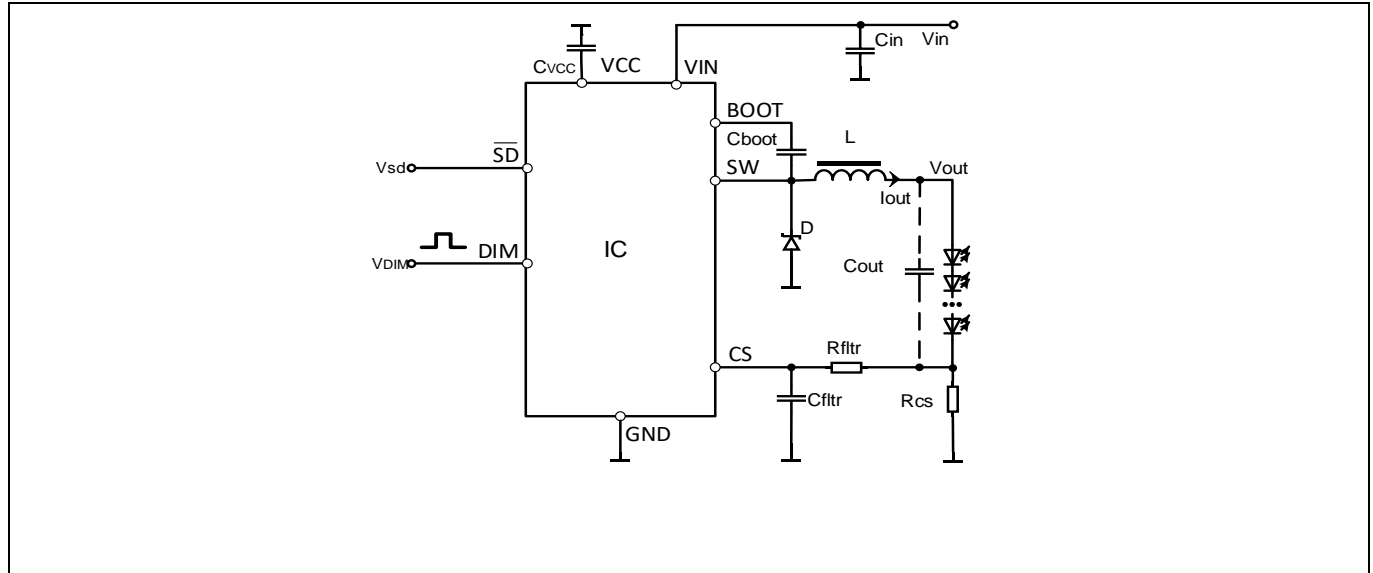


Figure 1 Typical application circuit

2.1.1 Current regulation

Figure 1 shows the typical application circuit. Current is controlled by the CS pin, which compares the voltage drop on R_{CS} to internal references. Output current is proportional to the voltage drop on R_{CS} . When the CS voltage drops below V_{CSL} the MOSFET switches on. Current and voltage on R_{CS} rise accordingly. When the CS voltage achieves V_{CSH} the MOSFET switches off, and stored energy in inductor L discharges through the diode D . In this way, the system maintains a constant average output current as shown in **Figure 2**.

$$I_{LED,AVG} = \frac{V_{CSH} + V_{CSL}}{2R_{CS}}$$

The output ripple of the instantaneous current is:

$$\Delta I_{OUT} = \frac{V_{CSH} - V_{CSL}}{R_{CS}}$$

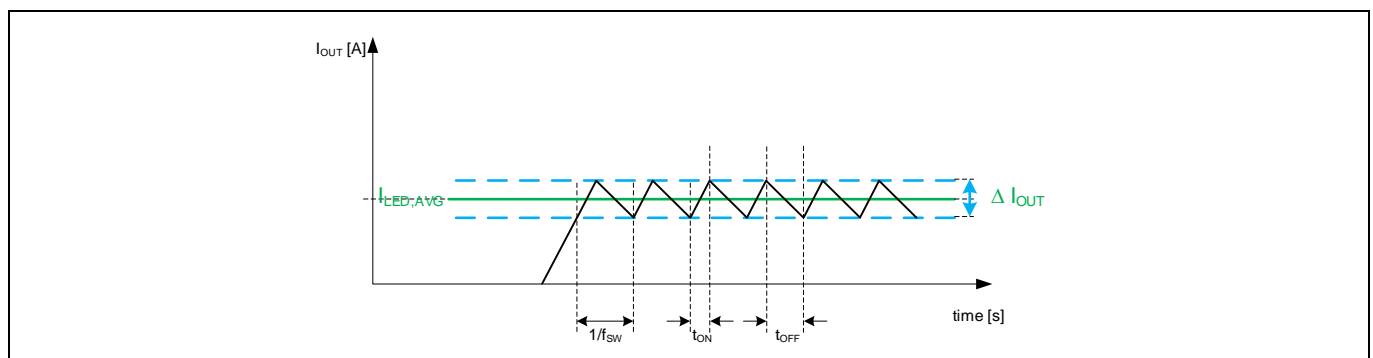


Figure 2 Current regulation

Current never goes down to zero, so the system operates in Continuous Conduction Mode (CCM), where

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

$$t_{ON} = \frac{\Delta I_{OUT} L}{V_{IN} - V_{OUT}} \text{ and } t_{OFF} = \frac{\Delta I_{OUT} L}{V_{OUT}}.$$

Output frequency is determined by the following equation:

$$f_{SW} = \frac{R_{CS}}{L(V_{CSH} - V_{CSL}) + R_{CS}V_{IN}t_{delay}} \cdot \frac{V_{OUT}(V_{IN} - V_{OUT})}{V_{IN}}, \text{ where } R_{CS}V_{IN}t_{delay} \text{ is the delay contribution, with}$$

$t_{delay} \approx t_{CSSW} + R_{fltr}C_{fltr}$. This part is negligible for low frequencies but it has a strong effect at high frequencies. **Figure 3** shows the frequency curves not including the delay in blue and including the delay in red.

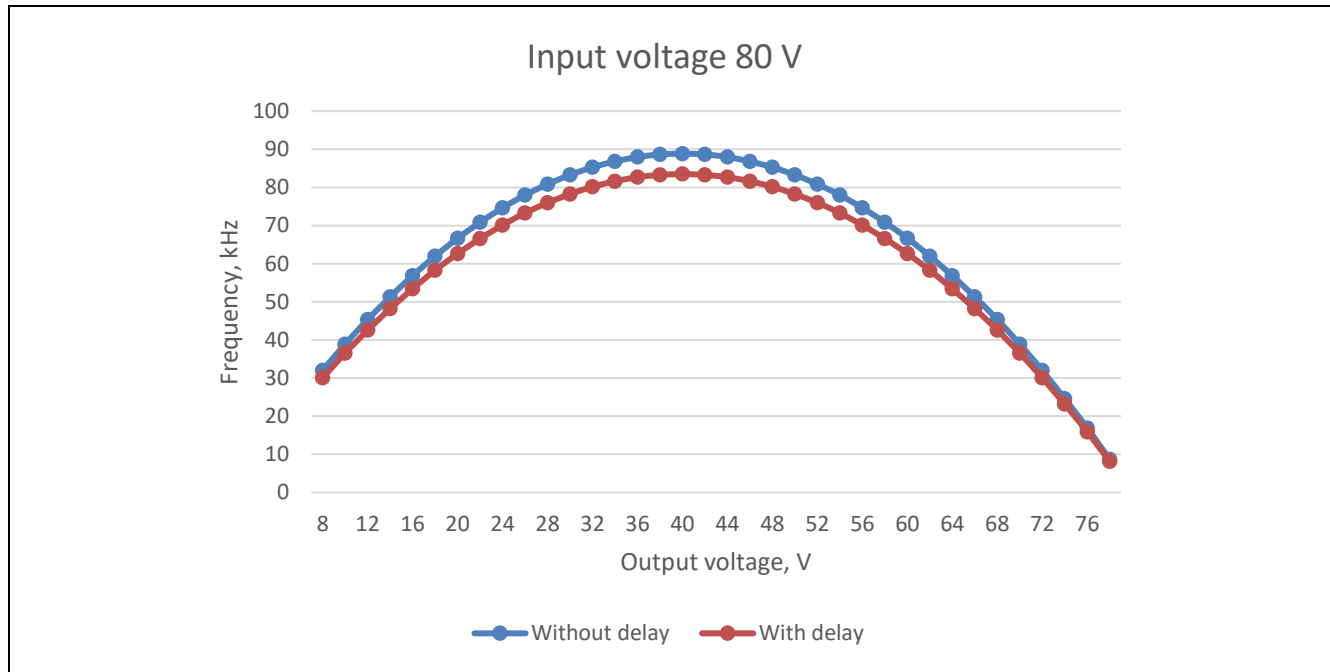


Figure 3 Typical frequency change character curve over output voltage, $V_{IN} = 80 \text{ V}$, $L = 680 \mu\text{H}$, $R_{CS} = 0.36 \Omega$, $R_{fltr} = 1.5 \text{ k}\Omega$, $C_{fltr} = 180 \text{ pF}$

R_{fltr} and C_{fltr} are the RC filter, which reduces the noise from R_{CS} , which can lead to unwanted operation.

2.2 Cycle-by-cycle current limitation

Because ILD8150 operates in current mode, it does not allow operation with higher current than it sets. Output current is limited cycle-by-cycle. Thus, it safely operates even when the LED output gets shorted. R_{CS} short-circuit may cause damage.

2.2.1 OTP

ILD8150 has integrated OTP based on the junction temperature measurement on the chip. OTP is required to prevent the IC from operating at a critical temperature. The high threshold when the IC turns off is $T_{OT,OFF}$; the low threshold when the IC turns on is $T_{OT,ON}$.

2.2.2 UVLO

ILD8150 has hysteretic UVLO protection against operation at insufficient supply voltage. ILD8150 also has UVLO that shuts down the IC when the minimum supply voltage drops below the internal threshold, typically $V_{IN_UVLO,OFF}$, and releases the IC from lockout at $V_{IN_UVLO,ON}$.

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

2.2.3 Dimming

Input dimming signal is PWM with minimal amplitude V_{DIM} with frequency f_{DIM_input} . Current accuracy over dimming is high enough, and so is the feedback speed, that any input voltage change does not affect output current (no flicker). The IC operates in hybrid dimming mode. The dimming curve is shown in [Figure 6](#), which eliminates color shift and audible noise. In the range from 12.5 to 100 percent it operates in analogue dimming mode as shown in [Figure 5](#), and from 0.5 to 12.5 percent in PWM mode as shown in [Figure 4](#), with fixed output frequency f_{out} .

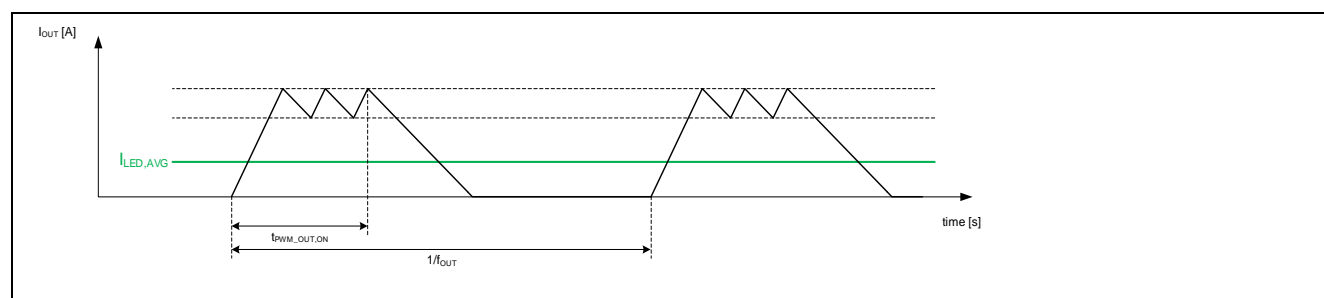


Figure 4 PWM dimming

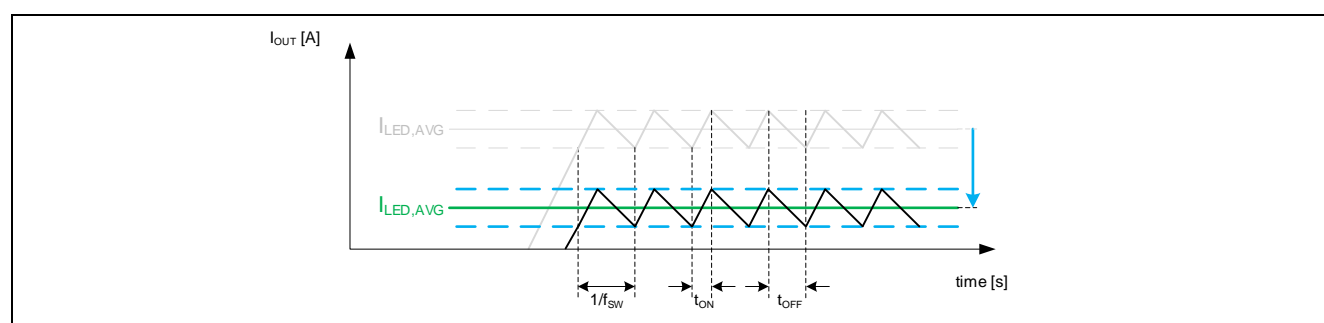


Figure 5 Analog dimming

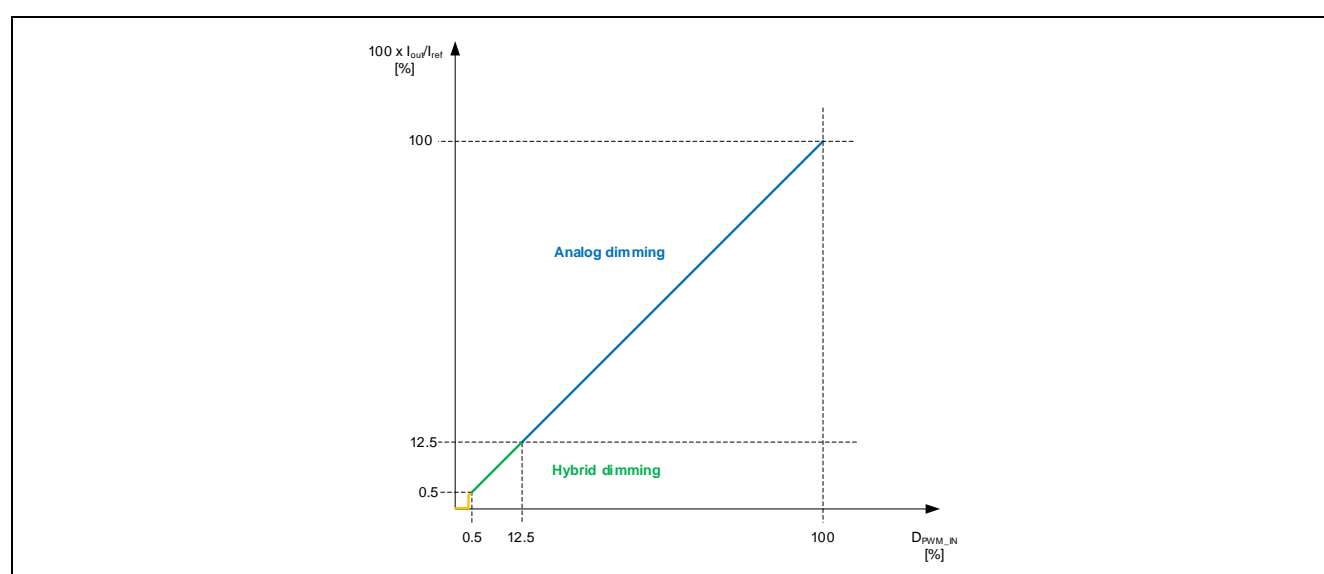


Figure 6 Hybrid dimming curve

Circuit description

2.2.4 Dim-to-off

ILD8150 turns the output stage off when the PWM dimming input signal duty cycle is less than

$D_{PWM_IN,OFF}$, and on when the PWM dimming input signal duty cycle is higher than $D_{PWM_IN,ON}$, as shown in [Figure 7](#). The dim-to-off hysteresic algorithm helps to avoid unstable states at the on/off boundary.

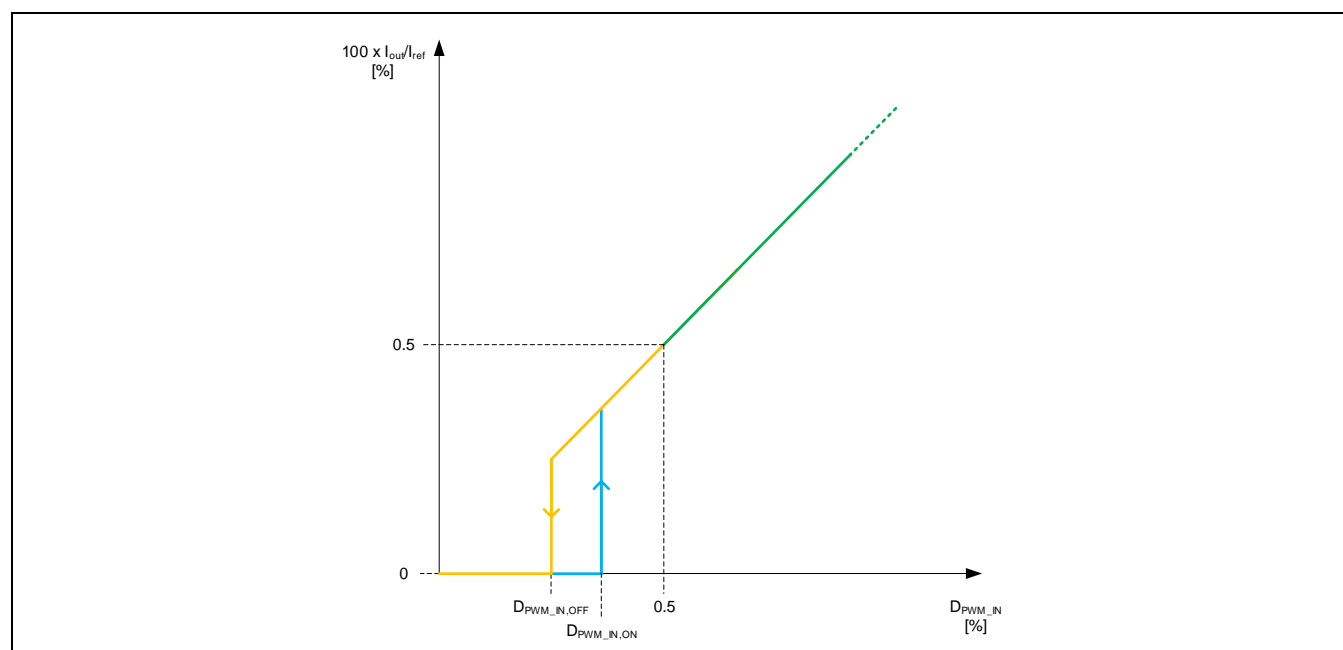


Figure 7 Dim-to-off

2.2.5 Soft-start

Soft-start helps to reduce component stress when the application starts. It further reduces under-shoot of the input voltage. The soft-start is digitally preset at $t_{SS,100}$ percent, defined as the maximum time to reach full light, in the undimmed condition and up to $10 \times T_{dim}$ in the dimmed condition where $T_{dim} = 1/f_{DIM_input}$. Start-up time may also be set by a microcontroller independently of the preset soft-start. The soft-start process is shown in [Figure 8](#). The number of current steps may vary depending on the actual and previous dimming level.

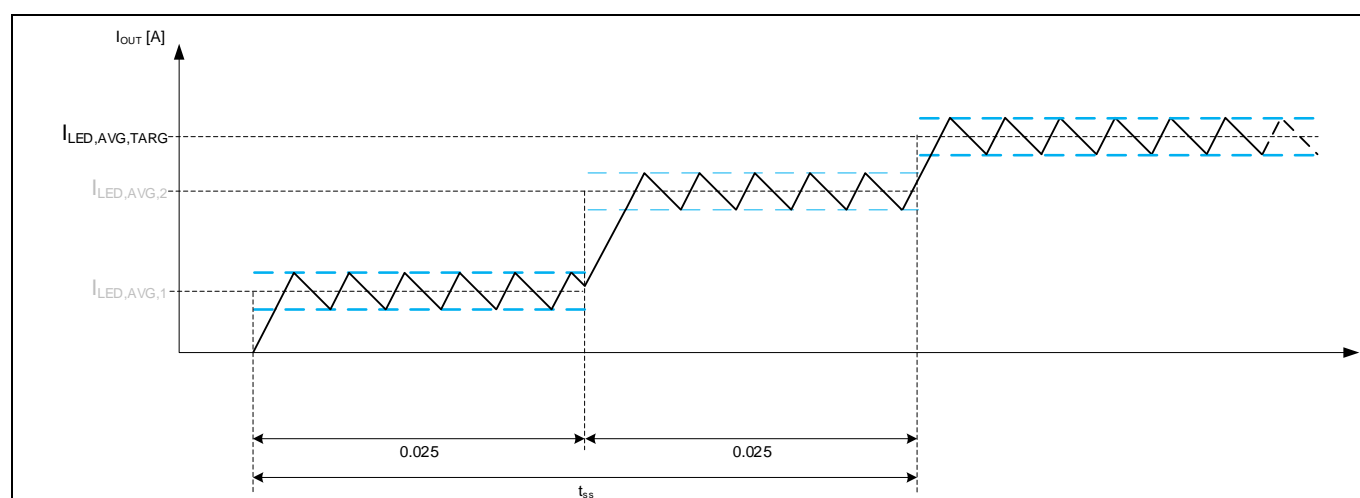


Figure 8 Soft-start

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

2.2.6 Shut-down

ILD8150 has a shut-down control pin SD. If the shut-down signal (SD neg.) is driven low for more than t_{SD_LO} the low power mode is active. If the shut-down signal is held high for more than t_{SD_HI} , the IC resumes from low power mode. $-I_{SD_HPU}$ dynamic current is needed to turn the IC into low power mode, then the current changes into static $-I_{SD_LPU}$. DIM pin needs to be driven externally with at least V_{DIM_SD} voltage during low power mode.

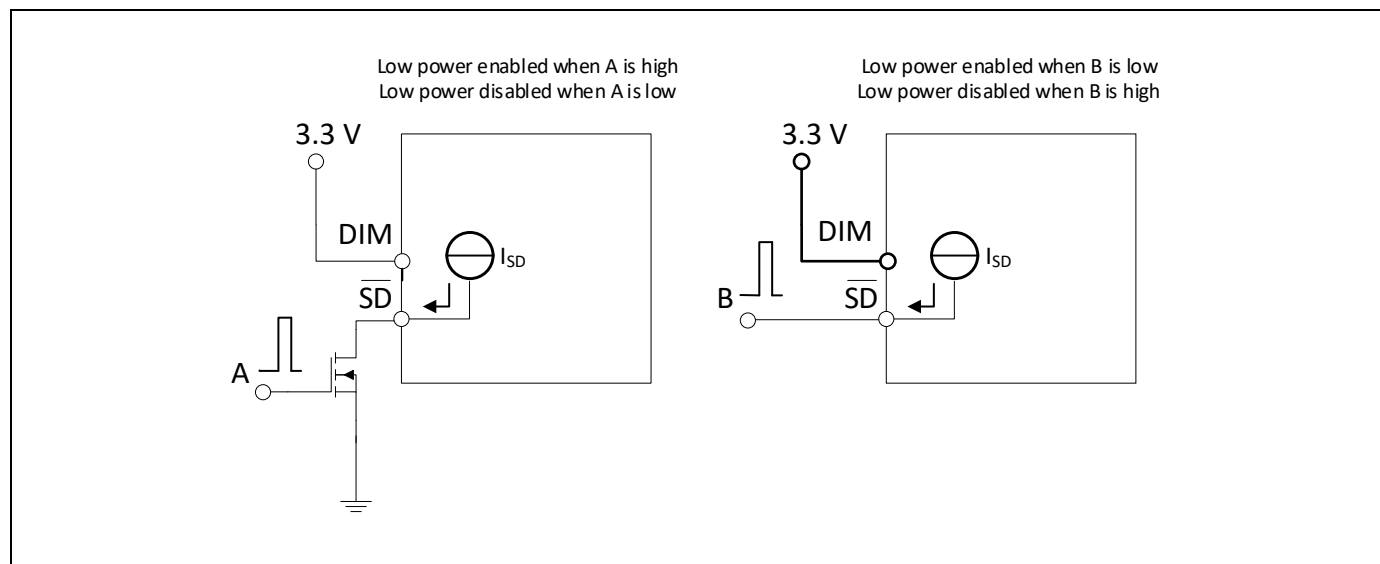


Figure 9 Shut-down signal interfacing

2.2.7 Floating driver and bootstrap supply

The high-side MOSFET gate driver is supplied by the bootstrap circuit. Capacitor C_{BOOT} is charged when the high-side MOSFET is switched off and the diode D conducts current from V_{CC} . C_{BOOT} can be calculated as:

$$C_{BOOT} > \frac{Q_G}{\Delta V_{Cboot}}$$

Where Q_G is the internal MOSFET gate charge, 2.5 nC and ΔV_{Cboot} is voltage deviation on the bootstrap capacitor. The internal supply circuit provides voltage to the bootstrap capacitor $V_{Cboot} \approx 8.6$ V, which is a little higher than V_{CC} . This circuit helps to maintain the voltage in dim-to-off and standby conditions. Higher voltage improves the R_{ON} of the internal MOSFET.

Circuit description

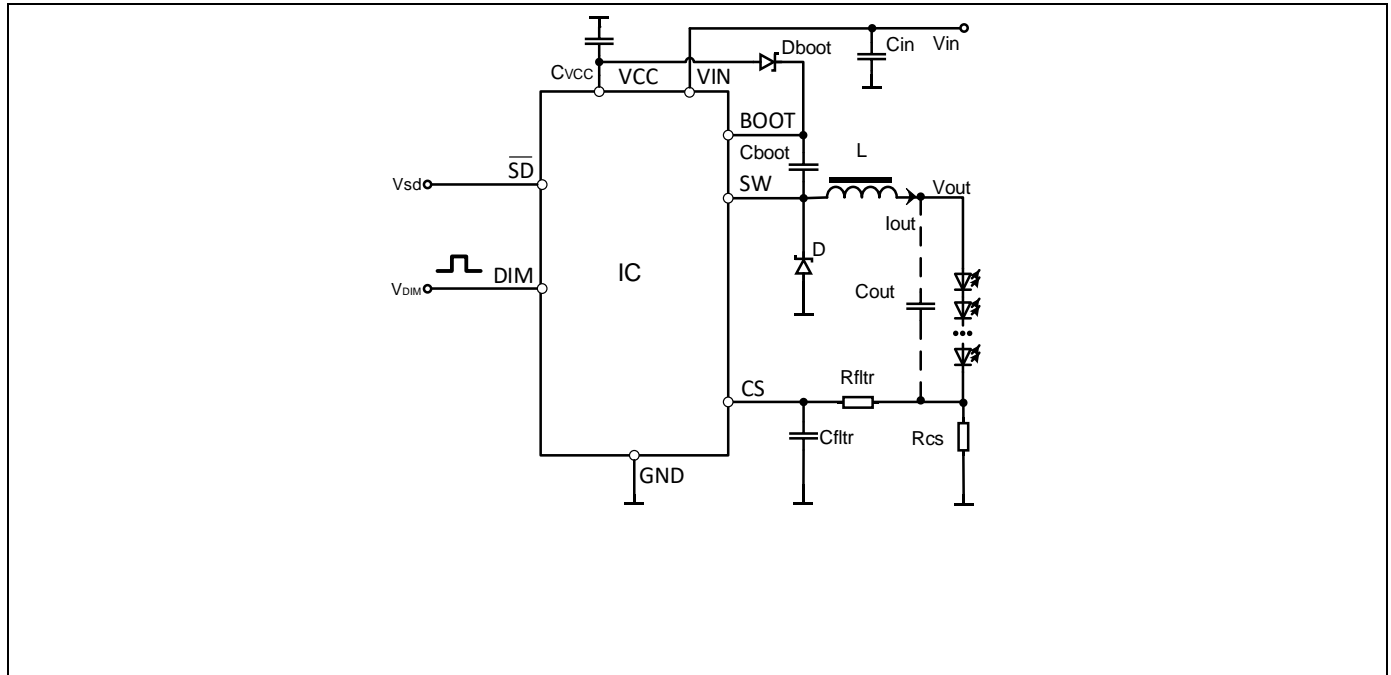


Figure 10 External bootstrap diode usage

The IC contains an internal bootstrap diode. An external high-speed signal or Schottky diode, with voltage robustness higher than V_{IN} , can be used between the V_{CC} and BOOT pins as shown in [Figure 10](#). This decreases IC power dissipation at high switching frequency.

2.2.8 V_{IN} pin ESD protection

The V_{IN} pin is protected by an internal ESD structure. If V_{IN} exceeds the absolute maximum ratings with a slew rate higher than 5 V/ns, which may happen not even by an ESD event, but might also occur if the LED driver gets hotplugged into a power supply and the V_{IN} blocking capacitor has a too small capacitance. ESD protection will remain triggered as long as the slew rate condition is met. If the ESD protection gets triggered while V_{IN} is supplied, the IC might be damaged. At HV spikes or hotplug, the ESD structure conducts and absorbs the ESD stress. If the application is a DC-DC LED driver with very low input capacitance and permanent ESD stress, it is recommended to use an external TVS diode, which protects the IC.

2.2.9 OVP by CS pin

If the load is disconnected, output voltage moves to the V_{IN} level. External output Over-Voltage Protection (OVP) may be used as shown in [Figure 11](#). The TVS diode conducts current when the output voltage achieves its level, voltage on the CS pin rises to V_{CSH} level, the high-side MOSFET switches off, and output voltage drops. TVS diodes have a high voltage deviation connected with technology and temperature. TVS voltage should be chosen, as this does not affect operation and also limits output voltage to the right level. R_{TVS} and R_{PR} limit the current through the TVS, reduce dissipated power and reduce switching frequency in OVP mode.

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

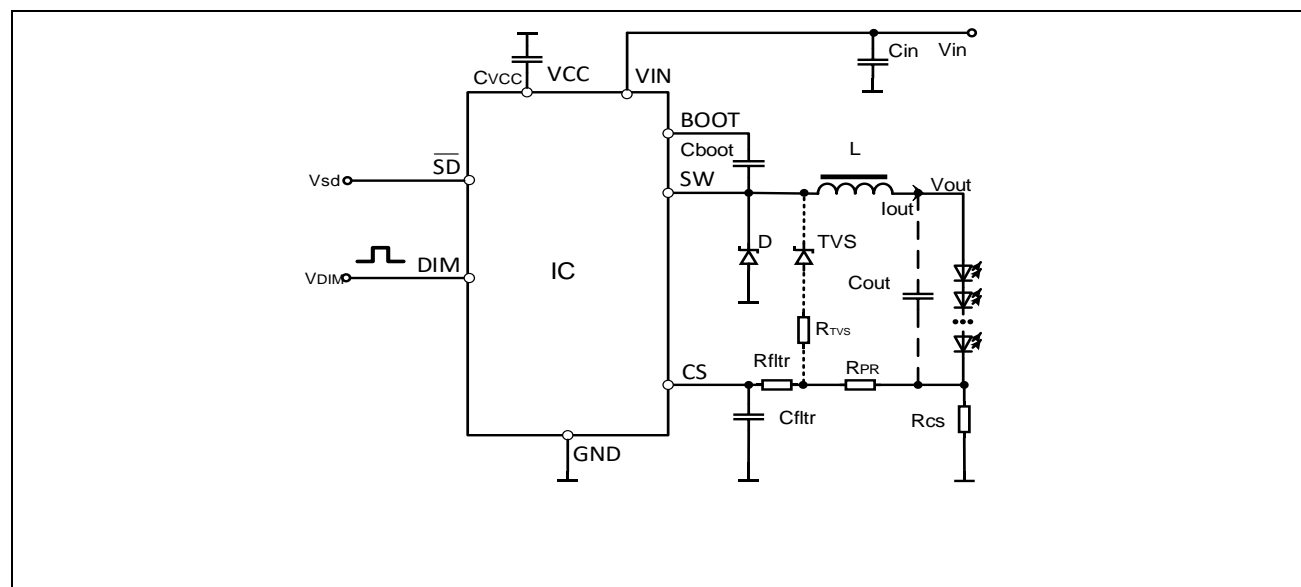


Figure 11 OVP by CS pin

2.2.10 Microcontroller use

A microcontroller may be used together with ILD8150. This enables control of dimming to read out the output voltage and drive the IC into shut-down mode. The microcontroller use case is shown in [Figure 12](#).

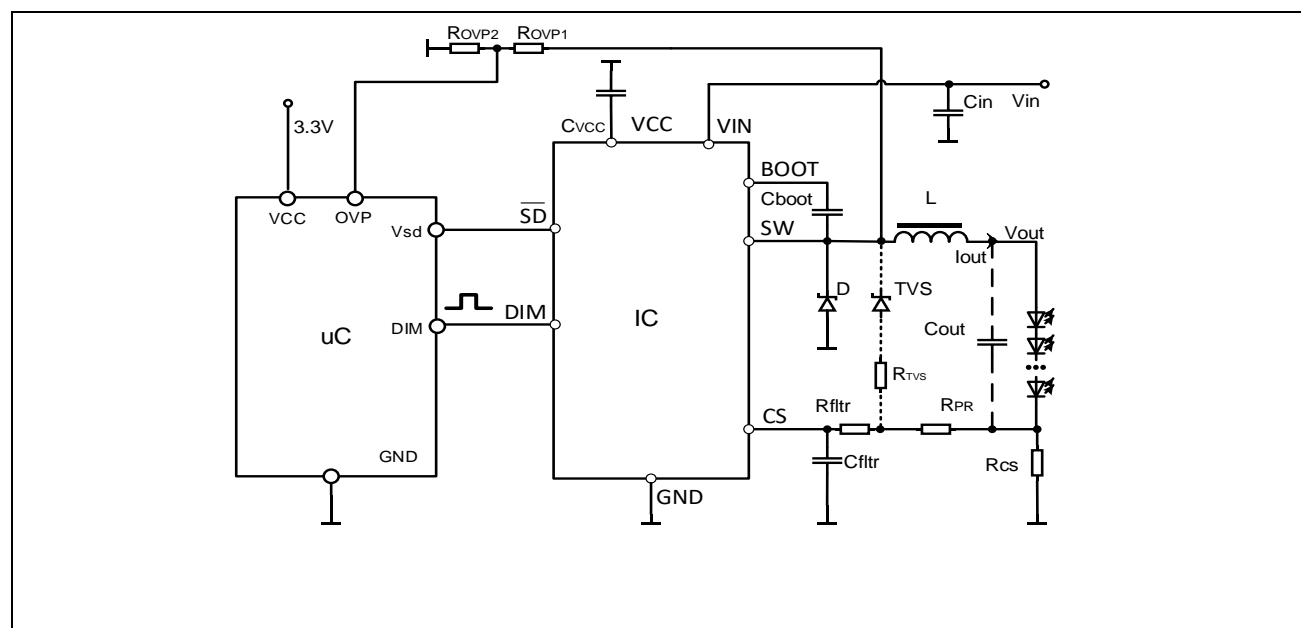


Figure 12 Microcontroller use

During the design, possible to bump up with an after-flash effect. In a two-stage configuration, when a LED driver input is disconnected from the AC line, short series of after-flashes may occur. ILD8150(E) has an internal current source that charges the bootstrap capacitor. It helps during start-up and also helps to achieve an extremely high duty cycle up to 99.9 percent. When the voltage on the bootstrap reaches $V_{GD_UVLO_ON}$ the gate driver activates, and the IC is active again until it discharges the bus capacitor to the voltage less than the LED voltage.

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

The issue can be fixed in two different ways: A 120 kOhm resistor bleeder between Boot and SW pins prevents the boot capacitor charge from the current source. Either a 20 kOhm resistor on the SD pin to GND. It switches the IC into the shut-down mode when voltage drops on the microcontroller, and it cannot control the circuit anymore.

2.3 Component selection

2.3.1 Current Sense (CS) resistor

The average LED current is determined by the value of the CS resistor R_{CS} . The mean CS threshold voltage is $V_{CS} = \frac{V_{CSH} + V_{CSL}}{2}$, $V_{CS} = 360$ mV. Hence, the proper value of R_{CS} is given by:

$$R_{CS} = \frac{360 \text{ mV}}{I_{LED,AVG}}$$

Power dissipated on the resistor also has to be considered:

$$P_{dis} = R_{CS} I_{LED,AVG}^2$$

2.3.2 Inductor and switching frequency selection

The inductor L has to maintain a constant current in the LEDs, so that the circuit operates in CCM. The inductor value L is related to the switching frequency f_{SW} , as shown below:

$$L = \frac{R_{CS}(V_{OUT} - V_{IN} t_{delay} f_{SW})}{f_{SW}(V_{CSH} - V_{CSL})} - \frac{R_{CS} V_{OUT}^2}{V_{IN} f_{SW}(V_{CSH} - V_{CSL})}$$

Where V_{IN} is the input voltage, V_{OUT} is the output voltage, V_{CSH} and V_{CSL} are high and low CS thresholds accordingly, and where $t_{delay} \approx t_{CSSW} + R_{fltr} C_{fltr}$, t_{CSSW} is the internal delay (less than 120 ns).

f_{SW} should be chosen so that it never runs in an audible range less than 20 kHz across all conditions. Lower inductance leads to smaller inductor size, but on the other hand it leads to higher switching losses, which has to dissipate the IC and efficiency decrease. An optimal frequency in which switching losses are not so critical should be found.

The saturation current (I_{sat}) of the chosen inductor has to be higher than the peak LED current $I_{PK} = I_{LED,AVG} + \Delta I_{OUT}/2$.

Because output ripple is very low it is recommended to use iron powder magnetics. The core should be a closed magnetic shape or shielded so as not to affect the IC's sensitive inputs, such as CS.

2.3.3 Diode D selection

Once the internal MOSFET turns off, the residual inductor energy is discharged through the diode D into the output capacitor and the LED load. Typically, a Schottky diode is used to reduce losses caused by the diode forward voltage and reverse recovery times.

The first parameter to consider when selecting a diode is its maximum reverse voltage V_{BR} . This voltage rating must be higher than the maximum input voltage V_{IN} of the circuit, V_{BR} more than V_{IN} .

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

The other two parameters defining the diode are average and RMS forward currents $I_{D,AVG}$ and $I_{D,RMS}$:

$$I_{D,AVG} = I_{LED,AVG} \cdot (1 - D)$$

$$I_{D,RMS} = I_{LED,AVG} \cdot \sqrt{1 - D} \cdot \sqrt{1 + \frac{1}{12} \cdot \left(\frac{\Delta I_{OUT}}{I_{LED,AVG}} \right)^2}$$

Where D is the duty cycle of the switching waveform and is given by:

$$D = \frac{V_{OUT}}{V_{IN}}$$

The diode must be chosen so that its respective current ratings are higher than these values.

2.3.4 Input capacitor C_{IN} selection

The input current of the buck regulator is identical to the current through the MOSFET, i.e. it is pulsating and thus causes a ripple voltage at the input. A capacitor on the V_{IN} pin reduces this ripple voltage by providing current when the switch is conducting. The RMS current through the input capacitor $I_{CIN,RMS}$ is purely AC and can be calculated from average and RMS input currents $I_{IN,AVG}$ and $I_{IN,RMS}$ as:

$$I_{CIN,RMS}^2 = I_{IN,RMS}^2 - I_{IN,AVG}^2$$

Hence,

$$I_{CIN,RMS} = I_{LED,AVG} \cdot \sqrt{D \cdot \left(1 - D + \frac{1}{12} \cdot \left(\frac{\Delta I_{OUT}}{I_{LED,AVG}} \right)^2 \right)}$$

Use low-ESR capacitors, especially under high switching frequency applications. With low-ESR capacitors, the input voltage ripple can be estimated by:

$$\Delta V_{IN} = \frac{I_{LED,AVG}}{f_{SW} \cdot C_{IN}} \cdot D \cdot (1 - D)$$

$$C_{IN} \geq \frac{I_{LED,AVG}}{f_{SW} \cdot \Delta V_{IN}} \cdot D \cdot (1 - D)$$

The input capacitor must be chosen so that it is capable of withstanding the calculated RMS current rate and reducing input voltage ripples to an acceptable level.

2.3.5 Output capacitor C_{OUT} selection

Due to the relatively low output ripple current, a capacitor in parallel to the LEDs is not needed in many applications. Due to the non-linear I-V characteristics of LEDs, it is very difficult to estimate the ripple voltage with and without an output capacitor. A generally accepted model is the approximation of LED V-I characteristics by a voltage source V_{FD} that models the forward voltage of the LED with a series resistor R_D to model differential resistance. Both parameters need to be determined from the LED datasheet. As a rule a V_{FD} of 3 V and a differential resistance R_D of 0.4 Ω (this parameter is being improved with every new LED generation) are very reasonable values for a typical white high-power LED. Consequently, for 17 LEDs in series this would lead to a V_{FD} of 51 V and a total R_D of 6.8 Ω . The ripple voltage without capacitor is then approximated as:

$$\Delta V_{OUT} \cong \Delta I_{OUT} \cdot R_D$$

A meaningful output capacitor should therefore have an impedance at f_{SW} , which is at least five to ten times lower than R_D :

$$C_{OUT} \geq \frac{5}{2\pi \cdot f_{SW} \cdot R_D}$$

Circuit description

2.3.6 Bootstrap capacitor C_{BOOT} selection

Integrated high-side MOSFET is driven by the gate driver. The bootstrap capacitor is defined as:

$$C_{BOOT} > \frac{Q_G}{\Delta V_{Cboot}}$$

Where Q_G is internal MOSFET gate charge 2.5 nC, ΔV_{Cboot} is the bootstrap capacitor voltage ripple.

2.4 Layout consideration

An optimized PCB layout leads to better performance, reliability and lower cost. Certain layout guidelines must be kept in mind while routing the PCB. The power components include the internal switch, Schottky diode, input capacitor, output capacitor and inductor. Place the input capacitor close to the IC, as parasitic inductance can be minimized by minimizing trace lengths and using short and wide traces. Extra parasitic inductance between the input capacitor's terminals and the IC's V_{IN} and GND terminals creates high dV/dt due to the switching process. This can lead to IC failure. Also, place the inductor as close as possible to the IC to reduce radiated EMI.

The output capacitor completes the routing of all the power components. It is the final component connected to the power ground terminal in the system. Improper output capacitor placement typically causes poor output current regulation. To ensure optimal operation, take care to minimize the area of the power-current loop.

The small-signal control components consist of all analog and digital components indirectly related to the power conversion, such as the CS pin, which is sensitive to noise. To reduce the noise coupling from the power stage to the control circuitry, it is necessary to keep the noisy switching traces far from the sensitive small-signal traces. The magnetic field from the inductor may cause noise on the CS path that could in turn lead to incorrect operation as double or triple pulses. To avoid this effect a shielded inductor should be used, but do not place this inductor close to the sensitive CS path. To minimize noise and ensure good output current regulation, it is critical to keep the V_{CS} path as short as possible, and it is desirable to return the ground of the small-signal component to a "clean" point. Poor routing of small-signal components may lead to poor output current regulation. A power inductor placed close to the CS path can influence the regulation loop. An example layout is shown in **Figure 13**.

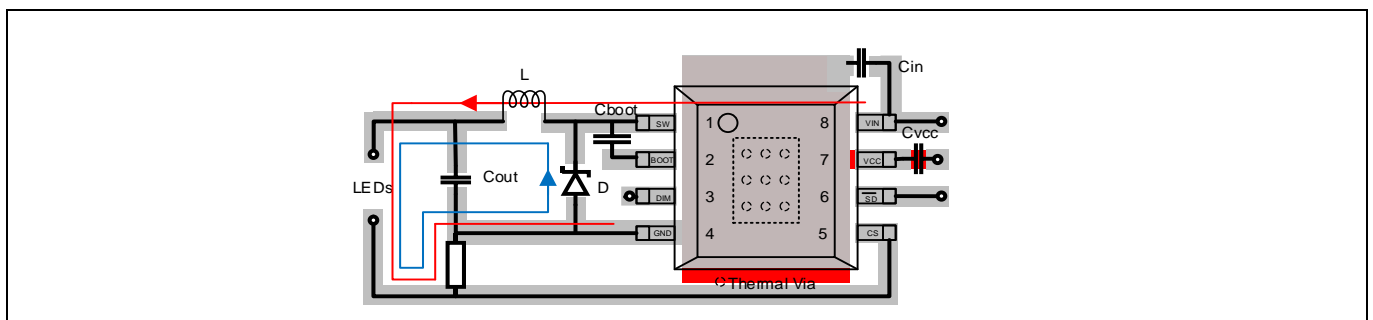


Figure 13 Layout example

Keep separate grounds for power components, which are noisy, and for the small-signal components, which are quiet. Then join these two grounds at one point, possibly the exposed pad under the IC, which is also the IC ground. A grid of thermal vias should be placed under the exposed pad to improve thermal conduction. The above guidelines ensure a well laid-out power supply design.

2.5 Design example

As an example, an LED driver with the following specification shall be designed:

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

- $V_{IN} = 70 \text{ V}$
- $I_{LED,AVG} = 1 \text{ A}$
- $V_{LED} = 51 \text{ V}$ (17 LEDs)

2.5.1 Determine R_{CS}

$$R_{CS} = \frac{0.36 \text{ V}}{1 \text{ A}} = 0.36 \Omega$$

2.5.2 Select switching frequency

80 kHz to 100 kHz may be a reasonable compromise between switching loss and inductor size. This needs to be verified by measurement of the finished design.

2.5.1 Inductor value and its current calculation

$$L = \frac{0.36 \Omega (51 \text{ V} - 70 \text{ V}) (120 + 270) \cdot 10^{-9} \text{ s} \cdot 100000 \text{ Hz}}{100000 \text{ Hz} (0.39 \text{ V} - 0.33 \text{ V})} - \frac{0.36 \Omega \cdot 51 \text{ V} \cdot 51 \text{ V}}{70 \text{ V} \cdot 100000 \text{ Hz} (0.39 \text{ V} - 0.33 \text{ V})}$$

$R_{fltr} C_{fltr}$ assumed as 270 ns (1.5 k Ω and 180 pF accordingly $F_{fltr} \approx 600 \text{ kHz}$)

$$L \approx 860 \mu\text{H}$$

The inductor average current is 1 A, while the peak current is $I_{pk} = I_{LED,AVG} + \Delta I_{OUT}/2 = I_{LED,AVG} \cdot 1.083 = 1.083 \text{ A}$. Saturation current I_{SAT} of the inductor must be higher than this value.

2.5.2 Diode selection

To calculate diode currents the duty cycle D is needed:

$$D = \frac{V_{OUT}}{V_{IN}} = \frac{51}{70} = 0.7285$$

$$1 - D = 0.2714$$

$$\text{RMS diode current: } I_{D,RMS} = 1 \cdot \sqrt{0.2714 \cdot \left(1 + \frac{1}{12} \cdot \left(\frac{0.167}{1}\right)^2\right)} = 0.52 \text{ A}$$

$$\text{Average diode current: } I_{D,AVG} = 1 \cdot 0.2714 = 0.27 \text{ A}$$

For a design with variable number of LEDs, the highest diode currents will occur at the lowest output voltage. “1-D” is close to 1 under such conditions, and diode currents are close to the output current. In general a 1 A diode is recommended as long as the output current is below 1 A.

The reverse blocking voltage V_{BR} of the diode must be higher than the maximum input voltage V_{IN} . A 100 V diode is sufficient in this example.

2.5.3 C_{IN} capacitor selection

$$C_{IN} \geq \frac{1}{80 \cdot 10^3 \cdot 0.01 \cdot 70} \cdot 0.7285 \cdot 0.2714 = 3.60 \mu\text{F}, \text{ decided to choose } 4.7 \mu\text{F}$$

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Circuit description

$$I_{CIN,RMS} = 1 \cdot \sqrt{0.7285 \cdot \left(1 - 0.2714 + \frac{1}{12} \cdot \left(\frac{0.167}{1}\right)^2\right)}, I_{CIN,RMS} = 0.73 \text{ A}$$

A 4.7 μF MLCC capacitor with a rated voltage of 100 V with RMS current rate of more than 0.73 A would be recommended in this case.

2.5.4 C_{OUT} capacitor selection

The value of C_{OUT} can be estimated as:

$$C_{OUT} \gg \frac{5}{2\pi \cdot 80 \text{ kHz} \cdot 6.8 \Omega} = 1.46 \mu\text{F}$$

For lower output voltage ripple a bigger output capacitor can be used. Because the value of this capacitor is relatively low even for low ripple demands, a MLCC capacitor is the best choice in terms of cost, lifetime and ESR. Switching frequency is very high and can be visible, so output capacitor may not be used just only 10 nF to improve EMI.

2.5.5 Bootstrap capacitor C_{BOOT} selection

$$C_{BOOT} > \frac{2.5 \cdot 10^{-9}}{1 \text{ V}} = 2.5 \text{ nF (deviation voltage assumed as 1 V, was chosen as 0.22 } \mu\text{F 25 V MLCC)}.$$

2.5.6 V_{CC} capacitor C_{VCC} selection

A 100 nF 25 V MLCC capacitor was selected, which has to be placed close to pin 7.

Application circuit

3 Application circuit

This section provides more information about the reference design available. The board is configurable to have an output current in the range 250 mA to 1500 mA, with current adjustment by jumpers X9 A, B and C, as shown in **Figure 17**. The operating voltage range for the demo board can be from 8 V to 80 V. Jumper J3 activates open-load protection and prevents output over-voltage to 60 V. The board is designed with two optional inductors – through-hole for high power and SMD for low power. The schematics and PCB layout are shown in **Figure 14** and **Figure 16**, respectively. The Bill of Materials (BOM) is in Appendix A.

3.1 Schematic layout

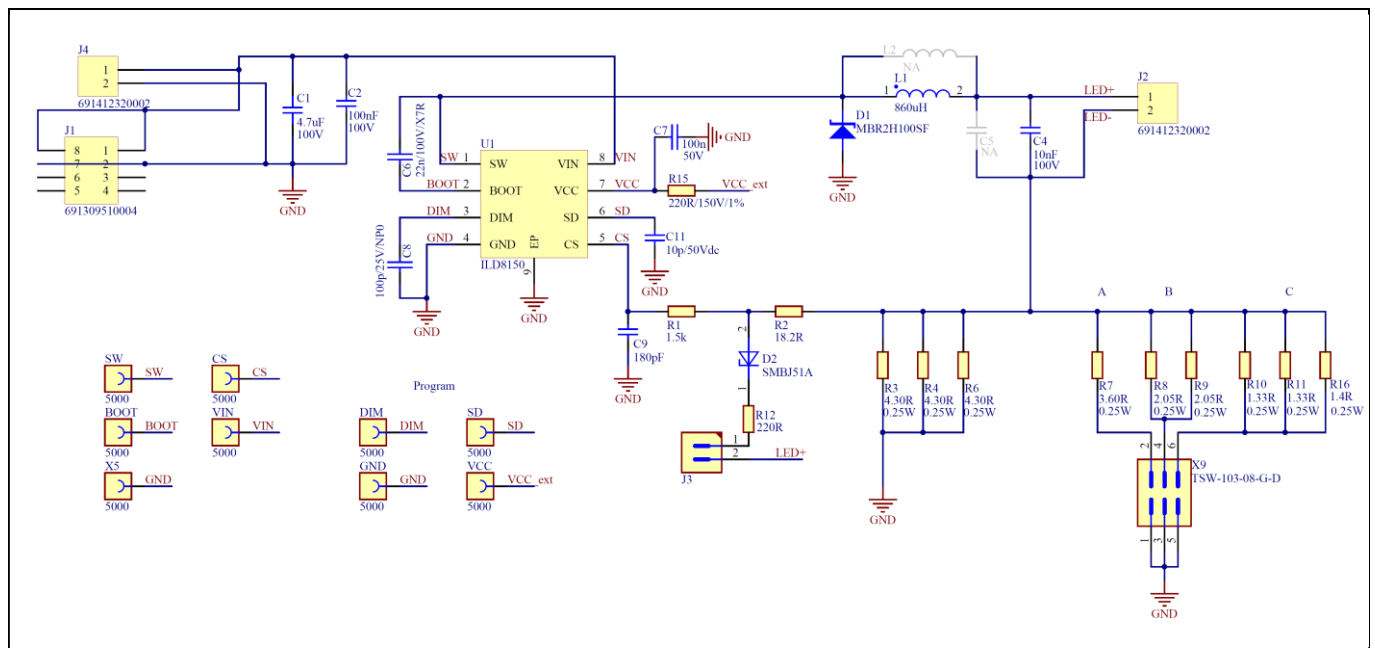


Figure 14 Reference design circuit

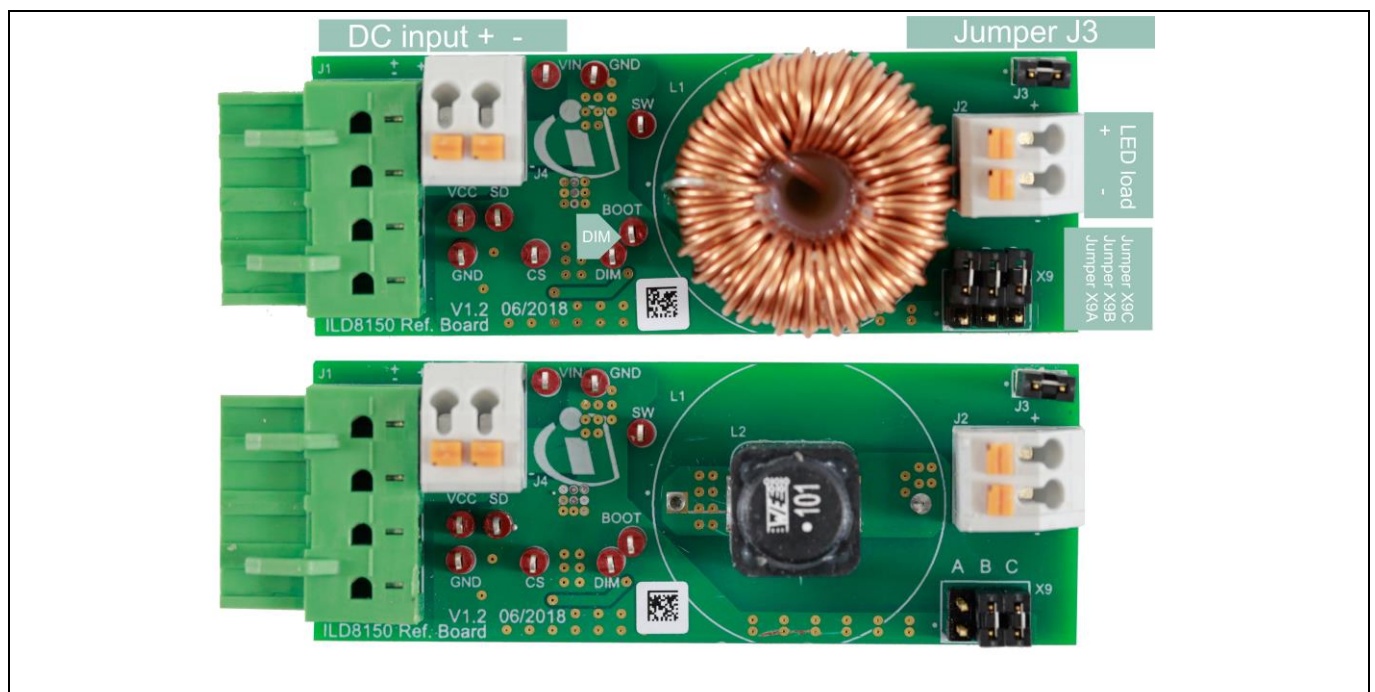


Figure 15 Reference design, dimensions 82(L)x26(W)x16(H) mm

3.2 PCB layout

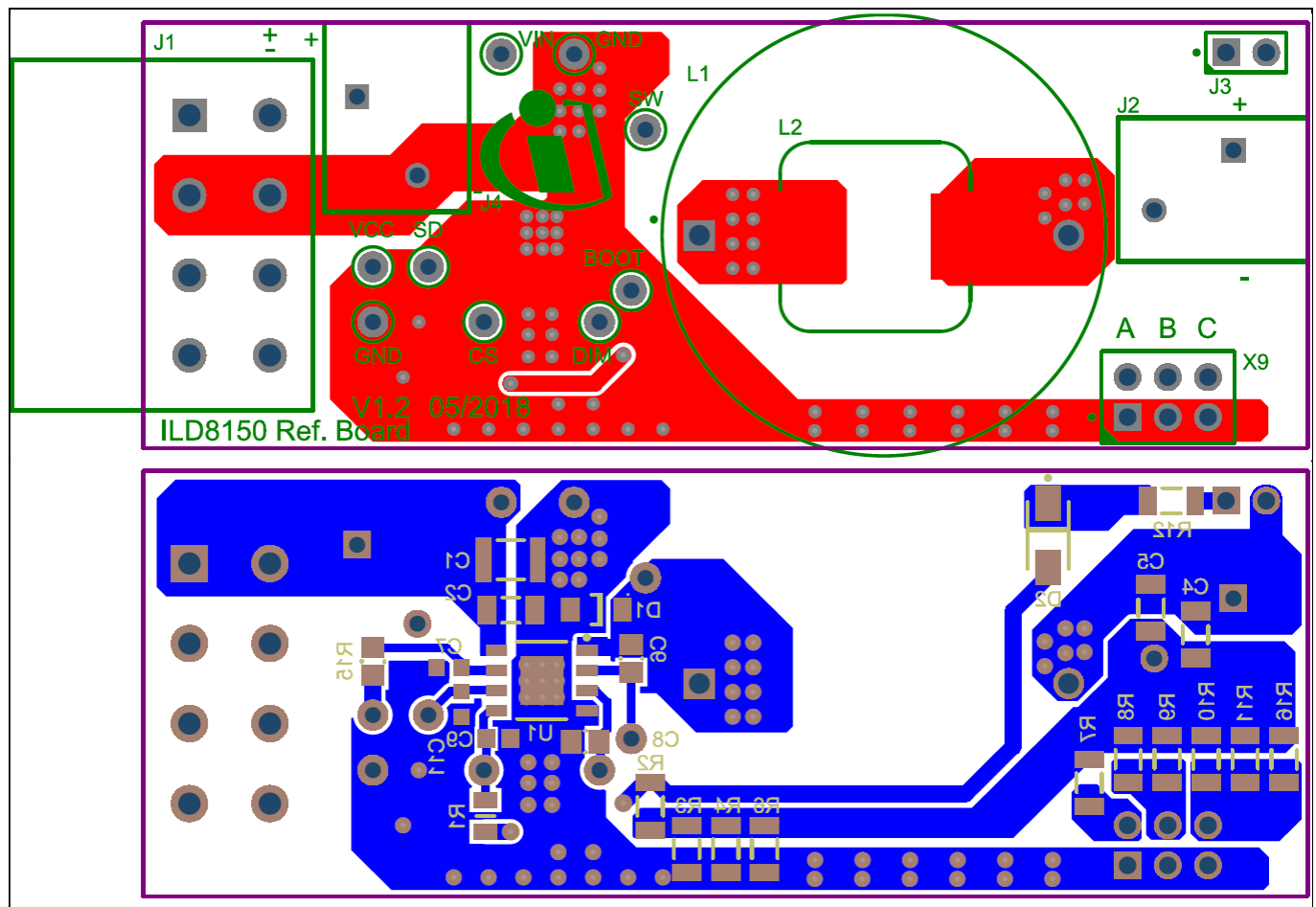


Figure 16 PCB layout of the reference design

	Jumper X9A	Jumper X9B	Jumper X9C	Output current (mA)
	-	-	-	250 (+/-3 percent)
	V	-	-	350 (+/-3 percent)
	-	V	-	600 (+/-3 percent)
	V	V	-	700 (+/-3 percent)
	-	-	V	1050 (+/-3 percent)
	V	-	V	1150 (+/-3 percent)
	-	V	V	1400 (+/-3 percent)
	V	V	V	1500 (+/-3 percent)

Figure 17 Jumper positions vs LED current

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Measurement results with reference design

4 Measurement results with reference design

Table 1 Typical condition for measurement

V_{IN}	R_{CS}	Inductance	LED load
70 V	0.36 Ω	860 μ H	17 pcs

Figure 18 shows the actual operating waveforms. The actual measured LED current is 1 A. The switching frequency is 85 kHz and the internal DMOS transistor on the duty cycle is 74 percent.

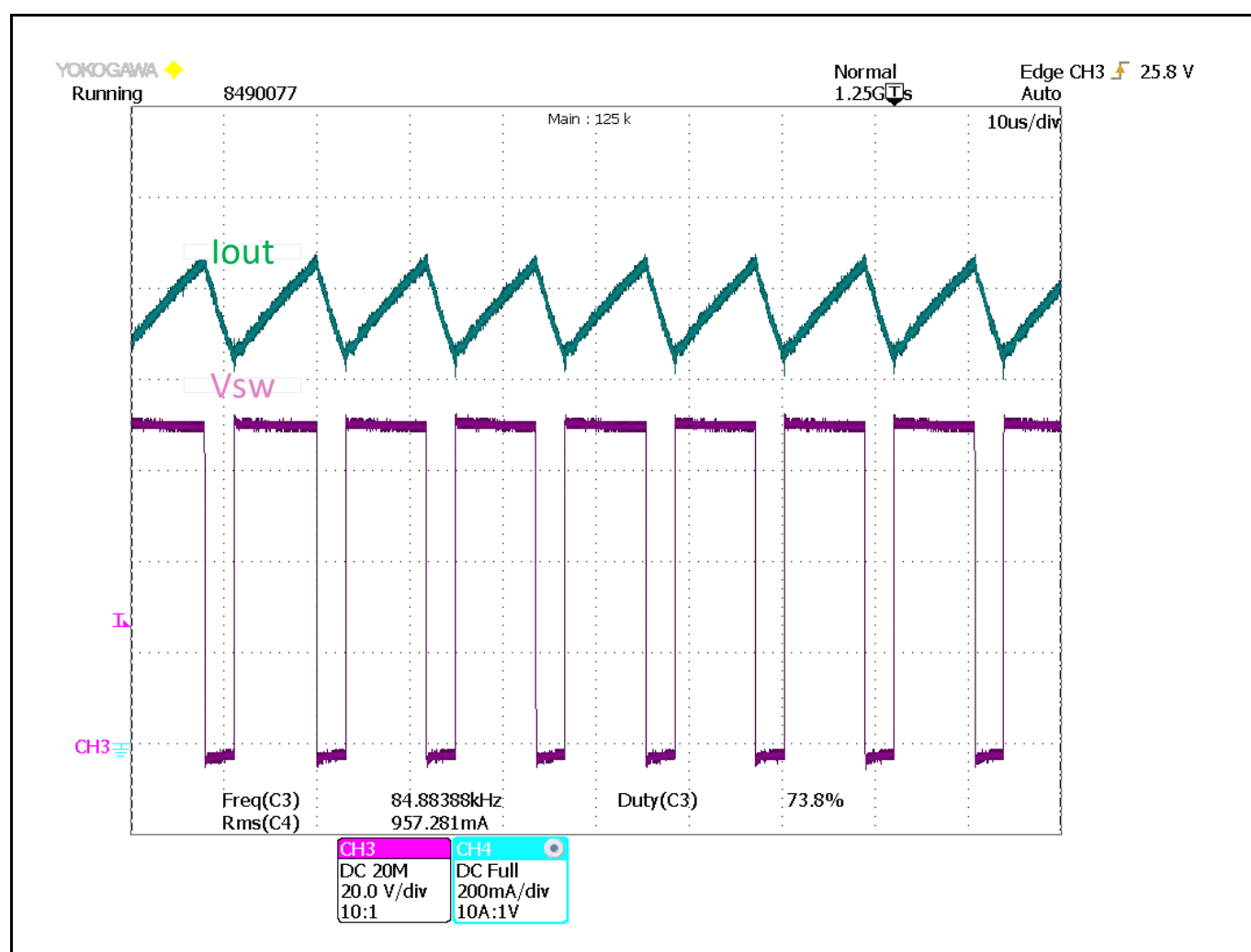


Figure 18 Normal operation waveform

4.1 LED current vs supply voltage

ILD8150 provides high output current accuracy despite the changes in supply voltage. **Figure 19** shows the output current vs supply voltage in the range 52 V to 70 V. Over the supply range, the output LED current only deviates in the range of 1 percent.

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Measurement results with reference design

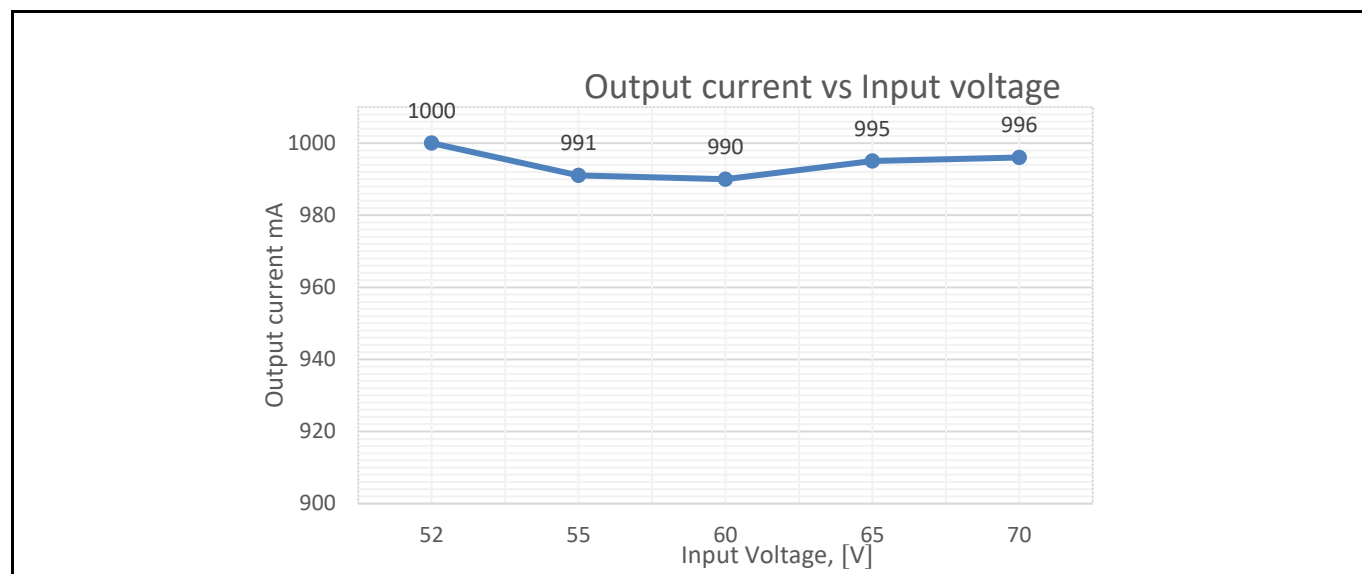


Figure 19 Output LED current vs supply voltage

4.2 Dimming

Table 2 Condition

V_{IN}	$I_{LED,AVG}$	Input PWM frequency	LED
70 V	700 mA	1 kHz	17 pcs

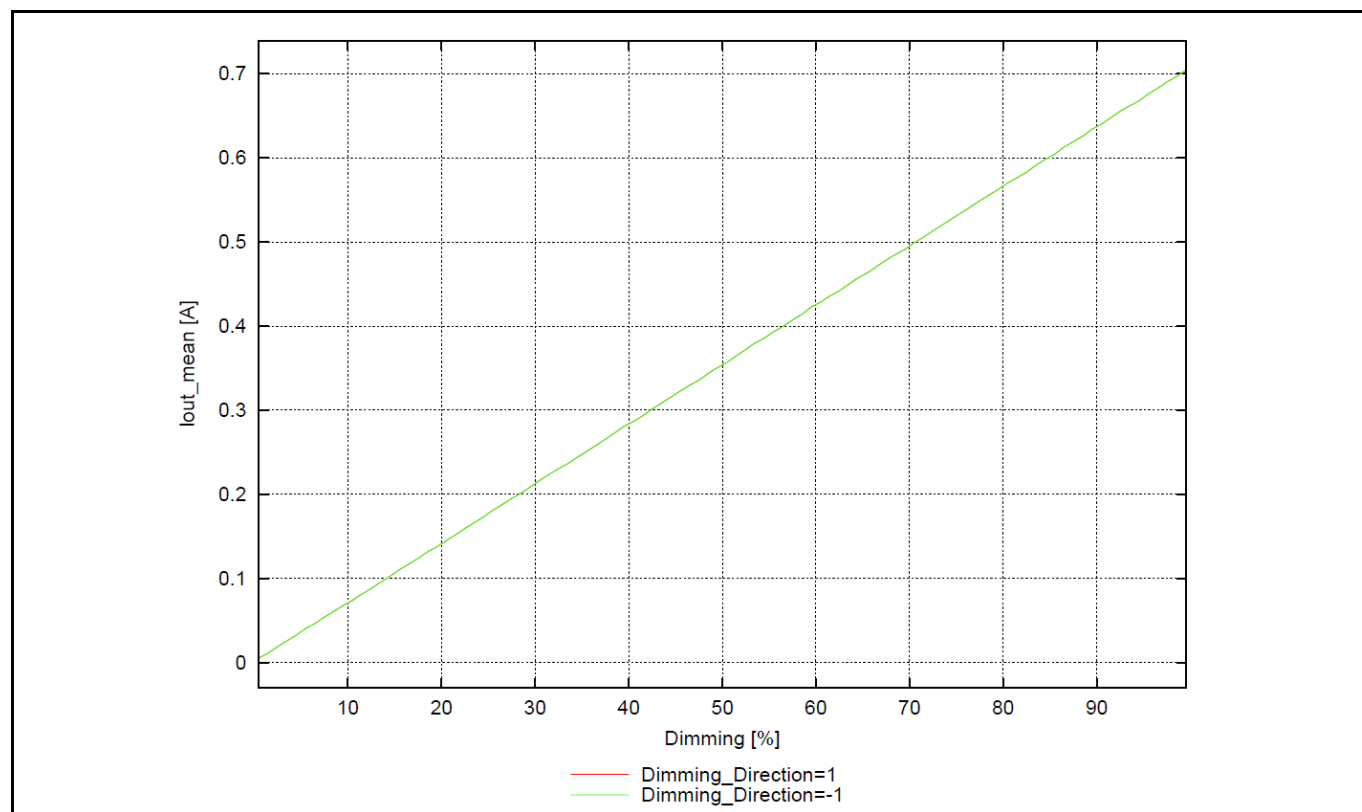


Figure 20 Output current vs duty cycle

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Measurement results with reference design

4.3 Soft-start

The soft-start process has two steps. **Figure 21** shows the digital soft-start process with the steps described earlier.

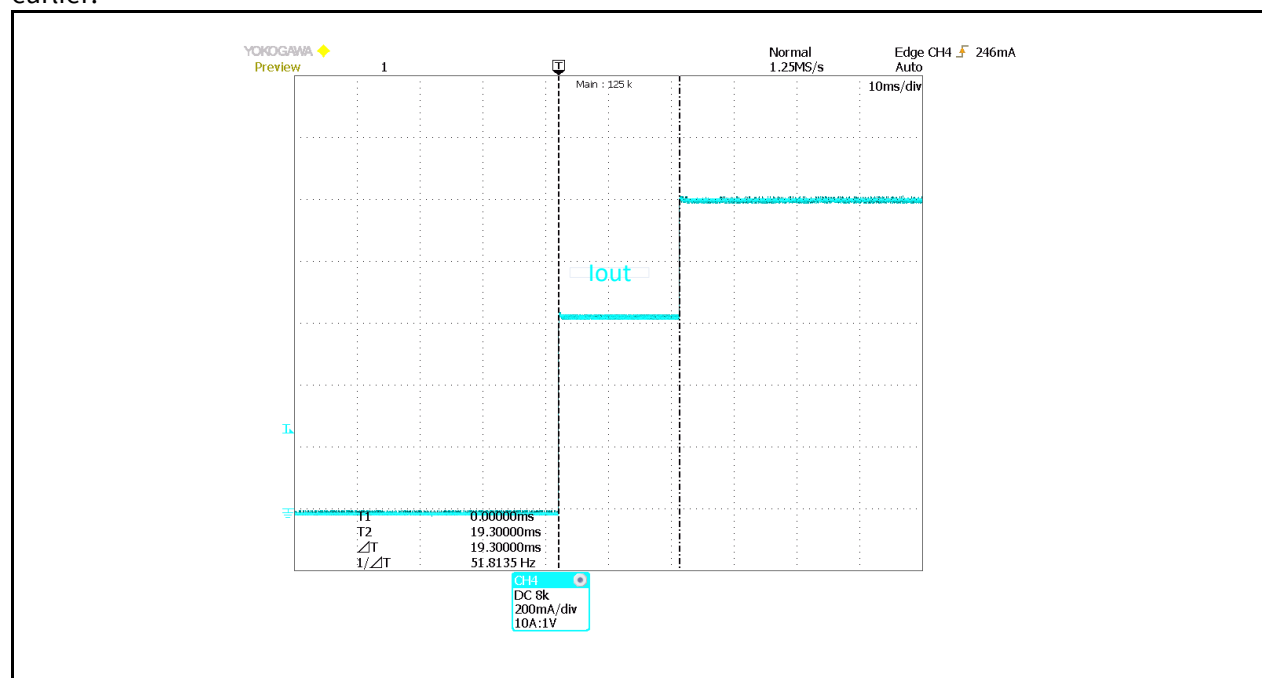


Figure 21 Soft-start, output current

4.4 Cycle-by-cycle current limitation

Figure 22 shows the waveforms under short-circuit condition where the IC limits output current cycle-by-cycle.

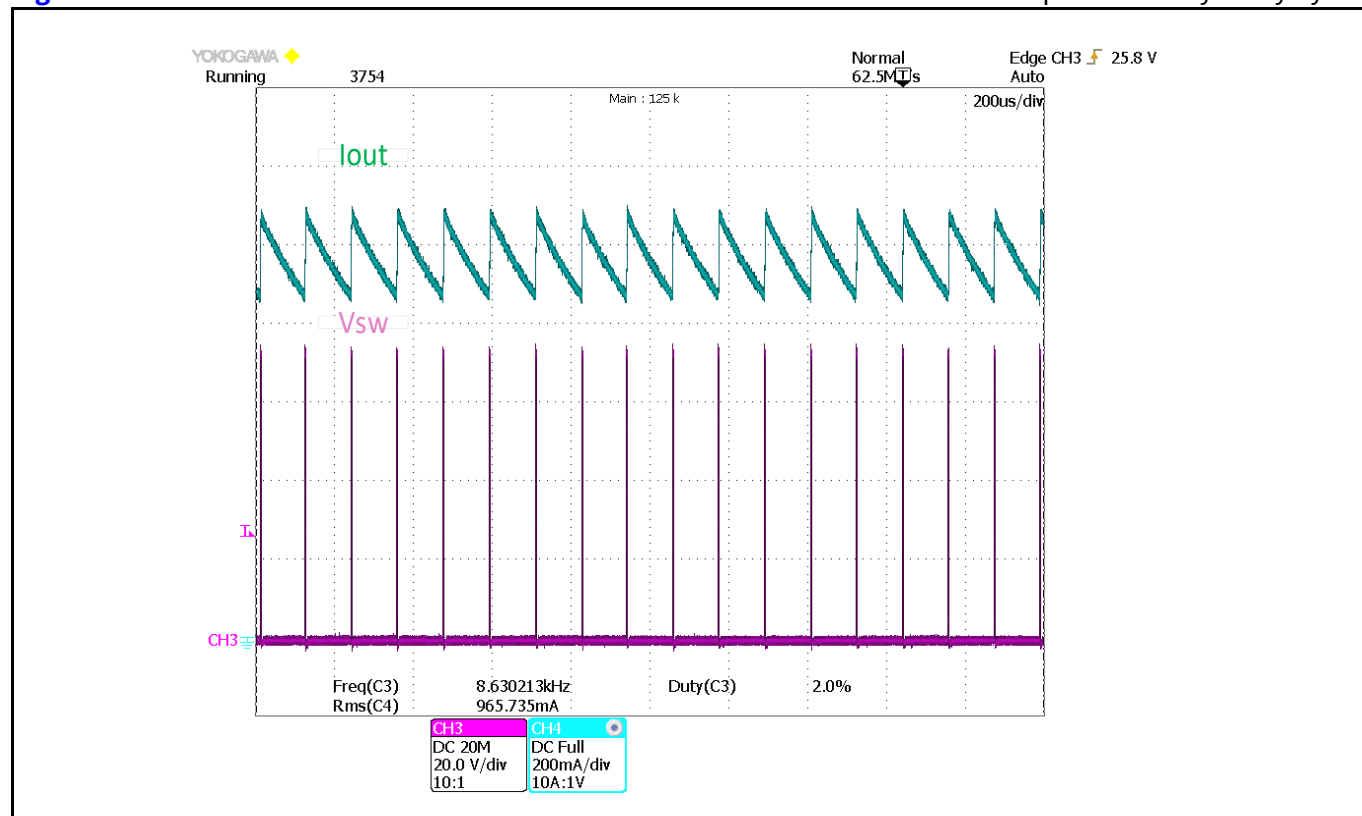


Figure 22 OCP waveforms

Measurement results with reference design

4.5 Efficiency

Efficiency measurement results in the input range 52 V to 70 V for 17 LEDs is shown in [Figure 23](#). The efficiency is measured with different inductors – 860, 150 and 100 μH . It reflects the maximum switching frequency – 86, 360 and 520 kHz accordingly. As seen from the character of the curves, when the difference between input and output voltage is quite low efficiency is quite high with a wide inductance range, because the switching frequency is relatively low. In applications with fixed output voltage, which is close to the output voltage, and low input voltage deviation/ripple, a small inductor may be used. In applications with wide output voltage range and input voltage ripple, such as 100 or 120 Hz, and 10 percent of ripple, which is normal on the primary stage, switching losses create additional power dissipation. In this case inductance should be increased or output current limited.

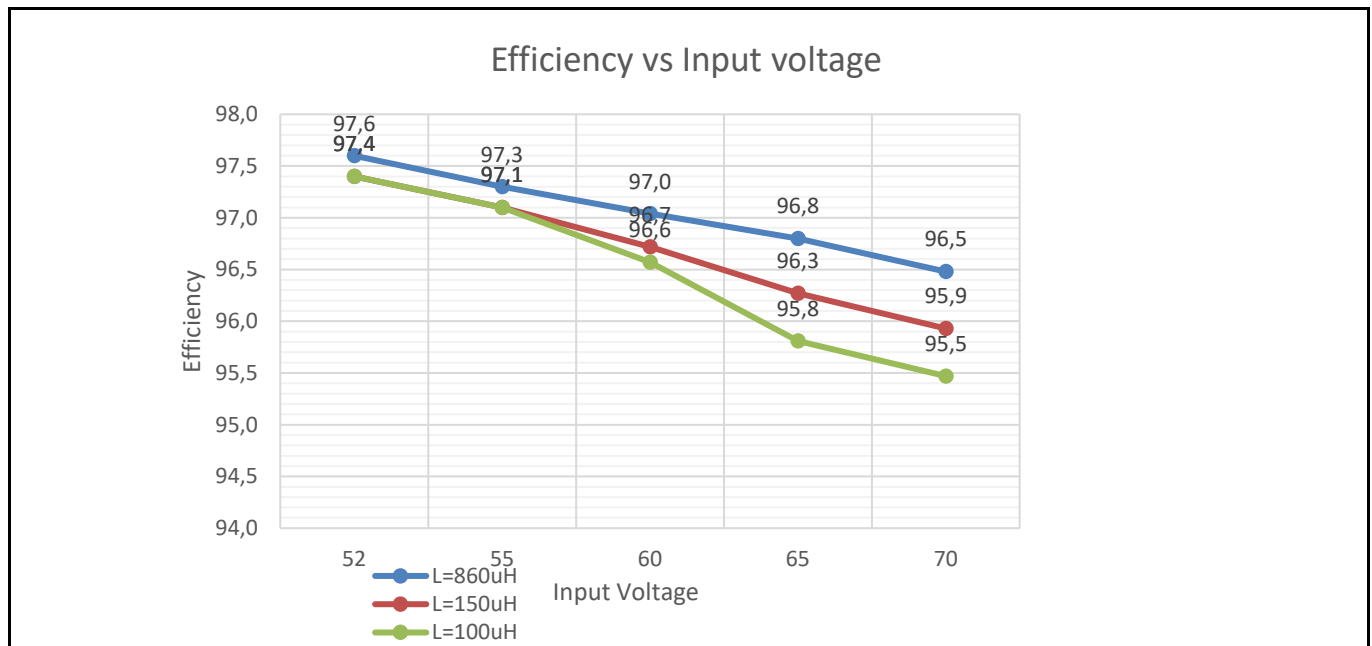


Figure 23 Efficiency vs supply voltage

4.6 Thermal behavior

The maximum temperature attained by the demonstration board is 73.8°C, as shown in [Figure 24](#). The test was performed with input 70 V and 17 LEDs.

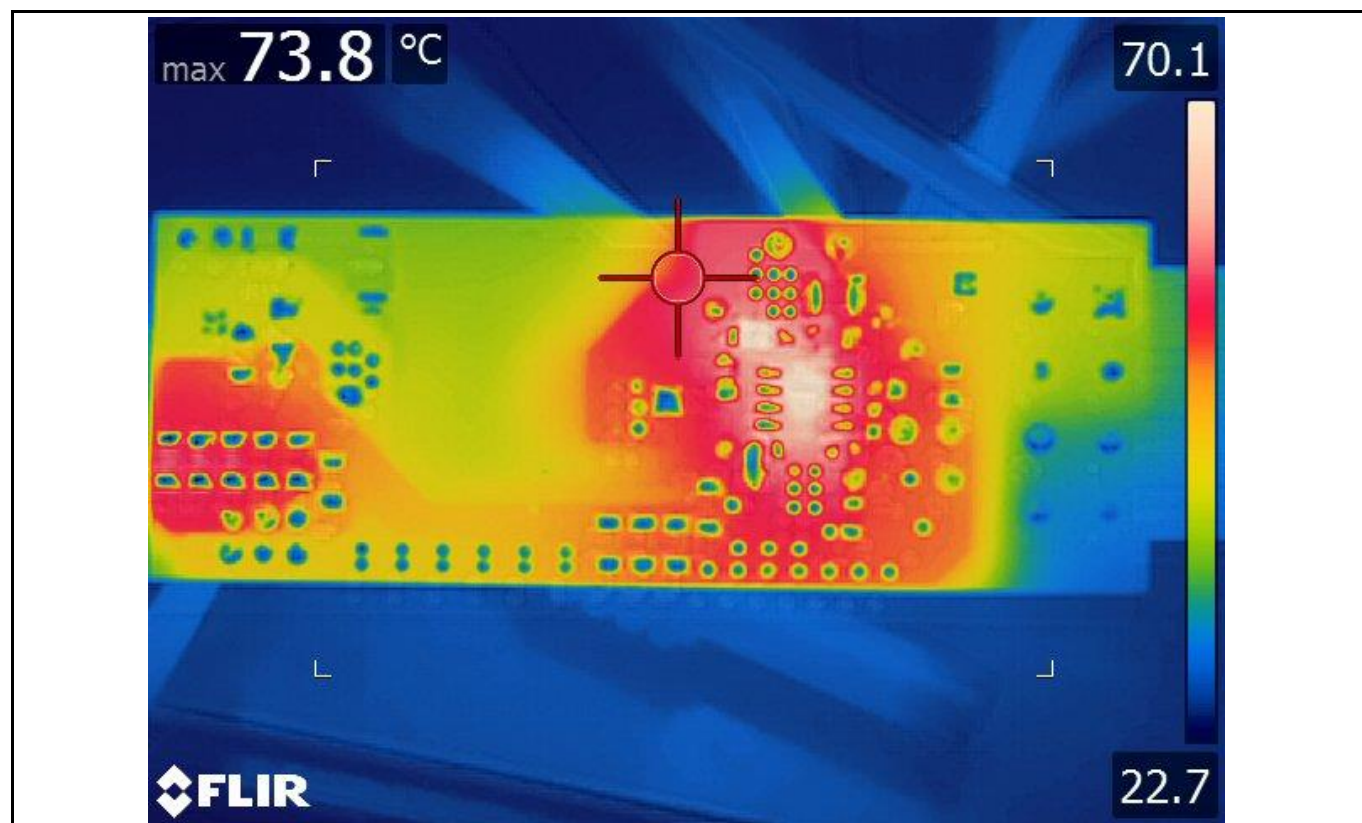


Figure 24 Thermal image

4.7 Output current ripple

Figure 25 shows output current waveforms with capacitors of 10 nF and 4.7 μ F accordingly. It can be seen that placing a 4.7 μ F capacitor in parallel with the LED reduces output ripple current from 21.6 percent to 5.6 percent.

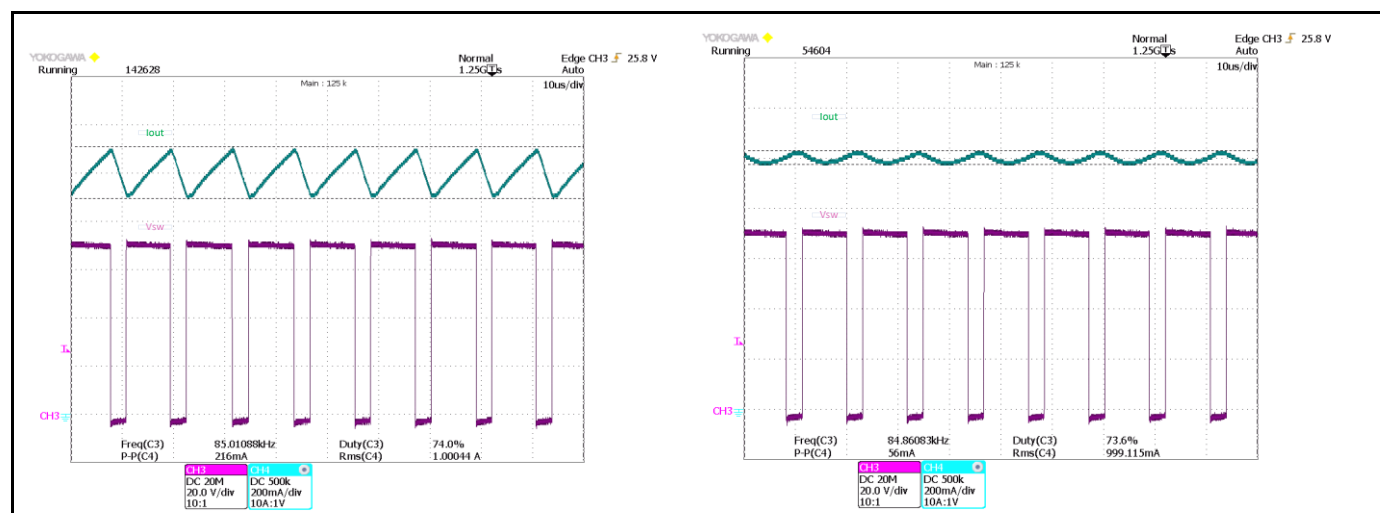


Figure 25 Output current ripple with $C_{OUT} = 10$ nF (left) and with $C_{OUT} = 4.7$ μ F (right)

Some applications, such as machine vision, are not allowed to use PWM dimming. In this case an output electrolytic capacitor, which filters output PWM, is recommended. **Figure 26** shows output current waveform with input voltage 70 V, 17 LEDs or 51 V, dimming level 6.25 percent, output capacitor 100 μ F. An electrolytic capacitor reduces output ripple to 12.5 percent peak-to-peak.

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Measurement results with reference design

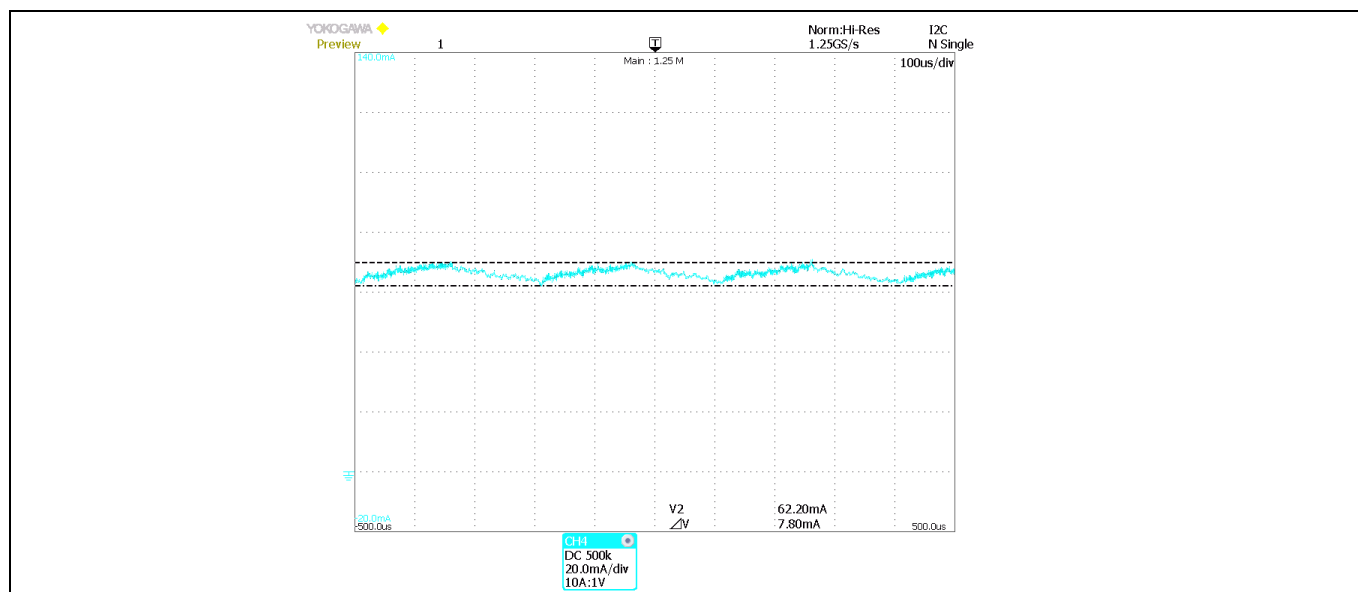


Figure 26 Output current waveform at 6.25 percent dimming level with electrolytic output 100 μ F

ILD8150 80 V high side buck LED driver IC with hybrid dimming

Application with flyback converter XDPL8219

5 Application with flyback converter XDPL8219

The ILD8150 IC operates as the secondary stage along with a primary-stage flyback or LLC converter. For example, it may be used together with a PFC flyback based on XDPL8219. XDPL8219 is a digitally configurable Secondary-Side Regulated (SSR) controller suitable for PFC flyback operating in Constant Voltage (CV) mode. The XDPL8219 board operates with a universal AC input of 90 V_{rms} to 305 V_{rms} and provides a constant voltage of 54 V. So the ILD8150 hysteretic buck converter operates with a fixed input voltage of 54 V and has constant output current. ILD8150 can provide a wide dimming range from 0.5 to 100 percent, with high accuracy across all conditions. It dumps 100 or 120 Hz ripples from the primary side, so the output current is pure DC, which eliminates flicker. The efficiency of such a system is shown in [Figure 27](#).

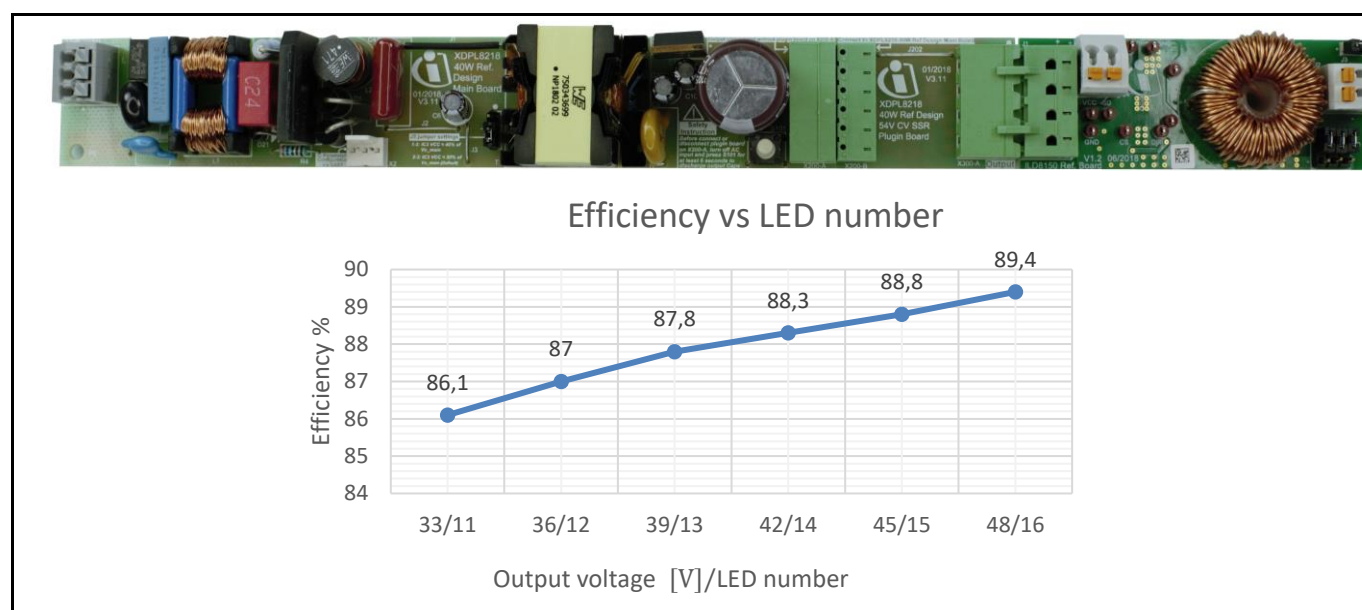


Figure 27 Efficiency of combined stages vs number of LEDs

Appendix A

6 Appendix A

Table 3 BOM

	Designator	Value	Description	Manufacturer	Manufacturer Part number
1	BOOT	5000	Test-point THT, red	Keystone	5000
2	C1	4.7 μ F	Commercial-grade multi-layer ceramic chip capacitor	TDK	C3225X7S2A475K200AB
3	C2	100 nF	Surface-mount multi-layer ceramic chip capacitor	TDK	C3216X7R2A104K160AA
4	C4	10 nF	Surface-mount ceramic capacitor automotive grade	AVX	12061C103K4Z2A
5	C5	–	Surface-mount ceramic capacitor automotive grade	AVX	12061C103K4Z2A
6	C6	22 n	Cap-0805-22n/100 V/0.1/X7R	AVX	08051C223K4Z2A
7	C7	100 n	Cap-0603-100 n/50 V/0.1/X7R	AVX	06035C104K4Z2A
8	C8	100 p	Cap-0805-100 p/25 V/0.1/NP0	Kemet	C0805C101K3GACTU
9	C9	180 pF	Surface-mount multi-layer ceramic chip capacitor	Kemet	C0603C181J5GACTU
10	C11	10 p	GCM-series general-purpose monolithic ceramic capacitor for automotive	Murata	GCM1885C1H100JA16#
11	CS	5000	Test-point THT, red	Keystone	5000
12	D1	MBR2H100SF	SMD Schottky power rectifier 2.0 A/100 V	ON Semiconductor	MBR2H100SFT3G
13	D2	SMBJ51A	SMBJ 600 W Transil, uni-directional TVS diode/51 V	Bourns	SMBJ51A
14	DIM	5000	Test-point THT, red	Keystone	5000
15	GND	5000	Test-point THT, red	Keystone	5000
16	J1	–	WR-TBL Serie 3095 – 5.08 mm reversed gender horizontal PCB header, 04 p	Würth Elektronik	691309510004
17	J2	–	WR-TBL Serie 4123 – 3.81 mm screwless 45-degree entry, 2 p	Würth Elektronik	691412320002
18	J3	HTSW-102-07-L-S	Through-hole .025" SQ post header, 2.54 mm pitch, 2-pin, vertical, single row	Samtec	HTSW-102-07-L-S
19	J4	–	WR-TBL Serie 4123 – 3.81 mm screwless 45-degree entry, 2 p	Würth Elektronik	691412320002
20	L1	860 μ H	Bobbin-type inductor	Würth Elektronik	7447075
21	L2	–	WE-PD SMD shielded power inductor, size 1210, 1.4 A, 0.56 Ω , 470 μ H	Würth Elektronik	7447709471
22	R1	1.5 k	1.5 k/150 V/1 percent	Vishay	CRCW08051K50FKEA
23	R2	18.2 R	18.2R/200 V/1 percent	Vishay	CRCW120618R2FKEA

Appendix A

24	R3	4.30 R	Standard thick-film chip resistor	Vishay	CRCW12064R30FK
25	R4	4.30 R	Standard thick-film chip resistor	Vishay	CRCW12064R30FK
26	R6	4.30 R	Standard thick-film chip resistor	Vishay	CRCW12064R30FK
27	R7	3.60 R	Standard thick-film chip resistor	Vishay	CRCW12063R60FK
28	R8	2.05 R	Standard thick-film chip resistor	Vishay	CRCW12062R05FK
29	R9	2.05 R	Standard thick-film chip resistor	Vishay	CRCW12062R05FK
30	R10	1.33 R	Standard thick-film chip resistor	Vishay	CRCW12061R33FK
31	R11	1.33 R	Standard thick-film chip resistor	Vishay	CRCW12061R33FK
32	R12	0 R	0 R/200 V/20 mΩ	Vishay	CRCW12060000Z0EA
33	R15	220 R	220 R/150 V/1 percent	Yageo/Phycomp	RC0805FR-07220R
34	R16	1.4 R	1.4 R/200 V/1 percent	Vishay	CRCW12061R40FKEA
35	SD	5000	Test-point THT, red	Keystone	5000
36	SW	5000	Test-point THT, red	Keystone	5000
37	U1	ILD8150E	DC-DC LED driver IC	Infineon	ILD8150E
38	VCC	5000	Test-point THT, red	Keystone	5000
39	VIN	5000	Test-point THT, red	Keystone	5000
40	X5	5000	Test-point THT, red	Keystone	5000
41	X9	TSW-103-08-G-D	2.54 mm pitch header strip, 6 pins, vertical, double row	Samtec	TSW-103-08-G-D

References

7 References

Please refer to the ILD8150 datasheet for more information:

[Link to ILD8150 datasheet](#)

References

Revision history

Document version	Date of release	Description of changes
V 1.0	November 2018	First release
V 1.1	10 March 2021	Shut-down explanation, ESD chapter update, after-flash effect explanation

Trademarks

All referenced product or service names and trademarks are the property of their respective owners.

Edition 2021-03-10

Published by

Infineon Technologies AG

81726 Munich, Germany

© 2021 Infineon Technologies AG.

All Rights Reserved.

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

AN_1809_PL21_1810_124440

IMPORTANT NOTICE

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office (www.infineon.com).

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

[Infineon:](#)

[REFILD8150DC15ATOBO1](#)