Advanced thermal protection for high power LEDs with 60 V LED driver IC ILD6150

About this document

Scope and purpose

This Application note introduces Infineon's Hysteritic Buck DC-DC LED driver ILD6150 for general lighting application. It describes the demo board, performance as well as design ideas for various applications. The ILD6150 offers high efficiency, various protection features, superior dimming performance and reliability for a high-performance lighting system.

Intended audience

This document is intended for users who wish to design a high efficiency, high reliability lighting system with Infineon's ILD6150/ILD6070 DC-DC LED driver.

Table of contents

Table of contents

About this document **1**
Table of contents **2**
1 Introduction **3**
1.1 Features 3
1.2 Applications 3
1.3 Product Brief 3
2 Application Information **5**
2.1 Schematic 5
2.2 PCB Layout 5
2.3 PCB Photo 6
3 Measurement Results **7**
3.1 LED current vs supply voltage 7
3.2 Analog dimming 8
3.3 Contrast ratio 9
3.4 Over temperature protection 11
3.5 Efficiency 12
3.6 Transition from DC to switch mode 13
3.7 Soft start 13
3.8 Overcurrent protection 14
3.9 PCB thermal resistance 15
3.10 Thermal protection with NTC thermistor 16
3.11 Slow start with additional PMOS for hot swapping 16
3.12 Driving of LEDs with current more than 1.5 A by external MOSFETs 17
References **18**
Revision history **19**
Disclaimer **20**

1 Introduction

1.1 Features

- Wide input voltage range from 4.5 V to 60 V
- Capable to provide up to 1.5 A output current
- Up to 1 MHz switching frequency
- Soft-start capability
- Analog and PWM dimming
- Integrated PWM generator for analog dimming input
- Typical 3% output current accuracy
- Very low LED current drift over temperature
- Undervoltage lockout
- Overcurrent protection
- Thermally optimized package: PG-DSO-8-27
- Adjustable overtemperature protection, reducing thermal load by decreasing the current



Figure 1 ILD6150

1.2 Applications

- LED driver for general lighting
- Retail, office, and residential downlights
- Street and tunnel lighting
- LED ballasts

1.3 Product Brief

The ILD6150 is a hysteretic buck LED driver IC for driving high power LEDs in general lighting applications with average currents up to 1.5 A.

The ILD6150 is suitable for LED applications with a wide range of supply voltages from 4.5 V to 60 V. A multifunctional PWM input signal allows dimming of the LEDs with an analog DC voltage or an external PWM signal. To minimize color shifts of the LEDs, an analog PWM voltage is converted to an internal 1.6 kHz PWM signal modulating the LED current.

The ILD6150 incorporates an undervoltage lock-out that will shut down the IC when the minimum supply voltage threshold is exceeded. The overcurrent protection turns off the output stage once the output current

exceeds the current threshold. An integrated overtemperature protection circuit will start to reduce the LED current by internal PWM modulation once the adjustable junction temperature threshold of the IC is exceeded. Realizing a thermal coupling between LED driver and LEDs, this feature eliminates the need of external temperature sensors, such as NTCs or PTCs.

The hysteretic concept is that the current control is extremely fast and always stable. A maximum contrast ratio of 3000:1 can be achieved depending on the dimensioning of the external components. The efficiency of the LED driver is remarkable high, reaching up to 98% of efficiency over a wide range. The output current accuracy from device to device and under all load conditions and overtemperature is limited to a minimum, making ILD6150 the perfect fit for LED ballasts.

2 Application Information

In this application note, you will find more information about the demo board available for evaluation. The demo board is configured to have an output current of 1 A. The operating voltage range for the demo board can be from 4.5 V up to 60 V. The schematic, PCB layout, and BOM list can be found in this section.

2.1 Schematic

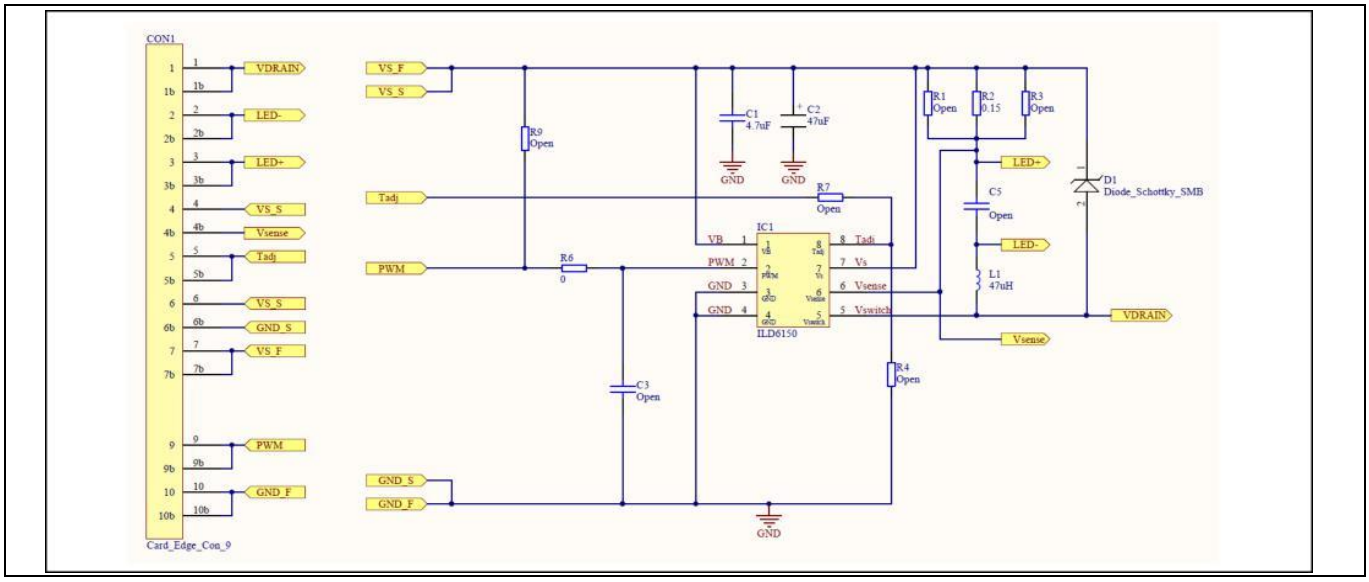


Figure 2 Schematic of the demonstration board

2.2 PCB Layout

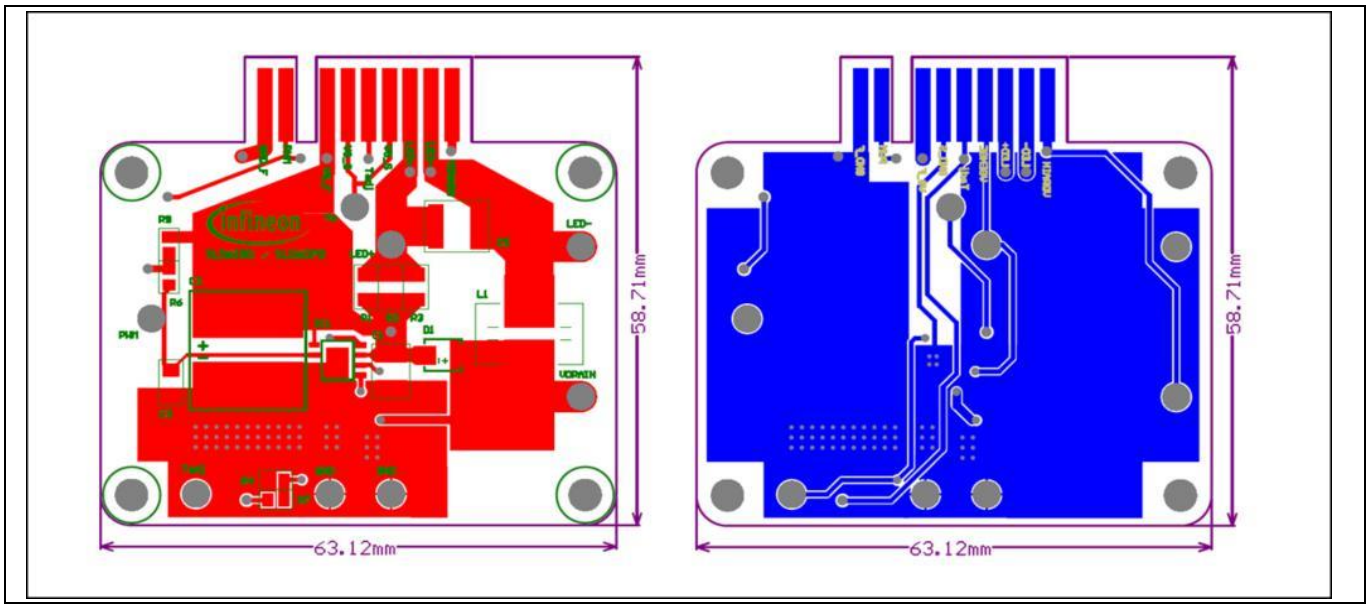


Figure 3 PCB layout of the demonstration board

2.3 PCB Photo

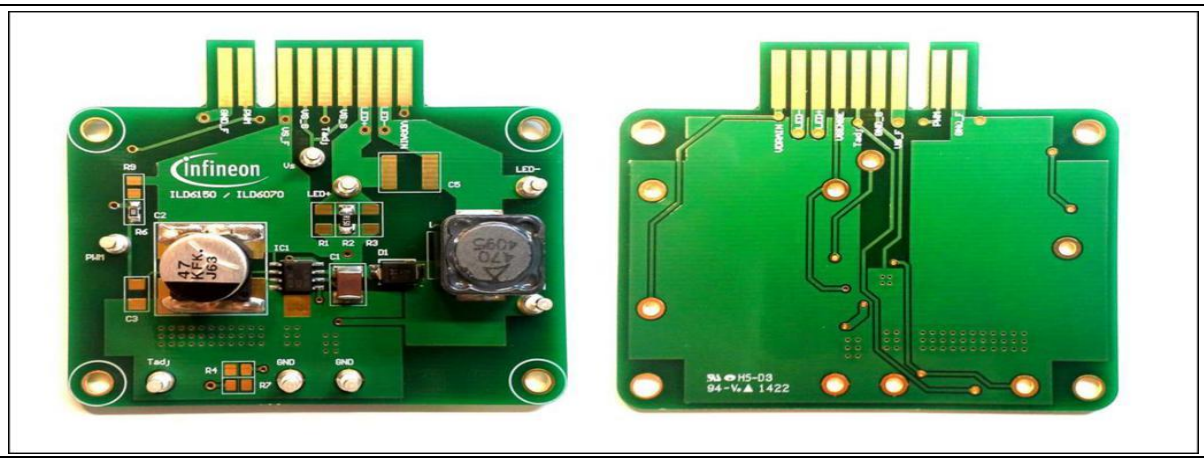


Figure 4 PCB photo of the demonstration board

Table 1 Bill of materials

Symbol	Value	Unit	Size	Manufacturer	Comment
IC1	ILD6150	–	DSO-8	Infineon	Hysteretic Buck controller and LED driver
R1	Open	O	1206	–	Current sense resistor
R2	0.15	O	1206	–	Current sense resistor
R3	Open	O	1206	–	Current sense resistor
R4	Open	O	0805	–	Resistor for TSD adjustment
R6	0	O	0805	–	Series resistor for PWM pin
R7	Open	O	0805	–	Series resistor for T_{adj} pin
R9	Open	O	0805	–	Pull-up resistor for PWM pin
C1	4.7	pF	1812	TDK	C4532X7S2A475M, Ceramic, 100 V
C2	47	pF	G	Panasonic	EEEFK1K470P, Electrolytic, 80 V
C3	Open	pF	1206	–	Filter capacitor for PWM pin
C4	Open	pF	1206	–	Filter capacitor for VB pin
C5	Open	pF	2220	–	Current ripple reduction capacitor
J1	0	O	0805	–	Jumper
D1	B2100-13-F		SMB	DIODES INC.	Schottky diode, 100 V, 2 A
L1	47	pH	12 x 12 mm	EPCOS	Shielded Power Inductor

The demo boards are available on request. Please contact your local sales representative for the updated information of the demo board's status.

3 Measurement Results

3.1 LED current vs supply voltage

The average LED current is determined by the value of the external current sense resistor (R_{sense}), formed by R1, R2, and R3 connected between V_s and V_{sense}. For ILD6150, the mean current sense threshold voltage is 152 mV. The equation that determines the output LED current is given:

$$I_{OUT} = \frac{V_S - V_{sense}}{R_{sense}} = \frac{152\ mV}{R_{sense}}$$

Equation 1

The target current setting for the demo board is 1 A. Based on the above equation, the R_{sense} is equal to 0.152 Ω. A resistor at the value of 0.15 Ω is chosen for the demo board.

The measurement results in this session are based on the condition below, unless otherwise specified:

Table 2 Typical condition for measurement

V_s	R_{sense}	Inductance	LED load
48 V	0.15 Ω	47 µH	12 pcs

Figure 5 shows the actual operating waveforms. The actual measured V_{sense} average voltage under this condition is 150 mV, and the LED current is 1 A. The switching frequency is 467 kHz and the internal DMOS transistor on duty-cycle is 73.8%.

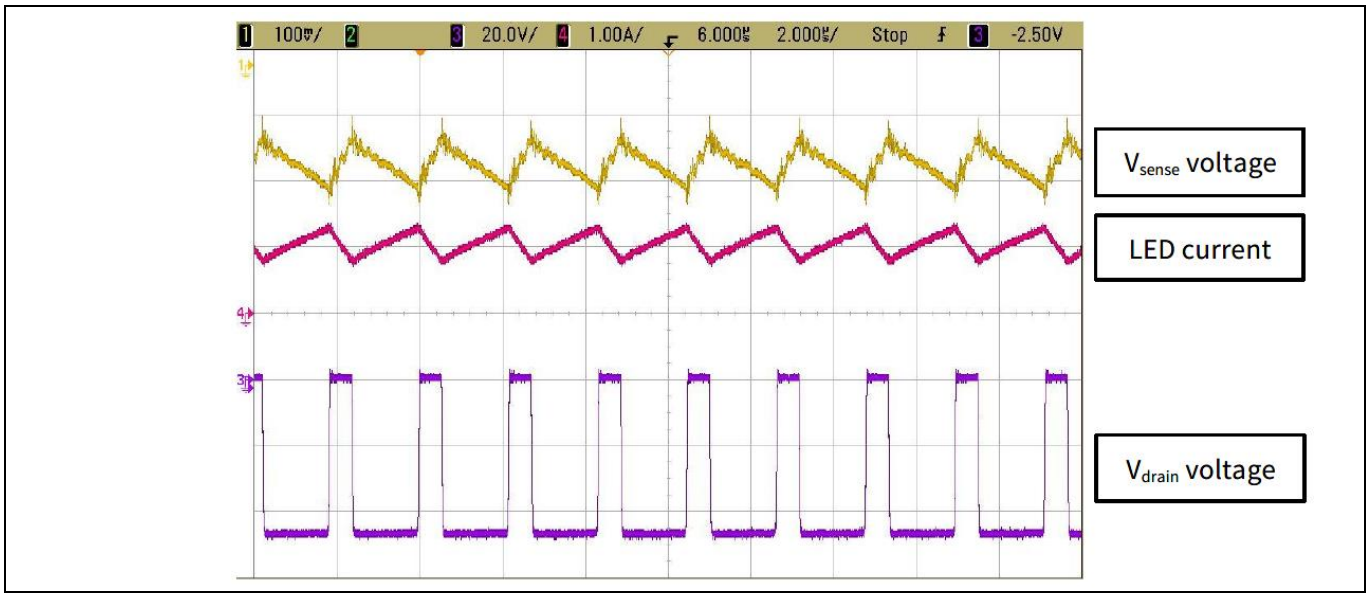


Figure 5 Normal operation waveforms

The ILD6150 offer a high accuracy of output current despite the changes in supply voltage. Figure 6 shows the output current vs supply voltage from the range of 40 V to 60 V. Over the supply range from 40 V to 60 V, the output LED current only deviated by 2%.

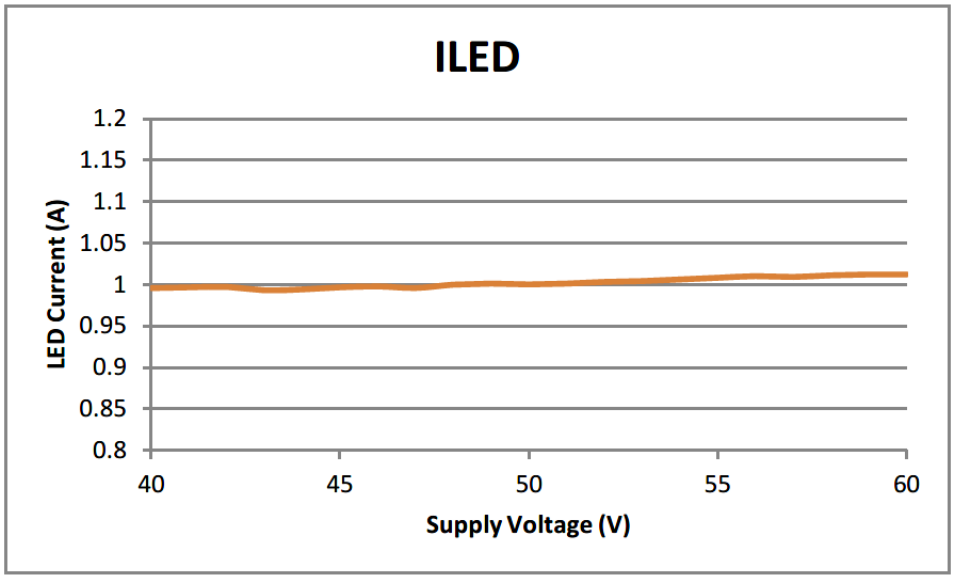


Figure 6 Output LED current vs suppy voltage

3.2 Analog dimming

The multifunctional PWM input pin allows dimming of the LEDs with an analog DC voltage. To minimize the color shifts of the LEDs, the analog DC voltage is converted into a 1.6 kHz PWM signal modulating the LED current.

The linear range of the analog dimming is from 0.5 V to 2.5 V. LEDs are fully turned on for voltage above 2.5 V and fully turned off for voltage below 0.5 V.

Figure 7 shows the analog dimming ratio vs PWM pin voltage.

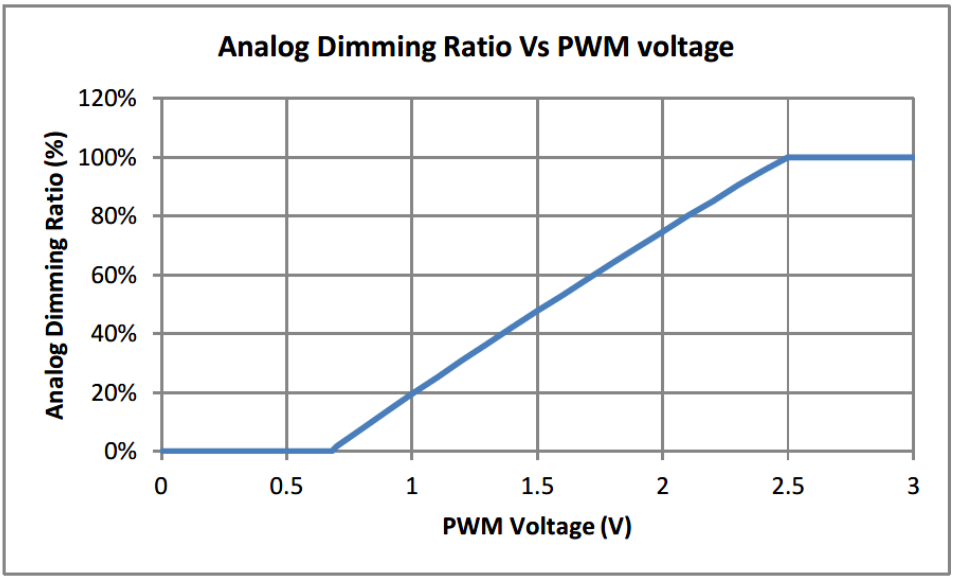


Figure 7 Analog dimming ratio vs PWM pin voltage

Figure 8 and Figure 9 show the waveforms while the PWM pin voltage is equal to 1 V and 2 V. The output current is modulated by the internal PWM signal at 1.6 kHz.

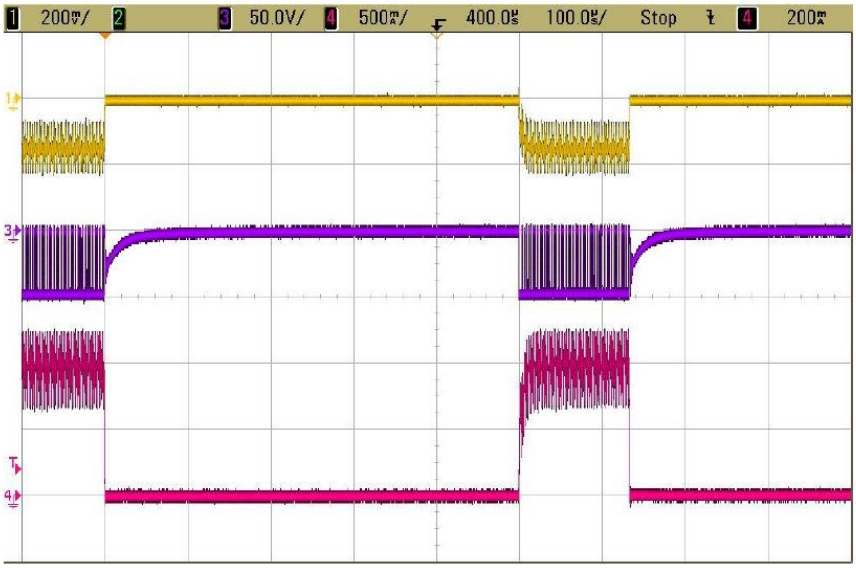


Figure 8 Output waveforms at V_{PWM} = 1 V

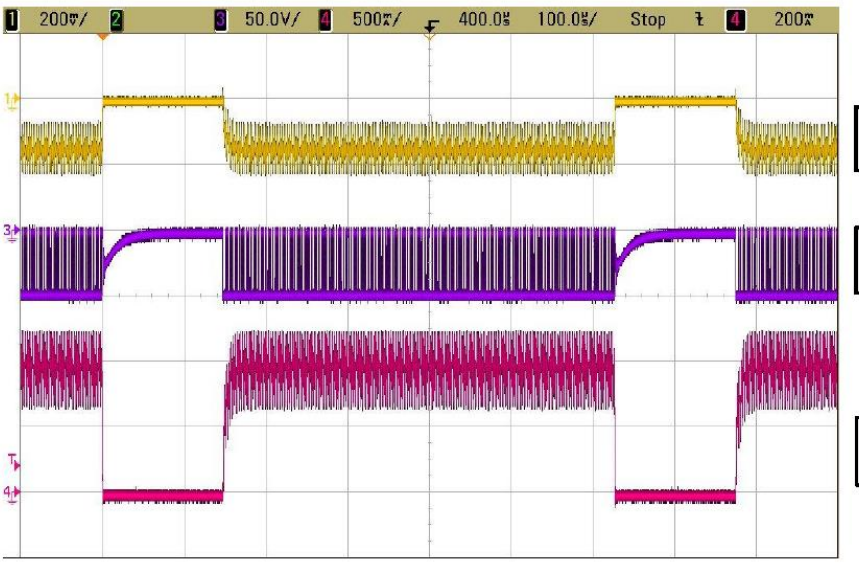


Figure 9 Output waveforms at V_{PWM} = 2 V

The multifunctional PWM pin allows both analog and PWM input for dimming control. However, it should not be operated with combining both analog and PWM input. For example, input a PWM signal with the input voltage of low level = 0 V and high level = 1.5 V, the output current will be modulated by the internal and external PWM frequency.

3.3 Contrast ratio

The contrast ratio of a system depends on the dimensioning of the external components, PWM frequency as well as supply voltage. The definition of the contrast ratio (CR) is given as:

$$CR = \frac{1}{D_{MIN}}$$

Equation 2

Where

$$D_{MIN} = \frac{t_D + t_{SU}}{T}$$

Equation 3

$$T = \frac{1}{f_{PWM}}$$

Equation 4

Figure 10 shows the relationship of the PWM and LED current waveforms.

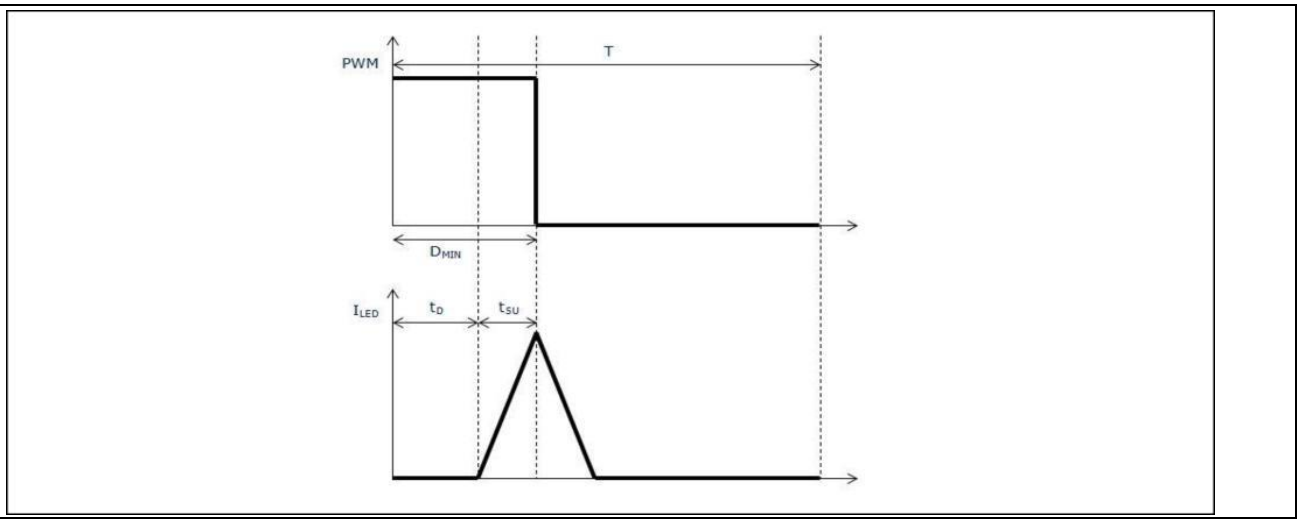


Figure 10 Contrast ratio definitions

Figure 11 shows the PWM and LED current waveform and Table 3 shows the measurement results for the demo board.

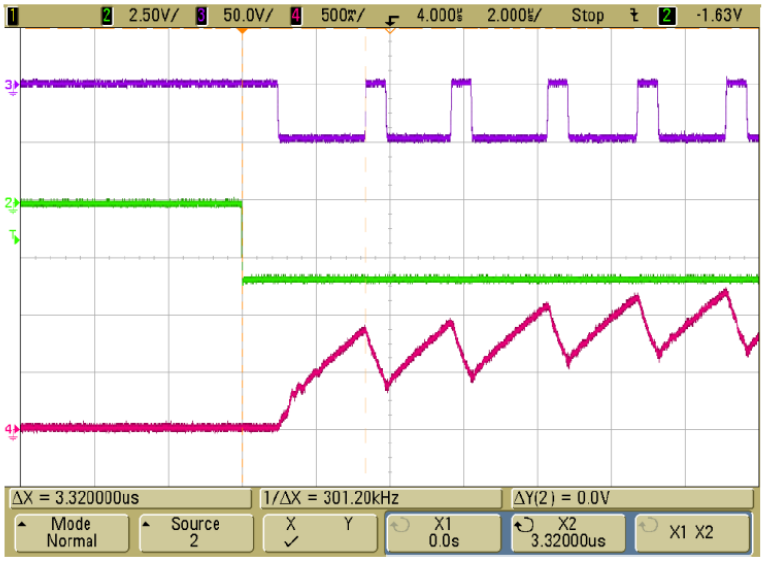


Figure 11 Contrast ratio – PWM and LED current waveforms

Table 3 Contrast ratio calculation

f_{PWM}	T	t_D	t_{SU}	D_{MIN}	CR
500 Hz	2 ms	1 ps	2.32 ps	1.66×10^{-3}	600
200 Hz	5 ms	1 ps	2.32 ps	6.64×10^{-4}	1500
100 Hz	10 ms	1 ps	2.32 ps	3.32×10^{-4}	3000

With the PWM frequency of 500 Hz, the contrast ratio of 600:1 can be achieved. On the other hand, with the PWM frequency of 100 Hz, the contrast ratio of 3000:1 can be achieved.

3.4 Over temperature protection

The ILD6150 feature with an integrated overtemperature protection (OTP) circuit will start to reduce the LED current by internal PWM modulation once the adjustable junction temperature threshold of the IC is exceeded. The OTP profile can be adjusted by using a resistor connect between the T_{adj} pin and GND pin.

Figure 12 shows the measurement results of OTP profile with output LED current's duty cycle vs junction temperature of the ILD6150 by using 0 Ω, 10 kΩ, 20 kΩ, 35 kΩ and open at T_{adj} pin.

With the adjustable OTP, it offers a great flexibility which the starting point of the current reduction at high temperature can be designed according to LED lamp requirement. This new OTP feature offers great flexibility for the adjustable of the roll-off temperature and eliminates the use of the NTC/PTC thermistor in the system.

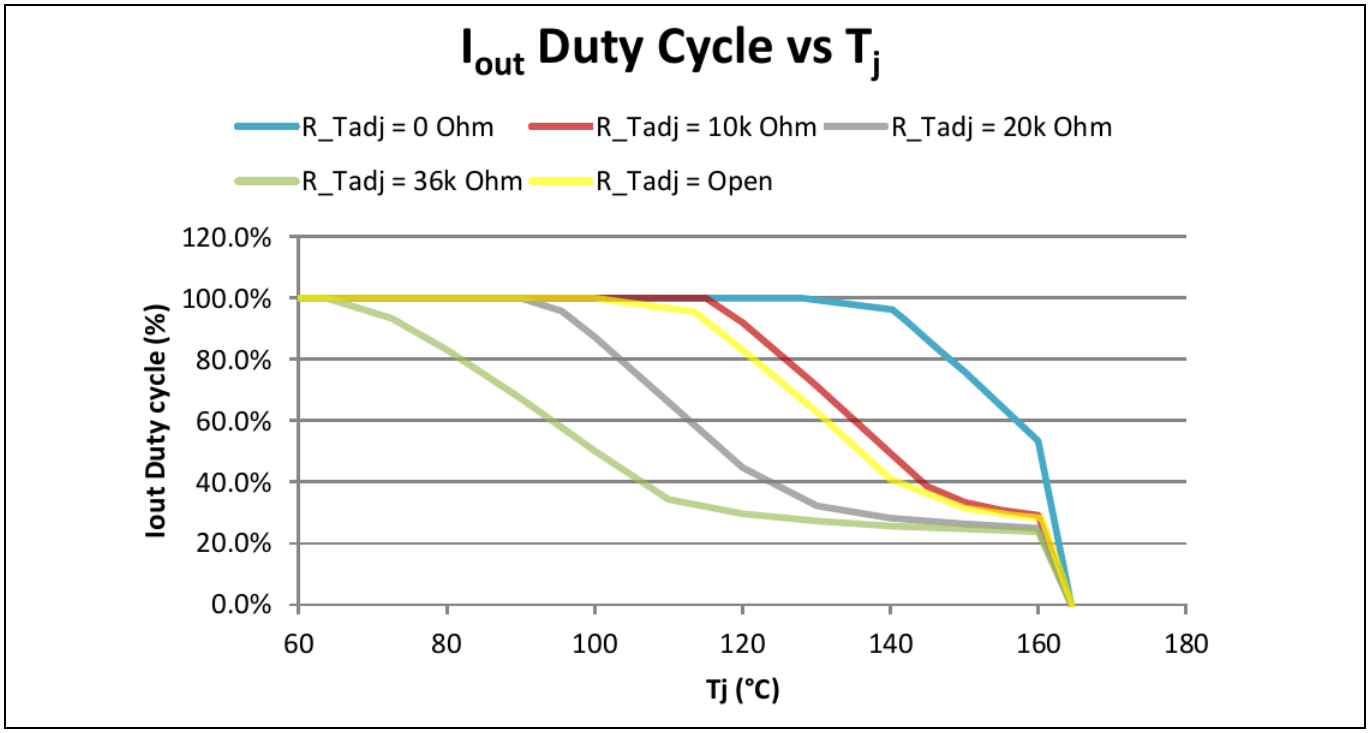


Figure 12 Over temperature protection

3.5 Efficiency

The measurement results of efficiency of the system for V_s = 40 V to 60 V can be found in Figure 13. For 12 pcs LED as a load, the efficiency is kept above 92% to 96% in the voltage range from 40 V to 60 V.

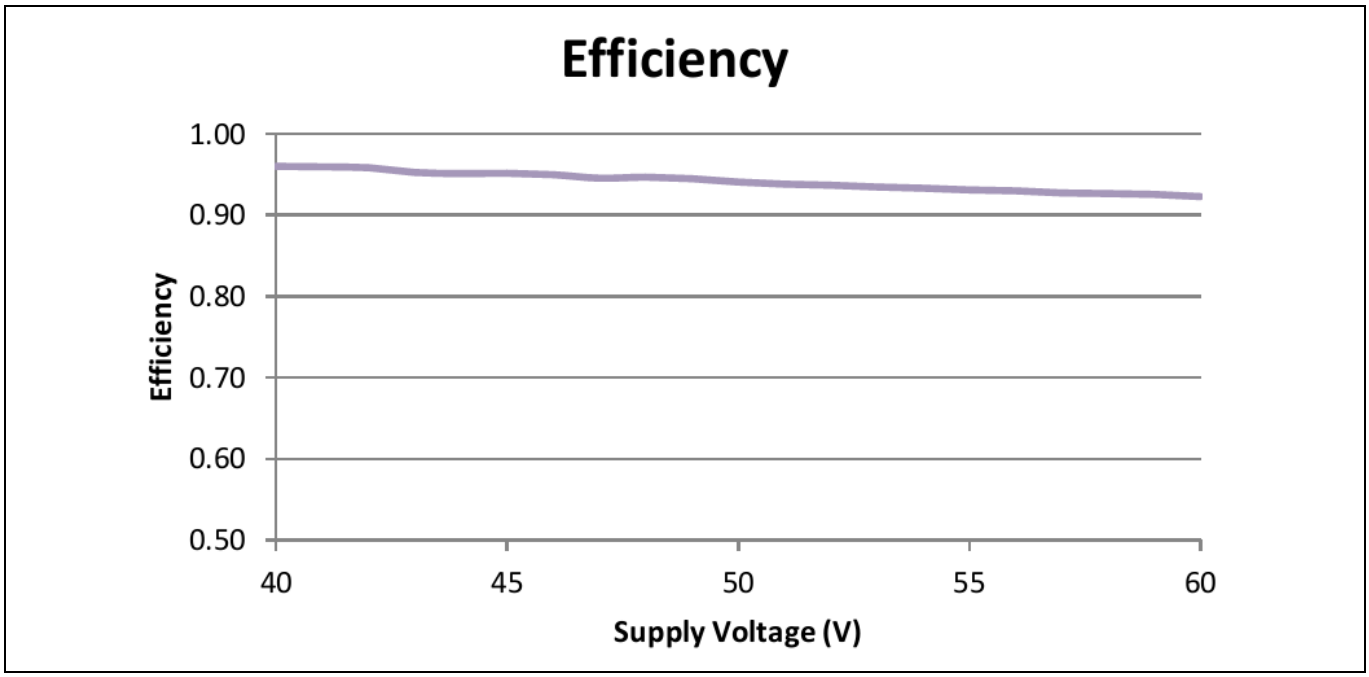


Figure 13 Efficiency vs Supply voltage

3.6 Transition from DC to switch mode

While the input supply voltage is less or close to the LEDs load forward voltage's requirement, the output current is not reaching the target setting value. Under this condition, the ILD6150 is working in the DC mode, meaning that the DMOS is fully turned on and no switching activities.

One of the nice features that ILD6150 offers is during the transition from the DC mode to switch mode, it will not have any overshoot in the output current.

Figure 14 shows the LED current measurement results for the entire operating voltage range from 4.5 V to 60 V, R_{sense} = 0.1 Ω with different number of LEDs as load.

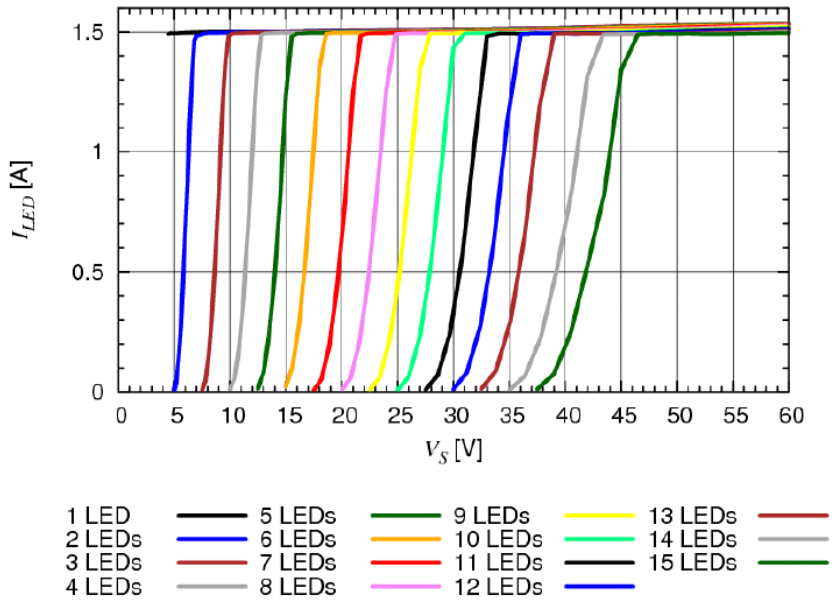


Figure 14 LED current at the transition from DC to switch mode

3.7 Soft start

The soft start of the LED light can be achieved by adding a capacitor at the PWM pin. The ILD6150 having an internal current source of 18 µA will charge up the capacitor at the PWM pin from 0 V to 4.7 V linearly. The soft start timing can be calculated using the below equation:

$$i = C\frac{dv}{dt}$$

Equation 5

$$\therefore dt = \frac{C \times dv}{i}$$

Equation 6

Refer to the specification of the analog dimming; the linear range of the output current from 0% to 100% is within the range from 0.67 V to 2.43 V. Hence the value of dv is equal to 1.76 V and the current i is equal to 18 µA.

For example, if a capacitor in the value of 10 µF is connected to the PWM pin, the soft start timing for the light output from 0% to 100% requires 0.978 second.

Figure 15 shows the LED current waveform which modulated by the PWM signal from 0% to 100% output. The actual measurement result for the soft start is 1.08 second. Figure 16 shows the average of the LED current during the soft start-up phase.

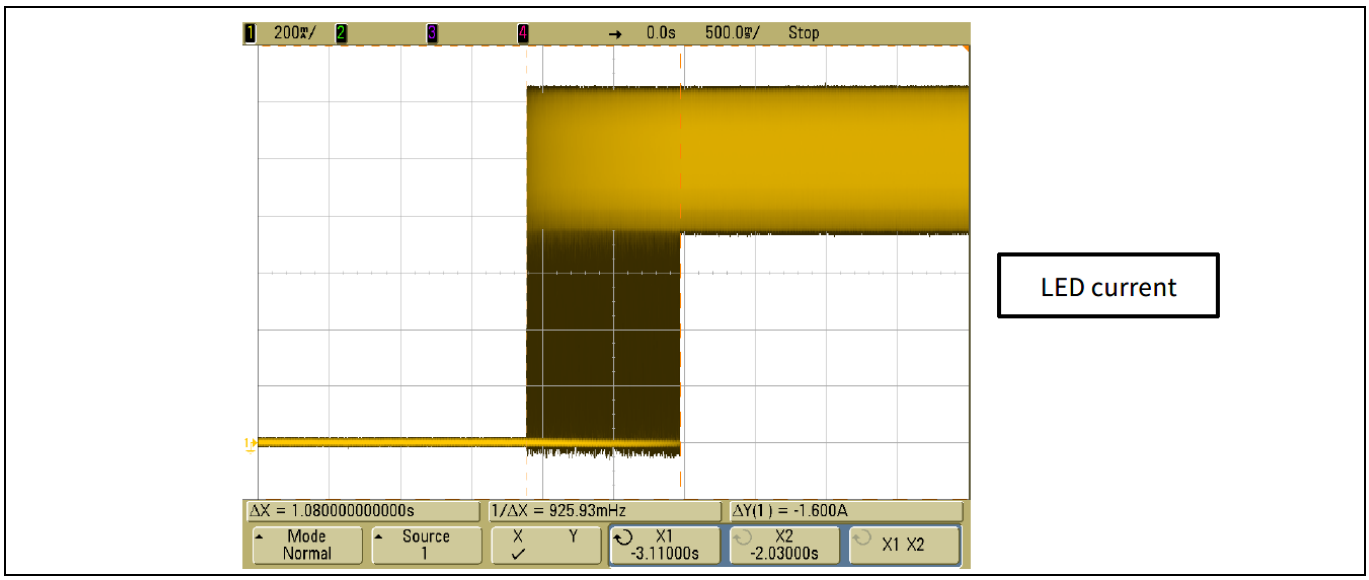


Figure 15 Soft start with 10 µF at the PWM pin

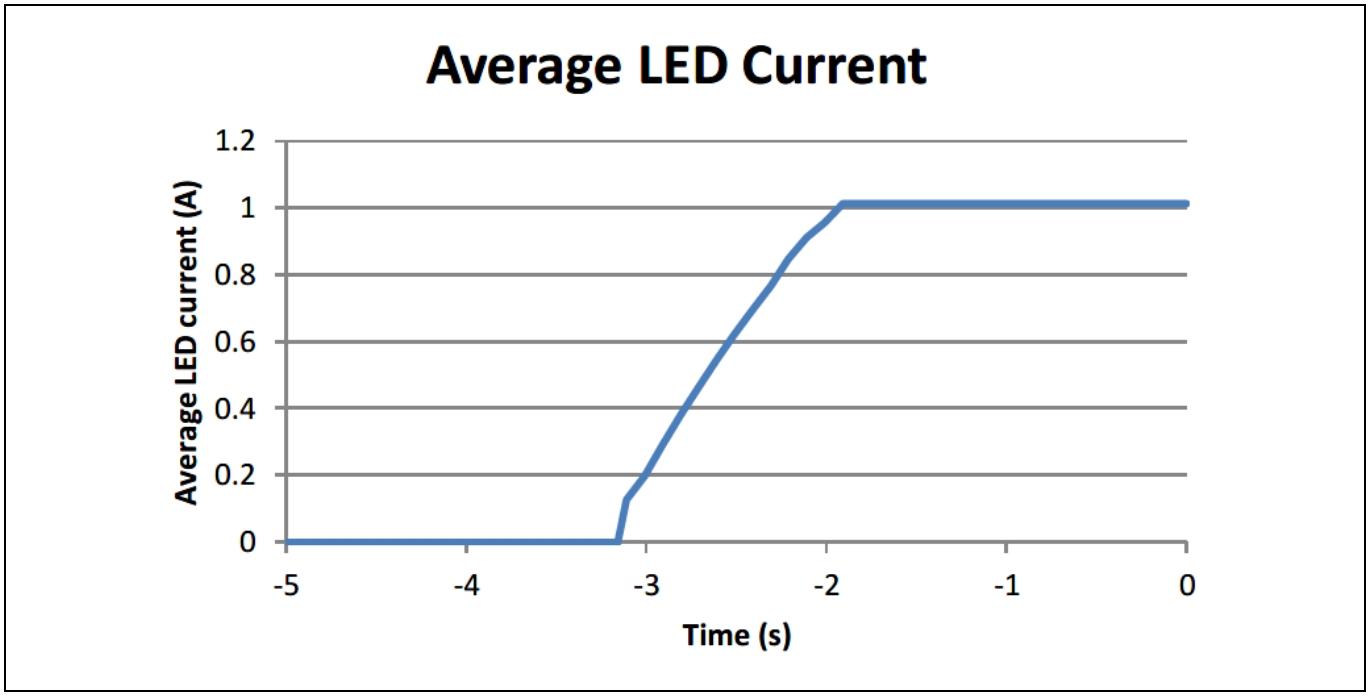


Figure 16 Average of LED current during the soft start with 10 µF at the PWM pin

3.8 Overcurrent protection

The ILD6150 feature with over current protection (OCP), in case when the R_{sense} is shorted accidentally, the driver will not be damaged by the large current flowing through the internal MOSFET. However, the overcurrent protection feature does not guarantee the protection for the LEDs load. This is because different types of LEDs having different maximum rating on the current specification. The threshold current to trigger the OCP for ILD6150 is 2.5 A.

Figure 17 below shows the waveforms where the ILD6150 is in the OCP mode. The R_{sense} is shorted, the LEDs load is replaced by a 3 Ω resistor and input supply voltage is 20 V.

During the OCP, the MOSFET will be turned off for about 60 µs when the 2.5 A current threshold is reached.

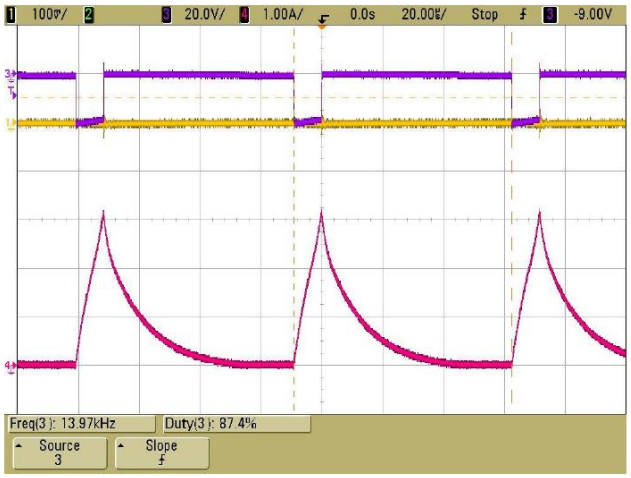


Figure 17 Overcurrent protection waveforms

3.9 PCB thermal resistance

As a reference for designing the surface area for the grounding for the PCB using FR4 to achieve a cer-tain thermal resistance between desired solder point temperature and expected ambient temperature, the following chart can be used.

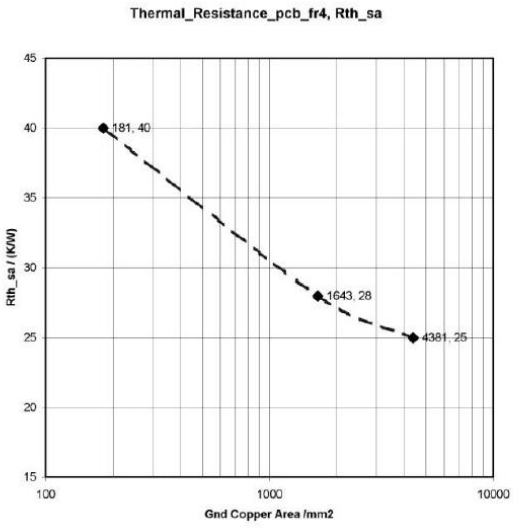


Figure 18 Thermal resistance of PCB-FR4 versus ground copper area

The data in Figure 18 is measured with the following conditions:

- Two copper layers
- 2 oz copper (70 µm thick) and board thickness of about 1.6 mm
- FR4 material
- No forced convection

- No heat sink
- No special mask opening for improved heat dissipation
- In the chart, only three points are marked by diamond symbol. These are measured data. The bro-ken line represents intermediate points which can be derived by linear interpolation

3.10 Thermal protection with NTC thermistor

The build in thermal protection offers flexibility for the adjustment of roll-off temperature. However, the ILD6150 is required to be placed near the LEDs lamp to optimize this feature.

In case where the ILD6150 is placed far away from the LEDs (for example, in the electronic control gear), an external NTC thermistor can be used to realize the thermal protection. The NTC thermistor shall be placed near to the LEDs to sense the temperature of the LEDs accurately. Please refer to Fig-ure 19 for the schematic. When the NTC thermistor is heated up, the resistance of the thermistor will drop and the voltage on the PWM pin will decrease. As the DC voltage on the PWM pin decreased, the output LED current will be reduced by analog dimming and the temperature of the LEDs will be re-duced also.

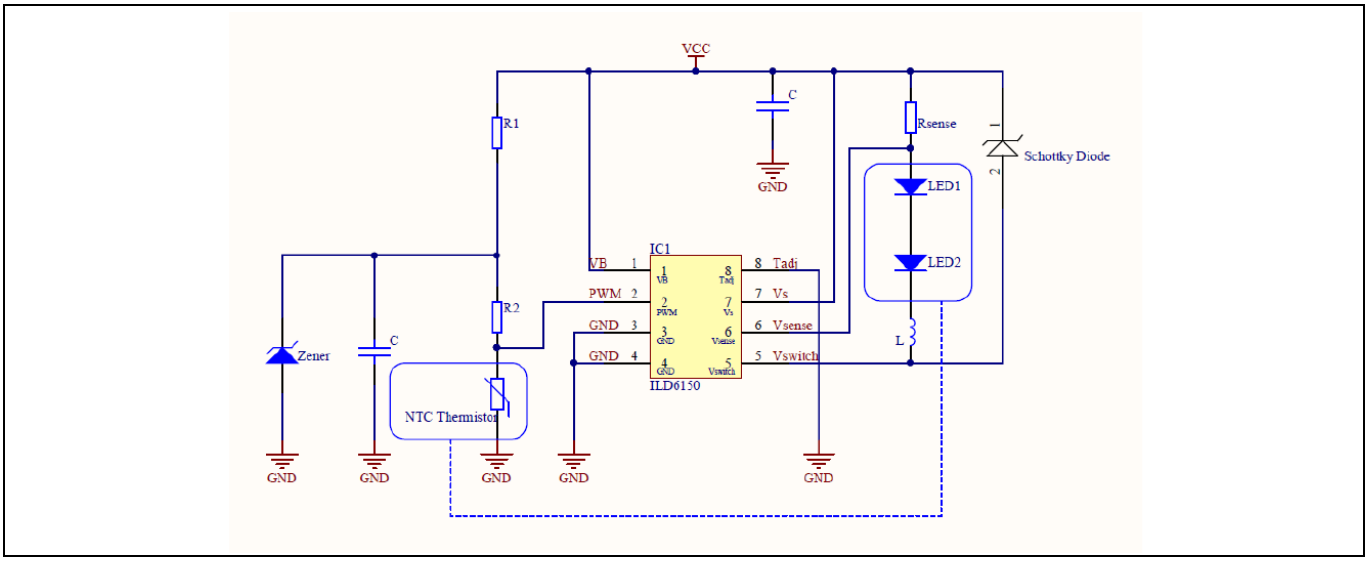


Figure 19 Thermal sensing with NTC thermistor

3.11 Slow start with additional PMOS for hot swapping

In the event where the LED light is required for hot swappable, there is a possibility where the rise time of V_s voltage is very fast. In order to prevent the fast rising time of the Vs which might trigger the inter-nal ESD structure of the ILD6150, it is require a larger blocking capacitor on the V_s pin as described in the datasheet [1].

To address this, with an additional PMOS by means of limiting the current flow during the hot swapping allows the user to choose a smaller size of ceramic capacitor. Figure 20 shows the option of using the PMOS for hot swapping application with a smaller size of capacitor.

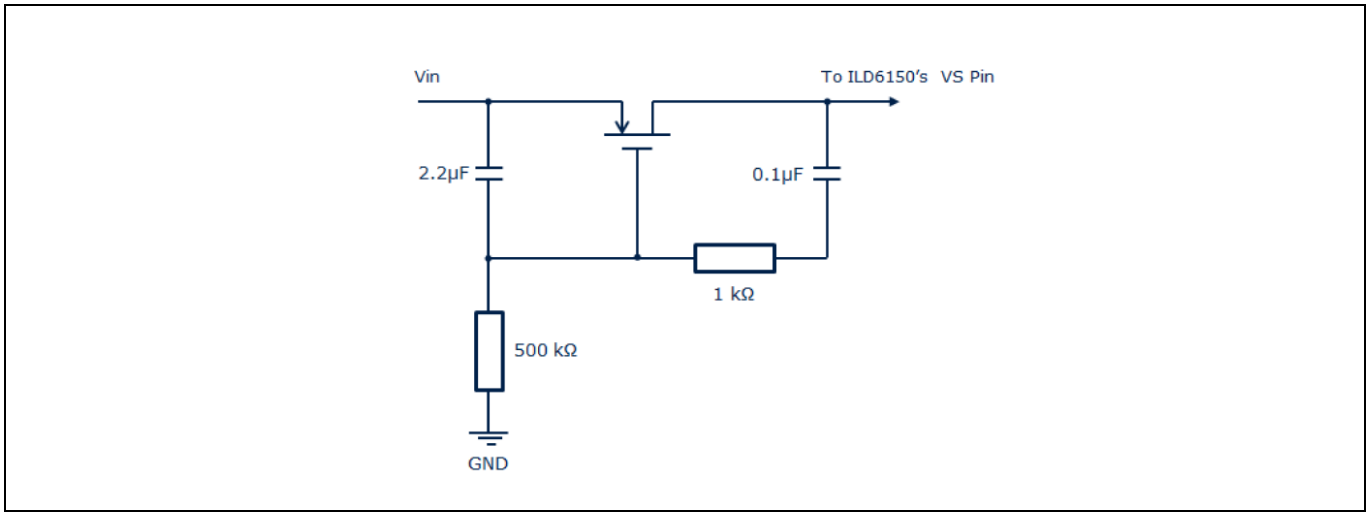


Figure 20 Schematic of additional PMOS circuitry

3.12 Driving of LEDs with current more than 1.5 A by external MOSFETs

The built-in MOSFET in the ILD6150 limits the output current up to 1.5 A. In the situation where the LED current of more than 1.5 A is needed, the ILD6070 can be used as a controller to drive an external MOSFET in order to boost the output current. This chapter describes the design idea on how to achieve higher output current for driving high power LEDs.

Figure 21 shows the schematic example of applying ILD6070 as a controller and additional components. The extra components required are: Two pull-up resistors, two zener diodes and two MOSFETs. The zener diodes at the gates are to prevent the Vgs breakdown of the external MOSFETs as the V_s could be higher than the maximum rating of the MOSFETs.

The ILD6070 is a DC-DC LED driver with built-in MOSFET up to 700 mA. For more information about the ILD6070, see [2].

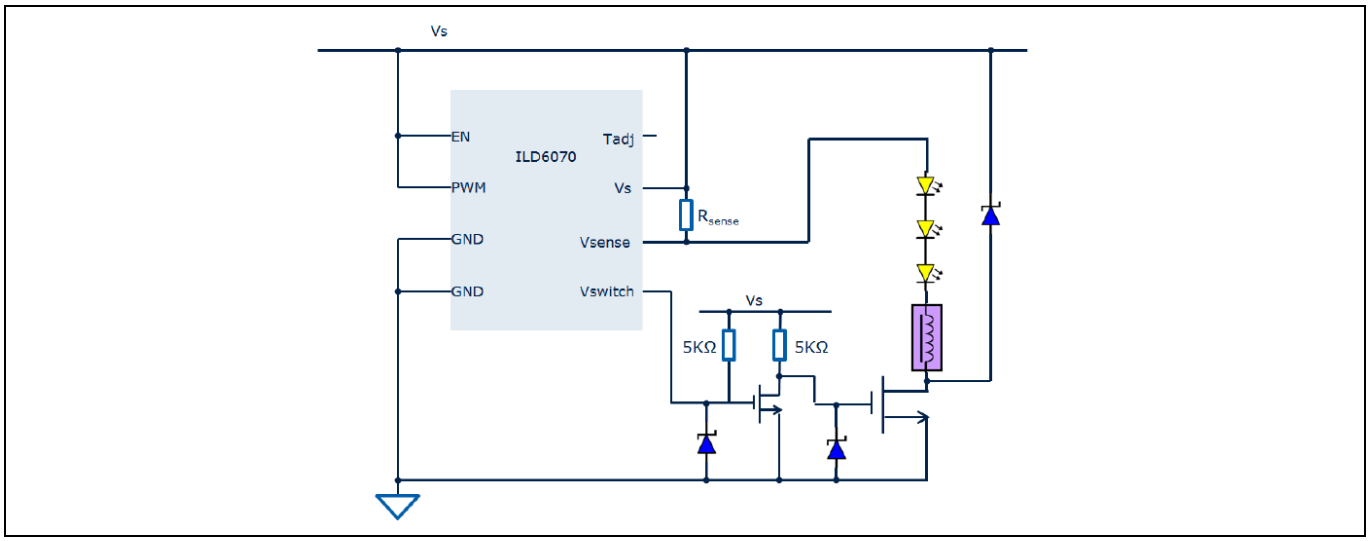


Figure 21 ILD6070 as a controller to drive external MOSFETs for high power LED application

References

[1] Infineon Technologies AG: *ILD6150 Datasheet*; Available online

[2] Infineon Technologies AG: *ILD6070 Datasheet*; Available online

Revision history

Document revision	Date	Description of changes
Revision 1.0		Initial release
Revision 1.1	2013-08-07	Table 1 EN pin changes to VB pin Figure 2 Schematic updated Figure 3 Schematic updated Figure 4 Schematic updated
Revision 2.1		16 Additional – Soft start 17 Additional – Overcurrent protection 13 Additional – Contrast ratio waveforms and CR at 200 Hz 1 Title description 5 Features description 18 Additional – PCB thermal resistance 19 Additional – Thermal protection with NTC thermistor
Revision 2.2	2015-03-20	21 Additional - Slow start with additional PMOS for hot swapping 22 Additional - Driving of LEDs with current more than 1.5 A by external MOSFETs
Revision 2.3	2025-05-19	Migrated to new template Changed document ID

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

Edition 2025-05-19

Published by

Infineon Technologies AG

81726 Munich, Germany

© 2025 Infineon Technologies AG. All Rights Reserved.

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

AN084150

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.

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.