

# LED Drivers for High Power LEDs

# ILD4035

350 mA Step Down LED Driver

# Data Sheet

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# Industrial and Multimarket

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<b>Revision Histo</b>	Revision History							
Page or Item	Subjects (major changes since previous revision)							
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Table 2	Maximum peak current specified for hysteretic peak condition							
Table 2	Maximum junction temperature increased to 150 °C							
Figure 3	Safe operating area increased							
Table 4	Maximum supply voltage reduced to 40 V							
Table 4	Overall current consumption and standby current reduced							
Table 4	Over temperature protection improved from flicker to sloped behaviour							
Table 5	Application setup changed							
Table 6	Voltage range of digital control signals changed							
Chapter 6.3	Over temperature protection improved from flicker to sloped behaviour							
Chapter 6.4	Figures of switching parameters changed							

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350 mA Step Down LED Driver with Internal Switch ILD4035

## 1 Features

- Wide input voltage range: 4.5 V ... 40 V
- Internal switch for up to 400 mA average LED current
- Up to 95 % efficiency
- Over current protection
- Over voltage protection
- Temperature protection mechanism
- Inherent open-circuit LED protection
- · Soft-start capability
- Low shut down current
- Analog and PWM dimming possible
- Typical 3 % output current accuracy
- Minimum external components required
- Small package: SC74



#### Applications

- LED driver for general lighting applications
- · Retail, office and residential luminaires and downlights
- LED replacement lamps
- Architectural lighting



Product Name	Package		Pin Configuration						
ILD4035	SC74-6-4	1 = V <sub>S</sub>	2 = GND	3 = EN	$4 = V_{switch}$	5 = GND	6 = V <sub>sense</sub>	35	

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#### **Product Brief**

## 2 Product Brief

The ILD4035 is a hysteretic step down LED driver IC for general lighting applications, which is capable to drive high power LEDs with average currents up to 400 mA.

The IC incorporates a wide input voltage range and an internal power switch. The output current level can be adjusted with an external sense resistor.

According to the multifunctional control pin the IC can be switched on and off by an external signal, which is also suitable to regulate brightness of the LEDs by PWM or analog voltage dimming.

Depending on the value of the switching inductor the switching frequency and the voltage ripple can be set.

The precise internal bandgap stabilizes the circuit and provides stable current conditions over temperature range.

To ensure a long lifetime of the LED system, the ILD4035 incorporates an overvoltage and an overcurrent protection.

In addition, the integrated thermal protection will reduce the output current to protect the LEDs and the IC against thermal stress.



Figure 1 Block Diagram



#### **Product Brief**

#### **Pin Definition**

#### Table 1 Pin Definition and Function

Pin No.	Name	Pin Type	Buffer Type	Function
1	V <sub>s</sub>	Input	_	Supply voltage
2	GND	GND	_	IC ground
3	EN / PWM	Input	_	<ul><li>Multifunctional pin:</li><li>Chip enable signal</li><li>Analog dimming signal</li><li>PWM dimming signal</li></ul>
4	V <sub>switch</sub>	Output	-	Power switch output
5	GND	GND	-	IC ground
6	V <sub>sense</sub>	Input	-	LED current sense input



#### **Maximum Ratings**

# 3 Maximum Ratings

#### Table 2 Maximum Ratings

Parameter	Symbol		Value	S	Unit	Note /
		Min.	Тур.	Max.		<b>Test Condition</b>
Supply voltage	$V_S$	_	_	45	V	_
Peak output current	I <sub>Switch</sub>	-	-	550	mA	Hysteretic peak current
Total power dissipation, $T_s \le 85^{\circ}C$	P <sub>tot</sub>	_	_	1000	mW	_
Junction temperature	$T_J$	_	_	150	°C	-
Storage temperature range	T <sub>STG</sub>	-65	_	150	°C	-
ESD capability	V <sub>ESD HBM</sub>				kV	HBM acc. to
at all pins		-	-	4		JESD22-A114

Attention: Stresses above the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.



**Thermal Characteristics** 

## 4 Thermal Characteristics

#### Table 3 Maximum Thermal Resistance

Parameter	Symbol		Values	Unit	Note /	
		Min.	Тур.	Max.		Test Condition
Junction - soldering point <sup>1)</sup>	R <sub>thJS</sub>	-	-	65	K/W	_

1) For calculation of R<sub>thJA</sub> please refer to application note AN077 (Thermal Resistance Calculation)



#### Figure 2 Total Power Dissipation

Equation (1) is gives an estimation for the power dissipation of ILD4035.

 $P_{tot} = 1.1V \cdot I_{LED} \cdot duty \ cycle + f_{Switch} \cdot 1\mu W \cdot \frac{I_{LED}}{350} \ mA$ 

(1)



**Thermal Characteristics** 



Figure 3 Safe Operating Area

**Figure 3** shows the safe operating area for the respective inductance values. The safe operating area consists of the minimum and maximum allowed average LED current and the resulting voltage overhead. The voltage overhead  $V_{overhead}$  is the difference between the supply voltage  $V_S$  and the sum of the LED forward voltages  $V_{\Sigma fLED}$ .

#### **Example calculation 1**

3 LEDs in series,  $V_{fLED}$ = 3V,  $I_{LED}$  = 350 mA,  $V_S$  = 12 V  $V_{overhead}$  =  $V_S$  -  $V_{\Sigma fLED}$  = 12 V - 9 V = 3 V → any of the above coil values can be used

#### Example calculation 2

6 LEDs in series,  $V_{fLED}$ = 3V,  $I_{LED}$  = 250 mA,  $V_S$  = 24 V  $V_{overhead}$  =  $V_S$  -  $V_{\Sigma fLED}$  = 24 V - 18 V = 6 V  $\rightarrow$  the coil values needs to be at least 68 µH

Outside the safe operating area the switching frequency, hysteretic peak current and associated power dissipation  $P_{tot}$  of ILD4035 will increase beyond the maximum ratings.

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**Electrical Characteristics** 

# 5 Electrical Characteristics

#### 5.1 DC Characteristics

All parameters at  $T_A$  = 25 °C, unless otherwise specified.  $V_S$  = 12 V, 3 LEDs,  $R_{sense}$  = 303 m $\Omega$  ( $I_{LED}$  = 375 mA), L = 100  $\mu$ H,  $V_{EN}$  = 3 V,  $V_{fLED}$  = 3 V

#### Table 4 DC Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition	
		Min.	Тур.	Max.			
Supply voltage	$V_S$	4.5	_	40	V		
Overall current consumption open load	I <sub>S open load</sub>	1.4	2.3	3.1	mA	$V_S = 4.5 V$ $I_{LED} = 0 mA$	
Overall current consumption open load	I <sub>S open load</sub>	1.5	2.4	3.2	mA	$V_S = 12 \text{ V}$ $I_{LED} = 0 \text{ mA}$	
Overall current consumption open load	I <sub>S open load</sub>	1.8	3.0	3.9	mA	$V_S = 40 \text{ V}$ $I_{LED} = 0 \text{ mA}$	
Overall standby current consumption	I <sub>S standby</sub>	-	-	1	μA	$V_{EN}$ = 0 V; $V_{S}$ = 12 V	
Overall standby current consumption	I <sub>S standby</sub>	-	_	5	μA	$V_{EN}$ = 0 V; $V_{S}$ = 40 V	
Enable voltage for standby mode	V <sub>EN</sub>	-0.3	_	0.4	V		
Enable voltage for analog dimming	$V_{EN}$	1	_	2	V	linear dimming range	
Input current of multifunctional control pin	I <sub>EN</sub>	-	50	140	μA	$V_{EN}$ = 3 V $V_{S}$ = 4.540 V	
Current of sense input	Isense	-	20	_	μA	at any LED current	
Over temperature protection	$T_{S,TSD}$	-	113	-	°C	$T_{S}$ for 10 % $I_{LED}$ reduction, defined by $T_{J}$	



**Electrical Characteristics** 

### 5.2 Switching Characteristics

All parameters at  $T_A$  = 25 °C, unless otherwise specified.

 $V_S$  = 12 V, 3 LEDs,  $R_{sense}$  = 303 m $\Omega$  ( $I_{LED}$  = 375 mA), L = 100  $\mu$ H,  $V_{EN}$  = 3 V,  $V_{fLED}$  = 3 V

#### Table 5 Switching Characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition	
		Min.	Тур.	Max.			
Switching frequency	$f_{Switch}$	-	120	_	kHz		
Maximum switching frequency	$f_{Switch max}$	_	_	500	kHz	for any coil value	
Mean current sense threshold voltage	V <sub>sense</sub>	_	114	_	mV		
Sense threshold hysteresis	V <sub>sensehys</sub>	_	±7.5	_	%		
Residual voltage at collector of power transistor	V <sub>switch on</sub>	-	1.1	-	V	output switch turned on	
Output current accuracy	Ioutacc	-	±3	_	%		

#### 5.3 Digital Signals

All parameters at  $T_A$  = 25 °C, unless otherwise specified.

#### Table 6 Digital Control Parameter at Pin EN/PWM

Parameter	Symbol	Values			Unit	Note / Test Condition	
		Min.	Тур.	Max.			
Input voltage for power on	V <sub>On</sub>	2.5	3	40	V	full LED current	
Input voltage for power off	V <sub>Off</sub>	-0.3	_	0.4	V		
Min. power on puls duration	t <sub>On</sub>	10	_		μs		



# 6 Basic Application Information

This section covers the basic information required for calculating the parameters for a certain LED application. For detailed application information please check the Application Note **AN215** (Driving 1 W LEDs with ILD4035) or visit our web site **http://www.infineon.com/led.appnotes** 

#### 6.1 Setting the average LED current

The average output current for the LEDs is set by the external sense resistor  $R_{sense}$ . To calculate the value of this resistor a first approximation can be calculated using **Equation (2)**.

 $V_{sense}$  is dependent on the supply voltage  $V_S$  and the number of LEDs in series.

$$R_{sense} = \frac{V_{sense}}{I_{LED}}$$

(2)

#### Example calculation 1

 $V_S$  = 12 V, 100 µH,  $V_{fLED}$  = 3 V, 3 LEDs in series  $\rightarrow V_{sense}$  = 114 mV  $I_{LED}$  = 375 mA  $\rightarrow R_{sense}$  = 303 m $\Omega$ 

#### Example calculation 2

 $V_S$  = 24 V, 100 µH,  $V_{fLED}$  = 3 V, 6 LEDs in series  $\rightarrow V_{sense}$  = 106 mV  $I_{LED}$  = 350 mA  $\rightarrow R_{sense}$  = 303 m $\Omega$ 

An easy way to achieve these resistor values is to connect standard resistors in parallel

#### 6.2 Dimming of the LEDs

#### Analog voltage dimming

The voltage level of the EN/PWM pin can be used for analog dimming of the LED current. To achieve a linear change in LED current versus control voltage the recommended voltage range at the EN/PWM pin is 1 V to 2 V. The maximum achievable LED current is defined by resistor  $R_{sense}$ . The maximum LED current will be achieved for  $V_{EN} \ge 2.5$  V. Below 0.4 V the ILD4035 is set to standby mode and the output is switched off. The typical dimming performance is shown in below figures.



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 $I_{\text{LED}}$  versus  $V_{\text{EN}}$ ,  $T_A$ =25 °C



 $I_{\text{LED}}$  versus  $V_{\text{EN}}$ , 333 m $\Omega$ , 100  $\mu$ H



#### **PWM Dimming**

Besides the analog dimming functionality the EN/PWM pin acts as input for a pulse width modulated (PWM) signal to control the dimming of the LED string. For PWM dimming the signal's logic high level should be at least 2.5 V and the PWM frequency should be lower than 5 kHz. For the ILD4035/4001 demo board a dimming frequency less than 330 Hz is recommended to maintain a maximum contrast ratio of 100:1. The achieveable contrast ratio is shown on **Figure 4** based on the measured average LED current deviating 3 dB from the linear reference. The maximum contrast ratio depends mainly on the rise time of the inductor current and is thus dependent on supply voltage, inductor size and LED string forward voltage.

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 $I_{\text{LED}}$  (relative) versus  $V_{\text{EN}}$ ,  $T_{A}$ =25 °C

110





Figure 4 PWM Dimming



LED current (relative) versus  $T_S$ ,  $V_S$  = 12 V

**Basic Application Information** 

#### 6.3 **Temperature Protection Circuit**

ILD4035 incorporates a temperature protection circuit referring to the junction temperature of ILD4035. The higher the junction temperature of ILD4035 the lower the current of the LEDs. This feature helps to reduce the power dissipation of ILD4035 and the LEDs. Yet still the product specific maximum ratings for junction temperature need to be observed to avoid a permanent damage of the devices.

ILD4035 has been characterized on ILD4035/4001 application board heated from the backside without additional air flow on the circuit board surface besides natural convection. Design and layout of the circuit board as well as the air flow influence the thermal resistance junction to ambient  $R_{thJA}$  of ILD4035 and thus its junction temperature. Below figures show the LED current versus soldering point temperature  $T_{S}$ .



LED current versus  $T_S$ ,  $V_S$  = 12 V

#### 6.4 Switching Parameters

For all shown parameters ILD4035 has been measured on evaluation board ILD4035/4001 at  $T_A$  = 25 °C. Used LEDs have a typical forward voltage  $V_{\text{fLED}}$  of 3 V. For details see application note AN215 (Driving 1W LEDs with ILD4035) or visit our web site http://www.infineon.com/lowcostleddrivers.



#### $R_{sense}$ = 303 m $\Omega$ , L= 47 $\mu$ H

 $I_{\rm LED}$  versus  $V_{\rm S}$  and Number of LEDs



#### Efficiency versus $V_{\rm S}$ and Number of LEDs





Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





#### $R_{sense}$ = 303 m $\Omega$ , L= 68 $\mu$ H

 $I_{\rm LED}$  versus  $V_{\rm S}$  and Number of LEDs



#### Efficiency versus $V_{\rm S}$ and Number of LEDs





Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





 $I_{\rm LED}$  versus  $V_{\rm S}$  and Number of LEDs



# Efficiency versus $V_{\rm S}$ and Number of LEDs





Duty Cycle versus  $V_{\rm S}$  and Number of LEDs







# Efficiency versus $V_{\rm s}$ and Number of LEDs



# $I_{\text{LED}}$ versus $V_{\text{S}}$ and Number of LEDs $f_{\text{Switch}}$ versus $V_{\text{S}}$ and Number of LEDs



Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





#### $R_{sense}$ = 367 m $\Omega$ , L= 47 $\mu$ H



#### $I_{\rm LED}$ versus $V_{\rm S}$ and Number of LEDs







Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





#### $R_{sense}$ = 367 m $\Omega$ , L= 68 $\mu$ H



#### $I_{\text{LED}}$ versus $V_{\text{S}}$ and Number of LEDs

 $f_{\rm Switch}$  versus  $V_{\rm S}$  and Number of LEDs



Efficiency versus  $V_{\rm S}$  and Number of LEDs



Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





#### $R_{sense}$ = 367 m $\Omega$ , L= 100 $\mu$ H

 $I_{\rm LED}$  versus  $V_{\rm S}$  and Number of LEDs



#### Efficiency versus $V_{\rm S}$ and Number of LEDs





Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





 $I_{\rm LED}$  versus  $V_{\rm S}$  and Number of LEDs



# Efficiency versus $V_{\rm S}$ and Number of LEDs



## $f_{\mathrm{Switch}}$ versus $V_{\mathrm{S}}$ and Number of LEDs



Duty Cycle versus  $V_{\rm S}$  and Number of LEDs





**Application Circuit** 

# 7 Application Circuit



# 8 Evaluation Board







**Package Information** 

# 9 Package Information



Figure 7 Package Outline SC74



#### Figure 8 Recommended PCB Footprint for Reflow Soldering





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