LED Drivers for High Power LEDs

ILD4035
350 mA Step Down LED Driver

Data Sheet
Revision 2.0, 2011-08-17

Industrial and Multimarket
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## Revision History

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<td>Compatibility with various LED types</td>
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<tr>
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Note: For more detailed specifications and information, please refer to the full data sheet and revision 2.0 from Infineon, dated 2011-08-17.
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

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Package</th>
<th>Pin Configuration</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILD4035</td>
<td>SC74-6-4</td>
<td>1 = V_S 2 = GND 3 = EN 4 = V_switch 5 = GND 6 = V_sense 35</td>
<td></td>
</tr>
</tbody>
</table>
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.

![Block Diagram](ILD4035_Block_diagram.vsd)
## Pin Definition

### Table 1 Pin Definition and Function

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Name</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( V_s )</td>
<td>Input</td>
<td>–</td>
<td>Supply voltage</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>GND</td>
<td>–</td>
<td>IC ground</td>
</tr>
<tr>
<td>3</td>
<td>EN / PWM</td>
<td>Input</td>
<td>–</td>
<td>Multifunctional pin:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Chip enable signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Analog dimming signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• PWM dimming signal</td>
</tr>
<tr>
<td>4</td>
<td>( V_{\text{switch}} )</td>
<td>Output</td>
<td>–</td>
<td>Power switch output</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>GND</td>
<td>–</td>
<td>IC ground</td>
</tr>
<tr>
<td>6</td>
<td>( V_{\text{sense}} )</td>
<td>Input</td>
<td>–</td>
<td>LED current sense input</td>
</tr>
</tbody>
</table>
# Maximum Ratings

Table 2  Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>$V_S$</td>
<td>–</td>
<td>–</td>
<td>45 V</td>
</tr>
<tr>
<td>Peak output current</td>
<td>$I_{Switch}$</td>
<td>–</td>
<td>–</td>
<td>550 mA</td>
</tr>
<tr>
<td>Total power dissipation, $T_s \leq 85^\circ C$</td>
<td>$P_{tot}$</td>
<td>–</td>
<td>–</td>
<td>1000 mW</td>
</tr>
<tr>
<td>Junction temperature</td>
<td>$T_J$</td>
<td>–</td>
<td>–</td>
<td>150 °C</td>
</tr>
<tr>
<td>Storage temperature range</td>
<td>$T_{STG}$</td>
<td>-65</td>
<td>–</td>
<td>150 °C</td>
</tr>
<tr>
<td>ESD capability at all pins</td>
<td>$V_{ESD HBM}$</td>
<td>–</td>
<td>–</td>
<td>4 kV</td>
</tr>
</tbody>
</table>

**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.
4 Thermal Characteristics

Table 3 Maximum Thermal Resistance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction - soldering point</td>
<td>$R_{thJS}$</td>
<td>–</td>
<td>–</td>
<td>65 K/W</td>
</tr>
</tbody>
</table>

1) For calculation of $R_{thJA}$ please refer to application note AN077 (Thermal Resistance Calculation).

![Figure 2 Total Power Dissipation](image)

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

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

(1)
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, $V_{fLED} = 3\, \text{V}$, $I_{LED} = 350\, \text{mA}$, $V_S = 12\, \text{V}$

$$V_{overhead} = V_S - V_{\Sigma fLED} = 12\, \text{V} - 9\, \text{V} = 3\, \text{V}$$

$\rightarrow$ any of the above coil values can be used

**Example calculation 2**

6 LEDs in series, $V_{fLED} = 3\, \text{V}$, $I_{LED} = 250\, \text{mA}$, $V_S = 24\, \text{V}$

$$V_{overhead} = V_S - V_{\Sigma fLED} = 24\, \text{V} - 18\, \text{V} = 6\, \text{V}$$

$\rightarrow$ the coil values needs to be at least $68\, \mu\text{H}$

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.
# 5 Electrical Characteristics

## 5.1 DC Characteristics
All parameters at $T_A = 25$ °C, unless otherwise specified.

$V_S = 12$ V, 3 LEDs, $R_{\text{sense}} = 303$ mΩ ($I_{\text{LED}} = 375$ mA), $L = 100$ μH, $V_{EN} = 3$ V, $V_{\text{LED}} = 3$ V

### Table 4 DC Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>$V_S$</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Overall current consumption open load</td>
<td>$I_S$</td>
<td>–</td>
<td>–</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>$open$ load</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Overall current consumption open load</td>
<td>$I_S$</td>
<td>1.5</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>$open$ load</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Overall current consumption open load</td>
<td>$I_S$</td>
<td>1.8</td>
<td>3.0</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>$open$ load</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Overall standby current consumption</td>
<td>$I_S$</td>
<td>–</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>standby</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Overall standby current consumption</td>
<td>$I_S$</td>
<td>–</td>
<td>–</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>standby</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>Enable voltage for standby mode</td>
<td>$V_{EN}$</td>
<td>–0.3</td>
<td>–</td>
<td>0.4</td>
</tr>
<tr>
<td>Enable voltage for analog dimming</td>
<td>$V_{EN}$</td>
<td>1</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input current of multifunctional control pin</td>
<td>$I_{EN}$</td>
<td>–</td>
<td>50</td>
<td>140</td>
</tr>
<tr>
<td>Current of sense input</td>
<td>$I_{\text{sense}}$</td>
<td>–</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>Over temperature protection</td>
<td>$T_{S,TSD}$</td>
<td>–</td>
<td>113</td>
<td>–</td>
</tr>
</tbody>
</table>
5.2 Switching Characteristics

All parameters at $T_A = 25 \, ^\circ\text{C}$, unless otherwise specified.

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

### Table 5  Switching Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching frequency</td>
<td>$f_{\text{Switch}}$</td>
<td>$- \quad 120 \quad -$</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>Maximum switching frequency</td>
<td>$f_{\text{Switch max}}$</td>
<td>$- \quad - \quad 500$</td>
<td>kHz</td>
<td>for any coil value</td>
</tr>
<tr>
<td>Mean current sense threshold voltage</td>
<td>$V_{\text{sense}}$</td>
<td>$- \quad 114 \quad -$</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Sense threshold hysteresis</td>
<td>$V_{\text{sensehys}}$</td>
<td>$- \quad \pm 7.5 \quad -$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Residual voltage at collector of power transistor</td>
<td>$V_{\text{switch on}}$</td>
<td>$- \quad 1.1 \quad -$</td>
<td>V</td>
<td>output switch turned on</td>
</tr>
<tr>
<td>Output current accuracy</td>
<td>$I_{\text{outacc}}$</td>
<td>$- \quad \pm 3 \quad -$</td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>

5.3 Digital Signals

All parameters at $T_A = 25 \, ^\circ\text{C}$, unless otherwise specified.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
<th>Note / Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage for power on</td>
<td>$V_{\text{On}}$</td>
<td>$2.5 \quad 3 \quad 40$</td>
<td>V</td>
<td>full LED current</td>
</tr>
<tr>
<td>Input voltage for power off</td>
<td>$V_{\text{Off}}$</td>
<td>$-0.3 \quad - \quad 0.4$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Min. power on puls duration</td>
<td>$t_{\text{On}}$</td>
<td>$10 \quad - \quad -$</td>
<td>$\mu\text{s}$</td>
<td></td>
</tr>
</tbody>
</table>
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 \( R_{\text{sense}} \). To calculate the value of this resistor a first approximation can be calculated using Equation (2).

\[ R_{\text{sense}} = \frac{V_{\text{sense}}}{I_{\text{LED}}} \]  

(2)

Example calculation 1

\( V_S = 12 \ \text{V}, \ 100 \ \mu\text{H}, \ V_{f\text{LED}} = 3 \ \text{V}, \ 3 \text{ LEDs in series} \)

\( \rightarrow V_{\text{sense}} = 114 \ \text{mV} \)

\( I_{\text{LED}} = 375 \ \text{mA} \)

\( \rightarrow R_{\text{sense}} = 303 \ \text{m} \Omega \)

Example calculation 2

\( V_S = 24 \ \text{V}, \ 100 \ \mu\text{H}, \ V_{f\text{LED}} = 3 \ \text{V}, \ 6 \text{ LEDs in series} \)

\( \rightarrow V_{\text{sense}} = 106 \ \text{mV} \)

\( I_{\text{LED}} = 350 \ \text{mA} \)

\( \rightarrow R_{\text{sense}} = 303 \ \text{m} \Omega \)

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 \( R_{\text{sense}} \). The maximum LED current will be achieved for \( V_{\text{EN}} \geq 2.5 \ \text{V} \). 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.
**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 achievable 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.
Figure 4  PWM Dimming
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 $R_{th,jA}$ 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

LED current (relative) 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 $T_d = 25$ °C. Used LEDs have a typical forward voltage $V_{fLED}$ of 3 V. For details see application note AN215 (Driving 1W LEDs with ILD4035) or visit our web site http://www.infineon.com/lowcostleddrivers.
$R_{\text{sense}} = 303 \, \text{m}\Omega$, $L = 47 \, \mu\text{H}$

**$I_{\text{LED}}$ versus $V_S$ and Number of LEDs**

$\text{Efficiency versus } V_S \text{ and Number of LEDs}$

$\text{Duty Cycle versus } V_S \text{ and Number of LEDs}$
**ILD4035**
350 mA Step Down LED Driver

**Basic Application Information**

\[ R_{\text{sense}} = 303 \, \text{m} \Omega, \, L = 68 \, \mu\text{H} \]

\[ I_{\text{LED}} \text{ versus } V_S \text{ and Number of LEDs} \]

\[ f_{\text{Switch}} \text{ versus } V_S \text{ and Number of LEDs} \]

\[ \text{Efficiency versus } V_S \text{ and Number of LEDs} \]

\[ \text{Duty Cycle versus } V_S \text{ and Number of LEDs} \]
$R_{\text{sense}} = 303 \, \text{m}\Omega$, $L = 100 \, \mu\text{H}$

$I_{\text{LED}}$ versus $V_S$ and Number of LEDs

$f_{\text{Switch}}$ versus $V_S$ and Number of LEDs

Efficiency versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs
$R_{\text{sense}} = 303 \, \text{m} \Omega, \ L = 220 \, \mu \text{H}$

$I_{\text{LED}}$ versus $V_S$ and Number of LEDs

$f_{\text{Switch}}$ versus $V_S$ and Number of LEDs

Efficiency versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs
$R_{\text{sense}} = 367 \, \text{m}\Omega$, $L = 47 \, \mu\text{H}$

$I_{\text{LED}}$ versus $V_S$ and Number of LEDs

$\delta_{\text{Switch}}$ versus $V_S$ and Number of LEDs

Efficiency versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs
$R_{\text{sense}} = 367 \, \text{m} \Omega$, $L = 68 \, \mu\text{H}$

$I_{\text{LED}}$ versus $V_S$ and Number of LEDs

$V_S$ and Number of LEDs

$f_{\text{Switch}}$ versus $V_S$ and Number of LEDs

$f_{\text{Switch}}$ versus $V_S$ and Number of LEDs

Efficiency versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs
$R_{\text{sense}} = 367 \, \text{m}\Omega, \, L = 100 \, \mu\text{H}$

$I_{\text{LED}}$ versus $V_S$ and Number of LEDs

$\frac{f_{\text{Switch}}}{\text{kHz}}$ versus $V_S$ and Number of LEDs

Efficiency versus $V_S$ and Number of LEDs

Duty Cycle versus $V_S$ and Number of LEDs
Rsense = 367 mΩ, L = 220 μH

I\text{LED} versus \(V_S\) and Number of LEDs

\(f\text{Switch}\) versus \(V_S\) and Number of LEDs

Efficiency versus \(V_S\) and Number of LEDs

Duty Cycle versus \(V_S\) and Number of LEDs
7 Application Circuit

Figure 5 Application Circuit

8 Evaluation Board

Figure 6 ILD4035 on Evaluation Board
9 Package Information

Figure 7 Package Outline SC74

Figure 8 Recommended PCB Footprint for Reflow Soldering

Figure 9 Tape Loading