Driving High Power LEDs at 350mA with Low Cost LED Controller IC **ILD4035**

Application Note 215

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1 Introduction

1.1 Features

- Wide Input Voltage Range: 4.5 V ... 40 V
- Internal switch for up to 400 mA average LED current
- 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 component required
- Small Package: SC74

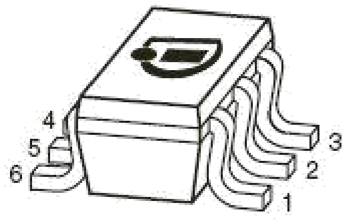

Figure 1 ILD4035

1.2 Applications

- LED driver for general lighting applications
- Retail, office and residential luminaires and downlights
- LED replacement lamps, e.g. MR16
- Architectural lighting

1.3 Description

This document contains informations about the LED-Less Demonstration Board for ILD4035.

IILD4035 is a hysteretic step-down LED driver. Please refer to the datasheet for the pins descriptions, functions descriptions and specifications.

The ILD4035 Demonstration Board has two versions. Version ILD4035 24V Board**'s** sense resistance is optimized to drive a string of 6 series LEDs at 350mA (max current) with an input voltage of 24V. Version ILD4035 12V Board**'s** sense resistance is optimized to drive a string of 3 series LEDs at 350mA (max current) with an input voltage of 12V.

ILD4035 maintains a constant current through a string of LEDs as long as the input voltage exceeds the sum of the forward voltages of the LEDs in the string by at least 3V. The maximum input voltage for this demonstration board must not exceed 30V; this restriction is due to the schottky diode installed which has a reverse breakdown voltage of 30V. If there is a need to test the board with a maximum supply voltage of 40V, please replace the schottky diode SD1 with a suitable breakdown voltage.

The ILD4035 incorporates the following protection features: Over-voltage protection, temperature protection and an over-current protection.

The board includes a **"**Multifunctional Pin**"** input terminal for digital or analog dimming control signal. PWM dimming frequencies up to 300Hz at 100:1 contrast ratio and at 100Hz contrast ratio of 300:1 are possible.

The complete demonstration board schematic is shown in Figure 2. Typical waveforms and performance curves are shown in Figure 4 to Figure 8.

Although a wide variety of LED combinations and currents can be driven with the ILD4035, the sense-resistors have to be altered to achieve maximum current of 350mA and inductance has to be changed to attain recommended switching frequencies below 500 kHz.

Table 1 Versions of Demo Board for ILD4035

Board Name	R1 /Ω	R2 /Ω	R3 /Ω	L1 /µH	Vs /V	Suitable number of LEDs	Typical Switch. Freq. /kHz	Measured Vrsense = Vs - VLED+ /V	LED Average Current /A
ILD4035 12V Board	1.1	1.1	1.1	100	12	3	133	0.116	0.31
ILD4035 24V Board	0.91	0.91	0.91	100	24	6	226	0.105	0.34

The above measured values are for typical case only.

1.3.1 Check List before powering up

Before powering on the ILD4035 demonstration board, please verify the following:

- Be sure that each LED can conduct 350mA dc current within its safe region of operation.
- Make sure that the input voltage supply is equal to the voltage rating of the board.
- Select the appropriate mode for EN/PWM:
    - to enable the ILD4035 dimming, please force the EN/PWM pin terminal to 3V or up to input voltage, or
    - to select analog dimming, supply a dc source (0 to 3V) to EN/PWM pin terminal, or
    - to select PWM dimming, supply a PWM signal source (0 to 5V) with frequency within range of (200Hz to 5 kHz) to EN/PWM pin terminal

1.3.2 Capacitor C20 for Ripple Reduction

This component C20 is optional and not installed on the standard demo board. This capacitor can help to reduce LED ripple current. The peak-to-peak ripple current values shown in Table 3 are without C20 installed. Recommended to use low ESR[1] capacitor and its rated voltage must be higher than the maximum input voltage.

1.3.3 Connection of LEDs

The ILD4035 demo board includes a 3-pin SIP [2] connector for the anode connection (LED +) and a 2-pin SIP connector for the cathode connection (LED -**) of the "LEDs in series". The anode connection is labeled as** *Con1-3* and cathode connection is labeled as *Con2-1* on the board.

1.3.4 Open Circuit of terminals LED+ and LED-

If the LED array is disconnected or fails with open state, the ILD4035 will operate at 100% duty cycle. The output voltage (at LED+) will rise to the level of the input voltage. The other output terminal (LED -) will fall to ground. Note that under the above said condition; please avoid reconnecting the LED array between LED+ and LED- terminals without powering down first. This precaution is to avoid excessive surge current that may damage the LEDs.

[1] Equivalent Series Resistance
[2] Single In-line Package

2 Application Information

2.1 Schematic

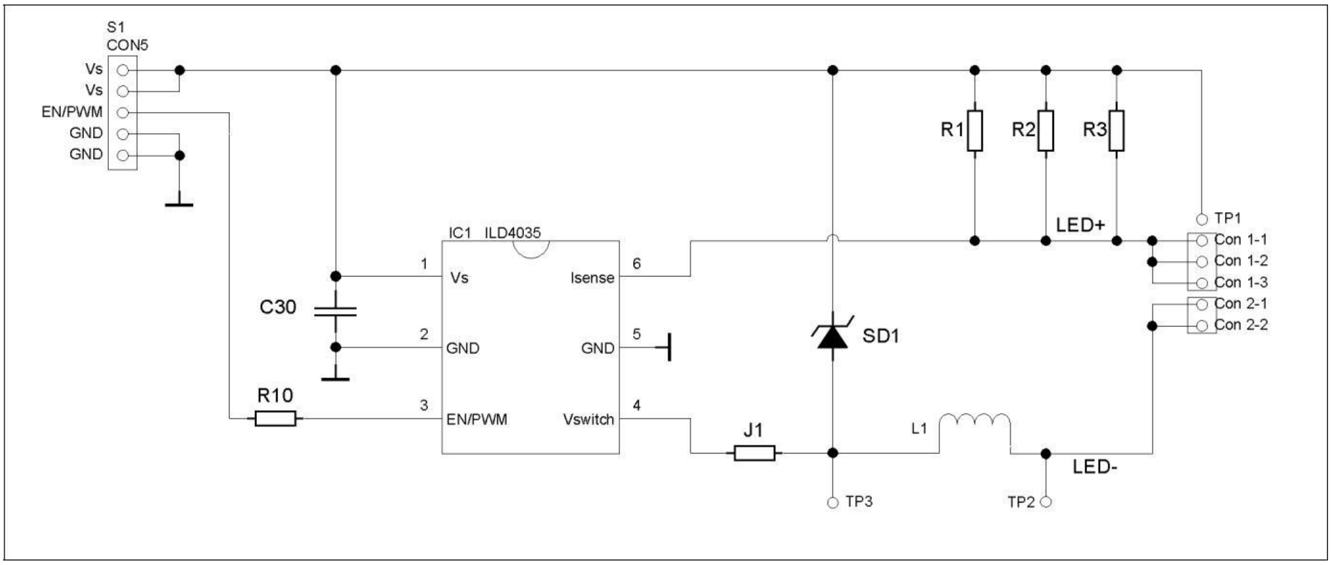

Figure 2Schematic of the demonstration board

Table 2 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
L1	100	µH	6.3x6.3mm	EPCOS	Shielded Power Inductor ,20%, 1A
R1	*see Table 1	Ω	1206		Part of the current sense resistor
R2	*see Table 1	Ω	1206		Part of the current sense resistor
R3	*see Table 1	Ω	1206		Part of the current sense resistor
R10	0	Ω	0805		Jumper
J1	0	Ω	0805		Jumper
SD1	BAS3010A-03W		SOD323	INFINEON	Medium Power AF Schottky Diode 1A 30V
IC1	ILD4035		SC74	INFINEON	Hysteretic Buck controller and LED driver
C30	4.7	µF	1812		Ceramic, 50V

2.2 Recommended method to measure Vsense w.r.t. Vs pin

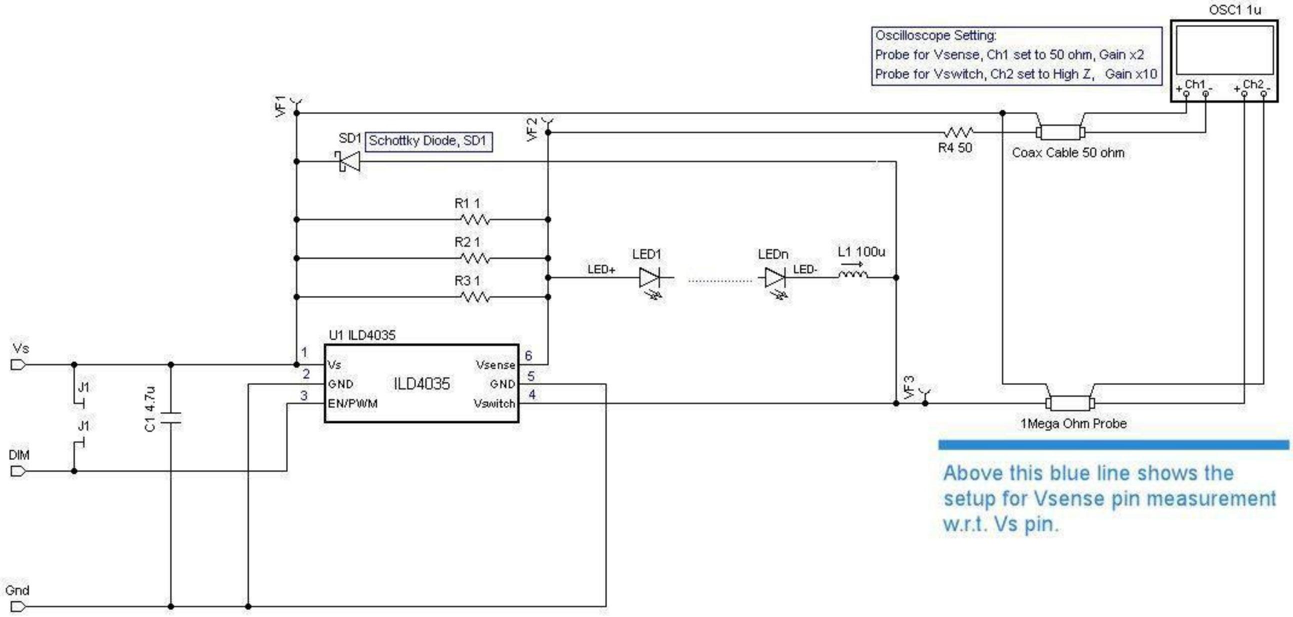

Figure 3 Measurement setup for measuring Vsense voltage w.r.t. Vs pin

By probing Vsense pin voltage with reference to Vs pin, it facilitates the observation and measurement of the ripple and average of Vsense vo**ltage at the same time with "Oscilloscope set to DC coupling"**, and without offsetting the DC voltage. This is shown in Figure 4, waveform 2.

2.3 Measured Graphs of the demonstration boards

Unless otherwise specified, the following condition labels apply:
Condition: Vs=12V, Ta=25°C

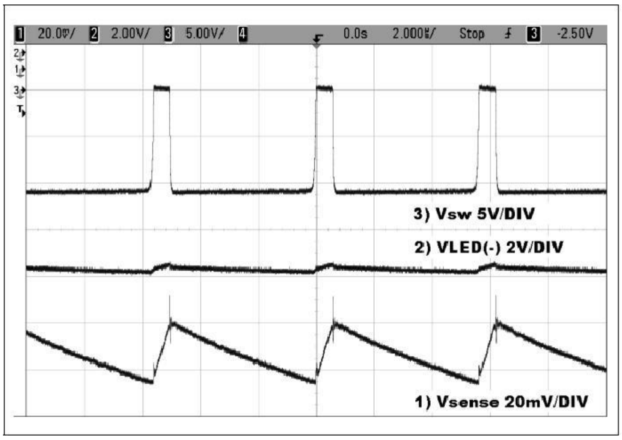

Figure 4 Vsw, Vsense and VLED(-), Vs=12

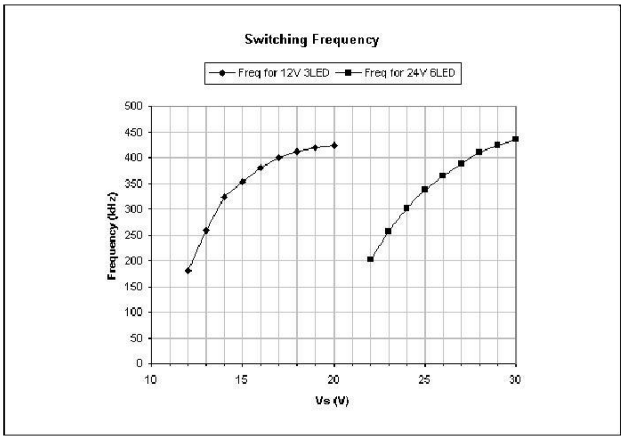

Figure 5 Switching Freq. vs Input Voltage,Vs

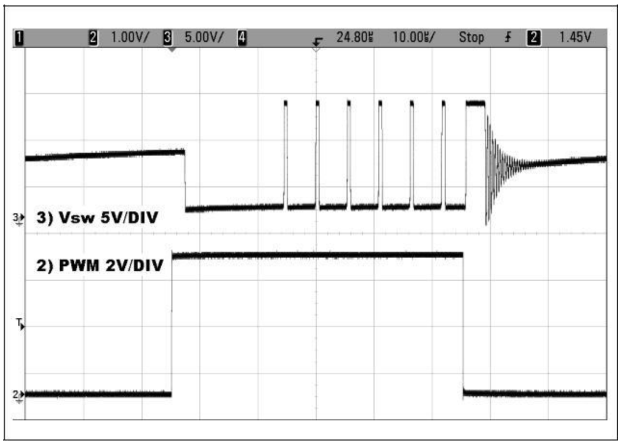

Figure 6 Dimming waveform

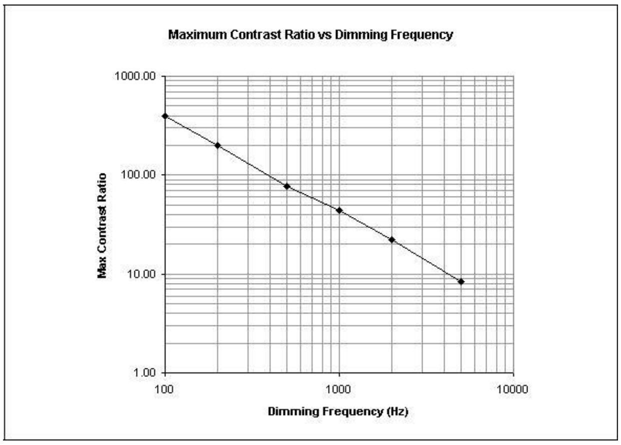

Figure 7 Maximum Contrast Ratio vs Dimming frequency (100:1=1% Duty)

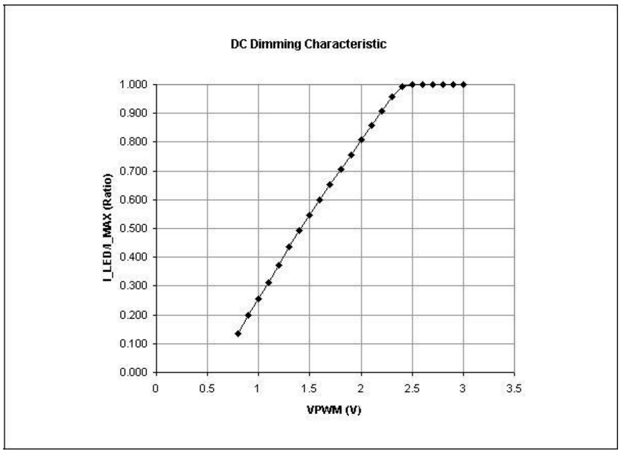

Figure 8 Analog Dimming Characteristic

2.4 Analog Dimming Characteristic

The analog dimming characteristic graph is shown Figure 8. To achieve a linear change in LED current versus control voltage, the recommended range of voltage at EN/PWM pin is from 0.8V to 2.5V.

Table 3 Percentage of max LED current vs DC voltage at en/pwm pin

Ven_pwm /V	Percentage of max. LED Current / %
< 0.4	0
0.7	10
1.0	25
1.4	50
1.9	75
2.2	90
>2.5	100

2.5 PWM Dimming

The EM/PWM terminal on the PCB is an input for the pulse width modulated (PWM) signal to control the **dimming of the LED string. The PWM signal's logic high level should be at least** 2.6V or higher. The period of this PWM signal should be higher than 200µs. For the default demo board circuit, a dimming frequency less than 300Hz is recommended to maintain a maximum contrast ratio of at least 100:1. The maximum contrast ratio is shown on Figure 7, and the minimum is based on the measured average LED current at 3dB below the linear reference. The maximum contrast ratio depends largely on the rise time of the inductor current, and hence is dependent on input voltage, inductor size, and LED string forward voltage. In addition, if C20 is installed, the maximum contrast ratio or DIM frequency will be further reduced.

2.6 Temperature Protection

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. The ILED temperature characteristic is shown on Figure 18. The LED current is reduced by 10% when the ambient temperature reaches 105°C for 12V, 3LEDs case.

2.7 Setting the nominal LED current

The internal reference for the voltage across the external sense resistor was design to be 0.114V as stated in the datasheet. A first order approximation for the LED current can be calculated with this formula:

$$I_{LED} = \frac{V_{ISENSE}}{R_{SENSE}} = \frac{0.114V}{R_{SENSE}}$$

If a certain level of LED current is desired; the estimation for the Rsense is given by:

$$R_{SENSE} = \frac{V_{ISENSE}}{I_{LED}} = \frac{0.114V}{I_{LED}}$$

The Visense can vary depending on the number of LEDs and voltage supply. Please take reference from Figure 9, Figure 10, and Figure 11 to help select the Rsense for your application.

3 Characteristic Graphs for different Inductors, no. of LEDs, Rs

3.1 ILED, Frequency versus Supply Voltage Characteristics (100µH)

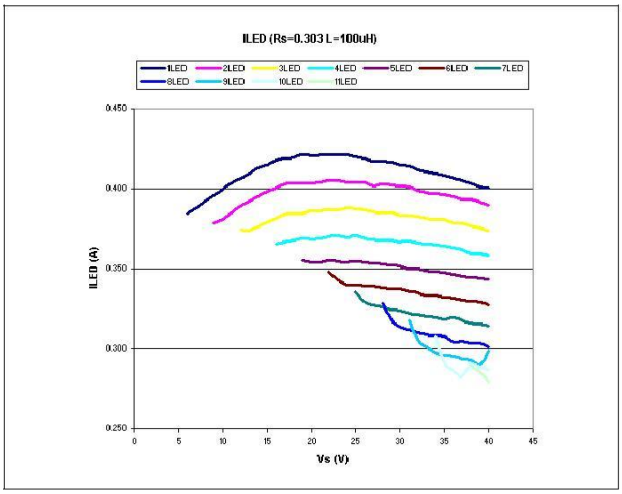

Figure 9 ILED vs Vs (Rs=0.303Ω, L=100µH)

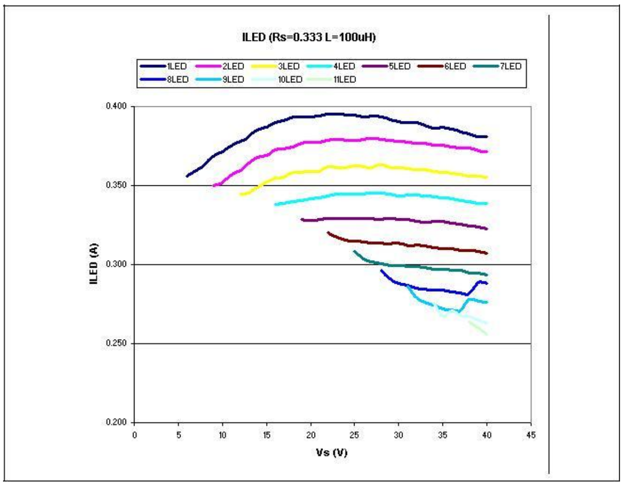

Figure 10 ILED vs Vs (Rs=0.333Ω, L=100µH)

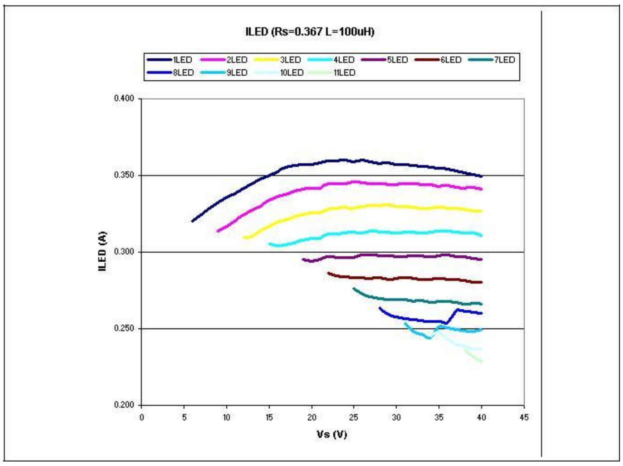

Figure 11 ILED vs Vs (Rs=0.367Ω, L=100µH)

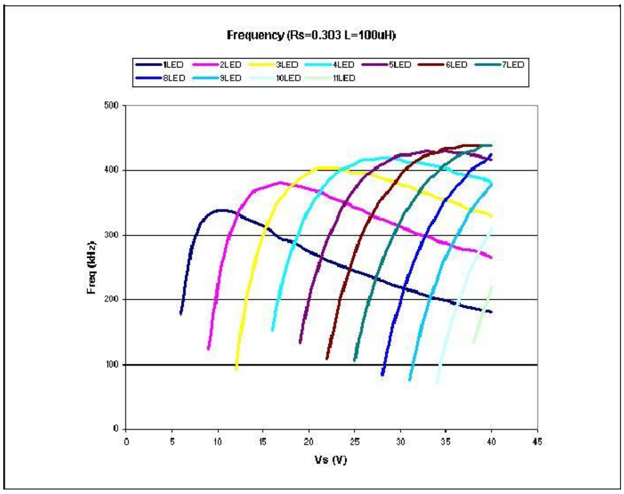

Figure 12 Frequency vs Vs (Rs=0.303Ω, L=100µH)

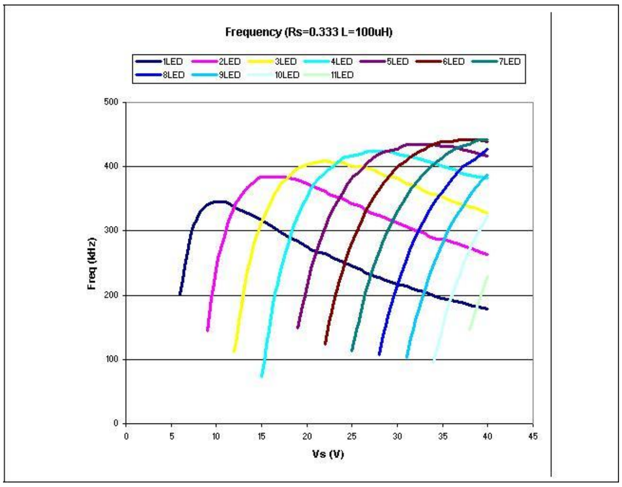

Figure 13 Frequency vs Vs (Rs=0.333Ω, L=100µH)

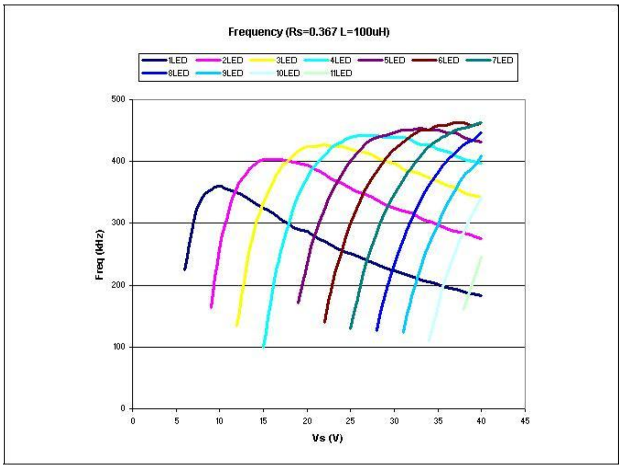

Figure 14 Frequency vs Vs (Rs=0.367Ω, L=100µH)

3.2 Efficiency versus Supply Voltage Characteristics (100µH)

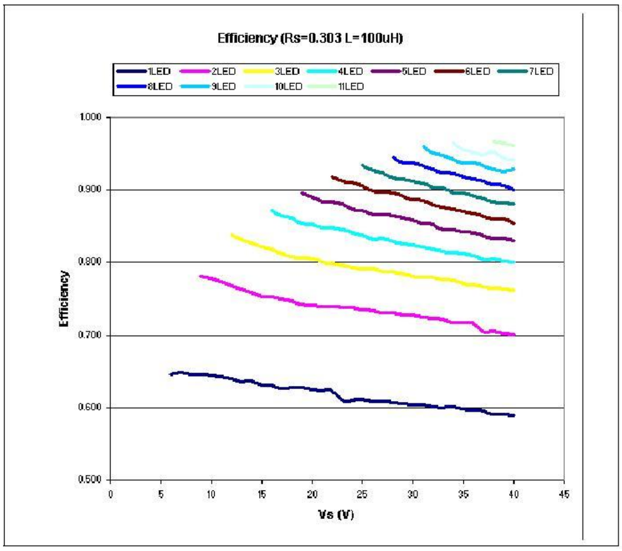

Figure 15 **Efficiency vs Vs (Rs=0.303Ω, L=100µH)**

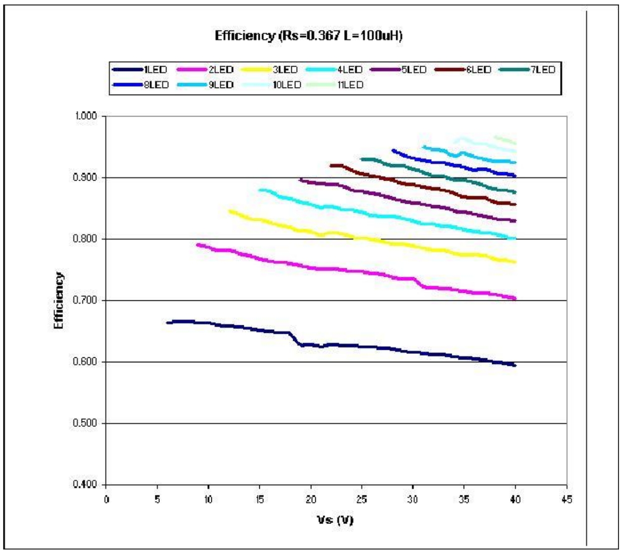

Figure 17 **Efficiency vs Vs (Rs=0.367Ω, L=100µH)**

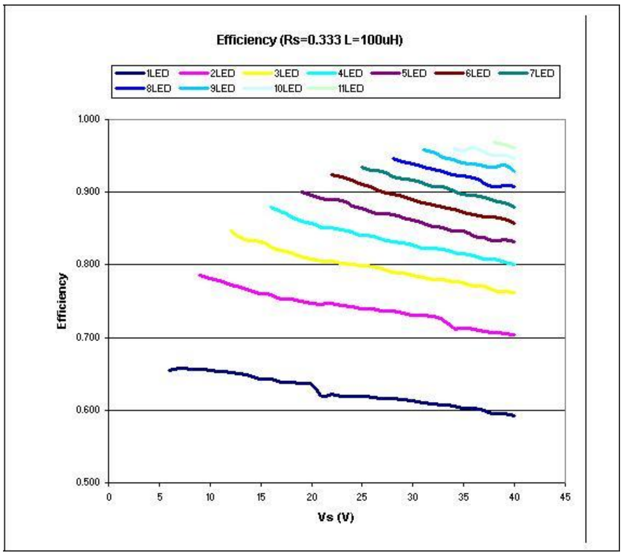

Figure 16 **Efficiency vs Vs (Rs=0.333Ω, L=100µH)**

3.3 Temperature Characteristics (Rs=0.333Ω L=100uH)

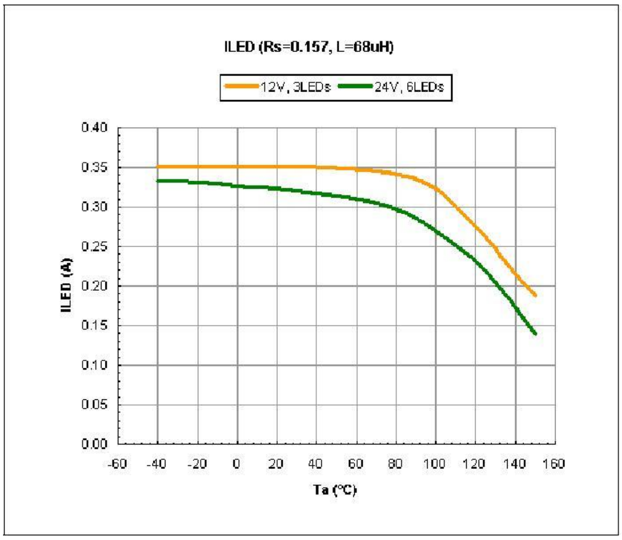

Figure 18 **ILED vs Ambient Temperature**

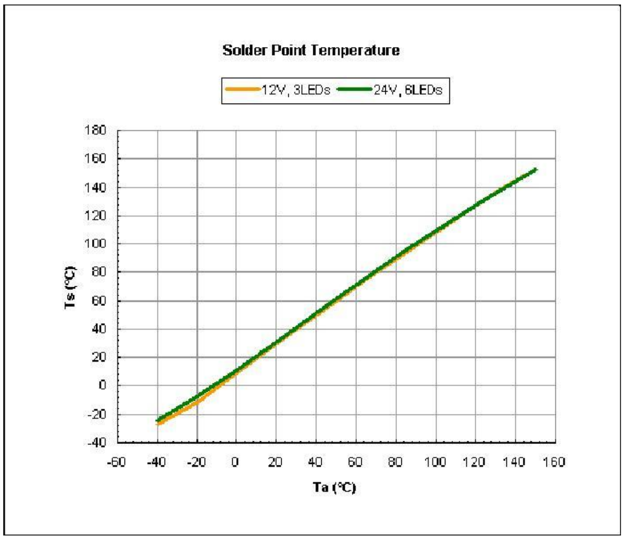

Figure 20 Soldering Temperature at Vswitch pin vs Ambient Temperature (with the present demo board)

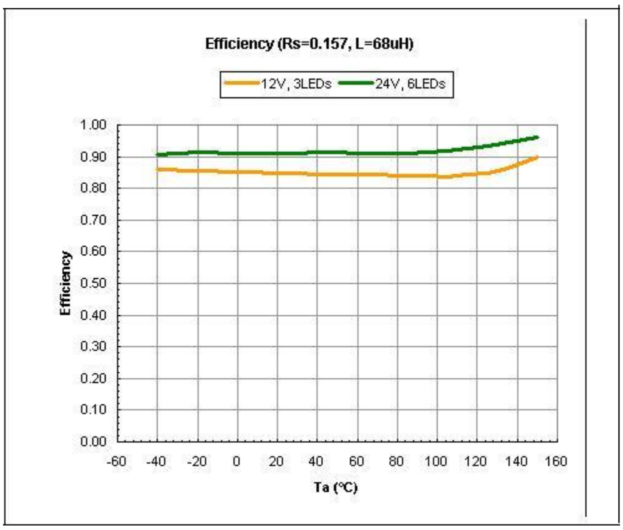

Figure 19 **Efficiency vs Ambient Temperature**

3.4 Power Limitation Characteristic of ILD4035

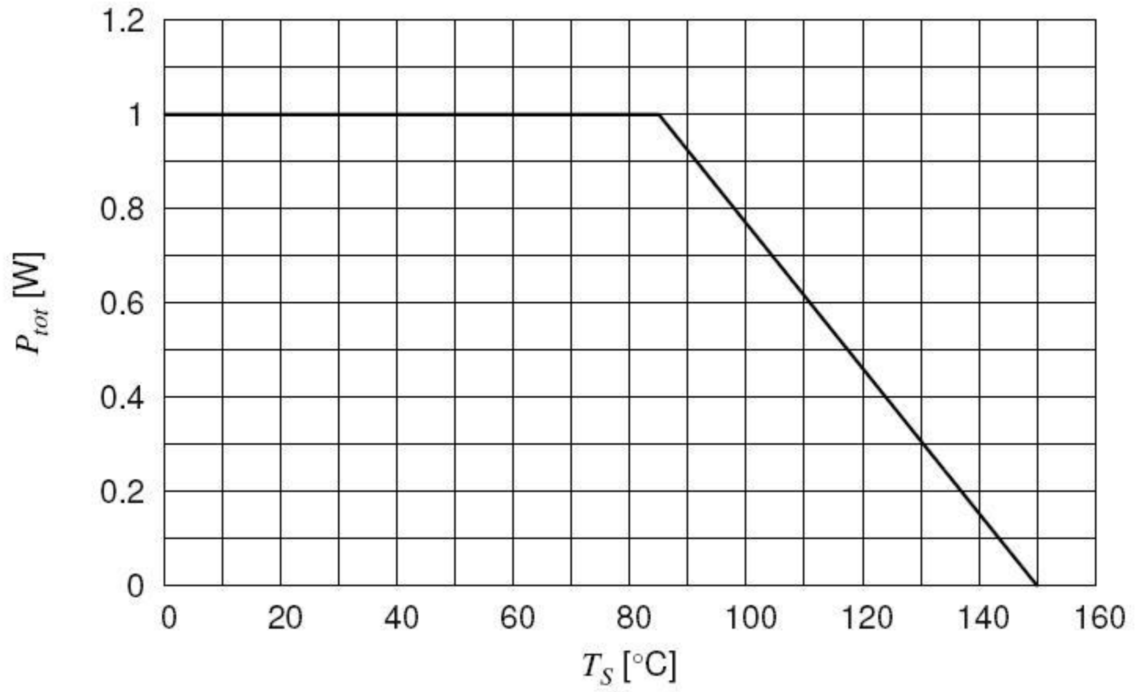

Figure 21 ILD4035's total power dissipation at different temperature

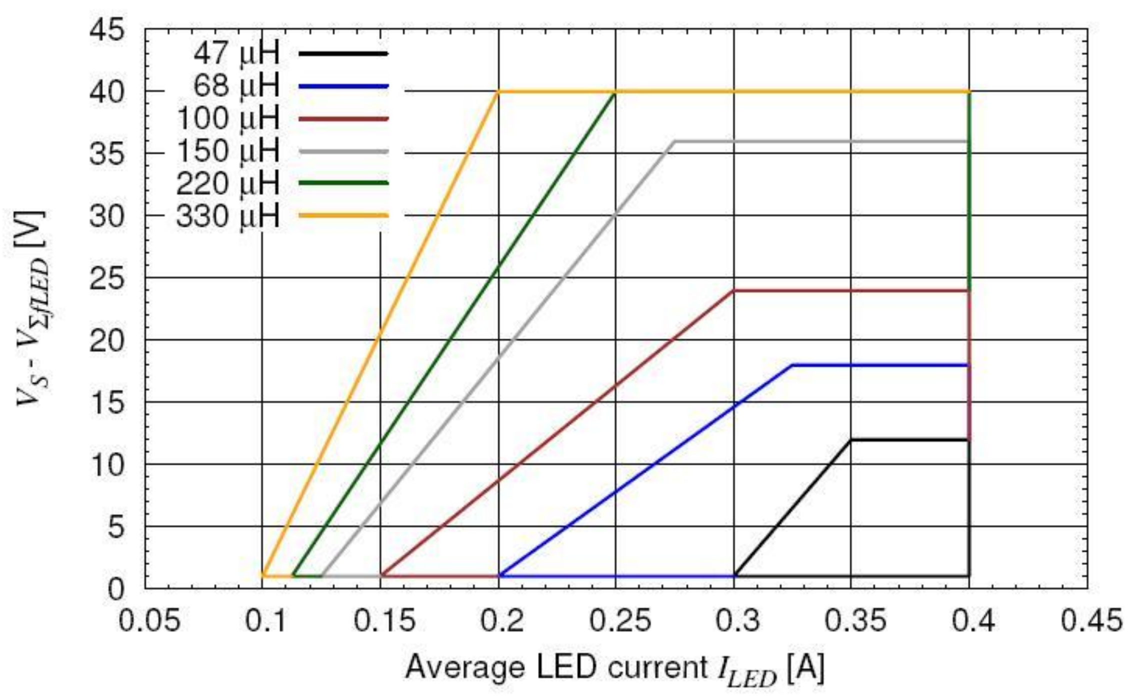

Figure 22 ILD4035's power transistor Safe Operating Area for different inductances

4 Evaluation Board and layout Information

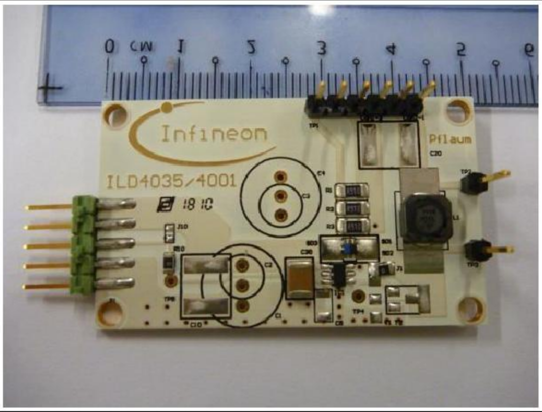

Figure 23 Photograph of Demo Board (size of PCB: 50mm x 30mm)

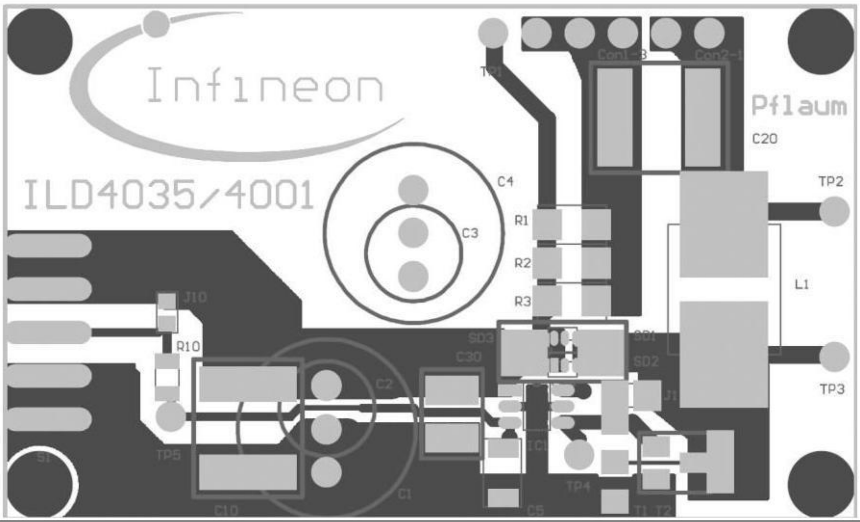

Figure 24 PCB Layer Information Top View

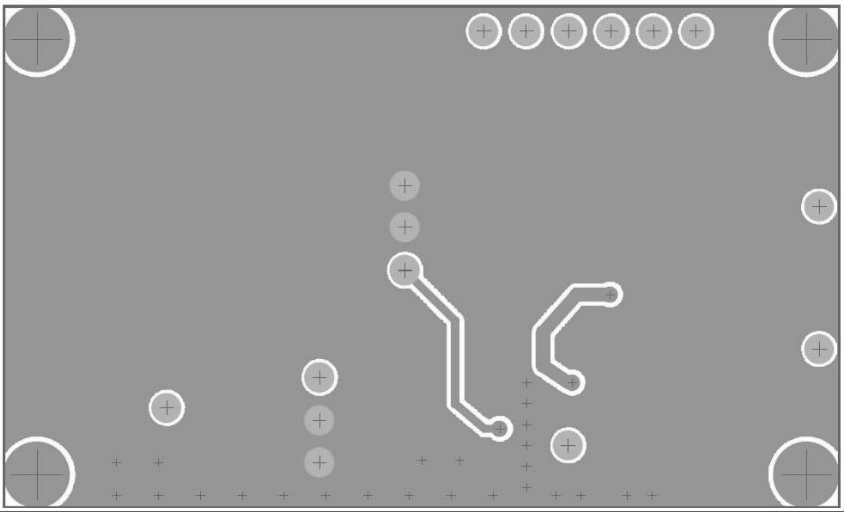

Figure 25 PCB Layer information Bottom View (unflip)

4.1 PCB Considerations

The free-**wheeling diode's path from inductor** to Vs pin of the integrated circuit is recommended to be as short a distance as possible. This is to minimize oscillation in the system.

The energy storage capacitor between Vs and Gnd is recommended to be placed as near to the IC as possible. This helps to stabilize the supply voltage when the IC draws large instantanoeus current during switching.

Ground plane should be as large as possible to improve heat dissipation.

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

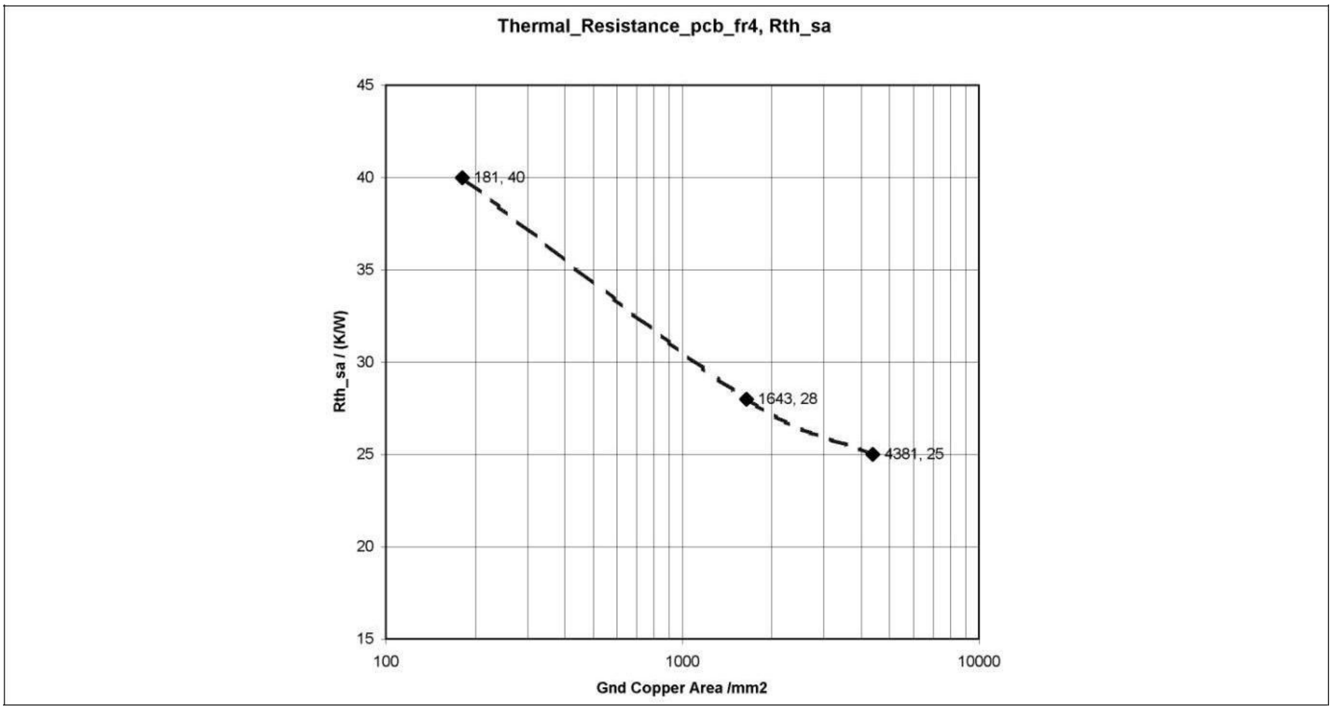

Figure 26 Thermal Resistance of PCB-FR4 versus Ground Copper Area

The data in the above Figure 26 were measured with following conditions:

- Two copper layers,
- 2 oz copper (70um thick) and board thickness of about 1.6mm,
- Ground pin connection of the IC is used to dissipate heat,
- 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 broken line represents intermediate points which can de derived by linear interpolation.

An example where **ILD4035's PCB i**s separated from LED**s' PCB** and there is not heat transmission between the two PCBs.

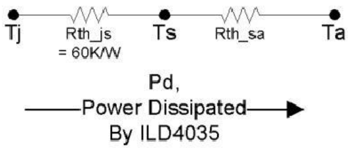

Figure 27 Thermal Resistance Representation of the LED-Less Demo Board

T_j **is the junction temperature of the ILD4035's output transistor connected to switch**

pin. T_S is the solder**ed temperature of the ILD4035's ground pin to FR4**-PCB.

T_a is the ambient temperature.

R_{th_js} is the thermal resistance from junction to soldered poin**t with reference to ILD4035's SC**74 package. This is stated as 65K/W in the datasheet.

R_{th_sa} is the thermal resistance from soldered point to ambient which is dependent on size of grounding area of PCB.

P_d is the power dissipated by ILD4035 which is approximately 10% of total power from supply (for rough calculation), or it can be derived by (Total power from supply **– LEDs' power –** Power Loss on other external components).

The above variables are related in the equations on the next line.

$$P_d = \frac{T_j - T_S}{R_{th\_js}} = \frac{T_S - T_a}{R_{th\_sa}}$$

With the above equations, and setting T_j (recommended to be below 100°C), the T_S can be calculated.

By choosing a desired T_a, the R_{th_sa} can be calculated.

With the calculated R_{th_sa}, reference Figure 26 to correlate the approximated ground copper area required in PCB layout.

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