

ILD4035

350 mA LED Driver

ILD4035

Data Sheet

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Revision History

| Page or Item | Subjects (major changes since previous revision) |
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| Revision 1.0, 2010-11-11 | |
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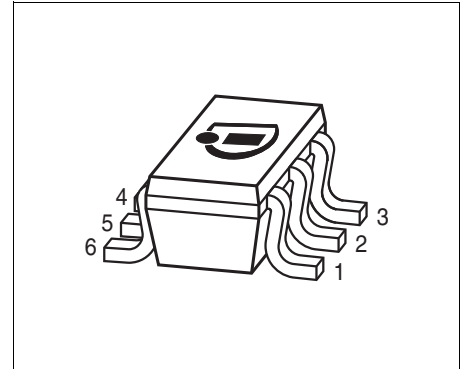
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350 mA LED Driver with Internal Switch ILD4035

1 Features

- Wide input voltage range: 4.5 V ... 42 V
- Internal switch
- 350 mA LED output current
- Over current protection
- Over voltage protection
- Reversible temperature shut down mechanism
- Inherent open- circuit LED protection
- Soft- start capability
- Low shut down current < 100 nA in operating voltage range
- Analog voltage and PWM dimming possible
- Typical 3% output current accuracy
- Very low LED current drift over temperature
- Minimum external components required
- Small Package: SC74



2 Applications

- LED Driver for general lighting applications
- Indoor illumination, residential lighting
- Outdoor illumination, street lighting
- Office lighting, downlights
- Architectural lighting

| Product Name | Package | Pin Configuration | | | | Marking |
|--------------|----------|-------------------|--|--|--|---------|
| ILD4035 | SC74-6-4 | | | | | 35 |

3 Product Brief

The ILD4035 is a hysteretic Step down LED converter IC for general lighting applications, which is capable to drive high power LEDs with currents up to 350 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 shutdown will protect the LEDs and the IC against thermal stress.

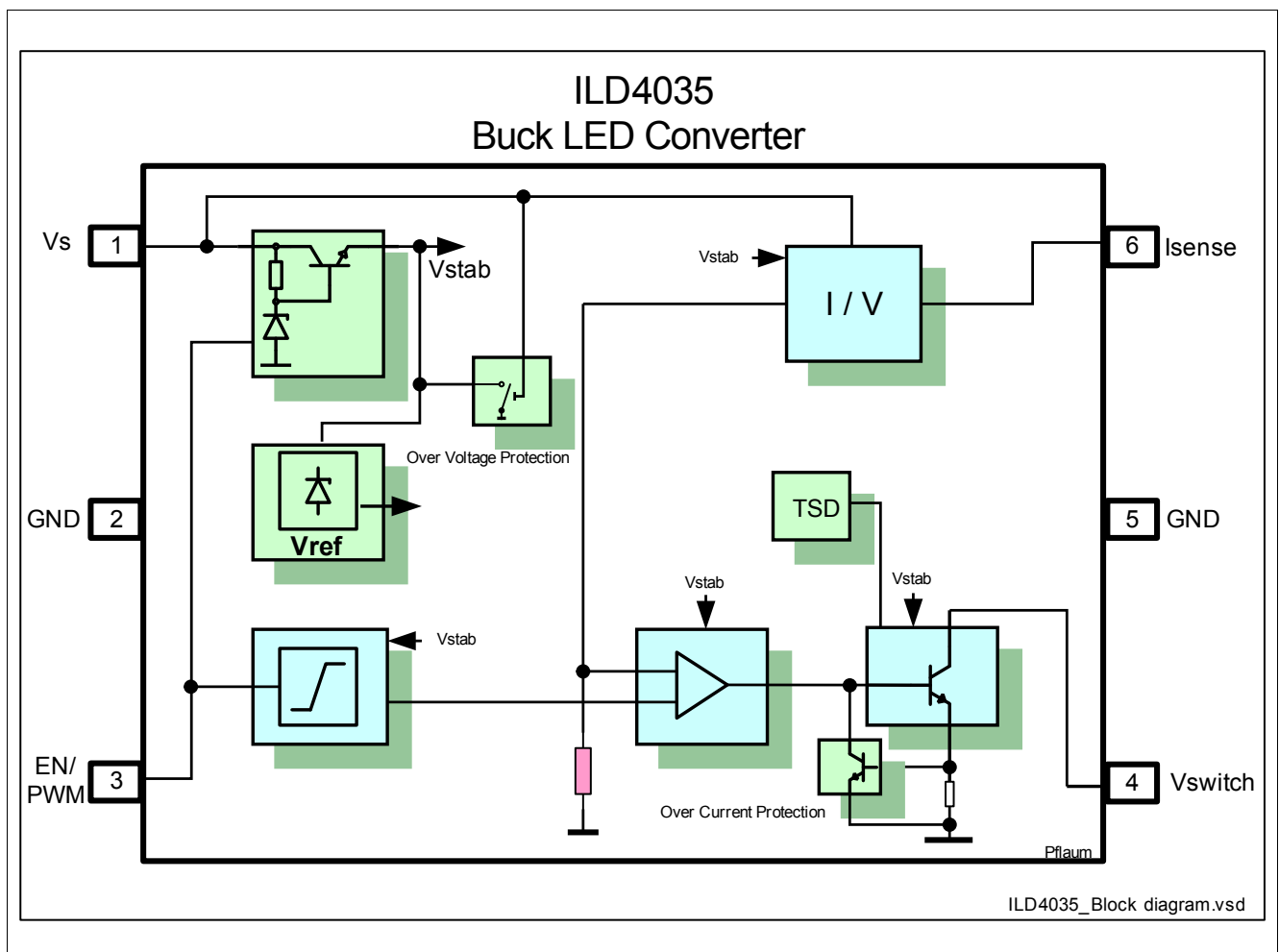


Figure 1 Block Diagram

Pin Definition
Table 1 Pin Definition and Function

| Pin Number | Pin Symbol | Function |
|------------|---------------------|--|
| 1 | V_s | Supply Voltage |
| 2 | <i>GND</i> | IC ground |
| 3 | <i>EN / PWM</i> | Multifunctional Pin; Power On control voltage pin (<i>PWM input</i>) |
| 4 | V_{switch} | Power Switch Output |
| 5 | <i>GND</i> | IC ground |
| 6 | I_{sense} | LED current sense pin |

Maximum Ratings
Table 2 Maximum Ratings

| Parameter | Symbol | Limit Value | Unit |
|---|-----------------------|-------------|------------------|
| Supply voltage | V_s | 45 | V |
| Peak Output current | I_{out} | 600 | mA |
| Total Power Dissipation; $T_s = 85^\circ\text{C}$ | P_{tot} | 1000 | mW |
| Junction temperature | T_J | 125 | $^\circ\text{C}$ |
| Solder Temperature of GND pins | T_{SGND} | 110 | $^\circ\text{C}$ |
| Storage temperature range | T_{STG} | -65... 150 | $^\circ\text{C}$ |
| ESD capability all pins ¹⁾ | $V_{\text{ESD_HBM}}$ | 4 | kV |

1) Refer to HBM: JESD22 - A114

Thermal Resistance
Table 3 Maximum Thermal Resistance

| Parameter | Symbol | Value | Unit |
|-------------------------|-------------------|-------|------|
| Junction - solder point | R_{thJS} | 65 | K/W |

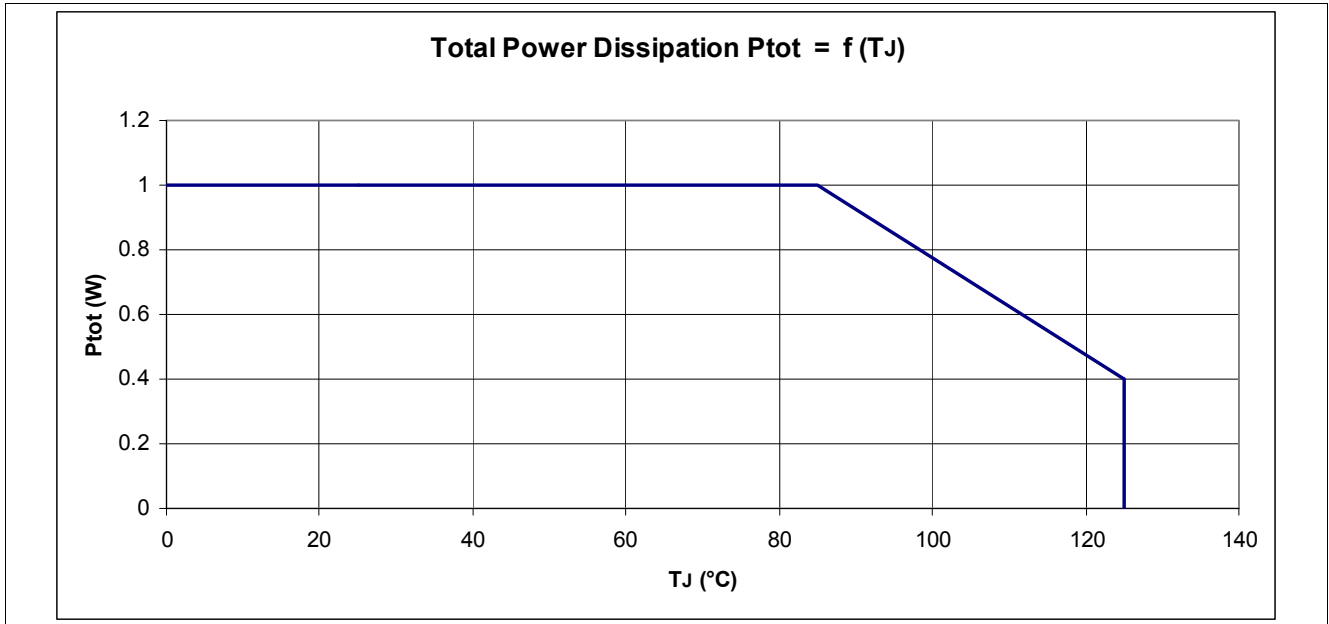


Figure 2 ILD4035; Total Power Dissipation

This formula is a first estimation to calculate the Power Dissipation of the IC

$$P_{tot} = 1.1 \text{ V} * I_{LED} * \text{duty cycle} + F_{OSC} * 1\mu\text{W} * I_{LED} / 350\text{mA} \quad (1)$$

For more precise analysis please measure T_s of ILD4035 at GND pin and use [Figure 2](#) as a reference.

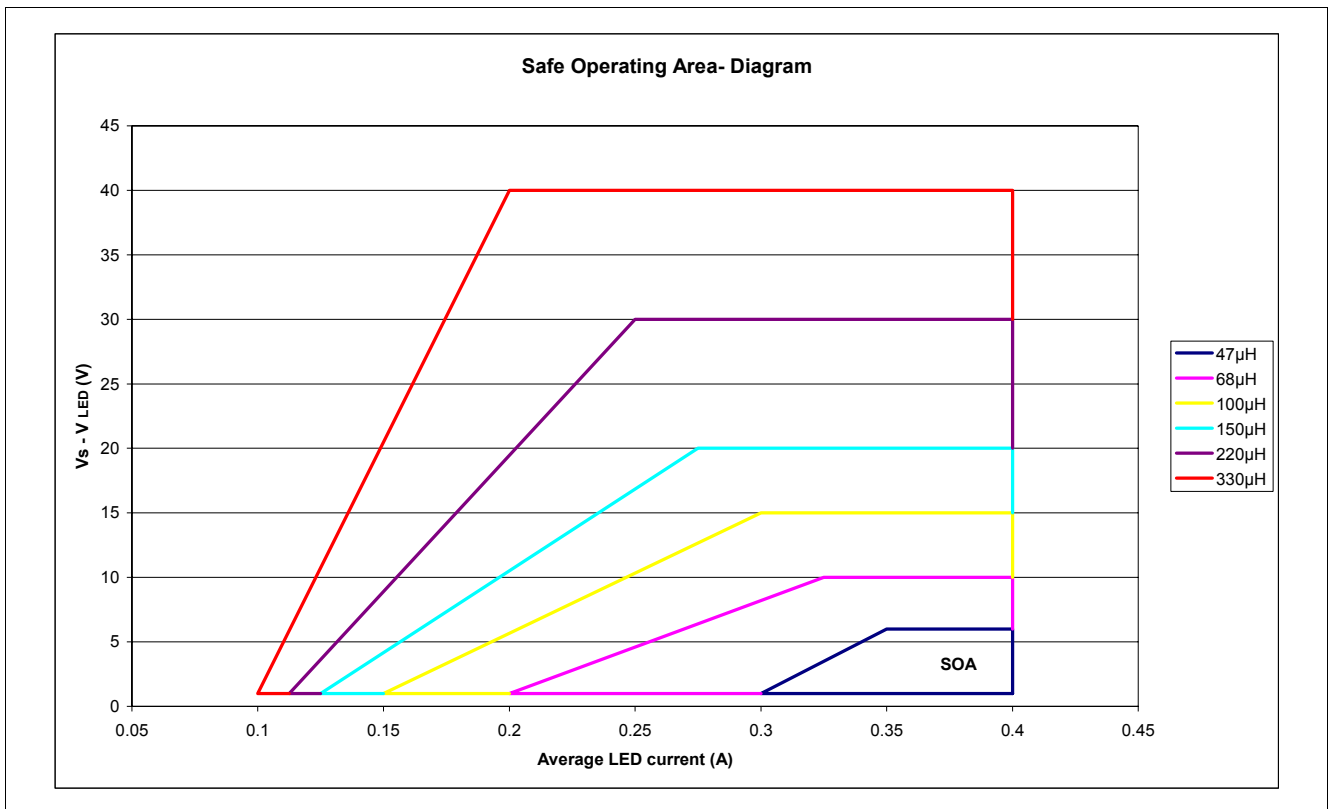


Figure 3 ILD4035; Safe Operating Area

This diagram shows the area of safe operation for the respective inductance values.

The safe area of operation consists of the minimum and maximum allowed average LED current and the resulting voltage overhead.

The voltage overhead is the difference between the sum of the LED forward voltages and the supply voltage.

Example Calculation 1

3 LEDs in series; $I_{LED} = 350 \text{ mA}$; $V_S = 12 \text{ V}$

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

=> every coil value could be used

Example Calculation 2

6 LEDs in series;

$$I_{LED} = 250 \text{ mA}; V_S = 24 \text{ V}$$

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

=> the coil values should be equal or above 100 μH

If $V_{overhead}$ is above the boundary of a certain coil value at wanted average LED current, the switching frequency and the associated power dissipation of the ILD4035 will increase beyond maximum ratings.

4 Electrical Characteristics

4.1 DC Characteristics

All voltages with respect to ground; positive; current flowing into pin; unless otherwise specified

All parameters have been measured at $T_{amb} = 25\text{ °C}$, unless otherwise specified.

$V_{en} = 3\text{ V}$

Table 4 DC Characteristics at $T_A = 25\text{ °C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|--|----------------------|--------|------|------|--------------------|--|
| | | Min. | Typ. | Max. | | |
| Supply voltage | V_S | 4.5 | | 42 | V | |
| Overall current consumption open load | $I_{S_{open\ load}}$ | 2.1 | 2.7 | 3.5 | mA | $V_S = 4.5\text{ V}$ $I_{LED} = 0\text{ mA}$ |
| Overall current consumption open load | $I_{S_{open\ load}}$ | 2.7 | 3.5 | 4.3 | mA | $V_S = 40\text{ V}$ $I_{LED} = 0\text{ mA}$ |
| Overall current consumption open load | $I_{S_{open\ load}}$ | 2.0 | 8.4 | 13.0 | mA | $V_S = 45\text{ V}$ $I_{LED} = 0\text{ mA}$ |
| Overall standby current consumption | $I_{S_{standby}}$ | | | 1000 | nA | $V_{en} = 0\text{ V}$; $V_S = 12\text{ V}$ |
| Overall standby current consumption | $I_{S_{standby}}$ | | | 50 | μA | $V_{en} = 0\text{ V}$; $V_S = 40\text{ V}$ |
| Input Current of multifunctional control pin | I_{EN} | | 140 | 200 | μA | $V_{en} = 3\text{ V}$ $V_S = 4.5..42\text{ V}$ |
| Current of Sense input | I_{sense} | | 20 | | μA | At any LED current |
| Temperature shut down | $Th_{TSD}^{1)}$ | 85 | 90 | 95 | $^{\circ}\text{C}$ | $I_{out} \rightarrow 0\text{ A}$; value refers to T_S under condition $V_S = 12\text{ V}$; 3 LEDs $L = 100\ \mu\text{H}$; $R_{sense} = 333\text{ m}\Omega$ |

- 1) This specified value corresponds to solder temperature when the IC goes into shut down mode.
Operating ambient temperature depends on $R_{th_{SA}}$ of the PCB.

4.2 AC Characteristics

All parameters have been measured at $T_{amb} = 25\text{ °C}$, unless otherwise specified.

$$V_s = 12\text{ V}, V_{fLED} = 3\text{ V}$$

$$R_{sense} = 333\text{ m}\Omega \rightarrow I_{LED} = 350\text{ mA}$$

$$V_{en} = 3\text{ V}$$

$L = 100\text{ }\mu\text{H}$, unless otherwise specified

Table 5 AC Characteristics at $T_A = 25\text{ °C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|--------------------|--------|---------|------|------|---|
| | | Min. | Typ. | Max. | | |
| Mean current sense threshold voltage | ΔV_{sense} | 115 | 118 | 121 | mV | 3 LEDs in series verified by sample test |
| Switching frequency | F_{sw} | | 180 | | kHz | 3 LEDs in series |
| Maximum switching frequency | F_{swmax} | | 500 | | kHz | Recommended, depends on coil value |
| Sense threshold hysteresis | $V_{sensehys}$ | | +/- 7.5 | | % | Not subject to production test - verified by design/characteri-zation |
| Residual voltage at collector of power transistor | VCE | | 1.1 | | V | Internal power transistor is switched on |
| Output current accuracy | $I_{outaccVs}$ | | +/- 3 | | % | 3 LEDs in series not subject to production test - verified by design/characteri-zation |
| Temperature drift of average LED current | $I_{driftTemp}$ | | + 3 | | % | 3 LEDs in series $T_J : 70 \rightarrow 110\text{ °C}$ not subject to production test - verified by design/characteri-zation |

4.3 Digital Signals

All parameters have been measured at $T_{amb} = 25\text{ °C}$, unless otherwise specified.

Table 6 AC Characteristics, $V_{CE} = 3\text{ V}$, $f = 150\text{ MHz}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|-----------|--------|------|------|------|-----------------------|
| | | Min. | Typ. | Max. | | |
| Multifunctional control pin voltage range | U_{Pon} | -0.3 | | 42 | V | |
| Control voltage for power on | U_{On} | 2.2 | 2.5 | 42 | V | Full LED current |
| Control voltage for power off | U_{Off} | -0.3 | | 0.7 | V | |
| Control voltage for analog dimming | U_{dim} | 1 | | 2.5 | V | Linear dimming range |

5 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>

5.1 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 this formula.

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

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

Figure 4 ILD4035; Rsense Calculation

Example Calculation 1

$V_s = 12\text{ V}$, $V_{fLED} = 3\text{ V}$, 3 LEDs in series

=> $V_{sense} = 118\text{ mV}$

$I_{LED} = 350\text{ mA}$

=> $R_{sense} = 337\text{ m}\Omega$

Example Calculation 2

$V_s = 24\text{ V}$, $V_{fLED} = 3\text{ V}$, 6 LEDs in series

=> $V_{sense} = 100\text{ mV}$

$I_{LED} = 350\text{ mA}$

=> $R_{sense} = 286\text{ m}\Omega$

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

5.2 Dimming of the LEDs

Typical operating conditions

All parameters have been measured at $T_{amb} = 25\text{ }^\circ\text{C}$, unless otherwise specified.

Analog voltage dimming

The analog dimming characteristic graph is shown in **Figure 5**. To achieve a linear change in LED current versus control voltage, the recommended range of voltage at En/PWM pin 3 is from 0.8 V to 2.5 V

$R_{sense} = 333\text{ m}\Omega$, $L = 100\text{ }\mu\text{H}$

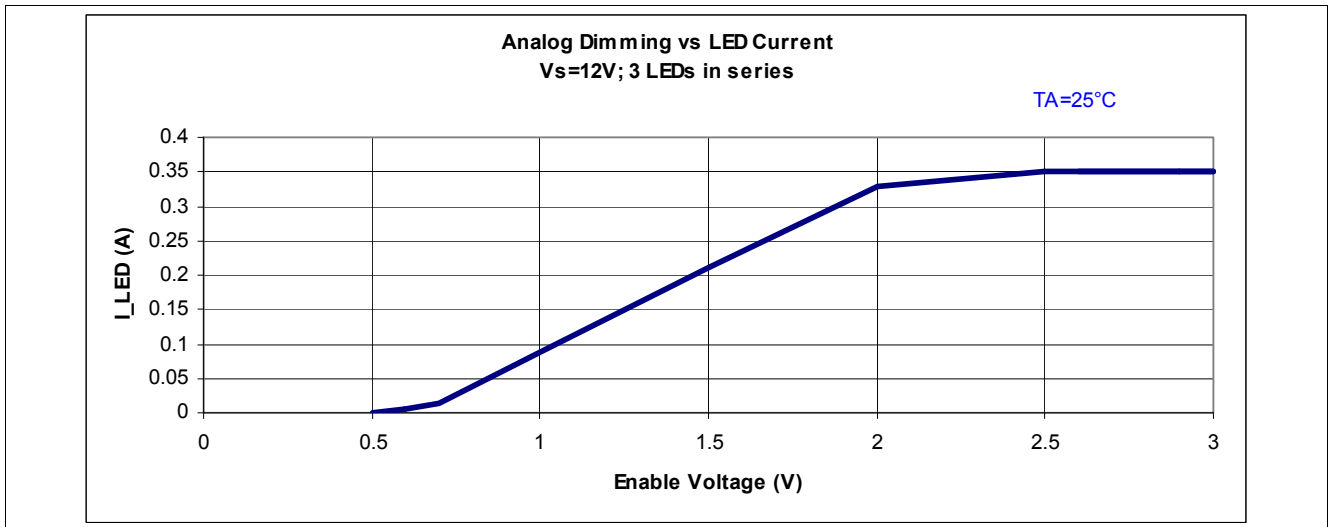


Figure 5 ILD4035; Analog Voltage Dimming

Table 7 Percentage of Max. LED Current vs. DC Voltage at Pin 3

| V_{en} / PWM | Percentage of max. LED current % | V_{en} / PWM | Percentage of max. LED current % |
|----------------|----------------------------------|----------------|----------------------------------|
| < 0.3 | 0 | 1.9 | 75 |
| 0.8 | 10 | 2.2 | 90 |
| 1.0 | 25 | > 2.5 | 100 |
| 1.4 | 50 | | |

Analog voltage dimming characteristics with different Rsense resistors

The maximum LED current is set by R_{sense} . The three different graphs show the behaviour of the analog dimming. Maximum LED current will be achieved at approx. 2.3 Volts in every case.

L = 100 μ H

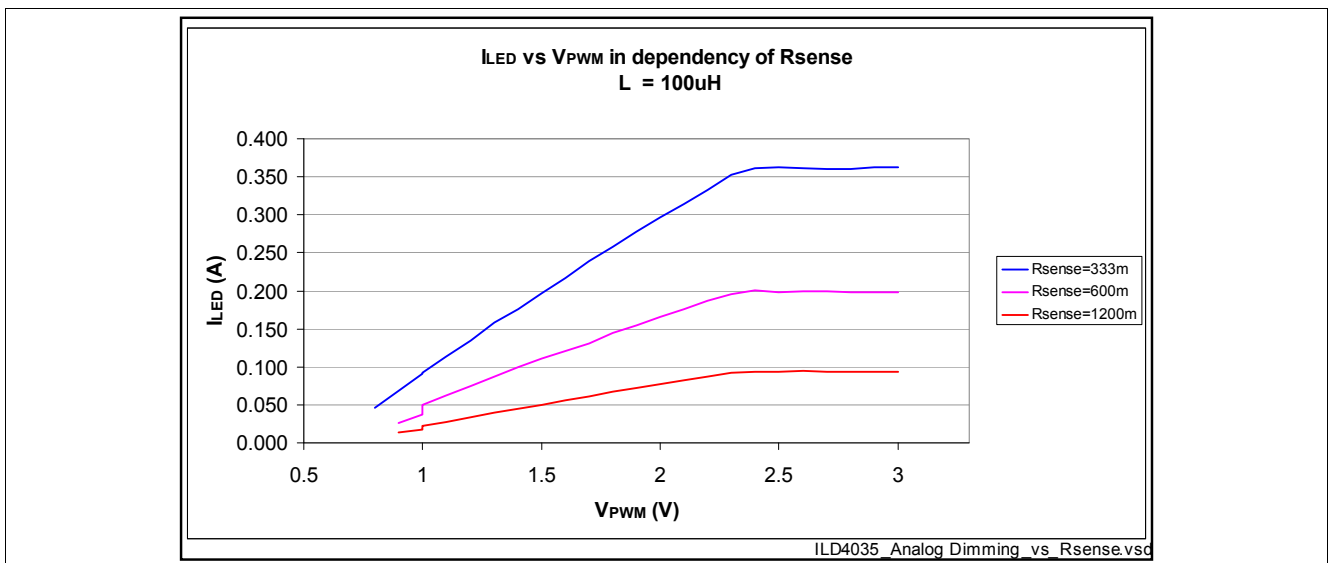


Figure 6 ILD4035; Analog Voltage Dimming with Different Rsense

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 2.6 V or higher. The period of this PWM signal should be higher than 200 μ s. For the default demo board circuit, a dimming frequency less than 300 Hz 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.

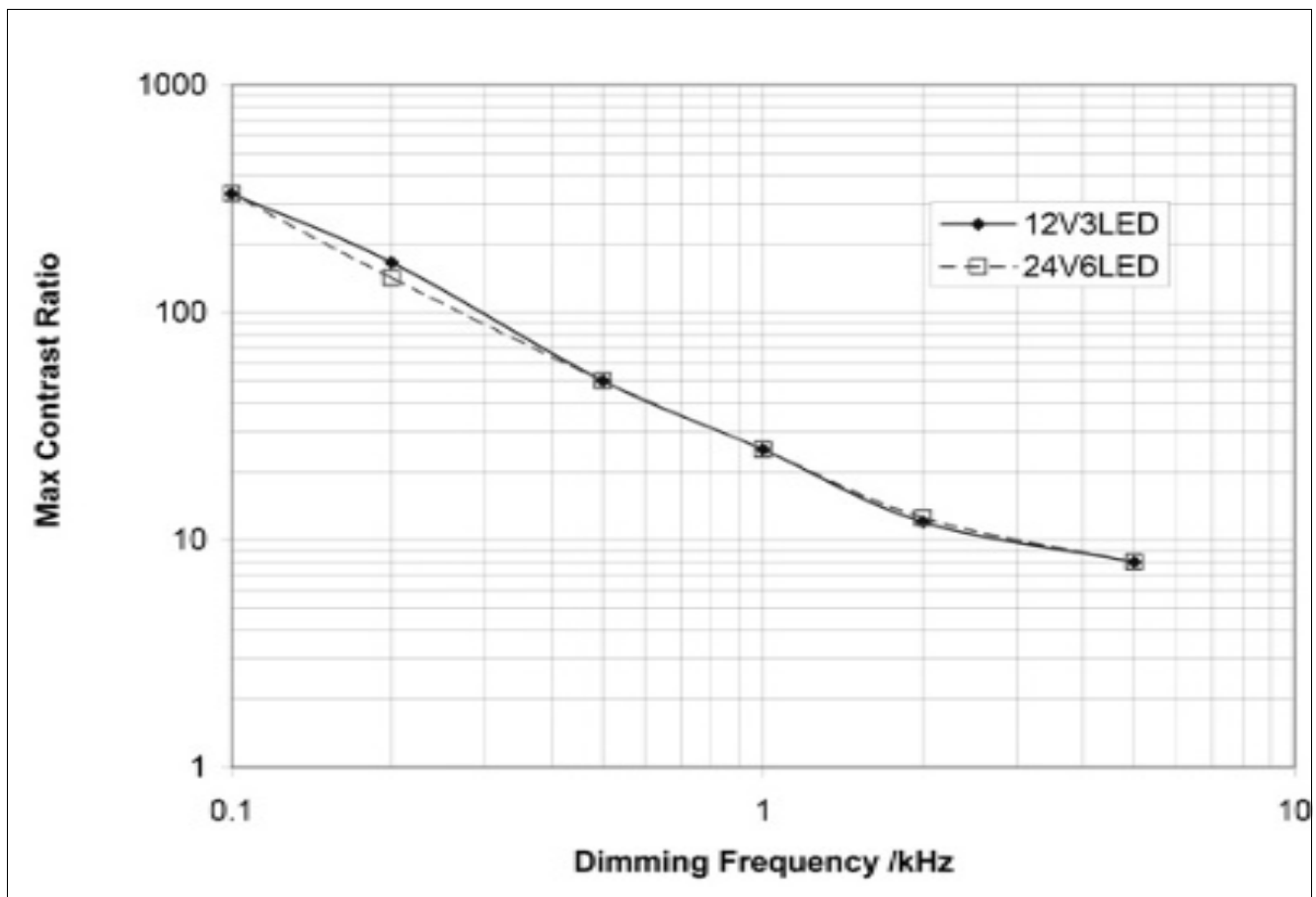


Figure 7 ILD4035; PWM Dimming

5.3 Temperature Characteristics of the ILD4035 Demo Board

The two charts below are related by the same supply voltage, V_s and number of LEDs.

For the same V_s and number of LEDs, the "solder point temperature at the ground pin" T_s and the "ambient temperature" T_A are measured at the same time.

Each curve on the charts defines two areas of operation.

The area below each curve defines normal operation.

The area above each curve defines the triggering of internal thermal shutdown.

When thermal shutdown is triggered, the LEDs start to flicker.

Conditions of Measurements

ILD4035 LED-Less board with

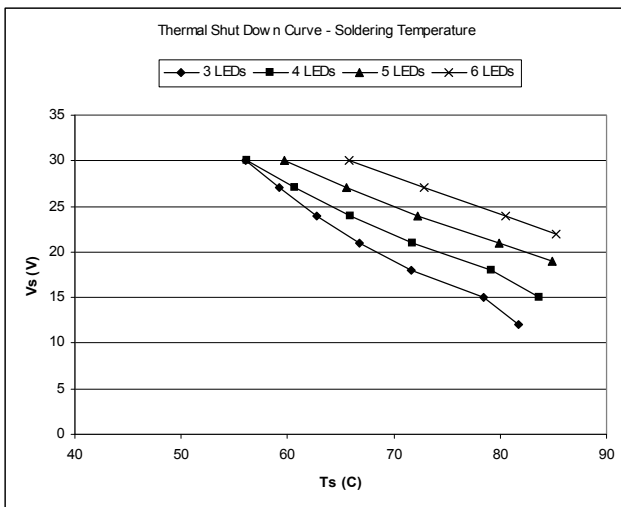
BAS3010A Schottky Diode,

Inductance=100uH (EPCOS 6x6mm)

R_{sense} =0.333 Ohm

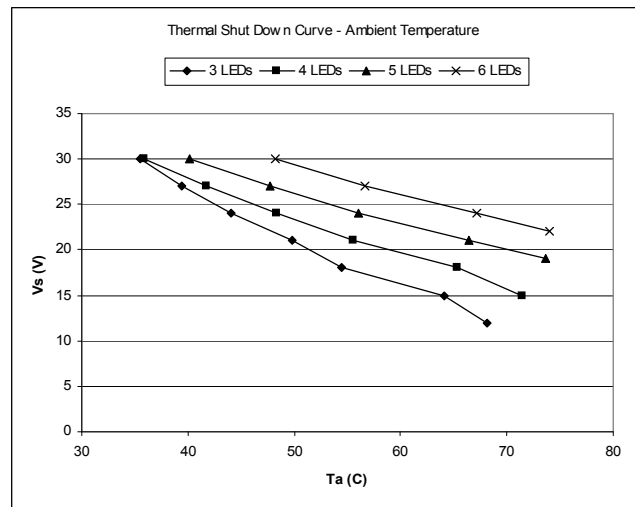
Environment = Inside chamber with force convection air flow.

Thermal shutdown vs. solder temperature T_s



ILD4035_TSD_over_Ts.vsd

Thermal shutdown vs. ambient temperature T_A



ILD4035_TSD_over_Ta.vsd

5.4 AC- Parameter

Typical operating conditions

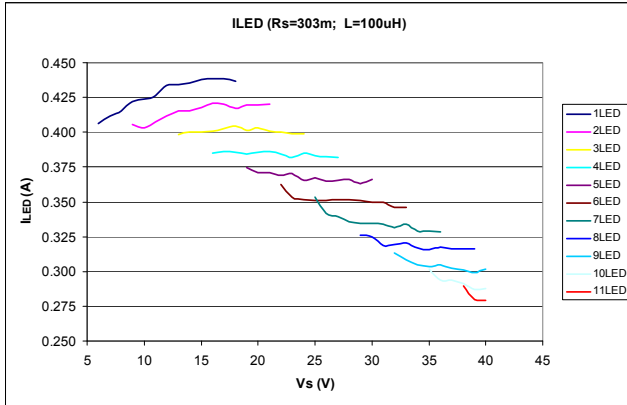
All parameters have been measured at $T_{amb} = 25\text{ °C}$, unless otherwise specified.

ILD4035 IC has been measured in test bench with undefined high thermal resistance

This is valid for all diagramed AC- Parameters.

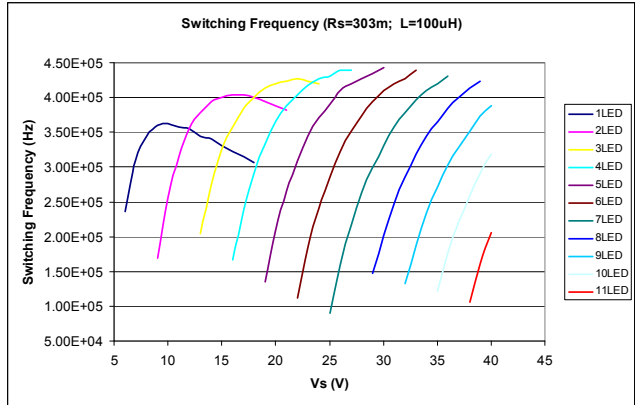
$R_{sense} = 303 \text{ m}\Omega$, $L = 100 \text{ }\mu\text{H}$
 $V_s = 24 \text{ V}$, 6 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



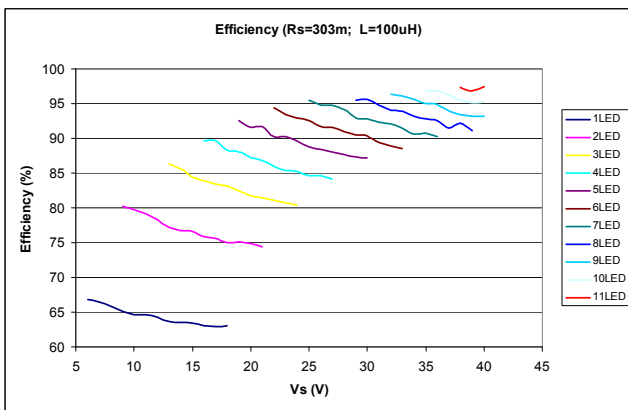
ILD4035_ILED_303m_100u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



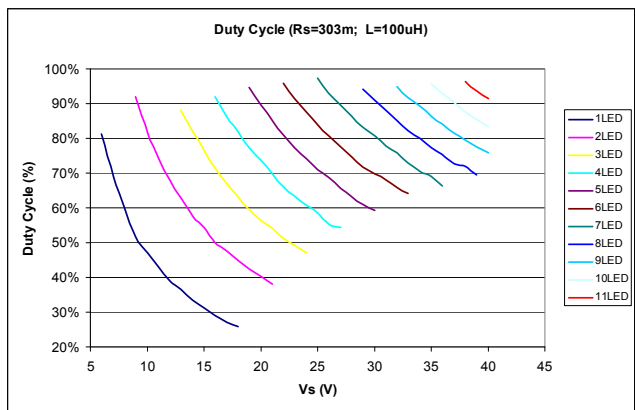
ILD4035_Switching_Frequency_303m_100u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_303m_100u.vsd

Duty Cycle vs. V_{Supply} and number of LEDs

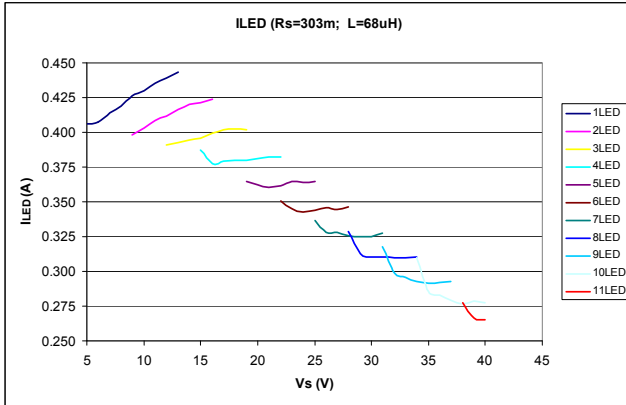


ILD4035_Duty_Cycle_303m_100u.vsd

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

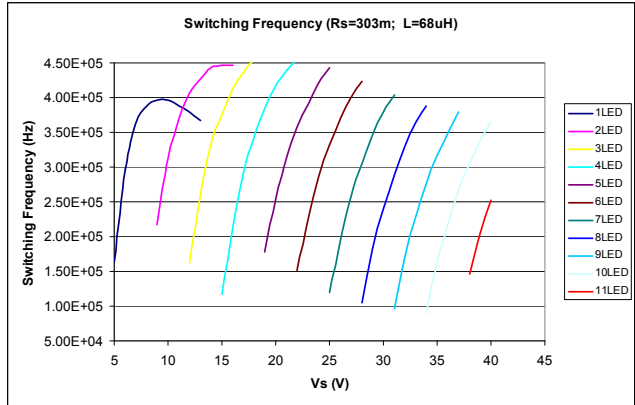
$V_s = 24 \text{ V}$, 6 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



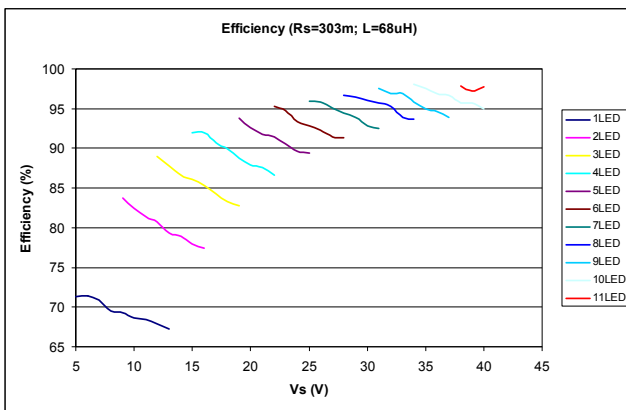
ILD4035_ILED_303m_68u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



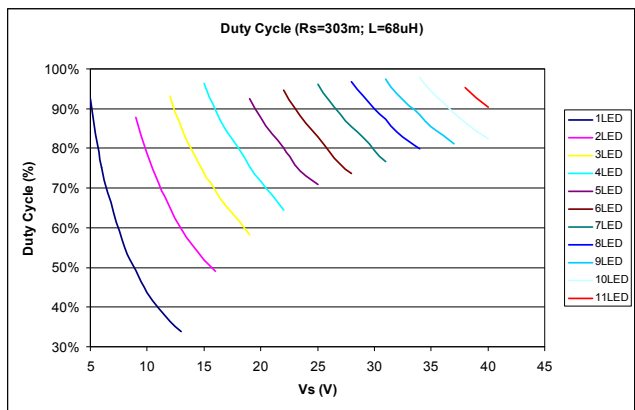
ILD4035_Switching_Frequency_303m_68u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_303m_68u.vsd

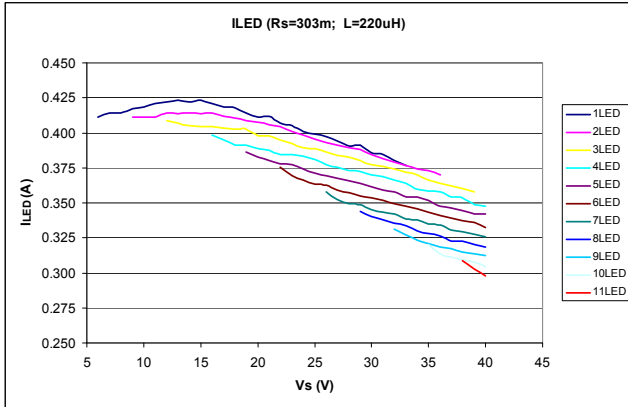
Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_303m_68u.vsd

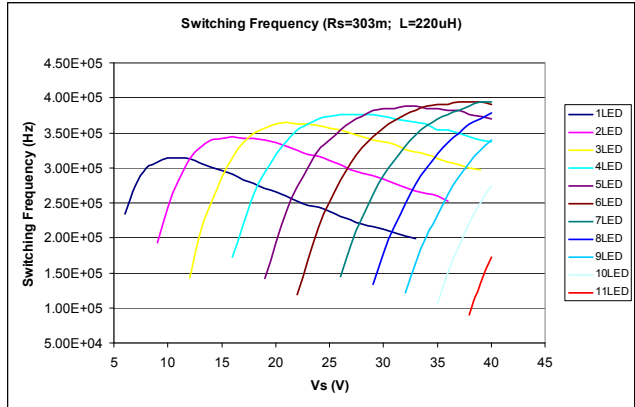
$R_{sense} = 303 \text{ m}\Omega$, $L = 220 \text{ }\mu\text{H}$
 $V_s = 24 \text{ V}$, 6 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



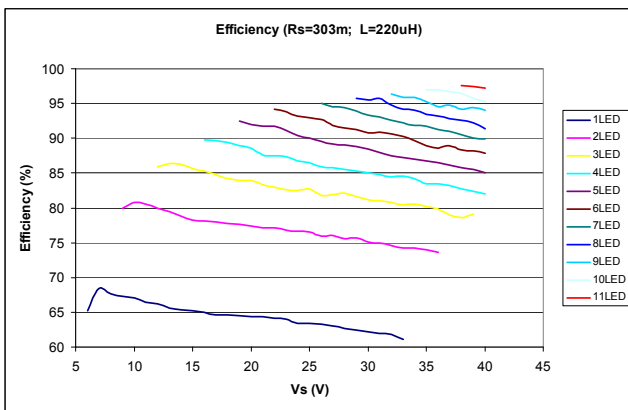
ILD4035_ILED_303m_220u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



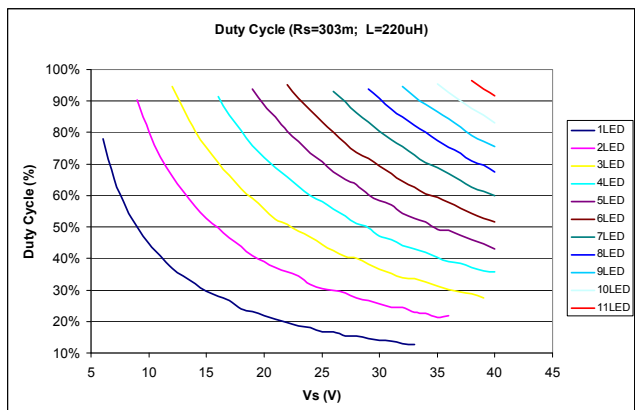
ILD4035_Switching_Frequency_303m_220u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_303m_220u.vsd

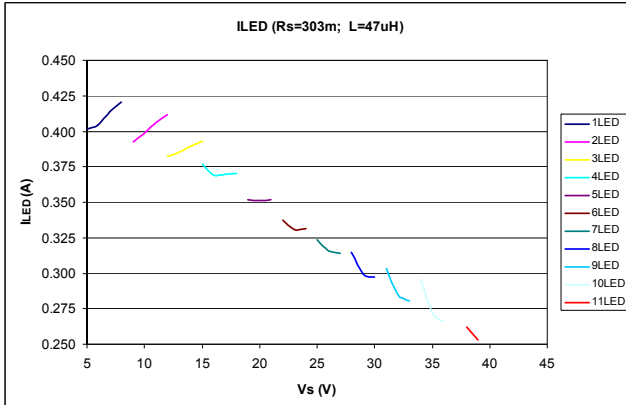
Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_303m_220u.vsd

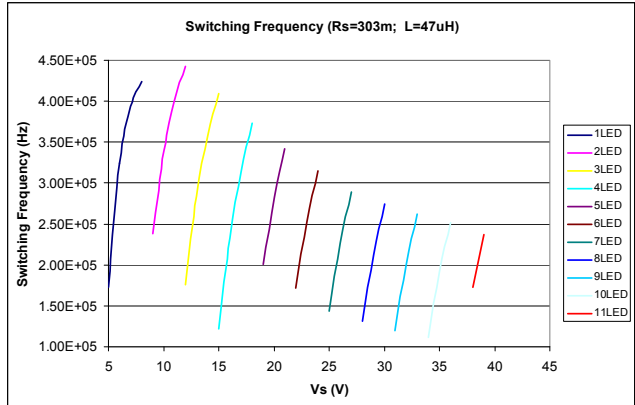
$R_{\text{sense}} = 303 \text{ m}\Omega$, $L = 47 \text{ }\mu\text{H}$
 $V_s = 24 \text{ V}$, 6 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



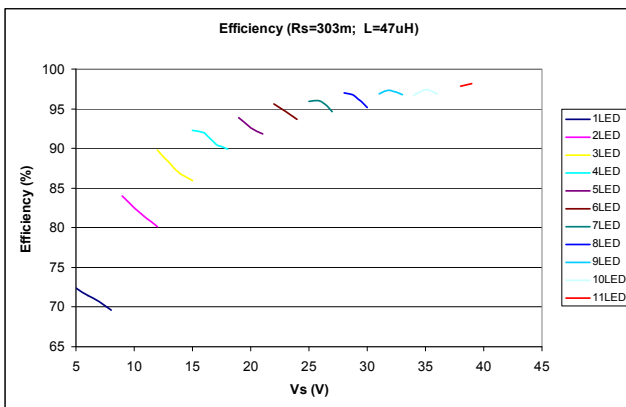
ILD4035_ILED_303m_47u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



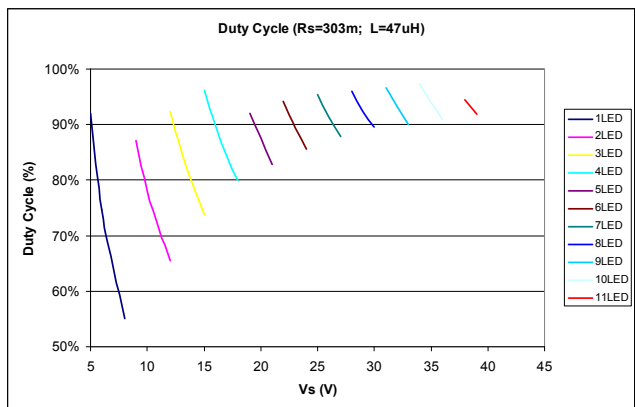
ILD4035_Switching_Frequency_303m_47u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_303m_47u.vsd

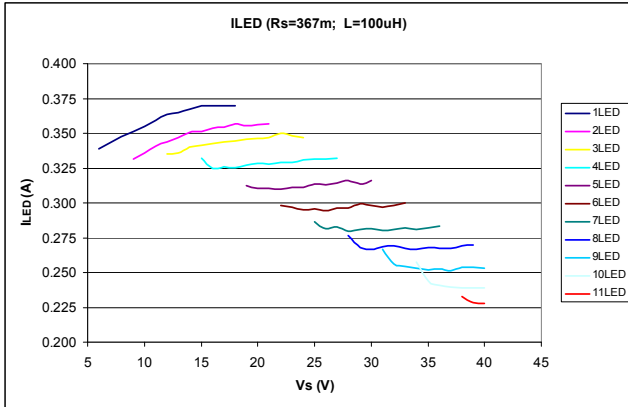
Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_303m_47u.vsd

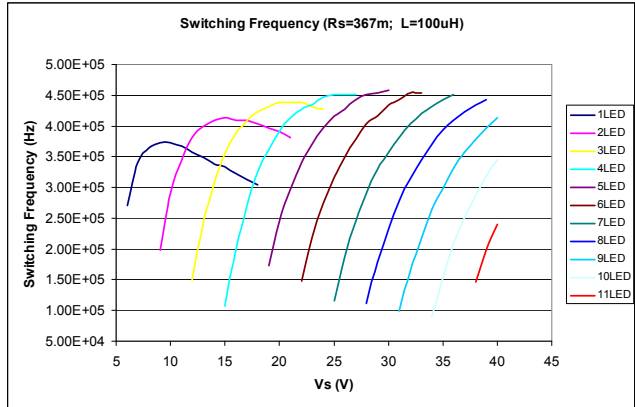
$R_{sense} = 367 \text{ m}\Omega$, $L = 100 \text{ }\mu\text{H}$
 $V_s = 24 \text{ V}$, 6 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



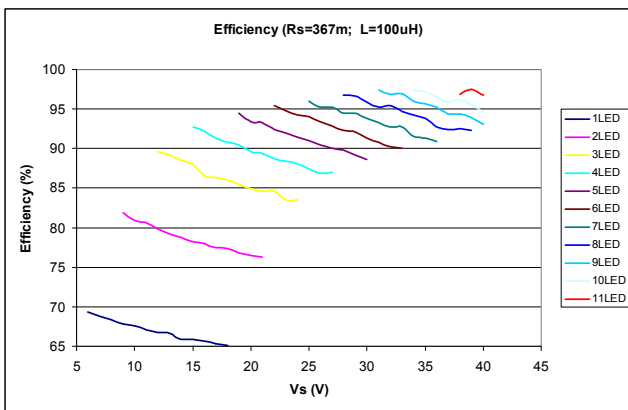
ILD4035_ILED_367m_100u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



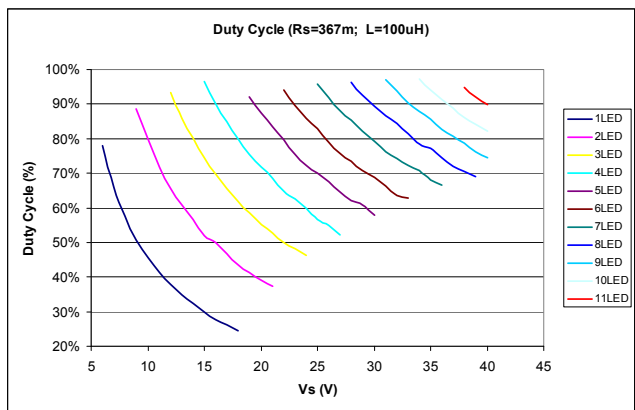
ILD4035_Switching_Frequency_367m_100u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_367m_100u.vsd

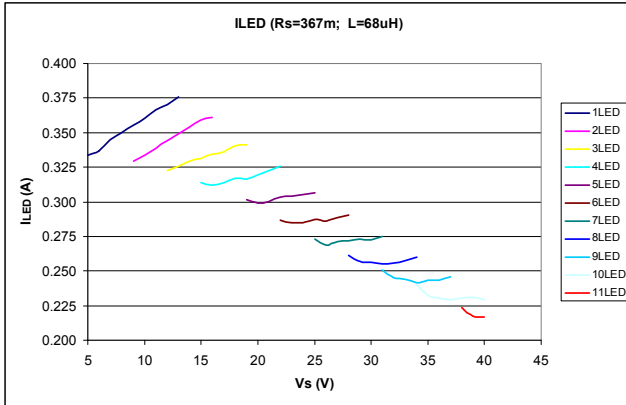
Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_367m_100u.vsd

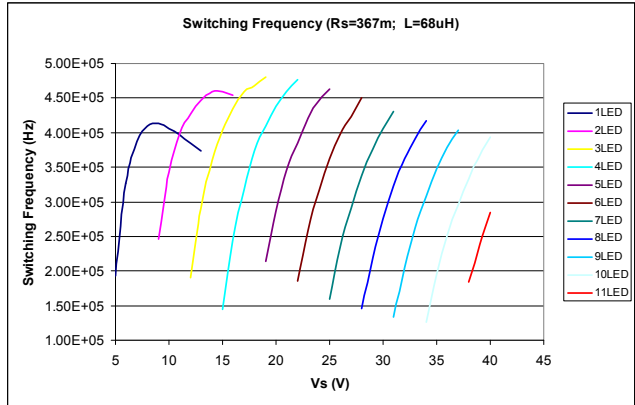
$R_{sense} = 367 \text{ m}\Omega$, $L = 68 \text{ }\mu\text{H}$
 $V_s = 12 \text{ V}$, 3 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



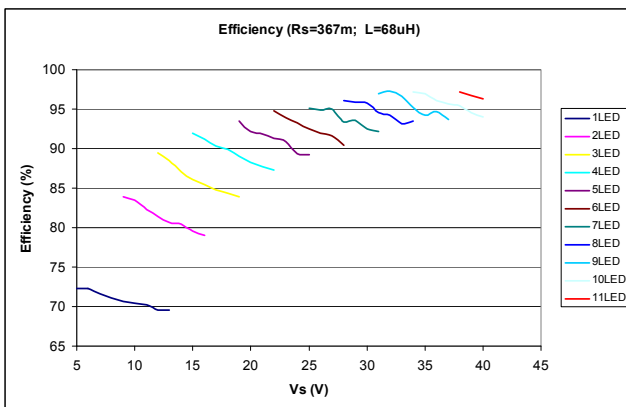
ILD4035_ILED_367m_68u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



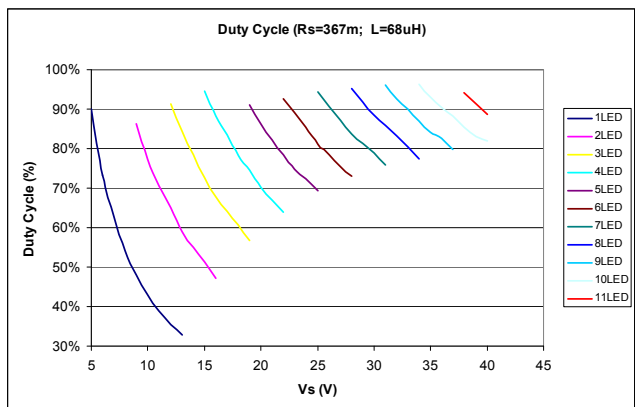
ILD4035_Switching_Frequency_367m_68u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_367m_68u.vsd

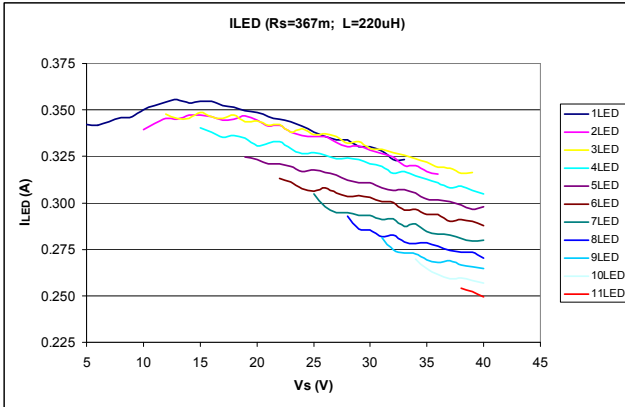
Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_367m_68u.vsd

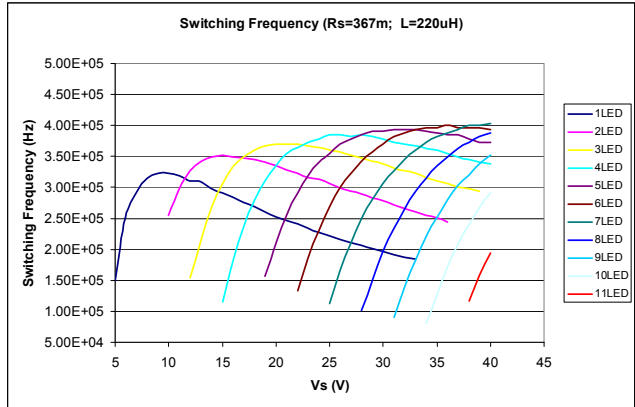
$R_{\text{sense}} = 367 \text{ m}\Omega$, $L = 220 \text{ }\mu\text{H}$
 $V_s = 12 \text{ V}$, 3 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



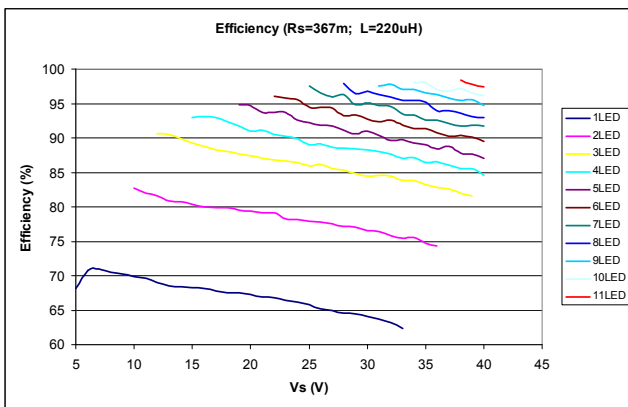
ILD4035_I_LED_367m_220u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



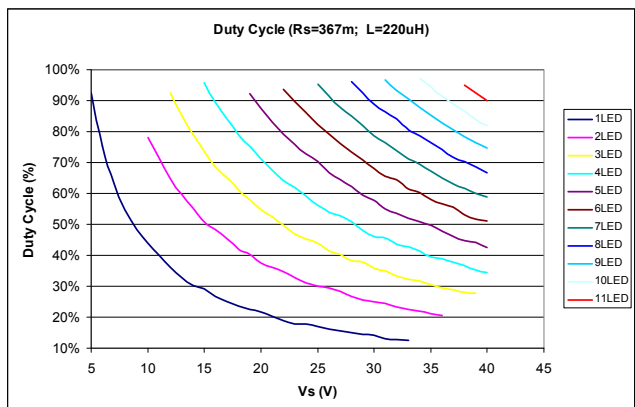
ILD4035_Switching_Frequency_367m_220u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_367m_220u.vsd

Duty Cycle vs. V_{Supply} and number of LEDs

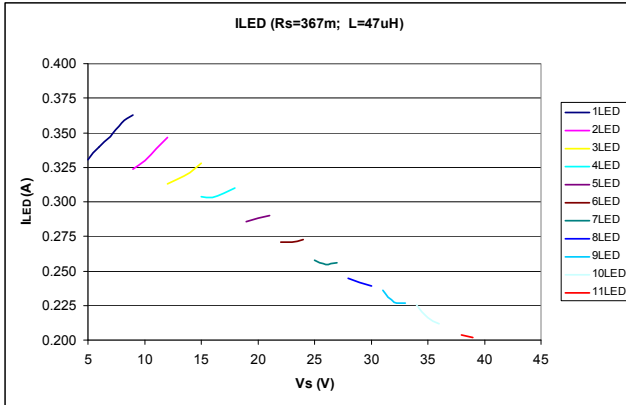


ILD4035_Duty_Cycle_367m_220u.vsd

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

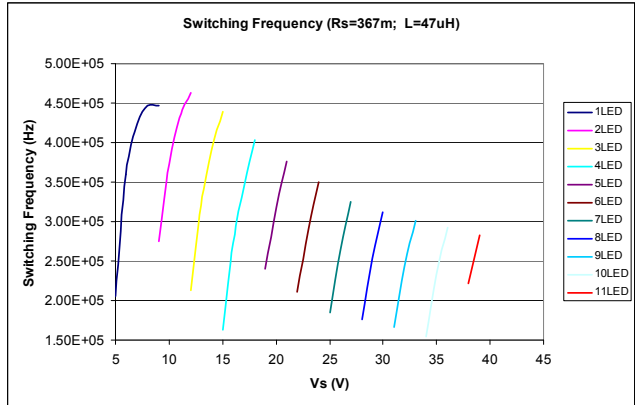
$V_s = 12 \text{ V}$, 3 LED with typ. $V_F = 3 \text{ V}$

I_{LED} vs. V_{Supply} and number of LEDs



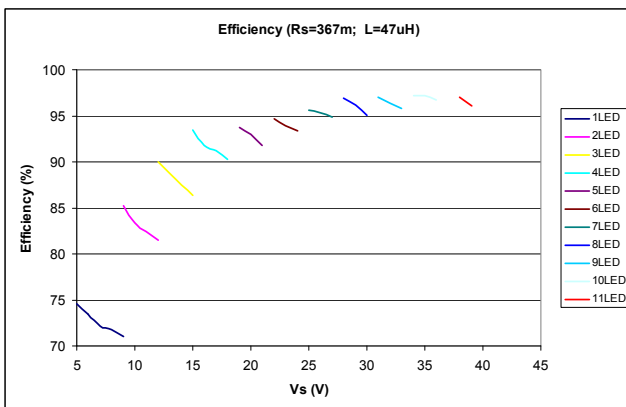
ILD4035_ILED_367m_47u.vsd

F_{Switch} vs. V_{Supply} and number of LEDs



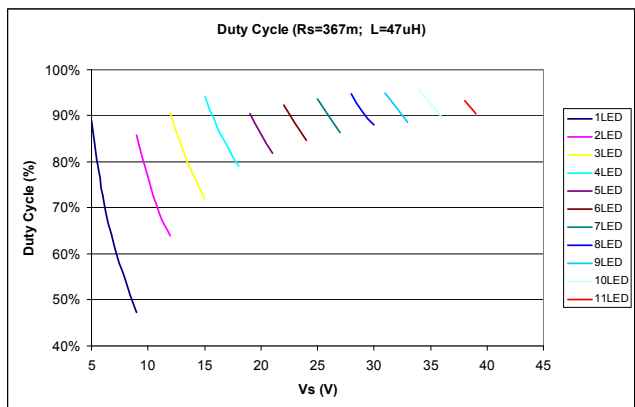
ILD4035_Switching_Frequency_367m_47u.vsd

Efficiency vs. V_{Supply} and number of LEDs



ILD4035_Efficiency_367m_47u.vsd

Duty Cycle vs. V_{Supply} and number of LEDs



ILD4035_Duty_Cycle_367m_47u.vsd

6 Application Circuit

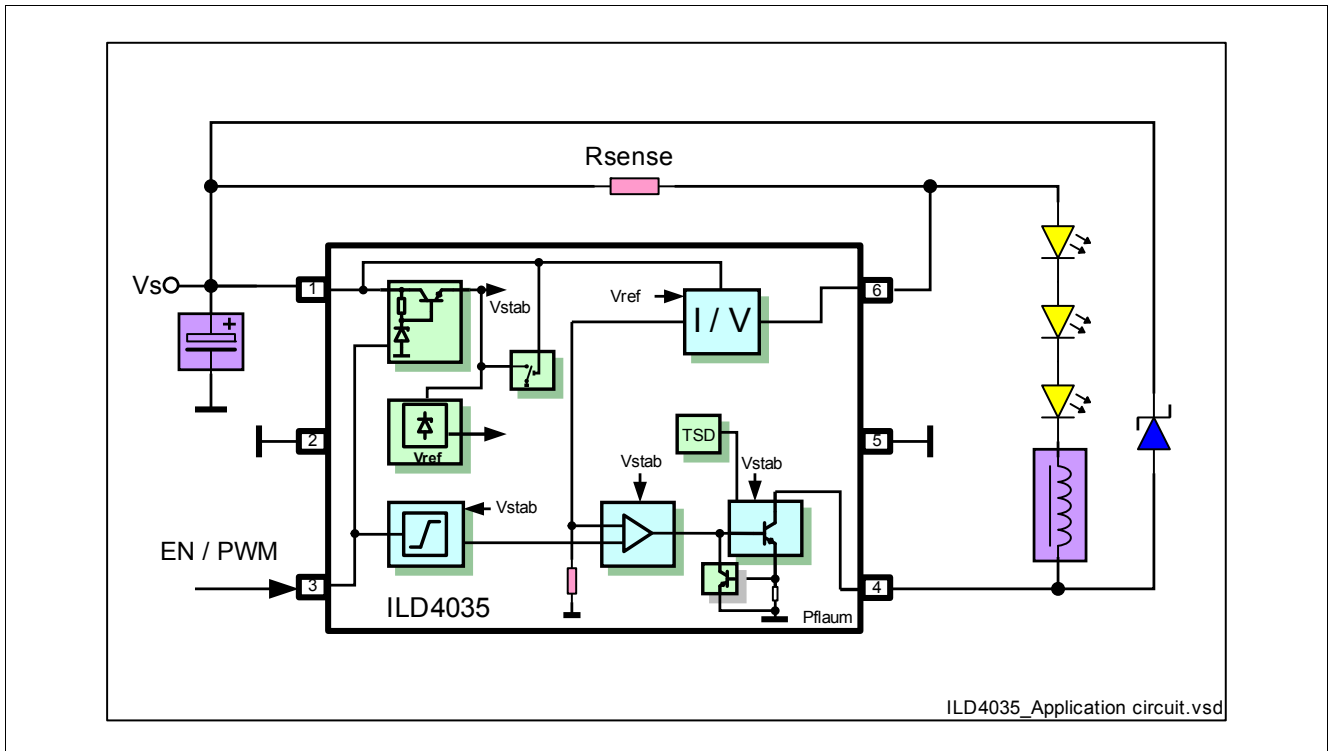


Figure 8 ILD4035; Application Circuit

7 Evaluation Board

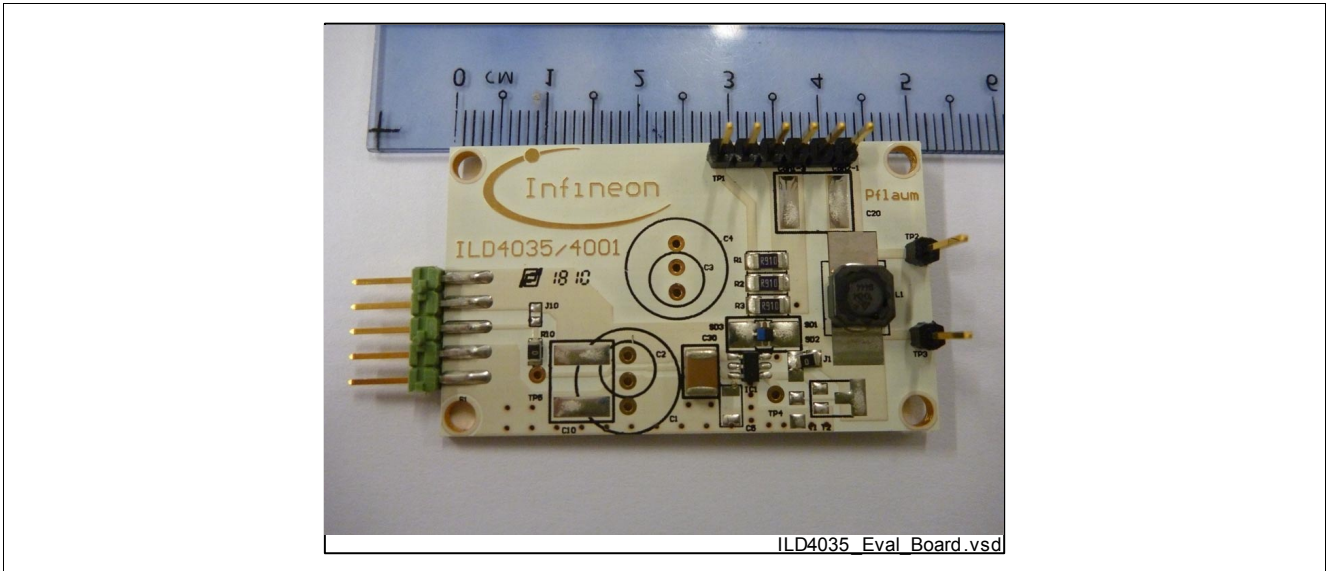


Figure 9 ILD4035; Evaluation- Board

8 Package Information SC74-6-4

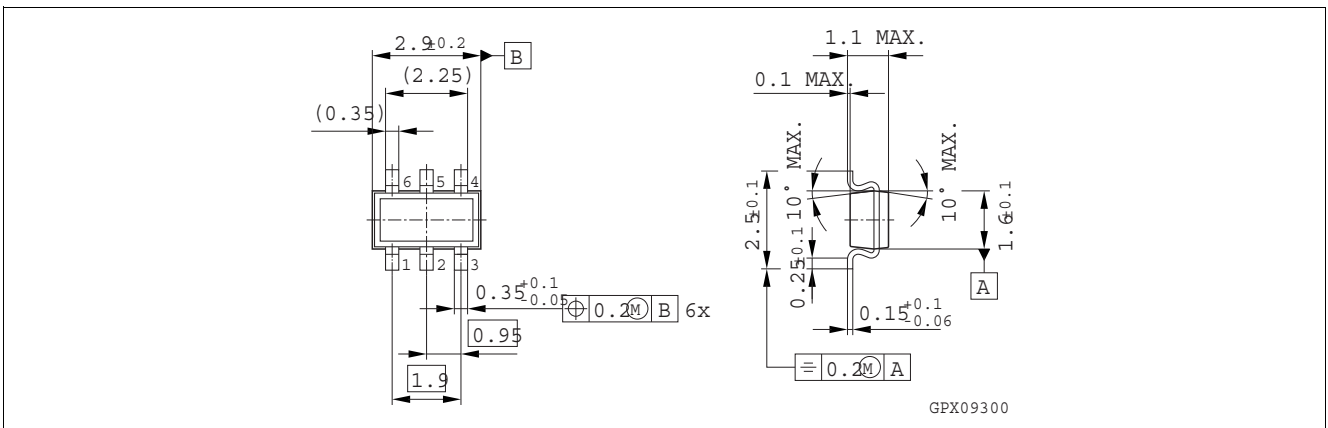


Figure 10 Package Outline

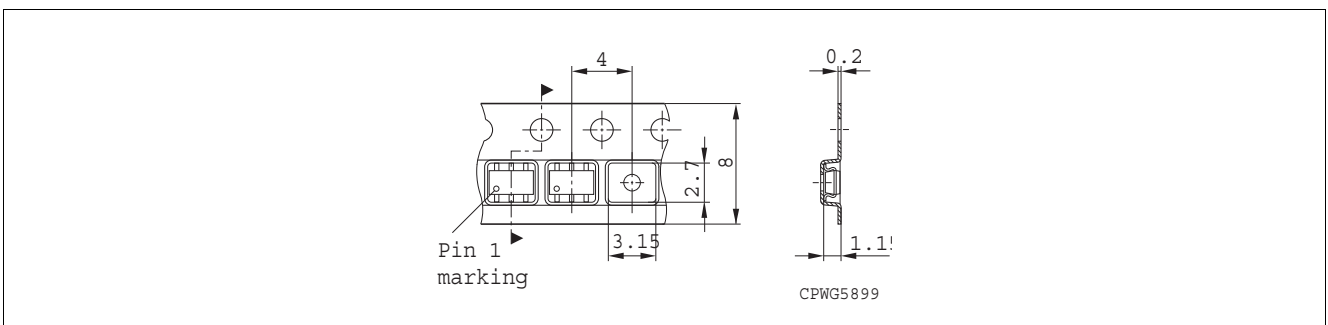


Figure 11 Tape Dimensions

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