

## Single-Stage Power Factor Corrected Off-Line Switching Regulator ICs

## Features and Benefits

- Integrated on-time control circuit (it realizes high power factor by average current control)
- Integrated startup circuit (no external startup circuit necessary)
- Integrated soft-start circuit (reduces power stress during start-up on the incorporated power MOSFET and output rectifier)
- Integrated bias assist circuit (improves startup performance, suppresses VCC voltage droop during operation, and allows use of low-rated ceramic capacitor on VCC pin)
- Integrated Leading Edge Blanking (LEB) circuit
- Integrated maximum on-time limit circuit
- Protection features:
  - Overcurrent protection (OCP): pulse-by-pulse
  - Overvoltage protection (OVP): latched shutdown
  - Overload protection (OLP): latched shutdown
  - Thermal shutdown (TSD): latched shutdown

**Package: 8-pin DIP**



*Not to scale*

### Description

The LC5540LD series is the power IC for the isolated type LED driver which has an incorporated power MOSFET, designed for input capacitorless applications, and making it possible for systems to comply with the harmonics standard (IEC61000-3-2 class C), even during light load condition. The controller adapts the average current control method for realizing high power factors, and the quasi-resonant topology contributes to high efficiency and low EMI noise. The series is housed in DIP8 packages.

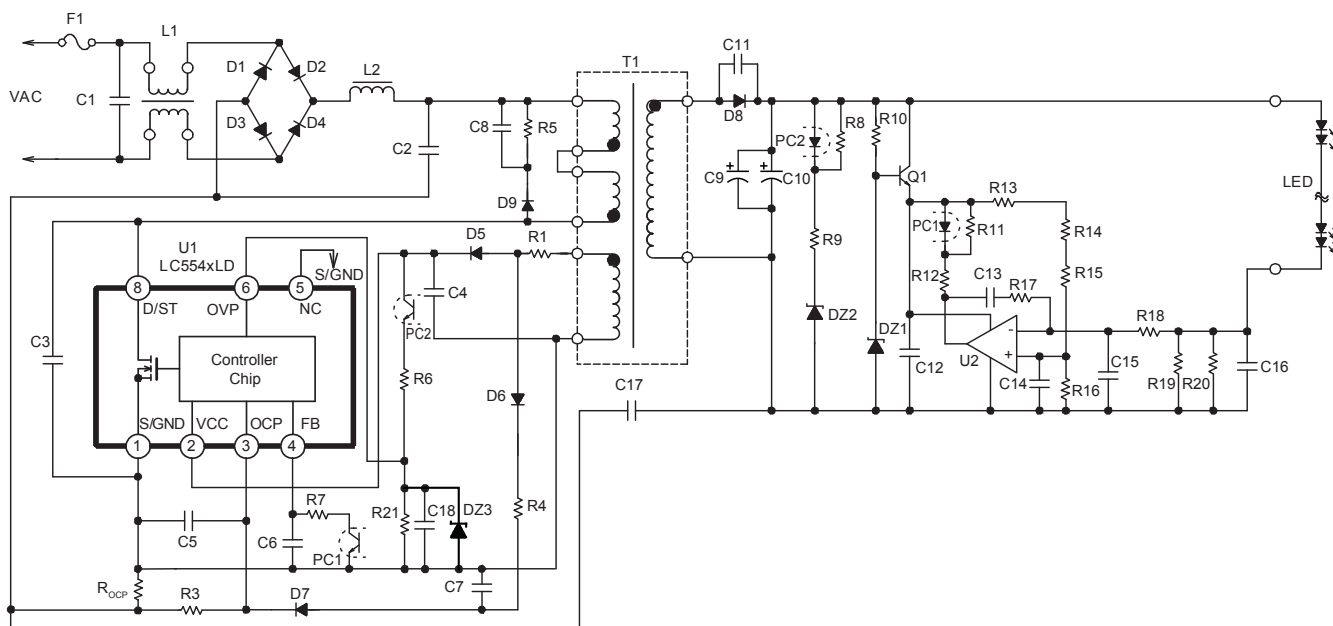
The rich set of protection features helps to realize low component counts, and high performance-to-cost power supply.

The incorporated MOSFET has a  $V_{DSS(min)}$  rating from 650 V (LC5545LD and LC5546LD) to 800 V (LC5548LD). The  $R_{DS(on)(max)}$  is 1.9  $\Omega$  (LC5546LD) to 3.95  $\Omega$  (LC5545LD). It is capable of a maximum output power of 20 W on 230 VAC supply to 16 W on universal input supply (85 to 265 VAC) (LC5546LD) based on the thermal rating. Note that the maximum output power can be up to 120% to 140% of this value. However, it may be limited in applications with low output voltage or short duty cycle.

## Applications

- LED lighting fixtures
- LED light bulbs

## Typical Application



## Selection Guide

| Part Number | MOSFET $V_{DS(s)}(\min)$ (V) | $R_{DS(on)}$ (max) ( $\Omega$ ) | PWM Operation Frequency, $f_{osc}(\text{typ})$ (kHz) | On-Time $t_{ON(MAX)}(\text{typ})$ ( $\mu\text{s}$ ) | $P_{OUT}^*$ (W) |               |
|-------------|------------------------------|---------------------------------|------------------------------------------------------|-----------------------------------------------------|-----------------|---------------|
|             |                              |                                 |                                                      |                                                     | 230 VAC         | 85 to 265 VAC |
| LC5545LD    | 650                          | 3.95                            | 72                                                   | 9.3                                                 | 13              | 10            |
| LC5546LD    |                              | 1.9                             | 60                                                   | 11.2                                                | 20              | 16            |
| LC5548LD    | 800                          | 3.5                             | 72                                                   | 9.3                                                 | 13              | 10            |

\*Based on the thermal rating; the allowable maximum output power can be up to 120% to 140% of this value. However, maximum output power may be limited in such an application with low output voltage or short duty cycle.

The polarity value for current specifies a sink as "+," and a source as "–," referencing the IC.

Absolute Maximum Ratings Unless specifically noted,  $T_A$  is 25°C

| Characteristic                                     | Symbol      | Notes                          |                                            | Pins  | Rating      | Unit |
|----------------------------------------------------|-------------|--------------------------------|--------------------------------------------|-------|-------------|------|
| Drain Current <sup>1</sup>                         | $I_{DPeak}$ | LC5545LD                       | Single pulse                               | 8 – 1 | 2.5         | A    |
|                                                    |             | LC5546LD                       |                                            |       | 4.0         | A    |
|                                                    |             | LC5548LD                       |                                            |       | 2.6         | A    |
| Single Pulse Avalanche Energy <sup>2</sup>         | $E_{AS}$    | LC5545LD                       | $I_{LPeak} = 2.0A, V_{DD} = 99V, L = 20mH$ | 8 – 1 | 47          | mJ   |
|                                                    |             | LC5546LD                       | $I_{LPeak} = 2.7A, V_{DD} = 99V, L = 20mH$ |       | 86          | mJ   |
|                                                    |             | LC5548LD                       | $I_{LPeak} = 2.3A, V_{DD} = 99V, L = 20mH$ |       | 56          | mJ   |
| Control Part Input Voltage                         | $V_{CC}$    |                                |                                            | 2 – 1 | 35          | V    |
| OCP Pin Voltage                                    | $V_{OCP}$   |                                |                                            | 3 – 1 | –2.0 to 5.0 | V    |
| FB Pin Voltage                                     | $V_{FB}$    |                                |                                            | 4 – 1 | –0.3 to 7.0 | V    |
| OVP Pin Voltage                                    | $V_{OVP}$   |                                |                                            | 6 – 1 | –0.3 to 5.0 | V    |
| Allowable Power Dissipation of MOSFET <sup>3</sup> | $P_{D1}$    | Mounted on a 15 mm × 15 mm PCB |                                            | 8 – 1 | 0.97        | W    |
| Operating Ambient Temperature                      | $T_{OP}$    |                                |                                            | —     | –55 to 125  | °C   |
| Storage Temperature                                | $T_{stg}$   |                                |                                            | —     | –55 to 125  | °C   |
| Channel Temperature                                | $T_{ch}$    |                                |                                            | —     | 150         | °C   |

<sup>1</sup>Refer to MOSFET Safe Operating Area Curve.

<sup>2</sup>Refer to MOSFET Avalanche Energy Derating Coefficient Curve.

<sup>3</sup>Refer to MOSFET Temperature versus Power Dissipation Curve.

**Electrical Characteristics of Control Part**  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 20\text{ V}$ , unless otherwise specified

| Characteristic                                         | Symbol            | Test Conditions        | Pins  | Min.  | Typ.  | Max.  | Unit             |
|--------------------------------------------------------|-------------------|------------------------|-------|-------|-------|-------|------------------|
| <b>Power Supply Startup Operation</b>                  |                   |                        |       |       |       |       |                  |
| Operation Start Voltage                                | $V_{CC(ON)}$      |                        | 2 – 1 | 13.8  | 15.1  | 17.3  | V                |
| Operation Stop Voltage*                                | $V_{CC(OFF)}$     |                        | 2 – 1 | 8.4   | 9.4   | 10.7  | V                |
| Circuit Current in Operation                           | $I_{CC(ON)}$      |                        | 2 – 1 | –     | –     | 4.7   | mA               |
| Startup Circuit Operation Voltage                      | $V_{STARTUP}$     |                        | 8 – 1 | 18    | 21    | 24    | V                |
| Startup Current                                        | $I_{CC(STARTUP)}$ | $V_{CC} = 13\text{ V}$ | 2 – 1 | –8.5  | –4.0  | –1.5  | mA               |
| Startup Current Threshold Biasing Voltage*             | $V_{CC(BIAS)}$    |                        | 2 – 1 | 9.5   | 11.0  | 12.5  | V                |
| <b>Normal Operation</b>                                |                   |                        |       |       |       |       |                  |
| PWM Operation Frequency                                | $f_{OSC}$         | LC5545LD               | 8 – 1 | 60    | 72    | 84    | kHz              |
|                                                        |                   | LC5546LD               |       | 50    | 60    | 70    | kHz              |
|                                                        |                   | LC5548LD               |       | 60    | 72    | 84    | kHz              |
| Maximum On-Time                                        | $t_{ON(MAX)}$     | LC5545LD               | 8 – 1 | 8.0   | 9.3   | 11.2  | $\mu\text{s}$    |
|                                                        |                   | LC5546LD               |       | 9.0   | 11.2  | 13.4  | $\mu\text{s}$    |
|                                                        |                   | LC5548LD               |       | 8.0   | 9.3   | 11.2  | $\mu\text{s}$    |
| FB Pin Control Minimum Voltage                         | $V_{FB(MIN)}$     |                        | 4 – 1 | 0.50  | 0.85  | 1.20  | V                |
| Maximum Feedback Current                               | $I_{FB(MAX)}$     |                        | 4 – 1 | –40   | –25   | –10   | $\mu\text{A}$    |
| Leading Edge Blanking Time                             | $t_{ON(LEB)}$     |                        | 3 – 1 | –     | 600   | –     | ns               |
| Quasi-Resonant Operation Threshold Voltage-1           | $V_{BD(TH1)}$     |                        | 3 – 1 | 0.14  | 0.24  | 0.34  | V                |
| Quasi-Resonant Operation Threshold Voltage-2           | $V_{BD(TH2)}$     |                        | 3 – 1 | 0.11  | 0.16  | 0.21  | V                |
| <b>Protection Operation</b>                            |                   |                        |       |       |       |       |                  |
| OCP Pin Overcurrent Protection (OCP) Threshold Voltage | $V_{OCP}$         |                        | 3 – 1 | –0.66 | –0.60 | –0.54 | V                |
| OCP Pin Source Current                                 | $I_{OCP}$         |                        | 3 – 1 | –120  | –40   | –10   | $\mu\text{A}$    |
| OCP Pin Overvoltage Protection (OVP) Operation Voltage | $V_{BD(OVP)}$     |                        | 3 – 1 | 2.2   | 2.6   | 3.0   | V                |
| Overload Protection (OLP) Threshold Voltage            | $V_{FB(OLP)}$     |                        | 4 – 1 | 4.1   | 4.5   | 4.9   | V                |
| OVP Pin OVP Threshold Voltage                          | $V_{OVP(OVP)}$    |                        | 6 – 1 | 1.6   | 2.0   | 2.4   | V                |
| VCC Pin OVP Threshold Voltage                          | $V_{CC(OVP)}$     |                        | 2 – 1 | 28.5  | 31.5  | 34.0  | V                |
| Thermal Shutdown Activating Temperature                | $T_{J(TSD)}$      |                        | –     | 135   | –     | –     | $^\circ\text{C}$ |

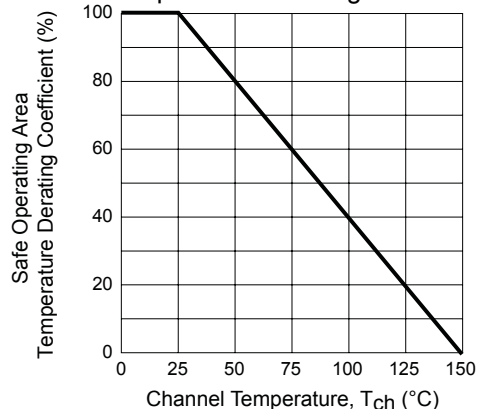
\* $V_{CC(BIAS)} > V_{CC(OFF)}$  always.

**ELECTRICAL CHARACTERISTICS of MOSFET**  $T_A = 25^\circ\text{C}$ , unless otherwise specified

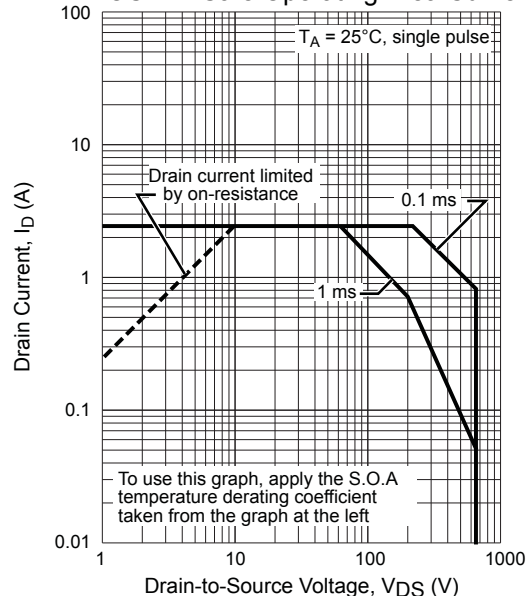
| Characteristic                    | Symbol            | Test Conditions |                                                                                                    | Pins  | Min. | Typ. | Max. | Unit               |
|-----------------------------------|-------------------|-----------------|----------------------------------------------------------------------------------------------------|-------|------|------|------|--------------------|
| Drain-to-Source Breakdown Voltage | $V_{DS}$          | LC5545LD        |                                                                                                    | 8 – 1 | 650  | —    | —    | V                  |
|                                   |                   | LC5546LD        |                                                                                                    |       | 650  | —    | —    | V                  |
|                                   |                   | LC5548LD        |                                                                                                    |       | 800  | —    | —    | V                  |
| Drain Leakage Current             | $I_{DSS}$         |                 |                                                                                                    | 8 – 1 | —    | —    | 300  | $\mu\text{A}$      |
| On-Resistance                     | $R_{DS(ON)}$      | LC5545LD        |                                                                                                    | 8 – 1 | —    | —    | 3.95 | $\Omega$           |
|                                   |                   | LC5546LD        |                                                                                                    |       | —    | —    | 1.9  | $\Omega$           |
|                                   |                   | LC5548LD        |                                                                                                    |       | —    | —    | 3.5  | $\Omega$           |
| Switching Time                    | $t_r$             | LC5545LD        |                                                                                                    | 8 – 1 | —    | —    | 250  | ns                 |
|                                   |                   | LC5546LD        |                                                                                                    |       | —    | —    | 400  | ns                 |
|                                   |                   | LC5548LD        |                                                                                                    |       | —    | —    | 400  | ns                 |
| Thermal Resistance                | $R_{\theta ch-c}$ | LC5545LD        | Between channel and case; case temperature, $T_C$ , measured at the center of the case top surface | —     | —    | —    | 42   | $^\circ\text{C/W}$ |
|                                   |                   | LC5546LD        |                                                                                                    |       | —    | —    | 35.5 | $^\circ\text{C/W}$ |
|                                   |                   | LC5548LD        |                                                                                                    |       | —    | —    | 40   | $^\circ\text{C/W}$ |

Characteristic Performance  
LC5545LD

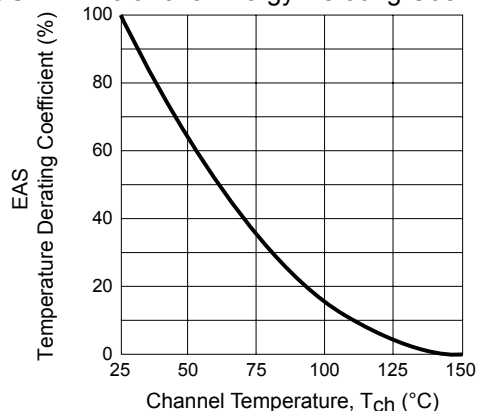
S. O. A. Temperature Derating Coefficient Curve



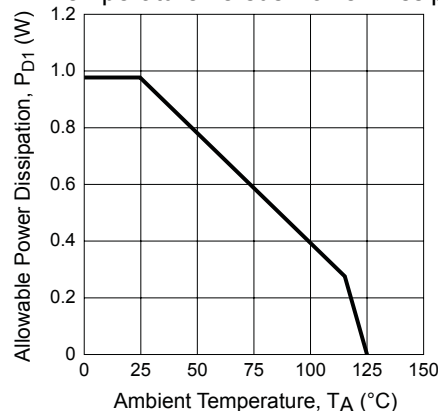
MOSFET Safe Operating Area Curve



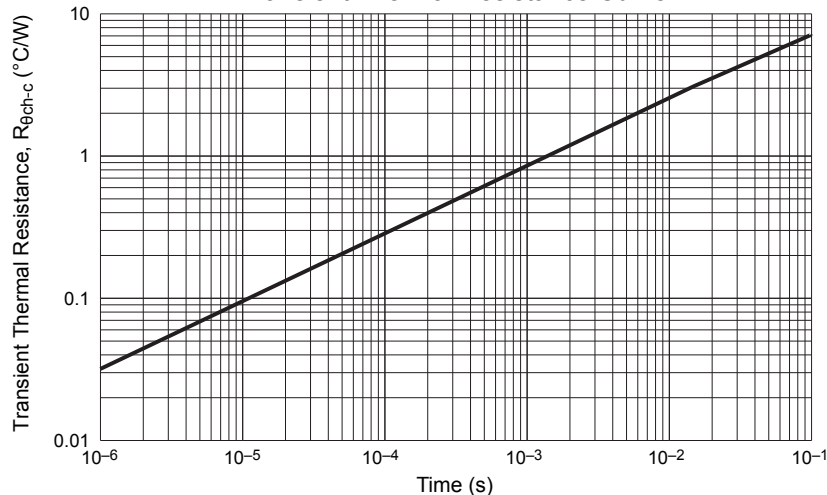
MOSFET Avalanche Energy Derating Coefficient Curve



MOSFET Temperature versus Power Dissipation Curve

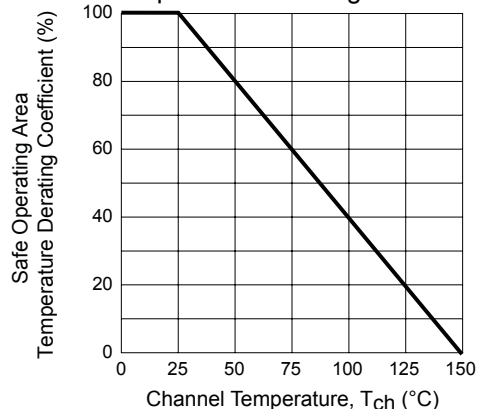


Transient Thermal Resistance Curve

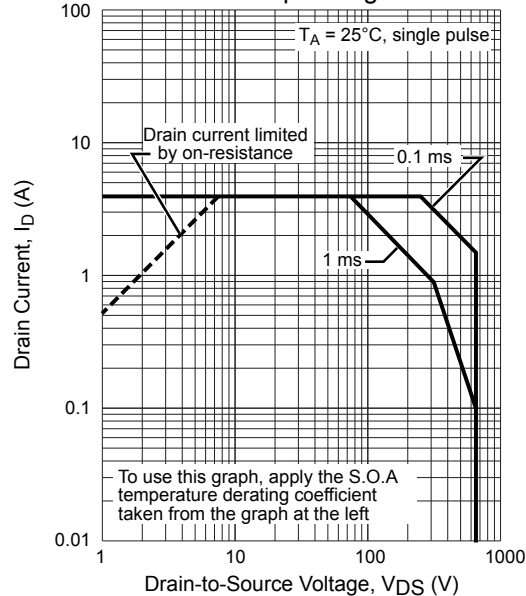


Characteristic Performance  
LC5546LD

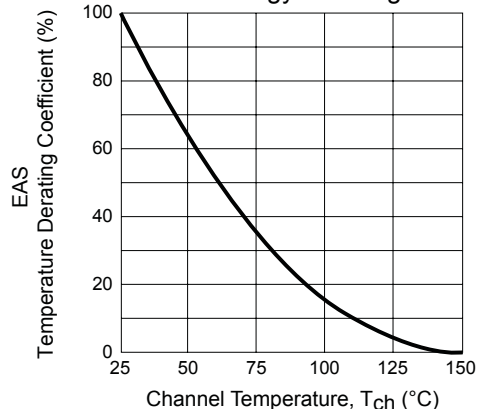
S. O. A. Temperature Derating Coefficient Curve



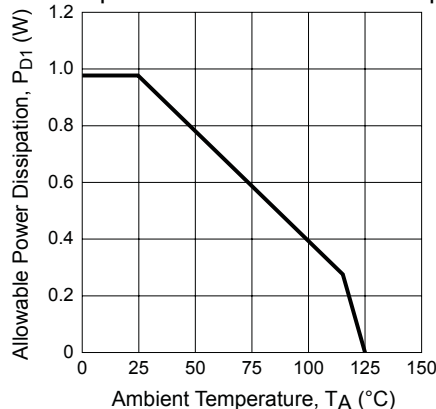
MOSFET Safe Operating Area Curve



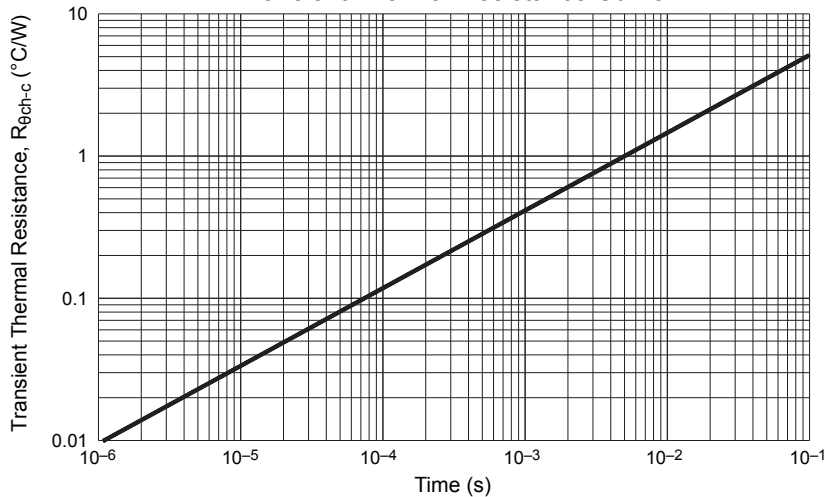
MOSFET Avalanche Energy Derating Coefficient Curve



MOSFET Temperature versus Power Dissipation Curve

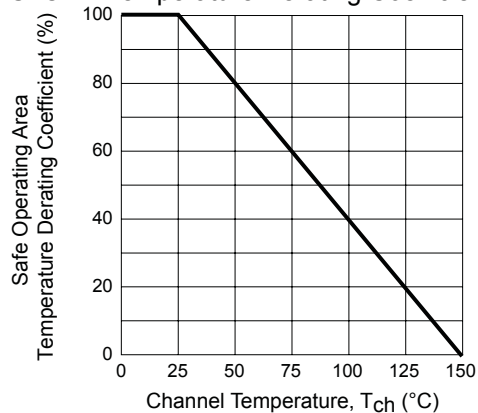


Transient Thermal Resistance Curve

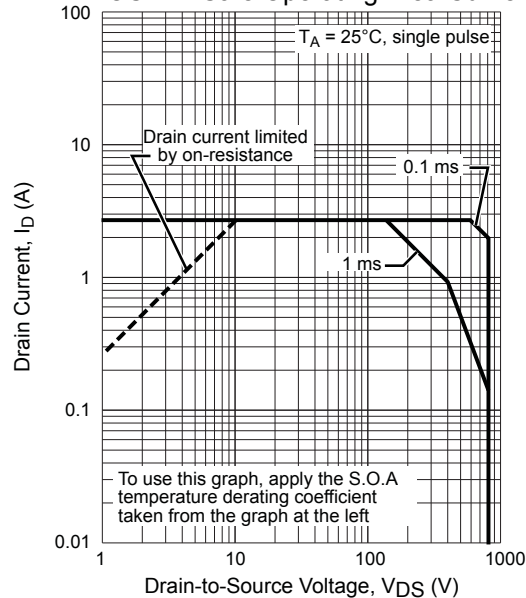


Characteristic Performance  
LC5548LD

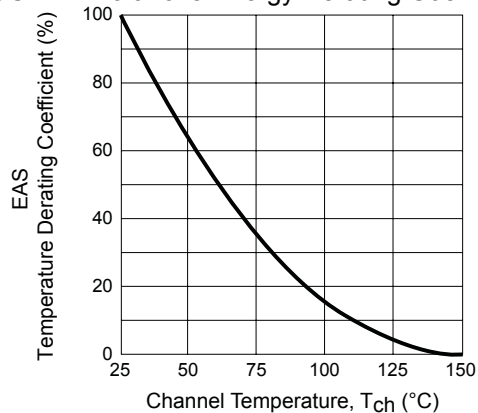
S. O. A. Temperature Derating Coefficient Curve



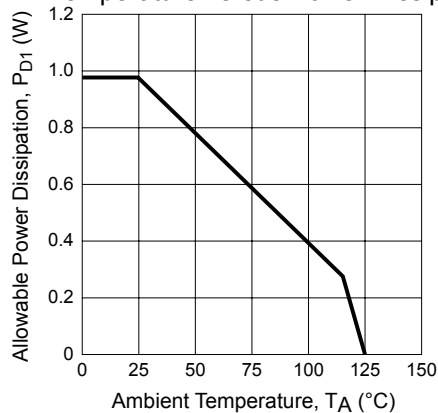
MOSFET Safe Operating Area Curve



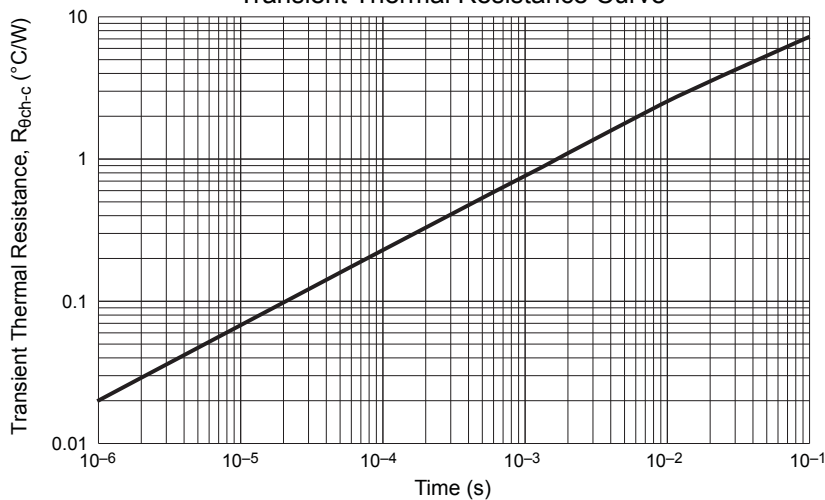
MOSFET Avalanche Energy Derating Coefficient Curve



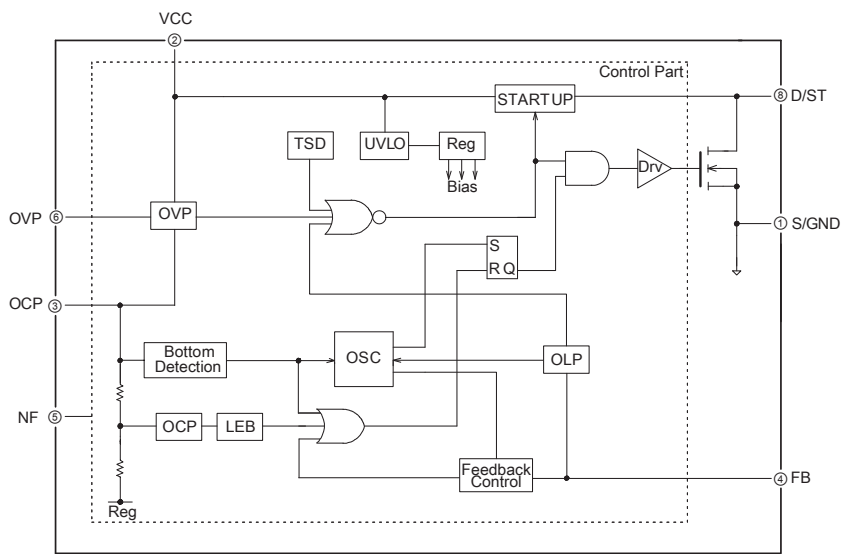
MOSFET Temperature versus Power Dissipation Curve



Transient Thermal Resistance Curve



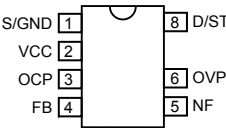
Functional Block Diagram



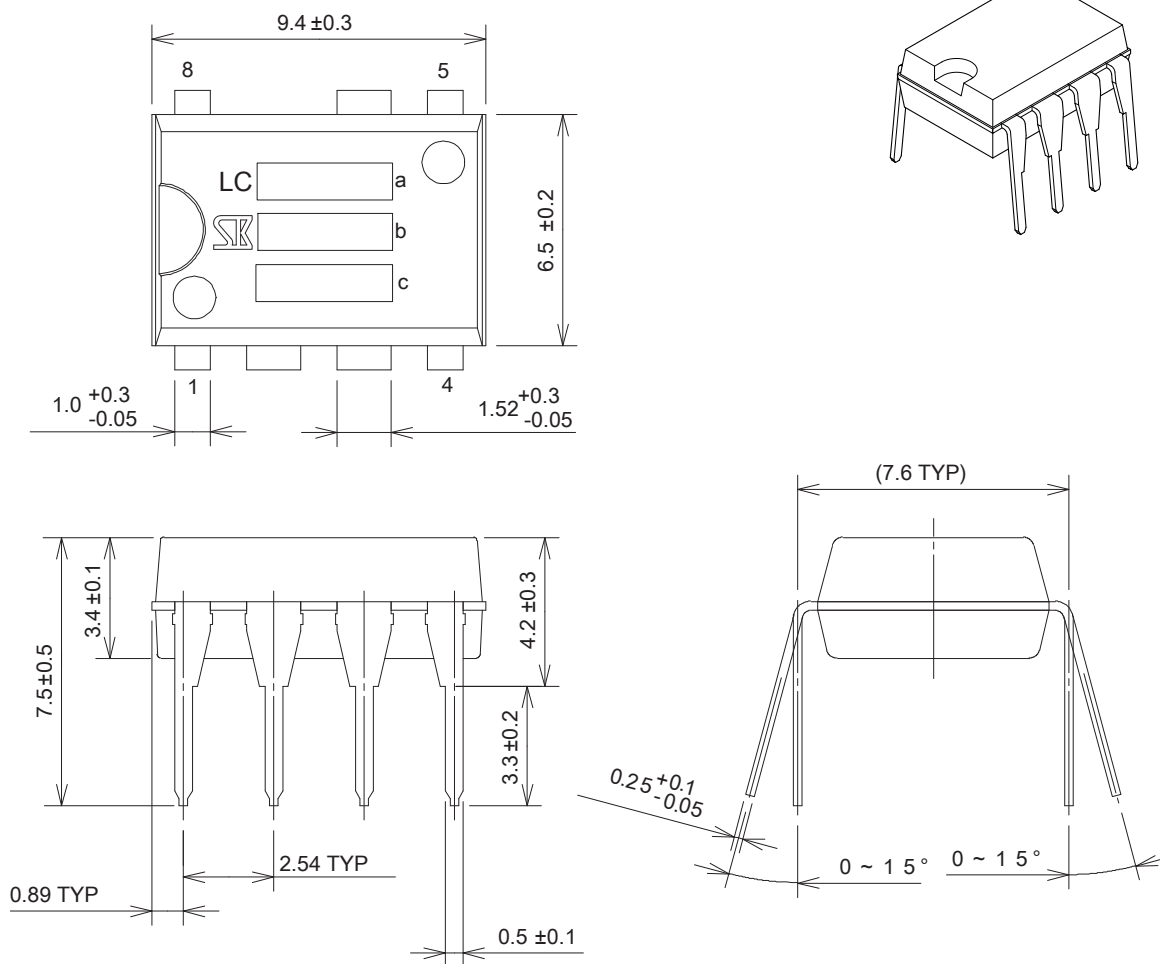
Pin List Table

| Number | Name  | Function                                                                                                                 |
|--------|-------|--------------------------------------------------------------------------------------------------------------------------|
| 1      | S/GND | MOSFET source and GND pin for the Control Part                                                                           |
| 2      | VCC   | Supply voltage input and Overvoltage Protection (OVP) signal input                                                       |
| 3      | OCP   | Overcurrent Protection (OCP), quasi-resonant signal input, and Overvoltage Protection (OVP) signal input                 |
| 4      | FB    | Feedback signal input and Overload Protection (OLP) signal input                                                         |
| 5      | NF    | No function; must be externally connected to S/GND pin with as short a trace as possible, for stable operation of the IC |
| 6      | OVP   | Overvoltage Protection (OVP) signal input                                                                                |
| 7      | —     | Pin removed                                                                                                              |
| 8      | D/ST  | MOSFET drain pin and input of the startup current                                                                        |

Pin-out Diagram



## Package Outline Drawing, DIP8



Unit: mm

- a: Part #: 554x  
b: Lot number 3 digits, plus L  
1<sup>st</sup> letter: Last digit of year  
2<sup>nd</sup> letter: Month  
Jan to September: Numeric  
October: O  
November: N  
December: D  
3<sup>rd</sup> letter: Week  
Date 1 to 10: 1  
Date 11 to 20: 2  
Date 21 to 31: 3  
c: Sanken control number



*Pb-free. Device composition compliant  
with the RoHS directive.*

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

**Cautions for Storage**

- Ensure that storage conditions comply with the standard temperature (5°C to 35°C) and the standard relative humidity (around 40% to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of the products that have been stored for a long time.

**Cautions for Testing and Handling**

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between the product pins, and wrong connections. Ensure all test parameters are within the ratings specified by Sanken for the products.

**Remarks About Using Silicone Grease with a Heatsink**

- When silicone grease is used in mounting the products on a heatsink, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce excess stress.
- Volatile-type silicone greases may crack after long periods of time, resulting in reduced heat radiation effect. Silicone greases with low consistency (hard grease) may cause cracks in the mold resin when screwing the products to a heatsink.

Our recommended silicone greases for heat radiation purposes, which will not cause any adverse effect on the product life, are indicated below:

| Type   | Suppliers                            |
|--------|--------------------------------------|
| G746   | Shin-Etsu Chemical Co., Ltd.         |
| YG6260 | Momentive Performance Materials Inc. |
| SC102  | Dow Corning Toray Co., Ltd.          |

**Soldering**

- When soldering the products, please be sure to minimize the working time, within the following limits:  
260±5°C 10±1 s (Flow, 2 times)  
380±10°C 3.5±0.5 s (Soldering iron, 1 time)
- Soldering should be at a distance of at least 1.5 mm from the body of the products.

**Electrostatic Discharge**

- When handling the products, the operator must be grounded. Grounded wrist straps worn should have at least 1 MΩ of resistance from the operator to ground to prevent shock hazard, and it should be placed near the operator.
- Workbenches where the products are handled should be grounded and be provided with conductive table and floor mats.
- When using measuring equipment such as a curve tracer, the equipment should be grounded.
- When soldering the products, the head of soldering irons or the solder bath must be grounded in order to prevent leak voltages generated by them from being applied to the products.
- The products should always be stored and transported in Sanken shipping containers or conductive containers, or be wrapped in aluminum foil.

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- In addition, it should be noted that since power devices or IC's including power devices have large self-heating value, the degree of derating of junction temperature affects the reliability significantly.
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