

Asynchronous Boost Converter for 10 WLEDs

General Description

The RT4533/A is a highly integrated LED driver IC capable of driving 10 WLEDs in series. It is composed of a current mode Boost converter integrated with a 36.5V/1.2A power switch.

The RT4533/A supports a wide input voltage range from 2.5V to 5.5V and runs at a fixed frequency of 1.1MHz. The LED current is set via an external resistor and the feedback voltage is regulated to 200mV / 300mV.

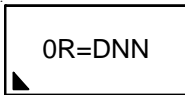
For brightness dimming, the RT4533/A supports PWM dimming which determines the feedback reference voltage.

Applications

- Cellular Phones
- Digital Cameras
- Probable Instruments

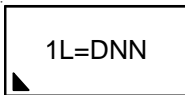
Marking Information

RT4533GJ6



0R= : Product Code
DNN : Date Code

RT4533AGJ6



1L= : Product Code
DNN : Date Code

Features

- 2.5V to 5.5V Input Voltage Range
- 36.5V Open LED Protection for 10 WLEDs
- PWM Dimming Brightness Control
- 200mV / 300mV Reference Voltage with $\pm 2\%$ Accuracy
- 1.1MHz Switching Frequency
- Built-In Soft-Start
- Over-Temperature Protection
- Internal Compensation
- Current Limit
- RoHS Compliant and Halogen Free

Ordering Information

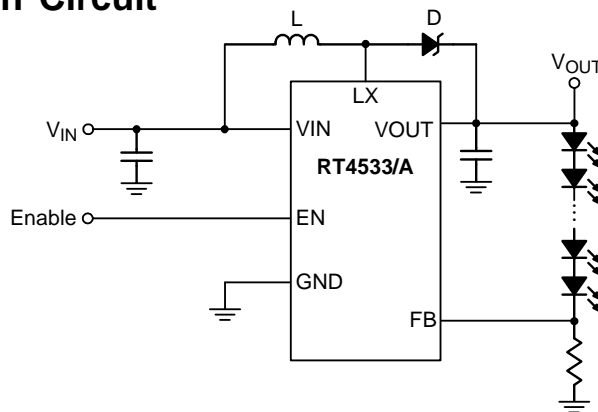
| | | |
|----------|---------|--------------------------------------|
| RT4533/A | □□ | |
| | □ | Package Type |
| | J6 | J6 : TSOT-23-6 |
| | □ | Lead Plating System |
| | G | G : Green (Halogen Free and Pb Free) |
| | □ | Feedback Voltage |
| | RT4533 | RT4533 : 200mV |
| | RT4533A | RT4533A : 300mV |

Note :

Richtek products are :

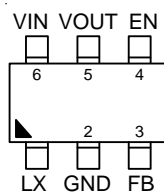
- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

Simplified Application Circuit



Pin Configurations

(TOP VIEW)

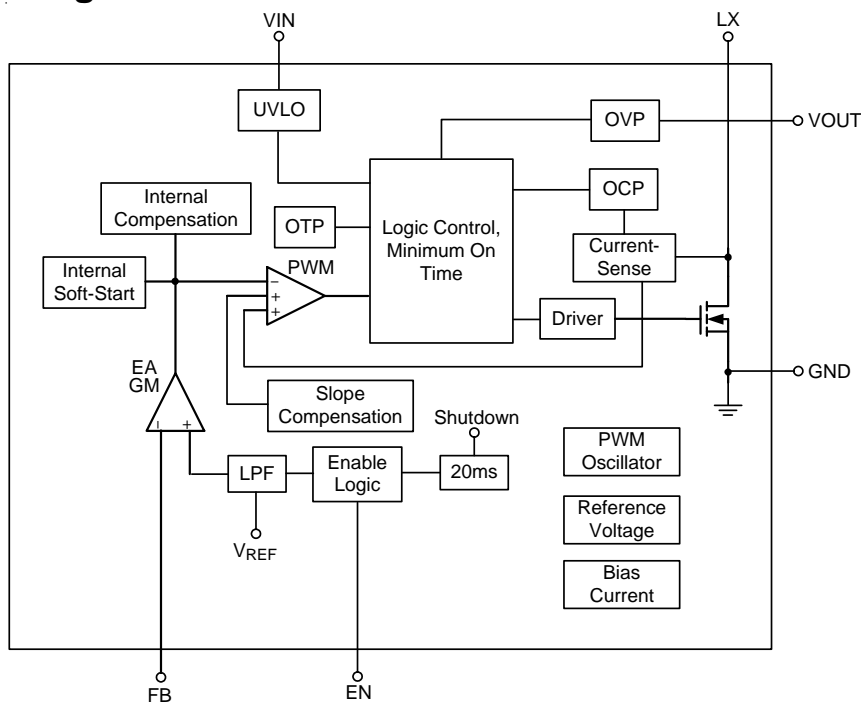


TSOT-23-6

Functional Pin Description

| Pin No. | Pin Name | Pin Function |
|---------|----------|---|
| 1 | LX | Switch Node. |
| 2 | GND | Ground. |
| 3 | FB | Feedback Voltage Input. Put a resistor to GND to setting the current. |
| 4 | EN | Enable Control Input (PWM Dimming). |
| 5 | VOUT | Output Voltage Pin. |
| 6 | VIN | Supply Voltage Input. |

Function Block Diagram



Operation

The RT4533/A is a constant frequency, current mode Boost LED driver. In normal operation, the N-MOSFET is turned on when the PWM Control circuit is set by the oscillator and is turned off when the current comparator resets the PWM Control circuit. While the N-MOSFET is turned off, the inductor current conducts through the external diode.

UVLO

When the input voltage is lower than the UVLO threshold (2.37V typ.), the driver will turn off. There is a 80mV for the UVLO hysteresis control.

Soft-Start

When the device is enabled, the Comp ramps up to the target voltage in a specific time. This ensures that the output voltage rises slowly to reduce the input inrush current.

EN Dimming

The EN pin is used for the control input for both PWM dimming mode and digital dimming mode. Shutdown delay when the EN voltage is logic low for more than specific time, the driver will be shut down.

OCP

The driver provides cycle-by-cycle current limit function to control the current on power switch. The boost switch turns off when the inductor current reaches this current threshold and it remains off until the beginning of the next switching cycle. This protects the RT4533/A and external component under overload conditions.

OVP

The Over Voltage Protection is detected by a resistor divider circuit from VOUT.

Once VOUT goes over the OVP voltage, LX pin stops switching and the power N-MOSFET will be turned off. Then, the VOUT will be discharged by external resistor. OVP will be released until EN goes from Lo to Hi again.

OTP

As the die temperature is higher than 160°C, the chip also will enter protection mode. The power MOSFET will be turned off during protection mode to prevent abnormal operation. The device is released from shutdown automatically when the junction temperature decreases by 15°C.

Absolute Maximum Ratings (Note 1)

| | | |
|---|-------|-----------------------|
| • VIN | ----- | -0.3V to 6V |
| • EN, FB to GND | ----- | -0.3V to (VIN + 0.3V) |
| • LX to GND | ----- | -0.3V to 38V |
| • VOUT to GND | ----- | -0.3V to 40V |
| • Power Dissipation, PD @ TA = 25°C | | |
| TSOT-23-6 | ----- | 0.5W |
| • Package Thermal Resistance (Note 2) | | |
| TSOT-23-6, θ_{JA} | ----- | 197.4°C/W |
| • Junction Temperature | ----- | 150°C |
| • Lead Temperature (Soldering, 10 sec.) | ----- | 260°C |
| • Storage Temperature Range | ----- | -65°C to 150°C |
| • ESD Susceptibility (Note 3) | | |
| HBM (Human Body Model) | ----- | 2kV |
| MM (Machine Model) | ----- | 200V |

Recommended Operating Conditions (Note 4)

| | | |
|------------------------------|-------|----------------|
| • Supply Input Voltage, VIN | ----- | 2.5V to 5.5V |
| • Junction Temperature Range | ----- | -40°C to 125°C |
| • Ambient Temperature Range | ----- | -40°C to 85°C |

Electrical Characteristics

(VIN = 3.6V, CIN = 4.7μF, COUT = 1μF, L = 22μH, fSW = 1.1MHz, TA = 25°C, unless otherwise specified)

| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--------------------------------------|------------|-----------------------|------------------------|------|------|-------|------|
| Power Supply | | | | | | | |
| IC Operating Current (switching) | | I _{Q_SW} | V _{FB} = 0V | 0.25 | 0.8 | 1.5 | mA |
| IC Quiescent Current (non-switching) | | I _Q | V _{FB} = 0.4V | 0.25 | 0.35 | 0.5 | mA |
| VIN Pin Shutdown Current | | I _{SD} | EN = GND | -- | 0.3 | 1 | μA |
| Under-Voltage Lockout Threshold, | | UVLO | VIN Rising Edge | 2.25 | 2.37 | 2.5 | V |
| Under-Voltage Lockout Hysteresis | | U _{VLO_hys} | VIN Falling Edge | -- | 80 | -- | mV |
| Enable and Reference Control | | | | | | | |
| EN Input Voltage | Logic-High | V _{IH} | | 1.4 | -- | -- | V |
| | Logic-Low | V _{IL} | | -- | -- | 0.4 | |
| EN Pull Low Resistance | | R _{EN} | | -- | 300 | -- | kΩ |
| EN Minimum Shut down Pulse Width | | T _{off} | | 20 | -- | -- | ms |
| EN Minimum Logic High Pulse Width | | T _{High_Min} | | 0.5 | -- | -- | μs |
| EN Minimum logic low pulse width | | T _{Low} | | 1 | -- | 10000 | μs |
| Internal Comp Resistance | | R _{comp} | | -- | 7 | -- | MΩ |
| PWM Minimum Duty | | D _{pwm min} | | -- | 3 | -- | % |
| PWM Frequency | | f _{PWM} | | 5 | -- | 100 | kHz |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|------------------------------------|-----------------|-----------------|------|------|------|-------------|
| Voltage And Current Control | | | | | | |
| Feedback Regulation Voltage | RT4533 | V_{FB} | 196 | 200 | 204 | mV |
| | RT4533A | | 294 | 300 | 306 | |
| Feedback Pin Bias Current | I_{FB} | | -- | -- | 0.1 | μA |
| Oscillator Frequency | f_{SW} | | 0.99 | 1.1 | 1.21 | MHz |
| Maximum Duty Cycle | D_{MAX} | | -- | 93 | -- | % |
| Power Switch | | | | | | |
| N-MOSFET On-Resistance | $R_{DS(ON)}$ | $V_{IN} = 3.6V$ | -- | 0.4 | 0.7 | Ω |
| OC and OLP | | | | | | |
| Peak N-MOSFET Current Limit | I_{LIM} | | 1.0 | 1.2 | 1.4 | A |
| Open LED Protection Threshold | OVP | | 35 | 36.5 | 38 | V |
| Thermal Shutdown | | | | | | |
| Thermal Shutdown Threshold | T_{SD} | | -- | 160 | -- | $^{\circ}C$ |
| Thermal Shutdown Hysteresis | ΔT_{SD} | | -- | 15 | -- | $^{\circ}C$ |

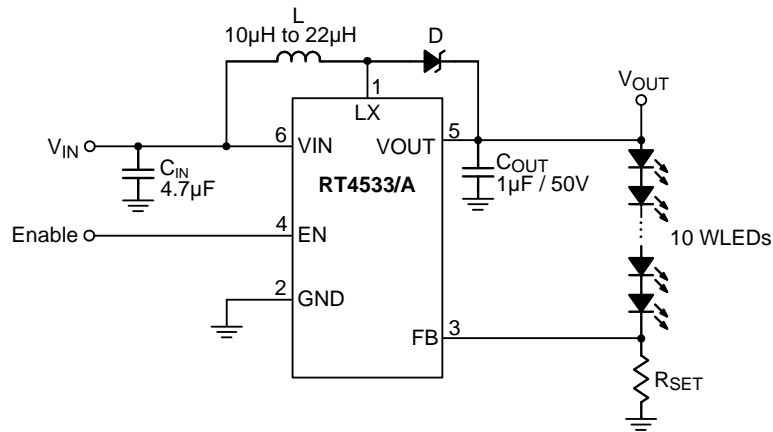
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at $T_A = 25^{\circ}C$ on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

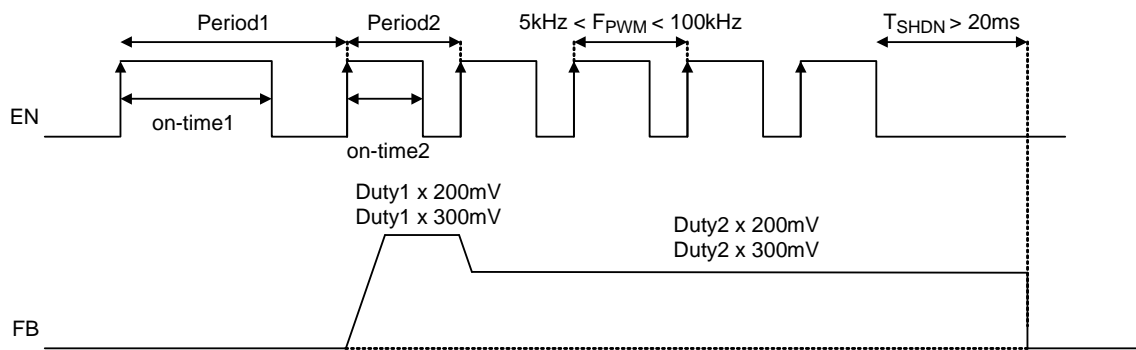
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Application Circuit

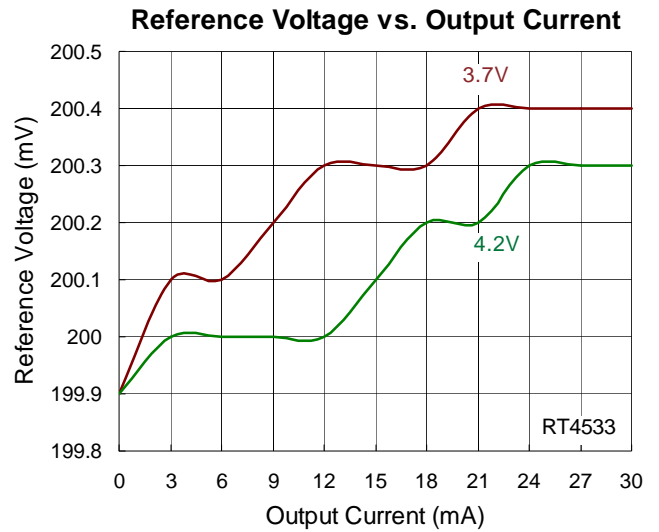
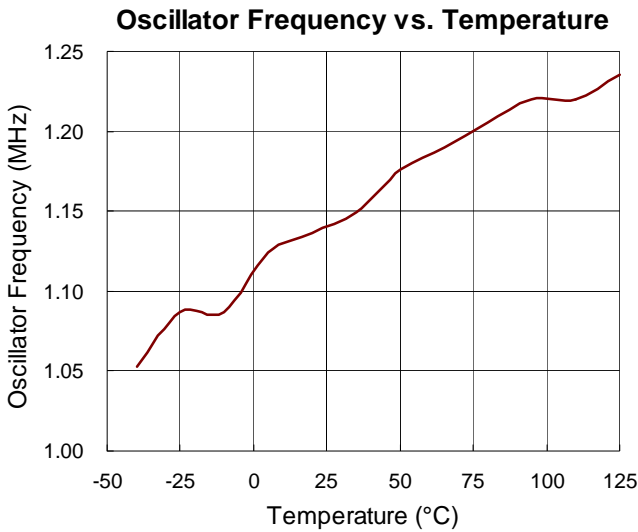
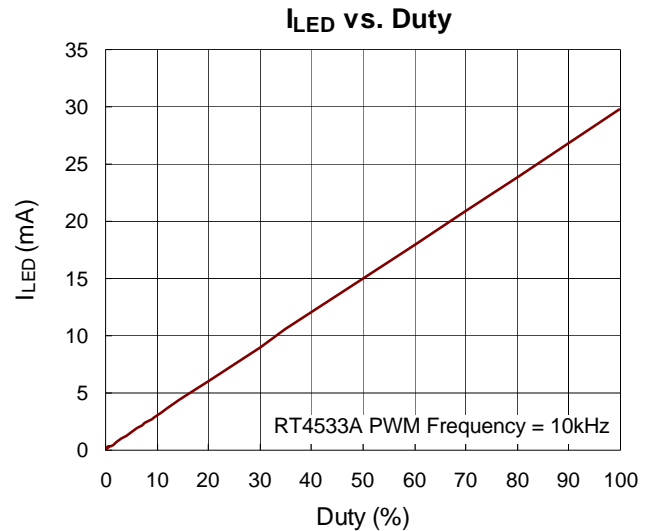
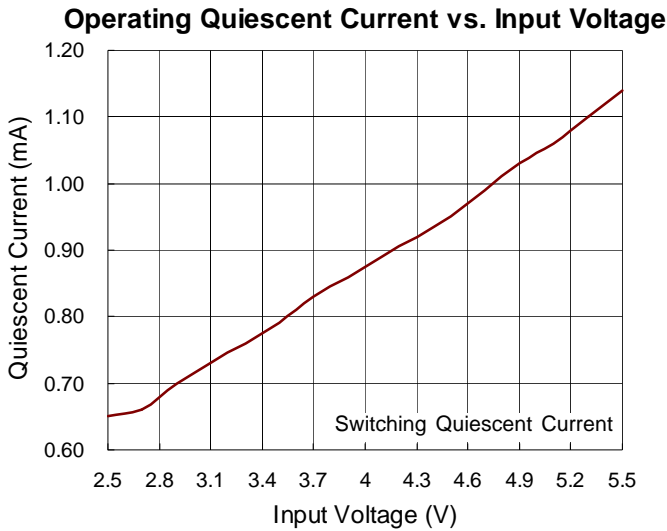
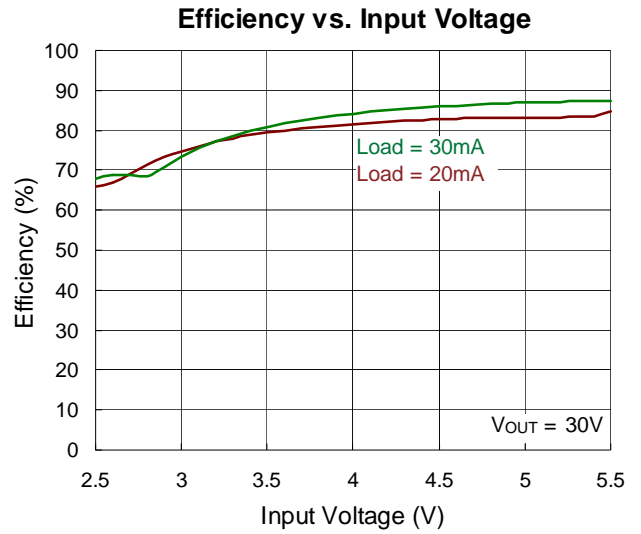
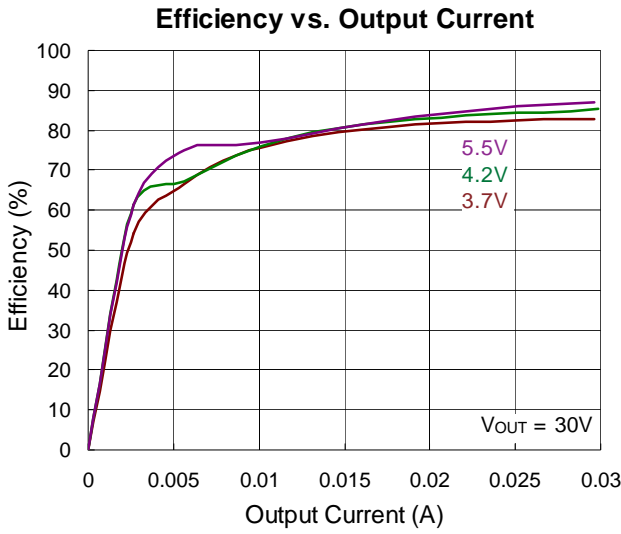


Timing Diagram



Duty1 : on-time1/Period1
 Duty2 : on-time2/Period2

Typical Operating Characteristics



Application Information

Soft-Start

The RT4533/A includes a soft-start function to avoid high inrush current during start-up. The soft-start function is achieved by clamping the output voltage of the error amplifier with another voltage source that is increased slowly from zero to near V_{IN} .

LED Current

The loop control of the Boost converter keeps V_{FB} equal to a reference voltage, V_{REF} . Therefore, when R_{SET} is connected between the FB pin and GND, the LED current will be determined by the current through R_{SET} , which is equal to V_{FB} / R_{SET} .

Current Limit

The current flowing through the inductor during a charging period is detected by a current sensing circuit. If the value exceeds the current limit, the N-MOSFET will be turned off. The inductor will then be forced to leave charging stage and enter discharging stage. Therefore, the inductor current will not increase to reach current limit.

Shutdown Delay

When the EN voltage is in logic low for 20ms during PWM dimming, the system will enter shutdown.

PWM Dimming

When the EN pin is constantly high, the FB voltage is regulated to 200mV / 300mV typically. The RT4533/A allows a PWM signal from EN pin to reduce the regulation voltage; and achieve LED brightness dimming. The relationship between the duty cycle and FB voltage is given by

$$V_{FB} = \text{Duty} \times V_{REF}$$

Where

Duty = duty cycle of the PWM signal V_{REF} = internal reference voltage (200mV / 300mV typ.)

The RT4533/A choose the internal 200mV reference voltage via the duty cycle of the PWM signal. Therefore, although a PWM signal is used for brightness dimming, only the LED DC current is modulated, which is often referred as

analog dimming. This eliminates the audible noise which often occurs when the LED current is pulsed in replica of the frequency and duty cycle of PWM control. For optimum performance, use the PWM dimming frequency in the range of 5kHz to 100kHz, and the PWM dimming frequency is strongly suggested to be over than 20kHz to avoid audio noise.

Inductor Selection

The recommended value of inductor for 10 LEDs or high brightness LED applications is 10 μ H to 22 μ H. Smaller size and better efficiency are the major concerns for portable devices. The inductor should have low core loss at 1MHz and low DCR for better efficiency. The inductor saturation current rating should be considered to cover the inductor peak current. Table 1 lists the recommended inductor for the RT4533/A.

Table 1

| Part Number | L (μ H) | DCR MAX (m Ω) | Saturation Current (A) | Size (L x W x H mm) | Vendor |
|-------------|--------------|-----------------------|------------------------|---------------------|--------|
| NR4018T100M | 10 | 216 | 1.2 | 4 x 4 x 1.8 | TAIYO |
| NR4018T220M | 22 | 432 | 0.8 | 4 x 4 x 1.8 | TAIYO |

Capacitor Selection

For low ripple voltage, ceramic capacitors with low ESR are recommended. X5R and X7R types are suitable because of their wide voltage range and good operating temperature characteristics. For the application of the RT4533/A to drive 10 LEDs in series, a 4.7 μ F for input capacitor, an 1 μ F / 50V for output capacitor.

Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA} , is layout dependent. For TSOT-23-6 package, the thermal resistance, θ_{JA} , is 197.4°C/W on the standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at $T_A = 25^\circ\text{C}$ can be calculated by following formula :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (197.4^\circ\text{C/W}) = 0.5\text{W for TSOT-23-6 package}$$

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA} . The derating curve in Figure 1 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

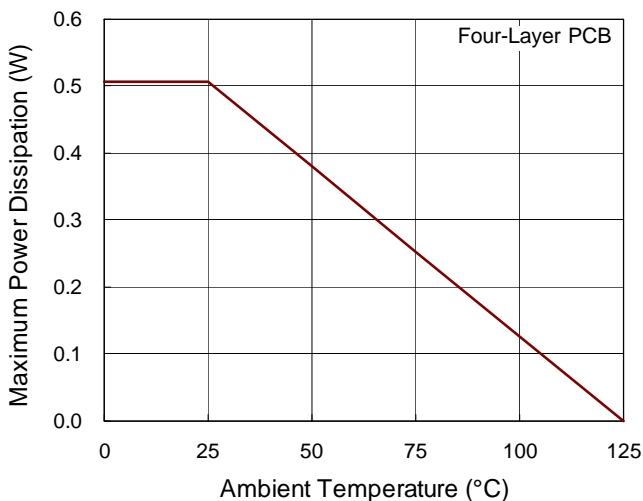


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Consideration

For best performance of the RT4533/A, the following guide lines must be strictly followed.

- ▶ Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.
- ▶ The GND and Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.
- ▶ Keep the main current traces as possible as short and wide.
- ▶ LX node of DC/DC converter is with high frequency voltage swing. It should be kept at a small area.
- ▶ Place the feedback components as close as possible to the IC and keep away from the noisy devices.

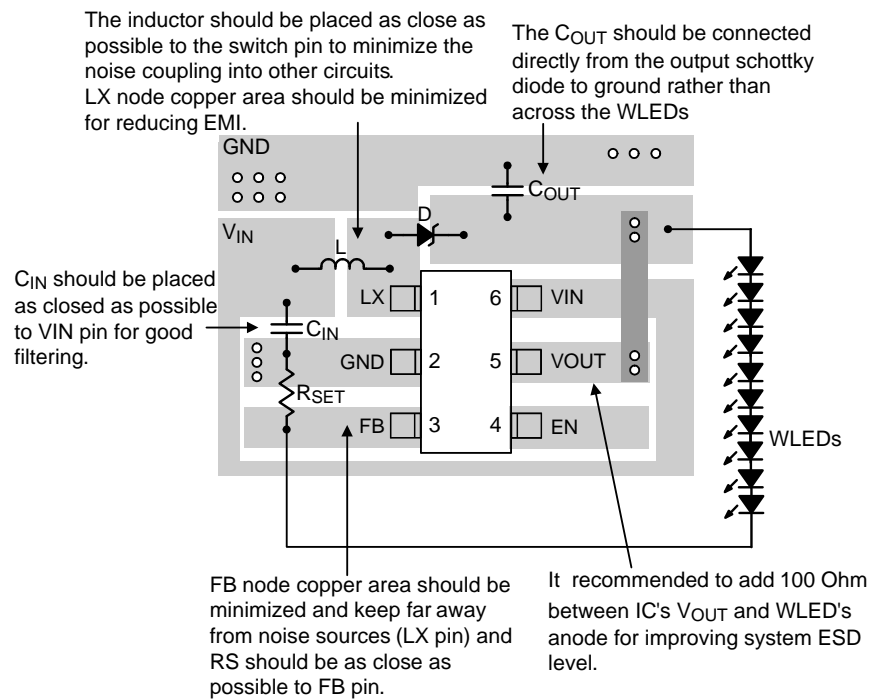
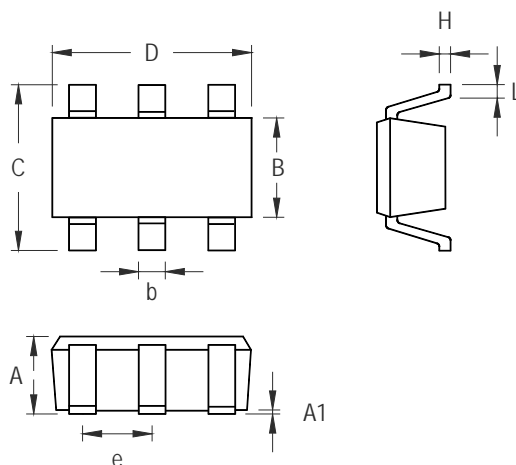


Figure 2. PCB Layout Guide

Outline Dimension



| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|--------|---------------------------|-------|----------------------|-------|
| | Min | Max | Min | Max |
| A | 0.700 | 1.000 | 0.028 | 0.039 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| B | 1.397 | 1.803 | 0.055 | 0.071 |
| b | 0.300 | 0.559 | 0.012 | 0.022 |
| C | 2.591 | 3.000 | 0.102 | 0.118 |
| D | 2.692 | 3.099 | 0.106 | 0.122 |
| e | 0.838 | 1.041 | 0.033 | 0.041 |
| H | 0.080 | 0.254 | 0.003 | 0.010 |
| L | 0.300 | 0.610 | 0.012 | 0.024 |

TSOT-23-6 Surface Mount Package

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