

# 36V High Efficiency Boost Converter with I<sup>2</sup>C Controlled 6-CH LED Driver

## Abstract

The [RT4539](#) device provides a highly integrated white LED driver solution for notebook and Tablet LCD backlight. The device is a white-LED driver featuring a 36V high efficiency asynchronous boost converter and six 35mA high precision current sinks with a maximum of  $\pm 2\%$  current mismatching for excellent brightness uniformity in each string of LEDs. The [RT4539](#) has five dimming modes including DC mode, direct PWM mode, PWM-26k mode, mix mode and mix-26K mode that can be controlled by PWM signal or an I<sup>2</sup>C master, or both. In addition, The [RT4539](#) has a wide input voltage operating range from 2.7V to 24V and contains I<sup>2</sup>C interface for controlling the dimming mode, operating frequency, LED current slope time and the LED current. It is suitable for single/two cell battery input to drive LED light bars which contain six strings in parallel.

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## 1. Brightness Control Function

### 1.1 Advanced Brightness Control

There are three ways to control the current of Current sink channels: by external PWM signal or an I<sup>2</sup>C master, or both as shown in Table 1. The PWM generator internally detects the duty cycle at the PWM pin, register or both and then it uses internal oscillator to generate a PWM data of a specific frequency. In addition, the PWM data will calculate via the PWM curve-shaper path and dimming function path which determines dimming Mode and kinds of LED current slope curve. In direct PWM mode, all current feedback channels are turned on and off and are synchronized with the input PWM signal.

**Table 1. Setting Advanced Brightness Control**

Address	Bit	Name	Default Value	Description	R/W
07h	[1:0]	Advanced brightness control	External PWM signal (B00)	B00: External PWM signal B01: I <sup>2</sup> C brightness register (04h, 05h) B10: External PWM signal multiplied with I <sup>2</sup> C brightness register (04h, 05h)	R/W

## 2. Power-On Sequence

### 2.1 Power-On Sequence by PWM Input Brightness Control Mode

When EN is above the minimal operational value, the [RT4539](#) enters start-up mode. During start-up mode, an VCP Voltage starts to ramp up and then EEPROM values loads to registers once VCP reaches power satisfactory level (POR). I<sup>2</sup>C is available after the start-up sequence has ended.

In standby mode, the device waits for the BL\_EN bit to go high to start the boost start-up sequence. Also, in standby mode the PWM input duty cycle signal is active. Moreover, the user can also set LED related configuration and functions via I<sup>2</sup>C interface.

Once the BL\_EN bit is set to 1, boost starts working, and the device enters normal mode with brightness set by PWM input duty cycle signal. If no brightness is set, the backlight stays in the same state continuously until PWM signal receives at least two PWM pulses.

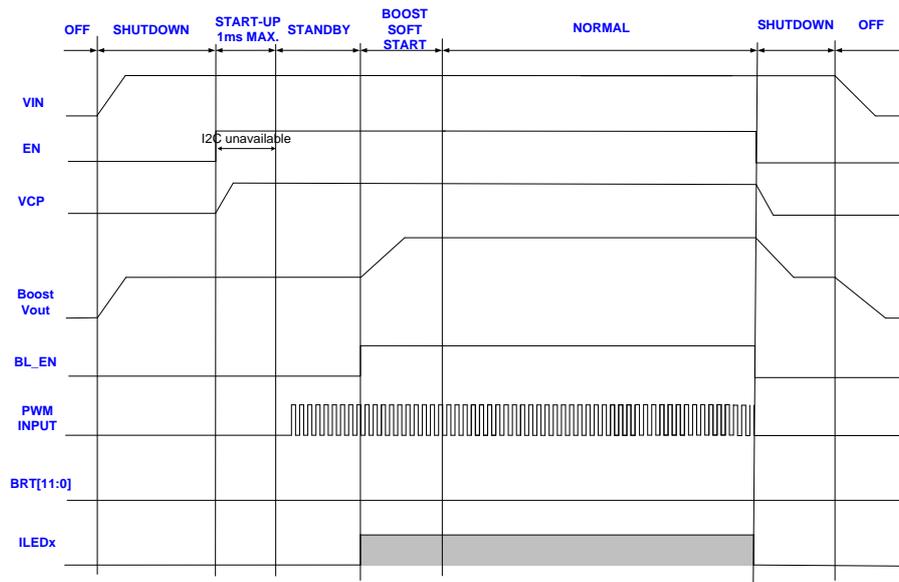


Figure 1. Start-Up and Shutdown with PWM Input Brightness Control

## 2.2 Power-On Sequence by I<sup>2</sup>C Brightness Control Mode

When EN is above the minimum operational value, the [RT4539](#) enters start-up mode. During start-up mode, an VCP voltage starts to ramp up and then EEPROM values load to registers once VCP reaches power satisfactory level (POR). I<sup>2</sup>C is available after the start-up sequence has ended.

In standby mode, the device waits for the BL\_EN bit to go high to start the boost start-up sequence. Also, in standby mode I<sup>2</sup>C is active, and brightness or other configuration registers can write via I<sup>2</sup>C interface.

Once the BL\_EN is set to 1, boost starts working, and device enters normal mode with brightness set by I<sup>2</sup>C brightness registers. If no brightness is set, the backlight stays at the same state continuously until the brightness value writes to the I<sup>2</sup>C register.

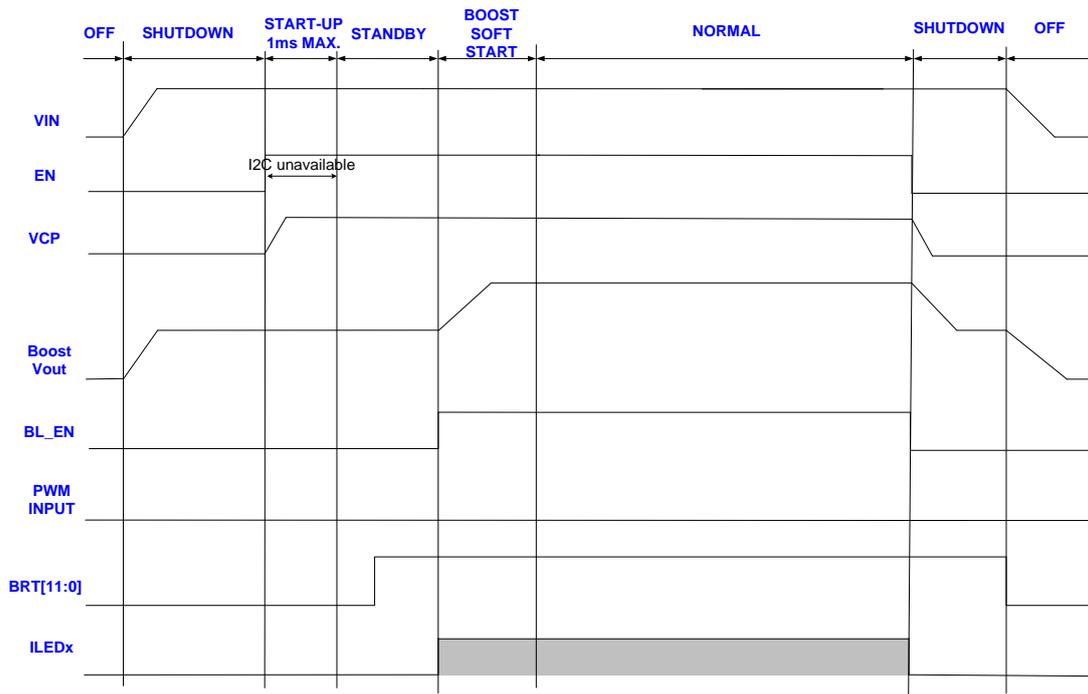


Figure 2. Start-Up and Shutdown with I<sup>2</sup>C Brightness Control

### 2.3 Power-On Sequence by I<sup>2</sup>C Control + PWM Input Brightness Control Mode

When EN is above the minimum operational value, the [RT4539](#) enters start-up mode. During start-up mode an VCP voltage starts to ramp up and then EEPROM values loads to registers once VCP reaches power satisfactory level (POR). I<sup>2</sup>C is available after the start-up sequence has ended.

In standby mode, the [RT4539](#) waits for the BL\_EN to go high to start the boost start-up sequence. Also, in standby mode I<sup>2</sup>C registers can write and PWM input duty cycle signal is active; in this mode, the LED current will be PWM duty cycle plus I<sup>2</sup>C Code.

Once the BL\_EN bit is set to 1, boost starts working, and device enters normal mode with brightness set by the PWM input duty cycle multiplied by I<sup>2</sup>C brightness register value. If no brightness is set, backlight stays at the same state continuously until I<sup>2</sup>C brightness register receives value and PWM signal receives atleast two PWM pulses.

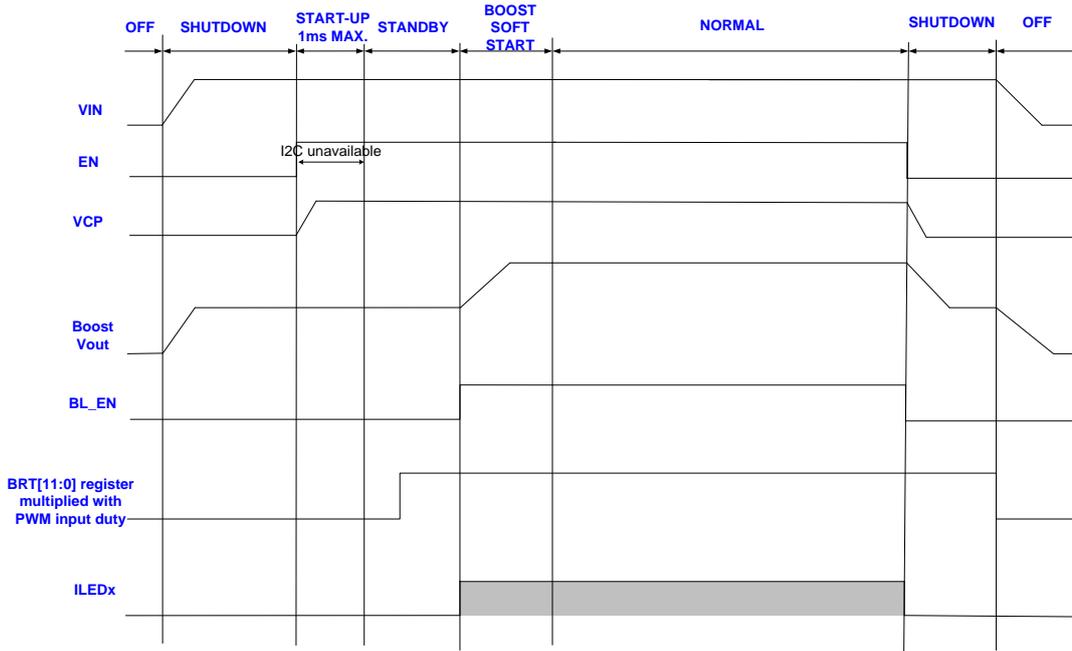


Figure 3. Start-Up and Shutdown with I<sup>2</sup>C + PWM Input Brightness Control

### 3. Dimming Mode

#### 3.1 Dimming Mode Selection

The [RT4539](#) provides five dimming modes for controlling the LED brightness. These functions include PWM mode, PWM-26k Mode, Mixed Mode, Mixed-26k Mode, and DC mode. The dimming control mode selection is programmable by register address 00h.

**Table 2. Dimming Control Mode Selection**

Address	Bit	Name	Default Value	Description	R/W
00h	[2:0]	Dimming mode selection	Mixed-26kHz mode (B011)	B000: PWM mode (Direct PWM) B001: PWM-26k mode (Non-Direct PWM) B010: Mixed mode B011: Mixed-26kHz mode B1xx: DC mode	R/W

Current sink channels current must program to the highest WLED current expected; each current sink channel current is programmable together from 10.04mA to 35mA by an EEPROM register through the I<sup>2</sup>C interface. The maximum current is programmable by register address 02h.

The brightness can be controlled using an external PWM signal, the brightness registers are accessible by users via an I<sup>2</sup>C interface or both. For the register control method, the 8bits in address 0x05h register (LSB) along the 4bits defined in address 0x04h register (MSB) allow LED brightness to be set in 12-bit fine steps. For the external PWM signal, the Brightness depends on PWM duty cycles.

### 3.2 PWM Mode

PWM control is the traditional way of controlling the brightness using PWM of the outputs with the same LED current across the entire brightness range. Brightness control is achieved by varying the duty cycle proportional to the input PWM as shown in Figure 4 below. In PWM mode, the PWM dimming frequency is synchronized with the input PWMI frequency. The LED maximum current of each channel and related LED functions can be set by I<sup>2</sup>C interface. The following Figure 4. is PWM mode behavior waveform. For example, LED maximum current is 20mA, if PWM duty cycle is 50%, the current sink output average current will be 10mA.

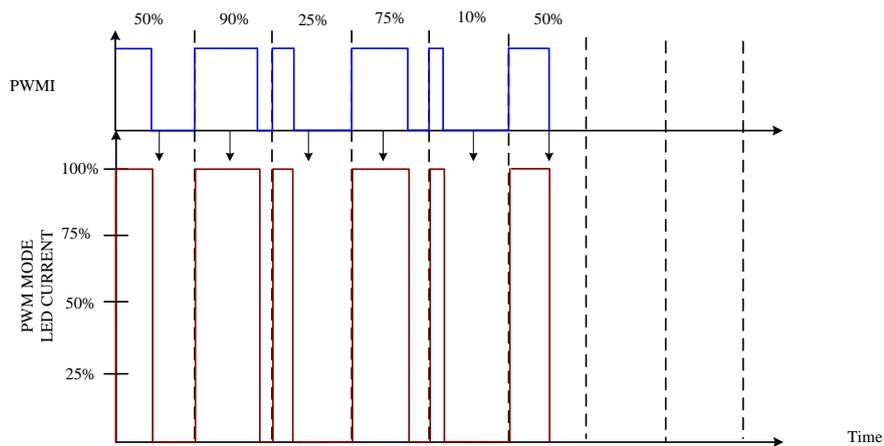


Figure 4. PWM Mode Behavior

The ON/OFF of the current source is synchronized to the PWM signal. The frequency of LED current is equal to the PWM input signal.

### 3.3 PWM-26k Mode

When user chooses PWM-26k dimming mode, the PWM output frequency will be fix as below Table 3 which can division five different frequency via I<sup>2</sup>C interface. Brightness control is achieved by varying the duty cycle proportional to the input PWM as below figure 5. Moreover, the 26kHz mode division frequency function only be used at PWM input control, if input control interface is I<sup>2</sup>C mode, the address 08h [7:5] must write B000.

**Table 3. 26kHz Mode Division Frequency**

Address	Bit	Name	Default Value	Description	Resolution	R/W
08h	[7:5]	26kHz mode division frequency	26kHz	PWMO frequency B000: 26kHz B001: 26kHz/2 B010: 26kHz/4 B011: 26kHz/8 B1xx: 26kHz/16	--	R/W

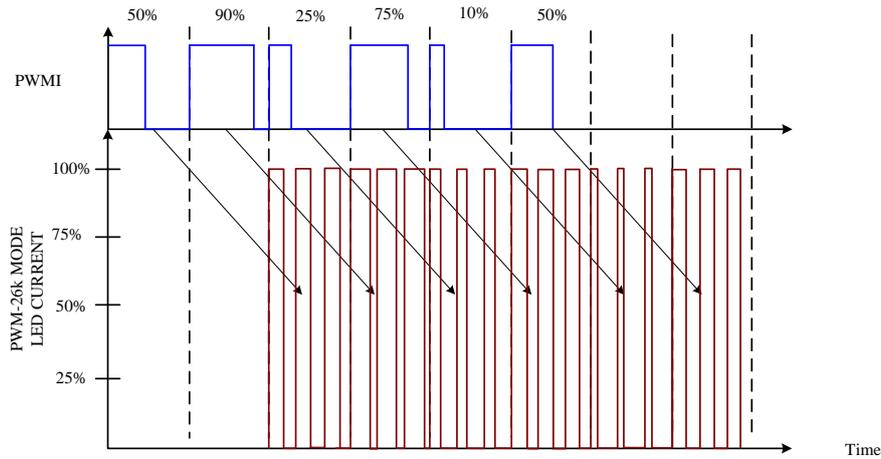


Figure 5. PWM-26k Mode Behavior

The LED current will have two-cycle delay in this mode, while the delay cycles are for average current calculation.

### 3.4 Mixed Mode

Mixed mode dimming combines PWM and DC modes for current sink current control. By using mix dimming, dimming ratio will be increased 4 times. In mix mode, PWM dimming is used for low brightness range of brightness, and DC dimming is used for high brightness levels as shown in Figure 6. Mixed-mode dimming provides the benefits of both the DC and PWM dimming. For 25% < PWM Duty < 100%, DC dimming benefits the low power requirement and increases the power to brightness transform efficiency. At light load conditions, PWM Duty < 25%, the PWM dimming provides both high accuracy brightness and low color distortion. In addition, For PWM Duty < 25%, each current sink turns on duty will be increased 4 times at translated duty cycle and same frequency to the input PWM, and in the LED on duty current is regulated at 25% of full scale. Moreover, The PWM and current modes transition threshold can be set at 25% or at 12.5% brightness.

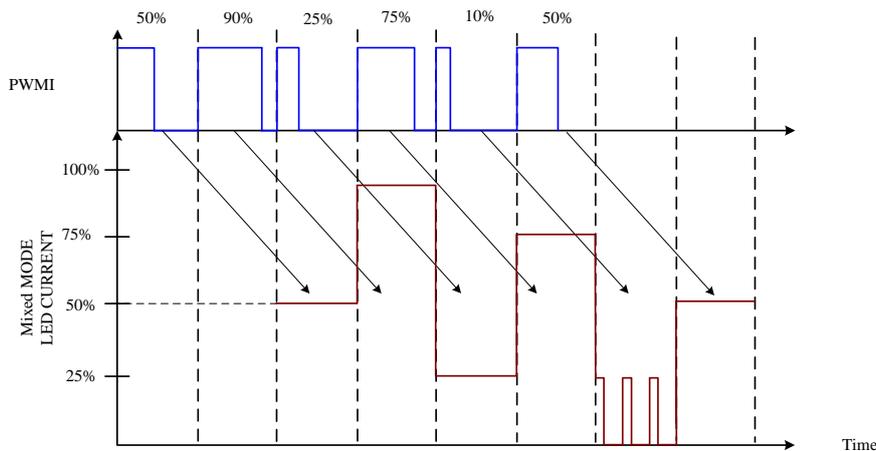


Figure 6. Mixed Mode Behavior

The LED current will have two-cycle delay in this mode, while the delay cycles are for average current calculation. When  $25\% \leq \text{PWM duty} \leq 100\%$ , the current source outputs are DC dimming, and the PWM duty cycle modulates the amplitude of the currents in 100% dimming.

PWM duty  $< 25\%$ , the DC dimming will translate to PWM dimming, controlling the PWM duty instead by amplitude. The LED current is fixed on quarter of LED current setting.

### 3.5 Mixed-26k Mode

When the user chooses Mixed-26k mode dimming, all behaviors are the same Mix mode, except PWM dimming output frequency. If PWM duty is lower than transition threshold point, the PWM dimming frequency is set to the 26kHz mode division frequency. Moreover, 26kHz mode division frequency function can only be used at PWM input control; if input control interface is I<sup>2</sup>C mode, the address 08h [7:5] must write B000.

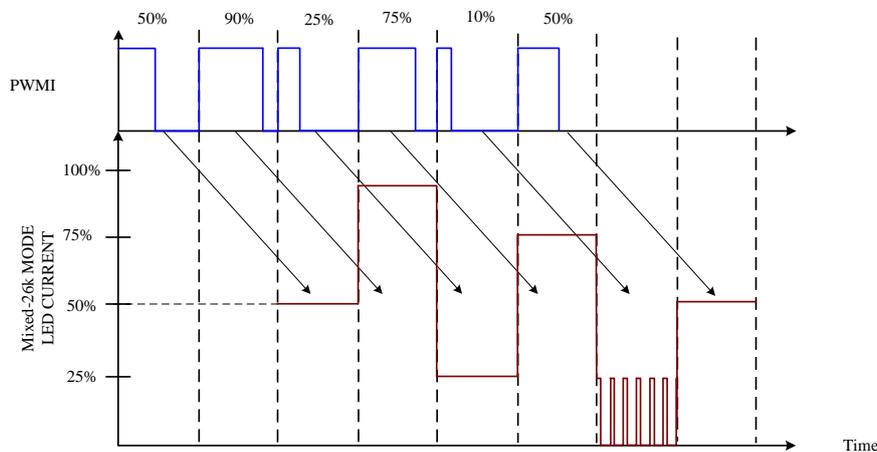


Figure 7. Mixed-26k Mode Behavior

The LED current will have two-cycle delay in this mode, while the delay cycles are for average current calculation. When  $25\% \leq \text{PWM duty} \leq 100\%$ , the current source outputs are DC dimming, and the PWM duty cycle modulates the amplitude of the currents in 100% dimming.

PWM duty  $< 25\%$ , the DC dimming will translate to PWM dimming, controlling the PWM duty instead by amplitude. The LED current is fixed on quarter of LED current setting.

### 3.6 DC Mode

In DC mode, [RT4539](#) features pure analog dimming all over the brightness range of full-scale LED current. DC dimming can provide potentially low power requirement for same WLED brightness output because of low voltage drop across each LED when the current is low. In DC mode, brightness control is achieved by changing the LED current proportionally from maximum value to a minimum value across the entire brightness range. The LED current of each channel can be set by I<sup>2</sup>C interface, and the maximum LED current setting is 35mA. The one-step of LED current is approximately 0.12mA. Current resolution in this mode is 12bits.

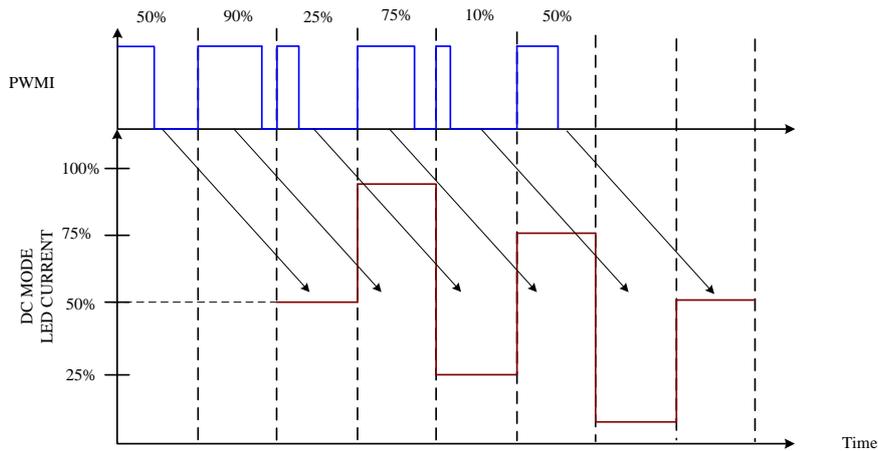


Figure 8. DC Mode Behavior

The LED current will have two-cycle delay in this mode, while the delay cycles are for average current calculation.

### 3.7 Resolution

#### 3.7.1 Resolution

The [RT4539](#) equips various dimming modes including PWM Mode, PWM-26k mode, Mixed Mode, Mixed-26k mode and DC Mode. If DC mode is selected, the maximum resolution will be 12bit and other resolution can eventually be determined according to equation 1. But in mix mode and mix mode-26k, the resolution will relate with PWM transition threshold point, for example, when PWM transient threshold point sets 25%, the resolution will be 11bit during PWM duty < 25%. When transient point sets 12.5%, the resolution will be 12bit during PWM duty < 12.5%. In addition, the following Table 4. describes resolution of each mode.

**Table 4. Each Dimming Mode Resolution by 26kHz PWM Frequency**

Oscillator = 16M	LED Frequency = 26kHz			
	Brightness < 25% (Set threshold is 25%)	Brightness > 25% (Set threshold is 25%)	Brightness < 12.5% (Set threshold is 12.5%)	Brightness > 12.5% (Set threshold is 12.5%)
<b>PWM Mode</b>	According to input PWM frequency to calculate resolution.			
<b>PWM-26k Mode</b>	9 bit	12 bit	9 bit	12 bit
<b>Mixed Mode</b>	According to input PWM frequency to calculate resolution. Calculate resolution +2bit	12 bit	According to input PWM frequency to calculate resolution. Calculate resolution +3bit	12 bit
<b>Mixed-26k Mode</b>	9+2 bit	12 bit	9+3 bit	12 bit
<b>DC Mode</b>	12 bit		12 bit	

$$\text{Resolution} = \text{Log}\left(\frac{\text{Oscillator}}{\text{PWM frequency}}, 2\right)$$

(1)

The following figures show the resolution of PWM at different transition point.

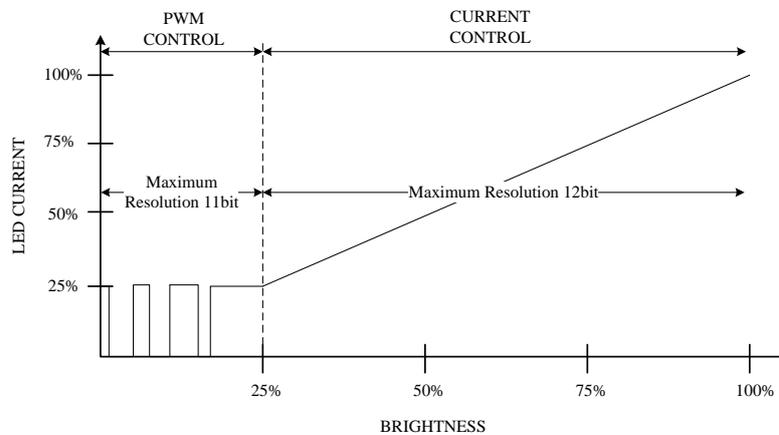


Figure 9. Duty Change Threshold is 25% in Mixed and Mixed-26k Mode

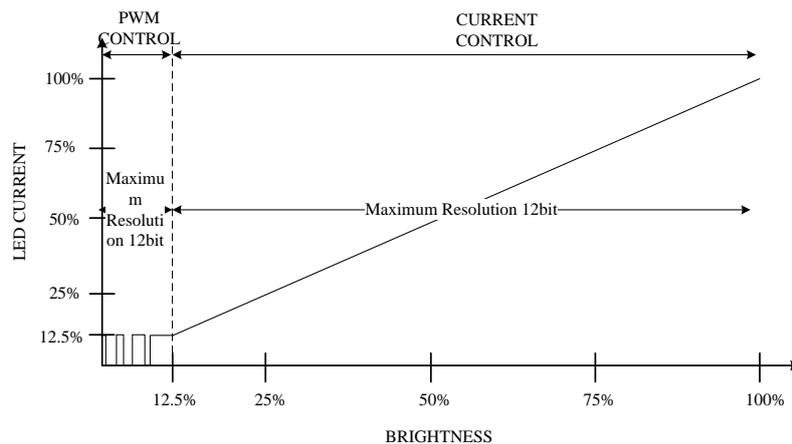


Figure 10. Duty Change Threshold is 12.5% in Mixed and Mixed-26k Mode

### 3.8 Linear and Exponential Function

The [RT4539](#) equips ILED Mapping mode including linear and exponential functions. In linear mapping mode, the dimming settings presented either via the PWM input or registers are translated linearly into the LED current. For a better visual experience, The [RT4539](#) can also translate the dimming settings via an exponential mapping to produce the LED current. Moreover, the exponential function is valid for DC mode only and an example is shown in the following Figure 11.

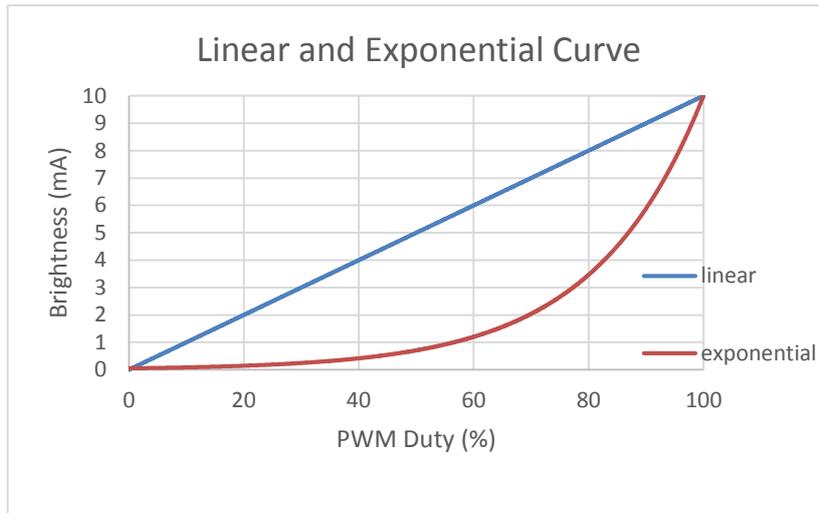


Figure 11. Linear and Exponential Curve

### 3.8.1 Exponential Function Example

#### 3.8.1.1 External PWM Signal

LED brightness mapping can be selected to be either linear or exponential (DC mode only) by address 0x03h [7].

When address 0x07h is set to B00 and exponential mode is selected by address 0x03h, the PWM duty will transfer cycle-to-current response with 11-bit resolution and target ILED is approximated by the following equation:

$$I_{LED} = 50\mu A \times 1.003042047 \times \text{PWM duty (for PWM duty} \neq 0) @ I_{LEDmax} = 25mA$$

It is valid for PWM duty cycles within 0 to 100%. If duty cycle is 0, the brightness will be disabled.

#### 3.8.1.2 External PWM Signal

When address 0x07h is set to B01 and exponential mode is selected by address 0x03h, the I2C interface will transfer code-to-current response with 11-bit resolution and target ILED is approximated by the following equation:

$$I_{LED} = 50\mu A \times 1.00304I2C \text{ code (for codes} > 0) @ I_{LEDmax} = 25mA$$

This equation is valid for I2C brightness codes between 1 and 2047. If Code is 0, the brightness will be disabled.

### 3.8.2 Linear Example

#### 3.8.2.1 External PWM Signal

When address 0x07h is set to B00 and linear mode is selected by address 0x03h, the PWM duty will transfer cycle-to-current response with 12-bit resolution and target ILED is approximated by the following equation:

$$I_{LED} = 6.105\mu A \times 4095 \times \text{PWM duty (for PWM duty} \geq 0) @ I_{LEDmax} = 25mA$$

It is valid for PWM duty cycles within 0 to 100%. If duty cycle is 0, the brightness will be disabled.

### 3.8.2.2 I<sup>2</sup>C Brightness Register

When address 0x07h is set to B01 and linear mode is selected by address 0x03h, the I2C interface will transfer code-to-current response with 12-bit resolution and target ILED is approximated by the following equation:

$$I_{LED} = 6.105\mu A \times I2C \text{ code (for codes } \geq 0) @ I_{LEDmax} = 25mA$$

This equation is valid for I2C brightness codes between 0 and 4095. If Code is 0, the brightness will be disabled.

### 3.8.2.3 External PWM Signal multiplied I<sup>2</sup>C Brightness Register

When address 0x07h is set to B10, this mode is only for DC mode and linear mapping. The target brightness code will be multiplied with the PWM duty cycle and I2C code. Moreover, resolution can support up to 12-bit.

The target ILED is approximated by the following equation:

$$I_{LED} = 6.105\mu A \times I2C \text{ code} \times 4095 \times PWM \text{ duty (for codes } \geq 0 \text{ \& PWM duty } \neq 0\% \text{ And } 100\%) @ I_{LED\_max} = 25mA$$

## 3.9 Slope Function

Transition time between two brightness value can be controlled linearly by address 06h [5:3] from 0 to 1024ms. Same Slope time is used for sloping up and down. With advanced Slope, the brightness changes can be more smoothing to a human eye.

**Table 5. Slope Time Setting**

Address	Bit	Name	Default Value	Description	R/W
06h	[5:3]	Slope Time Control	512ms (B101)	B000: 0ms B001: 1ms B010: 8ms B011: 128ms B100: 256ms B101: 512ms B110: 768ms B111: 1024ms	R/W
	[2:0]	Filter	Medium smoothing (B10)	B000: No filter (exponential) B001: Light smoothing B010: Medium smoothing B011: Heavy smoothing	R/W

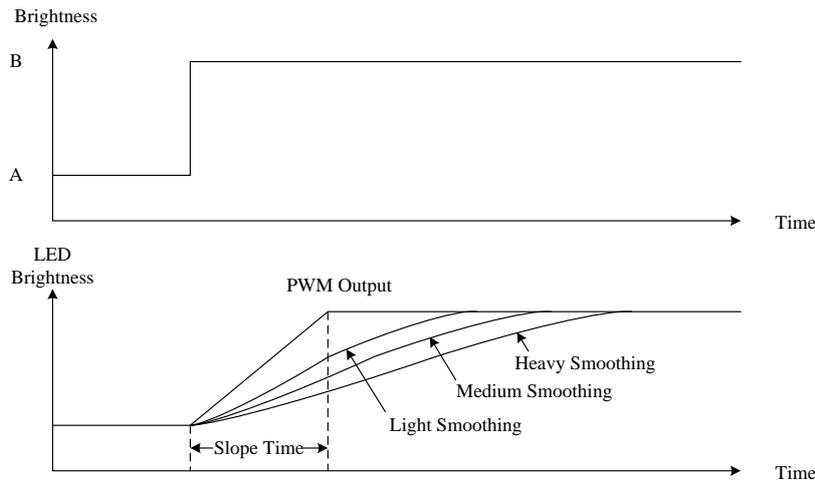


Figure 12. Smooth Function Behavior

## 4. Boost Converter

### 4.1 Introduction

The [RT4539](#) is a 6-CH LED driver with a boost converter. The boost converter is used to step up the input voltage to higher level. This typology consists of the components with the power switch, inductor, diode to store and release the energy at the output for the higher voltage. The application note provides the information about a boost converter built at the [RT4539](#) IC with a 250mΩ, 36V integrated power switch and operating in the different modes by the PWM control. According to the following introduction, it gives the equations to calculate the important parameters at the power stage of a boost converter and suggests how to choose related components. Table 6 shows the boost converter specifications of the [RT4539](#) and the electrical characteristics.

**Table 6. Boost Converter Specifications**

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Boost Converter</b>						
Input Supply Voltage	V <sub>IN</sub>		2.7	3.8	24	V
Switching Frequency Accuracy	f <sub>SW_ACC</sub>	Boost operates at PWM mode, f <sub>SW</sub> = 600kHz	-10	--	10	%
Switching Frequency Setting Range	f <sub>SW_RG</sub>	Boost operates at PWM mode Default = 600kHz @ 0x07h	0.3	--	1.6	MHz
Maximum Duty Cycle	D <sub>MAX_300kHz to 1MHz</sub>	f <sub>SW</sub> = 300kHz to 1MHz	--	90	--	%
	D <sub>MAX_1.22MHz to 1.6MHz</sub>	f <sub>SW</sub> = 1.22MHz to 1.6MHz	--	95	--	
Boost Switch R <sub>DS(ON)</sub>	R <sub>DS(ON)</sub>		--	0.25	--	Ω
Switching Current Limitation	I <sub>OCP</sub>		2	2.5	3	A
Boost Minimum on Time	t <sub>MON</sub>		--	100	--	ns

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
VOUT Over-Voltage Protection	VOVP		--	36	--	V

## 4.2 Duty Cycle Calculation

The maximum output voltage for the boost converter is highly based on switching the MOSFET or diode. The duty ratio (D) defines as the on-time of the MOSFET divided by the total switching period. For the boost converter, the approximate duty ratio (D) shows in the equation 2. The efficiency is added to the calculation because the converter also must consider the power dissipation. This calculation gives a result closer to the realistic statement. The maximum duty cycle of the [RT4539](#) is around 90% when VOUT is the maximum output voltage and VIN is the minimum input voltage.

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} = 1 - \frac{V_{IN} \times \eta}{V_{OUT}} \quad (2)$$

VIN = Input voltage

VOUT = Output voltage

D = Duty ratio

η = Efficiency of the converter

Take 12V to 36V application as an example, the duty ratio is about 0.67. The value must not exceed the IC's maximum duty ratio limitation. Otherwise, the output voltage of the boost converter cannot regulate normally. If the dimming mode control is selected as PWM mode or PWM-26k mode, the recommended conversion ratio is less than 0.75.

In addition to the maximum duty limitation, the [RT4539](#) has the minimum on-time about 100ns for the boost converter. When the on-time of the boost converter is lower than the minimum on-time, the switching frequency will decrease to avoid abnormal regulation is abnormal.

## 4.3 Maximum Output Current

Calculating the maximum current is crucial to determine the inductor ripple current. The switch current limit in [RT4539](#) protects the IC and circuit to avoid the damage from overcurrent. It clamps the peak inductor current. Therefore, the current ripple in a boost converter can be subtracted from the maximum current. Also, the maximum output current helps us to decide the appropriate inductor component. The following equations show the calculation with the related factors of the current.

$$\Delta I_L = \frac{V_{IN} \times D}{f_{SW} \times L} = \frac{(V_{OUT} - V_{IN}) \times (1 - D)}{f_{SW} \times L} \quad (3)$$

V<sub>IN</sub> = Input voltage  
 V<sub>OUT</sub> = Output voltage  
 D = Duty ratio  
 f<sub>sw</sub> = Switch frequency  
 L = Selected inductor value

After the change of the inductor current, this equation determines the maximum output current the [RT4539](#) can deliver.

$$I_{\text{MAXOUT}} = \left( I_{\text{OCP}} - \frac{\Delta I_L}{2} \right) \times (1 - D) \tag{4}$$

I<sub>OCP</sub> = Switching current limitation  
 ΔI<sub>L</sub> = Inductor ripple current  
 D = Duty ratio

The output current from the system required is necessarily less than the value of calculation. It represents the maximum current which the integrated power switch in [RT4539](#) can withstand. The operation condition about current level recommended under the 90% of OCP level is better. If the maximum value is just little smaller the needed one, it can be solved by an inductor component with higher inductance. The higher inductance reduces the ripple current and increases the maximum output current.

#### 4.4 Inductor Selection

The inductor plays a key role in the switching converter. It influences steady-state operation, transient response, and stability. We must consider important inductor specifications, such as inductor value, DC resistance, and saturation current when choosing the inductor component. The value of an inductor determines its ripple current. The higher inductance, the maximum current becomes higher because of reduced ripple current. The smaller inductance, the smaller size inductor can be used. It is recommended that the ripple current is set to 20% to 40% of the output DC current.

Inductor values commonly have ±20% tolerance with no current bias. When the inductor current approaches saturation level, its inductance may decrease 20% to 35%. In addition, inductors with low DCR values provide much more output current and higher conversion efficiency. The following equation is an estimation for the inductor.

$$L = \frac{V_{\text{IN}} \times (V_{\text{OUT}} - V_{\text{IN}})}{\Delta I_L \times f_{\text{SW}} \times V_{\text{OUT}}} \tag{5}$$

V<sub>IN</sub> = Input voltage  
 V<sub>OUT</sub> = Output voltage  
 ΔI<sub>L</sub> = Inductor ripple current  
 f<sub>sw</sub> = Switch frequency

A suitable estimation for the inductor ripple current is 20% to 40% of the output current.

$$\Delta I_L = (0.2 \text{ to } 0.4) \times \frac{V_{OUT} \times I_{OUTMAX}}{\eta \times V_{IN}} \quad (6)$$

V<sub>IN</sub> = Input voltage

V<sub>OUT</sub> = Output voltage

I<sub>OUTMAX</sub> = Maximum output current

η = Efficiency of the converter

The inductance can eventually be determined by combining the equation 5 and 6 below.

$$L = \frac{\eta \times (V_{IN})^2 \times (V_{OUT} - V_{IN})}{(0.2 \text{ to } 0.4) \times (V_{OUT})^2 \times I_{OUTMAX} \times f_{SW}} \quad (7)$$

V<sub>IN</sub> = Input voltage

V<sub>OUT</sub> = Output voltage

I<sub>OUTMAX</sub> = Maximum output current

η = Efficiency of the converter

f<sub>sw</sub> = Switch frequency

When the boost converter operates at the boundary state, the transition is from Discontinuous Conduction Mode (DCM) to Continuous Conduction Mode (CCM). The value of the inductance can be approximated by the following equation 8.

$$L = \frac{D \times (1-D)^2 \times V_{OUT}}{2 \times f_{SW} \times I_{OUT}} \quad (8)$$

V<sub>IN</sub> = Input voltage

V<sub>OUT</sub> = Output voltage

D = Duty ratio

f<sub>sw</sub> = Switch frequency

The inductor must be selected with a saturated current rating that is greater than the peak current as provided by the following equation 9.

$$I_{PEAK} = \frac{V_{OUT} \times I_{OUT}}{\eta \times V_{IN}} + \frac{V_{IN} \times D}{2 \times f_{SW} \times L} \quad (9)$$

- V<sub>IN</sub> = Input voltage
- V<sub>OUT</sub> = Output voltage
- D = Duty ratio
- f<sub>sw</sub> = Switch frequency
- η = Efficiency of the converter
- L = Selected inductor value

#### 4.5 Diode Selection

The Schottky diode is a good choice for any asynchronous boost converter with its small forward voltage. However, when selecting a Schottky diode, users must take important parameters such as power dissipation, reverse voltage rating, and pulsating peak current consideration. A suitable Schottky diode's reverse voltage rating must be greater than the maximum output voltage, and its average rating must exceed the average output current.

#### 4.6 Input Capacitor Selection

Low ESR ceramic capacitors recommend for input capacitor applications. Low ESR will effectively reduce the input voltage ripple caused by switching operation. Two 2.2μF low ESR ceramic capacitors are sufficient for most applications. Nevertheless, this value can decrease for applications with lower output current requirement.

Another consideration is the voltage rating of the input capacitor must be greater than the maximum input voltage.

#### 4.7 Output Capacitor Selection

Output ripple voltage is an important index for estimating the performance. This portion consists of two parts, one is the product of I<sub>IN</sub> and ESR of output capacitor, another part is formed by charging and discharging process of output capacitor. As shown in Figure 13., ΔV<sub>OUT1</sub> can evaluate based on the ideal energy equalization. According to the definition of Q, the Q value can calculate as following equation:

$$Q = \frac{1}{2} \times \left[ \left( I_{IN} - \frac{1}{2} \Delta I_L - I_{OUT} \right) + \left( I_{IN} - \frac{1}{2} \Delta I_L - I_{OUT} \right) \right] \times \frac{V_{IN}}{V_{OUT}} \times \frac{1}{f_{OSC}} = C_{OUT} \times \Delta V_{OUT1} \tag{10}$$

Where force is the switching frequency and ΔI<sub>L</sub> is the inductor ripple current. Move C<sub>OUT</sub> to left side to estimate the value of ΔV<sub>OUT1</sub> as the following equation:

$$\Delta V_{OUT1} = \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{OSC}} \tag{11}$$

Where D is the duty cycle and  $\eta$  is the boost converter efficiency. Finally, taking ESR into account, the overall output ripple voltage can be determined by the following equation:

$$\Delta V_{OUT} = \Delta V_{ESR} = \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{OSC}} \quad (12)$$

Where  $\Delta V_{ESR} = \Delta I_C \times R_{ESR} = I_{PEAK} \times R_{ESR}$

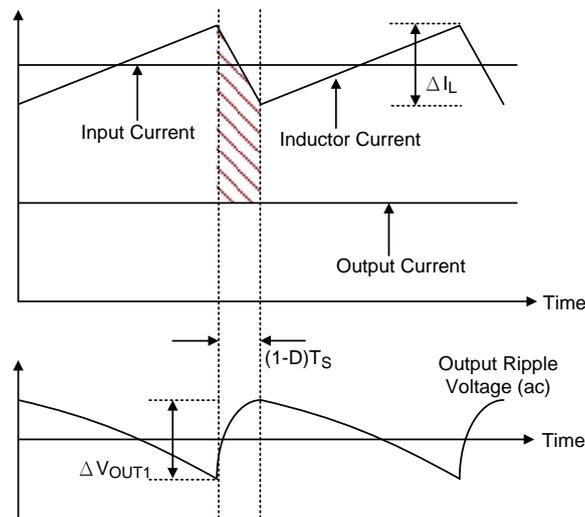


Figure 13. The Output Ripple Voltage without the Contribution of ESR

## 5. Layout Guideline

1. For good regulation, place the power components as close to the IC as possible. The traces should be wide and short, especially for the high current output loop.
2. The input and output bypass capacitor should be placed as close to the IC as possible and connected to the ground plane of the PCB.
3. Minimize the size of the L nodes and keep traces wide and short. Care should be taken to avoid running traces that carry any noise-sensitive signals near LX or high- current traces.
4. Separate power ground (PGND) and ground (GND). Connect the GND and the PGND islands at a single end. Make sure that there are no other connections between these separate ground planes.
5. Connect the exposed pad to a strong ground plane for maximum thermal dissipation.

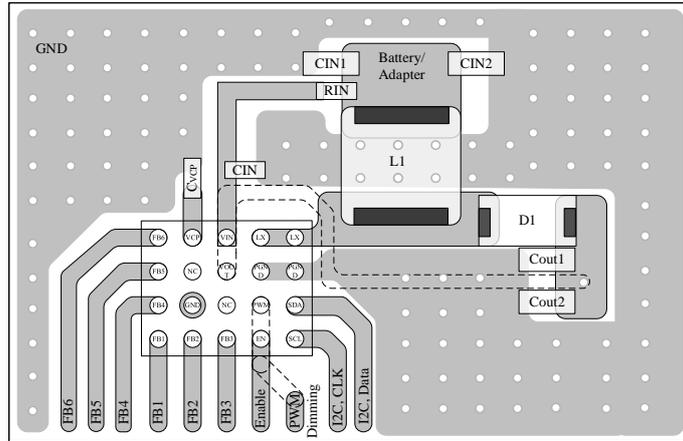


Figure 14. PCB Layout Guide

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**Richtek Technology Corporation**

14F, No. 8, Tai Yuen 1<sup>st</sup> Street, Chupei City  
Hsinchu, Taiwan, R.O.C.  
Tel: 886-3-5526789

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