RICHTEK®

RT4540A

36V High-Efficiency Boost Converter with I^2C Controlled 6-Channel LED Driver

1 General Description

The RT4540A is a high-efficiency driver for white LEDs. It is suitable for single/two cell battery input to drive LED light bars which contain six strings in parallel. The internal current sinks support a maximum of ±2% current mismatching for excellent brightness uniformity in each string of LEDs. To provide enough headroom for current sink operation, the boost controller monitors the minimum voltage of the feedback pins and regulates an optimized output voltage for power efficiency.

The RT4540A contains I^2C interface for controlling the dimming mode, operating frequency and the LED current. The internal 250mΩ, 36V power switch with current-mode control provides overcurrent protection.

The switching frequency of the RT4540A is also adjustable from 100kHz to 1.6MHz, which allows flexibility between efficiency and component size.

The RT4540A is available in a WQFN3x3-24 with pitch 0.4mm package. The recommended junction temperature range is –40°C to 150°C, and the ambient temperature range is –40°C to 125°C.

2 Ordering Information

RT4540A □□

Package Type(1)
QW: WQFN3x3-24

Lead Plating System
G: Richtek Green Policy Compliant(2)

Note 1.

- Marked with (1) indicated: Compatible with the current requirements of IPC/JEDEC J-STD-020.
- Marked with (2) indicated: Richtek products are Richtek Green Policy compliant.

3 Features

- **Wide Operating Input Voltage: 2.7V to 24V**
- **High Output Voltage: up to 36V**
- **Channel Current Programmable: 6mA to 25mA**
- **Channel Current Regulation with Accuracy ±3% and Matching ±2%**
- **Dimming Controls**
  - **Direct PWM up to 25kHz with Minimum 1% Duty**
  - **PWM to Analog up to 2kHz with 12-Bit Resolution, up to 4kHz with 11-Bit Resolution, up to 8kHz with 10-Bit Resolution**
  - **PWM to Mixed up to 2kHz with 12-Bit Resolution, up to 4kHz with 11-Bit Resolution, up to 8kHz with 10-Bit Resolution**
  - **PWM to Mixed-26kHz up to 2kHz with 12-Bit Resolution, 4kHz with 11-Bit Resolution, up to 8kHz with10-Bit Resolution**
- **I^2C Programs LED Current, Switching Frequency, Dimming Mode**
- **Switching Frequency: 100kHz to 1.6MHz**
- **Embedded Memory with MTP**
- **Protections**
  - **LED Strings Open Protection**
  - **Overcurrent Protection**
  - **Programmable Overvoltage Protection**
  - **Over-Temperature Protection**
  - **Strings Short Detection**

4 Applications

- Tablet and Notebook LED Backlights

5 Marking Information

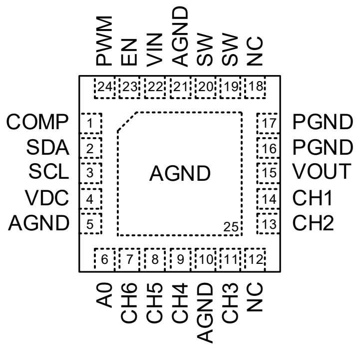
02KYM
DNN

02K : Product Code
YMDNN : Date Code

Table of Contents

6 Pin Configuration

(TOP VIEW)

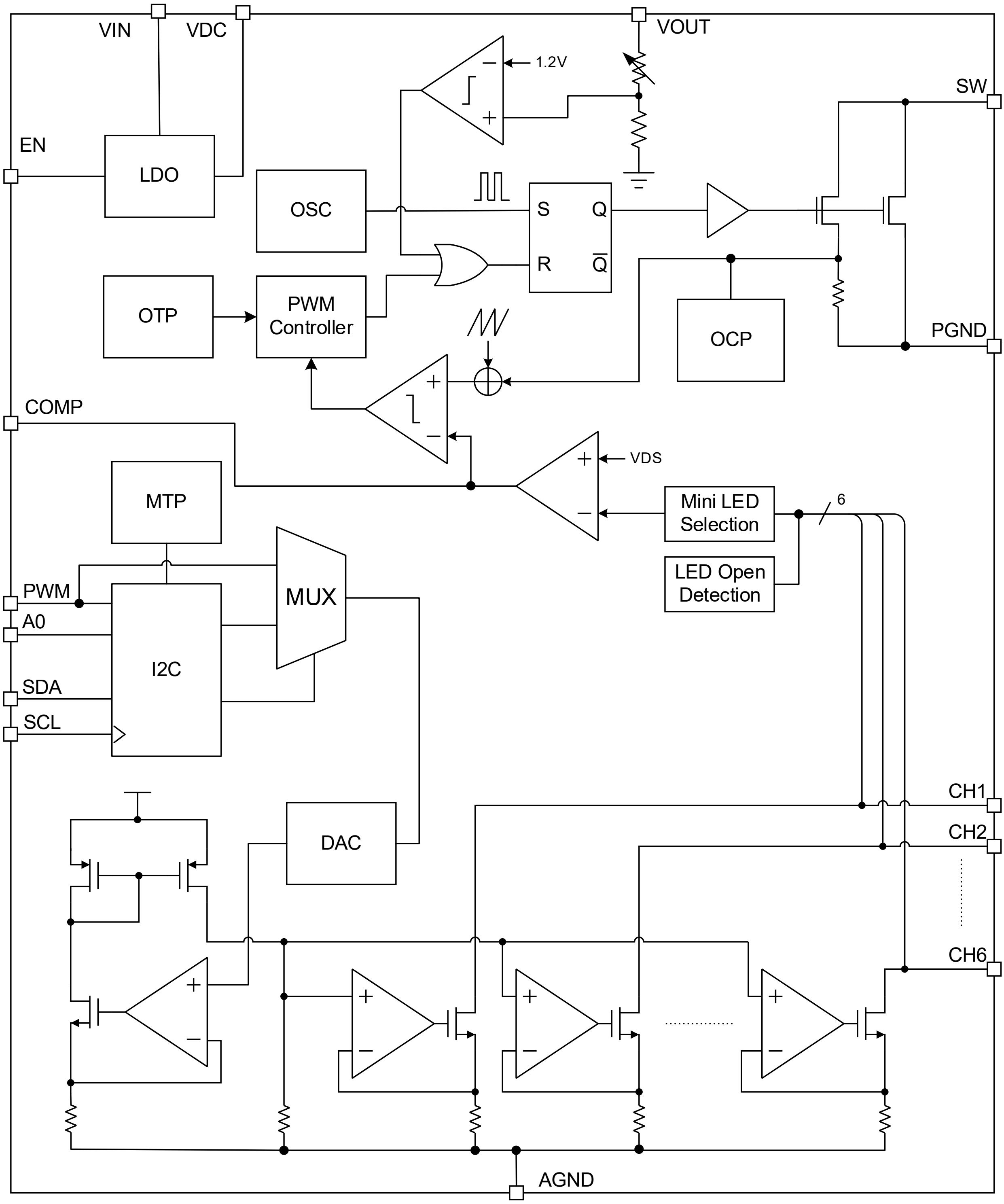


WQFN3x3-24

7 Functional Pin Description

Pin No.	Pin Name	Pin Function
1	COMP	Boost compensator pin.
2	SDA	I^2C compatible serial data input/output.
3	SCL	I^2C compatible serial clock input.
4	VDC	De-couple capacitor for internally generated supply rail.
5, 10, 21	AGND	Analog GND.
6	A0	Device Address Select (7bits), A0 = 0 (Low) → (0x6Ch), A0 = 1 (High) → (0x6Eh).
7	CH6	Current sink for LED6.
8	CH5	Current sink for LED5.
9	CH4	Current sink for LED4.
11	CH3	Current sink for LED3.
12, 18	NC	Not connected.
13	CH2	Current sink for LED2.
14	CH1	Current sink for LED1.
15	VOUT	Output of boost converter.
16, 17	PGND	Power ground (SW power return)
19, 20	SW	Drain of internal Power MOSFET.
22	VIN	Power supply input.
23	EN	Enable pin.
24	PWM	PWM dimming control input.
25 (Exposed Pad)	AGND	Power ground (SW power return). The exposed pad must be soldered to a large PCB and connected to AGND for maximum power dissipation.

8 Functional Block Diagram



9 Absolute Maximum Ratings

(Note 2)

- Supply Input Voltage ---------- –0.3V to 26.5V
- VIN, EN, PWM, A0 to AGND ---------- –0.3V to 26.5V
- SW, VOUT, CH1, CH2, CH3, CH4, CH5, CH6 to AGND ---------- –0.3V to 40V
- SDA, SCL, VDC, COMP to AGND ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
- WQFN3x3-24 ---------- 2.42W
- Package Thermal Resistance (Note 3)

  WQFN3x3-24, θ_{JA} ---------- 41.25°C/W

  WQFN3x3-24, θ_{JC} ---------- 7.16°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 4)

  HBM (Human Body Model) ---------- 2kV

  CDM (Charged Device Model) ---------- 1kV

Note 2. Stresses beyond those listed under “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 3. θ_{JA} is simulated under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard. θ_{JC} is simulated at the bottom of the package.

Note 4. Devices are ESD sensitive. Handling precautions are recommended.

10 Recommended Operating Conditions

(Note 5)

- Supply Input Voltage ---------- 2.7V to 24V
- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Note 5. The device is not guaranteed to function outside its operating conditions.

11 Electrical Characteristics

(V_{IN} = 4.2V, C_{VIN} = 1μF, T_A = 25°C, unless otherwise specified.)

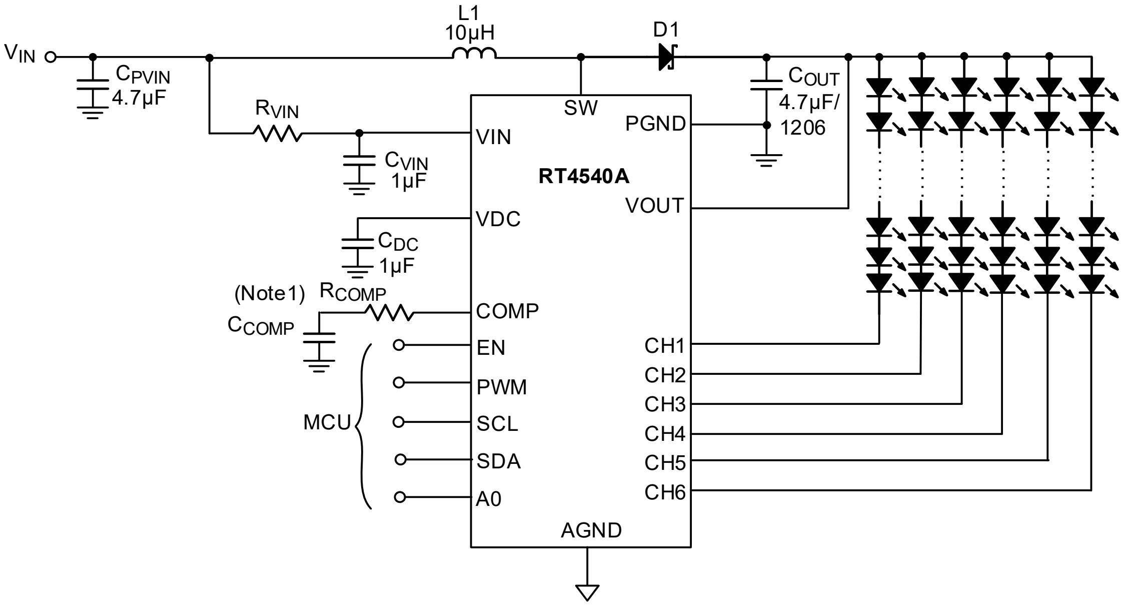
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Power Supply						
Input Supply Voltage	V_{IN}		2.7	4.2	24	V
Quiescent Current	I_Q	EN = H, SW switching 300kHz	--	2.8	--	mA
		EN = H, SW no switching, PWM = 0%	--	2.2	--	
Shutdown Current	I_{SHDN}	V_{IN} = 4.2V, EN = L	--	--	10	μA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Undervoltage-Lockout Threshold	V_{UVLO}		--	2.3	--	V
Undervoltage-Lockout Hysteresis	ΔV_{UVLO}		--	200	--	mV
Interface Characteristic						
EN, PWM, SCL, SDA, A0 Input Voltage	V_{IH}		1.2	--	--	V
	V_{IL}		--	--	0.6	V
Internal Pull-Low Resistor for EN, PWM	R_{PULL_LOW}		--	1	--	MΩ
Internal Pull-High Resistor for A0	R_{PULL_HIGH}		--	100	--	kΩ
Internal Pull-Low Current for SCL, SDA	I_{IH_2}		--	0.01	1	μA
Output Low Level for SDA	V_{OL_SDA}	External pull high current = 3mA	--	0.3	0.5	V
Output Leakage Current for SDA	V_{LK_DIO}	SDA pin voltage = 3.3V	--	--	1	μA
I^2C Interface Timing						
Maximum I^2C Clock Frequency	f_{SCL_MAX}		1	400	--	kHz
Hold Time for START and Repeated START Condition	t_{HD_STA}		0.6	--	--	μs
SCL Clock Low Time	t_{LOW}		1.3	--	--	μs
SCL Clock High Time	t_{HIGH}		600	--	--	ns
Setup Time for a Repeated START Condition	t_{SU_RSTART}		600	--	--	ns
SDA Data Hold Time	t_{HO_DAT}		50	--	--	ns
SDA Data Setup Time	t_{SU_DAT}		100	--	--	ns
Rise Time of SDA, SCL	t_R		--	--	300	ns
Fall Time of SDA, SCL	t_F		--	--	300	ns
Setup Time for STOP Condition	t_{SU_STO}		600	--	--	ns
I^2C Bus Free Time Between a STOP and a START	t_{FREE_BUS}		1.3	--	--	μs
Capacitive Load for I^2C Bus	C_b		--	--	400	pF
Boost Converter						
Switching Frequency Accuracy	f_{SW_ACC}	Boost operates at PWM mode, f_{SW} = 300kHz	–15	--	15	%
Switching Frequency Setting Range	f_{SW_RG}	Boost operates at PWM mode	0.1	--	1.6	MHz
Maximum Duty Cycle	D_{MAX}	f_{SW} = 300kHz	90	95	--	%
Boost Switch RDSON	$R_{DS(ON)}$	V_{IN} = 4.2V	--	250	--	mΩ
Overcurrent Protection	I_{OCP}		2	2.5	3	A

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Boost Minimum On-Time	t_{MON}		--	100	--	ns
VOUT Overvoltage Limit	V_{OVP}	Register address = "02h", 5 bits step = 1V, default = 36V, C_{OUT} = 4.7μF	--	36	--	V
LED Current						
Leakage Current of CHx	I_{LK_CSX}	V_{CHx} = 36V, I_{CHx} = 0mA	--	--	2	μA
Minimum CHx Regulation Voltage	V_{CS_MIN}	I_{CHx} = 20mA	0.35	0.5	--	V
Maximum LED Current Setting	I_{CS_MAX}	LED 100% setting	6	--	25	mA
Minimum LED Current Setting	I_{CS_MIN}	Setting by dimming	100	--	--	μA
LED Current Accuracy	I_{CS_ACC}	PWM duty = 100%, I_{CHx} = 20mA, PWM Freq = 1kHz	−3	--	3	%
		PWM duty = 15%, I_{CHx} = 20mA, PWM Freq = 1kHz	−3	--	3	
		PWM duty = 5%, I_{CHx} = 20mA, PWM Freq = 1kHz	−5	--	5	
		PWM duty = 1%, I_{CHx} = 20mA, PWM Freq = 1kHz	−15	--	15	
LED Current Matching	I_{CS_MAT}	PWM duty = 100%, I_{CHx} = 20mA, PWM Freq = 1kHz	−2	--	2	%
		PWM duty = 15%, I_{CHx} = 20mA, PWM Freq = 1kHz	−2	--	2	
		PWM duty = 5%, I_{CHx} = 20mA, PWM Freq = 1kHz	−5	--	5	
		PWM duty = 1%, I_{CHx} = 20mA, PWM Freq = 1kHz	−10	--	10	
DC Dimming Resolution	S_{res_2k}	PWM Freq ≤ 2kHz	--	4096	--	Steps
	S_{res_4k}	2 < PWM Freq ≤ 4kHz	--	2048	--	Steps
	S_{res_8k}	4 < PWM Freq ≤ 8kHz	--	1024	--	Steps
	S_{res_25k}	8 <PWM Freq ≤ 25kHz	--	512	--	Steps
PWM Minimum On-Time	t_{PWM_MIN}	PWM Dimming Freq = 25kHz	--	400	--	ns
Protection						
OTP Threshold	T_{OTP}		--	150	--	°C
OTP Hysteresis	T_{OTPHYS}		--	20	--	°C
Light Bar Open Threshold	V_{CS_OPEN}		--	0.1	--	V
Light Bar Short Threshold	V_{VLED_SHORT}		--	5.6	--	V
MTP						
Data Write Time	TWR	Timing of write one page into MTP (16 byte)	--	60	--	ms

Note 6. The VIN voltage must rise to at least 2.8V level before I^2C can write to MTP.

12 Typical Application Circuit



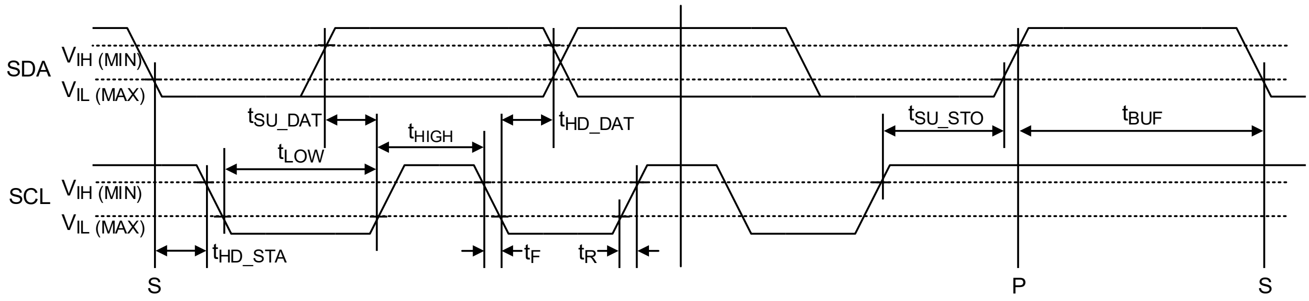
Note 7.

- It is recommended to use differential compensation parameters for low VIN applications.
- For typical applications, LED = 6P11S, boost switching frequency = 1.225MHz, I_{LED} = 20mA/CH, C_{OUT} = 4.7μF, L1 = 10μH, the recommended compensation values are provided in the following table.

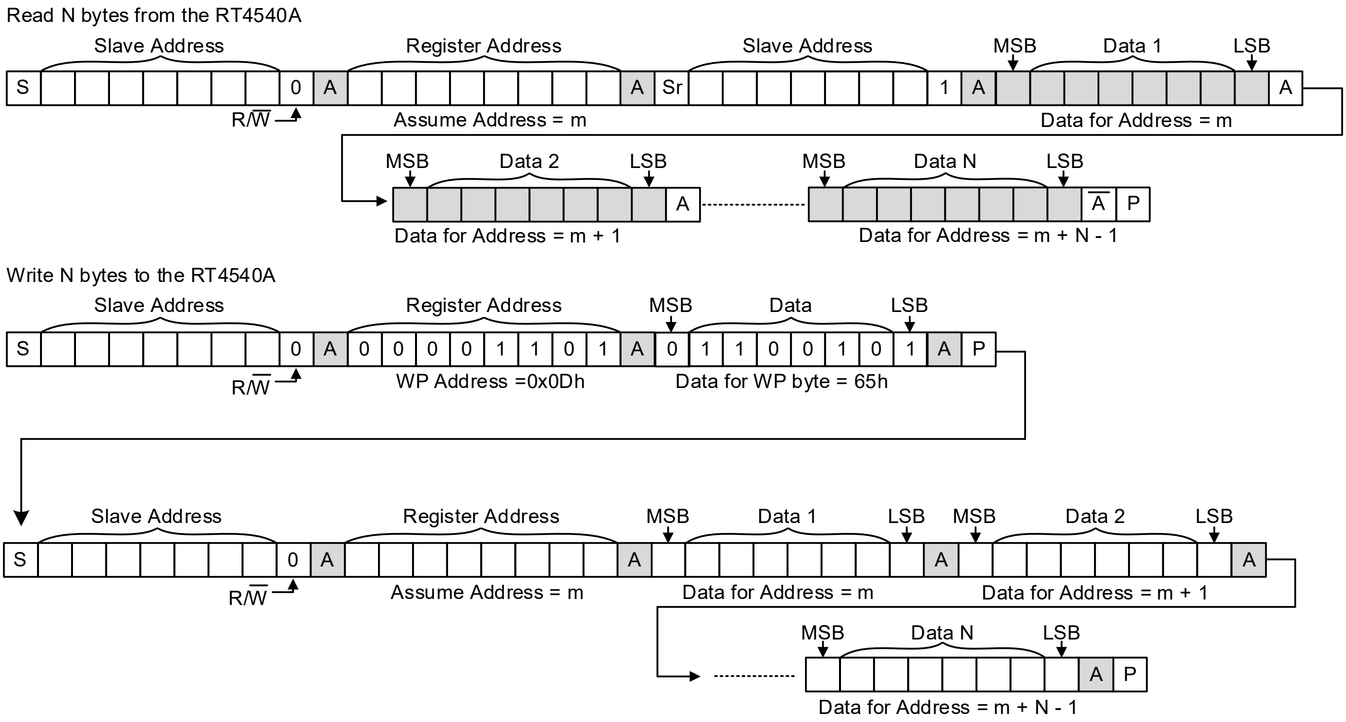
Case	V_{IN} Range (V)	R_{COMP} (kΩ)	C_{COMP} (nF)
Default	7 to 21V	20	1

13 Timing Diagram

13.1 I²C Interface

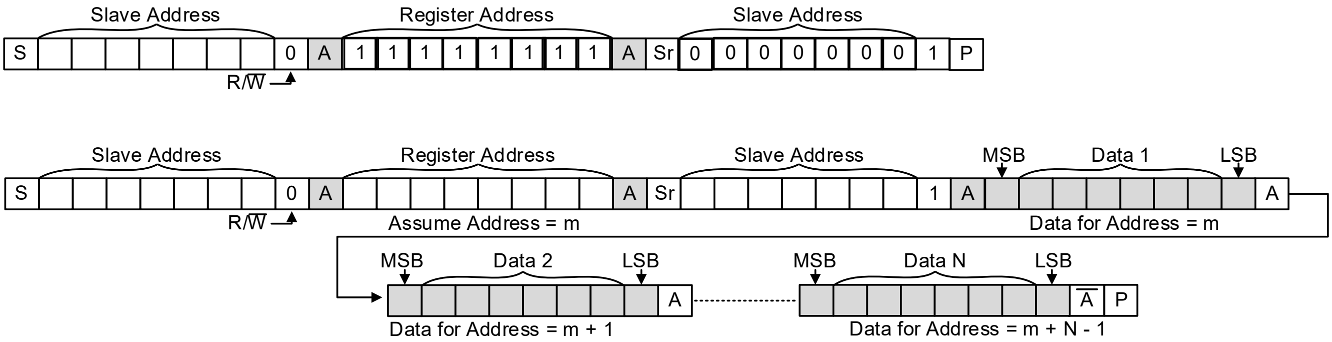


The RT4540A I²C slave address = 7'b0110_110 (A0 = 0) and 7'b0110_111(A0 = 1). I²C interface supports fast mode (bit rate up to 400kb/s). The write or read bit stream (N ≥ 1) is shown below:

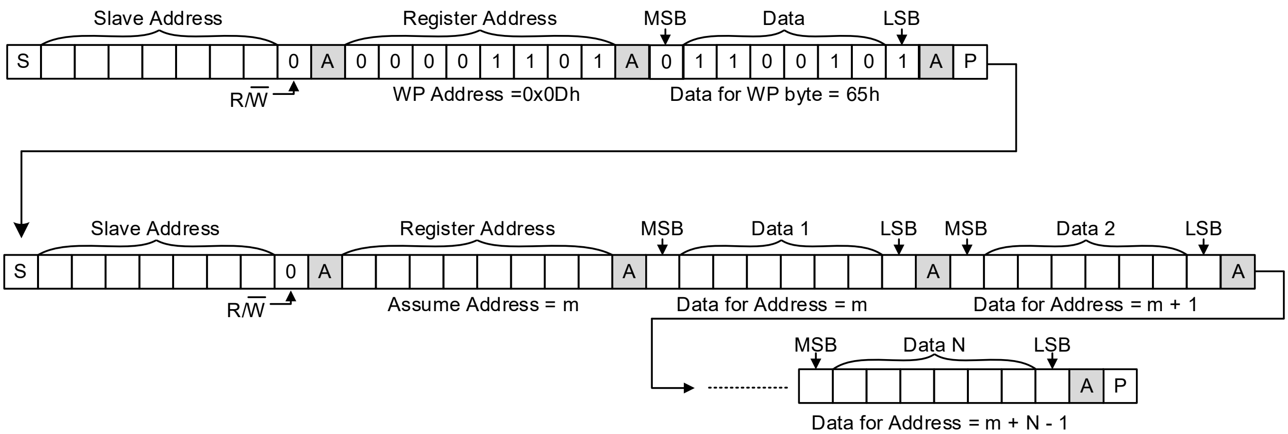


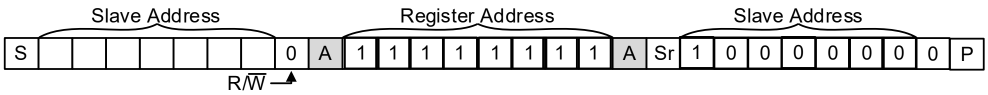
Driven by Master, Driven by Slave (RT4540A), P Stop, S Start, Sr Repeat Start

Read N bytes from the RT4540A (from EEPROM)



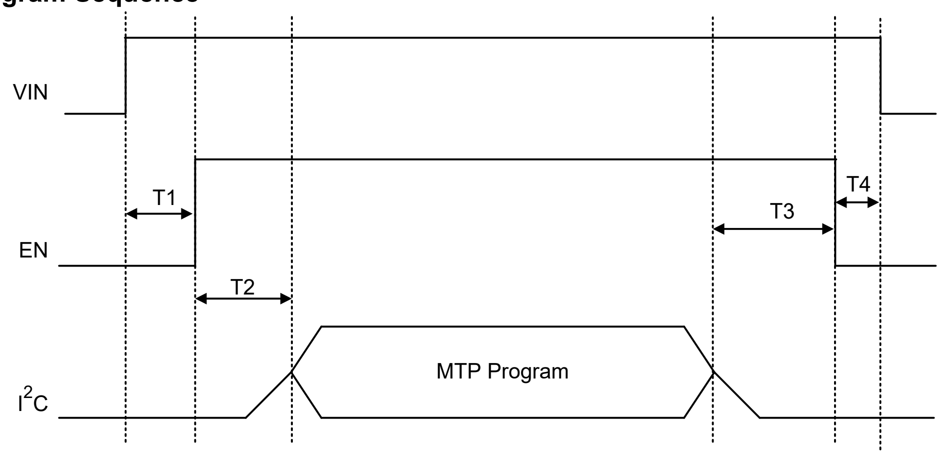
Write N bytes to the RT4540A (to EEPROM)





☐ Driven by Master, ☐ Driven by Slave (RT4540A), P Stop, S Start, Sr Repeat Start

13.2 MTP Program Sequence



Write:

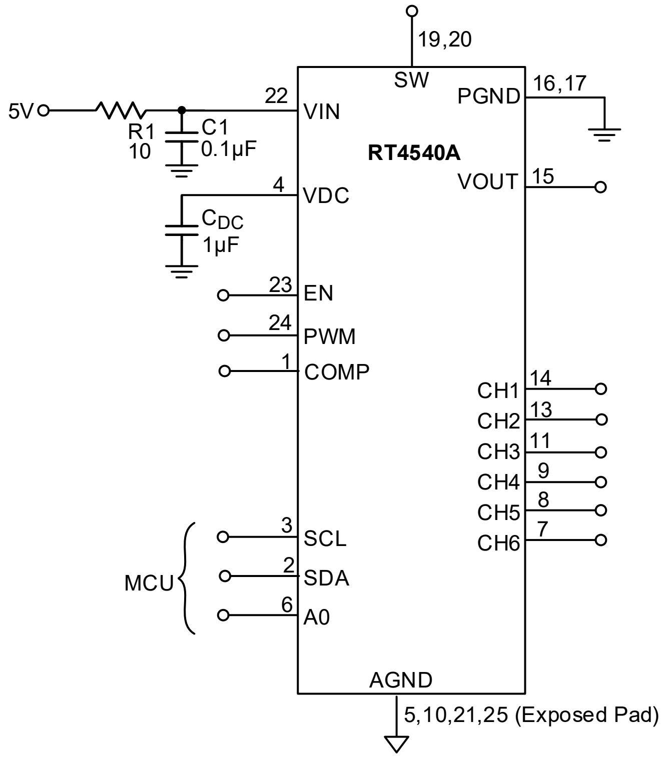
T1 = 30ms, T2 = 50ms, T3 = 500ms, T4 = 100ms

Read

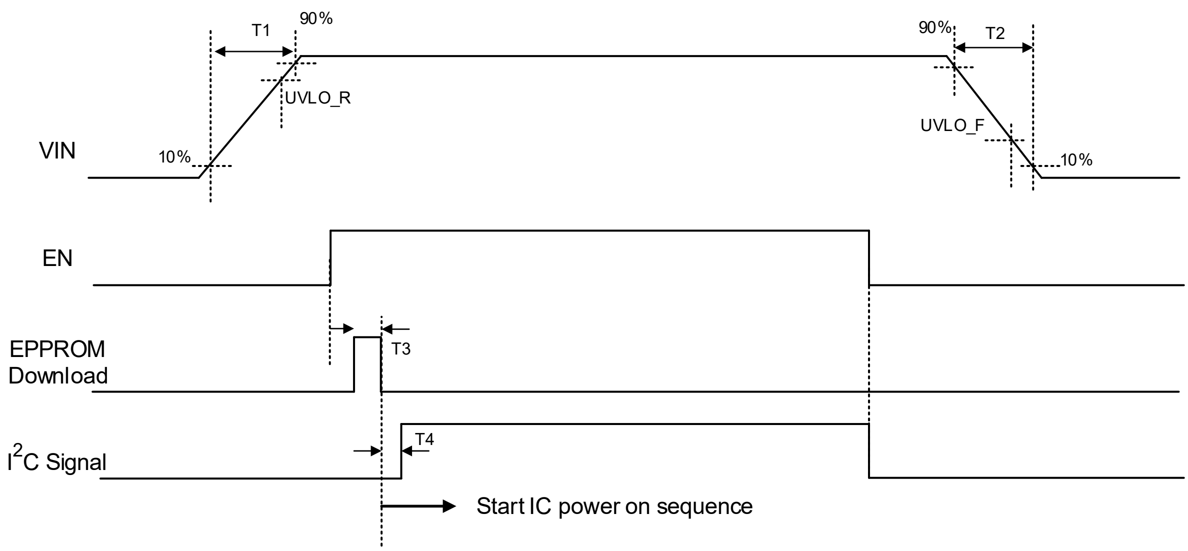
T1 = 30ms, T2 = 50ms, T3 = 10ms, T4 = 100ms

f_{SCL} = 400kHz

13.3 MTP Program Application Circuit for Single Chip



13.4 MTP Download Timing

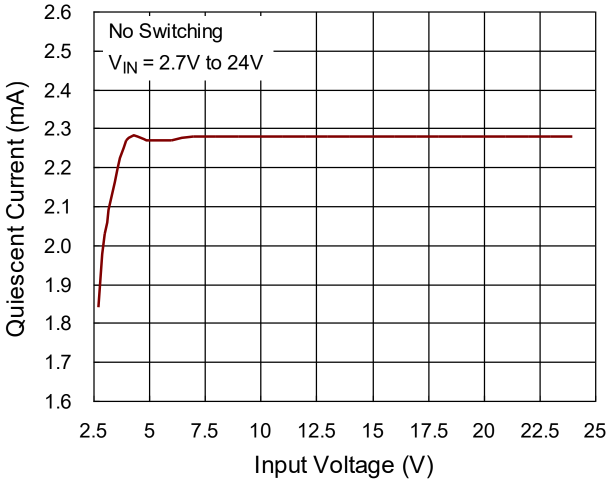


Symbol	Description	Min	Typ	Max	Unit
T1	VIN rising time	0.4	--	20	ms
T2	VIN falling time	0.5	--	3000	ms
T3	EEPROM download time	--	0.3	8 (Note 8)	ms
T4	I^2C setting time	--	1	--	ms

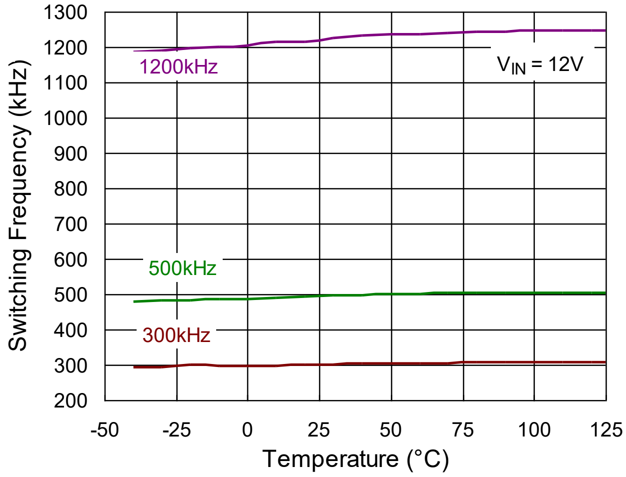
Note 8. Unstable VIN may trigger an extra delay mechanism in EEPROM download to ensure the accuracy of the EEPROM download. The maximum timeout period is 8ms.

14 Typical Operating Characteristics

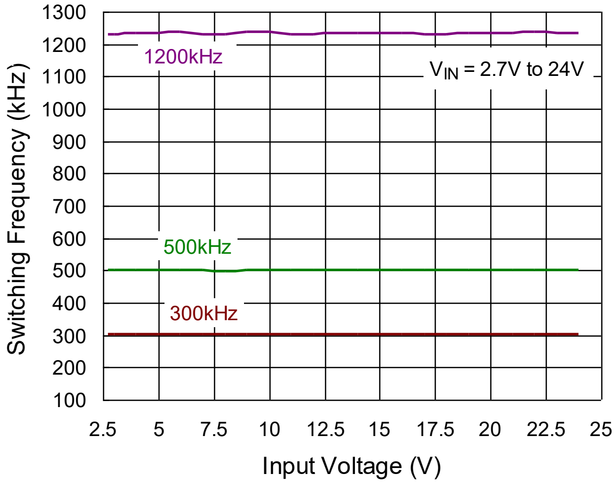
Quiescent Current vs. Input Voltage



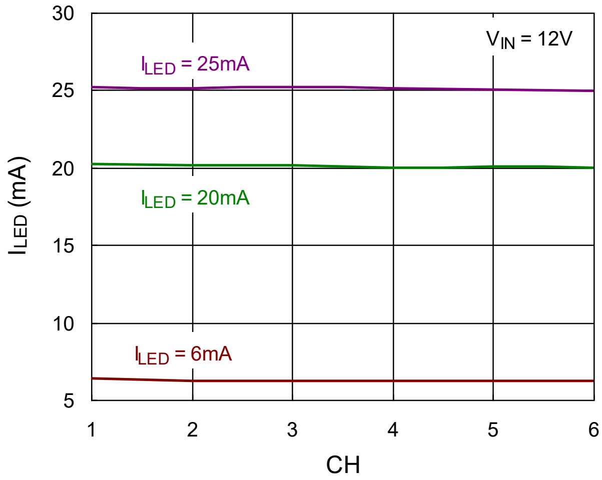
Switching Frequency vs. Temperature



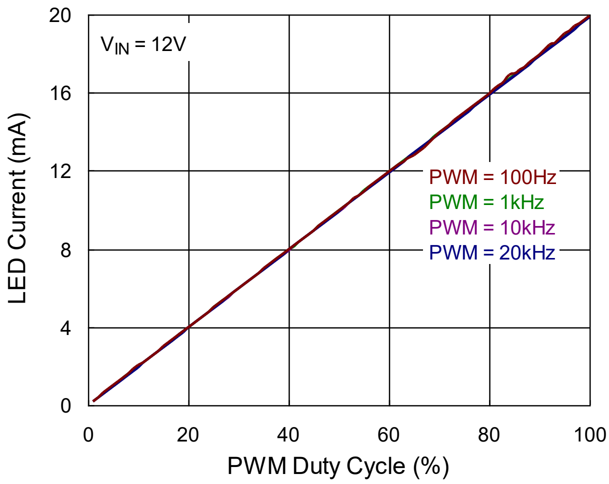
Switching Frequency vs. Input Voltage



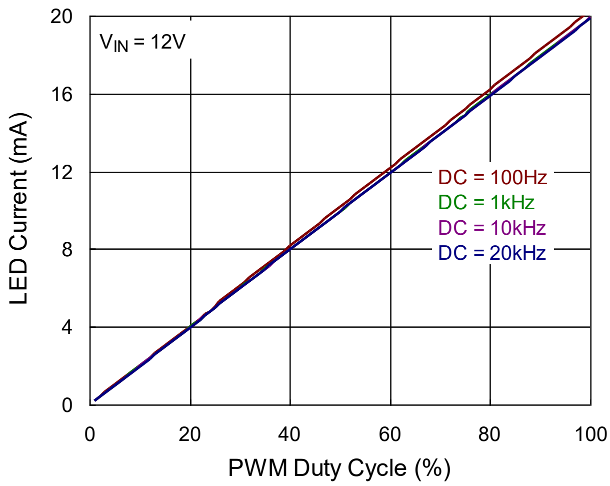
Channel Output Current vs. Channel



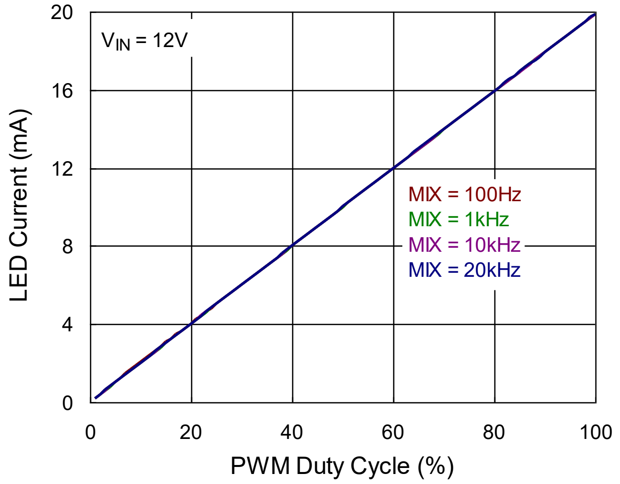
LED Current vs. PWM Duty Cycle PWM Mode



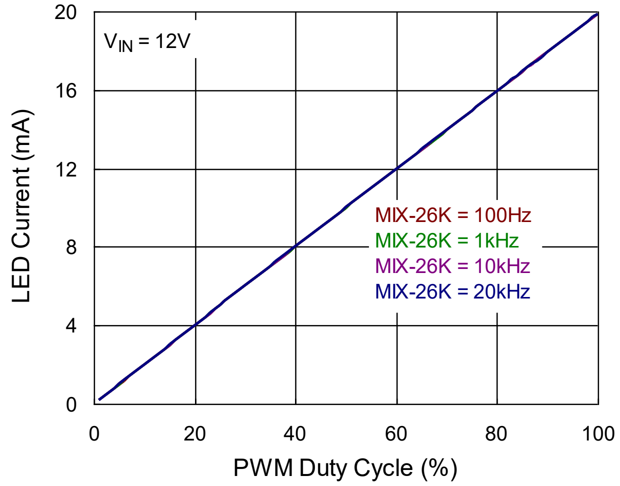
LED Current vs. PWM Duty Cycle DC Mode



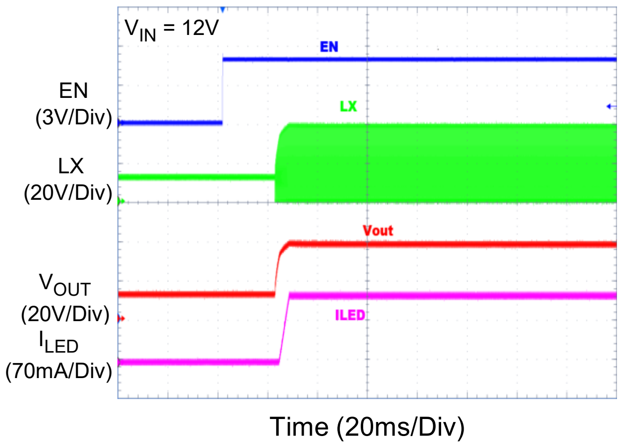
LED Current vs. PWM Duty Cycle MIX Mode



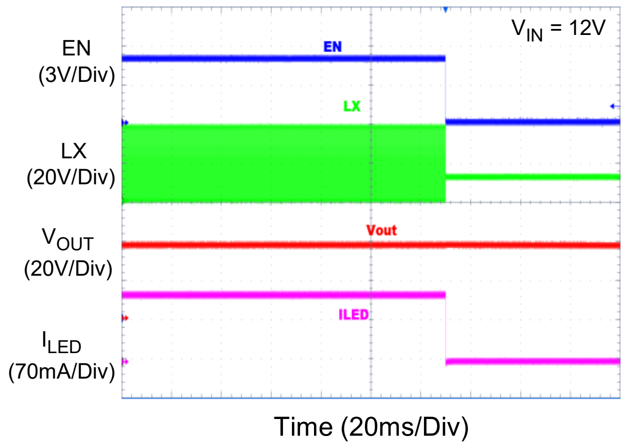
LED Current vs. PWM Duty Cycle MIX-26K Mode



Power On from EN



Power Off from EN



15 Operation

15.1 Enable Control

When VIN is higher than the UVLO voltage and the EN pin input voltage is higher than rising threshold, the VDC will be regulated around 3.3V if VIN is higher than 3.3V.

15.2 Switching Frequency

The LED driver switching frequency is adjusted by the I^2C. The switching frequency is from 100kHz to 1.6MHz.

15.3 PWM Controller

This controller includes some logic circuits to control SW N-MOSFET on/off. This block controls the minimum on-time and the maximum duty of SW. The RT4540A PWM controller is a current mode boost converter integrated with a 250mΩ, 40V power switch and can cover a wide VIN range from 2.7V to 24V and contains I^2C interface. The part integrates undervoltage-lockout, build-in soft-start, analog and digital dimming control; moreover, it provides the overvoltage, over-temperature and overcurrent limiting protection features.

15.4 OCP and OTP

When SW N-MOSFET peak current is higher than 2.5A (typically), the SW N-MOSFET is turned off immediately and resumed at next clock pulse. When the junction temperature is higher than 150°C (typically), the SW N-MOSFET will be turned off until the temperature is lower than the 130°C (typically).

15.5 Minimum LED Selection

This block detects all LEDx voltage and selects a minimum voltage to EA (Error Amplifier). This function guarantees that the minimum LED pin voltage is typically around 500mV, and VOUT can be boosted to the highest forward voltage of the LED strings.

15.6 LED Open Detection

If the voltage at LEDx pin is lower than 100mV, this channel is defined as open channel and the Minimum LED Selection function will discard it to regulate other used channels in proper voltage.

15.7 LED Strings Short Detection

If the CHx pin voltages exceed approximately 5.6V during normal operation, the channels will be turned off and can be reset by EN or UVLO.

16 Application Information

(Note 11)

16.1 Register Map

Note: Blank part in table is restricted register.

<table>
<tr><td colspan="10">Slave Address: b0110110/b0110111</td></tr>
<tr><th>Register Address</th><th>bit 7</th><th>bit 6</th><th>bit 5</th><th>bit 4</th><th>bit 3</th><th>bit 2</th><th>bit 1</th><th>bit 0</th><th>Default Value</th></tr>
<tr><td>0x00</td><td colspan="6">Reserved[7:2]</td><td colspan="2">Dimming Mode Selection</td><td>01h</td></tr>
<tr><td>0x01</td><td colspan="8">ILED Current Setting</td><td>8Dh</td></tr>
<tr><td>0x02</td><td>Boost Compensation Mode</td><td colspan="5">Overvoltage Protection Selection</td><td colspan="2">VIN UVLO Selection</td><td>E8h</td></tr>
<tr><td>0x03</td><td colspan="2">Reserved[7:6]</td><td>PFM Function Enable</td><td>Reserved</td><td colspan="4">Boost Switching Frequency</td><td>24h</td></tr>
<tr><td>0x04</td><td colspan="6">Lowest Switching Frequency for PFM</td><td colspan="2">SW Edge Rate Control</td><td>F3h</td></tr>
<tr><td>0x05</td><td colspan="8">Reserved[7:0]</td><td>00h</td></tr>
<tr><td>0x06</td><td colspan="6">Reserved[7:2]</td><td colspan="2">LED Driver Headroom</td><td>22h</td></tr>
<tr><td>0x07</td><td colspan="3">Reserved[7:5]</td><td>LED Short Protection</td><td colspan="2">Reserved[3:2]</td><td colspan="2">LED OVP Level</td><td>00h</td></tr>
<tr><td>0x08</td><td>Reserved</td><td>Fading Time Duty Change Threshold</td><td colspan="3">Fading Time_SEL2</td><td colspan="3">Fading Time_SEL1</td><td>00h</td></tr>
<tr><td>0x09</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0x0A</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0x0B</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0x0C</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0x0D</td><td colspan="8">Soft-ware WP Code [7:0]</td><td>65h</td></tr>
<tr><td>0x0E</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0x0F</td><td colspan="9">Reserved[7:0]</td></tr>
<tr><td>0xFF</td><td>MTP Programming</td><td colspan="6">Reserved[6:1]</td><td>MTP Read</td><td>00h</td></tr>
</table>

Note 9.Writing 0 when writing Reserved bit.

The RT4540A is a general purpose 6-channel LED driver and is capable of delivering a maximum 25mA LED current. The IC is a current mode boost converter integrated with a 2.5A power switch, supporting a wide VIN range from 2.7V to 24V. It features I^2C interface for controlling the dimming mode, operating frequency and the LED current. The internal 250mΩ, 40V power switch with current-mode control provides overcurrent protection. The switching frequency of the RT4540A is adjustable from 100kHz to 1.6MHz providing flexibility between efficiency and component size. The part integrates undervoltage-lockout, build-in soft-start, and both analog and digital dimming control. Additionally, it features overvoltage, over-temperature and overcurrent protection.

Programmable functions include:

- PWMO frequency
- LED constant current
- Boost switching frequency
- Slope for brightness changes
- Output current resolution

16.2 Brightness Control by PWM Pin

The RT4540A provides four dimming modes for controlling LED brightness: PWM mode, DC mode, Mix mode, and Mix-26k mode. The dimming mode can be set by register 00h. The RT4540A supports PWM to Analog, PWM to Mix and PWM to Mix-26kHz dimming up to 4kHz and 11-bit resolution.

Table 1. Dimming Control Mode Selection

Address	Bit	Name	Default Value	Description	R/W
00h	[1:0]	Dimming Mode Selection	DC Mode (01b)	00b: PWM mode 01b: DC mode 10b: MIX mode 11b: MIX-26k mode	R/W

16.3 LED Current Setting

The LED current for each channel can be set by I^2C command; it is shown in the Table 2.

Table 2. LED Current Setting

Address	Bit	Name	Default Value	Description	R/W
01h	[7:0]	LED Current Setting	20mA (0x8Dh)	Control the max current. 0x01h to 0xBFh: 6mA to 25mA (as shown in the table below)	R/W

The LED current step size is approximately 0.1mA.

LED_Curr <7:0>	I_{LED} (mA)	LED_Curr <7:0>	I_{LED} (mA)	LED_Curr <7:0>	I_{LED} (mA)	LED_Curr <7:0>	I_{LED} (mA)	LED_Curr <7:0>	I_{LED} (mA)	LED_Curr <7:0>	I_{LED} (mA)
BF	25	9E	21.7	7D	18.4	5C	15.1	3B	11.8	1A	8.5
BE	24.9	9D	21.6	7C	18.3	5B	15	3A	11.7	19	8.4
BD	24.8	9C	21.5	7B	18.2	5A	14.9	39	11.6	18	8.3
BC	24.7	9B	21.4	7A	18.1	59	14.8	38	11.5	17	8.2
BB	24.6	9A	21.3	79	18	58	14.7	37	11.4	16	8.1
BA	24.5	99	21.2	78	17.9	57	14.6	36	11.3	15	8
B9	24.4	98	21.1	77	17.8	56	14.5	35	11.2	14	7.9
B8	24.3	97	21	76	17.7	55	14.4	34	11.1	13	7.8
B7	24.2	96	20.9	75	17.6	54	14.3	33	11	12	7.7
B6	24.1	95	20.8	74	17.5	53	14.2	32	10.9	11	7.6
B5	24	94	20.7	73	17.4	52	14.1	31	10.8	10	7.5
B4	23.9	93	20.6	72	17.3	51	14	30	10.7	0F	7.4
B3	23.8	92	20.5	71	17.2	50	13.9	2F	10.6	0E	7.3
B2	23.7	91	20.4	70	17.1	4F	13.8	2E	10.5	0D	7.2
B1	23.6	90	20.3	6F	17	4E	13.7	2D	10.4	0C	7.1
B0	23.5	8F	20.2	6E	16.9	4D	13.6	2C	10.3	0B	7
AF	23.4	8E	20.1	6D	16.8	4C	13.5	2B	10.2	0A	6.9
AE	23.3	8D	20	6C	16.7	4B	13.4	2A	10.1	09	6.8
AD	23.2	8C	19.9	6B	16.6	4A	13.3	29	10	08	6.7
AC	23.1	8B	19.8	6A	16.5	49	13.2	28	9.9	07	6.6
AB	23	8A	19.7	69	16.4	48	13.1	27	9.8	06	6.5
AA	22.9	89	19.6	68	16.3	47	13	26	9.7	05	6.4
A9	22.8	88	19.5	67	16.2	46	12.9	25	9.6	04	6.3
A8	22.7	87	19.4	66	16.1	45	12.8	24	9.5	03	6.2
A7	22.6	86	19.3	65	16	44	12.7	23	9.4	02	6.1
A6	22.5	85	19.2	64	15.9	43	12.6	22	9.3	01	6
A5	22.4	84	19.1	63	15.8	42	12.5	21	9.2	00	0
A4	22.3	83	19	62	15.7	41	12.4	20	9.1		
A3	22.2	82	18.9	61	15.6	40	12.3	1F	9		
A2	22.1	81	18.8	60	15.5	3F	12.2	1E	8.9		
A1	22	80	18.7	5F	15.4	3E	12.1	1D	8.8		
A0	21.9	7F	18.6	5E	15.3	3D	12	1C	8.7		
9F	21.8	7E	18.5	5D	15.2	3C	11.9	1B	8.6		

16.4 VIN UVLO Selection

The VIN UVLO selection can be set by the I^2C, as shown in Table 3. When the VIN UVLO selection command is below B00, the VIN UVLO voltage will be kept at 2.3V. The maximum VIN UVLO voltage selection is 3.8V.

16.5 OVP Level Selection

The RT4540A integrates overvoltage protection. The overvoltage protection can be set by the I^2C, and the voltage of overvoltage protection (V_{OVP}) can be selected as Table 3.

16.6 Boost Compensation Mode

The Boost Compensation Mode can be set by the I^2C, as shown in Table 3.

Table 3. VIN UVLO Selection and OTP Selection

Address	Bit	Name	Default Value	Description	R/W
02h	[1:0]	VIN UVLO Selection	2.3V (00b)	VIN UVLO selection 00b: 2.3V 01b: 2.7V 10b: 3.2V 11b: 3.8V	R/W
	[6:2]	Overvoltage Protection Selection	36V (0x1Ah)	Boost output overvoltage protection 0x00h to 0x1Eh: 10V to 40V (as shown in the table below)	R/W
	[7:7]	Boost Compensation	Internal(01b)	Boost compensation mode 00b: External 01b: Internal	R/W

Overvoltage Protection Selection [6:2]	Boost Output Overvoltage (V)
0x00h	10
0x01h	11
0x02h	12
0x03h	13
0x04h	14
0x05h	15
0x06h	16
0x07h	17
0x08h	18
0x09h	19
0x0Ah	20
0x0Bh	21
0x0Ch	22
0x0Dh	23
0x0Eh	24
0x0Fh	25
0x10h	26
0x11h	27
0x12h	28
0x13h	29
0x14h	30

Overvoltage Protection Selection [6:2]	Boost Output Overvoltage (V)
0x15h	31
0x16h	32
0x17h	33
0x18h	34
0x19h	35
0x1Ah	36
0x1Bh	37
0x1Ch	38
0x1Dh	39
0x1Eh	40

16.7 Boost Switching Frequency Setting

The LED driver switching frequency is adjusted by the I^2C, the switching frequency setting range and resolutions are shown in Table 4.

16.8 PFM Function Enable

The PFM function can be set by I^2C command; it is shown in Table 4.

Table 4. Switching Frequency Setting

Address	Bit	Name	Default Value	Description	R/W
03h	[3:0]	Boost Switching Frequency	300kHz (0x04h)	0x00h: 100kHz 0x04h: 300kHz 0x0Fh: 1600kHz (as shown in the table below)	R/W
	[5:5]	PFM Function Enable	1b	0b: Off 1b: On	R/W

Boost Switching Frequency [3:0]	Frequency (kHz)
0x00h	100
0x01h	150
0x02h	200
0x03h	250
0x04h	300
0x05h	400
0x06h	500
0x07h	600
0x08h	700
0x09h	800
0x0Ah	900
0x0Bh	1000
0x0Ch	1225
0x0Dh	1335
0x0Eh	1450
0x0Fh	1600

16.9 SW Slew Rate Control

The LED driver SW slew rate is adjusted by the I^2C, the slew rate level and resolutions are shown in Table 5.

16.10 Lowest Switching Frequency for PFM

The lowest switching frequency for PFM is adjusted by the I^2C, with the setting formula shown in Table 5.

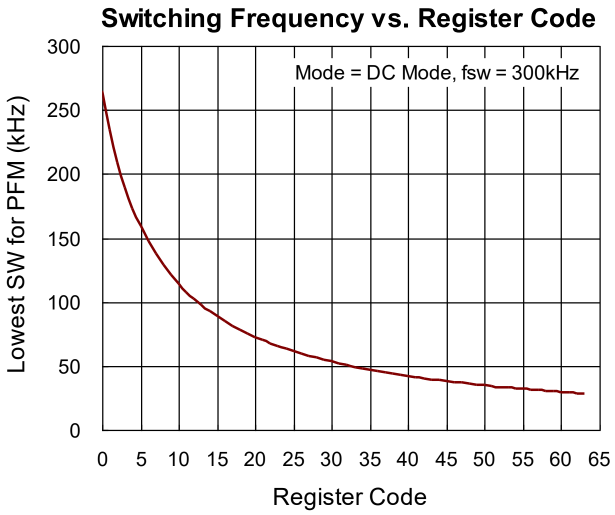
Table 5. SW Slew Rate and Lowest Switching Frequency of PFM Control

Address	Bit	Name	Default Value	Description	R/W
04h	[1:0]	SW Edge Rate Control	200% (11b)	00b: 25% 01b: 50% 10b: 100% 11b: 200%	R/W
	[7:2]	Lowest Switching Frequency for PFM	0x3Ch	Lowest switching frequency setting formula: 16000/{(16000/fsw)+(8*DAC)+7} (Note 10)	R/W

Note 10.

- f_{SW} = Boost switching frequency setting by address 0x03h[3:0]
- DAC = Lowest Switching Frequency for PFM setting by address 0x04h[7:2]

The PFM function can be enabled or disabled by address 03h[5:5]. When the bit is set to 0, the boost switching frequency is determined solely by the switching frequency setting. When set to 1, the boost switching frequency will decrease if the boost on-time falls below the minimum on-time.



16.11 LED Driver Headroom

The LED driver headroom can be set by the I^2C, as shown in Table 6.

Table 6. LED Driver Headroom Setting

Address	Bit	Name	Default Value	Description	R/W
06h	[1:0]	LED Driver Headroom	10b	LED driver headroom 00b: 400mV 01b: 460mV 10b: 500mV 11b: 560mV	R/W

This block detects all CHx voltage and selects a minimum voltage to EA (Error Amplifier). When the LED driver headroom command is below B00, the LED driver headroom will be kept at 500mV and Vout can be boosted to the highest forward voltage of LED strings. The maximum LED driver headroom voltage is 560mV.

LED Protection

The RT4540A has LED protection for LED OVP level. The LED protection can be set by the I^2C, as shown in Table 7.

Table 7. LED Protection Setting

Address	Bit	Name	Default Value	Description	R/W
07h	[1:0]	LED OVP Level	00b	LED OVP level 00b: 2.1V 01b: 2.52V 10b: 2.8V 11b: 3.5V	R/W
	[4:4]	LED Short Protection	0b	0b: Off 1b: On	R/W

16.12 LED OVP level

The LED OVP level can be configured by address 07h[1:0], with four selectable levels ranging from 2.1V to 3.5V. When the setting is below B00, the LED OVP level is fixed at 2.1V, ensuring the minimum CHx voltage up to the target level will be kept at 2.1V. This function can guarantee the highest LED OVP level is 3.5V. When the minimum CHx voltage exceeds the selected LED OVP level, the internal switch will turn off. Once the minimum CHx voltage drops below the LED OVP level setting, the internal switch will be turned on again. The minimum CHx voltage is clamped to the LED OVP level.

16.13 LED Short Protection

The LED short protection can be configured by address 07h[4:4]. If the bit equals to 0, it means the function is turned off. Otherwise, if the bit equals to 1, the function is turned on. If any CHx pin voltages exceed the threshold of approximately 5.6V during normal operation, the affected channels will be turned off and it can reset by EN or UVLO.

16.14 Fade IN/OUT Time Control

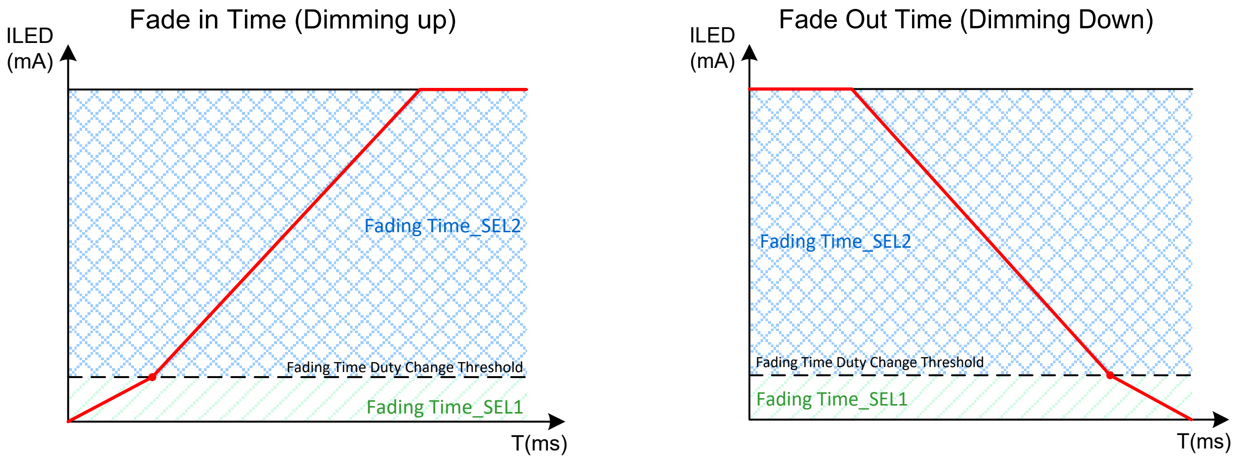
The fading time duty change threshold and fade in/out time control can be set by the I^2C, it is shown in Table 8.

Table 8. Fading Time Control

Address	Bit	Name	Default Value	Description	R/W
08h	[6:6]	Fading Time Duty Change Threshold	0b	0b: 12.5% 1b: 25%	R/W
	[5:3]	Fading Time_SEL2 (Duty > Fading Time Duty Change Threshold)	000b	000b: 1μs 001b: 4μs 010b: 16μs 011b: 64μs 100b: 512μs 101b: 1024μs 110b: 2048μs 111b: 4096μs	R/W
	[2:0]	Fading Time_SEL1 (Duty < Fading Time Duty Change Threshold)	000b	000b: 1μs 001b: 4μs 010b: 16μs 011b: 64μs 100b: 1024μs 101b: 4096μs 110b: 8192μs 111b: 16384μs	R/W

The fade in/out time can be adjusted through address 0x08[6:0] on the I^2C interface, offering 8-level of brightness times ranging from 1μs to 16384μs in Fading Time_SEL1 or 1μs to 4096μs in Fading Time_SEL2.

The fade time duty change threshold can be controlled by address 0x08[6]. If 0x08[6] = 0, and the PWM duty is less than 12.5%, the brightness time per step can be controlled by address 0x08[2:0]; otherwise, it can be controlled by address 0x08[5:3]. If 0x08[6] = 1, and the PWM duty is less than 25%, the brightness time per step can be controlled by address 0x08[2:0]; otherwise, it can be controlled by address 0x08[5:3]. Figure 1 shows the fade in/out time at 11 bits resolution.



(a) LED Current (Dimming Up) vs. Fade In Time (b) LED Current (Dimming Up) vs. Fade Out Time

Figure 1. LED Current (Dimming Down) vs. Fade In/Out Time

16.15 Write Protect function

The RT4540A offers a write-protect function for I2C miswrite scenarios in registers 0x00 through 0x0F. Before programing registers, users need to unlock the WP by writing 0x0D=65h first.

16.16 MTP (Non-Volatile Memory) Function

The RT4540A supports MTP function for MTP Programming, MTP Read. The MTP function can be set by the I^2C, as shown in Table 9. To enable MTP programming via I^2C, the VIN voltage must be raised to 5V.

Table 9. MTP Control Register

Address	Bit	Name	Default Value	Description	R/W
FFh	[0:0]	MTP Read	0b	MTP read 0b: I^2C read data from DAC 1b: I^2C read data from MTP	R/W
FFh	[7:7]	MTP Programming	0b	MTP programming 0b: Normal operation 1b: Start MTP programming sequence	R/W

The MTP register stores the RT4540A default settings. When power-on, the contents of the MTP register are transferred to the I^2C register. The I^2C register can be directly read from and written to for device control, while the MTP register remains unchanged. To update the MTP default values, first write all desired data to the I^2C register. Then, write 0x80 to address FFh; this action will copy all I^2C register data into the MTP register.

16.17 LED Connection

The RT4540A equips 6-CH LED drivers, and each channel supports up to 10 LEDs (Vf = 3V). The LED strings are connected from the output of the boost converter to the LEDx pins (x = 1 to 6), respectively. If one of the current sink channels is not used, the LEDx pin should be connected to GND. If an unused channel is not connected to GND, it will be detected as an open LED string; the channel will resume operation when the LED string is reconnected.

16.18 Open LED Protection

If the LEDx pin voltage drops to 0.1V, the LED driver will detect the channel as open. The LEDx pin voltage will not be regulated and will not latch. Once the LEDx pin is reconnected, normal operation will resume. If all LEDx pins are open (floating), the output voltage will be clamped to the OVP setting ($V_{OUT(OVP)}$).

16.19 Compensation

The regulator loop can be compensated by adjusting the external components connected to the COMP pin. The COMP pin is the output of the internal error amplifier. The compensation capacitor adjusts the integrator zero to maintain stability, and the resistor value adjusts the frequency integrator gain for a fast transient response. The typical values of the compensation components are C_{COMP} = 1nF and R_{COMP} = 20kΩ.

16.20 PWM, DC, Mix, and Mix-26k Mode Brightness Dimming

The RT4540A supports four dimming modes: PWM, DC, Mix and Mix-26K. The dimming mode can be selected via register 00h.

Table 10. Input PWM Dimming Frequency vs. Duty (Mixed, Mixed-26k, PWM, and DC Dimming Mode)

Dimming Frequency (Hz)	Duty (Min)	Duty (Max)
$100 < f_{PWM} \leq 200$	0.50%	100%
$200 < f_{PWM} \leq 500$	0.50%	100%
$500 < f_{PWM} \leq 1k$	0.50%	100%
$1k < f_{PWM} \leq 2k$	0.50%	100%

Note: The minimum duty values shown in the table are based on the application circuit and do not account for current linearity deviations when f_{PWM} > 2kHz. At duty (minimum), the I_{LED} may not reach the set value due to variations in the VOUT/VIN ratio. For high accuracy in LED current, it is recommended to set the I_{LED} current to the default code.

16.20.1 PWM Mode Dimming

When address 00h [1:0] = 00h, the dimming mode operates in PWM mode. In PWM dimming, the current source is turned on and off in synchronization with the PWM signal. The LED current frequency matches the PWM input frequency.

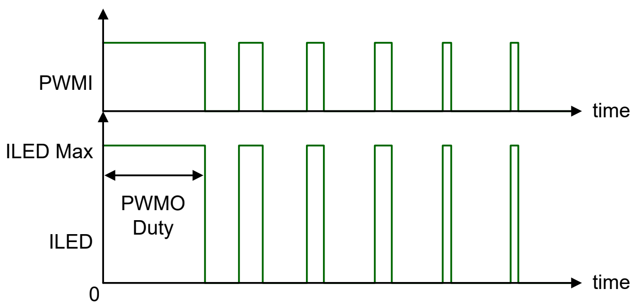


Figure 2. PWM Dimming

16.20.2 DC Mode Dimming

When address 00h [1:0] = 01h, the dimming mode operates in DC mode. In DC mode, both the PWM signal and ILED current experience a two-cycle delay. The first cycle delay is required for period synchronization, while the second cycle delay is used for duty rate calculation.

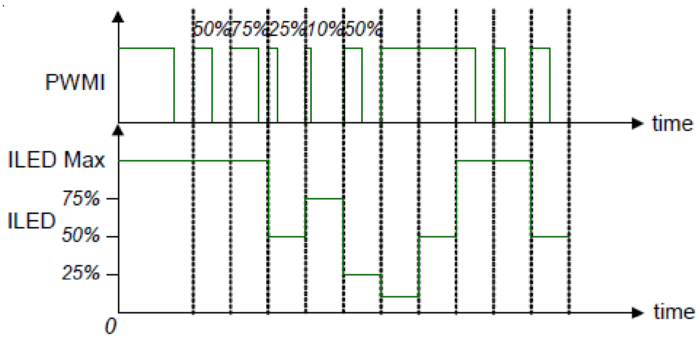


Figure 3. DC Dimming

16.20.3 Mix/Mix-26k Mode Dimming

When address 00h [1:0] = 02 ~ 03h, the dimming mode operates in Mix / Mix-26K mode. The PWM and ILED will delay two periods. First cycle delay is required for period, while the second cycle delay is for the duty rate calculation.

When 25% ≤ PWM duty ≤ 100%, the current source outputs are DC dimming, and the

PWM duty cycle modulates the amplitude of the currents in 100% dimming.

When PWM Duty < 25%, the DC dimming will transition to DC-PWM dimming to control the LED current. In this state, the LED current is fixed at 0.25 x ISET, and the effective dimming duty is 4 x PWM Duties. The dimming frequency in Mix-26K mode ranges from 24kHz to 27.5kHz.

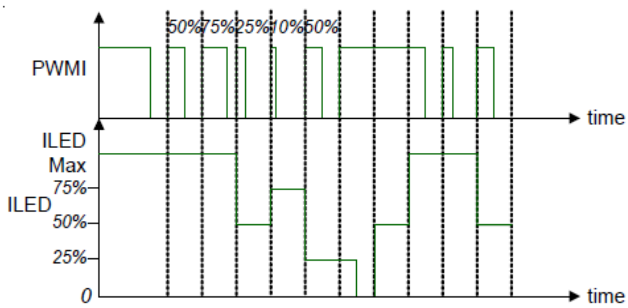


Figure 4. Mixed Mode Dimming

*During DC or Mix Mode dimming, the ILED behavior at PWM duty cycles of 100% and 0% is illustrated in

in Figure 5.

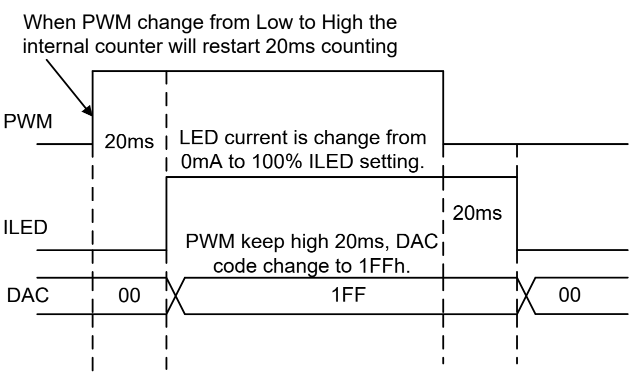


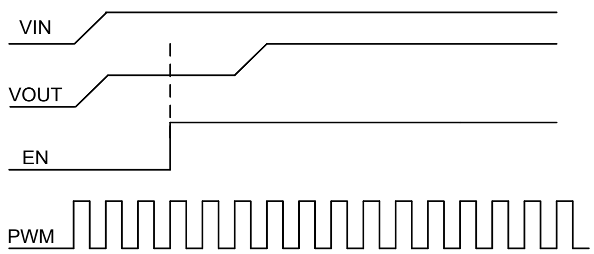
Figure 5. Duty 100% and Duty 0% ILED Behavior

Table 11. Resolution in DC/Mix/Mix-26 Mode

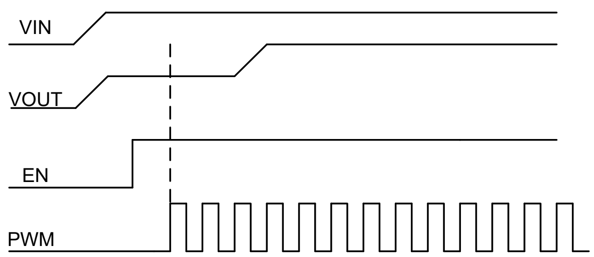
Dimming Frequency (Hz)	Resolution	Jitter Tolerance
100 < $f_{PWM} \leq$ 200	0.05%	±0.02%
200 < $f_{PWM} \leq$ 500	0.05%	±0.02%
500 < $f_{PWM} \leq$ 1k	0.05%	±0.02%
1k < $f_{PWM} \leq$ 2k	0.05%	±0.02%
2k < $f_{PWM} \leq$ 5k	0.1%	±0.04%
5k < $f_{PWM} \leq$ 10k	0.2%	±0.08%
10k < $f_{PWM} \leq$ 20k	0.2%	±0.08%

16.21 Power Sequence

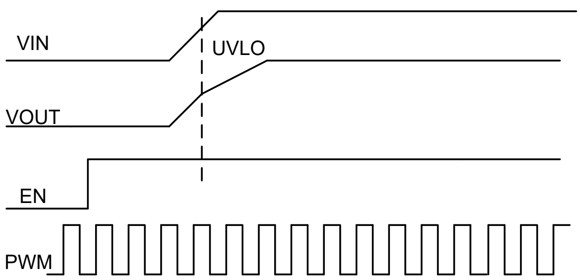
The LED driver does not require a specific power-on sequence; it is power sequence free. The figure illustrates various power-on sequences, all of which are acceptable. There are no concerns regarding power sequence under these conditions.



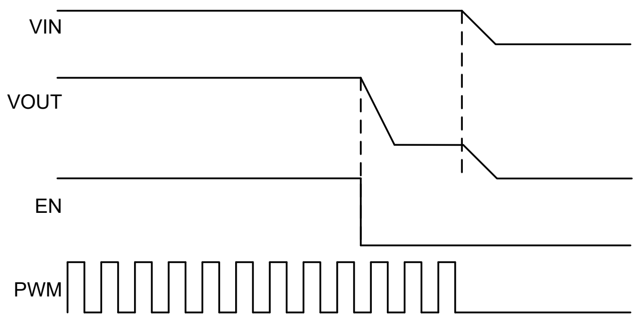
Power On Mode 1



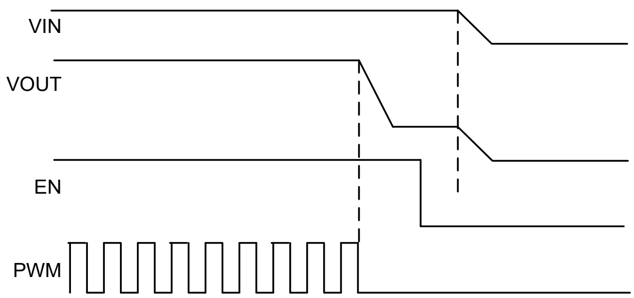
Power On Mode 2



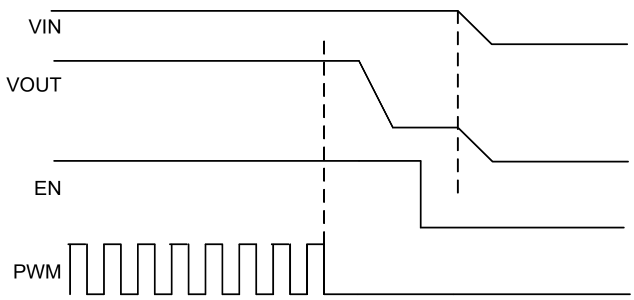
Power On Mode 3



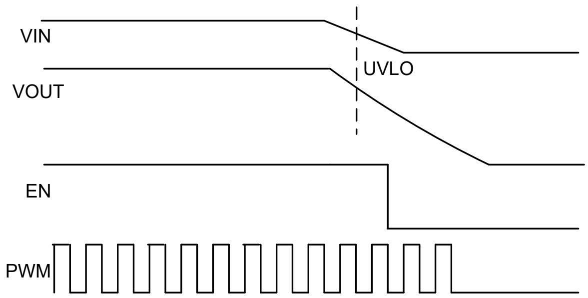
Power Off Mode 1



Power Off Mode 2 (PWM Mode)



Power Off Mode 2 (DC Mode)



Power Off Mode 3

16.22 LED Channel Short Protection

The RT4540A integrates LED Short Protection (SLP). If one of the LED1 to LED6 pin voltages exceeds approximately 5.6V during normal operation, the affected channel will be turned off and latched.

16.23 Overvoltage Protection

The RT4540A features an overvoltage protection (OVP) function, which can be configured via I^2C. When the OVP pin voltage exceeds 40V, the SW N- MOSFET is immediately turned off to protect the SW N-MOSFET.

16.24 Output Short to Ground Protection

The RT4540A integrates output to ground protection. If VOUT triggers an output fault, the IC will stop switching.

16.25 Overcurrent Protection

The RT4540A provides peak current limiting for overcurrent protection. The RT4540 senses the inductor current during the on period through the SW pin. The duty cycle is determined by comparing the current signal and internal slope compensation with the error signal. The internal switch turns off when the current signal exceeds the internal slope compensation. During the off period, the inductor current decreases until the internal transistor is reactivated by the oscillator.

16.26 Over-Temperature Protection

The RT4540A includes over-temperature protection to prevent overheating due to excessive power dissipation. The IC shuts down the IC when the junction temperature exceeds 150°C (typical). Normal operation resumes when the junction temperature cools down to 130°C (TOTP_hys = 20°C).

16.27 Input Capacitor Selection

Low ESR ceramic capacitors are recommended for input capacitor applications. Low ESR will effectively reduce the input ripple voltage caused by the switching operation. Two 2.2μF low ESR ceramic capacitors are sufficient for most applications, but this value can be reduced for lower output current requirements. The voltage rating of the input capacitor must be greater than the maximum input voltage

16.28 Boost Inductor Selection

The inductor value depends on the maximum input current. As a general rule, the inductor ripple current should be 20% to 40% of maximum input current. If 40% is selected as an example, the inductor ripple current can be calculated using the following equation:

$$I_{IN(MAX)} = \frac{V_{OUT} \times I_{OUT(MAX)}}{\eta \times V_{IN}}$$

$$I_{RIPPLE} = 0.4 \times I_{IN(MAX)}$$

where η is the efficiency of the boost converter, $I_{IN(MAX)}$ is the maximum input current, and I_{RIPPLE} is the inductor ripple current. The input peak current can be obtained by adding the maximum input current with half of the inductor ripple current as shown in the following equation:

$I_{PEAK} = 1.2 \times I_{IN(MAX)}$

Note that the saturated current of inductor must be greater than I_{PEAK}. The inductance can eventually be determined according to the following equation:

$$L = \frac{\eta \times (V_{IN})^2 \times (V_{OUT} - V_{IN})}{0.4 \times (V_{OUT})^2 \times I_{OUT(MAX)} \times f_{OSC}}$$

where f_{OSC} is the switching frequency. For better system performance, a shielded inductor is preferred to avoid EMI problems.

16.29 Boost Diode Selection

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

16.30 Boost Output Capacitor Selection

Output ripple voltage is an important index for estimating performance. This portion consists of two parts, one is the product of IIN and ESR of output capacitor, another part is formed by charging and discharging process of output capacitor. As shown in Figure 6, ΔV_{OUT1} can be evaluated based on the ideal energy equalization. According to the definition of Q, the Q value can be calculated as following equation:

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

where f_{OSC} is the switching frequency and ΔI_L is the inductor ripple current. Move C_{OUT} to left side to estimate the value of ΔV_{OUT1} as following equation:

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

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

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

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

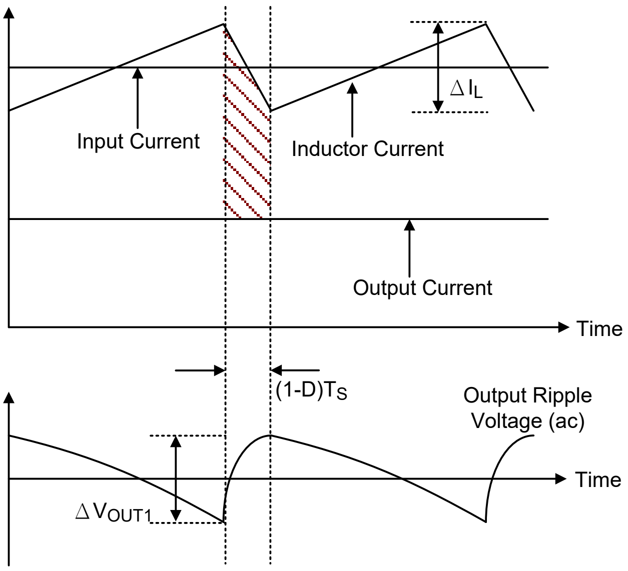


Figure 6. The Output Ripple Voltage Without the Contribution of ESR.

16.31 Peak Current Calculation in DCM

In typical backlight applications, load is low at reduced dimming duty, causing the boost converter to operate in DCM. The peak current through the inductor (I_{L_peak}) in DCM can be calculated using the following equation:

$$I_{L\text{-peak}} = \frac{V_{IN}}{L} D_{DCM} T_S$$

$$D_{DCM} = \sqrt{\frac{2LI_{OUT}(V_{OUT} - V_{IN}) \times fs}{V_{IN}^2}}$$

where D_{DCM} is the duty cycle of the switch turn-on in DCM.

16.32 Loop Compensation

The regulator loop can be compensated by adjusting the external components connected to the COMP pin. The COMP pin is the output of the internal error amplifier. The compensation capacitor will adjust the integrator zero to maintain stability and the resistor value will adjust the frequency integrator gain for fast transient response. Typical value of the compensation components is C_{COMP} = 1nF and R_{COMP} = 20kΩ.

The external compensation network of the RT4540A must be compensated by the designer to ensure the stability of the overall loop response. In power-supply design, a power supply is typically defined to be stable if the gain margin is greater than 10dB and the phase margin is greater than 45°. The loop should cross over with a -1 slope (-20dB/decade) near the crossover frequency.

There is a relationship exists between the phase margin of a second-order closed-loop system and the quality coefficient (Q) of its transfer function. A small phase margin can cause high output ringing, similar to an RLC circuit. On the contrary, a large phase margin reduces overshoot but slows response and recovery speed.

To achieve stability, shape the compensation circuit G(s) to provide adequate phase margin at the selected crossover frequency, together with high DC gain. Choose R_{COMP} to set the high-frequency integrator gain for fast transient response, and C_{COMP} to set the integrator zero for loop stability.

Converter bandwidth and stability are always a trade-off in loop compensation. In PWM mode, the LED current acts as a pulse load, requiring the boost converter to have a larger bandwidth for improved transient ripple performance. For typical applications, LED = 6P11S, boost switching frequency = 1.225MHz, ILED = 24mA/CH, COUT = 4.7μF, L1 = 10μH, while the recommended value for compensation is as follows table:

Case	V_{IN} Range (V)	R_{COMP} (kΩ)	C_{COMP} (nF)
Default	7 to 21V	20	1

16.33 Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula:

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

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

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a WQFN3x3-24 package, the thermal resistance, θ_{JA}, is 37.1°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below:

$P_{D(MAX)}$ = (125°C – 25°C) / (41.25°C/W) = 2.42W for a WQFN3x3-24 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curve in Figure 7 allows the user to see the effect of rising ambient temperature on the maximum power dissipation.

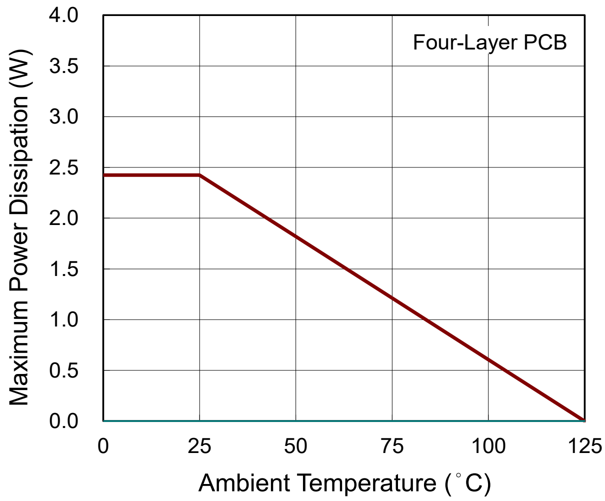
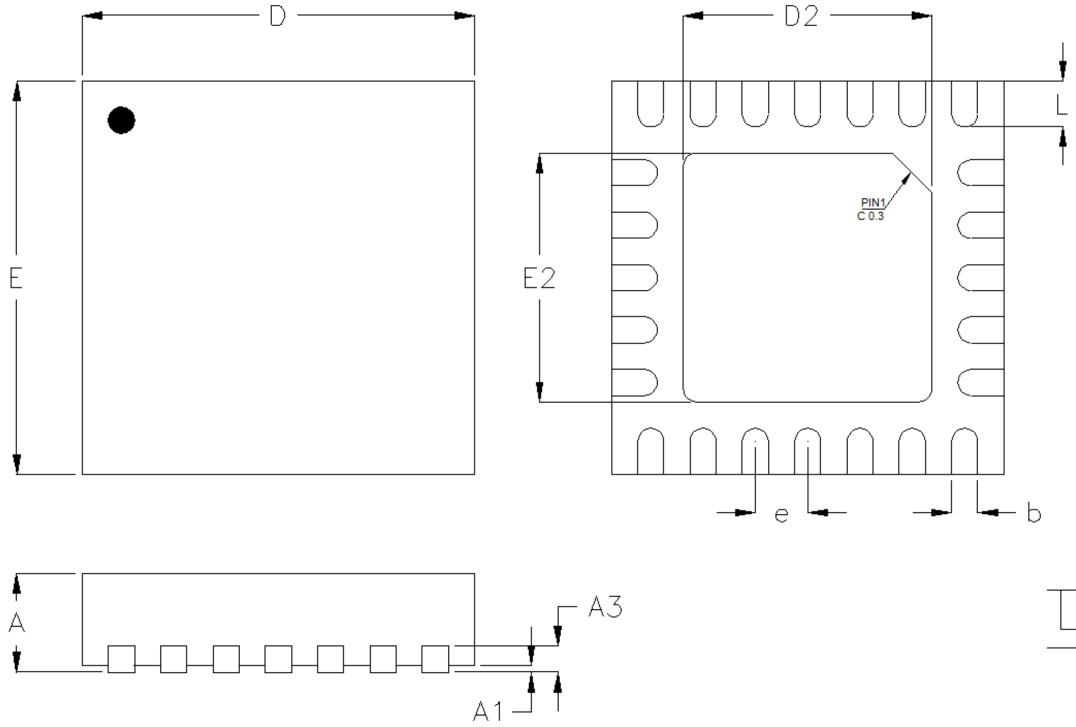
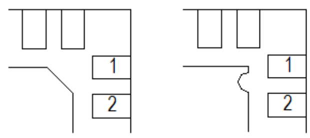


Figure 7. Derating Curve of Maximum Power Dissipation

Note 11. The information provided in this section is for reference only. The customer is solely responsible for designing, validating, and testing any applications incorporating Richtek's product(s). The customer is also responsible for applicable standards and any safety, security, or other requirements.

17 Outline Dimension





DETAIL A

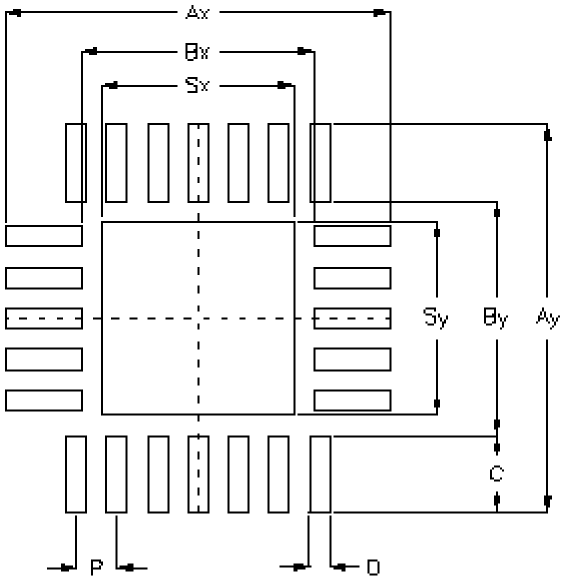
Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.150	0.250	0.006	0.010
D	2.900	3.100	0.114	0.122
D2	1.850	1.950	0.073	0.077
E	2.900	3.100	0.114	0.122
E2	1.850	1.950	0.073	0.077
e	0.400		0.016	
L	0.300	0.400	0.012	0.016

WQFN3x3-24 Package

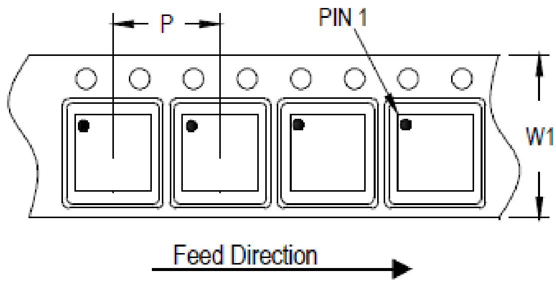
18 Footprint Information

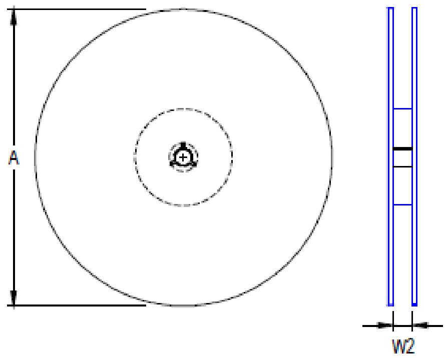


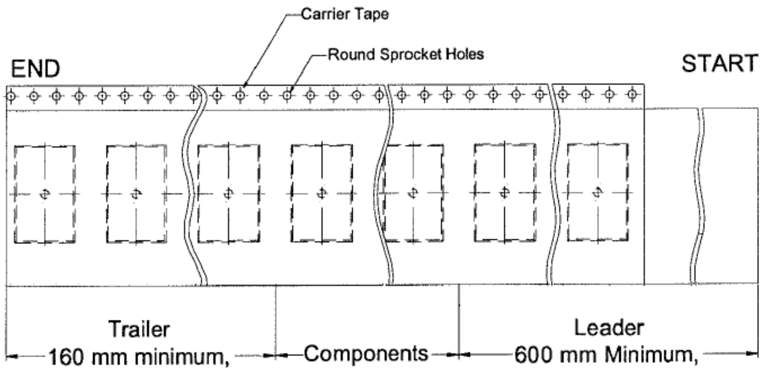
Package	Number of Pin	Footprint Dimension (mm)									Tolerance
		P	Ax	Ay	Bx	By	C	D	Sx	Sy	
V/W/U/XQFN3x3-24	24	0.40	3.80	3.80	2.30	2.30	0.75	0.20	1.90	1.90	±0.05

19 Packing Information

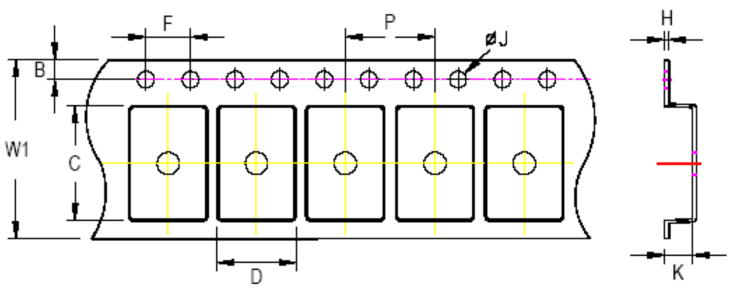
19.1 Tape and Reel Data







Package Type	Tape Size (W1) (mm)	Pocket Pitch (P) (mm)	Reel Size (A)		Units per Reel	Trailer (mm)	Leader (mm)	Reel Width (W2) Min/Max (mm)
			(mm)	(in)				
(V, W) QFN/DFN 3x3	12	8	180	7	1,500	160	600	12.4/14.4



C, D, and K are determined by component size. The clearance between the components and the cavity is as follows:

- For 12mm carrier tape: 0.5mm max.

Tape Size	W1	P		B		F		ØJ		K		H
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Max
12mm	12.3mm	7.9mm	8.1mm	1.65mm	1.85mm	3.9mm	4.1mm	1.5mm	1.6mm	1.0mm	1.3mm	0.6mm

19.2 Tape and Reel Packing

Step	Photo/Description	Step	Photo/Description
1	 Reel 7”	4	 3 reels per inner box **Box A**
2	 HIC & Desiccant (1 Unit) inside	5	 12 inner boxes per outer box
3	 Caution label is on backside of Al bag	6	 Outer box **Carton A**

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Unit
(V, W) QFN & DFN 3x3	7”	1,500	Box A	3	4,500	Carton A	12	54,000
			Box E	1	1,500	For Combined or Partial Reel.		

19.3 Packing Material Anti-ESD Property

Surface Resistance	Aluminum Bag	Reel	Cover tape	Carrier tape	Tube	Protection Band
Ω/cm^2	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**

Richtek Technology Corporation

14F, No. 8, Taiyuan 1st St., Zhubei City,

Hsinchu County 302082, Taiwan (R.O.C.)

Tel: 886-3-5526-789

20 Datasheet Revision History

Version	Date	Description	Item
00	2026/8/10	First Edition	