BCT3253

3ch Current Sink RGB LED driver for illumination

Introduction

The BCT3253 is a three channel current sink RGB LED driver. Each channel can be independent programmed by I2C interface and can be configured up to 256 constant current level. By synchronous clock function, combined operation of three channels is possible. It can be used to make amazing lighting effects of over 67 million colors for portable devices. With the build-in internal RAMs, the RGB lighting effects can be running independently, which can save the system(CPU/MCU/AP) resources. Less than 2 uA shut down current effective extend battery usage time, BCT3253 is lead-free environmental protection products, and the temperature range is -40 ℃ to + 85 ℃. It offers in tiny 12 Pin 1.56 x 1.26 WCSP package, with the thickness of 0.65 mm.

Features

- High speed I2C Interface with 400khz (Slave address is switchable.)
- Build-in 3ch LED Driver Circuit (Max Current Selectable of 63.75 / 31.875 / 25.50 / 12.75mA)
- Each channel has 256 level, programmed by I2C interface.
- Built-in POR (Power On reset) function
- Co-Anode LED level connection

- Direct Replacement for Panasonic AN32059
- 12Pin 1.6 x 1.2 WCSP package

Application

- Mobile phone
- MP3/MP4 /CD/Media Players
- RGB LED drivers
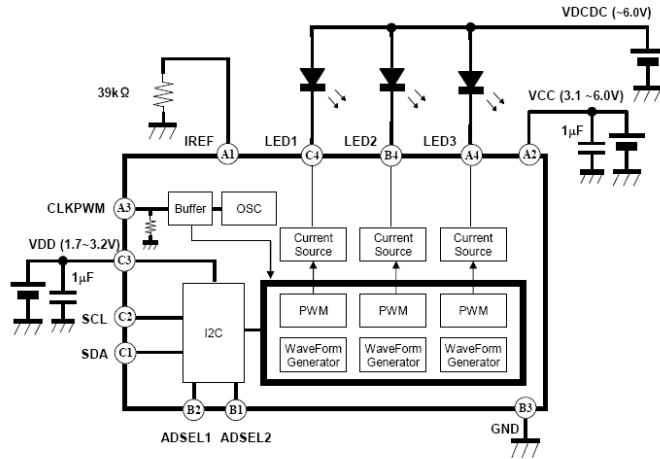- LED Status Indicators

Pin Descriptions (Bottom view)
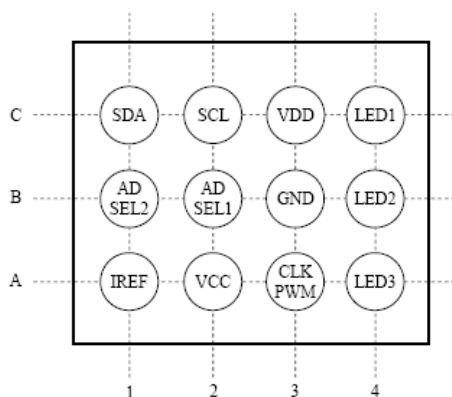
Ordering Information

Order Number	Package Type	Temperature Range	Marking	QTY/Reel
BCT3253EGG-TR	WCSP-12(1.56x1.26)	-40°C to +85°C	LAZ	3000

Typical Application

Notes

1. When LED output pins and CLKPWM pin are not used, it is recommended to leave them floating.
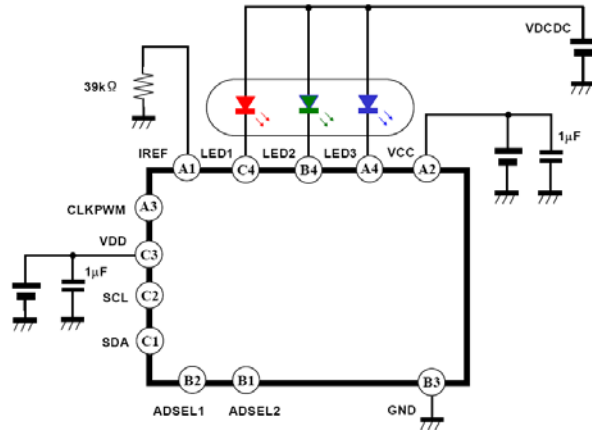
I2C Slave address

ADSEL2	ADSEL1	Address
L	L	30 h
L	H	31 h
H	L	32 h
H	H	33 h

Pin Description

Pin No.	Pin Name	Type	Description
A2	VCC	Power Supply	Power supply connection pin for LED Circuit
C3	VDD	Power Supply	Power Supply connection pin for interface
B3	GND	Ground	GND Pin
C4	LED1	Output	LED1 output pin
B4	LED2	Output	LED2 output pin
A4	LED3	Output	LED3 output pin
A1	IREF	Input	Resistor connection pin for constant current value setting
C2	SCL	Input	I2C Interface clock input pin
C1	SDA	Input/Output	I2C Interface data I/O pin
A3	CLKPWM	Input/Output	Reference clock input output /PWM input pin
B2	ADSEL1	Input	I2C Interface slave address switch pin 1
B1	ADSEL2	Input	I2C Interface slave address switch pin 2

More Application Circuit Examples
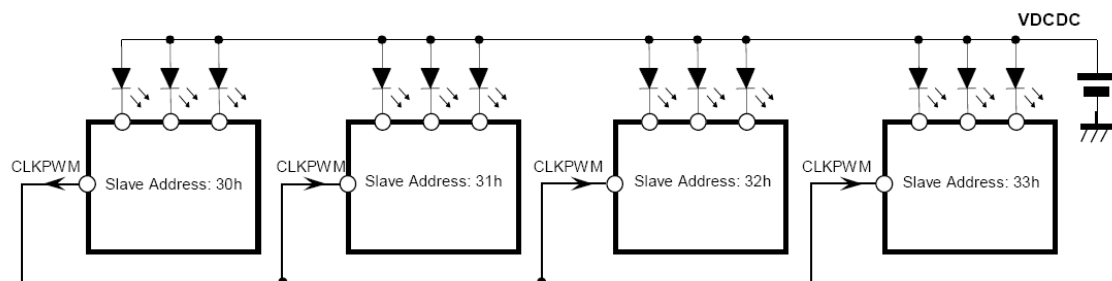
1. Basic RGB Application
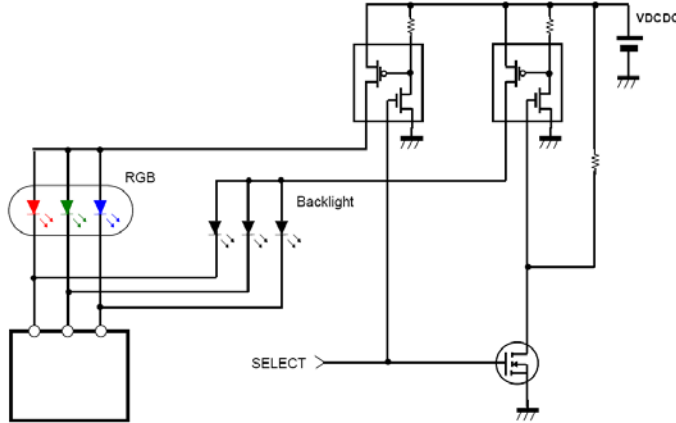

2. Typical Torch Application
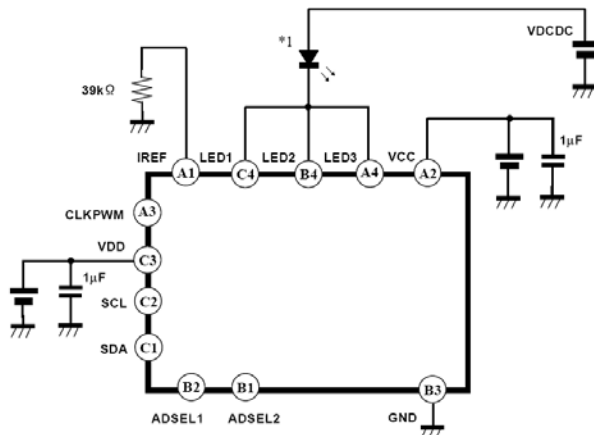
Note) *1 : The maximum current supported is 191.25mA (63.75mA x 3).

3. Connected Application

The IC can be connected and controlled individually by using different slave addresses. It is possible to connect up to 4 of the ICs by using synchronous clock.

4. Multiplex RGB and Backlight Application

Absolute Maximum Ratings

Supply voltage, VCC$_{MAX}$ -- +7.0V

Supply voltage, VDD$_{MAX}$ -- +4.6V

Supply crruent, I$_{cc}$ ---1mA

Power dissipation, P$_d$ --- 46.8 mW

Operating temperature, T$_{opr}$-- -30 °C to +85°C

Storage temperature, T$_{stg}$-- -55 °C to +125°C

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 condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Allowable Voltage Range

Supply voltage, VCC --- -0.2 V ~ +7.0V

Supply voltage, VDD --- -0.2 V ~ +4.6V

Voltage at output pin LED1,LED2,LED3-- 0 V ~ +7.0V

Voltage at input pin IREF --- 0V ~ VCC+0.3V

Voltage at Other input pins -- 0V ~ VDD+0.3V

Electrical Characteristic (part 1)

Note) T_A=25°C, VCC=3.6 V, VDD=1.8V unless otherwise specified.

B No.	Parameter	Symbol	Test Circuit	Conditions	Limits			Unit	Note
					Min	Typ	Max		
Current consumption									
1	Current consumption 1 OFF mode	ICC1	1	VDD=0V	—	0	2	µA	—
2	Current consumption 2 OFF mode	ICC2	1	VDD=1.8V	—	1	5	µA	—
3	Current consumption 3 LED lighting mode	ICC3	1	ILED=25.50 mA setting All LED = ON	—	0.6	1	mA	—
LED Driver									
4	Off time leak current	Ileak	1	Off setting LED*=6.0V	—	—	1.0	µA	—
5	Minimum setting current value 1	Imin1	1	IMAX[1:0]=01, LED*=1.0V	0.05	0.10	0.15	mA	—
6	Minimum setting current value 2	Imin2	1	IMAX[1:0]=01, LED*=1.0V	0.736	0.80	0.864	mA	—
7	Maximum setting current value	Imax	1	IMAX[1:0]=01, LED*=1.0V	23.46	25.50	27.54	mA	—
8	Current step	Istep	1	IMAX[1:0]=01, LED*=1.0V	0.00	0.10	0.18	mA	—
9	Minimum voltage for retainable constant current value	Vsat	1	IMAX[1:0]=01, Terminal minimum voltage of LED* becoming 95% of the LED current value in 1V.	—	0.2	0.4	V	—
10	Error between channels	Imatch	1	12.80mA setting, LED*=1.0V	-5	—	5	%	—

Electrical Characteristic (part 2)

Note) T$_A$=25°C, VCC=3.6 V, VDD=1.8V unless otherwise specified.

B NO	Parameter	Symbol	Test Circuit	Conditions	Min	Typ	Max	Unit	Note
SCL, SDA									
12	High-level input voltage range	VIH1	1	—	VDD×0.7	—	VDD+0.2	V	—
13	Low-level input voltage range	VIL1	1	—	−0.2	—	VDD×0.3	V	—
14	High-level input current	IIH1	1	Vin = 1.8 V	—	0	1	uA	—
15	Low-level input current	IIL1	1	Vin = 0 V	—	0	1	uA	—
16	Low-level output voltage (SDA)	VOL1H	1	Iin =3mA, VDD ＞ 2 V	0	—	0.4	V	—
17	Low-level output voltage (SDA)	VOL1L	1	Iin=3mA, VDD ＜ 2 V	0	—	VDD×0.2	V	—
CLKPWM									
18	High-level input voltage range	VIH2	1	—	VDD×0.7	—	VDD+0.2	V	—
19	Low-level input voltage range	VIL2	1	—	−0.2	—	VDD×0.3	V	—
20	Pin pull down resistance value	RPD2	1	—	0.5	1	2	MΩ	—
21	High-level output voltage	VOH2	1	Iout = −2 mA	VDD×0.8	—	VDD+0.2	V	—
22	Low-level output voltage	VOL2	1	Iout = 2 mA	-0.2	—	VDD×0.2	V	—
ADSEL1, ADSEL2									
23	High-level input voltage range	VIH3	1	—	VDD×0.7	—	VDD+0.2	V	—
24	Low-level input voltage range	VIL3	1	—	−0.2	—	VDD×0.3	V	—
25	High-level input current	IIH3	1	Vin = 1.8 V	—	0	1	uA	—
26	Low-level input current	IIL3	1	Vin = 0 V	—	0	1	uA	—

Electrical Characteristic (Reference values for design) (part 2)

Note) T_A=25°C, VCC=3.6 V, VDD=1.8V unless otherwise specified.

B No.	Parameter	Symbol	Test Circuit	Conditions	Reference Values Min	Reference Values Typ	Reference Values Max	Unit	Note
CLKPWM									
27	External PWM operation mode Data-enabled high pulse width	Wpwm	1	—	2	—	—	µs	—
I2C signal timing									
28	Input voltage hysteresis (1)	Vhys1	1	SCL, SDA hysteresis voltage VDD > 2V	0.05×VDD	—	—	V	—
29	Input voltage hysteresis (2)	Vhys2	1	SCL, SDA hysteresis voltage,VDD > 2V	0.1×VDD	—	—	V	—
30	Spike pulse width kept down by input filter	Tsp	1	—	0	—	50	ns	—
31	I/O pin capacitance	Ci	1	—	—	—	10	pF	—
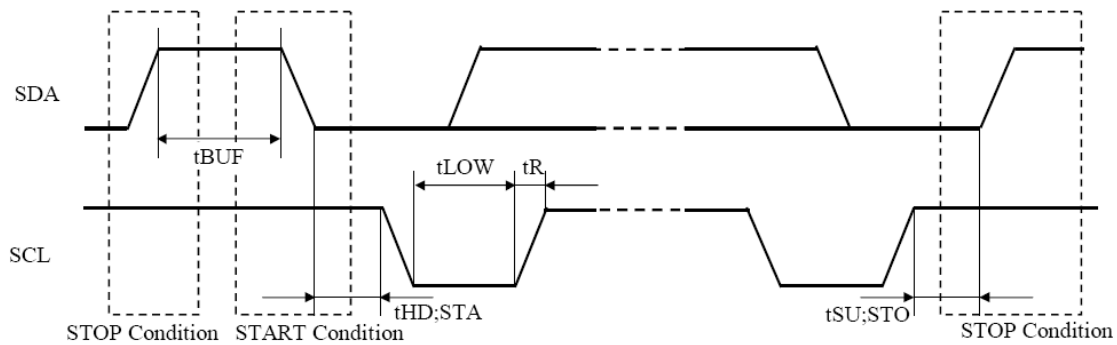
Data recognition condition

Electrical Characteristic (Reference values for design) (part 2)

Note) T_A=25°C, VCC=3.6 V, VDD=1.8V unless otherwise specified.

B No.	Parameter	Symbol	Test Circuit	Conditions	Reference Values Min	Typ	Max	Unit	Note
I2C signal timing									
32	Hold duration (recursive)	tHD:STA	1	After tHD:STA,. the first clock pulse is generated.	0.6	—	—	µs	—
33	SCL clock "L" duration	tLOW	1	—	1.3	—	—	µs	—
34	SCL clock "H" duration	tHIGH	1	—	0.6	—	—	µs	—
35	Recursive 「START」condition setting time	tSU:STA	1	—	0.6	—	—	µs	—
36	Data hold time	tHD:DAT	1	—	0	—	0.9	µs	—
37	Data setup time	tSU:DAT	1	—	100	—	—	ns	—
38	SDA, SCL signal rise up time	tr	1	—	20+0.1 Cb	—	300	ns	—
39	SDA, SCL signal fall time	tf	1	—	20+0.1 Cb	—	300	ns	—
40	Setup time under 「STOP」condition	tSU:STO	1	—	0.6	—	—	µs	—
41	Bus free time between under 「STOP」condition and 「START」condition	tBUF	1	—	1.3	—	—	µs	—
42	Noise margin of each connection device at "L" level	VaL	1	—	0.1×VDD	—	—	V	—
43	Noise margin of each connection device at "H" level	VaH	1	—	0.2×VDD	—	—	V	—

Timing definition of fast /standard mode device on I2C bus.

• Timing definition of fast /standard mode device on I2C bus

S : Start condition
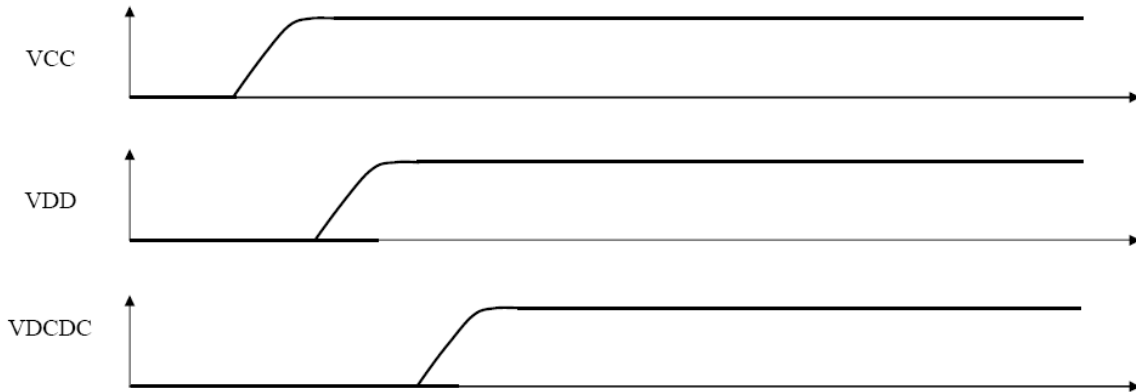Sr : Repetitive start condition
P : Stop condition
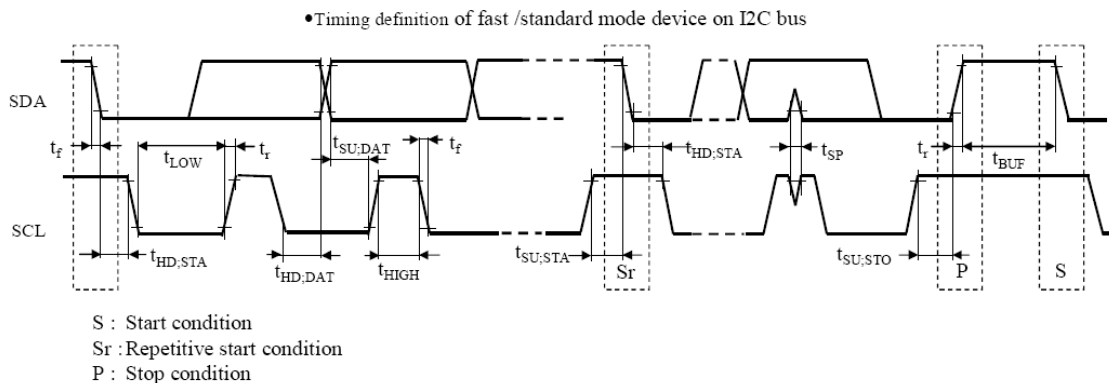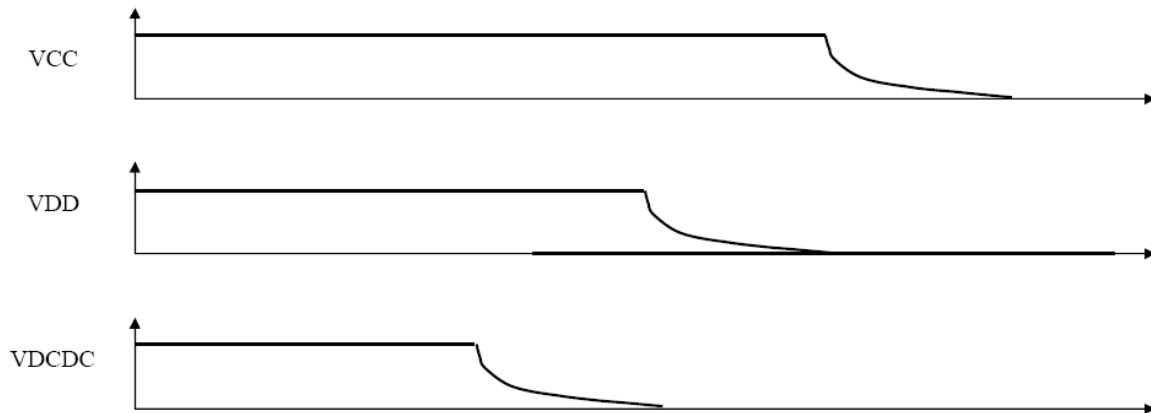
5. Function Block Diagram
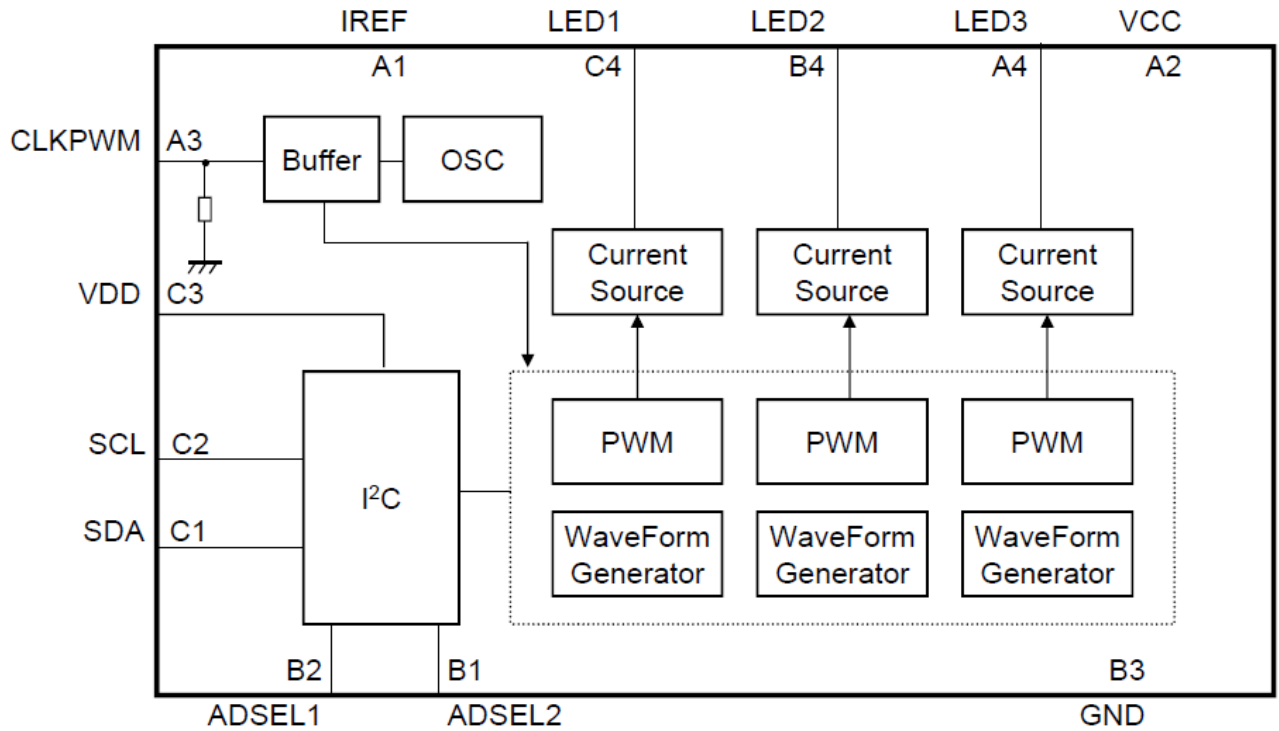
6. Power-on / Power-off Sequence

6.1 Power-on

Note) * : There is no problem if VCC and VDCDC rise at the same time.

6.2 Power-off

Note) * : There is no problem if VCC and VDCDC fall at the same time.

7. Register Map

Sub Address	R/W	Register Name	Data								Note
			D7	D6	D5	D4	D3	D2	D1	D0	
00h	W	SRESET	—	—	—	—	—	—	—	SRESET	
01h	R/W	LEDON	—	LED3MD	LED2MD	LED1MD	—	LED3ON	LED2ON	LED1ON	
02h	R/W	SEL	IMAX [1:0]		IOEN	CLKDIR	EXTPWM	DLYSEL3	DLYSEL2	DLYSEL1	
03h	R/W	LED1CC	LED1CC [7:0]								
04h	R/W	LED2CC	LED2CC [7:0]								
05h	R/W	LED3CC	LED3CC [7:0]								
06h	R/W	LED1SLP	SLP1TT2 [3:0]				SLP1TT1 [3:0]				
07h	R/W	LED2SLP	SLP2TT2 [3:0]				SLP2TT1 [3:0]				
08h	R/W	LED3SLP	SLP3TT2 [3:0]				SLP3TT1 [3:0]				
09h	R/W	LED1CNT1	DUTYMAX1 [3:0]				DUTYMID1 [3:0]				
0Ah	R/W	LED1CNT2	DELAY1 [3:0]				DUTYMIN1 [3:0]				
0Bh	R/W	LED1CNT3	SLP1DT2 [3:0]				SLP1DT1 [3:0]				
0Ch	R/W	LED1CNT4	SLP1DT4 [3:0]				SLP1DT3 [3:0]				
0Dh	R/W	LED2CNT1	DUTYMAX2 [3:0]				DUTYMID2 [3:0]				
0Eh	R/W	LED2CNT2	DELAY2[3:0]				DUTYMIN2 [3:0]				
0Fh	R/W	LED2CNT3	SLP2DT2 [3:0]				SLP2DT1 [3:0]				
10h	R/W	LED2CNT4	SLP2DT4 [3:0]				SLP2DT3 [3:0]				
11h	R/W	LED3CNT1	DUTYMAX3 [3:0]				DUTYMID3 [3:0]				
12h	R/W	LED3CNT2	DELAY3 [3:0]				DUTYMIN3 [3:0]				
13h	R/W	LED3CNT3	SLP3DT2 [3:0]				SLP3DT1 [3:0]				
14h	R/W	LED3CNT4	SLP3DT4 [3:0]				SLP3DT3 [3:0]				

Note) Read value in "-" is [0].

8. Details about Register Map

8.1 Address 00h to 14h

Register Name		SRESET							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
00 h	W	—	—	—	—	—	—	—	SRESET
Default	00 h	0	0	0	0	0	0	0	0

D0 : Software reset pin

   [0] : Normal condition (default)

   [1] : Reset (Reset all the other register and return to Low automatically)

Register Name		LEDON							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
01 h	R/W	—	LED3MD	LED2MD	LED1MD	—	LED3ON	LED2ON	LED1ON
Default	00 h	0	0	0	0	0	0	0	0

D6 : LED3MD LED3 lighting mode setting

   [0] : LED3 constant current mode (default)

   [1] : LED3 slope mode

D5 : LED2MD LED2 lighting mode setting

   [0] : LED2 constant current mode (default)

   [1] : LED2 slope mode

D4 : LED1MD LED1 lighting mode setting

   [0] : LED1 constant current mode (default)

   [1] : LED1 slope mode

D2 : LED3ON LED3 enable control

   [0] : LED3 OFF (default)

   [1] : LED3 ON

D1 : LED2ON LED2 enable control

   [0] : LED2 OFF (default)

   [1] : LED2 ON

D0 : LED1ON LED1 enable control

   [0] : LED1 OFF (default)

   [1] : LED1 ON

LED1 operation mode

D4	D0	LED1 operation mode
LED1MD	LED1ON	
0	0	OFF
1	0	OFF
0	1	ON (constant current mode)
1	1	ON (slope mode)

This mode applies to LED2, LED3 operation

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name		SEL							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
02 h	R/W	IMAX [1:0]		IOEN	CLKDIR	EXTPWM	DLYSEL3	DLYSEL2	DLYSEL1
Default	40 h	0	1	0	0	0	0	0	0

D7-6 : IMAX [1:0] Max value, Step value setting for current setting
    [00] : Max value 12.75mA, Step value 0.05mA
    [01] : Max value 25.50mA, Step value 0.10mA (default)
    [10] : Max value 31.875mA, Step value 0.125mA
    [11] : Max value 63.75mA, Step value 0.25mA

D5 : IOEN CLKPWM pin enable control
    [0] : CLKPWM pin invalid (default)
    [1] : CLKPWM pin valid

D4 : CLKDIR CLKPWM pin I/O mode setting
    [0] : CLKPWM pin input mode (default)
    [1] : CLKPWM pin output mode

D3 : EXTPWM CLKPWM pin PWM mode setting
    [0] : CLKPWM pin PWM mode invalid (default)
    [1] : CLKPWM pin PWM mode valid

D5	D4	D3	CLKPWM operation mode (Clock mode/PWM mode)
IOEN	CLKDIR	EXTPWM	
0	0 or 1	0 or 1	OFF
1	0 or 1	1	External PWM operation mode
1	0	0	External clock input mode
1	1	0	Internal clock output mode

D2 : DLYSEL3 Lighting delay time mode setting at LED3 Slope mode
    [0] : LED3 delay time Max 7.50s mode (default)
    [1] : LED3 delay time Max 1.875s mode

D1 : DLYSEL2 Lighting delay time mode setting at LED2 Slope mode
    [0] : LED2 Delay time Max 7.50s mode (default)
    [1] : LED2 Delay time Max 1.875s mode

D0 : DLYSEL1 Lighting delay time mode setting at LED1 Slope mode
    [0] : LED1 Delay time Max 7.50s mode (default)
    [1] : LED1 Delay time Max 1.875s mode

Please refer to a detail explanation of following register DELAY1 for DLYSEL* details.

<External PWM operation mode>
    LED lighting turns ON/OFF by High/Low setting of CLKPWM pin at the time of LED lighting setting.
    This mode enables LED lighting synchronization with music signal and brightness control by High/Low Duty ratio.

<External clock input mode>
    The reference clock for Slope control is CLKPWM pin. Synchronization with external signals is possible.

<Internal clock output mode>
    Internal reference clock for Slope control is generated via CLKPWM pin. Synchronized operation is possible between products, for example, when using more than one this product connected.

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name		LED1CC							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
03 h	R/W	LED1CC [7: 0]							
Default	00 h	0	0	0	0	0	0	0	0

D7-0 : LED1CC [7: 0] Current setting for LED1 constant current output

Register Name		LED2CC							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
04 h	R/W	LED2CC [7: 0]							
Default	00 h	0	0	0	0	0	0	0	0

D7-0 : LED2CC [7: 0] Current setting for LED2 constant current output

Register Name		LED3CC							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
05 h	R/W	LED3CC [7: 0]							
Default	00 h	0	0	0	0	0	0	0	0

D7-0 : LED3CC [7: 0] Current setting for LED3 constant current output

Output current value can be changed by IMAX setting as below.

LED*CC [7: 0]								IMAX [1: 0]			
D7	D6	D5	D4	D3	D2	D1	D0	00h	01h	10h	11h
0	0	0	0	0	0	0	0	0.000 mA	0.000 mA	0.000 mA	0.000 mA
0	0	0	0	0	0	0	1	0.050 mA	0.100 mA	0.125 mA	0.250 mA
0	0	0	0	0	0	1	0	0.100 mA	0.200 mA	0.250 mA	0.500 mA
:	:	:	:	:	:	:	:	0.050 mA Step :	0.100 mA Step :	0.125 mA Step :	0.250 mA Step :
1	1	1	1	1	1	1	0	12.700 mA	25.400 mA	31.750 mA	63.500 mA
1	1	1	1	1	1	1	1	12.750 mA	25.500 mA	31.875 mA	63.750 mA

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name		LED1SLP							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
06h	R/W	SLP1TT2 [3: 0]				SLP1TT1[3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

Total time of SLOPE operation for LED1 will be set.

Register Name		LED2SLP							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
07h	R/W	SLP2TT2 [3: 0]				SLP2TT1[3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

Total time of Slope operation for LED2 setting

Please refer to following " 11. LED control Slope lighting mode " for the details of slope operation.

SLP1TT1 [3: 0] is set as the chart below shows.

SLP1TT1 [3:0]				Total time of SLOPE operation 1,2
0	0	0	0	(PWM cycle = 53.3 μS)×75×125×0 = 0.0 s
0	0	0	1	(PWM cycle = 53.3 μS)×75×125×1 = 0.5 s
0	0	1	0	(PWM cycle = 53.3 μS)×75×125×2 = 1.0 s
				: 0.5 s Step :
1	1	0	0	(PWM cycle = 53.3 μS)×75×125×12 = 6.0 s
1	1	0	1	(PWM cycle = 53.3 μS)×75×125×13 = 6.5 s
1	1	1	0	(PWM cycle = 53.3 μS)×75×125×14 = 7.0 s
1	1	1	1	(PWM cycle = 53.3 μS)×75×125×15 = 7.5 s

SLP1TT2 [3: 0] is set as the chart below shows.

SLP1TT2 [3:0]				Total time of SLOPE operation 3,4
0	0	0	0	(PWM cycle = 53.3 μS)×75×125×0 = 0.0 s
0	0	0	1	(PWM cycle = 53.3 μS)×75×125×1 = 0.5 s
0	0	1	0	(PWM cycle = 53.3 μS)×75×125×2 =1.0 s
				: 0.5 s Step :
1	1	0	0	(PWM cycle = 53.3 μS)×75×125×12 = 6.0 s
1	1	0	1	(PWM cycle = 53.3 μS)×75×125×13 = 6.5 s
1	1	1	0	(PWM cycle = 53.3 μS)×75×125×14 = 7.0 s
1	1	1	1	(PWM cycle = 53.3 μS)×75×125×15 = 7.5 s

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name					LED1SLP				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
08h	R/W	SLP2TT2 [3: 0]				SLP2TT1[3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

Total time of Slope operation for LED3 will be set.
Please refer to following " 11. LED control Slope lighting mode " for the details of slope operation.

The Slope setting charts for LED2 and LED3 are same as the one for LED1 in the previous page.

Register Name					LED1CNT1				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
09h	R/W	DUTYMAX1 [3: 0]				DUTYMID1 [3: 0]			
Default	F8 h	1	1	1	1	1	0	0	0

D7-4 : DUTYMAX1 [3: 0] LED1 at Slope lighting maximum PWM Duty setting
D3-0 : DUTYMID1 [3: 0] LED1 at Slope lighting middle PWM Duty setting

Register Name					LED1CNT2				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Ah	R/W	DELAY1 [3: 0]				DUTYMIN1 [3: 0]			
Default	00h	0	0	0	0	0	0	0	0

D7-4 : DELAY1 [3: 0] LED1 starting delay time setting
D3-0 : DUTYMIN1 [3: 0] LED1 at Slope lighting minimum PWM Duty setting

Register Name					LED1CNT3				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Bh	R/W	SLP1DT2 [3: 0]				SLP1DT1 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT2 [3: 0] LED1 slope lighting, SLOPE operation 2 detention time setting
D3-0 : SLP1DT1 [3: 0] LED1 slope lighting, SLOPE operation 1 detention time setting

Register Name					LED1CNT4				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Ch	R/W	SLP1DT4 [3: 0]				SLP1DT3 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT4 [3: 0] LED1 slope lighting, SLOPE operation 4 detention time setting
D3-0 : SLP1DT3 [3: 0] LED1 slope lighting, SLOPE operation 3 detention time setting

Operation parameter of LED1 SLOPE operation will be set.
Please refer to following " 11. LED control Slope lighting mode " for the details of slope operation.

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

DUTYMAX1 [3: 0] correspond to the following PWM Duty setting as the following chart shows.

DUTYMAX1 [3: 0]				Duty setting for PWM operation [6: 0]						
D3	D2	D1	D0	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	1	1	1
0	0	0	1	0	0	0	1	1	1	1
0	0	1	0	0	0	1	0	1	1	1
0	0	1	1	0	0	1	1	1	1	1
~				~						
1	1	1	0	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	1	1	1

Duty setting for PWM operation [6: 0]
[0000111] : 7 / 128   =   5.47 %
[0001111] : 15 / 128   = 11.72 %
[0010111] : 23 / 128   = 17.97 %
[0011111] : 31 / 128   = 24.22 %
         :   :
[1110111] : 119 / 128 = 92.97 %
[1111111] : 127 / 128 = 99.22 %

DUTYMID1 [3: 0] correspond to the following PWM Duty setting as the following chart shows.

DUTYMID1 [3: 0]				Duty setting for PWM operation[6: 0]						
D3	D2	D1	D0	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1	1	1	1
0	0	1	0	0	0	1	0	1	1	1
0	0	1	1	0	0	1	1	1	1	1
~				~						
1	1	1	0	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	1	1	1

Duty setting for PWM operation [6: 0]
[0000000] : 0 / 128 = 0 %
[0001111] : 15 / 128 = 11.72 %
[0010111] : 23 / 128 = 17.97 %
[0011111] : 31 / 128 = 24.22 %
         :   :
[1110111] : 119 / 128 = 92.97 %
[1111111] : 127 / 128 = 99.22 %

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

DUTYMIN1 [3: 0] correspond to the following PWM Duty setting as the following chart shows.

DUTYMIN1 [3: 0]				Duty setting for PWM operation [6: 0]						
D3	D2	D1	D0	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1	0	0	0
0	0	1	0	0	0	1	0	0	0	0
0	0	1	1	0	0	1	1	0	0	0
~				~						
1	1	1	0	1	1	1	0	0	0	0
1	1	1	1	1	1	1	1	0	0	0

Duty setting for PWM operation [6: 0]

[0000000] : 0 / 128 = 0 %

[0001000] : 8 / 128 = 6.25 %

[0010000] : 16 / 128 = 12.5 %

[0011000] : 24 / 128 = 18.75 %

      :   :

[1110000] : 112 / 128 = 87.5 %

[1111000] : 120 / 128 = 93.75 %

DELAY1 [3: 0] is set as the following chart shows.

DELAY1 [3: 0]				Delay Time for LED1	
D7	D6	D5	D4	DLYSEL1 = 0	DLYSEL1 = 1
0	0	0	0	0.00 s	0.000 s
0	0	0	1	0.50 s	0.125 s
0	0	1	0	1.00 s	0.250 s
~				~	~
1	1	1	0	7.00 s	1.750 s
1	1	1	1	7.50 s	1.875 s

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

SLP1DT1 [3: 0] is set as the following chart shows.

SLP1DT1 [3: 0]				Detention time at each step
0	0	0	0	(PWM cycle = 53.3 μs) × 1 = 53.3 μs
0	0	0	1	(PWM cycle = 53.3 μs) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μs) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μs) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μs) × 75 × 15 = 60.0 ms

SLP1DT2 [3: 0] is set as the following chart shows.

SLP1DT2 [3: 0]				Detention time at each step
0	0	0	0	(PWM cycle = 53.3 μs) × 1 = 53.3 μs
0	0	0	1	(PWM cycle = 53.3 μs) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μs) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μs) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μs) × 75 × 15 = 60.0 ms

SLP1DT3 [3: 0] is set as the following chart shows.

SLP1DT3 [3: 0]				Detention time at each step
0	0	0	0	(PWM cycle = 53.3 μs) × 1 = 53.3 μs
0	0	0	1	(PWM cycle = 53.3 μs) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μs) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μs) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μs) × 75 × 15 = 60.0 ms

SLP1DT4 [3: 0] is set as the following chart shows.

SLP1DT4 [3: 0]				Detention time at each step
0	0	0	0	(PWM cycle = 53.3 μs) × 1 = 53.3 μs
0	0	0	1	(PWM cycle = 53.3 μs) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μs) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μs) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μs) × 75 × 15 = 60.0 ms

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name		LED2CNT1							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Dh	R/W	DUTYMAX1 [3: 0]				DUTYMID1 [3: 0]			
Default	F8 h	1	1	1	1	1	0	0	0

D7-4 : DUTYMAX1 [3: 0] LED2 at Slope lighting maximum PWM Duty setting

D3-0 : DUTYMID1 [3: 0] LED2 at Slope lighting middle PWM Duty setting

Register Name		LED2CNT2							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Eh	R/W	DELAY1 [3: 0]				DUTYMIN1 [3: 0]			
Default	00h	0	0	0	0	0	0	0	0

D7-4 : DELAY1 [3: 0] LED2 starting delay time setting

D3-0 : DUTYMIN1 [3: 0] LED2 at Slope lighting minimum PWM Duty setting

Register Name		LED2CNT3							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0Fh	R/W	SLP1DT2 [3: 0]				SLP1DT1 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT2 [3: 0] LED2 slope lighting, SLOPE operation 2 detention time setting

D3-0 : SLP1DT1 [3: 0] LED2 slope lighting, SLOPE operation 1 detention time setting
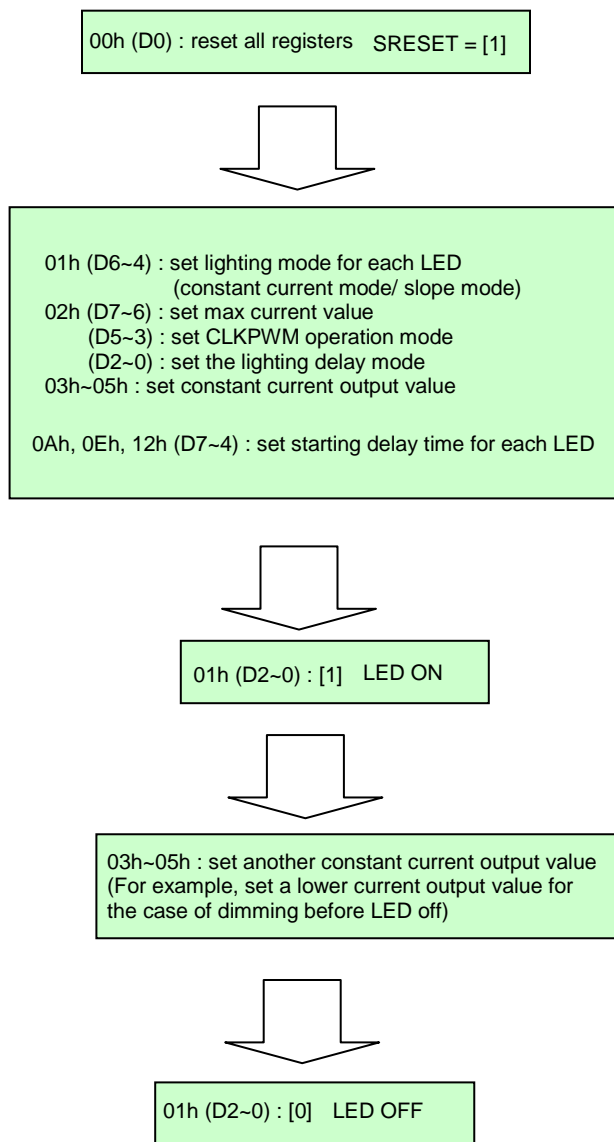
Register Name		LED2CNT4							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
10h	R/W	SLP1DT4 [3: 0]				SLP1DT3 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT4 [3: 0] LED2 slope lighting, SLOPE operation 4 detention time setting

D3-0 : SLP1DT3 [3: 0] LED2 slope lighting, SLOPE operation 3 detention time setting

Operation parameter of LED2 SLOPE operation will be set.

Please refer to following " 11. LED control Slope lighting mode " for the details of slope operation.

8. Details about Register Map (continued)

8.1 Address 00h to 14h (continued)

Register Name		D7	D6	D5	D4	D3	D2	D1	D0
					LED3CNT1				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
11h	R/W	DUTYMAX1 [3: 0]				DUTYMID1 [3: 0]			
Default	F8 h	1	1	1	1	1	0	0	0

D7-4 : DUTYMAX1 [3: 0] LED3 at Slope lighting maximum PWM Duty setting

D3-0 : DUTYMID1 [3: 0] LED3 at Slope lighting middle PWM Duty setting

Register Name		D7	D6	D5	D4	D3	D2	D1	D0
					LED3CNT2				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
12h	R/W	DELAY1 [3: 0]				DUTYMIN1 [3: 0]			
Default	00h	0	0	0	0	0	0	0	0

D7-4 : DELAY1 [3: 0] LED3 starting delay time setting

D3-0 : DUTYMIN1 [3: 0] LED3 at Slope lighting minimum PWM Duty setting

Register Name		D7	D6	D5	D4	D3	D2	D1	D0
					LED3CNT3				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
13h	R/W	SLP1DT2 [3: 0]				SLP1DT1 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT2 [3: 0] LED3 slope lighting, SLOPE operation 2 detention time setting

D3-0 : SLP1DT1 [3: 0] LED3 slope lighting, SLOPE operation 1 detention time setting

Register Name		D7	D6	D5	D4	D3	D2	D1	D0
					LED3CNT4				
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
14h	R/W	SLP1DT4 [3: 0]				SLP1DT3 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP1DT4 [3: 0] LED3 slope lighting, SLOPE operation 4 detention time setting

D3-0 : SLP1DT3 [3: 0] LED3 slope lighting, SLOPE operation 3 detention time setting

Operation parameter of LED3 SLOPE operation will be set.

Each parameter is the same as LED1 parameter.

Please refer to following " 11. LED control Slope lighting mode " for the details of slope operation.

9. Programming Sequence

9.1 Constant Current Mode Example

00h (D0) : reset all registers   SRESET = [1]

01h (D6~4) : set lighting mode for each LED
                    (constant current mode/ slope mode)
02h (D7~6) : set max current value
       (D5~3) : set CLKPWM operation mode
       (D2~0) : set the lighting delay mode
03h~05h : set constant current output value

0Ah, 0Eh, 12h (D7~4) : set starting delay time for each LED

01h (D2~0) : [1]   LED ON

03h~05h : set another constant current output value
(For example, set a lower current output value for
the case of dimming before LED off)

01h (D2~0) : [0]   LED OFF

9. Programming Sequence (continued)

9.2 Slope Mode Example

00h (D0) : reset all registers   SRESET = [1]
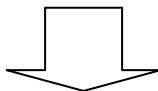
01h (D6~4) : set lighting mode for each LED
        (constant current mode/ slope mode)
02h (D7~6) : set max current value
    (D5~3) : set CLKPWM operation mode
    (D2~0) : set the lighting delay mode
03h~05h : set constant current output value

06h~08h : set total time of slope operation for each LED
        SLP*TT1 sets up-slope total time
        SLP*TT2 sets down-slope total time
09h, 0Dh, 11h (D7~4) : set max duty for each LED
09h, 0Dh, 11h (D3~0) : set mid duty for each LED
0Ah, 0Eh, 12h (D3~0) : set min duty for each LED

0Bh~0C, 0Fh~10h, 13h~14h : set detention time of slope for each LED
        SLP*DT1 sets detention time of slope operation 1
        SLP*DT2 sets detention time of slope operation 2
        SLP*DT3 sets detention time of slope operation 3
        SLP*DT4 sets detention time of slope operation 4

0Ah, 0Eh, 12h (D7~4) : set starting delay time for each LED
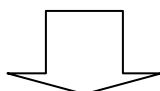
01h (D2~0) : [1] LED ON
(slope operation 1~4 is repeated as long as LED is on)
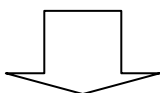
01h (D2~0) : [0]   LED OFF

10. I2C-bus Interface

10.1 Basic standards

- I2C bus of this product is designed to be compatible with the standard mode (100kbps) and fast mode of specification, version 2.1 by Philips, but not with HS mode (~ 3.4 Mbps).
- This product operates as a slave device in I2C bus system.
- An operation check has not been conducted in multimaster bus system and mixed speed bus system for this product. Connection confirmation with CBUS server has not been conducted. Please contact us if you use in this modes.
- By purchasing I2C bus enabled product of Semiconductor Company, Broadchip subject to be used in conformity with I2C bus standard specification authorized by Philips under the I2C patent right owned by Philips, the right to use these two products will be granted.

10.2 Start condition and Stop condition

- When SCL is "H", if SDA line is changed from "H" to "L", it is Start condition. When SCL is "H", if SDA line is changed from "L" to "H", it is Stop condition.
- Start condition is always generated by master. After Start condition is initiated, bus becomes busy state. After Stop condition is initiated, bus return to free state.
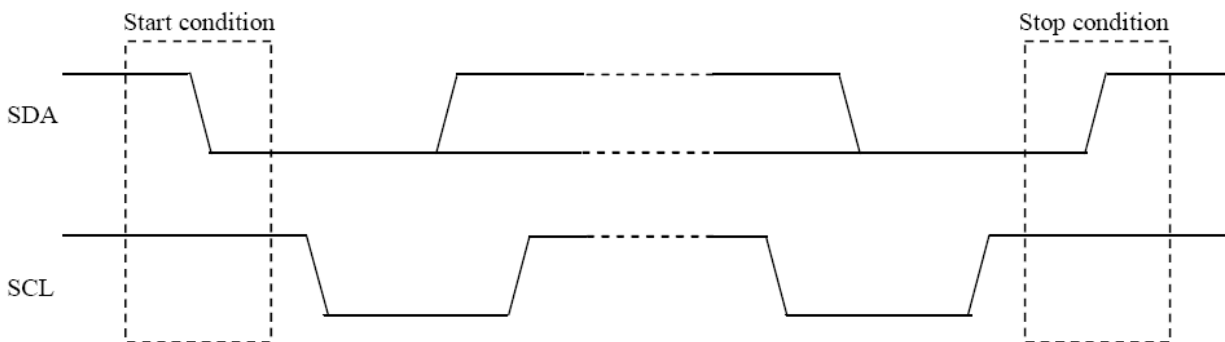
10.3 Data transfer
- Each length of byte output in SDA line is 8 bit.
- There is no limit for the number of byte in a single transfer.
- Each bit must be followed by Ack (acknowledge byte).
- Data is sequentially sent from the most significant byte (MSB).
- In case the receiver is unable to receive all the bytes which constitute data until it finished executing, for example, internal interruption service, transmitter can be set to standby state by keeping the clock line SCL in the state of "L". Data transfer will be resumed after the receiver becomes able to receive data byte and clock line SCL is released .
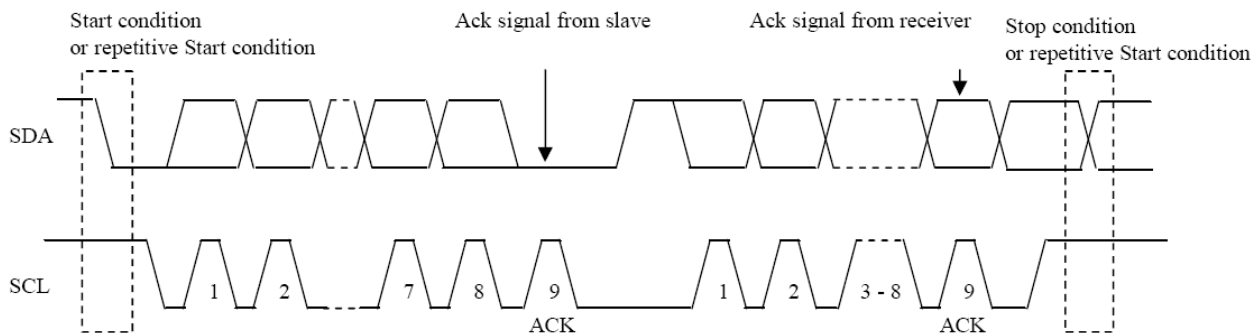
10. I2C-bus Interface (continued)

10.4 DATA format

Four different slave addresses can be selected by configuring the ADSEL1, ADSEL2 pin connections.
The chart below shows the possible slave addresses of this product.

ADSEL2	ADSEL1	Slave address
L (Ground)	L (Ground)	30 h
L (Ground)	H (VDD)	31 h
H (VDD)	L (Ground)	32 h
H (VDD)	H (VDD)	33 h

* Write mode

| S | Slave address | W | A | Sub-address | A | Data byte | A | P |

Start condition

Write
mode : 0

Ack

Stop condition
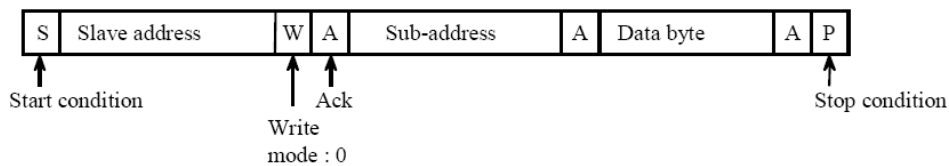
* Read mode

A) When sub-address is not assigned.

When data is read without assigning sub-address, it is possible to read the value of sub-address specified in Write mode
immediately before.

| S | Slave address | R | A | Data byte | $\overline{A}$ | P |

Start condition

Read
mode : 1

Ack

Stop condition
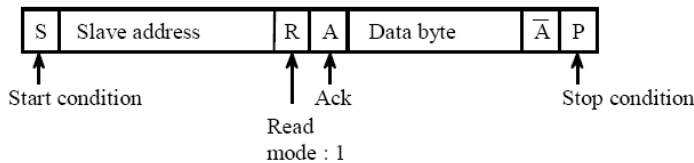
Ex) When writing data into address and reading data from "01 h"

Write | S | Slave address | 0 | A | Sub-address (01h) | A | Data byte | A | P |

Read | S | Slave address | 1 | A | Data byte | $\overline{A}$ | P |
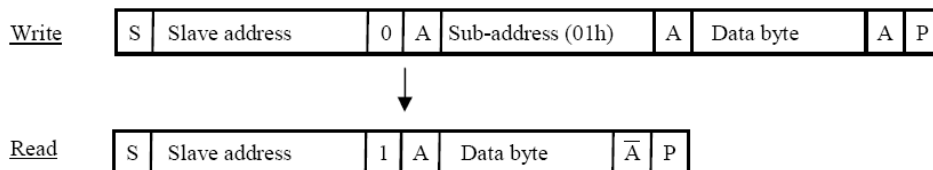
B) When specifying sub-address

| S | Slave address | 0 | A | Sub-address | A | S | Slave address | 1 | A | Data byte | $\overline{A}$ | P |

Start condition

Write
mode : 0

Acknowledge bit

Ack Repeated
start condition

Read
mode : 1

Ack

Stop
condition

Sub-address should be assigned first.
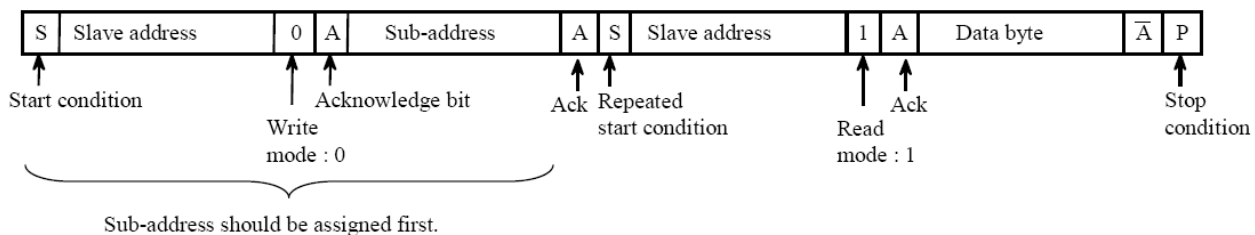
10. I2C-bus Interface (continued)

10.4 DATA format

* Continuous Write mode

When using the continuous Write mode, the most significant bit of Sub address should be set to [1].

S	Slave Address	W	A	Sub Address	A	Data Byte	A	P

↑ Start Condition
↑ Write mode : 0 / Ack
↑ Set most significant bit to [1].
↑ Stop Condition
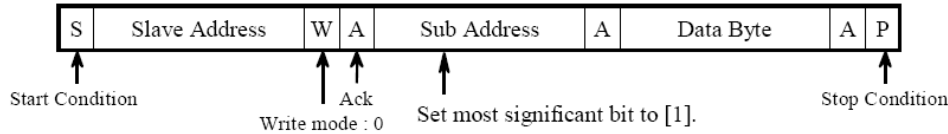
Ex) 05h → 85h, 11h → 91h

* Continuous Read mode

A) When Sub address is not specified

When the most significant bit specified in the last Write mode is [1], it is possible to perform the continuous Read mode operation directly after it.

S	Slave Address	R	A	Data byte	Ā	P

↑ Start Condition
↑ Read mode : 1 / Ack
↑ Stop condition
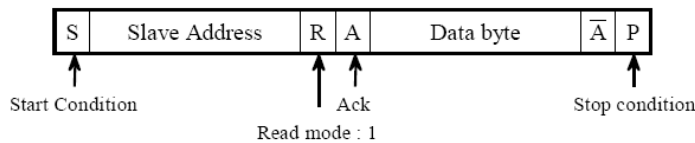
Ex) Case where data is read from Address 01h after data is written to Address 01h

Write:

S	Slave Address	0	A	Sub Address 81h	A	Data Byte	A	P

Read:

S	Slave Address	1	A	Data Byte	A	Data Byte	Ā	P

81h Data   82h Data
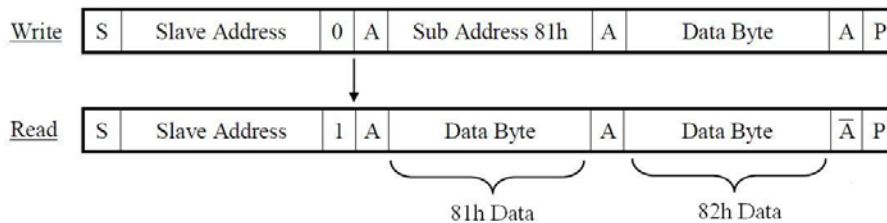
Sub address will be added 1, When using the continuous read mode,

B) When Sub address is specified

Set most significant bit to [1].

S	Slave Address	0	A	Sub Address	A	S	Slave Address	1	A	Data Byte	Ā	P

↑ Start Condition
↑ Write Mode : 0
↑ Acknowledge Bit
↑ Ack
↑ Repeated Start Condition
↑ Read Mode : 1
↑ Ack
↑ Stop Condition

Sub address is specified initially
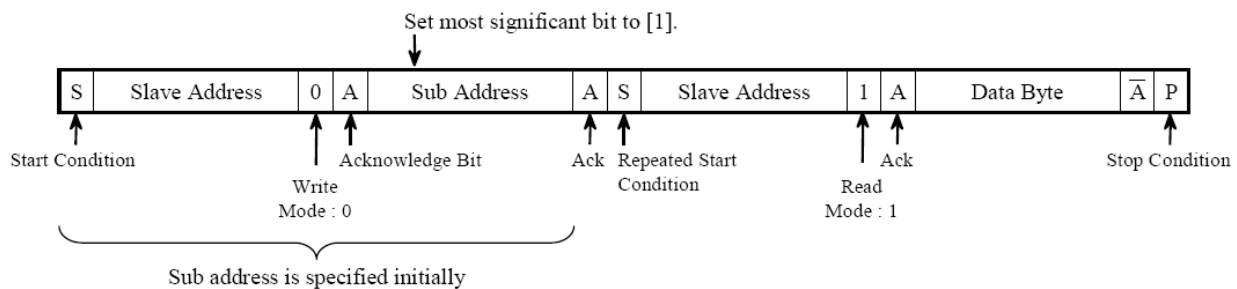
11. LED Driver Control

11.1 Function table about each LED driver

Functions / LED driver	LED1,2,3 (IMAX[1:0]=00h)	LED1,2,3 (IMAX[1:0]=01h)	LED1,2,3 (IMAX[1:0]=10h)	LED1,2,3 (IMAX[1:0]=11h)
Current value setting [1]	12.75 mA max. (8-bit, 0.05 mA step)	25.50 mA max. (8-bit, 0.10 mA step)	31.875 mA max. (8-bit, 0.125 mA step)	63.75 mA max. (8-bit, 0.25 mA step)
PWM duty setting (slope lighting mode)	128 steps [2]	128 steps [2]	128 steps [2]	128 steps [2]
Slope control	○	○	○	○

Notes) [1] : With use the register IMAX[1:0], Current value setting will be set.

[2] : When in constant current mode, it is impossible to fix PWM duty at any time.

11.2 Constant Current Lighting Mode

● It is possible to control the lighting mode of each LED driver.

● Choose 'Constant current lighting mode' and 'Slope lighting mode' by setting Register LED*MD.

To operate at 'Constant current mode', please set LED*MD at "0". ("*" can be 1, 2, or 3.)
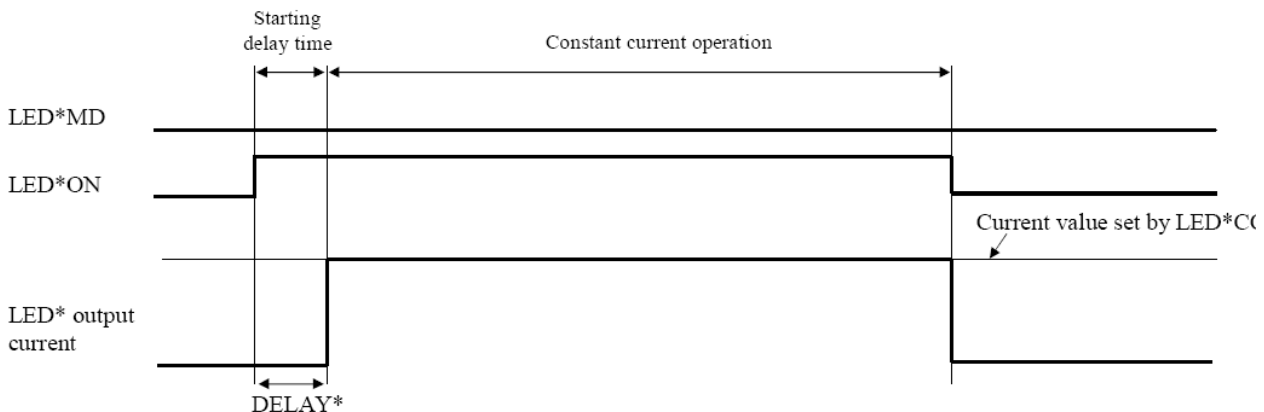
● Upon setting LED*On to "1", constant current operation will start after the previously set starting delay time, DELAY*.

● As described later, it is possible to turn on and off at High/Low of CLKPWM pin by making the external PWM operating mode for CLKPWM pin setting valid.

11. LED Driver Control (continued)

11.3 Slope Lighting Mode

- This mode allows easy control of gradual increase or decrease in brightness of each LED by PWM duty setting.
- Only minimum, middle, and maximum PWM duty ratios have to be specified. After that, the PWM duty is changed automatically.
- The slope operation is repeated over and over again, as long as the lighting mode is not changed and LED is always ON.
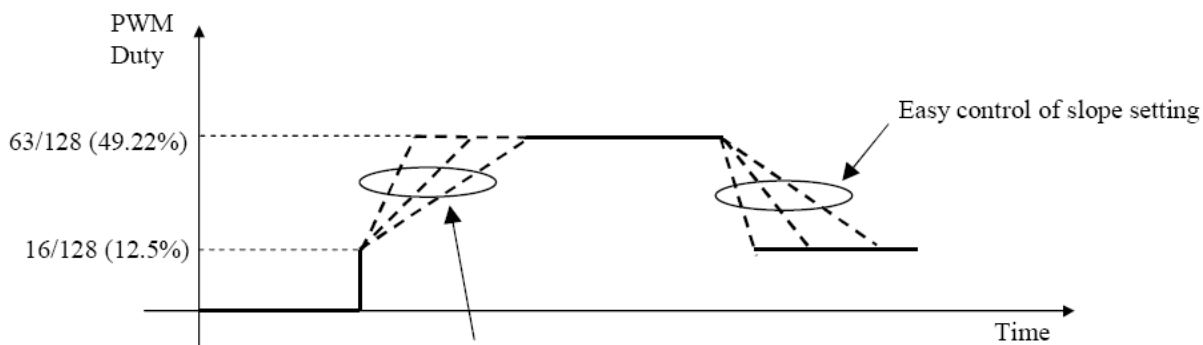
< Slope Explanation >

11. LED Driver Control (continued)

11.3 Slope Lighting Mode (continued)

- To operate at 'Slope lighting mode', please set LED*MD at "1". ("*" can be 1, 2, or 3.)
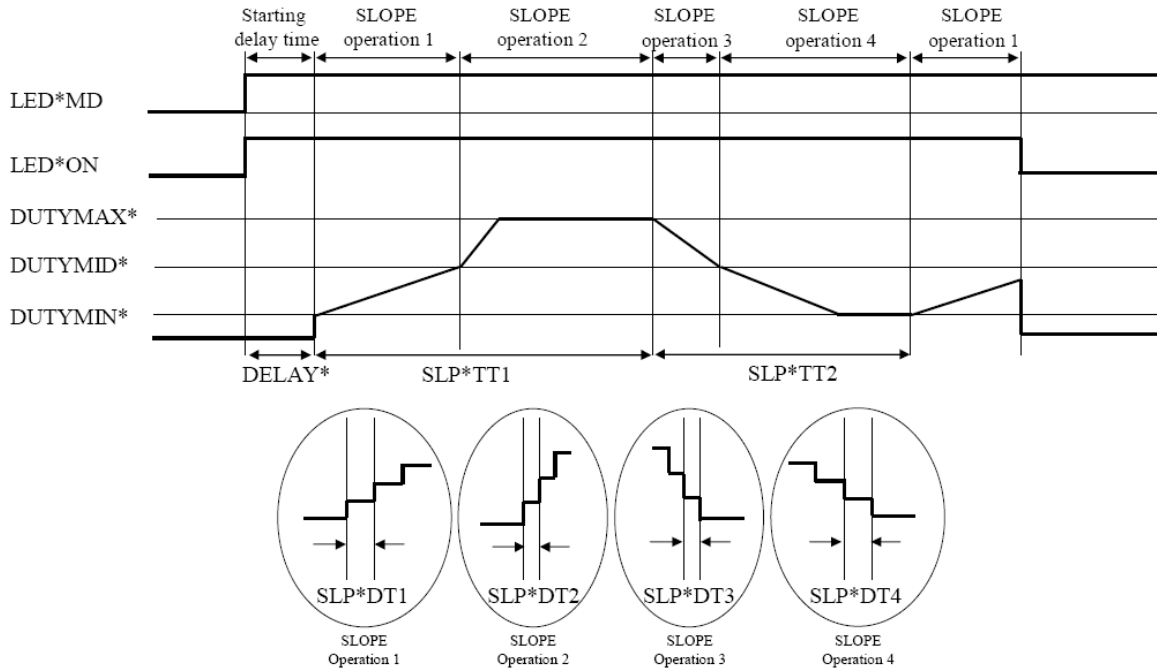
- To repeat Slope operation from 1 to 4 after the previously set starting delay time, DELAY*, please set Register LED*ON at "1".

- The minimum resolution of SLOPE sequence control is 2.40 MHz reference clock cycle as below.
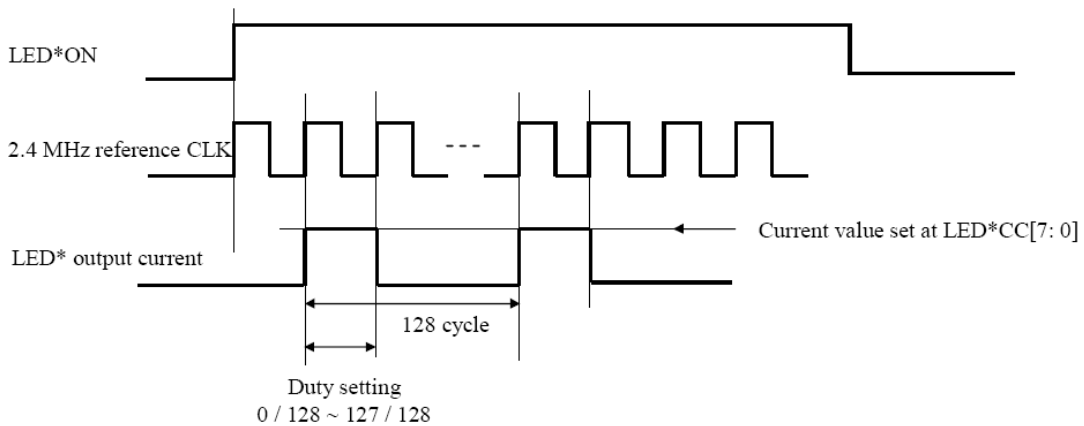
11. LED Driver Control (continued)

11.3 Slope Lighting Mode (continued)

1) Total time of Slope operation 1, 2

Total time of Slope operation 1, 2can be controlled by SLP*TT1[3: 0].
SLP* TT1[3: 0] is set as described before.

- SLP*TT1[3: 0] setting is preferred (has higher priority) in cases where SLP*TT1[3: 0] < 'SLOPE operation 1' + 'SLOPE operation 2'.
- Under the case where the time set by SLP*TT1[3: 0] is reached before SLOPE operation 2 starts, SLOPE operation 2 is omitted and transferred to SLOPE operation 3 from the position of DUTYMAX.

2) Total time of Slope operation 3,4

Total time of Slope operation 3, 4 can be controlled by SLP*TT2[3: 0].
SLP* TT2[3: 0] is set as described before.

- SLP*TT2[3: 0] setting is preferred (has higher priority) in cases where SLP*TT2[3: 0] < 'SLOPE operation 3' + 'SLOPE operation 4'.
- Under the case where the time set by SLP*TT1[3: 0] is reached before SLOPE operation 2 starts, SLOPE operation 4 is omitted and transferred to SLOPE operation 1 from the position of DUTYMIN.

3) DUTYMIN, DUTYMID, DUTYMAX setting for SLOPE operation

- SLOPE operation 1
PWM control can be added step by step from the value set at DUTYMIN* [3: 0] to the value set at DUTYMID* [3: 0].
Please set the detention time by SLP*DT1 [3: 0] for each step.
The value should be DUTYMIN* [3: 0] < DUTYMID* [3: 0].
SLOPE operation 1 operates at DUTYMIN = DUTYMID in case DUTYMIN* [3: 0] >= DUTYMID* [3: 0] .

- SLOPE operation 2
PWM control can be added step by step from the value set at DUTYMID* [3: 0] to the value set at DUTYMAX* [3: 0].
Please set the detention time by SLP*DT2 [3: 0] for each step.
The value should be DUTYMID* [3: 0] < DUTYMAX* [3: 0].
SLOPE operation 2 operates at DUTYMID = DUTYMAX in case DUTYMID* [3: 0] >= DUTYMAX* [3: 0] .

- Slope operation 3
PWM control can be subtracted step by step from the value set at DUTYMAX* [3: 0] to the value set at DUTYMID* [3: 0].
Please set the detention time by SLP*DT3 [3: 0] for each step.
The value should be DUTYMID* [3: 0] < DUTYMAX* [3: 0].
SLOPE operation 3 operates at DUTYMID = DUTYMAX in case DUTYMID* [3: 0] >= DUTYMAX* [3: 0] .

- SLOPE operation 4
PWM control can be subtracted step by step from the value set at DUTYMID* [3: 0] to the value set at DUTYMIN* [3: 0].
Please set the detention time by SLP*DT4 [3: 0] for each step.
The value should be DUTYMIN* [3: 0] < DUTYMID* [3: 0].
SLOPE operation 4 operates at DUTYMIN = DUTYMID in case DUTYMIN* [3: 0] >= DUTYMID* [3: 0] .

11. LED Driver Control (continued)

11.3 Slope Lighting Mode Example (LED1)

(1) Address 02h, Data 40h (SEL)
   Set IMAX = 25.5mA
   Set LED1 delay time max 7.5s mode (DLYSEL1 = 0)

(2) Address 03h, Data 10h (LED1CC)
   Set LED1 constant output current = 12.8mA

(3) Address 06h, Data 48h (LED1SLP)
   Set the total time of slope operation 1,2 (SLP1TT1) = 4s
   Set the total time of slope operation 3,4 (SLP1TT2) = 2s

(4) Address 09h, Data F7h (LED1CNT1)
   Address 0Ah, Data 22h (LED1CNT2)
   Set max PWM duty of LED1 (DUTYMAX1) = 127/128
   Set mid PWM duty of LED1 (DUTYMID1) = 63/128
   Set min PWM duty of LED1 (DUTYMIN1) = 16/128 (This is the duty at starting point of slope lighting.)
   Set LED1 starting delay time = 1s

(5) Address 0Bh, Data 18h (LED1CNT3)
   Address 0Ch, Data 42h (LED1CNT4)
   Set detention time of slope operation 1 (SLP1DT1) = 32ms
   Set detention time of slope operation 2 (SLP1DT2) = 4ms
   Set detention time of slope operation 3 (SLP1DT3) = 8ms
   Set detention time of slope operation 4 (SLP1DT4) = 16ms

(6) Address 01h, Data 11h (LEDON)
   Select slope lighting mode for LED1.
   Turn LED1 ON.
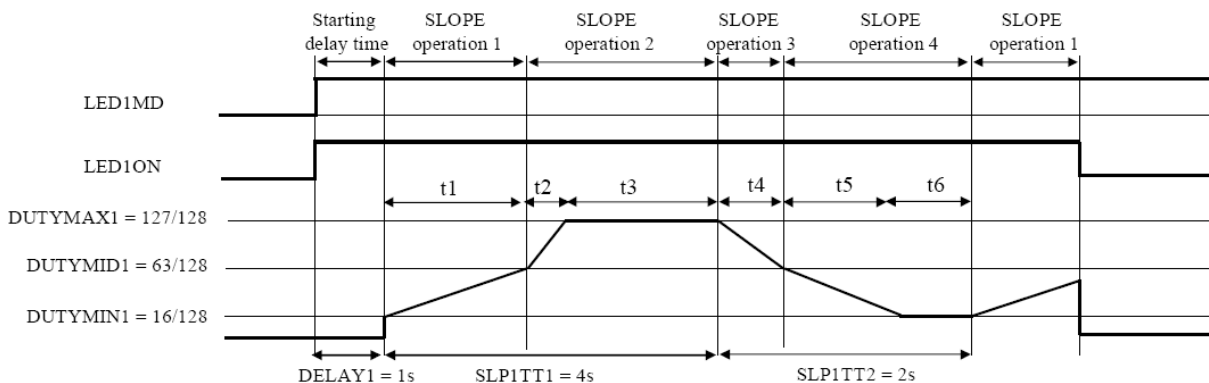
$t1 = 32ms \times 47steps = 1504ms$ $t4 = 8ms \times 64steps = 512ms$
$t2 = 4ms \times 64steps = 256ms$ $t5 = 16ms \times 47steps = 752ms$
$t3 = 2240ms$ $t6 = 736ms$

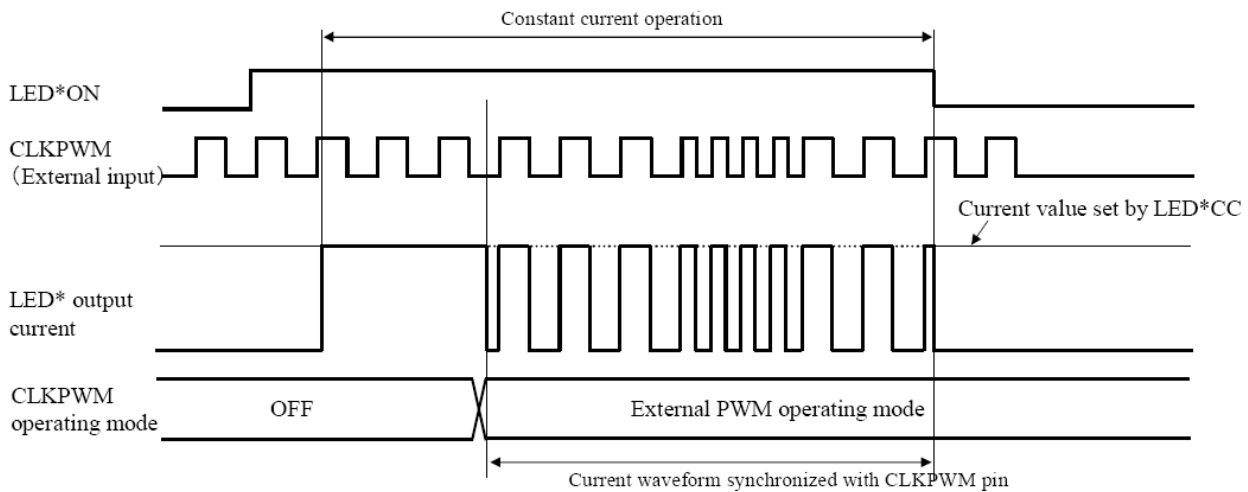< Slope Lighting Mode Example >

11. LED Driver Control (continued)
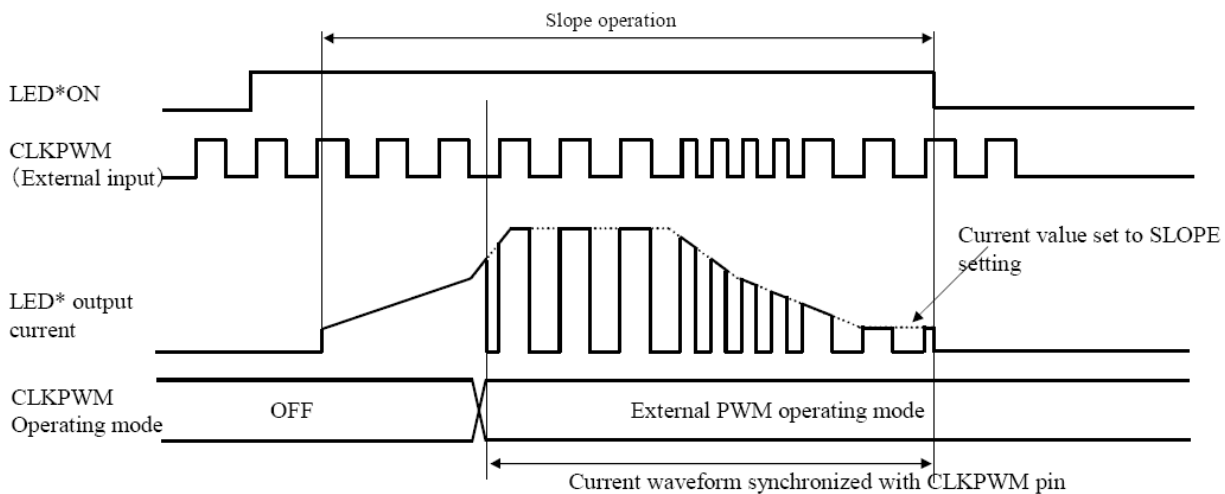
11.4 External PWM Operation Mode of CLKPWM Pin

The lighting synchronization with CLKPWM signal can be turned on by setting 'External PWM operation mode' in register setting.

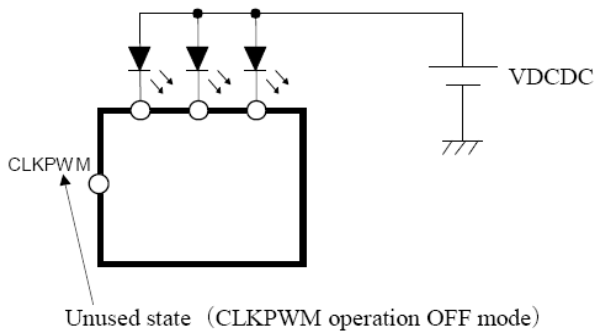The frequency which can be entered to CLKPWM pin is Max 20kHz.

< At Constant current mode >

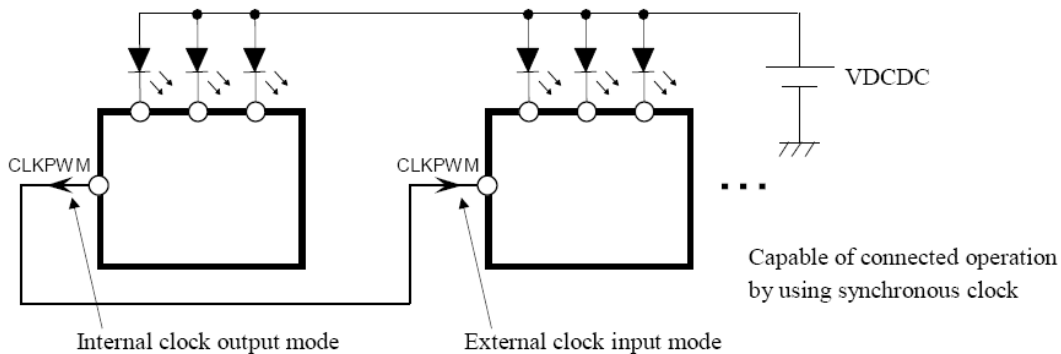< At Slope lighting mode >

11. LED Driver Control (continued)

11.5 External Clock Input Mode and Internal Clock Output Mode of CLKPWM Pin

The following configuration can be made up by choosing 'External clock input mode', 'Internal clock output mode' in register setting.
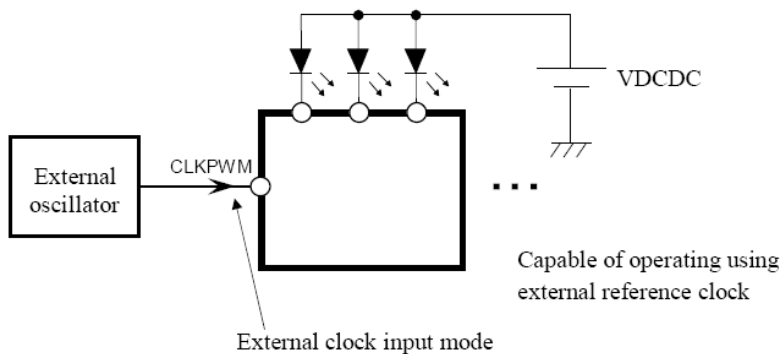
< Single application >

Unused state （CLKPWM operation OFF mode）

< Connected application >

Capable of connected operation by using synchronous clock

Internal clock output mode   External clock input mode

< External reference clock application >

Capable of operating using external reference clock

External clock input mode

12. Package Information

Unit：mm