Notification about the transfer of the semiconductor business

The semiconductor business of Panasonic Corporation was transferred on September 1, 2020 to Nuvoton Technology Corporation (hereinafter referred to as "Nuvoton"). Accordingly, Panasonic Semiconductor Solutions Co., Ltd. became under the umbrella of the Nuvoton Group, with the new name of Nuvoton Technology Corporation Japan (hereinafter referred to as "NTCJ").

In accordance with this transfer, semiconductor products will be handled as NTCJ-made products after September 1, 2020. However, such products will be continuously sold through Panasonic Corporation.

Publisher of this Document is NTCJ.
If you would find description “Panasonic” or “Panasonic semiconductor solutions”, please replace it with NTCJ.

※ Except below description page
“Request for your special attention and precautions in using the technical information and semiconductors described in this book”

Nuvoton Technology Corporation Japan

Panasonic

AN30259C

3-ch. LED Driver for Illumination

FEATURES

- I²C Interface (Slave address is switchable.)
- Built-in 3-ch. LED Driver Circuit
  (Max Current Selectable [63.75 mA / 31.875 mA / 25.50 mA / 12.75 mA])
- 2.4 MHz OSC
- 12 pin Wafer level chip size package (WLCSP)

DESCRIPTION

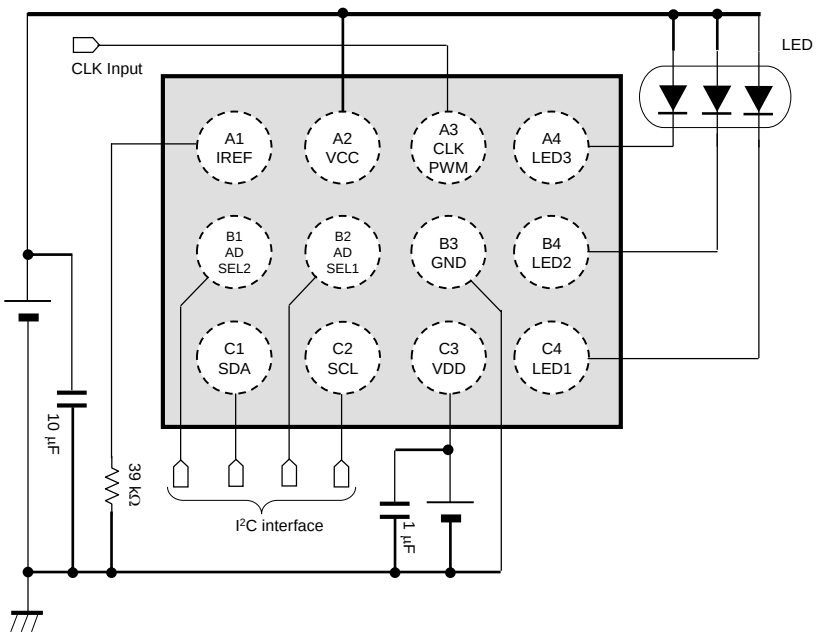
AN30259C has 3-ch. LED Driver, suitable for RGB illumination. By synchronous clock function, simultaneous LED turn ON/OFF operation of up to 4 ICs can be achieved.

APPLICATIONS

- Mobile, Wearable
- Smart Speaker
- PCs
- Game Consoles
- Home Appliances etc.

TYPICAL APPLICATION

TOP VIEW



Note:
The application circuit is an example. The operation of the mass production set is not guaranteed. Sufficient evaluation and verification is required in the design of the mass production set. The Customer is fully responsible for the incorporation of the above illustrated application circuit in the design of the equipment.

Established : 2013-12-26
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ORDERING INFORMATION

Order Number	Feature	Package	Packing Form
AN30259C-PR	LED Driver IC for Illumination	12 pin WLCSP	Emboss Taping

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Rating	Unit	Note
Supply voltage	VCC_{MAX}	7.0	V	*1
	VDD_{MAX}	4.6	V	*1
Operating ambience temperature	T_{opr}	–30 to + 85	°C	*2
Operating junction temperature	T_j	– 30 to + 125	°C	*2
Storage temperature	T_{stg}	– 55 to + 125	°C	*2
Input Voltage Range	V_{ADSEL1}, V_{ADSEL2}, V_{SCL}, V_{SDA}, V_{CLKPWM}	– 0.3 to 4.3	V	—
Output Voltage Range	V_{LED1}, V_{LED2}, V_{LED3}	– 0.3 to 6.5	V	—
ESD	HBM	2.0	kV	—

Note: This product may sustain permanent damage if subjected to conditions higher than the above stated absolute maximum rating. This rating is the maximum rating and device operating at this range is not guaranteed as it is higher than our stated recommended operating range. When subjected under the absolute maximum rating for a long time, the reliability of the product may be affected.

*1: VCC_{MAX} = VCC, VDD_{MAX} = VDD, the values under the condition not exceeding the above absolute maximum ratings and the power dissipation.

*2: Except for operating ambient temperature, operating junction temperature and storage temperature, all ratings are for T_a = 25°C.

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POWER DISSIPATION RATING

PACKAGE	θ_{JA}	P_D (Ta=25 °C)	P_D (Ta=85 °C)
12 pin Wafer Level Chip Size Package (WLCSP)	537.1 °C /W	0.186 W	0.074 W

Note: For the actual usage, please refer to the P_D-Ta characteristics diagram in the package specification, follow the power supply voltage, load and ambient temperature conditions to ensure that there is enough margin and the thermal design does not exceed the allowable value.

CAUTION

Although this IC has built-in ESD protection circuit, it may still sustain permanent damage if not handled properly. Therefore, proper ESD precautions are recommended to avoid electrostatic damage to the MOS gates

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Supply voltage range	V_{CC}	3.1	3.7	6.0	V	—
	V_{DD}	1.7	1.85	3.2	V	—
Input Voltage Range	V_{ADSEL1}, V_{ADSEL2}, V_{SCL}, V_{SDA}, V_{CLKPWM}	– 0.3	—	V_{DD} + 0.3	V	*1
Output Voltage Range	V_{LED1}, V_{LED2}, V_{LED3}	– 0.3	—	V_{CC} + 0.3	V	*1

Note: Voltage values, unless otherwise specified, are with respect to GND. GND is voltage for GND.
V_{DD} is voltage for VDD. V_{CC} is voltage for VCC.
*1 : (V_{DD} + 0.3) V must not exceed 4.6 V. (V_{CC} + 0.3) V must not exceed 7 V.

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ELECTRICAL CHARACTERISTICS

V_{CC} = 3.6 V, V_{DD} = 1.8 V

Note: T_a = 25 °C ± 2 °C unless otherwise specified.

Parameter	Symbol	Condition	Limits			Unit	Note
			Min	Typ	Max		
Current consumption							
Current consumption 1 OFF mode	I_{CC1}	V_{DD} = 0 V	—	0	2	µA	—
Current consumption 2 OFF mode	I_{CC2}	V_{DD} = 1.8 V	—	1	5	µA	—
Current consumption 3 LED lighting mode	I_{CC3}	$I_{LED1\ to\ 3}$ = 25.50 mA setting All LED = ON	—	0.6	1.0	mA	—
LED Driver							
Off time leak current	I_{LEAK}	Off setting $V_{LED1\ to\ 3}$ = 6.0 V	—	—	1.0	µA	—
Minimum setting current value 1	I_{MIN1}	IMAX[1:0] = 01, $V_{LED1\ to\ 3}$ = 1.0 V	0.05	0.10	0.15	mA	—
Minimum setting current value 2	I_{MIN2}	IMAX[1:0] = 01, $V_{LED1\ to\ 3}$ = 1.0 V	0.736	0.80	0.864	mA	—
Maximum setting current value	I_{MAX}	IMAX[1:0] = 01, $V_{LED1\ to\ 3}$ = 1.0 V	23.46	25.50	27.54	mA	—
Current step	I_{STEP}	IMAX[1:0] = 01, $V_{LED1\ to\ 3}$ = 1.0 V	0.00	0.10	0.18	mA	—
Minimum voltage for retainable constant current value	V_{SAT}	IMAX[1:0] = 01, Terminal minimum voltage of LED1 to 3 becoming 85% of the LED current value in 1 V.	—	0.2	0.4	V	—
Error between channels	I_{MATCH}	12.80 mA setting, $V_{LED1\ to\ 3}$ = 1.0 V	–5	—	5	%	—
Internal oscillator							
Oscillation frequency	f_{OSC}	—	1.92	2.40	2.88	MHz	—

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ELECTRICAL CHARACTERISTICS (continued)

V_{CC} = 3.6 V, V_{DD} = 1.8 V

Note: T_a = 25 °C ± 2 °C unless otherwise specified.

Parameter	Symbol	Condition	Limits			Unit	Note
			Min	Typ	Max		
SCL, SDA							
High-level input voltage range	V_{IH1}	Voltage which recognized that SDA and SCL are High-level	V_{DD} × 0.7	—	V_{DD} + 0.5	V	*1
Low-level input voltage range	V_{IL1}	Voltage which recognized that SDA and SCL are Low-level	– 0.5	—	V_{DD} × 0.3	V	*1
High-level input current	I_{IH1}	V_{SDA} ,V_{SCL} = 1.8 V	—	0	1	µA	—
Low-level input current	I_{IL1}	V_{SDA} ,V_{SCL} = 0 V	—	0	1	µA	—
Low-level output voltage1 (SDA)	V_{OL1H}	I_{SDA} = 3 mA, V_{DD} > 2 V	0	—	0.4	V	—
Low-level output voltage2 (SDA)	V_{OL1L}	I_{SDA} = 3 mA, V_{DD} < 2 V	0	—	0.2 × V_{DD}	V	—
SCL clock frequency	f_{SCL}	—	0	—	400	kHz	—
CLKPWM							
High-level input voltage range	V_{IH2}	—	V_{DD} × 0.7	—	V_{DD} + 0.2	V	—
Low-level input voltage range	V_{IL2}	—	– 0.2	—	V_{DD} × 0.3	V	—
Pin pull down resistance value	R_{PD2}	—	0.5	1.0	2.0	MΩ	—
High-level output voltage	V_{OH2}	I_{CLKPWM} = – 2 mA	V_{DD} × 0.8	—	V_{DD} + 0.2	V	—
Low-level output voltage	V_{OL2}	I_{CLKPWM} = 2 mA	–0.2	—	V_{DD} × 0.2	V	—
ADSEL1, ADSEL2							
High-level input voltage range	V_{IH3}	—	V_{DD} × 0.7	—	V_{DD} + 0.2	V	—
Low-level input voltage range	V_{IL3}	—	– 0.2	—	V_{DD} × 0.3	V	—
High-level input current	I_{IH3}	$V_{ADSEL1, 2}$ = 1.8 V	—	0	1	µA	—
Low-level input current	I_{IL3}	$V_{ADSEL1, 2}$ = 0 V	—	0	1	µA	—

Note:*1: The input threshold voltage of I²C bus (Vth) is linked to V_{DD} (I²C bus I/O stage supply voltage).
In case the pull-up voltage is not V_{DD}, the threshold voltage (Vth) is fixed to ((V_{DD} / 2) ± (Schmitt width) / 2) and High-level, Low-level of input voltage are not specified.
In this case, pay attention to Low-level (max.) value (V_{ILmax}).
It is recommended that the pull-up voltage of I²C bus is set to the I²C bus I/O stage supply voltage (V_{DD}).

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ELECTRICAL CHARACTERISTICS (continued)

V_{CC} = 3.6 V, V_{DD} = 1.8 V

Note: T_a = 25 °C ± 2 °C unless otherwise specified.

Parameter	Symbol	Condition	Limits			Unit	Note
			Min	Typ	Max		
CLKPWM							
External PWM operation mode Possible input high pulse width	W_{PWM}	—	—	2.5	—	µs	*2

Note: *2 : Typical design value

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ELECTRICAL CHARACTERISTICS (continued)

V_{CC} = 3.6 V, V_{DD} = 1.8 V

Note: T_a = 25 °C ± 2 °C unless otherwise specified.

Parameter	Symbol	Condition	Limits			Unit	Note
			Min	Typ	Max		
I²C bus (Internal I/O stage characteristics)							
Input voltage hysteresis (1)	V_{hys1}	SCL, SDA hysteresis voltage V_{DD} > 2 V	0.05 × V_{DD}	—	—	V	*3
Input voltage hysteresis (2)	V_{hys2}	SCL, SDA hysteresis voltage V_{DD} < 2 V	0.1 × V_{DD}	—	—	V	*3
Output fall time from V_{IHmin} to V_{ILmax}	t_{of}	Bus capacitance : 10 pF to 400pF $I_P \leq 6$ mA (V_{OLmax} = 0.6 V) I_P : Max. sink current	20 + 0.1×C_b	—	250	ns	*3
Spike pulse width kept down by input filter	t_{sp}	—	0	—	50	ns	*3
I/O pin capacitance	C_i	—	—	—	10	pF	*3

Notes: *3 : These are values checked by design but not production tested.

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ELECTRICAL CHARACTERISTICS (continued)

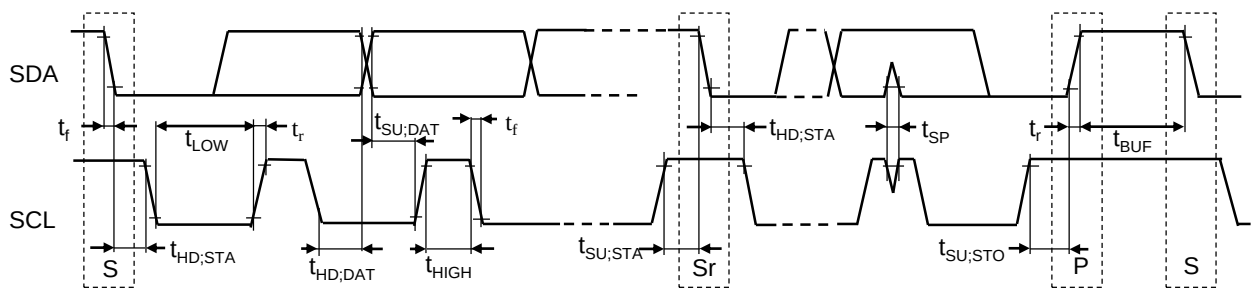
V_{CC} = 3.6 V, V_{DD} = 1.8 V

Note: T_a = 25 °C ± 2 °C unless otherwise specified.

Parameter	Symbol	Condition	Limits			Unit	Note
			Min	Typ	Max		
I²C bus (Bus line specifications)							
Hold duration (recursive)	$t_{HD:STA}$	After $t_{HD:STA,}$. the first clock pulse is generated.	0.6	—	—	µs	*3,4
SCL clock "L" duration	t_{LOW}	—	1.3	—	—	µs	*3,4
SCL clock "H" duration	t_{HIGH}	—	0.6	—	—	µs	*3,4
Recursive "START" condition setting time	$t_{SU:STA}$	—	0.6	—	—	µs	*3,4
Data hold time	$t_{HD:DAT}$	—	0	—	0.9	µs	*3,4
Data setup time	$t_{SU:DAT}$	—	100	—	—	ns	*3,4
SDA, SCL signal rise up time	t_r	—	20 + 0.1×C_b	—	300	ns	*3,4
SDA, SCL signal fall time	t_f	—	20 + 0.1×C_b	—	300	ns	*3,4
Setup time under "STOP" condition	$t_{SU:STO}$	—	0.6	—	—	µs	*3,4
Bus free time between under "STOP" condition and "START" condition	t_{BUF}	—	1.3	—	—	µs	*3,4
Capacitive load for each bus line	C_b	—	—	—	400	pF	*3,4
Noise margin of each connection device at Low-level	V_{nL}	—	0.1 × V_{DD}	—	—	V	*3,4
Noise margin of each connection device at High-level	V_{nH}	—	0.2 × V_{DD}	—	—	V	*3,4

Note: *3: These are values checked by design but not production tested.

*4: The timing of Fast-mode devices in I²C-bus is specified as follows.
All values referred to V_{IHmin} and V_{ILmax} level.



S : START condition
Sr : Repeat START condition
P : STOP condition

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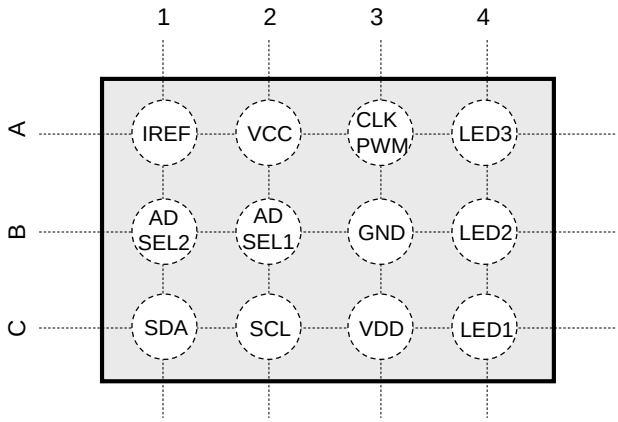
PIN CONFIGURATION

Top View



PIN FUNCTIONS

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

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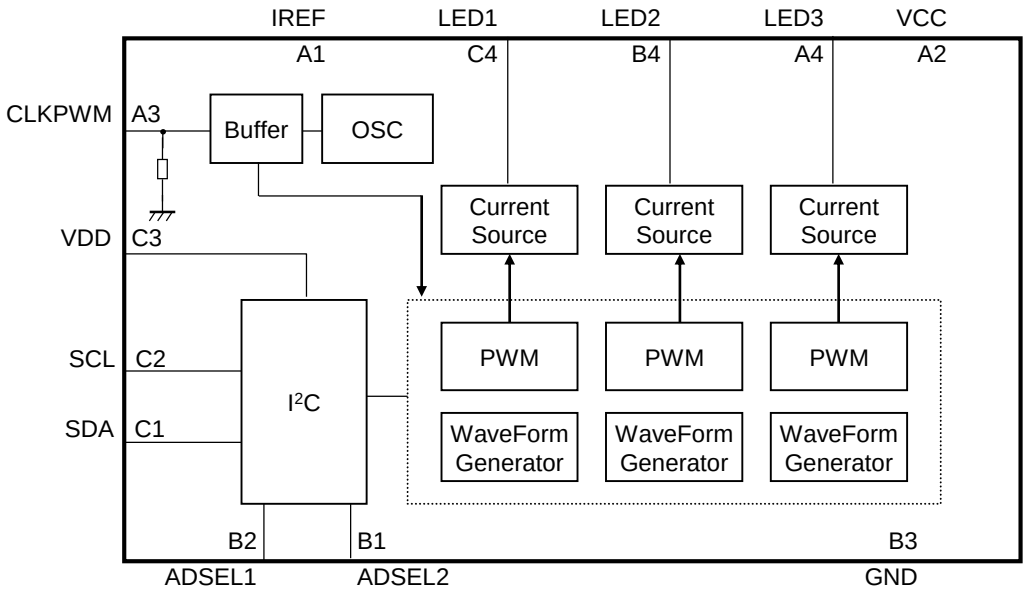
FUNCTIONAL BLOCK DIAGRAM



Note: This block diagram is for explaining functions. Part of the block diagram may be omitted, or it may be simplified.

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OPERATION

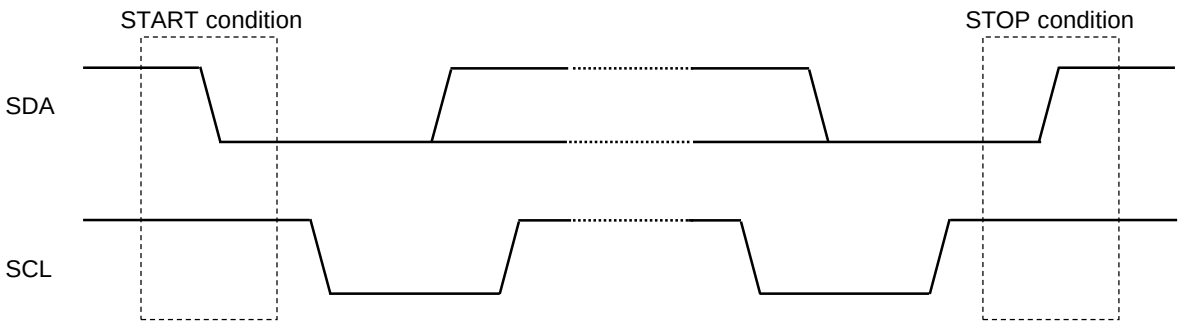
1. I²C-bus Interface

1) Basic Rules

- This IC, I²C-bus, is designed to correspond to the Standard-mode (100 kbps) and Fast-mode(400 kbps) devices in the version 2.1 of NXP's specification. However, it does not correspond to the H_S-mode (to 3.4 Mbps).
- This IC will be operated as a slave device in the I²C-bus system. This IC will not operate as a master device.
- The program operation check of this IC has not been conducted on the multi-master bus system and the mix-speed bus system, yet. The connected confirmation of this IC to the CBUS receiver also has not been checked. Please confirm with our company if it will be used in these mode systems. The I²C is the brand of NXP.

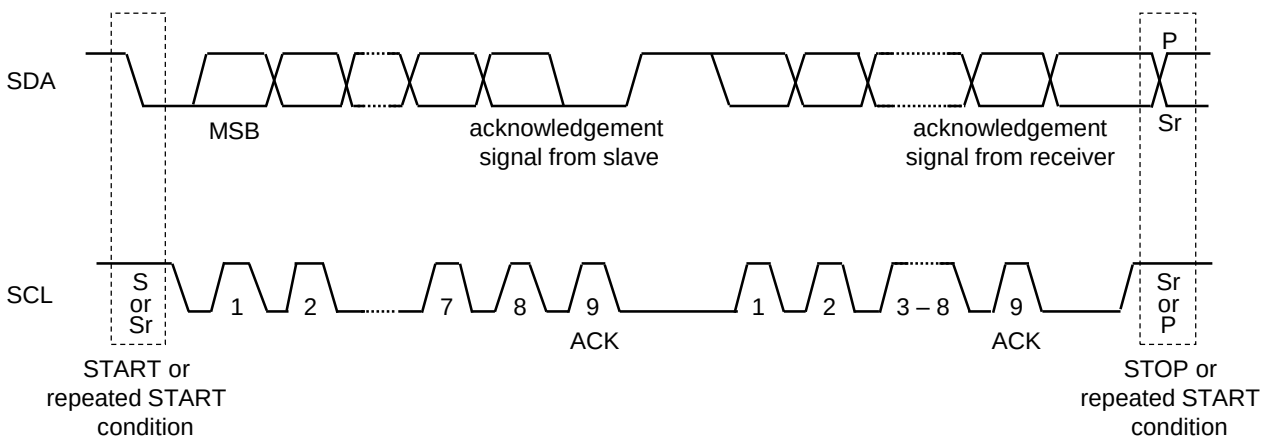
2) START and STOP conditions

A High to Low transition on the SDA line while SCL is High is one such unique case. This situation indicates START condition. A Low to High transition on the SDA line while SCL is High defines STOP condition. START and STOP conditions are always generated by the master. After START condition occurs, the bus will be busy. The bus is considered to be free again a certain time after the STOP condition.



3) Transferring Data

Every byte put on the SDA line must be 8-bits long. The number of bytes that can be transmitted per transfer is unrestricted. Each byte has to be followed by an acknowledge bit. Data is transferred with the most significant bit (MSB) first.



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OPERATION (continued)

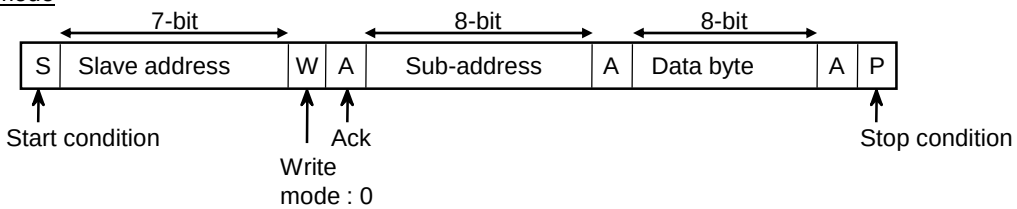
1. I²C-bus Interface (continued)

4) Data format

Slave address can be switched by ADSEL1, ADSEL2 pin connections. The chart on the right shows the slave address of this product.

ADSEL2	ADSEL1	Slave address
Low (Ground)	Low (Ground)	30 h (0110000)
Low (Ground)	High (VDD)	31 h (0110001)
High (VDD)	Low (Ground)	32 h (0110010)
High (VDD)	High (VDD)	33 h (0110011)

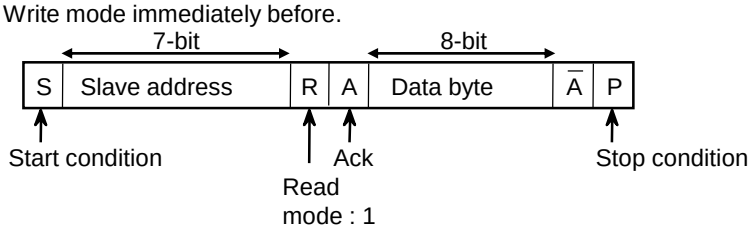
Write mode



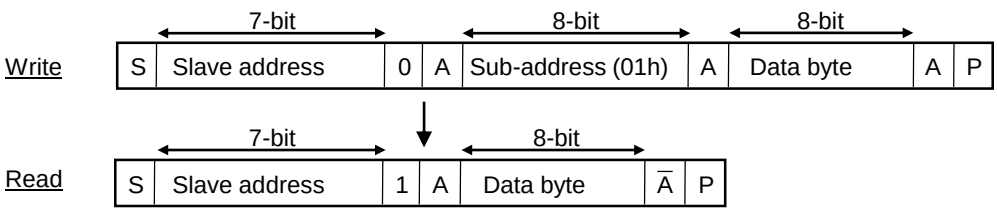
Read mode

A) When sub-address is not assigned.

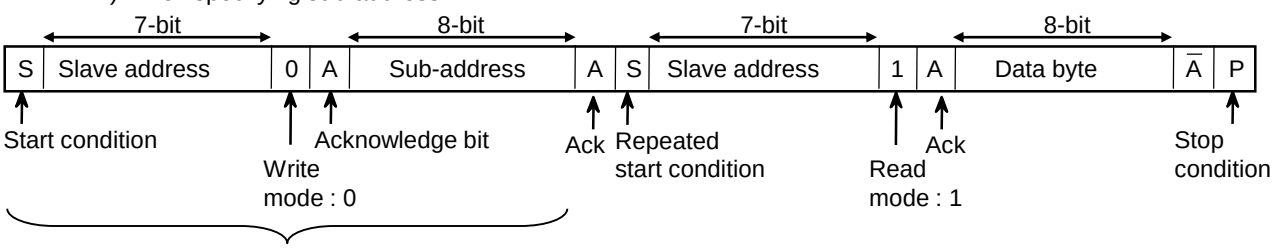
When data is read without assigning sub-address, it is possible to read the value of sub-address specified in Write mode immediately before.



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



B) When specifying sub-address



Sub-address should be assigned first.

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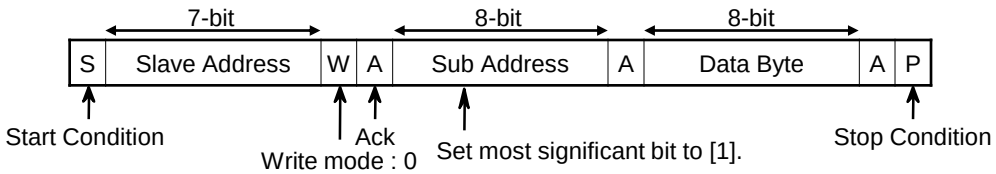
OPERATION (continued)

1. I²C-bus Interface (continued)

4) Data format (continued)

- Continuous Write mode

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

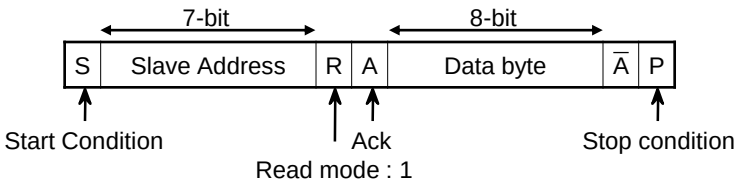


Ex) 05h → 85h, 11h → 91h

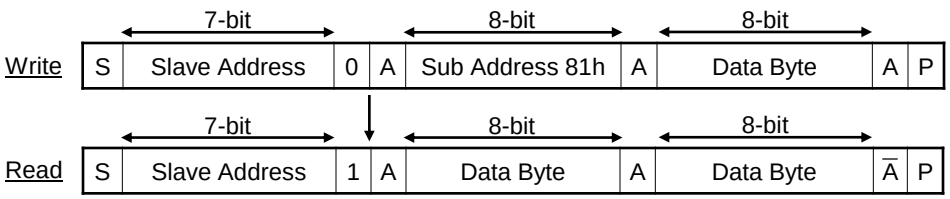
- Continuous Read mode

A) When Sub address is not specified

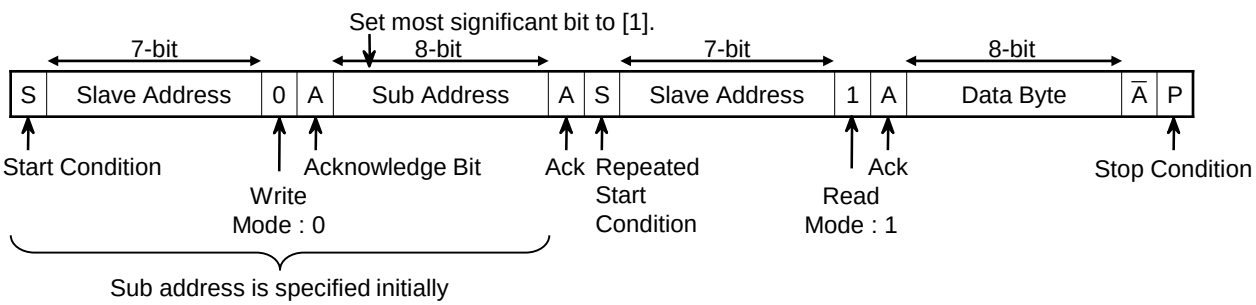
When the most significant bit specified in the last Write mode is [1], it is possible to perform the continuous Read mode operation directly after it.



Ex) Case where data is read from Address 01h after data is written to Address 01h



B) When Sub address is specified



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OPERATION (continued)

2. Register map

Sub Address	R/W	Register Name	Data							
			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].

OPERATION (continued)

3. Register map details

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 returns to Low automatically)

OPERATION (continued)

3. Register map details (continued)

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 modes, too.

OPERATION (continued)

3. Register map details (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] Maximum value, Step value setting for current setting
[00] : Maximum value 12.75 mA, Step value 0.05 mA
[01] : Maximum value 25.50 mA, Step value 0.10 mA (default)
[10] : Maximum value 31.875 mA, Step value 0.125 mA
[11] : Maximum value 63.75 mA, Step value 0.25 mA

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

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

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

D2 : DLYSEL3 Lighting delay time mode setting at LED3 Slope mode
[0] : LED3 delay time Max 7.50 s mode (default)
[1] : LED3 delay time Max 1.86 s mode

D1 : DLYSEL2 Lighting delay time mode setting at LED2 Slope mode
[0] : LED2 Delay time Max 7.50 s mode (default)
[1] : LED2 Delay time Max 1.86 s mode

D0 : DLYSEL1 Lighting delay time mode setting at LED1 Slope mode
[0] : LED1 Delay time Max 7.50 s mode (default)
[1] : LED1 Delay time Max 1.86 s mode

Please refer to the 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.
(The output clock will not be available when LED1ON=LED2ON=LED3ON=0.)
Synchronized operation can be possible when more than two pieces of this IC are connected.

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OPERATION (continued)

3. Register map details (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	0.100 mA	0.125 mA	0.250 mA
:	:	:	:	:	:	:	:	Step	Step	Step	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

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OPERATION (continued)

3. Register map details (continued)

Register Name		LED1SLP							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
06 h	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.
Please refer to following "4. 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 μ s) × 75 × 125 × 0 = 0.0 s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 125 × 1 = 0.5 s
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 2 = 1.0 s
:	:	:	:	:
:	:	:	:	0.5 s Step
:	:	:	:	:
1	1	0	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 12 = 6.0 s
1	1	0	1	(PWM cycle = 53.3 μ s) × 75 × 125 × 13 = 6.5 s
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 14 = 7.0 s
1	1	1	1	(PWM cycle = 53.3 μ s) × 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 μ s) × 75 × 125 × 0 = 0.0 s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 125 × 1 = 0.5 s
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 2 = 1.0 s
:	:	:	:	:
:	:	:	:	0.5 s Step
:	:	:	:	:
1	1	0	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 12 = 6.0 s
1	1	0	1	(PWM cycle = 53.3 μ s) × 75 × 125 × 13 = 6.5 s
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 125 × 14 = 7.0 s
1	1	1	1	(PWM cycle = 53.3 μ s) × 75 × 125 × 15 = 7.5 s

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OPERATION (continued)

3. Register map details (continued)

Register Name		LED2SLP							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
07 h	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 will be set.

Register Name		LED3SLP							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
08 h	R/W	SLP3TT2 [3 : 0]				SLP3TT1 [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 " 4. LED control Slope lighting mode " for the details of slope operation.

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

OPERATION (continued)

3. Register map details (continued)

Register Name		LED1CNT1							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
09 h	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
0A h	R/W	DELAY1 [3 : 0]				DUTYMIN1 [3 : 0]			
Default	00 h	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
0B h	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, the period of SLOPE operation 2 time
D3-0 : SLP1DT1 [3 : 0] LED1 slope lighting, the period of SLOPE operation 1 time

Register Name		LED1CNT4							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0C h	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, the period of SLOPE operation 4 time
D3-0 : SLP1DT3 [3 : 0] LED1 slope lighting, the period of SLOPE operation 3 time

Operation parameter of LED1 SLOPE operation will be set.
Please refer to following “ 4. LED control Slope lighting mode ” for the details of slope operation.

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OPERATION (continued)

3. Register map details (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 %

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OPERATION (continued)

3. Register map details (continued)

DUTYMIN1 [3 : 0] correspond to the following PWM Duty setting [6 : 0] 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]				DLYSEL1 = 0	DLYSEL1 = 1
0	0	0	0	0.00 s	0.000 s
0	0	0	1	0.50 s	0.124 s
0	0	1	0	1.00 s	0.248 s
~				~	~
1	1	1	0	7.00 s	1.736 s
1	1	1	1	7.50 s	1.860 s

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OPERATION (continued)

3. Register map details (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 μ s) × 1 = 53.3 μ s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μ s) × 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 μ s) × 1 = 53.3 μ s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μ s) × 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 μ s) × 1 = 53.3 μ s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μ s) × 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 μ s) × 1 = 53.3 μ s
0	0	0	1	(PWM cycle = 53.3 μ s) × 75 × 1 = 4.0 ms
0	0	1	0	(PWM cycle = 53.3 μ s) × 75 × 2 = 8.0 ms
~				~
1	1	1	0	(PWM cycle = 53.3 μ s) × 75 × 14 = 56.0 ms
1	1	1	1	(PWM cycle = 53.3 μ s) × 75 × 15 = 60.0 ms

OPERATION (continued)

3. Register map details (continued)

Register Name		LED2CNT1							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
0D h	R/W	DUTYMAX2 [3 : 0]				DUTYMID2 [3 : 0]			
Default	F8 h	1	1	1	1	1	0	0	0

D7-4 : DUTYMAX2 [3 : 0] LED2 at slope lighting, maximum PWM Duty setting
D3-0 : DUTYMID2 [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
0E h	R/W	DELAY2 [3 : 0]				DUTYMIN2 [3 : 0]			
Default	00 h	0	0	0	0	0	0	0	0

D7-4 : DELAY2 [3 : 0] LED2 starting delay time setting
D3-0 : DUTYMIN2 [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
0F h	R/W	SLP2DT2 [3 : 0]				SLP2DT1 [3 : 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP2DT2 [3 : 0] LED2 slope lighting, the period of SLOPE operation 2 time
D3-0 : SLP2DT1 [3 : 0] LED2 slope lighting, the period of SLOPE operation 1 time

Register Name		LED2CNT4							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
10 h	R/W	SLP2DT4 [3 : 0]				SLP2DT3 [3 : 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP2DT4 [3 : 0] LED2 slope lighting, the period of SLOPE operation 4 time
D3-0 : SLP2DT3 [3 : 0] LED2 slope lighting, the period of SLOPE operation 3 time

Operation parameter of LED2 SLOPE operation will be set.
Each parameter is the same as LED1 Parameter.
Please refer to following “ 4. LED control Slope lighting mode ” for the details of slope operation.

OPERATION (continued)

3. Register map details (continued)

Register Name		LED3CNT1							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
11 h	R/W	DUTYMAX3 [3 : 0]				DUTYMID3 [3 : 0]			
Default	F8 h	1	1	1	1	1	0	0	0

D7-4 : DUTYMAX3 [3 : 0] LED3 at slope lighting maximum PWM Duty setting
D3-0 : DUTYMID3 [3 : 0] LED3 at slope lighting middle PWM Duty setting

Register Name		LED3CNT2							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
12 h	R/W	DELAY3 [3 : 0]				DUTYMIN3 [3 : 0]			
Default	00 h	0	0	0	0	0	0	0	0

D7-4 : DELAY3 [3 : 0] LED3 starting delay time setting
D3-0 : DUTYMIN3 [3 : 0] LED3 at slope lighting minimum PWM Duty setting

Register Name		LED3CNT3							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
13 h	R/W	SLP3DT2 [3 : 0]				SLP3DT1 [3 : 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP3DT2 [3: 0] LED3 slope lighting, the period of SLOPE operation 2 time
D3-0 : SLP3DT1 [3: 0] LED3 slope lighting, the period of SLOPE operation 1 time

Register Name		LED3CNT4							
Address	R / W mode	D7	D6	D5	D4	D3	D2	D1	D0
14 h	R/W	SLP3DT4 [3: 0]				SLP3DT3 [3: 0]			
Default	88 h	1	0	0	0	1	0	0	0

D7-4 : SLP3DT4 [3: 0] LED3 slope lighting, the period of SLOPE operation 4 time
D3-0 : SLP3DT3 [3: 0] LED3 slope lighting, the period of SLOPE operation 3 time

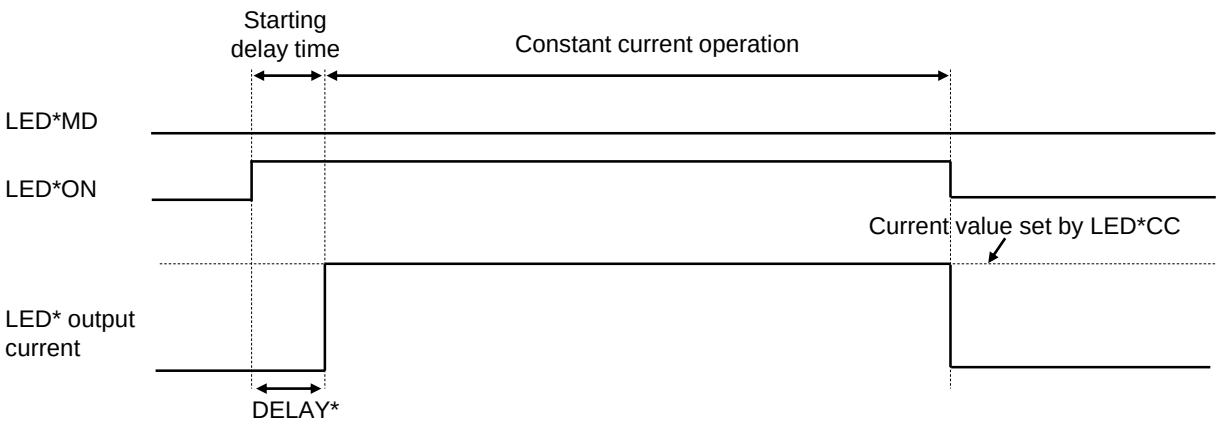
Operation parameter of LED3 SLOPE operation will be set.
Each parameter is the same as LED1 parameter.
Please refer to following “ 4. LED control Slope lighting mode ” for the details of slope operation.

OPERATION (continued)

4. LED control

4.1 Constant current lighting mode

- It is possible to 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 in page 30, 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.

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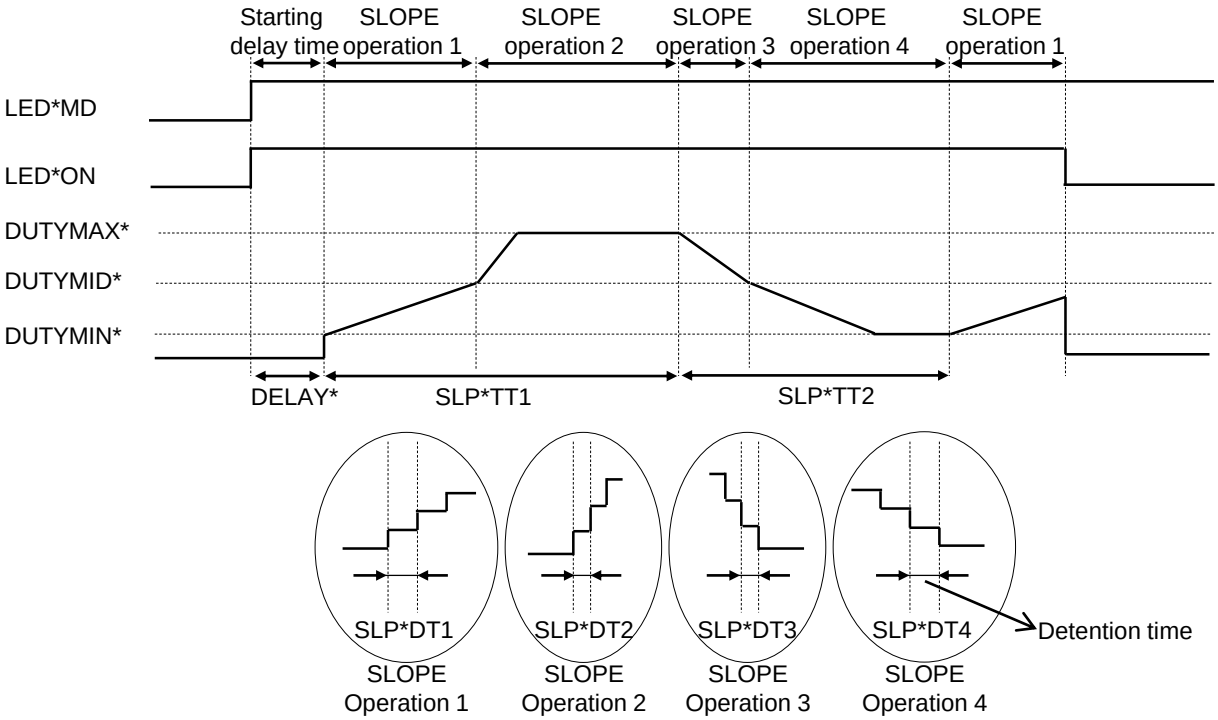
OPERATION (continued)

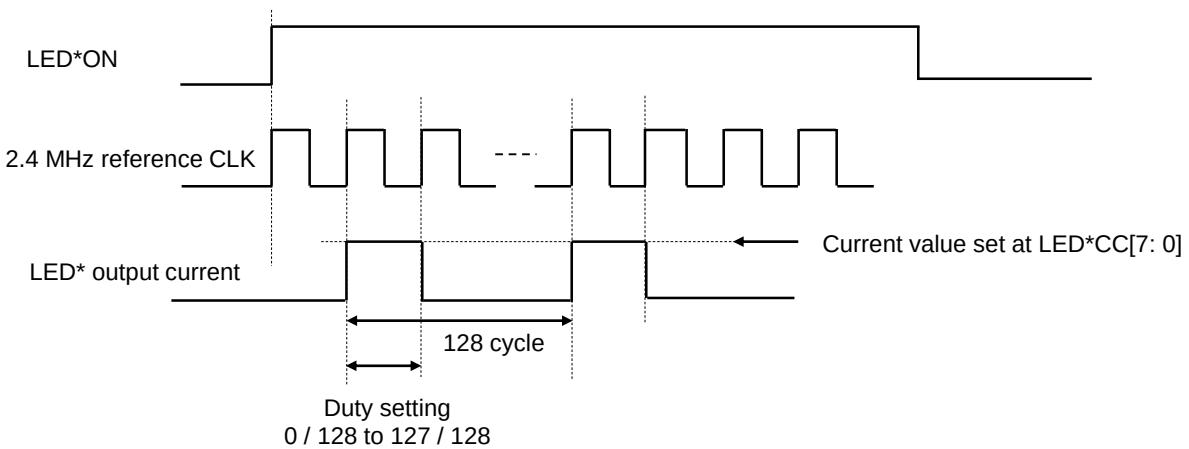
4. LED control (continued)

4.2 Slope lighting mode

- 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.



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OPERATION (continued)

4. LED control (continued)

4.3 Total time of Slope operation 1, 2

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

- SLP*TT1[3 : 0] setting has priority to the case of
  SLP*TT1[3 : 0] < "SLOPE operation 1" + "SLOPE operation 2".
- In case of that SLP*TT1[3 : 0] time is over during SLOPE operation 1 (before SLOPE operation 2), SLOPE operation 2 is omitted and transferred to SLOPE operation 3 from the position of DUTYMAX.

4.4 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 has priority to the case of
  SLP*TT2[3 : 0] < "SLOPE operation 3" + "SLOPE operation 4".
- In case of that SLP*TT2[3 : 0] time is over during SLOPE operation 3(before SLOPE operation 4), SLOPE operation 4 is omitted and transferred to SLOPE operation 1 from the position of DUTYMIN.

4.5 DUTYMIN, DUTYMID, DUTYMAX setting for SLOPE operation

- SLOPE operation 1
  PWM step increases step by step from the value set by DUTYMIN*[3 : 0] to the value set by DUTYMID*[3 : 0].
  Please set the period 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 step increases step by step from the value set by DUTYMID*[3 : 0] to the value set at DUTYMAX*[3 : 0].
  Please set the period 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 step decreases step by step from the value set by DUTYMAX*[3 : 0] to the value set by DUTYMID*[3 : 0].
  Please set the period 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 step decreases step by step from the value set by DUTYMID*[3 : 0] to the value set by DUTYMIN*[3 : 0].
  Please set the period 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] .

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OPERATION (continued)

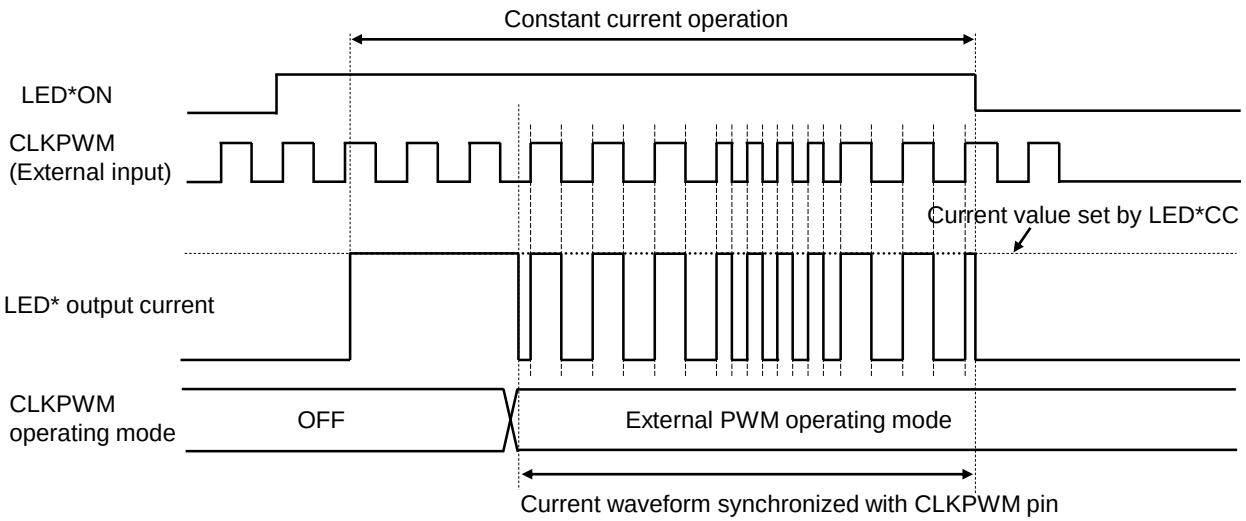
4. LED control (continued)

4.6 External PWM operation mode of CLKPWM pin

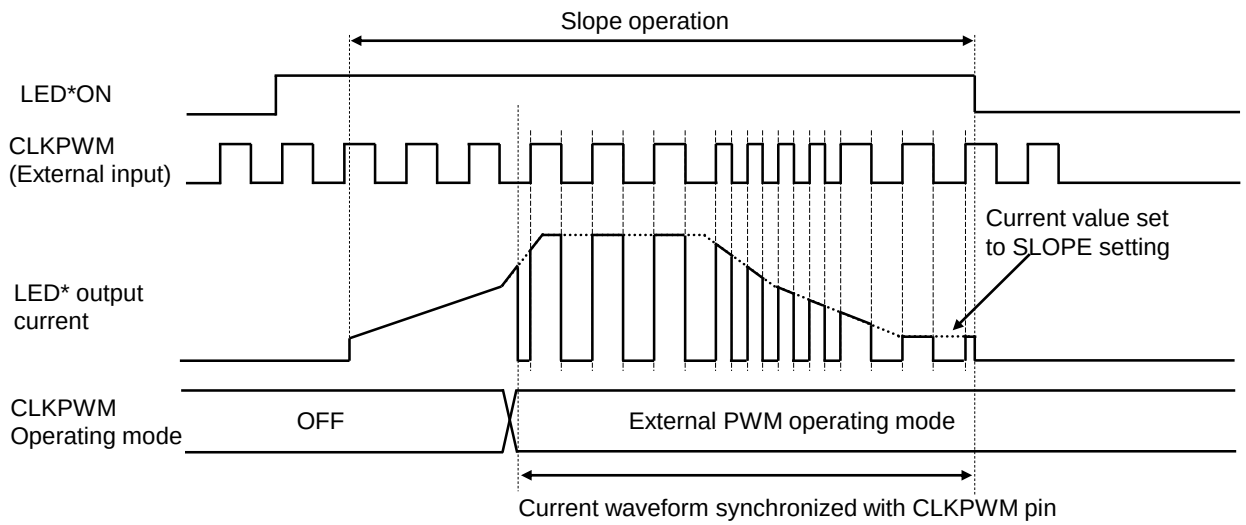
The lighting synchronization with CLKPWM signal can be turned on by setting "External PWM operation mode" in register setting.

The maximum frequency which can be input to CLKPWM pin is 20 kHz.

< At Constant current mode >



< At Slope lighting mode>



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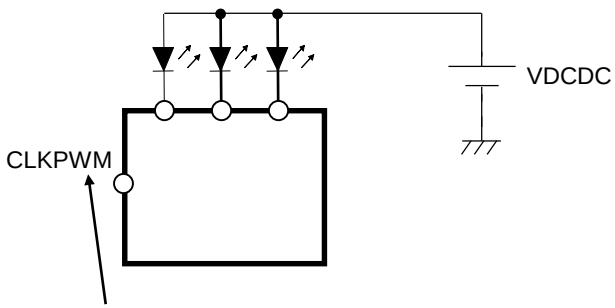
OPERATION (continued)

4. LED control (continued)

4.7 External clock input mode and internal clock output mode of CLKPWM pin

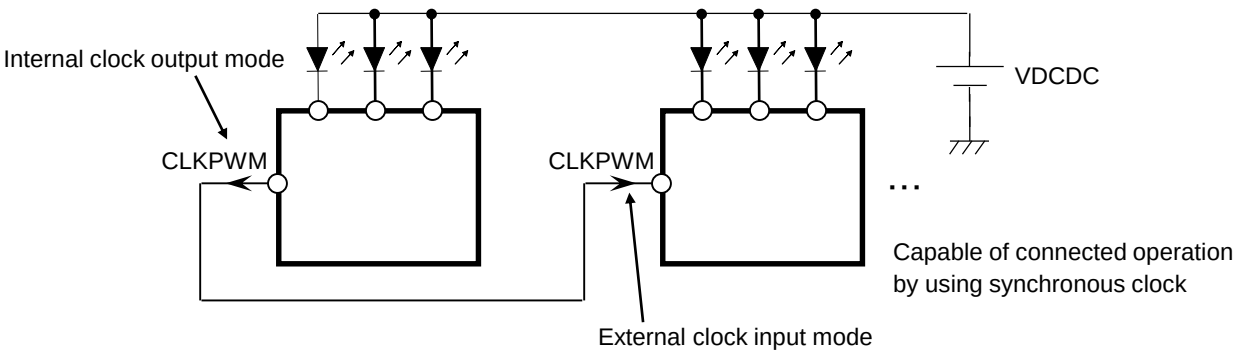
The following configuration can be made up by choosing "External clock input mode", "Internal clock output mode“ in register setting.

< Single application >



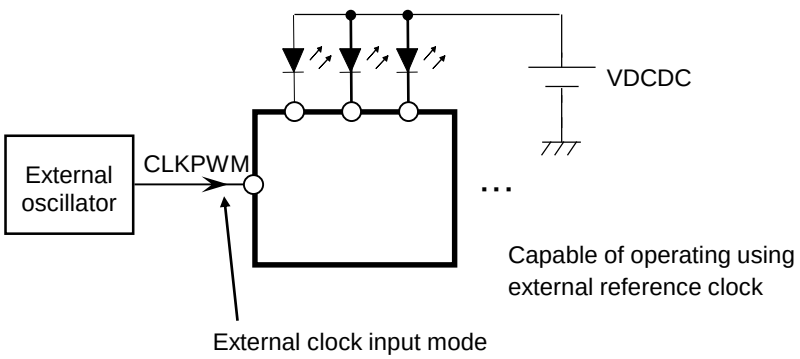
Unused state（CLKPWM operation OFF mode）

< Connected application >



(Please refer to the explanation of the operation mode of P.17 for the setting of CLKPWM)

< External reference clock application >



(Please refer to the explanation of the operation mode of P.17 for the setting of CLKPWM)

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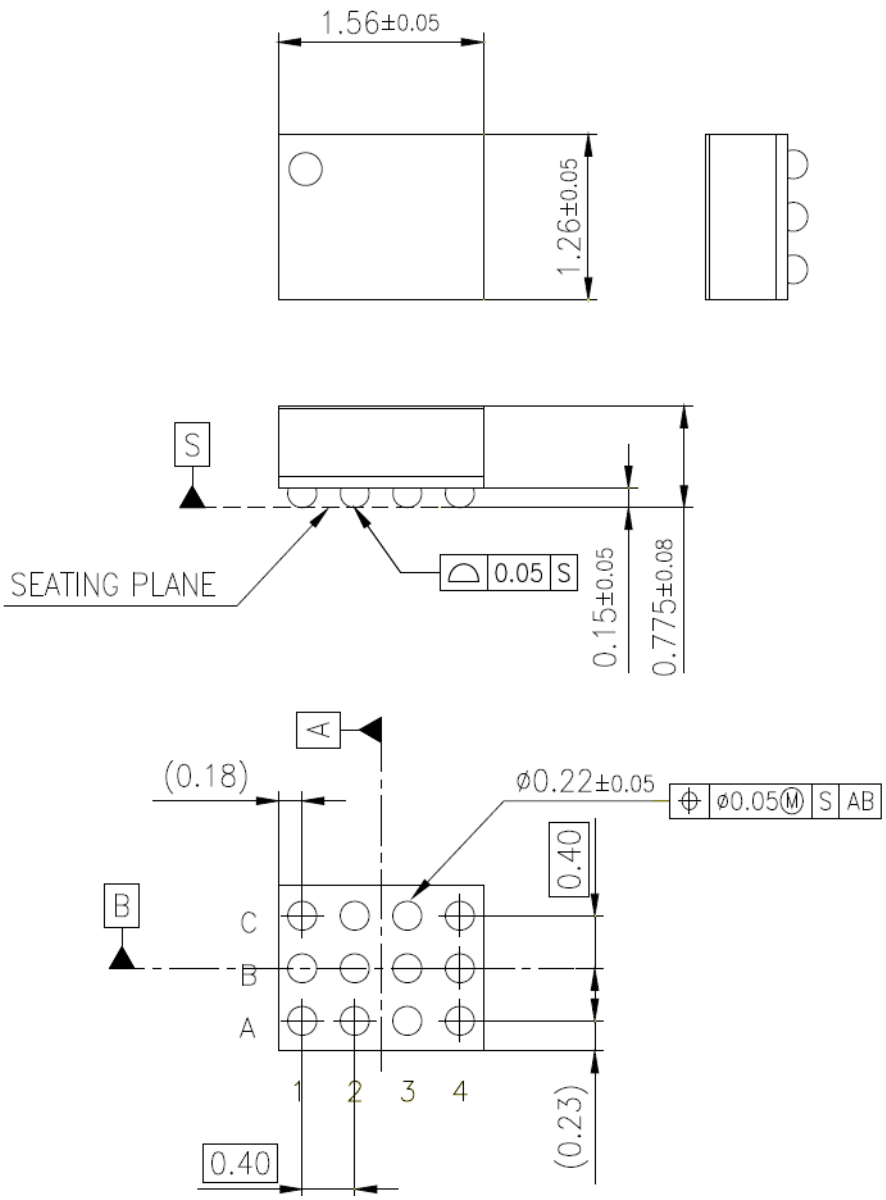
PACKAGE INFORMATION (Reference Data)

Unit:mm



Body Material : Br/Sb Free Epoxy Resin
Reroute Material : Cu
Bump : SnAgCu

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Revised : 2019-07-23

IMPORTANT NOTICE

1. When using the IC for new models, verify the safety including the long-term reliability for each product.

2. When the application system is designed by using this IC, please confirm the notes in this book.
   Please read the notes to descriptions and the usage notes in the book.

3. This IC is neither designed nor intended for use in automotive applications or environments unless the specific product is designated by our company as compliant with the ISO/TS 16949 requirements.
   Our company shall not be held responsible for any damage incurred by customers or any third party as a result of or in connection with the IC being used in automotive application, unless our company agrees to such application in this book.

4. Please use this product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Our company shall not be held responsible for any damage incurred as a result of our IC being used by our customers, not complying with the applicable laws and regulations.

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USAGE NOTES

1. Pay attention to the direction of IC. When mounting it in the wrong direction onto the PCB (printed-circuit-board), it might emit smoke or ignite.

2. Pay attention in the PCB (printed-circuit-board) pattern layout in order to prevent damage due to short circuit between pins. In addition, refer to the Pin Description for the pin configuration.

3. Perform visual inspection on the PCB before applying power, otherwise damage might happen due to problems such as solder-bridge between the pins of the IC. Also, perform full technical verification on the assembly quality, because the same damage possibly can happen due to conductive substances, such as solder ball, that adhere to the IC during transportation.

4. Take notice in the use of this IC that it might be damaged or occasionally emit smoke when an abnormal state occurs such as output pin-VCC short (Power supply fault), output pin-GND short (Ground fault), or output-to-output-pin short (load short). Safety measures such as installation of fuses are recommended because the extent of the above-mentioned damage and smoke emission will depend on the current capability of the power supply.

5. Due to the unshielded structure of this IC, functions and characteristics of the IC cannot be guaranteed under the exposure of light. During normal operation or even under testing condition, please ensure that the IC is not exposed to light.

6. Please ensure that your design does not have metal shield parts touching the chip surface as the surface potential is GND voltage.

7. Pay attention to the breakdown voltage of this IC when using.

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