

# **S1F76680**

## **Technical Manual**

## NOTICE

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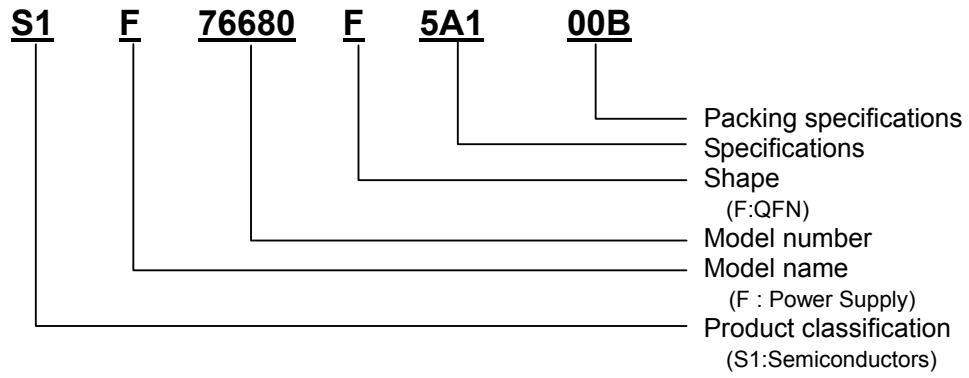
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## Configuration of product number

### ●DEVICES



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### 1. DESCRIPTION

S1F76680 is a LED driver that can drive four (three) white LEDs lamps for backlighting in parallel connection.

Necessary power is supplied to LED by the charge pump type DC/DC converter incorporated in S1F76680.

Also, the charge pump type DC/DC converter selects 1x or 1.5x voltages on its own according to necessity.

Maximum driving current to LED can be set with one external resistor.

With S1F76680, LED's current value is changed in harmony with ambient brightness level, when connected with an external luminance sensor.

In this IC, a two-wire serial interface I<sup>2</sup>C-Bus slave function is contained, and the current value in accordance with the ambient brightness can be set with a register of I<sup>2</sup>C.

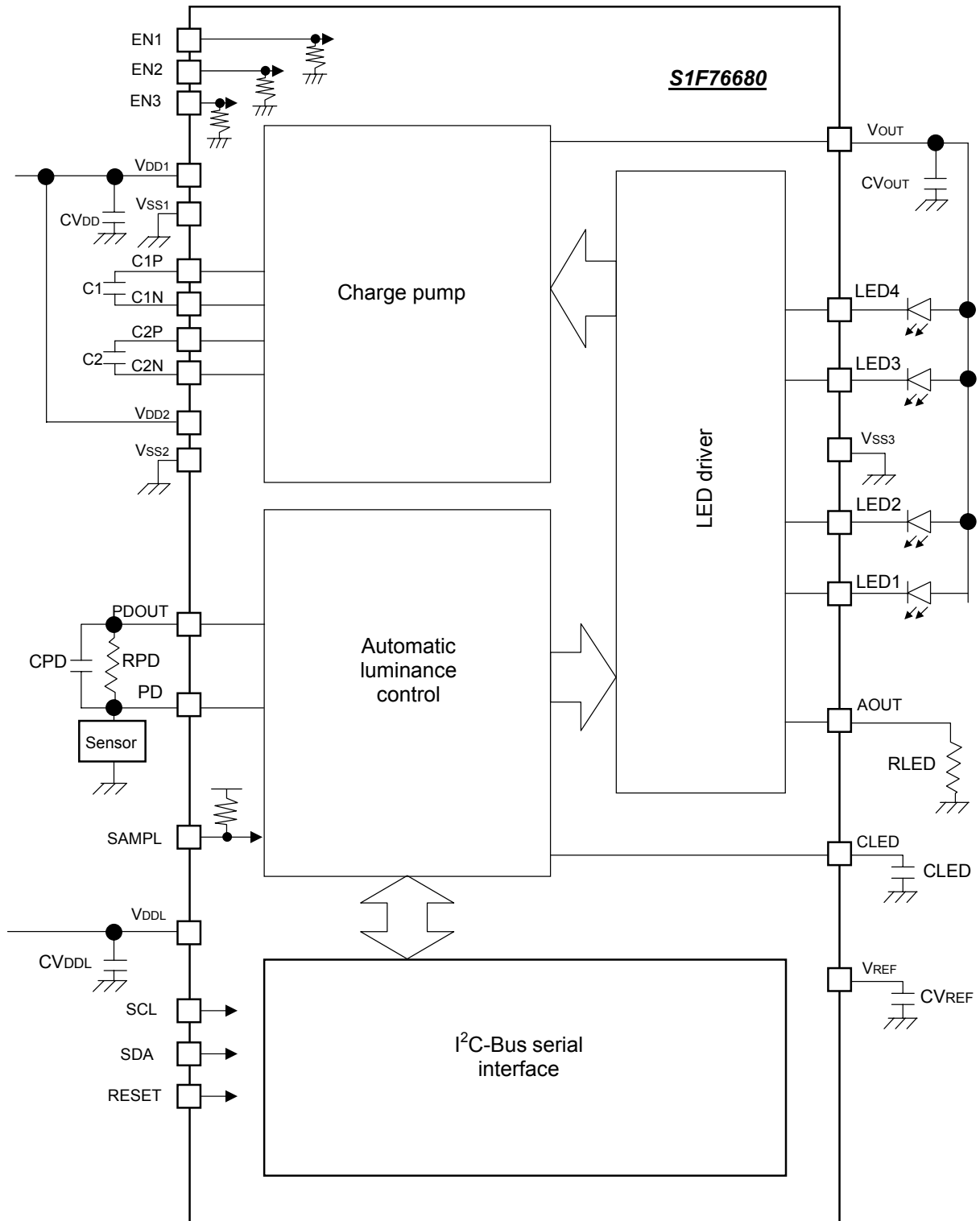
Allowing to configure the backlight that automatically selects optimal LED current value in accordance with the brightness level of the surrounding environment, this function makes this device a optimal LED driver for mobile devices realizing high viewability and low power consumption.

### 2. FEATURES

- Drives four (three) white LEDs lamps in parallel connection
- Sets LED maximum current value with an external resistor
- Power saving operation due to booster magnification automatic switching function of an amp circuit
- Driving with the LED current value changed in accordance to the ambient brightness level (automatic luminance control) when connected with a luminance sensor
- Allows setting of the automatic luminance control characteristic with I<sup>2</sup>C
- Enable automatic luminance control/imperative fixed current selection with I<sup>2</sup>C
- Acquires the information on ambient brightness with I<sup>2</sup>C
- Incorporates a soft start circuit for activation with EN1 pin
- Enable automatic luminance control circuit activation/stop selection with EN2 pin
- Allows a drive at set maximum current with EN3 pin
- Mass production form QFN5-32PIN (5.0mm × 5.0mm)
- Not radiation- or light-proofed

### 3. BLOCK DIAGRAM

### 3. BLOCK DIAGRAM



### 4. DESCRIPTION OF BLOCK DIAGRAM

(1) Charge pump

The charge pump is a circuit that generates voltage required for driving LED at VOUT pin.

As a pump-up capacitor required to operate the DC/DC converter, connect capacitors C1 and C2 with C1P, C1N, C2P and C2N pins respectively.

Connect CVOUT as a storage capacitor for booster voltage generated at VOUT pin.

(2) Automatic luminance control

A circuit that determines the LED current value in accordance with the ambient brightness.

The ambient brightness can be evaluated by connecting a luminance sensor between PD pin and VSS (GND), and an external resistor between PDOUT pin and PD pin.

(3) I<sup>2</sup>C -Bus serial interface

Advanced setting to this IC (selection of automatic luminance control operating status, characteristic setting, reading of brightness information, etc) can be performed externally by reading /writing an assigned register.

Since I<sup>2</sup>C on this IC only has slave function, control should be carried out externally by the master function.

(4) LED driver

The LED driver drives four (three) white LEDs lamps in parallel connection.

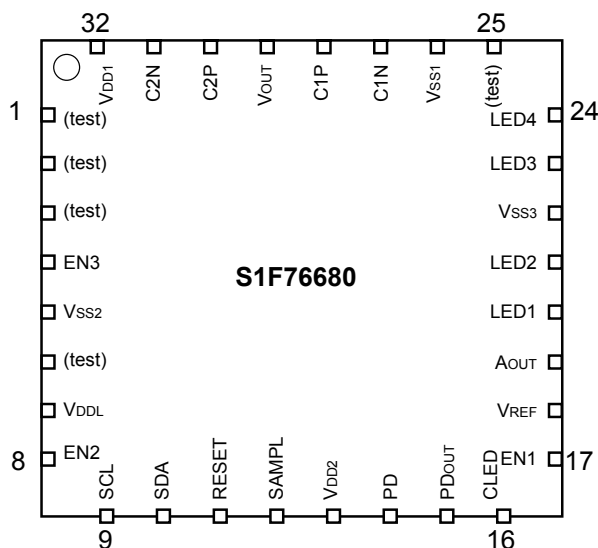
Connect it with RLED, a resistor for maximum current setting.

The LED driver drives LED based on the settings of I<sup>2</sup>C, automatic luminance control and RLED.

## 5. PIN ASSIGNMENT

### 5. PIN ASSIGNMENT

(QFN5-32PIN)



Pin Name	I/O	PIN No.	Function
		QFN5-32	
(test)	—	1	* Since this is a test pin, be sure to keep it "OPEN."
(test)	—	2	* Since this is a test pin, be sure to keep it "OPEN."
(test)	—	3	* Since this is a test pin, be sure to keep it "OPEN."
EN3	I	4	Automatic luminance control/forced full lighting select pin. It is pulled down Internally.
Vss2	—	5	Ground pin.
(test)	—	6	* Since this is a test pin, be sure to keep it "OPEN."
VDDL	I	7	Input power supply pin for I <sup>2</sup> C I/O.
EN2	I	8	Automatic luminance control circuit activation/stop select pin. It is pulled down internally.
SCL	I	9	I <sup>2</sup> C clock input pin.
SDA	I/O	10	I <sup>2</sup> C data I/O pin.
RESET	I	11	I <sup>2</sup> C reset (register initialization) pin
SAMPL	I	12	Brightness evaluation sampling cycle select pin. It is pulled up internally.
VDD2	—	13	Input power supply pin.
PD	I	14	Sensor connect pin.
PDOUT	O	15	Sense resistor connect pin.
CLED	O	16	Pin that connects to capacitor for LED current change delay
EN1	I	17	Input pin for activating IC. It is pulled down internally.
VREF	O	18	Internal reference voltage pin.
AOUT	O	19	Pin that connects to resistor for LED maximum current setting.
LED1	I	20	LED1 connect pin.
LED2	I	21	LED2 connect pin.
Vss3	—	22	Ground pin.
LED3	I	23	LED3 connect pin.
LED4	I	24	LED4 connect pin. * Be sure to connect this pin to ground when using three LEDs only.
(test)	—	25	* Since this is a test pin, be sure to keep it "OPEN."
Vss1	—	26	Ground pin.
C1N	—	27	Pump-up capacitor C1 connect pin.
C1P	—	28	Pump-up capacitor C1 connect pin.
Vout	O	29	LED drive voltage output pin (LED common anode)
C2P	—	30	Pump-up capacitor C2 connect pin.
C2N	—	31	Pump-up capacitor C2 connect pin.
VDD1	—	32	Input power supply pin.

\* EXPOSED DIE ATTACH PAD (refer to the outline drawing in No.P28) in the rear surface metal part of QFN5-32 package is grounded to the same potential as Vss1=Vss2=Vss3.  
Set the rear surface metal part to the open or grounding.



## 6. PIN DESCRIPTION

## (1) Power Supply Pin

Pin Name	PIN No. (QFN5-32)	Function
VDD1	32	Power supply pin.
VDD2	13	Supply voltage that obtains $V_{DD1} = V_{DD2} \geq V_{DDL}$ . Since VDD1 is a power supply pin for the charge pump circuit, connect a bypass capacitor CVDD immediately next to the VDD1 pin.
VDDL	7	Power supply pin for I <sup>2</sup> C I/O signal interface. Supply voltage that obtains $V_{DD1} = V_{DD2} \geq V_{DDL}$ . Connect a bypass capacitor CVDDL immediately next to VDDL pin.
VSS1	26	Ground pin.
VSS2	5	
VSS3	22	

## (2) Input pin ①

Pin Name	PIN No. (QFN5-32)	Function						
EN1	17	<p>Input pin for activating IC. It is pulled down internally.</p> <p>This IC is set to the standby mode as EN1=L is selected. Whenever starting this IC from the standby mode, change the state of EN1 from L to H. When EN1=L, too, also allows input to and output from I<sup>2</sup>C circuit. The standby current value depends on the setting of the EN2 pin to be described later or I<sup>2</sup>C register (SEN2). (See No.P22) Setting of EN2 (SEN)-L, in which the standby current value is reduce, is recommended for the standby mode.</p> <table border="1"> <thead> <tr> <th>EN1 (with pull-down)</th> <th>Function</th> </tr> </thead> <tbody> <tr> <td>L</td> <td>Standby state</td> </tr> <tr> <td>H</td> <td>Circuit operating state</td> </tr> </tbody> </table>	EN1 (with pull-down)	Function	L	Standby state	H	Circuit operating state
EN1 (with pull-down)	Function							
L	Standby state							
H	Circuit operating state							
EN2	8	<p>Input pin that selects activation/stop state for the automatic luminance control circuit. It is pulled down internally.</p> <p>The automatic luminance control circuit operates based on the setting of this EN2 pin or that of I<sup>2</sup>C register (SEN2), which will be explained later.</p> <p>If you do not select the operating state of the automatic luminance control circuit with the EN2 pin, fix EN2 pin to LOW, and select the operating state with I<sup>2</sup>C register (SEN2).</p> <table border="1"> <thead> <tr> <th>EN2 (with pull-down)</th> <th>Function</th> </tr> </thead> <tbody> <tr> <td>L</td> <td>Automatic luminance control circuit stop state</td> </tr> <tr> <td>H</td> <td>Automatic luminance control circuit activated state</td> </tr> </tbody> </table>	EN2 (with pull-down)	Function	L	Automatic luminance control circuit stop state	H	Automatic luminance control circuit activated state
EN2 (with pull-down)	Function							
L	Automatic luminance control circuit stop state							
H	Automatic luminance control circuit activated state							
EN3	4	<p>Forced full lighting select pin.</p> <p>It is pulled down internally.</p> <p>Fix EN3 pin to LOW when activating automatic luminance control.</p> <p>If EN3 pin is fixed to HIGH, LED will light at maximum luminance regardless of the setting of EN2.</p> <table border="1"> <thead> <tr> <th>EN3 (with pull-down)</th> <th>Function</th> </tr> </thead> <tbody> <tr> <td>L</td> <td>Automatic luminance control mode</td> </tr> <tr> <td>H</td> <td>Forced full lighting mode</td> </tr> </tbody> </table>	EN3 (with pull-down)	Function	L	Automatic luminance control mode	H	Forced full lighting mode
EN3 (with pull-down)	Function							
L	Automatic luminance control mode							
H	Forced full lighting mode							

## 6. PIN DESCRIPTION

### (3) Input pin ②

Pin Name	PIN No. (QFN5-32)	Function						
SCL	9	I <sup>2</sup> C clock input pin.						
SDA	10	I <sup>2</sup> C data input pin.						
RESET	11	I <sup>2</sup> C register hard reset pin. Cancel the reset after VDDL has risen. <table border="1" data-bbox="578 428 1390 512"> <thead> <tr> <th>RESET</th> <th>Function</th> </tr> </thead> <tbody> <tr> <td>L</td> <td>Resets I<sup>2</sup>C register</td> </tr> <tr> <td>H</td> <td>Exits reset</td> </tr> </tbody> </table>	RESET	Function	L	Resets I <sup>2</sup> C register	H	Exits reset
RESET	Function							
L	Resets I <sup>2</sup> C register							
H	Exits reset							
SAMPL	12	Brightness evaluation sampling cycle select pin. This pin is pulled up to VDD1=VDD2 level in the IC. <table border="1" data-bbox="578 617 1390 701"> <thead> <tr> <th>SAMPLE (with pull-up)</th> <th>Sampling cycle (TSAMPL)</th> </tr> </thead> <tbody> <tr> <td>H</td> <td>655msec</td> </tr> <tr> <td>L</td> <td>1310msec</td> </tr> </tbody> </table>	SAMPLE (with pull-up)	Sampling cycle (TSAMPL)	H	655msec	L	1310msec
SAMPLE (with pull-up)	Sampling cycle (TSAMPL)							
H	655msec							
L	1310msec							

### (4) Pin for charge pump circuit

Pin Name	PIN No. (QFN5-32)	Function
C1N	27	Pump-up capacitor C1 connect pin.
C1P	28	Pump-up capacitor C1 connect pin.
C2N	31	Pump-up capacitor C2 connect pin.
C2P	30	Pump-up capacitor C2 connect pin.
VOUT	29	LED drive voltage output pin (LED common anode)

### (5) Automatic luminance control and LED

Pin Name	PIN No. (QFN5-32)	Function
PDOUT	15	Sense resistor connect pin.
PD	14	Sensor connect pin.
CLED	16	Pin that connects to capacitor for delaying LED current change It is possible to add delay to the LED current change waveform by connecting an external capacitor CLED with this pin. (Connection of CLED=1μF is recommended)
LED1	20	LED 1 cathode connect pin.
LED2	21	LED 2 cathode connect pin.
LED3	23	LED 3 cathode connect pin.
LED4	24	LED 4 cathode connect pin. * Connect this pin to ground when using three LED lamps only.
AOUT	19	Connect pin for LED maximum current setting resistor

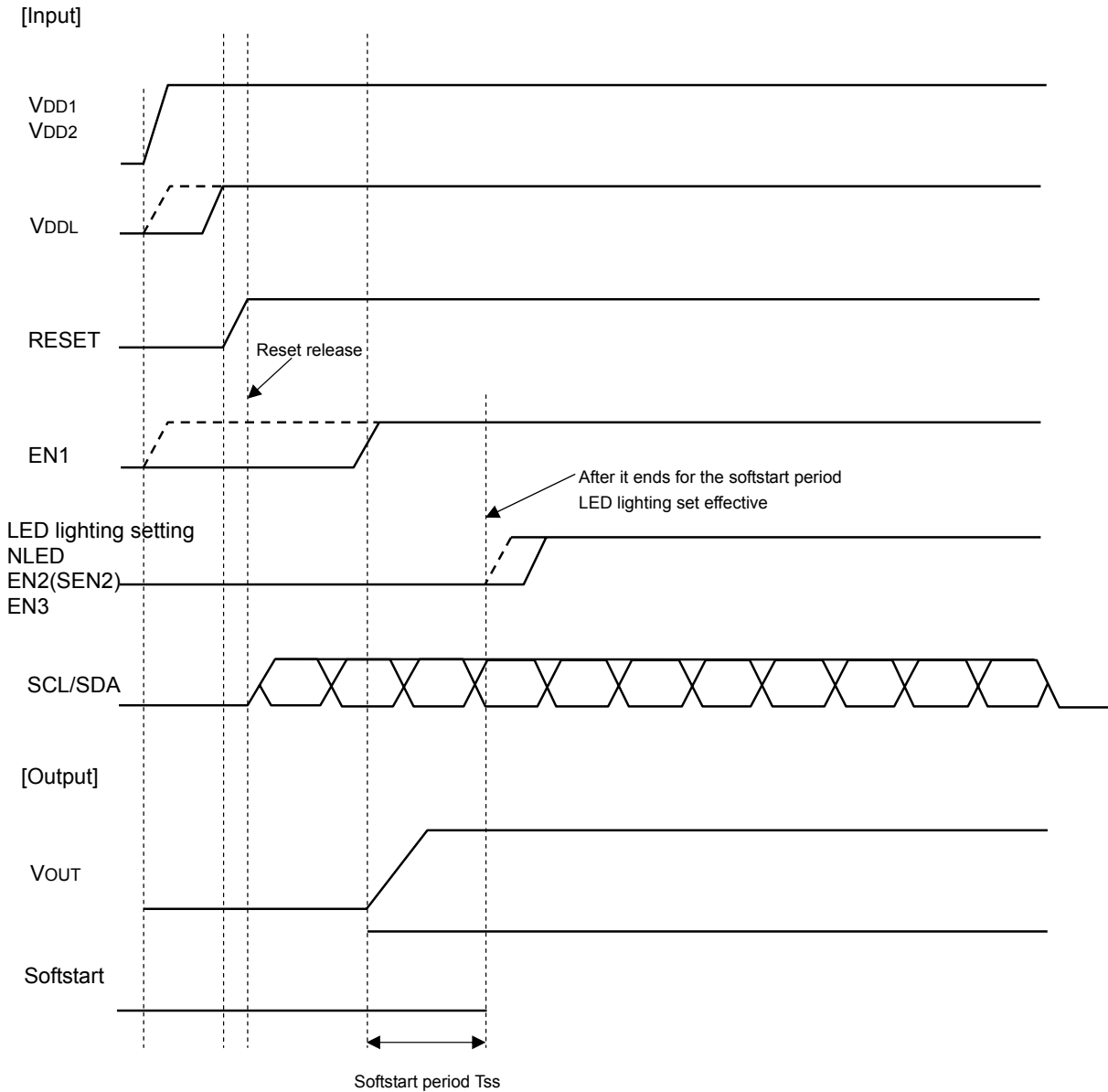
### (6) Miscellaneous

Pin Name	PIN No. (QFN5-32)	Function
VREF	18	Internal reference voltage pin. Connect capacitor CVREF immediately next to VREF pin.
(test)	1	Test pin.
(test)	2	* Set it to "OPEN."
(test)	3	
(test)	6	
(test)	25	

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

## 7.1 Activation sequence

S1F76680 activation sequence is shown below.



- ① VDD1 and VDD2 start. (The battery voltage is supplied.)
- ② VDDL starts. (It is possible to start this at the same time as ①.)
- ③ RESET = Low → High, and the resetting is cancelled.  
Resetting of the I<sup>2</sup>C register is cancelled, and SCL and SDA are become effective.
- ④ Start EN1. S1F76680 starts operating from the standby status.  
The software start begins. (It is possible to start ① and ② at the same time.)
- ⑤ After the software start period ends, the setting to turn on the LED will become effective.

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

### 7.2 Setting and operating state

EN1	EN2 *1	EN3	NLED (I <sup>2</sup> C register)	Operating state (After completion of soft start)
L	X *2	X	X	Standby
H	L	L	L	LED lights off
H	X	H	X	LED lights up ① (At maximum current)
H	H	L	L	LED lights up ② (Under automatic luminance control)
H	X	L	H	LED lights up ③ (At fixed current set in the register)

\*1 EN2=H when either EN2 pin or I<sup>2</sup>C register SEN2 (see No.P14) is set to HIGH.

\*2 The standby current value depends on the setting of EN2 pin I<sup>2</sup>C register (SEN2). (See No.P21)

### 7.3 LED current setting

#### 7.3.1 Setting of maximum current value

The LED's maximum current value is determined by the resistance value of resistor RLED connected with AOUT pin.

The current value that can be set with I<sup>2</sup>C register described later cannot exceed this maximum current value.  
(The current value can be set in the unit of one 127th of ILEDmax)

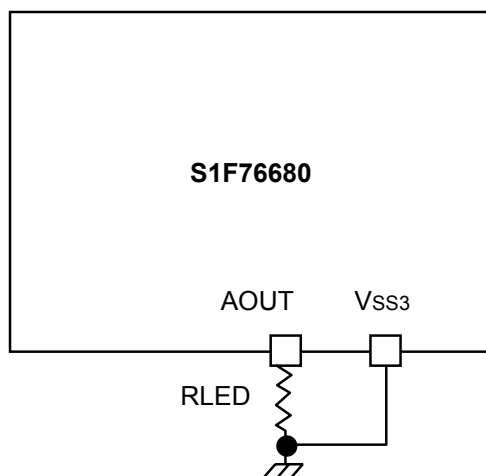
Connect resistor RLED as shown below, and be sure connect it between AOUT pin and Vss3.

Determine RLED from the following formula:

$$RLED = 200 / ILEDmax$$

Maximum current set value = ILEDmax (mA), resistance value = RLED (kΩ)

For example, when ILEDmax=20mA is to be set, RLED=10kΩ.



## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

### 7.3.2 Setting of automatic luminance control

#### [1] Connection of a sensor

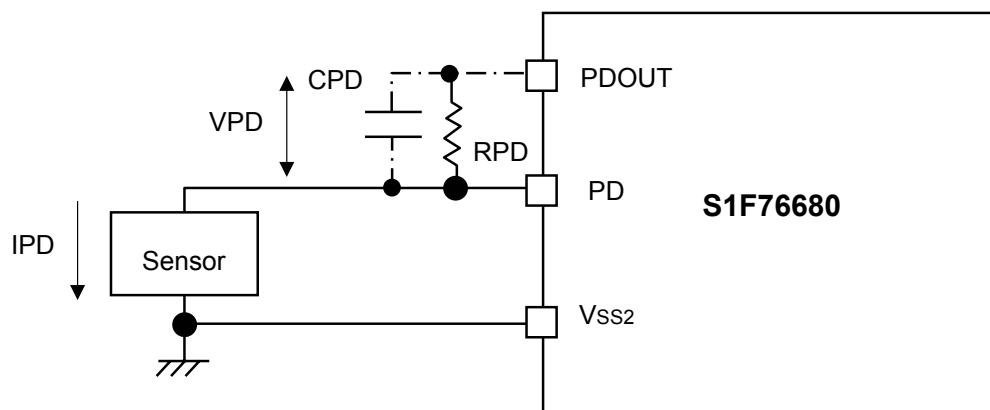
For enabling automatic luminance control, a luminance sensor and resistor have to be connected externally. Connect the sensor between VSS2 and PD pin, and sense resistor RPD between PDOOUT and PD pin as shown below.

When current flowing to the sensor is assumed IPD,  $VPD=IPD \times RPD$  is established. S1F76680 uses this VPD to evaluate brightness on the scale of 1 to 16.

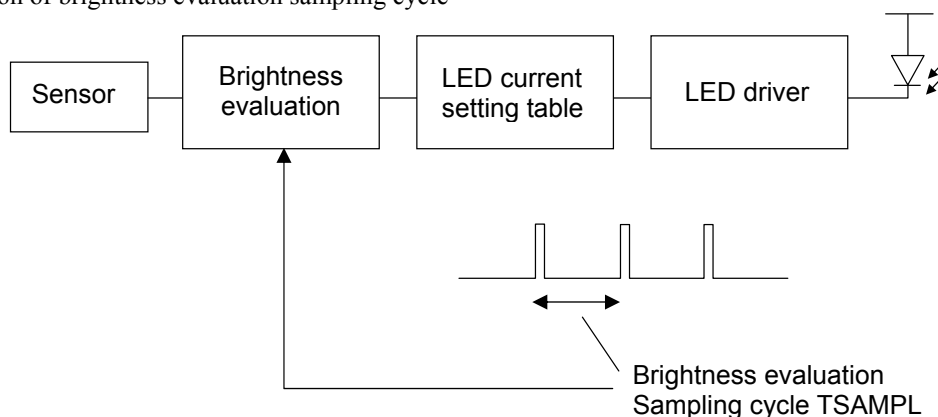
The voltage at PDOOUT and PD pins is 0V in the standby state.

Measures, such as shorter wiring between the sensor and sense resistor and S1F76680, stable VSS2 level supply, etc, are required to avoid noise influence as much as possible.

It is recommended that CPD, a capacitor in the range from 0.1 to 1 $\mu$ F, be connected between VPD and PDOOUT pin as shown below as a measure.



#### [2] Selection of brightness evaluation sampling cycle



The S1F76680 sensor evaluates brightness in the brightness evaluation sampling cycle (TSAMPL).

The following values can be selected for the sampling cycle by setting SAMPL pin.

When using default sampling cycle (655msec), set SAMPL pin to "OPEN."

SAMPL pin setting	Sampling cycle (TSAMPL)
H (pulled up)	655msec
L	1310msec

\* This pin is pulled up to  $VDD1=VDD2$  level in the IC.

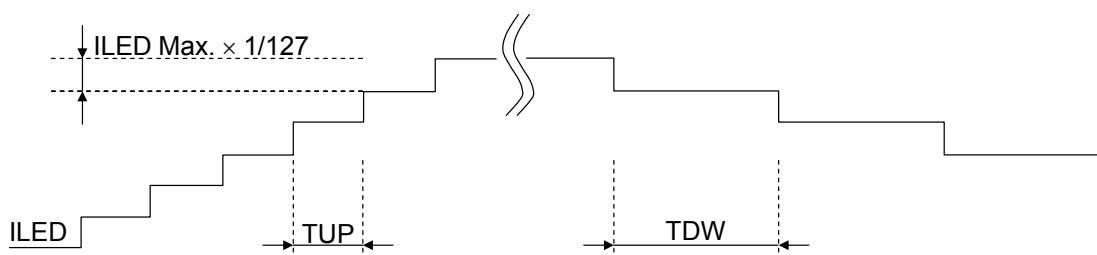
## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

[3] Selection of the change time of the automatic luminance control current  
S1F76680 judges brightness at every sampling cycle and then automatically changes LED current so that it may correspond to the brightness.

When the automatic luminescence control is turned on, LED current value changes in a unit of  $1/127$  of  $I_{LEDmax}$ .

You can set the current change time from the 1AH at an address (to be described later) of I<sup>2</sup>C-Bus. Independent setup is available for the increased current (TUP) and decreased current (TDW).

- Waveform of LED current changes in the automatic luminescence control



- Current change time selection register used in the automatic luminescence control

Address	Item	Register								Remarks
		TDW setting register				TUP setting register				
		D7	D6	D5	D4	D3	D2	D1	D0	
1AH	Register name	TDW3	TDW2	TDW1	TDW0	TUP3	TUP2	TUP1	TUP0	—
	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Initial value	0	1	1	1	0	1	0	1	

- Current change time setting table

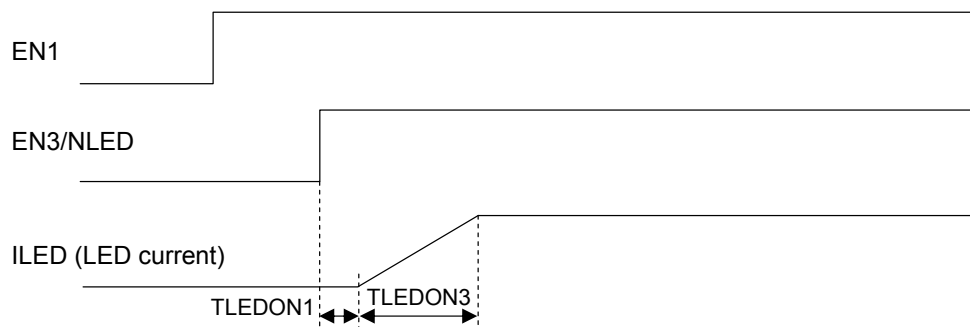
State of selection	Change time 4-bit register setting				Change time (Unit)		Remarks
	TDW3 TUP3	TDW2 TUP2	TDW1 TUP1	TDW0 TUP0			
0	0	0	0	0	0.32	msec	
1	0	0	0	1	0.64	msec	
2	0	0	1	0	1.28	msec	
3	0	0	1	1	2.56	msec	
4	0	1	0	0	5.12	msec	
5	0	1	0	1	10.24	msec	TUP initial value
6	0	1	1	0	20.48	msec	
7	0	1	1	1	40.96	msec	TDW initial value
8	1	0	0	0	81.92	msec	
9	1	0	0	1	163.84	msec	
10	1	0	1	0	327.68	msec	
11	1	0	1	1	655.36	msec	
12	1	1	0	0	1.31	sec	
13	1	1	0	1	2.62	sec	
14	1	1	1	0	5.24	sec	
15	1	1	1	1	10.48	sec	

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

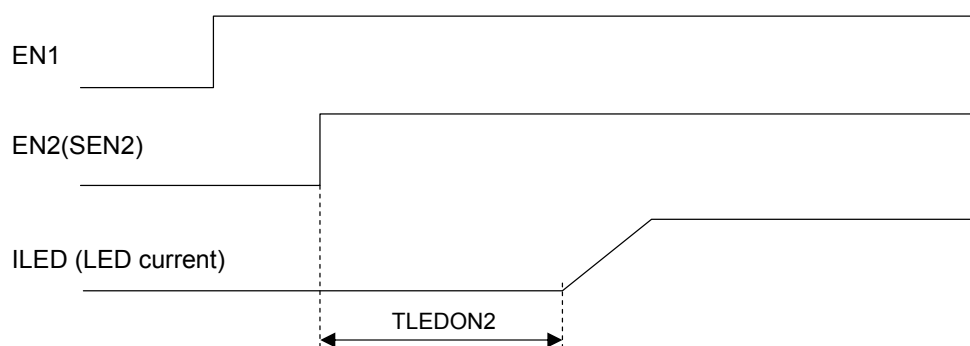
### [4] LED lighting sequence

Delay between the startup and LED lighting varies as shown below depending on the operating state.

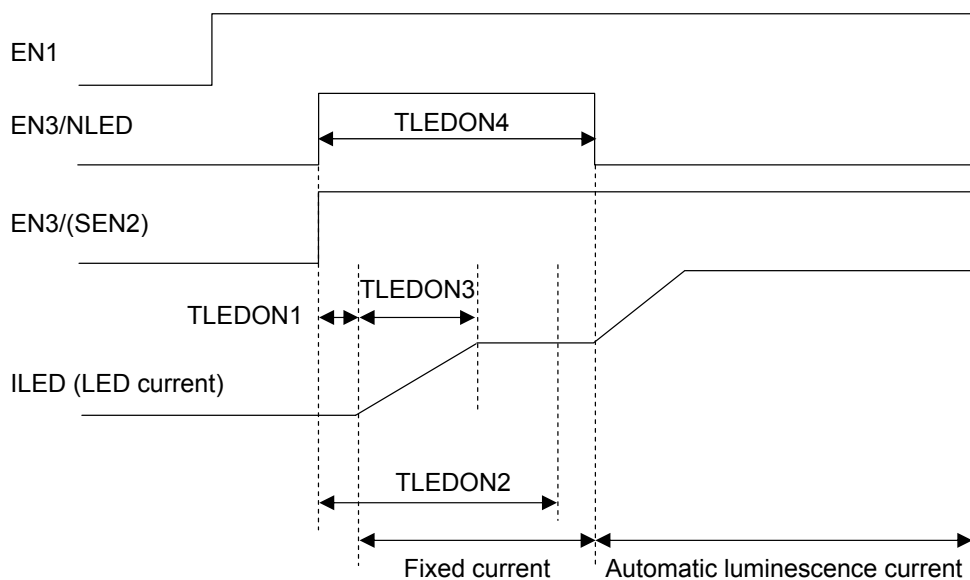
- In the case of LED lighting ① (Max. current) and LED lighting ③ (fixed current set from the register)



- In the case of LED lighting ② (Automatic luminescence control)  
When lighting LED automatically after startup, a delay of TLEDON2 occurs until LED is lit.



- \* You can cut the lighting delay time short during the automatic luminescence control mode by combining two operations as shown above and then lighting LED with the fixed current. Switching from the fixed current to the automatic luminescence control must be done after making sure that the time of  $TLEDON4 > TLEDON1 + TLEDON3$  and  $TLEDON4 > TLEDON2$  have elapsed.



## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

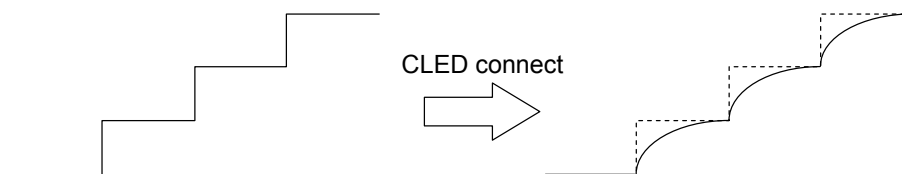
	When SAMPL=H (Pull up)	SAMPL=L	Remarks
TLEDON1(msec)	Max. 5msec+TUP		TUP is selected from the current change time setting table (No.P11)
TLEDON2(msec)	Max. 1180msec+TUP	Max. 2360msec+TUP	
TLEDON3(msec)	Max. 2100msec		CLED=1.0μF ILED 0%→90%,NLED=127

- After LED has been lit, change of TUP becomes available from 1AH register at an address (to be described later) of I<sup>2</sup>C-Bus.

### [5] Delay in LED current change

S1F76680 allows providing delay to the LED current change waveform and thus realizing a smoother current change by connecting the capacitor CLED to CLED pin. Connection of CLED=1μF is recommended.

- LED current change waveform

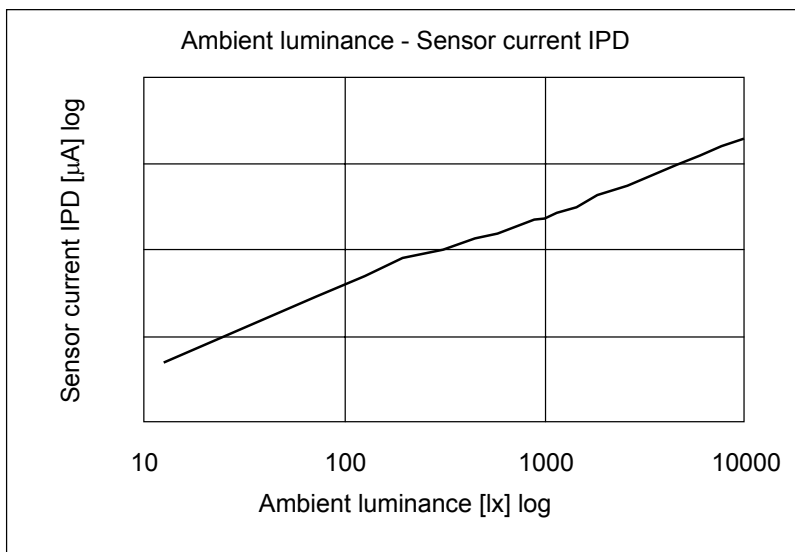




## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

[6] Constant setting

Ambient luminance evaluated by a luminance sensor and sensor current IPD typically shows the following inclination.



S1F76680 evaluates ambient brightness using value of sensor's VPD on the scale of 1 to 16. The following table shows relation between VPD and brightness.

VPD(V)	Brightness
VPD1=0.003	Brightness 1
VPD2=0.004	Brightness 2
VPD3=0.006	Brightness 3
VPD4=0.010	Brightness 4
VPD5=0.016	Brightness 5
VPD6=0.026	Brightness 6
VPD7=0.040	Brightness 7
VPD8=0.063	Brightness 8
VPD9=0.079	Brightness 9
VPD10=0.126	Brightness 10
VPD11=0.173	Brightness 11
VPD12=0.299	Brightness 12
VPD13=0.472	Brightness 13
VPD14=0.787	Brightness 14
VPD15=1.197	Brightness 15
	Brightness 16

Dark  
(low sensor current)

↑

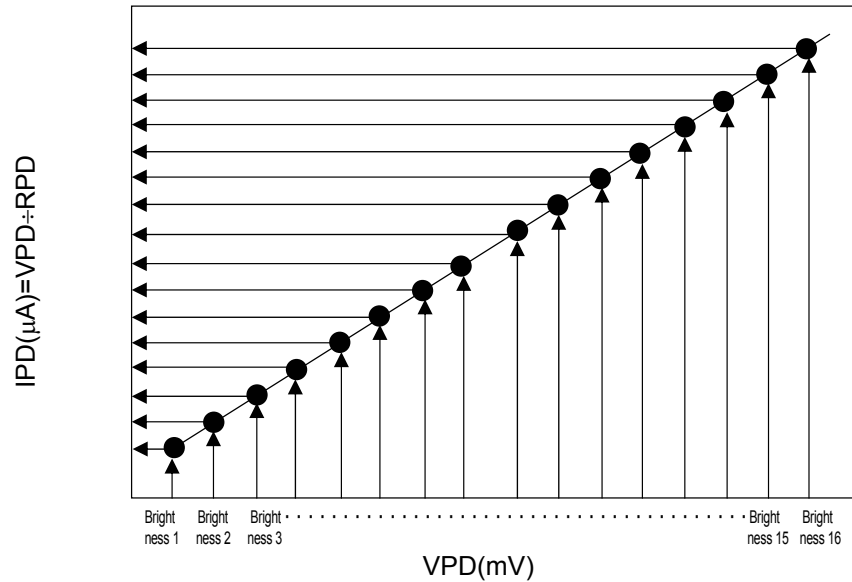
↓

Bright  
(high sensor current)

VPDn : Threshold of brigtness n and brigtness n+1

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

The appropriate RPD is determined by the characteristic of the luminance sensor being used and this IC's VPD for brightness evaluation.



The following table shows IPDs for brightness evaluation with sense resistor RPD=100kΩ.

VPD(V)	Brightness	RPD(kΩ)	Brightness is judged. IPD(μA) IPDn=VPDn/RPD
VPD1=0.003	Brightness 1	100	IPD1=0.03
VPD2=0.004	Brightness 2		IPD2=0.04
VPD3=0.006	Brightness 3		IPD3=0.06
VPD4=0.010	Brightness 4		IPD4=0.10
VPD5=0.016	Brightness 5		IPD5=0.16
VPD6=0.026	Brightness 6		IPD6=0.26
VPD7=0.040	Brightness 7		IPD7=0.40
VPD8=0.063	Brightness 8		IPD8=0.63
VPD9=0.079	Brightness 9		IPD9=0.79
VPD10=0.126	Brightness 10		IPD10=1.26
VPD11=0.173	Brightness 11		IPD11=1.73
VPD12=0.299	Brightness 12		IPD12=2.99
VPD13=0.472	Brightness 13		IPD13=4.72
VPD14=0.787	Brightness 14		IPD14=7.87
VPD15=1.197	Brightness 15		IPD15=11.97
	Brightness 16		

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

Next, determine the LED current values at respective brightness levels.

Set the current values to the following addresses with I<sup>2</sup>C-Bus, which will be explained later.

It is possible to set 128 gradations (SLED), from 0 to 127, for the LED current value and SLED (0 to 127) is set by setting 7-bit value, from D0 (LSB) to D6 (MSB), to each address.

D7 is a dummy.

When automatic luminance control is activated, LED drive current changes gradually between current values set to respective address.

This gradual change of the current value realizes the comfortable display during automatic luminance control. The current value can be obtained from the following formula:

$$I_{LED}(mA) = I_{LEDmax} \times SLED / 127$$

\* Note, however, that SLED (0 to 3) are not lighted but they are turned off.

Note that setting SLED (0 to 3) lights off LED.


When  $I_{LEDmax}=20mA$

If (D7,D6,D5,D4,D3,D2,D1,D0)=(X,1,1,1,1,1,1,1) is input, SLED=127, therefore,  $I_{LED}=20mA \times 127/127 = 20mA$ , which means LED is driven at maximum current.

If (D7,D6,D5,D4,D3,D2,D1,D0)=(X,0,0,0,0,0,0,0) is input, SLED=0, therefore,  $I_{LED}=20mA \times 0/127=0mA$ , which means LED goes off.

\* When variations in luminescence result from the minute LED lighting current setting (SLED being set to small), you can specify to increase the LED current value.

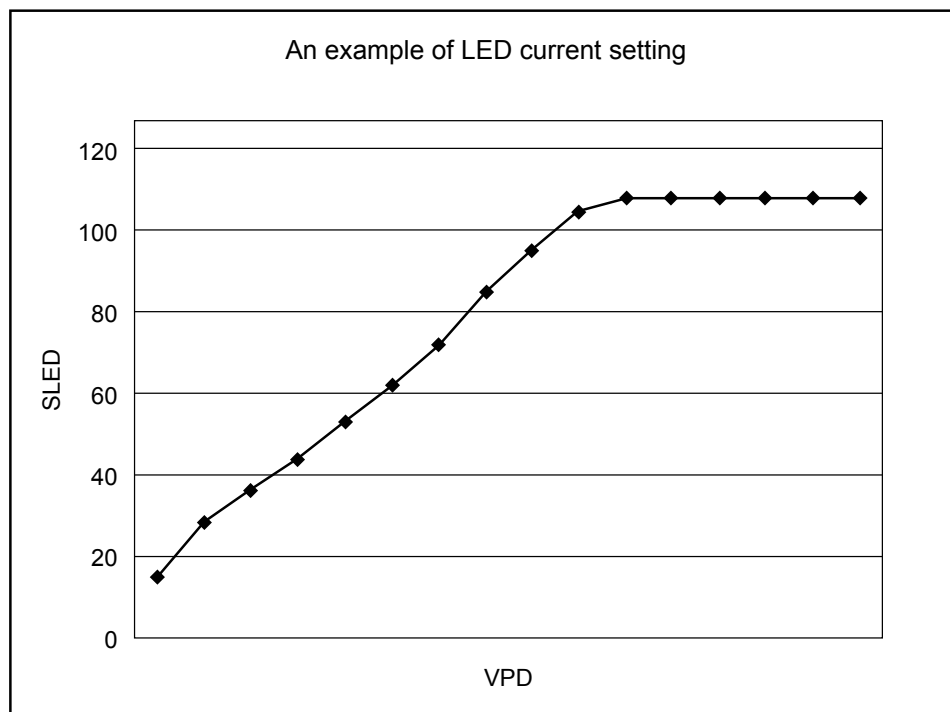
If LED setting address is not newly set, SLED will be operated at register default value.

Brightness		LED current setting address	Register default value
Brightness 1	Dark (low sensor current)    Bright (high sensor current)	02H	13
Brightness 2		03H	18
Brightness 3		04H	38
Brightness 4		05H	42
Brightness 5		06H	52
Brightness 6		07H	62
Brightness 7		08H	68
Brightness 8		09H	85
Brightness 9		0AH	100
Brightness 10		0BH	108
Brightness 11		0CH	127
Brightness 12		0DH	127
Brightness 13		0EH	127
Brightness 14		0FH	125
Brightness 15		10H	119
Brightness 16		11H	105

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

The following table shows an example of customized LED current setting for automatic luminance control.

Brightness		LED current setting address	Setup example:
Brightness 1	Dark (low sensor current) ↑ ↓ Bright (high sensor current)	02H	15
Brightness 2		03H	28
Brightness 3		04H	36
Brightness 4		05H	44
Brightness 5		06H	53
Brightness 6		07H	62
Brightness 7		08H	72
Brightness 8		09H	85
Brightness 9		0AH	95
Brightness 10		0BH	105
Brightness 11		0CH	108
Brightness 12		0DH	108
Brightness 13		0EH	108
Brightness 14		0FH	108
Brightness 15		10H	108
Brightness 16		11H	108



[7] Acquisition of brightness information

S1F76680 can read brightness information (brightness 1 to 16) as data.

Read data from address 00H with I<sup>2</sup>C, which will be explained later.

Brightness information will be output as 4-bit information of D7, D6, D5, D4 (register name: X3, X2, X1, X0) as follows:

Brightness 1 = (D7,D6,D5,D4,D3,D2,D1,D0) = (0,0,0,0,X,X,X,X)

Brightness 2 = (D7,D6,D5,D4,D3,D2,D1,D0) = (0,0,0,1,X,X,X,X)

·  
·  
·

Brightness 16 (D7,D6,D5,D4,D3,D2,D1,D0) = (1,1,1,1,X,X,X,X)

Setting of register-based fixed current

S1F76680 allows lighting LED forcibly at a fixed current value without resorting to brightness of the environment.

Just like the current setting in the automatic luminescence control, set this fixed current based on the following

formula and using 7 bits from D0 (LSB) to D6 (MSB) at address 01H. D7 is the dummy.

$$I_{LED}(mA) = I_{LEDmax} \times S_{LED} / 127$$

Note that setting of SLED (0 to 3) lights off LED.

To drive LED at this imperative fixed current value, set D2 register (register name: NLED) of address 00H to NLED = "1."

### 7.4 I<sup>2</sup>C slave function

S1F76680 incorporates a I<sup>2</sup>C-Bus controller with slave function, to enhance operability of the white LED driver, whose LED's current value can change according to the ambient brightness.

By sending specific commands to the I<sup>2</sup>C controller, you can read / write data in a register, and thus, perform advanced setting of the white LED driver.

I<sup>2</sup>C basic specifications

The basic operation is complied with "I<sup>2</sup>C-BUS SPECIFICATION VERSION2.1" of Philips.

[Address]            7-bit length  
Slave address 1010100X

[Pins being used]   SCL Clock input pin  
SDA Data I/O pin

[Voltage level]     VDDL level

Register map is shown below:

## 7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

### Register Map

Address	Item	Register								Remarks
		D7	D6	D5	D4	D3	D2	D1	D0	
00H	Name	X3	X2	X1	X0	—	NLED	SEN2	SRESET	"1" for "ON", "0" for OFF (same for the following functions) SEN2: Automatic luminance control operation signal NLED: Imperative fixed current mode SRESET: Reset signal X3 to X0: Brightness information
	R/W	R	R	R	R	—	R/W	R/W	R/W	
	Defaultvalue	—	—	—	—	—	0	0	0	
01H	Name	—	ILED6	ILED5	ILED4	ILED3	ILED2	ILED1	ILED0	Imperative fixed current setting
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	0	0	0	0	0	0	
02H	Name	—	Y06	Y05	Y04	Y03	Y02	Y01	Y00	LED current setting for brightness 1
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	0	0	1	1	0	1	
03H	Name	—	Y16	Y15	Y14	Y13	Y12	Y11	Y10	LED current setting for brightness 2
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	0	1	0	0	1	0	
04H	Name	—	Y26	Y25	Y24	Y23	Y22	Y21	Y20	LED current setting for brightness 3
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	1	0	0	1	1	0	
05H	Name	—	Y36	Y35	Y34	Y33	Y32	Y31	Y30	LED current setting for brightness 4
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	1	0	1	0	1	0	
06H	Name	—	Y46	Y45	Y44	Y43	Y42	Y41	Y40	LED current setting for brightness 5
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	1	1	0	1	0	0	
07H	Name	—	Y56	Y55	Y54	Y53	Y52	Y51	Y50	LED current setting for brightness 6
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	0	1	1	1	1	1	0	
08H	Name	—	Y66	Y65	Y64	Y63	Y62	Y61	Y60	LED current setting for brightness 7
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	0	0	0	1	0	0	
09H	Name	—	Y76	Y75	Y74	Y73	Y72	Y71	Y70	LED current setting for brightness 8
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	0	1	0	1	0	1	
0AH	Name	—	Y86	Y85	Y84	Y83	Y82	Y81	Y80	LED current setting for brightness 9
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	0	0	1	0	0	
0BH	Name	—	Y96	Y95	Y94	Y93	Y92	Y91	Y90	LED current setting for brightness 10
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	0	1	1	0	0	
0CH	Name	—	YA6	YA5	YA4	YA3	YA2	YA1	YA0	LED current setting for brightness 11
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	1	1	1	1	1	
0DH	Name	—	YB6	YB5	YB4	YB3	YB2	YB1	YB0	LED current setting for brightness 12
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	1	1	1	1	1	
0EH	Name	—	YC6	YC5	YC4	YC3	YC2	YC1	YC0	LED current setting for brightness 13
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	1	1	1	1	1	
0FH	Name	—	YD6	YD5	YD4	YD3	YD2	YD1	YD0	LED current setting for brightness 14
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	1	1	1	0	1	
10H	Name	—	YE6	YE5	YE4	YE3	YE2	YE1	YE0	LED current setting for brightness 15
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	1	0	1	1	1	
11H	Name	—	YF6	YF5	YF4	YF3	YF2	YF1	YF0	LED current setting for brightness 16
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	—	1	1	0	1	0	0	1	
1AH	Name	TDW3	TDW2	TDW1	TDW0	TUP3	TUP2	TUP1	TUP0	Automatic luminance control LED current change time setting
	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Defaultvalue	0	1	1	1	0	1	0	1	

\* Use of addresses 12H to 19H is prohibited.

### Description of the registers

- Address 00H  
 Register name X3, X2, X1, X0 : 4-bit read-only brightness information. X3=MSB, X0=LSB.  
 Brightness information can only be read under the condition of EN2=1 or SEN2=1.  
 Also, it is possible to read brightness information regardless of whether the imperative fixed current drive register is set to NLED=0 or NLED=1.
  
- Register name NLED : Register for imperative fixed current drive setting.  
 NLED=1 Enable driving at imperative fixed current value.  
 NLED=0 Default value.
  
- Register name SEN2 : Register for automatic luminance control operation setting.  
 SEN2=1 Enable driving with automatic luminance control.  
 SEN2=0 Default value.  
 \* Automatic luminance control is enabled if either this register SEN2 or EN2 pin is set to "1."
  
- Register name SRESET : Register for I<sup>2</sup>C soft reset.  
 SRESET=1 Executes soft reset.  
 SRESET=0 Default value.  
 \* I<sup>2</sup>C will be reset when SRESET=1 or RESET pin=0.  
 To exit reset, write as SRESET=0.  
 SRESET=0 can be written immediately after reset.
  
- Address 01H  
 Register name ILED6 to ILED0  
 Registers for imperative fixed current setting.
  
- Address 02H to 11H  
 Register name Y00 to YF6  
 Registers to set the current values for brightness 1 to 16 for auto luminance control.
  
- Address 1AH  
 Register name TDW3 to TDW0, TUP3 to TUP0  
 They are the registers used for selecting LED current change time.

### 7.5 Other functions

- Soft start function  
 S1F76680 is built in with the soft start function that prevents incoming current.  
 After power on of VDD1 and VDD2 voltage and that of EN1, soft start is carried out for 3msec.  
 Even if it causes no problem to power on EN2 and EN3 after soft start, nonetheless, LED starts to light up after soft start.
  
- Charge pump function  
 S1F76680 is equipped with a charge pump type DC/DC converter, which generates necessary voltage to light up LED from voltage supplied to VDD1 pin, and supplies it to VOUT pin.  
 This charge pump circuit operates while selecting the booster magnification from 1.5 and 1 times according to necessity, thus, provides a longer operating time to battery-operated devices.  
 To operate this circuit, pump-up capacitor C1 and C2, and storage capacitor CVOUT are required.

## 8. ABSOLUTE MAXIMUM RATINGS

### 8. ABSOLUTE MAXIMUM RATINGS

$$V_{SS1}=V_{SS2}=V_{SS3}=0V$$

Item	Symbol	Rated value		Unit	Applicable pin	Remarks
		Min.	Max.			
Input power voltage 1	VDD	-0.3	5.5	V	VDD1, VDD2	Note 1
Input pin voltage 1	VPIN1	-0.3	VDD +0.3	V	EN1, EN2, EN3, SAMPL	—
Input power voltage 2	VDDL	-0.3	3.3	V	VDDL	Note 1
Input pin voltage 2	VPIN2	-0.3	VDDL +0.3	V	SCL, SDA, RESET	—
Output current 1	IVOUT	—	120	mA	VOUT	Note 2
Output current 2	ILED	—	30	mA	LED1, LED2, LED3, LED4	Note 3
Allowable dissipation	PD	—	600	mW	—	—
Operating ambient temperature	T <sub>a</sub>	-25	85	°C	—	—
Storage temperature	T <sub>stg</sub>	-40	125	°C	—	—

<Note 1>  $V_{DD1}=V_{DD2} \geq V_{DDL}$

<Note 2>  $I_{VOUT}$ =Total of output current values of all LED channels

<Note 3> Output current value when  $I_{LED}=LED1ch$

<Note 4> Do not externally feed voltage to the output pin, test pin and capacitor connection pin.

<Note 5> The absolute maximum rating is not something that guarantees the equipment's electric characteristics. Operation beyond the above rating may lead to malfunction or unrecoverable damage. Moreover, the equipment may function normally temporarily but its reliability can be significantly deteriorated.



9. ELECTRICAL CHARACTERISTICS

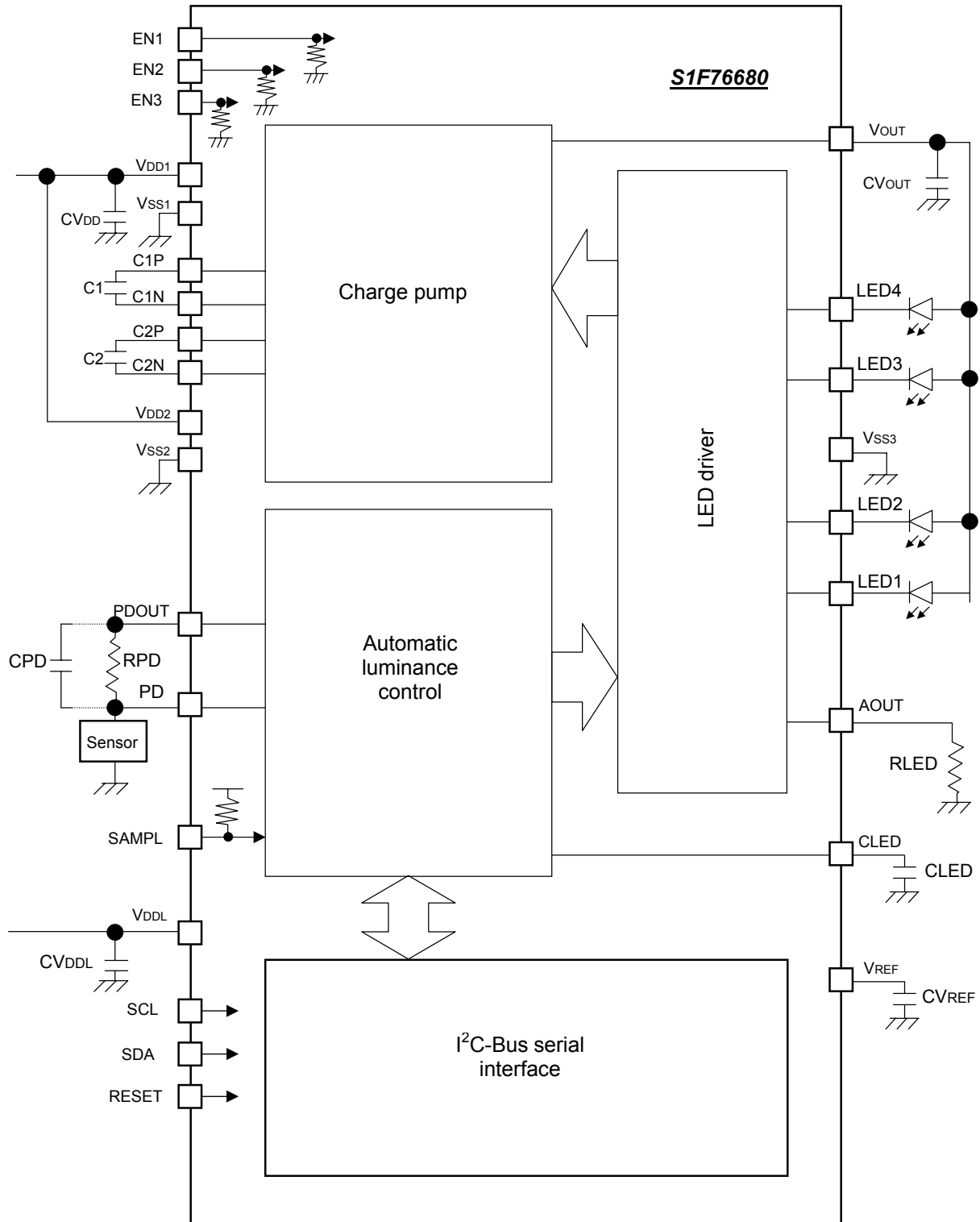
If unspecified, V<sub>DD1</sub>=V<sub>DD2</sub>=3.6V, V<sub>DDL</sub>=1.8V, T<sub>a</sub>=25°C and use external parts described in 10.2.

Item	Symbol	Specification			Unit	Applicable pin	Remarks
		Min.	Typ.	Max.			
Input voltage	V <sub>DD</sub>	3.0	3.6	4.6	V	V <sub>DD1</sub> , V <sub>DD2</sub>	
	V <sub>DDL</sub>	1.6	1.8	3.0	V	V <sub>DDL</sub>	
Self-consumption current	I <sub>opr</sub>	—	1.0	1.5	mA	V <sub>DD1</sub> , V <sub>DD2</sub>	1 times under no load
Standby current 1	I <sub>stby1</sub>	—	—	1.0	μA	V <sub>DD1</sub> , V <sub>DD2</sub>	EN1=EN3=L, EN2(SEN2)=L
		—	—	2.0	μA	V <sub>DD1</sub> , V <sub>DD2</sub>	EN1=EN3=L, EN2(SEN2)=H
Standby current 2	I <sub>stby2</sub>	—	—	5.0	μA	V <sub>DDL</sub>	EN1=EN2(SEN2)=EN3=L
Output voltage	V <sub>OUT</sub>	4.12	4.44	—	V	V <sub>OUT</sub>	1.5 boosting when I <sub>VOUT</sub> =80mA
		4.44	4.68	—	V	V <sub>OUT</sub>	1.5 boosting when I <sub>VOUT</sub> =60mA
Charge pump Output impedance	R <sub>VOUT</sub>	—	12	16	Ω	V <sub>OUT</sub>	1.5 boosting when I <sub>VOUT</sub> =80mA
Operating frequency	f <sub>osc</sub>	160	200	240	kHz	C1N	When operated with 1.5 times booster magnification
Soft start time	T <sub>ss</sub>	—	3.0	5.0	ms	—	See No.P8
LED maximum current setting resistance	R <sub>LED</sub>	50	—	8.0	kΩ	R <sub>LED</sub>	See No.P9
LED pin leak current	I <sub>LEAK</sub>	—	—	1.0	μA	LED1 to 4	V <sub>LED</sub> =4.6V
LED current	I <sub>LED1</sub>	-4	—	+4	%	LED1 to 4	S <sub>LED</sub> >17, V <sub>LED</sub> =1V, 1 times I <sub>LED1</sub> =ΔI <sub>LED1</sub> /I <sub>LEDMAX</sub>
	I <sub>LED2</sub>	-3.5	—	+3.5	%	LED1 to 4	S <sub>LED</sub> ≤ 16, V <sub>LED</sub> =1V, 1 times I <sub>LED2</sub> =ΔI <sub>LED2</sub> /I <sub>LEDMAX</sub>
LED pin saturation voltage	V <sub>LED</sub>	—	0.21	0.24	V	LED1 to 4	EN1=EN2=EN3=H I <sub>LED</sub> =20mA
Sense resistor RPD	RPD	10	—	500	kΩ	P <sub>DOUT</sub> , P <sub>D</sub>	See No.P9 to 15
Sensor application voltage	V <sub>SENS</sub>	0.8	1.0	1.2	V	P <sub>D</sub>	P <sub>D</sub> pin voltage
VPD	V <sub>PD15</sub>	0.956	1.196	1.436	V	P <sub>DOUT</sub> , P <sub>D</sub>	Brightness evaluation value
	V <sub>PD1</sub>	0.001	0.003	0.005			
	ΔV <sub>PD</sub>	V <sub>PDn+1</sub> -V <sub>PDn</sub> >0			V	P <sub>DOUT</sub> , P <sub>D</sub>	Monotonic increase
Sampling cycle	T <sub>SAMPL</sub>	524	655	786	ms	—	SAMPL=H (Pull up) SAMPL=L
		1048	1310	1572			
Current change time	T <sub>UP</sub> /T <sub>DW</sub>	Set value -20	—	Set value +20	%	LED1 to 4	See No.P12 setting table
LED lighting time	T <sub>LEDON1</sub>	—	—	5+T <sub>UP</sub>	ms	LED1 to 4	See No.P12
	T <sub>LEDON2</sub>	—	—	1180+T <sub>UP</sub>			SAMPL=H (Pull up)
		—	—	2360+T <sub>UP</sub>			SAMPL=L
	T <sub>LEDON3</sub>	—	—	2100			C <sub>LED</sub> =1.0μF, N <sub>LED</sub> =127 I <sub>LED</sub> 0%→90%
H level input voltage 1	V <sub>IH1</sub>	1.5	—	—	V	EN1, EN2, EN3	
L level input voltage 1	V <sub>IL1</sub>	—	—	0.3	V		
Input current 1	I <sub>IH1</sub>	—	1.5	5.0	μA		V <sub>IN</sub> =3.6V, pull-down current
H level input voltage 2	V <sub>IH2</sub>	0.7×V <sub>DD</sub>	—	—	V	SAMPL	V <sub>DD</sub> =V <sub>DD1</sub> =V <sub>DD2</sub>
L level input voltage 2	V <sub>IL2</sub>	—	—	0.3×V <sub>DD</sub>	V		
Input current 2	I <sub>IH2</sub>	—	7.2	14.0	μA		V <sub>IN</sub> =0V, pull up current
H level input voltage 3	V <sub>IH3</sub>	0.7×V <sub>DDL</sub>	—	—	V	SCL, SDA RESET	
L level input voltage 3	V <sub>IL3</sub>	—	—	0.3×V <sub>DDL</sub>	V		
Input current 3 (H)	I <sub>IH3</sub>	-1.0	—	1.0	μA		V <sub>IN</sub> =1.8V
Input current 3 (L)	I <sub>IL3</sub>	-1.0	—	1.0	μA		V <sub>IN</sub> =0V

## 10. EXTERNAL CONNECTION DIAGRAM

### 10. EXTERNAL CONNECTION DIAGRAM

#### 10.1 Standard Connection Examples



## 10.2 Recommended connection parts

Parts name	Application	Maximum applied voltage	Capacity value or Resistance value
CVDD	Bypass capacitor between VDD and VSS pin	VDD1, VDD2	0.47 $\mu$ F
C1	Pump-up capacitor for charge pump boosting 1	VDD1, VDD2	1 $\mu$ F
C2	Pump-up capacitor for charge pump boosting 2	VDD1, VDD2	1 $\mu$ F
RPD	Resistance for light sensor current-voltage conversion	VDD1, VDD2	See 7.3
CVDDL	Bypass capacitor between VDDL and VSS pin	VDDL	0.47 $\mu$ F
CVREF	Smoothing capacitor for internal reference voltage	VDD1, VDD2	0.1 $\mu$ F
RLED	LED current adjustment resistor	VDD1, VDD2	See 7.3
CVOUT	Output smoothing capacitor for charge pump	1.5 $\times$ VDD1, VDD2	1 $\mu$ F
Sensor	Luminance sensor	VDD1, VDD2	*
CPD	Noise removal	VDD1, VDD2	0.1 to 1 $\mu$ F
CLED	Current change delay	VDD1, VDD2	1 $\mu$ F

\* An example of recommended sensor TDK BCS2015G1

## <Precautions>

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### <Precautions>

When using this Development Specifications, you should remember the following points:

1. Information in this Development Specifications is subject to change without notice.
2. There is no representation or warranty that anything made in accordance with this material will be free from any patent or copyright infringement of a third party. The application examples in this Development Specification are provided to facilitate understanding of this product. It should be noted that SEIKO EPSON shall not be liable for any problem related to circuits that may arise from its use.
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When using this semiconductor, note on the following points:

#### “Precautions for Handling the IC against the Light”

If semiconductor chips are exposed to the strong light, their characteristics may change. Therefore, if the ICs are placed in the light, they may malfunction. To protect the ICs, the following general requirements must be satisfied for IC mount boards and products.

- (1) Design and mount the IC to prevent its exposure to light during actual operation.
- (2) Also, do not expose the ICs to the light in the inspection phase.
- (3) Take all surfaces, top, bottom and sides, of the IC chip into consideration when blocking out light.

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