EPSON
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S1F87110B0A Series
Technical Manual

SEIKO EPSON CORPORATION

Rev.1.0

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1. DESCRIPTIONS

The S1F87110 is a LED controller which automatically controls luminance of LEDs used in cell phones (e.g. backlight LED) in a linear sequence, based on evaluation of ambient brightness with a luminance sensor connected to the device.

The S1F87110 uses a unique algorithm for generating PWM signals which continuously modulate current flowing through LEDs, and by sending the signals to the LED driver, it controls the LED luminance automatically according to the ambient brightness level.
This function enables to achieve balance between visibility and low power consumption without requiring major modification of LED-related systems.

A two-wire serial interface I^2C-Bus slave function is provided with the S1F87110.
This I^2C register can be used to start/stop, or set conditions such as automatic luminance control mode/fixed brightness mode, as well as customize automatic luminance control characteristics (brightness and PWM duty settings).

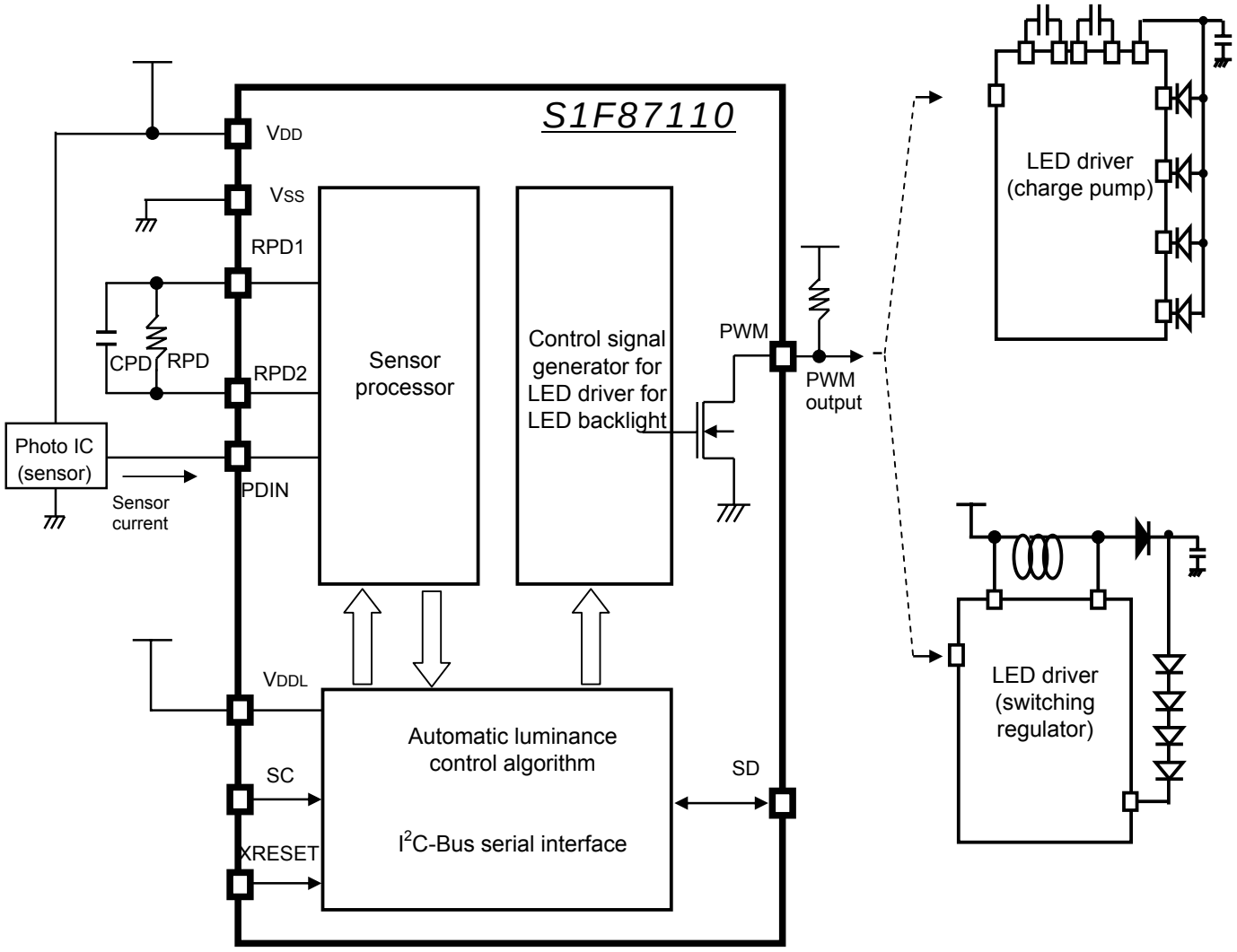
Use of the S1F87110 with an existing LED driver provided with PWM input for LED brightness control can add a function that automatically selects optimal LED current value in accordance with the brightness level of the surrounding environment.

2. FEATURES

- This IC enables automatic luminance control without modification of existing LED driver.
- Selectable between automatic luminance control mode and fixed brightness mode.
- ・Installs a compact photo IC (current output) type luminance sensor.
  ・Can also install a photodiode type luminance sensor which has lower power consumption under high illumination.
- 4-bit and 16-level brightness evaluation
- PWM output for brightness control of LED driver
  Selectable PWM cycle (Typ. 195Hz, 390Hz)
  Selectable phase when PWM operating
  Selectable ON/OFF of PWM output during standby
- Available 7-bit, 128-gray scale PWM duty settings for automatic luminance control mode/fixed brightness mode.
- Customizable luminance characteristics
  Selectable brightness evaluation sampling cycle
  Selectable setting for brightness evaluation - PWM duty
  Selectable rate of change for PWM duty
- Interface
  Two-wire serial interface I^2C (Max. 400kHz) slave controller
- Shipment package Compact and slim type WCSP (X 1.70mm×Y 2.20mm×t (0.72)mm)

3. BLOCK DIAGRAM

(Current output type photo IC is used for sensor)



4. DESCRIPTION OF BLOCK DIAGRAM

- Sensor processor
  Evaluates ambient brightness using current value that flows through the luminance sensor on the scale of 1 to 16.
  Either of photo IC (current output) type or photodiode type luminance sensor can be connected.

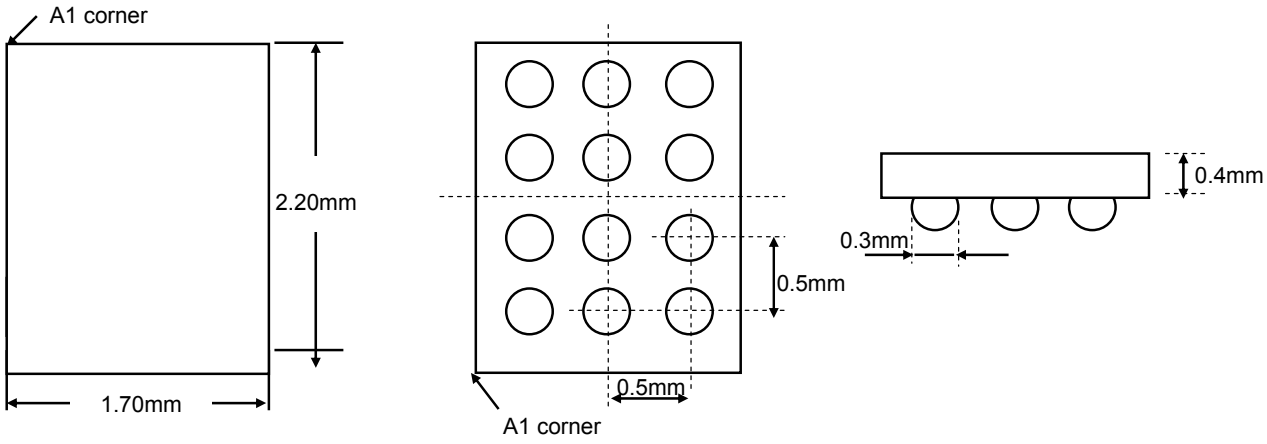
- Automatic luminance control algorithm
  Based on the brightness evaluated by the sensor processor, it controls PWM duty for changing LED brightness in a linear mode according to the ambient brightness.
  Relationship between brightness evaluation and rate of change for PWM duty can be customized with registers.

- Control signal generator for LED driver for LED backlight
  Outputs PWM signals to the LED driver for brightness control.
  PWM signal cycles and phases can be changed with registers.

- I^2C interface
  The I^2C slave controller is provided with the S1F87110.
  By sending specific commands from the I^2C master to the I^2C controller, it serves as an I^2C slave device, enabling advanced setting to this IC.
  * I^2C is referred for two-wire serial interface specifications proposed by Philips.

5. PIN ASSIGNMENT

Top View Bottom View Side View



Pin Name	I/O	Pin No.	Functions
		WCSP	
XRESET	I	A1	Reset (register initialization) pin
(test1)	I	A2	* Test pin for outgoing inspection. With internal pull down. Connect this pin to the ground.
SDA	I/O	A3	I^2C serial data I/O pin
PDIN	I	B1	Connection pin for current output type sensor. When this pin is not used, connect it to the ground.
(test2)	I	B2	* Test pin for outgoing inspection. With internal pull down. Connect this pin to the ground.
PWM	O	B3	PWM signal output pin for LED current control
RPD2	I	C1	Resistor RPD connect pin 2
V_{DD}	—	C2	Input power supply pin (+)
V_{DDL}	—	C3	Power supply pin for interface (+)
RPD1	O	D1	Resistor RPD connect pin 1
V_{SS}	—	D2	Ground pin (0V)
SCL	I	D3	I^2C serial clock input pin

6. PIN DESCRIPTION

(1) Power supply pins

Pin Name	Pin No. (WCSP)	Functions
V_{DD}	C2	Positive-side power supply pin. Supply voltage that obtains $V_{DD} \geq V_{DDL}$. Connect a 0.1μF bypass condenser to a point near the V_{DD}-V_{SS} pin.
V_{DDL}	C3	Positive-side input power supply pin for I^2C interface. Supply voltage that obtains $V_{DD} \geq V_{DDL}$. Connect a 0.1μF bypass condenser to a point near the V_{DDL}-V_{SS} pin.
V_{SS}	D2	The ground (GND) pin. This is the 0V pin connected to the system GND. The IC substrate potential.

(2) Sensor-related pin

Pin Name	Pin No. (WCSP)	Functions
RPD1	D1	Sense resistor connect pin 1
RPD2	C1	Sense resistor connect pin 2 When a photodiode type sensor is used, connect the sensor between RPD2 and V_{SS}. See No. P10.
PDIN	B1	Sensor (photo IC) connect pin When a photodiode type sensor is used, connect this pin to V_{SS}.

(3) I/O pin

Pin Name	Pin No. (WCSP)	Functions
SCL	D3	I^2C serial clock input pin. Supply input High level voltage to V_{DDL}.
SDA	A3	I^2C serial data I/O pin. Supply input High level voltage to V_{DDL}. The output is Nch open Drain output pin.
XRESET	A1	I^2C register hard reset (register initialization) pin. It is initialized to the default value of the register allocation (7.9.1, 7.9.2). Low: reset. Clear reset after V_{DDL} is powered on. Supply High level voltage to V_{DDL}.
PWM	B3	PWM signal output pin for LED brightness control The output is Nch open Drain output pin.

(4) Test pin

Pin Name	Pin No. (WCSP)	Functions
(test1)	A2	Test pin for outgoing inspection. It has been pulled down within the IC. Connect this pin to V_{SS}.
(test2)	B2	

7. OPERATIONAL AND FUNCTIONAL DESCRIPTION

7.1 Description of Function

This chapter describes functions of this IC in the following order.

7.2 Activation sequence
This section explains activation sequence of the S1F87110.

7.3 Operation Description
This section explains the overview of the S1F87110 operation.
This section explains about the standby mode, fixed brightness mode and automatic luminance control mode.

7.4 Brightness evaluation function
Evaluates ambient brightness using current value that flows through the luminance sensor on the scale of 1 to 16.
Either of photo IC type or photodiode type luminance sensor can be connected.
This section explains how to install the sensor, and how to evaluate brightness.

7.5 Automatic luminance control function
This section explains about the automatic luminance control and its setting method.

7.6 Acquisition of brightness evaluation result
This section explains about acquisition of brightness evaluation results.

7.7 Fixed brightness function
This section explains how to set the fixed brightness mode.

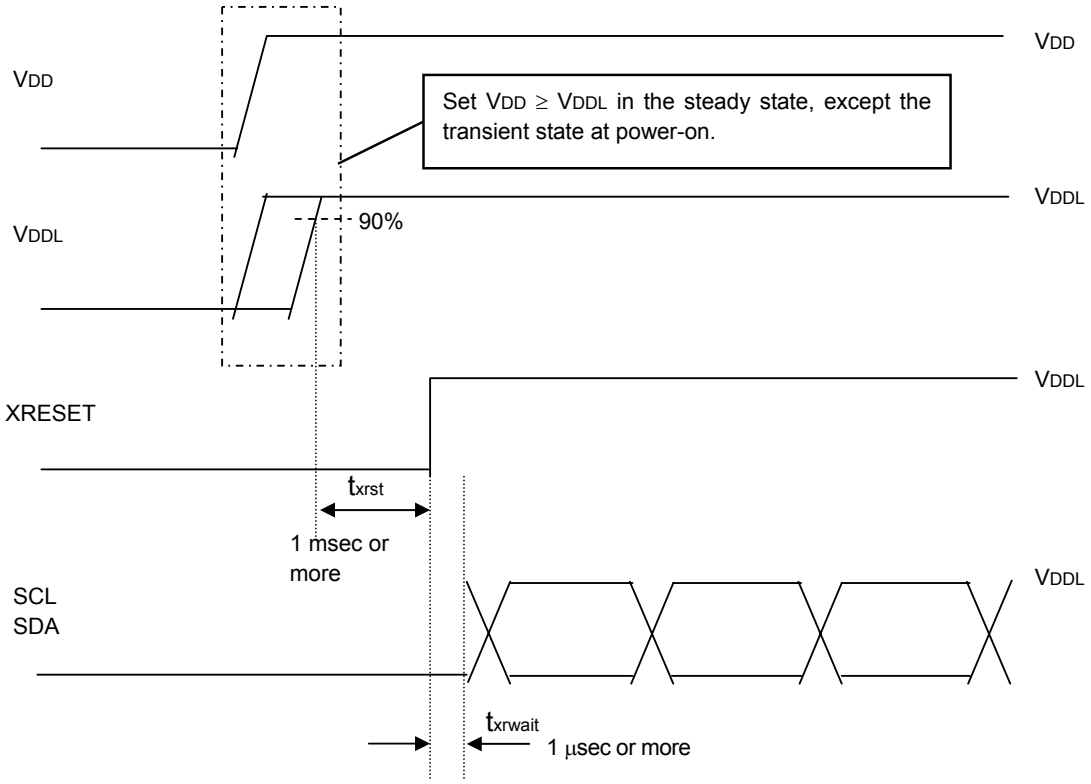
7.8 PWM output function
This section explains how to set the PWM output.

7.9 Register allocation
This section explains the register allocation.

7.10 I^2C interface
This section explains I^2C serial interface operations.

7.2 Activation sequence

The S1F87110 activation sequence is shown below.



① Power on V_{DD} and V_{DDL}. Set $V_{DD} \geq V_{DDL}$ in the steady state.
② Power on XRESET, and clear reset. Ensure 1 msec or more for reset width t_{xrst} when powered on.
③ Start I^2C communication to this IC at least t_{xrwait}=1µsec has past after clearing reset.

7.3 Operation Description

The S1F87110 operates with the following 3 modes depending on the register settings for activating SCONST and SAUTO.

Allocation of all registers is provided in Section 7.7.

① Standby mode
The device enters the standby mode with SCONST="0" & SAUTO="0".
This stops all the circuit operation.
This IC is in the standby mode when the device is in reset conditions immediately after powered on and immediately after clearing reset, as all the registers are initialized.

② Fixed brightness mode
The device enters the fixed brightness mode when the register is set to SCONST="1".
The PWM signal is output with the duty ratio that has been set to the fix duty set register, regardless of brightness evaluation results.

③ Automatic luminance control mode
The device enters the automatic luminance control mode when the register SCONST is set to "0", and SAUTO to "1".
The output PWM signal duty is changed linearly according to the brightness evaluation.

I^2C register (activation register)		**Operation Mode**
SCONST address 00H (D2)	**SAUTO address 00H (D1)**	
0 (Default value)	0 (Default value)	**① Standby mode** The system enters to the standby state, with the minimum power consumption.
1	X	**② Fixed brightness mode** Fixed duty cycle PWM signal is output according to the register setting.
0	1	**③ Automatic luminance control mode** Variable cycle PWM signal is output according to the brightness evaluation.

7.4 Brightness evaluation function

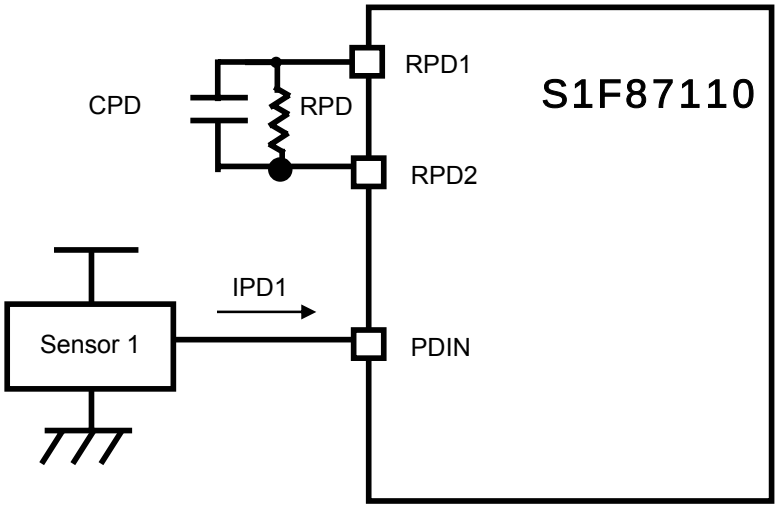
7.4.1 Connection of a sensor

The connection method differs depending on the sensor type as shown below.

① Photo IC (current output) type sensor
Connect the sensor current output pin to PDIN pin.

Suppose the current that the sensor provides to PDIN pin is IPD1. This sensor current IPD1 (A) and external RPD(Ω) will generate a voltage potential difference of **VPD(V)=(IPD1×1/10)×(RPD+0.1kΩ)** inside the IC.
Based on the VPD value, the S1F87110 determines the brightness level on the scale of 1 to 16.

$$VPD=(IPD1\times 1/10)\times(RPD+0.1k\Omega)$$

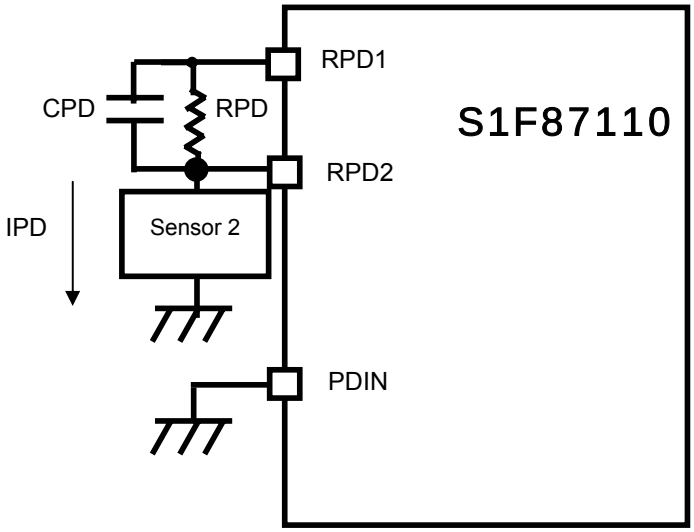


①Photo IC type sensor (sensor 1)

② Photodiode type sensor
Connect PDIN pin to the ground, and connect the sensor between RPD2 and Vss.

Suppose the sensor current is IPD2. This sensor current IPD2 (A) and external RPD (Ω) will generate a voltage potential difference of **VPD(V)=IPD2×(RPD+0.1kΩ)** inside the IC.
Based on the VPD value, the S1F87110 determines the brightness level on the scale of 1 to 16.

VPD=IPD2×(RPD+0.1kΩ)



②Photodiode type sensor (sensor 2)

In both the cases ① and ②, when the S1F87110 is operated in the fixed brightness mode and automatic luminance control mode, the potentials are RPD2=1(V) and RPD1=1(V)+VPD.
The potential is RPD1=0V in the standby mode.

Please minimize the wiring length between the sensor/sense resistor to the S1F87110, to avoid noise influence as much as possible.

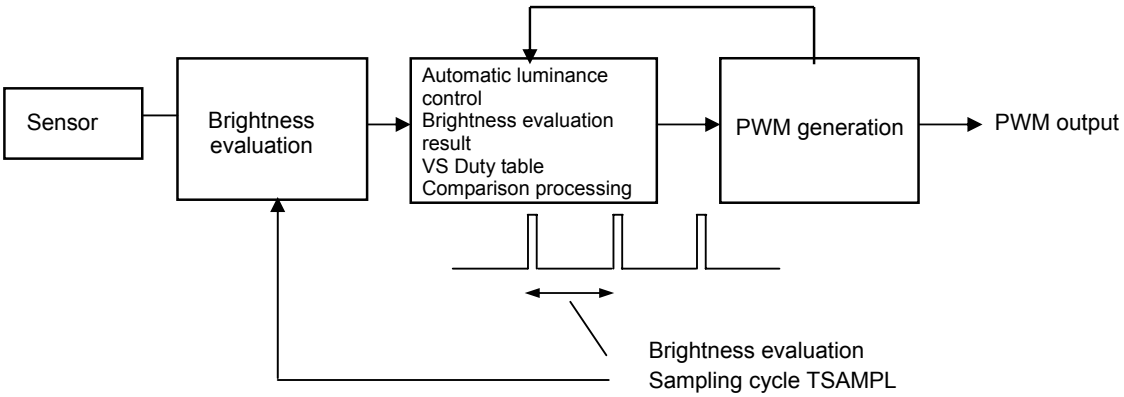
7.4.2 Brightness evaluation voltage VPD

The S1F87110 evaluates ambient brightness using the value of VPD on the scale of 1 to 16.
The following table shows relation between VPD threshold and brightness evaluation.
Determine the appropriate RPD based on the characteristic of the luminance sensor (IPD) and this IC's brightness evaluation VPD.

VPDn(V)	Brightness evaluation	
	Brightness 0	
VPD1=0.004 ←	Brightness 1	Dark (low sensor current)
VPD2=0.006 ←	Brightness 2	
VPD3=0.009 ←	Brightness 3	
VPD4=0.012 ←	Brightness 4	
VPD5=0.020 ←	Brightness 5	
VPD6=0.032 ←	Brightness 6	
VPD7=0.048 ←	Brightness 7	
VPD8=0.065 ←	Brightness 8	
VPD9=0.080 ←	Brightness 9	
VPD10=0.150 ←	Brightness 10	
VPD11=0.255 ←	Brightness 11	
VPD12=0.375 ←	Brightness 12	
VPD13=0.575 ←	Brightness 13	
VPD14=0.905 ←	Brightness 14	Bright (high sensor current)
VPD15=1.300 ←	Brightness 15	

VPDn: Threshed of brightness n and brightness n-1

7.4.3 Selection of brightness evaluation sampling cycle



The S1F87110 sensor evaluates brightness every brightness evaluation sampling cycle (TSAMPL).

It compares and processes the brightness evaluation result with the duties such as that corresponds to the set brightness evaluation on the register, and the PWM duty currently being output, and outputs PWM signal that automatically controls luminance linearly.

This sampling cycle TSAMPL can be changed with the register TPD0 to TPD2 settings.

I^2C register			Sampling cycle TSAMPL(sec)
TPD2 address 00H (D2)	TPD1 address 00H (D1)	TPD0 address 00H (D0)	
0	0	0	**20.48m**
0	0	1	**40.96m**
0	1	0	**81.92m**
0	1	1	**163.84m**
1	0	0	**327.68m**
1	0	1	**655.36m (default setting)**
1	1	0	**1.310**
1	1	1	**2.621**

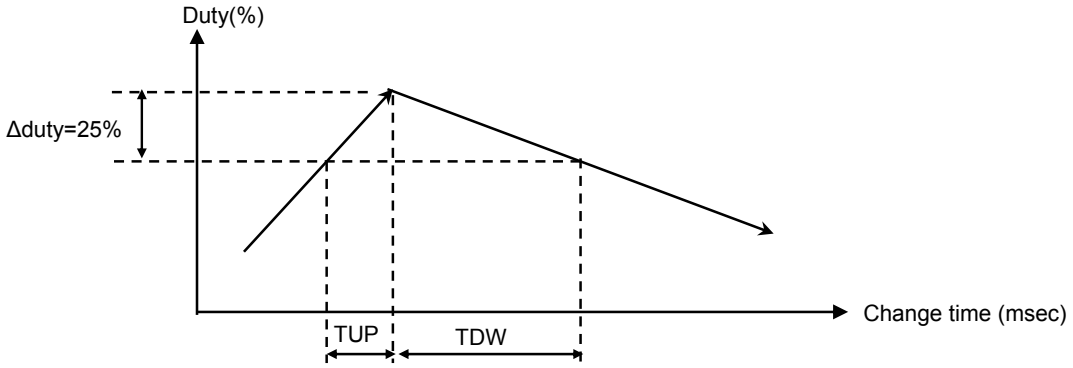
7.5 Automatic luminance control

7.5.1 Selection of current change time for automatic luminance control

The S1F87110 evaluates brightness in every brightness evaluation sampling cycle, and changes the duty automatically to correspond the result.
(For table setting of brightness evaluation - PWM duty, see 7.5.2 and 7.9.2.)
Duty change time = brightness change time can be changed with registers.

The time required for the duty (brightness) to increase 25% (TUP) and the time required for the duty (brightness) to decrease 25% (TDW) can be set independently.

● Definition of PWM duty change times TUP and TDW



● Registers for selecting PWM duty change time

Address	Item	Registers								Remarks
		TDW setting register				TUP setting register				
		D7	D6	D5	D4	D3	D2	D1	D0	
03H	Register Name	—	TDW2	TDW1	TDW0	—	TUP2	TUP1	TUP0	—
	R/W	—	R/W	R/W	R/W	—	R/W	R/W	R/W	
	Default value	—	0	1	1	—	0	1	0	

● PWM duty change time setting table

I^2C register			Duty change time (sec) (Δduty=25%)	Remarks
TDW2/TUP2	TDW1/TUP1	TDW0/TUP0		
0	0	0	**1.31**	
0	0	1	**2.62**	
0	1	0	**5.24**	**TUP default setting**
0	1	1	**10.48**	**TDW default setting**
1	0	0	**20.97**	
1	0	1	**41.94**	
1	1	0	**83.89**	
1	1	1	**167.77**	

7.5.2 Brightness evaluation - PWM duty table setting

Next, determine the PWM duties at respective brightness evaluation.
PWM duties can be set with 7 bit and 128 gradations (APWM).
Set 7-bit registers for D0 to D6 of address 10H to 1FH for 16 different levels. (See the table below.)

The PWM duty changes linearly between the set duty values determined at each brightness evaluation for automatic luminance control.
The PWM duty can be obtained from the following formula:

$$\text{Duty}(\%) = \text{APWM}(\text{decimal}) / 128(\text{decimal})$$

For example, the default value of address 1FH, which is the level 15 of PWM duty set register, is (D7,D6,D5,D4,D3,D2,D1,D0)=(X,1,1,0,0,1,1,0), or APWM(dec)=102.
The brightness level 15 is set to Duty=102/128 80% of PWM output value.

Brightness		LED current Set address	Register default value APWM	
			decimal	Hex
Brightness 0	Dark (low sensor current)	**10H**	13	0D
Brightness 1		**11H**	21	15
Brightness 2		**12H**	28	1C
Brightness 3		**13H**	36	24
Brightness 4		**14H**	44	2C
Brightness 5		**15H**	52	34
Brightness 6		**16H**	59	3B
Brightness 7		**17H**	68	44
Brightness 8		**18H**	75	4B
Brightness 9		**19H**	83	53
Brightness 10		**1AH**	91	5B
Brightness 11		**1BH**	102	66
Brightness 12		**1CH**	102	66
Brightness 13	Bright (high sensor current)	**1DH**	102	66
Brightness 14		**1EH**	102	66
Brightness 15		**1FH**	102	66

* Depending on the characteristics of the LED driver to be connected, settings may not match when the duty ratio, duty cycle or sampling cycle is low. This can be adjusted by changing duty ratio or sampling cycles. Please determine the settings based on your evaluation.

7.6 Acquisition of brightness evaluation result

The S1F87110 can read out data of the brightness evaluation result (brightness 0 to 15).
Read out data from address 00H with I^2C, which will be explained later. (See 7.9.1 Function register.)
Brightness information will be output as 4-bit information of D7, D6, D5, D4 (register name: X3, X2, X1, X0) as follows: (D7=MSB,D4=LSB)

Brightness 0= (D7,D6,D5,D4,D3,D2,D1,D0) = (0,0,0,0,X,X,X,X)
Brightness 1= (D7,D6,D5,D4,D3,D2,D1,D0) = (0,0,0,1,X,X,X,X)
•
•
•
Brightness 15 (D7,D6,D5,D4,D3,D2,D1,D0) = (1,1,1,1,X,X,X,X)

This function (brightness evaluation function) operates for both the automatic luminance control mode and fixed brightness mode.
The result of brightness evaluation can be read out except in the standby mode.

7.7 Fixed brightness function (mode)

In the fixed brightness mode, the PWM signal is output in a fixed duty regardless of the brightness evaluation result.
Set this fixed current using 7 bits from D0 (LSB) to D6 at address 01H. D7 is the dummy.
Similar to that in the automatic luminescence control, the PWM duty in the fixed brightness mode is obtained from the following formula:

$$\text{Duty}(\%) = \text{CPWM}(\text{decimal}) / 128(\text{decimal})$$

● Fixed brightness PWM duty set register

Address	Item	Registers								Remarks
		D7	D6	D5	D4	D3	D2	D1	D0	
01H	Register Name	—	CPWM6	CPWM5	CPWM4	CPWM3	CPWM2	CPWM1	CPWM0	—
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	1	1	1	1	1	

7.8 PWM output function

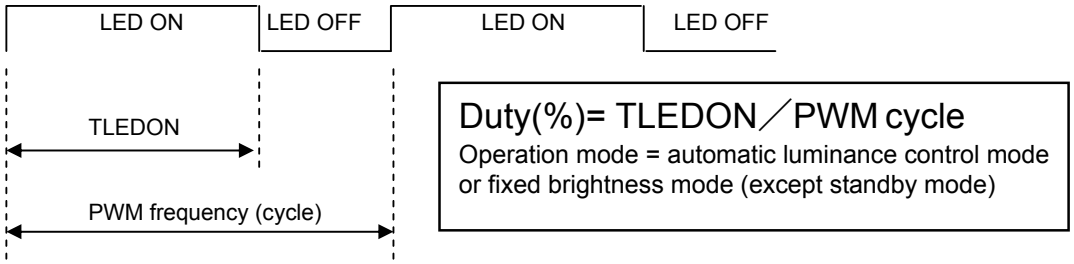
● PWM cycle select function

PWM output cycle can be selected with the PWM cycle register (TPWM) settings.
When TPWM=0, PWM cycle=390Hz (Typ.)
When TPWM=1, PWM cycle=195Hz (Typ.)

I²C register	PWM frequency
TPWM Address 02H (D4)	
0 (Default value)	390 (Hz)
1	195 (Hz)

● PWM phase inversion function in the operation mode

PWM signal of the S1F87110 is Nch open drain output.
PWM output phase can be inverted with the PWM phase select register (PPWM).
Definition of PWM duty is TLEDON/PWM cycle. At TLEDON, Nch open drain output can be selected from ON/OFF (Hi-Z).



I²C register		PWM output at TLEDON with operation mode
SPWM Address 02H (D6)	PPWM Address 02H (D5)	
X	0 (Default value)	Nch OFF output (Hi-Z)
X	1	Nch ON output (Vss)

● PWM output select function during standby

The S1F87110 can select Nch ON/OFF of PWM output during standby.
PWM output during standby is determined only with this SPWM, regardless of PPWM setting at the operation mode, as follows.

I²C register		PWM output in standby mode
SPWM Address 02H (D6)	PPWM Address 02H (D5)	
0	X	Nch ON output (Vss)
1 (Default value)	X	Nch OFF output (Hi-Z)

7.9 Register setting

7.9.1 Function register (address 00H to 03H)

Address	Item	Registers								Remarks
		D7	D6	D5	D4	D3	D2	D1	D0	
00H	Register Name	X3	X2	X1	X0	—	SCONST	SAUTO	SRESET	Each function active High X3 to X0: Brightness evaluation output
	R/W	R	R	R	R	—	R/W	R/W	R/W	
	Default value	—	—	—	—	—	0	0	0	
01H	Register Name	—	CPWM6	CPWM5	CPWM4	CPWM3	CPWM2	CPWM1	CPWM0	Fixed brightness PWM duty set Register
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	1	1	1	1	1	
02H	Register Name	—	SPWM	PPWM	TPWM	—	TPD2	TPD1	TPD0	SPWM: During standby PWM output PPWM: PWM phase during operation TPWM: PWM cycle TPD: Sampling cycle
	R/W	—	R/W	R/W	R/W	—	R/W	R/W	R/W	
	Default value	—	1	0	0	—	**1**	0	1	
03H	Register Name	—	TDW2	TDW1	TDW0	—	TUP2	TUP1	TUP0	TDW*: Duty reduction time TUP*: Duty increase time
	R/W	—	R/W	R/W	R/W	—	R/W	R/W	R/W	
	Default value	—	0	1	1	—	0	1	0	

7.9.2 Brightness evaluation - PWM duty set register (address 10H to 1FH)

Address	Item	Registers								Remarks
		D7	D6	D5	D4	D3	D2	D1	D0	
10H	Register Name	—	APWM06	APWM05	APWM04	APWM03	APWM02	APWM01	APWM00	PWM duty setting with brightness evaluation 0
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	0	0	1	1	0	1	
11H	Register Name	—	APWM16	APWM15	APWM14	APWM13	APWM12	APWM11	APWM10	PWM duty setting with brightness evaluation 1
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	0	1	0	1	0	1	
12H	Register Name	—	APWM26	APWM25	APWM24	APWM23	APWM22	APWM21	APWM20	PWM duty setting with brightness evaluation 2
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	0	1	1	1	0	0	
13H	Register Name	—	APWM36	APWM35	APWM34	APWM33	APWM32	APWM31	APWM30	PWM duty setting with brightness evaluation 3
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	0	0	1	0	0	
14H	Register Name	—	APWM46	APWM45	APWM44	APWM43	APWM42	APWM41	APWM40	PWM duty setting with brightness evaluation 4
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	0	1	1	0	0	
15H	Register Name	—	APWM56	APWM55	APWM54	APWM53	APWM52	APWM51	APWM50	PWM duty setting with brightness evaluation 5
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	1	0	1	0	0	
16H	Register Name	—	APWM66	APWM65	APWM64	APWM63	APWM62	APWM61	APWM60	PWM duty setting with brightness evaluation 6
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	0	1	1	1	0	1	1	
17H	Register Name	—	APWM76	APWM75	APWM74	APWM73	APWM72	APWM71	APWM70	PWM duty setting with brightness evaluation 7
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	0	0	0	1	0	0	
18H	Register Name	—	APWM86	APWM85	APWM84	APWM83	APWM82	APWM81	APWM80	PWM duty setting with brightness evaluation 8
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	0	0	1	0	1	1	
19H	Register Name	—	APWM96	APWM95	APWM94	APWM93	APWM92	APWM91	APWM90	PWM duty setting with brightness evaluation 9
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	0	1	0	0	1	1	
1AH	Register Name	—	APWMA6	APWMA5	APWMA4	APWMA3	APWMA2	APWMA1	APWMA0	PWM duty setting with brightness evaluation 10
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	0	1	1	0	1	1	
1BH	Register Name	—	APWMB6	APWMB5	APWMB4	APWMB3	APWMB2	APWMB1	APWMB0	PWM duty setting with brightness evaluation 11
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	1	0	0	1	1	0	
1CH	Register Name	—	APWMC6	APWMC5	APWMC4	APWMC3	APWMC2	APWMC1	APWMC0	PWM duty setting with brightness evaluation 12
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	1	0	0	1	1	0	
1DH	Register Name	—	APWMD6	APWMD5	APWMD4	APWMD3	APWMD2	APWMD1	APWMD0	PWM duty setting with brightness evaluation 13
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	1	0	0	1	1	0	
1EH	Register Name	—	APWME6	APWME5	APWME4	APWME3	APWME2	APWME1	APWME0	PWM duty setting with brightness evaluation 14
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	1	0	0	1	1	0	
1FH	Register Name	—	APWMF6	APWMF5	APWMF4	APWMF3	APWMF2	APWMF1	APWMF0	PWM duty setting with brightness evaluation 15
	R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	Default value	—	1	1	0	0	1	1	0	

7.10 I²C serial interface

The S1F87110 serves as the I²C slave device with a I²C-compatible two-wire serial interface.
This interface, by connecting to the I²C bus, achieves interactive communication among multiple devices that use serial data (SDA) and serial clock (SCL).
I²C is referred for two-wire serial interface proposed by Philips.

[Mode]	Slave exclusive
[Slave address]	7-bit length Slave address 0001010b
[Communication speed]	Max. 400kHz
[Pins being used]	SCL Clock input pin SDA Data I/O pin
[Voltage level]	High=V_{DDL} level, Low=V_{SS} level

■ Data transfer method is shown below. (See Attachment 1 for details.)

● Start conditions and start of communication
In the communication sequence of the I²C controller, the following START condition must be generated to initiate the communication.

START condition: SDA changes from High to Low when SCL is High.

The I²C master generates the START condition for data transfer.
As the S1F87110 is a slave device, it cannot generate the START condition.
The I²C master can initiate communication at any time.

● STOP condition and end of communication
To terminate the communication with the S1F87110, the I²C master generates the STOP condition after data transfer including ACK (Low)/NACK (High) has been finished successfully.

STOP condition: SDA changes from Low to High when SCL is High.

This interrupts the communication between the I²C master and the S1F87110, and releases the I²C bus.

● Slave address
After generating the START condition, the I²C master outputs 7-bit address starting from MSB (A6).
The slave address varies by ICs. The slave address for the S1F87110 is 0001010b.
The S1F87110 captures the data at the rising edge of the clock to be entered to SCL.

● Read/write (R/W) designated bit
Following the 7-bit slave address LSB (A0), the I²C master outputs the bit that shows data transfer direction.
The S1F87110 also captures this bit at the rising edge of SCL.
The relationship between bit and transfer direction are shown below.

R/W designated bit =“0”: Data wrote by I²C master (I²C master → S1F87110)
R/W designated bit =“1”: Data read by I²C master (S1F87110 → I²C master)

● Establishing communication

When the slave address and the R/W designated bit is captured, the S1F87110 compares the slave address with that set in the S1F87110.

If these addresses are met, SDA is set to Low for 1 clock from the SCL trailing edge followed by the capture of R/W designated bit.

This Low pulse is sent to the I^2C master as an ACK signal showing that the S1F87110 has received the slave address and R/W bit successfully. This establishes the communication between the I^2C master and the S1F87110, and starts data transfer.

● Data transfer

The followings explain data transfer sequence of I^2C master, from START condition till STOP condition. (See Attachment 1 for details.)

◎Data write

・START condition	: Generates the START condition.
・Send slave address → receive ACK	: Designates the slave address. (WRITE)
・Send register address → receive ACK	: Designates the register address to write data. (WRITE)
・Send write data → receive ACK	: Writes data to the designated address. (WRITE)
・STOP condition	: Generates the STOP condition, and terminates the communication.

◎Data read

・START condition	: Generates the START condition.
・Send slave address → receive ACK	: Designates the slave address. (WRITE)
・Send register address → receive ACK	: Designates the register address to read data. (WRITE)
・RESTART condition	: Generates the START condition again.
・Send slave address → receive ACK	: Designates the slave address. (READ)
・Read data from the S1F87110	: Reads data from the designated register address.
・STOP condition from NACK condition	: Generates the STOP condition from the NACK condition, and terminates the communication.

8. ABSOLUTE MAXIMUM RATINGS

V_{SS}=0V

Item	Symbol	Rated Value		Unit	Applicable pin	Remarks
		Min.	Max.			
Input power voltage 1	V_{DD}	-0.3	5.5	V	V_{DD}	Note 1
Input power voltage 2	V_{DDL}	-0.3	3.6	V	V_{DDL}	Note 1
Input pin voltage2	V_{PIN}	-0.3	V_{DDL}+0.3	V	SDL, SDA	—
Allowable dissipation	PD	—	200	mW	—	—
Storage temperature	T_{stg}	-40	125	°C	—	—

<Note 1> $V_{DD} \geq V_{DDL}$ must be set in the steady state, except in transient state at power-on.
<Note 2> Do not externally feed voltage to the output pin, RPD connect pin and test pin.
<Note 3> 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, normal function may be achieved temporarily but its reliability may be significantly low.

9. RECOMMENDED OPERATING CONDITIONS

V_{SS}=0V

Item	Symbol	Rated Value		Unit	Applicable pin	Remarks
		Min.	Max.			
Input power voltage 1	V_{DD}	2.7	3.6	V	V_{DD}	—
Input power voltage 2	V_{DDL}	1.6	3.0	V	V_{DDL}	—
Operating ambient temperature	T_a	-25	85	°C	—	—

10. ELECTRICAL CHARACTERISTICS

■ DC Characteristics

Unless otherwise specified,V_{DD}=3.0V,V_{DDL}=1.8V,T_a=25°C

Item	Symbol	Standard			Unit	Applicable pin	Remarks
		Min.	Typ.	Max.			
Self-consumption current	Iopr	—	0.20	0.40	mA	V_{DD}	SAUTO=H, SCONST=L SCL=SDA=L, Automatic luminance control mode, RPD connected, IPD=0
		—	4.0	15	μA	V_{DDL}	
Standby current	Istby	—	0.1	0.8	μA	V_{DD}	
		—	0.1	3.0	μA	V_{DDL}	
PWM cycle variations	ΔPWM	-20	—	+20	%	PWM	TPWM=0, Typ. 380Hz TPWM=1, Typ. 195Hz Error against set cycle
PWM duty variations	ΔDuty	-5	—	+5	%	PWM	Error against set duty value
PWM pin leak current	I_{LEAK}	—	0.01	0.5	μA	PWM	PWM=V_{DD}
PWM pin output current	I_{PWM}	0.8	—	2.0	mA	PWM	V_{OL}=0.2V
PWM change time	TUP TDW	-20	—	+20	%	PWM	Error against set change time
Sensor application voltage	VRPD2	0.9	1.0	1.1	V	RPD2	RPD2 pin voltage
VPD	VPD15	1.050	1.300	1.500	V	RPD1,2	Brightness evaluation value RPD=100kΩ
	VPD1	0.002	0.004	0.006			
	ΔVPD	VPDn-VPDn-1>0			V	—	Monotonic increase
RPD resistance value	RPD	1.0	—	500	kΩ	RPD1,2	
Brightness evaluation Sampling cycle	TSAMPL	-20	—	+20	%	—	Error against set cycle

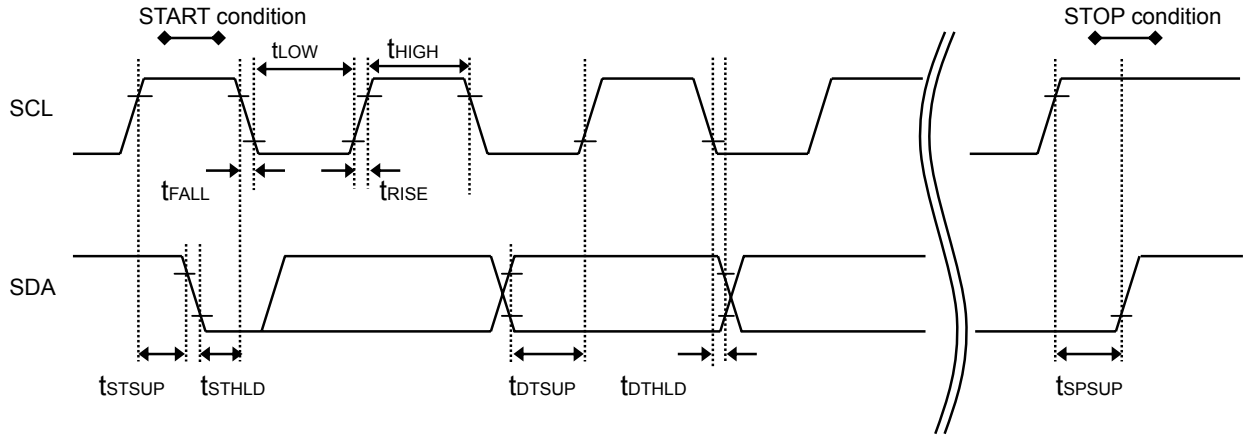
Unless otherwise specified, V_{DD}=3.0V,V_{DDL}=1.8V,T_a=25°C

Item	Symbol	Standard			Unit	Applicable pin	Conditions
		Min.	Typ.	Max.			
PDIN pin saturation voltage	VPDIN	—	1.05	1.35	V	PDIN	PDIN pin voltage when IPD1=1000μA is applied
RPD1 pin saturation voltage	VRPD1	2.65	—	—	V	RPD1	RPD1 pin voltage when IPD2=1000μA is applied
HIGH level input voltage	V_{IH}	0.8× V_{DDL}	—	—	V	SCL,SDA XRESET	
LOW level input voltage	V_{IL}	—	—	0.2× V_{DDL}	V		
Input current (H)	I_{IH}	-0.5	—	0.5	μA		V_{IN}=1.8V
Input current (L)	I_{IL}	-0.5	—	0.5	μA		V_{IN}=0V
SDA pin output current	ISDA	2.5	5.5	—	mA	SDA	V_{OL}=0.2V

■ AC Characteristics

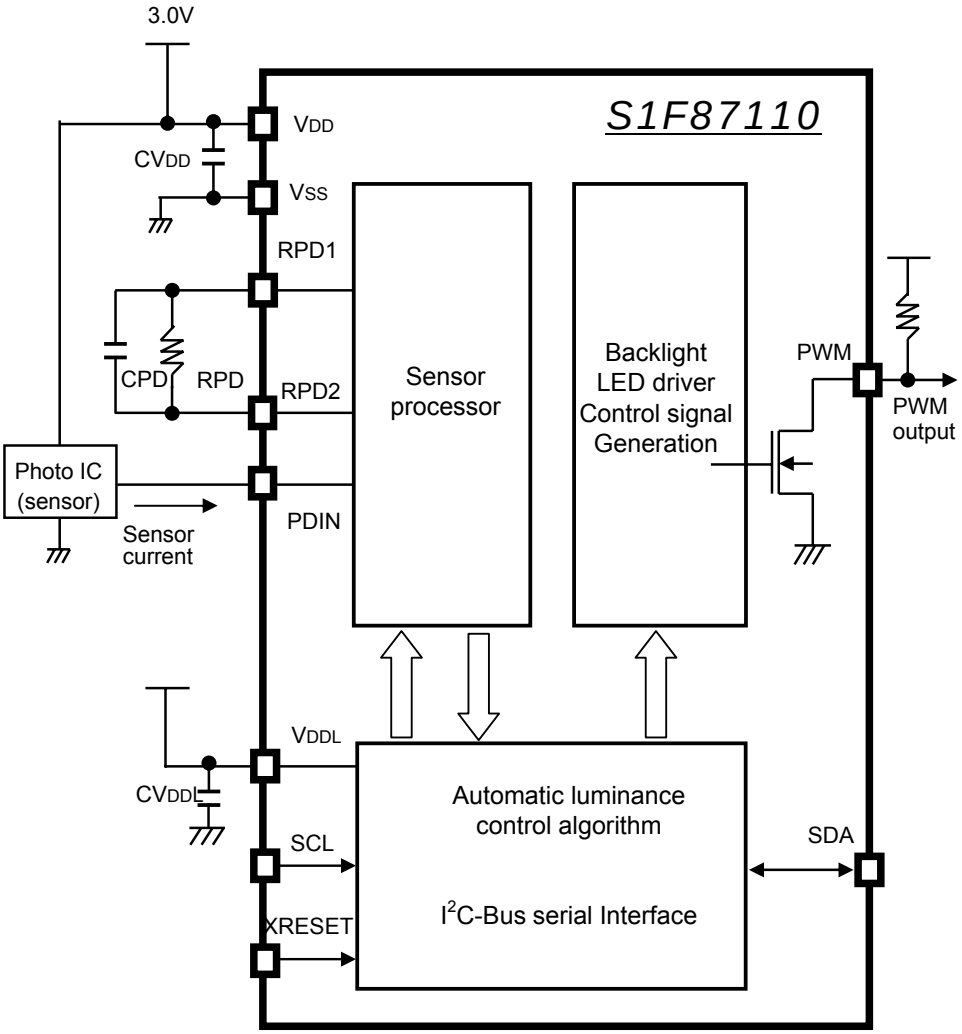
Unless otherwise specified, V_{DD}=3.0V,V_{DDL}=1.8V,T_a=25°C,V_{IH}=0.8・V_{DDL},V_{IL}=0.2・V_{DDL}

Item	Symbol	Standard			Unit	Applicable pin	Conditions
		Min.	Typ.	Max.			
SCL clock cycle	fscl	—	—	400	kHz	SCL	
SCL clock HIGH period	t_{HIGH}	0.6	—	—	µs	SCL	
SCL clock LOW period	t_{LOW}	1.3	—	—	µs	SCL	
Input signal rise time	t_{RISE}	—	—	0.3	µs	SCL,SDA	
Input signal fall time	t_{FALL}	—	—	0.3	µs	SCL,SDA	
START condition setup time	t_{STSUP}	0.6	—	—	µs	SCL,SDA	
START condition hold time	t_{STHLD}	0.6	—	—	µs	SCL,SDA	
STOP condition setup time	t_{SPSUP}	0.6	—	—	µs	SCL,SDA	
Data setup time	t_{DTSUP}	0.1	—	—	µs	SCL,SDA	
Data hold time	t_{DTHLD}	0	—	—	µs	SCL,SDA	
Reset pulse width	txr	1.0	—	—	µs	XRESET	XRESET= Low period
Reset pulse width at power on	txrst	1.0	—	—	ms	XRESET	See No.P9
Wait time after clearing reset	txrwait	1.0	—	—	µs	XRESET SCL,SDA	See No.P9

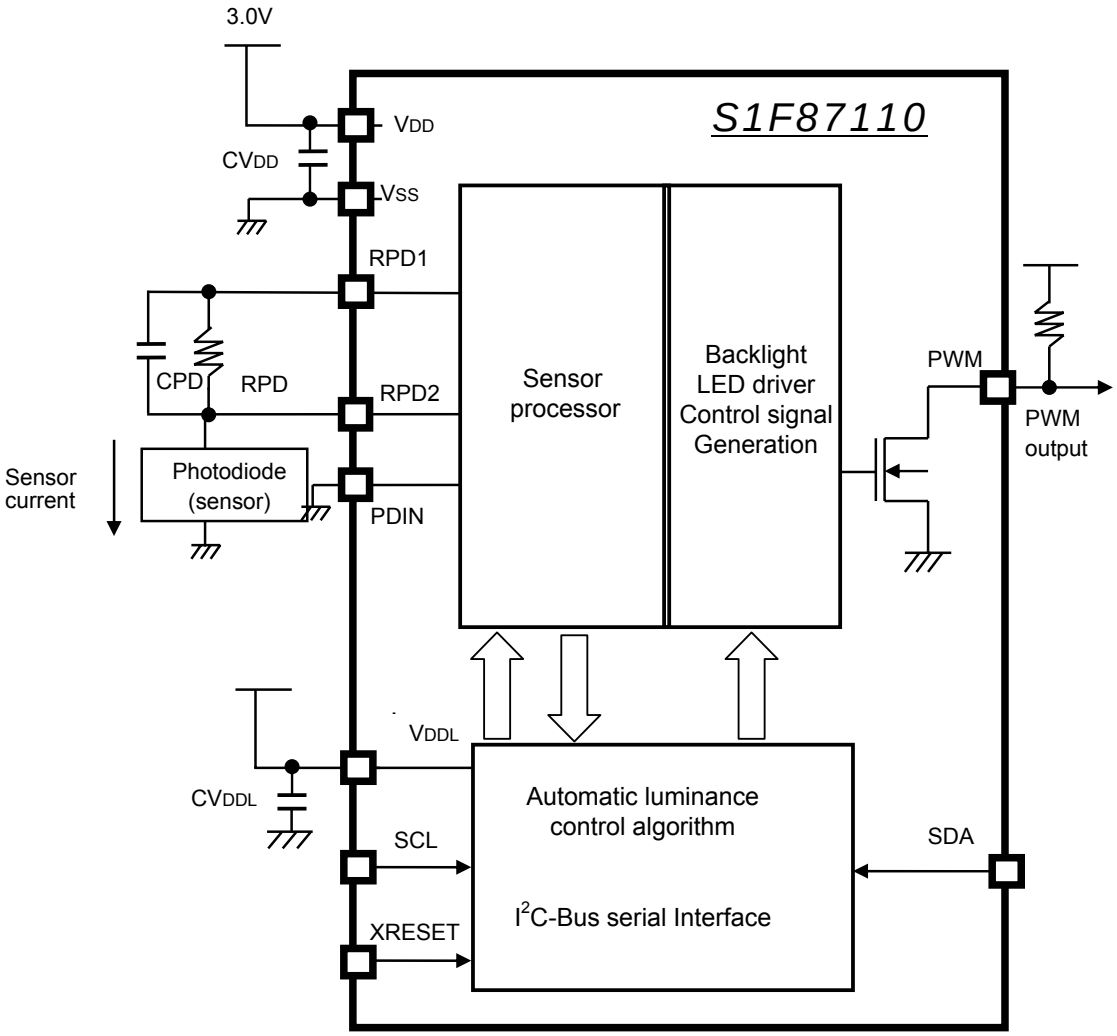


11. EXTERNAL CONNECTION DIAGRAMS

11.1 Example of photo IC type sensor connection



11.2 Example of photodiode type sensor connection



11.3 Example of recommended parts

Parts name	Use	Maximum applied voltage	Capacity value or Resistance value
CVDD	Bypass capacitor between V_{DD} and V_{SS}	V_{DD}	0.1μF
CVDDL	Bypass capacitor between V_{DDL} and V_{SS}	V_{DDL}	0.1μF
CPD	Noise suppressor capacitor	V_{DD}	0.1μF
RPD	VPD generating resistor	V_{DD}	See Section 7.4.
Photo IC	Luminance sensor Example of recommended part: TOSHIBA TPS853 TOSHIBA TPS852	—	—
Photodiode	Luminance sensor Example of recommended part: TDK BCS1210A1LP TDK BCS2015G1	V_{DD}	—

<Precautions>

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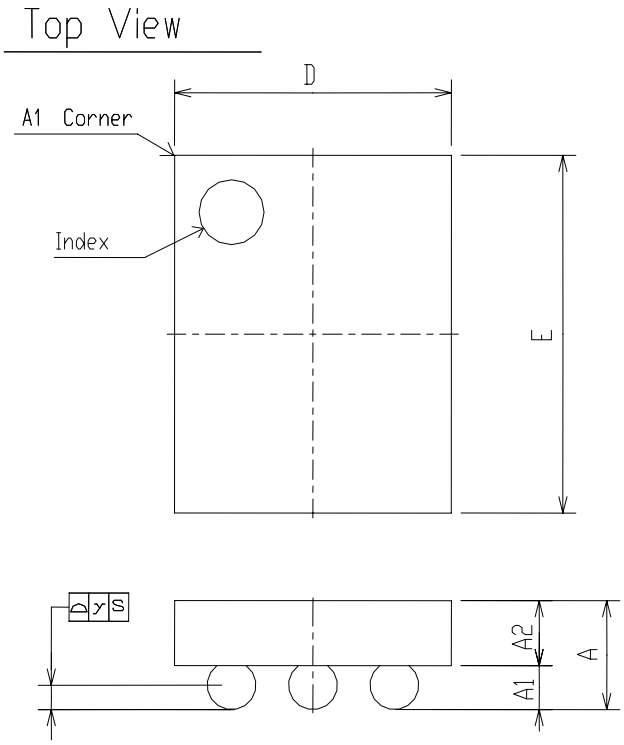
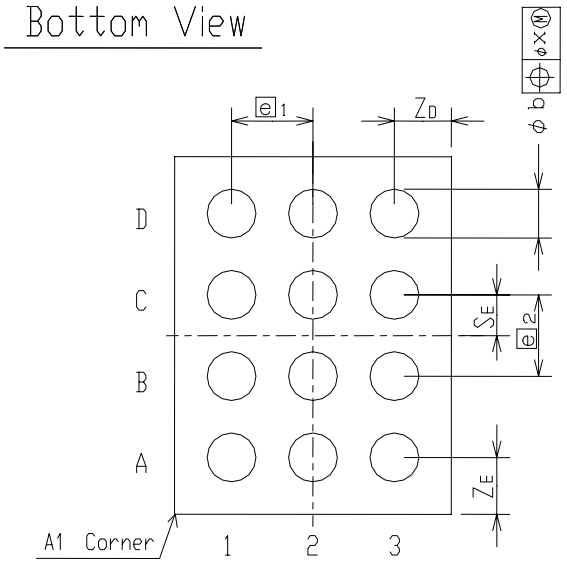
"Precautions for Handling the IC against the Light"
If semiconductor chips are exposed to the strong light, their characteristics may change. Therefore, exposure of the IC to the light may cause malfunction. To protect the ICs, the following general requirements must be satisfied for IC mount boards 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.

12. EXTERNAL DIMENSIONS





Symbol	Dimension in Milimeters		
	Min.	Nom.	Max.
D		1.700	
E		2.200	
A			0.72
A_1		0.26	
A_2			
e1		0.50	
e2		0.50	
b	0.27	0.30	0.33
x			0.08
y			0.05
S_D			
S_E		0.250	
Z_D		0.350	
Z_E		0.350	

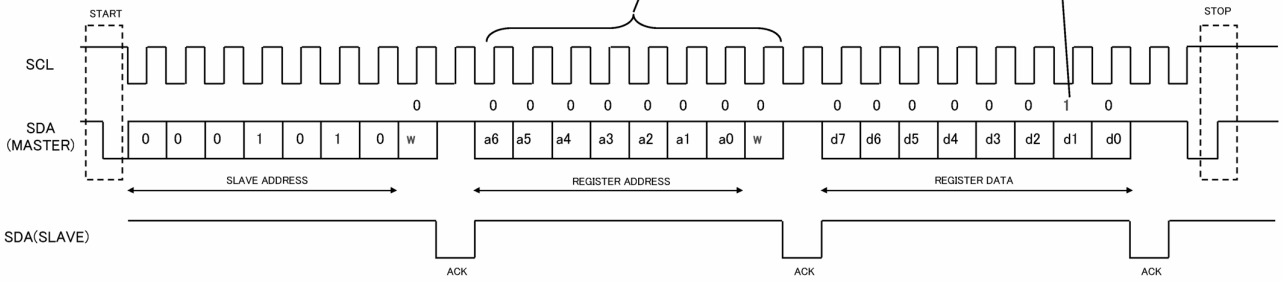
S1F87110 I2C I/F

MODE: SLAVE only
SLAVE ADDRESS: 7Bit **0001010b**
I/F MODE: Max400kHz FASTMODE
PINNAME: SDA DATA I/O
SCL CLOCK IN
VOLTAGE LEVEL HIGH = VDDL、LOW = VSS

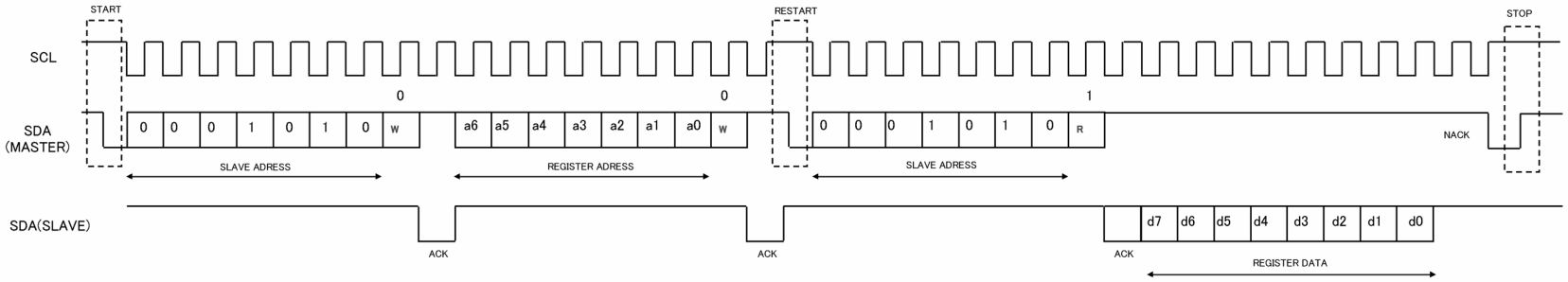
Ex. Register Address 00H

Ex.wake up rejister "SAUTO"=1
Starts with automatic luminance control mode

■DATA WRITE



■DATA READ



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