LITEON®
OPTOELECTRONICS

Optical Sensor
Product Data Sheet
LTR-309ALS-01

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Revision: A

LITE-ON DCC

RELEASE

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OPTICAL SENSOR
LTR-309ALS-01

Description

The LTR-309ALS-01 is an integrated low voltage I2C ambient light sensor (ALS) in a single 2.0x2.0mm miniature chipled lead-free surface mount package.

The ALS provides a linear response over a wide dynamic range, which is well suited to applications under very low or bright ambient brightness.

The sensor CMOS design and factory-set one time trimming capability ensure minimal sensor-to-sensor variations for ease of manufacturability to the end customers.

Application

- Control brightness of display panel

Features

- I^2C interface (Standard mode @100kHz or Fast mode @ 400kHz)
- Ambient Light in one ultra-small Chipled package
- Very low power consumption with sleep mode capability
- Operating voltage ranges: 1.7V to 3.6V
- Operating temperature ranges: -40 to +85 ºC
- RoHS and Halogen free compliant

ALS Features

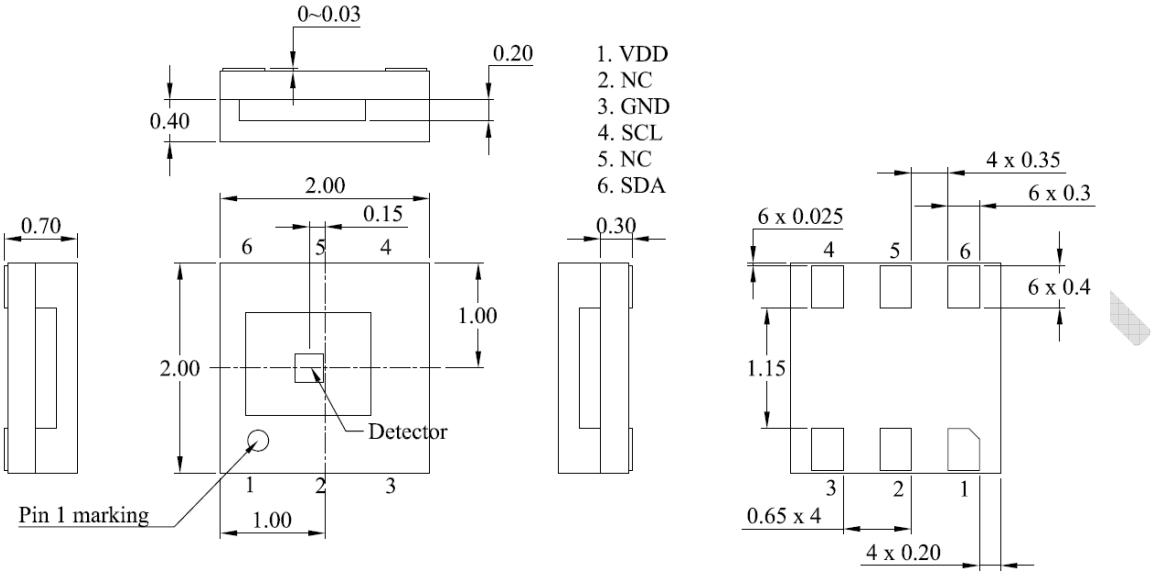
- 16 bits effective resolution
- Wide dynamic range with linear response
- Close to human eye spectral response
- Automatic rejection for 50Hz/60Hz lighting flicker

Ordering Information

Part Number	Packaging Type	Package	Quantity
LTR-309ALS-01	Tape and Reel	6-pin chipled package	2500pcs

OPTICAL SENSOR
LTR-309ALS-01

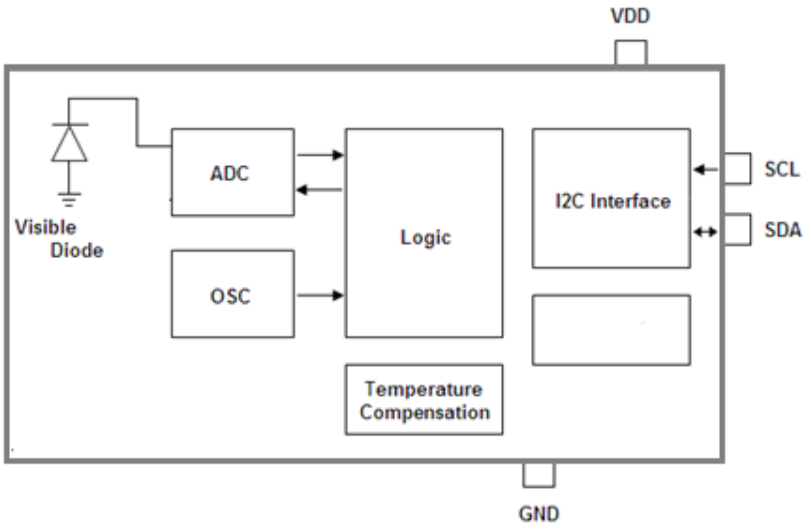
1. Outline Dimensions and Pins Configuration



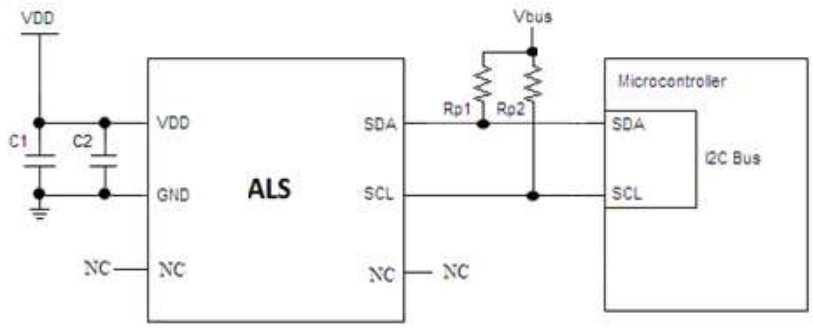
1. All dimensions in mm
2. Tolerances is +/-0.2
3. LTC reserve the right to to change the drawing till final datasheet release

2. Functional Block Diagram

The LTR-309ALS-01 contains a photodiodes for respective photocurrent measurement. The photodiode currents are converted to digital values by ADCs. The sensor also included some peripheral circuits such as an internal oscillator, a current course, voltage reference, and internal fuses to store trimming information.



3. Application Circuit



I/O Pins Configuration Table

Pin	I/O Type	Symbol	Description
1		VDD	Power Supply Voltage
2		NC	No connection to this pin
3		GND	Ground
4	I	SCL	I^2C serial clock
5		NC	No connection to this pin
6	I/O	SDA	I^2C serial data

Recommended Application Circuit Components

Component	Recommended Value
Rp1, Rp2 [1]	1 kΩ to 10 kΩ
C1	0.1uF
C2	1.0uF

[1] Selection of pull-up resistors value is dependent on bus capacitance values. For more details, please refer to I^2C Specifications: http://www.nxp.com/documents/user_manual/UM10204.pdf

4. Ratings and Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Min.	Max	Unit
Supply Voltage	VDD		4.5	V
Digital Voltage Range	SCL, SDA	-0.5	4.5	V
Storage Temperature	T_{stg}	-40	100	°C
Electrostatic Discharge Protection (Human Body Model JESD22-A114)	V_{HBM}		2000	V

Note: Exceeding these ratings could cause damage to the sensor. All voltages are with respect to ground.

Recommended Operating Conditions

Description	Symbol	Min.	Typ.	Max.	Unit
Supply Voltage	VDD	1.7		3.6	V
Interface signal input high	$V_{I2Chigh}$	1.5		VDD	V
Interface signal input low	V_{I2Clow}	0		0.4	V
Operating Temperature	T_{ope}	-40		85	°C

Electrical & Optical Specifications

All specifications are at VDD = 3V, T_{ope} = 25°C, unless otherwise noted.

Parameter	Min.	Typ.	Max.	Unit	Condition
ALS Active Supply Current			260	uA	100ms INT, 200ms MRR
Standby Current			5	uA	Shutdown Mode
Wakeup Time from Standby		5	10	ms	From Standby to Active mode where measurement can start

Characteristics Ambient Light Sensor

Parameter	Min.	Typ.	Max.	Unit	Condition
ALS Resolution			16	Bit	Programmable for 13, 14, 15, 16 Bit
ALS Lux accuracy		10		%	50lux, WLED 5626K
Dark Level Count			2	Count	0 Lux, 16-bit resolution, gain 64X
Integration time	50		400	ms	With 50/60Hz Rejection
50/60 Hz flicker noise error	-5		+5	%	

Typical Device Parameter

(VDD = 2.8V, Ta=25℃, Default power-up settings, un less otherwise noted)

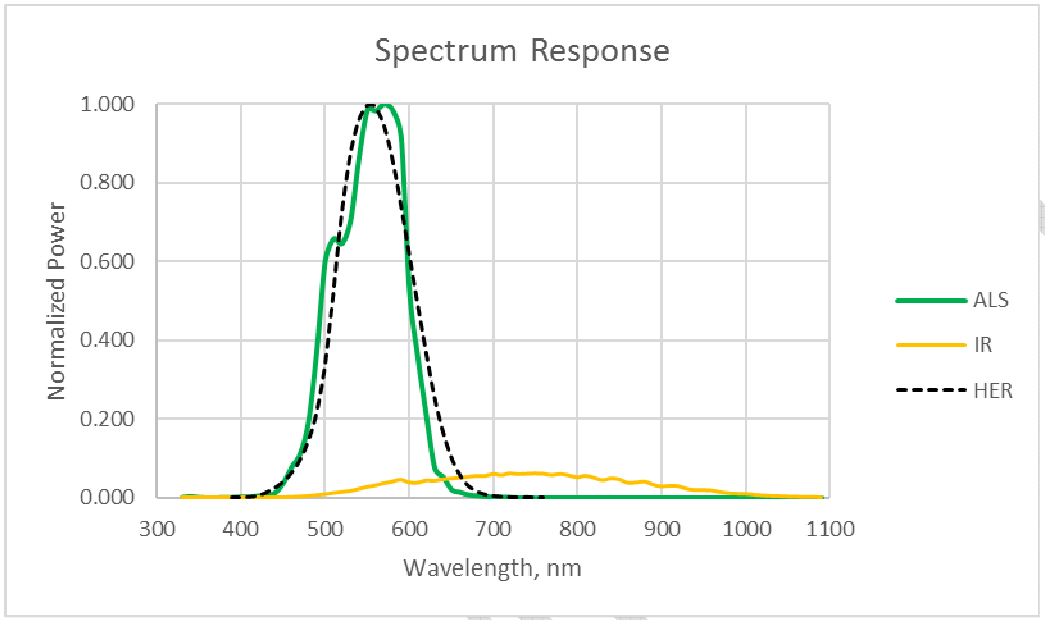


Figure 4.1 : ALS Spectral response

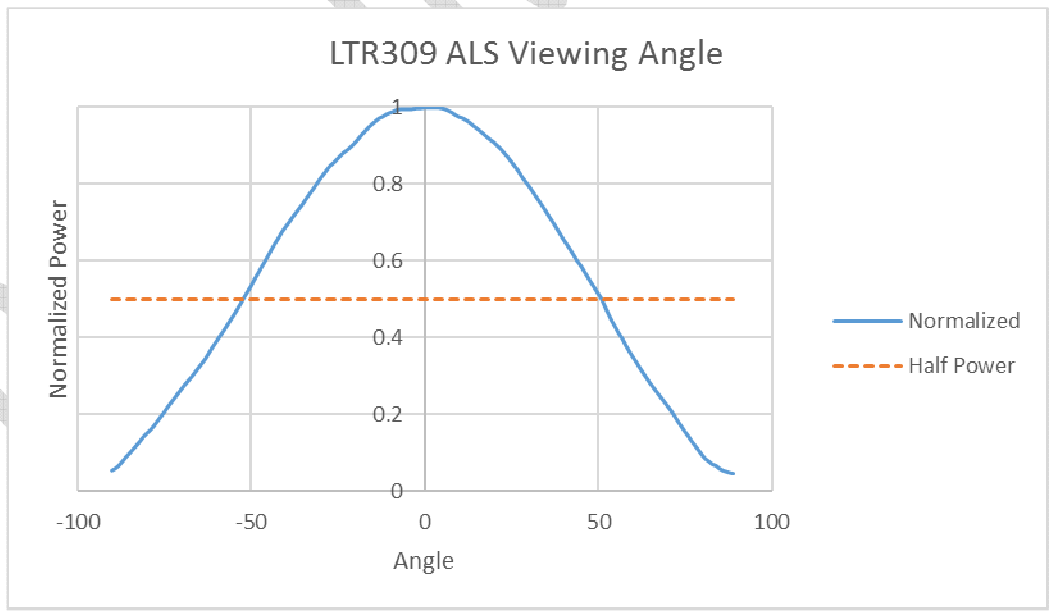
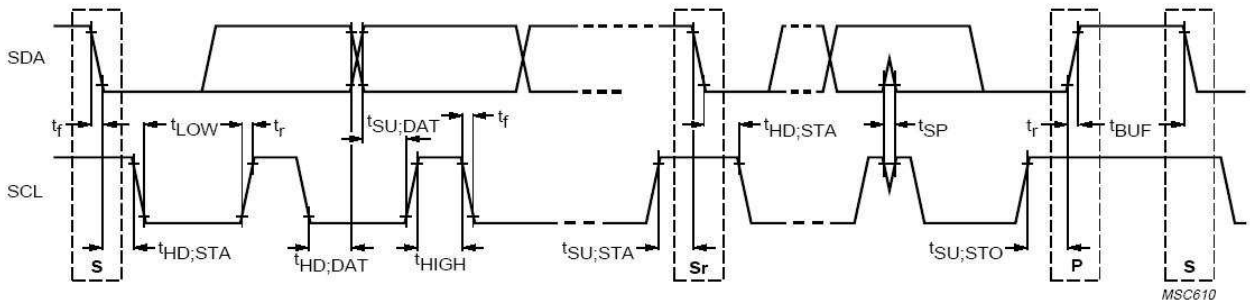


Figure 4.2: ALS viewing angle performance

AC Electrical Characteristics

All specifications are at VBus = 1.7V, T_{ope} = 25°C, unless otherwise noted.

Parameter	Symbol	Standard mode		Fast mode		
		Min.	Max.	Min.	Max.	Unit
SCL clock frequency	f_{SCL}	100		400		kHz
Bus free time between a STOP and START condition	t_{BUF}	4.7	-	1.3	-	us
Hold time (repeated) START condition. After this period, the first clock pulse is generated	$t_{HD;STA}$	4.0	-	0.6	-	us
LOW period of the SCL clock	t_{LOW}	4.7	-	1.3	-	us
HIGH period of the SCL clock	t_{HIGH}	4.0	-	0.6	-	us
Set-up time for a repeated START condition	$t_{SU;STA}$	4.7	-	0.6	-	us
Set-up time for STOP condition	$t_{SU;STO}$	4.0	-	0.6	-	us
Rise time of both SDA and SCL signals	t_r	-	1000	-	300	ns
Fall time of both SDA and SCL signals	t_f	-	300	-	300	ns
Data hold time	$t_{HD;DAT}$	0	-	0	-	us
Data setup time	$t_{SU;DAT}$	250	-	100	-	ns

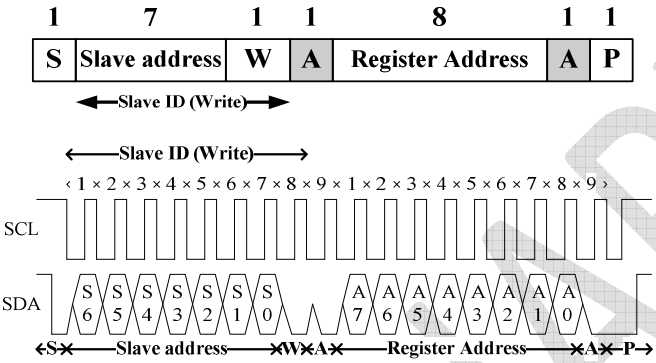


Definition of timing for I²C bus

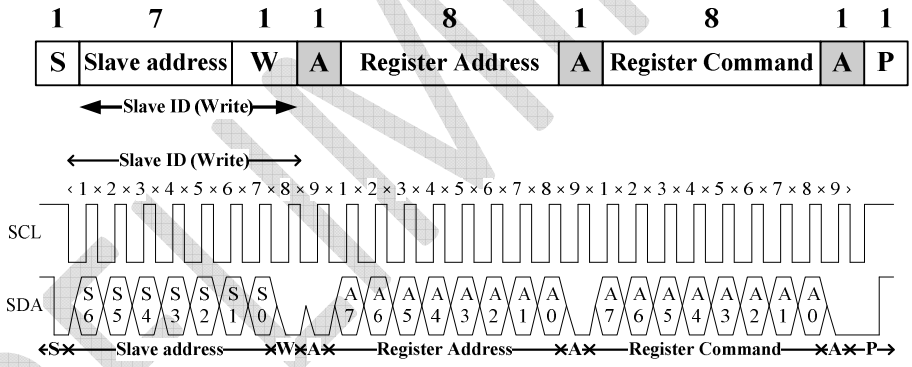
5. Principles of Operation

I²C Protocols

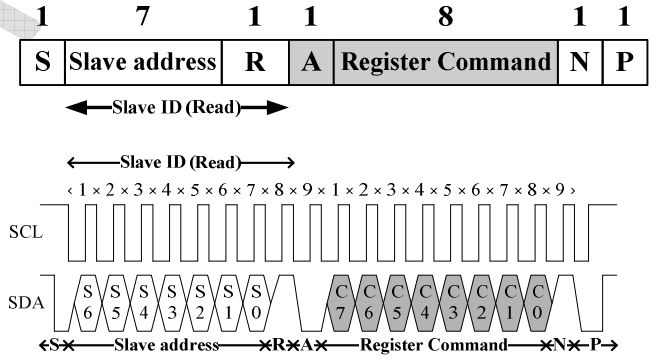
· I²C Write Protocol (type 1):



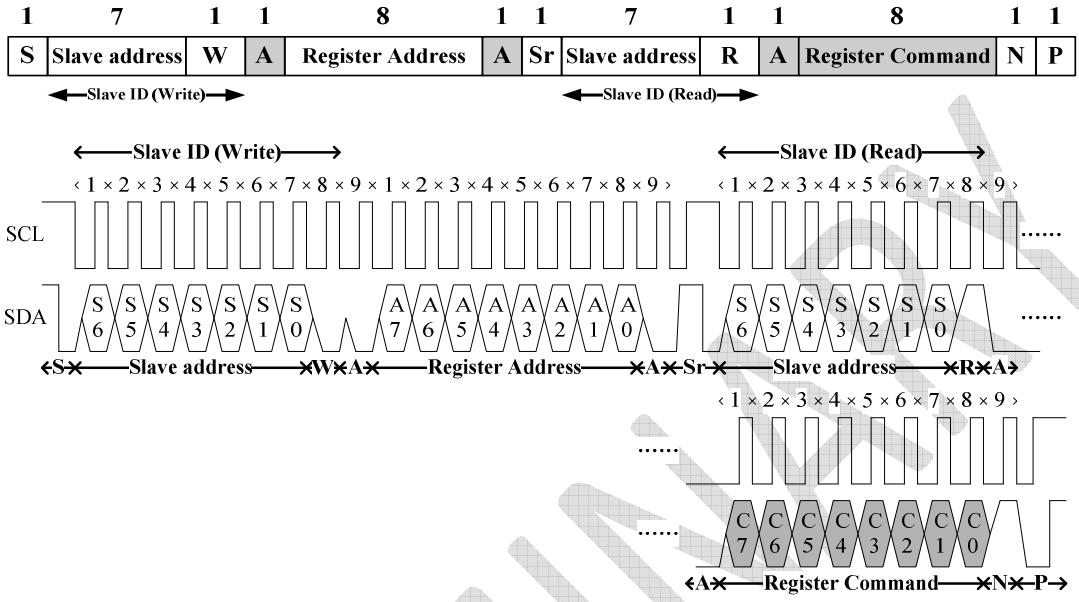
· I²C Write Protocol (type 2):



· I²C Read Protocol:



· I²C Read (Combined format) Protocol:



A	Acknowledge (0 for an ACK)	**N**	Non-Acknowledge(1 for an NACK)
S	Start condition	**Sr**	Repeated Start condition
P	Stop condition		
W	Write (0 for writing)	**R**	Read (1 for read)
▩	Slave-to-master	□	Master-to-Slave

I2C Slave Address

The 7 bits slave address for this sensor is 0x23H. A read/write bit should be appended to the slave address by the master device to properly communicate with the sensor.

I²C Slave Address									
Command Type	(0x23H)							(0x23H)	(0x23H)
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
Write	0	1	0	0	0	1	1	0	0x46H
Read	0	1	0	0	0	1	1	1	0x47H

6. Register Set

Address	R / W	Register Name	Description	Reset Value
0x7F	RW	ALS_CONFIG	ALS Config	0x07
0x80	RW	ALS_CONTR	ALS operation mode control	0x20
0x85	RW	ALS_INT_TIME	ALS integration time and measurement rate in active mode	0x06
0x86	R	PART_ID	Part Number ID and revision IDs	0x1C
0x88	R	ALS_STATUS	ALS Status	0x00
0x89	R	IR_DATA_LSB	ALS measurement IR data, LSB	0x00
0x8A	R	IR_DATA_MSB	ALS measurement IR data, MSB	0x00
0x8B	R	ALS_DATA_LSB	ALS data (Lower Byte)	0x00
0x8C	R	ALS_DATA_MSB	ALS data (Upper Byte)	0x00
0xAD	RW	MAIN_CONTR	Main Control Setting	0x00
0xB9	R	DARK_CONFIG	Dark Offset Map Value	0x00

ALS_CONFIG Register (0x7F) (Read/Write)

0x7F	ALS_CONFIG (default = 0x07)							
	Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
	Reserved							

Field	Bits	Default	Description
Reserved	7:0	00000111	**Must Write 00000000**

ALS_CONTR Register (0x80) (Read/Write)

The ALS_CONTR register controls the ALS operation modes for the sensor. The ALS sensor can be set to either standby mode or active mode. At either of these modes, the I2C circuitry is always active. The default mode after power up is standby mode. During standby mode, there is no ALS measurement performed but I2C communication is allowed to enable read/write to all the registers. **Register 0xAD must be set to 0x10 and register 0x7F must be set to 0x00 before enabling ALS.**

0x80	ALS_CONTR (default = 0x20)							
	Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
	ALS resolution		***Reserved***	***ALS_Gain***			***Reserved***	***ALS Mode***

Field	Bits	Default	Description	
ALS_DR	7:6	00	00	16Bits Integration **(default)**
			01	15Bits Integration
			10	14Bits Integration
			11	13Bits Integration
Reserved	5	1	1	**Must write 1**
ALS_GAIN	4:2	000	000	Gain 1X **(default) ***
			001	Gain 4X
			010	Gain 16X

			011	Gain 64X
			100	Gain 128X
Reserved	1	0	Must write 1	
ALS MODE*1	0	0	0	Stand-by mode **(default)**
			1	Active mode

- *1 *Prior to enabling ALS, 0xAD must be set to 0x18 and 0x7F must be set to 0x00. There are also certain programming steps to follow through in order to do dark offset via firmware. Please refer to **Enable ALS** pseudocode for complete instructions.*

ALS_INT_TIME Register (0x85) (Read/Write)

The ALS_MEAS_RATE register controls the integration time and timing of the periodic measurement of the ALS in active mode.

0x85	ALS_INT_TIME (default = 0x06)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Reserved				*ALS Integration Time*		*ALS Measurement Rate*	

Field	Bits	Default	Description	
Reserved	7:4	0000	**Must write as 1010**	
ALS Integration Time	3:2	01	00	50msec
			01	100msec (default)
			10	200msec
			11	400msec
ALS measurement rate	1:0	10	00	100msec
			01	200msec
			10	400msec (default)
			11	800msec

PART_ID Register (0x86) (Read Only)

The PART_ID register defines the part number and revision identification of the sensor.

0x86	PART_ID (default = 0x0C)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Part Number ID				*Revision ID*			

ALS_STATUS Register (0x88) (Read Only)

The ALS_ STATUS register stores information about ALS data status. New data means data has not been read before. Every time measurement is done and data is written to the data register, data status bit should be set to logic 1. Every time the data register is read, data status bit should be set to logic 0.

0x88	ALS_STATUS (default = 0x00)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Reserved	*Valid*	*ALS_Gain*			*ALS_SAR*	*Reserved*	*ALS Data Status*

Field	Bits	Default	Description	
Reserved	7	0	0	**Must write 0**
ALS Data Valid	6	0	0	ALS Data is Valid **(default)**
			1	ALS Data is Invalid
ALS Data Gain Range	5:3	000	000	Gain 1X **(default)**
			001	Gain 4X
			010	Gain 16X
			011	Gain 64X
			100	Gain 128X
ALS SAR (DR) Extension	2	0	0	No Extension (SAR code = 0)
			1	With Extension (SAR code != 0)
Reserved	1	0	Reserved	
ALS data status	0	0	0	OLD data (data already read), (default)

			1	NEW data (first time data is read)

IR_DATA Register (0x89,0x8A) (Read Only)

ALS measurement results are stored in ALS_DATA registers. **It is necessary to do a block read on both registers 0x89 and 0x8A to ensure the data integrity.**

Field	Bits	Default	Description
IR_ LSB	0x89	0	IR low byte data, bit 0 is LSB of the 16-bit data
IR_ MSB	0x8A	0	IR high byte data, bit 7 is MSB of the 16-bit data

ALS_DATA Register (0x8B,0x8C) (Read Only)

ALS measurement results are stored in ALS_DATA registers. **It is necessary to do a block read on both registers 0x8B and 0x8C to ensure the data integrity.**

Field	Bits	Default	Description
ALS_ LSB	0x8B	0	ALS low byte data, bit 0 is LSB of the 16-bit data
ALS_ MSB	0x8C	0	ALS high byte data, bit 7 is MSB of the 16-bit data

MAIN_CONFIG Register (0xAD) (Read/Write)

The MAIN_CONFIG register must be written with 0x10 before enabling ALS/PS

0xAD	MAIN_CONFIG Register (default = 0x00)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Reserved							

Field	Bits	Default	Description
Reserved	7:0	0000 0000	**Must write as 0001 0000**

DARK_OFFSET Register (0xB9) (Read)

The DARK_OFFSET register is a read-only register that stores the ALS Dark Count offset value. Firmware will need to offset the ALS count according to code in Bit <7:5>. Please refer to pseudocode under section Dark Offset.

0xB9	Dark Offset Register (default = 0x00)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	ALS Dark Offset			*Reserved*				

7. Application Information

7.1 ALS Lux Conversion formula

7.1.1 Lux formula for all Gains

Lux_Calc is the calculated lux reading based on the output ADC from ALS DATA regardless of light sources.

$$Lux_{Calc} = \frac{0.144 \times ALS_{DATA}}{(GAIN \times INT)} \times Window\ Factor$$

Where :

1. For device under tinted window with coated-ink of flat transmission rate at 400-600nm wavelength, window factor is to compensate light loss due to the lower transmission rate from the coated-ink.
   a. WFAC = 1 for NO window / clear window glass.
   b. WFAC >1 device under tinted window glass. Calibrate under white LED.

2. The Gain factors & Integration time factors:

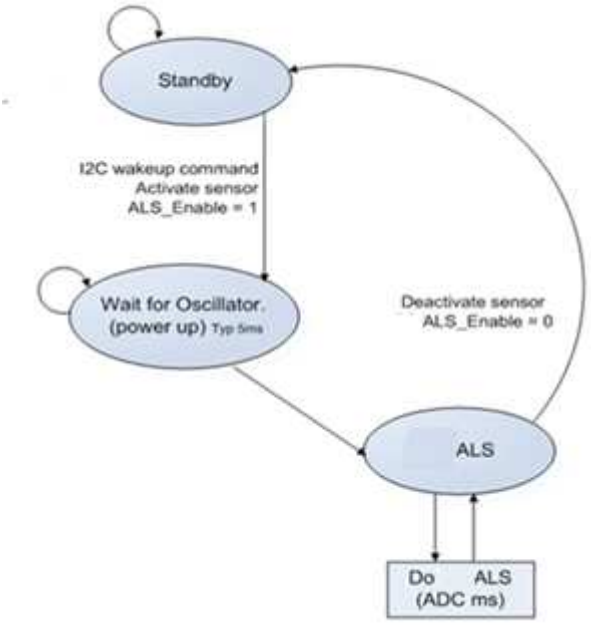
ALS Gain	GAIN
X1	**1**
X4	**4**
X16	**16**
X64	**64**
X128	**128**

Integration Time (ms)	INT
50	**0.5**
100	**1**
200	**2**
400	**4**

7.2 Device Operation (State Machine and Interrupt features)

State Machine

Below diagram is the main state machine of LTR-309ALS-01.



During the ALS Operation, ALS measurements can be activated by setting the ALS_Enable bit to 1. As soon as the ALS sensors become activated through an I2C command, the internal support blocks are powered on. Once the voltages and currents are settled (typically after 5ms), the state machine checks for trigger events from a measurement scheduler to start ALS conversions according to the selected measurement repeat rates. Once ALS_Enable is changed back to 0, a running conversion on the respective channel will be completed and the relevant ADCs and support blocks will move to power-down state.

8. Pseudo Codes Examples

ALS Integration Time

// The ALS_INT_TIME register controls the ALS integration time and ALS measurement rate.
// Default setting of the register is 0x06

Slave_Addr = 0x23 // Slave address of LTR-309ALS-01 device

// Set ALS integration time 50msec (with default ALS measurement rate 400ms)
Register_Addr = 0x85 // ALS_INT_TIME register
Command = 0xA2 // Integration time = 50msec
// For Integration time = 100msec, Command = 0xA6
// For Integration time = 200msec, Command = 0xAA
// For Integration time = 400msec, Command = 0xAE

// Set ALS measurement rate 100msec (with default ALS measurement time 100ms)
Register_Addr = 0x85 // ALS_INT_TIME register
Command = 0xA4 // measurement rate = 100msec
// measurement rate = 200msec, Command = 0xA5
// measurement rate = 400msec, Command = 0xA6
// measurement rate = 800msec, Command = 0xA7

WriteByte(Slave_Addr, Register_Addr, Command)

Control Registers

// The Control Registers define the operating modes and gain settings of the ALS of LTR-309ALS-01.
// Main Control Register (0xAD) must be set to 0x10 before turning on ALS function.
// It is recommended that Control Register for ALS (0x80) and PS (0x81) to be set at the end of the sequence.
// This is to ensure all register settings are the same for all started measurement.
// Default settings are 0x20 for ALS register in Standby mode after power up.

Slave_Addr = 0x23 // Slave address of LTR-309ALS-01 device

// Enable ALS
Register_Addr = 0x7F // ALS_CONFIG register
Command = 0x00 // Enable

Register_Addr = 0xAD // MAIN_CONTR register
Command = 0x10 // Enable

Register_Addr = 0x80 // ALS_CONTR register
Command = 0x21 // For Dynamic Range x1
// For Dynamic Range x4 , Command = 0x25
// For Dynamic Range x16 , Command = 0x29
// For Dynamic Range x64 , Command = 0x2D

WriteByte(Slave_Addr, Register_Addr, Command)

// Dark Offset

//Dark count control is available via firmware to control fine offset of dark count.
//To offset the dark count, upon power up, select and enable dark control register 0xB4.
//Then, device dark count reference will available in Register_Addr 0xB9<7:5>.
//Based on the value in 0xB9<7:5>, dark offset value needs to be deducted from ALS Count via firmware using the value in table below.

0xB9<7:5>	Dark Offset value
000	0

001	20
010	40
011	60
100	80
101	100
110	120
111	140

//Setting procedures below realizing the explanation

```
Register_Addr = 0xB4                    // Dark Control register
Command = 0x1C                          // For selecting Dark Offset register
Command = 0x1D                          // To confirm Dark Offset register selection

Register_Addr = 0xB9                    // ALS Dark Offset address
ReadByte(Slave_Addr, Register_Addr, Data0)
Data0 = ( Data0 >> 5 ) & 7              //Obtain dark offset references in 0xB9<7:5>

Register_Addr = 0x81
Command = 0x01                          // For IC Reset
```

Data Registers (Read Only)

// The ALS Data Registers contain the ADC output data.
// These registers should be read as a group, with the lower address being read first.

```
Slave_Addr = 0x23                       // Slave address of LTR-309ALS-01 device
```

// Read ALS_DATA

```
Register_Addr = 0x8B                    // ALS ADC low byte address
ReadByte(Slave_Addr, Register_Addr, Data0)
Register_Addr = 0x8C                    // ALS ADC high byte address
ReadByte(Slave_Addr, Register_Addr, Data1)

ALS_ADC_Data = (Data1 << 8) | Data0     // Combining lower and upper bytes to give 16-bit ALS ADC data
                                        (Direct conversion to illuminance in lux).

Slave_Addr = 0x23                       // Slave address of LTR-309ALS-01 device
```

ALS Status Register (Read Only)

// The ALS _STATUS Register contains the information on Interrupt, ALS data gain, validity and status.

```
Slave_Addr = 0x23                       // Slave address of LTR-309ALS-01 device

Register_Addr = 0x88                    // ALS_STATUS register address
ReadByte(Slave_Addr, Register_Addr, Data)

ALS valid = Data & 0x80                 // ALS data valid = 0x80 ➔ ALS data is invalid
                                        // ALS data valid = 0x00 ➔ ALS data is valid
```

ALS Gain Range= Data & 0x78

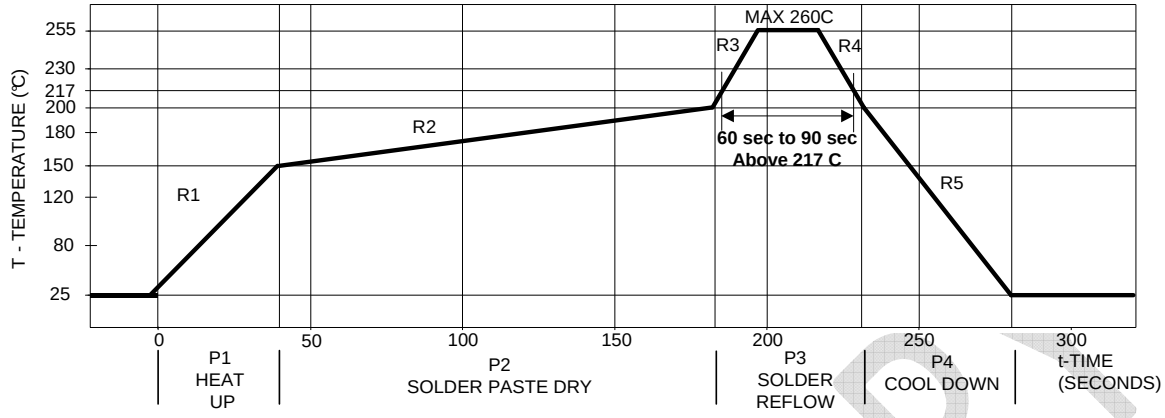
// Gain Range = 0x00 ➔ Gain x1
// Gain Range = 0x08 ➔ Gain x4
// Gain Range = 0x10 ➔ Gain x16
// Gain Range = 0x18 ➔ Gain x64
// Gain Range = 0x20 ➔ Gain x128

ALS Data_Status = Data & 0x01

// NewData_Status = 0x00 ➔ OLD data
// NewData_Status = 0x01 ➔ NEW data

9. Recommended Leadfree Reflow Profile

OPTICAL SENSOR
LTR-309ALS-01



Process Zone	Symbol	ΔT	Maximum ΔT/Δtime or Duration
Heat Up	P1, R1	25°C to 150°C	3°C/s
Solder Paste Dry	P2, R2	150°C to 200°C	100s to 180s
Solder Reflow	P3, R3 P3, R4	200°C to 260°C 260°C to 200°C	3°C/s -6°C/s
Cool Down	P4, R5	200°C to 25°C	-6°C/s
Time maintained above liquidus point , 217°C		> 217°C	60s to 90s
Peak Temperature		260°C	-
Time within 5°C of actual Peak Temperature		> 255°C	20s
Time 25°C to Peak Temperature		25°C to 260°C	8mins

NOTE: It is recommended to perform reflow soldering no more than twice.

10. Moisture Proof Packaging

All LTR-309ALS-01 are shipped in moisture proof package. Once opened, moisture absorption begins. This part is compliant to JEDEC J-STD-033A Level 3.

Time from Unsealing to Soldering

After removal from the moisture barrier bag, the parts should be stored at the recommended storage conditions and soldered within seven days. When the moisture barrier bag is opened and the parts are exposed to the recommended storage conditions for more than seven days, the parts must be baked before reflow to prevent damage to the parts.

Recommended Storage Conditions

Storage Temperature	10°C to 30°C
Relative Humidity	Below 60% RH

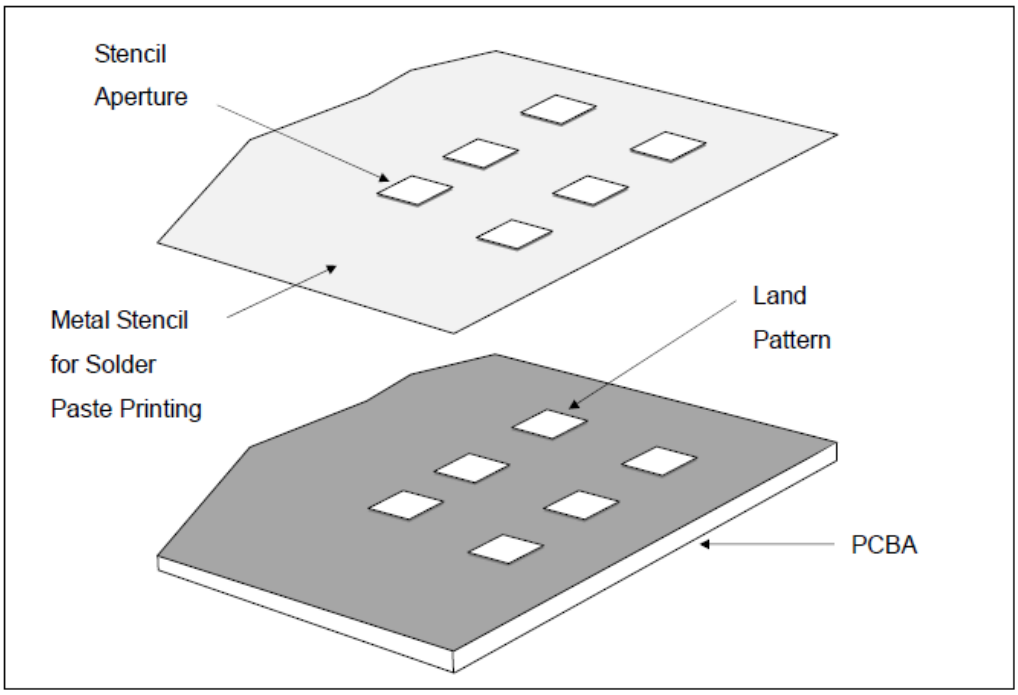
Baking Conditions

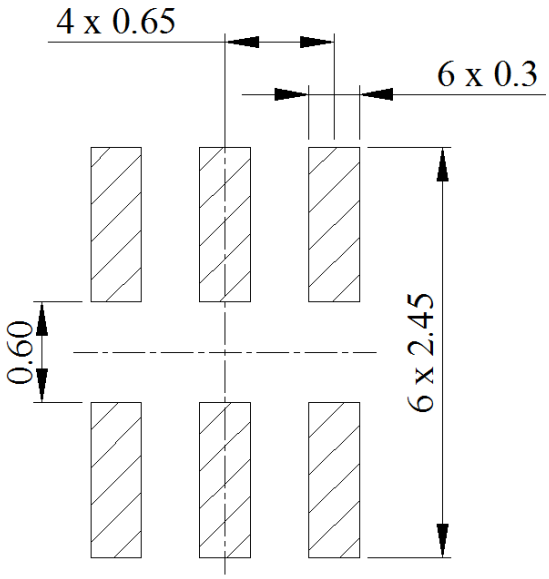
Package	**Temperature**	**Time**
In Reels	60°C	48 hours
In Bulk	100°C	4 hours

Baking should only be done once.

11. Recommended Land Pattern and Metal Stencil Aperture

Recommended Land Pattern



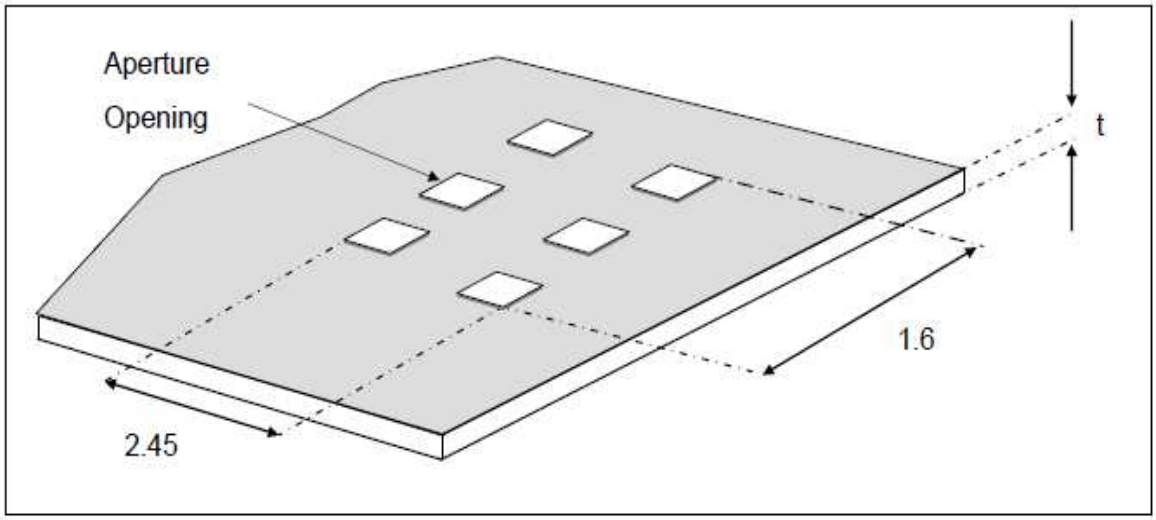


Note: All dimensions are in millimeters

12. Metal Stencil Aperture

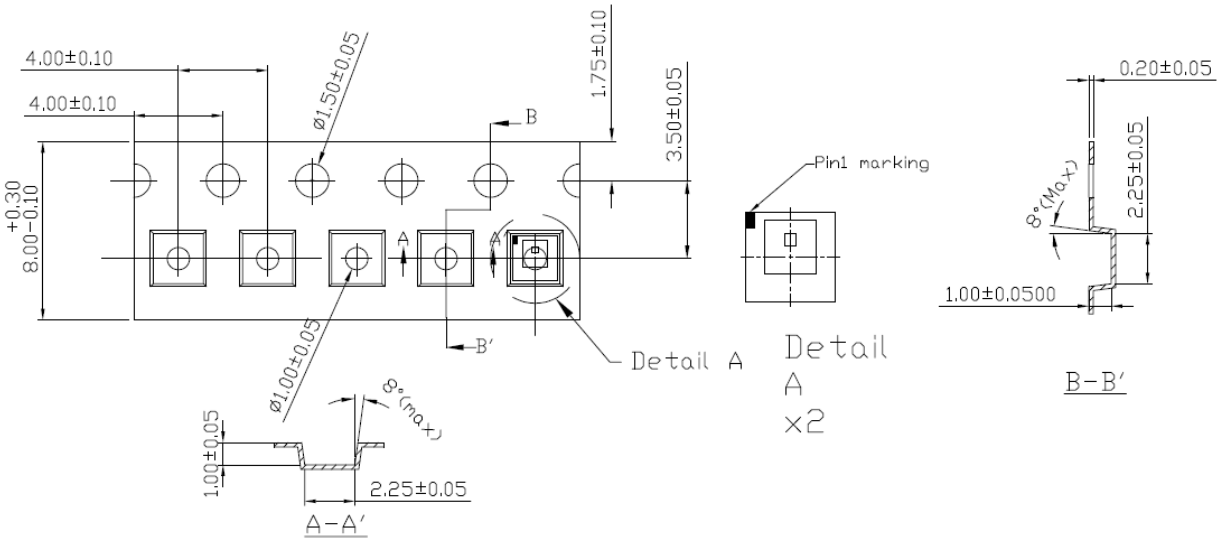
It is recommended that the metal stencil used for solder paste printing has a thickness (t) of 0.11mm (0.004 inches / 4 mils) or 0.127mm (0.005 inches / 5 mils).

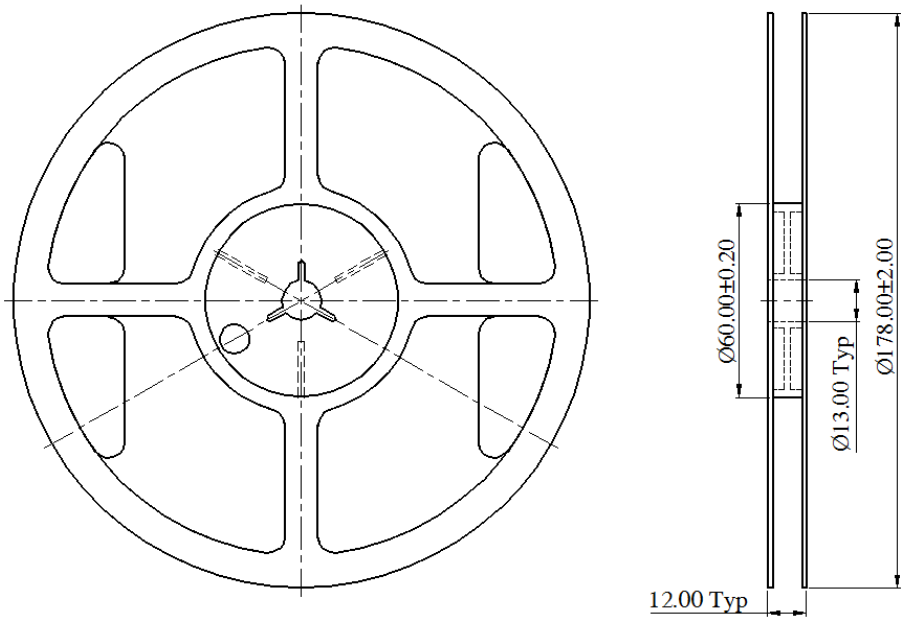
The stencil aperture opening is recommended to be 0.3mm x 0.65mm which has the same dimension as the land pattern. This is to ensure adequate printed solder paste volume and yet no shorting.



Note:
1. All dimensions are in millimeters

13. Package Dimension for Tape and Reel





Note:
1. All dimensions are in millimeters
2. Empty component pockets sealed with top cover tape
3. 7-inch reel--2500 pieces per reel
4. In accordance with ANSI/EIA481-1-A-1994 specification

OPTICAL SENSOR
LTR-309ALS-01

Revision Table:

Version	Update	Page	Date
1.0	Final datasheet as created	Total 25	4/5/20
1.1	Spec Update	Total 25	4/12/20
1.2	Update Gain Setting Register	Total 25	4/1/21
1.3	Remove MFG ID	Page 9 & 12	5/4/21
1.4	Revise I/O Pins Configuration Table	Page 3	24/3/22
1.5	Revise tape information	Page 28	24/3/22