

Optical Sensor
Product Data Sheet
LTR-X140A

Spec No. :DS86-2020-0009
Effective Date: 09/08/2020
Revision: -

LITE-ON DCC

RELEASE

BNS-OD-FC001/A4

OPTICAL SENSOR LTR-X140A

Description

The LTR-X140A is an integrated low voltage I2C ambient light sensor (ALS) in a single miniature chipled lead-free surface mount package of 2.84mm x 1.44mm x 0.7mm.

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

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

Application

- Control brightness of display panel

Features

- I²C interface (Standard mode @100kHz or Fast mode @400kHz)
- Ambient Light Sensing 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: -30 to +85 °C
- RoHS and Halogen free compliant

ALS Features

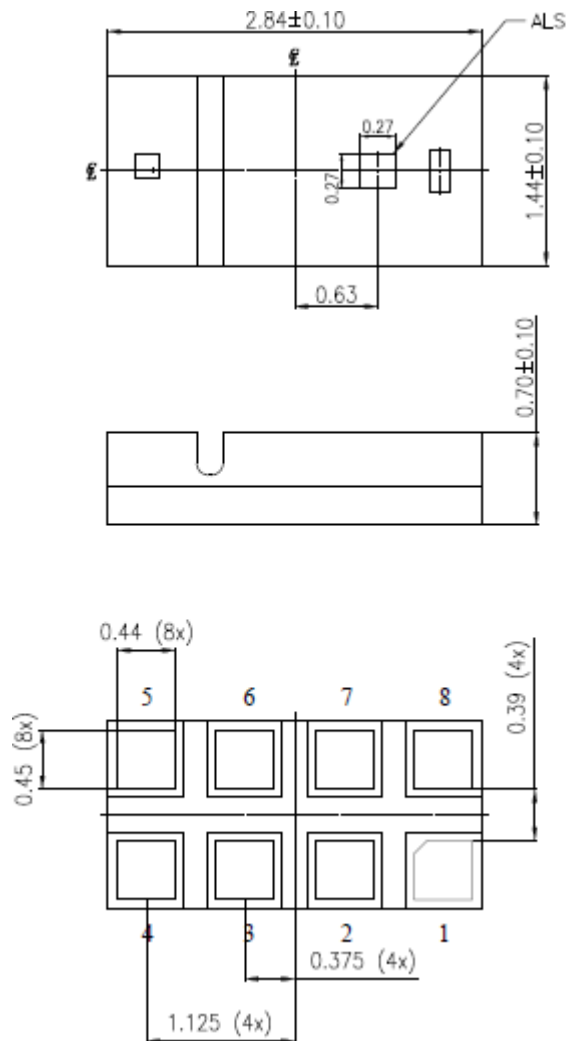
- 16 bits effective resolution
- Wide dynamic range with linear response
- Close to human eye spectral response
- Automatic rejection for 50Hz/60Hz lighting flicker

Ordering Information

Part Number	Packaging Type	Package	Quantity
LTR-X140A	Tape and Reel	8-pin chipled package	4000pcs

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1. Outline Dimensions and Pins Configuration



Pin-Out Assignment:

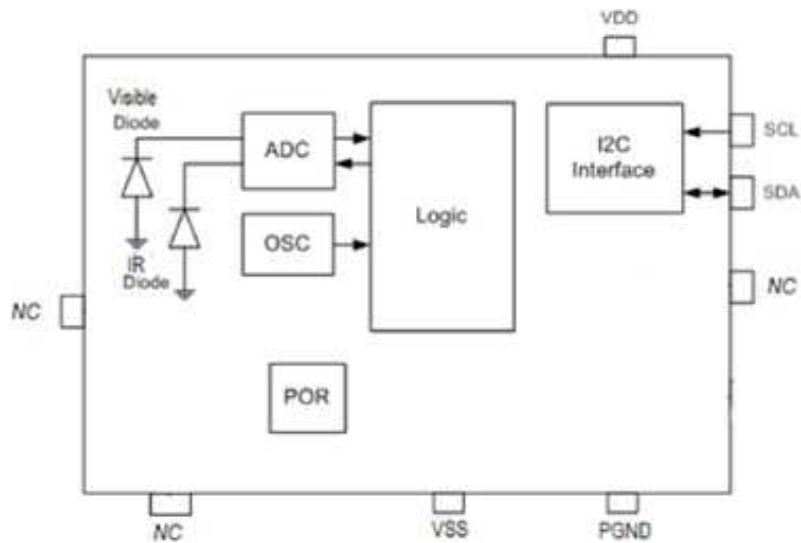
1. SCL	5. NC
2. VSS	6. VDD
3. PGND	7. NC
4. NC	8. SDA

Note: All dimensions in millimeter

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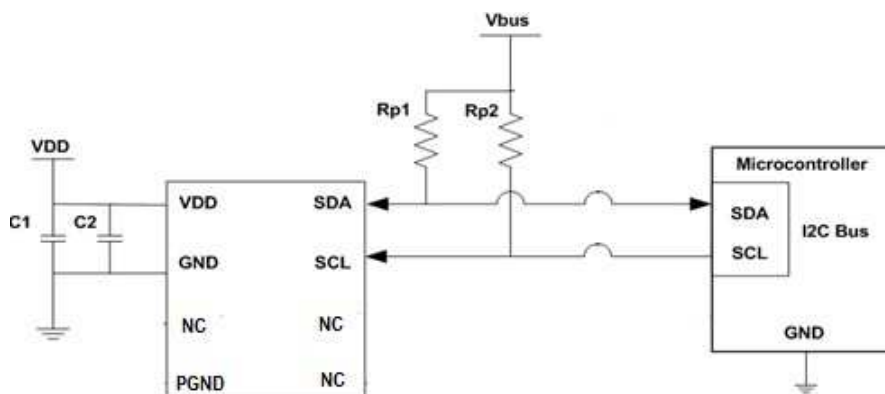
2. Functional Block Diagram

The LTR-X140A contains photodiodes for respective photocurrent measurement. The photodiode currents are converted to digital values by ADCs.



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3. Application Circuit



I/O Pins Configuration Table

Pin	I/O Type	Symbol	Description
1	IN	SCL	I ² C serial clock
2	<u>GND</u>	<u>GND</u>	GND. All voltages are referenced to PGND/GND and both pins must be connected to ground
3	GND	PGND	
4	NC	NC	No Connect
5	NC	NC	No Connect
6	Supply	VDD	Supply Voltage
7	NC	NC	No Connect
8	IN/OUT	SDA	I ² C serial data

Recommended Application Circuit Components

Component	Recommended Value
Rp1, Rp2	1 k Ω to 10 k Ω
C1	1 μ F $\pm$ 20%, X7R / X5R Ceramic
C2	0.1 μ F

[1] Selection of pull-up resistors value is dependent on bus capacitance values. For more details, please refer to I²C Specifications:
http://www.nxp.com/documents/user_manual/UM10204.pdf

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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	85	°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. Currents are positive into, negative out of the specified terminal.

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}	-30		85	°C

Electrical & Optical Specifications

All specifications are at VDD = 3.0 V, T_{ope} = 25°C, unless otherwise noted.

Parameter	Min.	Typ.	Max.	Unit	Condition
Supply Current		315	400	uA	100 ms MRR, 100 ms integration time
Standby Current			5	uA	Shutdown Mode
Wakeup Time from Standby		5	10	ms	From Standby to Active mode where measurement can start

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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		%	Across different light sources
Dark Level Count			2	Count	0 Lux, 16-bit resolution, Gain64
Integration time	50		400	ms	With 50/60Hz Rejection
50/60 Hz flicker noise error	-5		+5	%	

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Typical Device Parameter

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

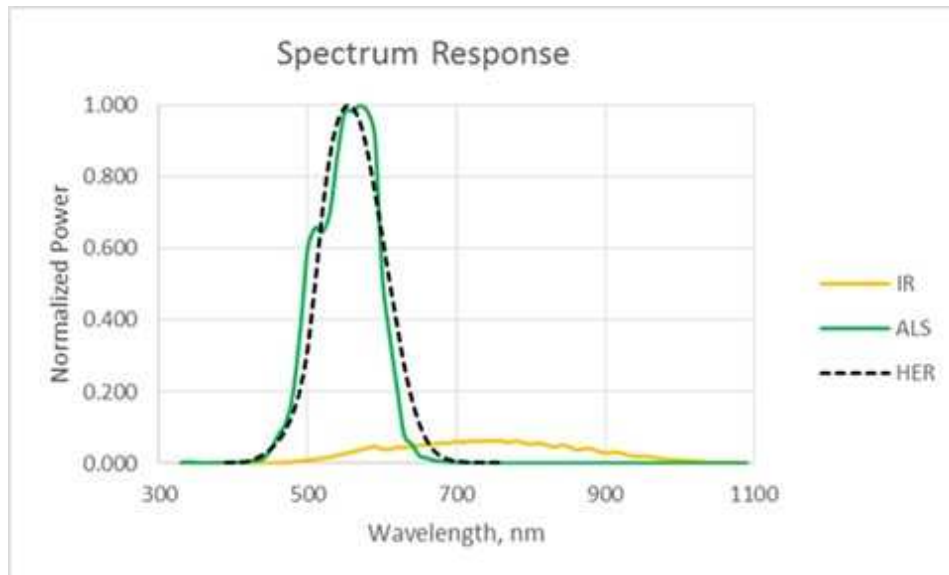


Figure 4.1 : ALS Spectral response

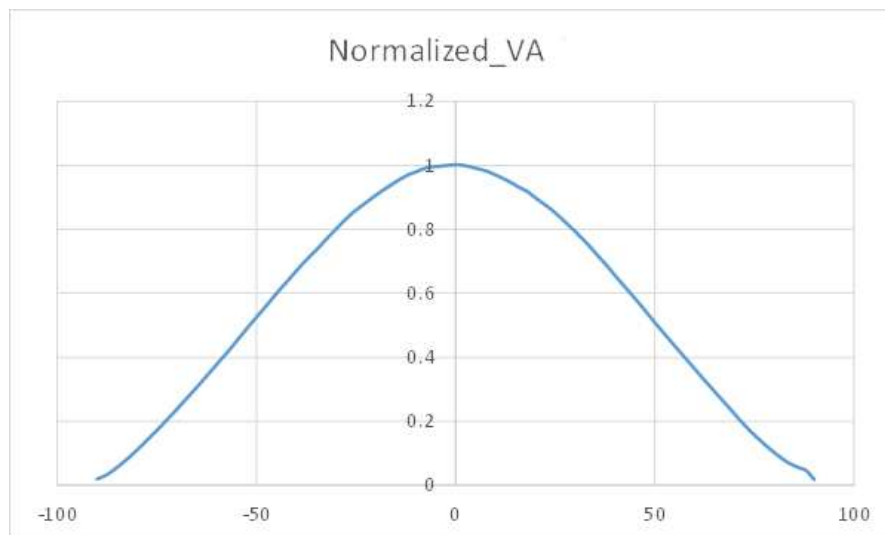


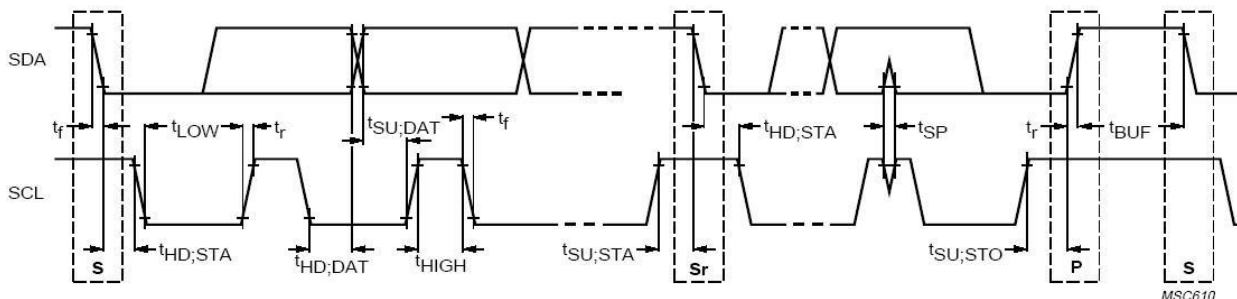
Figure 4.2: ALS viewing angle performance

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AC Electrical Characteristics

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

Parameter	Symbol	Standard mode		Fast mode		Unit
		Min.	Max.	Min.	Max.	
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



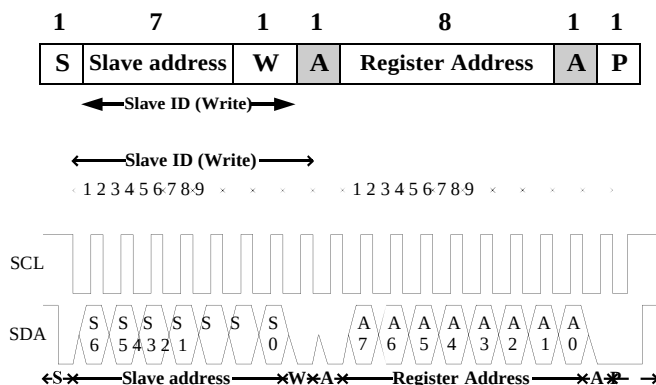
Definition of timing for I²C bus

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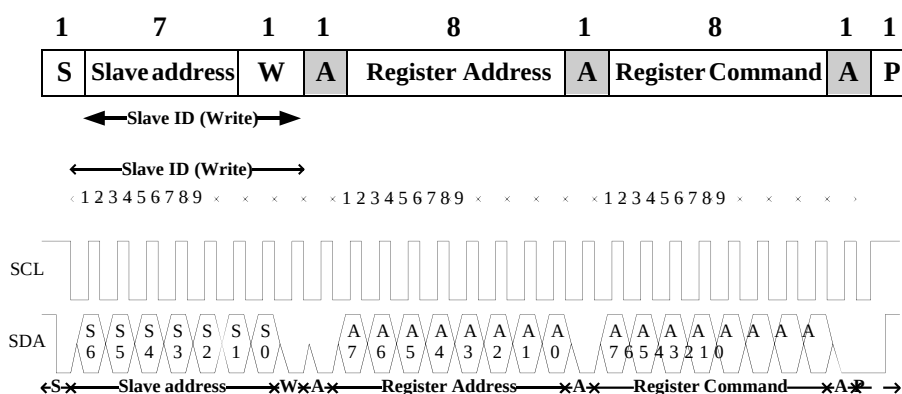
5. Principles of Operation

I²C Protocols

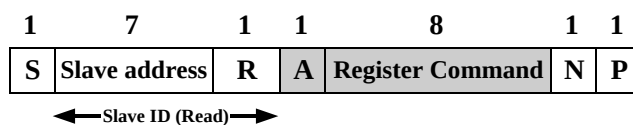
- I²C Write Protocol (type 1):



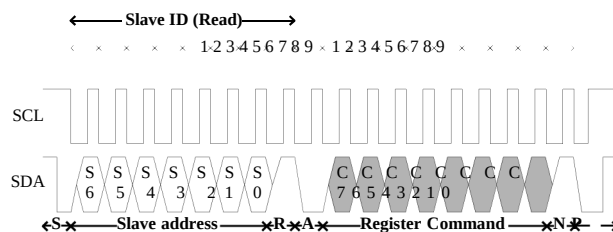
- I²C Write Protocol (type 2):



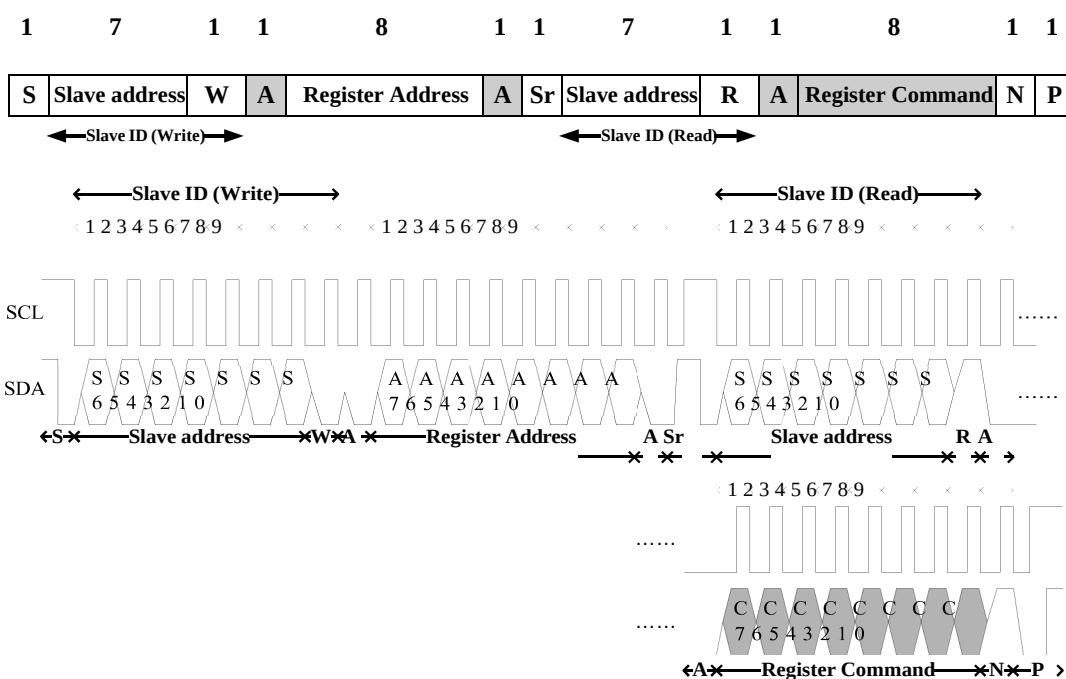
- I²C Read Protocol:



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- **I²C Read (Combined format) Protocol:**



A Acknowledge (0 for an ACK)

S Start condition

P Stop condition

W Write (0 for writing)

☐ Slave-to-master

N	Non-Acknowledge(1 for an NACK)
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Sr	Repeated Start condition
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R	Read (1 for read)
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☐ Master-to-Slave

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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.

I ² C 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
0x87	R	MANUFAC_ID	Manufacturer ID	0x05
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 measurement data, LSB	0x00
0x8C	R	ALS_DATA_MSB	ALS measurement data, MSB	0x00
0x95	R	ALS_SAR	ALS SAR value	0x00
0xAD	RW	MAIN_CONTR	Main Control Setting	0x00
0xB9	R	DARK_CONFIG	Dark Offset Map Value	0x00

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ALS CONFIG Register (0x7F) (Read/Write)

0x7F	ALS CONFIG Register (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	0000 0111	Must write as 0000 0000

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 0x18 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		ALS_SAR_ENB	ALS Mode

Field	Bits	Default	Description	
ALS_Resolution	7:6	00	00	16Bits Integration (default)
			01	15Bits Integration
			10	14Bits Integration
			11	13Bits Integration
Reserved	5:4	10	10	Reserved
ALS_GAIN	3:2	00	00	Gain 1X (default)
			01	Gain 4X
			10	Gain 16X

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			11	Gain 64X
ALS SAR_ENB*2	1	0	0	Enable (default)
			1	Disable
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.
- *2 When ALS_SAR_ENB=0 and under Gain=1, the ALS DATA may not be complete. Firmware needs to read the SAR value and reconstruct the actual ALS DATA.

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

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PART_ID Register (0x86) (Read Only)

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

0x86	PART_ID (default = 0x1C)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Part Number ID				Revision ID			

MANUFAC_ID Register (0x87) (Read Only)

The MANUFAC_ID register defines the manufacturer identification of the sensor.

0x87	MANUFAC_ID (default = 0x05)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Manufacturer ID							

ALS_STATUS Register (0x88) (Read Only)

The ALS_STATUS register stores information about ALS Gain, ALS SAR as well as 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 as 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)

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			001	Gain 4X
			010	Gain 16X
			011	Gain 64X
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)

The IR Channel measurement results are stored in the IR_DATA registers. **It is necessary to do a block read on both registers 0x89 and 0x93 to ensure the data integrity.**

Field	Bits	Default	Description
IR_ LSB	0x89	0000 0000	IR low byte data, bit 0 is LSB of the 16-bit data
IR_ MSB	0x8A	0000 0000	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	0000 0000	ALS low byte data, bit 0 is LSB of the 16-bit data
ALS_ MSB	0x8C	0000 0000	AS high byte data, bit 7 is MSB of the 16-bit data

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ALS Coarse Ambient Register (0x95) (Read Only)

ALS Coarse Ambient measured value is stored in this register.

Field	Bits	Default	Description
ALS_Coarse_Ambient	0x95<3:0>	00000000	4 bits ALS Coarse Ambient measured value

MAIN_CONFIG Register (0xAD) (Read/Write)

The MAIN_CONFIG register must be written with 0x18 before enabling ALS.

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 1000

DARK_CONFIG Register (0xB9) (Read)

The DARK_CONFIG 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 CONFIG Register (default = 0x00)							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	ALS Dark Offset			Reserved				

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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.

$$Lux_{Calc} = \frac{0.182 \times ALS_{DATA}}{(GAIN \times INT)} \times Window Factor$$

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

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

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7.1.2 Lux formula Gainx1 SAR extension

LTR-X140A has dynamic extension feature available only for Gainx1 by using conversion formula using SAR value read from register <0x95>.

$$Data = ALS_{Data} + \frac{2^{15} * (SAR_CODE - 1)}{IntFac}$$

SAR_CODE = 0x95<3:0>

7.2 Operating Mode

Stand-by Mode

The device is by default in stand-by mode after power-up. No measurement activity done in ALS. I2C communication is allowed to be able to read/write to the registers. The device can be reset from MCU by setting appropriate register control (SW reset). Start-up sequence is exactly the same as that when power-on reset is triggered.

Active Mode

Measurement data is expected to be available within a known fixed time (refer to measurement time parameter of ALS).

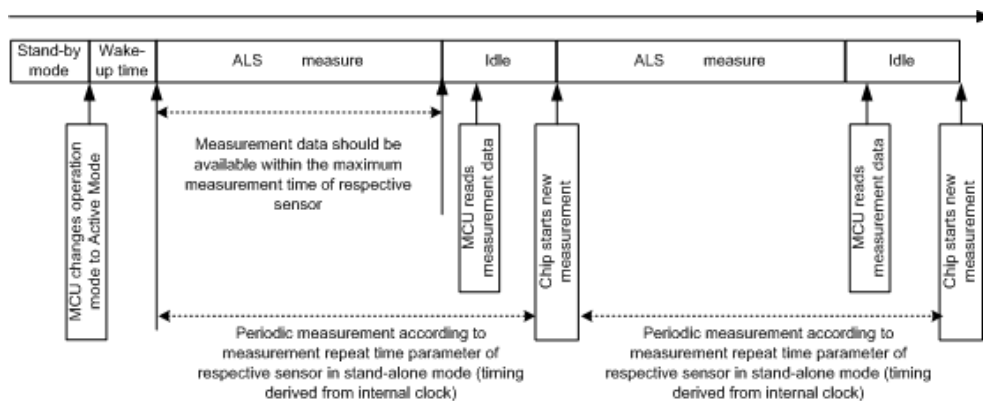


Figure 7.2.1 : ALS measurement sequence

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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-X140A 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 integration 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-X140A.
// Main Control Register (0xAD) must be set to 0x18 before turning on ALS function.
// It is recommended that Control Register for ALS (0x80) to be set at the end of the sequence.
// This is to ensure all register settings are the same for all started measurement.
// Default value is 0x20 for ALS register and (in Standby mode after power up).

Slave_Addr = 0x23 // Slave address of LTR-X140A device

// Enable ALS

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

Register_Addr = 0xAD // MAIN_CONTR register
Command = 0x18 // 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)

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//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

Command = 0x1C

Command = 0x1D

// Dark Control register

// For selecting Dark Offset register

// To confirm Dark Offset register selection

Register_Addr = 0xB9

ReadByte(Slave_Addr, Register_Addr, Data0)

Data0 = (Data0 >> 5) & 7

// ALS Dark Offset address

//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-X140A

device

// Read ALS_DATA

Register_Addr = 0x8B

ReadByte(Slave_Addr, Register_Addr, Data0)

Register_Addr = 0x8C

ReadByte(Slave_Addr, Register_Addr, Data1)

// ALS ADC low byte address

// ALS ADC high byte address

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-X140A device

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ALS Status Register (Read Only)

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

Slave_Addr = 0x23 // Slave address of LTR-X140A

device

Register_Addr = 0x88 // ALS_STATUS register address

ReadByte(Slave_Addr, Register_Addr, Data)

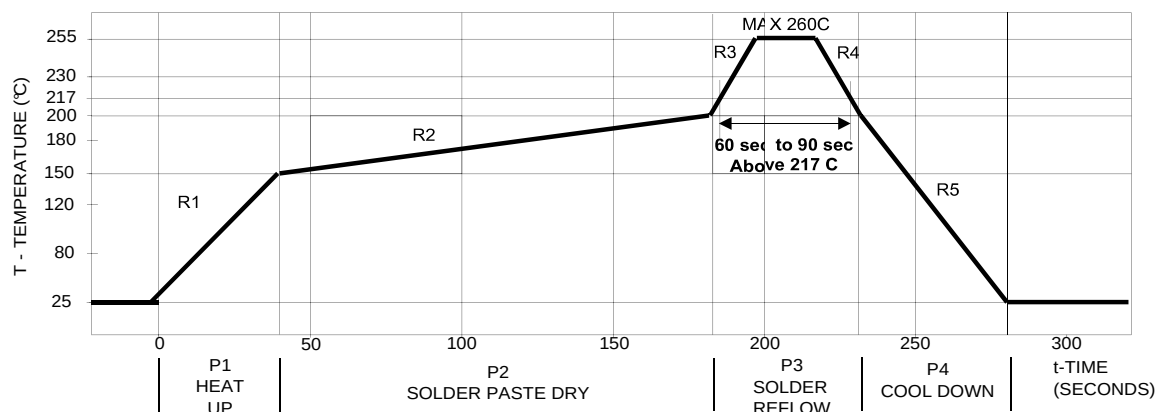
ALS valid = Data & 0x40 // ALS data valid = 0x80 → ALS data is invalid
// ALS data valid = 0x00 → ALS data is valid

ALS Gain Range= Data & 0x38 // Gain Range = 0x00 → Gain x1
// Gain Range = 0x08 → Gain x4
// Gain Range = 0x10 → Gain x16
// Gain Range = 0x18 → Gain x64

ALS Data_Status = Data & 0x01 // NewData_Status = 0x00 → OLD data
// NewData_Status = 0x01 → NEW data

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9. Recommended Leadfree Reflow Profile



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

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10. Moisture Proof Packaging

All LTR-X140A are shipped in moisture proof package. Once opened, moisture absorption begins. This part is compliant to JEDEC J-STD-033A Level 3.

10.1 Shelf Life

Device has the shelf life of 12 months if stored in an unopened moisture proof package. It is recommended to store in following condition.

- Shelf Life : 12 months
- Ambient Temperature : <40°C
- Relative Humidity: <90%

10.2 Floor Life

After removal from the moisture barrier bag, the parts should be stored at the recommended storage conditions and soldered within seven days.

- Floor Life : 168 hours
- Ambient Temperature : <30°C
- Relative Humidity: <60%

10.3 Rebaking information

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.

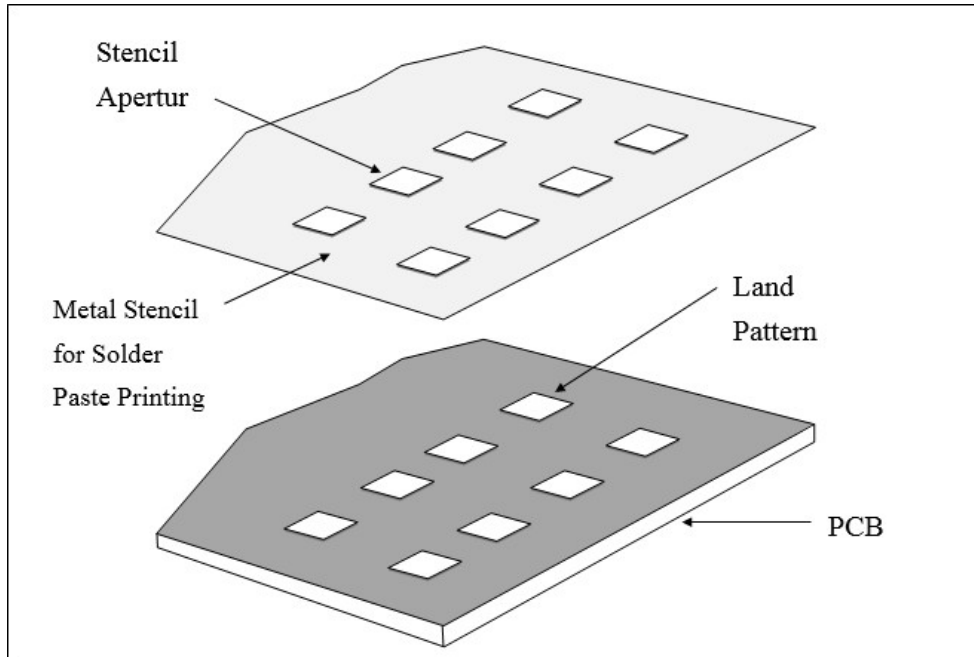
Baking Conditions

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

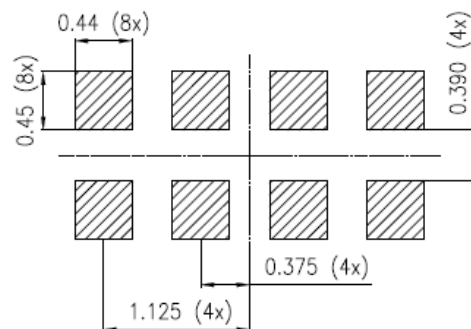
Baking should only be done once.

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11. Recommended Land Pattern and Metal Stencil Aperture



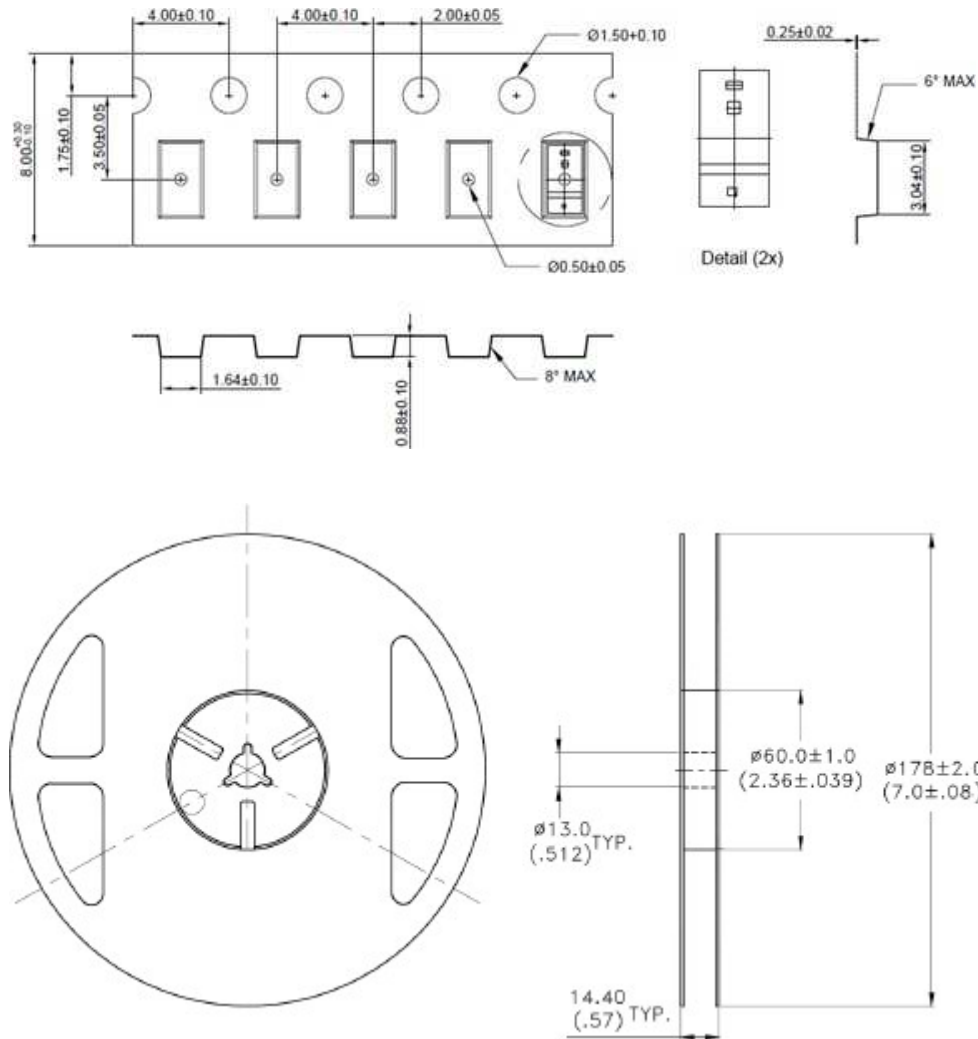
Recommended Land Pattern



Note: All dimensions are in millimeters

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12.Package Dimension for Tape and Reel



Notes:

1. All dimensions are in millimeters
2. Empty component pockets sealed with top cover tape
3. 7inch reel - 4000 pieces per reel
4. In accordance with ANSI/EIA 481-1-A-1994 specifications

Revision Table:

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Version	Update	Page	Date
1.0	Datasheet created	Total 26 pages	10/04/20
1.1	Updated MPQ	Total 26 pages	10/08/20