# Brief Description

The ZOPT2201 Sensor integrates an ambient light sensor (ALS) and ultraviolet energy sensor (UVBS). The device can be connected via an I²C interface to an external microcontroller. Other I²C or SMBus devices can be connected to the same interface. The device has a programmable interrupt with hysteresis to respond to events and reduce the microcontroller tasks.

A major application of the device is in smart phones or other mobile devices to enable brightness control of display panels (ALS) and diverse health care applications or contextual awareness algorithms (UVBS).
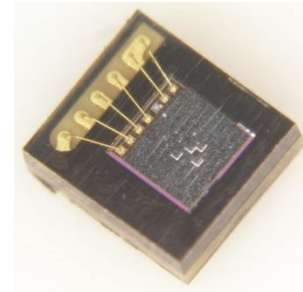
# Features

- High ambient light and UVB energy sensitivity
- Superior infrared energy suppression
- Very stable spectral response over angle of light incidence
- Wide dynamic range
- Excellent temperature compensation
- Lowest conversion repeat noise
- I²C interface capable of standard mode (100kHz) or fast mode (400kHz) communication; 1.8V logic compatible
- Programmable interrupt function for ALS and UVBS with upper and lower thresholds

# ALS Features

- Integrated ALS closely matches human eye response for high lux accuracy over different light sources
- Absolute sensitivity: 0.008 lux to 157000 lux
- Configurable output resolution: 13 to 20 bits
- Configurable analog gain: x1 to x18
- Linear output code
- 50Hz/60Hz light flicker immunity
- Fluorescent light flicker immunity

# UVBS Features

- Linear UV index measurement (1 to >11)
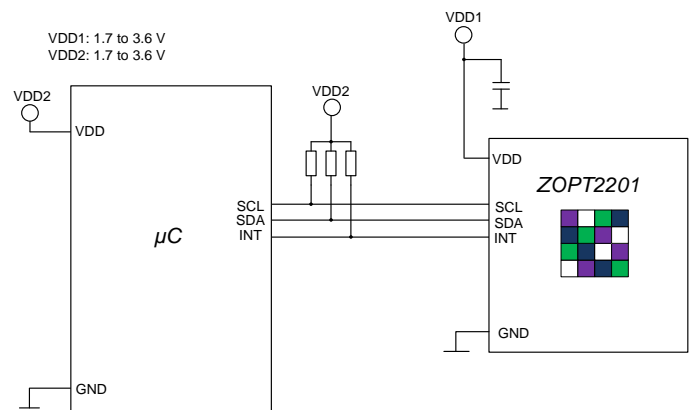- Tailored temperature compensation

# Physical Characteristics

- Wide operation temperature: - 40°C to +90°C
- Wide supply voltage: 1.7V to 3.6V
- Minimum active current at maximum duty cycle:
  — ALS: 110µA typical
  — UVBS: 100µA typical

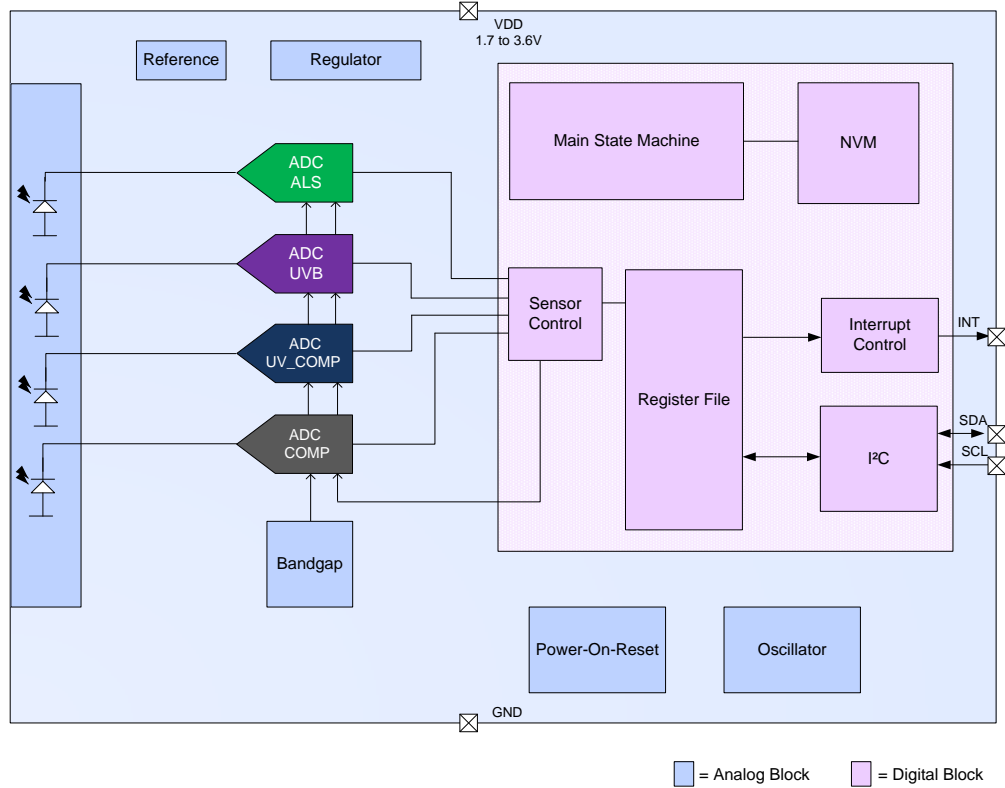  Note: Average current is proportionally lower with lower measurement rates.

- Low standby current: 1µA typical
- Packages:
  — LGA6 (2.0 × 2.2 × 0.7 mm)
  — TSV (1.1 × 1.2 × 0.26 mm)

# ZOPT2201 Application Circuit

# ZOPT2201
## Block Diagram

**Reference** | **Regulator**

VDD
1.7 to 3.6V

**Main State Machine** — **NVM**

**ADC ALS**

**ADC UVB**

**Sensor Control**

**ADC UV_COMP**

**Interrupt Control** — INT

**Register File**

**ADC COMP**

**I²C** — SDA, SCL

**Bandgap**

**Power-On-Reset** | **Oscillator**

GND

= Analog Block    = Digital Block

### Applications

- Cellular phones
- Notebooks
- Consumer devices

# Ordering Information

| Product Sales Code | Description | Delivery Package |
|---|---|---|
| ZOPT2201AC5R | ZOPT2201 LGA6 – Temperature range: -40 to +90°C | Reel |
| ZOPT2201AC9R | ZOPT2201 TSV – Temperature range: -40 to +90°C | Reel |
| ZOPT2201KIT V1.0 | ZOPT2201 Evaluation Kit, including ZOPT Control Board, mini-USB cable, and 1 ZOPT2201 sample mounted on the LGA6 Sensor Board; kit software is available for free download – see the *ZOPT Evaluation Kit Quick Start Guide* included in the kit for instructions. | |

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# 1. Characteristics

## 1.1 Absolute Maximum Ratings

The absolute maximum ratings are stress ratings only. The device might not function or be operable above the recommended operating conditions given in section 1.2. Stresses exceeding the absolute maximum ratings might also damage the device. In addition, extended exposure to stresses above the recommended operating conditions might affect device reliability. IDT does not recommend designing to the "Absolute Maximum Ratings."

| Parameter | Symbol | Conditions | Min. | Max. | Units |
|---|---|---|---|---|---|
| Maximum input supply voltage (VDD pin) | $V_{DD-GND}$ | | | 4.0 | V |
| Maximum voltage on SCL, SDA and INT pins | $V_{I2C}$ | | -0.5 | 4.0 | V |
| Maximum operating temperature range | $T_{AMB\_MAX}$ | | -40 | 90 | °C |
| Storage temperature | $T_{STOR}$ | | -45 | 95 | °C |
| Maximum input current into any pin except supply pins (latch-up) | $I_{IN}$ | | -100 | 100 | mA |
| Electrostatic discharge protection [a] | $V_{HBM}$ | Human Body Model, JESD22-A114 | 2000 | | V |

[a]    HBM: C = 100pF charged to $V_{HBM}$ with resistor R = 1.5k$\Omega$ in series; valid for all pins.

## 1.2 Operating Conditions

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| Voltage supply on VDD pin | $V_{DD}$ | | 1.7 | | 3.6 | V |
| Ambient operating temperature range | $T_{AMB}$ | | -40 | | 90 | °C |

## 1.3 Electrical and Optical Parameters

$V_{DD}$ = 2.8V, $T_{AMB}$= -40°C to +90°C, unless otherwise noted.

Note: See important table notes at the end of the table.

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Power On Reset** | | | | | | |
| DC power-on reset level | $POR_{LH}$ | Slow variation of VDD | 1.00 | 1.34 | 1.60 | V |
| | $POR_{HL}$ | | | | | |
| **Current Consumption** | | | | | | |
| ALS Mode [a] | $I_{ALS}$ | Maximum duty cycle, VDD = 2.8V, Gain Mode 3 | | 110 | | µA |
| UVBS Mode [b] | $I_{UVBS}$ | Maximum duty cycle, VDD = 2.8V | | 100 | | µA |
| ALS/UVBS_Raw Mode [a] | $I_{ALS+UVBS}$ | Maximum duty cycle, VDD = 2.8V | | 130 | | µA |
| Standby Mode | $I_{SBY}$ | ZOPT2201 in Standby Mode, no active I²C communication | | 1 | 2 | µA |
| **I²C Interface** | | | | | | |
| I²C signal input high | $V_{I2Chigh}$ | | 1.5 | | VDD | V |
| I²C signal input low | $V_{I2Clow}$ | | 0 | | 0.4 | V |
| **ALS Characteristics** | | | | | | |
| Spectral response | | | | See Figure 2.1. | | |
| Detection range at gain 1 | $G_1$ | Minimum specification applies to default setting of 18-bit resolution. Specification changes with the resolution setting as shown in Table 3.5. | 0.6 | | 157286 | lux |
| Detection range at gain 3 | $G_3$ | | 0.2 | | 52429 | lux |
| Detection range at gain 6 [c] | $G_6$ | | 0.1 | | 26214 | lux |
| Detection range at gain 9 [c] | $G_9$ | | 0.0667 | | 17476 | lux |
| Detection range at gain 18 [c] | $G_{18}$ | | 0.0333 | | 8738 | lux |
| Calibrated lux error at gain 3 | | White LED, 5000K, $T_{AMB}$ = +25°C | | | 10 | % |
| Light source matching | | Fluorescent versus incandescent light | | | 10 | % |
| ALS output resolution | $ALS_{RES}$ | Programmable to 13, 16, 17, 18, 19, or 20 bit | 13 | 18 | 20 | Bit |

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| 50/60 Hz flicker noise error | | | | | ±5 | % |
| Dark level count | $ALS_{DARK}$ | 0 lux, 18-bit range, $T_{AMB}$ = -40 to +60°C | | 0 | | Count |
| **UVBS Characteristics** | | | | | | |
| Spectral Response | | | See Figure 2.7 and Figure 2.8. | | | |
| Sensitivity at gain 1 | $G_1$ | | | 0.36 | | $\frac{\mu W/cm^2}{count}$ |
| Sensitivity at gain 3 | $G_3$ | | | 0.12 | | $\frac{\mu W/cm^2}{count}$ |
| Sensitivity at gain 6 [c] | $G_6$ | Specifications apply to 20-bit resolution setting. Specification changes with resolution setting as shown in Table 3.6. | | 0.06 | | $\frac{\mu W/cm^2}{count}$ |
| Sensitivity at gain 9 [c] | $G_9$ | | | 0.04 | | $\frac{\mu W/cm^2}{count}$ |
| Sensitivity at gain 18 [c] | $G_{18}$ | | | 0.02 | | $\frac{\mu W/cm^2}{count}$ |
| Calibrated error at gain 18 | | Calibration done with UVB LED, 310nm, $T_{AMB}$ = +25°C | | | 10 | % |
| UVBS output resolution | $UVBS_{RES}$ | Programmable to 13, 16, 17, 18, 19, or 20 bit | 13 | 18 | 20 | Bit |
| **Conversion Timing** | | | | | | |
| Minimum integration time [d] | $t_{INTmin1}$ | | | 3.125 | | ms |
| | $t_{INTmin2}$ | With 50/60 Hz rejection | | 50 | | ms |
| Maximum integration time [d] | $t_{INTmax}$ | With 50/60 Hz rejection | | 400 | | ms |
| Wake-up time from Standby Mode | $t_{WAKE-STB}$ | From Standby to Active Mode (measurement can start) | | 500 | | μs |
| Measurement repeat rate [d] | | Programmable | 25 | | 2000 | ms |
| Timing accuracy [e] | | | -25 | | +25 | % |

[a]    For ALS, the maximum duty cycle is selected with a 100ms measurement time (default) and 100ms repeat rate at an illumination of 1000 lux.

[b]    For UVBS, the maximum duty cycle is selected with 100ms measurement time (default), 100ms repeat rate.

[c]    Values valid up to 60°C.

[d]    Typical timing accuracy applied.

[e]    All specifications related to timing can vary by this value; for example, a repeat rate of 50ms could vary up to 62.5ms.

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# 2. Typical Device Parameters

$V_{DD}$ = 2.8V, default power-up setting, unless otherwise noted.

### Figure 2.1 Spectral Response ALS
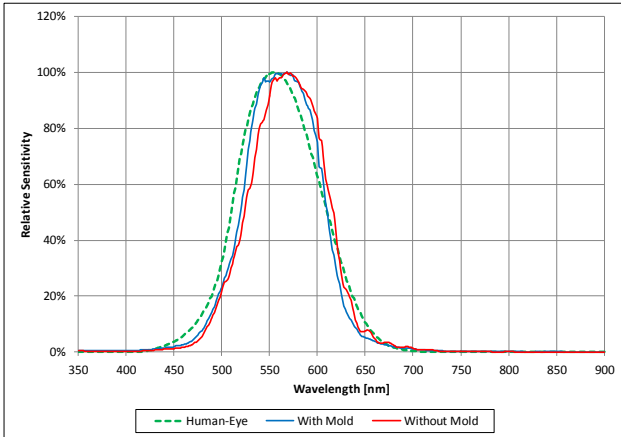


### Figure 2.2 ALS Sensitivity vs. Angle of Incidence
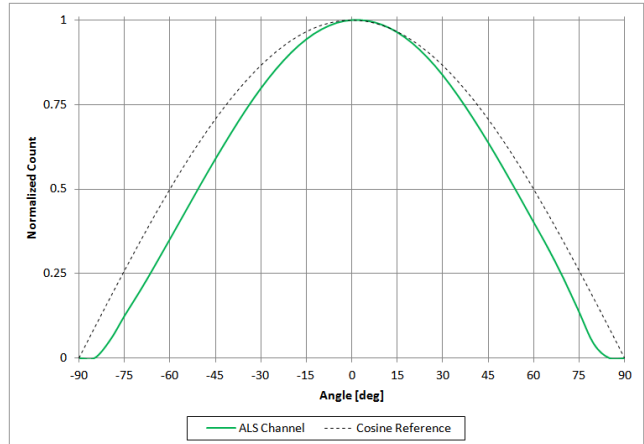


### Figure 2.3 ALS Linearity of all Gain Ranges

*Default 18-Bit Mode*
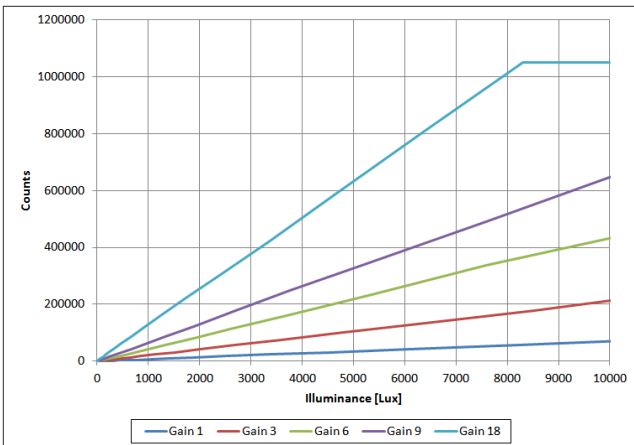


### Figure 2.4 ALS vs. Temperature at 1000 lux

*White LED*
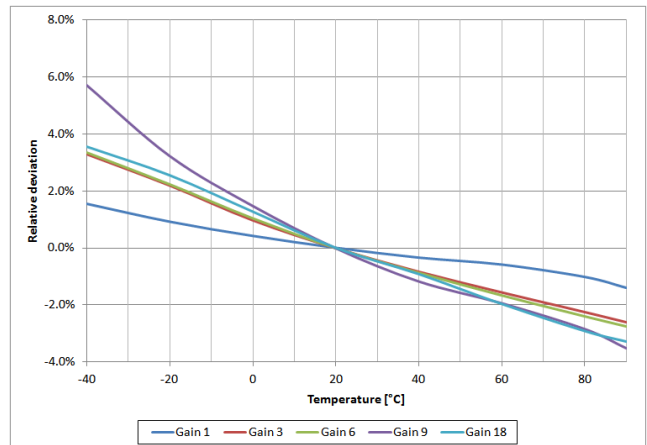
**Figure 2.5   ALS vs. Voltage at 1000 lux**
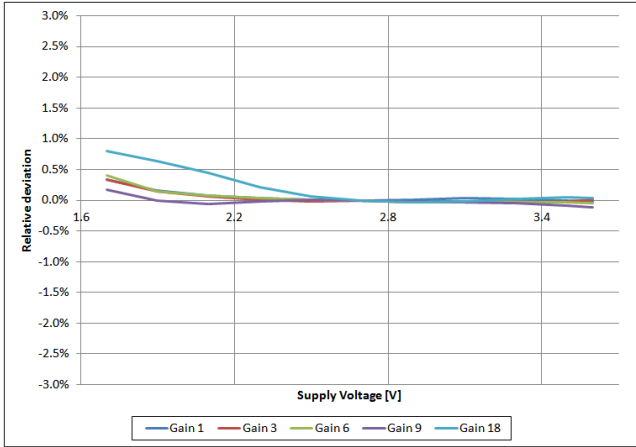


**Figure 2.6   ALS Typical Dark Count vs. Temperature**
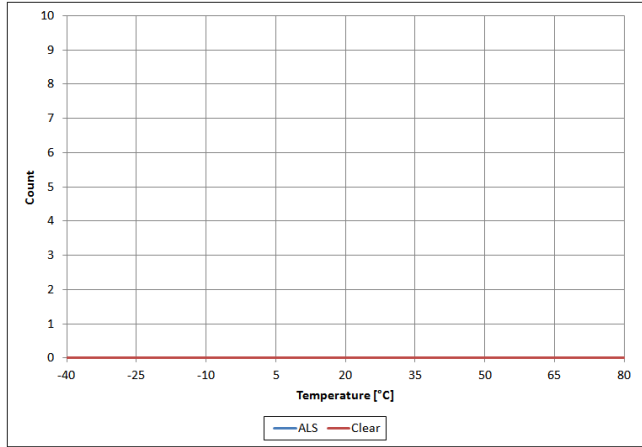


**Figure 2.7   Spectral Response UVBS, Linear**
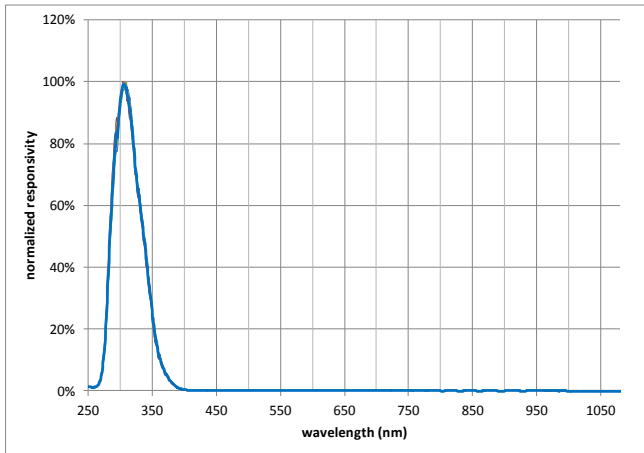


**Figure 2.8   Spectral Response UVBS, Logarithmic**
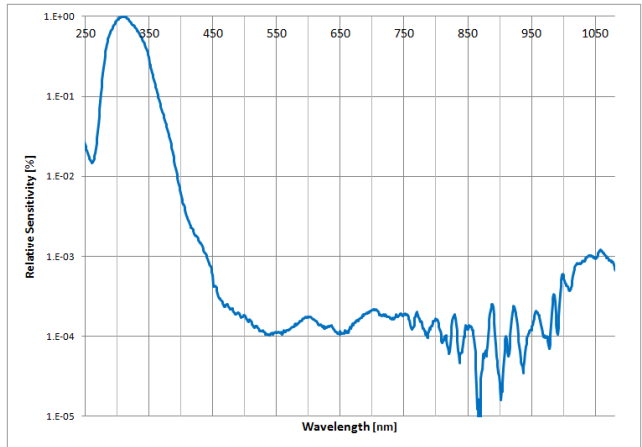


**Figure 2.9   UVBS Sensitivity vs. Angle of Incidence**

*310nm LED*
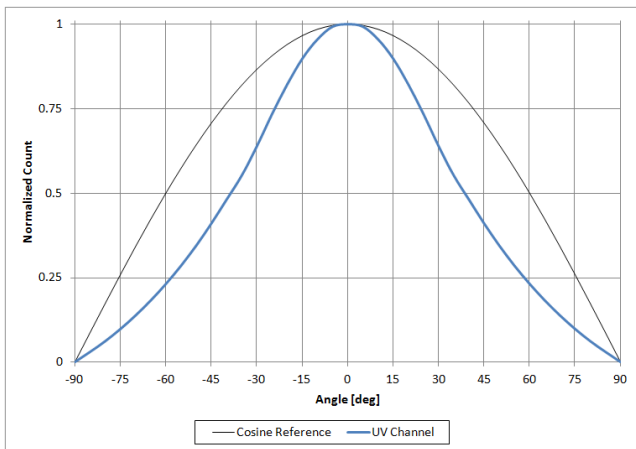


**Figure 2.10 UVBS Sensitivity vs. Angle of Incidence (Polar)**
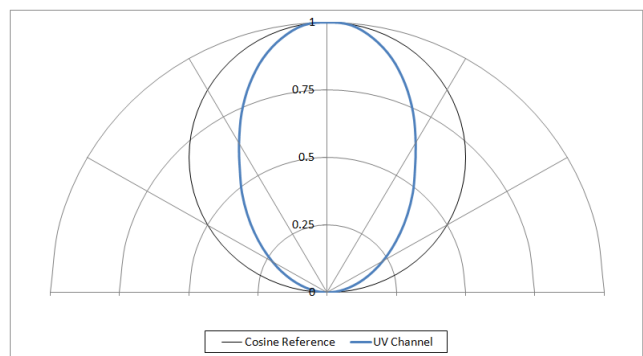
# Figure 2.11 UVBS Rotation in Horizontal Plane
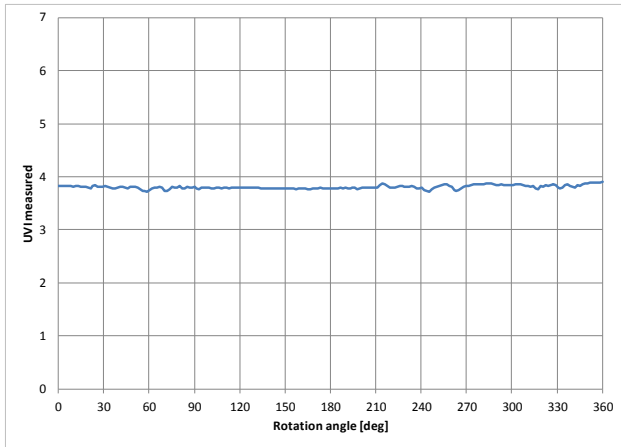


# Figure 2.12 UVBS Temperature Behavior for Several Sunlight Conditions
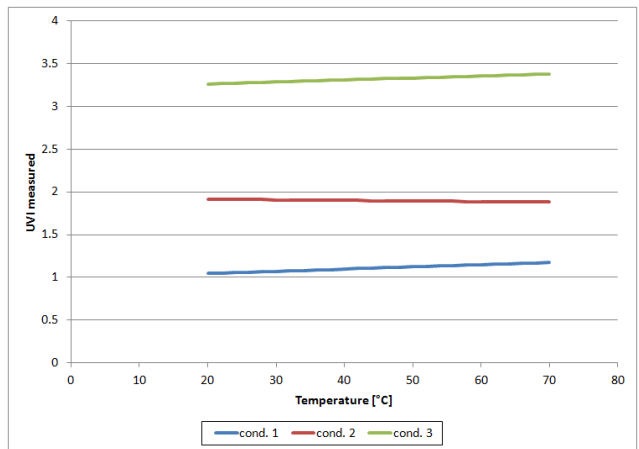


# Figure 2.13 Active Current vs. Supply Voltage

*ALS: default setting, UVBS: default setting*
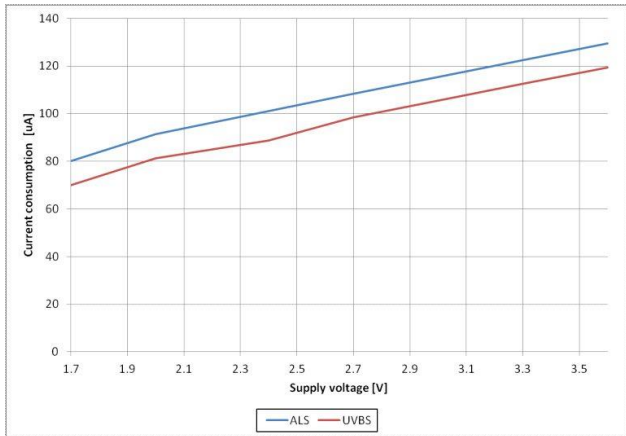


# Figure 2.14 Normalized Active Current vs. Temperature
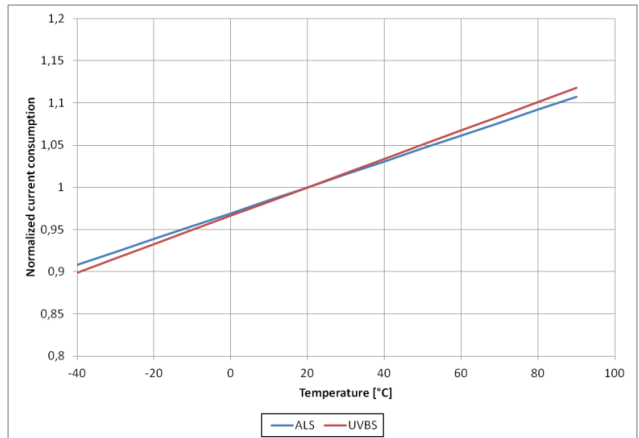
**Figure 2.15 Standby Current vs. Temperature**
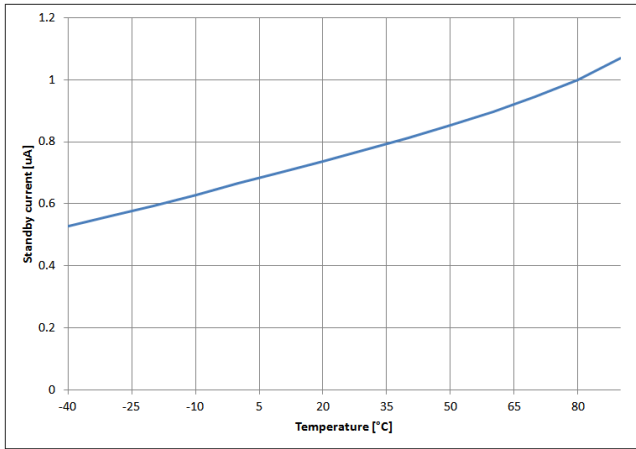
# 3. Detailed Description

The ZOPT2201 contains 4 different photodiode channels for ambient light measurement, UVB energy level measurement, and temperature compensation. The sensor diodes are arranged in a matrix array. The photodiode currents are converted to digital values by ADCs. The ZOPT2201 also includes some peripheral circuits such as an internal oscillator, current source, voltage reference, and internal one-time programmable non-volatile memory (NVM) to store trimming information.

## 3.1 Block Diagram of the ZOPT2201

**Figure 3.1 Simplified ZOPT2201 Block Diagram**
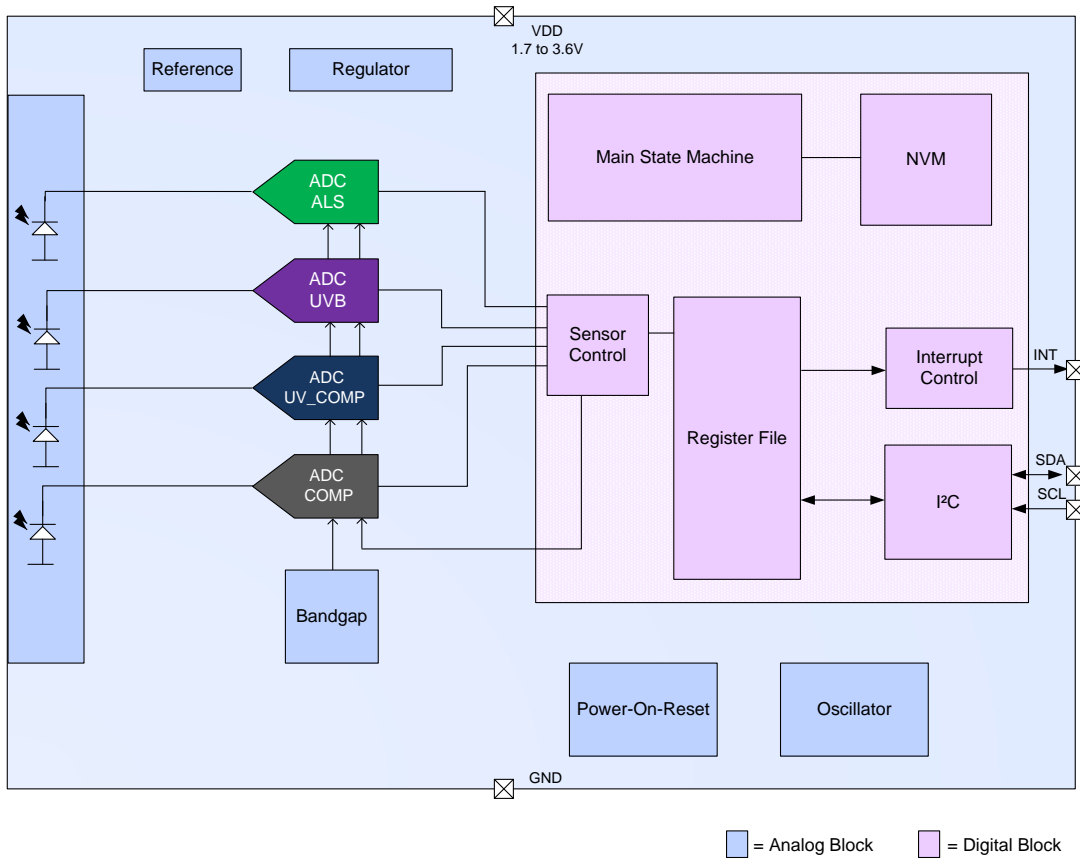
## 3.2 Application Circuit

**Figure 3.2  Typical Application Circuit**
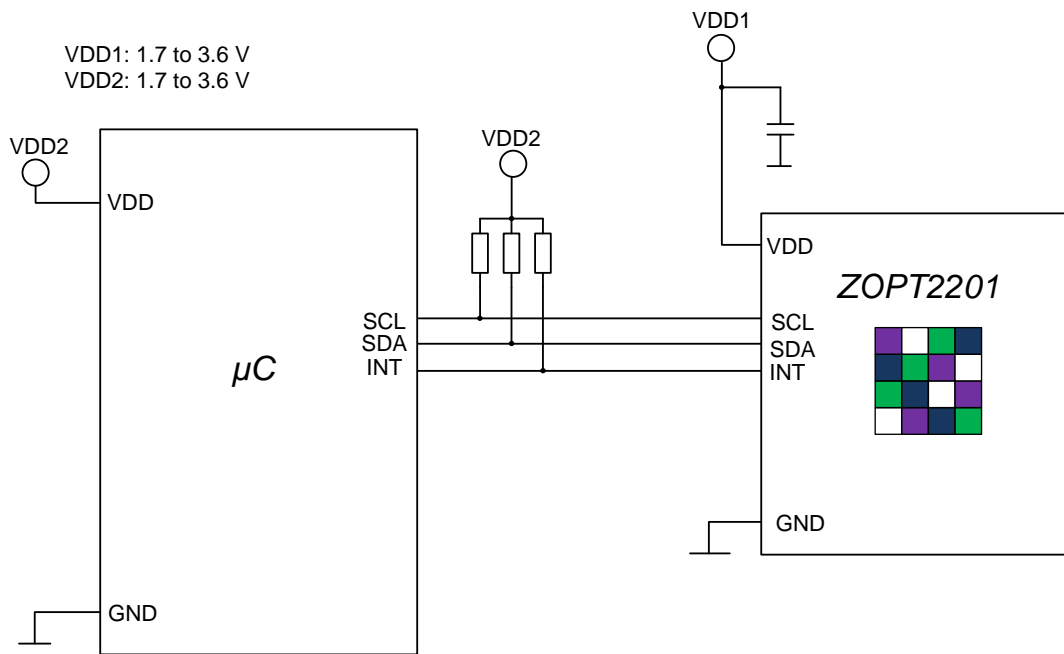
## 3.3    Pin Description

For pin layout and package dimensions, refer to sections 4.1 and 4.2 for the LGA6 and TSV packages respectively.

**Table 3.1    Pin Description (LGA6)**

| Number | Pin Name | I/O Type | Description |
|--------|----------|----------|-------------|
| 1 | SCL | IN | $I^2C$ serial clock line |
| 2 | SDA | IN/OUT | $I^2C$ serial data line |
| 3 | VDD | SUPPLY | Digital/analog power supply |
| 4 | INT | OUT | Interrupt pin |
| 5 | GND | GROUND | Digital/analog ground |
| 6 | N.C. | - | Not connected |

**Table 3.2    Pin Description (TSV)**

| Number | Pin Name | I/O Type | Description |
|--------|----------|----------|-------------|
| A1 | INT | OUT | Interrupt pin |
| A2 | SDA | IN/OUT | $I^2C$ serial data line |
| A3 | N.C. | - | Not connected |
| B1 | GND | GROUND | Digital/analog ground |
| B2 | VDD | SUPPLY | Digital/analog power supply |
| B3 | SCL | IN | $I^2C$ serial clock line |

## 3.4    Device Operation Modes

**Table 3.3   Operational Mode Descriptions**

| Mode Number | Mode Name | Description |
|---|---|---|
| 1 | Standby | Default mode after power-up.<br>In this mode, the oscillator, all internal support blocks, and the ADCs are switched off but I²C communication is fully supported. |
| 2 | ALS | <u>Active ADC Channels</u>: ALS, COMP<br>ALS Mode allows measurement of ambient light intensity. The sensor response is closely matched to human eye response to guarantee high lux value accuracy. Temperature compensation for the sensor elements is carried out internally via the COMP channel.<br>▪ ALS Mode is activated by setting the *LS_EN* bit to 1, the *LS_Mode* bit to 0 and the *RawMode_SEL* bit to 0 in the *MAIN_CTRL* register (see section 3.11.1).<br>   • Write $02_{HEX}$ to register $00_{HEX}$<br>▪ Internal temperature compensation runs following calculation before sensor data is stored in output register:<br>   • ALS = ALS_raw – COMP |
| 3 | UVBS | <u>Active ADC Channels</u>: UVB, UV_COMP<br>UVBS Mode allows high precision measurements of UVB energy intensity. The sensor response is chosen such that it can be used to calculate the UV index directly.<br>Temperature and stray light compensation for the sensor channel is performed internally via the UV_COMP channel.<br>▪ UVBS Mode is activated by setting the *LS_EN* bit and the *LS_Mode* bit to 1 in the *MAIN_CTRL* register (see section 3.11.1)<br>   • Write $0A_{HEX}$ to register $00_{HEX}$<br>▪ Internal temperature compensation runs following calculation before sensor data is stored in the output register:<br>   • UVB = UVB_raw – UV_COMP |

| Mode Number | Mode Name | Description |
|---|---|---|
| 4 | ALS/UVBS_Raw | Active ADC Channels: ALS, UVB, UV_COMP, COMP<br><br>ALS/UVBS_Raw Mode allows optimum temperature and stray light compensation for ALS and UVBS output data by external post-processing.<br><br>▪ ALS/UVBS_Raw Mode uses a special operation mode of the ZOPT2201. It requires a specific sequence to initialize after power up.<br><br>▪ The following commands must be sent via I²C *single byte* access to activate the special operation mode of ZOPT2201:<br>  • Write $B5_{HEX}$ to register $31_{HEX}$<br>  • Write $DF_{HEX}$ to register $30_{HEX}$<br>  • Write $04_{HEX}$ to register $31_{HEX}$<br><br>▪ ALS/UVBS_Raw operation is activated (after the sequence above has been sent) by setting the *LS_EN* and *RawMode_SEL* bits to 1 and setting the *LS_Mode* bit to 0 in the *MAIN_CTRL* register (see section 3.11.1)<br>  • Write $06_{HEX}$ to register $00_{HEX}$<br><br>▪ No internal temperature and stray light compensation is carried out. All channel data registers (see Table 3.10) carry the *uncompensated raw data* as received from the ADCs.<br><br>▪ Important: Proper temperature and stray light *compensation must be done on the application level* applying following formulas:<br>  • ALS = ALS_raw – COMP<br>  • UVB = UVB_raw – UV_COMP<br><br>Important: The internal digital trimming factors are not applied to the output data in the ALS/UVBS_Raw Mode. If this mode is used, contact IDT for the related application note (see contact information on last page). |

**Table 3.4   Channel Activation vs. Operation Mode**

| Mode Number | Mode Name | ALS | | UVB | | UV_COMP | | COMP | |
|---|---|---|---|---|---|---|---|---|---|
| | | Inactive | Active | Inactive | Active | Inactive | Active | Inactive | Active |
| 1 | Standby | ✓ | | ✓ | | ✓ | | ✓ | |
| 2 | ALS | | ✓ | ✓ | | ✓ | | | ✓ |
| 3 | UVBS | ✓ | | | ✓ | | ✓ | ✓ | |
| 4 | ALS/UVBS_Raw | | ✓ | | ✓ | | ✓ | | ✓ |

## 3.5   Conversion Control State Machine

### 3.5.1   Start Up after Power-On or Software Reset

The main state machine is set to "Start State" during a power-on or software reset. As soon as the reset is released, the internal oscillator is started and the programmed I²C address and the trim values are read from the internal NVM trimming data block. The ZOPT2201 enters Standby Mode as soon as the Idle State is reached (see Figure 3.3).

NOTE: If the I²C address has not yet been read, the device will respond with NACK to any I²C command and ignore any request to avoid responding to an incorrect I²C address.

If any of the sensor operation modes becomes activated through an I²C command (i.e., the *LS_EN* bit is set to 1 and the sensor mode is selected with the respective bits in the *MAIN_CTRL* register), the internal support blocks are immediately powered on. Once the voltages and currents are settled (typical after 500µs), the state machine checks for trigger events from a measurement scheduler to start conversions according to the selected measurement repeat rates (see section 3.11.2).

When the user resets the *LS_EN* bit to 0, a running conversion will be completed and the relevant ADCs and support blocks will move to Standby Mode thereafter.

**Figure 3.3  Main State Machine**
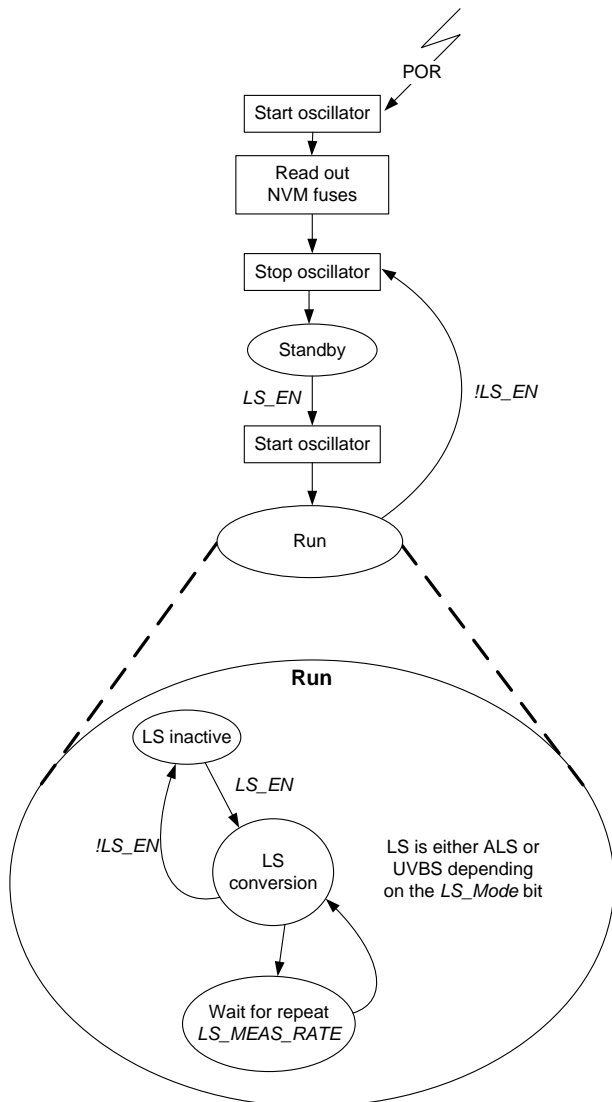
# 3.6 Light Sensor Sensitivity Configuration

## 3.6.1 Gain Modes, Resolution, and Measurement Time

There are five analog gain modes to adjust the sensitivity of the ZOPT2201 device to the needs of the application. The microcontroller can calculate the ambient light in lux by multiplying the ADC count value of the ALS channel with the appropriate output-scaling coefficient. A similar method can be used for UVI determination via UVBS channel.

If ALS/UVBS_Raw Mode is used, temperature and stray light compensation must be carried out in the microcontroller before output scaling coefficients are applied (see Table 3.3 for the ALS/UVBS_Raw Mode description).

Selected analog gain settings as well as resolution and measurement time settings are valid for all active ADC converter channels at the same time. The gain, resolution, and measurement time cannot be simultaneously set to different settings for different channels. If different gain or resolution settings are required for different channels, conversions must be performed consecutively with modified settings.

**Table 3.5   ALS Detection Ranges**

| Effective Output Resolution [Bits] | Measurement Time [ms] | Gain Mode 1 | | | Gain Mode 3 | | |
|---|---|---|---|---|---|---|---|
| | | Minimum Detection [lux] | Maximum Detection [lux] | Result Resolution [lux/Count] | Minimum Detection [lux] | Maximum Detection [lux] | Result Resolution [lux/Count] |
| 13 | 3.125 | 19.2000 | 157286 | 19.2000 | 6.4000 | 52429 | 6.4000 |
| 16 | 25 | 2.4000 | 157286 | 2.4000 | 0.8000 | 52429 | 0.8000 |
| 17 | 50 | 1.2000 | 157286 | 1.2000 | 0.4000 | 52429 | 0.4000 |
| **18 (default)** | **100** | **0.6000** | **157286** | **0.6000** | **0.2000** | **52429** | **0.2000** |
| 19 | 200 | 0.3000 | 157286 | 0.3000 | 0.1000 | 52429 | 0.1000 |
| 20 | 400 | 0.1500 | 157286 | 0.1500 | 0.0500 | 52429 | 0.0500 |

| Effective Output Resolution [Bits] | Measurement Time [ms] | Gain Mode 6 | | | Gain Mode 9 | | |
|---|---|---|---|---|---|---|---|
| | | Minimum Detection [lux] | Maximum Detection [lux] | Result Resolution [lux/Count] | Minimum Detection [lux] | Maximum Detection [lux] | Result Resolution [lux/Count] |
| 13 | 3.125 | 3.2000 | 26214 | 3.2000 | 2.1333 | 17476 | 2.1333 |
| 16 | 25 | 0.4000 | 26214 | 0.4000 | 0.2667 | 17476 | 0.2667 |
| 17 | 50 | 0.2000 | 26214 | 0.2000 | 0.1333 | 17476 | 0.1333 |
| **18 (default)** | **100** | **0.1000** | **26214** | **0.1000** | **0.0667** | **17476** | **0.0667** |
| 19 | 200 | 0.0500 | 26214 | 0.0500 | 0.0333 | 17476 | 0.0333 |
| 20 | 400 | 0.0250 | 26214 | 0.0250 | 0.0167 | 17476 | 0.0167 |

| Effective Output Resolution [Bits] | Measurement Time [ms] | Gain Mode 18 | | |
| --- | --- | --- | --- | --- |
| | | Minimum Detection [lux] | Maximum Detection [lux] | Result Resolution [lux/Count] |
| 13 | 3.125 | 1.0667 | 8738 | 1.0667 |
| 16 | 25 | 0.1333 | 8738 | 0.1333 |
| 17 | 50 | 0.0667 | 8738 | 0.0667 |
| **18 (default)** | **100** | **0.0333** | **8738** | **0.0333** |
| 19 | 200 | 0.0167 | 8738 | 0.0167 |
| 20 | 400 | 0.0083 | 8738 | 0.0083 |

**Table 3.6   UVBS Sensitivities**

Note: See section 3.11.3 for further details.

| Effective Output Resolution [Bits] | Measurement Time [ms] | Gain Mode 1 | Gain Mode 3 | Gain Mode 6 | Gain Mode 9 | Gain Mode 18 |
| --- | --- | --- | --- | --- | --- | --- |
| | | Sensitivity $\left[\frac{counts}{\mu W/cm^2}\right]$ | Sensitivity $\left[\frac{counts}{\mu W/cm^2}\right]$ | Sensitivity $\left[\frac{counts}{\mu W/cm^2}\right]$ | Sensitivity $\left[\frac{counts}{\mu W/cm^2}\right]$ | Sensitivity $\left[\frac{counts}{\mu W/cm^2}\right]$ |
| 13 | 3.125 | 0.022 | 0.065 | 0.130 | 0.195 | 0.391 |
| 16 | 25 | 0.174 | 0.521 | 1.042 | 1.563 | 3.125 |
| 17 | 50 | 0.347 | 1.042 | 2.083 | 3.125 | 6.250 |
| **18 (default)** | **100** | **0.694** | **2.083** | **4.167** | **6.250** | **12.500** |
| 19 | 200 | 1.389 | 4.167 | 8.333 | 12.500 | 25.000 |
| 20 | 400 | 2.778 | 8.333 | 16.667 | 25.000 | 50.000 |

## 3.7 UVB Sensor Match to UVI

Due to the specifically designed spectral sensitivity of the UVB sensor, a very good match between sensor readings and reference UVI meter readings is achieved for different weather conditions.

**Figure 3.4  Measured UV Index vs. Reference UVI Meter**
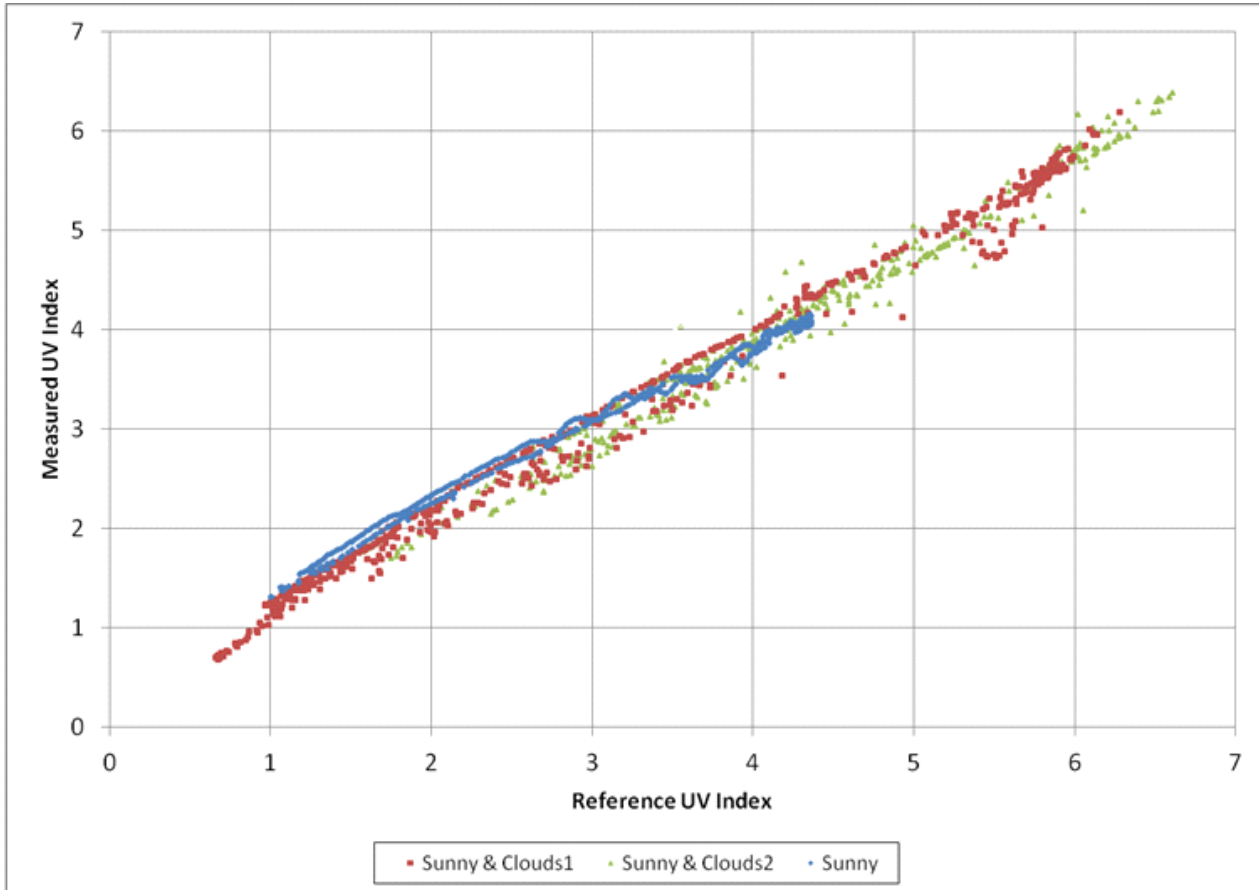
## 3.8  Interrupt Features

The ZOPT2201 can generate an interrupt signal on a user-selected sensor channel. Interrupts will be triggered if upper or lower threshold values are crossed or if the output count variation of consecutive conversions has exceeded a defined limit.

An interrupt can be displayed at the INT pin as an active-low signal or via a status register flag. Interrupt conditions are always evaluated after completion of a new conversion on the selected sensor channel.

The *ls_int* signal (output of LSIntGen in Figure 3.5) is also stored in the *MAIN_STATUS* register as the *LS interrupt status* (see section 3.11.5) flag. The flag is cleared by reading the *MAIN_STATUS* register. A cleared *LS interrupt status* flag will also clear the interrupt signal on the INT pin.

**Figure 3.5  Interrupt Unit**
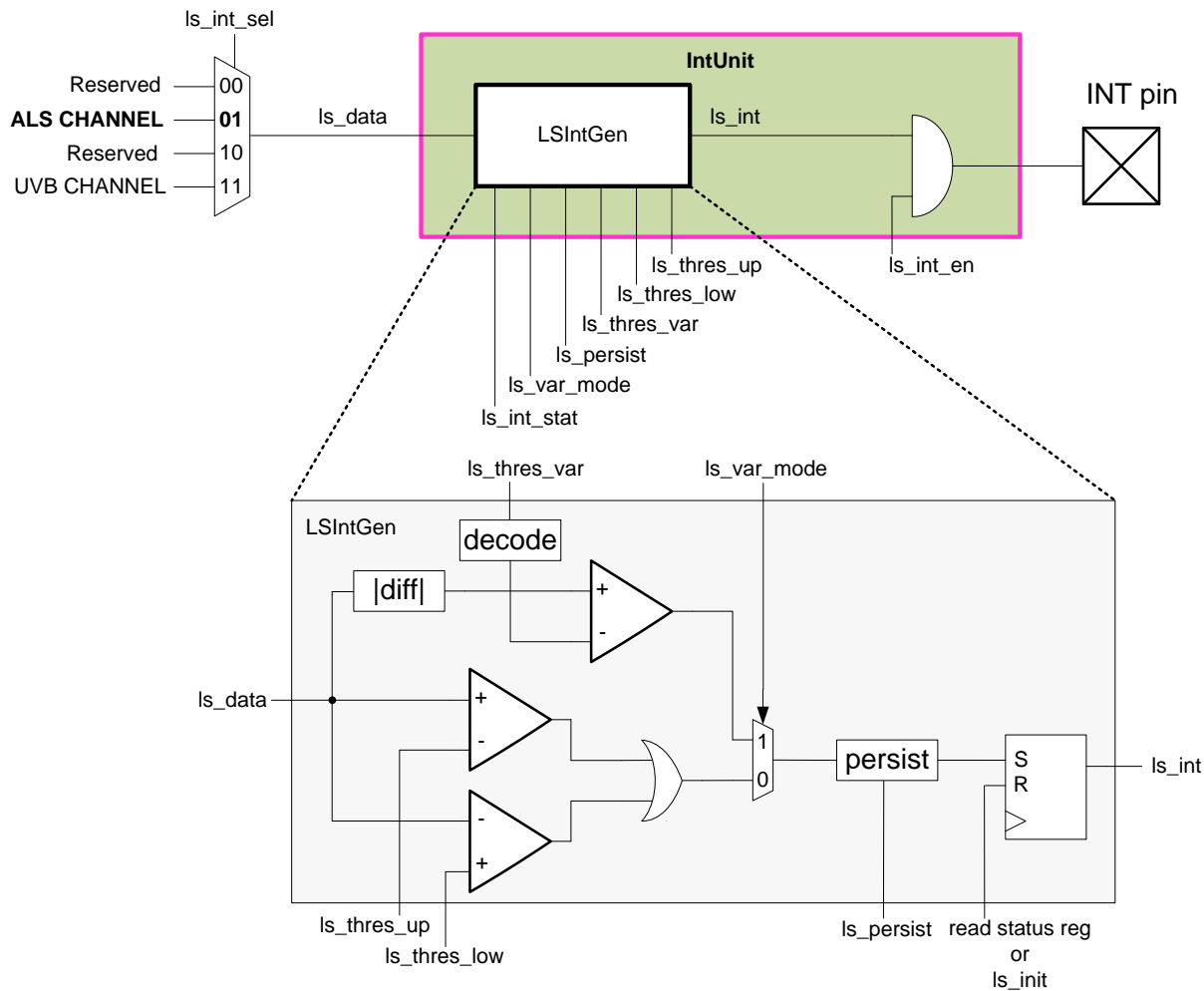


The interrupt is configured by the bits in the *INT_CFG* register (see section 3.11.10). It can function as either threshold triggered (*LS_VAR_MODE* = 0) or variance trigged (*LS_VAR_MODE* = 1).

The interrupt source generator is configurable to be one of the following input channels: ALS or UVBS. The interrupt source is selected by the *LS_INT_SEL* bits in the *INT_CFG* register (see section 3.11.10).

The threshold interrupt is enabled with *LS_INT_EN* = 1 and *LS_VAR_MODE* = 0. The interrupt is set when the respective *\*_DATA* register value of the selected interrupt source channel is above the upper or below the lower threshold configured in the *LS_THRES_UP* and *LS_THRES_LOW* registers (see sections 3.11.12 and 3.11.13 respectively) for a specified number of consecutive measurements as configured in the *INT_PST* register (1 + *LS_PERSIST*; see section 3.11.11).

The variance interrupt is enabled with *LS_INT_EN* = 1 and *LS_VAR_MODE* = 1. It is set when the absolute value difference between the preceding and the current output data of the selected interrupt source channel is above the decoded variance threshold (see section 3.11.14) for a specified number of consecutive measurements (1 + *LS_PERSIST*).

## 3.9   I²C Interface

The ZOPT2201 is equipped with an I²C interface for control and data communication. The chip always operates as a slave. The device offers two different 7-bit slave addresses that are selectable via NVM programming. A read/write bit must be appended to the slave address by the master device to properly communicate with the device.

The interface is compatible with standard mode (100kHz) and fast mode (400kHz) I²C communication.

**Table 3.7   Supported I²C Clock Frequencies**

| Mode | Frequency | Transient Noise Filter |
|---|---|---|
| Standard | 100kHz | 50ns |
| Fast | 400kHz | 50ns |

The I²C circuitry is always active (Standby or Active Mode of the ZOPT2201). If the I²C address is not yet read from the memory block, the device will respond with "NACK" to any request and ignore the possible commands. An attempt to read or write to non-existing addresses will be answered with "NACK."

### 3.9.1   I²C Address Decoding

The I²C address decoding is done during start up after a power-on-reset or software reset. Two different I²C addresses can be selected through NVM programming (see Table 3.8).

**Table 3.8   I²C Address**

| Address NVM Level | I²C Address | | |
|---|---|---|---|
| | 7 Bits | Write | Read |
| 0 – Default | 1010 011x$_{BIN}$ | A6$_{HEX}$ | A7$_{HEX}$ |
| 1 – Programmed | 1010 010x$_{BIN}$ | A4$_{HEX}$ | A5$_{HEX}$ |

### 3.9.2   I²C Register Read

The ZOPT2201 registers can be read individually or in block read mode. When two or more bytes are read in block read mode, reserved register addresses are skipped and the next valid address is referenced. If the last valid address has been reached, but the master continues with the block read, the address counter in the ZOPT2201 will not roll over and the ZOPT2201 returns 00$_{HEX}$ for every subsequent byte read.

The block read operation is the only way to ensure correct data read out of multi-byte registers and to avoid splitting of results with HIGH and LOW bytes originating from different conversions. During block read access on LS result registers, the result update is blocked.

If a read access is started on an address belonging to a non-readable register, the ZOPT2201 will return NACK until the I²C operation is ended.

Read operations must follow the timing diagram in Figure 3.6.

# Figure 3.6  I²C Register Read

**Register Read (I²C™ Read)**
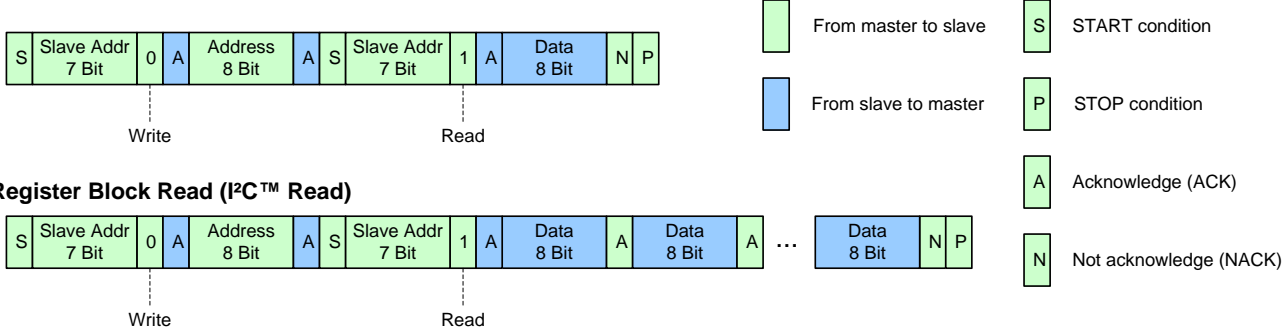


**Register Block Read (I²C™ Read)**
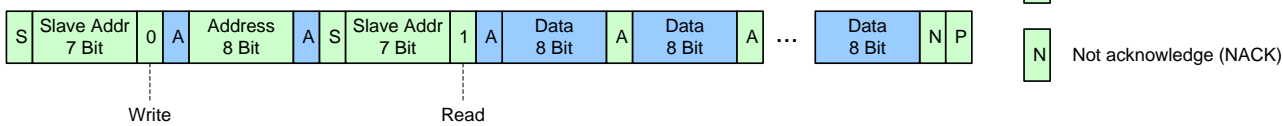


## 3.9.3    Register Write

The ZOPT2201 registers can be written to individually or in block write mode. When two or more bytes are written in block write mode; reserved registers and read-only registers are skipped. The transmitted data is automatically applied to the next writable register. If a register includes read (R) and read/write (RW) bits, the register is not skipped. Data written to read-only bits are ignored.

If the last valid address of the ZOPT2201's address range is reached but the master attempts to continue the block write operation, the address counter of the ZOPT2201 will not roll over. The ZOPT2201 will return NACK for every following byte sent by the master until the I²C operation is ended.

If a write access is started on an address belonging to a non-writeable register, the ZOPT2201 will return NACK until the I²C operation is ended.

Write operations must follow the timing diagram in Figure 3.7.

# Figure 3.7  I²C Register Write

**Register Write (I²C™ Write)**
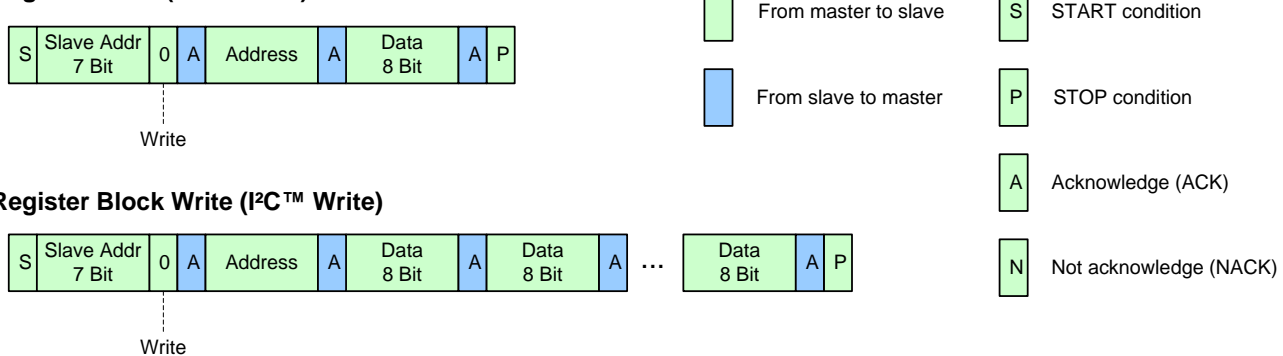


**Register Block Write (I²C™ Write)**
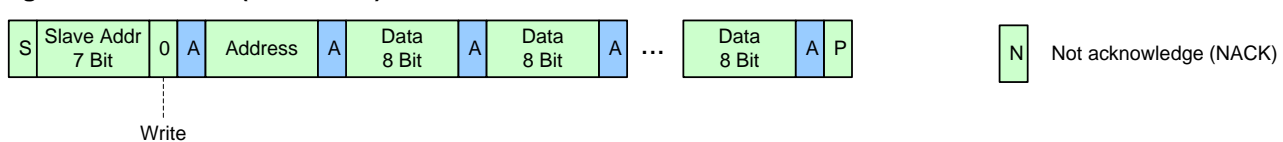
### 3.9.4 I²C Interface—Bus Timing

**Figure 3.8 Bus Timing**
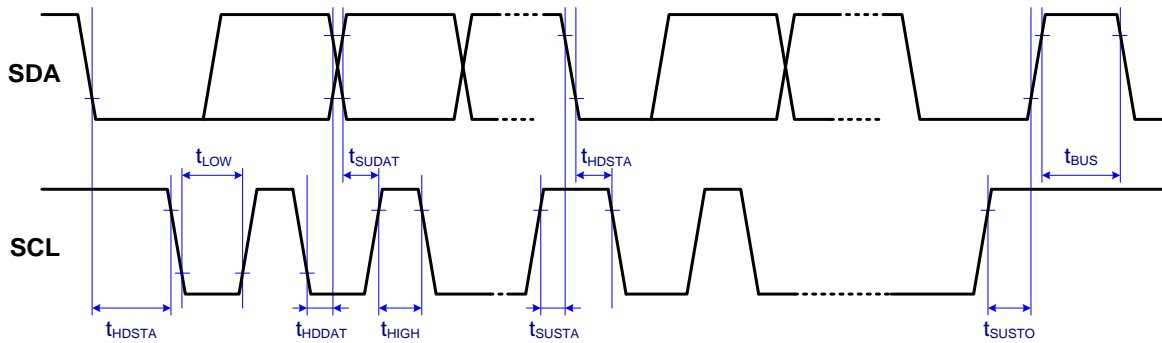


**Table 3.9 Bus Timing Characteristic**

| Parameter | Symbol | Standard Mode | Fast Mode | Units |
|---|---|---|---|---|
| Maximum SCL clock frequency | $f_{SCL}$ | 100 | 400 | kHz |
| Minimum START condition hold time relative to SCL edge | $t_{HDSTA}$ | 4 | | µs |
| Minimum SCL clock low width | $t_{LOW}$ | 4.7 | | µs |
| Minimum SCL clock high width | $t_{HIGH}$ | 4 | | µs |
| Minimum START condition setup time relative to SCL edge | $t_{SUSTA}$ | 4.7 | | µs |
| Minimum data hold time on SDA relative to SCL edge | $t_{HDDAT}$ | 0 | | µs |
| Minimum data setup time on SDA relative to SCL edge | $t_{SUDAT}$ | 0.1 | 0.1 | µs |
| Minimum STOP condition setup time on SCL | $t_{SUSTO}$ | 4 | | µs |
| Minimum bus free time between stop condition and start condition | $t_{BUS}$ | 4.7 | | µs |

## 3.10 Summary of Internal Registers

**Table 3.10 Register Overview**

| Address | Type | Name | Default Value | Description |
|---|---|---|---|---|
| 00$_{HEX}$ | RW | MAIN_CTRL | 00$_{HEX}$ | LS operation mode control, software (SW) reset |
| 04$_{HEX}$ | RW | LS_MEAS_RATE | 22$_{HEX}$ | LS measurement rate and resolution in Active Mode |
| 05$_{HEX}$ | RW | LS_GAIN | 01$_{HEX}$ | LS analog gain range |
| 06$_{HEX}$ | R | PART_ID | B2$_{HEX}$ | Part number ID and revision ID |
| 07$_{HEX}$ | R | MAIN_STATUS | 20$_{HEX}$ | Power-on status, interrupt status, data status |
| 0D$_{HEX}$ | R | ALS_DATA_0 | 00$_{HEX}$ | ALS – ADC measurement data, LSB |
| 0E$_{HEX}$ | R | ALS_DATA_1 | 00$_{HEX}$ | ALS – ADC measurement data |
| 0F$_{HEX}$ | R | ALS_DATA_2 | 00$_{HEX}$ | ALS – ADC measurement data, MSB |
| 10$_{HEX}$ | R | UVB_DATA_0 | 00$_{HEX}$ | UVBS – ADC measurement data, LSB |
| 11$_{HEX}$ | R | UVB_DATA_1 | 00$_{HEX}$ | UVBS – ADC measurement data |
| 12$_{HEX}$ | R | UVB_DATA_2 | 00$_{HEX}$ | UVBS – ADC measurement data, MSB |
| 13$_{HEX}$ | R | UV_COMP_DATA_0 | 00$_{HEX}$ | UVBS – COMP ADC measurement data, LSB |
| 14$_{HEX}$ | R | UV_COMP_DATA_1 | 00$_{HEX}$ | UVBS – COMP ADC measurement data |
| 15$_{HEX}$ | R | UV_COMP_DATA_2 | 00$_{HEX}$ | UVBS – COMP ADC measurement data, MSB |
| 16$_{HEX}$ | R | COMP_DATA_0 | 00$_{HEX}$ | COMP – ADC measurement data, LSB |
| 17$_{HEX}$ | R | COMP_DATA_1 | 00$_{HEX}$ | COMP – ADC measurement data |
| 18$_{HEX}$ | R | COMP_DATA_2 | 00$_{HEX}$ | COMP – ADC measurement data, MSB |
| 19$_{HEX}$ | RW | INT_CFG | 10$_{HEX}$ | Interrupt configuration |
| 1A$_{HEX}$ | RW | INT_PST | 00$_{HEX}$ | Interrupt persist setting |
| 21$_{HEX}$ | RW | LS_THRES_UP_0 | FF$_{HEX}$ | LS interrupt upper threshold, LSB |
| 22$_{HEX}$ | RW | LS_THRES_UP_1 | FF$_{HEX}$ | LS interrupt upper threshold, intervening bits |
| 23$_{HEX}$ | RW | LS_THRES_UP_2 | 0F$_{HEX}$ | LS interrupt upper threshold, MSB |
| 24$_{HEX}$ | RW | LS_THRES_LOW_0 | 00$_{HEX}$ | LS interrupt lower threshold, LSB |
| 25$_{HEX}$ | RW | LS_THRES_LOW_1 | 00$_{HEX}$ | LS interrupt lower threshold, intervening bits |
| 26$_{HEX}$ | RW | LS_THRES_LOW_2 | 00$_{HEX}$ | LS interrupt lower threshold, MSB |
| 27$_{HEX}$ | RW | LS_THRES_VAR | 00$_{HEX}$ | LS interrupt variance threshold |
| 2F$_{HEX}$ | RW | DEVICE_CONFIG | 00$_{HEX}$ | Control bit for I²C address |
| 30$_{HEX}$ | RW | SPECIAL_MODE_1 | | Special operation mode register 1 |
| 31$_{HEX}$ | RW | SPECIAL_MODE_2 | | Special operation mode register 2 |

## 3.11 Detailed Description of Registers

### 3.11.1 MAIN_CTRL

Address            $00_{HEX}$
Default value      $00_{HEX}$
Register access    RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| $00_{HEX}$ | 0 | 0 | 0 | SW reset | LS_Mode | RawMode_SEL | LS_EN | 0 |

Bit[4]          *SW reset*: If bit is set to 1, a software reset will be triggered.

Bit[3]          *LS_Mode*: This bit is only checked if LS_EN is active.

          0 **(default)**      ALS Mode:      ALS + COMP channels activated,
                                                  UVB and UV_COMP channels deactivated
          1                    UVBS Mode:    UVB + UV_COMP channels activated,
                                                  ALS and COMP channels deactivated
                                                    Mode takes precedence over other operation modes

Bit[2]          *RawMode_SEL:* This bit is only checked if LS_EN is active.
          0 **(default)**      ALS Mode:      ALS + COMP channels activated,
                                                  UVBS and UV_COMP channels deactivated
          1                    ALS/UVBS Raw_Mode:     ALS, UVB, UV_COMP, and COMP channels
                          activated. (Further actions are needed; see Table 3.3 for details.)

Bit[1]          *LS_ EN*
          1                    Light sensor active
          0 **(default)**      Light sensor standby

Bit[0]          Reserved

Writing to this register stops the ongoing measurements and starts new measurements (depending on the respective enable bits).

### 3.11.2 LS_MEAS_RATE

Address            04<sub>HEX</sub>
Default value      22<sub>HEX</sub>
Register access    RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 04<sub>HEX</sub> | 0 | LS Resolution / Bit Width | | | 0 | LS Measurement Rate | | |

Bit[6:4]    *Light Sensor Resolution/ Bit Width*. The resolution selected via this register will have an effect on the measurement time and the accuracy of the measurement:
$000_{BIN}$     20-bit; 400ms
$001_{BIN}$     19-bit; 200ms
$010_{BIN}$     18-bit; 100ms **(default)**
$011_{BIN}$     17-bit; 50ms
$100_{BIN}$     16-bit; 25ms
$101_{BIN}$     13-bit; 3.125ms
$110_{BIN}$     Reserved
$111_{BIN}$     Reserved

Bit[2:0]    *LS Measurement Rate.* This bit field controls the timing of the periodic measurements of the light sensor in Active Mode.
$000_{BIN}$     25ms
$001_{BIN}$     50ms
$010_{BIN}$     100ms **(default)**
$011_{BIN}$     200ms
$100_{BIN}$     500ms
$101_{BIN}$     1000ms
$110_{BIN}$     2000ms
$111_{BIN}$     2000ms

**Note:**    When the measurement repeat rate is programmed to be faster than possible for the specified ADC measurement time, the repeat rate will be lower than programmed (maximum speed).

Writing to this register stops the ongoing measurements and starts new measurements (depending on the respective enable bits).

### 3.11.3  LS_GAIN

| | |
|---|---|
| Address | $05_{HEX}$ |
| Default value | $01_{HEX}$ |
| Register access | RW |

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| $05_{HEX}$ | 0 | 0 | 0 | 0 | 0 | LS Gain Range | | |

Note:   The following ALS / UVBS detection ranges apply to the default resolution of 18-bit (measurement time = 100ms); see Table 3.5 and Table 3.6 respectively for details.

*LS Detection Ranges*

ALS Mode:

Bit[2:0]          ALS (temperature compensated):

| | | |
|---|---|---|
| $000_{BIN}$ | Gain: 1 | 0.6 to 157286 lux |
| $001_{BIN}$ | Gain: 3 | 0.2 to 52429 lux (**default)** |
| $010_{BIN}$ | Gain: 6 | 0.1 to 26214 lux |
| $011_{BIN}$ | Gain: 9 | 0.0667 to 17476 lux |
| $100_{BIN}$ | Gain: 18 | 0.0333 to 8738 lux |

UVBS Mode:

Bit[2:0]          UVBS (temperature compensated):

| | | |
|---|---|---|
| $000_{BIN}$ | Gain: 1 | 1.44 to 377487 µW/cm² |
| $001_{BIN}$ | Gain: 3 | 0.48 to 125829 µW/cm² (**default**) |
| $010_{BIN}$ | Gain: 6 | 0.24 to 62915 µW/cm² |
| $011_{BIN}$ | Gain: 9 | 0.16 to 41943 µW/cm² |
| $100_{BIN}$ | Gain: 18 | 0.08 to 20972 µW/cm² **(recommended for application)** |

Writing to this register stops the ongoing measurements and starts new measurements (depending on the respective enable bits).

### 3.11.4  PART_ID

Address            06$_{HEX}$
Default value      B2$_{HEX}$
Register access    R

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 06$_{HEX}$ | Part Number ID | | | | Revision ID | | | |

Bit[7:4]      *Part Number ID*
Bit[3:0]      *Revision ID* of the component. The value increases by one each time a new silicon revision is manufactured

### 3.11.5  MAIN_STATUS

Address            07$_{HEX}$
Default value      20$_{HEX}$
Register access    R

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 07$_{HEX}$ | 0 | 0 | Power-On status | LS interrupt status | LS data status | 0 | 0 | 0 |

Bit[5]      *Power-On status.* If set to 1, the part has had a power-up event, either because the part was turned on or because there was a power-supply voltage disturbance

**A value of 1 is the default for the first register read after power-on reset.**

Note:      All interrupt threshold settings in the registers have been reset to power-on default states and should be examined if the *Power-On status* flag is set. In the event of a power-up event while in the ALS/UVBS_Raw Mode, this special operation mode is turned off. To restore this mode, the initialization sequence described in Table 3.3 must be repeated before the mode can be reactivated.

**The flag is cleared after the register is read.**

Bit[4]      *LS interrupt status* (updated even if the interrupt pin is disabled)
　　　　　　　　0      interrupt condition has not occurred **(default)**
　　　　　　　　1      interrupt condition has occurred (cleared after read)

Bit[3]      *LS data status*
　　　　　　　　0      old data, already read **(default)**
　　　　　　　　1      new data, not yet read (cleared after read)

Bit[2:0]      Reserved

### 3.11.6 ALS_DATA

| | | |
|---|---|---|
| Address | 0D$_{HEX}$ and 0E$_{HEX}$ and 0F$_{HEX}$ | |
| Default value | 00$_{HEX}$ and 00$_{HEX}$ and 00$_{HEX}$ | |
| Register access | R | |

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 0D$_{HEX}$ | ALS_DATA_0[7:0] | | | | | | | |
| 0E$_{HEX}$ | ALS_DATA_1[15:8] | | | | | | | |
| 0F$_{HEX}$ | 0 | 0 | 0 | 0 | ALS_DATA_2[19:16] | | | |

ALS channel digital output data (unsigned integer, 13 to 20 bit, LSB aligned).

Register data is already temperature compensated. See Table 3.3 for details.

When an I²C read operation is active and points to an address in the range 07$_{HEX}$ to 18$_{HEX}$, all registers in this range are locked until the I²C read operation is completed or this address range is left.

This guarantees that the data in the registers belongs to the same measurement cycle. New measurement data is stored into temporary registers and the actual *_DATA registers are updated as soon as there is no on-going I²C read operation to the address range 07$_{HEX}$ to 18$_{HEX}$.

| | | |
|---|---|---|
| Register 0D$_{HEX}$ | Bit[7:0] | ALS diode data least significant data byte |
| Register 0E$_{HEX}$ | Bit[7:0] | ALS diode data intervening data byte |
| Register 0F$_{HEX}$ | Bit[3:0] | ALS diode data most significant data byte |

### 3.11.7 UVB_DATA

Address           $10_{HEX}$ and $11_{HEX}$ and $12_{HEX}$
Default value     $00_{HEX}$ and $00_{HEX}$ and $00_{HEX}$
Register access   R

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|---|---|---|---|---|---|---|---|
| $10_{HEX}$ | UVB_DATA_0[7:0] | | | | | | | |
| $11_{HEX}$ | UVB_DATA_1[15:8] | | | | | | | |
| $12_{HEX}$ | 0 | 0 | 0 | 0 | UVB_DATA_2[19:16] | | | |

UVB channel digital output data (unsigned integer, 13 to 20 bit, LSB aligned).

Register data is already temperature compensated. See Table 3.3 for details.

When an I²C read operation is active and points to an address in the range $07_{HEX}$ to $18_{HEX}$, all registers in this range are locked until the I²C read operation is completed or this address range is left.

This guarantees that the data in the registers belongs to the same measurement cycle. New measurement data is stored into temporary registers and the actual *_DATA registers are updated as soon as there is no on-going I²C read operation to the address range $07_{HEX}$ to $18_{HEX}$.

Register $10_{HEX}$     Bit[7:0]     UVB diode data least significant data byte
Register $11_{HEX}$     Bit[7:0]     UVB diode data intervening data byte
Register $12_{HEX}$     Bit[3:0]     UVB diode data most significant data byte

### 3.11.8  UV_COMP_DATA

Address                $13_{HEX}$ and $14_{HEX}$ and $15_{HEX}$
Default value          $00_{HEX}$ and $00_{HEX}$ and $00_{HEX}$
Register access        R

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| $13_{HEX}$ | UV_COMP_DATA_0[7:0] | | | | | | | |
| $14_{HEX}$ | UV_COMP_DATA_1[15:8] | | | | | | | |
| $15_{HEX}$ | 0 | 0 | 0 | 0 | UV_COMP_DATA_2[19:16] | | | |

UVBS compensation (UV_COMP) channel digital output data (unsigned integer, 13 to 20 bit, LSB aligned).

Register carries UVBS temperature compensation data. See Table 3.3 for details.

When an I²C read operation is active and points to an address in the range $07_{HEX}$ to $18_{HEX}$, all registers in this range are locked until the I²C read operation is completed or this address range is left.

This guarantees that the data in the registers belongs to the same measurement cycle. New measurement data is stored into temporary registers and the actual *_DATA registers are updated as soon as there is no on-going I²C read operation to the address range $07_{HEX}$ to $18_{HEX}$.

Register $13_{HEX}$        Bit[7:0]        UV_COMP diode data least significant data byte
Register $14_{HEX}$        Bit[7:0]        UV_COMP diode data intervening data byte
Register $15_{HEX}$        Bit[3:0]        UV_COMP diode data most significant data byte

### 3.11.9  COMP_DATA

Address              16$_{HEX}$ and 17$_{HEX}$ and 18$_{HEX}$
Default value        00$_{HEX}$ and 00$_{HEX}$ and 00$_{HEX}$
Register access      R

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| **16$_{HEX}$** | COMP_DATA_0[7:0] | | | | | | | |
| **17$_{HEX}$** | COMP_DATA_1[15:8] | | | | | | | |
| **18$_{HEX}$** | 0 | 0 | 0 | 0 | COMP_DATA_2[19:16] | | | |

ALS compensation channel (COMP) digital output data (unsigned integer, 13 to 20 bit, LSB aligned).

Register carries ALS temperature compensation data. See Table 3.3 for details.

When an I²C read operation is active and points to an address in the range 07$_{HEX}$ to 18$_{HEX}$, all registers in this range are locked until the I²C read operation is completed or this address range is left.

This guarantees that the data in the registers belongs to the same measurement cycle. New measurement data is stored into temporary registers and the actual *_DATA registers are updated as soon as there is no on-going I²C read operation to the address range 07$_{HEX}$ to 18$_{HEX}$.

Register 16$_{HEX}$      Bit[7:0]        COMP diode data least significant data byte
Register 17$_{HEX}$      Bit[7:0]        COMP diode data intervening data byte
Register 18$_{HEX}$      Bit[3:0]        COMP diode data most significant data byte

### 3.11.10 INT_CFG

Address             19HEX
Default value       10HEX
Register access     RW

| Bit | 7 | 6 | [5:4] | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| 19HEX | 0 | 0 | LS_INT_SEL | LS_VAR_MODE | LS_INT_EN | 0 | 0 |

Bit[5:4] *LS_INT_SEL*     Light sensor (LS) interrupt source select
                          00    Reserved
                          01    ALS channel **(default)**
                          10    Reserved
                          11    UVB channel

Bit[3] *LS_VAR_MODE*      Light sensor variation interrupt mode
                          0     LS Threshold Interrupt Mode **(default)**
                          1     LS Variation Interrupt Mode

Bit[2] *LS_INT_EN*        Light sensor interrupt enable
                          0     LS interrupt disabled **(default)**
                          1     LS interrupt enabled

### 3.11.11 INT_PST

Address             1AHEX
Default value       00HEX
Register access     RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 1AHEX | | LS_PERSIST | | | 0 | 0 | 0 | 0 |

Bit[7:4]          *LS_PERSIST* sets the number of similar consecutive LS interrupt events that must occur before the interrupt is asserted.

        0000BIN     Every LS value out of threshold range asserts an interrupt **(default)**.
        0001BIN     2 consecutive LS values out of threshold range assert an interrupt.
        …
        1111BIN     16 consecutive LS values out of threshold range assert an interrupt.

Bit[3:0]          Reserved.

### 3.11.12 LS_THRES_UP

Address             21$_{HEX}$ and 22$_{HEX}$ and 23$_{HEX}$
Default value       FF$_{HEX}$ and FF$_{HEX}$ and 0F$_{HEX}$
Register access     RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|---|---|---|---|---|---|---|---|
| 21$_{HEX}$ | LS_THRES_UP_0 | | | | | | | |
| 22$_{HEX}$ | LS_THRES_UP_1 | | | | | | | |
| 23$_{HEX}$ | 0 | 0 | 0 | 0 | LS_THRES_UP_2 | | | |

*LS_THRES_UP_x* sets the upper threshold value for the LS interrupt. The interrupt controller compares the value in *LS_THRES_UP_x* against the measured data in the *\*_DATA_x* registers of the selected LS interrupt channel. It generates an interrupt event if *\*_DATA_x* exceeds the threshold level.

The data format for *LS_THRES_UP_x* must match that of the *\*_DATA_x* registers.

| | | |
|---|---|---|
| Register 21$_{HEX}$ | Bit[7:0] | LS upper interrupt threshold value, LSB |
| Register 22$_{HEX}$ | Bit[7:0] | LS upper interrupt threshold value, intervening byte |
| Register 23$_{HEX}$ | Bit[3:0] | LS upper interrupt threshold value, MSB |

### 3.11.13 LS_THRES_LOW

Address             24$_{HEX}$ and 25$_{HEX}$ and 26$_{HEX}$
Default value       00$_{HEX}$ and 00$_{HEX}$ and 00$_{HEX}$
Register access     RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|---|---|---|---|---|---|---|---|
| 24$_{HEX}$ | LS_THRES_LOW_0 | | | | | | | |
| 25$_{HEX}$ | LS_THRES_LOW_1 | | | | | | | |
| 26$_{HEX}$ | 0 | 0 | 0 | 0 | LS_THRES_LOW_2 | | | |

*LS_THRES_LOW_x* sets the lower threshold value for the LS interrupt. The interrupt controller compares the value in *LS_THRES_LOW_x* against the measured data in the *\*_DATA_x* registers of the selected LS interrupt channel. It generates an interrupt event if the *\*_DATA_x* is below the threshold level.

The data format for *LS_THRES_LOW_x* must match that of the *\*_DATA_x* registers.

| | | |
|---|---|---|
| Register 24$_{HEX}$ | Bit[7:0] | LS lower interrupt threshold value, LSB |
| Register 25$_{HEX}$ | Bit[7:0] | LS lower interrupt threshold value, intervening byte |
| Register 26$_{HEX}$ | Bit[3:0] | LS lower interrupt threshold value, MSB |

## 3.11.14 LS_THRES_VAR

| | |
|---|---|
| Address | 27$_{HEX}$ |
| Default value | 00$_{HEX}$ |
| Register access | RW |

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 27$_{HEX}$ | 0 | 0 | 0 | 0 | 0 | LS_THRES_VAR | | |

Bit[2:1]      LS variance threshold

| **Code** | Interrupt generated when |
|---|---|
| 000$_{BIN}$ | new DATA_x varies by **8 counts** compared to previous result **(default)** |
| 001$_{BIN}$ | new DATA_x varies by **16 counts** compared to previous result |
| 010$_{BIN}$ | new DATA_x varies by **32 counts** compared to previous result |
| 011$_{BIN}$ | new DATA_x varies by **64 counts** compared to previous result |
| 100$_{BIN}$ | new DATA_x varies by **128 counts** compared to previous result |
| 101$_{BIN}$ | new DATA_x varies by **256 counts** compared to previous result |
| 110$_{BIN}$ | new DATA_x varies by **512 counts** compared to previous result |
| 111$_{BIN}$ | new DATA_x varies by **1024 counts** compared to previous result |

### 3.11.15 DEVICE_CONFIG

Address              2F$_{HEX}$
Default value        00$_{HEX}$
Register access      RW

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 2F$_{HEX}$ | 0 | 0 | 0 | 0 | Reserved | Reserved | I²C Address | Reserved |

Bit[1]          I²C address
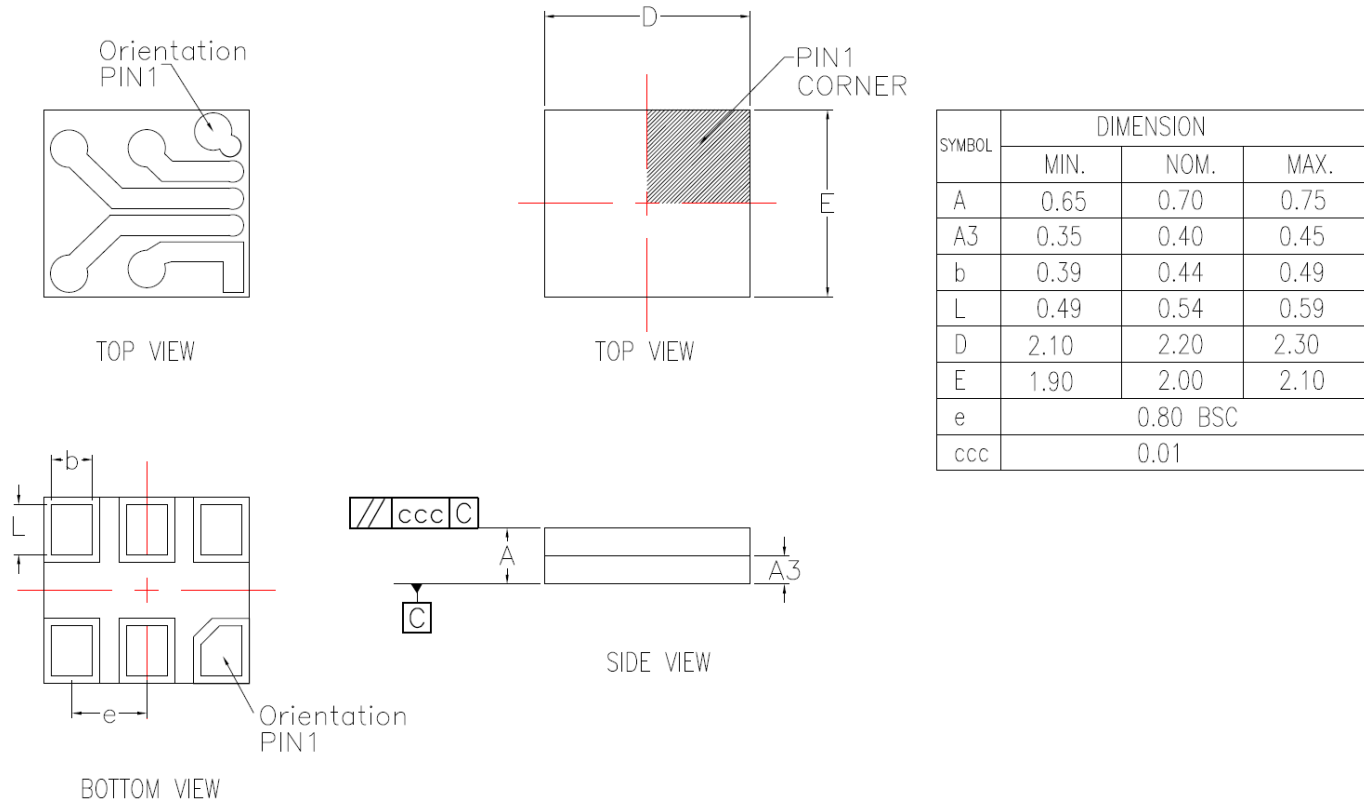                0 (**default**)   7-bit format (no R/W bit consideration):      53$_{HEX}$
                                  8-bit format (with R/W bit consideration):    A6$_{HEX}$ / A7$_{HEX}$

                1                 7-bit format (no R/W bit consideration):      52$_{HEX}$
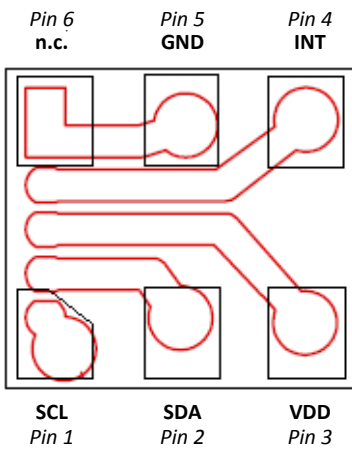                                  8-bit format (with R/W bit consideration):    A4$_{HEX}$ / A5$_{HEX}$

# 4. Packages

## 4.1 LGA6 Package (2.0 × 2.2 × 0.7 mm)

### 4.1.1 Mechanical Dimensions



| SYMBOL | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | 0.65 | 0.70 | 0.75 |
| A3 | 0.35 | 0.40 | 0.45 |
| b | 0.39 | 0.44 | 0.49 |
| L | 0.49 | 0.54 | 0.59 |
| D | 2.10 | 2.20 | 2.30 |
| E | 1.90 | 2.00 | 2.10 |
| e | 0.80 BSC | | |
| ccc | 0.01 | | |

### 4.1.2 Pin Assignment (Top View)



Pin 6 n.c.   Pin 5 GND   Pin 4 INT

SCL Pin 1   SDA Pin 2   VDD Pin 3
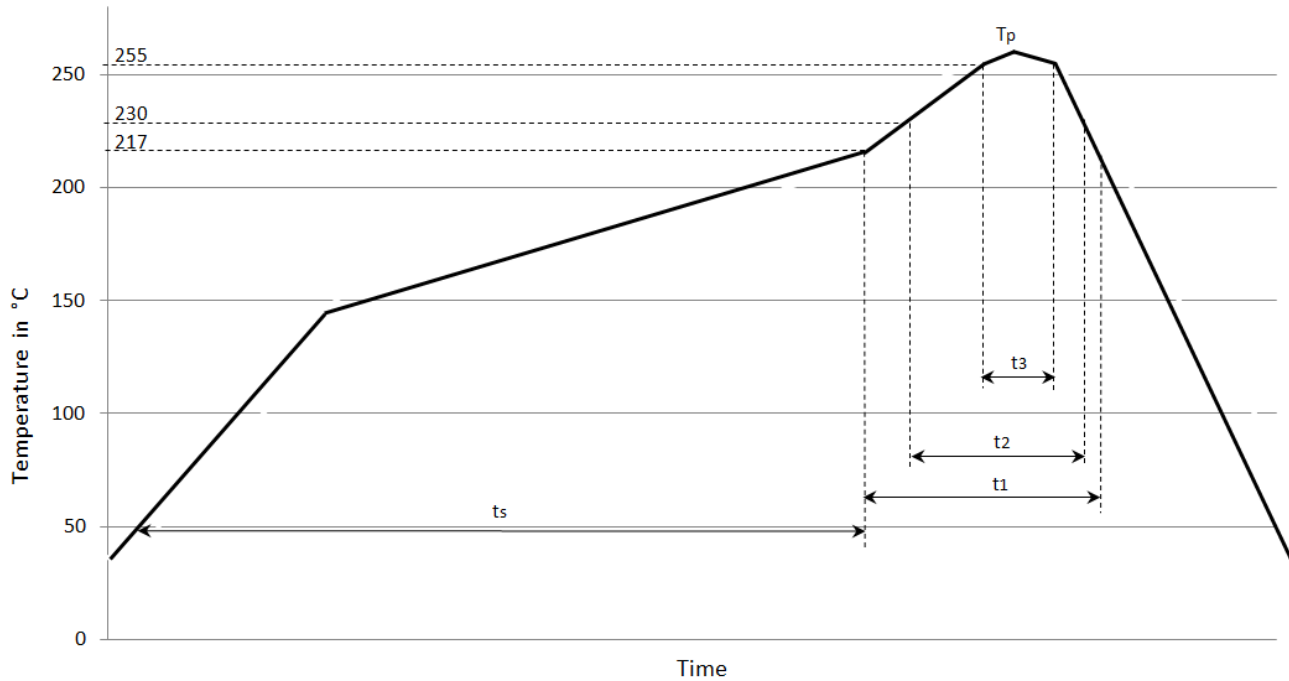
## 4.1.3 Reflow Profile



### Table 4.1 Reflow Profile Specification

| Parameter | Legend | Component |
|---|---|---|
| Time above 217°C | $t_1$ | ≤ 60 sec |
| Time above 230°C | $t_2$ | ≤ 50 sec |
| Time above 255°C | $t_3$ | ≤ 15 sec |
| Peak Temp | $T_p$ | ≤ 260°C |
| Soak Time (50°C – 217°C) | $t_s$ | ≤ 180 sec |
| Temperature Gradient Preheating | | < 3 °C/sec |
| Temperature Gradient Cooling | | < 5 °C/sec |

## 4.1.4    Tape Packaging Information
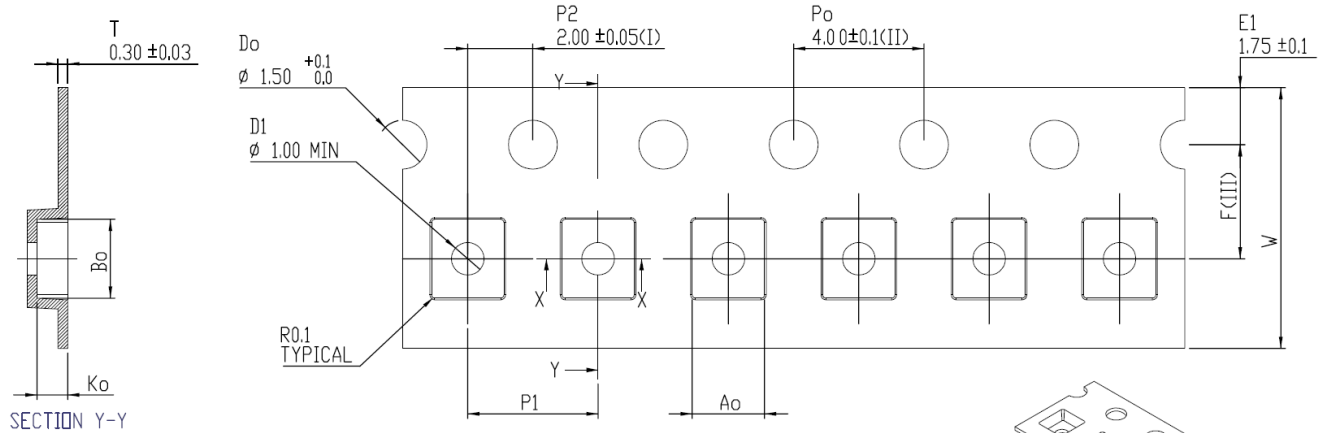


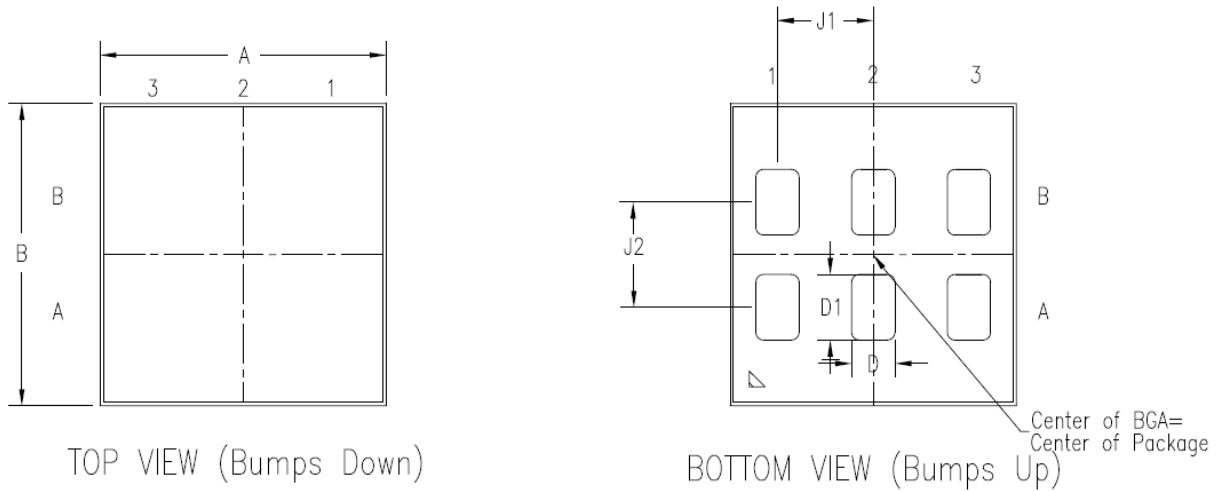| Ao | 2.22 +/- 0.1 |
|-----|-----|
| Bo | 2.42 +/- 0.1 |
| Ko | 0.95 +/- 0.1 |
| F | 3.50 +/- 0.05 |
| P1 | 4.00 +/- 0.1 |
| W | 8.00 +0.3/-0.1 |
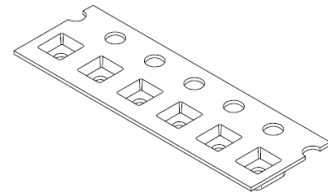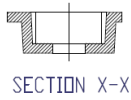
NOTES : (UNLESS OTHERWISE SPECIFIED)
1. SUPPLIER : C-PAK
2. SUPPLIER PART NUMBER : ODFN-2x2.2x0.7 (EM1089-16)
3. Po 10 PITCHES CUMULATIVE TOLERANCE ON TAPE : ±0.20 mm
4. REFER TO MSA-3018 FOR THE ALLOWABLE CAMBER REQUIREMENT.
5. MATERIAL : BLACK CONDUCTIVE POLYSTYRENE.
6. Ao AND Bo MEASURED FROM THE BOTTOM OF THE POCKET.
7. Ko MEASURED FROM A PLANE ON THE INSIDE BOTTOM OF THE POCKET TO THE TOP SURFACE OF THE CARRIER.
8. POCKET POSITION RELATIVE TO SPROCKET HOLE MEASURED AS TRUE POSITION OF POCKET, NOT POCKET HOLE.
9. POCKET CENTER AND POCKET HOLE CENTER MUST BE SAME POSITION.
10. REFER TO MAA-3092 & MSA-3018 FOR THE IDT STANDARD REQUIREMENT FOR CARRIER TAPE.
11. ALL THE DIMENSIONS ARE IN MILLIMETERS (MM).
12. LENGTH PER ROLL = 500 METERS.
13. ALLOWABLE CAMBER TO BE 2/250 MM MAXIMUM.

## 4.2    TSV Package (1.1 × 1.2 × 0.26 mm)

### 4.2.1    Mechanical Dimensions

Note: In the following mechanical diagram, the symbol N refers to the number of pins, N1 refers to the number of pin columns, and N2 refers to the number of rows.



Mechanical Diagram

TOP VIEW (Bumps Down)

BOTTOM VIEW (Bumps Up)

Center of BGA=
Center of Package

SIDE VIEW

NOTE:
1. DIMENSIONS in um.
2. The thickness of Bond-1 glass is 100 um (green glass x 1pcs).
3. The material of solder printing is SAC305.

| SYMBOL | PACKAGE DIMENSIONS | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | 1065 | 1090 | 1115 |
| B | 1125 | 1150 | 1175 |
| C | 203 | 263 | 323 |
| C1 | 5 | 10 | 15 |
| C2 | 218 | 263 | 308 |
| C3 | 125 | 145 | 165 |
| D | 135 | 165 | 195 |
| D1 | 250 | 280 | 310 |
| N | 6 (INC) | | |
| N1 | 3 | | |
| N2 | 2 | | |
| J1 | | 365 | |
| J2 | | 400 | |

# 5. Part Order Information

| Product Sales Code | Description | Delivery Package |
|---|---|---|
| ZOPT2201AC5R | ZOPT2201 LGA6 – Temperature range: -40 to +90°C | Reel |
| ZOPT2201AC9R | ZOPT2201 TSV – Temperature range: -40 to +90°C | Reel |
| ZOPT2201KIT V1.0 | ZOPT2201 Evaluation Kit, including ZOPT Control Board, mini-USB cable, and 1 ZOPT2201 sample mounted on the LGA6 Sensor Board; kit software is available for free download –  see the *ZOPT Evaluation Kit Quick Start Guide* included in the kit for instructions. | |

# 6. Glossary

| Term | Description |
|---|---|
| ADC | Analog-to -Digital Converter |
| ALS | Ambient Light Sensor |
| LGA | Land-Grid Array (package type) |
| LS | Light Sensor (can be either ALS or UVBS depending on the ZOPT2201 configuration) |
| NVM | Non-volatile Memory |
| SDA | Serial Data |
| SCL | Serial Clock |
| SW | Software |
| TSV | Through-Silicon Vias (package type) |
| UVBS | UVB Energy Sensor |

# 7. Document Revision History

| Revision Date | Description |
|---|---|
| September 2, 2016 | <ul><li>Update for UVBS sensitivity.</li><li>Addition of ALS/UVBS_Raw Mode as described in sections 3.4, 3.6, and 3.11.1; addition of ALS/UVBS_Raw Mode current consumption specifications in section 1.3.</li><li>Updates for Figure 3.3 and Figure 3.5.</li><li>Revision of name for bit 3 in the MAIN_CTRL register from *UVBS_Mode* to *LS_Mode*.</li><li>Addition of new package type TSV and TSV package information (see new section 4.2).</li><li>Addition of reflow profile for LGA6 package.</li><li>Update for "Mechanical Dimensions" drawing for LGA6.</li><li>Added new section 4.1.4 for tape packaging information.</li><li>Minor edits for clarity and formatting.</li></ul> |
| April 4, 2016 | Rebranding for IDT. Revision number is replaced by release date. |
| March 7, 2016 (Revision 1.00) | First release. |

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