



# THE DATASHEET OF TSL27723FN

# TSL2772

## Light-to-Digital Converter with Proximity Sensing

### General Description

The TSL2772 device family provides both ambient light sensing (ALS) and, when coupled with an external IR LED, proximity detection. The device family is based on the **ams** patented dual-diode technology that enables accurate ALS results and approximates human eye response to light intensity under a variety of lighting conditions.

The TSL2772 ALS includes a reduced-gain mode that extends the operating range to 60k lux in sunlight. The device package incorporates a UV-rejection filter that enables accurate ALS. The TSL2772 proximity detection includes improved signal-to-noise performance and selectable gain modes. A proximity offset register allows compensation for optical system crosstalk between the IR LED and the sensor. To prevent false proximity data measurement readings, a proximity saturation indicator bit signals that the internal analog circuitry has reached saturation.

*Ordering Information and Content Guide appear at end of datasheet.*

### Key Benefits & Features

The benefits and features of TSL2772, Light-to-Digital Converter with Proximity Sensing are listed below:

**Figure 1:**  
**Added Value Of Using TSL2772**

| Benefits                                                                                                                                            | Features                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Enables Operation in IR Light Environments</li></ul>                                                        | <ul style="list-style-type: none"><li>• Patented Dual-Diode Architecture</li></ul>   |
| <ul style="list-style-type: none"><li>• Enables Operation in 60K Lux Sunlight and Accurate Sensing Behind Spectrally Distorting Materials</li></ul> | <ul style="list-style-type: none"><li>• 8M:1 Dynamic Range</li></ul>                 |
| <ul style="list-style-type: none"><li>• Improves Lux Accuracy Across Varying Light Sources</li></ul>                                                | <ul style="list-style-type: none"><li>• UV-Rejection Package</li></ul>               |
| <ul style="list-style-type: none"><li>• Compensates for Internal System Offset or IR LED Crosstalk</li></ul>                                        | <ul style="list-style-type: none"><li>• Proximity Offset Adjustment</li></ul>        |
| <ul style="list-style-type: none"><li>• Prevents False Proximity Detection in Bright Light</li></ul>                                                | <ul style="list-style-type: none"><li>• Proximity Saturation Indicator Bit</li></ul> |

- Ambient Light Sensing and Proximity Detection in a Single Device
- Ambient Light Sensing (ALS)
  - Approximates Human Eye Response
  - Programmable Analog Gain and Integration Time
  - 8000000:1 Dynamic Range
  - Operation to 60000 lux in Sunlight
  - Very High Sensitivity — Ideally Suited for Operation Behind Dark Glass
  - Package UV Rejection Filter
- Proximity Detection
  - Programmable Analog Gain, Integration Time, and Offset
  - Current Sink Driver for External IR LED
  - Saturation Indicator
  - 16000:1 Dynamic Range
- Maskable ALS and Proximity Interrupt
  - Programmable Upper and Lower Thresholds with Persistence Filter
- Power Management
  - Low Power 2.2µA Sleep State with User-Selectable Sleep-After-Interrupt Mode
  - 90 µA Wait State with Programmable Wait Time from 2.7 ms to > 8 seconds
- I<sup>2</sup>C Fast Mode Compatible Interface
  - Data Rates up to 400 kbit/s
  - Input Voltage Levels Compatible with V<sub>DD</sub> or 1.8-V Bus
- Register Set- and Pin-Compatible with the TSL2x71 Series
- Small 2 mm × 2 mm Dual Flat No-Lead (FN) Package

## Applications

TSL2772, Light-to-Digital Converter with Proximity Sensing is ideal for:

- Display Backlight Control
- Cell Phone Touch Screen Disable
- Mechanical Switch Replacement
- Industrial Process Control
- Medical Diagnostics
- Printer Paper Alignment

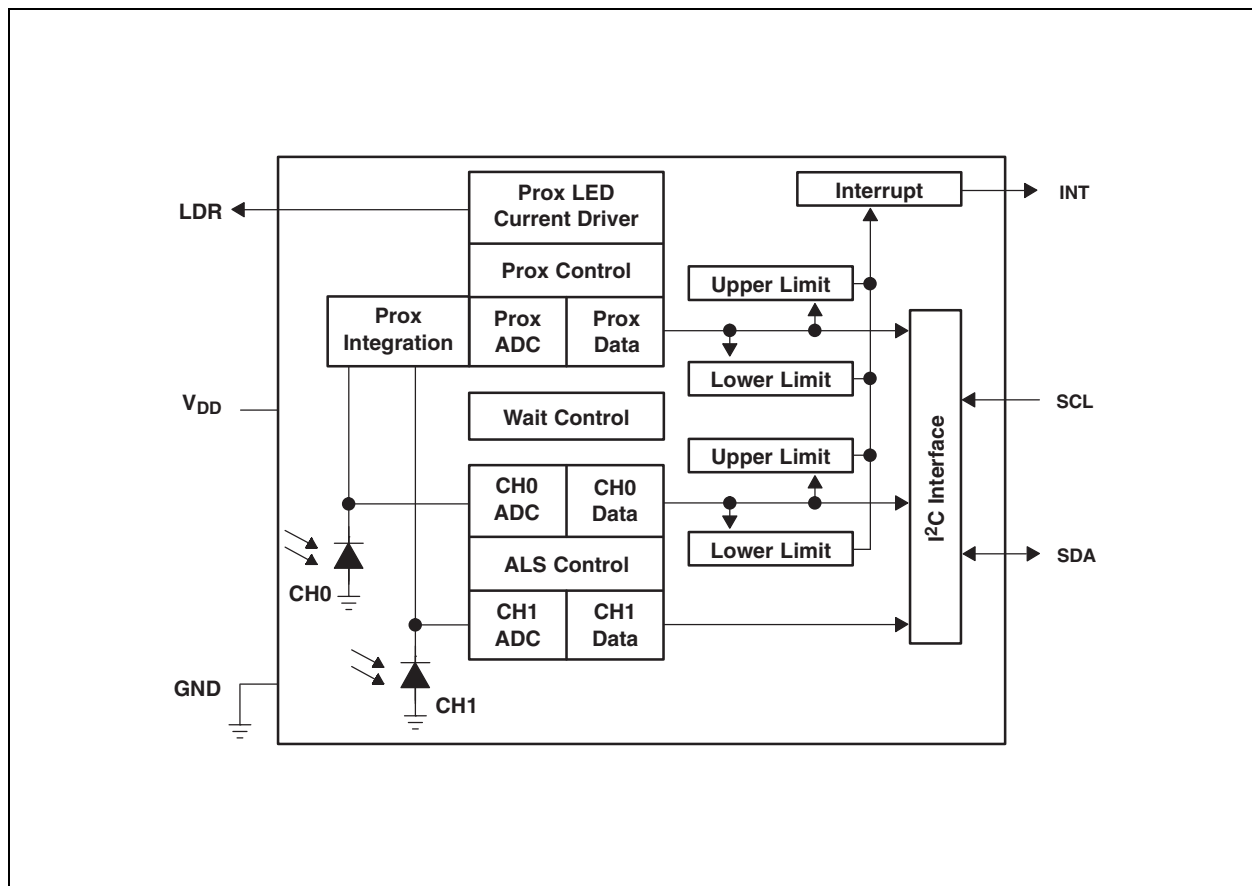
## End Products and Market Segments

- Mobile Handsets, Tablets, Laptops, HDTVs, Monitors, and PMP (Portable Media Players)
- Medical and Industrial Instrumentation
- White Goods
- Toys
- Industrial/Commercial Lighting
- Digital Signage
- Printers

## Block Diagram

The functional blocks of this device are shown below:

**Figure 2:**  
TSL2772 Block Diagram



## Detailed Description

The TSL2772 light-to-digital device provides on-chip photodiodes, integrating amplifiers, ADCs, accumulators, clocks, buffers, comparators, a state machine, and an I<sup>2</sup>C interface. Each device combines a Channel 0 photodiode (CH0), which is responsive to both visible and infrared light, and a channel 1 photodiode (CH1), which is responsive primarily to infrared light. Two integrating ADCs simultaneously convert the amplified photodiode currents into a digital value providing up to 16 bits of resolution. Upon completion of the conversion cycle, the conversion result is transferred to the data registers. This digital output can be read by a microprocessor through which the illuminance (ambient light level) in Lux is derived using an empirical formula to approximate the human eye response.

Communication to the device is accomplished through a fast (up to 400 kHz), two-wire I<sup>2</sup>C serial bus for easy connection to a microcontroller or embedded controller. The digital output of the device is inherently more immune to noise when compared to an analog interface.

The device provides a separate pin for level-style interrupts. When interrupts are enabled and a pre-set value is exceeded, the interrupt pin is asserted and remains asserted until cleared by the controlling firmware. The interrupt feature simplifies and improves system efficiency by eliminating the need to poll a sensor for a light intensity or proximity value. An interrupt is generated when the value of an ALS or proximity conversion exceeds either an upper or lower threshold. In addition, a programmable interrupt persistence feature allows the user to determine how many consecutive exceeded thresholds are necessary to trigger an interrupt. Interrupt thresholds and persistence settings are configured independently for both ALS and proximity.

Proximity detection requires only a single external IR LED. An internal LED driver can be configured to provide a constant current sink of 15 mA, 30 mA, 60 mA, or 120 mA of current. No external current limiting resistor is required. The power can also be reduced by a factor of 8 with the PDL bit. The number of proximity LED pulses can be programmed from 1 to 255 pulses. Each pulse has a 16-μs period. The programmable LED current, coupled with the programmable number of pulses, provides a 16000:1 contiguous dynamic range.

## Pin Assignments

The TSL2772 pin assignments are described below:

**Figure 3:**  
**Package FN Dual Flat No-Lead (Top View)**

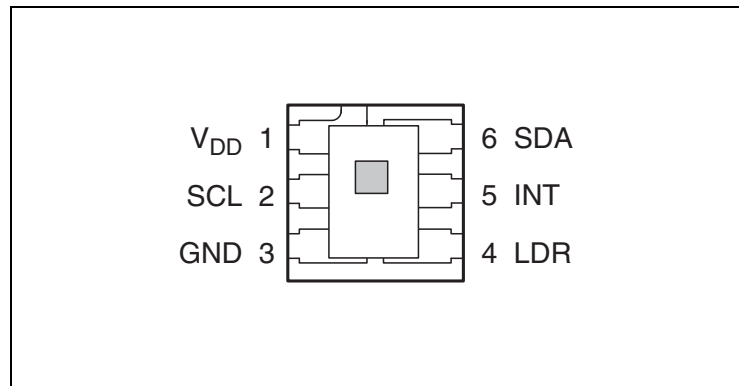


**Figure 4:**  
**Terminal Functions**

| Terminal        |    | Type | Description                                                                                   |
|-----------------|----|------|-----------------------------------------------------------------------------------------------|
| Name            | No |      |                                                                                               |
| V <sub>DD</sub> | 1  |      | Supply voltage.                                                                               |
| SCL             | 2  | I    | I <sup>2</sup> C serial clock input terminal — clock signal for I <sup>2</sup> C serial data. |
| GND             | 3  |      | Power supply ground. All voltages are referenced to GND.                                      |
| LDR             | 4  | O    | LED driver for proximity emitter — open drain.                                                |
| INT             | 5  | O    | Interrupt — open drain (active low).                                                          |
| SDA             | 6  | I/O  | I <sup>2</sup> C serial data I/O terminal — serial data I/O for I <sup>2</sup> C.             |

## Absolute Maximum Ratings

Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under [Recommended Operating Conditions](#) is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**Figure 5:**  
**Absolute Maximum Ratings Over Operating Free-Air Temperature Range (unless otherwise noted)**

| Symbol         | Parameter                            | Min        | Max | Units |
|----------------|--------------------------------------|------------|-----|-------|
| $V_{DD}^{(1)}$ | Supply voltage                       |            | 3.8 | V     |
|                | Input terminal voltage               | -0.5       | 3.8 | V     |
|                | Output terminal voltage (except LDR) | -0.5       | 3.8 | V     |
|                | Output terminal voltage (LDR)        |            | 3.8 | V     |
|                | Output terminal current (except LDR) | -1         | 20  | mA    |
| $T_{STRG}$     | Storage temperature range            | -40        | 85  | °C    |
| $ESD_{HBM}$    | ESD tolerance, human body model      | $\pm 2000$ |     | V     |

**Note(s):**

1. All voltages are with respect to GND.

**Figure 6:**  
**Recommended Operating Conditions**

| Symbol   | Parameter                      | Conditions                                        | Min | Nom | Max | Unit |
|----------|--------------------------------|---------------------------------------------------|-----|-----|-----|------|
| $V_{DD}$ | Supply voltage                 | (TSL27721 & TSL27725) ( $I^2C V_{bus} = V_{DD}$ ) | 2.4 | 3   | 3.6 | V    |
| $V_{DD}$ | Supply voltage                 | (TSL27723 & TSL27727) ( $I^2C V_{bus} = 1.8 V$ )  | 2.7 | 3   | 3.6 | V    |
| $T_A$    | Operating free-air temperature |                                                   | -30 |     | 70  | °C   |

**Figure 7:**  
**Operating Characteristics,  $V_{DD} = 3\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

| Symbol     | Parameter                           | Test Conditions                            | Min          | Typ | Max          | Unit          |
|------------|-------------------------------------|--------------------------------------------|--------------|-----|--------------|---------------|
| $I_{DD}$   | Supply current                      | Active — LDR pulse OFF                     |              | 200 | 250          | $\mu\text{A}$ |
|            |                                     | Wait state                                 |              | 90  |              |               |
|            |                                     | Sleep state - no I <sup>2</sup> C activity |              | 2.2 | 4            |               |
| $V_{OL}$   | INT, SDA output low voltage         | 3 mA sink current                          | 0            |     | 0.4          | V             |
|            |                                     | 6 mA sink current                          | 0            |     | 0.6          |               |
| $I_{LEAK}$ | Leakage current, SDA, SCL, INT pins |                                            | -5           |     | 5            | $\mu\text{A}$ |
| $I_{LEAK}$ | Leakage current, LDR pin            |                                            | -5           |     | 5            | $\mu\text{A}$ |
| $V_{IH}$   | SCL, SDA input high voltage         | TSL27721, TSL27725                         | $0.7 V_{DD}$ |     |              | V             |
|            |                                     | TSL27723, TSL27727                         | 1.25         |     |              |               |
| $V_{IL}$   | SCL, SDA input low voltage          | TSL27721, TSL27725                         |              |     | $0.3 V_{DD}$ | V             |
|            |                                     | TSL27723, TSL27727                         |              |     | 0.54         |               |

**Figure 8:**  
ALS Characteristics,  $V_{DD} = 3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , AGAIN = 16x, AEN = 1 (unless otherwise noted)

| Parameter                                      | Test Conditions                                                                                                      | Channel | Min   | Typ   | Max   | Unit                                     |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------|-------|-------|-------|------------------------------------------|
| Dark ADC count value                           | $E_e = 0$ , AGAIN = 120x,<br>ATIME = 0xDB (100 ms)                                                                   | CH0     | 0     | 1     | 5     | counts                                   |
|                                                |                                                                                                                      | CH1     | 0     | 1     | 5     |                                          |
| ADC integration time step size                 | ATIME = 0xFF                                                                                                         |         | 2.58  | 2.73  | 2.9   | ms                                       |
| ADC Number of integration steps <sup>(4)</sup> |                                                                                                                      |         | 1     |       | 256   | steps                                    |
| ADC counts per step <sup>(4)</sup>             | ATIME = 0xFF                                                                                                         |         | 0     |       | 1024  | counts                                   |
| ADC count value <sup>(4)</sup>                 | ATIME = 0xC0                                                                                                         |         | 0     |       | 65535 | counts                                   |
| ADC count value                                | White Light, $E_e = 263.9\text{ }\mu\text{W}/\text{cm}^2$ ,<br>ATIME = 0xF6 (27 ms). <sup>(2)</sup>                  | CH0     | 4000  | 5000  | 6000  | counts                                   |
|                                                |                                                                                                                      | CH1     |       | 680   |       |                                          |
|                                                | $\lambda_p = 850\text{ nm}$ , $E_e = 263.4\text{ }\mu\text{W}/\text{cm}^2$ ,<br>ATIME = 0xF6 (27 ms). <sup>(3)</sup> | CH0     | 4000  | 5000  | 6000  |                                          |
|                                                |                                                                                                                      | CH1     |       | 2850  |       |                                          |
| ADC count value ratio:<br>CH1/CH0              | White Light, ATIME 0xF6 (27 ms) <sup>(2)</sup>                                                                       |         | 0.086 | 0.136 | 0.186 |                                          |
|                                                | $\lambda_p = 850\text{ nm}$ , ATIME 0xF6 (27 ms) <sup>(3)</sup>                                                      |         | 0.456 | 0.570 | 0.684 |                                          |
| $R_e$<br>Irradiance responsivity               | White Light, ATIME =<br>0xF6 (27 ms) <sup>(2)</sup>                                                                  | CH0     |       | 18.9  |       | counts/<br>( $\mu\text{W}/\text{cm}^2$ ) |
|                                                |                                                                                                                      | CH1     |       | 2.58  |       |                                          |
|                                                | $\lambda_p = 850\text{ nm}$ , ATIME =<br>0xF6 (27 ms) <sup>(3)</sup>                                                 | CH0     |       | 19.0  |       |                                          |
|                                                |                                                                                                                      | CH1     |       | 10.8  |       |                                          |
| Gain scaling, relative to 1x<br>gain setting   | AGAIN = 1x and AGL = 1                                                                                               |         | 0.128 | 0.16  | 0.192 | x                                        |
|                                                | AGAIN = 8x and AGL = 0                                                                                               |         | 7.2   | 8.0   | 8.8   |                                          |
|                                                | AGAIN = 16x and AGL = 0                                                                                              |         | 14.4  | 16.0  | 17.6  |                                          |
|                                                | AGAIN = 120x and AGL = 0                                                                                             |         | 108   | 120   | 132   |                                          |

**Note(s):**

- Optical measurements are made using small-angle incident radiation from light-emitting diode optical sources. Visible white LEDs and infrared 850 nm LEDs are used for final product testing for compatibility with high-volume production.
- The white LED irradiance is supplied by a white light-emitting diode with a nominal color temperature of 4000k.
- The 850 nm irradiance  $E_e$  is supplied by a GaAs light-emitting diode with the following typical characteristics: peak wavelength  $\lambda_p = 850\text{ nm}$  and spectral halfwidth  $\Delta\lambda_{1/2} = 42\text{ nm}$ .
- Parameter ensured by design and is not tested.

**Figure 9:**  
**Proximity Characteristics,  $V_{DD} = 3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , PGAIN = 1x, PEN = 1 (unless otherwise noted)**

| Parameter                                         | Test Conditions                                                                                  |                              | Min  | Typ  | Max  | Unit                                     |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------|------------------------------|------|------|------|------------------------------------------|
| $I_{DD}$<br>Supply current                        | LDR pulse ON                                                                                     |                              |      | 3    |      | mA                                       |
| ADC conversion<br>time step size                  | PTIME = 0xFF                                                                                     |                              | 2.58 | 2.73 | 2.9  | ms                                       |
| ADC number of<br>integration steps <sup>(1)</sup> |                                                                                                  |                              | 1    |      | 256  | steps                                    |
| ADC counts per<br>step <sup>(1)</sup>             | PTIME = 0xFF                                                                                     |                              | 0    |      | 1023 | counts                                   |
| ADC count value                                   | $\lambda_p = 850\text{ nm}$ , $E_e = 263.4\mu\text{W}/\text{cm}^2$ ,<br>PTIME = 0xFB, PPULSE = 4 | CH0 diode                    | 1500 | 2000 | 2500 | counts                                   |
|                                                   |                                                                                                  | CH1 diode                    | 900  | 1200 | 1500 |                                          |
| ADC output<br>responsivity                        | $\lambda_p = 850\text{ nm}$ , PTIME = 0xFB,<br>PPULSE = 1                                        | CH0 diode                    |      | 1.90 |      | counts/<br>( $\mu\text{W}/\text{cm}^2$ ) |
|                                                   |                                                                                                  | CH1 diode                    |      | 1.14 |      |                                          |
| Gain scaling,<br>relative to 1x gain<br>setting   | PGAIN = 2x                                                                                       |                              |      | 2    |      | x                                        |
|                                                   | PGAIN = 4x                                                                                       |                              |      | 4    |      |                                          |
|                                                   | PGAIN = 8x                                                                                       |                              |      | 8    |      |                                          |
| Noise <sup>(1)(2)(3)</sup>                        | $E_e = 0$ , PTIME = 0xFB, PPULSE = 4 <sup>(6)</sup>                                              | CH0 diode                    |      | 0.5  |      | %FS                                      |
|                                                   |                                                                                                  | CH1 diode                    |      | 0.5  |      |                                          |
| LED pulse count <sup>(1)</sup>                    |                                                                                                  |                              | 0    |      | 255  | pulses                                   |
| LED pulse period                                  |                                                                                                  |                              |      | 16.0 |      | $\mu\text{s}$                            |
| LED pulse width —<br>LED ON time                  |                                                                                                  |                              |      | 7.3  |      | $\mu\text{s}$                            |
| LED drive current                                 | $I_{SINK}$ sink current<br>@ 1.6 V, LDR pin                                                      | 120 mA: PDRIVE = 0 & PDL = 0 | 87   | 116  | 145  | mA                                       |
|                                                   |                                                                                                  | 60 mA: PDRIVE = 1 & PDL = 0  |      | 58   |      |                                          |
|                                                   |                                                                                                  | 30 mA: PDRIVE = 2 & PDL = 0  |      | 29   |      |                                          |
|                                                   |                                                                                                  | 15 mA: PDRIVE = 3 & PDL = 0  |      | 14.5 |      |                                          |
|                                                   |                                                                                                  | 15 mA: PDRIVE = 0 & PDL = 1  |      | 12.9 |      |                                          |
|                                                   |                                                                                                  | 7.5 mA: PDRIVE = 1 & PDL = 1 |      | 6.4  |      |                                          |
|                                                   |                                                                                                  | 3.8 mA: PDRIVE = 2 & PDL = 1 |      | 3.2  |      |                                          |
|                                                   |                                                                                                  | 1.9 mA: PDRIVE = 3 & PDL = 1 |      | 1.6  |      |                                          |

| Parameter                               | Test Conditions                                                                                                                                                                                                                                 | Min | Typ | Max | Unit   |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|--------|
| Maximum operating distance<br>(1)(4)(5) | PDRIVE = 0 and PDL = 0 (116 mA), PPULSE = 64<br><br>Emitter: $\lambda_p = 850$ nm, 20° half angle, and 60 mW/sr<br>Object: 16 × 20-inch, 90% reflective Kodak Gray Card (white surface)<br>Optics: Open view (no glass, no optical attenuation) |     | 18  |     | inches |

**Note(s):**

1. Parameter is ensured by design or characterization and is not tested.
2. Proximity noise is defined as one standard deviation of 600 samples.
3. Proximity noise typically increases as  $\sqrt{PPULSE}$
4. Greater operating distances are achievable with appropriate optical system design considerations. See available **ams** application notes for additional information.
5. Maximum operating distance is dependent upon emitter and the reflective properties of the object's surface.
6. Proximity noise test was done using [Figure 10](#).

**Figure 10:**  
Proximity Noise Test Circuit

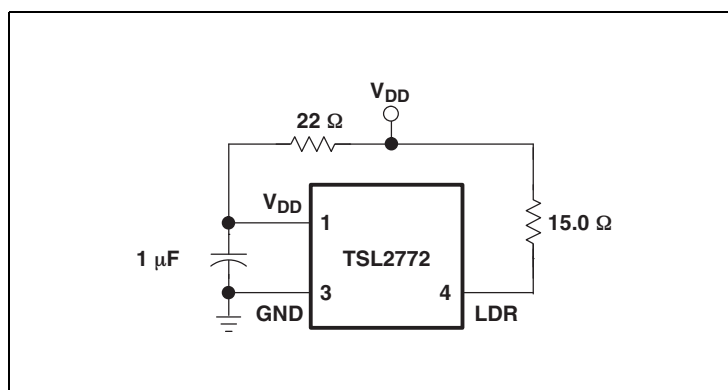


**Figure 11:**  
Wait Characteristics,  $V_{DD} = 3$  V,  $T_A = 25^\circ\text{C}$ , WEN = 1 (unless otherwise noted)

| Parameter                                       | Test Conditions | Channel | Min  | Typ  | Max | Unit  |
|-------------------------------------------------|-----------------|---------|------|------|-----|-------|
| Wait step size                                  | WTIME = 0xFF    |         | 2.58 | 2.73 | 2.9 | ms    |
| Wait number of integration steps <sup>(1)</sup> |                 |         | 1    |      | 256 | steps |

**Note(s):**

1. Parameter ensured by design and is not tested.

**Figure 12:**  
**AC Electrical Characteristics,  $V_{DD} = 3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , (unless otherwise noted)**

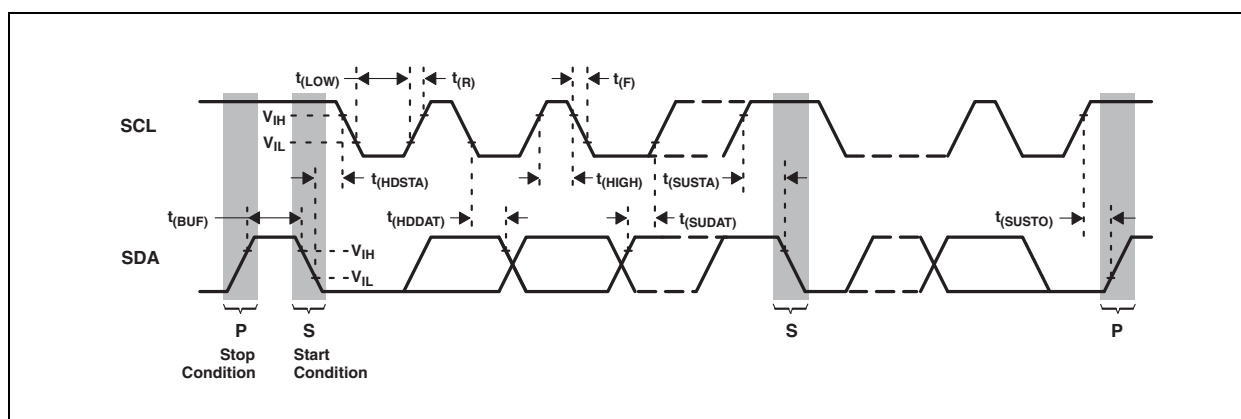
| Symbol        | Parameter <sup>(1)</sup>                                                                     | Test Conditions | Min | Typ | Max | Unit          |
|---------------|----------------------------------------------------------------------------------------------|-----------------|-----|-----|-----|---------------|
| $f_{(SCL)}$   | Clock frequency (I <sup>2</sup> C only)                                                      |                 | 0   |     | 400 | kHz           |
| $t_{(BUF)}$   | Bus free time between start and stop condition                                               |                 | 1.3 |     |     | $\mu\text{s}$ |
| $t_{(HDSTA)}$ | Hold time after (repeated) start condition. After this period, the first clock is generated. |                 | 0.6 |     |     | $\mu\text{s}$ |
| $t_{(SUSTA)}$ | Repeated start condition setup time                                                          |                 | 0.6 |     |     | $\mu\text{s}$ |
| $t_{(SUSTO)}$ | Stop condition setup time                                                                    |                 | 0.6 |     |     | $\mu\text{s}$ |
| $t_{(HDDAT)}$ | Data hold time                                                                               |                 | 0   |     |     | $\mu\text{s}$ |
| $t_{(SUDAT)}$ | Data setup time                                                                              |                 | 100 |     |     | ns            |
| $t_{(LOW)}$   | SCL clock low period                                                                         |                 | 1.3 |     |     | $\mu\text{s}$ |
| $t_{(HIGH)}$  | SCL clock high period                                                                        |                 | 0.6 |     |     | $\mu\text{s}$ |
| $t_F$         | Clock/data fall time                                                                         |                 |     |     | 300 | ns            |
| $t_R$         | Clock/data rise time                                                                         |                 |     |     | 300 | ns            |
| $C_i$         | Input pin capacitance                                                                        |                 |     |     | 10  | pF            |

**Note(s):**

1. Specified by design and characterization; not production tested.

## Parameter Measurement Information

**Figure 13:**  
**Timing Diagrams**



## Typical Characteristics

Figure 14:  
Spectral Responsivity

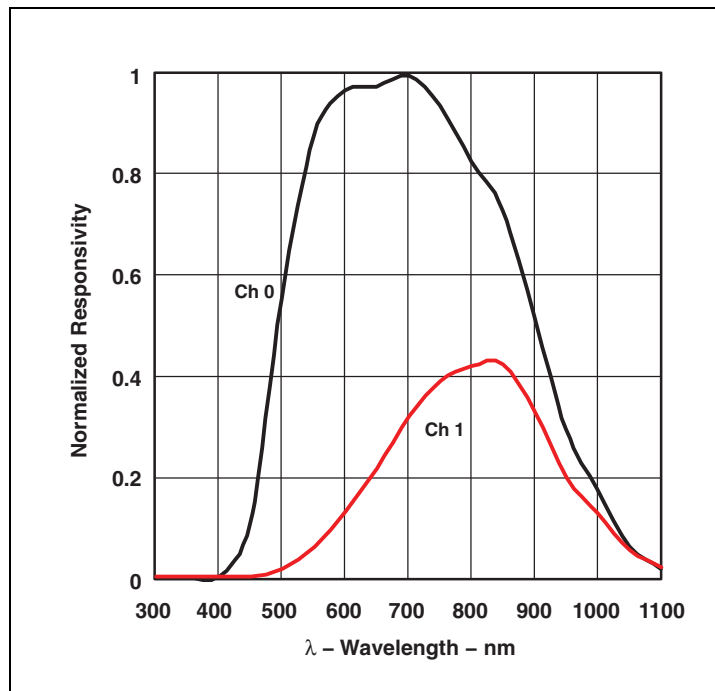


Figure 15:  
Normalized Responsivity vs. Angular Displacement

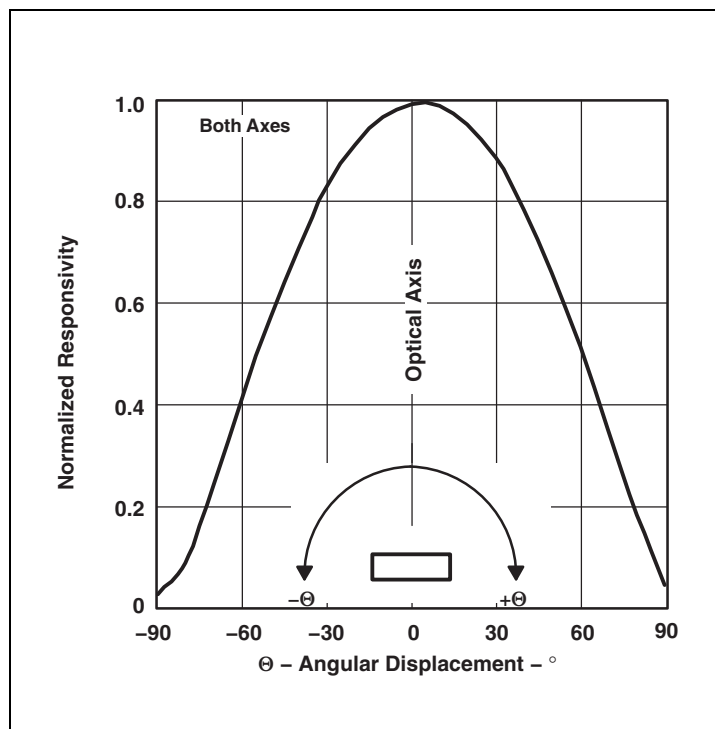


Figure 16:  
Typical LDR Current vs. Voltage

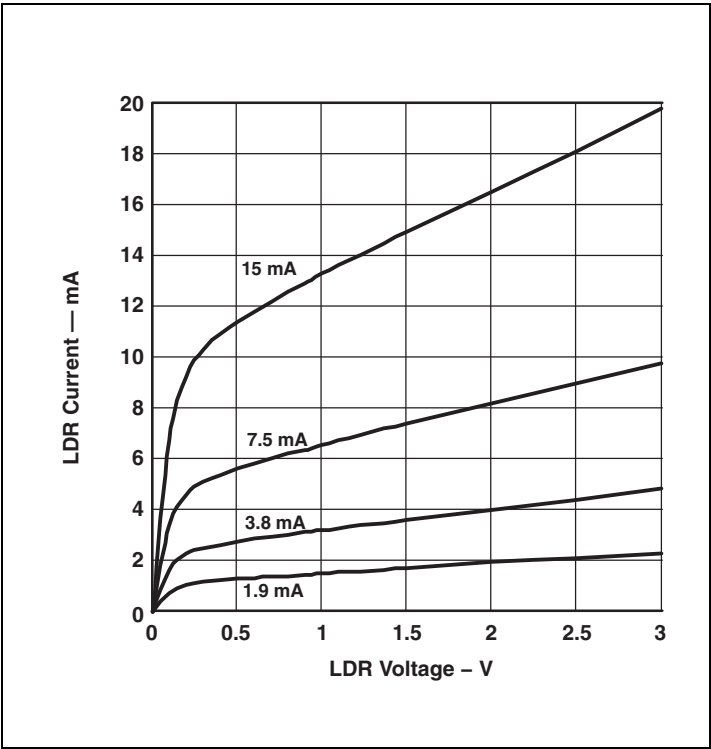


Figure 17:  
Typical LDR Current vs. Voltage

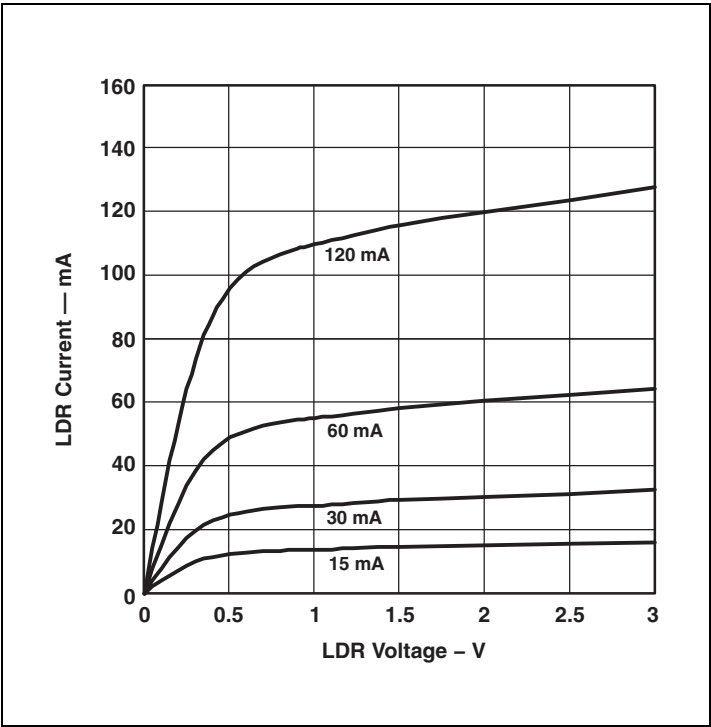


**Figure 18:**  
Response to White LED vs. Temperature

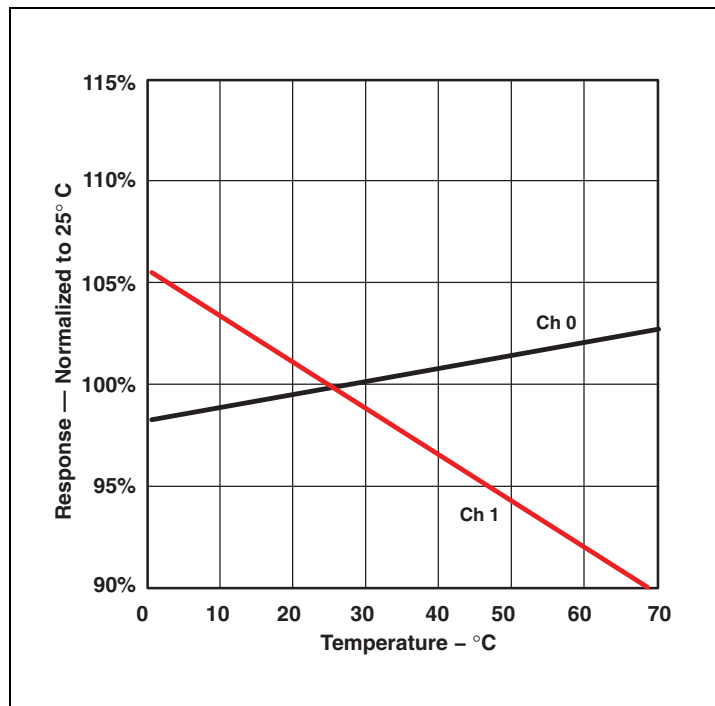


**Figure 19:**  
Response to IR (850 nm) LED vs. Temperature

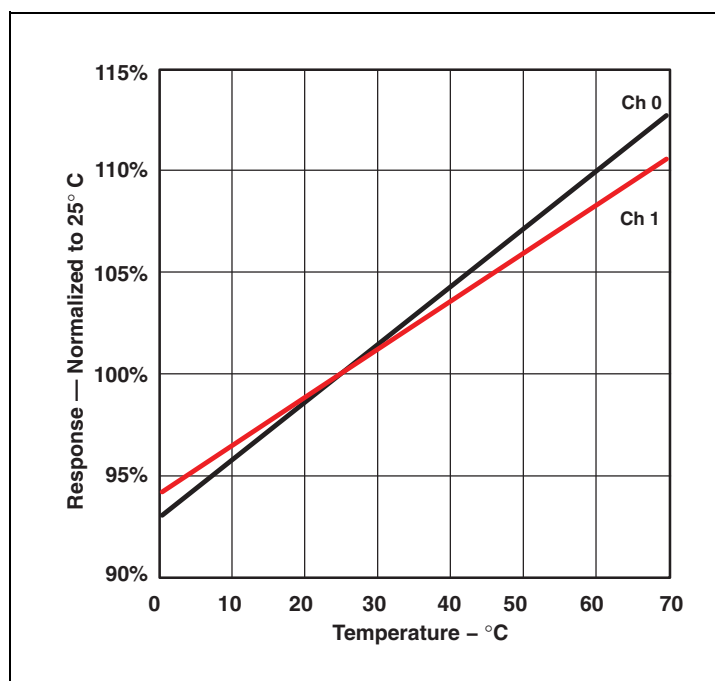
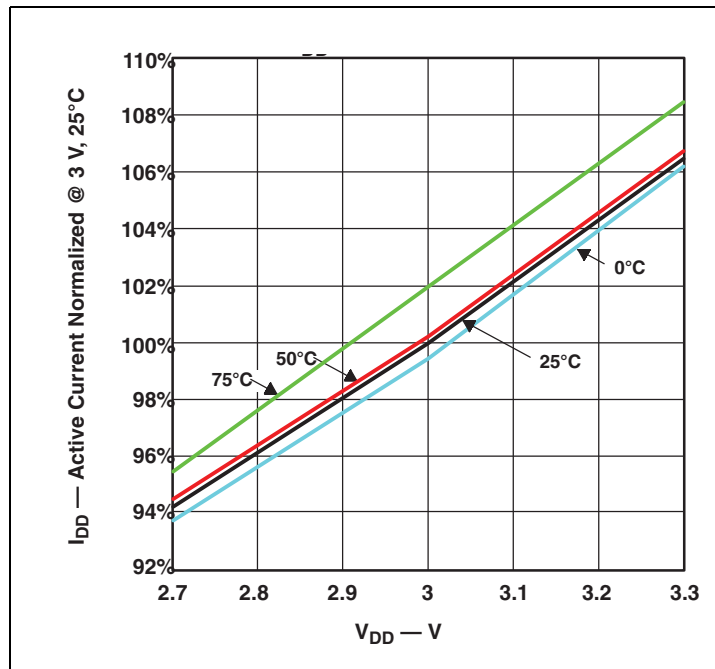


**Figure 20:**  
Normalized  $I_{DD}$  vs.  $V_{DD}$  and Temperature



## Principles Of Operation

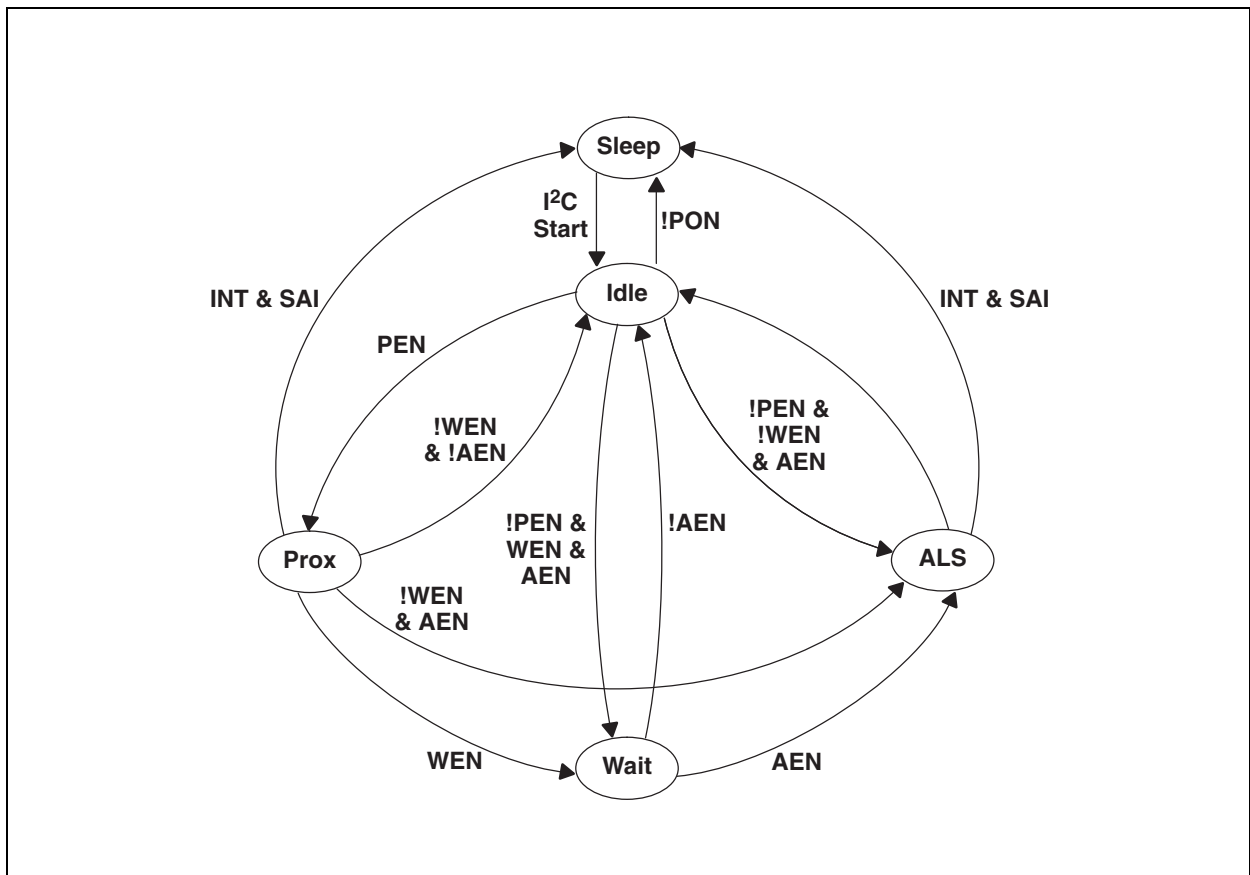
### System State Machine

An internal state machine provides system control of the ALS, proximity detection, and power management features of the device. At power up, an internal power-on-reset initializes the device and puts it in a low-power Sleep state.

When a start condition is detected on the I<sup>2</sup>C bus, the device transitions to the Idle state where it checks the Enable register (0x00) PON bit. If PON is disabled, the device will return to the Sleep state to save power. Otherwise, the device will remain in the Idle state until a proximity or ALS function is enabled. Once enabled, the device will execute the Prox, Wait, and ALS states in sequence as indicated in Figure 21. Upon completion and return to Idle, the device will automatically begin a new prox-wait-ALS cycle as long as PON and either PEN or AEN remain enabled.

If the Prox or ALS function generates an interrupt and the Sleep-After-Interrupt (SAI) feature is enabled, the device will transition to the Sleep state and remain in a low-power mode until an I<sup>2</sup>C command is received. See the Interrupts section for additional information.

Figure 21:  
Simplified State Diagram



## Photodiodes

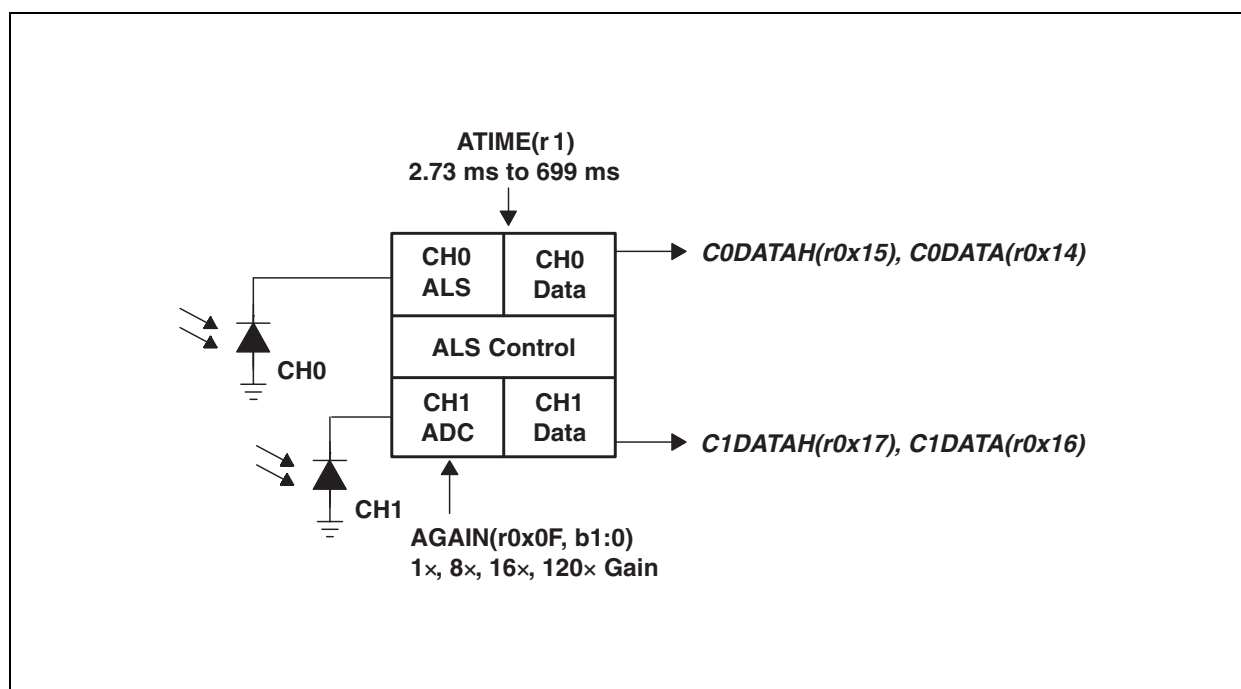
Conventional ALS detectors respond strongly to infrared light, which the human eye does not see. This can lead to significant error when the infrared content of the ambient light is high (such as with incandescent lighting).

This problem is overcome through the use of two photodiodes. The Channel 0 photodiode, referred to as the CH0 channel, is sensitive to both visible and infrared light, while the Channel 1 photodiode, referred to as CH1, is sensitive primarily to infrared light. Two integrating ADCs convert the photodiode currents to digital outputs. The ADC digital outputs from the two channels are used in a formula to obtain a value that approximates the human eye response in units of lux.

## ALS Operation

The ALS engine contains ALS gain control (AGAIN) and two integrating analog-to-digital converters (ADC), one for the CH0 and one for the CH1 photodiodes. The ALS integration time (ATIME) impacts both the resolution and the sensitivity of the ALS reading. Integration of both channels occurs simultaneously and upon completion of the conversion cycle, the results are transferred to the data registers (C0DATA and C1DATA). This data is also referred to as channel *count*. The transfers are double-buffered to ensure data integrity.

**Figure 22:**  
ALS Operation



The registers for programming the integration and wait times are a 2's complement values. The actual time can be calculated as follows:

$$\text{ATIME} = 256 - \text{Integration Time} / 2.73 \text{ ms}$$

Inversely, the time can be calculated from the register value as follows:

$$\text{Integration Time} = 2.73 \text{ ms} \times (256 - \text{ATIME})$$

In order to reject 50/60-Hz ripple strongly present in fluorescent lighting, the integration time needs to be programmed in multiples of 10 / 8.3 ms or the half cycle time. Both frequencies can be rejected with a programmed value of 50 ms (ATIME = 0xED) or multiples of 50 ms (i.e. 100, 150, 200, 400, 600).

The registers for programming the AGAIN hold a two-bit value representing a gain of 1x, 8x, 16x, or 120x. The gain, in terms of amount of gain, will be represented by the value AGAINx, i.e. AGAINx = 1, 8, 16, or 120. With the AGL bit set, the 1x and 8x gains are lowered to 1/6x and 8/6x, respectively, to allow for operation up to 60k lux. Do not enable AGL when AGAIN is 16x or 120x.

## Lux Equation

The lux calculation is a function of CH0 channel count (C0DATA), CH1 channel count (C1DATA), ALS gain (AGAINx), and ALS integration time in milliseconds (ATIME\_ms). If an aperture, glass/plastic, or a light pipe attenuates the light equally across the spectrum (300 nm to 1100 nm), then a scaling factor referred to as glass attenuation (GA) can be used to compensate for attenuation. For a device in open air with no aperture or glass/plastic above the device, GA = 1. If it is not spectrally flat, then a custom lux equation with new coefficients should be generated. (See **ams** application note).

Counts per Lux (CPL) needs to be calculated only when ATIME or AGAIN is changed, otherwise it remains a constant. The first segment of the equation (Lux1) covers fluorescent and incandescent light. The second segment (Lux2) covers dimmed incandescent light. The final lux is the maximum of Lux1, Lux2, or 0.

$$\text{CPL} = (\text{ATIME\_ms} \times \text{AGAINx}) / (\text{GA} \times 60)$$

$$\text{Lux1} = (1 \times \text{C0DATA} - 1.87 \times \text{C1DATA}) / \text{CPL}$$

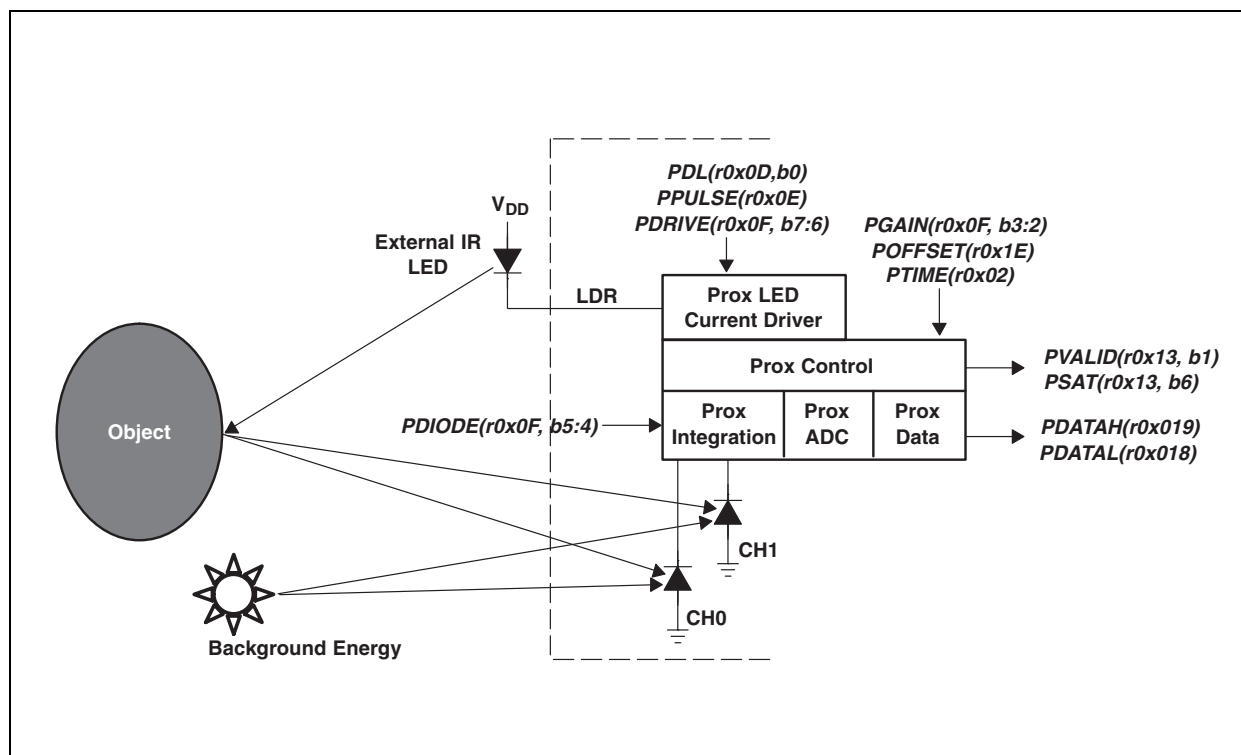
$$\text{Lux2} = (0.63 \times \text{C0DATA} - 1 \times \text{C1DATA}) / \text{CPL}$$

$$\text{Lux} = \text{MAX}(\text{Lux1}, \text{Lux2}, 0)$$

## Proximity Detection

Proximity detection is accomplished by measuring the amount of light energy, generally from an IR LED, reflected off an object to determine its distance. The proximity light source, which is external to the TSL2772 device, is driven by the integrated proximity LED current driver as shown in Figure 23.

**Figure 23:**  
Proximity Detection



The LED current driver, output on the LDR terminal, provides a regulated current sink that eliminates the need for an external current limiting resistor. The combination of proximity LED drive strength (PDRIVE) and proximity drive level (PDL) determine the drive current. PDRIVE sets the drive current to 120 mA, 60 mA, 30 mA, or 15 mA when PDL is not asserted. However, when PDL is asserted, the drive current is reduced by a factor of about 8 at  $V_{LDR} = 1.6$  V. To drive an external light source with more than 120 mA or to minimize on-chip ground bounce, LDR can be used to drive an external p-type transistor, which in turn drives the light source.

Referring to the Detailed State Machine figure, the LED current driver pulses the external IR LED as shown in Figure 24 during the Prox Accum state. Figure 24 also illustrates that the LED On pulse has a fixed width of 7.3  $\mu$ s and period of 16.0  $\mu$ s. So, in addition to setting the proximity drive current, 1 to 255 proximity pulses (PPULSE) can be programmed. When deciding on the number of proximity pulses, keep in mind that the signal increases proportionally to PPULSE, while noise increases by the square root of PPULSE.

**Figure 24:**  
**Proximity LED Current Driver Waveform**

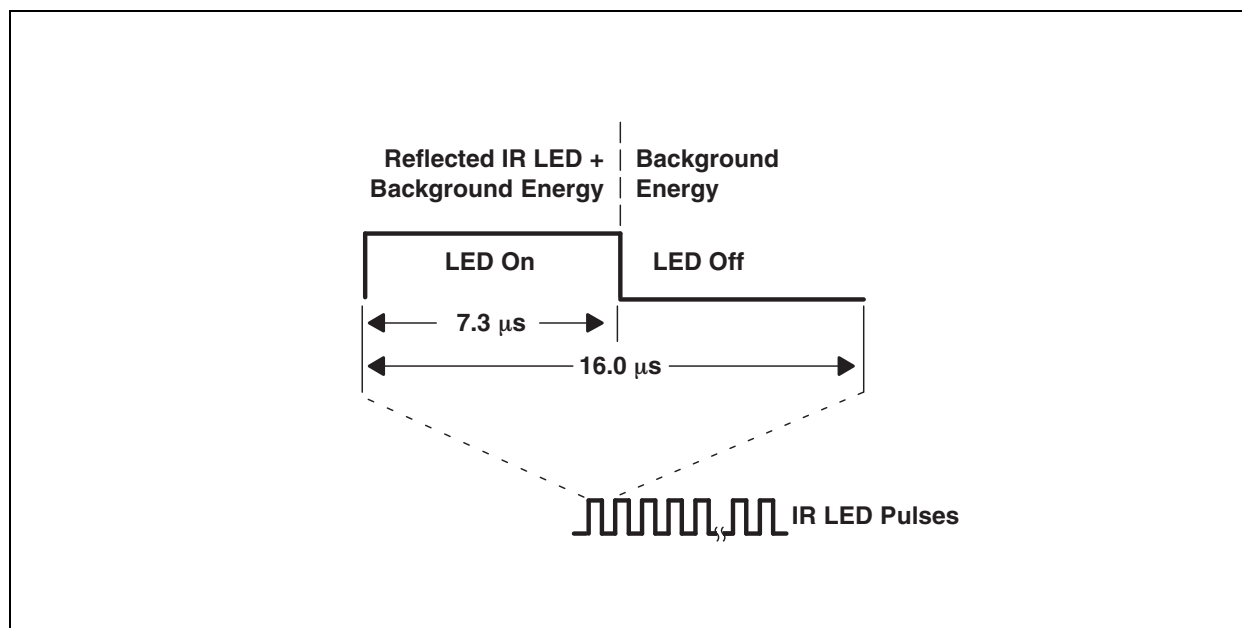


Figure 23 illustrates light rays emitting from an external IR LED, reflecting off an object, and being absorbed by the CH0 and CH1 photodiodes. The proximity diode selector (PDIODE) determines which of the two photodiodes is used for a given proximity measurement. Note that neither photodiode is selected when the device first powers up, so PDIODE must be set for proximity detection to work.

Referring again to Figure 24, the reflected IR LED and the background energy is integrated during the LED On time, then during the LED Off time, the integrated background energy is subtracted from the LED On time energy, leaving the external IR LED energy to accumulate from pulse to pulse. The proximity gain (PGAIN) determines the integration rate, which can be programmed to 1x, 2x, 4x, or 8x gain. At power up, PGAIN defaults to 1x gain, which is recommended for most applications. For reference, PGAIN equal to 8x is comparable to the TSL2771 1x gain setting. During LED On time integration, the proximity saturation bit in the Status register (0x13) will be set if the integrator saturates. This condition can occur if the proximity gain is set too high for the lighting conditions, such as in the presence of bright sunlight. Once asserted, PSAT will remain set until a special function proximity interrupt clear command is received from the host (see Command Register).

After the programmed number of proximity pulses have been generated, the proximity ADC converts and scales the proximity measurement to a 16-bit value, then stores the result in two 8-bit proximity data (PDATAx) registers. ADC scaling is controlled by the proximity ADC conversion time (PTIME) which is programmable from 1 to 256 2.73-ms time units. However, depending on the application, scaling the proximity data will equally scale any accumulated noise. Therefore, in general, it is recommended to leave PTIME at the default value of one

### 2.73-ms ADC conversion time (0xFF).

In many practical proximity applications, a number of optical system and environmental conditions can produce an offset in the proximity measurement result. To counter these effects, a proximity offset (POFFSET) is provided which allows the proximity data to be shifted positive or negative. Additional information on the use of the proximity offset feature is provided in available **ams** application notes.

Once the first proximity cycle has completed, the proximity valid (PVALID) bit in the Status register will be set and remain set until the proximity detection function is disabled (PEN).

For additional information on using the proximity detection function behind glass and for optical system design guidance, please see available **ams** application notes.

## Interrupts

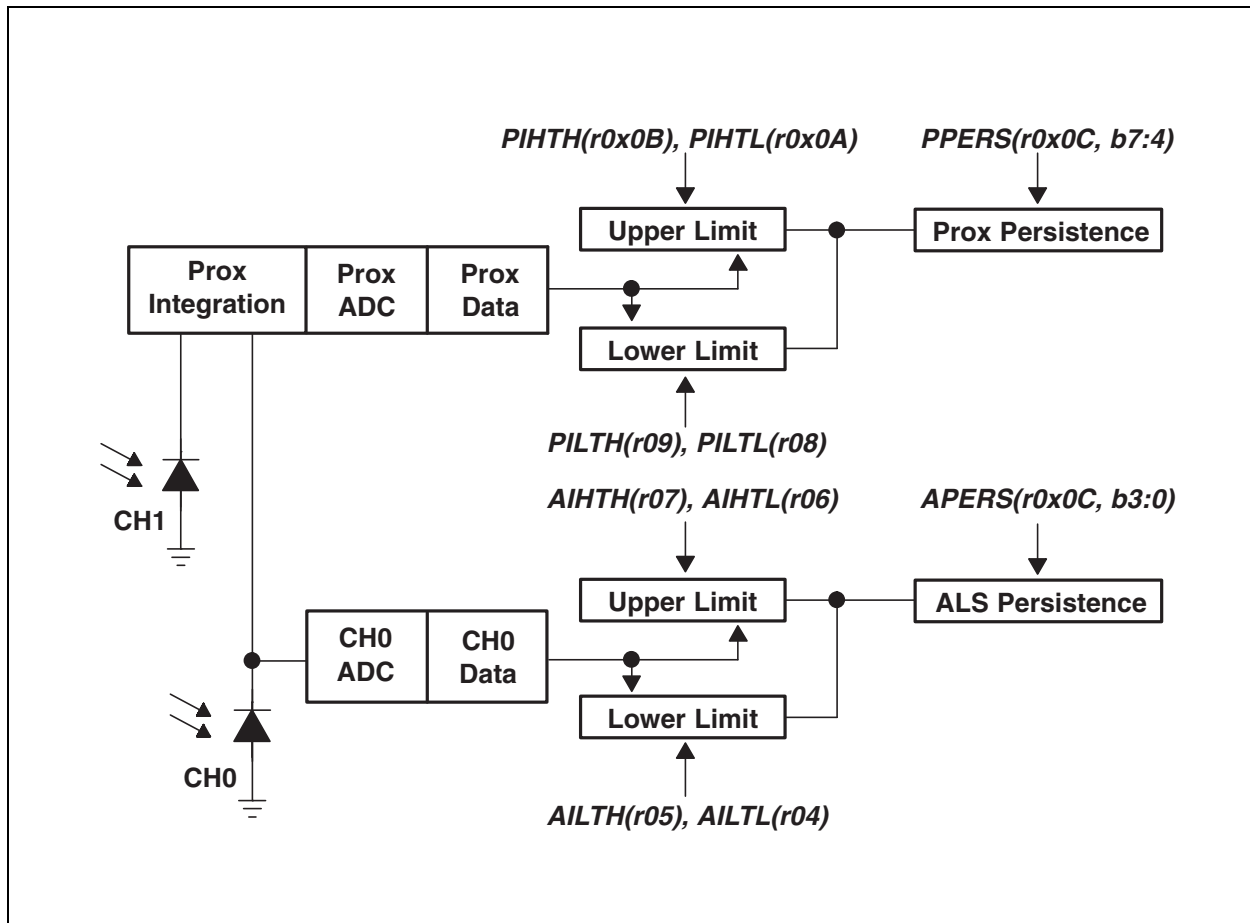
The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for light intensity or proximity values outside of a user-defined range. While the interrupt function is always enabled and its status is available in the status register (0x13), the output of the interrupt state can be enabled using the proximity interrupt enable (PIEN) or ALS interrupt enable (AIEN) fields in the enable register (0x00).

Four 16-bit interrupt threshold registers allow the user to set limits below and above a desired light level and proximity range. An interrupt can be generated when the ALS CH0 data (C0DATA) falls outside of the desired light level range, as determined by the values in the ALS interrupt low threshold registers (AILT<sub>x</sub>) and ALS interrupt high threshold registers (AIHT<sub>x</sub>). Likewise, an out-of-range proximity interrupt can be generated when the proximity data (PDATA) falls below the proximity interrupt low threshold (PILT<sub>x</sub>) or exceeds the proximity interrupt high threshold (PIHT<sub>x</sub>).

It is important to note that the thresholds are evaluated in sequence, first the low threshold, then the high threshold. As a result, if the low threshold is set above the high threshold, the high threshold is ignored and only the low threshold is evaluated.

To further control when an interrupt occurs, the device provides a persistence filter. The persistence filter allows the user to specify the number of consecutive out-of-range ALS or proximity occurrences before an interrupt is generated. The persistence filter register (0x0C) allows the user to set the ALS persistence filter (APERS) and the proximity persistence filter (PPERS) values. See the persistence filter register for details on the persistence filter values. Once the persistence filter generates an interrupt, it will continue until a special function interrupt clear command is received (see [Command Register](#)).

Figure 25:  
Programmable Interrupt



## System State Machine Timing

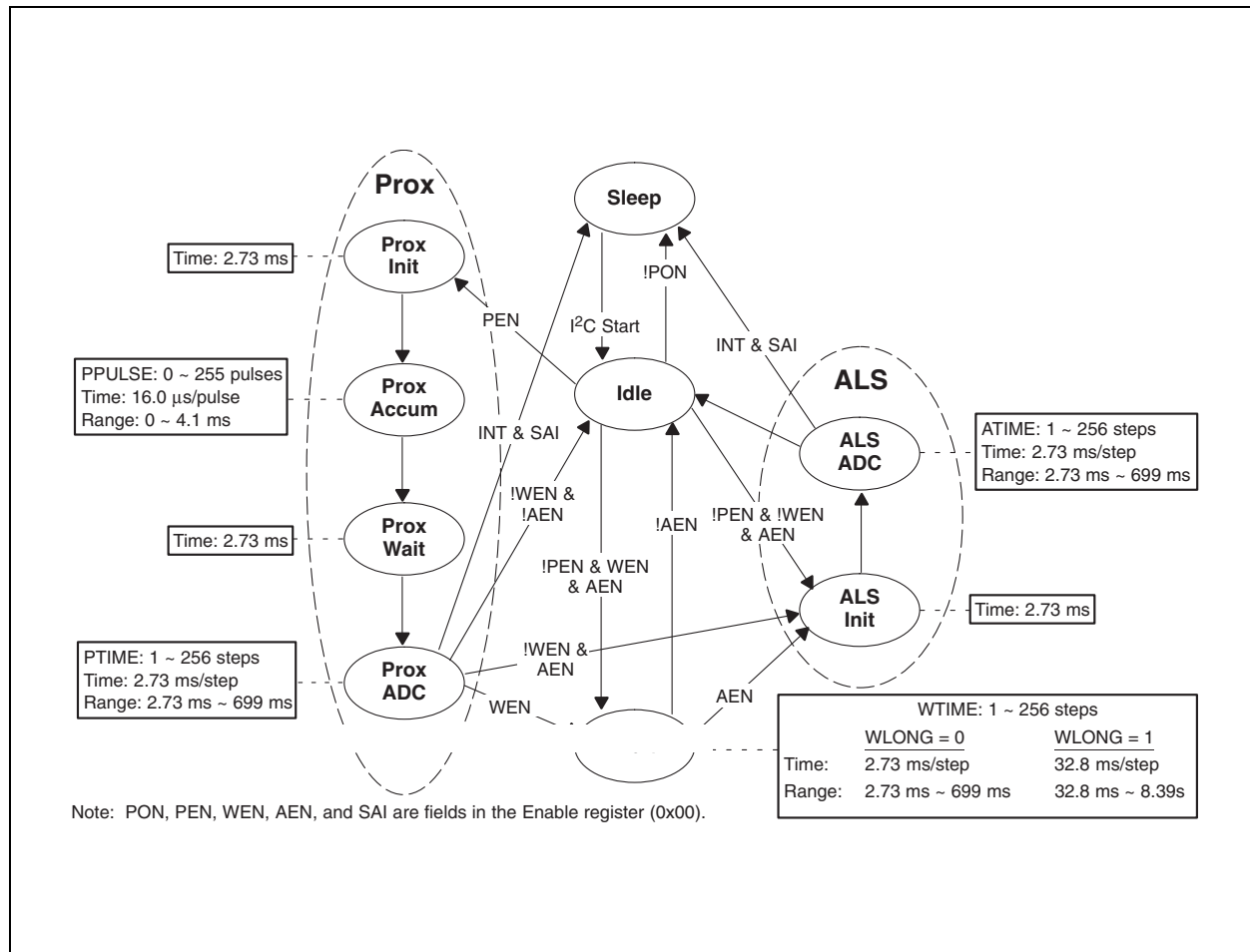
The system state machine shown in [Figure 21](#) provides an overview of the states and state transitions that provide system control of the device. This section highlights the programmable features, which affect the state machine cycle time, and provides details to determine system level timing.

When the proximity detection feature is enabled (PEN), the state machine transitions through the Prox Init, Prox Accum, Prox Wait, and Prox ADC states. The Prox Init and Prox Wait times are a fixed 2.73 ms, whereas the Prox Accum time is determined by the number of proximity LED pulses (PPULSE) and the Prox ADC time is determined by the integration time (PTIME). The formulas to determine the Prox Accum and Prox ADC times are given in the associated boxes in [Figure 24](#). If an interrupt is generated as a result of the proximity cycle, it will be asserted at the end of the Prox ADC state and transition to the Sleep state if SAI is enabled.

When the power management feature is enabled (WEN), the state machine will transition in turn to the Wait state. The wait time is determined by WLONG, which extends normal operation by 12× when asserted, and WTIME. The formula to determine the wait time is given in the box associated with the Wait state in [Figure 26](#).

When the ALS feature is enabled (AEN), the state machine will transition through the ALS Init and ALS ADC states. The ALS Init state takes 2.73 ms, while the ALS ADC time is dependent on the integration time (ATIME). The formula to determine ALS ADC time is given in the associated box in [Figure 26](#). If an interrupt is generated as a result of the ALS cycle, it will be asserted at the end of the ALS ADC state and transition to the Sleep state if SAI is enabled.

**Figure 26:**  
**Detailed State Diagram**



**Note(s):**

1. PON, PEN, WEN, AEN, and SAI are fields in the Enable register (0x00).

## Power Management

Power consumption can be managed with the Wait state, because the Wait state typically consumes only 90µA of  $I_{DD}$  current. An example of the power management feature is given below. With the assumptions provided in the example, average  $I_{DD}$  is estimated to be 182 µA.

**Figure 27:**  
Power Management

| System State<br>Machine State | Programmable<br>Parameter | Programmed<br>Value | Duration                | Typical<br>Current |
|-------------------------------|---------------------------|---------------------|-------------------------|--------------------|
| Prox Init                     |                           |                     | 2.73 ms                 | 0.200 mA           |
| Prox Accum                    | PPULSE                    | 0x04                | 0.064 ms                |                    |
| Prox Accum – LED ON           |                           |                     | 0.029 ms <sup>(1)</sup> | 119 mA             |
| Prox Accum – LED OFF          |                           |                     | 0.035 ms <sup>(2)</sup> | 0.200 mA           |
| Prox Wait                     |                           |                     | 2.73 ms                 | 0.200 mA           |
| Prox ADC                      | PTIME                     | 0xFF                | 2.73 ms                 | 0.200 mA           |
| Wait                          | WTIME                     | 0xEE                | 49.2 ms                 | 0.090 mA           |
|                               | WLONG                     | 0                   |                         |                    |
| ALS Init                      |                           |                     | 2.73 ms                 | 0.200 mA           |
| ALS ADC                       | ATIME                     | 0xEE                | 49.2 ms                 | 0.200 mA           |

**Note(s):**

1. Prox Accum - LED ON time =  $7.3\mu\text{s per pulse} \times 4 \text{ pulses} = 29.3\mu\text{s} = 0.029 \text{ ms}$
2. Prox Accum - LED OFF time =  $8.7 \mu\text{s per pulse} \times 4 \text{ pulses} = 34.7\mu\text{s} = 0.035 \text{ ms}$

$$\text{Average } I_{DD} \text{ Current} = ((0.029 \times 119) + (0.035 \times 0.200) + (2.73 \times 0.200) + (49.2 \times 0.090) + (49.2 \times 0.200) + (2.73 \times 0.200 \times 3)) / 109 \approx 182 \mu\text{A}$$

Keeping with the same programmed values as the example, [Figure 28](#) shows how the average  $I_{DD}$  current is affected by the Wait state time, which is determined by WEN, WTIME, and WLONG. Note that the worst-case current occurs when the Wait state is not enabled.

**Figure 28:**  
**Average  $I_{DD}$  Current**

| WEN | WTIME | WLONG | WAIT STATE | AVERAGE $I_{DD}$ CURRENT |
|-----|-------|-------|------------|--------------------------|
| 0   | n/a   | n/a   | 0 ms       | 258 $\mu$ A              |
| 1   | 0xFF  | 0     | 2.73 ms    | 251 $\mu$ A              |
| 1   | 0xEE  | 0     | 49.2 ms    | 182 $\mu$ A              |
| 1   | 0x00  | 0     | 699 ms     | 103 $\mu$ A              |
| 1   | 0x00  | 1     | 8389 ms    | 91 $\mu$ A               |

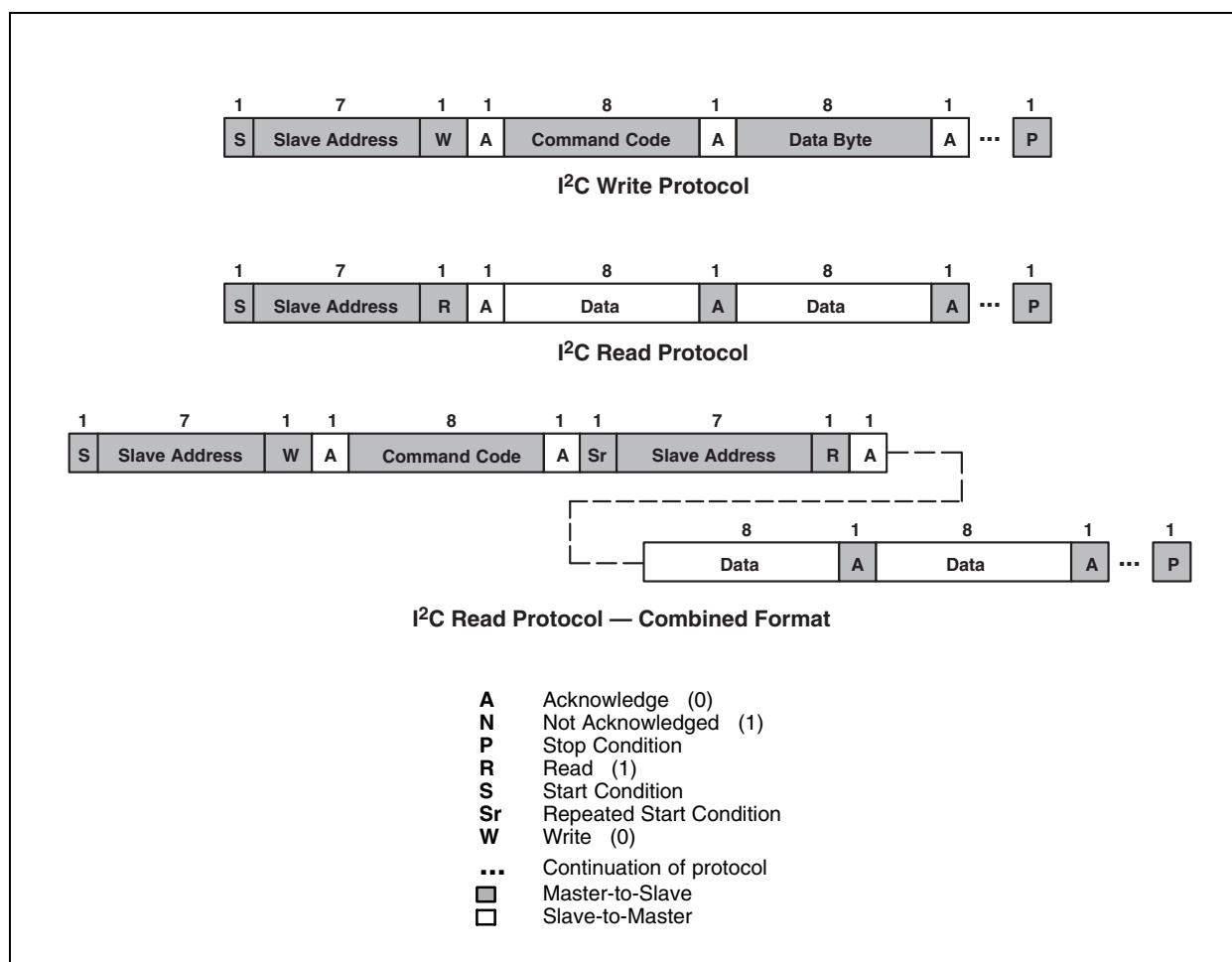
## I<sup>2</sup>C Protocol

Interface and control are accomplished through an I<sup>2</sup>C serial compatible interface (standard or fast mode) to a set of registers that provide access to device control functions and output data. The devices support the 7-bit I<sup>2</sup>C addressing protocol.

The I<sup>2</sup>C standard provides for three types of bus transaction: read, write, and a combined protocol (Figure 29). During a write operation, the first byte written is a command byte followed by data. In a combined protocol, the first byte written is the command byte followed by reading a series of bytes. If a read command is issued, the register address from the previous command will be used for data access. Likewise, if the MSB of the command is not set, the device will write a series of bytes at the address stored in the last valid command with a register address. The command byte contains either control information or a 5-bit register address. The control commands can also be used to clear interrupts.

The I<sup>2</sup>C bus protocol was developed by Philips (now NXP). For a complete description of the I<sup>2</sup>C protocol, please review the NXP I<sup>2</sup>C design specification at <http://www.i2c-bus.org/references/>.

**Figure 29:**  
I<sup>2</sup>C Protocols



## Register Set

The device is controlled and monitored by data registers and a command register accessed through the serial interface. These registers provide for a variety of control functions and can be read to determine results of the ADC conversions. The register set is summarized in [Figure 30](#).

**Figure 30:**  
Register Address

| Address | Register Name | R/W | Register Function                            | Reset Value |
|---------|---------------|-----|----------------------------------------------|-------------|
| --      | COMMAND       | W   | Specifies register address                   | 0x00        |
| 0x00    | ENABLE        | R/W | Enables states and interrupts                | 0x00        |
| 0x01    | ATIME         | R/W | ALS time                                     | 0xFF        |
| 0x02    | PTIME         | R/W | Proximity time                               | 0xFF        |
| 0x03    | WTIME         | R/W | Wait time                                    | 0xFF        |
| 0x04    | AILTL         | R/W | ALS interrupt low threshold low byte         | 0x00        |
| 0x05    | AILTH         | R/W | ALS interrupt low threshold high byte        | 0x00        |
| 0x06    | AIHTL         | R/W | ALS interrupt high threshold low byte        | 0x00        |
| 0x07    | AIHTH         | R/W | ALS interrupt high threshold high byte       | 0x00        |
| 0x08    | PILTL         | R/W | Proximity interrupt low threshold low byte   | 0x00        |
| 0x09    | PILTH         | R/W | Proximity interrupt low threshold high byte  | 0x00        |
| 0x0A    | PIHTL         | R/W | Proximity interrupt high threshold low byte  | 0x00        |
| 0x0B    | PIHTH         | R/W | Proximity interrupt high threshold high byte | 0x00        |
| 0x0C    | PERS          | R/W | Interrupt persistence filters                | 0x00        |
| 0x0D    | CONFIG        | R/W | Configuration                                | 0x00        |
| 0x0E    | PPULSE        | R/W | Proximity pulse count                        | 0x00        |
| 0x0F    | CONTROL       | R/W | Control register                             | 0x00        |
| 0x12    | ID            | R   | Device ID                                    | ID          |
| 0x13    | STATUS        | R   | Device status                                | 0x00        |
| 0x14    | C0DATA        | R   | CH0 ADC low data register                    | 0x00        |
| 0x15    | C0DATAH       | R   | CH0 ADC high data register                   | 0x00        |
| 0x16    | C1DATA        | R   | CH1 ADC low data register                    | 0x00        |

| Address | Register Name | R/W | Register Function                | Reset Value |
|---------|---------------|-----|----------------------------------|-------------|
| 0x17    | C1DATAH       | R   | CH1 ADC high data register       | 0x00        |
| 0x18    | PDATAH        | R   | Proximity ADC low data register  | 0x00        |
| 0x19    | PDATAH        | R   | Proximity ADC high data register | 0x00        |
| 0x1E    | POFFSET       | R/W | Proximity offset register        | 0x00        |

The mechanics of accessing a specific register depends on the specific protocol used. See the section on I<sup>2</sup>C Protocols on the previous pages. In general, the COMMAND register is written first to specify the specific control/status register for subsequent read/write operations.

### Command Register

The command registers specifies the address of the target register for future write and read operations

**Figure 31:**  
Command Register

|         |      |   |   |     |   |   |   |
|---------|------|---|---|-----|---|---|---|
| 7       | 6    | 5 | 4 | 3   | 2 | 1 | 0 |
| COMMAND | TYPE |   |   | ADD |   |   |   |

| Field                                                                                                             | Bits                              | Description                                                                                                                                                                      |                                          |
|-------------------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| COMMAND                                                                                                           | 7                                 | Select Command Register. Must write as 1 when addressing COMMAND register.                                                                                                       |                                          |
| TYPE                                                                                                              | 6:5                               | Selects type of transaction to follow in subsequent data transfers:                                                                                                              |                                          |
|                                                                                                                   |                                   | FIELD VALUE                                                                                                                                                                      | DESCRIPTION                              |
|                                                                                                                   |                                   | 00                                                                                                                                                                               | Repeated byte protocol transaction       |
|                                                                                                                   |                                   | 01                                                                                                                                                                               | Auto-increment protocol transaction      |
|                                                                                                                   |                                   | 10                                                                                                                                                                               | Reserved — Do not use                    |
|                                                                                                                   |                                   | 11                                                                                                                                                                               | Special function — See description below |
|                                                                                                                   |                                   | Transaction type 00 will repeatedly read the same register with each data access. Transaction type 01 will provide an auto-increment function to read successive register bytes. |                                          |
|                                                                                                                   |                                   | ADD                                                                                                                                                                              | 4:0                                      |
| FIELD VALUE                                                                                                       | DESCRIPTION                       |                                                                                                                                                                                  |                                          |
| 00000                                                                                                             | Normal — No action                |                                                                                                                                                                                  |                                          |
| 00101                                                                                                             | Proximity interrupt clear         |                                                                                                                                                                                  |                                          |
| 00110                                                                                                             | ALS interrupt clear               |                                                                                                                                                                                  |                                          |
| 00111                                                                                                             | Proximity and ALS interrupt clear |                                                                                                                                                                                  |                                          |
| other                                                                                                             | Reserved — Do not write           |                                                                                                                                                                                  |                                          |
| ALS/Proximity Interrupt Clear clears any pending ALS/Proximity interrupt. This special function is self clearing. |                                   |                                                                                                                                                                                  |                                          |
|                                                                                                                   |                                   |                                                                                                                                                                                  |                                          |

**Enable Register (0x00)**

The ENABLE register is used to power the device ON/OFF, enable functions, and interrupts.

**Figure 32:**  
**Enable Register**

|          |     |      |      |     |     |     |     |
|----------|-----|------|------|-----|-----|-----|-----|
| 7        | 6   | 5    | 4    | 3   | 2   | 1   | 0   |
| Reserved | SAI | PIEN | AIEN | WEN | PEN | AEN | PON |

| Field    | Bits | Description                                                                                                                                                                      |
|----------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reserved | 7    | Reserved. Write as 0.                                                                                                                                                            |
| SAI      | 6    | Sleep after interrupt. When asserted, the device will power down at the end of a proximity or ALS cycle if an interrupt has been generated                                       |
| PIEN     | 5    | Proximity interrupt mask. When asserted, permits proximity interrupts to be generated.                                                                                           |
| AIEN     | 4    | ALS interrupt mask. When asserted, permits ALS interrupts to be generated.                                                                                                       |
| WEN      | 3    | Wait enable. This bit activates the wait feature. Writing a 1 activates the wait timer. Writing a 0 disables the wait timer.                                                     |
| PEN      | 2    | Proximity enable. This bit activates the proximity function. Writing a 1 enables proximity. Writing a 0 disables proximity.                                                      |
| AEN      | 1    | ALS Enable. This bit activates the two channel ADC. Writing a 1 activates the ALS. Writing a 0 disables the ALS.                                                                 |
| PON      | 0    | Power ON. This bit activates the internal oscillator to permit the timers and ADC channel to operate. Writing a 1 activates the oscillator. Writing a 0 disables the oscillator. |

### ALS Time Register (0x01)

The ALS time register controls the internal integration time of the ALS channel ADCs in 2.73 ms increments. Upon power up, the ALS time register is set to 0xFF.

**Figure 33:**  
ALS Integration Time Register

| Field | Bits | Description |              |         |           |
|-------|------|-------------|--------------|---------|-----------|
| ATIME | 7:0  | VALUE       | INTEG_CYCLES | TIME    | MAX COUNT |
|       |      | 0xFF        | 1            | 2.73 ms | 1024      |
|       |      | 0xF6        | 10           | 27.3 ms | 10240     |
|       |      | 0xDB        | 37           | 101 ms  | 37888     |
|       |      | 0xC0        | 64           | 175 ms  | 65535     |
|       |      | 0x00        | 256          | 699 ms  | 65535     |

### Proximity Time Register (0x02)

The proximity timing register controls the integration time of the proximity ADC in 2.73 ms increments. Upon power up, the proximity time register is set to 0xFF. It is recommended that this register be programmed to a value of 0xFF (1 integration cycle).

**Figure 34:**  
Proximity Integration Time Control Register

| Field | Bits | Description |              |         |           |
|-------|------|-------------|--------------|---------|-----------|
| PTIME | 7:0  | VALUE       | INTEG_CYCLES | TIME    | MAX COUNT |
|       |      | 0xFF        | 1            | 2.73 ms | 1023      |

**Wait Time Register (0x03)**

Wait time is set 2.73 ms increments unless the WLONG bit is asserted in which case the wait times are 12x longer. WTIME is programmed as a 2's complement number. Upon power up, the wait time register is set to 0xFF.

**Figure 35:**  
**Wait Time Register**

| Field | Bits | Description    |           |                  |                  |
|-------|------|----------------|-----------|------------------|------------------|
| WTIME | 7:0  | REGISTER VALUE | WAIT TIME | TIME (WLONG = 0) | TIME (WLONG = 1) |
|       |      | 0xFF           | 1         | 2.73 ms          | 0.033 sec        |
|       |      | 0xB6           | 74        | 202 ms           | 2.4 sec          |
|       |      | 0x00           | 256       | 699 ms           | 8.4 sec          |

**Note(s):**

1. The Proximity Wait Time Register should be configured before PEN and/or AEN is/are asserted.

**ALS Interrupt Threshold Registers (0x04 - 0x07)**

The ALS interrupt threshold registers provides the values to be used as the high and low trigger points for the comparison function for interrupt generation. If C0DATA crosses below the low threshold specified, or above the higher threshold, an interrupt is asserted on the interrupt pin.

**Figure 36:**  
**ALS Interrupt Threshold Registers**

| Register | Address | Bits | Description                   |
|----------|---------|------|-------------------------------|
| AILTL    | 0x04    | 7:0  | ALS low threshold lower byte  |
| AILTH    | 0x05    | 7:0  | ALS low threshold upper byte  |
| AIHTL    | 0x06    | 7:0  | ALS high threshold lower byte |
| AIHTH    | 0x07    | 7:0  | ALS high threshold upper byte |

### ***Proximity Interrupt Threshold Registers (0x08 - 0x0B)***

The proximity interrupt threshold registers provide the values to be used as the high and low trigger points for the comparison function for interrupt generation. If the value generated by proximity channel crosses below the lower threshold specified, or above the higher threshold, an interrupt is signaled to the host processor.

**Figure 37:**  
**Proximity Interrupt Threshold Registers**

| Register | Address | Bits | Description                        |
|----------|---------|------|------------------------------------|
| PILTL    | 0x08    | 7:0  | Proximity low threshold low byte   |
| PILTH    | 0x09    | 7:0  | Proximity low threshold high byte  |
| PIHTL    | 0x0A    | 7:0  | Proximity high threshold low byte  |
| PIHTH    | 0x0B    | 7:0  | Proximity high threshold high byte |

**Persistence Filter Register (0x0C)**

The persistence filter register controls the interrupt capabilities of the device. Configurable filtering is provided to allow interrupts to be generated after every ADC cycle or if the ADC cycle has produced a result that is outside of the values specified by threshold register for some specified amount of time. Separate filtering is provided for proximity and ALS functions. ALS interrupts are generated using C0DATA.

**Figure 38:**  
**Persistence Filter Register**

|       |   |   |   |       |   |   |   |
|-------|---|---|---|-------|---|---|---|
| 7     | 6 | 5 | 4 | 3     | 2 | 1 | 0 |
| PPERS |   |   |   | APERS |   |   |   |

| Field | Bits | Description                                                                                 |                |                                              |
|-------|------|---------------------------------------------------------------------------------------------|----------------|----------------------------------------------|
| PPERS | 7:4  | Proximity interrupt persistence. Controls rate of proximity interrupt to the host processor |                |                                              |
|       |      | <b>FIELD VALUE</b>                                                                          | <b>MEANING</b> | <b>INTERRUPT PERSISTENCE FUNCTION</b>        |
|       |      | 0000                                                                                        | ---            | Every proximity cycle generates an interrupt |
|       |      | 0001                                                                                        | 1              | 1 proximity value out of range               |
|       |      | 0010                                                                                        | 2              | 2 consecutive proximity values out of range  |
|       |      | ...                                                                                         | ...            | ...                                          |
|       |      | 1111                                                                                        | 15             | 15 consecutive proximity values out of range |

| Field | Bits | Description                                                                             |                |                                        |
|-------|------|-----------------------------------------------------------------------------------------|----------------|----------------------------------------|
| APERS | 3:0  | ALS Interrupt persistence filter. Controls rate of ALS interrupt to the host processor. |                |                                        |
|       |      | <b>FIELD VALUE</b>                                                                      | <b>MEANING</b> | <b>INTERRUPT PERSISTENCE FUNCTION</b>  |
|       |      | 0000                                                                                    | Every          | Every ALS cycle generates an interrupt |
|       |      | 0001                                                                                    | 1              | 1 value outside of threshold range     |
|       |      | 0010                                                                                    | 2              | 2 consecutive values out of range      |
|       |      | 0011                                                                                    | 3              | 3 consecutive values out of range      |
|       |      | 0100                                                                                    | 5              | 5 consecutive values out of range      |
|       |      | 0101                                                                                    | 10             | 10 consecutive values out of range     |
|       |      | 0110                                                                                    | 15             | 15 consecutive values out of range     |
|       |      | 0111                                                                                    | 20             | 20 consecutive values out of range     |
|       |      | 1000                                                                                    | 25             | 25 consecutive values out of range     |
|       |      | 1001                                                                                    | 30             | 30 consecutive values out of range     |
|       |      | 1010                                                                                    | 35             | 35 consecutive values out of range     |
|       |      | 1011                                                                                    | 40             | 40 consecutive values out of range     |
|       |      | 1100                                                                                    | 45             | 45 consecutive values out of range     |
|       |      | 1101                                                                                    | 50             | 50 consecutive values out of range     |
|       |      | 1110                                                                                    | 55             | 55 consecutive values out of range     |
|       |      | 1111                                                                                    | 60             | 60 consecutive values out of range     |

**Configuration Register (0x0D)**

The configuration register sets the proximity LED drive level, wait long time, and ALS gain level.

**Figure 39:**  
**Configuration Register**

|          |   |   |   |   |     |       |     |
|----------|---|---|---|---|-----|-------|-----|
| 7        | 6 | 5 | 4 | 3 | 2   | 1     | 0   |
| Reserved |   |   |   |   | AGL | WLONG | PDL |

| Field    | Bits | Description                                                                                                                                                     |
|----------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reserved | 7:3  | Reserved. Write as 0.                                                                                                                                           |
| AGL      | 2    | ALS gain level. When asserted, the 1x and 8x ALS gain (AGAIN) modes are scaled by 0.16. Otherwise, AGAIN is scaled by 1. Do not use with AGAIN greater than 8x. |
| WLONG    | 1    | Wait Long. When asserted, the wait cycles are increased by a factor 12x from that programmed in the WTIME register.                                             |
| PDL      | 0    | Proximity drive level. When asserted, the proximity LDR drive current is reduced by 9.                                                                          |

**Proximity Pulse Count Register (0x0E)**

The proximity pulse count register sets the number of proximity pulses that the LDR pin will generate during the Prox Accum state.

**Figure 40:**  
**Proximity Pulse Count Register**

|        |   |   |   |   |   |   |   |
|--------|---|---|---|---|---|---|---|
| 7      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PPULSE |   |   |   |   |   |   |   |

| Field  | Bits | Description                                                                      |
|--------|------|----------------------------------------------------------------------------------|
| PPULSE | 7:0  | Proximity Pulse Count. Specifies the number of proximity pulses to be generated. |

### Control Register (0x0F)

The Control register provides eight bits of miscellaneous control to the analog block. These bits typically control functions such as gain settings and/or diode selection.

**Figure 41:**  
Control Register

|        |   |        |   |       |   |       |   |
|--------|---|--------|---|-------|---|-------|---|
| 7      | 6 | 5      | 4 | 3     | 2 | 1     | 0 |
| PDRIVE |   | PDIODE |   | PGAIN |   | AGAIN |   |

| Field  | Bits | Description                   |                              |                        |
|--------|------|-------------------------------|------------------------------|------------------------|
| PDRIVE | 7:6  | Proximity LED Drive Strength. |                              |                        |
|        |      | FIELD VALUE                   | LED STRENGTH — PDL = 0       | LED STRENGTH — PDL = 1 |
|        |      | 00                            | 120 mA                       | 15 mA                  |
|        |      | 01                            | 60 mA                        | 7.5 mA                 |
|        |      | 10                            | 30 mA                        | 3.8 mA                 |
|        |      | 11                            | 15 mA                        | 1.9 mA                 |
| PDIODE | 5:4  | Proximity Diode Selector.     |                              |                        |
|        |      | FIELD VALUE                   | DIODE SELECTION              |                        |
|        |      | 00                            | Proximity uses neither diode |                        |
|        |      | 01                            | Proximity uses the CH0 diode |                        |
|        |      | 10                            | Proximity uses the CH1 diode |                        |
|        |      | 11                            | Reserved — Do not write      |                        |
| PGAIN  | 3:2  | Proximity Gain.               |                              |                        |
|        |      | FIELD VALUE                   | PROXIMITY GAIN VALUE         |                        |
|        |      | 00                            | 1× gain                      |                        |
|        |      | 01                            | 2× gain                      |                        |
|        |      | 10                            | 4× gain                      |                        |
|        |      | 11                            | 8× gain                      |                        |

| Field | Bits | Description        |                             |
|-------|------|--------------------|-----------------------------|
| AGAIN | 1:0  | ALS Gain.          |                             |
|       |      | <b>FIELD VALUE</b> | <b>PROXIMITY GAIN VALUE</b> |
|       |      | 00                 | 1× gain                     |
|       |      | 01                 | 8× gain                     |
|       |      | 10                 | 16× gain                    |
|       |      | 11                 | 120× gain                   |

### ID Register (0x12)

The ID Register provides the value for the part number. The ID register is a read-only register.

**Figure 42:**  
ID Register

|    |   |   |   |   |   |   |   |
|----|---|---|---|---|---|---|---|
| 7  | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ID |   |   |   |   |   |   |   |

| Field | Bits | Description                |                            |
|-------|------|----------------------------|----------------------------|
| ID    | 7:0  | Part number identification | 0x30 = TSL27721 & TSL27725 |
|       |      |                            | 0x39 = TSL27723 & TSL27727 |

### Status Register (0x13)

The Status Register provides the internal status of the device. This register is read only.

**Figure 43:**  
Status Register

|          |      |      |      |          |        |        |   |
|----------|------|------|------|----------|--------|--------|---|
| 7        | 6    | 5    | 4    | 3        | 2      | 1      | 0 |
| Reserved | PSAT | PINT | AINT | Reserved | PVALID | AVALID |   |

| Field    | Bit | Description                                                                                                           |
|----------|-----|-----------------------------------------------------------------------------------------------------------------------|
| Reserved | 7   | Reserved. Bit reads as 0.                                                                                             |
| PSAT     | 6   | Proximity Saturation. Indicates that the proximity measurement saturated.                                             |
| PINT     | 5   | Proximity Interrupt. Indicates that the device is asserting a proximity interrupt.                                    |
| AINT     | 4   | ALS Interrupt. Indicates that the device is asserting an ALS interrupt.                                               |
| Reserved | 3:2 | Reserved. Bit reads as 0.                                                                                             |
| PVALID   | 1   | Proximity Valid. Indicates that the proximity channel has completed an integration cycle after PEN has been asserted. |
| AVALID   | 0   | ALS Valid. Indicates that the ALS channels have completed an integration cycle after AEN has been asserted..          |

**ADC Channel Data Registers (0x14 - 0x17)**

ALS data is stored as two 16-bit values. To ensure the data is read correctly, a two-byte read I<sup>2</sup>C transaction should be used with auto increment protocol bits set in the command register. With this operation, when the lower byte register is read, the upper eight bits are stored in a shadow register, which is read by a subsequent read to the upper byte. The upper register will read the correct value even if additional ADC integration cycles end between the reading of the lower and upper registers.

**Figure 44:**  
**ADC Channel Data Registers**

| Register | Address | Bits | Description            |
|----------|---------|------|------------------------|
| C0DATA   | 0x14    | 7:0  | ALS CH0 data low byte  |
| C0DATAH  | 0x15    | 7:0  | ALS CH0 data high byte |
| C1DATA   | 0x16    | 7:0  | ALS CH1 data low byte  |
| C1DATAH  | 0x17    | 7:0  | ALS CH1 data high byte |

**Proximity Data Registers (0x18 - 0x19h)**

Proximity data is stored as a 16-bit value. To ensure the data is read correctly, a two-byte read I<sup>2</sup>C transaction should be utilized with auto increment protocol bits set in the command register. With this operation, when the lower byte register is read, the upper eight bits are stored into a shadow register, which is read by a subsequent read to the upper byte. The upper register will read the correct value even if the next ADC cycle ends between the reading of the lower and upper registers.

**Figure 45:**  
**Proximity Data Registers**

| Register | Address | Bits | Description              |
|----------|---------|------|--------------------------|
| PDATA    | 0x18    | 7:0  | Proximity data low byte  |
| PDATAH   | 0x19    | 7:0  | Proximity data high byte |

### Proximity Offset Register (0x1E)

The 8-bit proximity offset register provides compensation for proximity offsets caused by device variations, optical crosstalk, and other environmental factors. Proximity offset is a sign-magnitude value where the sign bit, bit 7, determines if the offset is negative (bit 7 = 0) or positive (bit 7 = 1). At power up, the register is set to 0x00. The magnitude of the offset compensation depends on the proximity gain (PGAIN), proximity LED drive strength (PDRIVE), and the number of proximity pulses (PPULSE). Because a number of environmental factors contribute to proximity offset, this register is best suited for use in an adaptive closed-loop control system. See available **ams** application notes for proximity offset register application information.

**Figure 46:**  
Proximity Offset Register

|      |           |   |   |   |   |   |   |
|------|-----------|---|---|---|---|---|---|
| 7    | 6         | 5 | 4 | 3 | 2 | 1 | 0 |
| SIGN | MAGNITUDE |   |   |   |   |   |   |

| Field     | Bit | Description                                                                                                                                                                                                                                                                                        |
|-----------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SIGN      | 7   | Proximity Offset Sign. The offset sign shifts the proximity data negative when equal to 0 and positive when equal to 1.                                                                                                                                                                            |
| MAGNITUDE | 6:0 | Proximity Offset Magnitude. The offset magnitude shifts the proximity data positive or negative, depending on the proximity offset sign. The actual amount of the shift depends on the proximity gain (PGAIN), proximity LED drive strength (PDRIVE), and the number of proximity pulses (PPULSE). |

## Application Information

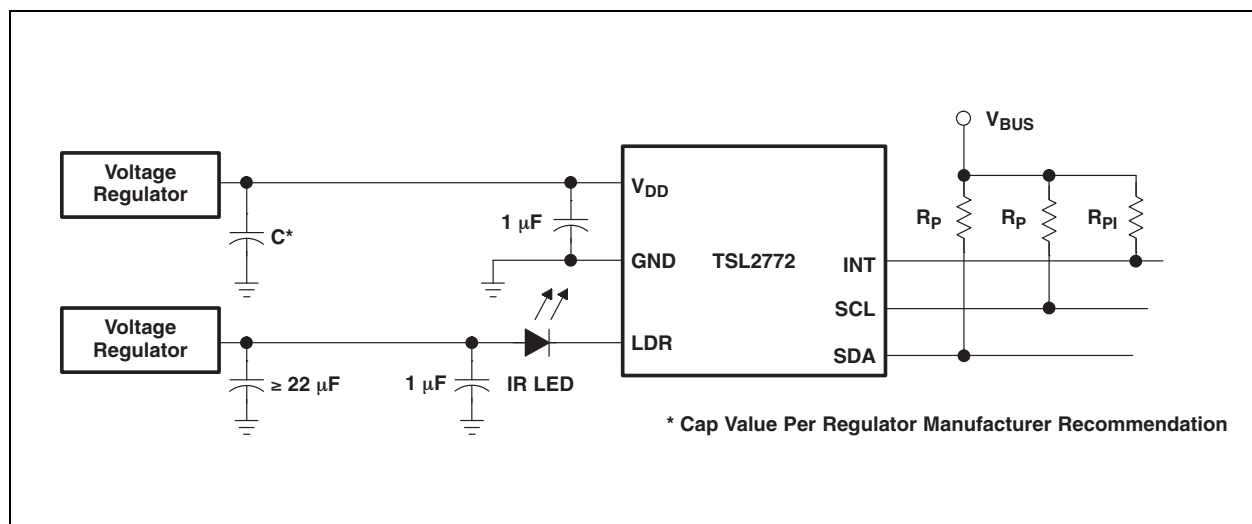
### Hardware

#### LED Driver Pin with Proximity Detection

In a proximity sensing system, the IR LED can be pulsed by the TSL2772 with more than 100 mA of rapidly switching current, therefore, a few design considerations must be kept in mind to get the best performance. The key goal is to reduce the power supply noise coupled back into the device during the LED pulses.

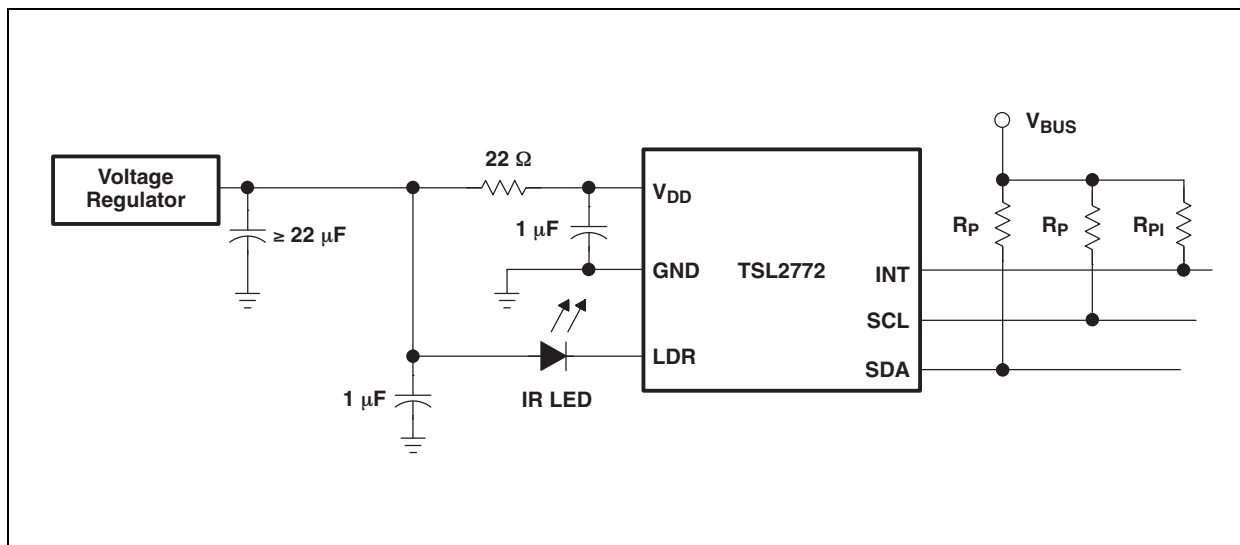
The first recommendation is to use two power supplies; one for the device  $V_{DD}$  and the other for the IR LED. In many systems, there is a quiet analog supply and a noisy digital supply. By connecting the quiet supply to the  $V_{DD}$  pin and the noisy supply to the LED, the key goal can be met. Place a 1- $\mu\text{F}$  low-ESR decoupling capacitor as close as possible to the  $V_{DD}$  pin and another at the LED anode, and a 22- $\mu\text{F}$  capacitor at the output of the LED voltage regulator to supply the 100-mA current surge.

**Figure 47:**  
Proximity Sensing Using Separate Power Supplies



If it is not possible to provide two separate power supplies, the device can be operated from a single supply. A 22- $\Omega$  resistor in series with the  $V_{DD}$  supply line and a 1- $\mu\text{F}$  low ESR capacitor effectively filter any power supply noise. The previous capacitor placement considerations apply.

**Figure 48:**  
Proximity Sensing Using Single Power Supply



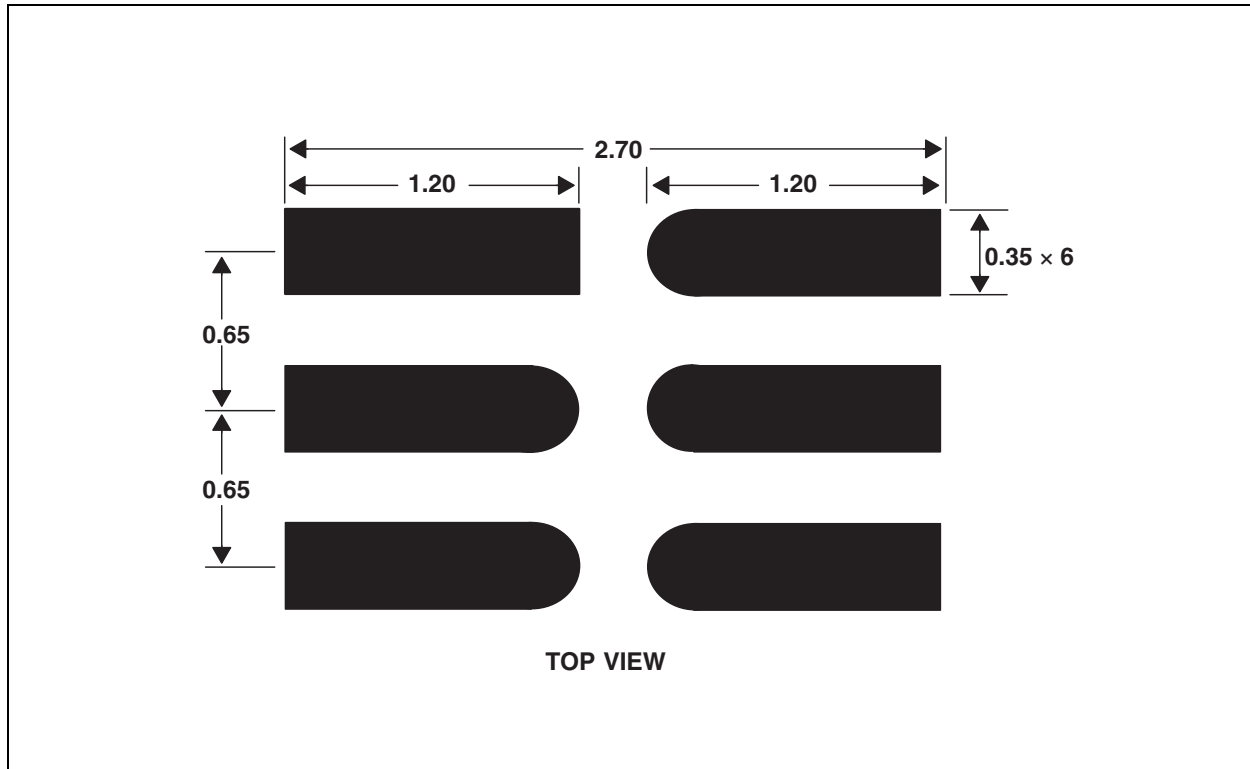
$V_{BUS}$  in the above figures refers to the I<sup>2</sup>C bus voltage which is either  $V_{DD}$  or 1.8 V. Be sure to apply the specified I<sup>2</sup>C bus voltage shown in the Ordering and Contact Information table for the specific device being used.

The I<sup>2</sup>C signals and the Interrupt are open-drain outputs and require pull-up resistors. The pull-up resistor ( $R_p$ ) value is a function of the I<sup>2</sup>C bus speed, the I<sup>2</sup>C bus voltage, and the capacitive load. The **ams** EVM running at 400 kbit/s, uses 1.5-k $\Omega$  resistors. A 10-k $\Omega$  pull-up resistor ( $R_{pl}$ ) can be used for the interrupt line.

## PCB Pad Layouts

Suggested land pattern based on the IPC-7351B Generic Requirements for Surface Mount Design and Land Pattern Standard (2010) for the small outline no-lead (SON) package is shown in [Figure 49](#).

**Figure 49:**  
**Suggested FN Package PCB Layout**

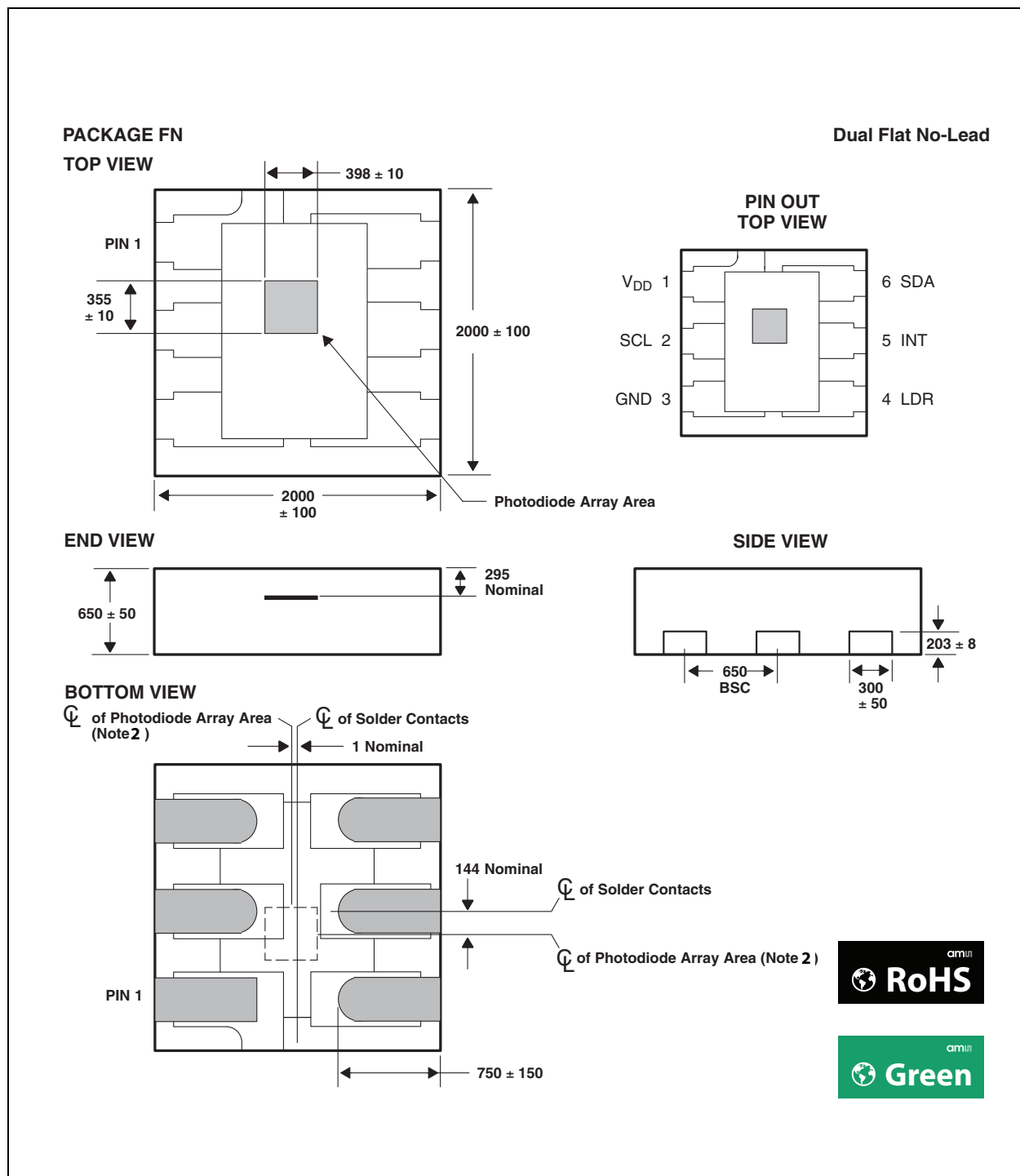


**Note(s):**

1. All linear dimensions are in millimeters.
2. This drawing is subject to change without notice.

## Package Information

**Figure 50:**  
Package FN — Dual Flat No-Lead Packaging Configuration

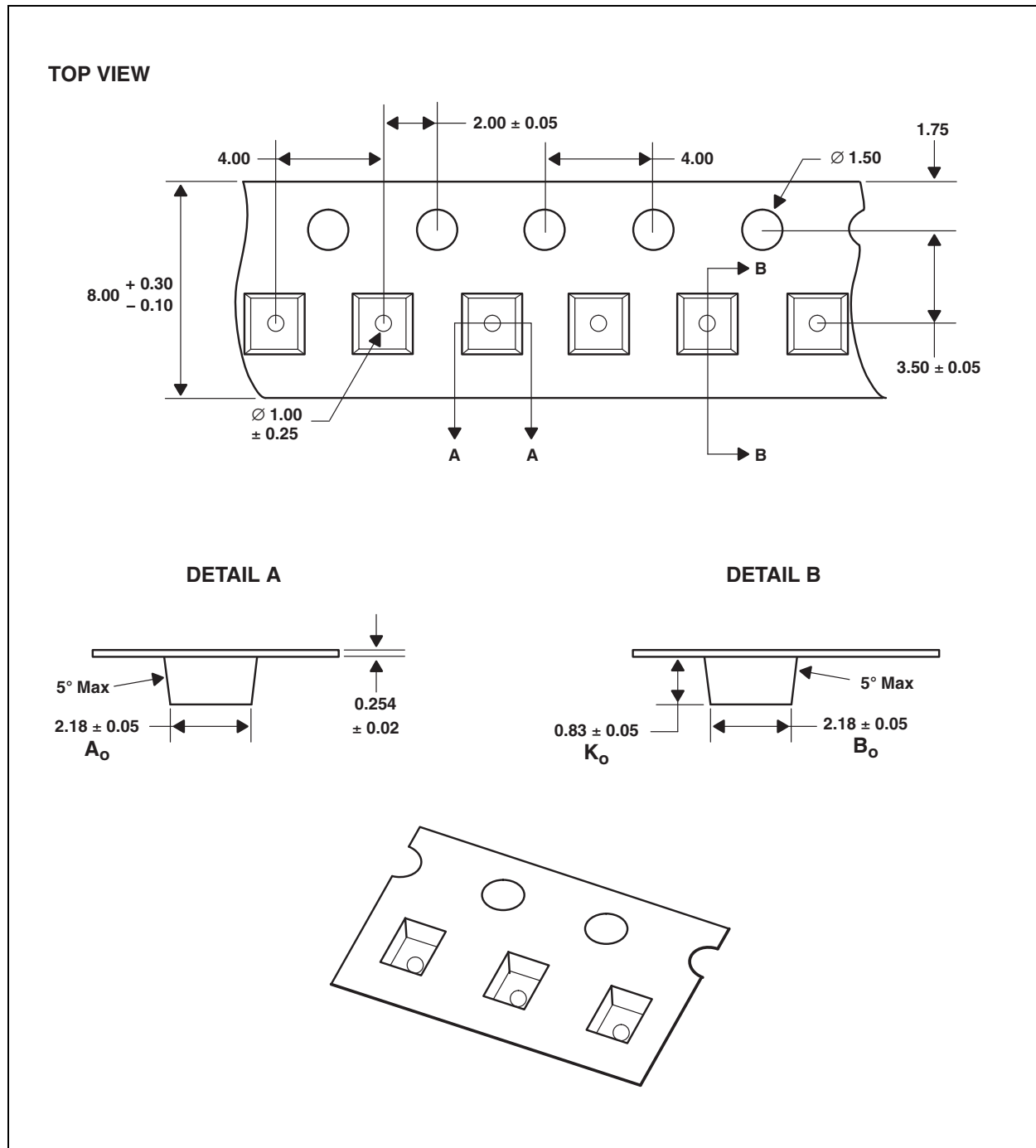


**Note(s):**

1. All linear dimensions are in micrometers.
2. The die is centered within the package within a tolerance of  $\pm 75 \mu\text{m}$ .
3. Package top surface is molded with an electrically nonconductive clear plastic compound having an index of refraction of 1.55.
4. Contact finish is copper alloy A194 with pre-plated NiPdAu lead finish.
5. This package contains no lead (Pb).
6. This drawing is subject to change without notice.

## Carrier Tape & Reel Information

**Figure 51:**  
Package FN Carrier Tape



**Note(s):**

1. All linear dimensions are in millimeters. Dimension tolerance is  $\pm 0.10$  mm unless otherwise noted.
2. The dimensions on this drawing are for illustrative purposes only. Dimensions of an actual carrier may vary slightly.
3. Symbols on drawing  $A_o$ ,  $B_o$ , and  $K_o$  are defined in ANSI EIA Standard 481–B 2001.
4. Each reel is 178 millimeters in diameter and contains 3500 parts.
5. ams packaging tape and reel conform to the requirements of EIA Standard 481–B.
6. In accordance with EIA standard, device pin 1 is located next to the sprocket holes in the tape.
7. This drawing is subject to change without notice.

## Soldering Information

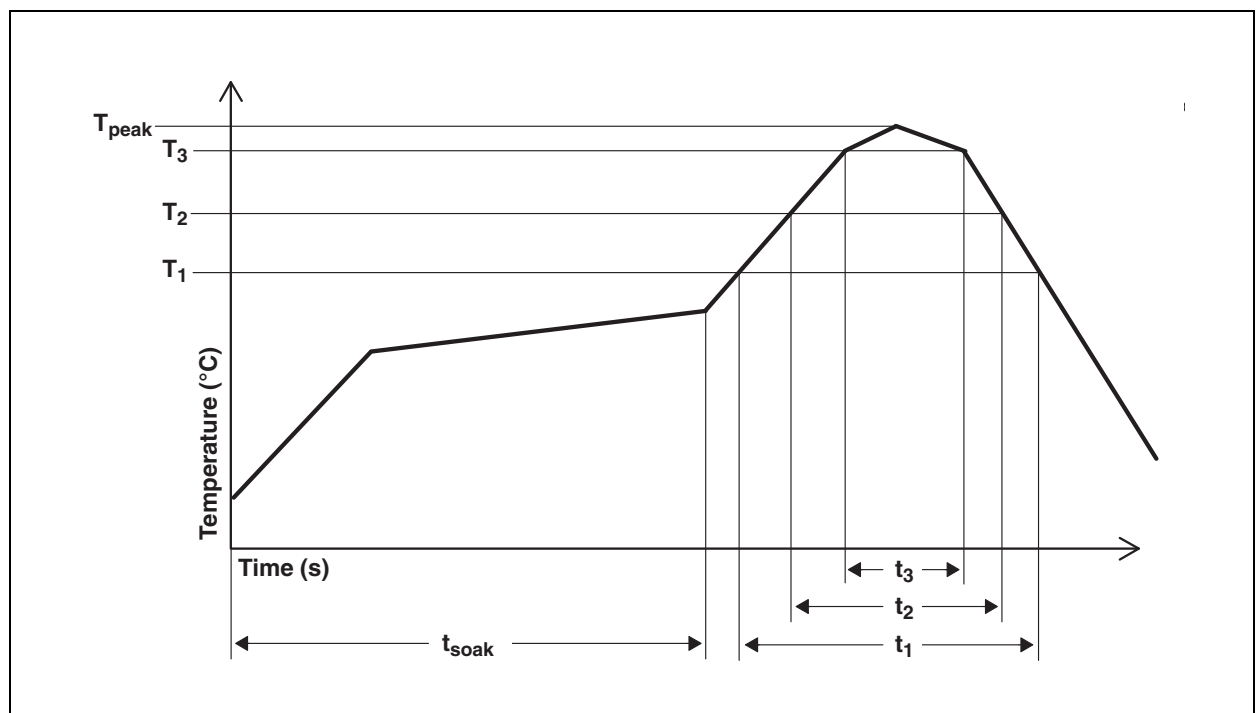
The FN package has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate.

The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The components should be limited to a maximum of three passes through this solder reflow profile.

**Figure 52:**  
**Solder Reflow Profile**

| Parameter                                            | Reference         | Device                   |
|------------------------------------------------------|-------------------|--------------------------|
| Average temperature gradient in preheating           |                   | 2.5°C/s                  |
| Soak time                                            | $t_{\text{soak}}$ | 2 to 3 minutes           |
| Time above 217°C (T1)                                | $t_1$             | Max 60 s                 |
| Time above 230°C (T2)                                | $t_2$             | Max 50 s                 |
| Time above $T_{\text{peak}} - 10^\circ\text{C}$ (T3) | $t_3$             | Max 10 s                 |
| Peak temperature in reflow                           | $T_{\text{peak}}$ | 260°C                    |
| Temperature gradient in cooling                      |                   | Max $-5^\circ\text{C/s}$ |

**Figure 53:**  
**Solder Reflow Profile Graph**



**Note(s):**

1. Not to scale — for reference only

## Storage Information

### Moisture Sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package. To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being packed for shipping. Devices are packed in a sealed aluminized envelope called a moisture barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

### Shelf Life

The calculated shelf life of the device in an unopened moisture barrier bag is 12 months from the date code on the bag when stored under the following conditions:

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

Rebaking of the devices will be required if the devices exceed the 12 month shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region.

### Floor Life

The FN package has been assigned a moisture sensitivity level of MSL 3. As a result, the floor life of devices removed from the moisture barrier bag is 168 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

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

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be rebaked prior to solder reflow or dry packing.

### Rebaking Instructions

When the shelf life or floor life limits have been exceeded, rebake at 50°C for 12 hours.

## Ordering & Contact Information

**Figure 54:**  
Ordering Information

| Ordering Code | Address | Package - Leads | Interface Description                             | Device                  |
|---------------|---------|-----------------|---------------------------------------------------|-------------------------|
| TSL27721FN    | 0x39    | FN-6            | I <sup>2</sup> C Vbus = V <sub>DD</sub> Interface | TSL27721                |
| TSL27723FN    | 0x39    | FN-6            | I <sup>2</sup> C Vbus = 1.8 V Interface           | TSL27723                |
| TSL27725FN    | 0x29    | FN-6            | I <sup>2</sup> C Vbus = V <sub>DD</sub> Interface | TSL27725 <sup>(1)</sup> |
| TSL27727FN    | 0x29    | FN-6            | I <sup>2</sup> C Vbus = 1.8 V Interface           | TSL27727 <sup>(1)</sup> |

**Note(s):**

1. Contact **ams** for availability.

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| Product Preview          | Pre-Development | Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice                                                                    |
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## Revision Information

| Changes from 131 (2011-Dec) to current revision 1-00 (2016-Aug-26) | Page |
|--------------------------------------------------------------------|------|
| Content of TAOS datasheet was updated to latest <b>ams</b> design  |      |
| Updated Key Benefits & Features                                    | 1    |

### Note(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision
2. Correction of typographical errors is not explicitly mentioned.

## Content Guide

|           |                                                       |
|-----------|-------------------------------------------------------|
| <b>1</b>  | <b>General Description</b>                            |
| 1         | Key Benefits & Features                               |
| 2         | Applications                                          |
| 3         | End Products and Market Segments                      |
| 3         | Block Diagram                                         |
| <b>4</b>  | <b>Detailed Description</b>                           |
| <b>5</b>  | <b>Pin Assignments</b>                                |
| <b>6</b>  | <b>Absolute Maximum Ratings</b>                       |
| 11        | Parameter Measurement Information                     |
| <b>12</b> | <b>Typical Characteristics</b>                        |
| <b>16</b> | <b>Principles Of Operation</b>                        |
| 16        | System State Machine                                  |
| 17        | Photodiodes                                           |
| 17        | ALS Operation                                         |
| 18        | Lux Equation                                          |
| 19        | Proximity Detection                                   |
| 21        | Interrupts                                            |
| 23        | System State Machine Timing                           |
| 25        | Power Management                                      |
| 27        | I <sup>2</sup> C Protocol                             |
| 28        | Register Set                                          |
| 30        | Command Register                                      |
| 31        | Enable Register (0x00)                                |
| 32        | ALS Time Register (0x01)                              |
| 32        | Proximity Time Register (0x02)                        |
| 33        | Wait Time Register (0x03)                             |
| 33        | ALS Interrupt Threshold Registers (0x04 - 0x07)       |
| 34        | Proximity Interrupt Threshold Registers (0x08 - 0x0B) |
| 35        | Persistence Filter Register (0x0C)                    |
| 37        | Configuration Register (0x0D)                         |
| 37        | Proximity Pulse Count Register (0x0E)                 |
| 38        | Control Register (0x0F)                               |
| 40        | ID Register (0x12)                                    |
| 40        | Status Register (0x13)                                |
| 41        | ADC Channel Data Registers (0x14 - 0x17)              |
| 41        | Proximity Data Registers (0x18 - 0x19h)               |
| 42        | Proximity Offset Register (0x1E)                      |
| <b>43</b> | <b>Application Information Hardware</b>               |
| 43        | LED Driver Pin with Proximity Detection               |
| 45        | PCB Pad Layouts                                       |
| <b>46</b> | <b>Package Information</b>                            |
| <b>47</b> | <b>Carrier Tape And Reel Information</b>              |
| <b>48</b> | <b>Soldering Information</b>                          |

|           |                                                 |
|-----------|-------------------------------------------------|
| <b>49</b> | <b>Storage Information</b>                      |
| 49        | Moisture Sensitivity                            |
| 49        | Shelf Life                                      |
| 49        | Floor Life                                      |
| 49        | Rebaking Instructions                           |
| <b>50</b> | <b>Ordering &amp; Contact Information</b>       |
| <b>51</b> | <b>RoHS Compliant &amp; ams Green Statement</b> |
| <b>52</b> | <b>Copyrights &amp; Disclaimer</b>              |
| <b>53</b> | <b>Document Status</b>                          |
| <b>54</b> | <b>Revision Information</b>                     |

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