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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
• Enables Operation in IR Light Environments	• Patented Dual-Diode Architecture
• Enables Operation in 60K Lux Sunlight and Accurate Sensing Behind Spectrally Distorting Materials	• 8M:1 Dynamic Range
• Improves Lux Accuracy Across Varying Light Sources	• UV-Rejection Package
• Compensates for Internal System Offset or IR LED Crosstalk	• Proximity Offset Adjustment
• Prevents False Proximity Detection in Bright Light	• Proximity Saturation Indicator Bit

- 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^2C Fast Mode Compatible Interface
    - Data Rates up to 400 kbit/s
    - Input Voltage Levels Compatible with V_{DD} 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

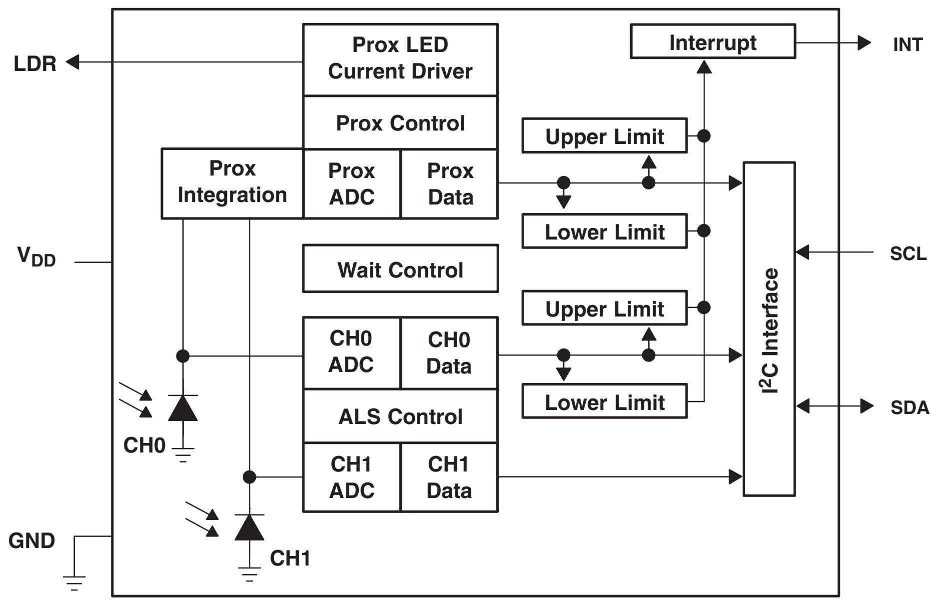
End Products and Market Segments

- 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^2C 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^2C 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)

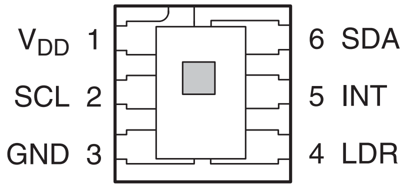


Figure 4:
Terminal Functions

Terminal		Type	Description
Name	No		
V_{DD}	1		Supply voltage.
SCL	2	I	I²C serial clock input terminal — clock signal for I²C 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	I²C serial data I/O terminal — serial data I/O for I²C.

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	±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 Vbus = 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 V, T_A = 25°C (unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply current	Active — LDR pulse OFF		200	250	μA
		Wait state		90		
		Sleep state - no I^2C 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	μA
I_{LEAK}	Leakage current, LDR pin		−5		5	μA
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 V, T_A = 25°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, 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 (4)			1		256	steps
ADC counts per step (4)	ATIME = 0xFF		0		1024	counts
ADC count value(4)	ATIME = 0xC0		0		65535	counts
ADC count value	White Light, E_e = 263.9 µW/cm², ATIME = 0xF6 (27 ms). (2)	CH0	4000	5000	6000	counts
		CH1		680		
	λ_p = 850 nm, E_e = 263.4 µW/cm², ATIME = 0xF6 (27 ms) . (3)	CH0	4000	5000	6000	
		CH1		2850		
ADC count value ratio: CH1/CH0	White Light, ATIME 0xF6 (27 ms) (2)		0.086	0.136	0.186	
	λ_p = 850 nm, ATIME 0xF6 (27 ms) (3)		0.456	0.570	0.684	
R_e Irradiance responsivity	White Light, ATIME = 0xF6 (27 ms) (2)	CH0		18.9		counts/ (µW/cm²)
		CH1		2.58		
	λ_p = 850 nm, ATIME = 0xF6 (27 ms) .(3)	CH0		19.0		
		CH1		10.8		
Gain scaling, relative to 1x 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):

1. 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.
2. The white LED irradiance is supplied by a white light-emitting diode with a nominal color temperature of 4000k.
3. The 850 nm irradiance E_e is supplied by a GaAs light-emitting diode with the following typical characteristics: peak wavelength λ_p = 850 nm and spectral halfwidth $\Delta\lambda½$ = 42 nm.
4. Parameter ensured by design and is not tested.

Figure 9:
Proximity Characteristics, V_{DD} = 3 V, T_A = 25°C, PGAIN = 1x, PEN = 1 (unless otherwise noted)

Parameter	Test Conditions		Min	Typ	Max	Unit
I_{DD} Supply current	LDR pulse ON			3		mA
ADC conversion time step size	PTIME = 0xFF		2.58	2.73	2.9	ms
ADC number of integration steps (1)			1		256	steps
ADC counts per step (1)	PTIME = 0xFF		0		1023	counts
ADC count value	λ_p = 850 nm, E_e = 263.4µW/cm^2, PTIME = 0xFB, PPULSE = 4	CH0 diode	1500	2000	2500	counts
		CH1 diode	900	1200	1500	
ADC output responsivity	λp = 850 nm, PTIME = 0xFB, PPULSE = 1	CH0 diode		1.90		counts/ (µW/cm^2)
		CH1 diode		1.14		
Gain scaling, relative to 1x gain setting	PGAIN = 2x			2		x
	PGAIN = 4x			4		
	PGAIN = 8x			8		
Noise (1)(2)(3)	Ee = 0, PTIME = 0xFB, PPULSE = 4 (6)	CH0 diode		0.5		%FS
		CH1 diode		0.5		
LED pulse count (1)			0		255	pulses
LED pulse period				16.0		µs
LED pulse width — LED ON time				7.3		µs
LED drive current	I_{SINK} sink current @ 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 (1)(4)(5)	PDRIVE = 0 and PDL = 0 (116 mA), PPULSE = 64 Emitter: λ_p = 850 nm, 20° half angle, and 60 mW/sr Object: 16 × 20-inch, 90% reflective Kodak Gray Card (white surface) 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

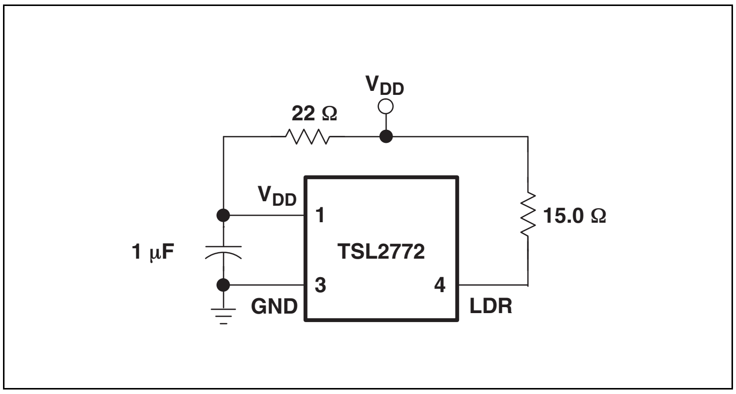


Figure 11:
Wait Characteristics, V_{DD} = 3 V, T_A = 25°C, WEN = 1 (unless otherwise noted)

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 (1)			1		256	steps

Note(s):

1. Parameter ensured by design and is not tested.

Figure 12:
AC Electrical Characteristics, V_{DD} = 3 V, T_A = 25°C, (unless otherwise noted)

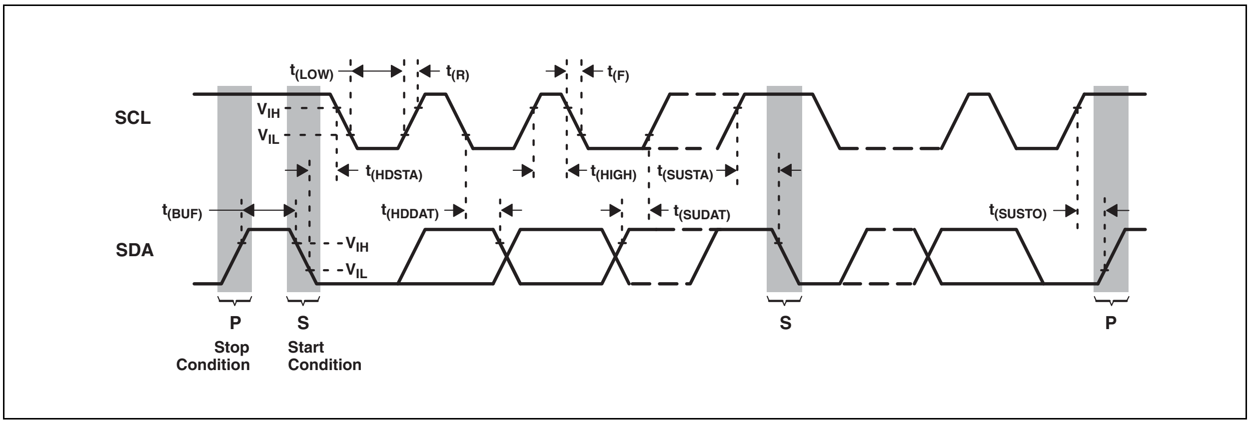
Symbol	Parameter (1)	Test Conditions	Min	Typ	Max	Unit
$f_{(SCL)}$	Clock frequency (I^2C only)		0		400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition		1.3			µs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.		0.6			µs
$t_{(SUSTA)}$	Repeated start condition setup time		0.6			µs
$t_{(SUSTO)}$	Stop condition setup time		0.6			µs
$t_{(HDDAT)}$	Data hold time		0			µs
$t_{(SUDAT)}$	Data setup time		100			ns
$t_{(LOW)}$	SCL clock low period		1.3			µs
$t_{(HIGH)}$	SCL clock high period		0.6			µs
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

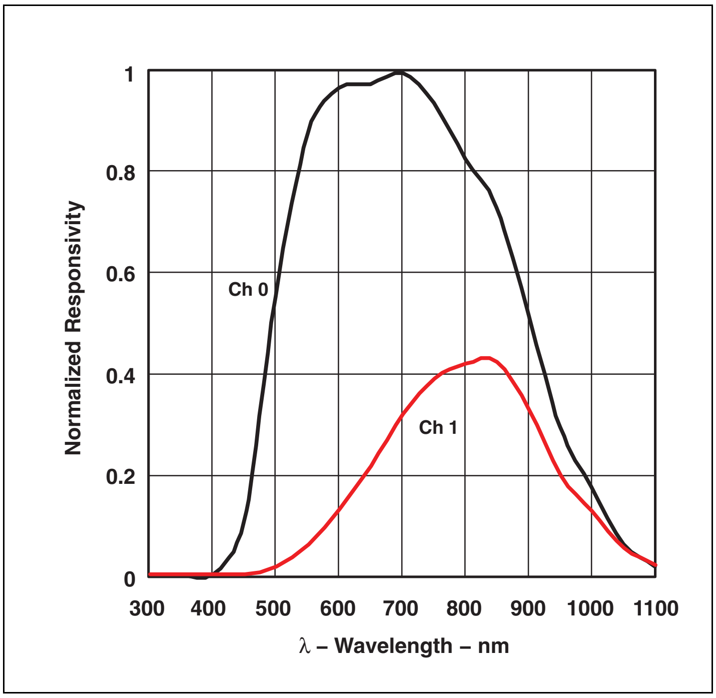


Figure 15:
Normalized Responsivity vs. Angular Displacement

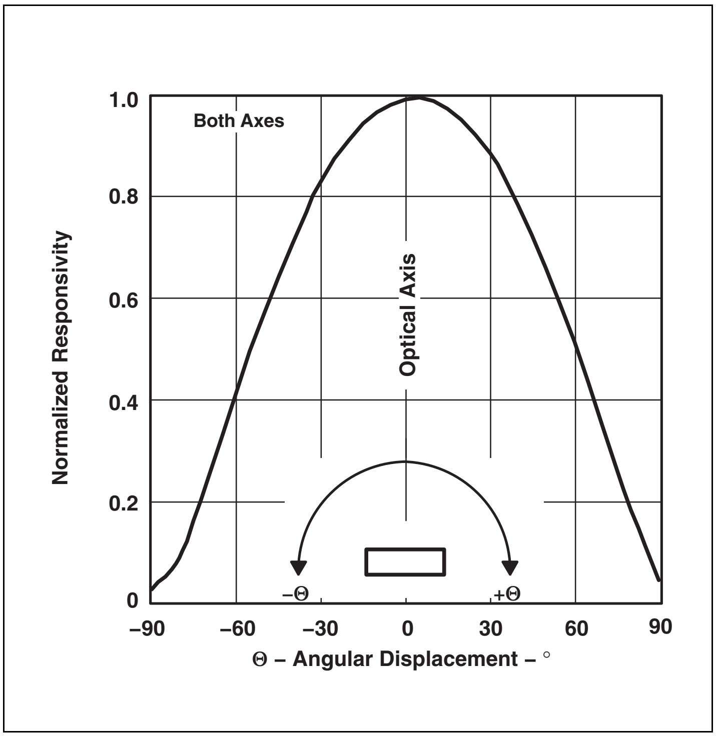


Figure 16:
Typical LDR Current vs. Voltage

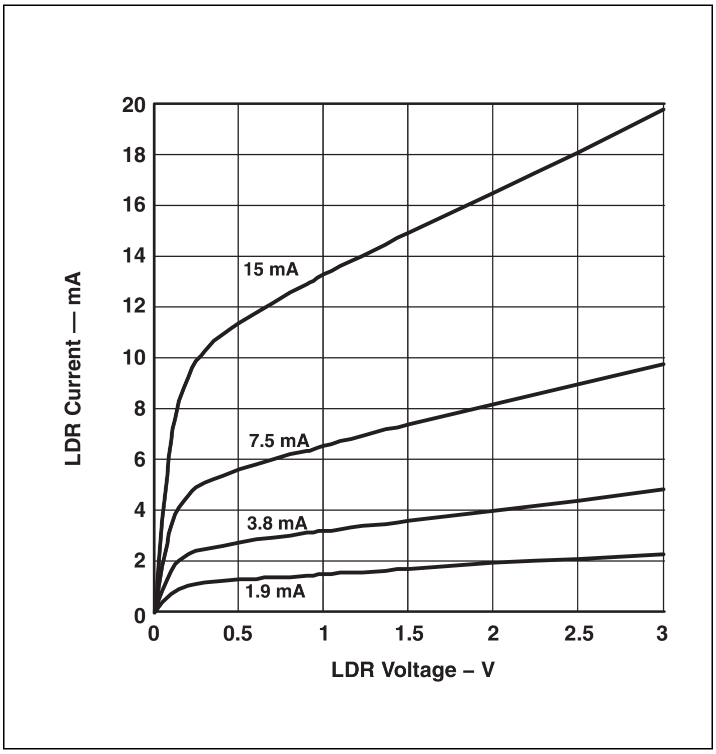


Figure 17:
Typical LDR Current vs. Voltage

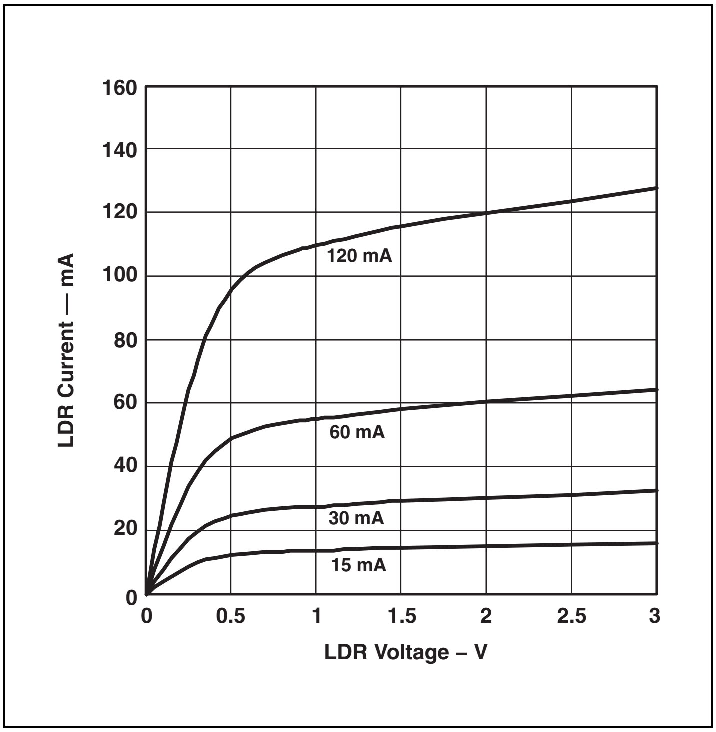


Figure 18:
Response to White LED vs. Temperature

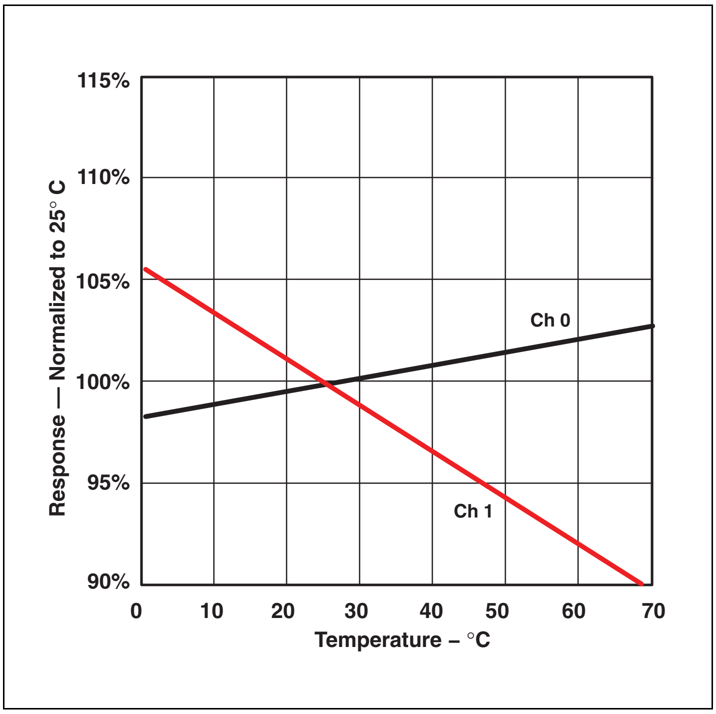


Figure 19:
Response to IR (850 nm) LED vs. Temperature

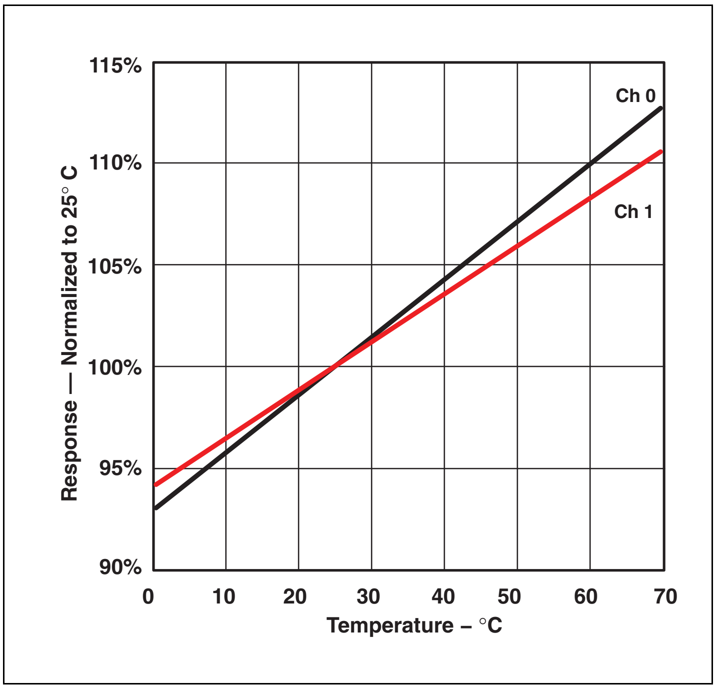
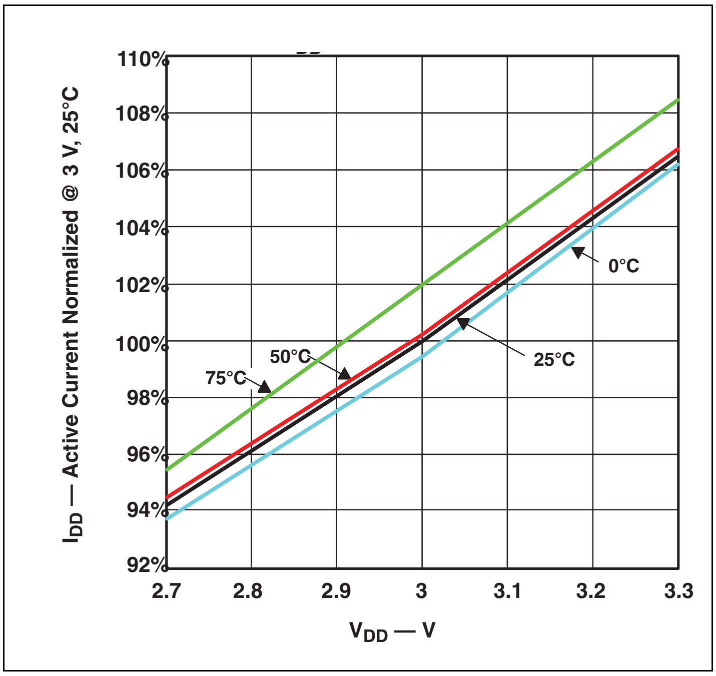


Figure 20:
Normalized I_{DD} vs.V_{DD} and Temperature



Principles Of Operation

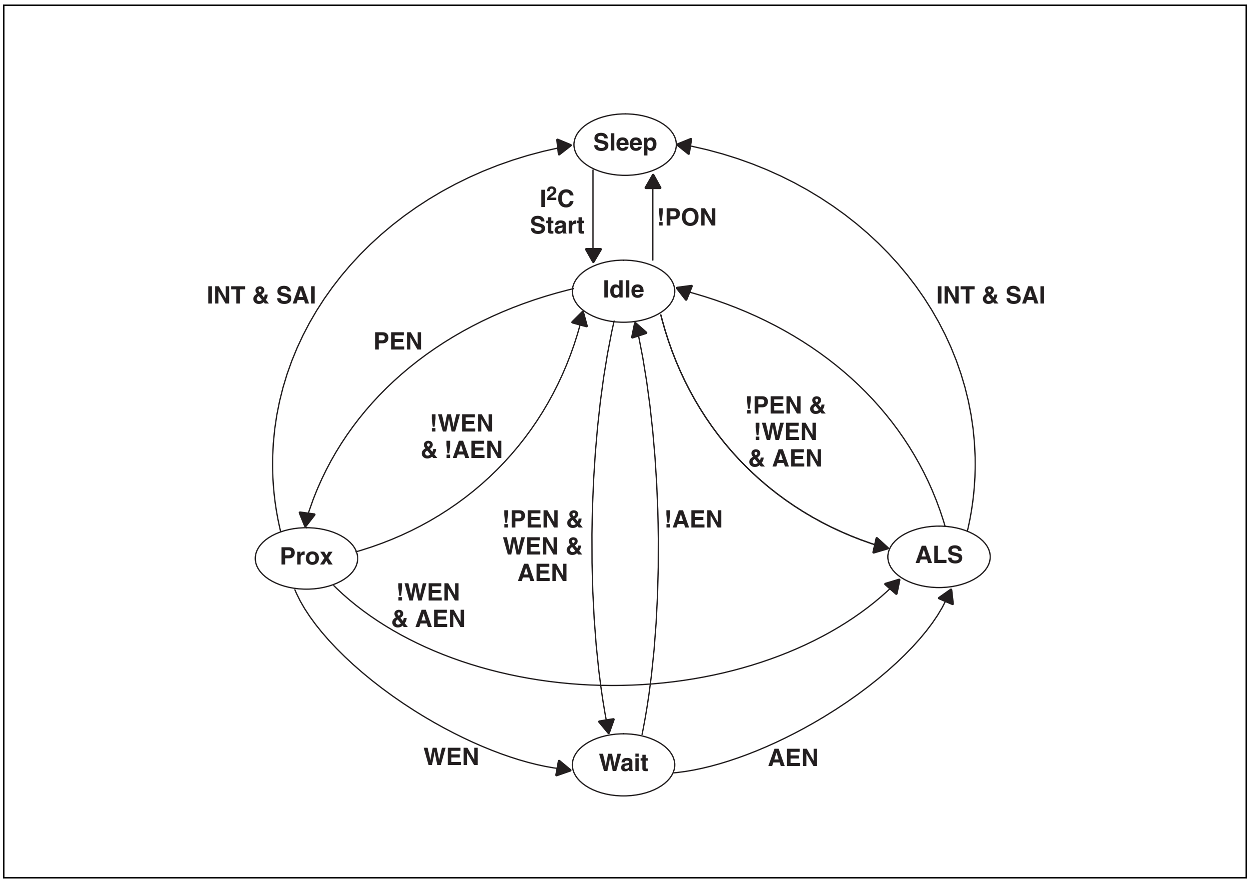
System State Machine

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^2C 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^2C command is received. See the Interrupts section for additional information.

Figure 21:
Simplified State Diagram



Photodiodes

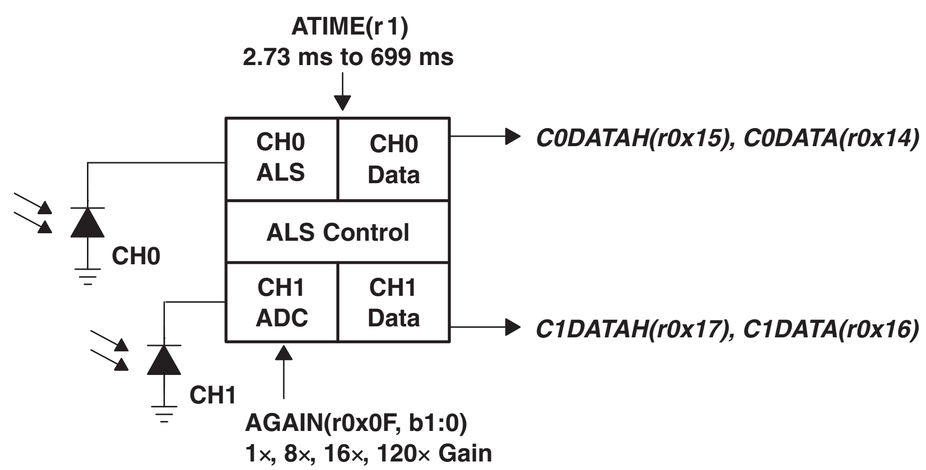
Conventional ALS detectors respond strongly to infrared light, which the human eye does not see. This can lead to significant error when the infrared content of the ambient light is high (such as with incandescent lighting).

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 compliment values. The actual time can be calculated as follows:

ATIME = 256 - Integration Time / 2.73 ms

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

Integration Time = 2.73 ms × (256 - 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.

CPL = (ATIME_ms × AGAINx) / (GA × 60)

Lux1 = (1 × C0DATA - 1.87 × C1DATA) / CPL

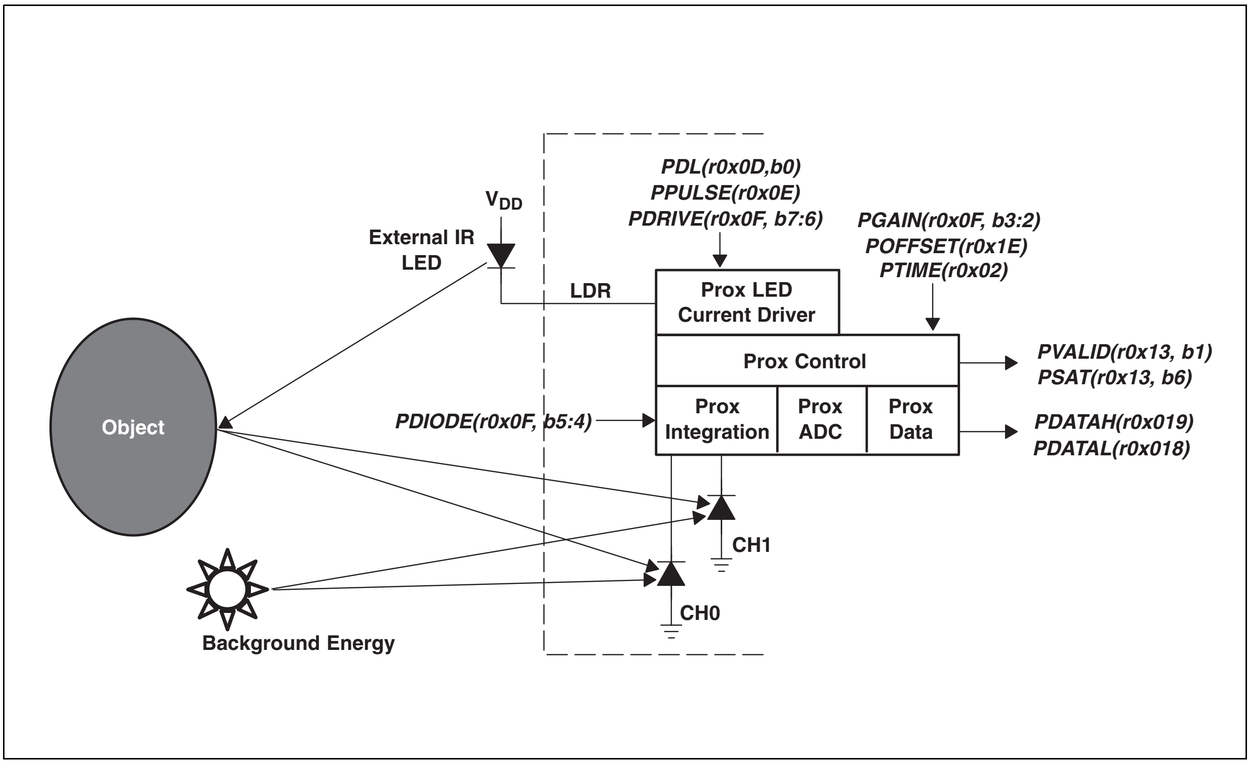
Lux2 = (0.63 × C0DATA - 1 × C1DATA) / CPL

Lux = MAX(Lux1, 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 µs and period of 16.0 µs. 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

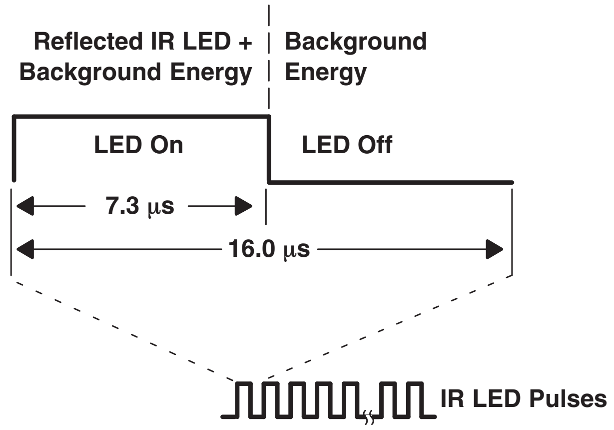


Figure 23 illustrates light rays emitting from an external IR LED, reflecting off an object, and being absorbed by the CH0 and CH1 photodiodes. The proximity diode selector (PDIODE) determines which of the two photodiodes is used for a given proximity measurement. Note that neither photodiode is selected 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

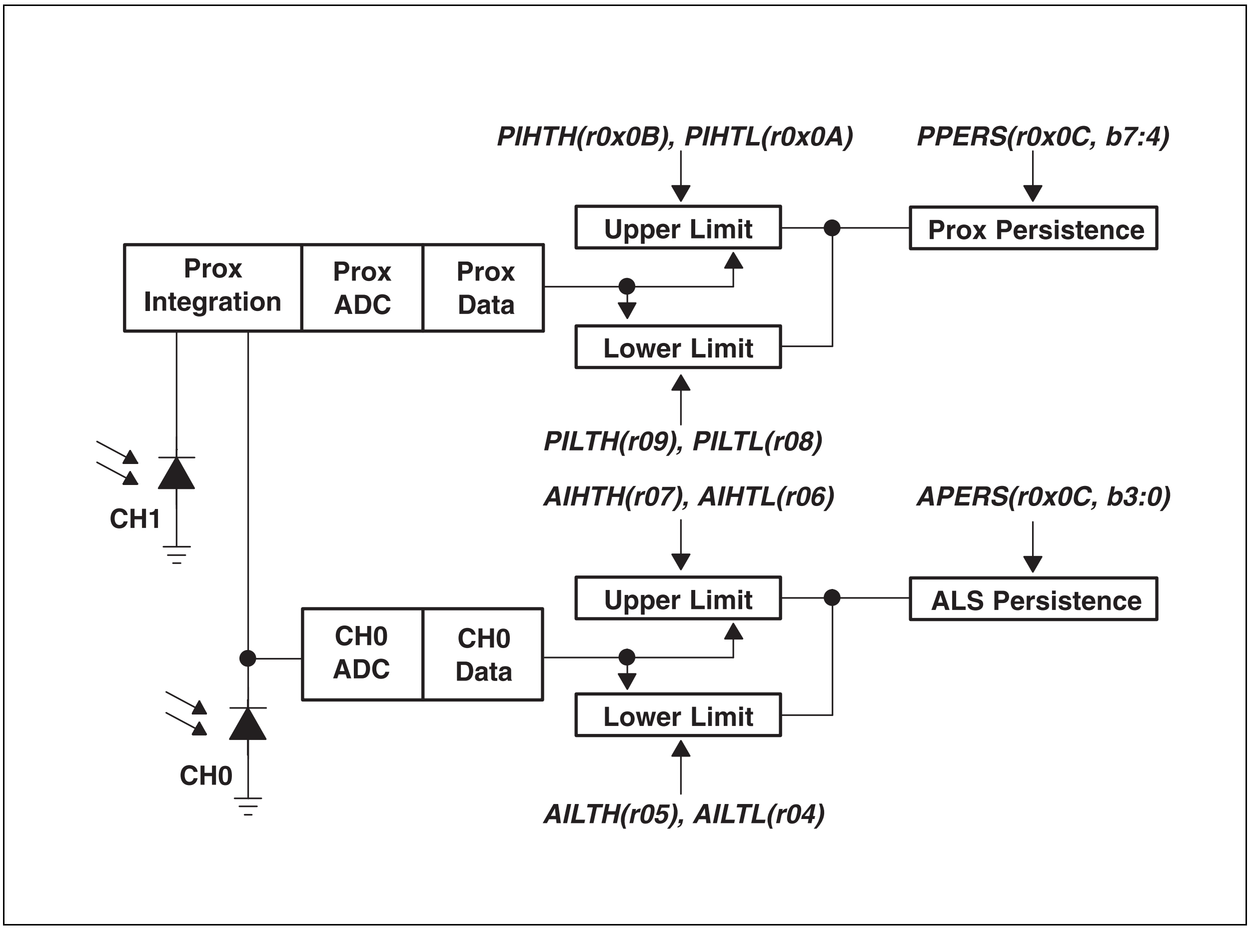
The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for light intensity or proximity values outside of a user-defined range. While the interrupt function is always enabled and it's status is available in the status register (0x13), the output of 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 (AILTx) and ALS interrupt high threshold registers (AIHTx). Likewise, an out-of-range proximity interrupt can be generated when the proximity data (PDATA) falls below the proximity interrupt low threshold (PILTx) or exceeds the proximity interrupt high threshold (PIHTx).

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

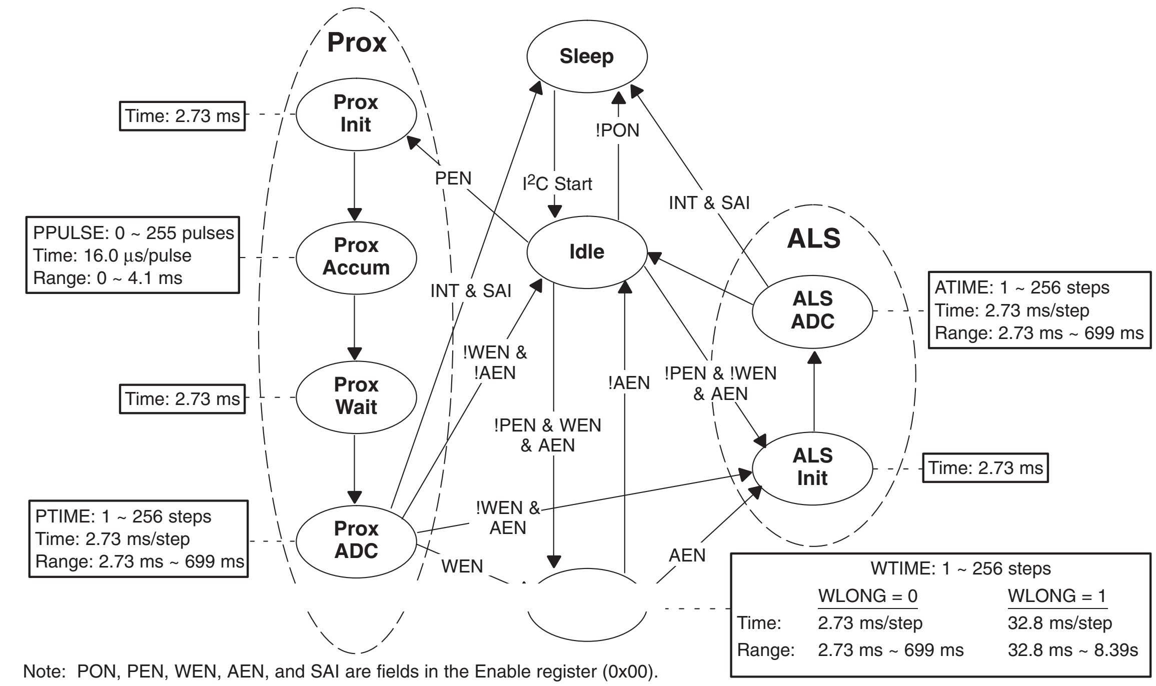
The system state machine shown in Figure 21 provides an overview of the states and state transitions that provide system control of the device. This section highlights the programmable features, which affect the state machine cycle time, and provides details to determine system level timing.

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 Machine State	Programmable Parameter	Programmed Value	Duration	Typical Current
Prox Init			2.73 ms	0.200 mA
Prox Accum	PPULSE	0x04	0.064 ms	
Prox Accum – LED ON			0.029 ms [1]	119 mA
Prox Accum – LED OFF			0.035 ms[2]	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 = 7.3µs per pulse × 4 pulses = 29.3µs = 0.029 ms
2. Prox Accum - LED OFF time = 8.7 µs per pulse × 4 pulses = 34.7µs = 0.035 ms

Average I_{DD} Current = ((0.029 × 119) + (0.035 × 0.200) + (2.73 × 0.200) + (49.2 × 0.090) + (49.2 × 0.200) + (2.73 × 0.200 × 3)) /109 ≈ 182 µA

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.