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TMD2771

Digital ALS and Proximity Module

General Description

The TMD2771 family of devices provides digital ambient light sensing (ALS), a complete proximity detection system, and digital interface logic in a single 8-pin package. The proximity detector includes a digital proximity sensor, LED driver, and IR LED, which are trimmed to eliminate the need for end-equipment calibration due to component variations. Excellent background light rejection allows the device to operate in environments from sunlight to dark rooms. The wide dynamic range allows for operation in short distance detection such as a cell phone (behind dark glass). An internal state machine provides the ability to put the device into a low-power mode in between ALS and proximity measurements, providing very low average power consumption.

The device is particularly useful for display management with the purpose of extending battery life and providing optimum viewing in diverse lighting conditions. Display panel and keyboard backlighting can account for up to 30 to 40 percent of total platform power. The ALS features are ideal for use in notebook PCs, LCD monitors, flat-panel televisions, and cell phones.

The proximity function specifically targets near-field proximity applications. In cell phones, the proximity detection can detect when the user positions the phone close to their ear. The device is fast enough to provide proximity information at a high repetition rate needed when answering a phone call. This provides both improved green power saving capability and the added security to lock the computer when the user is not present. The addition of the micro-optics lenses within the device, provide highly efficient transmission and reception of infrared energy, which lowers overall power dissipation.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of the TMD2771, Digital ALS and Proximity Module are listed below:

Figure 1:
Added Value of Using TMD2771

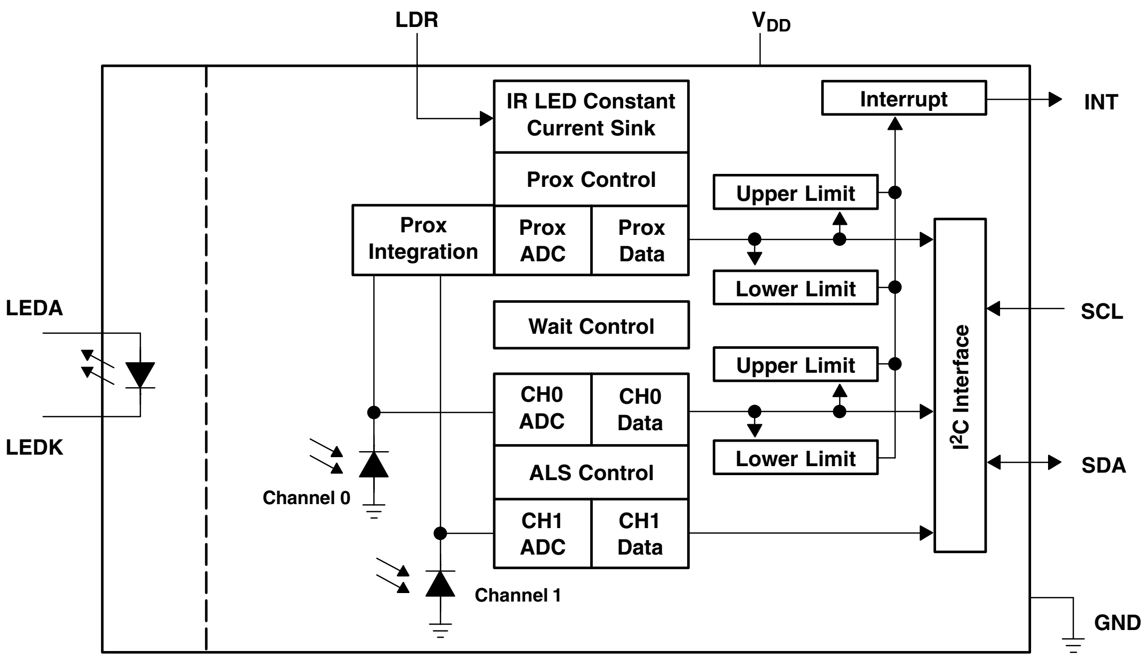
Benefits	Features
• Module Reduces Board Space and Design Effort	• Integrated Ambient Light Sensing, Proximity Detection and IR LED
• Enables Operation in IR Light Environments	• Ambient Light Sensing Based on Patented Dual-Diodes
• Allows accurate sensing behind spectrally distorting materials (e.g. dark glass)	• 1M:1 Dynamic Range
• Pre-calibration eliminates need for customer to end-product calibrate	• Proximity Detection Calibrated and Trimmed to Provide Consistent Reading
• Allows Multiple Power-Level Selection without External Passives	• Programmable LED Drive Current

- Ambient Light Sensing (ALS)
  - Approximates Human Eye Response
  - Programmable Analog Gain
  - Programmable Integration Time
  - Programmable Interrupt Function with Upper and Lower Threshold
  - Up to 16 Bits Resolution
  - Very High Sensitivity - Operates Behind Darkened Glass
  - Up to 1 000 000:1 Dynamic Range
- Proximity Detection
  - Calibrated to 100mm Detection
  - Eliminates Factory Calibration of Prox
  - Programmable Number of IR Pulses
  - Programmable Current Sink for the IR LED - No Limiting Resistor Needed
  - Programmable Interrupt Function with Upper and Lower Threshold
- Programmable Wait Timer
  - Wait State - 65µA Typical Current
  - Programmable from 2.72ms to > 8 Seconds
- I^2C Interface Compatible
  - Up to 400kHz (I^2C Fast Mode)
- Sleep Mode - 2.5µA Typical
- Dedicated Interrupt Pin
- 3.94mm × 2.4mm × 1.35mm Package

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
TMD2771 Block Diagram



Applications

The applications of TMD2771 include:

- Cell Phone Backlight Dimming
- Cell Phone Touch Screen Disable
- Notebook/Monitor Security
- Automatic Speakerphone Enable
- Automatic Menu Popup

Detailed Description

The 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 one photodiode (CH0), which is responsive to both visible and infrared light, and a second photodiode (CH1), which is responsive primarily to infrared light. Two integrating ADCs simultaneously convert the amplified photodiode currents to a digital value providing up to 16-bits of resolution. Upon completion of the conversion cycle, the conversion result is transferred to the Ch0 and Ch1 data registers. This digital output can be read by a microprocessor where the luminance (ambient light level in lux) is derived using an empirical formula to approximate the human eye response.

A fully integrated proximity detection solution is provided with an 850nm IR LED, LED driver circuit, and proximity detection engine. An internal LED driver (LDR) pin, is connected to the LED cathode (LEDK) to provide a factory calibrated proximity of 100mm, ±20mm. This is accomplished with a proprietary current calibration technique that accounts for all variances in silicon, optics, package, and most important, IR LED output power. This eliminates or greatly reduces the need for factory calibration that is required for most discrete proximity sensor solutions. While the device is factory calibrated at a given pulse count, the number of proximity LED pulses can be programmed from 1 to 255 pulses, which allows different proximity distances to be achieved. Each pulse has a 16µs period with a 7.2µs on time.

Communication with the device is accomplished through a fast (up to 400kHz), 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 photodiode 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.

Pin Assignment

Package drawing is not to scale

The TMD2771 pin assignments are described below:

Figure 3:
Pin Diagram of Package Module-8 (Top View)

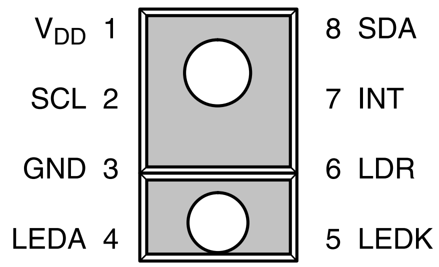


Figure 4:
Terminal Functions

Terminal		Type	Description
Name	No.		
V_{DD}	1		Supply voltage
SCL	2	I	I^2C serial clock input terminal - clock signal for I^2C serial data
GND	3		Power supply ground. All voltages are referenced to GND.
LEDA	4	I	LED anode
LEDK	5	O	LED cathode. Connect to LDR pin when using internal LED driver circuit.
LDR	6	I	LED driver input for proximity IR LED, constant current source LED driver
INT	7	O	Interrupt - open drain
SDA	8	I/O	I^2C serial data I/O terminal - serial data I/O for I^2C

Absolute Maximum Ratings

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. 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 rating 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	Unit
V_{DD}	Supply voltage (1)		3.8	V
V_O	Digital output voltage range	-0.5	3.8	V
I_O	Digital output current	-1	20	mA
LDR	Analog voltage range	-0.5	3.8	V
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.

Electrical Characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Figure 6:
Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Unit
V_{DD}	Supply voltage	2.5	3	3.6	V
V_{LED}	Voltage on LED anode	2.9		4.0	V
	Supply voltage accuracy, V_{DD} total error including transients	-3		3	%
T_A	Operating free-air temperature range [(1)]	-30		85	°C

Note(s):

1. While the device is operational across the temperature range, functionality will vary with temperature. Specifications are stated only at 25°C unless otherwise noted.

Figure 7:
Operating Characteristics, V_{DD} = 3V, T_A = 25°C (unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply current	Active - ATIME = 100ms		175	250	µA
		Wait mode		65		
		Sleep mode		2.5	4	
I_{DD}	Supply current - LDR pulse On			3		mA
V_{OL}	INT, SDA output low voltage	3mA sink current	0		0.4	V
		6mA sink current	0		0.6	
I_{LEAK}	Leakage current, SDA, SCL, INT pins		-5		5	µA
I_{LEAK}	Leakage current, LDR pin				10	µA
V_{IH}	SCL, SDA input high voltage	TMD27711	0.7 V_{DD}			V
		TMD27713	1.25			
V_{IL}	SCL, SDA input low voltage	TMD27711			0.3 V_{DD}	V
		TMD27713			0.54	

Figure 8:
ALS Characteristics, V_{DD} = V_{LEDA} = 3V, T_A = 25°C, AGAIN = 16×, AEN = 1 (unless otherwise noted) [1]

Parameter	Test Conditions	Channel	Min	Typ	Max	Unit
Dark ALS ADC count value	Ee = 0, AGAIN = 120×, ATIME = 0xDB (100ms)	CH0	0	1	5	counts
		CH1	0	1	5	
ALS ADC integration time step size	ATIME = 0xFF		2.58	2.72	2.9	ms
ALS ADC Number of integration steps			1		256	steps
ADC counts per step	ATIME = 0xFF		0		1024	counts
ADC count value	ATIME = 0xC0		0		65535	counts
ALS ADC count value	λ_p = 625nm, E_e = 60.5μW/cm^2, ATIME = 0xF6 (27ms) [2]	CH0	4000	5000	6000	counts
		CH1		790		
	λ_p = 850nm, E_e = 82.7μW/cm^2, ATIME = 0xF6 (27ms) [3]	CH0	4000	5000	6000	
		CH1		2800		
ALS ADC count value ratio: CH1/CH0	λ_p = 625nm, ATIME = 0xF6 (27 ms) [2]		10.8	15.8	20.8	%
	λ_p = 850nm, ATIME = 0xF6 (27 ms) [3]		41	56	68	
R_e Irradiance responsivity	λ_p = 625nm, ATIME = 0xF6 (27ms) [2]	CH0		82.6		counts/ (μW/cm^2)
		CH1		13.1		
	λ_p = 850nm, ATIME = 0xF6 (27ms) [3]	CH0		60.5		
		CH1		33.9		
Gain scaling, relative to 1× gain setting	8×		-10		10	%
	16×		-10		10	
	120×		-10		10	

Note(s):

1. Optical measurements are made using small-angle incident radiation from light-emitting diode optical sources. Visible 625nm LEDs and infrared 850nm LEDs are used for final product testing for compatibility with high-volume production.
2. The 625nm irradiance E_e is supplied by an AlInGaP light-emitting diode with the following typical characteristics: peak wavelength λ_p = 625nm and spectral halfwidth Δλ½ = 20nm.
3. The 850nm irradiance E_e is supplied by a GaAs light-emitting diode with the following typical characteristics: peak wavelength λ_p = 850nm and spectral halfwidth Δλ½ = 42nm.

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

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply current - LDR pulse on			3		mA
	ADC conversion time step size	PTIME = 0xFF		2.72		ms
	ADC number of integration steps		1		256	steps
	ADC counts per step	PTIME = 0xFF	0		1023	counts
	Proximity IR LED pulse count		0		255	pulses
	Proximity pulse period			16.3		µs
I_{LEDA}	LED current @ V 600mV, LDR pin sink [1]	PDRIVE = 0 (100% current level)	75	100	150	mA
		PDRIVE = 1 (50% current level)		50		
		PDRIVE = 2 (25% current level)		25		
		PDRIVE = 3 (12.5% current level)		12.5		
T_{LDR}	On time per pulse	PDRIVE = 1		7.2		µs
	Proximity response, no target (offset)	PDRIVE = 0, PPULSE = 8 [2]		100		counts
	Prox count, 100mm target [3]	73mm × 83mm, 90% reflective Kodak Gray Card, PPULSE = 8, PDRIVE = 0, PTIME = 0xFF [4]	414	520	624	counts

Note(s):

1. Value is factory-adjusted to meet the Prox count specification. Considerable variation (relative to the typical value) is possible after adjustment.
2. No reflective surface above the module. Proximity offset varies with power supply characteristics and noise.
3. I_{LEDA} is factory calibrated to achieve this specification. Offset and crosstalk directly sum with this value and is system dependent.
4. No glass or aperture above the module. Tested value is the average of 5 consecutive readings.
5. These parameters are ensured by design and characterization and are not 100% tested.
6. Proximity test was done using the following circuit. See Application Information: Hardware section for recommended application circuit.

Figure 10:
Proximity Test Circuit

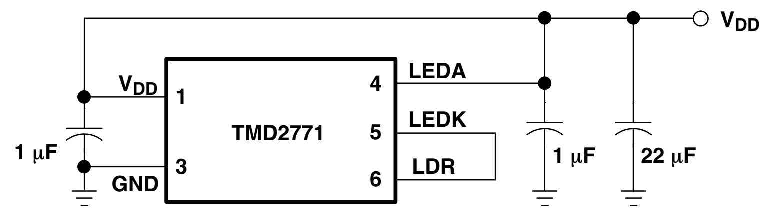


Figure 11:
IR LED Characteristics, V_{DD} = 3V, T_A = 25°C

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_F	Forward Voltage	I_F = 20mA		1.4	1.5	V
V_R	Reverse Voltage	I_R = 10µA	5			V
P_O	Radiant Power	I_F = 20mA	4.5			mW
λ_p	Peak Wavelength	I_F = 20mA		850		nm
Δ_λ	Spectral Radiation Bandwidth	I_F = 20mA		40		nm
T_R	Optical Rise Time	I_F = 100mA, T_W = 125ns, duty cycle = 25%		20	40	ns
T_F	Optical Fall Time	I_F = 100mA, T_W = 125ns, duty cycle = 25%		20	40	ns

Figure 12:
Wait Characteristics, V_{DD} = 3V, T_A = 25°C, WEN = 1 (unless otherwise noted)

Parameter	Test Conditions	Min	Typ	Max	Unit
Wait step size	WTIME = 0xFF		2.72	2.9	ms
Wait number of integration steps		1		256	steps

Figure 13:
AC Electrical Characteristics, V_{DD} = 3V, T_A = 25°C (unless otherwise noted)

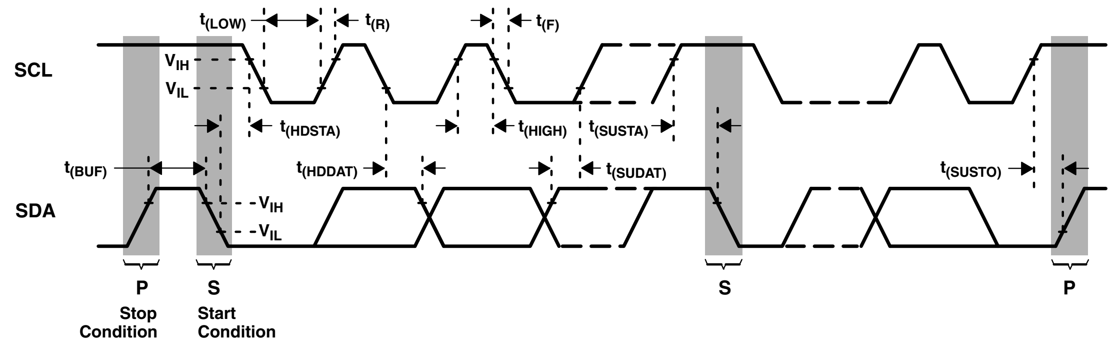
Symbol	Parameter (1)	Test Conditions	Min	Typ	Max	Unit
$f_{(SCL)}$	Clock frequency (I^2C only)		0		400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition		1.3			µs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.		0.6			µs
$t_{(SUSTA)}$	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 14:
Timing Diagrams



Typical Operating Characteristics

Figure 15:
Spectral Responsivity

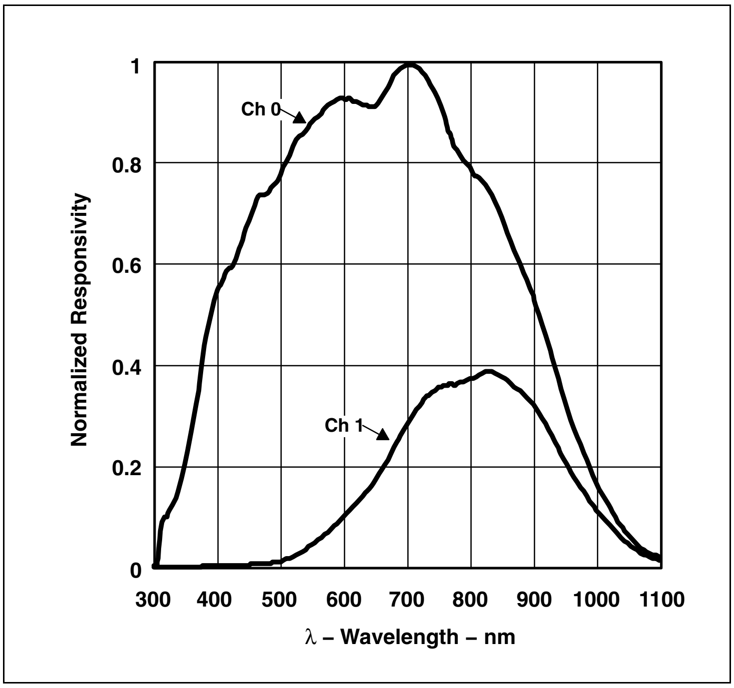


Figure 16:
LDR Output Compliance

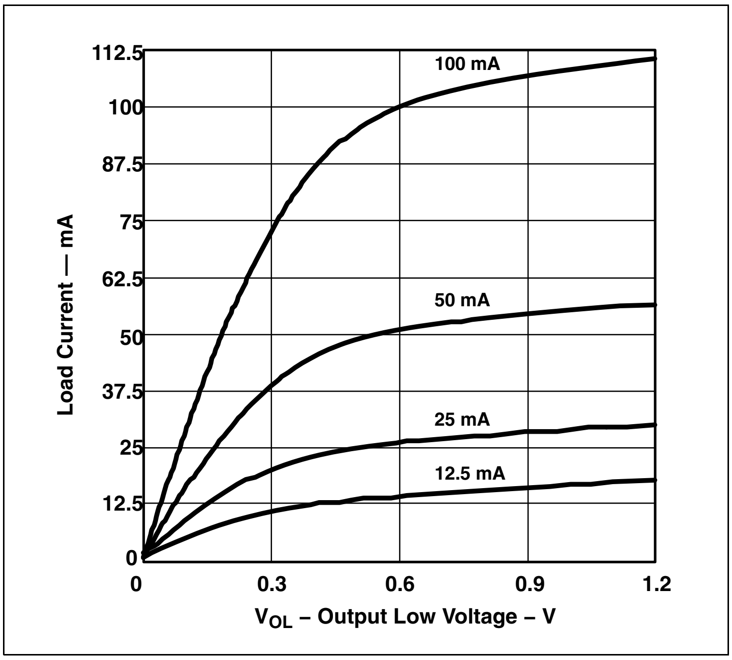


Figure 17:
Normalized I_{DD} vs. V_{DD} and Temperature

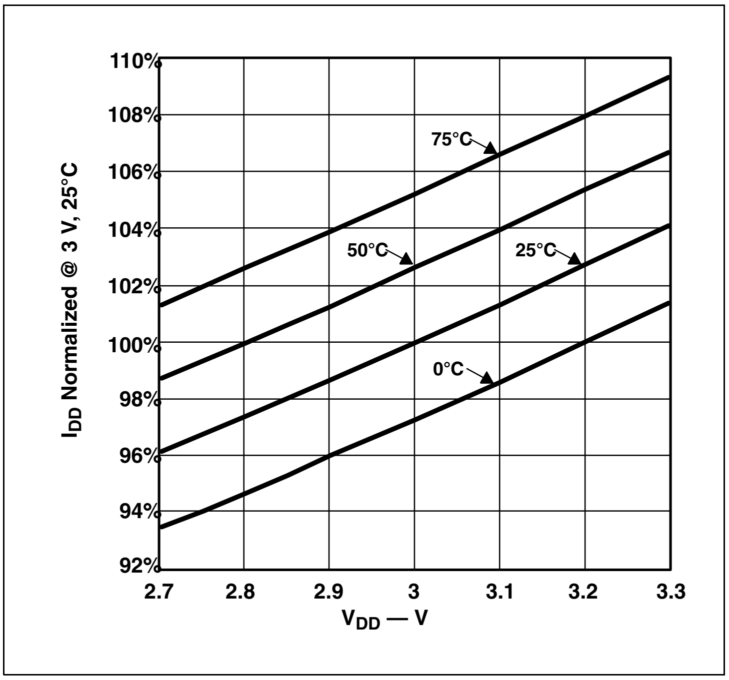
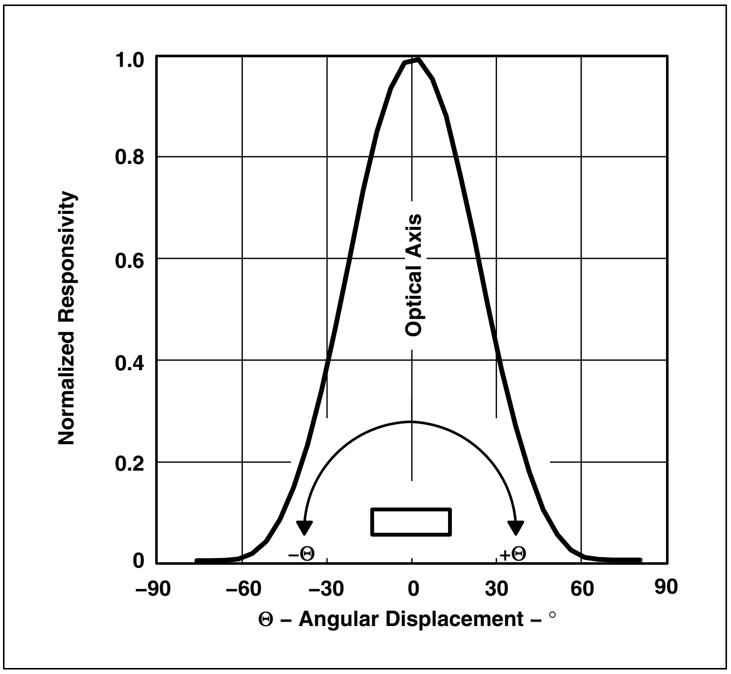


Figure 18:
Normalized Responsivity vs. Angular Displacement

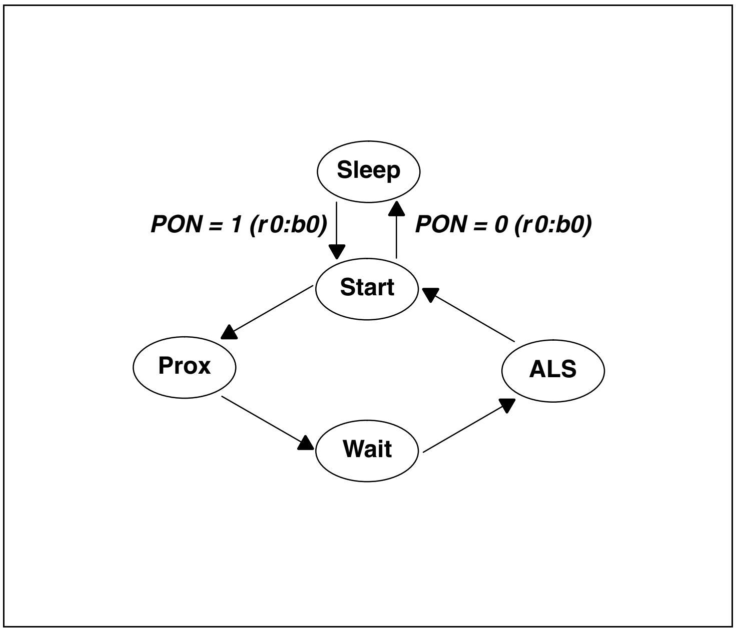


Principles of Operation

System State Machine

The device provides control of ALS, proximity detection and power management functionality through an internal state machine. After a power-on-reset, the device is in the sleep mode. As soon as the PON bit is set, the device will move to the start state. It will then continue through the Prox, Wait, and ALS states. If these states are enabled, the device will execute each function. If the PON bit is set to a 0, the state machine will continue until all conversions are completed and then go into a low-power sleep mode.

Figure 19:
Simplified State Diagram



Note(s):

1. In this document, the nomenclature uses the bit field name in italics followed by the register number and bit number to allow the user to easily identify the register and bit that controls the function. For example, the power on (PON) is in register 0, bit 0. This is represented as *PON (r0:b0)*.

Photodiodes

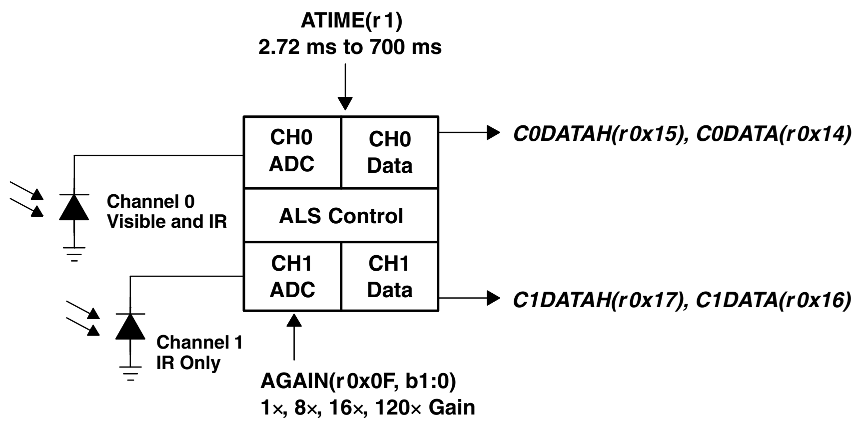
Conventional silicon detectors respond strongly to infrared light, which the human eye does not see. This can lead to significant error when the infrared content of the ambient light is high (such as with incandescent lighting) due to the difference between the silicon detector response and the brightness perceived by the human eye.

This problem is overcome through the use of two photodiodes. The Channel 0 photodiode is sensitive to both visible and infrared light, while the Channel 1 photodiode 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) for the two 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 20:
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 / 2.72ms

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

Integration Time = 2.72ms × (256 – ATIME)

In order to reject 50/60Hz ripple strongly present in fluorescent lighting, the integration time needs to be programmed in multiples of 10/8.3ms or the half cycle time. Both frequencies can be rejected with a programmed value of 50ms (ATIME = 0xED) or multiples of 50ms (i.e. 100, 150, 200, 400, 700).

The registers for programming the AGAIN hold a two-bit value representing a gain of 1×, 8×, 16×, or 120×. The gain, in terms of amount of gain, will be represented by the value AGAINx, i.e. AGAINx = 1, 8, 16, or 120.

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). For a device in open air with no aperture or glass/plastic above the device, lux can be calculated using the following. If an aperture, glass/plastic, or a light pipe attenuates the light equally across the spectrum (300nm to 1100nm), then a scaling factor can be used (referred to as GA in the equation below). For open air with no aperture, 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 × 24)

Lux1 = (C0DATA - 2 × C1DATA) / CPL

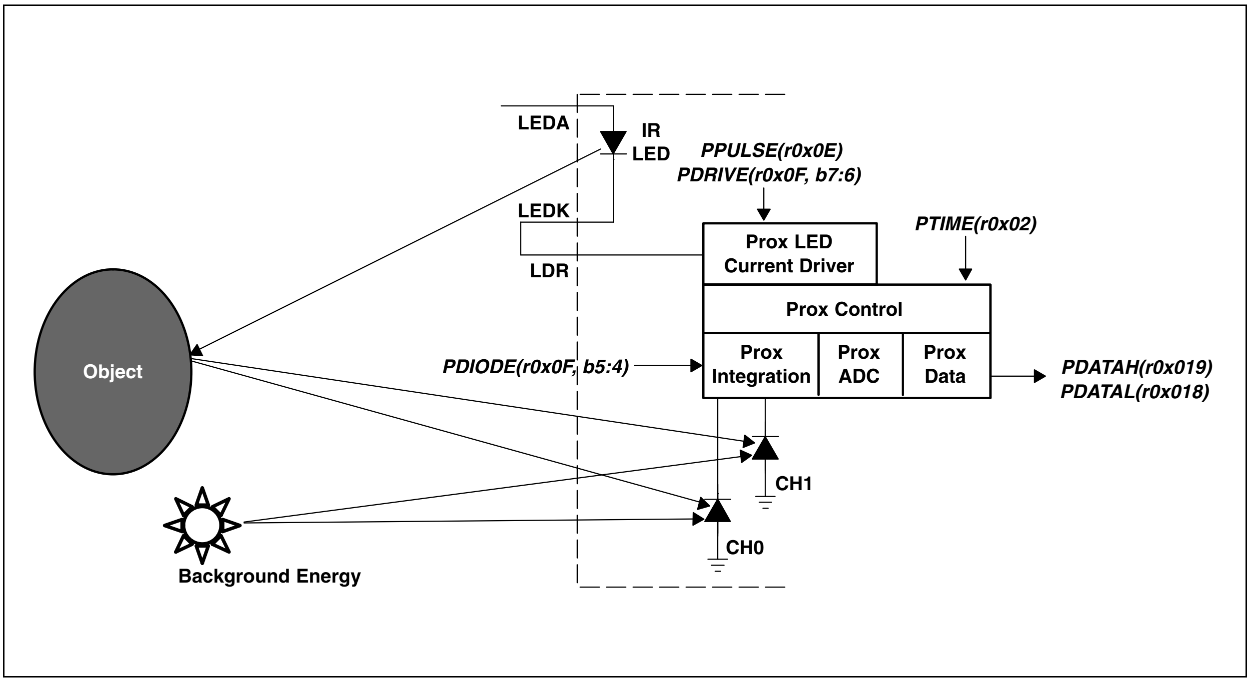
Lux2 = (0.6 × C0DATA - C1DATA) / CPL

Lux = MAX(Lux1, Lux2, 0)

Proximity Detection

Proximity detection is accomplished by measuring the amount of IR energy, from the internal IR LED, reflected off an object to determine its distance. The internal proximity IR LED is driven by the integrated proximity LED current driver as shown in Figure 21.

Figure 21:
Proximity Detection



The LED current driver provides a regulated current sink on the LDR terminal that eliminates the need for an external current limiting resistor. The PDRIVE register setting sets the sink current to 100%, 50%, 25%, or 12.5% of the factory trimmed full scale current.

Referring to the Detailed State Machine figure, the LED current driver pulses the IR LED as shown in Figure 22 during the Prox Accum state. Figure 22 also illustrates that the LED On pulse has a fixed width of 7.3μs and period of 16.0μs. 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 22:
Proximity LED Current Driver Waveform

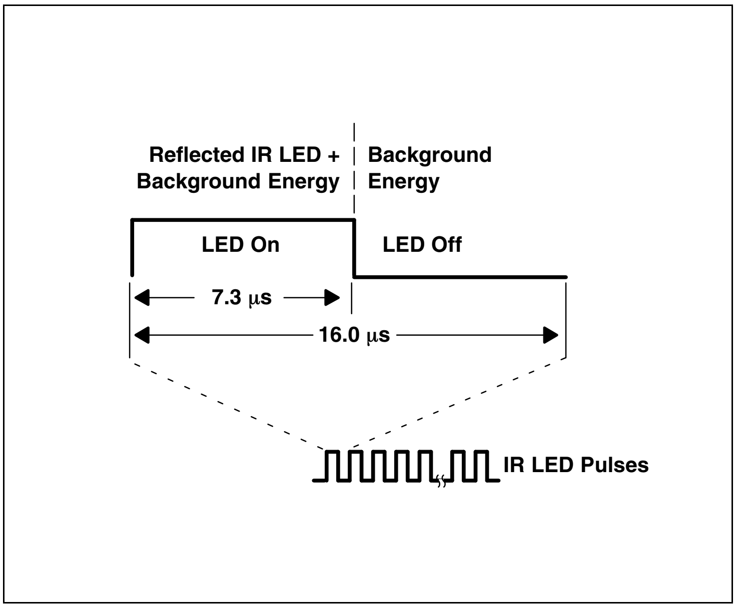


Figure 21 illustrates light rays emitting from the internal IR LED, reflecting off an object, and being absorbed by the CH0 and CH1 photodiodes. The proximity diode selector (PDIODE) determines which of the two photodiodes is used for a given proximity measurement. Note that neither photodiode is selected when the device first powers up, so PDIODE must be set for proximity detection to work.

Referring again to Figure 22, 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 IR LED energy to accumulate from pulse to pulse.

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

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

Optical Design Considerations

The TMD2771 device simplifies the optical system design by integrating an IR LED into the package, and also by providing an effective barrier between the LED and proximity sensor. In addition the package contains integrated lenses and apertures over both the LED and the sensor, which significantly extends the maximum proximity detection distance and helps to reduce optical crosstalk.

Although the package integrates an optical barrier between the IR LED and detector, placing the device behind a cover glass potentially provides another significant path for IR light to reach the detector, via reflection from the inside and outside faces of the cover glass. Because it is cost prohibitive to use anti-reflection coatings on the glass, the faces of the glass will reflect significantly (typically on the order of 4% of the light), and it is crucial that the system be designed so that this reflected light cannot find an efficient path back to the optical detector. See **ams** Application Note DN28: *Proximity Detection Behind Glass* for a detailed discussion of optical design considerations.

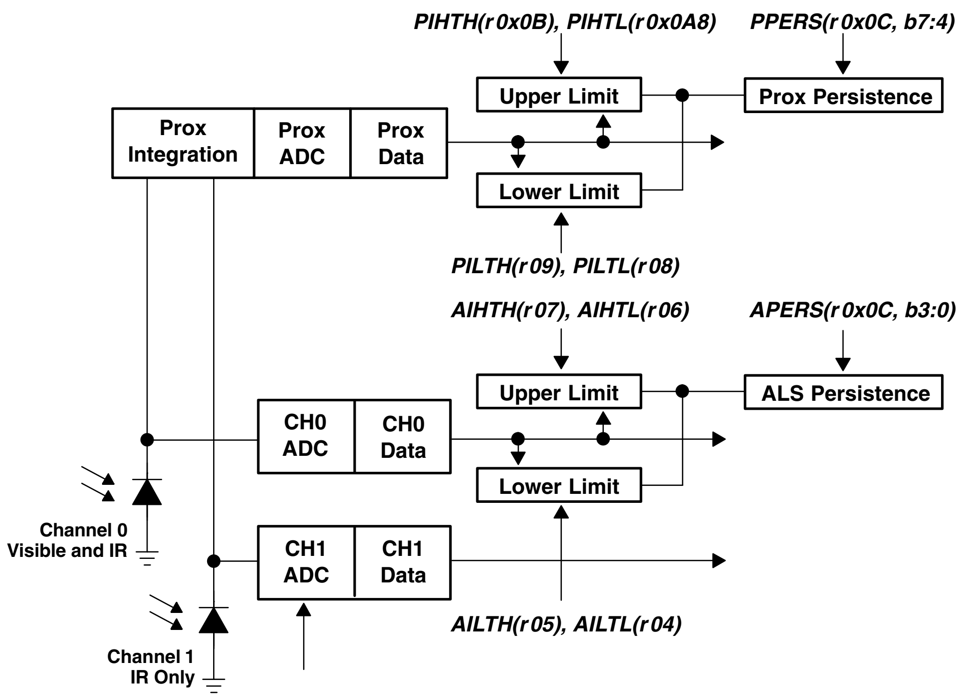
Interrupts

The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for a light intensity or proximity value. The interrupt mode is determined by the PIEN or AIEN field in the Enable Register.

Four 16-bit-wide interrupt threshold registers allow the user to define thresholds above and below a desired light level. For ALS, an interrupt can be generated when the ALS C0DATA exceeds the upper threshold value (AIHTx) or falls below the lower threshold (AILTx). For proximity, an interrupt can be generated when the proximity data (PDATA) exceeds the upper threshold value (PIHTx) or falls below the lower threshold (PILTx).

To further control when an interrupt occurs, the device provides an interrupt persistence feature. This feature allows the user to specify a number of conversion cycles for which an event exceeding the ALS interrupt threshold must persist (APERS) or the proximity interrupt threshold must persist (PPERS) before actually generating an interrupt. Refer to the register descriptions for details on the length of the persistence.

Figure 23:
Programmable Interrupt



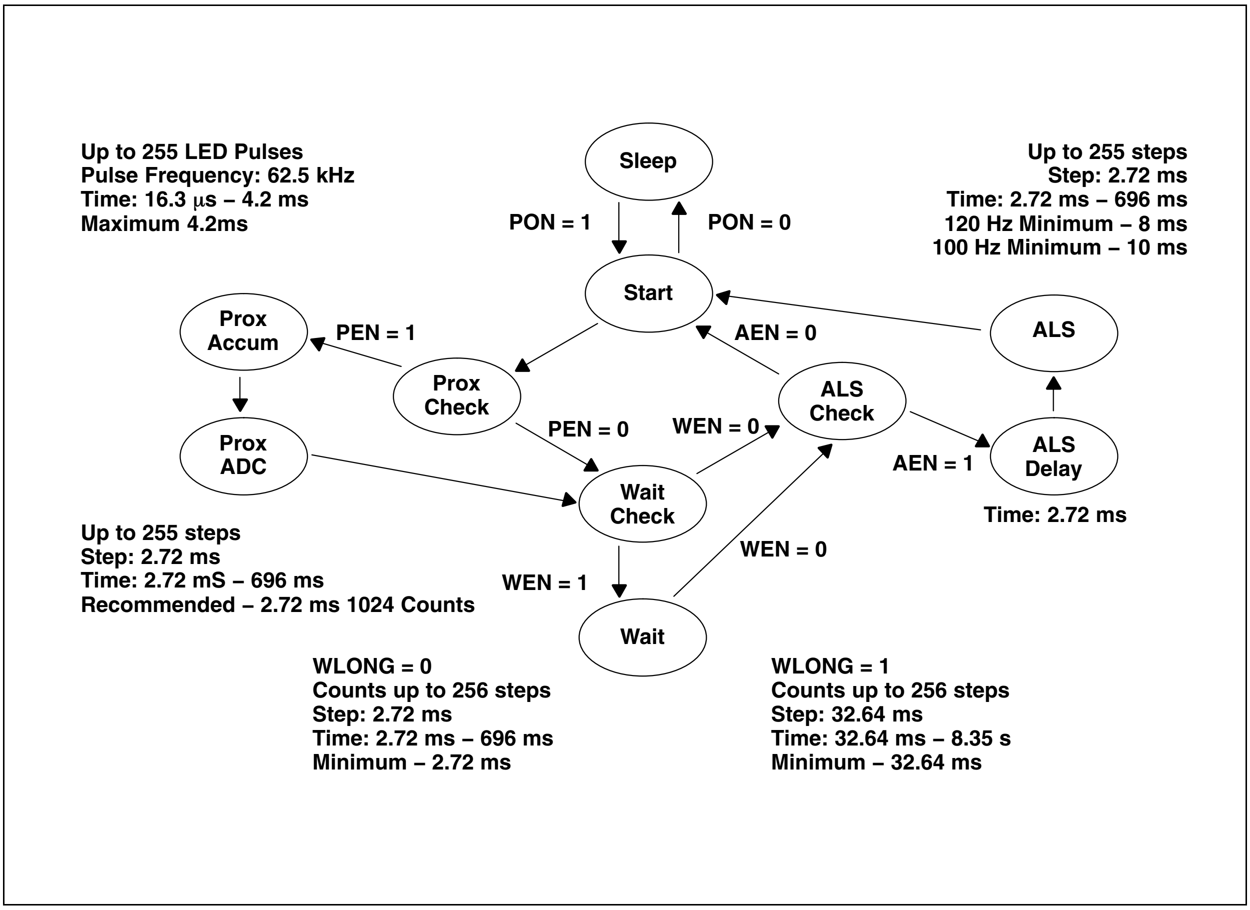
State Diagram

Figure 24 shows a more detailed flow for the state machine. The device starts in the sleep mode. The PON bit is written to enable the device. A 2.72ms delay will occur before entering the start state. If the PEN bit is set, the state machine will step through the proximity states of proximity accumulate and then proximity ADC conversion. As soon as the conversion is complete, the state machine will move to the following state.

If the WEN bit is set, the state machine will then cycle through the wait state. If the WLONG bit is set, the wait cycles are extended by 12× over normal operation. When the wait counter terminates, the state machine will step to the ALS state.

The AEN should always be set, even in proximity-only operation. In this case, a minimum of 1 integration time step should be programmed. The ALS state machine will continue until it reaches the terminal count at which point the data will be latched in the ALS register and the interrupt set, if enabled.

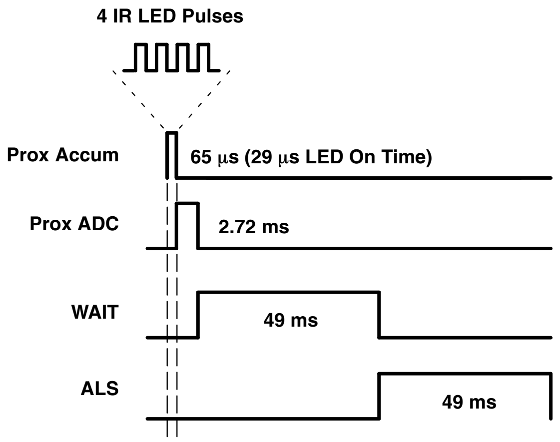
Figure 24:
Expanded State Diagram



Power Management

Power consumption can be controlled through the use of the wait state timing because the wait state consumes only 65µA of power. Figure 25 shows an example of using the power management feature to achieve an average power consumption of 151µA current with four 100mA pulses of proximity detection and 50ms of ALS detection.

Figure 25:
Power Consumption Calculations



Example: ~100 ms Cycle TIme

State	Duration (ms)	Current (mA)
Prox Accum	0.065 (Note 1)	
LED On	0.029 (Note 2)	100.0
Prox ADC	2.72	0.175
Wait	49	0.065
ALS	49	0.175

Avg = ((0.029 × 100) + (2.72 × 0.175) + (49 × 0.065) + (49 × 0.175)) / 100 = 151 µA

Note(s):

1. Prox Accum = 16.3µs per pulse × 4 pulses = 65µs = 0.065ms
2. LED On = 7.2µs per pulse × 4 pulses = 29µs = 0.029ms

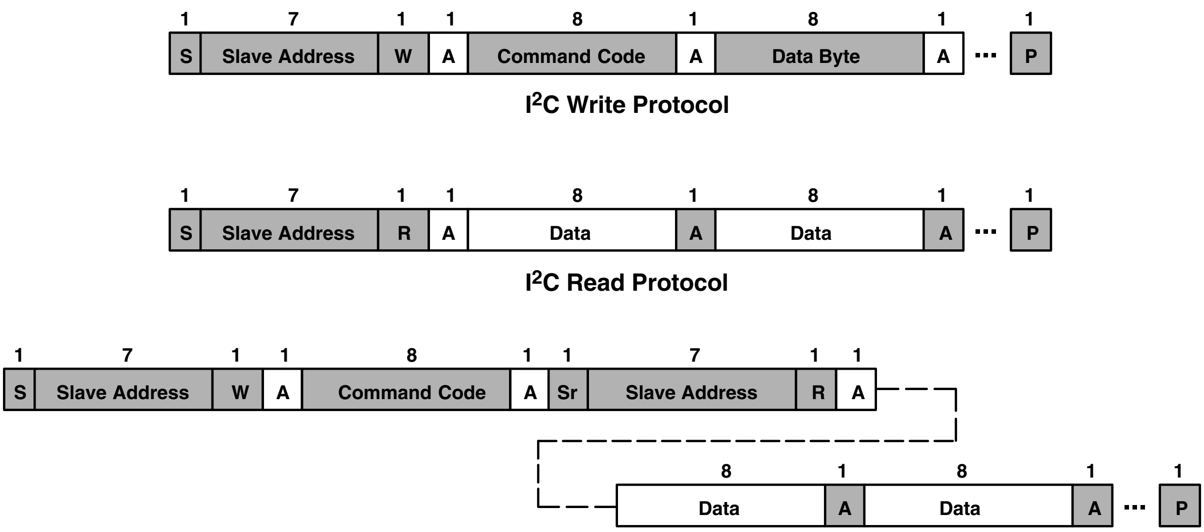
I²C Protocol

Interface and control are accomplished through an I²C 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 I²C addressing protocol.

The I²C standard provides for three types of bus transaction: read, write, and a combined protocol (Figure 26). 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 I²C bus protocol was developed by Philips (now NXP). For a complete description of the I²C protocol, please review the NXP I²C design specification at www.I2C-bus.org/references.

Figure 26:
I²C 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 27.

Figure 27:
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 ADC time	0x00 (1)
0x02	PTIME	R/W	Proximity ADC 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 filter	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