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TMD2772/ TMD2772WA

Digital ALS and Proximity Module

General Description

The TMD2772/TMD2772WA family of devices provides digital ambient light sensing (ALS), a complete proximity detection system, and digital interface logic in a single 8-pin surface mount module. The devices are register-set and pin-compatible with the TMD2771 family of devices and include new and improved ALS and proximity detection features and are available with 25° and 50° fields of view. The ALS enhancements include a reduced-gain mode that extends the operating range in sunlight. Proximity detection includes improved signal-to-noise performance and more accurate factory calibration. 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.

The TMD2772/TMD2772WA ALS is based on the **ams** patented dual-diode technology that enables accurate results and approximates human eye response to light intensity under a variety of lighting conditions. The proximity detection system includes an LED driver and an IR LED, which are factory trimmed to eliminate the need for end-equipment calibration due to component variations.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of TMD2772/TMD2772WA, Digital ALS and Proximity Module are listed below:

Figure 1:
Added Value of Using TMD2772/TMD2772WA

Benefits	Features
• Minimizes board space requirements	• Ambient light sensing, proximity detection, and IR LED in a single module
• Approximates human eye response over a wide variety of lighting conditions. Achieves accurate sensing behind spectrally dark glass.	• Ambient light sensing (ALS) • Wide variety of programmable features which enable 8,000,000:1 dynamic range with very high sensitivity

Benefits	Features

• Eliminates need for customer end-product calibration.
• Reduces the proximity noise
• Control of system crosstalk and offset
• Prevents false proximity detection in bright light
• Selectable IR power-level without external resistor
• Enables wide operating range
	• Proximity detection
	  • Calibrated and trimmed to provide consistent reading
	  • Reduced proximity count variation [(1)]
	  • Programmable offset [(1)]
	  • Saturation indicator bit [(1)]
	  • Programmable driver for IR LED
	  • 16,000:1 dynamic range

• Reduces external processor burden	• Maskable ALS and proximity interrupt • Programmable upper and lower thresholds with persistence filter

• Enables dynamic power dissipation control	• Power management
	  • Programmable average power consumption
	  • Programmable wait time from 2.7 ms to > 8 seconds

• Industry standard two-wire interface	• I^2C fast mode compatible interface
	  • Data rates up to 400 kbit/s
	  • Input voltage levels compatible with V_{DD} or 1.8V bus

• Small foot-print module	• 3.94 mm x 2.36 mm x 1.35 mm package
• Optimize ambient light sensing angle	• Available with standard 25° (TMD2772) and wide 50° (TMD2772WA)

Note(s):

1. New or Improved feature.

Applications

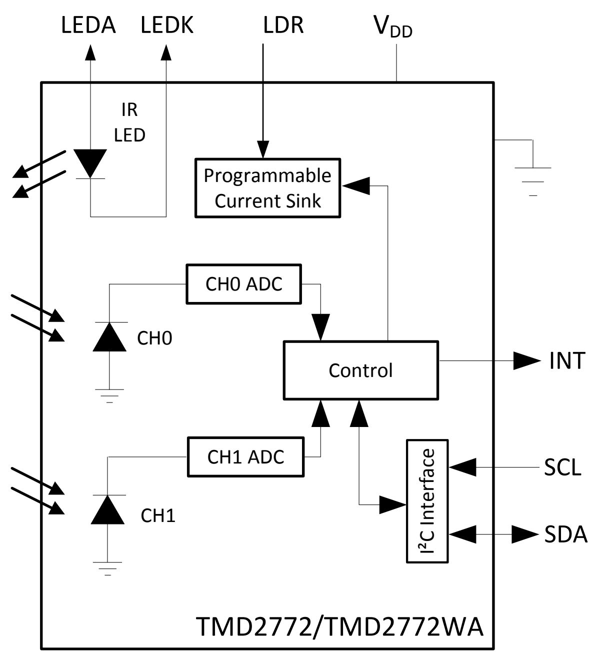
The TMD2772 applications include:

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

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
TMD2772/TMD2772WA Block Diagram



Pin Assignment

This is a Package Module - 8 pin diagram. Package drawing is not to scale.

Figure 3:
Pin Diagram (Top View)

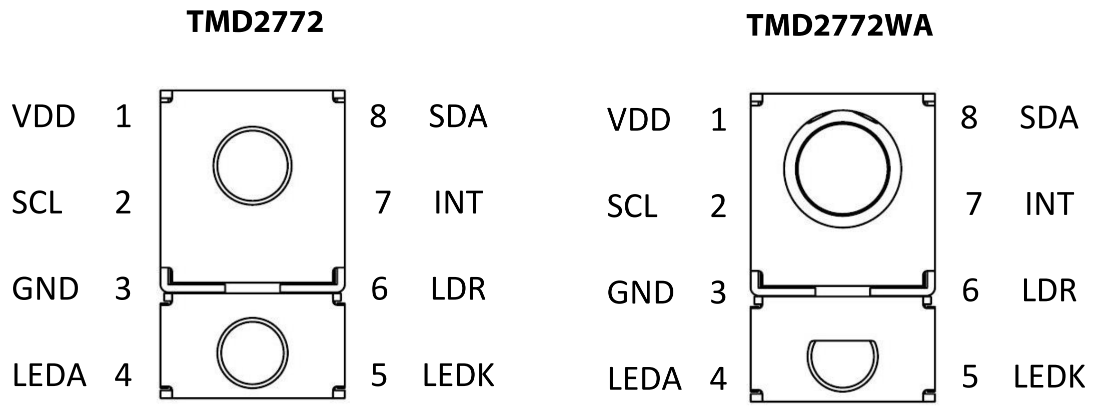


Figure 4:
Pin Description

Pin Number	Pin Name	Pin Type	Description
1	V_{DD}	Power	Supply voltage.
2	SCL	Input	I^2C serial clock input terminal — clock signal for I^2C serial data.
3	GND	Power	Power supply ground. All voltages are referenced to GND.
4	LEDA		LED anode.
5	LEDK		LED cathode. Connect to LDR pin when using internal LED driver circuit.
6	LDR		LED driver input for proximity IR LED, constant current source LED driver.
7	INT	Output	Interrupt — open drain (active low).
8	SDA	Input / Output	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

Symbol	Parameter	Min	Max	Unit
V_{DD} (1)	Supply Voltage		3.8	V
V_{LDR} (2)	Voltage on LDR signal with LDR = off. • T_A between 0° C - 70° C • T_A between -30° C - 70° C • T_A outside of -30° C - 85° C		4.8 4.6 4.4	V
V_{LEDA} (3)	LED supply voltage on LEDA input • T_A between 0° C - 70° C • T_A between -30° C - 70° C • T_A outside of -30° C - 85° C		4.8 4.6 4.4	V
V_{IO}	Digital I/O Voltage except LDR	-0.5	3.8	V
I_{Out}	Output terminal current except LDR	-1	20	mA
T_{stg}	Storage temperature range	-40	85	°C
T_A	Operating free-air temperature	-30	85	°C
I_{SCR}	Input Current (latch up immunity) JEDEC JESD78D Nov 2011	CLASS 1		µA
ESD_{HBM}	Electrostatic Discharge HBM JS-001-2014	± 2000		V
ESD_{CDM}	Electrostatic Discharge CDM JEDEC JESD22-C101F Oct 2013	± 500		V

Note(s):

1. All voltages are with respect to GND.
2. Maximum voltage with LDR = off.
3. Maximum 4.8V DC over 7 years lifetime. Maximum 5.0V spikes with up to 250s cumulative duration over 7 years lifetime. Maximum 5.5V spikes with up to 10s (=1000* 10ms) cumulative duration over 7 years lifetime.

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	Typ	Max	Unit
V_{DD}	Supply voltage	2.2	3	3.6	V
	Supply voltage accuracy, V_{DD} total error including transients	-3		3	%
T_A	Operating free-air temperature (1)	-30		85	°C
V_{LEDA}	LED supply voltage on LEDA input • T_A between 0-70° C • T_A outside of 0-70° C	2.5 2.5		4.8 4.4	V

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	Conditions	Min	Typ	Max	Units
I_{DD}	Supply current	Active — LDR pulse off		195	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
	Leakage current, LDR pin		-5		5	µA
V_{IH}	SCL, SDA input high voltage	TMD27721, TMD27725, TMD27721WA	0.7 V_{DD}			V
		TMD27723, TMD27727, TMD27723WA	1.25			
V_{IL}	SCL, SDA input low voltage	TMD27721, TMD27725, TMD27721WA			0.3 V_{DD}	V
		TMD27723, TMD27727, TMD27723WA			0.54	

Figure 8:
ADC Characteristics, V_{DD} = 3V, 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 = 120×, ATIME = 0xDB (100ms)	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			1		256	steps
ADC counts per step	ATIME = 0xFF		0		1023	counts
ADC count value	ATIME = 0xC0		0		65535	counts

Figure 9:
ALS Characteristics, V_{DD} = 3V, T_A = 25°C, AGAIN = 16x, AEN = 1 (unless otherwise noted)

Parameter	Test Conditions (1), (2), (3), (4)	Channel	Min	Typ	Max	Unit
ADC count value TMD2772 (25°)	λ_p = 625 nm, E_e = 46.8 µW/cm^2	CH0	4000	5000	6000	counts
		CH1		950		
	λ_p = 850 nm, E_e = 61.7 µW/cm^2	CH0	4000	5000	6000	counts
		CH1		2900		
ADC count value TMD2772WA (50°)	λ_p = 625 nm, E_e = 129.5 µW/cm^2	CH0	4000	5000	6000	counts
		CH1		950		
	λ_p = 850 nm, E_e = 181.2 µW/cm^2	CH0	4000	5000	6000	counts
		CH1		2900		
ADC count value ratio: CH1/CH0	λ_p = 625 nm		0.152	0.19	0.228	
	λ_p = 850 nm		0.43	0.58	0.73	
Re Irradiance responsivity TMD2772 (25°)	λ_p = 625 nm	CH0		107.2		counts /(µW/ cm^2)
		CH1		20.4		
	λ_p = 850 nm	CH0		81.5		
		CH1		47.3		
Re Irradiance responsivity TMD2772WA (50°)	λ_p = 625 nm	CH0		38.6		counts /(µW/ cm^2)
		CH1		7.3		
	λ_p = 850 nm	CH0		27.6		
		CH1		16.0		
Gain scaling, relative to 1× gain setting	AGAIN = 1× and AGL = 1			0.16		x
	AGAIN = 8× and AGL = 0		7.2	8.0	8.8	
	AGAIN = 16× and AGL = 0		14.4	16.0	17.6	
	AGAIN = 120× and AGL = 0		108	120	132	

Note(s):

1. Optical measurements are made using small-angle incident radiation from light-emitting diode optical sources. Red 625 nm and infrared 850 nm LEDs are used for final product testing for compatibility with high-volume production.
2. The 625 nm irradiance E_e is supplied by an AlInGaP light-emitting diode with the following typical characteristics: peak wavelength λ_p = 625 nm and spectral halfwidth Δ_λ½ = 20 nm.
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 Δ_λ½ = 42 nm.
4. Unless otherwise specified, measurements are taken with ATIME= 0xF6 (27 ms).

Figure 10:
Proximity Characteristics, V_{DD} = LEDA = 3V, T_A = 25°C, P_{EN} = 1 (unless otherwise noted)

Parameter	Test Conditions	Min	Typ	Max	Units
I_{DD} Supply current	LED On		3		mA
I_{LEDA} LEDA current [1]	LED On, PDRIVE = 0		100		mA
	LED On, PDRIVE = 1		50		
	LED On, PDRIVE = 2		25		
	LED On, PDRIVE = 3		12.5		
PTIME ADC conversion steps		1		256	steps
PTIME ADC conversion time	PTIME = 0xFF (= 1 conversion step)	2.58	2.73	2.9	ms
PTIME ADC counts per step	PTIME = 0xFF (= 1 conversion step)	0		1023	counts
PPULSE LED pulses [2]		0		255	pulses
LED On LED pulse width	PPULSE = 1, PDRIVE = 0		7.3		µs
LED pulse period	PPULSE = 2, PDRIVE = 0		16.0		µs
Proximity response, no target (offset)	PPULSE = 8, PDRIVE = 0, PGAIN = 4×, [3]		100		counts
Prox count, 100mm target, TMD2772 devices [4]	73 mm × 83 mm, 90% reflective Kodak Gray Card, PGAIN = 4×, PPULSE = 8, PDRIVE = 0, PTIME = 0xFF [5]	450	520	590	counts
Prox count, 100mm target, TMD2772WA devices [4]	73 mm × 83 mm, 90% reflective Kodak Gray Card, PGAIN = 4×, PPULSE = 8, PDRIVE = 0, PTIME = 0xFF [5]	235	275	315	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. These parameters are ensured by design and characterization and are not 100% tested.
3. Proximity offset varies with power supply characteristics and noise.
4. ILEDA is factory calibrated to achieve this specification. Offset and crosstalk directly sum with this value and is system dependent.
5. No glass or aperture above the module. Tested value is the average of 5 consecutive readings.
6. Proximity test was done using the circuit shown in Figure 12. See PCB Pad Layout for recommended application circuit.

Figure 11:
Proximity Test Circuit

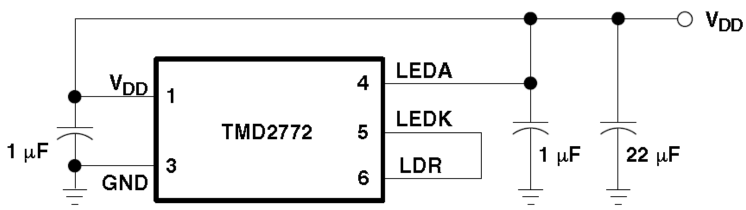


Figure 12:
IR LED Characteristics, V_{DD} = 3V, T_A = 25°C

Parameter	Test Conditions	Min	Typ	Max	Unit
V_F Forward Voltage	I_F = 100 mA	1.5		2.2	V
V_R Reverse Voltage	I_R = 10 µA	5			V
P_O Radiant Power	I_F = 20 mA	4.5			mW
λ_p Peak Wavelength	I_F = 20 mA		850		nm
Δ_λ Spectral Radiation Bandwidth	I_F = 20 mA		40		nm

Figure 13:
Wait Characteristics, V_{DD} = 3V, T_A = 25°C, WEN = 1 (unless otherwise noted)

Parameter	Conditions	Min	Typ	Max	Units
Wait steps		1		256	steps
Wait time	WTIME = 0xFF (= 1 wait step)		2.73	2.9	ms

Timing Characteristics

Figure 14:
AC Electrical Characteristics, V_{DD} = 3V, T_A = 25°C (unless otherwise noted)

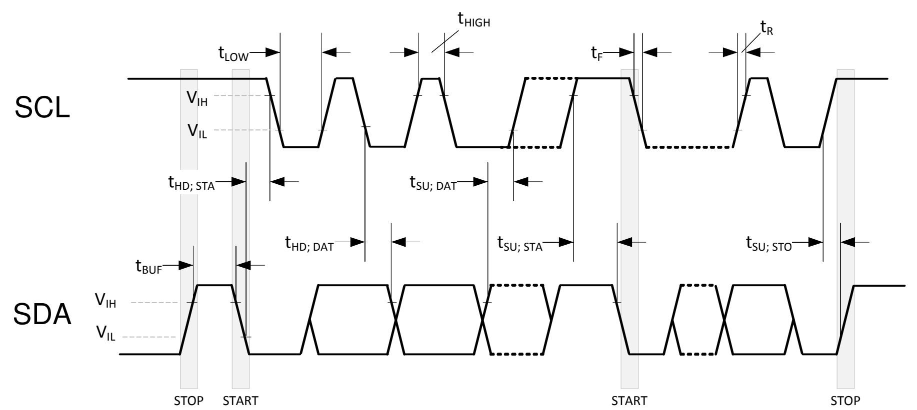
Parameter (1)	Conditions	Min	Max	Unit
f_{SCL}	Clock frequency (I^2C only)	0	400	kHz
t_{BUF}	Bus free time between start and stop condition	1.3		µs
$t_{HD;STA}$	Hold time after (repeated) start condition. After this period, the first clock is generated.	0.6		µs
$t_{SU;STA}$	Repeated start condition setup time	0.6		µs
$t_{SU;STO}$	Stop condition setup time	0.6		µs
$t_{HD;DAT}$	Data hold time	10		ns
$t_{SU;DAT}$	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.

Timing Diagrams

Figure 15:
Parameter Measurement Information



Typical Operating Characteristics

Figure 16:
Spectral Responsivity

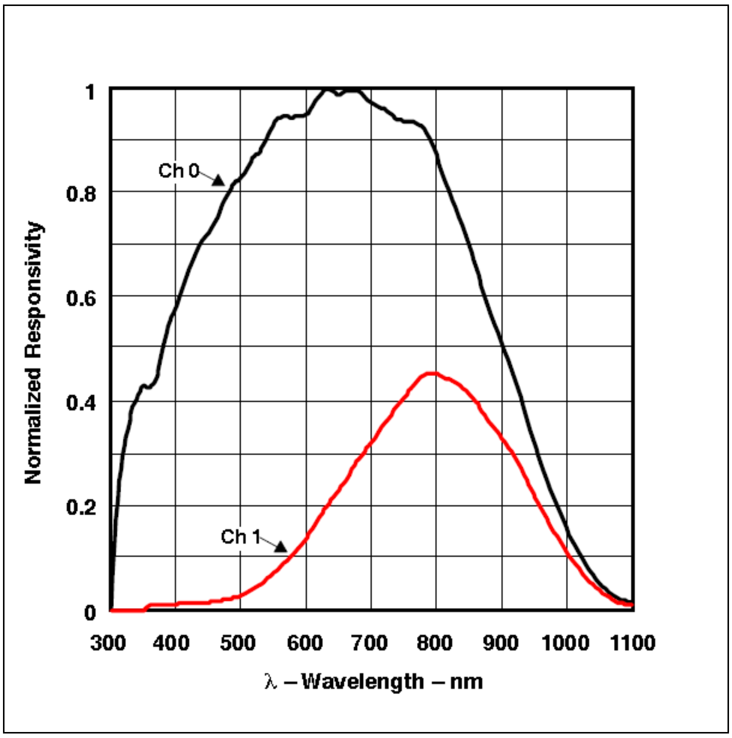


Figure 17:
Normalized I_{DD} vs. V_{DD} and Temperature

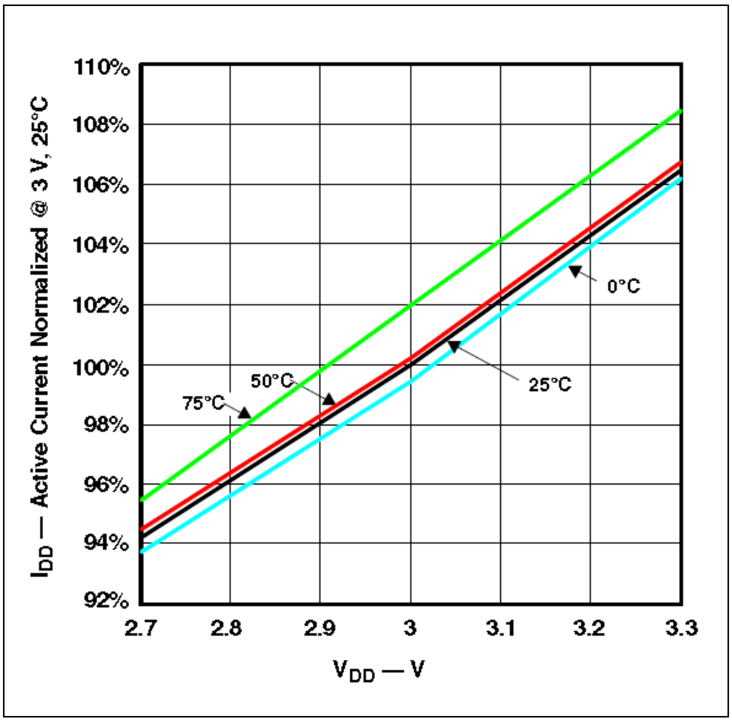


Figure 18:
Normalized Responsivity vs. Angular Displacement for Non-WA and WA Devices

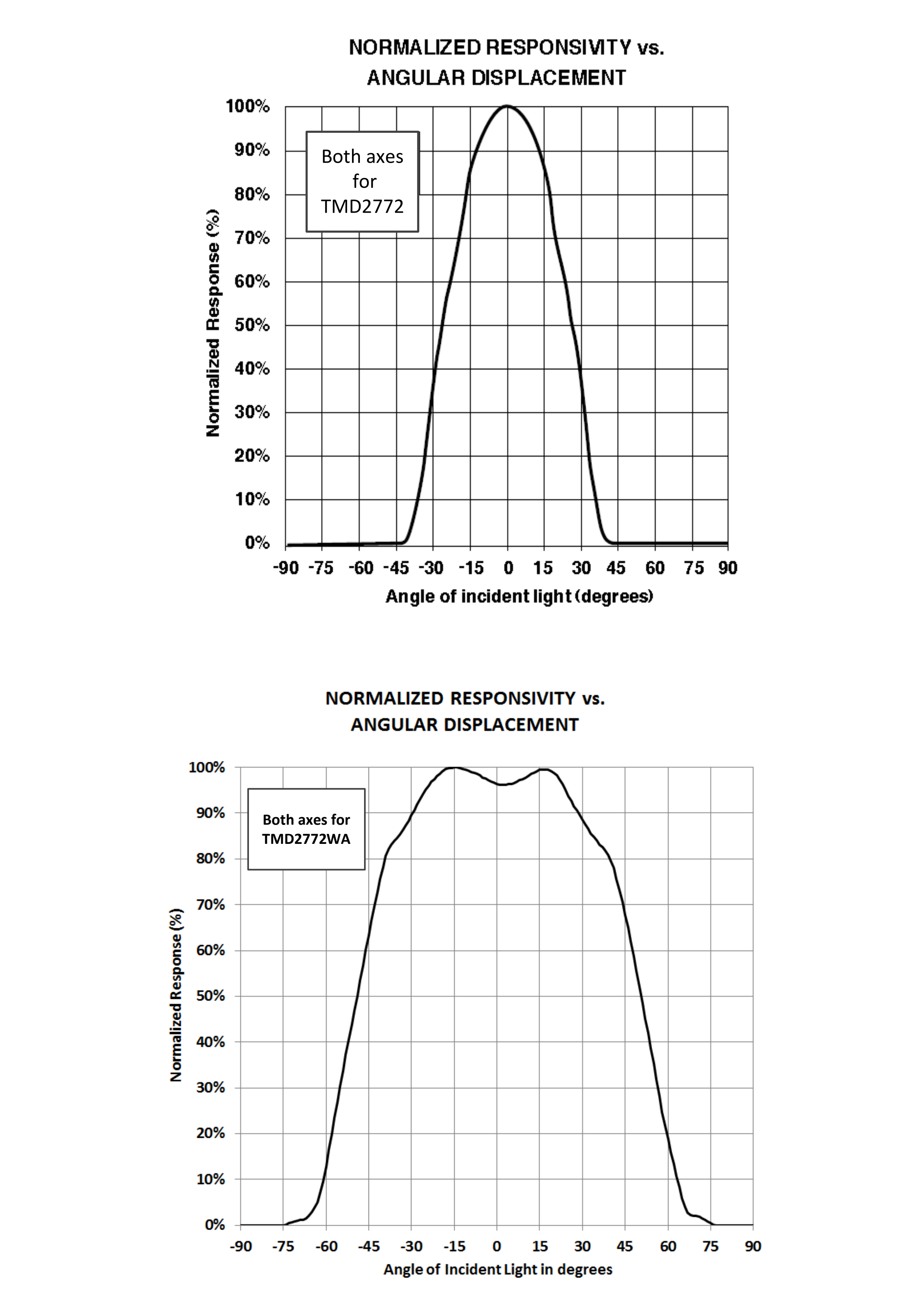


Figure 19:
Proximity Response of TMD2772 and TMD2772WA Modules

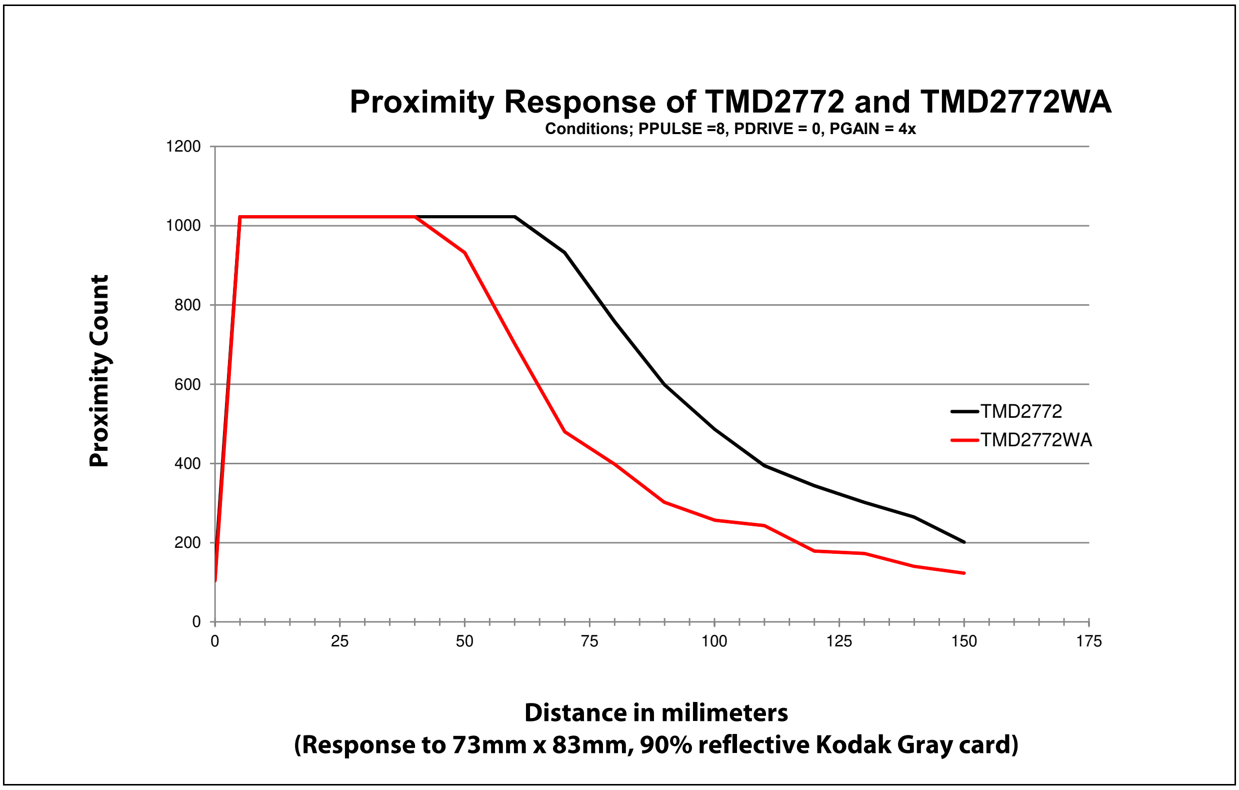
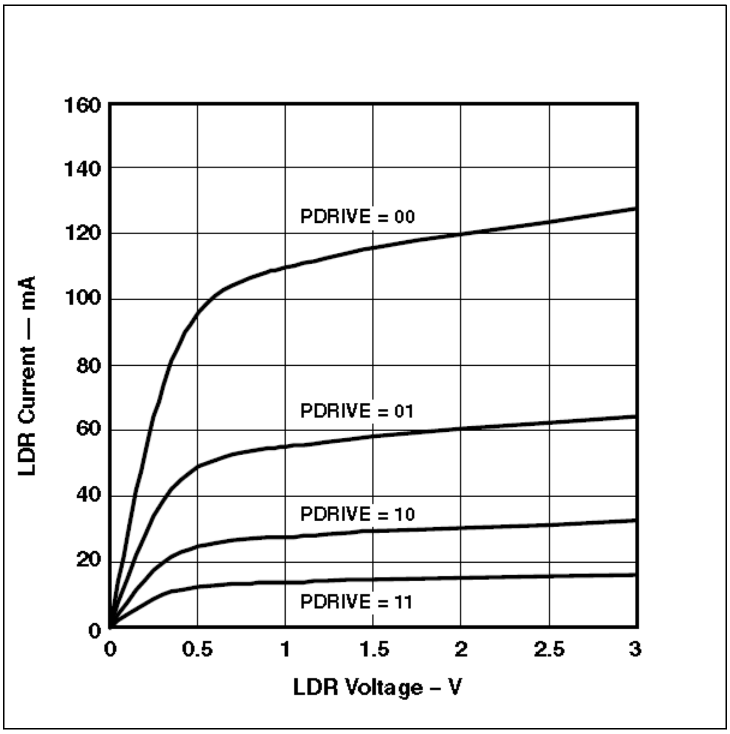


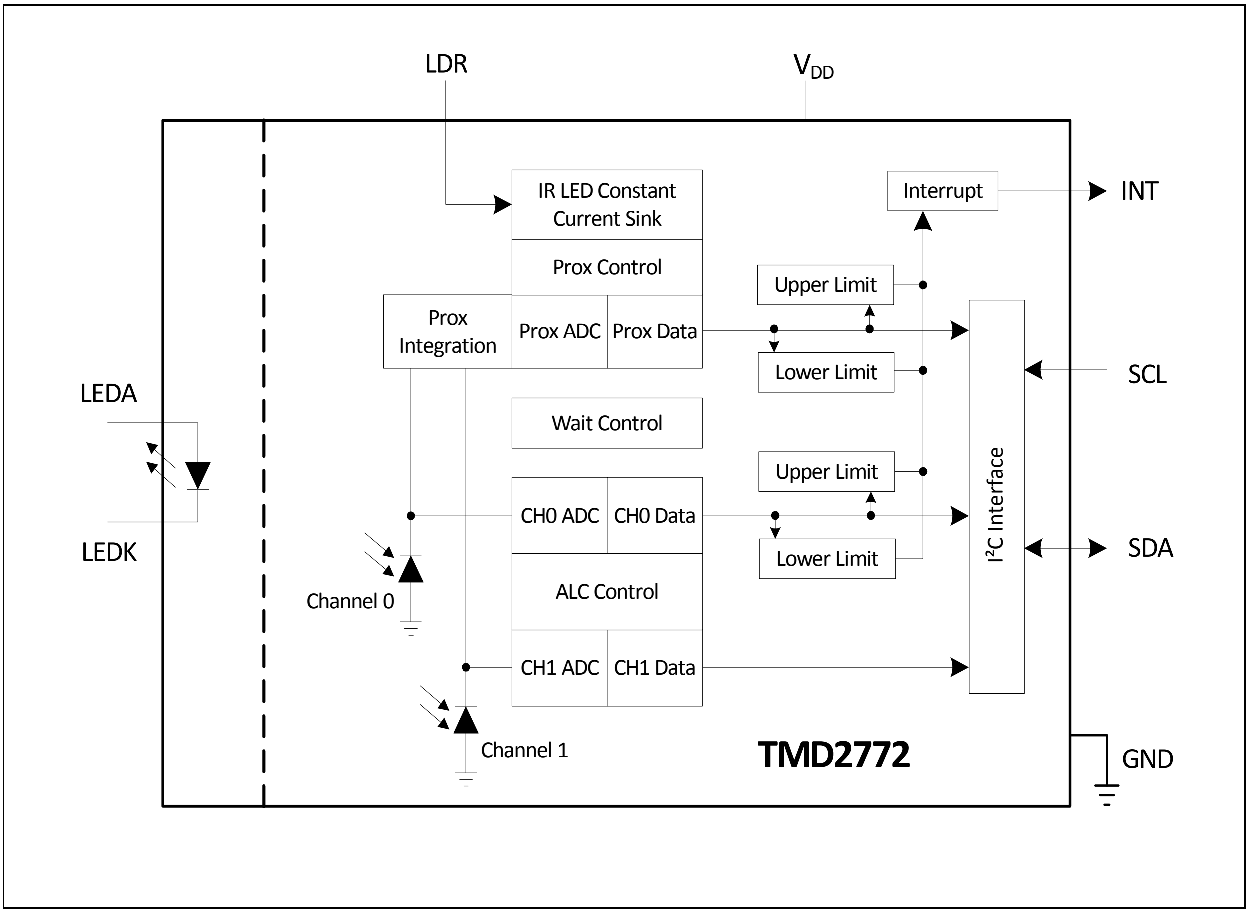
Figure 20:
Typical LDR Current vs. Voltage



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.

Figure 21:
Detailed Block Diagram of TMD2772/TMD2772WA



A fully integrated proximity detection solution is provided with an 850-nm IR LED, LED driver circuit, and proximity detection engine. An internal LED driver pin (LDR) is externally connected to the LED cathode (LEDK) to provide a controlled LED sink current. 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. The device is factory calibrated to achieve a proximity count reading at a specified distance with a specific number of pulses. In use, 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 16 µs period with a 7.2 µs on time.

Communication with 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 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.

Principles of Operation

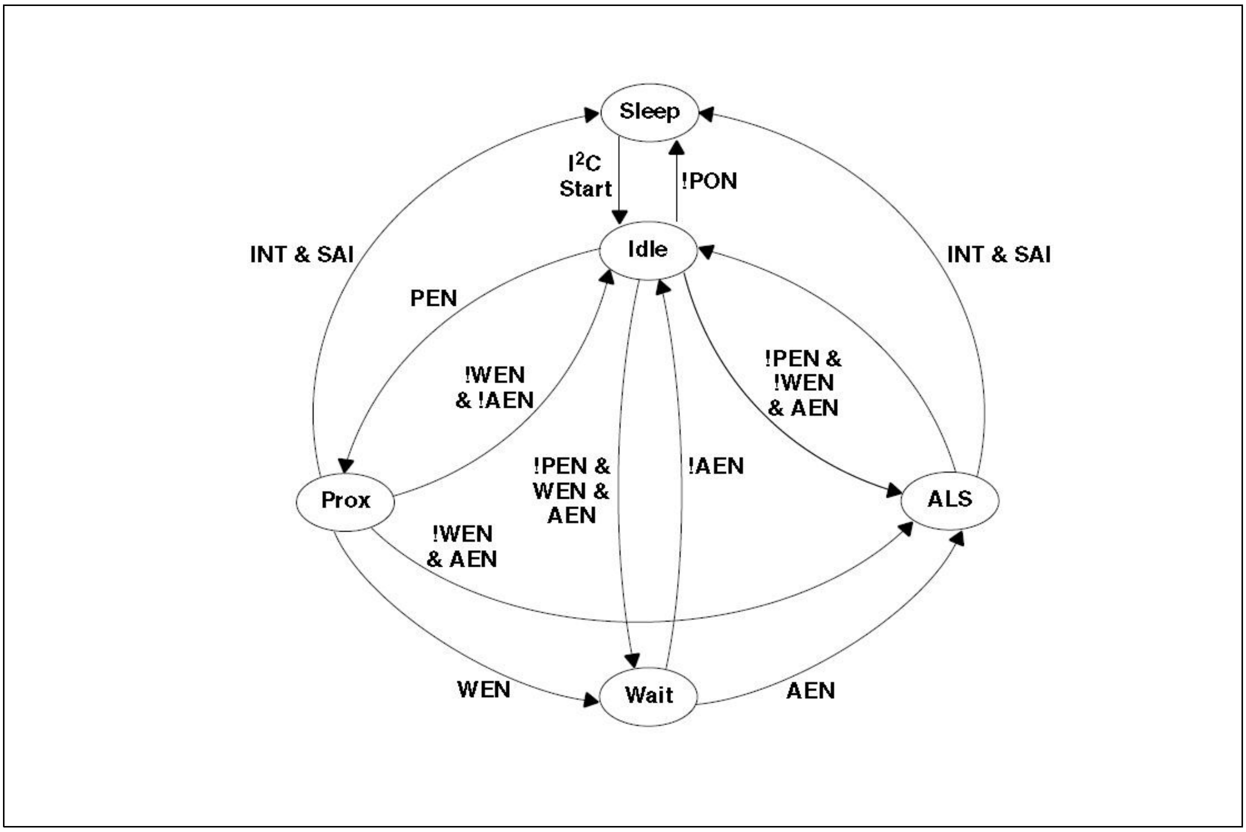
System State Machine

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 I²C 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 22. 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 I²C command is received. See Interrupts for additional information.

Figure 22:
Simplified State Diagram



Photodiodes

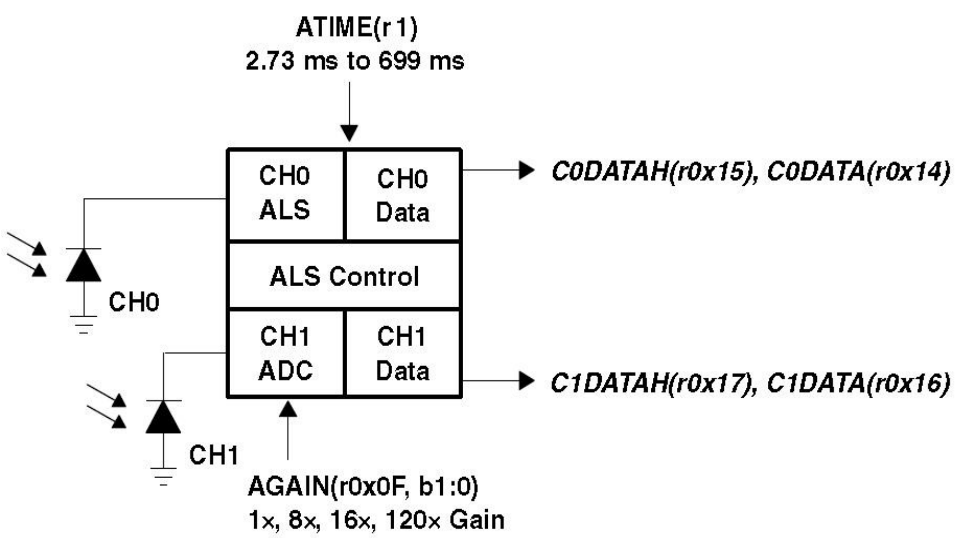
Conventional ALS detectors respond strongly to infrared light, which the human eye does not see. This can lead to significant error when the infrared content of the ambient light is high (such as with incandescent lighting).

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 23:
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 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. With the AGL bit set, the gains will be lowered to 1/6, 8/6, 16/6, and 20×, allowing for up to 60k lux.

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.

Lux formula for **TMD2772**:

CPL = (ATIME_ms × AGAINx) / 20

Lux1 = (C0DATA – (1.75 × C1DATA)) / CPL

Lux2 = ((0.63 × C0DATA) – (1.00 × C1DATA)) / CPL

Lux = MAX(Lux1, Lux2, 0)

Lux formula for **TMD2772WA**:

CPL = (ATIME_ms × AGAINx) / 1.16

Lux1 = (C0DATA - (1.8422 x C1DATA)) / CPL

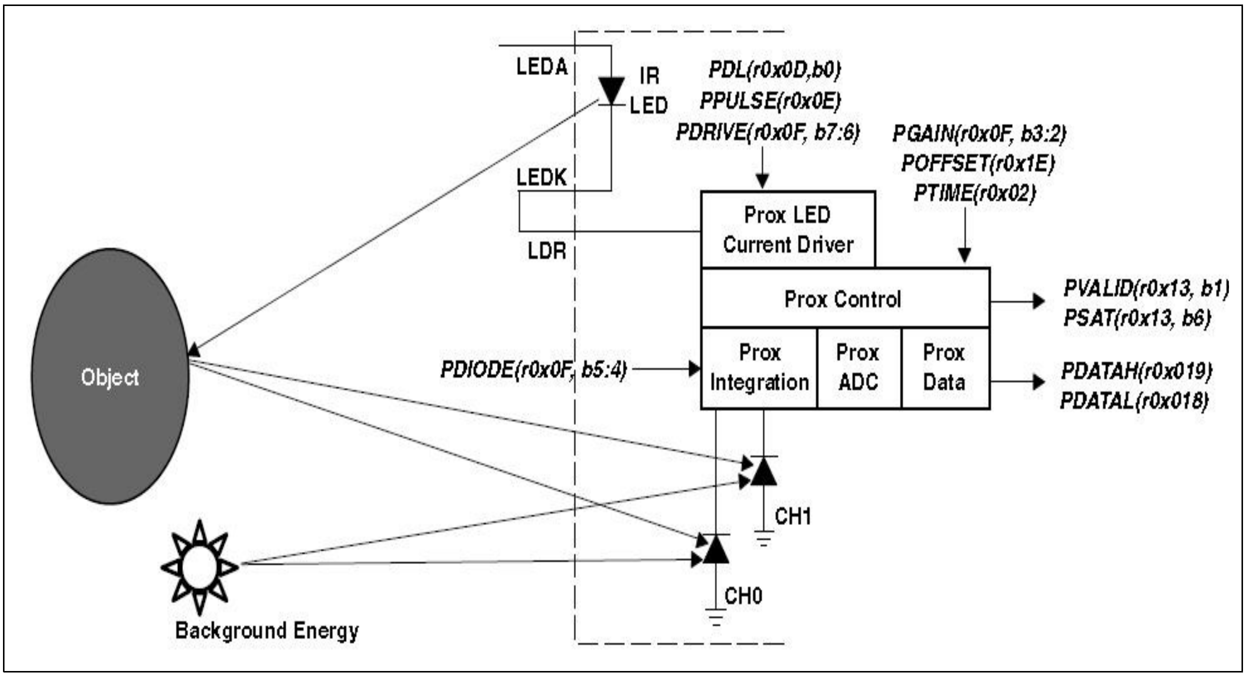
Lux2 = ((0.4106 x C0DATA) - (0.667 x C1DATA)) / CPL

Lux = MAX(Lux1, Lux2, 0)

Proximity Detection

Proximity detection is accomplished by measuring the amount of I_R 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 24.The proximity detector will see light reflected from the intended target as well as light reflected through any path. Both surfaces of a transparent cover will reflect some of the IR LEDs energy. An air gap of less the 0.5mm between the top of the module and the cover is recommended. For a detailed explanation of the of the effects of an air gap see **ams** application note; Application Note DN58: *Proximity Detection Behind Glass* for a detailed discussion of optical design considerations.

Figure 24:
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 100%, 50%, 25%, or 12.5% when PDL is not asserted. However, when PDL is asserted, the drive current is reduced by a factor of 9.

Referring to the Detailed State Machine figure, the LED current driver pulses the IR LED as shown in Figure 25 during the Prox Accum state. Figure 25 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 25:
Proximity LED Current Driver Waveform

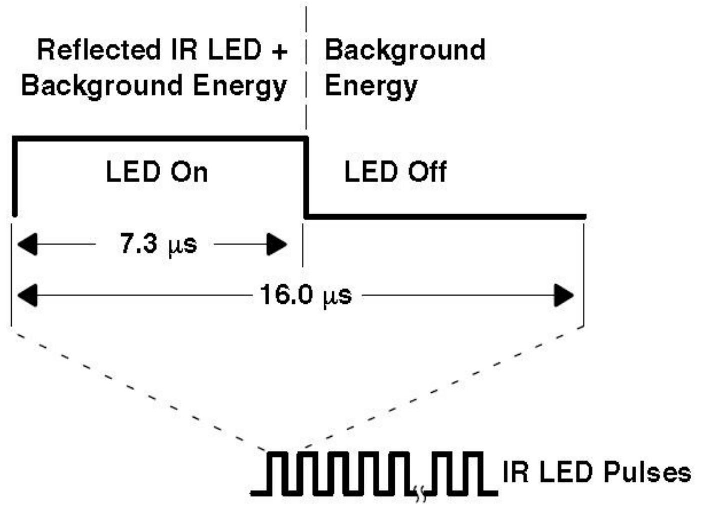


Figure 24 illustrates light rays emitting from the internal IR LED, reflecting off an object, and being absorbed by the CH0 and CH1 photodiodes. The proximity diode selector (PDIODE) determines which of the two photodiodes is used for a given proximity measurement. Note that neither photodiode is selected when the device first powers up, so PDIODE must be set for proximity detection to work.

Referring again to Figure 25, 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. The proximity gain (PGAIN) determines the integration rate, which can be programmed to 1×, 2×, 4×, or 8× gain. At power up, PGAIN defaults to 1× gain, which is recommended for most applications. For reference, PGAIN equal to 4× is comparable to the TMD2771's 1× 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 2.73ms 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).

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

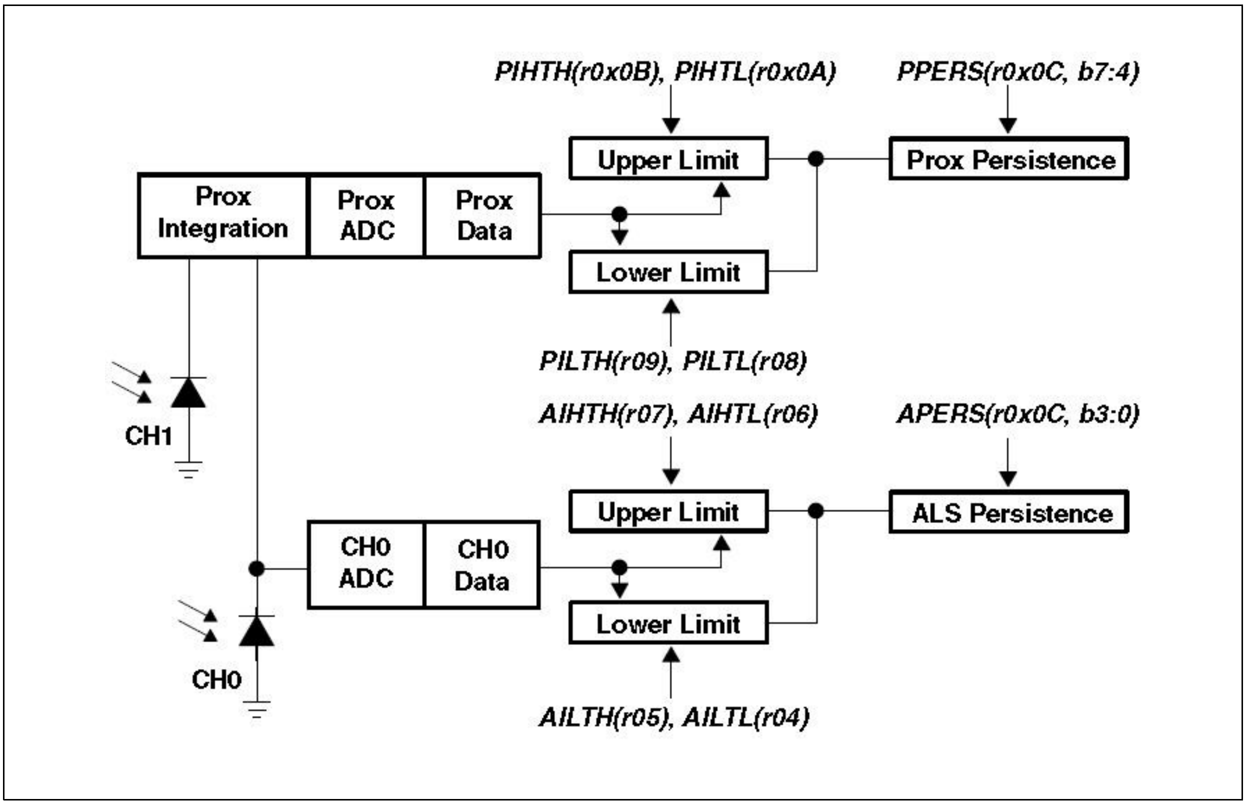
The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for light intensity or proximity values outside of a user-defined range. While the interrupt function is always enabled and its status is available in the status register (0x13), the output of the 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 (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 Interrupt register (0x0C) allows the user to set the ALS persistence filter (APERS) and the proximity persistence filter (PPERS) values. See the Interrupt Register (0x0C) 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 26:
Programmable Interrupt



System State Machine Timing

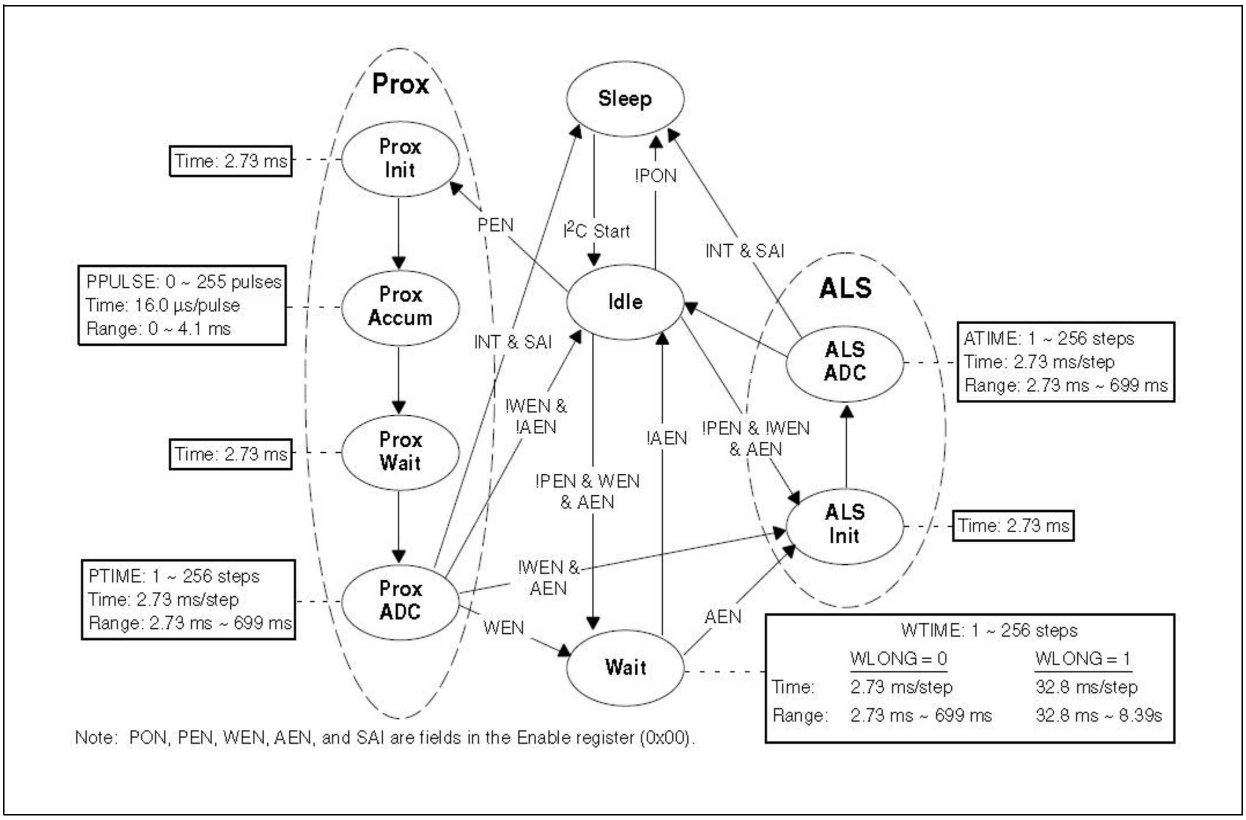
The system state machine shown in Figure 27 provides an overview of the states and state transitions that provide system control of the device. This section highlights the programmable features, which affect the state machine cycle time, and provides details to determine system level timing.

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 27. 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 27.

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 27. 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 27:
Detailed State Machine



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 176µA.

Figure 28:
Power Management

System State Machine State	Programmable Parameter	Programmed Value	Duration	Typical Current
Prox Init			2.73 ms	0.195 mA
Prox Accum	PPULSE	0x04	0.064 ms	
Prox Accum – LED On			0.029 ms (1)	103 mA
Prox Accum – LED OFF			0.035 ms (2)	0.195 mA
Prox Wait			2.73 ms	0.195 mA
Prox ADC	PTIME	0xFF	2.73 ms	0.195 mA
Wait	WTIME	0xEE	49 2 ms	0 090 mA
	WLONG			
ALS Init			2.73 ms	0.195 mA
ALS ADC	ATIME	0xEE	49 2 ms	0.195 mA

Note(s):
1. Prox Accum – LED On time = 7.3 µs 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