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TCS3772

Color Light-to-Digital Converter with Proximity Sensing

General Description

The TCS3772 device family provides red, green, blue, and clear (RGBC) light sensing and, when coupled with an external IR LED, proximity detection. These devices detect light intensity under a variety of lighting conditions and through a variety of attenuation materials, including dark glass. The proximity detection feature allows a large dynamic range of operation for accurate short distance detection, such as in a cell phone, for detecting when the user positions the phone close to their ear. An internal state machine provides the ability to put the device into a low power state in between proximity and RGBC measurements providing very low average power consumption.

The color sensing feature is useful in applications such as LED RGB backlight control, solid state lighting, reflected LED color sampler, or fluorescent light color temperature detection. With the addition of an IR blocking filter, the device is an excellent ambient light sensor, color temperature monitor, and general purpose color sensor.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of this device are listed below:

Figure 1:
Added Value of Using TCS3772

Benefits	Features
• Single Device Reduces Board Space	• Integrated RGB and Clear Color Sensing and Proximity Detection
• Enables Flexible Operation for Wide Range of Applications	• Programmable Color Sensing and Proximity Detection
• Enables Accurate Color and Ambient Light Sensing Under Varying Lighting Conditions	• Integrated IR Blocking Filter
• Enables Operation within Wide Range of Lighting Conditions	• 3.8M:1 Dynamic Range

- Color Light Sensing with IR-Blocking Filter
  - Programmable Analog Gain and Integration Time
  - 3 800 000:1 Dynamic Range
  - Very High Sensitivity – Ideally Suited for Operation Behind Dark Glass
- Proximity Detection
  - Ambient Light Rejection
  - Programmable Integration Time
  - Current Sink Driver for External IR LED
- Maskable Light and Proximity Interrupt
  - Programmable Upper and Lower Thresholds with Persistence Filter
- Power Management
  - Low Power – 2.5-µA Sleep State
  - 65-µA Wait State with Programmable Wait State Time from 2.4 ms to > 7 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 TCS3x71 Series
- Small 2 mm × 2.4 mm Dual Flat No-Lead (FN) Package

Applications

The applications of TCS3772 include:

- RGB LED Backlight Control
- Ambient Light Color Temperature Sensing
- Cell Phone Touch Screen Disable
- Mechanical Switch Replacement
- Industrial Process Control
- Medical Diagnostics

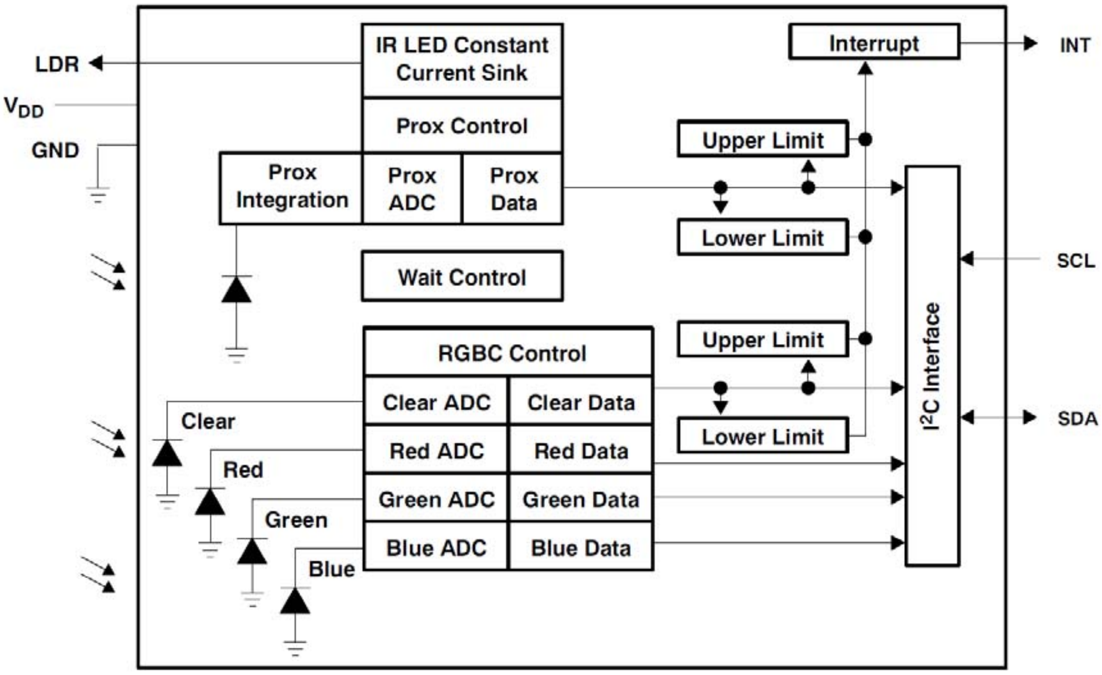
End Products and Market Segments

- HDTVs, Mobile Handsets, Tablets, and Portable Media Payers
- Medical and Commercial Instrumentation
- Toys
- Solid State and General Lighting

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
Functional Block Diagram of TCS3772



Pin Assignment

The TCS3772 pin assignments are described below.

Figure 3:
Pin Diagram

Package FN Dual Flat No-Lead (Top View):
Package drawing is not to scale.

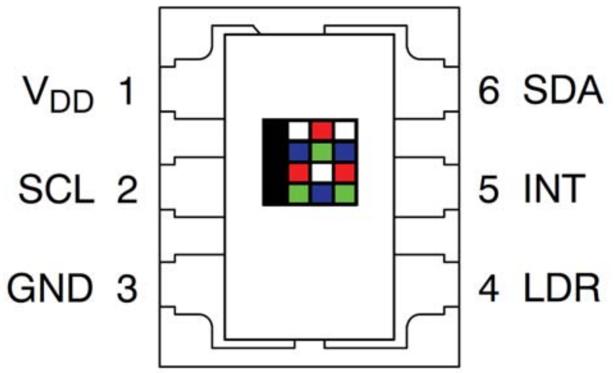


Figure 4:
Pin Description

Pin Number	Pin Name	Pin Type	Description
1	V_{DD}		Supply voltage
2	SCL	Input	I^2C serial clock input terminal – clock signal for I^2C serial data.
3	GND		Power supply ground. All voltages are referenced to GND.
4	LDR	Output	LED driver for proximity emitter – open drain.
5	INT	Output	Interrupt – open drain (active low).
6	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 rated conditions for extended periods may affect device reliability.

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

Parameter	Min	Max	Units	Comments
Supply voltage, V_{DD}		3.8	V	All voltages are with respect to GND
Input terminal voltage	−0.5	3.8	V	
Output terminal voltage (except LDR)	−0.5	3.8	V	
Output terminal voltage (LDR)	−0.5	3.8	V	
Output terminal current (except LDR)	−1	20	mA	
Storage temperature range, T_{STRG}	−40	85	°C	
ESD tolerance, human body model	±2000		V	

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	Conditions	Min	Typ	Max	Units
V_{DD}	Supply voltage	TCS37725 (I^2C $V_{BUS} = V_{DD}$)	2.7	3	3.6	V
		TCS37727 (I^2C V_{BUS} = 1.8 V)	2.7	3	3.3	
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	Conditions	Min	Typ	Max	Units
I_{DD}	Supply current	Active – LDR pulses off		235	330	µA
		Wait state		65		
		Sleep state - no I^2C activity		2.5	10	
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	
V_{IH}	SCL SDA input high voltage	TCS37725	0.7 V_{DD}			V
		TCS37727	1.25			
V_{IL}	SCL SDA input low voltage	TCS37725			0.3 V_{DD}	V
		TCS37727			0.54	

Figure 8:
Optical Characteristics, V_{DD} = 3 V, T_A = 25°C, AGAIN = 16×, ATIME = 0xF6 (unless otherwise noted)[1]

Parameter	Test Conditions	Red Channel		Green Channel		Blue Channel		Clear Channel			Unit
		Min	Max	Min	Max	Min	Max	Min	Typ	Max	
R_e Irradiance responsivity	λ_D= 465 nm[2]	0%	15%	10%	42%	65%	88%	11.0	13.8	16.6	counts /μW /cm^2
	λ_D= 525 nm[3]	4%	25%	60%	85%	10%	45%	13.2	16.6	20.0	
	λ_D= 615 nm[4]	80%	110%	0%	14%	5%	24%	15.6	19.5	23.4	

Note(s):

1. The percentage shown represents the ratio of the respective red, green, or blue channel value to the clear channel value.
2. The 465 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D=465nm, spectral halfwidth Δλ½ = 22 nm.
3. The 525 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D=525nm, spectral halfwidth Δλ½ = 35 nm.
4. The 615 nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics: dominant wavelength λ_D=615nm, spectral halfwidth Δλ½ = 15 nm.

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

Parameter	Conditions	Min	Typ	Max	Units
Dark ADC count value	E_e = 0, AGAIN = 60×, ATIME = 0xD6 (100 ms)	0	1	5	counts
ADC integration time step size	ATIME=0xFF	2.27	2.4	2.56	ms
ADC number of integration steps [1]		1		256	steps
ADC counts per step [1]		0		1024	counts
ADC count value [1]	ATIME=0xC0 (153.6 ms)	0		65535	counts
Gain scaling, relative to 1× gain setting	4×	3.8	4	4.2	×
	16×	15	16	16.8	
	60×	58	60	63	

Note(s):

1. Parameter ensured by design and is not tested.

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

Parameter	Conditions	Min	Typ	Max	Units
I_{DD} Supply current	LDR pulse on		3		mA
ADC conversion time step size	PTIME = 0xFF	2.27	2.4	2.56	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 = 770.1 µW/cm^2, PTIME = 0xFB, PPULSE= 1 [(3)]	1350		1900	counts
ADC output responsivity	λ_p = 850 nm, PTIME = 0xFF, PPULSE = 1 [(3)]	0.175	0.211	0.247	counts/ µW/ cm^2
Noise [(1)] [(2)] [(3)]	E_e = 0, PTIME = 0xFF, PPULSE = 8 [(6)]		2		% FS
LED pulse count [(1)]		0		255	pulses
LED pulse period			14.0		µs
LED pulse width – LED on time			6.3		µs
LED drive current	I_{SINK} sink current @ 1.6 V, LDR pin — PDRIVE = 0	80	106	132	mA
	PDRIVE = 1		50		
	PDRIVE = 2		25		
	PDRIVE = 3		12.5		
Maximum operating distance [(1)] [(4)] [(5)]	PDRIVE = 0 (100 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)		30		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 the Figure 11, “Proximity Noise Test Circuit,” on page 9.

Figure 11:
Proximity Noise Test Circuit

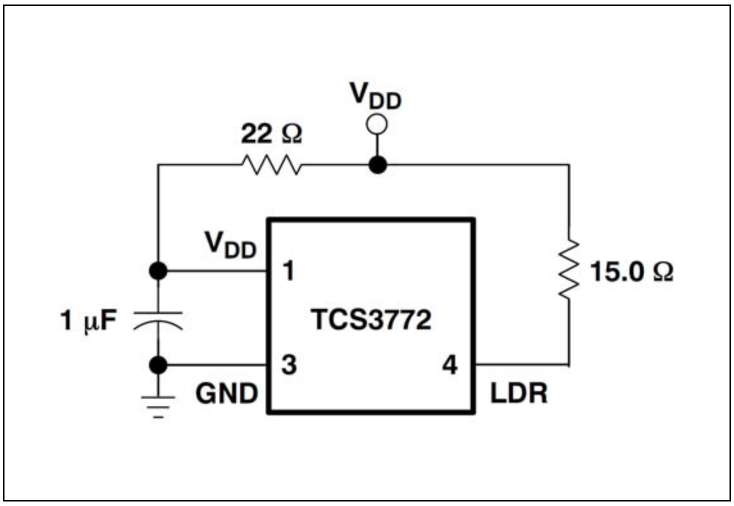


Figure 12:
Wait Characteristics, V_{DD} = 3 V, T_A = 25°C, WEN = 1 (unless otherwise noted)

Parameter	Conditions	Channel	Min	Typ	Max	Units
Wait step size	WTIME = 0xFF		2.27	2.4	2.56	ms
Wait number of steps (1)			1		256	steps

Note(s):

1. Parameter ensured by design and is not tested.

Timing Characteristics

The timing characteristics of TCS3772 are given below.

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

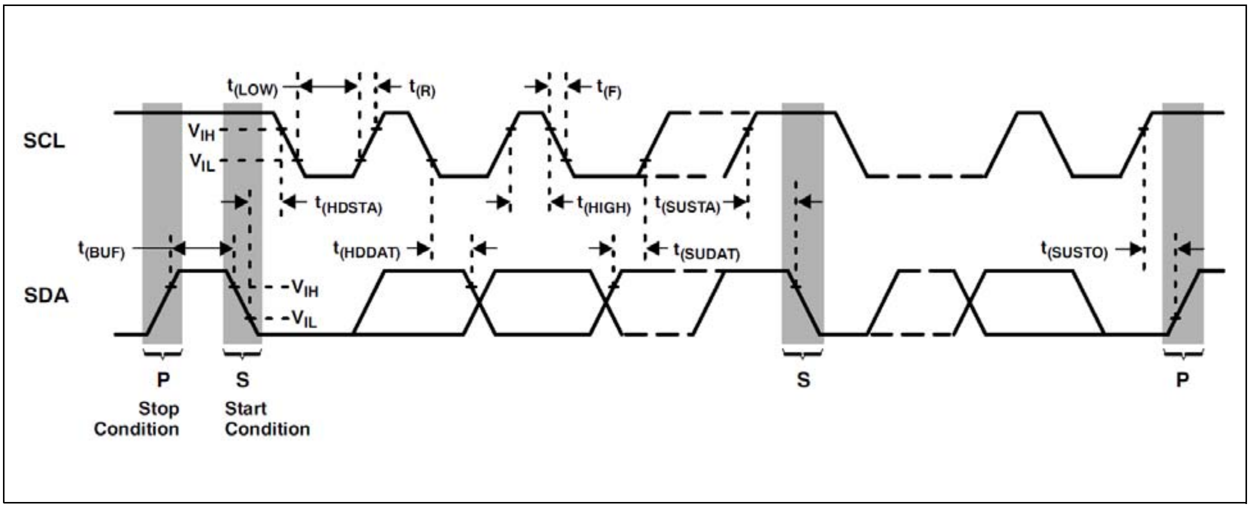
Parameter (1)	Description	Min	Max	Units
$f_{(SCL)}$	Clock frequency (I²C only)	0	400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition	1.3		µs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.	0.6		µs
$t_{(SUSTA)}$	Repeated start condition 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.

Timing Diagrams

Figure 14:
Parameter Measurement Information



Typical Operating Characteristics

Figure 15:
Photodiode Spectral Responsivity RGBC

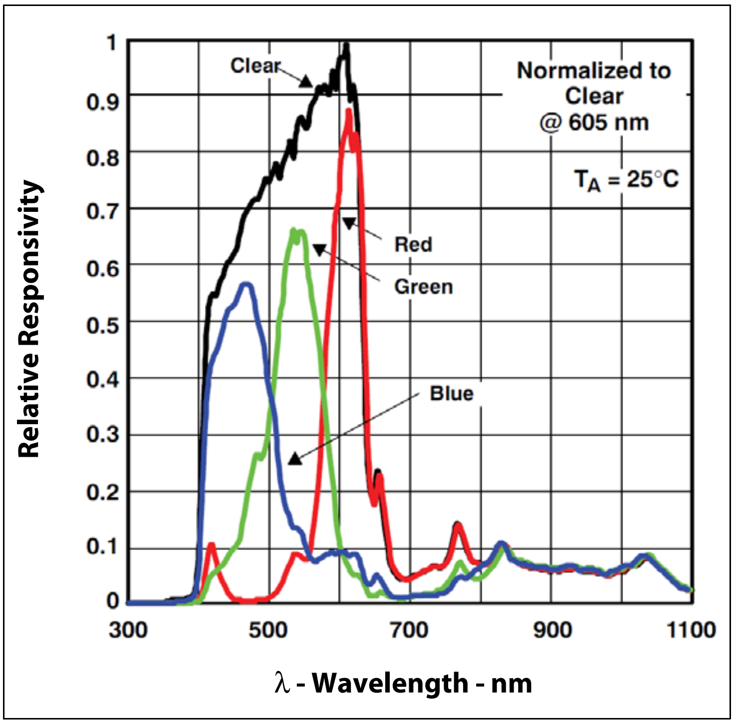


Figure 16:
Photodiode Spectral Responsivity Proximity

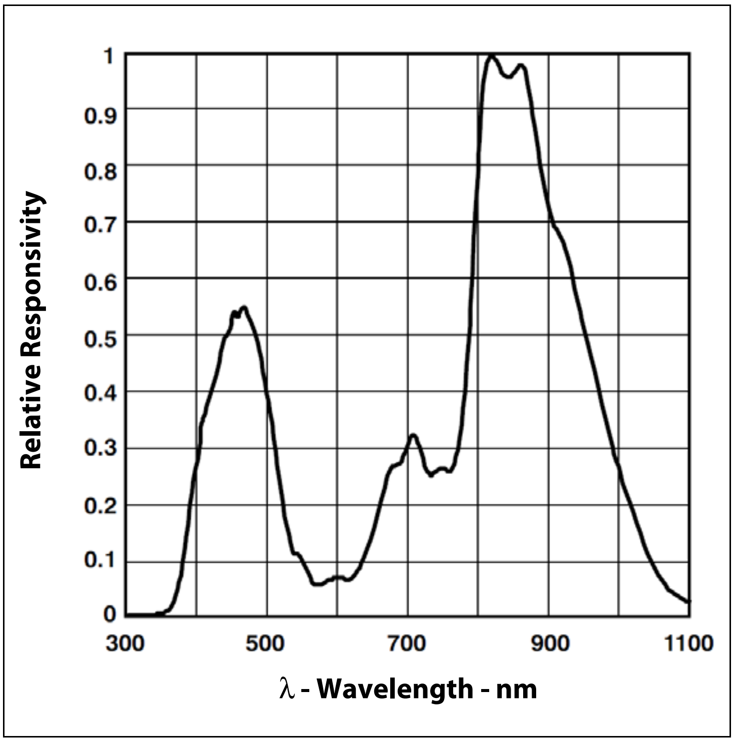


Figure 17:
Normalized Responsivity vs. Angular Displacement

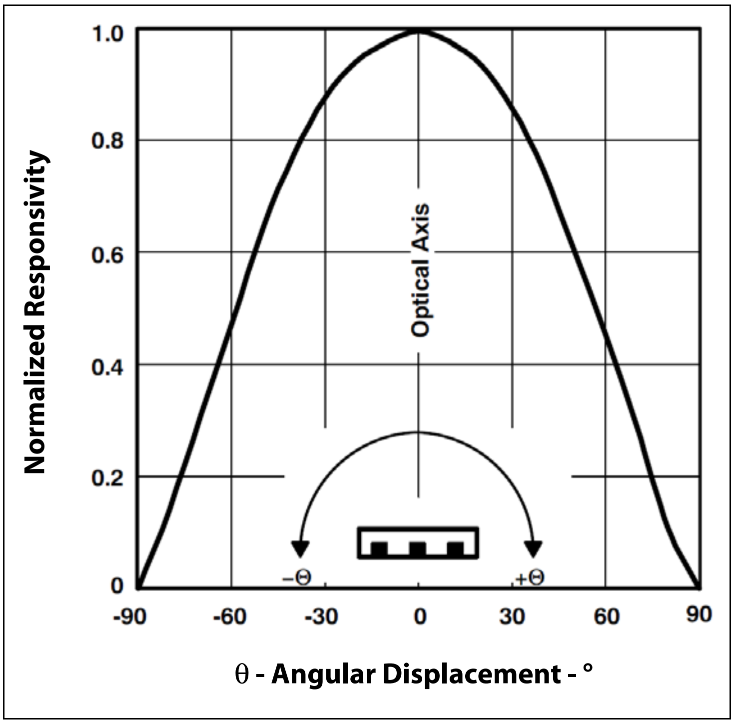


Figure 18:
Normalized Responsivity vs. Angular Displacement

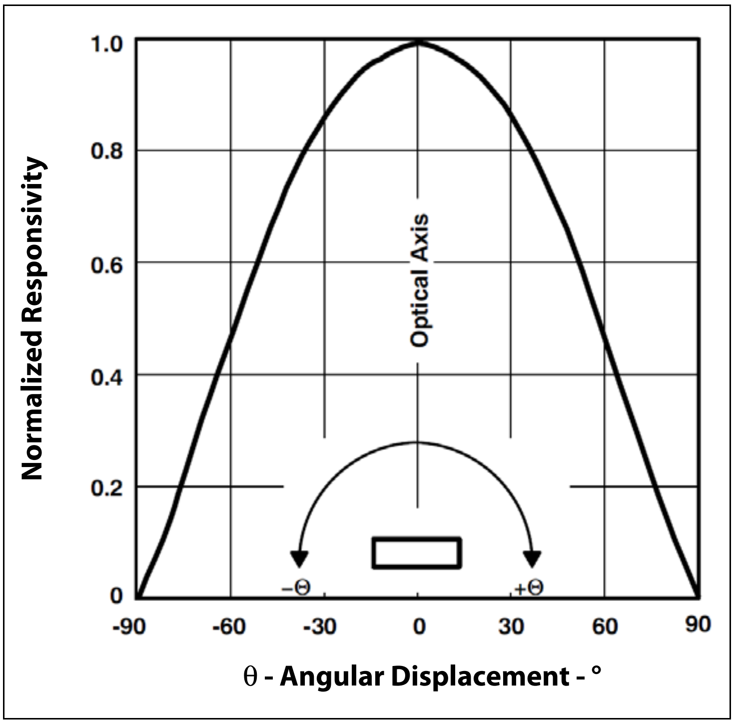


Figure 19:
Normalized I_{DD} vs. V_{DD} and Temperature

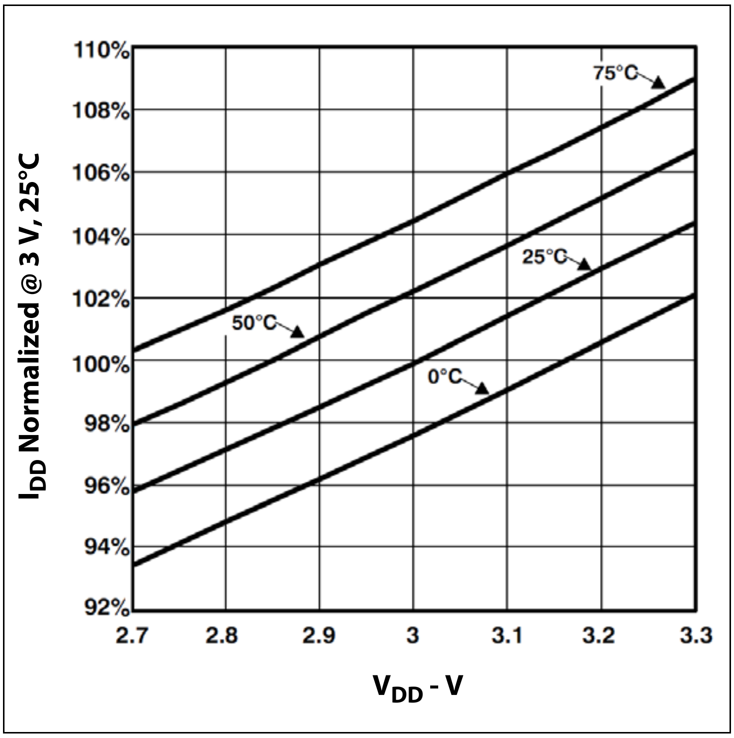


Figure 20:
Typical LDR Current vs. Voltage

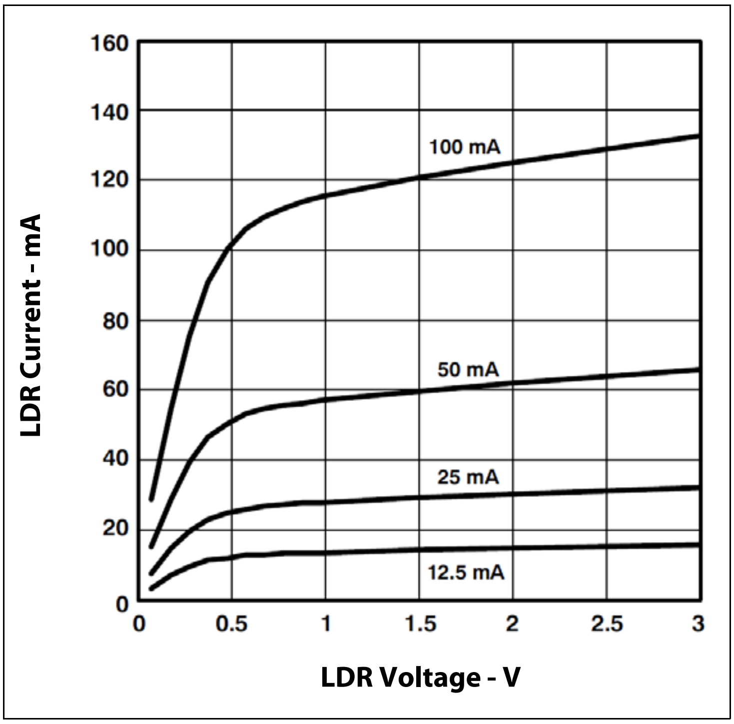
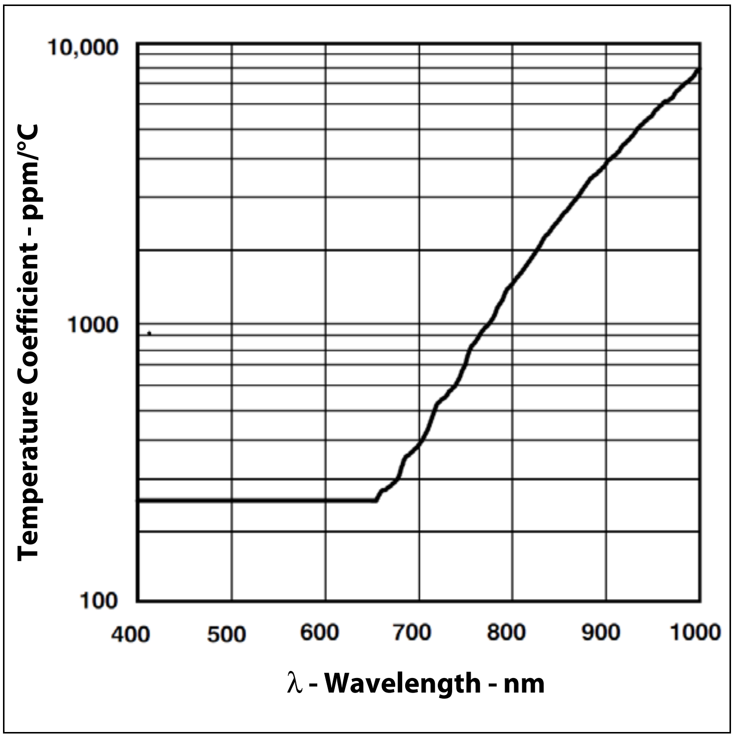


Figure 21:
Responsivity Temperature Coefficient



Detailed Description

The TCS3772 is a next-generation digital color light sensor device containing four integrating analog-to-digital converters (ADCs) that integrate currents from photodiodes. The device contains a 3 × 4 photodiode array used for color measurements and a 1 × 4 photodiode array used for proximity measurements. Integration of all color sensing channels occurs simultaneously. Upon completion of the conversion cycle, the conversion result is transferred to the corresponding data registers. The transfers are double-buffered to ensure that the integrity of the data is maintained. 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 device provides a separate pin for level-style interrupts. The interrupt feature simplifies and improves system efficiency by eliminating the need to poll a sensor for a light intensity value. When interrupts are enabled, an interrupt is generated when the value of a clear channel or proximity conversion is greater than an upper threshold or less than a lower threshold. Once the interrupt is asserted, it remains asserted until cleared by the controlling firmware. In addition, a programmable interrupt persistence filter allows the user to set the number of consecutive clear channel or proximity conversions outside of the threshold region that are necessary to trigger an interrupt. Interrupt thresholds and persistence filter settings are configured independently for both clear and proximity.

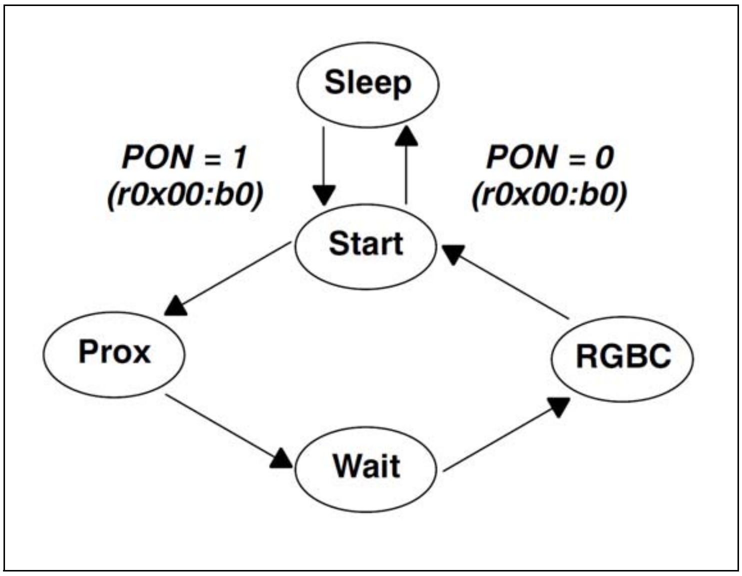
Proximity detection requires only a single external IR LED. An internal LED driver can be configured to provide a constant current sink of 12.5 mA, 25 mA, 50 mA, or 100 mA of current. No external current limiting resistor is required. The number of proximity LED pulses can be programmed from 1 to 255 pulses. Each pulse has a 14-µs period.

Principles of Operation

System State Machine

The TCS3772 provides control of RGBC, proximity detection, and power management functionality through an internal state machine (Figure 22). 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 RGBC states. If these states are enabled, the device will execute each function. If the PON bit is set to 0, the state machine will continue until all conversions are completed and then go into a low power sleep mode.

Figure 22:
Simplified State Diagram

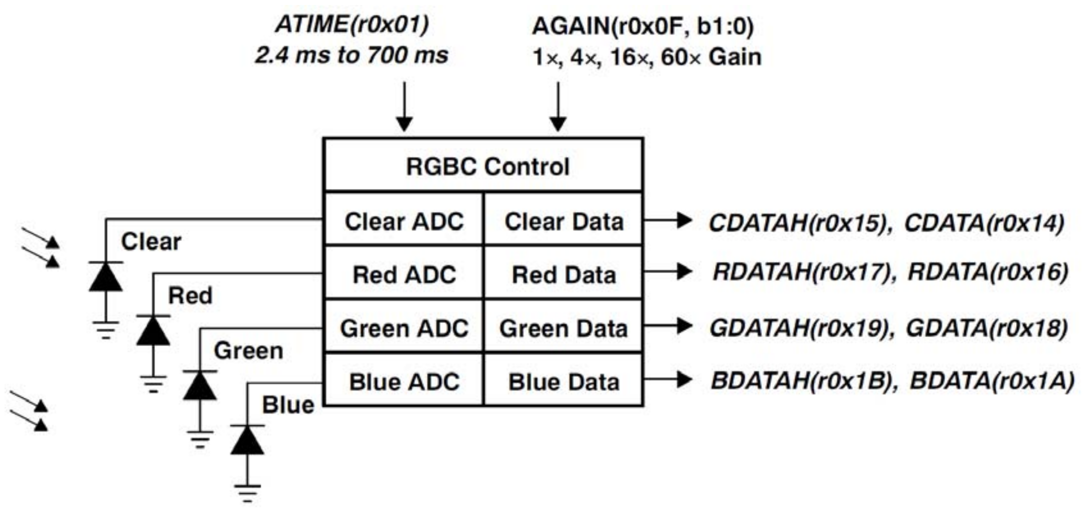


Note(s): In this document, the nomenclature uses the bit field name in italics followed by the register number and bit number to allow the user to easily identify the register and bit that controls the function. For example, the power on (PON) is in register 0, bit 0. This is represented as PON (r0x00:b0).

RGBC Operation

The RGBC engine contains RGBC gain control (AGAIN) and four integrating analog-to-digital converters (ADC) for the RGBC photodiodes. The RGBC integration time (ATIME) impacts both the resolution and the sensitivity of the RGBC reading. Integration of all four channels occurs simultaneously and upon completion of the conversion cycle, the results are transferred to the color data registers. This data is also referred to as channel count. The transfers are double-buffered to ensure that invalid data is not read during the transfer. After the transfer, the device automatically moves to the next state in accordance with the configured state machine.

Figure 23:
RGBC 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 / 2.4 ms

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

Integration Time = 2.4 ms × (256 - ATIME)

For example, if a 100-ms integration time is needed, the device needs to be programmed to:

256 - (100 / 2.4) = 256 - 42 = 214 = 0xD6

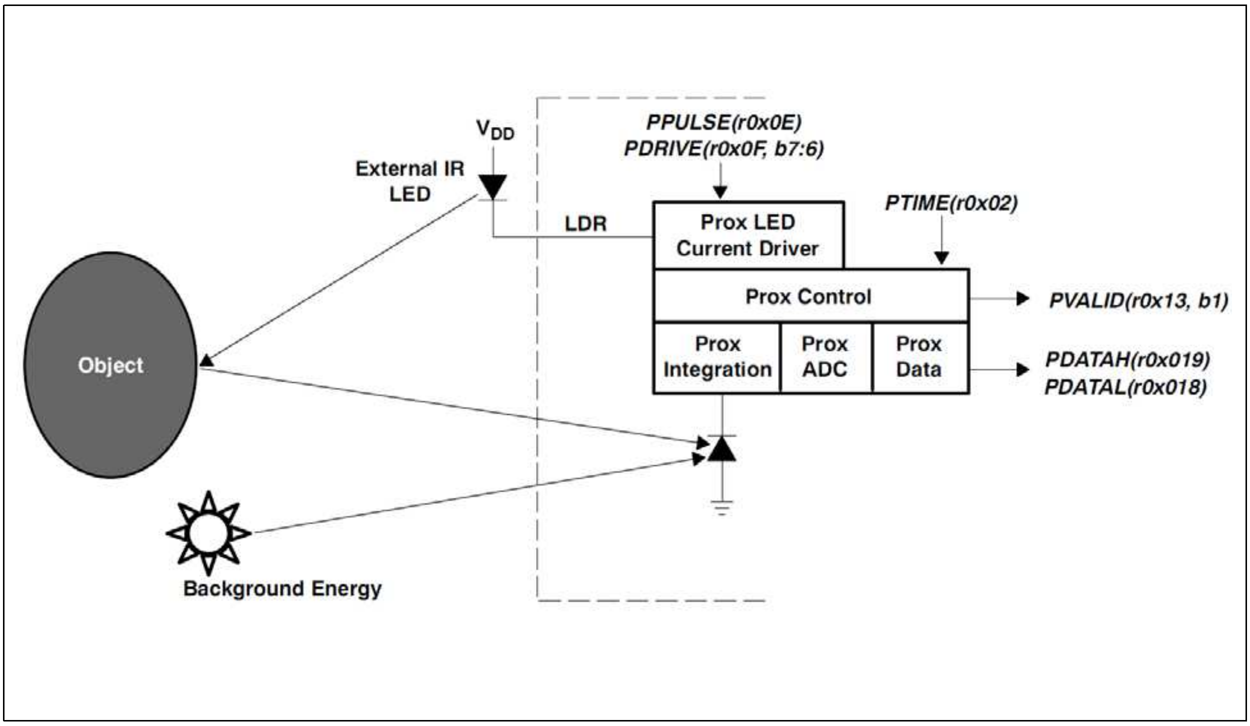
Conversely, the programmed value of 0xC0 would correspond to:

(256 - 0xC0) × 2.4 = 64 × 2.4 = 154 ms

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 TCS3772 device, is driven by the integrated proximity LED current driver.

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. PDRIVE sets the drive current to 100 mA, 50 mA, 25 mA. To drive an external light source with more than 100 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 25 during the Prox Accum state. Figure 25 also illustrates that the LED On pulse has a fixed width of 6.3 µs and period of 14.0 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 25:
Proximity LED Current Driver Waveform

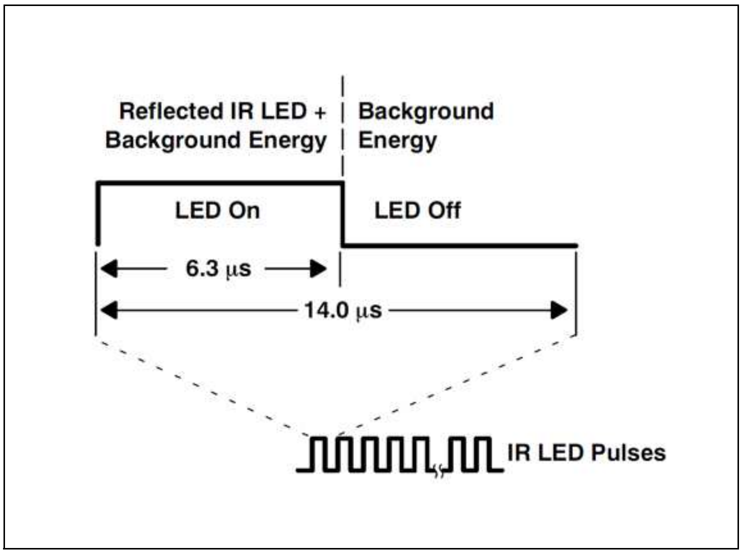


Figure 24 illustrates light rays emitting from an external IR LED, reflecting off an object, and being absorbed by the proximity photodiode.

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 external 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 2.4-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 2.4-ms ADC conversion time (0xFF).

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

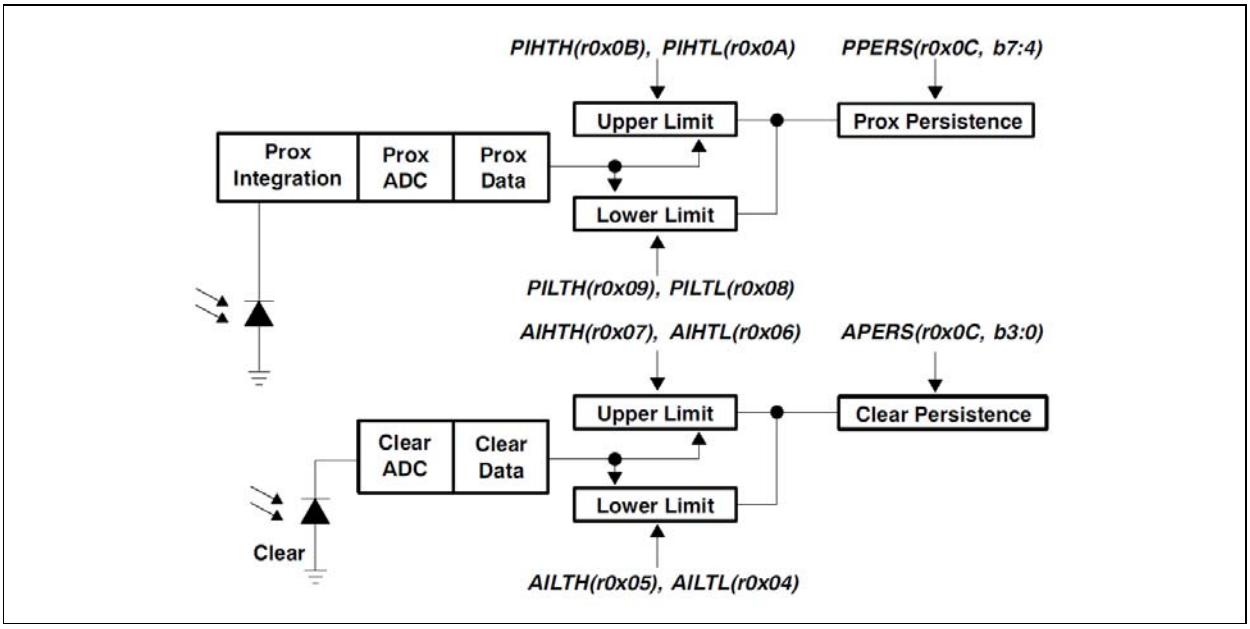
The interrupt feature simplifies and improves system efficiency by eliminating the need to poll the sensor for light intensity or proximity values outside of a user-defined range. While the interrupt function is always enabled and it's status is available in the status register (0x13), the output of the interrupt state can be enabled using the proximity interrupt enable (PIEN) or Clear 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 Clear data (CDATA) is less than the Clear interrupt low threshold registers (AILTx) or greater than the Clear 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 Clear or proximity occurrences before an interrupt is generated. The persistence register (0x0C) allows the user to set the Clear persistence (APERS) and the proximity persistence (PPERS) values. See the persistence 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 26:
Programmable Interrupt



System Timing

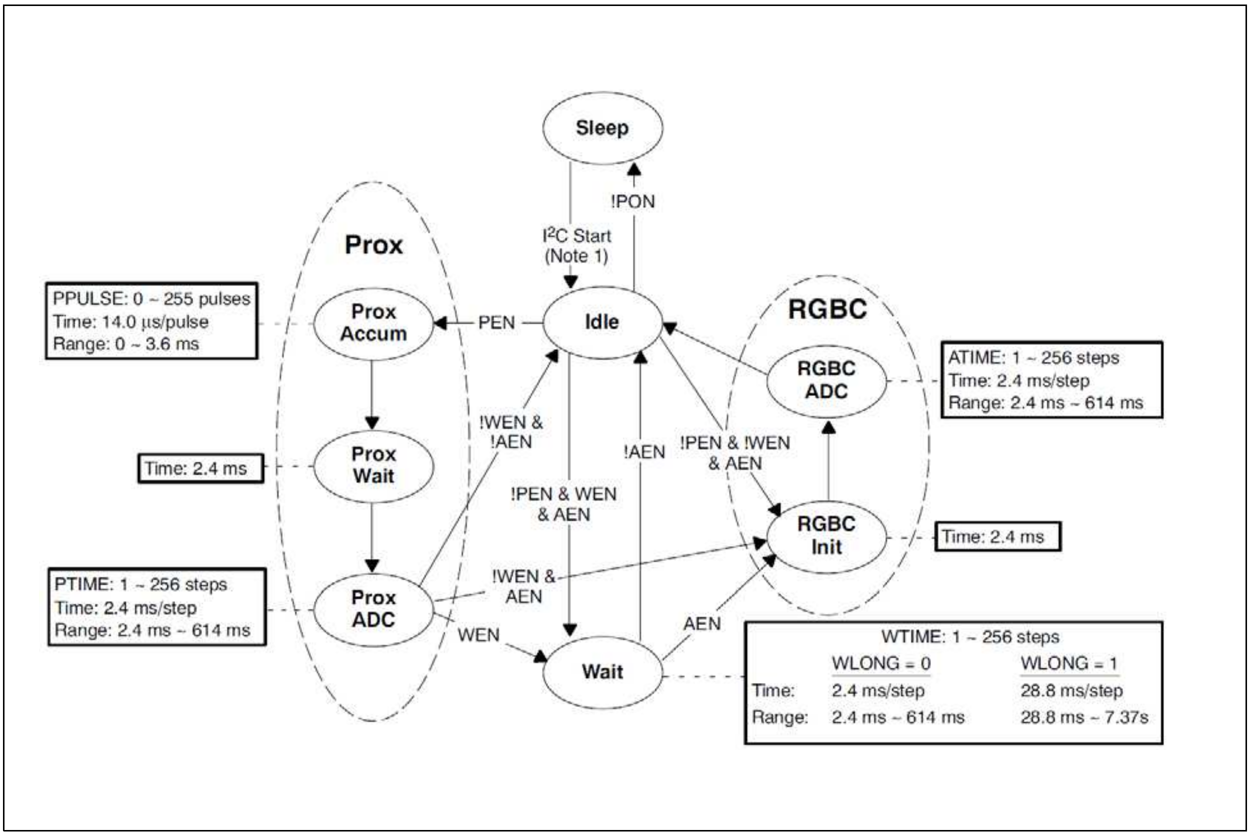
The system state machine shown in Figure 22 provides an overview of the states and state transitions that provide system control of the device. This section highlights the programmable features, which affect the state machine cycle time, and provides details to determine system level timing.

When the proximity detection feature is enabled (PEN), the state machine transitions through the Prox Accum, Prox Wait, and Prox ADC states. The Prox Wait time is a fixed 2.4ms, 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.

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 RGBC feature is enabled (AEN), the state machine will transition through the RGBC Init and RGBC ADC states. The RGBC Init state takes 2.4 ms, while the RGBC ADC time is dependent on the integration time (ATIME). The formula to determine RGBC ADC time is given in the associated box in Figure 27. If an interrupt is generated as a result of the RGBC cycle, it will be asserted at the end of the RGBC ADC.

Figure 27:
Detailed State Diagram



Note(s):

1. There is a 2.4 ms warm-up delay if PON is enabled. If PON is not enabled, the device will return to the Sleep state as shown.
2. PON, PEN, WEN, and AEN 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 65 µA 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 186 µA.

Figure 28:
Power Management

System State Machine State	Programmable Parameter	Programmed Value	Duration	Typical Current
Prox Accum	PPULSE	0x04	0.056 ms	
Prox Accum - LED ON			0.025 ms (1)	109 mA
Prox Accum - LED OFF			0.031 ms (2)	0.235 mA
Prox Wait			2.40 ms	0.235 mA
Prox ADC	PTIME	0xFF	2.40 ms	0.235 mA
Wait	WTIME	0xEE	43.1 ms	0.065 mA
	WLONG	0		
ALS Init			2.40 ms	0.235 mA
ALS ADC	ATIME	0xEE	43.1 ms	0.235 mA

Note(s):

1. Prox Accum - LED ON time = 6.3 µs per pulse × 4 pulses = 25.2 µs = 0.025 ms
2. Prox Accum - LED OFF time = 7.7 µs per pulse × 4 pulses = 30.9 µs = 0.031 ms
   Average I_{DD} Current = ((0.025 × 109) + (0.031 × 0.235) + (2.40 × 0.235) + (43.1 × 0.065) + (43.1 × 0.263) + (2.40 × 0.235 × 2)) / 93 ≈ 186 µA

Keeping with the same programmed values as the example, Figure 29 shows how the average I_{DD} current is affected by the Wait state time, which is determined by WEN, WTIME, and WLONG. Note that the worst-case current occurs when the Wait state is not enabled.

Figure 29:
Average I_{DD} Current

WEN	WTIME	WLONG	WAIT State	Average I_{DD} Current
0	n/a	n/a	0 ms	289 µA
1	0xFF	0	2.40 ms	279 µA
1	0xEE	0	43.1 ms	186 µA
1	0x00	0	613 ms	82 µA
1	0x00	1	7.36 s	67 µA

I²C Protocol

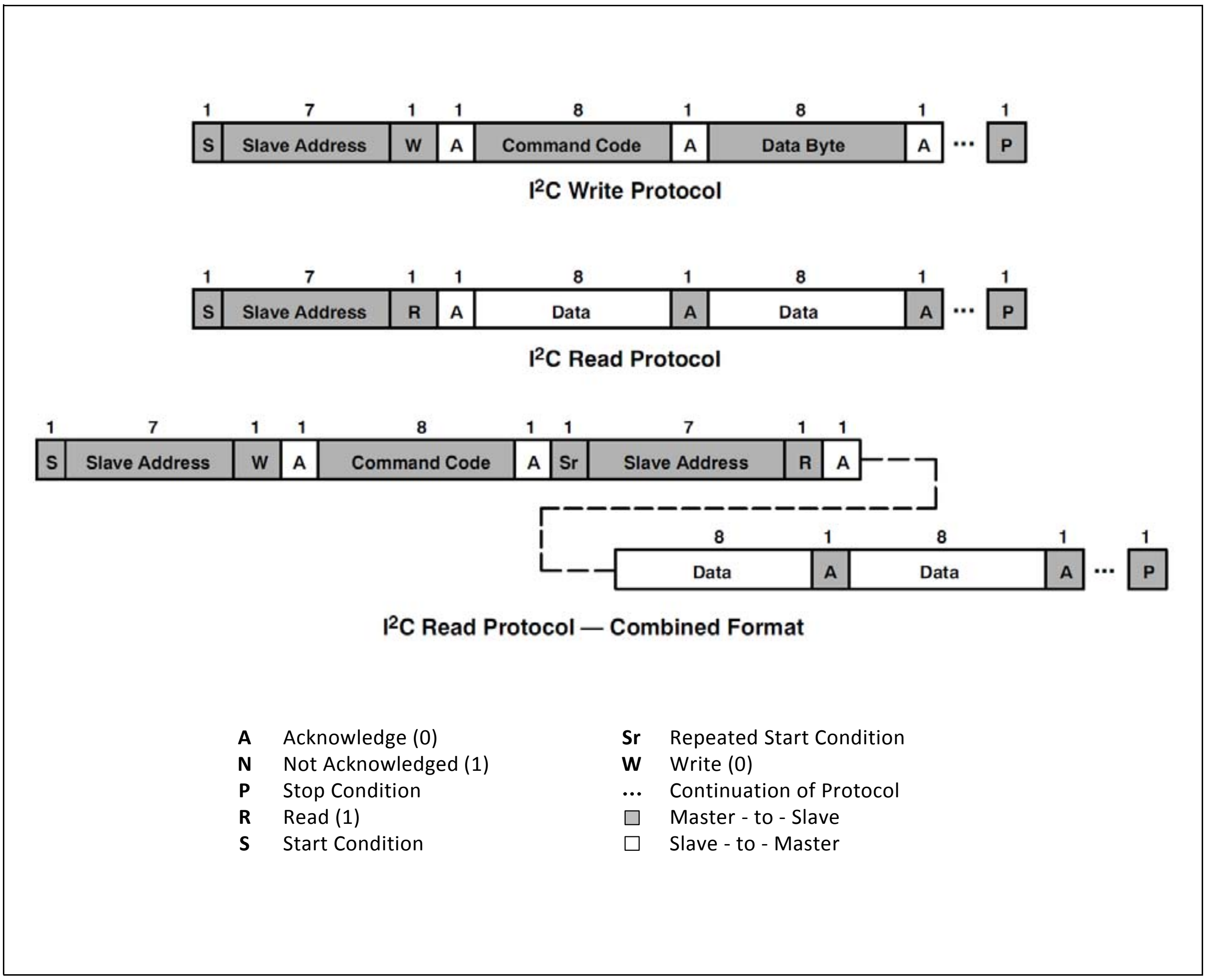
Interface and control are accomplished through an I²C serial compatible interface (standard or fast mode) to a set of registers that provide access to device control functions and output data. The devices support the 7-bit I²C addressing protocol.

The I²C standard provides for three types of bus transaction: read, write, and a combined protocol (Figure 30). 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:

http://www.i2c-bus.org/references/.

Figure 30:
I²C Protocols



Register Description

The TCS3772 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 31.

Figure 31:
Register Set

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	RGBC time	0xFF
0x02	PTIME	R/W	Proximity time	0xFF
0x03	WTIME	R/W	Wait time	0xFF
0x04	AILTL	R/W	Clear interrupt low threshold low byte	0x00
0x05	AILTH	R/W	Clear interrupt low threshold high byte	0x00
0x06	AIHTL	R/W	Clear interrupt high threshold low byte	0x00
0x07	AIHTH	R/W	Clear interrupt high threshold high byte	0x00
0x08	PILTL	R/W	Proximity interrupt low threshold low byte	0x00
0x09	PILTH	R/W	Proximity interrupt low threshold high byte	0x00
0x0A	PIHTL	R/W	Proximity interrupt high threshold low byte	0x00
0x0B	PIHTH	R/W	Proximity interrupt high threshold high byte	0x00
0x0C	PERS	R/W	Interrupt persistence filters	0x00
0x0D	CONFIG	R/W	Configuration	0x00
0x0E	PPULSE	R/W	Proximity pulse count	0x00
0x0F	CONTROL	R/W	Gain control register	0x00
0x12	ID	R	Device ID	ID
0x13	STATUS	R	Device status	0x00
0x14	CDATA	R	Clear ADC data low byte	0x00
0x15	CDATAH	R	Clear ADC data high byte	0x00
0x16	RDATA	R	Red ADC data low byte	0x00
0x17	RDATAH	R	Red ADC data high byte	0x00
0x18	GDATA	R	Green ADC data low byte	0x00
0x19	GDATAH	R	Green ADC data high byte	0x00