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TMG3993

Gesture, Color, ALS, and Proximity Sensor Module with mobeam™ Barcode Emulation

General Description

The device features advanced Gesture detection, Proximity detection, Digital Ambient Light Sense (ALS), Color Sense (RGBC), and optical pattern generation/transmission for broadcast. The slim modular package, 2.36mm × 3.95mm × 1.36mm, incorporates an IR LED and factory calibrated LED driver.

Gesture detection utilizes four directional photodiodes to sense reflected IR energy (sourced by the integrated LED) to convert physical motion information (i.e. velocity, direction and distance) to a digital information. The architecture of the gesture engine features automatic activation (based on Proximity engine results), ambient light subtraction, cross-talk cancelation, dual 8-bit data converters, power saving inter-conversion delay, 32-dataset FIFO, and interrupt driven I^2C communication. The gesture engine accommodates a wide range of mobile device gesturing requirements: simple North-South-East-West gestures or more complex gestures can be accurately sensed. Power consumption and noise are minimized with adjustable IR LED timing.

The Proximity detection feature provides object detection (E.g. mobile device screen to user's ear) by photodiode detection of reflected IR energy (sourced by the integrated LED). Detect/release events are interrupt driven, and occur whenever proximity result crosses upper and/or lower threshold settings. The proximity engine features offset adjustment registers to compensate for system offset caused by unwanted IR energy reflections appearing at the sensor. The IR LED intensity is factory trimmed to eliminate the need for end-equipment calibration due to component variations. Proximity results are further improved by automatic ambient light subtraction.

The Color and ALS detection feature provides red, green, blue and clear light intensity data. Each of the R, G, B, C channels have a UV and IR blocking filter and a dedicated data converter producing16-bit data simultaneously. This architecture allows applications to accurately measure ambient light and sense color which enables devices to calculate illuminance and color temperature, control display backlight, and chromaticity.

mobeam™ barcode emulation is achieved using the IRBeam optical pattern generation/transmission feature. IRBeam is primarily intended for 1-D barcode transmission over IR to point-of-sale (POS) terminals.

The IRBeam engine features a 1024-bit RAM for pattern storage and specialized control logic that is tailored to repetitively broadcast a barcode pattern using the integrated LED. The IRBeam engine features adjustable timing, looping, and IR intensity to maximize successful barcode reception rate among the multitude of different barcode scanner/readers currently in use globally.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of TMG3993, Gesture, Color, ALS, and Proximity Sensor Module with mobeam™ Barcode Emulation are listed below:

Figure 1:
Added Value of Using TMG3993

Benefits	Features
• Single Device Integrated Optical Solution	• Gesture Detection, Proximity, Color/ALS and IRBeam Support • Power Management Features
• Ambient Light Sensing	• UV and IR blocking filters • Programmable Gain & Integration Time • 16.7M:1 Dynamic Range
• Complex Gesture Sensing	• Four separate diodes sensitive to different directions • Ambient Light Rejection • Offset Compensation • Programmable Driver for IR LED current • 32 Dataset storage FIFO • Interrupt Driven I^2C Communication
• Ideal for Operation Behind Dark Glass	• Very High Sensitivity
• Proximity Detection	• Trimmed to provide consistent reading • Ambient Light Rejection • Proximity Offset Compensation • Saturation Indicator bit • Programmable Driver for IR LED current • 98000:1 Dynamic Range
• Barcode Pattern Generation and Transmission	• IRBeam Hardware Support • Pattern Storage in Internal RAM
• Dual Use of a Single Internal LED	• Integrated LED driver with current control for both Proximity and IRBeam

Applications

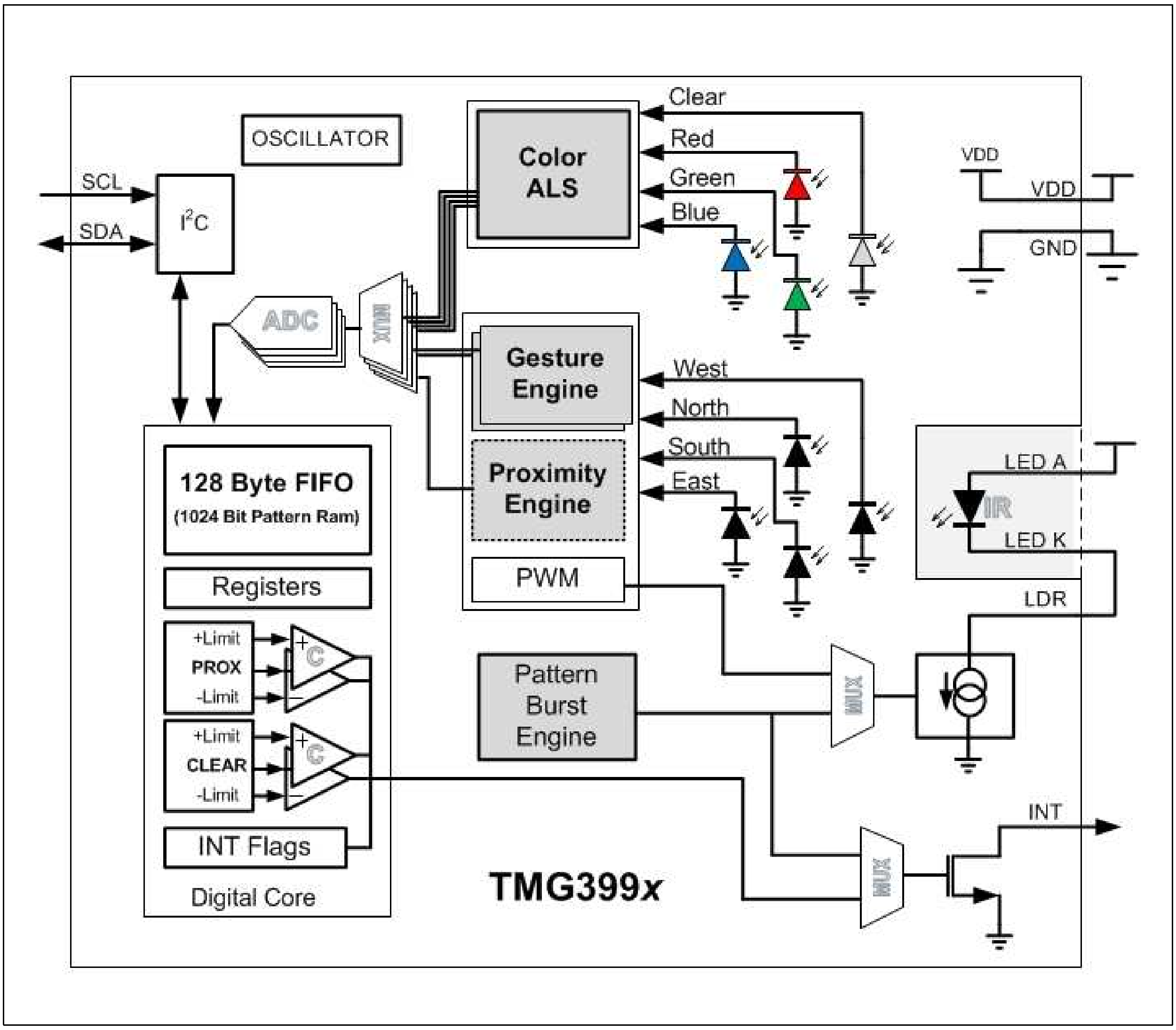
The TMG399x applications include:

- Gesture Detection
- Color Sense
- Ambient Light Sensing
- Cell Phone Touch Screen Disable
- Mechanical Switch Replacement
- Printed Bar Code Emulation

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
TMG3993 Block Diagram



Block Diagram: "Pattern Burst Engine" is used for IRBeam operational mode.

Pin Assignment

The TMG3993 pin assignments are described below.

Figure 3:
Pin Diagram

(Top View)
Package drawing is not to scale.

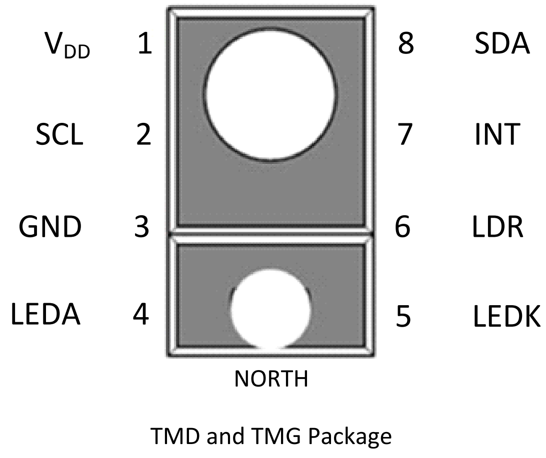


Figure 4:
Pin Description

Pin Number	Pin Name	Description
1	V_{DD}	Supply voltage.
2	SCL	I^2C serial clock input terminal.
3	GND	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 drive. Current sink for LED.
7	INT	Interrupt. Open drain output (active low) and logic level output for external IR LED circuit.
8	SDA	I^2C serial data I/O terminal.

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 [(1)]

Symbol	Parameter	Min	Max	Units	Comments
V_{DD}	Supply voltage		3.8	V	All voltages are with respect to GND
LEDA	Supply voltage		4.8	V	T_A = 0°C to 70°C
			4.4	V	T_A = -30°C to 85°C
	Digital I/O terminal voltage	- 0.5	3.8	V	
LDR	Max voltage		4.4	V	T_A = -30°C to 85°C [(2)]
			4.8	V	T_A = 0°C to 70°C [(2)]
			3.8	V	T_A = -30°C to 85°C [(3)]
(SDA, INT)	Output terminal current	- 1	20	mA	
T_{STRG}	Storage temperature range	- 40	85	°C	
ESD_{HBM}	ESD tolerance, human body model	±2000		V	

Note(s):

1. All voltages with respect to GND
2. Measured with LDR = OFF.
3. LDR = ON.

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	Units
V_{DD}	Supply voltage	2.4	3	3.6	V
T_A	Operating free-air temperature (1)	-30		85	ºC

Note(s):

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

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

Symbol	Parameter	Conditions	Min	Typ	Max	Units
f_{OSC}	Oscillator Frequency		3.525	3.675	3.825	MHz
IDD	Supply current (1)	Active ALS state (PON=AEN=1, PEN=PBEN=0)		220	330	µA
		Low slew rate (PON=PBEN=1, AEN=PEN=SLEW=0)		560		
		High slew rate (PON=PBEN=SLEW=1, AEN=PEN=0)		650		
		Proximity, During LDR Pulse (PPULSE: 8 pulses) (2)		790		
		Gesture, During LDR Pulse (GPULSE = 8) (3)		790		
		Wait state (PON=1, AEN=PEN=PBEN=0)		38		
		Sleep state (4)		1.0	10	
VOL	INT, SDA output low voltage	3 mA sink current 6 mA sink current	0 0		0.4 0.6	V

Symbol	Parameter	Conditions	Min	Typ	Max	Units
ILEAK	Leakage current, SDA, SCL, INT pins		−5		5	µA
	Leakage current, LDR pin		−10		10	
VIH	SCL, SDA input high voltage	TMG39931 TMG39935	0.7 V_{DD}			V
		TMG39933 TMG39937	1.26			
VIL	SCL, SDA input low voltage	TMG39931 TMG39935			0.3 V_{DD}	V
		TMG39933 TMG39937			0.54	

Note(s):

1. Values are shown at the V_{DD} pin and do not include current through the IR LED.
2. Current consumption during an LDR pulse is referenced as "$I_{DEVICE\ ANALOG}$" later in this document when calculating average power consumption.
3. Current consumption by the device during sleep is also used to approximate "$I_{DEVICE\ DRIVE}$" referenced later in this document when calculating average power consumption.
4. Sleep state occurs when PON = 0 and I^2C bus is idle. If Sleep state has been entered as the result of operational flow, SAI = 1, PON will remain high.

Figure 8:
Optical Characteristics (RGBC), V_{DD} = 3V, T_A = 25°C

Parameter	Test Conditions	Ratio of Color to Clear Channel					
		Red Channel		Green Channel		Blue Channel	
		Min	Max	Min	Max	Min	Max
Color ADC count value ratio: Color/Clear	White LED, 2700 K	45%	65%	19%	39%	12%	45%
	λ_D = 465 nm (1)	0%	15%	8%	42%	70%	100%
	λ_D = 525 nm (2)	4%	25%	55%	85%	10%	50%
	λ_D = 615 nm (3)	80%	110%	0%	14%	3%	32%

Note(s):

1. The 465nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 465nm, spectral halfwidth $\Delta\lambda½$ = 22nm.
2. The 525nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 525nm, spectral halfwidth $\Delta\lambda½$ = 35nm.
3. The 615nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics: dominant wavelength λ_D = 615nm, spectral halfwidth $\Delta\lambda½$ = 15nm.

Figure 9:
RGBC Characteristics, V_{DD} = 3 V, T_A = 25°C, AGAIN = 16×, AEN, ATIME = 0XF6 (unless otherwise noted)

Parameter	Conditions	Min	Typ	Max	Units
Dark ADC count value	Ee = 0, AGAIN : 64×, ATIME=0xDC (100ms)	0	1	3	counts [1]
ADC integration time step size	ATIME = 0xFF		2.78		ms
ADC number of integration steps		1		256	steps
ADC counts per step [2]		0		1024	counts
ADC count value	ATIME = 0xC0	0		65535	counts
Gain scaling, relative to 16× gain setting	AGAIN = 1×	0.058	0.062	0.067	X
	AGAIN = 4×	0.237	0.25	0.263	
	AGAIN = 64×	3.75	4	4.37	
Clear Channel Irradiance Responsivity [3]	White LED, 2700 K	17.6	22.0	26.4	counts/ (μW/ cm^2)
ADC Noise [4]	AGAIN =16x		0.005		% full Scale

Note(s):

1. The typical value based on 3-sigma distribution. An AGAIN setting of 16x correlates to a typically dark ADC count value less than or equal to 1.
2. Actual step sizes are 1024, however and addition count must be added when calculating the full-scale count value. For example, an ATIME setting of 0xFF results in a full-scale count value of 1025.
3. The white LED irradiance is supplied by a white light-emitting diode with a nominal color temperature of 2700K.
4. Number of data samples is 1000.

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

Parameter	Conditions	Min	Typ	Max	Units
ADC conversion time step size (1)			1.39		ms
LED pulse count (2)	GPULSE	1		64	pulses
LED pulse width (3)	GPLEN = 0		4.0		µs
	GPLEN = 1		8.0		
	GPLEN = 2		16.0		
	GPLEN = 3		32.0		
LED drive current (4)	GLDRIVE = 0		100		mA
	GLDRIVE = 1		50		
	GLDRIVE = 2		25		
	GLDRIVE = 3		12.5		
	LEDBOOST = 0		100		%
	LEDBOOST = 1		150		
	LEDBOOST = 2		200		
	LEDBOOST = 3		300		
Photodiode relative deviation (5)		-25		25	%
Gesture Noise (6)	GPULSE: 16 Pulses, GPLEN : 8 µs, GGAIN : 4x, GLDRIVE = 0, LEDBOOST = 0		0.78	1.25	% full Scale

Note(s):
1. Each N/S or E/W pair requires a conversion time of 696.6µs. For all four directions the conversion requires twice as much time.
2. This parameter ensured by design and characterization and is not 100% tested.
3. Value may be as much as 1.36µs longer than specified.
4. GLDRIVE current may vary from the typical value. LEDBOOST multiplies LDR current by the percentage selected.
5. This is the percent mismatch between the N, S, W, and E channels. No glass or aperture above the module.
6. Number of data samples is 128. This is the standard deviation expressed as percent of full scale signal.

Figure 11:
Gesture Optical Characteristics, V_{DD} = 3 V, T_A = 25°C, GGAIN = 8x, GEN = 1, Angle of Incident light = 0° (unless otherwise noted)

Parameter	Conditions	Min	Typ	Max	Units
ADC integration time step size	GDIMS = 0		1.36		ms
ADC count value		0		255	counts
Gain scaling, relative to 1× gain setting	GGAIN : 2x		2		X
	GGAIN : 4x		4		
	GGAIN : 8x		8		

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

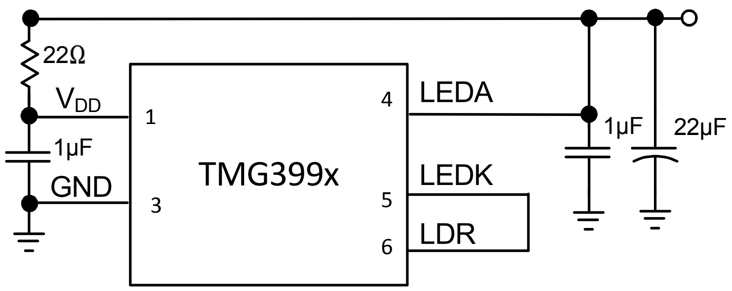
Parameter	Conditions	Min	Typ	Max	Units
ADC conversion time			696.6		µs
LED pulse count [(1)]	PPULSE	1		64	pulses
LED pulse width [(2)]	PPLEN = 0		4.0		µs
	PPLEN = 1		8.0		
	PPLEN = 2		16.0		
	PPLEN = 3		32.0		
LED drive current [(3), (4)]	LDRIVE = 0		100		mA
	LDRIVE = 1		50		
	LDRIVE = 2		25		
	LDRIVE = 3		12.5		
	LEDBOOST = 0		100		%
	LEDBOOST = 1		150		
	LEDBOOST = 2		200		
	LEDBOOST = 3		300		

Parameter	Conditions	Min	Typ	Max	Units
Proximity Offset (no target response) [5]	PGAIN = 2 (4x) LDRIVE = 0 LEDBOOST = 1 PPLEN = 2 PPULSE= 2 (3 pulses) 100mm X 100mm 90% reflective Kodak Grey Card at 100mm		4		counts
Proximity Response [6]	PGAIN = 2 (4x) LDRIVE = 0 LEDBOOST = 1 PPLEN = 2 PPULSE= 2 (3 pulses) 100mm X 100mm 90% reflective Kodak Grey Card at 100mm distance	106	132	158	Counts

Note(s):

1. This parameter ensured by design and characterization and is not 100% tested.
2. Value may be as much as 1.36µs longer than specified.
3. Value is factory-adjusted to meet the Proximity response specification. Considerable variation (relative to the typical value) is possible after adjustment. LEDBOOST increases current setting (as defined by LDRIVE or GLDRIVE). For example, if LDRIVE = 0 and LEDBOOST = 300%, LDR current is 300mA.
4. LEDBOOST multiplies LDR current by the percentage selected.
5. Proximity offset value varies with power supply characteristics and system noise.
6. Correlated result by characterization. Refer to Figure 25 and Figure 26 for typical operating settings.

Figure 13:
Proximity and Gesture Test Circuit



Note(s):

1. The circuit shown above is used during evaluation of the device and during characterization data collection.

Figure 14:
Wait Characteristics, V_{DD} = 3 V, T_A = 25°C, WEN = 1 (unless otherwise noted)

Parameter	Conditions	Min	Typ	Max	Units
Wait step size			2.78		ms

Figure 15:
Pattern Generation/Burst Operating Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$t_{(PBT\ min)}$	Minimum bit time	PBEN = 1		0.27		µs

Timing Characteristics

Figure 16:
AC Electrical Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

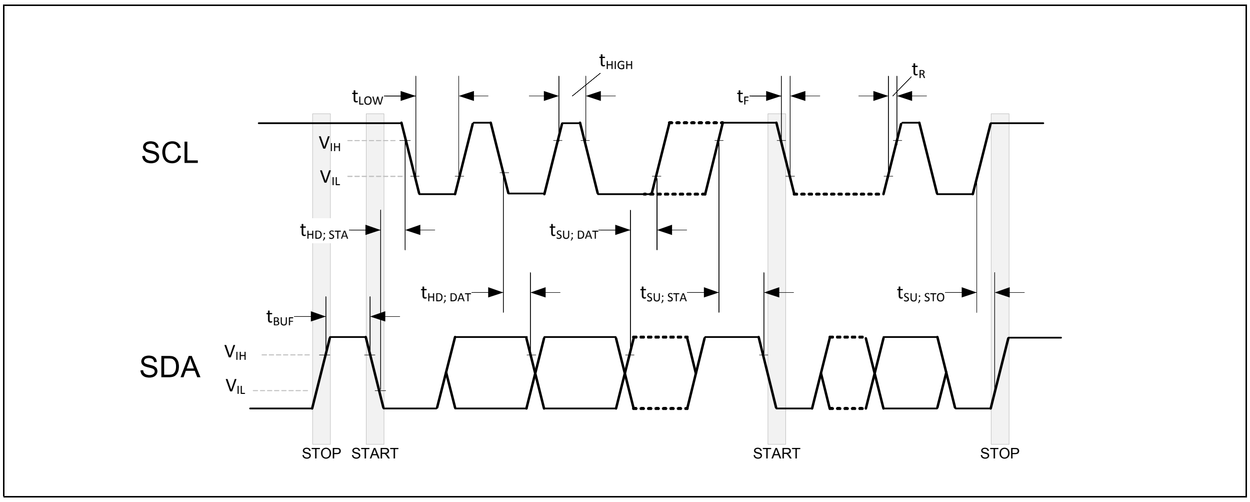
Parameter (1)	Description	Min	Max	Units
f_{SCL}	Clock frequency (I²C only)	0	400	kHz
t_{BUF}	Bus free time between start and stop condition	1.3		μs
$t_{HD;STA}$	Hold time after (repeated) start condition. After this period, the first clock is generated.	0.6		μs
$t_{SU;STA}$	Repeated start condition setup time	0.6		μs
$t_{SU;STO}$	Stop condition setup time	0.6		μs
$t_{HD;DAT}$	Data hold time	0		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 17:
Timing Parameter Measurement Drawing



Typical Operating Characteristics

Figure 18:
Spectral Responsivity

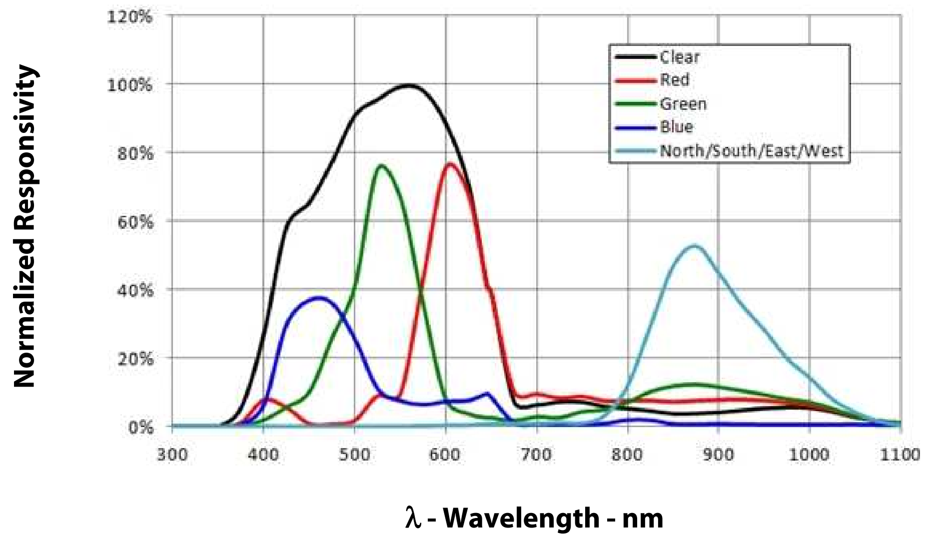


Figure 19:
RGBC Responsivity vs. Angular Displacement

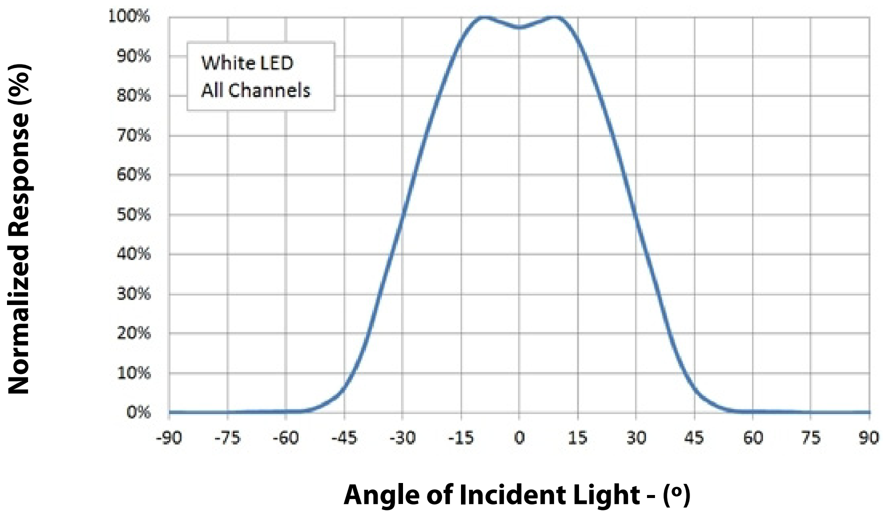


Figure 20:
Typical LDR Current vs. Voltage

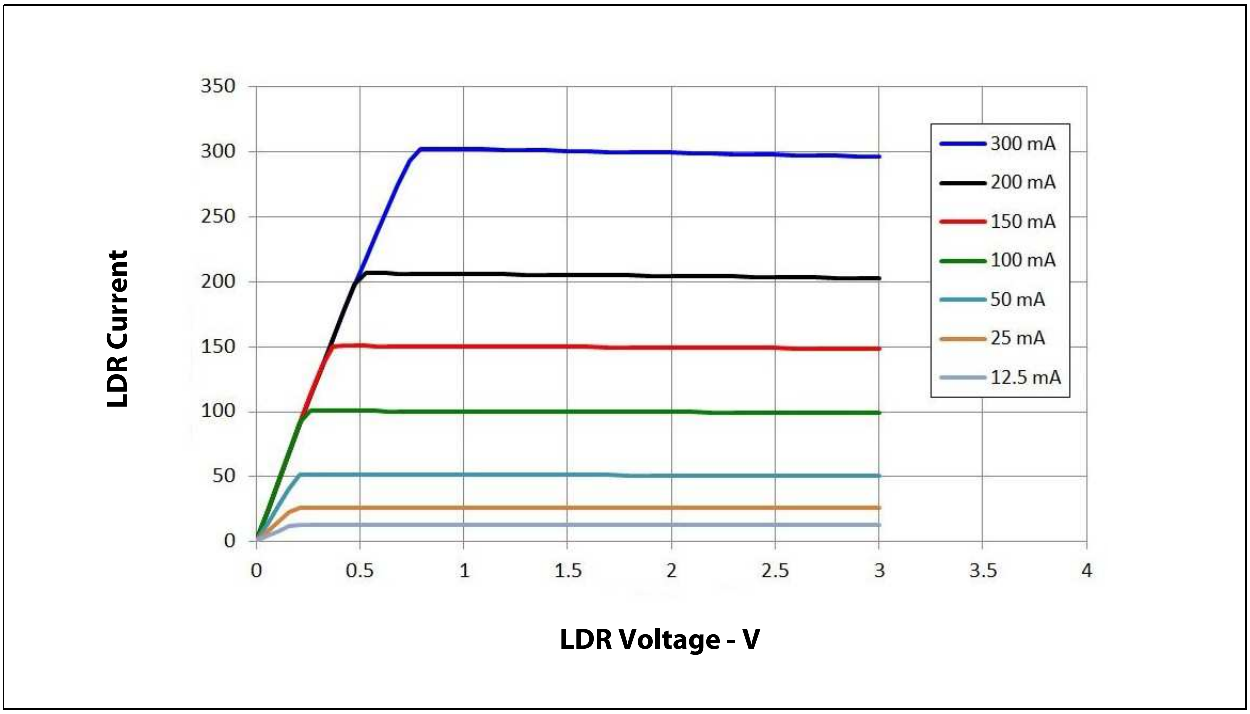


Figure 21:
Gesture Photodiodes Responsivity vs. Angular Displacement

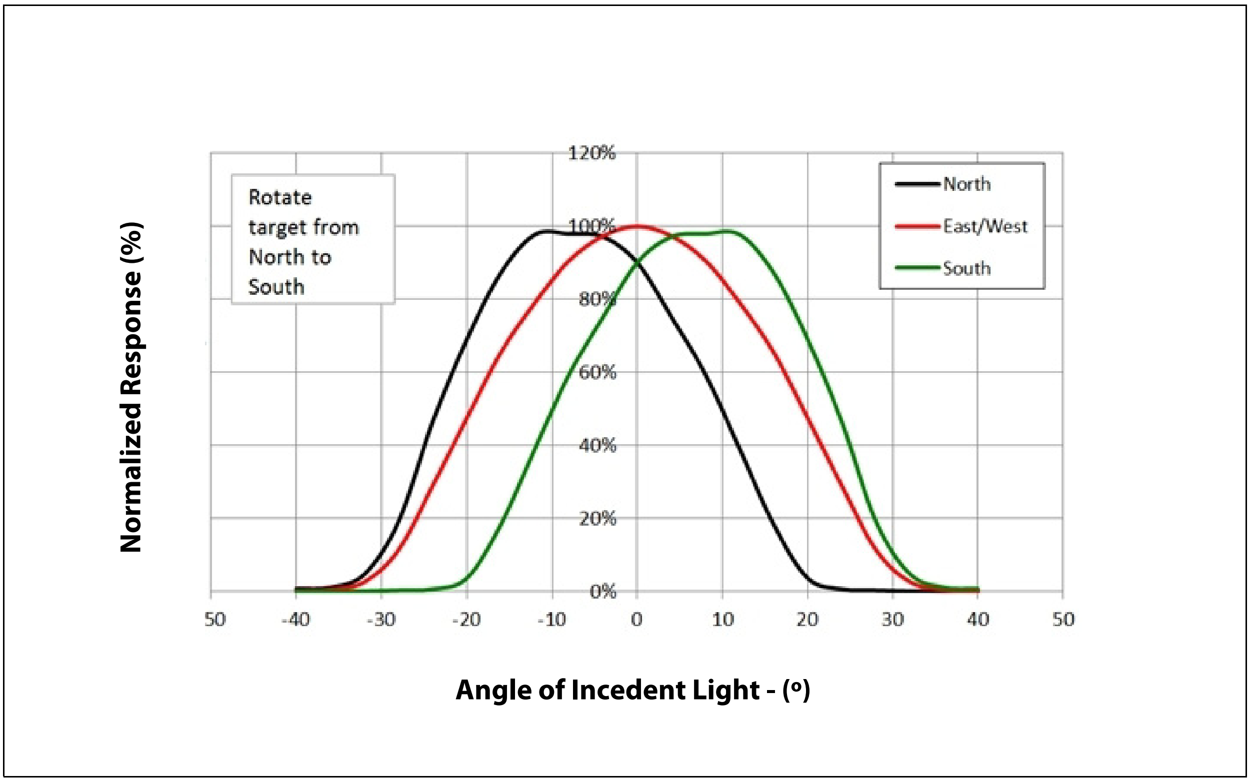


Figure 22:
Responsivity Temperature Coefficient

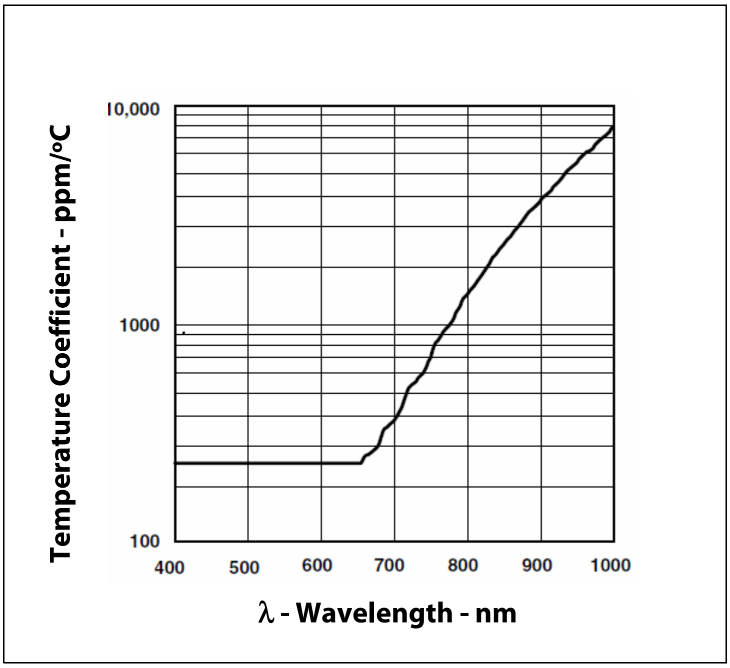
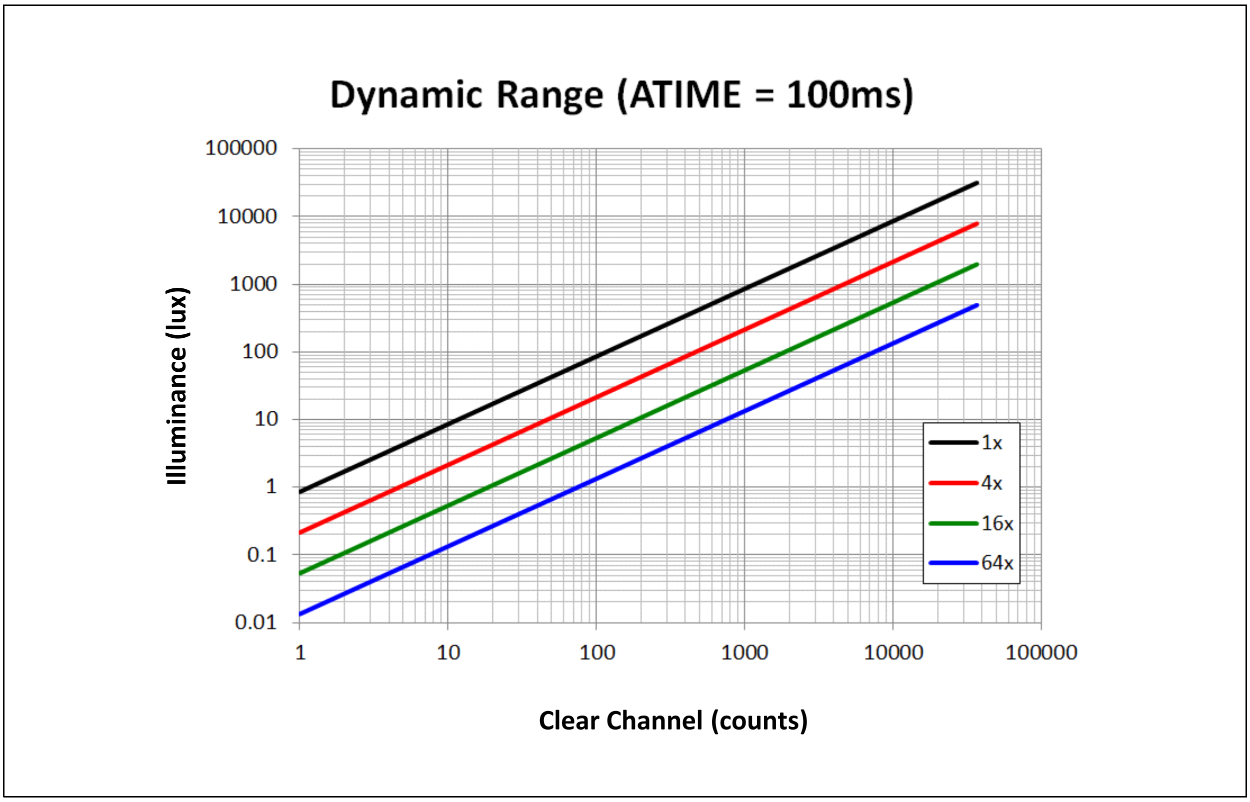


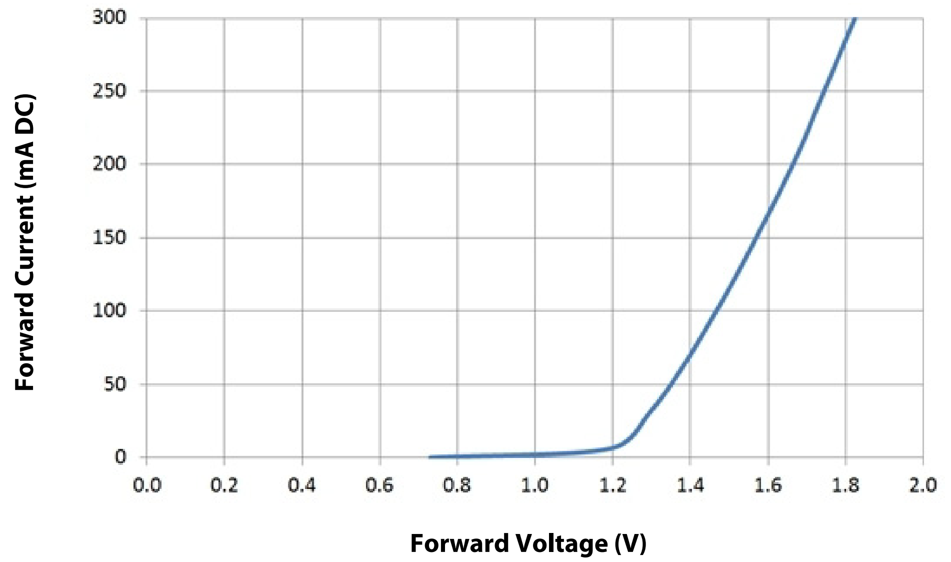
Figure 23:
Theoretical Illuminance (Lux) vs. Counts (Clear Channel)



Note(s):

1. Illustration depicts the theoretical relationship between illuminance and the Clear Channel result in Counts.

Figure 24:
950nm LED Forward Voltage vs. Current



Note(s):

1. The voltage on the LDR pin (V_{LEDA} − $V_{LED\ FORWORD}$) must be sufficiently large to guarantee proper operation of the regulated current sink.

Figure 25:
Proximity Response vs. Target Distance (4µs, 8µs)

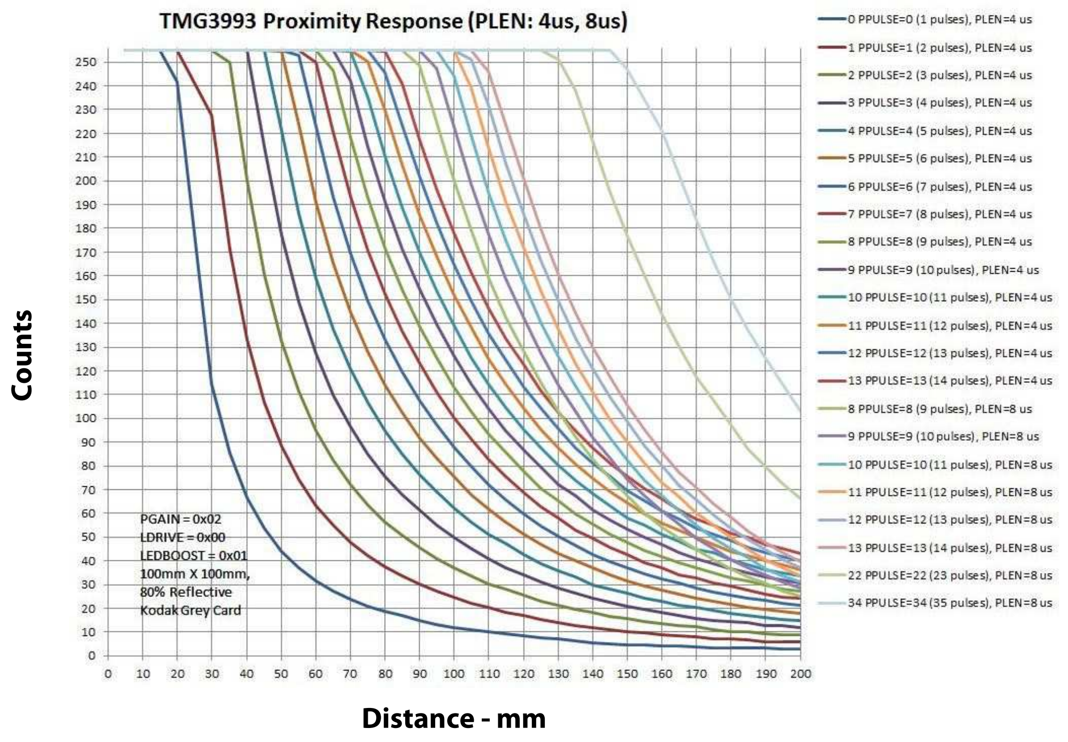
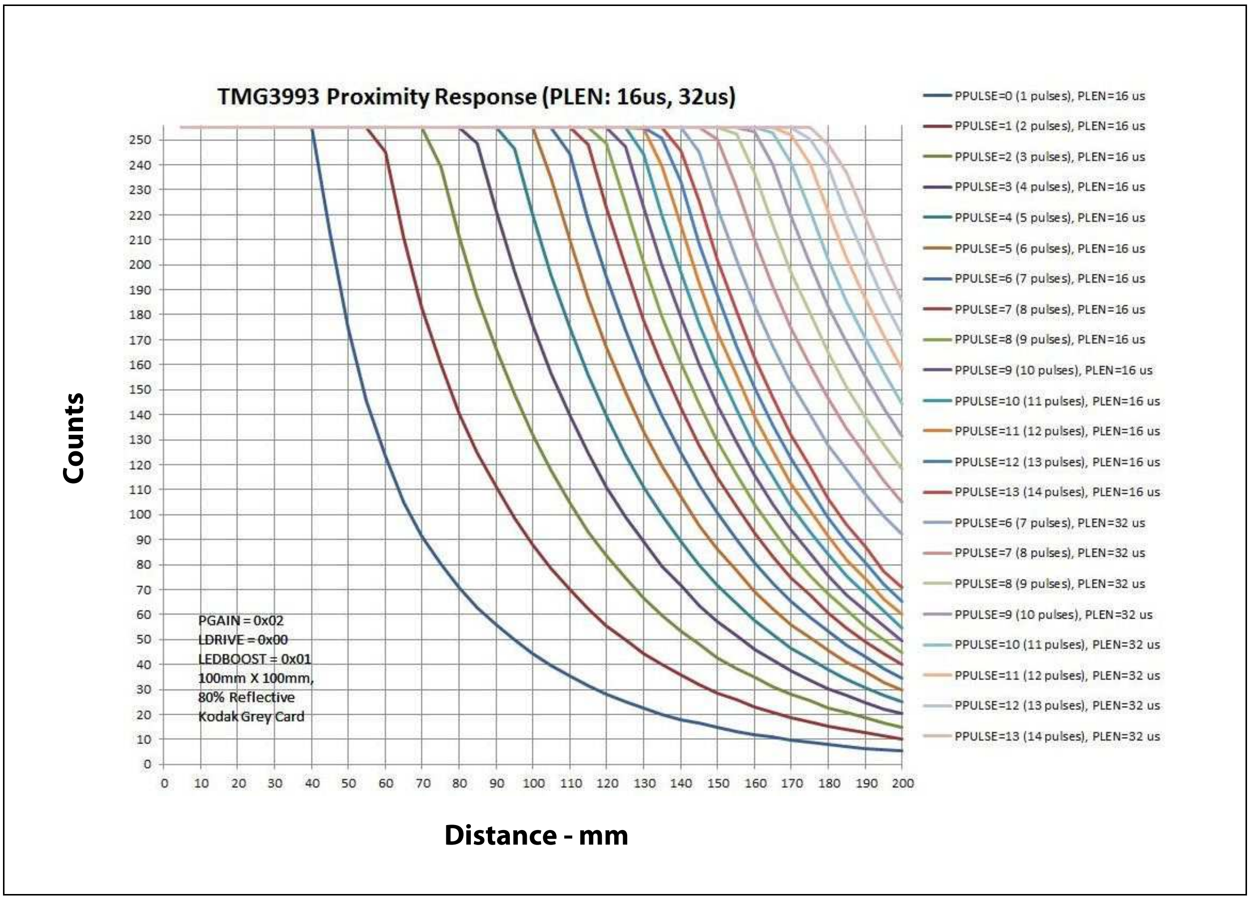


Figure 26:
Proximity Response vs. Target Distance (16µs, 32µs)



I²C Protocol

The device uses I²C serial communication protocol for communication. The device supports 7-bit chip addressing and both standard and fast clock frequency modes. Read and Write transactions comply with the standard set by Philips (now NXP).

Internal to the device, an 8-bit buffer stores the register address location of the desired byte to read or write. This buffer auto-increments upon each byte transfer and is retained between transaction events (I.e. valid even after the master issues a STOP command and the I²C bus is released). During consecutive Read transactions, the future/repeated I²C Read transaction may omit the memory address byte normally following the chip address byte; the buffer retains the last register address + 1.

I²C Write Transaction

A Write transaction consists of a START, CHIP-ADDRESS$_{WRITE}$, REGISTER-ADDRESS, DATA BYTE(S), and STOP. Following each byte (9TH clock pulse) the slave places an ACKNOWLEDGE/NOT-ACKNOWLEDGE (ACK/NACK) on the bus. If NACK is transmitted by the slave, the master may issue a STOP.

I²C Read Transaction

A Read transaction consists of a START, CHIP-ADDRESS$_{WRITE}$, REGISTER-ADDRESS, START, CHIP-ADDRESS$_{READ}$, DATA BYTE(S), and STOP. Following all but the final byte the master places an ACK on the bus (9TH clock pulse). Termination of the Read transaction is indicated by a NACK being placed on the bus by the master, followed by STOP.

Alternately, if the previous I²C transaction was a Read, the internal register address buffer is still valid, allowing the transaction to proceed without "re"-specifying the register address. In this case the transaction consists of a START, CHIP-ADDRESS$_{READ}$, DATA BYTE(S), and STOP. Following all but the final byte the master places an ACK on the bus (9TH clock pulse). Termination of the Read transaction is indicated by a NACK being placed on the bus by the master, followed by STOP.

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.

Detailed Description

Gesture detection, proximity detection, and RGBC color sense/ambient light sense functionality are controlled by a state machine, as depicted in Figure 32, which reconfigures on-chip analog resources when each functional engine is entered. Functional states/engines can be individually included or excluded from the progression of state machine flow. Each functional engine contains controls (E.g. Gain, ADC integration time, wait time, persistence, thresholds, etc.) that govern operation. Control of the Led Drive pin, LDR, is shared between Proximity, Gesture, and Pattern Burst functionality; consequently, while Pattern Burst functionality is activated, Gesture and Proximity should be deactivated.

Pattern Burst functionality uses a digital core that is independent of the analog sensor operation. The logic internal to the digital core is activated when PBEN=1, enabling Barcode Patterns (IRBeam) to be burst. The scanner receives the IR burst which emulates the pattern of reflected light during scan of a traditional paper barcode. In this operational mode the LDR pin is exclusively acquired. If proximity or gesture engines are also enabled, data generated will be invalid. The color/ALS engine does not use the IR LED, but cross talk from IR LED emissions during an optical pattern transmission may affect results.

Most of the functional engines are controlled by dedicated registers; however, controls for Gesture, and Pattern Burst are all accessed by the same address space: 0xA0 to 0xAF. Because each functional block serves a different purpose and utilizes common on-chip resources, only one may be activated at a time. For example, if Gesture and Pattern Burst engines are both activated simultaneously, the data stored in address 0xAx is available to both engines, but will only cause *the intended* engine to function properly.

Figure 27:
Simplified State Diagram

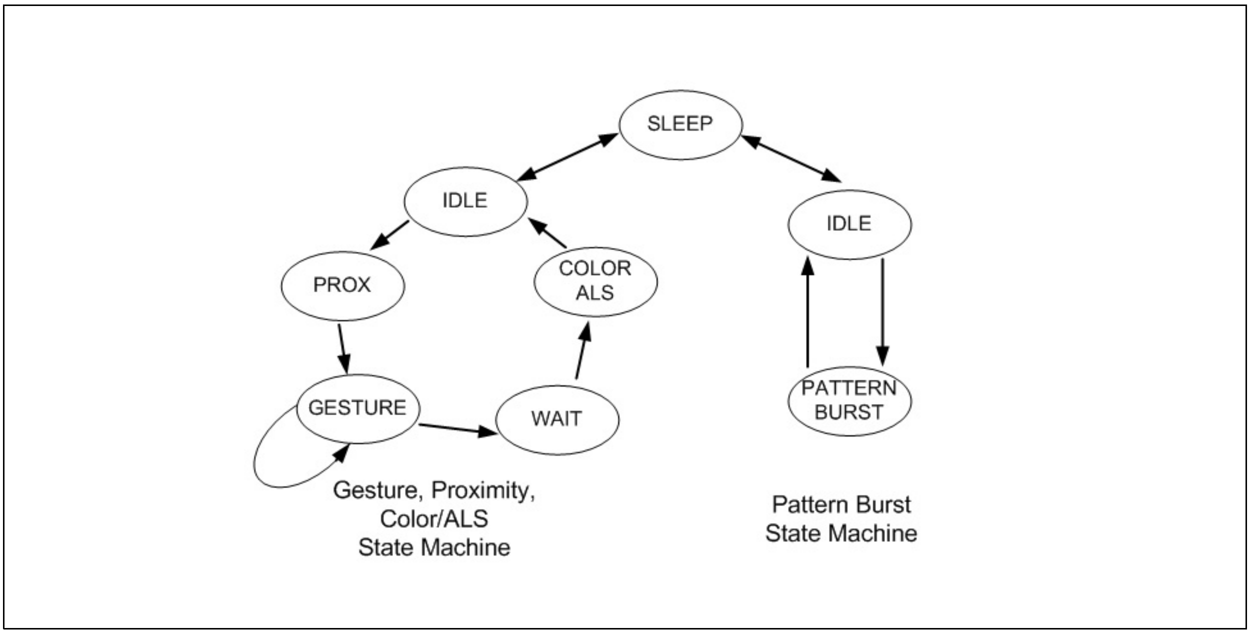
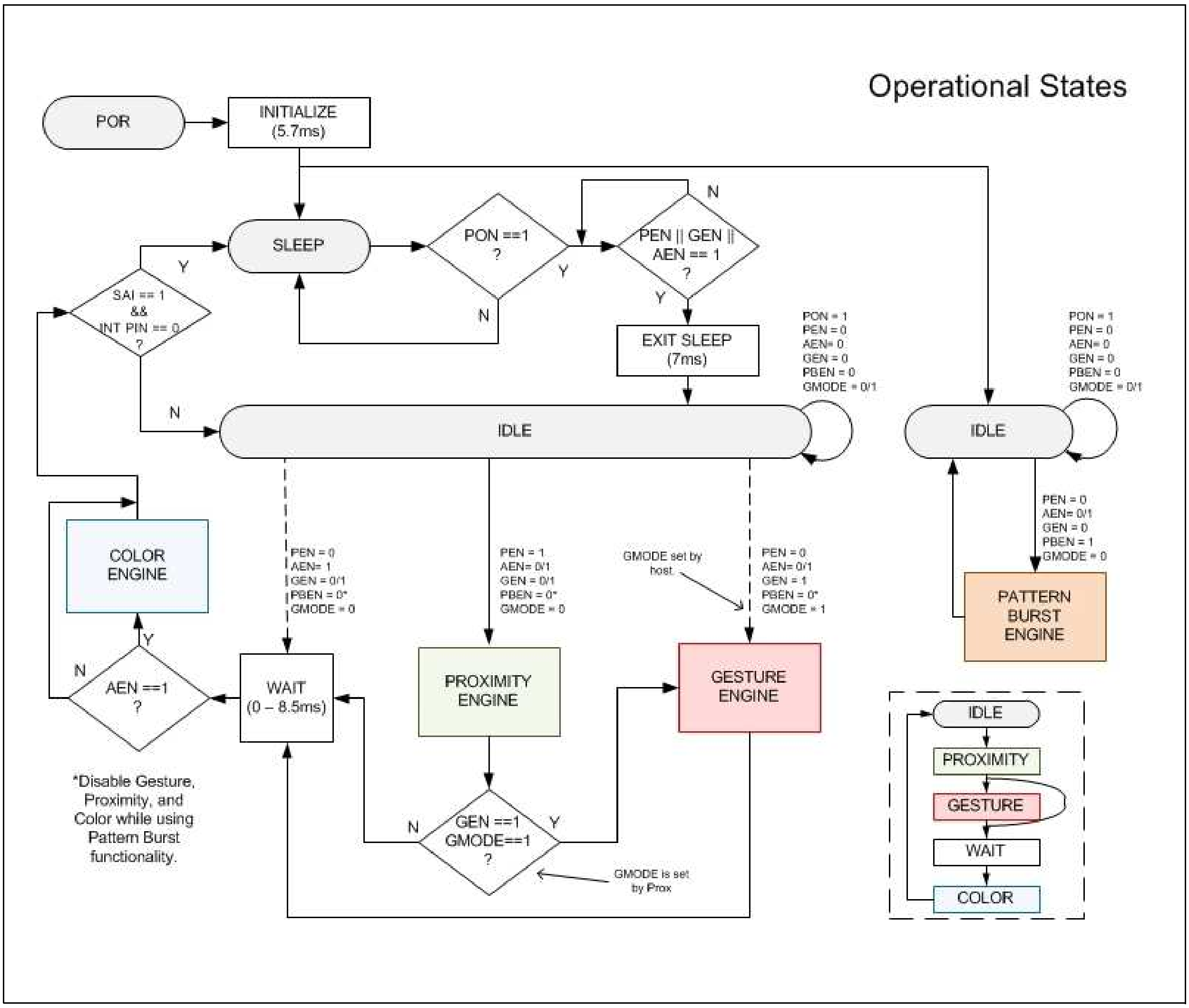


Figure 28:
Detailed State Diagram



As depicted in Figure 27 and Figure 28, the operational cycle of the device is divided into two parallel functional modes: Pattern Burst and Gesture/Proximity/Color.

Upon power-up, POR, the device initializes and immediately enters the low power SLEEP state. In this operational state the internal oscillator and other circuitry are not active, resulting in ultra-low power consumption. If I^2C transaction occurs during this state, the oscillator and I^2C core wakeup temporarily to service the communication. Once the Power ON bit, PON, is enabled, the internal oscillator and attendant circuitry are active, but power consumption remains low until one of the functional engine blocks are entered. The first time the SLEEP state is exited and any of the analog engines are enabled (PEN, GEN, AEN =1) an EXIT SLEEP pause occurs; followed by an immediate entry into the selected engine. If multiple engines are enabled, then the operational flow progresses in the following order: idle, proximity, gesture (if GMODE = 1), wait, color/ALS, and sleep (if SAI = 1 and INT pin is asserted).

The wait operational state functions to reduce the power consumption and data collection rate. If wait is enabled, WEN=1, the delay is adjustable from 2.78ms to 8.54s, as set by the value in the WTIME register and WLONG control bit.

Sleep After Interrupt Operation

After all the enabled engines/operational states have executed, causing a hardware interrupt, the state machine returns to either IDLE or SLEEP, as selected by the Sleep After Interrupt bit, SAI. SLEEP is entered when two conditions are met: SAI = 1, and the *INT* pin has been asserted. Entering SLEEP does not automatically change any of the register settings (E.g. PON bit is still high, but the normal operational state is over-ridden by SLEEP state). SLEEP state is terminated by an I^2C clear of the INT pin or if SAI bit is cleared.

Proximity Operation

The Proximity detection feature provides object detection measurement by photodiode detection of reflected IR energy sourced by the integrated LED. The following registers and control bits govern proximity operation and the operational flow is depicted in Figure 30.

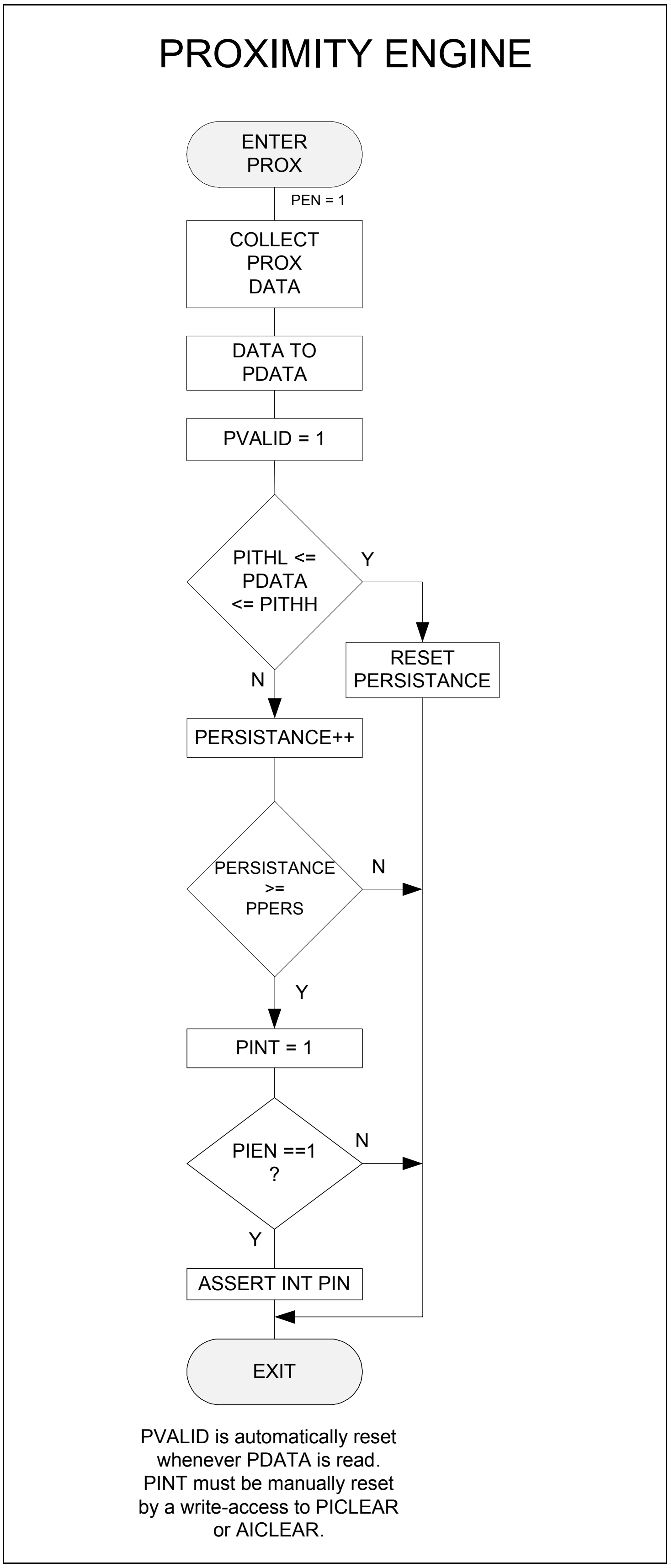
Figure 29:
Proximity Controls

Register/Bit	Address	Description
ENABLE<PON>	0x80<0>	Power ON
ENABLE<PEN>	0x80<2>	Proximity Enable
ENABLE<PIEN>	0x80<5>	Proximity Interrupt Enable
PITHL	0x89	Proximity low threshold
PITHH	0x8B	Proximity high threshold
PERS<PPERS>	0x8C<7:4>	Proximity Interrupt Persistence
PPULSE<PPLEN>	0x8E<7:6>	Proximity Pulse Length
PPULSE<PPULSE>	0x8E<5:0>	Proximity Pulse Count
CONTROL<PGAIN>	0x8F<3:2>	Proximity Gain Control
CONTROL<LDRIVE>	0x8F<7:6>	LED Drive Strength
CONFIG2<PSIEN>	0x90<7>	Proximity Saturation Interrupt Enable
CONFIG2<LEDBOOST>	0x90<5:4>	LED Boost
STATUS<PGSAT>	0x93<6>	Proximity Saturation
STATUS<PINT>	0x93<5>	Proximity Interrupt
STATUS<PVALID>	0x93<1>	Proximity Valid
PDATA	0x9C	Proximity Data
POFFSET_NE	0x9D	Proximity Offset North/East
POFFSET_SW	0x9E	Proximity Offset South/West
CONFIG3<PCMP>	0x9F<5>	Proximity Gain Compensation Enable
CONFIG3<PMSK_N>	0x9F<3>	Proximity Mask North Enable
CONFIG3<PMSK_S>	0x9F<2>	Proximity Mask South Enable
CONFIG3<PMSK_W>	0x9F<1>	Proximity Mask West Enable
CONFIG3<PMSK_E>	0x9F<0>	Proximity Mask East Enable
PICLEAR	0xE5	Proximity Interrupt Clear
AICLEAR	0xE7	All Non-Gesture Interrupt Clear

Note(s):

1. ENABLE<PBEN> must be low for proximity or gesture operation.

Figure 30:
Detailed Proximity Diagram



Proximity results are affected by three fundamental factors: IR LED emission, IR reception, and environmental factors, including target distance and surface reflectivity.

The IR reception signal path begins with IR detection from four [directional gesture] photodiodes and ends with the 8-bit proximity result in PDATA register. Signal from the photodiodes is combined, amplified, and offset adjusted to optimize performance. The same four photodiodes are used for gesture operation as well as proximity operation. Diodes are paired to form two signal paths: North/East and South/West. Regardless of pairing, any of the photodiodes can be masked to exclude its contribution to the proximity result. Masking one of the paired diodes effectively reduces the signal by half and causes the full-scale result to be reduced from 255 to 127. To correct this reduction in full-scale, the proximity gain compensation bit, PCMP, can be set, returning F.S. to 255. Gain is adjustable from 1x to 8x using the PGAIN control bits. Offset correction or cross-talk compensation is accomplished by adjustment to the POFFSET_NE and POFSET_SW registers. The analog circuitry of the device applies the offset value as a *subtraction* to the signal accumulation; therefore a positive offset value has the effect of decreasing the results.

Optically, the IR emission appears as a pulse train. The number of pulses is set by the PPULSE bits and the period of each pulse is adjustable using the PPLEN bits. The intensity of the IR emission is selectable using the LDRIVE control bits. These bits correspond to four factory calibrated current levels. If a higher intensity is required (E.g. longer detection distance or device placement beneath dark glass) then the LEDBOOST bits can be used to increase LDR current 150%, 200%, or 300% of LDRIVE setting.

LED duty cycle and subsequent power consumption of the integrated IR LED can be calculated using the following table shown in Figure 31, and equations. If proximity events are separated by a wait time, as set by AWAIT and WLONG, then the total LED OFF time must be increased by the wait time.

Figure 31:
Approximate Proximity Timing

PPLEN	t_{INIT} (µs)	$t_{LED\ ON}$ (µs)	t_{ACC} (µs)	t_{CNVT} (µs)
4 µs	40.8	5.4	28.6	796.6
8 µs	44.9	9.5	36.73	796.6
16 µs	53.0	17.7	53.1	796.6
32 µs	69.4	34.0	85.7	796.6