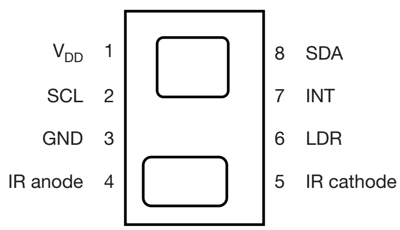
Fully Integrated Proximity and Ambient Light Sensor With Infrared Emitter, I²C Interface, and Interrupt Function (with multiple slave addresses)



LINKS TO ADDITIONAL RESOURCES

3D Models Design Tools Related Documents

DESCRIPTION

VCNL4030X01 integrates a proximity sensor (PS), ambient light sensor (ALS), and a high power IRED into one small package. It incorporates photodiodes, amplifiers, and analog to digital converting circuits into a single chip by CMOS process. The 16-bit high resolution ALS for excellent sensing capabilities with sufficient selections to fulfill most applications whether dark or high transparency lens design. Both ALS and PS offer a programmable interrupt with individual high and low thresholds offers the power savings on the microcontroller.

The proximity sensor features an intelligent cancellation scheme, so that cross talk is eliminated effectively. The proximity's smart persistence feature prevents the misjudgment of proximity sensing with a fast response time. Active force mode, one time trigger by one instruction, offers more design flexibility to fulfill different kinds of applications with more power savings.

The adoption of patented Filtron™ technology achieves the closest ambient light spectral sensitivity to real human eye responses and offers the best background light cancellation capability (including sunlight) without utilizing the microcontrollers' resources. VCNL4030X01 provides an excellent temperature compensation capability for keeping the output stable over temperature. ALS and PS functions are easily operated via the simple command format of I²C (SMBus compatible) interface protocol. Operating voltage ranges from 2.5 V to 3.6 V. VCNL4030X01 is packaged in a lead-free 8-pin QFN package, which offers the best market-proven reliability quality.

FEATURES

- Package type: surface-mount
- Dimensions (L x W x H in mm): 4.0 x 2.36 x 0.75
- AEC-Q101 qualified
- Integrated modules: infrared emitter (IRED), ambient light sensor (ALS), proximity sensor (PS), and signal conditioning IC
- Operates ALS and PS in parallel structure
- Filtron™ technology adoption for robust background light cancellation
- Low power consumption I²C (SMBus compatible) interface
- Orderable in four different slave addresses
- Output type: I²C bus (ALS / PS)
- Operation voltage: 2.5 V to 3.6 V
- Floor life: 168 h, MSL 3, according to J-STD-020
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

AUTOMOTIVE GRADE
Pb-free
e4
RoHS COMPLIANT
HALOGEN FREE
GREEN (5-2008)

PROXIMITY FUNCTION

- Immunity to red glow (940 nm IRED)
- Programmable IRED sink current
- Intelligent cancellation to reduce cross talk phenomenon
- Smart persistence scheme to reduce PS response time
- Selectable for 12- / 16-bit PS output data

AMBIENT LIGHT FUNCTION

- High accuracy of ALS ± 10 %
- Fluorescent light flicker immunity
- Spectrum close to real human eye responses

INTERRUPT

- Programmable interrupt function for ALS and PS with upper and lower thresholds
- Adjustable persistence to prevent false triggers for ALS and PS

APPLICATIONS

- Proximity sensor for
  - Mobile devices (e.g. smart phones, tablets) for touch screen locking, power saving etc.
  - Automotive for presence detection
- Integrated ambient light function for display / keypad contrast control and dimming of mobile devices
- Collision detection in robots and toys
- Proximity / optical switch for consumer, computing, automotive and industrial devices, and displays (like notebooks, tablet PCs, and automotive touch panels)
- Dimming control for consumer, computing, industrial, and automotive displays

PRODUCT SUMMARY								
PART NUMBER	OPERATING RANGE (mm)	OPERATING VOLTAGE RANGE (V)	I^2C BUS VOLTAGE RANGE (V)	IRED PULSE CURRENT (1) (mA)	AMBIENT LIGHT RANGE (lx)	AMBIENT LIGHT RESOLUTION (lx)	OUTPUT CODE	ADC RESOLUTION PROXIMITY / AMBIENT LIGHT
VCNL4030X01	0 to 300	2.5 to 3.6	1.8 to 5.5	200	0.004 to 16 768	0.004	16 bit, I^2C	16 bit / 16 bit

Note

(1) Adjustable through I^2C interface

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	VOLUME (1)	REMARKS
VCNL4030X01-GS08	Tape and reel	MOQ: 3300 pcs	4.0 mm x 2.36 mm x 0.75 mm
VCNL4030X01-GS18		MOQ: 13 000 pcs	
VCNL40301X01-GS08		MOQ: 3300 pcs	
VCNL40301X01-GS18		MOQ: 13 000 pcs	
VCNL40302X01-GS08		MOQ: 3300 pcs	
VCNL40302X01-GS18		MOQ: 13 000 pcs	
VCNL40303X01-GS08		MOQ: 3300 pcs	
VCNL40303X01-GS18		MOQ: 13 000 pcs	

Note

(1) MOQ: minimum order quantity

SLAVE ADDRESS OPTIONS	
ORDERING CODE	SLAVE ADDRESS (7 bit)
VCNL4030X01-GS08	0x60
VCNL4030X01-GS18	
VCNL40301X01-GS08	0x51
VCNL40301X01-GS18	
VCNL40302X01-GS08	0x40
VCNL40302X01-GS18	
VCNL40303X01-GS08	0x41
VCNL40303X01-GS18	

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)					
PARAMETER	TEST CONDITION	SYMBOL	MIN.	MAX.	UNIT
Supply voltage		V_{DD}	2.5	3.6	V
Operation temperature range		T_{amb}	-40	+105	°C
Storage temperature range		T_{stg}	-40	+110	°C

RECOMMENDED OPERATING CONDITIONS (T_{amb} = 25 °C, unless otherwise specified)					
PARAMETER	TEST CONDITION	SYMBOL	MIN.	MAX.	UNIT
Supply voltage		V_{DD}	2.5	3.6	V
Operation temperature range		T_{amb}	-40	+105	°C
I^2C bus operating frequency		$f_{(I2CCLK)}$	10	400	kHz

PIN DESCRIPTIONS			
PIN ASSIGNMENT	SYMBOL	TYPE	FUNCTION
1	V_{DD}	-	Power supply input
2	SCL	I	I^2C digital bus clock input
3	GND	-	Ground
4	IR ANODE	I	Anode for IRED
5	IR CATHODE	I	Cathode (IRED) connection
6	LDR	I	IRED driver input
7	INT	O	Interrupt pin
8	SDA	I / O (open drain)	I^2C data bus data input / output

BLOCK DIAGRAM

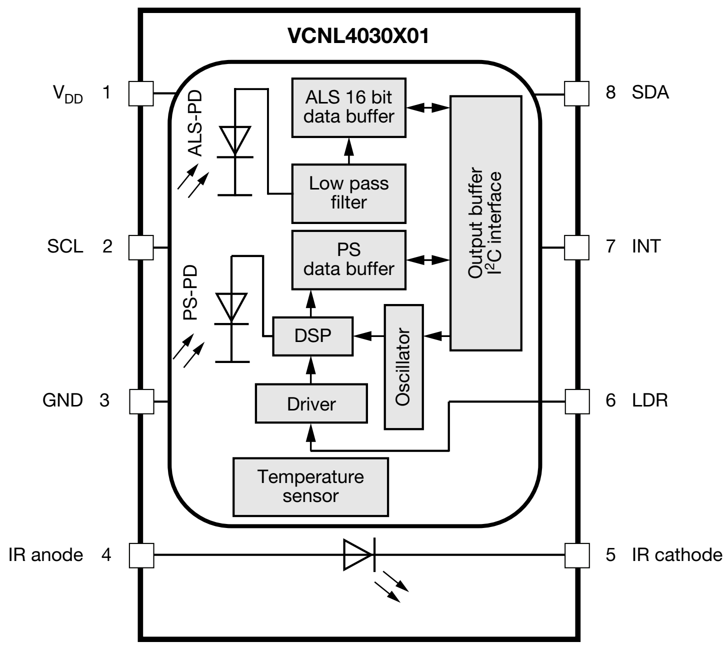


Fig. 1 - Detailed Block Diagram

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)							
PARAMETER		**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
Supply voltage			V_{DD}	2.5	-	3.6	V
Supply current		Excluded LED driving	I_{DD}	-	300	-	μA
		Light condition = dark, V_{DD} = 3.3 V	I_{DD} (SD)	-	0.2	-	μA
I^2C supply voltage			$V_{PULL\ UP}$	1.8	-	5.5	V
ALS shut down		ALS disable, PS enable	I_{ALSSD}	-	200	-	μA
PS shut down		ALS enable, PS disable	I_{PSSD}	-	260	-	μA
I^2C signal input	Logic high	V_{DD} = 3.3 V	V_{IH}	1.55	-	-	V
	Logic low		V_{IL}	-	-	0.4	
	Logic high	V_{DD} = 2.6 V	V_{IH}	1.4	-	-	V
	Logic low		V_{IL}	-	-	0.4	
Peak sensitivity wavelength of ALS			λ_p	-	550	-	nm
Peak sensitivity wavelength of PS			λ_p	-	850	-	nm
Full ALS counts		16-bit resolution		-	-	65 535	steps
Full PS counts		12-bit / 16-bit resolution		-	-	4096 / 65 535	steps
ALS sensing tolerance		White LED light source		-	-	± 10	%
Detectable intensity	Minimum	ALS_IT = 800 ms, 1 step (1)(2)		-	0.004	-	lx
	Maximum	ALS_IT = 50 ms, 65 535 step (1)(2)		-	16 768	-	
ALS dark offset		ALS_IT = 50 ms, normal sensitivity (1)		0	-	3	steps
PS detection range		Kodak gray card		0	-	300	mm
Operating temperature range			T_{amb}	-40	-	+105	°C
LED_Anode voltage				-	-	5.5	V
IRED driving current		(3)		-	200	-	mA

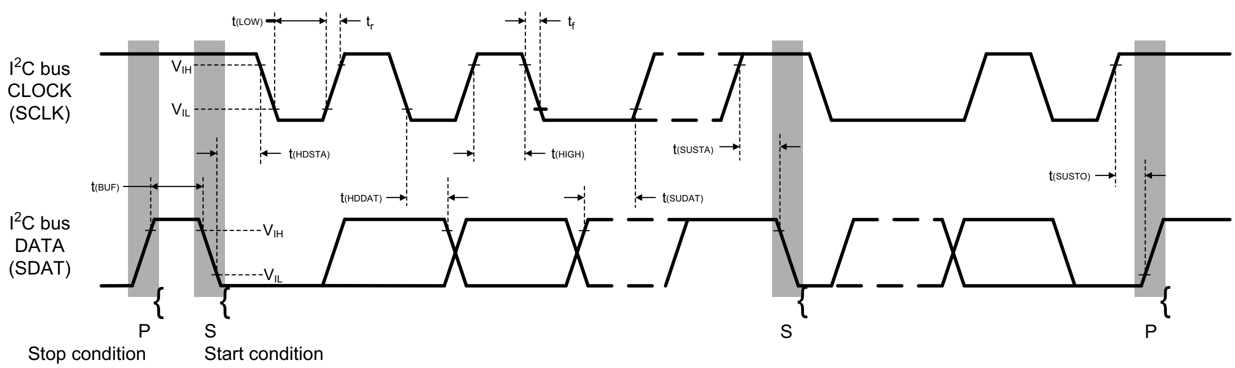
Notes

(1) Test condition: V_{DD} = 3.3 V, temperature: 25 °C

(2) Maximum detection range to ambient light can be determined by ALS refresh time adjustment and two sensitivity bits (ALS_HD and ALS_NS). Refer to table “ALS Resolution and Maximum Detection Range”

(3) Programmable between 50 mA and 200 mA; based on IRED on / off duty ratio = 1/40, 1/80, 1/160, and 1/320

I²C BUS TIMING CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	**SYMBOL**	**STANDARD MODE**		**FAST MODE**		**UNIT**
		MIN.	**MAX.**	**MIN.**	**MAX.**	
Clock frequency	$f_{(I2CCLK)}$	10	100	10	400	kHz
Bus free time between start and stop condition	$t_{(BUF)}$	4.7	-	1.3	-	μs
Hold time after (repeated) start condition; after this period, the first clock is generated	$t_{(HDSTA)}$	4.0	-	0.6	-	μs
Repeated start condition setup time	$t_{(SUSTA)}$	4.7	-	0.6	-	μs
Stop condition setup time	$t_{(SUSTO)}$	4.0	-	0.6	-	μs
Data hold time	$t_{(HDDAT)}$	-	3450	-	900	ns
Data setup time	$t_{(SUDAT)}$	250	-	100	-	ns
I²C clock (SCK) low period	$t_{(LOW)}$	4.7	-	1.3	-	μs
I²C clock (SCK) high period	$t_{(HIGH)}$	4.0	-	0.6	-	μs
Clock / data fall time	t_f	-	300	-	300	ns
Clock / data rise time	t_r	-	1000	-	300	ns



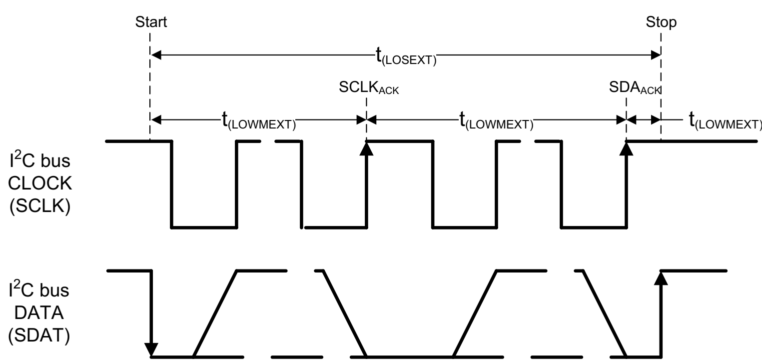


Fig. 2 - I²C Bus Timing Diagram

PARAMETER TIMING INFORMATION

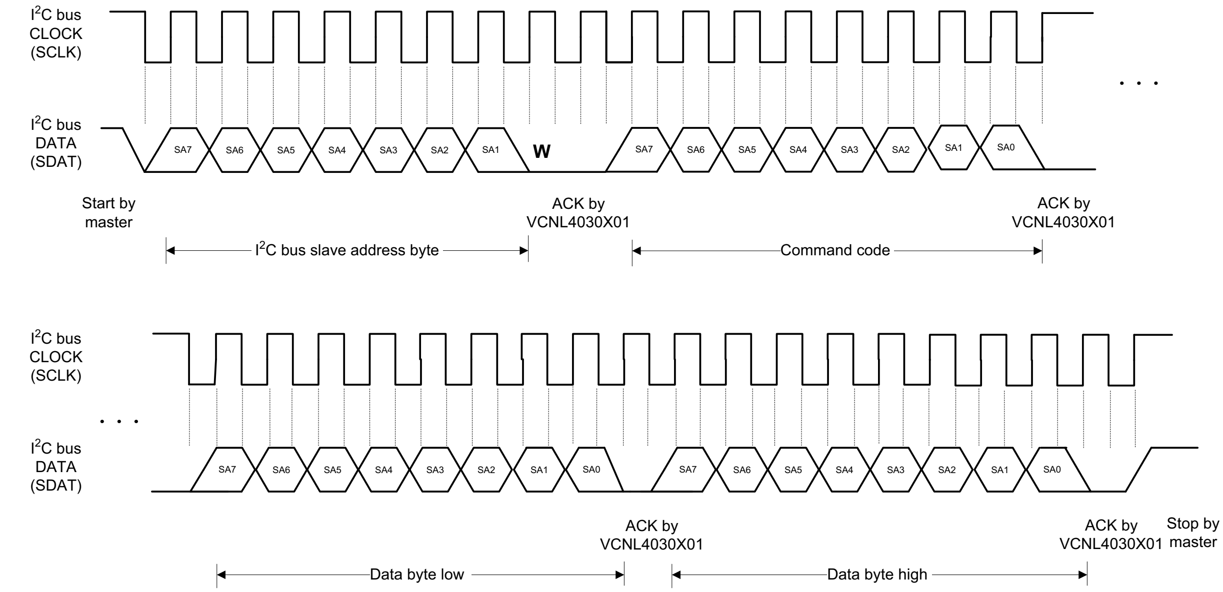


Fig. 3 - I^{2}C Bus Timing for Sending Word Command Format

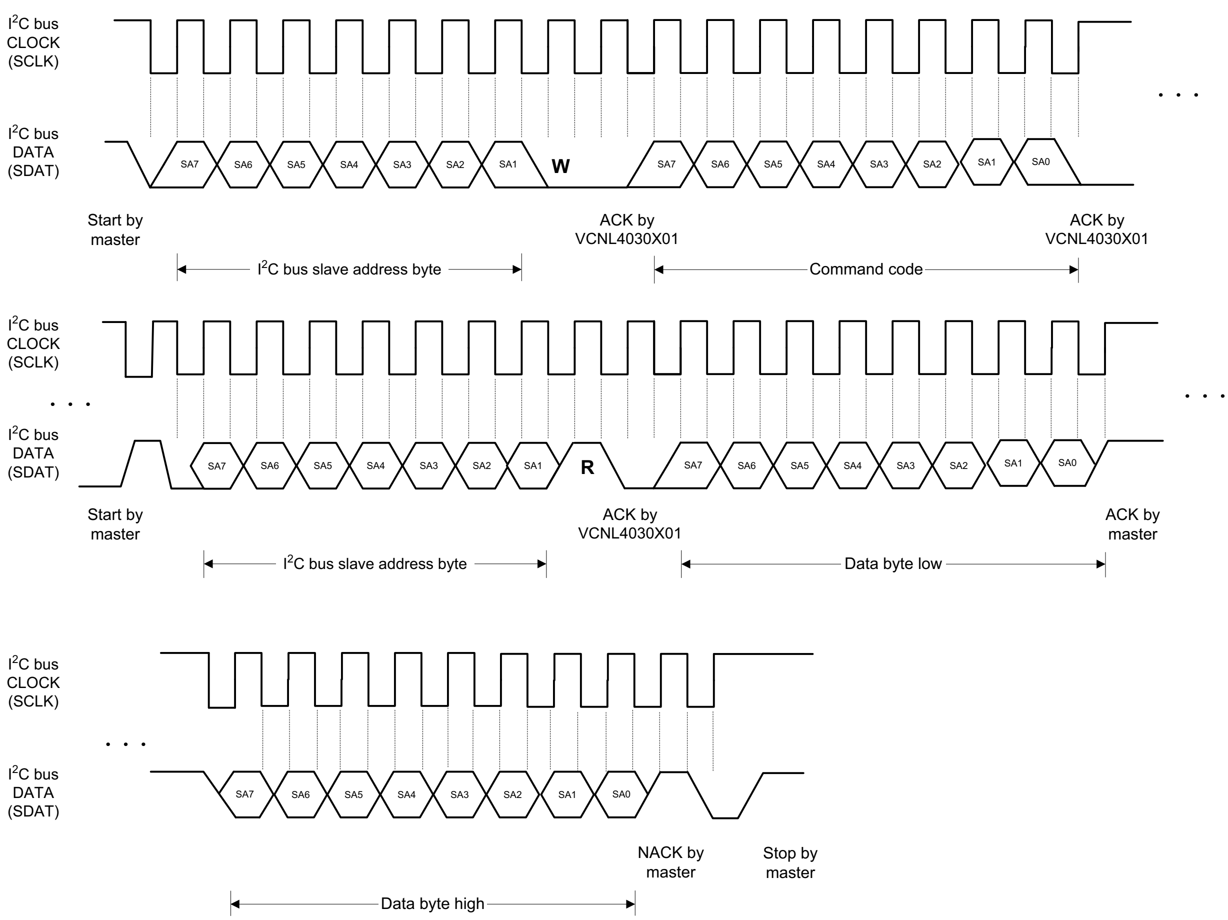


Fig. 4 - I^{2}C Bus Timing for Receiving Word Command Format

TYPICAL PERFORMANCE CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

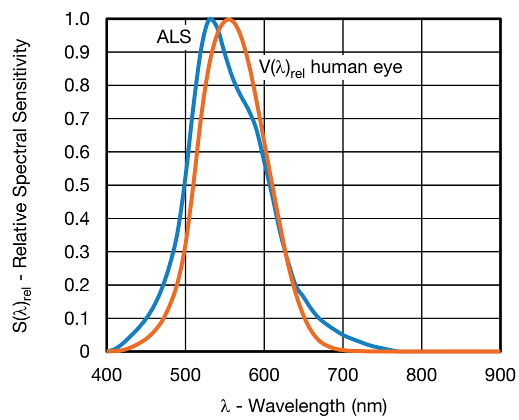


Fig. 5 - Normalized Spectral Response (ALS channel)

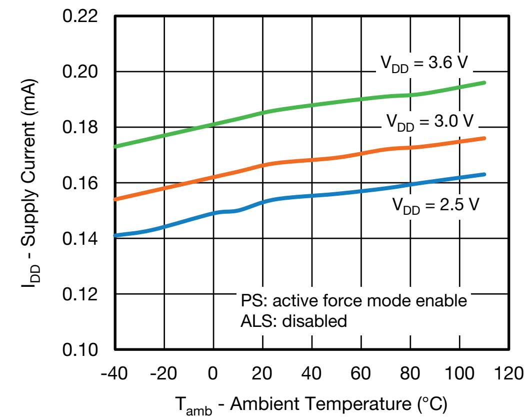


Fig. 8 - Supply Current vs. Ambient Temperature With Only PS = Active

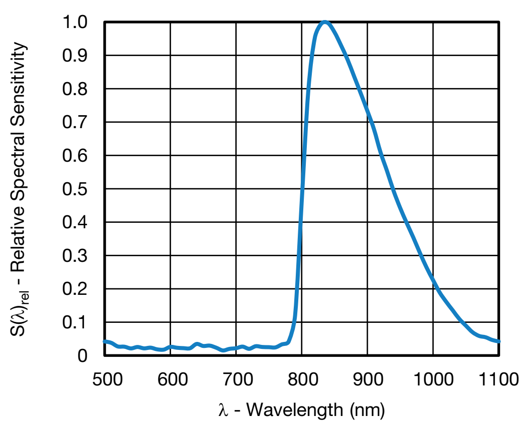


Fig. 6 - Normalized Spectral Response (PS channel)

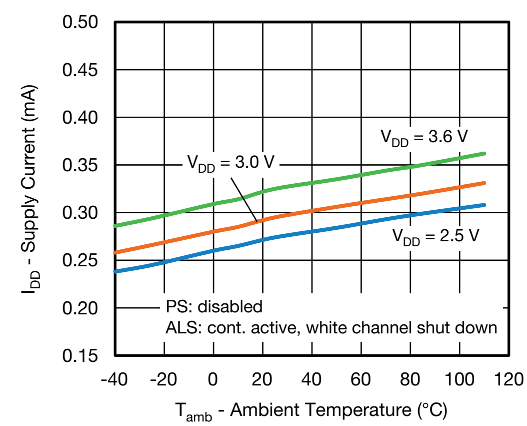


Fig. 9 - Supply Current vs. Ambient Temperature With Only ALS = Active

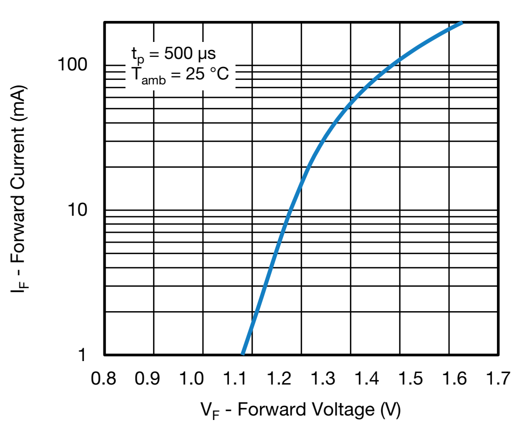


Fig. 7 - Forward Current $I_F = f(V_F)$ for LED

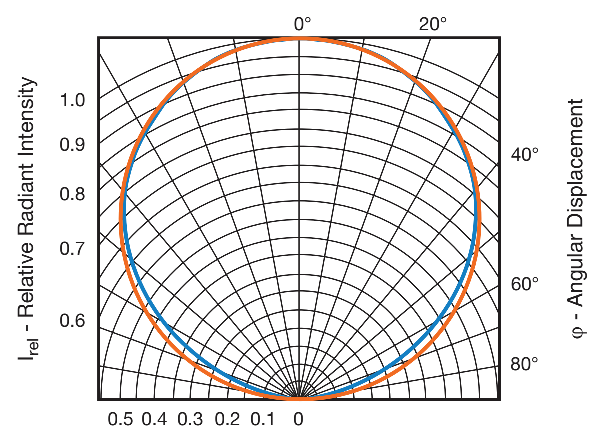


Fig. 10 - Relative Radiant Intensity Emitter vs. Angular Displacement

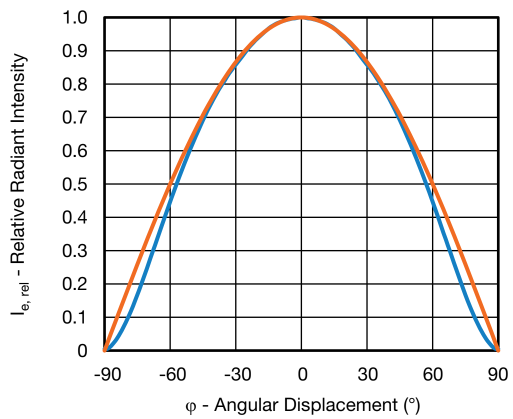


Fig. 11 - Relative Radiant Intensity Emitter vs. Angular Displacement

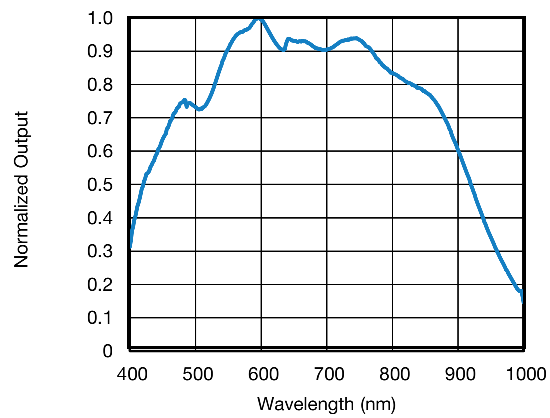


Fig. 14 - White Channel Spectral Response

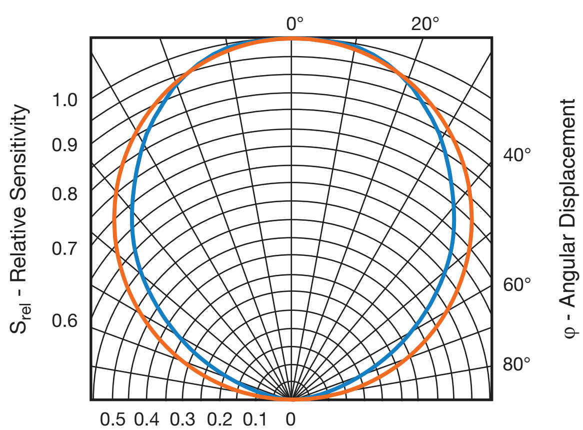


Fig. 12 - Relative Sensitivity vs. Angular Displacement (ALS)

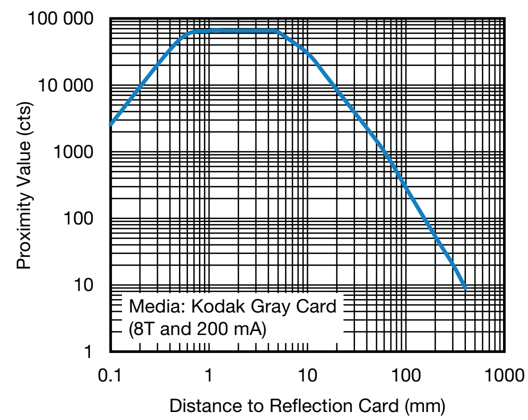


Fig. 15 - Proximity Value vs. Distance to Reflecting Card

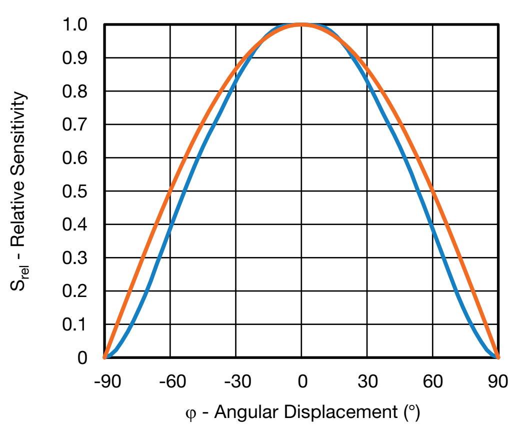


Fig. 13 - Relative Sensitivity vs. Angular Displacement

APPLICATION INFORMATION

Pin Connection with the Host

VCNL4030X01 integrates proximity sensor, ambient light Sensor, and IRED all together with I^2C interface. It is very easy for the baseband (CPU) to access PS and ALS output data via I^2C interface without extra software algorithms. The hardware schematic is shown in the following diagram.

Two additional capacitors in the circuit can be used for the following purposes: (1) the 0.1 μF capacitor near the V_{DD} pin is used for power supply noise rejection, (2) the 2.2 μF capacitor - connected to the anode - is used to prevent the IRED voltage from instantly dropping when the IRED is turned on, and (3) 2.2 kΩ is suitable for the pull up resistor of I^2C except for the 8.2 kΩ applied on the INT pin.

Note

- IR cathode and LDR: pins need to be connected together externally

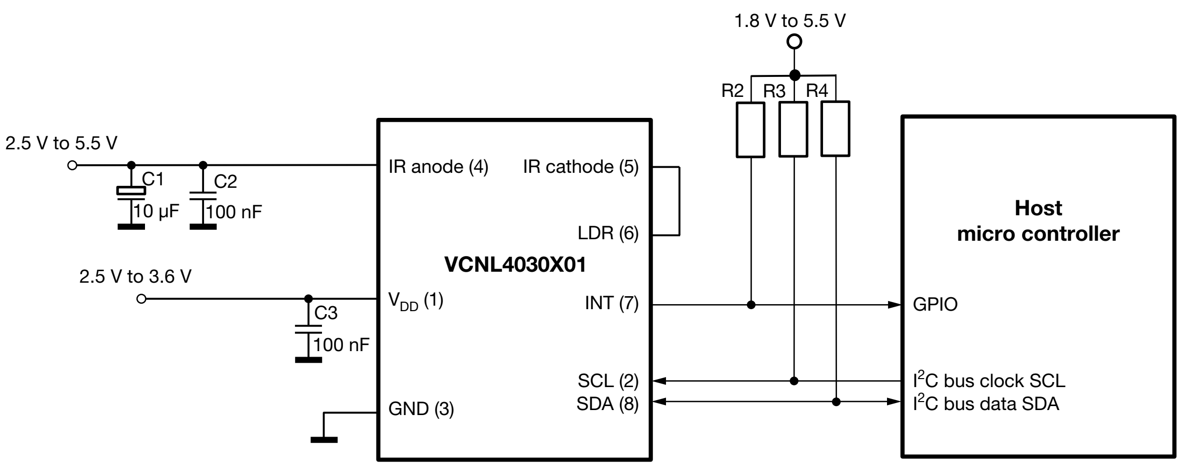


Fig. 16 - Circuitry with Two Separate Power Supply Sources

Digital Interface

VCNL4030X01 is available in four different salve addresses (0x60, 0x51, 0x40, and 0x41). Please refer to the table “Salve Address Options” at the beginning of the datasheet for an overview of the corresponding ordering codes. All operations can be controlled by the command register. The simple command structure helps users easily program the operation setting and latch the light data from VCNL4030X01. As Fig. 17 shows, VCNL4030X01’s I^2C command format is simple for read and write operations between VCNL4030X01 and the host. The white sections indicate host activity and the gray sections indicate VCNL4030X01’s acknowledgement of the host access activity. Write word and read word protocol is suitable for accessing registers particularly for 16-bit data ALS and 12-bit / 16-bit PS data. Interrupt can be cleared by reading data out from register: INT_Flag. All command codes should follow read word and write word protocols.

Send Byte → Write Command to VCNL4030X01

1	7	1	1	8	1	8	1	8	1	1
S	Slave Address	Wr	A	Command Code	A	Data Byte Low	A	Data Byte High	A	P

Receive Byte → Read Data from VCNL4030X01

1	7	1	1	8	1	1	7	1	1	8	1	8	1	1
S	Slave Address	Wr	A	Command Code	A	S	Slave Address	Rd	A	Data Byte Low	A	Data Byte High	N	P

S = start condition
P = stop condition
A = acknowledge
N = no acknowledge
Shaded area = VCNL4030X01 acknowledge

Fig. 17 - Write Word and Read Word Protocol

Function Description

VCNL4030X01 applies a 16-bit high resolution ALS that provides the best ambient light sensing capability down to 0.004 lux/step which works well under a low transmittance lens design (dark lens). A flexible interrupt function of ALS (register: ALS_CONF) is also supported. The INT signal will not be asserted by VCNL4030X01 if the ALS value is not over high INT threshold window level, or lower than low INT threshold window level of ALS. As long as the ALS INT is asserted, the host can read the data from VCNL4030X01. VCNL4030X01 detects different light sources such as fluorescent light, incandescent light, sunlight, and white LED with high accuracy ALS data output after detecting algorithm is implemented.

For proximity sensor function, VCNL4030X01 supports different kinds of mechanical designs to achieve the best proximity detection performance for any color of object with more flexibility. The basic PS function settings, such as duty ratio, integration time, interrupt, and PS enable / disable, and persistence, are handled by the register: PS_CONF1. Duty ratio controls the PS response time. Integration time represents the duration of the energy being received. The interrupt is asserted when the PS detection levels over the high threshold level setting (register: PS_THDH) or lower than low threshold (register: PS_THDL). If the interrupt function is enabled, the host reads the PS output data from VCNL4030X01 that saves host loading from periodically reading PS data. More than that, INT flag (register: INT_Flag) indicates the behavior of INT triggered under different conditions. PS persistence (PS_PERS) sets up the PS INT asserted conditions as long as the PS output value continually exceeds the threshold level. The intelligent cancellation level can be set on register: PS_CANC to reduce the cross talk phenomenon.

VCNL4030X01 also supports an easy use of proximity detection logic output mode that outputs just high / low levels saving loading from the host. Normal operation mode or proximity detection logic output mode can be selected on the register: PS_MS. A smart persistence is provided to get faster PS response time and prevent false trigger for PS. Descriptions of each slave address operation are shown in table 1

TABLE 1 - COMMAND CODE AND REGISTER DESCRIPTION					
COMMAND CODE	DATE BYTE LOW / HIGH	REGISTER NAME	R / W	DEFAULT VALUE	FUNCTION DESCRIPTION
0x00	L	ALS_CONF1	R / W	0x01	ALS integration time, ALS dynamic range, persistence, interrupt, and function enable / disable
	H	ALS_CONF2	R / W	0x01	ALS sensitivity, white channel enable / disable
0x01	L	ALS_THDH_L	R / W	0x00	ALS high interrupt threshold LSB byte
	H	ALS_THDH_M	R / W	0x00	ALS high interrupt threshold MSB byte
0x02	L	ALS_THDL_L	R / W	0x00	ALS low interrupt threshold LSB byte
	H	ALS_THDL_M	R / W	0x00	ALS low interrupt threshold MSB byte
0x03	L	PS_CONF1	R / W	0x01	PS duty ratio, integration time, persistence, and PS enable / disable
	H	PS_CONF2	R / W	0x00	PS gain, PS output resolution, PS interrupt trigger
0x04	L	PS_CONF3	R / W	0x00	PS smart persistence, active force mode
	H	PS_MS	R / W	0x00	LED current selection
0x05	L	PS_CANC_L	R / W	0x00	PS cancellation level setting
	H	PS_CANC_M	R / W	0x00	PS cancellation level setting
0x06	L	PS_THDL_L	R / W	0x00	PS low interrupt threshold setting LSB byte
	H	PS_THDL_M	R / W	0x00	PS low interrupt threshold setting MSB byte
0x07	L	PS_THDH_L	R / W	0x00	PS high interrupt threshold setting LSB byte
	H	PS_THDH_M	R / W	0x00	PS high interrupt threshold setting MSB byte
0x08	L	PS_Data_L	R	0x00	PS LSB output data
	H	PS_Data_M	R	0x00	PS MSB output data
0x09	L	Reserved	R	0x00	Reserved
	H	Reserved	R	0x00	Reserved
0x0A	L	Reserved	R	0x00	Reserved
	H	Reserved	R	0x00	Reserved
0x0B	L	ALS_Data_L	R	0x00	ALS LSB output data
	H	ALS_Data_M	R	0x00	ALS MSB output data
0x0C	L	White_Data_L	R	0x00	White LSB output data
	H	White_Data_M	R	0x00	White MSB output data
0x0D	L	Reserved	R	0x00	Reserved
	H	INT_Flag	R	0x00	ALS, PS interrupt flags, PS sunlight protection mode flag
0x0E	L	ID_L	R	0x80	Device ID LSB
	H	ID_M	R	0x00	For version with 0x60 as device address; 0x10 for version with 0x51, 0x20 for version with 0x40 and 0x30 for version with 0x41 as device address

Note

- All of reserved register are used for internal test. Please keep as default setting

Command Register Format

VCNL4030X01 provides an 8-bit command register for ALS and PS controlling independently. The description of each command format is shown in following tables.

TABLE 2 - REGISTER: ALS_CONF1 DESCRIPTION									
REGISTER NAME		COMMAND CODE: 0x00_L (0x00 DATA BYTE LOW)							
Command	Bit	7	6	5	4	3	2	1	0
		COMMAND CODE: 0x00_L (0x00 DATA BYTE LOW)							
Command	Bit	Description							
ALS_IT	7 : 5	(0 : 0 : 0) = 50 ms; (0 : 0 : 1) = 100 ms; (0 : 1 : 0) = 200 ms; (0 : 1 : 1) = 400 ms; (1 : 0 : 0) to (1 : 1 : 1) = 800 ms ALS integration time setting, longer integration time has higher sensitivity							
ALS_HD	4	0 = typical dynamic range x 1, 1 = typical dynamic range x 2							
ALS_PERS	3 : 2	(0 : 0) = 1, (0 : 1) = 2, (1 : 0) = 4, (1 : 1) = 8 ALS interrupt persistence setting							
ALS_INT_EN	1	0 = ALS interrupt disable, 1 = ALS interrupt enable							
ALS_SD	0	0 = ALS power on, 1 = ALS shut down, default = 1							

TABLE 3 - REGISTER: ALS_CONF2 DESCRIPTION		
		COMMAND CODE: 0x00_H (0x00 DATA BYTE HIGH)
Command	Bit	Description
Reserved	7 : 2	Default = (0 : 0 : 0 : 0 : 0 : 0)
ALS_NS	1	0 = typical sensitivity x 2, 1 = typical sensitivity x 1
WHITE_SD	0	0 = WHITE channel power on, 1 = WHITE channel shut down, default = 1

TABLE 4 - REGISTER ALS_THDH_L AND ALS_THDH_M DESCRIPTION		
		COMMAND CODE: 0x01_L (0x01 DATA BYTE LOW) OR 0x01_H (0x01 DATA BYTE HIGH)
Register	Bit	Description
ALS_THDH_L	7 : 0	0x00 to 0xFF, ALS high interrupt threshold LSB byte
ALS_THDH_M	7 : 0	0x00 to 0xFF, ALS high interrupt threshold MSB byte

TABLE 5 - REGISTER: ALS_THDL_L AND ALS_THDL_M DESCRIPTION		
		COMMAND CODE: 0x02_L (0x02 DATA BYTE LOW) AND 0x02_H (0x02 DATA BYTE HIGH)
Register	Bit	Description
ALS_THDL_L	7 : 0	0x00 to 0xFF, ALS low interrupt threshold LSB byte
ALS_THDL_M	7 : 0	0x00 to 0xFF, ALS low interrupt threshold MSB byte

TABLE 6 - REGISTER: PS_CONF1 DESCRIPTION		
REGISTER: PS_CONF1		**COMMAND CODE: 0x03_L (0x03 DATA BYTE LOW)**
Command	Bit	Description
PS_Duty	7 : 6	(0 : 0) = 1/40, (0 : 1) = 1/80, (1 : 0) = 1/160, (1 : 1) = 1/320 PS IRED on / off duty ratio setting
PS_PERS	5 : 4	(0 : 0) = 1, (0 : 1) = 2, (1 : 0) = 3, (1 : 1) = 4 PS interrupt persistence setting
PS_ IT	3 : 1	(0 : 0 : 0) = 1T, (0 : 0 : 1) = 1.5T, (0 : 1 : 0) = 2T, (0 : 1 : 1) = 2.5T, (1 : 0 : 0) = 3T, (1 : 0 : 1) = 3.5T, (1 : 1 : 0) = 4T, (1 : 1 : 1) = 8T, PS integration time setting
PS_SD	0	0 = PS power on, 1 = PS shut down, default = 1

TABLE 7 - REGISTER: PS_CONF2 DESCRIPTION		
REGISTER: PS_CONF2		**COMMAND CODE: 0x03_H (0x03 DATA BYTE HIGH)**
Command	Bit	Description
Reserved	7 : 6	(0 : 0), reserved
PS_Gain	5 : 4	(0 : 0) and (0 : 1) = two step mode, (1 : 0) = single mode x 8, (1 : 1) = single mode x 1
PS_HD	3	0 = PS output is 12 bits, 1 = PS output is 16 bits
PS_NS	2	0 = typical sensitivity (two step mode x 4), 1 = typical sensitivity mode (two step mode)
PS_INT	1 : 0	(0 : 0) = interrupt disable, (0 : 1) = trigger by closing, (1 : 0)= trigger by away, (1 : 1) = trigger by closing and away

TABLE 8 - REGISTER: PS_CONF3 DESCRIPTION		
REGISTER: PS_CONF3		**COMMAND CODE: 0x04_L (0x04 DATA BYTE LOW)**
Command	Bit	Description
LED_I_LOW	7	0 = disabled = normal current, 1 = enabled = 1/10 of normal current, with that the current is accordingly: 5 mA, 7.5 mA, 10 mA, 12 mA, 14 mA, 16 mA, 18 mA, 20 mA
Reserved	6 : 5	(0 : 0)
PS_SMART_PERS	4	0 = disable; 1 = enable PS smart persistence
PS_AF	3	0 = active force mode disable (normal mode), 1 = active force mode enable
PS_TRIG	2	0 = no PS active force mode trigger, 1 = trigger one time cycle VCNL4030X01 output one cycle data every time host writes in ‘1’ to sensor.The state returns to ‘0’ automatically.
PS_MS	1	0 = proximity normal operation with interrupt function, 1 = proximity detection logic output mode enable
PS_SC_EN	0	0 = turn off sunlight cancel; 1 = turn on sunlight cancel PS sunlight cancel function enable setting

TABLE 9 - REGISTER: PS_MS DESCRIPTION		
REGISTER: PS_MS		**COMMAND CODE: 0x04_H (0x04 DATA BYTE HIGH)**
Command	Bit	Description
Reserved	7	0
PS_SC_CUR	6 : 5	(0 : 0) = 1 x typical sunlight cancel current, (0 : 1) = 2 x typical sunlight cancel current, (1 : 0) = 4 x typical sunlight cancel current, (1 : 1) = 8 x typical sunlight cancel current
PS_SP	4	0 = typical sunlight capability, 1 = 1.5 x typical sunlight capability
PS_SPO	3	0 = output is 00h in sunlight protect mode, 1 = output is FFh in sunlight protect mode,
LED_I	2 : 0	(0 : 0 : 0) = 50 mA; (0 : 0 : 1) = 75 mA; (0 : 1 : 0) = 100 mA; (0 : 1 : 1) = 120 mA (1 : 0 : 0) = 140 mA; (1 : 0 : 1) = 160 mA; (1 : 1 : 0) = 180 mA; (1 : 1 : 1) = 200 mA LED current selection setting

TABLE 10 - REGISTER PS_CANC_L AND PS_CANC_M DESCRIPTION		
		COMMAND CODE: 0x05_L (0x05 DATA BYTE LOW) AND 0x05_H (0x05 DATA BYTE HIGH)
Register	Bit	Description
PS_CANC_L	7 : 0	0x00 to 0xFF, PS cancellation level setting_LSB byte
PS_CANC_M	7 : 0	0x00 to 0xFF, PS cancellation level setting_MSB byte

TABLE 11 - REGISTER: PS_THDL_L AND PS_THDL_M DESCRIPTION		
		COMMAND CODE: 0x06_L (0x06 DATA BYTE LOW) AND 0x06_H (0x06 DATA BYTE HIGH)
Register	Bit	Description
PS_THDL_L	7 : 0	0x00 to 0xFF, PS interrupt low threshold setting_LSB byte
PS_THDL_M	7 : 0	0x00 to 0xFF, PS interrupt low threshold setting_MSB byte

TABLE 12 - REGISTER: PS_THDH_L AND PS_THDH_M DESCRIPTION		
		COMMAND CODE: 0x07_L (0x07 DATA BYTE LOW) AND 0x07_H (0x07 DATA BYTE HIGH)
Register	Bit	Description
PS_THDH_L	7 : 0	0x00 to 0xFF, PS interrupt high threshold setting_LSB byte
PS_THDH_M	7 : 0	0x00 to 0xFF, PS interrupt high threshold setting_MSB byte

TABLE 13 - READ OUT REGISTER DESCRIPTION

Register	Command Code	Bit	Description
PS_Data_L	0x08_L (0x08 data byte low)	7 : 0	0x00 to 0xFF, PS1 LSB output data
PS_Data_M	0x08_H (0x08 data byte high)	7 : 0	0x00 to 0xFF, PS1 MSB output data
Reserved	0x09_L (0x09 data byte low)	7 : 0	Reserved
Reserved	0x09_H (0x09 data byte high)	7 : 0	Reserved
Reserved	0x0A_L (0x0A data byte low)	7 : 0	Reserved
Reserved	0x0A_H (0x0A data byte high)	7 : 0	Reserved
ALS_Data_L	0x0B_L (0x0B data byte low)	7 : 0	0x00 to 0xFF, ALS LSB output data
ALS_Data_M	0x0B_H (0x0B data byte high)	7 : 0	0x00 to 0xFF, ALS MSB output data
White_Data_L	0x0C_L (0x0C data byte low)	7 : 0	0x00 to 0xFF, white LSB output data
White_Data_M	0x0C_H (0x0C data byte high)	7 : 0	0x00 to 0xFF, white LSB output data
Reserved	0x0D_L (0x0D data byte low)	7 : 0	Default = 0x00
INT_Flag	0x0D_H (0x0D data byte high)	7 6 5 4 3 2 1 0	Reserved Reserved ALS_IF_L, ALS crossing low THD INT trigger event ALS_IF_H, ALS crossing high THD INT trigger event Reserved PS_SPFLAG, PS entering sunlight protection mode PS_IF_CLOSE, PS rises above PS_THDH INT trigger event PS_IF_AWAY, PS drops below PS_THDL INT trigger event
ID_L	0x0E_H (0x0E data byte low)	7 : 0	0x80
ID_M	0x0E_H (0x0E data byte high)	7 : 6 5 : 4 3 : 0	(0 : 0) (0:0) = slave address = 0x60 (7-bit) (0:1) = slave address = 0x51 (7-bit) (1:0) = slave address = 0x40 (7-bit) (1:1) = slave address = 0x41 (7-bit) Version code (0 : 0 : 0 : 0)

Adjustable Sampling Time

VCNL4030X01's embedded LED driver drives the internal IRED with the "LDR" pin by a pulsed duty cycle. The IRED on / off duty ratio is programmable by I^{2}C command at register: PS_Duty which is related to the current consumption and PS response time. The higher the duty ratio adopted, the faster response time achieved with higher power consumption. For example, PS_Duty = 1/320, peak IRED current = 100 mA, averaged current consumption is 100 mA/320 = 0.3125 mA.

Initialization

VCNL4030X01 includes default values for each register. As long as power is on, it is ready to be controlled by host via I^{2}C bus.

Threshold Window Setting

- ALS Threshold Window Setting (Applying ALS INT)

  Register: ALS_THDH_L and ALS_THDH_M defines 16-bit ALS high threshold data for LSB byte and MSB byte. Register: ALS_THDL_L and ALS_THDL_M defines 16-bit ALS low threshold data for LSB byte and MSB byte. As long as ALS INT function is enabled, INT will be asserted once the ALS data exceeds ALS_THDH or goes below ALS_THDL. To easily define the threshold range, multiply the value of the resolution (lux/step) by the threshold level (refer to table 14).

TABLE 14 - ALS RESOLUTION AND MAXIMUM DETECTION RANGE

ALS_IT		SENSITIVITY	MAXIMUM DETECTION RANGE
ALS_IT (7 : 5)	**INTEGRATION TIME (typ.)**	**UNIT (lx/step)**	**UNIT (lx)**
(0, 0, 0)	50 ms	0.064	4192
(0, 0, 1)	100 ms	0.032	2096
(0, 1, 0)	200 ms	0.016	1048
(0, 1, 1)	400 ms	0.008	524
(1, 0, 0) to (1, 1, 1)	800 ms	0.004	262

- ALS HD and ALS_NS

  These two options enhance the dynamic range by a factor of two each.
  With this the sensitivity shown within table 14 will be reduced by the factor 2, but the maximum possible detection range will be doubled for both options. With this the max. detection range goes up to 4192 lx x 2 x 2 = 16 768 lx

- ALS Persistence

  The ALS INT is asserted as long as the ALS value is higher or lower than the threshold window when ALS_PERS (1, 2, 4, 8 times) is set to one time. If ALS_PERS is set to four times, then the ALS INT will not be asserted if the ALS value is not over (or lower) than the threshold window for four continued refresh times (integration time)

- Programmable PS Threshold

  VCNL4030X01 provides both high and low thresholds for PS (register: PS_THDL, PS_THDH)

- PS Persistence

  The PS persistence function (PS_PERS, 1, 2, 3, 4) helps to avoid false trigger of the PS INT. For example, if PS_PERS = 3 times, the PS INT will not be asserted unless the PS value is greater than the PS threshold (PS_THDH) value for three periods of time continuously

- PS Active Force mode

  An extreme power saving way to use PS is to apply PS active force (register: PS_CONF3 command: PS_FOR = 1) mode. Anytime host would like to read out just one of PS data, write in '1' at register: PS_CONF3 command: PS_FOR_Trig. Without commands placed, there is no PS data output. VCNL4030X01 stays in standby mode constantly

- PS detection object

  Any color of object is detectable by VCNL4030X01

Data Access

All of VCNL4030X01 command registers are readable. To access 16-bit high resolution ALS output data, it is suitable to use read word protocol to read out data by just one command at register: ALS_DataL and ALS_DataM. To represent the 16-bit data of ALS, it has to apply two bytes. One byte is for LSB, and the other byte is for MSB as shown in table 18. In terms of reading out 8-bit PS data, it is also very convenient to read PS at register: PS_Data.

TABLE 15 - 16-BIT ALS DATA FORMAT

	VCNL4030X01															
Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Register	ALS_DataM								ALS_DataL							

Intelligent Cancellation

VCNL4030X01 provides an intelligent cancellation method to reduce cross talk phenomenon for the proximity sensor. The output data will be subtracted by the input value on register: PS_CANC.

Interruption (INT)

VCNL4030X01 has ALS and PS interrupt feature operated by a single pin "INT". The purpose of the interrupt feature is to actively inform the host once INT has been asserted. With the interrupt function applied, the host does not need to be constantly pulling data from the sensor, but to read data from the sensor while receiving interrupt request from the sensor. As long as the host enables ALS interrupt (register: ALS_INT_EN) or PS interrupt (register: PS_INT) function, the level of INT pin (pin 7) is pulled low once INT asserted. All registers are accessible even if INT is asserted.

ALS INT asserted when ALS value cross over the value set by register: ALS_THDH or lower than the value set by register: ALS_THDL. To effectively adopt PS INT function, it is recommended to use PS detection mechanism at register: PS_INTT = 1 for the best PS detection performance which can be adjusted by high / low THD level of PS. PS INT trigger way is defined by register: PS_INT.

Interruption Flag

Register: INT_Flag represents all of interrupt trigger status for ALS and PS. Any flag value changes from '0' to '1' state, the level of INT pin will be pulled low. As long as host reads INT_Flag data, the bit will change from '1' state to '0' state after reading out, the INT level will be returned to high afterwards.

PROXIMITY DETECTION LOGIC OUTPUT MODE

VCNL4030X01 provides a proximity detection logic output mode that uses INT pin (pin 7) as a proximity detection logic high / low output (register: PS_MS). When this mode is selected, the PS output (pin 7; INT/P_{out}) is pulled low when an object is closing to be detected and returned to level high when the object moves away. Register: PS_THDH / PS_THDL defines how sensitive PS detection is.

One thing to be stated is that whenever proximity detection logic mode applied, INT pin is only used as a logic high / low output. If host would like to use ALS with INT function, register: PS_MS has to be selected to normal operation mode (PS_MS = 0). Meanwhile, host has to simulate the GPIO pin as an INT pin function. If not, host needs to periodically reading the state of INT at this GPIO pin.

PROXIMITY DETECTION HYSTERESIS

A PS detection hysteresis is important that keeps PS state in a certain range of detection distance. For example, PS INT asserts when PS value over PS_THDH. Host switches off panel backlight and then clears INT. When PS value is less than PS_THDL, host switches on panel backlight. Any PS value lower than PS_THDH or higher than PS_THDL, PS INT will not be asserted. Host does keep the same state.

APPLICATION CIRCUIT BLOCK REFERENCE

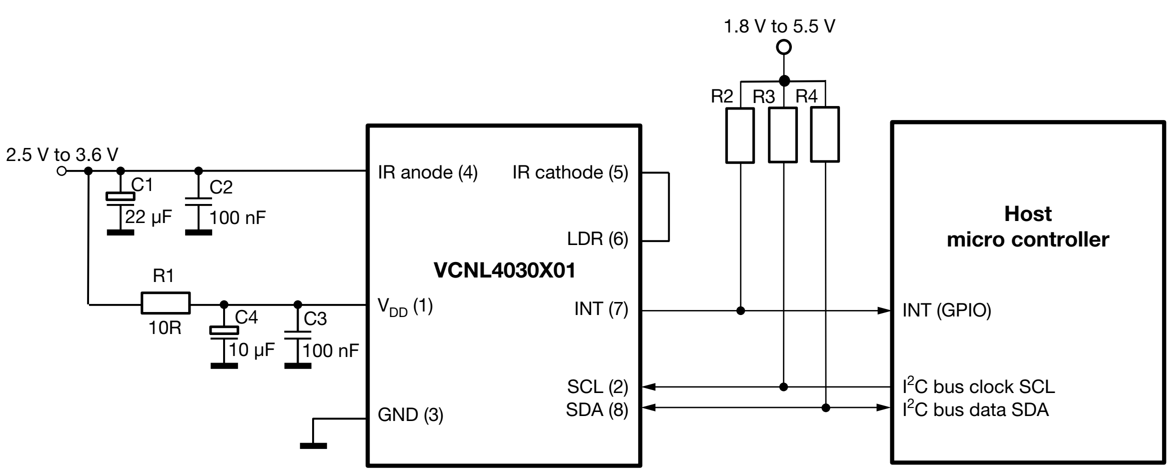
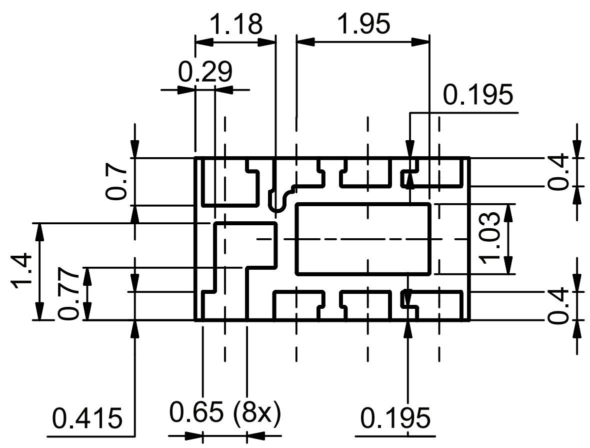
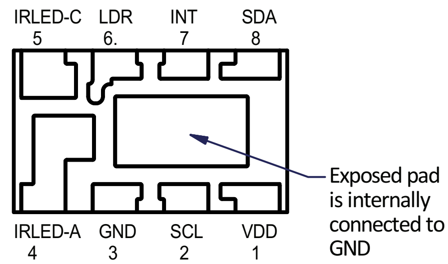


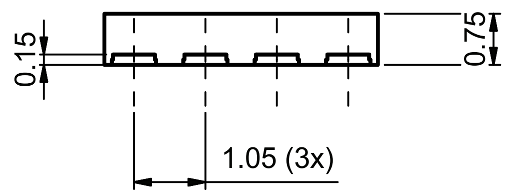
Fig. 18 - Circuitry with Just One Common Power Supply Source

PACKAGE DIMENSIONS in millimeters

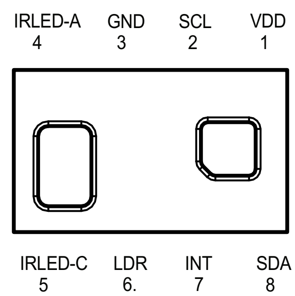


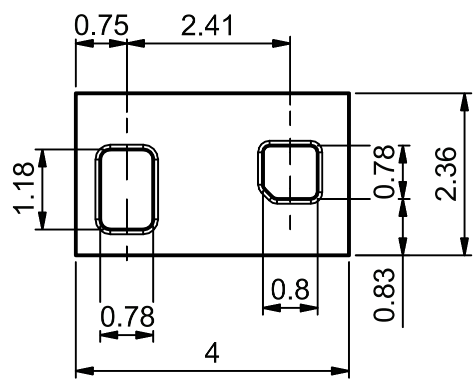
Pinning Bottom View



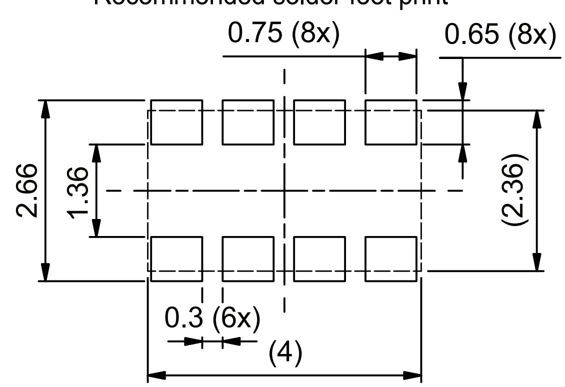


Pinning Top View



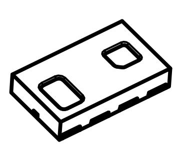


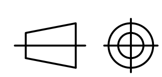
Recommended solder foot print



Drawing No.: 6.550-5326.01-4
Issue: 1, 21.07.2017

Not indicated tolerances ± 0.1 mm



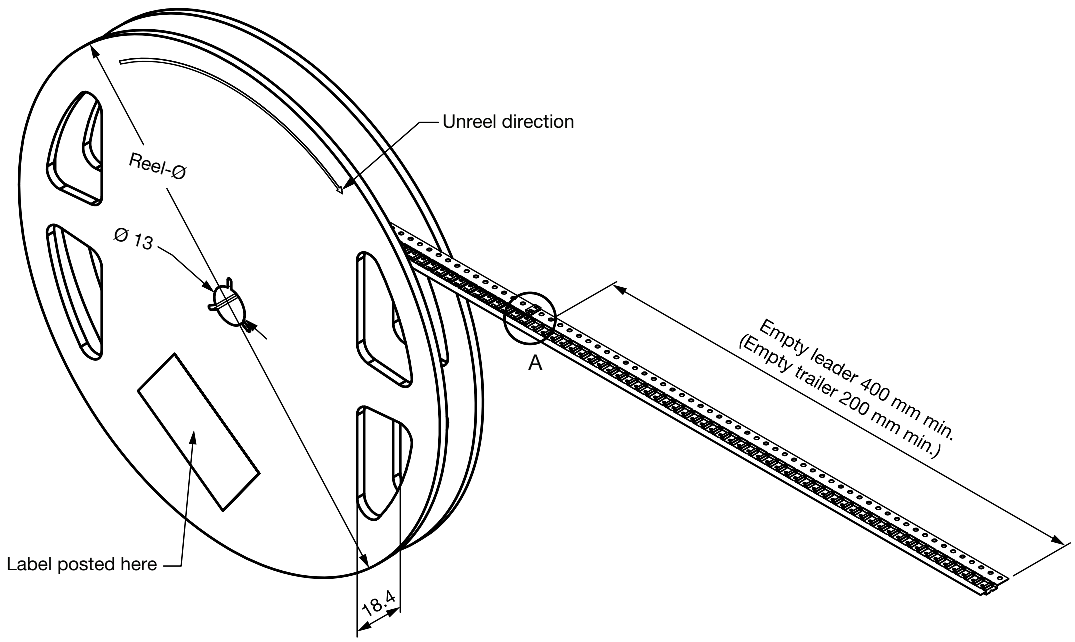


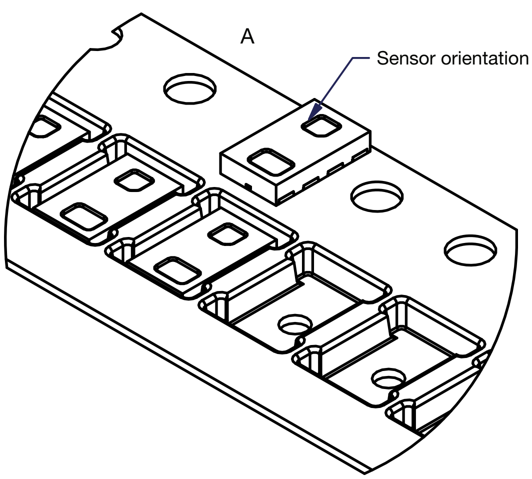
Technical drawings according to DIN specification.

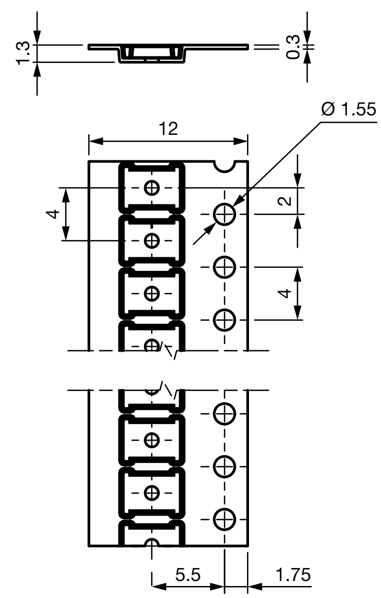
TAPE AND REEL DIMENSIONS in millimeters

Reel-Size:
GS 08: Ø 180 mm ± 2 mm = 3300 pcs.
GS 18: Ø 330 mm ± 2 mm = 13 000 pcs.
Reel-design is representative for different types

Non tolerated dimensions ± 0.1 mm







Drawing No.: 9.8000-5142.01-4
Issue: 1, 07.06.2017

SOLDER PROFILE

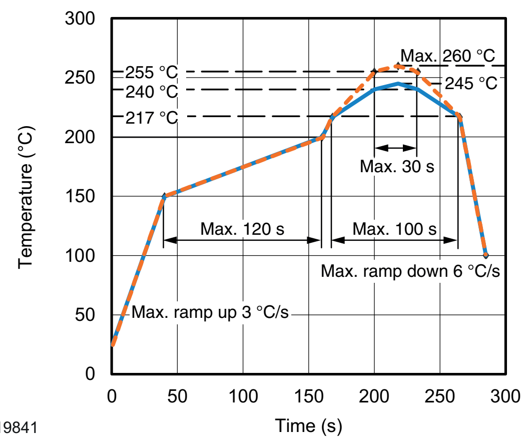


Fig. 19 - Lead (Pb)-free Reflow Solder Profile According to J-STD-020

DRYPACK

Devices are packed in moisture barrier bags (MBB) to prevent the products from moisture absorption during transportation and storage. Each bag contains a desiccant.

FLOOR LIFE

Floor life (time between soldering and removing from MBB) must not exceed the time indicated on MBB label:

Floor life: 168 h

Conditions: $T_{amb} < 30$ °C, RH < 60 %

Moisture sensitivity level 3, according to J-STD-020.

DRYING

In case of moisture absorption devices should be baked before soldering. Conditions see J-STD-020 or label. Devices taped on reel dry using recommended conditions 192 h at 40 °C (+ 5 °C), RH < 5 %.

Disclaimer

ALL PRODUCT, PRODUCT SPECIFICATIONS AND DATA ARE SUBJECT TO CHANGE WITHOUT NOTICE TO IMPROVE RELIABILITY, FUNCTION OR DESIGN OR OTHERWISE.

Vishay Intertechnology, Inc., its affiliates, agents, and employees, and all persons acting on its or their behalf (collectively, “Vishay”), disclaim any and all liability for any errors, inaccuracies or incompleteness contained in any datasheet or in any other disclosure relating to any product.

Vishay makes no warranty, representation or guarantee regarding the suitability of the products for any particular purpose or the continuing production of any product. To the maximum extent permitted by applicable law, Vishay disclaims (i) any and all liability arising out of the application or use of any product, (ii) any and all liability, including without limitation special, consequential or incidental damages, and (iii) any and all implied warranties, including warranties of fitness for particular purpose, non-infringement and merchantability.

Statements regarding the suitability of products for certain types of applications are based on Vishay's knowledge of typical requirements that are often placed on Vishay products in generic applications. Such statements are not binding statements about the suitability of products for a particular application. It is the customer's responsibility to validate that a particular product with the properties described in the product specification is suitable for use in a particular application. Parameters provided in datasheets and / or specifications may vary in different applications and performance may vary over time. All operating parameters, including typical parameters, must be validated for each customer application by the customer's technical experts. Product specifications do not expand or otherwise modify Vishay's terms and conditions of purchase, including but not limited to the warranty expressed therein.

Hyperlinks included in this datasheet may direct users to third-party websites. These links are provided as a convenience and for informational purposes only. Inclusion of these hyperlinks does not constitute an endorsement or an approval by Vishay of any of the products, services or opinions of the corporation, organization or individual associated with the third-party website. Vishay disclaims any and all liability and bears no responsibility for the accuracy, legality or content of the third-party website or for that of subsequent links.

Except as expressly indicated in writing, Vishay products are not designed for use in medical, life-saving, or life-sustaining applications or for any other application in which the failure of the Vishay product could result in personal injury or death. Customers using or selling Vishay products not expressly indicated for use in such applications do so at their own risk. Please contact authorized Vishay personnel to obtain written terms and conditions regarding products designed for such applications.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted by this document or by any conduct of Vishay. Product names and markings noted herein may be trademarks of their respective owners.

Designing the VCNL4030X01 Into an Application

By Reinhard Schaar

INTRODUCTION AND BASIC OPERATION

The VCNL4030X01 is a fully integrated proximity and ambient light sensor. It combines an infrared emitter, a photodiode for proximity measurement, an ambient light sensor, and signal processing IC in a single package with two 16-bit ADCs. The device provides ambient light sensing to support conventional backlight and display brightness auto-adjustment, and proximity sensing to minimize accidental touch inputs that can lead to call drops and camera launch.

With a range of up to 30 cm (12"), this component greatly simplifies the use and design-in of a proximity sensor in consumer and industrial applications. The VCNL4030X01 features a miniature, surface-mount 4.0 mm by 2.36 mm leadless package (LLP) with a low profile of 0.75 mm. The device is designed specifically to meet the low height requirements of smartphone, mobile phone, digital camera, and tablet PC applications.

Through its standard I^2C bus serial digital interface, it allows easy access to “proximity signal” and “light intensity” measurements. The programmable interrupt function offers wake-up functionality for the microcontroller when a proximity event or ambient light change occurs, which reduces processing overhead by eliminating the need for continuous polling.

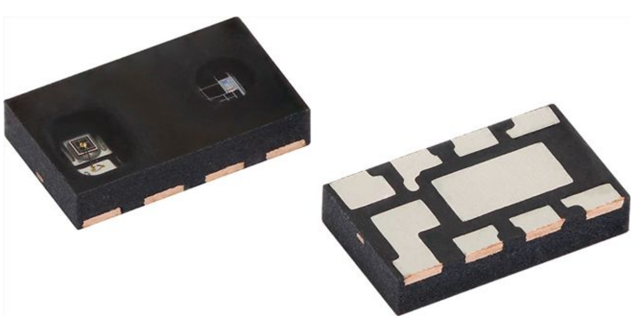


Fig. 1 - VCNL4030X01

COMPONENTS (BLOCK DIAGRAM)

The major components of the VCNL4030X01 are shown in the block diagram.

In addition to the ASIC with the ambient light and proximity photodiode, a powerful emitter is also implemented.

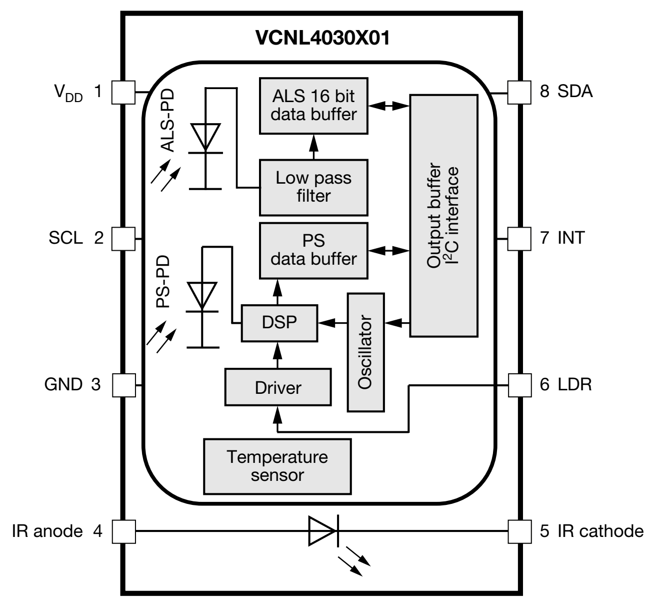


Fig. 2 - VCNL4030X01 Detailed Block Diagram

The internal infrared emitter comes with a peak wavelength of 940 nm to be totally in the “invisible” region but also good enough within the sensitivity of the proximity photodiode.

The ASIC has a programmable drive current from 50 mA to 200 mA in eight steps. The infrared light is emitted in short pulses with a programmable duty ratio from 1/40 to 1/320. The proximity photodiode receives the light that is reflected off the object and converts it to a current. It has a peak sensitivity of 850 nm. The sensitivity of the proximity stage is also programmable by choosing from eight different integration times. It is insensitive to ambient light. It ignores the DC component of light and compensates even for strong sunlight.

Designing the VCNL4030X01 Into an Application

The ambient light sensor receives the visible light and converts it to a current. The human eye can see light with wavelengths from 380 nm to 780 nm, with a peak of 555 nm. Vishay's ambient light sensor closely matches this range of sensitivity. It has peak sensitivity at 540 nm and a bandwidth from 430 nm to 610 nm.

The application-specific integrated circuit, or ASIC, includes an LED driver, I^2C bus interface, amplifier, integrated analog-to-digital converter, oscillator, and Vishay's "secret sauce" signal processor. For proximity, it converts the current from the photodiode to a 12-bit or 16-bit digital data output value. For ambient light sensing, it converts the current from the ambient light detector, amplifies it, and converts it to a 16-bit digital output stream.

PIN CONNECTIONS

Fig. 3 shows the pin assignments of the VCNL4030X01.

The connections include:

- Pin 1 - V_{DD} to the power supply
- Pin 2 - SCL to the microcontroller
- Pin 3 - connects to ground
- Pin 4 - IRED anode (to the power supply)
- Pin 5 - IRED cathode (to driver pin 6)
- Pin 6 - LDR (to IRED cathode)
- Pin 7 - INT to the microcontroller
- Pin 8 - SDA to the microcontroller

The power supply for the ASIC (V_{DD}) has a defined range from 2.5 V to 3.6 V. The anode of the infrared emitter can also be within this range. It is best if V_{DD} is connected to a regulated power supply and the anode of the IRED is connected directly to the battery. This eliminates any influence of the high infrared emitter current pulses on the V_{DD} supply line.

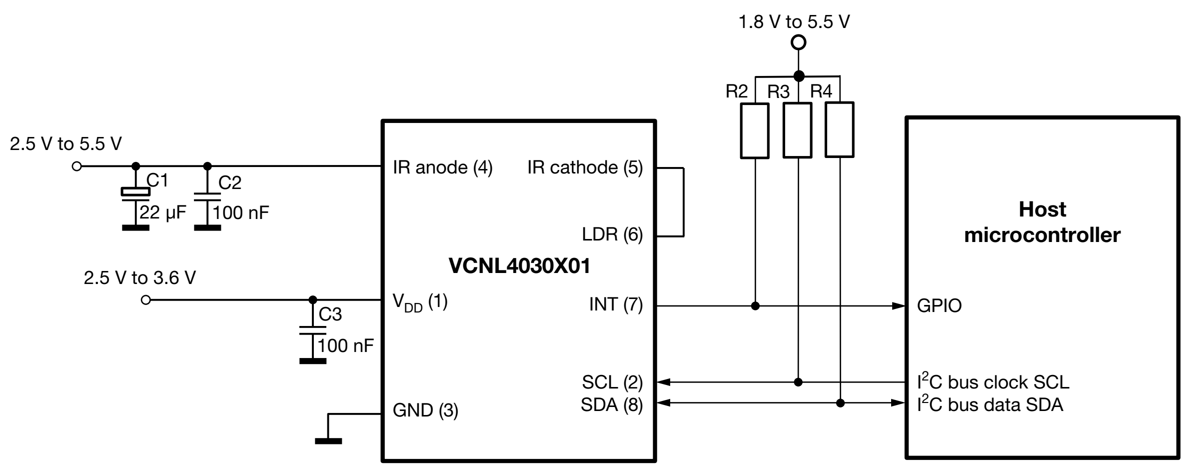


Fig. 3 - Circuitry With Two Separate Power Supply Sources

Three additional capacitors in the circuit are proposed for the following purposes: (1) the 100 nF capacitor near the V_{DD} pin is used for power supply noise rejection, (2) the 22 µF plus parallel 100 nF capacitors - connected to the anode of the IRED - are used to prevent the IRED voltage from instantly dropping when the IRED is switched on, and (3) 2.2 kΩ to 4.7 kΩ are recommended values for the pull-up resistor of the I^2C. The value of the pull-up resistor at the INT line could be 10 kΩ.

Designing the VCNL4030X01 Into an Application

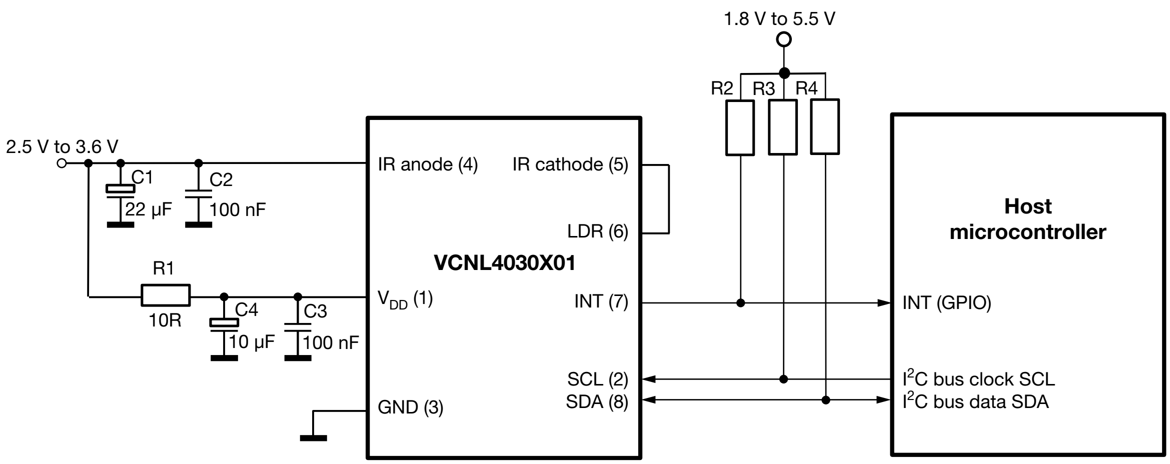


Fig. 4 - Circuitry With Just One Common Power Supply Source

For high currents of the IRED and / or power supply close to the lower limit of 2.5 V, this R-C decoupling will prevent the V_{DD} voltage drop below a specified minimum.

MECHANICAL DESIGN CONSIDERATIONS

The VCNL4030X01 comes with a very sensitive detector with high gain factors that requires a mechanical barrier to avoid direct crosstalk between emitter and detector. Placement below the application specific cover, possible close-by walls or other components will lead to crosstalk and with this to so-called offset counts. These total offset counts are fixed and can even be subtracted directly on-chip using the so-called “cancellation” register. Here the overall measured counts can be written in and are set to zero.

The only dimensions that the design engineer needs to consider are the distance from the top surface of the sensor to the outside surface of the window, and the size of the window. These dimensions will determine the size of the detection zone.

The relative radiant intensity of the emitter and the sensitivity of the photodiodes show an angle of half sensitivity of about ± 55°.

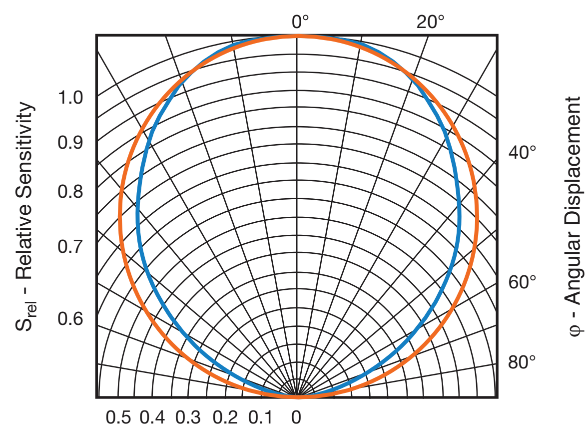


Fig. 5 - Relative Sensitivity vs. Angular Displacement (proximity sensor)

Designing the VCNL4030X01 Into an Application

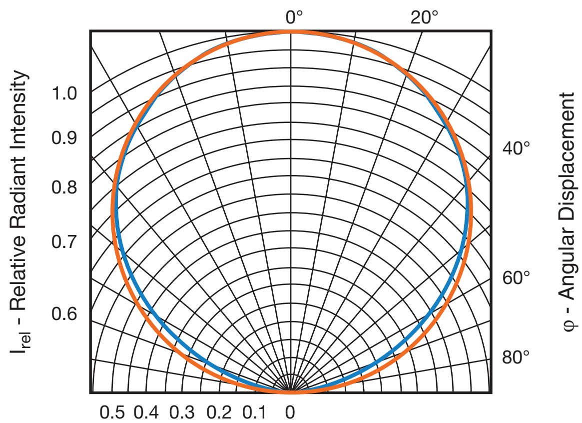


Fig. 6 - Relative Radiant Intensity vs. Angular Displacement

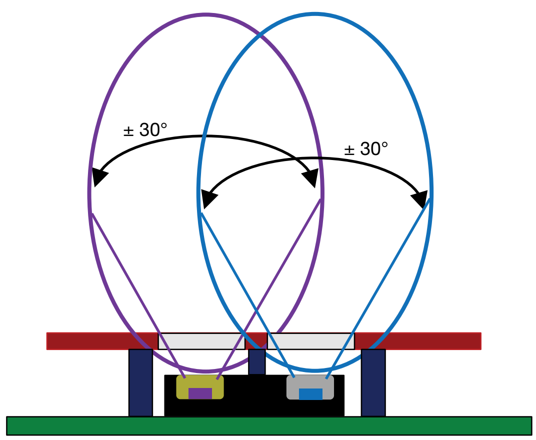


Fig. 7 - Proposal Angle of Relative Radiant Intensity and Sensitivity

To achieve a good ambient light response, the diameter of the hole within the cover glass should not be too small. An angle of ± 30° to ± 40° will be sufficient in most applications. The package drawing shows the position of the photosensitive area. The 30° lines should be set at the sides of the opening. The following are dimensions for the distance from the top surface of the sensor to the outside surface of the glass (a) and the width of the window (d).

The best solution would be to use two single round holes, where the diameter should be at least wide enough so that the openings can freely look through; so, about 1.1 mm if the cover is directly on top of the sensor. For any gap between sensor and cover an additional light barrier could be needed.

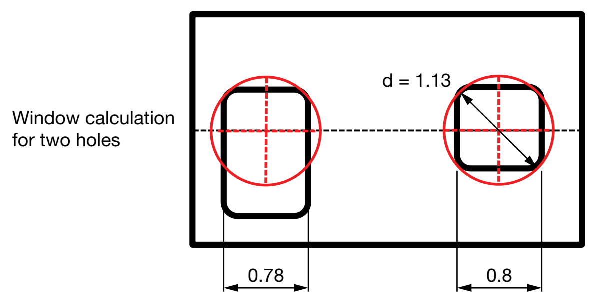


Fig. 8 - Light Hole Diameter (in millimeters)

The diameter needs to be increased with the distances between the sensor and cover glass according to the following calculation.

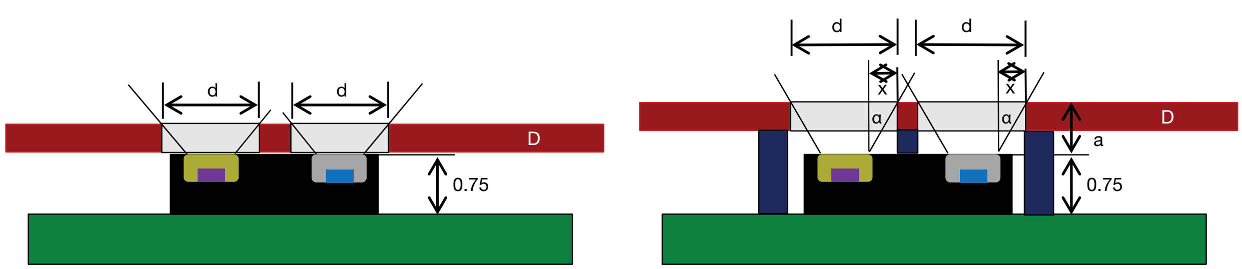


Fig. 9 - Window Dimensions (in millimeters)

The width calculation for distances from 0 mm to 1.0 mm results in:

a = 0.0 mm→ x = 0.00 mm→ d = 1.1 mm + 0.00 mm= 1.10 mm
a = 0.5 mm→ x = 0.29 mm→ d = 1.1 mm + 0.58 mm= 1.68 mm
a = 1.0 mm→ x = 0.58 mm→ d = 1.1 mm + 1.16 mm= 2.26 mm

Designing the VCNL4030X01 Into an Application

PROXIMITY SENSOR

The main DC light sources found in the environment are sunlight and tungsten (incandescent) bulbs. These kinds of disturbance sources will cause a DC current in the detector inside the sensor, which in turn will produce noise in the receiver circuit. The negative influence of this DC light can be reduced by optical filtering, but is reduced much more efficiently by a so-called DC kill function. The proximity photodiode shows its best sensitivity at about 850 nm, as shown in Fig. 11.

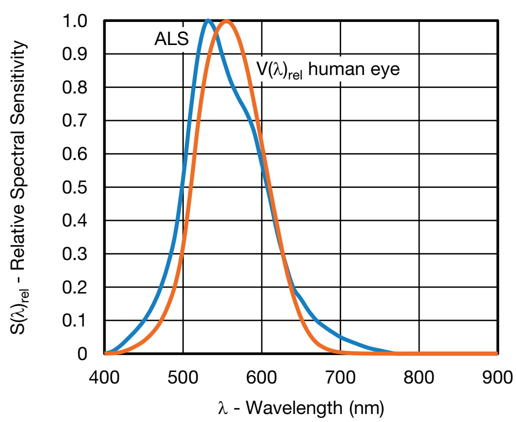


Fig. 10 - Normalized Spectral Response (ALS channel)

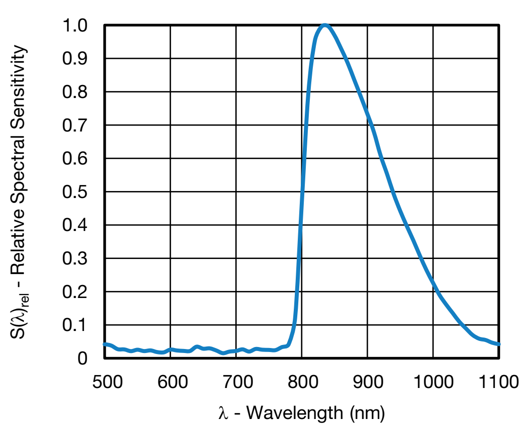


Fig. 11 - Normalized Spectral Response (PS channel)

The proximity sensor uses a short pulse signal of about 50 μs (PS_IT = 1T) up to 400 μs (PS_IT = 8T). The IRED on / off duty ratio setting now defines which repetition rate to be used, which can be programmed from 1/40 up to 1/320.

In addition to DC light source noise, there is some reflection of the infrared emitted light off the surfaces of the components surrounding the VCNL4030X01. The distance to the cover, proximity of surrounding components, tolerances of the sensor, defined infrared emitter current, ambient temperature, and type of window material used all contribute to this reflection. The result of the reflection and DC noise is the production of an output current on the proximity and light sensing photodiode. This current is converted into a count called the offset count.

In addition to the offset count, there could also be a small noise floor during the proximity measurement, which comes from the DC light suppression circuitry. This noise is typically just one or two counts. Only with light sources with strong infrared content could it be in the range from ± 5 counts to ± 10 counts.

The application should "ignore" this offset and small noise floor by subtracting them from the total proximity readings. The VCNL4030X01 offers a subtraction feature that automatically does this: PS_CANC. During the development of the end product, this offset count is evaluated and may now be written into register 5: PS_CANC_L/M. Now the proximity output data will just show the subtraction result of proximity counts - offset counts.

The results most often do not need to be averaged. If an object with very low reflectivity or at longer range needs to be detected, the sensor provides a register where the customer can define the number of consecutive measurements that the signal must exceed before producing an interrupt. This provides stable results without requiring averaging.

Designing the VCNL4030X01 Into an Application

PROXIMITY CURRENT CONSUMPTION

Both the ambient light sensor (ALS) and the proximity sensor (PS) within the VCNL4030X01 offer a separate shutdown mode. Default values after start-up have them both disabled. The application may activate just the one wanted or both.

The VCNL4030X01's embedded LED driver drives the IRED with a pulsed duty cycle. The IRED on / off duty ratio is programmable by an I²C command at register PS_Duty. Depending on this pulse / pause ratio, the overall proximity current consumption can be calculated. When higher measurement speed or faster response time is needed, PS_Duty may be selected to a maximum value of 1/40, which means one measurement will be made every 2 ms, but this will then also lead to the highest current consumption:

PS_Duty = 1/40: peak IRED current = 100 mA,
averaged current consumption is 100 mA/40 = 2.5 mA.

For proximity measurements executed just every 40 ms:
PS_Duty = 1/320 peak IRED current = 100 mA,
averaged current consumption is 100 mA/320 = 0.3125 mA.

The above is always valid for the normal pulse width of T = 1T = 50 µs, as well as for 2T, 4T, 8T, and all others in between. These pulse lengths are always doubled, resulting in 400 µs for 8T, but the repetition time is also doubled, ending in a period time of about 128 ms.

An extremely power-efficient way to execute proximity measurements is to apply a PS active force mode (register: PS_CONF3, command: PS_AF = 1).

If only a single proximity measurement needs to be done, PS_AF is set to "1" and then PS_SD = 0 = active. Setting PS_Trig = 1 will then execute just one single measurement.

In this mode, only the I²C interface is active. In most consumer electronic applications the sensor will spend the majority of time in sleep mode; it only needs to be woken up for a proximity or light measurement. In standby mode the power consumption is about 0.2 µA.

The pulse for proximity measurement looks to have a higher landing / step. This second trap is for smooth switch-off of the LED and is executed with very low IRED current. The pulse length in total is 200 µs. Amplitude of that first half is dependent on the IRED current. The higher this current is programmed, the higher that pulse amplitude will be. Taking a scope picture at IR_Cathode (pin 5) will look like shown with Fig. 12 and Fig. 13. IRED ON-time depending on programmed proximity integration time followed by a short switch-off time of about 5 µs.

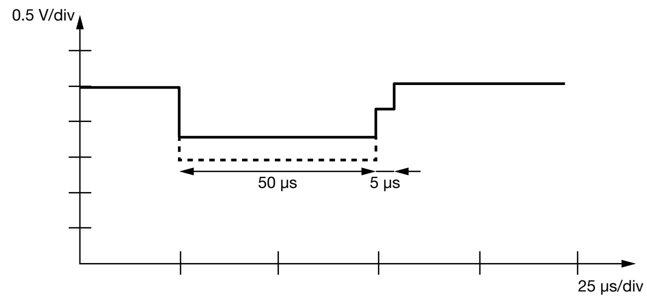


Fig. 12 - Proximity IRED Pulse for 1T

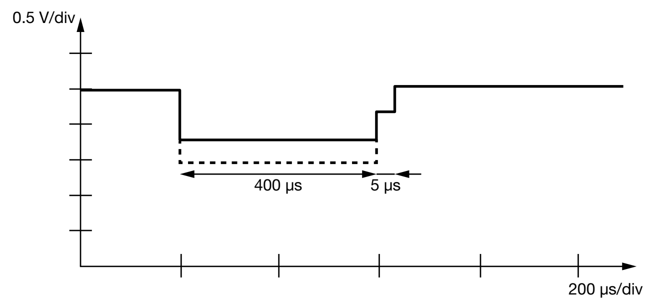


Fig. 13 - Proximity IRED Pulse for 8T

INITIALIZATION AND I²C TIMINGS

The VCNL4030X01 contains fifteen 16-bit command codes for operation control, parameter setup, and result buffering. All registers are accessible via I²C communication. The built-in I²C interface is compatible with the standard and high-speed I²C modes. The I²C H-level voltage range is from 1.7 V to 5.5 V.

There are only five registers out of the fifteen that typically need to be defined:

1. LED_I = 50 mA to 200 mA (IRED current)
   REGISTER PS_MS #04 [0x04h]
2. PS_Duty = 1/40 to 1/320 (proximity duty ratio),
   PS_IT (proximity integration time = pulse length),
   PS_PERS (number of consecutive measurements above / below threshold), and PS_SD (PS power_on)
   REGISTER PS_CONF1 #03 [0x03h]
3. ALS_IT (ALS_integration time)
   ALS_PERS (number of consecutive measurements above / below threshold), and
   ALS_SD (ALS power_on)
   REGISTER ALS_CONF #00 [0x00h]
4. and 5. Definition of the threshold value from the number of counts the detection of an object should be signaled.
   Proximity TOP Threshold REGISTER
   PS_THDL_L #06 [0x06h] for the low byte and
   PS_THDL_H #07 [0x07h] for the high byte

Designing the VCNL4030X01 Into an Application

To define the infrared emitter current, as well as the integration time (length of the proximity pulsing), evaluation tests should be performed using the least reflective material at the maximum distance specified.

Fig. 14 shows the typical digital counts output versus distance that are seen when operated with max. IRED current of 200 mA and highest proximity integration time of 400 µs. Here the so-called “two step” mode is used, and with PS_NS = 0 a four times higher gain is programmed for Fig.15 just the IRED current is reduced to avoid saturation for closer distances. The reflective reference medium is the Kodak Gray card. This card shows approximately 18 % reflectivity at 940 nm.

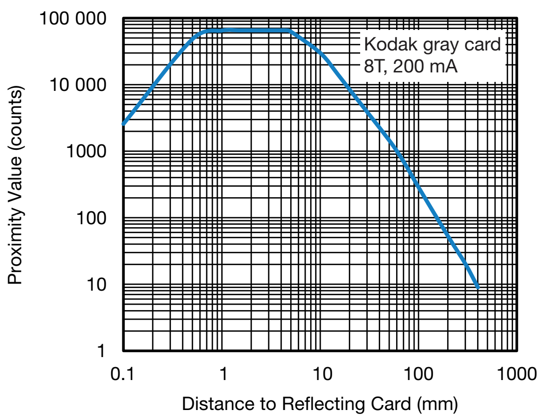


Fig. 14 - Proximity Value vs. Distance for 8T and 200 mA

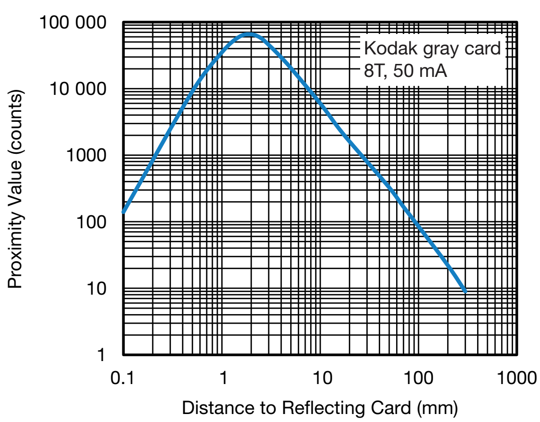


Fig. 15 - Proximity Value vs. Distance for 8T and 50 mA

This diagram shows the possible detection counts with a short pulse of 400 µs and so-called “two step” mode. Another mode is the “single mode”. For single mode the conversion speed (travel voltage) is also possible to multiply x 8; this leads to about 8 times lower counts, but the noise figure is slightly better.

To eliminate disturbance by direct sunlight this “sunlight cancellation” the bit PS_SC_EN has to be set. In addition, the compensation current can be modified with PS_SC-CUR in four possible steps from “typical” up to eight times this typical current. The bit PS_SP, also enhances the sunlight cancellation capability by 50 %, typically. The bit PS_SPO defines the counts that should be presented if too strong sun light causes protection, either zero counts or max. counts, 65 535 in 16-bit mode.

In order to reach the high reflection counts of the Kodak Gray card, one has to define the proximity range to 16 bit, otherwise the 12-bit range would just lead to 4095 counts. This is possible to select with: PS_HD = 1 within PS_CONF2 byte of command code #3.

With defining the duty time (PS_Duty), the repetition rate = the number of proximity measurements per second (speed of proximity measurements) is defined. This is possible between 2 ms (about 500 measurements/s) by programming PS_Duty with 1/40 and 16 ms (about 62 measurements/s) with programming PS_Duty with 1/320.

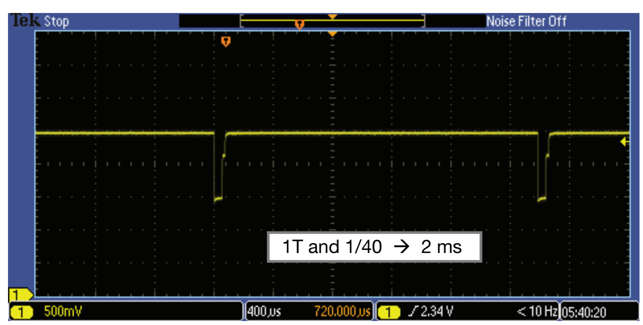


Fig. 16 - Proximity Measurements With PS_Duty = 1/40

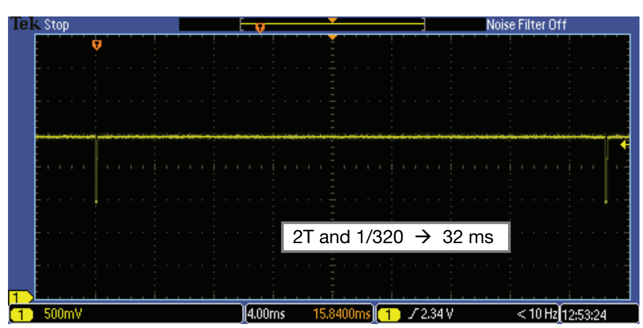


Fig. 17 - Proximity Measurements With PS_Duty = 1/320

Designing the VCNL4030X01 Into an Application

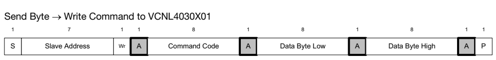
This duty cycle also determines how fast the application reacts when an object appears in, or is removed from, the proximity zone.

Reaction time is also determined by the number of counts that must be exceeded before an interrupt is set. This is possible to define with proximity persist: PS_PERS. Possible values are from 1 to 4.

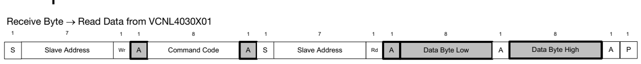
To define all these register values, an evaluation test should be performed. The SensorXplorer™ allows you to perform evaluation tests and properly set the registers for your application. The kit as well as the VCNL4030X01 sensor board is available from any of Vishay's distributors; availability and price please check here: www.vishay.com/optoelectronics/SensorXplorer.

Timing

For an I^{2}C bus operating at 100 kHz, to write or read an 8-bit byte, plus start (or stop) and bit acknowledgement, takes 100 µs. Together with the slave address byte and the 8-bit command code byte, plus the 16-bit data, this results in a total of 400 µs. When the device is powered on, the initialization with just these five registers needs 5 x 4 bytes (slave address, command register, and 16-bit data) for a total of 20 bytes. So, 20 x 100 µs = 2000 µs = 2 ms.



The read-out of 16-bit data would take a total of five bytes (slave address, command code, slave address with read bit set) and 16-bit data sent from the VCNL4030X01. So, 500 µs:



Power Up

The release of the internal reset, the start of the oscillator, and the signal processor need **2.5 ms**

Initialize Registers

Write to four registers **1600 µs**

- IRED current
- Proximity duty ratio
- ALS integration time
- Proximity interrupt TOP threshold

Once the device is powered on and the VCNL4030X01 is initialized, a proximity measurement can be taken.

Asking for one forced proximity measurement	**400 µs**
For (active forced, PS_IT = 8T)	
Time to trigger [0.5 x PS_IT]	**200 µs**
DC-kill ambient light [3 x PS_IT]	**1200 µs**
Proximity measurement [1 x PS_IT]	**400 µs**
IRED shutdown [1 x PS_IT]	**400 µs**
Read out of the proximity data	**500 µs**
total:	**3100 µs**

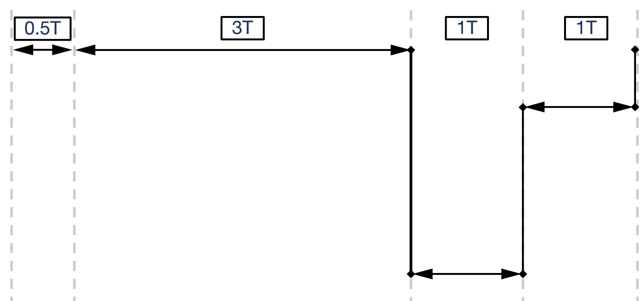


Fig. 18 - Timing Specification for Active Forced Mode

Designing the VCNL4030X01 Into an Application

AMBIENT LIGHT SENSING

Ambient light sensors are used to detect light or brightness in a manner similar to the human eye. They allow settings to be adjusted automatically in response to changing ambient light conditions. By turning on, turning off, or adjusting features, ambient light sensors can conserve battery power or provide extra safety by eliminating the need for manual adjustments.

Illuminance is the measure of the intensity of a light incident on a surface and can be correlated to the brightness perceived by the human eye. In the visible range, it is measured in units called “lux.” Light sources with the same lux measurement appear to be equally bright. In Fig. 22, the incandescent light and sunlight have been scaled to have the same lux measurement.

In the infrared region, the intensity of the incandescent light is significantly higher. A standard silicon photodiode is much more sensitive to infrared light than visible light. Using it to measure ambient light will result in serious deviations between the lux measurements of different light sources and human eye perception. Using Vishay’s ambient light sensors will solve this problem because they are most sensitive to the visible part of the spectrum.

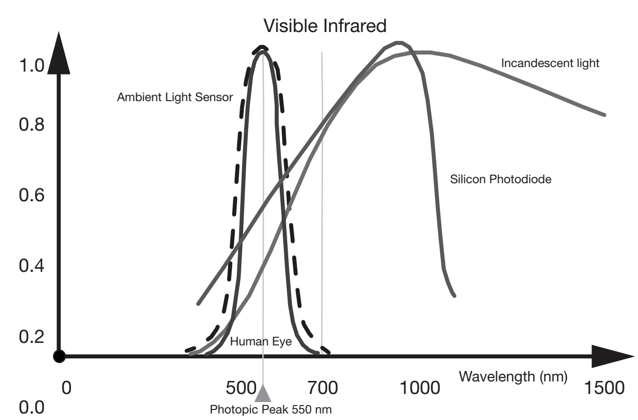


Fig. 19 - Relative Spectral Sensitivity vs. Wavelength

The human eye can see light with wavelengths from 400 nm to approximately 700 nm. The ambient light sensor array in the VCNL4030X01 closely matches this range of sensitivity and provides a digital output based on a 16-bit signal.

AMBIENT LIGHT MEASUREMENT, RESOLUTION, AND CALCULATION

The ambient light sensor’s measurement resolution is defined to about 0.004 lux/step for the highest sensitivity, with a 800 ms integration time. The 16-bit digital resolution is equivalent to 65 536 counts. This yields a measurement range from 0.004 lux to 262 lux. For higher illuminance, a shorter integration time needs to be selected, which results in lower resolution.

ALS RESOLUTION AND MAXIMUM DETECTION RANGE			
ALS_IT		SENSITIVITY	MAXIMUM DETECTION RANGE
ALS_IT (7 : 5)	INTEGRATION TIME (typ.)	UNIT (lx/step)	UNIT (lx)
(0, 0, 0)	50 ms	0.064	4192
(0, 0, 1)	100 ms	0.032	2096
(0, 1, 0)	200 ms	0.016	1048
(0, 1, 1)	400 ms	0.008	524
(1, 0, 0) to (1, 1, 1)	800 ms	0.004	262

There are two option bits (ALS_HD and ALS_NS) that enhance the dynamic range by a factor of two each.

With this the sensitivity shown within table above will be reduced by the factor 2, but the maximum possible detection range will be doubled for both options. With this the max. detection range goes up to 4192 lx x 2 x 2 = 16 768 lx.

The sensitivity curve below shows the behavior of this ALS photodiode.

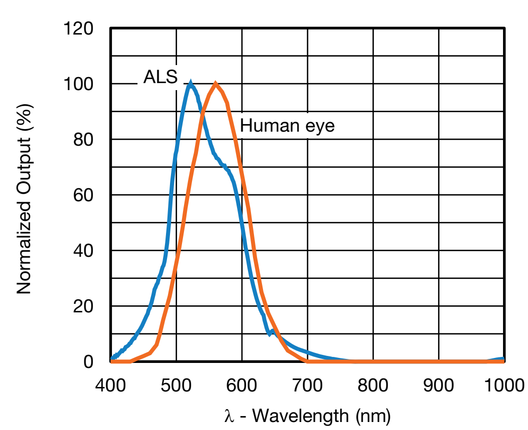


Fig. 20 - Relative Spectral Sensitivity vs. Wavelength

Besides the ALS, a white channel is also available.

Designing the VCNL4030X01 Into an Application

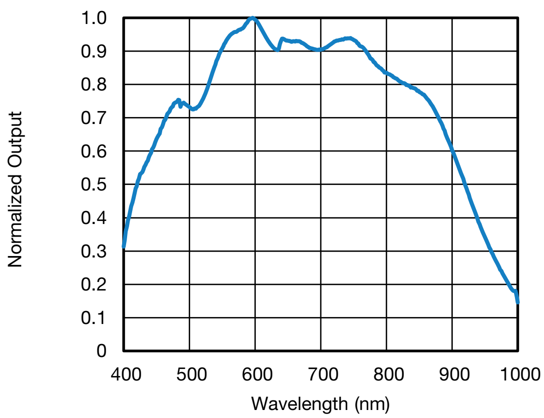


Fig. 21 - Relative Spectral Sensitivity vs. Wavelength (White Channel)

With the help of this white channel, more information can be determined, e.g. the kind of light source.

AMBIENT LIGHT SENSOR CURRENT CONSUMPTION

The ambient light sensor can operate with four selectable integration times from 50 ms to 800 ms.

During ALS measurements, the device consumes approximately 260 μA.

AMBIENT LIGHT INITIALIZATION AND I²C INTERFACE

For ambient light sensing, only the low byte of command code #0 needs to be initialized:

- ALS_SD (bit 0 = 0 = ALS Power_on)
- ALS_INT_EN (bit 1 = 1 = ALS interrupt enable)
- ALS_PERS (bit 2, 3: no. of interrupt persistence)
- ALS_IT (bit 5, 6, 7: integration time)

The rate for self-timed measurements is dependent on the integration time.

For unknown brightness conditions, it should always be started with the shortest integration time. This avoids possible overload / saturation. Only if ambient light result register values are very low, e.g. no content within the high byte of the 16-bit register (#11), should the next more sensitive integration time be used.

Calculating the available lux level is done by multiplying the ambient light result value from register 11 (L and H byte) with the integration time / resolution.

Example: integration time is at 50 ms and 0x0BH and 0x0BL show 01010100 and 01110110, expressed in decimals: 21 622 counts leading to 21 622 x 0.064 to 1384 lx.

Within the ready-made application, this factor should be fine-tuned, as cover glass and the size of the opening will also impact the result.

Interrupt

The VCNL4030X01 features a very intelligent interrupt function. The interrupt function enables the sensor to work independently until a predefined proximity or ambient light event or threshold occurs. It then sets an interrupt, which requires the microcontroller to awaken. This helps customers reduce their software effort, and reduces power consumption by eliminating polling communication traffic between the sensor and microcontroller.

The interrupt pin, pin 6, of the VCNL4030X01 should be connected to a dedicated GPIO of the controller. A pull-up resistor is added to the same power supply that the controller is connected to. This INT pull-up resistor may be in the range of 8.2 kΩ to 100 kΩ.

The events that can generate an interrupt include:

1. A lower and an upper threshold for the proximity value can be defined. If the proximity value falls below the lower limit or exceeds the upper limit, an interrupt event will be generated. In this case, an interrupt flag bit in the read-out register 0x0B will be set and the interrupt pad of the VCNL will be pulled to low by an open drain pull-down circuit. In order to eliminate false triggering of the interrupt by noise or disturbances, it is possible to define the number of consecutive measurements that have to occur before the interrupt is triggered.
2. A lower and an upper threshold for the ambient light value can be defined. If the ambient light value falls below the lower limit or exceeds the upper limit, an interrupt event will be generated. There are two sets of high and low threshold registers, so both thresholds for proximity and ambient light can be observed in parallel.

Beside this “normal” interrupt mode, an automatic mode is also available, which is called the logic output mode.

This mode automatically pulls the interrupt pin low when an object exceeds the programmed upper threshold and also resets it if the lower threshold is exceeded. So no actions from the controller are needed if, for example, a smartphone is held close to an ear but quickly taken away (e.g. for a short look at the display).

Application Example

The following example will demonstrate the ease of using the VCNL4030X01 sensor. The VCNL4030X01 sensor board is an add-on board to the SensorXplorer. More information about this demo kit can be found at www.vishay.com/optoelectronics/SensorXplorer.

Please purchase a VCNL4030X01 sensor board at any listed distributors: www.vishay.com/optoelectronics/SensorXplorer.

Designing the VCNL4030X01 Into an Application

Offset

During development, the application-specific offset counts for the sensor were determined. As previously mentioned, the offset count is affected by the components surrounding the VCNL4030X01, the window or cover being used, the distance from the sensor to the cover, and emitter intensity, which is controlled by the forward current.

In the following example, with a cover over the sensor and VSMY2940X01 emitter with emitter current set to 100 mA, the offset counts are 540 counts (Fig. 25). Offset counts vary by application and can be anywhere from 0 counts to several thousand counts. It is important to note that the offset count may change slightly over time due to, for example, the window becoming scratched or dirty, or being exposed to high temperature changes. If possible, the offset value should occasionally be checked and, if necessary, modified.

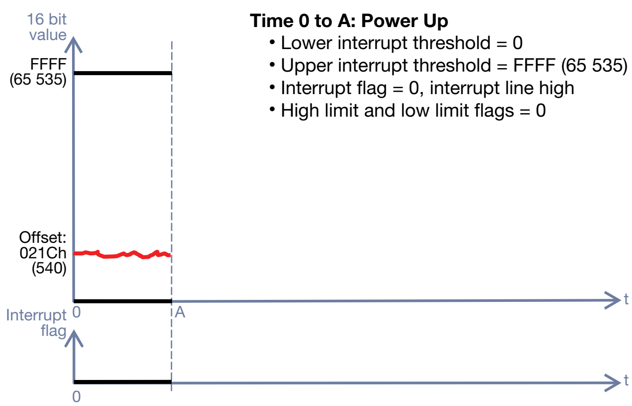


Fig. 22

Power Up

As mentioned, there are four variables for proximity measurement that need to be set in the register when the sensor is powered up: the emitter current, the number of occurrences that must exceed a threshold to generate an interrupt, the threshold values, and the number of proximity measurements per second.

The sensor should detect skin at a distance of 20 cm. Development testing determined that a current of 100 mA, together with a proximity integration time of PS_IT = 8T, produces adequate counts for detection. The proximity measurement rate is set so that about 20 measurements are done within a second and the number of occurrences to trigger an interrupt is set to four. Based on development testing, with a hand or skin approximately 20 cm above the window cover, the resulting total count is 550. This will be used as the upper threshold (high threshold).

For smartphone applications it would be typical to initially set this top threshold and a lower threshold (bottom threshold). This is needed to indicate the removal of the phone from the user's ear. The measured counts without any additional object close by will be around this offset count value, always below the lower threshold value, as shown in Fig. 26.

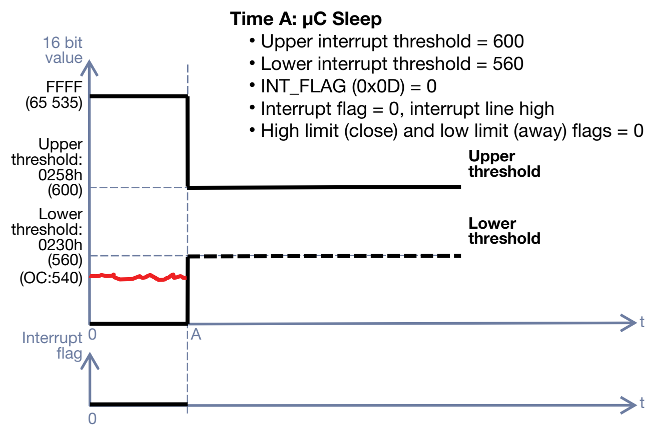


Fig. 23

By setting the number of occurences before generating an interrupt to four, a single proximity value above or below the thresholds will have no effect, as shown in Fig. 27.

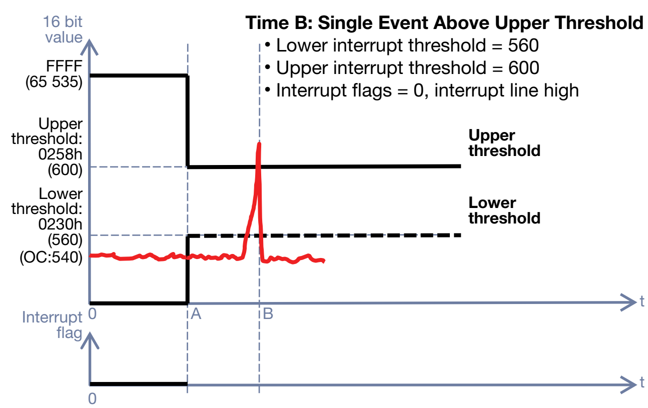


Fig. 24

A smartphone application will use a proximity sensor to detect when the phone is brought to the user's ear and disable the touchscreen and turn off the backlight. For other applications, such as automatic dispensing, the soap or towel will be dispensed.

Designing the VCNL4030X01 Into an Application

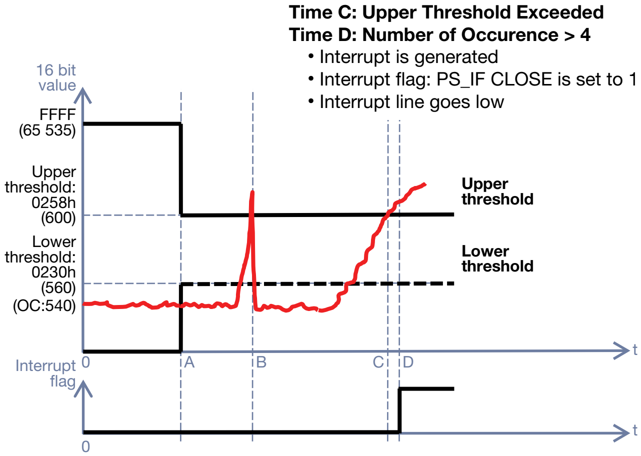


Fig. 25

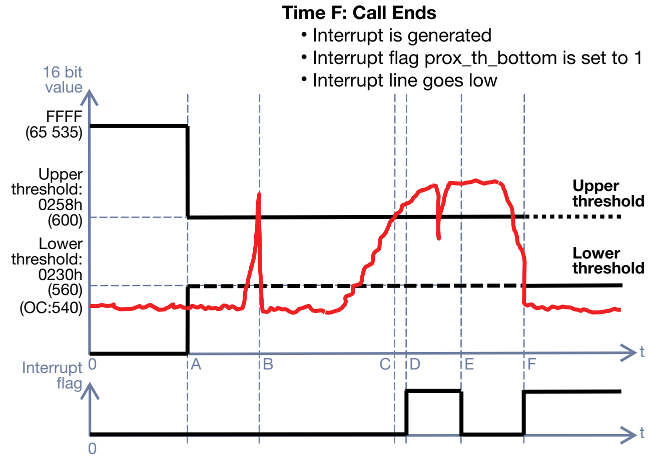


Fig. 26

In smartphone applications, the bottom threshold will also be programmed and waits for an interrupt signal. The prox_threshold_bottom should be set to "1" now and the prox_threshold_top cleared by entering a "1" again, since the phone is already next to the user's ear. A lower threshold will occur when the phone call is complete and the phone is brought away from the user's ear, and the backlight and touchscreen will be turned back on.

For this example, the upper threshold will only be set to 600 counts. The lower threshold is set to 560 counts; a value that is higher than the offset but low enough to indicate the removal of the phone from the user's ear.

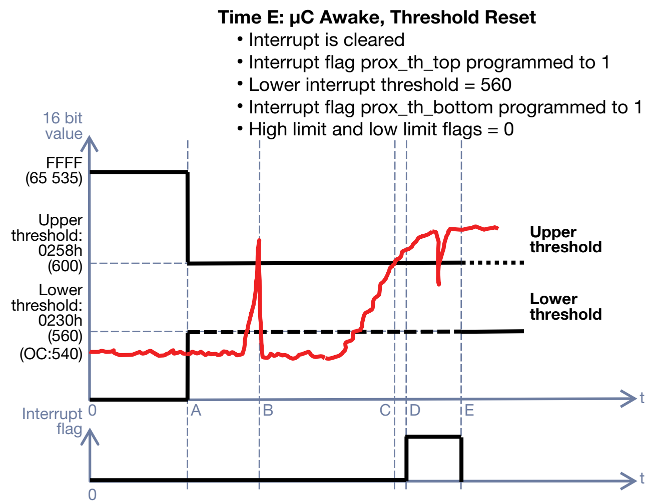
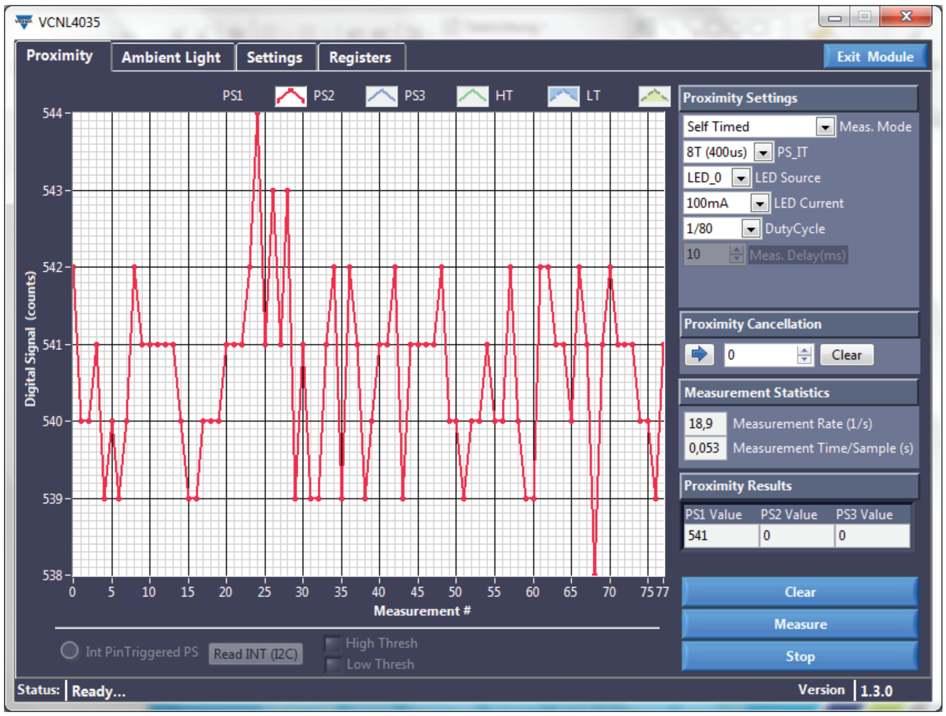


Fig. 27

Designing the VCNL4030X01 Into an Application

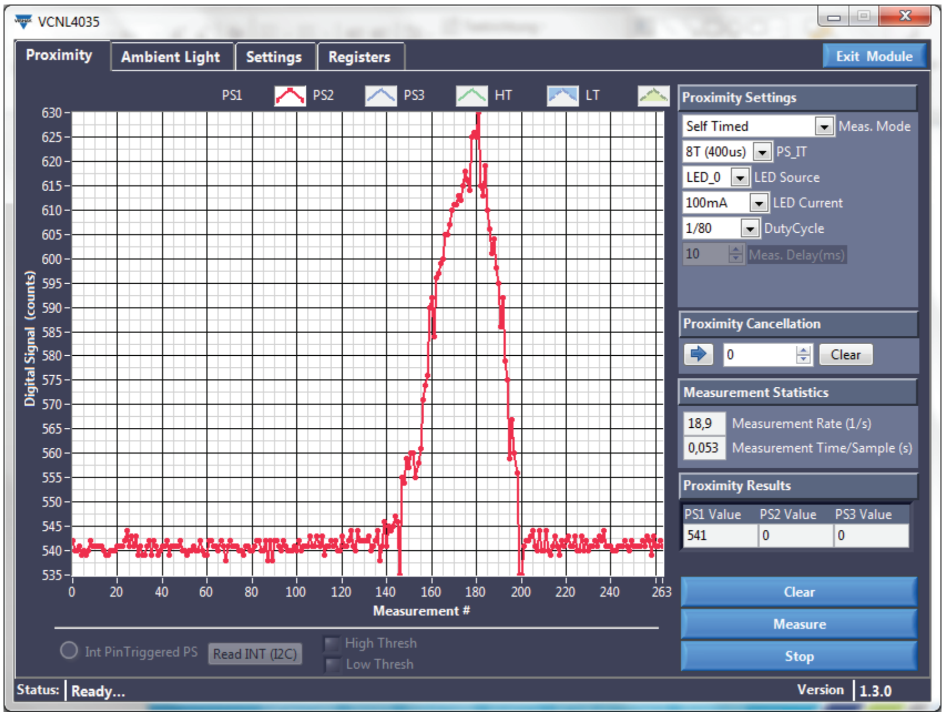
Some measurements and features are shown with the demo tool and demo software with a cover glass at about a 5 mm distance.

1. Proximity set-up with 8T wide pulses, 100 mA emitter current, and a duty cycle of 1/80, which results in about 30 measurements per second.

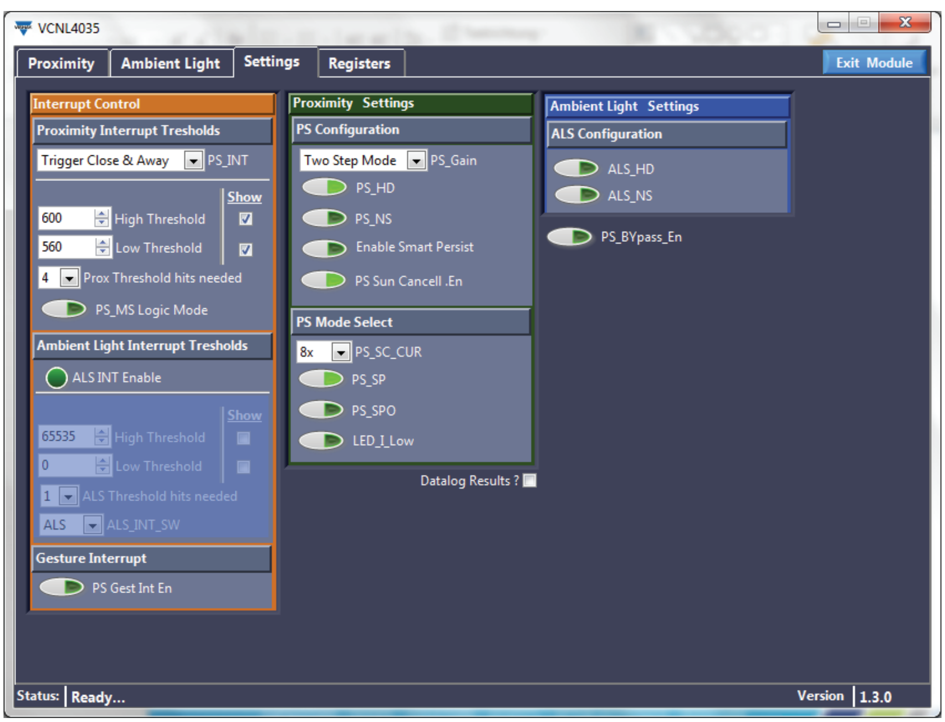


Designing the VCNL4030X01 Into an Application

2. If a hand or skin comes as close as 20 cm, these 540 counts rise up to more than 600 counts.

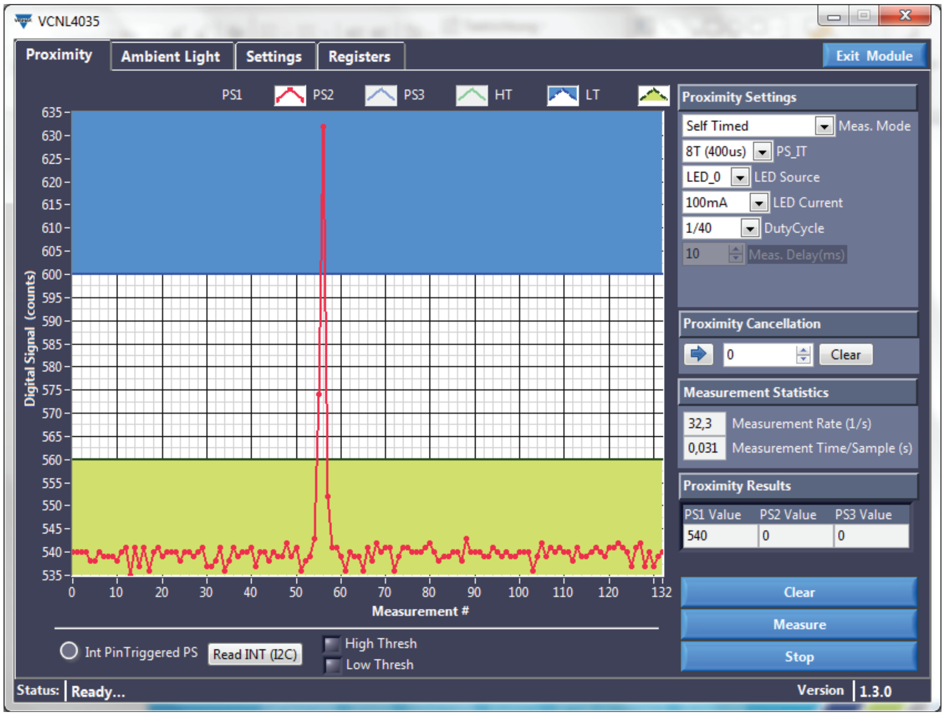


3. Here the thresholds are programmed as 600 for the upper and 560 for the lower. To see these, both "Show" buttons are activated. The presence of an object should only be recognized when four consecutive measurements are above that threshold.



Designing the VCNL4030X01 Into an Application

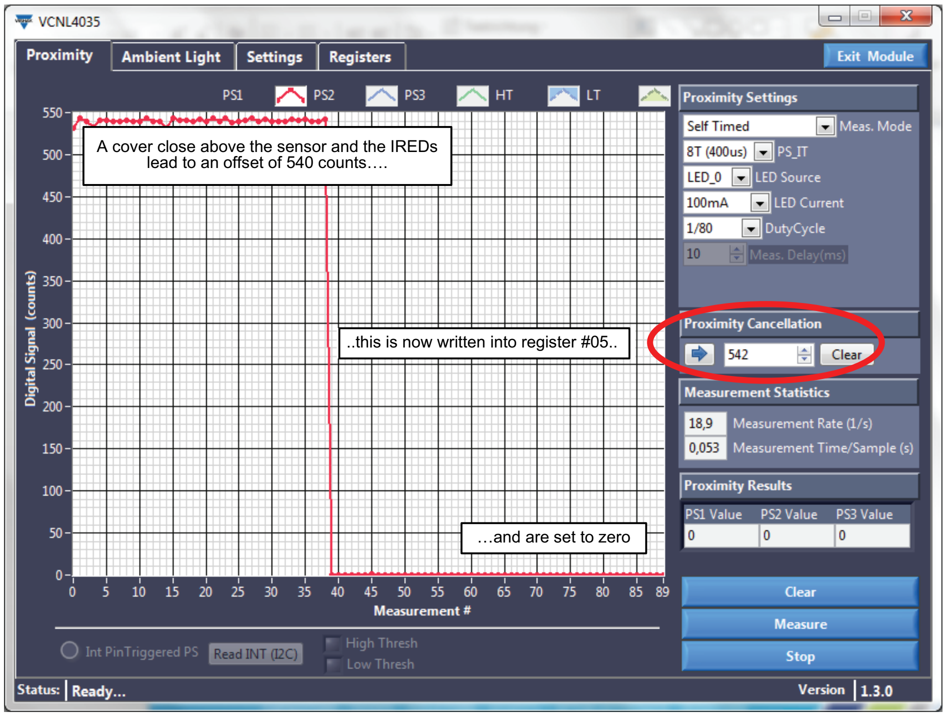
4. Just one or two measurements above the threshold will not activate the interrupt.



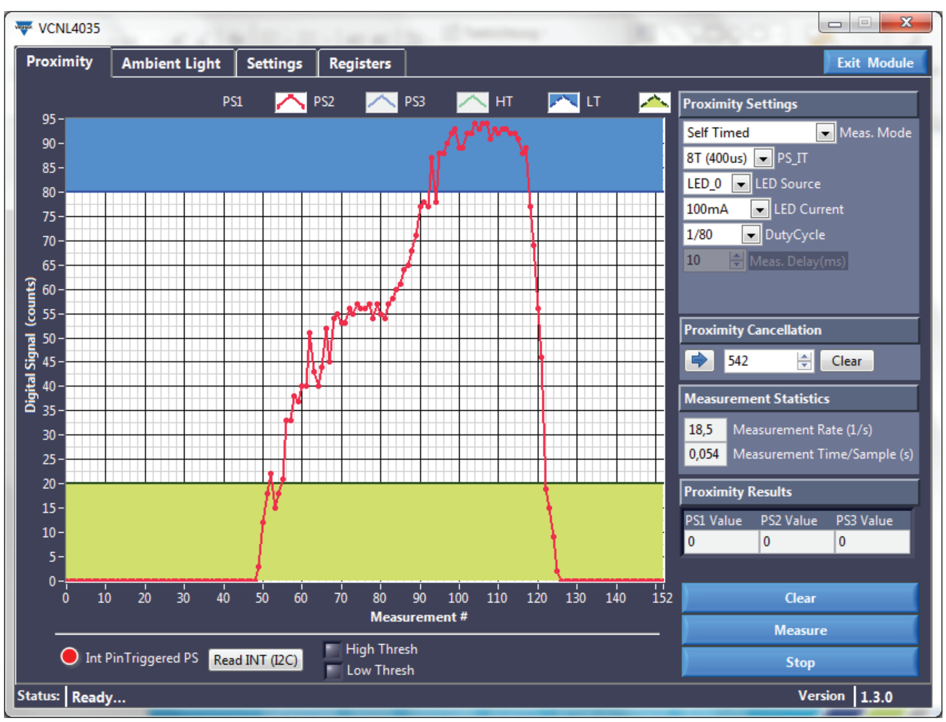
5. With more than four measurements above the threshold, however, the interrupt is pulled low, as indicated by the red LED on the demo board and the red light: “Int Pin Triggered PS.”

Designing the VCNL4030X01 Into an Application

6. The cancellation feature is used below. The "before seen" offset counts are subtracted. To do so, the value of 540 is entered for register number 05 = Prox_Cancellation.

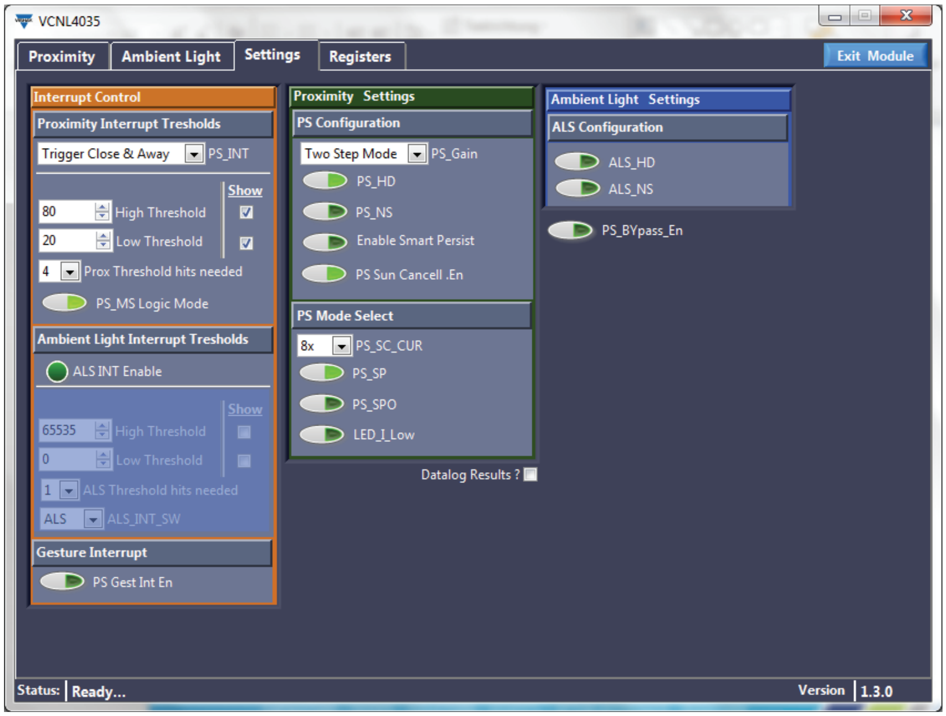


7. The "before seen" measured proximity result data of 541 is now 541 - 540 = 1. Also, the thresholds are now 540 counts lower. The higher threshold is 10 and lower is just 5.



Designing the VCNL4030X01 Into an Application

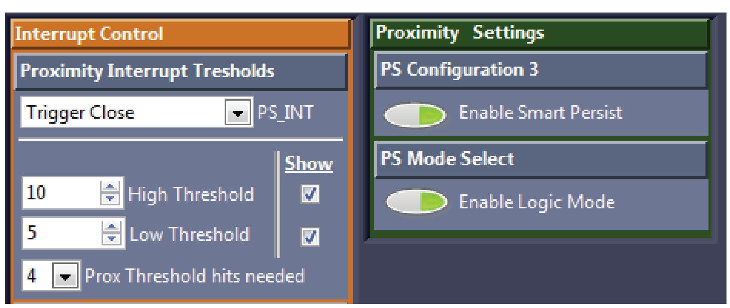
If one chooses “logic mode” now and redefines the high threshold to 10 and low threshold as 5...



… the interrupt will indicate the rise above the upper threshold and will also automatically be cleared when it falls below the lower threshold.

One special feature for faster proximity measurements is also implemented, which is called “smart persist.”

This feature reduces the total reaction time until the interrupt is set to active, although four consecutive measurements should be above (or below) the defined threshold for safe acknowledgment.



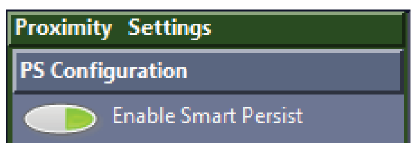
Designing the VCNL4030X01 Into an Application

Without "smart persist", but with programmed hits above the defined threshold set to four, it will take four times the time of PS_Duty. With PS_IT = 1T and PS_Duty set to 1/320 this would be 4 x 16 ms.

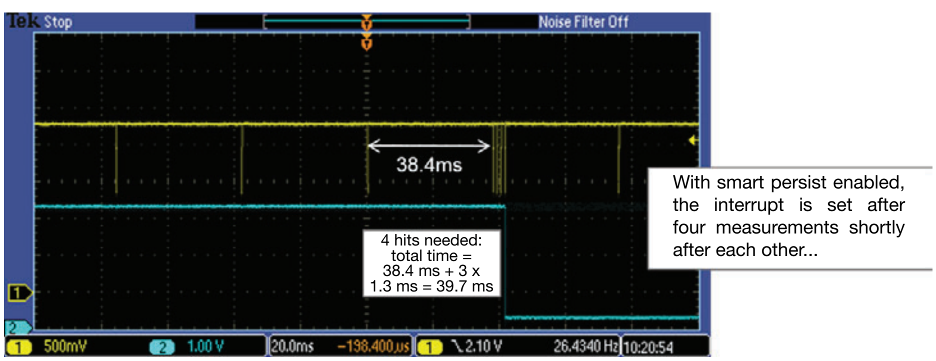
With "smart persist" activated (bit 4 of PS_CONF3):

REGISTER: PS_CONF3 DESCRIPTION		
REGISTER: PS_CONF3		**COMMAND CODE: 0x04_L (0x04 DATA BYTE LOW)**
Command	Bit	Description
LED_I_LOW	7	0 = disabled = normal current, 1 = enabled = 1/10 of normal current, with that the current is accordingly: 5 mA, 7.5 mA, 10 mA, 12.5 mA, 17.5 mA, 20 mA
IRED select	6 : 5	(0 : 0) = IRED1, (0 : 1) = IRED2, (1 : 0) = IRED3, (1 : 1) = IRED3
PS_SMART_PERS	4	0 = disable; 1 = enable PS smart persistence
PS_AF	3	0 = active force mode disable (normal mode), 1 = active force mode enable
PS_TRIG	2	0 = no PS active force mode trigger, 1 = trigger one time cycle VCNL4030X01 output one cycle data every time host writes in '1' to sensor. The state returns to '0' automatically.
PS_MS	1	0 = proximity normal operation with interrupt function 1 = proximity detection logic output mode enable
PS_SC_EN	0	0 = turn off sunlight cancel; 1 = turn on sunlight cancel PS sunlight cancel function enable setting

or within the demo-tool:



The total needed time is reduced to just one time of 16 ms, followed by three times of just 1.3 ms between the next three measurements, for a total of 39.7 ms.



Remark:

With "smart persist" enabled, there will always be four pulses shortly after each other, whether PS_PERS is set to 2, 3, or 4.