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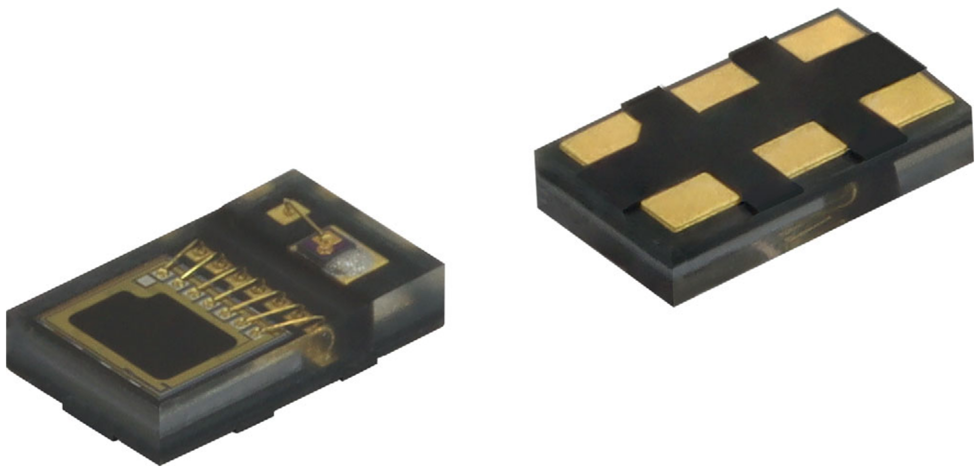
Application Note

Designing the VCNL36829UM Into an Application

By Jerry Liu



ABSTRACT

This application note provides an introduction to the functionality of the VCNL36829UM sensor, application circuits, and mechanical design considerations.

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APPLICATION NOTE

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Designing the VCNL36829UM Into an Application

1. INTRODUCTION

The VCNL36829UM is a fully integrated proximity sensor. It combines a vertical-cavity surface-emitting laser (VCSEL), photodiode, and application-specific integrated circuit (ASIC) within a single package. The VCNL36829UM has been developed for proximity detection applications that require a dual slave address, low power consumption, small package size, small window size, and short range operation up to 5 cm. In addition, given the rated supply voltage of 1.8 V to reduce power consumption, the sensor is intended for battery-powered applications such as:

- Presence detection in
  - Smartphones and true wireless stereo (TWS) earbuds
  - VR / AR headsets and smart glasses
  - Smartwatches
- Touchless button / dispensing

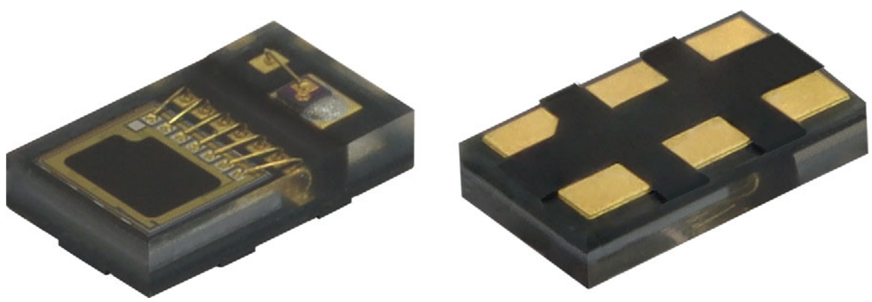

Fig. 1 - The VCNL36829UM

KEY BENEFITS OF USING VCNL36829UM	
BENEFITS	**DESCRIPTION**
Small package for tight space requirements	Very small 1.6 x 1.0 x 0.35 (L x W x H in mm) package
	A small package allows a design with a small window size
Low power consumption for battery-powered devices	A 1.8 V rated power supply and I^{2}C bus reduce the power consumption
	The low idle current of 5 µA allows a lower average current consumption
	The use of VCSEL instead of IRLED allows a lower driving current with comparable performance
Superior proximity detection	The proximity sensor can detect up to 5 cm distance
	The proximity sensor supports sunlight cancellation up to 200 klux of sunlight
Smart dual slave address	The smart dual slave address allows the connection of up to two proximity sensors with a microcontroller, without needing an I^{2}C multiplexer; the slave address can be changed by swapping the SCL and SDA pins

This application note describes the functionality, application circuits, register settings, and mechanical design considerations for the sensor.

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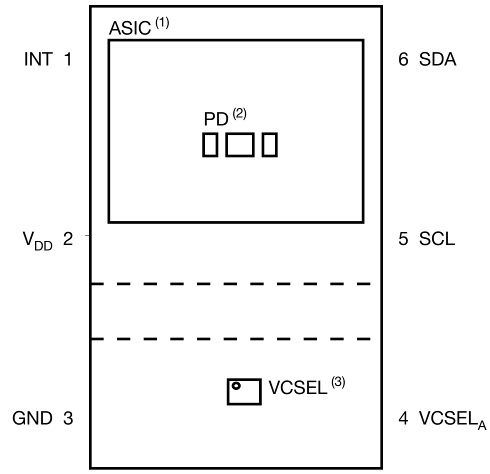
Designing the VCNL36829UM Into an Application

2. PIN DESCRIPTION AND BLOCK DIAGRAM

2.1 Pin Description



Notes
(1) ASIC - Application-specific integrated circuit
(2) PD - Photodiode
(3) VCSEL - Vertical-cavity surface-emitting laser

Fig. 2 - Pin Assignment (top view) of the VCNL36829UM

TABLE 1 - PIN DESCRIPTION

PIN NUMBER	PIN NAME	TYPE	DESCRIPTION
1	INT	O (open drain)	Interrupt
2	V_{DD}	I	Supply voltage
3	GND	I	Ground
4	$VCSEL_A$	I	VCSEL anode
5	SCL (1)	I / O (open drain)	I^2C serial clock
6	SDA (1)	I / O (open drain)	I^2C serial data

Note
(1) Pin 5 (SCL) and pin 6 (SDA) can be swapped to change the slave address from 0x60 to 0x51 (7-bit slave address)

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2.2 Block Diagram

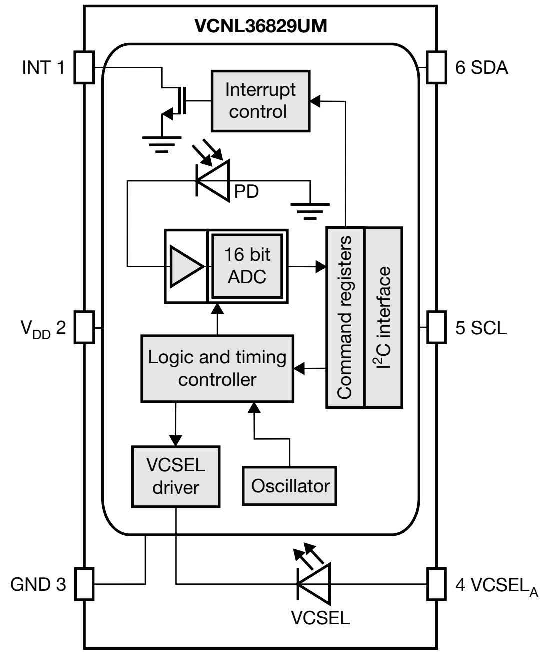

Fig. 3 - Block Diagram of the VCNL36829UM

TABLE 2 - BLOCK DIAGRAM DESCRIPTION	
COMPONENT	**DESCRIPTION**
Command registers	The command registers are the memory storage for writing and reading I^2C commands
I^2C interface	The I^2C interface is a communication interface with active low open drain circuitry
Interrupt control	Interrupt control is a circuit block with active low open drain output
PD	PD is a photodiode that converts the reflected infrared signal from the object into photocurrent; it is then fed to the 16-bit ADC
16-bit ADC	The 16-bit analog to digital converter converts the analog signal to the digital signal (1); the input signal is then amplified
Logic and timing controller	The logic and timing controller controls the timing for the proximity measurement
VCSEL driver	The VCSEL driver is a circuitry block that limits the driving current based on the selected setting
Oscillator	The oscillator generates the clock signal to synchronize all of the device functionalities

Note

(1) The actual bit resolution can vary between 14 bits and 16 bits, depending on the register settings PS_IT. If PS_IT = 12.5 μs to 175 μs, the full code is 14 bit /16 383 counts; if PS_IT = 200 μs to 375 μs, the full code is 16 bit / 65 535 counts

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3. APPLICATION CIRCUIT

3.1 Slave Address Selection

The VCNL36829UM supports a smart dual slave address in which the designer can change the slave address by swapping the SCL and SDA pins, as shown in Table 3.

TABLE 3 - SLAVE ADDRESS TABLE

PIN 5	PIN 6	7-BIT SLAVE ADDRESS	8-BIT SLAVE ADDRESS (WRITE)	8-BIT SLAVE ADDRESS (READ)
SCL	SDA	0x60	0xC0	0xC1
SDA	SCL	0x51	0xA2	0xA3

A smart dual slave address provides the flexibility for the designer to connect two devices from two different slave addresses on the same I^2C bus. The two slave address options allow designers to select a different slave address if one is used by the other slave devices on the same I^2C bus in a single device application.

3.2 Application Circuit With a Single Device

Fig. 4 and Fig. 5 show application circuit examples with a single device. As described in Table 3, when pins 5 and 6 are connected to the clock and data signal from the microcontroller, as shown in Fig. 4, they will then be configured as an SCL pin and SDA pin, respectively. The 7-bit slave address option of 0x60 will be automatically selected.

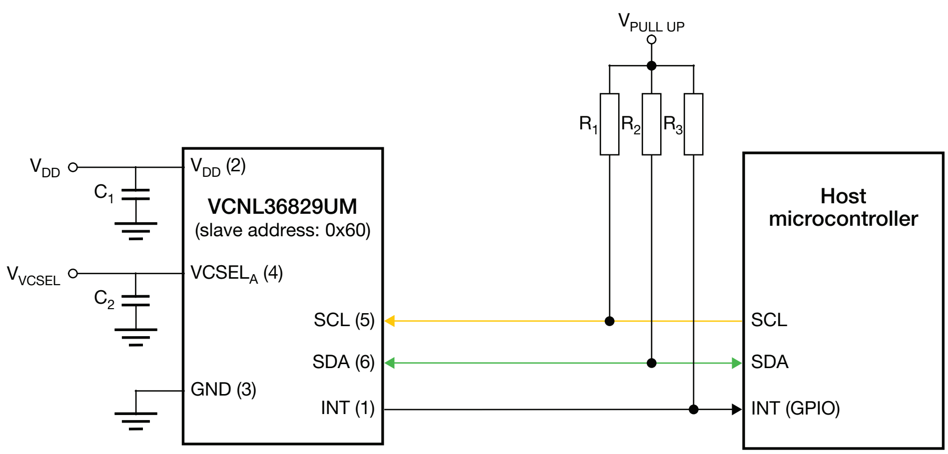

Fig. 4 - Application Circuit Example for a Single VCNL36829UM - Slave Address 0x60

On the other hand, when pins 5 and 6 are connected to the data and clock signal from the microcontroller, as shown in Fig. 5, they will then be configured as an SDA pin and SCL pin, respectively. The 7-bit slave address option of 0x51 will be automatically selected.

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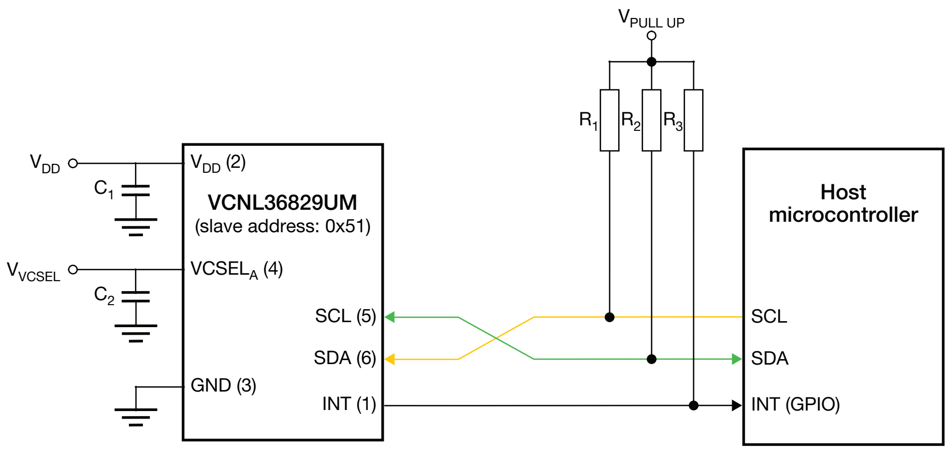

Fig. 5 - Application Circuit Example for a Single VCNL36829UM - Slave Address 0x51

Table 4 shows the required values and the explanation for the individual application circuit parameters.

TABLE 4 - APPLICATION CIRCUIT PARAMETERS

CIRCUIT PARAMETER	VALUE	DESCRIPTION
V_{DD}	1.65 V to 2.00 V	A stable power supply is recommended, such as a low dropout or switching regulator; the power supply isolation can be further improved with a decoupling capacitor C_1
V_{VCSEL}	2.80 V to 3.60 V	A stable power supply such as a low dropout or switching regulator that can supply an adequate amount of power (max. VCSEL pulse driving current of 18 mA) is recommended; the power supply isolation can be further improved with a decoupling capacitor C_2; the minimum voltage depends on the selected driving current of the VCSEL; please refer to Table 5 for reference
$V_{PULL\ UP}$	1.2 V to 3.6 V	A stable power supply such as a low dropout or switching regulator is recommended; a voltage level shifter is required if the I^2C bus voltage from the microcontroller is higher than 3.6 V
C_1 to C_4	100 nF to 1 µF	Decoupling capacitors are recommended to reduce the noise in the supply voltage
R_1 to R_2	2.2 kΩ to 4.7 kΩ	Pull-up resistors within the range of 2.2 kΩ to 4.7 kΩ are recommended; any increase in bus capacitance or resistance will increase the logic-high transition time
R_3	4.7 kΩ to 22 kΩ	A pull-up resistor within the range of 4.7 kΩ to 22 kΩ is recommended

VCSEL Driver

Fig. 6 shows the VCSEL driver circuit in the VCNL36829UM.

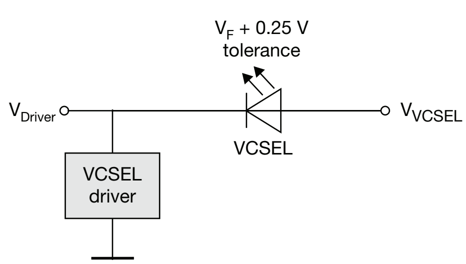

Fig. 6 - VCSEL Driver Circuit in the VCNL36829UM

The typical supply voltage for the VCSEL is 3.3 V. The designer could connect pin 4 $VCSEL_A$ with a lower supply voltage V_{VCSEL}. However, V_{VCSEL} should at least match the minimum required supply voltage for the VCSEL $V_{VCSEL,min.}$.

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$V_{VCSEL,min.}$ depends on:

- The selected driving current I_F of the VCSEL and its corresponding forward voltage V_F
- The forward voltage tolerance of the VCSEL, $V_{F, tolerance}$, which is 0.25 V
- The minimum voltage required by the driver circuit, $V_{Driver,min.}$, which is 0.6 V

Therefore,

$$V_{VCSEL, min.} = V_F(I_F) + V_{F, tolerance} + V_{Driver, min.} = V_F(I_F) + 0.25\text{ V} + 0.6\text{ V}$$

Fig. 7 and Table 5 show the computation of $V_{VCSEL,min.}$. The designer could use 3.3 V to provide sufficient voltage headroom. The maximum allowable supply voltage of the VCSEL $V_{VCSEL,max.}$ is 3.6 V.

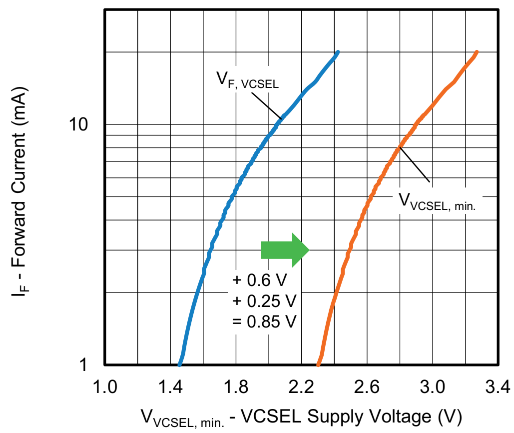

Fig. 7 - Forward Current vs. VCSEL Supply Voltage

TABLE 5 - $V_{VCSEL, MIN.}$						
I_{VCSEL} (I_F)	8 mA	10 mA	12 mA	14 mA	16 mA	18 mA
V_F	1.95 V	2.05 V	2.15 V	2.23 V	2.31 V	2.37 V
$V_{F, tolerance}$	0.25 V					
$V_{Driver, min.}$	0.6 V					
$V_{VCSEL, min.}$	2.80 V	2.90 V	3.00 V	3.08 V	3.16 V	3.22 V
$V_{VCSEL, max.}$	3.6 V					

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3.3 Application Circuit With a Smart Dual Slave Address

Fig. 8 shows an application circuit example with a smart dual slave address. By swapping the SCL and SDA pins of the second device, as shown in Table 3, the designer can change the 7 bit slave address of the VCNL36829UM. This provides the flexibility for the designer to connect two devices from two different slave addresses on the same I²C bus.

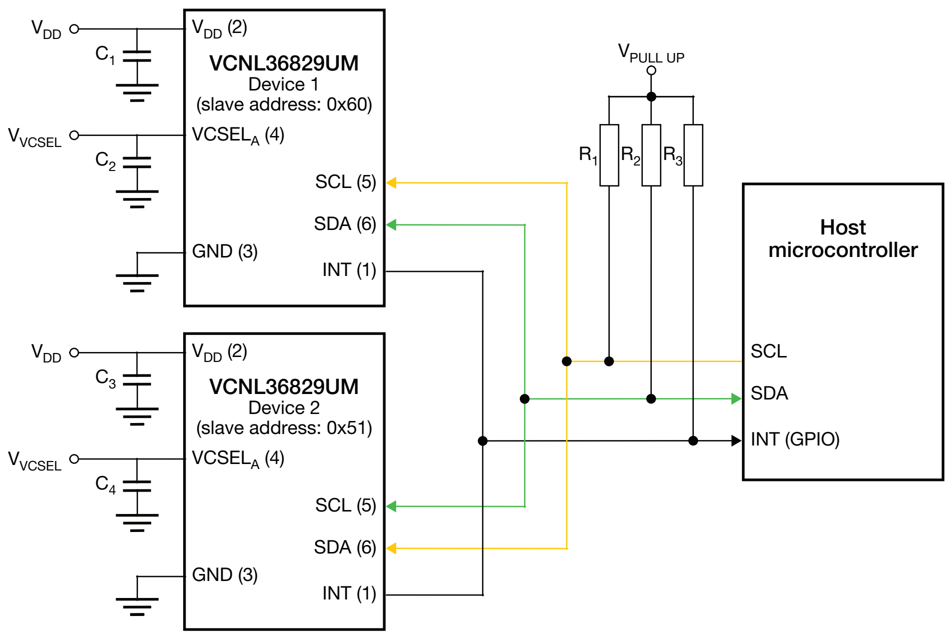

Fig. 8 - Application Circuit Example for Two VCNL36829UMs - Smart Dual Slave Address

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4. REGISTER DESCRIPTION

TABLE 6 - REGISTER DESCRIPTION OVERVIEW

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	DESCRIPTION	ACCESS
Basic initialization	PS_CAL	PS_CONF1_L	0x00	Enable / disable the internal calibration	Write and read
	PS_TRIG			Set the active force mode trigger; this bit will be reset to 0 after the measurement cycle	
	PS_MODE			Set the measurement mode of the sensor	
	PS_ON			Switch the sensor on / off	
	PS_SD	PS_CONF1_H		PS shutdown setting	
Emitter (VCSEL) settings	PS _IT	PS_CONF2_H	0x01	Set the integration time for one measurement	
	PS_CURRENT_EN	PS_CONF3_L	0x02	VCSEL driver enable setting	
	PS_CURRENT			Set the VCSEL driving current	
Detector settings	PS_HG	PS_CONF3_H		Set the gain of the ADC	
	PS_GAIN				
	PD3_EN			PD3 enable setting	
	PD2_EN			PD2 enable setting	
	PD1_EN			PD1 enable setting	
Wait time setting	PS_WAIT	PS_CONF2_L	0x01	PS wait time after PS detection	
-	Reserved	PS_CONF4_L	0x03	Reserved	
Sunlight cancellation	PS_SC_LEVEL	PS_CONF4_H		Sunlight cancellation level setting	
	PS_SC			Enable / disable the sunlight cancellation	
Offset count cancellation	PS_CANC_L	PS_CANC_L	0x06	Offset count cancellation value setting (low byte)	
	PS_CANC_H	PS_CANC_H		Offset count cancellation value setting (high byte)	
-	Reserved	PS_CONF5_L	0x08	Reserved (must be set to 0xA0)	
		PS_CONF5_H		Reserved	
Interrupt	PS_INT	PS_CONF1_H	0x00	Set the interrupt mode setting	
	PS_PERS			Set the amount of consecutive threshold crossing events necessary to trigger interrupt	
	PS_SMART_PERS			Enable / disable the smart persistence setting when the interrupt event is triggered	
	PS_SP_INT			Enable / disable the sunlight protection mode interrupt setting	
	PS_START_INT			After PS_SD disable, PS 1st detection Interrupt enable setting	
	PS_THDL_L	PS_THDL_L	0x04	Low threshold interrupt value setting (low byte)	
	PS_THDL_H	PS_THDL_H		Low threshold interrupt value setting (high byte)	
	PS_THDH_L	PS_THDH_L	0x05	High threshold interrupt value setting (low byte)	
	PS_THDH_H	PS_THDH_H		High threshold interrupt value setting (high byte)	
	PS_START_FALG	INT_FLAG	0xF9	PS finish 1st detection after SD disable	Read only
	PS_SPFLAG			Read the sunlight protection mode interrupt event flag	
	PS_IF_CLOSE			Read the high threshold crossing interrupt event flag	
	PS_IF_AWAY			Read the low threshold crossing interrupt event flag	
Readout registers	PS_DATA_L	PS_DATA	0xF8	Proximity output data (low byte)	
	PS_DATA_H			Proximity output data (high byte)	
	VCNL36829UM_ ID_L	VCNL36829UM _ID	0xFA	Device ID (1); slave address: 0x60, ID = 0x29; slave address: 0x51, ID = 0x29	
	VCNL36829UM_ ID_H			Device ID (1); slave address: 0x60, ID = 0x00; slave address: 0x51, ID = 0x10	

Notes

- All of the reserved registers are used for internal testing; these values must be kept constant

(1) The default ID depends on the connection of the SCL and SDA pins on the VCNL36829UM with the SCL and SDA pins on the host MCU; if pins 5 and 6 on the VCNL36829UM are connected to the SCL and SDA pins on the host, the default value will be 0x0029; on the other hand, if pins 5 and 6 on the VCNL36829UM are connected to the SDA and SCL pins on the host, the default value will be 0x1029

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4.1 Basic Initialization

The sensor can be initialized with the PS_CAL, PS_ON, PS_MODE, and PS_TRIG bits, which are found in three different registers: PS_CONF1_L.

<table>
<tr><th colspan="8">TABLE 7 - BASIC INITIALIZATION</th></tr>
<tr><th>REGISTER GROUP</th><th>BIT NAME</th><th>REGISTER NAME</th><th>COMMAND CODE</th><th>FUNCTION</th><th>BIT</th><th>VALUE</th><th>DESCRIPTION</th></tr>
<tr><td rowspan="13">Basic initialization</td><td rowspan="2">PS_CAL</td><td rowspan="11">PS_CONF1_L</td><td rowspan="13">0x00</td><td rowspan="2">Enable / disable the internal calibration</td><td rowspan="2">7</td><td>0x0 (0b0)</td><td>Disable (default)</td></tr>
<tr><td>0x1 (0b1)</td><td>Enable</td></tr>
<tr><td>Reserved</td><td>Reserved</td><td>6</td><td>0x0 (0b0)</td><td>Should be kept default</td></tr>
<tr><td rowspan="2">PS_TRIG</td><td rowspan="2">Set the active force mode trigger; this bit will be reset to 0 after the measurement cycle</td><td rowspan="2">5</td><td>0x0 (0b0)</td><td>Off (default)</td></tr>
<tr><td>0x1 (0b1)</td><td>Trigger</td></tr>
<tr><td rowspan="2">PS_MODE</td><td rowspan="2">Set the measurement mode of the sensor</td><td rowspan="2">4</td><td>0x0 (0b0)</td><td>Auto mode (default)</td></tr>
<tr><td>0x1 (0b1)</td><td>Active force mode</td></tr>
<tr><td>Reserved</td><td>Reserved</td><td>3 : 1</td><td>0x0 (0b000)</td><td>Should be kept default</td></tr>
<tr><td rowspan="2">PS_ON</td><td rowspan="2">Switch the sensor on / off</td><td rowspan="2">0</td><td>0x0 (0b0)</td><td>Turn off the sensor (shutdown) (default)</td></tr>
<tr><td>0x1 (0b1)</td><td>Turn on the sensor</td></tr>
<tr><td rowspan="2">PS_SD</td><td rowspan="2">PS_CONF1_H</td><td rowspan="2">PS shutdown setting</td><td rowspan="2">8</td><td>0x0 (0b0)</td><td>Disable</td></tr>
<tr><td>0x1 (0b1)</td><td>Enable (default)</td></tr>
</table>

PS_ON - The sensor can be turned on by setting this bit to 1 and turned off by setting it to 0. The sensor will mostly be in the idle state and only be in the active state during the measurement phase.

PS_MODE - Set this bit to 0 to activate the auto mode and 1 to activate the active force mode. Auto mode means the measurement will be triggered continuously with a rate defined by the measurement period. This measurement period depends on the PS_IT and PS_WAIT bits' setting. Active force mode means the measurement will have to be triggered manually by setting the PS_TRIG bit to 1.

PS_TRIG - This bit must be set to 1 when using active force mode to trigger a measurement. Otherwise, the bit must be set to 0.

PS_CAL - Set the sensor to factory calibration values, when set to "1", ensuring original accuracy and stability. This bit will automatically return to "0".

Fig. 9 and Fig. 10 show the basic initialization of the two available modes. The basic initialization steps are usually useful when first testing with the proximity sensor. The proximity measurement will be based on the default values. In practice, more sensor parameters to change the strength of the VCSEL infrared signal, the gain of the ADC, the measurement period, and the interrupt should be set before starting the measurement.

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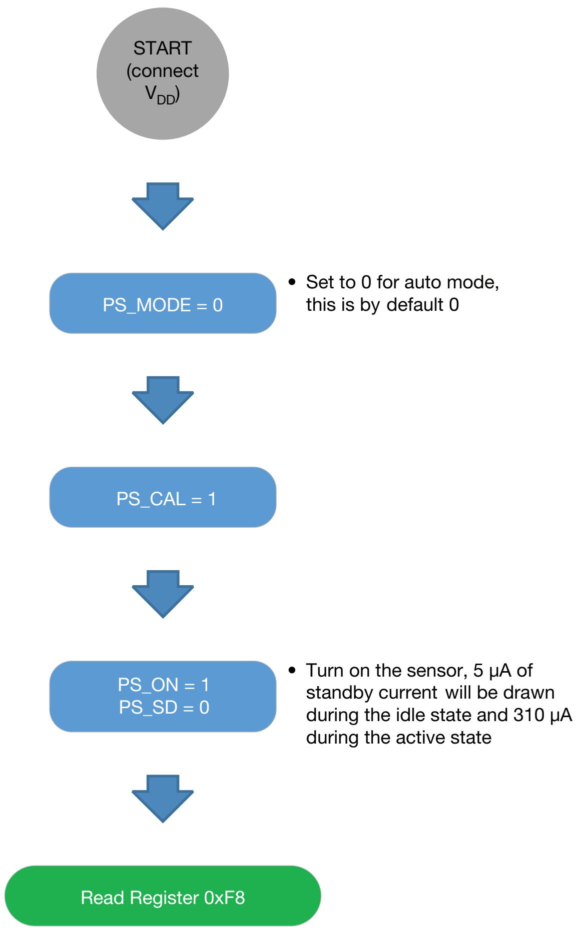

Fig. 9 - Basic Initialization Example Steps for Auto Mode

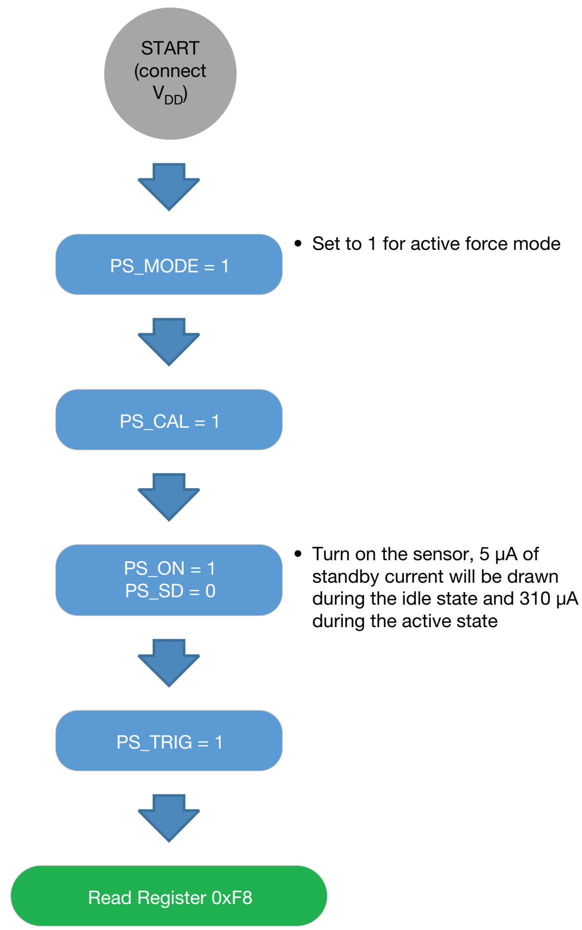

Fig. 10 - Basic Initialization Example Steps for Active Force Mode

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4.2 Emitter Settings (VCSEL)

TABLE 8 - EMITTER SETTINGS (VCSEL)

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Emitter (VCSEL) settings	Reserved	PS_CONF2_H	0x01	Reserved	15 : 12	0x0 (0b0000)	Should be kept default
	PS _IT			Set the integration time for one measurement	11 : 8	0x0 (0b0000)	12.5 μs (default)
						1 to 15	25 μs x PS_IT
	Reserved	PS_CONF3_L	0x02	Reserved	7 : 4	0x0 (0b0000)	Should be kept default
	PS_CURRENT_EN			VCSEL driver enable setting	3	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_CURRENT			Set the VCSEL driving current	2 : 0	0x0 (0b000)	Reserved (default)
						0x1 (0b001)	Reserved
						0x2 (0b010)	8 mA
						0x3 (0b011)	10 mA
						0x4 (0b100)	12 mA
						0x5 (0b101)	14 mA
						0x6 (0b110)	16 mA
						0x7 (0b111)	18 mA

Fig. 11 and Fig. 12 show the infrared signal of the VCSEL is a pulse with a width of T. This can be set via the parameter PS_IT. The length of T can be 12.5 μs to 375 μs. The magnitude of the pulse can be controlled via the VCSEL driver current parameter PS_CURRENT.

PS_CURRENT - The magnitude of the driving current of the VCSEL pulse.

Fig. 11 - The Behavior of the Pulse Magnitude With Different PS_CURRENT

PS_IT - The length of the VCSEL pulse width.

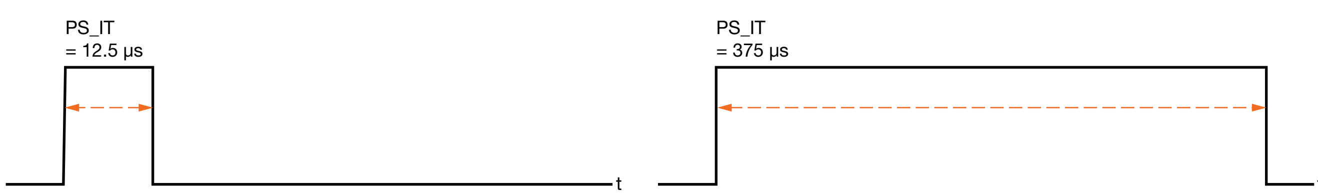

Fig. 12 - The Behavior of the Pulse Length With Different PS_IT

Fig. 13 and Fig. 14 show the behavior of the proximity counts as the setting values increase. It can be observed that the proximity counts increase significantly as the setting values are raised. If a longer detection distance is required, the designer could increase PS_IT and PS_CURRENT. The maximum proximity value is influenced by PS_IT only, which will be explained further in Table 10.

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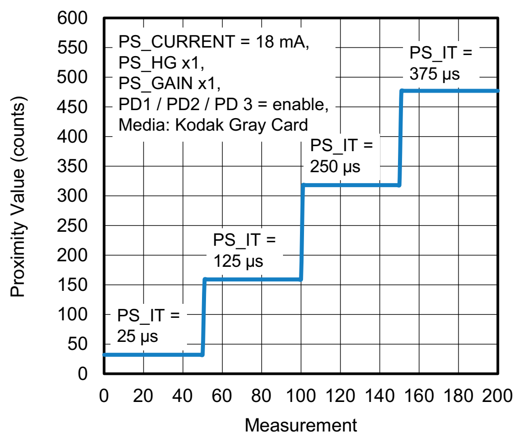

Fig. 13 - The Behavior of the Proximity Counts With Different PS_IT

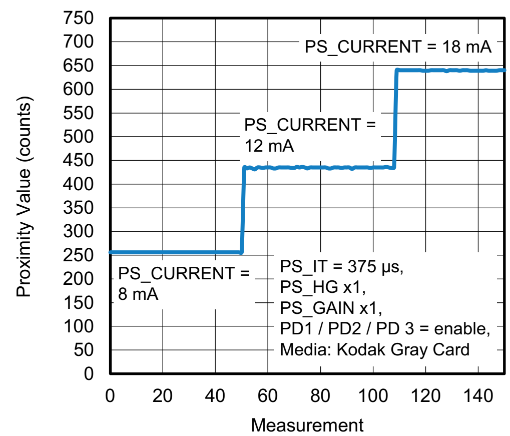

Fig. 14 - The Behavior of the Proximity Counts With Different PS_CURRENT

4.3 Detector Settings

TABLE 9 - DETECTOR SETTINGS

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Detector settings	Reserved	PS_CONF3_H	0x02	Reserved	15	0x0 (0b0)	Should be kept default
	PS_HG			Set the gain of the ADC	14	0x0 (0b0)	x1 gain (default)
						0x1 (0b1)	x2 gain
	PS_GAIN			Set the gain of the ADC	13 : 12	0x0 (0b00)	x4 gain (default)
						0x1 (0b01)	x2 gain
						0x2 (0b10)	x1 gain
						0x3 (0b11)	Reserved
	Reserved			Reserved	11	0x0 (0b0)	Should be kept default
	PD3_EN			PD3 enable setting	10	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PD2_EN			PD2 enable setting	9	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PD1_EN			PD1 enable setting	8	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable

The detector of the proximity sensor consists of the photodiode and the ADC. The detector-related parameters PS_HG, PS_GAIN, PD3_EN, PD2_EN, and PD1_EN in register PS_CONF3_H double or halve the magnitude of proximity counts given the same reflected infrared signal magnitude from the object arrived at the detector. These parameters will help increase the number of counts when a higher dynamic range is needed. Fig. 15 depicts the behavior of the proximity counts when changing the ADC parameters.

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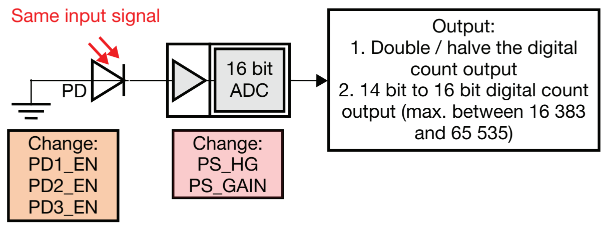

Fig. 15 - The Behavior of the Proximity Counts When Changing the ADC Parameters

PD1_EN / PD2_EN / PD3_EN - This is related to the PD area configuration, where PD3 is twice the size of PD1 and PD2. Please refer to Fig. 18. PD settings can be independently enabled or disabled. PD1_EN and PD2_EN have similar counts, while PD3_EN is double. At least one PD must be enabled to generate counts, and they can be used individually or combined for cumulative counting.

PS_GAIN - This bit sets the gain. When the bit is set to 0, the counts are quadrupled. When combined with PS_HG, if PS_GAIN is set to 0 and PS_HG is set to 1, the counts can be increased to eight times.

PS_HG - This bit sets the sensitivity in the ADC. The counts can be doubled when the bit is set to 1. When combined with PS_GAIN, the count can be increased to eight times when PS_GAIN is set to 0 and PS_HG is set to 1. The actual maximum resolution depends on PS_IT, as shown in Table 10.

TABLE 10 - MAXIMUM BIT RESOLUTION AND DIGITAL OUTPUT COUNTS

BIT NAME		PS_IT = 12.5 μs to 175 μs	PS_IT = 200 μs to 375 μs
PS_HG = 0	PS_GAIN = 00 (x4 gain)	14 bit / 16 383 counts	16 bit / 65 535 counts
	PS_GAIN = 01 (x2 gain)		
	PS_GAIN = 10 (x1 gain)		
PS_HG = 1	PS_GAIN = 00 (x4 gain)		
	PS_GAIN = 01 (x2 gain)		
	PS_GAIN = 10 (x1 gain)		

Note

- Of the three PD_EN settings, at least one must be set to 1, all cannot be 0; it is recommended to enable all (set to 1) to ensure adequate sensitivity

In many applications where the detection range is less than 5 cm, such as presence detection in TWS, AR / VR headsets, and touchless switches, a 14-bit resolution with maximum counts of 16 383 is usually enough to detect two distinct events of “close” and “away”.

Fig. 16 and Fig. 17 show the behavior of the parameters PS_GAIN and PS_HG on the proximity counts. The proximity counts will double with an increase in the gain or sensitivity of the ADC. The combination of double gain and high sensitivity allows the proximity counts to be quadrupled.

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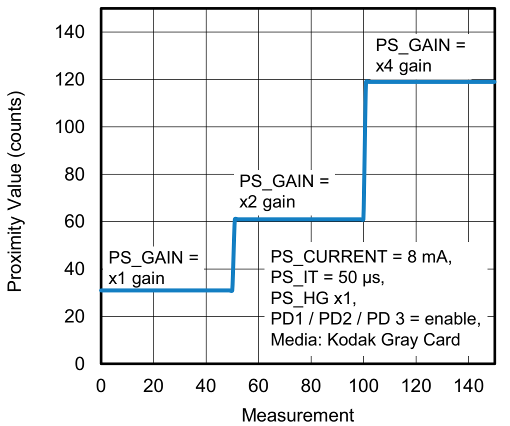

Fig. 16 - The Behavior of the Parameter PS_GAIN on the Proximity Counts

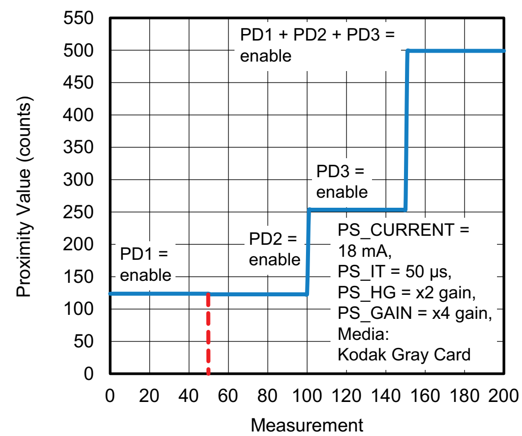

Fig. 18 - The Behavior of the Parameter PD_EN on the Proximity Counts

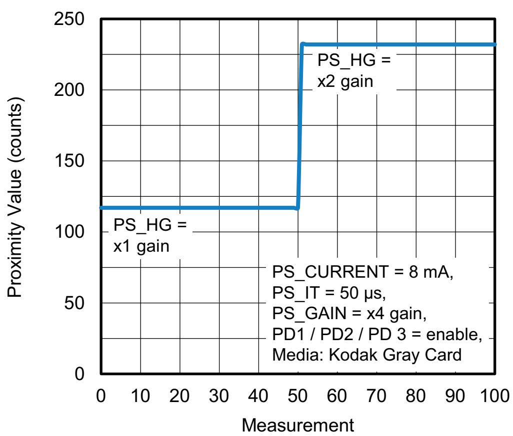

Fig. 17 - The Behavior of the Parameter PS_HG on the Proximity Counts

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4.4 Wait Time Settings

TABLE 11 - WAIT TIME SETTINGS

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Wait time settings	PS_WAIT	PS_CONF2_L	0x01	PS wait time after PS detection	7 : 0	0 to 254	2.5 ms x (PS_WAIT + 1)

PS_WAIT defines the wait time between each detection. In most applications, the wait time between 2.5 ms and 637.5 ms is enough to find a compromise between acceptable performance and low power consumption. A higher measurement rate (shorter wait time) increases the amount of data and decreases the possibility of false detection. However, the sensor will consume more current. The designer could select shorter wait time options in PS_WAIT if a high measurement rate is required. Fig. 19 and Fig. 20 show examples of the wait time setting.

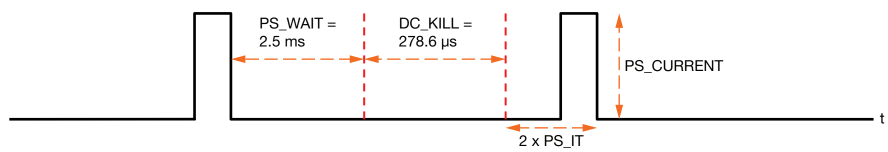

Fig. 19 - Wait Time of 2.5 ms

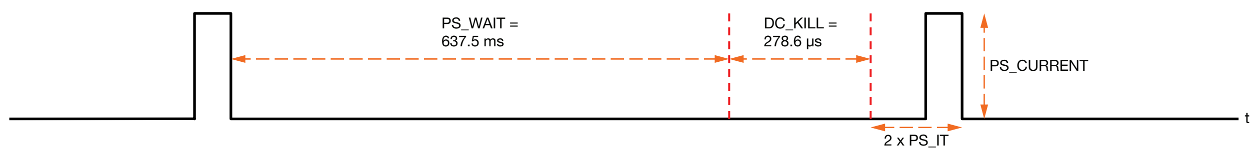

Fig. 20 - Wait Time of 637.5 ms

4.5 Offset Count Cancellation

TABLE 12 - OFFSET COUNT CANCELLATION

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Offset count cancellation	PS_CANC_L	PS_CANC	0x06	Set the offset count cancellation value	7 : 0	0 to 4095	Low byte
	PS_CANC_H				11 : 8		High byte

Crosstalk between the infrared signal from the VCSEL and the photodiode happens when introducing the window cover. This is because part of the light will be reflected back to the sensor due to fresnel reflection. Therefore, it is recommended to perform offset count cancellation by writing the PS_CANC register with the offset counts. Fig. 21 shows the offset count calibration by measuring the offset counts due to window cover, internal crosstalk, and noise. These offset counts can then be written to the register PS_CANC, as shown in Fig. 22. By using this approach, the change in counts is directly influenced by the object and the effect of the part to part tolerance can be reduced.

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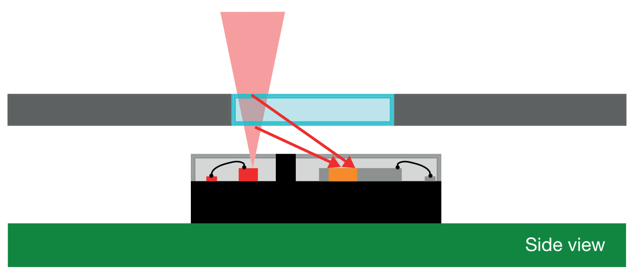

Fig. 21 - Offset Count Calibration

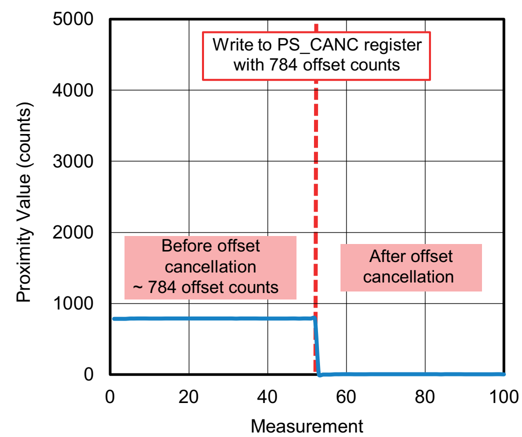

Fig. 22 - Offset Count Cancellation

4.6 Sunlight Cancellation

TABLE 13 - SUNLIGHT CANCELLATION

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Sunlight cancellation	PS_SC_LEVEL	PS_CONF4_H	0x03	Sunlight cancellation level setting cancellation value	11 : 10	0x0 (0b00)	Level 1 (default)
						0x1 (0b01)	Level 2
						0x2 (0b10)	Level 3
						0x3 (0b11)	Level 4
	PS_SC			Enable / disable the sunlight cancellation	9	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable

DC ambient light sources in the wavelength region between 800 nm and 1200 nm, such as sunlight and halogen, cause disturbances in the photodiode and the ADC circuitry. Therefore, the sensor needs to perform cancellation to reduce the noise from these disturbances. The sunlight cancellation PS_SC bit can be enabled to allow the sensor to measure the photocurrent contribution from the DC ambient light sources before driving the infrared signal pulse during the proximity measurement. After the proximity measurement, the sensor deducts the DC noise photocurrent from the total photocurrent. As a result, only the photocurrent due to the reflected signal from the object is converted by the ADC circuitry. This sunlight cancellation mechanism is depicted in Fig. 23.

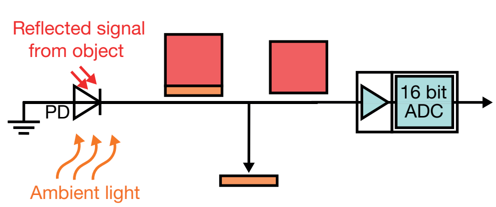

Fig. 23 - Sunlight Cancellation by Using the Active Sunlight Cancellation Current in the VCNL36829UM

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The sensor can perform the cancellation of sunlight up to 250 klux. The sensor then goes into the sunlight protection mode beyond 250 klux of sunlight. Sunlight protection mode is a mode in which the photodiode is in saturation due to high sunlight illuminance. Therefore, the sensor can no longer detect the object and will only output 0 in the PS_DATA register. This can be observed in Fig. 24. If the sunlight protection mode interrupt PS_SP_INT is enabled, the sensor will pull the interrupt line low each time the sensor goes into sunlight protection mode. As a result, the sunlight protection mode interrupt flag PS_SPFLAG changes from 0 to 1. This interrupt flag can be cleared by reading the INT_FLAG register. Therefore, the application should ignore the PS_DATA when it remains 0 and PS_SPFLAG consistently changes to 1 after clearing the INT_FLAG register.

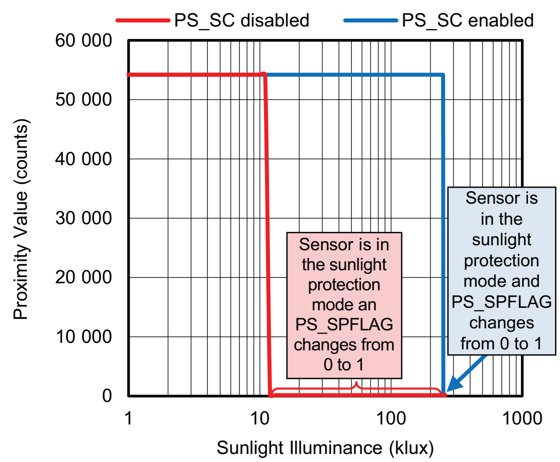

Fig. 24 - The Overall Behavior of the Sunlight Cancellation in the Proximity Sensor With Increasing Sunlight Illuminance

If the PS_SC bit is disabled, the sensor goes into the sunlight protection mode when the illuminance of the sunlight is beyond 10 klux. This can be observed in Fig. 24. When PS_SC_EN is set to 1, PS_SC_LEVEL can be used to select different sunlight cancellation levels. The Table 14 below shows the capability of each sunlight cancellation setting.

TABLE 14 - THE MAXIMUM SUNLIGHT LUX LOAD FOR SUN_LEVEL

Disable	10K
Level 1	90K
Level 2	140K
Level 3	180K
Level 4	250K

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4.7 Interrupt

TABLE 15 - INTERRUPT

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Interrupt	PS_INT	PS_CONF1_H	0x00	Set the interrupt mode setting	15 : 14	0x0 (0b00)	Interrupt disable (default)
						0x1 (0b01)	Logic high / low mode
						0x2 (0b10)	First high
						0x3 (0b11)	Trigger by each high / low threshold event
	PS_PERS			Set the amount of consecutive threshold crossing events necessary to trigger interrupt	13 : 12	0x0 (0b00)	1 time (default)
						0x1 (0b01)	2 times
						0x2 (0b10)	3 times
						0x3 (0b11)	4 times
	PS_SMART_PERS			Enable / disable the smart persistence setting when the interrupt event is triggered	11	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_SP_INT			Enable / disable the sunlight protection mode interrupt setting	10	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_START_INT			After PS_SD disable, PS 1st detection interrupt enable setting	9	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_THDL_L	PS_THDL	0x04	Set the low threshold interrupt value	7 : 0	0 to 65535	Low byte
	PS_THDL_H				15 : 8		High byte
	PS_THDH_L	PS_THDH	0x05	Set the high threshold interrupt value	7 : 0	0 to 65535	Low byte
	PS_THDH_H				15 : 8		High byte
	PS_START_FALG	INT_FLAG	0xF9	PS finish 1st detection after SD disable	11	0x0 (0b0)	No 1st detection flag
						0x1 (0b1)	Finish 1st detection flag
	PS_SPFLAG			Read the sunlight protection mode interrupt event flag	10	0x0 (0b0)	No sunlight protection mode flag
						0x1 (0b1)	Sunlight protection mode flag
	PS_IF_CLOSE			Read the high threshold crossing interrupt event flag	9	0x0 (0b0)	No high threshold crossing interrupt event flag
						0x1 (0b1)	High threshold crossing interrupt event flag
	PS_IF_AWAY			Read the low threshold crossing interrupt event flag	8	0x0 (0b0)	No low threshold crossing interrupt event flag
						0x1 (0b1)	Low threshold crossing interrupt event flag

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The interrupt pin allows the proximity sensor to autonomously send an interrupt signal to the microcontroller when the sensor reading exceeds the high threshold or falls below the low threshold. There are three modes of interrupt in the VCNL36829UM:

- Logic high / low mode
- First high
- Trigger by each high / low threshold event

Besides that, the proximity sensor also provides persistence and smart persistence features, which prevent the occurrence of false detection. The interrupt will only be triggered after a defined consecutive threshold-crossing event.

Logic High / Low Mode

- The interrupt line is pulled low when the proximity counts cross the high threshold, as indicated by the blue line in Fig. 25
- The interrupt line is pulled high when the proximity counts cross the low threshold, as indicated by the purple line in Fig. 25
- If the count is equal to the threshold, it cannot be triggered, as shown by the orange circles in Fig. 25
- Consecutive high threshold events cannot be triggered until the proximity count crosses the low threshold first, and vice versa, as shown by the green circles in Fig. 25
- Logic mode allows the proximity sensor to autonomously send an interrupt signal to the microcontroller directly without the need to read the INT_FLAG register

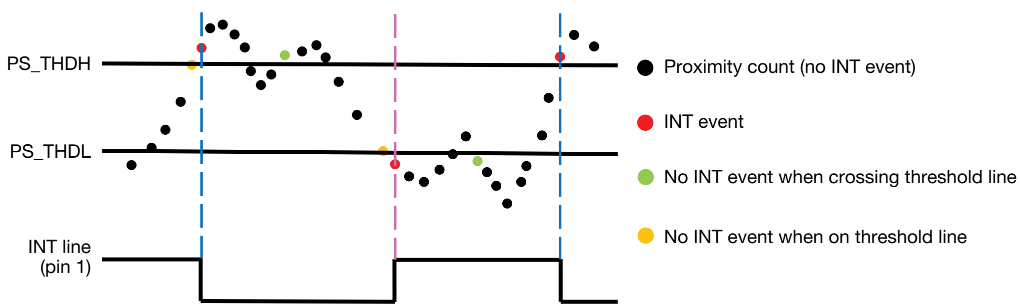

Fig. 25 - The Behavior of the INT Line (pin 1) Using Logic High / Low Mode With PS_PERS = 1

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Trigger by Each High / Low Threshold Event

- The interrupt line is pulled low when the proximity counts cross the high or low threshold, as indicated by the red circle in Fig. 26
- If the count is equal to the threshold, it cannot be triggered, as shown by the orange circles in Fig. 26
- The first interrupt event can be either a high or low threshold crossing event
- The interrupt flags PS_IF_CLOSE and PS_IF_AWAY change from 0 to 1 when the proximity counts cross the high and low thresholds, respectively
- The interrupt flag PS_IF_CLOSE or PS_IF_AWAY can be cleared by reading the INT_FLAG register, as indicated by the blue line in Fig. 26

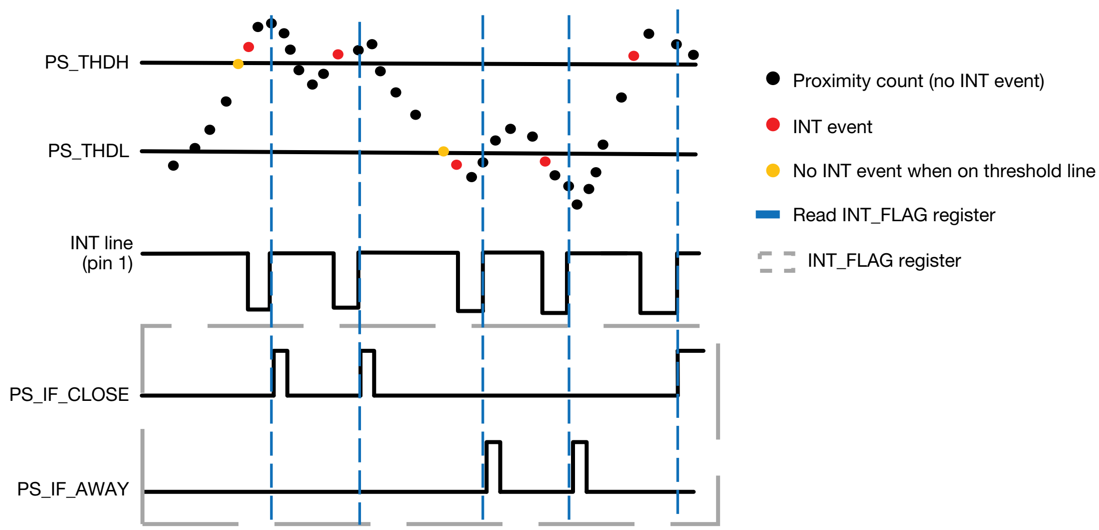

Fig. 26 - The Behavior of the INT Line (pin 1) and INT_FLAG Register Using the Trigger by Each High / Low Threshold Event With PS_PERS = 1

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First High

- The interrupt line is pulled low when the proximity counts cross the high or low threshold, as indicated by the red circle in Fig. 27
- Consecutive events can be triggered until the proximity count crosses the threshold first, as shown by the green circles in Fig. 27
- If the count is equal to the threshold, it cannot be triggered, as shown by the orange circles in Fig. 27
- The first interrupt event can be either a high or low threshold crossing event
- The interrupt flags PS_IF_CLOSE and PS_IF_AWAY change from 0 to 1 when the proximity counts cross the high and low thresholds, respectively
- The interrupt flag PS_IF_CLOSE or PS_IF_AWAY can be cleared by reading the INT_FLAG register, as indicated by the blue line in Fig. 27

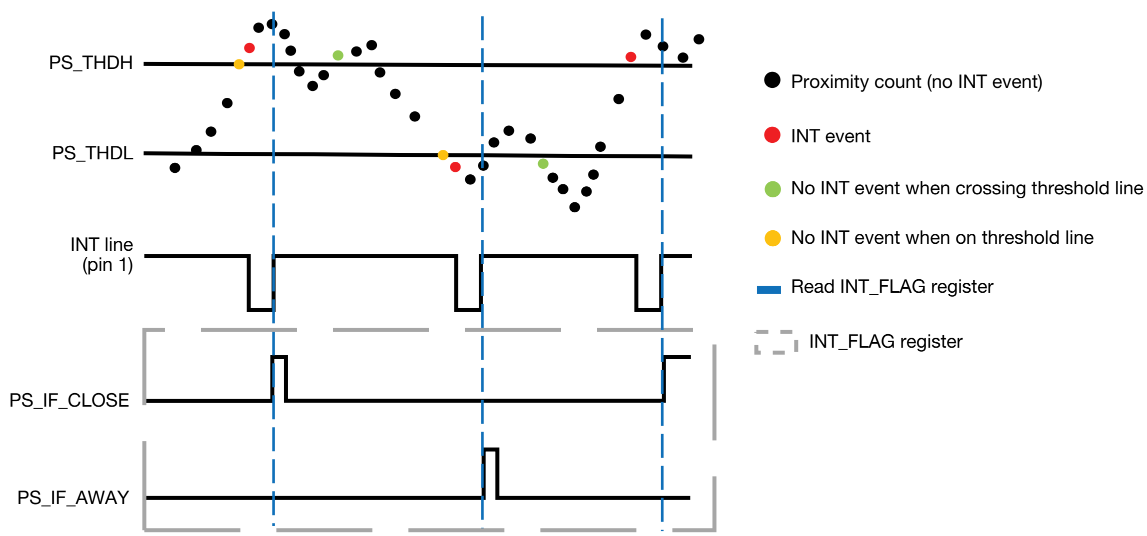

Fig. 27 - The Behavior of the INT Line (pin 1) and INT_FLAG Register Using the First High With PS_PERS = 1

Persistence and Smart Persistence Mode

PS_PERS determines the number of consecutive threshold-crossing events required to trigger an interrupt. When PS_PERS is set between 2 and 4, three additional measurements are taken after the initial threshold crossing event to confirm the persistence of the crossing, ensuring false detections are minimized. The interrupt is only triggered after the number of consecutive threshold-crossing events, as specified by the PS_PERS setting, has been reached. This applies to all interrupt modes. Fig. 28 illustrates the behavior of the INT line (pin 1) with a measurement period as defined by the red line formula, where the period equals PS_WAIT + DC_KILL + (2 × PS_IT). Fig. 28 also shows how the INT line performs under different PS_PERS settings. For example, when PS_PERS is set to 2, the interrupt is pulled low after the second threshold-crossing measurement out of the four measurements following the initial threshold-crossing event. The same logic applies to other PS_PERS settings.

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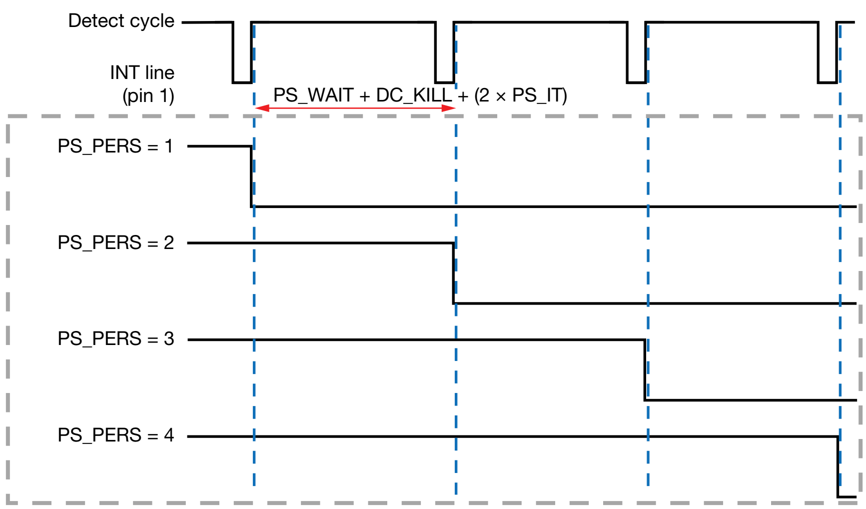

Fig. 28 - The Behavior of the INT Line (pin 1), Disabled PS_SMART_PERS, and all PS_PERS

When smart persistence (PS_SMART_PERS) is enabled after the first threshold event occurs, three consecutive rapid measurements are taken. After the third measurement, the system resumes its regular measurement period. The intervals between these measurements are depicted by the green line in the figure, and the interval is 1.4 ms. Fig. 29 shows the behavior of the INT line (pin 1), where the measurement period follows the red line formula in the figure, with the period equal to PS_WAIT + DC_KILL + (2 × PS_IT). Fig. 29 also illustrates how the INT line performs under different PS_PERS settings. For example, when PS_PERS is set to 3, the interrupt is pulled low after the third consecutive rapid measurement that crosses the threshold. The same logic applies to other PS_PERS settings.

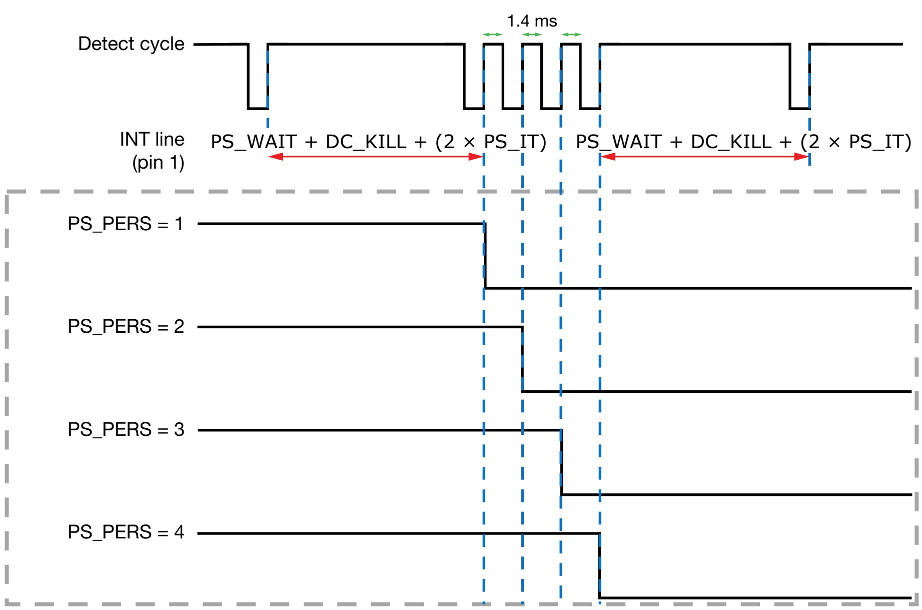

Fig. 29 - The Behavior of the INT Line (pin 1), Enabled PS_SMART_PERS, and all PS_PERS

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PS INT Response Time

Disabled PS_SMART_PERS:

$$\text{Response time (ms)} = \text{PS\_PERS} \times (\text{PS\_WAIT} + \text{DC\_KILL} + (2 \times \text{PS\_IT}))$$

Enabled PS_SMART_PERS:

$$\text{Response time (ms)} = (\text{PS\_PERS - 1}) \times (1.4 + \text{total time}) + (\text{PS\_WAIT} + \text{DC\_KILL} + (2 \times \text{PS\_IT}))$$

$$\text{Total time} = \text{DC\_KILL} + (2 \times \text{PS\_IT})$$

Sunlight Protection Mode

The sensor enters the sunlight protection mode when the photodiode is in saturation due to very high sunlight illuminance. Therefore, the sensor can no longer detect the object and will only output 0 in the PS_DATA register. The application can detect this situation by enabling PS_SP_INT and reading the PS_SPFLAG when the interrupt line has been pulled low and PS_DATA suddenly goes into 0 to confirm this situation.

PS Start Interrupt

- The interrupt line is pulled low when finished with the first detection after PS_SD disable, as indicated by the blue line in Fig. 30
- The interrupt flag PS_START_FLAG can be cleared by reading the INT_FLAG register, as indicated by the purple line in Fig. 30

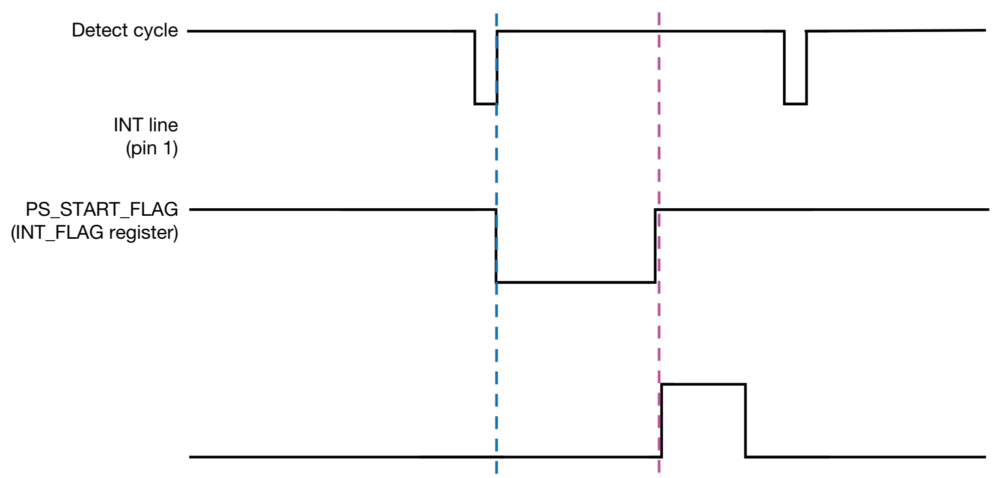

Fig. 30 - The Behavior of the INT Line (pin 1), Enabled PS_START_INT and INT_FLAG Register

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4.8 Readout Registers

<table>
<tr><th colspan="8">TABLE 16 - READOUT REGISTERS</th></tr>
<tr><th>REGISTER GROUP</th><th>BIT NAME</th><th>REGISTER NAME</th><th>COMMAND CODE</th><th>FUNCTION</th><th>BIT</th><th>VALUE</th><th>DESCRIPTION</th></tr>
<tr><td rowspan="5">Readout registers</td><td>PS_DATA_L</td><td rowspan="2">PS_DATA</td><td rowspan="2">0xF8</td><td rowspan="2">Read the proximity output data</td><td>7 : 0</td><td rowspan="2">0 to 65 535</td><td>Low byte</td></tr>
<tr><td>PS_DATA_H</td><td>15 : 8</td><td>High byte</td></tr>
<tr><td>VCNL36829UM_ID_L</td><td rowspan="3">VCNL36829UM_ID</td><td rowspan="3">0xFA</td><td rowspan="3">Read the device ID</td><td>7 : 0</td><td>0x29 (0b00101001)</td><td>Should be kept default</td></tr>
<tr><td rowspan="2">VCNL36829UM_ID_H</td><td rowspan="2">15 : 8</td><td>0x00 (0b00000000)</td><td>Device with a slave address of 0x60</td></tr>
<tr><td>0x10 (0b00010000)</td><td>Device with a slave address of 0x51</td></tr>
</table>

The VCNL36829UM has two readout registers, which are PS_DATA and VCNL36829UM_ID. PS_DATA is the 16-bit register in which the proximity counts data will be stored after each measurement. The register can be read via the I^2C communication from a microcontroller. There are two methods of reading the register PS_DATA:

- Data polling - continuously reading the register PS_DATA
- Interrupt - read the register PS_DATA after the INT line (pin 1) has been triggered

Depending on the application's requirements, the interrupt method is recommended to reduce power consumption.

On the other hand, VCNL36829UM_ID is the register in which the device ID is stored. This allows the sensor to be identified with a specific slave address depending on the connection of pins 5 and 6 of the sensor with the microcontroller. Therefore, the register VCNL36829UM_ID can be a good first register to read when first communicating with the sensor to test the I^2C communication and to check the slave address.

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5. I²C AND TIMING

5.1 I²C Write and Read Protocol

The communication with the VCNL36829UM can be performed via I²C. The I²C write and read protocol when communicating with the proximity sensor is shown in Fig. 31.

Fig. 31 - I²C Write and Read Protocol

It is imperative that only the restart condition for the I²C read is implemented instead of the stop and restart condition. For example, Fig. 32 shows a logic analyzer screenshot of the SCL (pin 5) and SDA line (pin 6) when reading the register VCNL36829UM_ID for the VCNL36829UM with a slave address of 0x60. Here, the restart condition, indicated by the blue box, has been implemented and the low data byte of 0x29 matches the device ID stated in the datasheet for the VCNL36829UM with the slave address of 0x60.

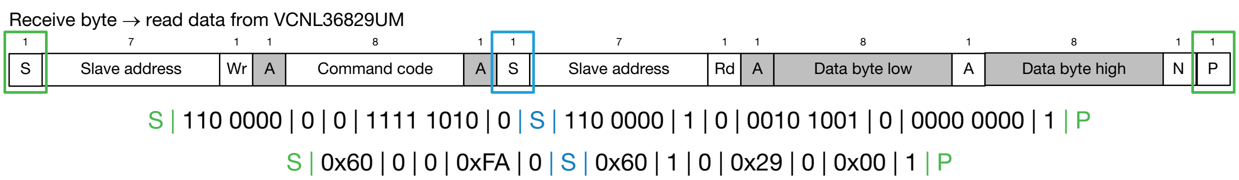

Fig. 32 - The Correct I²C Read When Reading the Register VCNL36829UM_ID With a Restart Condition

5.2 Timing

5.2.1 Proximity Measurement Timing

One active measurement period for both depends on the register settings PS_IT, as well as DC_KILL, as shown below:

$$t_{\text{measurement, active}} = 1.2 \times (\text{DC\_KILL} + (2 \times \text{PS\_IT}))$$

Factor 1.2 is included in the equation above to consider the part to part tolerance of 20 %. On the other hand, the term DC_KILL is the process where the sensor measures the DC noise in the background before the actual measurement pulse from the VCSEL is emitted. This DC noise signal will then be deducted from the total reflected signal.

Example - Active Measurement Time

For example, given PS_IT = 25 μs, the total active measurement time can be calculated as follows:

$$t_{\text{measurement, active}} = 1.2 \times (278.6\ \mu\text{s} + (2 \times 25\ \mu\text{s})) = 394\ \mu\text{s}$$

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5.2.2 Timing Specification

Fig. 33 and Fig. 34 show the timing specification for the auto and active force modes, respectively.

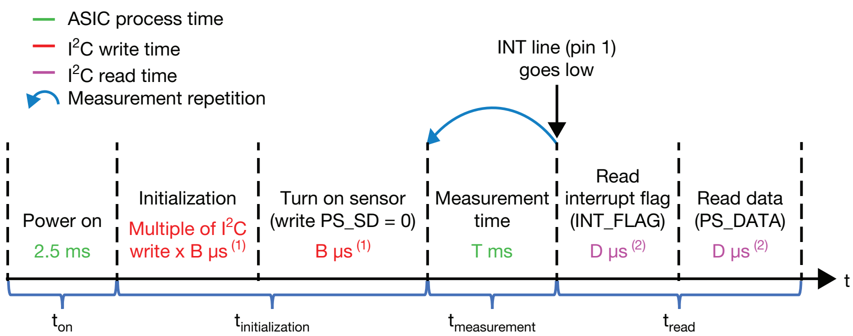

Fig. 33 - Timing Specification for the Auto Mode

Notes

(1) B µs - The parameter B refers to the time taken for a complete write I²C protocol. This depends on the selected I²C mode. Please refer to Table 17

(2) D µs - The parameter D refers to the time taken for a complete read I²C protocol. This depends on the selected I²C mode. Please refer to Table 17

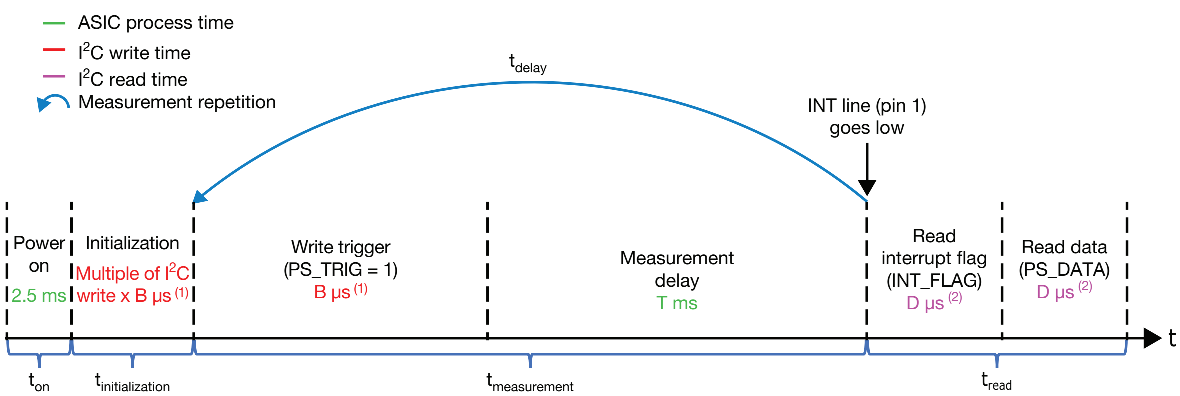

Fig. 34 - Timing Specification for the Active Force Mode

Notes

(1) B µs - The parameter B refers to the time taken for a complete write I²C protocol. This depends on the selected I²C mode. Please refer to Table 17

(2) D µs - The parameter D refers to the time taken for a complete read I²C protocol. This depends on the selected I²C mode. Please refer to Table 17

A measurement delay equal to the active measurement time is required for the measurement to be completed after the trigger of the active force mode. The delay depends on the register settings of PS_IT. The required delay is:

$$\text{Measurement delay} = t_{\text{measurement, active}} = (1.2 \times \text{DC\_KILL} + (2 \times \text{PS\_IT}))$$

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Factor 1.2 in the equation is needed to consider the 20 % part to part tolerance of the measurement.

The individual I^2C write and read time per byte depends on the I^2C mode, as shown in Table 17:

TABLE 17 - I^2C WRITE AND READ PROTOCOL TIME PER BYTE

I^2C MODE	CLOCK FREQUENY (kHz) (1)	I^2C WRITE PROTOCOL TIME (μs) (2)	I^2C READ PROTOCOL TIME (μs) (2)
Standard	100	400	500
Fast	400	100	125

Notes

(1) Maximum limit

(2) Typical value with tolerance; it could vary depending on master

Example - Auto Mode With Standard I^2C Mode

Table 18 shows an example of the timing specification for the auto mode when initializing seven registers, as well as when turning on the sensor. The sensor needs approximately 5.7 ms for the total initialization phase. The exact timing depends on the I^2C clock configuration from the master and the number of registers written. On the other hand, the sensor needs one measurement period to complete a measurement. In the case of when a PS_WAIT of 2.5 ms and PS_IT of 100 μs has been selected, the measurement time is 3 ms. In many cases, the application uses the interrupt method to read the sensor and reduce power consumption. In this case, once the INT line (pin 1) has been pulled low, the interrupt service routine in the microcontroller will be executed and the microcontroller will then read the register INT_FLAG to clear the interrupt flag. The register PS_DATA will then be read. Both reading processes will each need 0.5 ms for the standard I^2C mode. Therefore, the total measurement time is 4 ms.

TABLE 18 - TIMING SPECIFICATION EXAMPLE FOR AUTO MODE AND STANDARD I^2C MODE

PARAMETER	REGISTER	REMARKS	TIME (ms)
t_{on}	-	The power on reset after the V_{DD} pin is connected to the power supply	2.5
$t_{initialization}$	PS_CONF1_L/H	Write the sensor settings	0.4
	PS_CONF2_L/H		0.4
	PS_CONF3_L/H		0.4
	PS_CONF4_L/H		0.4
	PS_CONF5_L/H		0.4
	PS_THDL_L/H	Write the low threshold setting	0.4
	PS_THDH_L/H	Write the high threshold setting	0.4
	PS_CONF1_L/H	Turn on the sensor by writing PS_SD = 0	0.4
$t_{initialization\_total}$	-	-	5.7
$t_{measurement}$	-	Actual measurement time depends on the selected PS_WAIT and PS_IT; here is an example of when PS_WAIT = 2.5 ms, PS_IT = 100 μs	3
t_{read}	INT_FLAG	Read the interrupt flag	0.5
	PS_DATA	Read the proximity data	0.5
$t_{measurement\_total}$	-	-	4

Notes

(1) Standard I^2C mode comes with a 100 kHz clock frequency. One can approximate the time taken for a complete write and read I^2C protocol to be 400 μs and 500 μs per byte, respectively. Please refer to Table 17

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6. PROXIMITY MEASUREMENT

6.1 Software Flow Chart for the Proximity Measurement

Fig. 35 shows a typical software flow chart for the proximity measurement using the auto mode and enabled interrupt. The measurement starts with the initialization code. Please note that the provided sensor initialization code is just an example. In practice, the designer should change the initialization code based on the application's requirements. After the initialization, the sensor should perform the offset count cancellation by reading the proximity count without the object. This offset count should then be written to the offset cancellation register PS_CANC. After writing the cancellation register, the sensor should perform proximity measurement in a loop. Next, the microcontroller should wait for the interrupt line to be pulled low via an interrupt service routine. When the interrupt has been pulled low, the interrupt flag register and the proximity data will be read.

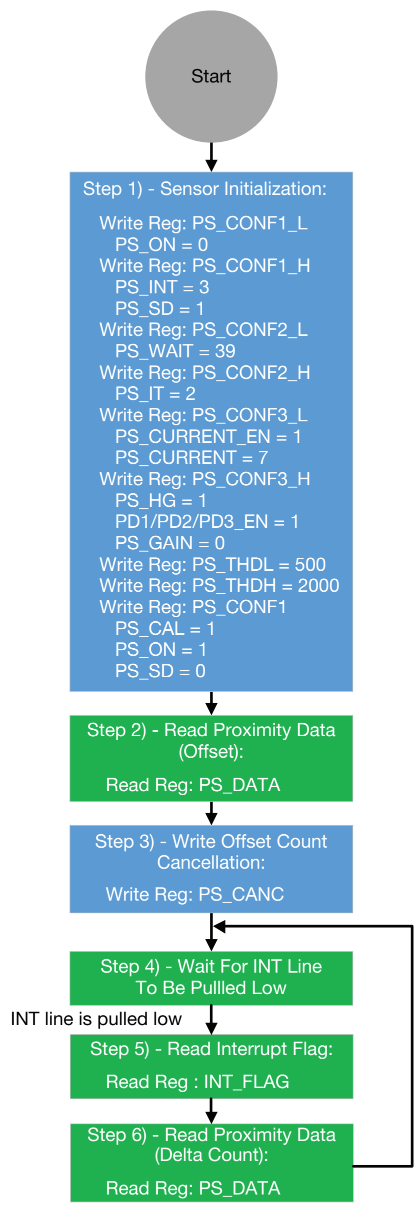

Fig. 35 - Typical Software Flow Chart for the Auto Mode

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6.2 Proximity Value vs. Distance Curve

The behavior of the proximity sensor can be characterized by the proximity value against the distance. In some applications, the sensor will not be placed underneath a window cover. The designer could then use the proximity value against the distance for the case without the window cover as a reference. On the other hand, most applications will have the requirement of placing the sensor underneath a window cover. Here, the proximity value against the distance for the case with the window cover can be used as a reference. The designer can expect a decrease in the dynamic range due to the increase of crosstalk from the window cover.

6.2.1 Proximity Value vs. Distance Curve Without a Window Cover

Fig. 36 and Fig. 37 show the typical proximity counts output against distance for three different driving currents and two integration times. Here, the measured reference object medium is the Kodak Gray Card. This card has approximately 18 % reflectivity at 940 nm. The sensor can detect up to 5 cm with a minimum of 960 delta counts when measuring with the Kodak Gray Card and when higher sensor settings of PS_IT = 200 μs and PS_CURRENT = 18 mA have been selected. The dashed red line indicates this in Fig. 37. The minimum of 960 delta counts is usually enough to consider the sensor's tolerance of around ± 20 % and account for the noise from the disturbing sources.

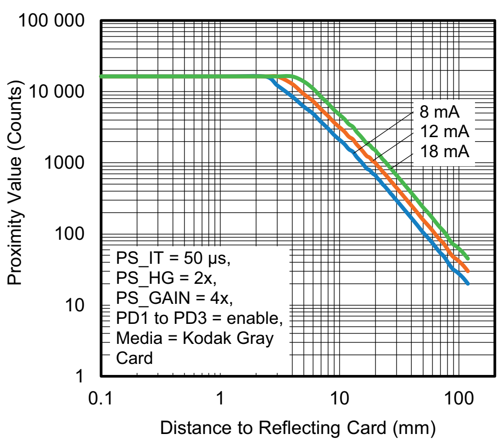

Fig. 36 - Proximity Value vs. Distance; PS_IT = 50 μs (14 bit)

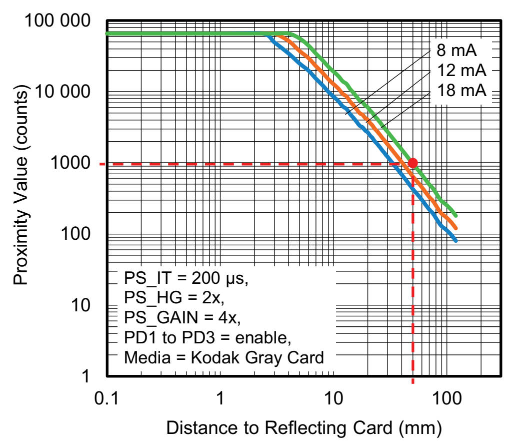

Fig. 37 - Proximity Value vs. Distance; PS_IT = 200 μs (16 bit)

While the Kodak Gray Card is used as a reference, in practice, the proximity values change with the different objects' reflectivity at the same distance. Therefore, the designer should consider this effect during the design phase.

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6.3 Temperature Behavior

When designing the VCNL36829UM for the end application, the temperature behavior of the proximity counts should also be considered. Fig. 38 shows the average relative proximity counts against ambient temperature of the VCNL36829UM.

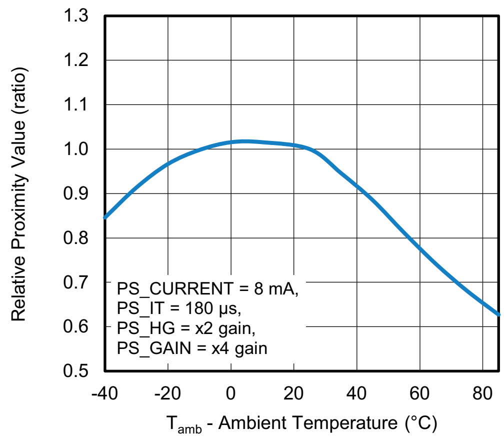

Fig. 38 - Average Relative Proximity Counts vs. Ambient Temperature of the VCNL36829UM

The sensor has a negative temperature coefficient as the temperature increases from room temperature to 85 °C. The designer should consider this behavior and design the end application with enough headroom for the proximity count's fluctuation with temperature.

Another good design approach to reduce the effect of the proximity count's fluctuation due to temperature is regular calibration without an object. One can observe that the change in proximity counts with temperature happens slower than the change in proximity counts with changing distance of an object. By observing the increase or decrease of offset counts, the system can recognize that as the change of temperature and proximity correction could be implemented.

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7. AVERAGE CURRENT CONSUMPTION

The VCNL36829UM proximity sensor has been developed for battery-powered devices such as true wireless stereo (TWS) earbuds, smart watches, etc. The designer needs to compromise between the performance and current consumption for such applications.

Fig. 39 shows the current consumption components through the pins.

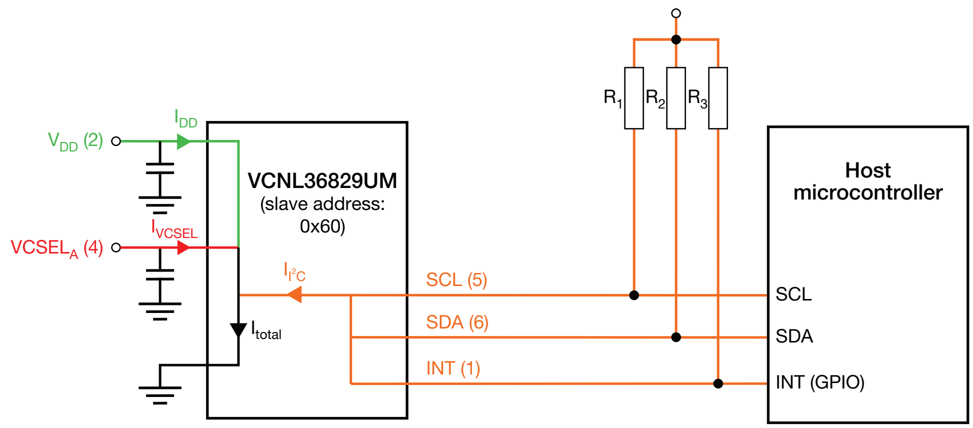

Fig. 39 - Current Consumption Components Through the Pins

The general total current consumption can be calculated as follows:

$$I_{total} = I_{DD} + I_{VCSEL} + I_{I^2C}$$

The main current components are from I_{DD} and I_{VCSEL}. The current contribution from I_{I^2C} for I^2C communication is negligible if the interrupt is activated. However, if the polling mode is used, the current contribution from these pins should be considered in the calculation.

Fig. 40 shows the current consumption profile of the VCNL36829UM.

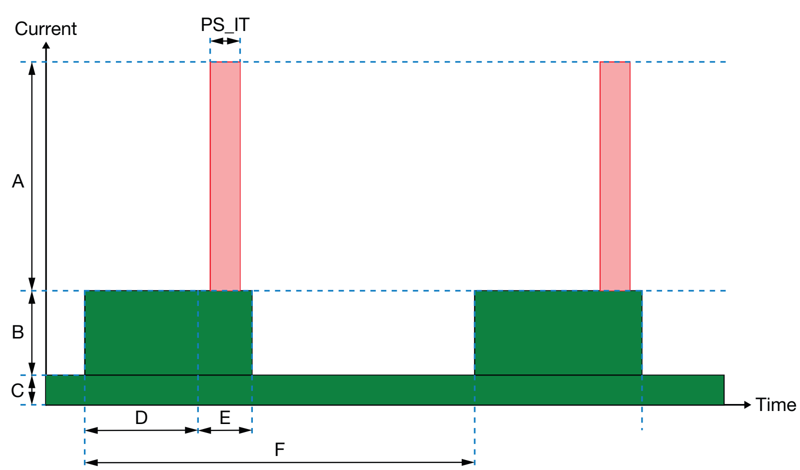

Fig. 40 - Current Consumption Profile of the VCNL36829UM

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Table 19 describes the parameters of the current consumption profile in Fig. 40.

TABLE 19 - AVERAGE CURRENT CONSUMPTION PARAMETER			
PARAMETER	PARAMETER NAME	VALUE	DESCRIPTION
A	I_{VCSEL}	8 mA to 18 mA	The magnitude of I_{VCSEL} depends on the selected PS_CURRENT setting; this current is drawn by the pin $VCSEL_A$
B	I_{DD} (Active)	310 μA	I_{DD} (active) is the supply current consumed during the active state by the pin V_{DD}
C	I_{DD} (Idle)	5 μA	I_{DD} (idle) is the supply current consumed during the idle state by the pin V_{DD}
D	DC_KILL	278.6 μs	DC_KILL is the period where the sunlight and DC noise cancellation happens
E	Proximity measurement pulse	2 x PS_IT	Proximity measurement is the duration in which the sensor sends the VCSEL pulse/s; the values depend on PS_IT
D + E (1)	Active measurement period	DC_KILL + (2 x PS_IT)	The active measurement period is the duration during which the sensor performs the complete proximity measurement, which consists of DC_KILL and proximity measurement pulse
F	Measurement period	DC_KILL + (2 x PS_IT) + PS_WAIT	The measurement period in which the measurement is repeated, which depends on the selected PS_IT and PS_WAIT setting

Note

(1) The active measurement period could have ± 20 % part to part tolerance, which is not considered here

A low current consumption can be achieved in the VCNL36829UM due to a low supply current of 5 μA during the idle state. When the sensor is switched on, it will always consume 5 μA. This is indicated by the parameter "C" in Fig. 40 over the whole time, as long as the sensor is switched on. During the active measurement period, as indicated by the parameters "D" and "E", the sensor consumes an additional current of 310 μA on top of 5 μA. Besides that, during the active measurement period, the sensor will emit a short current pulse PS_CURRENT with a duration of PS_IT.

The average current consumption over the measurement period in the VCNL36829UM with interrupt mode can be calculated as follows:

$$I_{average} = I_{DD}(idle) + \frac{((DC\_KILL + (2 \times PS\_IT)) \times I_{DD}(active)) + (PS\_IT \times PS\_CURRENT)}{DC\_KILL + (2 \times PS\_IT) + PS\_WAIT}$$

Example - Average Current Consumption Calculation

Table 20 shows the average current consumption example for PS_IT = 25 μs for different PS_WAIT and PS_CURRENT.

TABLE 20 - AVERAGE CURRENT CONSUMPTION															
PS_IT (μs)	PS_CURRENT (mA)	PS_WAIT (ms)													
		2.5	50	100	150	200	250	300	350	400	450	500	550	600	637.5
25	8	111.7	11.0	8.0	7.0	6.5	6.2	6.0	5.9	5.8	5.7	5.6	5.5	5.5	5.5
25	10	129.4	12.0	8.5	7.3	6.8	6.4	6.2	6.0	5.9	5.8	5.7	5.6	5.6	5.6
25	12	147.1	13.0	9.0	7.7	7.0	6.6	6.3	6.1	6.0	5.9	5.8	5.7	5.7	5.6
25	14	164.7	14.0	9.5	8.0	7.3	6.8	6.5	6.3	6.1	6.0	5.9	5.8	5.8	5.7
25	16	182.4	15.0	10.0	8.3	7.5	7.0	6.7	6.4	6.3	6.1	6.0	5.9	5.8	5.8
25	18	200.1	16.0	10.5	8.7	7.8	7.2	6.8	6.6	6.4	6.2	6.1	6.0	5.9	5.9

For example, given PS_IT = 25 μs, PS_WAIT = 100 ms, and PS_CURRENT = 8 mA, the average current consumption with negligible I_{I^2C} can be calculated as follows:

$$I_{average} = 5\ \mu A + \frac{((278.6\ \mu s + (2 \times 25\ \mu s)) \times 310\ \mu A) + (25\ \mu s \times 8\ mA)}{278.6\ \mu s + (2 \times 25\ \mu s) + 100\ ms} = 8\ \mu A$$

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Table 21 shows the average current consumption example for PS_IT = 200 μs for different PS_WAIT and PS_CURRENT.

TABLE 21 - AVERAGE CURRENT CONSUMPTION

PS_IT (μs)	PS_CURRENT (mA)	PS_WAIT (ms)													
		2.5	50	100	150	200	250	300	350	400	450	500	550	600	637.5
200	8	574.5	40.7	23.0	17.0	14.0	12.2	11.0	10.2	9.5	9.0	8.6	8.3	8.0	7.8
200	10	700.4	48.6	27.0	19.7	16.0	13.8	12.4	11.3	10.5	9.9	9.4	9.0	8.7	8.5
200	12	826.2	56.5	30.9	22.3	18.0	15.4	13.7	12.4	11.5	10.8	10.2	9.7	9.3	9.1
200	14	952.1	64.4	34.9	25.0	20.0	17.0	15.0	13.6	12.5	11.7	11.0	10.5	10.0	9.7
200	16	1077.9	72.3	38.9	27.6	22.0	18.6	16.3	14.7	13.5	12.6	11.8	11.2	10.7	10.3
200	18	1203.8	80.2	42.8	30.3	24.0	20.2	17.7	15.9	14.5	13.5	12.6	11.9	11.3	11.0

8. MECHANICAL AND OPTICAL DESIGN

As light waves propagate through space, they naturally spread out. This phenomenon also occurs with the infrared light emitted by the VCSEL, which broadens as it moves farther from the sensor. Consequently, the diameter of the window cover must be carefully adjusted to meet the minimum size requirements, ensuring that the opaque housing does not obstruct the infrared signal. This minimum diameter is influenced by the distance between the top of the cover and the top of the sensor, the emission angle of the VCSEL, and the photodiode's field of view.

Typically, the window diameter needs to increase as the distance from the sensor increases. The VCSEL in the sensor emits light with an angle of ± 4.5°. Conversely, the photodiode in the sensor has a half-sensitivity angle of ± 60° in the X-axis or the Y-axis direction. These angles are illustrated in Fig. 41 and Fig. 42.

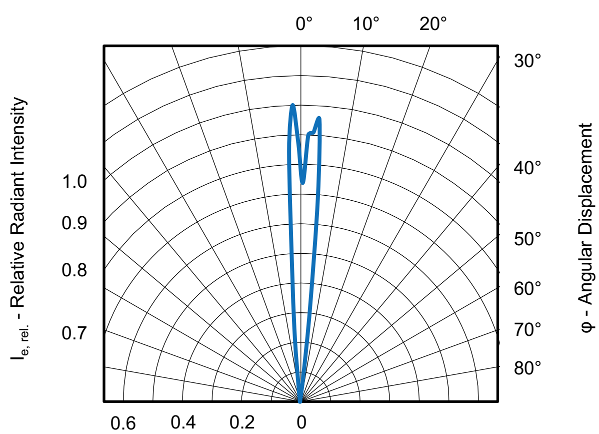

Fig. 41 - Relative Sensitivity vs. Angular Displacement of the VCSEL in the VCNL36829UM

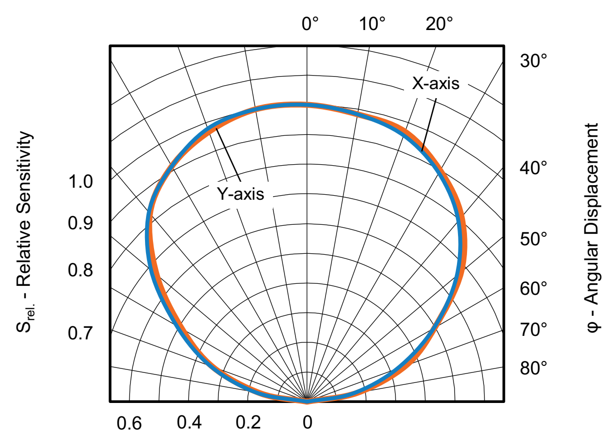

Fig. 42 - Relative Sensitivity vs. Angular Displacement of the Photodiode in the VCNL36829UM

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Window Design

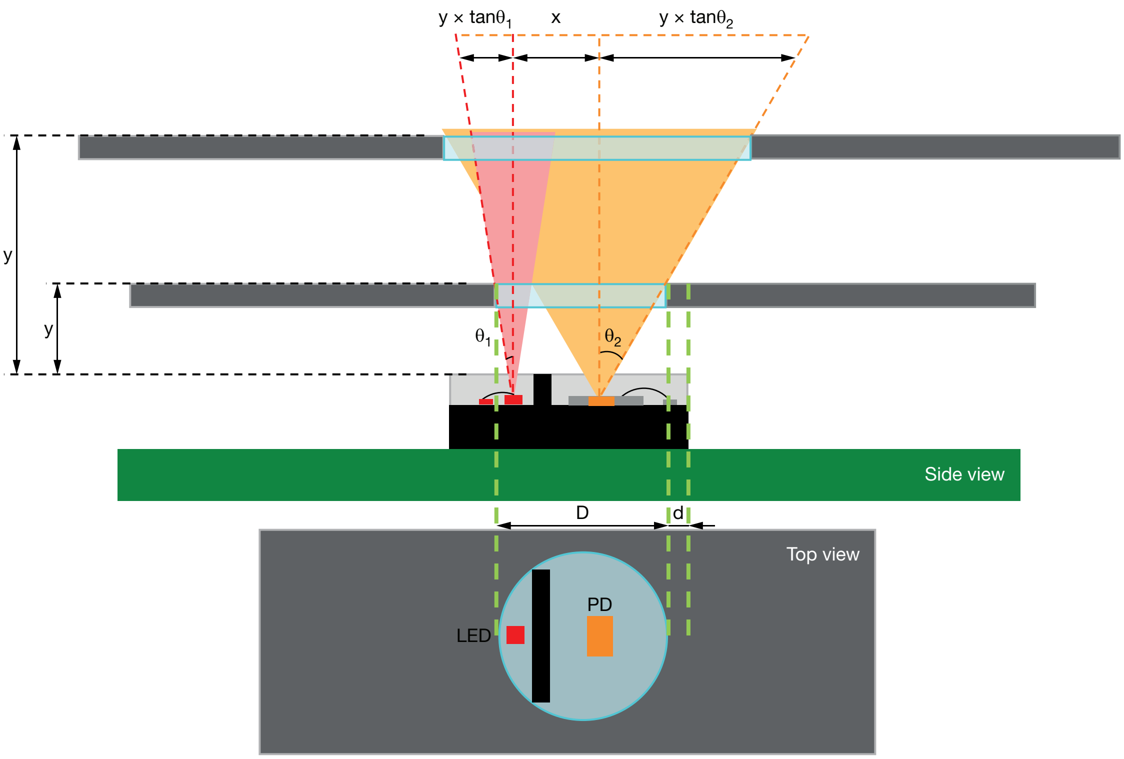

Fig. 43 - The Calculation of the Window Cover Diameter With an Air Gap

Explanation of Variables

- x: this represents the distance between the center of the VCSEL and the center of the photodiode (PD). In Fig. 43, this is the horizontal distance between the red and orange blocks. The value of x is given as 0.85 mm, which includes the mechanical placement tolerance of the VCSEL and photodiode within the sensor package
- y: this is the distance from the top of the window cover to the top of the sensor. It represents the vertical distance between the black line at the top (which marks the position of the window cover) and the top of the sensor. This is an important parameter, as it determines the necessary window cover size to avoid blocking the infrared signal
- θ1: this angle represents the emission angle of the VCSEL. It is the angle between the red dashed line (indicating the direction of the emitted signal) and the vertical axis. Fig. 43 suggests that θ1 should ideally be 4.5°, but a larger angle (e.g., 10°) may be used to account for mechanical tolerance and ensure proper signal transmission
- θ2: this angle represents the field of view of the photodiode (PD). It is the angle between the orange dashed line (indicating the field of view) and the vertical axis. Fig. 43 shows this as an angle that allows the photodiode to capture the reflected infrared signal from the object. The recommended value is θ2 = 50°, though the photodiode's total field of view is ± 60°
- d: represents the distance between the edge of the package near the photodiode (PD) and the window cover. This distance assists with alignment during assembly

Calculation of Minimum Window Cover Diameter D

The minimum window cover diameter D can be calculated using the following formulas:

$$D = y \times \tan\theta_2 + x + y \times \tan\theta_1$$

This formula considers both the emission angle θ1 and the field of view θ2 to determine the necessary window cover diameter, ensuring that the infrared signal is not blocked during either emission or reception.

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Calculation of Minimum Distance d

The distance between the photodiode (PD) and the edge of the package can be calculated using the following formula:

$$d = 0.48 - y \times \tan\theta_2$$

When y exceeds 0.4 mm, d becomes negative, indicating that the edge of the window will be on the right side of the package. Conversely, if d is positive, the edge of the window will be on the left side of the package.

Additional Considerations

The placement of the window cover directly on top of the sensor is usually preferred, as this avoids the sensor's peak sensitivity area and helps reduce crosstalk. However, achieving this during assembly can be challenging due to mechanical tolerance, which often results in an air gap. If an air gap is present, it should ideally be less than 1 mm to minimize its impact on the sensor's performance.

TABLE 22 - MINIMUM WINDOW COVER DIAMETER

y (mm)	D (mm)	d (mm)
0.5	1.53	0.12
1.0	2.22	0.71
1.5	2.90	1.31
2.0	3.59	1.90
2.5	4.27	2.50
3.0	4.95	3.10
3.5	5.64	3.69
4.0	6.32	4.29

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