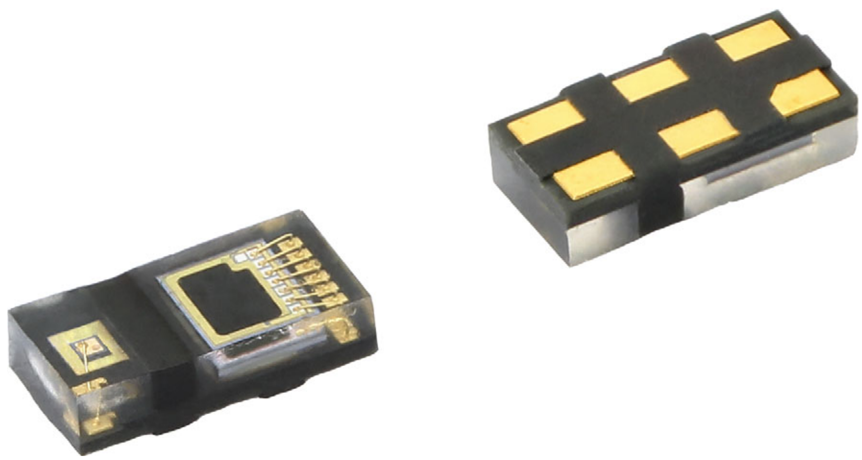
Designing the VCNL36828P Into an Application

By Hakimi Wan Yusof



ABSTRACT

This application note provides an introduction to the functionality of the VCNL36828P sensor, application circuits, and mechanical design considerations.

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1. INTRODUCTION

The VCNL36828P 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 VCNL36828P 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 20 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
- Presence detection in VR / AR headsets and smart glasses
- Presence detection in smartwatches
- Touchless button / dispensing

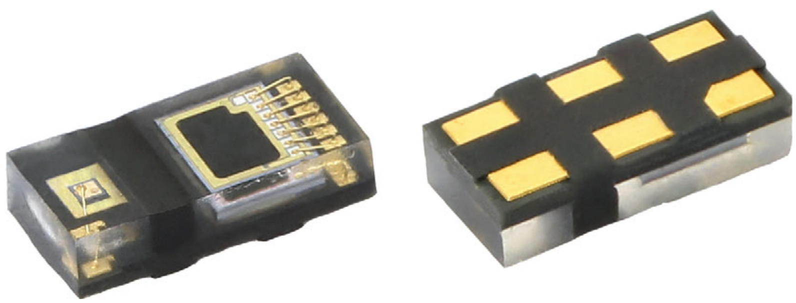

Fig. 1 - VCNL36828P

KEY BENEFITS OF USING VCNL36828P	
BENEFITS	**DESCRIPTION**
Small package for a tight space requirement	Very small 2.0 x 1.0 x 0.5 (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	1.8 V rated power supply and I^2C bus reduce the power consumption
	The low idle current of 5 μA allows a lower average current consumption
	The use of VCSEL instead of IRED allows a lower driving current with comparable performance
Superior proximity detection	The proximity sensor can detect up to 20 cm distance
	The proximity sensor supports sunlight cancellation up to 140 klx of sunlight
Smart dual slave address	Smart dual slave address allows the connection of up to two proximity sensors with a microcontroller without needing an I^2C 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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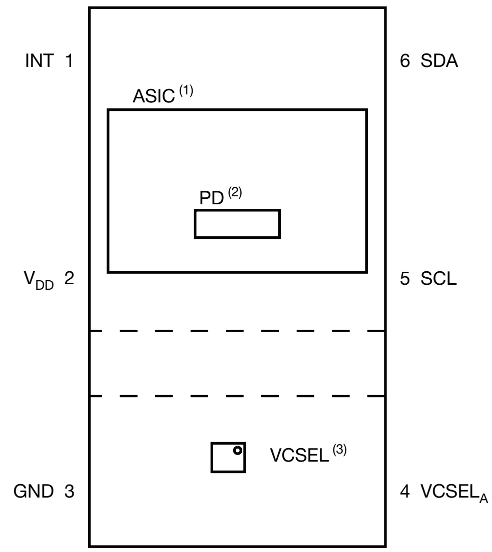
2. PIN DESCRIPTION AND BLOCK DIAGRAM

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 VCNL36828P

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

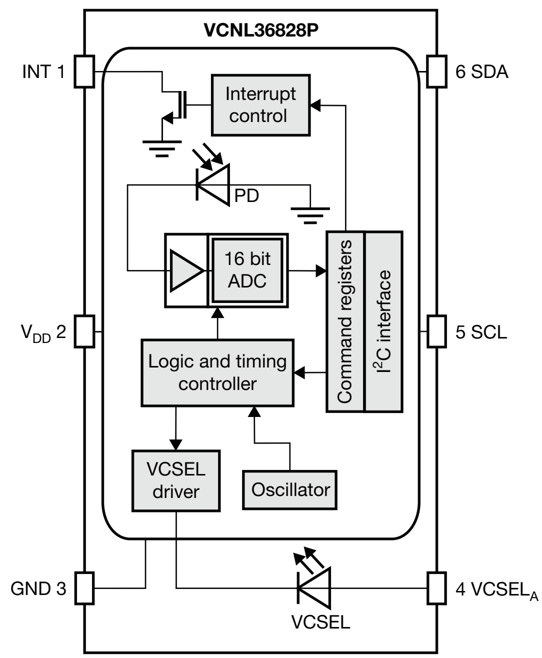

Fig. 3 - Block Diagram of the VCNL36828P

TABLE 2 - BLOCK DIAGRAM DESCRIPTION	
COMPONENT	**DESCRIPTION**
Command registers	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 12 and 16 bit depending on the register settings PS_IT, PS_GAIN, and PS_HD

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3. APPLICATION CIRCUIT

3.1 Slave Address Selection

The VCNL36828P supports a smart dual slave address where 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 I²C 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 I²C 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.

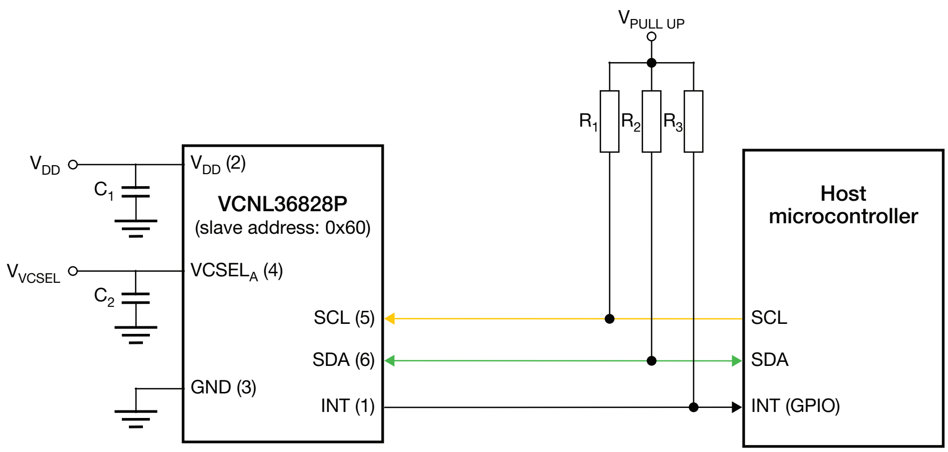

Fig. 4 - Application Circuit Example for a Single VCNL36828P - Slave Address 0x60

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.

APPLICATION NOTE

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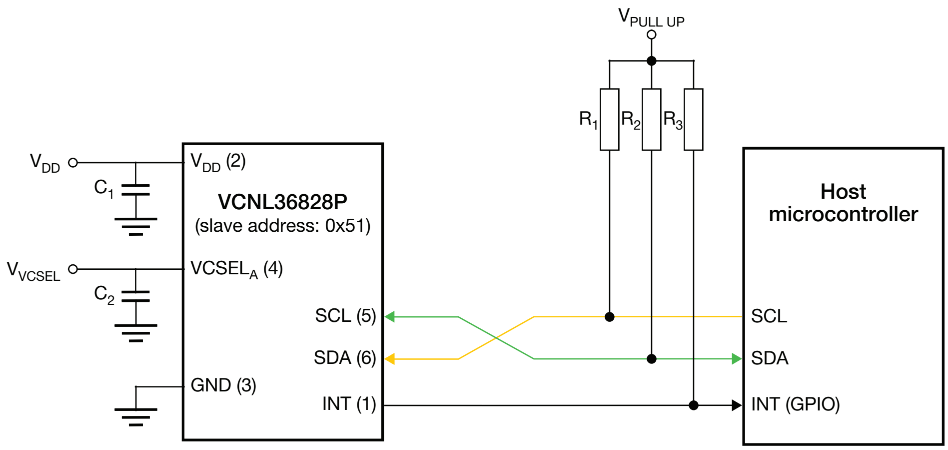

Fig. 5 - Application Circuit Example for a Single VCNL36828P - Slave Address 0x51

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}	2.62 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 20 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 VCNL36828P.

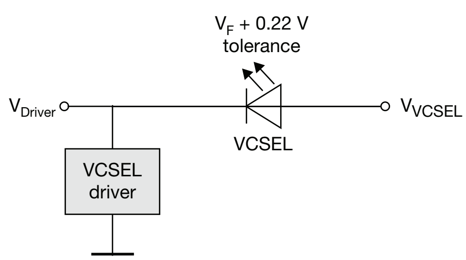

Fig. 6 - VCSEL Driver Circuit in the VCNL36828P

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 0.22 V
- The minimum voltage required by the driver circuit, $V_{Driver,min.}$, which is 0.6 V

Therefore,

$$V_{VCSEL, min.} = V_F(I_F) + V_{F, tolerance} + V_{Driver, min.} = V_F(I_F) + 0.22\ V + 0.6\ V \quad (1)$$

Fig. 7 and Table 5 show the computation of $V_{VCSEL,min.}$. The designer could use 3.3 V (except for 20 mA, which has a $V_{VCSEL,min.}$ of 3.36 V) to provide sufficient voltage headroom. The maximum allowable supply voltage of the VCSEL $V_{VCSEL,max.}$ is 3.6 V.

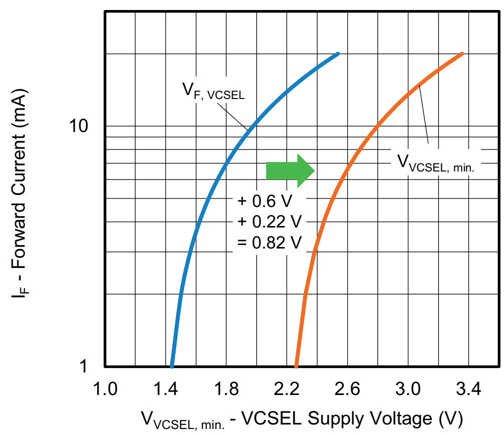

Fig. 7 - Forward Current vs. VCSEL Supply Voltage

TABLE 5 - $V_{VCSEL, MIN.}$								
I_{VCSEL} (I_F)	7 mA	9 mA	11 mA	12 mA	15 mA	17 mA	19 mA	20 mA
V_F	1.80 V	1.92 V	2.04 V	2.09 V	2.26 V	2.37 V	2.48 V	2.54 V
$V_{F, tolerance}$	0.22 V							
$V_{Driver, min.}$	0.6 V							
$V_{VCSEL, min.}$	2.62 V	2.74 V	2.86 V	2.91 V	3.08 V	3.19 V	3.3 V	3.36 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 VCNL36828P. This provides the flexibility for the designer to connect two devices from two different slave addresses on the same I^2C bus.

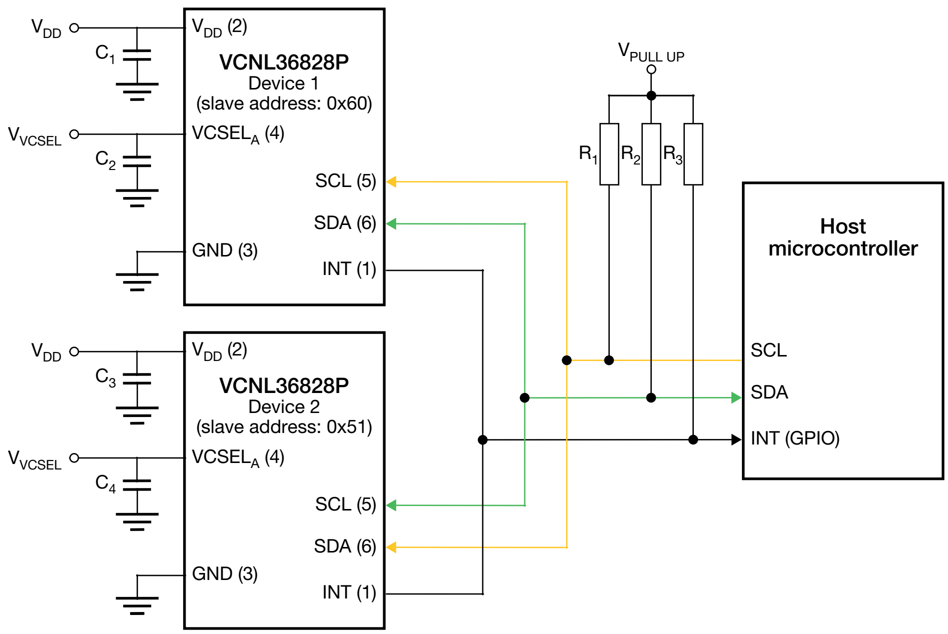

Fig. 8 - Application Circuit Example for Two VCNL36828Ps - Smart Dual Slave Address

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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_ON			Switch the sensor on / off	
	PS_OFFSET	PS_CONF2_H	0x01	Enable / disable the internal crosstalk cancellation	
	PS_MODE	PS_CONF3_L	0x02	Set the mode of the sensor to either auto or active force mode	
	PS_TRIG			Set the bit to 1 to trigger an individual active force mode measurement	
Emitter settings (VCSEL)	PS_ITB	PS_CONF2_L	0x01	Set the pulse length "T" for PS_IT to either 25 μs or 50 μs	
	PS_IT			Set the integration time for one measurement pulse (1 T, 2 T, 4 T, or 8 T)	
	PS_MPS			Set the number of infrared measurement pulses	
	PS_CURRENT	PS_CONF2_H		Set the VCSEL driving current (7, 9, ..., 20 mA)	
Detector settings	PS_HD	PS_CONF1_H	0x00	Set the maximum output data to either 12 bit or 16 bit	
	PS_GAIN	PS_CONF2_L	0x01	Set the digital gain in the ADC	
	PS_SENS	PS_CONF2_H		Set the sensitivity in the ADC	
Measurement period / rate	PS_PERIOD	PS_CONF2_L	0x01	Set the measurement period (50 ms, 100 ms, 200 ms, or 400 ms)	
	PS_SPERIOD	PS_CONF3_H	0x02	Set the measurement period (6.25 ms, 12.5 ms, or 25 ms)	
Offset count cancellation	-	PS_CANC	0x05	Set the offset count cancellation value	
Sunlight cancellation	PS_SC	PS_CONF3_H	0x02	Enable/disable the sunlight cancellation	
Interrupt	PS_INT	PS_CONF1_H	0x00	Set the interrupt mode setting	
	PS_PERS			Set the interrupt persistence number (1, 2, 3, or 4)	
	PS_SMART_PERS			Enable/disable the smart persistence	
	PS_SP_INT			Enable/disable the sunlight protection mode interrupt	
	-	PS_THDL	0x03	Set the low threshold interrupt value	
	-	PS_THDH	0x04	Set the high thershold interrupt value	
	PS_AWAY	INT_FLAG	0xF9	Low threshold crossing interrupt event flag	Read only
	PS_CLOSE			High threshold crossing interrupt event flag	
	PS_SPFLAG			Sunlight protection mode interrupt event flag	
Readout registers	-	PS_DATA	0xF8	Proximity output data	Read only
	VCNL36828P_ID_L	VCNL36828P_ID	0FA	Slave address 0x60: ID = 0x28, Slave address 0x51: ID = 0x29	
	VCNL36828P_ID_H			ID = 0x01	

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4.1 Basic Initialization

The sensor can be initialized with the PS_CAL, PS_ON, PS_MODE, PS_TRIG, and PS_OFFSET bits, which are found in three different registers: PS_CONF1_L, PS_CONF2_H, and PS_CONF3_L.

TABLE 7 - BASIC INITIALIZATION

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Basic initialization	PS_CAL	PS_CONF1_L	0x00	Enable/disable the internal calibration	7	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_ON			Switch the sensor on / off	0	0x0 (0b0)	Turn off the sensor (shutdown) (default)
						0x1 (0b1)	Turn on the sensor
	PS_OFFSET	PS_CONF2_H	0x01	Enable / disable the internal crosstalk cancellation	12	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_TRIG	PS_CONF3_L	0x02	Set the active force mode trigger; This bit will be reset to 0 after the measurement cycle	5	0x0 (0b0)	Off (default)
						0x1 (0b1)	Trigger
	PS_MODE			Set the measurement mode of the sensor	4	0x0 (0b0)	Auto mode (default)
						0x1 (0b1)	Active force mode

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_PERIOD and PS_SPERIOD 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_OFFSET - This bit can be set to 1 during initialization to perform internal crosstalk cancellation. The internal crosstalk is the crosstalk between the infrared signal from the VCSEL and the photodiode in the open air (without a window cover). The signal from the internal crosstalk is measured in the final test and is stored internally. If this bit is enabled, the count from the crosstalk will be deducted. This crosstalk is usually between 5 to 20 counts.

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 analog-digital converter (ADC), the measurement period, and the interrupt should be set before starting the measurement.

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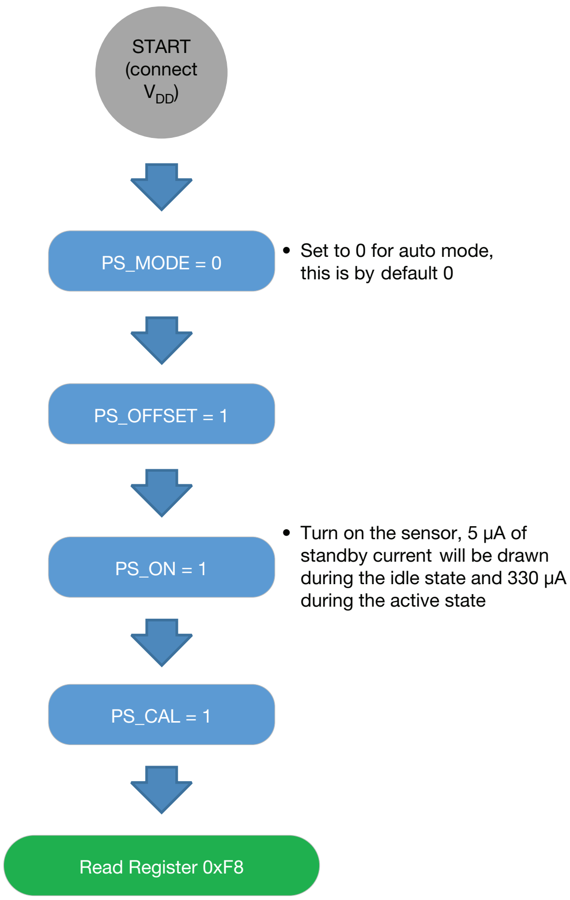

Fig. 9 - Basic initialization Example Steps for Auto Mode

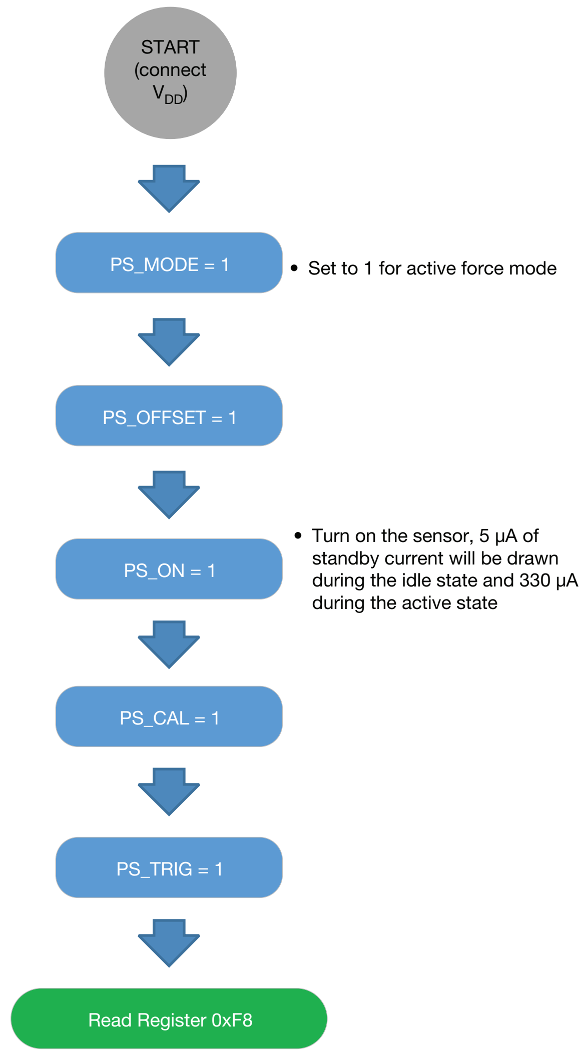

Fig. 10 - Basic initialization Example Steps for Active Force Mode

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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 settings (VCSEL)	PS_IT	PS_CONF2_L	0x01	Set the integration time for one measurement; the pulse length "T" is determined by PS_ITB	5 : 4	0x0 (0b00)	1T (default)
						0x1 (0b01)	2T
						0x2 (0b10)	4T
						0x3 (0b11)	8T
	PS_MPS			Set the number of infrared signal pulses per measurement	3 : 2	0x0 (0b00)	1 pulse (default)
						0x1 (0b01)	2 pulses
						0x2 (0b10)	4 pulses
						0x3 (0b11)	8 pulses
	PS_ITB			Set the pulse length "T" for PS_IT	1	0x0 (0b0)	T = 25 μs (default)
						0x1 (0b1)	T = 50 μs
	PS_CURRENT	PS_CONF2_H		Set the VCSEL driving current	10 : 8	0x0 (0b000)	7 mA (default)
						0x1 (0b001)	9 mA
						0x2 (0b010)	11 mA
						0x3 (0b011)	12 mA
						0x4 (0b100)	15 mA
						0x5 (0b101)	17 mA
						0x6 (0b110)	19 mA
						0x7 (0b111)	20 mA

Fig. 11 depicts the behavior of the VCSEL infrared signal register settings on the infrared signal magnitude of the sensor. When the parameters PS_ITB, PS_IT, PS_CURRENT, and PS_MPS in two different registers PS_CONF2_L and PS_CONF2_H have been increased from lower value settings to higher value settings, the infrared signal magnitude of the VCSEL will increase. This increases the object's detection distance because the reflected infrared signal magnitude and proximity counts increase as well.

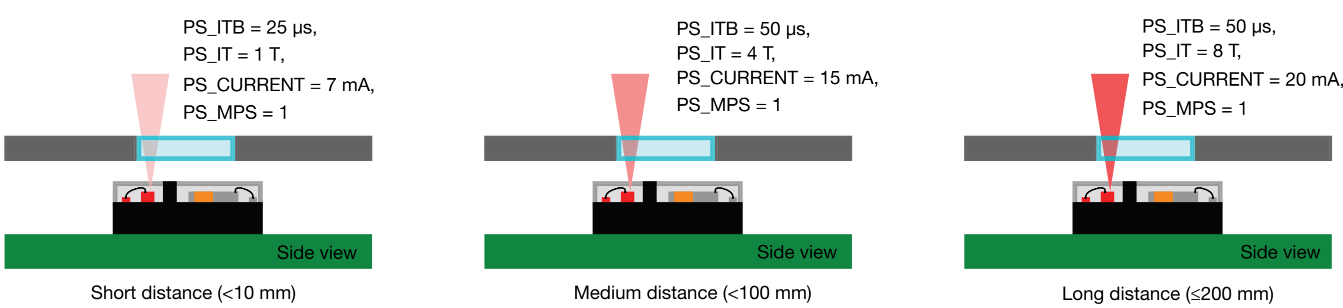

Fig. 11 - The Behavior of the VCSEL Register Settings on the Infrared Signal Magnitude of the Sensor

The infrared signal of the VCSEL is a pulse with a pulse width of multiple values of T. This can be set via the parameter PS_IT. The length of T can be either 25 μs or 50 μs, which can be set via the parameter PS_ITB. The magnitude of the pulse can be controlled via the VCSEL driver current parameter PS_CURRENT.

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

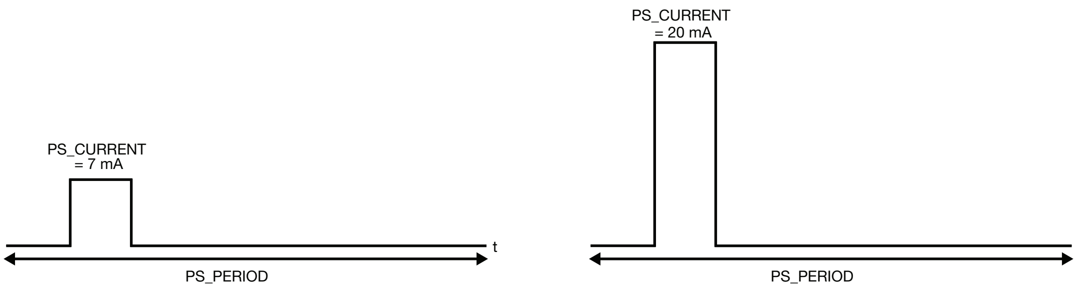

Fig. 12 - The Behavior of the Pulse Magnitude With Different PS_CURRENT

PS_ITB - The length of T in parameter PS_IT. This can be either 25 μs or 50 μs. The setting 25 μs could be used when low power consumption is a requirement.

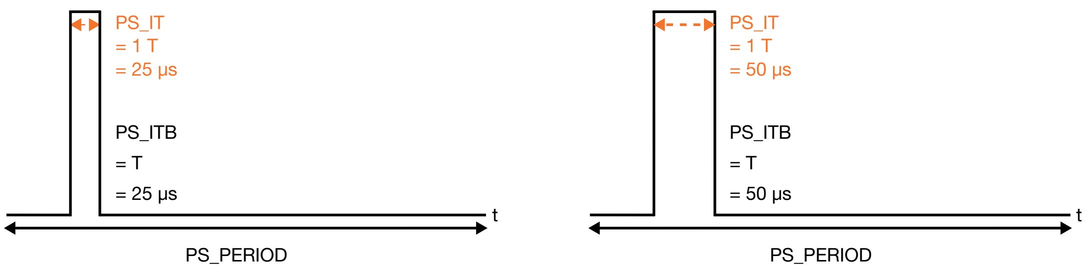

Fig. 13 - The Behavior of the Pulse Length With Different PS_ITB

PS_IT - The length of the VCSEL pulse width with multiple values of T. The length of T is defined by the parameter PS_ITB.

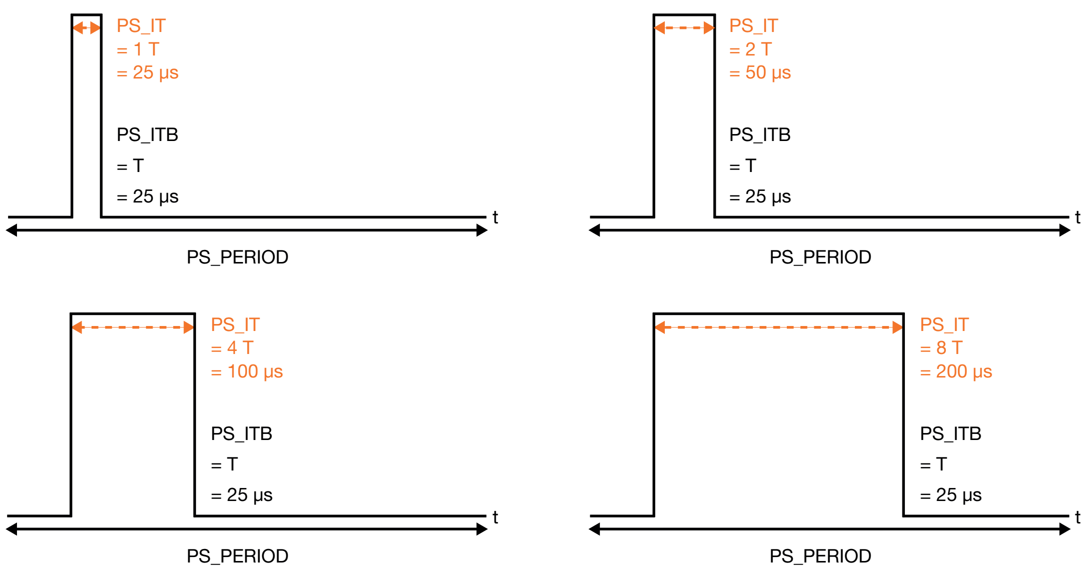

Fig. 14 - The Behavior of the Pulse Length With Different PS_IT

PS_MPS - The number of VCSEL pulses within one measurement period.

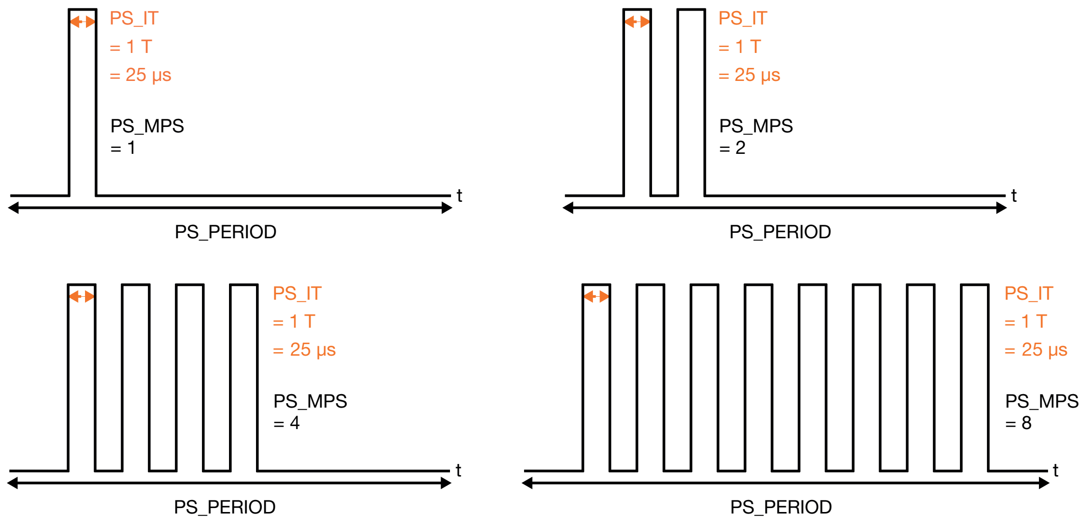

Fig. 15 - The Number of Pulses' Behavior With Different PS_MPS

Fig. 16, Fig. 17, Fig. 18, and Fig. 19 show the behavior of the proximity counts with increasing setting values. It can be observed that the proximity counts are approximately doubled when the setting values have been doubled. The designer could increase PS_IT, PS_ITB, PS_CURRENT, and PS_MPS if a longer detection distance is required. It is recommended to start with PS_ITB = 25 µs and then increase the setting PS_IT, PS_CURRENT, and PS_ITB = 50 µs. This sequence allows for current consumption optimization. PS_MPS should only be the last setting to be increased when a longer detection distance is required. The maximum proximity value depends on PS_IT, PS_HD, and PS_GAIN. This will be explained further in Table 10 in the section 4.3. Fig. 11 shows example settings for different distances. For example, for applications with detection distances up to 200 mm, it is recommended to use PS_ITB = 50 µs, PS_IT = 8 T, and PS_CURRENT = 20 mA.

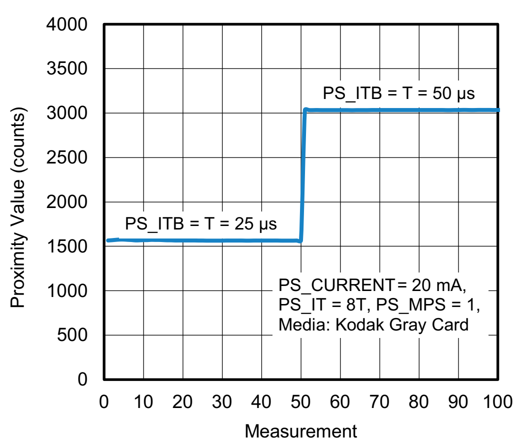

Fig. 16 - The Behavior of the Proximity Counts With Different PS_ITB

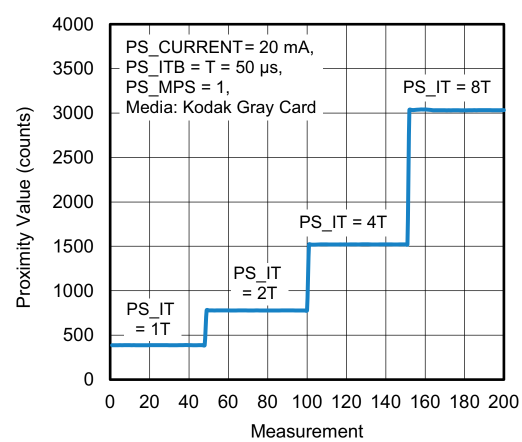

Fig. 17 - The Behavior of the Proximity Counts With Different PS_IT

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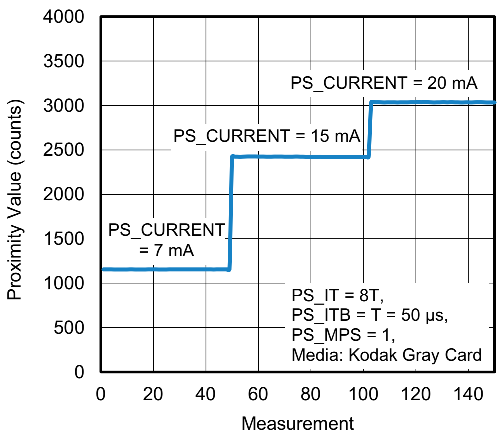

Fig. 18 - The Behavior of the Proximity Counts With Different PS_CURRENT

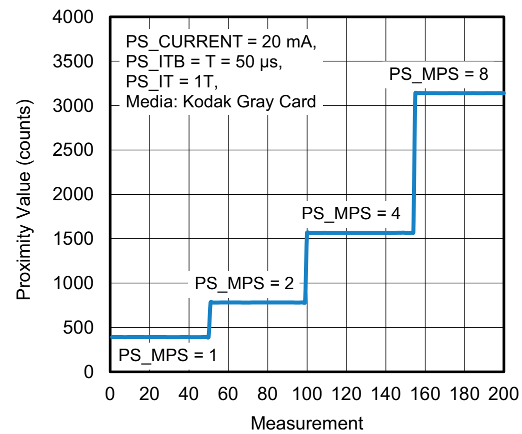

Fig. 19 - The Behavior of the Proximity Counts With Different PS_MPS

4.3 DETECTOR SETTINGS

TABLE 9 - DETECTOR SETTINGS							
REGISTER GROUP	**BIT NAME**	**REGISTER NAME**	**COMMAND CODE**	**FUNCTION**	**BIT**	**VALUE**	**DESCRIPTION**
Detector settings	PS_HD	PS_CONF1_H	0x00	Enable/disable high dynamic range (12/16 bit) ADC output setting	14	0x0 (0b0)	Disable (12 bit) (default)
						0x1 (0b1)	Enable (16 bit)
	PS_GAIN	PS_CONF2_L	0x01	Set the gain of the ADC	0	0x0 (0b0)	x 1 gain (default)
						0x1 (0b1)	x 2 gain
	PS_SENS	PS_CONF2_H		Set the sensitivity of the ADC	13	0x0 (0b0)	Normal sensitivity (default)
						0x1 (0b1)	High sensitivity

The detector of the proximity sensor consists of the photodiode and the analog-digital converter (ADC). The detector-related parameters PS_HD, PS_GAIN, and PS_SENS in three different registers PS_CONF1_H, PS_CONF2_L, and PS_CONF2_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. 20 depicts the behavior of the proximity counts when changing the analog-digital converter parameters.

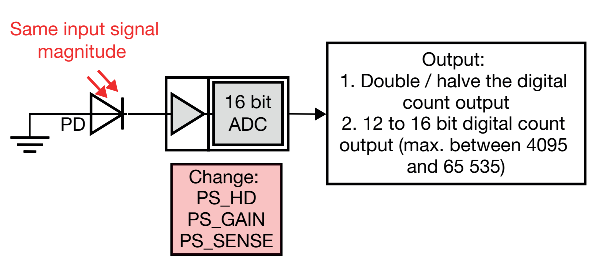

Fig. 20 - The Behavior of the Proximity Counts When Changing the Analog-Digital Converter Parameters

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PS_HD - This bit sets the maximum resolution of the ADC. For example, when PS_HD is set to 12 bit, the maximum possible counts are always 4095. However, when PS_HD is set to 16 bit, the actual maximum resolution and counts depend on PS_GAIN and PS_IT, as shown in Table 10. This can be between 12 bit and 16 bit or between 4095 counts and 65 535 counts.

PS_GAIN - This bit sets the gain and changes the maximum resolution in the ADC when PS_HD is set to 16 bit. The counts can be doubled when the bit is set to 1. When combined with PS_SENS, the count can be quadrupled when both bits are set to 1. The actual maximum resolution depends on PS_HD and PS_IT, as shown in Table 10.

PS_SENS - 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 quadrupled when both bits are set to 1. The actual maximum resolution depends on PS_HD, PS_GAIN, and PS_IT, as shown in Table 10.

TABLE 10 - MAXIMUM BIT RESOLUTION AND DIGITAL OUTPUT COUNTS

BIT NAME		PS_IT = 1T	PS_IT = 2T	PS_IT = 4T	PS_IT = 8T
PS_HD = 0 (12 bit)	PS_GAIN = 0 (x1 gain)	12 bit / 4095 counts			
	PS_GAIN = 1 (x2 gain)				
PS_HD = 1 (16 bit)	PS_GAIN = 0 (x1 gain)	12 bit / 4095 counts	13 bit / 8191 counts	14 bit / 16 383 counts	15 bit / 32 767 counts
	PS_GAIN = 1 (x2 gain)	13 bit / 8191 counts	14 bit / 16 383 counts	15 bit / 32 767 counts	16 bit / 65 535 counts

In many applications where the detection range is less than 5 cm, such as presence detection in TWS, AR / VR headsets, and touchless switches, 12 bit resolution with maximum counts of 4095 is usually enough to detect two distinct events of “close” and “away”.

However, higher dynamic range output counts are required when detecting a longer range and more distinctive events or threshold requirements are needed. Therefore, the designer can set PS_HD to 16 bit and select the appropriate PS_GAIN and PS_IT based on Table 10 to reach a higher maximum count up to 65535.

Fig. 21 and Fig. 22 show the behavior of the parameters PS_GAIN and PS_SENS 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.

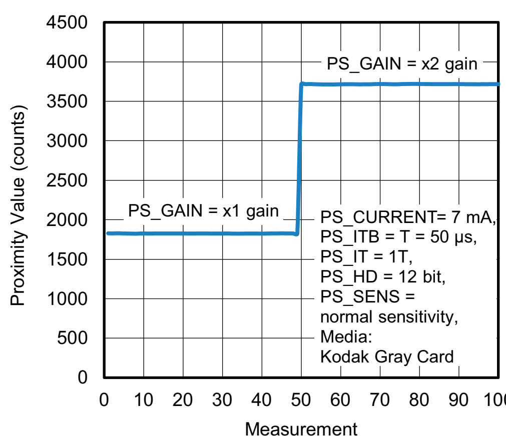

Fig. 21 - The Behavior of the Parameter PS_GAIN on the Proximity Counts

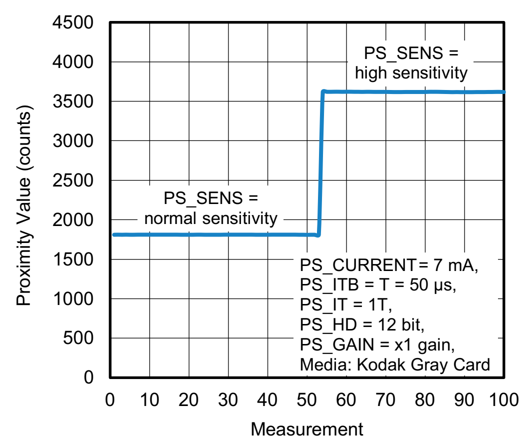

Fig. 22 - The Behavior of the Parameter PS_SENS on the Proximity Counts

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4.4 Measurement Period / Rate

TABLE 11 - MEASUREMENT PERIOD / RATE							
REGISTER GROUP	**BIT NAME**	**REGISTER NAME**	**COMMAND CODE**	**FUNCTION**	**BIT**	**VALUE**	**DESCRIPTION**
Measurement Period/Rate	PS_PERIOD	PS_CONF2_L	0x01	Set the measurement period	7 : 6	0x0 (0b00)	50 ms, which translates into 20 measurements/s (default)
						0x1 (0b01)	100 ms, which translates into 10 measurements/s
						0x2 (0b10)	200 ms, which translates into 5 measurements/s
						0x3 (0b11)	400 ms, which translates into 2.5 measurements/s
	PS_SPERIOD	PS_CONF3_H	0x02	Set the short measurement period	15 : 14	0x0 (0b00)	Disable the short period (follow PS_PERIOD setting) (default)
						0x1 (0b01)	6.25 ms, which translates into 160 measurements/s
						0x2 (0b10)	12.5 ms, which translates into 80 measurements/s
						0x3 (0b11)	25 ms, which translates into 40 measurements/s

PS_PERIOD and PS_SPERIOD define the period at which the infrared signal pulses are executed to perform proximity measurements. In most applications, the measurement period between 50 ms and 400 ms is enough to find a compromise between acceptable performance and low power consumption. A higher measurement rate increases the amount of data and decreases the possibility of false detection. However, the sensor will consume more current. The designer could select shorter measurement period options in PS_SPERIOD if a high measurement rate is required. Fig. 23 and Fig. 24 show examples of the measurement period that can be seen from the $VCSEL_A$ pin with a 15 Ω resistor.

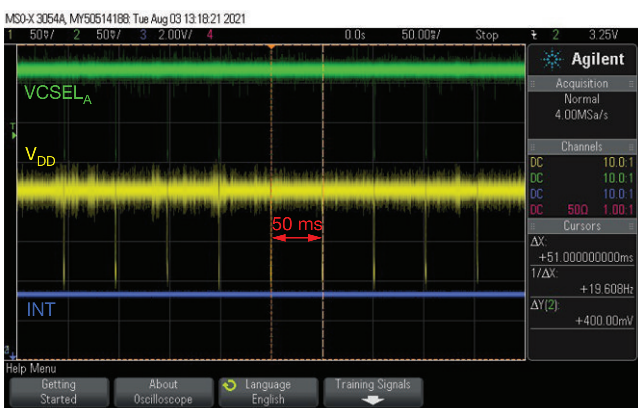

Fig. 23 - Oscilloscope Screenshot of the $VCSEL_A$ Pin for the Measurement Period of 50 ms

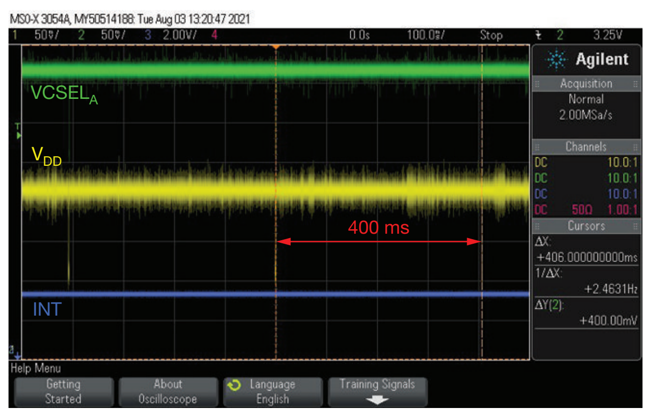

Fig. 24 - Oscilloscope Screenshot of the $VCSEL_A$ Pin for the Measurement Period of 400 ms

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Fig. 25 and Fig. 26 show examples of the short measurement period that can be seen from the $VCSEL_A$ pin with a 15 Ω resistor.

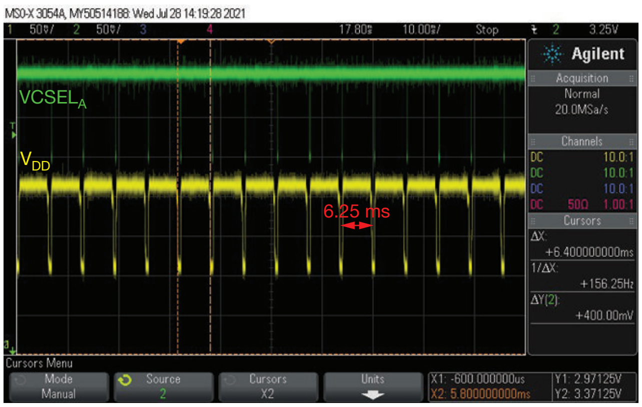

Fig. 25 - Oscilloscope Screenshot of the $VCSEL_A$ for the Short Measurement Period of 6.25 ms

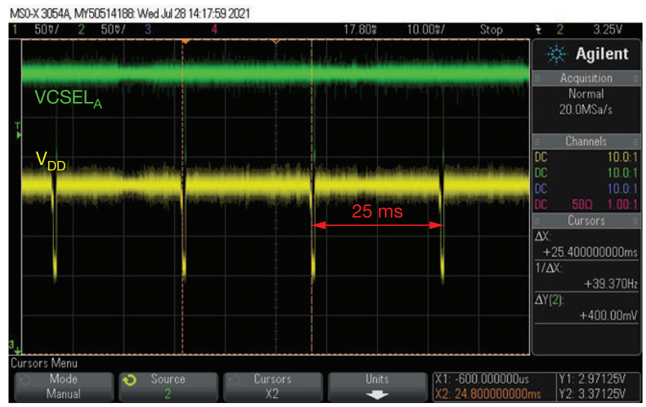

Fig. 26 - Oscilloscope Screenshot of the $VCSEL_A$ for the Short Measurement Period of 25 ms

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	0x05	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. 27 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. 28. 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.

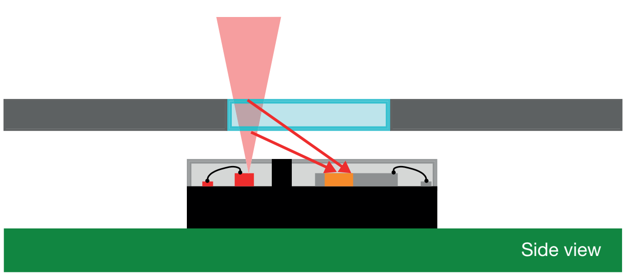

Fig. 27 - Offset Count Calibration

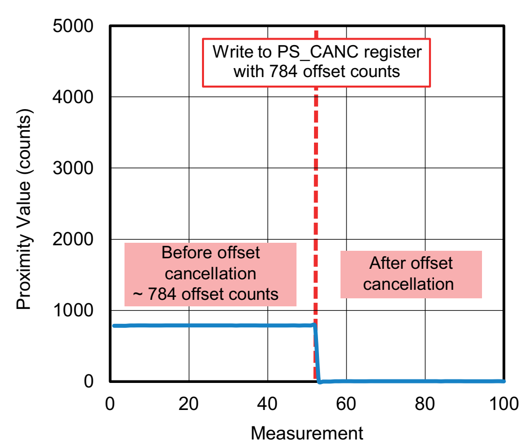

Fig. 28 - Offset Count Cancellation

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4.6 Sunlight Cancellation

TABLE 13 - SUNLIGHT CANCELLATION

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Sunlight cancellation	PS_SC	PS_CONF3_H	0x02	Enable / disable the sunlight cancellation	12 : 10	0x0 (0b000)	Disable (default)
						0x7 (0b111)	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. 29.

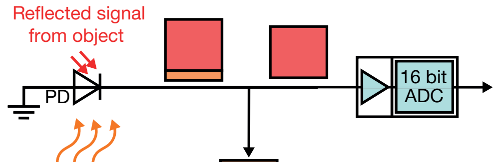

Fig. 29 - Sunlight Cancellation by Using the Active Sunlight Cancellation Current in the VCNL36828P

The sensor can perform the cancellation of sunlight up to 140 klux. The sensor then goes into the sunlight protection mode beyond 140 klux of sunlight. Sunlight protection mode is a mode where 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. 30. 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.

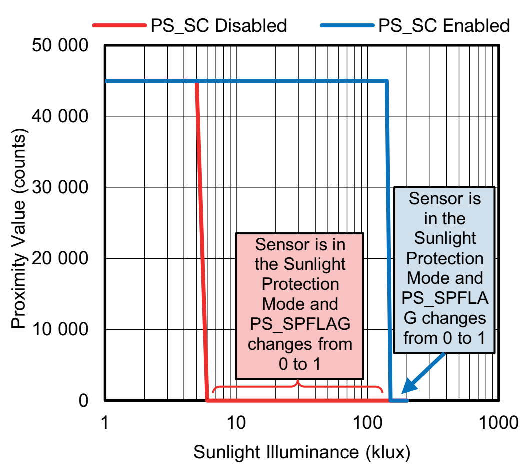

Fig. 30 - The Overall Behavior of the Sunlight Cancellation in the Proximity Sensor With Increasing Sunlight Illuminance

If the PS_SC bit is disabled, the sensor goes into the sunlight protection mode when the illuminance of the sunlight is beyond

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5 klux. This can be observed in Fig. 30.

4.7 Interrupt

TABLE 14 - INTERRUPT

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Interrupt	PS_SP_INT	PS_CONF1_H	0x00	Enable / disable the sunlight protection mode interrupt setting	13	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_SMART_PERS			Enable / disable the smart persistence setting when the interrupt event is triggered	12	0x0 (0b0)	Disable (default)
						0x1 (0b1)	Enable
	PS_PERS			Set the amount of consecutive threshold crossing events necessary to trigger interrupt	11 : 10	0x0 (0b00)	1 time (default)
						0x1 (0b01)	2 times
						0x2 (0b10)	3 times
						0x3 (0b11)	4 times
	PS_INT			Set the interrupt mode setting	9 : 8	0x0 (0b00)	Interrupt disable (default)
						0x1 (0b01)	Logic high / low mode
						0x3 (0b11)	Trigger by each high / low threshold event
	PS_THDL_L	PS_THDL	0x03	Set the low threshold interrupt value	7 : 0	0 to 65 535	Low byte
	PS_THDL_H				15 : 8		High byte
	PS_THDH_L	PS_THDH	0x04	Set the high threshold interrupt value	7 : 0	0 to 65 535	Low byte
	PS_THDH_H				15 : 8		High byte
	PS_SPFLAG	INT_FLAG	0xF9	Read the sunlight protection mode interrupt event flag	12	0x0 (0b0)	No sunlight protection mode interrupt event flag
						0x1 (0b1)	Sunlight protection mode interrupt event flag
	PS_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_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

The interrupt pin allows the proximity sensor to autonomously send an interrupt signal to the microcontroller when the sensor's measured proximity crosses the defined high and low thresholds. There are two modes of interrupt in the VCNL36828P:

- Logic mode
- Enable mode

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.

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Persistence and Smart Persistence Mode

PS_PERS determines the event number after crossing the threshold that triggers the interrupt. When PS_PERS is set between 2 and 4, three consecutive measurements after the first threshold crossing event will be performed with the measurement period defined by PS_PERIOD. This is to check whether the interrupt crossing events persist to prevent the occurrence of false detection. The interrupt will only be triggered after a consecutive threshold crossing event number as defined by the selected PS_PERS has occurred. This is valid for all of the interrupt modes. Fig. 31 shows the oscilloscope screenshot of pin 2 - V_{DD} and pin 1 - INT for the measurement period of 50 ms, disabled smart persistence, and persistence of 2. The interrupt is pulled low after the second measurement that crosses the threshold out of the four measurements after the first interrupt crossing event. Fig. 32 shows the oscilloscope screenshot for the measurement period of 50 ms, disabled smart persistence, and persistence of 4. The interrupt is pulled low after the fourth measurement that crosses the threshold out of the four measurements after the first interrupt crossing event.

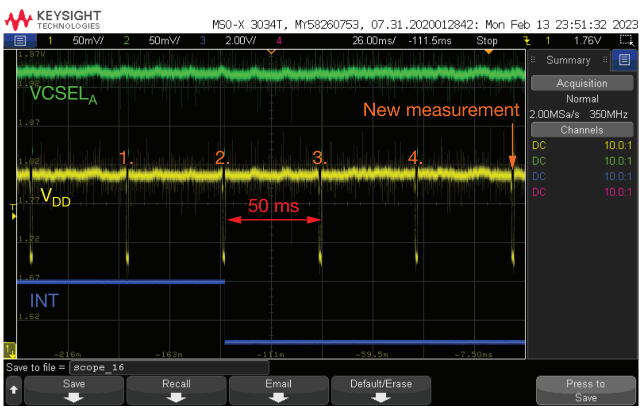

Fig. 31 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 50 ms, Disabled Smart Persistence, and Persistence of 2

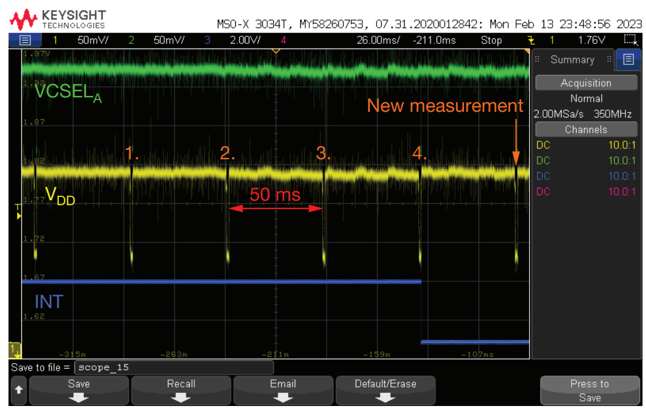

Fig. 32 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 50 ms, Disabled Smart Persistence, and Persistence of 4

Otherwise, when PS_PERS is set to 1, the persistence events will not be counted and a new measurement will be performed after the defined PS_PERIOD. The interrupt will be triggered immediately after the first threshold event, regardless of whether PS_SMART_PERS is enabled or disabled, as shown in Fig. 33.

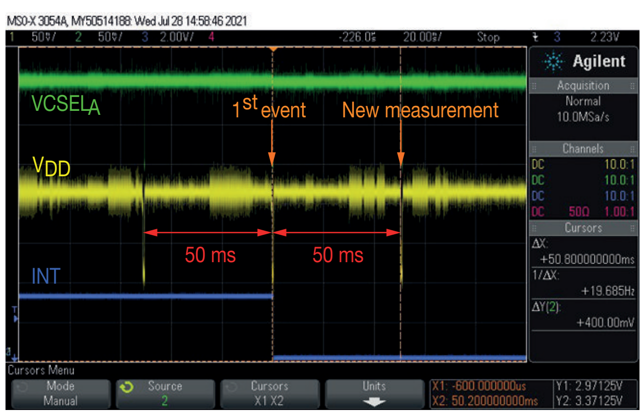

Fig. 33 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 50 ms, Disabled Smart Persistence, and Persistence of 1

When PS_SMART_PERS is enabled and PS_PERS is set between 2 and 4, four consecutive measurements will be performed with the time difference between pulses changing dynamically with PS_PERIOD/4 or PS_SPERIOD/4, as shown in Fig. 34, Fig. 35, and Fig. 36.

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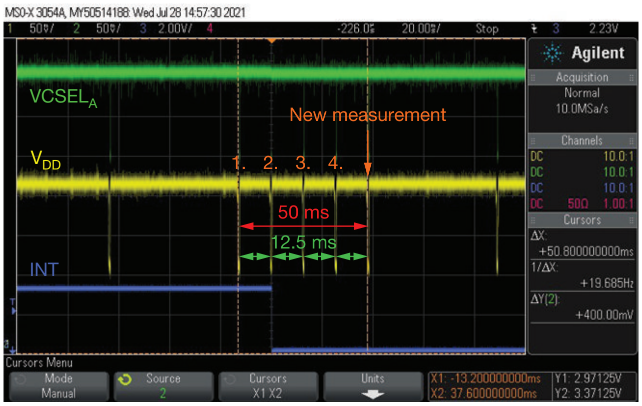

Fig. 34 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 50 ms, Enabled Smart Persistence, and Persistence of 2

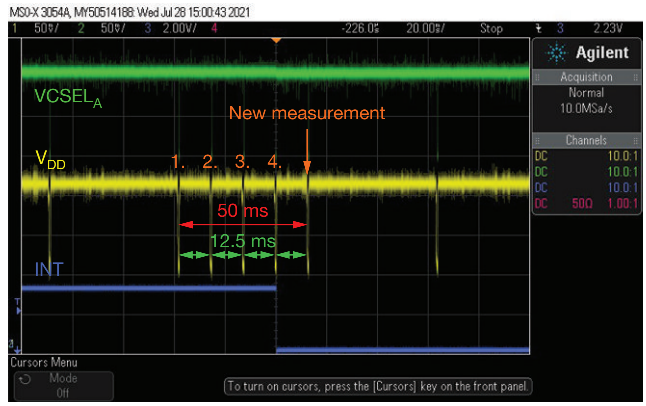

Fig. 35 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 50 ms, Enabled Smart Persistence, and Persistence of 4

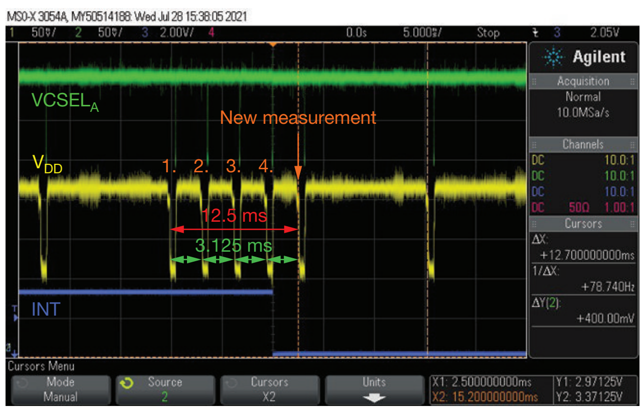

Fig. 36 - Oscilloscope Screenshot of the Pin 2 - V_{DD} and Pin 1 - INT for the Measurement Period of 12.5 ms, Enabled Smart Persistence, and Persistence of 4

Logic Mode

- The interrupt line is pulled low when the proximity counts cross the high threshold, as indicated by the blue line in Fig. 37
- The interrupt line is pulled high when the proximity counts cross the low threshold, as indicated by the purple line in Fig. 37
- PS_PERS determines the event number after crossing the threshold that triggers the interrupt, as shown in Fig. 37
- 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. 37
- 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

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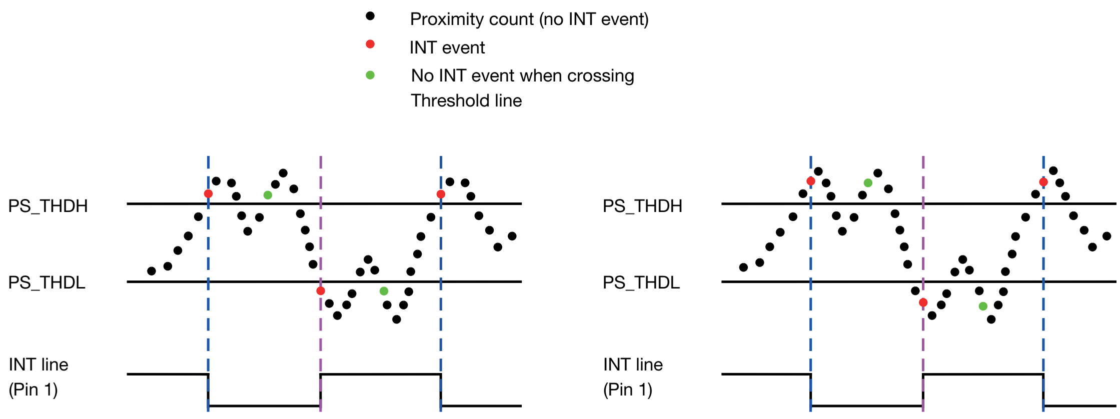

Fig. 37 - The Behavior of the INT Line (pin 1) Using Logic Mode With PS_PERS = 1 (left) and PS_PERS = 2 (right)

Enable Mode

- The interrupt line is pulled low when the proximity counts cross the high or low threshold, as indicated by the red circle in Fig. 38
- 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
- PS_PERS determines the event number after crossing the threshold that triggers the interrupt
- The interrupt flag PS_IF_CLOSE or PS_IF_AWAY can be cleared by reading the INT_FLAG register

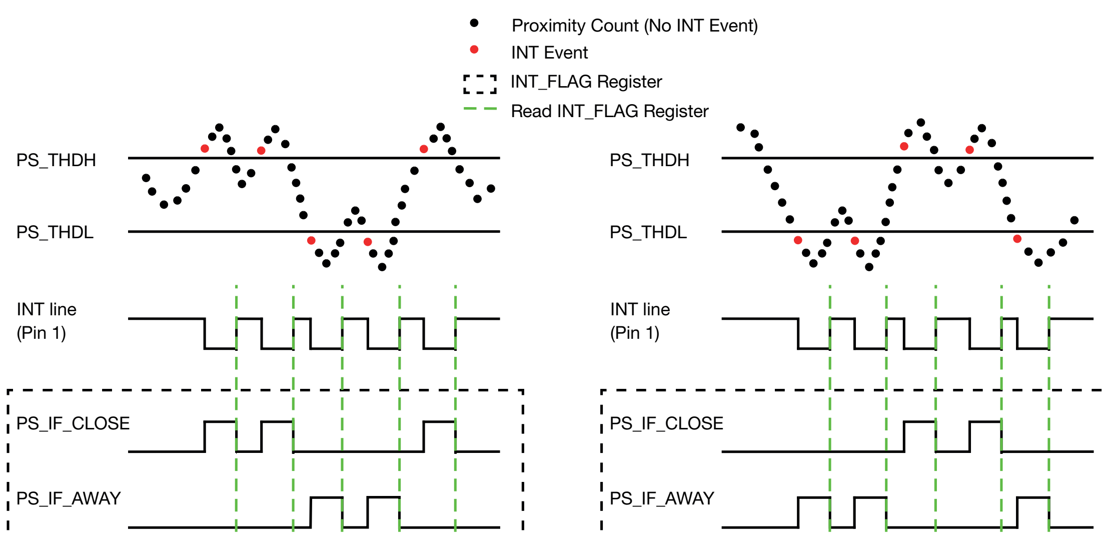

Fig. 38 - The Behavior of the INT Line (pin 1) and INT_FLAG Register Using the Enable Mode and PS_PERS = 1
With High Threshold Crossing as the First Event (left) and Low Threshold Crossing as the First Event (right)

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. This is explained in section 4.6.

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4.8 Readout Registers

TABLE 15 - READOUT REGISTERS

REGISTER GROUP	BIT NAME	REGISTER NAME	COMMAND CODE	FUNCTION	BIT	VALUE	DESCRIPTION
Readout registers	PS_DATA_L	PS_DATA	0xF8	Read the proximity output data	7 : 0	0 to 65 535	Low byte
	PS_DATA_H				15 : 8		High byte
	VCNL36828P_ID_L	VCNL36828P _ID	0xFA	Read the device ID	7 : 0	0x28 (0b00101000)	Device with a slave of address 0x60
						0x29 (0b00101001)	Device with a slave address of 0x51
	VCNL36828P_ID_H				15 : 8	0x01 (0b00000001)	Should be kept default

The VCNL36828P has two readout registers, which are PS_DATA and VCNL36828P_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 applications' requirements, the interrupt method is recommended to reduce power consumption.

On the other hand, VCNL36828P_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 VCNL36828P_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 VCNL36828P can be performed via I²C. The I²C write and read protocol when communicating with the proximity sensor is shown in Fig. 39.

Fig. 39 - 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. 40 shows a logic analyzer screenshot of the SCL (pin 5) and SDA line (pin 6) when reading the register VCNL36828P_ID for the VCNL36828P with a slave address of 0x60. Here, the restart condition, indicated by the blue box, has been implemented and the low data byte of 0x28 matches the device ID stated in the datasheet for the VCNL36828P with the slave address of 0x60.

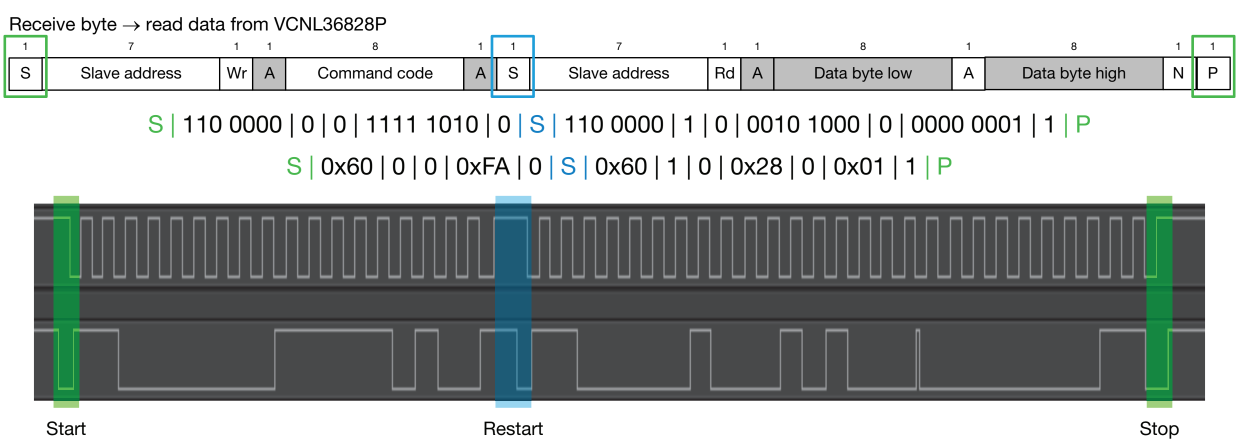

Fig. 40 - The Correct I²C Read When Reading the Register VCNL36828P_ID With a Restart Condition

On the other hand, Fig. 41 shows the logic analyzer screenshot, but with an incorrect read I²C protocol when reading the register VCNL36828P_ID. Here, the stop and restart conditions have been applied, causing an error in the data field. As a result, the sensor writes a constant 0xFF and 0x07 in the PS_DATA register.

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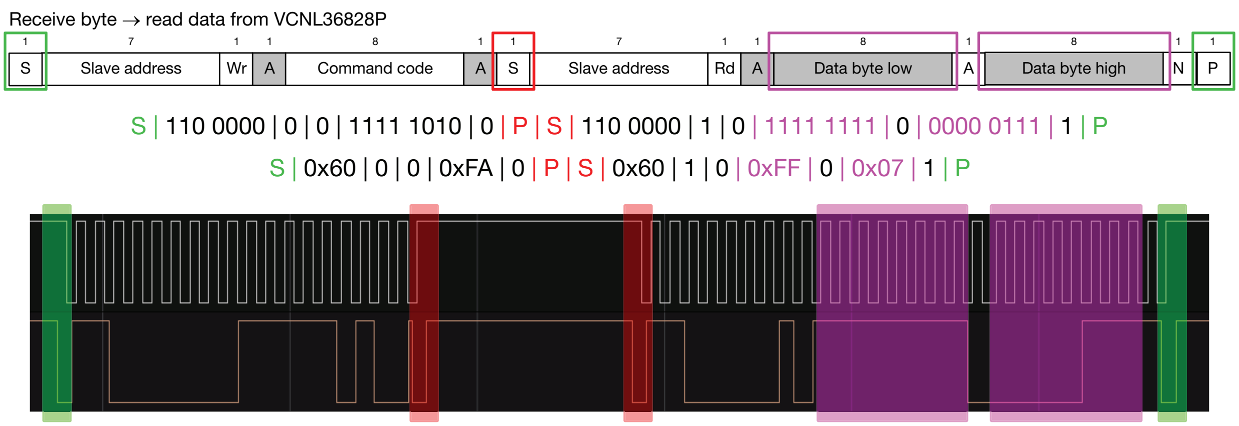

Fig. 41 - The Incorrect I²C Read When Reading the Register VCNL36828P_ID With Both Stop and Restart Conditions

Therefore, the designer should use the correct I²C library, especially the I²C read, from the microcontroller manufacturer that implements only the restart condition, without the stop condition before the restart condition. This is usually a typical mistake when communicating with the VCNL36828P, as shown in Fig. 41.

5.2 Timing

5.2.1 Proximity Measurement Timing

In auto mode, one complete proximity measurement depends on the PS_PERIOD or PS_SPERIOD setting. However, the sensor is only active within a short time, as shown in Fig. 42.

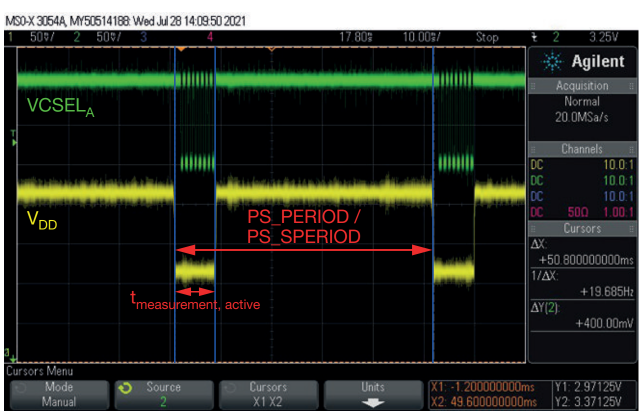

Fig. 42 - Proximity Measurement in Auto Mode

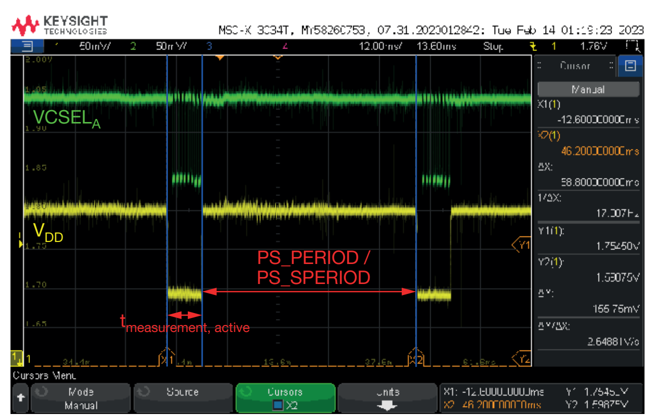

Fig. 43 - Proximity Measurement in Active Force Mode

On the other hand, one complete measurement in the active force mode requires adding both the active measurement period and PS_PERIOD or PS_SPERIOD as shown in Fig. 43.

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

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

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. The time taken to complete the DC_KILL process depends on the PS_ITB setting. When PS_ITB = T = 25 µs, DC_KILL takes 450 µs to complete. Otherwise, when
PS_ITB = T = 50 µs, DC_KILL takes 900 µs to complete. These are shown in Fig. 44 and Fig. 45.

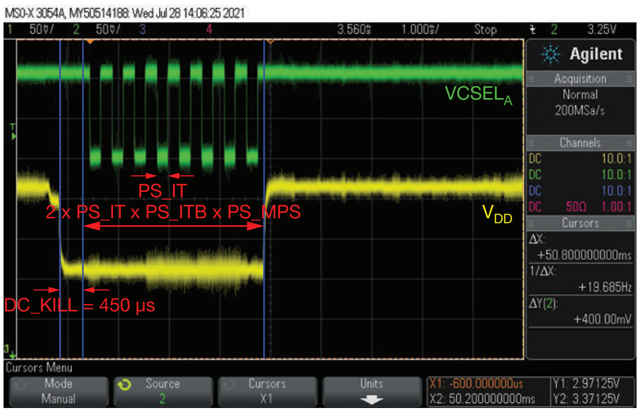

Fig. 44 - The Measurement Time When PS_ITB = T = 25 µs

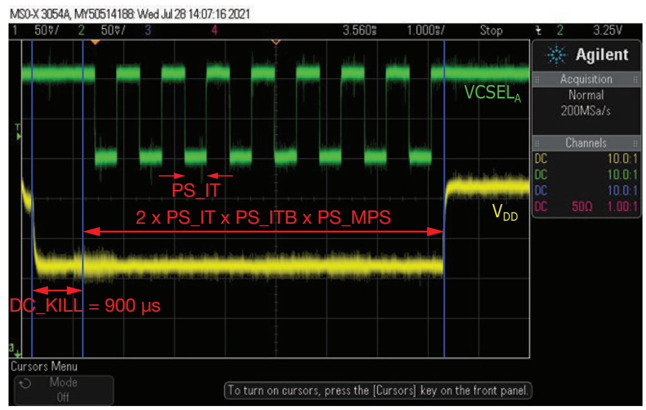

Fig. 45 - The Measurement Time When PS_ITB = T = 50 µs

Example - Active Measurement Time With PS_ITB = 25 µs and PS_MPS = 1

For example, given PS_IT = 1T, PS_ITB = T = 25 µs, PS_MPS = 1, the total active measurement time can be calculated as follows:

$$t_{\text{measurement, active}} = 1.2 \text{ x } (450\ \mu s + (2 \text{ x } 1 \text{ x } 25\ \mu s \text{ x } 1)) = 600\ \mu s$$

Example - Active Measurement Time With PS_ITB = 50 µs and PS_MPS = 8

For example, given PS_IT = 1T, PS_ITB = T = 50 µs, PS_MPS = 8, the total active measurement time can be calculated as follows:

$$t_{\text{measurement, active}} = 1.2 \text{ x } (900\ \mu s + (2 \text{ x } 1 \text{ x } 50\ \mu s \text{ x } 8)) = 2.04 \text{ ms}$$

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5.2.2 Timing Specification

Fig. 46 and Fig. 47 show the timing specification for the auto and active force mode, respectively.

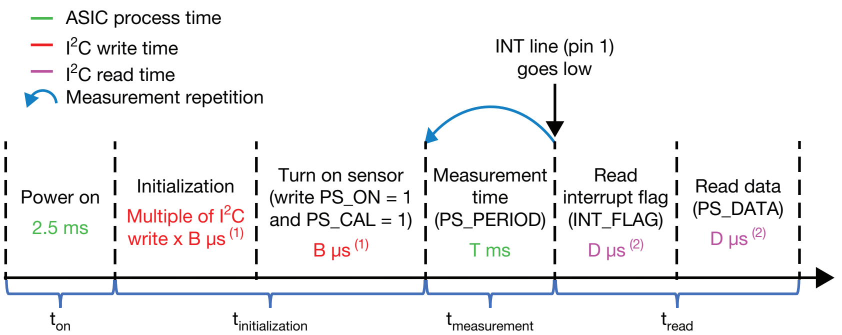

Fig. 46 - Timing Specification for the Auto Mode

Notes

(1) B μs - The parameter B refers to the time taken for a complete write I^2C protocol. This depends on the selected I^2C mode. Please refer to Table 16.

(2) D μs - The parameter D refers to the time taken for a complete read I^2C protocol. This depends on the selected I^2C mode. Please refer to Table 16.

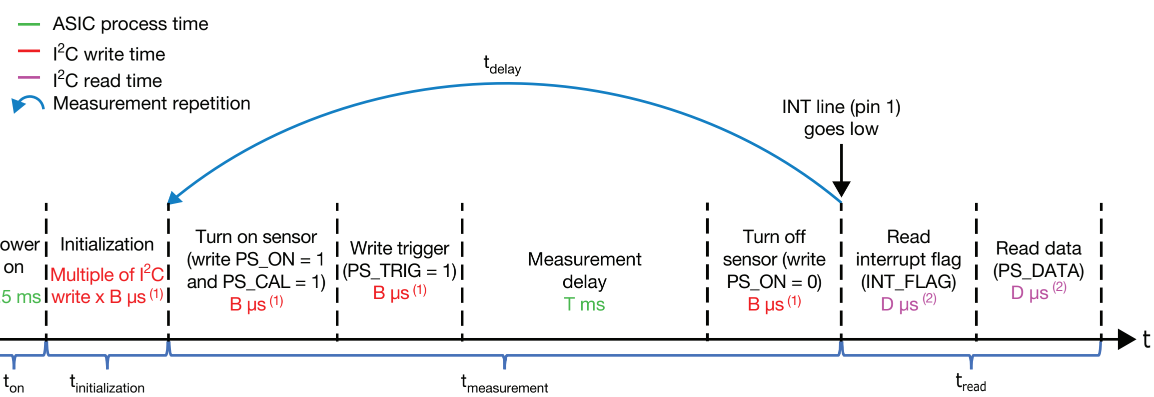

Fig. 47 - Timing Specification for the Active Force Mode

Notes

(1) B μs - The parameter B refers to the time taken for a complete write I^2C protocol. This depends on the selected I^2C mode. Please refer to Table 16.

(2) D μs - The parameter D refers to the time taken for a complete read I^2C protocol. This depends on the selected I^2C mode. Please refer to Table 16.

A measurement delay equal to the active measurement time defined by Equation 2 plus PS_PERIOD 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, PS_ITB, PS_MPS, and PS_PERIOD. The required delay is:

$$\text{Measurement delay} = 1.2 \times (\text{time to trigger} \times t_{\text{measurement, active}} + \text{PS\_PERIOD}) = 1.2 \times ((0.5 \times \text{PS\_IT} \times \text{PS\_ITB}) + \text{DC\_KILL} + (2 \times \text{PS\_IT} \times \text{PS\_ITB} \times \text{PS\_MPS}) + \text{PS\_PERIOD}) \quad (3)$$

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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^{2}C write and read time per byte depends on the I^{2}C mode, as shown in Table 16:

TABLE 16 - I^{2}C WRITE AND READ PROTOCOL TIME PER BYTE			
I^{2}C MODE	CLOCK FREQUENY (kHz) (1)	I^{2}C WRITE PROTOCOL TIME (μs) (2)	I^{2}C 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^{2}C Mode

Table 17 shows an example of the timing specification for the Auto Mode when initializing five registers, as well as when turning on the sensor. The sensor needs approximately 4.9 ms for the total initialization phase. The exact timing depends on the I^{2}C 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_PERIOD of 50 ms has been selected, the measurement time is 50 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^{2}C mode. Therefore, the total measurement time is 51 ms.

TABLE 17 -TIMING SPECIFICATION EXAMPLE FOR AUTO MODE AND STANDARD I^{2}C MODE (1)			
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_THDL	Write the low threshold setting	0.4
	PS_THDH	Write the high threshold setting	0.4
	PS_CONF1_L/H	Turn on the sensor by writing PS_ON = 1 and PS_CAL = 1	0.4
$t_{initialization\_total}$	-	-	4.9
$t_{measurement}$	-	Actual measurement time depends on the selected PS_PERIOD; here is an example of when PS_PERIOD = 50 ms	50
t_{read}	INT_FLAG	Read the interrupt flag	0.5
	PS_DATA	Read the proximity data	0.5
$t_{measurement\_total}$	-	-	51

Notes

(1) Standard I^{2}C mode comes with a 100 kHz clock frequency. One can approximate the time taken for a complete write and read I^{2}C protocol to be 400 μs and 500 μs per byte respectively. Please refer to Table 16.

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6. PROXIMITY MEASUREMENT

6.1 Software Flow Chart for the Proximity Measurement

Fig. 48 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.

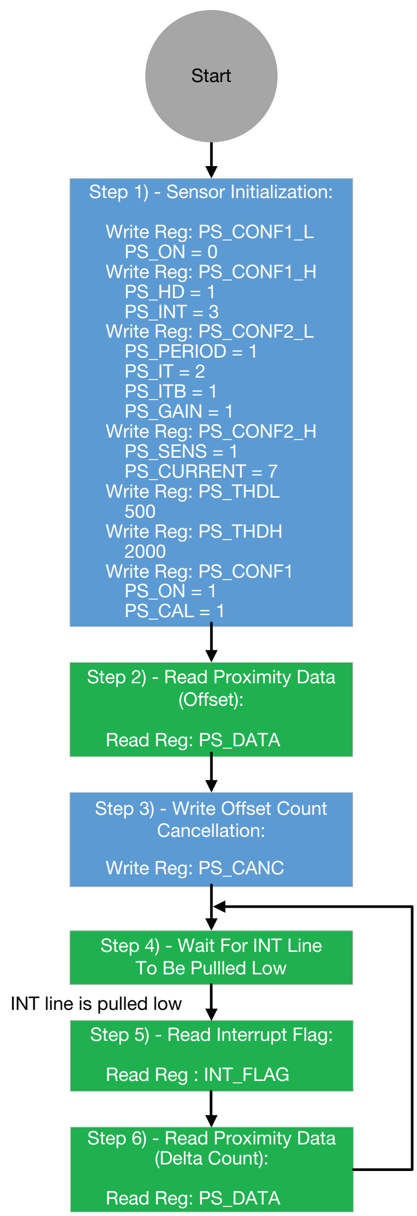

Fig. 48 - Typical Software Flow Chart for the Auto Mode

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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 the Window Cover

Fig. 49 and Fig. 50 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 20 cm with a minimum of 70 delta counts when measuring with the Kodak Gray Card and when higher sensor settings of PS_IT = 8T and PS_CURRENT = 20 mA have been selected. The dashed red line indicates this in Fig. 50. The minimum of 70 delta counts is usually enough to consider the sensor's tolerance of around ± 20 % and account for the noise from the disturbing sources.

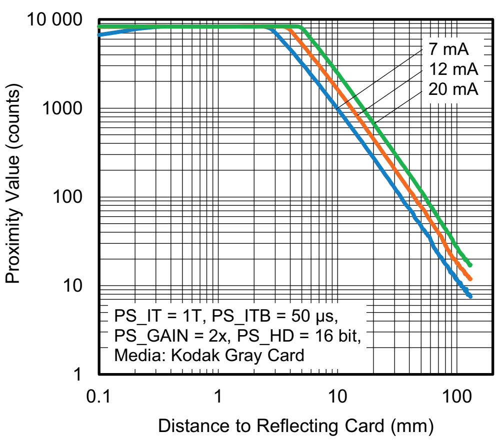

Fig. 49 - Proximity Value vs. Distance; PS_IT = 1T (13 bit)

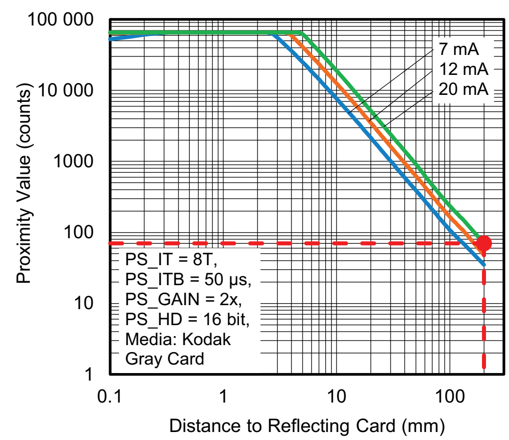

Fig. 50 - Proximity Value vs. Distance; PS_IT = 8T (16 bit)

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.

The VCNL36828P also has a peak sensitivity between 0.6 mm and 1 mm as shown in Fig. 51. Peak sensitivity is the distance away from the sensor, in which the sensor has the highest response.

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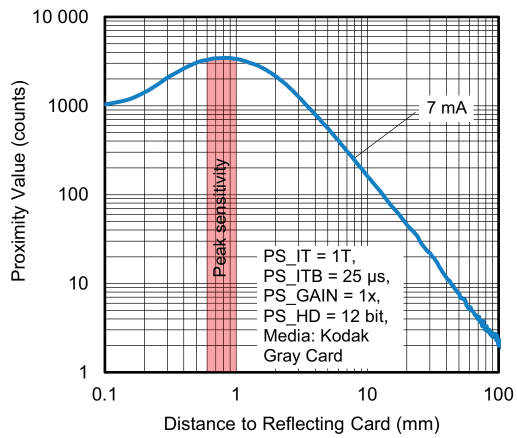

Fig. 51 - Proximity Value vs. Distance; PS_IT = 1T

The sensor's detection range can be extended beyond 20 cm if the number of pulse PS_MPS increases from the lowest possible pulse of 1 to the highest possible of 8.

6.3 Temperature Behavior

When designing the VCNL36828P for the end application, the temperature behavior of the proximity counts should also be considered. Fig. 52 shows the average relative proximity counts against ambient temperature of VCNL36828P.

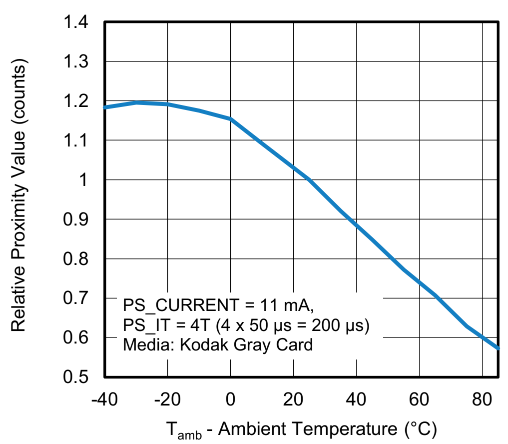

Fig. 52 - Average Relative Proximity Counts vs. Ambient Temperature of VCNL36828P

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 counts fluctuation with temperature.

Another good design approach to reduce the effect of the proximity counts 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 proximity sensor VCNL36828P 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. VCNL36828P offers an average current consumption down to 5.85 μA.

Fig. 53 shows the current consumption components through the pins.

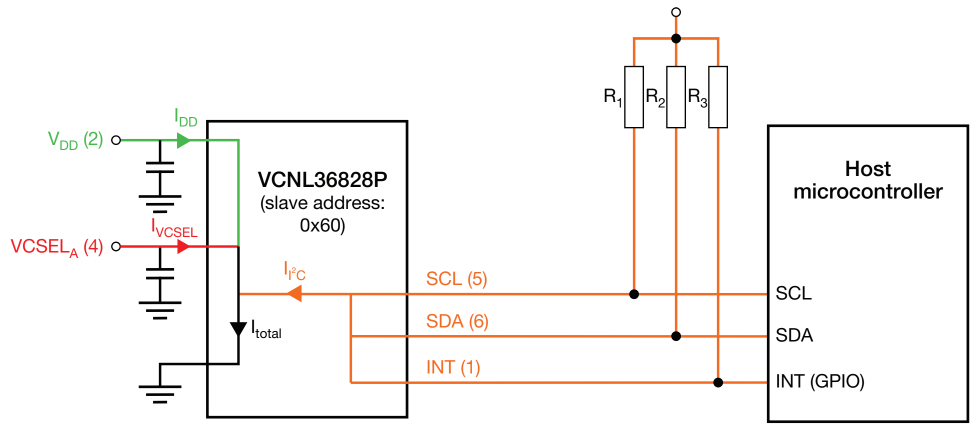

Fig. 53 - Current Consumption Components Through the Pins

The general total current consumption can be calculated as follows:

$$I_{total} = I_{DD} + I_{VCSEL} + I_{I^2C} \tag{4}$$

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. 54 shows the current consumption profile of VCNL36828P.

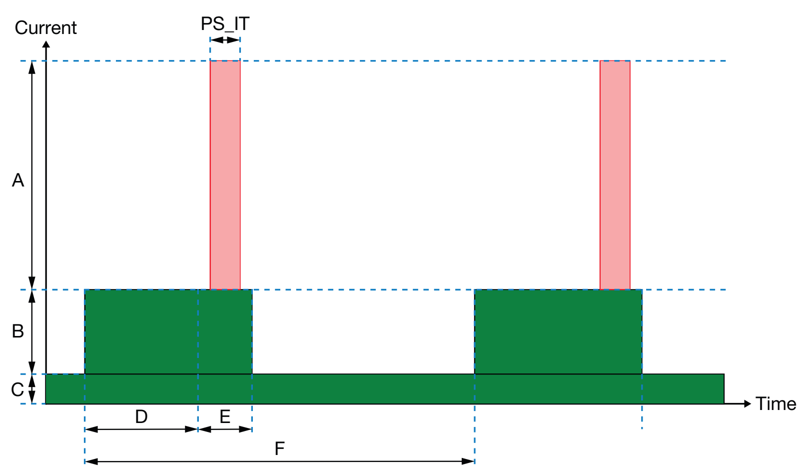

Fig. 54 - Current Consumption Profile of VCNL36828P

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Table 18 describes the parameters of the current consumption profile in Fig. 54.

TABLE 18 - AVERAGE CURRENT CONSUMPTION PARAMETER

PARAMETER	PARAMETER NAME	VALUE	DESCRIPTION
A	I_{VCSEL}	7 mA to 20 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)	330 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	450 µs / 900 µs	DC_KILL is the period where the sunlight and DC noise cancellation happens; the duration depends on the selected PS_ITB. When PS_ITB = 25 µs, DC_KILL = 450 µs and when PS_ITB = 50 µs, DC_KILL = 900 µs
E	Proximity measurement pulse	2 x PS_IT x PS_ITB x PS_MPS	Proximity measurement is the duration in which the sensor sends the VCSEL pulse/s; The values depend on PS_IT, PS_ITB, and PS_MPS
D + E (1)	Active measurement period	DC_KILL + (2 x PS_IT x PS_ITB x PS_MPS)	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	6.25 ms to 400 ms	The measurement period in which the measurement is repeated, which depends on the selected PS_PERIOD / PS_SPERIOD 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 VCNL36828P 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. 54 over the whole time as long as the sensor is switched on. During the active measurement period, as indicated by the parameter "D" and "E", the sensor consumes an additional current of 330 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 number of pulses within the duration "E" will also be multiplied by the parameter PS_MPS.

The average current consumption over the measurement period PS_PERIOD in VCNL36828P with interrupt mode can be calculated as follows:

$$I_{average} = I_{DD}(idle) + \frac{((DC\_KILL + (2 \times PS\_IT \times PS\_ITB \times PS\_MPS)) \times I_{DD}(active)) + (PS\_IT \times PS\_ITB \times PS\_CURRENT \times PS\_MPS)}{PS\_PERIOD} \quad (5)$$

Example - Average current Consumption Calculation

Table 19 shows the average current consumption example for PS_IT = 1T with PS_ITB = T = 25 µs for different PS_PERIOD and PS_CURRENT.

TABLE 19 - AVERAGE CURRENT CONSUMPTION (PS_ITB = T = 25 µs, PS_IT = 1T)

		PS_PERIOD / PS_SPERIOD (ms)						
PS_IT (µs)	PS_CURRENT (mA)	6.25	12.5	25	50	100	200	400
25	7	59.40	32.20	18.60	11.80	8.40	6.70	5.85
25	9	67.40	36.20	20.60	12.80	8.90	6.95	5.98
25	11	75.40	40.20	22.60	13.80	9.40	7.20	6.10
25	12	79.40	42.20	23.60	14.30	9.65	7.33	6.16
25	15	91.40	48.20	26.60	15.80	10.40	7.70	6.35
25	17	99.40	52.20	28.60	16.80	10.90	7.95	6.48
25	19	107.40	56.20	30.60	17.80	11.40	8.20	6.60
25	20	111.40	58.20	31.60	18.30	11.65	8.33	6.66

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For example, given PS_IT = 1T, PS_ITB = T = 25 μs, PS_MPS = 1, PS_PERIOD = 400 ms and PS_CURRENT = 7 mA, the average current consumption with negligible I_{I^2C} can be calculated as follows:

$$I_{average} = 5\ \mu A + \frac{((450\ \mu s + (2 \times 1 \times 25\ \mu s \times 1)) \times 330\ \mu A) + (1 \times 25\ \mu s \times 7\ mA \times 1)}{400\ ms} = 5.85\ \mu A$$

Table 20 shows the average current consumption example for PS_IT = 4T with PS_ITB = T = 50 μs and PS_MPS = 1 for different PS_PERIOD and PS_CURRENT.

TABLE 20 - AVERAGE CURRENT CONSUMPTION (PS_ITB = T = 50 μs, PS_IT = 4T)

		PS_PERIOD / PS_SPERIOD (ms)						
PS_IT (μs)	PS_CURRENT (mA)	6.25	12.5	25	50	100	200	400
200	7	297.64	151.32	78.16	41.58	23.29	14.15	9.57
200	9	361.64	183.32	94.16	49.58	27.29	16.15	10.57
200	11	425.64	215.32	110.16	57.58	31.29	18.15	11.57
200	12	457.64	231.32	118.16	61.58	33.29	19.15	12.07
200	15	553.64	279.32	142.16	73.58	39.29	22.15	13.57
200	17	617.64	311.32	158.16	81.58	43.29	24.15	14.57
200	19	681.64	343.32	174.16	89.58	47.29	26.15	15.57
200	20	713.64	359.32	182.16	93.58	49.29	27.15	16.07

For example, given PS_IT = 4T, PS_ITB = T = 50 μs, PS_MPS = 1, PS_PERIOD = 400 ms and PS_CURRENT = 20 mA, the average current consumption with negligible I_{I^2C} can be calculated as follows:

$$I_{average} = 5\ \mu A + \frac{((900\ \mu s + (2 \times 4 \times 50\ \mu s \times 1)) \times 330\ \mu A) + (4 \times 50\ \mu s \times 20\ mA \times 1)}{400\ ms} = 16.07\ \mu A$$

The designer could use the current calculator tool to calculate the average current consumption based on the selected settings here: https://www.vishay.com/en/optoelectronics/proximity-sensor-current-calculator/

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8. MECHANICAL AND OPTICAL DESIGN

The light wave spreads as it travels in space. This also applies to infrared light from the VCSEL, where it spreads with increasing distance from the sensor. Therefore, the window cover diameter needs to be adjusted to meet the minimum diameter requirement so that the opaque housing will not block the infrared signal. This minimum diameter depends on the distance between the top of the cover and the top of the sensor, the emission angle of the VCSEL, and the field of view of the photodiode. In general, the window diameter increases with increasing distance away from the sensor. The VCSEL in the sensor has an emission angle of ± 4.5°. On the other hand, the photodiode in the sensor has an angle of half sensitivity of ± 60° in the X-axis direction and ± 45° in the Y-axis direction. These are shown in Fig. 55 and Fig. 56.

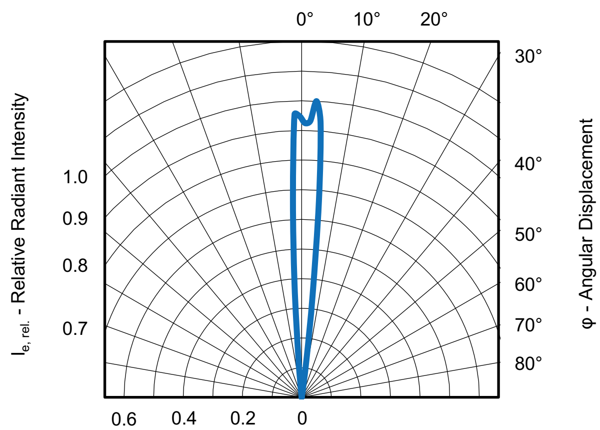

Fig. 55 - Relative Radiant Intensity vs. Angular Displacement of the VCSEL in the VCNL36828P

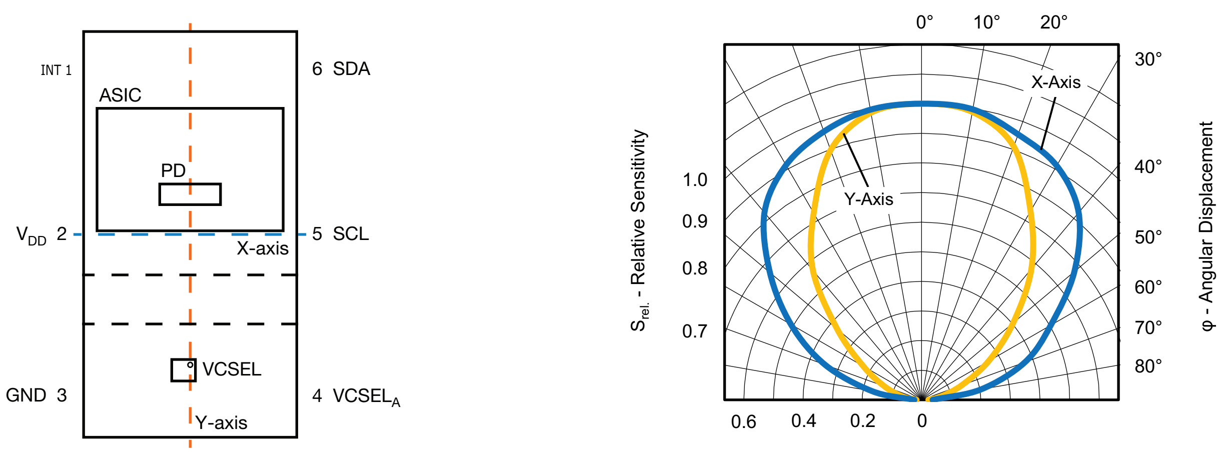

Fig. 56 - Relative Sensitivity vs. Angular Displacement of the Photodiode in the VCNL36828P

Since the VCSEL has a narrower emission angle than the field of view of the photodiode, it is possible to design the window asymmetrically. This is shown in Fig. 57.

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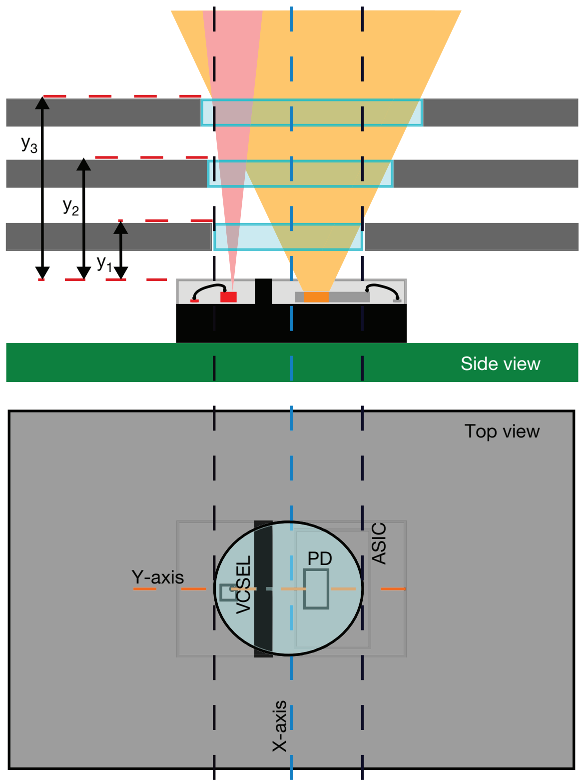

Fig. 57 - Asymmetric Window Design Where the Diameter Increases With Increasing Distance From the Sensor

The minimum window cover diameter D can be calculated as follows:

$$D = x + (y \times \tan(\theta_1)) + (y \times \tan(\theta_2)) = 1.5\text{ mm} + (y \times \tan(\theta_1)) + (y \times \tan(\theta_2)) \quad (6)$$

where x is the distance between the edge of the VCSEL and the edge of the photodiode, y is the distance between the top of the window cover and the top of the sensor, θ_1 is the emission angle of the VCSEL, and θ_2 is the field of view of the photodiode. x is equal to 1.5 mm after including the mechanical placement tolerance of the VCSEL and photodiode die in the sensor package. Fig. 58 shows the diameter calculation of the window cover with thickness T with increasing distance between the top of the window cover and the top of the sensor. The placement of the window cover directly on top of the sensor is usually preferred because it will avoid the peak sensitivity of the sensor. This will help to reduce the crosstalk. However, this is generally difficult to achieve in the assembly because there will likely be an air gap due to mechanical tolerance. If this is the case, an air gap of less than 1 mm is acceptable.

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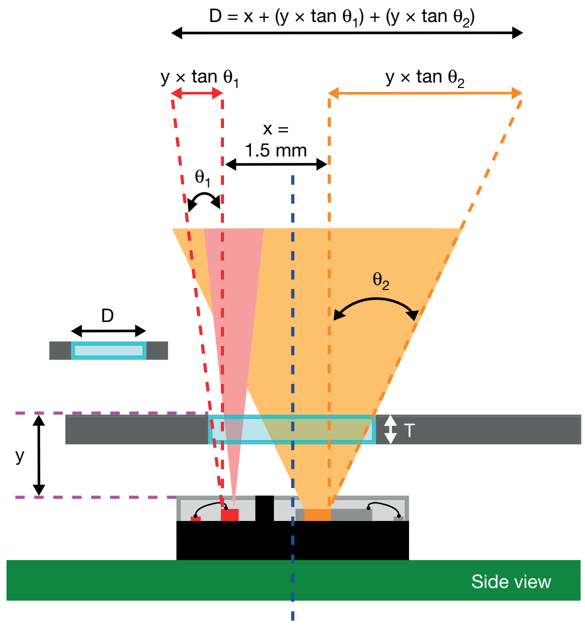

Fig. 58 - The Calculation of the Window Cover Diameter With an Air Gap

Due to mechanical design requirements, the window cover sometimes needs to be placed at a certain distance away from the sensor (with an air gap). In this case, the designer should meet the minimum diameter requirement and avoid placing it at the peak sensitivity of the sensor. The actual minimum diameter requirement depends on the assembly's mechanical tolerance capability so that the window cover positioning is accurate enough to prevent misalignment. Any misalignment of the housing and displacement of the PCB, especially the VCSEL side, could block the infrared signal, and this will cause an error in the measurement.

From Fig. 55, the theoretical value of θ_1 should be 4.5°. However, the mechanical tolerance during the assembly cannot be guaranteed. Therefore, it is recommended to consider a higher value θ_1 during the mechanical design process. This reduces the possibility of a blocked infrared signal, which increases the production yield of the end product. θ_1 = 10° is usually sufficient to transmit the infrared signal from the sensor to the surrounding objects. On the other hand, θ_2 = 50° is generally adequate to capture the reflected infrared signal from the object back to the photodiode of the sensor, even though the total field of view of the photodiode is ± 60°. Table 21 shows the minimum window cover diameter calculation using Equation 6 with the distance y of between 0.5 mm and 4 mm.

TABLE 21 - MINIMUM WINDOW COVER DIAMETER

y (mm)	x (mm)	θ_1 (°)	θ_2 (°)	D (mm)
0.5	1.5	10	50	2.18
1	1.5	10	50	2.87
1.5	1.5	10	50	3.55
2	1.5	10	50	4.24
2.5	1.5	10	50	4.92
3	1.5	10	50	5.60
3.5	1.5	10	50	6.29
4	1.5	10	50	6.97