Designing the VCNL36687S Into an Application

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INTRODUCTION AND BASIC OPERATION

The VCNL36687S is a fully integrated proximity sensor. It combines a high power VCSEL (vertical-cavity surface-emitting laser) and photodiode for proximity measurement and signal processing IC in a single package with a 12-bit ADC. The device provides proximity sensing to minimize accidental touch inputs that can lead to call drops and camera launch.

With a range of up to 20 cm (7.9"), this stand-alone component greatly simplifies the use and design-in of a proximity sensor in consumer and industrial applications, because no mechanical barriers are required to optically isolate the emitter from the detector. The VCNL36687S features a miniature, surface-mount 3.05 mm by 2 mm leadless package (LLP) with a low profile of 1 mm. The device is designed specifically to meet the low height requirements of smartphone, mobile phone, digital camera, and tablet PC applications.

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

Fig. 1 - VCNL36687S Top View

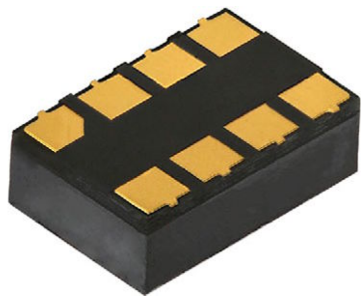

Fig. 2 - VCNL36687S Bottom View

COMPONENTS (BLOCK DIAGRAM)

The major components of the VCNL36687S are shown in the block diagram.

In addition to the ASIC with the proximity photodiode, the VCSEL emitter is also implemented. Its cathode is connected to the driver internally and need not be connected externally.

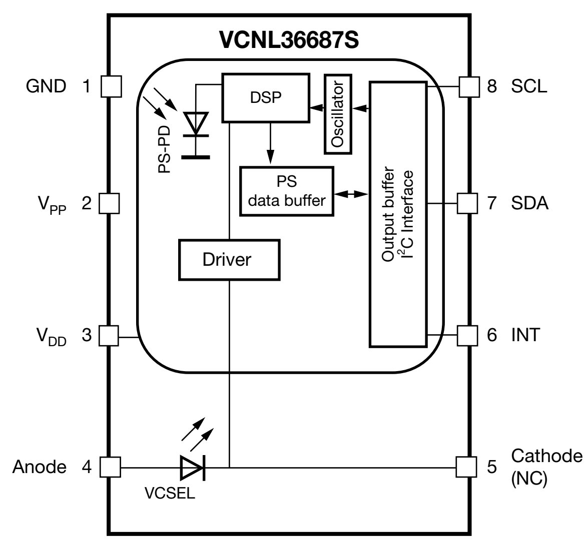

Fig. 3 - VCNL36687S Detailed Block Diagram

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The integrated VCSEL emitter has a peak wavelength of 940 nm. It emits light that reflects off an object within 20 cm of the sensor. An added lens helps to increase peak intensity due to enabling a small angle of just ± 3°, as shown in Fig. 4.

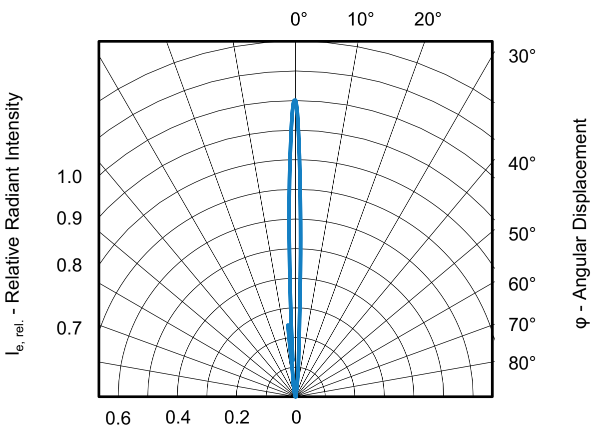

Fig. 4 - Angle of Half Intensity of the Emitter

The VCSEL emitter has a programmable drive current from 7 mA to 20 mA in five steps. The infrared light is emitted in short pulses with a programmable period time from 8 ms to 64 ms. The proximity photodiode receives the light that is reflected off the object and converts it to a current. It has a peak sensitivity of 940 nm, matching the peak wavelength of the emitter. The sensitivity of the proximity stage is also programmable by choosing from four different integration times. It is insensitive to ambient light. It ignores the DC component of light and "looks for" the pulsed light at the proximity frequency used by the emitter.

The application-specific integrated circuit, or ASIC, includes a VCSEL driver, I²C bus interface, amplifier, integrated analog-to-digital converter, oscillator, and signal processor. For proximity, it converts the current from the photodiode to a 12-bit digital data output value.

PIN CONNECTIONS

Fig. 3 shows the pin assignments of the VCNL36687S.

The connections include:

- Pin 1 - connect to ground
- Pin 2 - V_{PP} to the power supply
- Pin 3 - V_{DD} to the power supply
- Pin 4 - VCSEL anode to the power supply
- Pin 5 - VCSEL cathode (no connection)
- Pin 6 - INT to microcontroller
- Pin 7 - SDA to microcontroller
- Pin 8 - SCL to microcontroller

The power supply for the ASIC (V_{DD}) has a defined range from 1.65 V to 1.95 V. The VCSEL needs to be connected to a supply between 2.68 V and 3.3 V depending on the required current, see detailed description with the datasheet. It is best if V_{DD} is connected to a regulated power supply and pin 4, the anode, is connected directly to the battery. This eliminates any influence of the high infrared emitter current pulses on the V_{DD} supply line.

On both power supplies, for the V_{DD} and the VCSEL a ceramic 1 µF should be placed close to the respective pin. The SCL and SDA, as well as the interrupt lines, need pull-up resistors. The resistor values depend on the application and on the I²C bus speed. Common values are about 2.2 kΩ to 4.7 kΩ for the SDA and SCL, and about 8.2 kΩ to 22 kΩ for the interrupt lines.

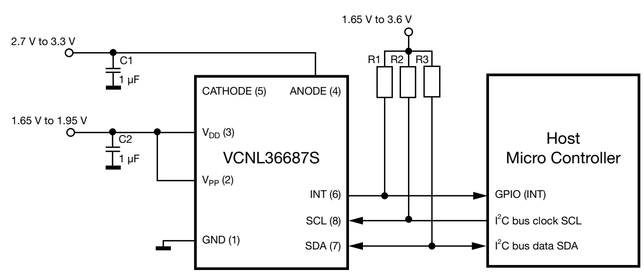

Fig. 5 - VCNL36687S Application Circuit

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MECHANICAL DESIGN CONSIDERATIONS

The VCNL36687S does not require a mechanical barrier. The signal processor continuously compensates for the light reflected from windows, thus ensuring a proper proximity reading. As a fully integrated sensor, the design process is greatly simplified.

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

The angle of half intensity of the emitter is about ± 3°, as shown in Fig. 6, and the sensitivity of the photodiode is showing about ± 55°.

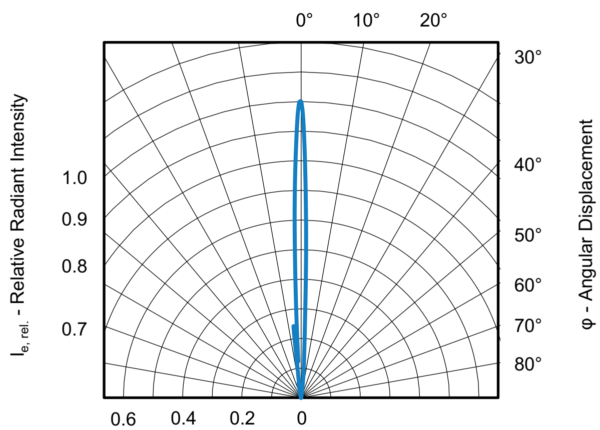

Fig. 6 - Angle of the Half Intensity of the Emitter

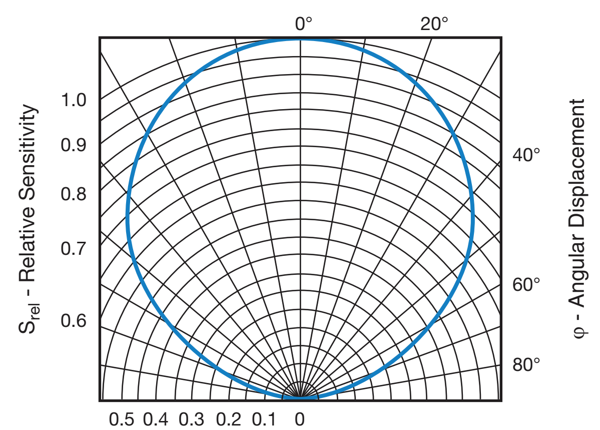

Fig. 7 - Angle of the Half Sensitivity of the Photodiode

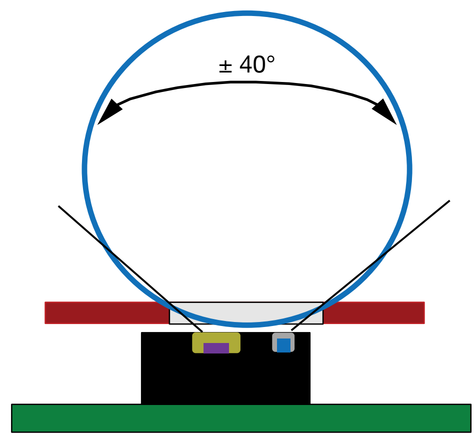

Fig. 8 - Emitter and Detector Angle

To achieve good performance, the diameter of the hole within the cover glass should not be too small. An angle of ± 40° will be sufficient in most applications. The package drawing shows the position of the VCSEL and photosensitive area. The ± 40° lines are set to outer edges of the photodiode and VCSEL. The following are dimensions for the distance from the top surface of the sensor to the outside surface of the glass, a, and the width of the window, d.

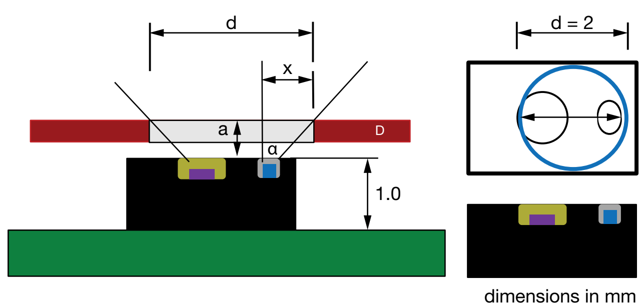

Fig. 9 - Window Dimensions for One Hole

For a single round hole, the diameter should be at least wide enough that the openings can freely look through; so, about 2 mm.

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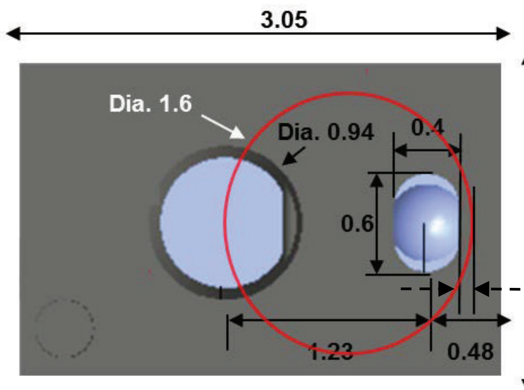

Fig. 10 - Light Hole Diameter

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

The width calculation for distances from 0.5 mm to 1.5 mm results in:

a = 0.5 mm → x = 0.42→ d = 2 mm + 0.84 = 2.84 mm
a = 1.0 mm → x = 0.84→ d = 2 mm + 1.68 = 3.68 mm
a = 1.5 mm → x = 1.26→ d = 2 mm + 2.52 = 4.52 mm

Calculation is: $\tan \alpha = x/a$ → with $\alpha = 40°$ and $\tan 40° = 0.84 = x/a$ → $x = 0.84 \times a$. Then total width / diameter for the opening is $d = 2\ mm + 2 \times x$.

The results above represent the ideal diameters of the window. The mechanical design of the device may not allow for these diameters. Fig. 10 shows that also a smaller opening could be used. To allow for this, the gap between sensor and cover should be as small as possible (≤ 0.2 mm) and the cover also quite thin (≤ 0.6 mm).

PROXIMITY SENSOR

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

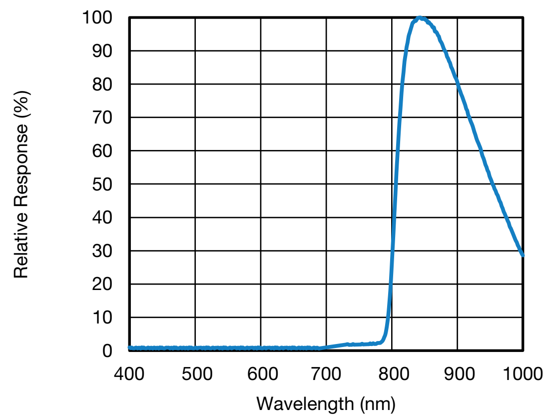

Fig. 11 - Spectral Sensitivity of the Proximity Photodiode

The proximity sensor uses a short pulse signal of about 50 μs (PS_IT = 1T) up to 400 μs (PS_IT = 8T). PS_ITB sets the duration of T in PS_IT. It is recommended to set PS_ITB to 50 μs because it improves the sensitivity and sunlight protection of the sensor. The period time for this single pulse can be programmed between 8 ms and 64 ms.

In addition to DC light source noise, there is some reflection of the infrared emitted light off the surfaces of the components surrounding the VCNL36687S. The distance to the cover, proximity of surrounding components, tolerances of the sensor, defined infrared emitter current, ambient temperature, and type of window material used all contribute to this reflection. The result of the reflection and DC noise is the production of an output current on the proximity and light sensing photodiode. This current is converted into a count called the offset count.

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

The application should "ignore" this offset and small noise floor by subtracting them from the total proximity readings. The VCNL36687S offers a subtraction feature that automatically does this: PS_CANC. During the development of the end product, this offset count is evaluated and may now be written into register 7: PS_CANC_L/M. Now the proximity output data will just show the subtraction result of proximity counts - offset counts.

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

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PROXIMITY CURRENT CONSUMPTION

The VCNL36687S offers a shutdown mode. Default values after start-up have this disabled. The application needs to activate with PS_SD = 0.

The VCNL36687S's embedded VCSEL driver drives the internal VSCEL with a pulsed duty cycle that could also be measured at pin 5. The VCSEL on / off duty ratio is programmable by an I²C command at register PS_Period. Depending on this pulse / pause ratio, the overall proximity current consumption can be calculated. When higher measurement speed or faster response time is needed, PS_Period may be selected to a short time of 8 ms, but this will then also lead to the highest current consumption:

PS_Period = 8 ms: peak VCSEL current = 20 mA, PS_ITB = 50 µs, averaged current consumption is 20 mA x 50 µs/8000 µs = 0.125 mA.

For proximity measurements executed just every 64 ms:
PS_Period = 64 ms, peak VCSEL current = 20 mA, averaged current consumption is 20 mA x 50 µs/64 000 µs = 0.016 mA.

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

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

In this mode, only the I²C interface is active. In most consumer electronic applications the sensor will spend the majority of time in sleep mode; it only needs to be woken up for a proximity measurement. In standby mode the power consumption is about 0.5 µA.

The pulse for proximity measurement looks to have a higher landing / step. This second trap is for smooth switch-off of the VCSEL and is executed with very low VCSEL current. The pulse length in total is 50 µs. Amplitude of that 50 µs pulse is dependent on the VCSEL current. The higher this current is programmed, the higher that pulse amplitude will be. Taking a scope picture at IR_Cathode (pin 5) will look like this:

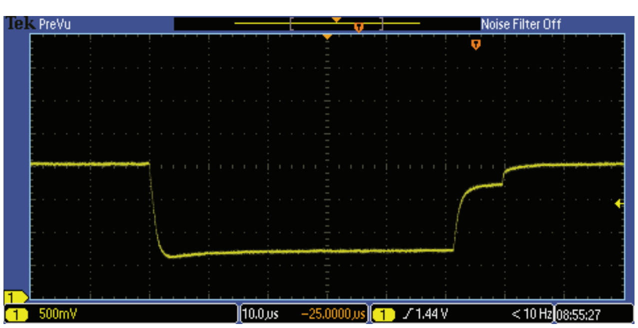

Fig. 12 - Proximity VCSEL Pulse for 1T

INITIALIZATION AND I²C TIMINGS

The VCNL36687S contains nine 16-bit command codes for operation control, parameter setup, and result buffering. All registers are accessible via I²C communication. The built-in I²C interface is compatible with the standard and high-speed I²C modes. The I²C H-level voltage range is from 1.65 V to 3.6 V.

There are only four registers out of the nine that typically need to be defined:

1. VCSEL_I = 7 mA to 20 mA (VCSEL current)
   REGISTER CONF4 #04 [0x04h]
2. PS_Period = 8 ms to 64 ms (proximity duty ratio), PS_IT (proximity integration time = pulse length), PS_ITB = 50 µs (IT bank setting of 50 µs recommended for better sensitivity).
   PS_PERS (number of consecutive measurements above / below threshold), and PS_SD (PS power_on)
   REGISTER PS_CONF1 and PS_CONF2 #03 [0x03h]
3. and 4. Definition of the threshold value from the number of counts the detection of an object should be signaled.
   Proximity TOP threshold REGISTER
   PS_THDL_L #05 [0x05h] for the low byte and
   PS_THDL_H #06 [0x06h] for the high byte

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

Fig. 13 shows the typical digital counts output versus distance for three different emitter currents for integration time 1T. The reflective reference medium is the Kodak Gray card. This card shows approximately 18 % reflectivity at 940 nm.

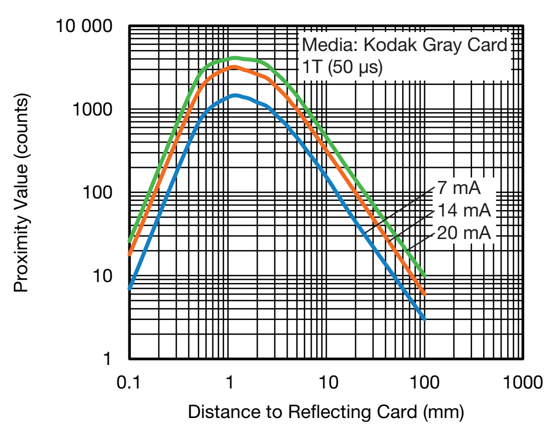

Fig. 13 - Proximity Value vs. Distance for 1T

This first diagram shows the possible detection counts with a short pulse of just 50 µs.

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If higher detection distances and / or objects with very low reflectivity need to be detected, there is the option to extend these proximity pulses up to about 400 μs for 8T. This results in higher counts but may also lead to saturation effects for very close and very bright objects. This leads then to the diagram in Fig. 14 below.

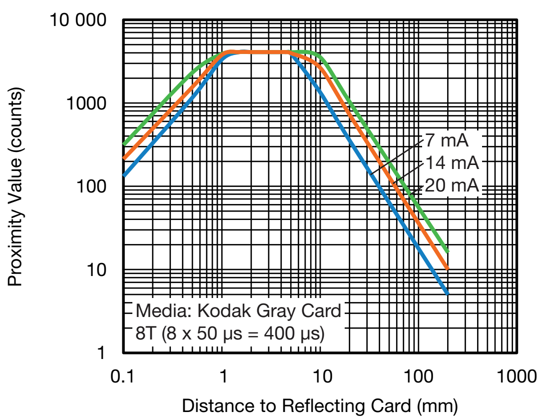

Fig. 14 - Proximity Value vs. Distance; PS_IT = 8T

With defining the period time (PS_Period), the repetition rate = the number of proximity measurements per second (speed of proximity measurements) is defined. This is possible between 8 ms (about 67 measurements/s) and 64 ms (about 14 measurements/s).

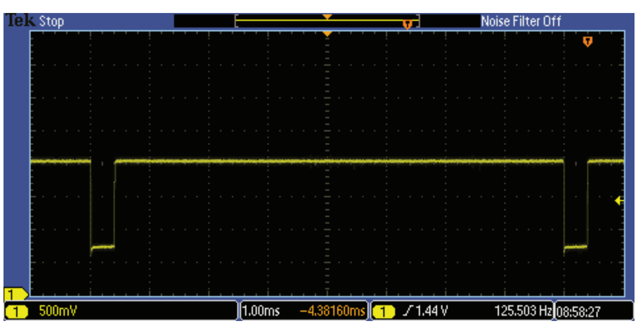

Fig. 15 - Proximity Measurements with PS_Period = 8 ms

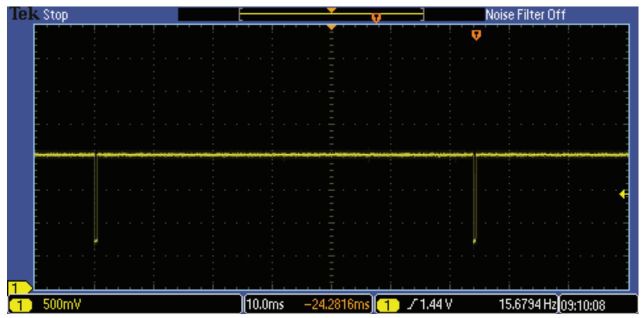

Fig. 16 - Proximity Measurements with PS_Period = 64 ms

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

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

To eliminate disturbance by direct sunlight this "sunlight cancellation" bit PS_SC_EN has to be set. In addition, the compensation current can be modified with PS_SC-CUR in four possible steps from "typical" up to eight times this typical current.

To define all these register values, an evaluation test should be performed. These tests can be made just using the VCNL36687S sensor board together with the SensorXplorer™. Both boards are available from any of Vishay's distributors. Please see: www.vishay.com/optoelectronics/SensorXplorer.

Timing

For an I²C bus operating at 100 kHz, to write or read an 8-bit byte, plus start (or stop) and bit acknowledgement, takes 100 μs. Together with the slave address byte and the 8-bit command code byte, plus the 16-bit data, this results in a total of 400 μs. When the device is powered on, the initialization with just these five registers needs 5 x 4 bytes (slave address, command register, and 16-bit data) for a total of 20 bytes. So, 20 x 100 μs = 2000 μs = 2 ms.

Send Byte → Write Command to VCNL36687S

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

The read-out of 16-bit data would take a total of five bytes (slave address, command code, slave address with read bit set) and 16-bit data sent from the VCNL36687S. So, 500 μs:

Receive Byte → Read Data from VCNL36687S

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

Power Up

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

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Initialize Registers

Write to four registers	**1600 µs**
- VCSEL current	
- Proximity duty ratio	
- Proximity interrupt TOP threshold	

Once the device is powered on and the VCNL36687S is initialized, a proximity measurement can be taken.

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

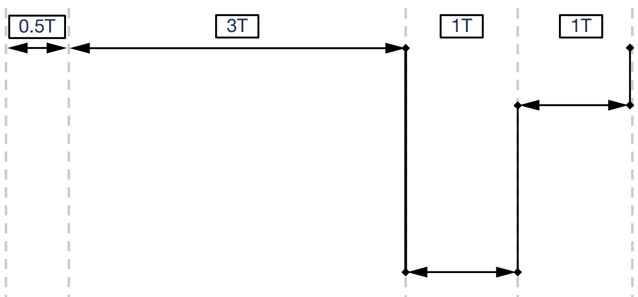

Fig. 17 - Timing Specification for Active Forced Mode

INTERRUPT

The VCNL36687S features a very intelligent interrupt function. The interrupt function enables the sensor to work independently until a predefined proximity event or threshold occurs. It then sets an interrupt which requires the microcontroller to awaken. This helps customers reduce their software effort, and reduces power consumption by eliminating polling communication traffic between the sensor and microcontroller.

The interrupt pin, pin 6, of the VCNL36687S should be connected to a dedicated GPIO of the controller. A pull-up resistor is added to the same power supply that the controller is connected to. This INT pull-up resistor may be in the range of 8.2 kΩ to 100 kΩ.

The events that can generate an interrupt include:

1. A lower and an upper threshold for the proximity value can be defined. If the proximity value falls below the lower limit or exceeds the upper limit, an interrupt event will be generated. In this case, an interrupt flag bit in the read-out register 0xF3 will be set and the interrupt pad of the VCNL will be pulled to low by an open drain pull-down circuit. In order to eliminate false triggering of the interrupt by noise or disturbances, it is possible to define the number of consecutive measurements that have to occur before the interrupt is triggered
2. A too high infrared level as it could be with strong direct sunlight or also close halogen / incandescent lamp can be observed with checking the bit: PS_SPFLAG

Application Example

The following example will demonstrate the ease of using the VCNL36687S sensor.

Offset

During development, the application-specific offset counts for the sensor were determined. As previously mentioned, the offset count is affected by the components surrounding the VCNL36687S, the window or cover being used, the distance from the sensor to the cover, and emitter intensity, which is controlled by the forward current.

In the following example, with a cover over the sensor and setting the emitter current to 20 mA, the offset counts are 300 counts (Fig. 18). Offset counts vary by application and can be anywhere from 0 counts to several thousand counts. It is important to note that the offset count may change slightly over time due to, for example, the window becoming scratched or dirty, or being exposed to high-temperature changes. If possible, the offset value should occasionally be checked and, if necessary, modified.

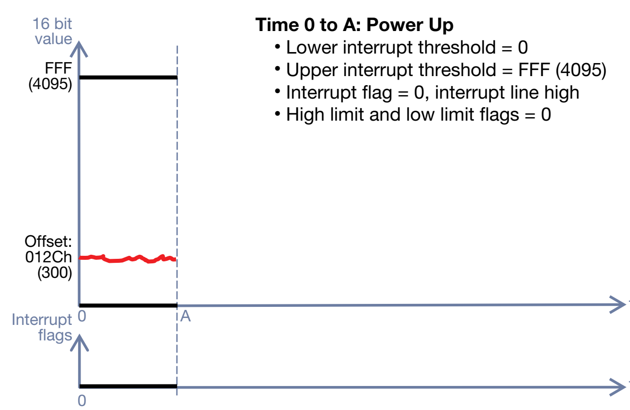

Fig. 18

APPLICATION NOTE

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Power Up

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

The sensor should detect skin at a distance of 5 cm. Development testing determined that a current of 20 mA produces adequate counts for detection. The proximity measurement rate is set so that about 14 measurements are done within a second and the number of occurrences to trigger an interrupt is set to four. Based on development testing, with a hand or skin approximately 5 cm above the window cover, the resulting total count is > 500. This will be used as the upper threshold (high threshold).

For smartphone applications it would be typical to initially set this top threshold and a lower threshold (bottom threshold). This is needed to indicate the removal of the phone from the user's ear. The measured counts without any additional object close by will be around this offset count value, always below the lower threshold value, as shown in Fig. 19.

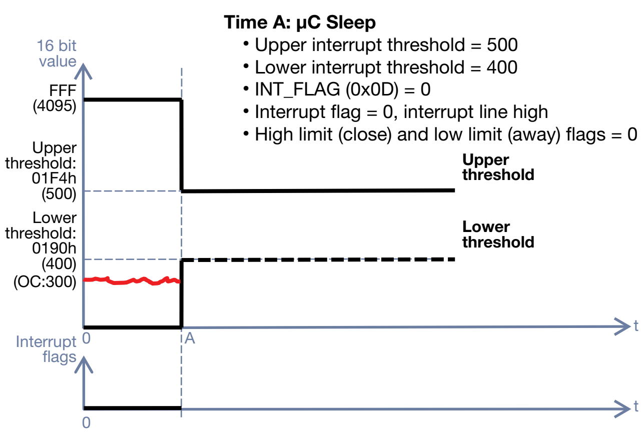

Fig. 19

By setting the number of occurences before generating an interrupt to 4, a single proximity value above or below the thresholds will have no effect, as shown in Fig. 20.

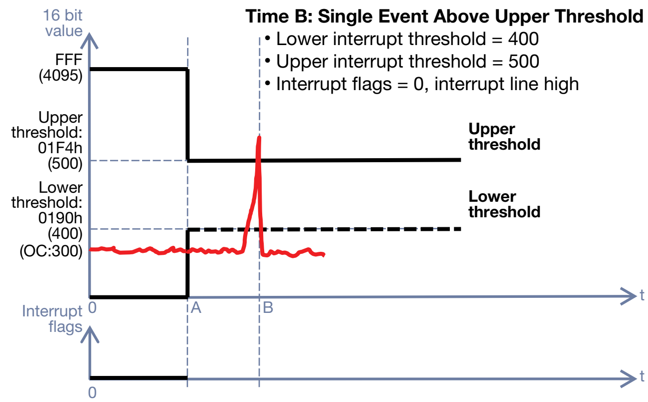

Fig. 20

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

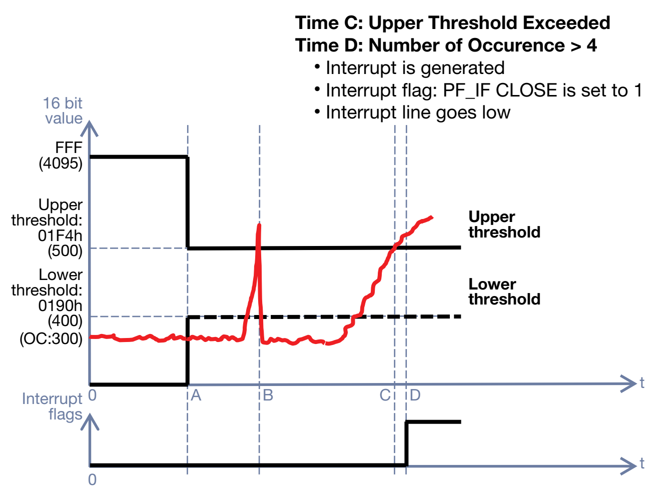

Fig. 21

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

For this example, the upper threshold will be set to 500 counts. The lower threshold is set to 400 counts; a value that is higher than the offset but low enough to indicate the removal of the phone from the user's ear.

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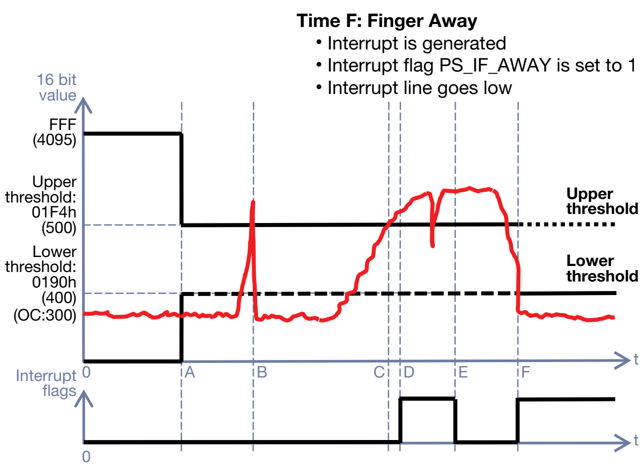

Fig. 22

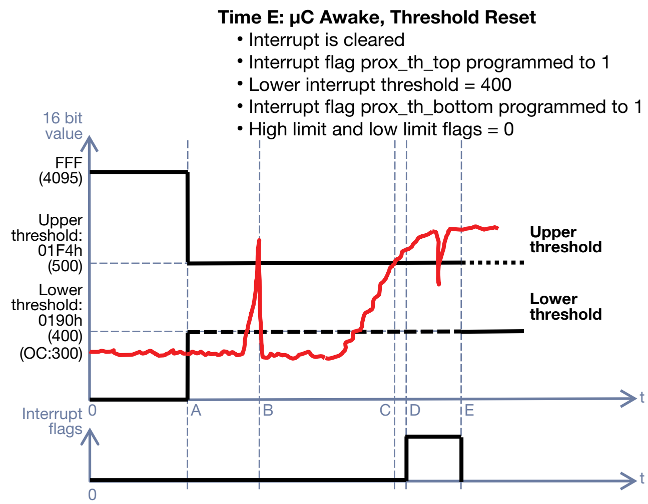

Fig. 23

Some measurements and features are shown with the demo tool and demo software with a cover glass at about a 2 mm distance.

1. Proximity set-up with 8T wide pulses, 20 mA VCSEL current, and a period of 64 ms, which results in about 15 measurements per second

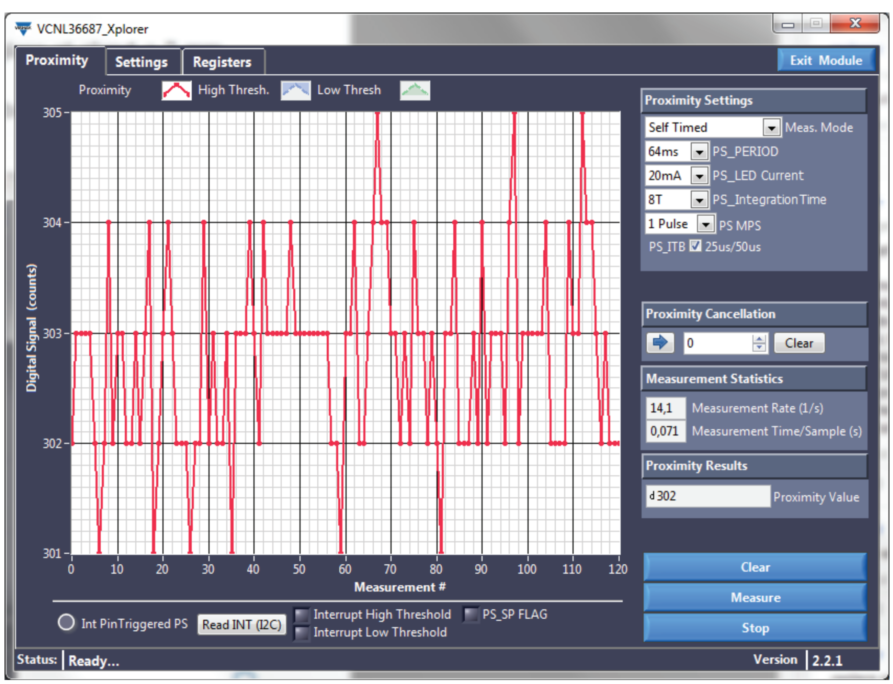

Fig. 24 - Screenshot of VCNL36687 Demo Software

2. If a hand or skin now comes as close as 5 cm, these 300 counts rise up to more than 500 counts.

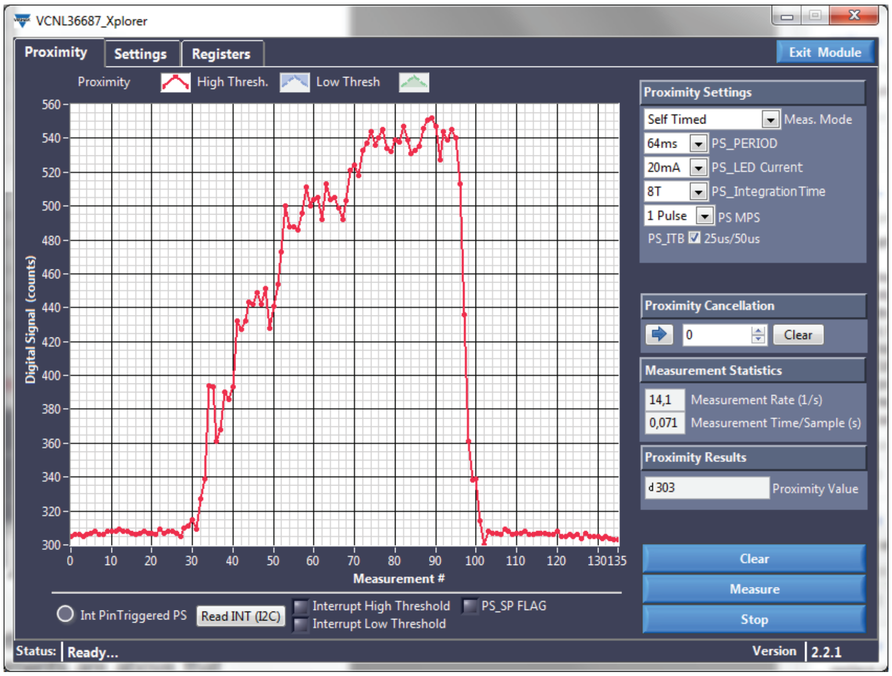

Fig. 25 - Hand in About 5 cm Distance Will Lead to More Than 500 Counts

3. Here the thresholds are programmed as 500 for the upper and 400 for the lower. To see these, both “Show” buttons are activated. The presence of an object should only be recognized when four consecutive measurements are above that threshold.

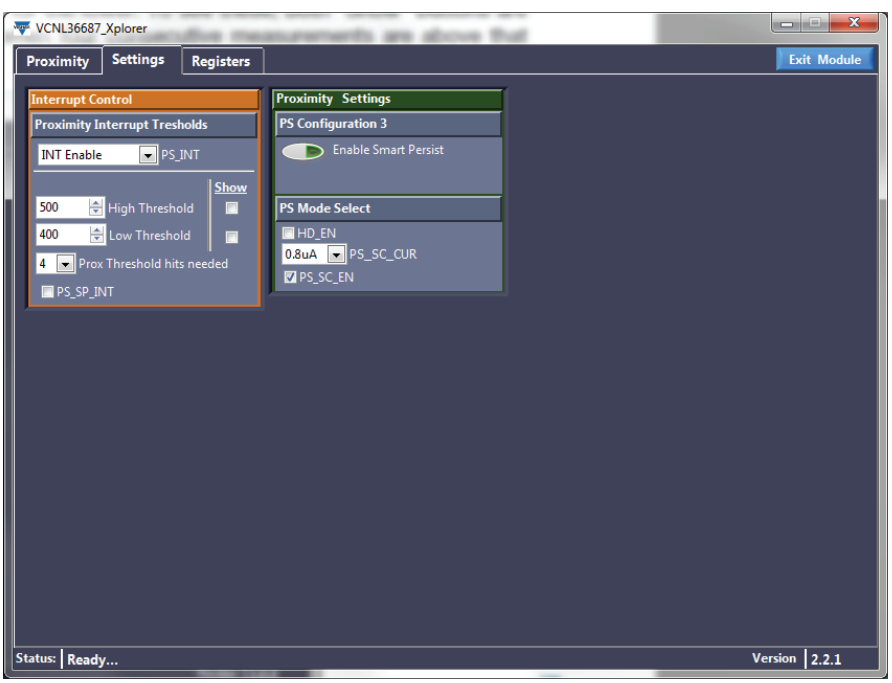

Fig. 26 - “Settings” Menu Within Demo Software

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

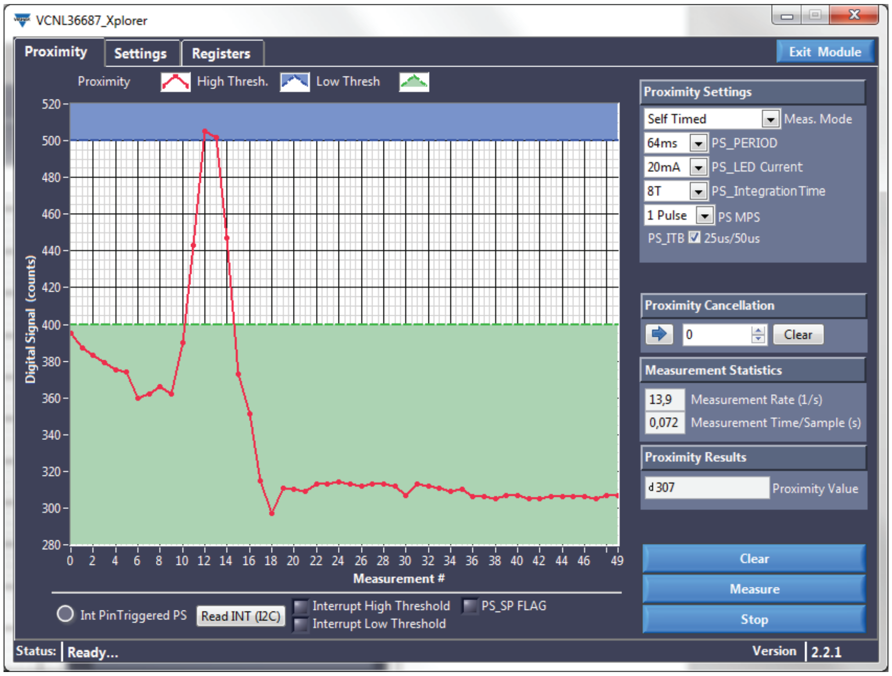

Fig. 27 - Upper and Lower Threshold Set and Hand in About 5 cm Distance

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

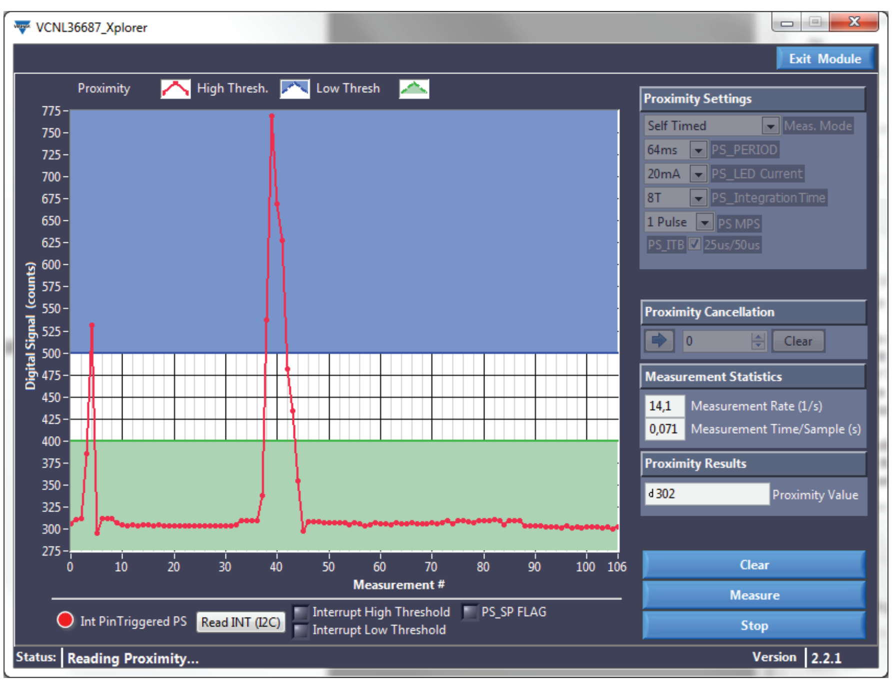

Fig. 28 - Hand in About 5 cm Distance for More Than 4 Consecutive Measurements Above Higher Threshold

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6. The cancellation feature is used below. The "before seen" offset counts are subtracted. To do so, the value of 300 is entered for register number 05 = Prox_Cancellation.

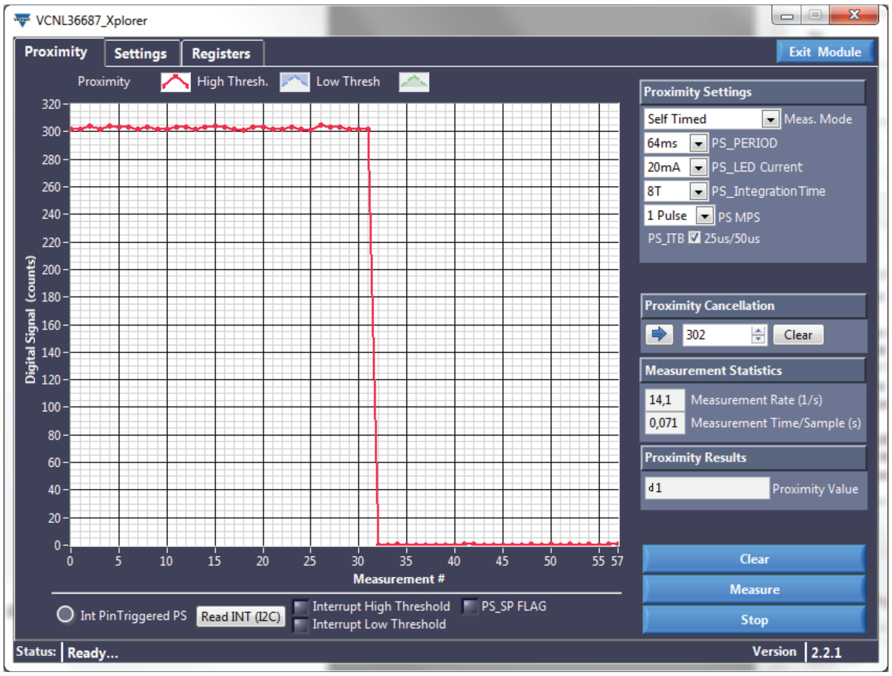

Fig. 29 - Cancellation Activated

7. The "before seen" offset counts of about 300 are now subtracted: 300 - 300 = 0. Also, the thresholds are now 300 counts lower. The higher threshold is 200 and lower is just 100.

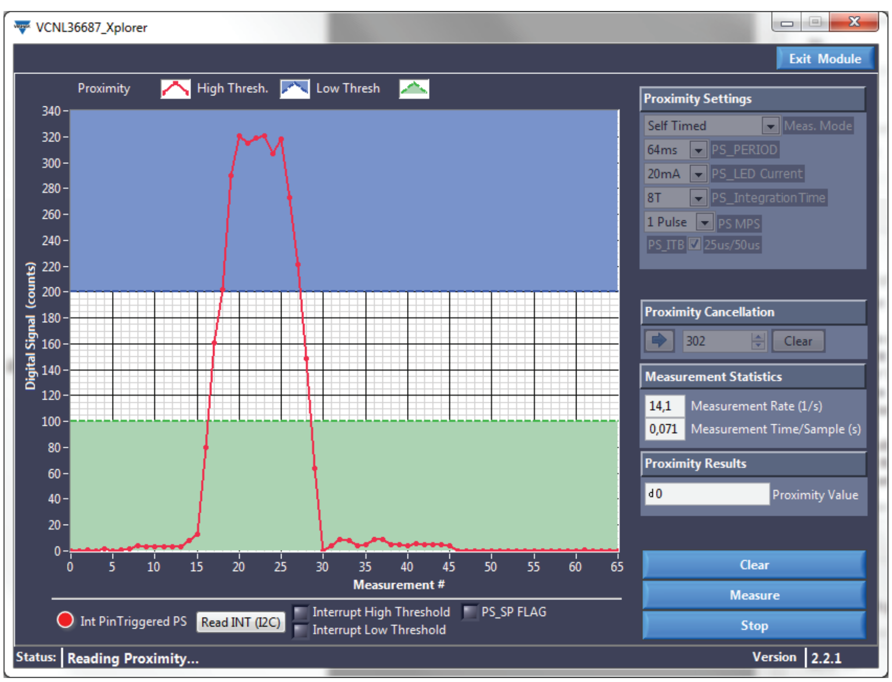

Fig. 30 - New Defined Thresholds With Cancellation Feature

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If one chooses “logic mode” now and redefines the high threshold to 200 and low threshold as 100...

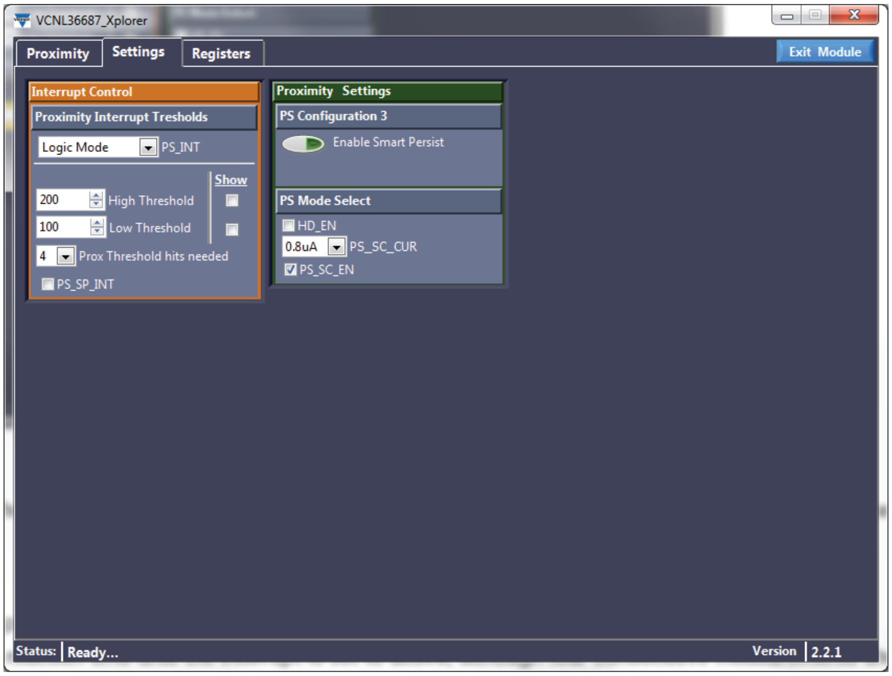

Fig. 31 - Logic Mode

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

SMART PERSIST

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

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

Without “smart persist”, but with programmed hits above the defined threshold set to four, it will take three times the time of PS_Period. With PS_Period set to 32 ms this would be 3 x 32 ms.

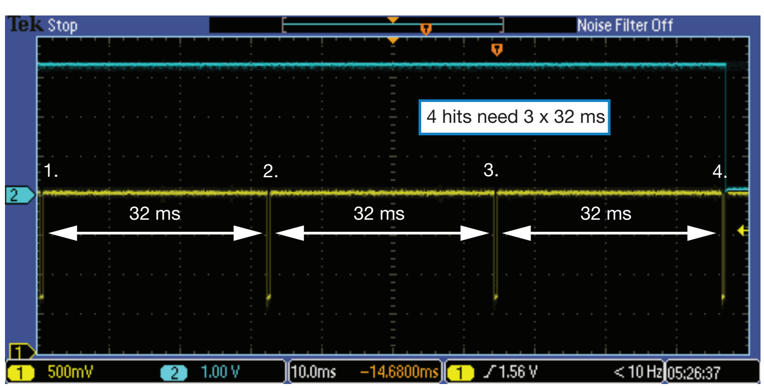

Fig. 32 - Interrupt Active After 4 Hits Above Threshold

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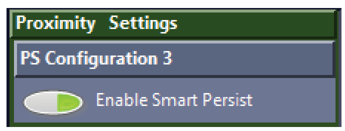
With “smart persist” activated (bit 1 of PS_CONF1):

REGISTER: PS_CONF1 DESCRIPTION		
REGISTER NAME		**COMMAND CODE: 0x03_L (0x00 DATA BYTE LOW)**
Command	Bit	Description
PS_Period	7 : 6	(0 : 0) = 8 ms, (0 : 1) = 16 ms, (1 : 0) = 32 ms, (1 : 1) = 64 ms PS sample period setting
PS_PERS	5 : 4	(0 : 0) = 1, (0 : 1) = 2, (1 : 0) = 3, (1 : 1) = 4 PS interrupt persistence setting
PS_ INT	3 : 2	(0 : 0) = interrupt disable, (0 : 1) = interrupt disable, (1 : 0) = interrupt enable, (1 : 1) = trigger by logic high / low mode
PS_SMART_PERS	1	0 = disable ; 1 = enable PS smart persistence
PS_SD	0	0 = PS power on, 1 = PS shut down, default = 1

or within the demo-tool:



The total needed time is reduced to just about 6.4 ms.

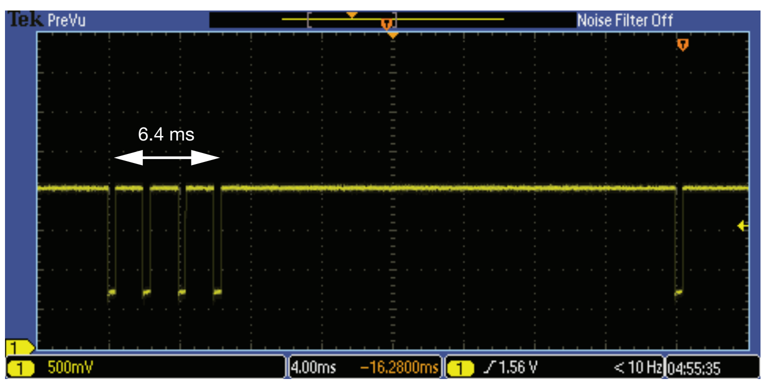


Fig. 33 - Smart Persist With PS_IT = 8T = 400 μs and PS_Period = 32 ms

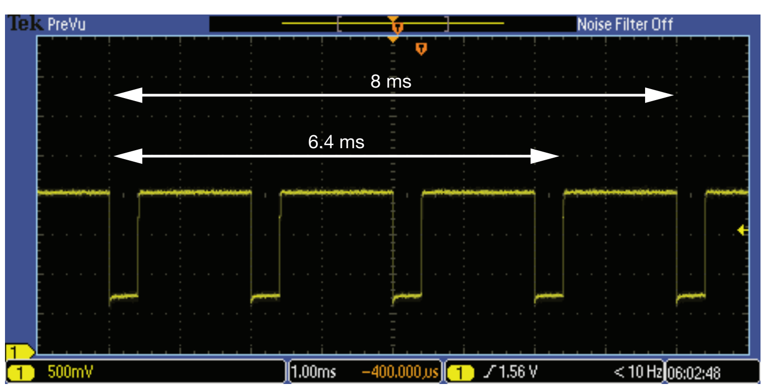


Fig. 34 - Always About 6.4 ms for These 4 Hits, Also When PS_Period is Programmed to Just 8 ms

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MULTI PULSE FEATURE

For high detection ranges, the intensity for each proximity measurement will be chosen to the maximum possible value. This can be achieved by programming the VCSEL current to a maximum of 20 mA and longest measurement pulse PS_IT of 400 μs.

Even further increase is possible using this so-called Multi-Pulse feature, PS_MPS.

With this it is possible to send more than one pulse for a single proximity measurement. As shown within the table and illustrated with Fig. 35 and Fig. 36 below, a burst with either 2, 4, or even 8 pulses one after the other is possible.

REGISTER: PS_CONF2 DESCRIPTION		
		COMMAND CODE: 0x03_H (0x03 DATA BYTE HIGH)
Command	Bit	Description
PS_IT	7 : 6	(0 : 0) = 1T, (0 : 1) = 2T, (1 : 0) = 4T, (1 : 1) = 8T
PS_MPS	5 : 4	(0 : 0) = 1, (0 : 1) = 2, (1 : 0) = 4, (1 : 1) = 8; PS multi-pulse setting
PS_ITB	3	0 = 25 μs, 1 = 50 μs, PS IT bank setting
Reserved	2 : 0	Default = 0

With PS_IT of 400 μs and PS_MPS = 8 this needs then about 6 ms for one measurement, see Fig. 35 below. Fig. 36 shows it with 4 pulses and Fig. 37 shows these 8 pulses within a period of 64 ms.

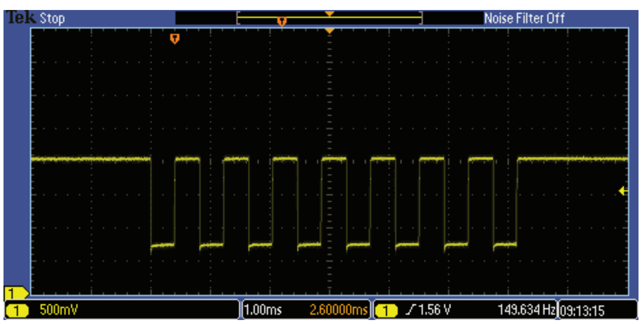

Fig. 35 - PS_IT = 8T (400 μs) and MPS = 8

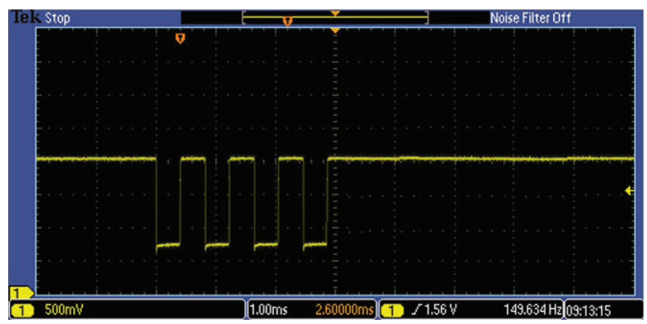

Fig. 36 - PS_IT = 8T (400 μs) and MPS = 4

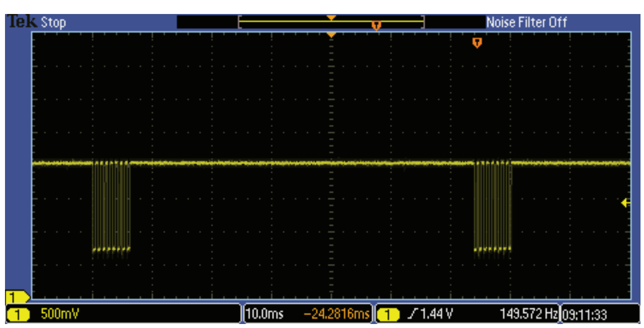

Fig. 37 - PS_Period = 64 ms and PS_IT = 8T (400 μs) and MPS = 8

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With this much higher energy the detection distance could be increased up to about 40 cm (15 inch).

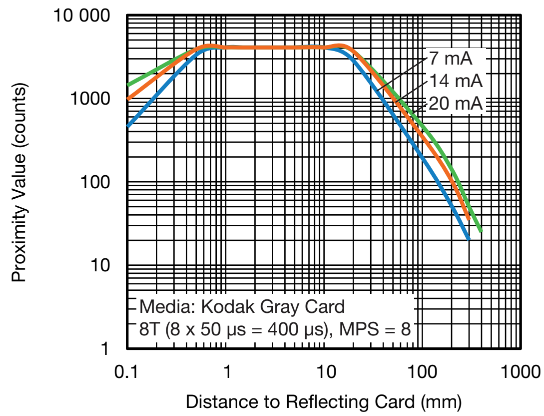

Fig. 38 - Proximity Value vs. Distance for PS_IT = 8T (400 µs) and MPS = 8

Remark:

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