Extended Detection Range with VCNL Family of Proximity Sensors

by Reinhard Schaar

1. INTRODUCTION AND BASIC OPERATION

The VCNL4010, VCNL4020, VCNL4020X01, and VCNL3020 are proximity sensors with I^2C interfaces. Each device combines an infrared emitter, PIN photodiode, and signal processing IC in a single package with a 16-bit ADC. With a range of up to 20 cm (7.9 in), these stand-alone, single-component solutions greatly simplify the use and design-in of proximity sensors in consumer and industrial applications, because no mechanical barriers are required to optically isolate the emitter from the detector. Through the standard I^2C bus serial digital interface, VCNL devices allow easy access to a “Proximity Signal” measurement without complex calculations or programming. The programmable interrupt function offers wake-up functionality for the microcontroller when a proximity event occurs, which reduces processing overhead by eliminating the need for continuous polling.

The integrated infrared emitters have a peak wavelength of 890 nm. They emit light that reflects off an object within 20 cm of the sensor. To achieve this range the highest current, 200 mA, needs to be programmed (see fig. 1 below).

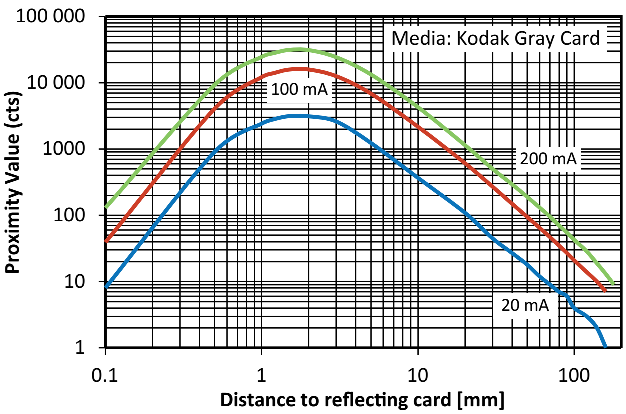

Fig. 1 - Proximity Value vs. Distance

2. IRED CONNECTION AND CIRCUITRY

Some applications may require higher intensities from the emitter, because only a very weak signal is reflected from the object that needs to be detected, or the object could be at a larger distance from the sensor.

All VCNL sensors allow the connection of a more powerful external emitter, such as an infrared emitting diode (IRED) with a lens.

In this case, the internal IRED will not be powered; its anode will not be connected to the power supply.

The cathode, which normally is not connected, can now be used to add an external IRED to the VCNL’s internal driver. With this configuration, all controlling and programming is the same as with the internal IRED. Fig. 2 shows the principle behind the VCNL’s operation.

Instead of the internal emitter, an external IRED is connected to the VCNL internal driver and programmable current source, while its anode is connected to the power supply.

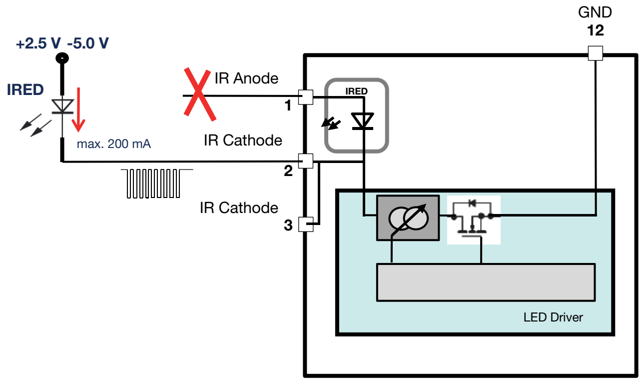

Fig. 2 - VCNL4010 Principle Operation

Fig. 3 and fig. 4 show the different pinning for the VCNL4010 and VCNL4020, VCNL4020X01, or VCNL3020 packages.

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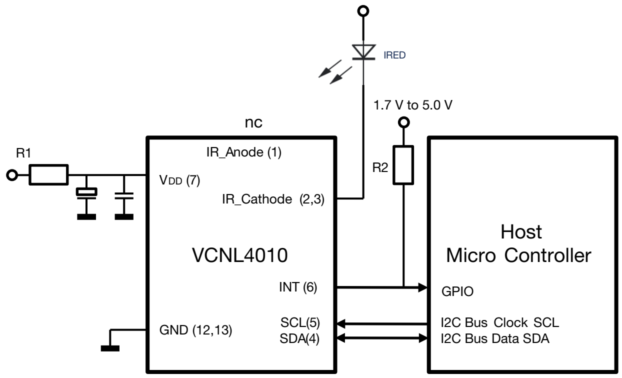

Fig. 3 - VCNL4010 Circuitry with an External IRED

For the VCNL4010, pin 1 (IR_Anode) is not connected and the cathode of an external IRED is connected at pin 2 and pin 3.

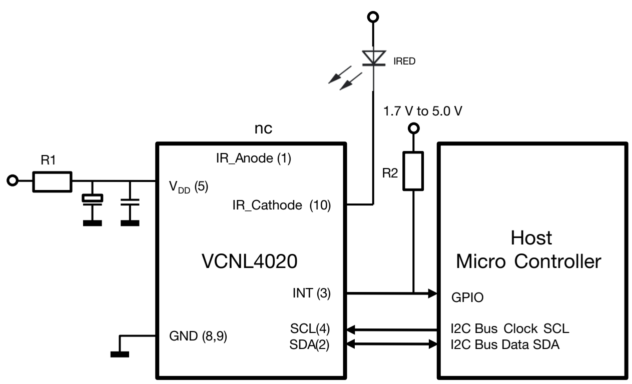

Fig. 4 - VCNL4020, VCNL4020X01, or VCNL3020 Circuitry with an External IRED

For the VCNL4020, VCNL4020X01, and VCNL3020 package, pin 1 (IR_Anode) is not connected and the cathode of an external IRED can be connected at pin 10.

The power supply for the ASIC (V_{DD}) has a defined range from 2.5 V to 3.6 V. The infrared emitter (internal as well as external) may be connected in the range of 2.5 V to 5.0 V. It is best if V_{DD} is connected to a regulated power supply and IR_Anode is connected directly to the battery or power supply. This prevents any influence of the high infrared emitter current pulses on the V_{DD} supply line.

The integrated infrared emitter has a peak wavelength of 890 nm and the PIN photodiode, receiving the light that is reflected off the object and converting it to a current, has a peak sensitivity of 890 nm, perfectly matching the peak wavelength of the emitter.

The chosen external IRED should have a peak wavelength of 890 nm, but down to 850 nm is also possible. At 850 nm the sensitivity of the photodiode is approximately 70 %.

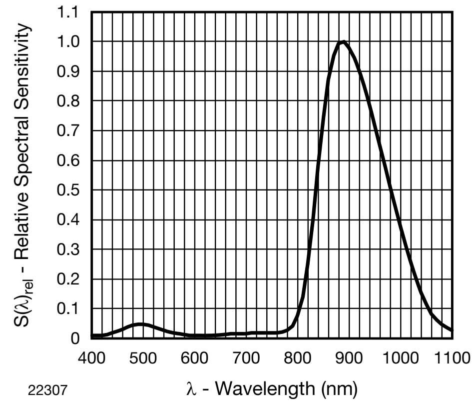

Fig. 5 - Spectral Sensitivity of Proximity PIN Photodiode

One possible IRED that could be used is the VSMF2890GX01, as featured on the sensor boards available for the VCNL4010, VCNL4020, VCNL4020X01, and VCNL3020.

Fig. 6 - VCNL4020 Sensor Board

More about these sensor boards can be found here: www.vishay.com/doc?84242

3. MECHANICAL DESIGN CONSIDERATIONS

The VCNL family features a 16-bit ADC. While there is crosstalk between the external emitter and the VCNL sensor when using the demo kit and software, the 16-bit ADC provides more than enough headroom to continue functioning over the entire 20 cm range. These "offset" counts may be significant, possibly up to 5000 counts, but more than 60 000 counts remain before saturating the detector.

This high crosstalk can be avoided if a light barrier is placed between the IRED and sensor. A decoupling capacitor, which is needed anyway, can serve as a light barrier when placed in-between.

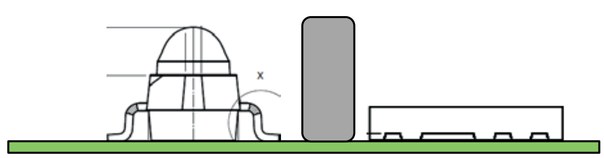

Fig. 7 - Light Barrier in-between IRED and Sensor

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The emitter package in fig. 7 is called a gullwing package. Instead of this package, a reverse gullwing emitter can be used as shown in fig. 8. Because the emitter chip is below the PCB with this package, crosstalk is eliminated.

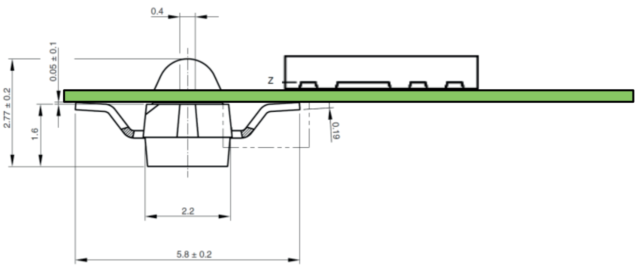

Fig. 8 - Reverse Gullwing used as an External IRED

Using the VSMF2890 as the external IRED provides much higher intensity than the sensor's internal emitter. This enables object detection at distances of up to 50 cm. Of course this always depends on the material and color of the object that needs to be detected. An overview is given in table 1 at the end of this note.

Using more powerful devices like the TSHF6210 would further increase the distance, and / or result in higher detection counts as indicated by the diagrams of both IREDs in fig. 9 and fig. 10.

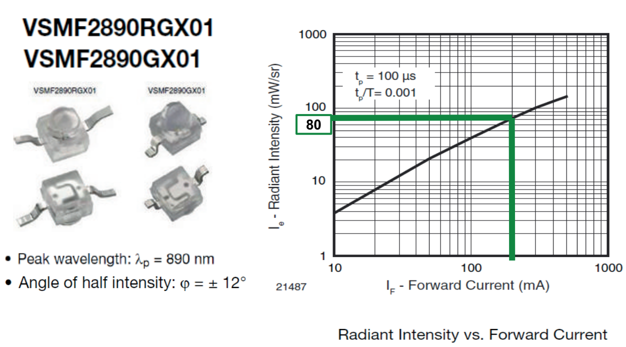

Fig. 9 - VSMF2890X01 and Radiant Intensity Diagram

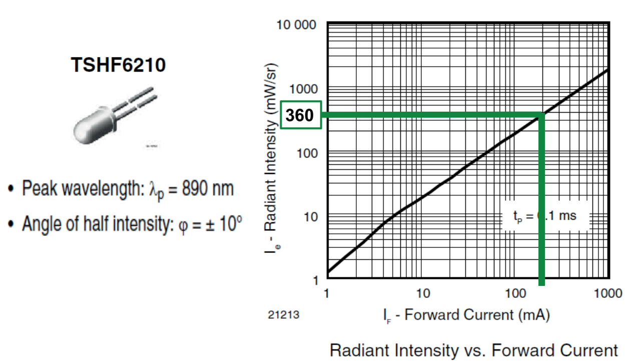

Fig. 10 - TSHF6210 and Radiant Intensity Diagram

Both the absolute peak value and its position within the diagram for the proximity counts versus distance to the object depend on the distance between this external IRED and the sensor. Below, the graph for the VCNL sensor board with approximately 9 mm between them is shown.

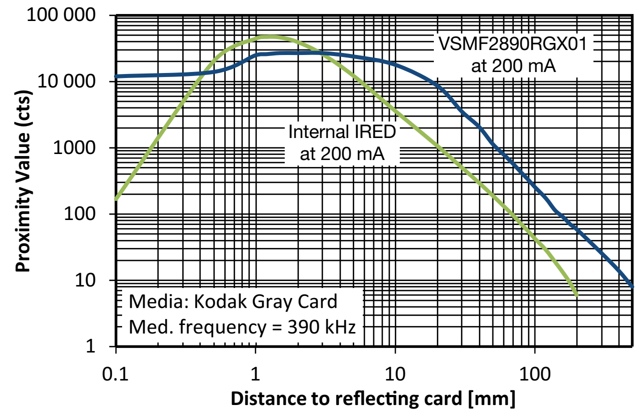

Fig. 11 - Proximity Value vs. Distance for Internal and External IRED (VSMF2890GX01)

For the distance from 0 mm to 3 mm, the proximity counts are lower when using an external emitter than with the internal IRED. For object distances greater than 10 mm, the proximity counts are significantly higher. For example, when the Kodak Gray card is 200 mm from the sensor, six counts were read with the VCNL's internal IRED, but 60 counts were read with the external VSMF2890GX01. Even at a distance of 500 mm, eight counts were still measured using the external emitter.

4. APPLICATIONS IN HARSH ENVIRONMENTS

For critical environments, where dust and water may cover the window for example, it is wise to have a light barrier that extends up to the cover window. To avoid possible reflection from water drops, separate windows for the emitter and detector are recommended.

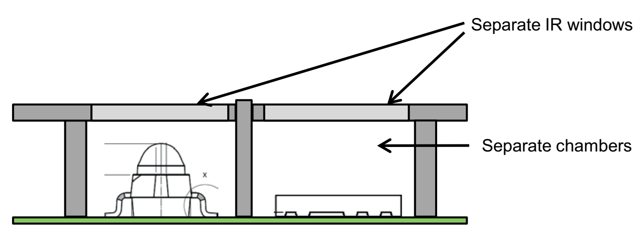

Fig. 12 - Emitter and Detector Totally Separated

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5. LONGER DISTANCES

For even longer distances or less reflective objects, two external IREDs in series can be used. With two TSHF6210 emitters, more than 1 meter can be achieved, depending on the reflectivity of the object.

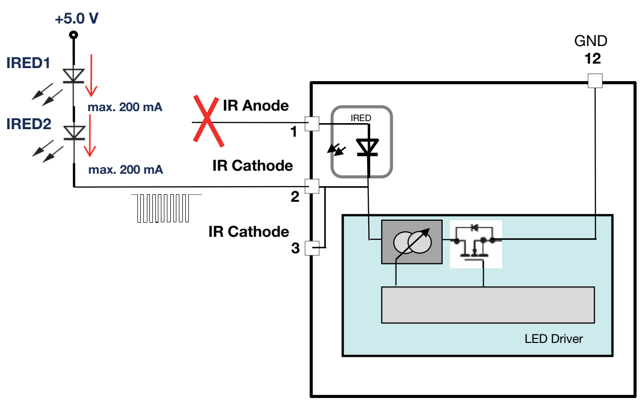

Fig. 13 - Two IREDs in Series Connected to the VCNL4010

6. SOLUTION FOR DETECTION DISTANCES GREATER THAN 100 cm

If the application requires even longer detection distances, the VCNL's internal current source will not be powerful enough.

For power IREDs with operating currents up to 5 A, the VCNL can provide the current burst to an external driver, where the power IRED is connected to this driver.

Possible circuitry, as well as component proposals and measurement results, are available by request by sending an e-mail to sensorstechsupport@vishay.com.

TABLE 1 - REFLECTION INDEX OF VARIOUS MATERIALS / COLORS			
Kodak Neutral Card		**Plastics, Glass**	
White side (reference medium)	100 %	White PVC	90 %
Gray side	20 %	Gray PVC	11 %
Paper		Blue, green, yellow, red PVC	40 % to 80 %
Typewriting paper	94 %	White polyethylene	90 %
Drawing card, white (Schoeller Durex)	100 %	White polystyrene	120 %
Card, light gray	67 %	Gray partinax	9 %
Envelope (beige)	100 %	**Fiber Glass Board Material**	
Packing card (light brown)	84 %	Without copper coating	12 % to 19 %
Newspaper paper	97 %	With copper coating on the reverse side	30 %
Pergament paper	30 % to 42 %	Glass, 1 mm thick	9 %
Black on White Typewriting Paper		Plexiglass, 1 mm thick	10 %
Drawing ink (Higgins, Pelikan, Rotring)	4 % to 6 %	**Metals**	
Foil ink (Rotring)	50 %	Aluminum, bright	110 %
Fiber-tip pen (Edding 400)	10 %	Aluminum, black anodized	60 %
Fiber-tip pen, black (Stabilo)	76 %	Cast aluminum, matt	45 %
Photocopy	7 %	Copper, matt (not oxidized)	110 %
Plotter Pen		Brass, bright	160 %
HP fiber-tip pen (0.3 mm)	84 %	Gold plating, matt	150 %
Black 24 needle printer (EPSON LQ-500)	28 %	**Textiles**	
Ink (Pelikan)	100 %	White cotton	110 %
Pencil, HB	26 %	Black velvet	1.5 %

Note
- Relative collector current (or coupling factor) of thereflex sensors for reflection on various materials. Reference is the white side of the Kodak neutral card. The sensor is positioned perpendicular to the surface. The wavelength is 950 nm.