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Optical Sensors

Application Note

## Designing the VCNT2030 Into an Application

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# Designing the VCNT2030 Into an Application

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## Designing the VCNT2030 Into an Application

### 1. INTRODUCTION

The VCNT2030 is a reflective sensor in a miniature SMD package with dimensions of 1.85 mm x 1.2 mm x 0.6 mm (L x W x H). The emitter uses vertical cavity surface emitting laser (VCSEL) chip technology with high radiant intensity, high optical power, and high speed. The operating infrared wavelength is 940 nm. The detector consists of a silicon phototransistor. The sensor's analog output signal at the phototransistor is dependent on the amount of light emitted by the VCSEL and reflected off of an object in the sensor's field of view.

Typical applications are:

- Position sensors
- Touchless, optical buttons under transparent covers
- Optical encoders
- Object detection

Due to its high sensitivity and high radiant power, the VCNT2030 can be used for detection distances up to 20 mm. The narrow emission angle of the VCSEL significantly reduces the offset caused by a cover in front of the sensor, making it particularly suitable for operation under transparent materials.

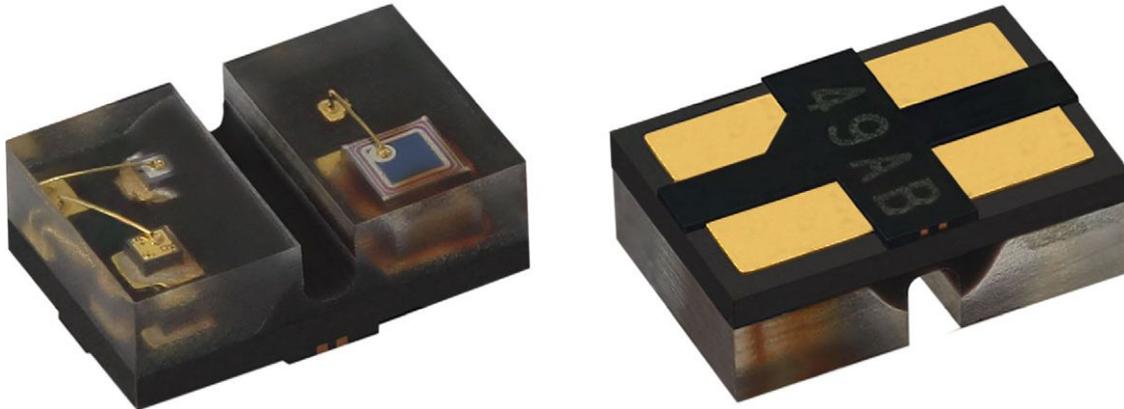


Fig. 1 - The VCNT2030 (top and bottom view)



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### 2. ABSOLUTE MAXIMUM RATINGS AND BASIC CHARACTERISTICS

The datasheet provides information about the absolute maximum ratings and the basic electrical and optical characteristics of the sensor, as shown in the two tables below. The sensor must be operated inside the limits given in the absolute maximum ratings table for reverse and forward voltage, collector current, power dissipation, and ambient and storage temperature. In practice, applications should be designed so that a large safety margin between the operating conditions and the absolute maximum ratings is achieved.

The electrical and optical characteristics that are given in the basic characteristics table indicate the performance of the sensor under specific operating conditions. The given minimum / maximum values are guaranteed and are tested during the manufacturing of the sensor. Typical values should only be used as a guide in the design process.

<b>ABSOLUTE MAXIMUM RATINGS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
<b>INPUT (VCSEL)</b>				
Reverse voltage		$V_R$	5	V
Forward current		$I_F$	15	mA
Power dissipation		$P_{VCSEL}$	38	mW
Junction temperature		$T_J$	100	$^{\circ}\text{C}$
Thermal resistance junction to ambient	JESD 51	$R_{thJA}$	410	K/W
<b>OUTPUT (DETECTOR)</b>				
Collector emitter breakdown voltage	$I_C = 0.1\text{ mA}, E = 0$	$V_{(BR)CEO}$	20	V
Emitter collector voltage		$V_{ECO}$	7	V
Collector current		$I_C$	50	mA
Power dissipation		$P_{PTR}$	100	mW
Thermal resistance junction to ambient	JESD 51	$R_{thJA}$	380	K/W
<b>SENSOR</b>				
Total power dissipation		$P_{tot}$	138	mW
Ambient temperature range		$T_{amb}$	-40 to +85	$^{\circ}\text{C}$
Storage temperature range		$T_{stg}$	-40 to +85	$^{\circ}\text{C}$
Soldering temperature	In accordance with Fig. 14	$T_{sd}$	260	$^{\circ}\text{C}$

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<b>BASIC CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
<b>INPUT (VCSEL)</b>						
Forward current <sup>(1)</sup>		$I_F$	-	5	-	mA
Forward voltage	$I_F = 8\text{ mA}$	$V_F$	1.7	1.9	2.1	V
	$I_F = 15\text{ mA}$		-	2.3	-	
Temperature coefficient of $V_F$	$I_F = 8\text{ mA}$	$TKV_F$	-	-4	-	mV/K
Angle of half intensity	$I_F = 8\text{ mA}$	$\phi$	-	17	-	$^{\circ}$
Reverse current		$I_R$	Not designed for reverse operation			
Peak wavelength	$I_F = 8\text{ mA}$	$\lambda_P$	-	940	-	nm
<b>OUTPUT (DETECTOR)</b>						
Emitter collector voltage	$I_E = 100\text{ }\mu\text{A}$ , $E = 0$	$V_{ECO}$	7	-	-	V
Collector emitter dark current	$V_{CE} = 5\text{ V}$ , $E = 0$	$I_{CEO}$	-	1	100	nA
<b>SENSOR</b>						
Collector current	$V_{CE} = 5\text{ V}$ , $I_F = 8\text{ mA}$ , $d = 1\text{ mm}$	$I_C$	1.8	2.5	5.4	mA
Current transfer ratio	$I_C/I_F$ , $d = 1\text{ mm}$ , $V_{CE} = 5\text{ V}$	CTR	-	31	-	%
Rise time	$I_C = 0.8\text{ mA}$ , $V_{CE} = 5\text{ V}$ , $R_L = 100\text{ }\Omega$	$t_r$	-	10	-	$\mu\text{s}$
Fall time	$I_C = 0.8\text{ mA}$ , $V_{CE} = 5\text{ V}$ , $R_L = 100\text{ }\Omega$	$t_f$	-	15	-	$\mu\text{s}$

**Note**

(1) It is recommended to apply at least 5 mA forward current, to ensure expected device performance

The basic characteristics of the sensor are only valid for a standard test setup, as described in Fig. 2. This standard setup includes a Kodak Gray Card with a reflectivity of 18 % on top of the sensor at a distance of 1 mm.

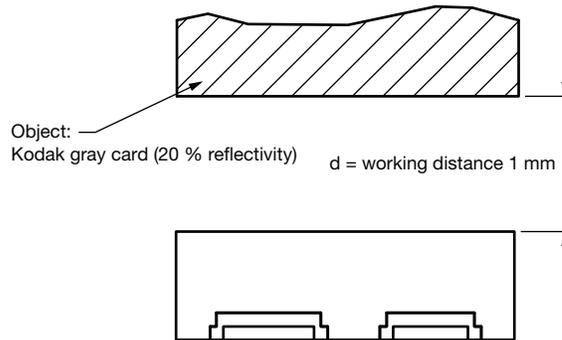


Fig. 2 - Test Setup

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### 3. FUNCTIONAL DESCRIPTION

The VCNT2030 is a reflective proximity sensor with an analog transistor output. The VCSEL sends out a beam of infrared (IR) light. A close object will subsequently reflect part of that light back towards the sensor. The reflected signal induces a photocurrent that is amplified at the detector. The amplitude of the output current correlates directly and proportionally to the amount of the received IR irradiation. On the other hand, the amount of radiation that is reflected back depends on various factors, the most prominent of which are the distance between the sensor and the reflective object and the reflectivity of the object. This leads to a dependence of the output current on the distance to a reflective object, as shown in Fig. 3. The distance curves were recorded using a Kodak Gray Card that has a calibrated, diffuse reflecting surface of 20 %. The distance is measured from the top of the sensor. The emitter current  $I_F$  is held constant at 8 mA.

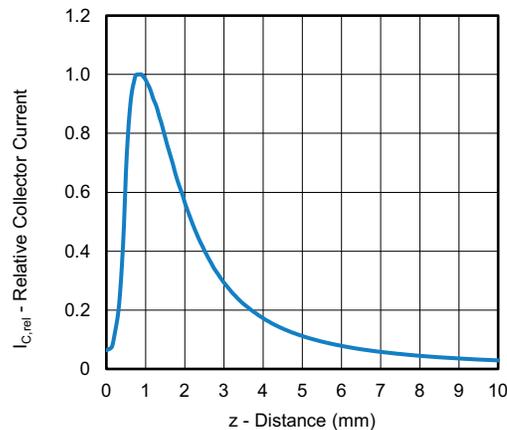


Fig. 3 - Relative Collector Current vs. Distance

The distance curves of all reflective sensors have a peak at a certain distance that is determined mechanically by the position of the emitter and detector and their spatial characteristics. The relative distance curve of the VCNT2030 has its peak at about 0.9 mm from the top center of the sensor. The sensor is particularly sensitive for any approaching object in this area. The distance curve is an important input to a reflective circuit design. Choosing an operating distance at or near the sensor's maximum sensitivity will provide greater design flexibility. The distance curve and the information derived from it play an important role when placing the sensor under a cover or a surrounding aperture. More information on this matter can be found in Chapter 6: Mechanical Considerations.

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### 4. APPLICATION CIRCUITS

This chapter covers three application examples that show how the circuitry around the VCNT2030 can be laid out and designed to suit several situations. The underlying circuit in Fig. 4 and the procedure for designing the circuit always remain similar and can be summarized in the following five steps. The table below gives estimates for the reflectivity of various materials.

#### Prerequisites that define the scenario:

1. Definition of the sensing distance
2. Estimation for the reflectivity of the object to detect

#### Calculation steps:

3. Calculation of the current transfer ratio
4. Selection of a suitable forward current and calculation of the according collector current
5. Dimensioning of the emitter resistor  $R_E$  and load resistor  $R_L$

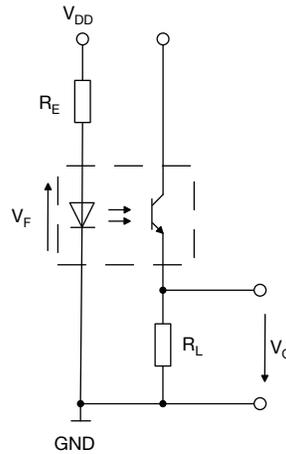


Fig. 4 - Typical Application Circuit



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REFLECTION INDEX OF VARIOUS MATERIALS / COLORS			
<b>Kodak Neutral Card</b>		<b>Plastics, Glass</b>	
White side (reference medium)	100 %	White PVC	90 %
Gray side	20 %	Gray PVC	11 %
<b>Paper</b>		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 %	<b>Fiber Glass Board Material</b>	
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 %
<b>Black or White Typewriting Paper</b>		Plexiglass, 1 mm thick	10 %
Drawing ink (Higgins, Pelikan, Rotring)	4 % to 6 %	<b>Metals</b>	
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 %
<b>Plotter Pen</b>		Brass, bright	160 %
HP fiber-tip pen (0.3 mm)	84 %	Gold plating, matt	150 %
Black 24 needle printer (EPSON LQ-500)	28 %	<b>Textiles</b>	
Ink (Pelikan)	100 %	White cotton	110 %
Pencil, HB	26 %	Black velvet	1.5 %

**Note**

- Relative collector current (or coupling factor) of the reflex 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



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### 4.1 Example Calculation 1 - Close Distance, High Reflectivity

Assumptions:

1. The sensing distance is 2 mm from the sensor
2. The reflectivity of the object is greater than 90 %

Calculation steps:

3. With the goal of to designing a robust sensor system, it is vital to estimate the minimum current transfer ratio. The minimum transfer ratio gives information about the collector current that can be expected in a worst-case scenario. Even the sensor with the poorest sensitivity due to part to part tolerances must be capable of triggering a detection.

From the basic characteristics table, the minimum collector current  $I_{C, \text{min.}}$  is given as 1.8 mA (at  $d = 1 \text{ mm}$  and  $I_F = 8 \text{ mA}$ ). This corresponds to a CTR of  $1.8 \text{ mA} / 8 \text{ mA} = 0.225$ .

However, this value applies for an object at 1 mm, and therefore has to be further reduced since the distance from the sensor in this scenario was defined as 2 mm. From the distance curve in Fig. 3, the relative collector current at a distance of 2 mm is estimated as about 0.55 times the maximum collector current. Compared with the collector current at 1 mm, a distance of 2 mm leads to a reduction in of the collector current of  $0.55 / 0.95 = 0.58$ .

At last, taking the reflectivity of the object into account, which is about 90 % / 20 % - times higher than that of a Kodak Gray Card, the final  $CTR_{\text{min.}}$  can be calculated as:

$$CTR_{\text{min.}} = \frac{I_{C, \text{min.}}}{I_F} \times \frac{I_{c, \text{rel.}}(2 \text{ mm})}{I_{c, \text{rel.}}(1 \text{ mm})} \times \text{reflectivity} = 0.225 \times 0.58 \times 4.5 = 0.59$$

4.  $I_F$  can be chosen low to 5 mA. With the  $CTR_{\text{min.}}$  from above, the minimum current that can be expected at the phototransistor's collector is

$$I_{C, \text{min.}} = 5 \text{ mA} \times 0.59 = 2.95 \text{ mA}$$

5. Assuming a supply voltage of 5 V, the emitter resistor should limit the forward current to 5 mA, which and calculates to

$$R_E = \frac{5 \text{ V} - V_F}{I_F} = \frac{5 \text{ V} - 1.8 \text{ V}}{5 \text{ mA}} = 640 \Omega \rightarrow \text{E12: } 560 \Omega$$

The corresponding load resistor can be calculated as

$$R_L = \frac{5 \text{ V} - V_{CE, \text{sat.}}}{I_{C, \text{min.}}} = \frac{5 \text{ V} - 0.4 \text{ V}}{2.95 \text{ mA}} = 1559 \Omega \rightarrow \text{E12: } 1.8 \text{ k}\Omega$$



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### 4.2 Example Calculation 2 - Further Distance, High Reflectivity

Assumptions:

1. The sensing distance is 6 mm from the sensor
2. The reflectivity of the object is greater than 90 %

Calculation steps:

3. Calculation of  $CTR_{min.}$ :

$$CTR_{min.} = \frac{I_{C, min.}}{I_F} \times \frac{I_{c, rel. (6 mm)}}{I_{c, rel. (1 mm)}} \times \text{reflectivity} = 0.225 \times \frac{0.05}{0.95} \times 4.5 = 0.053$$

4.  $I_F$  is set to 15 mA. With the  $CTR_{min.}$  from above, follows that:

$$I_{C, min.} = 15 \text{ mA} \times 0.053 = 0.8 \text{ mA}$$

5. Assuming a supply voltage of 5 V, the emitter resistor should limit the forward current to 15 mA, which calculates to

$$R_E = \frac{5 \text{ V} - V_F}{I_F} = \frac{5 \text{ V} - 2.3 \text{ V}}{15 \text{ mA}} = 180 \ \Omega \rightarrow \text{E12: } 180 \ \Omega$$

The corresponding load resistor can be calculated as

$$R_L = \frac{5 \text{ V} - V_{CE, sat.}}{I_{C, min.}} = \frac{5 \text{ V} - 0.4 \text{ V}}{0.8 \text{ mA}} = 5750 \ \Omega \rightarrow \text{E12: } 6.8 \text{ k}\Omega$$

In this case, the load resistor  $R_L$  is already starting to become high ohmic. The issue that comes with high load resistors is that the circuit gets more sensitive, and subsequently even small photocurrents will lead to a relevant output voltage. Consequently, the sensor must be protected from light sources with a high IR component, which interfere with the reflected signal and can cause false detections.



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### 4.3 Example Calculation 3 - Far Distance, Low Reflectivity

Assumptions:

1. The sensing distance is 6 mm from the sensor
2. Human skin with 40 % reflectivity shall be detected

Calculation steps:

3. Calculation of  $CTR_{min.}$ :

$$CTR_{min.} = \frac{I_{C, min.}}{I_F} \times \frac{I_{c, rel.} (6 \text{ mm})}{I_{c, rel.} (1 \text{ mm})} \times \text{reflectivity} = 0.225 \times \frac{0.05}{0.95} \times \frac{40 \%}{20 \%} = 0.024$$

4.  $I_F$  is set to 15 mA. With the  $CTR_{min.}$  above, it follows that:

$$I_{C, min.} = 15 \text{ mA} \times 0.024 = 0.36 \text{ mA}$$

5. Assuming a supply voltage of 5 V, the emitter resistor should limit the forward current to 15 mA, which calculates to

$$R_E = \frac{5 \text{ V} - V_F}{I_F} = \frac{5 \text{ V} - 2.3 \text{ V}}{15 \text{ mA}} = 180 \ \Omega \rightarrow \text{E12: } 180 \ \Omega$$

The corresponding load resistor can be calculated as

$$R_L = \frac{5 \text{ V} - V_{CE, sat.}}{I_{C, min.}} = \frac{5 \text{ V} - 0.4 \text{ V}}{0.36 \text{ mA}} = 12\,778 \ \Omega \rightarrow \text{E12: } 15 \text{ k}\Omega$$

Similar to the previous example, the load resistor  $R_L$  again is quite high ohmic and the sensor has to be protected from disturbing external light sources with high IR components.

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### 4.4 Alternative Circuitry - Additional Transistor for an Increased Switching Time

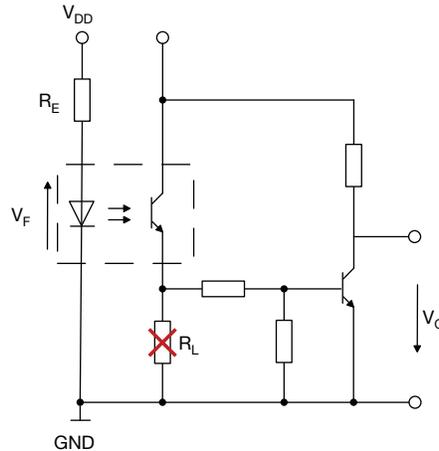


Fig. 5 - Alternative Circuitry for the VCNT2030 With an External Transistor

As shown in Fig. 5, the circuitry around the VCNT2030 can be adapted to ensure higher detection speeds compared to the circuitry shown for the previous examples. The smaller load at the detector's collector in the adapted circuitry causes the sensor system to be less sensitive; however, the threshold for triggering a detection can be fine-tuned with the voltage divider at the base of an external transistor.

### 4.5 Alternative Circuitry - DC Decoupling for Ambient Light Suppression

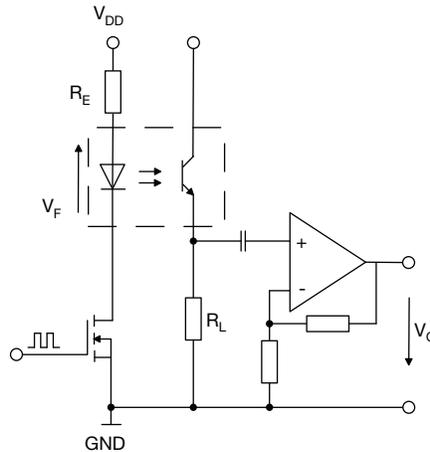


Fig. 6 - Circuit Example With Added AC-Coupled Amplification

Bright environments will cause a DC-offset signal at the detector. Specifically, sunlight with a high IR component can interfere with the emitter's radiation. To compensate for this, higher forward currents will lead to a better signal to noise ratio and the detector's load resistor can be decreased to lower the sensor's sensitivity. Additionally, the emitter can be pulsed as indicated in the schematic in Fig. 6. By decoupling the signal at the detector with an additional capacitor prior to amplification, the DC-offset caused by ambient light will be reduced significantly.

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### 5. DERATING AND TEMPERATURE LIMITS

The VCNT2030 is specified for a temperature range of -40 °C up to 85 °C. However, following Fig. 7, the consumed power must be controlled accordingly for operation above 45 °C ambient temperature. Otherwise, the internal heat dissipation can lead to a junction temperature that exceeds the absolute maximum limit of  $T_J$ .

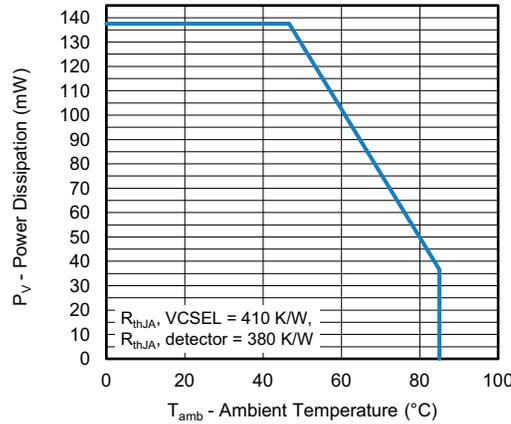


Fig. 7 - Power Dissipation vs. Ambient Temperature

The internally generated heat of the part consists of the sum of the VCSEL's portion and the detector's.

The collector current vs. ambient temperature curve in Fig. 8 shows about a 45 % lower current for -40 °C, while for higher temperatures only a small increase is seen. For higher temperatures, the dark current increases as shown in Fig. 9. This may end up at about 400 nA at 85 °C and has to be kept in mind when choosing high load resistors.

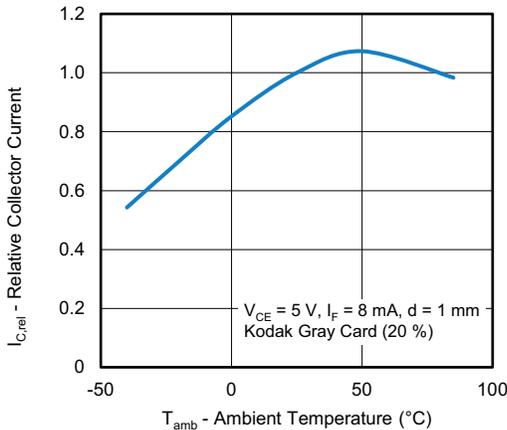


Fig. 8 - Relative Collector Current vs. Ambient Temperature

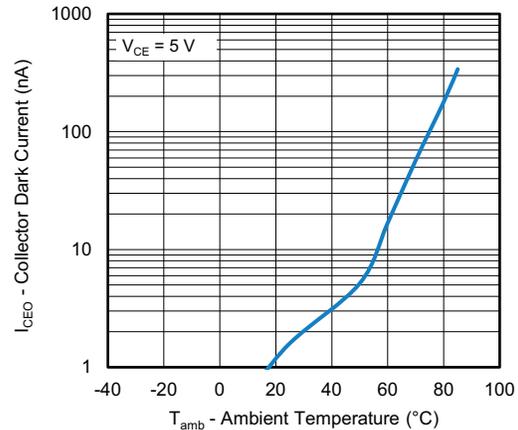


Fig. 9 - Collector Dark Current vs. Ambient Temperature

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### 6. MECHANICAL CONSIDERATIONS

The VCNT2030 was designed for the use as an optical, touchless button under a transparent cover. The sensor should be installed in such a way that disturbing environmental influences, as well as offsets that can be caused by the aperture around the sensor, are kept small.

#### 6.1 Usage Under a Transparent Cover

The sensor has properties that make it particularly suitable for use under a transparent cover. Due to the emitting characteristic of the VCSEL, the reflected amount of light at a cover is minimized and the largest part of the signal is transmitted instead. The narrow-angled radiation pattern allows the sensor to become “blind” to smooth materials like glasses or mirrors in a small range directly above the sensor. In Figure 6.1, this circumstance is explained by means of a sketch. If the distance to the cover is small, the reflected light does not hit the photosensitive area of the detector, but is rather absorbed by the package. Therefore, it does not add to an offset signal.

This effect can be observed in a distance curve that was recorded with a transparent cover instead of a diffuse reflecting Kodak Gray Card, as shown in Fig. 10 and Fig. 11, respectively. Whereas the graph with the diffuse Kodak Gray Card has its peak at a distance of 0.9 mm, the graph with the transparent cover stays at a minimum until a distance of 2 mm. This means that in order to minimize the influence of a transparent cover, it is best placed in a range between 0 mm to 2 mm from the sensor.

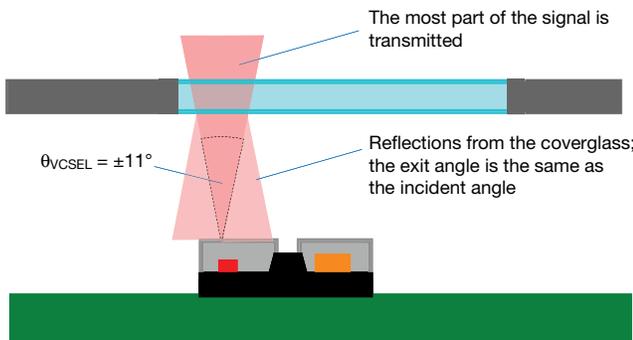


Fig. 10 - The VCNT2030 Under a Transparent Cover; Most of the Emitted Signal Is transmitted; a Small Amount Is Reflected Back Towards the Sensor but Does not Hit the Photosensitive Area of the Detector

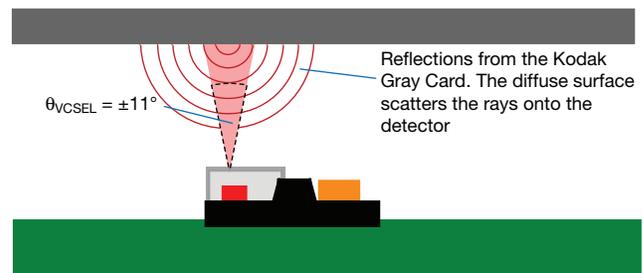


Fig. 11 - The VCNT2030 Under a Kodak Gray Card; the Emitted Signal is Diffusely Reflected and Scattered Towards the Detector

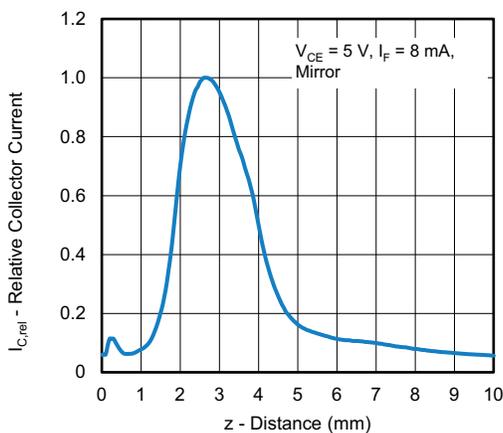


Fig. 12 - Relative Collector Current vs. Distance to a Smooth Reflecting Surface (mirror); the Collector Current Stays at a Minimum Until a Distance of About 2 mm

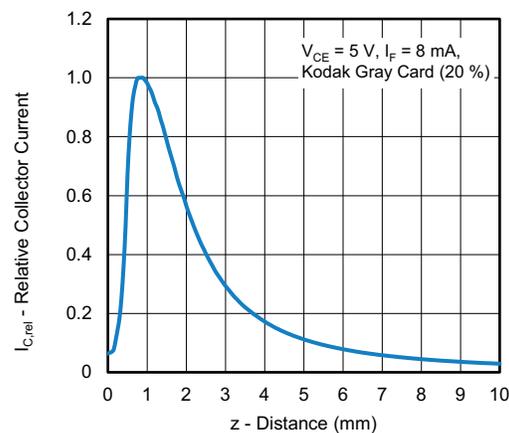


Fig. 13 - Relative Collector Current vs. Distance to a Diffuse Reflecting Material (Kodak Gray Card, 18 % Reflectivity); the Collector Current is Maximized at a Distance of 0.9 mm

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### 6.2 Further Recommendations

- In order to achieve the lowest possible influence of a cover, it is recommended to keep the cover thinner than 2 mm, or as thin as possible
- Tinted covers with IR-pass filter characteristics block ambient light and can reduce DC-offsets in a bright environment
- The sensor should be protected from direct sunlight or any light source with an (IR) component by using an aperture that has a viewing hole. An estimation for the window diameter is given in the following abstract

### 6.3 Dimensions of a Viewing Hole

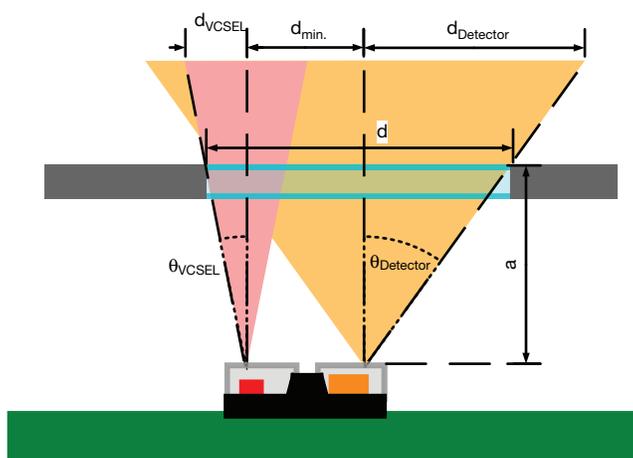


Fig. 14 - The VCNT2030 Under a Transparent Cover

The angle of half intensity of the emitter is about  $\pm 17^\circ$  and the viewing angle of the phototransistor is characterized as  $\pm 55^\circ$ . These angles should be considered during the design of a window on top of the sensor. The window diameter must not be too small to avoid limiting the viewing angle of the detector or blocking the emitter's signal. In either case, the sensor's crosstalk can increase significantly. The following calculation example provides a good estimate for the minimum window sizes to guarantee a viewing / emission angle of  $55^\circ / 17^\circ$ , respectively, as indicated in Fig. 14.

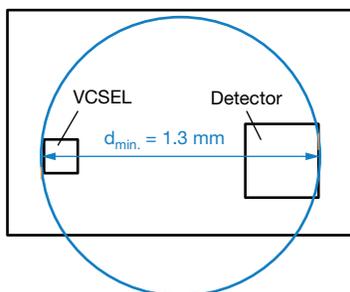


Fig. 15 - The VCNT2030 (top view); the Orange Circle Indicates the Minimum Diameter of a Viewing Window Directly on Top of the Sensor

The circular window size comprises a minimum width  $d_{min.}$  of 1.3 mm that arises from the distance between the emitter and detector (see Fig. 15), and the components  $d_{VCSEL}$  and  $d_{Detector}$ , which that increase with the distance "a" of the cover from the sensor. If the cover is placed further away from the sensor, the diameter of the window has to be increased accordingly.

From the drawing in Fig. 14, the window diameter "d" can be calculated

$$d = d_{min.} + d_{VCSEL} + d_{Detector} = d_{min.} + (\tan(\theta_{VCSEL}) \times a) + (\tan(\theta_{detector}) \times a)$$



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The width calculation for distances from 0 mm to 3 mm yields:

$$a = 0.0 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.00 \text{ mm}, d_{\text{Detector}} = 0.00 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.00 \text{ mm} + 0.00 \text{ mm} = 1.30 \text{ mm}$$

$$a = 0.5 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.15 \text{ mm}, d_{\text{Detector}} = 0.71 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.15 \text{ mm} + 0.71 \text{ mm} = 2.16 \text{ mm}$$

$$a = 1.0 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.31 \text{ mm}, d_{\text{Detector}} = 1.42 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.31 \text{ mm} + 1.42 \text{ mm} = 3.03 \text{ mm}$$

$$a = 1.5 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.46 \text{ mm}, d_{\text{Detector}} = 2.14 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.46 \text{ mm} + 2.14 \text{ mm} = 3.90 \text{ mm}$$

$$a = 2.0 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.61 \text{ mm}, d_{\text{Detector}} = 2.86 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.61 \text{ mm} + 2.86 \text{ mm} = 4.77 \text{ mm}$$

$$a = 2.5 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.76 \text{ mm}, d_{\text{Detector}} = 3.57 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.76 \text{ mm} + 3.57 \text{ mm} = 5.63 \text{ mm}$$

$$a = 3.0 \text{ mm} \rightarrow d_{\text{VCSEL}} = 0.92 \text{ mm}, d_{\text{Detector}} = 4.28 \text{ mm} \rightarrow d = 1.3 \text{ mm} + 0.92 \text{ mm} + 4.28 \text{ mm} = 6.50 \text{ mm}$$

## Designing the VCNT2030 Into an Application

### 7. DISPLACEMENT CURVES

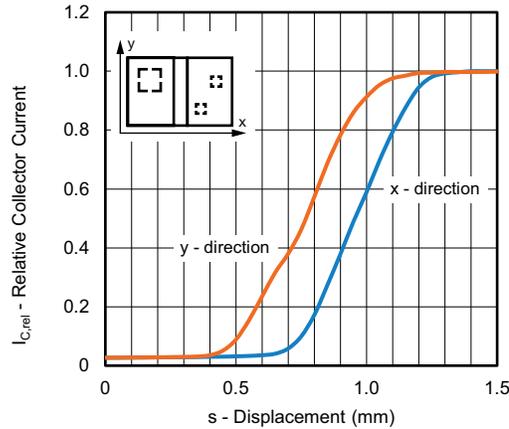


Fig. 16 - Relative Collector Current vs. Displacement

Fig. 16 shows the relative collector current versus the displacement of an object in x- and y- directions and at a distance of 1 mm above the sensor. It can be seen that in either the y- or x-direction the width of an object has to be wider than 0.5 mm (10 % to 90 %) in order to achieve the maximum possible signal amplitude. The most sensitive spot in the x-y plane is at the location with the steepest part of the curve. This is where a small change in displacement causes the highest change in signal. In the case of the VCNT2030, this spot is located about 0.95 mm and 0.75 mm in the x- and y-direction, respectively.

### 8. SWITCHING TIMES

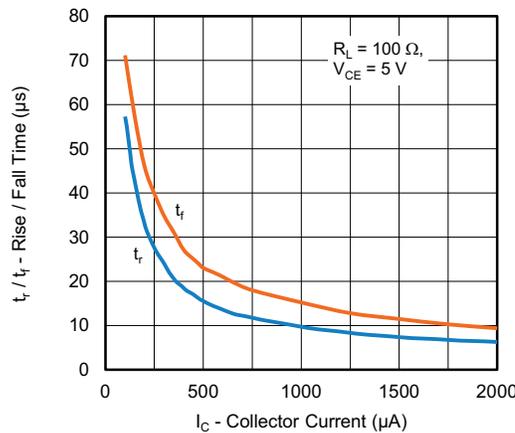


Fig. 17 - Rise / Fall Time vs. Collector Current

Rise and fall times of the sensor are characterized as  $t_r = 10 \mu s$  and  $t_f = 15 \mu s$ . However, these were measured with small load resistors  $R_L$  of  $100 \Omega$  and a reverse voltage  $V_{CE}$  of  $5 V$ . Higher loads or lower reverse voltages will delay the switching time of the sensor.



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## Designing the VCNT2030 Into an Application

### 9. SUMMARY

This application note covers the key characteristics of the VCNT2030 for typical applications. Key dependencies on tolerances, window design, and the distance curve were covered, as well as typical circuitries. Depending on the application, further specifics such as switching times, mechanical placement tolerances, degradation of the emitter, and others may need to be taken into consideration. This is, however, beyond the scope of this application note.