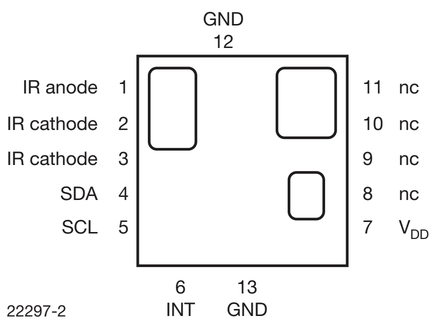
Fully Integrated Proximity and Ambient Light Sensor with Infrared Emitter, I^2C Interface, and Interrupt Function



DESCRIPTION

The VCNL4010 is a fully integrated proximity and ambient light sensor. Fully integrated means that the infrared emitter is included in the package. It has 16 bit resolution. It includes a signal processing IC and features standard I^2C communication interface. It features an interrupt function.

APPLICATIONS

- Proximity sensor for mobile devices (e.g. smart phones, touch phones, PDA, GPS) for touch screen locking, power saving, etc.
- Integrated ambient light function for display/keypad contrast control and dimming of mobile devices
- Proximity/optical switch for consumer, computing and industrial devices and displays
- Dimming control for consumer, computing and industrial displays

FEATURES

- Package type: surface mount
- Dimensions (L x W x H in mm): 3.95 x 3.95 x 0.75
- Integrated modules: infrared emitter (IRED), ambient light sensor (ALS-PD), proximity sensor (PD), and signal conditioning IC
- Interrupt function
- Supply voltage range V_{DD}: 2.5 V to 3.6 V
- Supply voltage range IR anode: 2.5 V to 5 V
- Communication via I^2C interface
- I^2C Bus H-level range: 1.7 V to 5 V
- Floor life: 168 h, MSL 3, acc. J-STD-020
- Low stand by current consumption: 1.5 μA
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

Pb-free
e4
RoHS COMPLIANT
HALOGEN FREE
GREEN (5-2008)

PROXIMITY FUNCTION

- Built-in infrared emitter and photo-pin-diode for proximity function
- 16 bit effective resolution for proximity detection range ensures excellent cross talk immunity
- Programmable LED drive current from 10 mA to 200 mA in 10 mA steps
- Excellent ambient light suppression by modulating the infrared signal
- Proximity distance up to 200 mm

AMBIENT LIGHT FUNCTION

- Built-in ambient light photo-pin-diode with close-to-human-eye sensitivity
- 16 bit dynamic range from 0.25 lx to 16 klx
- 100 Hz and 120 Hz flicker noise rejection

PRODUCT SUMMARY

PART NUMBER	OPERATING RANGE (mm)	OPERATING VOLTAGE RANGE (V)	I^2C BUS VOLTAGE RANGE (V)	LED PULSE CURRENT [1] (mA)	AMBIENT LIGHT RANGE (lx)	AMBIENT LIGHT RESOLUTION (lx)	OUTPUT CODE	ADC RESOLUTION PROXIMITY / AMBIENT LIGHT
VCNL4010	1 to 200	2.5 to 3.6	1.7 to 5	10 to 200	0.25 to 16 383	0.25	16 bit, I^2C	16 bit / 16 bit

Note

[1] Adjustable through I^2C interface

ORDERING INFORMATION			
ORDERING CODE	**PACKAGING**	**VOLUME [1]**	**REMARKS**
VCNL4010-GS08	Tape and reel	MOQ: 1800 pcs	3.95 mm x 3.95 mm x 0.75 mm
VCNL4010-GS18		MOQ: 7000 pcs	
Sensor starter kit [2]	-	MOQ: 1 pc	-

Notes

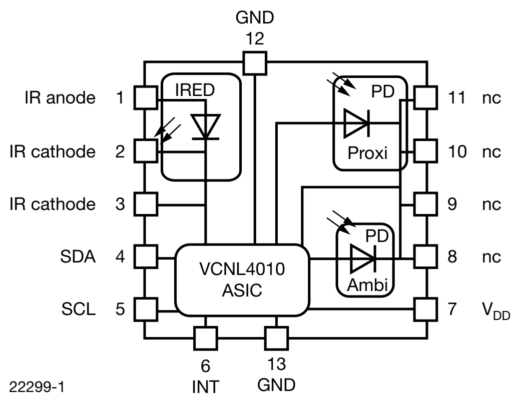
[1] MOQ: minimum order quantity

[2] A sensor starter kit is available, along with an add-on demo board for each of the sensors.
Please visit www.vishay.com/moreinfo/vcnldemokit/ for more information.
Contact any catalog distributor or a local Vishay sales representative to purchase the sensor starter kit and contact sensorstechsupport@vishay.com to receive an add-on sensor board.

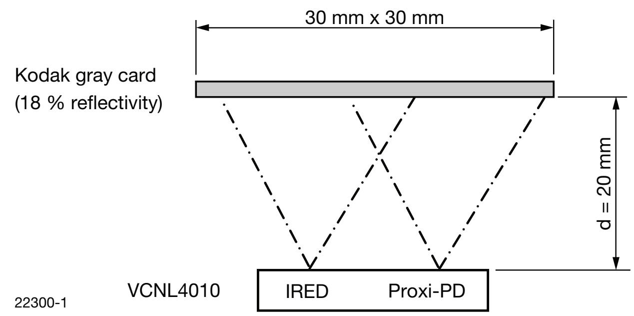
ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)					
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**MAX.**	**UNIT**
Supply voltage		V_{DD}	-0.3	5.5	V
Operation temperature range		T_{amb}	-25	+85	°C
Storage temperature range		T_{stg}	-40	+85	°C
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}		50	mW
Junction temperature		T_j		100	°C

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
Supply voltage V_{DD}			2.5		3.6	V
Supply voltage IR anode			2.5		5	V
I^2C Bus H-level range			1.7		5	V
INT H-level range			1.7		5	V
INT low voltage	3 mA sink current				0.4	V
Current consumption	Standby current, no IRED-operation			1.5	2	µA
Current consumption proximity mode incl. IRED (averaged)	2 measurements per second, IRED current 20 mA			5		µA
	250 measurements per second, IRED current 20 mA			520		µA
	2 measurements per second, IRED current 200 mA			35		µA
	250 measurements per second, IRED current 200 mA			4.0		mA
Current consumption ambient light mode	2 measurements per second averaging = 1			2.5		µA
	8 measurements per second averaging = 1			10		µA
	2 measurements per second averaging = 64			160		µA
	8 measurements per second averaging = 64			640		µA
Ambient light resolution	Digital resolution (LSB count)			0.25		lx
Ambient light output	E_V = 100 lx averaging = 64			400		counts
I^2C clock rate range		f_{SCL}			3400	kHz

CIRCUIT BLOCK DIAGRAM



TEST CIRCUIT



Note

- nc must not be electrically connected
  Pads 8 to 11 are only considered as solder pads

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

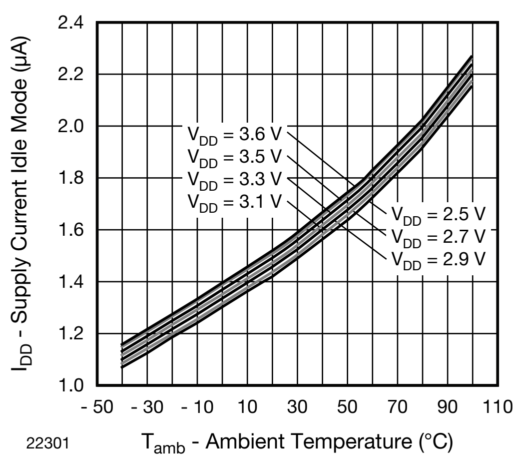


Fig. 1 - Idle Current vs. Ambient Temperature

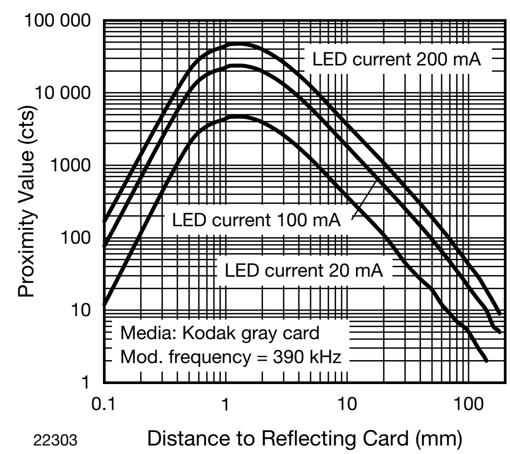


Fig. 3 - Proximity Value vs. Distance

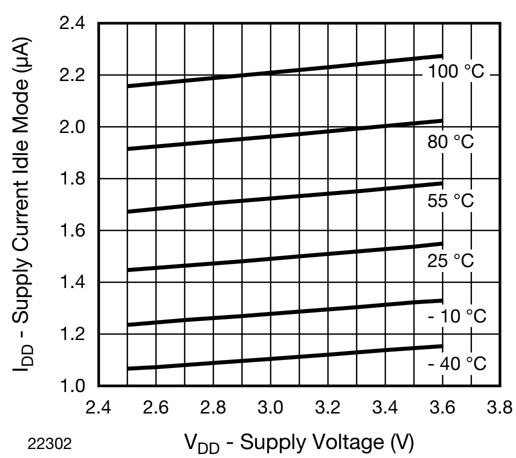


Fig. 2 - Idle Current vs. V_{DD}

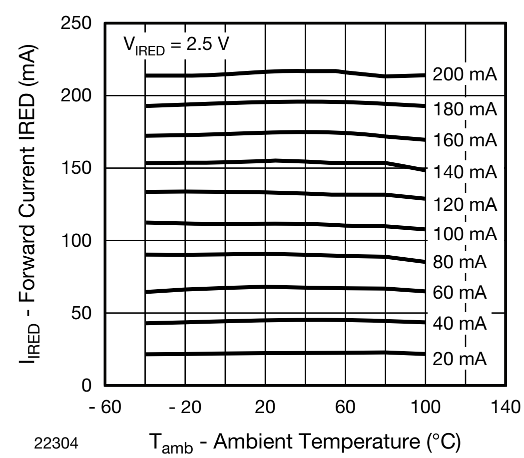


Fig. 4 - Forward Current vs. Temperature

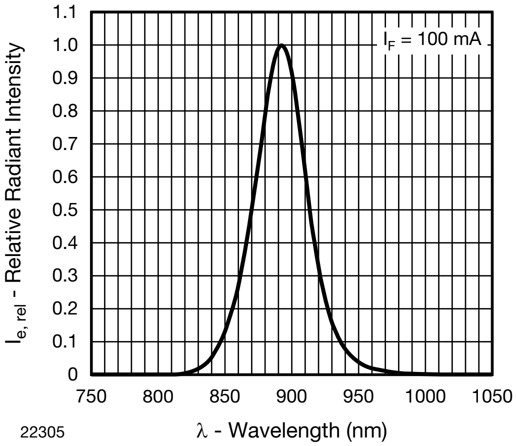


Fig. 5 - Relative Radiant Intensity vs. Wavelength

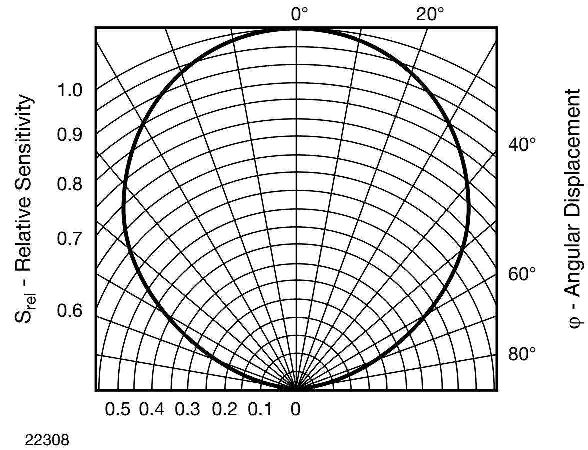


Fig. 8 - Relative Radiant Sensitivity vs. Angular Displacement (Proximity Sensor)

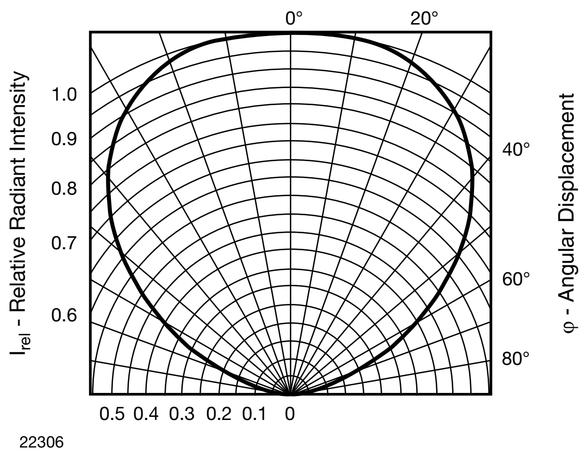


Fig. 6 - Relative Radiant Intensity vs. Angular Displacement

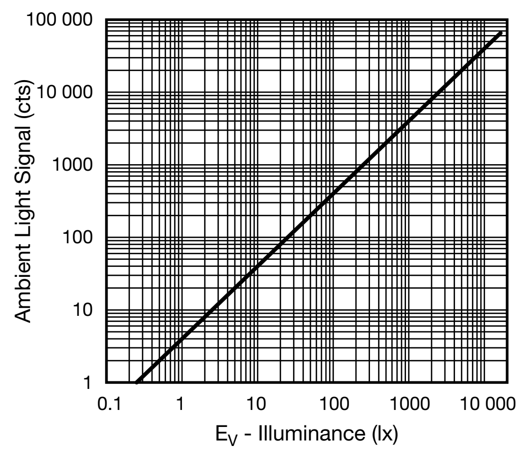


Fig. 9 - Ambient Light Value vs. Illuminance

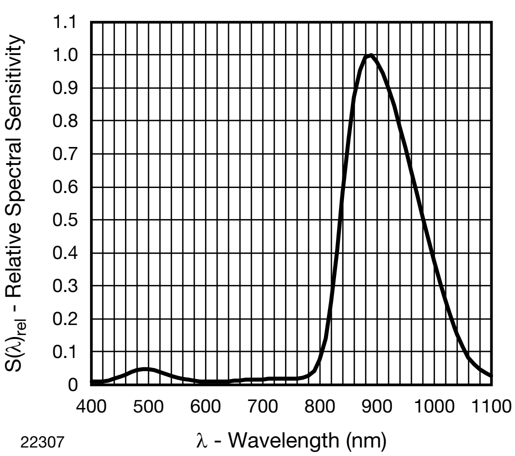


Fig. 7 - Relative Spectral Sensitivity vs. Wavelength (Proximity Sensor)

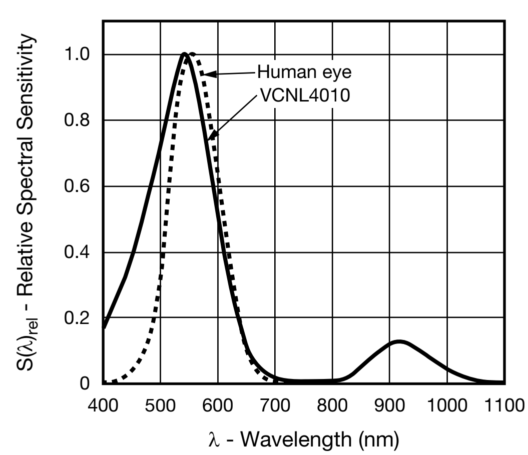


Fig. 10 - Relative Spectral Sensitivity vs. Wavelength (Ambient Light Sensor)

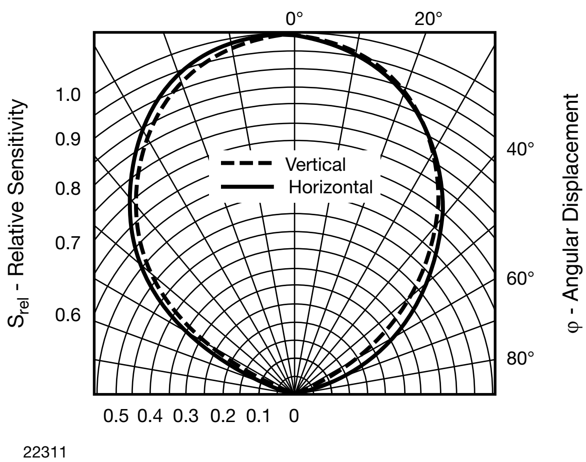


Fig. 11 - Relative Radiant Sensitivity vs. Angular Displacement (Ambient Light Sensor)

APPLICATION INFORMATION

VCNL4010 is a cost effective solution of proximity and ambient light sensor with I^2C bus interface. The standard serial digital interface is easy to access "Proximity Signal" and "Light Intensity" without complex calculation and programming by external controller. Beside the digital output also a flexible programmable interrupt pin is available.

1. Application Circuit

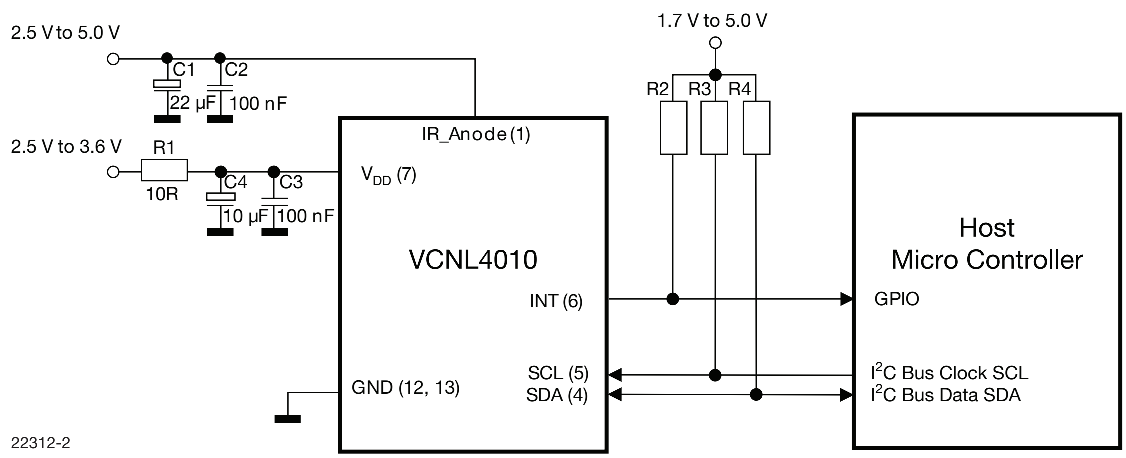


Fig. 12 - Application Circuit
(x) = Pin Number

Notes

- The interrupt pin is an open drain output. The needed pull-up resistor may be connected to the same supply voltage as the application controller and the pull-up resistors at SDA/SCL. Proposed value R2 should be >1 kΩ , e.g. 10 kΩ to 100 kΩ.
  Proposed value for R3 and R4, e.g. 2.2 kΩ to 4.7 kΩ, depend also on the I^2C bus speed.
  For detailed description about set-up and use of the interrupt as well as more application related information see AN: "Designing VCNL3020 into an Application".
- IR_Cathode needs no external connection. The needed connection to the driver is done internally.

2. I²C Interface

The VCNL4010 contains seventeen 8 bit registers for operation control, parameter setup and result buffering. All registers are accessible via I²C communication. Figure 13 shows the basic I²C communication with VCNL4010.

The built in I²C interface is compatible with all I²C modes (standard, fast and high speed).

I²C H-level range = 1.7 V to 5 V.

Please refer to the I²C specification from NXP for details.

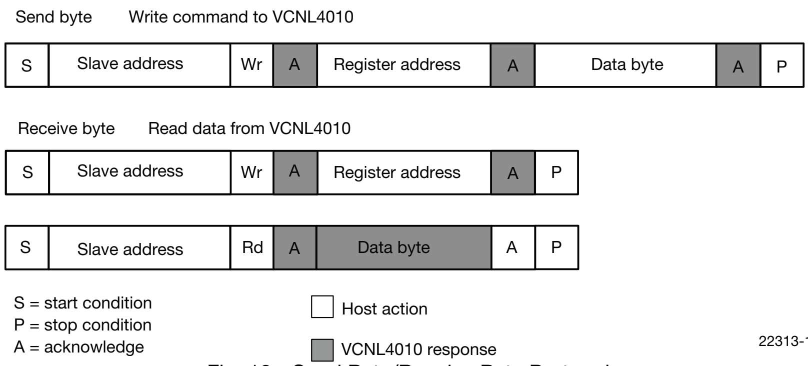


Fig. 13 - Send Byte/Receive Byte Protocol

Device Address

The VCNL4010 has a fix slave address for the host programming and accessing selection. The predefined 7 bit I²C bus address is set to 0010 011 = 13h. The least significant bit (LSB) defines read or write mode. Accordingly the bus address is set to 0010 011x = 26h for write, 27h for read.

Register Addresses

VCNL4010 has seventeen user accessible 8 bit registers. The register addresses are 80h (register #0) to 90h (register #16).

REGISTER FUNCTIONS

Register #0 Command Register

Register address = 80h

The register #0 is for starting ambient light or proximity measurements. This register contains 2 flag bits for data ready indication.

TABLE 1 - COMMAND REGISTER #0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
config_lock	als_data_rdy	prox_data_rdy	als_od	prox_od	als_en	prox_en	selftimed_en

Description	
config_lock	Read only bit. Value = 1
als_data_rdy	Read only bit. Value = 1 when ambient light measurement data is available in the result registers. This bit will be reset when one of the corresponding result registers (reg #5, reg #6) is read.
prox_data_rdy	Read only bit. Value = 1 when proximity measurement data is available in the result registers. This bit will be reset when one of the corresponding result registers (reg #7, reg #8) is read.
als_od	R/W bit. Starts a single on-demand measurement for ambient light. If averaging is enabled, starts a sequence of readings and stores the averaged result. Result is available at the end of conversion for reading in the registers #5(HB) and #6(LB).
prox_od	R/W bit. Starts a single on-demand measurement for proximity. Result is available at the end of conversion for reading in the registers #7(HB) and #8(LB).
als_en	R/W bit. Enables periodic als measurement
prox_en	R/W bit. Enables periodic proximity measurement
selftimed_en	R/W bit. Enables state machine and LP oscillator for self timed measurements; no measurement is performed until the corresponding bit is set

Note

- With setting bit 3 and bit 4 at the same write command, a simultaneously measurement of ambient light and proximity is done. Beside als_en and/or prox_en first selftimed_en needs to be set. On-demand measurement modes are disabled if selftimed_en bit is set. For the selftimed_en mode changes in reading rates (reg #4 and reg #2) can be made only when b0 (selftimed_en bit) = 0. For the als_od mode changes to the reg #4 can be made only when b4 (als_od bit) = 0; this is to avoid synchronization problems and undefined states between the clock domains. In effect this means that it is only reasonable to change rates while no selftimed conversion is ongoing.

Register #1 Product ID Revision Register

Register address = 81h. This register contains information about product ID and product revision.

Register data value of current revision = 21h.

TABLE 2 - PRODUCT ID REVISION REGISTER #1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Product ID				Revision ID			
Description							
Product ID		Read only bits. Value = 2					
Revision ID		Read only bits. Value = 1					

Register #2 Rate of Proximity Measurement

Register address = 82h.

TABLE 3 - PROXIMITY RATE REGISTER #2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
n/a					Rate of Proximity Measurement (no. of measurements per second)		
Description							
Proximity rate		R/W bits. 000 - 1.95 measurements/s (DEFAULT) 001 - 3.90625 measurements/s 010 - 7.8125 measurements/s 011 - 16.625 measurements/s 100 - 31.25 measurements/s 101 - 62.5 measurements/s 110 - 125 measurements/s 111 - 250 measurements/s					

Note

- If self_timed measurement is running, any new value written in this register will not be taken over until the mode is actualy cycled.

Register #3 LED Current Setting for Proximity Mode

Register address = 83h. This register is to set the LED current value for proximity measurement.

The value is adjustable in steps of 10 mA from 0 mA to 200 mA.

This register also contains information about the used device fuse program ID.

TABLE 4 - IR LED CURRENT REGISTER #3							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Fuse prog ID		IR LED current value					
Description							
Fuse prog ID		Read only bits. Information about fuse program revision used for initial setup/calibration of the device.					
IR LED current value		R/W bits. IR LED current = Value (dec.) x 10 mA. Valid Range = 0 to 20d. e.g. 0 = 0 mA , 1 = 10 mA, …., 20 = 200 mA (2 = 20 mA = DEFAULT) LED Current is limited to 200 mA for values higher as 20d.					

Register #4 Ambient Light Parameter Register

Register address = 84h.

TABLE 5 - AMBIENT LIGHT PARAMETER REGISTER #4

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Cont. conv. mode	als_rate			Auto offset compensation	Averaging function (number of measurements per run)		

Description	
Cont. conversion mode	R/W bit. Continuous conversion mode. Enable = 1; Disable = 0 = DEFAULT This function can be used for performing faster ambient light measurements. Please refer to the application information chapter 3.3 for details about this function.
Ambient light measurement rate	R/W bits. Ambient light measurement rate 000 - 1 samples/s 001 - 2 samples/s = DEFAULT 010 - 3 samples/s 011 - 4 samples/s 100 - 5 samples/s 101 - 6 samples/s 110 - 8 samples/s 111 - 10 samples/s
Auto offset compensation	R/W bit. Automatic offset compensation. Enable = 1 = DEFAULT; Disable = 0 In order to compensate a technology, package or temperature related drift of the ambient light values there is a built in automatic offset compensation function. With active auto offset compensation the offset value is measured before each ambient light measurement and subtracted automatically from actual reading.
Averaging function	R/W bits. Averaging function. Bit values sets the number of single conversions done during one measurement cycle. Result is the average value of all conversions. Number of conversions = $2^{decimal\_value}$ e.g. 0 = 1 conv., 1 = 2 conv, 2 = 4 conv., ...7 = 128 conv. DEFAULT = 32 conv. (bit 2 to bit 0: 101)

Note

- If self_timed measurement is running, any new value written in this register will not be taken over until the mode is actualy cycled.

Register #5 and #6 Ambient Light Result Register

Register address = 85h and 86h. These registers are the result registers for ambient light measurement readings.

The result is a 16 bit value. The high byte is stored in register #5 and the low byte in register #6.

TABLE 6 - AMBIENT LIGHT RESULT REGISTER #5

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
Read only bits. High byte (15:8) of ambient light measurement result							

TABLE 7 - AMBIENT LIGHT RESULT REGISTER #6

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
Read only bits. Low byte (7:0) of ambient light measurement result							

Register #7 and #8 Proximity Measurement Result Register

Register address = 87h and 88h. These registers are the result registers for proximity measurement readings.

The result is a 16 bit value. The high byte is stored in register #7 and the low byte in register #8.

TABLE 8 - PROXIMITY RESULT REGISTER #7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
Read only bits. High byte (15:8) of proximity measurement result							

TABLE 9 - PROXIMITY RESULT REGISTER #8

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
Read only bits. Low byte (7:0) of proximity measurement result							

Register #9 Interrupt Control Register

Register address = 89h.

TABLE 10 - INTERRUPT CONTROL REGISTER #9

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Int count exceed			n/a	INT_PROX_ ready_EN	INT_ALS_ ready_EN	INT_THRES_EN	INT_THRES_ SEL

Description	
Int count exceed	R/W bits. These bits contain the number of consecutive measurements needed above/below the threshold 000 - 1 count = DEFAULT 001 - 2 count 010 - 4 count 011 - 8 count 100 -16 count 101 - 32 count 110 - 64 count 111 - 128 count
INT_PROX_ready_EN	R/W bit. Enables interrupt generation at proximity data ready
INT_ALS_ ready_EN	R/W bit. Enables interrupt generation at ambient data ready
INT_THRES_EN	R/W bit. Enables interrupt generation when high or low threshold is exceeded
INT_THRES_SEL	R/W bit. If 0: thresholds are applied to proximity measurements If 1: thresholds are applied to als measurements

Register #10 and #11 Low Threshold

Register address = 8Ah and 8Bh. These registers contain the low threshold value. The value is a 16 bit word. The high byte is stored in register #10 and the low byte in register #11.

TABLE 11 - LOW THRESHOLD REGISTER #10

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
R/W bits. High byte (15:8) of low threshold value							

TABLE 12 - LOW THRESHOLD REGISTER #11

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
R/W bits. Low byte (7:0) of low threshold value							

Register #12 and #13 High Threshold

Register address = 8Ch and 8Dh. These registers contain the high threshold value. The value is a 16 bit word. The high byte is stored in register #12 and the low byte in register #13.

TABLE 13 - HIGH THRESHOLD REGISTER #12

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
R/W bits. High byte (15:8) of high threshold value							

TABLE 14 - HIGH THRESHOLD REGISTER #13

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Description							
R/W bits. Low byte (7:0) of high threshold value							

Register #14 Interrupt Status Register

Register address = 8Eh. This register contains information about the interrupt status for either proximity or ALS function and indicates if high or low going threshold exceeded.

TABLE 15 - INTERRUPT STATUS REGISTER #14

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
n/a				int_prox_ready	int_als_ready	int_th_low	int_th_hi
Description							
int_prox_ready	R/W bit. Indicates a generated interrupt for proximity						
int_als_ready	R/W bit. Indicates a generated interrupt for als						
int_th_low	R/W bit. Indicates a low threshold exceed						
int_th_hi	R/W bit. Indicates a high threshold exceed						

Note

- Once an interrupt is generated the corresponding status bit goes to 1 and stays there unless it is cleared by writing a 1 in the corresponding bit. The int pad will be pulled down while at least one of the status bit is 1.

Register #15 Proximity Modulator Timing Adjustment

Register address = 8Fh.

TABLE 16 - PROXIMITY MODULATOR TIMING ADJUSTMENT #15							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Modulation delay time			Proximity frequency		Modulation dead time		

Description	
Modulation delay time	R/W bits. Setting a delay time between IR LED signal and IR input signal evaluation. This function is for compensation of delays from IR LED and IR photo diode. Also in respect to the possibility for setting different proximity signal frequency. Correct adjustment is optimizing measurement signal level. (DEFAULT = 0)
Proximity frequency	R/W bits. Setting the proximity IR test signal frequency The proximity measurement is using a square IR signal as measurement signal. Four different values are possible: 00 = 390.625 kHz (DEFAULT) 01 = 781.25 kHz 10 = 1.5625 MHz 11 = 3.125 MHz
Modulation dead time	R/W bits. Setting a dead time in evaluation of IR signal at the slopes of the IR signal. (DEFAULT = 1) This function is for reducing of possible disturbance effects. This function is reducing signal level and should be used carefully.

Note

- The settings for best performance will be provided by Vishay. With first samples this is evaluated to: delay time = 0; dead time = 1 and prox. frequency = 0. With that register#15 should be programmed with 1 (= default value).

Register #16 Ambient IR Light Level Register

Register address = 90h.

This register is not intended to be used by customer.

3. IMPORTANT APPLICATION HINTS AND EXAMPLES

3.1 Receiver standby mode

In standby mode the receiver has the lowest current consumption of about 1.5 μA. In this mode only the I^2C interface is active. This is always valid, when there are no measurement demands for proximity and ambient light executed. Also the current sink for the IR-LED is inactive, so there is no need for changing register #3 (IR LED current).

3.2 Data Read

In order to get a certain register value, the register has to be addressed without data like shown in the following scheme. After this register addressing, the data from the addressed register is written after a subsequent read command.

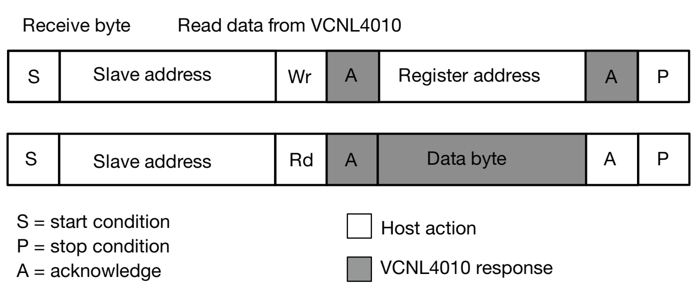


Fig. 14 - Send Byte/Receive Byte Protocol

The stop condition between these write and read sequences is not mandatory. It works also with a repeated start condition.

Note

- For reading out 2 (or more) subsequent registers like the result registers, it is not necessary to address each of the registers separately. After one read command the internal register counter is increased automatically and any subsequent read command is accessing the next register.

Example: read register "Ambient Light Result Register" #5 and #6:

Addressing:command: 26h, 85h (VCNL4010_I²C_Bus_Write_Adr., Ambient Light Result Register #5 [85])

Read register #5:command: 27h, data (VCNL4010_I²C_Bus_Read_Adr., {High Byte Data of Ambient Light Result register #5 [85])}

Read register #6:command: 27h, data (VCNL4010_I²C_Bus_Read_Adr., {Low Byte Data of Ambient Light Result register #6 [86])}

3.3 Continuous Conversion Mode in Ambient Light Measurement

In the following is a detail description of the function "continuous conversion" (bit 7 of register #4)

Standard mode (bit 7 of reg #4 = 0):
In standard mode the ambient light measurement is done during a fixed time frame of 100 ms. The single measurement itself takes actually only appr. 300 µs.

The following figures show examples of this measurement timing in standard mode using averaging function 2 and 8 as examples for illustration (possible values up to 128).

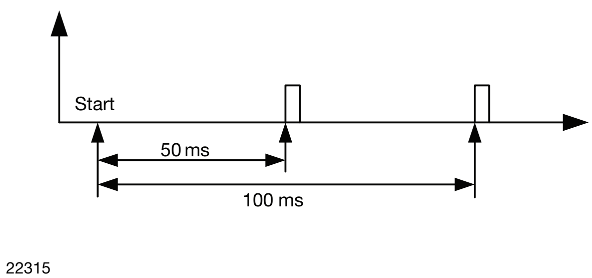


Fig. 15 - Ambient Light Measurement with Averaging = 2; Final Measurement Result = Average of these 2 Measurements

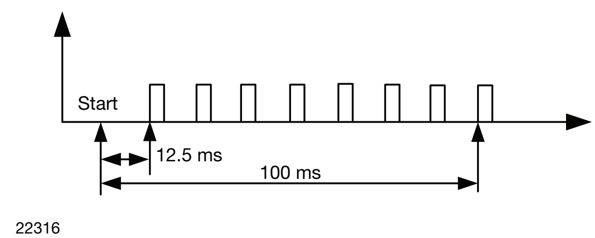


Fig. 16 - Ambient Light Measurement with Averaging = 8; Final Measurement Result = Average of these 8 Measurements

Note
- ≥ Independent of setting of averaging the result is available only after 100 ms.

Continuous conversion mode (bit 7 of register #4 = 1):
In continuous conversion mode the single measurements are done directly subsequent after each other.

See following examples in figure 17 and 18

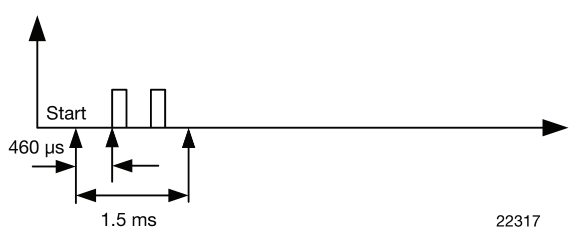


Fig. 17 - Ambient Light Measurement with Averaging = 2; using Continuous Conversion Mode

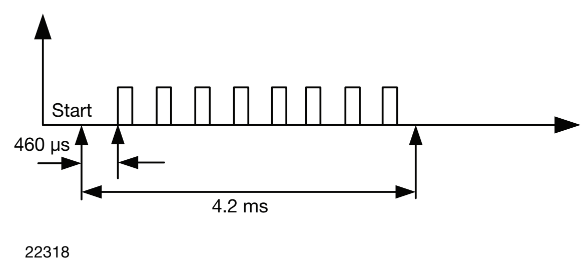
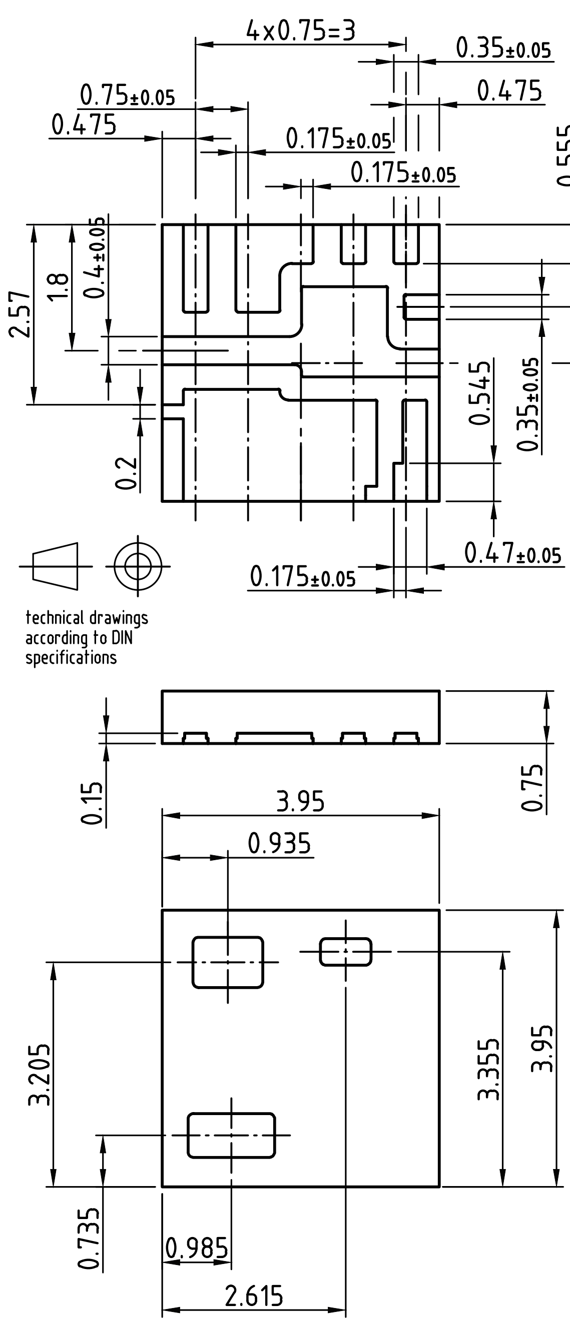
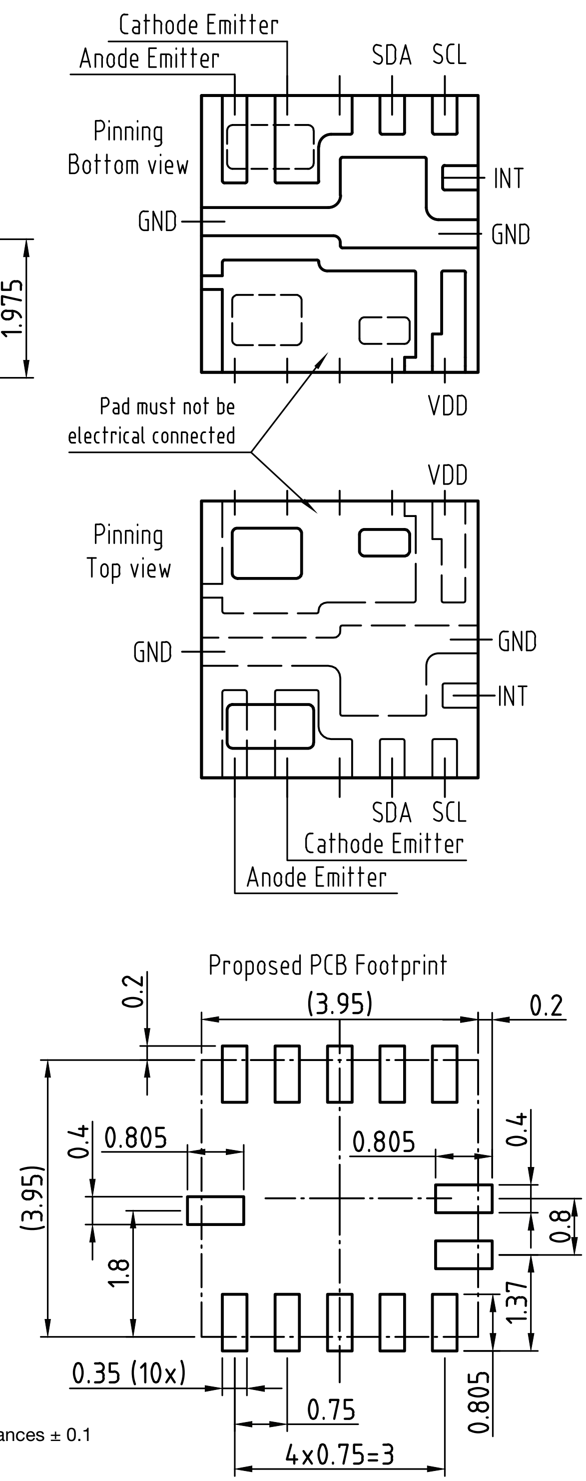


Fig. 18 - Ambient Light Measurement with Averaging = 8; using Continuous Conversion Mode

PACKAGE DIMENSIONS in millimeters

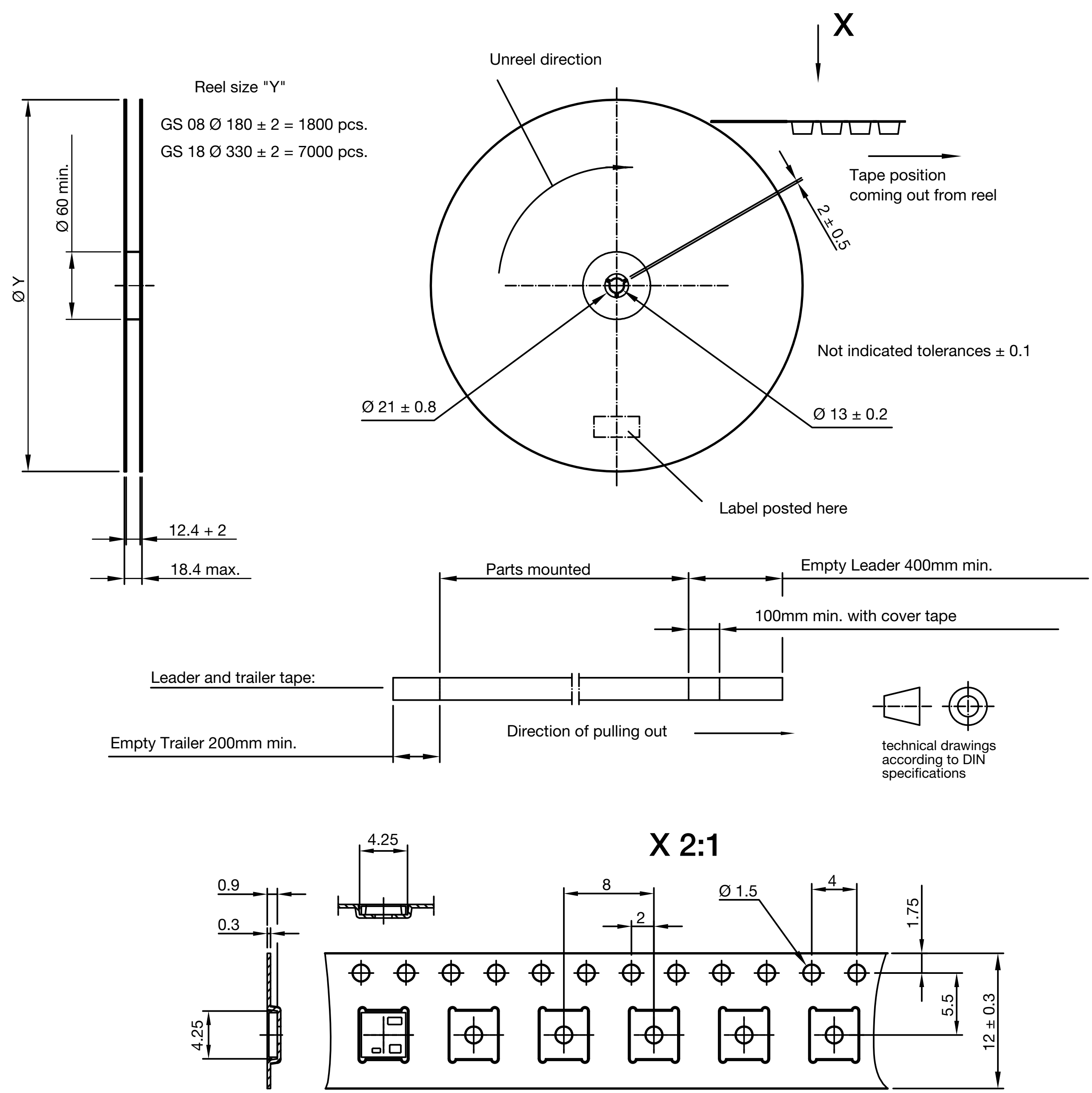




Drawing-No.: 6.550-5317.01-4

Not indicated tolerances ± 0.1

TAPE AND REEL DIMENSIONS in millimeters



Drawing-No.: 9.800-5103.01-4

SOLDER PROFILE

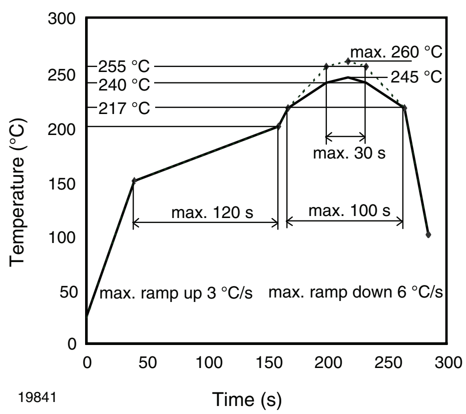


Fig. 19 - Lead (Pb)-free Reflow Solder Profile acc. J-STD-020

DRYPACK

Devices are packed in moisture barrier bags (MBB) to prevent the products from moisture absorption during transportation and storage. Each bag contains a desiccant.

FLOOR LIFE

Floor life (time between soldering and removing from MBB) must not exceed the time indicated on MBB label:

Floor life: 168 h

Conditions: T_{amb} < 30 °C, RH < 60 %

Moisture sensitivity level 3, according to J-STD-020

DRYING

In case of moisture absorption devices should be baked before soldering. Conditions see J-STD-020 or label. Devices taped on reel dry using recommended conditions 192 h at 40 °C (+ 5 °C), RH < 5 %.

Extended Detection Rangewith VCNL Family of Proximity Sensor
采用 VCNL 系列接近传感器扩展探测范围

作者：Reinhard Schaar

1、简介及基本操作

VCNL4010、VCNL4020 和 VCNL3020 是带有 I^2C 接口的接近传感器。每个器件都带有 16 位 ADC，在一个单独的封装中集成了一个红外线发射管、一个 PIN 光电二极管和一个信号处理器 IC。由于不再需要屏蔽罩将发射管与接收管进行光学隔离，因此凭借其最高 20cm（7.9 英寸）的探测距离，独立型，集成型的特点，大大简化了接近传感器在消费类和工业类应用中的设计。通过标准的 I^2C 总线串行数字接口，VCNL 器件无需复杂的计算或编程，即可以轻松对 “ 接近信号 ” 进行接入，当出现接近事件时，可编程的中断信号为微处理器提供唤醒功能，因此可以省去持续查询的需求，从而缩减了平均的处理时间和功耗。

集成型红外发射管的发射波长为 890nm，可以探测 20cm 范围内的目标物体。为了探测这一范围，可以对发射电流从 10mA 到最高 200mA 进行编程。（参见下图 1）。

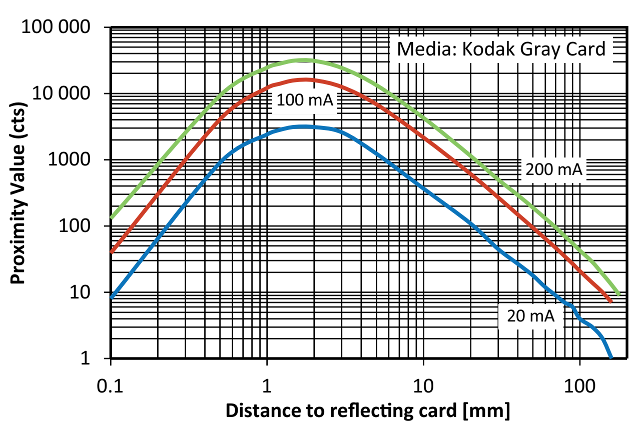


图 1 - 接近值与距离

2. IRED （红外线发光二极管）连接和电路

一些应用可能要求发射管发出更高的光强，因为需要探测的目标物体反射过来的信号非常弱，或者目标物体可能位于传感器较远的位置。

所有VCNL传感器都可以与高光强的外部发射管互连，甚至可以用带有透镜的红外线发射二极器（IRED）。

这种情况下，需要外部电源为 IRED 供电，而 VCNL 的正极不与电源相连。

通常可以将一个外部IRED连接到VCNL的负极并利用其内部驱动器，而所有的控制和编程都与使用内部 IRED 的情况相同。图 2 展示了 VCNL 运行的原则。

外部IRED取代内部发射管与VCNL内部驱动器和可编程电流源相连，该 IRED 正极与电源相连。

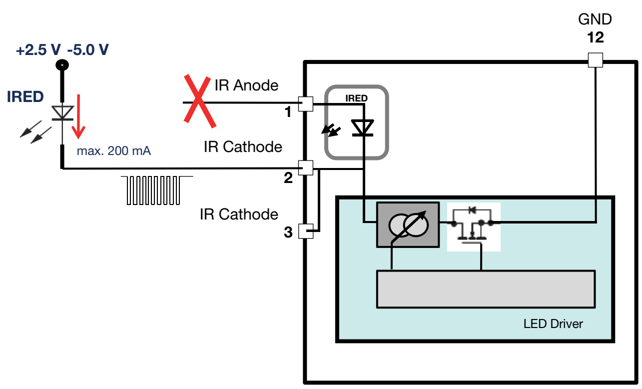


图 2 - VCNL4010 原理运行图

图3和图4显示出针对VCNL4010和VCNL4020/VCNL3020封装的不同引脚定位。

Extended Detection Range with VCNL Family of Proximity Sensor
采用 VCNL 系列接近传感器扩展探测范围

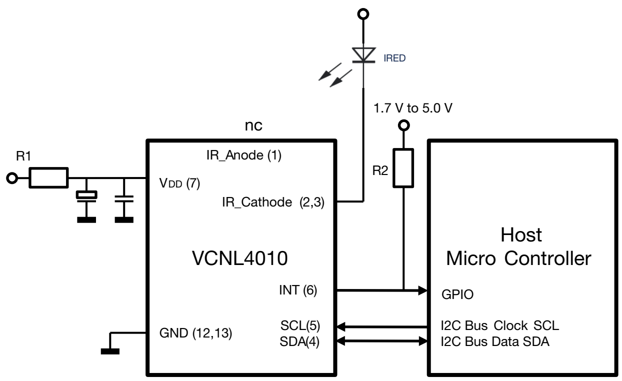


图 3 - 带有外部 IRED 的 VCNL4010 电路

对于 VCNL4010，引脚 1 （IR_Anode）并没有连接，而外部 IRED 的负极在引脚 2 和引脚 3 上进行连接。

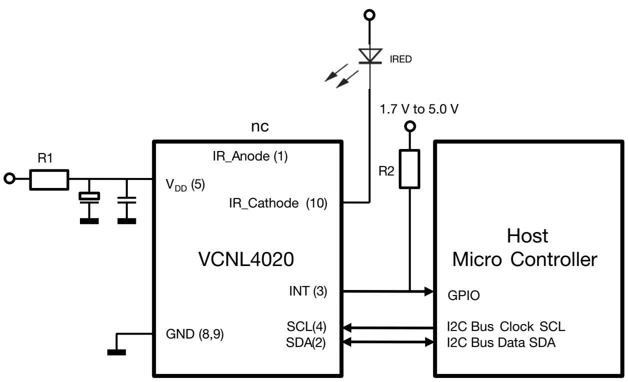


图 4 - 带有外部 IRED 的 VCNL4020 / VCNL3020 电路

对于 VCNL4020 和 VCNL3020 封装，引脚 1(IR_Anode) 未连接，而外部 IRED 的负极可以与引脚 10 连接。

ASIC(VDD) 的电源具有一个 2.5V 至 3.6 的确定的电压范围。红外线发射器 （内部及外部）可以在 2.5V 至 5V 的电压范围进行连接。如果 VDD 与调制电源或电池相连接，或者 IR_Anode 直接与电池或或电源相连则为最优选择。这就避免了 VDD 电源线上高红外线发射器电流脉冲所带来的任何影响。

集成型红外线发射管具有 890nm 的峰值波长和 PIN 光电二极管，接收目标物体的反射光并将其转换成电流，接收管与 890nm 的峰值敏感度完全匹配。

如果选择外部 IRED，应该具有中心波长 890nm，最低 850nm 波长。在 850nm 波长状态下，光电二极管的敏感度约为 70%。

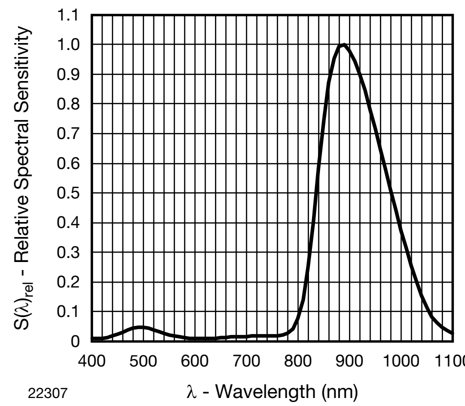


图 5 - 按近式 PIN 光电二极管的光谱敏感性

可以用到的一个合适的 IRED 是 VSMF2890GX01，因为传感器面板上的特性适用于 VCNL4010、 VCNL4020 和 VCNL3020。

图 6 - VCNL4020 传感器板

关于传感器板的更多信息，请参考：
www.vishay.com/docs/83395/vcnl4000_demo_kit.pdf

3. 结构设计注意事项

VCNL 系列具有一个 16 位的 ADC。如果采用演示套件和软件时，外部发射管和 VCNL 传感器之间会有干扰，这些干扰产生的 " 底噪 " 数值可能比较大，最多可能达到 5000，而 16 位 ADC 提供绰绰有余的上部空间，在传感器饱合前，仍有超过 60000 的数值空间。

如果在 IRED 和传感器之间放置一个挡光板，那么就可以避免这种干扰。由于实际电路中都会用到电容器，将其放置于 IRED 和传感器之间，就可以起到挡光板的效果。

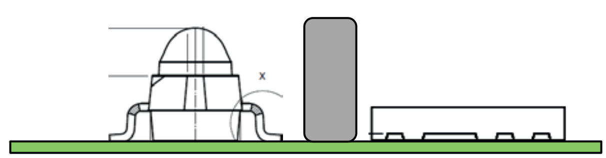


图 7 - IRED 和传感器之间的挡光板

图 7 中的发射管封装称为翼形封装。也可以像图 8 那样采用一个反向的翼形发射管来取代这种封装。由于在封装中，发射管的芯片在 PCB 下面，因此就消除了干扰。

Extended Detection Range with VCNL Family of Proximity Sensor
采用 VCNL 系列接近传感器扩展探测范围

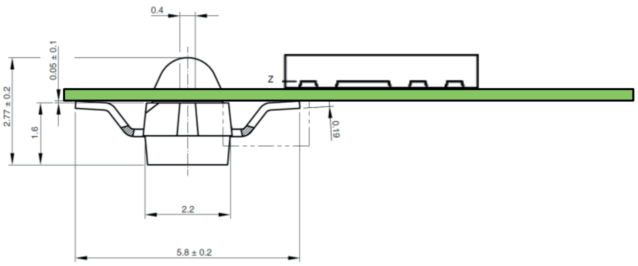


图 8 - 用作外部 IRED 的反向翼形

将VSMF2890用作外部IRED，提供了比传感器的内部发射管更高的光强，可实现探测 50cm 的目标物体。当然，这要取决于目标物体的材料和颜色。该文本结尾处的图表 1 中，可以查找到相关资料。

图9和图10采用更高发光强度的器件，如TSHF6210可进一步加大探测距离，如图9和图10中，IRED框图中所显示的数据。

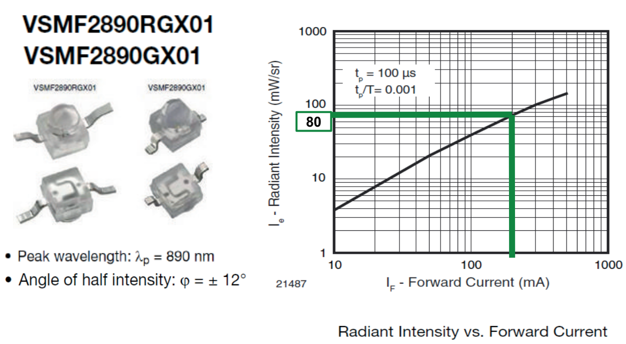


图 9 - VSMF2890X01 和辐射强度图

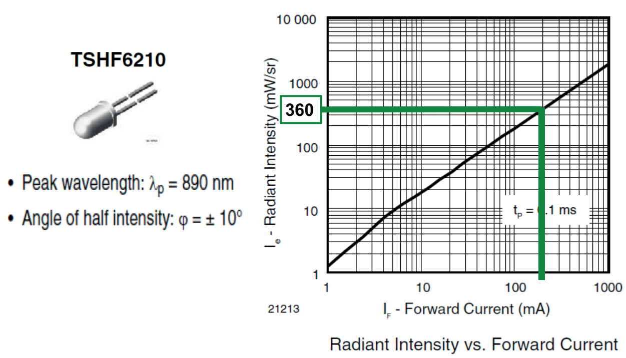


图 10 - TSHF6210 和辐射强度图

图（11）中是目标物体接近时 VCNL 的读数值与接近的距离之间关系，其绝对峰值的数值取决于外部IRED和传感器之间的放置距离，下图展示的是放置距离约为 9mm 的情形。

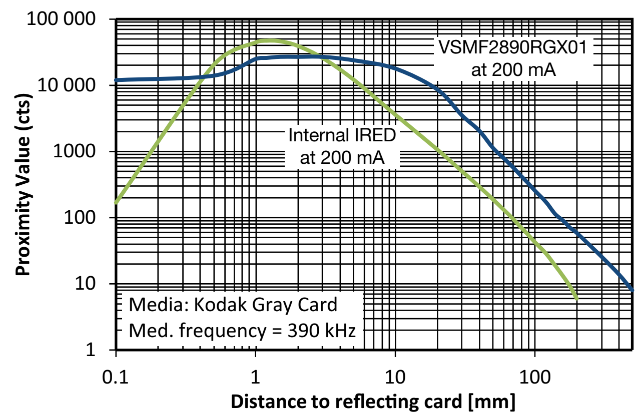


图 11 - 内部与外部 IRED 的接近值与距离 (VSMF2890GX01)

对于0mm至3mm的距离，当采用外部发射器时，接近读取数值比采用内部 IRED 更少。对于目标物体的距离大于 10mm 的情况，接近数值将明显升高。例如，当柯达灰色卡距离传感器 200mm 时，利用 VCNL 内部 IRED，读取数值为 6，但是利用外部 VSMF2890GX01，读取数值为 60。即使在 500mm 的距离，用外部发射管读取数量仍可达到 8。

4. 恶劣条件下的应用

对于极端的环境，如灰尘和水汽覆盖到表面的情况，最明智的办法就是采用一个延伸至覆盖窗口的挡光板。为了避免可能产生的水滴，推荐为发射管和接收管采用各自的窗口。

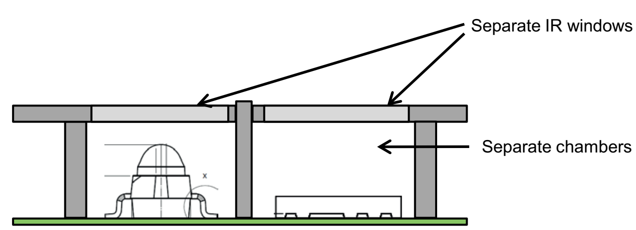


图 12 - 完全隔离的发射器和检测器

Extended Detection Range with VCNL Family of Proximity Sensor
采用 VCNL 系列接近传感器扩展探测范围

5. 更长的距离

对于探测更长的距离或反射率低的目标物体，也可以采用这一系列的 IRED。利用两个 TSHF6210 发射器，根据目标物体的反射性能，可以实现大于 1 米的探测距离。

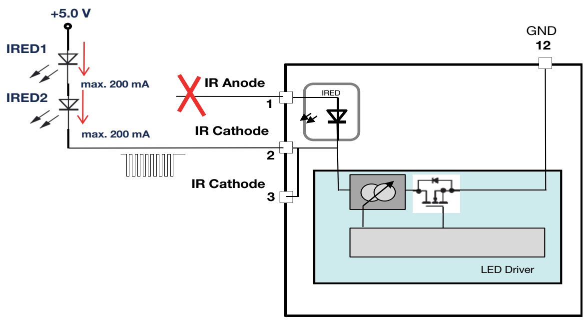


图 13 - 两个 IRED 与 VCNL4010 进行串连

6. 适用于超过 100cm 探测距离的解决方案

如果应用需要更长的探测距离，VCNL内部电流源的强度则不够。

对于工作电流最高 5A 的功率 IRED， VCNL 可以为连接功率 IRED 的外部驱动器提供脉冲信号。

通过发送电子邮件到sensorstechsupport@vishay.com，即可以获取适当的电路以及元件建议，测量结果。

表 1 – 不同材料 / 颜色的反射目录

柯达测试卡		**塑料，类别**	
白卡 （基准介质）	100 %	白色 PVC	90 %
灰卡	20 %	灰色 PVC	11 %
纸		蓝色、绿色、黄色和红色 PVC	40 % to 80 %
打印纸	94 %	白色聚乙烯	90 %
绘图卡、白 （Schoeller Durex）	100 %	白色聚苯乙烯	120 %
卡，浅灰色	67 %	灰色胶纸板	9 %
封皮 （米黄色）	100 %	**纤维板材**	
包装卡 （浅棕色）	84 %	没有铜涂层	12 % to 19 %
报纸用纸	97 %	背面没有铜涂层	30 %
革纸	30 % to 42 %	1 类， 1mm 厚	9 %
白色打印纸上的黑色部分		树脂玻璃， 1mm 厚	10 %
绘制油墨 （Higgins、 Pelikan、 Rotring）	4 % to 6 %	**材料**	
金属箔油墨 （Rotring）	50 %	铝，光亮型	110 %
光纤头笔 （Edding 400）	10 %	铝，黑色阳极化处理	60 %
光纤头笔，黑色 （Stabilo）	76 %	铸造铝，亚光	45 %
复印件	7 %	铜，亚光 （未氧化）	110 %
绘图笔		黄铜，光亮型	160 %
HP 光纤头笔 （0.3 mm）	84 %	镀金，亚光	150 %
黑色 24 针打印机 （EPSON LQ-500）	28 %	**纺织品**	
油墨 （Pelikan）	100 %	白色棉制品	110 %
铅笔， HB	26 %	黑色丝绒	1.5 %

注

- 针对不同材料，反射传感器的相关集电极电流 （或耦合因数）。基准为柯达中性卡的白边。传感器与表面垂直设置。波长为 950 nm。

VCNL4000, VCNL4010, and VCNL4020 Demo Kit Installation Guide

WINDOWS 7

Installing the Evaluation Software

Click on the CD from My computer.

Open the USB Sensor Kit Software file folder.

Click on Setup (Type: Application)

The kit software installer launches.

Click Next >>

Choose the destination directory.

Click Next >>

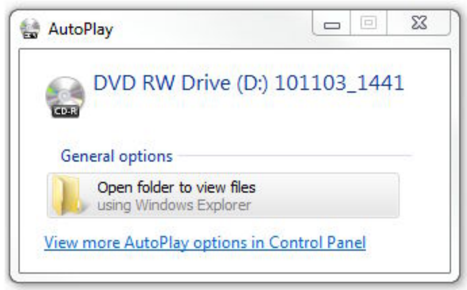
Accept the software licensing terms and conditions.

⦿ I accept the License Agreement

Click Next >>

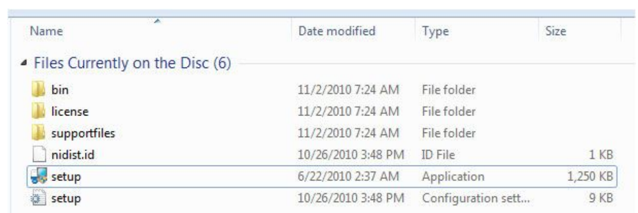
The software will install. This may take several minutes.

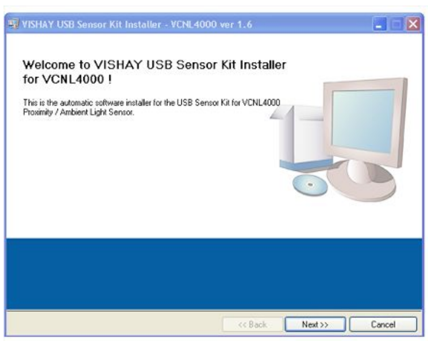
Click Finish

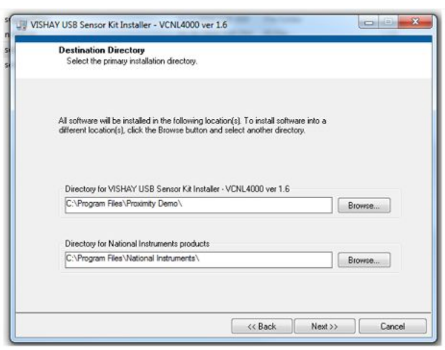


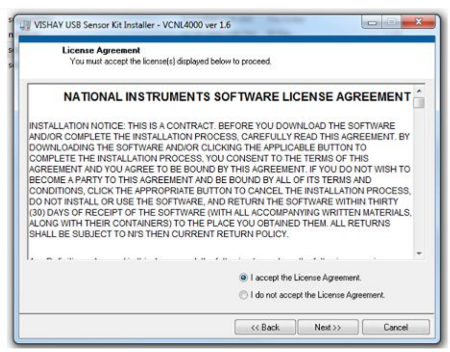
Note

- Administrative privledges are required to install this software



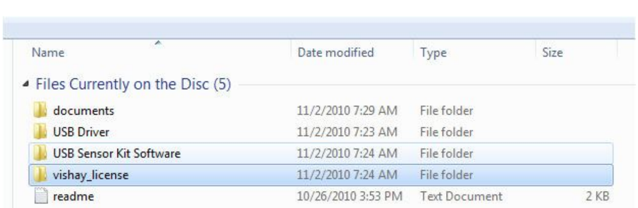


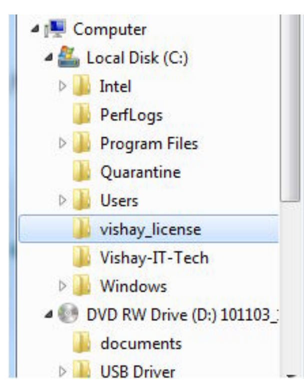




License

Copy the “vishay_license” file folder from the CD to C: root directory. The software will not run unless the license folder is found in the root directory.





VCNL4000, VCNL4010, and VCNL4020
Demo Kit Installation Guide

Installing the Driver

Create a folder on the C drive called VCNL4000 Driver

Copy the USB Driver folder from the disc to VCNL4000 Driver

Click on Start

Right click on Computer

Click on Manage

Click on Device Manager

Right click on "Unknown device"

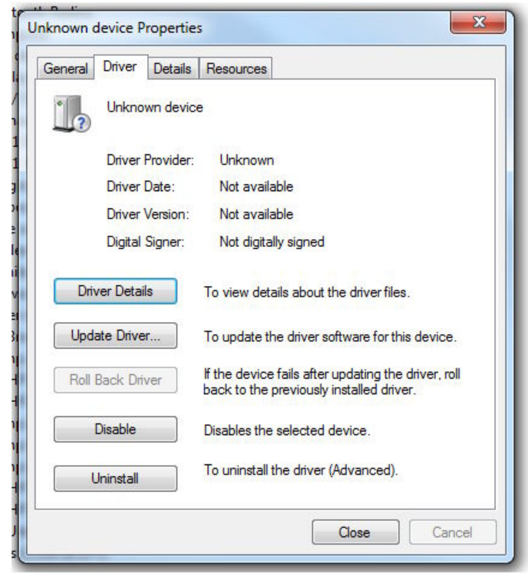
Select "Properties"

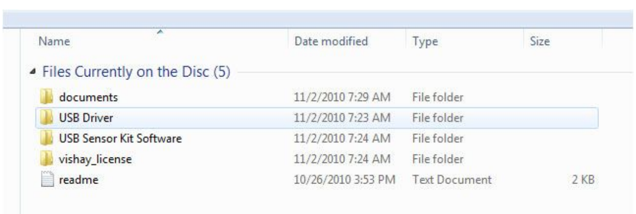
Select Driver tab

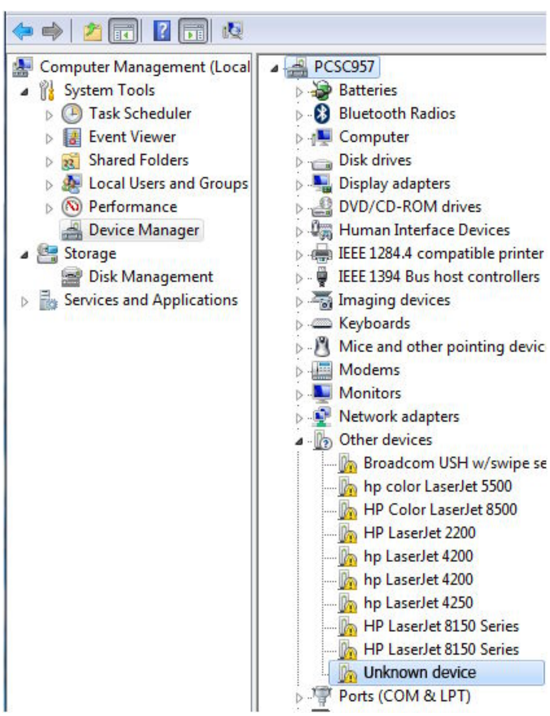
Click on Update Driver

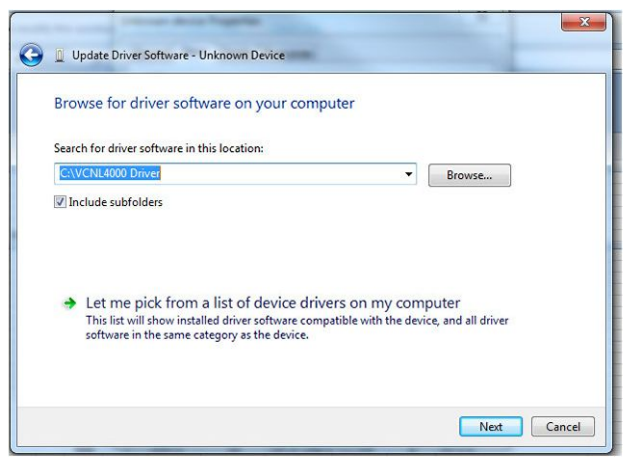
Click on Browse

Select C:\VCNL4000 Driver





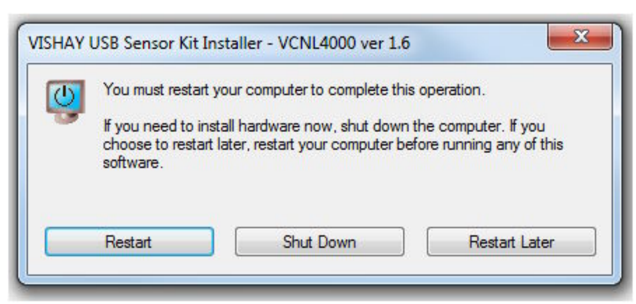




Restart and Run Program

Restart computer

Click on Start, Programs, Vishay USB Sensor Kit VCNL4000.



VCNL4000, VCNL4010, and VCNL4020 Demo Kit Installation Guide

VCNL4010 AND VCNL4020 SOFTWARE

Once the VCNL400 software has been loaded and is working, unplug the USB stick.

Remove the VCNL4000 sensor board from the USB adaptor stick.

Plug in the VCNL4010 or VCNL4020 sensor board in its place.

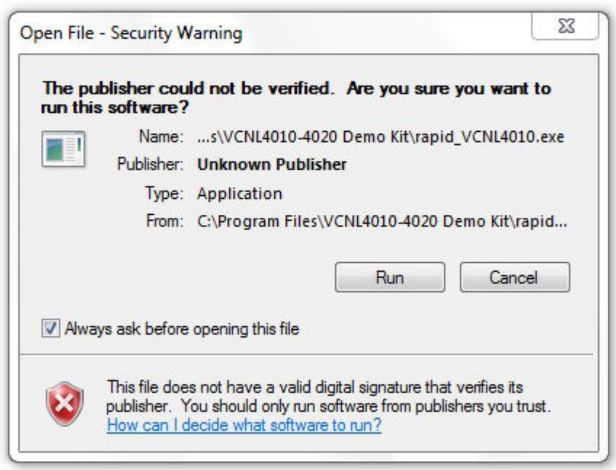
Create a folder under Programs called VCNL4010-4020 Demo Kit.

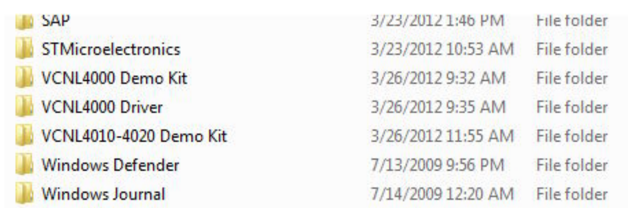
Copy the contents of the VCNL4010 4020 CD to this folder.

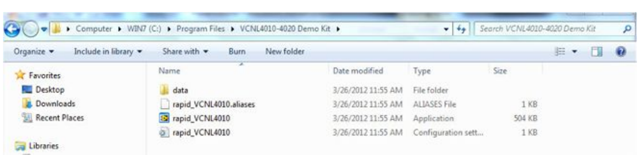
Plug in the USB stick with the VCNL4010 or VCNL4020 sensor board.

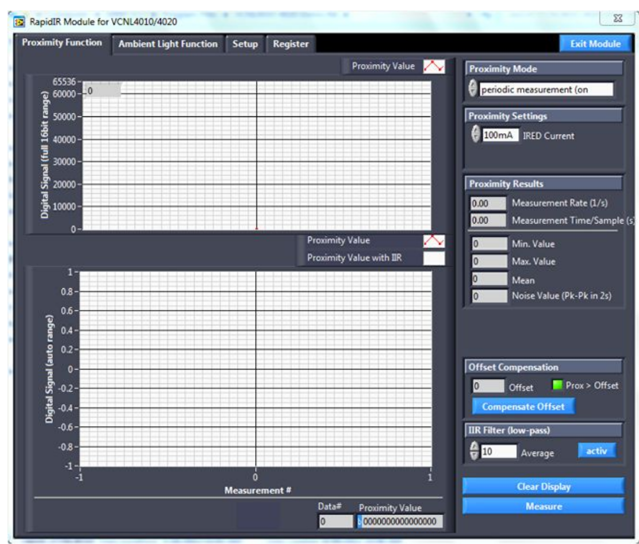
Double click rapid_VCNL4010 application

Select Run. The Proximity Function screen will be displayed. Click Measure and have fun.









APPLICATION NOTE

VCNL4000, VCNL4010, and VCNL4020 Demo Kit Installation Guide

WINDOWS XP

Installing the USB-Driver

Insert the USB connector into your computer. Administrative privileges are required to load this software. The Found New Hardware Wizard will start.

Can Windows connect to Windows Update to search for software?

⦿ Yes, this time only

Click Next >

What do you want the wizard to do?

⦿ Install from a list or specific location

Click Next >

“Search for the best driver in these locations and Search removable media (floppy, CD-ROM, …)” will already be selected

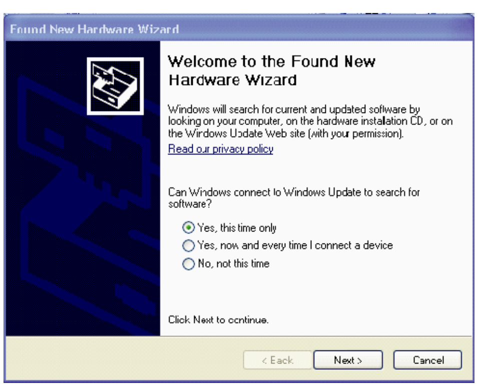
Click Next >

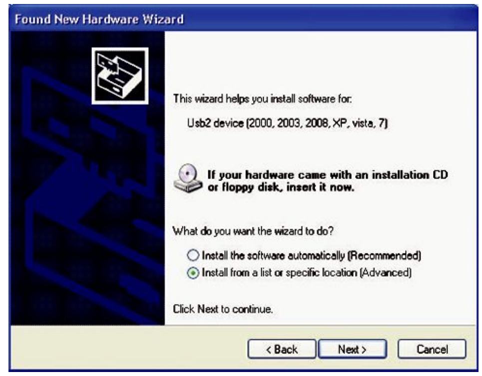
For Windows 7, Vista, XP, 2008, 2007, and 2000, the driver “cyusb” will be installed. For Windows ME and 98, the driver EXUSB_old or CYUSB_old will be installed.

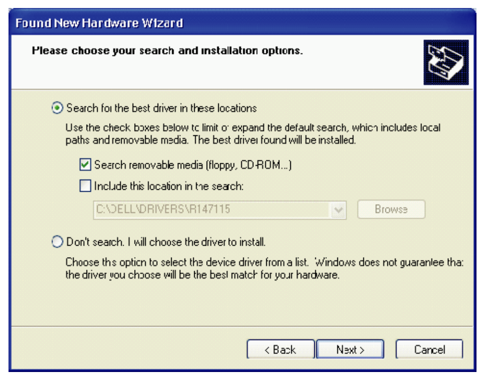
Click Finish

License

Copy the “vishay_license” file folder from the CD to C: root directory. The software will not run unless the license folder is found in the root directory.







Installing the Evaluation Software

Click on the CD from My computer. Open the USB Sensor Kit Software file folder.

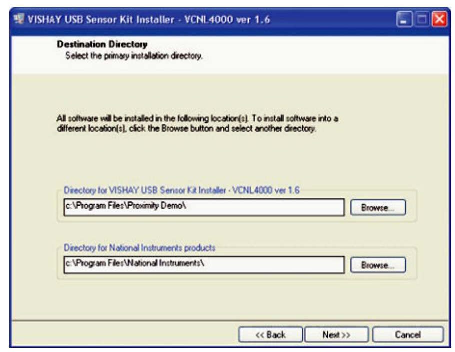
Click on Setup (Type: Application)

VCNL4000, VCNL4010, and VCNL4020 Demo Kit Installation Guide

The kit software installer launches.

Click Next >>

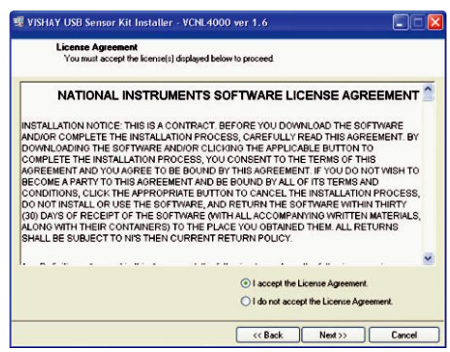
Choose the destination directory.



Click Next >>

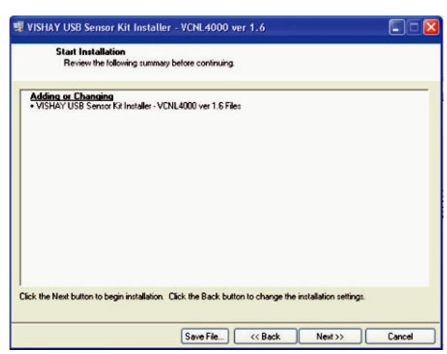
Accept the software licensing terms and conditions.

⦿ I accept the License Agreement



Click Next >>

The software will install. This may take several minutes.



Click Finish

Restart

Restart your computer.

Run Program

Click on Start, Programs, Vishay USB Sensor Kit VCNL4000

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

This application note provides an overview of C++ software code that is available for the VCNL4010, VCNL4020, and VCNL3020. There are three files included: **main.ccp**, the header file **VCNL40x0.h**, and the C-code file **VCNL40x0.ccp**.

To receive a copy of the complete software code along with the four text files that show screen results for the four applications listed below, send an e-mail to sensorstechsupport@vishay.com.

The **main.cpp** contains four examples:

1. main #1 Read proximity on demand and ambient light on demand in endless loop
2. main #2 Proximity measurement in self-timed mode with 4 measurements/s
   Read proximity value if ready with conversion, endless loop
3. main #3 Proximity measurement in self-timed mode with 31 measurements/s
   Interrupt waiting on proximity value > upper threshold limit
4. main #4 Proximity measurement and ambient light measurement in self-timed mode
   Proximity with 31 measurements/s, ambient light with 2 measurement/s
   Interrupt waiting on proximity value > upper threshold limit
5. main #5 Read proximity on demand in an endless loop

main.cpp

The delivered **main.cpp** shows:

```
#define VERSION "\n Version: 1.2  01/2012\n"
#define MAIN4              // select MAIN1, MAIN2, MAIN3, MAIN4, or MAIN5
                           // * please note that MAIN1 and MAIN4 must be modified to be used with VCNL3020 *
                              (no ambient measurements) e.g. MAIN5
#define BAUD    115200     // increase up to 921600 for high speed communication (depends on terminal programm
and USB mode)

#include "mbed.h"
#include "VCNL40x0.h"

VCNL40x0 VCNL40x0_Device (p28, p27, VCNL40x0_ADDRESS);      // Define SDA, SCL pin and I2C address
DigitalOut mled0(LED1);                                     // LED #1
DigitalOut mled1(LED2);                                     // LED #2
DigitalOut mled2(LED3);                                     // LED #3
Serial pc(USBTX, USBRX);                                    // Tx, Rx USB transmissiondefine VERSION "
```

mbed.h takes care of all necessary I^2C-Bus, port, and internal and peripheral handling.

This header file comes with the mbed board: (www.mbed.org).

The function of the LEDs is just to show the I^2C transmissions and interrupt activation. More information about the microcontroller and the compiler can be found at the end of this document.

The main #4 is the most complex software code and is shown below.

For main #4, the proximity measurement speed is 31 measurements per second in self-timed mode. The ambient light measurement which is made at the same time has a rate of 2 measurements per second.

The interrupt is assigned to the proximity measurement and the upper threshold is set to 100 counts above the previously measured offset counts.

When the count exceeds the upper threshold and an interrupt is generated, a red indicator light is illuminated on the VCNL40x0 demo kit sensor board.

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

main.cpp [Example 4]

```
//////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
// main #4
// Proximity Measurement and Ambient light Measurement in selftimed mode
// Proximity with 31 measurements/s, Ambient light with 2 measurement/s
// Interrupt waiting on proximity value > upper threshold limit
//////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
# ifdef MAIN4

int main() {
    unsigned int i=0;
    unsigned char ID=0;
    unsigned char Command=0;
    unsigned char Current=0;
    unsigned int  ProxiValue=0;
    unsigned int  SummeProxiValue=0;
    unsigned int  AverageProxiValue=0;
    unsigned int  AmbiValue=0;
    unsigned char InterruptStatus=0;
    unsigned char InterruptControl=0;

    pc.baud(BAUD);

    // print information on screen
    pc.printf("\n\n VCNL4010/4020/3020 Proximity/Ambient Light Sensor");
    pc.printf("\n library tested with mbed LPC1768 (ARM Cortex-M3 core) on www.mbed.org");
    pc.printf(VERSION);
    pc.printf("\n Demonstration #4:");
    pc.printf("\n Proximity Measurement and Ambient light Measurement in selftimed mode");
    pc.printf("\n Proximity with 31 measurements/s, Ambient light with 2 measurement/s");
    pc.printf("\n Interrupt waiting on proximity value > upper threshold limit");

    VCNL40x0_Device.ReadID (&ID);                          // Read VCNL40x0 product ID revision register
    pc.printf("\n\n Product ID Revision Register: %d", ID);

    VCNL40x0_Device.SetCurrent (20);                       // Set current to 200mA
    VCNL40x0_Device.ReadCurrent (&Current);                // Read back IR LED current
    pc.printf("\n IR LED Current: %d", Current);

    // stop all activities (necessary for changing proximity rate, see datasheet)
    VCNL40x0_Device.SetCommandRegister (COMMAND_ALL_DISABLE);

    // set proximity rate to 31/s
    VCNL40x0_Device.SetProximityRate (PROX_MEASUREMENT_RATE_31);

    // enable prox and ambi in selftimed mode
    VCNL40x0_Device.SetCommandRegister (COMMAND_PROX_ENABLE |
                                        COMMAND_AMBI_ENABLE |
                                        COMMAND_SELFTIMED_MODE_ENABLE);

    // set interrupt control for threshold
    VCNL40x0_Device.SetInterruptControl (INTERRUPT_THRES_SEL_PROX |
                                         INTERRUPT_THRES_ENABLE |
                                         INTERRUPT_COUNT_EXCEED_1);

    // set ambient light measurement parameter
    VCNL40x0_Device.SetAmbiConfiguration (AMBI_PARA_AVERAGE_32 |
                                          AMBI_PARA_AUTO_OFFSET_ENABLE |
                                          AMBI_PARA_MEAS_RATE_2);

    // measure average of prox value
    SummeProxiValue = 0;

    for (i=0; i<30; i++) {
        do {                                                   // wait on prox data ready bit
            VCNL40x0_Device.ReadCommandRegister (&Command);    // read command register
        } while (!(Command & COMMAND_MASK_PROX_DATA_READY));    // prox data ready ?

        VCNL40x0_Device.ReadProxiValue (&ProxiValue);          // read prox value

        SummeProxiValue += ProxiValue;                          // Summary of all measured prox values
    }

    AverageProxiValue = SummeProxiValue/30;                     // calculate average

    VCNL40x0_Device.SetHighThreshold (AverageProxiValue+100);   // set upper threshold for interrupt
    pc.printf("\n Upper Threshold Value: %i cts\n\n", AverageProxiValue+100);

    wait_ms(2000);                                              // wait 2s (only for display)

// endless loop /////////////////////////////////////////////////////////////////////////////////
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
    while (1) {

        // wait on data ready bit
        do {
            VCNL40x0_Device.ReadCommandRegister (&Command); // read command register
        } while (!(Command & (COMMAND_MASK_PROX_DATA_READY | COMMAND_MASK_AMBI_DATA_READY))); // data ready ?

        // read interrupt status register
        VCNL40x0_Device.ReadInterruptStatus (&InterruptStatus);

        // check interrupt status for High Threshold
        if (InterruptStatus & INTERRUPT_MASK_STATUS_THRES_HI) {
            mled2 = 1;                                              // LED on, Interrupt
            VCNL40x0_Device.SetInterruptStatus (InterruptStatus);  // clear Interrupt Status
            mled2 = 0;                                              // LED off, Interrupt
        }

        // prox value ready for using
        if (Command & COMMAND_MASK_PROX_DATA_READY) {
            mled0 = 1;                                       // LED on, Prox Data Ready
            VCNL40x0_Device.ReadProxiValue (&ProxiValue);    // read prox value

            // print prox value and interrupt status on screen
            pc.printf("\nProxi: %5.0i cts \tInterruptStatus: %i", ProxiValue, InterruptStatus);

            mled0 = 0;                                       // LED off, Prox data Ready
        }

        // ambi value ready for using
        if (Command & COMMAND_MASK_AMBI_DATA_READY) {
            mled1 = 1;                                       // LED on, Ambi Data Ready
            VCNL40x0_Device.ReadAmbiValue (&AmbiValue);      // read ambi value

            // print ambi value and interrupt status on screen
            pc.printf("\n                                               Ambi: %i", AmbiValue);

            mled1 = 0;                                       // LED off, Ambi Data Ready
        }
    }
}
# endif
```

VCNL40x0.h

This **VCNL40x0.h** header file contains all VCNL40x0 register numbers and registers bit information:

```
#ifndef VCNL40x0_H
#define VCNL40x0_H

#include "mbed.h"

// Library for the Vishay Proximity/Ambient Light Sensor VCNL4010/4020/3020
// The VCNL4x00 is a I2C digital Proximity and Ambient Light Sensor in a small SMD package

#define VCNL40x0_ADDRESS               (0x26) // 001 0011 shifted left 1 bit = 0x26

// registers
#define REGISTER_COMMAND               (0x80)
#define REGISTER_ID                    (0x81)
#define REGISTER_PROX_RATE             (0x82)
#define REGISTER_PROX_CURRENT          (0x83)
#define REGISTER_AMBI_PARAMETER        (0x84)
#define REGISTER_AMBI_VALUE            (0x85)
#define REGISTER_PROX_VALUE            (0x87)
#define REGISTER_INTERRUPT_CONTROL     (0x89)
#define REGISTER_INTERRUPT_LOW_THRES   (0x8a)
#define REGISTER_INTERRUPT_HIGH_THRES  (0x8c)
#define REGISTER_INTERRUPT_STATUS      (0x8e)
#define REGISTER_PROX_TIMING           (0xf9)
#define REGISTER_AMBI_IR_LIGHT_LEVEL   (0x90)   // This register is not intended to be use by customer

// Bits in Command register (0x80)
#define COMMAND_ALL_DISABLE            (0x00)
#define COMMAND_SELFTIMED_MODE_ENABLE  (0x01)
#define COMMAND_PROX_ENABLE            (0x02)
#define COMMAND_AMBI_ENABLE            (0x04)
#define COMMAND_PROX_ON_DEMAND         (0x08)
#define COMMAND_AMBI_ON_DEMAND         (0x10)
#define COMMAND_MASK_PROX_DATA_READY   (0x20)
#define COMMAND_MASK_AMBI_DATA_READY   (0x40)
#define COMMAND_MASK_LOCK              (0x80)
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
// Bits in Product ID Revision Register (0x81)
#define PRODUCT_MASK_REVISION_ID        (0x0f)
#define PRODUCT_MASK_PRODUCT_ID         (0xf0)

// Bits in Prox Measurement Rate register (0x82)
#define PROX_MEASUREMENT_RATE_2         (0x00)    // DEFAULT
#define PROX_MEASUREMENT_RATE_4         (0x01)
#define PROX_MEASUREMENT_RATE_8         (0x02)
#define PROX_MEASUREMENT_RATE_16        (0x03)
#define PROX_MEASUREMENT_RATE_31        (0x04)
#define PROX_MEASUREMENT_RATE_62        (0x05)
#define PROX_MEASUREMENT_RATE_125       (0x06)
#define PROX_MEASUREMENT_RATE_250       (0x07)
#define PROX_MASK_MEASUREMENT_RATE      (0x07)

// Bits in Proximity LED current setting (0x83)
#define PROX_MASK_LED_CURRENT           (0x3f)    // DEFAULT = 2
#define PROX_MASK_FUSE_PROG_ID          (0xc0)

// Bits in Ambient Light Parameter register (0x84)
#define AMBI_PARA_AVERAGE_1             (0x00)
#define AMBI_PARA_AVERAGE_2             (0x01)
#define AMBI_PARA_AVERAGE_4             (0x02)
#define AMBI_PARA_AVERAGE_8             (0x03)
#define AMBI_PARA_AVERAGE_16            (0x04)
#define AMBI_PARA_AVERAGE_32            (0x05)    // DEFAULT
#define AMBI_PARA_AVERAGE_64            (0x06)
#define AMBI_PARA_AVERAGE_128           (0x07)
#define AMBI_MASK_PARA_AVERAGE          (0x07)

#define AMBI_PARA_AUTO_OFFSET_ENABLE    (0x08)    // DEFAULT enable
#define AMBI_MASK_PARA_AUTO_OFFSET      (0x08)

#define AMBI_PARA_MEAS_RATE_1           (0x00)
#define AMBI_PARA_MEAS_RATE_2           (0x10)    // DEFAULT
#define AMBI_PARA_MEAS_RATE_3           (0x20)
#define AMBI_PARA_MEAS_RATE_4           (0x30)
#define AMBI_PARA_MEAS_RATE_5           (0x40)
#define AMBI_PARA_MEAS_RATE_6           (0x50)
#define AMBI_PARA_MEAS_RATE_8           (0x60)
#define AMBI_PARA_MEAS_RATE_10          (0x70)
#define AMBI_MASK_PARA_MEAS_RATE        (0x70)

#define AMBI_PARA_CONT_CONV_ENABLE      (0x80)
#define AMBI_MASK_PARA_CONT_CONV        (0x80)    // DEFAULT disable

// Bits in Interrupt Control Register (x89)
#define INTERRUPT_THRES_SEL_PROX        (0x00)
#define INTERRUPT_THRES_SEL_ALS         (0x01)

#define INTERRUPT_THRES_ENABLE          (0x02)

#define INTERRUPT_ALS_READY_ENABLE      (0x04)

#define INTERRUPT_PROX_READY_ENABLE     (0x08)

#define INTERRUPT_COUNT_EXCEED_1        (0x00)    // DEFAULT
#define INTERRUPT_COUNT_EXCEED_2        (0x20)
#define INTERRUPT_COUNT_EXCEED_4        (0x40)
#define INTERRUPT_COUNT_EXCEED_8        (0x60)
#define INTERRUPT_COUNT_EXCEED_16       (0x80)
#define INTERRUPT_COUNT_EXCEED_32       (0xa0)
#define INTERRUPT_COUNT_EXCEED_64       (0xc0)
#define INTERRUPT_COUNT_EXCEED_128      (0xe0)
#define INTERRUPT_MASK_COUNT_EXCEED     (0xe0)

// Bits in Interrupt Status Register (x8e)
#define INTERRUPT_STATUS_THRES_HI       (0x01)
#define INTERRUPT_STATUS_THRES_LO       (0x02)
#define INTERRUPT_STATUS_ALS_READY      (0x04)
#define INTERRUPT_STATUS_PROX_READY     (0x08)
#define INTERRUPT_MASK_STATUS_THRES_HI  (0x01)
#define INTERRUPT_MASK_THRES_LO         (0x02)
#define INTERRUPT_MASK_ALS_READY        (0x04)
#define INTERRUPT_MASK_PROX_READY       (0x08)
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
typedef enum {
    VCNL40x0_ERROR_OK = 0,              // Everything executed normally
    VCNL40x0_ERROR_I2CINIT,             // Unable to initialize I2C
    VCNL40x0_ERROR_I2CBUSY,             // I2C already in use
    VCNL40x0_ERROR_LAST
} VCNL40x0Error_e;


class VCNL40x0 {
public:
// Creates an instance of the class.
// Connect module at I2C address addr using I2C port pins sda and scl.

    VCNL40x0 (PinName sda, PinName scl, unsigned char addr);

// Destroys instance

    ~VCNL40x0();

// public functions

    VCNL40x0Error_e Init (void);

    VCNL40x0Error_e SetCommandRegister (unsigned char Command);
    VCNL40x0Error_e SetCurrent (unsigned char CurrentValue);
    VCNL40x0Error_e SetProximityRate (unsigned char ProximityRate);
    VCNL40x0Error_e SetAmbiConfiguration (unsigned char AmbiConfiguration);
    VCNL40x0Error_e SetLowThreshold (unsigned int LowThreshold);
    VCNL40x0Error_e SetHighThreshold (unsigned int HighThreshold);
    VCNL40x0Error_e SetInterruptControl (unsigned char InterruptControl);
    VCNL40x0Error_e SetInterruptStatus (unsigned char InterruptStatus);
    VCNL40x0Error_e SetModulatorTimingAdjustment (unsigned char ModulatorTimingAdjustment);

    VCNL40x0Error_e ReadID (unsigned char *ID);
    VCNL40x0Error_e ReadCurrent (unsigned char *CurrentValue);
    VCNL40x0Error_e ReadCommandRegister (unsigned char *Command);
    VCNL40x0Error_e ReadProxiValue (unsigned int *ProxiValue);
    VCNL40x0Error_e ReadAmbiValue (unsigned int *AmbiValue);
    VCNL40x0Error_e ReadInterruptStatus (unsigned char *InterruptStatus);
    VCNL40x0Error_e ReadInterruptControl (unsigned char *InterruptControl);

    VCNL40x0Error_e ReadProxiOnDemand (unsigned int *ProxiValue);
    VCNL40x0Error_e ReadAmbiOnDemand (unsigned int *AmbiValue);

private:
    I2C _i2c;
    int _addr;
    char _send[3];
    char _receive[2];

};

#endif
```

VCNL40x0.cpp

This **VCNL40x0.cpp** file contains all definitions and public functions:

```
#include "VCNL40x0.h"

//////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0::VCNL40x0(PinName sda, PinName scl, unsigned char addr) : _i2c(sda, scl), _addr(addr) {
    _i2c.frequency(1000000);                                // set I2C frequency to 1MHz
}

VCNL40x0::~VCNL40x0() {
}

//////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetCommandRegister (unsigned char Command) {

    _send[0] = REGISTER_COMMAND;                            // VCNL40x0 Configuration register
    _send[1] = Command;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadCommandRegister (unsigned char *Command) {

    _send[0] = REGISTER_COMMAND;                            // VCNL40x0 Configuration register
    _i2c.write(VCNL40x0_ADDRESS,_send, 1);                  // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1,_receive, 1);              // Read 1 byte on I2C

    *Command = (unsigned char)(_receive[0]);

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadID (unsigned char *ID) {

    _send[0] = REGISTER_ID;                                 // VCNL40x0 product ID revision register
    _i2c.write(VCNL40x0_ADDRESS, _send, 1);                 // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1, _receive, 1);             // Read 1 byte on I2C

    *ID = (unsigned char)(_receive[0]);

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetCurrent (unsigned char Current) {

    _send[0] = REGISTER_PROX_CURRENT;                       // VCNL40x0 IR LED Current register
    _send[1] = Current;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadCurrent (unsigned char *Current) {

    _send[0] = REGISTER_PROX_CURRENT;                       // VCNL40x0 IR LED current register
    _i2c.write(VCNL40x0_ADDRESS,_send, 1);                  // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1,_receive, 1);              // Read 1 byte on I2C

    *Current = (unsigned char)(_receive[0]);

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetProximityRate (unsigned char ProximityRate) {

    _send[0] = REGISTER_PROX_RATE;                          // VCNL40x0 Proximity rate register
    _send[1] = ProximityRate;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetAmbiConfiguration (unsigned char AmbiConfiguration) {

    _send[0] = REGISTER_AMBI_PARAMETER;                     // VCNL40x0 Ambient light configuration
    _send[1] = AmbiConfiguration;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetInterruptControl (unsigned char InterruptControl) {

    _send[0] = REGISTER_INTERRUPT_CONTROL;                  // VCNL40x0 Interrupt Control register
    _send[1] = InterruptControl;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadInterruptControl (unsigned char *InterruptControl) {

    _send[0] = REGISTER_INTERRUPT_CONTROL;                  // VCNL40x0 Interrupt Control register
    _i2c.write(VCNL40x0_ADDRESS,_send, 1);                  // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1,_receive, 1);              // Read 1 byte on I2C

    *InterruptControl = (unsigned char)(_receive[0]);

    return VCNL40x0_ERROR_OK;
}

/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetInterruptStatus (unsigned char InterruptStatus) {

    _send[0] = REGISTER_INTERRUPT_STATUS;                   // VCNL40x0 Interrupt Status register
    _send[1] = InterruptStatus;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetModulatorTimingAdjustment (unsigned char ModulatorTimingAdjustment) {

    _send[0] = REGISTER_PROX_TIMING;                        // VCNL40x0 Modulator Timing Adjustment register
    _send[1] = ModulatorTimingAdjustment;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadInterruptStatus (unsigned char *InterruptStatus) {

    _send[0] = REGISTER_INTERRUPT_STATUS;                   // VCNL40x0 Interrupt Status register
    _i2c.write(VCNL40x0_ADDRESS,_send, 1);                  // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1,_receive, 1);              // Read 1 byte on I2C

    *InterruptStatus = (unsigned char)(_receive[0]);

    return VCNL40x0_ERROR_OK;
}

/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadProxiValue (unsigned int *ProxiValue) {

    _send[0] = REGISTER_PROX_VALUE;                         // VCNL40x0 Proximity Value register
    _i2c.write(VCNL40x0_ADDRESS, _send, 1);                 // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1, _receive, 2);             // Read 2 bytes on I2C
    *ProxiValue = ((unsigned int)_receive[0] << 8 | (unsigned char)_receive[1]);

    return VCNL40x0_ERROR_OK;
}

/////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadAmbiValue (unsigned int *AmbiValue) {

    _send[0] = REGISTER_AMBI_VALUE;                          // VCNL40x0 Ambient Light Value register
    _i2c.write(VCNL40x0_ADDRESS, _send, 1);                  // Write 1 byte on I2C
    _i2c.read(VCNL40x0_ADDRESS+1, _receive, 2);              // Read 2 bytes on I2C
    *AmbiValue = ((unsigned int)_receive[0] << 8 | (unsigned char)_receive[1]);

    return VCNL40x0_ERROR_OK;
}
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

```
////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetLowThreshold (unsigned int LowThreshold) {

    unsigned char LoByte=0, HiByte=0;

    LoByte = (unsigned char)(LowThreshold & 0x00ff);
    HiByte = (unsigned char)((LowThreshold & 0xff00)>>8);

    _send[0] = REGISTER_INTERRUPT_LOW_THRES;                // VCNL40x0 Low Threshold Register, Hi Byte
    _send[1] = HiByte;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    _send[0] = REGISTER_INTERRUPT_LOW_THRES+1;              // VCNL40x0 Low Threshold Register, Lo Byte
    _send[1] = LoByte;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::SetHighThreshold (unsigned int HighThreshold) {

    unsigned char LoByte=0, HiByte=0;

    LoByte = (unsigned char)(HighThreshold & 0x00ff);
    HiByte = (unsigned char)((HighThreshold & 0xff00)>>8);

    _send[0] = REGISTER_INTERRUPT_HIGH_THRES;               // VCNL40x0 High Threshold Register, Hi Byte
    _send[1] = HiByte;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    _send[0] = REGISTER_INTERRUPT_HIGH_THRES+1;             // VCNL40x0 High Threshold Register, Lo Byte
    _send[1] = LoByte;
    _i2c.write(VCNL40x0_ADDRESS,_send, 2);                  // Write 2 bytes on I2C

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadProxiOnDemand (unsigned int *ProxiValue) {

    unsigned char Command=0;

    // enable prox value on demand
    SetCommandRegister (COMMAND_PROX_ENABLE | COMMAND_PROX_ON_DEMAND);

    // wait on prox data ready bit
    do {
        ReadCommandRegister (&Command);                     // read command register
    } while (!(Command & COMMAND_MASK_PROX_DATA_READY));

    ReadProxiValue (ProxiValue);                            // read prox value

    SetCommandRegister (COMMAND_ALL_DISABLE);               // stop prox value on demand

    return VCNL40x0_ERROR_OK;
}

////////////////////////////////////////////////////////////////////////////////////////////////////////////////

VCNL40x0Error_e VCNL40x0::ReadAmbiOnDemand (unsigned int *AmbiValue) {

    unsigned char Command=0;

    // enable ambi value on demand
    SetCommandRegister (COMMAND_PROX_ENABLE | COMMAND_AMBI_ON_DEMAND);

    // wait on ambi data ready bit
    do {
        ReadCommandRegister (&Command);                     // read command register
    } while (!(Command & COMMAND_MASK_AMBI_DATA_READY));

    ReadAmbiValue (AmbiValue);                              // read ambi value

    SetCommandRegister (COMMAND_ALL_DISABLE);               // stop ambi value on demand

    return VCNL40x0_ERROR_OK;
}
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

The five text files included within the zip show the results that would be seen on-screen when running the five separate listed applications.

These five examples are related to the “main #1” to “main #5” routines within the **main.ccp**:

Logging_Main1.txt

In addition to the proximity on demand value, this “main #1” also shows the ambient light on demand value and calculated illuminance.

```
...

Proxi:  3012 cts        Ambi:   710 cts         Illuminance:  177.50 lx
Proxi:  2974 cts        Ambi:   709 cts         Illuminance:  177.25 lx
Proxi:  3003 cts        Ambi:   709 cts         Illuminance:  177.25 lx
Proxi:  3074 cts        Ambi:   708 cts         Illuminance:  177.00 lx

...
```

To get the illuminance value from the counts, just divide them by four, e.g.: 708 cts/4 = 177.00 lx.

Logging_Main2.txt

This “main #2” shows some results of proximity measurement in self-timed mode with 4 measurements/s.

```
...

Proxi:  2458 cts
Proxi:  2390 cts
Proxi:  2444 cts

...
```

The endless loop enables evaluation of the offset counts within the used application, as well as testing for the amount of counts that will be read out with the object in a defined distance.

Logging_Main3.txt

The “main #3” shows results of proximity measurement in self-timed mode with 31 measurements/s and also the corresponding interrupt status.

```
...

Proxi:  2930 cts        InterruptStatus: 0
Proxi:  3002 cts        InterruptStatus: 0
Proxi:  3043 cts        InterruptStatus: 0
Proxi:  3218 cts        InterruptStatus: 1
Proxi:  3257 cts        InterruptStatus: 1
Proxi:  3307 cts        InterruptStatus: 1

...
```

Within the line where the interrupt status changes from “0” to “1,” one can also see the change to 3218 counts from just 3043 which is more than 100 over the defined limit.

Logging_Main4.txt

The “main #4” shows the results of parallel proximity measurements AND ambient light measurements in self-timed mode with 31 measurements/s for proximity and 2 measurements/s for ambient light.

The interrupt is assigned to proximity and a subroutine is averaging 30 samples to define currently available offset counts. The upper threshold is set at 100 counts higher than this averaged result.

Only this fourth example “Logging_Main4.txt” is shown here completely, and explained on the next page.

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

Logging_Main4.txt

```
VCNL4010/4020/3020 Proximity/Ambient Light Sensor
library tested with mbed LPC1768 (ARM Cortex-M3 core) on www.mbed.org
Version: 1.2  01/2012

Demonstration #4:
Proximity Measurement and Ambient light Measurement in selftimed mode
Proximity with 31 measurements/s, Ambient light with 2 measurement/s
Interrupt waiting on proximity value > upper threshold limit

Product ID Revision Register: 33
IR LED Current: 20
Upper Threshold Value: 2570 cts

Proxi:  2492 cts        InterruptStatus: 0
Proxi:  2416 cts        InterruptStatus: 0
Proxi:  2479 cts        InterruptStatus: 0
Proxi:  2475 cts        InterruptStatus: 0
Proxi:  2483 cts        InterruptStatus: 0
Proxi:  2487 cts        InterruptStatus: 0
Proxi:  2437 cts        InterruptStatus: 0
Proxi:  2446 cts        InterruptStatus: 0
Proxi:  2454 cts        InterruptStatus: 0
Proxi:  2479 cts        InterruptStatus: 0
Proxi:  2423 cts        InterruptStatus: 0
                                                Ambi: 1118
Proxi:  2483 cts        InterruptStatus: 0
Proxi:  2436 cts        InterruptStatus: 0
Proxi:  2407 cts        InterruptStatus: 0
Proxi:  2437 cts        InterruptStatus: 0
Proxi:  2407 cts        InterruptStatus: 0
Proxi:  2438 cts        InterruptStatus: 0
Proxi:  2451 cts        InterruptStatus: 0
Proxi:  2489 cts        InterruptStatus: 0
Proxi:  2432 cts        InterruptStatus: 0
Proxi:  2504 cts        InterruptStatus: 0
Proxi:  2504 cts        InterruptStatus: 0
Proxi:  2443 cts        InterruptStatus: 0
Proxi:  2424 cts        InterruptStatus: 0
Proxi:  2428 cts        InterruptStatus: 0
Proxi:  2481 cts        InterruptStatus: 0
                                                Ambi: 1075
Proxi:  2538 cts        InterruptStatus: 0
Proxi:  2435 cts        InterruptStatus: 0
Proxi:  2521 cts        InterruptStatus: 0
Proxi:  2482 cts        InterruptStatus: 0
Proxi:  2533 cts        InterruptStatus: 0
Proxi:  2523 cts        InterruptStatus: 0
Proxi:  2544 cts        InterruptStatus: 0
Proxi:  2575 cts        InterruptStatus: 1
Proxi:  2632 cts        InterruptStatus: 1
Proxi:  2658 cts        InterruptStatus: 1
Proxi:  2671 cts        InterruptStatus: 1
Proxi:  2780 cts        InterruptStatus: 1
Proxi:  2754 cts        InterruptStatus: 1
Proxi:  2808 cts        InterruptStatus: 1
Proxi:  2863 cts        InterruptStatus: 1
Proxi:  2848 cts        InterruptStatus: 1
                                                Ambi: 779
Proxi:  2926 cts        InterruptStatus: 1
Proxi:  2889 cts        InterruptStatus: 1
```

From here the actual proximity offset count is printed as available with the used application. It is about 2470 (± 60 cts).

For every 15/16 proximity values, one ambient result is visible.
This is due to programs
PROX_MEASUREMENT_RATE_31
and
AMBI_PARA_MEAS_RATE_2

With the evaluated offset count of 2470 above (30 measurements averaged (see main.cpp)) and the definition of the high threshold to be at offset cts + 100 cts = 2570, at 2575 cts this threshold is exceeded and the interrupt is set.

What is also possible to see here:
The closer the hand, the higher the proximity counts AND the lower the ambient counts.
This is due to shadowing created by the light source straight above.

Logging_Main5.txt

The "main #5" shows the proximity on demand values. It is a modified version of "main #1" in order to be used with the VCNL3020.

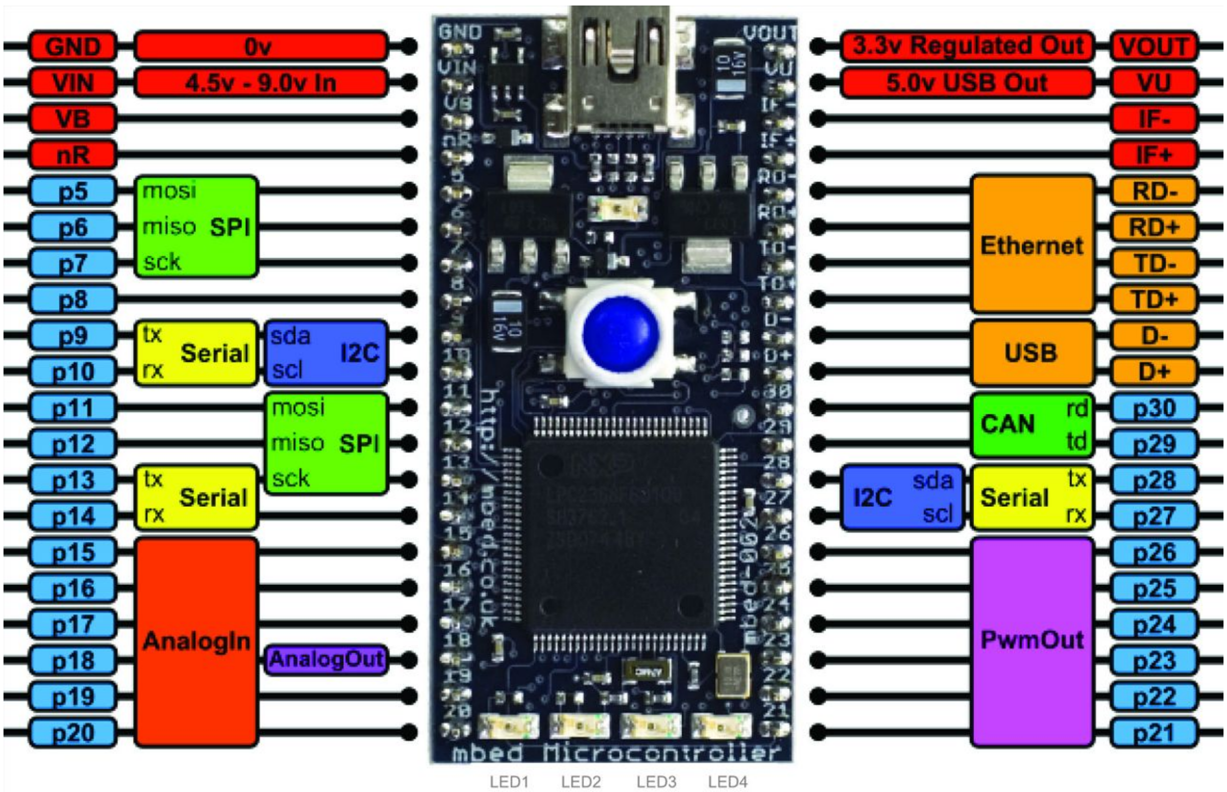
```
...
Proxi:  3012 cts
Proxi:  2974 cts
Proxi:  3003 cts
Proxi:  3074 cts

...
```

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

The controller used for developing this code was an ARM Processor (NXP LPC1768), which is available on a so-called “mbed Board” and can be ordered here: http://mbed.org/handbook/order.

More useful information is available under: www.mbed.org.



Microcontroller board: mbed NXP LPC1768
Rapid Prototyping for general microcontroller applications, Ethernet, USB and 32-bit ARM® Cortex™-M3 based designs

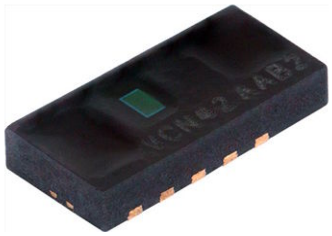
The I²C bus of the VCNL40x0 demo board is connected towards P28 (SDA) and P27 (SCL), as shown within the mbed NXP LPC1768 board picture above.

The Interrupt pin is not routed from the VCNL40x0 towards the mbed board because the red LED at the VCNL40x0 demo board indicates this event.

LED0 indicates an available proximity measurement and LED1 an available ambient light measurement.

C++ Software Code for VCNL4010, VCNL4020, and VCNL3020

Software for Android Platform VCNL4020 and VCNL3020



This document is supplied with Vishay's Android software solution for the VCNL4020 and VCNL3020. This complete software package comes with all the necessary parts to simplify the integration of the VCNL4020 or VCNL3020 into an Android platform running Android version 4.0.1 or later. For demonstration purposes, the BeagleBoard-xM running Android v4.0.1 was used as a reference platform. If the same hardware is to be used, further information regarding where to purchase such a BeagleBoard-xM can be found here.

The provided zip file "**VCNL4020_Android-SW v 1.0.zip**," depicted in Figure 2, contains the documentation, source, and patch files required to allow an Android-based platform to communicate with the VCNL4020 or VCNL3020. This communication follows the standard Android sensors framework, as depicted in Figure 1.

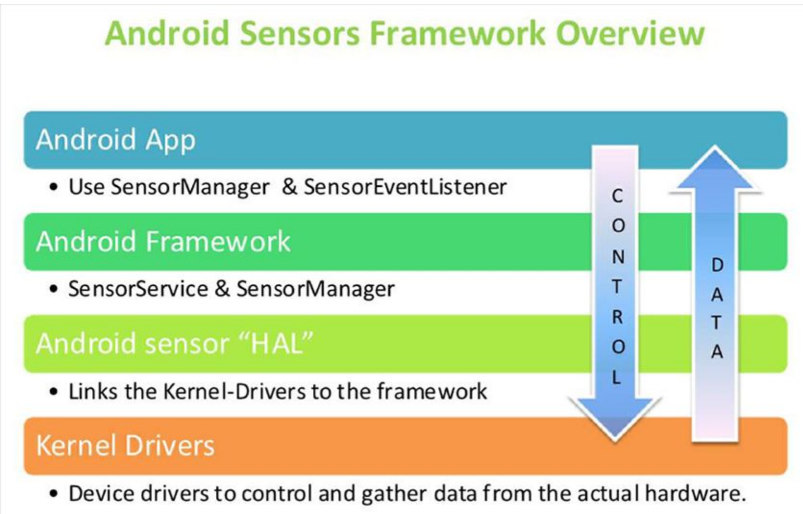


Fig. 1

The supplied Android VCNL4020 driver consists of two parts: the kernel module responsible for the data control and acquisition from the VCNL4020 or VCNL3020; and the subsequent HAL (Hardware Abstraction Layer) module to link the kernel to the main Android framework, allowing the information supplied by the sensor to be used by Android applications. An example Android app has also been included (**VCNL40x0-DemoApp.apk**), along with its associated source code, upon which user-specific Android applications can be built.

APPLICATION NOTE

Software for Android Platform VCNL4020 and VCNL3020

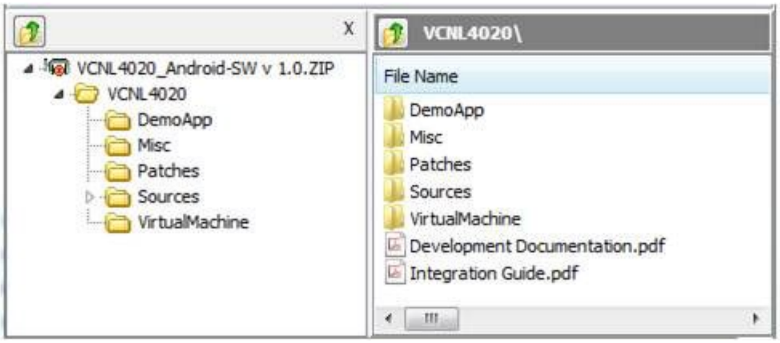


Fig. 2

DOCUMENTATION

The provided documentation files are **Development Documentation.pdf** and **Integration Guide.pdf**.

The Development Documentation file describes how the sources are to be compiled in order to be used with the reference platform. When successfully compiled, the kernel and HAL modules are generated. In order to further simplify the build process, a build script is supplied, which is also documented in this file.

The Integration Guide file describes how the VCNL4020 or VCNL3020 is to be integrated with the BeagleBoard xM. A description of both the kernel and the user space Android HAL module required for the integration is supplied. Furthermore, the document supplies information regarding the source files used to build these modules, which are also included in the zip file. The modules patches and the corresponding sources are supplied both in the form of the integration patch for all device repositories and specifically for the integration into the HAL of the reference repository. Information on how to apply these patches is also given in the guide.

INCLUDED FILES

Figure 3 includes an overview of the files supplied with the VCNL4020 software package.

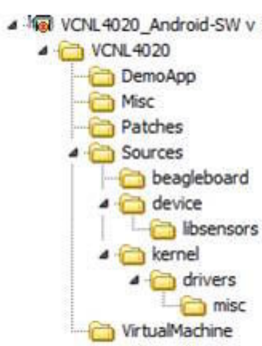


Fig. 3

The DemoApp folder contains the demonstration app along with its source code.

The Sources folder contains all the necessary sources in order to compile the required Android kernel and HAL patches. Further information regarding the files located in the sub folders can be found in the Integration Guide. The current versions of the compiled patches can be found in the Patches folder. If the source code is expanded and the source needs to be recompiled, the build script used to ease this process is located in the Misc folder.

The remaining VirtualMachine folder contains an incomplete virtual machine for our set-up build environment. The folder is incomplete as it is only needed for our own evaluation with the BeagleBoard-xM reference platform. The entire environment has not been included as the zip file size would increase to about 50 GB. However, if the build environment is required, please contact sensorstechsupport@vishay.com.

Software for Android Platform VCNL4020 and VCNL3020

BEAGLEBOARD-XM EXPANSION

The development was done using the BeagleBoard-xM as a reference platform, with the VCNL4020 sensor board connected via the expansion connector. This connector provides the I²C lines required to interface with the VCNL4020 or VCNL3020. The general set-up is shown in Figure 4.

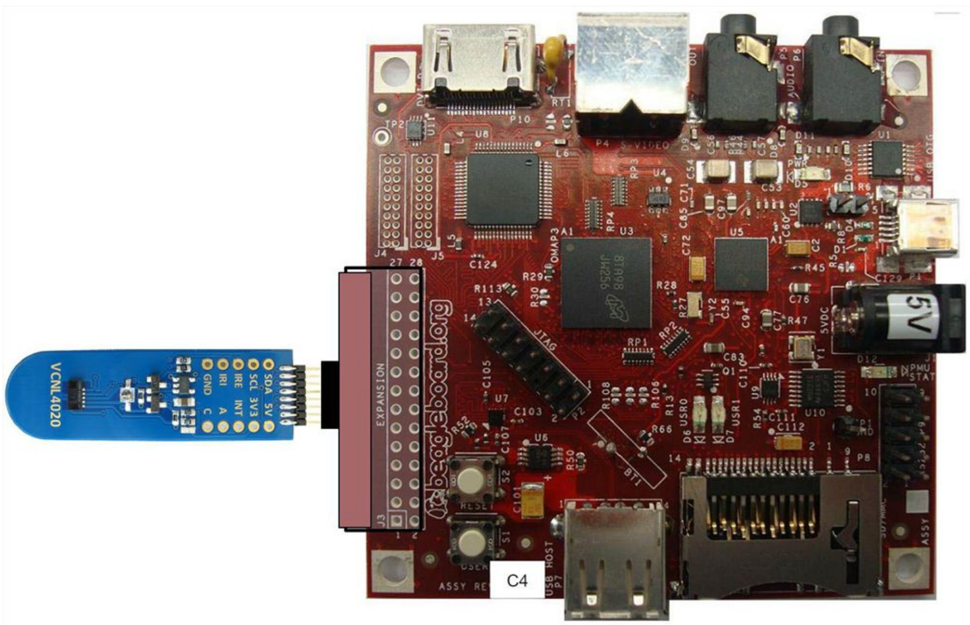


Fig. 4

This interconnection board takes care of the I²C bus as well as the needed power supply. The 3.3 V supply voltage for the sensor is created by a small voltage regulator tied to 5 V. The necessary I²C bus pull-up resistors are connected to 1.8 V. The connections are depicted in Figure 5.

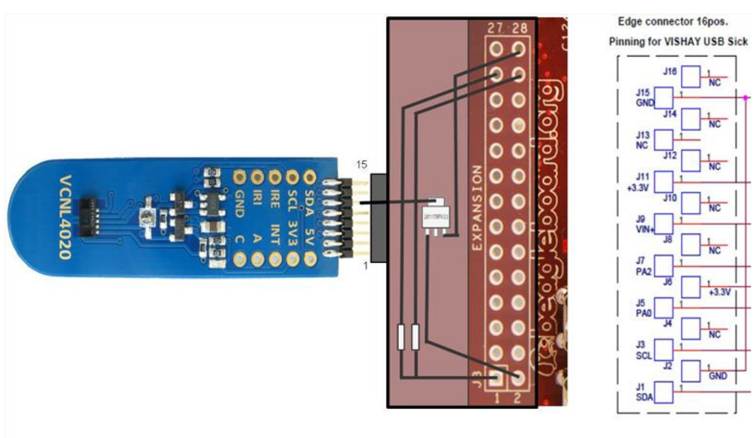


Fig. 5

Software for Android Platform VCNL4020 and VCNL3020

VCNL40x0 DEMO APP

The Android software package comes with an Android demonstration app, **VCNL40x0-DemoApp.apk**, which can be run on any Android platform running v.4.0.1 or higher. It is to be used both for testing purposes and by developers as a base for building further Android applications.

To install this .apk, simply use an Android file manager such as “ASTRO File Manager” or copy the file onto a web server in order to open the file via a link directly from the phone. The Android Debug Bridge can also be used with the command: *adb install -r <application.apk>*.

After successful installation, the icon shown in Figure 6 will be added to your home screen.

Fig. 6

Selecting the icon will launch the application and take you to the “**Proximity**” tab, as shown in Figure 7.

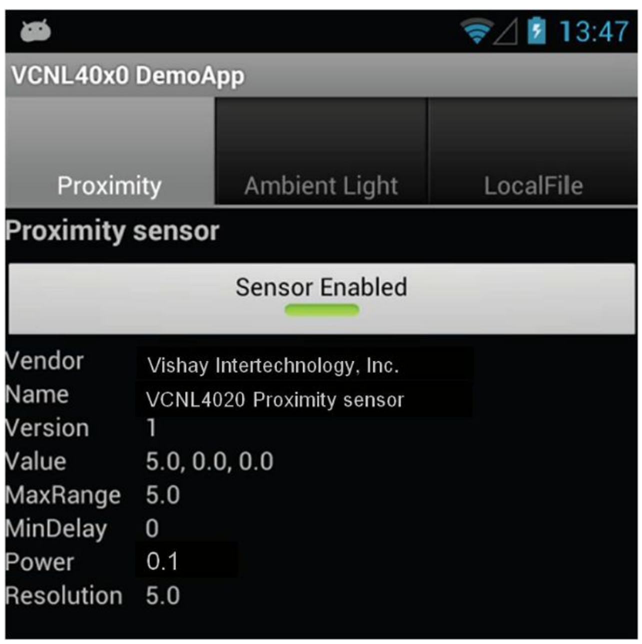


Fig. 7

The displayed information shows that the device is successfully communicating with the VCNL4020 or VCNL3020. The “Value” is an indication of the information sent to the app through the Android sensor manager. This value changes to 0.0 when an object is within 5 mm of the sensor, as a proximity event has been through the Android sensor API. The "Sensor Enabled" button registers the app for system updates.

Software for Android Platform VCNL4020 and VCNL3020

Selecting the “**Ambient Light**” tab will display the ambient light menu, as shown in Figure 8.

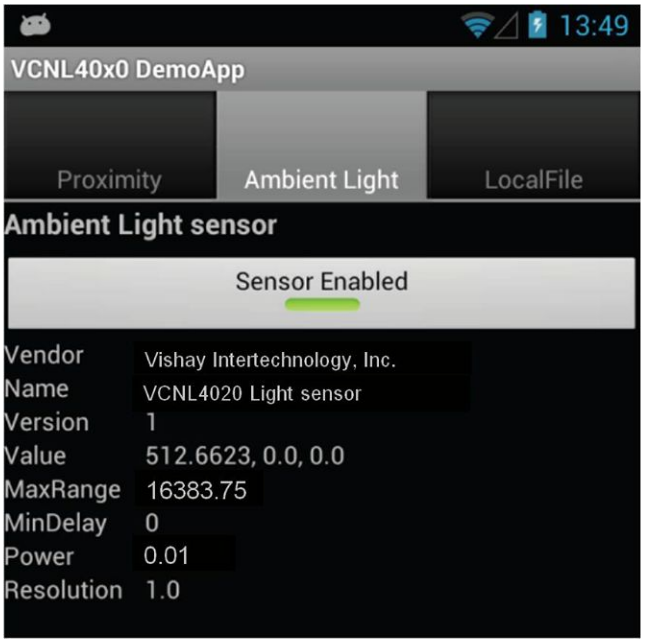


Fig. 8

Again the sensor information is read and displayed and the “Sensor Enabled” button registers the app for system updates. The “Value” field continuously updates with the current ambient light value as read by the VCNL4020. Note that the VCNL3020 does not contain an ambient light sensor.

The “**LocalFile**” tab brings up a blank screen unless the VCNL4020 is being used (Figure 9).

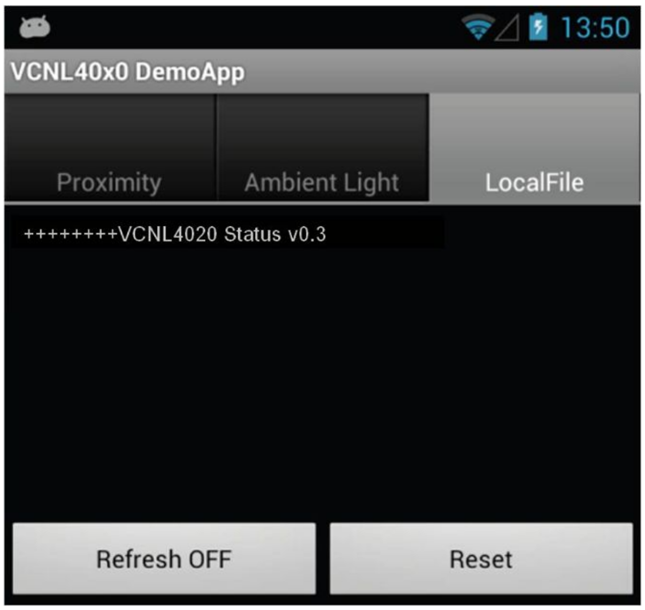


Fig. 9

Software for Android Platform VCNL4020 and VCNL3020

After setting up the reference platform and applying the patches, the LocalFile menu displays what is shown in Figure 10.

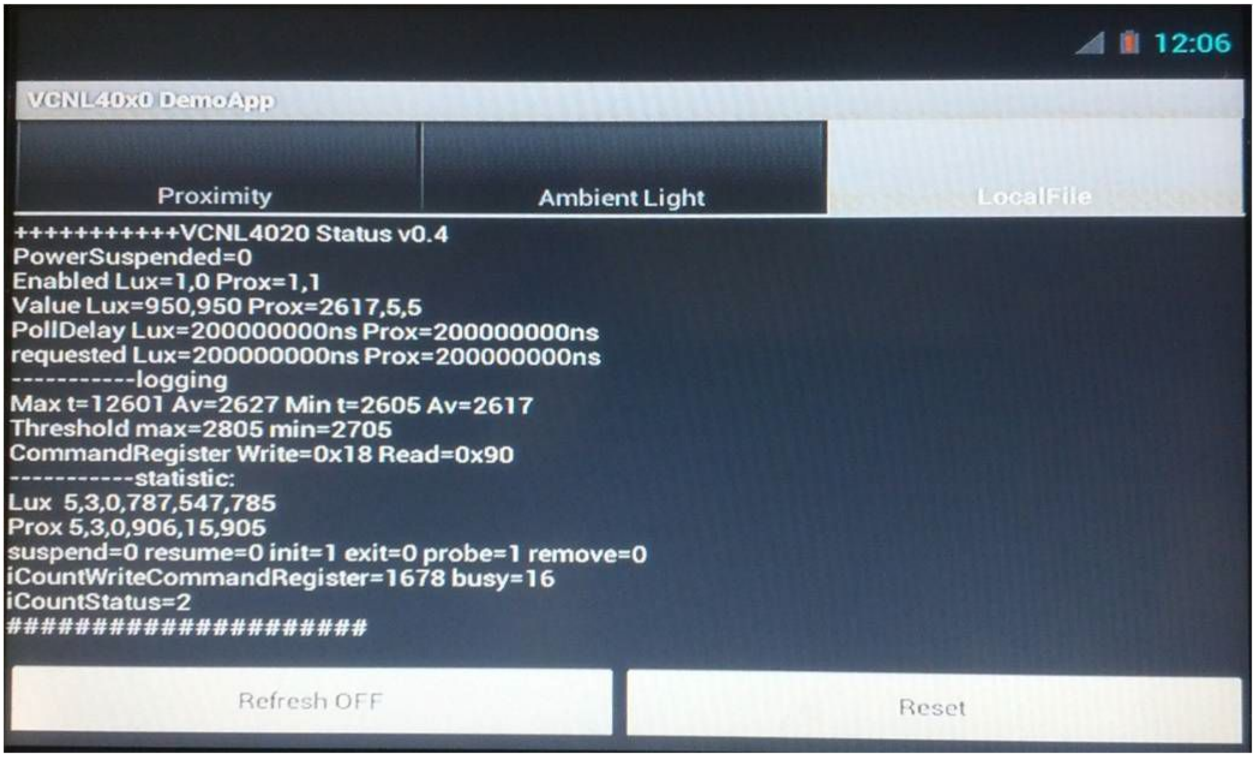


Fig. 10

Here the current status of the proximity and ambient light measurements are displayed, along with the corresponding threshold values. If the “Refresh” button on the bottom left is toggled ON, these values are continuously updated and the latest values read by the VCNL4020 sensor are shown.

The “Reset” button resets the values along with the threshold values. For example, if the environment is changed by placing glass over the sensor - as it would be in a mobile phone - the “Reset” button can be pressed after the glass has been put into place. The proximity detection in the Proximity menu will now react to the newly set threshold, taking the new offset values into consideration.

The new threshold values are taken and the new upper limit is set 200 counts above this. The new lower limit used to switch on again is taken as half the upper limit counts (i.e. 100 counts). These values are displayed as “Threshold max.” and “Threshold min.” in the logging data.

Further information such as the amount of measurements taken, “iCountStatus,” or an average of the measured proximity values, “Av,” is also displayed.

REMARK:

This Android software may also be used for the VCNL4010 without any changes.

Designing VCNL4010 into an Application

INTRODUCTION AND BASIC OPERATION

The VCNL4010 is a fully integrated proximity and ambient light sensor. It combines an infrared emitter and PIN photodiode for proximity measurement, ambient light sensor, and signal processing IC in a single package with a 16 bit ADC. The device provides ambient light sensing to support conventional backlight and display brightness auto-adjustment, and proximity sensing to minimize accidental touch input that can lead to call drops and camera launch. With a range of up to 20 cm (7.9"), this stand-alone, single 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 VCNL4010 features a miniature leadless package (LLP) for surface mounting in a 3.9 mm x 3.9 mm package with a low profile of 0.75 mm designed specifically for the low height requirements of smart phone, mobile phone, digital camera, and tablet PC applications. Through its standard I^{2}C bus serial digital interface, it allows easy access to a “Proximity Signal” and “Light Intensity” measurements without complex calculations or programming. The programmable interrupt function offers wake-up functionality for the microcontroller when a proximity event or ambient light change occurs which reduces processing overhead by eliminating the need for continuous polling.

Fig. 1 - VCNL4010 Top View

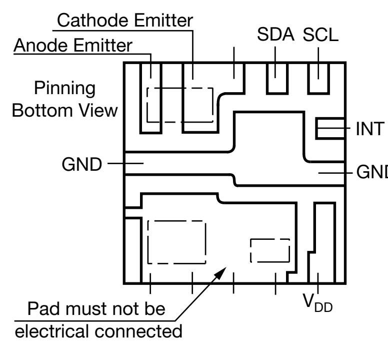


Fig. 2 - VCNL4010 Bottom View

COMPONENTS (BLOCK DIAGRAM)

The major components of the VCNL4010 are shown in the block diagram.

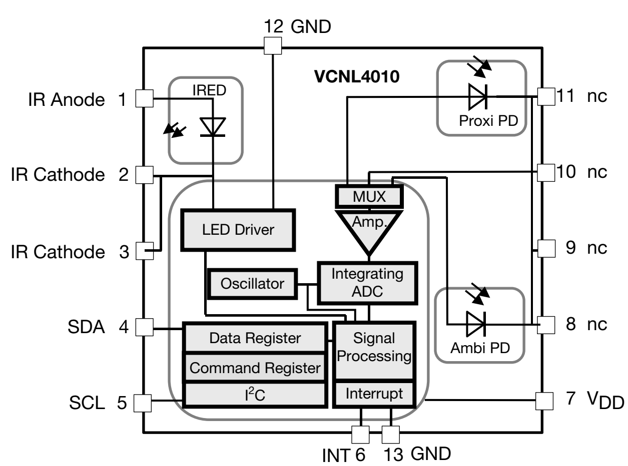


Fig. 3 - VCNL4010 Detailed Block Diagram

Designing VCNL4010 into an Application

The integrated **infrared emitter** has a peak wavelength of 890 nm. It emits light that reflects off an object within 20 cm of the sensor. The infrared emitter spectrum is shown in Figure 4.

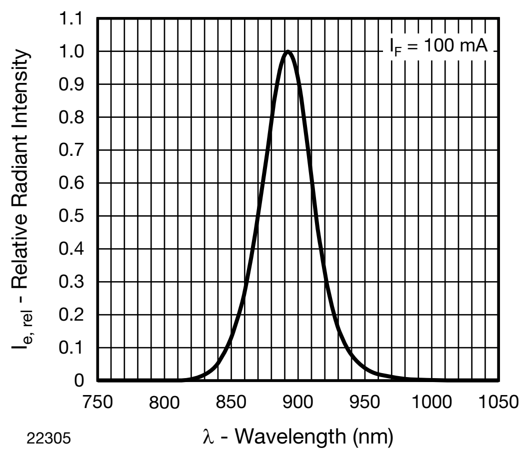


Fig. 4 - Relative Radiant Intensity vs. Wavelength

The infrared emitter has a programmable drive current from 10 mA to 200 mA in 10 mA steps. The infrared light emitted is modulated at one of four user defined carrier frequencies: 390.625 kHz, 781.25 kHz, 1.5625 MHz (not recommended), or 3.125 MHz (not recommended).

The **PIN photodiode** receives the light that is reflected off the object and converts it to a current. It has a peak sensitivity of 890 nm, matching the peak wavelength of the emitter. It is insensitive to ambient light. It ignores the DC component of light and "looks for" the pulsed light at one of the two recommended frequencies used by the emitter. Using a modulated signal for proximity provides distinct advantages over other sensors on the market.

The **ambient light sensor** receives the visible light and converts it to a current. The human eye can see light of wavelengths from 400 nm to 700 nm with a peak of 560 nm. Vishay's ambient light sensor closely matches this range of sensitivity. It has peak sensitivity at 540 nm and a bandwidth from 430 nm to 610 nm.

The application specific integrated circuit or ASIC includes an LED driver, I^2C bus interface, amplifier, integrating analog to digital converter, oscillator, and Vishay's "secret sauce" signal processor. For proximity, it converts the current from the PIN photodiode to a 16-bit digital data output value. For ambient light sensing, it converts the current from the ambient light detector, amplifies it and converts it to a 16-bit digital output stream.

PIN CONNECTIONS

Figure 3 shows the pin assignments of the VCNL4010.

The connections include:

- Pin 1 - IR anode to the power supply
- Pin 2 - IR cathode
- Pin 3 - IR cathode
- Pin 4 - SDA to microcontroller
- Pin 5 - SCL to microcontroller
- Pin 6 - INT to microcontroller
- Pin 7 - V_{DD} to the power supply
- Pin 8 thru 11 - must not beconnected
- Pin 12, pin 13 - GND

The power supply for the ASIC (V_{DD}) has a defined range from 2.5 V to 3.6 V. The infrared emitter may be connected in the range from 2.5 V to 5.0 V. It is best if V_{DD} is connected to a regulated power supply and pin 1, IR Anode, is connected directly to the battery. This eliminates any influence of the high infrared emitter current pulses on the V_{DD} supply line. The ground pins 12 and 13 are electrically the same. They use the same bottom metal pad and may be routed to the same stable ground plane. The power supply decoupling components shown in Figure 5 are optional. They isolate the sensor from other possible noise on the same power rail but in most applications are not needed. If separate power supplies for the V_{DD} and the infrared emitter are used and there are no negative spikes below 2.5 V, only one capacitor at V_{DD} could be used. The 100 nF capacitor should be placed close to the V_{DD} 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 I^2C bus speed. Common values are about 2.2 kΩ to 4.7 kΩ for the SDA and SCL and 10 kΩ to 100 kΩ for the Interrupt.

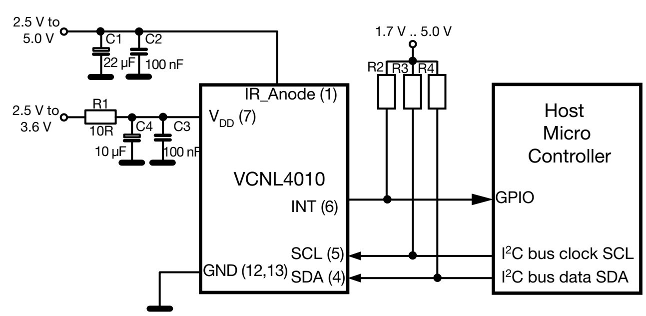


Fig. 5 - VCNL4010 Application Circuit

Designing VCNL4010 into an Application

MECHANICAL DESIGN CONSIDERATIONS

The VCNL4010 is a fully integrated proximity and ambient light sensor. Some competing sensors use a discrete infrared emitter which leads to complex geometrical calculations to determine the position of the emitter. Competing sensors also require a mechanical barrier between the emitter and detectors to eliminate crosstalk; light reflecting off the inside of the window cover which can produce false proximity readings. **The VCNL4010 does not require a mechanical barrier.** The signal processor continuously compensates for the light reflected from windows 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 and the angle of half sensitivity of the PIN photodiode are ± 55° as shown in Figure 6 and Figure 7.

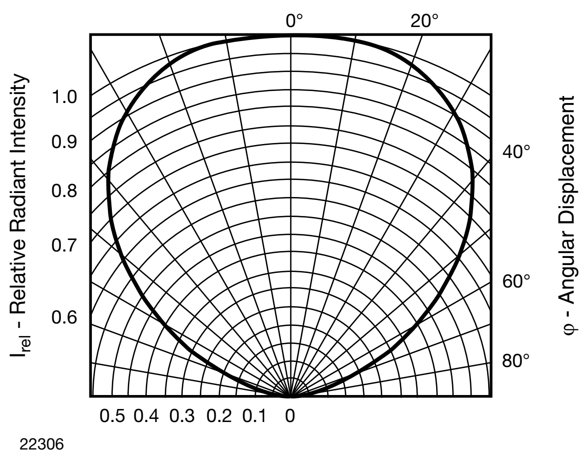


Fig. 6 - Angle of the Half Intensity of the Emitter

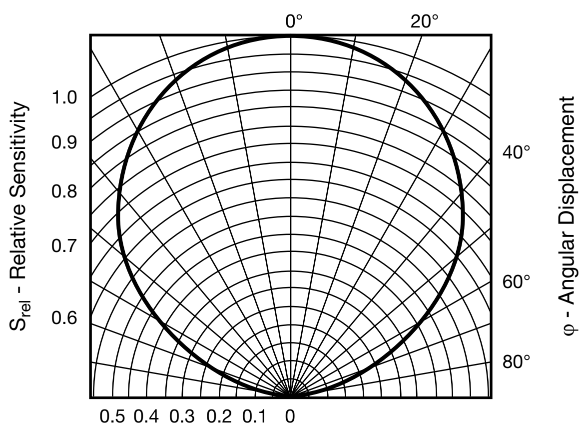


Fig. 7 - Angle of the Half Sensitivity of the PIN Photodiode

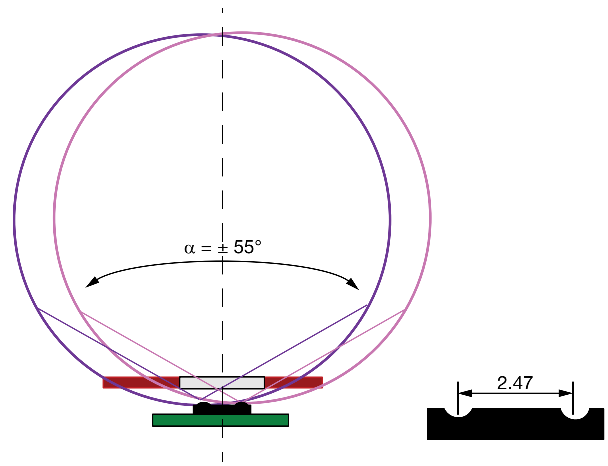


Fig. 8 - Emitter and Detector Angle and Distance

The center of the sensor and center of the window should be aligned. Assuming the detection zone is a cone shaped region with an angle of ± 40°, the following are dimensions for the distance from the top surface of the sensor to the outside surface of the glass, d, and the width of the window, w. The distance from the center of the infrared emitter to the center of the PIN photodiode is 2.47 mm. The height of the sensor is 0.75 mm.

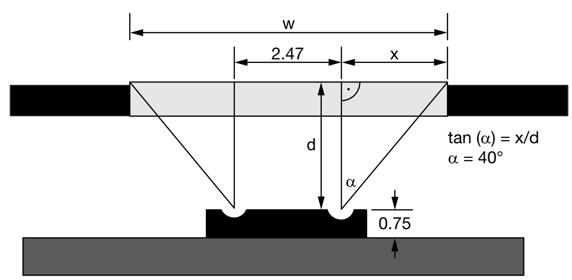


Fig. 9 - Window Dimensions

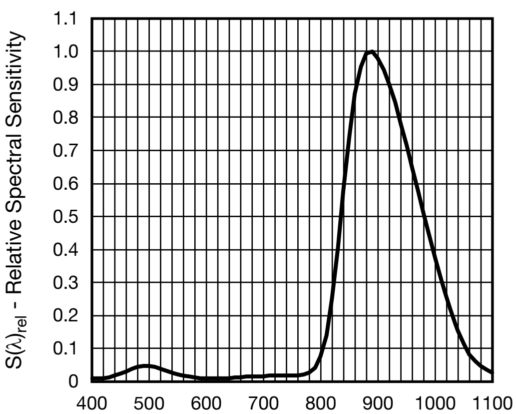
d (mm)	x (0.84 d)	w (2.47 + 2 x)
0.5	0.42	3.31
1.0	0.84	4.15
1.5	1.26	4.99
2.0	1.68	5.83
2.5	2.10	6.67
3.0	2.52	7.51

The results above represent the ideal width of the window. The mechanical design of the device may not allow for this size.

Designing VCNL4010 into an Application

PROXIMITY SENSOR

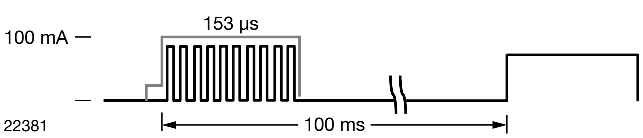
The main DC light sources found in the environment are sunlight and tungsten (incandescent) bulbs. These kinds of disturbance sources will cause a DC current in the detector inside the sensor, which in turn will produce noise in the receiver circuit. The negative influence of such DC light can be reduced by optical filtering. Light in the visible range, 400 nm to 700 nm, is completely removed by the use of an optical cut-off filter at 800 nm. With filtering, only longer wavelength radiation above 800 nm can be detected. The PIN photodiode therefore receives only a limited band from the original spectrum of these DC light sources as shown in Figure 10.



22307

Fig. 10 - Spectral Sensitivity of Proximity PIN Photodiode

As mentioned earlier, the proximity sensor uses a modulated carrier signal on one of four user selected frequencies. These frequencies are far from the ballast frequencies of fluorescent lights ensuring that the sensor is unaffected by them. The infrared emitter sends out a series of pulses, a burst, at the selected frequency and the PIN photodiode which features a band pass filter set to this same frequency, receives the reflected pulses, Figure 11.

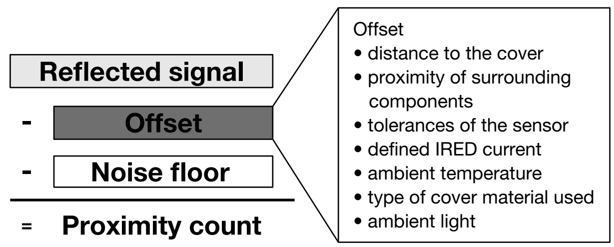


22381

Fig. 11 - Emitter Pulses

In addition to DC light source noise, there is some reflection of the infrared emitted light off the surfaces of the components which surround the VCNL4010. The distance to the cover, proximity of surrounding components, the tolerances of the sensor, the defined infrared emitter current, the ambient temperature, and the type of window material used all contribute to this reflection. The result of the reflection and DC noise produces an output current on the proximity and light sensing photodiode. This current is converted in to a count called the offset count.

In addition to the offset, there is also a small noise floor during the proximity measurement which comes from the DC_light suppression circuitry. This noise is in the range from ± 5 counts to ± 20 counts. The application should “ignore” this offset and small noise floor by subtracting them from the total proximity readings. The application specific offset is easily determined during the development of the end product.



22382

Fig. 12 - Proximity Calculation

Results typically 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 above a user-defined threshold before producing an interrupt. This provides stable results without requiring averaging.

PROXIMITY CURRENT COSUMPTION

The standby current of the VCNL4010 is 1.5 µA. In this mode, only the I²C interface is active. In most consumer electronic applications the sensor will spend the majority of time in standby mode. For proximity sensing, the current consumption of the VCNL4010 is primarily a function of the infrared emitter current and, secondarily, signal processing done by the ASIC. Example current consumption calculations are shown below for the range of IRED current and measurement rates. The current between burst pulse frames is equivalent to the standby mode. The duty cycle of the emitter is 50 %.

10 measurement per second, emitter current = 100 mA

ASIC: 2.71 mA x 164 µs x 10/1 s =	**4.45 µA**
IRED: 100 mA x 153 µs/1 s x 0.5 x 10/1 s =	**76.50 µA**
total:	**80.95 µA**

250 measurement per second, emitter current = 200 mA

ASIC: 2.71 mA x 164 µs x 250/1 s =	**111.0 µA**
IRED: 200 mA x 153 µs x 0.5 x 250/1 s =	**3.825 mA**
total:	**3.936 mA**

Designing VCNL4010 into an Application

PROXIMITY INITIALIZATION

The VCNL4010 contains seventeen 8-bit registers for operation control, parameter setup and result buffering. All registers are accessible via I^2C communication. The built in I^2C interface is compatible with all I^2C modes: standard, fast and high speed. I^2C H-Level voltage range is from 1.7 V to 5.0 V.

1. IRED Current = 10 mA… 200 mA
   IR LED Current Register #3 [83h]
2. Proximity Measurement Rate = 1.95 to 250 meas/s
   Proximity Rate Register #2 [82h]
3. Proximity and Light Sensor: Number of consecutive measurements above/below threshold:

- int_count_exceed = 1 to 128
  defines number of consecutive measurements above threshold
- int_thres_en = 1
  enables interrupt when threshold is exceeded
- int_thres_sel = 0
  definines thresholds for proximity

Interrupt Control Register # 9 [89h].

For ambient light sensing, the default averaging value is 32 measurements. If this value needs to be changed or if "Continuous conversion" mode is desired, a fourth register may be defined:

4. ALS Measurement Rate, auto offset = on, averaging
   Ambient Light Parameter Register # 4 [84h]

To define the infrared emitter current, evaluation tsets should be performed using the least reflective material at the maximum distance specified.

Figure 13 shows the typical digital counts output versus distance for three different emitter currents. The reflective reference medium is the Kodak Gray card. This card shows approximately 18 % reflectivity at 890 nm.

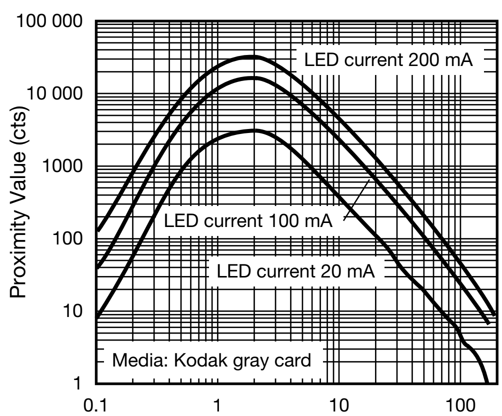


Fig. 13 - Proximity Value vs. Distance

The proximity measurement rate 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.

To define these register values, evaluation test should be performed. The sensor starter kit1 allows you to perform evaluation tests and properly set the registers for your application. The kit is available from any of Vishay's distributors. It comes with the VCNL4020 sensor board. The VCNL4010 sensor board can be requested by sending an e-mail to sensorstechsupport@vishay.com.

Timing

For an I^2C bus operating at 100 kHz, an 8-bit write or read command which includes the start, stop and acknowledge bits takes 100 µs. When the device is powered on, the initialization with just these 3 registers needs 3 write commands, each requiring 3 bytes: slave address, register and data.

Power Up

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

Initialize Registers

Write to 3 registers **900 µs**

- IR LED current
- Proximity rate
- Interrupt control

Once the device is powered on and the VCNL4010 initialized, a proximity measurement can be taken. Before the first read out of the proximity count, a wait time is required. Subsequent reads do not require this wait time.

Start measurement	**300 µs**
Measurement being made	**170 µs**
Wait time prior to first read	**400 µs**
Read out of the proximity data	**600 µs**
Total:	**1470 µs**

Designing VCNL4010 into an Application

AMBIENT LIGHT SENSING

Ambient light sensors are used to detect light or brightness in a manner similar to the human eye. They allow settings to be adjusted automatically in response to changing ambient light conditions. By turning on, turning off, or adjusting features, ambient light sensors can conserve battery power or provide extra safety while eliminating the need for manual adjustments.

Illuminance is the measure of the intensity of light incident on a surface and can be correlated to the brightness perceived by the human eye. In the visible range, it is measured in units called “lux.” Light sources with the same lux measurement appear to be equally bright. In Figure 14, the incandescent light and sunlight have been scaled to have the same lux measurement. In the infrared region, the intensity of the incandescent light is significantly higher. A standard silicon photodiode is much more sensitive to infrared light than visible light. Using it to measure ambient light will result in serious deviations between the lux measurements of different light sources and human-eye perception. Using Vishay’s ambient light sensors will solve this problem because they are most sensitive to the visible part of the spectrum.

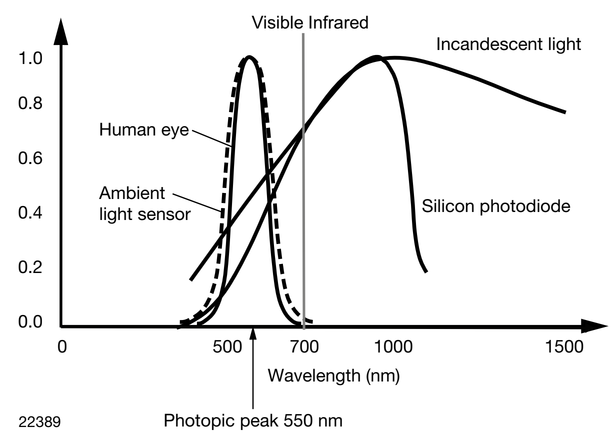


Fig. 14 - Relative Spectral Sensitivity vs. Wavelength

The human eye can see light with wavelengths from 400 nm to 700 nm. The ambient light sensor in the VCNL4010 closely matches this range of sensitivity and provides a digital output based on a 16-bit signal.

AMBIENT LIGHT MEASUREMENT, RESOLUTION AND OFFSET

The ambient light sensors measurement resolution is 0.25 lux/count. The 16-bit digital resolution is equivalent to 65 536 counts. This yields a measurement range from 0.25 lux to 16 383 lux.

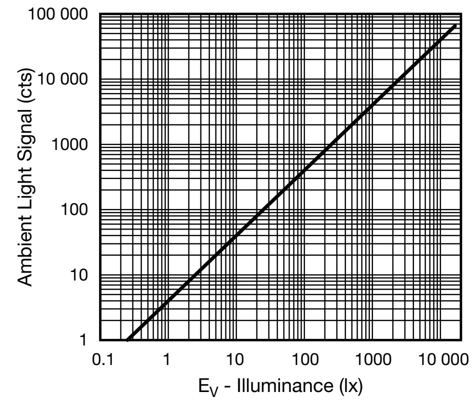


Fig. 15 - Ambient Light Values vs. Illuminance

In most applications a cosmetic window or cover is placed in front of the sensor. These covers reduce the amount of light reaching the sensor. It is not uncommon for only 10 % of the ambient light to pass through the window. The resulting sensor resolution in relation to cover transparency is shown in Table 11.

TABLE 11 - RESOLUTION VS. TRANSPARENCY

COVER VISIBLE LIGHT TRANSPARENCY (%)	RESULTING SENSOR RESOLUTION (LUX/COUNT)
100	0.25
50	0.5
20	1.25
10	2.5

Similar to the proximity measurements, there is a digital offset deviation of - 3 counts which has to be considered when setting up the application thresholds. This offset comes from tolerances within the digital compensation process. In single-digit lux ambient lighting where the transparency of the window is 10 % or less these 3 counts should be added to the actual ambient light value.

AMBIENT LIGHT SENSOR CURRENT CONSUMPTION

The ambient light sensor can operate in single or continuous mode. In single mode operation, an ambient light measurement consists of up to 128 individual measurement cycles which are averaged. The timing diagram for an individual measurement cycle is shown in Figure 16.

Designing VCNL4010 into an Application

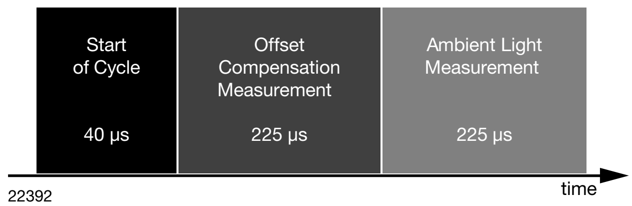


Fig. 16 - Timing Diagram for Individual Measurement Cycle

In single-mode operation, an ambient light measurement takes 100 ms. The single measurement cycles are evenly spread inside this 100 ms frame. Figure 17 shows an example where 8 individual measurement cycles are averaged. The maximum number of single measurement cycles that can be used to calculate an average is 128. The maximum number of times this average can be calculated in one second is 10.

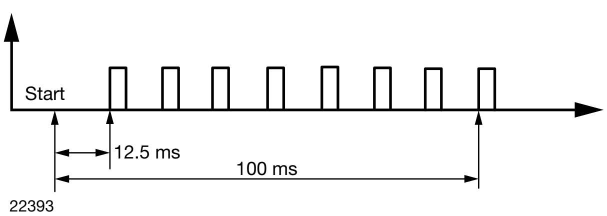


Fig. 17 - Ambient Light Measurement with Averaging = 8

A higher number of measurement cycles increases the accuracy of the reading and reduces the influence of modulated light sources. However, a higher number of cycles also consume more power. During an individual measurement cycle, the ASIC consumes approximately 2.7 mA. Between the individual measurements, the current consumption is 9 µA. Example current consumption calculations are shown below.

Current Calculations for Ambient Light Measurements:

1 measurement per second, AVG = 32

2.7 mA x 450 µs/1 cycle x 32 cycles x 1 = **39 µA**

10 measurement per second, AVG = 128

2.7 mA x 450 µs/1 cycle x 128 cycles x 10 = **1.55 mA**

The current consumption for the ambient light sensor is strongly dependent on the number of measurements taken. In single-mode operation, the highest average current is 1.55 mA. Figure 18 shows that increasing the number of cycles averaged reduces the standard deviationof the measurement.

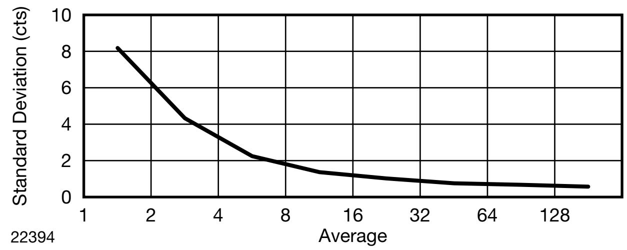


Fig. 18 - Ambient Light Noise vs. Averaging

In continuous conversion mode, the ambient light sensor measurement time can be reduced. A timing example of continuous mode where 8 measurements are averaged is shown in Figure 19.

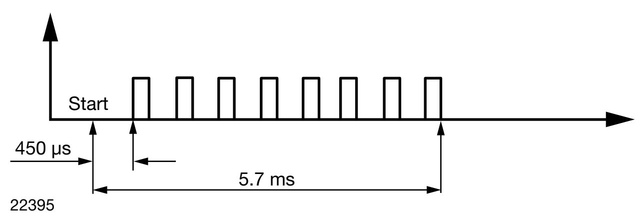


Fig. 19 - Ambient Light Measurement with Averaging = 8 Using Continuous Conversion Mode

The individual measurements are done sequentially. Recall that one individual measurement cycle, including offset compensation, takes approximately 450 µs. The gap time is 180 µs. As shown in Figure 19, the result of the 8 cycles is already accessible after about 6 ms. However, fluorescent light suppression is less effective in this mode.

There will be no influence on the ambient measurement from the infrared emitter used for proximity because the proximity measurements are made between the ambient light measurements. They are not performed at the same time.

AMBIENT LIGHT INITIALIZATION

For ambient light sensing, only register #4 parameters need to be initialized

- Continuous conversion ON/OFF (register #4b7)
- Offset compensation ON/OFF (register #4b3)
- Number of average measurements (register #4b0 to 4b2)

The default settings are:

- Continuous conversion = OFF
- Offset compensation = ON
- Number of average measurements = 32

Designing VCNL4010 into an Application

INTERRUPT

The VCNL4010 features an interrupt function. The interrupt function enables the sensor to work independently until a predefined proximity or ambient light 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 VCNL4010, should be connected to a dedicated GPIO of the controller. A pull-up resistor is added to the same power supply to which the controller is connected. This INT pull-up resistor may be in the range of 1 kΩ to 100 kΩ. Its current sinking capability is greater than 8 mA, typically 10 mA, and less than 20 mA.

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 one of the registers of the device will be set and the interrupt pad of the ASIC 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 lower and an upper threshold for the ambient light value can be defined. If the ambient light value falls below the lower limit or exceeds the upper limit, an interrupt event will be generated. There is only one set of high and low threshold registers. You will have to decide if the thresholds will be defined for proximity or ambient light.
3. An interrupt can be generated when a proximity measurement is ready.
4. An interrupt can be generated when an ambient light measurement is ready.

For each of these conditions a separate bit can activate or deactivate the interrupt. This means that a combination of different conditions can occur simultaneously. Only condition 1 and 2 cannot be activated at the same time. For them, one bit indicates that the threshold interrupt is on or off, a second bit indicates if it for proximity or ambient light.

When an interrupt is generated, the information about the condition that has generated the interrupt will be stored and is available for the user in an interrupt status register which can be read out via I^2C. Each condition that can generate an interrupt has a dedicated result flag. This allows independent handling of the different conditions. For example, if the interrupt is generated by the upper threshold condition and a measurement ready condition, both flags are set.

To clear the interrupt line, the user has to clear the enabled interrupt flag in the interrupt status register, Register 14. Resetting the interrupt status register is done with an I^2C write command. One interrupt bit can be cleared without affecting another. If there was a second interrupt source, it would have to be cleared separately. With a write command where all four interrupt bits are set to "1" all these bits and the interrupt line is cleared or reset.

Designing VCNL4010 into an Application

REGISTER FUNCTIONS

Register #0 Command Register

Register address = 80h
Register #0 is for starting ambient light or proximity measurements. The register contains 2 flag bits for data indication.

TABLE 1 - COMMAND REGISTER #0							
BIT 7	**BIT 6**	**BIT 5**	**BIT 4**	**BIT 3**	**BIT 2**	**BIT 1**	**BIT 0**
config_lock	als_data_ rdy	prox_data_ rdy	als_od	prox_od	als_en	prox_en	selftimed_ en
DESCRIPTION							
Config_lock	Read only bit. Value = 1						
als_data_rdy	Read only bit. Value = 1 when ambient light measurement data is available in the result registers. This bit will be reset when one of the corresponding result registers (reg #5, reg #6) is read.						
prox_data_rdy	Read only bit. Value = 1 when proximity measurement data is available in the result registers. This bit will be reset when one of the corresponding result registers (reg #7, reg #8) is read.						
als_od	R/W bit. Starts a single on-demand measurement for ambient light. If averaging is enabled, starts a sequence of readings and stores the averaged result. Result is available at the end of conversion for reading in the registers #5 (HB) and #6 (LB).						
prox_od	R/W bit. Starts a single on-demand measurement for proximity. Result is available at the end of conversion for reading in the registers #7 (HB) and #8 (LB).						
als_en	R/W bit. Enables periodic als measurement						
prox_en	R/W bit. Enables periodic proximity measurement						
selftimed_en	R/W bit. Enables state machine and LP oscillator for selftimed measurements; no measurement is performed until the corresponding bit is set.						

When single on demand measurements are made bit 3 and bit 4 are set with the same write command, ambient light and proximity measurements will both occur. For periodic measurements, the selftimed_en bit must be set first, then the als_en and/or prox_en bit(s) can be set.
On-demand measurement modes are disabled when the selftimed_en bit is set.

To avoid synchronization problems and undefined states between the clock domains, changes to the proximity or ambient light measurement rates in register #2 and register #4 respectively can be made only when there are no selftimed measurements being made, b0 (selftimed_en bit) = 0.

Register #1 Product ID Revision Register

Register address = 81h. This register contains information about product ID and product revision.
Register data value of current revision = 21h.

TABLE 2 - PRODUCT ID REVISION REGISTER #1							
BIT 7	**BIT 6**	**BIT 5**	**BIT 4**	**BIT 3**	**BIT 2**	**BIT 1**	**BIT 0**
PRODUCT ID				**REVISION ID**			
DESCRIPTION							
Product ID	Read only bits. Value = 2						
Revision ID	Read only bits. Value = 1						

Designing VCNL4010 into an Application

Register #2 Rate of Proximity Measurement

Register address = 82h. This register contains the rate of proximity measurements to be carried out within 1 second.

TABLE 3 - PROXIMITY RATE REGISTER #2							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
n/a					Rate of proximity measurement (no. of measurements per second)		
DESCRIPTION							
Proximity rate		R/W bits. 000 - 1.95 measurements/s (default setting) 001 - 3.90625 measurements/s 010 - 7.8125 measurements/s 011 - 16.625 measurements/s 100 - 31.25 measurements/s 101 - 62.5 measurements/s 110 - 125 measurements/s 111 - 250 measurements/s					

Again, if selftimed measurements are being made, any new measurement rate written to this register will not be made until selftimed_en measurement is stopped.

Register #3 LED Current Setting for Proximity Mode

Register address = 83h. This register is to set the current of the infrared emitter for proximity measurements. The value is adjustable from 0 mA to 200 mA in 10 mA steps. This register also contains information about the used device fuse program ID.

TABLE 4 - IR LED CURRENT REGISTER #3							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Fuse prog ID					Infrared emitter current		
DESCRIPTION							
Fuse prog ID		Read only bits. Information about fuse program revision used for initial setup/calibration of the device.					
Infrared emitter current value		R/W bits. IR LED current = Value (dec.) x 10 mA. Valid Range = 0 - 20d (00 - 14 h) 0 = 0 mA 1 = 10 mA 2 = 20 mA (default setting) . . 20 = 200 mA, LED Current is limited to 200 mA. If higher values than 20 (20d) are written, the current will be set to 200 mA.					

Designing VCNL4010 into an Application

Register #4 Ambient Light Parameter Register

Register address = 84h.

TABLE 5 - AMBIENT LIGHT PARAMETER REGISTER #4

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Continuous conversion mode	als_rate			Auto offset compensation	Average function (number of measurements per run)		

DESCRIPTION	
Continuous conversion mode	R/W bit. Continuous conversion mode. Enable = 1 ; Disable = 0 (default) This function can be used for performing faster ambient light measurements. Please refer to the application information chapter 3.3 for details about this function.
Ambient light measurement rate	R/W bits. Ambient light measurement rate 000 - 1 samples/s 001 - 2 samples/s (default setting) 010 - 3 samples/s 011 - 4 samples/s 100 - 5 samples/s 101 - 6 samples/s 110 - 8 samples/s 111 - 10 samples/s
Auto offset compensation	R/W bit. Automatic offset compensation. Enable = 1 (default) ; Disable = 0 In order to compensate for temperature related drift of the ambient light values, there is a built-in, automatic offset compensation function. With auto offset compensation enabled, the offset value is measured before each ambient light measurement and subtracted automatically from the actual reading.
Averaging function	R/W bits. Averaging function. Bit value sets the number of single conversions done during one measurement cycle. Result is the average value of all conversions. Number of conversions = 2 decimal_value Bit 2, bit1, bit 0 000 - 1 conversion 001 - 2 conversions 010 - 4 conversions 011 - 8 conversions 100 - 16 conversions 101 - 32 conversions (default setting) 110 - 64 conversions 111 - 128 conversions

Again, if selftimed measurements are being made, any new measurement rate written to this register will not be made until selftimed_en measurement is stopped.

Designing VCNL4010 into an Application

Register #5 and #6 Ambient Light Result Register

Register address = 85h and 86h. These registers are the result registers for ambient light measurement readings. The result is a 16 bit value. The high byte is stored in register #5 and the low byte in register #6.

TABLE 6 - AMBIENT LIGHT RESULT REGISTER #5							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
Read only bits. High byte (15:8) of ambient light measurement result							

TABLE 7 - AMBIENT LIGHT RESULT REGISTER #6							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
Read only bits. Low byte (7:0) of ambient light measurement result							

Register #7 and #8 Proximity Measurement Result Register

Register address = 87h and 88h. These registers are the result registers for proximity measurement readings. The result is a 16 bit value. The high byte is stored in register #7 and the low byte in register #8.

TABLE 8 - PROXIMITY RESULT REGISTER #7							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
Read only bits. High byte (15:8) of proximity measurement result							

TABLE 9 - PROXIMITY RESULT REGISTER #8							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
Read only bits. Low byte (7:0) of proximity measurement result							

Register #9 Interrupt Control Register

Register address = 89h.

TABLE 10 - INTERRUPT CONTROL REGISTER #9							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
int_count_exceed			n/a	int_prox_ready_en	int_als_ready_en	int_thres_ en	int_thres_ sel
DESCRIPTION							
int_count_exceed	R/W bits. These bits contain the number of consecutive measurements needed above/below the threshold 000 - 1 count (default setting) 001 - 2 counts 010 - 4 counts 011 - 8 counts 100 - 16 counts 101 - 32 counts 110 - 64 counts 111 - 128 counts						
int_prox_ready_en	R/W bit. Enables interrupt generation when proximity data is ready						
int_als_ready_en	R/W bit. Enables interrupt generation when ambient data is ready						
int_thres_en	R/W bit. Enables interrupt generation when high or low threshold is exceeded						
int_thres_sel	R/W bit. If 0: thresholds are applied to proximity measurements If 1: thresholds are applied to ambient light measurements						

Designing VCNL4010 into an Application

Register #10 and #11 Low Threshold

Register address = 8Ah and 8Bh. These registers contain the low threshold value. The value is a 16 bit word. The high byte is stored in register #10 and the low byte in register #11

TABLE 11 - LOW THRESHOLD REGISTER #10							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
R/W bits. High byte (15:8) of low threshold value							

TABLE 12 - LOW THRESHOLD REGISTER #11							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
R/W bits. Low byte (7:0) of low threshold value							

Register #12 and #13 High Threshold

Register address = 8Ch and 8Dh. These registers contain the high threshold value. The value is a 16 bit word. The high byte is stored in register #12 and the low byte in register #13

TABLE 13 - HIGH THRESHOLD REGISTER #12							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
R/W bits. High byte (15:8) of high threshold value							

TABLE 14 - HIGH THRESHOLD REGISTER #13							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DESCRIPTION							
R/W bits. Low byte (7:0) of high threshold value							

Register #14 Interrupt Status Register

Register address = 8Eh. This register contains information about the interrupt status for either proximity or ambient light measurement and indicates a threshold was exceeded.

TABLE 15 - INTERRUPT STATUS REGISTER #14							
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
N/A				int_prox_ ready	int_als_ ready	int_th_low	int_th_high
DESCRIPTION							
int_prox_ready				R/W bit. Indicates a generated interrupt for proximity			
int_als_ready				R/W bit. Indicates a generated interrupt for als			
int_th_low				R/W bit. Indicates a low threshold was exceed			
int_th_high				R/W bit. Indicates a high threshold was exceed			

Once an interrupt is generated, the corresponding status bit goes to 1 and stays there until it is cleared by writing a 1 in the corresponding bit. For example, when an upper threshold is exceeded, an interrupt is generated. The int_th_hi status bit goes to 1. It will stay at 1 until it is cleared by overwriting a 1 in the int_th_hi bit. The interrupt pad will be pulled down as long as one of the status bits is 1.

Designing VCNL4010 into an Application

Register #15 Proximity Modulator Timing Adjustment

Register address = 8Fh.

TABLE 16 - MODULATOR TIMING ADJUSTMENT REGISTER #15							
BIT 7	**BIT 6**	**BIT 5**	**BIT 4**	**BIT 3**	**BIT 2**	**BIT 1**	**BIT 0**
MODULATION DELAY TIME			**PROXIMITY FREQUENCY**		**MODULATION DEAD TIME**		
DESCRIPTION							
Modulation delay time			R/W bits. Sets a delay time between infrared emitter signal and infrared input signal evaluation. This function is to compensate for delays between the emitter and photo diode when external emitters are used and may also be used with the faster proximity frequencies. It is used to optimize the measurement signal level.				
Proximity frequency			R/W Bits. Sets the proximity infrared signal frequency The proximity measurement uses a square signal as measurement signal. Four different frequencies are possible: 00 = 390.625 kHz (Default Setting) 01 = 781.25 kHz 10 = 1.5625 MHz (not recommended) 11 = 3.125 MHz (not recommended)				
Modulation dead time			R/W bits. Sets a time period when the reflected infrared signal is not read. This compensates for the rise time slope of the emitter and resulting slope of the reflected signal. Values of 0 to 7 are allowed. The default value is 1. This function reduces possible disturbance effects but also can reduce signal levels.				

User access for this register was maintained for applications using external infrared emitters. For applications using only the internal emitter, the default register values are already optimized for proximity operation: delay time = 0, proximity frequency = 390 kHz, and dead time = 1.

Modulation Delay Time

The proximity function works with a modulated signal. The proximity signal demodulator is frequency and phase sensitive and references to the transmitted signal. In case of external infrared emitters with additional driver stages, there might be signal delays that could cause signal loss. By adjusting the “delay time” setting, this additional delay can be compensated. The delay time can be set to values between 0 and 7. Using external infrared emitters the optimum setting is determined by trying different settings. The setting with highest readings for proximity at a certain reflection condition should be selected. Since most applications will use the internal emitter, the default value is 0.

Proximity Frequency

This parameter was used during the development of the VCNL4010. The default setting of f = 390 kHz is the optimum setting.

Modulation Dead Time

Due to the emitter rise and fall times, the modulation signal is not a perfect square wave. Instead a slight slope occurs at the start and end of the signal. The modulation dead time defines a time window or range where the slopes from the received modulated signal are blanked out. This function eliminates effects from slow slopes, glitches and other noise disturbances on the received signal. If the modulation dead time is set too long, a portion of the reflected signal will be lost in addition to the rise time slope. The modulation dead time can be set to values between 0 and 7. The default setting is 1. This setting is sufficient to suppress noise transients. It is NOT recommended to use the value “0” as a “dead time” setting. When using an external driver and emitters, it might be necessary to adjust this parameter. An external driver might cause slow slopes, unstable readings or higher noise. Such effects could be reduced by adjusting this parameter.

Designing VCNL4010 into an Application

APPLICATION EXAMPLE

The following example will demonstrate the ease of using the VCNL4010 sensor. Customers are strongly encouraged to purchase a sensor starter kit and request a VCNL4010 sensor board from: sensorstechsupport@vishay.com

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 VCNL4010, 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 100 mA, the offset counts are 5400 counts, Figure 20. Offset counts vary by application and can be anywhere from 5000 counts to 20 000 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.

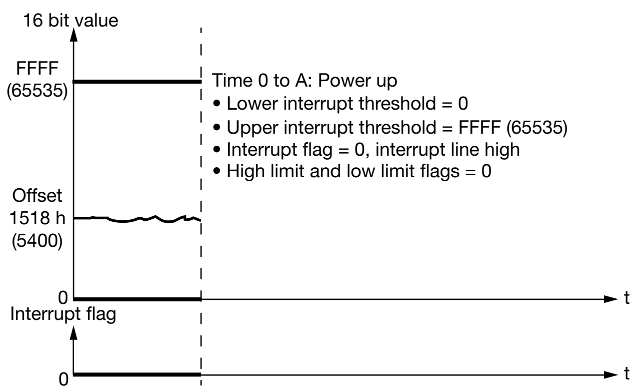


Fig.20

Power Up

As mentioned, there are three variables 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 and the number of proximity measurements per second. For the application, the sensor should detect an object at 5 cm distance. Development testing determined that a current of 100 mA produces adequate counts for detection. The proximity measurement rate is set to 7.8125 measurements per second and the number of occurrences to trigger an interrupt is set to 4. Based on development testing, with a hand approximately 5 cm above the window cover, the resulting count is 5500. This will be used as the upper threshold.

For smart phone applications it would be typical to initially set only an upper threshold. However, in other sensing applications, a lower threshold may also be set. This creates an operating band where any change in the objects position would trigger a threshold as shown in Figure 21.

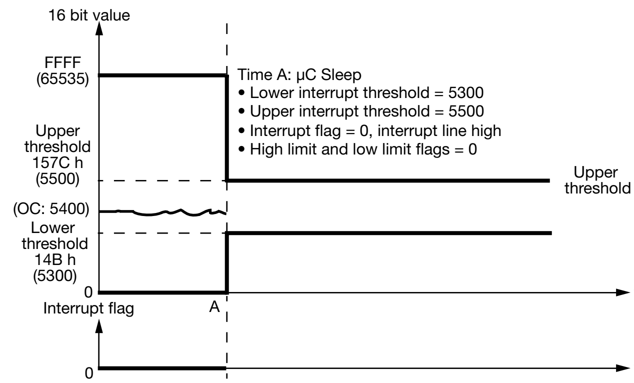


Fig.21

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 Figure 22.

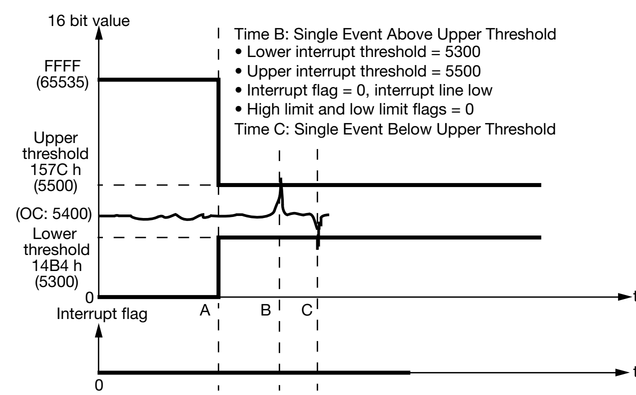


Fig. 22

Once an object is detected, the sensor can be switched to continuous polling or the thresholds can be reprogrammed. A smartphone application will use a proximity sensor to detect when the phone is brought to the user's ear and disable the touch screen and turn off the backlight. For other applications, the action taken when an object is detected is very application specific. For example, soap may be dispensed, paper towels may be unrolled, a blower turns on, or a lid is opened.

Designing VCNL4010 into an Application

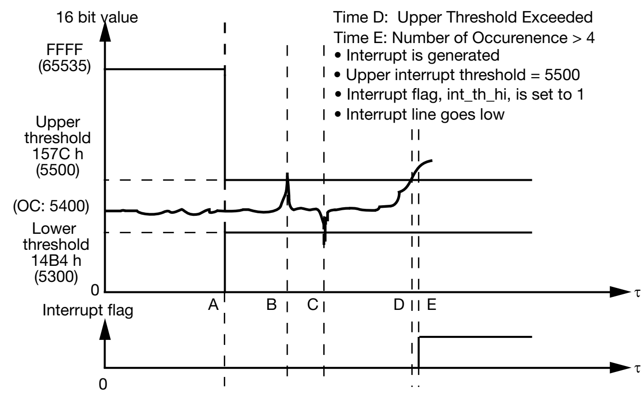


Fig. 23

In smart phone applications, the thresholds will be reprogrammed and the sensor will wait for another interrupt signal. In this case, the upper threshold should be set to a maximum value since the phone is already next to the user's ear and a lower threshold set so when the phone call is complete and the phone brought away from the ear, the backlight and touch screen will be turned back on.

The upper threshold needs to be set as high as possible since an interrupt has already been generated; set to FFFF (65535). The lower threshold is set to 5450 counts; a value that is higher than the offset but low enough to indicate the removal of the phone from the users ear.

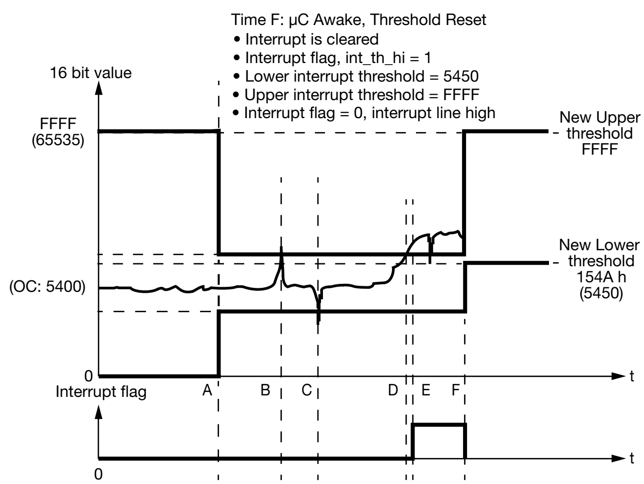


Fig. 24

When the object is removed, the sensor counts will return to 5400 counts and the lower threshold will generate an interrupt, **int_th_low = 1**.

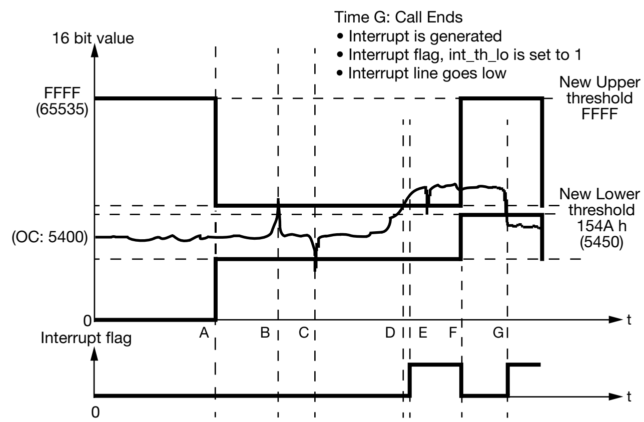


Fig. 25

Designing VCNL4010 into an Application

EXAMPLE REGISTER SETTINGS

When the sensor is powered-up the first time, the default register settings are made for the application.

ACTION	REGISTER SETTING
Set infrared emitter current to 100 mA	REGISTER #3 [83h]: 26, 83, 0A
Set proximity measurement rate to 7.8125 measurements/s	REGISTER # 2 [82h]: 26, 82, 02
Set ambient light sensor mode to normal, the measurement rate to 2 measurements/s and the averaging to 32 conversions	REGISTER #4 [84h]: 26, 84, 1D
Set number of consecutive measurements that must occur to initiate an interrupt to 4: Generate an interrupt when the threshold is exceeded . . . . Thresholds are for proximity measurements	Register # 9 [89h]: 26, 89, 42 42 h: int_count_exceed = 4 int_thres_en = 1 int_thres_sel = 0

DEFAULT VALUE SET-UP ONLY AS HEXADECIMAL CODE IS:		
26, 83, 0A	write: IRED current = 10	(= 100 mA)
26, 82, 02	write: Prox rate = 02	(= 8 measure/s)
26, 84, 1D	write: ALS mode = 1D	(= measure/s, auto-offset = on, averaging = 5)
26, 89, 42	write: Int cntr reg = 42	(= int_count_exceed = 4, int_thres_en = 1, int_thres_sel = 0)

Set an upper threshold for detecting an object and do not set a lower threshold.

ACTION	REGISTER SETTING
Set lower threshold value to 0 counts	Register #10 (8Ah): 26, 8A, 00 Register #11 (8Bh): 26, 8B, 00
Set upper threshold value to 5860 counts - 16E4 (hex)	Register #12 (8Ch): 26, 8C, 16 Register #13 (8Dh): 26, 8D, E4
Start periodic proximity measurements	Register #0 (80h): 26, 80, 03
Read interrupt status register	Register #14 (8Eh): 26, 8E, 27, xx

THIS PROXIMITY SET-UP SHOWN ONLY AS HEXADECIMAL CODE IS:	
26, 8A, 00	write: L_TH_HB = 00
26, 8B, 00	write: L_TH_LB = 00
26, 8C, 16	write: H_TH_HB = 16
26, 8D, E4	write: H_TH_LB = E4
26, 80, 03	write: 3: prox_en = 1, selftimed_en = 1
WAIT	at least 400 μs
26, 8E, 27, xx	read: xxxxxxx1, indicates int_th_hi = 1

Assuming an object was detected, the interrupt was cleared and the software reprograms the thresholds to be able to respond when the object is no longer present. The upper threshold is reset to FFFF counts while the lower threshold is set to 5810 counts.

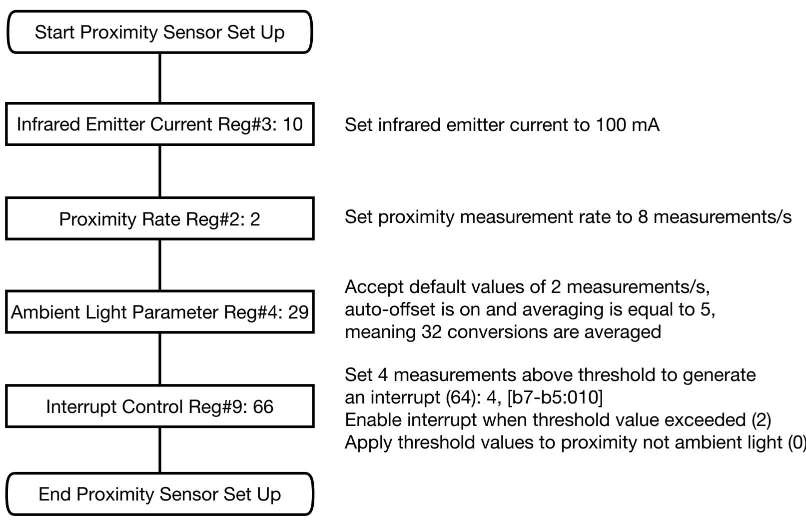
ACTION	REGISTER SETTING
Set lower threshold to 5810 counts - 16B2 (hex)	Register #10 (8Ah): 26, 8A, 16 Register #11 (8Bh): 26, 8B, B2
Set upper threshold to maximum counts - FFFF (hex)	Register #12 (8Ch): 26, 8C, FF Register #13 (8Dh): 26, 8D, FF
Start periodic proximity measurements	Register #0 (80h): 26, 80, 03
Read interrupt status register	Register #14 (8Eh): 26, 8E, 27, xx

Designing VCNL4010 into an Application

THIS PROXIMITY SET-UP SHOWN ONLY AS HEXADECIMAL CODE IS:	
26, 8A, 16	write: L_TH_HB = 16
26, 8B, B2	write: L_TH_LB = B2
26, 8C, FF	write: H_TH_HB = FF
26, 8D, FF	write: H_TH_LB = FF
26, 80, 03	write: 3: prox_en = 1, selftimed_en = 1
WAIT	at least 400 µs
26, 8E, 27, xx	read: xxxxxx1x, indicates int_th_lo = 1

PROGRAMM FLOW CHART

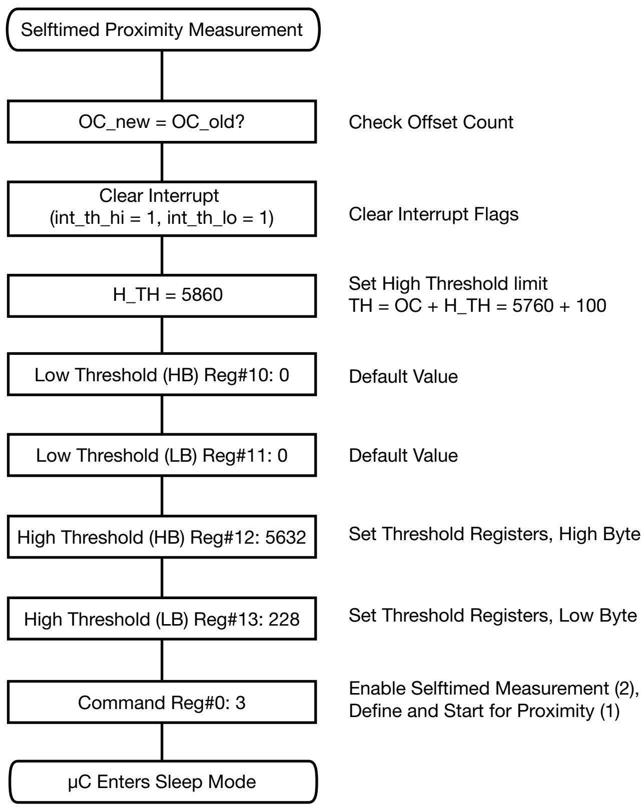
Initial setup for proximity sensor. Note that default values do not need to be programmed.



Designing VCNL4010 into an Application

Defining the Upper Threshold

The upper threshold value is set so that an interrupt is generated when an object comes close enough to the sensor to create a defined increase in counts. In this example, the offset counts are 5760 and the upper threshold is set 100 counts above the offset.

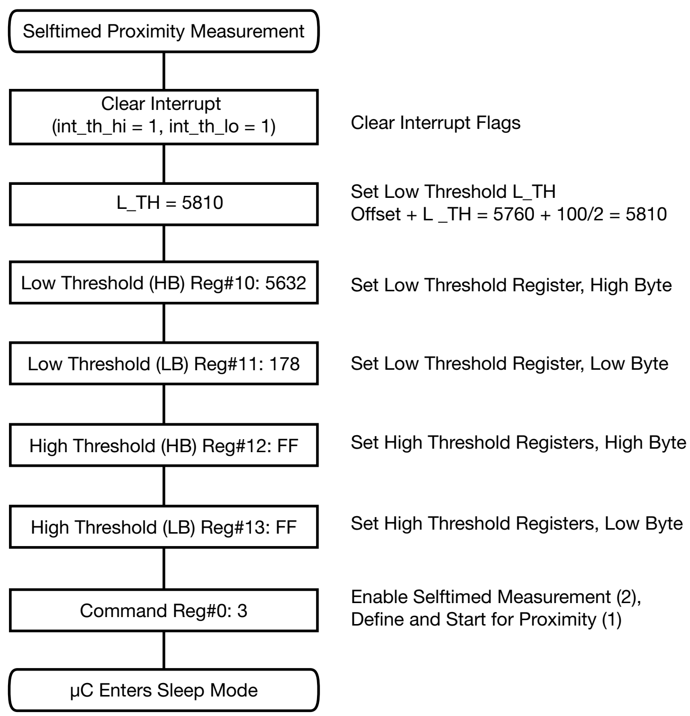


When an object does come close enough to the sensor to generate 100 counts and 4 consecutive measurements occur at or above this level, the interrupt line will go LOW and the interrupt can be read by the microcontroller in register 14 where int_th_hi will equal 1.

Designing VCNL4010 into an Application

Redefine Thresholds

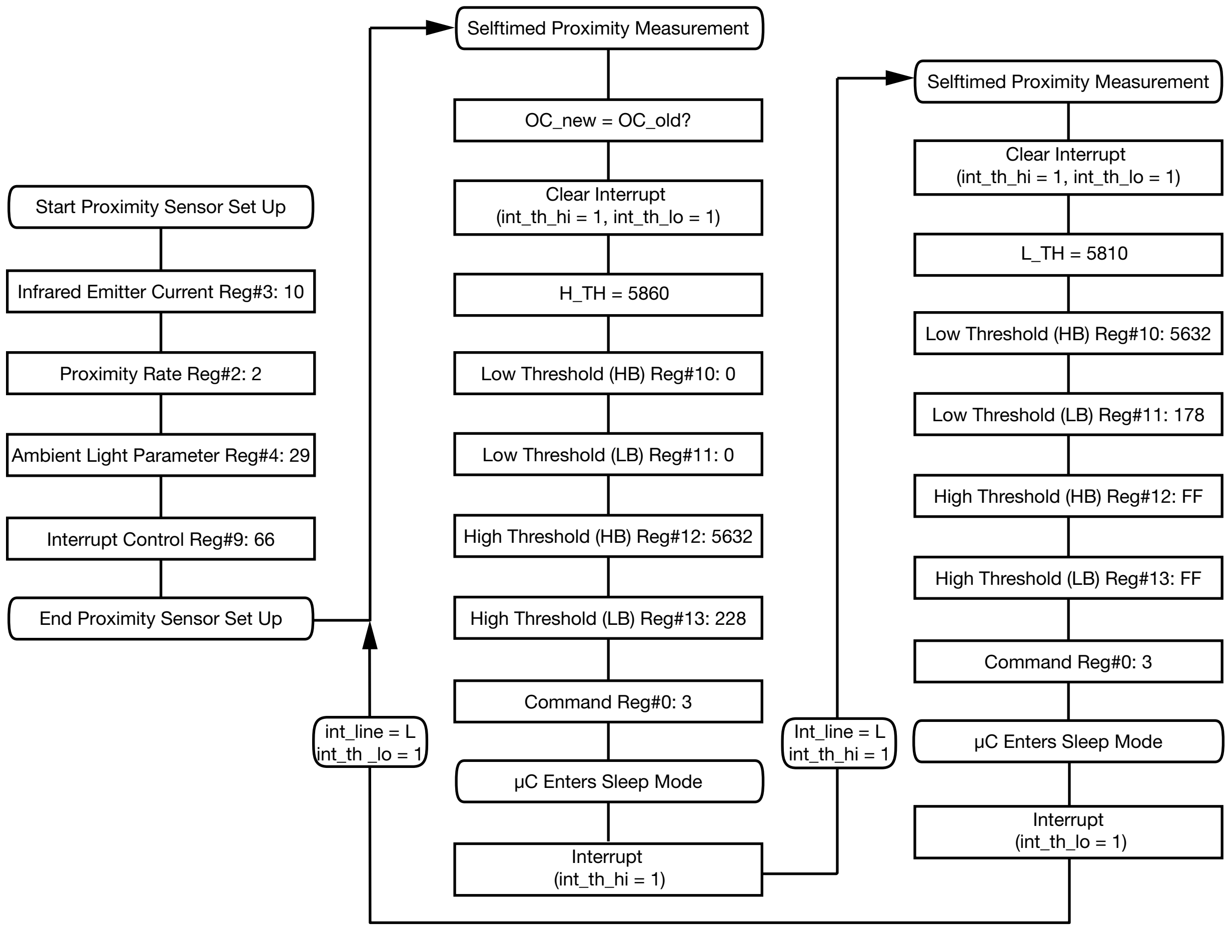
Once the counts have surpassed the initial high threshold, a low threshold needs to be set to generate an interrupt when the object is removed. The upper threshold is redefined to the maximum value. With the offset counts equal to 5760 counts and the initial upper threshold equal to 100 counts, the lower threshold will be set to half the initial upper threshold value or 50 counts.



When the object is removed and 4 consecutive measurements occur at or below the lower threshold, the interrupt line will go LOW and the interrupt can be read by the microcontroller in register 14 where int_th_lo will equal 1.

Designing VCNL4010 into an Application

Complete Flow Chart



Sensor Starter Kit User Guide

By Reinhard Schaar

INTRODUCTION

With the first digital sensors featuring the possibility to be controlled via the I²C-bus Vishay offered a demo kit that allowed for an easy connection to any Windows PC.

This demo kit was for the very first proximity / ambient light sensor (VCNL4000) and it looked as follows:

Fig. 1 - VCNL4000 Demo Kit

This VCNL4000 demo kit came with a mini-CD containing the USB driver and software, a USB dongle and the VCNL4000 sensor board.

This kit has now been replaced with the Sensor Starter Kit.

Fig. 2 - Sensor Starter Kit

The Sensor Starter Kit includes a USB dongle and mini-CD, which includes the needed USB driver and updated software. This is now the base for all of Vishay's sensor boards.

This kit (order name: **SensorStarterKit**) can be purchased from any of our catalogue distributors. It serves as the base for the VCNL4010, VCNL4020, VCNL4020X01, and VCNL3020 sensor boards and the VCNL4020 gesture demo board.

Every new digital sensor will also be available on a new sensor board, which can be connected to the USB dongle and operated with the Sensor Starter Kit software.

Sensor Starter Kit User Guide

For the sensor boards, please contact sensorstechsupport@vishay.com and we will send you the requested board absolutely free of charge. Software upgrades will be provided by e-mail and are also available as a download, under the "Software" section from the Sensor Starter Kit website:

www.vishay.com/moreinfo/vcnldemokit/

The VCNL4020 is the default sensor board attached to the Sensor Starter Kit because this is best starting point to learn about proximity and ambient light sensors.

Fig. 3 - VCNL4020 Sensor Board

The VCNL4010 and VCNL3020 are function and feature-wise the same as the VCNL4020, except the VCNL3020 does not include the ambient light sensor. The VCNL4020X01 is nearly identical to the VCNL4020, although it covers the higher temperature range required for automotive applications and comes with a bit higher internal emitter intensity.

For complete details on the VCNLs please read their datasheets

www.vishay.com/optical-sensors/reflective-outputis-16/

and corresponding application notes "Designing VCNLxyz into an Application":

www.vishay.com/doc?84138 (VCNL4010)
www.vishay.com/doc?84136 (VCNL4020)
www.vishay.com/doc?84139 (VCNL3020)

There will soon be more digital sensors, an ambient light sensor, an RGB sensor and the next generation of proximity / ambient light sensors. This common base will be used for all these new devices. All available sensor boards that can be driven with the Sensor Starter Kit are shown here: www.vishay.com/moreinfo/vcnldemokit/

ESD WARNING

The VCNLs are sensitive to electrostatic discharge. Please take necessary precautions when handling the sensors and kit. For further information please read "Assembly Instructions" and "Packaging and Ordering".

KIT COMPONENTS

There are three main components to the kit:

1. The blue sensor board, on which is soldered the VCNL4020, a decoupling capacitor, an additional IRED (VSMF2890GX01), some switching components, and the 2 x 8 pin connector
2. The USB dongle, which takes care of delivering the needed I^2C-bus and supplies "clean" power to the sensor board (plus some GPIOs)
3. The development software found on the CD

The sensor board can be plugged into the USB dongle in the up or down orientation. An indicator light within the dongle will be illuminated when the sensor board is receiving power and the development software is started. The CD also contains a software license file. Note that the license file will be installed automatically by the installer. If for some reason this does not happen, the license folder is also included on the CD and should be saved to the C: drive before the software will run:

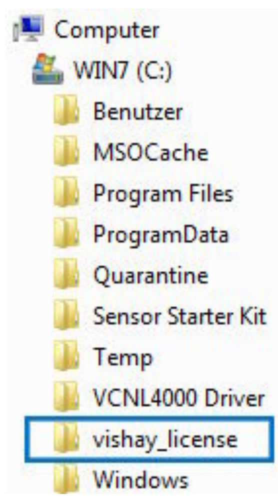


Fig. 4 - Vishay License in C:/ Directory

Please follow the Sensor Starter Kit installation guide, www.vishay.com/doc?84242

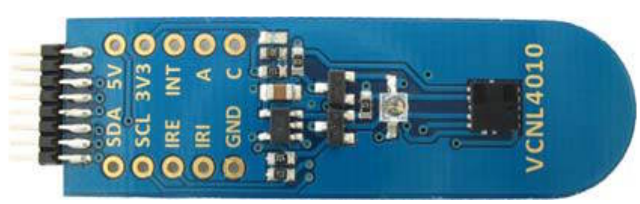


Fig. 5 - VCNL4010 Sensor Board

Sensor Starter Kit User Guide

VCNL Sensor Board Layout

The VCNL sensor boards, figure 3 and 5, have test points to allow simple evaluation and / or connection to the customer's application board. The boards also include an external emitter (VSMF2890GX01) to increase the measurement range to 500 mm and supporting FETs to use the integrated emitter and external emitter in series.

For more information on extending the detection range, please read www.vishay.com/doc?84225

Sensor Board Description, Functions, and Features, as well as a Schematic of the Board

For the VCNL4020 gesture control sensor board, this information can be found at: www.vishay.com/doc?84218

Every new sensor board can be connected to the Sensor Starter Kit. Please see:
www.vishay.com/moreinfo/vcnldemokit/

and the last page of this document.

Other Useful Links

I^2C specification version 3.0:

www.nxp.com/documents/user_manual/UM10204.pdf

Male pin connector 2199SB-XXG-301523

Female pin connector 2200SB-XXG-A1

www.almita-connectors.com/connector/pcb-connectors.html

VCNL40x0 Development Software

After installing the software, run the following command: Rapid_VCNL40x0.exe. When executing the program, the Proximity Function screen is displayed. There are four tabbed files: Proximity Function, Ambient Light Function, Setup, and Register.

PROXIMITY FUNCTION

Proximity Mode

- select a single measurement, periodic measurement, or self-timed measurement. The periodic measurement rates are set in the Measurement Speed window within Setup menu. The default setting is "periodic measurement (on demand)." Selecting periodic measurement sets the 'prox_od' bit 3 of the command register #0 (80h) to "1." See screen shot 1.
  When chosen "selftimed mode" one additional window will appear what allows then the to program the proximity rate between 1.95 and 250 measurements per second as specified within datasheet: proximity rate register #2 (82h) bits 0 to 2.

Proximity Settings

- sets the infrared emitter current. The infrared emitter current determines the effective range of the sensor; higher current will translate to longer sensing range. This feature can also be used to determine the impact of the cover or window on the sensing range. To compensate for the infrared light absorbed by the window, the current can be increased. The current can be set by either toggling up or down or by left clicking in the window and a current select bar will pop-up. The default setting is 100 mA.

Proximity Results

- shows the chosen measurement rate, which is dependent on the delay time selected in conjunction with the measurement speed. The default is 10 ms ("10"), which results in about 30 measurements per second. So the time needed for one measurement is 1/30 s = 0.033 s, which is shown within the "Measurement Time / Sample" field. The next four items show the actual proximity counts, their max., min., and mean values as well as the averaged peak to peak noise value.

Clear Display

- clears the upper and lower window graphs and resets the 'Data#' to zero.

Proximity Value

Changes the unit of measure for the proximity value. Click on the small blue letter on its left side. This letter indicates the selected format: b = binary, d = decimal, x = hexadecimal, o = octal, and p stands for SI notation.

Infinite Impulse Response (IIR) Filter

This low pass filter is activated with the "active" button and shows an average of the measurement results. The average value can be changed from 1 to 20 by clicking on the toggle arrow where 1 corresponds to no averaging and 20 to strong averaging. When active the button will be red.

Upper Window

Displays the entire 16-bit measured signal from 0 to 65 535 counts.

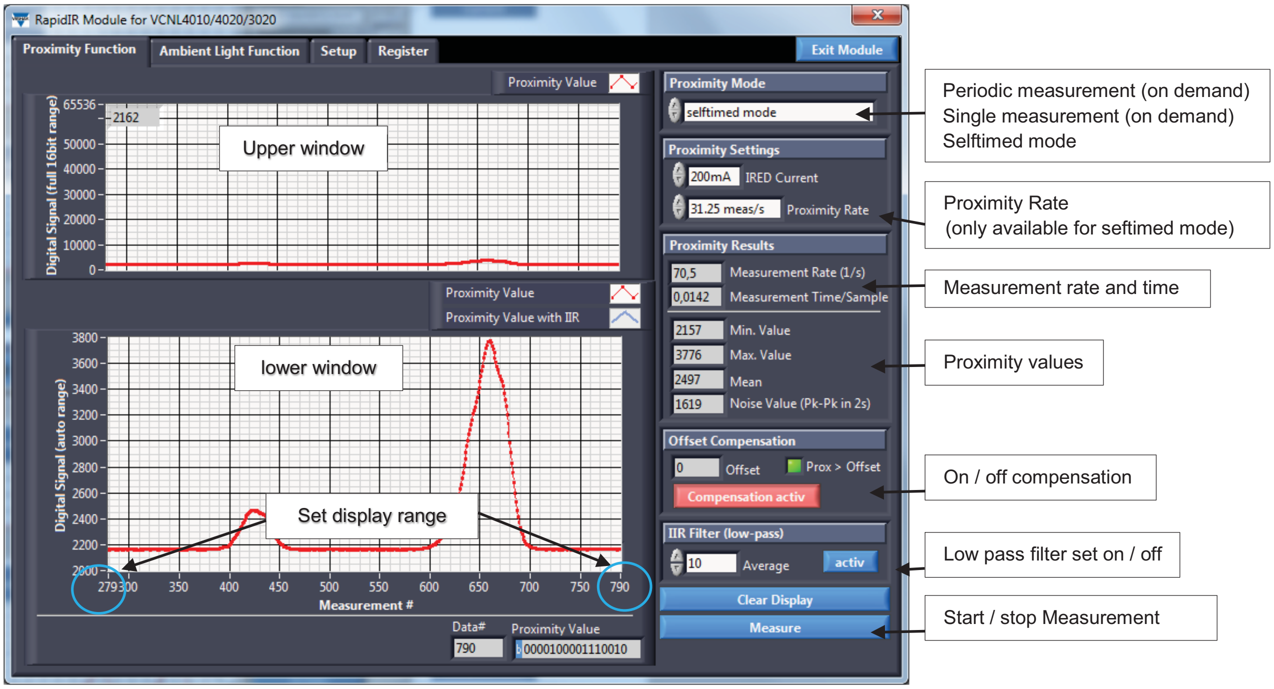
Lower Window

Displays only the active or dynamic range. The y-axis represents the number of counts and will change depending on the sensor reading.

Proximity Measurement

Click on the measure button to initiate a measurement.

Sensor Starter Kit User Guide



Screen Shot 1

Offset

Without an object in range, the upper window shows an offset of approximately 2000 counts. The lower windows shows the exact values. This offset is a result of optical crosstalk and digital noise. In an application where a window is placed over the top of the sensor, the offset value can be as high as 5000 to 20 000 counts.

For the kit, the offset value is calculated by averaging the last 2 seconds of counts. In a ready-made application the offset value should be subtracted from incoming proximity readings and the resultant used to determine object proximity.

Object with Range of 200 mm and 100 mm

Assuming the offset value is 2170 counts, at a range of 200 mm, the reflection from a hand results in an output count of 2190 counts. This is 20 counts higher than the offset or noise floor. At a range of 100 mm, the reflection of the object results in an output count of 2270 counts. This is 100 counts higher than the offset value. By clicking the “Compensate Offset” button, the software simulates this subtraction. When this function is active, the button will be red as in screen shot 1. With compensation offset active, the digital signal in the lower frame will display only the counts related to the reflected signal, effectively zeroing the offset. This is a feature of the kit only. In actual applications, the offset value should be subtracted to obtain actual proximity or ambient counts.

Object with Range of 10 mm and 5 mm

With compensation offset active, at a range of 10 mm, the reflection of the object (hand) results in an output count of approximately 8000 counts. At a range of 5 mm, the reflection results in an output count of approximately 30 000 counts. Again, with compensation offset active, the digital signal in the lower frame shows only the counts related to the reflected signal.

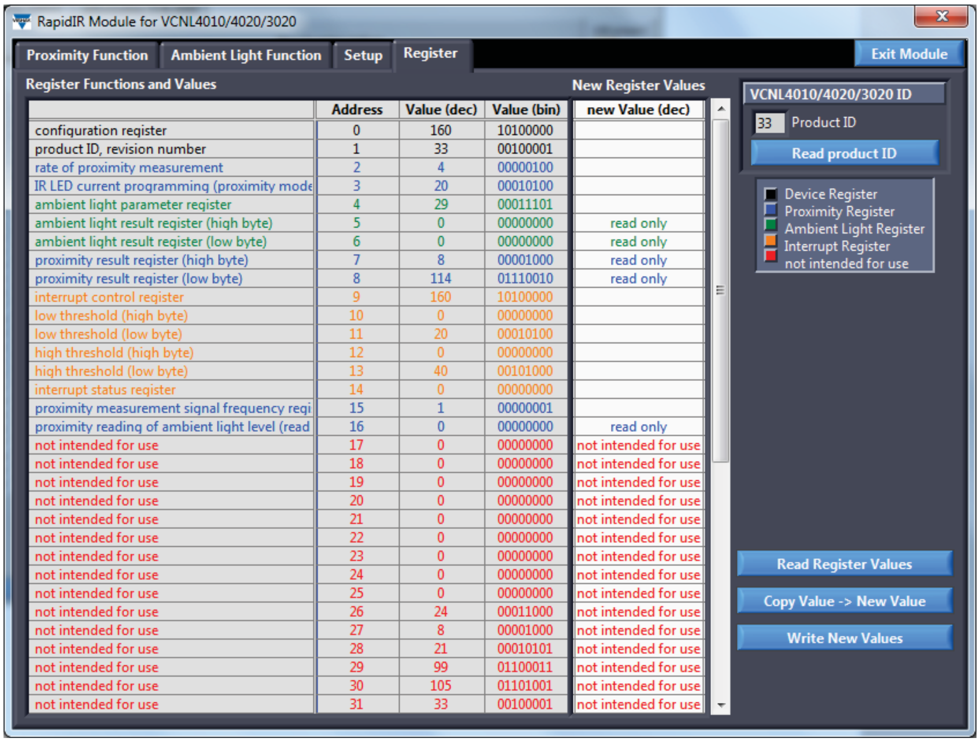
Display Range

Displays a specific range of readings by entering a minimum reading number on the right side of the x-axis and the maximum reading number on the left side of the x-axis. Type over the existing displayed value. This feature is only available when measurements have stopped.

Register Values

The actual proximity value is available by selecting the Register Value tab. The high 16-bit value is stored in register #7 and the low value is stored in register #8. Register #7 equals 8 (dec) [00001000] and register #8 equals 114 (dec) [01110010]. See screen shot 2.

Sensor Starter Kit User Guide



Screen Shot 2

FORMAT FEATURES - PROXIMITY

To Copy Graph

Right click within the upper or lower window and select "Copy Data" = "Daten kopieren."

To Change Line Color

Click inside the small white rectangle located between the upper and lower signal windows to change line colors, patterns, and other features.

AMBIENT LIGHT FUNCTION

Ambient Mode

Select a single, periodic, or selftimed measurement. The default setting is "periodic measurement (on demand)." Click 'Measure' to execute the measure function. See screen shot 3.

Upper Window

The upper window displays the entire 16-bit measured signal from 0 to 65 535 counts.

Lower Window

The lower window displays only the active or dynamic range. The y-axis represents the number of counts and will change depending on the sensor reading.

Ambient Light Settings

Defines the number of measurements used in the averaging function. Use the toggle button located left of the "Samples taken in 100 ms" title to scroll through available settings or click within the white value box and a pull down menu opens displaying all available values. The advantage of this function is that disturbance from 50 Hz / 60 Hz sources (100 Hz / 120 Hz) is significantly reduced by averaging. The default setting is 32 which sets bit 0, bit 1 and bit 2 of register #4 to 5(dec) (101); translated, 2^5 or 32 measurements within 100 ms. These 32 measurements are averaged and the result is then available within Ambient Light Result register #5 and #6.

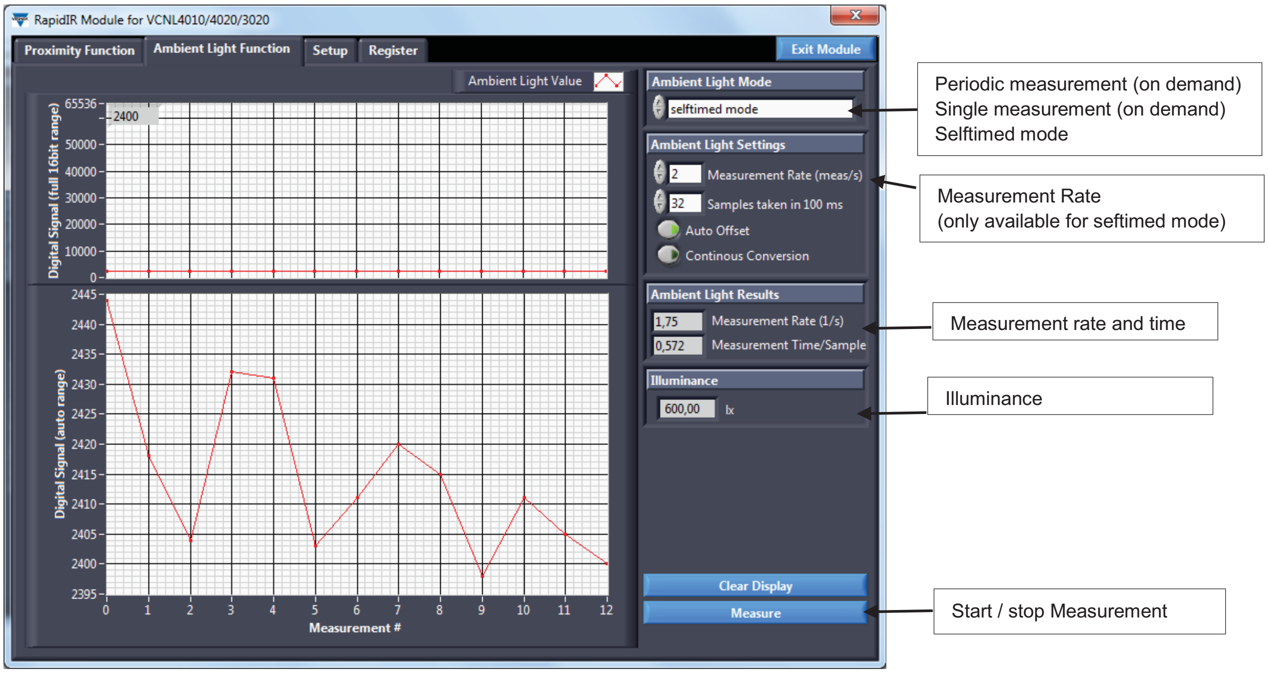
Auto Offset

Compensates for temperature related drift of the ambient light measurements. With auto offset active, the offset value is measured before each ambient light measurement and subtracted automatically from the actual reading. The default setting is "Auto Offset" active. "Auto Offset" is bit 3 of Ambient Light Parameter Register #4 (84h).

Continuous Conversion

Allows for faster measurements. With this selected, single conversions are made in a much shorter time.

Sensor Starter Kit User Guide



Screen Shot 3

Clear Display

Clears the upper and lower window graphs and resets the “Data#” to zero.

Illuminance

Displays the ambient light level in lux. It is calculated by dividing the number of counts by four. For example, there are 2400 counts which, when divided by four, results in 600 lx, see screen shot 3.

Figure of Merit

The ideal ambient light sensor will produce exactly the same output (counts) for the same brightness regardless of the source of light. In reality, silicon-based ambient light sensors will produce slightly different readings for halogen (2856 K CIE illuminant A), incandescent, fluorescent, and white LED sources. Figure 7 shows the average response for the VCNL40x0 ambient light sensors for all the above light sources and graphs the number of counts versus lux value for each light source. The halogen lamp shows a factor of 5.1 for digital counts versus lux, the fluorescent lamp shows a factor of 3.2 and white LEDs shows a factor of 4.1. The average response is a factor of 4 counts per lux. As shown in figure 6, a count of 1000 corresponds to 250 lx. This same count could be 200 lx for the halogen lamp or 310 lx for the fluorescent lamp. The overall tolerance for the VCNL40x0 ambient light sensor for different light sources is -22 % to +24 %.

The VCNL4010 and VCNL4020 have a sensitivity of 0.23 lux per count.

Sensor Starter Kit User Guide

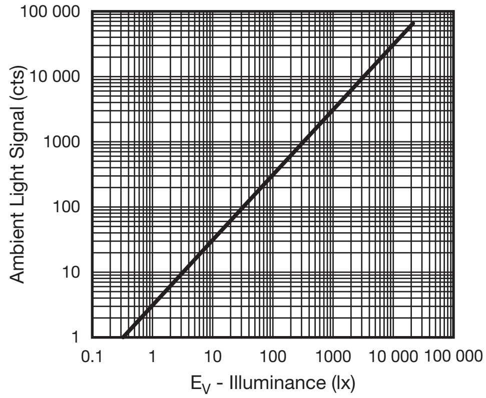


Fig. 6 - Ambient Light Signal (cts) vs. Illuminance E_V (lx)

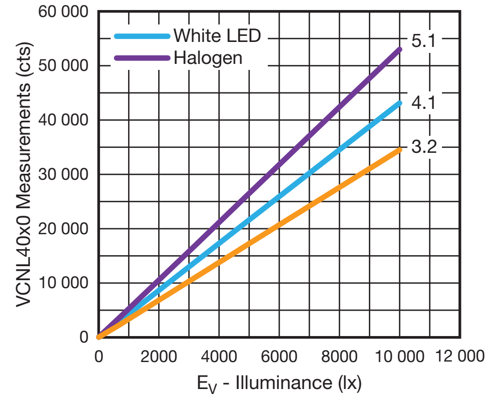
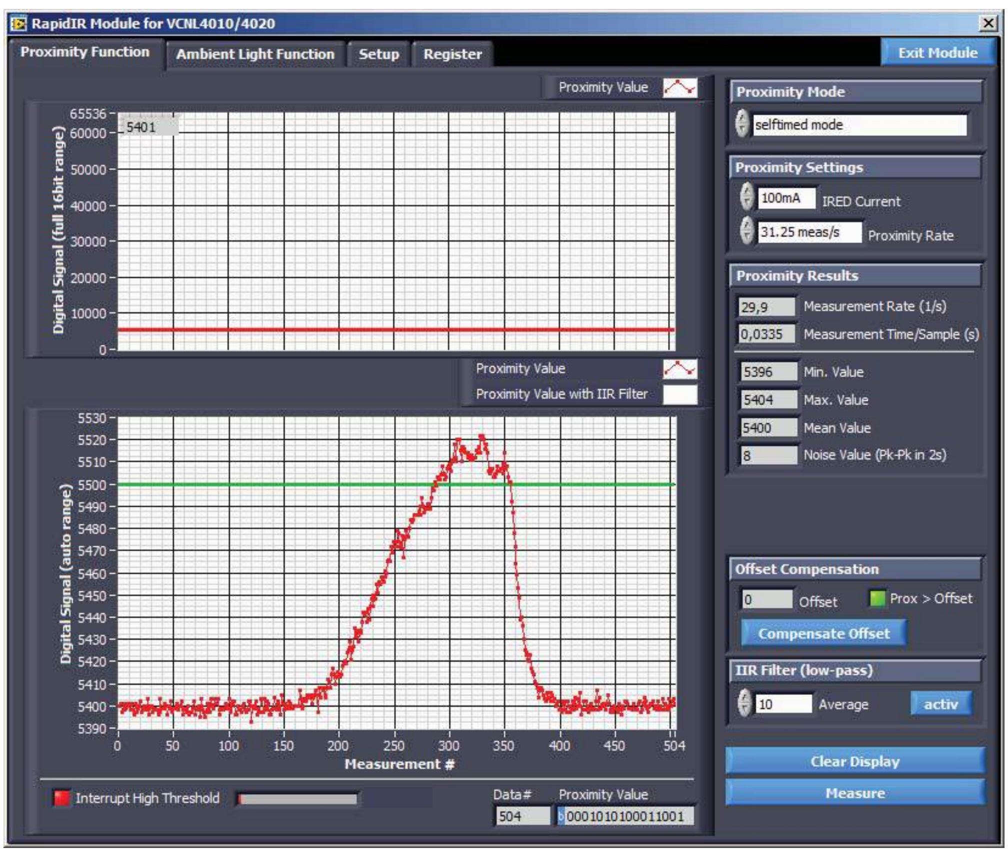


Fig. 7 - VCNL40x0 Measurements (cts) vs. Illuminance (lx)



Screen Shot 4

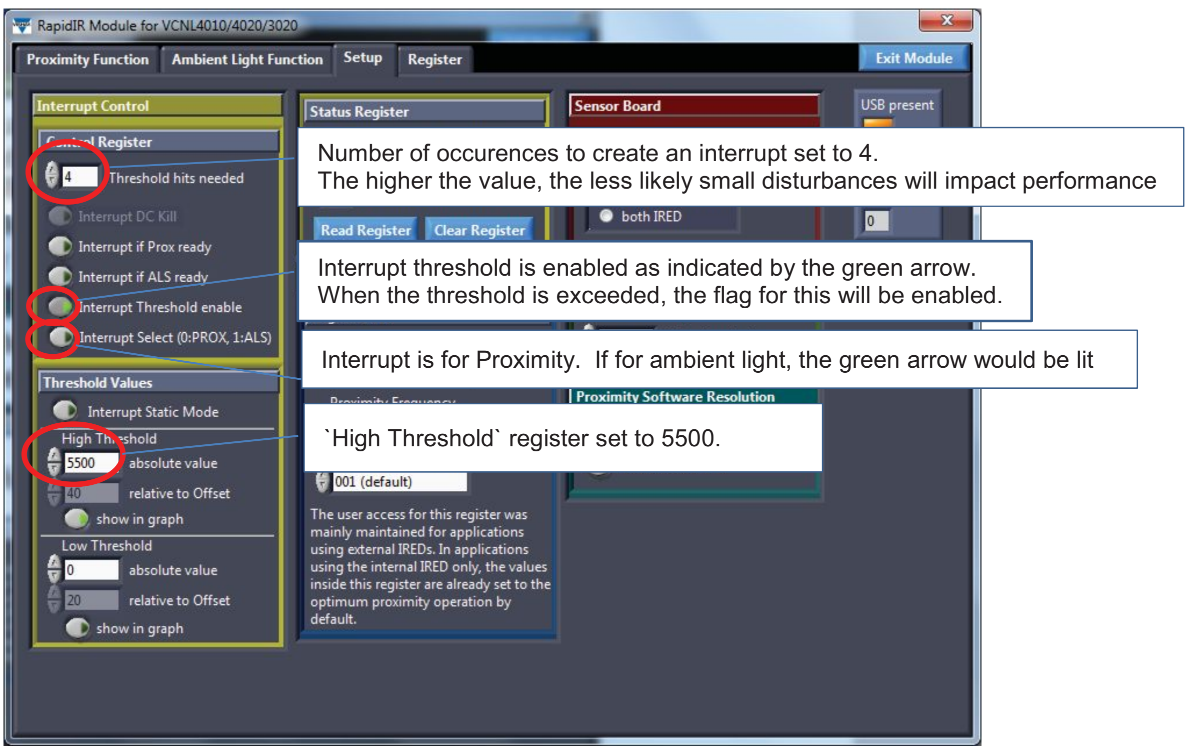
Sensor Starter Kit User Guide

Interrupt

In order to set interrupt thresholds, it is necessary to determine the offset counts for the sensor. The offset count is application specific so it can only be determined by assembling the sensor with surrounding components with the cover or window above it. Offset counts are initially determined during development and may again be measured during assembly or final test of the end product. To determine the offset counts, the sensor's proximity performance must be determined using the worst-case reflective object required to be detected at the desired distance it is to be detected. By adjusting the current of the infrared emitter, the range can be established. By adjusting the measurement speed, the response rate desired can be established. All these parameters together yield the total offset counts of the sensor without an object in range.

Example:

The sensor without any cover and close surrounding of other objects / components delivers about 2300 counts with an infrared emitter current of 100 mA. With some higher components close by and with a less transmissive cover this easily could rise up to 5000 or even 20 000 counts, depending on the distance and reflectivity of the cover used. As shown in screen shot 4, the offset counts are 5400. As an example, the application needs to detect an object at a distance of 5 cm. After some development trials, the sensor measures 5500 counts when the object is 5 cm distance and the forward current is 100 mA. For the application, the upper threshold will be set to 5500 counts, the green line in screen shot 4. When the counts exceed this threshold, in other words when an object is at 5 cm distance or less, an interrupt will be generated.



Screen Shot 5

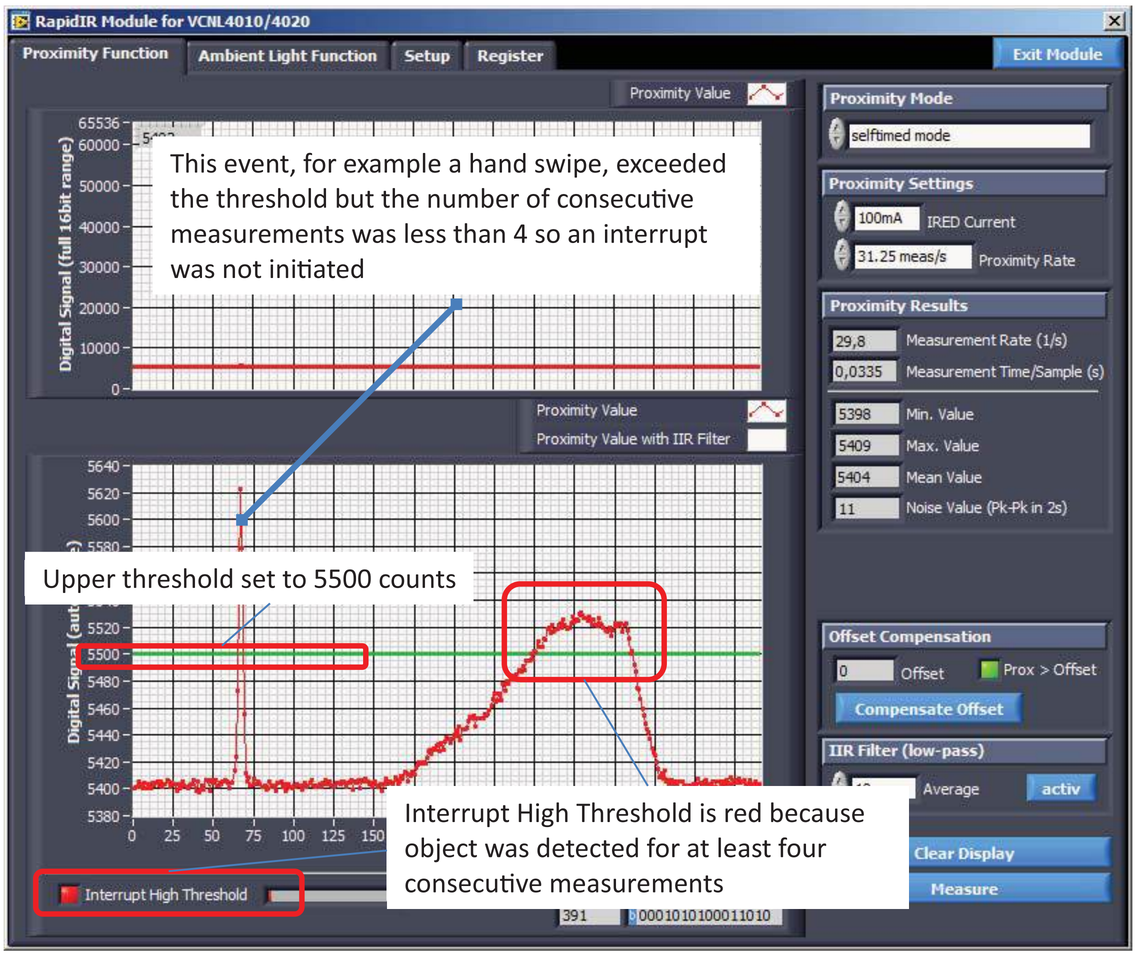
Screen shot 5 shows the Setup page where the Interrupt Control variables are set or defined:

- Upper threshold val
- Lower threshold value
- Number of measurements above or below a threshold needed to generate an interrupt
- Enable interrupt threshold function
- Threshold applies to proximity or ambient light

To avoid reacting to momentary object proximity, some applications will want to wait until several measurements are taken indicating an object is present or has been removed before generating an interrupt. The "Threshold hits needed" value is set to 4 in screen shot 5. The upper threshold is set to 5500 counts as discussed above. There is no lower threshold. The interrupt is enabled as indicated by the green arrow on the toggle button. Finally, the interrupt is for

Sensor Starter Kit User Guide

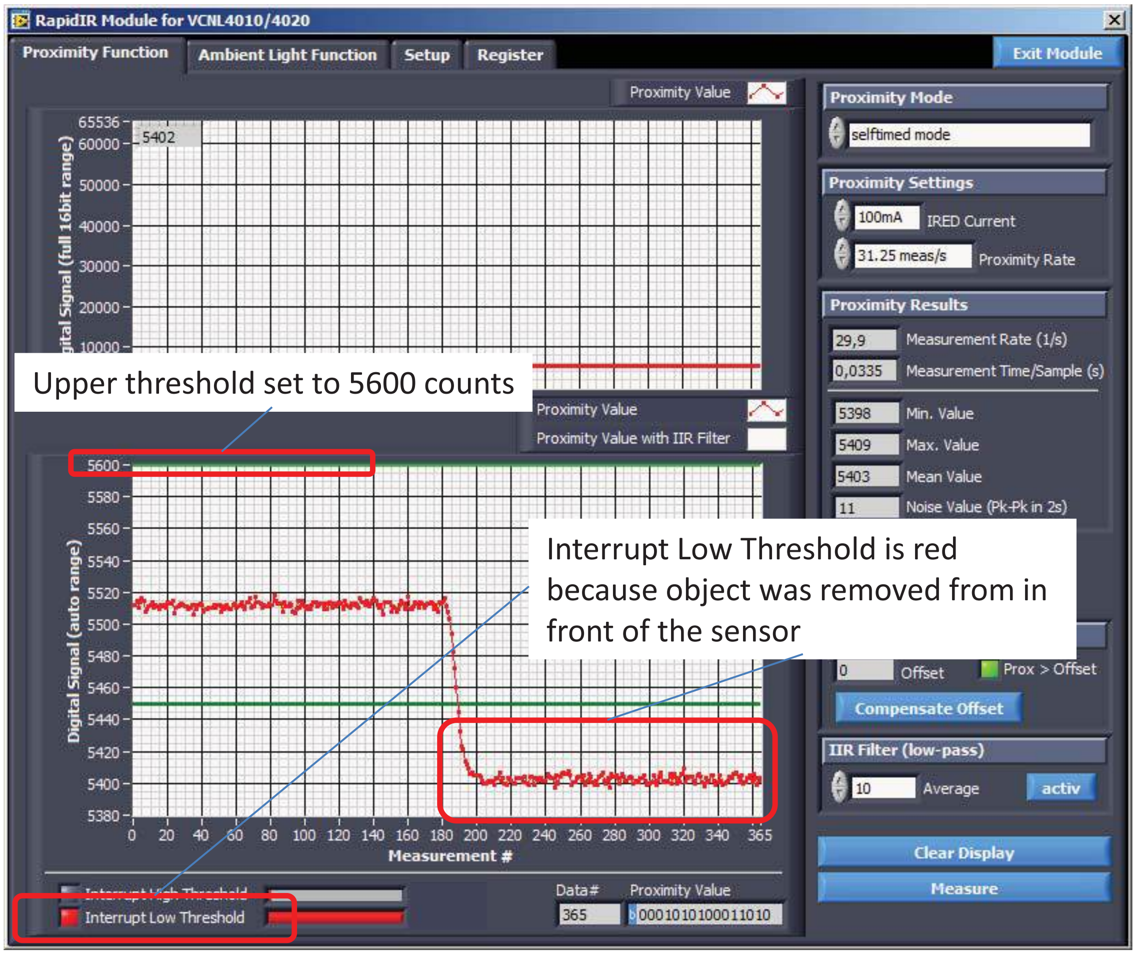
proximity because the green arrow is not illuminated. If it were for ambient light, the green arrow would be illuminated. Note that by clicking on the “show in graph” button under each threshold value, the user will graphically be shown the threshold value in relation to the offset and current readings.



Screen Shot 6

Screen shot 6 demonstrates how a brief event, for example a quick swipe of a hand, exceeded the threshold but the number of consecutive measurements was less than 4 so an interrupt was not generated. Following this event, an object is within 5 cm for long enough for an interrupt to be generated. The “Interrupt High Thresold” indicator in the lower left corner is illuminated (red). Once an object is detected, there are a number of possible actions an application can take. Continuous polling can be initiated to monitor the object’s proximity. Or, the current interrupt could be cleared, threshold values reprogrammed and the microcontroller freed to perform other activities or to sleep until an event occurs that generates a new interrrupt.

Sensor Starter Kit User Guide



Screen Shot 7

Screen shot 7 shows how the upper threshold is reprogrammed to be high enough so that it will not “be in play” anymore, for example 65 535 counts. To be able to show it in the lower window, the value has been set to 5600 for this example. The application needs to now initiate an action when the object is no longer present. In a smart phone application for example, the screen backlight and touch function is turned off when the phone is brought to the users ear (upper threshold) and should turn back on when the phone is removed from being near the user’s ear (lower threshold). The lower threshold should be above the offset counts but below the present proximity counts. In this example, the lower threshold is set to 5450 counts. Screen shot 7 also shows that the object is removed and the signal goes below the lower threshold. The “Interrupt Low Thresold” indicator in the lower left corner is illuminated (red).

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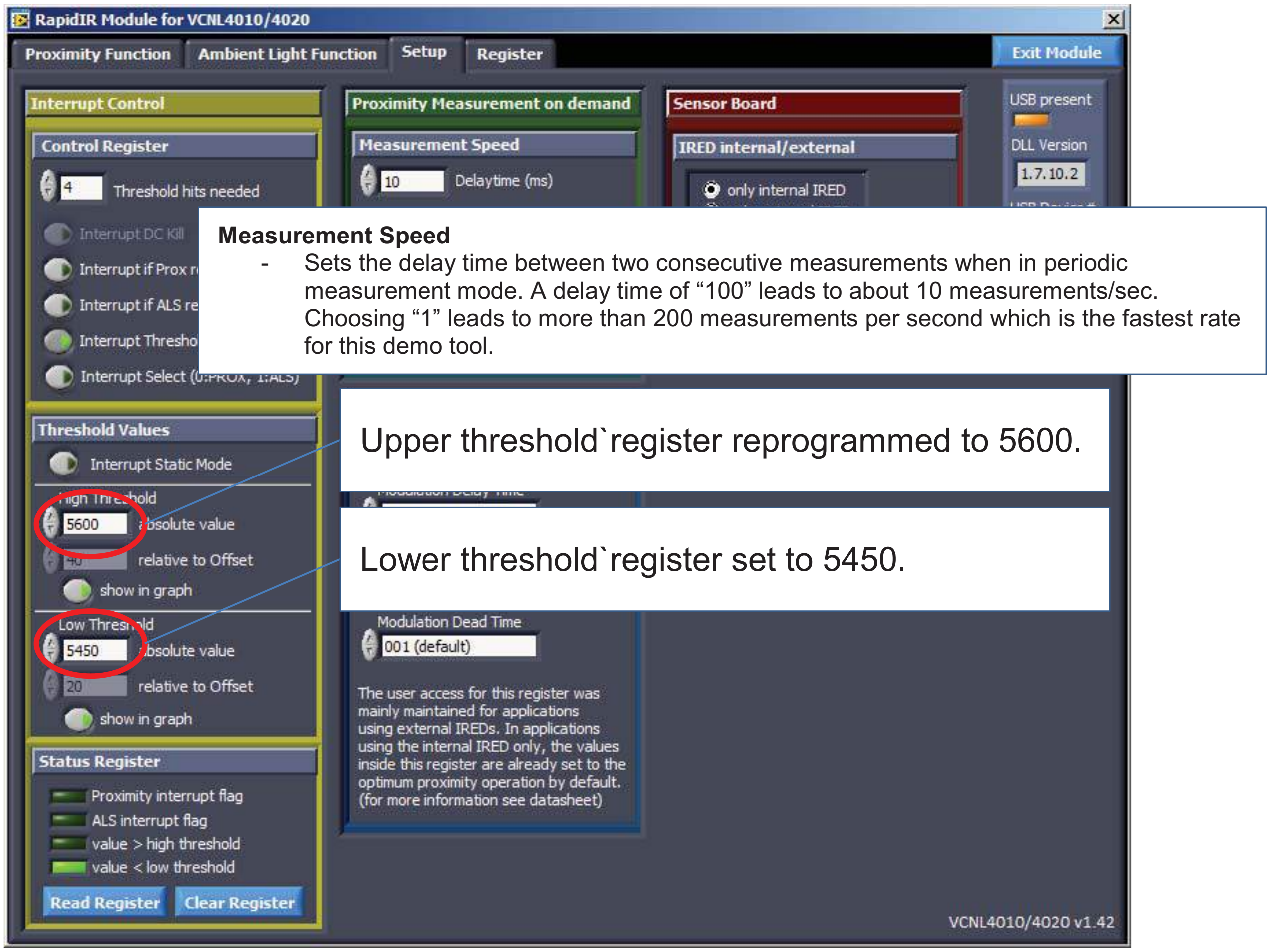

Screen Shot 8

Screen shot 8 shows that the status bit indicator for low threshold, "value < low threshold," has been illuminated **(int_th_lo = 1)**.

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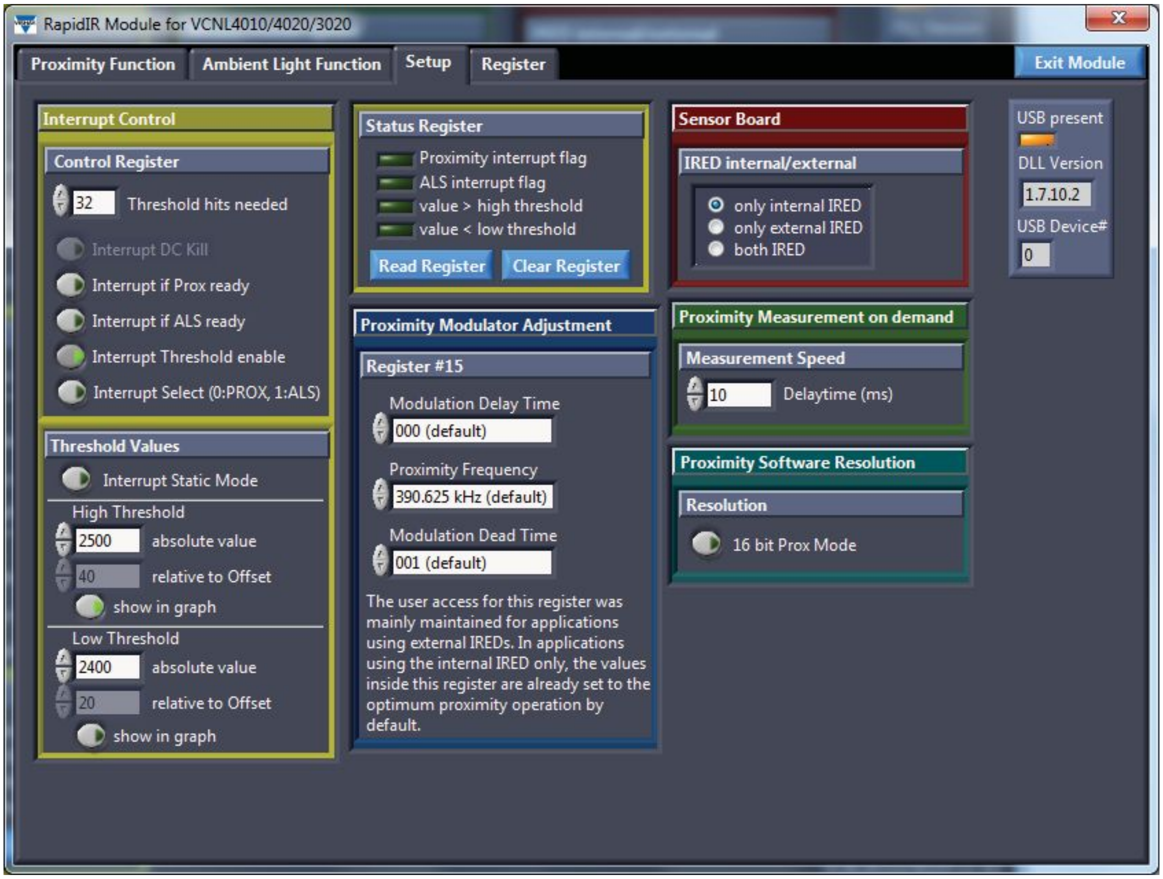


Screen Shot 9

External Emitter Settings

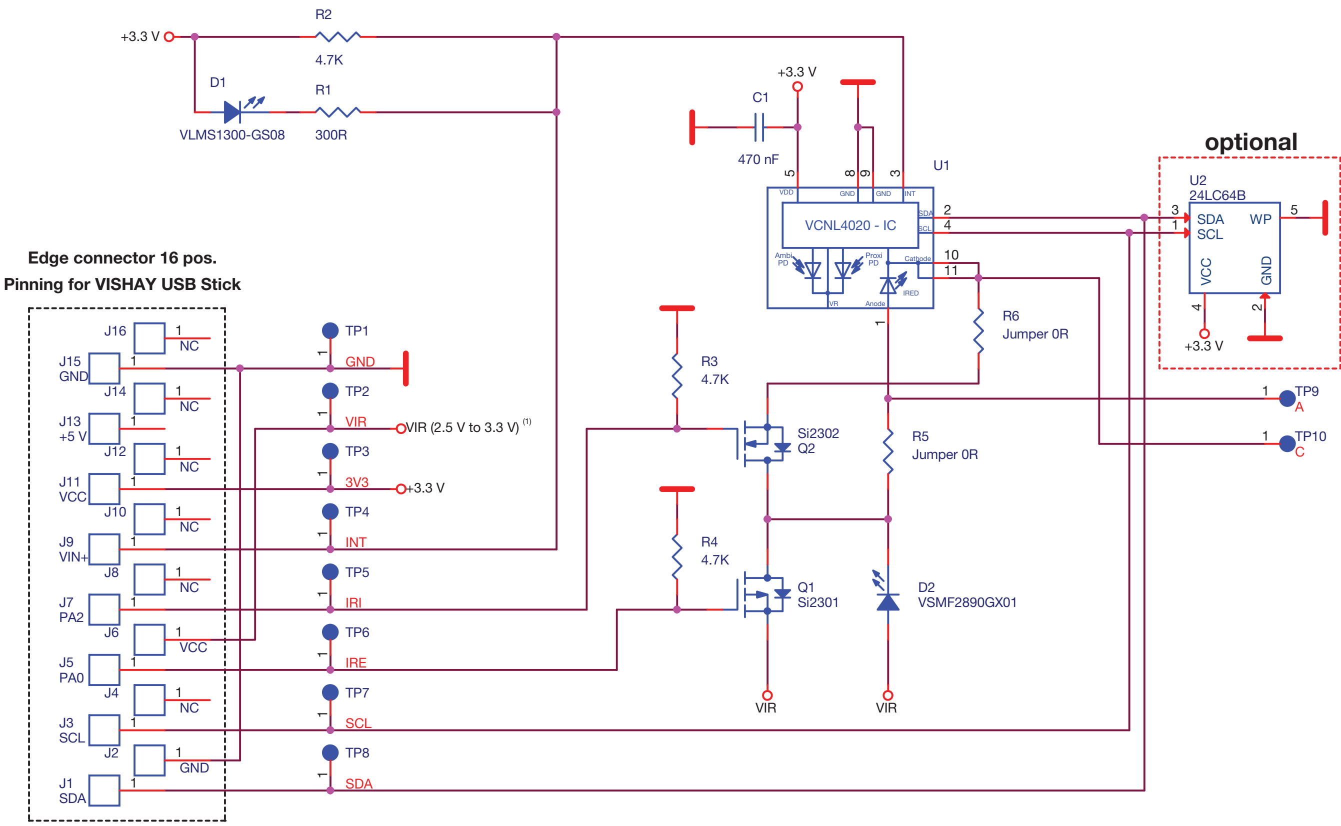
In screen shot 9 the Setup screen for the VCNL4010 and VCNL4020 is shown. For the VCNL4020X01 and also for the VCNL3020 - which comes without the ambient light sensor - the same demo software is used. Under the red Sensor Board section, the default “internal emitter” indicator is illuminated. Users have the option of selecting the use of an external emitter or using both internal and external emitter. The supply voltage for the external emitter is called VIR and connected via the USB controller board to a 3.3 V power supply, see figure 8 and 9. It can be connected to a separate power supply. If internal and external infrared emitters will be driven in series, they need to be connected to a higher voltage.

The blue Proximity Modulator Adjustment section of the Setup screen shows default values for the use of the integrated infrared emitter. When using external emitters or a combination of an internal and external emitter, the modulation delay time, modulation dead time, and proximity frequency may need to be adjusted. Please refer to the VCNL4010, VCNL4020, or VCNL3020 Application Notes for further details.

The green Proximity Measurement On Demand section of the Setup screen allows users to adjust the delay between two consecutive measurements. Any value between 0 and 10 000 can be entered in the field. A value of 0 results in 1 ms between measurements (200 measurement per second) while a value of 10 000 results in about 10 seconds between measurements.

Sensor Starter Kit User Guide

SCHEMATIC



IRI	IRE	IRED operating
L or open	L or open	only internal IRED
L or open	H	both IREDs
H	L or open	forbidden
H	H	only external IRED

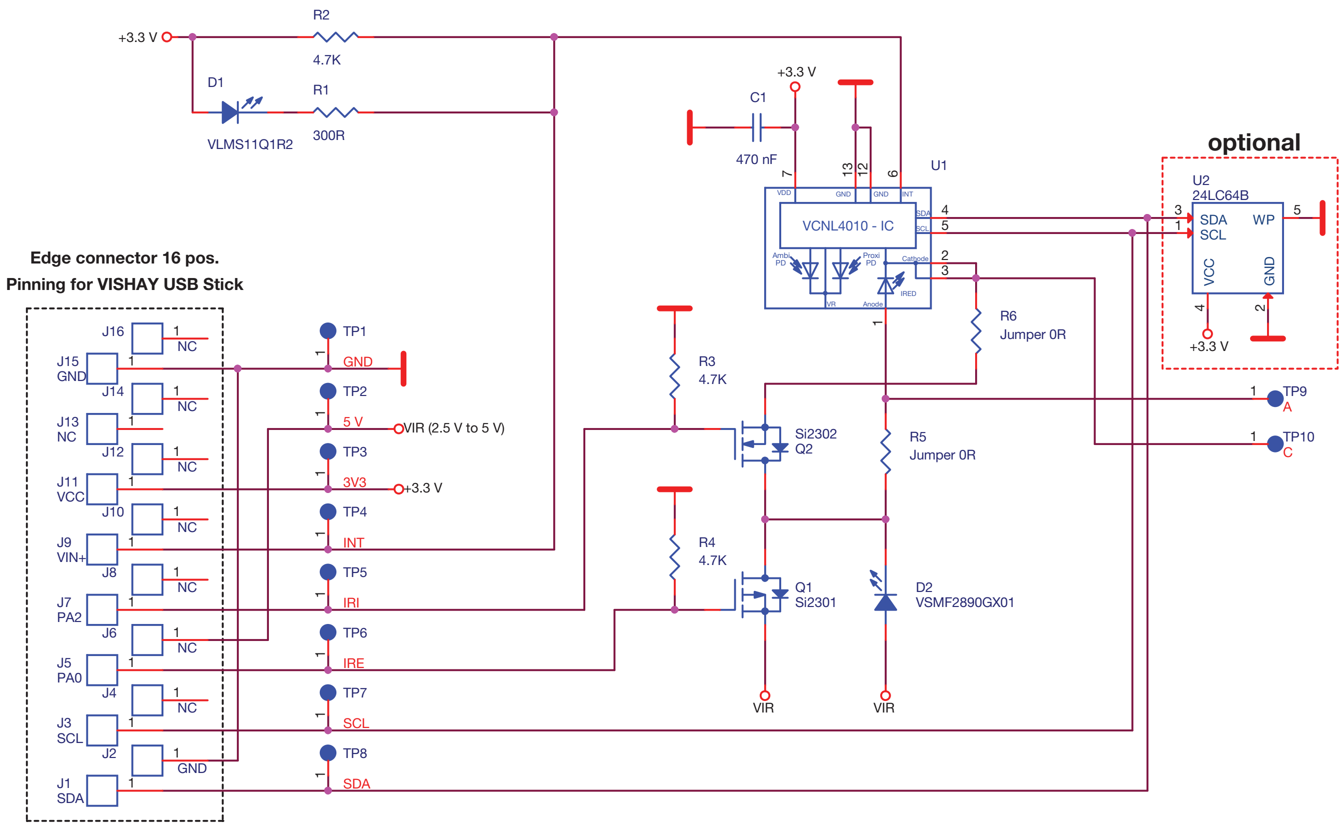
When using the VCNL4020 sensor board without VISHAY USB stick, an additional pullup resistors (2.4 to 10K) on SDA and SCL is necessary

Note

(1) VIR may be set > 3.3 V (< 5 V), however then Q1 will no longer short circuit the external emitter D2

Fig. 8 - Circuit Diagram of VCNL4020 Sensor Board

Sensor Starter Kit User Guide



IRI	IRE	IRED operating
L or open	L or open	only internal IRED
L or open	H	both IREDs
H	L or open	forbidden
H	H	only external IRED

For using VCNL4010 sensor board without VISHAY USB stick additional pullup resistors (2.4 to 10K) on SDA and SCL necessary

Fig. 9 - Circuit Diagram of VCNL4010 Sensor Board

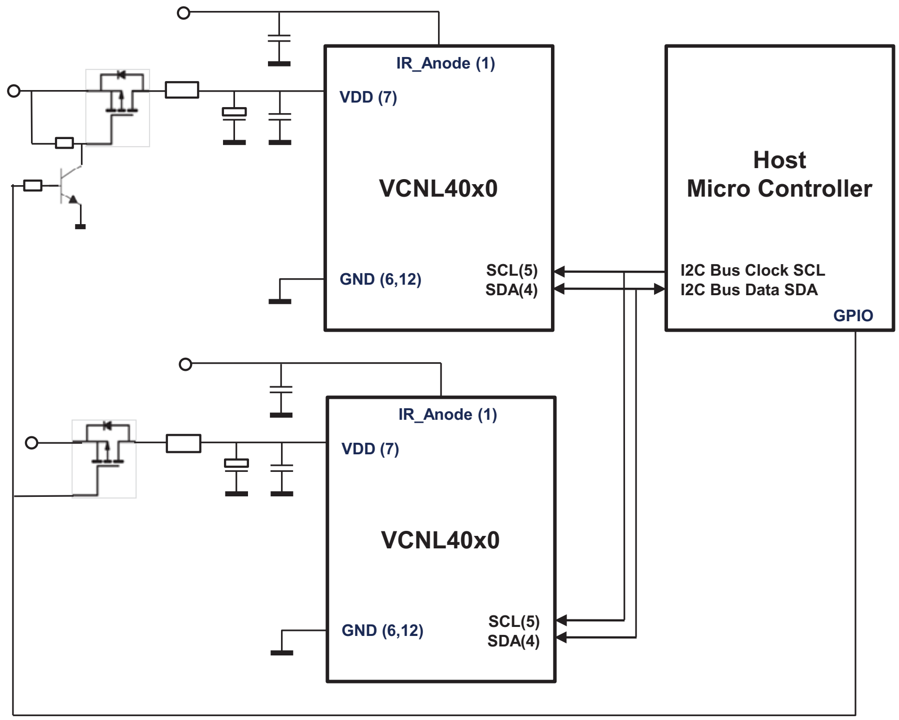
The switching information (IRI and IRE) is delivered from the USB controller and the specification given above.

ADDITIONAL REMARKS

1. The demo software behind this Sensor Starter Kit is LabVIEW based. Due to licensing issues we cannot provide the LabVIEW source code.
2. The controller within the USB dongle is a Cypress CY7C68013.
3. The nominal I^2C-bus speed is about 100 kHz.
4. The required pull-up resistors at the SDA and SCL lines are within the dongle and connected to 3.3 V.
5. A small regulator provides all sensor boards with 3.3 V. Eventually the needed 2.5 V are created on the corresponding boards.
6. For additional handling of analog voltages, an A/D converter (MCP3421) is included within this dongle. Its address is “A0.”
7. These added rows of “test pins” shown in figures 3 and 5) allow a connection to your own application. Do not forget to add the needed SDA / SCL pull-up resistors in this case. For all VCNL40x0 and VCNL3020 sensor boards it should also be noted, that the anode side of the available external IRED needs to be connected to a supply voltage between 2.5 V and 5 V. This is done within the USB dongle.
8. All VCNLs come with one and the same I^2C-bus address: 26h for write and 27h for read. If more than one VCNL is used within an application, a switch for the I^2C-bus lines is needed. Please see some proposals on next pages.

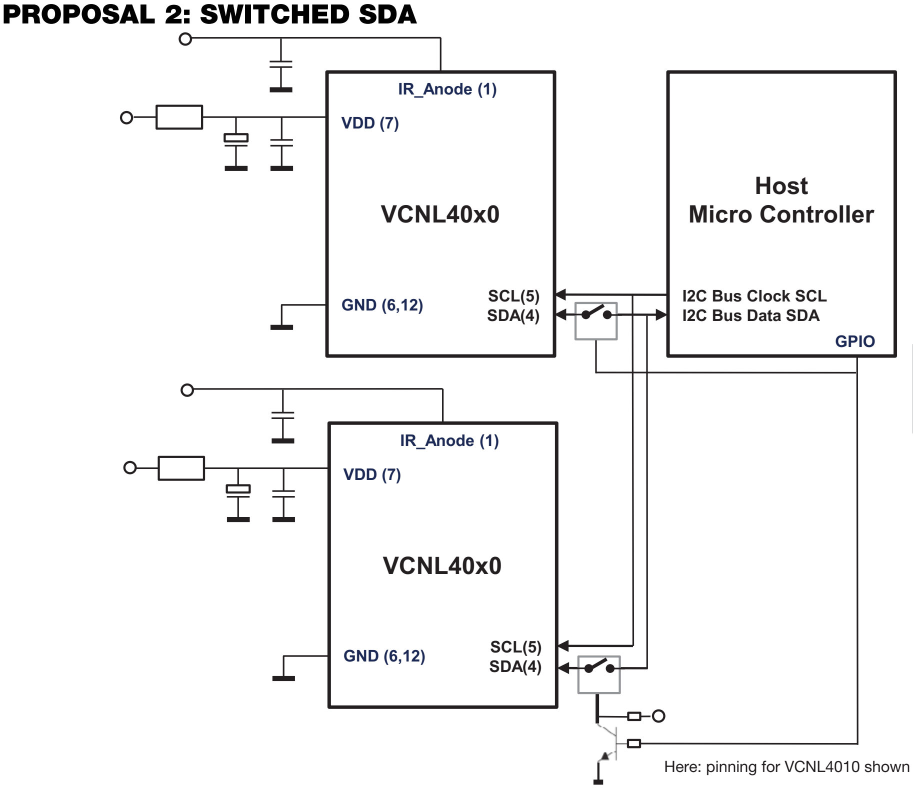
Sensor Starter Kit User Guide

PROPOSAL 1: SWITCHED V_{DD}

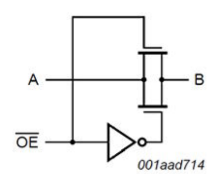


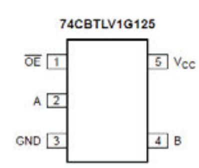
Here: pinning for VCNL4010 shown

PROPOSAL 2: SWITCHED SDA



switching the SDA line,
e.g. With single bus switch as
74CBTLV1G125





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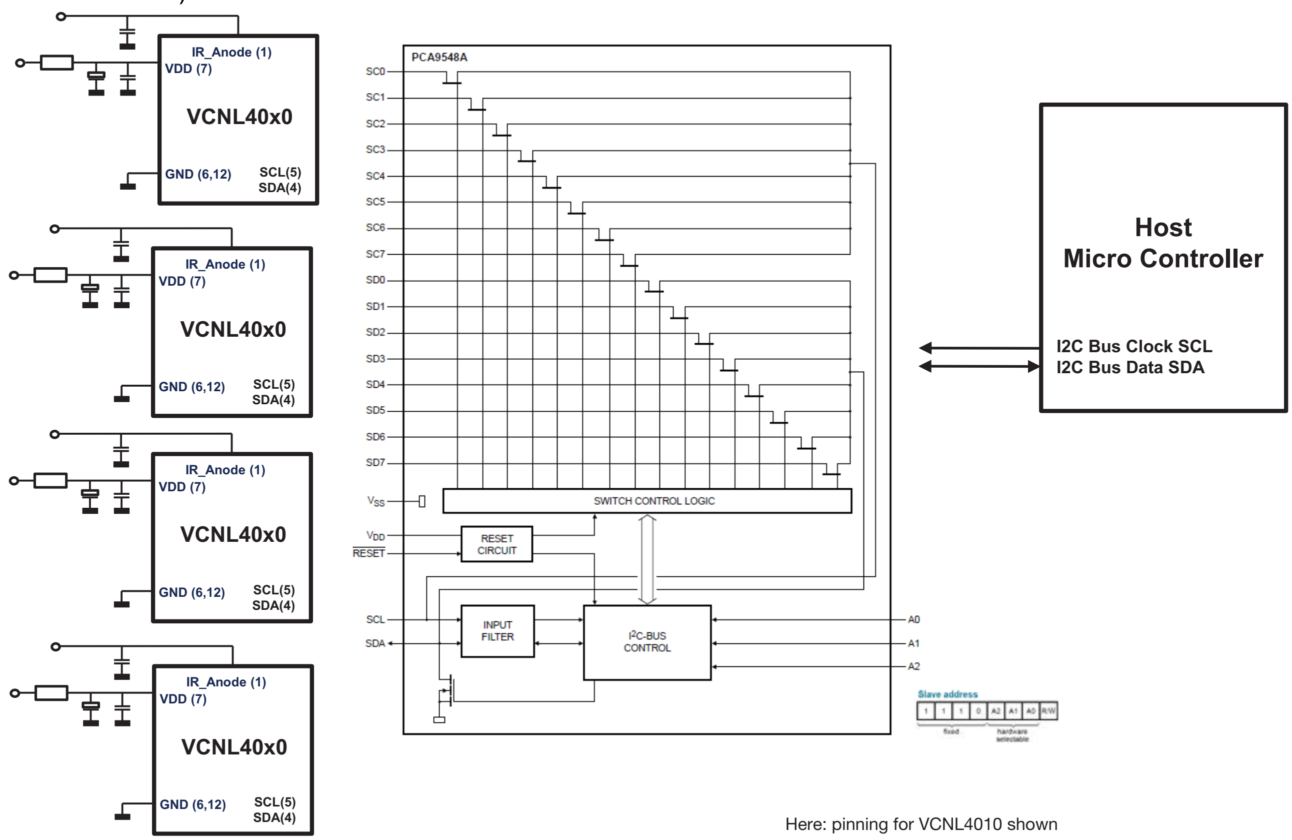
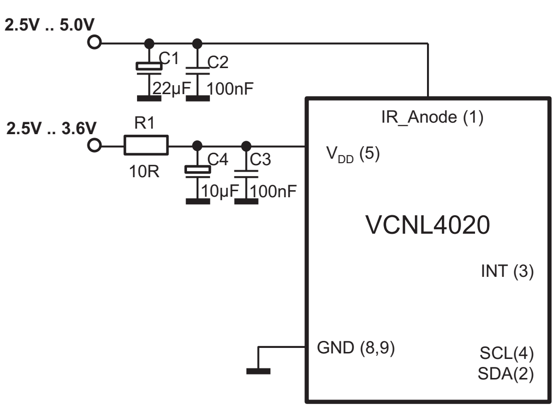
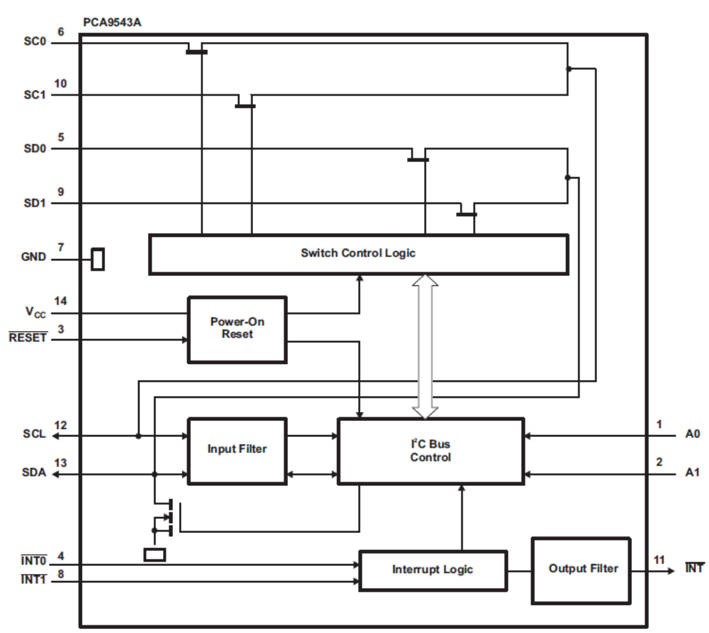
PROPOSAL 3: VIA A DEDICATED I²C-BUS SWITCH IC, E.G. PCA9548 OR PCA9543A

(for two channels)



Here: pinning for VCNL4010 shown





Sensor Starter Kit User Guide

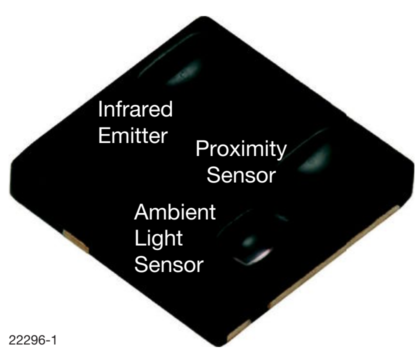
A web page shows all available sensor boards that can be used with the Sensor Starter Kit:

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

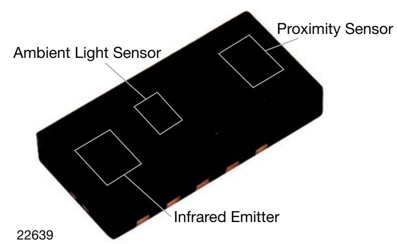
INTRODUCTION

The VCNL40x0 sensors are fully integrated proximity and ambient light sensors. They combine an infrared emitter and PIN photodiode for proximity measurement, ambient light sensor, and signal processing IC in a single package with a 16 bit ADC. The devices provide ambient light sensing to support conventional backlight and display brightness auto-adjustment, and proximity sensing to minimize accidental touch input that can lead to call drops and camera launch for smart phones. With a range of up to 20 cm (7.9"), these stand-alone, single components greatly simplify 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 sensors feature a miniature leadless package (LLP) for surface mounting with a low profile of 0.75 mm for VCNL4000 and VCNL4010 and 0.83mm for VCNL4020 and VCNL3020. Through the standard I^2C bus serial digital interface, they allow easy access to a “Proximity Signal” and “Light Intensity” measurement without complex calculations or programming. All versions besides the VCNL4000 offer a programmable interrupt function which may be used as a wake-up function for the microcontroller when a proximity event or ambient light change occurs; reducing processing overhead by eliminating the need for continuous polling.

For complete details on the VCNL40x0 please read “Designing VCNL40x0 into an Application”
www.vishay.com/doc?84138 for VCNL4010
www.vishay.com/doc?84136 for VCNL4020
www.vishay.com/doc?84139 for VCNL3020.



VCNL3020 is a ‘Proximity-only’ device without ambient light sensor. It has the same package size as the VCNL4020.



VCNL4020

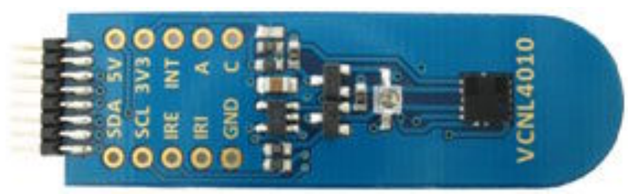
VCNL3020

ESD WARNING

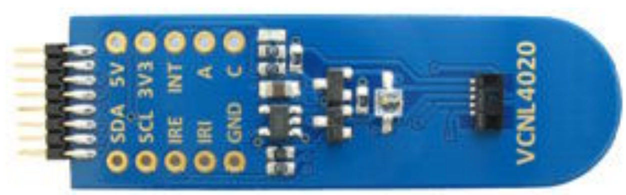
The VCNL40x0 are sensitive to electrostatic discharge. Please take necessary precautions when handling the sensor and kit. For further information please read Assembly Instructions and Packaging and Ordering.

The VCNL4000 Demo Kit comes with a mini-CD containing the USB driver and software, a USB dongle and the VCNL4000 sensor board. This kit can be purchased from any of our catalog distributors. It serves as the base for the VCNL4010, VCNL4020, and VCNL3020 demo kits. For these sensors, please contact sensorstechsupport@vishay.com and we will send you the sensor board of your choice absolutely free. Software upgrades are available on our website at www.vishay.com/optoelectronics/moreinfo/vcnldemokit.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit



VCNL4010 Sensor Board



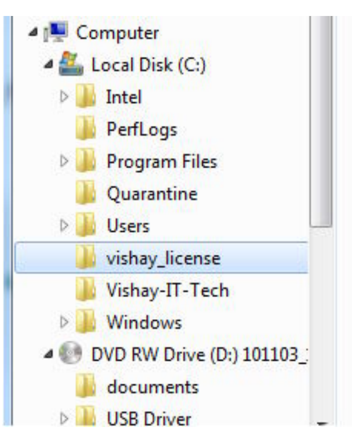
VCNL4020 Sensor Board

KIT COMPONENTS

There are three main components to the kit:

1. The blue sensor board on which is soldered the VCNL40x0, a decoupling capacitor, and the 2 x 8 pin connector
2. The USB dongle which takes care of delivering the needed I^{2}C-Bus and supplies “clean” power to the sensor board
3. The development software found on the CD.

The sensor board can be plugged into the USB dongle in the up or down orientation. An indicator light will be illuminated when the sensor board is receiving power and connected to the development software. The CD also contains a Quick Start guide (www.vishay.com/doc?83396) menu and a software licensing agreement. Note that the licensing agreement must be saved in the C-drive root directory before the software will run:



Vishay License in C:/Directory

VCNL4000 Development Software

After installing the software, run the following command: USB_Sensor_Kit_VCNL4000.exe or double click on the application software in the VCNL4000 Demo Kit folder. When executing the program, the Proximity Function screen is displayed. There are four tabbed files: Proximity Function, Ambient Light Function, Register Values, and Information VCNL4000

PROXIMITY FUNCTION

Proximity Mode

- select a single measurement or periodic measurement. The periodic measurement rates are set in the Measurement Speed window. The default setting is “single measurement (on demand)”. Selecting periodic measurement sets the ‘prox_od’ bit3 of the command register #0 (80h) to “1”. Compensation offset and IIR filtering is only available with periodic measurements. Screen shot 1.

Measurement Parameter

- sets the infrared emitter current. The infrared emitter current determines the effective range of the sensor; higher current will translate to longer sensing range. This feature can also be used to determine the impact of the cover or window on the sensing range. To compensate for the infrared light absorbed by the window, the current can be increased. The current can be set by either toggling up or down or by left clicking in the window and a current select bar will pop-up. The default setting is 100 mA.

Measurement Speed

- sets the delay time between two consecutive measurements when in periodic measurement mode. A delay time of “100” leads to about 10 measurements/s Choosing “1” leads to more than 200 measurements/s which is the fastest rate for this demo tool.

Clear Display

Clears the upper and lower window graphs and resets the ‘Data#’ to zero. The Proximity Value field near the bottom of the screen is not cleared. This field will be updated with the next measurement.

Proximity Value

Changes the unit of measure for the proximity value. Click on the small blue letter on its left side. This letter indicates the selected format: b = binary, d = decimal, x = hexadecimal, o = octal and p stands for SI notation

Infinite Impulse Response (IIR) Filter

This low pass filter is activated with the ‘active’ button and shows an average of the measurement results. The average value can be changed from one to twenty by clicking on the toggle arrow where 1 corresponds to no averaging and 20 to strong averaging. When active the button will be red.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Upper Window

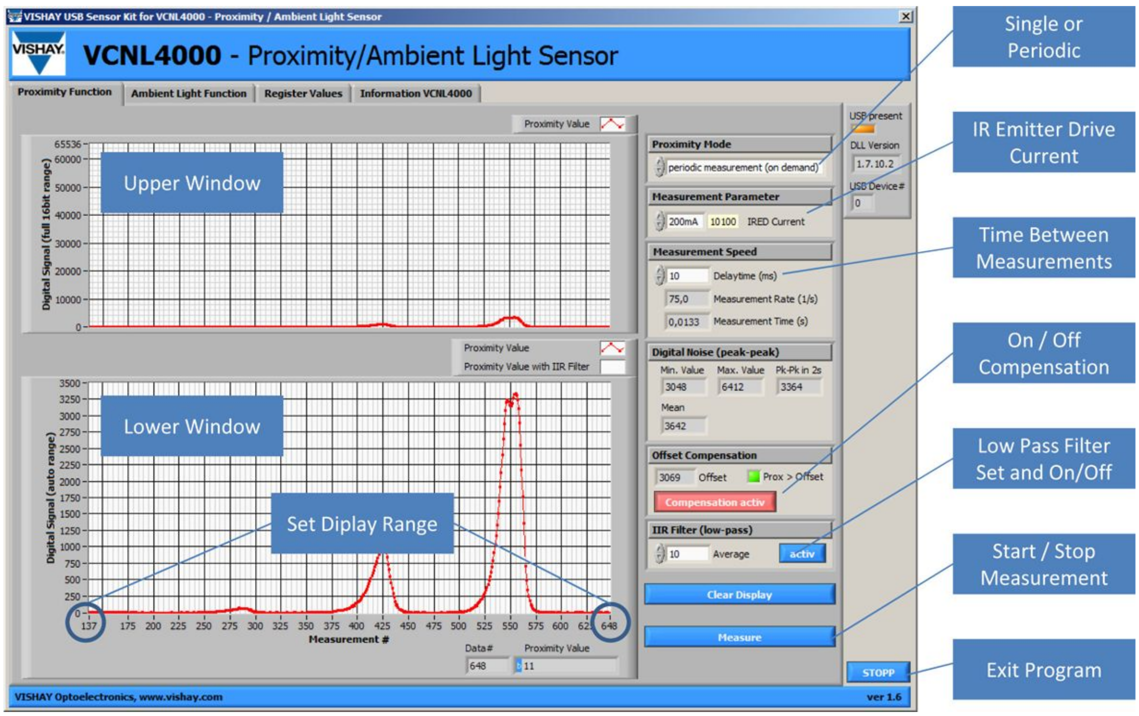
Displays the entire 16-bit measured signal from 0 to 65 535 counts.

Lower Window

Displays only the active or dynamic range. The y-axis represents the number of counts and will change depending on the sensor reading.

Proximity Measurement

Click on the measure button to initiate a measurement.



Screen Shot 1

Offset

Without an object in range, the upper window shows an offset of approximately 3000 counts. The lower windows shows the exact values. This offset is a result of optical crosstalk and digital noise. In an application where a window is placed over the top of the sensor, the offset value can be as high as 10 000 to 15 000 counts. For the kit, the offset value is calculated by averaging the last 2 seconds of counts. In a smart phone application the offset value should be subtracted from incoming proximity readings and the resultant used to determine object proximity.

Object with Range of 200 mm and 100 mm

Assuming the offset value is 3070 counts, at a range of 200 mm, the reflection from a hand results in an output count of 3090 counts. This is 20 counts higher than the offset or noise floor. At a range of 100 mm, the reflection of the object results in an output count of 3130 counts. This is 50 counts higher than the offset value. By clicking the “Compensate Offset” button, the software simulates this subtraction. When this function is active, the button will be red as in screen shot 1. With compensation offset active, the digital signal in the lower frame will display only the counts related to the reflected signal; effectively zeroing the offset. This is feature of the kit. In actual applications, the offset value should be subtracted to obtain actual proximity or ambient counts.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Object with Range of 10 mm and 5 mm

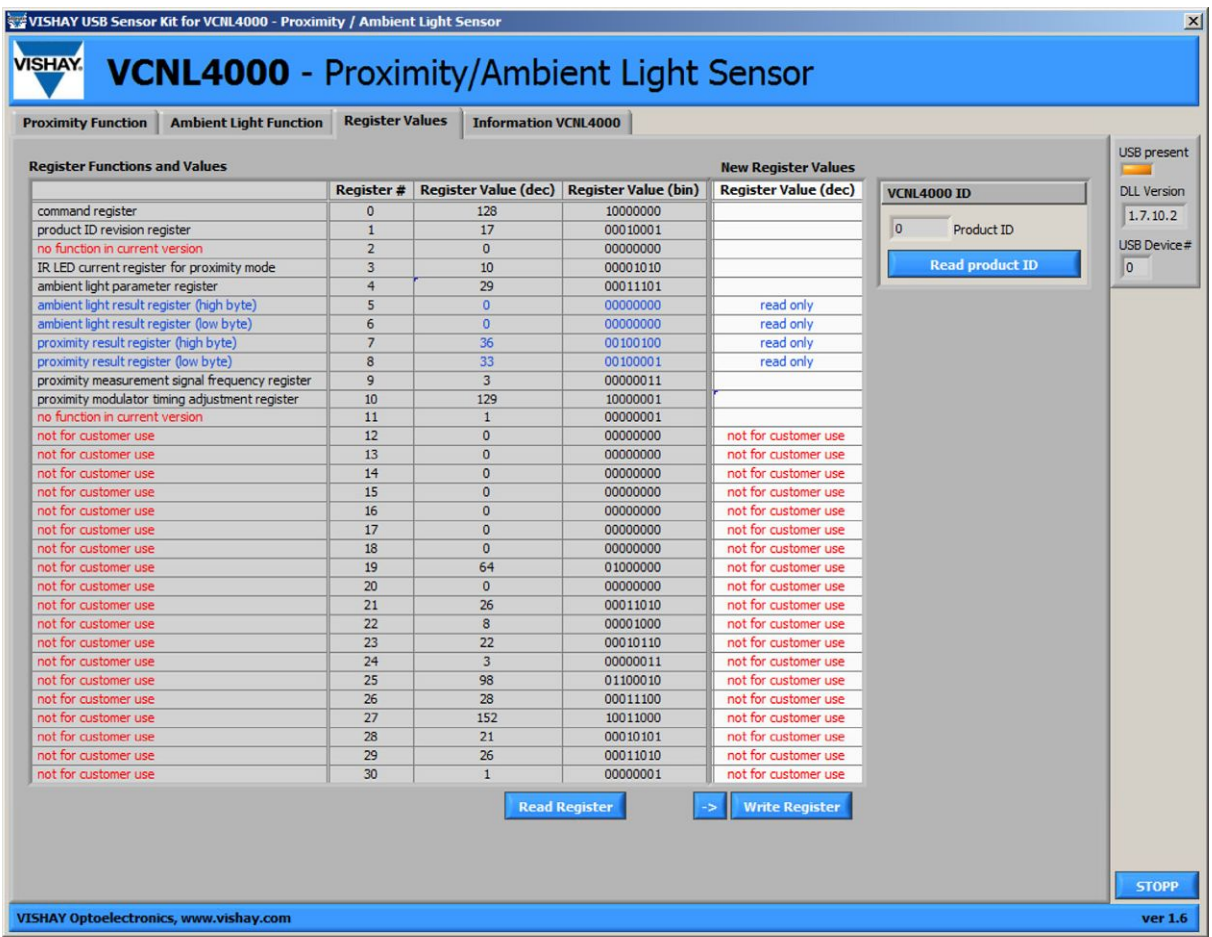
With compensation offset active, at a range of 10 mm, the reflection of the object results in an output count of approximately 1000 counts. At a range of 5 mm, the reflection of the object results in an output count of approximately 3000 counts. Again, with compensation offset active, the digital signal in the lower frame shows only the counts related to the reflected signal.

Display Range

Display a specific range of readings by entering a minimum reading number on the right side of the x-axis and the maximum reading number on the left side of the x-axis. Type over the existing displayed value. This feature is only available when measurements have stopped.

Register Values

The actual proximity value is available by selecting the Register Value tab. The high 16-bit value is stored in register#7 and the low value is stored in register #8. Register #7 equals 36 (dec) [00100100] and register #8 equals 33 (dec) [00100001]. See screen shot 2.



	Register #	Register Value (dec)	Register Value (bin)	Register Value (dec)
command register	0	128	10000000	
product ID revision register	1	17	00010001	
no function in current version	2	0	00000000	
IR LED current register for proximity mode	3	10	00001010	
ambient light parameter register	4	29	00011101	
ambient light result register (high byte)	5	0	00000000	read only
ambient light result register (low byte)	6	0	00000000	read only
proximity result register (high byte)	7	36	00100100	read only
proximity result register (low byte)	8	33	00100001	read only
proximity measurement signal frequency register	9	3	00000011	
proximity modulator timing adjustment register	10	129	10000001	
no function in current version	11	1	00000001	
not for customer use	12	0	00000000	not for customer use
not for customer use	13	0	00000000	not for customer use
not for customer use	14	0	00000000	not for customer use
not for customer use	15	0	00000000	not for customer use
not for customer use	16	0	00000000	not for customer use
not for customer use	17	0	00000000	not for customer use
not for customer use	18	0	00000000	not for customer use
not for customer use	19	64	01000000	not for customer use
not for customer use	20	0	00000000	not for customer use
not for customer use	21	26	00011010	not for customer use
not for customer use	22	8	00001000	not for customer use
not for customer use	23	22	00010110	not for customer use
not for customer use	24	3	00000011	not for customer use
not for customer use	25	98	01100010	not for customer use
not for customer use	26	28	00011100	not for customer use
not for customer use	27	152	10011000	not for customer use
not for customer use	28	21	00010101	not for customer use
not for customer use	29	26	00011010	not for customer use
not for customer use	30	1	00000001	not for customer use

Screen Shot 2

FORMAT FEATURES - PROXIMITY

To Copy Graph

Right click within the upper or lower window and select "Copy Data".

To Change Line Color

Click inside the small white rectangle located between the upper and lower signal windows to change line colors, patterns and other features.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

AMBIENT LIGHT FUNCTION

Ambient Mode

Select a single measurement or periodic measurement. The default setting is "single measurement (on demand)". Click 'Measure' to execute the measure function.
See screen shot 3.

Upper Window

The upper window displays the entire 16-bit measured signal from 0 to 65 535 counts.

Lower Window

The lower window displays only the active or dynamic range. The y-axis represents the number of counts and will change depending on the sensor reading.

Measurement Parameter

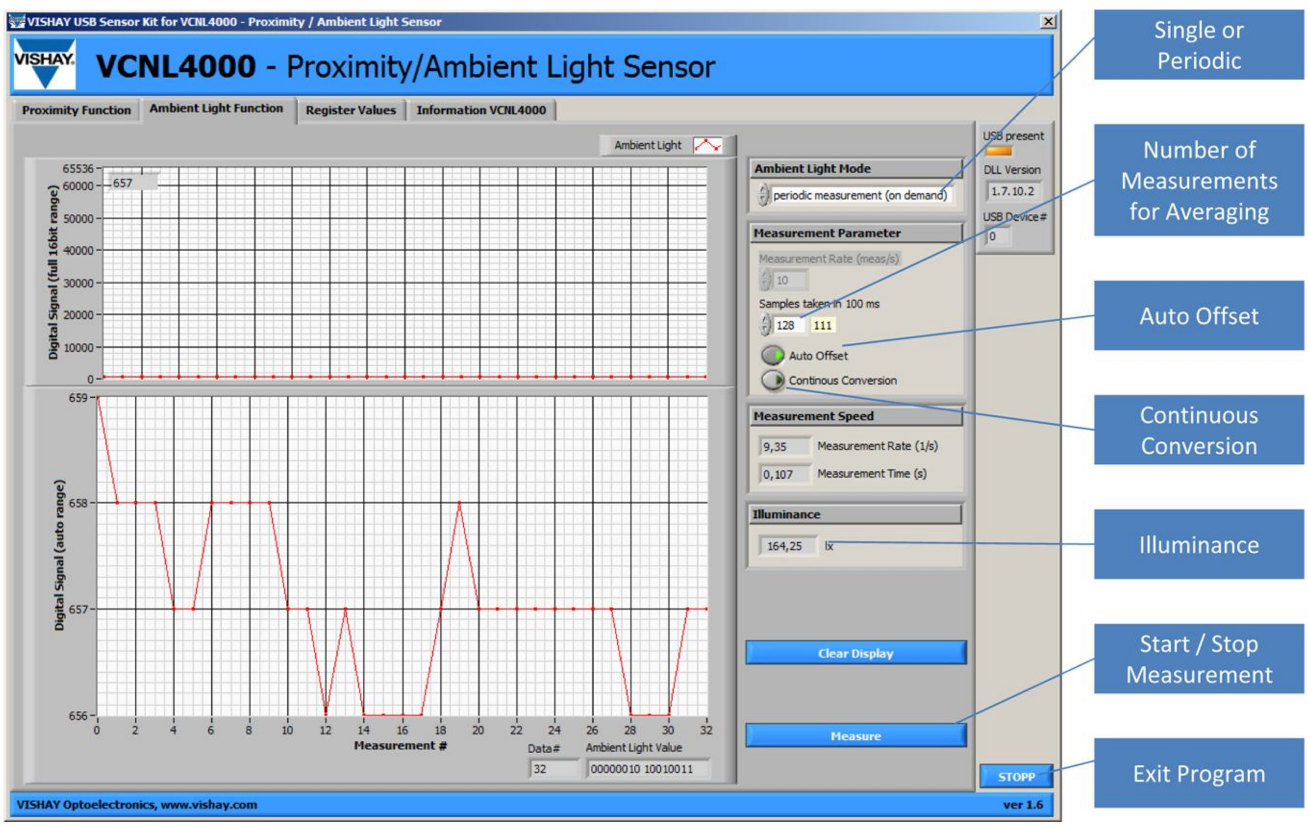
Defines the number of measurements used in the averaging function. Use the toggle button located under the "Sampled Values in 100 ms" title to scroll through available settings or click within the white value box and a pull down menu opens displaying all available values. The advantage of this function is that disturbance from 50 Hz/60 Hz sources (100 Hz/120 Hz) is significantly reduced by averaging. The default setting is 128 which sets bit 0, bit 1 and bit 2 of register #4 to 7(dec) (111); translated, 2^7 or 128 measurements within 100 ms. These 128 measurements are averaged and the result is then available within Ambient Light Result register #5 and #6.

Auto Offset

Compensates for temperature related drift of the ambient light measurements. With auto offset active, the offset value is measured before each ambient light measurement and subtracted automatically from the actual reading. The default setting is "Auto Offset" active. "Auto Offset" is bit 3 of Ambient Light Parameter Register #4 (84h).

Continuous Conversion

Allows for faster measurements. With this selected, single conversions are made in a much shorter time.



Screen Shot 3

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Clear Display

Clears the upper and lower window graphs and resets the 'Data#' to zero. The Proximity Value field near the bottom of the screen is not cleared. This field will be updated with the next measurement.

Ambient Light Value

Displays the ambient light value in binary form only.

Illuminance

Displays the ambient light level in lux. It is calculated by dividing the number of counts by four. For example, there are 615 counts which, when divided by four, results in 153.75.

Figure of Merit

The ideal ambient light sensor will produce exactly the same output (counts) for the same brightness regardless of the source of light. In reality, silicon-based ambient light sensors will produce slightly different readings for halogen (2856 K CIE illuminant A), incandescent, fluorescent and white LED sources. Figure 2 shows the average response for the VCNL4000 ambient light sensors for all the above light sources and graphs the number of counts versus lux value for each light source. The halogen lamp shows a factor of 5.1 for digital counts versus lux, the fluorescent lamp shows a factor of 3.2 and white LEDs shows a factor of 4.1. The average response is a factor of 4 counts per lux. As shown in Figure 1, a count of 1000 corresponds to 250 lx. This same count could be 200 lx for the halogen lamp or 310 lx for the fluorescent lamp. The overall tolerance for the VCNL4000 ambient light sensor for different light sources is - 22 % to + 24 %.

While the VCNL4000 has a sensitivity of 0.25 lux per count, the VCNL4010 and VCNL4020 have a sensitivity of 0.23 lux per count.

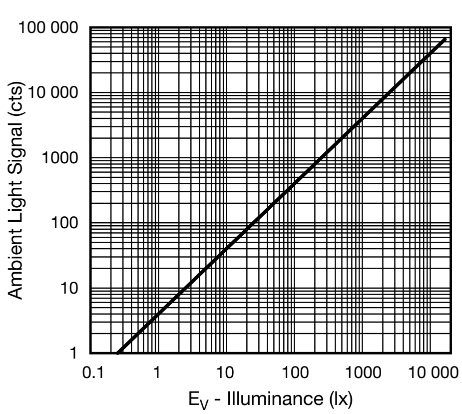


Fig. 1 - Ambient Light Values vs. Illuminance

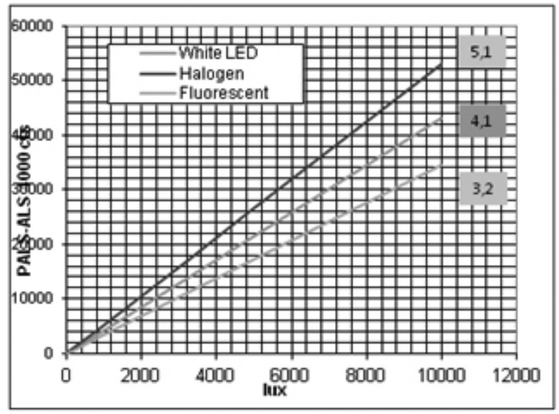


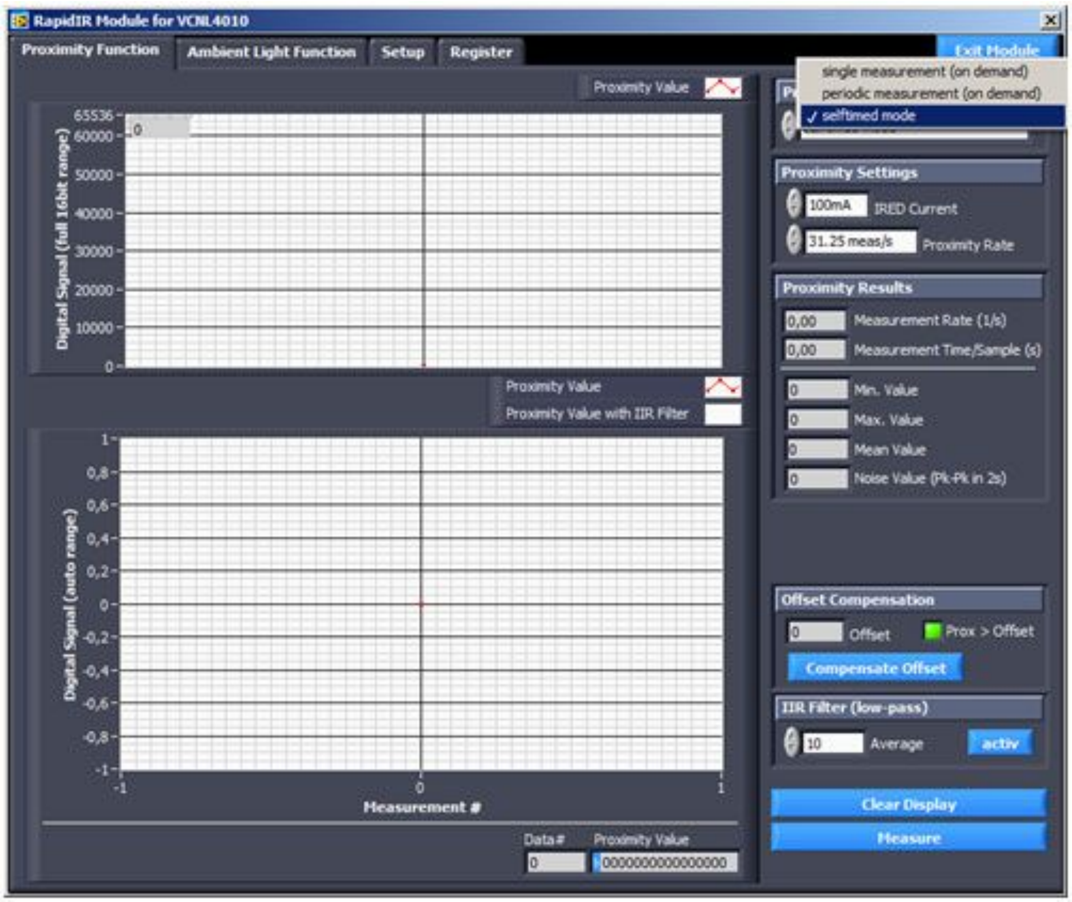
Fig. 2 - VCNL40x0 Measurements (cts) vs. Illuminance (lx)

VCNL4010 AND VCNL4020 DEMO KITS

The VCNL4010, VCNL4020, and VCNL3020 have two additional features compared to the VCNL4000: the first is an additional measurement mode called 'self timed mode' and the second is the interrupt feature. These two features required an upgrade in software.

For proximity, the 'selftimed mode' was added to 'single measurement' and 'periodic measurement' as a selection under the proximity mode section. The measurement parmeter section has been retitled as proximity settings. Under this section the measurement rate selection window was added. Rather than setting a delay time that was convereted to a rate, users can actually select the measurement rate. The measurement speed and digital noise title headers were eliminated but the data under these sections is still displayed in the new software. All other features are unchanged for proximity. See screen shot 4.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit



Screen Shot 4

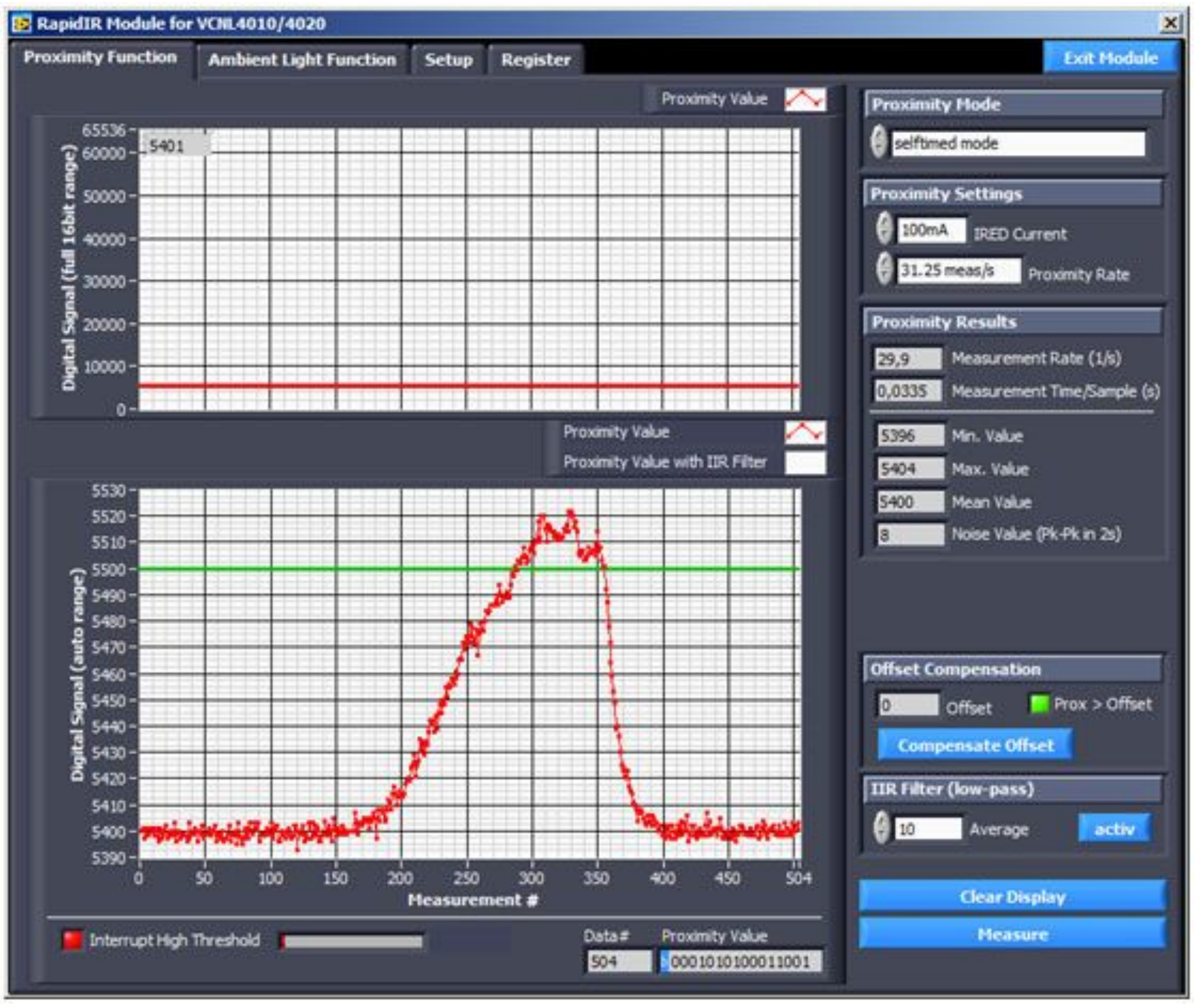
Interrupt

In order to set interrupt thresholds, it is necessary to determine the offset counts for the sensor. The offset count is application specific so it can only be determined by assembling the sensor with surrounding components with the cover or window above it. Offset counts are initially determined during development and may again be measured during assembly or final test of the end product. To determine the offset counts, the sensor's proximity performance must be determined using the worst reflective object required to be detected at the desired distance it is to be detected. By adjusting the current of the infrared emitter, the range can be established. By adjusting the measurement speed, the response rate desired can be established. All these parameters together yield the total offset counts of the sensor without an object in range.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Example:

The sensor without any cover and close surrounding of other objects/components delivers about 2300 counts with an infrared emitter current of 100 mA. With some higher components close by and with a less transmissive cover this easily could rise up to 5000 or even 20 000 counts, depending on the distance and reflectivity of the cover used. As shown in screen shot 5, the offset counts are 5400. As an example, the application needs to detect an object at a distance of 5 cm. After some development trials, the sensor measures 5500 counts when the object is 5 cm distance and the forward current is 100 mA. For the application, the upper threshold will be set to 5500 counts, the green line in screen shot 5. When the counts exceed this threshold, in other words when an object is at 5 cm distance or less, an interrupt will be generated.



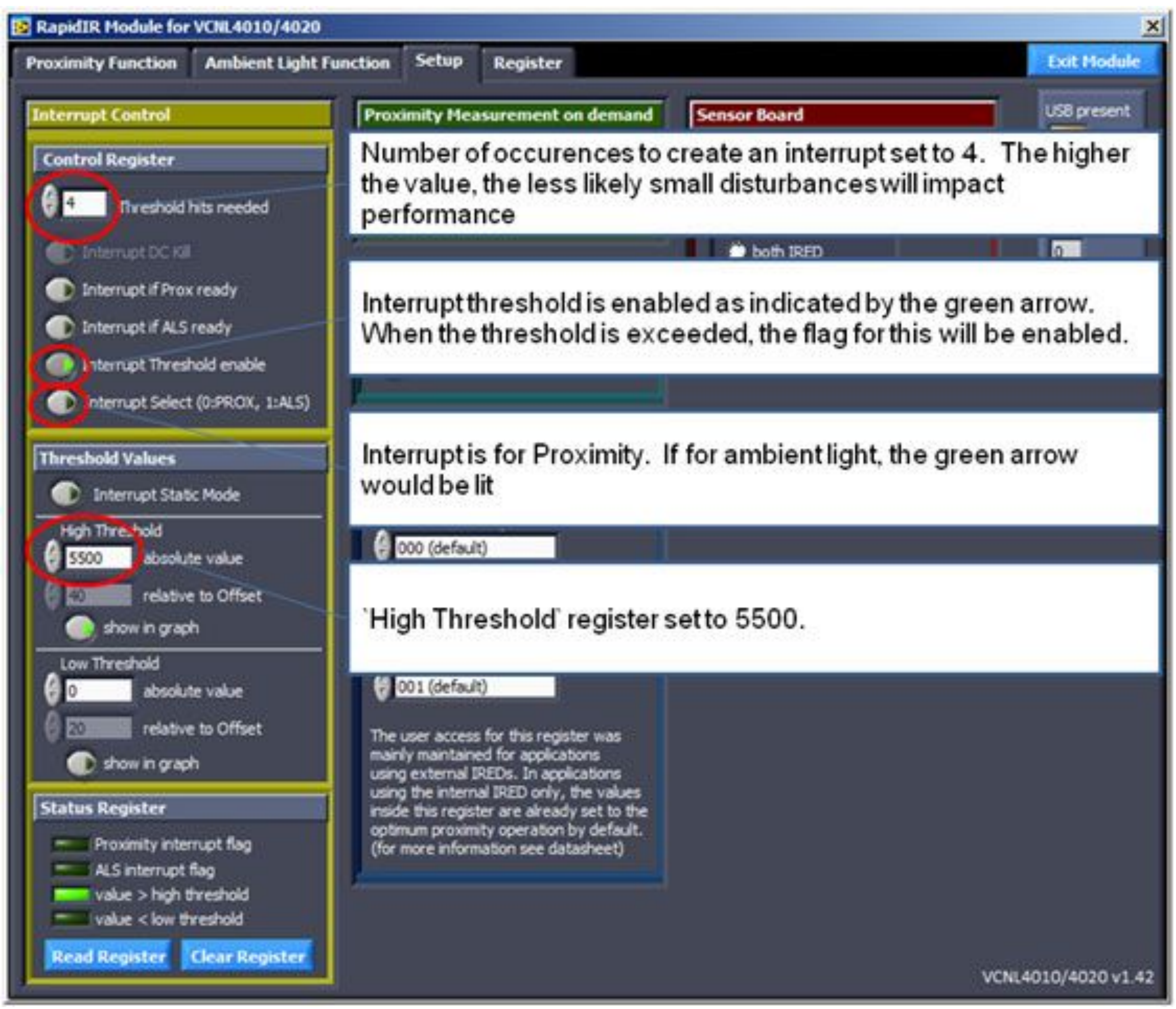
Screen Shot 5

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Screen shot 6 shows the Setup page where the Interrupt Control variables are set or defined:

- Upper threshold value
- Lower threshold value
- Number of measurements above or below a threshold needed to generate an interrupt
- Enable interrupt threshold function
- Threshold applies to proximity or ambient light.

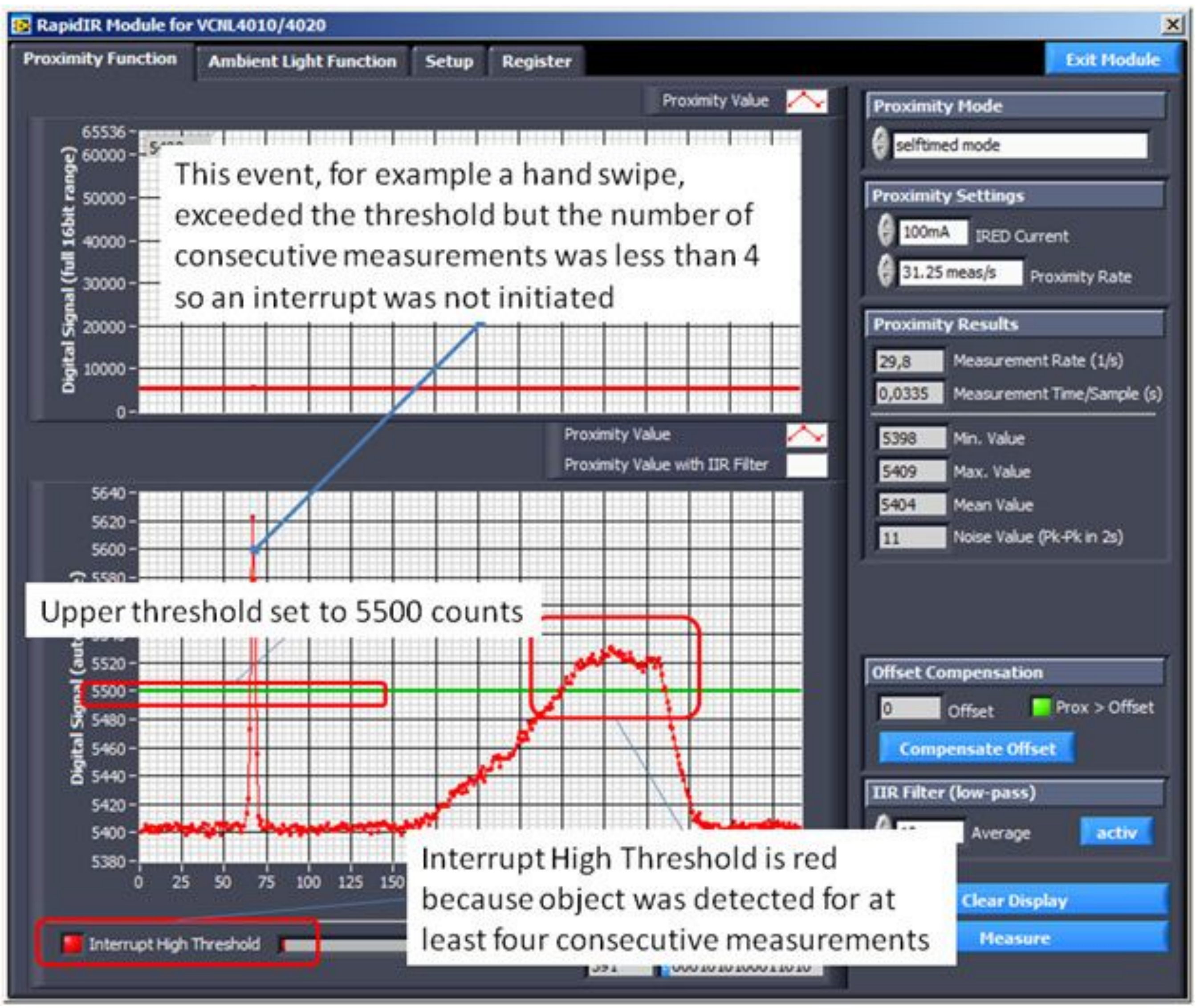
To avoid reacting to momentary object proximity, some applications will want to wait until several measurements are taken indicating an object is present or has been removed before generating an interrupt. The "Threshold hits needed" value is set to 4 in screen shot 6. The upper threshold is set to 5500 counts as discussed above. There is no lower threshold. The interrupt is enabled as indicated by the green arrow on the toggle button. Finally, the interrupt is for proximity because the green arrow is not illuminated. If it were for ambient light, the green arrow would be illuminated. Note that by clicking on the "show in graph" button under each threshold value, the user will graphically be shown the threshold value in relation to the offset and current readings.



Screen Shot 6

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

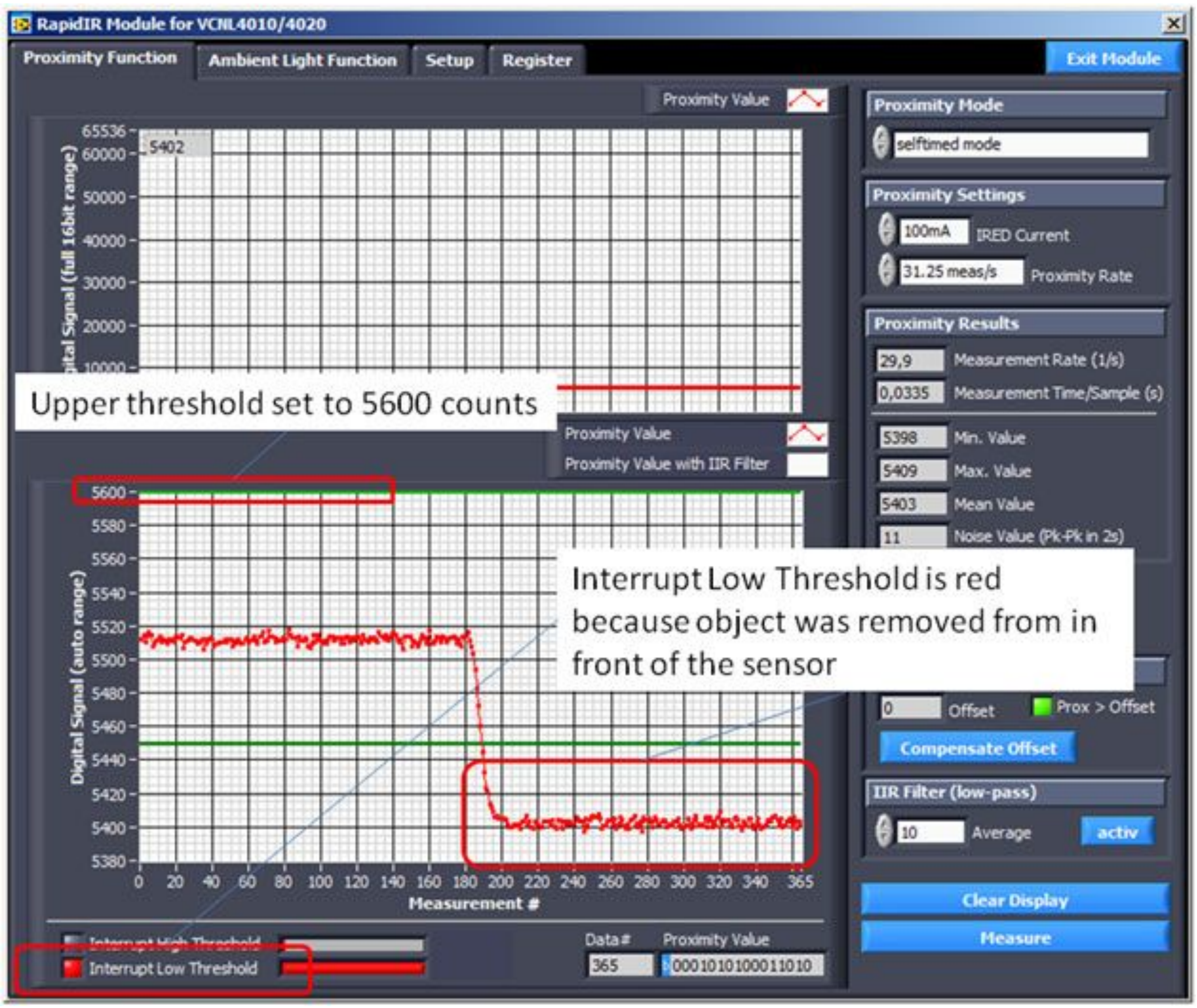
Screen shot 7 demonstrates how a brief event, for example a quick swipe of a hand, exceeded the threshold but the number of consecutive measurements was less than 4 so an interrupt was not generated. Following this event, an object is within 5 cm for long enough for an interrupt to be generated. The "Interrupt High Threshold" indicator in the lower left corner is illuminated (red). Once an object is detected, there are a number of possible actions an application can take. Continuous polling can be initiated to monitor the object's proximity. Or, the current interrupt could be cleared, threshold values reprogrammed and the microcontroller freed to perform other activities or to sleep until an event occurs that generates a new interrrupt.



Screen Shot 7

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

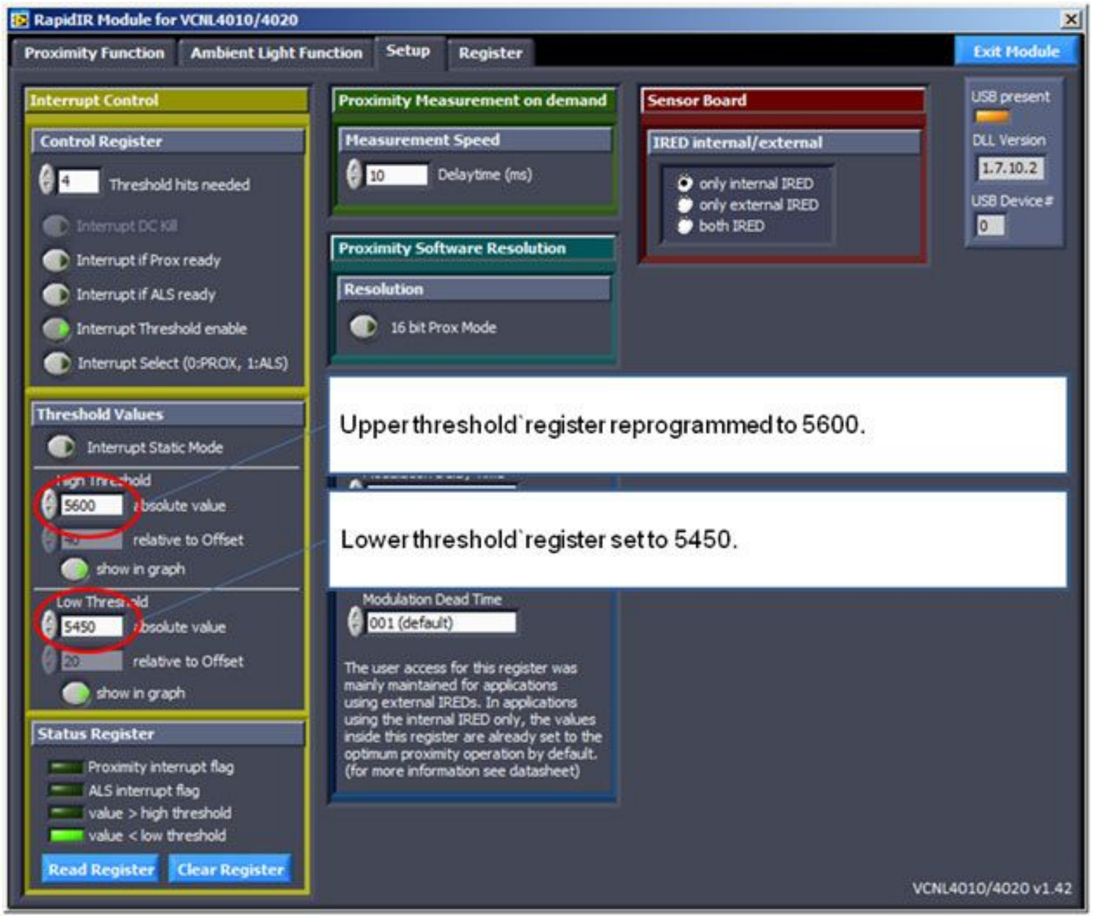
Screen shot 8 shows how the upper threshold is reprogrammed to be high enough so that it will not 'be in play' anymore, for example 65 535 counts. To be able to show it in the lower window, the value has been set to 5600 for this example. The application needs to now initiate an action when the object is no longer present. In a smart phone application for example, the screen backlight and touch function is turned off when the phone is brought to the users ear (upper threshold) and should turn back on when the phone is removed from being near the user's ear (lower threshold). The lower threshold should be above the offset counts but below the present proximity counts. In this example, the lower threshold is set to 5450 counts. Screen shot 8 also shows that the object is removed and the signal goes below the lower threshold. The "Interrupt Low Thresold" indicator in the lower left corner is illuminated (red).



Screen Shot 8

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

Screen shot 9 shows that the status bit indicator for low threshold, “value < low threshold”, has been illuminated **(int_th_lo = 1)**.



Screen Shot 9

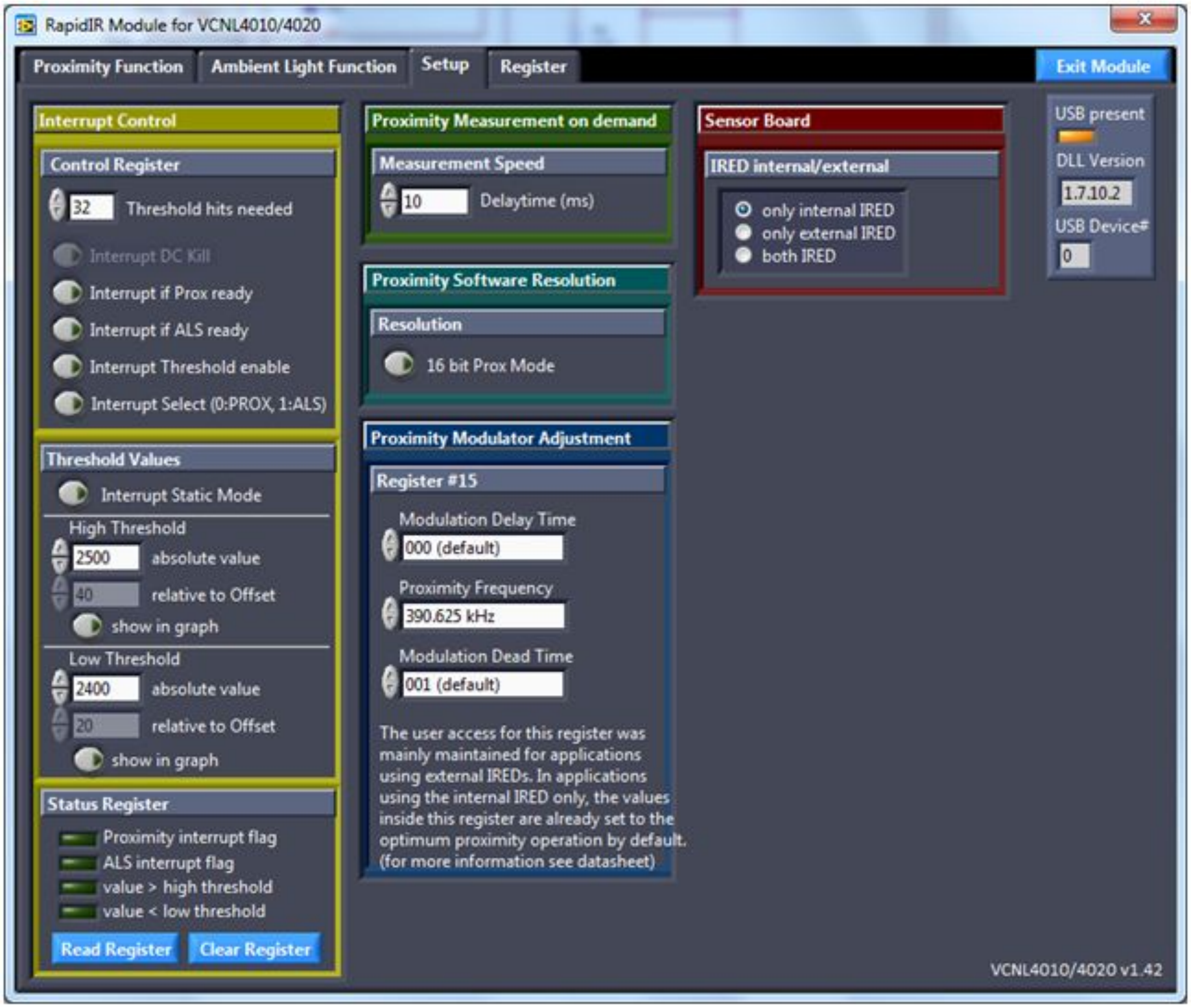
External Emitter Settings

In screen shot 10 the setup screen for the VCNL4010 and VCNL4020 is shown. Under the red sensor board section, the default “internal emitter” indicator is illuminated. Users have the option of selecting the use of an external emitter or using both internal and external emitter. The supply voltage for the external emitter is called VIR and connected via the USB controller board to a 3.3 V power supply, see Figure 6, 7, and 8. It can be connected to a separate power supply. If internal and external infrared emitters will be driven in series, they need to be connected to a higher voltage.

The blue proximity modulator adjustment section of the setup screen shows default values for the use of the integrated infrared emitter. When using external emitters or a combination of an internal and external emitter, the modulation delay time, modulation dead time, and proximity frequency may need to be adjusted. Please refer to the VCNL4010 and VCNL4020 Application Notes for further details.

The green proximity measurement on demand section of the Setup screen allows users to adjust the delay between two consecutive measurements. Any value between 1 and 10 000 can be entered in the field. A value of 1 results in 1 ms between measurements (200 measurement/s) while a value of 10 000 results in about 10 s between measurements.

VCNL4000, VCNL4010, and VCNL4020 Demo Kit



Screen Shot 10

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

SCHEMATIC

VCNL4000 Board Layout

The sensor board includes the VCNL4000 sensor and a 470nF capacitor. It is connected to the common 3.3 V power supply used for the infrared emitter on Pin1 and the ASIC_V_{DD} on Pin7. As is shown in Figure 3, large areas of the top side are ground plane to avoid ESD problems when handling the board. The odd-numbered pins are on top side and the even-numbered on the bottom side

Fig. 3 - VCNL4000 Sensor Board

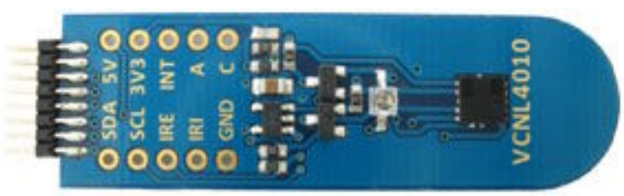


Fig. 4 - VCNL4010 Sensor Board

Fig. 5 - VCNL4020 Sensor Board

VCNL4010 and VCNL4020 Board Layout

The VCNL4010 and VCNL4020 sensor boards, Figure 4 and 5, have test points to allow simple evaluation and/or connection to the customer's application board. The boards also include an external emitter (VSMF2890GX01) to increase the measurement range to 500 mm and supporting FET's to use the integrated emitter, the external emitter or both in series.

Schematic

Only 4 wires are needed to connect to VCNL40x0:

- SDA (J1) and SCL (J3) need to be connected to the microcontroller
- V_{DD} (J11) needs to be connected to the power supply
- Ground pin (J2/J15) needs to be connected to the application ground plane.

See Figure 6, 7, and 8.

Useful Links

I^{2}C specification Version 2.1:
www.nxp.com/acrobat_download2/literature/9398/39340011.pdf

I^{2}C specification Version 3.0:
www.nxp.com/documents/user_manual/UM10204.pdf

Male pin connector 2199SB-XXG-301523
www.almita.com.tw/pro25.htm
Female pin connector 2200SG-XG-A1 ???

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

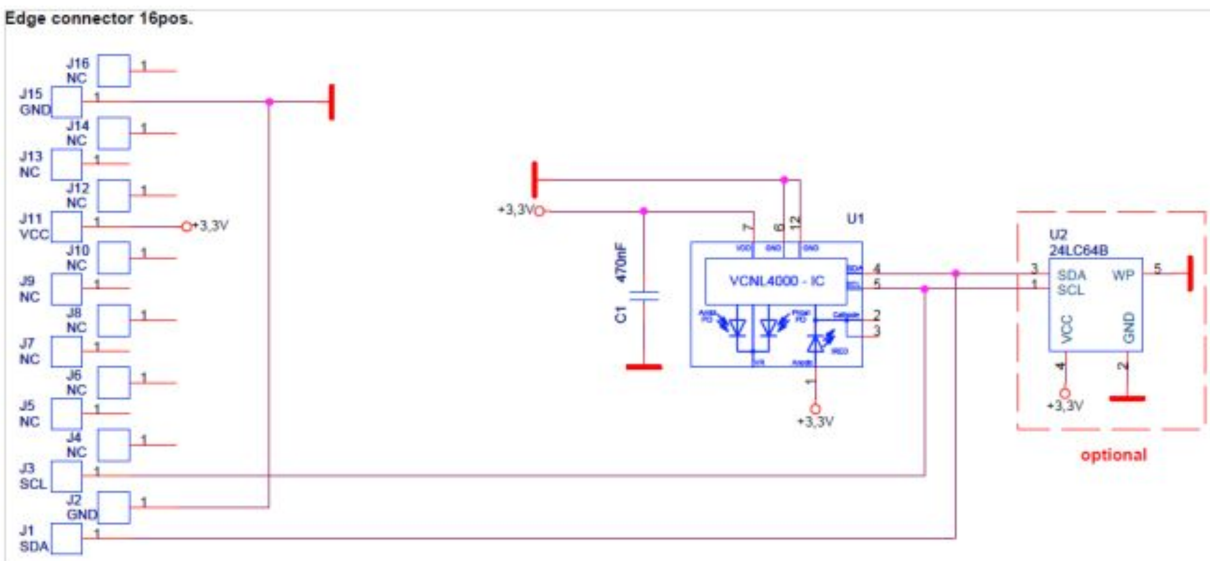


Fig. 6 - Circuit diagram of VNCL4000 Sensor Board

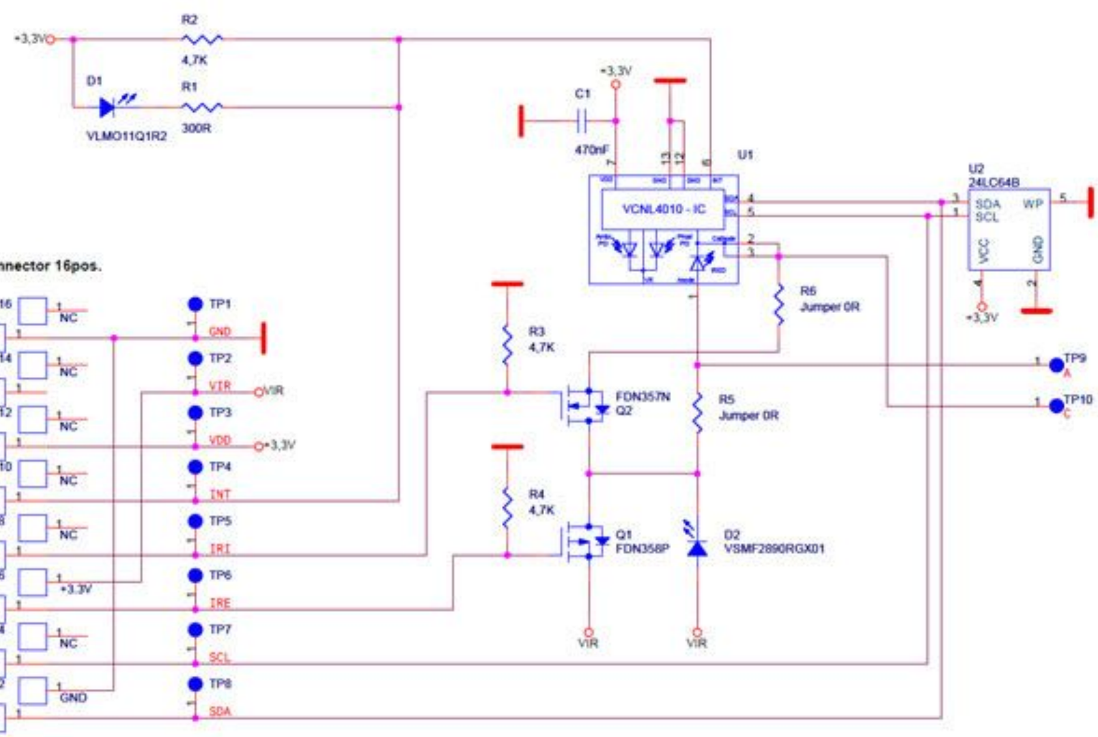


Fig. 7 - Circuit diagramm of VNCL4010 Sensor Board

VCNL4000, VCNL4010, and VCNL4020 Demo Kit

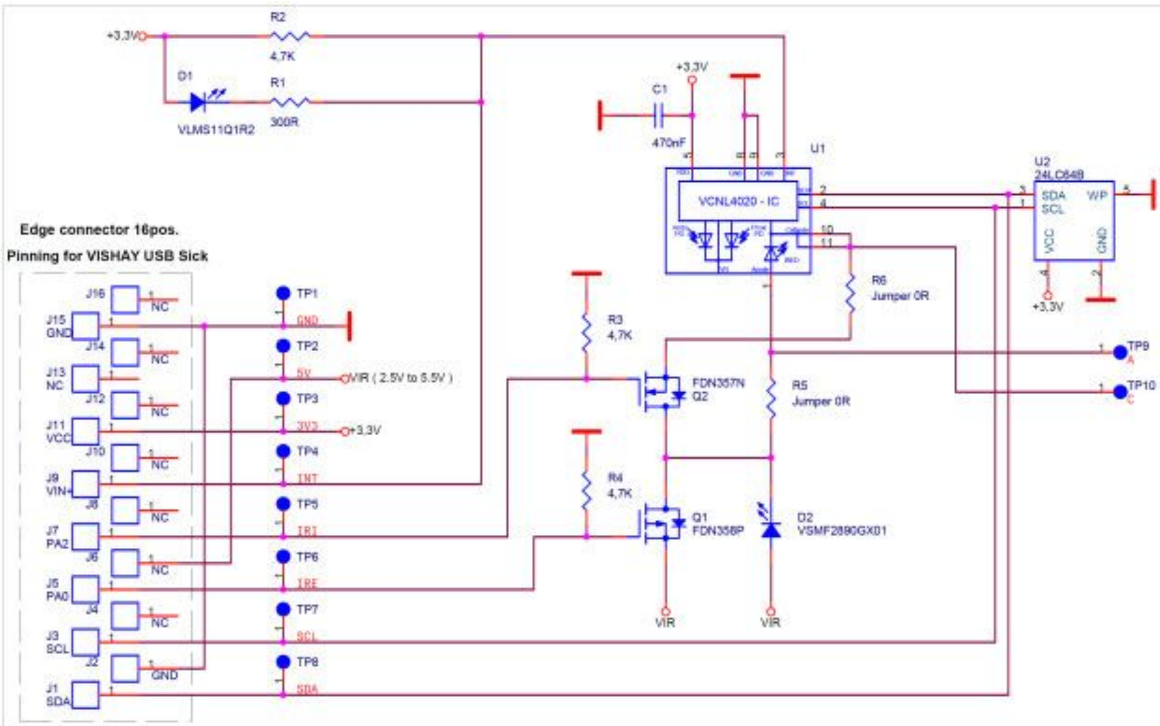


Fig. 8 - Circuit diagramm of VCNL4020 Sensor Board

The two switching information (IRI and IRE) are delivered from the USB controller and follow below given specification:

IRI	IRE	IRED operating
L	L	only internal IRED
L	H	both IREDs
H	L	forbidden
H	H	only external IRED

Fig. 9 - GPIO signals for VCNL4010 Sensor Board

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).

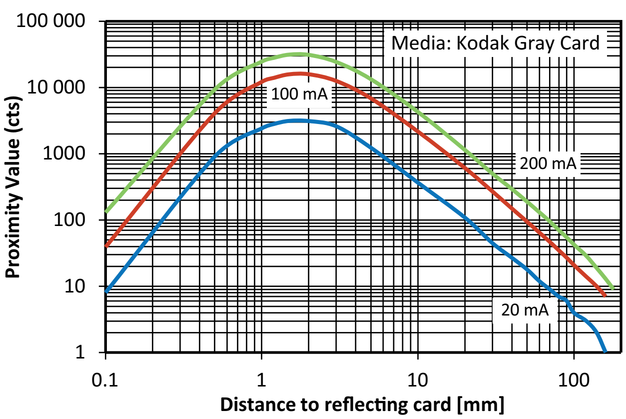


Fig. 1 - Proximity Value vs. Distance

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.

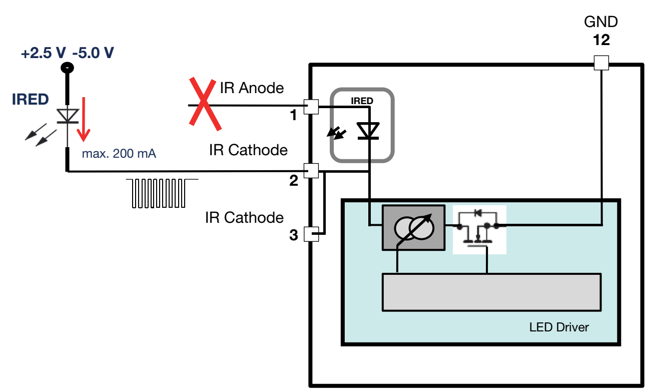


Fig. 2 - VCNL4010 Principle Operation

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

Extended Detection Range with VCNL Family of Proximity Sensors

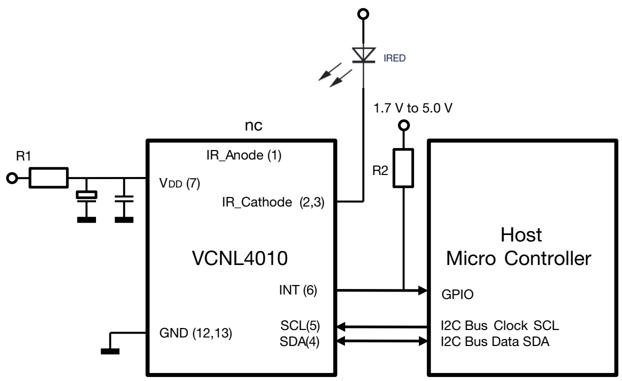


Fig. 3 - VCNL4010 Circuitry with an External IRED

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.

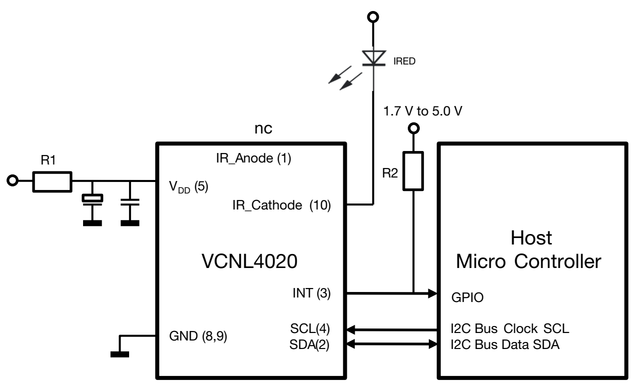


Fig. 4 - VCNL4020, VCNL4020X01, or VCNL3020 Circuitry with an External IRED

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 %.

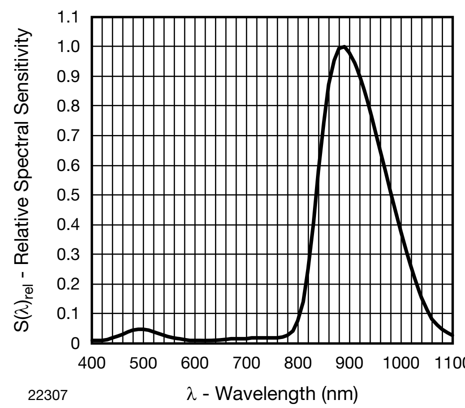


Fig. 5 - Spectral Sensitivity of Proximity PIN Photodiode

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.

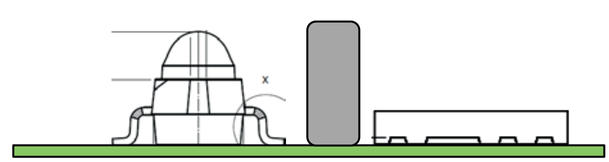


Fig. 7 - Light Barrier in-between IRED and Sensor

Extended Detection Range with VCNL Family of Proximity Sensors

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.

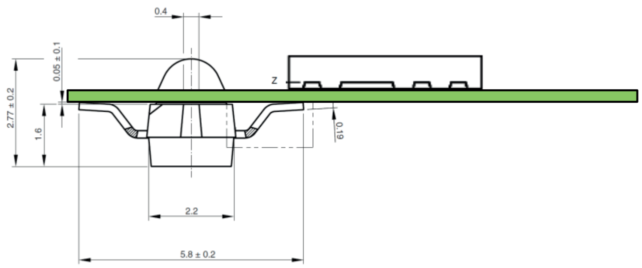


Fig. 8 - Reverse Gullwing used as an External IRED

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.

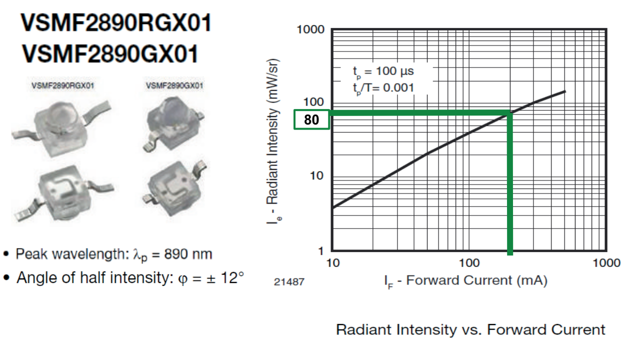


Fig. 9 - VSMF2890X01 and Radiant Intensity Diagram

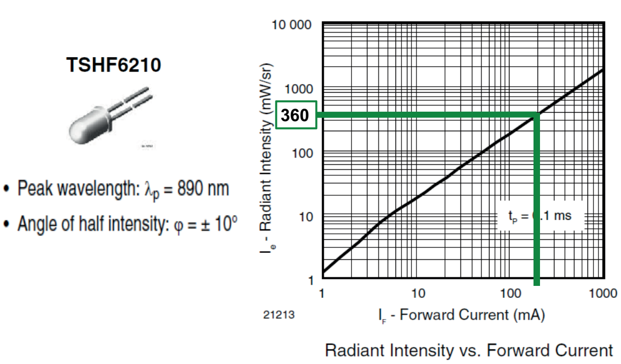


Fig. 10 - TSHF6210 and Radiant Intensity Diagram

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.

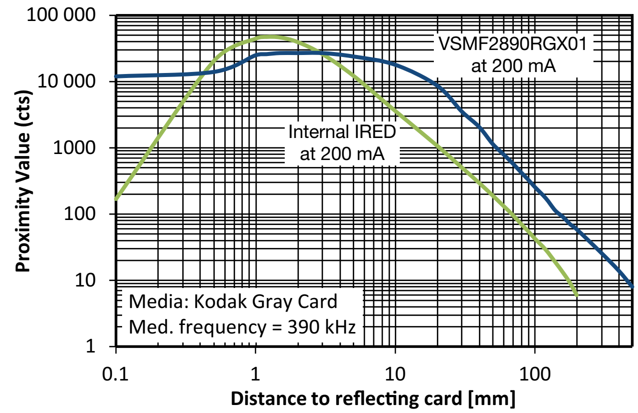


Fig. 11 - Proximity Value vs. Distance for Internal and External IRED (VSMF2890GX01)

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.

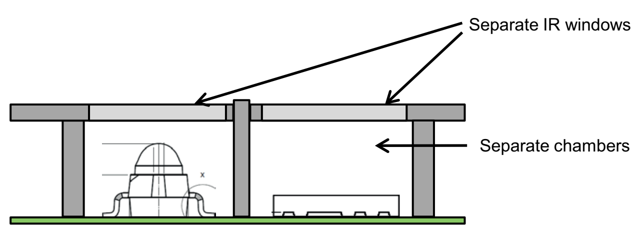


Fig. 12 - Emitter and Detector Totally Separated

Extended Detection Range with VCNL Family of Proximity Sensors

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.

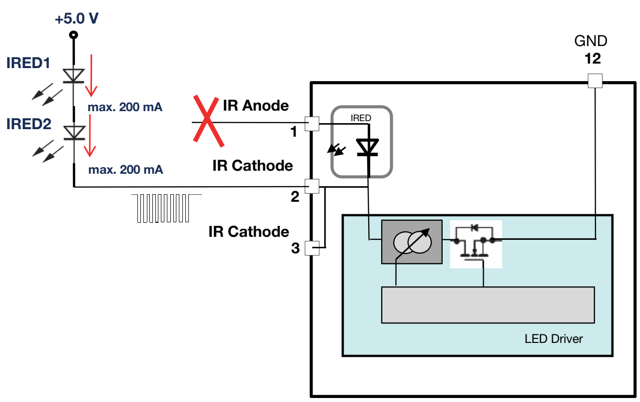


Fig. 13 - Two IREDs in Series Connected to the VCNL4010

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.

Symbols and Terminology

A **Anode**, anode terminal

A **Ampere**, SI unit of electrical current

A **Radiant sensitive area**, that area which is radiant sensitive for a specified range

a **Distance**, e.g. between the emitter (source) and the detector

B **Base**, base terminal

BER **Bit Error Rate**

bit/s **Data rate or signaling rate** 1000 bit/s = 1 kbit/s, 10^6 bit/s = 1 Mbit/s

C **Capacitance,** unit: F (farad) = C/V

C **Coulomb,** C = s x A

C **Cathode**, cathode terminal

C **Collector**, collector terminal

°C **Degree Celsius,** Celsius temperature, symbol t, and is defined by the quantity equation $t = T - T_0$. The unit of Celsius temperature is the degree Celsius, symbol °C. The numerical value of a Celsius temperature t expressed in degrees Celsius is given by t/°C = T/K - 273.15
It follows from the definition of t that the degree Celsius is equal in magnitude to the Kelvin, which in turn implies that the numerical value of a given temperature difference or temperature interval whose value is expressed in the unit degree Celsius (°C) is equal to the numerical value of the same difference or interval when its value is expressed in the unit Kelvin (K).

C_{CEO} **Collector emitter capacitance,** Capacitance between the collector and the emitter with open base

cd **Candela,** SI unit of luminous intensity. The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 Hz x 1012 Hz and that has a radiant intensity in that direction of 1/683 W per steradian. (16th General Conference of Weights and Measures, 1979), 1 cd = 1 lm · sr^{-1}

C_D **Diode capacitance,** total capacitance effective between the diode terminals due to case, junction and parasitic capacitances

Cj **Junction capacitance,** capacitance due to a p-n junction of a diode, decreases with increasing reverse voltage

d **Apparent (of virtual) source size** (of an emitter), the measured diameter of an optical source used to calculate the eye safety laser class of the source. See IEC 60825-1 and EN ISO 11146-1

D* **Detectivity** $\sqrt{A}/NEP$

E **Emitter,** Emitter terminal (phototransistor)

E_A **Illumination at standard illuminant A**, according to DIN 5033 and IEC 306-1, illumination emitted from a tungsten filament lamp with a color temperature T_f = 2855.6 K, which is equivalent to standard illuminant A, unit: lx (Lux) or klx

$E_{A\ amb}$ **Ambient illumination** at standard illuminant A

echo-off Unprecise term to describe the behavior of the output of IrDA® transceivers during transmission. “Echo-off” means that by blocking the receiver the output RXD is quiet during transmission

echo-on Unprecise term to describe the behavior of the output of IrDA® transceivers during transmission. “Echo-on” means that the receiver output RXD is active but often undefined during transmission. For correct data reception after transmission the receiver channel must be cleared during the latency period

E_e, E **Irradiance** (at a point of a surface), quotient of the radiant flux $d\Phi_e$ incident on an element of the surface containing the point, by the area dA of that element. Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \cdot d\Omega$, where L_e is the radiance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point

$$E_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} (L_e \cdot \cos\theta \cdot d\Omega)$$

unit: W · m^{-2}

E_v, E **Illuminance** (at a point of a surface), quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element. Equivalent definition. Integral, taken over the hemisphere visible from the givenpoint, of the expression $L_v \cdot \cos\theta \cdot d\Omega$, where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point

$$E_v = \frac{d\Phi_v}{dA} = \int_{2\pi sr} (L_v \cdot \cos\theta \cdot d\Omega)$$

unit: lx = lm · m^{-2}

F **Farad,** unit: F = C/V

f **Frequency,** unit: s^{-1}, Hz (Hertz)

f_c, f_{cd} **Cut-off frequency** - detector devices, the frequency at which, for constant signal modulation depth of the input radiant power, the demodulated signal power has decreased to ½ of its low frequency value. Example: The incident radiation generates a photocurrent or a photo voltage 0.707 times the value of radiation at f = 1 kHz
(3 dB signal drop, other references may occur as e.g. 6 dB or 10 dB)

f_s **Switching frequency**

FIR **Fast infrared,** as SIR, data rate 4 Mbit/s

I_a **Light current,** general: current which flows through a device due to irradiation/illumination

I_B **Base current**

I_{BM} **Base peak current**

I_C **Collector current**

I_{ca} **Collector light current,** collector current under irradiation. Collector current which flows at a specified illumination/irradiation

I_{CEO} **Collector dark current, with open base,** collector emitter dark current. For radiant sensitive devices with open base and without illumination/radiation (E = 0)

I_{CM} **Repetitive peak collector current**

idle Mode of operation where the device (e.g. a transceiver) is fully operational and expecting to receive a signal for operation e.g in case of a transceiver waiting to receive an optical input or to send an optical output as response to an applied electrical signal.

I_e, I **Radiant intensity** (of a source, in a given direction), quotient of the radiant flux d Φ_e leaving the source and propagated in the element of solid angle dΩ containing the given direction, by the element of solid angle.
$I_e = d\Phi_e/d\Omega$, unit: W · sr $^{-1}$
Note: The radiant intensity I_e of emitters is typically measured with an angle < 0.01 sr on mechanical axis or off-axis in the maximum of the irradiation pattern.

I_F **Continuous forward current,** the current flowing through a diode in the forward direction

I_{FAV} **Average (mean) forward current**

I_{FM} **Peak forward current**

I_{FSM} **Surge forward current**

I_k **Short-circuit current,** that value of the current which flows when a photovoltaic cell or a photodiode is short circuited ($R_L << R_i$) at its terminals

I_o **DC output current**

I_{ph} **Photocurrent,** that part of the output current of a photoelectric detector, which is caused by incident radiation.

I_R **Reverse current, leakage current,** current which flows through a reverse biased semiconductor p-n-junction

IR **Abbreviation for infrared**

I_{ra} **Reverse current under irradiation,** reverse light current which flows due to a specified irradiation/illumination in a photoelectric device
$I_{ra} = I_{ro} + I_{ph}$

IrDA® **Infrared Data Association,** no profit organization generating infrared data communication standards

IRED **Infrared emitting diode,** solid state device embodying a p-n junction, emitting infrared radiation when excited by an electric current. See also LED: solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current.

I_{ro} **Reverse dark current, dark current,** reverse current flowing through a photoelectric device in the absence of irradiation

IRPHY Version 1.0, **SIR IrDA®, data communication specification** covering data rates from 2.4 kbit/s to 115.2 kbit/s and a guaranteed operating range more than one meter in a cone of ± 15°

IRPHY Version 1.1, MIR and FIR were implemented in the IrDA® standard with the version 1.1, replacing version 1.0

IRPHY Version 1.2, added the SIR low power standard to the IrDA® standard, replacing version 1.1. The SIR low power standard describes a current saving implementation with reduced range (min. 20 cm to other low power devices and min. 30 cm to full range devices).

IRPHY Version 1.3, extended the low power option to the higher bit rates of MIR and FIR replacing version 1.2.

IRPHY Version 1.4, VFIR was added, replacing version 1.3

I_{SB} **Quiescent current**

I_{SD} **Supply current in dark ambient**

I_{SH} **Supply current in bright ambient**

I_v, I **Luminous intensity** (of a source, in a given direction), quotient of the luminous flux dΦ_v leaving the source and propagated in the element of solid angle dΩ containing the given direction, by the element of solid angle. $I_e = d\Phi_V/d\Omega$, unit: cd · sr $^{-1}$
Note: The luminous intensity I_v of emitters is typically measured with an angle < 0.01 sr on mechanical axis or off-axis in the maximum of the irradiation pattern.

K **luminous efficacy** of radiation, quotient of the luminous flux Φ_v by the corresponding radiant flux Φ_e: $K = \Phi_v / \Phi_e$, unit: lm · W^{-1}
Note: When applied to monochromatic radiations, the maximum value of K(λ) is denoted by the symbol K_m.
K_m = 683 lm · W^{-1} for $\nu_m = 540 \times 10^{12}$ Hz
($\lambda_m \approx$ 555 nm) for photopic vision.
K'_m = 1700 lm · W^{-1} for $\lambda'_m \approx$ 507 nm for scotopic vision. For other wavelengths :
$K(\lambda) = K_m V(\lambda)$ and $K'(\lambda) = K'_m V'(\lambda)$

K **Kelvin,** SI unit of thermodynamic temperature, is the fraction 1/273.15 of the thermodynamic temperature of the triple point of water (13th CGPM (1967), Resolution 4). The unit Kelvin and its symbol K should be used to express an interval or a difference of temperature.
Note: In addition to the thermodynamic

temperature (symbol T), expressed in Kelvins, use is also made of Celsius temperature (symbol t) defined by the equation $t = T - T_0$, where $T_0 = 273.15$ K by definition. To express Celsius temperature, the unit "degree Celsius", which is equal to the unit "Kelvin" is used; in this case, "degree Celsius" is a special name used in place of "Kelvin". An interval or difference of Celsius temperature can, however, be expressed in Kelvins as well as in degrees Celsius.

Latency **Receiver latency allowance** (in ms or µs) is the maximum time after a node ceases transmitting before the node's receiving recovers its specified sensitivity

LED and IRED
Light **E**mitting **D**iode, LED: solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current. The term LED is correct only for visible radiation, because light is defined as visible radiation (see Radiation and Light). For infrared emitting diodes the term IRED is the correct term. Nevertheless it is common but not correct to use "LED" also for IREDs.

L_e; L **Radiance** (in a given direction, at a given point of a real or imaginary surface).
Quantity defined by the formula

$$L_e = \frac{d\Phi_v}{dA \cdot \cos\theta \cdot d\Omega},$$

where $d\Phi_e$ is the radiant flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point; θ is the angle between the normal to that section and the direction of the beam, unit: $W \cdot m^{-2} \cdot sr^{-1}$

lm **Lumen,** unit for luminous flux

lx **Lux,** unit for illuminance

m **Meter,** SI unit of length

M_e; M **Radiant exitance** (at a point of a surface) - Quotient of the radiant flux $d\Phi_e$ leaving an element of the surface containing the point, by the area dA of that element. Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \cdot d\Omega$, where L_e is the radiance at the given point in the various directions of the emitted elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

$$M_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} L_e \cdot \cos\theta \cdot d\Omega$$

unit: $W \cdot m^{-2}$

MIR **Medium speed IR,** as SIR, with the data rate 576 kbit/s to 1152 kbit/s

Mode Electrical input or output port of a transceiver device to set the receiver bandwidth

N.A. **Numerical Aperture,** N.A. = sin α/2
Term used for the characteristic of sensitivity or intensity angles of fiber optics and objectives

NEP **Noise equivalent power**

P_{tot} **Total power dissipation**

P_v **Power dissipation, general**

Radiation and Light
Visible radiation, any optical radiation capable of causing a visual sensation directly.
Note: There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

Radiation and Light
Optical radiation, electromagnetic radiation at wavelengths between the region of transition to X-rays (λ = 1 nm) and the region of transition to radio waves (λ = 1 mm)

Radiation and Light IR
Infrared radiation, optical radiation for which the wavelengths are longer than those for visible radiation.
Note: For infrared radiation, the range between 780 nm and 1 mm is commonly sub-divided into:
IR-A 780 nm to 1400 nm
IR-B 1.4 µm to 3 µm
IR-C 3 µm to 1 mm

R_D **Dark resistance**

R_F **Feedback resistor**

R_i **Internal resistance**

R_{is} **Isolation resistance**

R_L **Load resistance**

R_S **Serial resistance**

R_{sh} **Shunt resistance,** the shunt resistance of a detector diode is the dynamic resistance of the diode at zero bias. Typically it is measured at a voltage of 10 mV forward or reverse, or peak-to-peak

R_{thJA} **Thermal resistance,** junction to ambient

R_{thJC} **Thermal resistance,** junction to case

RXD **Electrical data output** port of a transceiver device

s **Second,** SI-unit of time 1 h = 60 min = 3600 s

S **Absolute sensitivity**
Ratio of the output value Y of a radiant-sensitive device to the input value X of a physical quantity: S = Y/X, units: e.g. A/lx, A/W, A/(W/m^2)

s(λ_p) **Spectral sensitivity** at a wavelength λ_p

$s(\lambda)$ **Absolute spectral sensitivity** at a wavelength λ, the ratio of the output quantity y to the radiant input quantity x in the range of wavelengths
λ to $\lambda + \Delta\lambda$
$s(\lambda) = dy(\lambda)/dx(\lambda)$
E.g., the radiant power $\Phi_e(\lambda)$ at a specified wavelength λ falls on the radiationsensitive area of a detector and generates a photocurrent $I_{ph} \cdot s(\lambda)$ is the ratio between the generated photocurrent Iph and the radiant power $\Phi_e(\lambda)$ which falls on the detector. $s(\lambda) = I_{ph} / \Phi_e(\lambda)$, unit: A/W

$s(\lambda)_{rel}$ **Spectral sensitivity, relative,** ratio of the spectral sensitivity $s(\lambda)$ at any considered wavelength to the spectral sensitivity $s(\lambda_0)$ at a certain wavelength λ_0 taken as a reference
$s(\lambda)_{rel} = s(\lambda)/s(\lambda_0)$

$s(\lambda_0)$ **Spectral sensitivity** at a reference wavelength λ_0

SC Electrical input port of a transceiver device to set the receiver sensitivity

SD Electrical input port of a transceiver device to shut down the transceiver

Shutdown
Mode of operation where a device is switched to a sleep mode (shut down) by an external signal or after a quiescent period keeping some functions alive to be prepared for a fast transition to operating mode. Might be in some cases identical with “standby”

SIR **Serial Infrared,** term used by IrDA® to describe infrared data transmission up to and including 115.2 kbit/s. SIR IrDA® data communication covers 2.4 kbit/s to 115.2 kbit/s, equivalent to the basic serial infrared standard introduced with the physical layer version IrPhy version 1.0

Split power supply
Term for using **separated power supplies** for different functions in transceivers. Receiver circuits need well-controlled supply voltages. IRED drivers do not need a controlled supply voltage but need much higher currents. Therefore it safes cost not to control the IRED current supply and have a separated supply. For that some modified design rules have to be taken into account for designing the ASIC. This is used in nearly all Vishay transceivers and is described in US-Patent no. 6,157,476

sr **Steradian** (sr), SI unit of solid angle Ω. Solid angle that, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere. (ISO, 31/1-2.1, 1978)
Example: The unity solid angle, in terms of geometry, is the angle subtended at the center of a sphere by an area on its surface numerically equal to the square of the radius (see figures below). Other than the figures might suggest, the shape of the area does not matter at all. Any shape on the surface of the sphere that holds the same area will define a solid angle of the same size. The unit of the solid angle is the **steradian (sr)**. Mathematically, the solid angle is dimensionless, but for practical reasons, the steradian is assigned.

Standby
Mode of operation where a device is prepared to be quickly switched into an idle or operating mode by an external signal.

T **Period of time** (duration)

T **Temperature,** 0 K = - 273.15 °C, unit: K (Kelvin)

t **Temperature,** °C (degree Celsius). Instead of t sometimes T is used not to mix up temperature T with time t

t **Time**

T_{amb} **Ambient temperature,** if self-heating is significant: temperature of the surrounding air below the device, under conditions of thermal equilibrium. If self-heating is insignificant: air temperature in the surroundings of the device

T_{amb} **Ambient temperature range,** as an absolute maximum rating: the maximum permissible ambient temperature range

T_C **Temperature coefficient,** the ratio of the relative change of an electrical quantity to the change in temperature (ΔT) which causes it under otherwise constant operating conditions

T_C **Colour temperature** (BE), the temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus, unit: K
Note: The **reciprocal colour temperature** is also used, unit K^{-1} (BE).

T_{case} **Case temperature,** the temperature measured at a specified point on the case of a semiconductor device. Unless otherwise stated, this temperature is given as the temperature of the mounting base for devices with metal can

t_d **Delay time**

t_f **Fall time,** the time interval between the upper specified value and the lower specified value on the trailing edge of the pulse.
Note: It is common to use a 90 % value of the signal for the upper specified value and a 10 % value for the lower specified value.

T_j **Junction temperature,** the spatial mean value of the temperature during operation. In the case of phototransistors, it is mainly the temperature of the collector junction because its inherent temperature is the maximum.

t_{off} **Turn-off time,** the time interval between the upper specified value on the trailing edge of the applied input pulse and the lower specified value an the trailing edge of the output pulse. $t_{off} = t_{d(off)} + t_f$

t_{on} **Turn-on time,** the time interval between the lower specified value on the trailing edge of the applied input pulse and the upper specified value an the trailing edge of the output pulse. $t_{on} = t_{d(on)} + t_f$

t_p **Pulse duration,** the time interval between the specified value on the leading edge of the pulse and the specified value an the trailing edge of the output pulse.
Note: In most cases the specified value is 50 % of the signal

t_{pi} **Input pulse duration**

t_{po} **Output pulse duration**

t_r **Rise time,** the time interval between the lower specified value and the upper specified value on the trailing edge of the pulse.
Note: It is common to use a 90 % value of the signal for the upper specified value and a 10 % value for the lower specified value t_s storage time

t_s **Storage time**

T_{sd} **Soldering temperature,** maximum allowable temperature for soldering with a specified distance from the case and its duration

T_{stg} **Storage temperature range,** the temperature range at which the device may be stored or transported without any applied voltage

TXD Electrical data input port of a transceiver device

V **Volt**

$V(\lambda)$ **Standard luminous efficiency function** for photopic vision (relative human eye sensitivity)

$V(\lambda)$, $V'(\lambda)$
Spectral luminous efficiency (of a monochromatic radiation of wavelength λ); $V(\lambda)$ for photopic vision; $V'(\lambda)$ for scotopic vision).
Ratio of the radiant flux at wavelength λ_m to that at wavelength λ such that both radiations produce equally intense luminous sensations under specified photometric conditions and λ_m is chosen so that the maximum value of this ratio is equal to 1

V_{BEO} **Base emitter voltage, open collector**

$V_{(BR)}$ **Breakdown voltage,** reverse voltage at which a small increase in voltage results in a sharp rise of reverse current. It is given in technical data sheets for a specified current

$V_{(BR)}$ **CEO Collector emitter breakdown voltage, open base**

$V_{(BR)EBO}$ **Emitter base breakdown voltage, open collector**

$V_{(BR)ECO}$ **Emitter collector breakdown voltage, open base**

V_{CBO} **Collector-base voltage, open emitter,** generally, reverse biasing is carried out by applying a voltage to any of two terminals of a transistor in such a way that one of the junctions operates in reverse direction, whereas the third terminal (second junction) is specified separately.

V_{CC} **Supply voltage (positive)**

V_{CE} **Collector emitter voltage**

V_{CEO} **Collector emitter voltage, open base** ($I_B = 0$)

V_{CEsat} **Collector emitter saturation voltage,** the saturation voltage is the DC voltage between collector and emitter for specified (saturation) conditions, i.e., I_C and E_V (E_e or I_B), whereas the operating point is within the saturation region.

V_{dd} **Supply voltage (positive)**

V_{EBO} **Emitter base voltage, open collector**

V_{ECO} **Emitter collector voltage, open base**

V_F **Forward voltage**, the voltage across the diode terminals which results from the flow of current in the forward direction

VFIR As SIR, data rate 16 Mbit/s

V_{logic} **Reference voltage** for digital data communication ports

V_{no} **Signal-to-noise ratio**

V_O **Output voltage**

ΔV_O **Output voltage change** (differential output voltage)

V_{OC} **Open circuit voltage,** the voltage measured between the photovoltaic cell or photodiode terminals at a specified irradiance/illuminance (high impedance voltmeter!)

V_{OH} **Output voltage high**

V_{OL} **Output voltage low**

V_{ph} **Photovoltage,** the voltage generated between the photovoltaic cell or photodiode terminals due to irradiation/ illumination

V_R **Reverse voltage** (of a junction), applied voltage such that the current flows in the reverse direction

V_R **Reverse (breakdown) voltage,** the voltage drop which results from the flow of a defined reverse current

V_S **Supply voltage**

V_{ss} (Most negative) **supply voltage** (in most cases: ground)

$\pm \varphi_{1/2}$ **Angle of half transmission distance**

η **Quantum efficiency**

$\theta_{1/2}$; $\pm \varphi = \alpha/2$
Half-intensity angle, in a radiation diagram, the angle within which the radiant (or luminous) intensity is greater than or equal to half of the maximum intensity.
Note: IEC 60747-5-1 is using $\theta_{1/2}$. In Vishay datasheets mostly $\pm \varphi = \alpha/2$ is used

$\theta_{1/2}$; $\pm \varphi = \alpha/2$
Half-sensitivity angle, in a sensitivity diagram, the angle within which the sensitivity is greater than or equal to half of the maximum sensitivity.
Note: IEC 60747-5-1 is using $\theta_{1/2}$. In Vishay datasheets mostly $\pm \varphi = \alpha/2$ is used

Ω **Solid angle,** see sr, steradian for IEC 60050(845)-definition. The space enclosed by rays, which emerge from a single point and lead to all the points of a closed curve. If it is assumed that the apex of the cone formed in this way is the center of a sphere with radius r and that the cone intersects with the surface of the sphere, then the size of the surface area (A) of the sphere subtending the cone is a measure of the solid angle Ω. $\Omega = A/r^2$. The full sphere is equivalent to 4πsr. A cone with an angle of $\alpha/2$ forms a solid angle of $\Omega = 2\pi(1 - \cos\alpha/2) = 4\pi\sin^2\alpha/4$, unit: sr

λ_m **Wavelength** of the maximum of the spectral luminous efficiency function $V(\lambda)$

$\Delta\lambda$ **Range of spectral bandwidth (50 %),** the range of wavelengths where the spectral sensitivity or spectral emission remains within 50 % of the maximum value

Φ_e; Φ; P
Radiant flux; radiant power, power emitted, transmitted or received in the form of radiation.
unit: W, W = Watt

Φ_v; Φ; **Luminous flux,** quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer. For photopic vision

$$\Phi_v = K_m\int_0^\infty \frac{d\Phi_e\lambda}{d\lambda}\cdot V(\lambda)d\lambda,$$

where $\frac{d\Phi_e\lambda}{d\lambda}$ is the spectral distribution of the radiant flux and $V(\lambda)$ is the spectral luminous efficiency, unit : lm, lm: lumen, K_m = 683 lm/W:
Note: For the values of K_m (photopic vision) and K'm (scotopic vision), see IEC 60050 (845-01-56).

λ **Wavelength,** general

λ_c **Centroid wavelength,** centroid wavelength λ_c of a spectral distribution, which is calculated as "centre of gravity wavelength" according to

$$\lambda_c = \int_{\lambda_1}^{\lambda_2} \lambda\cdot S_X(\lambda)d\lambda / \int_{\lambda_1}^{\lambda_2} S_X\cdot(\lambda)d\lambda$$

λ_D **Dominant wavelength**

λ_p **Wavelength** of peak sensitivity or peak emission

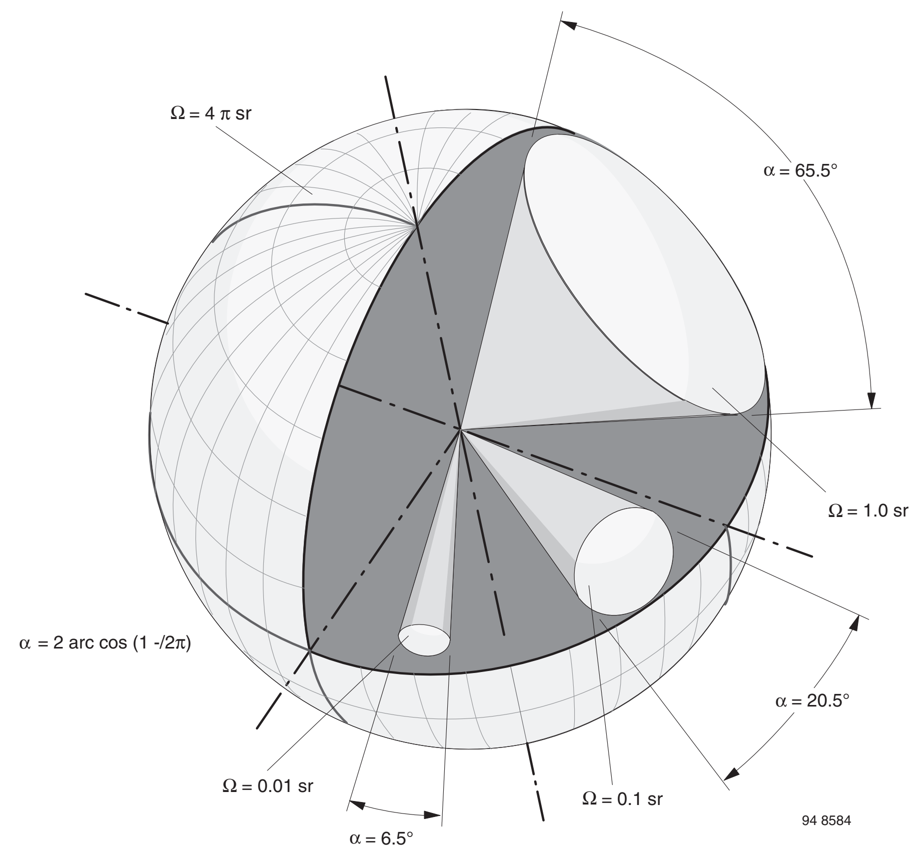


Fig. 1

DEFINITIONS

Databook Nomenclature

The nomenclature, symbols, abbreviations and terms inside the Vishay Semiconductors data book is based on ISO and IEC standards.

The special optoelectronic terms and definitions are referring to the IEC Multilingual Dictionary (Electricity, Electronics and Telecommunications), Fourth edition (2001-01), IEC 50 (Now: IEC 60050). The references are taken from the current editions of IEC 60050 (845), IEC 60747-5-1 and IEC 60747-5-2. Measurement conditions are based on IEC and other international standards and especially guided by IEC 60747-5-3.

Editorial notes: Due to typographical limitations variables cannot be printed in an italics format, which is usually mandatory. Our booklet in general is using American spelling. International standards are written in UK English. Definitions are copied without changes from the original text. Therefore these may contain British spelling.

Radiant and Luminous Quantities and Their Units

These two kinds of quantities have the same basic symbols, identified respectively, where necessary, by the subscript e (energy) or v (visual), e.g. Φ_e, Φ_v. See note.

Note: Photopic and scotopic quantities. Luminous (photometric) quantities are of two kinds, those used for photopic vision and those used for scotopic vision. The wording of the definitions in the two cases being almost identical, a single definition is generally sufficient with the appropriate adjective, photopic or scotopic added where necessary.

The symbols for scotopic quantities are prime (Φ'_v, I'_v, etc), but the units are the same in both cases.

In general, optical radiation is measured in radiometric units. Luminous (photometric) units are used when optical radiation is weighted by the sensitivity of the human eye, correctly spoken, by the CIE standard photometric observer (Ideal observer having a relative spectral responsivity curve that conforms to the V(λ) function for photopic vision or to the V'(λ) function for scotopic vision, and that complies with the summation law implied in the definition of luminous flux).

Note: With a given spectral distribution of a radiometric quantity the equivalent photometric quantity can be evaluated. However, from photometric units without knowing the radiometric spectral distribution in general one cannot recover the radiometric quantities.

Radiometric Terms, Quantities and Units

The radiometric terms are used to describe the quantities of optical radiation.

The relevant radiometric units are:

TABLE 1 - RADIOMETRIC QUANTITIES AND UNITS

RADIOMETRIC TERM	SYMBOL	UNIT	REFERENCE
Radiant power, radiant flux	Φ_e	W	IEC 50 (845-01-24)
Radiant intensity	I_e	W/sr	IEC 50 (845-01-30)
Irradiance	E_e	W/m^2	IEC 50 (845-01-37)
Radiant exitance	M_e	W/m^2	IEC 50 (845-01-47)
Radiance	L_e	W/(sr · m^2)	IEC 50 (845-01-34)

Photometric Terms, Quantities and Units

The photometric terms are used to describe the quantities of optical radiation in the wavelength range of visible radiation (generally assumed as the range from 380 nm to 780 nm). The relevant photometric terms are:

TABLE 2 - PHOTOMETRIC QUANTITIES AND UNITS

PHOTOMETRIC TERM	EQUIVALENT RADIOMETRIC TERM	SYMBOL	UNIT	REFERENCE
Luminous power or luminous flux	Radiant power or radiant flux Φ_e	Φ_v	lm	Φ_v: IEC 50 (845-01-25) lm: IEC 50 (845-01-51)
Luminous intensity	Radiant intensity I_e	I_v	lm/sr = cd	I_v: IEC 50 (845-01-31) cd: IEC 50 (845-01-50)
Illuminance	Irradiance E_e	E_v	lm/m^2 = lx (lux)	E_v: IEC 50 (845-01-38) lx: IEC 50 (845-01-52)
Luminous exitance	Radiant exitance M_e	M_v	lm/m^2	IEC 50 (845-01-48)
Luminance	Radiance L_e	L_v	cd/m^2	IEC 50 (845-01-35)

Photometric units are derived from the radiometric units by weighting them with a wavelength dependent standardized human eye sensitivity V(λ) - function, the so-called CIE-standard photometric observer. There are different functions for photopic vision (V(λ)) and scotopic vision (V'(λ)).

In the following is shown, how the luminous flux is derived from the radiant power and its spectral distribution. The equivalent other photometric terms can be derived from the radiometric terms in the same way.

Relation between distance r, irradiance (illuminance) E_e (E_V) and intensity I_e (I_V)

The relation between intensity of a source and the resulting irradiance in the distance r is given by the basic square root rule law.

An emitted intensity I_e generates in a distance r the irradiance $E_e = I_e/r^2$.

This relationship is not valid under near field conditions and should be used not below a distance d smaller than 5 times the emitter source diameter.

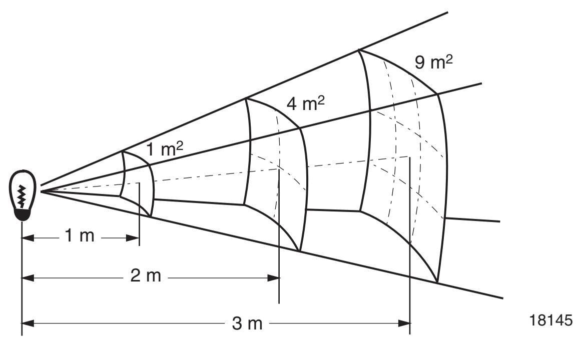


Fig. 2

Using a single radiation point source, one gets the following relation between the parameter E_e, Φ_e, r:

$$E_e = \frac{d\Phi_e}{dA}\left[\frac{W}{m^2}\right]$$

use

$$I_e = \frac{d\Phi}{d\Omega}, \quad \Omega = \frac{A}{r^2} \quad \text{and get}$$

$$E_e = \frac{d\Phi_e}{dA} = I_e\frac{d\Omega}{dA} = \frac{I_e}{r^2}\left[\frac{W}{m^2}\right]$$

Examples

1. Calculate the irradiance with given intensity and distance r: Transceivers with specified intensity of I_e = 100 mW/sr will generate in a distance of 1m an irradiance of $E_e = 100/1^2 = 100\ mW/m^2$. In a distance of 10 m the irradiance would be $E_e = 100/10^2 = 1\ mW/m^2$.
2. Calculate the range of a system with given intensity and irradiance threshold. When the receiver is specified with a sensitivity threshold irradiance $E_e = 20\ mW/m^2$, the transmitter with an intensity I_e = 120 mW/sr the resulting range can be calculated as

$$r = \sqrt{\frac{I_e}{E_e}} = \sqrt{\frac{120}{20}} = \sqrt{6} = 2.45\ m$$

Gesture Demo Board Installation Guide

DRIVER AND LICENSE FILES

In order to use any of the sensor demo boards, first the driver for the USB plug adapter should be installed and the folder with the corresponding license files need to be saved to the C: root directory. Please follow the sensor starter kit installation guide, located under www.vishay.com/doc?84242, which will guide you step-by-step through this process.

In order to use the VCNL Gesture demo board the software installer for the sensor starter kit found on the CD is not required. If you however wish to use the VCNL4020, VCNL3020, or VNCL4010 demo boards please install the sensor starter kit software as well.

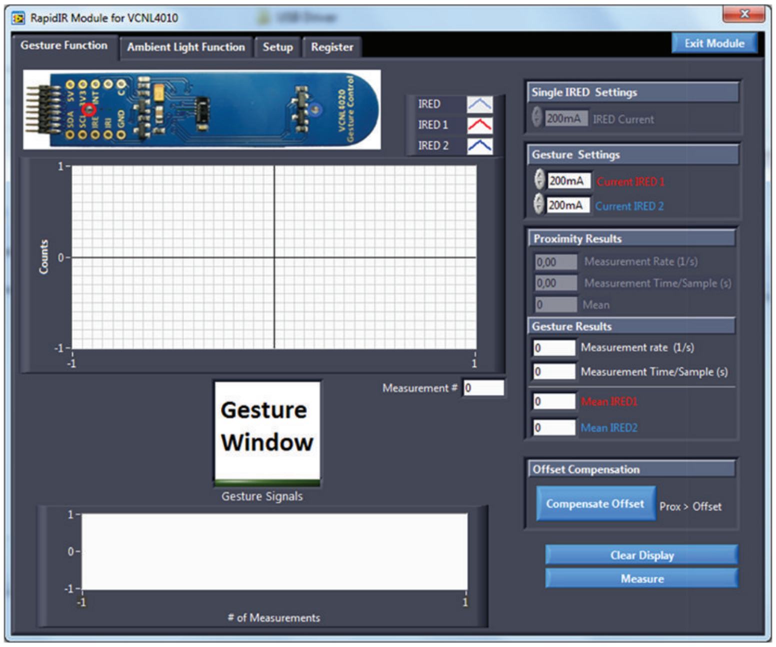
VCNL40x0 base software, license files, and USB driver	Vishay USB Dongle	VCNL4020	VCNL4010	VCNL3020	VCNL4020 Gesture Control	VCNL4020X01

GESTURE DEMO BOARD

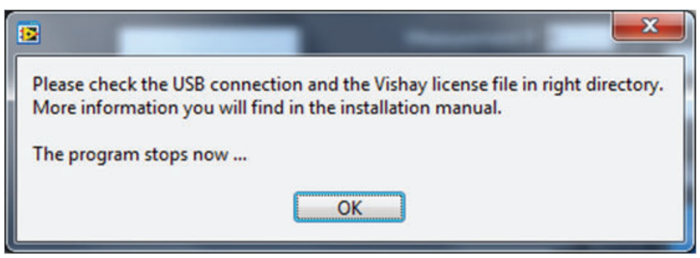
The software for the gesture demo board is built using a newer version of labview so a new installer is required for this. The license files and driver found in the demo kit however are still valid and do not need to be renewed.

You will find the required installer on our web page at: www.vishay.com/optoelectronics/moreinfo/vcnldemokit/ “VCNL4020_Gesture_Sensor_Board_Installer.zip”

Once the software is started you will see the following screen.



If you get the following error message…



… please double check if the license files are in the correct place and the driver is installed, as described in the demo kit installation guide. Also make sure that the USB dongle and board are plugged in before you start the software.

For further information on how to use the gesture demo software, please refer to the application note “VCNL4020 Proximity Sensor - Gesture Control Sensor Board”, www.vishay.com/doc?84218.

Packaging and Order Information

PACKAGING SURVEY

TABLE 1 - PACKAGING OPTIONS OF DETECTOR AND EMITTER DEVICES

PACKAGE FORM	SERIES	PACKAGING OPTION			
		BULK	TAPE	BLISTER TAPE	TUBE
Metal can	BPW./TS.	X			
Side view lens	TEKS5400.		X		
	TEKS5400S TEKT5400S TSKS5400S	X	X		
	TSKS542.X01		X		
SMD	TEM./TSM./ VEM./VSM.			X	
Top view mold	BP104 BPW34	X			
	BP104S BPW34S				X
Other leaded packages	BP./TE./TS.	X	X		

MOISTURE PROOF PACKAGING

The reel is packed in a moisture proof aluminum bag to protect devices from absorbing moisture during transportation and storage.

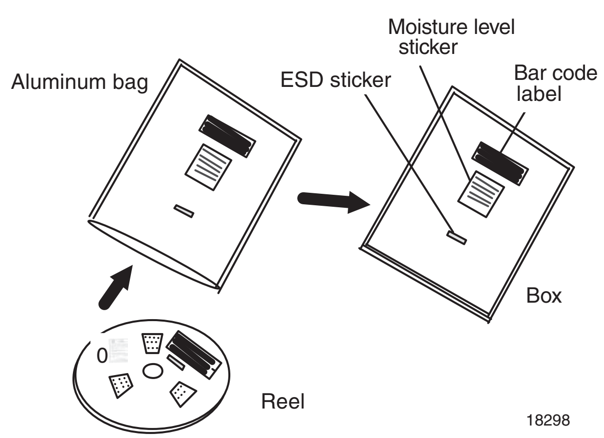


Fig. 1 - Moisture Proof Packaging

RECOMMENDED METHOD OF STORAGE

Dry box storage is recommended as soon as the dry bag has been opened to prevent moisture absorption.

The following conditions should be observed if dry boxes are not available:

- Storage temperature 10 °C to 30 °C
- Storage humidity ≤ 60 % RH max.

After storage longer than the specified floor life (see table 2), moisture content will be too high for reflow soldering. In case of moisture absorption, the devices will recover to their former condition by drying using conditions according to the individual moisture sensitivity level (MSL) specified on a sticker affixed to the dry bags (e.g. figure 2, MSL 2a).

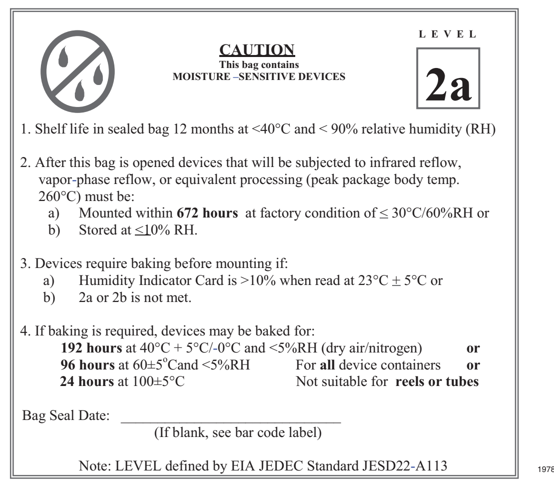


Fig. 2 - Example of MSL Sticker

TABLE 2 - MOISTURE SENSITIVITY LEVEL, FLOOR LIFE AND FLOOR CONDITIONS

MSL	FLOOR LIFE	CONDITIONS
1	No limit	≤ 30 °C/90 % RH
2	1 year	≤ 30 °C/60 % RH
2a	672 h	
3	168 h	
4	72 h	
5	24h/48 h	
6	6 h	

TABLE 3 - MOQ/DELIVERY UNIT SURVEY		
PACKAGE FORM/DEVICE TYPE	**MINIMUM ORDER QUANTITY**	**DELIVERY UNIT**
LEADED		
5 mm		
Bulk e.g. TSAL, TSHF, BPV	4000	4000/bulk
Tape e.g. TSHF5210-ES21	5000	1000/reel
3 mm		
Bulk e.g. TSAL, VSLB, TEFT	5000	5000/bulk
Tape e.g. VSLB3940-MSZ	10 000	2000/reel
1.8 mm		
Bulk e.g. CQY37N, BPW17N	5000	5000/bulk
Tape e.g. CQY37N-CS12	4000	2000/reel
Side View Lens		
Bulk e.g. TSKS, TEKT	2000	2000/bulk
Tape e.g. TSKS5400S-ASZ	2000	2000/reel
Side View Micro		
Bulk e.g. TEST2600, TSSS2600	5000	5000/bulk
Tape e.g. TEST2600-MS21	5000	1000/reel
Top View Detector		
Bulk e.g. BP104, BPW34	3000	3000/bulk
Tube e.g. BP104S	1800	45/tube
Side View Detector		
Bulk e.g. BPV22F, BPW46	4000	4000/bulk
Tape e.g. BPV22F-AS12	5000	1000/reel
Metal Can TO-5		
Bulk e.g. BPW21R, BPW20RF	500	500/bulk
Metal Can TO-18		
Bulk e.g. BPW76, TSTS7100	1000	1000/bulk
SMD		
PLCC-2		
e.g. VSMF3710-GS08	7500	1500/reel
e.g. VSMF3710-GS18	8000	8000/reel
0805		
e.g. TEMT6200FX01	3000	3000/reel
1206		
e.g. TEMT6000X01	3000	3000/reel
SMD Top View		
e.g. TEMD5010X01	1500	1500/reel
SMD Gullwing, Reverse Gullwing		
e.g. VBP104S, VBPW34FASR	1000	1000/reel
Little Star		
e.g. VSMY7850X01	2000	2000/reel
Dome Lens 1.8 mm		
e.g. VSMB2020X01, VEMD2020X01	6000	6000/reel
Dome Lens 1.8 mm, Side Looker		
e.g. VSMB2943SLX01, VEMD2023SLX01	3000	3000/reel
Dome Lens 1.9 mm		
e.g. TSML1020, TEMT1020	1000	1000/reel

ESD PRECAUTION

Proper storage and handling procedures should be followed to prevent ESD damage to the devices, especially when they are removed from the antistatic shielding bag.

BAR CODE LABELS

Vishay Semiconductor standard bar code labels are printed on the final package. Labels containing Vishay Semiconductor specific data are affixed to each package unit.

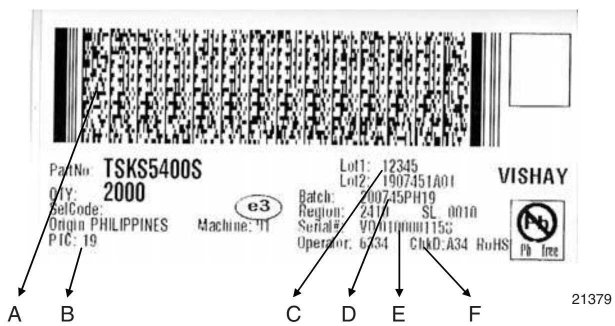


Fig. 3 - Bar code design and information

A) PDF417 bardoce including 325 char

B) Plant code according TQD9021 http://intra.hn.vishay.com/quality/docs/tqd/tqd_9021.htm

C) Lot1 and Lot2 reflects the lot numbers. Lot2 is a combination of 19 (PTC), 0745 (YYWW), 1 (production day MO=1, TU=2), A (Shift A,B,C) and 01 as production equipment

D) Batch contains the datecode 200745 (YYYYWW), origin (PH=Philippines), 19 (PTC)

E) Unique label serial number: VO production location (ISO), 01=label station ID, 00001158 (serial number)

F) Check digit: counting number starting at A00 up to Z99 to give e.g. a manufactured reel a serial number (track and trace information)

TAPING OF SMD

Vishay SMD IR emitters and detectors are packed in antistatic blister tapes (in accordance with DIN IEC 40 (CO) 564) for automatic component insertion. The blister tapes are plastic strips with impressed component cavities, which are covered by a glued top tape.

Missing Devices

A maximum of 0.5 % of the total number of components per reel may be missing, excluding missing components at the beginning and at the end of reel. A maximum of three consecutive components may be missing. This gap is followed by ≥ 6 consecutive components (minimum).

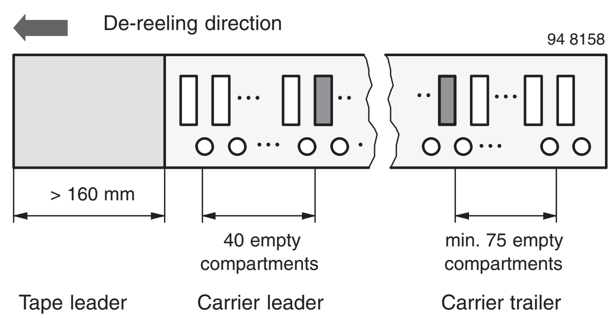


Fig. 4 - Beginning and End of Reel

TAPING SMD PLCC-2 PACKAGE

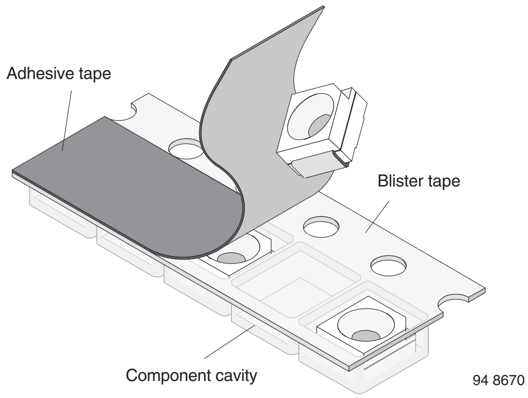


Fig. 5 - Blister Tape

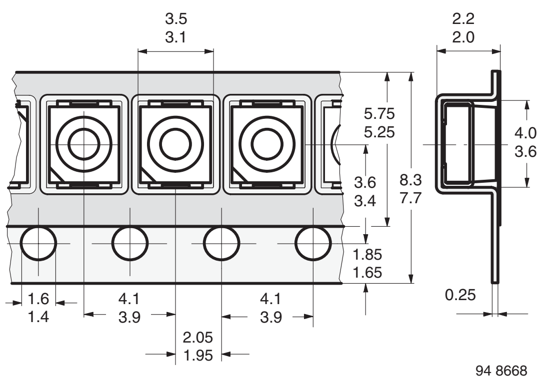


Fig. 6 - Tape Dimensions in mm for PLCC-2

TAPING STANDARDS GS08 AND GS18

GS08: 1500 pcs/reel
GS18: 8000 pcs/reel

The tape leader is at least 160 mm and is followed by a carrier tape leader with at least 40 empty compartments (figure 3). The tape leader may include carrier tape as long as the cover tape is not connected to carrier tape.

The last component is followed by a carrier tape trailer with at least 75 empty compartments, sealed with cover tape.

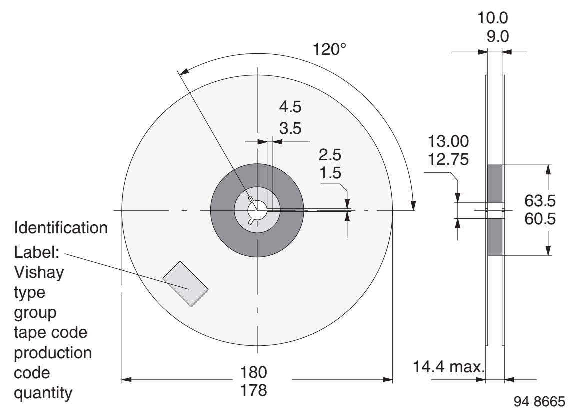


Fig. 7 - Reel Dimensions: GS08

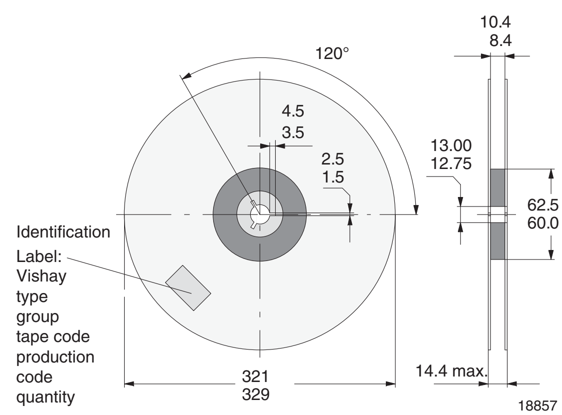


Fig. 8 - Reel Dimensions: GS18

COVER TAPE REMOVAL FORCE

The removal force may vary in strength between 0.1 N and 1.0 N at a removal speed of 5 mm/s.

In order to prevent components from popping out of blisters, the cover tape must be pulled off at an angle of 180° relative to the feed direction.

TAPING SMD WITH PCB OR DOME PACKAGE

Dimensions in millimeters

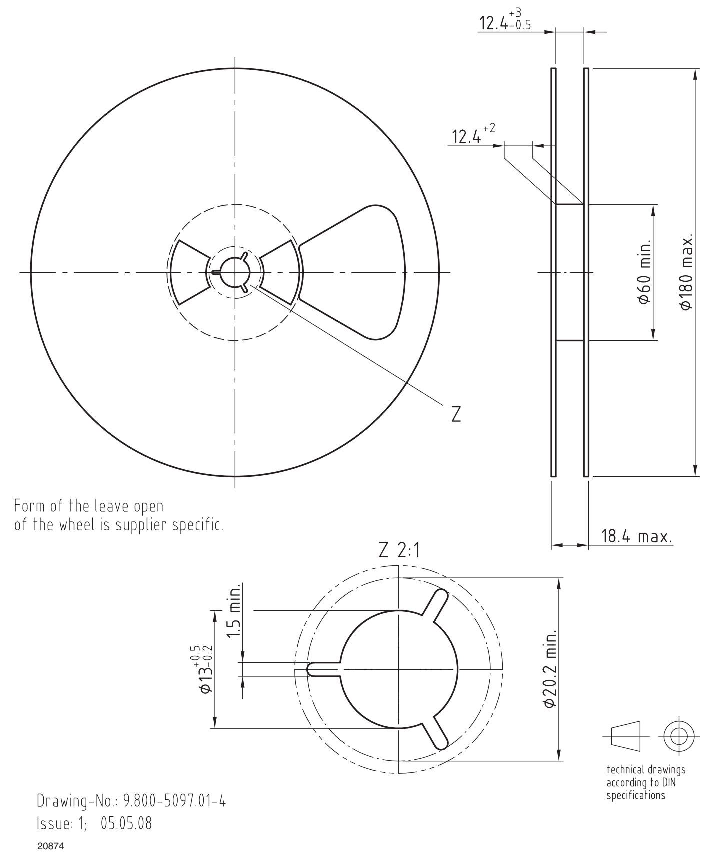


Fig. 9 - Reel of TEMD5010X01, TEMD5020X01, TEMD5110X01, TEMD5120X01, and TEMD5510FX01

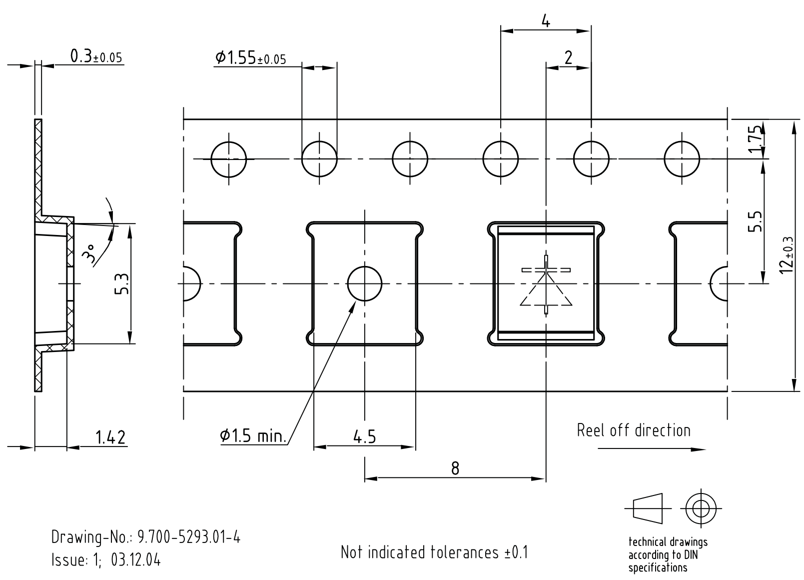


Fig. 10 - Blister Tape of TEMD5010X01, TEMD5020X01, TEMD5110X01, TEMD5120X01, and TEMD5510FX01

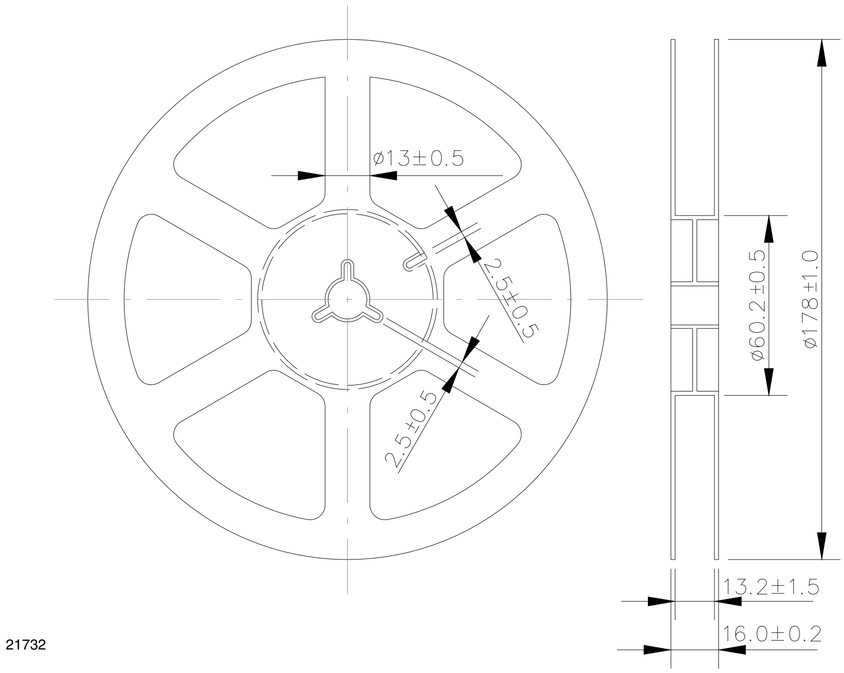


Fig. 11 - Reel of VBP104S, VPB104SR Series and VBPW34S, VBPW34SR Series

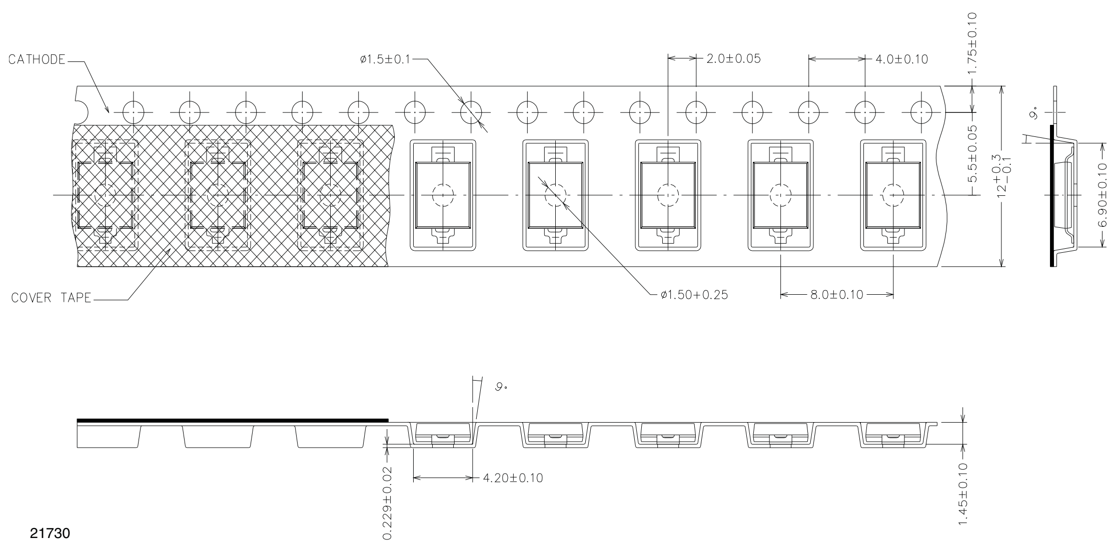


Fig. 12 - Blister Tape VBP104S Series and VBPW34S Series

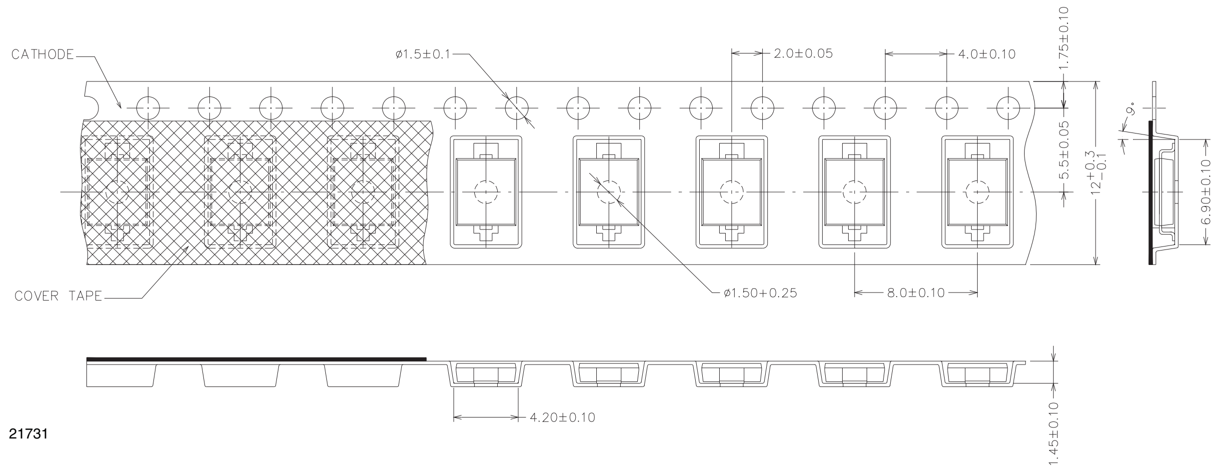
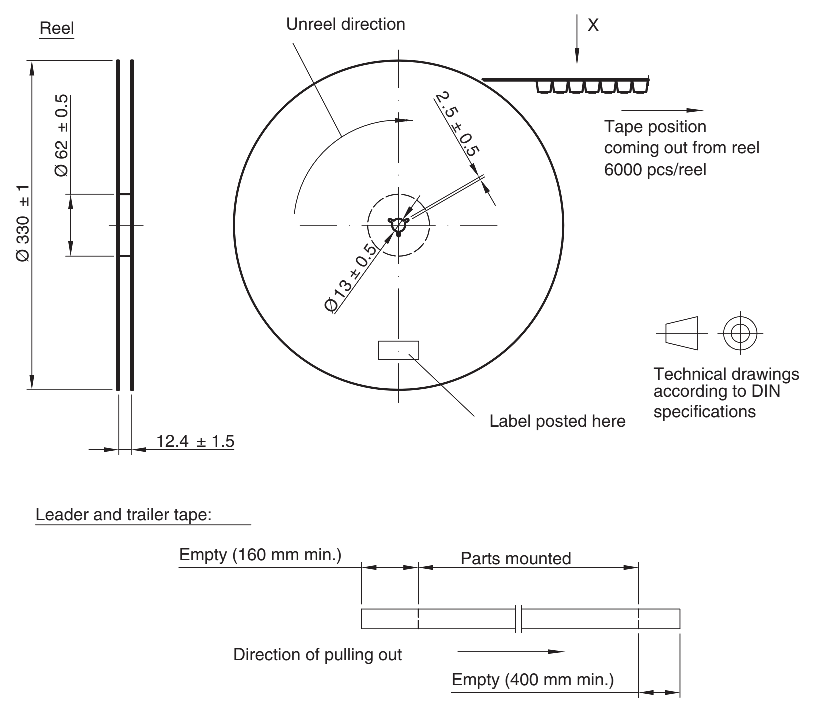
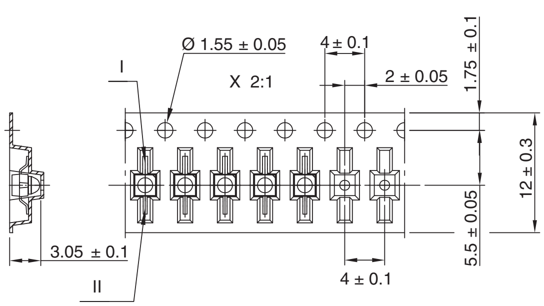


Fig. 13 - Blister Tape VBP104SR Series and VBPW34SR Series



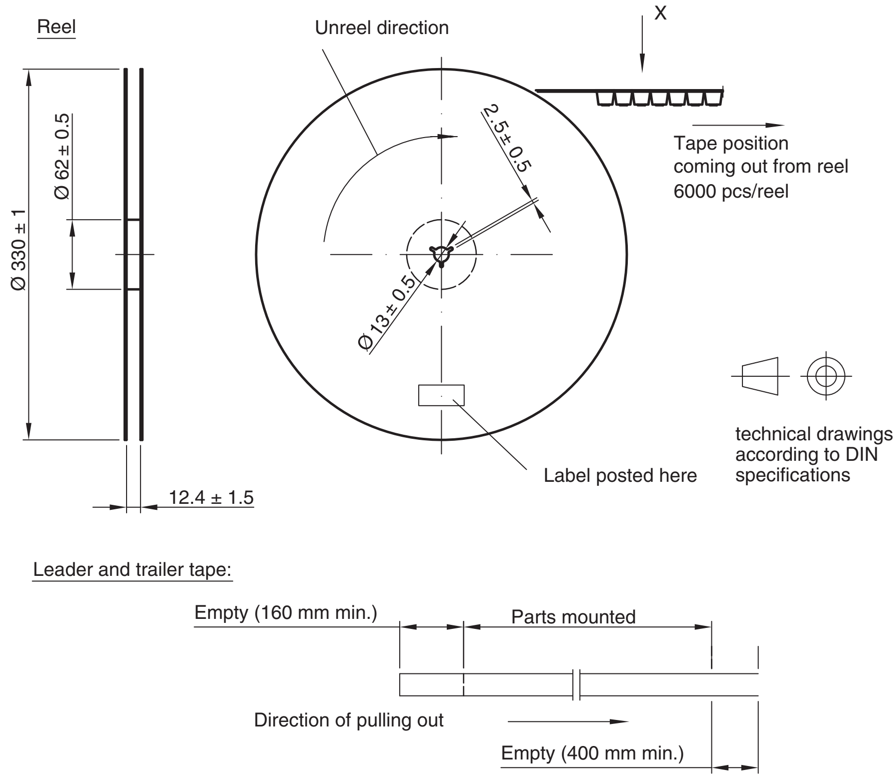
Terminal position in tape

Device	Lead I	Lead II
VEMT2000	Collector	Emitter
VEMT2500		
VEMD2000	Cathode	Anode
VEMD2500		
VSMB2000		
VSMG2000		
VSMY2850RG	Anode	Cathode



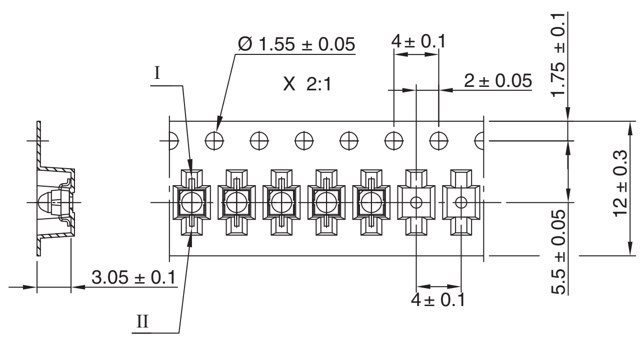
Drawing-No.: 9.800-5100.01-4
Issue: 2; 18.03.10
21572

Fig. 14 - Reel and Blister Tape of SMD Dome Lens, 1.8 mm, Reverse Gullwing



Terminal position in tape

Device	Lead I	Lead II
VEMT2020	Collector	Emitter
VEMT2520		
VSMB2020	Cathode	Anode
VSMG2020		
VEMD2020		
VEMD2520		
VSMY2850G	Anode	Cathode

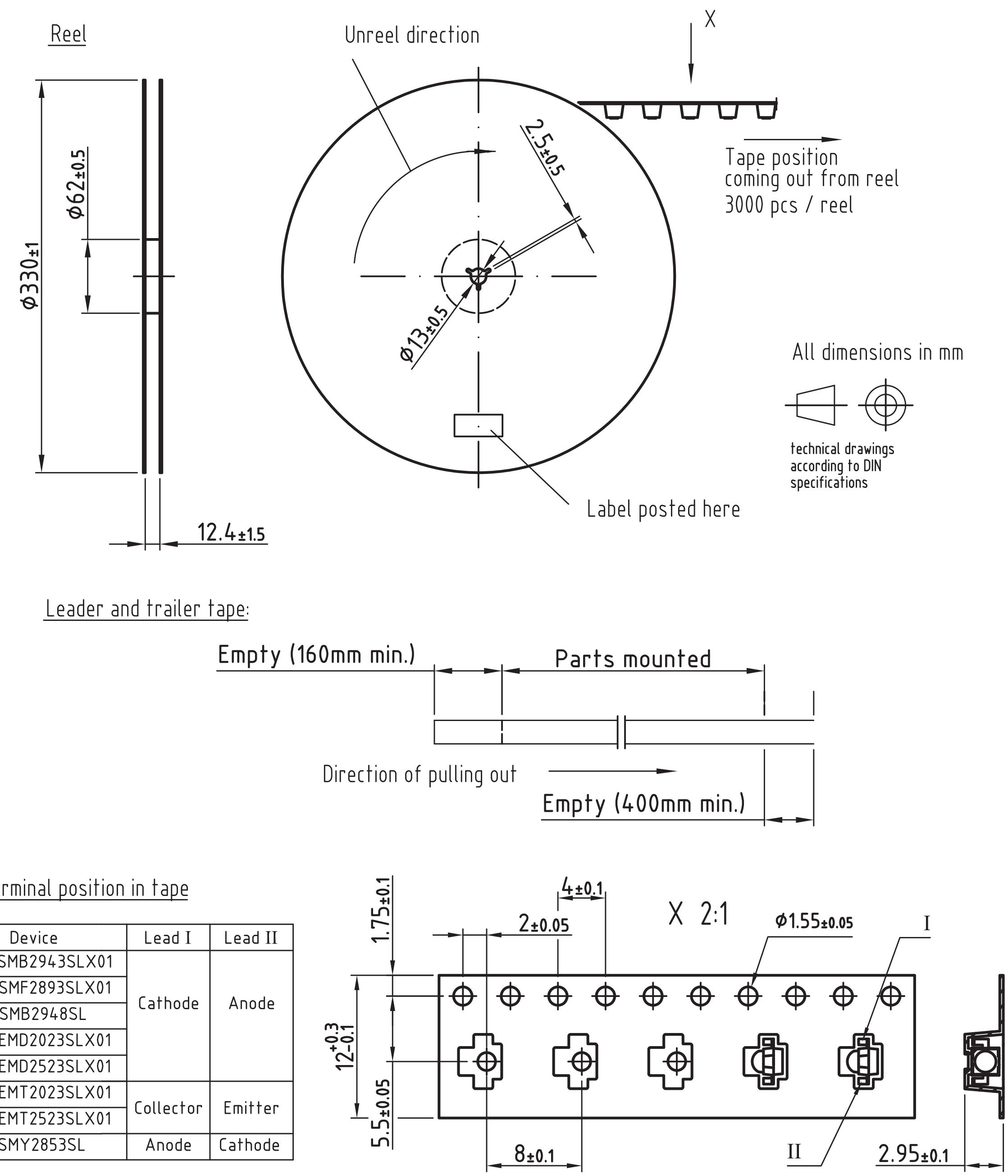


Drawing-No.: 9.800-5091.01-4

Issue: 3; 18.03.10

21571

Fig. 15 - Reel and Blister Tape of SMD Dome Lens, 1.8 mm, Gullwing



Terminal position in tape

Device	Lead I	Lead II
VSMB2943SLX01	Cathode	Anode
VSMF2893SLX01		
VSMB2948SL		
VEMD2023SLX01		
VEMD2523SLX01		
VEMT2023SLX01	Collector	Emitter
VEMT2523SLX01		
VSMY2853SL	Anode	Cathode

Drawing refers to following types: see table
Reel dimensions and tape

Drawing-No.: 9.800-5123.01-4
Issue: prel; 03.08.12

Fig. 16 - Reel and Blister Tape of SMD Dome Lens, 1.8 mm, Side Looker

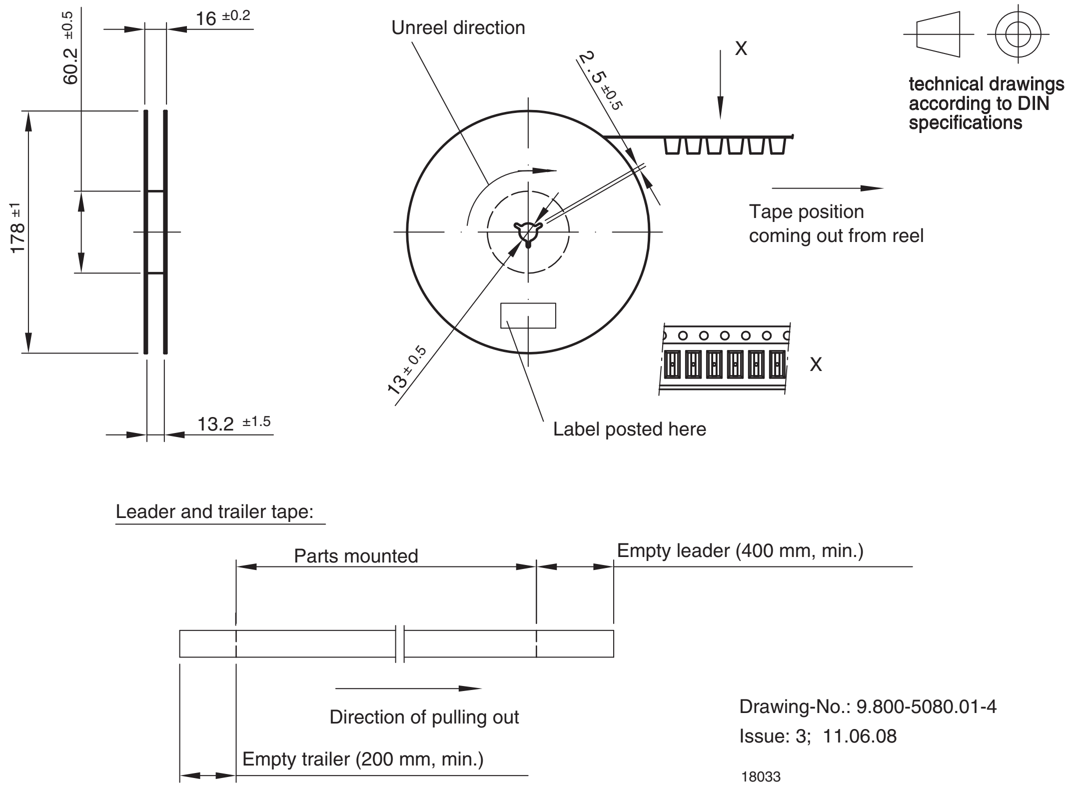


Fig. 17 - Reel of TEMx1000 Series and TSMx1000 Series
Quantity per Reel: 1000 pcs

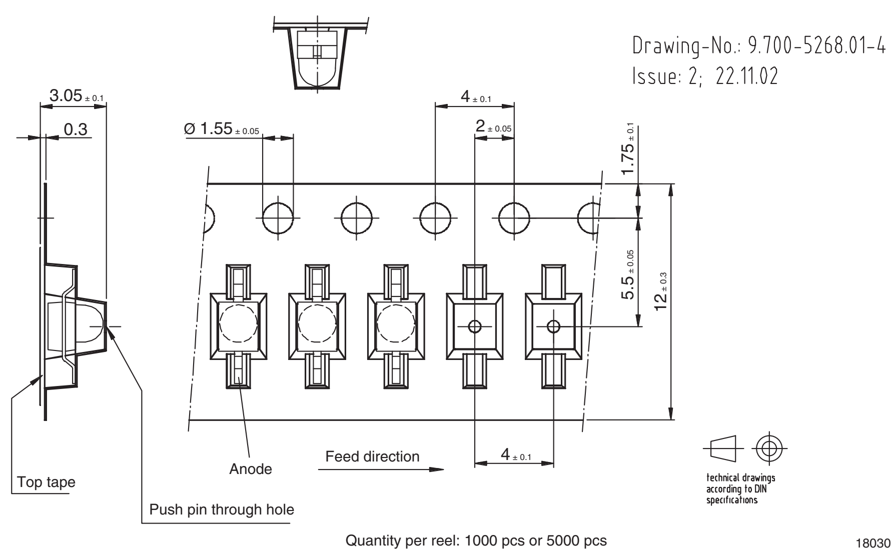


Fig. 18 - Blister Tape of TSMF1000, TSML1000, and TEMD1000

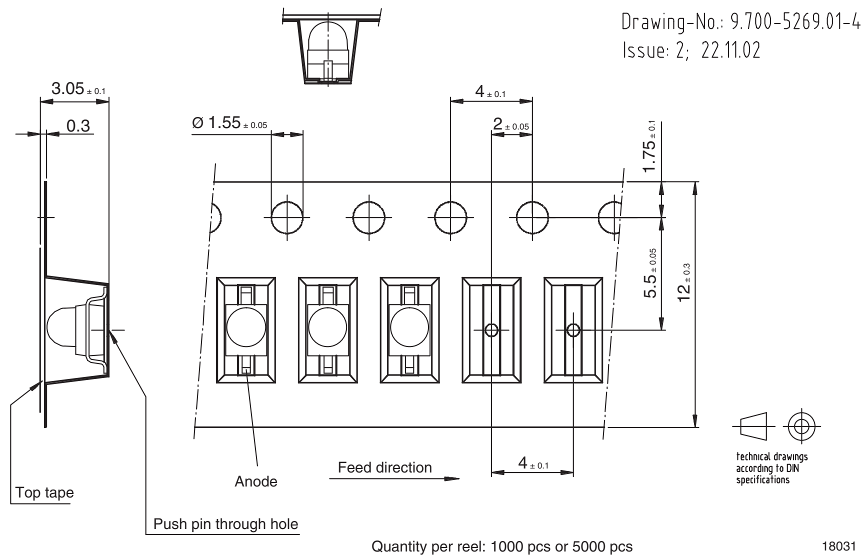


Fig. 19 - Blister Tape of TSMF1020, TSML1020, and TEMD1020

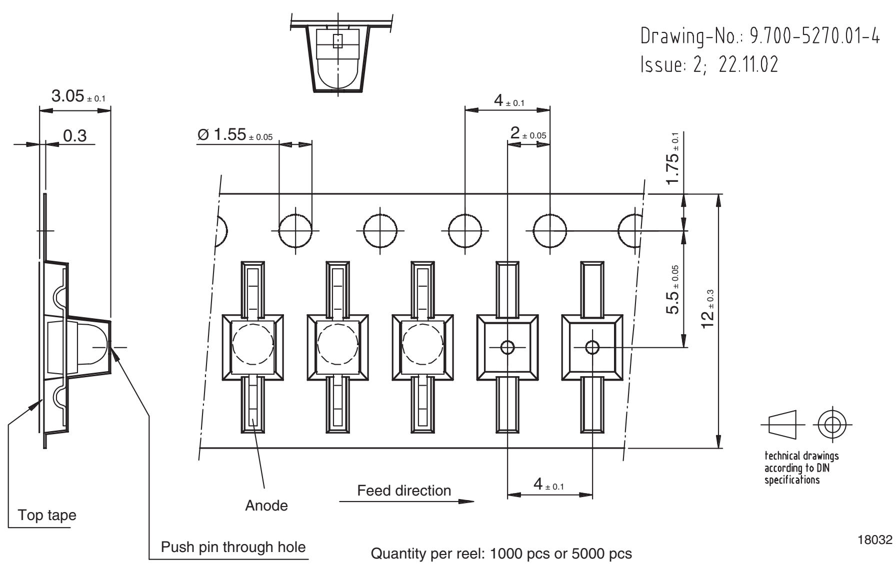


Fig. 20 - Blister Tape of TSMF1030, TSML1030, and TEMD1030

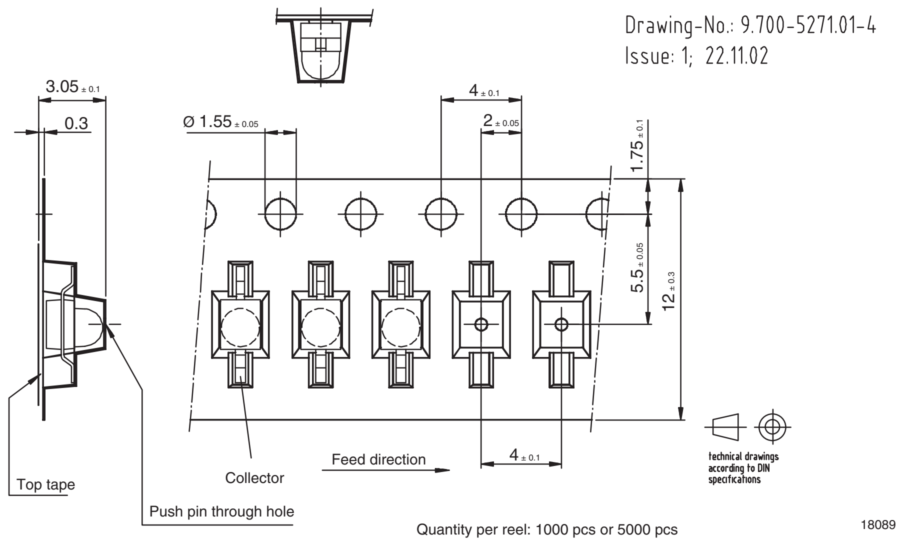


Fig. 21 - Blister Tape of TEMT1000

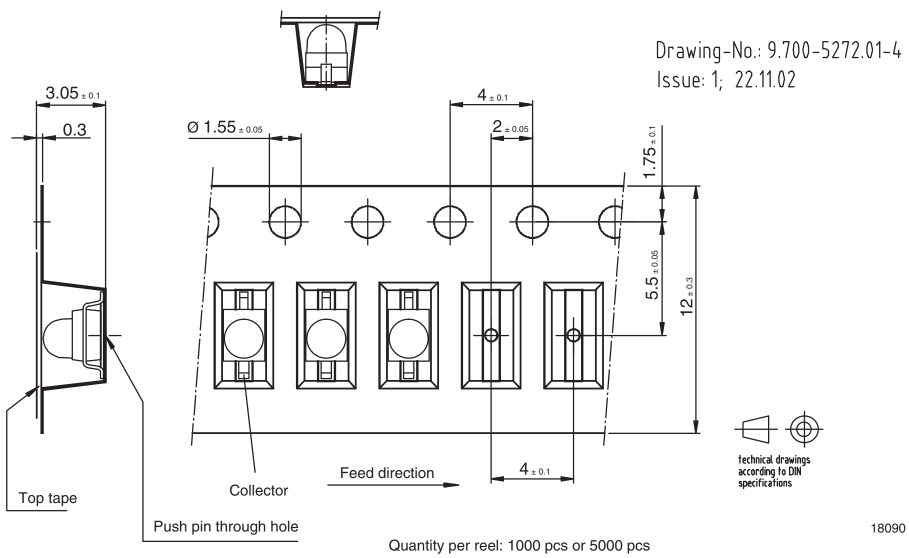


Fig. 22 - Blister Tape of TEMT1020 and TEMT1520

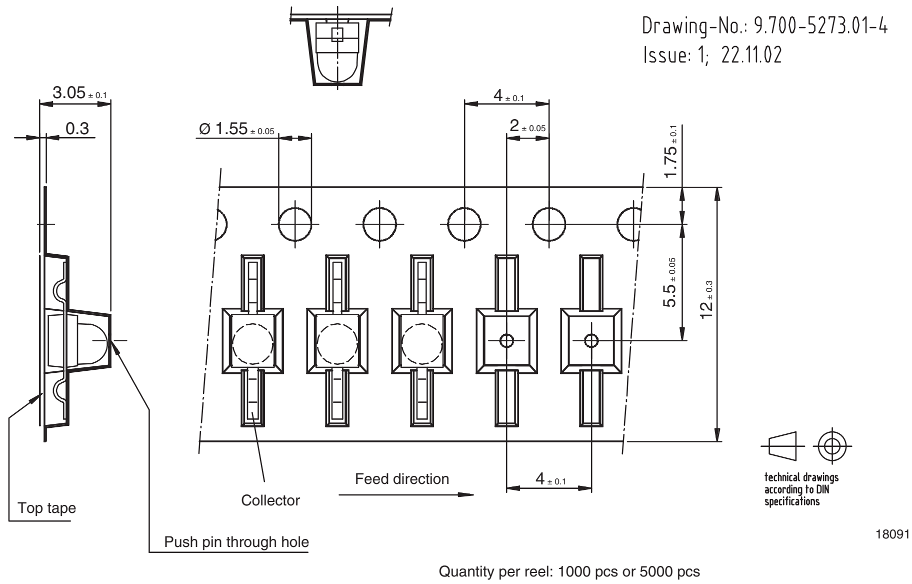


Fig. 23 - Blister Tape of TEMT1030

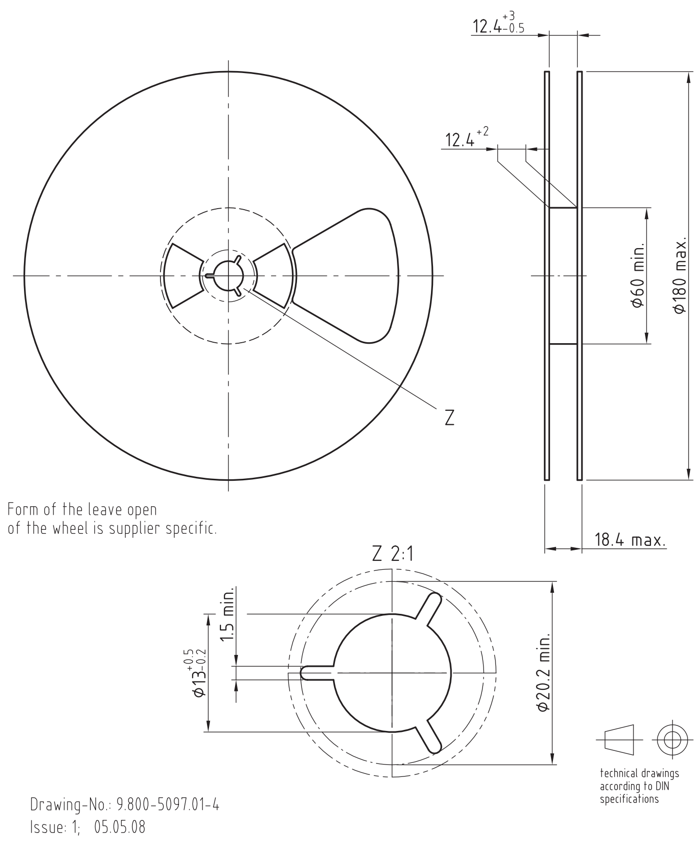


Fig. 24 - Reel of TEMx6000, VEML60x0FX01 Series
Quantity per Reel: 3000 pcs

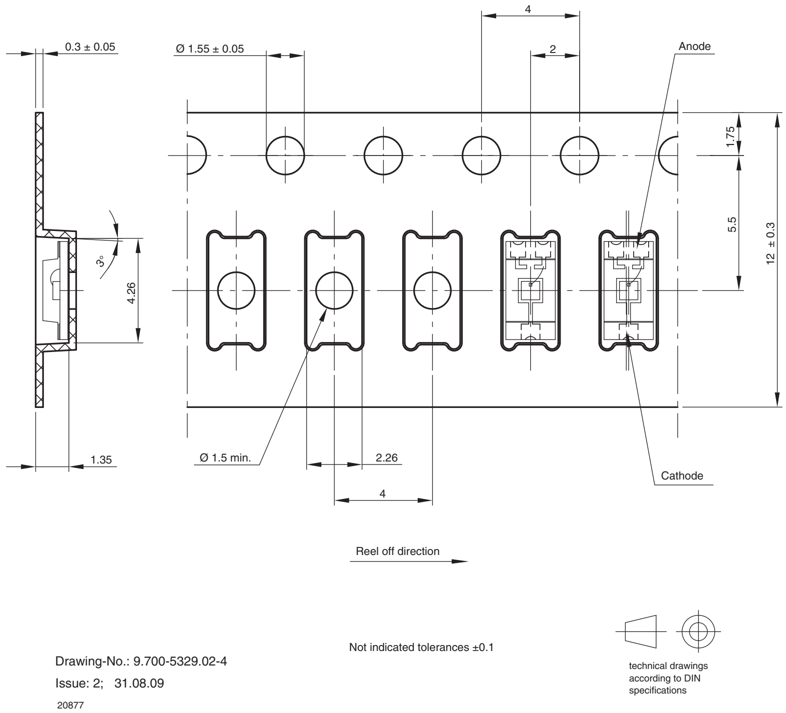


Fig. 25 - Blister Tape of TEMD6010FX01

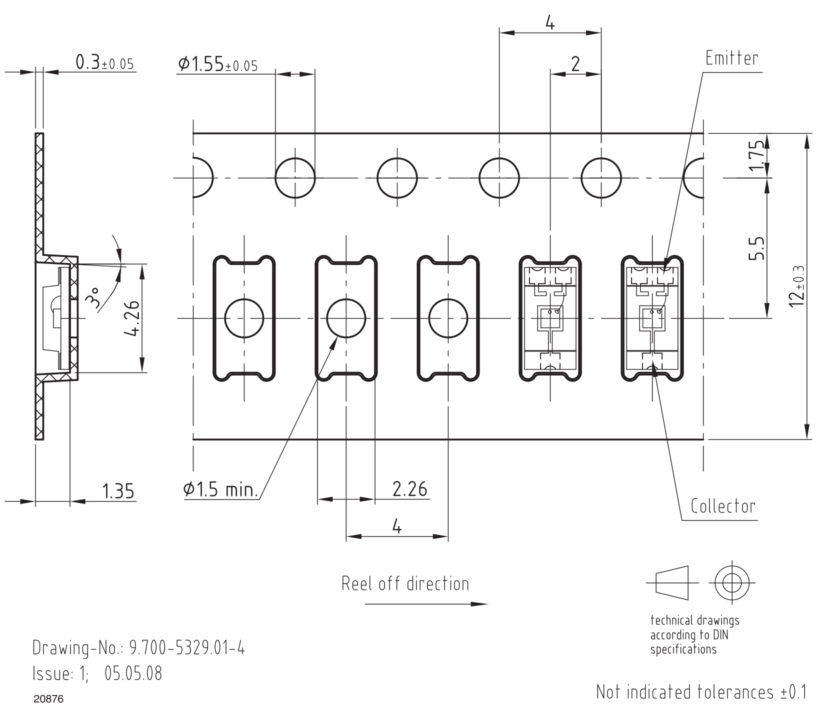


Fig. 26 - Blister Tape of TEMT6000X01

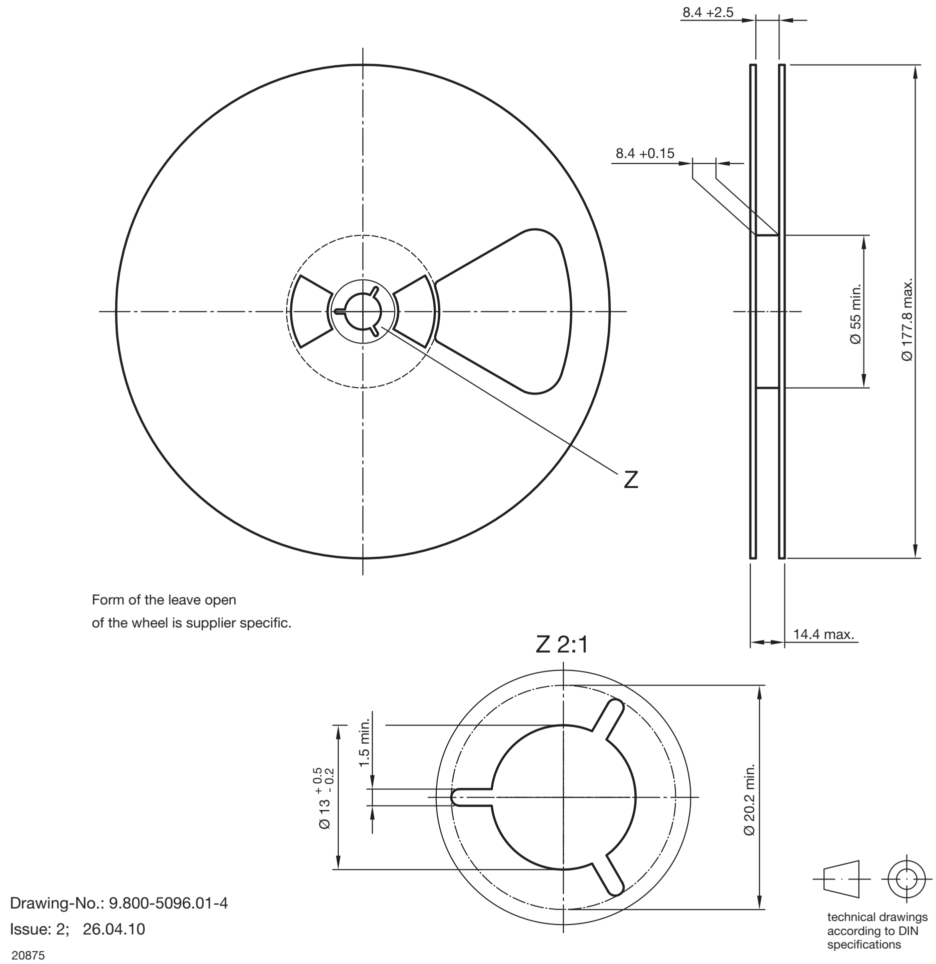


Fig. 27 - Reel of TEMx6200X01, TEMx7x00X01, VSMB1940X01, VSMY1850X01 Series
Quantity per reel: 3000 pcs

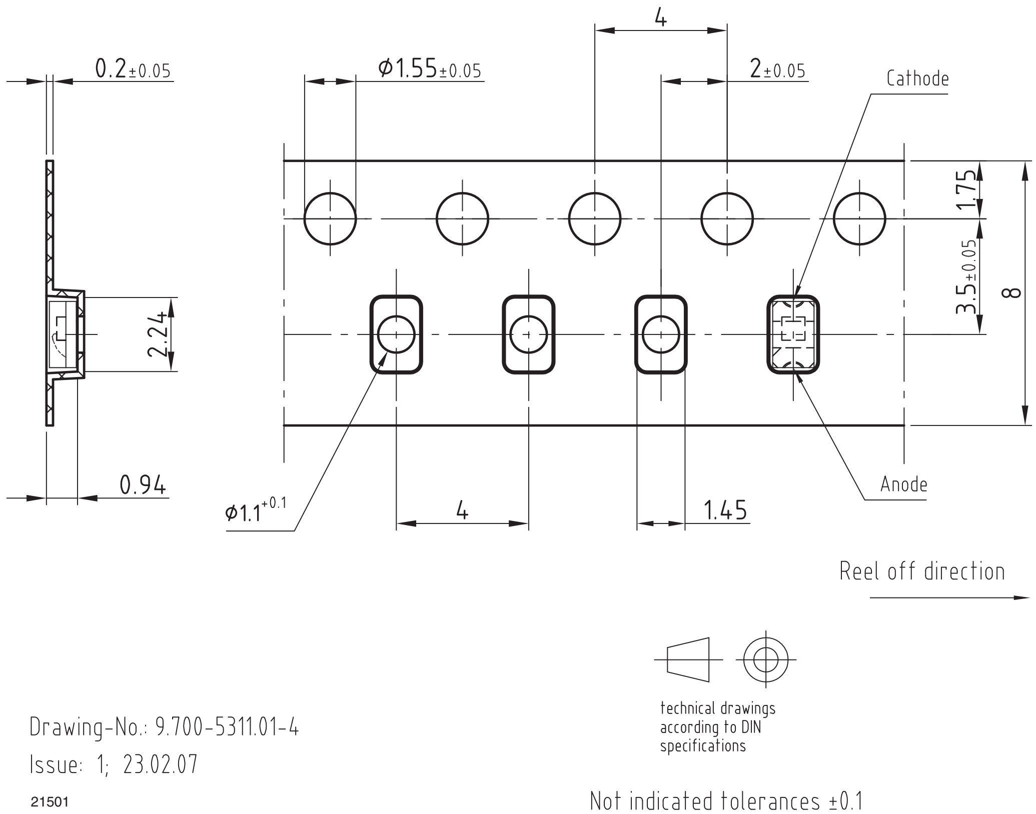


Fig. 28 - Blister Tape of TEMD7x00X01, VSMB1940X01

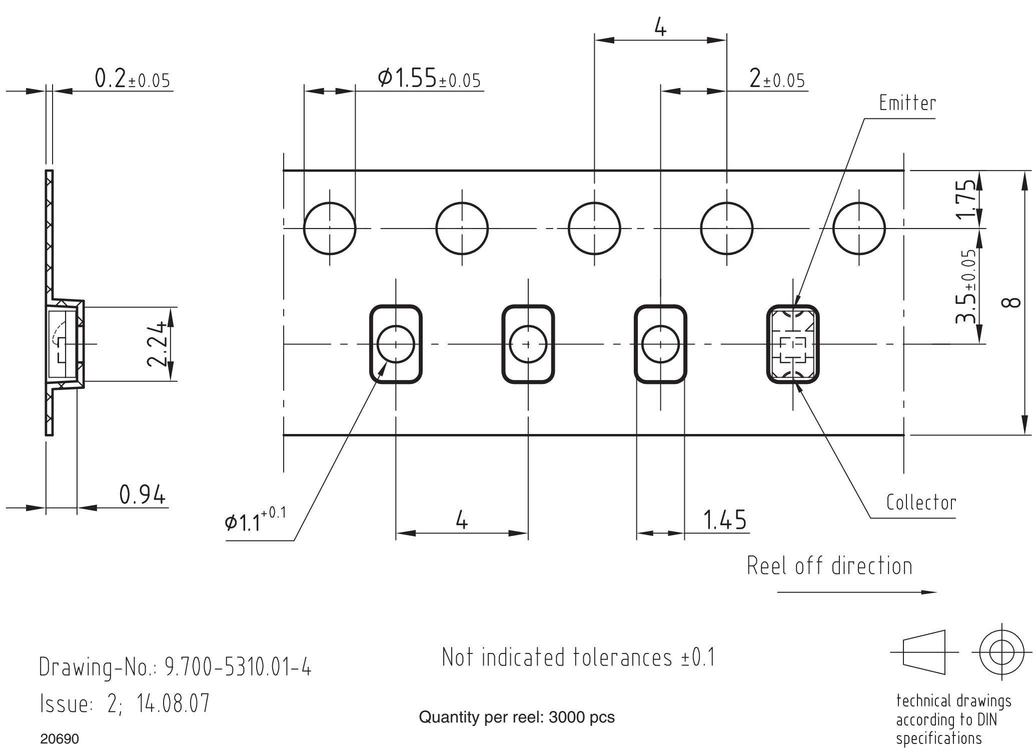


Fig. 29 - Blister Tape of TEMT7x00X01, TEMT6200FX01

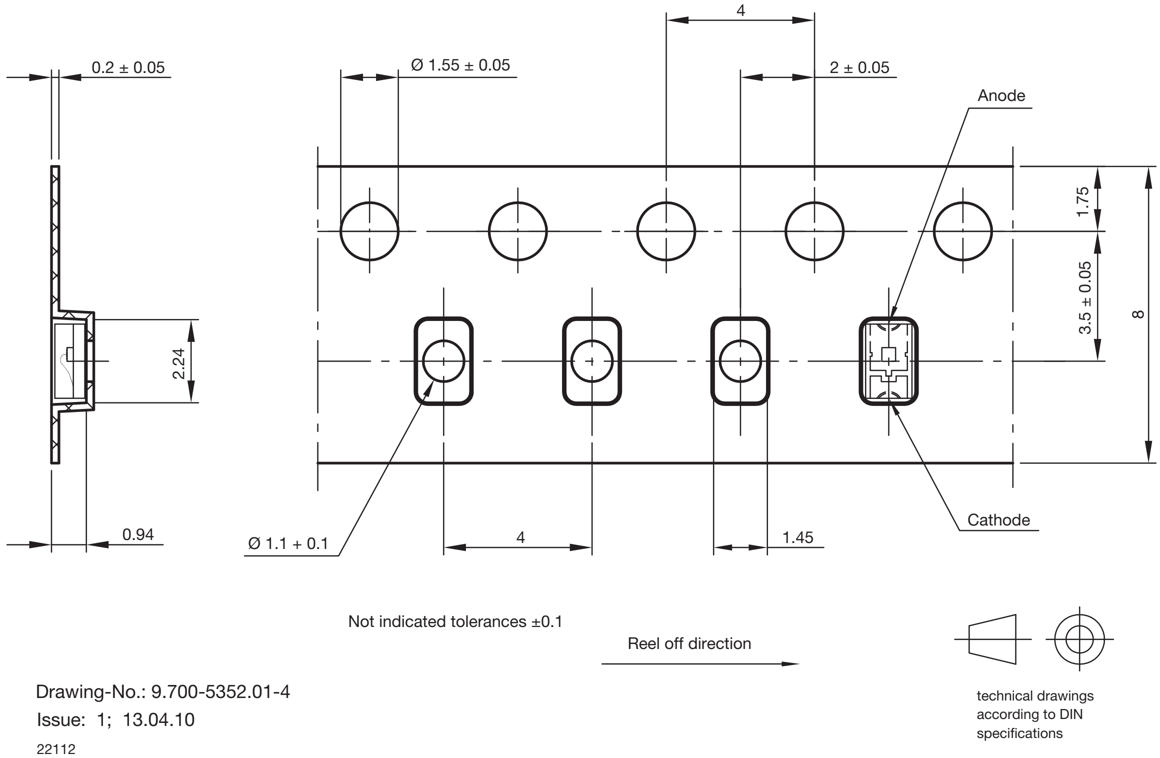


Fig. 30 - Blister Tape of VSMY1850, VSMY1850X01

TAPING OF T-1 (3 mm) AND T-1¾ (5 mm) DEVICES

The taping specification is based on IEC publication 286, taking into account industrial requirements for automatic insertion.

Absolute maximum ratings, mechanical dimensions, optical and electrical characteristics for taped devices are identical to basic catalog types and can be found in specifications for untaped devices.

Note that the lead wires of taped components may be shorted or bent in accordance to the IEC standard.

PACKAGING

The tapes of components are available on reels or in Ammopack. Each reel and each box is marked with label containing the following information:

- Vishay
- Type
- Group
- Tape code (see figure 24)
- Productions code
- Quantity

CODE FOR TAPED DEVICES

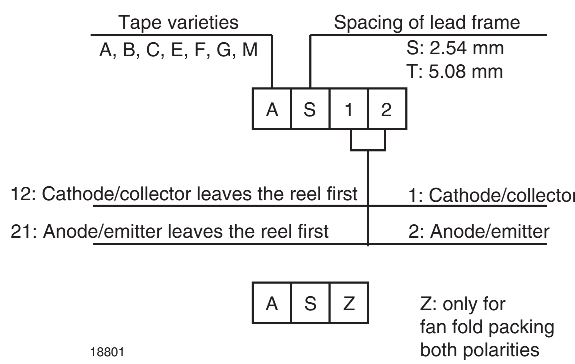


Fig. 31 - Taping Code

Number of Packed Components

T-1 (3 mm): 2000 pcs

T-1¾ (5 mm): 1000 pcs

MISSING COMPONENTS

Up to 3 consecutive components may be missing but the gap is followed by at least 6 components. A maximum of 0.5 % of components per reel quantity may be missing. At least 5 empty positions are present at the start and the end of the tape to enable tape insertion.

Tensile strength of the tape: ≥ 15 N

Pulling force in plane of the tape, at right angles to reel: ≥ 5 N

Note

- Shipment in fan-fold packages is standard for radial taped devices.
  Shipment in reel packing is only possible if the customer guarantees removal of empty reels.
  According to what is stated in a German packaging decree (Verpackungsverordnung) we are not able to accept return of reels.

ORDERING CODE

Type designations are extended by a code for the taping standard.

Example:

TSAL6200-AS12 (reel packing)

TSAL6200-ASZ (fan-fold packing)

BPW85-AS12 (reel packing)

TABLE 4 - TAPING SURVEY OF LEADED COMPONENTS

CODE FOR TAPING STANDARD	“H“ - HEIGHT OF TAPING IN mm (TOLERANCES ± 0.5 mm)			PREFERENCES	REMARKS
	3 mm	5 mm	SIDEVIEW’S		
AS12	17.3	17.3	16.0	Standard	Reel, cathode / collector leaves first
AS21					Reel, anode / emitter leaves first
ASZ					Ammopack
KS12	19.3	19.3	-	-	Reel, cathode / collector leaves first
KS21					Reel, anode / emitter leaves first
KSZ					Ammopack
CS12	22.0	22.0	-		Reel, cathode / collector leaves first
CS21					Reel, anode / emitter leaves first
CSZ					Ammopack
ES12	-	24.0	24.0	Standard	Reel, cathode / collector leaves first
ES21					Reel, anode / emitter leaves first
ESZ					Ammopack
EGZ	-	-	24.0		Ammopack 2 mm pin distance lead to lead
MS12	25.5	25.5	-		Reel, cathode / collector leaves first
MS21					Reel, anode / emitter leaves first
MSZ					Ammopack
GSZ	-	-	29.0		Ammopack 2 mm pin distance lead to lead
FSZ	-	-	27.0	Standard	Ammopack
FGZ	-	-	27.0		Ammopack 2 mm pin distance lead to lead

REEL DIMENSIONS in millimeters

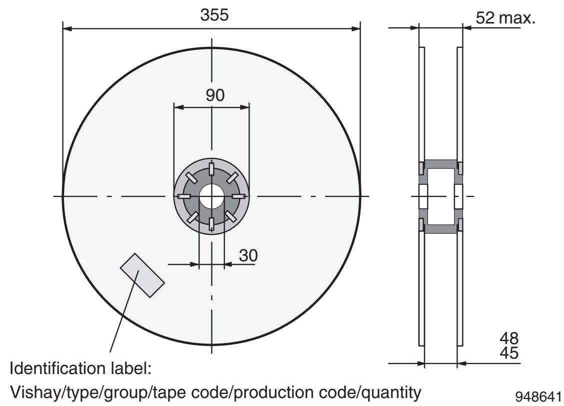


Fig. 32 - Dimensions of the Reel

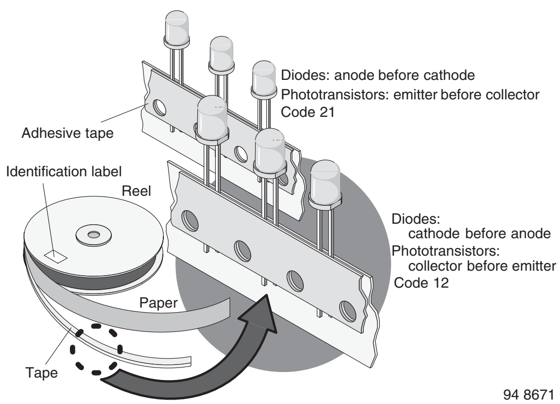


Fig. 33 - Components on Tape and Reel

AMMOPACK

The tape is folded in a concertina arrangement and laid in a cardboard box.

If components are required to have the cathode or collector leave the box first (figure 27), then open the box at the side marked with the "-" symbol. If anode or emitter should leave the box first, then open at the side marked with the "+" symbol.

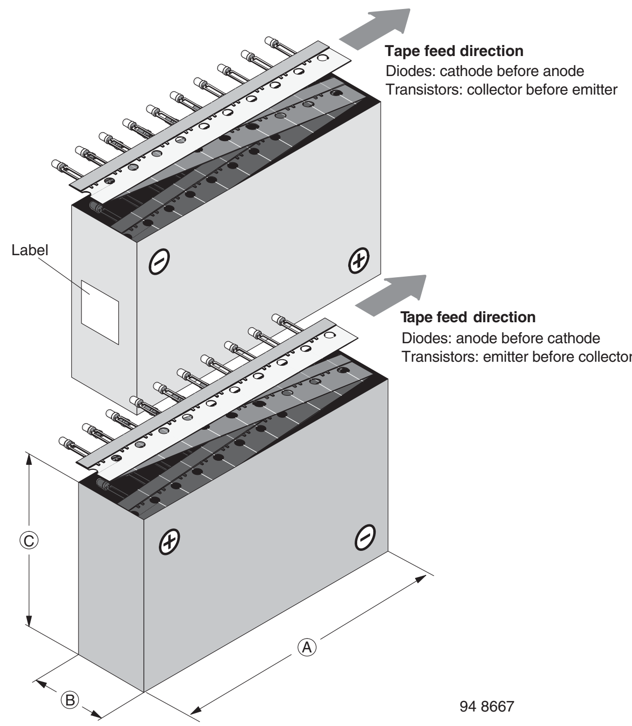


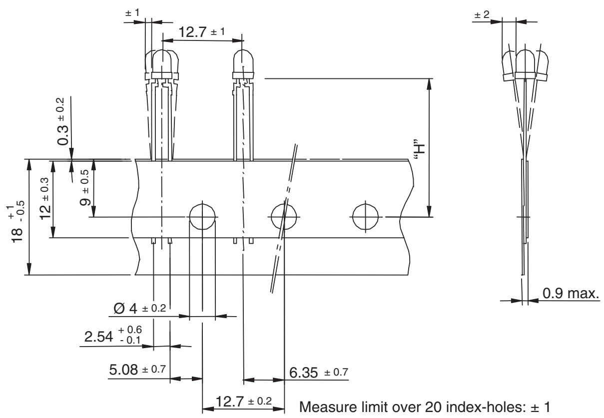
Fig. 34 - Tape Feed Direction

TABLE 5 - INNER DIMENSIONS OF AMMOPACK			
A mm	B mm	C mm	COMPONENTS
340	46	125	T-1¾ (5 mm)
340	34	140	T-1 (3 mm) AS-taping
340	41	140	T-1 (3 mm) other than AS-taping
348	43	125	FSZ side view lens
348	46	125	GSZ side view lens

TAPING OF T-1 (3 mm) PACKAGES

Polarity options: Z, 12, 21

TABLE 6 - POSITION OF T-1 (3 mm) COMPONENTS IN TAPE		
OPTION	**H**	**PREFERENCE**
AS	17.3 ± 0.5 mm	recommended
MS	25.5 ± 0.5 mm	recommended
CS	22.0 ± 0.5 mm	



Quantity per:	Reel (Mat. - No. 1764)
	2000

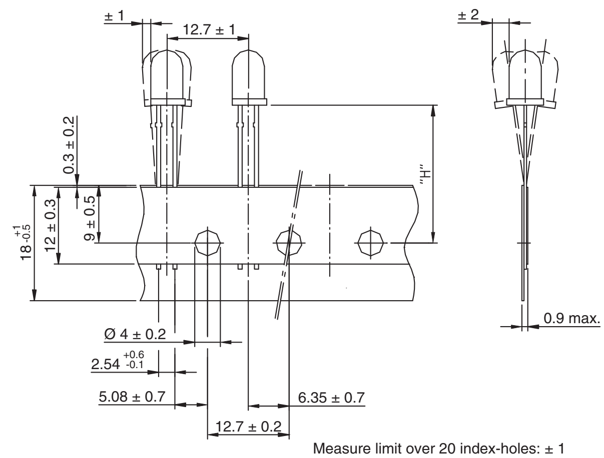
94 8171

Fig. 35 - Taping of T-1 (3 mm) Devices

TAPING OF T-1¾ (5 mm) PACKAGES

Polarity options: Z, 12, 21

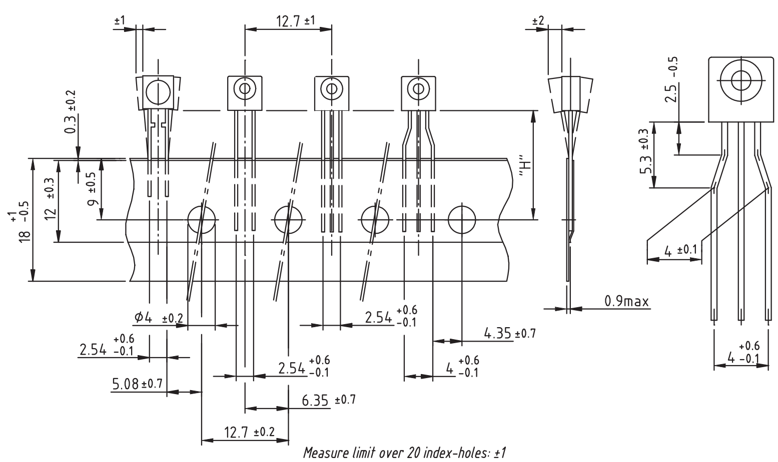
TABLE 7 - POSITION OF T-1¾ (5 mm) COMPONENTS IN TAPE		
OPTION	**H**	**PREFERENCE**
AS	17.3 ± 0.5 mm	recommended
KS	19.3 ± 0.5 mm	
MS	25.5 ± 0.5 mm	recommended
CS	22.0 ± 0.5 mm	
ES	24.0 ± 0.5 mm	



Quantity per:	Reel (Mat.-no. 1764)
	1000

94 8172

Fig. 36 - Taping of T-1¾ (5 mm) Devices



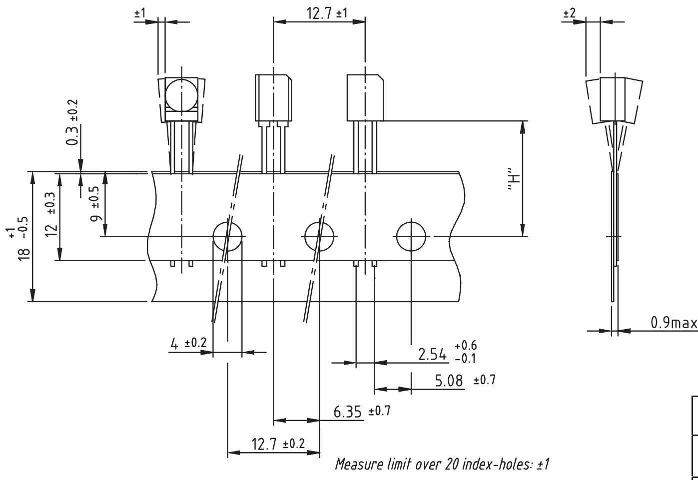
Bend leads:
Lead standard xG
Straight leads:
Lead standard xS

Option	H
AS	16 ± 0.5 mm
ES	24 ± 0.5 mm
FS	27 ± 0.5 mm
GS	29 $^{+0.2}_{-0.5}$ mm
EG	24 ± 0.5 mm
FG	27 ± 0.5 mm

Quantity per:	Ammopack (Mat. - No. 1763)
	2000

18886

Fig. 37 - Taping of Side View Lens Packages



Option	H
AS	16 ± 0.5 mm
ES	24 ± 0.5 mm
MS	25.5 ± 0.5 mm

Quantity per:	Reel (Mat. - No. 1764)
	1000

18887

Fig. 38 - Taping of Side View PIN Photodiodes

TUBE PACKAGING OF TOP VIEW PIN PHOTODIODES BP104S AND BPW34S

Dimensions in millimeters

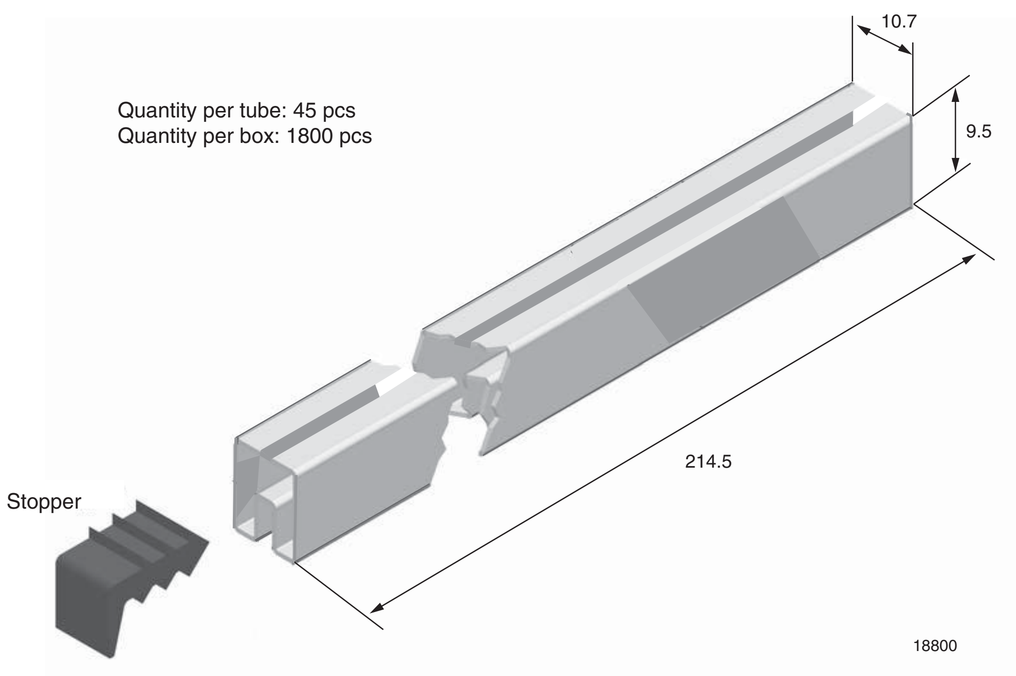


Fig. 39 - Drawing Proportions Not Scaled

OPTOELECTRONICS

Emitters, Detectors, Sensors

Infrared Emitters, Photo Detectors, and Optical Sensors

Infrared Emitters

PIN Photo Diodes

Phototransistors

Reflective Sensors – Analog

Transmissive Sensors – Analog

Ambient Light Sensors

Fully Integrated Proximity and Ambient Light Sensors

RESOURCES

- Optical sensors product portfolio http://www.vishay.com/optical-sensors/
- Infrared emitters product portfolio http://www.vishay.com/ir-emitting-diodes/
- Photo detectors product portfolio http://www.vishay.com/photo-detectors/
- Optoelecronics complete product portfolio http://www.vishay.com/optoelectronics/
- Technical support:
  - emittertechsupport@vishay.com
  - sensorstechsupport@vishay.com
  - detectortechsupport@vishay.com
- Sales contacts: http://www.vishay.com/doc?99914

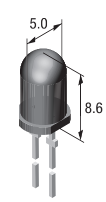
A WORLD OF SOLUTIONS

Infrared Emitters

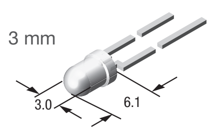
Vishay offers emitters in more wavelengths than any other supplier: 830 nm, 850 nm, 870 nm, 890 nm, 940 nm, and 950 nm. Providing fast rise and fall response times, Vishay also has the broadest selection of double hetero infrared emitters. They are the highest-power infrared emitters with the lowest forward voltages on the market and ideal for high-current applications. The latest surface emitter technology based devices, which provide highest radiant intensities, round up our extensive IR emitter portfolio.

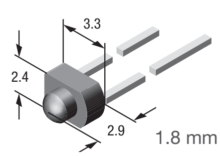
Package	Part Number	Peak Wavelength (nm)	Angle of Half Intensity (+/-°)	Radiant Intensity, I_e (mW/sr) [1]	Rise and Fall Time, t_r/t_f (ns)	Remark
Through-Hole Packages						
5mm	TSAL6100	940	10	170	15	No stand-off
	TSAL6200	940	17	72	15	No stand-off
	TSAL6400	940	25	50	15	No stand-off
	TSFF5210	870	10	180	15	Stand-off
	TSFF5410	870	22	70	15	Stand-off
	TSFF5510	870	38	32	15	Stand-off
	TSFF6210	870	10	180	15	No stand-off
	TSFF6410	870	22	70	15	No stand-off
	TSHA5203	875	12	65	600	Stand-off
	TSHA5500	875	24	30	600	Stand-off
	TSHA6203	875	12	65	600	No stand-off
	TSHA6500	875	24	30	600	No stand-off
	TSHF5210	890	10	180	30	Stand-off
	TSHF5410	890	22	70	30	Stand-off
	TSHF6210	890	10	180	30	No stand-off
	TSHF6410	890	22	70	30	No stand-off
	TSHG5210	850	10	230	20	Stand-off
	TSHG5410	850	18	90	20	Stand-off
	TSHG5510	830	38	32	15	Stand-off
	TSHG6200	850	10	180	20	No stand-off
	TSHG6210	850	10	230	20	No stand-off
	TSHG6400	850	22	70	20	No stand-off
	TSHG6410	850	18	90	20	No stand-off
	TSHG8200	830	10	180	20	No stand-off
	TSHG8400	830	22	70	20	No stand-off
	TSUS5202	950	15	30	800	Stand-off
	TSUS5402	950	22	20	800	Stand-off
	TSUS6402	950	22	30	800	
	VSLY5850	850	3	600	10	Stand-off
	VSLY5940	940	3	600	10	Stand-off
3 mm	TSAL4400	940	25	30	800	No stand-off
	TSHA4400	875	20	20	600	No stand-off
	TSUS4300	950	16	18	800	No stand-off
	TSUS4400	950	18	15	800	No stand-off
	VSLB3940	940	22	65	15	No stand-off
	VSLB3948	940	22	65	15	No stand-off
1.8 mm	CQY36N	950	55	1.50	800	No stand-off
	CQY37N	950	12	5	800	No stand-off

5 mm



3 mm



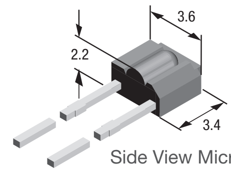


1.8 mm

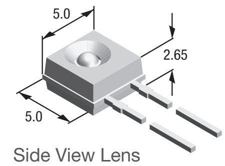
Infrared Emitters (continued)

Package	Part Number	Peak Wavelength (nm)	Angle of Half Intensity (+/-°)	Radiant Intensity, I_e (mW/sr) (1)	Rise and Fall Time, t_r/t_f (ns)	Remark
Through-Hole Packages						
Side View Micro	TSSS2600	950	25H, 65V	2.6	800	No stand-off
Side View Lens	TSKS5400S	950	30	4.5	800	No stand-off
TO-18	TSTA7100	875	5	50	600	No stand-off
	TSTA7300	875	12	20	600	No stand-off
	TSTA7500	875	30	6	600	No stand-off
	TSTS7100	950	5	18	800	No stand-off
	TSTS7300	950	12	6	800	No stand-off
	TSTS7500	950	30	1.6	800	No stand-off

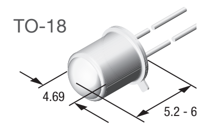
(1) I_f = 100 mA

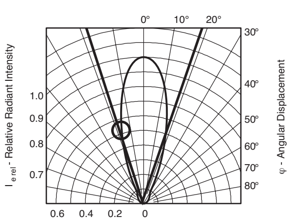


Side View Micro



Side View Lens

TO-18




Stand-Off

To control the height of the emitter when inserted into the PCB for soldering, some leaded emitters and photo detectors feature a standoff option (shown at left). The stand off is the tab on the leads. It is sometimes called a stopper.

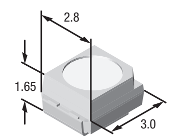
Angle of Half Intensity, $\varphi_{0.5}$ or θ

In a radiation diagram, the angle within which the radiant intensity is greater than or equal to half of the maximum intensity. In Vishay datasheets, the symbol $\varphi_{0.5}$ is most commonly used for the angle of half intensity. For visible LEDs this is sometime called the viewing angle. There is still light, be it infrared or visible, outside of this angle.

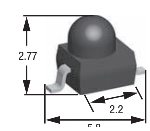
Infrared Emitters (continued)

Package	Part Number(2)	Peak Wavelength (nm)	Angle of Half Intensity (+/-°)	Radiant Intensity, I_e (mW/sr)(1)	Rise and Fall Time, t_r/t_f (ns)	Remark
Surface-Mount Packages						
PLCC-2	VSMB3940X01	940	60	13	15	
	VSMY3940X01	940	60	15	10	
	VSMF3710	890	60	10	30	
	VSMF4710	870	60	10	15	
	VSMF4720	870	60	16	15	
	VSMF9700	800	60	8	50	
	VSMF970011X01	890	60	9	50	
	VSMG2700	830	60	10	20	
	VSMG2720	830	60	14	20	
	VSMG3700	850	60	10	20	
	VSML3710	940	60	6	800	
	VSMS3700	950	60	4.5	800	
	VSMY3850	850	60	17	10	
	VSMY385010	850	60	9	10	I_F = 70 mA
1.8 mm	VSMY2850RG, -G	850	10	100	10	
	VSMG2000X01, -2020X01	850	12	40	20	
	VSMG285011RG, -G	850	12	40	20	
	VSMY2853RG, -G	850	28	35	10	
	VSMF2890RGX01, -GX01	890	12	40	30	
	VSMF2893RGX01, -GX01	890	25	20	30	
	VSMB294008RG, -G	940	7	60	15	
	VSMY2940RG, -G	940	10	120	10	
	VSMB2000X01, -2020X01	940	12	40	15	
	VSMB2943RGX01, - GX01	940	25	20	15	
	VSMB2948RG, -G	940	25	20	15	
	VSMY2943RG, -G	940	28	35	10	
	VSMY294310RG, -G	940	25	25	10	I_F = 70 mA
1.8 mm Side View	VSMY2853SL	850	28	35	10	
	VSMF2893SLX01	890	25	20	30	
	VSMB2943SLX01	940	25	20	15	Max pulse current: 1A
	VSMB2948SL	940	25	20	15	Max pulse current: 500mA
	VSMY294310SL	940	25	32	10	I_F = 70 mA
	VSMY2943SL	940	28	35	10	
0805	VSMY1940X01	940	60	10	10	
	VSMB1940X01	940	60	6	15	
	VSMY1850	850	60	12	10	
Little Star®	VSMY7850X01	850	60	170	18	I_F = 1.0 A
	VSMY7852X01	850	60	42	10	I_F = 250 mA

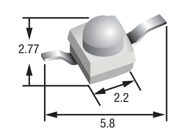
(1) I_f = 100 mA unless otherwise stated (2) Products ending in "X01" are AEC Q101 qualified



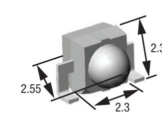
PLCC-2



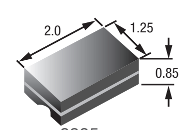
1.8 mm Gullwing



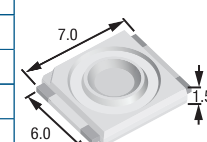
1.8 mm Reverse Gullwing



1.8 mm Side View



0805

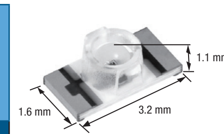


Little Star

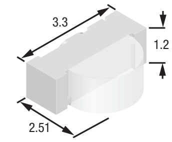
Inner Lens PCB

Package	Part Number[2]	Peak Wavelength (nm)	Angle of Half Intensity (+/-°)	Radiant Intensity, I_e (mW/sr)[1]	Rise and Fall Time, t_r/t_f (ns)	Remark
Surface-Mount Packages						
Inner Lens PCB	VSMY12850	850	40	16	10	I_F = 70 mA
	VSMY12940	940	40	16	10	I_F = 70 mA
SMD SV ultra wide view	VSMB10940	940	75	1	15	I_F = 20 mA
	VSMB10940X01	940	75	1	15	I_F = 20 mA
	VSMB11940X01	940	75	1	15	I_F = 20 mA
	VSMG10850	850	75	1	15	I_F = 20 mA
SMD SV	VSMB14940	940	9	35	15	I_F = 70 mA
	VSMY14940	940	9	35	15	I_F = 70 mA
	VSMB14942	940	16	26	15	side view
High-power QFN	VSMY98545	850	45	350	15	I_F = 1.0 A
	VSMY98545DS	850	45	600	30	I_F = 1.0 A

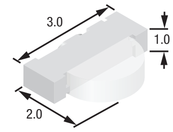
(1) I_f = 100 mA unless otherwise stated (2) Products ending in "X01" are AEC Q101 qualified



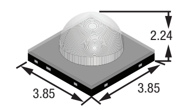
Inner Lens PCB



SMD SV
Ultra Wide View



SMD SV



High-Power-QFN

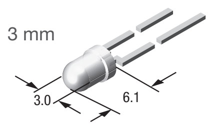
PIN Photo Diodes

Vishay has the broadest portfolio of PIN photodiodes on the market. With lower capacitance, they provide high-speed response, low noise and low dark current along with excellent sensitivity. They are ideal for high-speed data transfer, light barriers, alarm systems, and linear light measurement.

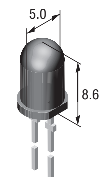
Package	Part Number	Peak Wave length (nm)	Bandwidth $\lambda_{0.5}$ (nm)	Sensitivity I_{ra} (µA)(1)	Angle of Half Sensitivity (+/-°)	Photo Area (mm)	Rise/Fall Time, t_r/t_f (ns)(2)	Remark
Through-Hole Packages								
3 mm	TEFD4300	950	350 to 1120	17	20	0.23	100	
	TEFD4300F	950	770 to 1070	17	20	0.23	100	
5 mm	BPV10	920	380 to 1140(7)	70	20	0.78	2,5(3)	Stand-off
	BPV10NF	940	790 to 1050	60	20	0.78	2,5(3)	Stand-off
Side View	BPW41N	950	870 to 1050	45	65	7.5	100	5 x 4 x 6.8
	BPW46 (L)	900	430 to 1100(7)	50	65	7.5	100	5 x 3 x 6.4
	BPW82	950	790 to 1050	45	65	7.5	100	5 x 4 x 6.8
	BPW83	950	790 to 1050	45	65	7.5	100	5 x 3 x 6.4
Side View High Perfor-mance	BPV22F	950	870 to 1050	80	60	7.5	100	
	BPV22NF	940	790 to 1050	85	60	7.5	100	
	BPV23F	950	870 to 1050	63	60	4.4	70	
	BPV23NF	940	790 to 1050	65	60	4.4	70	
TO-5	BPW20RF	920	400 to 1100(7)	42	50	7.5	3600(6)	
TO-18	BPW24R	900	430 to 1100(7)	60	12	0.78	7(4)(5)	
Top View Leaded	BP104	950	870 to 1050	45	65	7.5	100	
	BPW34	900	430 to 1100(7)	55	65	7.5	100	

Notes: (1) Sensitivity: VR = 5 V, E_e = 1 mW/cm², λ = 950 nm; (2) Speed: R_L = 1 kΩ, λ = 820 nm, VR = 10 V, (3) VR = 50 V, R_L = 50 Ω, λ = 820 nm; (4) R_L = 50 Ω; (5) VR = 20 V; (6) VR = 0V (7) Bandwidth $\lambda_{0.1}$ (nm)

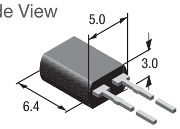
3 mm



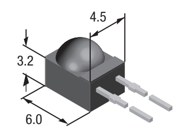
5 mm



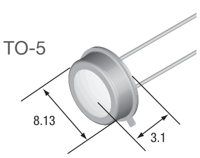
Side View



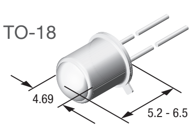
Side View,
High Performance



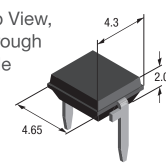
TO-5



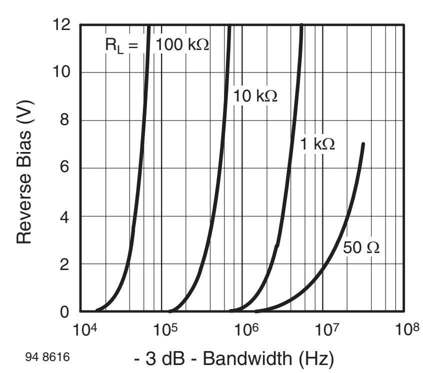
TO-18



Top View,
Through
Hole

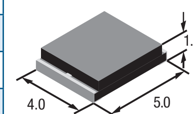


Rise and Fall Time: Switching times of photo detectors are strongly dependent on the measurement conditions. Shown in the diagrams are two major conditions: the reverse bias and the value of the load resistor used in the circuit. The switching time of a photo diode varies by two orders of magnitude when the load resistor value changes from 50 Ω to 10 kΩ. The lower the value of the load resistor, the faster the diode becomes. Also, the higher the reverse bias, the faster the switching times.

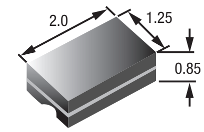


PIN Photo Diodes (continued)

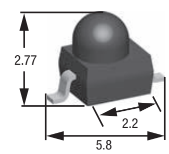
Package	Part Number[5]	Peak Wave length (nm)	Bandwidth $\lambda_{0.5}$ (nm)	Sensitivity I_{ra} (µA)[1]	Angle of Half Sensitivity (+/-°)	Photo Area (mm²)	Rise/Fall Time, t_r/t_f (ns)[2]	Remark
Surface-Mount Packages								
Top View	TEMD5080X01	940	350 to 1100[4]	60	65	7.5	40[4]	AEC-Q101
	TEMD5020X01	940	430 to 1100[4]	35	65	4.4	100	AEC-Q101
	TEMD5120X01	940	790 to 1050	35	65	4.4	100	AEC-Q101
	TEMD5010X01	940	430 to 1100[4]	55	65	7.5	100	AEC-Q101
	TEMD5110X01	940	790 to 1050	55	65	7.5	100	AEC-Q101
	VBP104S	940	430 to 1100[4]	35	65	4.4	100	Gullwing
	VBP104SR	940	430 to 1100[4]	35	65	4.4	100	Reverse gullwing
	VBP104FAS	950	780 to 1050	35	65	4.4	100	Gullwing
	VBP104FASR	950	780 to 1050	35	65	4.4	100	Reverse gullwing
	VBPW34S	940	430 to 1100[4]	55	65	7.5	100	Gullwing
	VBPW34SR	940	430 to 1100[4]	55	65	7.5	100	Reverse gullwing
	VBPW34FAS	950	780 to 1050	55	65	7.5	100	Gullwing
	VBPW34FASR	950	780 to 1050	55	65	7.5	100	Reverse gullwing
1206	VEMD6010X01	900	430 to 1100	9.5	60	0.85	100	
	VEMD6110X01	950	750 to 1050	9.5	60	0.85	100	
QFN	VEMD5010X01	940	430 to 1100	48	65	7.5	100	
	VEMD5110X01	940	790 to 1050	48	65	7.5	100	
0805	TEMD7000X01	900	350 to 1120[4]	3	60	0.23	100	
	TEMD7100X01	950	750 to 1050	3	60	0.23	100	
1.8 mm	VEMD2000X01	940	750 to 1050	12	15	0.23	100	Reverse gullwing
	VEMD2020X01	940	750 to 1050	12	15	0.23	100	Gullwing
	VEMD2500X01	900	350 to 1120[4]	12	15	0.23	100	Reverse gullwing
	VEMD2520X01	900	350 to 1120[4]	12	15	0.23	100	Gullwing
	VEMD2503X01	900	350 to 1120[4]	10	30	0.23	100	Reverse gullwing
	VEMD2523X01	900	350 to 1120[4]	10	30	0.23	100	Gullwing
	VEMD2003X01	940	750 to 1050	10	30	0.23	100	Reverse gullwing
	VEMD2023X01	900	750 to 1050	10	30	0.23	100	Gullwing
1.8 mm Side View	VEMD2523SLX01	900	350 to 1120[4]	10	30	0.23	100	
	VEMD2023SLX01	940	750 to 1050	10	30	0.23	100	
SMD SV ultra wide view	VEMD10940F	920	780 to 1050	3	75	0.23	100	side view
	VEMD10940FX01	950	790 to 1070	3	75	0.23	1000	side view
	VEMD11940FX01	950	780 to 1050	1.13	75	0.053	1000	side view



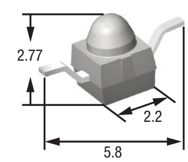
Top View, Surface-Mount



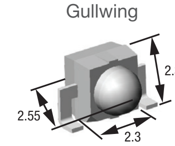
0805



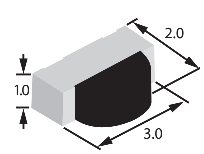
1.8 mm Gullwing



1.8 mm Reverse Gullwing



1.8 mm Side View



SMD SV ultra wide view

Notes: (1) Sensitivity: VR = 5 V, E_e = 1 mW/cm², λ = 950 nm; (2) Speed: R_L = 1 kΩ, λ = 820 nm, VR = 10 V, (3) R_L = 50 Ω; (4) Bandwidth $\lambda_{0.1}$ (nm) (5) Products ending in "X01" are AEC-Q101 qualified

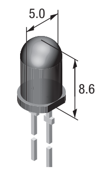
Phototransistors

Vishay provides the industry's widest selection of phototransistors. Offered in over 10 different packages, Vishay's phototransistors are exceptionally sensitive and simplify circuit design by eliminating the need for a separate amplifier.

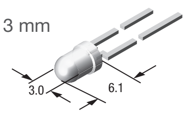
Package	Part Number	Peak Wave-length (nm)	Bandwidth $\lambda_{0.5}$ (nm)	Collector Light Current, I_{ca} (mA)(1)	Angle of Half Sensitvity (+/-°)	Rise and Fall Time, t_r/t_f (µs)(2)	Remark
Through-Hole Packages							
5 mm	BPV11	850	450 to 1080(3)	10	15	6	With base pin
	BPV11F	930	900 to 980	9	15	6	With base pin
	BPW96C	850	450 to 1080(3)	8	20	2	Stand-off
3 mm	BPW85C	850	450 to 1080(3)	5	25	2	Stand-off
	TEFT4300	925	875 to 1000	3.2	30	2	No stand-off
1.8 mm	BPW16N	825	450 to 1040(3)	0.14	40	4.8	
	BPW17N	825	450 to 1040(3)	1	12	4.8	
Side View Micro	TEST2600	920	850 to 980	2.5	30H, 60V	6	
Side View Lens	TEKT5400S	920	850 to 980	4	37	6	
TO-18	BPW76B	850	450 to 1080(3)	1.2	40	6	
	BPW77NB	850	450 to 1080(3)	20	10	6	

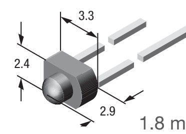
Notes: (1) Collector light current: V_{CE} = 5 V, E_e = 1 mW/cm², I = 950 nm, typical (2) Speed: V_S = 5 V, I_C = 5 mA, R_L = 100 Ω
(3) Bandwidth $\lambda_{0.1}$ (nm)

5 mm

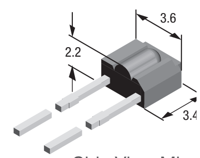


3 mm

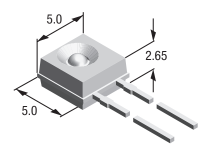




1.8 mm

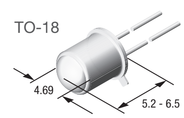


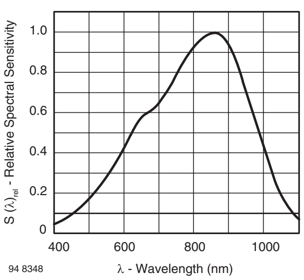
Side View Micro



Side View Lens

TO-18





Bandwidth: $\lambda_{0.5}$ and $\lambda_{0.1}$

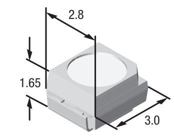
The diagram to the left shows the relative spectral sensitivity of the BPV11 phototransistor. The peak sensitivity is found at 850 nm. The bandwidth of the detector can be defined by using a relative spectral sensitivity value of 0.5 or 0.1. Vishay datasheets will show one of these values. In the case of the BPV11, the bandwidth in the datasheet is 450 nm to 1080 nm, $\lambda_{0.1}$.

VMN-SG2123-1703
www.vishay.com

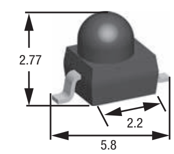
Phototransistors (continued)

Package	Part Number[4]	Peak Wave-length (nm)	Bandwidth $\lambda_{0.5}$ (nm)	Collector Light Current, I_{ca} (mA)[1]	Angle of Half Sensitvity (+/-°)	Rise and Fall Time, t_r/t_f (µs)[2]	Remark
Surface-Mount Packages							
PLCC-2	VEMT3700	850	450 to 1080[3]	0.5	60	2	
	VEMT3700F	940	850 to 1050	0.5	60	2	
	VEMT4700	850	450 to 1080[3]	0.5	60	2	With base pin
1.8 mm	VEMT2000X01	860	790 to 970	6	15	2	Reverse gullwing
	VEMT2020X01	860	790 to 970	6	15	2	Gullwing
	VEMT2500X01	850	470 to 1090[3]	6	15	2	Reverse gullwing
	VEMT2520X01	850	470 to 1090[3]	6	15	2	Gullwing
	VEMT2503X01	860	470 to 1090[3]	4	30	10	Reverse gullwing
	VEMT2523X01	860	470 to 1090[3]	4	30	10	Gullwing
	VEMT2003X01	860	790 to 970	4	30	10	Reverse gullwing
	VEMT2023X01	860	790 to 970	4	30	10	Gullwing
1.8 mm Side View	VEMT2523SLX01	850	470 to 1090[3]	4	30	10	
	VEMT2023SLX01	860	790 to 970	4	30	10	
0805	TEMT7000X01	850	470 to 1090[3]	0.45	60	2	
	TEMT7100X01	870	750 to 1010	0.45	60	2	

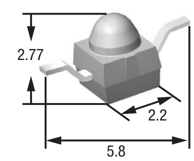
Notes: (1) Collector light current: V_{CE} = 5 V, E_e = 1 mW/cm², I = 950 nm, typical (2) Speed: V_S = 5 V, I_C = 5 mA, R_L = 100 Ω (3) Bandwidth $\lambda_{0.1}$ (nm) (4) Products ending in “X01” are AEC-Q101 qualified



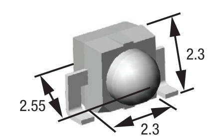
PLCC-2



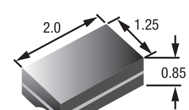
1.8 mm Gullwing



1.8 mm Reverse Gullwing



1.8 mm Side View



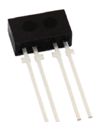
0805

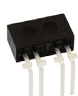
Reflective Sensors, Analog Output

Part Number[1][3]	Package		Peak Operating Range[2] (mm)	Peak Operating Distance (mm)	Typical Output Current (mA)
	L x W (mm)	H (mm)			
TCND5000[3]	6.0 x 4.3	3.75	2 to 25	6.0	0.0015
TCRT1000/1010	7.0 x 4.0	2.5	0.2 to 4.0	1.0	0.5
TCRT5000(L)	10.2 x 5.8	7.0	0.2 to 15	2.5	1
CNY70	7.0 x 7.0	6.0	0 to 5.0	0	1

Notes: [1] All optical sensors have phototransistor output except where noted
[2] Relative collector current > 20 %
[3] TCND5000 has a PIN photodiode output


TCND5000


TCRT1000


TCRT1010


TCRT5000(L)


CNY70

Transmissive Sensors, Analog Output

Part Number[1][3]	Package		Gap (mm)	Aperture (mm)	Typical Output Current (mA)	On / Off Time t_{on} / t_{off} (µs)	Operating Temp. Max.
	L x W (mm)	H (mm)					
TCPT1300X01	5.5 x 4.0	4.0	3.0	0.3	0.6	20 / 30	+105 °C
TCUT1300X01[2]	5.5 x 4.0	4.0	3.0	0.3	0.6	20 / 30	+105 °C
TCPT1350X01	5.5 x 4.0	4.0	3.0	0.3	1.6	9 / 16	+125 °C
TCUT1350X01[2]	5.5 x 4.0	4.0	3.0	0.3	1.6	9 / 16	+125 °C
TCPT1600X01	5.5 x 4.0	5.7	3.0	0.3	1.6	9 / 16	+105 °C
TCUT1600X01[2]	5.5 x 4.0	5.7	3.0	0.3	1.6	9 / 16	+105 °C
TCST1030	8.3 x 4.7	8.15	3.1	none	2.4	15 / 10	+85 °C
TCST1103	11.9 x 6.3	10.8	3.1	1.0	4.0	10 / 8	+85 °C
TCST1202	11.9 x 6.3	10.8	3.1	0.5	2.0	10 / 8	+85 °C
TCST1230	9.2 x 4.8	5.4	2.8	0.5	2.0	15 / 10	+85 °C
TCST1300	11.9 x 6.3	10.8	3.1	0.25	0.5	10 / 8	+85 °C
TCST2103	24.5 x 6.3	10.8	3.1	1.0	4.0	10 / 8	+85 °C
TCST2202	24.5 x 6.3	10.8	3.1	0.5	2.0	10 / 8	+85 °C
TCST2300	24.5 x 6.3	10.8	3.1	0.25	0.5	10 / 8	+85 °C
TCST5250	14.3 x 6.0	9.5	2.7	0.5	1.5	15 / 10	+85 °C

Notes: [1] All optical sensors have phototransistor output
[2] Dual channel
[3] Products ending in “X01” are AEC-Q101 qualified


TCPT13x0X01


TCUT13x0X01


TCST1030


TCST1230


TCST1x0x


TCST2x0x


TCPT1600X01


TCUT1600X01

Ambient Light Sensors

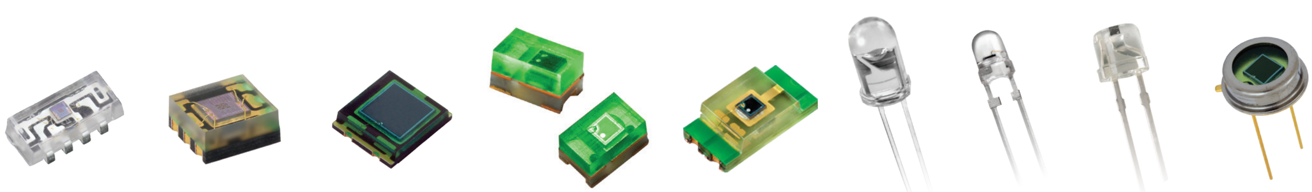
Ambient light sensors are used to detect light or brightness in a manner similar to the human eye. They are most commonly found in industrial lighting, consumer electronics, and automotive systems, where they allow settings to be adjusted automatically in response to changing ambient light conditions. By turning on, turning off, or adjusting features, ambient light sensors can conserve battery power or provide extra safety while eliminating the need for manual adjustments.

Package	Part Number(3)	Peak Wave-length (nm)	Band-width $\lambda_{0.5}$ (nm)	Angle of Half Sensitvity (+/-°)	Light Current(1) Incandescent (µA)	Light Current(2) Fluorescent (µA)	Remark
Photo Diodes							
0805, SMD	TEMD6200FX01	540	430 to 610	60	0.04	0.03	Stand-off
1206, SMD	TEMD6010FX01	540	430 to 610	60	0.04	0.03	
Top View SMD	TEMD5510FX01	540	430 to 610	65	1	0.7	
TO-5, Leaded	BPW21R	565	420 to 675	50	0.9	0.75	
Phototransistors							
0805, SMD	TEMT6200FX01	550	450 to 610	60	12	7	
1206, SMD	TEMT6000X01	570	430 to 800	60	50	21	
5 mm, flat top	TEPT5700	570	430 to 800	50	75	31	Leaded
5 mm	TEPT5600	570	430 to 800	20	350	145	Leaded
3 mm	TEPT4400	570	430 to 800	30	200	83	Leaded

Notes: (1) Ev = 100 lux, V_{CE} = 5 V, CIE illuminant A, typical (2) Ev = 100 lux, V_{CE} = 5 V, e.g. Sylvania color abbrev. D830, typical
(3) Products ending in "X01" are AEC-Q101 qualified

Part number	Mounting	Size (mm)	Ambient Light Range (lx)	Operating Voltage Range (V)	I²C bus voltage range (V)	Ambient Light Resolution (lx/ct)	Output Code
I²C Output							
VEML6030	SMD	2.0 x 2.0 x 0.85	0 to 120 000	2.5 to 3.6	1.7 to 3.6	0.0036	16-bit, I²C
VEML7700	SMD	6.8 x 2.35 x 3	0 to 120 000	2.5 to 3.6	1.7 to 3.6	0.0036	16-bit, I²C

F	Part numbers with an F contain an infrared filtering epoxy to further improve the ambient light sensing performance	**X01**	Part numbers with an X01 are qualified to the AEC Q101 standard and support operating temperatures from -40 °C to +100 °C



VEML7700 **VEML6030** **TEMD5510FX01** **TEMT6200FX01 TEMD6200FX01** **TEMD6010FX01 TEMT6000X01** **TEPT5600** **TEPT4400** **TEPT5700** **BPW21R**

High-Accuracy Digital Light Sensors

Based on patented Filtron™ technology implementation, digital light sensors introduced by Vishay provide red, green, blue, IR, and UVAB light sensing for precise color measurement. All digital light sensors have 16-bit resolution and feature miniature transparent OPLGA packages. These are fully integrated sensors — including a high-sensitivity photodiode, a low noise amplifier, and a 16-bit A/D converter — with support for an easy-to-use I^2C bus communication.

Features and Benefits

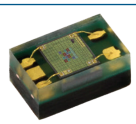
- On-chip coating provides best spectral sensitivity to cover visible and UV spectrum (Filtron™ technology)
- Shutdown mode with < 1µA power consumption
- 16-bit range for ambient light detection, RGB, and UV
- ALS output tolerance< 10%
- I^2C Interface

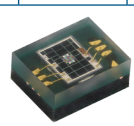
Applications

- Health monitoring
- AWB correction
- Control display brightness
- Home lightning control

Color Sensors

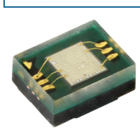
Part Number	Package		Peak Sensitivity (nm)	Operating Voltage Range (v)	Output Code	Operating Temp. Range (°C)	AEC-Q101
	L x W (mm)	H (mm)					
VEML6040	2.0 x 1.25	1	650, 550, 450 (R,G,B)	2.5 to 3.6	16 bit, I^2C	-40 to 85	x
VEML6090	2.35 x 1.8	1	620, 530, 450, 360, 850 (R,G,B,UV,IR)	1.7 to 3.6	16 bit, I^2C	-40 to 85	x

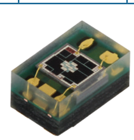

VEML6040


VEML6090

UV Sensors

Part Number	Package		Peak Sensitivity (nm)	Operating Voltage Range (v)	Output Code	Operating Temp. Range (°C)	AEC-Q101
	L x W (mm)	H (mm)					
VEML6070	2.35 x 1.8	1	355	2.7 to 5.5	16 bit, I^2C	-40 to 85	x
VEML6075	2.0 x 1.25	1	365, 330	1.7 to 3.6	16 bit, I^2C	-40 to 85	x


VEML6070


VEML6075

Fully Integrated Proximity and Ambient Light Sensors

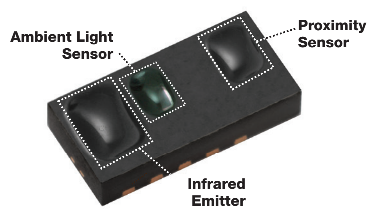
To simplify the design process, Vishay has integrated the infrared emitter, proximity photodiode, ambient light sensor and signal processing IC in one package. Window design and sensor placement are no longer geometric puzzles and the need for mechanical cross-talk barriers is eliminated. Each sensor is a leadless surface-mount package with standard I²C communication and features an interrupt function. Interrupts reduce power consumption by eliminating polling traffic between the sensor and microcontroller.

FEATURES AND BENEFITS

- Low profile; height less than 0.83 mm
- 16-bit dynamic range
- Programmable emitter drive current
  - 10 mA to 200 mA (in 10 mA steps)
- Detection range up to 1 m
- Light sensing from 0.004 lux to 16 klux
- I²C Interface

APPLICATIONS

- Mobile devices (smart phones, touch phones, PDA, GPS)
- Consumer (white goods, cameras, game systems)
- Computing devices (notebooks, tablet PCs)
- Automotive and industrial device (presence detection and displays)



PROXIMITY SENSORS

Part Number	PACKAGE		IINTEGRATED COMPONENTS			Operating temp range (°C)	AEC-Q101
	L x W (mm)	H (mm)	Infrared Emitter	Proximity Detector	Ambient Light Sensor		
VCNL4020X01	4.90 x 2.40	0.83	.	.	.	-40 to 105	.
VCNL4035X01	4.0 x 2.36	0.75	x	.	.	-40 to 105	.
VCNL3020	4.90 x 2.40	0.83	.	.	x	-25 to 85	x
VCNL4010	3.95 x 3.95	0.75	.	.	.	-25 to 85	x
VCNL4020	4.90 x 2.40	0.83	.	.	.	-25 to 85	x
VCNL4040	4.0 x 2.0	1.1	.	.	.	-25 to 85	x
VCNL4100	8.0 x 3.0	1.8	.	.	.	-40 to 85	x

VMN-SG2123-1703
www.vishay.com

Optoelectronics - IR Emitters with Radiant Intensity up to 600 m/W/sr at 100 mA

830 nm, 850 nm, and 870 nm High Intensity and High Optical Power Infrared Emitters

KEY FEATURES

- Radiant intensity up to 600 mW/sr at 100 mA
- Broad option of viewing angles from ± 3° to ± 60°
- Up to 5x longer life than competing devices
- Six different packages
- 850 nm based on Light Up® surface emitting technology)

BENEFITS

- Reduce the number of emitters required to produce equivalent optical power – longer range and better resolution
- Extremely fast switching times for high-speed applications
- 4x the radiant intensity of competing devices. Continuous or pulsed current source

APPLICATIONS

- Illumination for closed circuit TV (night vision) and CMOS image sensors
- Wireless audio transmission in concert halls, museums, and home theatre surround sound systems
- Emergency response remote control of traffic lights
- Emitter for 3DTV active glasses synchronization
- Automotive - illumination for heads up display and back up camera

RESOURCES

- Datasheets: http://www.vishay.com/ir-emitting-diodes/
- Optoelectronis Portfolio: http://www.vishay.com/optoelectronics/
- For technical questions, contact emittertechsupport@vishay.com

FARTHER WITH FEWER

Reduce the number of infrared emitters by up to half while achieving the same resolution and range by using Vishay's infrared emitters for night time **illumination** in closed circuit television (CCTV), security camera, and CMOS image sensor applications. For **data transmission** in museums, concert halls, and other public venues these emitters feature switching times from 10 to 20 ns, meeting the requirements for high-modulation operation and supporting data transmission rates of up to 16 Mbit/sec.

MINIMIZE DEGRADATION

Applications rely on the emitter to maintain performance over time. Designers can not afford to use an emitter that rapidly degrades. Vishay has the lowest degradation when tested against the other leading infrared emitters. The lowest degradation means the best emitters, the longest life.

PART NUMBER	Angle of Half Intensity (°)	Intensity (mW/sr)		Degradation (%)
		0 hours	4000 hours	
Vishay TSHG5210	± 10	230	225	2 %
Vishay TSHG5410	± 18	80	79	2 %
Competitor A	± 8	171	145	15 %
Competitor B	± 12	107	96	10 %
Competitor C	± 10	130	98	25 %


Little Star


5 mm (T1¾)


Reverse Gullwing


Gullwing


PLCC2


0805

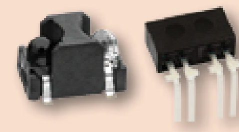
PORTFOLIO

PEAK WAVELENGTH (nm)	PART NUMBER	PACKAGE	RADIANT INTENSITY[1] (mW/sr)	ANGLE OF HALF INTENSITY (°)	RISE, FALL TIME (ns)
830	TSHG5510	5 mm (T1¾)	32	± 38	15
	TSHG8200	5 mm (T1¾)	180	± 10	20
	TSHG8400	5 mm (T1¾)	70	± 22	20
	VSMG2720	PLCC2	14	± 60	15
850	TSHG5210	5 mm (T1¾)	230	± 10	20
	TSHG5410	5 mm (T1¾)	90	± 18	20
	TSHG6400	5 mm (T1¾)	70	± 22	20
	VSLY5850	5 mm (T1¾)	600	± 3	10
	VSMY1850	0805	12	± 60	10
	VSMY2850G	Gullwing	100	± 10	10
	VSMY2850RG	Reverse Gullwing	100	± 10	10
	VSMY3850	PLCC2	17	± 60	15
	VSMY7850X01	Little Star	170[2]	± 60	15
	VSMY7852X01	Little Star	42[3]	± 60	15
870	TSFF5210	5 mm (T1¾)	180	± 10	15
	TSFF5410	5 mm (T1¾)	70	± 22	
	TSFF5510	5 mm (T1¾)	32	± 38	
	VSMF4720	PLCC2	16	± 60	

[1]I_F=100 mA , [2]I_F=1 A, [3]I_F=250 mA

Vishay Intertechnology, Inc.

Optical Sensors



REFLECTIVE SENSORS

Reflective Sensors with Analog Output

TCXT1600X01

Turn-and-Push Function

AMBIENT LIGHT SENSORS

Ambient Light Sensors with Analog and Digital Output

TRANSMISSIVE SENSORS

Sensors with Analog Output

VCNL FAMILY

Integrated Proximity and Ambient Light Sensors with Digital Output

TCXT13X0X01

Single-and Dual-Channel Transmissive Sensors

COLOR SENSORS

Integrated Multiple Band Sensors

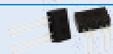
UV SENSORS

High-Resolution Sensors for UVI Calculation

OPTICAL SENSORS

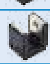
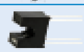
Focus Products

Reflective Sensors, Analog Output

Part Number(1)(3)		Package L x W (mm)	Package H (mm)	Peak Operating Range(2) (mm)	Peak Operating Distance (mm)	Typical Output Current (mA)
TCND5000(3)		6.0 x 4.3	3.75	2 to 25	6.0	0.0015
TCRT1000/1010		7.0 x 4.0	2.5	0.2 to 4.0	1.0	0.5
TCRT5000(L)		10.2 x 5.8	7.0	0.2 to 15	2.5	1
CNY70		7.0 x 7.0	6.0	0 to 5.0	0	1

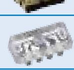
Notes: (1) All optical sensors have phototransistor output except where noted (2) Relative collector current > 20 % (3) TCND5000 has a PIN photodiode output

Transmissive Sensors, Analog Output

Part Number(1)(3)		Package L x W (mm)	Package H (mm)	Gap (mm)	Aperture (mm)	Typical Output Current (mA)	On / Off Time t_{on} / t_{off} (µs)	Operating Temp. Max.
TCPT1300X01		5.5 x 4.0	4.0	3.0	0.3	0.6	20 / 30	+105 °C
TCPT1350X01		5.5 x 4.0	4.0	3.0	0.3	1.6	9 / 16	+125 °C
TCUT1300X01(2)		5.5 x 4.0	4.0	3.0	0.3	0.6	20 / 30	+105 °C
TCUT1350X01(2)		5.5 x 4.0	4.0	3.0	0.3	1.6	9 / 16	+125 °C
TCPT1600X01		5.5 x 4.0	5.7	3.0	0.3	1.6	9 / 16	+105 °C
TCUT1600X01(2)		5.5 x 4.0	5.7	3.0	0.3	1.6	9 / 16	+105 °C
TCST1030		8.3 x 4.7	8.15	3.1	none	2.4	15 / 10	+85 °C
TCST1103		11.9 x 6.3	10.8	3.1	1.0	4.0	10 / 8	+85 °C
TCST1202		11.9 x 6.3	10.8	3.1	0.5	2.0	10 / 8	+85 °C
TCST1300		11.9 x 6.3	10.8	3.1	0.25	0.5	10 / 8	+85 °C
TCST1230		9.2 x 4.8	5.4	2.8	0.5	2.0	15 / 10	+85 °C
TCST2103		24.5 x 6.3	10.8	3.1	1.0	4.0	10 / 8	+85 °C
TCST2202		24.5 x 6.3	10.8	3.1	0.5	2.0	10 / 8	+85 °C
TCST2300		24.5 x 6.3	10.8	3.1	0.25	0.5	10 / 8	+85 °C
TCST5250		14.3 x 6.0	9.5	2.7	0.5	1.5	15 / 10	+85 °C

Notes: (1) All optical sensors have phototransistor output (2) Dual channel (3) Products ending in "X01" are AEC-Q101-qualified

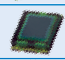
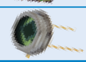
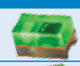
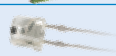
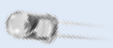
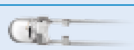
Ambient Light Sensors, Digital Output

Part Number		Package L x W (mm)	Package H (mm)	Ambient Light Resolution (lx)	Ambient Light Range (lx)	Operating Voltage Range (V)	Output Code	Operating Temp. Range (°C)	AEC-Q101
VEML6030		2 x 2	0.85	0.0036	0 to 120 000	2.5 to 3.6	16 bit, I²C	-25 to 85	x
VEML7700		6.8 x 2.35	3	0.0036	0 to 120 000	2.5 to 3.6	16 bit, I²C	-25 to 85	x

OPTICAL SENSORS

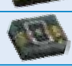
Focus Products

Ambient Light Sensors, Analog Output

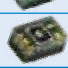
Part Number[3]		Package			Peak Wave-length (nm)	Band-width $\lambda_{0.5}$ (nm)	Angle of Half Sensitivity (±°)	Light Current[1] Incandescent (µA)	Light Current[2] Fluorescent (µA)	Remark
		Type	L x W (mm)	H (mm)						
Photo Diodes										
TEMD6200FX01		0805, SMD	2 x 1.25	0.85	540	430 to 610	60	0.04	0.03	Stand-off
TEMD6010FX01		1206, SMD	4 x 2	1.05	540	430 to 610	60	0.04	0.03	
TEMD5510FX01		Top-View SMD	5 x 4.24	1.12	540	430 to 610	65	1	0.7	
BPW21R		TO-5, leaded	Ø 8.13		565	420 to 675	50	0.9	0.75	
Phototransistors										
TEMT6200FX01		0805, SMD	2 x 1.25	0.85	550	450 to 610	60	23	7	
TEMT6000X01		1206, SMD	4 x 2	1.05	570	440 to 800	60	50	21	
TEPT5700		5 mm, flat top	Ø 5		570	440 to 800	50	75	31	Leaded
TEPT5600		5 mm	Ø 5		570	440 to 800	20	350	145	Leaded
TEPT4400		3 mm	Ø 3		570	440 to 800	30	200	83	Leaded

Notes: [1] E_v = 100 lux, V_{CE} = 5 V, CIE illuminant A, typical [2] E_v = 100 lux, V_{CE} = 5 V, e.g. Sylvania color abbrev. D830, typical
[3] Products ending in "X01" are AEC-Q101-qualified

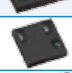
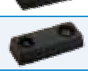
Color Sensors

Part Number		Package		Peak Sensitivity (nm)	Operating Voltage Range (V)	Output Code	Operating Temp. Range (°C)	AEC-Q101
		L x W (mm)	H (mm)					
VEML6040		2.0 x 1.25	1.0	650, 550, 450 (R,G,B)	2.5 to 3.6	16 bit, I²C	-40 to 85	x
VEML6090		2.35 x 1.8	1.0	620, 530, 450, 360, 850 (R,G,B, UV, IR)	1.7 to 3.6	16 bit, I²C	-40 to 85	x

UV Sensors

Part Number		Package		Peak Sensitivity (nm)	Operating Voltage Range (V)	Output Code	Operating Temp. Range (°C)	AEC-Q101
		L x W (mm)	H (mm)					
VEML6070		2.35 x 1.8	1.0	355	2.7 to 5.5	16 bit, I²C	-40 to 85	x
VEML6075		2.0 x 1.25	1.0	365, 330	1.7 to 3.6	16 bit, I²C	-40 to 85	x

Integrated Proximity and Ambient Light Sensors, Digital Output

Part Number		Package		Integrated Components			Operating Temp. Range (°C)	AEC-Q101
		L x W (mm)	H (mm)	Infrared Emitter	Proximity Detector	Ambient Light Sensor		
VCNL4020X01		4.90 x 2.40	0.83				-40 to 105	
VCNL3020		4.90 x 2.40	0.83			x	-25 to 85	x
VCNL4010		3.95 x 3.95	0.75				-25 to 85	x
VCNL4020		4.90 x 2.40	0.83				-25 to 85	x
VCNL4040		4.0 x 2.0	1.1				-40 to 85	x
VCNL4100		8.0 x 3.0	1.8				-40 to 85	x

Optoelectronics

Bright Ideas, Stellar Products

VISHAY®

Advantages of Vishay Optical Sensors

- Comprehensive range of package types supporting a wide range of applications
- In-house chip manufacturing and assembly including AEC-Q101 Automotive Grade production lines

For the Following **Applications**

- Sensors for motion, speed, and direction
- Position sensors for encoders in high-temperature environments
- Proximity / optical switch for consumer, computing, automotive, and industrial devices
- Dimming control for consumer, computing, industrial, and automotive displays

No matter what car you drive, optical sensors are close by. Think automotive, think Vishay.

Vishay's proximity, reflective, transmissive, and ambient light sensors put the "smart" into smart devices with best-in-class performance

Useful **Links**

- Optical sensors gateway www.vishay.com/optical-sensors/
- Reflective and transmissive sensors product sheet www.vishay.com/doc?49870
- VCNL product family www.vishay.com/moreinfo/vcnlfamily/
- Current estimator calculator www.vishay.com/optoelectronics/opto-sensors-calculator/
- Optoelectronics applications guide www.vishay.com/doc?49070
- Sensor Starter kit www.vishay.com/moreinfo/vcnldemokit/

AEC-Q101 QUALIFIED

AUTOMOTIVE GRADE

RoHS COMPLIANT

A WORLD OF SOLUTIONS

VMN-MS6936-1609

Assembly Instructions

GENERAL

Optoelectronic semiconductor devices can be mounted in any position. Connection wires may be bent provided the bend is not less than 1.5 mm from bottom of case. During bending, no forces must be transmitted from pins to case (e.g., by spreading the pins).
If the device is to be mounted near heat generating components, the resultant increase in ambient temperature should be taken into account.

SOLDERING INSTRUCTIONS

Protection against overheating is essential when a device is being soldered. It is recommended, therefore, that the connection wires be left in place as long as possible. The maximum permissible device junction temperature should be exceeded for as little time as possible, and for no longer than specified in the solder profiles, during the soldering process. In case of plastic encapsulated devices, the maximum permissible soldering temperature is governed by the maximum permissible heat that may be applied to encapsulants rather than by the maximum permissible junction temperature.
Maximum soldering iron (or solder bath) temperatures are given in table 1. During soldering, no forces must be transmitted from pins to case (e.g., by spreading pins).

SOLDERING METHODS

There are several methods in use to solder devices onto the substrate. Some of them are listed in the following sections.

Vapor Phase Soldering

Soldering in saturated vapor is also known as condensation soldering. This soldering process is used as a batch system (dual vapor system) or as a continuous single vapor system. Both systems may also include preheating of the assemblies to prevent high-temperature shock and other undesired effects.

Infrared soldering

With infrared (IR) reflow soldering the heating is contact-free and the energy for heating the assembly is derived from direct infrared radiation and from convection (Refer to CECC00802).
The heating rate in an IR furnace depends on the absorption coefficients of the material surfaces and on the ratio of component's mass to its irradiated surface.
The temperature of components in an IR furnace, with a mixture of radiation and convection, cannot be determined in advance. Temperature measurement may be performed by measuring the temperature of a certain component while it is being transported through furnace.
The temperatures of small components, soldered together with larger ones, may rise up to 280 °C.
The following parameters influence the internal temperature of a component:

- Time and power
- Mass of component
- Size of component
- Size of printed circuit board
- Absorption coefficient of surfaces
- Packaging density
- Wavelength spectrum of radiation source
- Ratio of radiated and convected energy

Temperature-time profiles of the entire process and the above parameters are given in figures 1 and 2.

TABLE 1- MAXIMUM SOLDERING TEMPERATURES

	IRON SOLDERING			WAVE SOLDERING		
	IRON TEMPERATURE	DISTANCE OF THE SOLDERING POSITION FROM THE LOWER EDGE OF THE CASE	MAXIMUM ALLOWABLE SOLDERING TIME	SOLDERING TEMPERATURE SEE TEMPERATURE TIME PROFILES	DISTANCE OF THE SOLDERING POSITION FROM THE LOWER EDGE OF THE CASE	MAXIMUM ALLOWABLE SOLDERING TIME
Devices in metal case	≤ 245 °C	≥ 1.5 mm	5 s	245 °C	≥ 1.5 mm	5 s
	≤ 245 °C	≥ 5.0 mm	10 s			
	≤ 350 °C	≥ 5.0 mm	5 s	300 °C	≥ 5.0 mm	3 s
Devices in plastic case > 3 mm	≤ 260 °C	≥ 2.0 mm	5 s	235 °C	≥ 2.0 mm	8 s
	≤ 300 °C	≥ 5.0 mm	3 s	260 °C	≥ 2.0 mm	5 s
Devices in plastic case ≤ 3 mm	≤ 300 °C	≥ 5.0 mm	3 s	260 °C	≥ 2.0 mm	3 s

Wave soldering

In wave soldering, one or more continuously replenished waves of molten solder are generated, while the substrates to be soldered are moved in one direction across the wave's crest.
Temperature-time profiles of the entire process are given in figure 3.

Iron soldering

This process cannot be carried out in a controlled way.
It should not be considered for use in applications where reliability is important. There is no SMD classification for this process.

Laser soldering

This is an excess heating soldering method. The energy absorbed may heat device to a much higher temperature than desired. There is no SMD classification for this process at the moment.

Resistance soldering

This is a soldering method which uses temperature controlled tools (thermodes) for making solder joints. There is no SMD classification for this process at the moment.

WARNING

Surface-mount devices are sensitive to moisture release if they are subjected to infrared reflow or a similar soldering process (e.g. wave soldering). After opening the bag, they must be:

1. stored at ambient of < 20 % relative humidity (RH)
2. mounted within floor life specified on MSL sticker under factory conditions of T_{amb} < 30 °C/RH < 60 %

Devices require baking before mounting if 1. or 2. is not met and the humidity indicator card is > 20 % at 23 ± 5 °C. If baking is required, devices may be baked for 192 h at 40 °C + 5 °C - 0 °C and < 5 % RH.

TEMPERATURE-TIME PROFILES

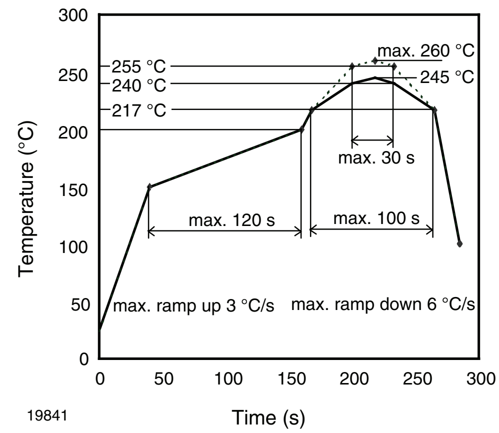


Fig. 1 - Lead (Pb)-free (Sn) Infrared Reflow Solder Profile acc. J-STD020D for Surface-Mount Components

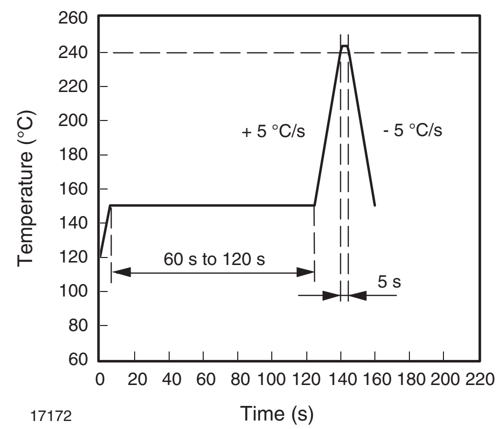


Fig. 2 - Infrared Reflow SnPb Solder Profile for Surface-Mount Components like TEMx1xxx and TSMx1xxx

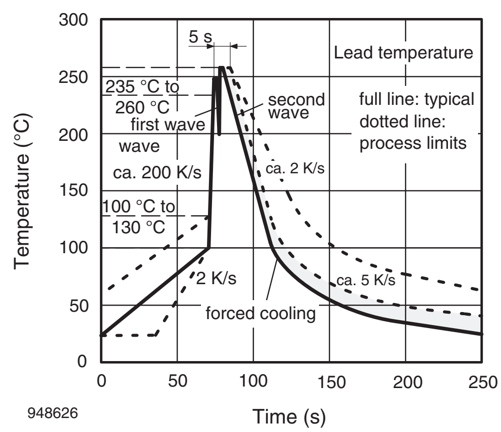


Fig. 3 - Double Wave Solder Profile for Leaded Components

HEAT REMOVAL

To maintain thermal equilibrium, the heat generated in the semiconductor junction(s) must be removed to keep the junction temperature below specified maximum.

In case of low-power devices, the natural heat conductive path between the case and surrounding air is usually adequate for this purpose. The heat generated in the junction is conveyed to the case or the header by conduction rather than convection. A measure of the effectiveness of heat conduction is the inner thermal resistance or the junction-to-case thermal resistance, R_{thJC}, which is governed by the device construction.

Any heat transfer from the case to the surrounding air involves radiation convection and conduction, the effectiveness of transfer being expressed in terms of an R_{thCA} value, i.e., external or case ambient thermal resistance. The total junction-to-ambient thermal resistance is consequently:

$R_{thJA} = R_{thJC} + R_{thCA}$

The total maximum power dissipation, $P_{totmax.}$ of a semiconductor device can be expressed as follows:

$$P_{totmax.} = \frac{T_{jmax.} - T_{amb}}{R_{thJA}} = \frac{T_{jmax.} - T_{amb}}{R_{thJC} + R_{thCA}}$$

where:

- $T_{jmax.}$ the maximum allowable junction temperature
- T_{amb} the highest ambient temperature likely to be reached under the most unfavorable conditions
- R_{thJC} junction-to-case thermal resistance
- R_{thJA} the junction-to-ambient thermal resistance, is specified for the components. The following diagram shows how the different installation conditions effect the thermal resistance
- R_{thCA} the case-to-ambient thermal resistance, R_{thCA}, depends on cooling conditions. If a heat dissipator or sink is used, R_{thCA} depends on the thermal contact between the case and heat sink, upon the heat propagation conditions in the sink, and upon the rate at which heat is transferred to the surrounding air

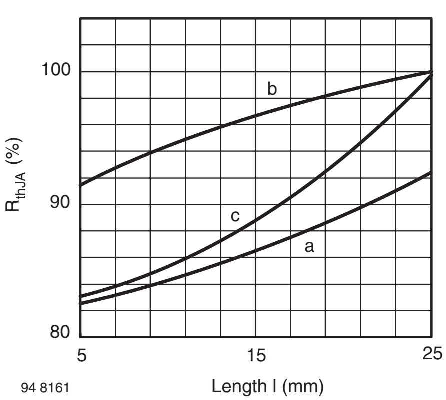


Fig. 4 - Junction-to-Ambient Thermal Resistance vs.

Lead Length at Different Assembly

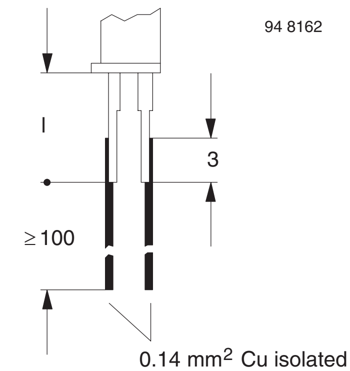


Fig. 5 - In Case of Wire Contacts (Curve B, Figure 4)

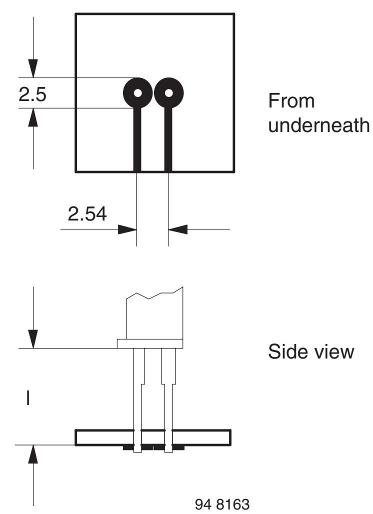


Fig. 6 - In Case of Assembly on PC Board, no Heatsink (Curve C, Figure 4)

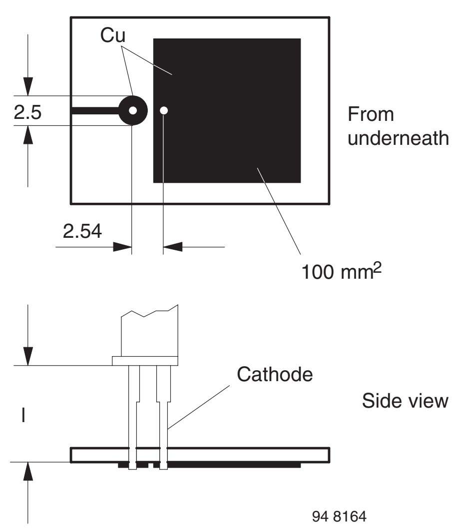


Fig. 7 - In Case of Assembly on PC Board, with Heatsink (Curve A, Figure 4)

Reliability and Statistics Glossary

DEFINITIONS

Accelerated Life Test: A life test under conditions that are more severe than usual operating conditions. It is helpful, but not necessary, that a relationship between test severity and the probability distribution of life be ascertainable.

Acceleration Factor: Notation: f(t) = the time transformation from more severe test conditions to the usual conditions. The acceleration factor is f(t)/t. The differential acceleration factor is df(t)/dt.

Acceptance Number: The largest numbers of defects that can occur in an acceptance sampling plan and still have the lot accepted.

Acceptance Sampling Plant: An accept/reject test the purpose of which is to accept or reject a lot of items or material based on random samples from the lot.

Assessment: A critical appraisal including qualitative judgments about an item, such as importance of analysis results, design criticality, and failure effect.

Attribute (Inspection by): A term used to designate a method of measurement whereby units are examined by noting the presence (or absence) of some characteristic or attribute in each of the units in the group under consideration and by counting how many units do (or do not) possess it. Inspection by attributes can be two kinds: either the unit of product is classified simply as defective or not defective or the number of defects in the unit of product is counted with respect to a given requirement or set of requirements.

Attribute Testing: Testing to evaluate whether or not an item possesses a specified attribute.

Auger Electron Spectrometer: An instrument, that identifies elements on the surface of a sample. It excites the area of interest with an electron beam and observes the resultant emitted Auger electrons.
These electrons have the specific characteristics of the near surface elements. It is usually used to identify very thin films, often surface contaminants.

Availability (Operational Readiness): The probability that at any point in time the system is either operating satisfactorily or ready to be placed in operation on demand when used under stated conditions.

Average Outgoing Quality (AOQ): The average quality of outgoing product after 100 % inspection of a rejected lot, with replacement by good units of all defective units found in inspection.

Bathtub Curve: A plot of the failure rate of an item (whether repairable or not) vs. time. The failure rate initially decreases, then stays reasonably constant, then begins to rise rather rapidly. It has the shape of bathtub. Not all items have this behavior.

Bias:

1. The difference between the s-expected value of an estimator and the value of the true parameter
2. Applied voltage.

Burn-in: The initial operation of an item to stabilize its characteristics and to minimize infant mortality in the field.

Confidence Interval: The interval within which it is asserted that the parameters of a probability distribution lie.

Confidence Level:
Equals 1 - α

where

α = the risk (%).

Corrective Action: A documented design, process, procedure, or materials change to correct the true cause of a failure. Part replacement with a like item does not constitute appropriate corrective action. Rather, the action should make it impossible for that failure to happen again.

Cumulative Distribution Function (CDF): The probability that the random variable takes on any value less than or equal to a value x, e.g.
F (x) = CDF (x) = Pr (x $\leq$ X).

Defect: A deviation of an item from some ideal state. The ideal state usually is given in a formal specification.

Degradation: A gradual deterioration in performance as a function of time.

Derating: The intentional reduction of the stress/strength ratio in the application of an item, usually for the purpose of reducing the occurrence of stress-related failures.

Duty Cycle: A specified operating time of an item, followed by a specified time of no operation.

Early Failure Period: That period of life, after final assembly, in which failures occur at an initially high rate because of the presence of defective parts and workmanship. This definition applies to the first part of the bathtub curve for failure rate (infant mortality).

EDX Spectrometer: Generally used with a scanning electron microscope (SEM) to provide elemental analysis of X-rays generated on the region being hit by the primary electron beam.

Effectiveness: The capability of the system or device to perform its function.

EOS - Electrical Overstress: The electrical stressing of electronic components beyond specifications. May be caused by ESD.

ESD - Electrostatic Discharge: The transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. Many electronic components are sensitive to ESD and will be degraded or fail.

Expected Value: A statistical term. If x is a random variable and F (x) it its CDF, the E (x) = xdF (x), where the integration is over all x. For continuous variables with a pdf, this reduces to E (x) = ∫ x pfd (x) dx. For discrete random variables with a pfd, this reduces to
E (x) = Σ $x_n p$ (x_n) where the sum is over all n.

Exponential Distribution: A 1 parameter distribution ($\lambda > 0$, $t \leq 0$) with: pfd (t) = lexp (-λt);
Cdf (t) 0 1 - exp (-λt); Sf (t) = exp (-λt) ;
failure rate = λ; mean time-to-failure = 1/λ. This is the constant failure-rate-distribution.

Failure: The termination of the ability of an item to perform its required function.

Failure Analysis: The identification of the failure mode, the failure mechanism, and the cause (i.e., defective soldering, design weakness, contamination, assembly techniques, etc.). Often includes physical dissection.

Failure, Catastrophic: A sudden change in the operating characteristics of an item resulting in a complete loss of useful performance of the item.

Failure, Degradation: A failure that occurs as a result of a gradual or partial change in the operating characteristics of an item.

Failure, Initial: The first failure to occur in use.

Failure, Latent: A malfunction that occurs as a result of a previous exposure to a condition that did not result in an immediately detectable failure. Example: Latent ESD failure.

Failure Mechanism: The mechanical, chemical, or other process that results in a failure.

Failure Mode: The effect by which a failure is observed. Generally, describes the way the failure occurs and tells "how" with respect to operation.

Failure Rate: (A) The conditional probability density that the item will fail just after time t, given the item has not failed up to time t; (B) The number of failures of an item per unit measure of life (cycles, time, miles, events, etc.) as applicable for the item.

Failure, Wearout: Any failure for which time of occurrence is governed by rapidly increasing failure rate.

FIT: Failure Unit; (also, Failures In Time) Failures per 109 h.

Functional Failure: A failure whereby a device does not perform its intended function when the inputs or controls are correct.

Gaussian Distribution: A 2 parameter distribution with:

$$\text{pfd (x)} = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{1}{2}\left(\frac{x-u}{\sigma}\right)^2}$$

Cdf (x) = guaf (x). SF (x) = gaufc (x). “Mean value of x” u, “standard deviation of x” = σ

Hazard Rate: Instantaneous failure rate.

Hypothesis, Null: A hypothesis stating that there is no difference between some characteristics of the parent populations of several different samples, i.e., that the samples came from similar populations.

Infant Mortality: Premature catastrophic failures occurring at a much greater rate than during the period of useful life prior to the onset of substantial wear out.

Inspection: The examination and testing of supplies and services (including when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to specified requirements.

Inspection by Attributes: Inspection whereby either the unit of product or characteristics thereof is classified simply as defective or not defective or the number of defects in the unit of product is counted with respect to a given requirement.

Life Test: A test, usually of several items, made for the purpose of estimating some characteristic(s) of the probability distribution of life.

Lot: A group of units from a particular device type submitted each time for inspection and/or testing is called the lot.

Lot Reject Rate (LRR): The lot reject rate is the percentage of lots rejected form the lots evaluated.

Lot Tolerance Percent Defective (LTPD): The percent defective, which is to be accepted a minimum or arbitrary fraction of the time, or that percent defective whose probability of rejection is designated by **b**.

Mean: (A) The arithmetic mean, the expected value; (B) As specifically modified and defined, e.g., harmonic mean (reciprocals), geometric mean (a product), logarithmic mean (logs).

Mean Life: R(t)dt; where R(t) = the s-reliability of the item; t = the interval over which the mean life is desired, usually the useful life (longevity).

Mean-Life-Between-Failures: The concept is the same as mean life except that it is for repaired items and is the mean up-time of the item. The formula is the same as for mean life except that R(t) is interpreted as the distribution of up-times.

Mean-time-between-failures (MTBF): For a particular interval, the total functioning life of a population of an item divided by the total number of failures within the population during the measurement interval. The definition holds for time, cycles, miles, events, or other measure of life units.

Mean-Time-To-Failure (MTTF): See "Mean Life".

Mean-Time-To-Repair (MTTR): The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

MTTR: = G(t)dt; where G(t) = CDF of repair time;
T - maximum allowed repair time, i.e., item is treated as no repairable at this echelon and is discarded or sent to a higher echelon for repair.

Reliability and Statistics Glossary

Operating Characteristic (OC) Curve: A curve showing the relation between the probability of acceptance and either lot quality or process quality, whichever is applicable.

Part Per Million (PPM): PPM is arrived at by multiplying the percentage defective by 10 000.
Example: 0.1 % = 1.000 PPM.

Population: The totality of the set of items, units, measurements, etc., real or conceptual that is under consideration.

Probability Distribution: A mathematical function with specific properties, which describes the probability that a random variable will take on a value or set of values. If the random variable is continuous and well behaved enough, there will be a pdf. If the random variable is discrete, there will be a pmf.

Qualification: The entire process by which products are obtained from manufacturers or distributors, examined and tested, and then identified on a Qualified Product List.

Quality: A property, which refers to the tendency of an item to be made to specific specifications and / or the customer's express needs. See current publications by Juran, Deming, Crosby, et al.

Quality Assurance: A system of activities that provides assurance that the overall quality control job is, in fact, being done effectively. The system involves a continuing evaluation of the adequacy and effectiveness of the overall quality control program with a view to having corrective measures initiated where necessary. For a specific product or service, this involves verifications, audits, and the evaluation of the quality factors that affect the specification, production inspection, and use of the product or service.

Quality Characteristics: Those properties of an item or process, which can be measured, reviewed, or observed and which are identified in the drawings, specifications, or contractual requirements. Reliability becomes a quality characteristic when so defined.

Quality Control (QC): The overall system of activities that provides a quality of product or service, which meets the needs of users; also, the use of such a system.

Random Samples: As commonly used in acceptance sampling theory, the process of selecting sample units in such a manner that all units under consideration have the same probability of being selected.

Reliability: The probability that a device will function without failure over a specified time period or amount of usage at stated conditions.

Reliability Growth: Reliability growth is the effort, and the resource commitment, to improve design, purchasing, production, and inspection procedures to improve the reliability of a design.

Risk: α: The probability of rejecting the null hypothesis falsely.

Scanning Electron Microscope (SEM): An instrument which provides a visual image of the surface features of an item. It scans an electron beam over the surface of a sample while held in a vacuum and collects any of several resultant particles or energies. The SEM provides depth of field and resolution significantly exceeding light microscopy and may be used at magnifications exceeding 50 000 times.

Screening Test: A test or combination of tests intended to remove unsatisfactory items or those likely to exhibit early failures.

Significance: Results that show deviations between hypothesis and the observations used as a test of the hypothesis, greater than can be explained by random variation or chance alone, are called statistically significant.

Significance Level: The probability that, if the hypothesis under test were true, a sample test statistic would be as bad as or worse than the observed test statistic.

SPC: Statistical Process Control.

Storage Life (Shelf Life): The length of time an item can be stored under specified conditions and still meet specified requirements.

Stress: A general and ambiguous term used as an extension of its meaning in mechanics as that which could cause failure. It does not distinguish between those things which cause permanent damage (deterioration) and those things which do not (in the absence of failure).

Variance: The average of the squares of the deviations of individual measurements from their average. It is a measure of dispersion of a random variable or of data.

Wearout: The process of attribution which results in an increase of hazard rate with increasing age (cycles, time, miles, events, etc.) as applicable for the item.

ABBREVIATIONS

AQL	Acceptable quality level
CAR	Corrective action report/request
DIP	Dual in-line package
ECAP	Electronic circuit analysis program
EMC	Electro magnetic compatibility
EMI	Electro magnetic interference
EOS	Electrical overstress
ESD	Electrostatic discharge
FAR	Failure analysis report/request
FIT	(Failure in time) Failure unit; Failures/109 h
FMEA	Failure mode and effects analysis
FTA	Fault tree analysis
h (t)	Hazard rate
LTPD	Lot tolerance percent defective
MOS	Metal oxide semiconductor
MRB	Material review board
MTBF	Mean-time-between-failures
MTTF	Mean-time-to-failure

MTTR	Mean-time-to-repair
PPM	Parts per million
PRST	Probability ratio sequential test
QA	Quality assurance
QC	Quality control
QPL	Qualified products list
RPM	Reliability planning and management
SCA	Sneak circuit analysis
SEM	Scanning electron microscope
TW	Wearout time
Z (t)	Hazard rate
λ	Failure rate (Lambda)

Physics and Technology

EMITTERS

Materials

Infrared emitting diodes (IREDs) can be produced from a range of different III-V compounds. Unlike the elemental semiconductor silicon, compound III-V semiconductors consist of two or more different elements of group three (e.g., Al, Ga, In) and five (e.g., P, As) of periodic table. The bandgap energies of these compounds vary between 0.18 eV and 3.4 eV. However, the IREDs considered here emit in the near infrared spectral range between 800 nm and 1000 nm, and, therefore, the selection of materials is limited to GaAs and mixed crystal $Ga_{1-X}Al_XAs$, $0 \leq X \leq 0.8$, made from pure compounds GaAs and AlAs.

Infrared radiation is produced by the radiative recombination of electrons and holes from the conduction and valence bands. Emitted photon energy, therefore, corresponds closely to bandgap energy E_g. The emission wavelength can be calculated according to the formula λ (µm) = 1.240/Eg (eV). Internal efficiency depends on band structure, doping material and doping level. Direct bandgap materials offer high efficiencies, because no phonons are needed for recombination of electrons and holes. GaAs is a direct gap material and $Ga_{1-X}Al_XAs$ is direct up to X = 0.44. Doping species Si provides the best efficiencies and the shifts emission wavelength below the bandgap energy into the infrared spectral range by about 50 nm typically. Charge carriers are injected into the material via pn junctions. Junctions of high injection efficiency are readily formed in GaAs and $Ga_{1-X}Al_XAs$. P-type conductivity can be obtained with metals of valency two, such as Zn and Mg, and n-type conductivity with elements of valency six, such as S, Se and Te. However, silicon of valency four can occupy sites of III-valence and V-valence atoms, and, therefore, acts as donor and as acceptor. Conductivity type depends primarily on material growth temperature. By employing exact temperature control, pn junctions can be grown with the same doping species Si on both sides of the junction. Ge, on the other hand, also has a valency of four, but occupies group V sites at high temperatures i.e., p-type.

Only mono crystalline material is used for IRED production. In the mixed crystal system $Ga_{1-X}Al_XAs$, $0 \leq X \leq 0.8$, lattice constant varies only by about 1.5 x 10^{-3}. Therefore, mono crystalline layered structures of different $G_{a1-X}Al_XAs$ compositions can be produced with extremely high structural quality. These structures are useful because the bandgap can be shifted from 1.40 eV (GaAs) to values beyond 2.1 eV which enables transparent windows and heterogeneous structures to be fabricated. Transparent windows are another suitable means to increase efficiency, and heterogeneous structures can provide shorter switching times and higher efficiency. Such structures are termed single hetero (SH) or double hetero structures (DH). DH structures consist normally of two layers that confine a layer with a much smaller bandgap.

The best production method for all materials needed is liquid phase epitaxy (LPE). This method uses Ga-solutions containing As, possibly Al, and a doping substance. The solution is saturated at a high temperature, typically 900 °C, and GaAs substrates are dipped into the liquid. The solubility of As and Al decreases with decreasing temperature. In this way epitaxial layers can be grown by slow cooling of the solution. Several layers differing in composition may be obtained using different solutions one after another, as needed e.g. for DHs.

In liquid phase epitaxial reactors, production quantities of up to 50 wafers, depending on type of structure required, can be handled.

IRED CHIPS AND CHARACTERISTICS

In the past IRED chips are made only from GaAs. The structure of the chip is displayed in figure 1.

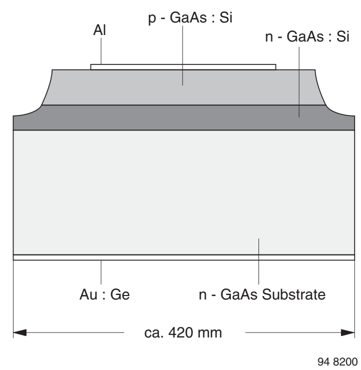


Fig. 1

On an n-type substrate, two Si-doped layers are grown by liquid phase epitaxy from the same solution producing an emission wavelength of 950 nm. Growth starts as n-type at high temperature and becomes p-type below about 820 °C. A structured Al-contact on p-side and a large area Au:Ge contact on back side provide a very low series resistance.

The angular distribution of emitted radiation is displayed in figure 2.

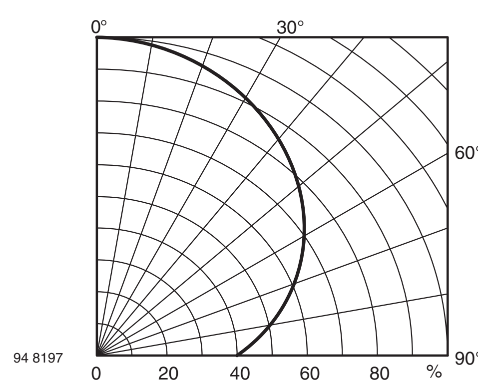


Fig. 2

The package of the chip has to provide good collection efficiency of radiation emitted sideways, and has to diminish the refractive index step between the chip (n = 3.6) and the air (n = 1.0) with an epoxy of refractive index of 1.55. In this way, the output power of chip is increased by a factor of 3.5 for the assembled device.

The chip described is the most cost-efficient one. Its forward voltage at I_F = 1.5 A has the lowest possible value. Total series resistance is typically only 0.60 Ω; output power and linearity (defined as optical output power increase, divided by current increase between 0.1 A and 1.5 A) are high. Relevant data on chip and a typical assembled device are given in table 1.

The technology used for a chip emitting at 880 nm eliminates the absorbing substrate and uses only a thick epitaxial layer. The chip is shown in figure 3.

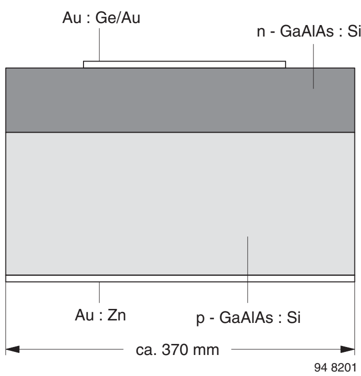


Fig. 3

Originally, the GaAs substrate was adjacent to the n-side. Growth of $Ga_{0.7}Al_{0.3}As$ started as n-type and became p-type - as in the first case - through the specific properties of the doping material Si. A characteristic feature of the Ga-Al-As phase system causes the Al-content of growing epitaxial layer to decrease. This causes the Al-concentration at the junction to drop to 8 % ($Ga_{0.92}Al_{0.08}As$), producing an emission wavelength of 880 nm. During further growth the Al-content approaches zero. The gradient of the Al-content and correlated gradient of bandgap energy produce an emission band of a relatively large half width. The transparency of the large bandgap material results in a high external efficiency on this type of chip.

The chip is mounted n-side up, and the front side metallization is Au:Ge/Au, whereas the reverse side metallization is Au:Zn.

The angular distribution of the emitted radiation is displayed in figure 4.

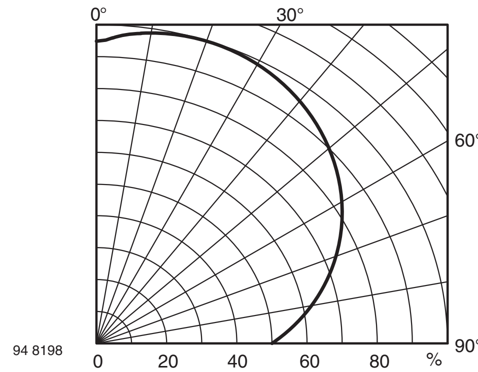


Fig. 4

Due to its shorter wavelength, $Ga_{1-X}Al_XAs$ chip described above offers specific advantages in combination with a Si detector. Integrated opto ICs, like amplifiers or Schmitt Triggers, have higher sensitivities at shorter wavelengths. Similarly, phototransistors are also more sensitive. Finally, the frequency bandwidth of pin diodes is higher at shorter wavelengths. This chip also has the advantage of having high linearity up to and beyond 1.5 A. The forward voltage, however, is higher than the voltage of a GaAs chip. Table 2 (see “Symbols and Terminology”) provides more data on the chip.

A technology combining some of the advantages of the two technologies described above is summarized in figure 5.

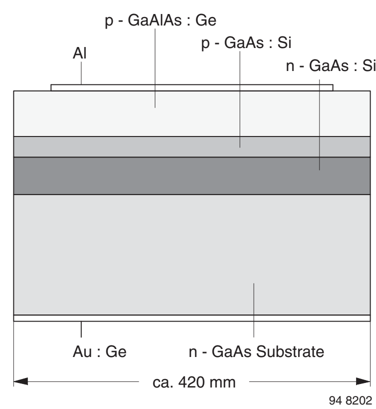


Fig. 5

Starting an with n-type substrate, n- and p-type GaAs layers are grown in a similar way to the epitaxy of a standard GaAs:Si diode. After this, a highly transparent window layer of $Ga_{1-X}Al_XAs$, doped p-type is grown. The upper contact to the p-side is made of Al and the rear side contact is Au:Ge. The angular distribution of emitted radiation is shown in figure 6.

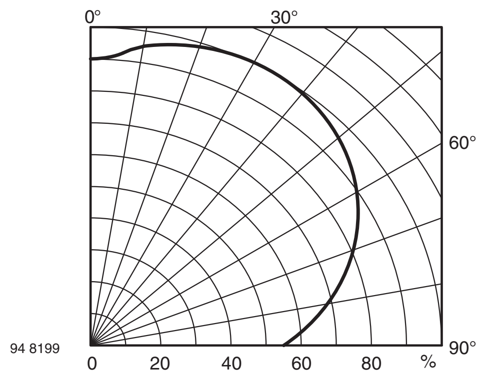


Fig. 6

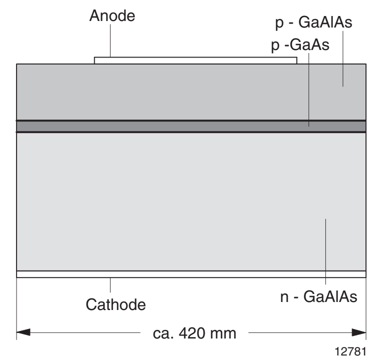


Fig. 7

This chip type combines a relatively low forward voltage with a high electro-optical efficiency, offering an optimized combination of the advantageous characteristics of the two other chips. Refer again to table 2 (see "Symbols and Terminology") for more details.

As mentioned in the previous section, double heterostructures (DH) provide even higher efficiencies and faster switching times. A schematic representation of such a chip is shown in figure 7.

The active layer is depicted as the thin layer between the p- and n- type $Ga_{1-X}Al_XAs$ confinement layers.

The contacts are dependent on the polarity of the chip. If p is up, then the p-side contact is Al and the back side Au:Ge; if n is up, then this side has an Au:Ge contact and the back side Au:Zn.Two such chips that are also very suitable for IrDA applications are given in table 1.

BULK AND SURFACE EMITTER TECHNOLOGY

A more recent technology, the surface emitter chip technology, involves bonding the Infrared emitting diode structure to a metalized conducting carrier substrate, after which the substrate, which was originally used for the epitaxial growth of the Infrared emitting crystal layers, is chemically removed. The layer structure of these diodes is extremely thin which has the favorable consequence that side wall emission is minimized.

The layers of the surface emitter IRED structures are deposited by metal-organic chemical vapor deposition (MOVPE) on suitable substrates. The active region consists of a multiple-quantum-well (MQW) or a DH structure. MQW active regions for Infrared emitting diodes contain typically one or more 5 nm thick InGaAs quantum wells which are separated by 15 nm thick GaAlAsP barriers.

High electro-optical efficiencies are achieved by the implementation of a metallic mirror on the back side of the layer structure which redirects the incident radiation effectively towards the top surface as well as a treatment of the top surface to increase the extraction efficiency. As sidewall emission is negligible radiance scales with chip area and large devices can be realized without significant increase of reabsorption losses.

In order to provide a good current spreading and a uniform current distribution surface emitter diodes are grown n-side up. Both contacts, the structured top electrode to the n-side and the large area back side contact, are made of gold.

The angular distribution of the emitted radiation corresponds nearly perfectly to the lambertian emission pattern of point sources $I_0 = I(\phi) \times \cos\phi$ and enables an efficient coupling of the output power into optical systems.

Exemplary data on chip and assembled device are given in table 1.

A further Infrared emitter chip technology, which makes use of metal organic chemical vapor deposition, is the bulk emitter chip technology. On an n-type GaAs substrate a MQW structure similar to the one described above is grown producing an emission wavelength of 940 nm. As the substrate is transparent at this wavelength the bulk emitter technology offers the high efficiencies of double hetero structures in combination with exceptional low forward voltages and very fast response times. With these favorable characteristics bulk emitter chips can substitute conventional GaAlAs/GaAs chips in many technical applications. As electrode material for the top p-type contact Al or Au are in use, whereas the back side contact consists of an Au alloy. The angular distribution of the emitted radiation resembles the one shown in figure 6. Relevant chip and device data are given in table 1.

TABLE 1: CHARACTERISTICS DATA OF IRED CHIPS									
TECHNOLOGY	TYPICAL CHIP DATA				TYPICAL DEVICE	TYPICAL DEVICE DATA			
	Φ_e at 0.1 A (mW)	λ_p (nm)	$\Delta\lambda$ (nm)	POLARITY		Φ_e at 0.1 A (mW)	V_F at 0.1 A (V)	V_F at 1.0 A (V)	t_r at 0.1 A (ns)
GaAs	7.7	950	50	p up	TSUS540.	20	1.3	2.1	800
GaAlAs	12.8	875	80	n up	TSHA550.	27	1.5	3.4	600
GaAlAs (DDH)	20	890	40	p up	TSHF5410	45	1.5	2.3	30
GaAlAs (DDH)	26	870	40	p up	TSFF5410	50	1.5	2.3	15
Bulk Emitter	21	940	30	p up	VSLB3940	40	1.35	2.1	15
GaAlAs MQW	22	940	30	p up	TSAL6200	40	1.35	2.2	15
Surface Emitter	30	850	25	n up	VSLY5850	55	1.65	2.9	10

UV, VISIBLE, AND NEAR IR SILICON PHOTODETECTORS

(adapted from ”Sensors, Vol 6, Optical Sensors, Chapt. 8, VCH - Verlag, Weinheim 1991”)

Silicon Photodiodes (PN and PIN Diodes)

The physics of silicon detector diodes

Absorption of radiation is caused by the interaction of photons and charge carriers inside a material. The different energy levels allowed and the band structure determine the likelihood of interaction and, therefore, the absorption characteristics of the semiconductors. The long wavelength cutoff of the absorption is given by the bandgap energy. The slope of the absorption curve depends on the physics of interaction and is much weaker for silicon than for most other semiconducting materials. This results in a strong wavelength-dependent penetration depth which is shown in figure 8. (The penetration depth is defined as that depth where 1/e of the incident radiation is absorbed.)

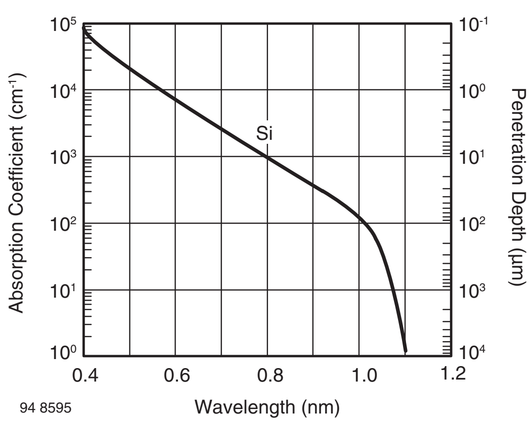


Fig. 8 - Absorption and Penetration Depth of Optical Radiation in Silicon

Depending on the wavelength, the penetration depth varies from tenths of a micron at 400 nm (blue) to more than 100 µm at 1 µm (IR). For detectors to be effective, an interaction length of at least twice the penetration depth should be realized (equivalent to $1/e^2$ = 86 % absorbed radiation). In the pn diode, generated carriers are collected by the electrical field of the pn junction. Effects in the vicinity of a pn junction are shown in figure 9 for various types and operating modes of the pn diode. Incident radiation generates mobile minority carriers - electrons on the p-side, holes on the n-side. In the short circuit mode shown in figure 9 (top), the carriers drift under the field of the built-in potential of the pn junction. Other carriers diffuse inside the field-free semiconductor along a concentration gradient, which results in an electrical current through the applied load, or without load, in an external voltage, open circuit voltage, V_{OC}, at contact terminals. Bending of the energy bands near the surface is caused by surface states. An equilibrium is established between generation, recombination of carriers, and current flow through the load.

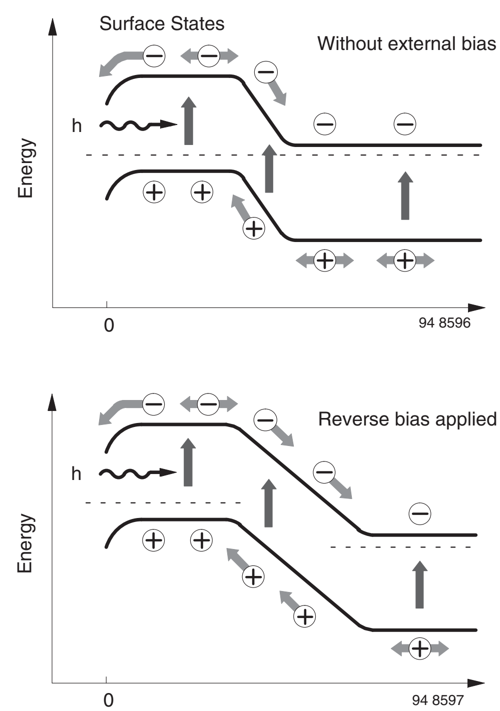


Fig. 9 - Generation-Recombination Effects in the Vicinity of a PN Junction
Top: Short Circuit Mode, Bottom: Reverse Biased

Recombination takes place inside the bulk material with technology- and process-dependent time constants which are very small near the contacts and surfaces of the device. For short wavelengths with very small penetration depths, carrier recombination is the efficiency limiting process. To achieve high efficiencies, as many carriers as possible should be separated by the electrical field inside the space charge region. This is a very fast process, much faster than typical recombination times (for data, see chapter 'Operating modes and circuits').

The width, W, of the space charge is a function of doping the concentration N_B and applied voltage V:

$$W = \sqrt{\frac{2 \times \varepsilon_S \times \varepsilon_o \times (V_{bi} + V)}{q \times N_B}} \quad (1)$$

(for a one-sided abrupt junction), where V_{bi} is built-in voltage, ε_s dielectric constant of Si, ε_o vacuum dielectric constant and q is electronic charge. The diode's capacitance (which can be speed limiting) is also a function of the space charge width and applied voltage. It is given by

$$C = \frac{\varepsilon_S \times \varepsilon_o \times A}{W} \quad (2)$$

where A is the area of the diode. An externally applied bias will increase the space charge width (see figure 8) with the result that a larger number of carriers are generated inside this zone which can be flushed out very fast with high efficiency under the applied field. From equation (1), it is evident that the space charge width is a function of the doping concentration N_B. Diodes with a so-called pin structure show according to equation (1) a wide space charge width where i stands for intrinsic, low doped. This zone is also sometimes nominated as n or p rather than low doped n, n- or p, p-zone indicating the very low doping. Per equation (2), the junction capacitance C, is low due to the large space charge region of PIN photodiodes. These photodiodes are mostly used in applications requiring high speed.

Figure 10 shows a cross section of PIN photodiodes and PN diodes. The space charge width of the PIN photodiodes (bottom) with a doping level ($n = N_B$) as low as N_B = 5 x 1011 cm^{-3} is about 80 µm wide for a 2.5 V bias in comparison with a pn diode with a doping (n) of N_B = 5 x 1015 cm^{-3} with only 0.8 mm.

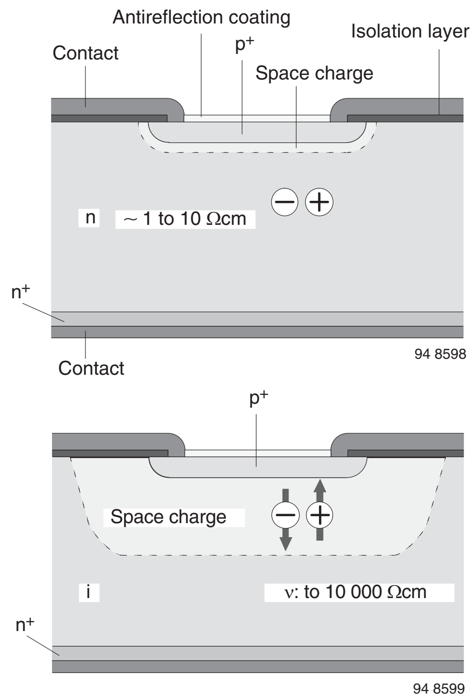


Fig. 10 - Comparison of PN Diode (Top) and PIN Photodiode (Bottom)

PROPERTIES OF SILICON PHOTODIODES

I-V Characteristics of illuminated pn junction

The cross section and I-V-characteristics of a photodiode are shown in figure 11 and 12. The characteristic of the illuminated diode is identical to the characteristic of a standard rectifier diode. The relationship between current, I, and voltage, V, is given by

$$I = I_S \times \left(\frac{\exp V}{V_T - 1}\right) \quad (3)$$

with $V_T = kT/q$

$k = 1.38 \times 10^{-23}$ JK^{-1}, Boltzmann constant

$q = 1.6 \times 10^{-19}$ As, electronic charge.

I_S, the dark-reverse saturation current, is a material- and technology-dependent quantity. The value is influenced by the doping concentrations at pn junction, by carrier lifetime, and especially by temperature. It shows a strongly exponential temperature dependence and doubles every 8 °C.

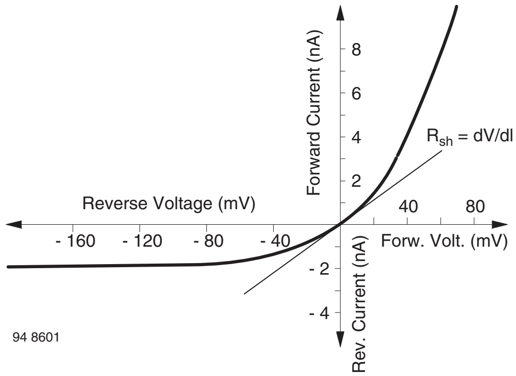


Fig. 11 - Measured I-V-Characteristics of an Si Photodiode in the Vicinity of the Origin

The typical dark currents of Si photodiodes are dependent on size and technology and range from less than picoamps up to tens of nanoamps at room temperature conditions. As noise generators, dark current I_{r0} and the resistance R_{sh} (defined and measured at a voltage of 10 mV forward or reverse, or peak-to-peak) are limiting quantities when detecting very small signals.

The photodiode exposed to optical radiation generates a photocurrent I_r exactly proportional to incident radiant power Φ_e.

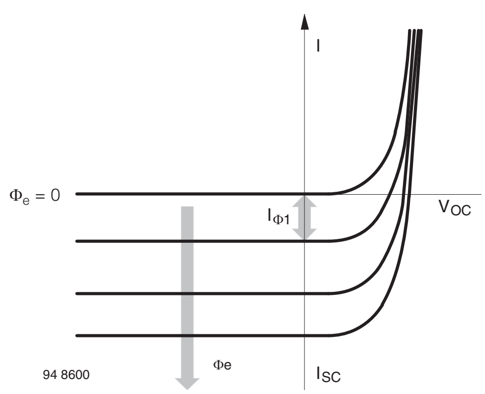


Fig. 12 - I-V-Characteristics of an Si Photodiode under Illumination. Parameter: Incident Radiant Flux

The quotient of both is spectral responsibility s(λ),

$$S(\lambda) = \frac{I_r}{\phi_e[A/W]} \tag{4}$$

The characteristic of the irradiated photodiode is then given by

$$I = I_S \times \left(\frac{\exp V}{V_T - 1}\right) - S(\lambda) \times \phi_e \tag{5}$$

and in case V ≈ 0, zero or reverse bias we find,

$$I = -I_S - S(\lambda) \times \phi_e \tag{6}$$

Dependent on load resistance, R_L, and applied bias, different operating modes can be distinguished. An unbiased diode operates in photovoltaic mode. Under short circuit conditions (load R_L = 0 Ω), short circuit current, I_{SC} flows into the load. When R_L increases to infinity, the output voltage of the diode rises to the open circuit voltage, V_{OC}, given by

$$V_{OC} = V_T \times \left(\frac{S(\lambda) \times \phi_e}{I_S + 1}\right) \tag{7}$$

Because of this logarithmic behavior, the open circuit voltage is sometimes used for optical light meters in photographic applications. The open circuit voltage shows a strong temperature dependence with a negative temperature coefficient. The reason for this is the exponential temperature coefficient of the dark reverse saturation current I_S. For precise light measurement, a temperature control of the photodiode is employed. Precise linear optical power measurements require small voltages at the load, typically smaller than about 5 % of the corresponding open circuit voltage. For less precise measurements, an output voltage of half the open circuit voltage can be allowed. The most important disadvantage of operating in photovoltaic mode is the relatively large response time. For faster response, it is necessary to implement an additional voltage source reverse-biasing the photodiode. This mode of operation is termed photoconductive mode. In this mode, the lowest detectable power is limited by the shot noise of the dark current, I_S, while in photovoltaic mode, the thermal (Johnson) noise of shunt resistance, R_{sh}, is the limiting quantity.

SPECIAL RESPONSITIVITY

Efficiency of Si photodiodes:

The spectral responsivity, s_λ, is given as the number of generated charge carriers (η x N) per incident photons N of energy h x ν (η is percent efficiency, h is the Plancks constant, and ν is the radiation frequency). Each photon will generate one charge carrier at the most. The photocurrent I_{re} is then given as

$$I_{re} = \eta \times N \times q \tag{8}$$

$$S(\lambda) = \left(\frac{I_{re}}{\phi_e}\right) = \frac{\eta \times N \times q}{h \times \nu \times N} = \frac{\eta \times q}{h \times \nu} \tag{9}$$

$$S(\lambda) = \frac{\lambda(\mu m)}{1.24}[A/W]$$

At fixed efficiency, a linear relationship between wavelength and spectral responsivity is valid.

Figure 8 shows that the semiconductors absorb radiation similar to a cut-off filter. At wavelengths smaller than the cut-off wavelength, the incident radiation is absorbed. At larger wavelengths the radiation passes through the material without interaction. The cut-off wavelength corresponds to the bandgap of the material. As long as the energy of the photon is larger than the bandgap, carriers can be generated by absorption of photons, provided that the material is thick enough to propagate photon-carrier interaction. Bearing in mind that the energy of photons decreases with increasing wavelength, we can see, that the curve of the spectral responsivity vs. wavelength in ideal case (100 % efficiency) will have a triangular shape (see figure 13). For silicon photodetectors, the cut-off wavelength is near 1100 nm.

In most applications, it is not necessary to detect radiation with wavelengths larger than 1000 nm. Therefore, designers use a typical chip thickness of 200 µm to 300 µm, which results in reduced sensitivity at wavelengths larger than 950 nm. With a typical chip thickness of 250 µm, an efficiency of about 35 % at 1060 nm is achieved. At shorter wavelengths (blue-near UV, 500 nm to 300 nm) sensitivity is limited by recombination effects near the surface of the semiconductor. A reduction in efficiency starts near 500 nm and increases as the wavelength decreases. Standard detectors designed for visible and near IR radiation may have poor UV/blue sensitivity and poor UV stability. Well designed sensors for wavelengths of 300 nm to 400 nm can operate with fairly high efficiencies. At shorter wavelengths (< 300 nm), efficiency decreases strongly.

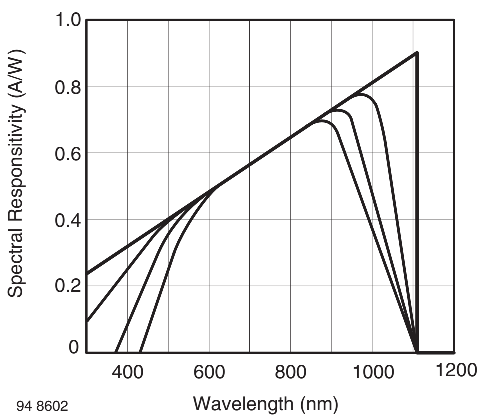


Fig. 13 - Spectral Responsivity as a Function of Wavelength of a Si Photodetector Diode, Ideal and Typical Values

Temperature dependence of spectral responsivity

The efficiency of carrier generation by absorption and the loss of carriers by recombination are the factors which influence spectral responsivity. The absorption coefficient increases with temperature. The radiation of the long wavelength is therefore more efficiently absorbed inside the bulk and results in increased response. For shorter wavelengths (< 600 nm), reduced efficiency is observed with increasing temperature because of increased recombination rates near the surface. These effects are strongly dependent on technological parameters and therefore cannot be generalized to the behavior at longer wavelengths.

Uniformity of spectral responsivity

Inside the technologically defined active area of photodiodes, spectral responsivity shows a variation of sensitivity on the order of < 1 %. Outside the defined active area, and especially at lateral edges of the chips, local spectral response is sensitive to applied reverse voltage. Additionally, this effect depends on wavelength. Therefore, the relation between power (W) related spectral responsivity, s_λ (A/W), and power density (W/cm^2) related spectral responsivity, s_λ [A/(W/cm^2)] is not a constant. Rather, this relation is a function of wavelength and reverse bias

Stability of spectral responsivity

Si detectors for wavelengths between 500 nm and 800 nm appear to be stable over very long periods of time. In the literature concerned here, remarks can be found on instabilities of detectors in blue, UV, and near IR under certain conditions. Thermal cycling reversed the degradation effects.

Surface effects and contamination are possible causes but are technologically well controlled.

Angular dependence of responsivity

The angular response of Si photodiodes is given by the optical laws of reflection. The angular response of a detector is shown in figure 14.

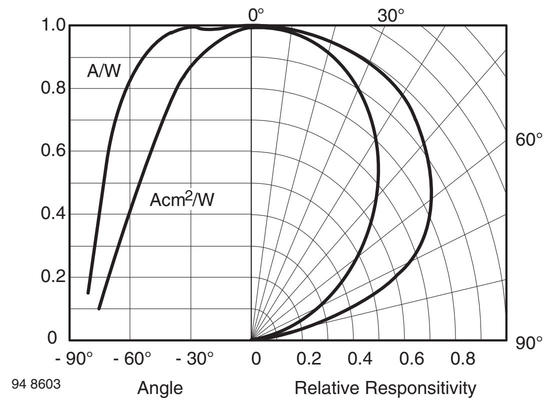


Fig. 14 - Responsivity of Si Photodiodes as a Function of the Angle of Incidence

Semiconductor surfaces are covered with quarter wavelength anti-reflection coatings. Encapsulation is performed with uncoated glass or sapphire windows.

The bare silicon response can be altered by optical imaging devices such as lenses. In this way, nearly every arbitrary angular response can be achieved.

Dynamic Properties of Si Photodiodes

Si photodiodes are available in many different variations. The design of diodes can be tailored to meet special needs. Si photodiodes may be designed for maximum efficiency at given wavelengths, for very low leakage currents, or for high speed. The design of a photodiode is nearly always a compromise between various aspects of a specification.

Inside the absorbing material of the diode, photons can be absorbed in different regions. For example at the top of a p^+n^--diode there is a highly doped layer of p^+ - Si. Radiation of shorter wavelengths will be effectively absorbed, but for larger wavelengths only a small amount is absorbed. In the vicinity of the pn junction, there is the space charge region, where most of the photons should generate carriers. An electric field accelerates the generated carrier in this part of the detector to a high drift velocity. Carriers which are not absorbed in these regions penetrate into field-free region where the motion of the generated carriers fluctuates by a slow diffusion process.

The dynamic response of the detector is composed of different processes which transport carriers to contacts. The dynamic response of photodiodes is influenced by three fundamental effects:

- Drift of carriers in an electric field
- Diffusion of carriers
- Capacitance x load resistance

Carrier drift in the space charge region occurs rapidly with very small time constants. Typically, transit times in an electric field of 0.6 V/µm are on the order of 16 ps/µm and 50 ps/µm for electrons and holes, respectively. At (maximum) saturation velocity, the transit time is on the order of 10 ps/µm for electrons in p-material. With a 10 µm drift region, traveling times of 100 ps can be expected. Response time is a function of the distribution of the generated carriers and is therefore dependent on wavelength.

The diffusion of the carriers is a very slow process. Time constants are on the order of some ms. The typical pulse response of the detectors is dominated by these two processes. Obviously, carriers should be absorbed in large space charge regions with high internal electrical fields. This requires material with an adequate low doping level.

Furthermore, a reverse bias of rather large voltage is useful. Radiation of shorter wavelength is absorbed in smaller penetration depths. At wavelengths shorter than 600 nm, decreasing wavelength leads to an absorption in the diffused top layer. The movement of carriers in this region is also diffusion limited. Because of the small carrier lifetimes, the time constants are not as large as in homogeneous substrate material.

Finally, capacitive loading of output in combination with load resistance limits frequency response.

PROPERTIES OF SILICON PHOTOTRANSISTORS

The phototransistor is equivalent to a photodiode in conjunction with a bipolar transistor amplifier (figure 15). Typically, the current amplification, B, is between 100 and 1000 depending on type and application. The active area of phototransistor is usually about 0.5 x 0.5 mm^2.

The data of spectral responsivity are equivalent to those of photodiodes, but must be multiplied by the factor current amplification, B.

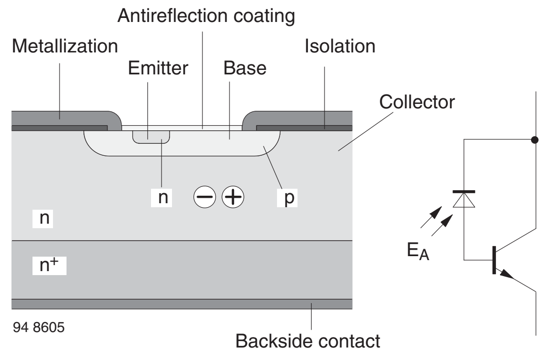


Fig. 15 - Phototransistor, Cross Section and Equivalent Circuit

The switching times of phototransistors are dependent on current amplification and load resistance and are between 30 ms and 1 ms. The resulting cut-off frequencies are a few hundred kHz.

The transit times, t_r and t_f, are given by

$$t_{r,\,f} = \sqrt{\left(\frac{1}{2 \times f_t^2}\right)^2 + b \times (RC_B \times V)^2} \qquad (10)$$

f_t: Transit frequency

R: Load resistance, 1.6

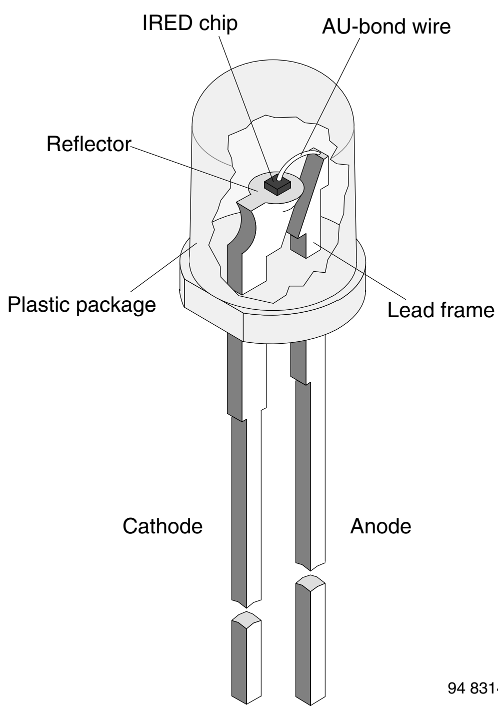
C_B: Base-collector capacitance, b = 4 to 5

V: Amplification

Phototransistors are most frequently applied in transmissive and reflective optical sensors.

Component Construction

Photodetector and infrared emitter components are available in plastic or metal packages.
Plastic devices mostly include a lens to improve radiant sensitivity or radiant intensity. Detector chips are mounted on flat leadframe surfaces while leadframes for emitters have a silver plated reflector performing higher radiant intensity.
Devices in metal packages are hermetically sealed, are released for extended operating temperature range and have small optical and mechanical tolerances.



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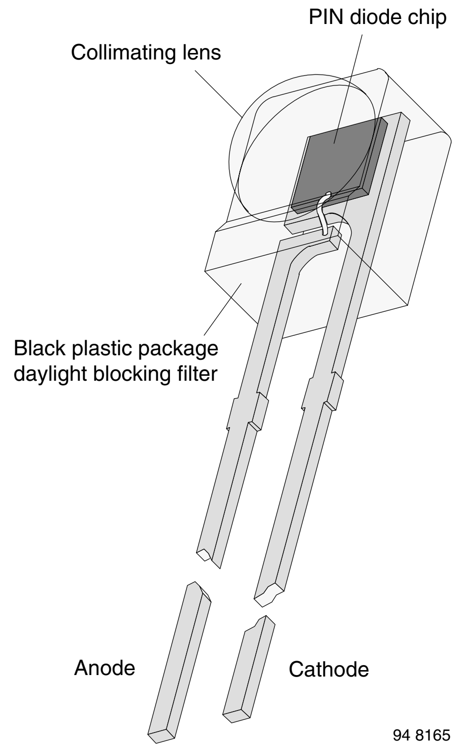

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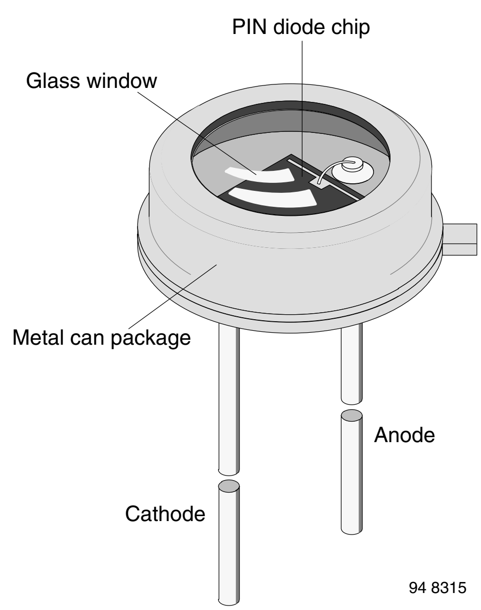

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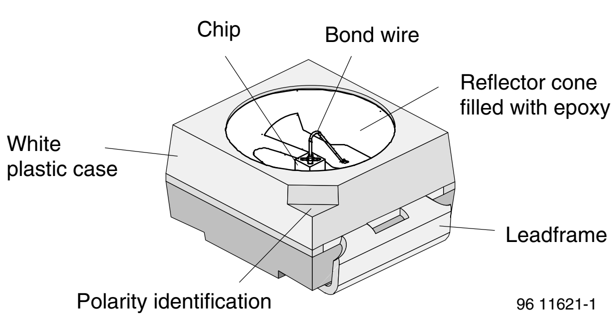

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Measurement Techniques

INTRODUCTION

The characteristics of optoelectronics devices given in datasheets are verified either by 100 % production tests followed by statistic evaluation or by sample tests on typical specimens. These tests can be divided into following categories:

- Dark measurements
- Light measurements
- Measurements of switching characteristics, cut-off frequency and capacitance
- Angular distribution measurements
- Spectral distribution measurements
- Thermal measurements

Dark and light measurements limits are 100 % measurements. All other values are typical. The basic circuits used for these measurements are shown in the following sections. The circuits may be modified slightly to accommodate special measurement requirements.

Most of the test circuits may be simplified by use of a source measure unit (SMU), which allows either to source voltage and measure current or to source current and measure voltage.

DARK AND LIGHT MEASUREMENTS

EMITTER DEVICES

IR Diodes

Forward voltage, V_F, is measured either on a curve tracer or statically using the circuit shown in figure 1. A specified forward current (from a constant current source) is passed through the device and the voltage developed across it is measured on a high-impedance voltmeter.

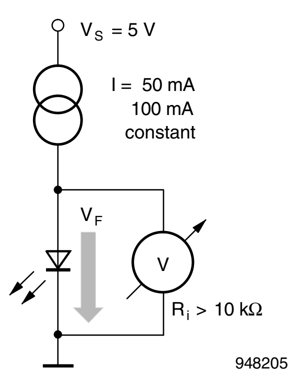

Fig. 1

To measure reverse voltage, V_R, a 10 µA or 100 µA reverse current from a constant current source is impressed through the diode (figure 2) and the voltage developed across is measured on a voltmeter of high input impedance (≥ 10 MΩ).

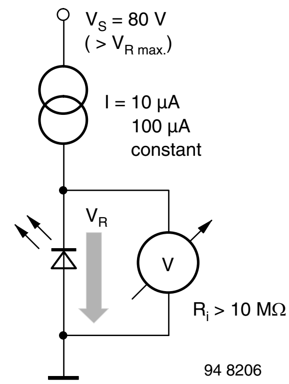

Fig. 2

For most devices, V_R is specified at 10 µA reverse current. In this case either a high impedance voltmeter has to be used, or current consumption of DVM has to be calculated and added to the specified current. A second measurement step will then give correct readings.

In case of IR diodes, total radiant output power, Φ_e, is usually measured. This is done with a calibrated large-area photovoltaic cell fitted in a conical reflector with a bore which accepts the test item - see figure 3. An alternative test set uses a silicon photodiode attached to an integrating sphere. A constant DC or pulsating forward current of specified magnitude is passed through the IR diode. The advantage of pulse-current measurements at room temperature (25 °C) is that results can be reproduced exactly.

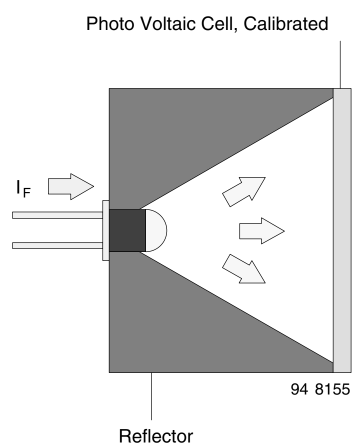

Fig. 3

If, for reasons of measurement economy, only DC measurements (figure 4) are to be made, then the energizing time should be kept short (below 1 s) and of uniform duration, to minimize any fall-off in light output due to internal heating.

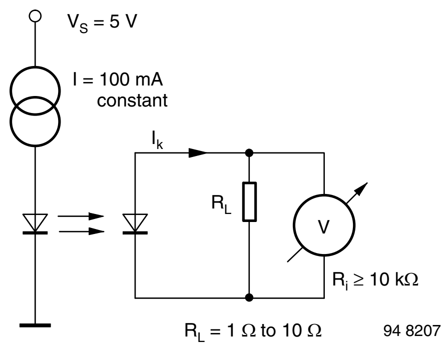

Fig. 4

To ensure that the relationship between irradiance and photocurrent is linear, the photodiode should operate near the short-circuit configuration. This can be achieved by using a low resistance load (≤ 10 Ω) of such a value that the voltage dropped across is very much lower than the open circuit voltage produced under identical illumination conditions ($R_{meas} << R_i$). The voltage across the load should be measured with a sensitive DVM.

A knowledge of radiant intensity, I_e, produced by an IR emitter enables customers to assess the range of IR light barriers. The measurement procedure for this is more or less the same as the one used for measuring radiant power. The only difference is that in this case the photodiode is used without a reflector and is mounted at a specified distance from, and on the optical axis of, the IR diode (figure 5). This way, only the radiant power of a narrow axial beam is considered.

The radiant power within a solid angle of Ω = 0.01 steradian (sr) is measured at a distance of 100 mm. Radiant intensity is then obtained by using this measured value for calculating the radiant intensity for a solid angle of Ω = 1 sr.

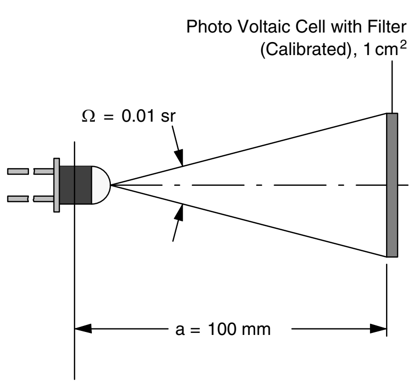

Fig. 5

DETECTOR DEVICES

Photovoltaic cells, photodiodes

- Dark measurements

The reverse voltage characteristic, V_R, is measured either on a curve tracer or statically using the circuit shown in figure 6. A high-impedance voltmeter, which draws only an insignificant fraction of device's reverse current, must be used.

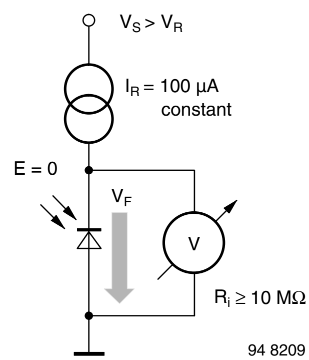

Fig. 6

Dark reverse current measurements, I_{ro}, must be carried out in complete darkness - reverse currents of silicon photodiodes are in the range of nanoamperes only, and an illumination of a few lx is quite sufficient to falsify the test result. If a highly sensitive DVM is to be used, then a current sampling resistor of such a value that voltage dropped across it is small in comparison with supply voltage must be connected in series with the test item (figure 7). Under these conditions, any reverse voltage variations of the test samples can be ignored. Shunt resistance (dark resistance) is determined by applying a very slight voltage to the photodiode and then measuring dark current. In case of 10 mV or less, forward and reverse polarity will result in similar readings.

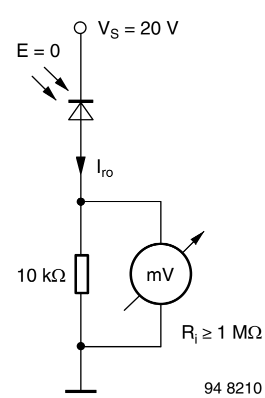

Fig. 7

- Light measurements

The same circuit as used in dark measurement can be used to carry out light reverse current, I_{ra}, measurements on photodiodes. The only difference is the diode is now irradiated and a current sampling resistor of lower value must be used (figure 8), because of the higher currents involved.

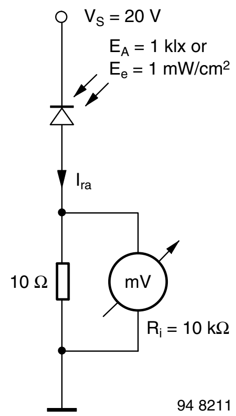

Fig. 8

The open circuit voltage, V_O, and short circuit current, I_k, of photovoltaic cells and photodiodes are measured by means of the test circuit shown in figure 9. The value of the load resistor used for the I_k measurement should be chosen so that the voltage dropped across it is low in comparison with the open circuit voltage produced under conditions of identical irradiation.

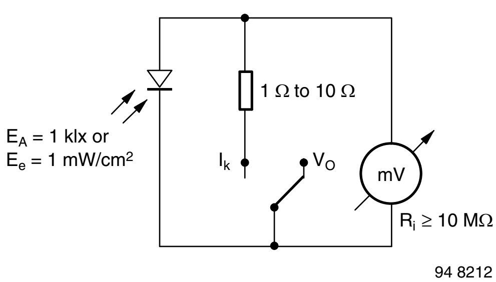

Fig. 9

The light source used for the light measurements is a calibrated incandescent tungsten lamp with no filters.
The filament current is adjusted for a color temperature of 2856 K (standard illuminant A to DIN 5033 sheet 7). A specified illumination, E_v, (usually 100 lx or 1000 lx) is produced by adjusting the distance, a, between the lamp and a detector on an optical bench. E_v can be measured on a V(λ)-corrected luxmeter, or, if luminous intensity, I_v, of the lamp is known, E_v can be calculated using the formula: $E_v = I_v/a^2$.

It should be noted that this inverse square law is only strictly accurate for point light sources, that is for sources where the dimensions of the source (the filament) are small (≤ 10 %) in comparison with the distance between the source and detector.

Since lux is a measure for visible light only, near-infrared radiation (800 nm to 1100 nm) where silicon detectors have their peak sensitivity is not taken into account. Unfortunately, the near-infrared emission of filament lamps of various construction varies widely. As a result, light current measurements carried out with different lamps (but the same lux and color temperature calibration) may result in readings that differ up to 20 %.

The simplest way to overcome this problem is to calibrate (measure the light current) some items of a photodetector type with a standard lamp (OSRAM WI 41/G) and then use these devices for adjustment of the lamp used for field measurements.

An IR diode is used as a radiation source (instead of a Tungsten incandescent lamp), to measure detector devices being used mainly in IR transmission systems together with IR emitters (e.g., IR remote control, IR headphone). Operation is possible both with DC or pulsed current.

The adjustment of irradiance, E_e, is similar to the above mentioned adjustment of illuminance, E_v. To achieve a high stability similar to filament lamps, consideration should be given to the following two points:

- The IR emitter should be connected to a good heat sink to provide sufficient temperature stability.
- DC or pulse-current levels as well as pulse duration have great influence on self-heating of IR diodes and should be chosen carefully.
- The radiant intensity, I_e, of the device is permanently controlled by a calibrated detector.

Phototransistors

The collector emitter voltage, V_{CEO}, is measured either on a transistor curve tracer or statically using the circuit shown in figure 10. Normal bench illumination does not change the measured result.

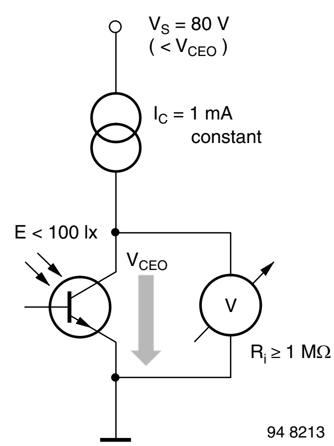

Fig. 10

In contrast, however, the collector dark current, I_{CEO} or I_{CO}, must be measured in complete darkness (figure 11). Even ordinary daylight illumination of the wire fed-through glass seals would falsify the measurement result.

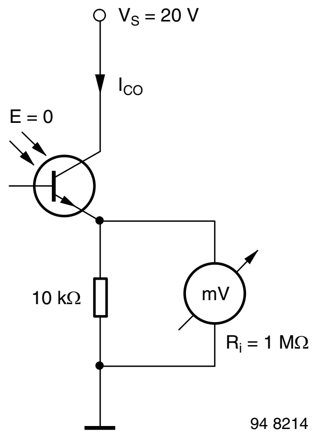

Fig. 11

The same circuit is used for collector light current, I_{ca}, measurements (figure 12). The optical axis of the device is aligned to an incandescent tungsten lamp with no filters, producing a CIE illuminance A of 100 lx or 1000 lx with a color temperature of T_f = 2856 K. Alternatively an IR irradiance by a GaAs diode can be used (refer to the photovoltaic cells and photodiodes section). Note that a lower sampling resistor is used, in keeping with the higher current involved.

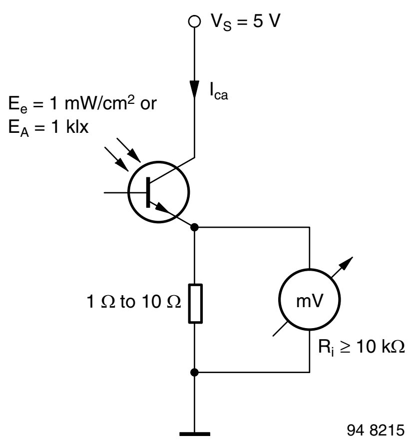

Fig. 12

To measure collector emitter saturation voltage, V_{CEsat}, the device is illuminated and a constant collector current is passed through. The magnitude of this current is adjusted below the level of the minimum light current, $I_{ca\ min}$, for the same illuminance (figure 13). The saturation voltage of the phototransistor (approximately 100 mV) is then measured on a high impedance voltmeter.

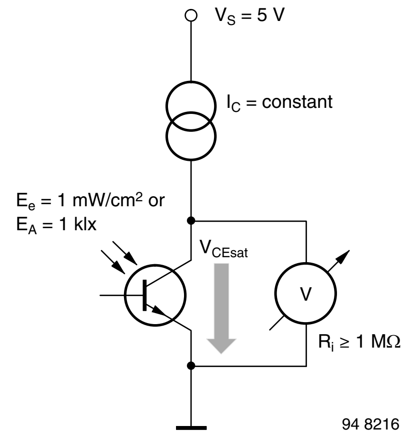

Fig. 13

SWITCHING CHARACTERISTICS

Definition

Each electronic device generates a certain delay between input and output signals as well as a certain amount of amplitude distortion. A simplified circuit (figure 14) shows how input and output signals of optoelectronic devices can be displayed on a dual-trace oscilloscope.

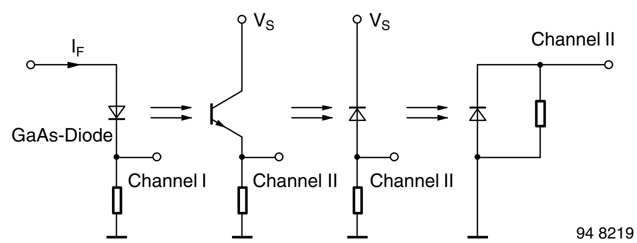

Fig. 14

The switching characteristics can be determined by comparing the timing of output current waveform with the input current waveform (figure 15).

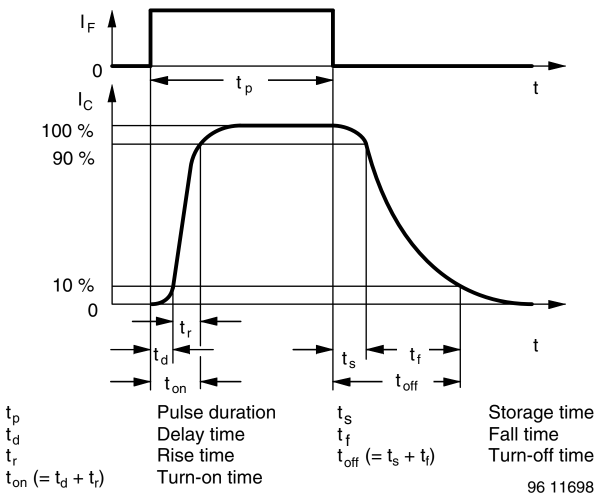

Fig. 15

These time parameters also include the delay existing in a luminescence diode between forward current (I_F) and radiant power Φ_e).

Notes Concerning the Test Set-up

Circuits used for testing IR emitting, emitting sensitive and optically coupled isolator devices are basically the same (figure 14). The only difference is the way in which test device is connected to the circuit.

It is assumed that rise and fall times associated with the signal source (pulse generator) and dual trace oscilloscope are insignificant, and that the switching characteristics of any radiant sensitive device used in set-up are considerably shorter than those of the test item. The switching characteristics of IR emitters, for example ($t_r \approx$ 10 ns to 1000 ns), are measured with aid of a PIN Photodiode detector ($t_r \approx$ 1 ns).

Photo- and darlington transistors and photo- and solar cells ($t_r \approx$ 0.5 µs to 50 µs) are, as a rule, measured by use of fast IR diodes ($t_r <$ 30 ns) as emitters.

Red light-emitting diodes are used as light sources only for devices which cannot be measured with IR diodes because of their spectral sensitivity (e.g. BPW21R). These diodes emit only 1/10 of radiant power of IR diodes and consequently generate only very low signal levels.

Switching Characteristic Improvements on Phototransistors and Darlington Phototransistors

As in any ordinary transistor, switching times are reduced if drive signal level, and hence collector current, is increased. Another time reduction (especially in fall time t_f) can be achieved by use of a suitable base resistor, assuming there is an external base connection, although this can only be done at the expense of sensitivity.

TECHNICAL DESCTIPTION - ASSEMBLY

Emitter

Emitters are manufactured using the most modern liquid phase epitaxy (LPE) process. By using this technology, the number of undesirable flaws in the crystal is reduced. This results in a higher quantum efficiency and thus higher radiation power. Distortions in the crystal are prevented by using mesa technology which leads to lower degradation. A further advantage of the mesa technology is that each individual chip can be tested optically and electrically, even on the wafer.

DETECTOR

Vishay Semiconductor detectors have been developed to match perfectly to emitters. They have low capacitance, high photosensitivity, and extremely low saturation voltage. Silicon nitride passivation protects surface against possible impurities.

Assembly

Components are fitted onto lead frames by fully automatic equipment using conductive epoxy adhesive. Contacts are established automatically with digital pattern recognition using well-proven thermosonic techniques. All component are measured according to the parameter limits given in the datasheet.

Applications

Silicon photodetectors are used in manifold applications, such as sensors for radiation from near UV over visible to near infrared. There are numerous applications in measurement of light, such as dosimetry in UV, photometry, and radiometry. A well known application is shutter control in cameras.

Another large application area for detector diodes, and especially phototransistors, is position sensing.
Examples are differential diodes, optical sensors, and reflex sensors.

Other types of silicon detectors are built-in as parts of optocouplers.

One of the largest application areas is remote control of TV sets and other home entertainment appliances.

Different applications require specialized detectors and also special circuits to enable optimized functioning.

Equivalent circuit

Photodetector diodes can be described by the electrical equivalent circuit shown in figure 16.

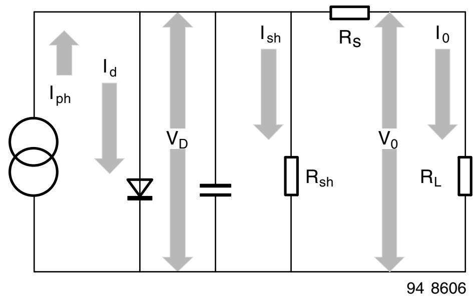

Fig. 16

$$I_O = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I_O = I_{ph} - I_s\left(\exp\frac{qV_D}{kT} - 1\right) - I_{sh}$$

$$V_{OC} = V_T \times \ln\left(\frac{S(\lambda) \times \phi_e - I_{sh}}{I_s} + 1\right) \quad (2)$$

As described in the chapter “I-V Characteristics of illuminated pn junction”, the incident radiation generates a photocurrent loaded by a diode characteristic and load resistor, R_L. Other parts of the equivalent circuit (parallel capacitance, C, combined from junction, C_j, and stray capacitances, serial resistance, R_S, and shunt resistance, R_{sh}, representing an additional leakage) can be neglected in most standard applications, and are not expressed in equations 5 and 7 (see “Physics and Technology”). However, in applications with high frequencies or extreme irradiation levels, these parts must be regarded as limiting elements.

Searching for the right detector diode type

The BPW 20 RF photodiode is based on rather highly doped n-silicon, while BPW34 is a PIN photodiode based on very lightly doped n-silicon. Both diodes have the same active area and spectral response as a function of wavelength is very similar. These diodes differ in their junction capacitance and shunt resistance. Both can influence the performance of an application.

Detecting very small signals is the domain of photodiodes with their very small dark currents and dark/shunt resistances.

With a specialized detector technology, these parameters are very well controlled in all Vishay photodetectors.

The very small leakage currents of photodiodes are offset by higher capacitances and smaller bandwidths in comparison to PIN photodiodes.

Photodiodes are often operated in photovoltaic mode, especially in light meters. This is depicted in figure 17, where a strong logarithmic dependence of the open circuit voltage on the input signal is used.

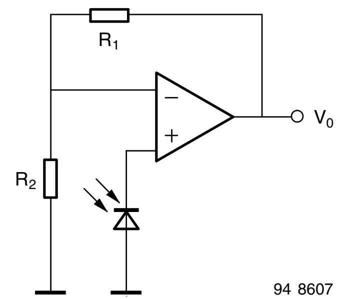

Fig. 17 - Photodiode in the Photovoltaic Mode Operating with a Voltage Amplifier

$$V_O \approx V_{OC} \times \left[1 + \frac{R_1}{R_2}\right] \text{ with} \quad (3)$$

$$V_{OC} = V_T \times \ln\left(\frac{S(\lambda) \times \phi_e - I_{sh}}{I_s} + 1\right) \quad (2)$$

It should be noted that extremely high shunt/dark resistance (more than 15 GΩ) combined with a high-impedance operational amplifier input and a junction capacitance of about 1 nF can result in slow switch-off time constants of some seconds. Some instruments therefore have a reset button for shortening the diode before starting a measurement.

The photovoltaic mode of operation for precise measurements should be limited to the range of low ambient temperatures, or a temperature control of the diode (e.g., using a Peltier cooler) should be applied. At high temperatures, dark current is increased (see figure 18) leading to a non-logarithmic and temperature dependent output characteristic (see figure 19). The curves shown in figure 18 represent typical behavior of these diodes. Guaranteed leakage (dark reverse current) is specified with I_{ro} = 30 nA for standard types. This value is far from that one which is typically measured. Tighter customer specifications are available on request. The curve shown in figure 19 show the open circuit voltage as a function of irradiance with dark reverse current, I_S, as a parameter (in a first approximation increasing I_S and I_{sh} have the same effect). The parameter shown covers the possible spread of dark current. In combination with figure 18 one can project the extreme dependence of the open circuit voltage at high temperatures (figure 20).

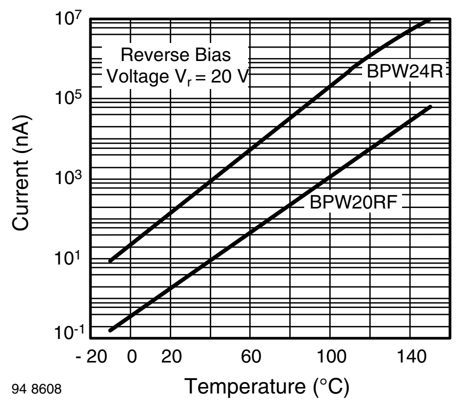

Fig. 18 - Reverse Dark Current vs. Temperature

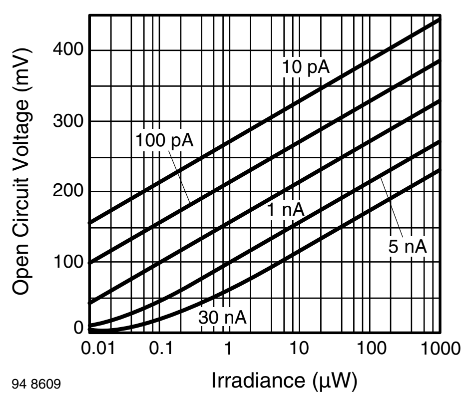

Fig. 19 - Open Circuit Voltage vs. Irradiance, Parameter: Dark Reverse Current, BPW20RF

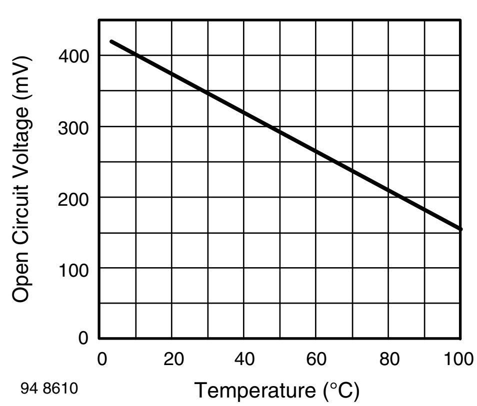

Fig. 20 - Open Circuit Voltage vs. Temperature, BPW46

Operating modes and circuits

The advantages and disadvantages of operating a photodiode in open circuit mode have been discussed.

For operation in short circuit mode (see figure 21) or photoconductive mode (see figure 22), current-to-voltage converters are typically used. In comparison with photovoltaic mode, the temperature dependence of the output signal is much lower. Generally, the temperature coefficient of the light reverse current is positive for irradiation with wavelengths > 900 nm, rising with increasing wavelength. For wavelengths < 600 nm, a negative temperature coefficient is found, likewise with increasing absolute value to shorter wavelengths.

Between these wavelength boundaries the output is almost independent of temperature. By using this mode of operation, the reverse biased or unbiased (short circuit conditions), output voltage, V_O, will be directly proportional to incident radiation, ϕ_e (see equation in figure 21).

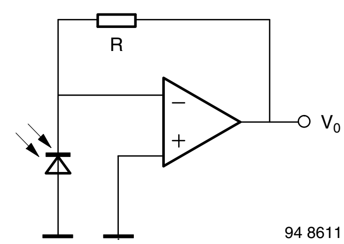

Fig. 21 - Transimpedance Amplifier, Current to Voltage Converter, Short Circuit Mode

$$V_O = - R \times \Phi_e \times S(\lambda) \qquad (4)$$

$$V_{OC} = - I_{sc} \times R \qquad (5)$$

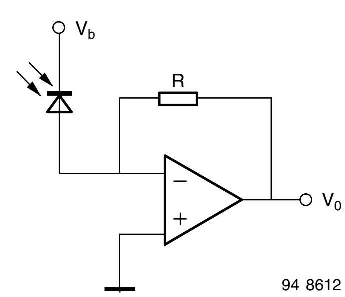

Fig. 22 - Transimpedance Amplifier, Current to Voltage Converter, Reverse Biased Photodiode

The circuit in figure 21 minimizes the effect of reverse dark current while the circuit in figure 22 improves the speed of the detector diode due to a wider space charge region with decreased junction capacitance and field increased velocity of the charge carrier transport.

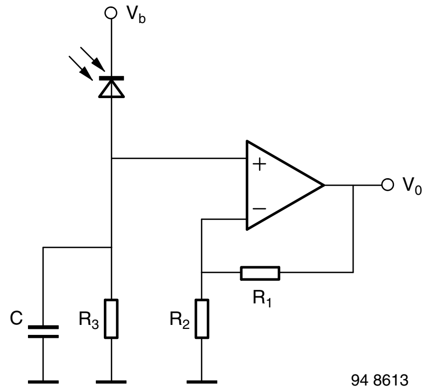

Fig. 23 - RC-Loaded Photodiode with Voltage Amplifier

Figure 23 shows photocurrent flowing into an RC load, where C represents junction and stray capacity while R_3 can be a real or complex load, such as a resonant circuit for the operating frequency.

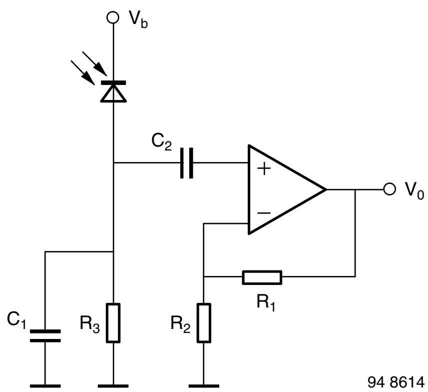

Fig. 24 - AC-Coupled Amplifier Circuit

$$V_O \approx \phi_e \times S(\lambda) \times R_3 \times \left[1 + \frac{R_1}{R_2}\right] \tag{6}$$

The circuit in figure 24 is equivalent to figure 23 with a change to AC coupling. In this case, the influence of background illumination can be separated from a modulated signal. The relation between input signal (irradiation, ϕ_e) and output voltage is given by the equation in figure 24.

Frequency response

The limitations of switching times in photodiodes are determined by carrier lifetime. Due to the absorption properties of silicon, especially in photodiodes, most of incident radiation at longer wavelengths is absorbed outside the space charge region. Therefore, a strong wavelength dependence of the switching times can be observed (figure 25).

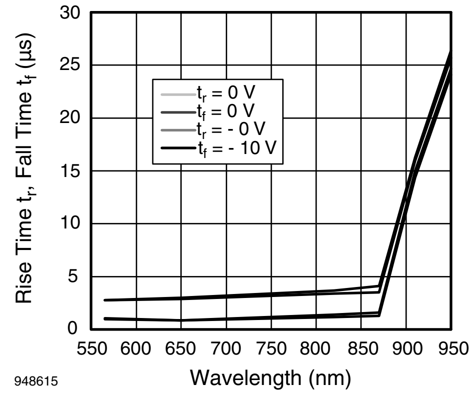

Fig. 25 - Switching Times vs. Wavelength for Photodiode BPW20RF

A drastic increase in rise and fall times is observed at wavelengths > 850 nm. Differences between unbiased and biased operation result from the widening of the space charge region.

However, for PIN photodiodes (BPW34/TEMD5000 family) similar results with shifted time scales are found. An example of such behavior, in this case in the frequency domain, is presented in figure 26 for a wavelength of 820 nm and figure 27 for 950 nm.

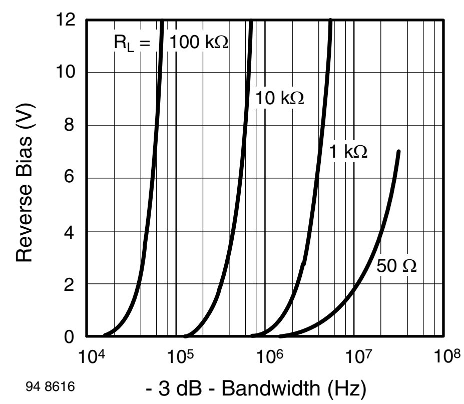

Fig. 26 - BPW34, TEMD5010X01, Bandwidth vs. Reverse Bias Voltage, Parameter: Load Resistance, λ = 820 nm

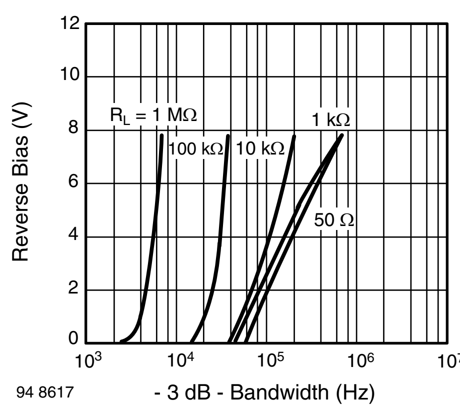

Fig. 27 - BPW41, TEMD5110X01, Bandwidth vs. Reverse Bias Voltage, Parameter: Load Resistance λ = 950 nm

Below about 870 nm, only slight wavelength dependence can be recognized, while a steep change of cut-off frequency takes place from 870 nm to 950 nm (different time scales in figure 26 and figure 27). Additionally, the influence of load resistances and reverse bias voltages can be taken from these diagrams.

For cut-off frequencies greater than 10 MHz to 20 MHz, depending on the supply voltage available for biasing the detector diode, PIN photodiodes are also used. However, for this frequency range, and especially when operating with low bias voltages, thin epitaxially grown intrinsic (i) layers are incorporated into PIN photodiodes.

As a result, these diodes (e.g., Vishay's TESP5700) can operate with low bias voltages (3 V to 4 V) with cut-off frequencies of 300 MHz at a wavelength of 790 nm. With application-specific optimized designs, PIN photodiodes with cut-off frequencies up to 1 GHz at only a 3 V bias voltage with only an insignificant loss of responsivity can be generated.

The main applications for these photodiodes are found in optical local area networks operating in the first optical window at wavelengths of 770 nm to 880 nm.

WHICH TYPE FOR WHICH APPLICATION?

In table 1, selected diode types are assigned to different applications. For more precise selection according to chip sizes and packages, refer to the tables in introductory pages of this data book.

TABLE 1 - PHOTODIODE REFERENCE TABLE

DETECTOR APPLICATION	PIN PHOTODIODE	PHOTODIODE
Photometry, light meter		BPW21R
Radiometry	TEMD5010X01, BPW34, BPW24R, ...	BPW20RF
Light barriers	BPV10NF, BPW24R	
Remote control, IR filter included, $\lambda > 900$ nm	BPV20F, BPV23F, BPW41N, S186P, TEMD5100X01	
IR Data Transmission fc < 10 MHz IR filter included, $\lambda > 820$ nm	BPV23NF, BPW82, BPW83, BPV10NF, TEMD1020, TEMD5110X01	
IR Data Transmission, fc > 10 MHz, no IR filter	BPW34, BPW46, BPV10, TEMD5010X01	
Densitometry	BPW34, BPV10, TEMD5010X01	BPW20RF, BPW21R
Smoke detector	BPV22NF, BPW34, TEMD5010X01	

PHOTOTRANSISTOR CIRCUITS

A phototransistor typically operates in a circuit shown in figure 28. Resistor R_B can be omitted in most applications. In some phototransistors, the base terminal is not connected. R_B can be used to suppress background radiation by setting a threshold level (see equation 7 and 8)

$$V_O = V_S - B \times \phi_e \times S(\lambda) \times R_L \tag{7}$$

$$V_{OC} \approx V_S - \left(B \times \phi_e \times S(\lambda) - \frac{0.6}{R_B}\right) \times R_L \tag{8}$$

For the dependence of rise and fall times on load resistance and collector-base capacitance, see the chapter "Properties of Silicon Phototransistors".

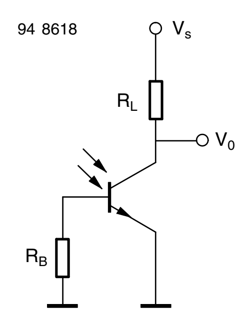

Fig. 28 - Phototransistor with Load Resistor and Optional Base Resistor

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