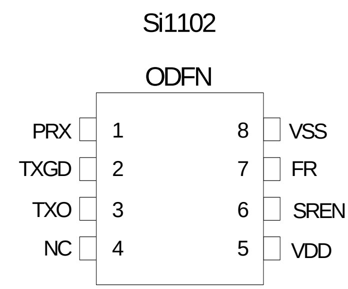
Si1102

OPTICAL PROXIMITY DETECTOR

Features

- High-performance proximity detector with a sensing range of up to 40 cm.
- Threshold reflectance principle overcomes ambiguity associated with motion-based systems
- Adjustable detection threshold and strobe frequency
- Proximity (PRX) status latched between consecutive strobes
- High EMI immunity without shielded packaging
- 2 to 5.5 V power supply
- Operating temperature range: –40 to +85 °C
- Typical 10 µA current consumption
- Current driven (400 mA) or saturated LED driver output
- Cancels dc ambient of at least 100 klux (direct sunlight).
- Small outline: 3x3 mm (ODFN)

Pin Assignments



U.S. Patent 5,864,591
U.S. Patent 6,198,118
Other patents pending

Applications

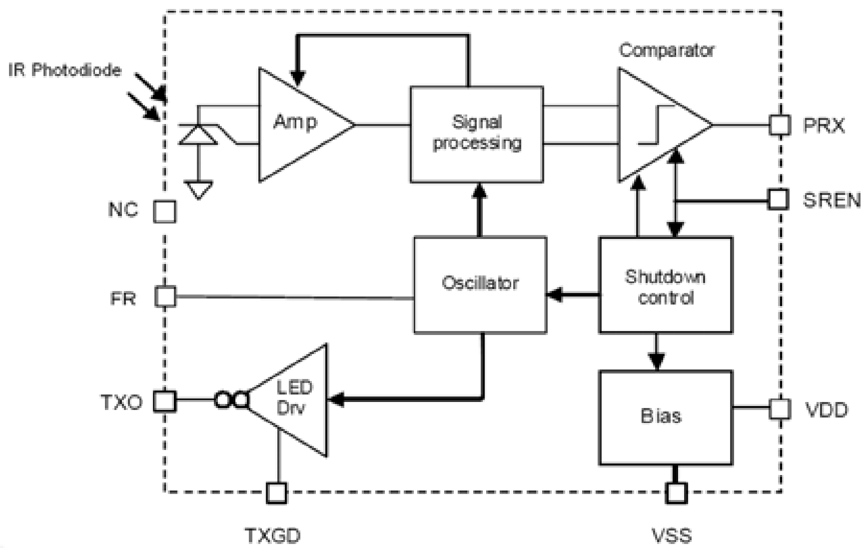
- Proximity sensing
- Photo-interrupter
- Occupancy sensing
- Touchless switch
- Object detection
- Handsets

Description

The Si1102 is a high-performance (0–40 cm) active proximity detector. Because it operates on an absolute reflectance threshold principle, it avoids the ambiguity of motion-based proximity systems. To achieve maximum performance, high optical isolation (less than 10^{-6} coupling) is required between two millimeter-sized light ports, one for the transmit LED and the other for the Si1102. For reduced-range applications (~10 cm), existing holes with high optical loss may be reused as optical ports (e.g. product case display windows, illumination light piping, camera windows, infrared receiver windows, or headphone/microphone holes). The detector even works without a dedicated window if a semi-opaque plastic case is used.

The Si1102 consists of a patented, high-EMI immunity, differential photodiode and a signal-processing IC with LED driver and high-gain optical receiver. Proximity detection is based on measurements of reflected light from a strobed, optically-isolated LED. The standard package for the Si1102 is an 8-pin ODFN.

Functional Block Diagram



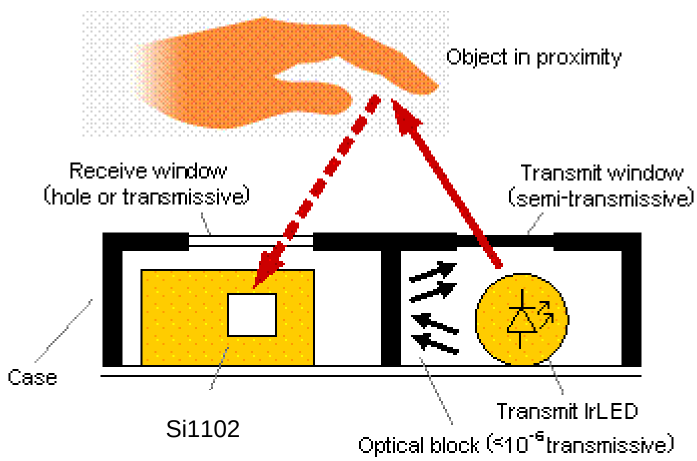


Figure 1. Reflectance-Based Proximity Detection

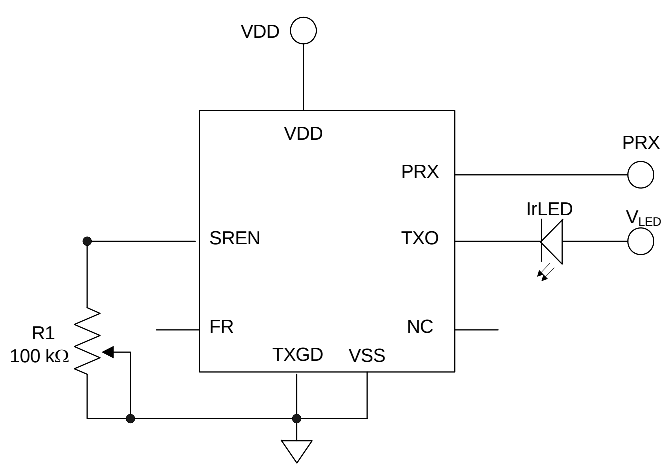


Figure 2. Simple On/Off Detector

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1. Electrical Specifications

Table 1. Absolute Maximum Ratings

Parameter	Conditions	Min	Typ	Max	Units
Supply Voltage		TBD	—	TBD	V
Operating Temperature		–55	—	125	°C
Storage Temperature		–65	—	150	°C
Voltage on TXO with respect to GND		TBD	—	TBD	V
Voltage on all other pins with respect to GND		TBD	—	TBD	V
Maximum total current through TXO		—	—	TBD	mA
Maximum total current through TXGD and VSS		—	—	TBD	mA
Maximum total current through all other pins		—	—	TBD	mA
ESD Rating	Human body model	—	—	2	kV

Table 2. Recommended Operating Conditions

Parameter	Symbol	Conditions/Notes	Min	Typ	Max	Units
Typical Operating Conditions (T_A = 25 °C)						
Supply Voltage	V_{DD}	–40 to +85 °C, V_{DD} to VSS	2	3.3	5.5	V
Operating Temperature			–40	—	85	°C
SREN High Threshold	SR_{VIH}	V_{DD} = 3.3 V	TBD	—	—	V
SREN Low Threshold	SR_{VIL}	V_{DD} = 3.3 V	—	—	TBD	V
Peak-to-Peak Power Supply Noise Rejection		V_{DD} = 3.3 V, 1 kHz–10 MHz no spurious PRX or less than 20% reduction in range	—	—	50	mVPP on V_{DD}
DC Ambient light	Edc	V_{DD} = 3.3 V	—	—	100	klux
LED Emission Wavelength			850	—	950	nm
LED Emission Wavelength (degraded performance)			600	—	950	nm
***Note:** Measured with N Lux of ambient halogen light.						

Table 3. Electrical Characteristics

Parameter	Symbol	Conditions/Notes	Min	Typ	Max	Units
PRX logic high level	VOH	V_{DD} = 3.3 V, Iprx = 5 mA	—	2.8	—	V
PRX logic low level	VOL	V_{DD} = 3.3 V, Iprx = –5 mA	—	TBD	—	V
I_{DD} Shutdown	I_{DD}	SREN = V_{DD}, FR = 0, V_{DD} = 3.3 V	—	0.1	1.0	µA
I_{DD} average current		SREN = 0 V, V_{DD} = 3.3 V, FR = 0	—	120	—	µA
I_{DD} average current		SREN = 0 V, V_{DD} = 3.3 V, FR = open	—	3	—	µA
I_{DD} current during transmit, Saturated Driver		V_{DD} = 3.3 V, LED I = 100 mA	—	8	—	mA
I_{DD} current during transmit, Not Saturated		V_{DD} = 3.3 V, LED I = 400 mA	—	14	—	mA
Sample Strobe Rate	FR	V_{DD} = 3.3 V, R2 = 0 Ω	—	250	—	Hz
Sample Strobe Rate	FR	V_{DD} = 3.3 V, R2 = 100 kΩ	—	5	—	Hz
Sample Strobe Rate	FR	V_{DD} = 3.3 V, R2 = (open)	—	2.5	—	Hz
Min. Detectable Reflectance Input	Emin	V_{DD} = 3.3 V, 880 nm source*	—	1	—	$\mu W/cm^2$
SREN low to TXO active	Tden	V_{DD} = 3.3 V	—	500	—	µs
TXO Leakage Current	Itxo_sd	V_{DD} = 3.3 V, no strobe	—	0.01	1	µA
TXO Current	$Itxo_{1V}$	V_{TXO} = 1 V, V_{DD} = 3.3 V	—	400	—	mA
TXO Current Temperature Coefficient	TC	V_{TXO} = 1 V, V_{DD} = 3.3 V	—	+0.47	—	%/°C
TXO Saturation Voltage	Vsat	$I_{TXO} = I_{TXO1V}$ x 80%	—	0.3	TBD	V

2. Typical Application Schematic

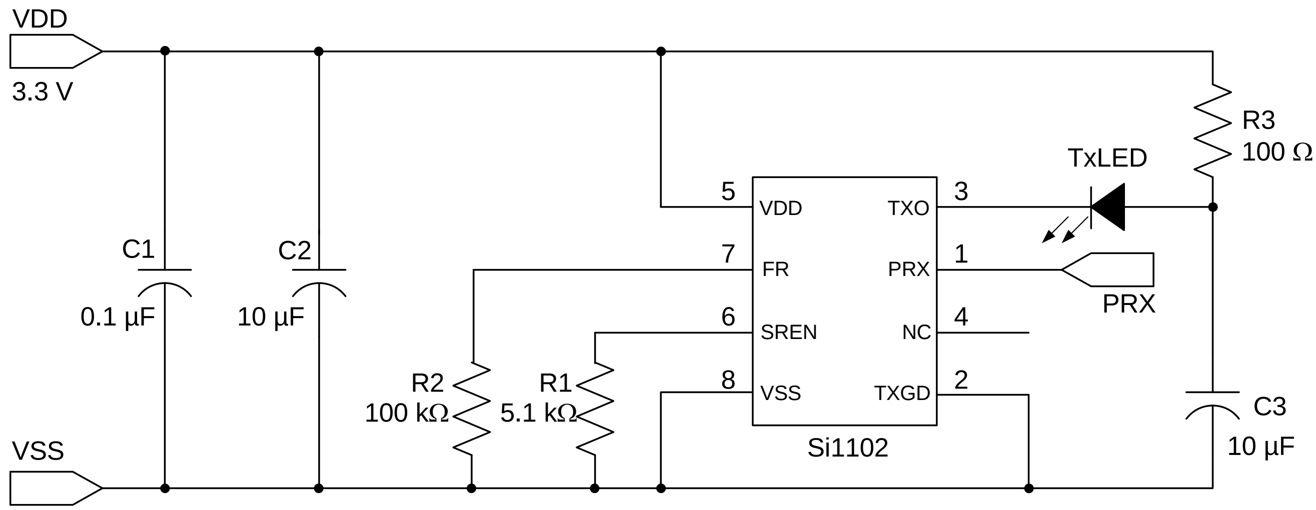

Figure 3. Application Example of the Proximity Sensor Using a Single Supply

3. Application Information

3.1. Theory of Operation

The Si1102 is an active optical reflectance proximity detector with a simple on/off digital output whose state is based upon the comparison of reflected light against a set threshold. An LED sends light pulses whose reflection reaches a photodiode and is processed by the Si1102's analog circuitry. If the reflected light is above the detection threshold, the Si1102 asserts the active-low PRX output to indicate proximity. This output can be used as a control signal to activate other devices or as an interrupt signal for microcontrollers.

The dual-port, active reflection proximity detector has significant advantages over single-port, motion-based infrared systems, which are good only for triggered events. Motion detection only identifies proximate moving objects and is ambiguous about stationary objects. The Si1102 allows in- or out-of-proximity detection, reliably determining if an object has left the proximity field or is still in the field even when not moving.

An example of a proximity detection application is controlling the display and speaker of a cellular telephone. In this type of application, the cell phone turns off the power-consuming display and disables the loudspeaker when the device is next to the ear, then reenables the display (and, optionally, the loudspeaker) when the phone moves more than a few inches away from the ear.

For small objects, the drop in reflectance is as much as the fourth power of the distance; this means that there is less range ambiguity than with passive motion-based devices. For example, a sixteen-fold change in an object's reflectance means only a fifty-percent drop in detection range.

The Si1102 proximity detector is designed to operate with a minimum number of external components. It requires only an LED and a sensitivity-adjustment resistor, as shown in Figure 3. The Si1102 periodically detects proximity at a rate that can be programmed by a single resistor. The part is powered down between measurements. The resulting average current, including that of the LED, is only a few microamperes, which is well below a typical lithium battery's self-discharge current of 10 µA, thus ensuring the battery's typical life of 10 years.

When enabled (SREN low), the Si1102 powers up, then pulses the output of the LED driver. Light reflected from a proximate object is detected by the receiver, and, if it exceeds a threshold set by the resistor at the SREN pin, the proximity status is latched to the active-low PRX output pin. The output is updated once per cycle.

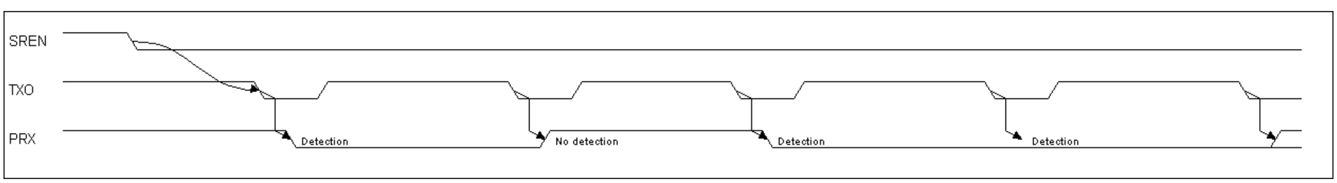

Figure 4.

3.2. Choice of LED and LED Current

In order to maximize detection distance, the use of an infrared LED is recommended. However, red (visible) LEDs are viable in applications where a visible flashing LED may be useful and a shorter detection range is acceptable. White LEDs have slow response and do not match the Si1102's spectral response well; they are, therefore, not recommended.

Although the Si1102 maintains excellent sensitivity in high ambient and optically noisy environments (most notably from fluorescent lights), an adaptive ambient-noise circuit reduces the detect threshold if the optical noise becomes large enough to trigger spurious proximity detection. In very noisy environments, the maximum sensitivity may drop by a factor of up to one hundred, causing a significant reduction in proximity range. With reduced sensitivity, the effect of optical environmental noise is reduced. For this reason, it is best to drive the LED with the maximum amount of current available, and an efficient LED should be selected. With careful system design, the duty cycle can be made very low, thus enabling most LEDs to handle the peak current of 400 mA while keeping the LED's average current draw on the order of a few microamperes.

3.3. Power-Supply Transients

Despite the Si1102's extreme sensitivity, it has good immunity from power-supply ripple, which should be kept below 50 mVpp for optimum performance. Power-supply transients (at the given amplitude, frequency, and phase) can cause either spurious detections or a reduction in sensitivity if they occur at any time within the 300 µs prior to the LED being turned on. Supply transients occurring after the LED has been turned off have no effect since the proximity state is latched until the next cycle. The Si1102 itself produces sharp current transients on its VDD pin, and, for this reason, must also have a low-impedance capacitor on its supply pins. Current transients at the Si1102 supply can be up to 20 mA.

The typical LED current peak of 400 mA can induce supply transients well over 50 mVpp, but those transients are easy to decouple with a simple R-C filter because the duty-cycle-averaged LED current is quite low. The TXO output can be allowed to saturate without problem. Only the first 10 µs of the LED turn-on time are critical to the detection range; this further lessens the need for large reservoir capacitors on the LED supply. In most applications, 10 µF is adequate. If the LED is powered directly from a battery or limited-current source, it is desirable to minimize the load peak current by adding a 100 Ω to 1 kΩ resistor in series with the LED's supply capacitor.

If a regulated supply is available, the Si1102 should be connected to the regulator's output and the LED to the unregulated voltage, provided it is less than 7 V. There is no power-sequencing requirement between VDD and the LED supply.

3.4. Mechanical and Optical Implementation

It is important to have an optical barrier between the LED and the Si1102. The reflection from objects to be detected can be very weak since, for small objects within the LED's emission angle, the amplitude of the reflected signal decreases in proportion with the fourth power of the distance. The receiver is capable of detecting less than one millionth (1 $\mu W/cm^2$) of the maximum signal. In order to detect this tiny signal, it is important that the internal optical coupling from the LED to the Si1102 be minimized by the same order of magnitude (10^6). This is usually not a problem. If an existing case is being reused and does not have designated openings for the LED or the Si1102, the proximity detector may still work if the optical loss factor through improvised windows (e.g. nearby microphone or fan holes) or semi-opaque material is not more than one hundred in each direction. Likewise, the partial reflection from an encased device's PMMA (acrylic glass) window (common in cellular telephones, PDAs, etc.) has only a minimal effect on the detection range. For optimal performance, the distance from the LED and the Si1102 should be maximized, and the distance between both components and the PMMA window should be minimized.

Table 4. Summary of External Component Values and Operating Conditions

R1	R2	Strobe Frequency	Distance[1]	IDD Average Current Consumption[2]
50 kΩ	0	250 Hz	5 cm	100 µA
50 kΩ	Open	2.5 Hz	5 cm	3 µA
5 kΩ	0	250 Hz	40 cm	120 µA
30 kΩ	0	250 Hz	10 cm	100 µA

Notes:
1. Distance measured with SFH4650 IR LED and without external lens or optical filter.
2. Average current consumption at VDD = 3.3 V, 25 °C and dark ambient conditions (<100 lx).

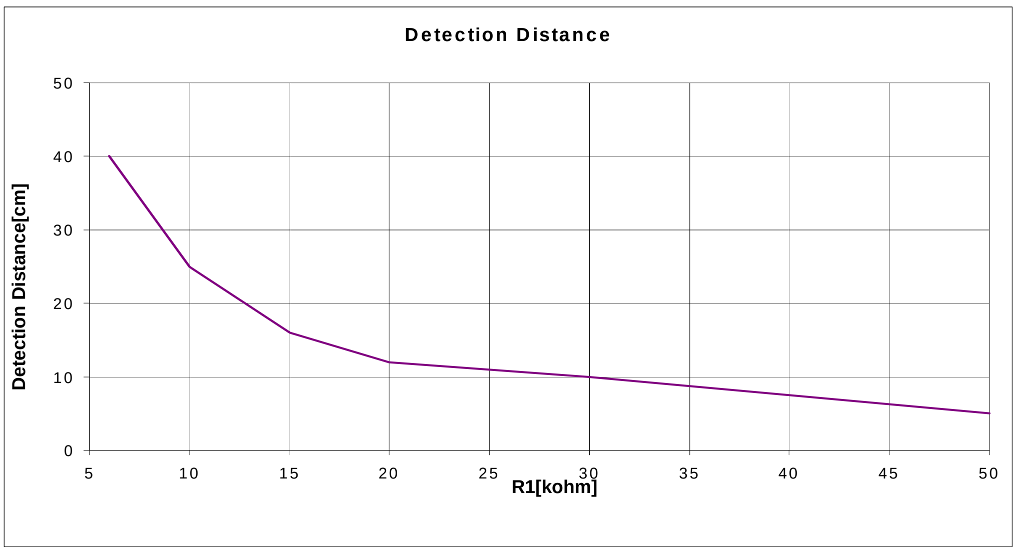

Figure 5. Proximity Detection Distance vs. R1 (SFH4650 IR LED 850 nm/40 mW)*

***Note:** Detection range measured using Kodak Gray cards (18% reflectance) under dark ambient conditions (<100 lx).

3.5. Typical Characteristics

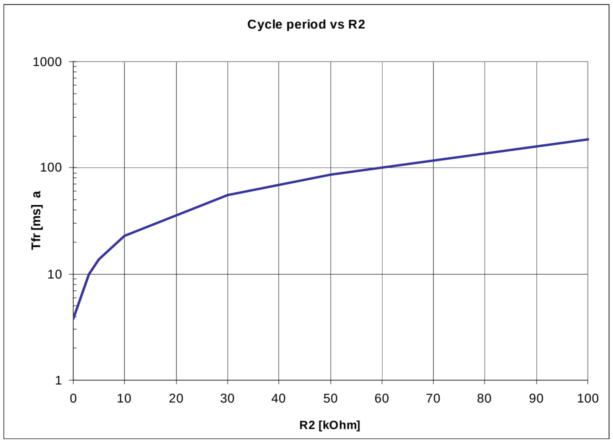

Figure 6. Cycle Period vs. R2 (V_{DD} = 3 V, R1 = 5.1 kΩ, Vtxo = 1 V)

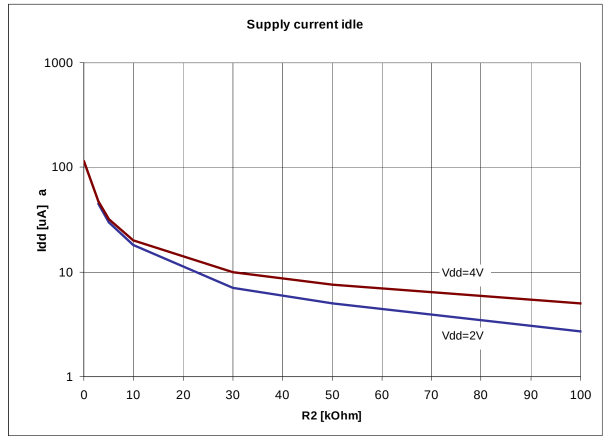

Figure 9. Idle Supply Current vs. R2 (V_{DD} = 3 V, R1 = 5.1 kΩ, Vtxo = 1 V)

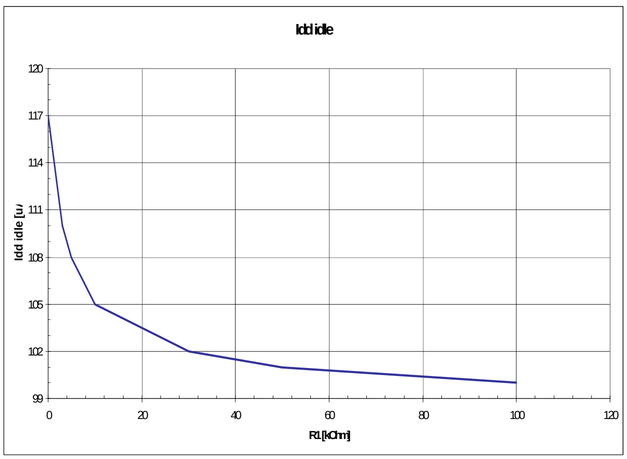

Figure 7. Idle Supply Current vs. R1 (V_{DD} = 3 V, R2 = 0 kΩ, Vtxo = 1 V)

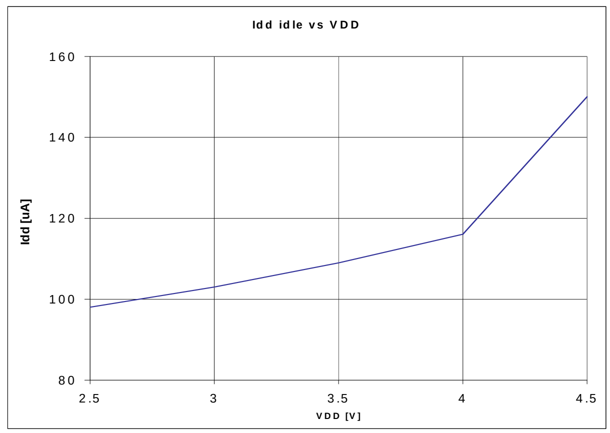

Figure 10. Idle Supply Current vs V_{DD} (R1 = 5.1 kΩ, R2 = 0 Ω, Vtxo = 1 V)

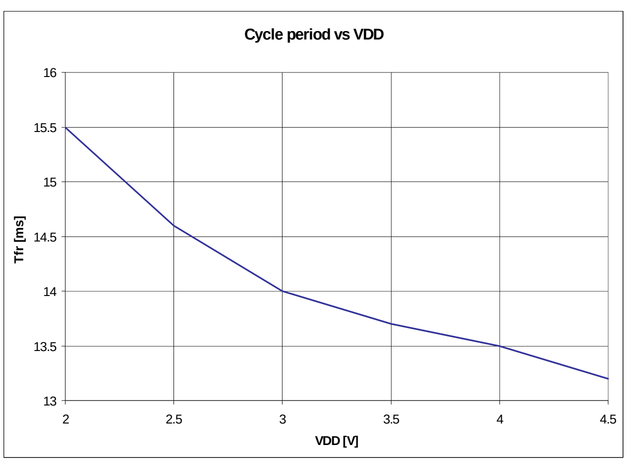

Figure 8. Cycle Period vs. V_{DD} (R2 = 4.7 kΩ, R1 = 5.1 kΩ, Vtxo = 1 V)

Figure 11. Proximity Detection Distance vs. LED Current

Figure 12. Proximity Detection Distance vs. Ambient Light

4. Pin Descriptions—Si1102

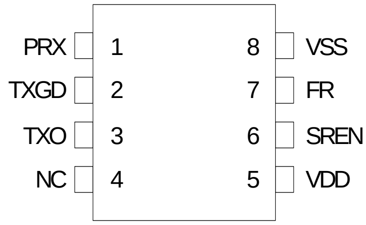

Figure 13. Pin Configuration

Table 5. Pin Descriptions

Pin	Name	Type	Description
1	PRX	Output	**Proximity Output**. Normally high; goes low when proximity is detected. When device is not enabled, the PRX pulls-up to V_{DD}.
2	TXGD	Ground	**TXGD**. Transmit ground (includes PRX return and other digital signals).
3	TXO	Output	**Transmit Output Strobe**. Normally connected to an infrared LED cathode. This output can be allowed to saturate, and output current can be limited by the addition of a resistor in series with the LED. It can also be connected to an independent unregulated LED supply even if the V_{DD} supply is at 0 V without either drawing current or causing latchup problems.
4	NC		**Reserved.**
5	VDD	Input	**Power Supply**. 2 to 5.5 V voltage source
6	SREN	Input	**Sensitivity Resistor/ENable**. Driving SREN below 1 V or connecting resistor from SREN to VSS enables the chip and immediately starts a proximity measurement cycle. A resistor to VSS controls proximity sensitivity. R_1=0 yields maximum detection distance. If SREN is high and FR is low (SREN=V_{DD}, FR=0), part is in shutdown.
7	FR	Input	**Frequency Resistor**. A resistor to VSS controls the proximity-detection cycle frequency. With no resistor, the sample frequency is 2.5 Hz. With FR shorted to VSS the sample frequency is 250 Hz. With a 100 kΩ resistor, the sample frequency is ~5 Hz. The voltage on FR relative to ground is only about 30 mV.
8	VSS	Ground	**VSS**. Ground (analog ground).

5. Ordering Guide

Part Ordering #	Temperature	Package
Si1102-A-GM	–40 to +85 °C	3x3 mm ODFN8

6. Package Outline (8-Pin ODFN)

Figure 14 illustrates the package details for the Si1102 ODFN package. Table 6 lists the values for the dimensions shown in the illustration.

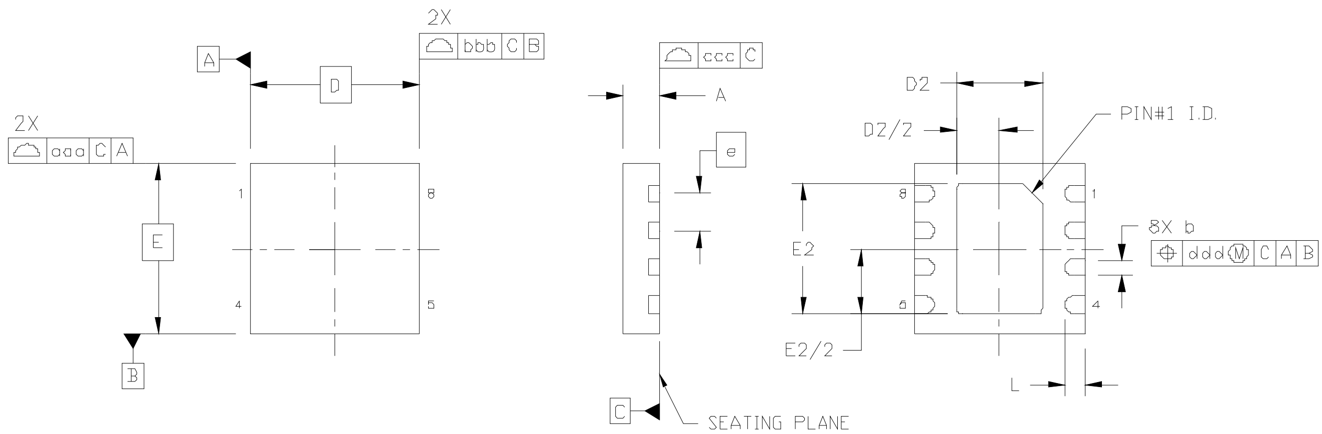

Figure 14. ODFN Package Diagram Dimensions

Table 6. Package Diagram Dimensions

Dimension	Min	Nom	Max
A	0.55	0.65	0.75
b	0.25	0.30	0.35
D		3.00 BSC.	
D2	1.40	1.50	1.60
e		0.65 BSC.	
E		3.00 BSC.	
E2	2.20	2.30	2.40
L	0.30	0.35	0.40
aaa		0.10	
bbb		0.10	
ccc		0.08	
ddd		0.10	

Notes:
1. All dimensions shown are in millimeters (mm).
2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.

DOCUMENT CHANGE LIST

Revision 0.6 to Revision 0.7

- Revised outline drawing for 3x3 ODFN.
  - Adjusted pin width to match true scale
  - Tightened tolerance on body dimensions

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