OB1203 Pulse Oximeter Module Electrical, Thermal, and Optical Design Guide

This application note explains the basic application circuit, circuit layout, and optical/mechanical enclosure guidelines for the OB1203 pulse oximeter module.

Contents

1. OB1203 Overview

The Renesas OB1203 pulse oximeter module optically detects heart rate and blood oxygen saturation (SpO2). Respiratory rate and other health information that can be inferred from the optical pulse waveform (PPG) signal. The OB1203 also features a proximity sensor and ambient light color sensor. A unique feature is OB1203's 690nm far red LED which allows for use of IR-transmissive inks to hide the sensor under a cover glass, as is typical for proximity sensors.

The OB1203 module is a 4.2×2×1.2 mm OSIP (optical system in package) allowing for very compact industrial designs using the reflective PPG sensing mode. The OB1203 3D CAD model can be downloaded from the OB1203 product page.

Figure 1. OB1203 Package Rendering

1.1 Package Overview

1.1.1. Cavities

The reflowable module package comprises a substrate on which the ASIC and two LEDs are mounted (see Figure 1). A black LCP plastic lid encloses the PCB, forming two interior cavities with openings for light transmission and reception. The package is designed to reduce optical crosstalk between the transmit and receive cavities. The light transmission cavity has two LEDs: red and infrared. The light-receiving cavity has the ASIC with its large proximity/biosensor photodiode nearer the LEDs, and the multi-pixel color sensor. A 0.2mm thick, non-allergenic glass lid protects the enclosure.

Strength to moderate compression forces (like a finger being placed on top) is excellent. However, because the package has a hollow cavity, the connection between the plastic enclosure and substrate is limited to the perimeter of the PCB, so *avoid shear forces* to the package plastic lid from a mechanical assembly or finger support shifting laterally relative to the PCB.

1.1.2. Pinout

The microscope image in Figure 2 shows the actual package top, side, and bottom views of the module. The pin array is 2×7 shape with 0.5mm pad pitch.

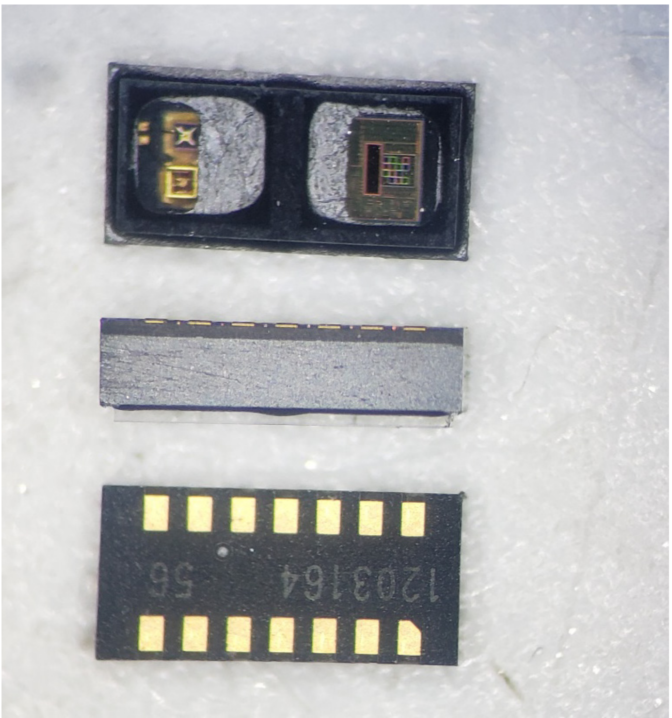

Figure 2. Package Top, Side, and Bottom-view with Transmit (LED) Cavity on Left and Receive (ASIC) Cavity on Right

1.1.3. Package Pinout and Layout Notes

1. The pads are slightly recessed, so use sufficiently large openings in the solder mask to ensure contact for all pins.
2. Pin 1 is indicated by a missing corner as noted in the datasheet package outline diagram.
3. Pins 1 and 14 have no internal connection and can be used for routing traces.
4. Solder mask land pattern for the pins can extend outward laterally a short distance such that the solder joints can be visually inspected.
5. The substrate has a small opening on the bottom side near pins 9 and 10 to relieve air pressure during reflow. Take care to *avoid siphoning of excess flux into the hole* during cooling, which could reduce optical performance. Low-flux/no-flux solder paste is a preferred option.
6. The *LVDD pins assist with heat sinking* the package and should be connected by a common copper pour/flood (see Figure 3 for a minimum acceptable heat spreader size – larger is better). Additional heat sinking vias to a heat spreading copper pour on the PCB backside are recommended. Vias conduct heat and electrical current similarly, so design the vias as if you were trying to conduct large amounts of current (e.g., not a few microvias). For an example of a copper pour with heat sinking vias to a backside heat spreader (not shown), which can be much larger in area, see Figure 3. Good heat sinking prevents thermal drift affecting LED intensities and *improves acquisition of the initial HR and SpO2 values, as well as LED efficiency*.
7. *LVDD and LGND* pins are high current. Provide sufficiently wide traces. For 1oz. copper, use at least *0.25mm traces*. Keep traces short, both to reduce noise generation on other sensitive circuits and to avoid voltage drops during LED operation.

8. *IR LED and RED LED pins* are normally not connected to the user circuit. These are provided for (1) heat sinking and (2) optional use of external LEDs (see example in section 0). If connected, these are high current pins and should be sufficiently wide, similar to LVDD and LGND traces.
9. For low current traces INT, SDA, SCL, and VDD use 0.15mm traces or smaller.
10. Connect LGND (LED ground current) and GND (digital and analog) on the PCB at a node with high-current capacity (low impedance), such as a ground plane. If the LGND and GND pins are connected prior to a significant series resistance, such as a long trace or wire, the high current on LGND will raise the circuit ground level and “ground bounce” will be observed which lowers accuracy for things like proximity sensing that rely on absolute thresholds.
11. *VDD is the most critical pin to protect from noise***.** Place a 0.1uF decoupling cap nearby (e.g., on the opposite side of the PCB). Design the VDD trace layout to avoid noise pickup.
12. LVDD supplies the pulsed currents of up to 250mA to the LEDs for ~50 to 200 µs. When suppling from an LDO or battery, provide a 4.7µF capacitor nearby (e.g., on the opposite side of the PCB to reduce voltage drop as the LDO or boost regulator adjusts).

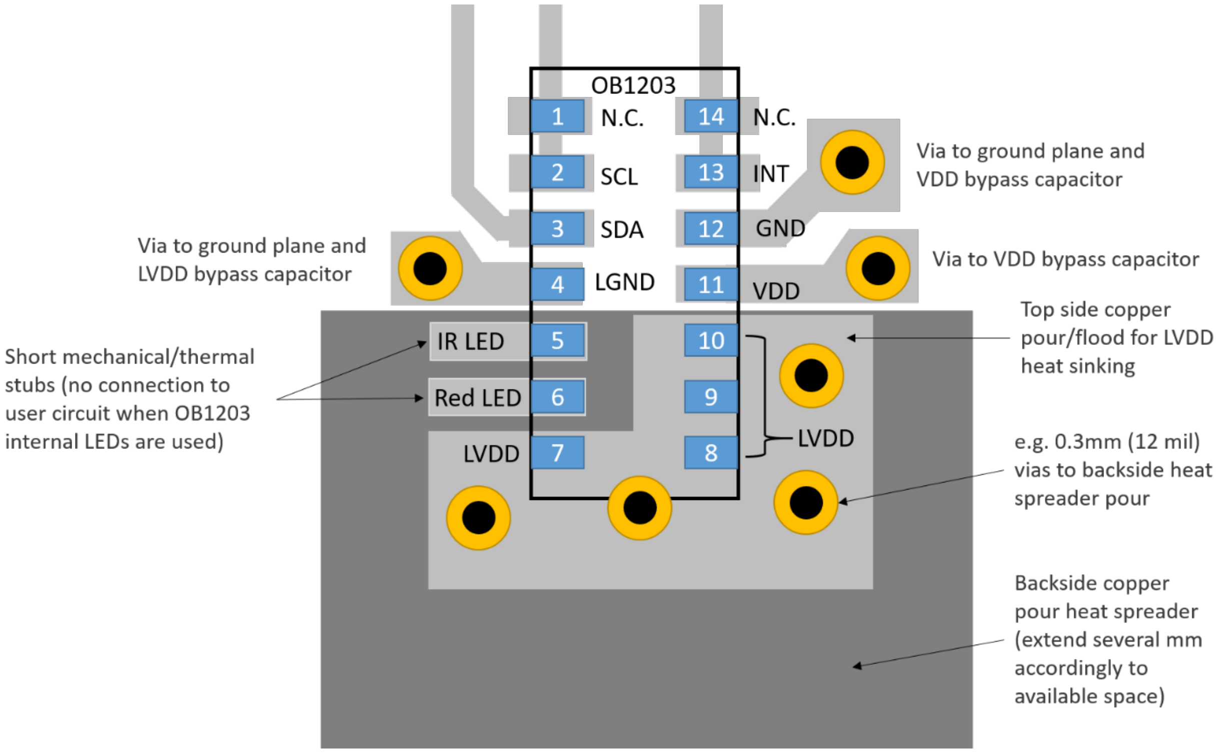

Figure 3. Top (Through Package) View of Pinout and Layout Concept

2. Electrical Design

The following sections provide several application circuit options for (1) nominal high performance, (2) high performance, (3) extended high performance and (4) Li-Ion powered, as well as general guidance.

2.1 General Guidance

The keys to a high-performance optical sensor design are low-noise supplies. The OB1203 has two voltage inputs to be powered:

- LVDD (sometimes referred to VLED in the product documentation) supplies current to the red and infrared LEDs. Suppling directly from a Li-Ion battery is an option. Two AAA batteries will typically require a boost regulator to 3.3V.

- VDD supplies the digital and analog circuitry including the LED driver and ADC and should be protected from noise pickup. *Do not supply VDD directly from a switching boost regulator. This will reduce signal to noise below recommended limits for bio measurements on individuals with low perfusion.*

2.1.1. Notes on Supply Voltage and Current

- The internal LED drivers are regulated current drivers and have some power supply rejection ratio (PSRR), typically about -35dB to -40dB. With the sensor operating at about 12 bits ENOB, LVDD can tolerate 25 to 50mV of ripple. If supplying from a boost regulator via a RF choke damping circuit, measure the actual ripple during high current operation when tuning the RF choke inductor.
- VDD has an internal regulator to 1.8V that provides some PSRR, typically about -35dB. In a worst case, this line can be supplied by the same supply as the LED driver; however, they should be well isolated up to a low impedance node to avoid pulsed current on the LED supply resulting in ripple on VDD.
- *VDD is a low-current pin* (~1mA) and can be supplied by a GPIO. This allows resetting the OB1203 via software by toggling the GPIO off and on.
- *Best case is separate LDOs for VDD and LVDD.*
- Note that the maximum voltage for LVDD depends on VDD as described in the datasheet's "Absolute Maximum Ratings." If OB1203 VDD is powered, LVDD can be as high as 5V. *If VDD is not powered (as in a reset condition), LVDD maximum voltage is 3.6V***.**
- *LVDD = 3.3V is typically sufficient* for operation of the red and IR LEDs up to maximum currents. This range is based on the internal LED drivers' overhead voltages (~0.6V) and the forward voltage of the red LED at maximum current. LEDs have manufacturing variance in their forward voltages so conservative design is recommended.
- VDD can be as low as 1.8V; however, supplying voltage above 1.8V is recommended because it allows the on-chip LDO to provide additional noise reduction. For example, a circuit with a 3.3V supply could use a 2.5V regulator for VDD. In this case the external LDO to 2.5V provides a first noise reduction and the internal LDO at 1.8V provides additional PSRR.

2.1.2. Notes on I2C Communication

The OB1203 communicates via I2C, a two-wire protocol. It also includes a separate interrupt line (interrupt out) to signal a sleeping microcontroller when data is ready or indicate a change in ambient light or proximity levels crossed a threshold.

- I2C uses open-drain pins (can pull lines down but not assert them), so all three pins *INT, SDA, and SCL must be pulled up* to the host controller's logic level (e.g., 3.3V) by suitable pull-up resistors.
- The OB1203 operates up to the 400kHz "high speed" I2C rate, which is useful when reading out biosensor data. Accordingly, pull-up resistors should be about *2.5 to 5 k*Ω, not 10kΩ as is used in common normal speed (100kHz) I2C applications. *Putting a smaller pull-up resistor on SCL* will typically allow VDD to come up first, then SCL before SDA to avoid disrupting OB1203 startup and initial configuration or when resetting.
- Conveniently, INT, VDD, and SCL can be pulled up to 3.3V typical (3.6V maximum) *even if VDD supply is lower*, so there is no need for level shifting when communicating with a host microcontroller up to 3.3V. For example**,** *supply VDD from a 2.5V LDO and pull up the communication lines to 3.3V* for communication with an MCU at 3.3V.
- *It is recommended to power VDD, then SCL, followed by SDA and INT*, for example, by putting a smaller pull-up resistor on SCL to VDD. Sensitivity to startup conditions can vary from device to device, but conservative design to handle device variation is recommended.
- The OB1203 uses 7-bit address 0x53 (8-bit address 0xA6). If there is a device address conflict on your board, the OB1203 can be factory-configured to an alternate 7-bit address 0x52 (0xA4 8-bit address) – longer lead times may apply.

2.2 Typical Application Circuit

This high-performance application circuit strikes a balance between cost and signal to noise ratio. Two AAA batteries are boosted to 3.3V for LVDD and to supply the MCU and display, then regulated to 2.5V for VDD. LVDD is isolated using an RF-choke to reduce ripple. While providing slightly lower performance than a dual-LDO design, this saves the cost and space of a high-current LDO for LVDD.

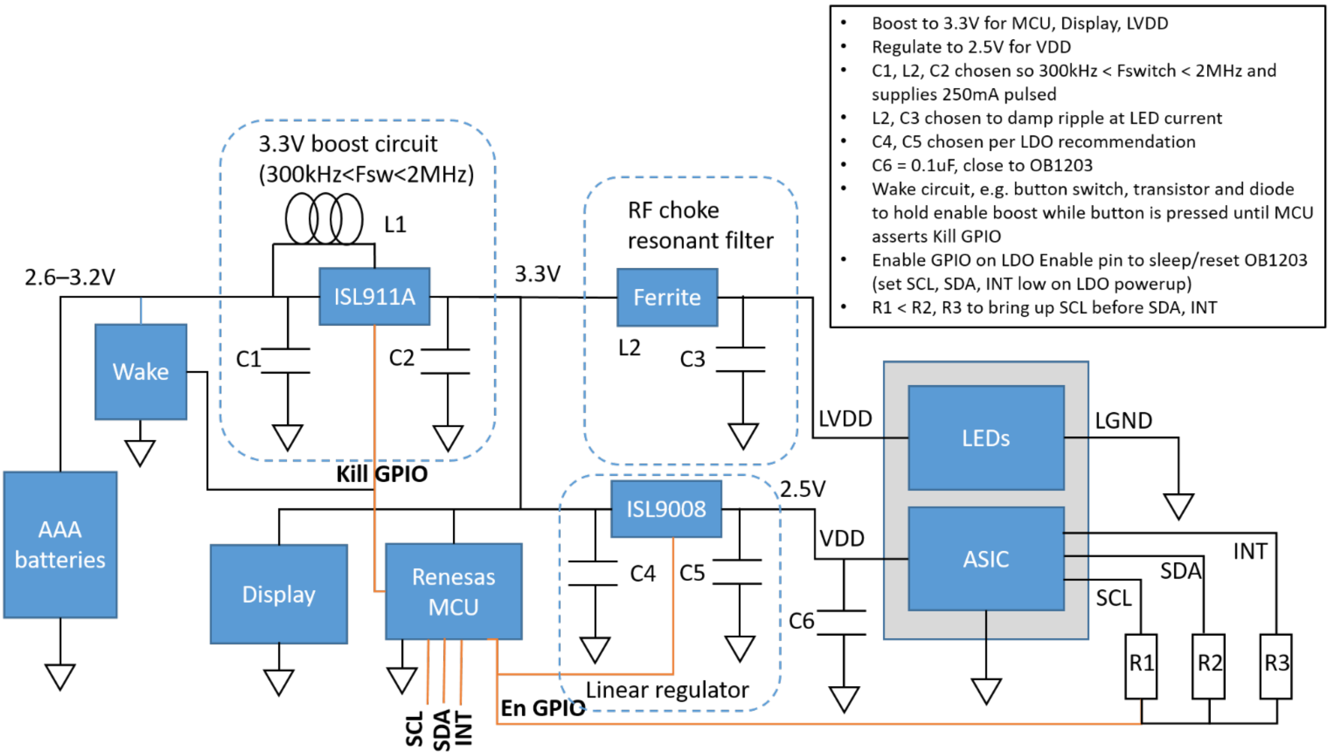

Figure 4. Nominal High Performance Application Circuit: One LDO

A wake circuit, such as a button, transistor, and diode holds the boost regulator enable pin up while the MCU boots. The MCU asserts the kill GPIO to keep power on and shuts it off when the device has timed out to kill power to all circuits.

An enable GPIO controls the LDO operation to power or reset/sleep the OB1203. *The ability to toggle VDD is always recommended since VDD functions as the reset pin*. The MCU keeps SCL, SDA, and INT lines low during LDO power up; otherwise, if control of those pins is not convenient, a separate I2C GPIO can be used to supply/shutdown the I2C pull-up voltage (3.3V).

If powering the MCU from the LDO, VDD (~1mA) can optionally be supplied from a GPIO.

Note the voltage drop from the 3.3V boost regulator to the 2.5V LDO output. This is necessary because (1) the boost regulator swing can be quite large ~0.5V, and (2) linear regular noise suppression is a function of the voltage drop from input to output. 2.5V provides a drop prior to the OB1203 and leads headroom for an additional drop to 1.8V in the internal ASIC LDO.

If the MCU has an on-chip voltage detect circuit, be sure to set it low enough (~2.5V) to avoid tripping during power up or LED operation.

2.3 Performance-Optimized Application Circuit

The signal-to-noise ratio of the typical application circuit can further be improved by providing a high-current LDO on the LVDD line. The boost regulator is set to 3.6V output or higher to provide some voltage overhead for the regulator. The MCU, display, and low power LDO are powered from the output of the high power regulator at 3.3V. Again, the communication lines can be held low during the low power LDO power on, or else a separate GPIO used to enable the pull-ups after powering VDD.

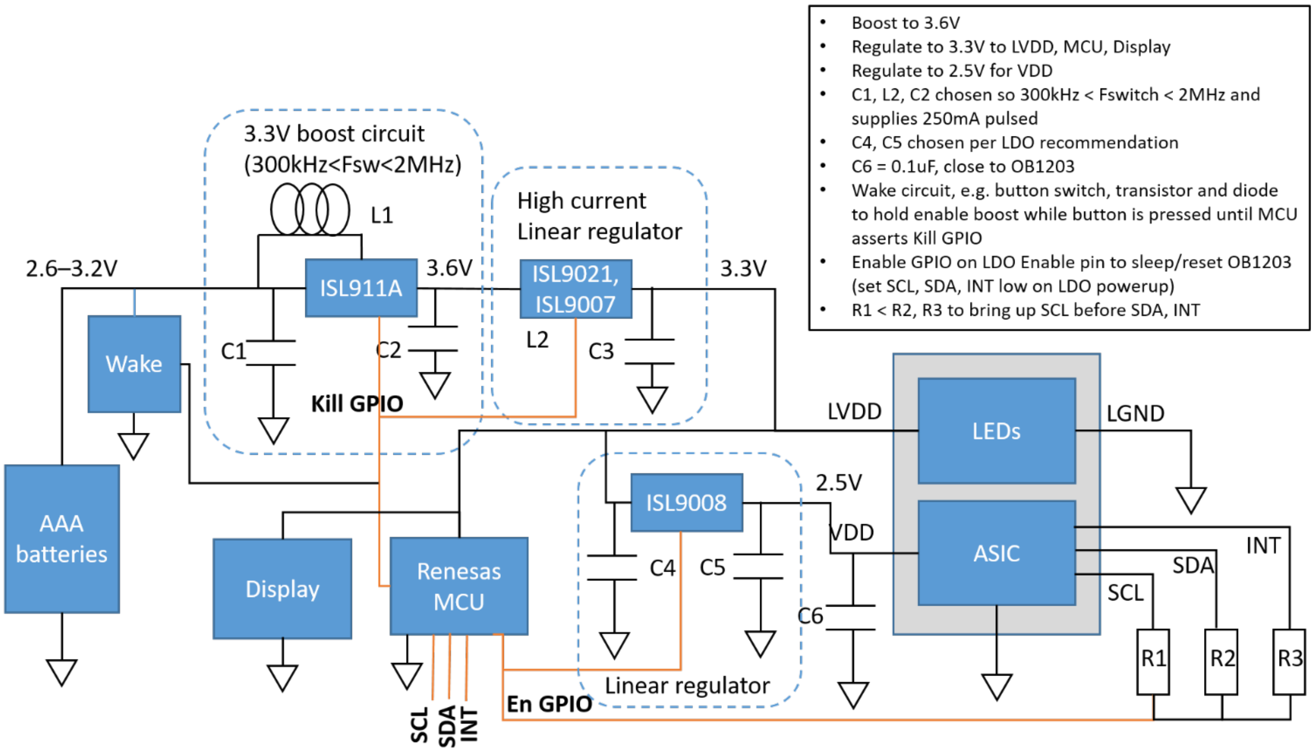

Figure 5. High-Performance Application Circuit: Two LDOs

2.4 External LED Application Circuit

Using external LEDs achieves larger AC pulse signals which improves the performance at low perfusion index (e.g., cold, pale fingers). The longer path length through the tissue creates more absorption leading to 1.75 to 2x larger observed level of perfusion (pulsile AC amplitude/DC signal). The LVDD pin on the OB1203 is left unpowered and the IR and Red channel current drive inputs (low side drive) are connected to the external LED cathodes.

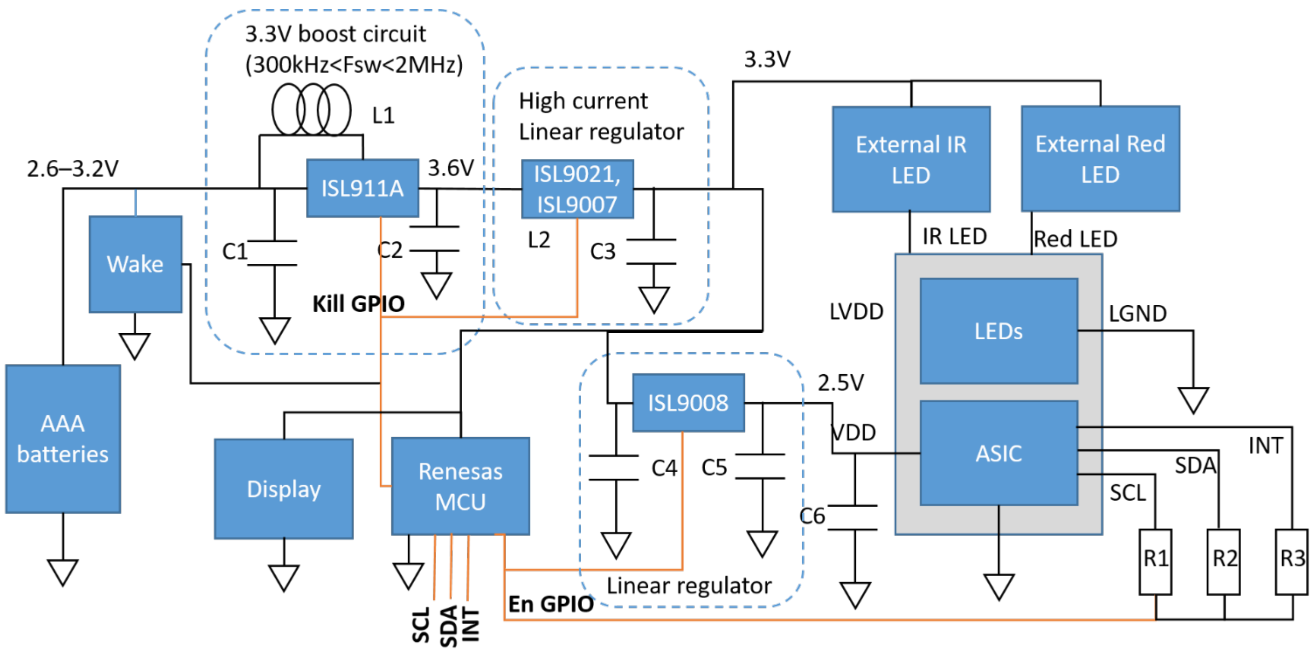

Figure 6. Extended High Performance using Eternal LEDs, Possible with One or Two LDOs

Note, the maximum IR LED drive current is 250mA (for proximity sensing), and the maximum Red LED drive current is 125mA, appropriate to the rating and size of the internal LED. However, for some applications it may be desirable to have a larger Red LED current. When using external LEDs the LED drivers can be swapped: connect the red LED to the IR LED driver, and vice-versa. Simply assert the LED_FLIP bit in the OB1203 in the PPG_PS_CFG register and the OB1203 ASIC will swap the LED drive order to keep the data output order the same.

Also, note that the OB1203 has a red color filter over the photoreceiver so green LEDs will not work. However, for LEDs with high overhead voltage, it may be preferable to set the low power LDO to 3.3V and power the MCU and display, and power the OB1203 VDD from a GPIO, as in the following circuit.

Options for external LEDs include separate 660nm and IR LED packages or modules packaged with both, such as Vishay VSMD66694 or Osram SFH 7015.

2.5 Li-ion Battery Application Circuit

The Lithium-ion or Lithium-polymer battery application trades a boost converter for a battery charger. In this example the linear regulator supplies the display and MCU. The OB1203 is powered from GPIO. LEDs are supplied directly from the battery. A high-side switch (high-current PMOS transistor) is provided to power the LEDs at LVDD only when VDD is powered. The datasheet's Absolute Maximum Ratings specify a maximum of 3.6V on LVDD when VDD is unpowered. Note the LED enable pin may have to be boosted via an external transistor and resistor (level shift inverter) if the threshold voltage of the PFET switch is too low to be shut off at 3.3V when the battery is at 4.2V. This switch should have a pull-up resistor to the battery voltage, so it is normally not conducting.

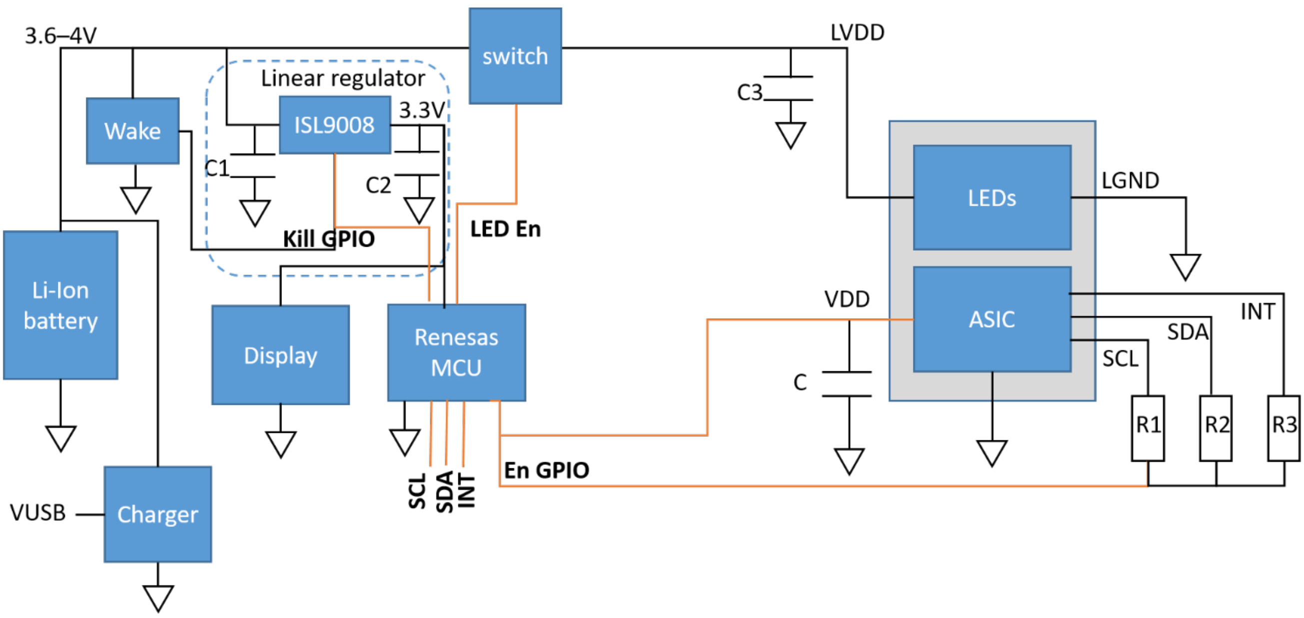

Figure 7. Li-ion Battery Application Circuit

2.6 Optical and Mechanical Design

Design of an enclosure for the OB1203 should take into consideration the following goals:

1. User experience – The user should be easily and repeatedly able to place their finger on the sensor.
2. Motion – The finger should be stable, for instance, by using a cradled. Controlled finger pressure is useful.
3. Optical crosstalk – Any optical cover material should be clear, NOT translucent, scratch-free, as close as possible to the OB1203 and as thin as possible. These things help to reduce the amount of deleterious light scattered or reflected directly back into the sensor, as opposed to useful light that passed through human tissue.

4. Manufacturing tolerance – Evaluation of the design should include work case tolerances for lid placement distance and alignment.
5. Industrial design and aesthetics – Contact Renesas if you have special requirements for color or want to implement a hidden sensor or for design specifications for proximity sensor modules in phones and tablets. Due to its unique deep red LED at 690 to 700nm, the OB1203 can be hidden behind infrared transmissive in a display bezel.

2.6.1. Mechanical Support

Mechanical support for the finger is critical to accurate measurements. Putting a bare finger on the exposed sensor on a PCB is not recommended, both for electrical and physiological reasons. Likewise, putting the sensor at the bottom of a deep hole is problematic from a blood flow, SNR, and stability perspective. See Figure 8 for examples of bad designs.

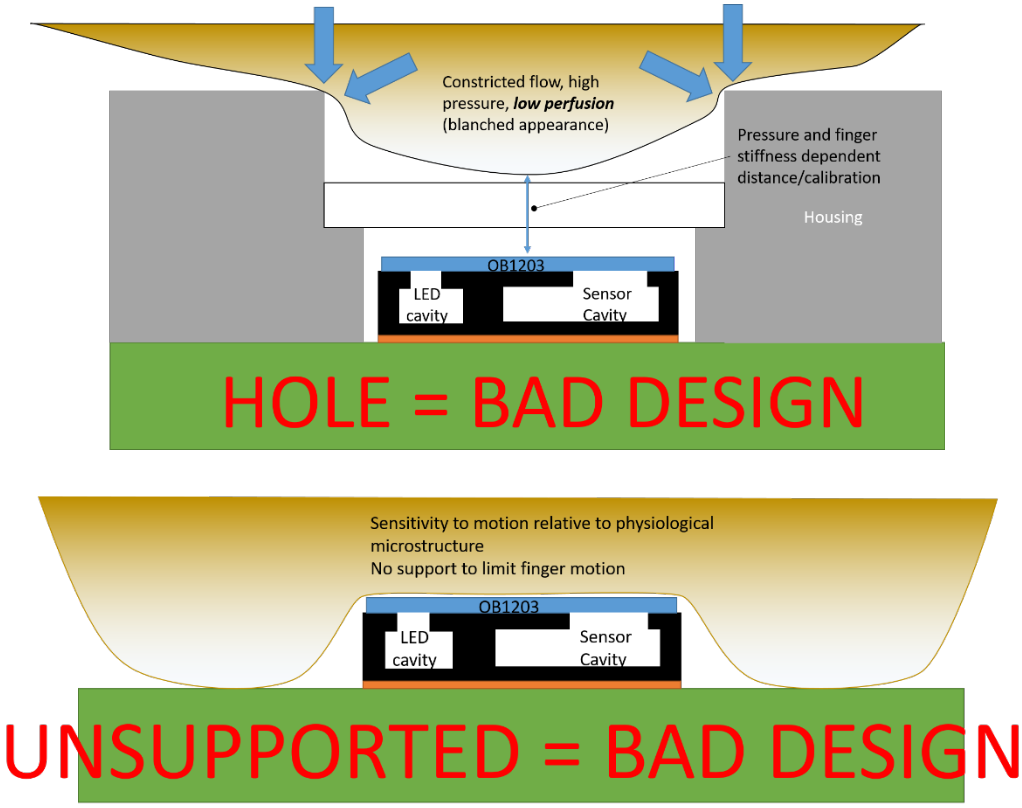

Figure 8. Bad Designs

Better designs shown in Figure 9 include designs based on (1) a recessed (shelf) lid that allows for a small lid, (2) a pocket design that surrounds OB1203 with support material and allows direct contact with OB1203's lid (sealant around the device may be necessary if UL approval is required), and (3) a lid supported from an inward facing shelf/recess. The inward facing lid is wider to avoid creating a "hole" that the user has to push their finger into. Unsupported inner lids are not recommended as pressure from the top and the lid could become detached. It is better to not rely on the adhesion strength of the lid.

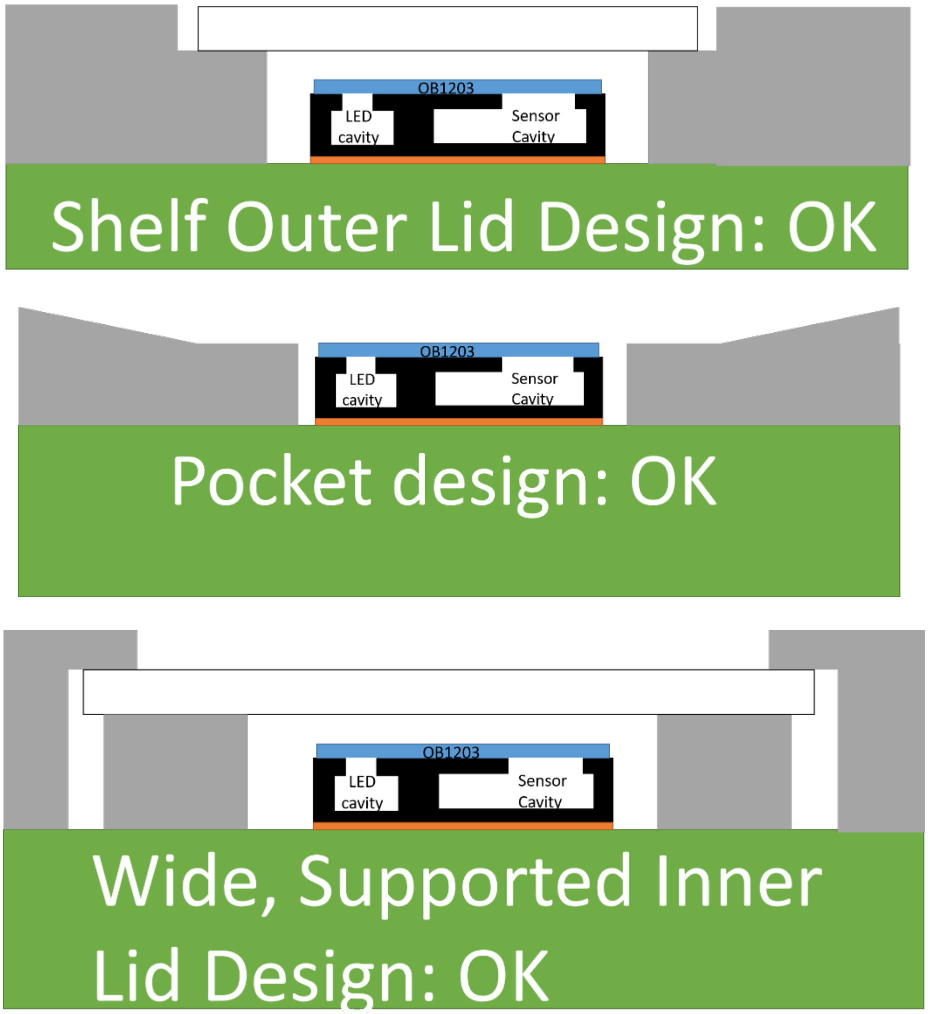

Figure 9. Better Design Options

2.6.2. Cover Glass/Cover Lens

A cover glass or cover lens material should be transmissive and low scattering from at least 600nm to 1000nm wavelength. Suitable materials include acrylic, polycarbonate, glass, silicone potting, and polyethylene terephthalate (PET). Polyolefins like high-density polyethylene (HDPE) and polypropylene (PPE) are more difficult to glue, though they can be heat welded and translucency (scattering) becomes an issue for thicker windows.

First priority is limiting the distance between the top of OB1203 and the cover glass and second priority is limiting the cover glass thickness, as shown in Figure 10.

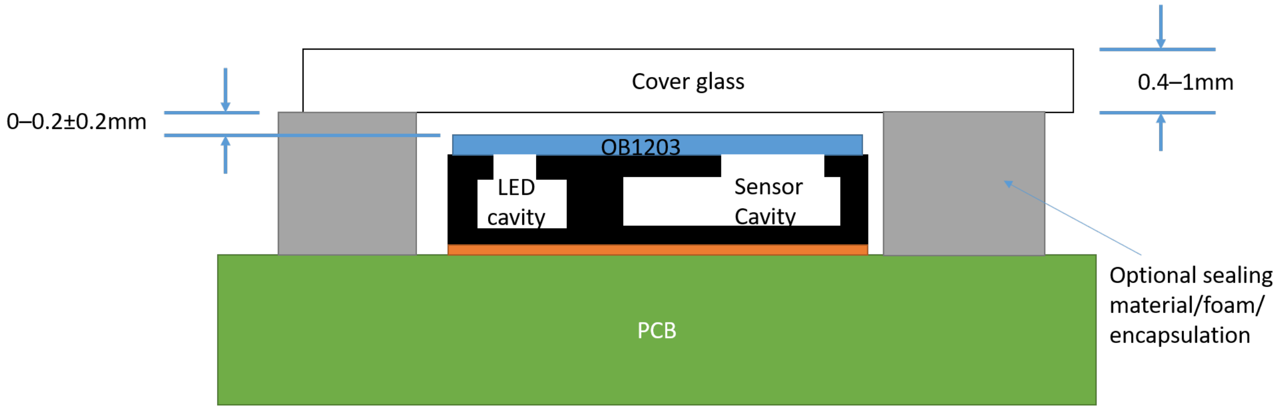

Figure 10. Cross-Section Diagram of OB1203 with a Transparent Cover Glass

2.6.3. Enclosure Color

Note that due to the OB1203's compact design, the material surrounding the OB1203 can be white, without significantly increasing crosstalk or reducing perfusion index. Different from transmission-based PPG sensors, this compact reflectance PPG sensor tolerates a white material around the sensor such as a finger support or foam encapsulant, which helps to recycle light and to reduce the required LED current by about 1.4. Note that changing the color, roughness, thickness, etc., of any surrounding material will alter the R-curve (SpO2 calibration) and necessitate a recalibration.

3. Revision History

Revision	Date	Description
1.00	Jan 12, 2022	Initial release.

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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