Heart Rate Monitoring with the Mpression Odyssey BLE Sensor Board and Silicon Labratories Si1147 Sensor

Overview

Heart rate and blood oxygen level monitoring is no longer used in just hospitals and medical offices. In today's health-conscious society, it is often desirable to have consumer devices that can measure and monitor heart rate and blood oxygen levels. This paper will take a look at the technology used to create a heart rate monitor with pulse oximetry in a compact, Bluetooth-connected device implementing a proof-of-concept design using the Silicon Laboratories Si1147 optical sensor.

Principles of Pulse Oximetry

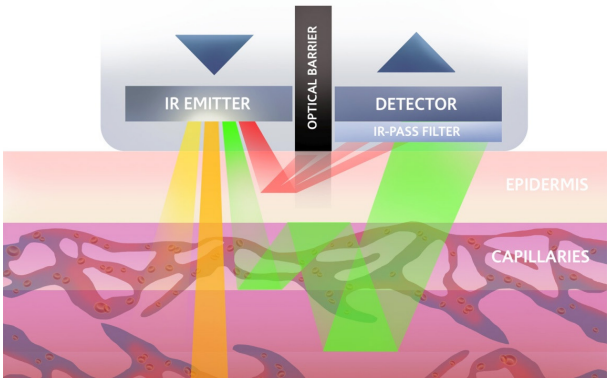
The principle of pulse oximetry is based on the absorption characteristics of oxygenated and deoxygenated hemoglobin in the blood using red and infrared light. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated hemoglobin absorbs more red light and allows more infrared light to pass through. In this case, we are using red light in the 600-750 nm wavelength band and infrared light in the 850-1000 nm wavelength band.

There are two methods of sending light through the measuring site: transmission and reflectance. In the transmission method, the light emitters and the photodetector are located on opposite sides of the measuring site. This method is typical of the pulse oximetry sensors seen in hospitals on patient monitors. The other method is the reflective method where the light emitters and the photodetector are next to each other at the measuring site. This method is more suitable to consumer devices because it allows a wider choice of placement for the monitor and is the method used in the example device we will look at.

There will be some constant light reflection back to the sensor due to tissue, bone, venous blood, and non-pulsed arterial blood. With each heartbeat, there is a surge in arterial blood volume as the heart contracts. This results in much more light reflection back to the sensor during each pulse. Therefore, the light received by the sensor will resemble a waveform with periodic peaks at each heartbeat and troughs in between the heartbeats. If the reflection value in the troughs are treated as the constant reflection and subtracted from the peak sensed values, the result is the reflection value due to arterial pulsed blood flow. Since the peaks occur with each heartbeat or pulse, the term "pulse oximetry" was coined.

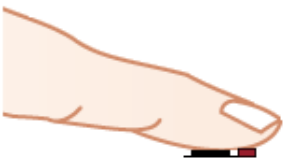
Pulse Oximetry Measurements Using the Silicon Laboratories' Si1147

The Silicon Laboratories' Si114x sensor with integrated LED drivers enables reflective based heart rate and blood oxygen measurements. In the graphic shown, the IR emitter is directed into the skin where some of it is absorbed, some scattered, and some reflected back to the optical sensor. The sensor detects the reflected light levels as blood is pumped through the body. This allows signal processing algorithms in an adjacent microcontroller to calculate heart rate by subtracting the constant reflection values from the peaks to determine arterial blood pulse peaks. Blood oxygen readings require both IR (940nm) and Red (660nm) LEDs to be used. The ratio of the IR to Red response is then used to calculate blood oxygen levels as mentioned previously by comparing the reflections of the two wavelengths by the hemoglobin in the blood.

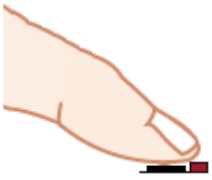


Proper finger position in relation to the sensor and LEDs as well as proper finger pressure is essential for accurate measurements.. As illustrated in in the figure below, the finger should be lightly placed on the sensor covering both the sensor and LEDs. Too much pressure will restrict blood flow in the finger and, therefore, not allow the sensor to measure a heart rate.

Correct finger position

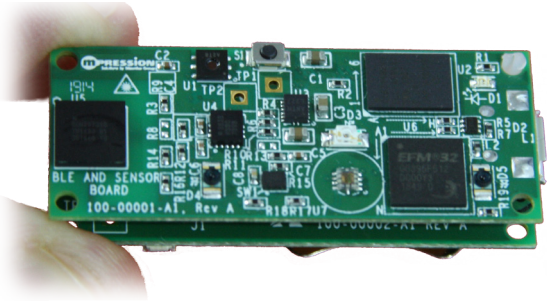


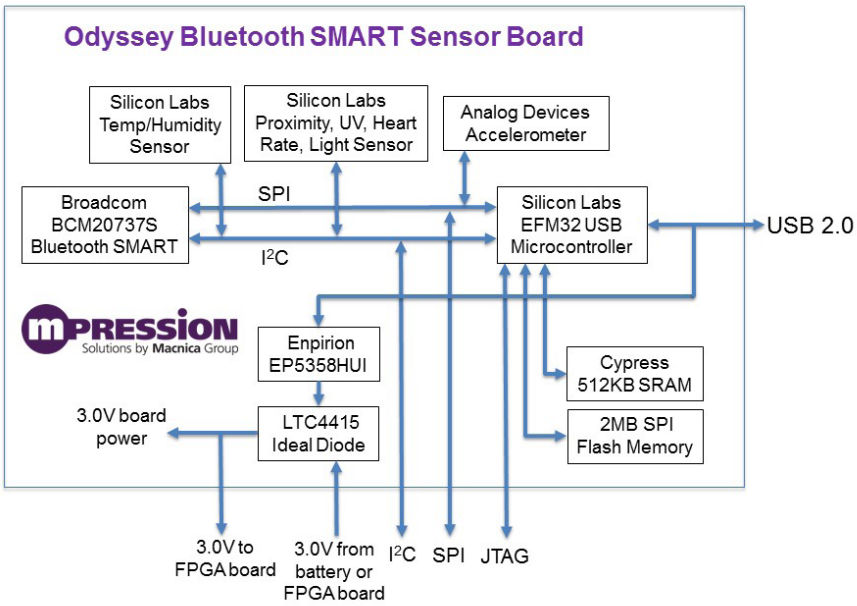
Incorrect finger position



Example Application Using the Mpression Odyssey BLE Sensor Board

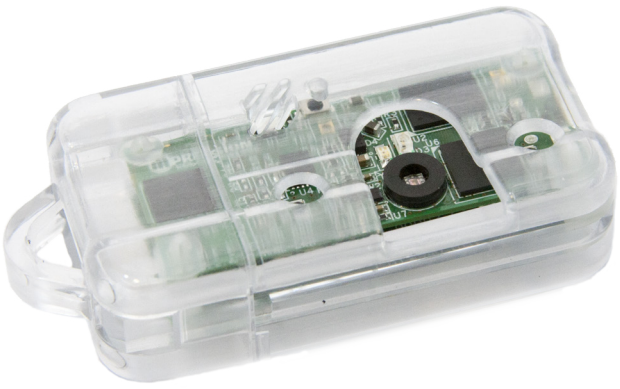
One example of heart rate and blood oxygen monitoring using the Silicon Laboratories' Si114x sensor is the Mpression Odyssey BLE Sensor Board which is part of the Mpression Odyssey MAX 10 FPGA and BLE Sensor Kit. This compact device is only 1.8" x .73" (46mm x 19mm), yet it contains sensors for ambient light, proximity, heart rate, blood oximetry, temperature, and humidity from Silicon Laboratories, and an accelerometer from Analog Devices, combined with a low-power USB-enabled EFM32TM Gecko microcontroller from Silicon Laboratories and a WICED Bluetooth® SMART connectivity module from Broadcom. This tiny but powerful package can be controlled with the free Mpression Odyssey smartphone app that uses Bluetooth SMART (BLE) technology to communicate with the board.

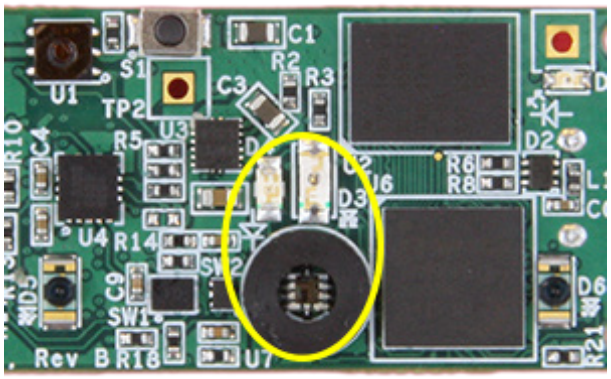




On the Odyssey BLE Sensor board, the Silicon Laboratories Si1147 Proximity/UV/Ambient Light Sensor is used which is capable of monitoring pulse rate (HRM) and oxygen saturation (SpO2). It also does proximity and gesture recognition using two IR LEDs, but for HRM and SpO2 measurements a combination of a red LED and an IR LED is used.

The Odyssey BLE Sensor board comes with a plastic case that can hold the sensor board connected to the optional coin cell battery board. This case has an opening in the top that guides the user to position their finger properly over the Si1147 sensor and the adjacent IR and red LEDs (shown by the yellow oval below). As mentioned previously, it is important to have the proper finger position covering both the emitter LEDs and the sensor with a light pressure to get accurate HRM and SpO2 measurements.





Silicon Laboratories provides an API library of functions that run on the EFM32 Gecko microcontroller. This library, referred to as the HRM-SpO2 API, performs the signal processing on the data from the Si1147, removing static level reflection values and noise and returning accurate pulse or blood oxygen levels. This allows the user to focus on using the data and deciding how the user interface will function to select and display data while relieving them of the need to worry about the underlying signal processing of the sensor data.

The Odyssey smartphone app communicates with the BLE Sensor Board through a Broadcom WICED Bluetooth SMART (BLE) module on the board. The app comes with a number of pre-loaded personalities that combine a reference design and smartphone interface. With these personalities, you can quickly access and control sensors on the Odyssey BLE Sensor board.

One such personality is for HRM functionality using the Si1147 sensor. The HRM-SpO2 API library is resident in the EFM32 microcontroller. The HRM personality requests to the BLE module are offloaded as calls to functions in the HRM-SpO2 API library to collect and process the sensor data and the EFM32 controller is given the use of the I2C bus to communicate with the Si1147 sensor. The EFM32 then returns the data to the BLE module for transfer to the smartphone app formatting and display. This personality allows a user to very quickly get up and running with the board and start doing HRM measurements. The user can also use the Odyssey web utility to customize the personality as they develop their design.

As a user develops their design further, they can develop a complete Bluetooth SMART connected application with their own user interface and processing that communicates directly with the API library in the EFM32 or interacts with the Si1147 sensor directly and replaces the functions in the Odyssey smartphone app.

Summary

The Silicon Laboratories Si114x sensor is a compact and versatile device with multiple LED drivers and the ability to do UV, ambient light, proximity, gesture, and pulse oximetry measurements. As used on the Mpression Odyssey BLE Sensor Board, the combination of the Si114x sensor and the EFM32 Gecko microcontroller work together to enable accurate HRM and SpO2 measurements without complicated programming by a user. The Odyssey Smartphone app allows a user to easily use these capabilities and create designs without writing any code, while still allowing more detailed development later when the designer is ready.

Further Information

Information on the Mpression Odyssey MAX 10 and BLE Sensor Kit is available at:
www.m-pression.com/odyssey-fpga

Information on the Silicon Labratories Si114x Optical Sensor is available at:
http://www.silabs.com/products/sensors/infraredsensors/pages/si114x.aspx