Benchmark Biometric Sensor System for Wearable Devices

Features

- Market-leading optical heart rate (HR), step rate / count, distance, cycling cadence, calories, at-rest R-R interval (RRi) measurements and running/lifestyle activity recognition.
- Benchmark® sensor and processor are provided separately for flexibility and to minimize space impact on the wearable design
- Sensor module contains LED, detector, and accelerometer mounted to a window assembly optimized for sensor system accuracy
- PerformTek low-power (Ambiq Micro® based) processor performs sensor data processing and provides a host system communication interface

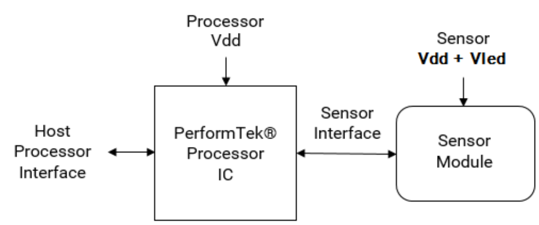
Figure 1: Benchmark Wearable 2.1 Processor and Sensor

- Sensor Dimensions: (15.2 x 13.6 x 2.4) mm
- Processor Package: CSP-49, 0.35 mm pitch, (2.56 x 2.59 x 0.45) mm
- Sensor Weight: 0.42 grams
- 400 kHz I2C or 57.6 kbps UART Interface
- Processor V_{DD}: 1.8 VDC to 3.3 VDC
- Sensor V_{DD}: 1.8 VDC to 3.3 VDC
- Sensor V_{LED}: 5 VDC
- Processor V_{DD} Current: 255uA standard operating;173µA Standby mode
- Sensor V_{DD} Current: 0.06 mA standard operating
- Sensor V_{LED} Current: 0.46 mA standard operating
- Field updatable processor firmware
- Patented optomechanical designs
- 100% factory-tested
- Additional design and test services available upon request

Description

The PerformTek powered Benchmark Wearable 2.1 Sensor Systems are lower power versions of the BW2.0 biometric sensor technology developed by Valencell, Inc. This sensor module is approximately 30% smaller than BW1.2. This sensor plus the PerformTek processor helps you quickly develop your own biometric wearable products. The modular design brings together the best available parts of a successful biometric sensor system in a smaller form factor and includes emitter/detector sensor electronics in an optimized optical package with a processor that is pre-programmed with Valencell's PerformTek advanced biometric algorithms.

Figure 2: Benchmark Wearable 2.1 Simplified Block Diagram



Applications

- Wearable Devices / Lifestyle / Activity Bands
- Smart Watches
- Wrist, Forearm, and Upper Arm Bands for Sports
- Helmets and Headbands

Reference Documentation

Table 1: Related Documents

Document	Title
000832	PerformTek Wearable Integration Guide
000982	Benchmark BW2.0 Sensor Drawing and 3D CAD models
001917	PerformTek Low Power MCU Integration Guide
001113	Valencell Heart Rate Variability Review

Change Record

Table 2: Change Record

Author	Revision	Date	Description of change(s)
SWC / MEP	01.00	07SEP2018	Initial Release
MEP	02.00	13MAY2019	Added reference to PerformTek Lower Power MCU Integration Guide and removed redundant information
MEP	02.01	21MAY2019	Resolved broken reference link Updated host interface signals in Figure 3
MEP	02.02	08AUG2019	Relaxed VLED ripple specification

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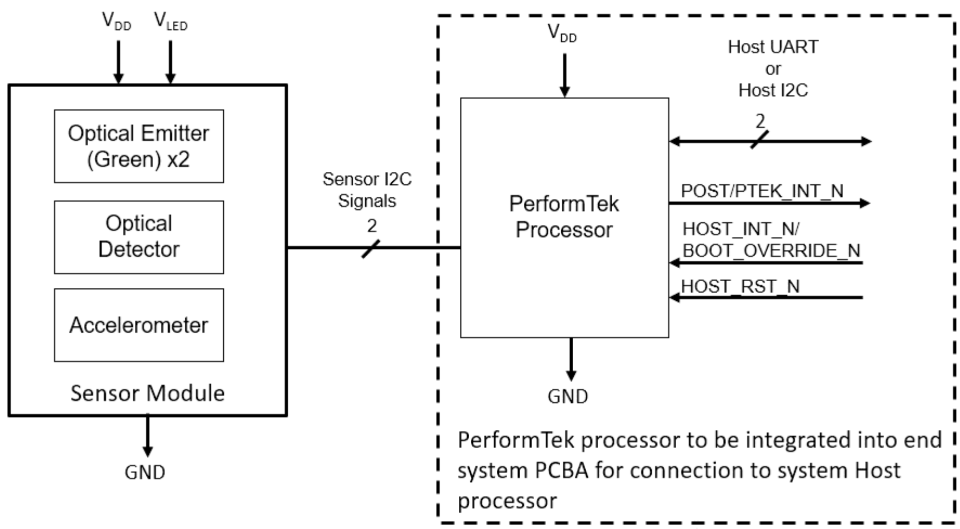
1 Block Diagram / System Overview

Figure 3: Benchmark Wearable 2.1 Functional Block Diagram



The Benchmark Wearable 2.1 Biometric Sensor solution is provided in two pieces, the sensor and the PerformTek processor. Figure 3 shows how these pieces work together and is described below.

On the left of the diagram, the sensor module contains a digital optical detector system, two LEDs, and an accelerometer. The detector, LEDs, and accelerometer work together to collect biometric information via reflected light and movement from the wearer. This information is transmitted over the I2C bus when requested by the PerformTek processor.

The PerformTek processor collects the sensor data and runs Valencell's patent protected algorithms to convert the raw measurements into biometric values such as heart rate or cadence and processes those values further into higher level user assessments like calories burned. In addition, sensor module diagnostics such as signal quality, error codes, and serial number ID are available. This information is available to the Host processor via the Host Interface.

The Host Interface is shown on the right side of the diagram. Control lines for interfacing the host processor with the PerformTek processor include an I2C or UART, power-on self-test / sensor interrupt output (POST / PTEK_INT_N), and sensor interrupt / bootloader mode select input (HOST_INT_N / BOOT_OVERRIDE_N). For I2C serial communications with the Host Processor, the PerformTek processor acts as the I2C slave role and the Host Processor acts as the I2C Master.

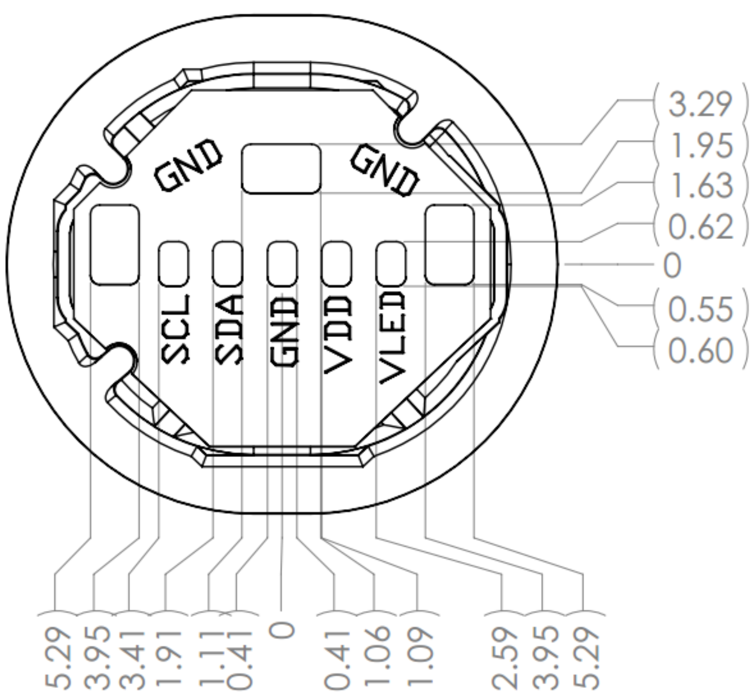
2 Pin Descriptions

Table 3 shows the pinout for the sensor. Figure 4 shows the sensor solder pads that are provided for individual wire or custom flex cable connection. See the BW2.0 or BW2.0L Sensor Drawing for more details.

Table 3: Sensor Pinout

Pin Number	Symbol	Description
1	V_{LED}	5.0 VDC Power. Connect to V_{LED} supply voltage
2	$V_{DD(SENSE)}$	1.8 to 3.3 VDC Sensor Power. Connect to sensor supply voltage
3	GND	Connect to system ground / reference plane
4	SDA	I2C Data Line. Connect to PerformTek Processor
5	SCL	I2C Clock Line. Connect to PerformTek Processor

Figure 4: Sensor Drawing with Solder Pads



3 Electrical Characteristics

Table 4: Recommended Operating Conditions for Sensor

Parameter	Symbol	Conditions	Min	Typ	Max	Units
V_{LED} Supply Voltage	V_{LED}	Min and Max are inclusive of V_{LED} ripple requirement	4.875	5.0	5.50	VDC
V_{LED} Ripple	V_{ripple_10}	Sensor system active	----	----	250	mV_{pp}
Sensor Supply Voltage	$V_{DD(SENSE)}$	Min and Max are inclusive of V_{DD} ripple requirement	1.76	3.3	3.6	VDC
Sensor Supply Ripple Voltage_10	V_{ripple_10}	Sensor system active: 0 to 10 MHz Ripple	-	-	50	mV_{pp}
Sensor Supply ripple voltage_100	V_{ripple_100}	Sensor system active: >10 MHz to 100 MHz Ripple	-	-	100	mV_{pp}
Operating Temperature	-	Device operating in Standby, Idle, or Active Modes	-10	25	50	ºC

Table 5: Operating Characteristics of Sensor

Parameter	Symbol	Conditions	Min	Typ	Max	Units
I_{DD} + I_{LED} Sensor OFF Mode	-	No V_{DD} supply given to sensor module	-	0	-	µA
I_{DD} + I_{LED} Sensor Standby and Idle Modes	-	System is in Standby mode	-	5	32	µA
I_{DD} Sensor Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate	-	0.061	-	mA

Parameter	Symbol	Conditions	Min	Typ	Max	Units
I_{DD} Sensor Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate	-	0.248	-	mA
I_{DD} Sensor Active Mode with Best-Precision RRi	-	System is in Active mode and operating at fastest RRi sampling rate	-	0.482	-	mA
I_{LED} Sensor Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate	-	0.461	0.580	mA
I_{LED} Sensor Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate	-	2.30	2.88	mA
I_{LED} Sensor Active Mode Best-Precision RRi	-	System is in Active mode and operating at fastest RRi sampling rate	-	4.61	5.77	mA
I_{LED} Sensor Pulse Current	I_{pulse}	System is in Active mode	-	39	49	mA

Absolute limits are provided below. If these limits are exceeded, permanent device damage may occur. Additionally, if the sensor is exposed to these limits for an extended period of time, the sensor reliability may be impacted.

Table 6: Sensor Absolute Maximum Limits

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Operating Temperature	-	Device operating in Standby, Idle, or Active Modes – performance not guaranteed	-20	-	70	ºC
Storage Temperature	-	Device powered off, device will require time to equalize with normal operating temperature	-50	-	85	ºC

		after exposure to limits of storage temperature				
ESD Rating	-	Human Body Model[1]	-	-	2	kV

Note 1: The sensor module is designed to support system level ESD compliance testing up to 15 kV; however, ESD protection for the standalone sensor module is intended only to protect the sensor during normal handling in a typical electronic manufacturing environment with typical ESD protection in place.

4 Power Supply Design Guidelines

4.1 MCU Design Guidelines

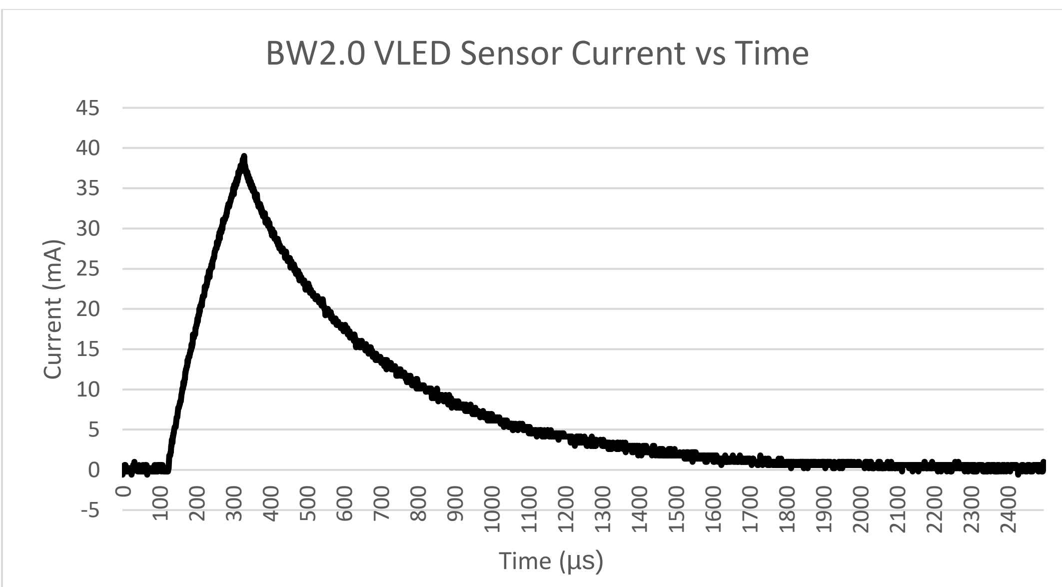
See the PerformTek Low Power MCU Integration Guide

4.2 Power Supply Loading

The PerformTek processor and sensor may be supplied from the same rail (V_{DD} and $V_{DD(SENSE)}$ combined) or may be supplied separately. If they are supplied together, care must be taken to ensure that the voltage tolerances and ripple specifications for the sensor are still followed. The system power supply or supplies should be designed to meet the requirements in Section 3 during transients from both the Benchmark sensor and processor.

Peak V_{LED} current will be periodic where the period of the peaks will depend on the mode of operation Heart Rate and Standard-Precision RRi (40 ms) and High-Precision RRi (8 ms). A typical current peak profile for sensor V_{LED} is shown in Figure 5.

Figure 5: Typical Benchmark Sensor Current Pulse



The V_{LED} current profile shown here and the V_{LED} and V_{DD} current peaks listed in Section 3 are based on measured system performance. Processor V_{DD} current peaks are of smaller amplitude and much smaller duration than V_{LED} current peaks and $V_{DD(SENSE)}$ current peaks are negligible. Actual peak and average V_{DD} processor current peak and average numbers will vary depending on the unique characteristics of the system design and how the PerformTek features are used within the system. Because of this, Valencell recommends testing our sensors in a manner representative of their intended use as early as possible in the design cycle. To facilitate this, Valencell supplies development kits that support early prototyping and power measurement and can provide design support and review services upon request.

4.3 Power Supply Sequencing

The system V_{LED} supply should come up at the same time or before the V_{DD} supply to ensure correct sensor operation. This requirement is met if V_{LED} = 1.4 V (0.77 x V_{DD}) at the same time or before V_{DD} = 1.8 V on initial power up.

5 Sensor Optical-Mechanical Integration

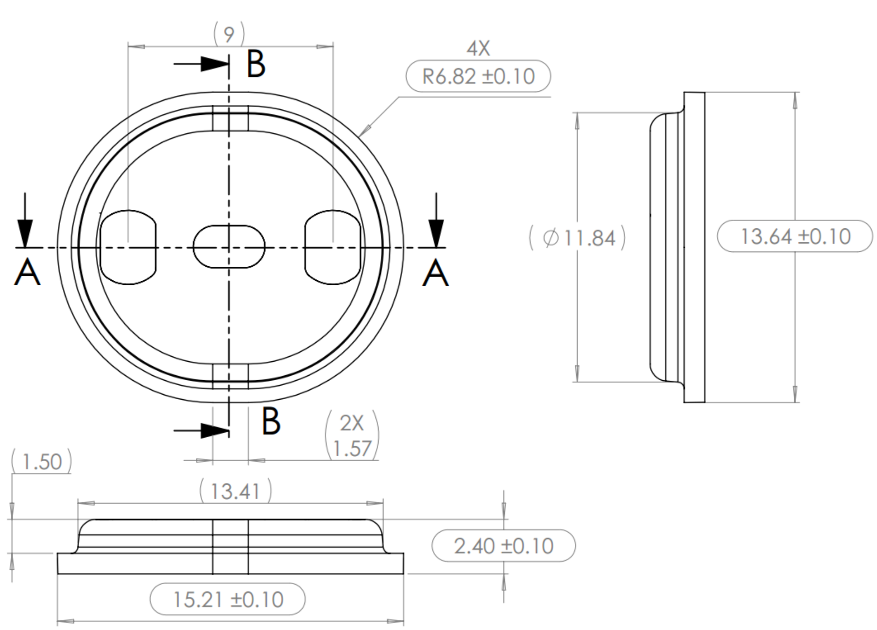
The optical lens system is a critical component of the sensor module, ensuring good optical coupling from the emitters and sensors to the user's skin. This is necessary for accurate measurement. The lens frame is an overmolded PC/ABS opaque frame onto an optical grade film lens. The PCB and opto-mechanical lens is tested as an assembly and should not be disassembled.

The mechanical design has been optimized to reduce the impact of the sensor module on industrial design, especially in total sensor height when built into the device housing. It is designed for easy integration into the bottom shell of a wristband, wristwatch, or armband with part of the module protruding into the interior of the wearable product and part protruding from the bottom of the wearable product. This design balance provides optimal sensor accuracy with minimal disruption to other components of the interior of the product design.

The BW2.1 sensor may be integrated with a glue joint or with an ultrasonic weld. To achieve the thinnest possible profile, the BW 2.1 sensor does not provide an energy director to support ultrasonic welding. For ultrasonic weld assembly, an energy director may be added to the mating assembly.

For additional capture feature design and adhesive process guidelines and more complete details on sensor integration refer to the Benchmark Wearable Sensor Integration Guide and BW2.0 Sensor 3D CAD models and drawings.

Figure 6: Wearable Sensor Drawing (For Reference Only)



6 Sensor Ordering Guide and Comparison Chart

Part Number	Description
001738	Benchmark Wearable 2.1

001738 Benchmark Wearable 2.1 consists of two components.

BW2.1-Set

1. BW2.1-Sensor
2. BW2.1-AMAPH1KK-KCR

7 Valencell Product Development Design and Test Services

Valencell has years of experience helping customers bring accurate biometric hearable and wearable devices to market. Much of our experience has been captured in application notes and in the integration and user guides, but additional design and test support is available upon request to help reduce your time to market and lower your technical development risks. Our support can span all stages of the product development process, from concept development through mass production and marketing. Design support examples include assisting with placement and mechanical integration of the sensor module within the product being worn; product fit and comfort; power-supply design; and audio design considerations for hearable designs.

Additionally, product performance should be backed by a solid test plan. Valencell has a sophisticated exercise and sport physiology test lab where products using our sensors are tested for proper performance. Our biometric sensors have been tested on thousands of test subjects with the statistical analysis done in a way that conforms to medical and sports journal publication standards. Testing is carried out both indoors and outdoors under many different activities with pools of subjects that have different skin tones, weight, hair, and fitness levels. Results from our sensor tests can be seen in the form of technical white papers on the Valencell website here: www.valencell.com/white-papers. Valencell Labs is located in the U.S. where there is a good diversity of test subjects. Our lab can validate the accuracy and performance of your product design and provide a statistical analysis as part of a design feedback report along with suggestions to improve the product design. This type of testing is the best and only way to know how well your product will perform when introduced into the market.

For more information about our support options, please contact Valencell.

8 Contact Information

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