Benchmark Biometric Sensor System for Hearable Devices

Features

- Chest-Strap quality optical heart rate (HR), step rate / count, distance cycling cadence, calories, and at-rest R-R interval (RRi) measurement
- Separate Benchmark® sensor and PerformTek® processor minimize space impact to the system design and provide design flexibility
- Sensor module contains an LED, optical detector with data conversion circuitry, and an accelerometer mounted to a lens assembly optimized for sensor system accuracy
- PerformTek low-power ARM® Cortex® processor performs sensor data processing and provides a communication interface to the system Host processor

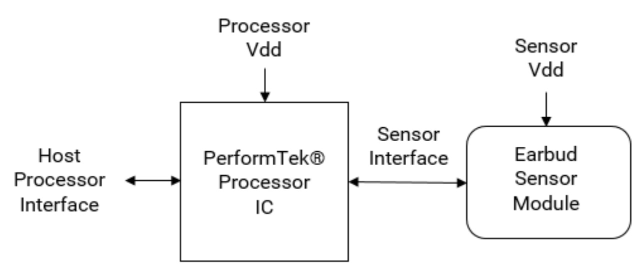
Figure 1: BE4.0 Processor and Sensor with Dime for Scale

- Ear Sensor Dimensions: (10.0 x 4.4 x5.0) mm
- Processor: CSP-49, 0.35 mm pitch,
- (2.56 x 2.59 x 0.45) mm
- Sensor Weight 0.175 grams
- 400 kHz I2C or 57.6 kbps UART interface
- Processor V_{DD}: 1.8 VDC to 3.3 VDC
- Sensor V_{DD}: 3.3 VDC
- Processor V_{DD} Current: 255 μA standard operating; 142 uA Standby, and Idle modes
- Sensor V_{DD} Current: 0.2 mA standard operating
- Field updatable processor firmware
- Patented optomechanical designs
- 100% factory-tested
- Additional design & test services available upon request

Description

The PerformTek powered Benchmark Ear 4.0 (BE4.0) Sensor System is an update to the BE2.0 biometric sensor technology developed by Valencell, Inc. to integrate a lower power processor. 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: BE4.0 Simplified Block Diagram



Applications

- In-canal or in-concha wired or wireless headphones
- Hearing aids
- Mono Bluetooth headsets
- Wireless smart audio assistants

Reference Documentation

Table 1: Related Documents

Document	Title
002140	Benchmark Earbud Integration Guide BE1.2/2.0/4.0
000881	Benchmark BE2.0 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

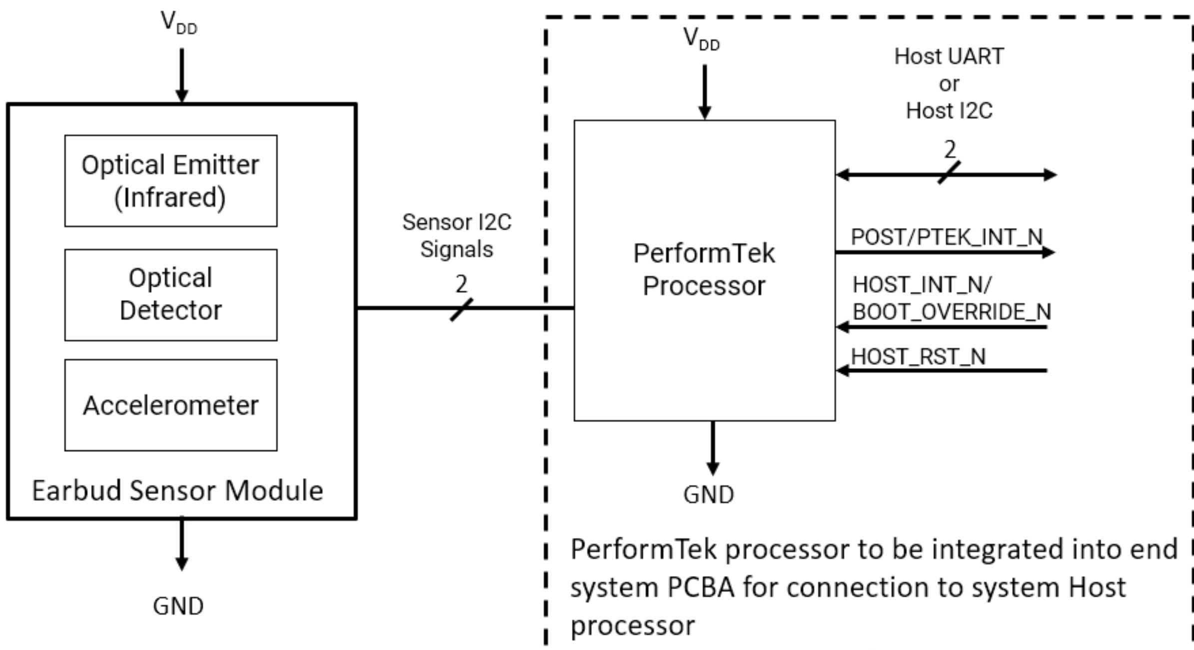
Author	Revision	Date	Description of change(s)
MEP	01.00	05AUG2018	Initial Release
MEP	01.01	30NOV2018	Removed TBDs and Updated Ordering Information
MEP	02.00	13MAY2019	Added reference to PerformTek Lower Power MCU Integration Guide and removed redundant information
MEP	02.01	21MAY2019	Resolved broken reference link
MEP	02.02	07AUG2019	Changed “$V_{DD(SENSE)}$” to “VDD” to aid clarity Clarified language in Section 4.2 Power Supply Loading and changed section name to Power Supply Guidelines
SMS	02.03	04OCT2019	Updated reference documentation to reflect new P/N for Benchmark Earbud Integration Guide 002140.

Table of Contents

1 Block Diagram / System Overview

The Benchmark Ear 4.0 Biometric Sensor solution is provided in two pieces, the sensor (described in this datasheet) and the Low Power PerformTek processor (described in the PerformTek Lower Power MCU Integration Guide). Figure 3 shows how these pieces work together and is described below.

Figure 3: Benchmark Ear 4.0 Functional Block Diagram



On the left of the diagram, the sensor module circuit board contains a digital optical detector system, an infrared LED, and an accelerometer. The detector, LED, and accelerometer work together to collect biometric information via reflected light and movement from the wearer. This information is transmitted over the sensor's 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.

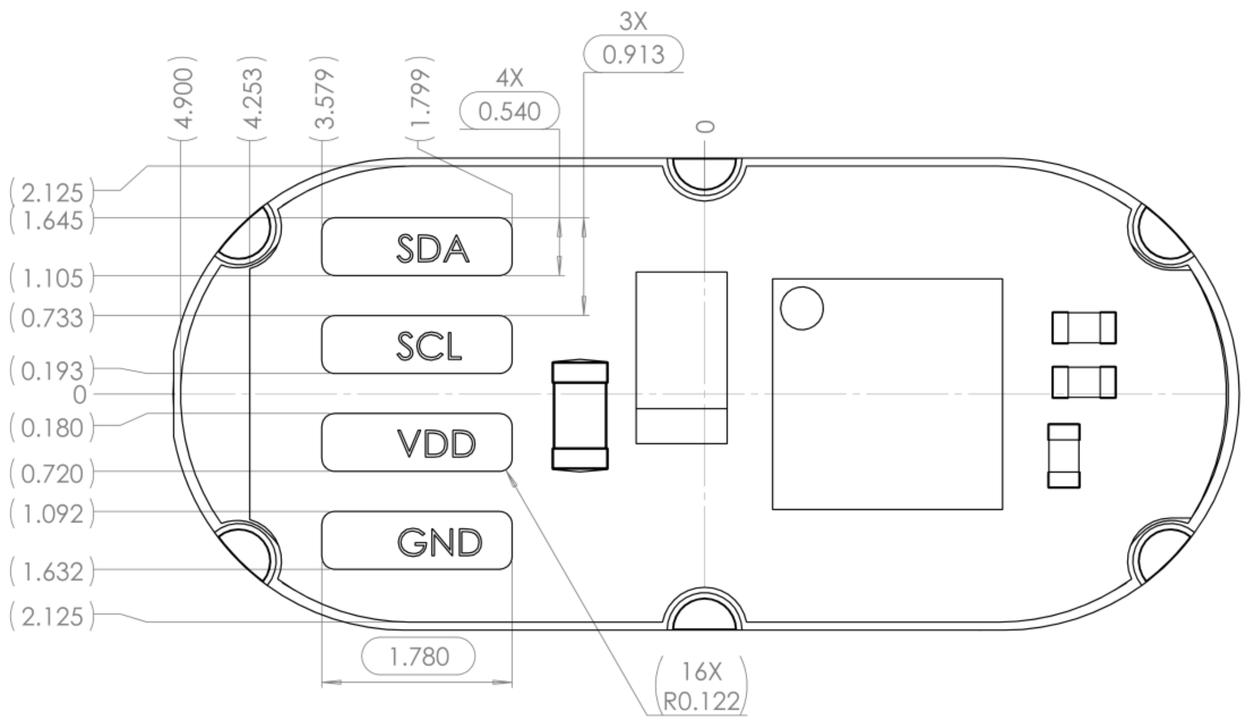
2 Pin Descriptions

Table 3 and Figure 4 show the pinout for the Earbud sensor. Solder pads are provided for individual wire or custom flex cable connection.

Table 3: Sensor Pinout

Pin Number	Symbol	Description
1	GND	Connect to system ground / reference plane
2	VDD	Sensor 3.3 VDC Power. Connect to sensor supply voltage
3	SENSOR_I2C_SCL	I2C Clock Line. Connect to PerformTek Processor
4	SENSOR_I2C_SDA	I2C Data Line. Connect to PerformTek Processor

Figure 4: BE2.0 / BE4.0 Sensor Drawing and Solder Pads



3 Electrical Characteristics

Operating requirements and characteristics of the sensor are provided below.

Table 4: Recommended Operating Conditions for Sensor

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Sensor Supply Voltage	VDD	Min and Max are inclusive of V_{DD} ripple requirement	3.2	3.3	3.6	VDC
Sensor ripple voltage_10	V_{ripple_10}	Sensor system active: 0 to 10 MHz Ripple	-	-	50	mV_{pp}
Sensor 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
Sensor Current OFF Mode	-	No V_{DD} supply given to sensor module	-	0	-	µA
Sensor Current Standby and Idle Modes	-	System is in Standby mode	-	5	32	µA
Sensor Current Active Mode, Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate	-	0.204	0.240	mA
Sensor Current Active Mode, High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate	-	0.965	1.15	mA

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Sensor Current Active Mode, Best-Precision RRi	-	System is in Active mode and operating at fastest RRi sampling rate	-	1.91	2.04	mA
Sensor Pulse Current	I_{pulse}	System is in Active mode	-	23	29	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 come to equalize with normal operating temperature after exposure to limits of storage temperature	-50	-	85	ºC
ESD Rating	-	Human Body Model[1]	-	-	2	kV

Note 1: The sensor module is designed to support system level ESD compliance testing up to 4 kV contact and 8 kV air discharges; 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 Additional Electrical Design Guidelines

4.1 MCU Design Guidelines

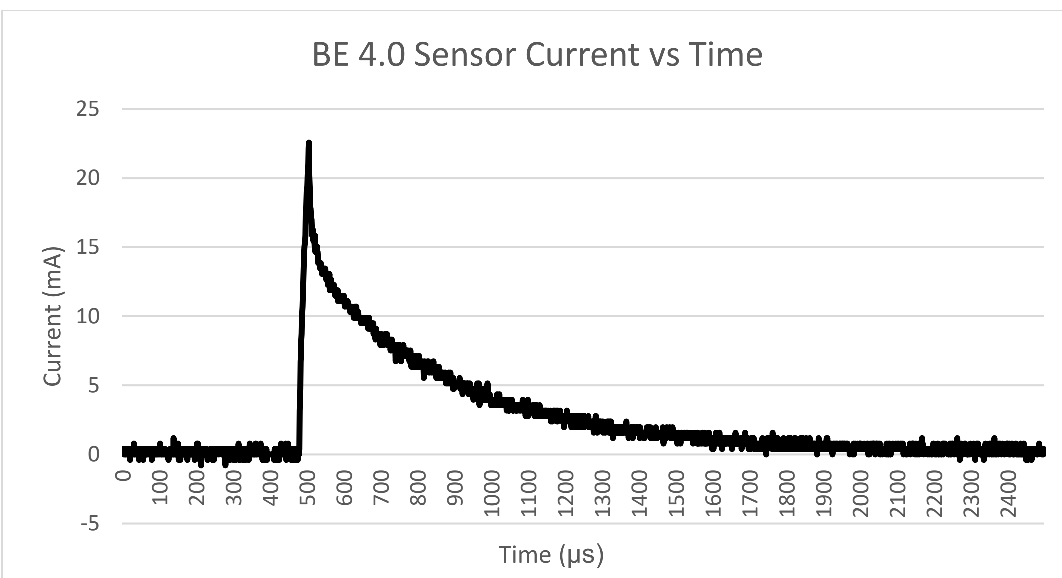
See the PerformTek Low Power MCU Integration Guide

4.2 Power Supply Guidelines

The PerformTek processor and sensor may be supplied from the same rail or may be supplied separately. If they are supplied separately voltage levels must be the same or level translators must be added to ensure that device logic levels are still met. If the MCU and sensor supplies are combined, care must still be taken to ensure that the voltage tolerances and ripple specifications for the sensor and MCU are still followed. The system power supply or supplies should be designed to meet the requirements in Section 3 of this datasheet and the requirement in the PerformTek Low Power MCU Integration Guide during transients from both the Benchmark sensor and processor.

Peak VDD sensor 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), High-Precision RRi (8 ms), and Best-Precision RRi (4 ms). A typical current peak profile for sensor VDD is shown in Figure 5. Note: Under certain circumstance and use cases, a reduced peak current profile and / or reduced voltage requirement may be achievable. Contact Valencell for more details if this may be appropriate for your application.

Figure 5: Typical BE4.0 Sensor Current Pulse



The sensor VDD current profile shown here and the current peak listed in Section 3 are based on measured system performance. Processor VDD current peaks are of smaller amplitude and much smaller duration than sensor current peaks. Actual peak and average 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 Audio Quality Design Guidelines

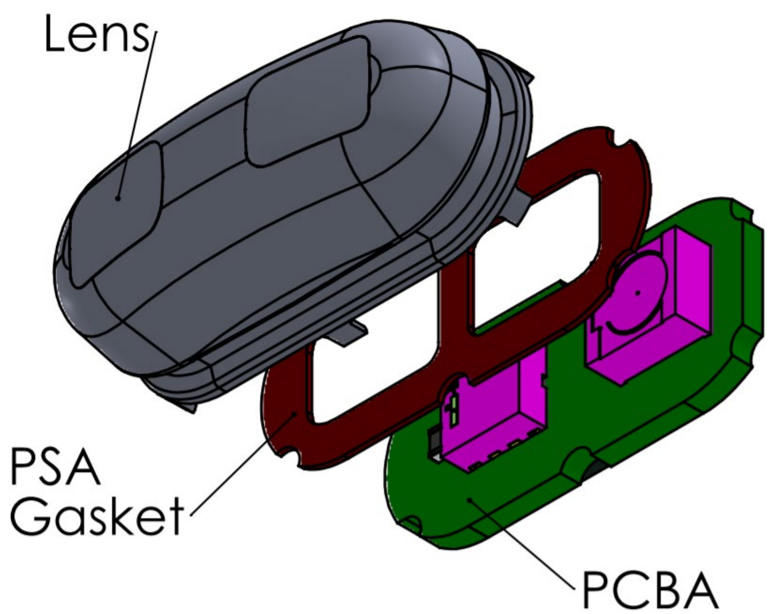
While the Benchmark sensor does not generate any perceptible audible noise on its own, it is possible for system power supply noise or crosstalk from the sensor I2C lines to interfere with audio quality if appropriate system design considerations are not followed. To mitigate potential noise issues, design considerations should include:

- Good power and ground plane design and decoupling to minimize conducted system noise into sensor and / or audio cabling
- Appropriate audio circuit and system grounding to ensure any coupled noise is either returned to the system reference as appropriate or blocked by appropriate isolation
- Isolation of audio circuitry signals from sensor I2C, power, and ground lines to minimize crosstalk (This may be accomplished by a combination of PCB routing and or cable design as appropriate)

5 Sensor Optical-Mechanical Integration

The sensor component is a critical part of the measurement system and is designed to ensure good optical coupling from the emitter and detector to the user's skin. Placement and proper integration of the sensor into the hearable system housing is critical for accurate measurement. The lens frame is a two-shot molded PC opaque frame onto an optical grade PC lens. The PCB and opto-mechanical lens is tested at module production as an assembly and should not be disassembled.

Figure 6: Earbud Sensor Image



The optical lens system is shown in Figure 6. There is a mating rib along the outer edge of the lens frame. This rib is used as a capture feature to ensure a good seal using adhesive to the customer's system enclosure.

The mechanical design has been optimized to reduce the impact of the sensor module on the industrial design, while still maintaining the necessary positioning for sensor accuracy. It is designed for easy integration into the shell of a hearable assembly and the design balance provides optimal sensor accuracy with minimal disruption to other components of the interior of the enclosure design.

For capture feature design and adhesive process guidelines and more complete details on sensor integration refer to the Benchmark Ear Sensor Integration Guide and BE2.0 Sensor 2D and 3D CAD models. Note, the BE2.0 sensor is identical to the BE4.0, so the BE2.0 mechanical design files apply to both BE2.0 and BE4.0.

6 Benchmark Sensor Ordering Guide

Part Number	Description
001706	Benchmark Ear 4.0

001706 Benchmark Ear 4.0 consists of two components where BE4.0 and BE2.0 share the same sensor.

BE4.0-Set

1. BE2.0-Sensor
2. BE4.0-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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