

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.
- Separate Benchmark[®] sensor and PerformTek[®] processor minimize space impact to the system design and provide design flexibility
- Sensor module contains an updated Analog Front End (AFE), photodetector, and accelerometer mounted to a window 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: Benchmark Wearable 4.0 Processor and Sensor



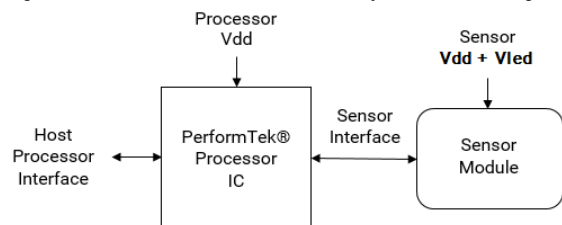
- Sensor window mechanically equivalent to BW2.0
- Sensor Dimensions: (15.2 x 13.6 x 3.60) mm
- Processor: CSP-49, 0.35 mm pitch, (2.56 x 2.59 x 0.45) mm
- 400 kHz I2C Slave or 57.6 kbps UART Interface
- RoHS / REACH / Halogen Free
- Sensor V_{DD}: 1.8 to 1.9 VDC or 2.1 to 3.3 VDC
- Sensor V_{LED}: 3.2* to 5.25 VDC
- Sensor V_{DD} Current: 40 µA @ 1.85 VDC
- Sensor V_{LED} Current: 110 µA @ 3.7 VDC
- Total average operating power with MCU: <1 mW**
- Field updatable processor firmware

- Patented optomechanical designs
- 100% factory-tested
- Additional design & test services available upon request

Description

The PerformTek powered Benchmark Wearable 4.0 Sensor System integrates new optical and motion detection technology with a new, ultra-low power processor. This new sensor provides a path to future enhancements while maintaining the same mechanical footprint as our BW2.0 sensor. 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 small, optically optimized package with a processor that is pre-programmed with Valencell's PerformTek advanced biometric algorithms.

Figure 2: Benchmark Wearable 4.0 Simplified Block Diagram



Applications

- Wearable Devices / Lifestyle / Activity Bands
- Smart Watches
- Wrist, Forearm, and Upper Arm Bands
- Helmets and Headbands
- Bio-monitoring Patches

*Note 1: VLED operation below 3.5 VDC requires connection to unregulated battery supply

**Note 2: assumes VDD = 1.85VDC, VLED = 3.7VDC, standard sampling rate

Reference Documentation

Table 1: Related Documents

Document	Title
000832	PerformTek Wearable Integration Guide
001917	PerformTek Low Power MCU Integration Guide
002335	PerformTek Low Power Motion Detect Addendum
001113	Valencell Heart Rate Variability Review

Change Record

Table 2: Change Record

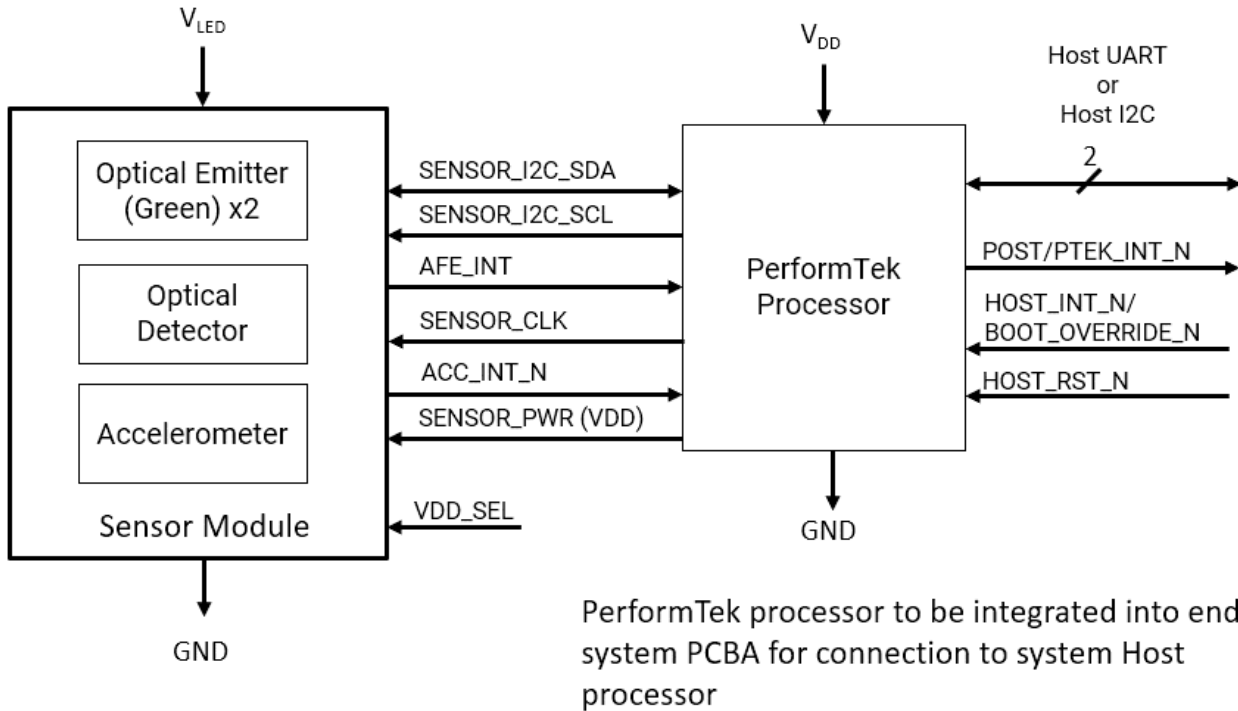
Author	Revision	Date	Description of change(s)
MEP	01.00	13JUN2018	Initial Release of Preliminary Datasheet
MEP	01.01	07AUG2018	Removed "Preliminary" markings. Updated sensor drawing and called out sensor connector part number. Updated BW4.0 Block Diagram and generally cleaned up typos. Updated sensor power numbers based on latest measurements
MEP	01.02	07SEP2018	Corrected z-height dimension for sensor on page 1 Updated t_{POST} to show both typical and maximum times Updated Ordering Guide
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	03.00	08AUG2019	Updated Figure 3 and Table 3 to provide additional details on connections to sensor Relaxed V_{LED} ripple specification Further constrained storage temperature: low storage temperature increased to $-40^{\circ}C$ (from $-50^{\circ}C$)
MEP	04.00	12OCT2020	Updates based on Official firmware release, version 1742 Added RoHS, REACH, Halogen Free Statement on cover Updated section 3: <ul style="list-style-type: none"> - Added information for Sleep mode - Changed current characterization from 1.80VDC to 1.85VDC - Updated current consumption - Relaxed VLED Requirements - Reduced average and peak VLED current

Table of Contents

1	Block Diagram / System Overview	4
2	Pin Description	6
3	Electrical Characteristics	8
4	Power Supply Design Guidelines	12
4.1	MCU Design Guidelines	12
4.2	Power Supply Sequencing	12
5	Sensor Optical-Mechanical Integration	13
6	Sensor Ordering Guide and Comparison Chart	14
7	Valencell Product Development Design and Test Services	15
8	Contact Information	16
9	Statements	17

1 Block Diagram / System Overview

Figure 3: Benchmark Wearable 4.0 Functional Block Diagram



The Benchmark Wearable 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.

On the left of the diagram, the sensor module circuit board 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 internal I2C bus when requested by the PerformTek processor.

The PerformTek processor collects the sensor data and runs Valencell’s patent protected motion cancellation 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 and error codes 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 output / sensor interrupt output (POST / PTEK_INT_N), and sensor interrupt input / 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 Description

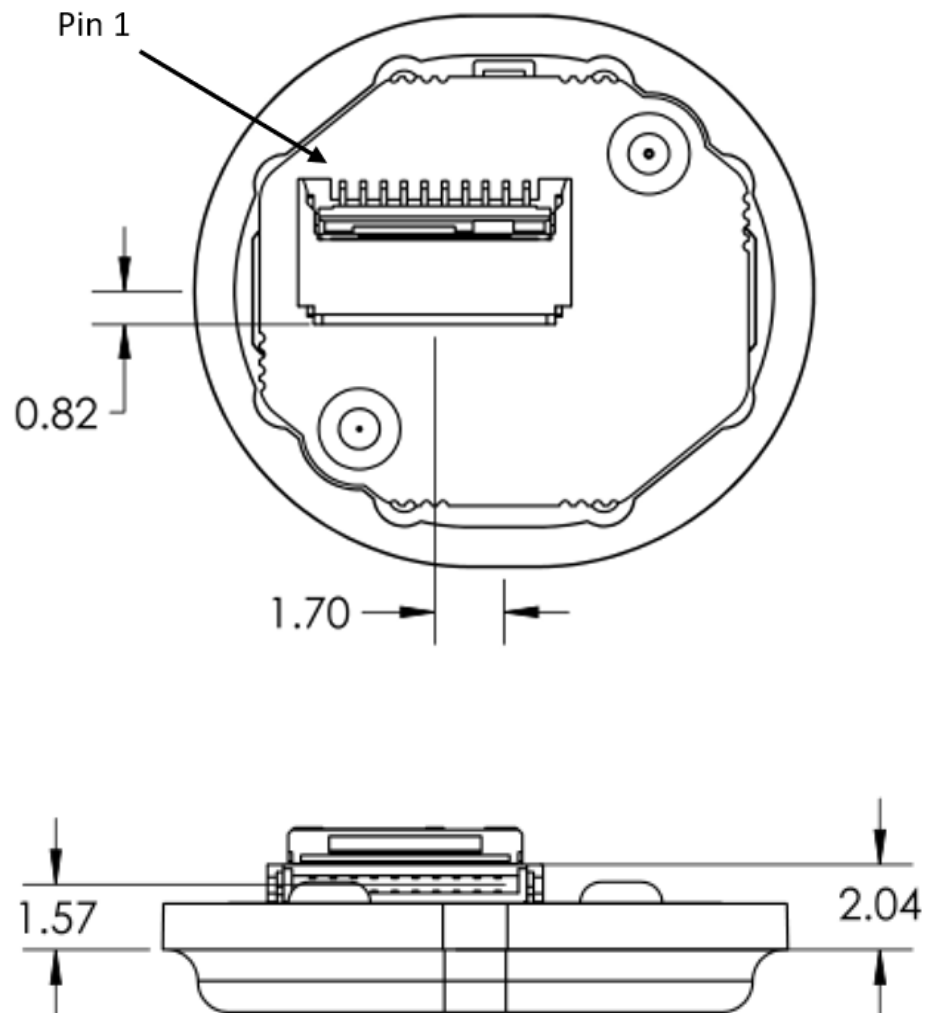
Table 3 shows the pinout for the sensor. A Molex 5034801000 ten pin, zero insertion force (ZIF), flexible flat cable (FFC) connector is provided on the sensor for easy connection to a Host system. Molex provides off-the-shelf FFCs that may be used with this connector or a custom FFC may be designed per the guidelines provided in the connector datasheet / drawing.

Table 3: Sensor Pinout

Pin Number	Direction with Respect to Sensor	Name	Description
1	N/A	GND	Connect to system ground / reference
2	Input / Output	SENSOR_I2C_SDA	I2C Data Line. Connect to PerformTek Processor
3	Input	SENSOR_I2C_SCL	I2C Clock Line. Connect to PerformTek Processor
4	Output	AFE_INT	Sensor Interrupt Output. Connect to PerformTek Processor
5	Input	SENSOR_CLK	Sensor Clock Input. Connect to PerformTek Processor
6	Input	VDD_SEL	VDD_SEL = GND: LDO On, RX_SUP ≥ 2V VDD_SEL = VDD: LDO Off, RX_SUP = 1.8 to 1.9V
7	Output	ACC_INT_N	Active low accelerometer interrupt
8	Input	V _{LED}	LED Power Input. Connect to V _{LED} supply voltage
9	Input	N/C	No Connect - Reserved for Future Use
10	Input	V _{DD(SENSE)}	VDD Sensor Power Input. Connect to SENSOR_PWR from Low Power PerformTek MCU. No extra capacitance should be added to this pin.

The mating height for the FFC and the location of the center of the sensor connector relative to the center of the sensor is shown in Figure 4.

Figure 4: Connector Location and Orientation



3 Electrical Characteristics

Operating requirements and characteristics of the sensor are provided below. The operating characteristics defined in Table 5 apply to operation for both $V_{DD(SENSE_LOW)}$ and $V_{DD(SENSE_HIGH)}$.

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_{ripple} requirement	3.5 (3.2 ³)	3.7	5.25	VDC
V_{LED} Ripple	V_{ripple}	Sensor system active	---	---	250	mV _{pp}
Sensor Supply Voltage (Low-Range) ^{1 2}	$V_{DD(SENSE_LOW)}$	Requires V_{DD_SEL} to be pulled high to disable the sensor's on-board LDO. In this mode of operation, the sensor is more sensitive to VDD power supply noise.	1.8	1.85	1.9	VDC
Sensor Supply Voltage (High-Range) ^{1 2}	$V_{DD(SENSE_HIGH)}$	Requires V_{DD_SEL} to be pulled low to enable the sensor's on-board LDO, otherwise damage may occur. In this mode of operation. Sensor power consumption is lower when V_{DD} is low.	2.0	2.1	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	-20	25	70	°C
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Note 1: $V_{DD} > 1.9$ and $V_{DD} < 2.0V$ not defined

Note 2: Supplied by SENSOR_PWR from the Low Power PerformTek MCU, which is a switched pass-through of VDDP supplied to the PerformTek MCU

Note 3: VLED minimum can be lowered to 3.2 V if a direct battery connection is supplied for VLED. If a regulated supply is used, the 3.5 VDC specification holds to allow for additional noise margin.

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_SENSOR} Sleep ¹ and Idle Modes	-	System is in Sleep or Idle mode $V_{DD(SENSE)} = 1.85$ VDC	-	5	-	μA
I_{DD_SENSOR} Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate $V_{DD(SENSE)} = 1.85$ VDC	-	40	-	μA
I_{DD_SENSOR} Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate $V_{DD(SENSE)} = 1.85$ VDC	-	110	-	μA
I_{DD_SENSOR} Sleep ¹ and Idle Modes	-	System is in Sleep or Idle mode $V_{DD(SENSE)} = 3.3$ VDC	-	15	-	μA
I_{DD_SENSOR} Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate $V_{DD(SENSE)} = 3.3$ VDC	-	50	-	μA

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 V _{DD(SENSE)} = 3.3 VDC	-	130	-	μA
I _{LED_SENSOR} Sleep ¹ and Idle Modes	-	System is in Sleep or Idle mode V _{LED} = 3.7 VDC	-	10	-	μA
I _{LED_SENSOR} Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate V _{LED} = 3.7 VDC	-	110	-	μA
I _{LED_SENSOR} Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate V _{LED} = 3.7 VDC	-	510	-	μA
I _{LED_SENSOR} Pulse Current	I _{pulse}	System is in Active mode V _{LED} = 3.7 VDC	-	5	-	mA

Note 1: See PerformTek Low Power Motion Detect Addendum for more details on this feature.

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
Storage Temperature	-	Device powered off, device will require time to equalize with normal operating temperature after exposure to limits of storage temperature	-40	-	85	°C
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 Sequencing

The system V_{LED} supply should come up at the same time as the V_{DD} supply to the Low Power PerformTek MCU (within ± 10 ms) to ensure correct sensor operation. Additionally, if either power rail is removed, the other rail should be removed at the same time to prevent excessive leakage currents from occurring.

5 Sensor Optical-Mechanical Integration

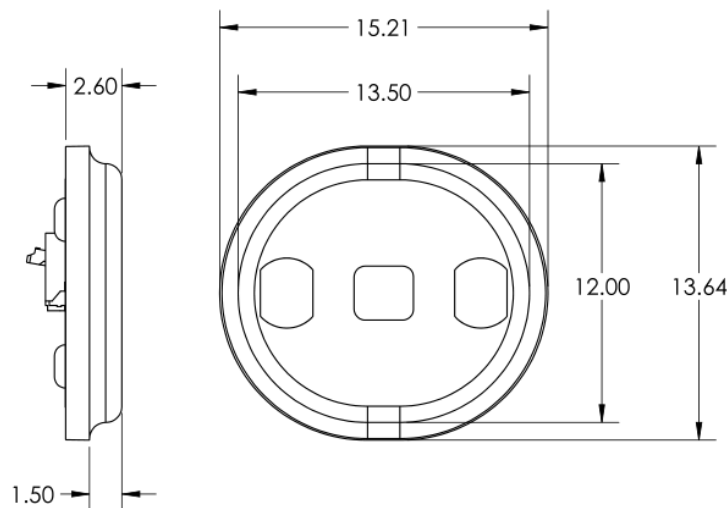
The optical lens system is a critical component of the sensor module, ensuring good optical coupling from the emitters and sensors to the user’s skin. This is necessary for accurate measurement. The main housing is a multi-shot component, consisting of an opaque housing and three optically transparent windows. The PCB and opto-mechanical housing are tested as an assembly and should not be disassembled.

The mechanical design has been optimized to reduce the impact of the sensor module on the overall industrial design of the device, especially in total sensor height when built into the device housing. It is designed for ease of integration into the bottom shell of a wristband, wristwatch, or armband with a portion of the module protruding into the interior of the wearable product and a portion 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 BW4.0 sensor may be integrated with a glue joint or with an ultrasonic weld. For ultrasonic weld assembly, an energy director should be added to the mating assembly. The BW4.0 sensor does not provide one as it would add extra depth in an application that uses glue.

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 BW4.0 Sensor 3D CAD models and drawings.

Figure 5: BW4.0 Wearable Sensor Drawing (Dimensions in millimeters)



6 Sensor Ordering Guide and Comparison Chart

Part Number	Description
001701	Benchmark Wearable 4.0

001701 Benchmark Wearable 4.0 consists of two components.

BW4.0-Set

1. BW4.0-Sensor
2. BW4.0-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

For additional information please contact:

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