# Benchmark Biometric Sensor System for Wearable Devices

## Features

- Market-leading quality optical heart rate (HR) measurement, step rate / count, distance, cycling cadence, calories, R-R interval (RRi) and activity recognition (running/lifestyle)
- Single Benchmark® module simplifies system integration
- Sensor module contains a processor, LEDs, a detector, and an 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 1.5 Sensor**

- Wearable Sensor Dimensions: (19.5 x 14.5 x 3.56) mm
- Sensor Weight: 0.85 grams
- Pressure Rating: 5 ATM
- 400 kHz I2C Interface
- RoHS / REACH / Halogen Free
- Sensor $V_{DD}$: 1.8 to 1.9 VDC or 2.1 to 3.3 VDC
- Sensor $V_{LED}$: 3.1[*] to 5.25 VDC
- $V_{LED}$ Current: 90 µA
- $V_{DD}$ Current: 275 µA @1.85 VDC

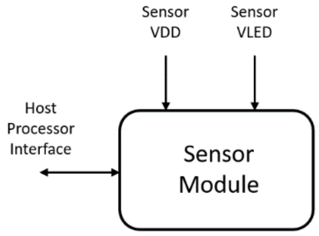
[*] *Note 1: VLED operation below 3.4 VDC requires connection to unregulated battery supply*

- Field updatable processor firmware
- Patented optomechanical designs
- 100% factory-tested
- Additional design and test services available upon request

## Description

The PerformTek-powered BW1.5 sensor system is an evolution of the BW1.4 sensor technology developed by Valencell, Inc. BW1.5 has been updated to simplify system design by supporting LED operation with a power input directly from a lithium polymer battery. This sensor is intended to be a drop-in replacement for BW1.4 I2C-based sensors. The modular design brings together the best available parts of a successful biometric sensor system in a single, optically optimized package pre-programmed with Valencell's PerformTek advanced biometric algorithms.

**Figure 2: Benchmark Wearable 1.5 Simplified Block Diagram**



## Wearable Device Applications

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

# Reference Documentation

Table 1: Related Documents

| Document | Title |
|---|---|
| 002205 | BW1.5 Integration Dimensions and CAD |
| 002204 | BW1.5L Integration Dimensions and CAD |
| 000638 | PerformTek Interface Protocol Document |
| 000964 | PerformTek User Guide |
| 000832 | PerformTek Wearable Integration Guide |
| 001569 | PerformTek Migration Guide Gen 1 to Gen 2 |
| 002335 | PerformTek Low Power Motion Detect Addendum |
| DS-A2-1p2 (External) | Ambiq Micro Apollo2 MCU Datasheet (Revision 1.2 at time of this document release) |
| Doc. ID: DS-A3-0p15p0 (External) | Ambiq Micro Apollo3 Blue MCU Datasheet (Revision 0.15.0 at time of this document release) |

# Change Record

Table 2: Change Record

| Author | Revision | ECO | Date | Description of change(s) |
|---|---|---|---|---|
| MEP | 01.00 | ECO 156 | 11FEB2020 | Initial release of preliminary datasheet |
| MEP | 01.01 | ECO 171 | 31MAR2020 | Corrected minor typos. Updated power numbers based on configuration updates. Added documentation for Lens-less and low power options. |
| MEP | 02.00 | ECO 190 | 13OCT2020 | Updates based on first Official firmware release, version 1742.<br>Removed preliminary markings.<br>Updated section 5.2:<br>- Added information for sleep mode<br>- Corrected ILED pulse current typical value<br>- Updated current consumption<br>- Changed current characterization from 1.80VDC to 1.85VDC<br>- Added current characterization for 2.1VDC operation<br>Removed redundant sensor communication example from section 10.<br>Corrected typo related to XMODEM 1K protocol. |
| MEP | 03.00 | ECO 231 | 16AUG2021 | Updates based on introduction of Apollo 2 BGA and Apollo 3 CSP variants.<br>Updated currents based on Official firmware release version 2154.<br>Removed references to LDO power supply option. |

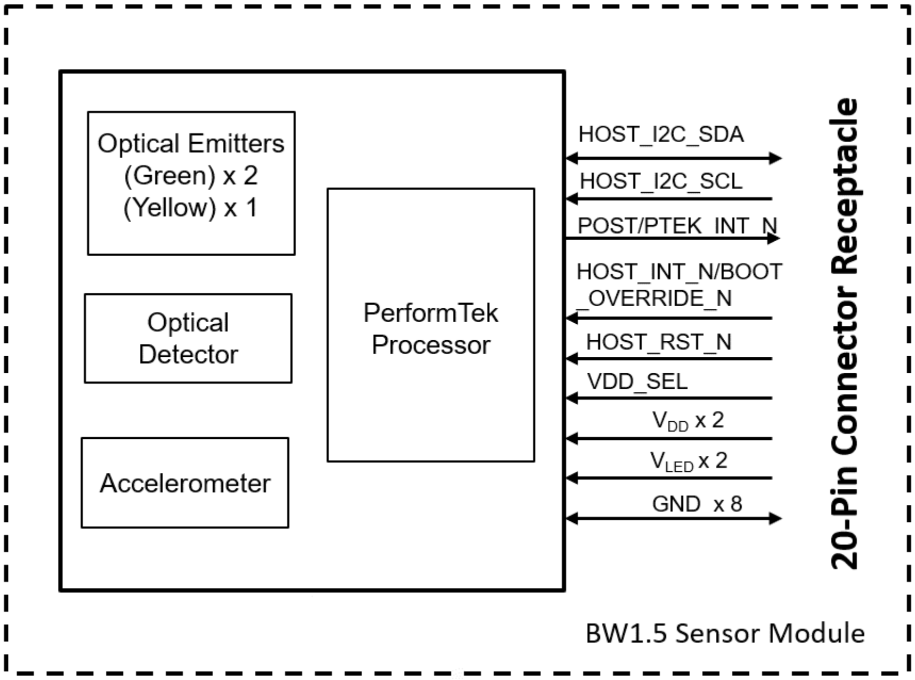
| | | | | |
|---|---|---|---|---|
| SDN | 03.01 | ECO 254 | 31MAR2022 | Fixed Figure 6 on page 21<br>Added MCU light sensitivity notes (copied from PerformTek MCU Integration Guide) to Section 10, minor change to Section 10 title |

# Table of Contents

# 1 Block Diagram / System Overview

Figure 3 shows a high-level block diagram of the Benchmark Wearable 1.5 Biometric Sensor plus associated interface signals.

Figure 3: Benchmark Wearable 1.5 Functional Block Diagram



The sensor module circuit board contains a digital optical detector system, three LEDs, and an accelerometer. The detector, LEDs, and accelerometer work together to collect biometric information via reflected light and movement from the wearer. The integrated low power, PerformTek processor controls the sensing devices over the internal I2C bus.

The integrated 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 I2C and other discrete control lines.

# 2 BW1.5 Variants

Valencell supports different options for the BW1.5 sensor and may use different MCU types. See below for a description of these options variations and see section 11 for ordering information.

## 2.1 Lens-less

The BW1.5 can be ordered with or without a window (lens). Ordering without a window allows for direct integration of the sensor PCBA into a custom housing. See section 9 for more details on both standard and Lens-less sensor integration.

## 2.2 Differences between MCU Types

The BW1.5 sensor's PerformTek processor may be implemented in an Ambiq Apollo 2 CSP (A2 CSP), Apollo 2 BGA (A2 BGA), or Apollo 3 CSP (A3 CSP). The A2 CSP and A2 BGA use the same silicon but different packages. The A3 CSP performs similarly to the A2 MCUs but has slightly different reset requirements and slightly different pull-up resistance values. When appropriate, differences related to these implementation variations are identified in this document.

# 3 BW1.5 comparison to BW1.4 and BW1.2

## 3.1 BW1.5 differences from BW1.4

Key differences between BW1.5 and BW1.4 are listed below. Consult the relevant device datasheet for more details.

1. Updates to LEDs and sensor configuration provide support for direct LED power from lithium polymer battery
2. VDD current consumption higher but largely offset by power savings from direct battery supply for LED since there is no efficiency loss from boost regulator to supply 5VDC
3. LED peak current increased due to removal of current limiting filter circuit
4. Removal of support for UART Host Interface. I2C interface only supported
5. Sensor operates from an internal RC oscillator

## 3.2 BW1.5 and BW1.4 differences from BW1.2

Key differences between BW1.5/1.4 and BW1.2 are listed below. Consult the relevant device datasheet for more details.

1. BW1.4/1.5 pinout changed location of UART interface and added additional control pins. For existing BW1.2 designs operating on I2C, no change to the interface may be required but customers should carefully review the BW1.4/1.5 pinout
2. I2C interface updated to PerformTek I2C Gen 2 as described in the PerformTek Interface protocol document and Gen 1 to Gen 2 Migration Guide
3. Added restriction on VDD supply, where the sensor cannot operate between 1.90 to 2.00 VDC. 1.80VDC to 1.90 VDC and 2.00 VDC to 3.30 VDC operation is supported
4. If supply is less than 1.90 VDC, then the VDD_SEL pin on the interface should be pulled high to VDD. VDD_SEL has a weak internal pull-down resistor so it is recommended that customers add their own pull-down resistor for operation greater than or equal to 2.00 VDC

# 4 Sensor Pin Descriptions

## 4.1 Sensor Pinout

Table 3 and Figure 4 show the pinout for the sensor. Figure 5 shows an image of the BW1.5 sensor connector orientation.

Table 3: Sensor Connector Pinout

| Pin | Name | I/O | Description |
|---|---|---|---|
| 1, 2, 9, 10, 11, 12, 19, 20 | Input / Output | GND | Connect to system ground / reference plane |
| 3, 4 | Input | $V_{DD}$ | VDD Sensor Power Input. Connect to sensor supply voltage. |
| 5, 6 | Input | $V_{LED}$ | LED Power Input. Connect to $V_{LED}$ supply voltage. |
| 7 | N/A | NC | No Connect |
| 8 | Output | POST/PTEK_INT_N | MCU Host (Slave) Interface:<br>Active High POST Indicator<br>Active Low PTEK Interrupt |
| 13 | Input / Output | HOST_I2C_SDA | PerformTek Host (Slave) I2C Interface |
| 14 | Input | HOST_INT_N/BOOT_OVERRIDE_N | MCU Host (Slave) Interface:<br>Active low HOST_INT and Active low BOOT_OVERRIDE |
| 15 | Input | HOST_I2C_SCL | PerformTek Host (Slave) I2C Interface |
| 16 | Input | HOST_RST_N | MCU Reset |
| 17 | N/A | NC | No Connect |
| 18 | Input | VDD_SEL | VDD_SEL = GND: LDO On, RX_SUP >=2V<br>VDD_SEL = VDD: LDO Off, RX_SUP = 1.8 to 1.9V |

## 4.2 Sensor Connector Description

The BW1.5 sensor interface uses a Hirose BM20B(0.6)-20DS-0.4V(51) connector as shown in Figure 4. Pin 1 of the connector is on the bottom, left side of the connector as viewed in

Figure 5 and is indicated by a white dot on the PCBA. A Hirose BM20B(0.6)-20DP-0.4V(51) or equivalent connector should be used on the system host side to interface to it.

Figure 4: Benchmark Wearable 1.5 Connector

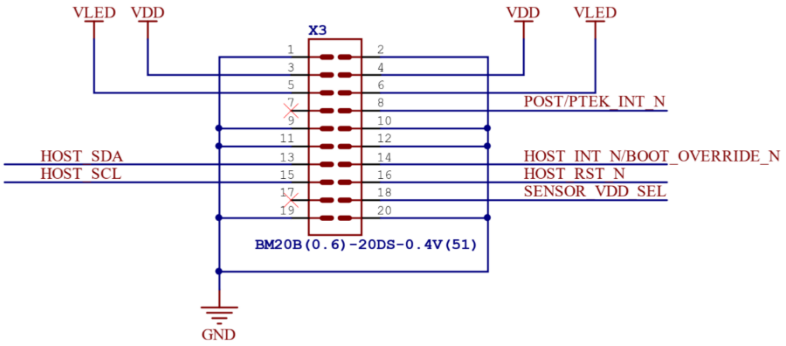
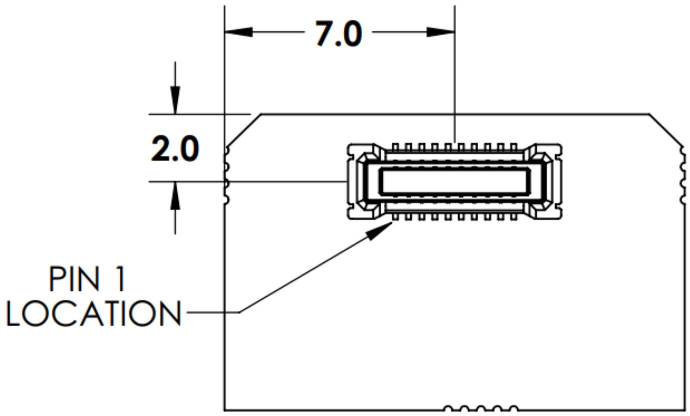


Figure 5: Benchmark Wearable 1.5 Sensor Image



# 5 Sensor Electrical Characteristics

## 5.1 Recommended Operating Conditions for Sensor

The I2C interface can operate up to 400kHz. The PerformTek processor internal I2C internal pullup resistor setting is RSEL = 0x00. For A2 CSP and A2 BGA based sensors, this results in a 1.4 kΩ pull resistor value; for A3 CSP based sensors, this pull up value will be 1.5 kΩ. Output drive setting is 2mA for all sensor variants. For additional details on I2C timing and logic level specifications see the Ambiq Apollo 2 or Apollo 3 Blue Datasheet.

The following table describes the remaining recommended operating condition for the sensor.

Table 4: Recommended Operating Conditions for Sensor

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $V_{LED}$ Supply Voltage[1] | $V_{LED}$ | Min and Max are inclusive of $V_{LED}$ ripple requirement | 3.4<br>(3.1[1]) | 3.7 | 5.25 | VDC |
| $V_{LED}$ Ripple | $V_{ripple}$ | Sensor system active | ---- | ---- | 250 | $mV_{pp}$ |
| Sensor Supply Voltage (Low-Range)[2] | $V_{DD(SENSE\_LOW)}$ | Requires VDD_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.<br>Note: $V_{DD} > 1.9$ and $V_{DD} < 2.0V$ not defined | 1.8 | 1.85 | 1.9 | VDC |
| Sensor Supply Voltage (High-Range)[2] | $V_{DD(SENSE\_HIGH)}$ | Requires VDD_SEL to be pulled low to enable the sensor's on-board LDO, otherwise damage may occur.<br>Sensor noise immunity is higher in this operating mode, but | 2.0 | 2.1 | 3.6 | VDC |

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| | | sensor power consumption increases as $V_{DD}$ increases. | | | | |
| Sensor Supply Ripple Voltage | $V_{ripple}$ | Sensor system active | - | - | 50 | $mV_{pp}$ |
| Operating Temperature | - | Device operating in Standby, Idle, or Active Modes | -20 | 25 | 70 | °C |

Note 1: VLED minimum can be lowered to 3.1 V if a direct battery connection is supplied for VLED. If a regulated supply is used, the 3.4 VDC specification holds to allow for additional noise margin.

Note 2: $V_{DD} > 1.9$ and $V_{DD} < 2.0V$ not defined

## 5.2 Operating Characteristics of Sensor

Operating characteristics are representative of sensor configured with Valencell firmware version 1742.

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 |
| $I_{DD}$ Sleep Mode[4] | - | $V_{DD}$ = 1.85VDC<br>System is in Sleep Mode | - | 70[3] | - | μA |
| $I_{DD}$ Standby Mode / Idle Mode | - | $V_{DD}$ = 1.85VDC<br>System is in Standby Mode / Idle Mode | - | 135[3] | - | μA |
| $I_{DD}$ Active Mode, HR + HA or Standard-Precision RRi[1] | - | $V_{DD}$ = 1.85VDC<br>System is in Active mode and operating at standard RRi sampling rate | - | 275[3] | - | μA |
| $I_{DD}$ Active Mode with High-Precision RRi[1] | - | $V_{DD}$ = 1.85VDC<br>System is in Active mode and operating at fast RRi sampling rate | - | 530[3] | - | μA |
| $I_{DD}$ Sleep Mode[4] | - | $V_{DD}$ = 2.1VDC<br>System is in Sleep Mode | - | 65[3] | - | μA |
| $I_{DD}$ Standby Mode / Idle Mode | - | $V_{DD}$ = 2.1VDC<br>System is in Standby Mode / Idle Mode | - | 130[3] | - | μA |
| $I_{DD}$ Active Mode, HR + HA or Standard-Precision RRi[1] | - | $V_{DD}$ = 2.1VDC<br>System is in Active mode and operating at standard RRi sampling rate | - | 255[3] | - | μA |

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD}$ Active Mode with High-Precision RRi[1] | - | $V_{DD}$ = 2.1VDC System is in Active mode and operating at fast RRi sampling rate | - | 530[3] | - | µA |
| $I_{DD}$ Sleep Mode[4] | - | $V_{DD}$ = 3.3VDC System is in Sleep Mode | - | 65 [3] | - | µA |
| $I_{DD}$ Standby Mode / Idle Mode | - | $V_{DD}$ = 3.3VDC System is in Standby Mode / Idle Mode | - | 110[3] | - | µA |
| $I_{DD}$ Active Mode, HR + HA or Standard-Precision RRi[1] | - | $V_{DD}$ = 3.3VDC System is in Active mode and operating at standard RRi sampling rate | - | 245[3] | - | µA |
| $I_{DD}$ Active Mode with High-Precision RRi[1] | - | $V_{DD}$ = 3.3VDC System is in Active mode and operating at fast RRi sampling rate | - | 65[3] | - | µA |
| $I_{LED}$ Sensor Standby, Idle, and Sleep Modes | - | System is in Sleep or Standby mode | - | <1 | - | µA |
| $I_{LED}$ Sensor Active Mode with Standard-Precision RRi[1] | - | System is in Active mode and operating at standard RRi sampling rate | - | 90 | - | µA |
| $I_{LED}$ Sensor Active Mode with High-Precision RRi[1] | - | System is in Active mode and operating at fast RRi sampling rate | - | 450 | - | µA |
| $I_{LED}$ LED Pulse Current[2] | - | System is in Active mode | - | 25 |  | mA |
| $I_{DD}$ Pulse Current | - | System is in Active mode | - | 10 | - | mA |

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Start-up time before POST response | $t_{POST}$ | On Start-up, time measured after $V_{DD}$ equal to or above 1.8V | - | 140 | 250 | ms |

Note 1: High-Precision operation and current draw applies to RRi only. Best-precision heart rate monitoring is available in standard Active Mode.

Note 2: LED pulse current duration 100us per pulse and is dependent on sample rate, 25 Hz for standard-precision and 125 Hz for high-precision. Actual pulse current demand on power supply may be considerably lower dependent on system capacitance and power delivery system impedance. If pulse current is a significant system constraint, contact Valencell for additional design options.

Note 3: A3 CSP sensor variants consume slightly less power while actively running algorithms. Non-Active Sleep and Standby mode current are effectively equivalent across all variants.

Note 4: See PerformTek Low Power Motion Detect Addendum for more details on this feature.

## 5.3 Absolute Maximum Limits for Sensor

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, 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 |
| Voltage on any Pin | $V_{INPUT}$ | Valid input signal voltage | $V_{SS}$ -0.3V | - | $V_{DD}$ + 0.3V | V |
| 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.

## 5.4 Sensor Power Supply Configuration

Valencell recommends operating with VDD = 2.1 VDC to minimize power consumption and maximize sensor noise immunity as described in Table 4.

In its standard configuration, the BW1.5 sensor operates with an internal LDO supply instead of the internal buck supply that the BW1.4 uses. This means that VDD current consumption is higher in BW1.5 than BW1.4 and that VDD power consumption will increase linearly with an increase in VDD voltage. This increased power consumption is largely offset by the system power savings realized by the sensor's support for an unregulated battery voltage level VLED input since there will be no power losses due to VLED regulator inefficiency in a typical boost supply. If absolute lowest power consumption is critical to your system design, the low power version of the BW1.5 sensor with an internal buck supply should be selected.

# 6 PerformTek Sensor Connections and Features

## Host Interface – I2C

The Host Interface connecting the system processor to the PerformTek processor supports I2C communications. For optimal power savings, it is recommended to exercise the ports so that the PerformTek processor can correctly configure the I2C port on startup. Additionally, no external pull-up resistors are required for correct operation of the PerformTek MCU I2C port, since it provides internal pull-ups. If pull-ups are required for other devices on the I2C bus while the PerformTek MCU is powered off or in reset, external pull-up resistors may be added. If external pull-ups are added, the interface will consume additional power through those resistors.

For I2C host communications, the I2C_SDA line is the data line and I2C_SCL line is the clock line. The sensor module acts as an I2C slave device accepting SCL clock frequencies of 10kHz to 400KHz bus speed and a 7-bit I2C address of 0x45. This interface has been updated from previous generations of the PerformTek I2C interface to support the Ambiq lower power interface. For more information about communication protocols or to see more details on updates associated with the I2C interface, see the PerformTek Interface Protocol Document.

## Host Interface – POST / PTEK_INT_N

Once VDD power is applied, the processor will attempt to initialize all components on the module. This startup time is defined by tPOST in section 5.2. If startup is successful, the POST / PTEK_INT_N pin will assert high, otherwise, the pin will stay low. If the POST pin is not utilized, the Max time for tPOST should be observed before interaction with the PerformTek processor begins.

Diagnostic information associated with this pin is stored in the sensor module's registers and can be read via the Host Interface. As part of the POST, the PerformTek processor tests communications with the sensor peripherals and exercises the axes of the accelerometer while checking for a response within bounds. If a failure is detected but the processor can still communicate, the POST will still assert high. To ensure correct system operation, the POST_RESULTS register should be examined at startup.
After successful bootup and assertion of the POST status, the POST / PTEK_INT_N provides software configurable interrupt output functionality from the PerformTek processor to the Host. Refer to the PerformTek Interface Protocol Document for further information on the POST, other diagnostic registers, and interrupt configuration.

## Host Interface – HOST_INT_N / BOOT_OVERRIDE_N

Upon application of $V_{DD}$ power or upon release of reset, the PerformTek processor will enter Bootloader mode if HOST_INT_N / BOOT_OVERRIDE_N is asserted low.

During normal operation, HOST_INT_N / BOOT_OVERRIDE_N provides software configurable interrupt input functionality from the Host to the PerformTek processor.

Host Interface – HOST_RST_N

HOST_RST_N is an active low reset signal connected to the HOST controller to allow it to control reset of the PerformTek processor. Valencell recommends connecting this line to the Host controller as part of a robust system reset strategy.

Note: Current consumption is undefined while the PerformTek processor is held in reset. HOST_RST_N should not be used as a method to hold the PerformTek processor in a low power state. Removing power from the MCU or placing the MCU in Standby mode is the best method for achieving minimum power consumption when the sensor is not in use.

Host Interface – VDD_SEL

For VDD >=2V, connect VDD_SEL to ground via a 1kOhm resistor
For VDD = 1.8V to 1.9V, connect VDD_SEL to VDD via a 1kOhm resistor

# 7 Sensor Power Supply Design Guidelines

## 7.1 Power Supply Loading

Actual peak and average current loading on the system power rails 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 ensure that the power supply requirements are met. To facilitate this, Valencell supplies development kits that support early prototyping and power measurement and Valencell can provide additional design support and review services upon request.

## 7.2 Power Supply Sequencing

The system $V_{LED}$ supply should come up at the same time as the $V_{DD}$ supply (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.

## 7.3 Power Supply Rise Time

There are no known issues with fast rise time during power up. However, there are power supply constraints related to power down. See Section 7.5 for more details.

## 7.4 VDD Transients

Voltage transients greater than 2 kV/s on VDD should be avoided during normal device operation. Small voltage dips <50 mV can be tolerated.

## 7.5 Power Down Requirements

When power is removed from the sensor, it must drop below 0.3V for at least 200ms before power is reapplied to ensure that the internal MCU analog circuitry properly reinitializes.

## 7.6 Reset Requirements

When asserting HOST_RST_N, a minimum reset pulse width of 4.5 ms is recommended. Note, if only A2-based sensors are used, the minimum reset pulse width is 15 µs.

# 8 Firmware Updates

Valencell recommends that all systems be designed to support firmware updates to take advantage of the latest feature updates as they become available. PerformTek MCUs include a bootloader designed to accept encrypted firmware update files (.val files), which are available for download on Valencell's ShareFile site.

## 8.1 Firmware Update Interface

Firmware updates are delivered to the PerformTek MCU via the I2C Host Interface using an XMODEM 1K protocol. See the PerformTek User Guide for more details.

## 8.2 Flash Memory Erase Time

The PerformTek User Guide indicates that the Host system must add a delay of one to five seconds after the first XMODEM 1K packet is sent to allow time for the PerformTek MCU to erase the existing firmware image. For the PerformTek Low Power MCU, the required delay time is up to 2.5 seconds to support the worst-case erase time of 2.5 seconds while the typical erase time for the Apollo 2 is 0.5 seconds.

## 8.3 Bootloader Protection

To perform firmware updates, it is necessary for the PerformTek MCU to erase its existing application image. However, the bootloader is protected and will not be erased or over-written. This prevents the PerformTek MCU from becoming “bricked” in case of an improper firmware update attempts. While the bootloader will always be present if an error occurs during firmware updates, a new .val load must be successfully transferred before normal PerformTek operation can be restored.

# 9 Sensor Optical-Mechanical Integration

The Benchmark sensor housing is a critical component of the sensor module, ensuring optical coupling from the emitters and sensors to the user's skin. This intentional opto-mechanical system design is necessary for accurate measurement.

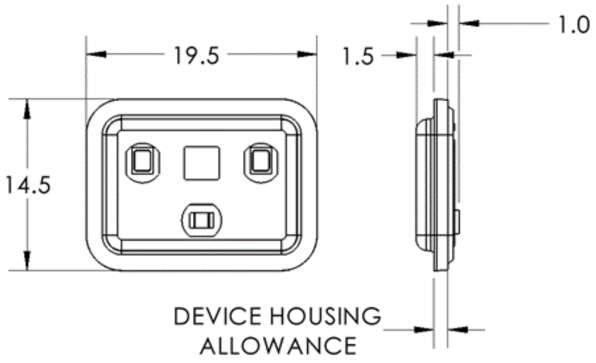
Information in this section is provided for both the integration of the BW1.5 sensor with an included window and for the BW1.5L where the sensor PCBA will be integrated into the system-provided window. In this case, the integrator is responsible for ensuring optimized implementation of Valencell's reference design guidelines.

## 9.1 BW1.5 Integration

The PCB and opto-mechanical housing are tested as an assembly and should not be disassembled. Typically, an ultrasonic weld will be used to place the sensor into the system device housing. Alternately, an adhesive bond can be used between the sensor housing and the system device housing. Please reference additional Valencell documentation for more information.

The mechanical design has been optimized to reduce the impact of the sensor module on industrial design. The sensor is designed for easy integration into the bottom shell of a device with portions of the module protruding into the interior and from the bottom of the wearable product as shown in Figure 6. This design balance provides optimal sensor accuracy with minimal disruption to other components of the interior of the product design.

Figure 6: BW1.5 Sensor Module Drawing



For additional design and implementation guidelines, please refer to the Benchmark Wearable Sensor Integration Guide and the BW1.5 Integration Dimensions Drawing and models.

## 9.2 BW1.5 Lensless Integration

For enhanced integration flexibility, all variants of BW1.5L can be purchased without a housing included in the assembly as shown in Figure 7, Figure 8 , and Figure 9. This allows the integrator the most flexibility in their design options, further reducing impact on system industrial design.

Figure 7: 002206 BW1.5LP A2 CSP Sensor Module Drawing

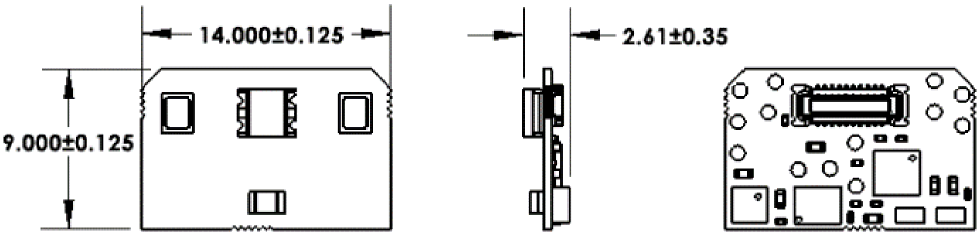


Figure 8: 002498 BW1.5LP A2 BGA Sensor Module Drawing

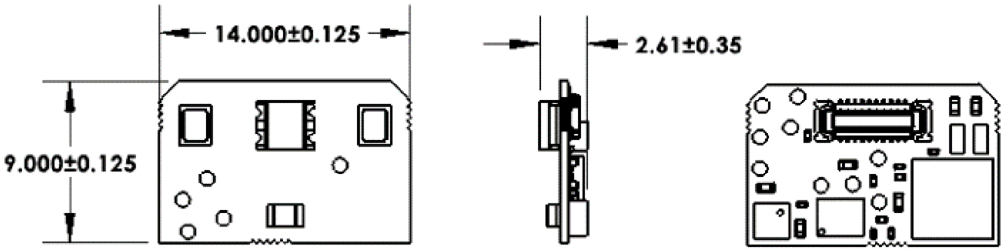
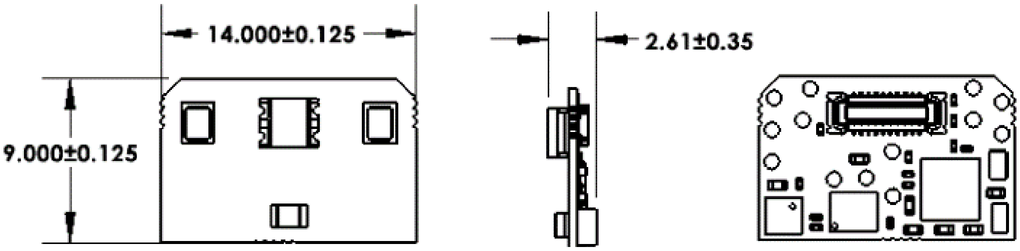
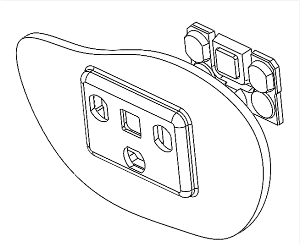


Figure 9: 002504 BW1.5LP A3 CSP Sensor Module Drawing



For BW1.5L, Valencell provides geometry and guidelines for the optomechanical features that should be included in the device housing design with an example presented in Figure 10. Window aperture geometry and PSA gasket interface features should replicate Valencell reference CAD. Gasket design files are also available. Ensure gate vestiges and flash are not present on interface or optomechanical surfaces to ensure good optomechanical isolation and correct integration between the PCBA, gasket, and enclosure optical features.

Figure 10 : BW1.5L Optomechanical Reference Design



For additional design and implementation guidelines, please refer to the Benchmark Wearable Sensor Integration Guide and the BW1.5L Integration Dimensions Drawing and models, including window reference design files.

# 10 BW1.5 Sensor MCU

The BW1.5 sensor MCU uses a slightly different I2C communication scheme compared to BW1.2. For details on the I2C differences, see the PerformTek Migration Guide Gen 1 to Gen 2. For information on how to interface to the sensor, see the PerformTek Interface Protocol Document.

The PerformTek MCU is based on the Ambiq Micro Apollo 2 49-pin chip scale package (CSP). Like many other CSP devices, the MCU package should be protected from light sources during operation. See the Ambiq Micro Apollo 2 MCU Datasheet for a package drawing, PCB footprint, reflow profile recommendations, and additional details related to light sensitivity.

# 11 Sensor Ordering Guide

| Part Number | Description |
|---|---|
| **002207** | Benchmark Wearable 1.5, Low Power, A2 CSP |
| **002523** | Benchmark Wearable 1.5, Low Power, A3 CSP |
| **002206** | Benchmark Wearable 1.5, Lens-less, Low Power, A2 CSP |
| **002498** | Benchmark Wearable 1.5, Lens-less, Low Power, A2 BGA |
| **002504** | Benchmark Wearable 1.5, Lens-less, Low Power, A3 CSP |

# 12 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.

# 13 Contact Information

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