Benchmark™ Biometric Sensor System for Wearable Devices

Features

- Market-leading optical heart rate (HR) measurement, HR zone, HR recovery, resting HR, step rate / count, distance cycling cadence, calories, at-rest R-R interval (RRi) and activity recognition (running/lifestyle)
- Benchmark sensor and processor provided separately for direct system integration to provide flexibility and minimize space impact to the wearable design
- Sensor module contains an updated Analog Front End (AFE), photodetector, and accelerometer mounted to a window assembly optimized for sensor system accuracy
- Ultra-low-power PerformTek™ (Ambiq Micro® Apollo2) processor performs sensor data processing and provides a communication interface to the host system

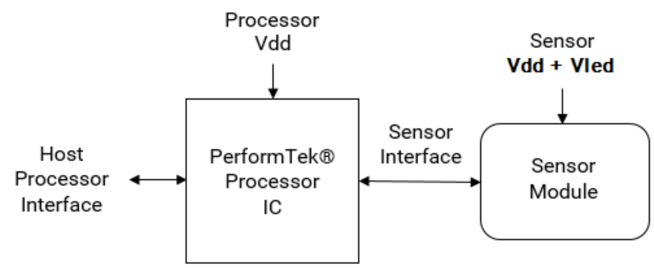
Figure 1: Benchmark Wearable 4.0 Processor and Sensor

- Wearable Sensor: (15.2 x 13.6 x 3.14)
- Sensor window mechanically equivalent to BW2.0
- 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
- Processor V_{DD}: 1.8 VDC to 3.3 VDC, less than 260 µA average operating current
- Sensor $V_{DD(SENSE)}$: 1.8 to 1.9 VDC or 2.1 to 3.3 VDC, 58 µA average operating current
- Sensor VLED: 5 VDC, 405 µA average operating current
- Total average operating power: 2.6 mW*
- Field updatable processor firmware
- Patented optomechanical designs
- 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: assumes VDD = 1.85VDC, VLED = 5VDC, standard sampling rate

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Reference Documentation

Table 1: Related Documents

Document	Title
000638	PerformTek Interface Protocol Document
000964	PerformTek User Guide
000832	PerformTek Wrist Integration Guide
001113	Valencell Heart Rate Variability Review
DS-A2-1p0 (External)	Ambiq Micro Apollo2 MCU Datasheet (Revision 1.0 at time of 001621 Release)

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

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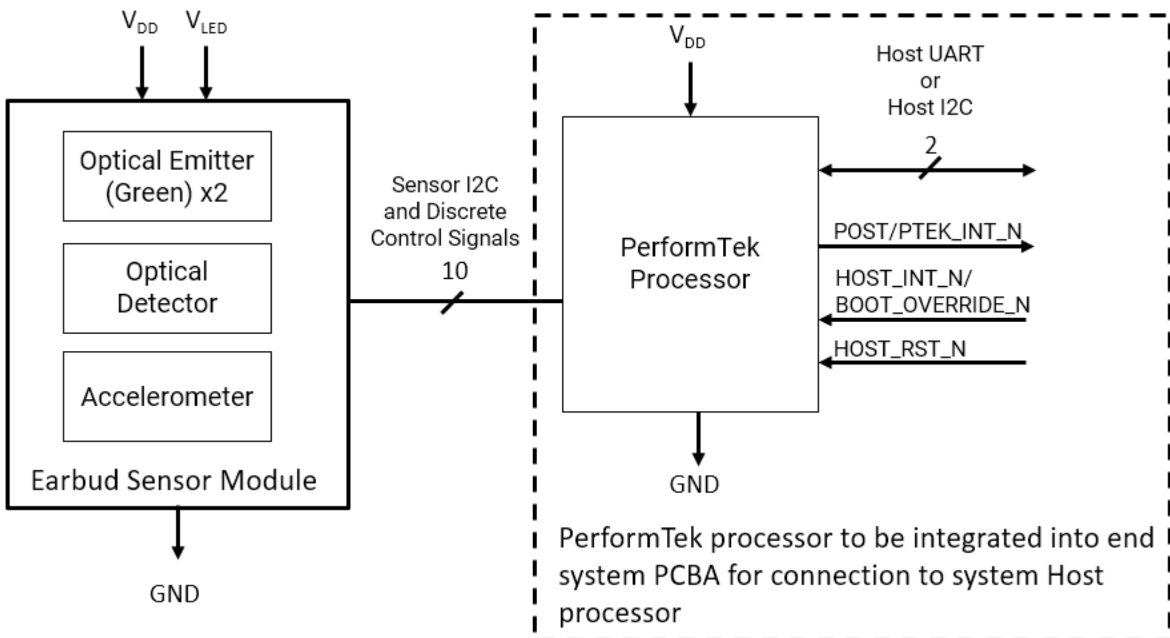
1 Block Diagram / System Overview

Figure 3: Benchmark Wearable 4.0 Functional Block Diagram (I2C Interface Shown)



The Benchmark Wearable 4.0 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 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 / sensor interrupt

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output (POST / PTEK_INT_N), and sensor interrupt / bootloader mode select input (HOST_INT_N / BOOT_OVERRIDE_N). More details on this interface are provided in Section 0. 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.

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2 Pin Descriptions

2.1 Sensor Pinout

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 = 0: LDO On, RX_SUP ≥ 2V VDD_SEL = 1: 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 supply voltage

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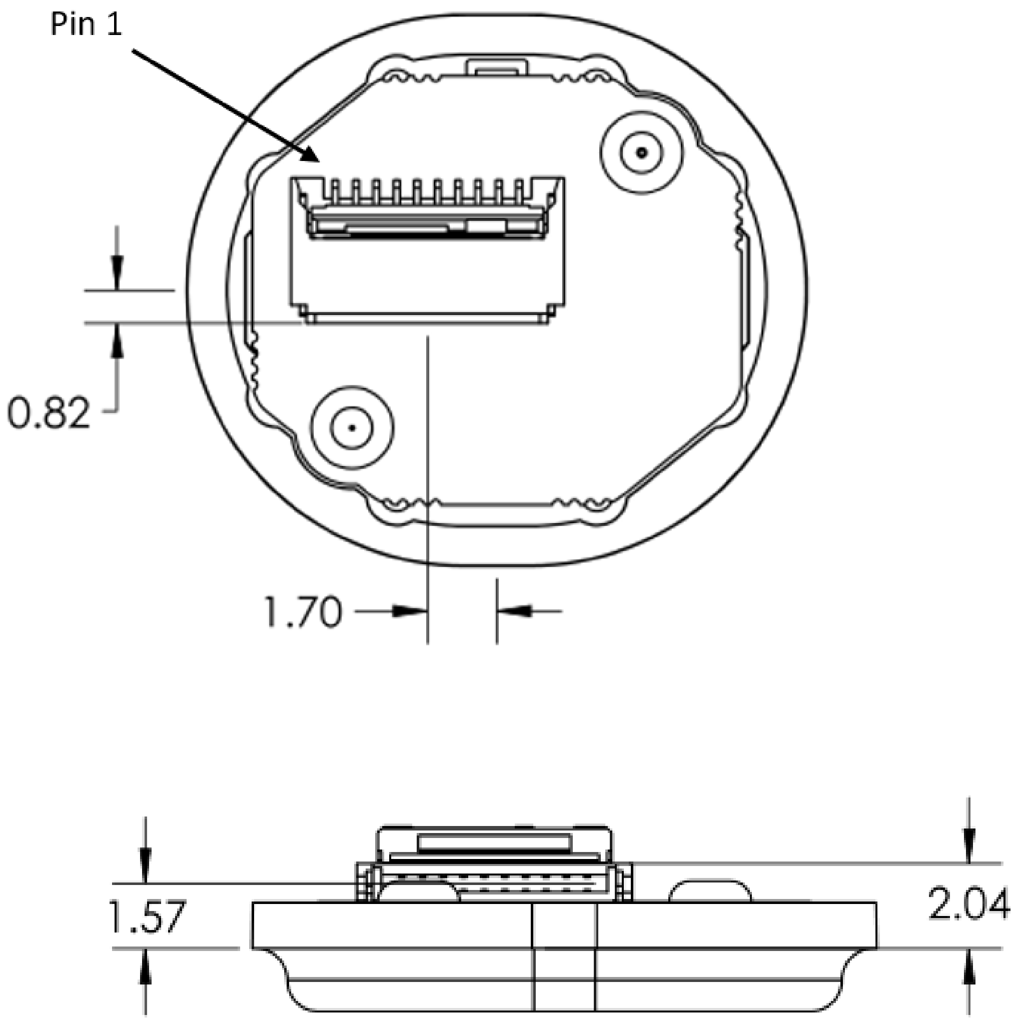
The mating height for the FFC and the location of the center of the sensor connector relative to the center of the sensor is shown in Figure 4.

Figure 4: Connector Location and Orientation



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2.2 PerformTek Processor Pin Description

Table 4 provides a description of the pin assignments to the PerformTek processor. See the Ambiq Micro Apollo2 MCU Datasheet for the 49-pin WLCSP processor package information.

Table 4: Processor Pinout

MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD0	G7	Input	HOST_I2C_SCL	SLSCL	Host to PeformTek MCU Interface: I2C Clock Note: I2C is one of two supported Host Interfaces. Connect the Host to either the I2C or UART interface pins and leave the ununsed Host interface pins unconnected.
PAD1	F5	Input / Output	HOST_I2C _SDA	SLSDA	Host to PerformTek MCU Interface: I2C Data Note: I2C is one of two supported Host Interfaces. Connect Host to either the I2C or UART interface pins and leave the ununsed Host interface pins unconnected.
PAD2	E4	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD3	F7	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD4	G1	N/A	N/C	N/A	No Connect - Reserved for Future Use

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD5	E5	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD6	D7	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD7	D5	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD8	F2	Output	SENSOR_I2C_SCL	M1SCL	Sensor Interface: Sensor I2C SCL
PAD9	G3	Input / Output	SENSOR_I2C _SDA	M1SDA	Sensor Interface: Sensor I2C SDA
PAD10	G2	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD11	B3	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD12	B2	N/A	N/C	N/A	No Connect / Reserved for Future Use
PAD13	C2	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD14	B1	Output	HOST_UART_TX	UART1TX	Host to PerformTek MCU Interface: UART TX to Host from MCU Note: UART is one of two supported Host Interfaces. Connect Host to either the I2C or UART interface pins and leave the ununsed Host interface pins unconnected.

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD15	A1	Input	HOST_UART_RX	UART1RX	Host to PerformTek MCU Interface: UART RX from Host to MCU Note: UART is one of two supported Host Interfaces. Connect Host to either the I2C or UART interface pins and leave the ununsed Host interface pins unconnected.
PAD16	C3	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD17	D3	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD18	B4	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD19	A4	Input	N/C	N/A	No Connect - Reserved for Future Use
PAD20	E1	Input	DBG_SWDCK	SWDCK	Serial Wire Debug Clock If space allows it, connect to test point / pad for debug support
PAD21	D6	Input / Output	DBG_SWDIO	SWDIO	Serial Wire Debug Data If space allows it, connect to test point / pad for debug support
PAD22	F4	N/A	N/C	N/A	No Connect - Reserved for Future Use

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD23	C1	Input	HOST_INT_N / BOOT_OVERRIDE_N	GPIO23	Host to PerformTek MCU Interface: This pin serves two functions: 1. HOST_INT: A software configurable input 2. BOOT_OVERRIDE: May be asserted by the Host Processor during the PerformTek processor bootup to enter bootloader mode.
PAD26	E3	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD28	D2	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD29	A3	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD39	E2	Input	ACC_INT_N	GPIO39	PerformTek MCU Sensor Interface: Active-low sensor accelerometer interrupt input
PAD40	D1	Input	AFE_INT	GPIO40	PerformTek MCU Sensor Interface: Active-high sensor analog front and interrupt input

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD41	G6	Output	SENSOR_PWR	GPIO41	PerformTek MCU Sensor Interface: SENSOR_PWR High-Side Switch / Power control for the sensor. This pin may be used to control a load switch for the sensor. Alternatively, this pin may be connected directly to sensor $V_{DD(SENSE)}$ to supply sensor power directly*. (See note below) Use of this pin as a power supply for the sensor has an impact on MCU and sensor power supply design. See Section 5 for more details. Note: This feature is still in development. Contact Valencell before implementing in design.
PAD44	F1	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD47	E6	N/A	N/C	N/A	No Connect - Reserved for Future Use
PAD48	E7	Output	SENSOR_CLK	GPIO48	PerformTek MCU Sensor Interface: Sensor clock output

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
PAD49	F6	Output	POST / PTEK_INT_N	GPIO49	Perform Tek MCU Host Interface: This pin serves two functions: 1. Power-on self-test (POST) output: This pin will present a logic high after the power up process is complete 2. Software configurable output
ADC_VREF	A2	Input	ADC_REF	N/A	No Connect - Reserved for Future Use
nRST	G4	Input	HOST_RST_N	nRST	PerformTek MCU Reset: A logic low input on this pin will reset the processor Connect to system reset and add a capacitor as shown in Figure 5. Note that an external resistor is not required because of the MCU's internal pull-up on this net.
XO	A4	Output	XO	N/A	Crystal oscillator circuit output pin Connect to 32.768 kHz Crystal
SWC	A7	Output	COREBUCK_SW	N/A	Core Buck Converter Inductor Switch Node Connect to 2.2 µH Inductor

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
XI	B5	Input	XI	N/A	Crystal oscillator circuit input pin Connect to 32.768 kHz Crystal Note: The crystal input is highly sensitive to external leakage on the XI pin. Therefore, it is recommended to minimize the components on XI and to use low leakage load capacitors. Good quality ceramic capacitors will usually meet this low leakage guideline.
SMM	B7	Output	MEMBUCK_SW	N/A	Memory Buck Converter Inductor Switch Node Connect to 2.2 µH Inductor
VDDC	A6	Input	VDDC	N/A	Core Buck Converter Voltage Output Supply (Input to PerformTek MCU Core). Typical value: 0.7 VDC
VDDF	D4	Input	VDDF	N/A	Memory Buck Converter Voltage Output Supply (Input to PerformTek MCU Memory). Typical value: 0.9 VDC
VDDP	B6, B7	Power	VDDP	N/A	Pad Supply Voltage
VDDA	C5	Power	VDDA	N/A	Analog Supply Voltage
VDDH	G5	Power	VDDH	N/A	Digital Supply Voltage

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MCU Pad	Pin / Ball	Direction with respect to MCU	Name	MCU Pad Function Selection	Description
VSSL, VSSA, VSSP	F3, C4, C6	Ground	GND	N/A	Power Input References

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3 Electrical Characteristics

3.1 Sensor

Operating requirements and characteristics of the sensor are provided below. The operating characteristics defined in Table 6 apply to operation for both $V_{DD(SENSE\_LOW)}$ and $V_{DD(SENSE\_HIGH)}$.

Table 5: 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	5.25	VDC
V_{LED} Ripple voltage_30k	V_{ripple_10}	Sensor system active: 0 to 30 kHz Ripple	----	----	250	mV_{pp}
V_{LED} Ripple voltage_100M	V_{ripple_100}	Sensor system active: >30 kHz to 100 MHz Ripple	----	----	100	mV_{pp}
Sensor Supply Voltage (Low-Range)	$V_{DD(SENSE\_LOW)}$	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. Note: V_{DD} > 1.9 and V_{DD} < 2.0V not defined	1.8	1.85	1.9	VDC
Sensor Supply Voltage (High-Range)	$V_{DD(SENSE\_HIGH)}$	Requires VDD_SEL to be pulled low to enable the sensor's on-board LDO, otherwise damage may occur. In this mode of operation. Sensor power	2.0	2.1	3.6	VDC

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		consumption is lower when V_{DD} is low.				
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	60	°C

Table 6: 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} Standby and Idle Modes	-	Standby mode is to be defined $V_{DD(SENSE)}$ = 1.8 VDC	-	10	-	µA
I_{DD_SENSOR} Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate $V_{DD(SENSE)}$ = 1.8 VDC	-	43	-	µA
I_{DD_SENSOR} Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate $V_{DD(SENSE)}$ = 1.8 VDC	-	128	-	µA
I_{DD_SENSOR} Standby and Idle Modes	-	Standby mode is to be defined $V_{DD(SENSE)}$ = 3.3 VDC	-	53	-	µA

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Parameter	Symbol	Conditions	Min	Typ	Max	Units
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	-	62	-	µA
I_{DD_SENSOR} Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate $V_{DD(SENSE)}$ = 3.3 VDC	-	167	-	µA
I_{LED_SENSOR} Standby and Idle Modes	-	Standby mode is to be defined	-	14	-	µA
I_{LED_SENSOR} Active Mode with Standard-Precision RRi	-	System is in Active mode and operating at standard RRi sampling rate	-	405	-	µA
I_{LED_SENSOR} Active Mode with High-Precision RRi	-	System is in Active mode and operating at fast RRi sampling rate	-	2.03	-	mA
I_{LED_SENSOR} Pulse Current	I_{pulse}	System is in Active mode	-	20	-	mA

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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 7: 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 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 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.

3.2 PerformTek Processor

PerformTek-specific and high-level processor characteristics are provided below. See the processor datasheet for more details.

Table 8: Recommended Operating Conditions for PerformTek Processor

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Processor Supply Voltage[1]	V_{DD}	Valid processor power supply range	1.76	-	3.63	V
Voltage on any Pin	V_{INPUT}	Valid input signal voltage	0	-	V_{DD}	V

Note 1: Processor $V_{DD} = V_{DDP} = V_{DDH} = V_{DDA}$

Table 9: Operating Characteristics for PerformTek Processor

Parameter	Symbol	Conditions	Min	Typ	Max	Units
I_{DD} Standby Mode	I_{STBY}	System is in Standby mode (currently Idle Mode recommended Standby mode not yet supported)	-	TBD	-	µA
I_{DD} Idle Mode	-	V_{DD} = 1.8VDC System is in Idle mode	-	135	-	µA
I_{DD} Active Mode with Standard-Precision RRi[1]	-	V_{DD} = 1.8VDC System is in Active mode and operating at standard RRi sampling rate	-	255	-	µA
I_{DD} Active Mode with High-Precision RRi[1]	-	V_{DD} = 1.8VDC System is in Active mode and operating at fast RRi sampling rate	-	420	-	µA
I_{DD} Idle Mode	-	V_{DD} = 3.3VDC System is in Idle mode	-	112	-	µA

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Parameter	Symbol	Conditions	Min	Typ	Max	Units
I_{DD} Active Mode with Standard-Precision RRi[1]	-	V_{DD} = 3.3VDC System is in Active mode and operating at standard RRi sampling rate	-	218	-	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	-	476	-	µA
I_{DD} Processor Pulse Current[2]	I_{pulse}	System is in Active mode	-	10	-	mA
Start-up time before POST response	t_{POST}	On Start-up, time measured after V_{DD} equal to or above 1.8V	-	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: Estimate only. Processor pulse current will be dependent on local decoupling design and layout

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4 PerformTek Processor Integration

4.1 PerformTek Processor Schematic

The included PerformTek Processor is implemented on an Ambiq Micro Apollo2 processor. This processor provides significant power savings from Ambiq's patented Subthreshold Power Optimized Technology (SPOT). This is an ARM Cortex-M4 based processor and is provided in a 49-pin Chip Scale Package (CSP).

The processor is programmed by Valencell, Inc. with PerformTek custom firmware and algorithms. To interface with this programmed processor, please utilize the schematic diagram shown in Figure 5, the recommended component list in Table 10, and the associated interface descriptions that follow. For additional electrical and physical specifications for this processor, consult the Apollo2 datasheet and associated documentation available at https://ambiqmicro.com or contact your local Ambiq Micro sales representative.

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Figure 5: Processor Connection Schematic (Both I2C and UART Host Connections Shown)

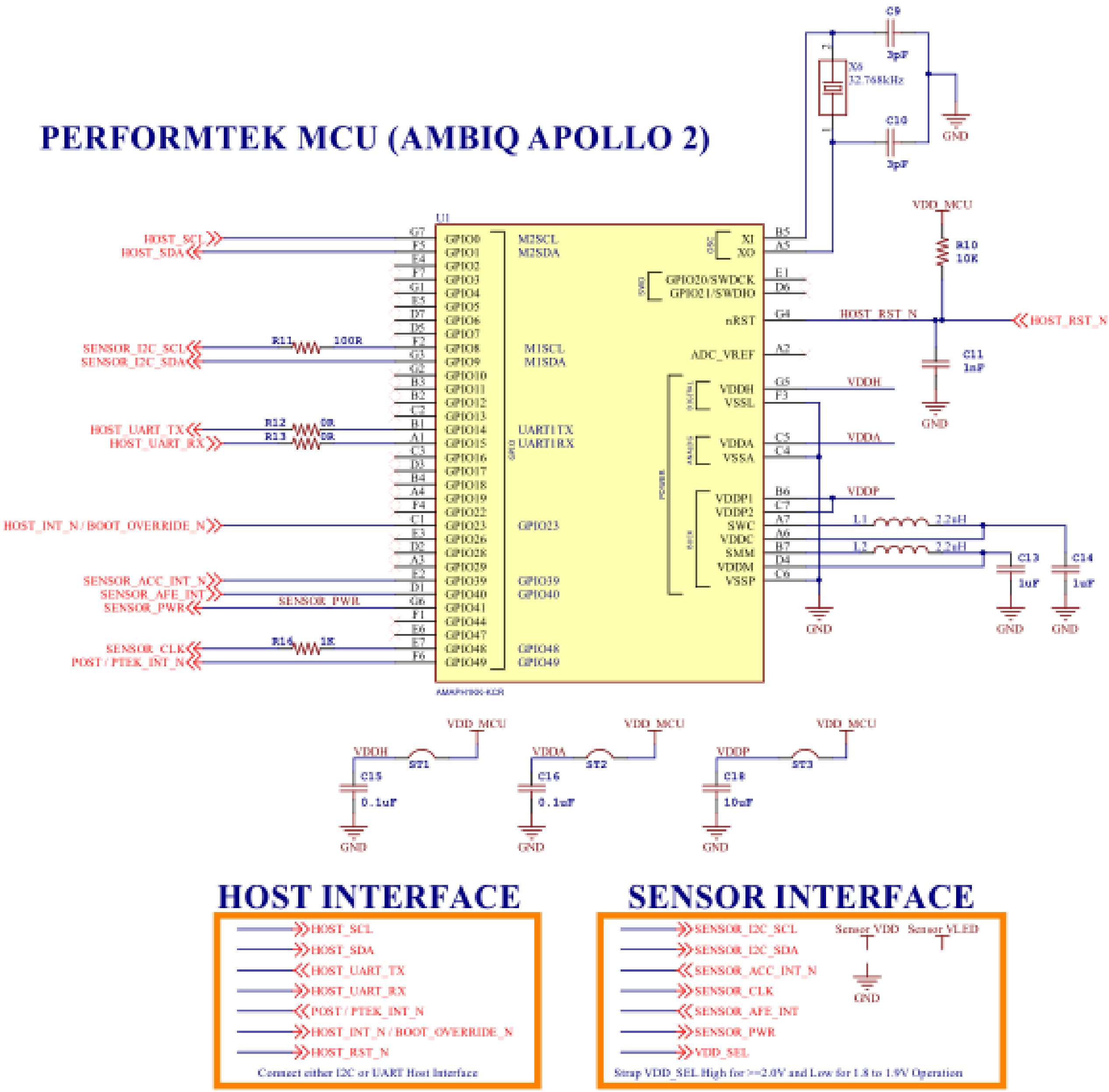

Table 10: Recommended Supporting Components

Description	Manufacturer	Manufacturer Part Number
2.2 µH Buck Supply Inductors	Taiyo Yuden Bourns	MBKK1608T2R2M (0603) package) SRN2010TA-2R2M (0806 package)
32 kHz Crystal	KDS Abracon	DST1610A 32.768kHz (1.6x1.0x0.5 mm) ABS06-107-32.768KHZ-T (2.0x1.2x0.6 mm)

4.2 PerformTek Processor Connections

Host Interface – UART / I2C

The Host interface that connects the system processor to the PerformTek processor supports both I2C and UART communications. Either I2C or UART should be connected to the Host since only one interface can be used at a time. The PerformTek processor will automatically detect the active interface. On boot up, the PerformTek processor will scan both communications ports until activity is detected on one of them. For optimal power savings, it is recommended to exercise one of the ports so that the PerformTek processor can shut down the unused port. 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 the external resistors.

For UART host communications, the HOST_UART_RX pin is the receive line for data sent to the module from the host processor and the HOST_UART_TX pin is the transmit line from the sensor module to the host. The port settings are 57.6 kbps, 8, N, 1. There is no hardware or software flow control.

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 with up 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 the UART or I2C communication protocols or to see more details on updates associated with the I2C interface, see the PerformTek Interface Protocol Document.

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Host Interface – POST / PTEK_INT_N

Once V_{DD} power is applied, the processor will attempt to initialize all components on the module. This startup time is defined by t_{POST} in Table 9. 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 t_{POST} 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 UART/ I2C 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.

Refer to the PerformTek Interface Protocol Document for further information on Bootloader mode and interrupt configuration.

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. HOST_RST_N should be tied to a decoupling capacitor placed close to the HOST_RST_N processor pin as shown in Figure 5.

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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.

Crystal Oscillator

A clock reference is required for correct operation of the PerformTek MCU. Valencell recommends a KDS DST1610A 32.768kHz crystal, an Abracon ABS06-107-32.768KHZ-T, or equivalent. Note; for maximum space savings the KDS DST1210A 32.768kHz may also be used but has not been tested by Valencell. See the Apollo2 datasheet and associated documentation for more information on the use of the crystal including additional crystal selection criteria and design guidance.

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Inductors

To minimize power consumption, the PerformTek processor uses internal buck regulators to convert VDD to the lower voltages used by the processor. To support this functionality, two external inductors are required along with the capacitors shown in Figure 5. To minimize the impact to the overall processor footprint, Valencell recommends the Taiyo Yuden MBKK1608T2R2M, 2.2 µH 0603 inductor.

Decoupling

The capacitors shown in Figure 5 are necessary to reduce noise and ensure measurement accuracy and proper processor functionality. These capacitors should be placed physically near the V_{DD} pins of the processor.

Firmware Updates

The PerformTek processor supports in-field firmware updates via the Host Interface. Driving the PerformTek processor's HOST_INT_N / BOOT_OVERRIDE_N pin high low during boot up puts the device into bootloader mode. Refer to the PerformTek User Guide for further information on this feature.

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5 Power Supply Design Guidelines

5.1 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. If SENSOR_PWR is used to supply $V_{DD(SENSE)}$, system power supply design and overall layout can still impact power quality, and the design must still be verified to meet all specified power requirements.

Peak V_{LED} current will be periodic where the period of the peaks will depend on the mode of operation: Heart Rate measurement and Standard-Precision RRi will pulse every 40 ms and High-Precision RRi will pulse every 8 ms. The V_{LED} current profile discussed 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 current loading on the 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.

5.2 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 V_{LED} (or V_{DD}) is removed from the sensor, V_{DD} (or V_{LED}) should also be removed at the same time to prevent excessive leakage currents from occurring.

5.3 Power Supply Rise Time

The power supplied to the processor's VDDP pin must not exceed a rise time of 2kV/s. This rise time is impacted by the system power supply, bulk capacitance on VDDP and bulk capacitance and loading on the processor's SENSOR_PWR pin. Early testing should be performed with the system power supply design to ensure that this rise time limit is not violated.

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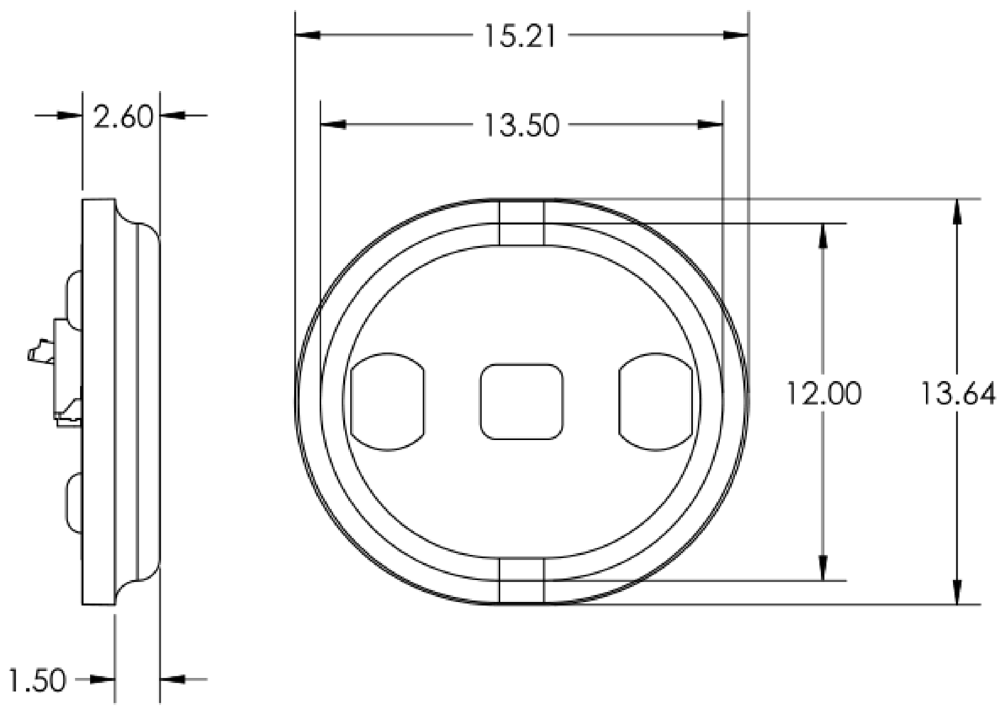
6 Sensor Optical-Mechanical Integration

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.

Figure 6: BW4.0 Wearable Sensor Drawing (Dimensions in millimeters)



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 wrist product and a portion protruding from the bottom of the wrist product. This design balance provides optimal sensor accuracy with minimal disruption to other components of the interior of the product design.

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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 Wrist Sensor Integration Guide and BW4.0 Sensor 3D CAD models and drawings.

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7 Processor Communication Interface Example

An example of the processor communications interface protocol is described in short detail below. Simple packet-based commands are used to Get or Set measurement readings or parameters, or to control the PerformTek processor. For a full description of the interface protocol, please refer to the 000638 Valencell PerformTek Interface Protocol document.

Command: Get(0x08)

The GET command issues requests for parameters and measured values from the PerformTek output registers. The purpose of these register values can range from declarations about the firmware features to the most recently calculated value for heart rate.

Following is an example of a GET command that requests three values (heart rate, step rate, and calories):

PerformTek Start	Byte Count	GET Command	BPM Request	SPM Request	CALS Request
0x44	0x04	0x08	0x20	0x30	0x42

Command: Set (0x04)

The SET command writes configuration values to PerformTek registers. The purpose of these register values can range from declarations about the capability of the application, to information needed by the algorithms about the user.

Here is an example of a typical SET command that sends three user information parameters (age, gender, and weight):

PerformTek Start	Byte Count	SET Command
0x44	0x0A	0x04

. . .

. . .

age	34.5 years old		gender	female		weight	140 lbs	
0x10	0x01	0x9E	0x11	0x00	0x00	0x12	0x02	0x7B

Other interface commands control PerformTek processor operation. For full specifications, consult the PerformTek Interface Protocol document.

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8 Sensor Ordering Guide and Comparison Chart

Part Number	Description
000945	BE 2.0
001701	BW 4.0
001034	BW 2.0
000954	BW 1.2

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9 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.

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10 Contact Information

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