BME473L/474L (Fall 2021): Bicep PPG and Accelerometer Wearable

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DUKE BME

CLINICAL MOTIVATION

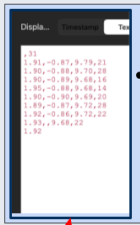
- Problem: Current internal temperature sensor needs additional data to improve performance
- Population: High school football athletes in the United States
- Outcome: A robust wearable device that measures and transmits heart rate and motion data in real time

SPECIFICATIONS & CONSTRAINTS

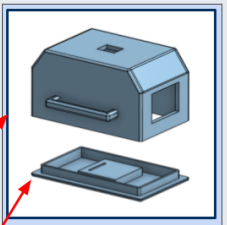
Need	Ideal Spec	Marginal Spec	Competitive Spec
Impact Resistance	Meets IEC 60601-1 Standards 100% of the time (95% confidence interval)	Meets IEC 60601-1 Standards 80% of the time (95% confidence interval)	Meets IEC 60601-1 Standards 100% of the time (95% confidence interval)
Low-cost	Sum Total Cost of All Components to Manufacture Device <= $100.00	Sum Total Cost of All Components to Manufacture Device <= $300.00	Sum Total Cost of All Components to Manufacture Device <= $100.00
Accurate	Polar Heart Rate Sensor Quantity is Within 95% Confidence Intervals of New Heart Rate Sensor	Polar Heart Rate Sensor Quantity is Within 68% Confidence Intervals of New Heart Rate Sensor	Polar Heart Rate Sensor Quantity is Within 95% Confidence Intervals of New Heart Rate Sensor
Compatible with current sensor	Bluetooth connection established with no unwanted connections with no unwanted noise I2C connection established	Bluetooth connection established with minor connection issues and some unwanted noise I2C connection established with wire noise being an issue in rigorous physical activity	Bluetooth connection established with no unwanted connections with no unwanted noise I2C connection established
Long battery life	Have Code Output Battery Life under Most Active Use which must be >= 50% Battery Life after 4 Days	Have Code Output Battery Life under Most Active Use which must be >= 50% Battery Life after 1 Day	Have Code Output Battery Life under Most Active Use which must be >= 50% Battery Life after 2 Days

MECHANICAL, ELECTRICAL, & SOFTWARE DESIGN

- One-size-fits-most adjustable Velcro armband
- Threads through enclosure loops
- Maintains tight skin-sensor contact

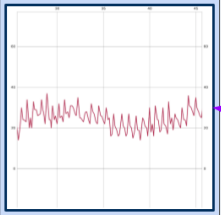


- Data output to UART can be saved to a comma-separated values file (.CSV)

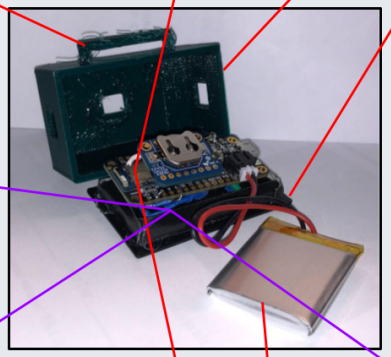


- Two-piece 3D printed PLA enclosure
- Attachment points for armband
- Access points for power switch, charging, PPG insert

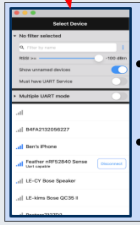
- 10 peak moving average HR algorithm



- PPG data stream from Bicep Signal

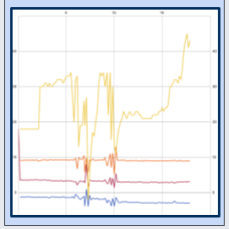


- PPG sensor board flush with bottom of enclosure
- PPG optics press firmly into epidermis
- No exposed wires



- User interacts with raw data via Bluefruit Connect app
- 500 mAh LiPo battery level display

- Bluetooth connection to Bluefruit Connect App
- Accelerometer and PPG data graphed versus time



TESTING ANALYSIS

PPG and Heart Rate Accuracy Testing

	Mean ± 95 % CI of Measured Heart Rate (bpm)		
Movement	Polar Heart Rate H10 Sensor	Wearable Device at Finger	Wearable Device at Bicep
Walking	81.3 ± 5.0	85.9 ± 26.6	95.2 ± 44.4*
Jogging	111.7 ± 16.0	100.6 ± 34.6	82.8 ± 67.0*

Statistical Significance with respect to the H10 Sensor is denoted by an asterisk (*)

LBM Analysis	Cost*
PLA for enclosure	$20.50
Bicep band	$0.75
Internal components	$59.53
PCB Milling	$20.00
Complete assembly	$20.00
Total	$120.78

Impact Resistance Testing

Mean % Survival	91.7%
Standard Deviation	11.8%
95% CI	(68.1%, 115.3%)

CONCLUSIONS/FUTURE WORK

Our current prototype is a proof of concept for a wearable device that acquires PPG and accelerometry data at the bicep. This information will complement an existing internal temperature sensing wearable device to reduce the incidence of heat stroke.

Next Steps:

- Reduce enclosure size
- Optimize power consumption to achieve 8 day battery life
- Test PPG accuracy under more rigorous forms of exercise
- Test enclosure impact resistance with more representative impactor
- Establish local flash memory storage when bluetooth connection is lost

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