CALERA Specification Sheet

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FEATURES

- Compact sensor solution
- Medical grade accuracy
- Environmental compensation
- Non-invasive measurement
- Enabling continuous monitoring
- Integration in any wearable
- Ultra-low power consumption (< 70uW)
- Self-calibration
- Compensates for internal device heating
- Thermal reproducibility
- Can be fully encapsulated in a housing (no direct skin contact is required)

GENERAL DESCRIPTION

greenteg's CALERA® solution is the only non-invasive, continuous, and accurate core body temperature monitoring solution available on the market that is compact and energy-efficient enough for integration into consumer and medical wearable devices.

This innovative solution is composed of a miniature highly sensitive heat flux sensor from greenteg (gSKIN®XU), a skin temperature sensor, for example, AS6221 from amsOSRAM, and a powerful algorithm that enables real-time core body temperature estimation. With minimal footprint, power- and memory-consumption, the CALERA® core body temperature monitoring solution can be integrated into any wearable device and attached to numerous body positions.

Use cases

- Healthcare
- Sports performance analysis
- Sleep tracking (Circadian cycle)
- Ovulation tracking
- Patient monitoring
- Sepsis screening
- Heat stroke prevention
- Animal health monitoring

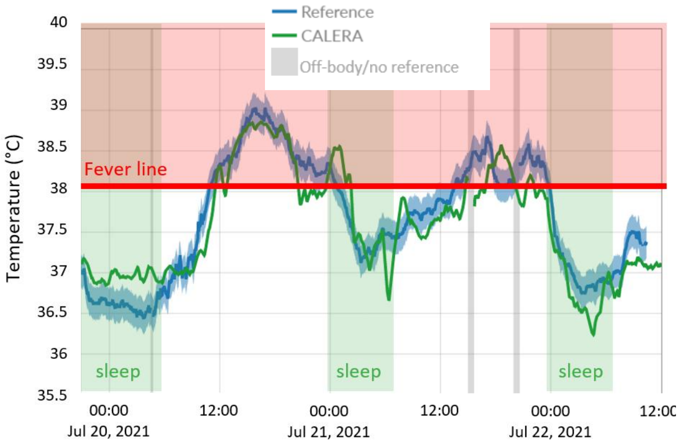


Figure 1: Validation of core body temperature sensor on the clavicula position compared to ePill

Measurement position

- Chest (Apical, clavicular or sternum)
- Upper arm
- Wrist
- Finger

Clinically validated solution

The accuracy of the CALERA® core body temperature monitoring solution has been validated through independent clinical studies and numerous internal case studies.

The best accuracy is attained in the chest position and decreases toward the extremities. Nonetheless, all our algorithms already fulfil FDA requirements or will be certified in the future.
Additionally, our solution has been validated in numerous environments and conditions including, but not limited to:

- Controlled environment
  - Hospital
  - Sleep monitoring
- Uncontrolled environment
  - Real-life conditions
  - Fever detection
  - Sport performance analysis

THE SOLUTION

greenteg's CALERA® solution is a unique and proprietary solution enabling the accurate, non-invasive, and continuous monitoring of core body temperature.

Designed for integration into wearable devices, greenteg's solution is highly compact and with minimal requirements for powering the components.

The solution is composed of greenteg's miniature gSKIN®XU sensor, the digital temperature sensor AS6221* of amsOSRAM, greenteg's algorithm and several off-the-shelf components required to enable a non-invasive core body temperature monitoring. Our integration process is thermally reproducible and can be done on a standard electronic mass manufacturer line.

Principle of operation

The basic principle of core body temperature estimation is to use heat-flux information (thermal energy transfer) to calculate the difference between skin temperature and core body temperature.

Due to heat dissipation from the body, the energy transfer from the body to the ambient air creates a temperature gradient between the body core and the skin. As soon as the ambient temperature goes down, skin temperature goes down as well, but heat loss increases, leading to a higher energy transfer signal. The rise in energy transfer will compensate for the drop in skin temperature, maintaining a valid core body temperature estimation.

This energy transfer approximation is dependent on a multitude of factors, such as:

- Measurement position on the body
- Individual characteristics like skin type, hairiness, BMI, age, gender etc.
- Attachment method to the skin
- Occurrence of sweat (e.g., during sports)
- Thermo-physiological reactions to cold, fever or stress.

To overcome the physiological complexity of measurement, greenteg has developed a powerful artificial intelligence algorithm, able to deliver accurate, reliable, and continuous monitoring of core body temperature.

Measurement Position

The following body positions algorithms are available for:

- Chest (apical, clavicular and sternum)
- Upper arm
- Wrist
- Finger

Existing algorithms for chest, upper arm, wrist and finger were developed due to their convenience to wear and thus enable the most reliable predictions of core body temperature. Additional positions like the forehead are possible but require a joint development project.

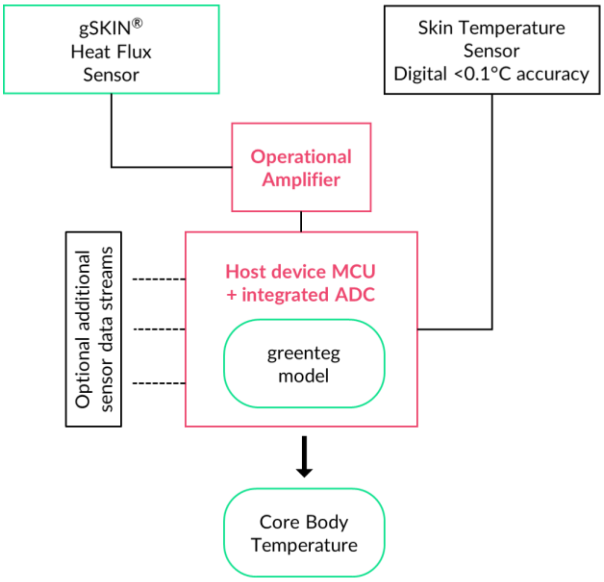
We want to provide the best performance for each use case, therefore for each position, algorithms for different use case scenarios were developed. These algorithms can be combined on the microcontroller either with automated or manual switching.

Hardware

The following components are required:

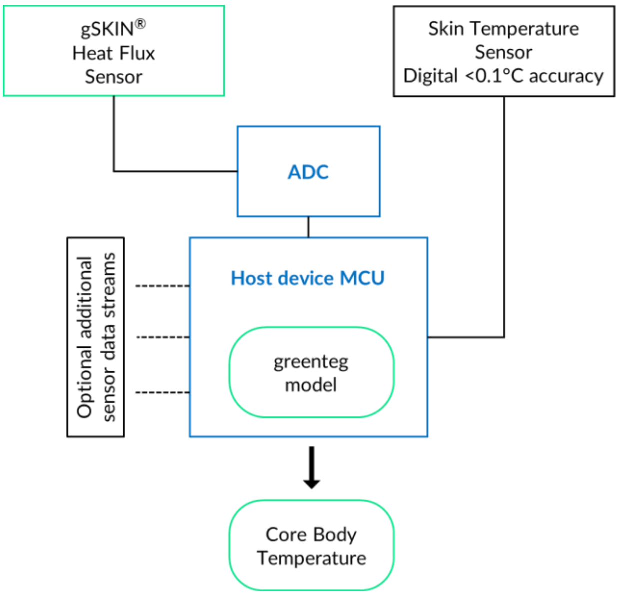
- gSKIN®XU heatflux sensor (2mm x 2mm)
- Digital skin temperature sensor with an accuracy <0.1 °C (for example AS6221)
- Either a high-resolution ADC to resolve 4uV or using your internal 12-bit ADC with a preamplification circuit
- Minimal size requirements: Area of ~ 4-5 mm in diameter
- Energy requirements: < 70uW (mainly temp sensor and ADC operation)

Integrated ADC configuration



A high-precision, chopper-stabilized operational amplifier is required, with an input offset voltage ≤ 5 µV, low 0.01–10 Hz noise (< 5 µVpp), excellent linearity (THD < 0.001%), offset drift < 50 nV/°C, and rail-to-rail I/O on a single supply.

Standalone ADC configuration



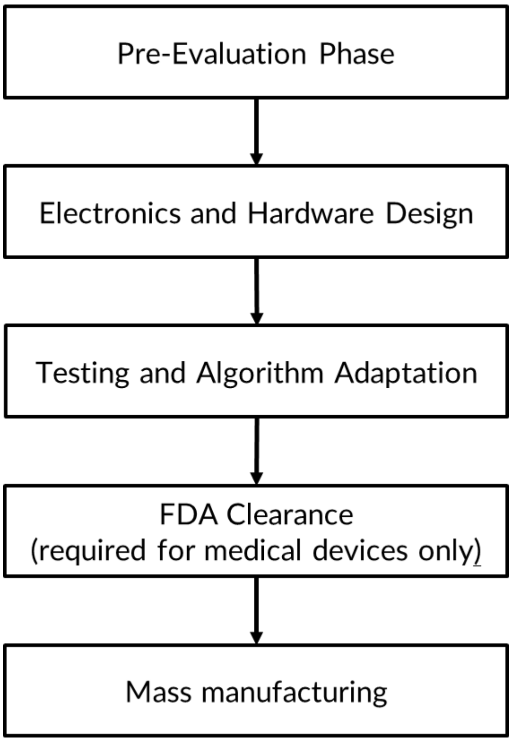
The standalone ADC must have a differential input with 2 µV resolution, a maximum offset of ±5 µV, and support at least a ±1 mV input range. It should operate at a minimum acquisition rate of 0.5 Hz, with high linearity, low drift, and include at least 20 kB of flash and 4 kB of RAM.

CUSTOMER JOURNEY

This guide outlines the general description, operation, and requirements of the CALERA® Core Body Temperature monitoring solution.
greenteg has extensive experience in the integration process and we know that every device is specific, and every use case has its own requirements. Thus, this guide should be viewed as a tentative approach to yield the most timely and efficient results.

To get more information and discuss your specific use case please get in touch with our team and we will answer any open questions you may have.

A full integration guide will be available after a signed NDA and the commitment to the integration in terms of buying the CALERA® development KIT which also comes with consulting hours.



ON-TOP-ALGORITHMS

In addition to core body temperature as a metric, get additional insights by a choice of our on-top-algorithms to satisfy the needs of your customer base.

SportOnTop
Get access to training zones and Heat Strain Index (HSI) based on core body temperature.

gRETRO – Ovulation Prediction
Get intelligence on your ovulation cycle based on basal body temperature.

Circadian Cycle Tracking*
Track your sleep quality by interpreting your CBT change over the night.

Fever Tracking*
Get alerts when reaching critical core body temperature during sickness.

*Under development

CONVINCE YOURSELF

Chest – Free living / sport / fever algorithm
Buy a CALERAresearch at our shop
https://shop.greenteg.com/

Chest – Baby algorithm
Buy a CALERAresearch and get in contact with us to update the firmware for you.

Upper arm – Free living / Fever algorithm
Buy a CALERAresearch and get in contact with us to update the firmware for you.

Wrist – Free living / Fever algorithm
Contact us to get a quote for the wrist prototype.

Wrist – Free living algorithm
Reference design with greenteg's integrated CBT solution will be made available soon

GREENTEG AG OVERVIEW

At greenteg, we are focused on delivering the highest quality thermal sensing solutions.
Founded as a spin-off from ETH Zürich, greenteg's expertise in thermal sensing solutions has been developed for more than 15 years through partnerships with our international customer base.
greenteg develops, manufactures, and markets thermal sensor solutions for a growing customer base active in photonics, building physics, MedTech, automotive, processing industry, and R&D.

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APPENDIX

gSKIN® XU SPECIFICATIONS

- Ultra-Compact Heat Flux Sensor
- Compatible with Standard SMT Manufacturing
- Zero Current Consumption
- Minimal Thermal Invasiveness
- Low Impedance
- Low Noise

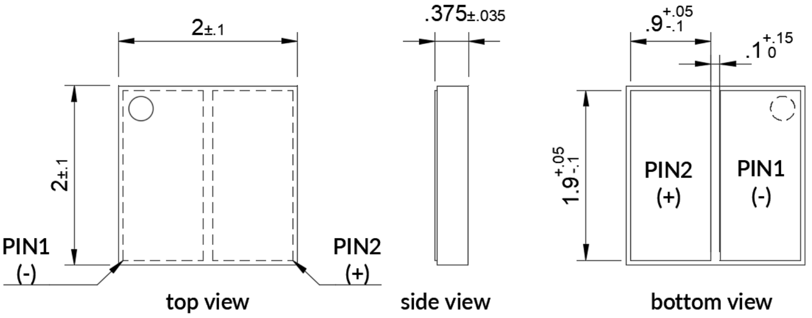
Parameter	**gSKIN® XU**	**Unit**
Detector Type	Thermoelectric – passive	-
Surface Material (Sensing Area)	Copper and polyimide	-
Sensing Area	2 x 2	mm
Sensor Thickness	0.4	mm
Absolute Thermal Resistance	~198	K/W
Electrical Connection	Bottom side SMD solder pads	-

Parameter	**Min**	**Max**	**Unit**
Sensitivity (Factory) @ 25°C	0.7	2.0	µV/(W/m^2)
Calibration Error	-5	+5	%
Sensitivity Drift	-	0.25	%/°C
Heat Flux Resolution [a)]	1.0	1.6	W/m^2
Electrical Resistance	1	10	Ohm

[a)] Assuming ADC LSB resolution of 2 µV

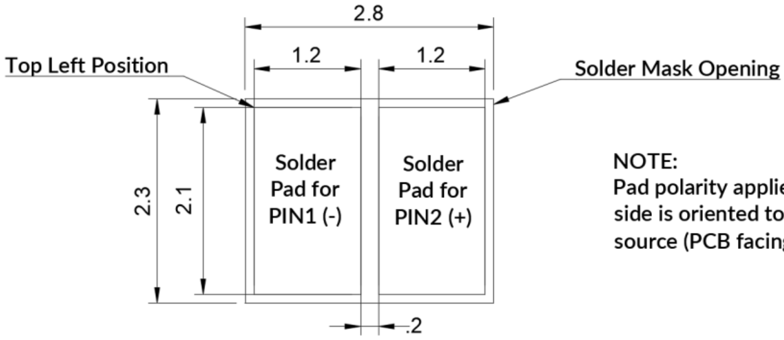
Parameter	**Min**	**Max**	**Unit**
Current at Any Pin	-10	10	mA
Storage Temperature Range	-50	80	°C
Operating Temperature Range	-50	150	°C
Heat Flux Range (Thermal Destruction Limit)	-150	150	kW/m^2
Compressive Clamping Force	-	0.5	Kgf

Mechanical Information



NOTE:
Pad polarity applies if sensor top side is oriented towards heat source (PCB facing cold side)

Recommended Footprint



NOTE:
Pad polarity applies if sensor top side is oriented towards heat source (PCB facing cold side)

ESD Considerations

Due to its electrical, geometric, and physical properties, gSKIN®XU sensors are not sensitive to ESD surges.

Further Information

A more detailed version of the HFS specifications will be delivered when entering an integration project with greenteg

ALGORITHM PORTFOLIO

Body Position Algorithms

Following Datasheets show the specifications of our validated CALERA solution for several body positions.

Chest Baby algorithm v1.0

Medical and daily use

Description

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution), skin temperature sensor, and heart rate monitor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as smartwatches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

The algorithm was validated under general life conditions not including fever.

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Daily activities
- Nighttime conditions (for Basal Body Temperature readings and cycle tracking)
- Physical or sports activities

The algorithm is not suitable for heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure, fever tracking and sauna

Input parameter requirements

Input	Sampling frequency*	Accuracy
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heart Rate	1 Hz	< 20 beats
Position	Mid-axillary line at inframammary level	
Age	0-18 months	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to down sample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Accuracy metrics*

Metric	Value
Bias	-0.1 °C
Limits of Agreement (LoA)	-0.79 / +0.59 °C
Unbiased LoA	0.69 °C
Mean Absolute Error (MAE)	0.29°C
Correlation coefficient	0.69

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Chest algorithm v1.0

Medical and consumer use

Datasheet v1.0 - 20250818

Description

The algorithm chestSC9823c208 delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution) and skin temperature sensor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as medical patches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

The algorithm was validated under general life conditions including fever.

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Daily activities
- Nighttime conditions (for Basal Body Temperature readings and cycle tracking)
- Physical or sports activities
- Fever tracking (similar accuracy to a tympanic thermometer)
- General ward and home monitoring

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure and sauna

Input parameter requirements

Input	Sampling frequency*	Accuracy
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Mounting position	Mid-axillary line at inframammary level	
Age	18 – 99 years	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to downsample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Accuracy metrics*

Metric	Value
Bias	-0.01 °C
Limits of Agreement (LoA)	-0.55 / +0.77 °C
Unbiased LoA	0.66 °C
Mean Absolute Error (MAE)	0.11°C
Correlation coefficient	0.89

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Chest sport algorithm v1.0

Elevated body temperature caused by high activity

Datasheet v1.0 - 20250818

Description

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution) and skin temperature sensor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as chest belts, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios and was optimized particularly for high activities.

The algorithm was validated under general life conditions including sport sessions.

The algorithm is often combined with the Chest algorithm V1 for daily life activities, which shows an improved performance for sleep and ovulation applications

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- High heart rate activities like (endurance) sport

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure, fever tracking and sauna

Input parameter requirements

Input	Sampling frequency*	Accuracy
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heartrate	1HZ	< 20 beats
Mounting position	Mid-axillary line at inframammary level	
Age	18 – 99 years	

Accuracy metrics*

Metric	Value
Bias	-0.1 °C
Limits of Agreement (LoA)	-0.62 / +0.59 °C
Unbiased LoA	0.61 °C

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Wrist algorithm v2.0

Daily use

Datasheet v1.0 - 20250815

Description

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution), skin temperature sensor, and heart rate monitor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as smartwatches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

The algorithm was validated under general life conditions including fever.

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Daily activities
- Nighttime conditions (for Basal Body Temperature readings and cycle tracking)
- Physical or sports activities
- Fever tracking (similar accuracy to a screening device like a forehead temperature gun)

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure and sauna

Input parameter requirements

Input	**Sampling frequency***	**Accuracy**
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heart Rate	1 Hz	< 20 beats
Posistion	Wrist	
Age	18-99 years	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to down sample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Accuracy metrics*

Metric	Value
Bias	-0.05 °C
Limits of Agreement (LoA)	-0.79 / +0.69 °C
Unbiased LoA	0.74 °C
Mean Absolute Error (MAE)	0.29°C
Correlation coefficient	0.73

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and the accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Wrist algorithm v2.0

Medical use

Datasheet v1.0 - 20250815

Description

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution), skin temperature sensor, and heart rate monitor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as smartwatches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

For medical applications the algorithm was validated according to ISO 8060 1-2-56 43 containing febrile candidates and non-fibral candidates collected in several clinical trials

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Daily activities
- Nighttime conditions (for Basal Body Temperature readings and cycle tracking)
- Physical or sports activities
- Fever tracking (similar accuracy to a screening device like a forehead temperature gun)
- General ward and home monitoring

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure and sauna

Input parameter requirements

Input	**Sampling frequency***	**Accuracy**
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heart Rate	1 Hz	< 20 beats
Position	Upper side of the wrist	
Age	18-99 years	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to down sample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Accuracy metrics*

Metric	Value
Bias	-0.09 °C
Limits of Agreement (LoA)	-0.98 / +0.79 °C
Unbiased LoA	0.88 °C
Mean Absolute Error (MAE)	0.35 °C
Correlation coefficient	0.73
True positive rate (TPR)	0.51
False positive rate (FNR)	0.05

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Wrist sport algorithm V1

For elevated body temperature cause by high activity

Datasheet v1.0 - 20250818

DESCRIPTION

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution) and skin temperature sensor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as chest belts, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios and was optimized particularly for high activities.

The algorithm was validated under general life conditions including sport sessions.

The algorithm is often combined with the Wrist algorithm V2 for daily life activities, which shows an improved performance for sleep, fever and ovulation applications.

FEATURES

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- High activities like sport

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure, fever tracking and sauna

INPUT PARAMETER REQUIREMENTS

Input	Sampling frequency*	Accuracy
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heartrate	1HZ	< 20 beats
Mounting position	Wrist	
Age	18 – 99 years	

ACCURACY METRICS*

Metric	Value
Bias	-0.02 °C
Limits of Agreement (LoA)	-0.85 / +0.82 °C
Unbiased LoA	0.84 °C
Correlation	0.8
Mean absolute Error (MAE)	0.34

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

DEVICE REQUIREMENTS

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Finger algorithm v1.0

For consumer health devices / smart-rings

Datasheet v1.0 - 20250815

Description

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution), skin temperature sensor, and heart rate monitor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as smartwatches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

The algorithm was validated under general life conditions not including fever.

Features

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Daily activities
- Nighttime conditions (for Basal Body Temperature readings and cycle tracking)
- Physical or sports activities

The algorithm is not suitable for heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure, fever tracking and sauna

Input parameter requirements

Input	**Sampling frequency***	**Accuracy**
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heart Rate	1 Hz	< 20 beats
Position	Finger	
Age	18 – 99 years	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to down sample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Accuracy metrics*

Metric	Value
Bias	-0.1 °C
Limits of Agreement (LoA)	-0.79 / +0.59 °C
Unbiased LoA	0.69 °C
Mean Absolute Error (MAE)	0.29°C
Correlation coefficient	0.69

*Accuracy metrics are based on our internal validation study. For more details, see the attached validation study document. It is a statistical model, and accuracy can change based on the integration, the situations, and the candidates. The integrator is responsible for testing the model for its use case.

Device requirements

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

Arm algorithm v2.0

Work Safety and Sports use

Datasheet v1.0 - 20260205

DESCRIPTION

The algorithm delivers reliable and accurate estimations of Core Body Temperature by fusing data from heat flux sensor (greenteg's Calera® solution), skin temperature sensor, and heart rate monitor.

It is designed to perform robustly under varying physiological and environmental conditions, ensuring consistent and precise output. Optimized for integration into wearable devices such as smartwatches, the algorithm enables continuous, non-invasive core temperature monitoring in real-world scenarios.

FEATURES

The algorithm can provide accurate Core Body Temperature predictions from wrist-worn devices in these scenarios:

- Physical or sports activities
- Work safety scenarios (including physically intensive tasks, heat-exposed environments)

The algorithm is not suitable for the ICU, heat stroke detection, clinical hypothermia, people with thermoregulatory problems, direct sun exposure and sauna

INPUT PARAMETER REQUIREMENTS

Input	Sampling frequency*	Accuracy
Heat flux	1 Hz	< 1W/m2
Skin temperature	1 Hz	< 0.1 °C
Heart Rate	1 Hz	< 20 beats
Position	Upper Arm	
Age	18-99 years	

*While the algorithm is designed to operate with input data at 1 Hz frequency, it is possible to down sample the input signals and reuse the most recent values over short intervals within defined limits that should be validated for specific use cases.

Validation results: data on arm*

Data	Bias [°C]	Lower LoA [°C]	Upper LoA [°C]	Width LoA [°C]	MAE [°C]	Correlation Coefficient	Percentage within 0.3°C / within 0.5°C
All data	0.02	-0.8	0.83	1.63	0.32	0.81	54.9% / 79.4%
Reference temp> 38.5°C	-0.2	-1.07	0.66	1.73	0.39	0.41	45.6% / 71.9%

DEVICE REQUIREMENTS

Requirement	Specification
Operating environmental conditions	The algorithm will not allow for negative heat fluxes Skin temperature below 10 °C should not be undershot
Time for first value/high quality value	2min / ~15min
Flash Size	28.4 kB
RAM	<1.3 kB (sum of all stack usage, this will never happen at the same time)

On-Top Algorithms

Following Datasheets show the specifications of our On-Top Algorithms.

gRetro

Ovulation Algorithm

Datasheet v1.5 - 20250820

Features

- Automatic detection of Ovulation based on the core body temperature (non-invasive, from the skin)
- Cloud or app based
- Easy to implement
- Suggestion for UX process
- Works with greenteg`s Calera® solution

Description

gRetro is a compiled algorithm that runs on the customer's cloud infrastructure or mobile app. It detects ovulation based on non-invasive core body temperature, heat flux, skin temperature, and heart rate readings. Using the identified ovulation date along with additional parameters—such as the date of the last period and the average cycle length—the algorithm predicts the ovulation date for the next cycle, assuming the individual has a regular menstrual pattern.

Process flow

The diagram illustrates a two-step process of gRetro algorithm:

Step 1: Data Collection and Basal Data Analysis

Continuous measurements (heat flux, skin temperature, heart rate, and core body temperature) are captured and transmitted to the customer's cloud infrastructure where the gRetro algorithm processes this information. After 24 hours of analysis, the algorithm extracts basal data, including basal core body temperature and nominal values for heat flux, skin temperature, and heart rate.

Step 2: Cycle Analysis and Prediction

This basal data from step 1 is stored alongside user-provided information in the customer's database, including:

- Cycle start date (mandatory)
- Initial average cycle length (optional: only for the first cycle)
- Ovulation dates confirmed via LH test strips (optional)

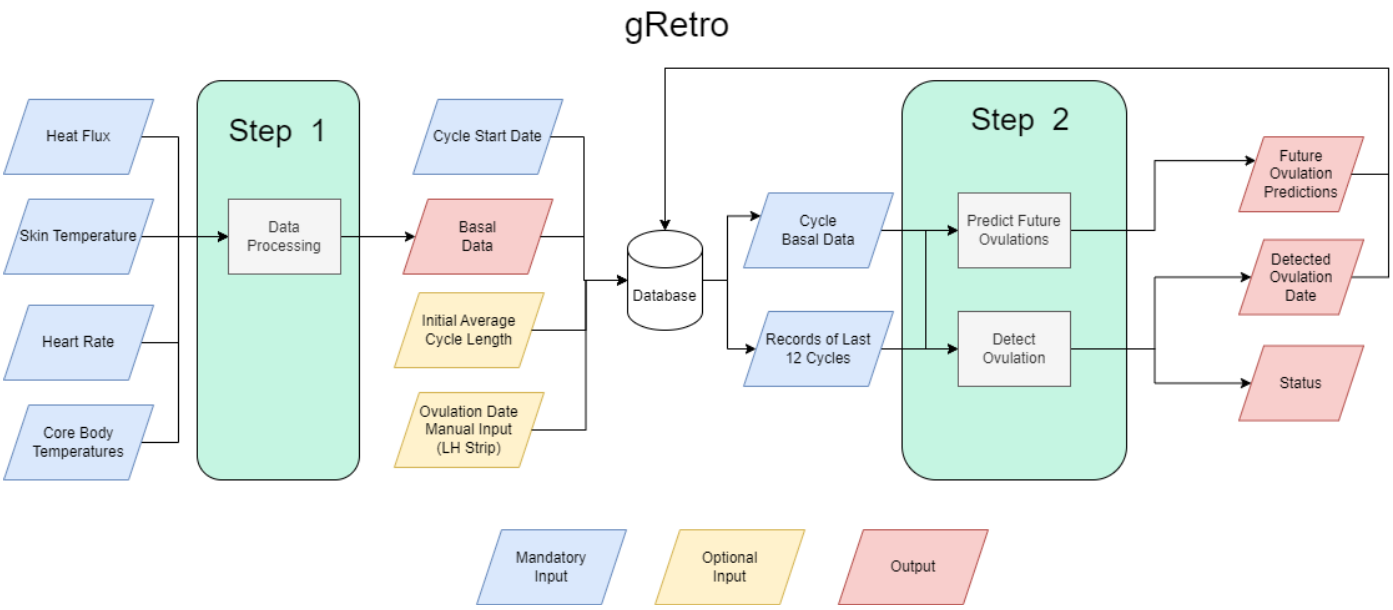
The system retrieves basal data and records from the previous 12 cycles from the database. This information feeds into two parallel analytical models:

- A basal-based ovulation detection model (identifies recent ovulation)
- A calendar-based prediction model (forecasts future cycles)

The outputs from both models are aggregated to produce:

- Predicted ovulation dates for the next 12 cycles
- The detected date of the most recent ovulation
- Status reports highlighting any issues

The predictions and detected ovulation are then stored back in the database



Input parameter requirements

Parameter	Sampling rate	Comments
Heat flux	Every 5 min 1 sample	
Skin temperature	Every 5min 1 sample	
Heart Rate	Every 5 min 1 sample	
Core body temperature	Every 5 min 1 sample	
Cycle start date	Once per cycle	Otherwise, will use the average cycle length to extrapolate
Initial average cycle length	During the installation of the app	Otherwise, 28 days will be considered
LH Strip positive days	Once per cycle	Optional to improve the accuracy
Cycle basal data	One value for every 24h	At least 9 values for the cycle, each value includes the basal core body temperature as well as the nominal heat flux, skin temperature and heart rate.
Records of the last 12 cycles	One record for each cycle	Each record consists of the cycle start and end date, the predicted date, detected date and if provided ovulation date based on LH strip

Output parameters

Parameter	Sampling rate	Comments
Basal data	Every 24h at 10am	Includes the basal core body temperature as well as the nominal heat flux, skin temperature and heart rate.
Detected ovulation date	Every Ovulation cycle 6 Days after temperature rise	
Future ovulation predictions	Every Ovulation cycle for the next 12 cycles	
Status	Status of the detection (see Section 6 for list of all statuses)	

Status

Status
Ovulation detected successfully
Too early to detect ovulation. No ovulation could be detected before day 9
Not enough basal data to detect ovulation. Data has been missing for more than 2 consecutive days.
Basal data are out of range
No ovulation detected

Accuracy

Accuracy of gRetro is evaluated on a large dataset with data from more than 4000 cycles by measuring the mean absolute error compared to the reference.

Cycle Type	Detection Accuracy (Days)	Prediction Accuracy (Days)
Regular	1.3	1.6
Irregular	1.7	1.8
Overall	1.4	1.7

Cloud/app requirements to run the algorithm

- Memory usage 2MB
- Database to store the user data

HSI wrist

Heat strain index

Datasheet v7.7 - 2024042

Features (which we enable)

- Overheating
- Heat training
- Heat load
- Heat pacing

Description

The Heat Strain Index is a patented algorithm that combines core body temperature and skin temperature to generate a value on a scale from 1 to 10, indicating the level of heat strain on the body. In addition, greenteg provides a lookup table that categorizes this index into four heat zones, ranging from "no heat strain" to "extremely high heat strain".

Process flow

The algorithm is delivered as a compiled library, designed to run directly on the microcontroller of the customer's device. It requires skin temperature and core body temperature as input parameters and outputs a Heat Strain Index value ranging from 1 to 10.

Input parameter requirements

Parameter	Sampling rate	Requirements
Core body temperature	0.3 - 1 Hz	LOA <0.8 °C /Correlation > 0.7
Skin temperature	0.3 - 1 Hz	Accuracy: < 0.2 °C

Output parameters

Parameter	Sampling rate	
Heat strain Index (1-10)	0.3 - 1 Hz	

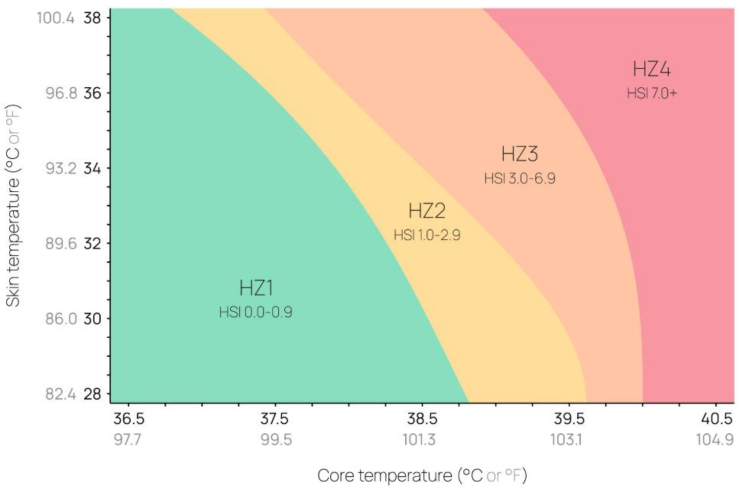
Requirement on the MCU

Ram	<1kB	
Memory	<1kb	

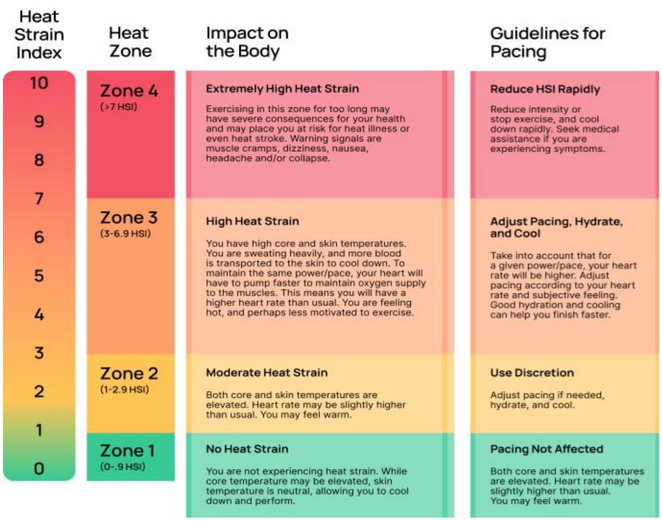
To compile the library for your micro controller, we need to know the exact Model number, your toolchain and the compiler flags you have set.

Data interpretation

The diagram below illustrates the correlation between skin and core body temperature, along with the definition of the four heat strain zones.



The meaning of each heat strain zone is explained in the table below.



Heat Strain Index	Heat Zone	Impact on the Body	Guidelines for Pacing
10 9 8 7	Zone 4 (>7 HSI)	**Extremely High Heat Strain** Exercising in this zone for too long may have severe consequences for your health and may place you at risk for heat illness or even heat stroke. Warning signals are muscle cramps, dizziness, nausea, headache and/or collapse.	**Reduce HSI Rapidly** Reduce intensity or stop exercise, and cool down rapidly. Seek medical assistance if you are experiencing symptoms.
6 5 4 3	Zone 3 (3-6.9 HSI)	**High Heat Strain** You have high core and skin temperatures. You are sweating heavily, and more blood is transported to the skin to cool down. To maintain the same power/pace, your heart will have to pump faster to maintain oxygen supply to the muscles. This means you will have a higher heart rate than usual. You are feeling hot, and perhaps less motivated to exercise.	**Adjust Pacing, Hydrate, and Cool** Take into account that for a given power/pace, your heart rate will be higher. Adjust pacing according to your heart rate and subjective feeling. Good hydration and cooling can help you finish faster.
2	Zone 2 (1-2.9 HSI)	**Moderate Heat Strain** Both core and skin temperatures are elevated. Heart rate may be slightly higher than usual. You may feel warm.	**Use Discretion** Adjust pacing if needed, hydrate, and cool.
1 0	Zone 1 (0-.9 HSI)	**No Heat Strain** You are not experiencing heat strain. While core temperature may be elevated, skin temperature is neutral, allowing you to cool down and perform.	**Pacing Not Affected** Both core and skin temperatures are elevated. Heart rate may be slightly higher than usual. You may feel warm.