Core Body Temperature Sensor Solution (CALERA®) for OEM Integration

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- 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 Osram, and a powerful algorithm that enables real-time core body temperature estimation. With minimal footprint and 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

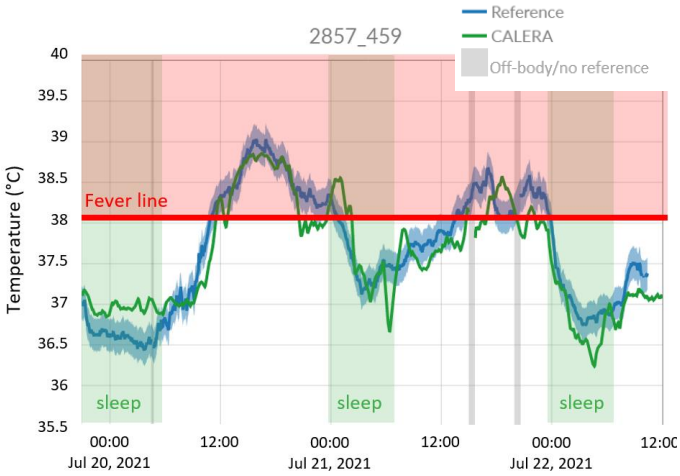


Figure 1: Validation of core body temperature sensor on the clavicula position compared to ePill

Measurement position

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

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. Nevertheless, 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 ultra-compact and with minimal requirements for power consumption.

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:

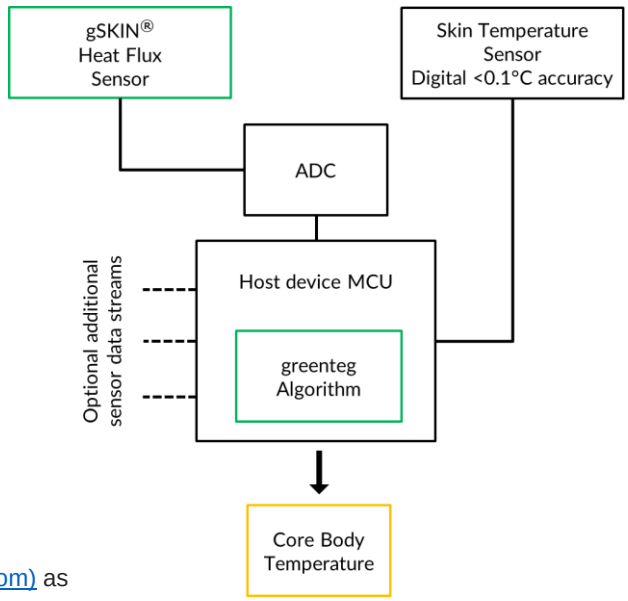
- Measurement position on the body
- Individual characteristics like skin type, hairiness, BMI, age, gender etc.
- Attachment method to the skin
- Occurrence of sweat (e.g., during sports)
- Thermo-physiological reactions to cold, fever or stress.

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

Hardware

The following electrical 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)



* Preferred sensor option, please review the datasheet ams AS6221 Temperature Sensor Temperature Sensors | ams OSRAM (ams-osram.com) as well as the announcement of the partnership between our companies: https://ams-osram.com/de/support/partner-network/partner-search/greenteg-ag

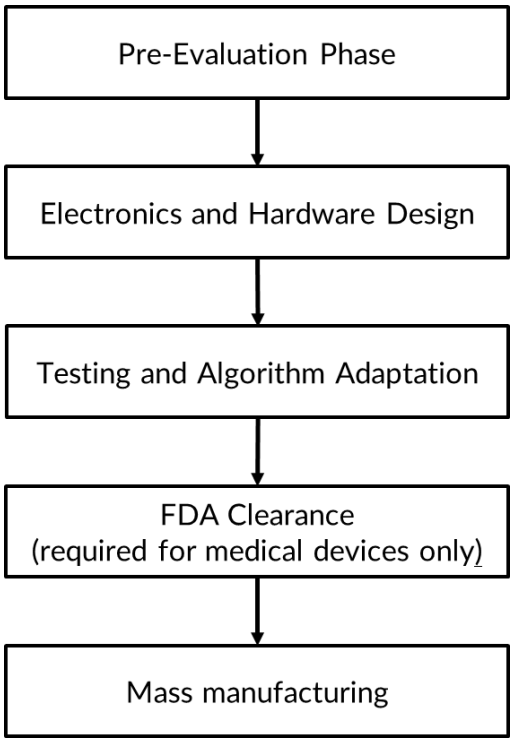
Measurement Position

The following body positions algorithms are available:

- Torso (apical, clavicular and sternum)
- Upper arm
- Wrist

Algorithms for chest, upper arm, and wrist positions were developed due to their convenience and thus enable the most reliable predictions of core body temperature. Additional positions like forehead would be 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.



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.

CONVINCE YOURSELF

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

Chest – Baby algorithm
Buy a CORE and ask us to update the firmware for you.

Upper arm – Free living / Fever algorithm
Buy a CORE and ask us to update the firmware for you.

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

Wrist – Fever
Contact us to get a quote or ask us to update the wrist prototype for the fever firmware.

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 10 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.

CONTACT

greenteg AG

Hofwisenstrasse 50A
8153 Rümlang
Zürich, Switzerland

+41 44 515 09 15

info@greenteg.com
www.greenteg.com

APPENDIX

gSKIN® XU SPECIFICATIONS

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

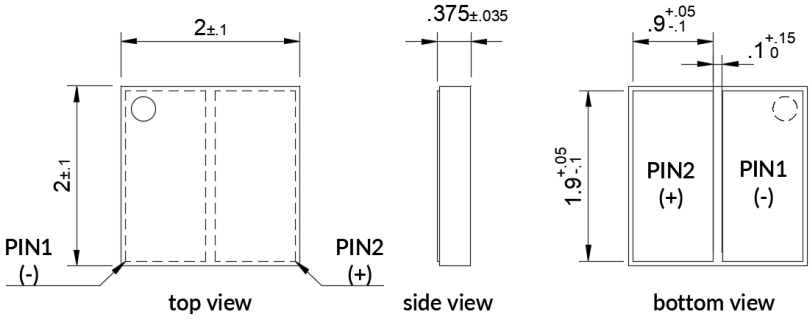
Parameter	gSKIN® XU	Unit
Detector Type	Thermoelectric – passive	-
Surface Material (Sensing Area)	Copper and polyimide	-
Sensing Area	2 x 2	mm
Sensor Thickness	0.4	mm
Absolute Thermal Resistance	~198	K/W
Electrical Connection	Bottom side SMD solder pads	-

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

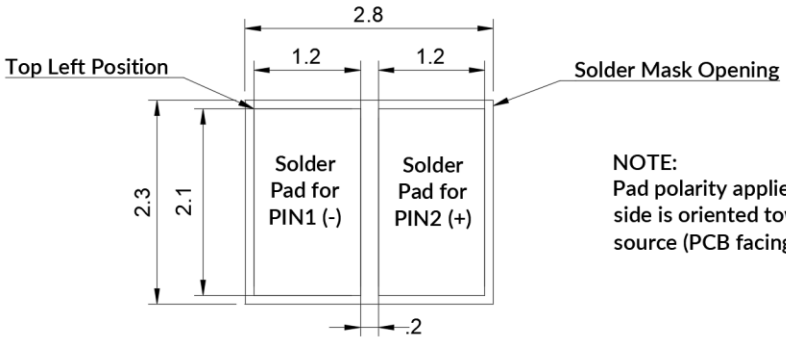
Parameter	Min	Max	Unit
Current at Any Pin	-10	10	mA
Storage Temperature Range	-50	80	°C
Operating Temperature Range	-50	150	°C
Heat Flux Range (Thermal Destruction Limit)	-150	150	kW/m^2
Compressive Clamping Force	-	0.5	Kgf

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.

ALGORITHM SPECIFICATION SHEETS

Chest model specification sheet

Algorithm name	Chest free-living/fever	Chest sport	Chest Baby
Measurement position	Apical / under clavicula	Apical	Apical
Use case	Daily life Circadian cycle Fever Ovulation	High intensity activity	The model is calibrated for babies from 2-24 month
Version	chestSC9823c208	X (only available via CORE as of now)	20211220_baby_chest_B0
Input data streams	T, HF	T, HF, HR	T, HF
Input data stream frequencies	T, HF: 1HZ	T, HF: 1 Hz HR: 1 per minute	T, HF: 1HZ
Accuracy* (°C) Bias (°C) LoA (°C) unbiased LoA (°C) Correlation MAE (°C)	 -0.003 -0.55/0.77 0.66 0.89 0.11	 -0.1 -0.62/+0.59 0.61 x x	 -0.05 -0.97/+0.88 0.93 0.68 0.37
Reference	https://doi.org/10.3390/s22134760	https://www.mdpi.com/1424-8220/21/17/5932	greenteg's chest baby validation study
Time for first value/high quality value	2min / ~15min	2min / ~15min	2min / ~15min
Outside temperature range	< 35 °C, > 5 °C	< 35 °C, > 5 °C	< 35 °C, > 5 °C
Flash Size (kb)	~20	~20	~20
RAM requirements	~4	~4	~4
Comments	Not suitable for heat stroke, clinical hypothermia, cold fever, persons with thermoregulatory problems.	The model was developed and validated for cycling and running. Not suitable for heat stroke, clinical hypothermia, 24h temperature tracking, fever	Not suitable for heat stroke, clinical hypothermia, cold fever, babies with thermoregulatory problems, prenatal babies.

*See references. 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.

Upper Arm model specification sheet

Algorithms name	Upper arm free-living/fever (no HR)	Upper arm free-living/fever (with HR)	Upper Arm sport
Measurement position	Upper Arm	Upper Arm	Upper Arm
Use case	Daily life Fever Circadian cycle	Daily life Fever Circadian cycle	Sport
Version	upperarmSC72f46898	upperarmSCHR72f46898	See chest sport
Input data streams	T, HF	T, HF, HR	
Input data stream frequencies	T, HF: 1 Hz	T, HF: 1 Hz HR: 1 per minute	
Accuracy* (°C) Bias (°C) LoA (°C) unbiased LoA (°C) Correlation MAE (°C)	 -0.05 -0.81 / + 0.91 0.86 0.63 0.34	 0.04 -0.87/+ 0.77 0.82 0.71 0.32	
Reference	greenteg's Upper-arm free-living /fever validation study	greenteg's Upper-arm free-living /fever validation study	
Time for first value/high quality value	2min / ~15min	2min / ~15min	
Environmental temperature	< 35 °C, > 5 °C	< 35 °C, > 5 °C	
Flash Size (kb)	~20	~20	
RAM requirements	~4	~4	
Comments	Not suitable for heat stroke, clinical hypothermia, cold fever, persons with thermoregulatory problems	Not suitable for heat stroke, clinical hypothermia, cold fever, persons with thermoregulatory problems, persons with any abnormal heartrate	

*See references. 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.

Wrist model specification sheet

Algorithms name	Wrist free-living	Wrist fever	Wrist sport
Measurement position	Wrist	Wrist	Wrist
Use case	Daily life Circadian cycle	Fever	High intensity activities
Version	wristSCHR72f46898	wristSCHR 99c64bfb	CBTAWristSCHRSportsLib
Input data streams	T, HF, HR, Acc	T, HF, HR, Acc	T, HF, HR, Acc
Input data stream frequencies	T, HF, Acc: 1 Hz HR: 1 per minute	T, HF, Acc: 1 Hz HR: 1 per minute	T, HF, HR, Acc: 1 Hz
Accuracy* (°C) Bias (°C) LoA (°C) unbiased LoA (°C) Correlation MAE (°C)	 -0.06 -0.53/+0.58 0.56 0.66 0.24	 0.11 -0.67 / + 0.93 0.82 0.72 0.34	 -0.02 -0.85/+0.82 0.84 0.80 0.34
Reference	greenteg's wrist free-living validation study	biomedcentral.com	greenteg's wrist sport model validation study
Time for first value/high quality value	2min / ~15min	2.5 h	2min / ~15min
Environmental temperature	< 35 °C, > 5 °C	< 35 °C, > 5 °C	< 35 °C, > 5 °C
Flash Size (kb)	~20	~60	~20
RAM requirements	~4	~24	~4
Comments	Not suitable for heat stroke, clinical hypothermia, any fever, persons with thermoregulatory problems, direct sun exposure	Not suitable for heat stroke, clinical hypothermia, cold fever, persons with thermoregulatory problems, direct sun exposure, daily life, elevated activity	The model was developed and validated for cycling and running. Not suitable for heat stroke, clinical hypothermia, 24h temperature tracking, fever

*See references. 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.