BodyPoweredSenSE RTD 2013

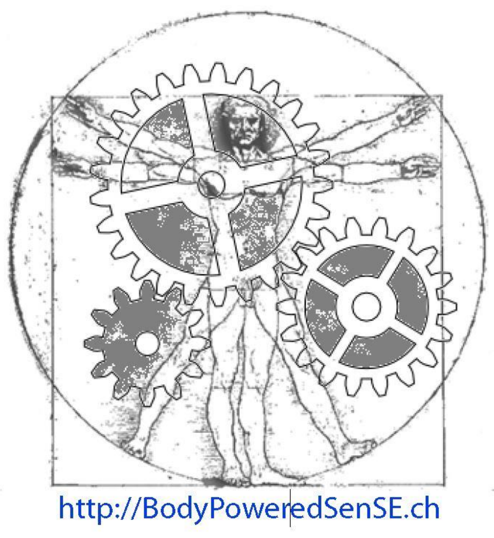
nano-tera.ch
swiss scientific initiative in health / security / environment systems

FNSNF

Thermoelectric Energy Harvesting for autonomous Body Sensor Networks

M. Thielen[1], P. Streit[1], M. Muoth[1], W. Glatz[2], C. Hierold[1]

[1]Micro and Nanosystems, ETHZ [2]greenTEG AG



http://BodyPoweredSenSE.ch

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE · ETH zürich · CHUV Centre hospitalier universitaire vaudois · KINDERSPITAL ZÜRICH · EXPLORIS · ByElement Solutions

BPS Project overview

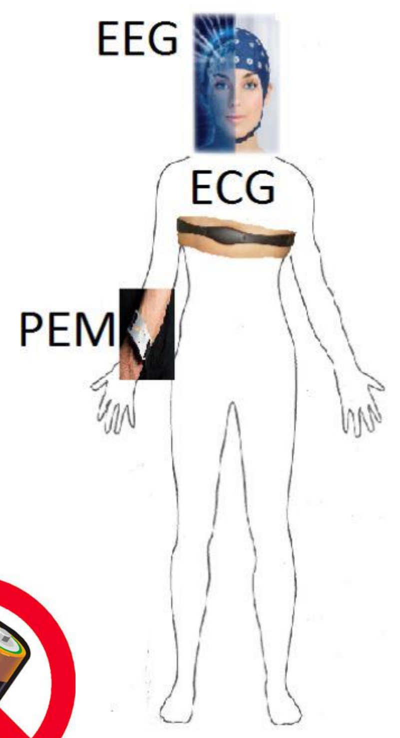
Goal: Energy autonomous body sensor network

System: A portable system monitoring ECG, EEG and the patient's environment (PEM)

Attributes: Unobtrusive, fit and forget, easy to use

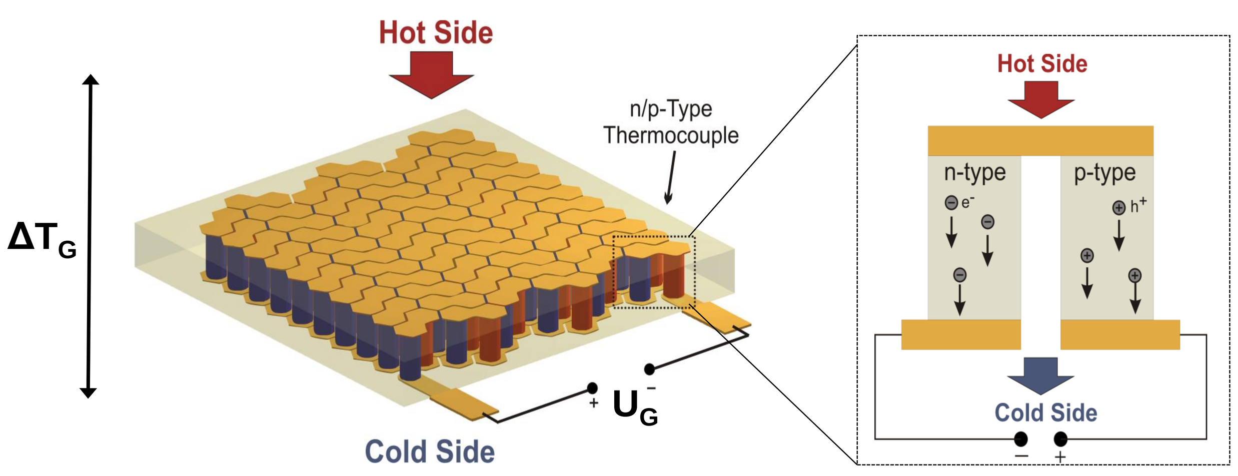
Application: Long-term monitoring for the
- Diagnosis of absence epilepsy in children
- Early detection of Alzheimer's in elderly

Zero-power paradigm:
Energy harvesting instead of batteries

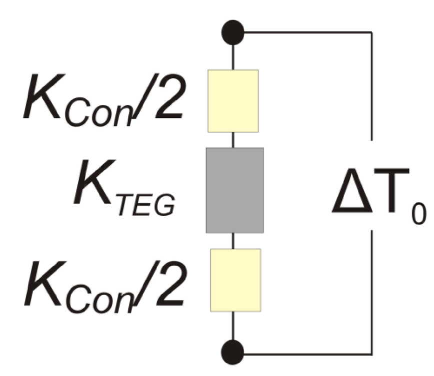


Thermoelectric generators (TEG)

Seebeck effect: Direct conversion of heat into electricity



Thermal resistance model:



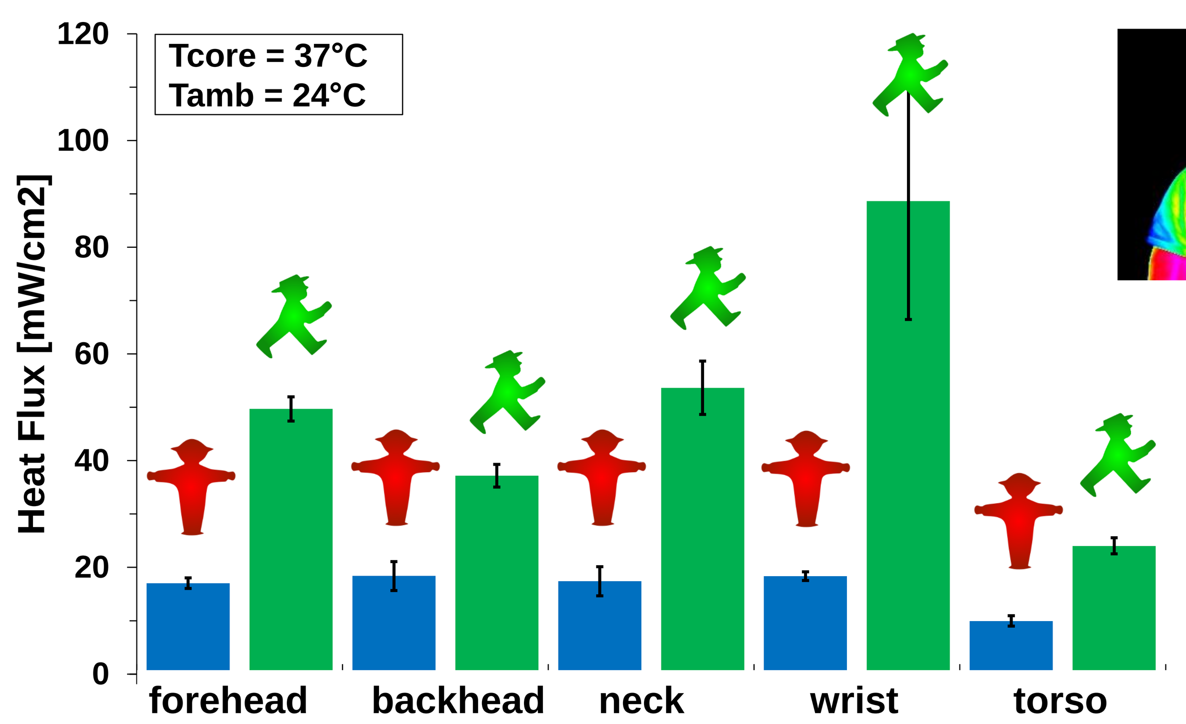
$$P_{TEG} = \frac{(m\alpha)^2}{4R_{El}} \bullet \left(\frac{K_{TEG}}{K_{TEG}+K_{Con}} \right)^2 \Delta T_0^2$$

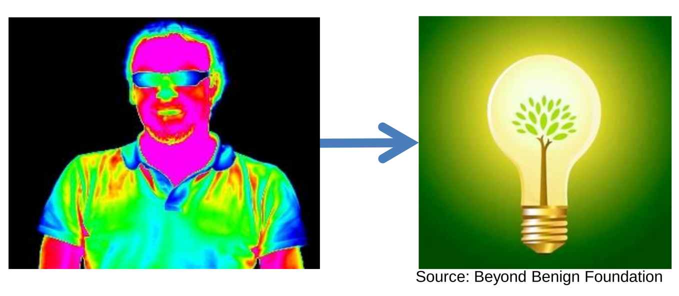
m = number of thermocouples
α = Seebeck coefficient
R_{El} = Electric resistance of the generator
K_{TEG} = Thermal resistance of generator
K_{Con} = Thermal contact resistance on hot and cold side
ΔT_0^2 = Temperature gradient from heat source to ambient

Advantages: Compact, robust, no moving parts, silent

Thermal harvesting from the human body

Harvesting potential: heat flux through skin





Sensor: greenTEG gSKIN®

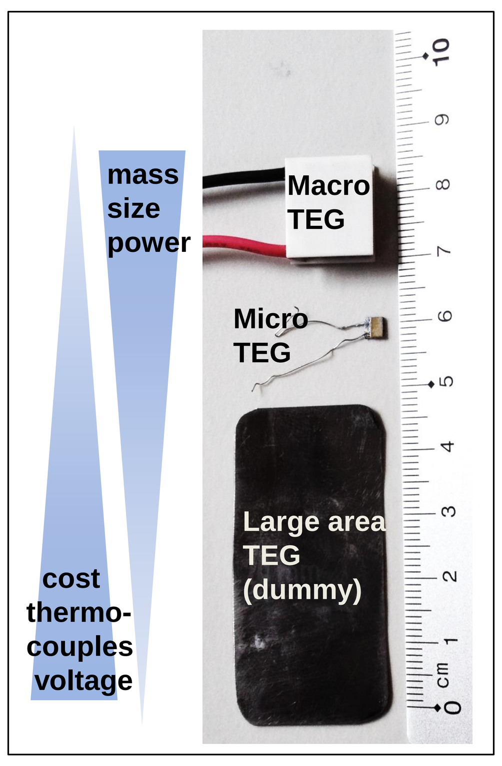
Challenges for the application on the human body
- Small temperature differences → **Generator optimization**
- High thermal resistance of the skin → **Optimized interfaces**
- Low generator voltages → **Integration with power conversion**
- Dynamic power output → **Integration with storage**
- Human centered design → **Size, weight, wearing comfort**

Contact: Moritz Thielen (thielenm@ethz.ch) www.micro.mavt.ethz.ch

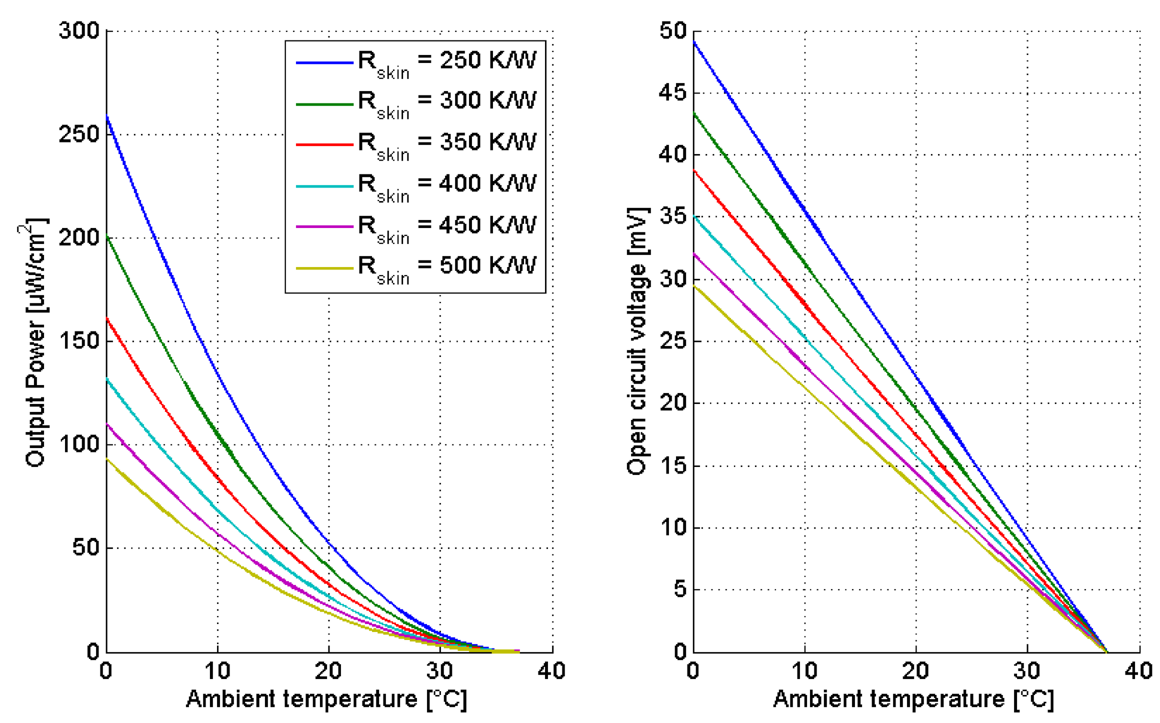
Simulation of output characteristics

Evaluation of different generator types (simulation)

Specification	Macro TEGs	Micro TEGs	Large area TEG
Open circuit voltage (mV)	10 - 17	32 - 75	200 - 240
Output resistance (Ω)	1	200	5000
Expected power (µW)	25 - 72	1.3 – 7.0	2 – 3.1
Power per area (µW/cm2)	11 - 32	3.4 – 14.3	0.4 – 0.6
Size (mm)	15 x 15 x 3	7 x 7 x 1	15 x 35 x 1
Weight (g)	~ 5-10	< 1	~ 5
Cost (CHF)	10 – 80	100 – 150	not available yet
Flexible	no	no	yes
Evaluation for BPS requirements	Good for general power generation	Interesting for active electrode	Not well suited for application



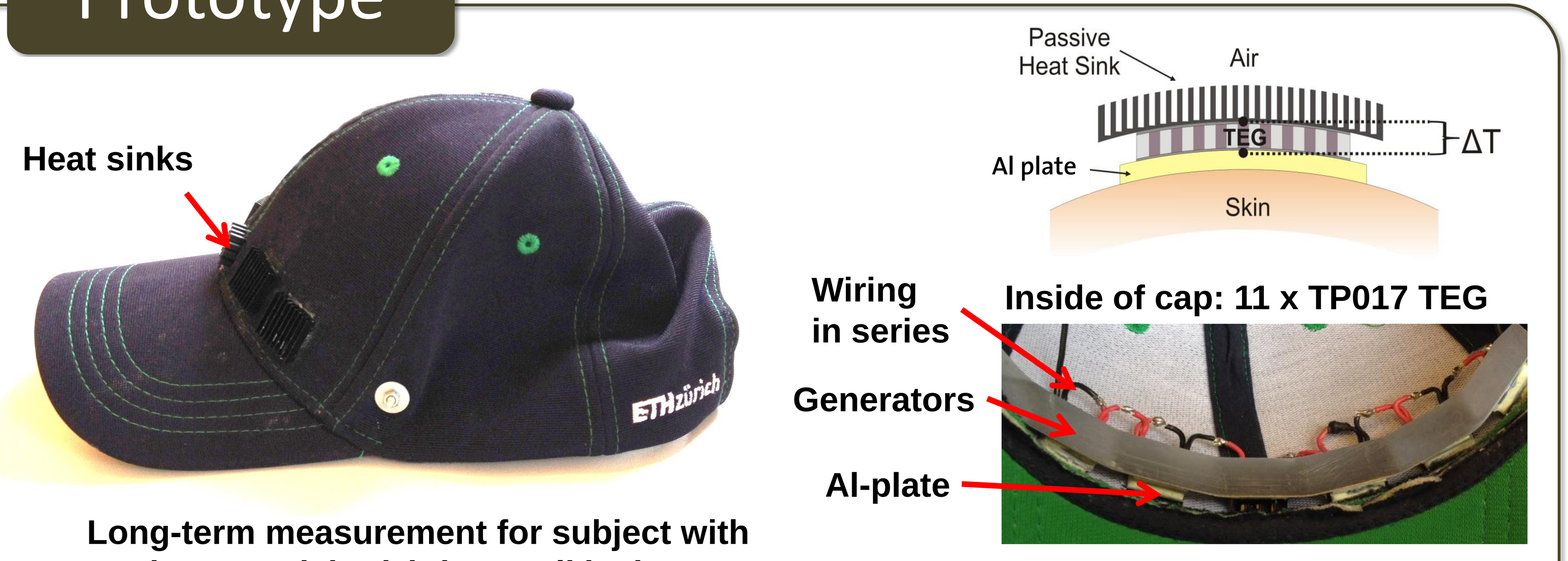
Simulated output of commercial macro TEG on skin at different ambient temperatures



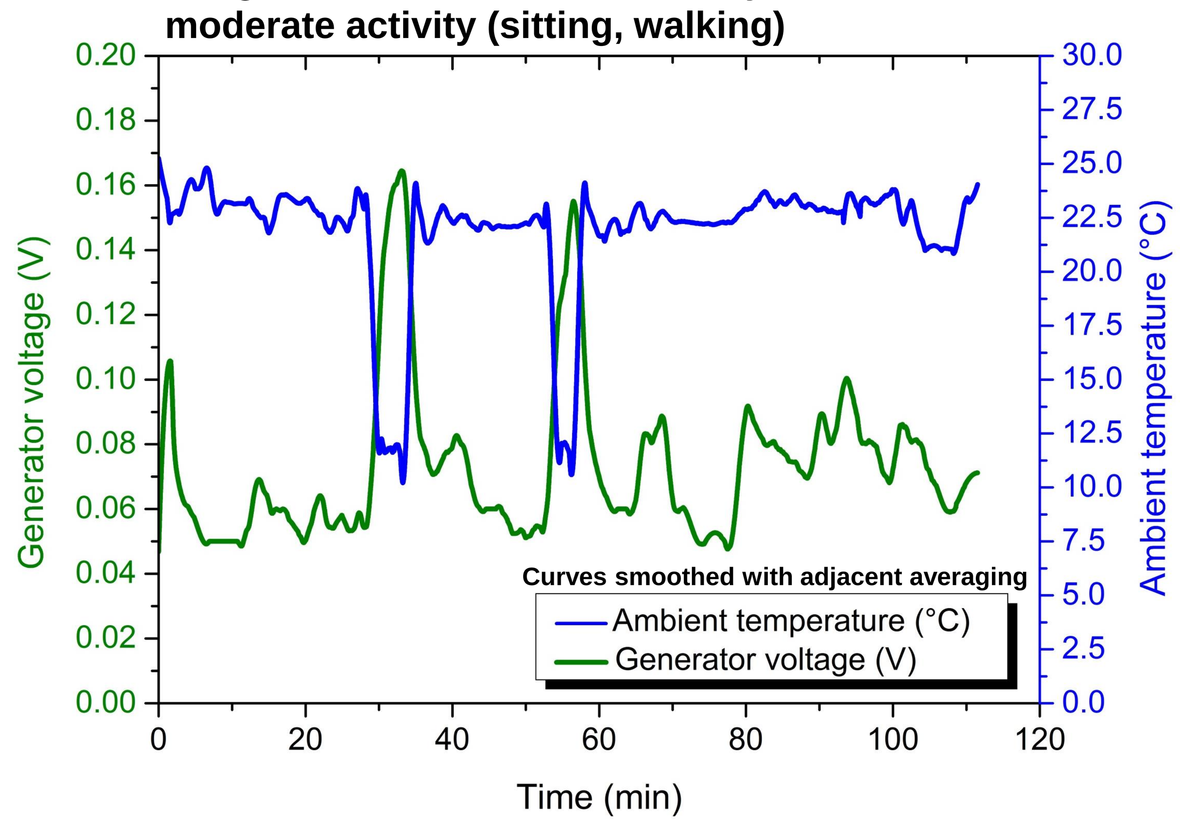
Generator specifications
Model : **TP017, 2 stack**
LxBxH : **15x15x7 mm**
Weight : **18 g**
R_{therm} : **59 K/W**
Rel : **0.46 Ohm + wiring**
R_{HS} : **21 K/W**

Approach
Several low electrical resistivity generators in series
→ Increased thermal contact area

Prototype



Long-term measurement for subject with moderate activity (sitting, walking)



Specifications
Location : Forehead
Area covered : 20 cm²
Weight : 100 g
Thermocouple : 187
R_{el} : 2.6 Ohm + wiring

Meas. time	2	h
Ave. voltage	74	mV
Max. voltage	170	mV
Min. voltage	40	mV
Ave. power	0.53	mW
Max. power	2.78	mW
Min. power	0.15	mW

Power calculated for ideal electrical matching of generator and load resistor

Findings and outlook

Highlights
- Power generation in the mW regime from human body heat
- Compact systems that can be comfortably worn for several hours

Outlook
- Decreased size and weight while retaining output power
- Energy autonomous EEG electrodes with integrated thermoelectric harvesting