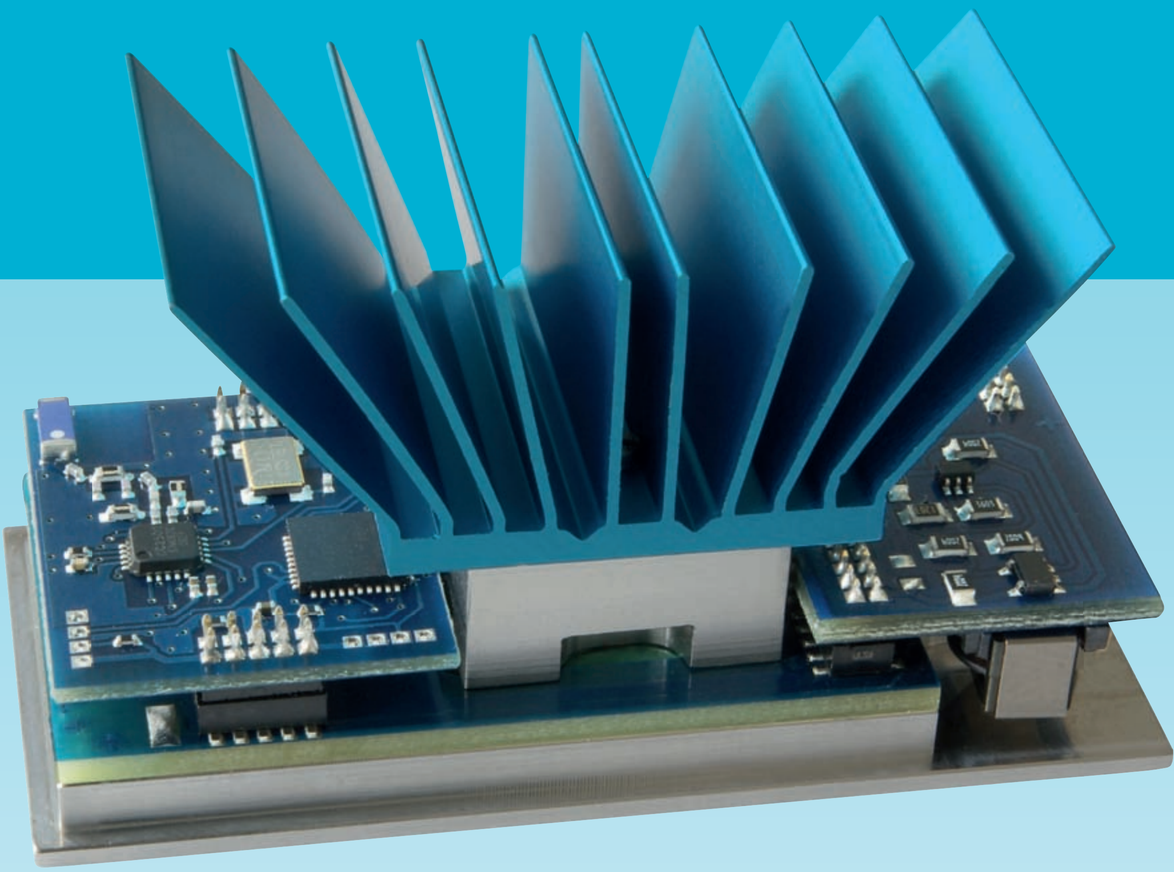
TE-Power NODE

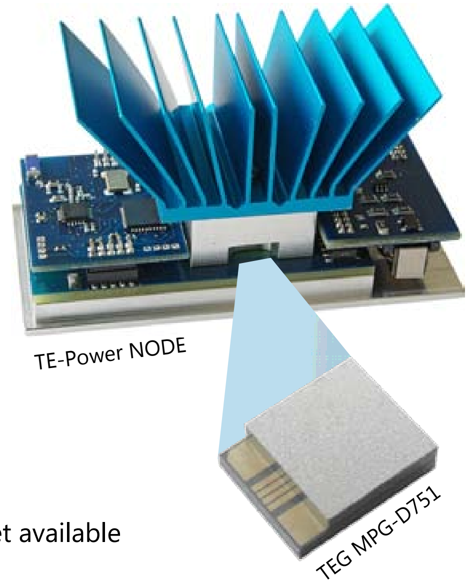
Self-Sufficient
Wireless Sensor System
Thermoharvesting Explorer



micropelt
Power generation.

1. General Description

Micropelt's energy harvesting technology is capable of replacing a battery-based energy supply with infinite thermoharvesting that feeds on local excess heat. Benefits of this type of power supply are: High reliability and low environmental impact through the absence of battery chemistry, virtually service-free operation, true wireless installation.

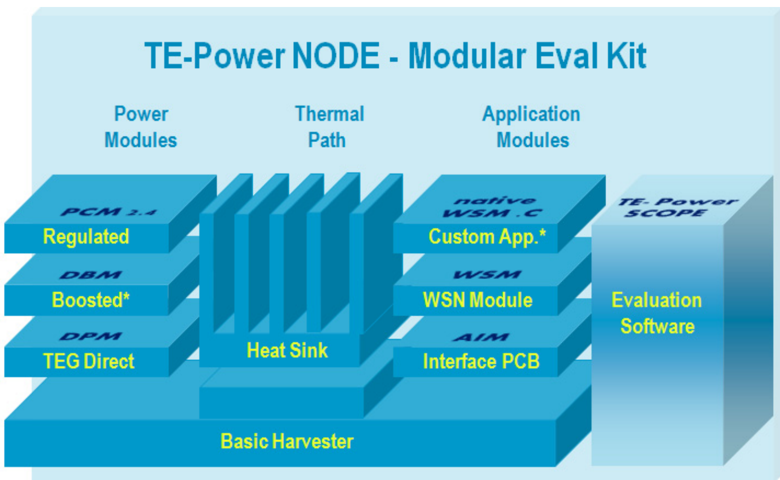


Gross ΔT [°C] (ambient to heat source)	mAh per year	Equivalent number of AA type batteries
35	3,628	2-4
75	21,207	11-20

Micropelt offers various evaluation kits to help determine the power budget available through thermoharvesting:

Evaluation Kit Overview		Plug-On Modules *					Other *	
Evaluation Kit Overview	Description	Direct Power Module **DPM**	DC Booster Module **DBM**	Power Conditioning Module **PCM**	Application Interface Module **AIM**	Wireless Sensor Module **WSM**	USB Radio Receiver	TE-Power SCOPE
TE-Power NODE (this document)	Wireless 2,4 GHZ temp. sensing system with power management	√		√	√	√	√	√
TE-Power PLUS	DC-boosted variable output voltage (1.6 - 5.0 V)	√	√					
TE-Power ONE	Direct TEG output power with temp. sensor	√						

* individual modules available on request



The TE-Power NODE kit consists of an aluminum heat spreader (63 x 30mm, 2.48" x 1.18") that carries one MPG-D751 thermoelectric generator (TEG). The DC Booster Module converts the thermo-voltage from the generator to 2.4 V, buffered by a 100 µF reservoir capacitor. This in turn supplies the Wireless Sensor Module which is based on Texas Instrument's (TI) ultra-low power technology.
A temperature difference as little as 10 °C of 'gross' ΔT between target surface and ambient air is sufficient for the TE-Power NODE to transmit 13 bytes worth of information once every second. A computer reads the data through a USB radio receiver. On the PC, the TE-Power SCOPE application software provides a convenient user interface which clearly informs about harvesting results. The software displays current temperatures and voltages. Beyond this it is capable of simulating the charge and subsequent discharge of an energy reservoir.

1.1 Features & Benefits of the TE-Power NODE Kit

- High voltage micro-thermogenerator MPG-D751 with best thermo-electric efficiency starting from low DT
- Modular layout for flexible exploration of all harvesting dimensions and remote system aspects
- Wireless module with additional digital sensor interfaces and re-programming option
- Wireless operation facilitates fast and flexible temperature exploration and power budgeting
- TE-Power SCOPE evaluation software for quick and easy assessment and simulation
- Optional add-on modules facilitate test-driving of target application

1.2 Applications

- Wireless Sensor Networks (WSN)
- Industrial Process Monitoring
- Condition Monitoring
- Intelligent Data Loggers
- Automated Meter Reading (AMR)
- Building Automation and HVAC
- Energy Monitoring and Control
- Triggering & Powerless Switching

2. System Overview

2.1 Kit Components

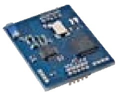


Fig. 1b - **USB Radio Receiver** catches transmissions of Wireless Sensor Module

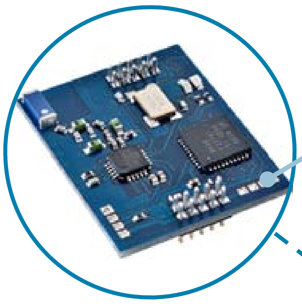


Fig. 1a - 2.4 GHz **Wireless Sensor Module**; incl. *TI* MCU *MSP430F2274* and radio *CC2500*. Auxiliary I²C digital inputs and programming interfaces on-board.

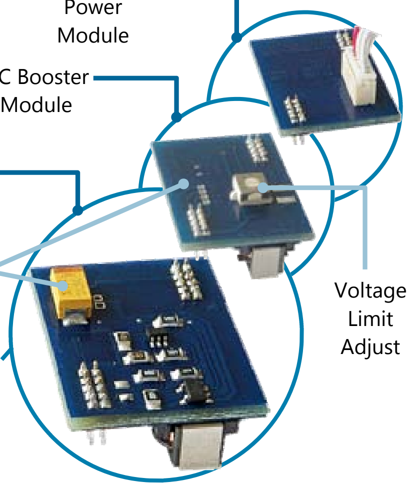
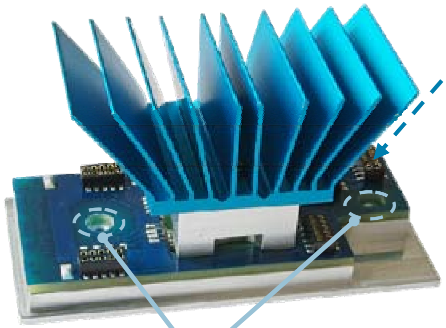


Fig. 2 - **Power Modules**

- Direct Power: TEG direct output & ΔT sensing
- DC Booster: 1.6 ... 5 V
- Power Conditioning: 2.4 V



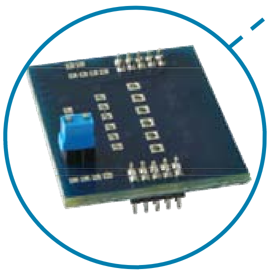


Fig. 3 - **Application Interface Module** links custom applications to the TE-Power Base assembly

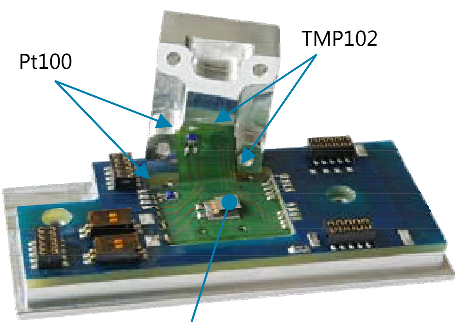


Fig. 4 - **MPG-D751** thermoelectric generator chip mounted on Al heat spreader along with digital TMP102 and analog Pt100 temperature sensors.

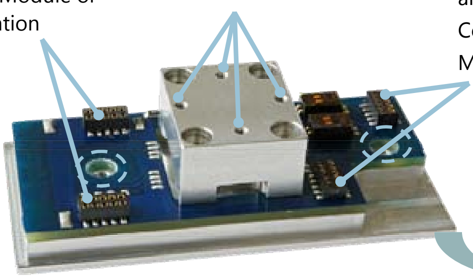


Fig. 5 - **TE-Power Base** assembly with heatsink adaptor and routing PCB. Module interfaces and TEG polarity-inverting DIP switches.

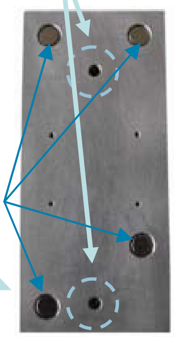
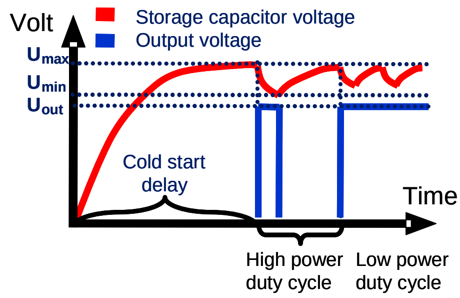


Fig. 6 - Bottom of TE-Power Base assembly with permanent magnets and tapped mounting holes for easy attachment to surfaces and adaptors.

2.2 Power Output & Conditioning



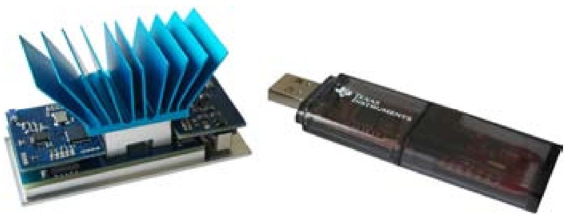
Energy harvesting using a thermoelectric generator (TEG) is ideal for low duty cycle applications. The raw TEG output is converted to a constant voltage which directly supplies the system's sleep power consumption. Surplus power is stored in a capacitor or rechargeable battery for use during the load's active cycle. The following power supply modules are compatible with the TE-Power NODE:

Level 1: Direct Power Module for external power conditioning.
TEG output voltage increases with ΔT. Module is part of kit.

Level 2: Voltage-adjustable (1.6 .. 5 V) DC Booster Module for external power conditioning. Not part of kit.

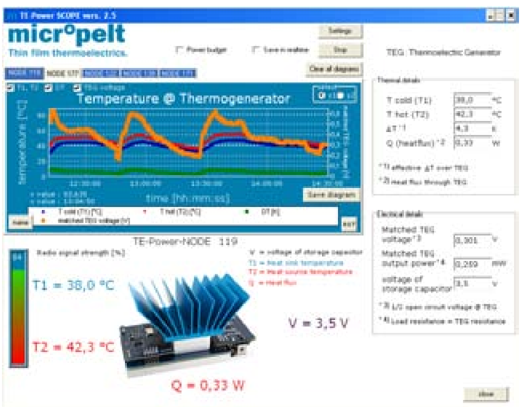
Level 3: Voltage-regulated (2.4 V) Power Conditioning Module for direct supply of application. Fitted by default.

2.3 Wireless Sensor Module



The pluggable Wireless Sensor Module is built around TI's MSP430 ultra-low power microcontroller (MCU) and a TI CC2500 2.4 GHz transceiver chip. Two digital temperature sensors are connected to the MCU's I²C interface. They are mounted close to the thermogenerator's hot and cold side, sensing the so-called "net ΔT' across the TEG chip. Two more I²C-compatible sensors may be connected. A TI ez430-RF2500 USB receiver links to a computer running the TE-Power SCOPE graphical user interface software . Data transmission is governed by TI's 'Simplicity' protocol stack, set up as unidirectional star network. Unique transmitter address for each TE-Power NODE ensure proper data allocation. A transmission time <1 ms avoids data collision in multi-NODE environments.

2.4 TE-Power SCOPE Graphical User Interface



TE-Power SCOPE receives and presents the samples transmitted by the TE-Power NODE on a one-per-second basis:

- Temperature, hot side of thermogenerator
- Temperature, cold side of thermogenerator
- Supply voltage before regulation

Several other values are derived from the above measurements:

- Effective temperature difference (net ΔT)
- Heat flux through harvester
- Gross harvesting power
- Net harvesting power
- Capacitor/battery charge current
- Charge progress indicator
- Charge level
- Energy balance

When load parameters* of a target application are specified, TE-Power SCOPE calculates average power and net energy balance.

* sleep / active power consumption, duty cycle terms

3. Electrical Parameters

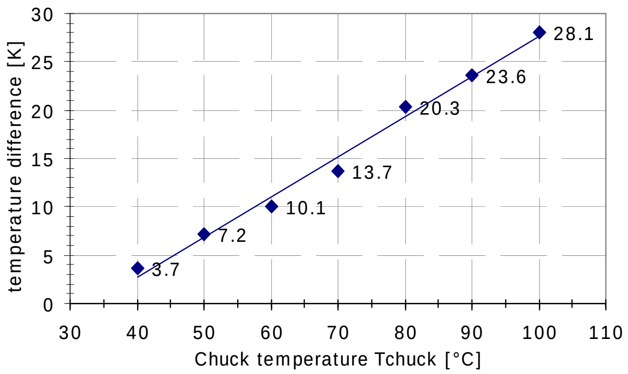
Test Conditions:
Natural convection, vertically mounted (Fig. B1, page 8), no airflow (lab environment)

typical thermoelectric characteristics of the assembly before DC boosting

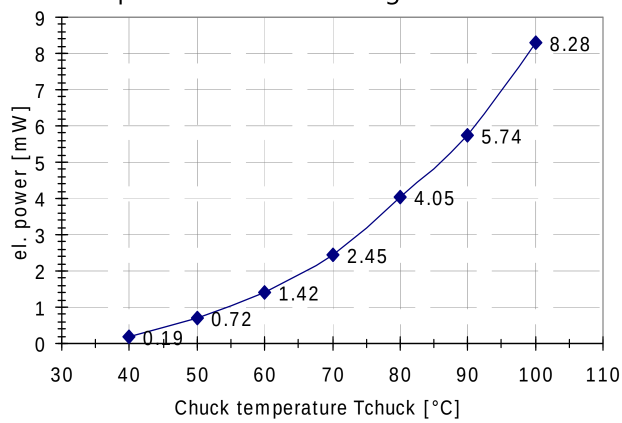
Tchuck* [°C]	Net ΔT [°C] across TEG	TEG open circuit voltage [V]	TEG power at load matching [mW]
40	3,7	0,6	0,2
50	7,2	1,2	0,7
60	10,1	1,7	1,4
70	13,7	2,3	2,5
80	20,3	2,9	4,1
90	23,6	3,6	5,7
100	28,1	4,3	8,3

* Tchuck = temperature of heat source

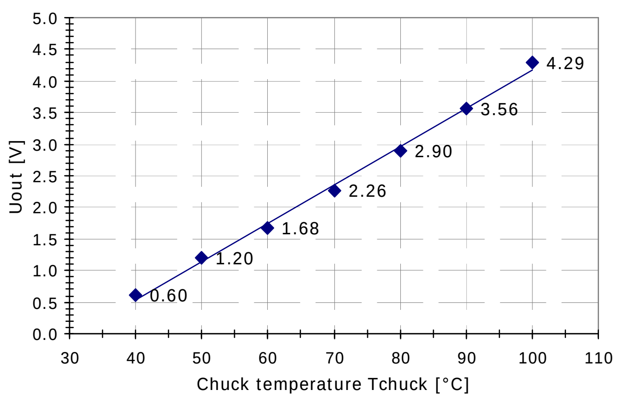
temperature difference (ΔT) across MPG-D751



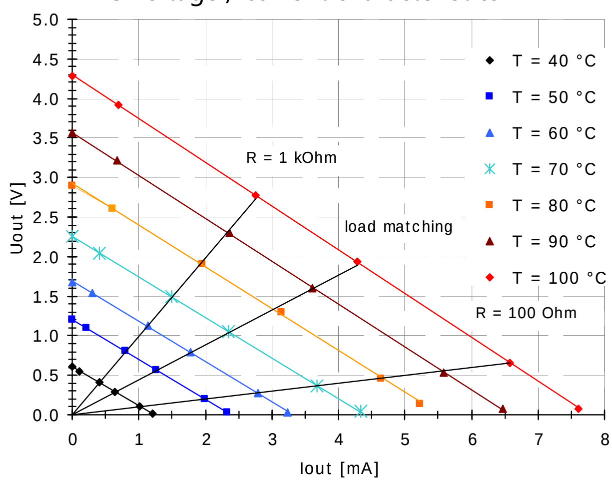
TEG power at load-matching



TEG open-circuit voltage ($R_L = \infty$)



TEG voltage / current characteristics



4. Application of the TE-Power NODE

4.1 Attaching the Assembly to a Harvesting Target

Attachment of a thermoharvester to its target heat source is a critical factor in any application. The TE-Power NODE helps to explore the effects of mounting pressure, surface flatness / roughness and various thermal interfaces materials on the harvesting result. The base of the assembly attaches to the target either through magnetic force or through 2 tapped mounting holes (M2.6).

4.2 Heatsink Positioning and Orientation

Both positioning and orientation of the TE-Power NODE are of major importance for the power yield, particularly when the power density of the heat source is low. The alignment of the heatsink fins relative to the heat source and the direction of natural convection deserves special attention. To help optimize this, the heatsink adaptor has been designed so that the heatsink can be removed and then re-attached perpendicular to its default orientation. Note that it is thermally inefficient to place the TE-Power NODE horizontally on top of a heat source (figure A) where hot air warms the heat-sink. This reduces the effective temperature difference across the thermogenerator thus lowering the thermovoltage and consequently the TEG's power output. A forced air flow over the heatsink instead maximizes power, regardless of position and orientation.

4.3 Radiation Suppression

Hot surfaces radiate in the infrared spectrum. This can cause the TE-Power NODE's heatsink to heat up, diminishing effective ΔT and thus the power output of the device. In such cases it may be helpful to cover the hot surface near the TE-Power NODE such that radiation is inhibited. Alternatively, a block of thermally conductive material may be used to increase the distance between radiating surface and heatsink, thereby improving natural convection.

Convection Stream

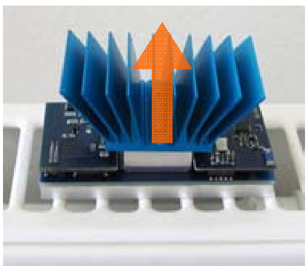


Figure A: Inferior positioning

TE-Power NODE mounted on top of the heat source, surrounded by a bubble of warm air warming the heatsink. This arrangement yields low ΔT and low power output.

Figure B1: Preferred positioning

TE-Power NODE mounted on a vertical surface with the heatsink fins aligned horizontally. Results in acceptable performance.

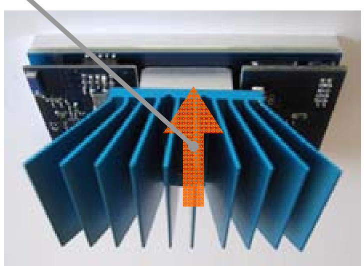


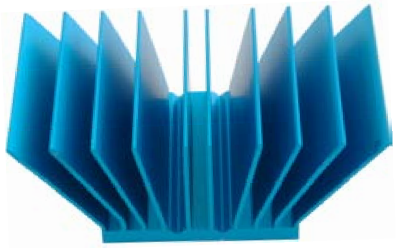
Figure B2: Ideal positioning

TE-Power NODE mounted on a vertical surface with the heatsink fins aligned vertically. This is best supporting natural convection and results in the highest possible ΔT and power output.

4.4 Thermal Path Optimization

The standard heatsink of the TE-Power NODE is a compromise between physical size and thermal performance. The heatsink is a stock part, selected for superior performance with lower temperature gradients. For high temperature gradients, the heatsink should be verified.

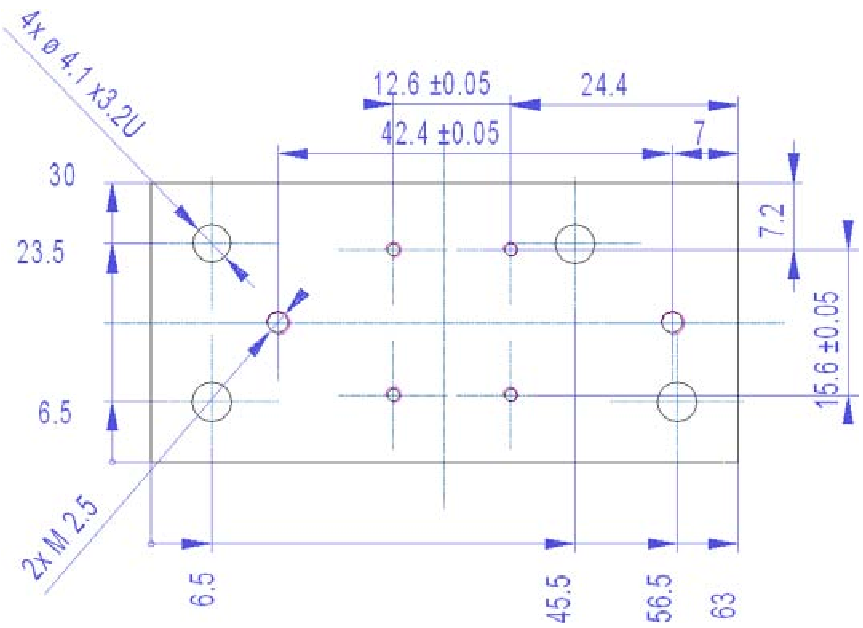
Different applications ask for different heatsink designs, so the TE-Power NODE features an aluminum adaptor for easy attachment of alternative heatsinks. This allows for thorough and comprehensive exploration of the thermal path under varying thermal conditions. A more suitable heatsink will, under otherwise identical conditions, stay cooler. Both the cold side temperature shown by the TE-Power SCOPE software and the power yield of the TEG will reflect this.



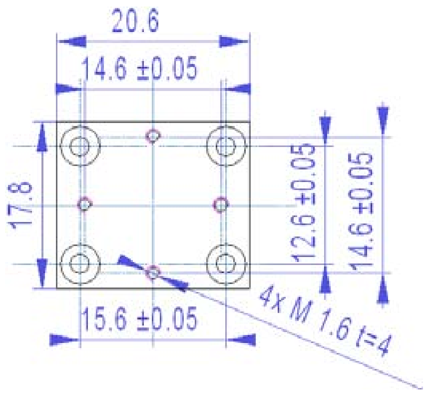
Finned heatsink for low heat flux under natural convection

5. Dimensions of Heat Spreader and Heatsink Adaptor

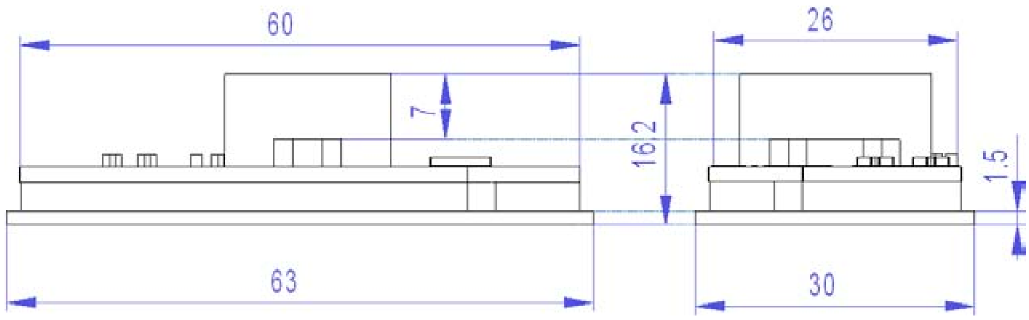
Heat spreader, bottom view (dimensions in mm)



Heatsink adaptor, top view (dimensions in mm)



Heatsink adaptor mounted on heat spreader, side view (dimensions in mm)



6. Technical Data

	Parameter	Value
General	Max. operating temperature	
	hot side	105°C
	ambient air	85°C
Thermal Path	Thermogenerator	MPG-D751
	Footprint	3.3 x 4.2 mm
	Thermovoltage	140 mV/K
	Thermal resistance	12.5 K/W
	Heatsink adaptor	
	Mounting face	20.6 x 17.8 mm
	Heatsink attachment	4x M1.6 x 4 mm tapped blind hole
	Heatsink (standard blue fin type)	ATS-50270P-C2-R0, Advanced Thermal Solutions Inc
	Thermal resistance	approx. 31 K/W under natural convection
	Mounting holes	2x 1.8 mm through hole
Power Modules	Power Conditioning Module	
	Max. operating temperature	105°C
	Output voltage	2.4 V fixed, regulated
	Storage capacitor	100 µF
	Capacitor extension interface	Through hole for solder connection
	DC Booster Module	
	Max. operating temperature	105°C
	Output voltage	1.6 ... 5 V adjustable, regulated
	Capacitor extension interface	Through hole for solder connection
	Direct Power Module	
	Max.. operating temperature	105°C
	Connector signals:	6 wires, open end
	TEG cold side temperature pins 1-2	Pt100 sensor
	TEG hot side temperature, pins 3-4	Pt100 sensor
	TEG voltage output, pins 5-6	ΔT x thermovoltage (140 mV/K)
Wireless Module	Wireless Sensor Module	
	Max. operating temperature	105°C
	System supply voltage	2.4 V DC
	Microcontroller	TI MSP 430-F2274
	Wireless device	TI CC2500
	Digital sensor interface	I^2C, 4 channels, thereof 2 unused
	Programming interface	TI ByWire
	Wireless USB receiver	TI EZ430-F2500
	Wireless protocol stack	Proprietary / TI Simplicity
	Topology	Unidirectional star network
	Payload	10 byte
	Active cycle (collect, compute, transmit)	2 ms
	Signal acquisition:	
	Temperature, hot side & cold side	2x TI TMP102 on I^2C
	2x user signal	2x I^2C (unused)
	System voltage	MSP430 internal
Custom Applications	Application Interface Module	
	Supply voltage	2.4 V or 1.6 ... 5 V, depending on power module
Dimensions	Base / heat spreader W x L	30 mm x 63 mm
	Total height incl. standard heatsink	33.6 mm
	Height with heatsink adaptor only	16.2 mm
	Weight TE-Power NODE with 2 plug-on modules	49 g

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