

ECT 310 – POWERING FROM TEMPERATURE DIFFERENCE

New DC/DC converter to operate batteryless wireless modules

Temperature differences contain a lot of energy. Just the cooling of a drop of water by 1 degree Celsius releases energy for about 20,000 EnOcean wireless telegrams. That is enough to operate not just a wireless sensor but even a number of wireless actuators. The energy is delivered by thermo generators.

By Armin Anders, Co-founder and VP Product Management, EnOcean GmbH

In 2003 EnOcean went to market with its first series of energy harvesting wireless products. These were powered by energy produced by motion or from the sun. Last year saw the launch of the third generation, the Dolphin system architecture, integrating a miniaturized chip to enable bidirectional and energy-autonomous wireless devices. The new possibility of operating sensors from differences in temperature is of special interest for a whole number of applications: in heating, ventilation and air-conditioning, in process automation, vehicles and even on the human body. Virtually all tanks and piping that carry fluids or gases have at least temporary differences in temperature from their surroundings, for example. But why did EnOcean wait so long before going to market with a generator that allows energy to be harvested in this way?



Fig. 1: ECT 310 DC/DC converter - works on as little as 20 mV, corresponding to 2°K temperature difference

BASIC PRINCIPLE OF ECT 310

The answer is simple – energy harvesting must be cost-attractive. You find inexpensive standard thermoelectric elements in cooler boxes for instance, where the contents are cooled by current. EnOcean reverses the effect: the cool contents feed energy to a sensor. But such low-cost Peltier elements have a pronounced drawback, namely that they only produce very small voltages of about 10 mV per degree Kelvin. Electronic circuitry connected to this, an EnOcean sensor module for example, needs a typical supply voltage of 3 V. An entirely new kind of converter concept had to be invented and readied for production in series: EnOcean's ECT 310 DC/DC converter, an optimized oscillator that

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already starts to resonate upwards of 10 mV input voltage. On 20 mV or more (i.e. about 2 °C) a useful output voltage of more than 3 V is produced. To enable this exceptionally high converter efficiency of 30%, the output voltage is only roughly regulated to less than 5 V over the entire input voltage range up to 500 mV. This is no problem for connected EnOcean modules because they are accustomed to working on unregulated supply voltage such as that from solar cells. A central component of the ECT 310 is the coil seen in Fig. 1, a transformer with high gain of 1:100. The dimensions of the ECT module in surface-mount technology are 16 x 16 x 5 mm.

Output of ECT310 versus Input

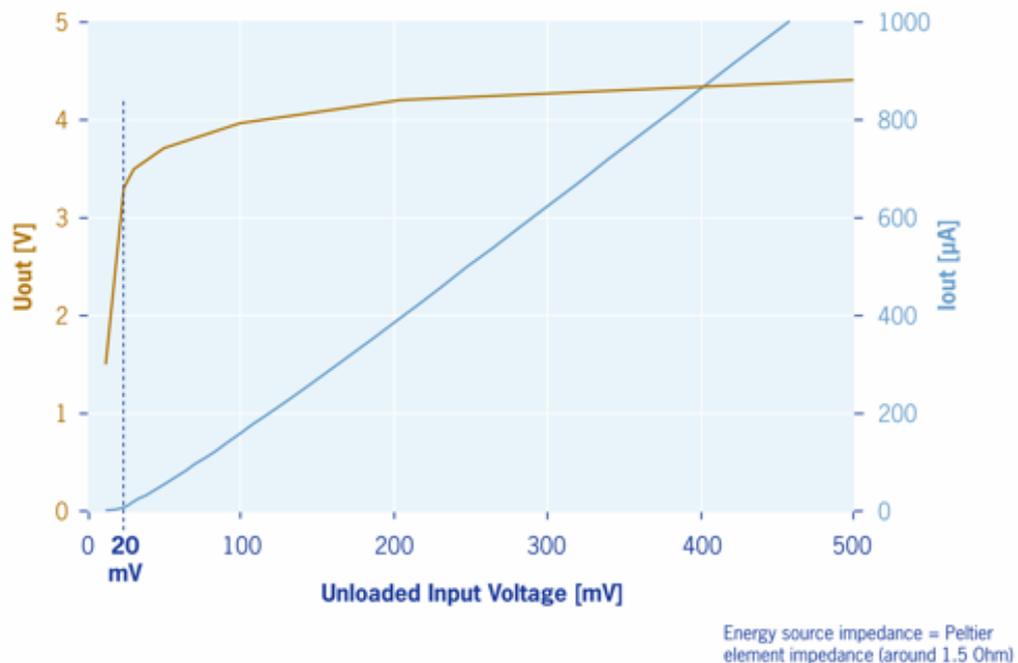


Fig. 2: ECT 310 output voltage versus input voltage

THERMALLY POWERED SENSOR – ECT 310 WITH STM 312

Fig. 3 illustrates a prototype of an energy-autonomous sensor for air flow temperature. In the wall of the tube is a Peltier element consisting of two square ceramic wafers with edge length of 15 mm and 4 mm apart. Attached between them are special semiconductor junctions. The inside is brought up to air flow temperature through a thin copper film, a heatsink on the outside creates a difference in temperature from the second ceramic wafer. The air flow temperature inside the tube thus causes the Peltier voltage to power the sensor. This is quite simple in structure (Fig. 4), based on the all-in-one STM 312 wireless sensor module.

The STM 310 family enables highly compact design of a modular energy-autonomous wireless sensor. Attached to the rear is either the ECT 310 converter or a solar cell. Variants are flexible with a whip or helical antenna, operating on 868 MHz (Europe) or 315 MHz (in the USA, Japan, China). Ready integrated in the all-in-one module is energy storage and energy management for a typical duration of four days without energy input.

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Three analog (e.g. 10/8/6 bits) and three digital measuring inputs are implemented on a connector. The module additionally features a processor for data processing including a software stack for the wireless protocol (equipment profile of EEP 2.0 specification), and predefined firmware that the user can reprogram for a specific application, to preprocess sensor data for instance.

What is important is that the energy supply is fully isolated from the sensor circuitry. In other words powering is by temperature but entirely different process variables can be measured such as pressure or humidity.



Fig. 3: Energy-autonomous sensor for air flow temperature

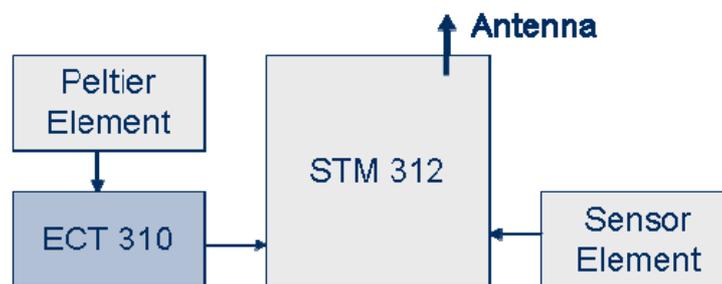


Fig. 4: Block diagram of thermally powered wireless sensor

THERMALLY POWERED ACTUATOR – ECT 310 WITH STM 300

Fig. 5 shows the output power of the thermal generator as a function of temperature difference. Two curves are plotted; the yellow curve is the temperature difference directly on the Peltier element, while the blue one indicates the difference from the temperature of the surroundings. Seeing as a heatsink represents a thermal transfer resistance and thus loss of energy, the blue curve is below the first one. It is possible to read, for example, that

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even when using a heatsink, approximately 100 μW of energy is already produced for a temperature difference of only 7 $^{\circ}\text{C}$. A typical EnOcean wireless module that is waked every two minutes to send a telegram needs about 5 μW . The remaining 95 μW is enough to power a number of actuators, to drive water valves, air flaps or other mechanical devices.

Fig. 6 is a block diagram of such a wireless actuator. In contrast to the all-in-one STM 312 module, the emphasis with the STM 300 used here is on flexibility of application. In addition to the bidirectional wireless communication important for the actuator mechanism, the charging circuit and thus the scaling of the energy storage is flexibly configured. Details can be found in the STM 300 user manual.

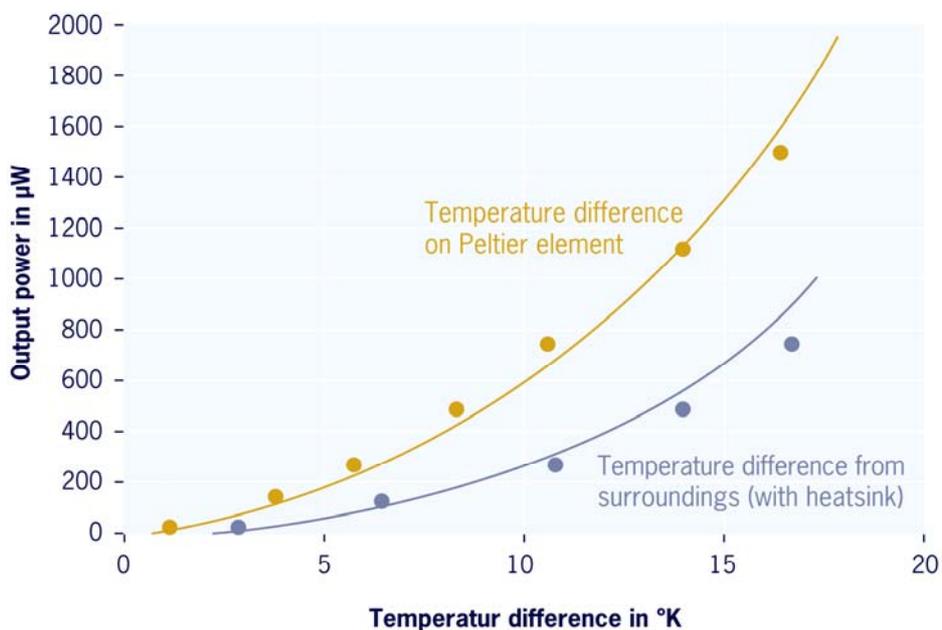


Fig. 5: ECT 310 output power versus temperature difference - approx. 100 μW for 7 $^{\circ}\text{C}$ difference from surroundings

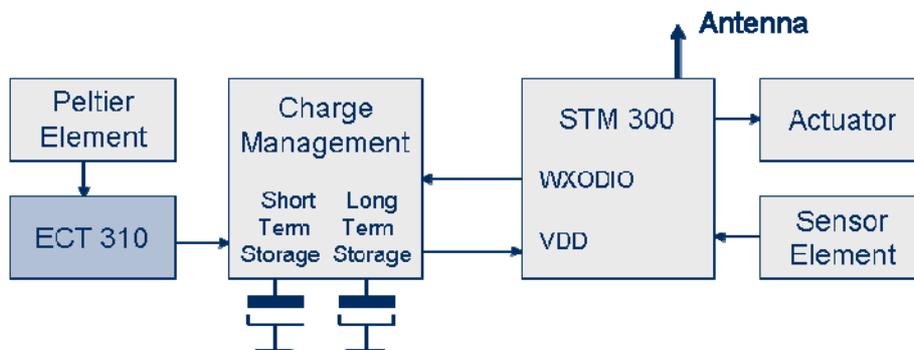


Fig. 6: Block diagram of thermally powered bidirectional wireless actuator - approx. 5 μW consumption without actuator technology (for wake-up every 2 min)

MECHANICAL INTEGRATION OF PELTIER ELEMENT

Fig. 7 illustrates typical integration of a low-cost Peltier element. The efficiency of energy generation depends on the thermal transfer resistance between the hot and cold sides of the Peltier element. It is consequently necessary to ensure good thermal insulation of the two ceramic wafers, for instance by using suitable plastic or styrofoam. The size of the Peltier element should allow the use of insulating material of suitable thickness but without any considerable effort at mechanical integration (e.g. TEC2L from Eureka measuring 15 x 15 x 5.6 mm). In use of a heatsink it should be noted that the effective thermal resistance depends on heatsink geometry and the heat flow of the surrounding air.

The ECT 310 is unipolar so it is important to ensure correct polarity of the Peltier element. If both cold and hot temperatures are to be used, two ECT 310 modules can be connected to the Peltier element in antiparallel circuit.

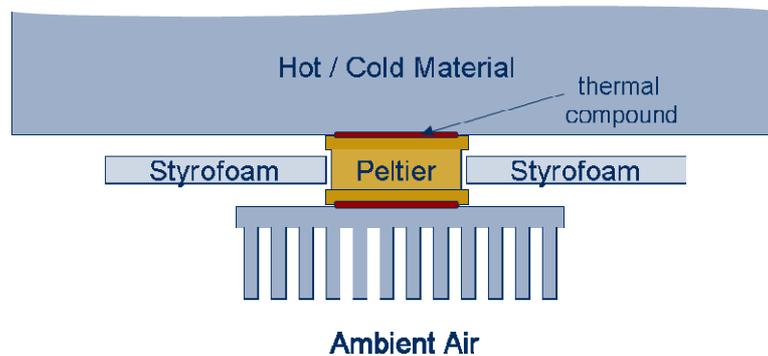


Fig. 7: Thermal insulation of the two sides of the Peltier element

THERMAL EVALUATION KIT EDK 312

For speedy evaluation of a thermally powered sensor, the ECT 310 can be simply soldered to the back of the STM 312. All components needed are contained in the EnOcean EDK 312 evaluation kit:

- STM 312 all-in-one wireless sensor module with integrated energy storage
- ECT 310 ultra-low-voltage DC/DC converter
- TEC2L-15-15-15-5.6 Peltier element
- Detailed documentation

Given the high efficiency of the system (already works at a temperature difference of 2 °K), simply placing a finger on one of the ceramic wafers of the Peltier element will cause the wireless sensor to transmit. The opposite ceramic wafer must of course contact a somewhat cooler surface.

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SUMMARY

ECT 310 is an ultra-low-voltage DC/DC converter developed to power batteryless EnOcean wireless modules by means of thermal energy, using low-cost standard Peltier elements. The ECT 310 works on as little as 20 mV, corresponding to a temperature difference of about 2° K, and exhibits high efficiency of 30% for 25 mV input voltage. Here we have looked at the implementation of thermally powered wireless sensors as well as wireless actuators.

PATENT PROTECTION

EnOcean GmbH has a comprehensive patent protection in the field of self-powered wireless sensor technology. This is listed under the following link: <http://www.enocean.com/en/patents/>

The purchase of ECT 310 converter modules does not entitle the user to operate this component by wireless technologies other than the EnOcean wireless standard.

EXCLUSION OF LIABILITY

The information contained in this document describes typical characteristics of EnOcean wireless systems, and should not be interpreted as specified operating features. No liability is accepted for errors and/or omissions. EnOcean reserves the right to make changes without prior notification. For the latest documentation visit the EnOcean website at www.enocean.com.