THERMO APPLICATIONS:
EnOcean Gets Wireless Actuators To Work Without Batteries

The EnOcean standard continues to develop with the new Dolphin system architecture. Now it is also possible to implement actuators without the need for cables and batteries.

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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 both the wireless and the actuator technology. The energy is delivered by thermo generators.

Reducing average room temperature is one of the most effective ways to save heating energy. According to figures from the Bremer Energie Institut, energy consumption can be cut by some 20 to 30 percent if a system reduces heating temperature as a function of time, place and human presence. For this purpose there are so called single room thermostats that can regulate the temperature of the air in different rooms from a central point according to different time and temperature presettings.

Fig. 1: Concept demonstrator of a wirelessly controlled heating valve powered by the radiator temperature instead of batteries.

WIRELESSLY CONTROLLED HEATING VALVE WITHOUT BATTERIES

Remotely controlled heating valves generally need a cable on which the controlled power supply is fed to their motor actuator. But wireless solutions are also possible. Control is by radio signals, and power is supplied by batteries. A heating valve takes a relatively large amount of energy to adjust the temperature. With the result that batteries have to be replaced every year. That is not only bothersome and costly, it is also a burden on the environment.

The alternative is battery-less or self-powered wireless solutions. Meaning that the energy needed is derived from the process itself or the environment. This is made possible by a Peltier element, an electronic component that generates electric current when there is a difference in temperature between its two sides. This is the basis on which EnOcean created a concept demonstrator (see Fig. 1 and Fig. 2)

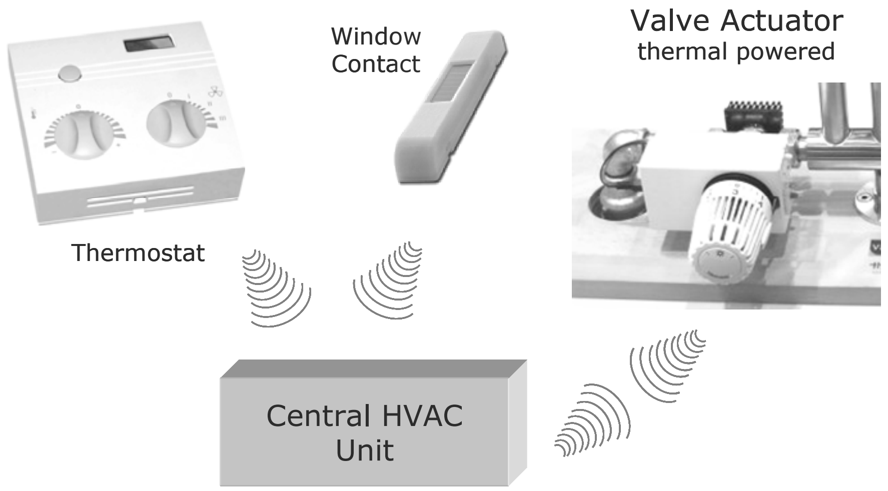

Fig. 2: Components of the self-powered wireless heating valve control

ENERGY OBTAINED FROM TEMPERATURE DIFFERENCE

The low-cost Peltier element that is used here consists of two square ceramic plates with an edge length of 15 mm and 4 mm apart. Attached between them are special metal junctions. One side is fitted to the radiator or the heater pipe. The other side requires a heatsink that is cooled by the ambient air.

A simple principle, but one that nevertheless presents a problem. The voltage of the thermo element is very small, only about 12 mV per degree of temperature difference. And the generated power of the Peltier element is also low at about 400 µW per 5 degrees of temperature difference. So the output voltage first has to be transformed up to a few volts, and then the relatively small amounts of energy have to be collected in a capacitor. The EnOcean circuit will already work upwards of 20 mV thermo voltage. This means that a temperature difference of about 2 degrees and more on the Peltier element will enable it to function.

An electronic contact cuts in the actuator as soon as sufficient energy is collected. The energy needed to operate the actuator is the product of power and time ($E = P \times t$). So it is only necessary to wait long enough to generate sufficient energy. The energy requirement of the load must consequently be kept as low as possible to produce small control time constants.

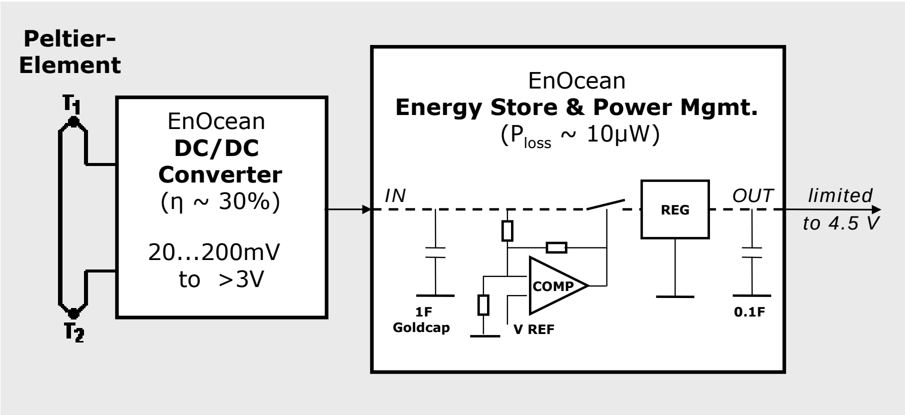

Fig. 3: Conversion of thermo element output voltage

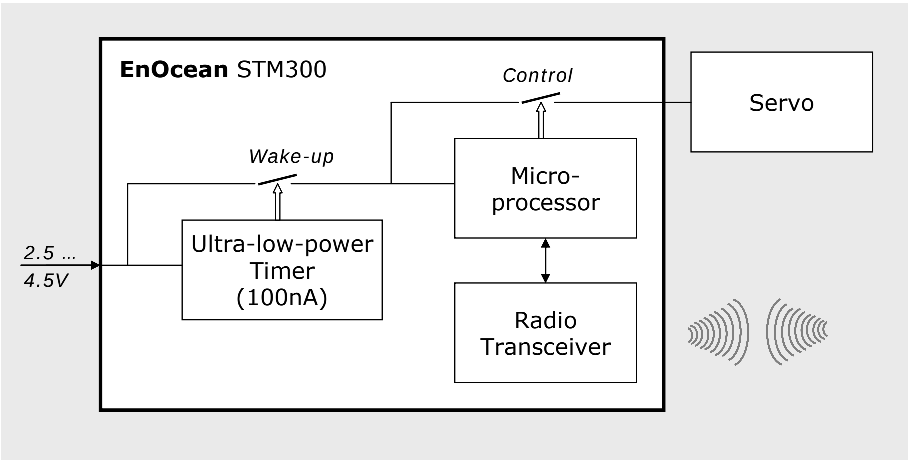

Fig. 4: Wake-up timer and wireless communication

ULTRA-LOW-POWER BIDIRECTIONAL COMMUNICATION

The load consists of the motor actuator for valve control on the one hand plus the electronic circuitry to receive the control signals and drive the motor. Both the motor and the wireless receiver require a relatively large amount of energy in operation. EnOcean technology resolves this by operating the "energy-hungry" components for only a very short average time and otherwise consistently shutting them down. A permanently running wake-up timer is of ultra-low-power design. This only wakes the processor from time to time. On demand the valve is speedily adjusted, and then the actuator returns to its energy-economizing sleep for a certain time. The overall energy requirement of this actuator is minimal as long as the sleep phases are substantially dominant as a function of average time.

ENERGY BALANCE OF ENERGY-AUTONOMOUS HEATING VALVE

The following rough calculation of the energy balance illustrates the potential of the approach presented here. It should be remembered that this calculation is based on a technical example of implementation that can be matched to the details of an application and thus optimized:

a) Thermogenerator (Fig. 3):

The power produced by the thermogenerator depends firstly very much on the temperature difference on the Peltier element and thus on the volume of the heatsink that is used. Secondly, the efficiency of the voltage transformer is very decisive. In the meantime EnOcean has been able to optimize this to about 30 percent. The result is output power as a function of temperature as shown in the graphic (Fig. 5). For further calculation an approximate value of **100 µW** for 7 degrees temperature difference from the surroundings will be taken as the order of magnitude of the average generated power.

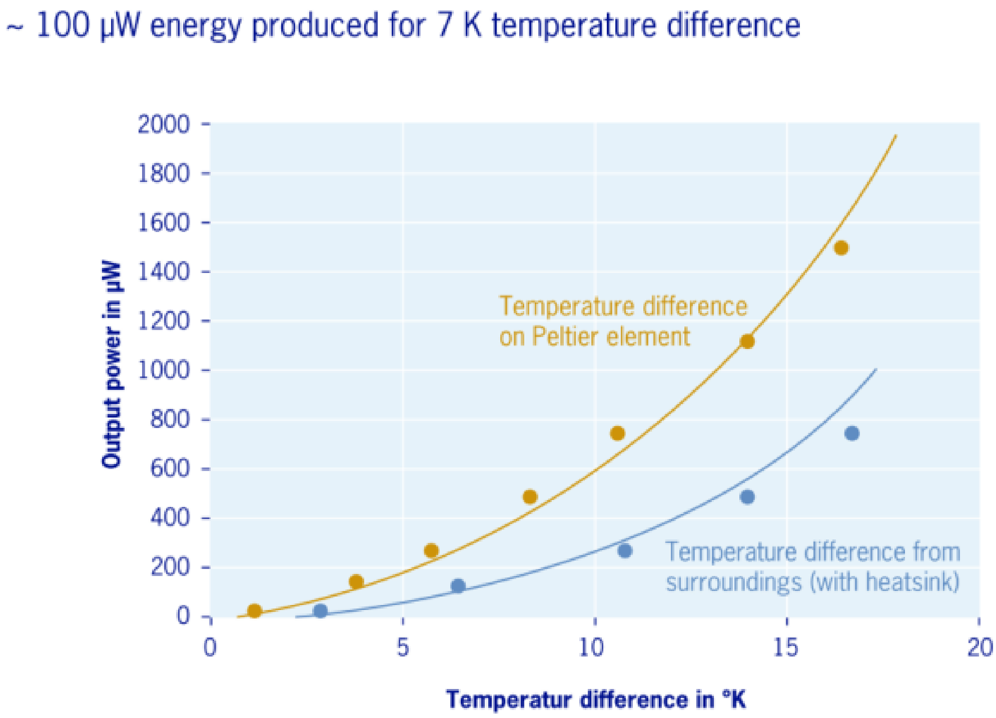

Fig. 5: Output power of DC/DC converter in Fig. 3 versus temperature difference

b) Wake-up Timer and Wireless Communication (Fig. 4):

The EnOcean wake-up timer has a permanent requirement of about 100 nA at 3 V, in other words some 0.3 µW, which is negligible. The microcontroller and the wireless receiver are waked about every 2 minutes to send and receive a telegram. This takes about 10 ms, the current drain is about 20 mA. On average communication will consequently require some **5 µW** (3 V x 20 mA x 10 ms/120 s).

c) Motor Actuator:

A typical low-cost actuator with two 1.5-V batteries takes about 3 seconds to run down from normal operation – for an average current drain of 120 mA. So a typical rundown operation requires some 1.1 Ws (2 x 1.5 V x 120 mA x 3 s). Assuming a mean number of four setting operations per day, that means about **50 µW** (4 x 1.1 Ws/24 h).

RESTARTING AFTER SUMMER BREAK

During a break in operation the radiator assumes the temperature of its surroundings and the energy source extinguishes. To bridge a shortish period, the energy needed to start can be stored in a capacitor during the active operating phase.

For energy reasons it is best not to operate the single valves in a three-step mode but to drive them about one operating point. In this way the valves can be corrected according to the need for control and the available energy. Then, during a break in operation of the complete installation, the heating valves are not closed but instead the central circulating pump is shut down. But this also means that a single valve cannot be fully closed by a central command. Complete turn-off of a single radiator has to be performed manually – as does turning it on again.

AIR-CONDITIONING PLANT: COMPARABLE PRODUCTION OF ENERGY

What has been said up to now can also be applied to air-conditioning plant and/or mixed systems. In general the thermogenerator requires a temperature difference to produce energy. For cold the voltage polarity is simply reversed. An appropriate polarity reversal circuit for alternating cold/warm operation is currently being developed.

If a ventilating flap is to be driven instead of the fluid valve (see Fig. 6), the process of obtaining energy and control can be very similar. For a ventilating flap on the ceiling the light is also a good energy source.

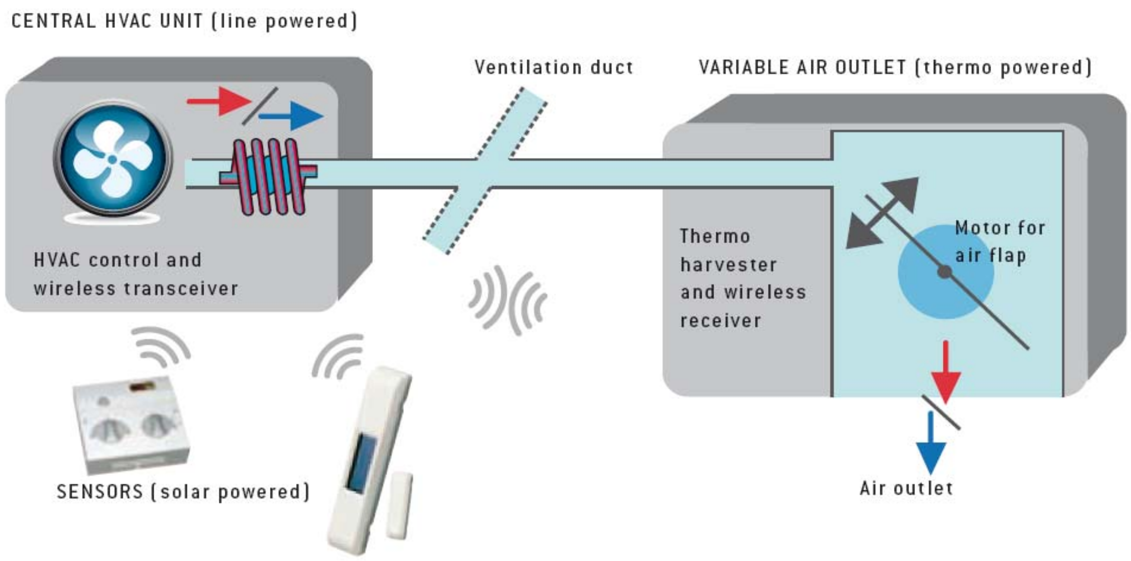

Fig. 6: Air-conditioning with thermo powered air flap control

FURTHER USES OF THERMO POWERED SENSORS

In building engineering there are possibilities for the use of thermo powered sensors in heating, air-conditioning and ventilation, in plumbing or in heating cost allocators and heating meters. A variety of interesting industrial applications can also be envisaged, for instance temperature or early failure monitoring.

EDK 312 THERMO EVALUATION KIT

What has been spoken of here is a concept study. The energy balance is positive and the technical feasibility is proven. For further system evaluation EnOcean is offering the EDK 312 thermo kit. This is a kit upgrade to the standard EnOcean EDK 300 evaluation kit containing all components needed to evaluate the thermal converter: ECT 310 DC/DC transformer, Peltier element, sensor evaluation board with STM 312 wireless module and documentation.