LINE POWER SUPPLIES –
Low-Loss Supplies for Line Powered EnOcean Modules

A line power supply has to offer the required energy to supply the actuator electronic and to supply the EnOcean TCM/RCM radio control module. This paper contains some considerations about line power supply circuitries with respect to low power loss in standby operation, circuitry operation in a wide voltage range, and low bill of material.

Before designing the power supply, please also consult the application note “AN101 POWER SUPPLY LAYOUT” that contains some layout design notes to avoid electromagnetic interference (EMI). EMI can strongly reduce the TCM/RCM radio range performance.

1. GENERAL POWER SUPPLY CONSIDERATIONS

In buildings the actuator circuitry is often located within a junction box. The load should be switched on and off or should be dimmed by radio control. Two typical installations can be found. In the first case the neutral conductor N is available, according to Figure 1.

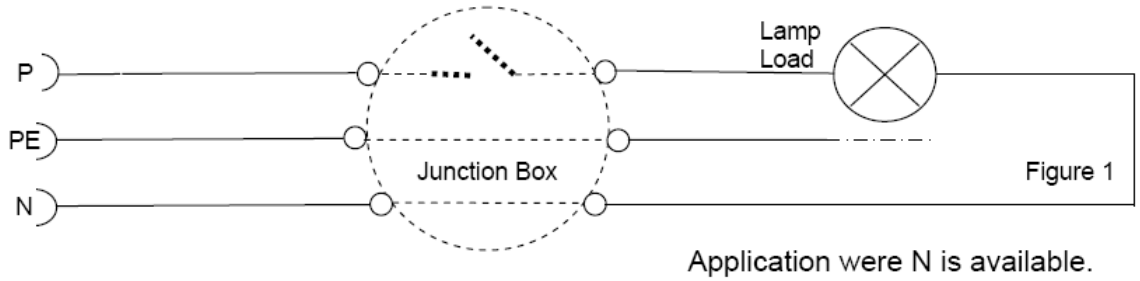

Figure 1

Application were N is available.

In the second case the neutral conductor N is not available, according to Figure 2. Often such a situation is given if a conventional light switch in a wall box shall be replaced by an EnOcean radio switch actuator.

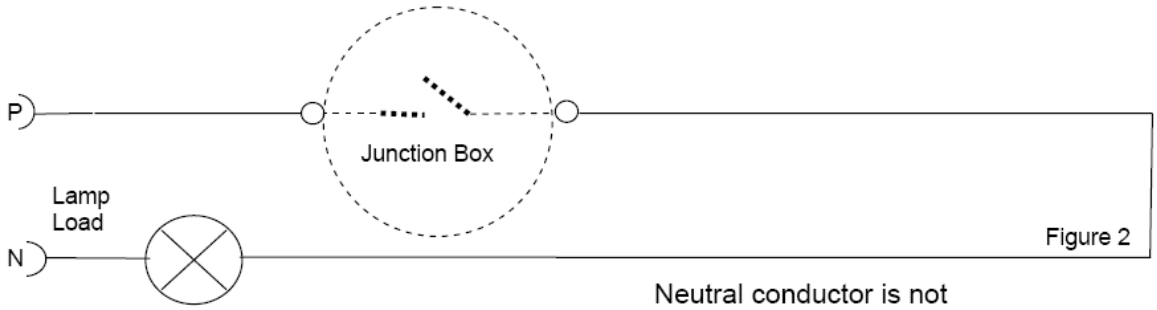

Figure 2

Neutral conductor is not available in the junction box.

If the neutral conductor N is available a **Parallel Power Supply PPS** can be simply used to power the actuator electronics, according to Figure 3.

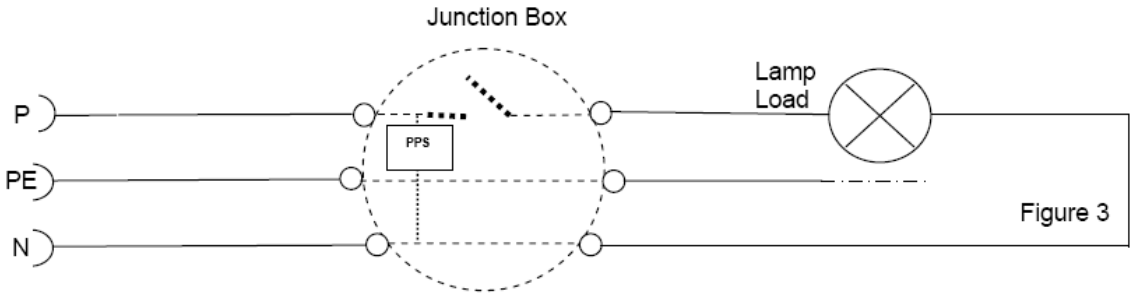

Figure 3

If the neutral connector is not available, a PPS is not sufficient. According to Figure 4 supply voltage is only available as long as the switch is open. As soon as the switch is closed no voltage difference is available anymore (The protected earth must not be used as neutral conductor if it is available because of safety reasons!). In this case an additional **Serial Power Supply SPS** is required, according to Figure 5. The later described combination of a PPS and a SPS will give this possibility to supply EnOcean radio receiver without having a neutral conductor by using only the available two wires in a usual wall junction box.

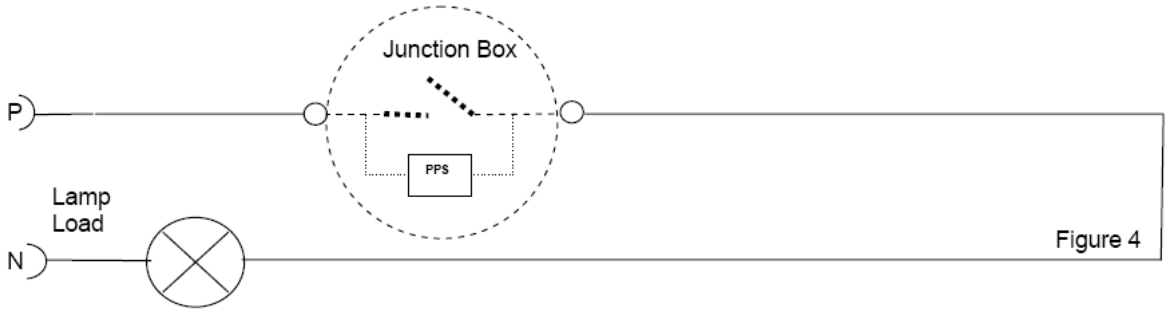

Figure 4

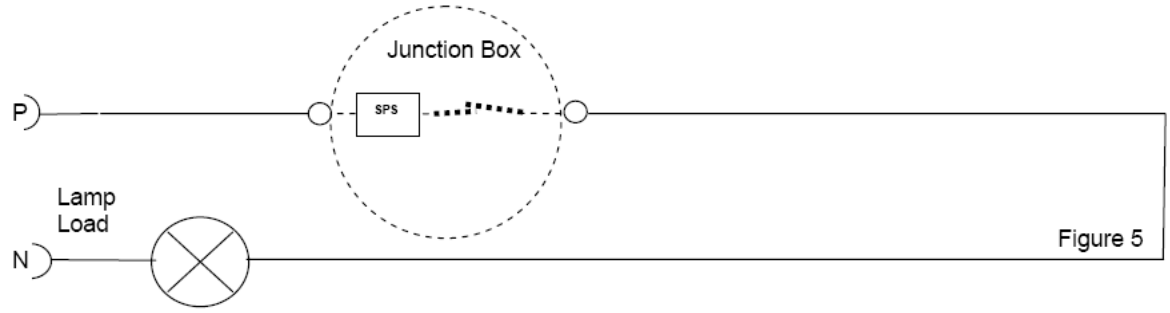

Figure 5

2. LOW-LOSS POWER SUPPLIES

2. 1 Low-Loss Parallel Power Supply (PPS)

In applications were N is available a simple PPS like Figure 6 is used typically. Disadvantage of this power supply concept is the poor efficiency. An output power of around 0.1W is required to power a typical radio receiver and the typical stand-by power dissipation of such a simple power supply is around 1.3W.

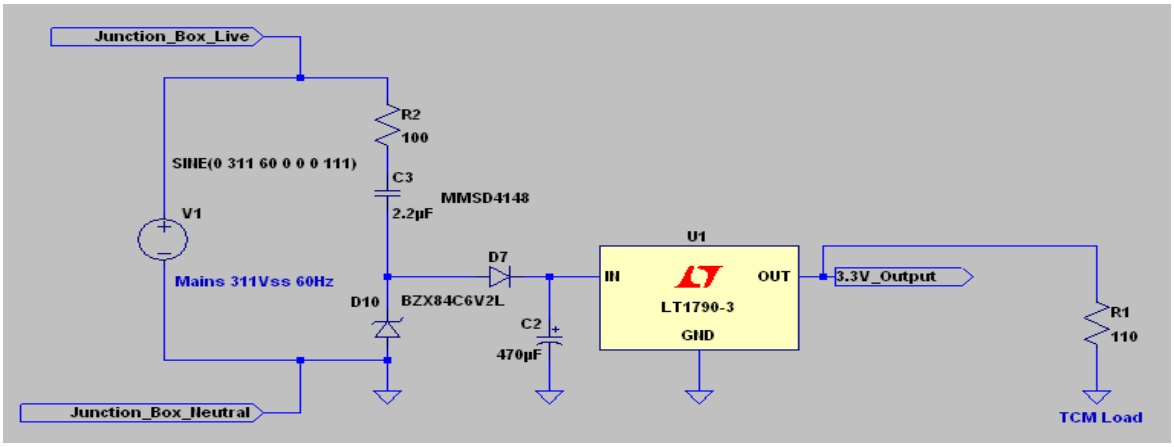

Figure 6: Typical low efficiency power supply (approx. 0.60€ BOM @ 100k units)

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Low unit power consumption is important, because the power supply is permanently in operation, also in radio receiver standby mode when the load is switched off. EnOcean has prototyped a high efficiency PPS that allows very efficient line powering of radio modules. It operates in a very wide voltage range and can replace existing power supplies in a green manner.

Key Features of the Low-loss PPS Prototype:

- Output power: 3.3V or 5.0V, e.g. 35mA
- Input voltage range: Operating from 15Vac to 307Vac
- Power consumption: 0.3W at 110Vac or 0.5W at 230Vac at 0.1W output power
- Costs: < 1.4€ BOM @ 100k units

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	15		307	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
Output						
Output Voltage 1	V_{OUT1}	3.1	3.3	3.5	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			135	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}		0.035		A	
Total Output Power						
Continuous Output Power	P_{OUT}			0.1	W	
Peak Output Power	P_{OUT_PEAK}			0.33	W	
Efficiency						
Full Load	η	12		40	%	Measured at P_{OUT} 25 °C
Ambient Temperature	T_{AMB}	0		70	°C	Free convection, sea level

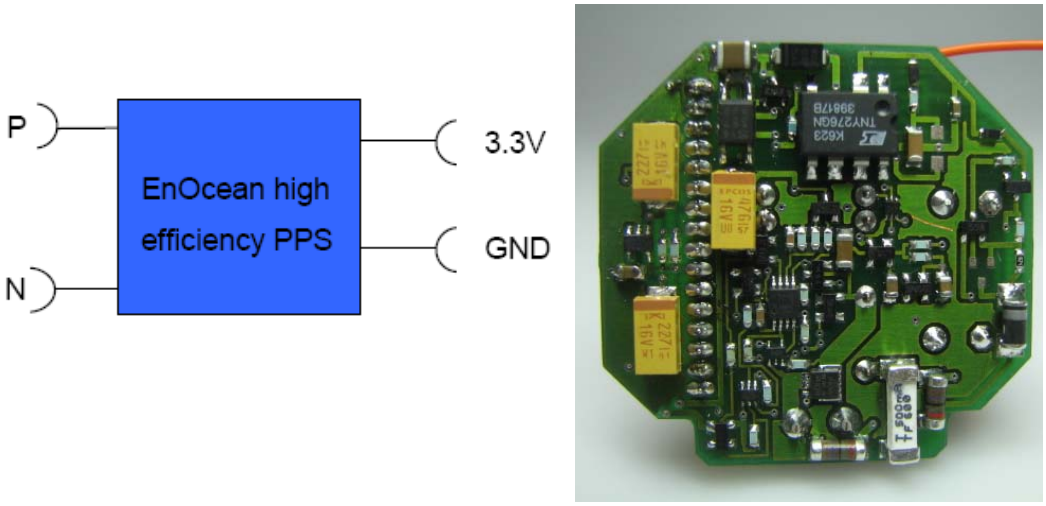

Figure 7: Typical technical data (3V version), connecting diagram and prototype of the high efficiency PPS

2. 1 High-Efficiency Serial Power Supply (SPS)

Picture 8 shows the principle configuration of a SPS. According to Figure 5, supply voltage is only available if the switch is opened. Disadvantage is the very poor efficiency if it is realized by an ohmic voltage drop only. For generation of e.g. 3V/35mA output power a resistors voltage drop of minimum 0.5V is required (The best step up converter starts at 0.5V). At a load current of 10 A the power loss is 5W, that results in probably critical unit internal heating!

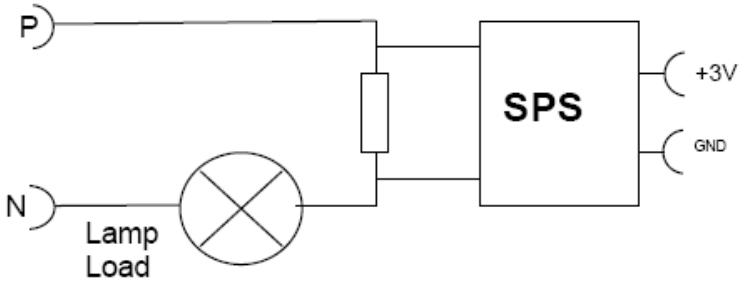

Figure 8: Principle configuration of a Serial Power Supply

EnOcean has prototyped a special high efficiency serial power supply. Key Features of EnOcean SPS:

- Output power: 1.5V/3.3V/5.0V, e.g. 35mA
- Input voltage range: Operating from 15Vac to e.g. 307Vac
- Power consumption: 0.1W at 110Vac or 0.1W at 230Vac
- Costs: Below 1.4€ BOM @ 100k units

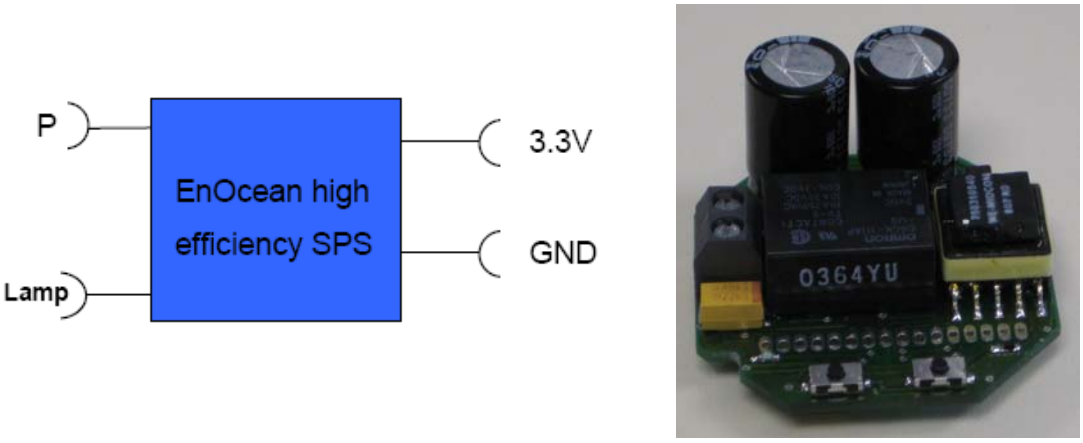

Figure 9: Connecting diagram and prototype of the high efficiency EnOcean SPS

3. TYPICAL APPLICATIONS

3.1 PPS for radio actuators in a junction box with neutral conductor

If the phase and a neutral conductor are permanently available, the described PPS offers a low-loss and wide voltage range solution for supplying the radio electronics of RCM or TCM radio communication module. In comparison to other typical supplies the low-loss PPS offers 50% reduction of stand-by power losses.

3.2 PPS for radio Dimmers without neutral conductor

At dimmer application only a part of sine wave is used for lamp current supply. For example the shaded part of the sine wave in Figure 11 is not used and the voltage drop between zero crossing and leading edge can be used to power a TCM module via a energy storage capacitor. The low-loss PPS offers a good approach for radio dimmers because of its high efficiency in a wide voltage range.

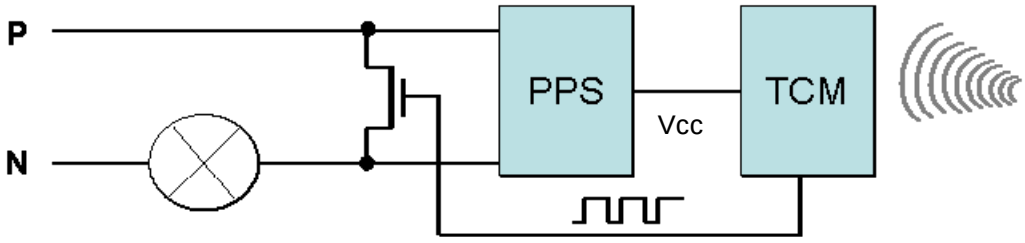

Figure 10: Low-loss PPS offers a good approach to supply high efficiency dimmers

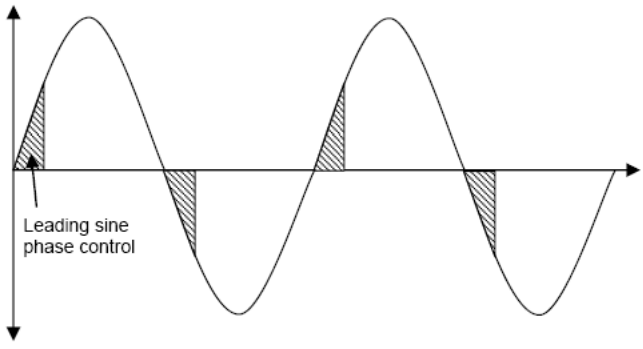

Figure 11: TCM powered by PPS phase control

3.3 PPS/SPS for switching actuators without neutral conductor

For switching applications without neutral conductor, e.g. in a wall box, the PPS can operate in combination with the SPS like shown in the Figure 12. The operation of the PPS is serial in the supply current of the load. If the serial load current is 0.1A for a minimum the SPS is able to generate 1.5V, 3.3V or 5.0V by phase control. This allows operation at very low switching loads like 10W at 110V in US. Depending on the used power transistor and the switching relay the SPS can be loaded as well with high currents like 10A and more.

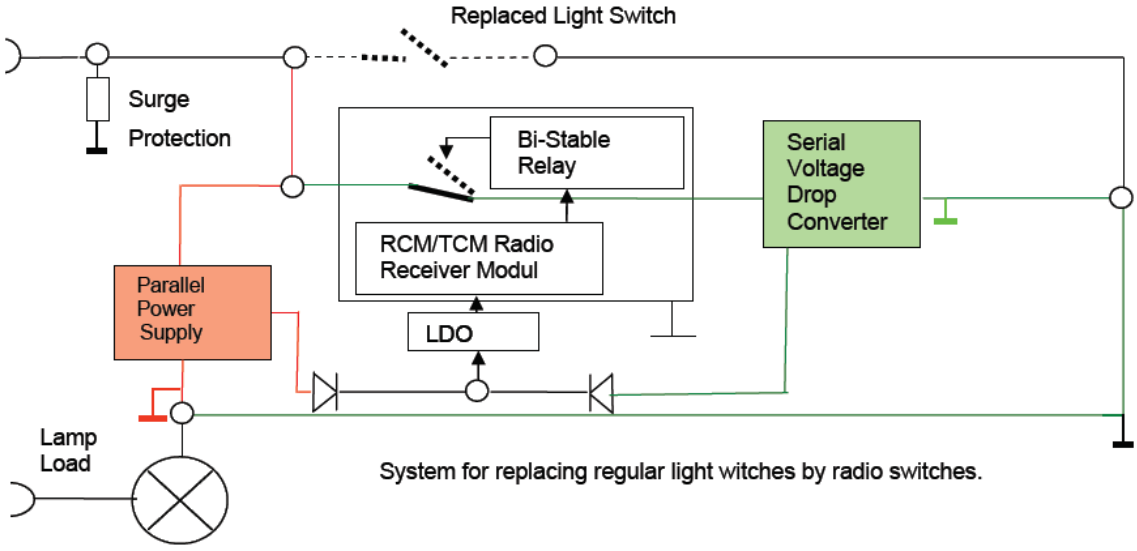

Figure 12: PPS in combination with the SPS for high efficiency supply of a RCM or TCM module in a light switch junction box without neutral conductor

3.4 Key Features of Low-loss PPS/SPS Power Supply

The prototyped PPS/SPS power supply system is designed for switching applications without neutral conductor. With its low loss in a very wide voltage and current range it is possible to realize switching actuators with a broad load range and to supply EnOcean radio electronic with excellent stand-by efficiency. Please note that the PPS/SPS power supply does not work expedient with diming applications. The key features of the prototyped PPS/SPS power supply are as follows:

- Generation of dc-output for power supply of TCM or RCM (1.5V, 3.3V or 5.0V)
- Easy to install:
  - No neutral conductor required
  - This allows easy replacing of a conventional light switch by an EnOcean radio switch
- Very flexible load range:
  - The loads can be very low power fluorescent lamps as well as high power bulbs

- The loads can be capacitive or inductive as well
- Low lamp current down to 100mA is sufficient
- High lamp currents such as 10Aac or 2300W can be handled
- Operation even from minimal remaining voltage of 15Vac is sufficient too
- Operation at high supply voltage like 305V can be handled
- Low loss, high efficiency

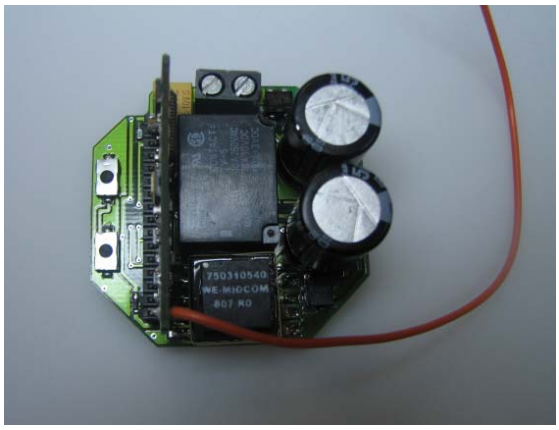

Figure 13: TCM radio module, load relay, energy storage capacitors and the transformer of the PPS

Figure 14: The total switching receiver electronics fits into a standard in-wall unit (PPS and SPS power supplies, TCM radio module, bi-stable switching relay)

3.5 SPS for sensor applications without neutral conductor

The SPS can also be used for other applications, for example remote load currents or temperature measurements without neutral conductor. The EnOcean TCM transceiver module or the STM sensor transmitter module both can be easily supplied by the SPS.

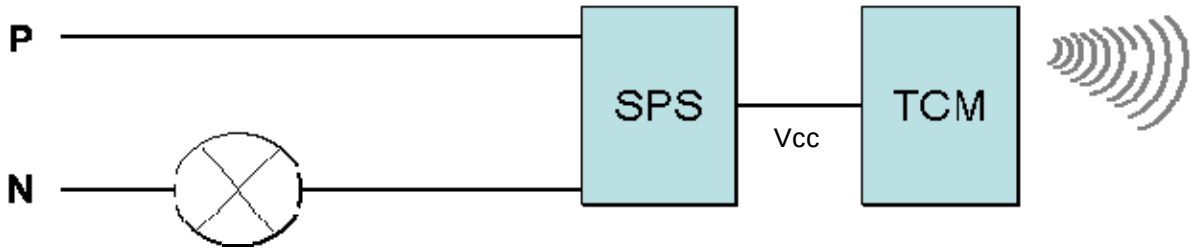

Figure 15: TCM or STM radio modules can be easily supplied by the SPS

4. DEVELOPMENT STATUS – Role of EnOcean

This paper describes prototypes that prove the technical feasibility of the solution to OEMs. The EnOcean power supply concepts are proven for laboratory use but are not developed to a final product yet. Patents are pending. EnOcean offers the circuitry details of the high efficiency PPS and the SPS prototypes on a licensing base. EnOcean sees itself as a component and technology supplier, which provides OEM customers with energy generators, energy management, radio components, and communication firmware. The customers of EnOcean develop and produce the final devices (power modules, housings, etc.), have system integration competence (control centre, control algorithms, actuators, etc.), and access to final product market.