
Christian Viehweger, Technische Universität Chemnitz, Chemnitz, Germany
Thomas Keutel, Technische Universität Chemnitz, Chemnitz, Germany
Laura Kasper, Technische Universität Chemnitz, Chemnitz, Germany
Tim Pfeifer, Technische Universität Chemnitz, Chemnitz, Germany
Olfa Kanoun, Technische Universität Chemnitz, Chemnitz, Germany

ABSTRACT

A standardized characterization method for solar cells is only available for outdoor use. For the supply of wireless sensor nodes with energy harvesting also indoor applications are of interest. Without comparable values it is difficult to select the proper cell for defined environmental conditions. Therefore it is necessary to make an investigation on their behavior individually to be able to make a selection. The work presented here shows the characterization of solar cells according to their spectral behavior, the influence of illumination and the usage of this information about the maximum power to design an energy management. Therefore a test structure with a monochromator, different light sources, source measure units and instruments for measuring intensity and spectra has been developed. The measurements help to select the best solar cell out of a repertory for indoor energy harvesting applications. As for indoor applications also the ability to make use of weak light and a high efficiency is important, the energy management has been improved using a dual DC/DC strategy that allows it to make efficient use of solar cells within difficult situations.

Keywords: Dual DC/DC, Indoor Energy Harvesting, Monochromator, Solar Cell Characterization, Wireless Sensor Node

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1. INTRODUCTION

Modern sensor systems enable the acquirement of data in many different and complex fields. They are used for home automation, ambient assisted living, monitoring of production sites and environmental monitoring to name only a few. With a network of such systems it becomes possible to monitor a widespread area or a high number of objects (or both). This helps to gather information about the state of function of the monitored structure, to surveil defined parameters or to react to and control different procedures. For example a pollution monitoring system could gather information about fine dust in an entire city. With the integration of embedded systems in the recent years single sensor nodes became equipped with wireless communication electronics. This simplifies the collection of data and allows the control of a large number of nodes with reduced effort. This is one of the most important reasons for the growing interest in this field.

Today there are multiple solutions for the communication already existing, like Bluetooth, wireless LAN or Zigbee (Lee, 2007). There are also protocols which are still in the standardization process or already standardized like ISA100 (ISA, 2013) or wirelessHART (HART, 2013). The most important issue for those network implementations is the energy efficiency, which means in detail to have a low power communication, ideally with a wakeup functionality, which is failsafe nevertheless and able to handle a large number of transmitters per area. To reach this functionalities an energy aware routing strategy is absolutely necessary (Hasenfratz, 2010). For security issues also encryption plays an important role (Chenjun, 2008).

A problem that still exists is the energy supply of those sensor nodes. If a data cable can be avoided by radio communication the power cable should also be removed. An easy way to replace the wired connection would be to use a battery instead. This is not a sustainable solution. It causes toxic waste and depending on the system to supply it will have a short lifetime. This results in enhanced maintenance effort according to the replacement of empty batteries. Especially in networks with a large number of nodes this will be very cost intensive. To avoid these extra expenditures and reach a long lifetime energy harvesting is a suitable solution. This means the use of ambient non-electrical energy which is being converted to electrical for the supply an electronic system.

Depending on the environment different sources with different energetic intensities can be available. Light from the sun or artificial light can be converted using solar cells, temperature gradients can be converted using thermoelectric transducers, vibrations or movement can be converted with the use of piezoelectric or electrodynamic converters and many more. An overview about typical energy densities is given in Table 1. It shows a comparison between thermal, solar and kinetic transducers. As the absolute values always depend on the environmental conditions this should be treated as rough overview.

Table 1. Comparison of energy densities of typical sources for energy harvesting according to their power output (Mueller, 2012; Zhu, 2010; Wan, 2011)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>W/cm² resp. W/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>solar</td>
<td>10µ - 10m</td>
</tr>
<tr>
<td>thermal</td>
<td>10µ - 1m</td>
</tr>
<tr>
<td>piezoelectric</td>
<td>1µ - 100µ</td>
</tr>
<tr>
<td>electromagnetic</td>
<td>1µ - 1m</td>
</tr>
</tbody>
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