ECS 300/310 Solar Panel - Design Considerations

Solar Panel Design Basics

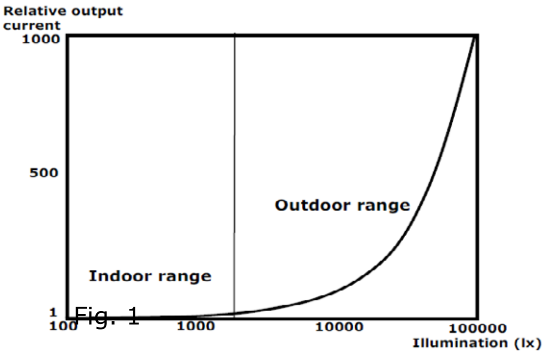

Fig. 1

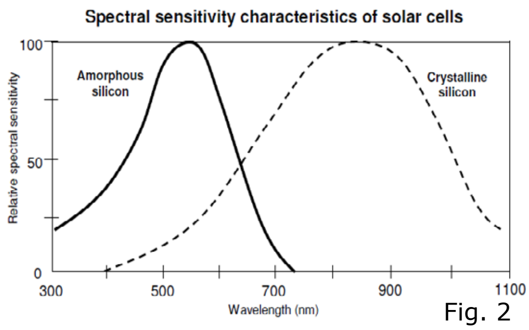

Fig. 2

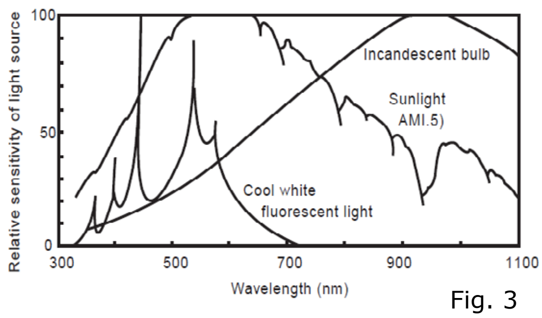

Fig. 3

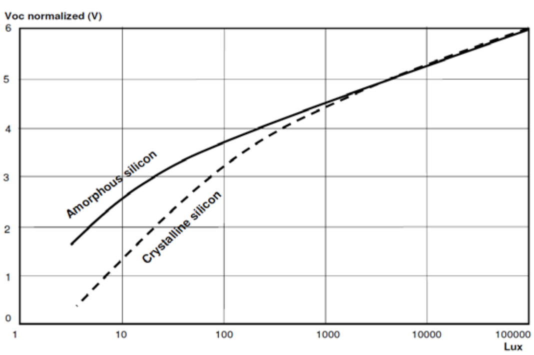

Fig. 4

One of the most common energy harvesters today is the solar cell. Solar radiation represents the largest energy resource of the terrestrial ecosys-tem. The discovery of the photovoltaic effect opened entirely new perspectives on the use of solar light for electricity generation. Unfortunately only about 0.1% of the sunlight level is available indoors (Fig. 1). Important factors for the right solar panel choice are the specific light source and application energy requirements.

EnOcean offers an indoor solar panel family ECS 300/310 (**E**nOcean **C**onverter **S**olar, in two dimen-sions: ECS 300 small and ECS 310 medium) optimized for its typical applications. This Appnote is a short introduction to indoor use of the solar panels as energy harvesters for typical EnOcean applications. For more details regarding typical indoor light levels and measurement recommendations, consult EnOcean AN 201.

Solar cell efficiency depends on manufacturing technology (spectral sensitivity Fig. 2 and light source Fig. 3).

Technologically there are two major solar cell types: for outdoor and indoor applications:

Crystalline silicon solar cells, also called "outdoor", reach best efficiency under sunlight (peak sensitivity at 800 nm).

Amorphous (non-crystalline) silicon cells, also called "indoor", with peak sensitivity at 500 nm are "specialized" for poor and fluorescent light (FL) conditions (Fig. 4, output voltage). While conventional crystalline solar cells are about two times more efficient by optimum light conditions (outdoors), amorphous cells beat them by far at poor indoor light levels and win on the 24-hour energy cycle, because they can also use poor artificial light and early morning or evening light. Also because of their larger bandgap amorphous silicon solar cells typically have higher open-circuit voltages, up to 0.9 V/cell.

Solar cells work as light-dependent current generators. While their (open-circuit) output tage depends only relatively slightly on illumination over decades, their (short-circuit) current varies directly proportional to light intensity and solar cell area (Fig. 5). The delivered power is however not quite linear (slightly reduced due to its voltage dependence and internal peripheral leakage currents). These effects become more considerable the smaller the cell area and lower the light intensity. Brightness is the term that describes how intense a light source is perceived by the human eye and is measured in lux (lx).

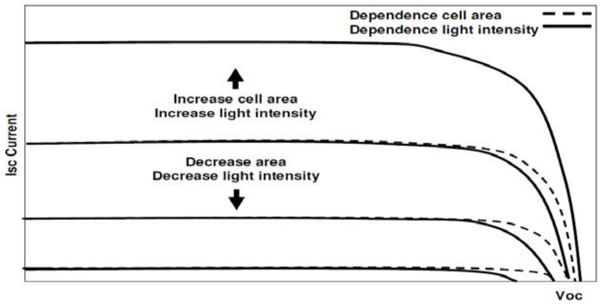

Fig. 5

As a rough, conservative estimation, indoors and for small area amorphous solar panels (a few cm²) an operating current in the range 10 μA/cm² @ 200 lx (FL) can be considered. This value can be roughly linearly extrapolated using a de-rating factor for lower illumination and/or smaller area. That corresponds e.g. to 4.5 μA/cm² @ 100 lx. A similar extrapolation approach is shown in Fig. 6.

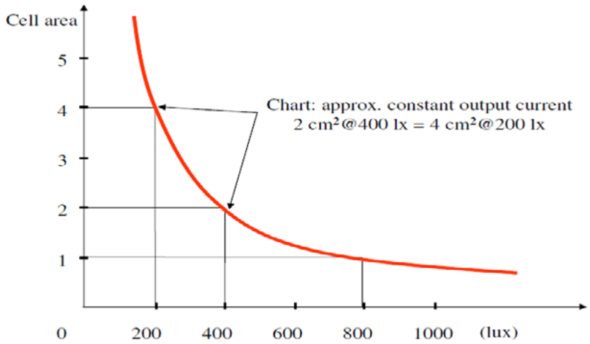

Fig. 6

Additionally, amorphous cells deliver indoors nominal power densities of around 4 μW/cm² @ 200 lx or <2 μW/cm² @ 100 lx (i.e. about 4.5 μA x 0.35 V).

For best performance the solar panel output voltage should be near the required application operating voltage. The amount of output voltage mainly depends on the number of serial connected cells (Fig. 7).
Make sure that in worst cases (i.e. poor light or full sunlight) the delivered output voltage remains within the specifications of the powered electronics (e.g. provide appropiate limitation).

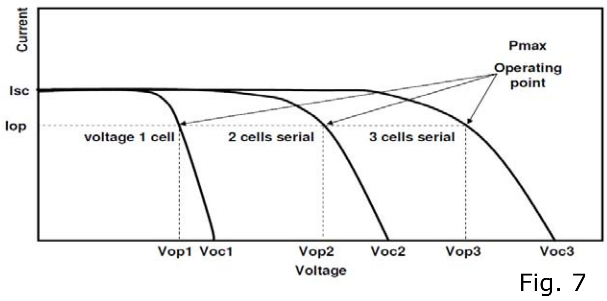

Fig. 7

General Recommendations:

Do not forget that these are only rough estimates depending on very many variables. First carefully check the specific environment, define worst case application requirements and add an additional reserve of 20% by the solar panel dimensioning. Verify your assumptions by measuring the real solar panel values in worst case. Generally consider 25 lx as a lower brightness limit for designing ambient light powered devices. Below this limit solar cell efficiency drops dramatically.

Calculation Example:

An EnOcean STM 300 based room sensor is to transmit environment data every 100 seconds. The ambient brightness is 100 lx continuously. What dimensions are needed for its solar panel?

Current requirement: STM 300 current consumption can be determined from the STM 300 user manual (§ 2.11, see also AN 209). This is about 160 μC (= 160 μAs) for each transmission (including an external sensor circuit and external storage capacitor leakage current). By one wake-up and transmission every 100 seconds a storage capacitor recharge current of > 1.6 µA during the next 100 seconds is needed for the next transmission (1.6 µA x 100 s = 160 µAs).

A 1 cm^2 single solar cell delivers an operational current of about 4.5 µA @ 100 lx (at <2 µW, see considerations above), so half a 1 cm^2/cell will be enough to deliver 2 µA @ 0.35 V.

Voltage requirement: the STM 300 needs a supply voltage between 2.6 and 5 V. Therefore at 100 lx eight single cells (@ 0.35V) serially connected are needed.

These two conditions (voltage and current requirements @ 100 lx) give the minimal solar panel area needed for the required application: eight cells x 0.5 cm^2 = 4 cm^2.

An amorphous silicon solar panel, consisting of eight single solar cells connected serial, with an overall area of 4 cm^2 is therefore needed. EnOcean's smallest ECS 300 solar panel, with the dimensions 3.5 x 1.28 cm (= 4.4 cm^2) consisting of eight serial amorphous cells, would fulfill these requirements (see data sheet for more details).

For applications that need more energy like bidirectional room controllers (Smart Ack, see AN 501) larger solar panels like ECS 310 (eight serial cells, 5 x 2 cm = 10 cm^2) are required.

For application examples that need even larger solar panels consult AN 306, AN 311 (motion sensors).

Note: The indoor solar panels ECS 300/310 can deliver under sunlight an open-circuit voltage (unloaded)> 6 V. To limit the STM 300(C) input supply voltage below 5 V by accidentally longer sunlight exposure, its VDD and VDDLIM terminals must be connected together (see STM 300(C) user manual). By the way, longer exposure of "indoor" amorphous silicon cells in direct sunlight (i.e. hundreds of hours > 10,000 lx) leads to degradation of their efficiency by up to 25% due to the so called Staebler-Wronski effect (light induced degradation processes). Conversely at such light levels the delivered power will be more than enough even in this case.

New developments:

New solar panel technologies, like the Dye Sensitised Solar Cells for Indoor from G24 Innovations Ltd. (www.g24i.com) are very promising. They are lightweight, flexible, thin film (thickness typ. 0.35 mm), easy to be applied on most every surface and can be easy manufactured and cut according customer specific design. Additional they deliver indoors, especially by low and diffuse light levels about double efficiency vs. the standard amorphous solar cell technology.