SOLAR CELL SELECTION

Product Family: **EM850x**

Part Number: EM8500
Keywords: Harvesting, Solar

1. ABSTRACT

EM850x is a family of power management controllers with interface to different energy harvesting sources. The device is used to extract power at maximum efficiency from a solar cell to supply an application and to charge storage elements.

Solar energy is provided by a photovoltaic element. Solar cells are available in different process technologies and dimensions and need to be closely matched to the chosen application.

This document outlines the main solar cell characteristics and parameters. A selection guide is provided to assist with proper solar cell selection as a function of application requirements.

2. ABBREVIATIONS

STS	Short term storage element (capacitor connected to VDD_STS)
LTS	Long term storage element (rechargeable battery connected to VDD_LTS)
HRV	Harvester, main source of energy for the EM8500
MPP	(Maximum Power Point) This operating point is reached when the harvester delivers the maximum power for a given condition
V_{MPP}	Solar cell output voltage at MPP
V_{OV}	Solar cell open voltage (no load, when the EM8500 DCDC converter is disabled)

3. SOLAR CELL OVERVIEW

3.1 KEY PARAMETERS

V_{OV}: Open Voltage
Vov is the voltage across the cell when there is no load current. EM8500 uses this constant voltage method (also named open voltage method) to track the maximum power out of a solar cell.
This voltage depends mainly on the process technology for a given solar cell element.

I_{SC}: Short Circuit Current
The short circuit current is the current through the solar cell when the cell output is shorted. This current is changing with the light intensity (lux). This parameter is measured by the EM8500 lux-meter and gives a range of current. With a known solar cell characteristic versus light, the corresponding light intensity can be determined.
Solar cell manufacturers usually provide this parameter as current density J_{SC} (mA/cm2)

MPP: Maximum Power Point and associate Voltage V_{MPP}
For a source with a pure ohmic characteristic (R_{out}), maximum power is extracted when the resistive load R_{load} equals R_{out} (matching resistance).

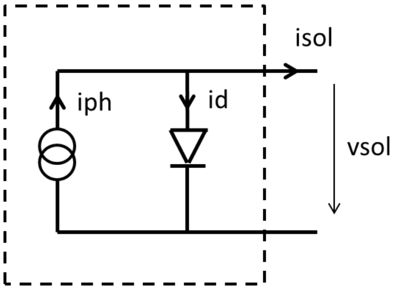
For a solar cell, the output impedance is non-linear, thus it is more difficult to match the impedance. The maximum power delivered by the solar is measured by sweeping the load and measuring voltage across the cell (IV curve). The power reaches the Maximum Power Point (MPP) at V_{MPP} voltage.

MPP_{RATIO}
There are many ways to extract the MPP. The EM8500 uses the open voltage method by measuring the open voltage V_{OV} without load followed by loading the solar cell to obtain a voltage that satisfies the equation $V_{SOL} = V_{OV} * MPP_{RATIO}$.

The ideal ratio for a given cell is $MPP_{RATIO} = V_{MPP}/V_{OV}$. For most solar cells this ratio is approximately 0.8. It is changing with the technology and needs to be adapted for each cell type. This ratio is also changing slightly as a function of light intensity.

3.2 CHARACTERISTICS

A solar cell is modelled as a current source with a parallel diode. The current generated is proportional to the light intensity.



$$iph = k \times G$$

Iph: photo-generated current
k: constant
G: illuminance

$$isol = k \times G - Is \times \left(e^{\frac{Vsol}{V_T}} - 1 \right)$$

Is: reverse saturation current
V_T: the thermal voltage

The IV characteristic of a solar cell is shown in Figure 1. Power (P_{sol}) is plotted on the same graph to illustrate the maximum power point (MPP) that the cell is able to deliver.

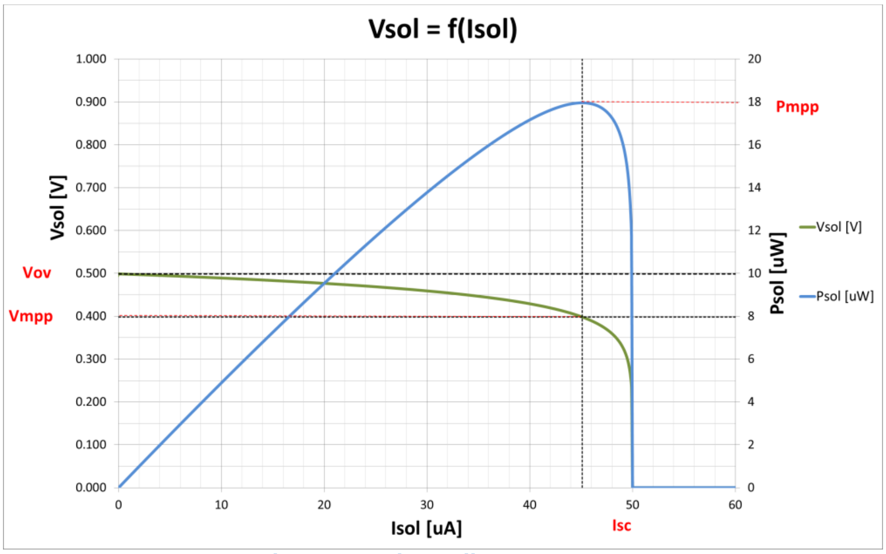


Figure 1: Solar Cell IV Curve

3.3 TECHNOLOGY

There are different process technologies used to manufacture solar cells. The main processed used for the power range of application targeted by the EM850x family are shown below.

- **Monocrystalline silicon (mono-Si):** Good overall efficiency vs. illumination.
- **Polycrystalline silicon (multi-Si):** Lower cost, however low efficiency.
- **Amorphous silicon (a-Si):** Most developed thin-film technology. Good efficiency for low intensity illumination
- **Gallium arsenide thin-film (GaAs):** Best efficiency, expensive process.
- **Copper indium gallium selenide (CiGs):** Thin-film, high efficiency; still in R&D phase, Production cost expected to be low.

4. SELECTION GUIDELINE

For proper solar cell selection for a specific application, several inputs need to be considered.

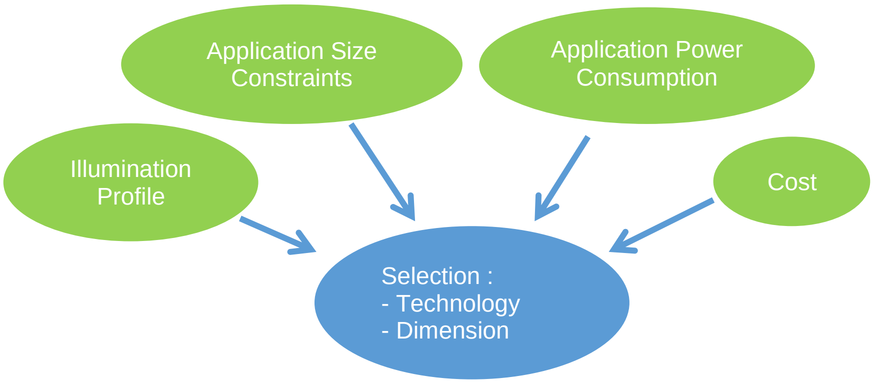


Figure 2 : Selection Guide Inputs

4.1 APPLICATION POWER CONSUMPTION PROFILE

The power load profile should be characterized versus time and the average power consumption should be calculated.

4.2 ILLUMINATION PROFILE

The application will be exposed to the light with varying intensities. Indoor vs. outdoor use cases influence the solar cell technology choice.

4.3 COST

Solar cell cost depends on the process and manufacturer.

4.4 SIZE CONSTRAINTS

Solar cell output power increases with the cell area.
For a chosen technology, the solar cell area/size can be calculated for the required application power.

5. AVAILABLE PARTS

A sample list of open market solar cells is shown in Table 1.

Manufacturer	Technology	Open voltage (Vov)	Size	MPP	VMPP	Part number
IXYS	Monocrystalline	0.63V	22.0 x 7.0 mm	18.6mW/cm²@1sun*	0.5V	KXOB22-12X1
AltaDevice	Gallium Arsenide	1.09 V	50.0 x 19.6 mm	18uW/cm² @200lux 25mW/cm²@1sun*	0.96V	Reference non available (www.altadevices.com)
Cymbet	Amorphous Silicon	1.2V	67.3 x 26.7 mm	4.9uW/cm²@200lux	0.8V	CBC-PV-02
Panasonic	Amorphous Silicon	3.6V	15.0 x 15.0 mm	3.58uW/cm²@200lux	2.6V	AM-1606C-MEL
TDK	Amorphous Silicon	3.8V	46.0 × 30.0 mm	5.23uW/cm²@200lux	Data not available	BCS4630B9

Table 1 : Solar Cell List with Main Parameters

*1 sun = irradiance 1000 W/m²

6. APPLICATION EXAMPLE WITH EM8500 AND SOLAR APPLICATION SIMULATOR

The “Solar Application Simulator” is used to perform all relevant calculations.

This tool is available on EM’s website under:
http://www.emmicroelectronic.com/products/power-management/power-management-tools-support

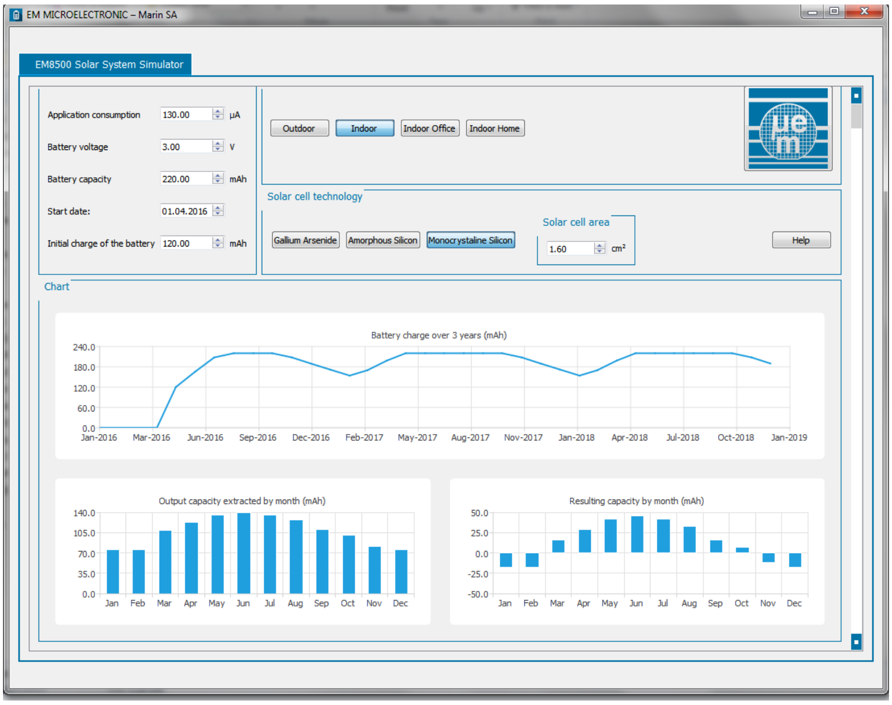


Figure 3 : Solar Application Tool Overview

6.1 “USER INPUTS” SECTION:

The user selects the following five parameters in the “User Inputs” section.

- *<u>“Application consumption”</u>*
  The average current consumption is entered in µA. If the application current profile consists of a more complicated current profile, an average current consumption has to be calculated and entered for this simulation.

- *<u>“Battery Voltage”</u>*
  The nominal voltage for the battery used in this system is entered.

- *<u>“Battery Capacity”</u>*
  The nominal capacity in (mAh) for the battery used in this system is entered.

- *<u>“Start Date”</u>*
  The tool calculates the battery charge level over the course of three years. The start date entered is used to properly account for seasonal variations of light intensity

- *<u>“Initial Charge of the Battery”</u>*
  This values describes the battery energy (in mAh) available at the start date.

6.2 ILLUMINATION PROFILE

To define profiles the illuminance range is split into four categories:

- Low: 0 to 100 lux
- Normal: 100 to 1000 lux
- Good: 1000 to 10000 lux
- Sunny: 10000 to 100000 lux

The illumination is reported monthly (in hours) based on a series of typical use-cases.

Illumination Profile				
Exposure	low	normal	good	sunny
Illuminance range (lux)	**[0-100]**	**[100-1000]**	**[1000-10000]**	**[10000-100000]**
Month	**Hour/month**	**Hour/month**	**Hour/month**	**Hour/month**
January	24.80	49.60	124.00	49.60
February	25.20	50.40	126.00	50.40
March	37.20	74.40	186.00	74.40
April	42.00	84.00	210.00	84.00
May	46.50	93.00	232.50	93.00
June	48.00	96.00	240.00	96.00
July	46.50	93.00	232.50	93.00
August	43.40	86.80	217.00	86.80
September	37.50	75.00	187.50	75.00
October	34.10	68.20	170.50	68.20
November	27.00	54.00	135.00	54.00
December	24.80	49.60	124.00	49.60
Total	437.00	874.00	2185.00	874.00

Table 2 : Illumination example profile report

Based on these profiles the simulation tools pre-defines four use cases shown in the "Solar Illumination Profile" section. The case most closely representing the system under analysis is selected. For all use cases the statistics are based on sun illumination in Central Europe Paris.

- *"Indoor" Profile*
  Solar cell placed inside a building, close to a window with direct sun light.

- *"Outdoor" Profile*
  Solar cell used outdoor with direct exposure to the sun.

- *"Indoor House" Profile*
  Solar cell placed inside a building, without direct exposure to the sun.

- *"Indoor Office" Profile*
  Solar cell placed inside an office, without direct exposure to the sun.

6.3 "TECHNOLOGY", SOLAR CELL SELECTION

Three pre-defined solar cell types (manufacturing technology) can be selected:

- Amorphous silicon:

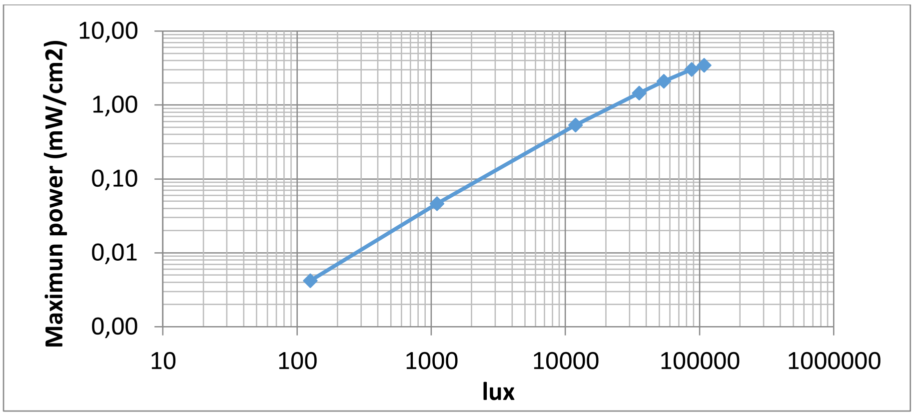


Figure 4 : Amorphous Silicon Solar Cell

- Monocrystalline Silicon

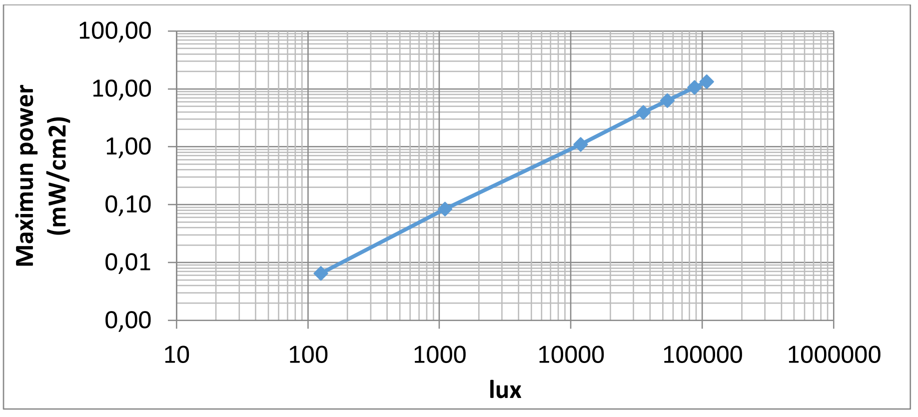


Figure 5 : Monocrystalline Silicon Solar Cell

- Gallium arsenide

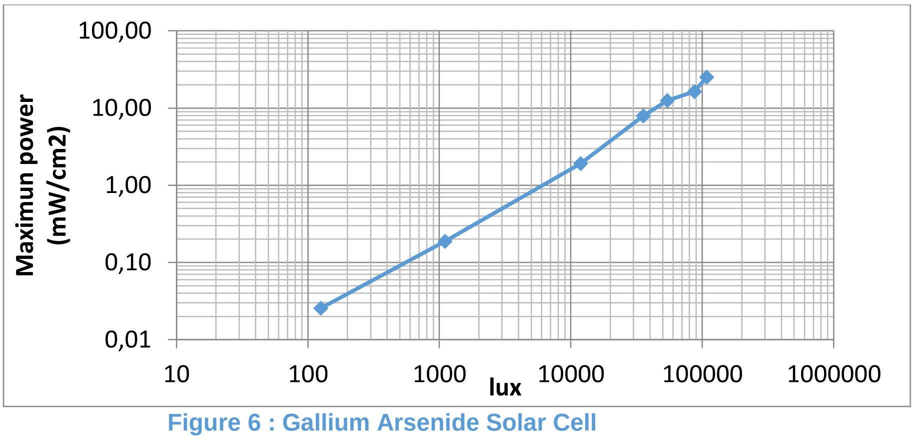


Figure 6 : Gallium Arsenide Solar Cell

6.4 APPLICATION POWER ANALYSIS

The tool “Solar application simulator” calculates the energy extracted from the solar cell including the EM8500 component efficiency. The resulting battery charge profile is plotted over a period of three years.

The battery charge profile helps to define the battery capacity. The graph provides an easy means to assess battery capacity (application power budget margin). In this example the minimum charge level at any time within the simulation interval remains at about 80 mAh.

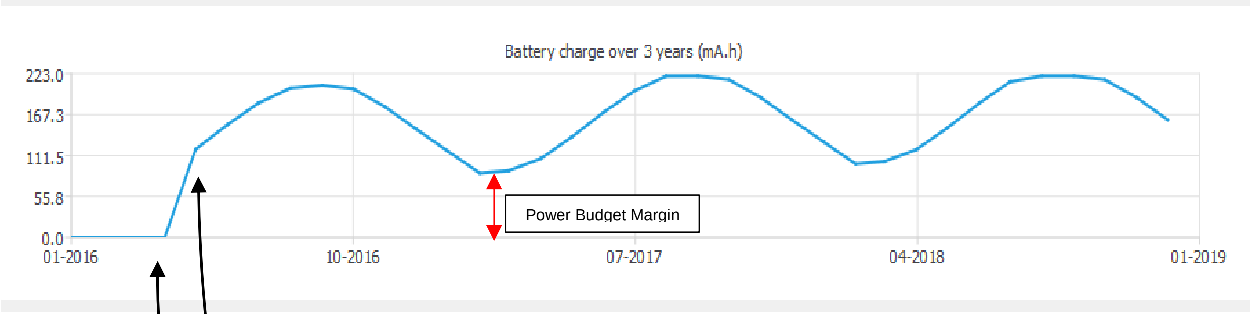


Figure 7 : Battery Charge Profile, Example

Battery characteristic		
Battery voltage	3	V
Battery capacity	220	mAh
Initial condition		
Initial charge of battery	120	mAh
Start date	10.04.2016	

Figure 8 : Input Parameters

The start time of the application and the initial battery charge can be set to simulate the insertion of a partially charged battery at a different point in time during the year.

The application tool plots the energy provided by the solar cell through the EM8500 to the battery (Figure 9), and the difference between the energy provided and used by the application (Figure 10).

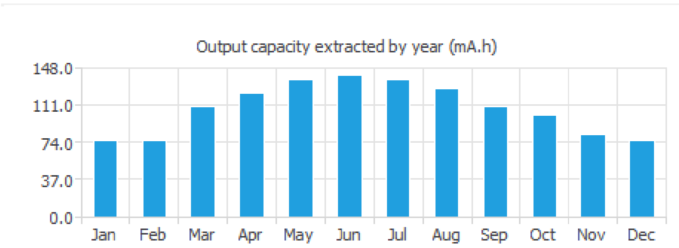


Figure 9 : Capacity available from Solar Energy

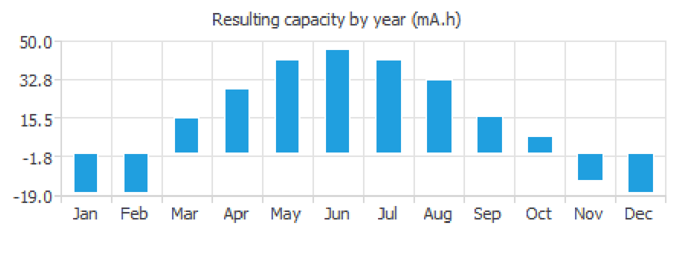


Figure 10 : Resulting Capacity after subtracting Energy used to power the Application

7. DOCUMENT HISTORY

Release	Author	Date	Description
1.0	EM	November 2, 2016	Initial release

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