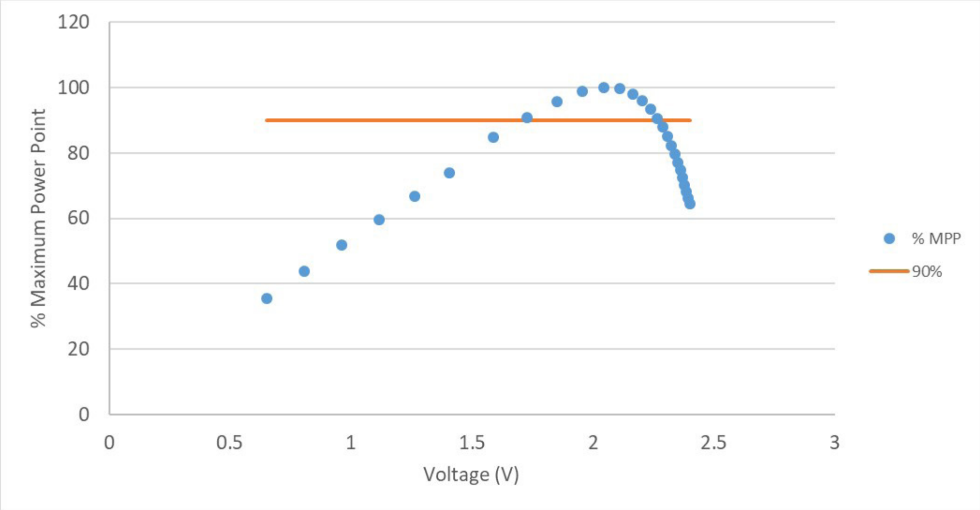
Direct coupling diode selection guide

Introduction

Energy harvesting (EH) is growing in popularity as a method for powering small scale internet of things (IoT) wireless sensor nodes. However, majority of EH sources don't produce sufficient power to run a target application continuously. Therefore, it is necessary to accumulate the power in an intermittent storage such as a capacitor or a battery.

In the case of the energy harvesting source that has the maximum power point in the range of the operating voltage of the target application by directly connecting the source to the storage element the highest efficiency can be achieved. The figure below demonstrates the range of voltages where the AM1417 solar cell will be operating above 90% efficiency. This voltage range is sufficient for majority of sensing applications and in this way additional circuitry is avoided thus keeping the efficiency high as there are no additional losses introduced by DC/DC converters.



Maximum power point and the >90% efficiency operating range of a AM1417 solar cell.

The maximum power point vs voltage and the 90% efficiency line. For the storage operating between 1.7V and 2.25V the solar cell would be operating always above 90%.

In order use direct coupling it is necessary to prevent the flow of charge from the storage unit back into the energy harvester when the harvester stops producing power and starts behaving as a load. An example is a solar cell that behave as diode when placed in dark environment.

To prevent the backflow of charge a diode is typically used. It is possible also to use active rectification at a cost of increased power consumption, however we will focus on passive direct coupling methods as the target for this guide are low power wireless sensor nodes that wouldn't have sufficient power budget to justify active rectification nor the cost that it brings with placing additional components.

The shortcoming of the direct coupling method is its inability to charge the storage if the voltage on the output of the harvester is below the voltage of the storage. However, this issue can be application specific and should be investigated before the final decision on the method for transferring power from the energy harvester to the storage is selected.

When selecting diodes two things have to be taken into consideration:

1. Forward voltage drop - the voltage required to develop over the diode for the diode to start conducting
2. Reverse leakage - the current that will flow through the diode when reverse voltage is applied over it

We have performed a series of tests on different types of diodes and recorded their forward voltage drop for small currents expected coming from solar cells and the reverse leakage current at voltages expected to be encountered in these types of systems.

The diodes tested can be divided into 4 categories:

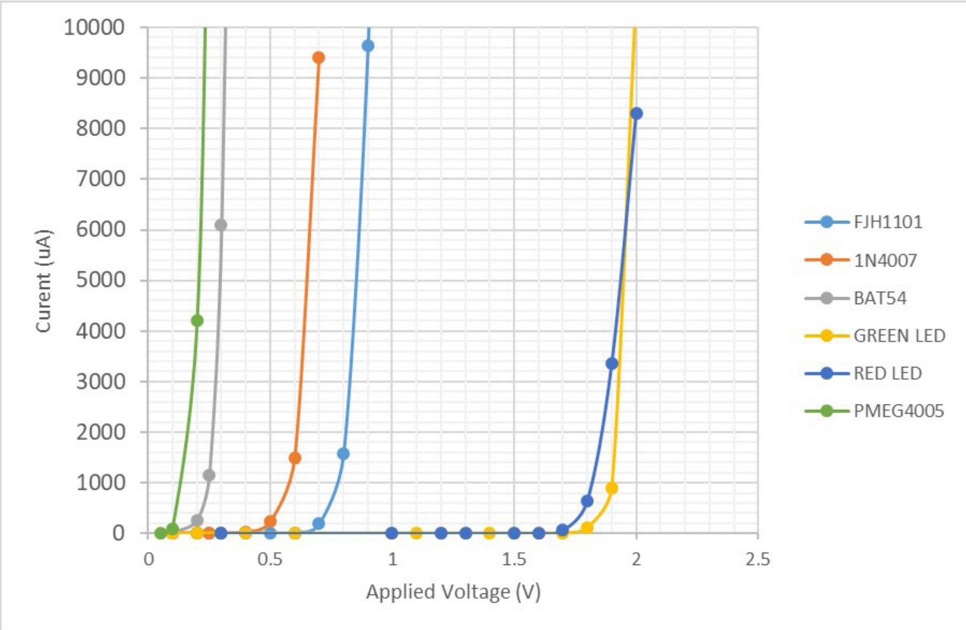
1. Schottky diode barrier diodes
2. Silicon based diodes
3. Low Leakage silicon-based diodes
4. LEDs

Schottky diodes have a low forward voltage drop however they typically have higher reverse leakage currents. Examples of these diodes tested are: BAT54, BAT20, SBR130, PMEG4005.

Silicon based diodes and Low leakage silicon diodes have higher forward voltage drop but come at substantially smaller leakage currents.

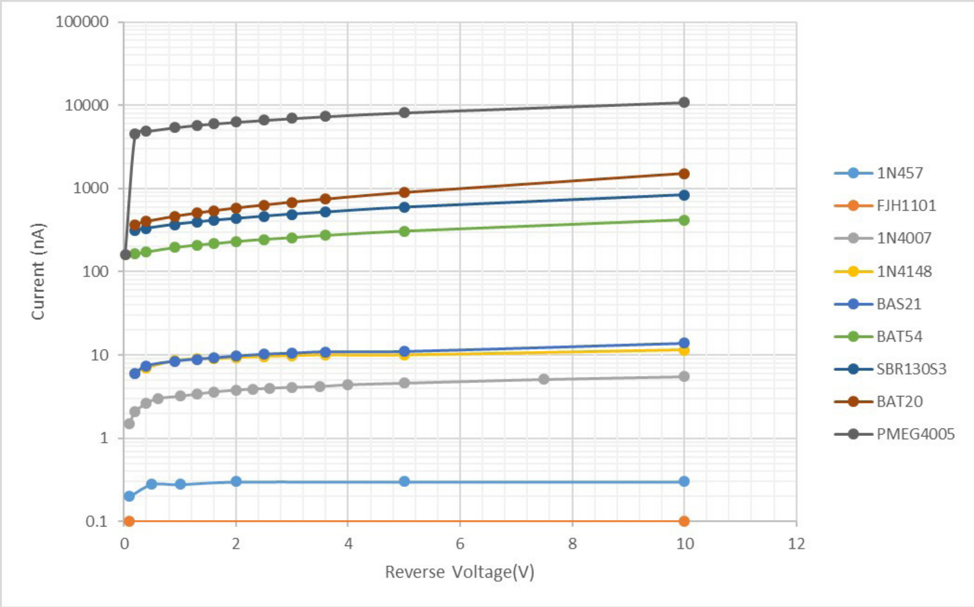
The LEDs can be used if a voltage drop of few volts is required as these diodes conduct close to no current until higher voltage levels are reached.

The forward voltage drop of different diodes is shown in the figure below:



Forward Voltage drop of different types of diodes.

The reverse current for different diodes is shown in the figure below:



The current through the diode as a function of the applied reverse voltage.

From the previous figures it can be easily seen how different types of diodes are grouping together based on their properties.

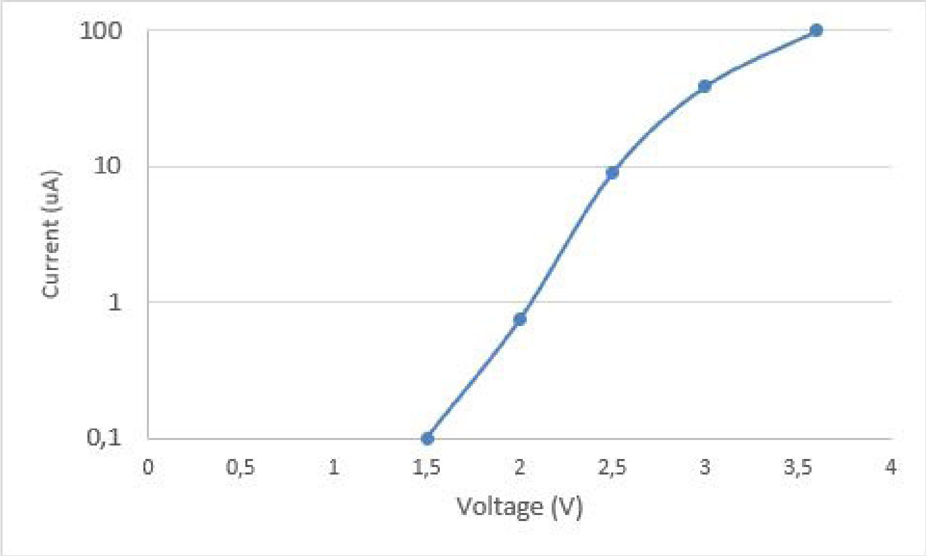
Diode selection

When selecting the diode, it is important to start with the current and voltage requirement of the target system and the storage element selected. Based on these choices we can determine the average current consumption of the application and leakage currents of the storage. This is especially important if supercapacitors are used as storage elements as they can have large leakage currents.

After determining the operating voltage of the storage element, we can need to determine how much current will the solar cell be generating at our target operating condition. This current will be used to determine the diode to be chosen as the voltage drop over the diode is a function of the current running through it. Select the diode and the solar cell in a way that the combination of the voltage on the storage element and the voltage drop over diode when the solar cell is operating at maximum current, falls within the range of voltages that will keep the solar cell within its maximum efficiency.

Among the selected diodes based on their forward voltage drop a diode with highest acceptable leakage current should be selected. Selecting the highest acceptable leakage current would allow for the lowest forward voltage drop. Typically, the reverse leakage current shouldn't exceed 10% of the application's power consumption budget when the application is using the from the storage element.

Note that in the case of solar cell applications the leakage current would be reduced as the solar cell is effectively a diode and it requires a forward voltage drop to start conducting current as shown in the figure below. This means that the effective reverse voltage on the diode would be reduced for the value of the forward voltage drop over the solar cell.



The current consumption of a solar cell in dark as a function of applied reverse voltage.

Conclusions

Using a diode for connecting the solar cell or other EH sources that have output voltages in the range of the desired operating voltage range of the storage can provide high efficiency and a low cost solution. When selecting the diode, it is important to select a device that will keep the voltage on the storage element within the operating rage while keeping the solar cell at the optimal power point.

Want to know more?

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