# Hot Spots on a Solar Panel

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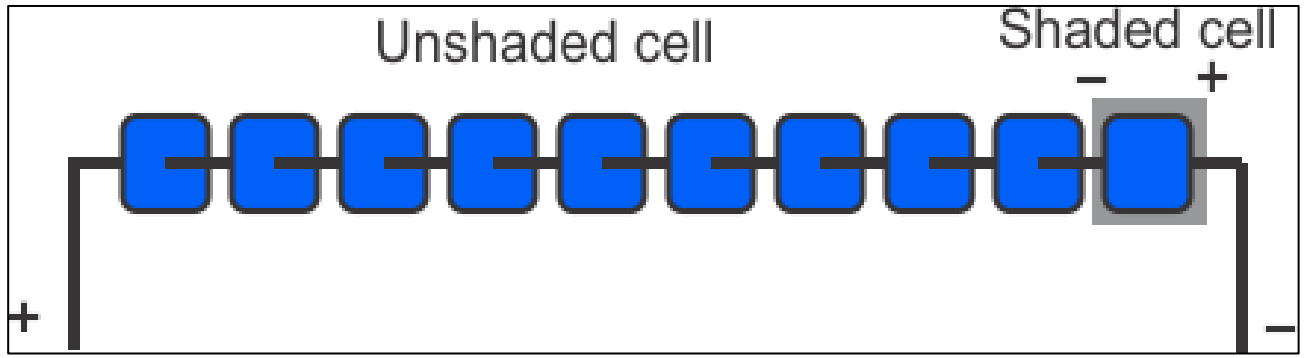
# What is a Hot Spot?

- Occurs when there is one low or no-current solar cell connected in a string of several high-current solar cells.
- This can be caused by a leaf falling on a panel, a branch creating shade on a panel, etc.
- Results in local over-heating which leads to destructive effects like glass cracking, solder melting, or a general degrade in quality of the panel.

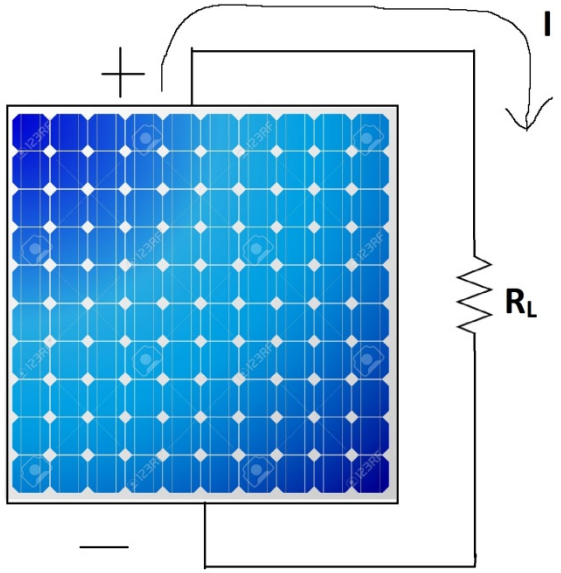


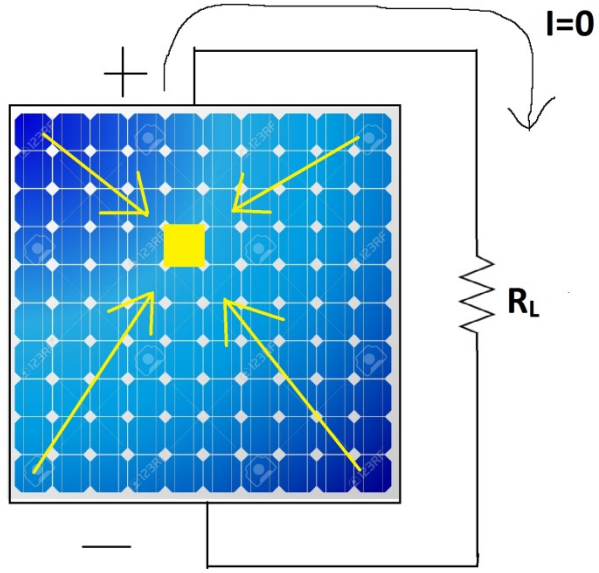
# Visual of Hot Spot

Normally, with all solar cells active, the current generated by the minority carriers are able to flow through the load resistance.

If all cells are connected in series and one cell is not allowing current to flow, there is no current in all of the cells.

Since all other cells are on, the hot spot has characteristics that will force it to draw a lot of power from the surround cells, leading to destructive properties.



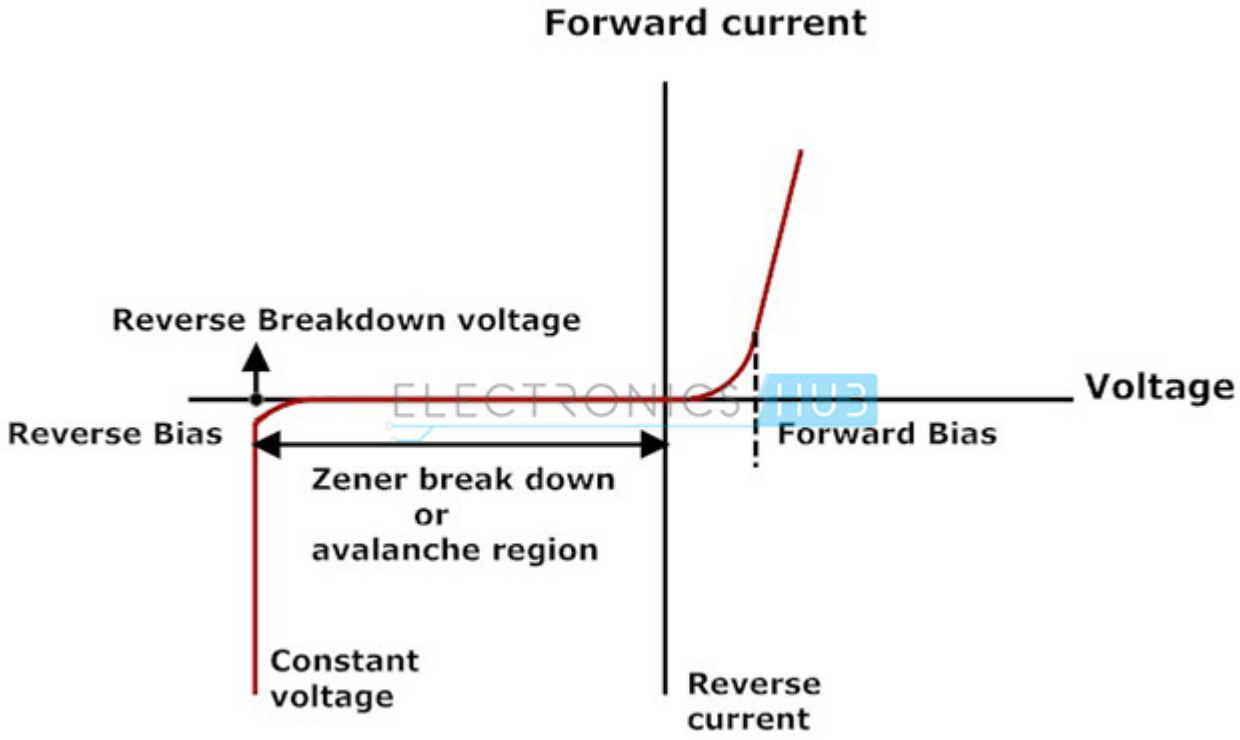



# IV-Curve of Diode

If the voltage across the diode is above the turn on voltage, it is forward biased and current is allowed to flow through.

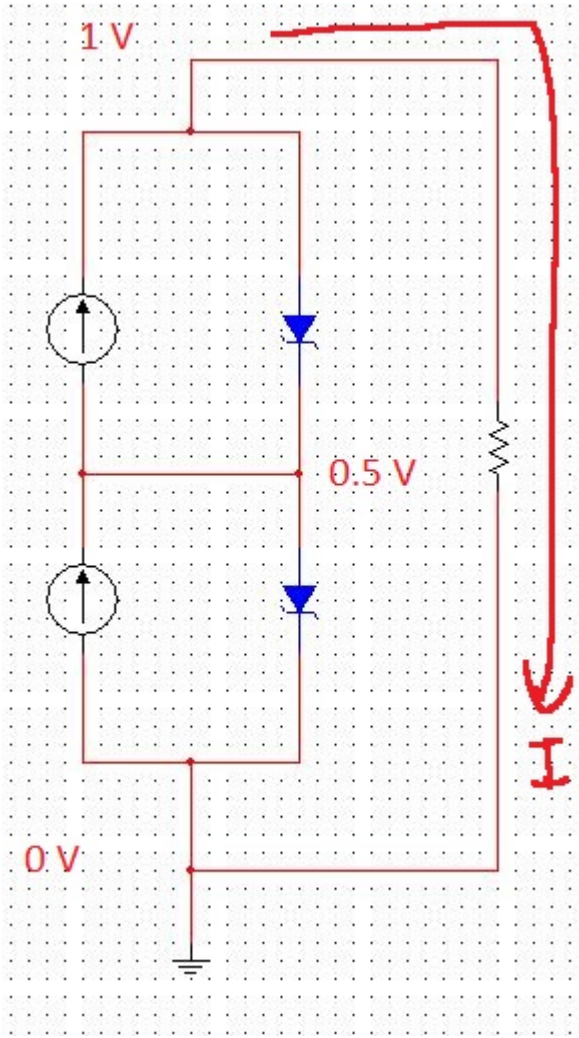
If voltage across diode is negative, no current can pass through.

If voltage is very negative, the diode becomes reversed biased and reaches breakdown and current is allowed to flow in the other direction.



# Two Matched Solar Cells

Suppose each solar cell diode has a drop of 0.5 V. When both of these panels are completely turned on, current is allowed to flow through both the load resistor and the diodes.



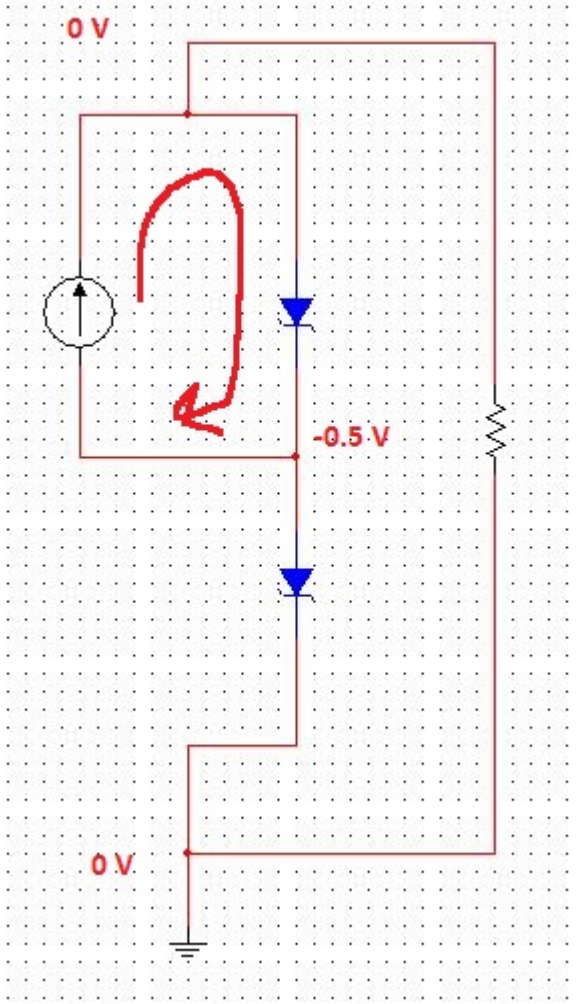
# Two Mismatched Solar Cells

Suppose one solar cell is not receiving any sunlight and thus is not able to turn on.

No current is able to flow through the load resistor so there is no voltage drop across it.

Light is still providing energy to one cell and causing it to operate. This forces a 0.5 V drop from 0 V.

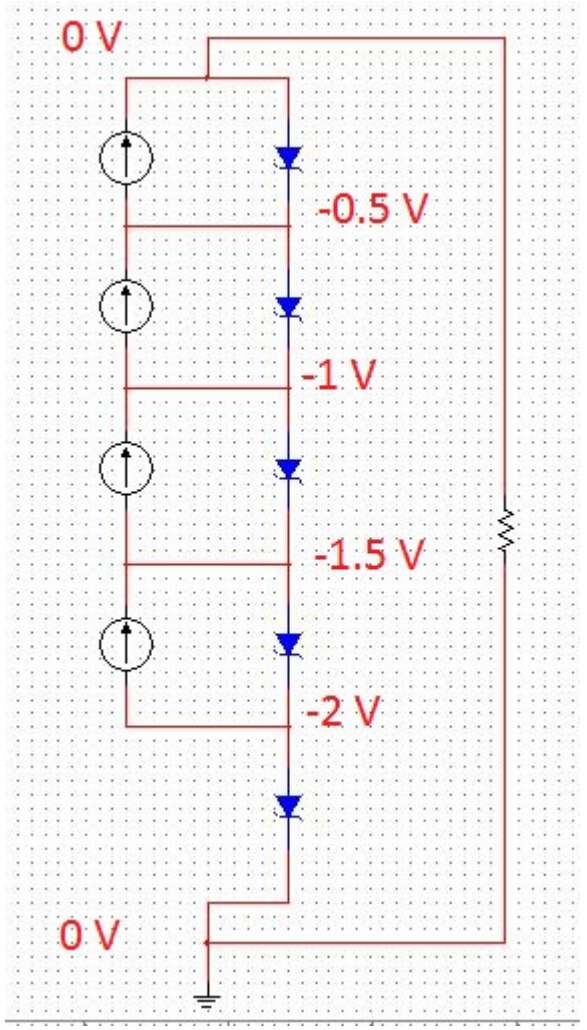
This in turn causes the second diode to have a slight reverse bias, which means 0 current.



# Add More Solar Cells

With more solar cells being placed in series with the shaded cell, the reverse bias seen by the cell gets even greater.

It does not take long before the diode enters its breakdown region and starts allow current flow.

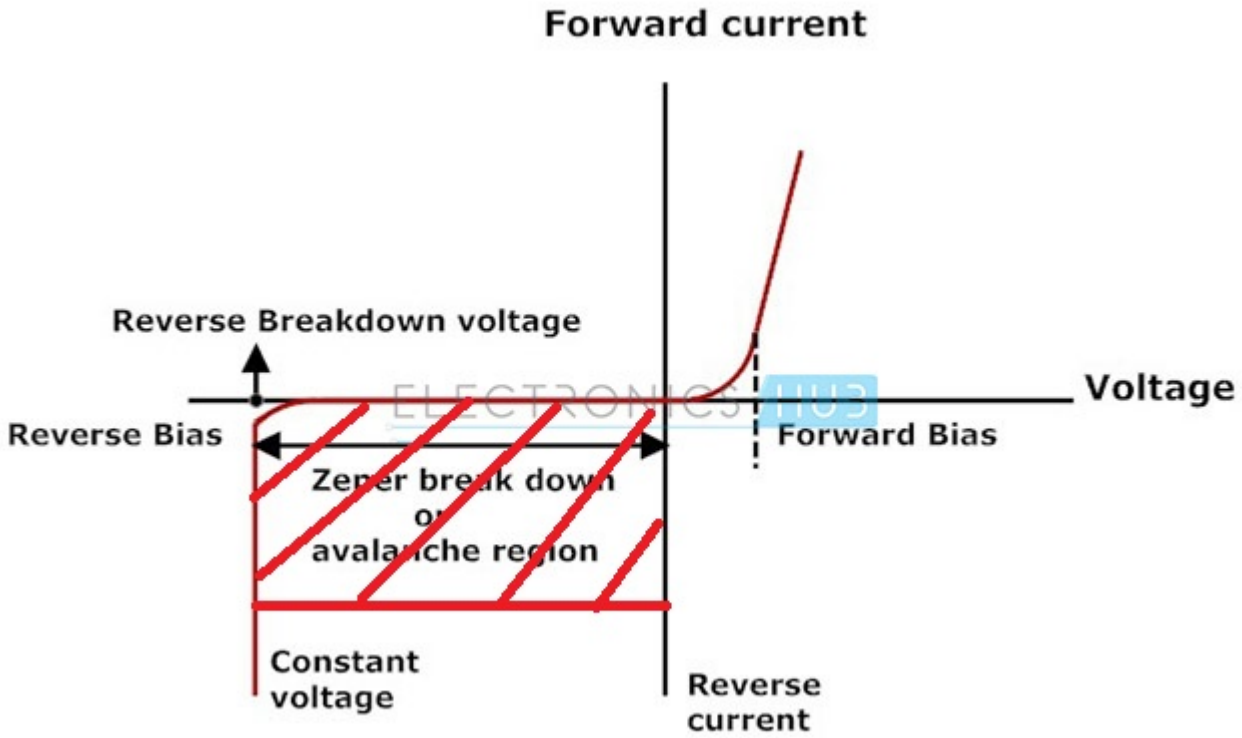


# Effect of the Reverse Bias

P=IV

This reverse bias leads to the entire generating capabilities of the “good” solar cells to dissipate into the shaded cell.

This turns out to be a very large amount of power, especially in such a small area. This results in a hot spot which can damage the cell.

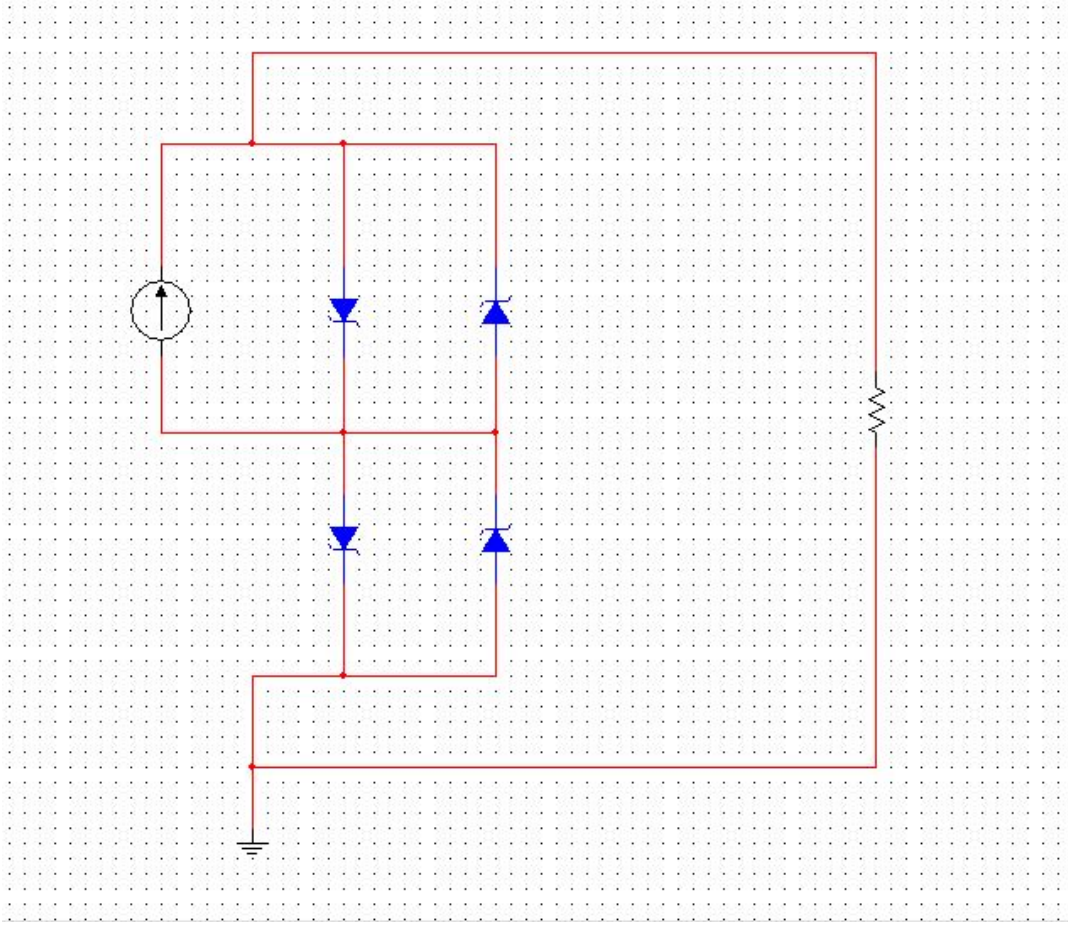


# Bypass Diode Solution

In order to prevent hot spots, a bypass diode is added in parallel to the solar cell. This diode is placed with opposite orientation.

It is not necessary to place a bypass diode for every single cell.

The maximum group size per diode, without causing damage, is about 15 cells/bypass diode, for silicon cells. For a normal 36 cell module, therefore, 2 bypass diodes are used to ensure the module will not be vulnerable to hot-spot damage.

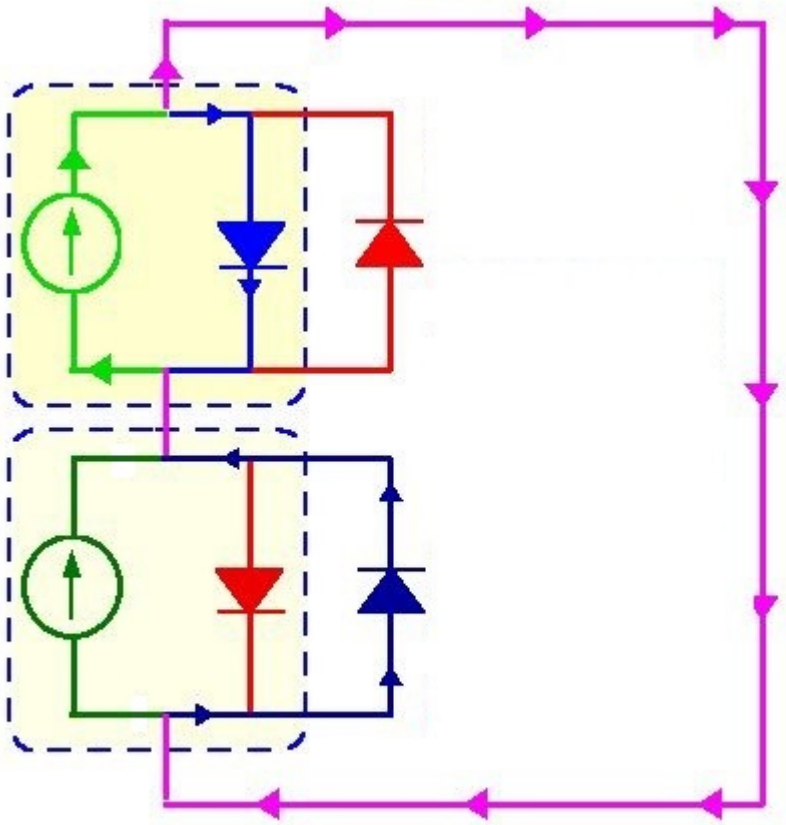


# Current Flow With Bypass Diode

With the bypass diode in place, when a shaded cell would normally reach its breakdown reverse bias state, the bypass diode actually becomes forward bias

This allows current to flow through the load resistor again, preventing any of the diodes to reach breakdown voltages.

Less current flows through the load than if all the cells were lit, but at least there is some and no hot spots will occur.

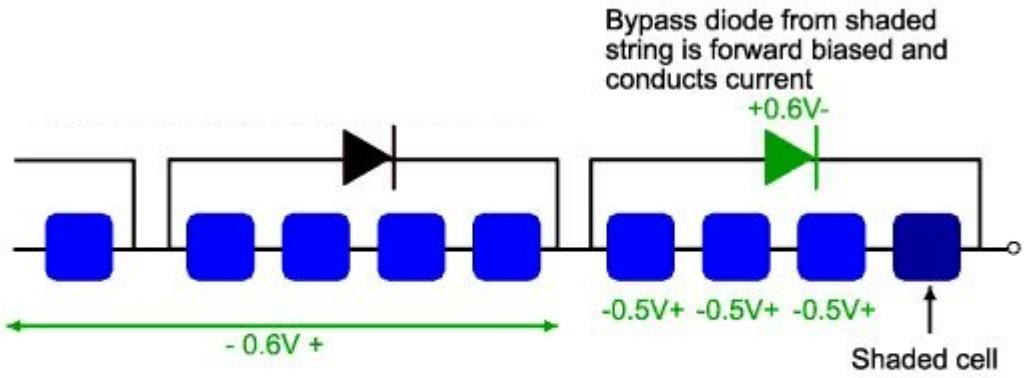


# Grouping with Bypass Diode

Bypass diodes from the groups with unshaded cells are reversed biased and have no impact.

Current from a series of cells is limited by the lowest current cell.

With the bypass diode active, current is allowed to flow through the load and cell, so the voltage drop associated with the cell isn't as large. 0.5 V compared to 0.6 V in the figure showed.



# Referenced Images

- http://www.pveducation.org/pvcdrom/modules/bypass-diodes
- http://www.electronicshub.org/zener-diode-tutorial/
- http://static6.depositphotos.com/1027309/624/v/950/depositphotos_6242062-solar-cells-pattern.jpg