solantro
SEMICONDUCTOR CORP.

Celestica™
Solid partners. Flexible solutions.

DC Power Optimizer & Intelligent Disconnect

Chipset and Development Platform Overview

DC-POD PLATFORM | JUNE 2014

Contents

Solantro Chipset Description (SA1001)

Analog Power Manager (APM)

- High voltage interfacing (up to 80V)
- 2 half bridge drivers
- Driver cross-conduction protection
- Adjustable under-voltage lockout protection
- Flyback controller with power switch
- 2 high-speed high-voltage sense inputs and 3 accurate high voltage sense inputs corresponding to 5 low-voltage analog outputs
- Serial interface for setting parameters
- Complete analog front-end for DC-DC power conversion

Complete analog front-end for DC-DC power conversion

Solantro Chipset Description (SA3101)

Maximizer - DC Controller (MAXC)

- 32-bit RISC microcontroller core
- 32kB of memory
- 2 interleaved advanced PWM timers
- 5 comparators with adjustable trigger levels set by 2 independent DACs
  - Can trigger timers
- 3 10-bit fast ADC (1 MS/s)
  - 2 independent, 1 mixed
- Chopper stabilized current sense inputs
- Serial interfaces (includes SPI & 2 UART)
- Galvanically isolated serial interface

Microcontroller for managing real-time power converters

DC-POD – Solantro Chipset-based Evaluation Platform

Intelligent Disconnect

- Reduces PV-panel output to 0 V

Power Optimizer

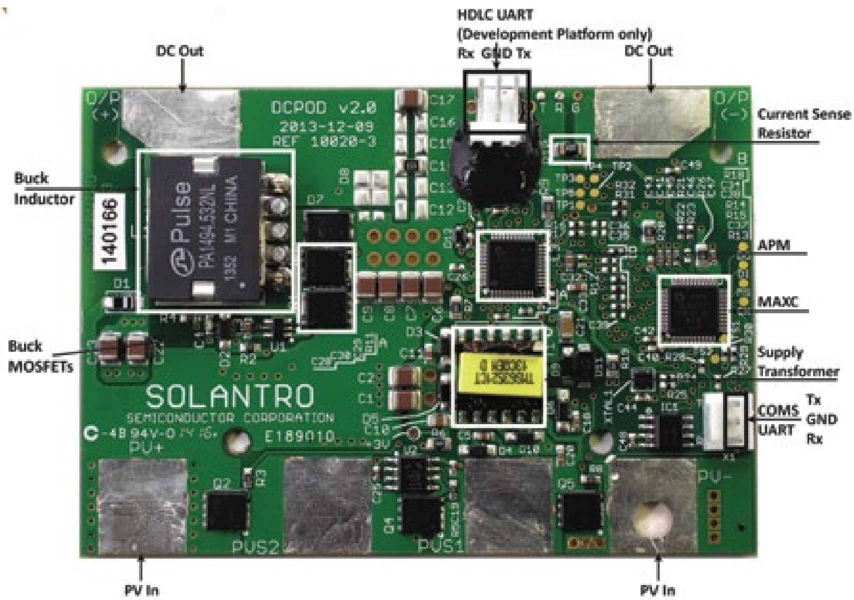
- PV-panel level optimization increases output by 5- 25%

Substring Cool Bypass

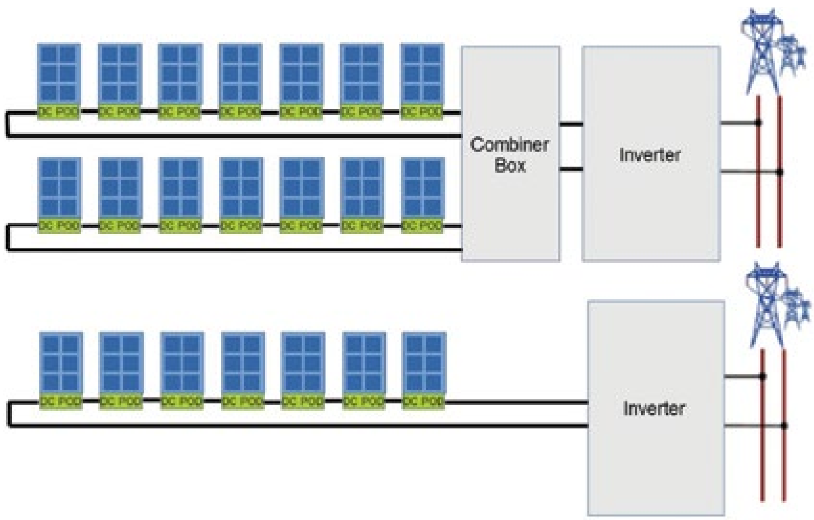
- Replaces traditional bypass diodes with smart electronics that can bypass individual PV-panel substrings

Parameters	Specification – DC-POD
MPPT Operating Range	10-48 V
Maximum Output Current	10.5 A
Efficiency	>99%

DC-POD Evaluation Board

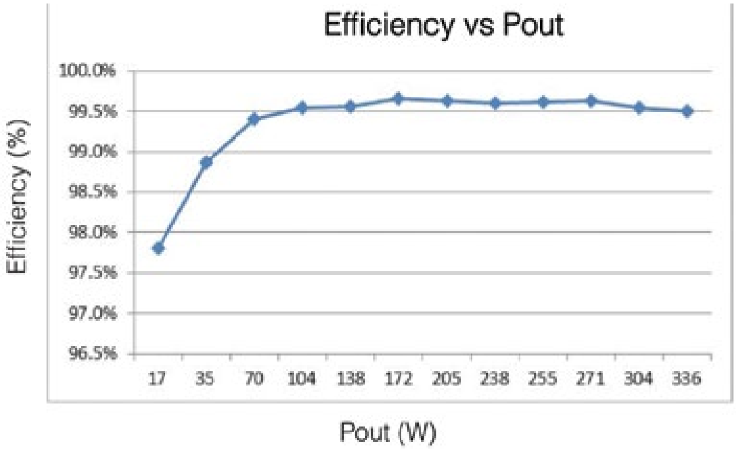


DC-POD/DC-POD Typical Applications



Power Efficiencies

Measured efficiencies from DC-POD evaluation board



- Peak efficiency at 99.7%
- CEC weighted efficiency at 99.48%
- European weighted efficiency at 99.57%

DC Optimizer Comparison

	Development platforms enabled with Solantro chipset	Product 1*	Product 2*	Product 3*
PV-panel side input parameters				
MPPT Input Voltage Range	10-48V	16-48V	5-55V	25-80V
Maximum input power (STC)	350W	300W	300W	360W
String output Parameters				
Output voltage (connected)	-0.3V to 48V	29 to 40V (max)	5 to 60V	63.6V (max)
Output voltage (disconnect)	0V (no pulses)	N/A	N/A	N/A
Output sourcing current (continuous)	10.5 A (max)	9.5A (max)	15A (max)	6.7A (max)
Maximum efficiency	99.7%	99.6%	99.5%	99.2%
Weighted efficiency	99.57%	N/A	98.9%	N/A
Miscellaneous Parameters				
eBOM Count	87 (DC-PODX) 96 (DC-POD)	N/A	186	N/A
Intelligent Disconnect Switch	YES		YES	
Active Bypass	YES (String & Sub-string)		NO (Diode)	
Ambient Temperature Range	-40°C to 70°C	-40°C to 85°C	-40°C to 85°C	-40°C to 70°C
Dimensions (cm)	8.0 x 5.3 x 0.9 (PCB)	17.1 x 17.1 X 2.2 (in box)	20.8 x 15.5 x 2.95 (in box)	10.7 x 7.6 x 1.7(in box)

DC Optimizer Value Proposition

Integration of three major functions

- Power optimizer
- Intelligent disconnect
- Substring cool bypass

Relative small board foot-print

- Lowest eBOM count (87 components)
- Smallest board size: 8.0 x 5.3 x 0.9 cm
- J-box compatible dimensions

High power efficiency

- Highest weighted efficiency ~ 99.5% (see Power Efficiency slide)
- Lowest power dissipation (< 4W worst case at 10A max)

Simple to use

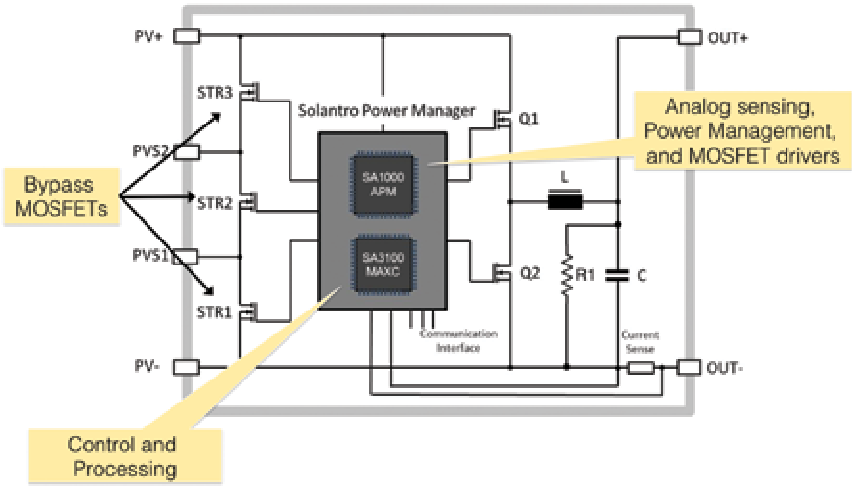
- Integrated computing capability for operating without external communications

Platform

- DC-POD-E-01 (Evaluation): Now

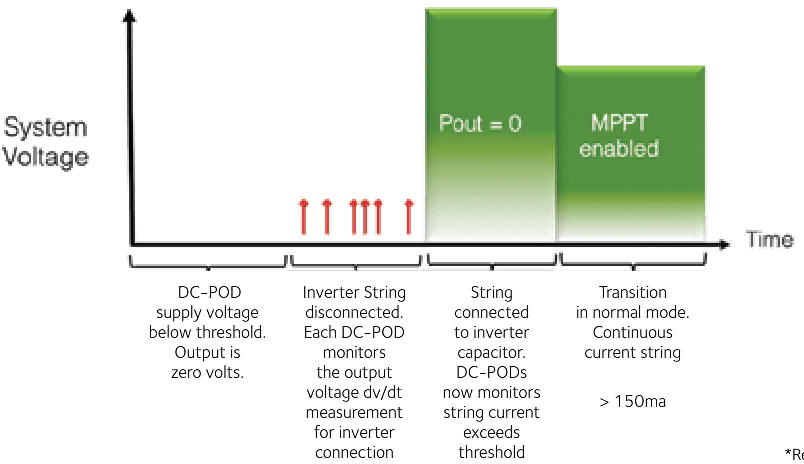
DC-POD Architecture

Evaluation board block diagram



DC-POD- Reconnect Operation Return to Normal Mode

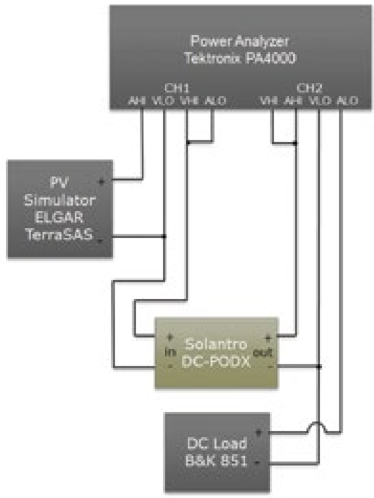
Sequence of events*



*Reference appendix for details on modes of operation

Set-up Requirements

Equipment configuration



Test Equipment Description

Device	Manufacturer	Description
PV Simulator	ELGAR TerraSAS	Power supplies to emulate PV source
DC Load	B&K Precision 851	600W DC Electronic Load – using constant current regulation to emulate a string inverter load
Power Analyzer	Tektronix PA4000	Power analyzer to monitor voltage and current into & out of the DC-POD and calculate efficiency

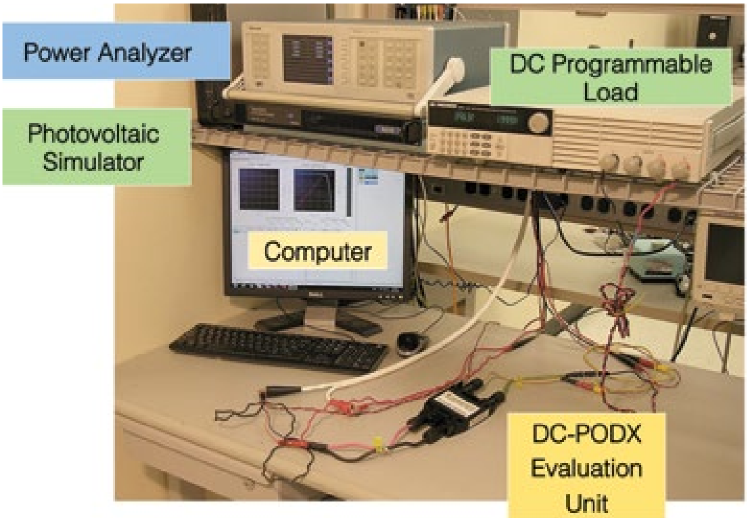
Test Setup Notes

1. Power analyzer voltage monitoring should be connected as close as possible to the DC-POD in order to properly measure the efficiency of just the DC-POD by avoiding voltage drops in the high-current paths.

2. The connectors and wire gauge used in the high-current paths should be selected to handle a 10.5 ampere current load.

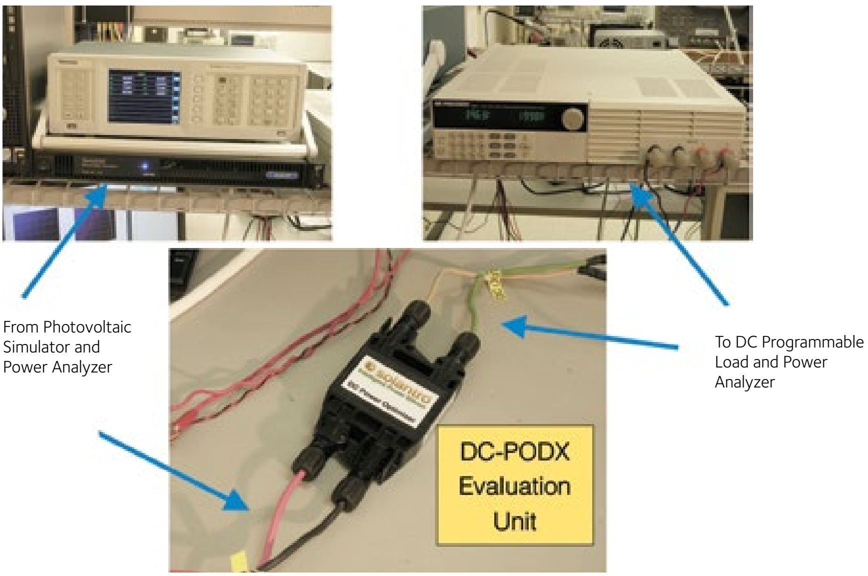
3. The DC Load and the output of the PV Simulator should be disabled prior to the start of each test.

Installation Set-up



* The above equipment, used for internal testing, is shown for demonstration purposes only.

Installation Set-up (DC-PODX Evaluation Unit)



Test Procedure and Results (Constant Current)

Test procedure for constant current

1. Set the solar panel parameters on the PV Simulator. Set the DC load to the output current shown on the first line of the table.

2. Observe the voltage and current readings on the Power Analyzer. The loss at 1A should be less than 1W, depending on the voltages.

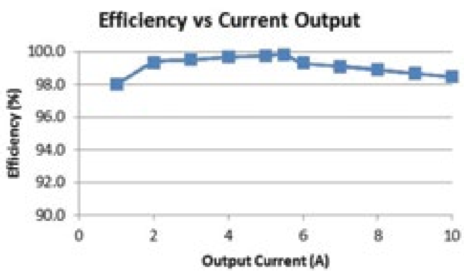
3. The load current may be increased through each of the cases in the table below and the values observed.

Settings and readouts for constant current

Current Out	Voltage In	Voltage Out	Current In	Power In	Power Out	Efficiency *
1A	48.2	44.0	.9	44.9	43.9	98.0
2A	47.2	46.9	2.0	94.8	94.1	99.3
3A	46.3	46.0	3.0	139.0	138.0	99.5
4A	45.0	44.8	4.0	180.2	178.9	99.7
5A	43.0	42.7	5.0	214.6	213.2	99.7
6A	40.1	37.1	5.6	224.8	222.4	99.3
7A	40.2	31.7	5.6	225.0	221.6	99.1
8A	40.5	31.7	5.6	225.1	221.1	98.9
9A	40.5	24.5	5.6	225.0	220.3	98.7
10A	40.5	22.0	5.6	225.1	219.7	98.5

*Efficiency results are based on a zero loss connection. The setup used to get the numbers had a ~15mOhm loss in the connectors, so values were adjusted accordingly. It is very important to get the voltage sensing as close to the DC POD as possible.

Test results for constant current



Notes:

1. The readouts of Input Voltage and Input Current are approximate and there will be minor unit-to-unit variation.

2. The PV panel profile used was that of the SunPower 230 (72 cell) panel.

Test Procedure and Results (Constant Voltage)

Test procedure for constant voltage

1. Using the setup shown in Figure 3, add a DC power supply with output parallel with the load. Set the load voltage and the PV simulator to the values in the table and turn on the simulator, followed by the load, and DC power supply.

2. Once the DC-POD is delivering current, disconnect the power supply to avoid reverse current flow into the supply. Observe the current and voltage readings on the Power Analyser.

3. Adjust the irradiance on the PV simulator for each of the cases and observe the values.

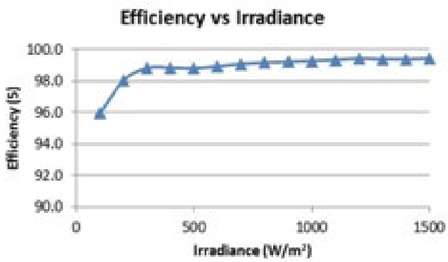
Settings and readouts for constant voltage

Load voltage set to 36V

Irradiance (W/m2)	Voltage In	Voltage Out	Current In	Current Out	Power In	Power Out	Efficiency*
100	37.3	36.2	0.6	0.6	21.2	20.3	95.9
200	38.8	36.3	1.2	1.2	44.1	43.1	98.1
300	38.3	36.4	1.7	1.8	66.9	65.6	98.8
400	39.2	36.6	2.3	2.4	89.2	88.0	98.9
500	38.5	36.7	2.9	3.0	112.3	110.6	98.8
600	39.9	36.9	3.4	3.6	135.2	133.4	98.9
700	40.5	37.0	4.0	4.2	156.9	155.5	99.1
800	39.0	37.2	4.6	4.8	179.9	177.7	99.2
900	40.5	37.3	5.0	5.4	201.7	199.3	99.2
1000	41.0	37.4	5.5	5.8	224.8	221.8	99.3
1100	40.9	37.5	6.1	6.5	246.8	244.0	99.3
1200	40.9	37.7	6.6	7.1	269.1	265.1	99.4
1300	40.0	37.7	7.2	7.6	291.6	288.0	99.4
1400	40.6	37.9	7.6	8.2	313.1	311.0	99.4
1500	40.9	38.9	8.4	8.7	335.9	331.8	99.4

*Efficiency results are based on a zero loss connection. The setup used to get the numbers had a ~15mOhm loss in the connectors, so values were adjusted accordingly. It is very important to get the voltage sensing as close to the DC-POD as possible.

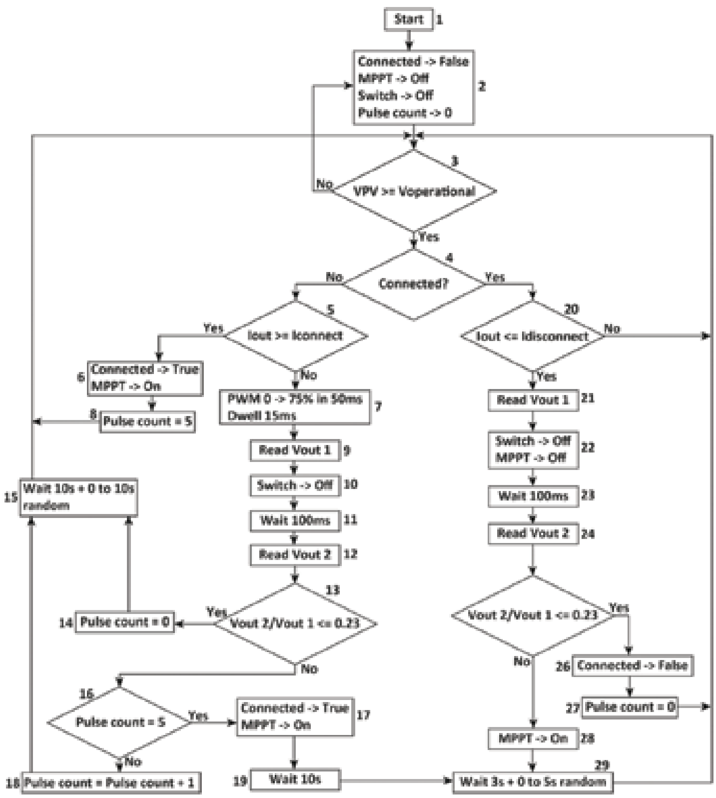
Test results for constant voltage



Notes:

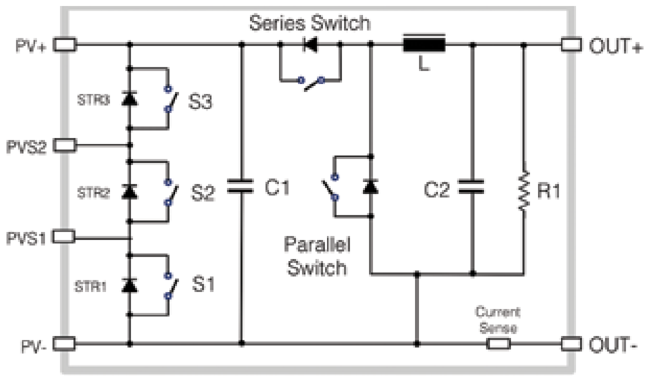
1. The readouts of Input Voltage and Input Current are approximate and there will be minor unit-to-unit variation.
2. The PV panel profiles used were SunPower 230 (72 cell) panel.
3. The DC power supply in parallel is to provide starting current for the DC-POD. If it is already delivering current due to load conditions, then the DC power supply may not be necessary (such as setting the load to 1A current then changing it to a voltage load).

Modes of Operation (Algorithm)



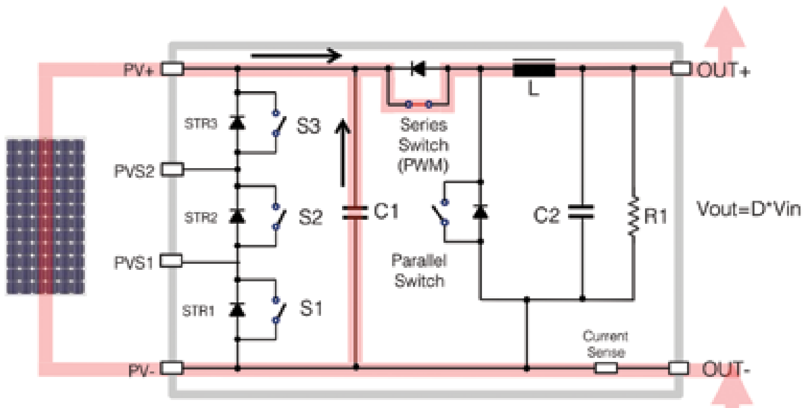
Modes of Operation

Equivalent functional block diagram



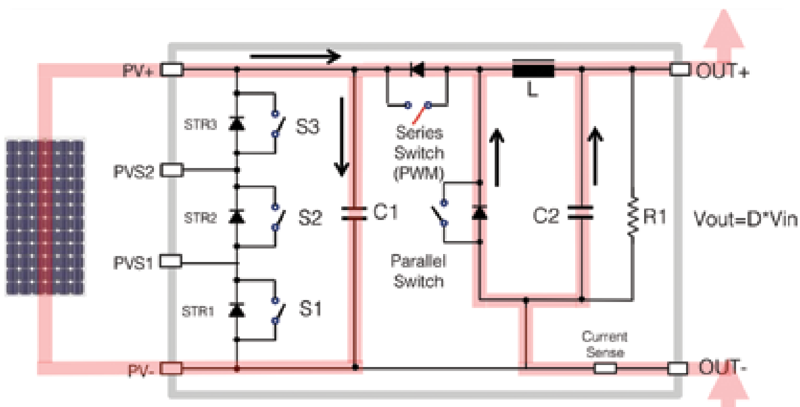
Normal operating mode – MPPT enabled

Efficiency >99%



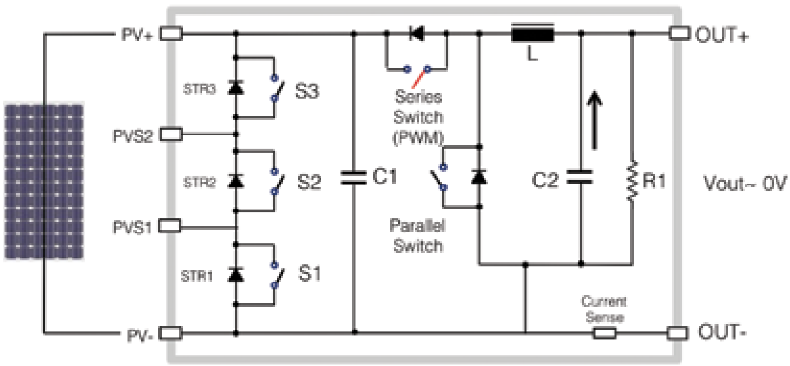
Normal operating mode – MPPT enabled

Efficiency >99%



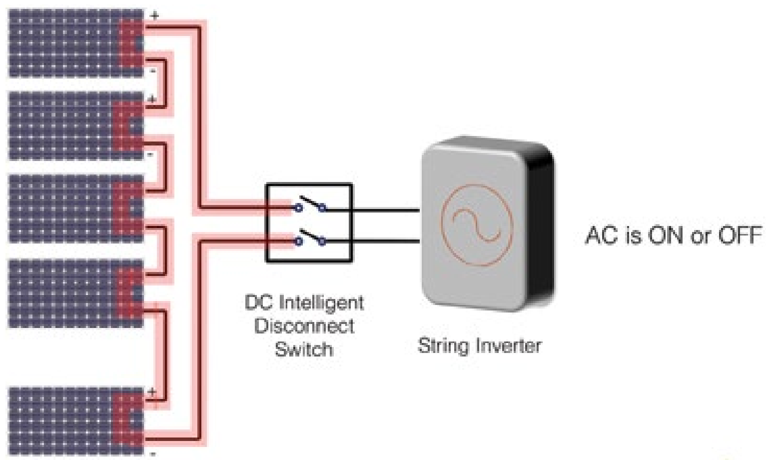
Unpowered Mode

- PV-panel is in darkness and/or covered; does not produce sufficient power for the internal APM DC/DC bias converter to start and power the DC-POD itself.
- No local supply voltage, both the series and the parallel switches (as well as bypass switches) are open.
- String disconnected from inverter capacitor and no current flowing with Vout ~ 0V.



Connecting Operation – Open Circuit Detected

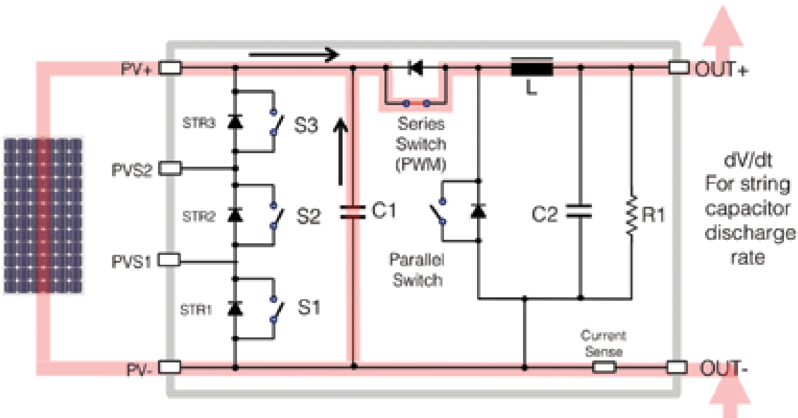
The DC-PODs on the string monitor output voltage for indication of inverter connection. If DC Intelligent Disconnect Switch is OPEN, then Vout = 0V.



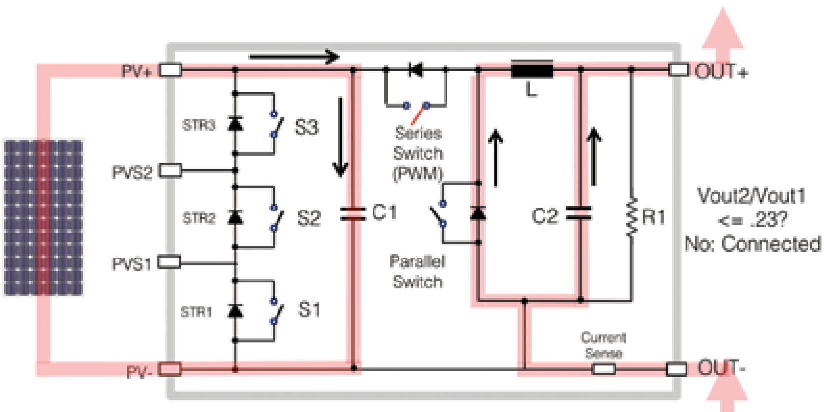
- PV-panel producing sufficient power for the internal APM DC/DC bias converter to start and power the DC-POD itself. (Boxes 1 to 3 from algorithm state diagram; page 12)
- Parallel switch low-voltage-drop diode bypass the PV-panel and allow string-current to flow. Each DC-POD monitors string current to determine if connected to the inverter (Box 5). If yes DC-POD enters normal mode and activates MPPT (Box 6)
- If String not yet connected to inverter capacitor, activate PWM to attempt charging this large capacitor. Measure DC-POD output voltage twice to determine rate of discharge. (Boxes 9 to 13).
- If rate is fast, restart measurements after random time period which is programmable (Box 15). If rate is slower, repeat procedure (i.e. five times; programmable) before declaring string inverter connectivity (Boxes 16 to 17).
- DC-POD activates MPPT and enters normal mode after random time period which is programmable (Box 19 and 29).

Connecting Operation – Closed Circuit Detected

With the DC Intelligent Disconnect Switch CLOSED, DC-POD output voltage measurements indicate inverter connected to the string



- After 100ms if measured output voltage is greater than 20% of the first measurement, indication inverter is connected to the string
- If DC-POD output voltage remains above 20% of initial measurement, then series switch fully turned on for 30 seconds
- If second voltage measurement is not greater than 20% of the first measurement, indicates no inverter present and the system will wait 5 seconds before repeating measurements

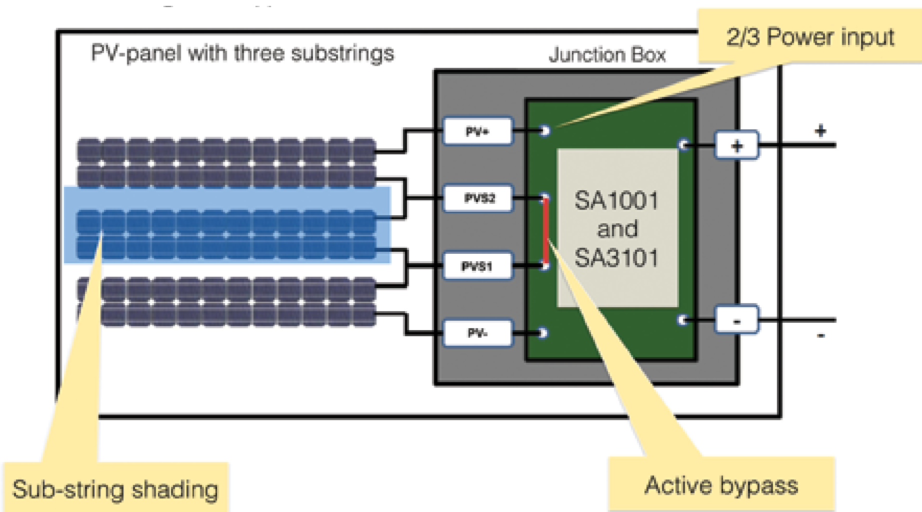


Normal Operation – MPPT Activated

- "Inverter present" state detected.
- Maintain MPPT If string current exceeds disconnect threshold which is programmable (Box 20)
- If string current falls below threshold then verify string connectivity to the inverter capacitor (Boxes 21 to 25)

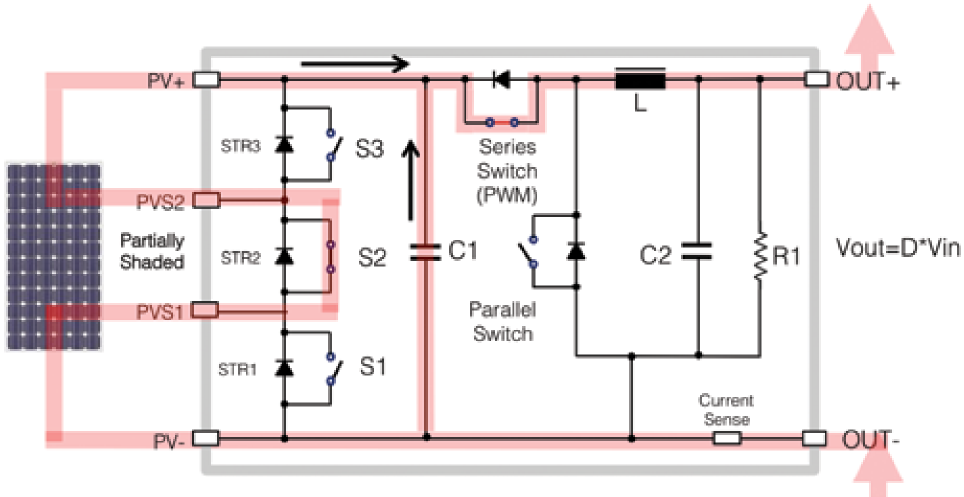
Active Bypass at Work

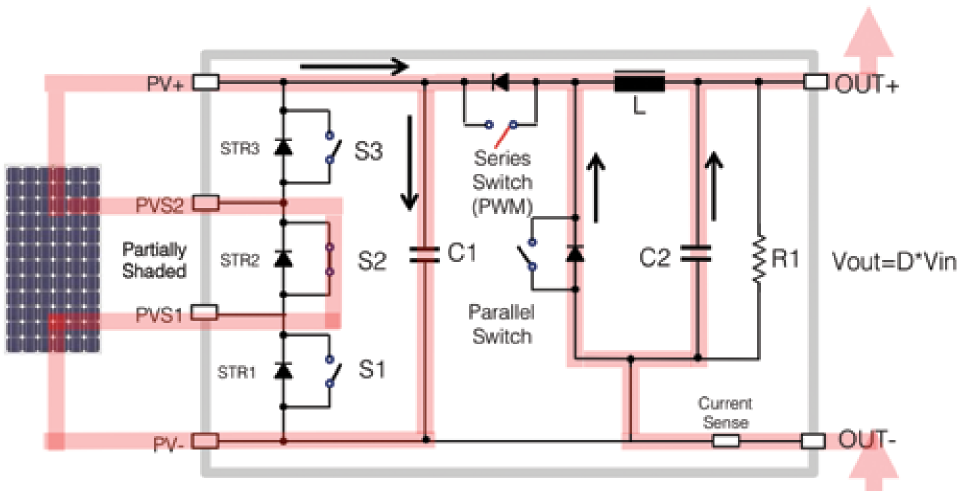
- Supports bypass features for up to three substrings in PV-panel with integrated bypass MOSFETs



Substring Bypass

Partially shaded PV-panel. Substring STR2 is bypassed

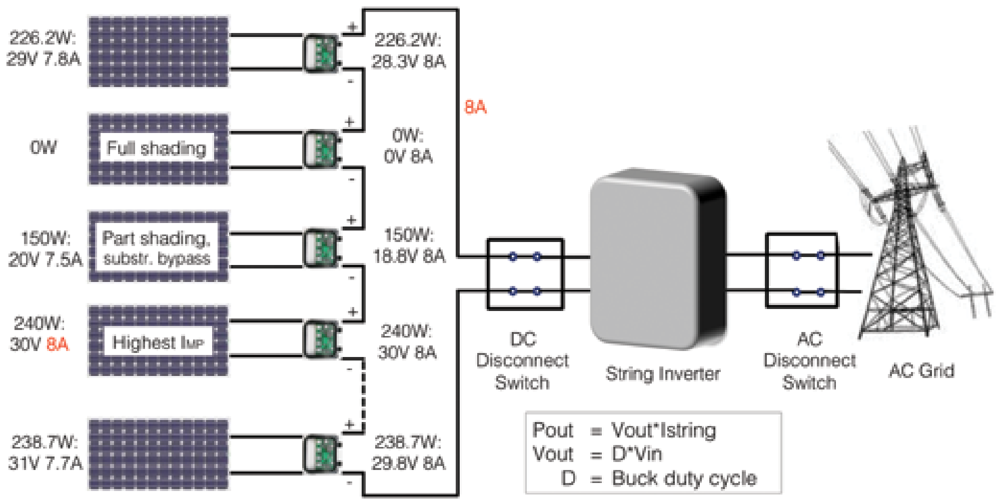




Optimization of PV Installation with Mismatch

PV-panels fitted with DC-POD wired in series strings

Modules are mismatched (shading, soiling, age). DC-POD operates within each module by turning ON all substring bypass MOSFET (full shading) or a subset (partial shading).



Glossary

ADC	Analog to Digital Converter
APM	Analog Power Manager integrated circuit
BOM	Bill Of Material
CEC	California Energy Commission
DAC	Digital to Analog Converter
DC-POD	DC Power Optimizer and Disconnect (with PV-panel Active Substring Bypass)
DC-POD	DC Power Optimizer and Disconnect (with no PV-panel Active Substring Bypass)
MAXC	Maximizer DC Controller integrated circuit
MOSFET	Metal Oxide Semiconductor Field-Effect Transistor (MOSFET, MOS-FET, or MOS FET) is a transistor used for amplifying or switching electronic signals
MPP	Maximum Power Point is where maximum power is generated by the system
MPPT	Maximum Power Point Tracking allows for maximum power generation of the system
PV-panel	Photovoltaic Module that generates DC power when in the sun
PWM	Pulse Width Modulation
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus

Celestica™

Solid partners. Flexible solutions.