Sensors Converge

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Pre-Conference Symposium 1: Charge controllers, who needs them? Optimizing MPPT for Energy Harvesting Applications

June 20, 2023 | Santa Clara, CA

Brad Scandrett, VP of Engineering, PowerFilm, Inc

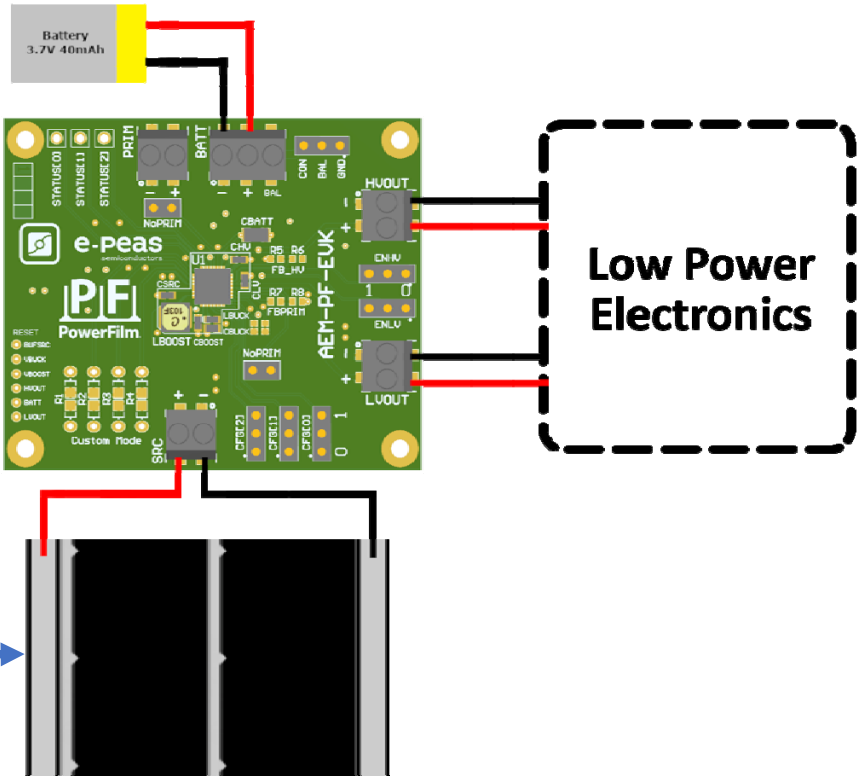
#SensorsConverge

Components of an EH System

Storage Element

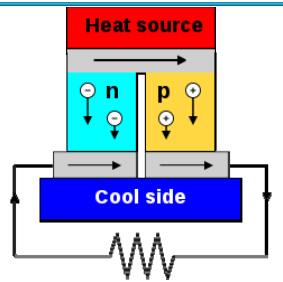
Charge Controller or EH PMIC

Transducer (TEG, Piezo, RF, Solar)

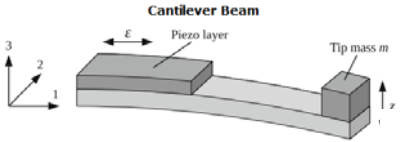


Energy Harvesting Power Sources

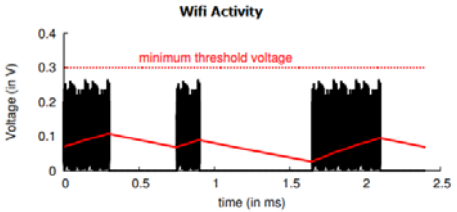
Thermoelectric (TEG): Heat energy is converted into electric power. Charges in thermoelectric materials diffuse from the hot to the cold, producing a current. Up to 0.6uW/cm^2/Deg K.



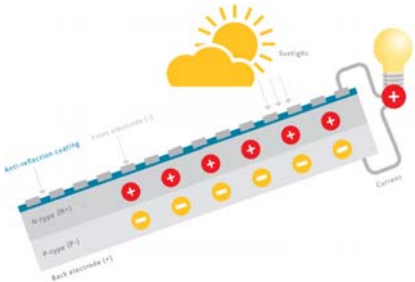
Piezo and Electrodynamic: Motion (kinetic energy) is converted into electric power using the piezoelectric effect or magnetic induction.



Radio Frequency (RF): Radio waves contain energy which can by converted to electric power using a rectifying antenna (far field) or magnetic coupling (near field). Up to 1.6uW/cm^2

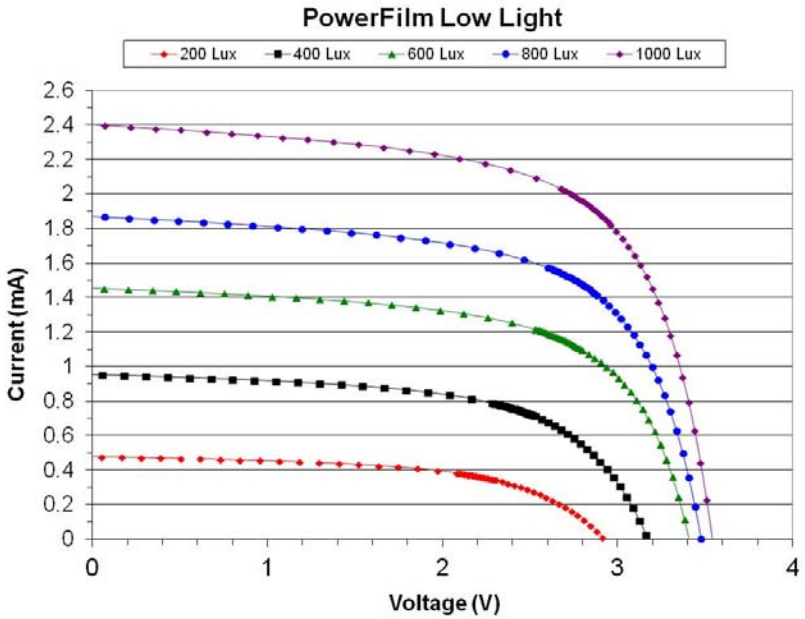


Photovoltaic (Solar): Solar cells absorb light and convert the energy to electric power. An electric field inside the material forces charges apart producing a current. 3.2uW/cm^2/100lux



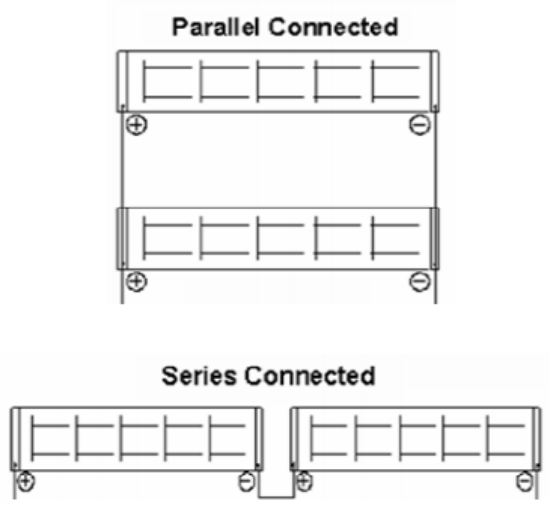
Solar Cell IV Curve

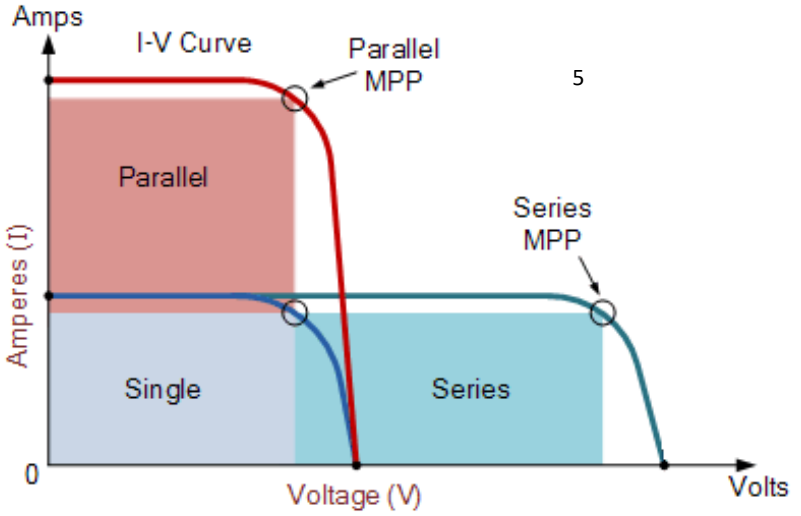
- Power output of module based on operating point on IV curve which is determine by the impedance of the connected load
- Current changes proportionally with light intensity
- Voltage only slightly decreases until <10% light intensity
- Below 10% light voltages changes are no longer insignificant



Why do I need a charge controller? - IV Curve

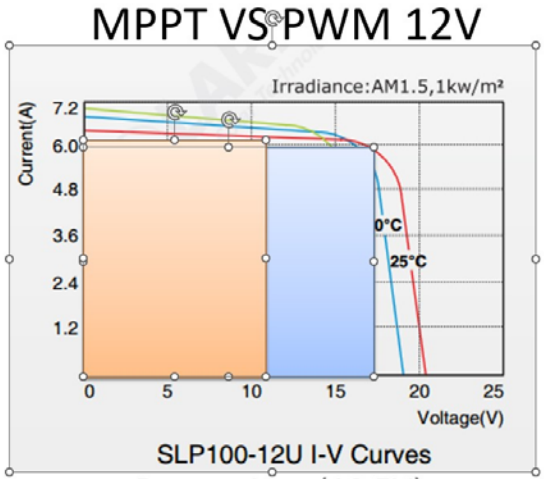
- To maximize power collection from a generator the load and source impedance must match. The charge controller serves this function.
- Impedance of the source will change depending on configuration



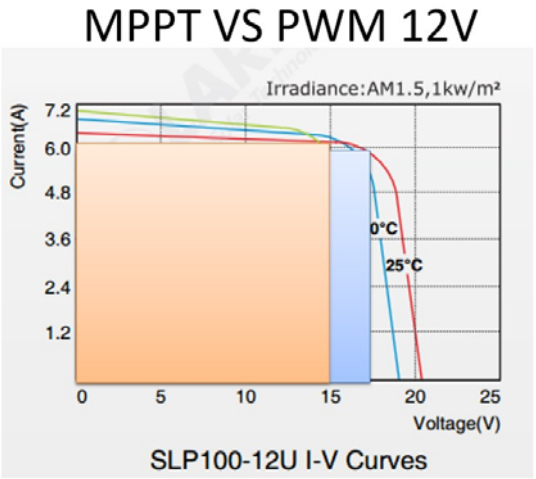


Why do I need a charge controller? - IV Curve

- MPPT vs PWM Power difference depending on state of charge for a battery.
- MPPT will provide a increase of 20% in power delivered to a battery at the end of the charge vs PWM. While providing over 55% more power when a battery is fully depleted.



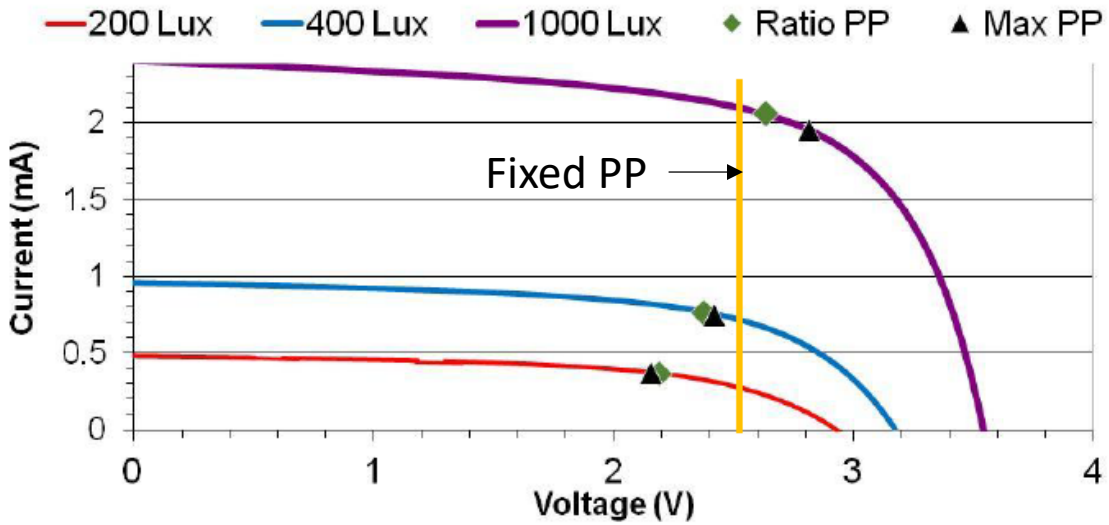
Battery Low (10.5V)



Battery Full 13.5V

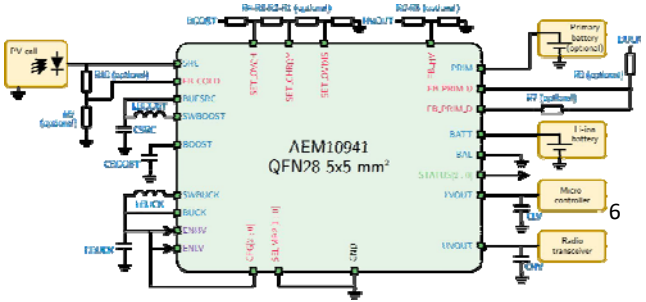
What Does MPPT Mean on a Data Sheet?

- Types of MPPT
  - Fixed voltage set point
  - Ratio power point (Vpp/Voc)
  - True Maximum power point (MPPT)



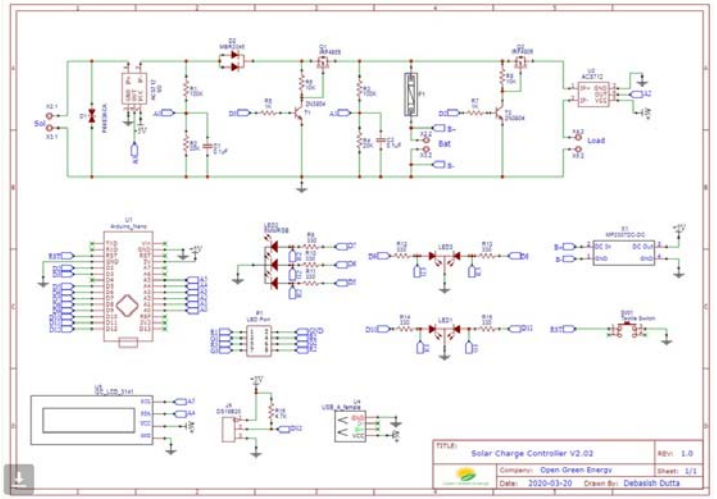
Charge Controllers

- DC-DC Converters with Maximum Power Point Tracking (MPPT)
  - Boost – Track input voltage and increase voltage to battery voltage on output
  - Buck – Track input voltage and decrease voltage to battery voltage on output
  - Power Management IC (PMIC) – Boost or buck designed specifically for low power operation
  - Works well with all battery types and chemistries.



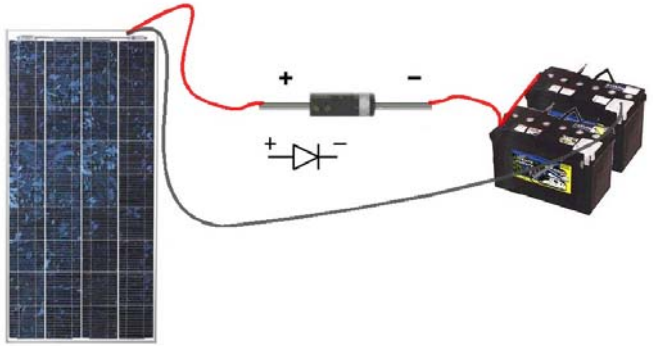
Charge Controllers

- Pulse Wave Modulation (PWM) – Uses pulses to connect solar panel to battery to control charging rate and maximum charge voltage
- Typically microprocessor or dedicated PWM charging IC
- Low Cost, fewer parts than MPPT charging circuits
- Very reliable for non-Microprocessor based designs
- Works with all battery types and chemistries



Charge Controllers

- Direct Charging
  - Directly connects panel to battery
  - Panel voltage must be designed to match battery
  - Can include over voltage protection
  - Unprotected systems must have solar current output less than 1% of battery amp-hour capacity
  - Not recommended to pair with lithium batteries technologies
  - Works well with capacitors and lead acid batteries



Features Offered by PMICs

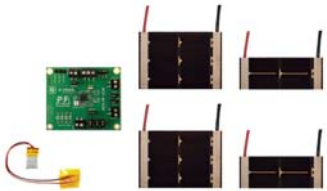
- Very low power collection (≥80mV, ≥1μA)
- Very low current consumption (<0.5μA)
- Integrated battery charging
- Switcher shutdown for reduced EMI during wireless transmission
- UV/OV protection
- Power Good Output Signals
- Integrated comparator
- Primary battery backup
- 2s super cap balancer
- Dual EH inputs
- Regulated outputs
- High efficiency (>90%)

Selection Criteria

	PWM	Fixed PPT	Ratio PPT	Maximum PPT	Direct
Power	uW to W	uW to W	uW to W	uW to W	uW to W
Efficiency	60-90%	85-95%	90-95%	90-95%	80-95%
Topology	Buck	Buck, Boost	Buck, Boost	Buck, Boost	Direct
Low or Varying Power Transducer Optimized	No	No	Yes	Yes	No
Cost	$$	$$	$$$	$$$$	$

Getting Started

Development kits are a great way to start and available with many different harvesters and radios

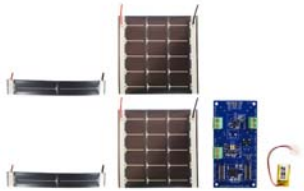


AEM10941 – EPeas[7]

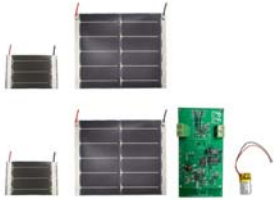
EMH-UNIV-1 – Xidas[8]

SPV1040 – STMicro[9]

MAX20361 – Maxim[14]



BQ25570 – TI and nRF52832 – Nordic[11]



BQ25570 & CC2650 – TI[12]

ADP5091 – Analog Devices[13]

EH IC Comparison Chart

IC Part Number	MFG	startup voltage	Sampling Time	Min Current Power	Max Current Power	MPPT programmable	Input voltage range	AC Input	Quiescent Current	LDO Reg	LDO Reg	Protection	Primary Battery	Super Cap	size(mm)	Price 100pcs
AEM10941	EPeas	380mV	5 sec	3uW	110mA	Ratio 70,75,85,90%	50mv-5V	No	400nA	1.2/1.8V	20mA	OC/ODC	yes	Yes	5 x 5	3.87
EHM-UNIV-1	Xidas	380mV		6uW	150mA	MPPT	3.6V	Yes (EM)	390nA	1.5-3.6V	150mA	OC/ODC	No	Yes	25 x 25	45.5
SPV1040	STMicro	300mV			1.8A	MPPT	0.3-5.5V	No	60uA	2-5.2V	NA	OV/OC/OT	No	No	3 x 4.4	3.28
BQ25570RGRR	Ti	600mV	16 Sec	5uW	230mA	MPPT programmable	0.1-5.1	No	488nA	2-5.5V	110mA	OV/ODC	No	Yes	3.5 x 3.5	5.42
ADP5091/2	Analog Devices	380mV	16 Sec	6mW	600mW	MPPT	0.08-3.3V	No	510nA	1.5-3.6V	150mA	OV/ODC	Yes	No	4 x 4	5.81
MAX20361	Analog Devices	400mV	64 Sec	15uW	300mW	Ratio Programmable	0.225-2.5V	No	1.43uA	NA	NA	OV	No	Yes	1.63 x 1.23	3.30(Qty1k)
CC2650	TI	Bluetooth Low Energy Transceiver														
nRF52832	Nordic Semi	Bluetooth Low Energy Transceiver, Bluetooth Mesh														

Questions??


Back
Heart Rate Monitor
Solar_HRM
Finger
Location
190
bpm
HEART RATE MONITOR
BPM
Time (s)
DISCONNECT
NORDIC
SEMICONDUCTOR
PF
PowerFilm

References

1. HEHN, THORSTEN. Cmos Circuits for Piezoelectric Energy Harvesters. SPRINGER, 2016.
2. Paul, Douglas. “Thermoelectric Energy Harvesting.” School of Engineering University of Glasgow, U.K, School of Engineering University of Glasgow, U.K.
3. http://www.stion.com/technology/photovoltaic-effect/
4. Pinuela, Manuel, et al. “Ambient RF Energy Harvesting in Urban and Semi-Urban Environments.” IEEE Transactions on Microwave Theory and Techniques, vol. 61, no. 7, 2013, pp. 2715–2726., doi:10.1109/tmtt.2013.2262687.
5. “Solar Cell I-V Characteristic and the Solar Cell I-V Curve.” Alternative Energy Tutorials, www.alternative-energy-tutorials.com/energy-articles/solar-cell-i-v-characteristic.html.
6. AEM10941 Solar Harvesting | Photovoltaic Energy Harvesting | e-peas, https://e-peas.com/product/aem10941/
7. https://www.digikey.com/en/products/detail/powerfilm-inc/DEV-EPEAS/14008990 or https://www.powerfilmsolar.com/products/development-kits/aem-pf-evk-solar-development-kit-with-e-peas-pmic
8. https://xidasiot.com/power/eh-edu-1
9. https://www.digikey.com/en/products/detail/stmicroelectronics/STEVAL-ISV012V1/3083468
10. https://www.digikey.com/en/products/detail/nowi/NH2D0245-EVAL-BOARD/13694744
11. https://www.digikey.com/en/products/detail/powerfilm-inc/DEV-BLE-NS/12088517 or https://www.powerfilmsolar.com/products/development-kits/solar-development-kit-with-nordic-ble
12. https://www.digikey.com/en/products/detail/powerfilm-inc/DEV-BLE-TI/9559450 or https://www.powerfilmsolar.com/products/development-kits/solar-development-kit-with-ti-ble
13. https://www.digikey.com/en/products/detail/analog-devices-inc/ADP5091-2-EVALZ/6189737
14. https://www.digikey.com/en/products/detail/maxim-integrated/MAX20361EVKIT/13279720
15. https://www.instructables.com/ARDUINO-PWM-SOLAR-CHARGE-CONTROLLER-V-202/
16. https://www.pcdvd.com.tw/showthread.php?t=1200800&page=2