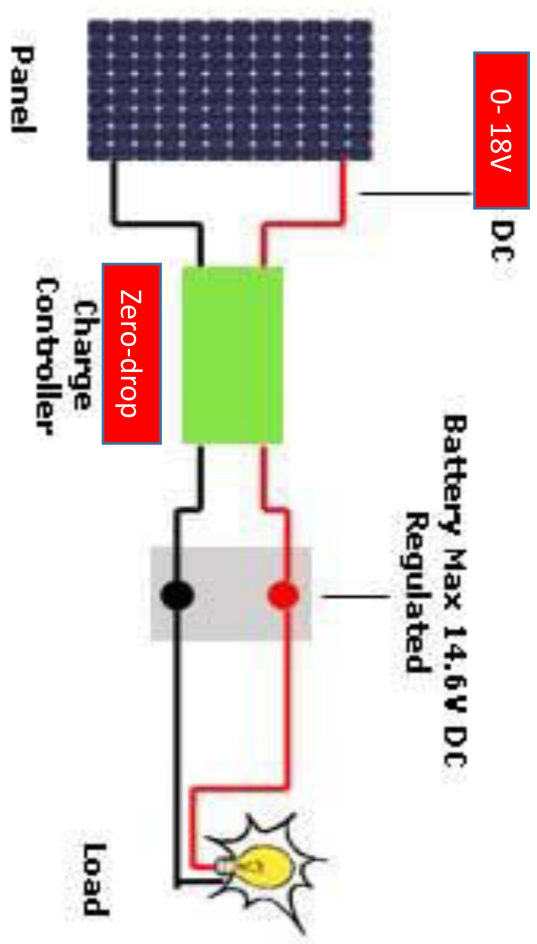
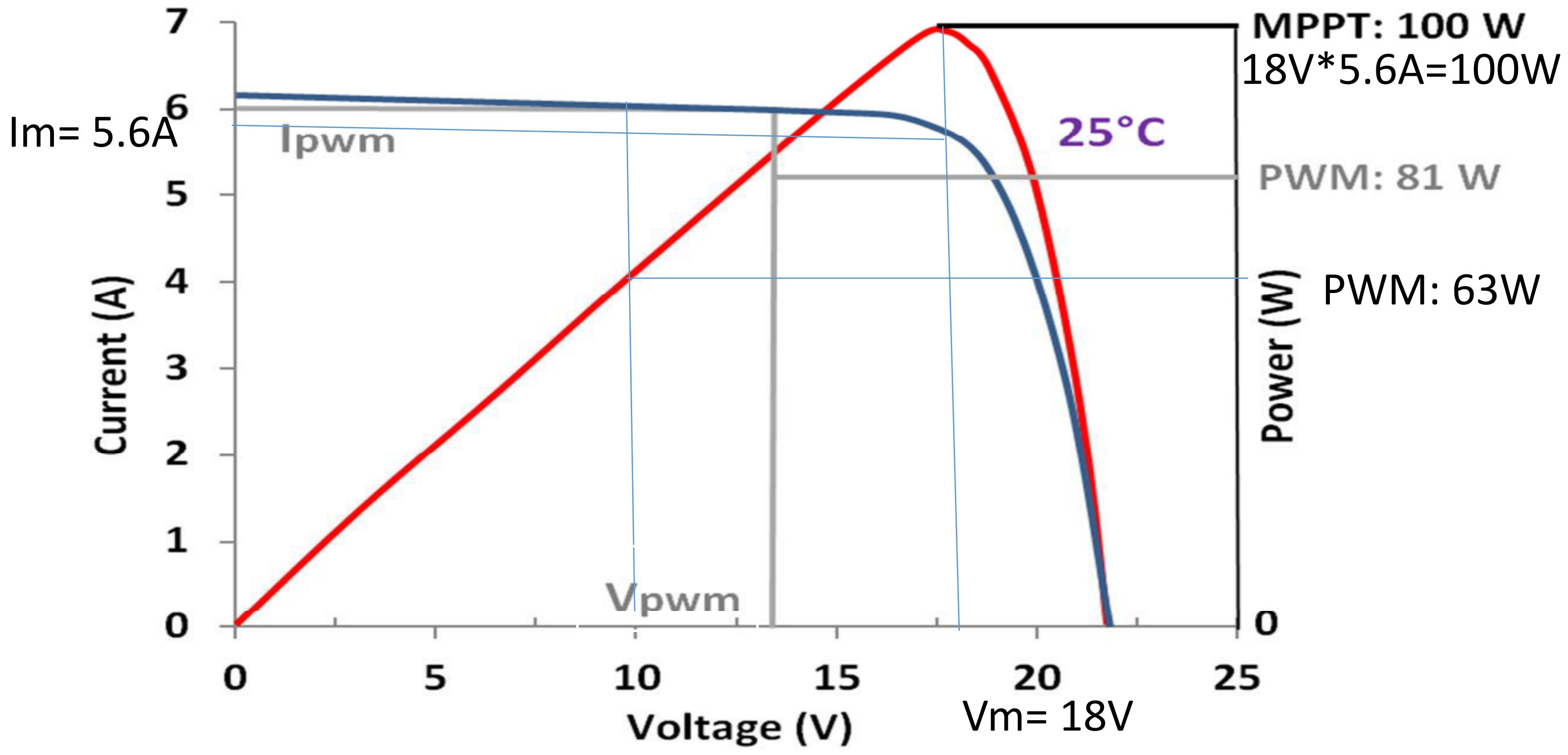
# MPPT and Zero-Drop (PWM) Charge Controllers

# Quick Summary

- MPPT and Zero-drop (PWM) controllers are both widely used to charge batteries
- MPPT controllers are more sophisticated (and more expensive) than Zero-drop
- MPPT uses DC to DC transformer and Zero-drop uses simpler switching circuit technology
- MPPT provides an additional 10-15% charging capability compared to Zero-drop
- MPPT advantage increases in colder climates, higher latitudes and low battery conditions
- PV array and battery voltage must be carefully matched in Zero drop controllers, whereas these are decoupled in MPPT controllers

The Zero-drop (PWM) controller is in essence a switch that connects a solar array to a battery. The result is that the voltage of the array will be pulled down to near that of the battery

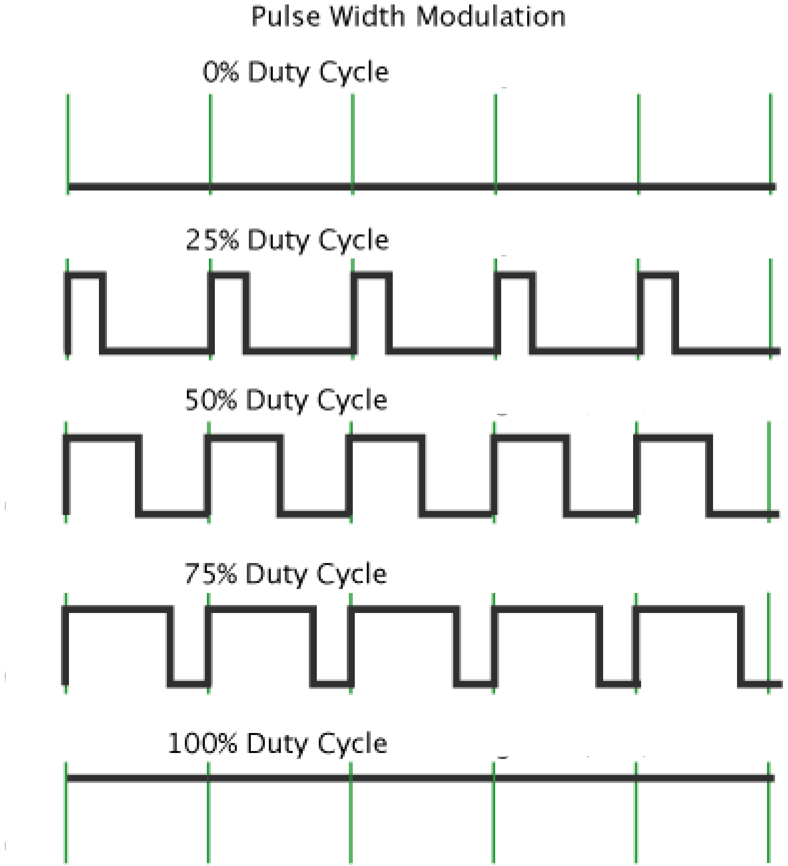


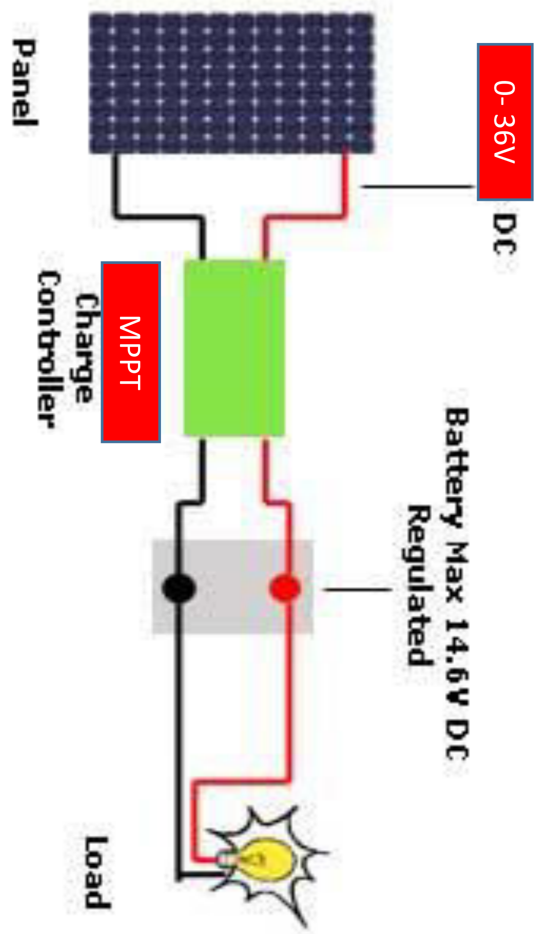

1. $V_{bat}$ = 13 V and $V_{pwm} = V_{bat}$ +0.5 V = 13.5 V,
power harvested from the panel is $V_{pwm} \times I_{pwm}$ = 13.5 V x 6 A = 81 W
2. $V_{bat}$ = 10 V and $V_{pwm} = V_{bat}$ +0.5 V = 10.5 V,
power harvested from the panel is $V_{pwm} \times I_{pwm}$ = 10.5 V x 6 A = 63 W

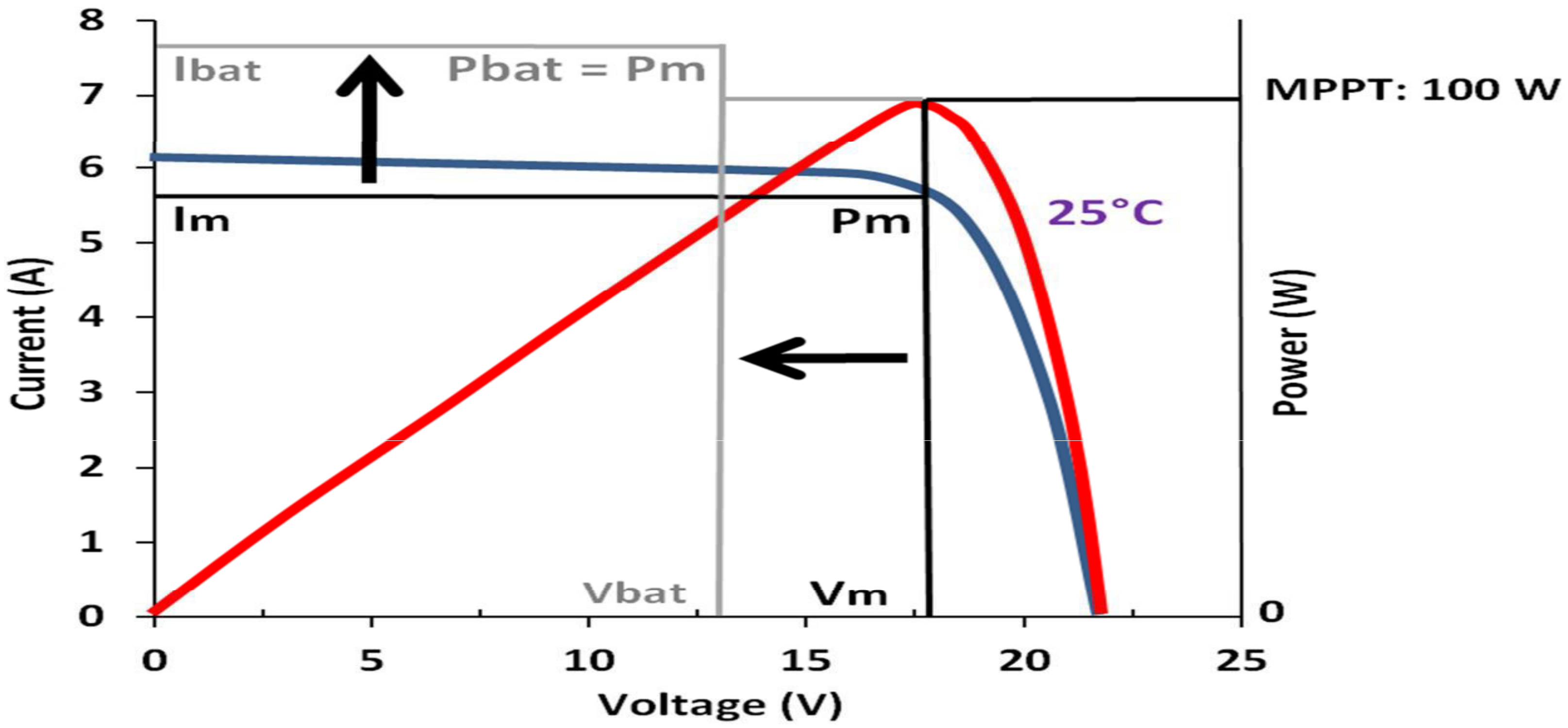
# Zero-drop (PWM) controller

- When a solar array has PWM controller, battery charging is done by constantly checking the current battery voltage state and self-adjusting the charging accordingly
- When the battery is nearly discharged, the pulses may be long and continuous (bulk charging), and as it becomes charged, the pulses become shorter or trickled off
- This trickle or finish type charging mode is important for systems that can go days or weeks with excess energy during periods when very little of the solar energy is consumed
- Provide several key benefits: higher charging efficiency, rapid recharging, and healthier batteries that operate at full capacity



The MPPT charge controller is a DC to DC transformer that can transform power from a higher voltage to power at a lower voltage



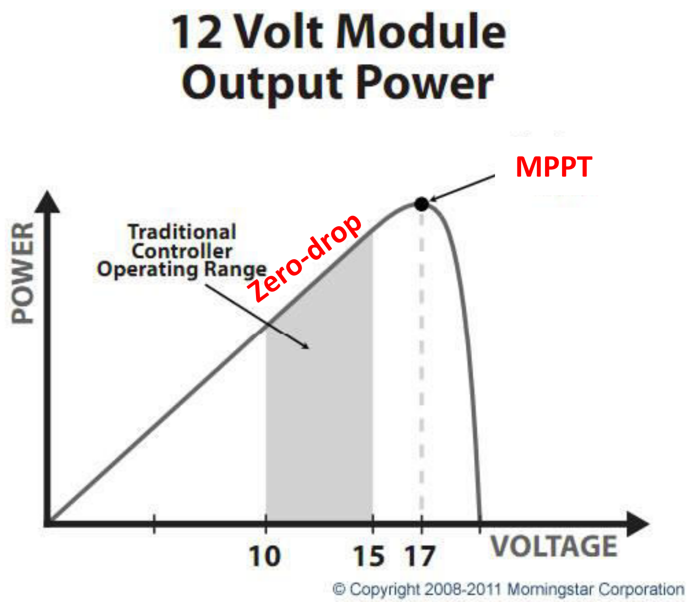

MPPT controller, graphical representation of the DC to DC transformation

$P_m = V_m \times I_m$ = 18 V x 5,6 A = 100 W, and

$P_{bat} = V_{bat} \times I_{bat}$ = 13 V x 7,7 A = 100 W

# Key Differences

| Zero-Drop Charge Controller | MPPT Charge Controller |
|---|---|
| PV array and battery voltages must match | PV array voltage can be much higher than battery voltage |
| Operates at battery voltage so it performs well in warm temperatures and when the battery is almost full | Operates above battery voltage so it is can provide “boost” in cold temperatures and when the battery is low |
| Typically recommended for use in smaller systems where “boost” benefits are minimal | 170W or higher to take advantage of “boost” benefits |
| Must use off-grid PV modules typically with Vmp ≈ 17 to 18 Volts for every 12V nominal battery voltage | Enables the use of lower cost/grid-tie PV Modules helping bring down the overall PV system cost |
| PV array sized in Amps (based on current produced when PV array is operating at battery voltage) | PV array sized in Watts (based on the Controller Max. Charging Current x Battery Voltage) |
| Simpler series switching charge control circuit | Additional Energy Harvest by operating at PV peak power point rather than battery voltage |



# Appendix

# Maximum Power Point & Cell Temperature