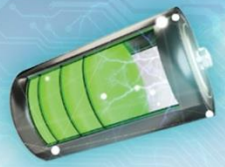
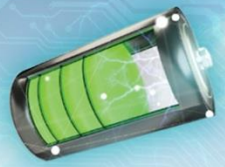
How to implement maximum power point tracking for low power solar charging



Agenda

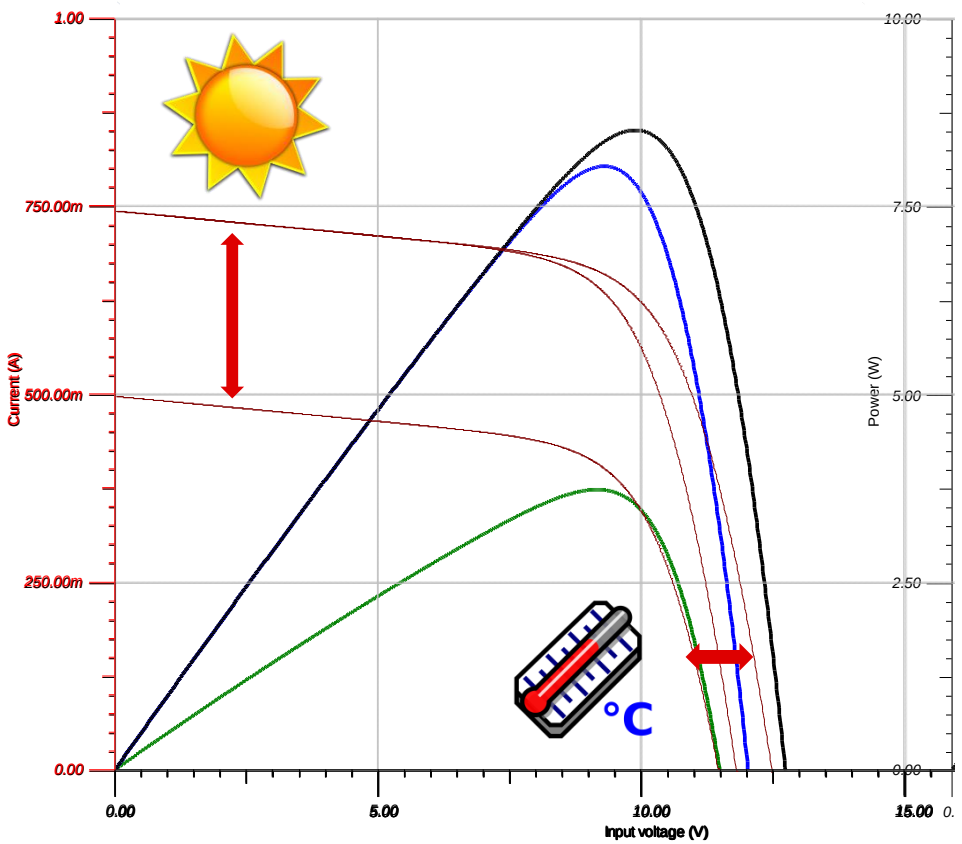
- Application definition and solution
- MPPT algorithm implementation



Solar panel application definition

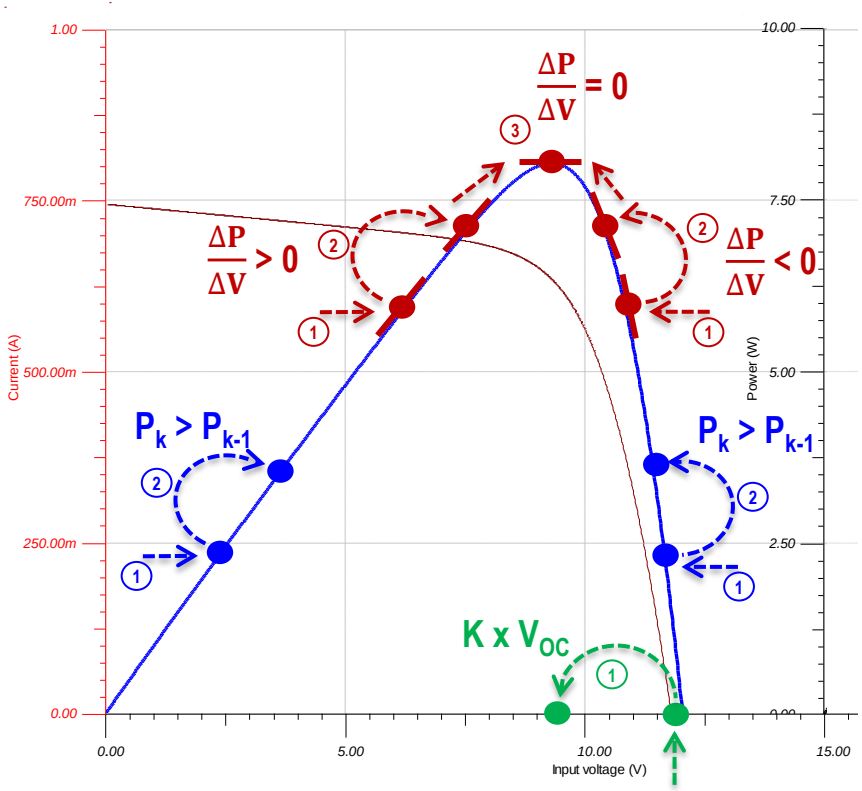
The solar problem

- I-V Characteristic
  - High Impedance Source
  - Non-ideal parameters affect curve
    - Resistive losses
    - Diode leakage
    - Material properties
- Maximum Power Point
  - Irradiance
    - Affects short circuit current
  - Temperature
    - Shifts open circuit voltage
  - Causes MPP to move



The Solar Solution

- Maximum Power Point Tracking Algorithm
  - Fractional Open Circuit Voltage (F.OCV)
    - Fixed ratio of the instantaneous open-circuit
  - Perturb & Observe (P&O)
    - Manipulates load and monitors change in power continuously
  - Incremental Conductance (IC)
    - Manipulates load and monitors change in conductance



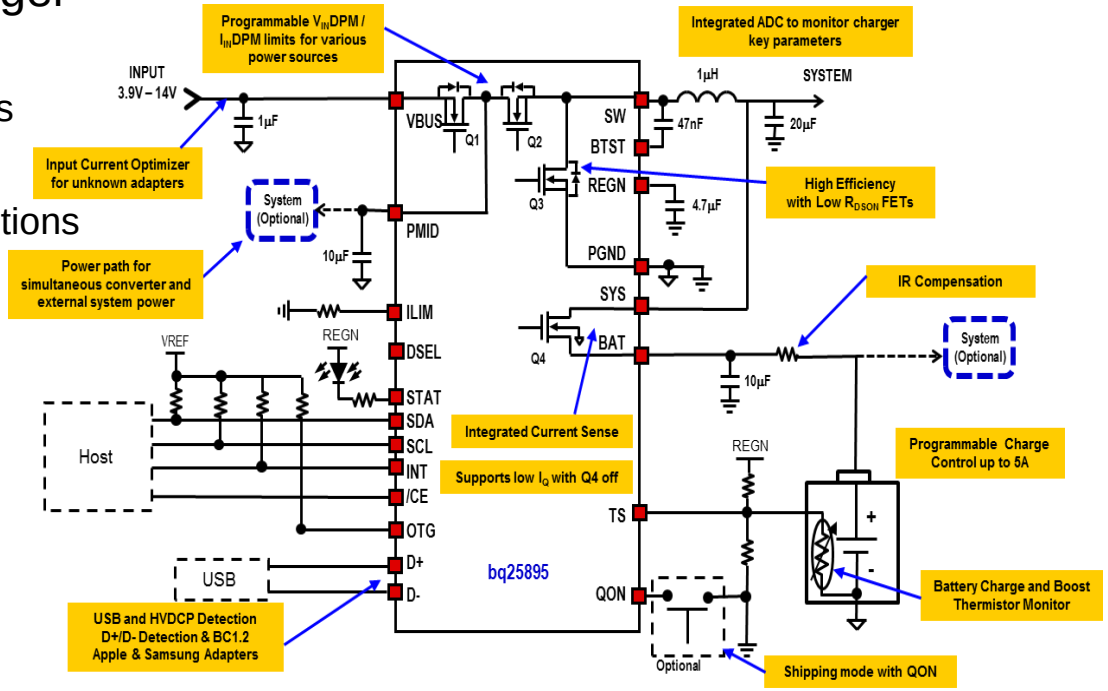
Solution Comparisons

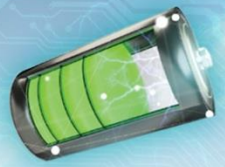
- Algorithm/Controller Considerations
  - Software
    - Calculation | Measurement | Storage
    - Processing | Power | Speed
  - Hardware
    - Sensing | Memory | Control
    - Cost | Size | Speed | Efficiency
  - Tracking Ability
    - Accuracy | Adaptability | Timing

MPPT	Software Complexity	Hardware Complexity	Tracking Ability
P&O	• Calculate (P) • Store Previous States	• (V) and (I) Sensors • Multiplier • Memory or State Machine	• Continuously tracks power • Suffers from oscillation • Step size determines tracking time
IC	• Calculate (I), (V) Slope and (P) • Store Previous States	• (V) and (I) Sensors • Controller (memory, multiplier)	• Can suffer from oscillation under certain conditions • Step size determines tracking time
F.OCV	• Calculate K*V_{OC}	• Resistor divider	• Ratiometrically follows open circuit voltage • Estimate of power point; good for single solar cell • Partial shading affects estimate

The Solar Charging Solution – 3M Approach

- Basic Functions for a Solar Charger
  - →Monitor
    - Key Charging and Input Parameters
  - →Manipulate
    - Operating Point and Loading Conditions
  - →Maximize
    - Input Power and Charging Current

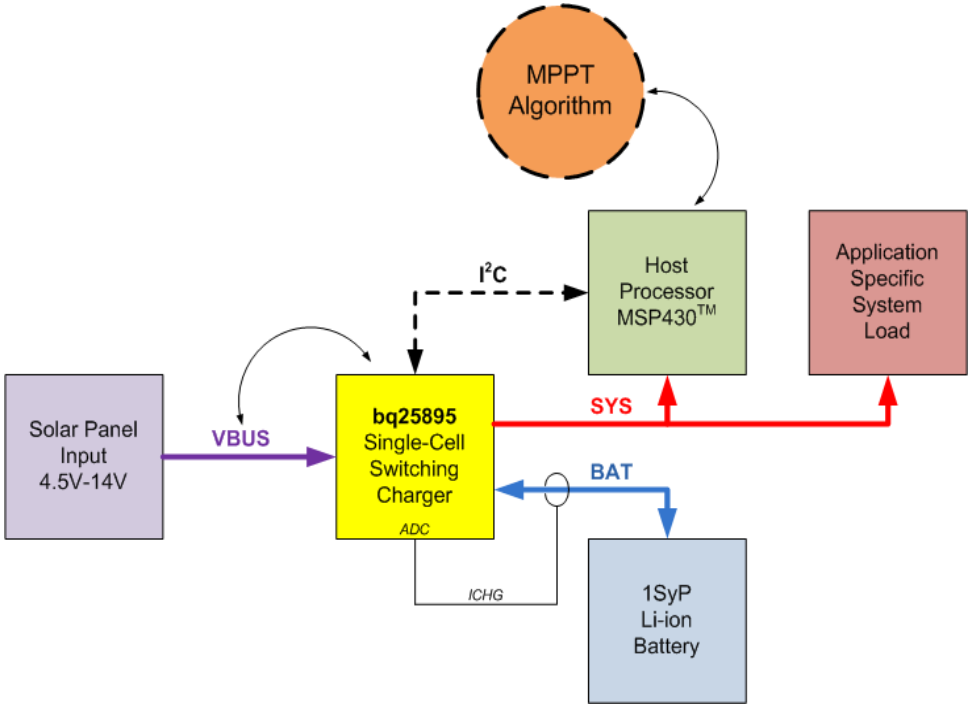




MPPT Algorithm Implementation

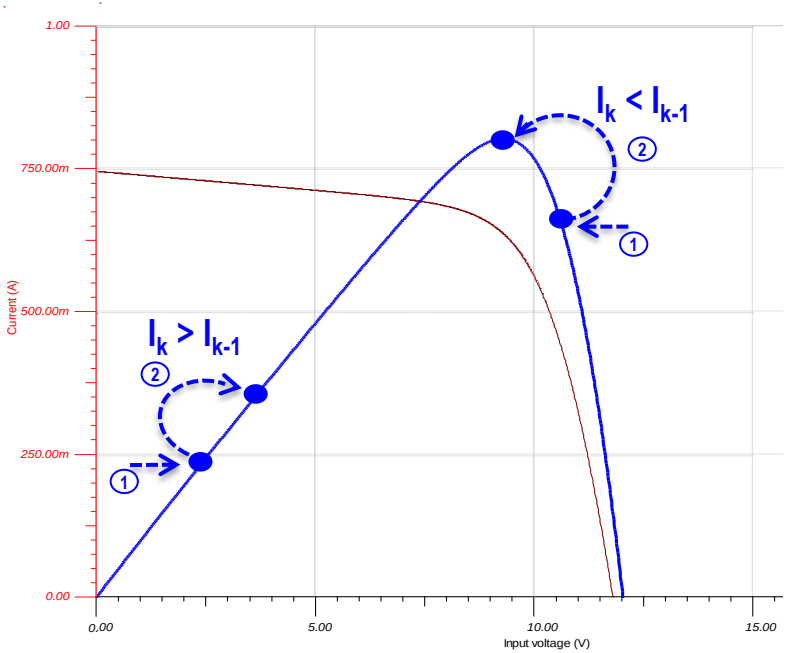
Maximizing Charging Current

- Implementation
  - Prioritize battery charging
  - Adjust operating point to get max charge
- Assumptions
  - Battery voltage constant
    - CC Charge
  - Low/constant System Load
    - $I_{SYS} < I_{CHG} << I_{IN}DPM \rightarrow$ Supplement Mode
- Goals
  - Time
    - Tracking within 5s
  - Accuracy
    - ±50mA of I_{MPP}
    - ± 300mV of V_{MPP}



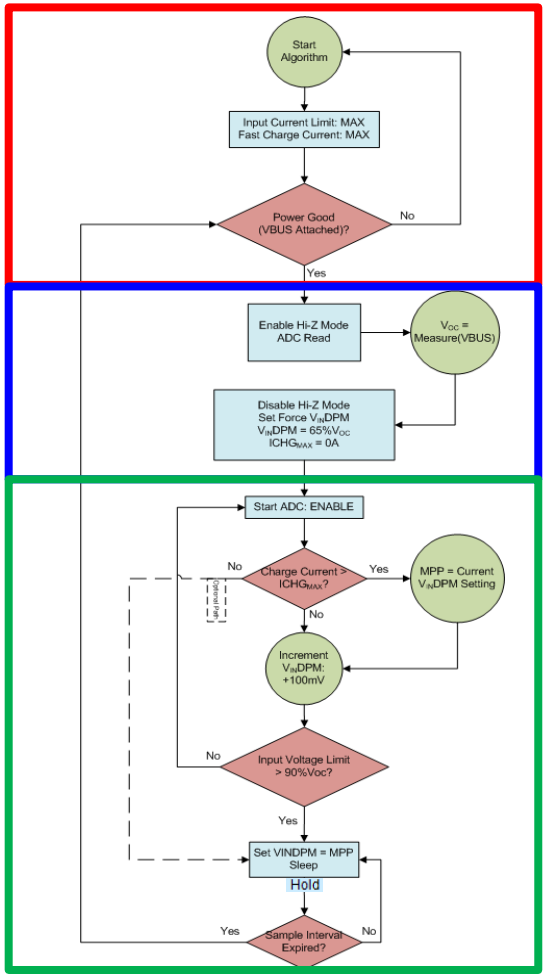
Algorithm Methodology

- Working Principle
  - With given V_{BAT} and I_{SYS} → **charge current will move proportionally with input power**
    - Neglect efficiency
    - Neglect dynamic loading
  - Based on **P&O MPPT**



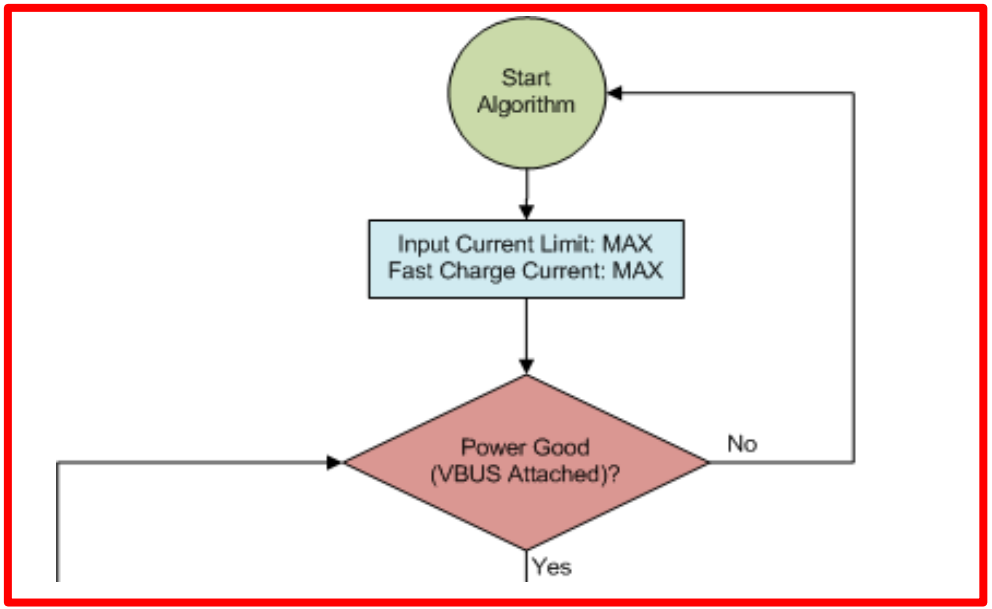
Algorithm Flow Diagram

- Core Blocks
  - Device Initialization
    - Setting Preconditions
    - Is there power from the Panel?
  - MPPT Initialization
    - Setting Limits to the Algorithm
    - Redefining Parameters
  - MPP Tracker
    - Manipulate the operating point
    - Monitor outputs
    - Maximize charging current



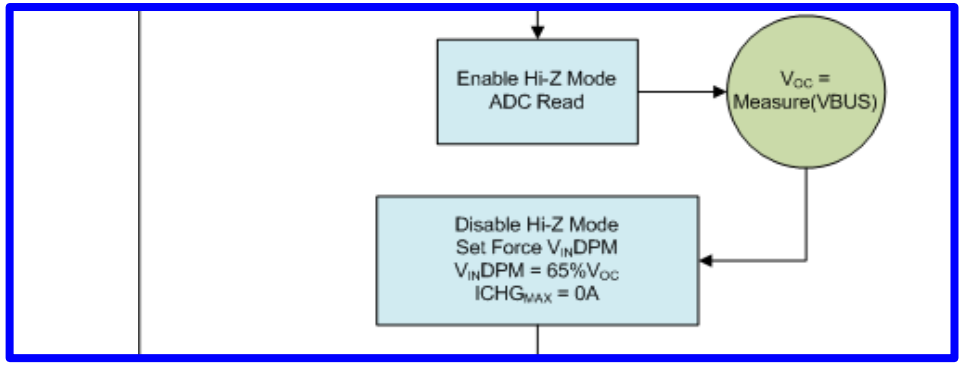
Core Sub-Blocks

- Device Initialization
  - Unclamped Power Point
    - I_{IN}DPM
    - Charge Current
    - FORCE_VINDPM
  - Power Good
    - Heavily shaded?
    - Damaged?
    - Power Not Good
      - Default Hi-Z



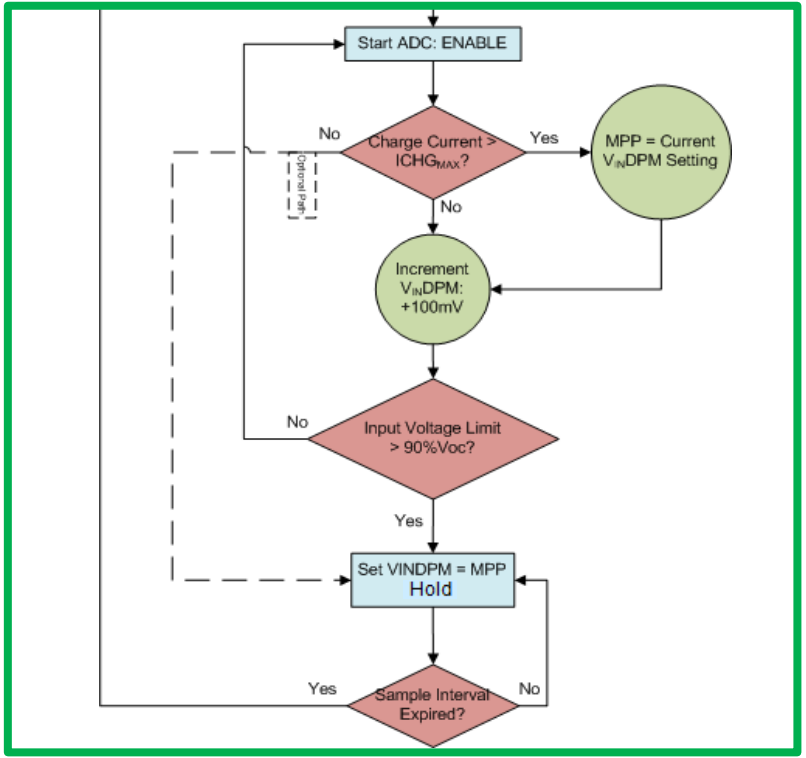
Core Sub-Blocks

- MPPT Initialization
  - Hi-Z mode for V_{OC}
  - 65%V_{OC}
    - Definable
    - Optimize
      - Tracking Time
      - IV Curve
    - Start Condition
  - $ICHG_{MAX}$
    - Compare to instant ICHG
    - Update



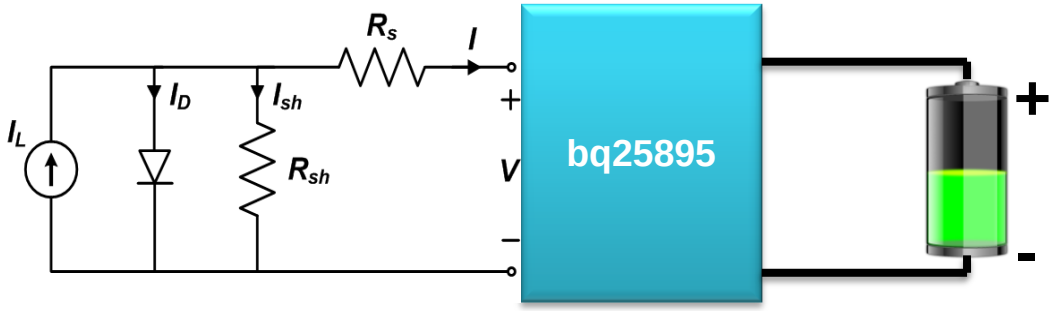
Core Sub-Blocks

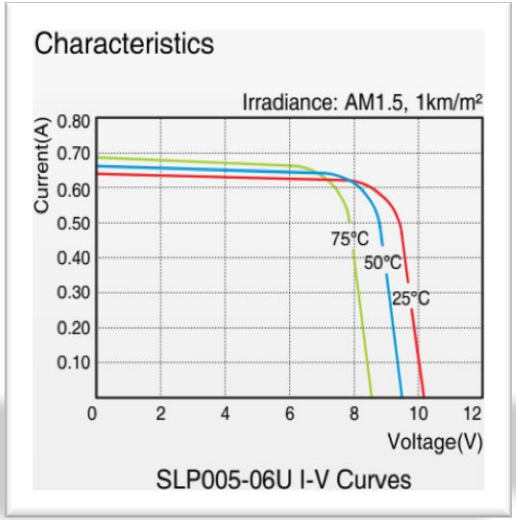
- MPP Tracker
  - ADC Read
    - Burst Mode
    - Multiple reads = Precision
  - Charge Current > $ICHG_{MAX}$?
    - Current increasing/decreasing
    - Update Max Charge
  - Increment $V_{IN}DPM$
    - Step Size
  - Optional: Stop after decrease
    - Improves speed of algorithm
  - Sample Interval
    - Sunlight variance

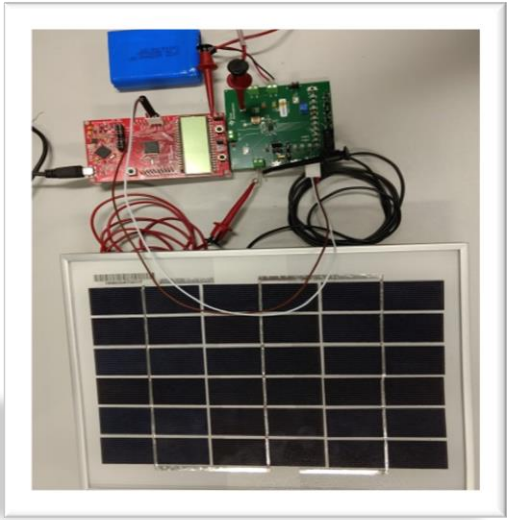


Test Conditions

- Model (Simulated Panel)
  - Standard 4-Component Model
- Outdoor (Real Panel)
  - *SolarLand Model* #: SLP005-06U
  - Polycrystalline
  - 5W, 6V, 10.5V V_{OC}, 0.67A I_{SC}
  - 3.1V V_{BAT}, 6Ah capacity
- Testing Conditions
  - 4.5V – V_{MPP+1}
  - Stop after Max Power

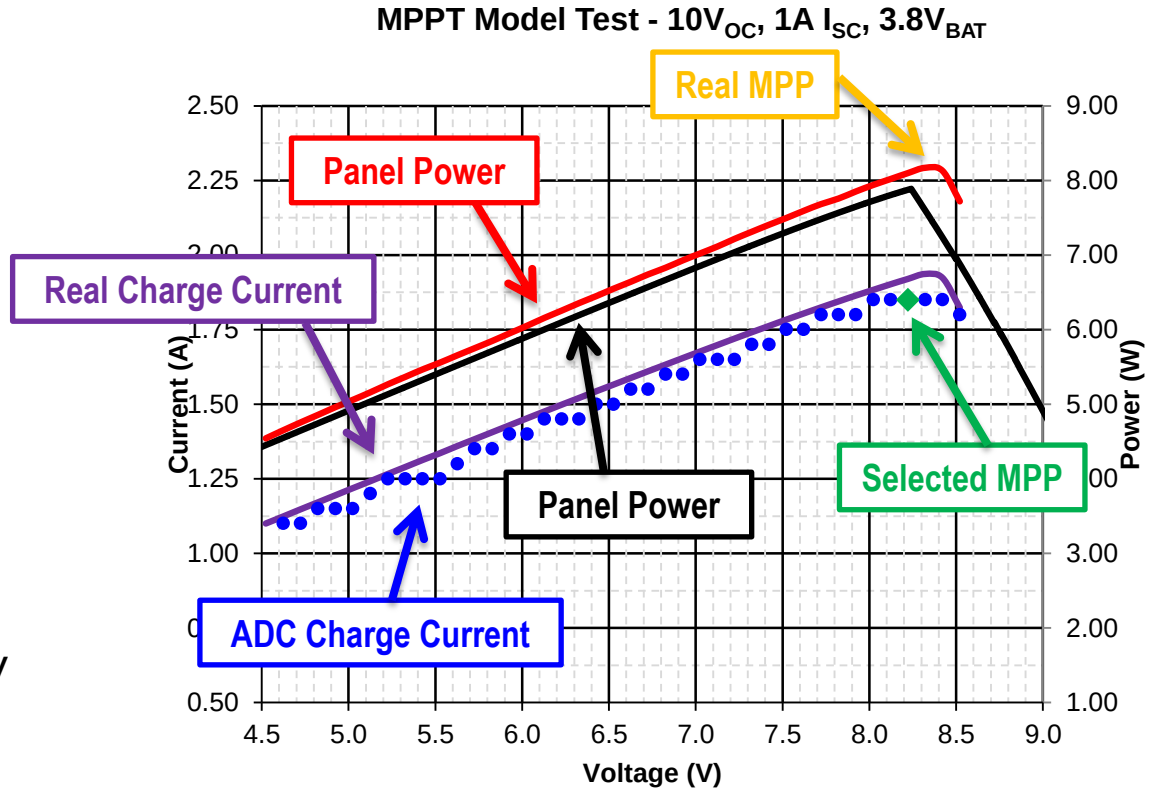






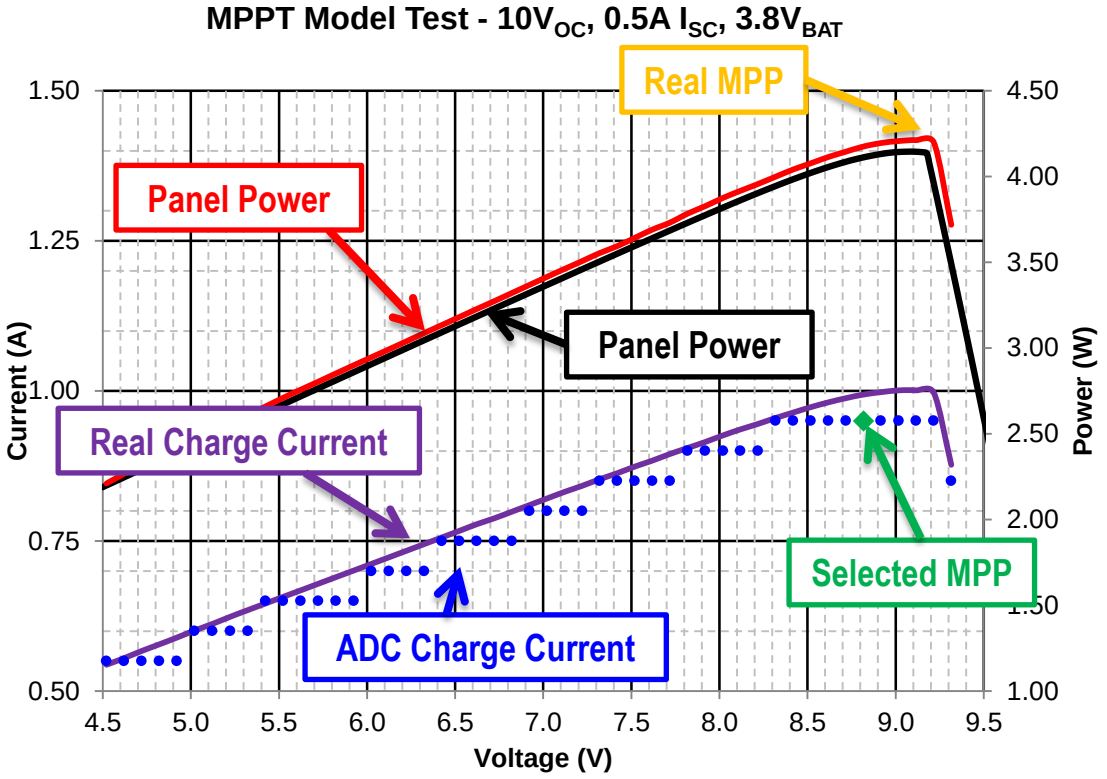
High Irradiance Model: 1A Short Circuit Current

- High Irradiance Test
- Results
  - Charge current = Max
    - ➢Stop Tracking
  - Similar I_{CHG} readings
    - Near V_{MPP}
    - Could affect reading
    - Select Midpoint as Max
  - $V_{MPP(Real)}$ - $V_{MPP(Selected)}$ = 100mV
  - $P_{MPP(Real)}$ - $P_{MPP(Selected)}$ = 70mW

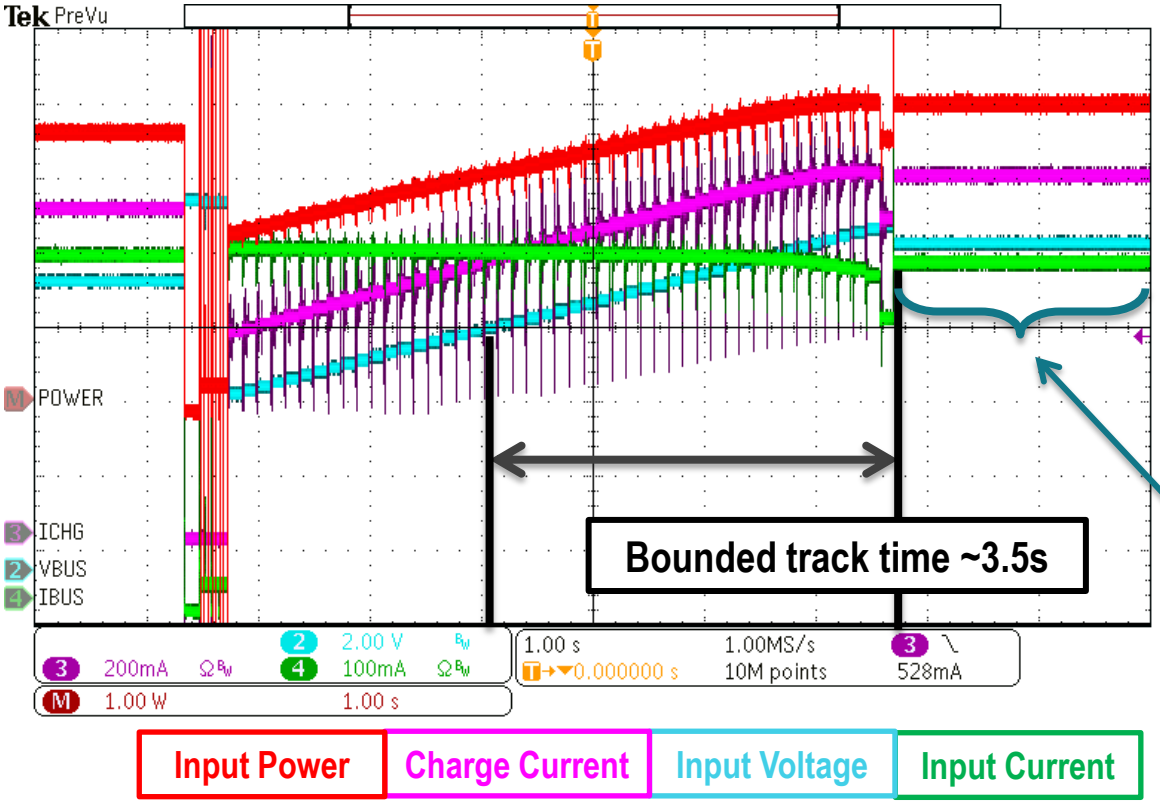


Low Irradiance Model: 0.5A Short Circuit Current

- Low Irradiance Test
- Results
  - Similar behavior to 1A I_{SC}
  - Power has sharp corner
    - Non-ideal Solar Model
  - $V_{MPP(Real)}$ - $V_{MPP(Selected)}$ = 300mV
  - $P_{MPP(Real)}$ - $P_{MPP(Selected)}$ = 40mW



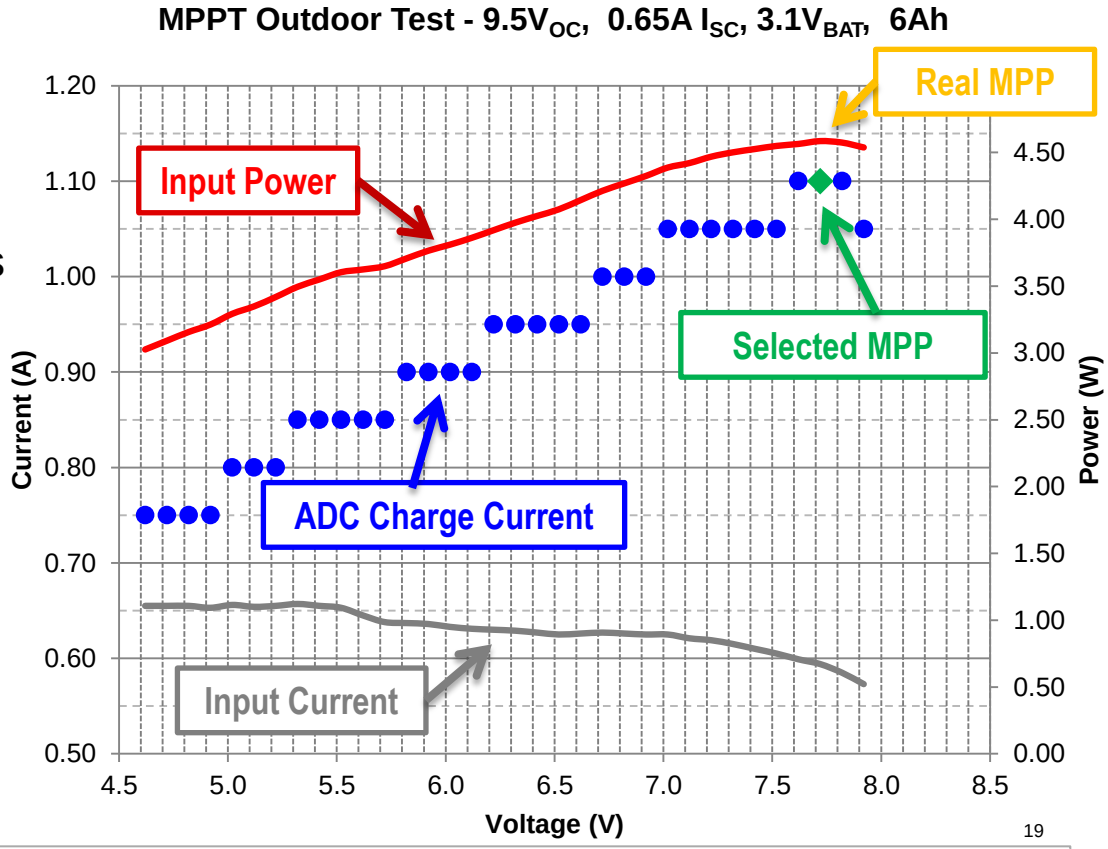
Test Results - Model



- Results
  - Sweeps/Tracks in 6.4s
    - Faster if 65-90%V_{OC}
  - Near V_{OC}, sharp corner in power
    - No effect on tracking
  - Customizable hold time

Test Results – Outdoor: Real Panel

- Results
  - $P_{MPP(Selected)} = P_{MPP(Real)}$
  - Sunlight can change in seconds
    - Affects Temperature
    - Shifts Power curve



bq25895 I²C Controlled Single Cell 5-A Charger with Power Management for MPPT with Solar Input

Features

- Integrated 7-Bit ADC to Monitor Input Voltage, Battery Voltage, and Charge Current
- Adjustable Input Voltage Power Management threshold with 100 mV Resolution
- High Charge Efficiency with 93% @ 2 A and 91% @ 3 A
- Wide Input Voltage Operating Range from 3.9 V to 14 V
- Integrated Reverse Blocking at Input

Applications

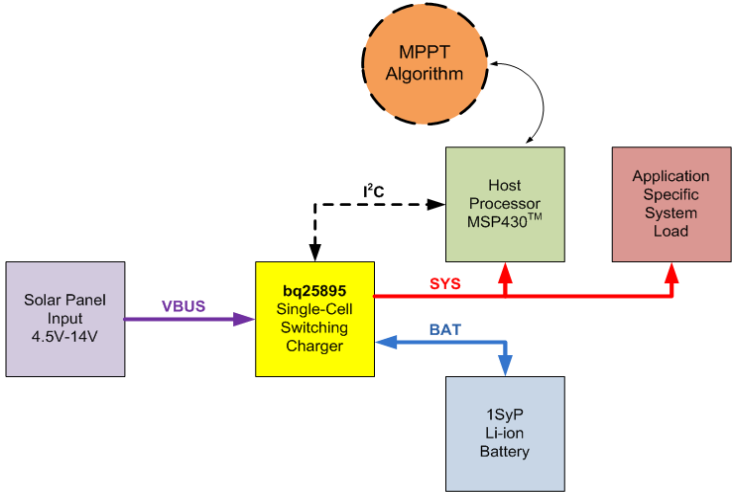
- Smart Shared Bikes
- IP Cameras
- Portable Speakers

Tools & Resources

- **TIDA-01556 Tools Folder**
- **Design Guide**
- **Design Files:** Software
- **Device Datasheets:**
  - bq25895
  - MSP430FR4133

Benefits

- Measure Solar Panel Open-Circuit Voltage with 100mV resolution, Charging Current with 50mA resolution, and Battery Voltage with 20mV resolution
- Adjust Solar Panel Power Point through VINDPM
- Optimized Input Power Conversion for Maximum Charge
- Operate with High Voltage Solar Panels up to 14V
- Provide Reverse Current Protection to the Solar Panel



Conclusion / Summary

- Solar Power Tracking
  - Max Power moves with Sunlight and Temperature
    - Algorithms: F.OCV | P&O | IC
    - Trackers: Software | Hardware | Accuracy
  - 3M: Monitor | Manipulate | Maximize

- Simple MPPT Implementation
  - Max ICHG → P_{MPP}
    - P&O approach
    - Reflected P_{IN}

- TIDA-01556: *I^2C Controlled Single Cell 5-A Charger with Power Management for MPPT with Solar Input*