Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

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AUTONOMOUS SOLAR PANEL MAXIMUM POWER POINT TRACKING WITH FULLY INTEGRATED BUCK-BOOST CHARGERS

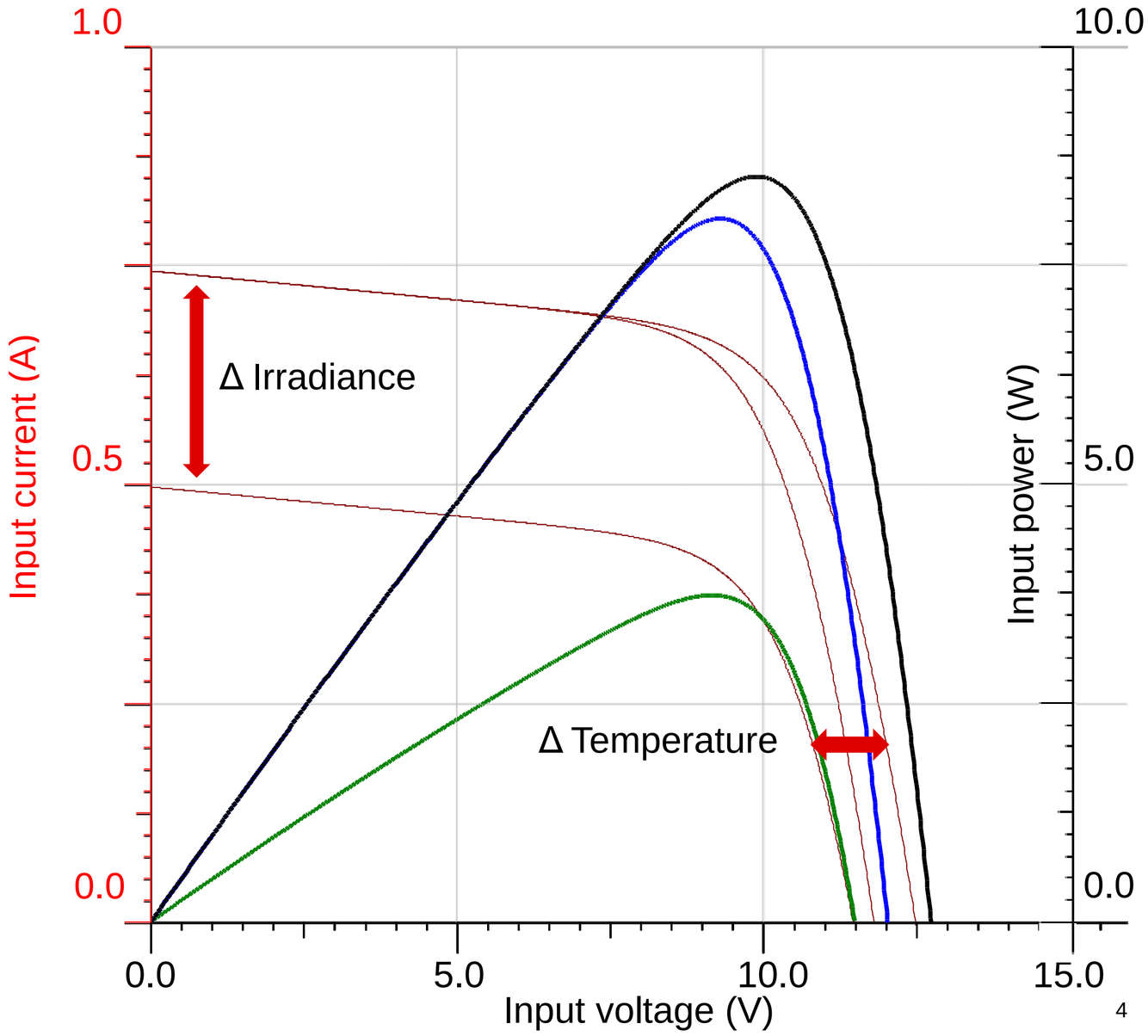
Agenda

- Solar panel application solutions
- Key charger features for solar panel maximum power point tracking (MPPT)
- MPPT algorithm implementation and results

SOLAR PANEL APPLICATION SOLUTIONS

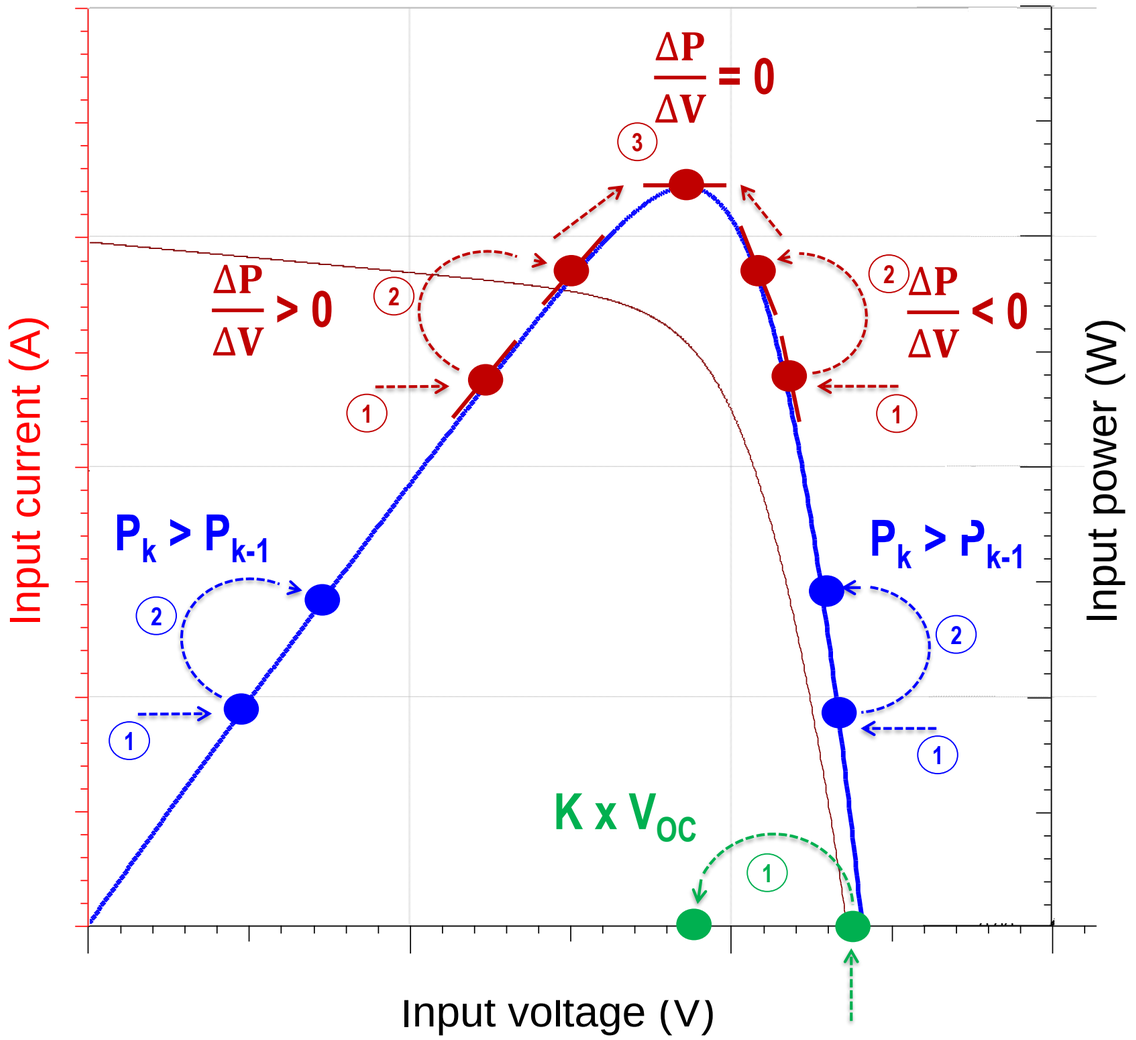
Solar characteristics

- I-V characteristic:
  - High impedance source
  - Non-ideal parameters affect curve:
    - Resistive losses
    - Diode leakage
    - Material properties
- Maximum power point (MPP):
  - Irradiance:
    - Affects short circuit current
  - Temperature:
    - Affects open circuit voltage
  - Causes MPP to move



Solar panel MPPT solutions

- Maximum power point tracking algorithm:
  - Fractional open circuit voltage (F.OCV)
    - Fixed ratio of the instantaneous open-circuit voltage
  - Perturb & observe (P&O)
    - Manipulates load and monitors the input power
  - Incremental conductance (IC)
    - Manipulates load and monitors the derivative of the input power with respect to voltage



Solution comparison

- Algorithm/controller considerations:
  - Software:
    - Calculation, measurement and storage
    - Processing, power and speed
  - Hardware:
    - Sensing, memory and control
    - Cost, size, speed and efficiency
  - Implementation:
    - Timing and power consumption

MPPT	Software	Hardware	Implementation
F.OCV	• Calculate K*V_{OC}	• (V) sensor • Requires disabling input current draw	• Algorithm doesn't directly account for different irradiances
P&O	• Calculate (P) • Store previous states	• (V) and (I) sensors • Multiplier and memory	• Requires fine stepping of input voltage
IC	• Calculate (P) and (dP/dV) • Store previous states	• (V) and (I) sensors • Multiplier and memory	• Requires instantaneous conductance to be calculated • Requires fine stepping of input voltage
Proposed MPPT	• Calculate K*V_{OC} • Store minimal previous states	• (V) and (I) sensors • Requires disabling input current draw • Memory	• Requires only infrequent open circuit voltage and battery current measurements

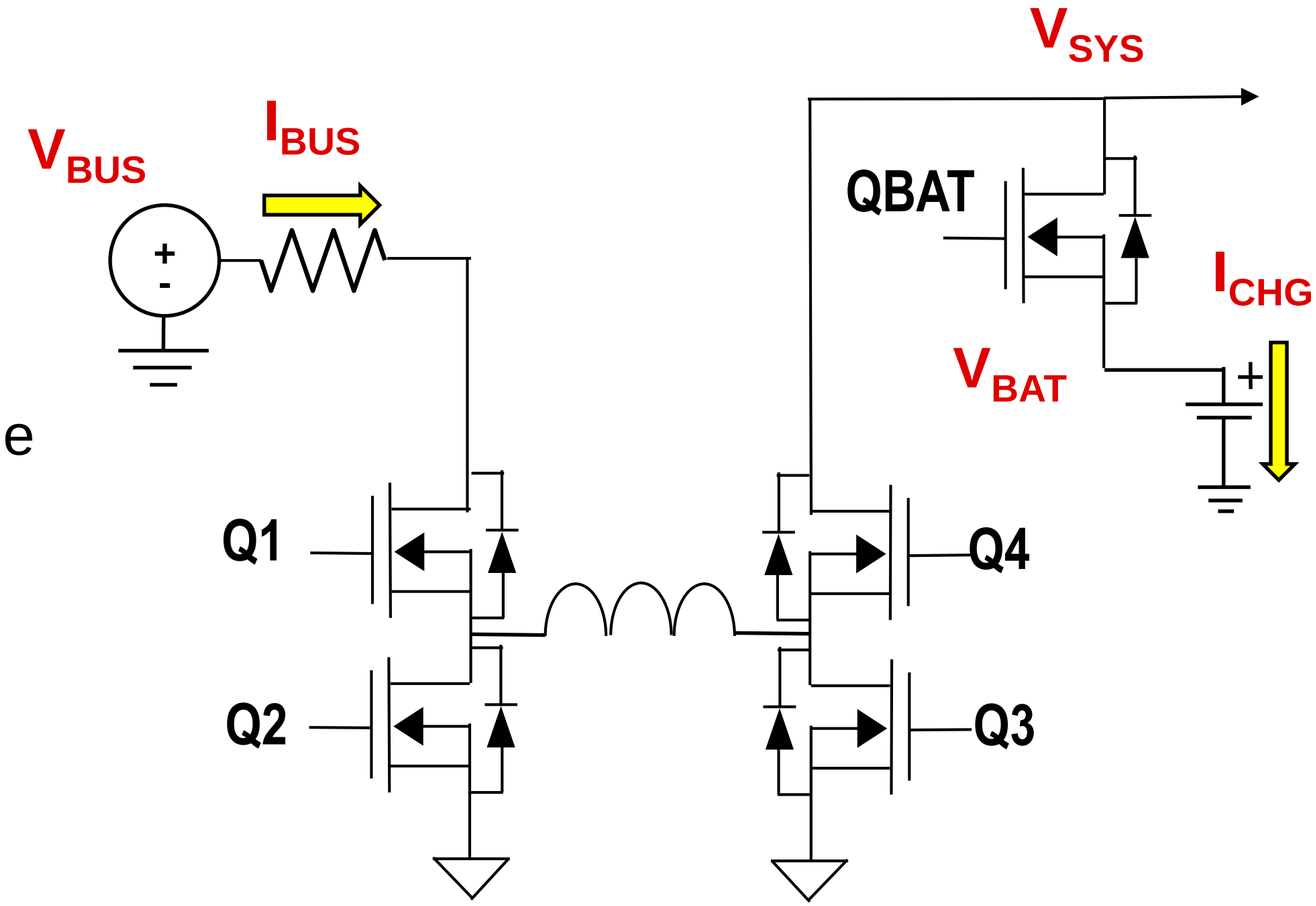
The solar charging solution: 3M approach

- Basic solar charger functions:
  - Manipulate:
    - Operating point and load conditions
    - Requires temporarily stopping converter
      - High-impedance (Hi-Z) mode
  - Monitor:
    - Key charging and input parameters
    - Requires measurement capability
      - Analog-to-digital converter (ADC)
  - Maximize:
    - Input power and charging current
    - Requires control of operating point:
      - V_{IN}DPM selection
    - Requires wide input range for converter
- Charging MPPT algorithm needs:
  - Accuracy:
    - Measurement and tracking
  - Simplicity:
    - Communication
    - Implementation
    - Integration
  - Low power consumption

KEY CHARGER FEATURES FOR SOLAR PANEL MPPT

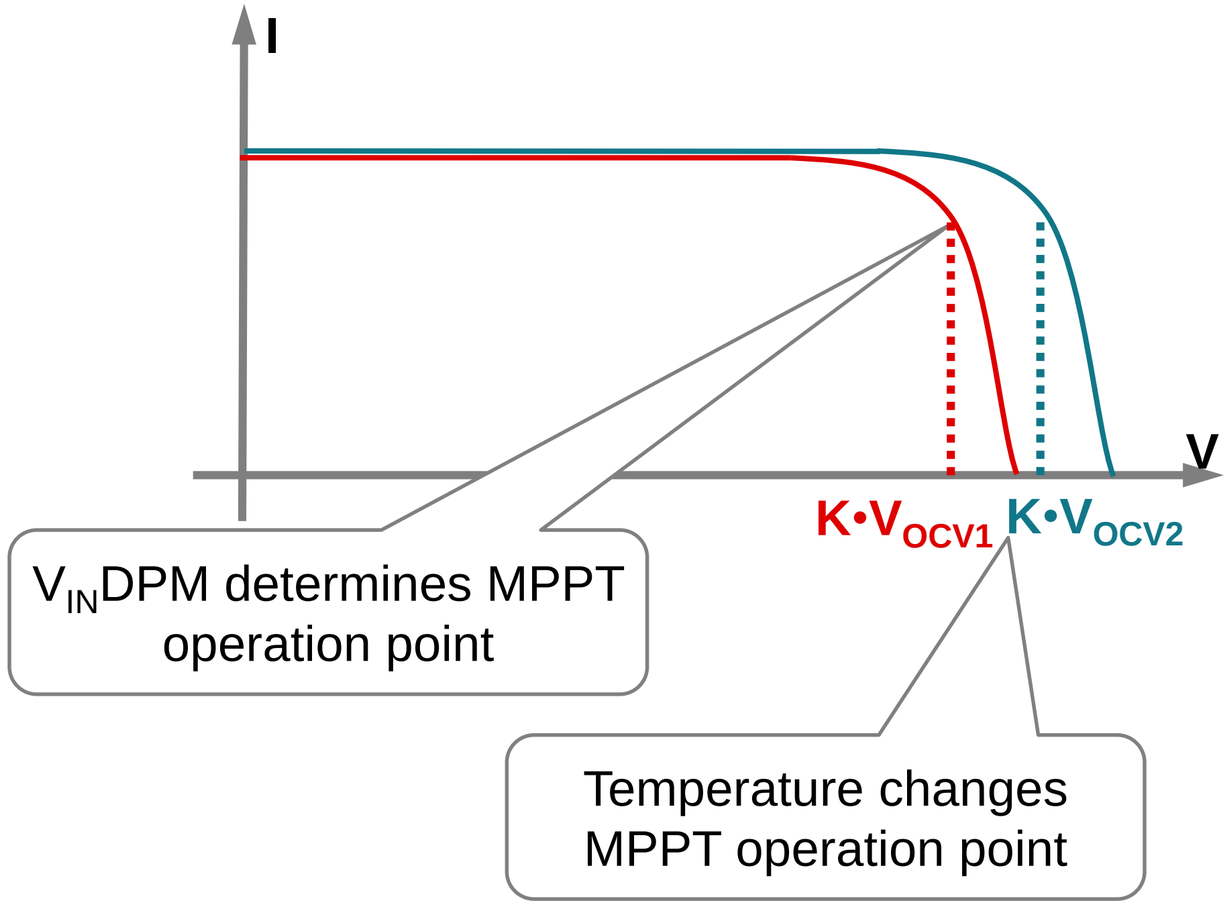
MPPT solar charger features

- Manipulate and Monitor:
  - Open circuit voltage (OCV) measurement:
    - Input Hi-Z mode
    - ADC
  - "Multiplier" to calculate K • V_{OCV}
  - V_{IN}DPM to set the MPPT input voltage
- Maximize:
  - Charge current measurement for optimization
- Buck and boost topology:
  - Wide input voltage range of input and battery



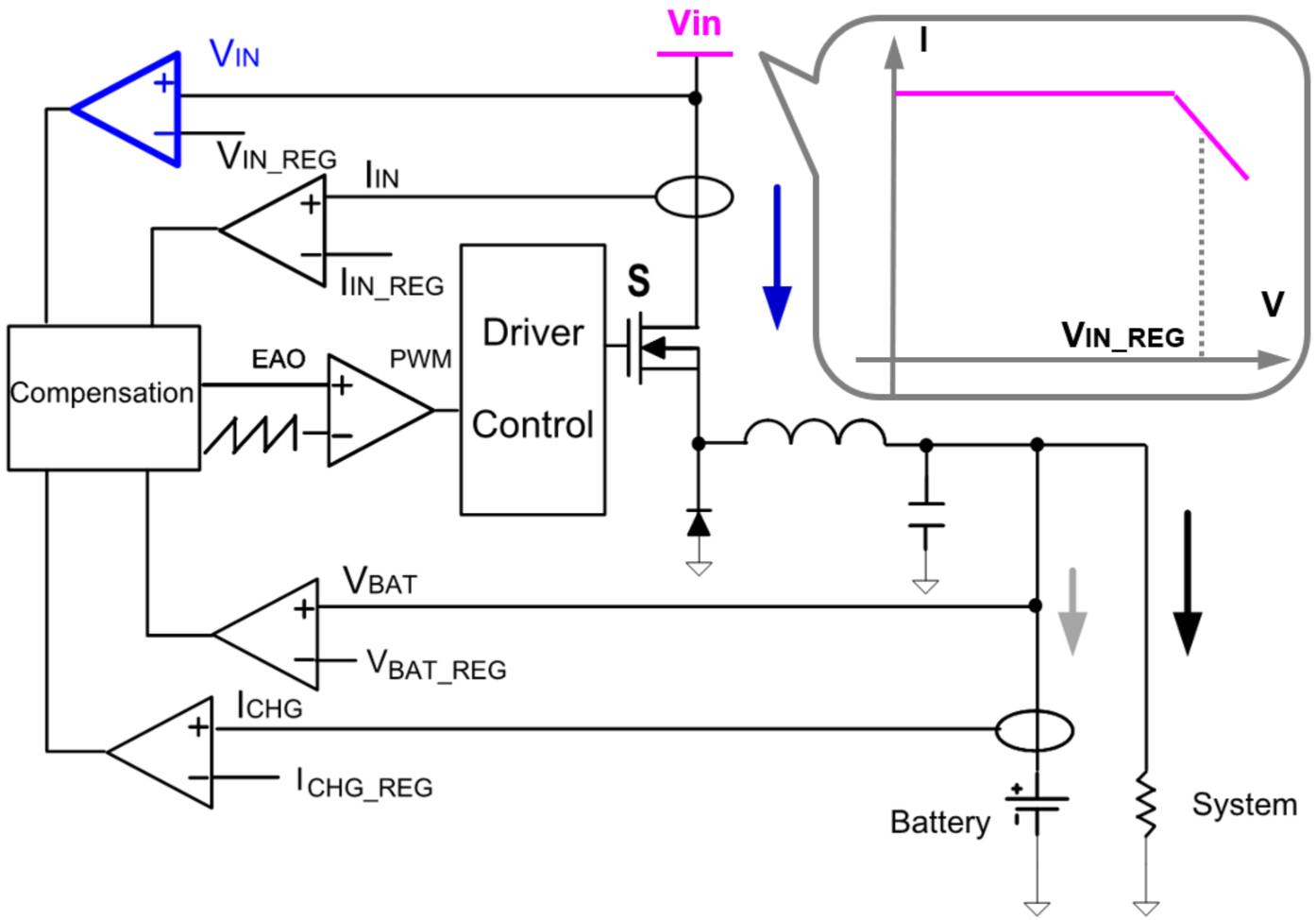
Manipulate: Regulating voltage to achieve MPPT

- In a solar application:
  - Need to manipulate operating point
  - Panel voltage may collapse when overloaded
  - Need to prevent “brown-out” condition
- Autonomous MPPT implementation:
  - Periodic measurement of OCV
  - K factor determined
  - K • V_{OCV} (V_{IN}DPM) determines the MPPT



Autonomous charging: V_{IN}DPM

- Input voltage dynamic power management (V_{IN}DPM):
  - Set minimum input voltage to prevent input voltage drop below this threshold
- Autonomous MPPT implementation:
  - Set K • V_{OCV} as V_{IN}DPM



K factor selection

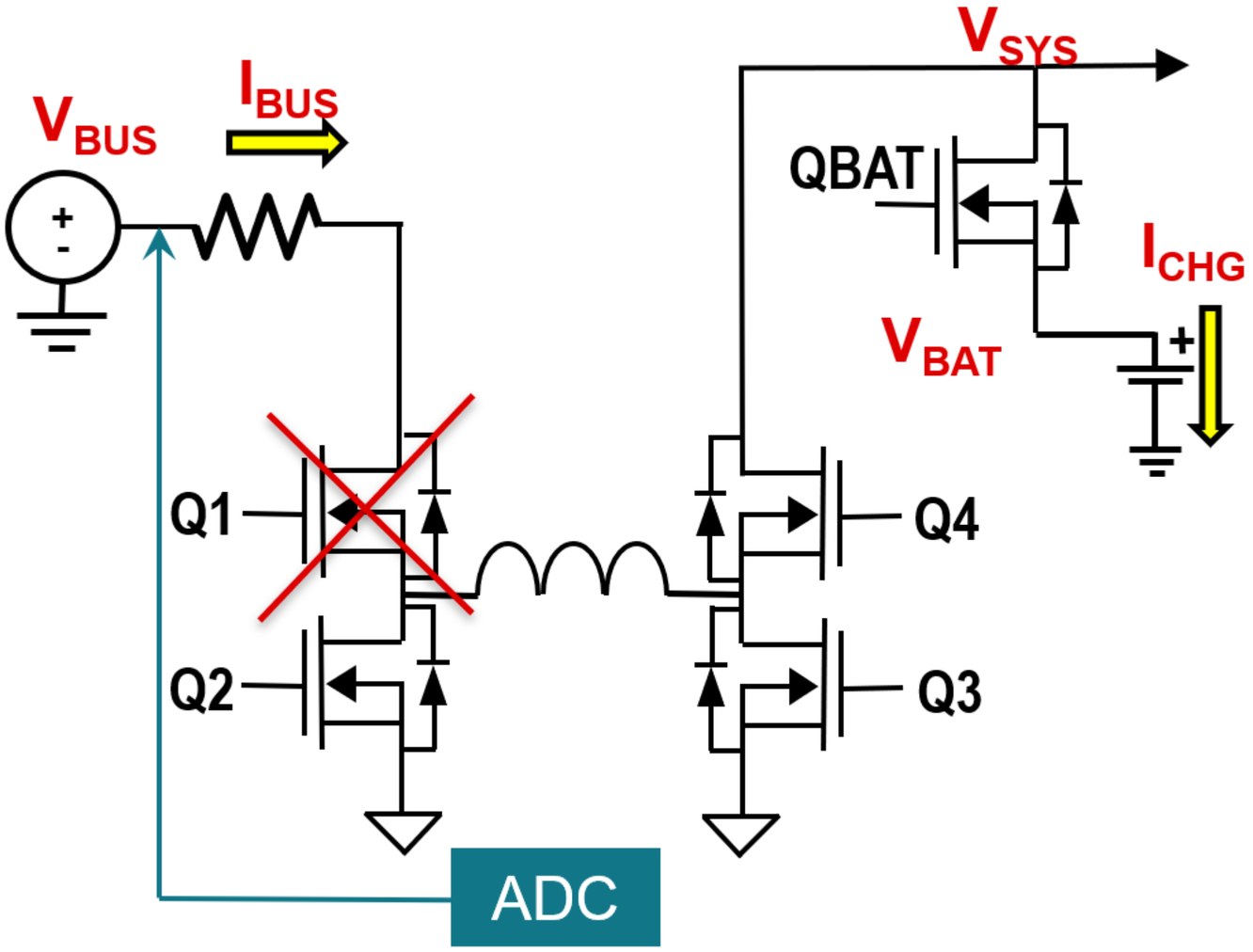
Table 8-31. REG15_MPPT_Control Register Field Descriptions

Bit	Field	Type	Reset	Notes	Description
7-5	VOC_PCT_2:0	R/W	5h	Reset by: REG_RST	To set the VINDPM as a percentage of the VBUS open circuit voltage when the VOC measurement is done. Type : RW POR: 101b 0h = 0.5625 1h = 0.625 2h = 0.6875 3h = 0.75 4h = 0.8125 5h = 0.875 (default) 6h = 0.9375 7h = 1

- Determined by the solar panel, temperatures, sunlight, etc.
- BQ25798 offers different options from 56.3% to 93.8% – configurable via I^2C
- Implement the “multiplier” automatically

Manipulate and monitor: OCV measurement

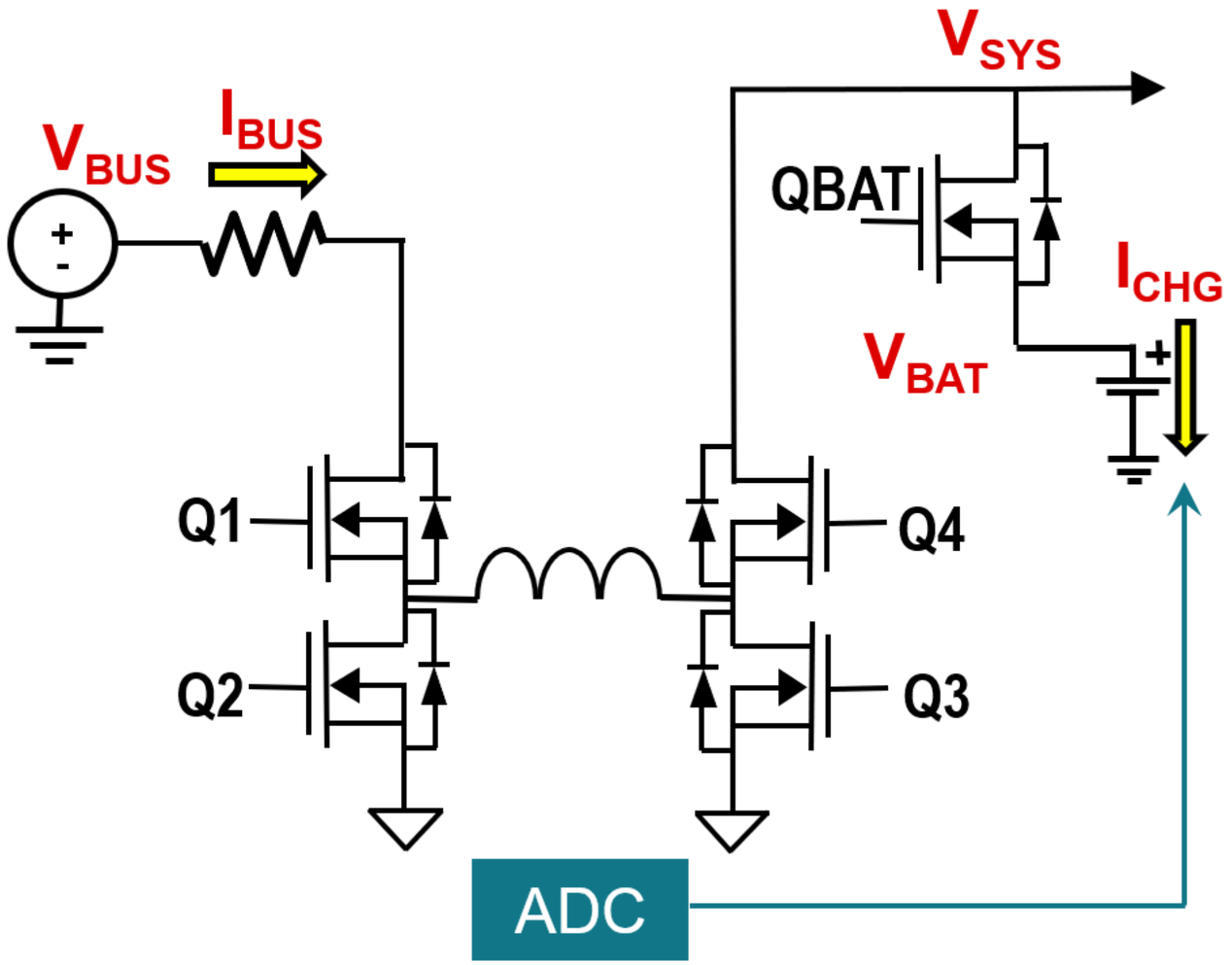
- Input Hi-Z mode:
  - Disables converter and internal biasing
  - VBUS sees unloaded input source voltage
- In a solar application:
  - Manipulate the input voltage of the panel
  - Monitor the input voltage of the panel
  - Good option for F. OCV MPPT



Maximize: Monitoring the charging current (I_{CHG})

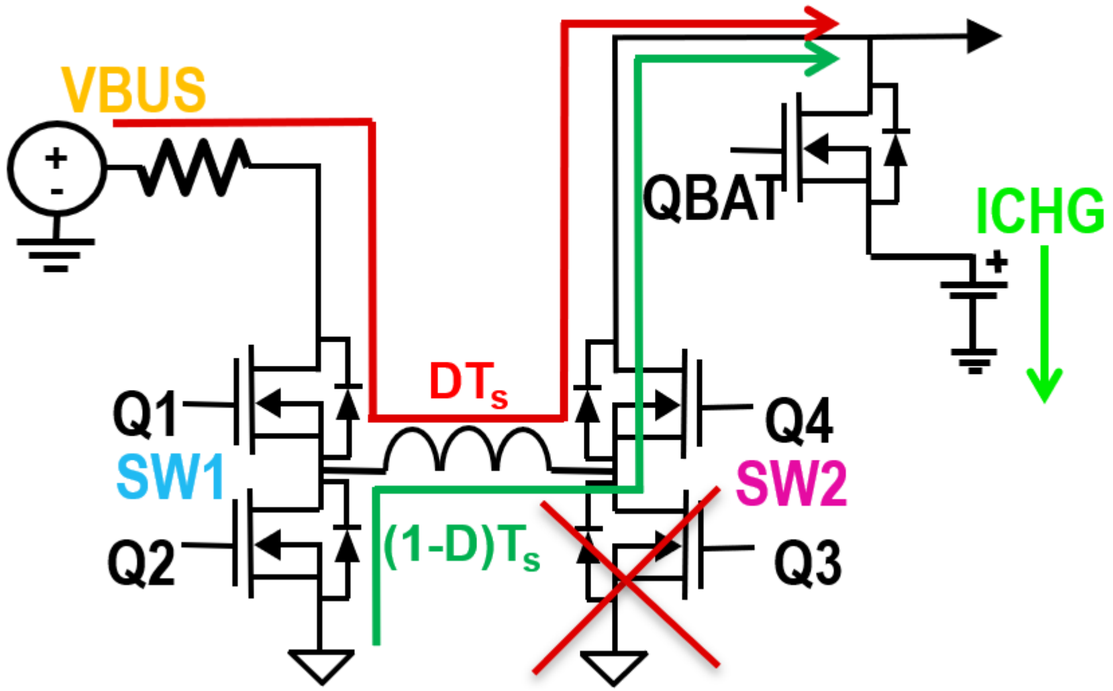
- Host control of the ADC:
  - Measure I_{CHG} to measure output power
  - Checking I_{CHG} maximizes the input power
  - $P = V_{BAT} \times \boldsymbol{I_{CHG}}$

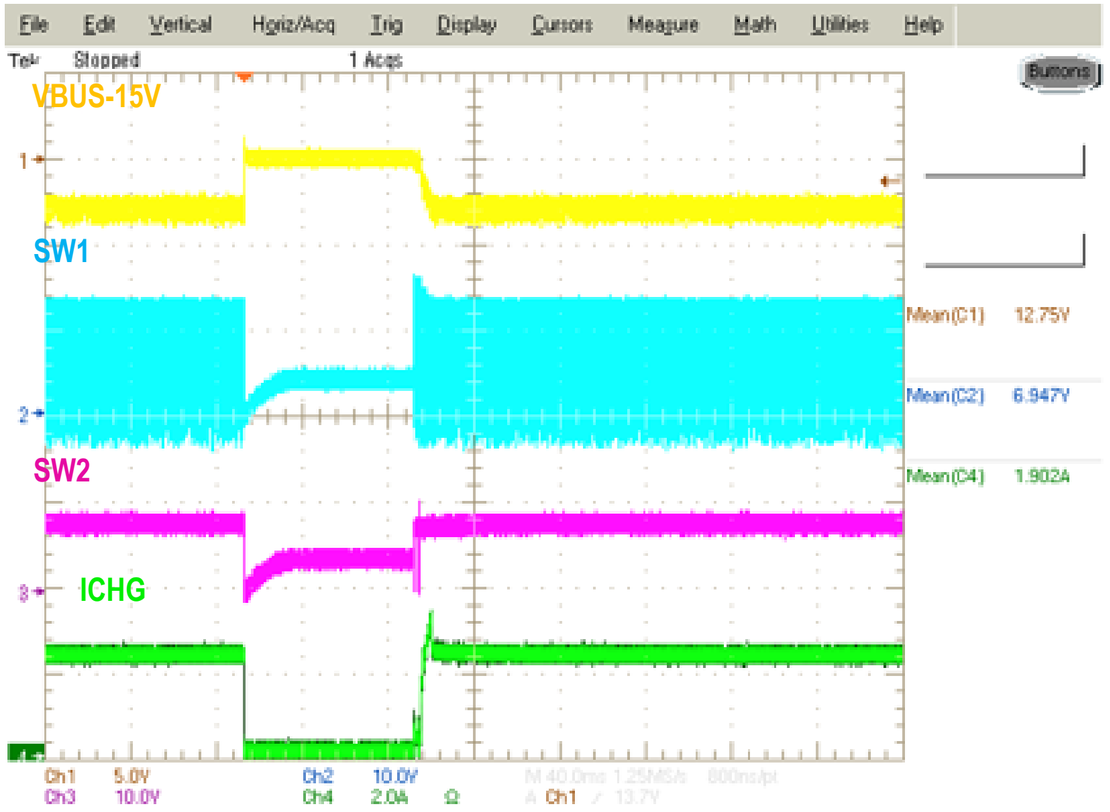
Remains constant in a short time period



MPPT ALGORITHM IMPLEMENTATION AND RESULTS

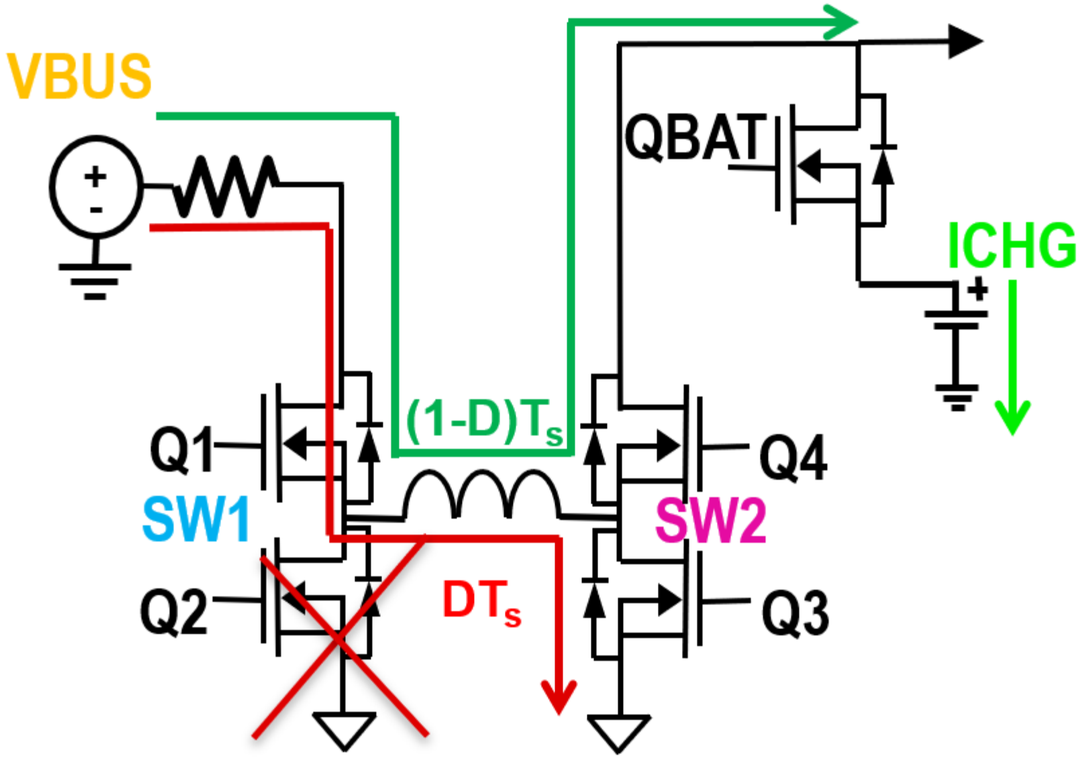
Autonomous MPPT: Buck operation (7.3 V_{BAT})

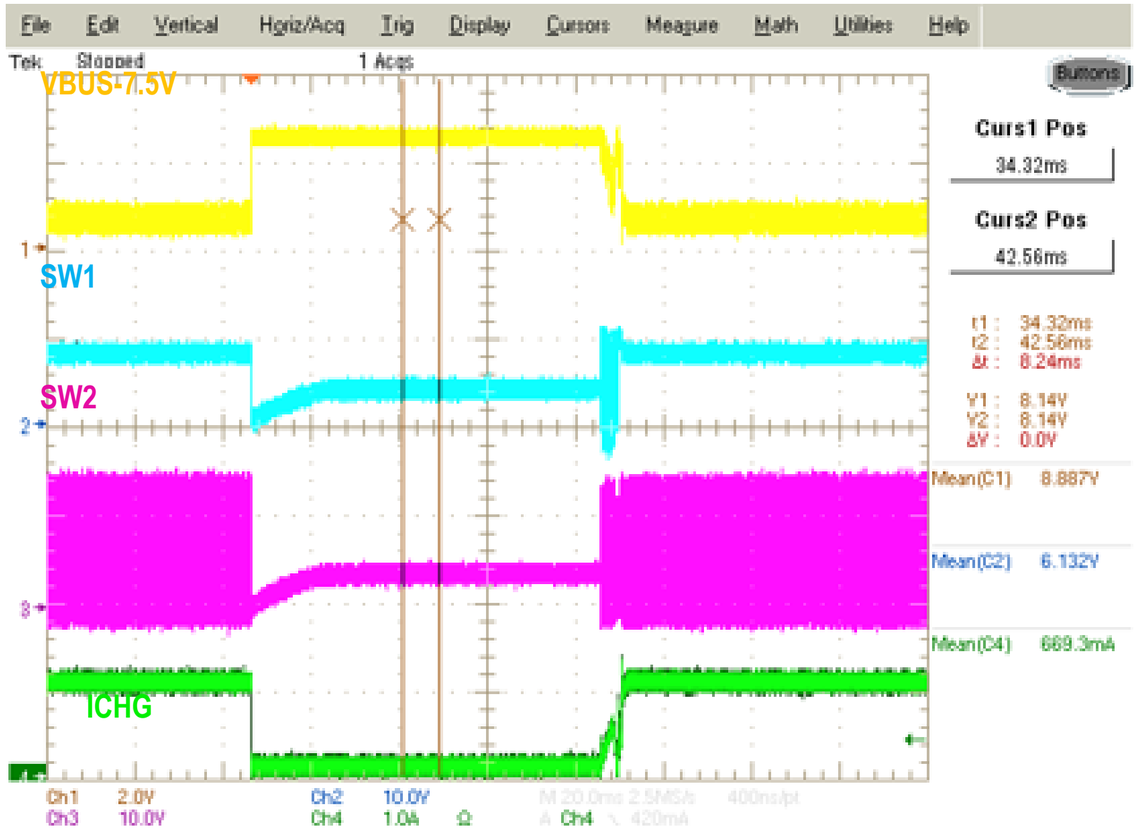




- Converter turns off to measure open-circuit voltage and update V_{IN}DPM
- Charging resumes for 30 seconds
- 15 V_{IN}, 1.5-A supply current limit and 7.3-V battery

Autonomous MPPT: Boost operation (11.5 V_{BAT})

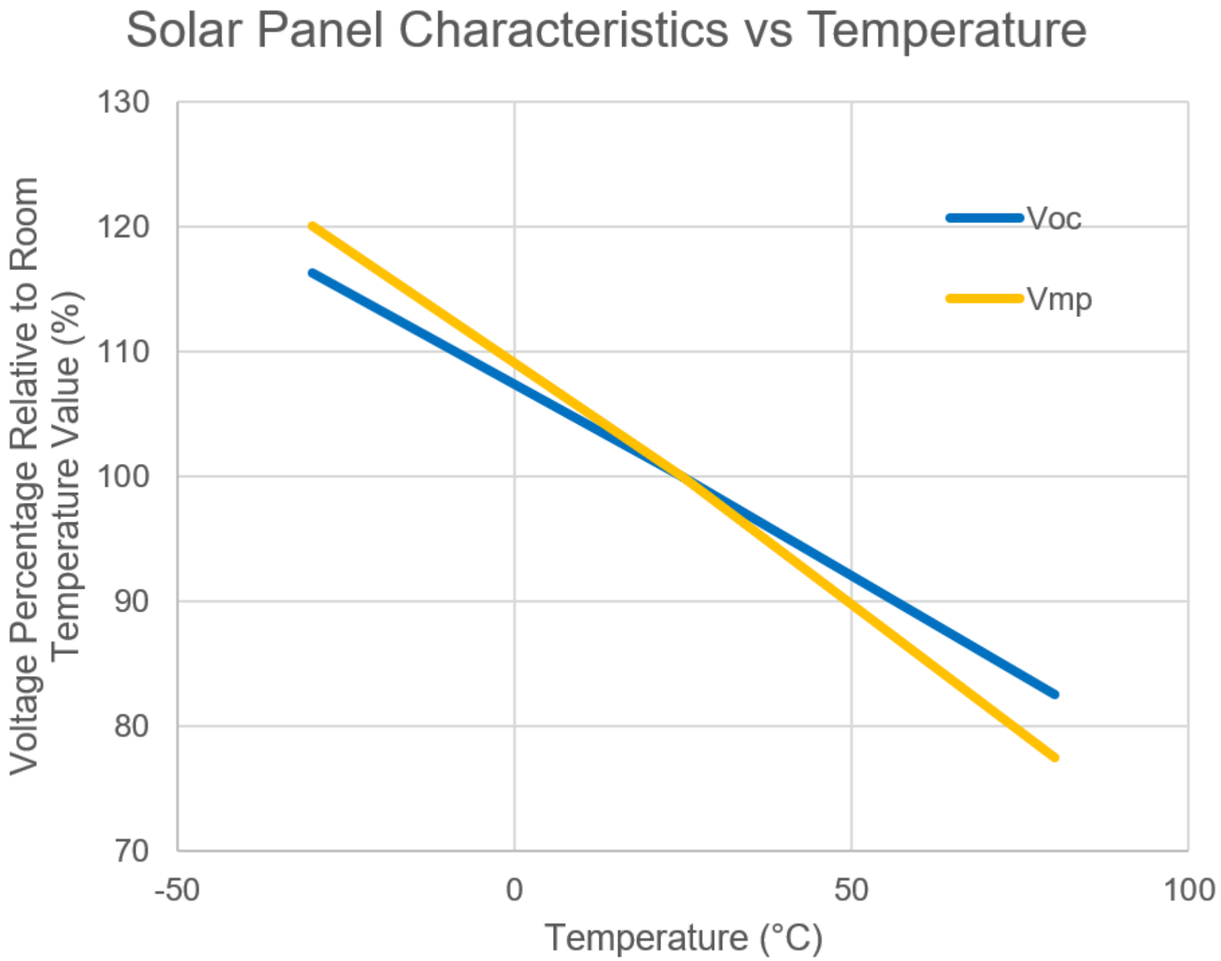




- Converter turns off to measure open-circuit voltage and update V_{IN}DPM
- Charging resumes for 30 seconds
- 10 V_{IN}, 1.5-A supply current limit, 11.5-V battery

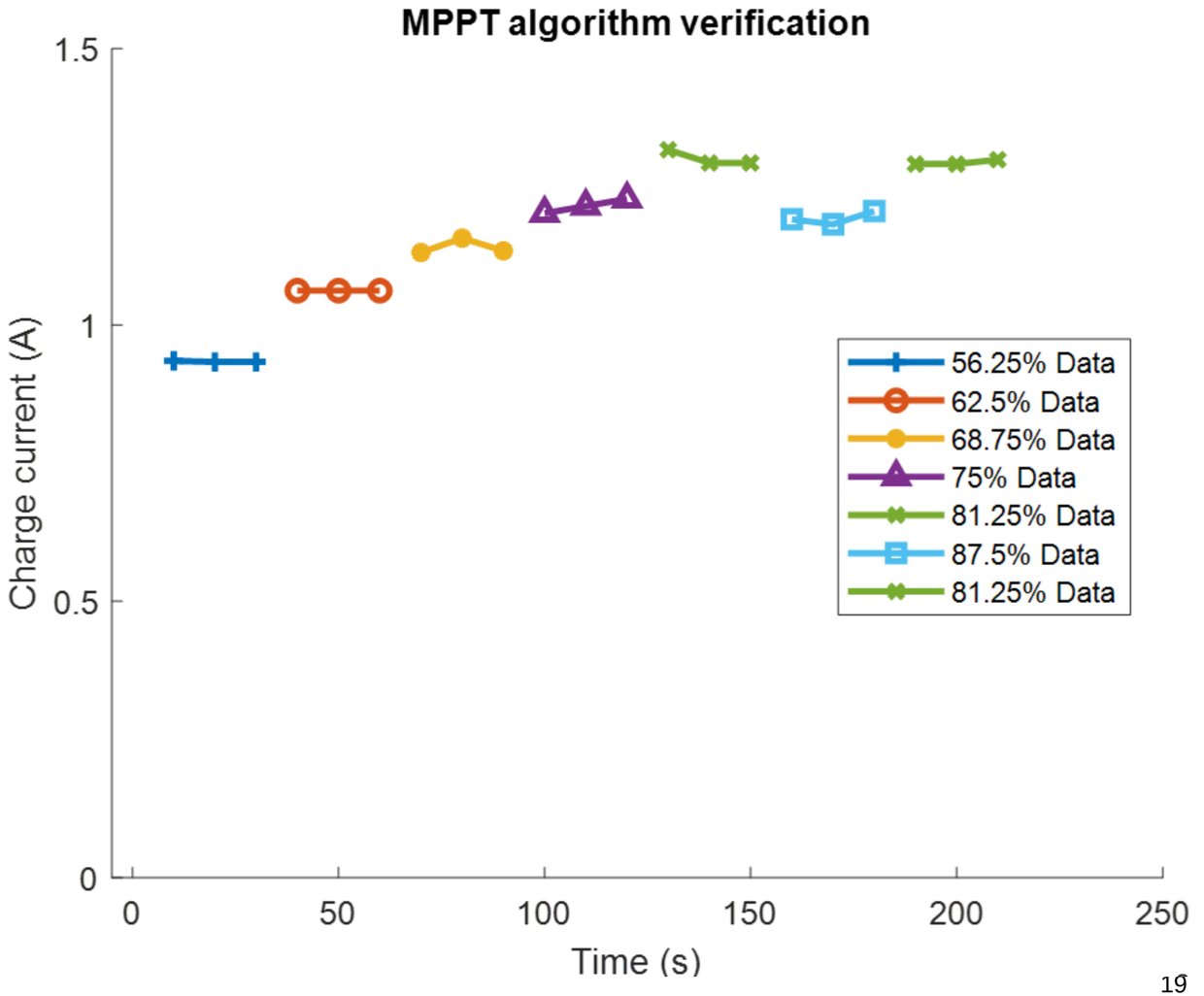
MPPT across temperature

- As temperature changes, the MPPT voltage and the open circuit voltage change by roughly the same percentage
- For a fully sunny day, a fixed percentage of the open circuit voltage will maximize the power throughout the day as the temperature changes



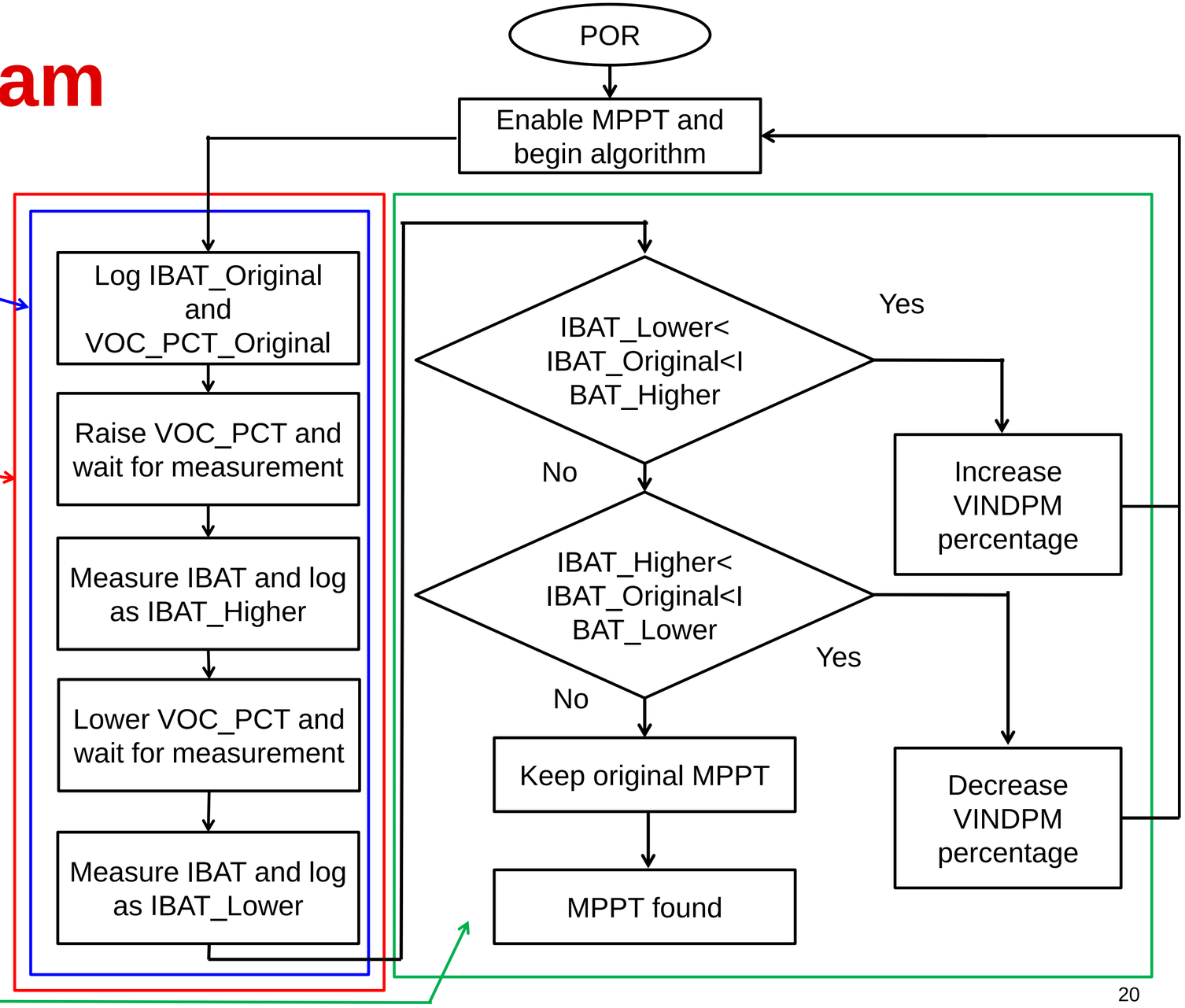
Algorithm flow example

- Monitor:
  - Input voltage and charge current using an ADC
- Manipulate:
  - Test different operating points using Hi-Z and V_{IN}DPM
- Maximize:
  - Update V_{IN}DPM percentage based upon which setting yielded the most charge current
  - Repeat as conditions change



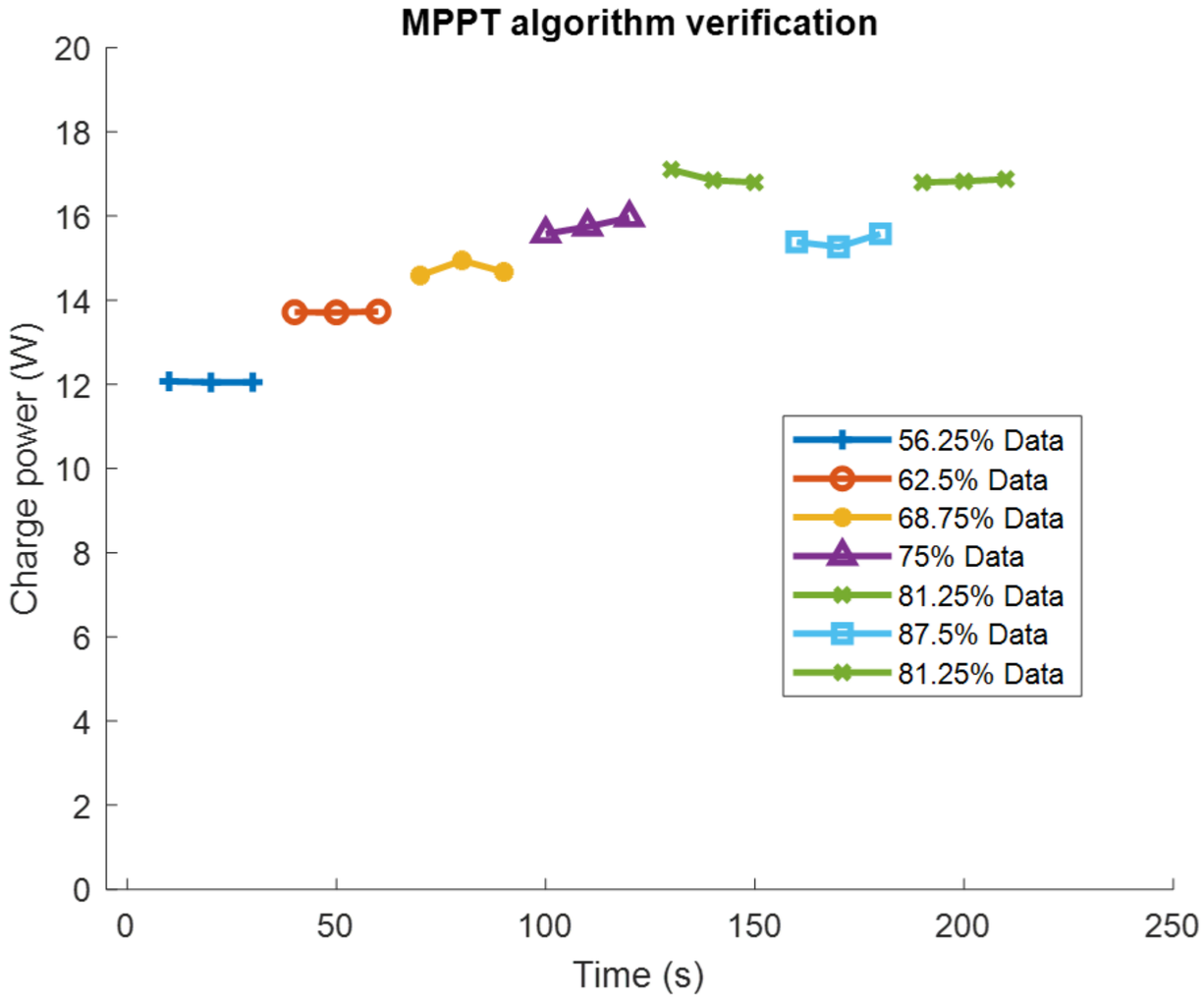
Algorithm flow diagram

- Monitor:
  - Input voltage and charge current using an ADC
- Manipulate:
  - Test three different operating points using Hi-Z and V_{IN}DPM
- Maximize:
  - Update V_{IN}DPM percentage based upon which setting yielded the most charge current
  - Repeat as conditions change



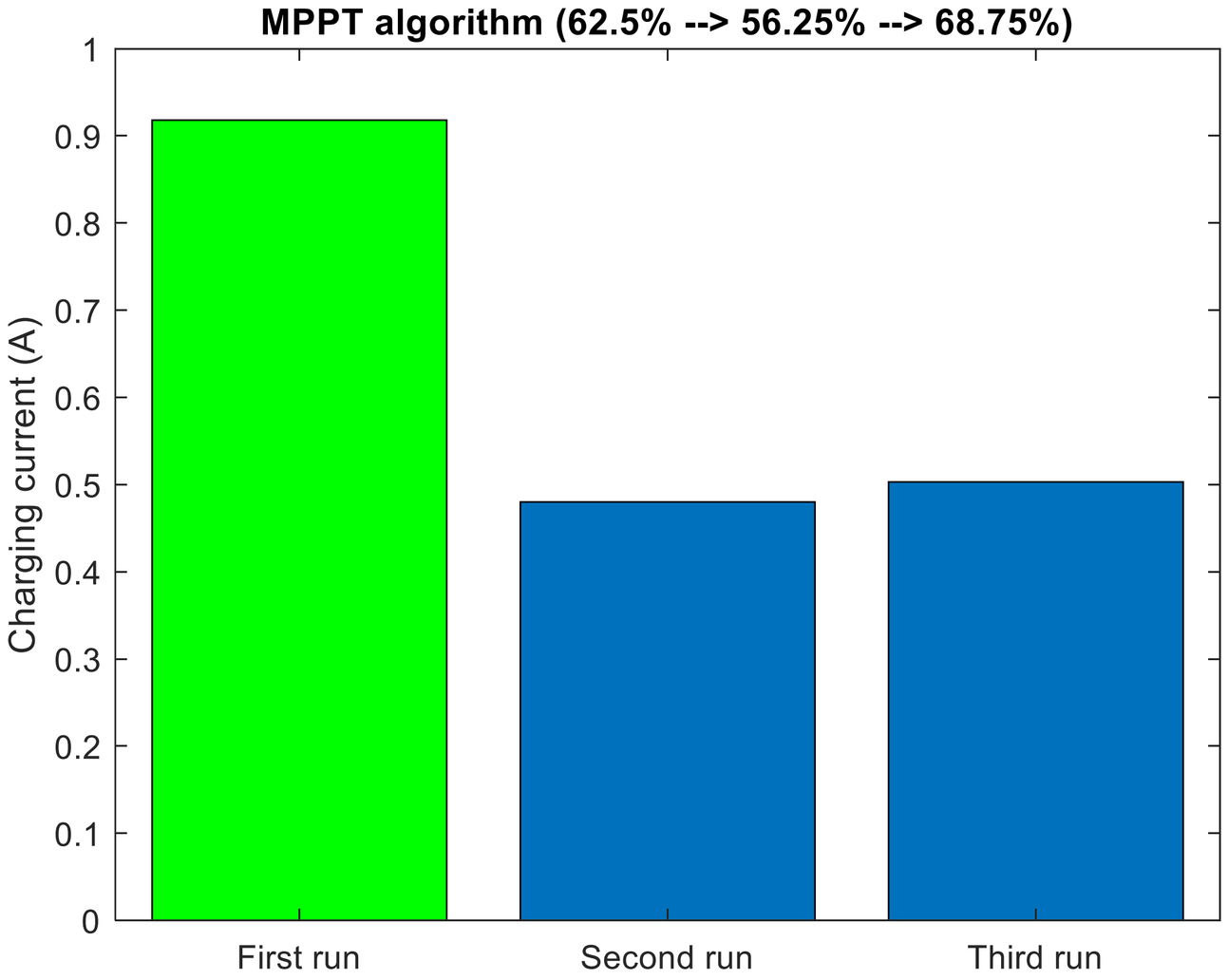
Maximize: Sunny day charge power

- Very sunny
- Approximately 13-V battery with solar input voltage of …
  - 10.1-V (boost)
  - 11.3-V (boost)
  - 12.4-V (boost)
  - 13.5-V (buck-boost)
  - 14.6-V (buck)
  - 15.8-V (buck)
- 81.25% V_{IN}DPM maximizes charging current



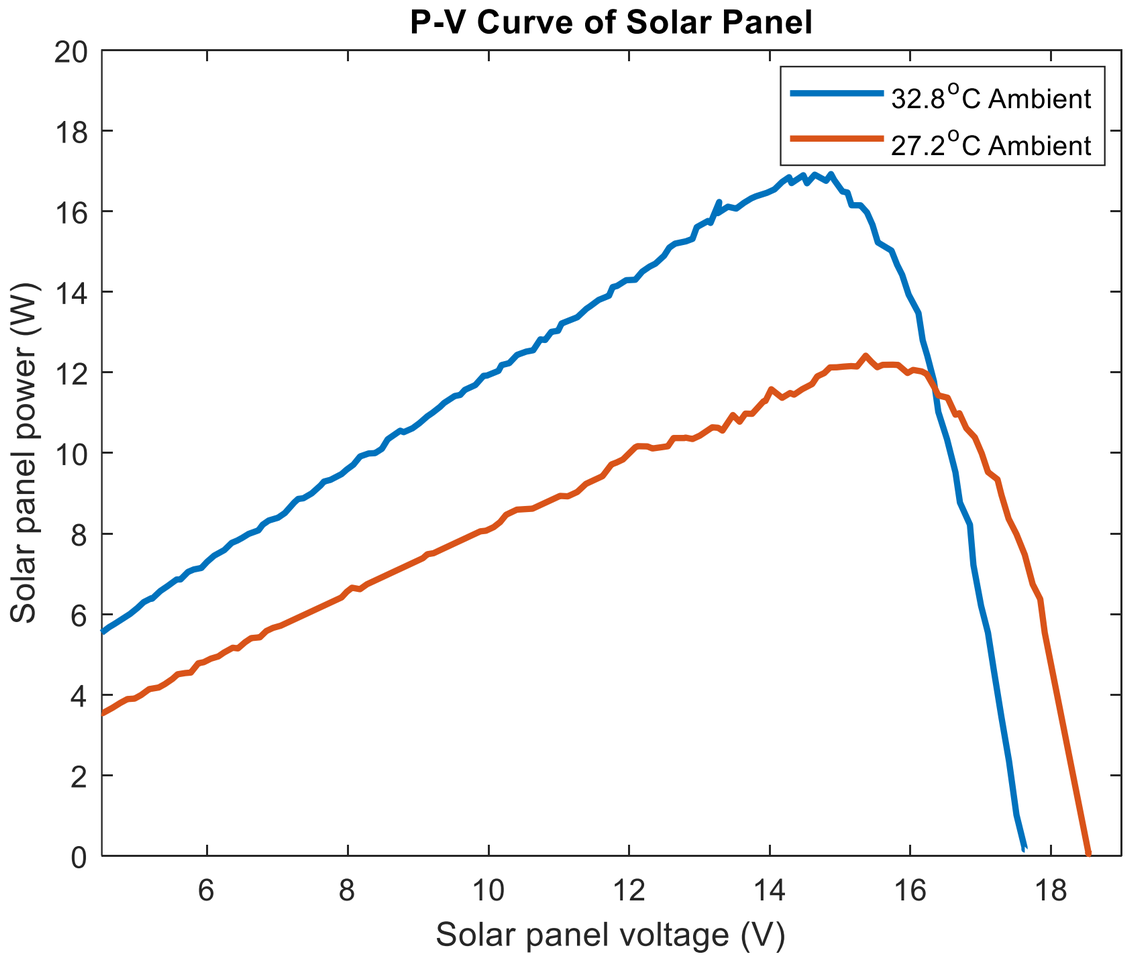
Maximize: Partly cloudy run charge current

- Intermittent cloud activity
- 13-V battery with solar input voltage of …
  - 11.3-V (boost)
  - 10.1-V (boost)
  - 12.0-V (boost)
- 62.5% V_{IN}DPM maximizes charging current



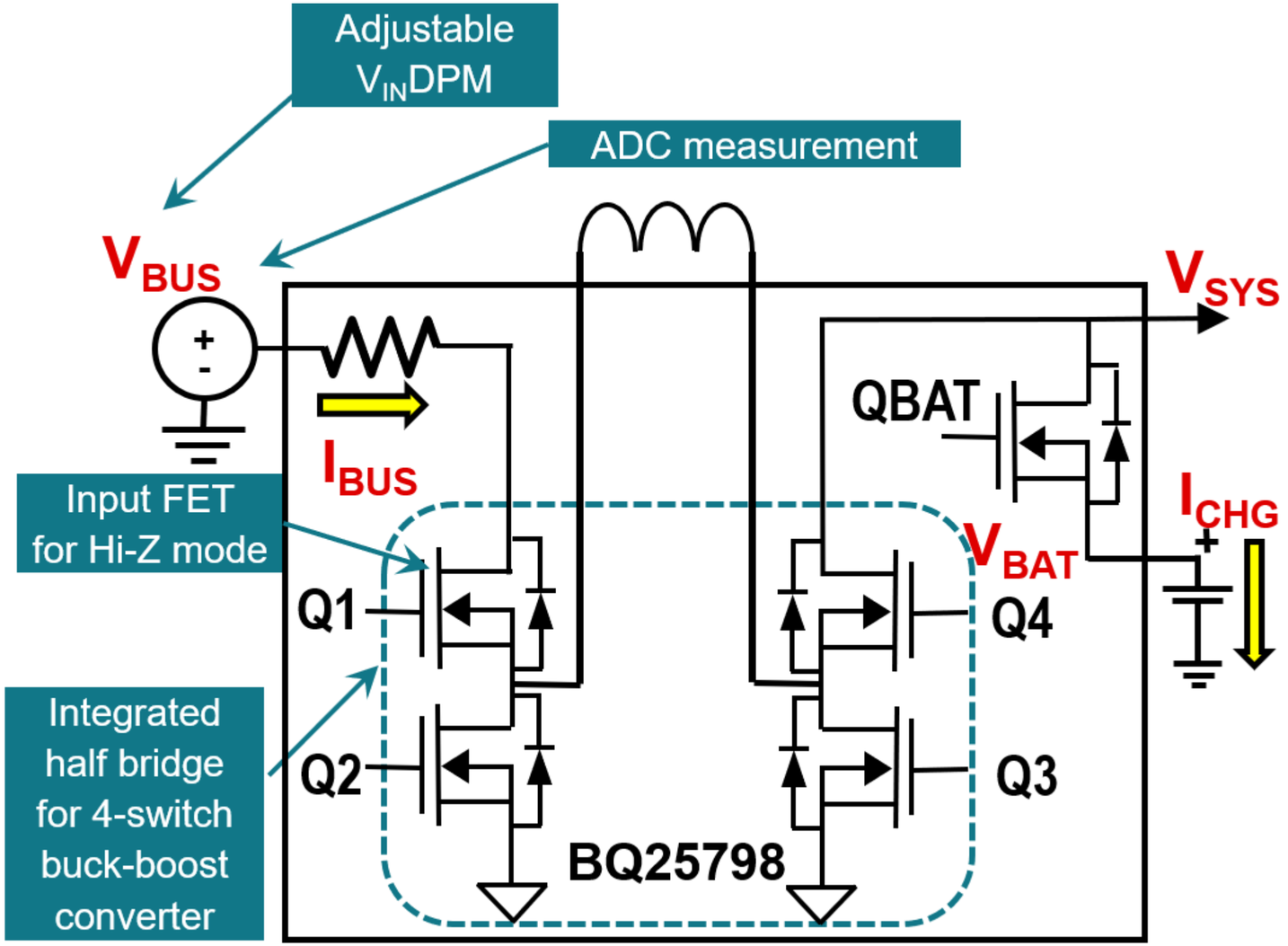
Maximize: Solar panel characterization

- Different irradiance and temperature test environment
- Approximately 12.8-V battery
  - Converter operating in buck and boost mode
- MPPT occurs around …
  - 14.6-V for brighter test
  - 15.5-V for less bright test
- 81.25% setting maximizes input power



Solar charger: BQ25798

- Autonomous MPPT for solar input
  - Input Hi-Z mode
  - 16-bit integrated ADC for further system optimization
  - Only need to set K factor for K • V_{OCV} (V_{IN}DPM)
- Buck-boost topology with wide input voltage range
  - 3.6-V ~ 24-V



Summary

- Solar power tracking:
  - Max power dependent on sunlight and temperature
  - Three algorithms compared
  - Manipulate, monitor, and maximize input and output conditions for faster charging
- BQ25798: Manipulate and Monitor
  - Autonomous MPPT with K factor setting: integrated features for easy design and small solution size
- Simple MPPT implementation: Maximize
  - Max I_{CHG} indicates maximum power point due to steady battery voltage
  - Proposed algorithm combines fractional open circuit voltage and perturb and observe approaches
- MPPT operation achieved under varying weather conditions and with various solar panels

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