# Experiment #7

## Battery Management

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The objectives of this experiment are:

- To design and implement a battery management control system that incorporates three modes: bulk charging (MPPT), charge taper (constant voltage), and float (trickle) modes.
- Develop charge taper and float mode control algorithms that are compatible with your MPPT algorithm developed in Exp. 6, and that allow smooth transitions between modes during charging.
- Implement smooth transitions that change mode in opposite direction (increasing power) as needed when battery is discharged or loaded.
- To experimentally demonstrate your working battery management controller

In this experiment, you will add charge taper and float modes to the maximum power point tracking controller that you developed in Experiment 6. design, construct, test, and demonstrate maximum power point tracking, to charge the battery at a faster rate than would be attained with direct energy transfer. Figure 1 is a high-level depiction of the power circuitry, in which your SEPIC interfaces your solar panel to your battery, and in which the PV panel voltage/current operating point can be

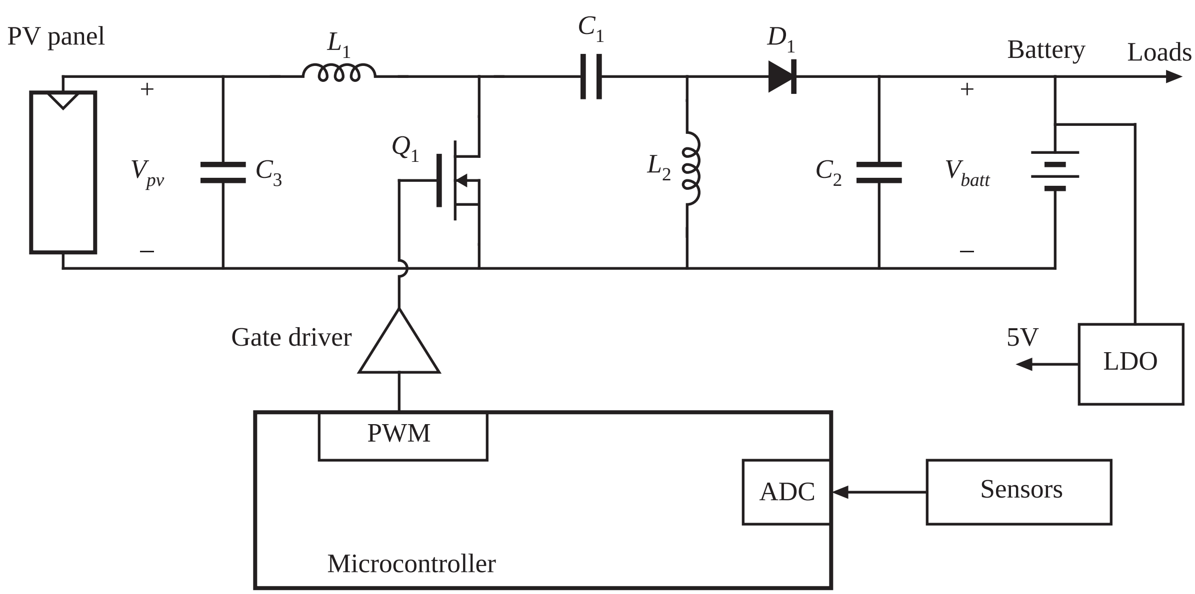


**Figure 1** SEPIC battery management system.

controlled by selection of the SEPIC duty cycle. Your microcontroller will implement a maximum power point tracking (MPPT) algorithm that maximizes the current charging the battery.

## 1. MATLAB/Simulink Model for Charge Taper Mode

Modify your MATLAB/Simulink system model and its controller algorithm to include the charge taper mode in addition to maximum power point tracking. Your algorithm should:

- Operate in MPPT mode when the measured battery voltage is less than a threshold value $V_{threshold}$
- Operate in charge taper mode when the measured battery voltage is greater than the threshold value $V_{threshold}$
- Smoothly transition between MPPT and charge taper modes, in both directions

In the charge taper mode, the controller should adjust the duty cycle such that the battery voltage is regulated at $V_{threshold}$. Since the battery voltage changes slowly, this could be done using duty cycle increments, similar to the MPPT perturb-and-observe algorithm, but with battery voltage regulated rather than by maximizing battery current. As the battery state of charge increases, its internal voltage will increase and the charging current will decrease. To reduce simulation time, you may reduce the battery model amp-hour capacity $C$ as appropriate.

When your controller algorithm has been implemented and debugged in your MATLAB/Simulink system model, then perform the following two simulations:

1. Charge the battery and illustrate the transition from MPPT mode to charge taper mode. Your simulation should show how the battery current decreases as the battery approaches a high state of charge.
2. With the system operating in charge taper mode, apply a step increase in load current so that the battery state of charge decreases. Your simulation should show how the system goes back into MPPT mode when the battery voltage is sufficiently discharged.

For your report, capture scope waveforms of the battery voltage, battery current, and duty cycle, for the above two simulations. Also document your controller code.

## 2. Float mode

Modify your MATLAB/Simulink controller algorithm to add a third mode, in which charging is terminated (or reduced to a very small value) when the battery voltage reaches a higher threshold indicative of a battery state of charge near 100%. Your algorithm should resume the charge taper mode if the battery voltage decreases sufficiently. When your three-mode controller algorithm has been implemented and debugged, then perform the following two simulations:

1. Charge the battery and illustrate the transition from charge taper mode to float mode Your simulation should show how the battery current is terminated when the battery approaches a sufficiently high state of charge.

2. With the system operating in float mode, apply a step increase in load current so that the battery state of charge decreases. Your simulation should show how the system goes back into charge taper mode when the battery voltage is sufficiently discharged.

For your report, capture scope waveforms of the battery voltage, battery current, and duty cycle, for the above two simulations. Also document your controller code.

## 3. Hardware Demonstration

Implement your three-mode control algorithm in your microcontroller. Verify the following:

1. With the battery sufficiently discharged, verify that the system continues to operate in MPPT mode. Capture oscilloscope waveforms of the battery voltage and current when the system operates in this mode.
2. With the battery in a sufficiently high state of charge, verify that the system operates in charge taper mode. Capture oscilloscope waveforms of the battery voltage and current when the system operates in this mode, as necessary to show that your charge taper mode is functional.

For your report: document the part of the interrupt service routine code that implements your three-mode control algorithm. Include your waveforms showing operation in MPPT and charge taper modes.

## Grading Rubric

### 1. Charge taper mode in MATLAB/Simulink model

(40 points total)

- Report documents the working controller code that implements MPPT and charge taper modes in the MATLAB/Simulink model (15 points)
- Report documents the simulation waveforms of battery voltage, battery current, and duty cycle for operation in the charge taper mode (15 points)
- Report documents the transition from MPPT mode to charge taper mode in the MATLAB/Simulink simulation. (5 points)
- Report documents the transition from charge taper mode to MPPT mode when the battery becomes sufficiently discharged. (5 points)

### 2. Float mode in MATLAB/Simulink model

(15 points total)

- Report documents the working controller code that implements three-mode (MPPT/charge taper/float) control in the MATLAB/Simulink model (5 points)
- Report documents the transition from charge taper mode to float mode, in the simulation (5 points)

- Report documents the transition from float mode to charge taper mode, in the simulation (5 points)

**3. Hardware demonstration of three-mode control**

(45 points total)

- Report documents the working microcontroller code that implements three-mode (MPPT/charge taper/float) control. The relevant interrupt service routine code should be included. (15 points)
- Report documents experimental data showing that the system operates in MPPT mode when the battery is sufficiently discharged (15 points)
- Report documents experimental data showing that the system operates in charge taper mode when the battery state of charge is sufficiently high (15 points)