Power Management Solution: Constant Voltage (CV) Pulse Charging of Hybrid Capacitors

By Gerald Tatschl

ENYCAP™ 196 HVC SERIES

GENERAL INFORMATION

In order to fully utilize the performance of ENYCAP™ 196 HVC capacitors, a reliable charging solution has to be applied. This document proposes to use constant voltage (CV) pulse charging as the most cost-efficient solution. Major building blocks and design considerations are discussed.

HYBRID CAPACITOR TECHNOLOGY AND PRODUCT PROPERTIES

Hybrid systems combine electrostatic and faradaic energy storage. Therefore, faster charging than a battery is possible. Hybrid capacitor systems surpass the power density of batteries and have significantly higher energy density than double-layer capacitors.

Due to the faradaic energy storage component, hybrid capacitors have a limited and narrow operating voltage range, similar to batteries. While this voltage stability is beneficial in many applications, capacitor voltage and current have to be carefully managed in order to maintain optimum performance over a long operational life.

The maximum cell voltages must not be exceeded. Consequently, for an optimum lifespan power management has to safeguard the operation limits with absolute accuracy in the mV range.

It also has to be taken into account that the current flow through hybrid capacitors is partly related to faradaic conversion processes. As these processes require some time, the maximum permissible currents have to be ensured for charging and discharging.

Self-discharge of hybrid capacitors is significantly lower than for EDLCs. For example, self-discharge is below 5 % / month for ENYCAP 196 HVC capacitors.

As faradaic storage processes always include some material conversion, it is evident that overcharging must be avoided. Even if ENYCAP 196 HVC devices have some short time tolerance in this respect, it has to be considered that over long periods of time, without proper control measures, even low charge currents can overcharge the capacitor.

The cycle life performance of hybrid capacitors is superior to batteries. For example, ENYCAP 196 HVC capacitors can achieve more than 50 000 cycles.

CV PULSE CHARGING

For applications requiring a constantly high charge state of the energy storage device, such as backup systems, a CV pulsed charging method (PCM) is recommended. PCM can be implemented in a rather simple power management environment and will ensure the safe operation of the hybrid storage component within recommended limits and conditions.

Pulsed charging is the preferred method to compensate self-discharge while avoiding regular or permanent overcharging. This can greatly improve the lifetime of the energy storage system.

Pulsed or intermittent charging can be implemented with a CV source controlled by a timer. The voltage source has to be accurately adjusted to the charging voltage of the storage system.

Typical operation sequence (see Fig. 1):

1. An initial charge step ensures sufficient energy for the next backup operation (load)
2. Check for available energy by testing the open circuit voltage (OCV) of the storage element
3. Monitor state of health (SOH)
4. Apply a charge pulse to compensate self-discharge and backup load
5. Restart at step 2

Note

- Steps 2 to 5 compensate self-discharge effects and keep storage elements by this kind of **trickle charging** in healthy condition, also over extended long periods of time.

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PCM

FLOW CHART

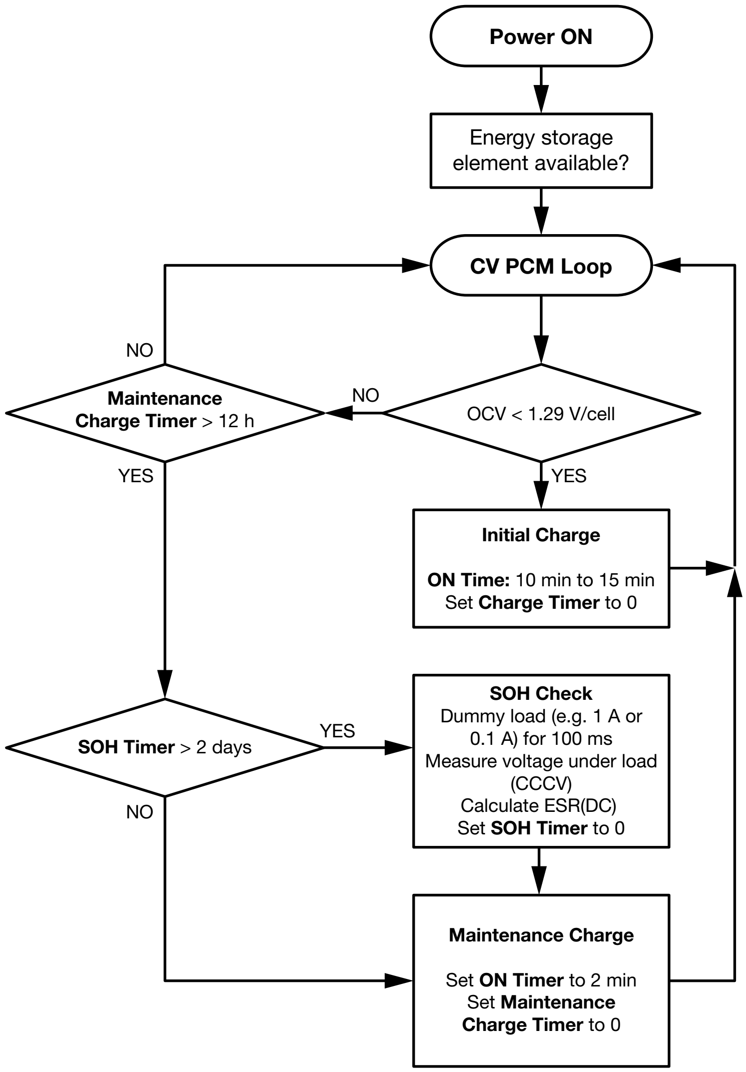

Fig. 1 - Flowchart for operation of a backup system with pulsed charging method

INITIAL CHARGE

An initial charge is necessary if the capacitor voltage is lower than 1.29 V per cell.

For a system with n = 3 cells, the limit to start an initial charge cycle is 3 x 1.29 V = 3.87 V.

The nominal voltage of this system would be 3 x 1.4 V = 4.2 V.

This initial charge voltage of 1.29 V per cell is temperature-independent.

The "ON Time" of 15 minutes is a typical example. "ON Time" has to be long enough to sufficiently charge the ENYCAP 196 HVC storage system for the next operation cycle (e.g. backup).

"ON Time" can be reduced if significantly less energy than specified in the datasheet is required (e.g. for a 90 F type with energy of 115 J per cell).

Initial charge cycles are most likely necessary if the system is switched on for the first time, after a backup event, or after power off for several days or weeks.

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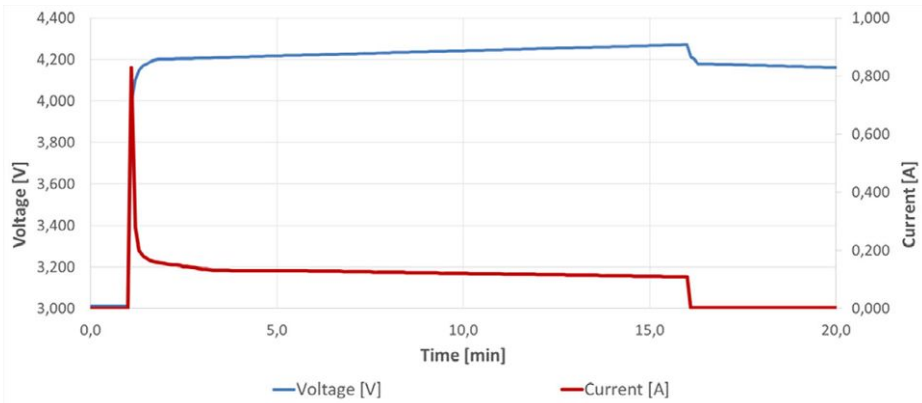

Fig. 2 - The first 15 minutes of initial charge (example 90 F, 4.2 V)

MAINTENANCE CHARGE

Maintenance charge pulse timing is controlled by a timer. Short charge pulses (durations less than two minutes) will keep the hybrid ENYCAP 196 HVC system sufficiently charged and will compensate for self-discharge (see the example for ENYCAP 196 HVC 90 F, 4.2 V type in Fig. 4).

The charging periods are short in comparison to total operating time. Due to this relation, pulse charging for only a few minutes per day minimizes the amount of unintended overcharge to safe limits.

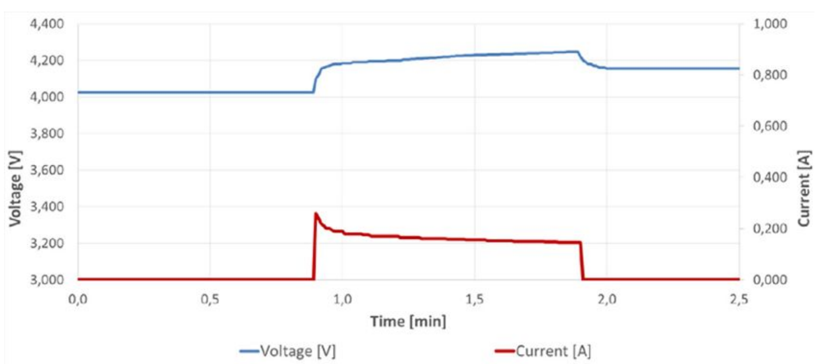

Fig. 3 - The first maintenance charge pulse (1 minute) after 6 h (example 90 F, 4.2 V)

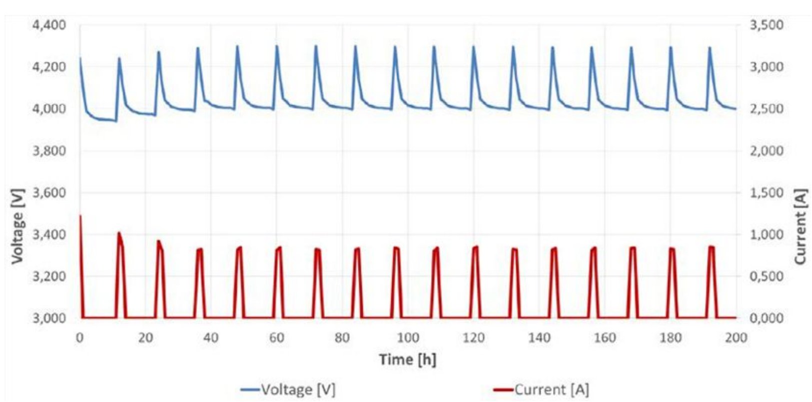

Fig. 4 - Intermittent charging with 1 minute pulses every 6 h (example 90 F, 4.2 V)

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TEST CONFIGURATION

The above diagrams show typical measurements of ENYCAP 196 HVC 90 F, 4.2 V (three cells) capacitors for intermittent charging. The CV source is set to 4.26 V.

The current limit of the source has been programmed to 1.5 A, but measured peak currents for this system are well below 1.0 A.

For the correct selection and setting of charge voltage limits, please refer to the separate application note "Constant Voltage (CV) Pulse Charging of Hybrid Capacitors ENYCAP™ 196 HVC Series."

Pulsed charging is performed by charge pulses with a 1 minute duration every six hours. These maintenance charge pulses fully charge the chosen hybrid storage element and compensate self-discharge effects. An initial charge is sufficient for the next backup operation.

APPLICATION EXAMPLE

BLOCK DIAGRAM

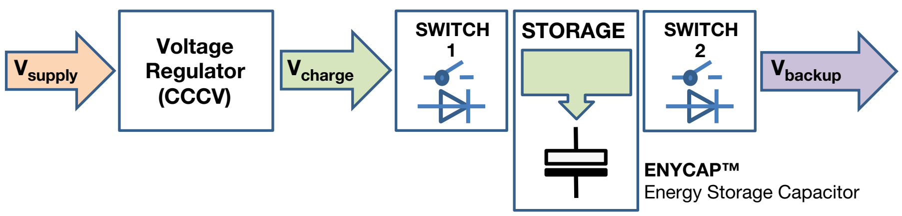

Fig. 5 - Typical block diagram for a backup application, storage element permanently loaded

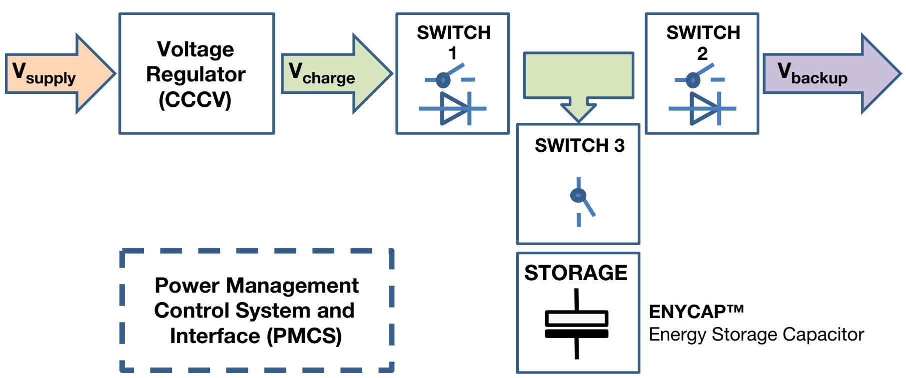

Fig. 6 - Typical block diagram for a pulse charging and backup application, the storage element is disconnected during idle state in order to reach optimum performance regarding operational lifetime and to allow extended SOH testing and adaptive charge sequences

FUNCTIONAL DESCRIPTION

The voltage regulator provides the constant charging voltage V_{charge} for the ENYCAP 196 HVC storage element. V_{charge} has to be restricted within tight absolute limits (ideally no overshoot).

Usually a current limiter is installed as well. This will protect the storage element from charge currents that are too high.

Linear supply circuits are common and inexpensive solutions with good regulation properties (e.g. LT1086-ADJ, LM317DCY, NCP59152MNADJTYG, etc.).

Switching regulators are especially suitable if a wide input voltage range has to be covered.

Switch 1 ensures that in the case of a failing V_{supply} (backup situation), the storage capacitor is not discharged into the voltage regulator. To protect from this failure mode, a diode may be sufficient. As an additional feature, a combination with switch 2 would allow the storage element to disconnect from supply lines, and would support an optional SOH test.

For technical questions, contact: aluminumcaps1@vishay.com

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The ENYCAP 196 HVC storage element has to be protected properly from over- and under-voltages, as well as from high current flow, overcharging, deep discharge, and high temperatures.

In the configuration in Fig. 5, the storage element is permanently loaded. This condition may not support an optimum lifetime in all applications. To overcome this drawback a separate switch 3 can be added (Fig. 6).

Switch 2 can be used for protection against overvoltage from the V_{backup} side as well as to disconnect the storage element. If both switches 1 and 2 are present, or switch 3 is installed, the storage capacitor can be isolated to perform a full SOH test in unloaded as well as in standard load conditions. Typical SOH parameters are the voltages over the storage capacitor in unloaded and loaded situations. A standard load condition can, for example, be simulated by a constant current discharge pulse. 100 ms and 1 A are typical values for a 90 F part. This method allows a sufficiently accurate estimation of the current SOC.

EXAMPLE BUILDING BLOCKS FOR ENYCAP 196 HVC

Voltage Regulator

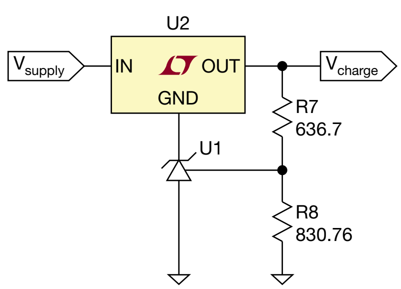

Fig. 7 - U2 linear regulator: LT1086-ADJ, LM317ADJ, ...
U1 adjustable precision reference: TL432

Switches - Bi-Directional Versions

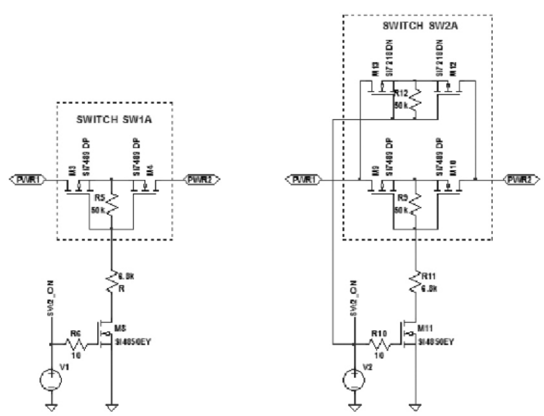

Fig. 8 - SWITCH SW A - Bi-directional switch for switching voltages PWR1, PWR2 > 4 V
SWITCH SW B - Bi-directional switch for switching voltages PWR1, PWR2 > 0 V

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Simplified Simulation Model for Pulse Charging

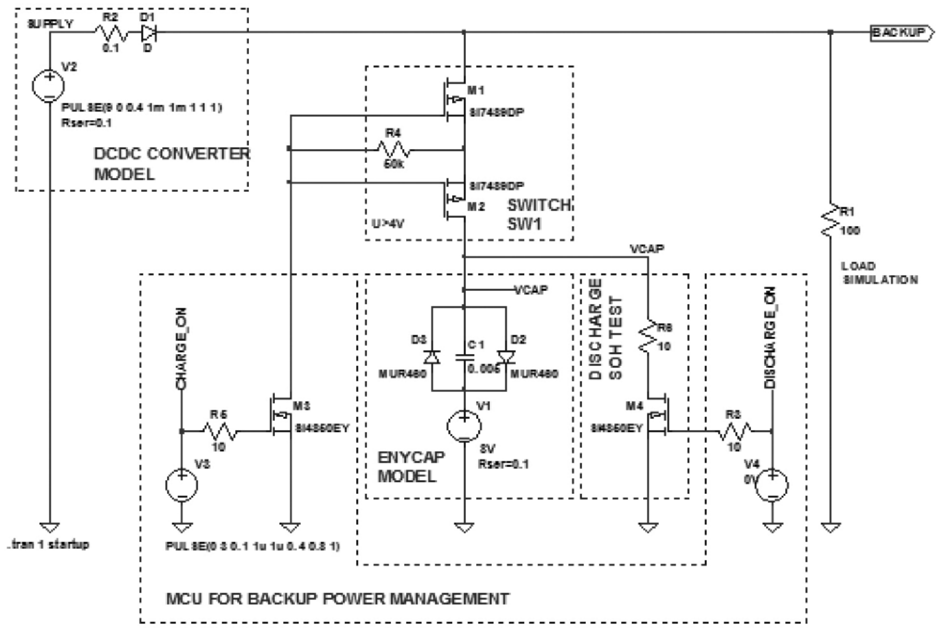

Fig. 9 - Simplified simulation model with minimum part count

REFERENCES

1. Datasheet ENYCAP 196 HVC Series
   www.vishay.com/doc?28409
2. Vishay application note "Constant Voltage (CV) Pulse Charging of Hybrid Capacitors ENYCAP™ 196 HVC Series"
   www.vishay.com/doc?28427
3. This document