Application Note

Battery or Capacitor Backup Operation with the LM51772

Stefan Schauer

ABSTRACT

Backup systems are often required to verify operation when the main supply drops or is lost. The energy for that backup time can be stored in a battery or capacitor. This application report shows how the LM51772 can be used to control the charging and discharging of such a backup system with maintaining a stable application supply voltage.

Table of Contents

Trademarks

1 Introduction

To implement a backup system the energy storage element can be selected as a battery or capacitor. Depending on the application requirements, both have advantages and disadvantages.

- Number of charge and discharge cycles
- Energy storage size

The LM51772 can be used as controller for both variants and provides most of the required features. In this report the implementation and use cases are discussed.

Throughout this document following names are used:

- V_{System}: supply voltage for the target application (supply which is backup supported)
- $V_{Storage}$: supply voltage for the storage element (battery or capacitor)
- V_{Supply}: main supply voltage for the application used as standard supply for the application and to charge the backup supply

For a backup system a constant voltage control loop (CV) and constant current control loop (CC) must be implemented. To keep the voltage at V_{System} stable a CV is required for the output of the backup supply (when V_{Supply} is not available).

2 Power Stage Design

To charge the storage element first a CC control is required to provide a constant charging current. Once the maximum charge voltage is reached, a CV control must take over to stop charging and maintain the $V_{Storage}$ voltage.

Within the LM51772, the voltage control (CV) with the higher response rate is available on the FB pin. Therefore, the FB is typically used to maintain the system voltage V_{System}. As a result, the target application is connected to VOUT and the storage element is connected to VIN.

The LM51772 supports two different average current limit methods:

- I_{SET}: Current limit is set by current sense resistor and resistor at ILIMCOMP/ISET pin. The current limit is set and fixed by this components.
- I_{LIMIT}: Current limit is set by current sense resistor and internal DAC which can be set through an I2C dynamically through the ILIM_THRESHOLD register.

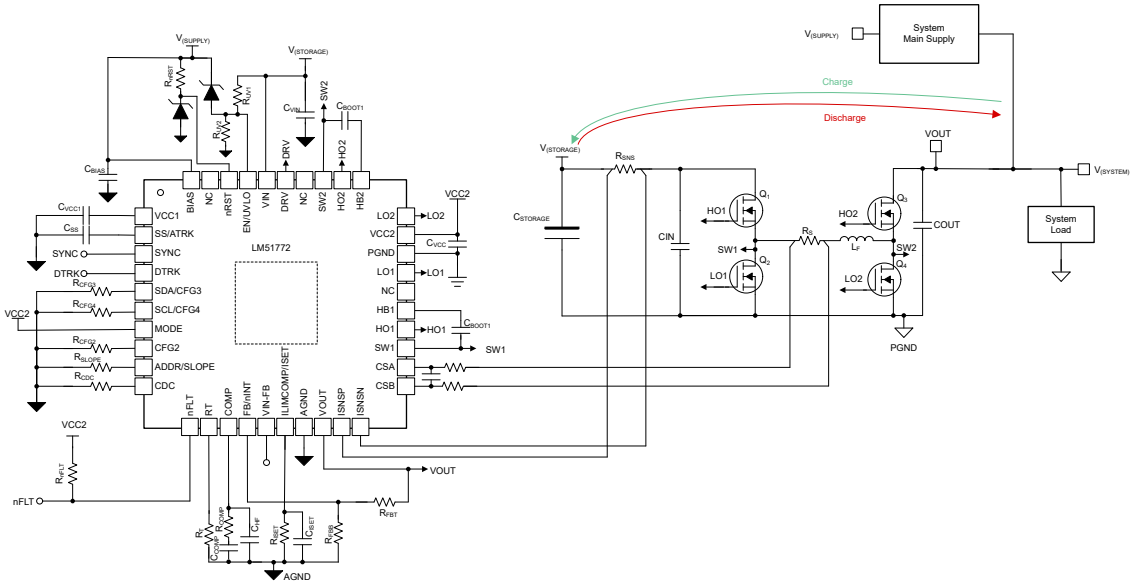

Figure 2-1. Schematic with I_{SET} and No I2C

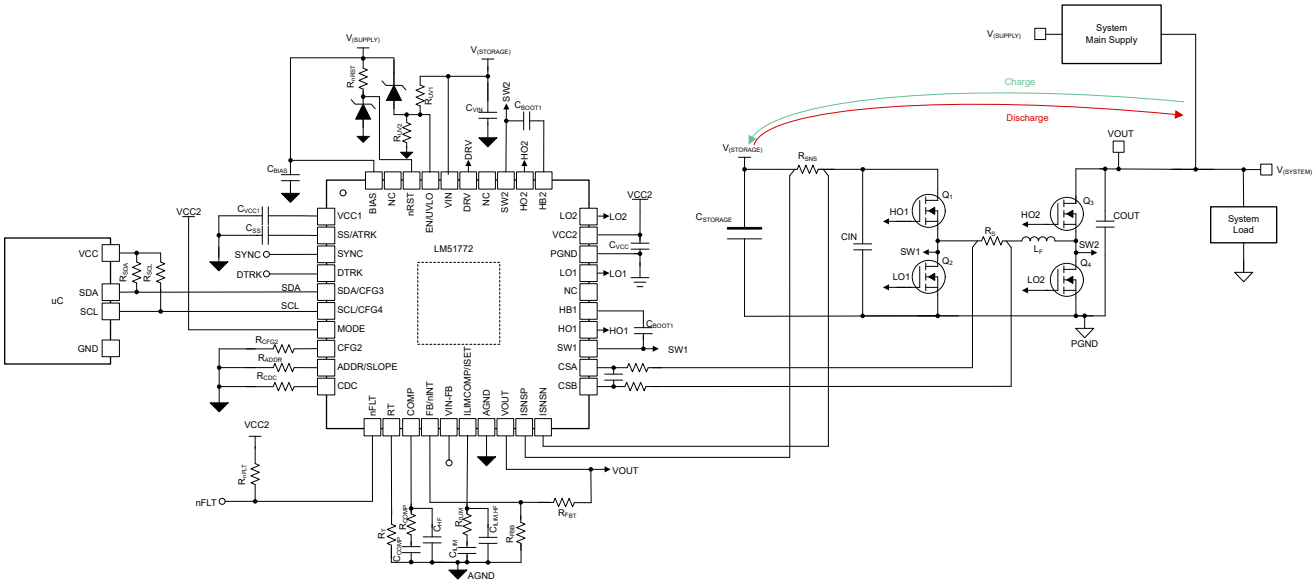

Figure 2-2. Schematic with I_{LIMIT} and I2C

3 Functional Blocks

3.1 Average Current

The current sensor connected to ISNSx input is used as the average current sensor and the controller regulates and limit the average current based on that information.

For the backup system the shunt for this current measurement must be placed on the $V_{Storage}$ side and the shunt must be configured as current limit in negative direction. This enables a constant charging current into the storage element. The setting can be done through:

- R2D interface:

  Use CFG4 pin to set: negative current limit and current limit setting

- I2C interface:

  Set MFR_SPECIFIC_D0 register bits: IMON_LIMITER_EN and EN_NEG_CL_LIMIT

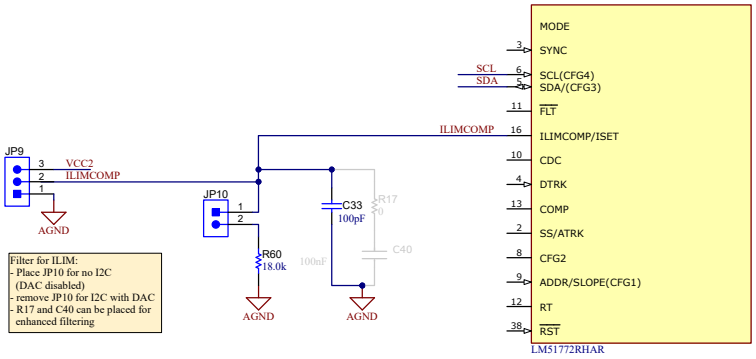

Figure 3-1. I_{SET} Configuration

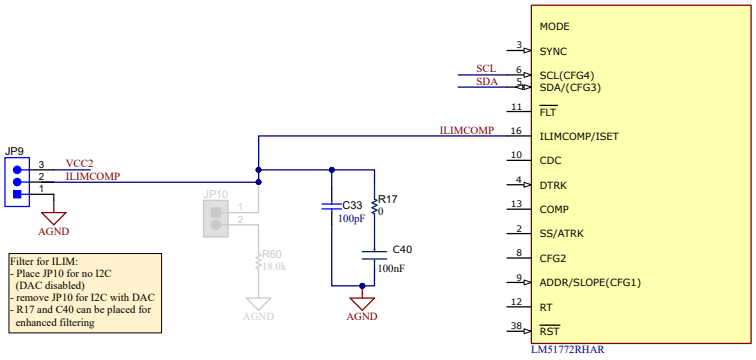

Figure 3-2. I_{LIMIT} Configuration

Check the LM51772 data sheet chapter: Current Monitor/Limiter for the calculation and component selection of the current limit.

3.2 IVP and IVR

The LM51772 provides an input voltage protection (IVP) and input voltage regulation (IVR) the IVR can be enabled through an I2C and also the levels for the IVP and IVR can be set through I2C. Once enabled as IVR, the input voltage is observed and once the input voltage reaches the defined voltage level the charging current is stopped.

3.3 VDET

The LM51772 has a VDET on the input side which, in addition to the UVLO, enables the device only if a certain voltage level is reached. This can be used for backup systems where the storage element is a battery, so that the battery is not discharged below that defined level. But if the battery is triggered another method is required to enable the system again for charging, for example, set the level lower or disable VDET if V_{Supply} is available again. This can be done through an I2C.

For systems with a Capacitor as storage element the VDET feature typically must be disabled to allow a charging of the capacitor as soon as VSupply is available.

VDET can be disabled through the CFG2 pin or through an I2C register MFR_SPECIFIC_D3 bit VDET_EN.

When VDET must be used, for example, with a battery as charging element, the falling and rising levels can be also set through an I2C register MFR_SPECIFIC_D3 and MFR_SPECIFIC_D4.

Figure 3-3. VDET Configuration Through a GUI

3.4 UVLO

The UVLO input can be used to:

- Protect the system from deep discharge
- Protect the power stage from operating with too low input voltage in backup operation. In case the backup supply $V_{Storage}$ has already discharged to a very low voltage level, a large input current and current in the power stage can be required to provide the required output power.
- Prevent the power stage from starting the operation before I2C the configuration has been finished (if required)

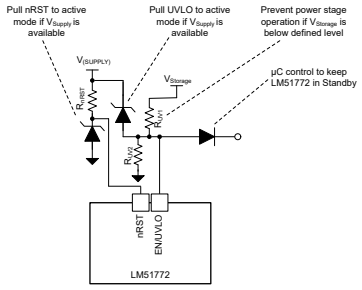

Figure 3-4. UVLO Control Circuit

3.5 FB

The output voltage regulation through the FB pin observes the output voltage and controls the direction of the energy flow in the power stage.

As long as the output voltage is above the set level the power stage operates in reverse operation. CC mode is active and the storage element is charged until IVR stops the negative current.

3.6 GUI Config for Reverse Current

The LM51772 can operate with configuration settings done through the CFG pins. To get access to all possible settings, the I2C interface must be used.

The LM51772 GUI allows to configure and control the LM51772 through the integrated I2C interface.

The following are important settings for backup operation mode:

- Converter enable
- IMON limiter enable
- ISET enable or disable (depending on the operation mode of the current limiter: ISET or ILIM)
- Negative current limit enable (Neg. CL Limit Enable)

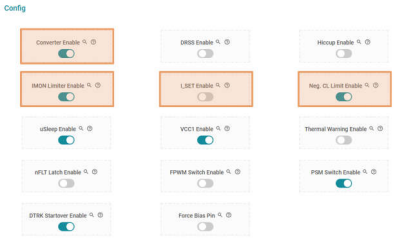

Figure 3-5. GUI Configuration Elements

3.6.1 EVM Configuration and Setup

Figure 3-6 shows the EVM configuration setup with using I2C to configure and control the device.

Figure 3-7 shows the EVM configuration setup not using I2C.

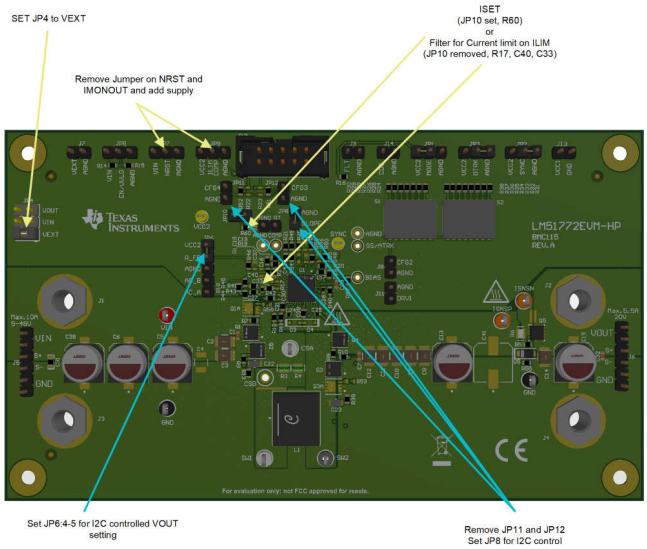

Figure 3-6. EVM Setup and Control Elements for Backup Operation with I2C

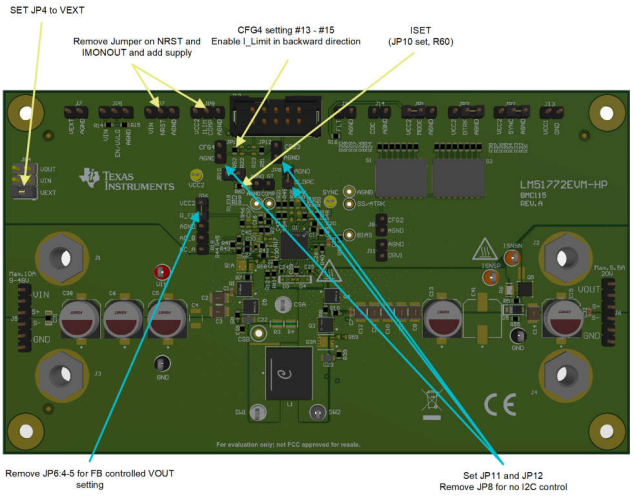

Figure 3-7. EVM Setup and Control Elements for Backup Operation without I2C

Note

The LM51772EVM-HP has the shunt for the average current measurement on the output side while for backup configuration this typically is placed on the input side to enable a constant charging current for the storage element.

4 Quickstart Configuration Tool

The *LM51772 Buck-Boost Quickstart Calculator Tool* can be used to configure and select the required external components for this application setup. As the tool currently does not provide the calculation of the C_{ILIM} filter in reverse operation mode, enter the storage capacitance for this configuration step as the output capacitor.

Figure 4-1 shows the configuration settings for using ILIM functionality with the option to adjust the current limit through the I2C.

Figure 4-2 shows the configuration settings for using ISET functionality with a fixed current limit set through the R_{SNS} and R_{SET}.

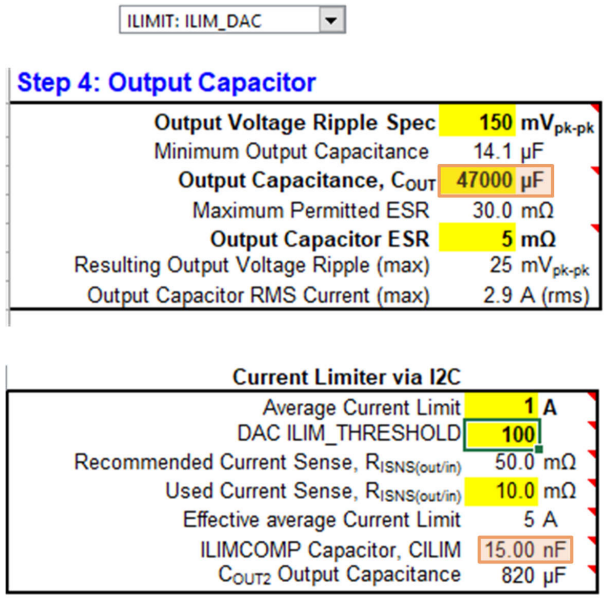

Figure 4-1. Configuration of Current Limit Through Quickstart Calculator with ILIM

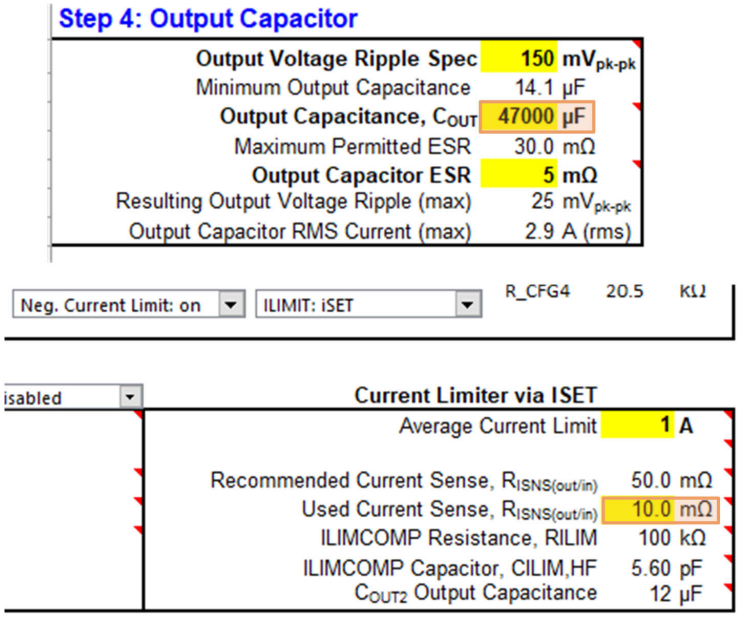

Figure 4-2. Configuration of Current Limit Through Quickstart Calculator with ISET

5 Hardware Implementation and Measurement Results

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

5.1 Hardware Setup

A simplified hardware setup was used for the following measurements. The following list shows the setup and settings.

- BIAS supply from an external power supply with 7V
- nRST is connected to BIAS
- UVLO is connected to BIAS
- Storage capacitance: 47mF/40V (KEMET ALS30A473KE040)
- Load on Application (V_{System}) = 0.5A (CC)
- V_{Supply} = 12V
- Settings via GUI
  - VOUT = 11.5V
  - Current limit via DAC set to 1A (decimal value in register = 10) in negative direction
  - VDET disabled
- The LM51772EVM-HP has the average current sense resistor assembled on the output side. This allows constant current control on the output side. As for this application, constant charging current into the storage capacitor is preferable the average current sense resistor must be on the input side of the board. The EVM has been modified for that. See Figure 5-1 and Figure 5-2 for board modifications.

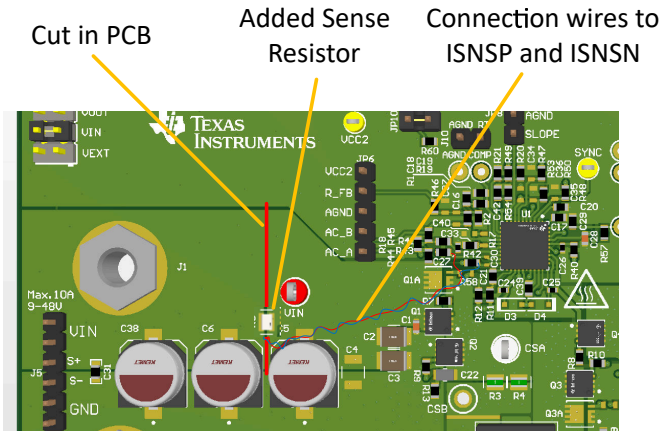

Figure 5-1. EVM Modifications

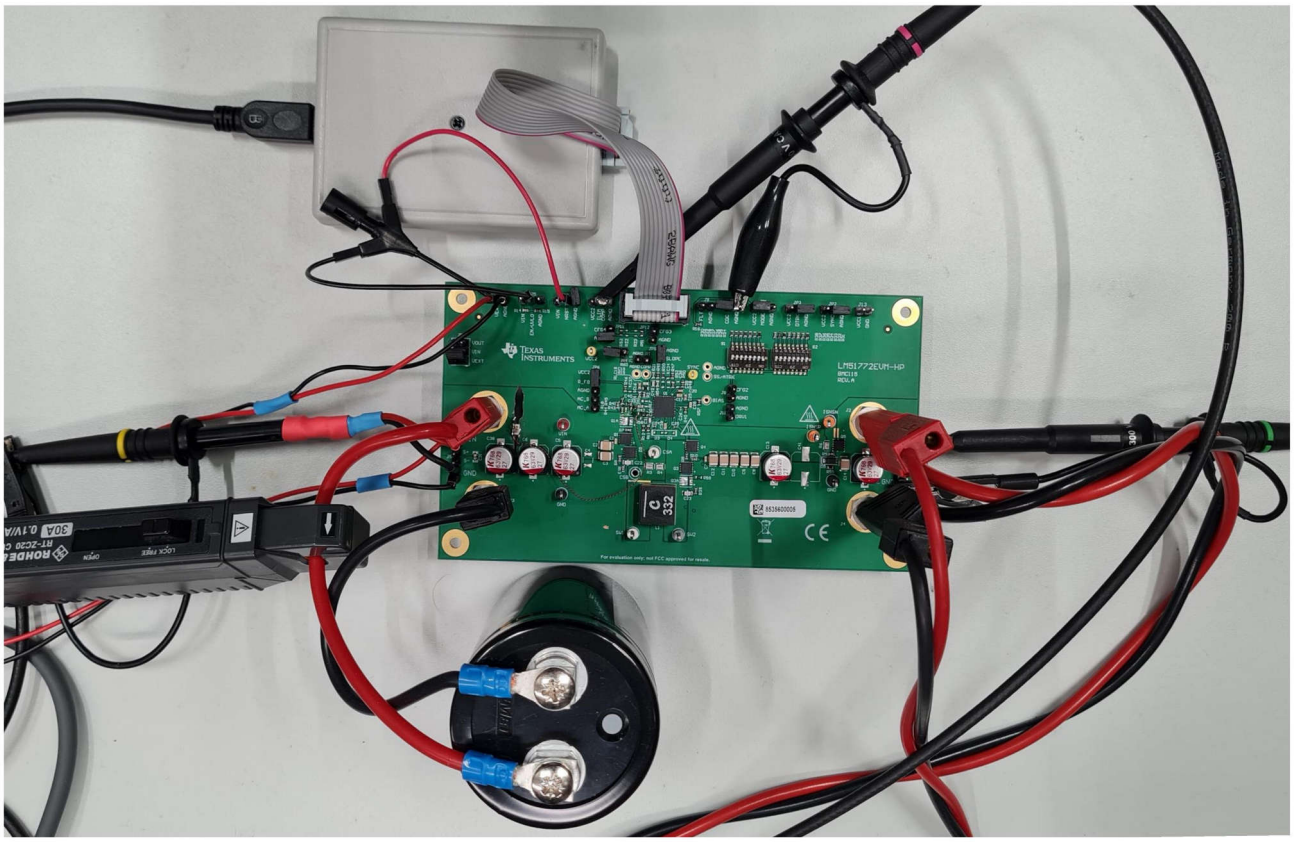

Figure 5-2. Hardware Setup

5.2 Measurement Results

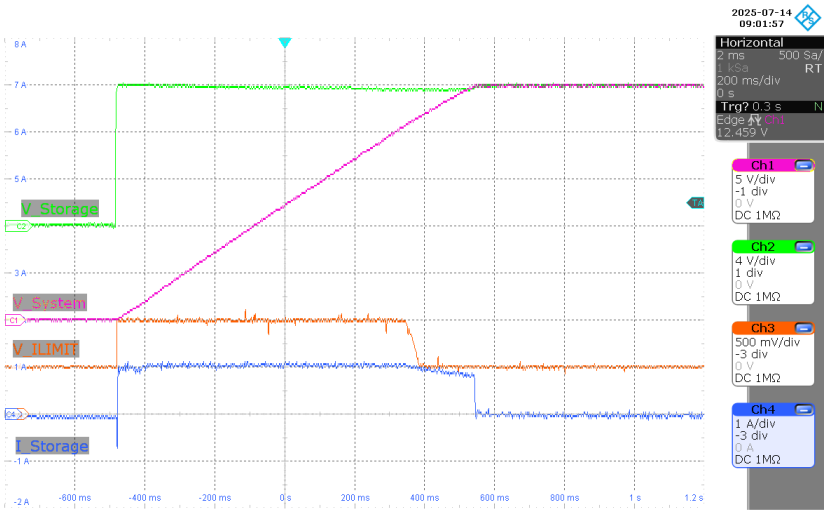

Figure 5-3. Scope Plot Charge with 1A Constant Current up to 25V

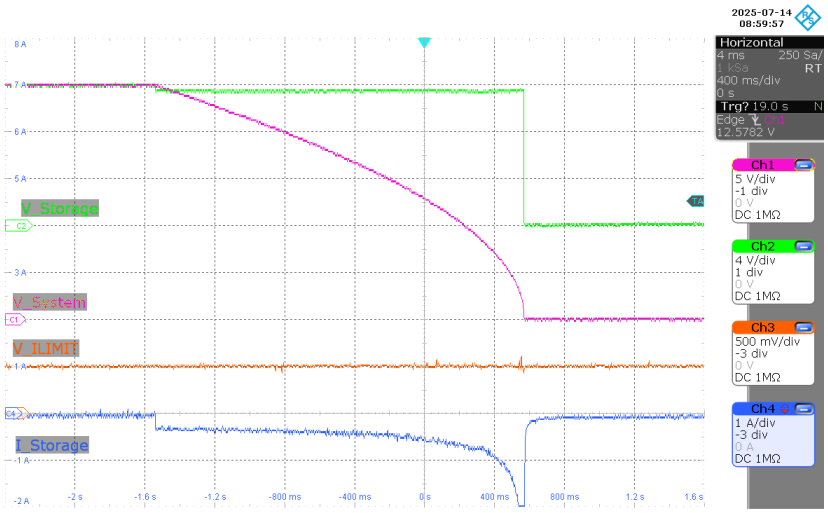

Figure 5-4. Scope Plot Discharge with 0.5A Load Current

6 References

- Texas Instruments, *LM51772 80V Wide VIN Bidirectional 4-Switch Buck-Boost Controller* data sheet.
- Texas Instruments, *LM51772 Buck-Boost Quickstart Calculator Tool*
- Texas Instruments, *LM51772 GUI for configuration via I2C*
- Texas Instruments, *Constant Current Operation Using the Internal Current Limiter* application brief.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265