Application Note

Supercap Backup Power for Dying Gasp Application

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ABSTRACT

The TPS61381 is a bidirectional boost with LDO based charger which can be used as a backup power supply during dead battery or input supply failure. The device can be used to specify smooth transition of the system to be powered by the backup supply in case of sudden power failure. The system mechanism behaves as a charger during charger operation and regulates the output voltage during power failure.

This application note is targeted to generate a warning message (dying gasp) when the system input power supply fails; this is especially important in systems such as servers, routers, access points, CPE or other system hardware with dying gasp implementation, to aid in the debugging of the system.

By sending out a final signal, the access point can help minimize the impact of the shutdown on the network, support graceful failover, and provide vital diagnostic information that can assist in maintaining network reliability and uptime. This feature is particularly useful in environments where high availability is critical.

TPS61381 supports the message generation during dead battery condition by receiving power from the supercapacitor backup, VBUB.

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Trademarks

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1 Introduction

A *dying gasp* or *last gasp* refers to a final, brief signal or message that is sent by a system or device just before the device loses power or is shut down. This is commonly used in the context of network equipment, such as routers, servers, or other hardware, to send an alert or notification that the device is about to stop functioning due to power loss or failure. This can involve error messages, status updates or even smooth shutdown process. In some cases, the *dying gasp* is sent as a type of emergency signal, helping administrators or monitoring systems detect and respond to imminent outages before the full loss of service occurs.

In the context of access points, which allows wireless devices (like laptops, smartphones, or tablets) to connect to a wired network using Wi-Fi or other wireless communication standards, acting as a bridge between the wired network (such as a router or switch) and wireless clients, providing network connectivity to the wireless devices. A dying gasp can help in achieving battery health monitoring, provide graceful shutdown, and make sure that power loss protection occurs during failover cases, as a result enhancing the reliability of the system.

The *dying gasp* in access points serves as a crucial tool for network administrators and IT systems to detect, diagnose, and respond to power loss or device failure issues. This feature is particularly useful in environments where high availability is critical, such as business offices, schools, and data centers.

This application uses TPS61381-Q1 as a boost converter with LDO charging operation which can be used to maintain a backup battery or supercap through charging during normal power operation and this is then used during failover cases to issue a final message and even act as a backup power supply, which can be tailored to the requirements of the required application.

2 System Overview

The TPS61381-Q1 is a bidirectional boost converter with CC/CV and battery health detection feature. The device provides an integrated power design in back-up power systems. The TPS61381-Q1 has 40V load-dump tolerant to support connecting with 12V supply directly. The benefits of the proposed backup power supply architecture include:

- Reduction of system cost through elimination of separate supercapacitor charging circuitry.
- The supercapacitor can be charged up to the desired voltage level, depending on the application and the backup duration needed
- Provides seamless transition between charging mode and backup mode, which in the case of an outage specifies rapid switchover to backup power without interruption.
- Programmable limits to the charge current are available as an optional feature, along with changing the number of cells and backup battery type.

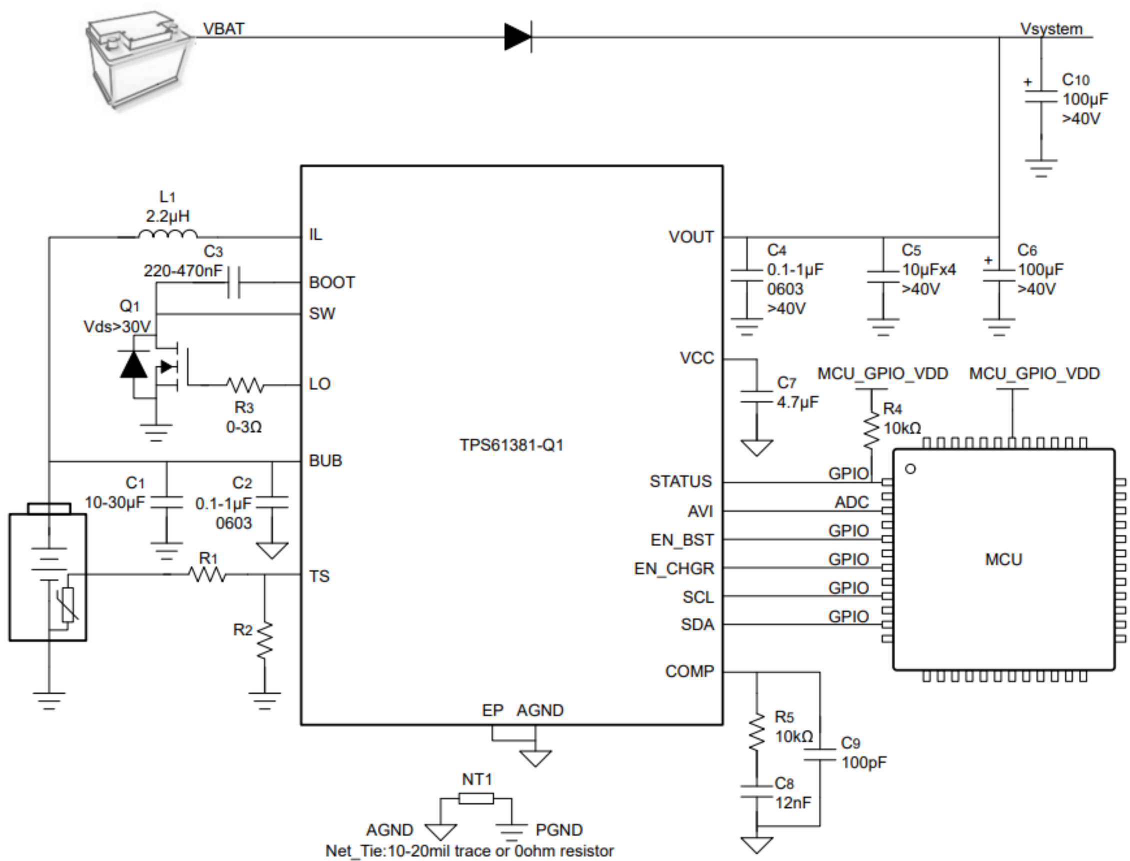

Figure 2-1. TPS61381-Q1 Functional Block Diagram

The TPS61381-Q1 integrates a configurable constant-current and constant-voltage (CC/CV) with programmable timer to charge the battery, which can support one to five cell NiMH, one to two cell Li-Ion, Li-Poly, and LiFePO4, one to four cell supercap. Figure 2-1 shows the corresponding functional block diagram.

The device has a battery temperature monitor feature and controls the back-up battery discharge current by an I2C interface and an output analog signal for MCU for diagnosing the battery health. This is available in a 3mm × 4mm QFN package with wettable flank.

2.1 Design Considerations

This design is meant to extract the energy stored in the supercapacitors with maximum efficiency to provide the required energy to generate the last gasp message and transmit this loss of power message to the system manager.

The TPS61381 supports maximum Iout depending on backup battery voltage (VBUB), by drawing the required energy from the supercapacitors through the boost convertor action. The transition from the main supply to the backup supply is meant to take place during power down situation without disruption of the load. The duration for backup power can be designed as needed by varying the capacitance value or by increasing the number of backup cells.

Here, the system is designed to sustain a maximum power draw of 28W for a period of 75ms. This application follows the below given design specifications; see Table 2-1.

Table 2-1. Reference Design Specifications

Parameters	Values
Battery Input Voltage	Typical: 10.5-12V
Back Up Battery	2S Supercapacitor
Backup Battery Voltage	5.2-5.4V
Charging Current	200mA
Charger Mode	LDO
Boost Output Voltage	12V
Boost Output Current	2-2.33A
Mode Selection	Automatic Charger and Boost
Voltage Drop during mode transition	< 0.5V
Backup Duration	75ms
Backup Power Needed	28W

2.2 System Design Theory

Figure 2-2 denotes a simplified block diagram which shows the various modes of operation. The working of the system can be categorized into three modes: standby, charging and boost operation mode. When the main supply is available to the system, the main supply is directly routed to the output with Vin = Vout. During the charging phase, the backup battery depending on the battery type is charged through LDO operation leveraging the input supply. In this case, use the supercapacitor for the backup power and the LDO performs the charging.

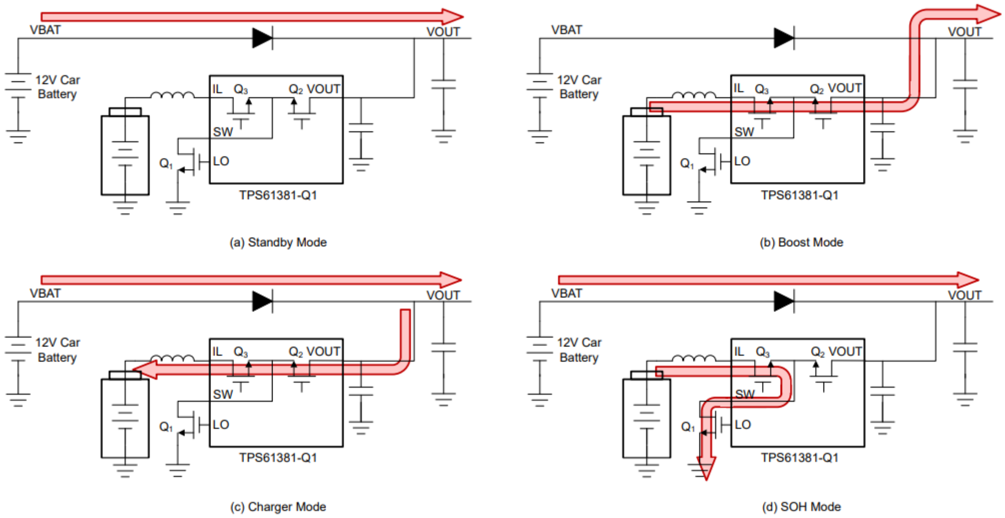

Figure 2-2. Block Diagram for System Operation

Now, when the main input supply fails, and Vin goes below a certain designated threshold value, the device enters the boost mode and draws energy from the backup battery to regulate the output voltage. The boost operation can be operated at 400kHz.

The battery type and count, the charging topology, charging current, operation frequency and boost threshold can be configured through the I2C interface.

2.2.1 Supercapacitor Charging Operation

When the system is first powered on, if the supercapacitor is uncharged, it must be charged from the main supply through the operation of the LDO. The TPS61381 IC can charge the supercapacitor from 0V to the set VBUB based on the application requirement.

At the start of the charging process, the TPS61381-Q1 detects system voltage with VOUT pin and automatically transition into boost mode when a power interruption of your system is detected. In this application involving automatic boost and standby mode, the device works in standby mode when Vout is normal. When the power failure occurs and Vout drops below than min{VBST_WAKEUP (Set by I2C bits BST_WAKE), VBST_STANDBY (BST_VOUT ×106%)}, the device enters boost mode to maintain the output voltage. When the 12V main battery recovers and Vout rises higher than VBST_STANDBY, the device enters standby mode again.

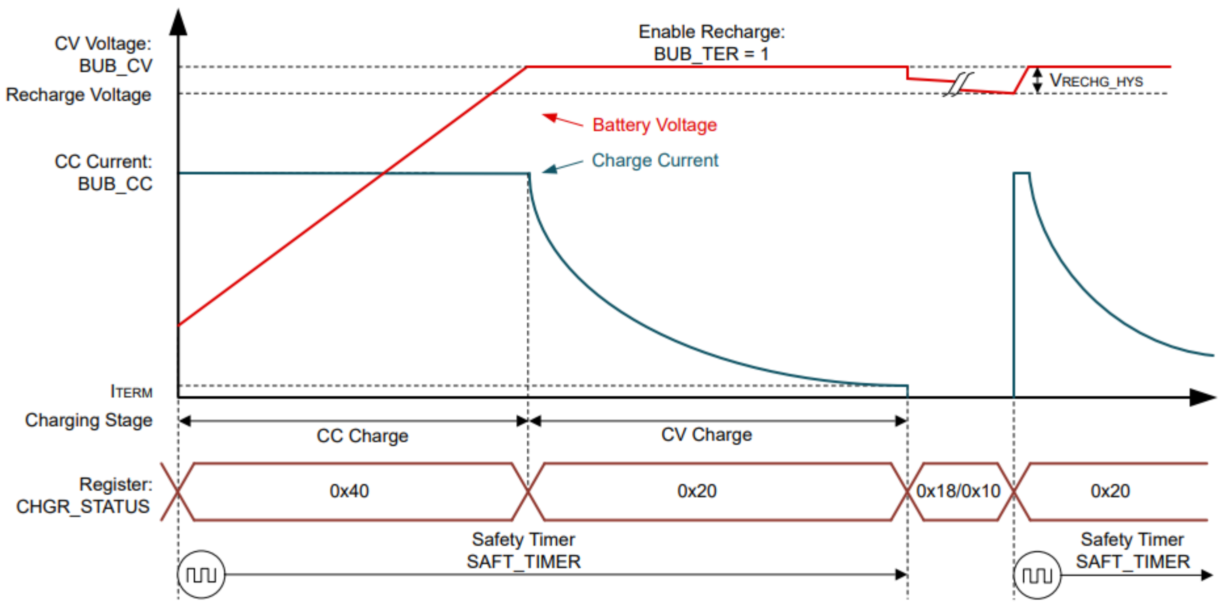

Figure 2-3. Supercapacitor Charging Behavior

2.2.1.1 Calculation for Backup Supercapacitor Selection

The selection the supercapacitor for the backup operation is majorly dependent on output load requirements, the backup duration and the internal resistance of the supercapacitor in question. The working schematic during the backup and boost mode operation is shown in Figure 2-4.

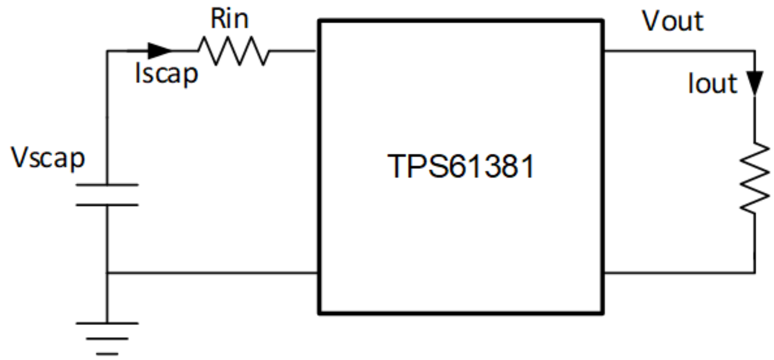

Figure 2-4. Effective Discharge During Boost Mode

.Depending on the required backup time and backup power, the following equation calculates the minimum required value of the backup capacitor as given where:

$$C_{min} = (2 \times P \times T)/(\eta \times [(V_C F)^2 - (V_C L)^2]) \quad (1)$$

- C**min**: Minimum value of the required backup capacitor
- V_{CF}: Backup capacitor voltage at comparator falling threshold
- V_{CL}: Minimum discharge voltage of the backup capacitor, given by the minimum input voltage of TPS61381
- η: Efficiency of the TPS61381
- T: Backup Time
- P: Backup Power

However, V_{CL} is greatly affected by supercap internal resistance R**in**. The V**CL** must be calculated by Equation 2

$$V_{CL} = min((V_{out} I_{out})/(\eta I_{lim}) + I_{lim} R_{in}, V_{BUBUV} + (V_{out} I_{out} R_{in})/(\eta V_{BUBUV})) \quad (2)$$

Where:

- V**BUBUV** is the TPS61381 BUB UVLO threshold
- **Ilim** is the current set by I2C interface

Supercap internal resistance is usually 5-10 times larger than the IC MOSFET R**dson**. So, efficiency mainly depends on the loss on internal resistance. The effect of the internal resistance on the backup boost operation can be calculated. See Automotive E-Latch Systems Design Guideline Using TPS61383 for detailed calculations.

2.2.1.1.1 Design Calculations

For this design, a backup time duration of 75ms with a maximum backup power requirement of 28W is required. Here, use the 2S supercapacitors with total internal resistance to be around 45mΩ with V**CH** = 5.4V. Therefore, calculate the needed minimum capacitance as:

1. $$V_{CL} = min((V_{out}I_{out})/(\eta I_{lim}) + I_{lim}Rin), \quad V_{BUBUV} + (V_{out}I_{out}R_{in})/(\eta V_{BUBUCV})) \tag{3}$$

$$V_{CL} = 28W \;/\; ((0.95 \times 15A) + (15A \times 45m\Omega)) = 2.64V \tag{4}$$

2. Calculate VCL:
3. Calculate parameter b and k:

$$b = (4V_{out}I_{out}R_{in})/\eta = 5.305W.\Omega \tag{5}$$
$$k = \left[V_{CH}{}^2 - V_{CL}{}^2 + V_{CL}\sqrt{\left(V_{CL}{}^2 - b\right)} - V_{CH}\sqrt{\left(V_{CH}{}^2 - b\right)} + b\left(ln\left(V_{CH} + \sqrt{\left(V_{CH}{}^2 - b\right)}\right) - ln\left(V_{CL} + \sqrt{\left(V_{CL}{}^2 - b\right)}\right)\right)\right]/4 = 7.445V^2$$

4. Calculate C_{min}:

$$C_{min} = \left(2V_{out}I_{out}T\right)/\left(\eta\left(V_{CH}{}^2 - V_{CL}{}^2\right) - 2k\right) = 0.68F \tag{6}$$

5. Verifying Results:

According to the previous calculation results, when a 0.68F super capacitor is selected. So the maximum energy that can be discharged is:

$$E_{scap} = \left[C_{scap}V_{CH}{}^2 - C_{scap}V_{CL}{}^2\right] \;/2 = 7.544J \tag{7}$$

The energy consumption for load is:

$$E_{load} = V_{out}I_{out}T = 2.1J \tag{8}$$

The loss on TPS61381 is:

$$loss_{BST} = E_{load}((1/\eta) - 1) = 110.52mJ \tag{9}$$

The total energy consumption is:

$$E_{total} = E_{load} + loss_{BST} + loss_{Rin} = 7.273J \tag{10}$$

The energy margin is:

$$E_{margin} = E_{scap} - E_{total} = 271mJ \tag{11}$$

Here, select a supercapacitor of capacitance 5F with a V_{CH} of 5.4V and an internal resistance of 45mΩ. While selecting a supercapacitor, it is critical to make sure that the internal resistance of the selected supercapacitor is as low as possible to minimize any power loss, to maximize the energy being transferred to the output.

3 Test Results

3.1 Standby Operation

The working of the system during startup is denoted in Figure 3-1. The main power is directly connected to the system and both have the same voltage level. The startup curve can be seen the in the oscilloscope capture.

Similarly, in the scenario when no backup battery is present in the system, the output level droops down. When there is a power failure at the supply or battery terminal, the output voltage plummets to the same level.

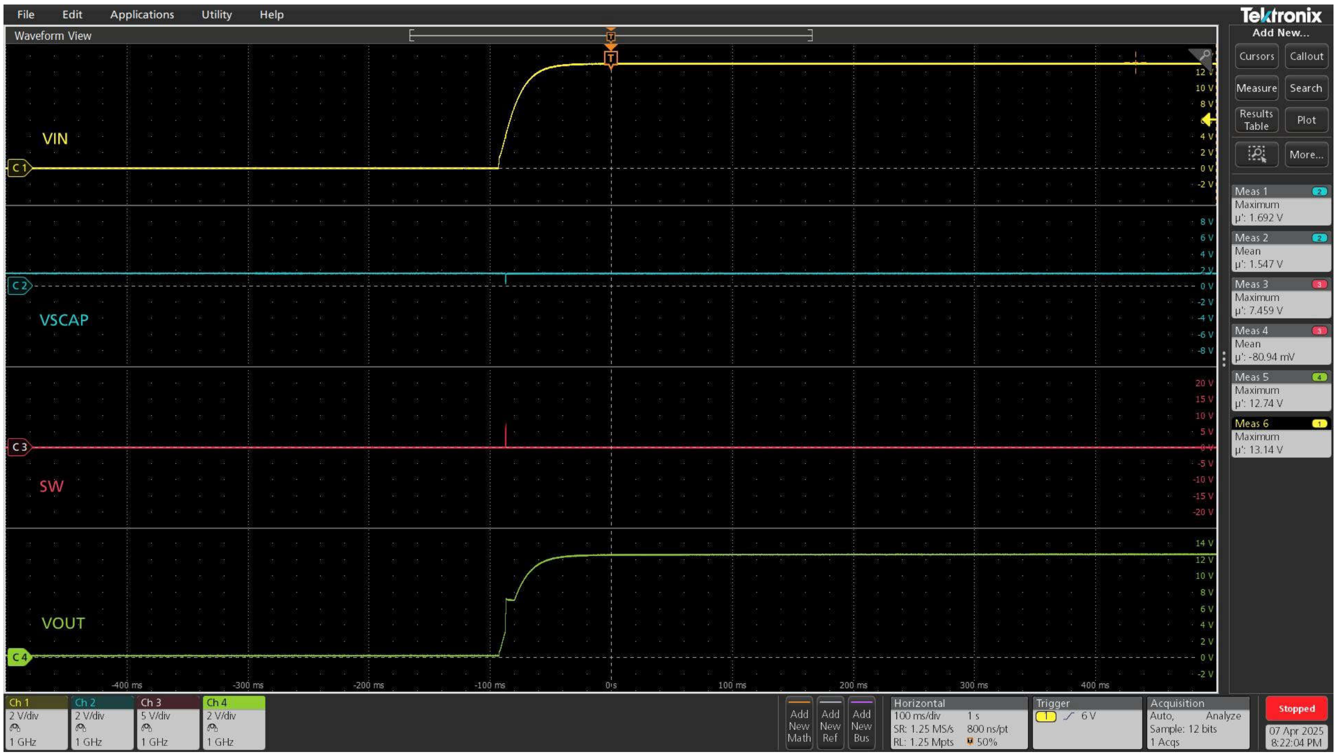

Figure 3-1. Device Startup

3.2 Charging Operation

The supercapacitor charging operation is shown in Figure 3-2. As soon as the mains supply of 12V is present, the capacitor starts being charged through the internal regulator. At the programmed voltage level of 2.7V per supercap, the converter voltage goes low and the converter stops charging the supercapacitor.

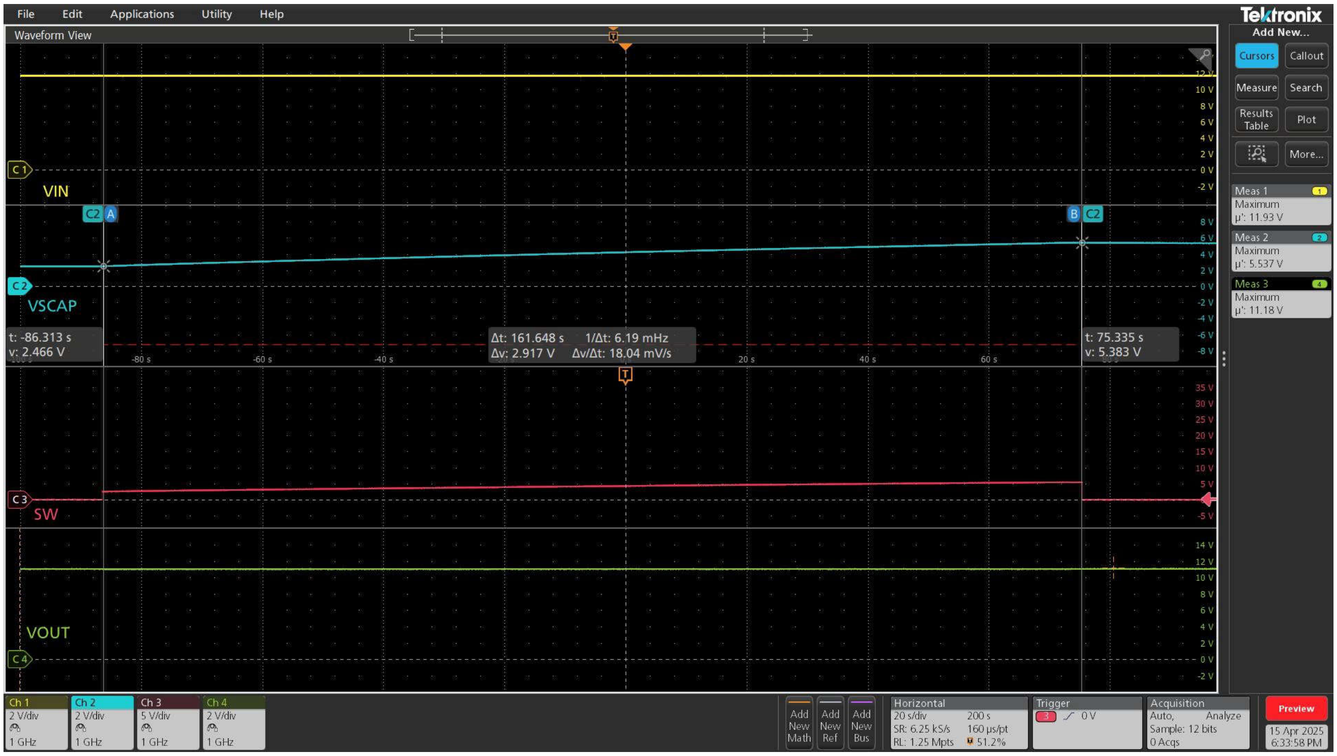

Figure 3-2. Charging with Vin at 12V

3.3 Boost Operation

Figure 3-3 shows the backup action of the system in play. If the mains supply fails, the TPS61381 converter immediately starts regulating the system voltage to the programmed output voltage. The supercapacitor is discharged and the voltage decreases slowly. When the backup capacitor voltage reaches the IC current limit or the minimum voltage of the TPS61381 (around 1V), the converter stops operating and the system voltage decreases to zero.

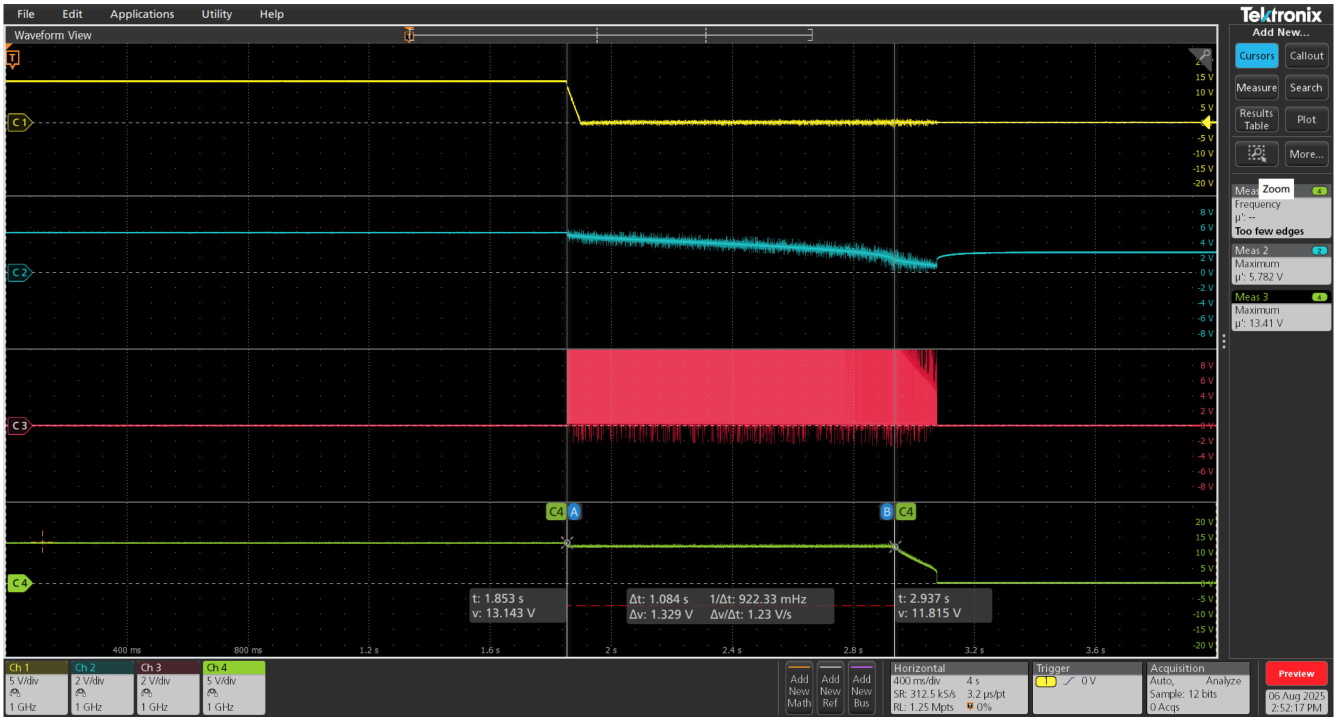

Figure 3-3. Backup Operation with Vbub=5.4V, Vout=12V

In this scope plot, the backup time is approximately 200ms. Larger backup capacitor values result in a longer backup time, in accordance with the previous equation described in section 2.3.2.

4 Summary

The TPS61381-Q1 can be used as a backup supply by charging the backup battery. This supports various battery types including Li-ion, NiMH, LiFePO4 and supercapacitors, the charging current and the output voltage. During this backup period, the energy stored in the battery is used and regulated at the desired output level, which can be used to issue a dying gasp message, even after the main supply is lost.

5 References

- Texas Instruments, *TPS61381-Q1 Automotive 400kHz, 40V, 15A Boost Converter with LDO Charger and Battery State of Health Detection*, datasheet.
- Texas Instruments, *TPS61381-Q1EVM-126 Evaluation Module User's Guide*, EVM user's guide.