**Design Guide: TIDA-050033**  
**Smart Meter PLC Module Backup Power Supply Reference Design**

### Description

The TIDA-050033 reference design demonstrates the backup power supply solution for smart meter PLC module. A simple linear charger circuit for super capacitor is included. By using a cost-effective boost converter TLV61048, minimum operating voltage is extended to maximize super capacitor usage rate. Smaller size (lower capacitance) super capacitor could be selected hence the total bill of material (BOM) is reduced. The detailed design theory, component selection, and the test results are also discussed.

### Features

- **Smart Meter PLC Module Backup Power Supply:** 12 V  
- **Super Capacitor Minimum Operating Voltage:** 1.3 V  
- **High Efficiency**  
- **Small Size**  
- **Approximately 60 mA Linear Charger**

### Applications

- **Smart Meter**

### Resources

- **TIDA-050033** | Design Folder  
- **TLV61048** | Product Folder  
- **TPS560430** | Product Folder  
- **TL431** | Product Folder  
- **CSD25310Q2** | Product Folder

Search Our E2E™ support forums

---

An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.
1 System Description

Currently, power line communications (PLC) technology applied to smart meter is developing at a high speed. The new national grid standard requires that the 12 V voltage of the smart meter bus should report the necessary information within specified time after the bus voltage browns out. Thus, PLC module backup power supply is needed. The size of the backup power must be as small as possible due to limited space, at the same time, a cost effective solution is desired.

The TIDA-050033 reference design focuses on the above requirements. This reference design includes a linear charger, a super capacitor, a high step up ratio, high efficiency boost converter TLV61048 and a synchronous step down converter.

1.1 Key System Specifications

Table 1 gives the performance specification of the TIDA-050033 reference design. The TLV61048 boost converter can output a stable 12 V DC voltage when the super capacitor voltage drops to 1.3 V.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super capacitor operating voltage</td>
<td>1.3 V to 2.5 V</td>
</tr>
<tr>
<td>Super capacitor charging time</td>
<td>330 seconds</td>
</tr>
<tr>
<td>Super capacitor charging current</td>
<td>60 mA</td>
</tr>
<tr>
<td>Back up power lasting time</td>
<td>45 seconds</td>
</tr>
<tr>
<td>Boost converter output voltage</td>
<td>12 V</td>
</tr>
<tr>
<td>PLC Module current</td>
<td>200mA for 5ms, 25mA for 995ms rest</td>
</tr>
</tbody>
</table>
2 System Overview

2.1 Block Diagram

Figure 1 shows the block diagram of TIDA-050033. It uses a super capacitor as the energy storage cell. When VBUS exists, the PLC module is powered by Vbus and the super capacitor is charged by a linear charger. The super capacitor will be charged to 2.5 V. The synchronous step-down DC-DC converter TPS560430 will generate a 3.3 V dc voltage as MCU power supply and TLV61048 external bias. When Vbus fails (Vbus < 12 V), boost converter TLV61048 starts switching and provides a 12 V seamlessly to supply the PLC line driver amplifier.

Figure 1. TIDA-050033 Block Diagram

2.2 Design Considerations

The reference design features the TLV61048, TPS560430, TL431, and CSD25310Q2. The following subsections briefly summarize the key performance of each device. To find more details about each device, see their respective data sheets at TI.com.

2.3 Highlighted Products

2.3.1 TLV61048

The TLV61048 is a non-synchronous boost converter that integrates a power switch with 3.7-A typical current limit to extend the discharge capability of the input source without sacrificing maximal load delivery. The TLV61048 could be configured at 600 kHz for higher efficiency. At the light load, the device enters into the PFM operation to achieve higher efficiency. Other key features of this device include:

- Internal Compensation
- Internal 2-ms soft-start time
- 1-uA shutdown current
- Thermal shutdown protection
- 2.9-mm × 1.6mm 6-pin SOT-23 package

2.3.2 TPS560430

The TPS560430 is an easy to use synchronous step-down DC-DC converter capable of driving up to 600-mA load current. With a wide input range of 4 V to 36 V, the device is suitable for a wide range of applications from industrial to automotive for power conditioning from an unregulated source. Other key features of this device include:

- Cycle-by-cycle current limit
- Short circuit protection with hiccup mode
• ±1.5% tolerance voltage reference over temperature from -40°C to 125°C
• Integrated synchronous rectification
• Integrated compensation for ease of use
• SOT-23-6 package

2.3.3 **TL431**
The TL431 is a three-terminal adjustable shunt regulator, with specified thermal stability. Other key features of this device include:
- Adjustable output voltage: 2.5 to 36 V
- Operation from -40°C to 125°C
- Low output noise
- Sink-current capability: 1 mA to 100 mA

2.3.4 **CSD25310Q2**
This -20 V P-channel device is designed to deliver the lowest on resistance and gate charge in the smallest outline possible with excellent thermal characteristics in an ultra-low profile. Its low on resistance coupled with an extremely small footprint in a SON 2 mm * 2 mm plastic package make the device ideal for battery operated space constrained operations. Other key features of this device include:
- Ultra-low Qg and Qgd
- Low thermal resistance

2.4 **System Design Theory**
The entire schematic of the TIDA-050033 can be found in the TIDA-050033 design folder. The following subsections explain the behavior the each sub circuit.

2.4.1 **Super Capacitor Linear Charger Circuit**
Figure 2 shows the super capacitor linear charger circuit of TIDA-050033. A linear charger is implemented in this reference design. The benefits of the linear charger are simplicity and low cost. TI’s P-Channel MOSFET CSD25310Q2 (Q1) is the core of the discrete charger circuit. Since a P-Channel MOSFET remains off when the gate-source voltage is zero and turns on when the voltage is negative. A low cost PNP device Q2 is used to drive Q1. The current sense resistor R1 connected to Q2 defines the charging current, which is around 60mA. The adjustable shunt regulator TL431 limits the charging voltage to 2.5 V. The circuit behaves like a linear regulator. Nearly all of the losses are converted to heat, so the power dissipation must be kept below the thermal limit. The current charging time is about 330 seconds for a super capacitor of 7 F.
2.4.2 Boost Converter Solution

Figure 3 shows the TLV61048 boost converter, which is the main circuit of TIDA-050033. Most of the external components are selected based on the suggestion in the data sheet. The device operates at 600kHz (FREQ = floating) for higher efficiency and higher duty cycle. An external 3.3 V bias supply is applied at VIN pin so the device can operate down to 1.3 V. When Vbus exists, TLV61048 stops switching so it consumes minimum current, only 100uA (typical). Once Vbus fails, TLV61048 could work immediately and provide 12 V supply seamlessly.

2.4.3 Buck Converter Solution

Figure 4 shows the TPS560430 buck converter. TPS560430 operates at 1.1 MHz switching frequency for high efficiency. It provides 3.3 V to supply MCU and boost converter TLV61048 VIN pin. At light load condition, the TPS560430 operates in PFM mode to maintain high efficiency. When Vbus fails, TLV61048 boost output supplies the PLC line driver, as well as the buck input.
Figure 4. TPS560430 Buck Converter
3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

3.1.1 Hardware

This reference design uses the following hardware to do the measurement.

- One DC power supply
- One E-Load
- One digital oscilloscope
3.2 Testing and Results

3.2.1 Test Setup

This section describes how to properly connect the setup of the TIDA-050033.

- Connect the positive terminal of DC power supply to pad BUS, and its GND terminal to pad GND on PCB.
- Connect the positive input of the E-Load to pad 12 V, and its GND input to pad GND on PCB.
- Keep the DC power supply and E-Load off. Set the DC power supply to 13 V and E-Load to 200mA for 5ms, 25mA for 995mA.
- Turn on the DC power supply and E-load.
- After the super capacitor is charged to 2.5 V, turn off the DC power supply.

3.2.2 Test Results

3.2.2.1 Linear Charger Operating Waveform

Figure 5 shows the voltage of 7 F super capacitor during charge-up, output voltage of boost converter and buck converter. The super capacitor voltage rises from 0 V to 2.5 V within approximately 330 seconds.

![Figure 5. Super Capacitor Charging Waveform](image)

3.2.2.2 Transient Waveform When Vbus fails

Figure 6 shows the transient when Vbus fails. When Vbus fails from 13 V to 0 V, TLV61048 starts working immediately and keeps output voltage stable at 12 V. The boost converter draws power from super capacitor so the super capacitor discharges.
3.2.2.3 Super Capacitor Discharging Waveform

Figure 7 shows the super capacitor discharging waveform. When Vbus fails, the super capacitor takes the role of backup power source. Boost converter TLV61048 draws power from super capacitor and supply the PLC module. The test result shows TLV61048 could provide stable 12 V/200 mA even super capacitor voltage decreases to 1.3 V. The discharging time lasts 45 seconds. It maximizes the super capacitor usage rate.
4 Design Files

4.1 Schematics
To download the schematics, see the design files at TIDA-050033.

4.2 Bill of Materials
To download the bill of materials (BOM), see the design files at TIDA-050033.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints
To download the layer plots, see the design files at TIDA-050033.

4.4 Altium Project
To download the Altium Designer® project files, see the design files at TIDA-050033.

4.5 Gerber Files
To download the Gerber files, see the design files at TIDA-050033.

4.6 Assembly Drawings
To download the assembly drawings, see the design files at TIDA-050033.

5 Software Files
To download the software files, see the design files at TIDA-050033.

6 Related Documentation
1. TLV61048 14-V Output Voltage Non-synchronous Boost Converter in SOT-23 package
2. TPS560430 SIMPLE SWITCHER 4-V to 36-V, 600-mA Synchronous Step-Down Converter

6.1 Trademarks
E2E is a trademark of Texas Instruments.
Altium Designer is a registered trademark of Altium LLC or its affiliated companies.
All other trademarks are the property of their respective owners.

6.2 Third-Party Products Disclaimer
TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), 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, 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 (www.ti.com/legal/termsofsale.html) 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated