

设计指南: TIDA-050033 智能仪表 PLC 模块备用电源参考设计



说明

TIDA-050033 参考设计展示了适用于智能仪表 PLC 模块的备用电源解决方案。适用于超级电容器的简单线性充电器电路也包括在内。通过使用具有成本效益的升压转换器 TLV61048, 提高最低工作电压, 从而最大限度地提高超级电容器的使用率。可通过选择更小尺寸 (电容更小) 的超级电容器减少物料清单 (BOM) 总量。此外还讨论了详细的设计原理、组件选择和测试结果。

资源

TIDA-050033	设计文件夹
TLV61048	产品文件夹
TPS560430	产品文件夹
TL431	产品文件夹
CSD25310Q2	产品文件夹

特性

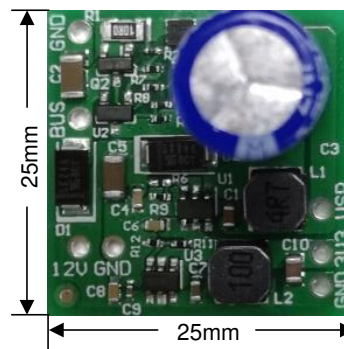
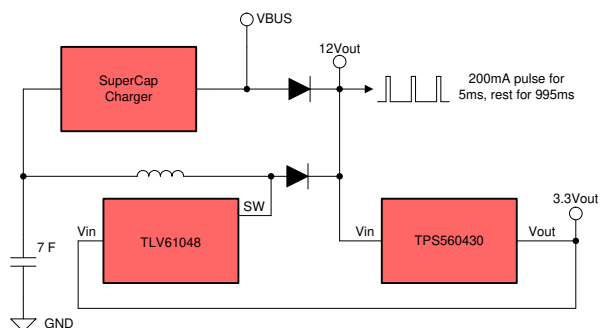
- 智能仪表 PLC 模块备用电源: 12V
- 超级电容器最低工作电压: 1.3V
- 高效率
- 小尺寸
- 线性充电器电流约为 60mA

应用

- 智能仪表



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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

表 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.

表 1. Key System Specifications

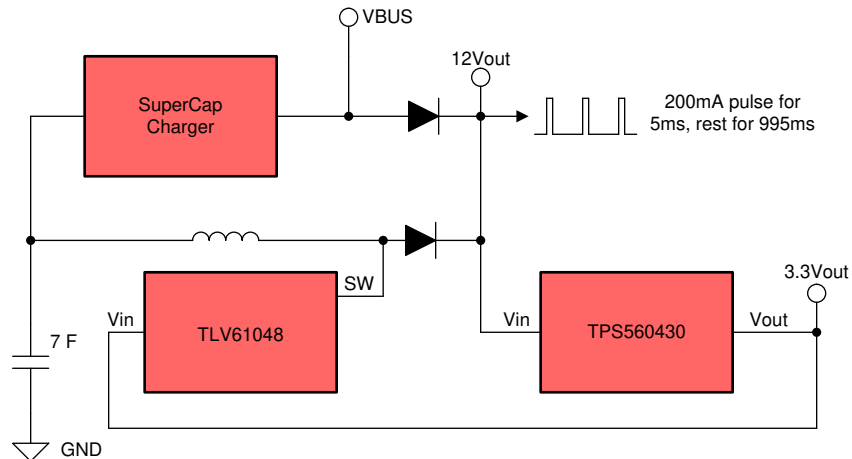
PARAMETER	DESCRIPTION
Super capacitor operating voltage	1.3 V to 2.5 V
Super capacitor charging time	330 seconds
Super capacitor charging current	60 mA
Back up power lasting time	45 seconds
Boost converter output voltage	12 V
PLC Module current	200mA for 5ms, 25mA for 995ms rest

2 System Overview

2.1 Block Diagram

图 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 ($V_{bus} < 12\text{ V}$), boost converter TLV61048 starts switching and provides a 12 V seamlessly to supply the PLC line driver amplifier

图 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](http://www.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
- $\pm 1.5\%$ 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

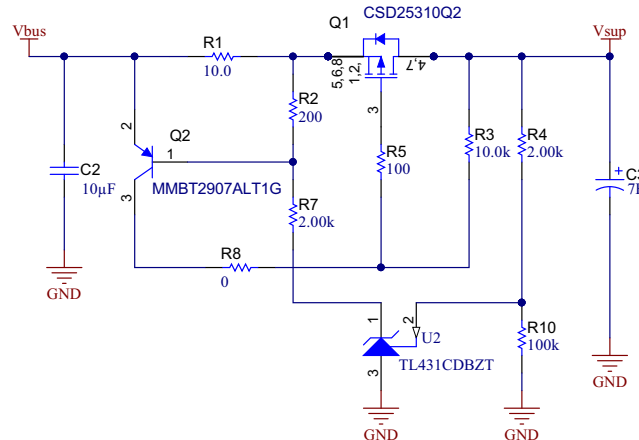
2.4 System Design Theory

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

图 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.

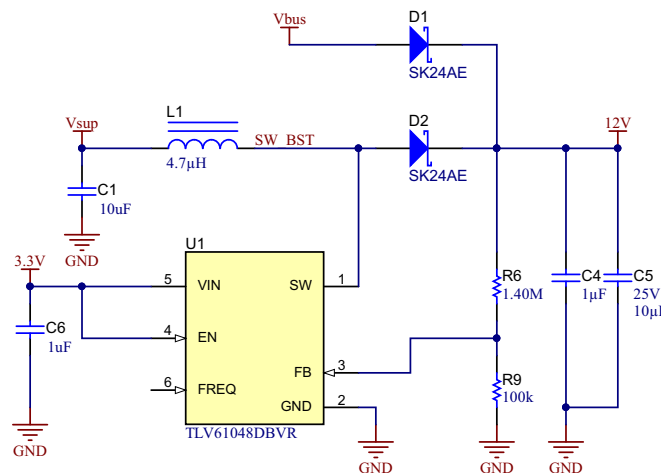
图 2. Super Capacitor Linear Charger Circuit



2.4.2 Boost Converter Solution

图 3 显示了 TLV61048 升压转换器，它是 TIDA-050033 的主要电路。大多数外部元件是根据数据表中的建议选择的。该设备以 600kHz (FREQ = floating) 运行，以获得更高的效率和更高的占空比。在 VIN 引脚上施加一个外部 3.3 V 偏置电源，以便设备可以低至 1.3 V 运行。当 Vbus 存在时，TLV61048 停止开关，因此它消耗最小电流，仅为 100µA (典型)。一旦 Vbus 失效，TLV61048 可以立即工作并提供 12 V 电源无缝切换。

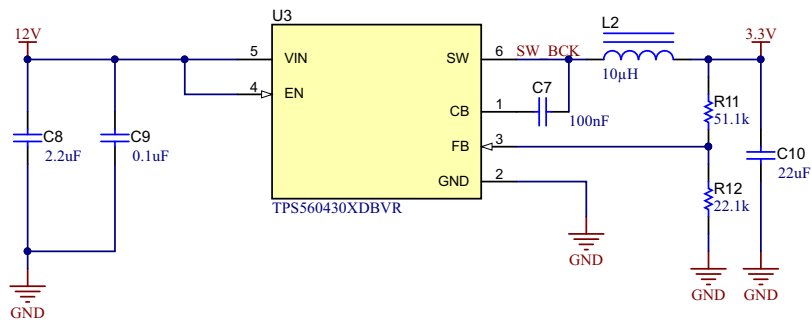
图 3. TLV61048 Boost Converter



2.4.3 Buck Converter Solution

图 4 显示了 TPS560430 降压转换器。TPS560430 以 1.1 MHz 开关频率运行，以获得高效率。它提供 3.3 V 电源，为 MCU 和升压转换器 TLV61048 的 VIN 引脚供电。在轻载条件下，TPS560430 工作在 PFM 模式，以保持高效率。当 Vbus 失效时，TLV61048 升压输出为 PLC 线驱动器供电，以及降压输入。

图 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.

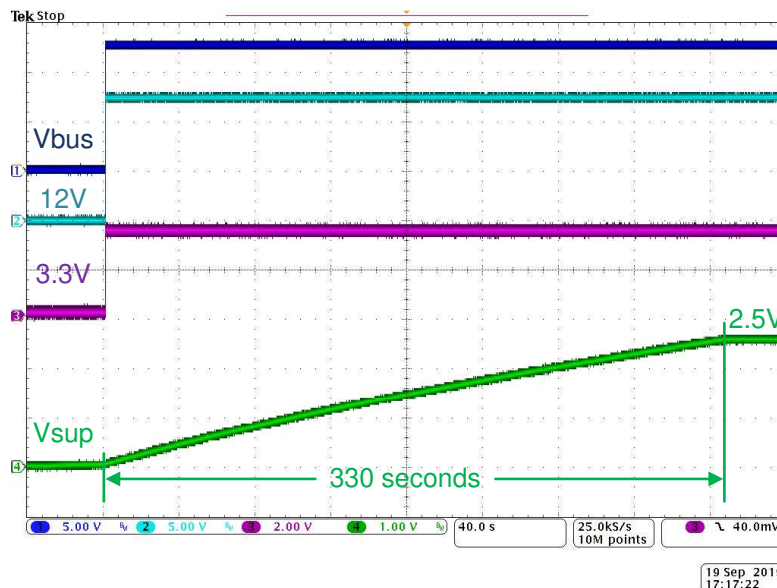
- Connect the positive terminal of DC power supply to pad BUS, and its GND terminal to pad GND on PCB.
- Connect the positive input of the E-Load to pad 12 V, and its GND input to pad GND on PCB.
- Keep the DC power supply and E-Load off. Set the DC power supply to 13 V and E-Load to 200mA for 5ms, 25mA 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

图 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.

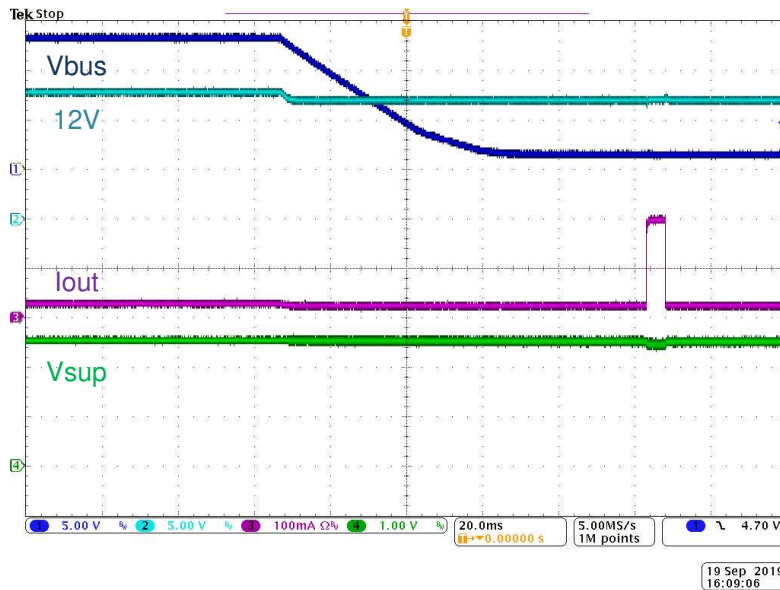
图 5. Super Capacitor Charging Waveform



3.2.2.2 Transient Waveform When Vbus fails

图 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.

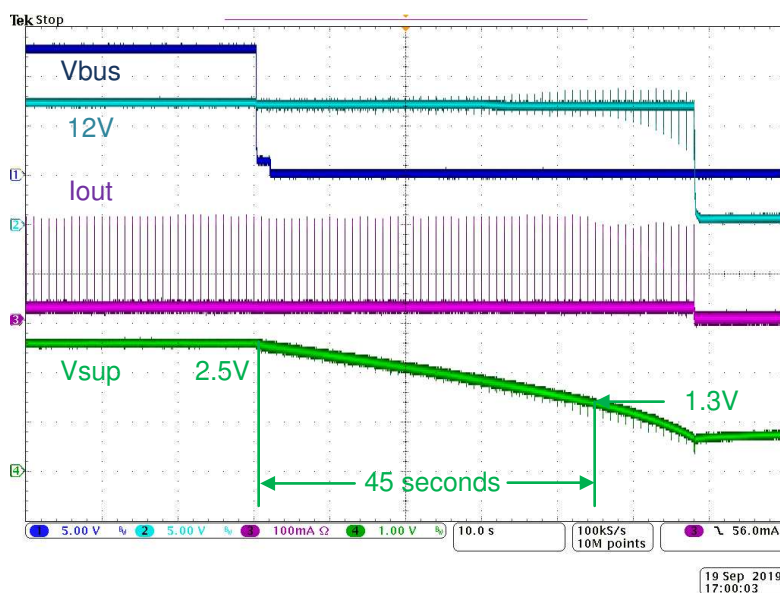
图 6. Transient Waveform When Vbus Fails



3.2.2.3 Super Capacitor Discharging Waveform

图 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.

图 7. Super Capacitor Discharging Waveform



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](#)

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