TI Designs：TIDA-050010

*采用 **LiSOCl2** 电池的智能仪表中的窄带物联网调制解调器电源参考设计*

说明

该参考设计可以为采用 LiSOCl2 电池的智能仪表应用中的 NB-IoT（窄带物联网）提供电源 解决方案。该设计是一款高效的低待机电流解决方案，可将电池使用时间延长 50% 以上。

资源

TIDA-050010	设计文件夹
TPS61099	产品文件夹
LMC555	产品文件夹
CSD18533KCS	产品文件夹

TI E2E™ Community

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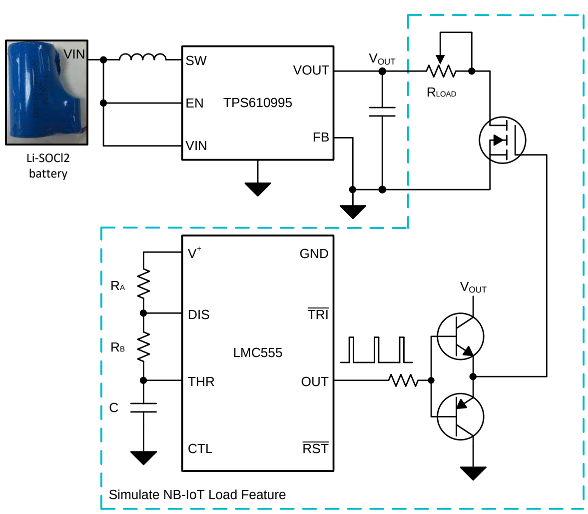
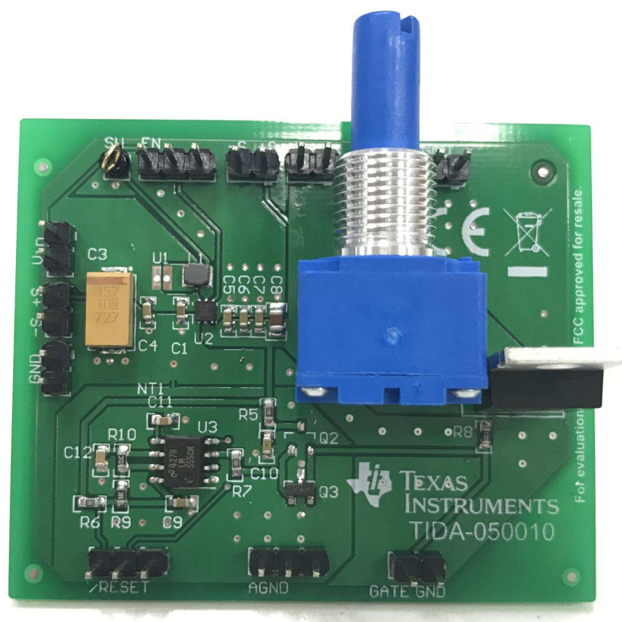
特性

- 工作输入电压范围：2V 至 4V
- 3.6V 固定输出电压
- 高达 320mA 的输出电流
- 在轻负载情况下具有 1μA 的静态电流
- 在开路负载情况下且温度为 85℃ 时具有约 4μA 的待机电流
- 在 10mA 至 320mA 负载下具有高达 93% 的效率
- 具有宽输入电压范围和高效率，从而延长电池寿命
- 可模拟窄带物联网负载特性，以便轻松进行测试
- 外部组件数量较少，可实现小解决方案尺寸

应用

- 燃气表
- 热量计
- 水表





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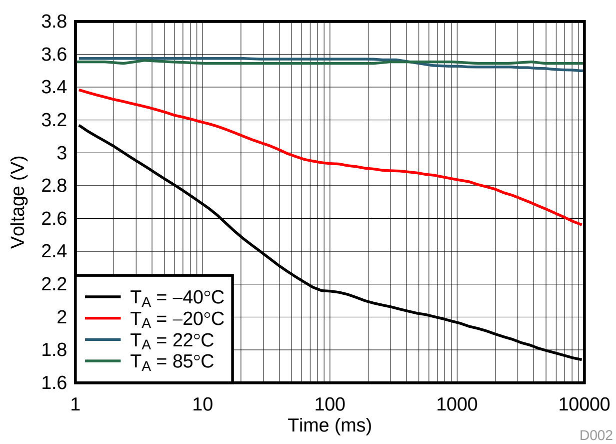
1 System Description

Smart meters consists of electricity meters, gas meters, heat meters and water meters. Some smart meters use NarrowBand-Internet of Things (NB-IoT) to transfer data and information. This technology supports battery life of more than 10 years for a wide range of use cases. The typical range of input voltage of NB-IoT modules (such as the ZTE ZM8300G module) is from 3 V to 4.2 V (with a typical voltage 3.6 V). The typical maximum peak current for these modules is up to 300 m A.

The Li-SOCl2 battery currently has the highest energy density, the longest storage period, and the least self-discharge rate (less than 1% per year at room temperature). This battery is very useful for smart meters including e-meters, water meters, and trackers, which are long-term products. The typical voltage of a Li-SOCl2 battery is approximately 3 to 3.6 V, and the maximum continuous output current is approximately 150 mA for an 8.5-Ah battery. Because the continuous output current of a Li-SOCl2 battery is not enough for NB-IoT, a super capacitor is connected with Li-SOCl2 battery in parallel to provide a pulse high current.

图 1 shows the voltage curves for a Li-SOCl2 battery (3.67 V) in parallel with super capacitor (SPC1520) with a discharge current is 350 mA. At low ambient temperature, the output voltage of the Li-SOCl2 battery is less than 3 V. The NB-IoT module connected directly to a Li-SOCl2 battery stops working even though a large capacity (about 2/3 capacity at –20℃) is still available, so a boost converter is needed. The TPS610995 can boost the battery voltage to 3.6 V to give a steady power to NB-IoT module.

图 1. Voltage Curves for Li-SOCl2 Battery (3.67 V) In Parallel With Super Capacitor, 350 mA



(1) See the *EVE SPC (Super Pulse Capacitor cell) Model SPC1520*.data sheet. for more information.

1.1 Key System Specifications

表 1. Key System Specifications

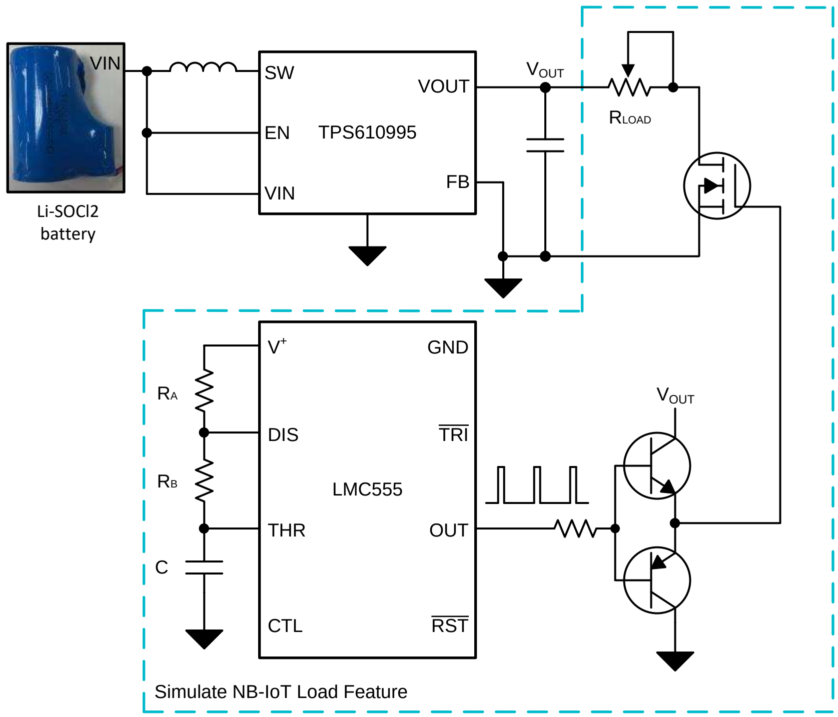
PARAMETER	SPECIFICATIONS
Input voltage range	2 V to 4 V
Output voltage	3.6 V
Output current	up to 320 mA
No load input current (V_{in}= 3 V)	1 µA
Efficiency (V_{in}= 3 V, I_{out}= 300 mA)	94 %
Monitor load range	2 Ω to 1 kΩ

2 System Overview

2.1 Block Diagram

图 2 shows the system block diagram. This system has two parts. One is the TPS610995 boost converter to boost the Li-SOCl2 battery to 3.6 V, the other part is simulate NB-IoT load feature.

图 2. TIDA-050010 Block Diagram



2.2 Design Considerations

2.2.1 Load Monitor

This reference design uses the LMC555 device to generate a pulse that drives a MOSFET to monitor the NB-IoT load feature. Users can change the resistance by sliding the rheostat (R_{LOAD}) to change the peak output current.

Use 公式 1 to calculate the pulse width of the output load current of the LMC555 device.

$$t_{on} = 0.693 \times (R_A + R_B) \times C = 0.693 \times (1\ \text{k}\Omega + 23.2\ \text{k}\Omega) \times 10\ \mu\text{F} = 167\ \text{ms} \quad (1)$$

Use 公式 2 to calculate the frequency of the output load current of the LMC555 device.

$$f = \frac{1.44}{(R_A + 2 \times R_B) \times C} = \frac{1.44}{(1\ \text{k}\Omega + 2 \times 23.2\ \text{k}\Omega) \times 10\ \mu\text{F}} = 3\ \text{Hz} \quad (2)$$

2.3 Highlighted Products

2.3.1 TPS610995

The TPS610995 is part of the TPS61099 family of devices. The TPS610995 device is a fixed output voltage (V_{out}= 3.6 V) version. The TPS610995 boost converter uses a hysteretic control topology to obtain maximum efficiency at minimal quiescent current. The TPS610995 device only consumes 1-µA quiescent current and can achieve up to 75% efficiency at a 10-µA load. The TPS610995 device can also support up to 320-mA output current from 2 V to 3.6 V conversion and achieve up to 93% at a 320-mA load. The TPS610995 device also offers Down Mode operation. In Down Mode, the output voltage can still be regulated at a target value even when the input voltage is higher than the output voltage. The TPS610995 device supports true shutdown function when it is disabled, which disconnects the load from the input supply to reduce the current consumption. The TPS610995 device is available in a 6-pin, 2-mm × 2-mm, WSON package, the total boost converter size is about 14mm*8mm, including a input tantalum capacitor and a output 0603 ceramic capacitor.

2.3.2 LMC555

The LMC555 device is a CMOS version of the industry standard 555 series general-purpose timers. The LMC555 offers the same capability of generating accurate time delays and frequencies as the LM555 but with much lower power dissipation and supply current spikes. When operated as a one-shot, the time delay is precisely controlled by a single external resistor and capacitor. In the astable mode the oscillation frequency and duty cycle are accurately set by two external resistors and one capacitor. The use of TI's LMCMOS process extends both the frequency range and the low supply capability.

2.3.3 CSD18533KCS

The CSD18533KCS is a 5.0 mΩ, 60 V TO-220 NexFET™ power MOSFET, which is designed to minimize losses in power conversion applications.

3 Hardware, Testing Requirements, and Test Results

3.1 Required Hardware

3.1.1 Hardware

The reference design used this hardware to test the design:

- DC power source
- Digital oscilloscope
- Multimeters

3.2 Testing and Results

3.2.1 Test Setup

See 4.1 节 and 4.2 节 for the test schematic and bill of materials.

To test the design:

1. Check that pin 1 and pin 2 of U1 are connected by a line.
2. Connect the EN pin (pin 2) to the input voltage (pin 3) through the EN jumper.
3. Connect the $\overline{\text{RESET}}$ pin (pin 2) to the input voltage (pin 3) through the $\overline{\text{RESET}}$ jumper.

4. Connect the input terminal of the reference board to the DC power source.

3.2.2 Test Results

3.2.2.1 Comparison

图 3 and 图 4 show a comparison of the test results. Channel 2 is the output of a Li-SOCl2 battery connected to the super capacitor. Channel 1 is the output of the TPS610995 boost converter. Channel 4 is the output current.

A 320-mA, 130-ms pulse current was used to monitor the NB-IoT load feature. 图 3 shows the test result using a Li-SOCl2 battery connected directly to a super capacitor. At –40℃ ambient temperature, the output of the Li-SOCl2 battery decreases to 2.8 V at a 320-mA pulse current. The NB-IoT module stops in this case. 图 4 shows the test result using the TPS610995 boost converter. The output of the TPS610995 boost converter is stable at the pulse output current. The NB-IoT module continues steady operation.

图 3. Simulate NB-IoT Working Without TPS610995 at T_A = –40℃

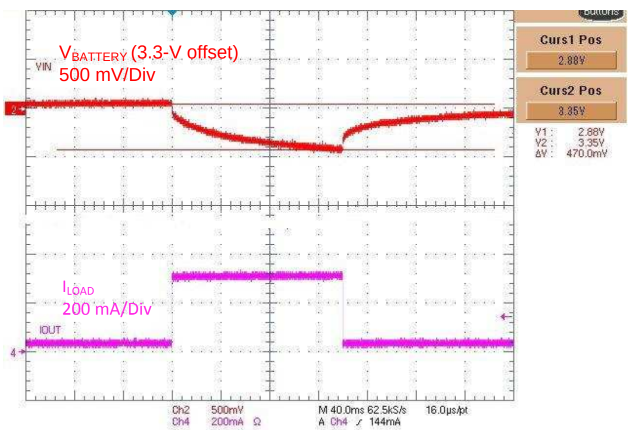
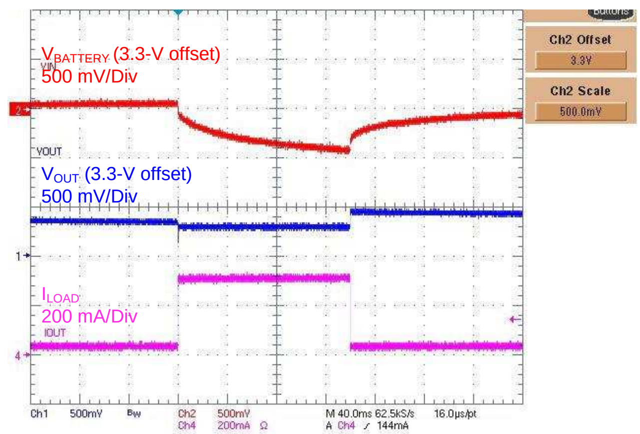


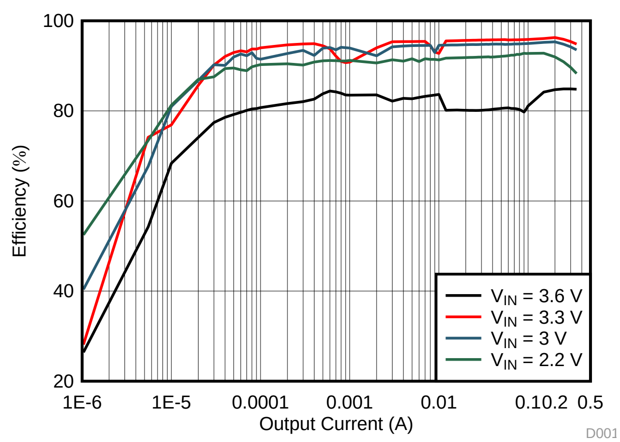
图 4. Simulate NB-IoT Working With TPS610995 at T_A = –40℃



3.2.2.2 Efficiency Curves

图 5 shows the efficiency curves for each input voltage.

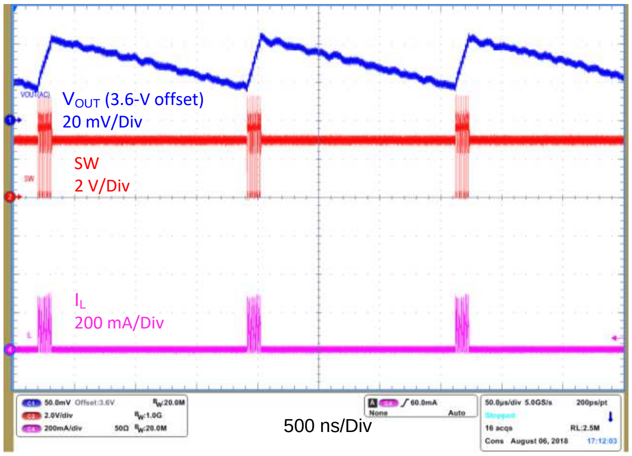
图 5. TPS610995 Load Efficiency for Different Input Voltages



3.2.2.3 Output Voltage Ripple

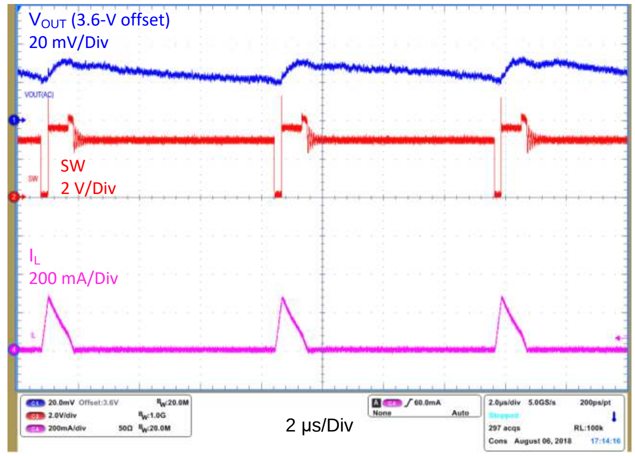
图 6, 图 7, and 图 8 show the waveforms for output voltage ripple. 图 6 shows burst mode operation, 图 7 shows discontinuous current operation and 图 8 shows continuous current operation.

图 6. Output Voltage Ripple



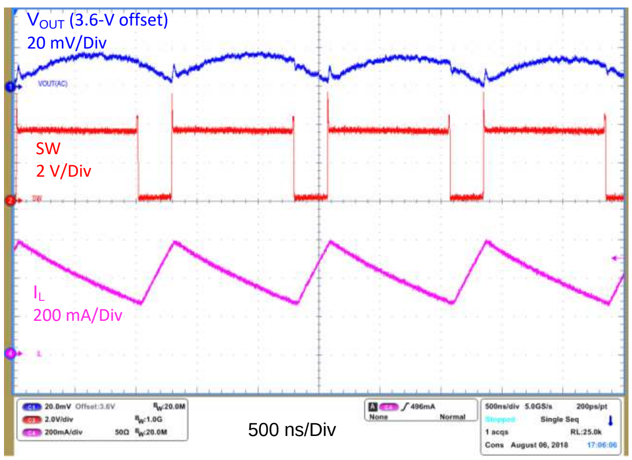
V_{IN} = 3 V; Open Load

图 7. Output Voltage Ripple



V_{IN} = 3 V; I_{OUT} = 10 mA

图 8. Output Voltage Ripple

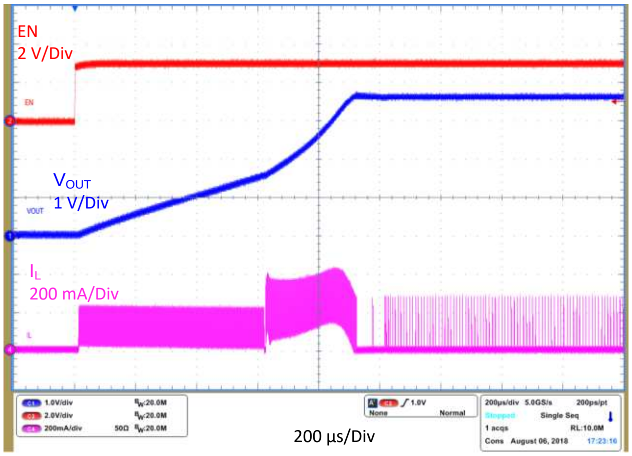


V_{IN} = 3 V; I_{OUT} = 320 mA

3.2.2.4 Start Up by EN

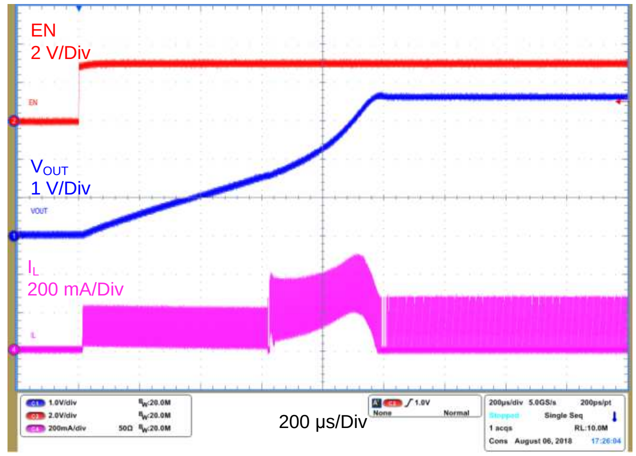
图 9 and 图 10 show the waveforms for start up by EN.

图 9. Startup by EN



V_{IN} = 3 V; I_{OUT} = 10 mA

图 10. Startup by EN

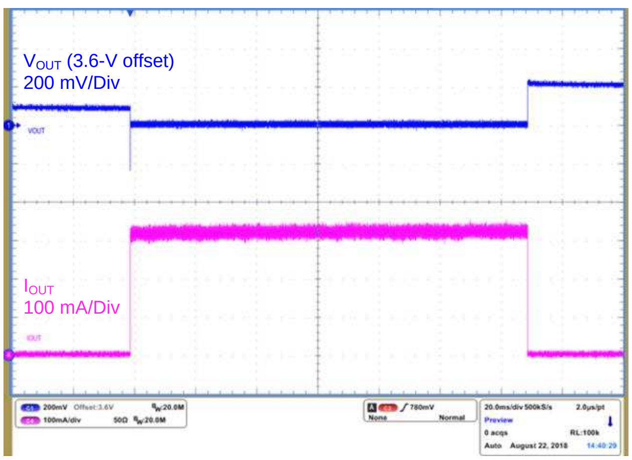


V_{IN} = 3 V; I_{OUT} = 50 mA

3.2.2.5 Load Transient

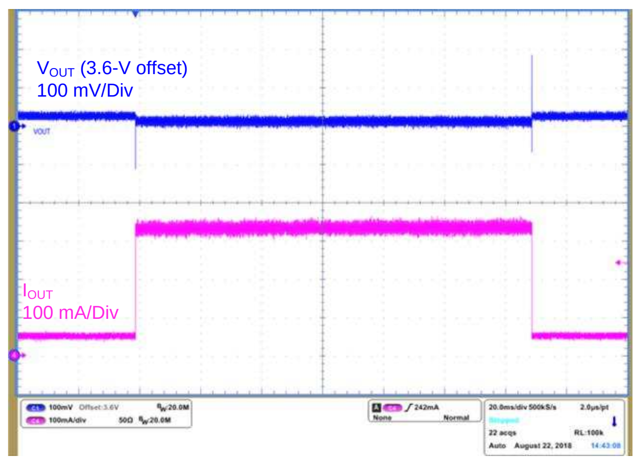
图 11 and 图 12 show the load transient waveforms.

图 11. Load Transient



V_{IN} = 3 V; I_{OUT} from 0 mA to 320 mA

图 12. Load Transient

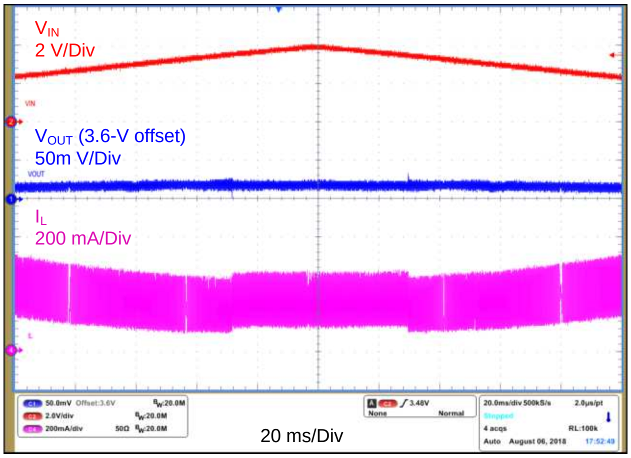


V_{IN} = 3 V; I_{OUT} from 50 mA to 320 mA

3.2.2.6 Line Regulation

图 13 shows the line regulation waveform.

图 13. Line Regulation



4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-050010.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050010.

4.3 Layout Prints

To download the layer plots, see the design files at TIDA-050010.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050010.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050010.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050010.

5 Related Documentation

1. Texas Instruments, *CSD18533KCS 60 V N-Channel NexFET™ Power MOSFET* data sheet
2. Texas Instruments, *LMC555 CMOS Timer* data sheet
3. Texas Instruments, *TPS61099x Synchronous Boost Converter with Ultra-Low Quiescent Current* data sheet
4. Endrich, *EVE SPC (Super Pulse Capacitor cell) Model SPC1520*.data sheet.

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