Design Guide: TIDA-050032

5 V Output, 4000 V Isolation Power Supply Reference Design

Description

This reference design introduces a 5-V, 200-mA output Flyback DC-DC power converter targeting RS485 application in data concentrator. The 4000-Vac isolation power circuit is a simple and cost-effective solution as it uses a fully integrated converter TLV61046A and off-the-shelf transformer. The entire circuit is easy to copy into the system board to power RS485 device, greatly reducing the design time of circuit schematic and layout. Detail bench test results such as efficiency, load regulation and operating waveform are provided in the user guide for reference.

Resources

TIDA-050032	Design Folder
TLV61046A	Product Folder

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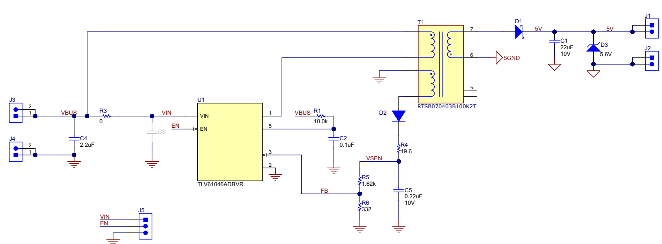
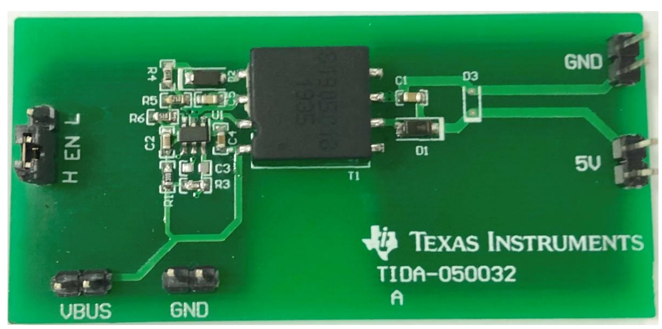
Features

- 4.5-V to 5.5-V input-voltage range
- 5-V output voltage with 200-mA maximum output
- 4000-VAC isolation-voltage transformer
- Primary-side regulation to minimize solution cost
- Circuit tested with evaluation board

Applications

- Electricity meter
- Data concentrators





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1 System Description

The reference design introduces a 5-V, 200-mA output Flyback converter based on the TLV61046A used for the power supply of the RS485 in the electricity meter and data concentrator. The input voltage ranges from 4.5 V to 5.5 V and the switching frequency is typical 1MHz. By utilizing a third winding to regulate the output voltage, high cost and complex secondary control circuit can be removed. However, the output voltage would change 5.3 V to 4.75 V with output current from 20 mA to 200 mA. The isolation voltage of the transformer used in the reference design is 4000-V AC.

1.1 Key System Specifications

Table 1 provides the electrical specification of the reference design. Operating conditions outside the range of the table are also possible if the electrical specification is within the value specified in the TLV61046A data sheet (SLVSD82A).

Table 1. Key System Specifications

PARAMETER	MINIMUM	TYPICAL	MAXIMUM	UNIT
V_{BUS}, Input voltage	4.5	5	5.5	V
V_{OUT}, Output voltage	4.5	5	5.5	V
I_{OUT}, Output current	20	—	200	mA
Isolation voltage	4000	—	—	Vac

2 System Overview

2.1 Design Considerations

The two important technical problems to design a flyback DC-DC converter are the control IC and the transformer design. Considering the voltage rating of the switching MOSFET and output current of the reference design, TLV61046A is selected. The primary side control method is adopted to reduce the solution cost. Because the target loading is RS485 IC, which can accept wide voltage range. The transformer is built by Sunlord Electronics. This helps to provide consistent behavior in reference design board and customer's system board.

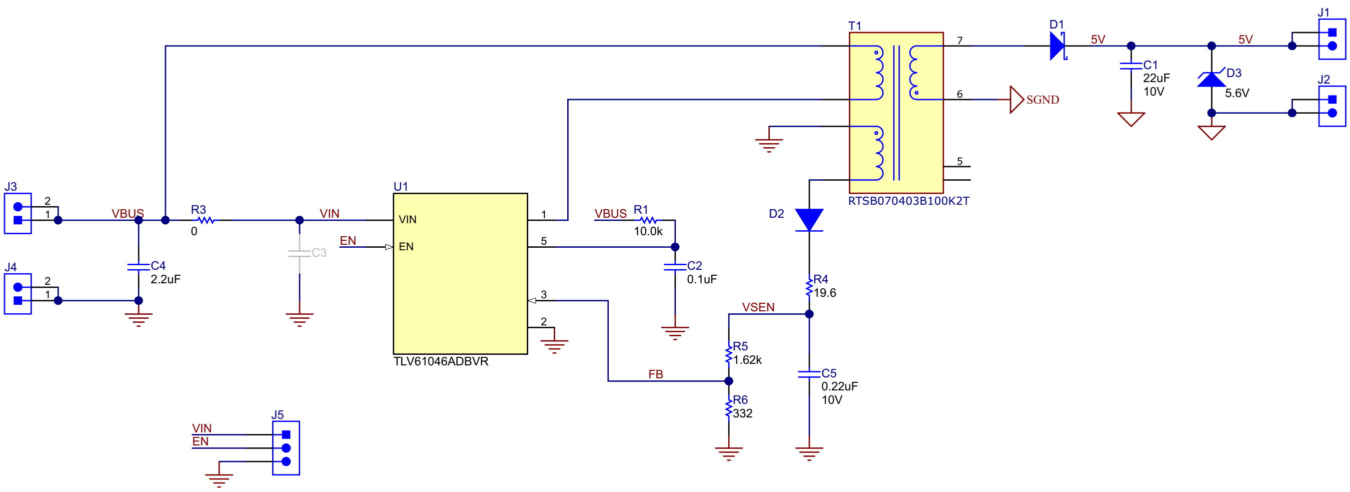
2.2 System Design Theory

Figure 1 shows the schematic of the reference design based on a flyback topology DC-DC. The main components in the circuit are the boost converter IC TLV61046A, transformer T1, Schottky diode D1, output capacitor and voltage sensing resistors.

The TLV61046A is boost converter integrated both the low side MOSFET and high side rectifier. The TLV61046A use a peak current, adaptive off-time control topology to regulate its FB pin voltage at 0.8 V. The winding ratio of the transformer is 1:1:1. The auxiliary winding between pin 3 and pin 4 is used to generate a voltage VSEN which is controlled by TLV61046A. By regulating the voltage at VSEN to approximately 5 V, the V_{OUT} will be 5 V. The transformer has 10-µH inductance if the current is lower than 1 A.

The DC voltage stress of D1 is (V_{BUS}+V_{OUT}), which is typical 10 V. Considering voltage spike during converter switching, the Schottky voltage rating should be not lower than 20 V, and its current rating should be higher than 200 mA.

Figure 1. TIDA-050032 Schematic



The output capacitor is selected by the output ripple requirement, defined by Equation 1. Setting 25-mV output voltage ripple at 200-mA loading condition, the effective output capacitance will be 4 µF. Considering DC bias effect of the ceramic capacitor, at least a 10-µF capacitor should be selected.

$$\Delta V_{OUT} = \frac{I_{OUT} \times D}{C_{OUT} \times f_{SW}} \quad (1)$$

where

- f_{sw} = 1 MHz, the switching frequency of the TLV61046A in CCM
- D = 0.5, typical duty cycle at CCM

The ratio of R5 and R6 and internal reference voltage defines the voltage level at VSEN node, as shown in Equation 2. Considering the forward voltage gap between the diode D2 and the Schottky D1, the VSEN voltage is set to typical 4.7 V. The sum of the R5 and R6 is approximately 2 KΩ, which adds 2.4 mA dummy load to VSEN. The dummy load is to improve the load regulation performance resulted from the non-ideal transformer and diodes. The R1 also acts as the same purpose.

$$V_{SEN} = \frac{R5 + R6}{R6} \times V_{REF} \tag{2}$$

where

- V_{REF} = 0.798 V
- R5 and R6 can be found in Figure 1

The C2 connected to the V_{OUT} pin of the TLV61046A is to provide stable voltage for the IC's internal circuit. The capacitor also acts as snubber capacitor to reduce the voltage spike in the SW pin.

3 Hardware, Testing Requirements and Test Results

3.1 Required Hardware

3.1.1 Hardware

One DC power supply, one electronic load, and an oscilloscope are required in the test. the DC power supply is used to power the board with voltage from 4.5 V to 5.5 V, while the e-load can easily add 20 mA to 200 mA loading to the board. The oscilloscope is to observe the operating waveform of input, output, and other pins in the board.

3.2 Testing and Results

3.2.1 Test Setup

The test is set up with TIDA-050032 board. A 5-V power supply is connected to the VBUS and GND connection. An e-load is connected to 5-V output connection. The EN pin is connected to H to enable the board. The waveform can be captured in the connection or the pins of each of the components.

3.2.2 Test Results

The efficiency and load regulation at different input voltage and ambient temperature can be found in Figure 2 to Figure 7.

Figure 2. Efficiency at Ta = 25°C

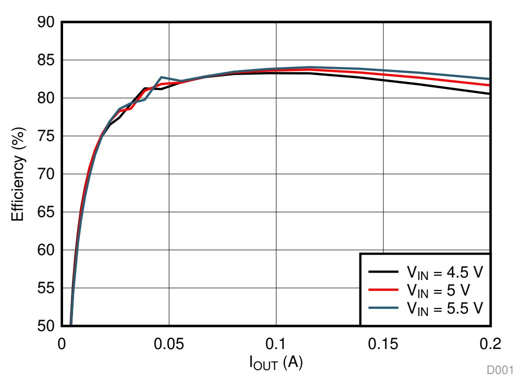


Figure 3. Efficiency at Ta = -40°C

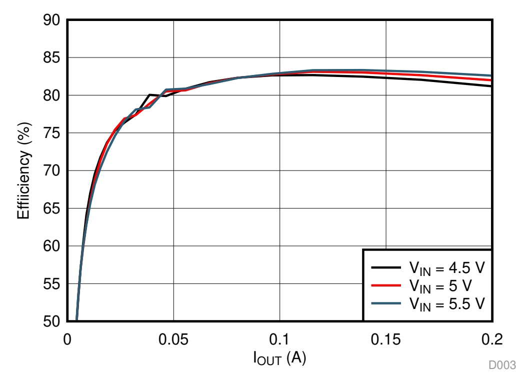


Figure 4. Efficiency at Ta = 85°C

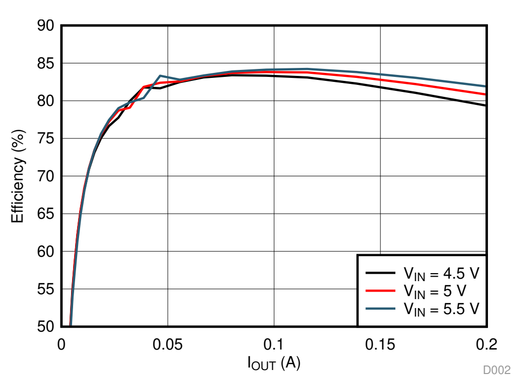


Figure 5. Load Regulation at Ta = 25°C

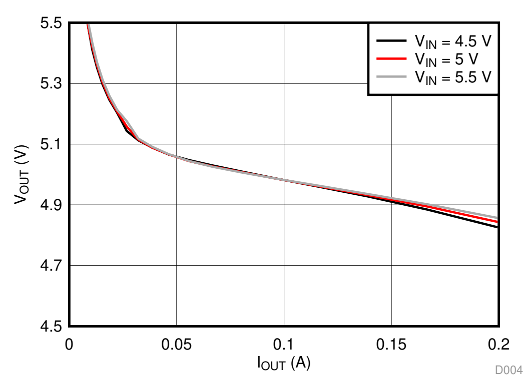


Figure 6. Load Regulation at Ta = -40°C

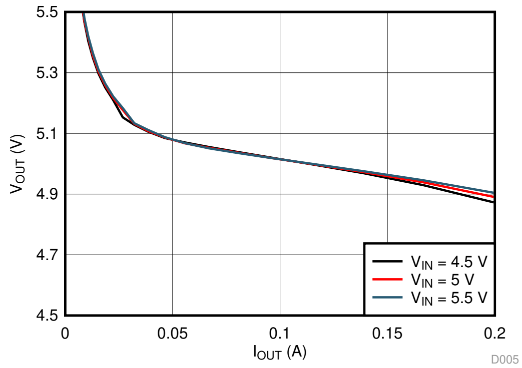
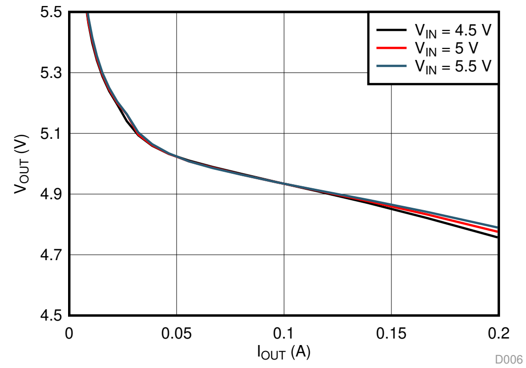


Figure 7. Load Regulation at Ta = 85°C



The stable output ripple at 20mA and 200mA output current condition is shown in Figure 8 and Figure 9 respectively. The TLV61046A operates at power save mode at 20-mA loading condition. The ripple is less than 50 mV. At 200-mA loading condition, the ripple frequency is 1 MHz, and its peak-to-peak value is approximately 30 mV.

Figure 8. Output Voltage Ripple at I_{OUT} = 20 mA

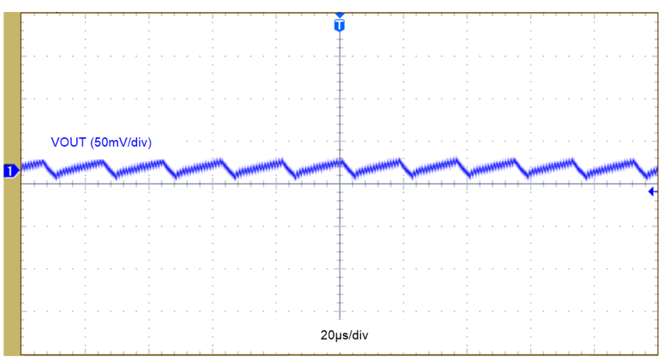
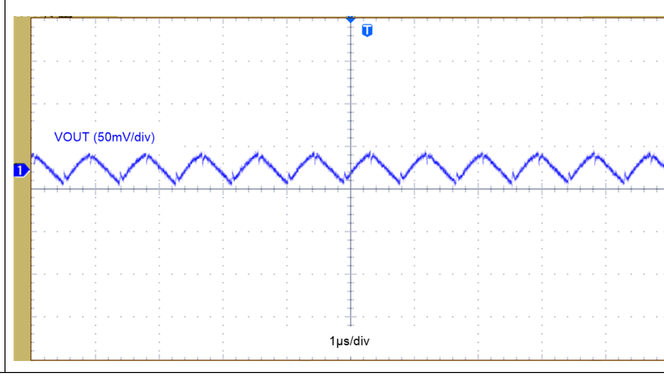


Figure 9. Output Voltage Ripple at I_{OUT} = 200 mA



The load transient between 20mA and 200mA is shown in Figure 10. The waveform clearly shows that the DC output voltage drops 400 mV at full loading condition, but there is not oscillation during the load transient.

The startup waveform at 20mA loading condition is shown in Figure 11.

Figure 10. Load Transient from 20 mA to 200mA

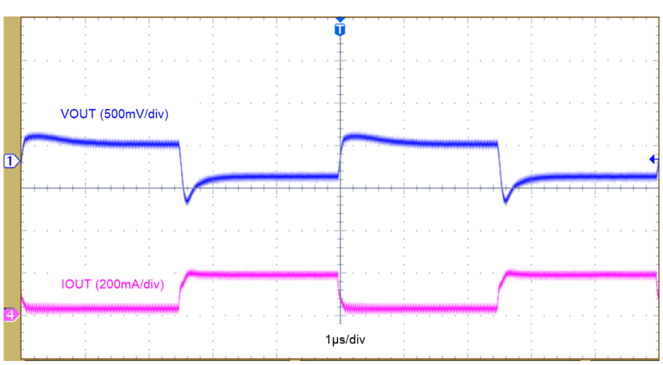
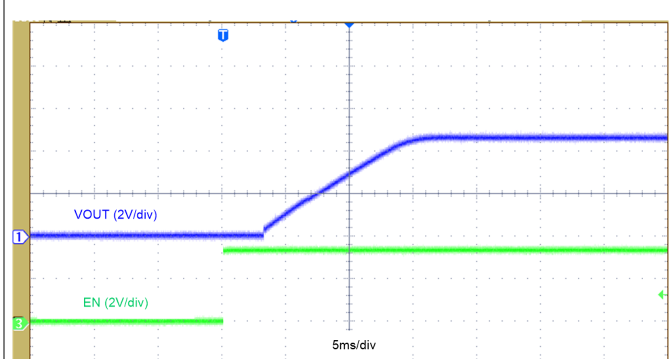


Figure 11. Startup Waveform at 20-mA Loading



4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-050032.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050032.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050032.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050032.

5 Related Documentation

1. TLV61046A 28-V Output Voltage Boost Converter with Power Diode and Isolation Switch data sheet (SLVSD82A)

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