Automotive Buck-Boost DC-DC Converter for USB PD

Reference Guide

RD227-RGUIDE-02

Toshiba Electronic Devices & Storage Corporation

Table of Contents

1. Introduction

This Reference Guide (hereafter referred to as this Guide) describes the specifications and operation procedures of the Automotive Buck-Boost DC-DC Converter for USB PD (hereafter referred to as this Power Supply).

Recently, USB Power Delivery (hereafter referred to as USB PD) power supply (for recharging) has become popular for smart phones, tablets, laptop PC, etc. In response to the growing demand for power supply not only indoors but also inside vehicles, USB Type-C® connectors have been installed, and power supply by USB PD has become popular. Since the output voltage is determined by the power receiving device in USB PD, DC-DC converter for automotive USB PD requires a buck-boost converter to generate the output voltage from the vehicle battery voltage. This power supply is an H-bridge type buck-boost DC-DC converter with four switching elements. By using our small-package automotive MOSFETs as switching devices, we have realized an automotive buck-boost DC-DC converter that is highly efficient and has a small board mounting area.

We have prepared two types of automotive MOSFETs which are used in the H-bridge buck-boost DC-DC converter section of this power supply. Option 1 uses a XPN7R104NC, and Option 2 uses a XSM6K519NW. In addition, our automotive MOSFET XPN3R804NC is used as a switching device in reverse-connection protection circuit and shield short-circuit protection circuit.

2. Specifications

Table 2.1 lists the main specifications of this power supply.

Table 2.1 Specifications of Automotive Buck-Boost DC-DC Converter for USB PD

Item	Specifications
Power Topology	H-bridge buck-boost circuit
Input Voltage	DC 5 to 18 V, 12.6 V (Typ.)
Output Voltage	DC 3.3 to 21 V
Rated Power	60 W (Max.)
Switching Frequency	400 kHz (Typ.)
Protective Function	Reverse connection protection Overvoltage, overcurrent, and shield short-circuit protection (controlled by the controller)
Cooling System	Convection cooling
Board Size	90 x 40 mm
Substrate Layer Configuration	Four-layer through-hole (surface layer: 70 µm, inner layer: 70 µm)

2.1. Circuit Block Diagram

Fig. 2.1 shows the block diagram of this power supply.

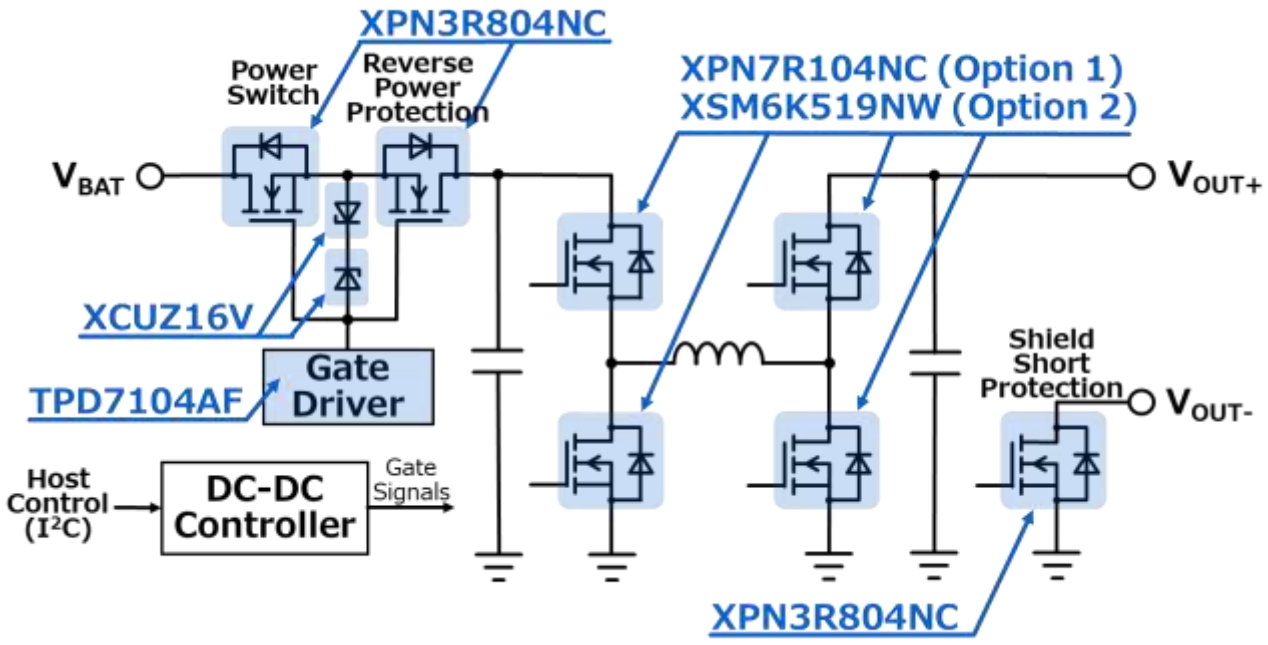
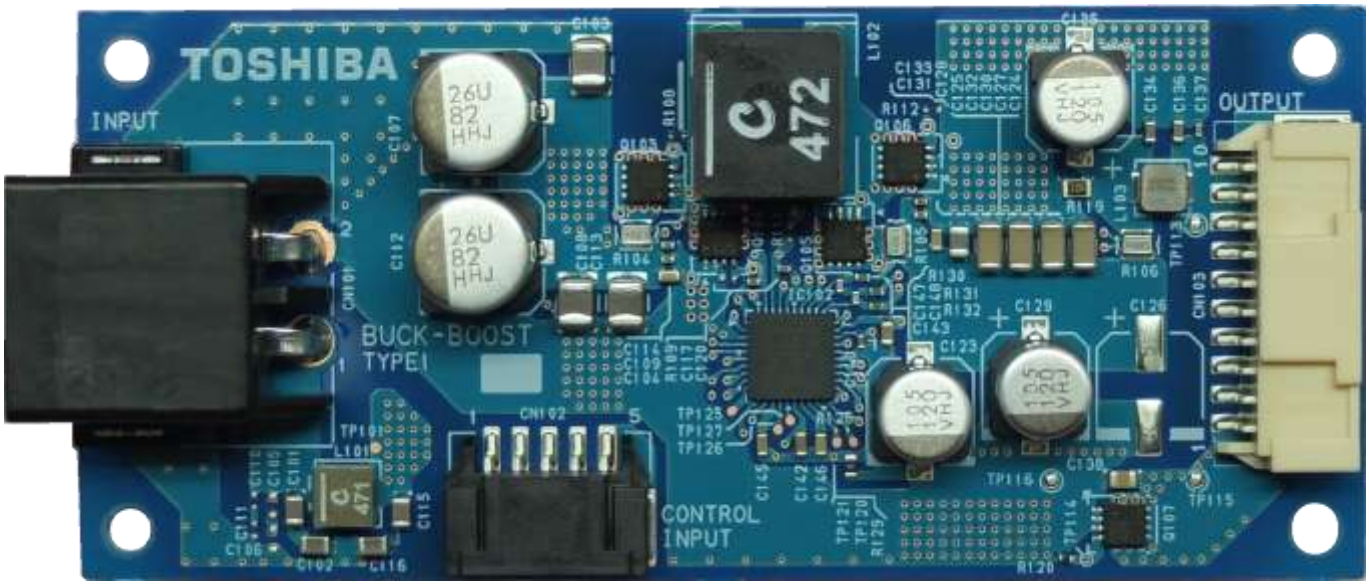


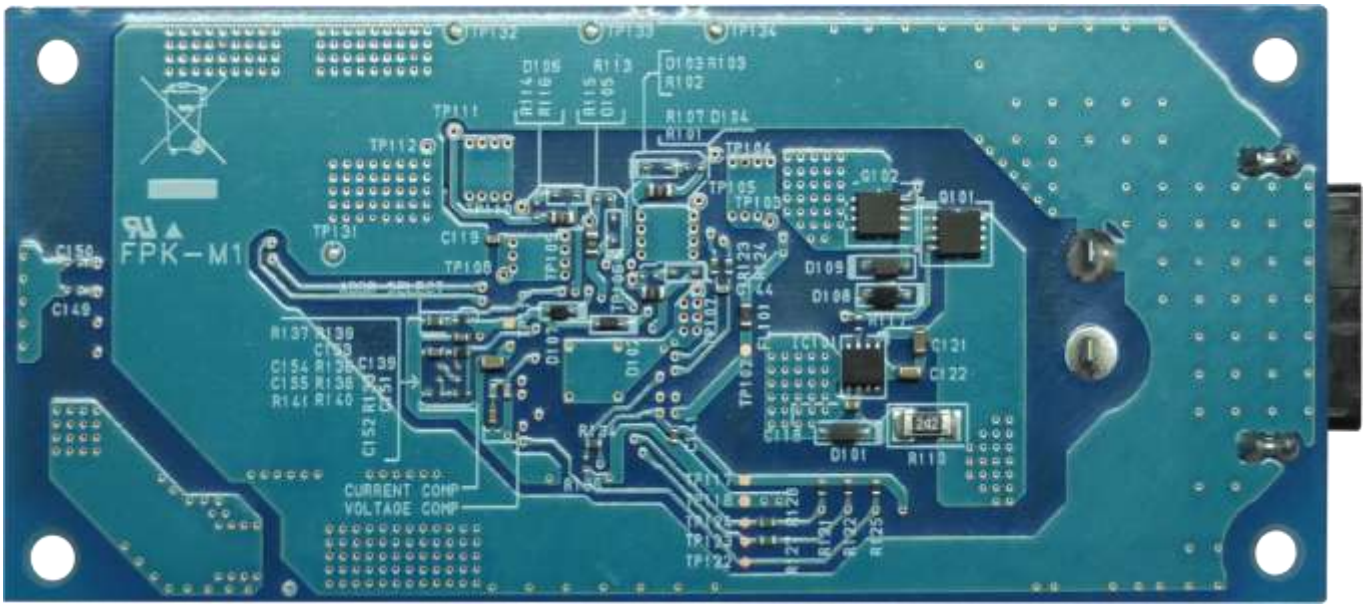
Fig. 2.1 Block Diagram of Automotive Buck-Boost DC-DC Converter for USB PD

2.2. Appearance and Component Arrangement

Fig. 2.2 and Fig. 2.3 show the appearance of this power supply, and Figs. 2.4 and 2.5 show the layout of main components.

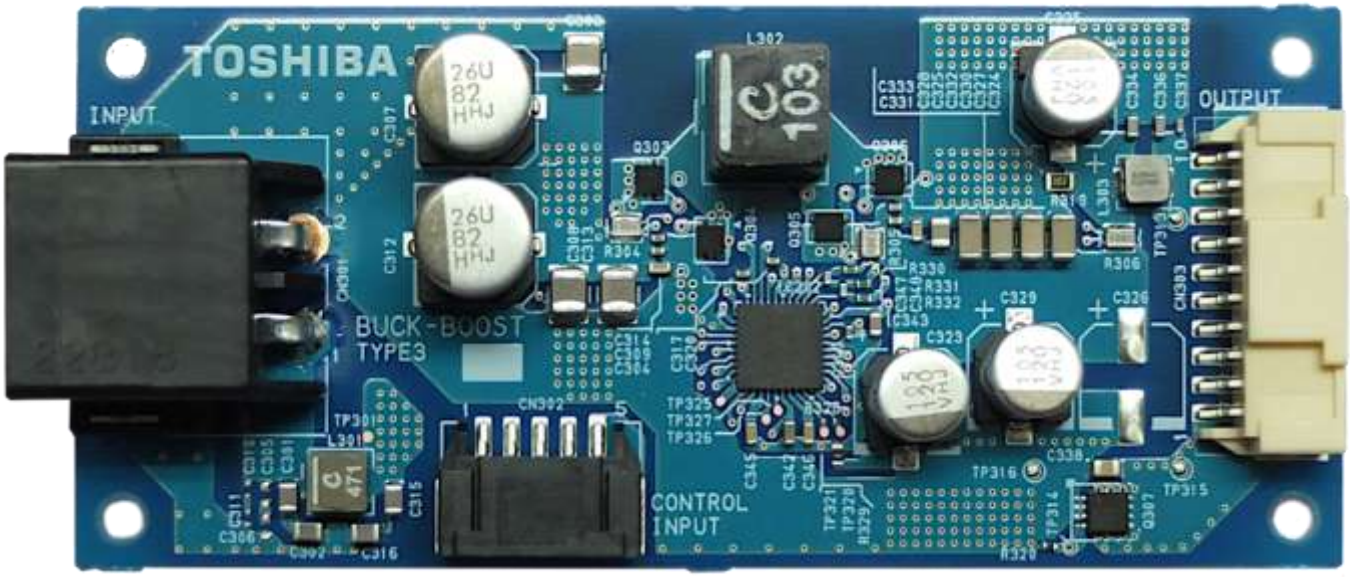


<Front>

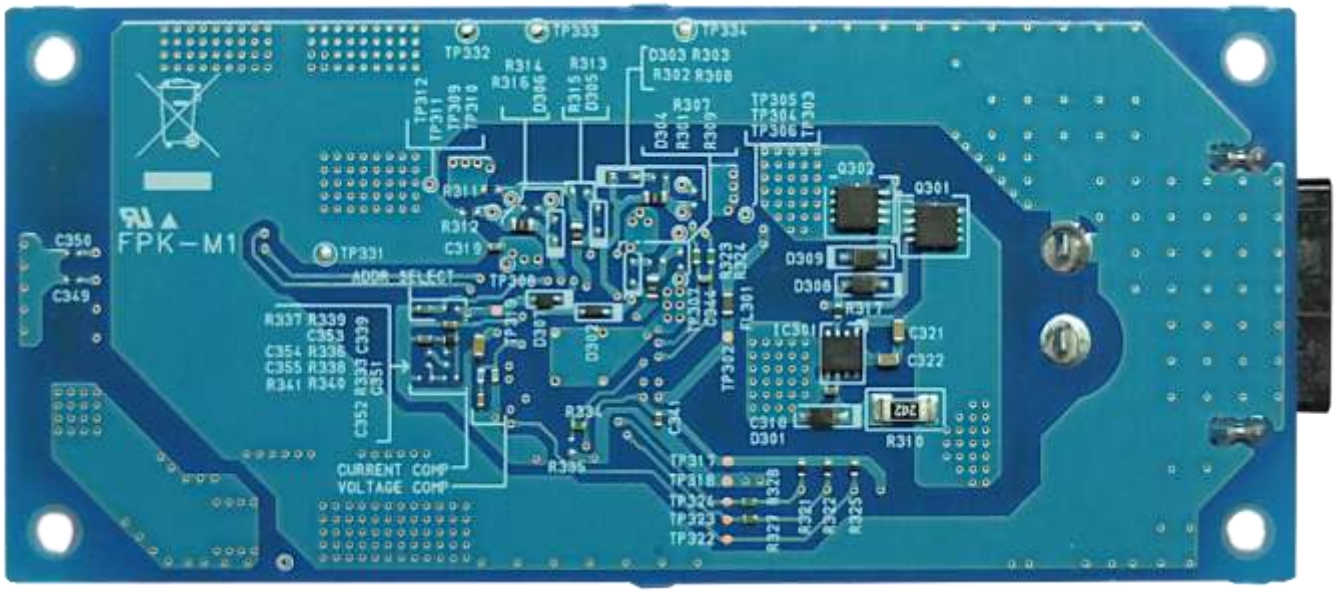


<Back>

Fig. 2.2 Board Appearance (Option 1)

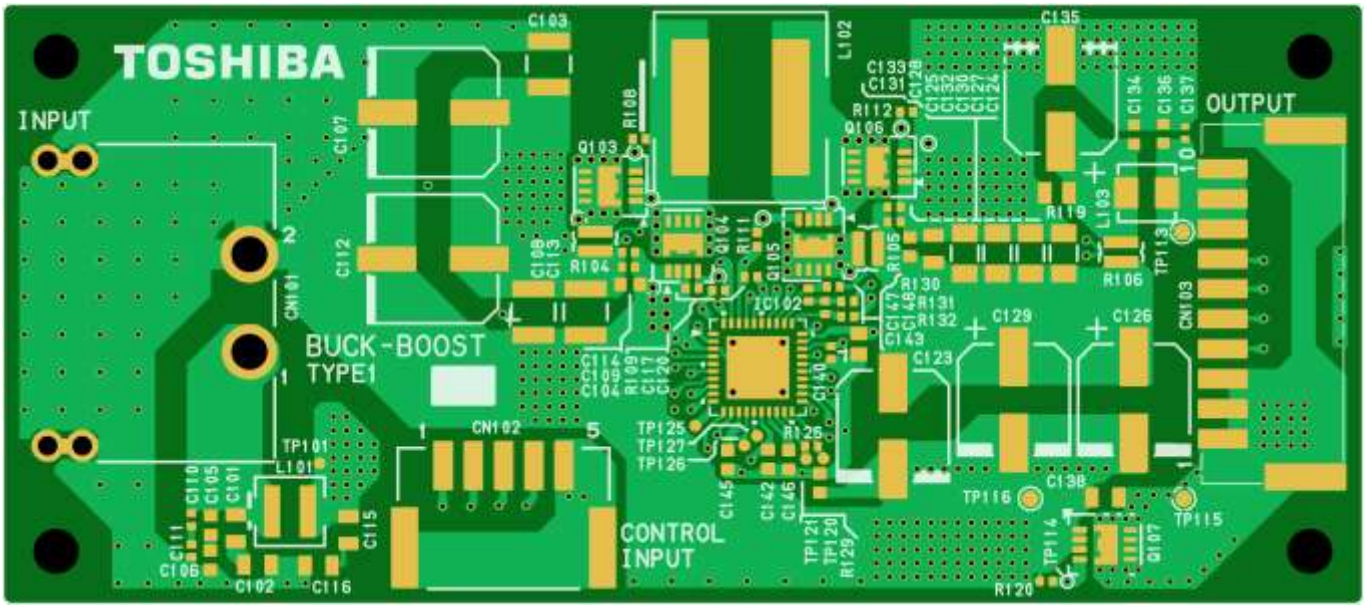


<Front>

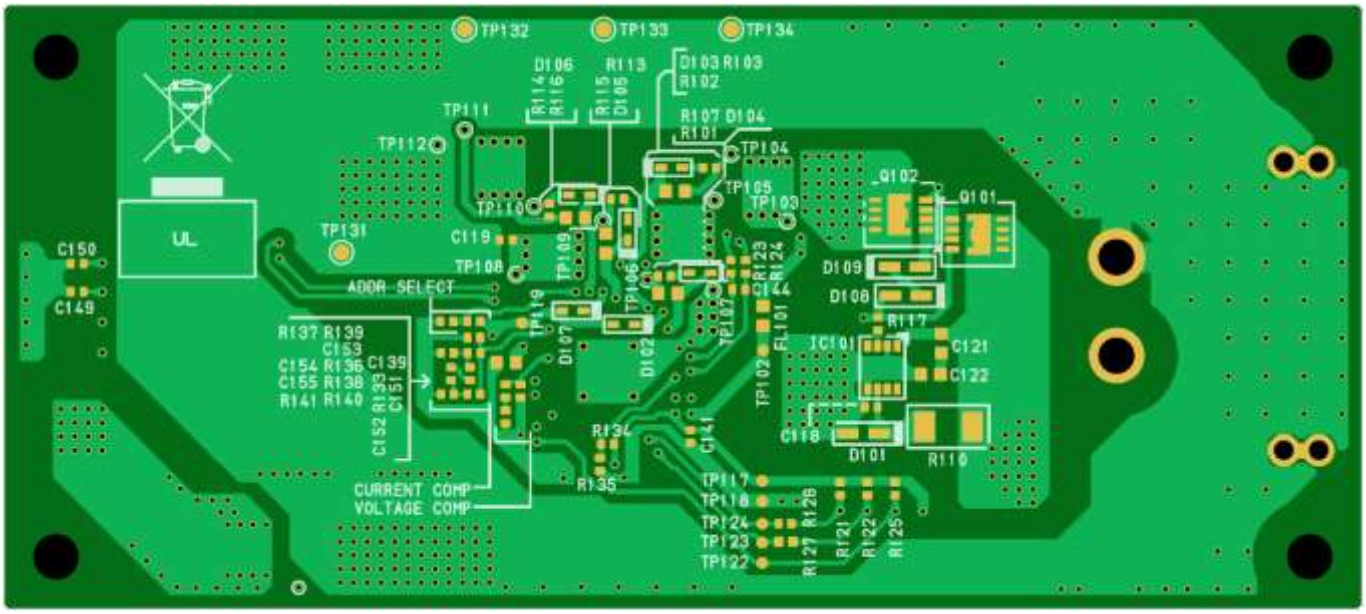


<Back>

Fig. 2.3 Board Appearance (Option 2)

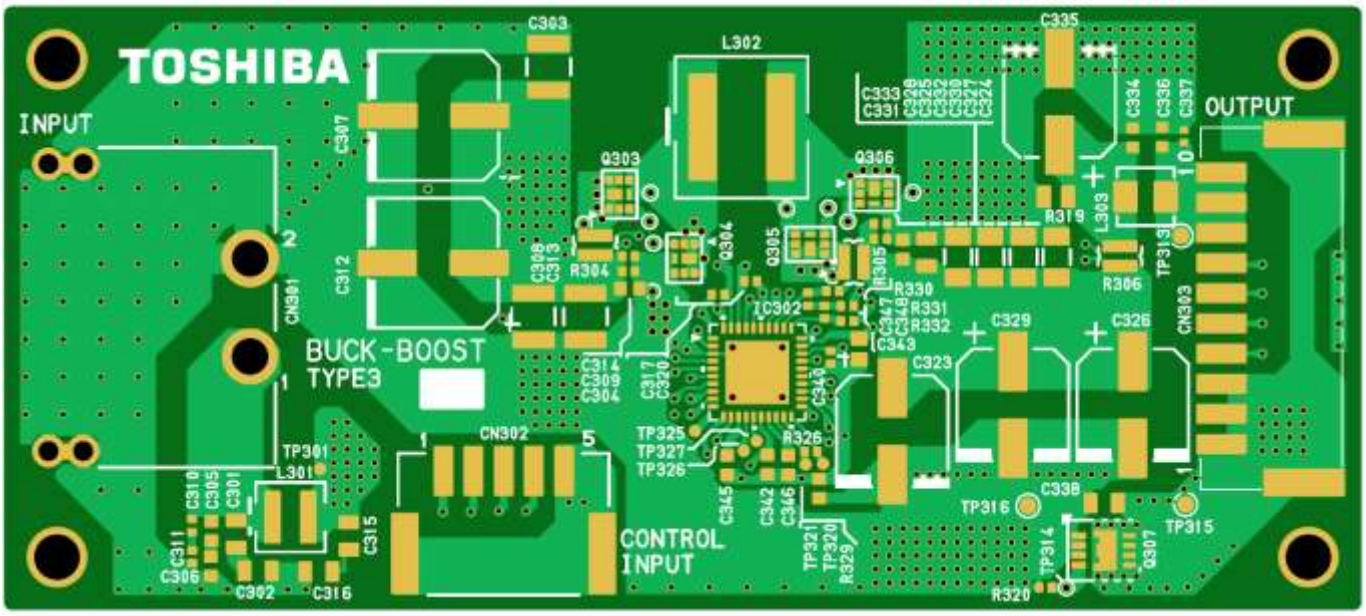


<Front>

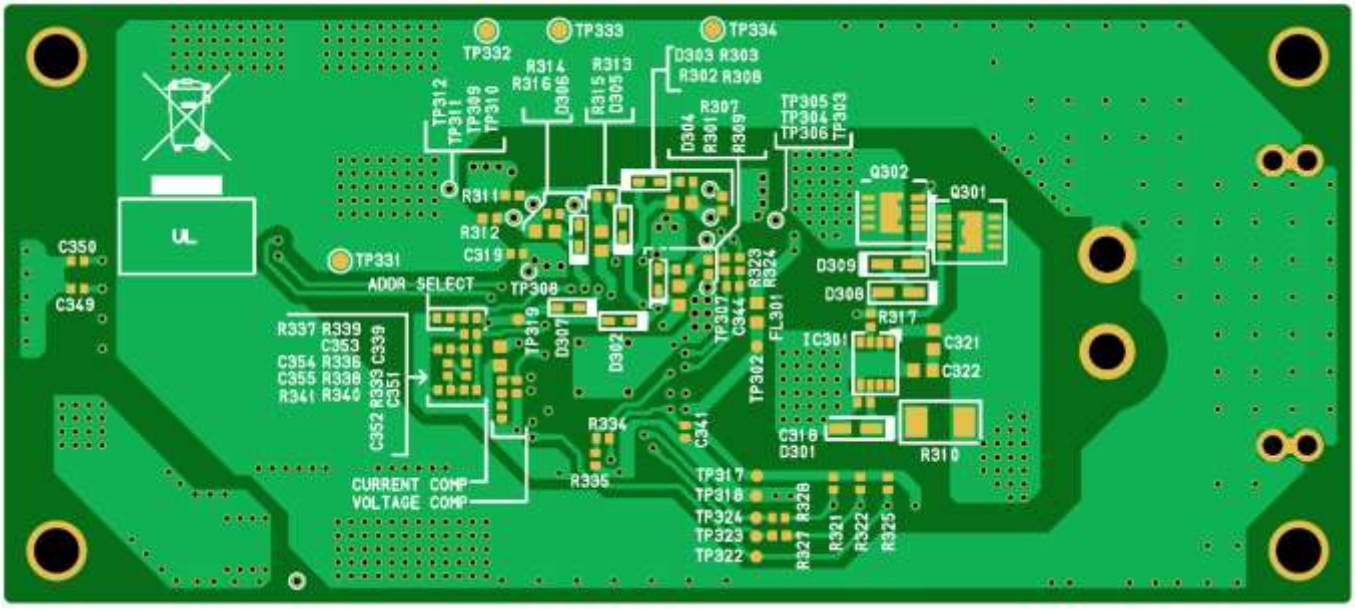


<Back>

Fig. 2.4 Main Component Layout (Option 1)



<Front>



<Back>

Fig. 2.5 Main Component Layout (Option 2)

3. Schematic, Bill of Material, and PCB Pattern

3.1. Schematic

Refer to the following files:

RD227-SCHEMATIC1-xx.pdf (optional 1, using XPN7R104NC)

RD227-SCHEMATIC2-xx.pdf (optional 2, using XSM6K519NW)

(xx is the revision number.)

3.2. Bill of Material

Refer to the following files:

RD227-BOM1-xx.pdf (optional 1, using XPN7R104NC)

RD227-BOM2-xx.pdf (optional 2, using XSM6K519NW)

(xx is the revision number.)

3.3. PCB Pattern

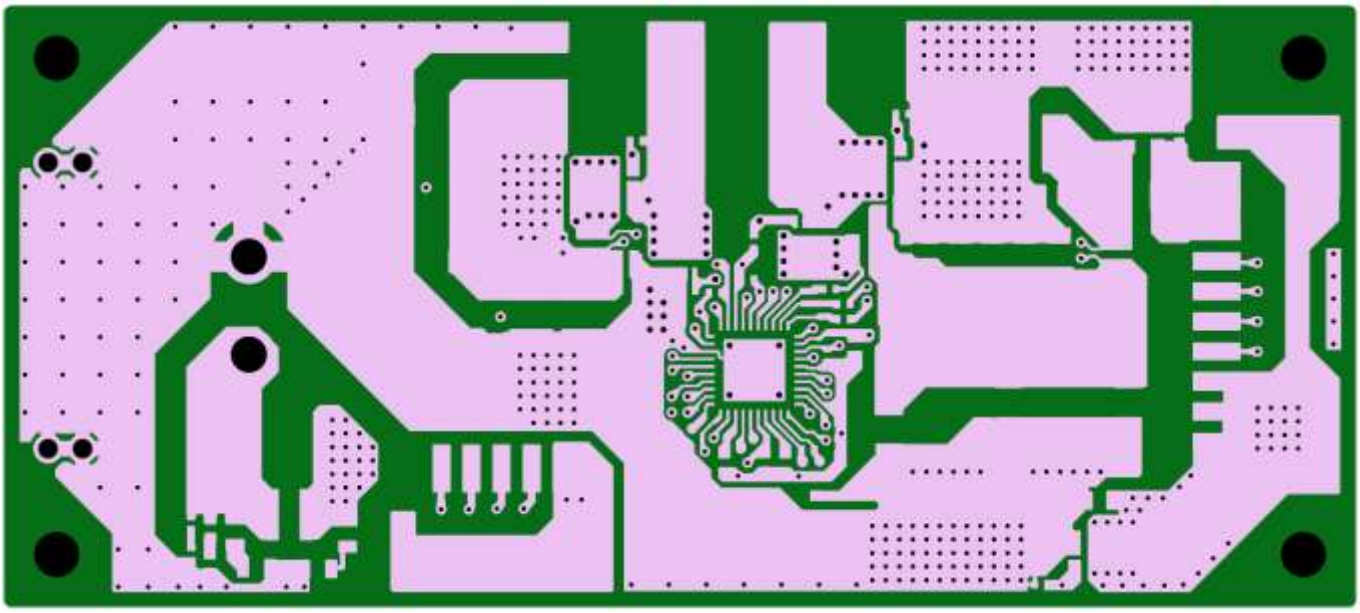
Fig. 3.1 and Fig. 3.2 show the PCB pattern of this power supply.

Also, refer to the following files:

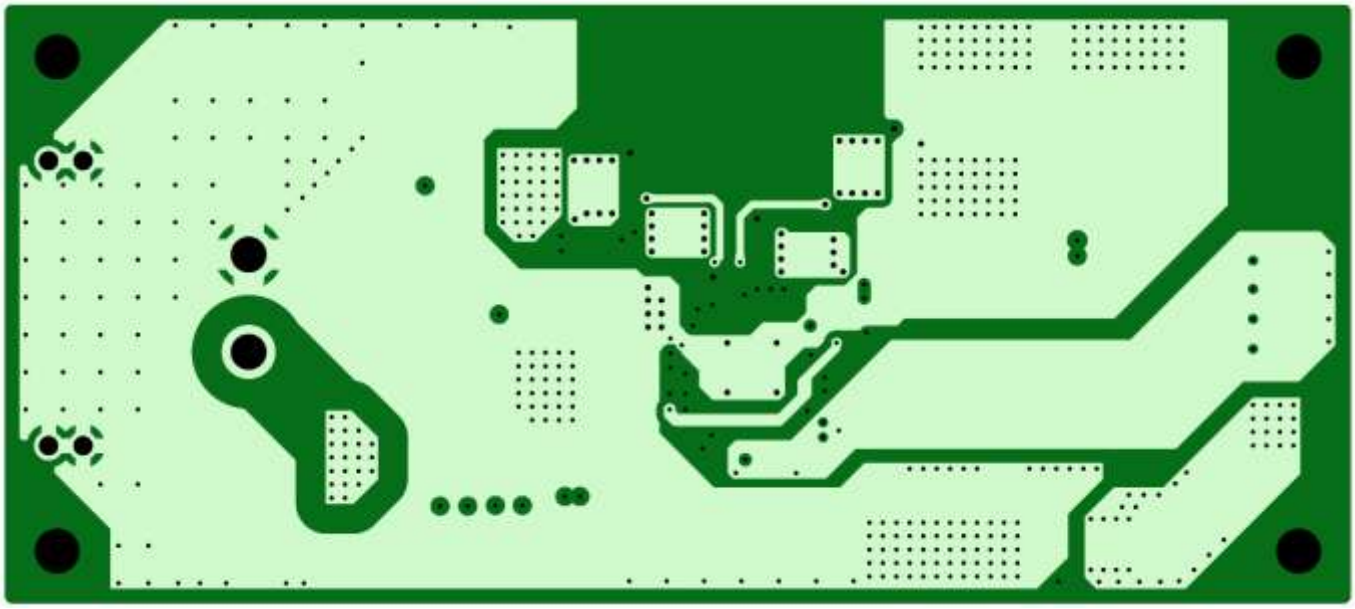
RD227-LAYER1-xx.pdf (optional 1, using XPN7R104NC)

RD227-LAYER2-xx.pdf (optional 2, using XSM6K519NW)

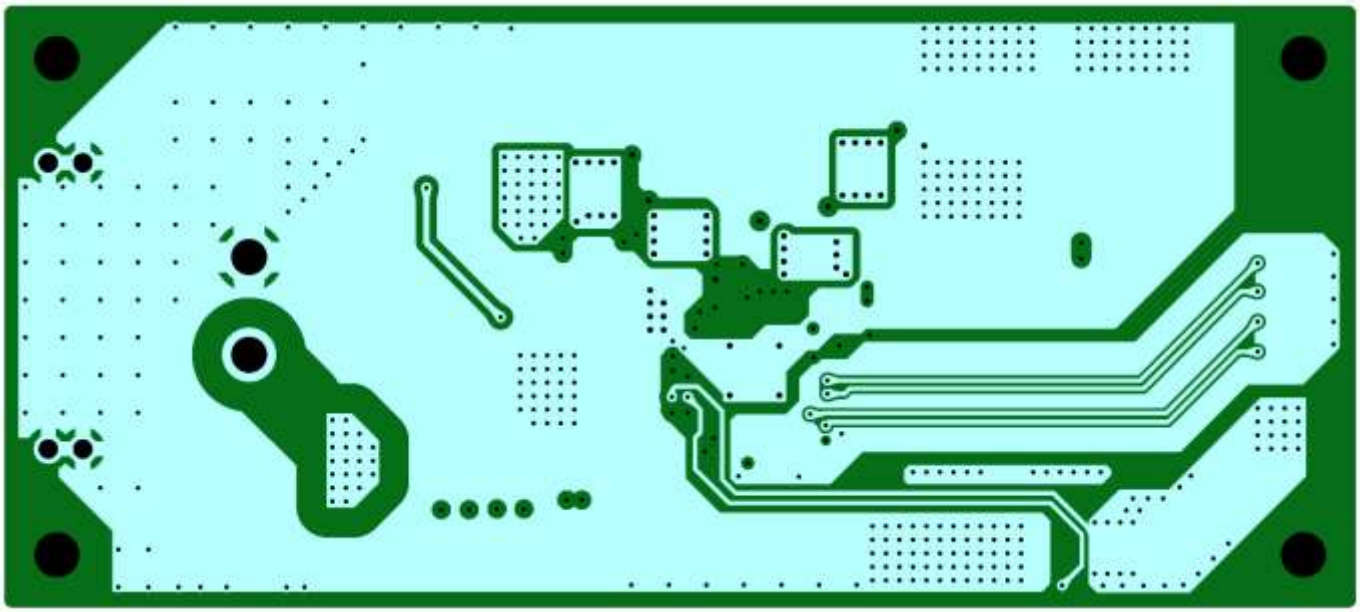
(xx is the revision number.)



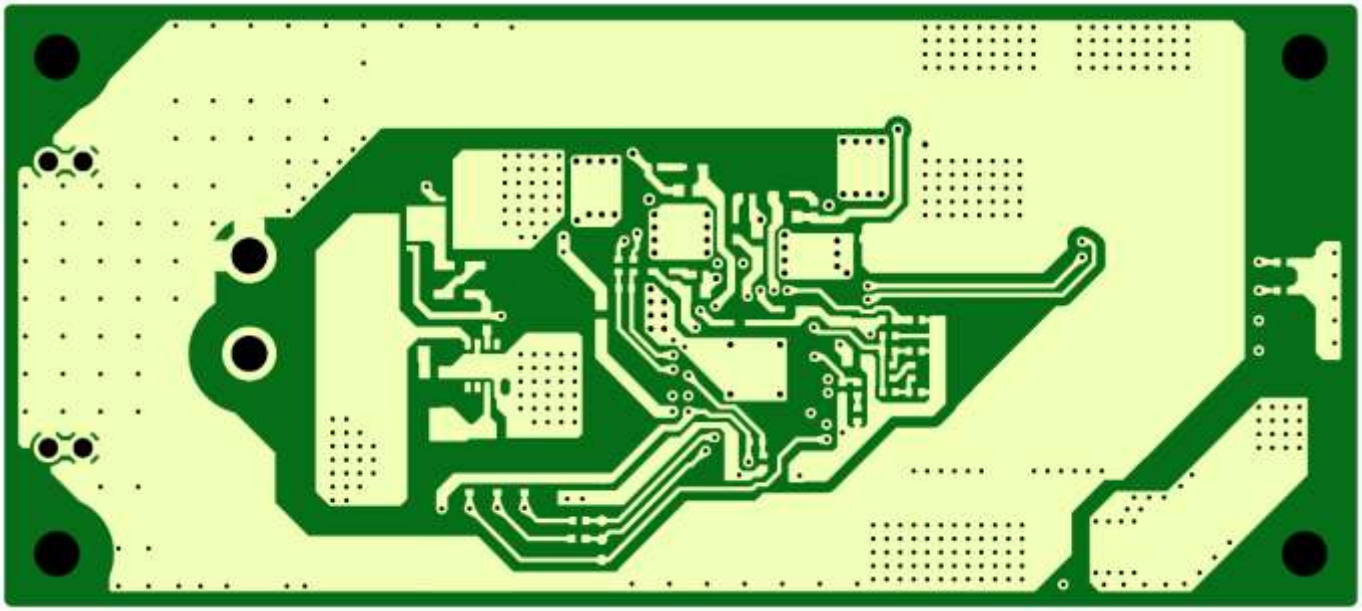
<Layer 1 Front>



<Layer 2>

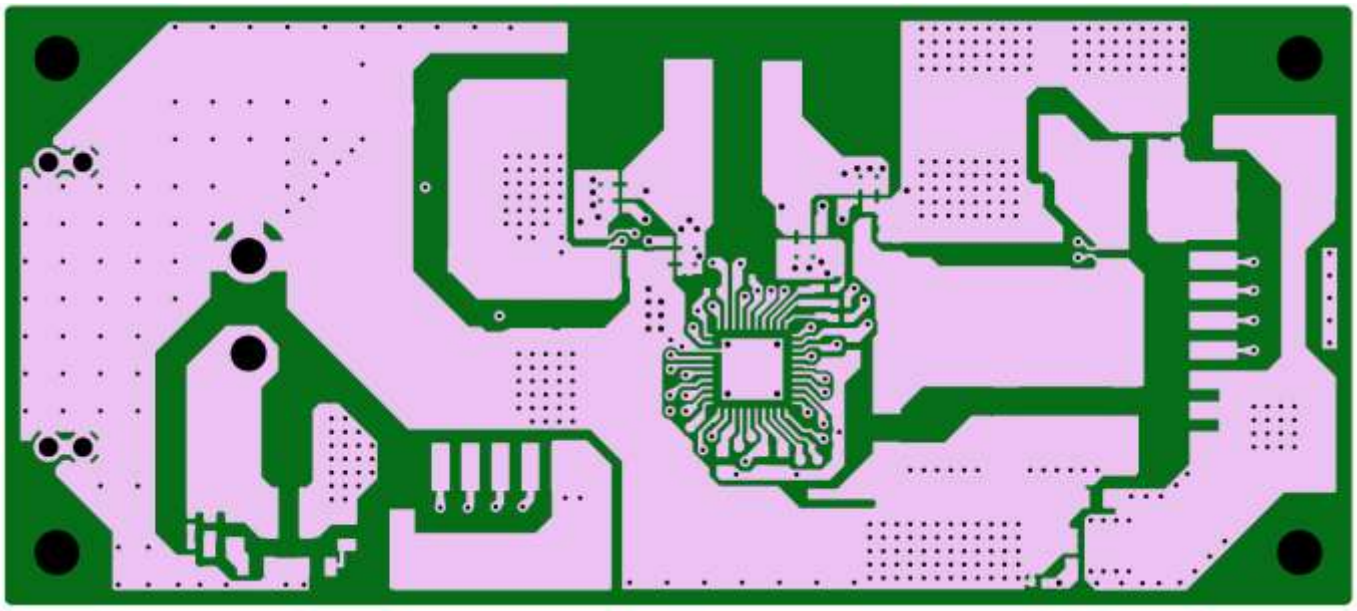


<Layer 3>

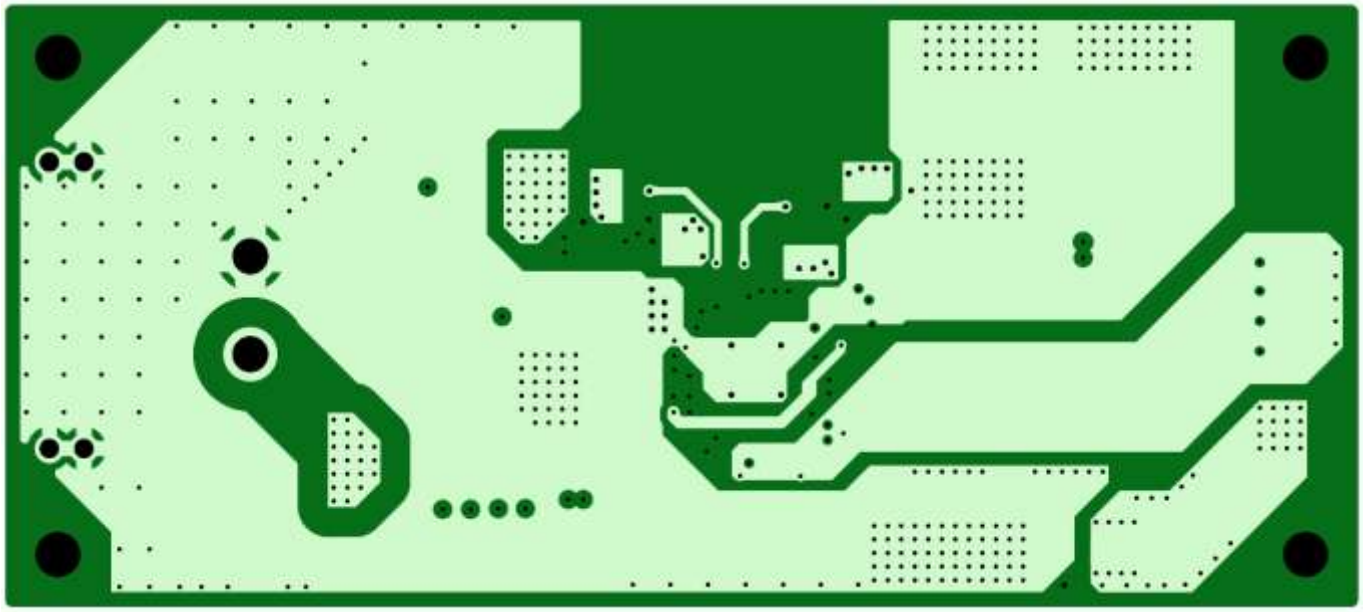


<Layer 4 Back>

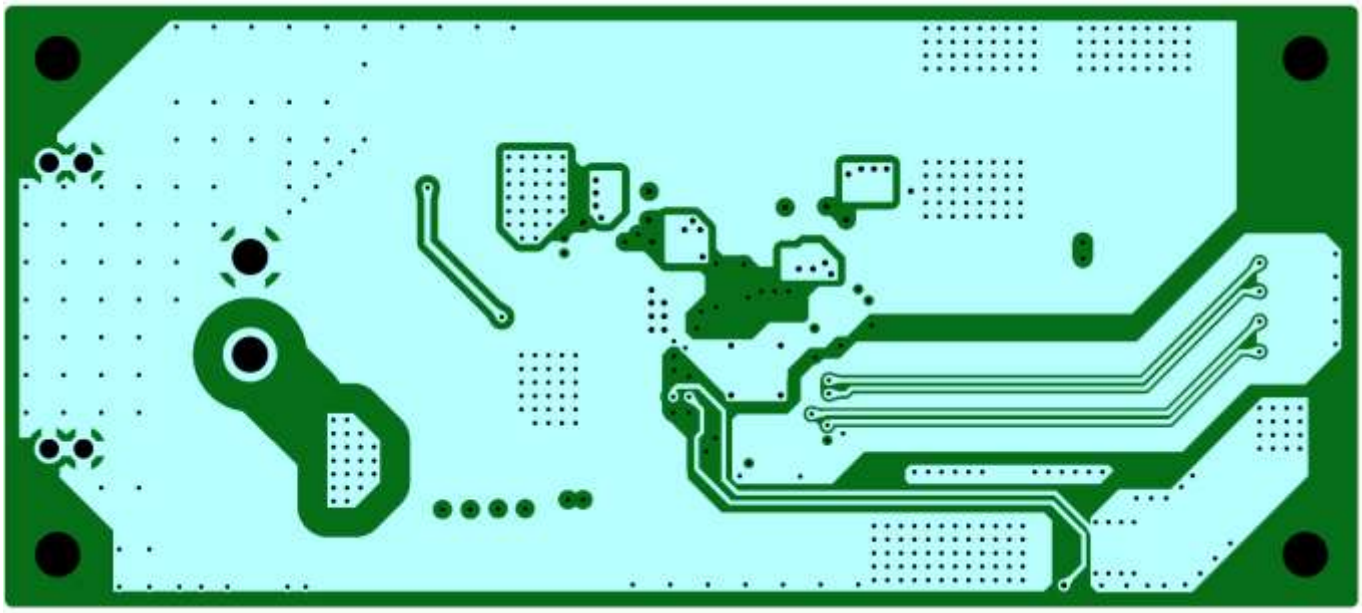
Fig. 3.1 PCB Pattern (Front View) (Option 1)



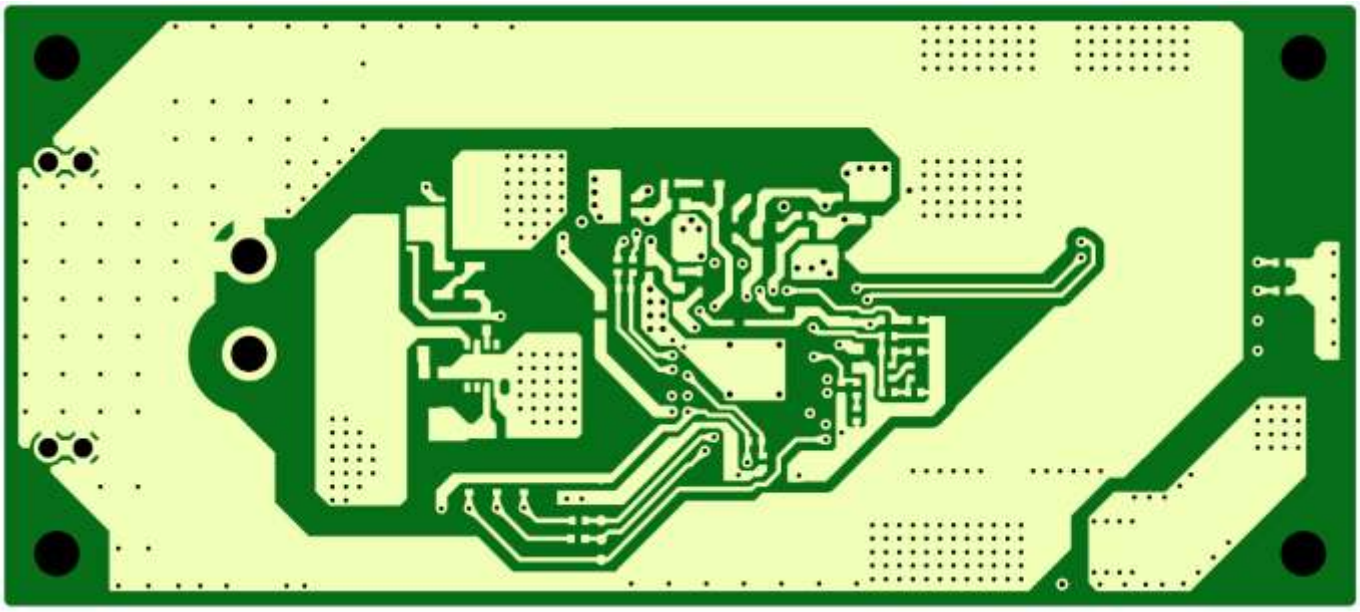
<Layer 1 Front>



<Layer 2>



<Layer 3>



<Layer 4 Back>

Fig. 3.2 PCB Pattern (Front View) (Option 2)

4. Operation

4.1. Name and Function of Components

4.1.1. Power Input Connector (CN101, CN201)

This connector is used to input power. HVH-280-2P-6.5DS (Hirose) is being used.

Fig. 4.1 Power Input Connector

Table 4.1 Power Input Connector Specifications

Pin	Net name	Description
1	VIN	Power input (+)
2	GND_P	Power Input (-)

4.1.2. Power Output Connector (CN103, CN203)

This connector is used to output power. 502352-1000 (Molex) is being used. To control the power with USB Power Delivery, connection to the specified terminal of the external USB Type-C® connector is required.

Fig. 4.2 Power Output Connector

Table 4.2 Power Output Connector Specifications

Pin	Net name	Description
1	SHLD_SNS	Power Output (-)
2		
3		
4	HVDP	Connect to USB Type-C® connector D+ terminal
5	HVDM	Connect to USB Type-C® connector D- terminal
6	HVCC2	Connect to USB Type-C® connector CC2 terminal
7	HVCC1	Connect to USB Type-C® connector CC1 terminal
8	VBUS	Power Output (+)
9		
10		

4.1.3. Host Connector (CN102, CN202)

It is used to connect to a host such as an external MCU. 502352-0501 (Molex) is being used. It connects I^2C interface between the host and the controller mounted on the power supply. I^2C address defaults to 50 (hexadecimal), but I^2C address can be changed by setting the resistor on the board. A control power supply (3.3 V or 5 V) is required to operate the controller installed in this power supply.

Fig. 4-3 Host Connector

Table 4-3 Host Connector Specifications

Pin	Net name	Description
1	VDD	Control power (3.3 V or 5.5 V)
2	ALERT	Error signal output (L output at error)
3	SCL	I2C Clock-Signal Input (SCL)
4	SDA	I2C Input/Output (SDA)
5	GND_A	Control Power/Signal Ground

4.2. Operation Checking Procedure

4.2.1. Preparation

Connect a host device to the host connector. A host device could be a MCU board that controls the controller mounted on this power supply. For details, refer to the data sheet of the installed controller. Connect the battery or other input power to the power input connector. Connect USB Type-C® connector to the power output connector.

4.2.2. Operation Procedure

Apply control power (3.3 V or 5 V) to pin 1 of the host connector. Initialize the controller mounted on this power supply from the host. By connecting a USB Power Delivery load device (Sink Device) to USB Type-C® connector connected to the power output connector, the power is controlled by USB Power Delivery and the required power is supplied to the load device.

4.2.3. Operation During Error Detection

When the controller mounted on this power supply detects an error, the ALERT (pin 2) of the host connector is set to low.

4.3. Precautions (To Prevent Electric Shock, Burn Injury, etc.)

Pay special attention to the following when operating.

- Make sure the polarity of the connector is correct before supplying power.
- When checking the operation, cover the BOARD with an acrylic case for safety.
- MOSFET and other components generate heat during operation. Some components of the circuit board contain high voltage. Be very careful of burns and electric shocks when handling the circuit board.

Common Precautions for Evaluation

Please read and follow the precautions below to ensure safe evaluation work.

● Precautions for Electric Shock Prevention

- Before applying power, **confirm that the polarity of connectors, terminals, and wiring is correct**.
- Some parts of the board may be exposed to high voltage. **Do not touch the board or components while power is applied**.
- Even after the power is turned off, capacitors may retain residual charge. **Ensure that all capacitors are fully discharged before touching the board**.
- When measuring voltage or current waveforms, **take sufficient precautions to avoid electric shock and maintain a safe distance**.

● Precautions for Burn Prevention (High-Temperature Components)

- MOSFETs, diodes, inductors, coils, and semiconductor devices may become **very hot during operation**. Handle them carefully to avoid burns.
- Under high load conditions, heat generation increases. **Use appropriate cooling (such as fans)**.
- Component temperatures may remain high immediately after power-off. **Allow sufficient cooling time before touching**.

● Precautions for the Evaluation Environment

- During operation checks, implement safety measures such as **covering the board with a non-conductive enclosure** if necessary **(e.g., acrylic case)**.
- When using motors or other moving parts, **take measures to prevent contact during operation**.
- For designs with shunt or jumper settings, **verify that the settings are correct before operation**.

● Other Precautions

- Loads connected to output terminals may generate heat. **Pay attention to load temperature rise**.
- Keep flammable and conductive materials away during evaluation to **avoid short circuits and accidents**.

Terms of Use

This terms of use is made between Toshiba Electronic Devices and Storage Corporation (“We”) and Customer who downloads or uses this Reference Design. Customer shall comply with this terms of use. This Reference Design means all documents and data in order to design electronics applications on which our semiconductor device is embedded.

Section 1. Restrictions on usage

1. This Reference Design is provided solely as reference data for designing electronics applications. Customer shall not use this Reference Design for any other purpose, including without limitation, verification of reliability.
2. Customer shall not use this Reference Design for sale, lease or other transfer.
3. Customer shall not use this Reference Design for evaluation in high or low temperature, high humidity, or high electromagnetic environments.
4. This Reference Design shall not be used for or incorporated into any product or system whose manufacture, use, or sale is prohibited under any applicable laws or regulations.
5. This Reference Design shall not be used in any manner that is contrary to the precautions specified by us.

Section 2. Limitations

1. We reserve the right to make changes to this Reference Design without notice.
2. This Reference Design should be treated as a reference only. WE ARE NOT RESPONSIBLE FOR ANY INCORRECT OR INCOMPLETE DATA AND INFORMATION.
3. Semiconductor devices can malfunction or fail. When designing electronics applications by referring to this Reference Design, Customer is responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of semiconductor devices could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Customer must also refer to and comply with the latest versions of all relevant our information, including without limitation, specifications, data sheets and application notes for semiconductor devices, as well as the precautions and conditions set forth in the "Semiconductor Reliability Handbook".
4. Designing electronics applications by referring to this Reference Design, Customer must evaluate the whole system sufficiently. Customer is solely responsible for applying this Reference Design to Customer's own product design or applications. WE ASSUME NO LIABILITY FOR CUSTOMER'S PRODUCT DESIGN OR APPLICATIONS.
5. WE SHALL NOT BE RESPONSIBLE FOR ANY INFRINGEMENT OF PATENTS OR ANY OTHER INTELLECTUAL PROPERTY RIGHTS OF THIRD PARTIES THAT MAY RESULT FROM THE USE OF THIS REFERENCE DESIGN. NO LICENSE TO ANY INTELLECTUAL PROPERTY RIGHT IS GRANTED BY THIS TERMS OF USE, WHETHER EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE.
6. THIS REFERENCE DESIGN IS PROVIDED "AS IS". WE (a) ASSUME NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (b) DISCLAIM ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO THIS REFERENCE DESIGN, INCLUDING WITHOUT LIMITATION, WARRANTIES OR CONDITIONS OF FUNCTION AND WORKING, WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

Section 3. Terms and Termination

It is assumed that Customer agrees to any and all this terms of use if Customer downloads or uses this Reference Design. We may, at its sole and exclusive discretion, change, alter, modify, add, and/or remove any part of this terms of use at any time without any prior notice. We may terminate this terms of use at any time and without any cause. Upon termination of this terms of use, Customer shall eliminate this Reference Design. Furthermore, upon our request, Customer shall submit to us a written confirmation to prove elimination of this Reference Design.

Section 4. Export Control

Customer shall not use or otherwise make available this Reference Design for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). This Reference Design may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Act and the U.S. Export Administration Regulations. Export and re-export of this Reference Design is strictly prohibited except in compliance with all applicable export laws and regulations.

Section 5. Governing Laws

This terms of use shall be governed and construed by laws of Japan, without reference to conflict of law principle.

Section 6. Jurisdiction

Unless otherwise specified, Tokyo District Court in Tokyo, Japan shall be exclusively the court of first jurisdiction for all disputes under this terms of use.