# Bidirectional USB Type-C 100W PD Reference Design

**Hynetek Semiconductor Co., Ltd.** **RD-2011**

## FEATURES

- USB Type-C port support Power Delivery (PD) Dual-Role
- Single USB Type-C port support charging or discharging mode
- Attach/Detach Detection as Host, Device or DRP
- Support dead battery mode
- Seamless transition among Buck, Buck-boost and Boost operation
- Low Quiescent Current
- Comprehensive power path management and protection
- Flexible monitoring and configuration via $I^2C$ interface

## APPLICATIONS

- Power tools
- Smart speakers
- Portable electronics
- Internet of Things (IoT) devices
- Handsets
- Power bank
- Industrial applications

## GENERAL DESCRIPTION

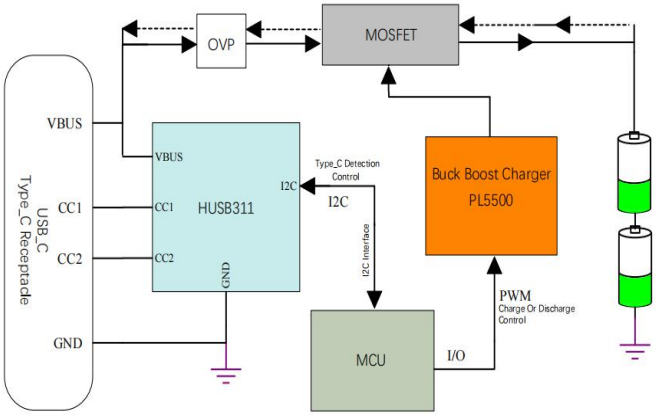
This reference design includes a highly integrated USB PD DRP controller HUSB311, a Buck-boost charger PL5500, and a MCU module. This reference design can support charging or discharging of a single USB Type-C port 100W PD. The HUSB311 negotiates with a USB PD power adapter (PD source) or a USB Type C port device (PD sink). It can be set as host, device or DRP. This reference supports charging 1-6 cell batteries, also supports PD power up to 100W discharge function which depends on the battery string number and capacity. Through the $I^2C$ interface, the PD negotiation can be set up. The Vbus voltage, the battery voltage, the battery charging current and component temperature can be monitored in real time.

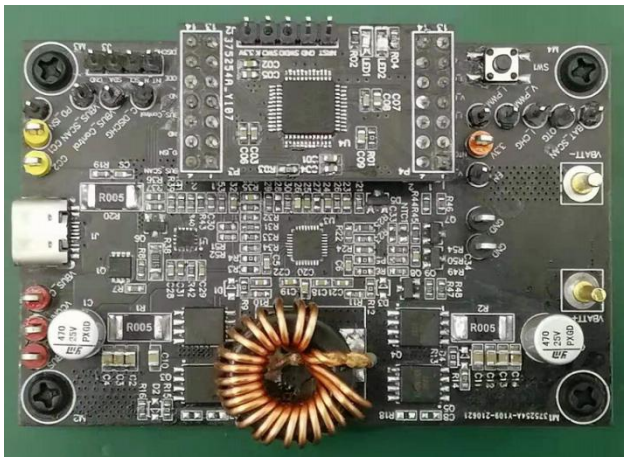
## DESIGN RESOURCES

HUSB311

PL5500

## APPLICATION BLOCK DIAGRAM AND EVB FIGURE



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# INTRODUCTION

This reference design is a power management solution with MCU, PD PHY HUSB311 and a buck-boost charger PL5500, which features PD 100W fast charging and discharging function through a single USB Type-C port.

The PD PHY HUSB311 with the MCU build a Type-C port manager, also called TCPM. Due to the TCPM, this EVB can automatically switch its role as host, device or DRP according to the type of the electronic product that the USB Type-C accesses. According to the number of battery strings and battery capacity used by the user, this evaluation board can achieve up to 100W PD fast charging and discharging function, which is very suitable for power bank or power tool applications.

Furthermore, both the HUSB311 and the PL5500 integrate $I^2C$ interfaces as slave devices. The monitoring and advanced configurations can be achieved through the microprocessor communicating via the $I^2C$ interface, such as monitoring of the source capacity of PD power source, the negotiated PDO through the HUSB311. With $I^2C$ interface of the PL5500, the PL5500 can be flexibly programmed the charging parameters, such as input current limit, input voltage limit, charging current, battery full regulation voltage and so on. It can also provide the status and faults in operation through registers.

## DESIGN SPECIFICATIONS

The reference design shows how a USB Type-C PD DRP controller combined with a battery charge management system can efficiently charge 1-6 cell batteries or discharge the laptop or mobile phone with a large-capacity battery pack . This design can be used for power tools, IoT devices, power banks and portable electronics. The biggest advantage of this reference design is that, with USB PD negotiation, it can achieve PD 100W fast charging and discharging function through a single USB Type-C port.

**Table1.**

| PARAMETER | SPECIFICATIONS | DETAILS |
|---|---|---|
| EVB USB Type-C as sink | | |
| PD sink capabilities | 5V-20V | VBUS from USB Type-C input |
| Cell configurations | 1 cell - 6 cells | Battery cell number |
| Charge current | Up to 5A, up to 100W | Battery charging power |
| EVB USB Type-C as source | | |
| PD source capabilities | 5V3A, 9V3A, 12V3A, 15V3A, 20V3.25A | VBUS from USB Type-C output |
| Cell configurations | 4-6 cells (recommend) | Battery cell number |
| Discharge current | Up to 5A, up to 100W | Battery discharging power |

# DESIGN OVERVIEW

## BLOCK DIAGRAM

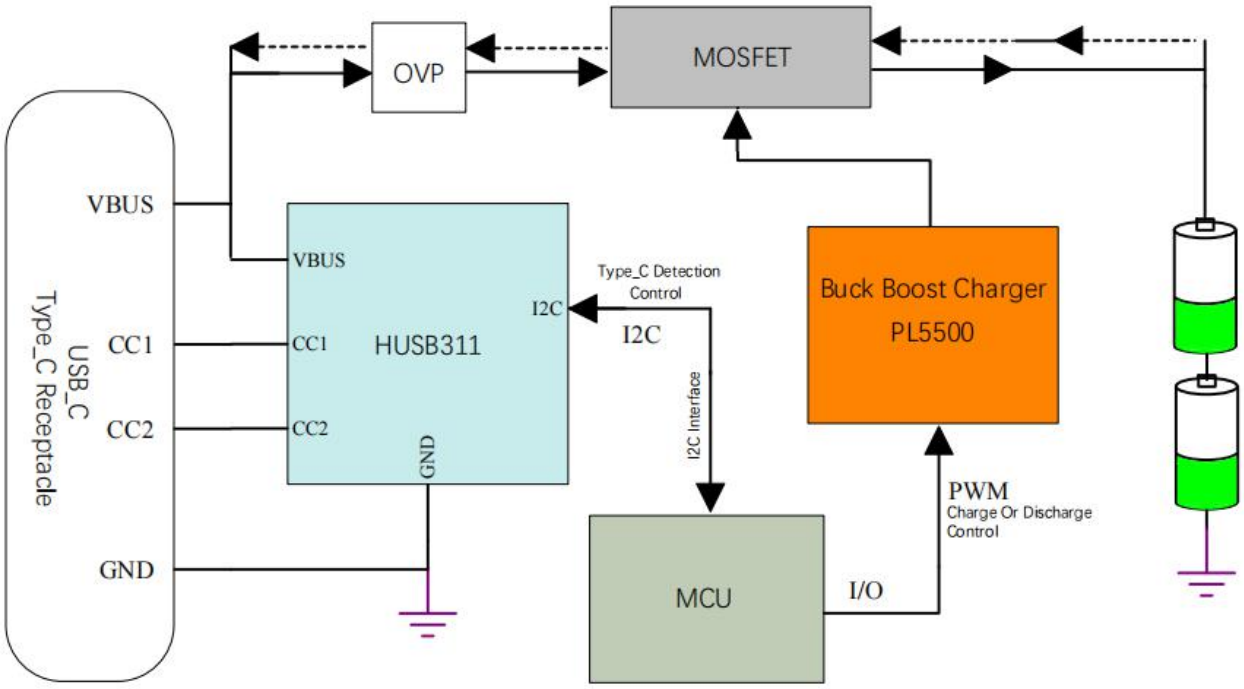



*Figure 1. RD-2011 Application Block Diagram*

## KEY PRODUCTS

### HUSB311 – USB Type-C PD Controller

The HUSB311 is a USB Type-C controller that complies with the latest USB Type-C and PD standards. The HUSB311 integrates a complete Type-C Transceiver including the Rp and Rd resistors. It does the USB Type-C detection including attach and orientation. The HUSB311 integrates the physical layer of the USB BMC power delivery protocol to allow up to 100W of power and role swap. The BMC PD block enables full support for alternative interfaces of the Type-C specification.

Key features of HUSB311:

- Dual-Role PD Compatible
- Attach/Detach Detection as Host, Device or DRP
- Current Capability Definition and Detection
- Cable Recognition
- VCONN Support
- Dead Battery Support
- Ultra-low Power Mode for Attach Detection
- Simple I2C Interface with AP or EC
- BIST Mode Supported
- e-fuse IP
- 9-Ball WL-CSP and 14-Lead QFN Packages
- Two I2C addresses

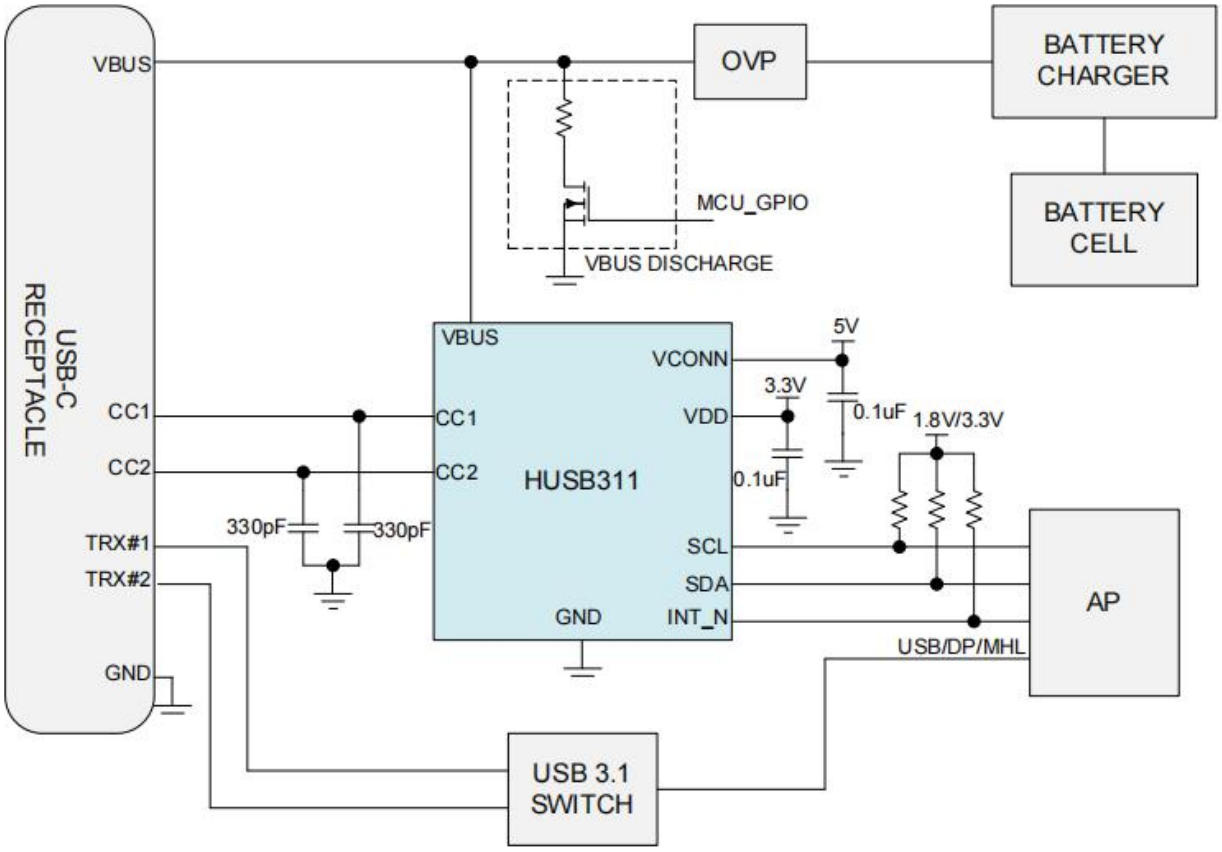



*Figure 2. HUSB311 Typical Application Circuit*

## PL5500 – Buck-boost Battery Charger

The PL5500 is a synchronous 4-switch bidirectional Buck-Boost controller capable of regulating the output voltage at, above, or below the input voltage. PL5500 operates over a wide input voltage range of 3.0 V to 32 V (36 V maximum) to support a variety of applications. PL5500 can operate at charger mode for 1, 2, 3, 4, 5 and 6 cells battery charge. PL5500 employs Constant ON time control in buck, boost and buck-boost operation modes for superior load and line regulation. The switching frequency could be set to 150kHz, 300kHz, 600kHz or 1200kHz based on different resistor value between FREQ pin and GND pin. The device also features a programmable soft-start function and offers all kinds of protection features including cycle-by-cycle current limiting, input under voltage lockout (UVLO), output over voltage protection (OVP), input Over Voltage Protection, thermal shutdown and output short protection etc. VADJ, IADJ pins are used to program output VBUS voltage and output current limit at battery discharging mode when OTG is high, which makes PL5500 an excellent option for USB Power Deliver (PD) application. PL5500 provides voltage control loop, constant current loop, thermal regulation loop, battery temperature sensing, which makes it a perfect solution for batter charge management.

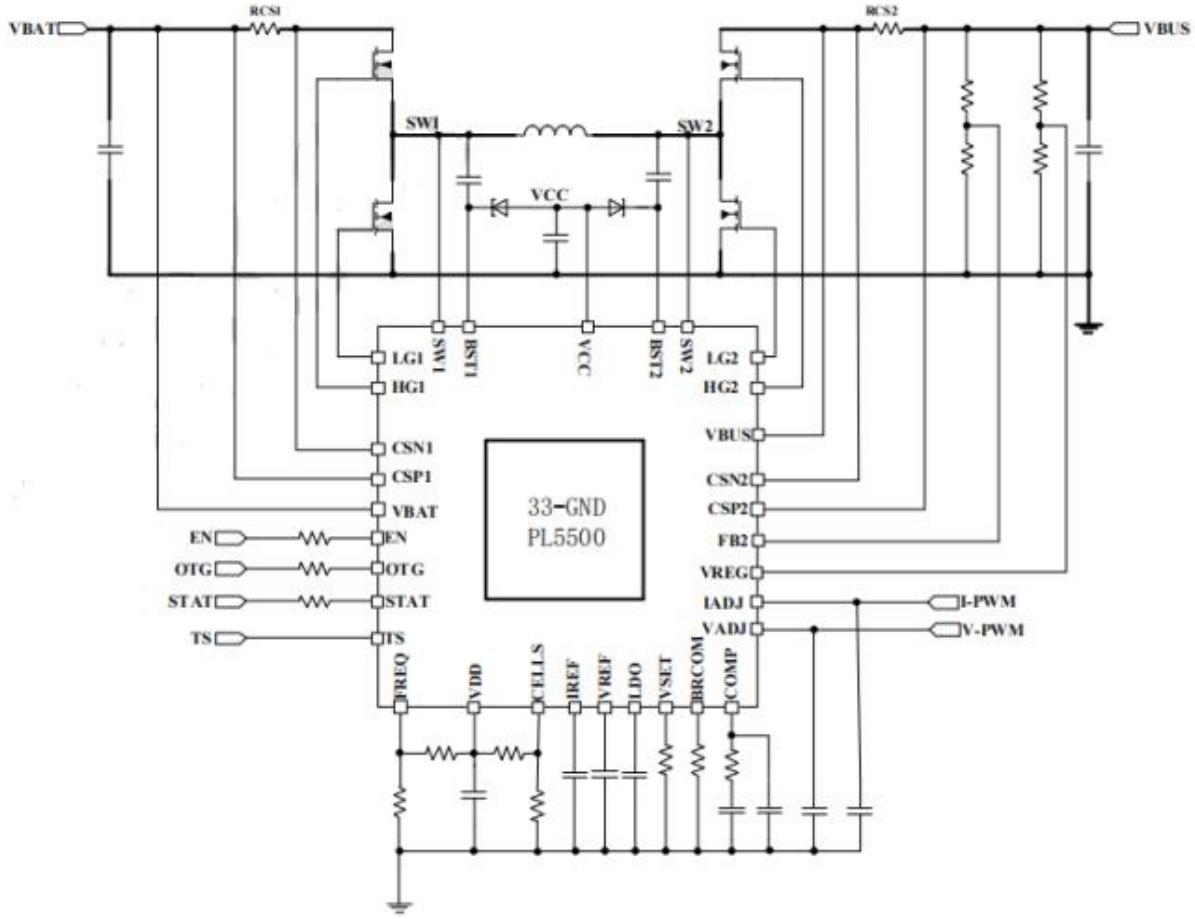



*Figure 3. PL5500 Typical Application Circuit*

# TEST RESULT

## TEST CONDITIONS

Room temperature test condition.

1. EVB USB Type-C as sink role :

Input : Apple 96W PD Adapter or NB-55W PD Adapter.

Output : Select the DC electronic load as CV mode , set the voltage range to the voltage of 4 strings of batteries.

2. EVB USB Type-C as source role :

Input : 4 series of 3000mAh battery pack

Output : Select the DC electronic load as CC mode , set the load current is 2A.

## TEST EQUIPMENT

Oscilloscope Tektronix MDO3024, AC source, Power Meter UTE1010A, DC ELECTRONIC LOAD IT8510, Apple 96W PD Adapter and NB-55W PD Adapter, Power-Z KT001, Battery Pack.

## TEST SETTING

Figure 4 shows the test connection using Apple 96W PD adapter as the power supply, and EVB USB Type-C as sink role.

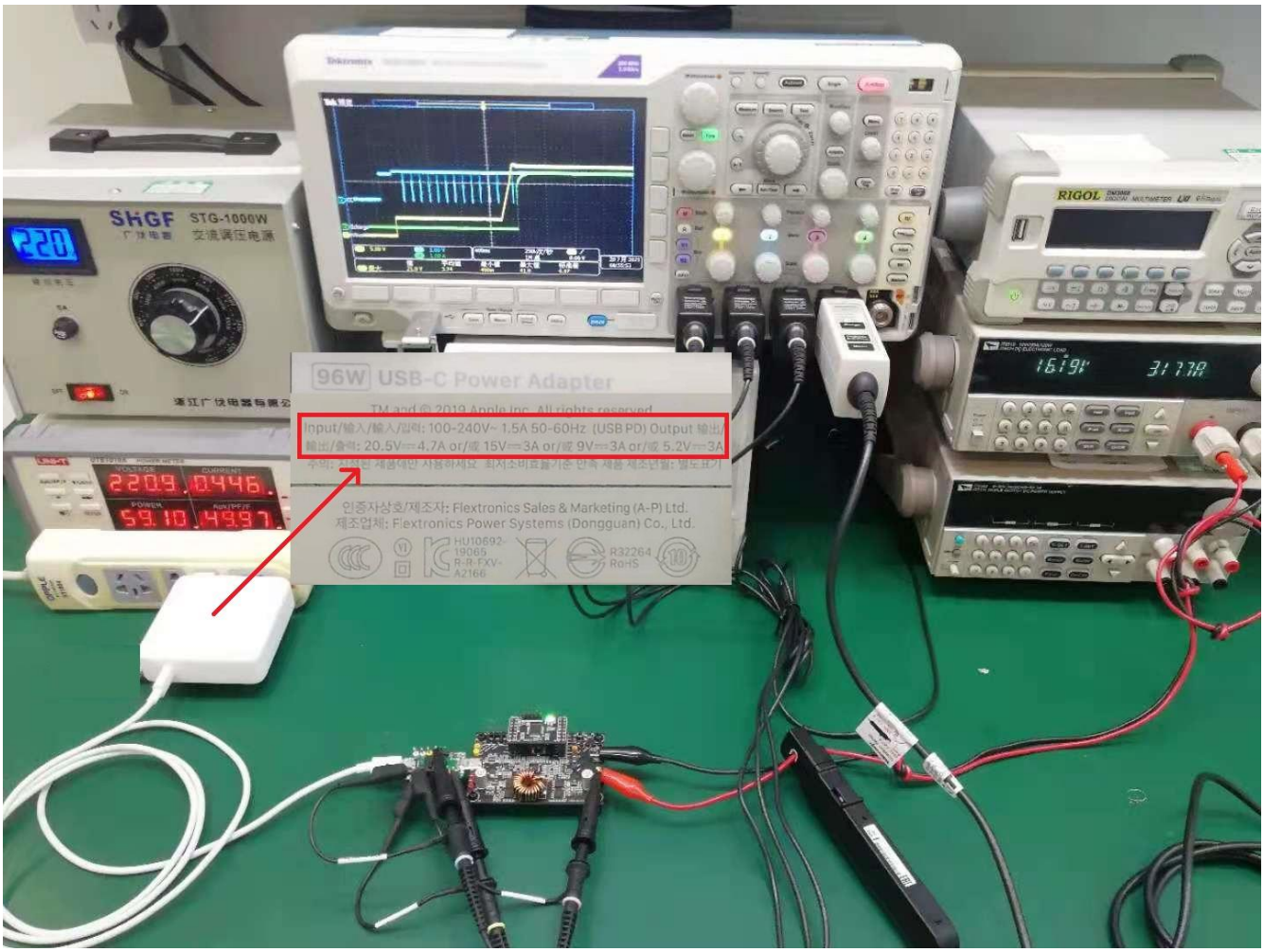



*Figure4. 96W PD input, EVB as sink test connection diagram*

Figure 5 shows the test connection using NB-55W PD adapter as the power supply, and EVB USB Type-C as sink role.

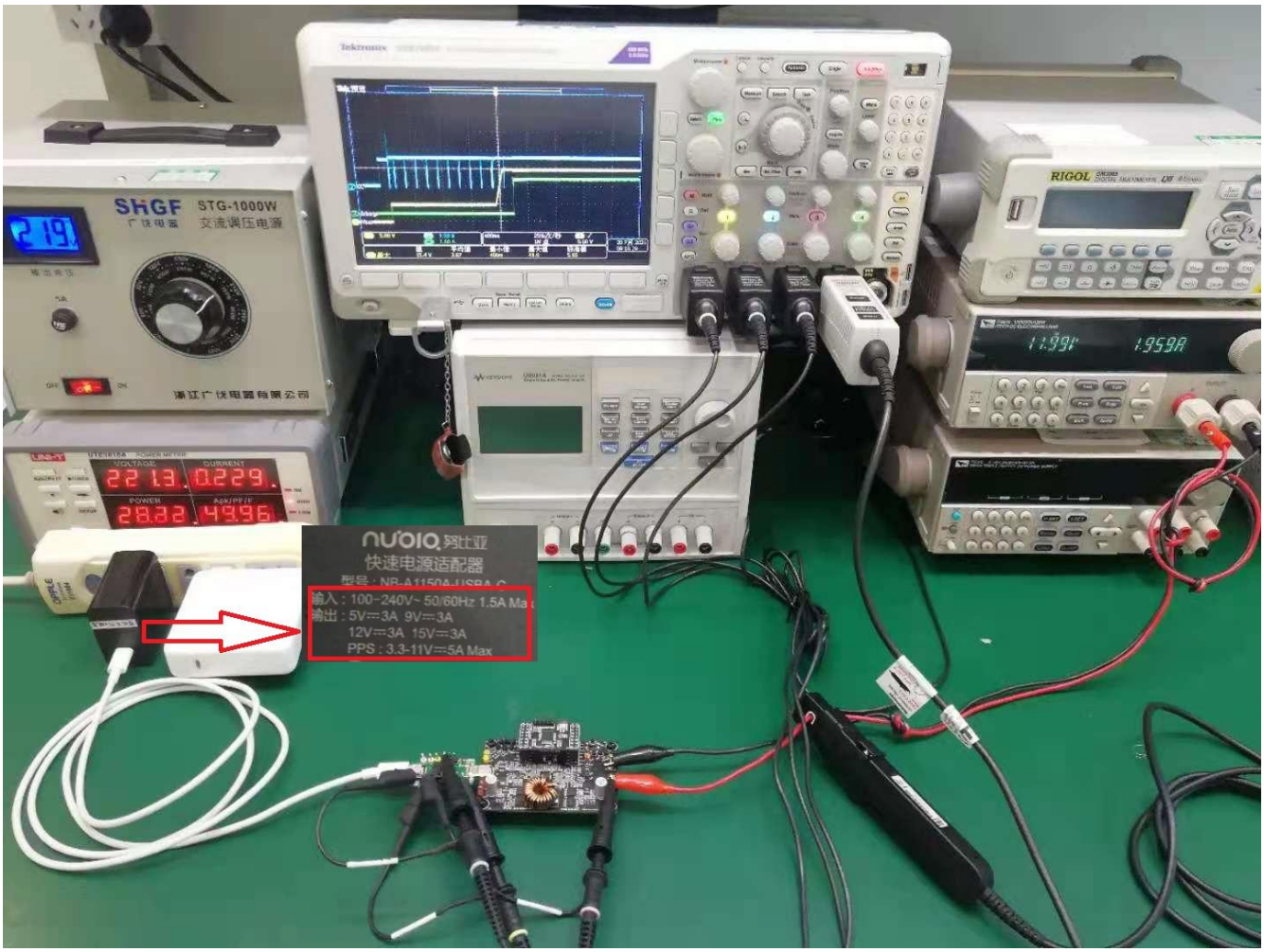



*Figure5. 55W PD input, EVB as sink test connection diagram*

Figure 6 shows the test connection using 4 series battery pack as the power supply, and EVB USB Type-C as source role.

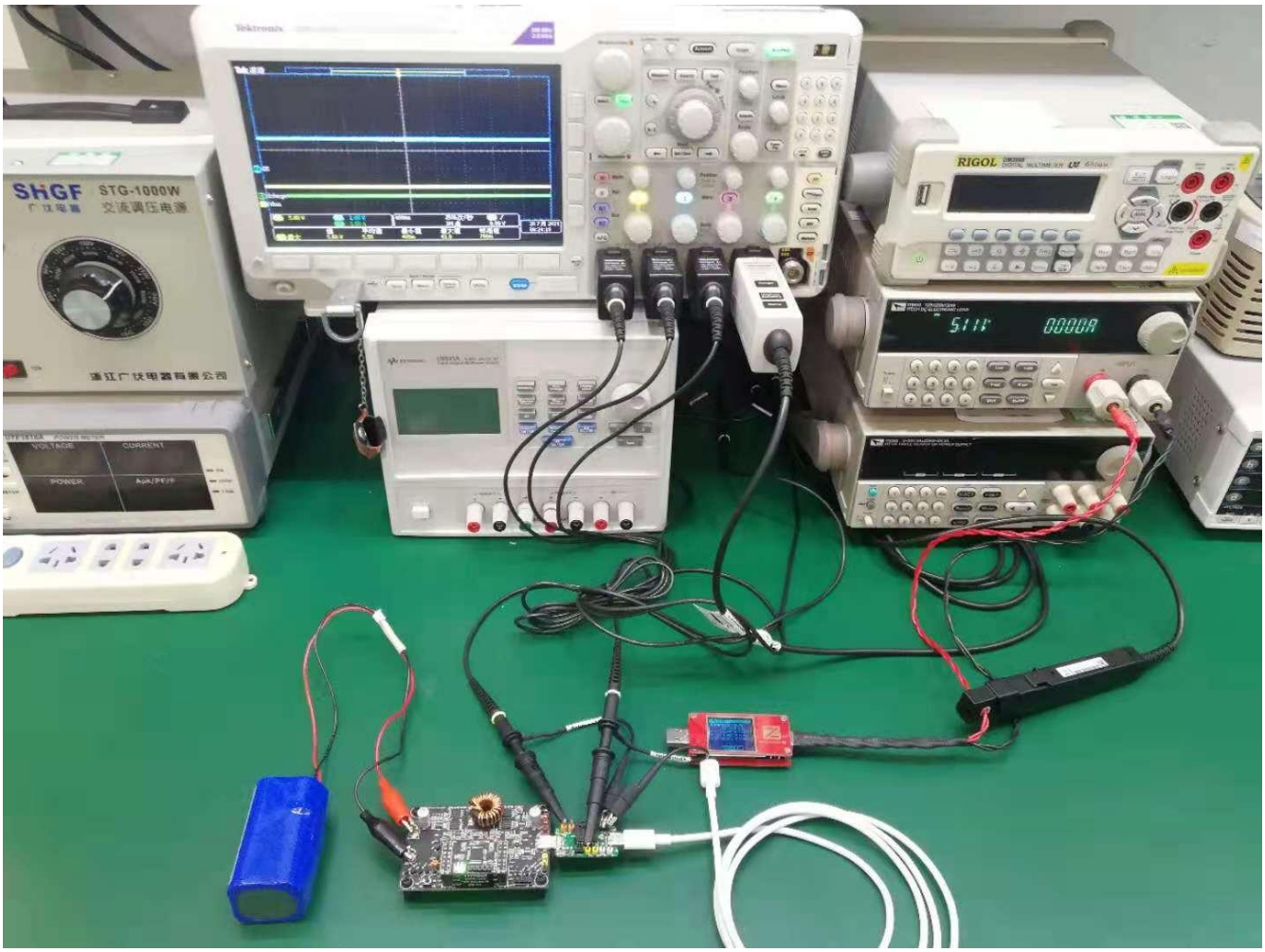



*Figure6. EVB as source test connection diagram*

## TEST PROCESS

EVB USB Type-C as a sink, **the system works in charging mode.**

1. Connect the positive electrode of the DC electronic load to the VBATT+ pin. Connect the negative electrode of the DC electronic load to the VBATT- pin.
2. The USB PD power adapter is connected to the Type-C interface of the EVB through a USB-C cable.
3. Connect the oscilloscope probes to the test points of the VBUS, CC1/2, VBATT respectively. Place the current probe coil on the DC electronic load positive cable.
4. Apply 220V AC power source on the power adapter.
5. Perform the test.

EVB USB Type-C as a source, **the system works in discharging mode.**

6. Connect the positive electrode of the 4 cell batteries to the VBATT+ pin. Connect the negative electrode of the 4 cell batteries to the VBATT- pin.
7. The Power-Z KT001 is connected to the Type-C interface of the EVB through a USB-C cable, and the DC electronic load is connected to the Type-A interface of the Power-Z KT001 through a USB-A cable.

8. Connect the oscilloscope probes to the test points of the VBUS, CC1/2, VBATT respectively. Place the current probe coil on the DC electronic load positive cable.
9. Apply 220V AC power source on the power adapter.
10. Perform the test.

## TEST RESULTS

After the circuit is connected and before the power on, the users should make sure that the MCU module has been programmed with the correct TCPM program. This program includes the PD communication protocol, input and output voltage detection, overvoltage and undervoltage protection mechanisms, input and output current limiting protection mechanisms, and VBUS discharge functions, etc.

When EVB is used as a sink, the mechanism of EVB requesting PDO is to request the highest PDO from the source capability. When we use 96W and 55W PD adapters for power input, HUSB311 requests the highest grade 20V and 15V of the PD adapter to power the system respectively. Figures 7 and 8 show the test results.

When EVB is used as a source, it supports 5V, 9V, 15V and 20V FPDOS, and the total output power up to 100W. We can use Power-Z to switch PDOs, we can see that the voltage switch is very smooth, and the discharge circuit is set at 2A, which is very stable. Figures 9 and 10 show the test results.

In addition, this EVB has a very high conversion efficiency, up to 98%, and very low ripple. This reference design is very suitable for the use of power banks or power tools.

## TEST WAVEFORMS

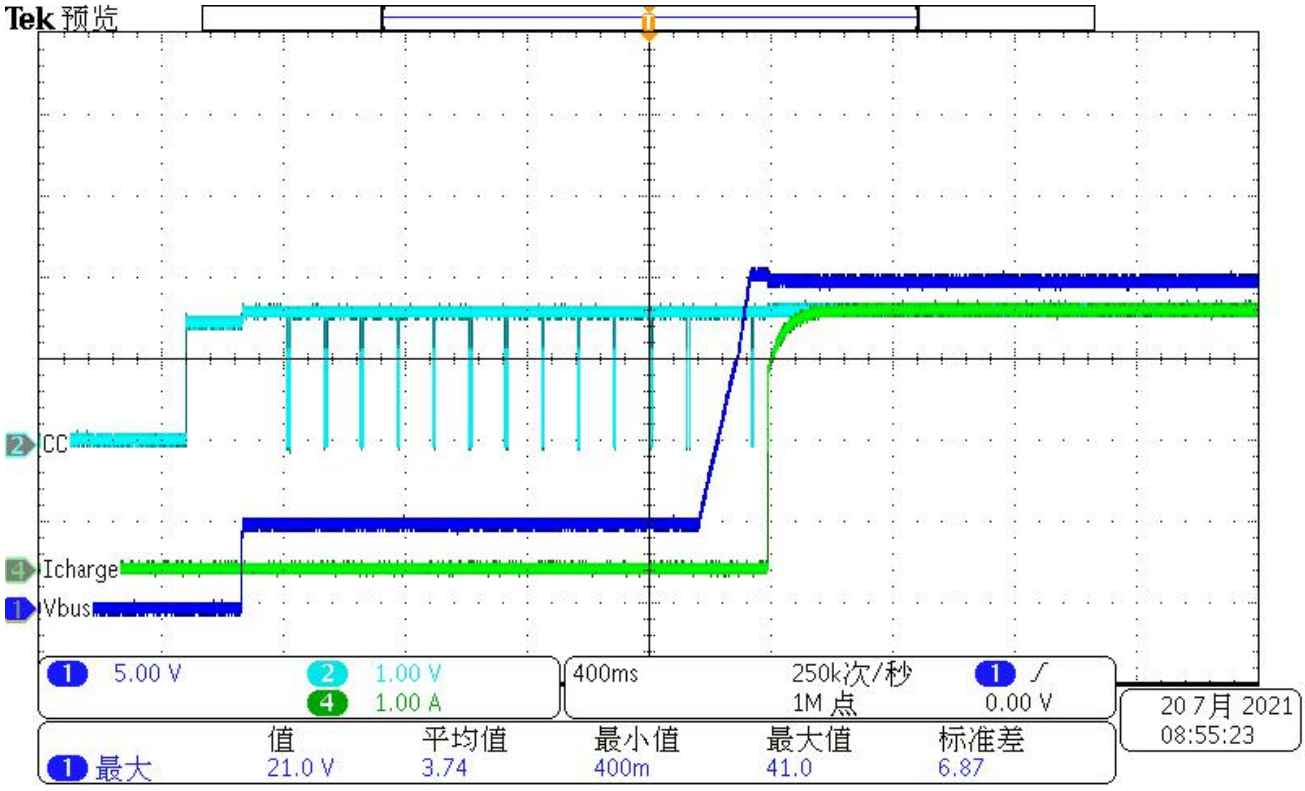



*Figure 7. HUSB311 Request 20V PDO@96W PD input*

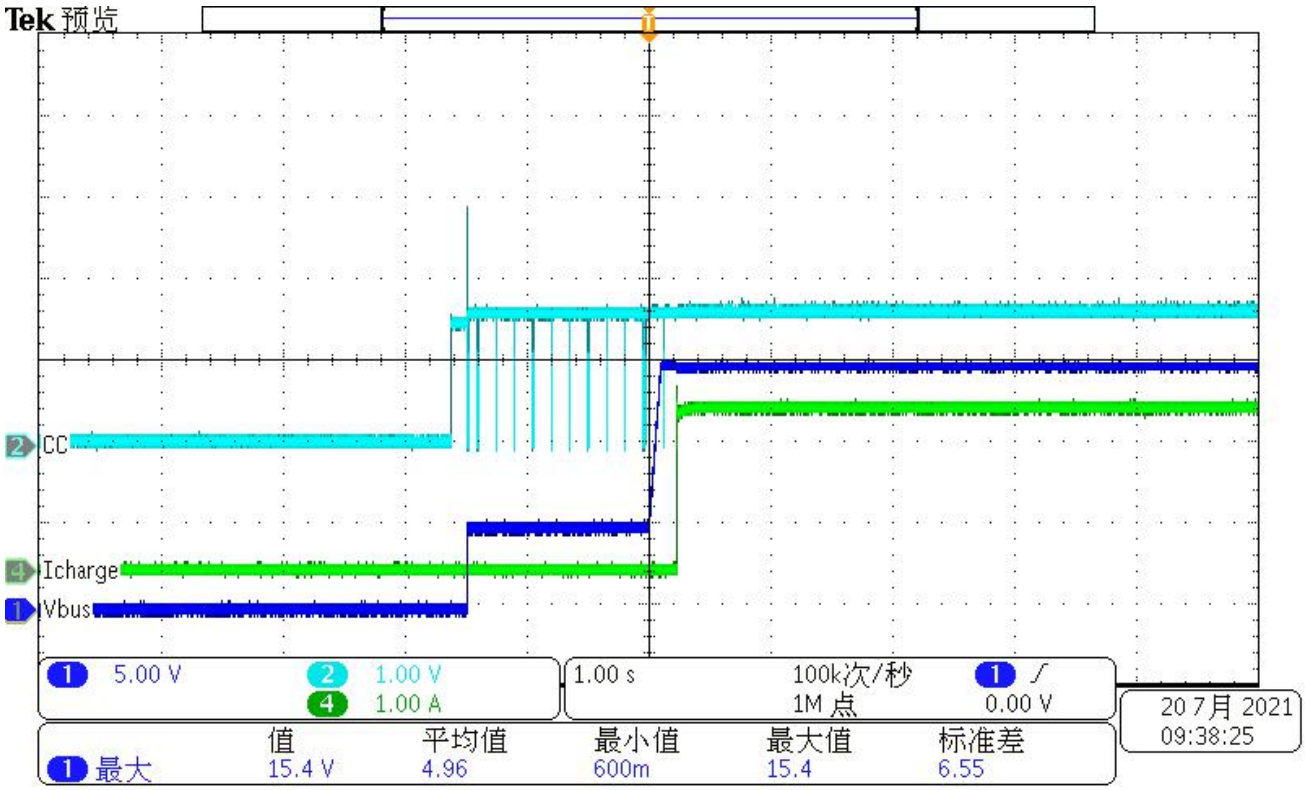



*Figure8. HUSB311 Request 15V PDO@55W PD input*

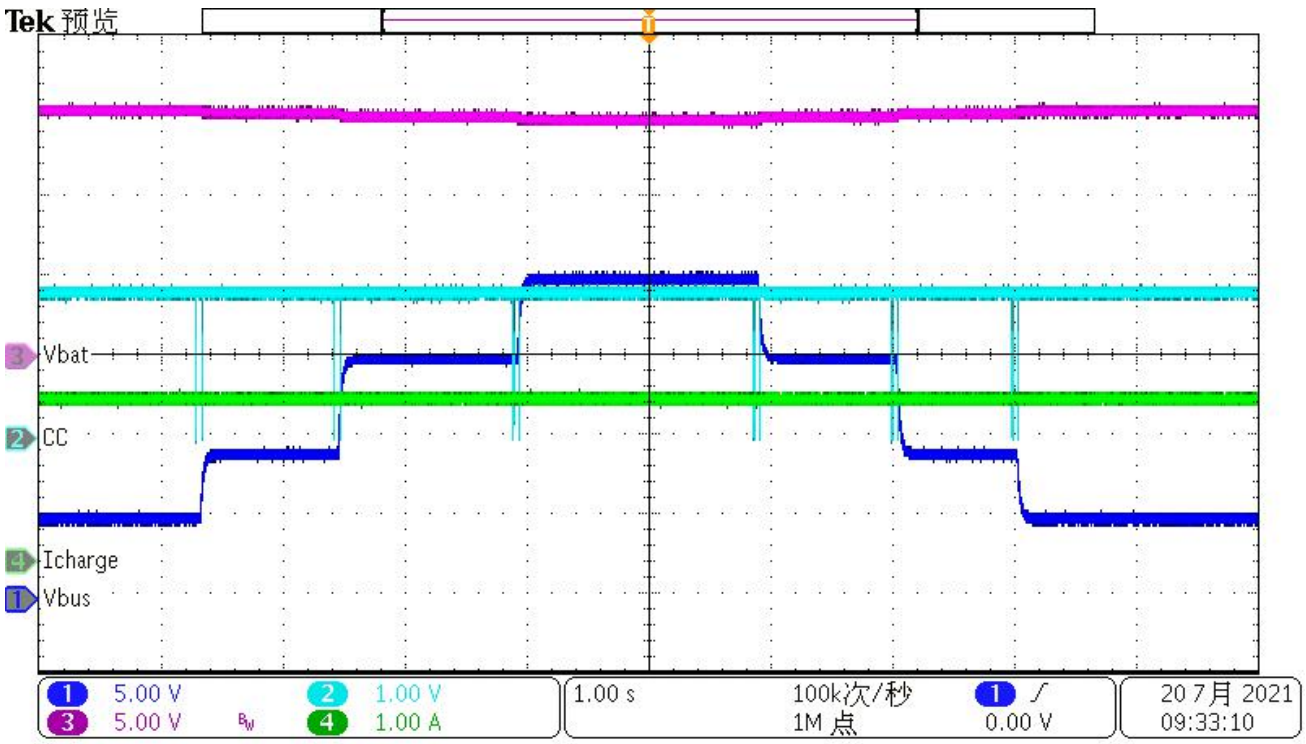



*Figure 9. 4 cells battery pack discharging current at 2A with all PDO*

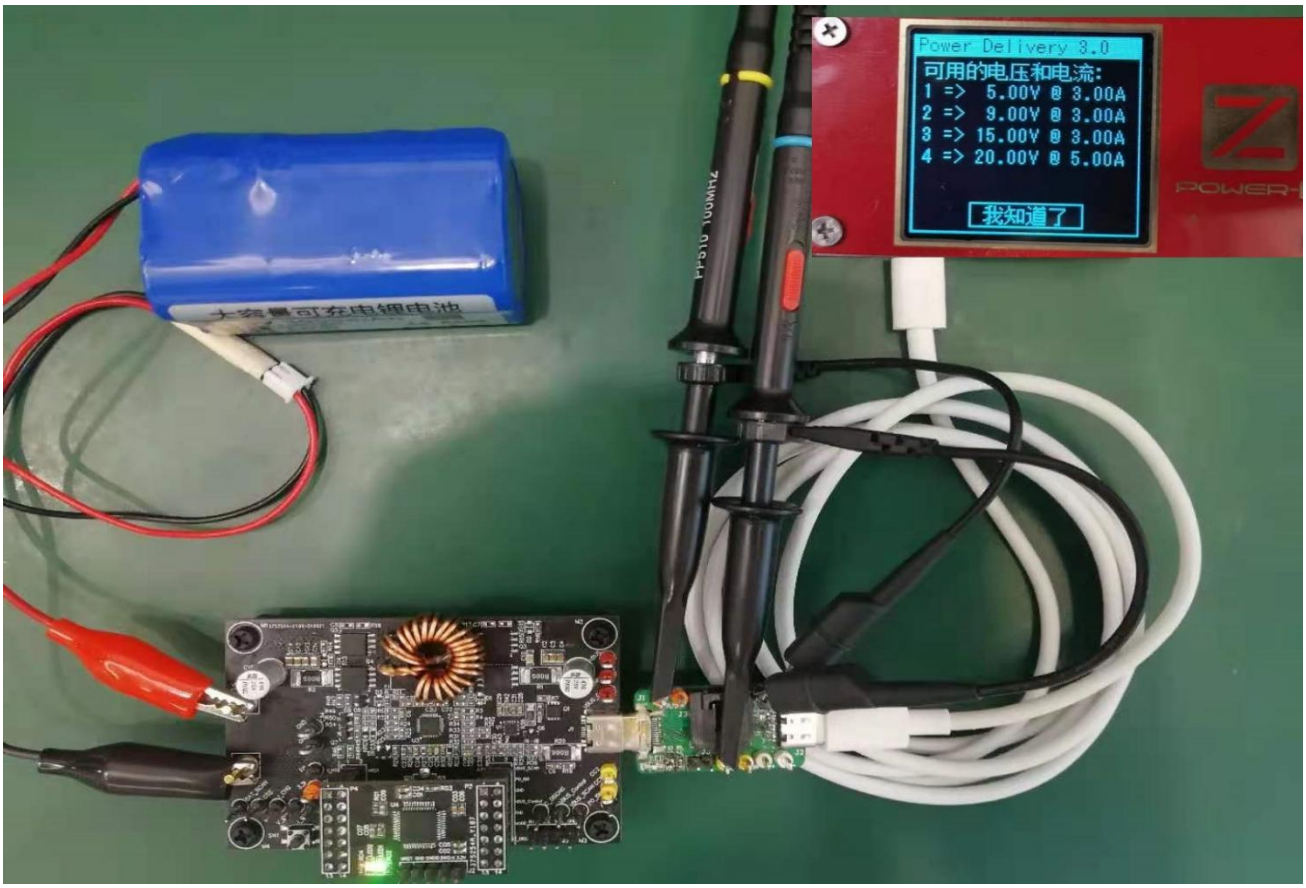
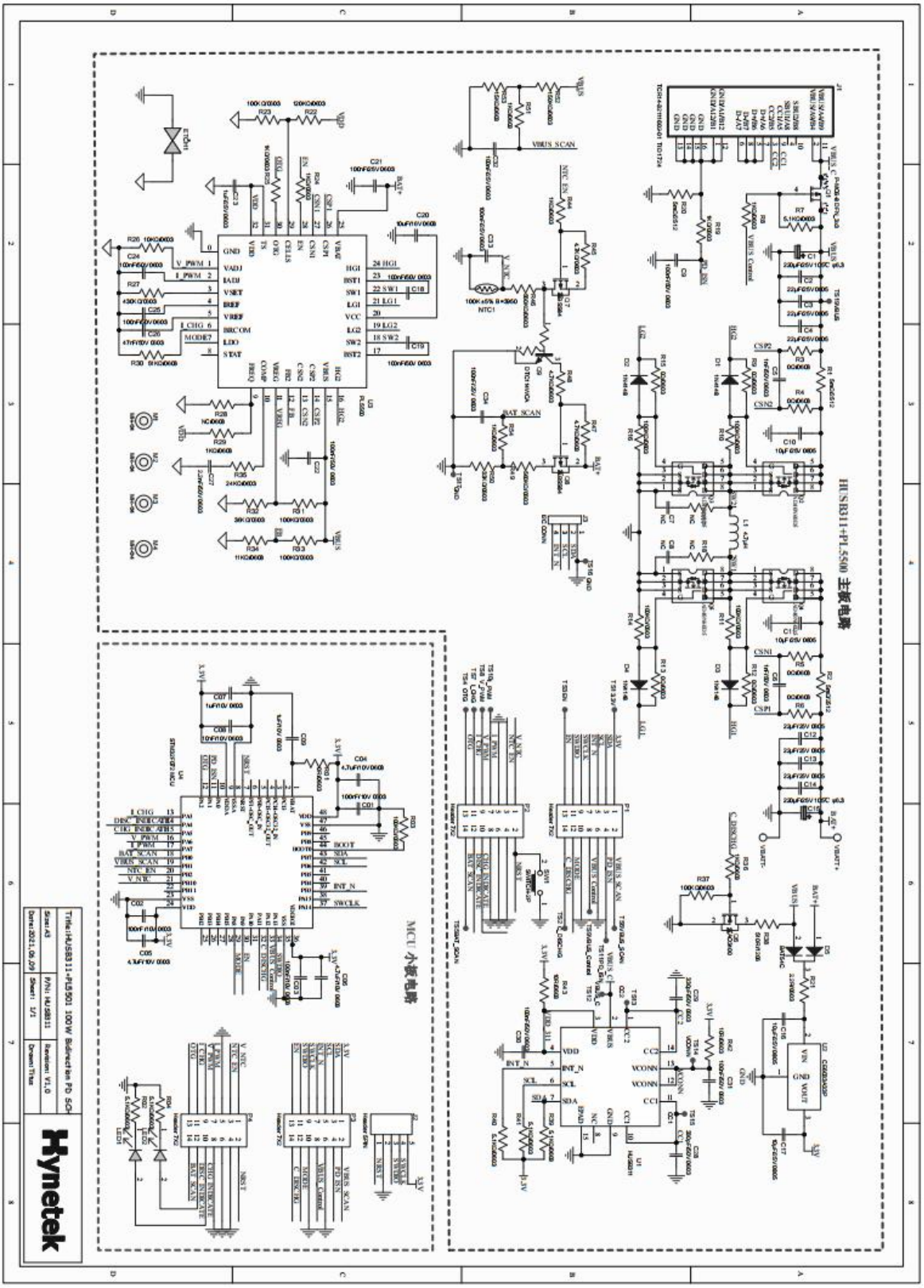



*Figure 10. HUSB311 source capability PDO*

# DESIGN DOCUMENTS

## SCHEMATIC



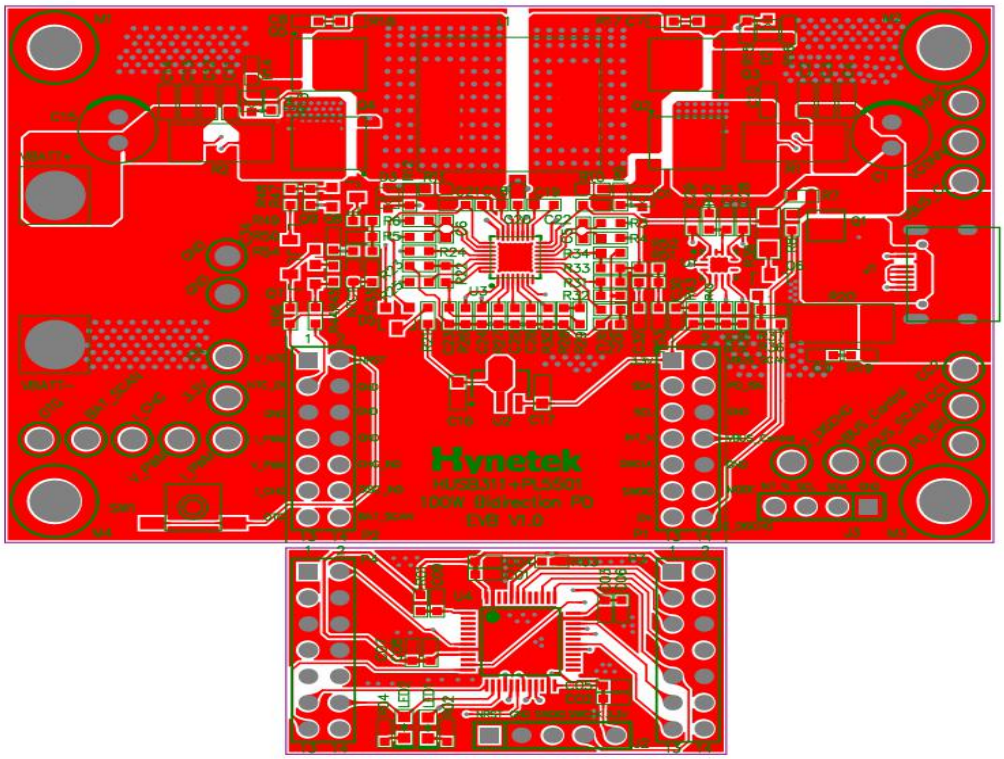
## BOM LIST

| Reference Design BOM REV1.0 | | | | | |
|---|---|---|---|---|---|
| **No.** | **Material Name** | **Specification Description** | **Item** | **PCS** | **Remark** |
| **HUSB311+PL5500 Bi-direction PD 100W MCU Module Part BOM REV1.0** | | | | | |
| 1 | PCB | 20*35.6*12mm/1oZ | PCB | 1 | |
| 2 | Capacitor | 100nF/10V 0603 | C01, C02, C03 | 1 | |
| 3 | Capacitor | 4.7uF/10V 0603 | C04, C05, C06 | 9 | |
| 4 | Capacitor | 1uF/10V 0603 | C07, C09 | 1 | |
| 5 | Capacitor | 10nF/10V 0603 | C08 | 1 | |
| 6 | Resistor | 0R/0603 | R01 | 1 | |
| 7 | Resistor | 100KΩ/0603 | R03 | 2 | |
| 8 | Resistor | 5.1KΩ/0603 | R02，R04 | 1 | |
| 9 | LED/SMD/0805 | BL-HGE35A-TRB | LED1, LED2 | 2 | |
| 10 | Header 5PIN | Connector | J2 | 1 | |
| 11 | Header 7X2 | Connector | P3, P4 | 2 | |
| 12 | STM32F072 MCU | STM32F072 MCU | U4 | 1 | |
| **HUSB311+PL5500 Bi-direction PD 100W Motherboard Part BOM REV1.0** | | | | | |
| 13 | solid electrolytic capacitor | 220μF/25V 105℃ φ6.3 | C1, C15 | 2 | |
| 14 | Capacitor | 1nF/50V 0603;25V;X5R | C5, C6 | 2 | |
| 15 | Capacitor | NC;25V;X5R | C7, C8 | | |
| 16 | Capacitor | 100nF/50V 0603;25V;X5R | C9, C18, C19, C21, C22, C24, C25, C30, C31, C32, C33, C34 | 12 | |
| 17 | Capacitor | 10uF/16V 0603;25V;X5R | C20 | 1 | |
| 18 | Capacitor | 1uF/25V 0603;25V;X5R | C23 | 1 | |
| 19 | Capacitor | 47nF/50V 0603;25V;X5R | C26 | 1 | |
| 20 | Capacitor | 2.2nF/50V 0603;25V;X5R | C27 | 1 | |
| 21 | Capacitor | 330pF/50V 0603;25V;X5R | C28, C29 | 2 | |
| 22 | Capacitor | 22μF/25V 0805;25V;X5R | C2, C3, C4, C12, C13, C14 | 6 | |
| 23 | Capacitor | 10μF/25V 0805;25V;X5R | C10, C11, C16, C17 | 4 | |
| 24 | Diode | 1N4148 | D1, D2, D3, D4 | 4 | |
| 25 | Diode | BAT54C | D5 | 1 | |
| 26 | Point to Point connect | ETCH0402 | ETCH1 | 1 | |
| 27 | Connector | Type-C Connector;TCR14-32111602-01 TID 1724 | J1 | 1 | |
| 27 | Connector | Header, 18-Pin, Dual row | P1, P2 | 1 | |
| 28 | Connector | CONN HEADER VERT 4POS 2.54MM | J3 | 1 | |
| 29 | Power Inductor | 4.7uH;0.0173ohms;12A | L1 | 1 | |
| 30 | MH-Φ4 | MH-Φ4 | M1, M2, M3, M4 | 4 | |
| 31 | NTC Resistor | 100K ±5% B=3950 | NTC1 | 1 | |
| 32 | PMOS | AD30P47; DFN_3x3 | Q1 | 1 | |
| 33 | NMOS | AD40N60D5; DFN_5x6 | Q2, Q3, Q4, Q5 | 4 | |
| 34 | NMOS | AO3400; SOT-23 | Q6 | 1 | |
| 35 | PMOS | BSS84; SOT-23 | Q7, Q8 | 2 | |
| 36 | NPN | DTC114WCA ; NPN Digital Transistors (Built-in | Q9 | 1 | |

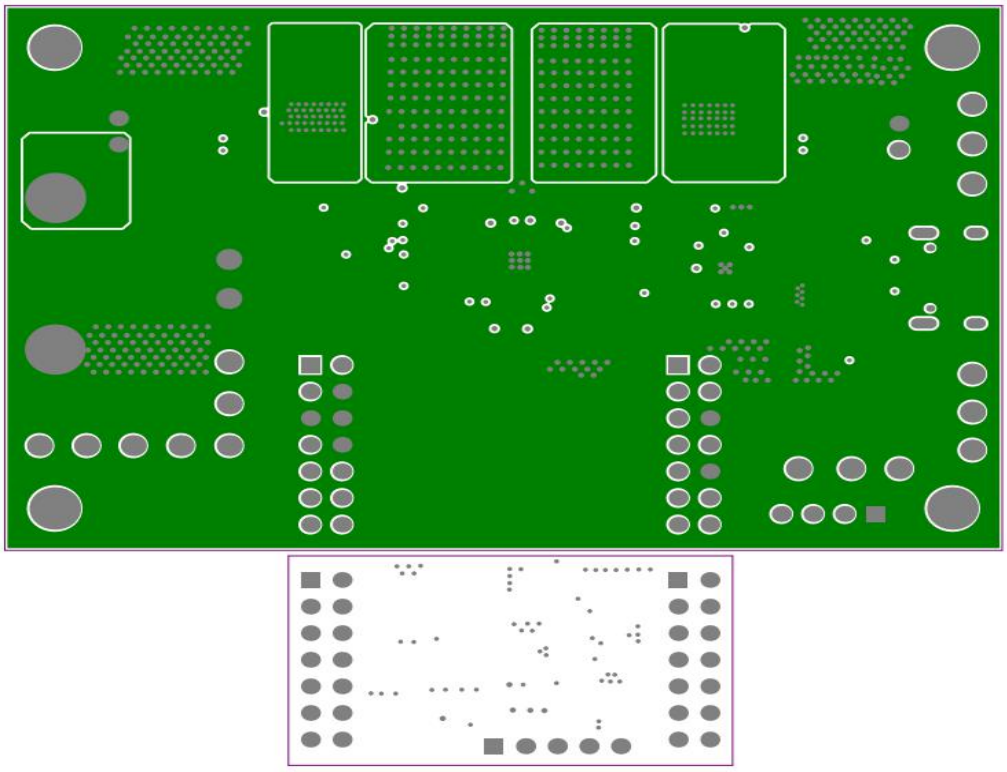
| | | | | | |
|---|---|---|---|---|---|
| | | Resistors) | | | |
| 37 | Film Resistor | 5mΩ/2512; ;1%;1W; | R1, R2, R20 | 3 | |
| 38 | Resistor;1% | 0R/0603 | R3, R4, R5, R6, R9, R12, R13, R15 | 8 | |
| 39 | Resistor;1% | 5.1KΩ/0603 | R7, R39, R40, R41 | 4 | |
| 40 | Resistor;1% | 1KΩ/0603 | R8, R19, R24, R25, R29, R36, R44, R51, R54 | 9 | |
| 41 | Resistor;1% | 100KΩ/0603 | R10, R11, R14, , R16, R23, R31, R33, R37 | 8 | |
| 42 | Resistor;1% | 2.2R/0603 | R21 | 1 | |
| 43 | Resistor;1% | 120KΩ/0603 | R22 | 1 | |
| 44 | Resistor;1% | NC/0603 | R17, R18, R28 | | |
| 45 | Resistor;1% | 36KΩ/0603 | R32 | 1 | |
| 46 | Resistor;1% | 10KΩ/0603 | R26 | 1 | |
| 47 | Resistor;1% | 430KΩ/0603 | R27 | 1 | |
| 48 | Resistor;1% | 51KΩ/0603 | R30 | 1 | |
| 49 | Resistor;1% | 11KΩ/0603 | R34 | 1 | |
| 50 | Resistor;1% | 24KΩ/0603 | R35 | 1 | |
| 51 | Resistor;1% | 10R/0603 | R42, R43 | 2 | |
| 52 | Resistor;1% | 4.7KΩ/0603, | R45, R47, R48 | 3 | |
| 53 | Resistor;1% | 560KΩ/0603 | R46, R49 | 2 | |
| 54 | Resistor;1% | 33KΩ/0603 | R50 | 1 | |
| 55 | Resistor;1% | 150KΩ/0603 | R52 | 1 | |
| 56 | Resistor;1% | 15KΩ/0603 | R53 | 1 | |
| 57 | Film Res., 1% | 510R/1206 | R38 | 1 | |
| 58 | SWITCH-2P | SWITCH-2P | SW1 | 1 | |
| 59 | Test Point | 3.3V, C_DISCHG, EN, OTG, BAT_SCAN, VBUS_SCAN, I_CHG, V_PWM, VBUS_Control, I_PWM, PD_ISN, VBUS_C, CC2, VCONN, CC1, GND, VBUS Test Point | TS1~TS17 | 17 | |
| 60 | IC | HUSB311 QFN14 2.5X2.5 | U1 | 1 | **Hynetek** |
| 61 | IC | CE6033A33P | U2 | 1 | |
| 62 | IC | PL5500 | U3 | 1 | |
| 63 | Connector | Connector | VBATT+ | 1 | |
| 64 | Connector | Connector | VBATT- | 1 | |

## PCB LAYOUT

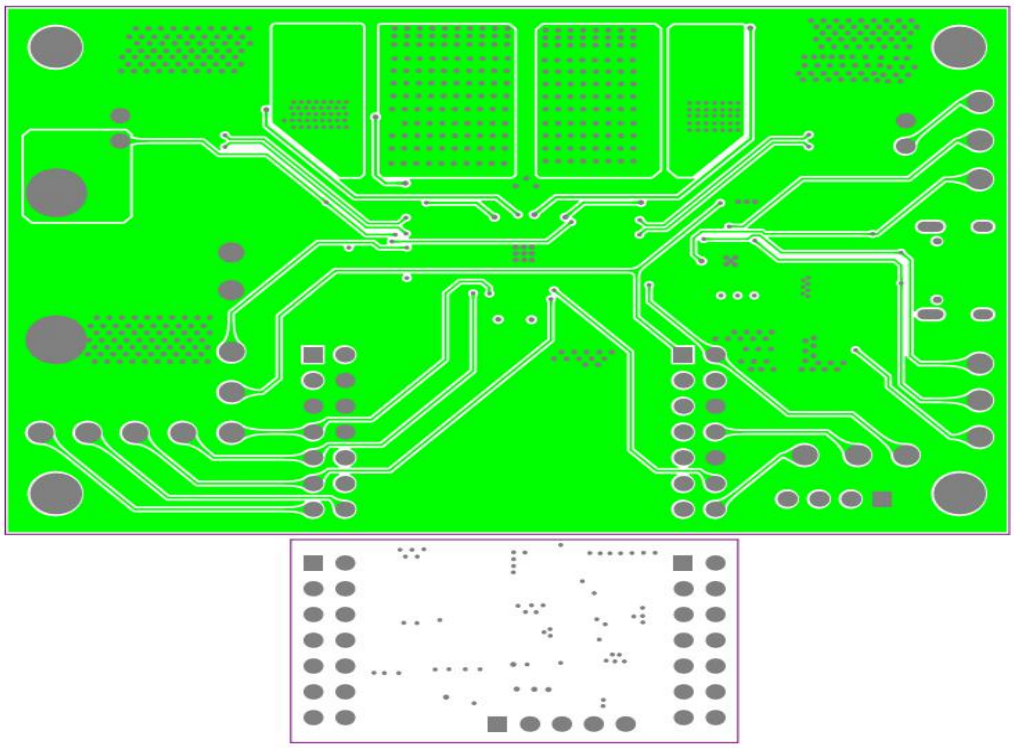
Top Layer



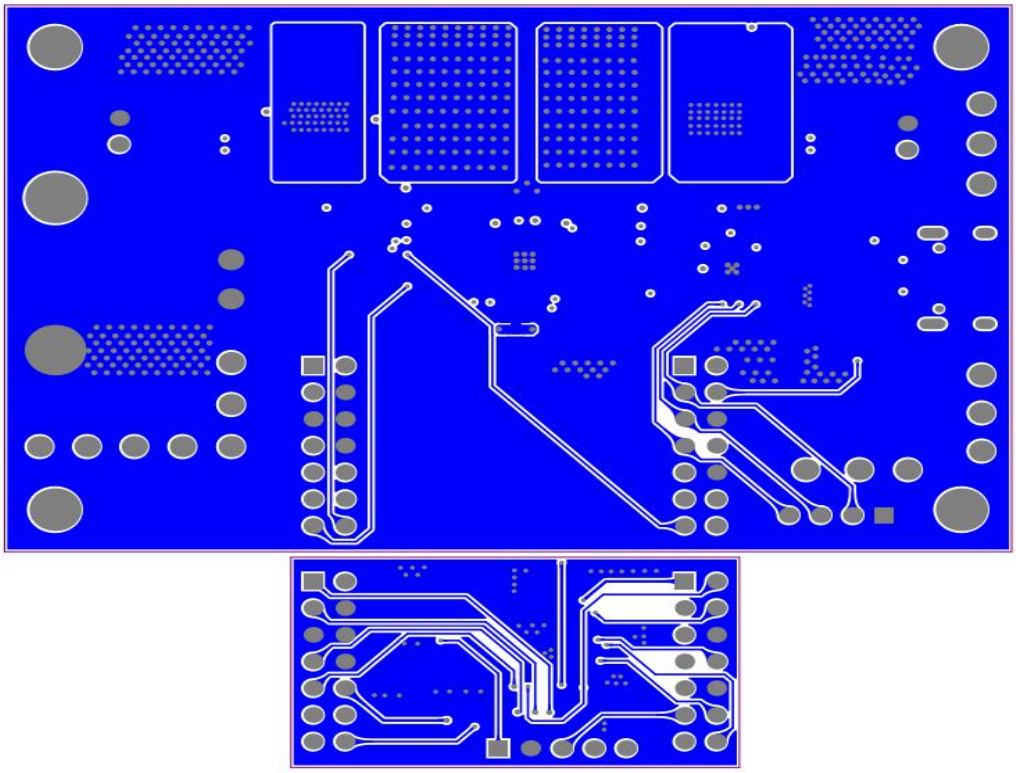

Mid Layer1



Mid Layer2



Bottom Layer



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