Integrated USB Type-C PD and 1-4 Cell Batteries Charging Reference Design

Hynetek Semiconductor Co., Ltd. **RD-2008**

FEATURES

- USB Power Delivery (PD) sink-only power role
- Support charging of 1 to 4 cell batteries
- Seamless transition among Buck, Buck-boost and Boost operation
- Support type-C 1.4 & USB PD3.0 version 1.1
- 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
- Wireless chargers
- Industrial applications

GENERAL DESCRIPTION

This reference design includes a highly integrated USB PD sink controller HUSB238 and a highly integrated Buck-boost charger MP2651. This reference design can support charging 1 to 4 cell batteries through a USB Type-C port. The HUSB238 negotiates with a USB PD power adapter (PD source). It can be set to request the any available Power Data Object (PDO), charging 1-4 cell batteries through the charger MP2651. Through the I^2C interface, the PD negotiation can be set up. The bus voltage, the battery voltage, the battery charging current and component temperature can be monitored in real time. This board features maximum input power of up to 20V3A, without the need for any external FETs enabling a much smaller design size, reducing total BOM cost.

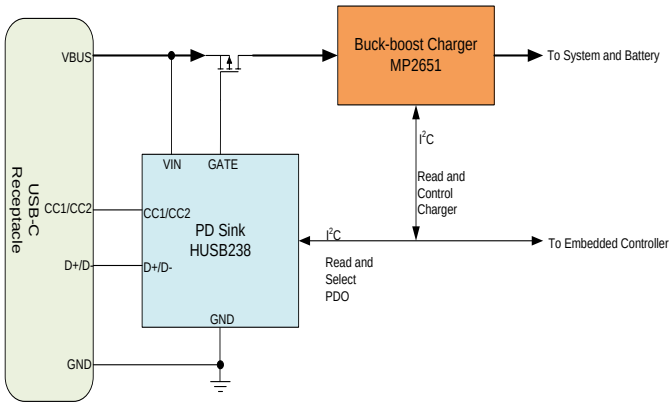
This reference design provides an ultra-miniature, high reliability integrated USB PD and 1-4 cell batteries charging solution.

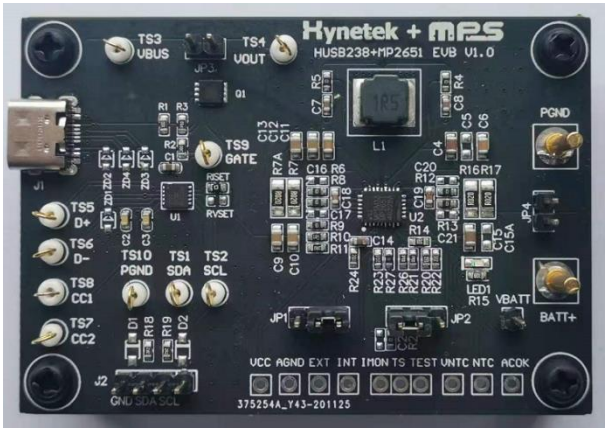
DESIGN RESOURCES

HUSB238

MP2651

APPLICATION BLOCK DIAGRAM AND EVB FIGURE





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INTRODUCTION

This integrated USB Type-C PD and 1-4 cell batteries charging reference design is a USB Type-C and PD controller system along with a battery charging system capable of 60W sinking. This reference design can support charging 1-4 cell batteries via a USB Type-C port, in addition to Type-C communication and PD negotiations.

This reference design board features charging up to 20V at 3A. Furthermore, both the HUSB238 and the MP2651 integrate I^2C interfaces as slave devices. The monitoring and advanced configurations can be achieved through an external microprocessor communicating via the I^2C interface, such as monitoring of the source capacity of PD power source, the negotiated PDO through the HUSB238. With I^2C interface of the MP2651, the MP2651 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 sink controller combined with a battery charge management system can efficiently charge 1-4 cell batteries. 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, the MP2651 can easily charge 1-4 cell batteries without considering the USB PD power level and output specifications.

Table1.

PARAMETER	SPECIFICATIONS	DETAILS
PD sink capabilities	5V-20V	VBUS from type-C input
Cell configurations	1 cell - 4 cells	Battery cell number
Charge current	Up to 3A	Battery charging current

DESIGN OVERVIEW

BLOCK DIAGRAM

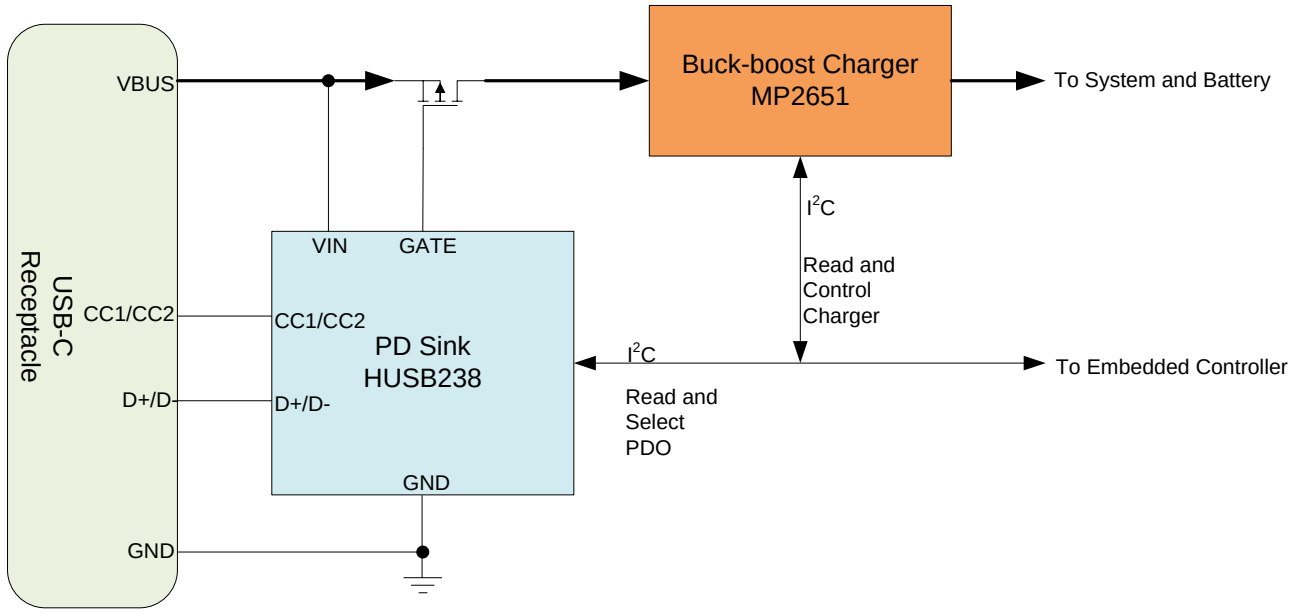


Figure1. RD-010 Application Block Diagram

KEY PRODUCTS

HUSB238 – USB PD Sink Controller

The HUSB238 is a highly integrated USB Power Delivery (PD) controller as sink role. It's compatible with PD3.0 and Type-C V1.4. It can also support Apple Divider 3, BC1.2 SDP, DCP and CDP while the source is attached. When the HUSB238 is attached to a power adapter (power source), it applies Rd resistance to both CC lines, trying to establish USB Type-C connection. After the USB Type-C connection is established, it monitors the CC lines to get source capabilities pack from USB PD source. If there is valid source capabilities pack before time out, the HUSB238 policy engine requests a power supply with a voltage no greater than the programmed request voltage. If there is no valid source capabilities pack after time out, the HUSB238 switches to Apple divider 3 or BC1.2 mode trying to determine corresponding charging protocol.

The HUSB238 is typically used as barrel connector replacement (Barrel Connector Replacement, BCR), designed to replace traditional barrel connectors and DC sockets (DC JACK).

Key features of HUSB238:

- USB-IF certified PD sink controller with TID 3666
- 3mmx3mm DFN-10L ultra-small package
- Support type-C 1.4 & USB PD3.0 version 1.1
- Support legacy charging sink, BC1.2 SDP, CDP & DCP detection, Apple Divider 3 detection
- 3.0V to 25V operation range
- 30V voltage rating on VBUS, GATE pins, and 25V voltage rating on CC1, CC2 pins
- External resistor to set the target RDO voltage and current
- I^2C interface access for advanced PDO request
- eMarker emulator for cable application with output current>3A
- Integrated load switch gate drivers (PMOS)

- VBUS over-voltage (OVP) and under-voltage (UVP) protection
- OTP protection, over-temperature protection with configurable thresholds
- Low power consumption
- Operating temperature -40 °C to 125 °C

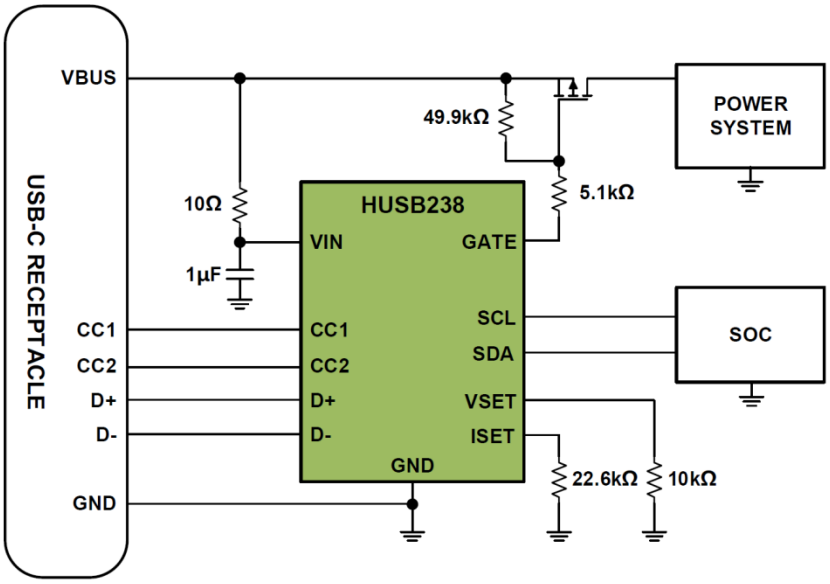


Figure 2. HUSB238 Typical Application Circuit

MP2651 – Buck-boost Battery Charger

The MP2651 is a Buck-Boost charger IC designed for battery pack with 1 to 4 cells in series. It can accept a wide range (4V to 21V) of input operation voltage for charging the battery. The battery voltage can be either lower or higher than input voltage due to the buck-boost topology. When the input is present, the MP2651 operates in charge mode. It measures the battery voltage and charges the battery with four phases: constant current trickle charge, constant current pre-charge, constant current fast charge and constant voltage charge. Other features include charge termination and auto recharge. The MP2651 also integrates the input current limit and input voltage limit to avoid overloading the input power source. This is compliant to the USB and PD specification. The MP2651 can also supply a wide range (3V to 21V) of voltage at input when source mode is enabled. It also has output current limit with high resolution in source mode. These allows the MP2651 to be compliant to the USB PD PPS.

With I^2C/SMBUS interface, the MP2651 can be flexibly programmed the charging and discharge parameters, such as input current limit, input voltage limit, charging current, battery full regulation voltage, output voltage and current in source mode and so on. It can also provide the status and faults in operation through registers. To guarantee safe operation, the IC limits the die temperature to a programmable threshold. Other safety features include input over-voltage protection, battery over-voltage protection, system over-voltage protection, thermal shutdown, and a programmable timer to prevent prolonged charging of a dead battery.

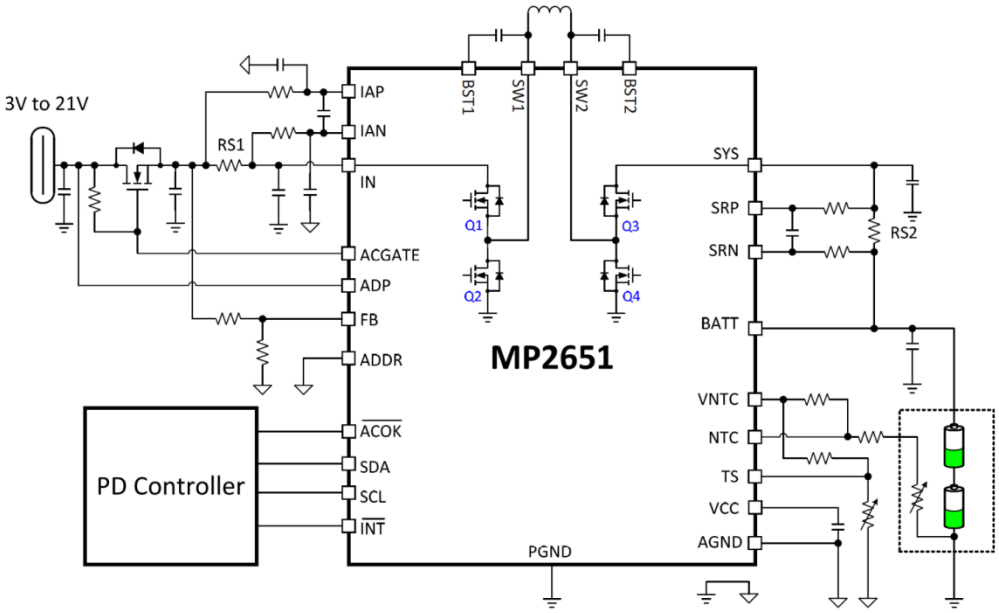


Figure 3. MP2651 Typical Application Circuit

TEST RESULT

TEST CONDITIONS

Room temperature test condition.

Input: 60W or above USB PD power adapter, or 5V3A USB-C power adapter.

Output: 1-4 cell batteries.

TEST EQUIPMENT

Oscilloscope Tektronix MDO3024, Lenovo 65 W PD power adapter or 5V3A USB-C power adapter, multi-meter.

I^2C interface monitoring requires additional equipment, including: a computer with USB interface, USB data lines, USB-to-I2C Communication Kit (EVKT-USBI2C-02), package Programming Tool -MP2651

TEST SETTING

Figure 4 shows the connection diagram of the test setup. To achieve the best evaluation performance, 60W or above PD power adapters are preferred as input power source.

Figure4. EVB test connection diagram

TEST PROCESS

1. Connect the positive electrode of the 1 to 4 cell batteries to the BATT+ pin. Connect the negative electrode of the 1 to 4 cell batteries to the PGND 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 battery positive cable.
4. Apply 220V AC power source on the power adapter.
5. Perform the test.

TEST RESULTS

After the circuit is connected and before the power on, the users can use the software in the computer to preset the cells and charging current of the battery through the I^2C interface. The users also can preset the PDO request of the HUSB238 (in this test, we set the RDO through the VSET and ISET pins). After configuration of these parameters, then power on the PD power adapter, the users can see the HUSB238 negotiating with the PD source to request a voltage to charge the batteries. Whether the requested voltage is 5V or 20V, the 1-4 cells batteries can be charged

due to that the MP2651 operates in the buck-boost topology. At the same time, the software Programming Tool - MP2651 can monitor a series of fault indications such as input voltage, battery voltage and charging current, system working mode and device temperature in real time.

Through the I^2C interface the HUSB238, the monitoring functions and setting functions can be realized. Monitoring functions include: Type-C cable direction, Type-C connection state, PD negotiation response state, PD negotiated voltage and current, PD adapter Source Capabilities. Setting functions include: RDO selection, matching rules, GATE pin action, VBUS discharge time, enabling or closing support for data communication, OTP threshold VID and PID etc.

TEST WAVEFORMS

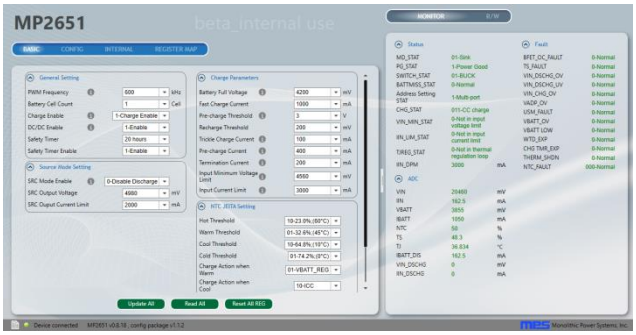


Figure 5. 1 cell charging current at 1A

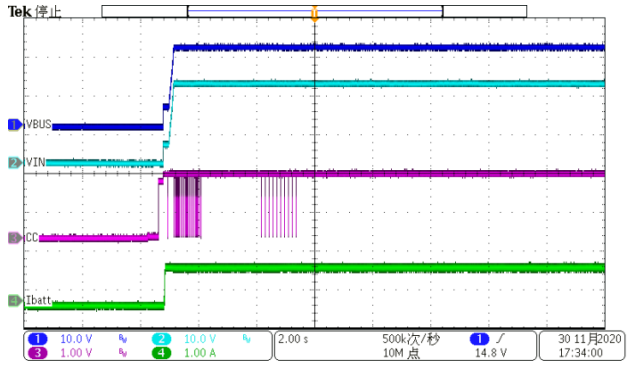


Figure 6. HUSB238 Request 20V input

Figure 7. 4 cells charging current at 3A

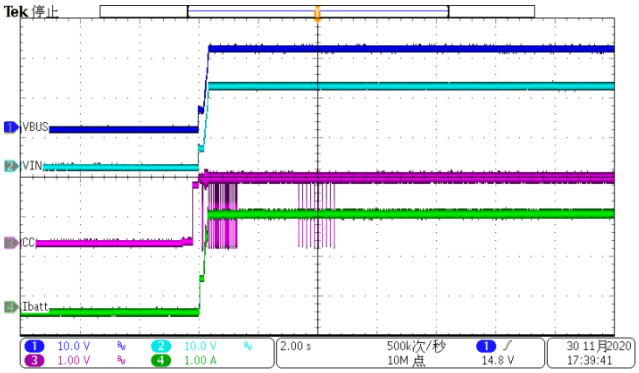


Figure8. HUSB238 Request 20V input

Figure 9. 4 cells charging current at 2A

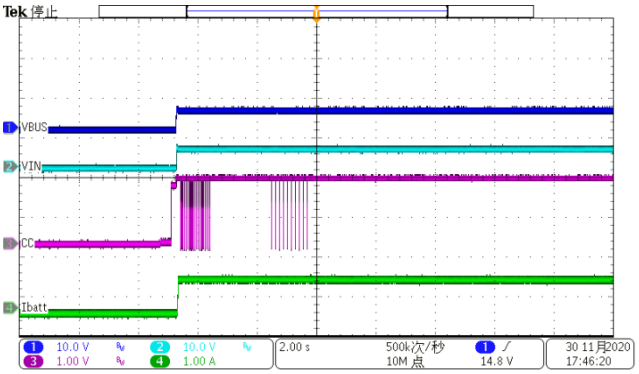


Figure 10. HUSB238 Request 5V input

Figure 11. 1 cell charging current at 3A

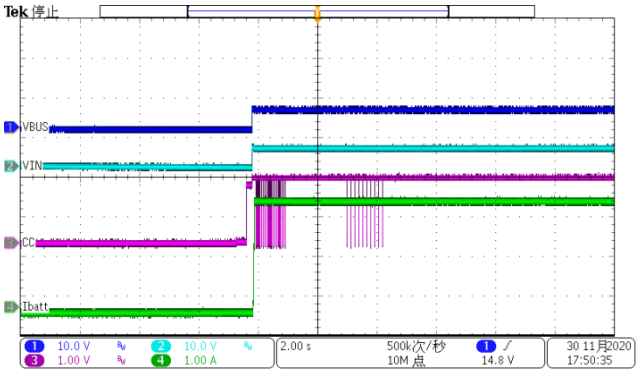
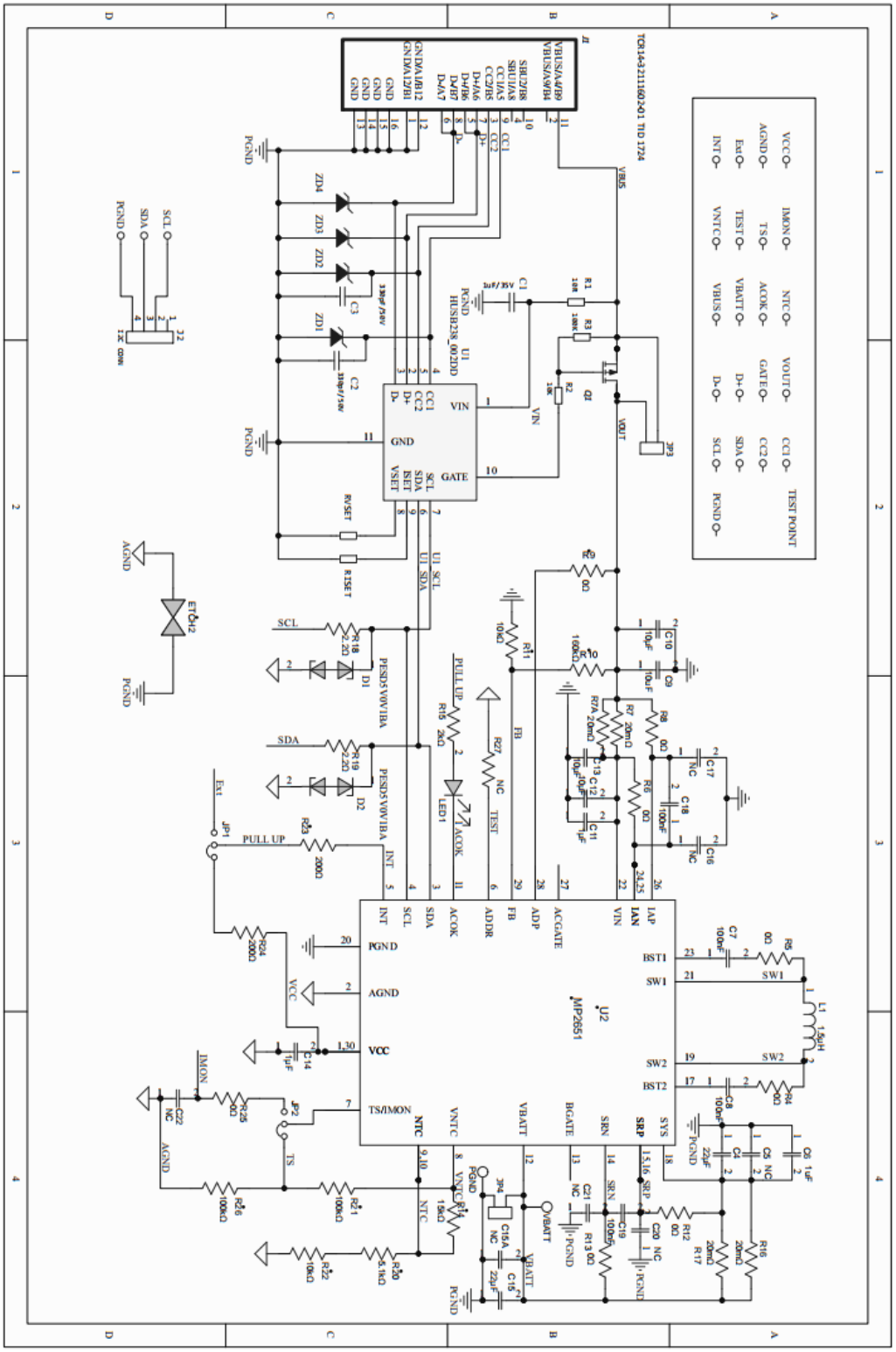


Figure 12. HUSB238 Request 5V input

DESIGN DOCUMENTS

SCHEMATIC

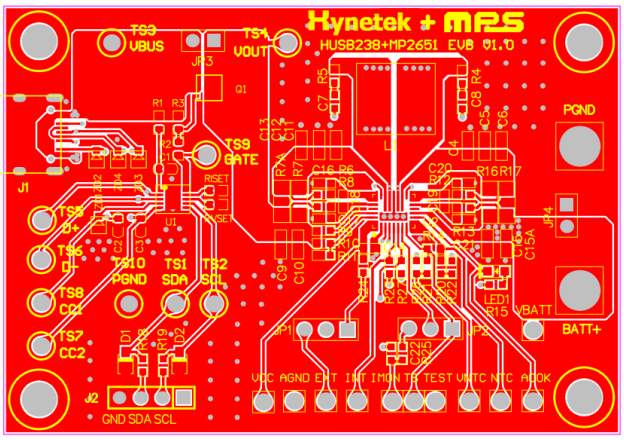


BOM LIST

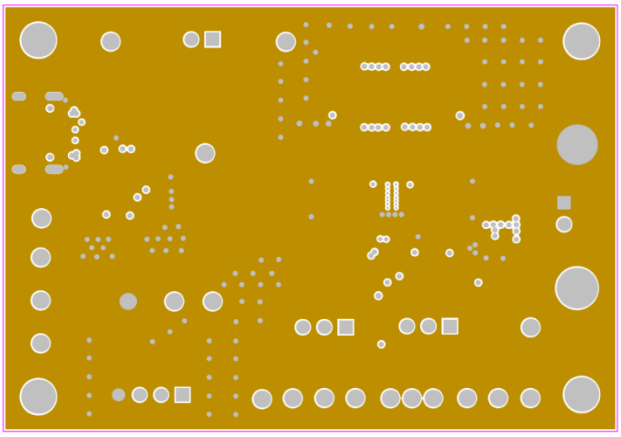
Reference Design BOM					
No.	**Material Name**	**Specification Description**	**Item**	**pcs**	**Remark**
Plug-in Part					
1	PCB	72.5*50*1.6mm/1oZ		1	
2	pin needle	Header, Male 2-pin, 2.54mm spacing	JP3,JP4	2	
3	pin needle	Header, Male 3-pin, 2.54mm spacing	JP1,JP2	2	
4	pin needle	Header, Male 4-pin, 2.54mm spacing	J2	1	
5	pin needle	Connector 2.0pin	BATT+/PGND	2	
6	Connector	TCR14-32111602-01	J1	1	
Patch Part					
7	Resistor	10Ω 0603 5%	R1	1	
8	Resistor	10KΩ 0603 5%	R2	1	
9	Resistor	100KΩ 0603 5%	R3	1	
10	Resistor	0Ω 0603 5%	RISET	1	
11	Resistor	NC	RVSET		
12	capacitor	330P50V X7R 0603	C2.3	2	
13	capacitor	105K35V X7R 0603	C1	1	
14	MOSFET	AD30P47D3 DFN3*3 -30V	Q1	1	
15	ESD pipe	NC	ZD1,ZD2,ZD3,ZD4,D1,D2		
16	Resistor	0Ω 0603 5%	R4,R5,R6,R8,R9,R12,R13	7	
17	Resistor	20mR 1206 1%	R7,R7A, R16,R17	4	
18	Resistor	160KΩ 0603 1%	R10	1	
19	Resistor	10KΩ 0603 1%	R11	1	
20	Resistor	15KΩ 0603 1%	R14	1	
21	Resistor	2KΩ 0603 1%	R15	1	
22	Resistor	2.2Ω 0603 1%	R18,R19	2	
23	Resistor	5.1KΩ 0603 5%	R20	1	
24	Resistor	100KΩ 0603 5%	R21,R26	2	
25	Resistor	5.1KΩ 0603 5%	R22	1	
26	Resistor	200Ω 0603 5%	R23,R24	2	
27	Resistor	0Ω 0603 5%NC	R25,R27	2	
28	Capacitor	22uF25V X7R 0805	C4,C15	2	
29	Capacitor	NC	C5,C15A,C16,C17,C18,C19,C20, C21,C22		
30	Capacitor	1uF25V X7R 0805	C6,C11,C14	3	
31	Capacitor	100nF25V X7R 0603	C7,C8	2	
32	Capacitor	10uF25V X7R 0805	C9,C10,C12,C13	4	
33	LED indicator	BLHGE35A-AVTRB LED, Green	LED1	1	
34	Patch Inductance	Inductor, 1.5μH, 9mΩ, 14.5A SMD	L1	1	
35	IC	MP2651GVT QFN 4X5	U2	1	
36	IC	**HUSB238_002DD-DFN-10L**	U1	1	**Hynetek**

PCB LAYOUT

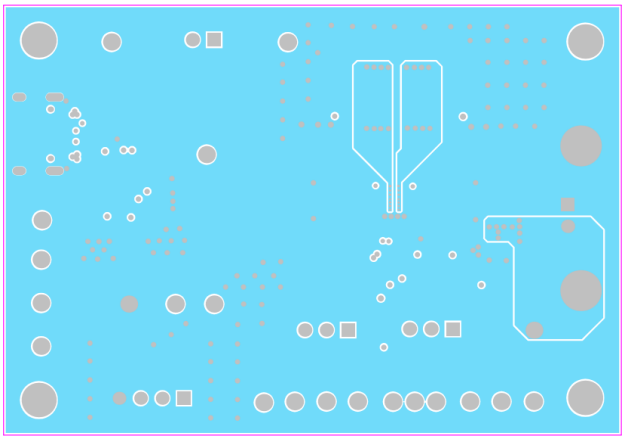
Top Layer



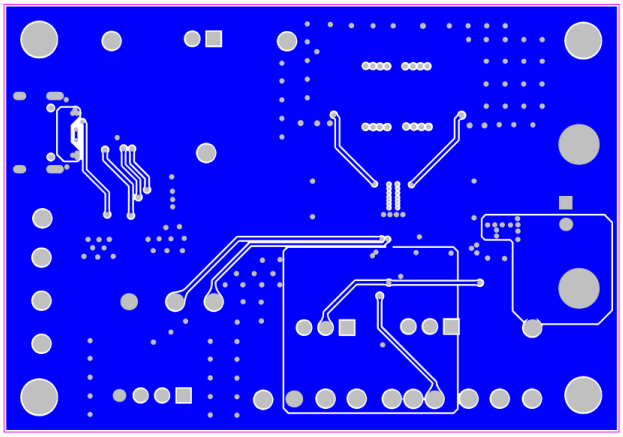
Mid Layer1



Mid Layer2



Bottom Layer



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