USB Type-C PD Controller with Integrated Power Switch

Hynetek Semiconductor Co., Ltd.

HUSB351

FEATURES

- **USB Type-C 1.4 and USB PD3.0 compliant**
  - **Support 5V, 9V and 12V FPDOs**
  - **Support 5V Prog and 9V Prog APDOs**
- **Support BC1.2 DCP and HVDCP protocols**
  - **BC 1.2 DCP mode**
  - **Divider 3 mode**
  - **QC2.0/3.0 Class A**
  - **AFC**
  - **FCP and SCP**
- **Support Constant Voltage Loop (CV) and Constant Current Loop (CC) Operation**
- **Compatible with Opto-Coupler and Direct Feedback Configurations**
- **Integrated N-MOSFET with Softstart**
- **Integrated VIN OVP, VIN UVP, VIN UVLO, OCP, SCP and OTP protections**
- **9-Lead Panel Level DFN and Flip Chip DFN (3mm × 3mm) Package Available**
- **±2kV HBM ESD Rating for USB IO pins**

APPLICATIONS

AC-DC power adapter

Car charger

GENERAL DESCRIPTION

The HUSB351 is designed for a low power Type-C product. The HUSB351 supports PD2.0, PD3.0, PPS, QC2.0/3.0, Divider 3, BC1.2 DCP, AFC, FCP and SCP protocols. It supports 5V, 9V and 12V three FPDOs and 5V Prog, 9V Prog two APDOs which are fully compliant with USB Power Delivery Specification Revision 3.0, version 2.0.

The HUSB351 integrates the VBUS power switch and current sensing resistor to save board space and BOM cost.

The HUSB351 integrates all required protections such as Over Voltage Protection (OVP), Under Voltage Protection (UVP), Under Voltage Lock Out (UVLO), Over Current Protection (OCP), Fast Over Current Protection (FOCP) and Thermal Shut Down (TSD).

It is available in a PLDFN-9L and FCDFN-9L, 3mm x 3mm package.

TYPICAL APPLICATION CIRCUIT

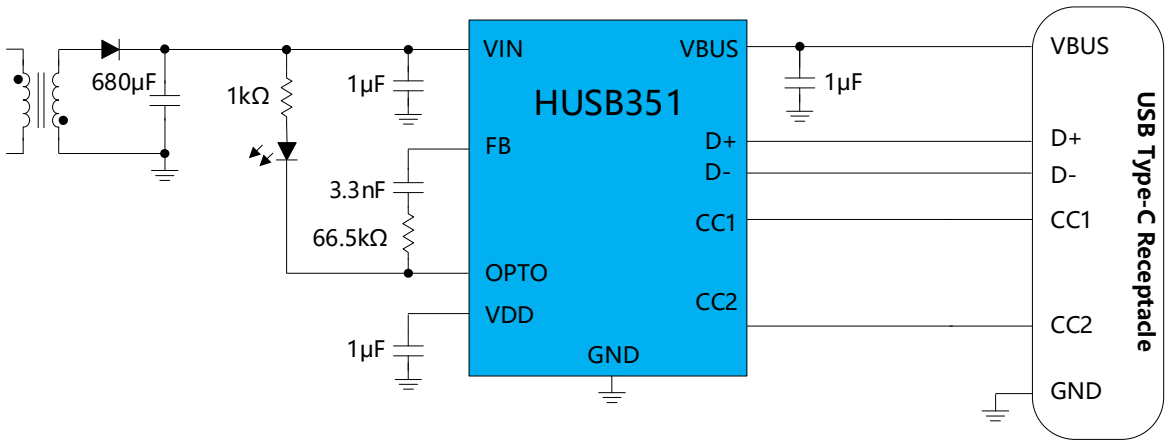

Figure 1. Typical Application Circuit

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REVISION HISTORY

Version	Date	Descriptions
Rev. 0.0	05/2021	Preliminary version
Rev. 0.1	8/2022	Add models HUSB351_008TC& HUSB351_008HB
Rev. 0.2	9/2022	Complete the description at IR COMPENSATION
		Modify the package information of the chip
Rev. 0.3	9/2022	Revised packaging and ordering guide information

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

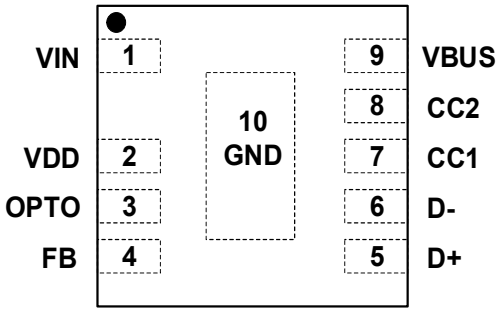


Figure 2. Pin Configuration (Top View)

Table 1. Pin Function Descriptions

Pin No.	Pin Name	Type[1]	Description
1	VIN	P	Supply voltage input. Connect this pin to GND via a recommended 1μF ceramic capacitor.
2	VDD	AO	Internal 3.3V regulator output for system power. Connect 1μF ceramic capacitor at this pin to ground.
3	OPTO	AI	Connection of Opto-coupler feedback.
4	FB	AI	Feedback point of Constant Voltage (CV) loop, connect CV compensation network to this pin in Opto-Coupler configuration. Connect this pin to the feedback point of a power supply in direct feedback configuration.
5	D+	DIO	USB D+ line.
6	D-	DIO	USB D- line.
7	CC1	AIO	Type-C CC1 line.
8	CC2	AIO	Type-C CC2 line.
9	VBUS	P	Output of the integrated power switch. Connect this pin to USB Type-C connector.
10	GND	A	Exposed pad. Connect this pad to the ground of the system board.

1 Legend:
A = Analog Pin
P = Power Pin
D = Digital Pin
I = Input Pin
O = Output Pin

SPECIFICATIONS

V_{IN} = 5V, T_A = 25°C, unless otherwise noted.

Table 2.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
POWER SUPPLY						
Supply Voltage	V_{IN}		3.15		12.6	V
Supply Voltage UVLO Threshold	V_{IN_UVLO}	Rising edge		3.0		V
Supply Voltage UVLO Hysteresis	$V_{IN\_UVLO\_HYS}$			300		mV
Supply Current	I_{CC}	CC is attached, normal operation		3		mA
Quiescent Current	I_Q	CC1 and CC2 pins are floating		300		μA
VDD						
Internal Regulator Output	V_{DD}			3.3		V
Type-C						
1.5A Mode Pull-Up Current Source	I_{CC_1P5}		166	180	194	μA
3.0A Mode Pull-Up Current Source	I_{CC_3P0}		304	330	356	μA
UFP Detection Threshold at 1.5A Current	$vR_{d\_OPEN\_1.5A}$			1.6		V
UFP Detection Threshold at 3.0A Current	$vR_{d\_OPEN\_3A}$			2.6		V
BMC COMMAN PARAMETERS						
Bit Rate	$f_{BitRate}$		270	300	330	Kbps
BMC TX PARAMETERS						
Falling Time	t_{Fall}	10% and 90% amplitude points, unloaded condition	300			ns
Rising Time	t_{Rise}	10% and 90% amplitude points, unloaded condition	300			ns
Voltage Swing	V_{Swing}	CC pull down resistor > 800Ω	1.05	1.125	1.2	V
Transmitter Low Voltage	V_{Low}	CC pull down resistor > 800Ω	-75		75	mV
Transmitter Output Impedance	Z_{Driver}	Source output impedance at 750kHz with CC attached	35	55	75	Ω
BMC RX PARAMETERS						
RX Bandwidth Limiting Filter	$t_{RXFilter}$	Time constant of a single pole filter	100			ns
Receiver Input Impedance	Z_{BMC_RX}		1			MΩ
BC1.2 DCP MODE						
D+ and D- Shorting Resistance	R_{DPM_SHORT}	V_{DP} = 0.6V		20		Ω
D+ Leakage Resistance	R_{DP_LKG}	V_{DP} = 0.6V		800		kΩ
D− Leakage Resistance	R_{DM_LKG}	V_{DM} = 0.6V		800		kΩ
DCP Mode Entry Threshold	V_{SEL_REF}		1.8	2	2.2	V
APPLE DIVIDER3 MODE						
D+ Output Voltage	V_{DP_APP}	V_{IN} = 5V		2.7		V
D− Output Voltage	V_{DM_APP}	V_{IN} = 5V		2.7		V
D+ Output Impedance	R_{DP_PAD}	I_{DP} = −5μA		30		kΩ
D− Output Impedance	R_{DM_PAD}	I_{DM} = −5μA		30		kΩ
HVDCP MODE						
Data Detect Voltage	V_{DAT_REF}			0.325		V
Output Voltage Selection Reference	V_{SEL_REF}			2		V
D+ High Glitch Filter Time	$T_{GLITCH\_BC\_MODE}$		1	1.25	1.5	s

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
D− Low Glitch Filter Time	$T_{GLITCH\_DM\_LOW}$		1	2		ms
Output Voltage Glitch Filter Time	$T_{GLITCH\_V\_CHANGE}$		20	40	60	ms
D− Pull-Down Resistance	R_{DM_DWM}			15		kΩ
QC MODE						
Pulse Glitch Filter Time	$T_{GLITCH\_CONT\_CHANGE}$	For QC3.0 in continues mode	100	150	200	μs
FCP MODE						
D− FCP TX Valid Output High	V_{TX_VOH}		2.55		3.6	V
D− FCP TX Valid Output Low	V_{TX_VOL}				0.3	V
D− FCP RX Valid Input High	V_{RX_VIH}		1.4		3.6	V
D− FCP RX Valid Input Low	V_{RX_VIL}				1	V
D− Output Pull-Low Resistance	R_{DMPL}			500		Ω
Unit Interval for FCP	UI	125kHz clock		160		μs
VOLTAGE CONTROL (FB PIN)						
Voltage Sense Scaling Factor				10		
VIN Step LSB				20		mV
Default Voltag	V_{IN_DEF}			5.1		V
Regulation Accuracy		VIN=3.3-12V	-5		5	%
OPTO PIN						
Minimum OPTO Current				30		μA
Maximum Pull Down Current				10		mA
POWER SWITCH						
ON Resistance		VIN pin to VBUS pin		15		mΩ
OVER VOLTAGE PROTECTION						
OVP Protection Threshold	V_{IN_OV}	Reference to internal V_{IN} reference	115	120	125	%
OVP De-bounce Time	t_{OV_DEB}			10		μs
UNDER VOLTAGE PROTECTION						
UVP Protection Threshold	V_{IN_UV}	Reference to internal V_{IN} reference	75	80	85	%
UVP De-bounce Time	t_{UV_DEB}			1		ms
OVER CURRENT PROTECTION						
OCP Protection Threshold	I_{IN_OC}	Reference to internal I_{IN} reference		125		%
OCP De-bounce Time	t_{OC_DEB}			2.5		Ms
FOCP Protection Threshold	I_{IN_FOCP}			12		A
THERMAL SHUT DOWN						
Thermal Shut Down Threshold	T_{TSD}			150		ºC
Thermal Shut Down Hysteresis	T_{TSD_HYS}			20		ºC

RECOMMENDED OPERATING CONDITIONS

Table 3.

Parameter	Rating
VIN Input Voltage	3.15V to 12.6V
Operating Temperature Range (Junction)	−40°C to +125°C
Ambient Temperature Range (TA)	-40°C to 85°C

ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
VIN, VBUS, OPTO	−0.3V to +16V
CC1, CC2, D+, D−	−0.3V to +16V
VDD, FB	−0.3V to +7V
Operating Temperature Range (Junction)	−40°C to +125°C
Soldering Conditions	JEDEC J-STD-020
Electrostatic Discharge (ESD)	
Human Body Mode	2000V
Charged Device Mode	±500V

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Thermal performance is directly linked to printed circuit board (PCB) design and operating environment. Close attention to PCB thermal design is required.

θ_{JA} is the natural convection junction to ambient thermal resistance measured in a one cubic foot sealed enclosure.

θ_{JC} is the junction to case thermal resistance.

Table 5. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
PLDFN3x3-9L	75	54	°C/W
DFNFC3x3-9	87	56	°C/W

ESD CAUTION

Electrostatic Discharge Sensitive Device.

Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

THEORY OF OPERATION

The HUSB351 is designed for PD power adapter under 27W. With power switch integrated inside the chip, the HUSB351 minimizes the quantities of external components and achieves highly integrated total system solution.

The HUSB351 supports two kinds of voltage regulation methods with the AC-DC or DC-DC power stages: the traditional opto-coupler connection and the direct feedback connection. The default setting is the opto-coupler connection.

OPTO-COUPLER CONNECTION

The HUSB351 is able to control an AC-DC using opto-coupler feedback as shown in Figure 3. The HUSB351 senses the VIN voltage and an internal voltage reference is set to the target voltage. The internal error amplifier compares the voltage difference between scaled VIN and the reference voltage. The OPTO current is controlled by error amplifier to fine tune the VIN voltage through the external opto-coupler. As this is a close loop control, it provides a VIN voltage with high accuracy.

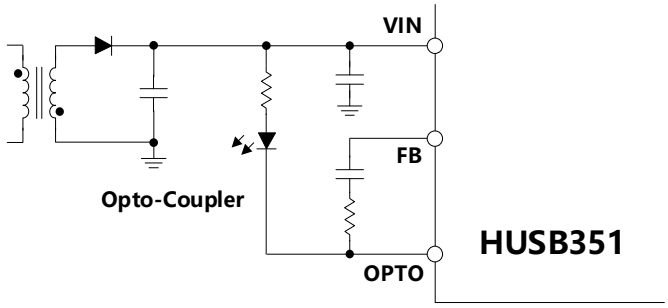


Figure 3. Opto-Coupler Connection

DIRECT FEEDBACK CONNECTION

The HUSB351 can be configured to support the direct feedback control by internal fuse option, if the front end power supply is an integrated AC-DC or a non-isolated DC-DC. As shown in Figure 4, the FB pin is designed to be tied directly to the resistor network of the power stage. The FB pin is capable of sourcing or sinking a current to the external resistor network. Under this kind of configuration, the top feedback resistor should be 100kΩ. A compensation capacitor is placed at OPTO pin to compensate internal loop.

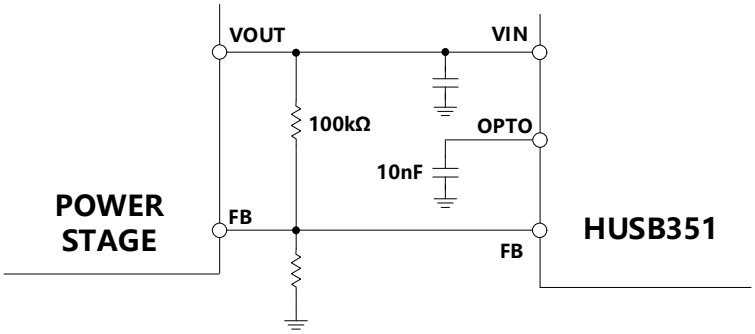


Figure 4. Direct Feedback Connection

VIN AND VBUS PINS

VIN PIN

VIN pin is the power supply input, which is derived from the output of the AC-DC or DC-DC converter. Connect a 1μF decoupling MLCC between VIN pin and GND pin.

In the voltage loop control, the output voltage is sensed on VIN pin with an internal resistance divider. The scaling factor is set to 10.

The VIN pin is also connected to the drain of internal power switch.

VBUS PIN

VBUS pin is the power output pin of the HUSB351. When Type-C connection is established, the internal power switch is turned on with a soft start time of 1ms, and the VIN voltage is passed to VBUS pin.

The VBUS pin is connected to the source of internal power switch.

DISCHARGE FUNCTION

There are discharge circuits on both VIN pin and VBUS pin to help discharge the voltage quickly when any fault or a disconnection event happens.

During discharge mode, a typical 200Ω resistor is connected between VIN or VBUS pin to GND pin. The typical discharge time out is 300ms.

INTERNAL REGULATOR

An internal liner regulator is used to provide 3.3V for internal circuits. Connect a 1μF MLCC to VDD pin for decoupling.

CONTROL LOOP COMPENSATION CIRCUIT (FB, OPTO PINS)

In the HUSB351, the constant voltage loop (CV loop) compensation and constant current loop (CC loop) compensation are implemented. VIN voltage is scaled by a resistor divider to be as the feedback voltage. It is compared with the internal voltage reference to generate an error signal. The CV loop can compensate this error signal. And then the compensated signal is employed to drive the primary side of the opto-coupler and control the AC-DC power loop.

SLEW RATE CONTROL

The HUSB351 implements a fixed voltage slew rate, which is 83mV/ms.

IR COMPENSATION

IR compensation is only available when VIN is set to 5V. If PPS is available in any power level, IR compensation will be disabled even if 5V APDO is selected. The default IR compensation is 50mV/A.

For example, if 50mV/A IR compensation is selected, then for the 5V/3A condition (except 5V APDO), the actual VIN voltage is:

$$5V + 3A \times 50mV/A = 5.15V$$

CC1 AND CC2 PINS

CC1 and CC2 pins are used to detect Type-C connection and performs BMC driver operation as well.

TYPE-C CC FUNCTION

CC1 and CC2 are the Configuration Channel pins used for connection and attachment detection, plug orientation determination and system configuration management across USB Type-C cable.

The HUSB351 monitors the status of CC1 and CC2 pins and decide which state should HUSB351 enter.

CC1 and CC2 are configured as Source only mode with 1.5A and 3A current advertising. The default Rp current on CC1 and CC2 is ICC_3P0, which means 3A current advertising.

The CC1 and CC2 can tolerance a voltage up to 16V. This is helpful for the HUSB351 to survive in the failure when the CC1 or CC2 is shorted to the VBUS pin.

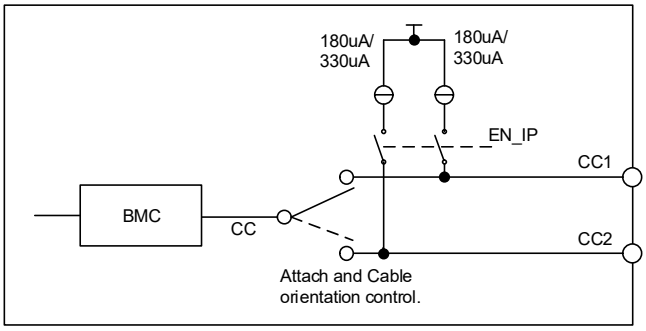


Figure 5. CCx Hardware Diagram

BMC DRIVER

Through the Type-C detection, one of the CC pins will be connected to the internal BMC block to achieve PD communication.

CHARGING PROTOCOLS AUTO SELECTION (D+ AND D- PIN)

The HUSB351 supports various fast charging protocols including BC1.2 DCP, Divider 3, QC 2.0/3.0 Class A, AFC, FCP and SCP. According to the different status of D+ and D- pins, the HUSB351 recognizes the attached Sinks and apply the fast charging protocol automatically.

DPDM_APP MODE

The DPDM_APP mode is the mode that the HUSB351 supports the Divider 3 charging protocol. In the DPDM_APP mode, the HUSB351 outputs 2.7 V DC voltage on both D+ and D- pins. The 2.7 V can be pulled down by the attached Sink. If D+ or D- pin is pulled down below VSEL_REF, the HUSB351 exits the DPDM_APP mode and enters into DPDM_DCP mode.

DPDM_DCP MODE

The DPDM_DCP mode is the mode that the HUSB351 supports BC1.2 DCP protocol. The 2.7 V DC sources are removed and the D+ and D- pins are shorted through RDPM_SHORT resistor. It is possible for the attached Sink to start primary, secondary and HVDCP detection processes when the HUSB351 is in DPDM_DCP mode.

DPDM_HVDCP MODE

After successful detection of the DCP, the HUSB351 notify the Sink that the HUSB351 enters into HVDCP mode. In the HVDCP mode, the HUSB351 monitors the D+/D- status and enters into different modes depending on the status of D+/D- pins.

OVER VOLTAGE PROTECTION

The HUSB351 detects the VIN pin voltage to achieve over-voltage protection function. The threshold to trigger over-voltage protection has two options that is configured by internal fuse options. The default option is 120% of the regulated voltage. When the over-voltage condition occurs, the HUSB351 turns of the internal power switch and enters into discharge mode. When the over-voltage condition is removed, HUSB351 re-negotiates with attached device again.

UNDER VOLTAGE PROTECTION

The HUSB351 detects the VIN pin voltage to achieve under-voltage protection function. The threshold to trigger under-voltage protection is 80% of the regulated voltage. When the under-voltage condition occurs and the UVP function is enabled, the HUSB351 turns of the internal power switch and enters into discharge mode. When the under-voltage condition is removed, the HUSB351 re-negotiates with attached device again.

OVER CURRENT PROTECTION AND CONSTANT CURRENT

The HUSB351 senses the current flowing through the internal power switch. This current information is used to perform the Over Current Protection (OCP) or Constant Current (CC) control when current limit event happens.

There are four options of the non-PPS current limit thresholds that can be set by internal fuses and the default value is 120% of the rating current. In PPS mode, the constant current threshold is fixed as 100% of the RDO current.

OCP

When the sensed current exceeds the internal current limit threshold, the over-current protection takes action and the HUSB351 turns off the internal power switch, resets internal status and re-negotiates with attached device again in auto-recover mode (default) or latches off in latch mode.

CC

If the HUSB351 is configured as constant current mode, the constant current threshold is sent to the current loop as the reference. When the sensed current reaches the constant current threshold, the constant current loop takes in charge of the control and VIN decreases so that the output current remains constant.

FAST OVER CURRENT PROTECTION

The HUSB351 integrates SCP protection function. When the VBUS is hard shorted by fault, the output current increases sharply. When the output current reaches the SCP threshold, the protection circuit takes action and turns off the internal power switch after the SCP de-bounce time. When the short condition is removed, the HUSB351 is reset to standby mode and will automatic recover again.

The typical SCP threshold is 12A to protect the internal power switch from being damaged.

THERMAL SHUT DOWN

The HUSB351 has internal temperature sensing circuit that monitors the junction temperature. When the junction temperature rises above 150°C, over-temperature protection takes action and the internal power switch is turned off immediately. When the junction temperature falls below 130°C, the HUSB351 is reset to standby mode and will automatically recover again.

TYPICAL APPLICATION CIRCUITS

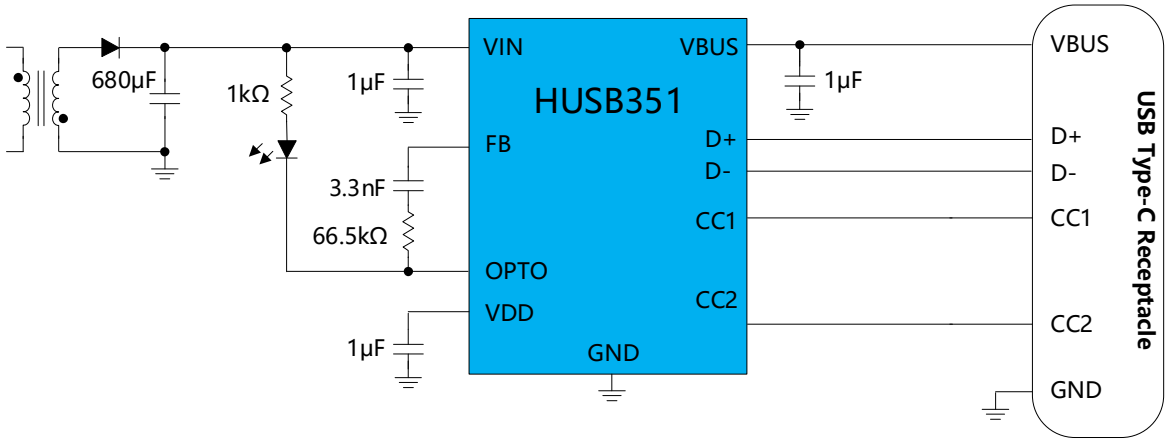


Figure 6. PD Adapter Application Circuit

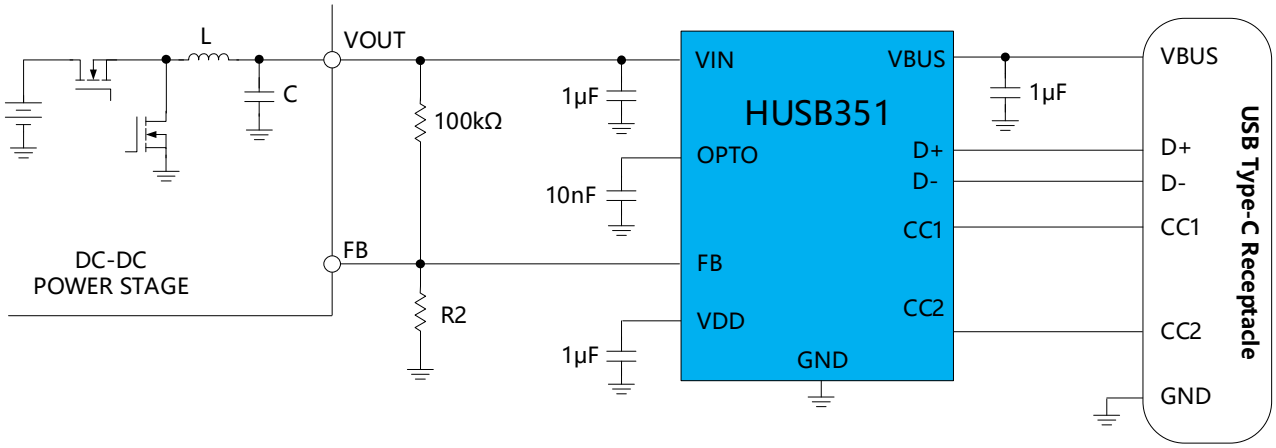
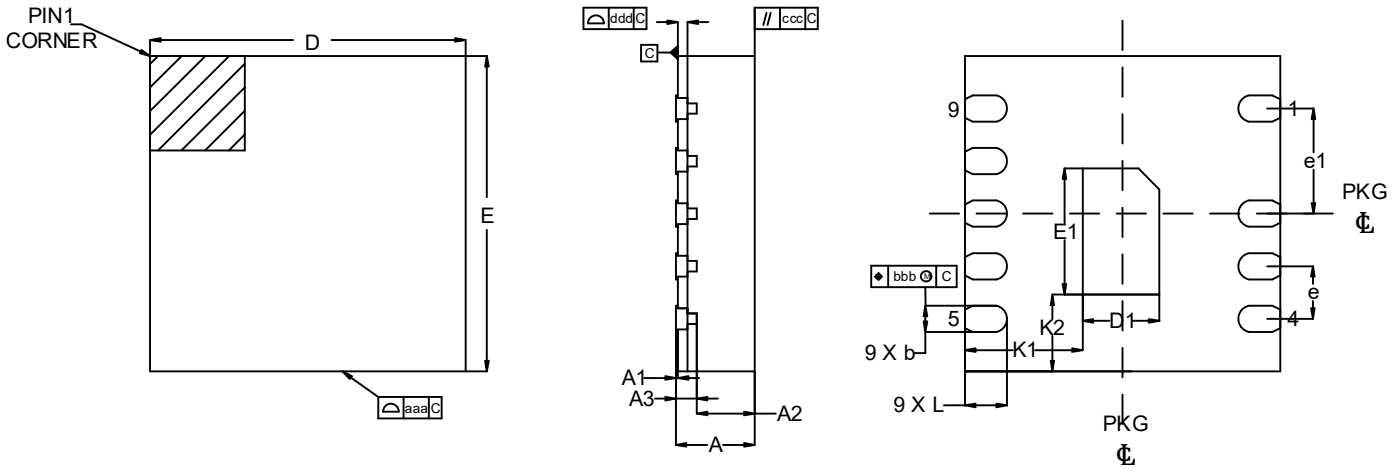


Figure 7. Car Charger Application Circuit

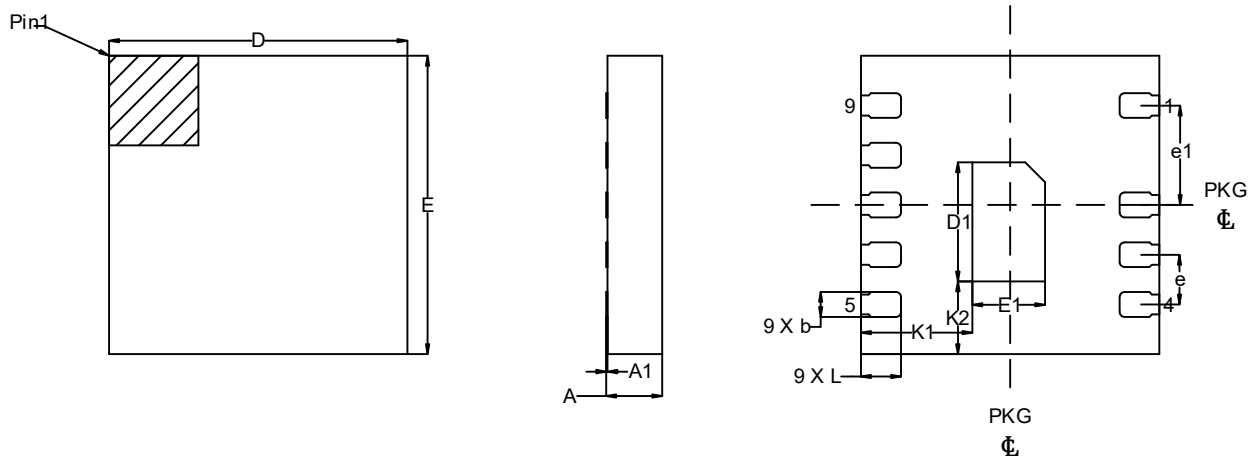
PACKAGE OUTLINE DIMENSIONS



TOP VIEW SIDE VIEW BOTTOM VIEW

	DIMENSION IN MILLIMETERS		
SYMBOLS	MIN	NOM	MAX
A	0.700	0.750	0.800
A1	0.000	0.020	0.050
A2		0.550	
A3		0.203 REF	
b	0.200	0.250	0.300
D		3.000	
E		3.000	
D1	0.630	0.730	0.830
E1	1.100	1.200	1.300
e		0.500	
e1		1.000	
L	0.350	0.400	0.450
K1		1.120 REF	
K2		0.730 REF	
aaa		0.100	
bbb		0.100	
ccc		0.100	
ddd		0.050	

Figure 8. FCDFN-9L Package, 3 mm × 3 mm



TOP VIEW SIDE VIEW BOTTOM VIEW

	DIMENSION IN MILLIMETERS		
SYMBOLS	MIN	NOM	MAX
A	0.512	0.562	0.612
A1	0.000	0.012	0.017
b	0.200	0.250	0.300
D	2.900	3.000	3.100
E	2.900	3.000	3.100
D1	0.630	0.730	0.830
E1	1.10	1.20	1.30
e	0.450	0.500	0.550
e1	0.950	1.000	1.050
L	0.350	0.400	0.45
K1	1.12		
K2	0.73		

Figure 9. PLDFN-9L Package, 3 mm × 3 mm

PACKAGE TOP MARKING

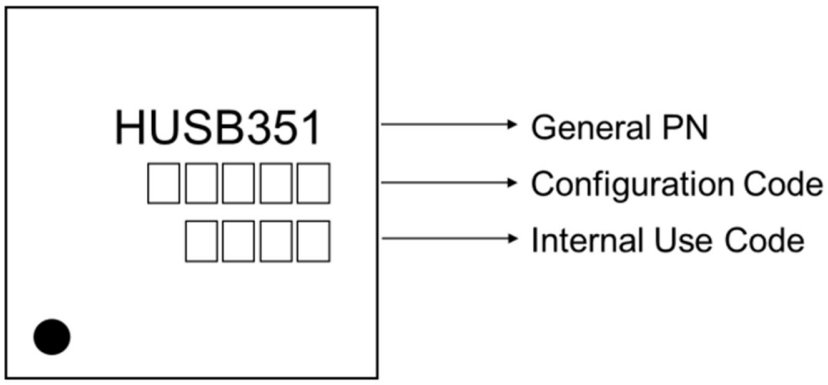


Figure 10. HUSB351 Package Top Marking

ORDERING GUIDE

Model[1]	T_J Temp (°C)	PDP	5V	9V	12V	5V Prog	9V Prog	Pkg Type	Pkg Opt	Pkg Qty
HUSB351_001TC	-40 to 125	20	Y	Y	Y	N	N	FCDFN3x3-9L	Tape & Reel	4000
HUSB351_002TC	-40 to 125	25	Y	Y	N	Y	Y	FCDFN3x3-9L	Tape & Reel	4000
HUSB351_008TC	-40 to 125	20	Y	Y	N	N	N	FCDFN3x3-9L	Tape & Reel	4000
HUSB351_001HB	-40 to 125	20	Y	Y	Y	N	N	PLDFN3x3-9L	Tape & Reel	5000
HUSB351_002HB	-40 to 125	25	Y	Y	N	Y	Y	PLDFN3x3-9L	Tape & Reel	5000
HUSB351_008HB	-40 to 125	20	Y	Y	N	N	N	PLDFN3x3-9L	Tape & Reel	5000

[1] Contact Hynetek for more configuration info.

IMPORTANT NOTICE

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