Buck-Boost SOC with UFCS/PD2.0/PD3.0/ERP28V Protocol

1 Features

- **Synchronous-Rectified Buck-Boost controller**
  - ✧ Input voltage range: 5V~31V
  - ✧ Support gate driver of path NMOS
  - ✧ Support CV/CC output mode
- **USB-C and PD protocol**
  - ✧ Support 5V/9V/12V/15V/20V/28V output
  - ✧ Support dual separate PD3.1/PPS/ERP28V protocol
  - ✧ Support 3.3V-21V, 10mV/step PPS
  - ✧ Support E-Marker cable
- **Fast charge output**
  - ✧ Support PD3.1/PPS/ERP28V protocol for USB-C port
  - ✧ Support BC1.2 and Apple protocol
  - ✧ Support QC2.0/QC3.0/QC3+/QC4+/QC5 protocol
  - ✧ Support FCP/HSCP protocol
  - ✧ Support AFC protocol
  - ✧ Support MTK protocol
  - ✧ Support UFCS protocol
- **Dual output ports**
  - ✧ Dual ports automatic detection of device plug-in and plug-out
  - ✧ Support AC/CC output
- **Multi-protection and high reliability**
  - ✧ Support input OVP and UVP
  - ✧ Support output OVP, OCP and SCP
  - ✧ Over temperature protection
  - ✧ NTC Board-level temperature detection
  - ✧ ESD 4KV

2 Applications

- **Car Charger**

3 Description

IP6557 integrates a Synchronous-Rectified Buck-Boost controller and gate drivers of path NMOS and it supports PD3.1/PPS/ERP28V protocols for USB-C port, which provides complete solutions for car charger.

IP6557 needs one inductor and power MOSFETs to achieve charging solutions with Buck-Boost function, which can reduce overall solution size effectively.

IP6557 can provide maximum 140W (28V5A) output and it supports NTC board-level temperature detection, can intelligently adjust the output power according to the temperature.

IP6557 integrates built-in 14-bit ADC to accurately measure the voltage and current of the input/output.

IP6557 output supports CV/CC features, when the output current is lower than preset value, the output voltage will be constant in CV output mode; when the output current is higher than preset value, the output voltage will decrease as CC output mode.

IP6557 integrates with a variety of protection functions, including input over voltage, under voltage and output over current, over voltage, under voltage, short circuit protection.

Package: QFN40 (5mm*5mm)

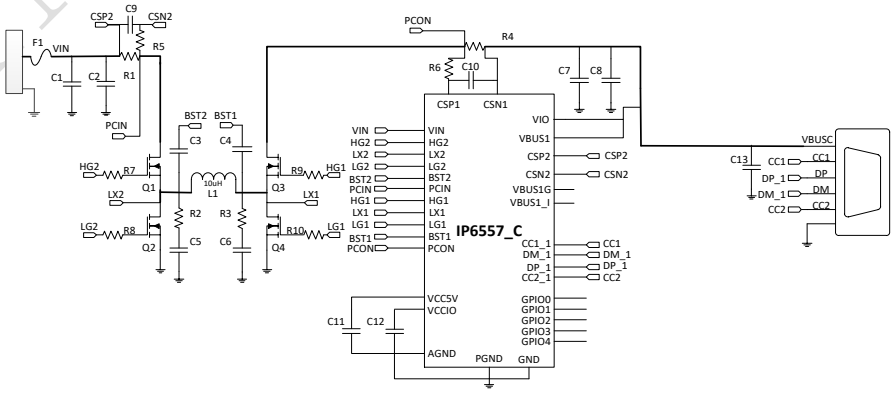

Figure 1 Simplified application schematic diagram of IP6557 single C port output

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4 Revision History

Notes: The page number of the previous version may different from the page number of the current version

Initial Release V 1.10 (Apr 2023)

1. Update the application schematic diagram of IP6557 single C port output

5 Typical Application Schematic Diagram

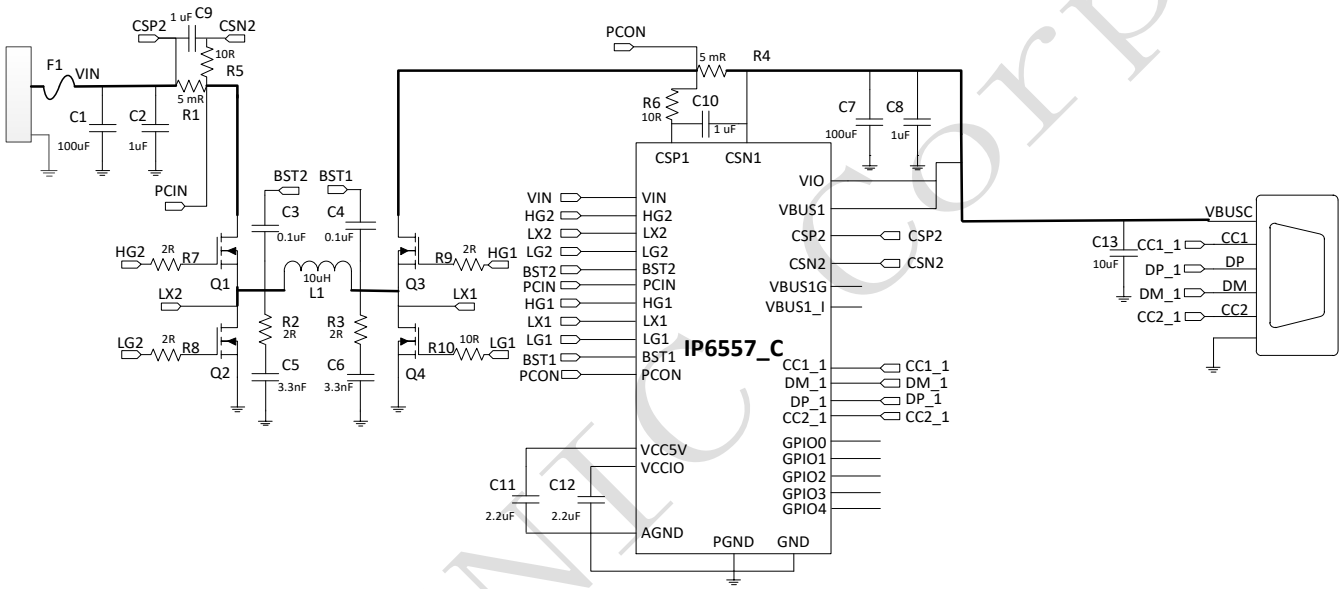


Figure 2 Application schematic diagram of IP6557 single C port output

6 Pin Functions

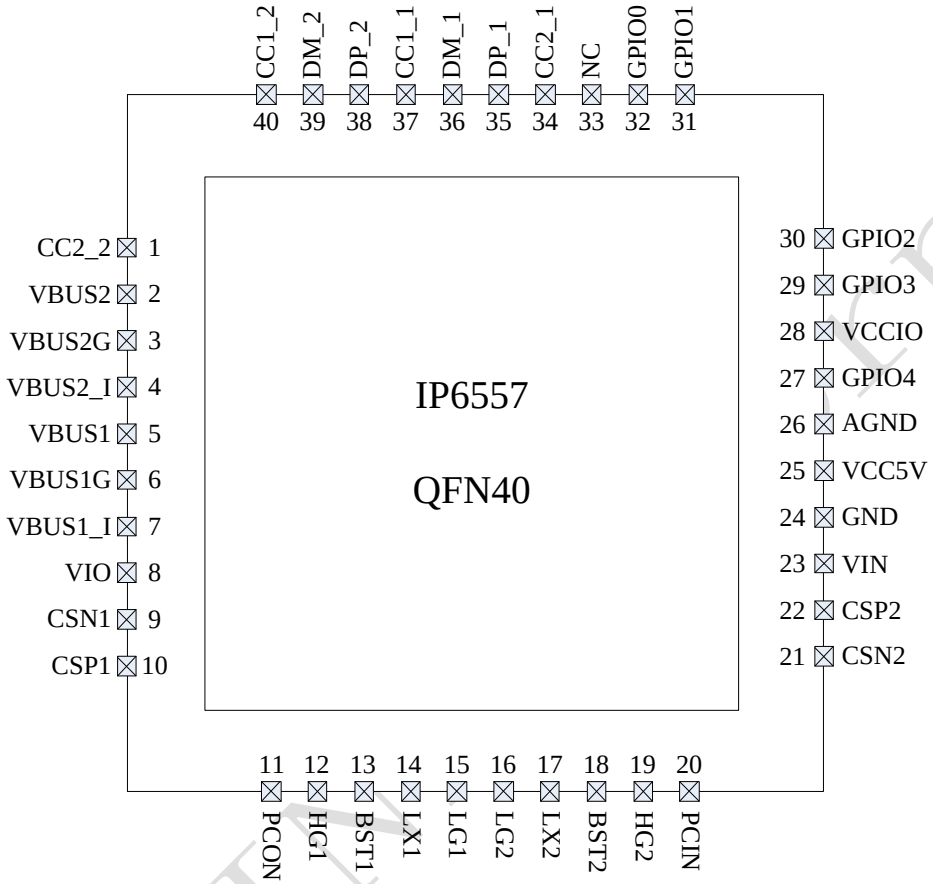


Figure 3 IP6557 Pin functions

Pins		Description
Pin No.	Pin Name	
1	CC2_2	USB C2 port detection and fast charge communication pin CC2
2	VBUS2	Port2 path NMOS current detection negative input/voltage detection pin
3	VBUS2G	NMOS in port2 output path driver pin
4	VBUS2_I	Port2 path NMOS current detection positive input
5	VBUS1	Port1 path NMOS current detection negative input/voltage detection pin
6	VBUS1G	NMOS in port1 output path driver pin
7	VBUS1_I	Port1 path NMOS current detection positive input
8	VIO	Buck-boost output voltage feedback pin
9	CSN1	Current sampling negative terminal of VIO
10	CSP1	Current sampling positive terminal of VIO
11	PCON	Output peak current sampling pin

12	HG1	The upper tube control pin at H-bridge power output end
13	BST1	Bootstrap voltage pin at H-bridge power output end
14	LX1	Inductor connection pin at the output of the H-bridge power tube
15	LG1	The lower tube control pin at H-bridge power output end
16	LG2	The lower tube control pin at H-bridge power input end
17	LX2	Inductor connection pin at the input of the H-bridge power tube
18	BST2	Bootstrap voltage pin at the input of the H-bridge power tube
19	HG2	The upper tube control pin at H-bridge power input end
20	PCIN	Input peak current sampling pin
21	CSN2	Current sampling negative terminal of VIN
22	CSP2	Current sampling positive terminal of VIN
23	VIN	VIN input pin
24	GND	System ground
25	VCC5V	VCC5V 5V LDO output pin
26	AGND	Analog ground
27	GPIO4	General GPIO/Analog input
28	VCCIO	VCCIO 3.3V LDO output pin
29	GPIO3	General GPIO/Analog input
30	GPIO2	General GPIO/Analog input
31	GPIO1	General GPIO/Analog input
32	GPIO0	General GPIO/Analog input
33	NC	Test pin, floating
34	CC2_1	USB C1 port detection and fast charge communication pin CC2
35	DP_1	USB C1 port fast charge communication pin DP
36	DM_1	USB C1 port fast charge communication pin DM
37	CC1_1	USB C1 port detection and fast charge communication pin CC1
38	DP_2	USB C2 port fast charge communication pin DP
39	DM_2	USB C2 port fast charge communication pin DM
40	CC1_2	USB C2 port detection and fast charge communication pin CC1
41	EPAD	Power ground

7 IP Series Model Selection Table

7.1 Car charger IC

IC Model	Output current	Dual ports	Supported Protocols										Package	
			DCP	QC2.0	QC3.0	FCP	SCP	AFC	MTK PE	SFCP	PD2.0	PD3.0 (PPS)	Pkg	P2P
IP6536	2.4A	√	√	-	-	-	-	-	-	-	-	-	ESOP8	PIN2PIN
IP6523S_NU	3.4A	-	√	-	-	-	-	-	-	-	-	-	ESOP8	
IP6525TQ	18W	-	√	√	√	√	-	√	-	-	-	-	ESOP8	
IP6525T_NU	18W	-	√	√	√	√	-	√	-	-	-	-	ESOP8	PIN2PIN
IP6525S	18W	-	√	√	√	√	√	√	√	√	-	-	ESOP8	
IP6525S_OC	18W	-	√	√	√	√	√	√	-	√	-	-	ESOP8	
IP6520	18W	-	√	√	√	√	√	√	√	-	√	-	ESOP8	PIN2PIN
IP6520T	20W	-	√	√	√	√	-	√	-	-	√	-	ESOP8	
IP6520T_PPS	20W	-	√	√	√	√	-	√	-	-	√	√	ESOP8	
IP6537_C	18W	-	√	√	√	√	√	√	√	√	√	√	QFN24	PIN2PIN
IP6537_C_30W20V	30W	-	√	√	√	√	√	√	√	√	√	√	QFN24	
IP6538U_AA	24W	√	√	√	√	√	√	√	√	-	-	-	QFN32	PIN2PIN
IP6538U_AC	27W	√	√	√	√	√	√	√	√	-	√	√	QFN32	
IP6551	4.8A	√	√	-	-	-	-	-	-	--	-	-	QFN32	
IP6527U_A	24W	-	√	√	√	√	√	√	√	-	-	-	QFN32	PIN2PIN
IP6527U_C	27W	-	√	√	√	√	-	√	√	-	√	√	QFN32	
IP6559_C	100W	-	√	√	√	√	√	√	-	-	√	√	QFN64	PIN2PIN
IP6559_AC	100W	√	√	√	√	√	√	√	-	-	√	√	QFN64	
IP6557_C	140W	-	√	√	√	√	√	√	√	√	√	√	QFN40	

7.2 IP6557 Series Product Selection

Product	Introduction
IP6557_C	Single C port PD fast charge output.

Notes:

1. IP6557 supports a maximum power output of 140W (28V/5A).
2. IP6557 supports indicating its own status through IO/IIC or controlling other modules in the solution, which is convenient to achieve multi-port solutions.

8 Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Input voltage	V_{IN}	-0.3 ~ 35	**V**
LX1/BST1/HG1/LX2/BST2/HG2 voltage	$V_{LX1/BST1/HG1}$ $V_{LX2/BST2/HG2}$	-0.3 ~ 50	**V**
BST1/HG1-LX1 voltage	$V_{BST1/HG1-LX1}$	-0.3 ~ 6	**V**
BST2/HG2-LX2 voltage	$V_{BST2/HG2-LX2}$	-0.3 ~ 6	**V**
VIO voltage	V_{VIO}	-0.3 ~ 30	**V**
VBUS1/VBUS1_I VBUS2/VBUS2_I voltage	$V_{VBUS1/VBUS1\_I}$ $V_{VBUS2/VBUS2\_I}$	-0.3 ~ 30	**V**
CSP2/CSN2/PCIN voltage	$V_{CSP2/CSN2/PCIN}$	-0.3 ~ 35	**V**
CSP1/CSN1/PCON voltage	$V_{CSP1/CSN1/PCON}$	-0.3 ~ 30	**V**
CC1_1/CC2_1 /CC1_2/CC2_2 voltage	$V_{CC1\_1/CC2\_1/\ CC1\_2/CC2\_2}$	-0.3 ~ 30	**V**
DM_1/DP_1/DM_2/DP_2 voltage	$V_{DM\_1/DP\_1/\ DM\_2/DP\_2}$	-0.3 ~ 22	**V**
Junction temperature	T_J	-40 ~ 125	**℃**
Storage temperature	Tstg	-60 ~ 150	**℃**
Thermal resistance (junction to ambient)	θ_{JA}	40	**℃/W**
Human body model (HBM)	ESD	4	**KV**

*Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
Exposure to Absolute Maximum Rated conditions for extended periods may affect device reliability.

9 Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Input voltage	V_{IN}	5	12/24	31	V

*Device's performance cannot be guaranteed when working beyond those Recommended Operating Conditions.

10 Electrical Characteristics

Unless otherwise specified, the test IC is IP6557_C, TA =25℃, L=10uH

Parameters	Symbol	Test Condition	Min.	Typ.	Max	Unit
Input system						
Input voltage	V_{IN}		5	12/24	31	V
Input under voltage	V_{IN-UV}	Lowering voltage	4.3	4.5	4.7	V
	$V_{IN-UV-TH}$	Hysteresis voltage		0.5		V
Input over voltage	V_{IN-OV}	Rising voltage	30.6	31	31.4	V
	$V_{IN-OV-TH}$	Hysteresis voltage		0.4		V
Input quiescent current	I_{Q1}	VIN=24V, VOUT=5V@0A		3.5		mA
Drive system						
HG1/HG2 pull-up resistor	R_{HG_PU}			2		Ω
HG1/HG2 pull-down resistor	R_{HG_PD}			1		Ω
LG1/LG2 pull-up resistor	R_{LG_PU}			2		Ω
LG1/LG2 pull-down resistor	R_{LG_PD}			1		Ω
Dead time	$T_{Deadtime}$	VIN=24V, VOUT=5V		35		ns
Switching frequency	F_S	VIN=24V, VOUT=5V	225	250	275	kHz
Output system						
Output voltage	V_{OUT}		3.3		28	V
Output voltage ripple Cout: 100uf solid-state cap	ΔV_{OUT}	VIN=24V, VOUT=5.0V, fs=250KHz, Iout=3A		100		mV
		VIN=24V, VOUT=12V, fs=250KHz, Iout=3A		100		mV
		VIN=24V, VOUT=28V, fs=250KHz, Iout=5A		150		mV
Soft start time	T_{SS}	VIN=24V, VOUT=5V	1.3	1.9	2.5	ms
Output line compensate voltage	V_{COMP}	VIN=24V, VOUT=5V, IOUT=3A		150		mV
Maximum Output current in CC mode	I_{OUT}	VIN=24V, VOUT=5V		3		A
		VIN=24V, VOUT=9V		3		A
		VIN=24V, VOUT=12V		3		A
		VIN=24V, VOUT=20V E-Marker cable		5		A

		VIN=24V, VOUT=28V E-Marker cable		5		A
Output overvoltage threshold	V_{OUT}	After the output enters CC mode, the output hiccup restart voltage		2.6		V
Thermal shutdown temperature	T_{OTP}	Rising temperature		150		℃
Thermal shutdown temperature hysteresis	ΔT_{OTP}	Lowering temperature		40		℃

11 Function Description

11.1 Internal Block Diagram

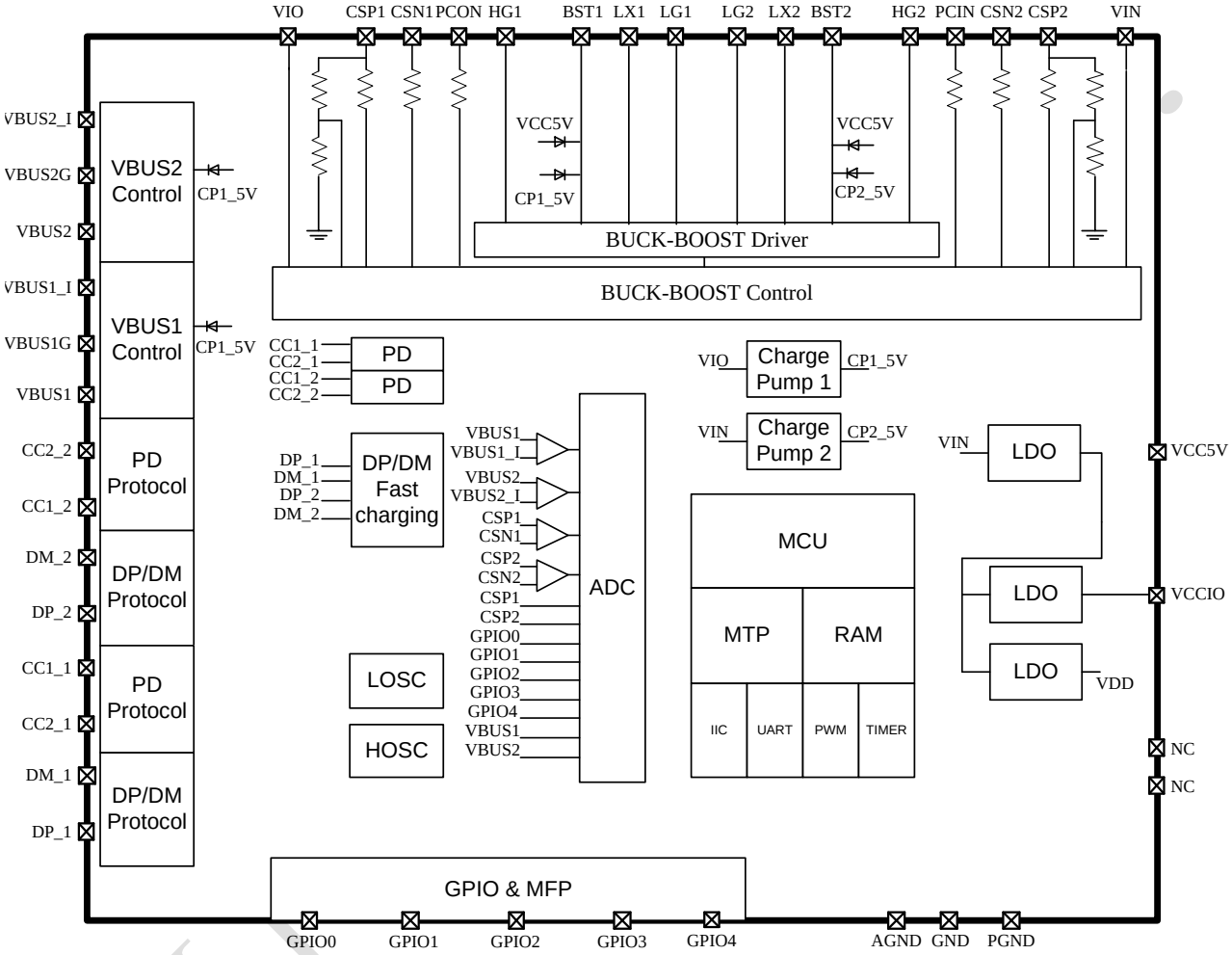


Figure 4 IP6557 Internal block diagram

11.2 Synchronous-Rectified Buck-Boost controller

IP6557 integrates a Synchronous-Rectified Buck-Boost controller, wide input voltage ranges from 5V to 31V and output from 3.3V to 28V.

IP6557 integrates input peak inductance current limiting and output average current limiting functions.

The output switching frequency of IP6557 is 250kHz, It can be adjusted internally.

IP6557 has soft start function, preventing the huge inrush current cause damage to the IC.

When VIN=12V, VOUT=5V, the soft start time is 1.6ms.

The MOSFET $R_{DS(ON)}$ = 8mohm@ $V_{GS} = 4.5V$ When VIN=12V, VOUT=5V@3A, the conversion efficiency is 94%.

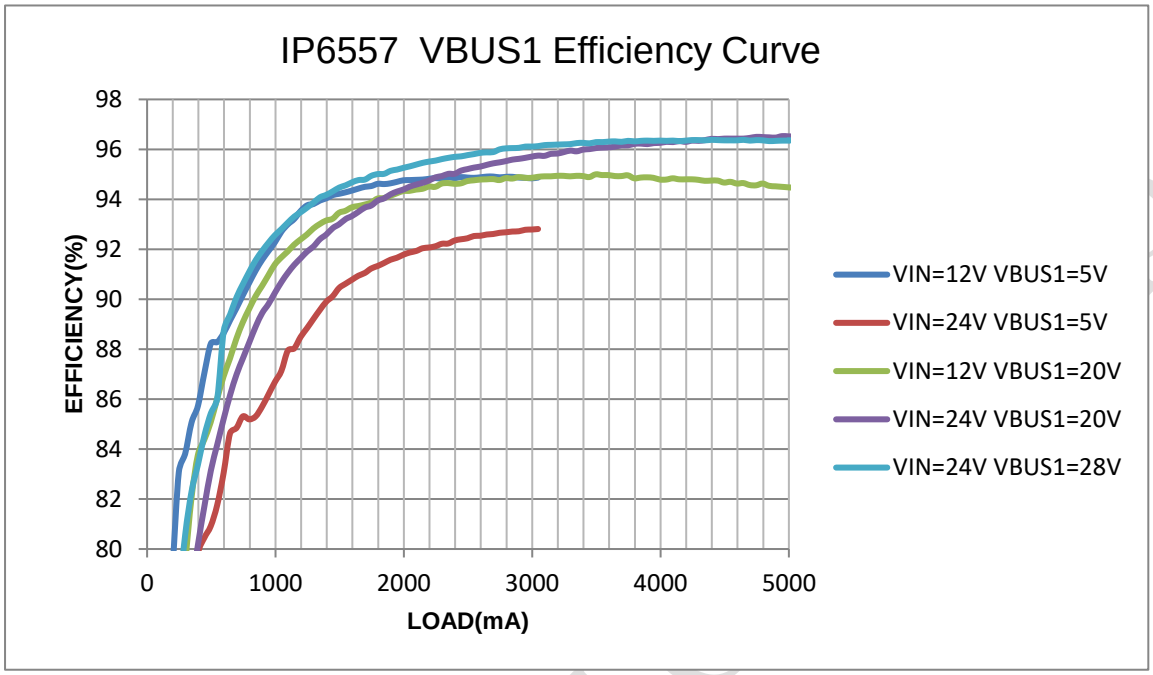


Figure 5 IP6557 VBUS1 output efficiency curve

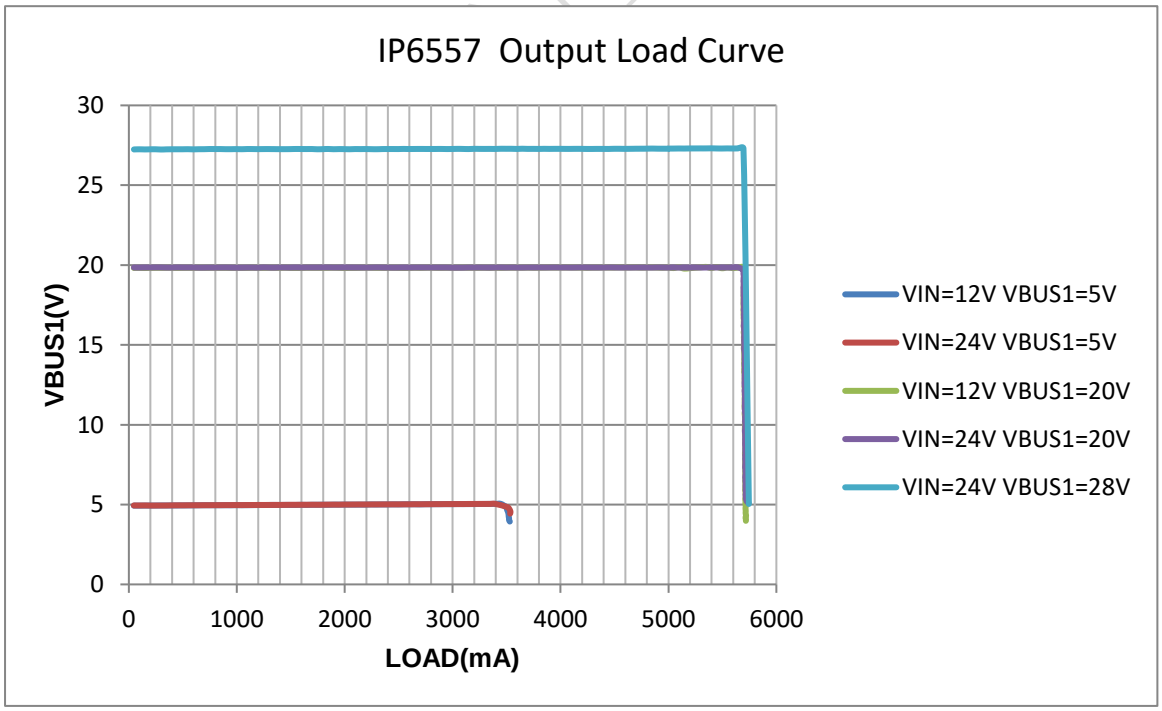


Figure 6 IP6557 VBUS1 output load curve

11.3 Output Voltage Line Compensate

IP6557 supports output line compensate, output voltage will increase about 50mV as output current increase 1A.

11.4 Output CV/CC Characteristic

IP6557 output has CV/CC mode: when the output current is lower than preset value, the output is in CV mode with constant voltage; when the output current is higher than preset value, the output is in CC mode with decreasing output voltage. The output current continues to increase and the output voltage rapidly decreases until the output voltage undervoltage protection is triggered.

11.5 Output CC Current Set

IP6557 output current limit can be adjusted by regulate the 5mohm sensing resistor between CSP1 and CSN1. The output current is measured by detect the voltage drop between CSP1 and CSN1.

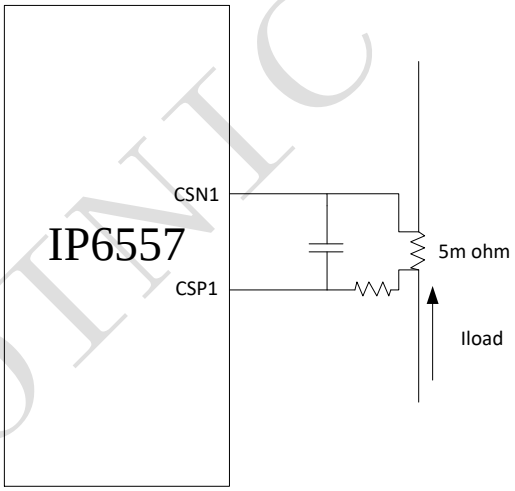


Figure 7 IP6557 output current limiting circuit

When the value of 5mohm current detect resistor is changed, the IP6557 output current limit will be changed accordingly.

In PCB layout, pay attention to the trace routing of CSP1 and CSN1, the trace should go out directly from the two side of 5mOhm resistor, avoiding introduce current limit deviation because of additional PCB trace resistor.

Other than that, the 5mohm resistor should use alloy resistor with good temperature coefficient (100ppm) and high precision of 1%.

11.6 Protection Function

IP6557 supports input over voltage protection: When the VIN voltage is higher than 31V, IP6557 will shut down the output because of the VIN over voltage. When the VIN drops under 29V, IP6557 will consider the VIN normal and reopen the output.

IP6557 supports output under voltage protection: When the VBUS1 voltage is lower than 2.6V, IP6557 will shut down the output because of the output under voltage. After 2sec, it will hiccup reopen.

IP6557 supports short circuit protect: 10ms after the circuit is working, when VBUS1 voltage is under 2.6V, IP6557 will shut down the output because of the output short circuit. After 2sec, it will hiccup reopen.

IP6557 supports over temperature protection: When the temperature is detected higher than 150℃, the output will be shut down. When the temperature drops under 110℃, IP6557 will consider the temperature normal and will reopen the output.

11.7 Dual Output Ports

IP6557 supports dual USB-C or USB-A and USB-C dual output ports, either port supports fast charge output. Dual ports output voltage is 5V when dual ports are connected to devices.

When dual ports are both connected device, dual ports overall output power is 5V/4.8A.

IP6557 integrates dual ports automatic detection of device plug-in and plug-out detection function, either port can support fast charge output.

11.8 Fast Charge Protocol Output

IP6557 supports fast charge protocol output, the specifications are as follows:

- ✧ Support PD3.1/PPS/ERP28v protocol for USB-C port
- ✧ Support BC1.2 and Apple protocol
- ✧ Support QC2.0/QC3.0/QC3+/ QC4+/QC5 protocol
- ✧ Support FCP/HSCP protocol
- ✧ Support AFC protocol
- ✧ Support MTK protocol
- ✧ Support UFCS protocol

12 Application Notes

12.1 Input Capacitance Selection

The ESR of the input capacitor should be as small as possible. The ESR will affect the conversion efficiency of the system.

When the input voltage is significantly greater than the output voltage, the device works in buck mode. The maximum ripple current supported by the input capacitor must be greater than the maximum VIN ripple current of the system. The ripple current RMS value ($I_{RMS(VIN)}$) of the input capacitor is calculated as follows:

$$I_{RMS(VIN)} = I_{LOAD} * \sqrt{\frac{V_{OUT}}{V_{IN}} * (1 - \frac{V_{OUT}}{V_{IN}})}$$

I_{LOAD} is the output current, V_{IN} is the input voltage, V_{OUT} is the output voltage.

12.2 Inductance Selection

The inductor with 10uH is recommended for most applications.

The DCR of inductor has great influence on the conversion efficiency of the system, low DCR inductors are recommended. For solutions above 30W, it is recommended to use an inductor with a DCR of less than 10mohm.

The inductor saturation current should be at least 20% greater than the system's peak inductor current limit, in order to avoid inductance saturation, resulting in a decrease in inductance, system instability.

The calculation formula of the PEAK current ($I_{L(PEAK)-BUCK}$) in buck mode is as follows:

$$I_{L(PEAK)-BUCK} = I_{LOAD} + \frac{V_{OUT}*(V_{IN}-V_{OUT})}{2*V_{IN}*F_S*L}$$

The calculation formula of the PEAK current ($I_{L(PEAK)-BOOST}$) in boost mode is as follows:

$$I_{L(PEAK)-BOOST} = \frac{V_{OUT}*I_{LOAD}}{V_{IN}*EFF} + \frac{V_{IN}*(V_{OUT}-V_{IN})}{2*V_{OUT}*F_S*L}$$

I_{LOAD} is the output current, V_{IN} is the input voltage, V_{OUT} is the output voltage, L is the inductance, F_S is the switching frequency，EFF is the conversion efficiency of DCDC.

12.3 Output Capacitance Selection

When the output voltage is significantly greater than the input voltage, the device works in boost mode. The maximum ripple current supported by the output capacitor must be greater than the maximum VOUT ripple current of the system. The ripple current RMS value ($I_{RMS(VOUT)}$) of the output capacitor is calculated as follows:

$$I_{RMS(VOUT)} = I_{LOAD} * \sqrt{\frac{V_{OUT}}{V_{IN}} - 1)}$$

I_{LOAD} is the output current, V_{IN} is the input voltage, V_{OUT} is the output voltage.

The output capacitance is used to keep the output stable. The value of ESR and capacitance has an effect on the output ripple.

The output ripple voltage $V_{OUT(RIPPLE)-BUCK}$ in buck mode can be calculated as follows:

$$V_{OUT(RIPPLE)-BUCK} = \frac{V_{OUT}*(V_{IN}-V_{OUT})}{V_{IN}*L*F_S} * (R_{ESR} + \frac{1}{8*F_S*C_{OUT}})$$

R_{ESR} is the equivalent serial resistance value of the output capacitance, F_S is the switching frequency, C_{OUT} is the output capacitance value.

The output ripple voltage $V_{OUT(RIPPLE)-BOOST}$ in boost mode can be calculated as follows:

$$V_{OUT(RIPPLE)-BOOST} = \frac{I_{LOAD}*V_{OUT}*R_{ESR}}{V_{IN}} + \frac{(V_{OUT}-V_{IN})*I_{LOAD}}{V_{OUT}*F_S*C_{OUT}}$$

R_{ESR} is the equivalent serial resistance value of the output capacitance, F_S is the switching frequency, C_{OUT} is the output capacitance value.

12.4 MOSFET Selection

MOSFET devices that $V_{(BR)DSS}$ at least 20% higher than the input voltage are recommended.

$R_{DS(ON)}$ of MOSFET causes the power loss of the on-device, which has a direct impact ON the conversion efficiency of the system. Generally, it is recommended to choose a 10mohm MOSFET with $R_{DS(ON)}$.If the solution requires higher power output, lower $R_{DS(ON)}$ devices are recommended.

The C_{ISS} of MOSFET affects its switching speed. It is necessary to adjust the resistance of HG and LG in series according to different MOSFET, and adjust the driving speed of MOSFET to ensure the system stability. The MOSFET which its C_{ISS} value is less than 1000pF is advised to choose.

The RC buffer circuit of LX1/LX2 can suppress the burr of LX. The proper RC buffer circuit can make the system have better EMI effect.

For the circuit of the driving part, it is recommended to reserve HG1/HG2 and LG1/LG2 series resistors of 0603 specifications and RC buffer circuit as shown in the following figure.

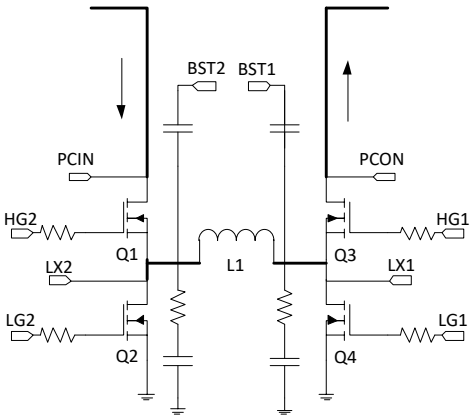


Figure 8 IP6557 MOSFET drive circuit diagram

13 Typical Application Schematic

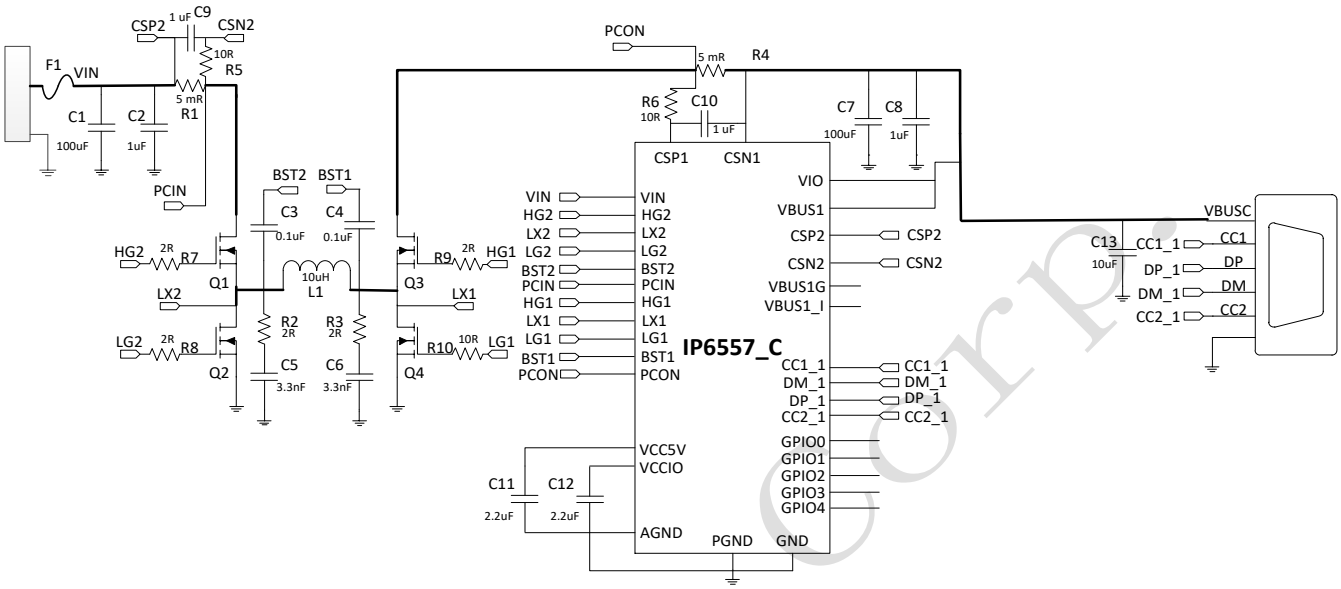


Figure 9 Typical application schematic diagram of IP6557 single C port

14 BOM List

With the application of IP6557_C single USBC output port, the finished BOM is as follows:

No.	Part Name	Type	Unit	Qty	Location	Notes
1	IC	IP6557_C	PCS	1	U1	
2	Inductor	10uH+/-20%, current 15A DCR<10mohm	PCS	1	L1	
3	Solid-state capacitor	100uF	PCS	1	C1	Withstand voltage higher than 50V
4	SMD capacitor	0603 0.1uF 10%	PCS	2	C3, C4	Withstand voltage higher than 35V
5	SMD capacitor	0603 3.3nF 10%	PCS	2	C5, C6	Withstand voltage higher than 35V
6	Solid-state capacitor	100uF	PCS	1	C7	Withstand voltage higher than 35V
7	SMD capacitor	0603 1uF 10%	PCS	4	C2, C8, C9, C10	Withstand voltage higher than 35V
8	SMD capacitor	0603 2.2uF 10%	PCS	2	C11, C12	Withstand voltage higher than 25V
9	SMD capacitor	0603 10uF 10%	PCS	1	C13	Withstand voltage higher than 35V
10	SMD resistor	1206 5mohm 1% precision, temperature coefficient less than 100ppm	PCS	2	R1、R4	Current sense resistor
11	SMD resistor	0603 2R 5%	PCS	5	R2, R3, R7, R8, R9	
12	SMD resistor	0603 10R 5%	PCS	3	R5, R6, R10	
13	MOSFET	MOSFET	PCS	4	Q1, Q2, Q3, Q4	
14	Fuse	F1	PCS	1	F1	

15 Precautions for PCB layout

IP6557 integrates a Synchronous-Rectified Buck-Boost controller. PCB layout is important for system stability, EMI, and other performance indicators. The PCB layout suggestions are as follows:

1. The loop composed of input capacitor and upper tube NMOS (controlled by HG2) and lower tube NMOS(controlled by LG2) should be as small as possible.

2. The loop composed of output capacitor and upper tube NMOS (controlled by HG1) and lower tube NMOS(controlled by LG1) should be as small as possible.

3. The inductor cable connecting the upper power tube and the lower power tube should be as wide and short as possible, so that the node area can ensure the maximum output current capacity.

4. The lines of HG1/LG1 and HG2/LG2 are parallel and the distance between those lines should be as wide as possible.

5. The loop composed of LX1/LX2 buffer circuit and PGND should be as small as possible.

6. The current sampling line for 5mohm resistance is directly drawn from both ends of the resistance（including PCON/CSP2/CSN2/PCIN/CSP1/CSN1）. These lines are parallel, should be as short as possible and avoid LX/BST/HG/LG and other switching nodes.

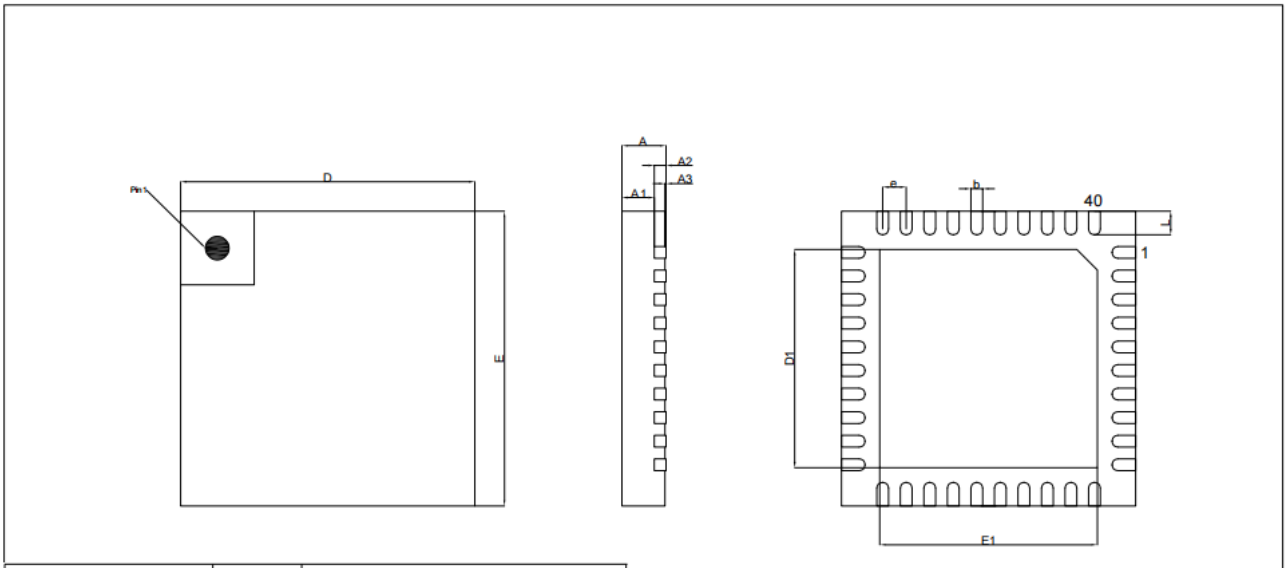
7. The capacitance of VCC5V and VCCIO is placed close to the device PIN.

8. The GND of the input and output capacitors must be connected to the PGND of a large area.

9. For better ESD protection, it is recommended to reserve the positions of resistors in series and diodes to ground in the CC1/CC2/DP/DM lines, and reserve capacitors to ground in CC1/CC2.

10. Please refer to the IP6557 Application Notes for further information.

16 Package



	POD	QFN40L(0505X0.75-0.40)(B)		
		Size unit: mm		
	Symbol	Minimum	Normal	Maximum
Total Thickness	A	0.70	0.75	0.80
Molding Thickness	A1	-	0.55	-
LF Thickness	A2	0.18	0.20	0.25
Stand Off	A3	0.00	0.02	0.05
Body Size	D	4.90	5.00	5.10
	E	4.90	5.00	5.10
Exposed Pad Size	D1	3.60	3.70	3.80
	E1	3.60	3.70	3.80
Lead Width	b	0.15	0.20	0.25
Lead Length	L	0.35	0.40	0.45
Lead Pitch	e	0.40 BSC		

QFN40L(0505X0.75-0.40)(B)

Figure 10 Package diagram

17 Silkscreen description

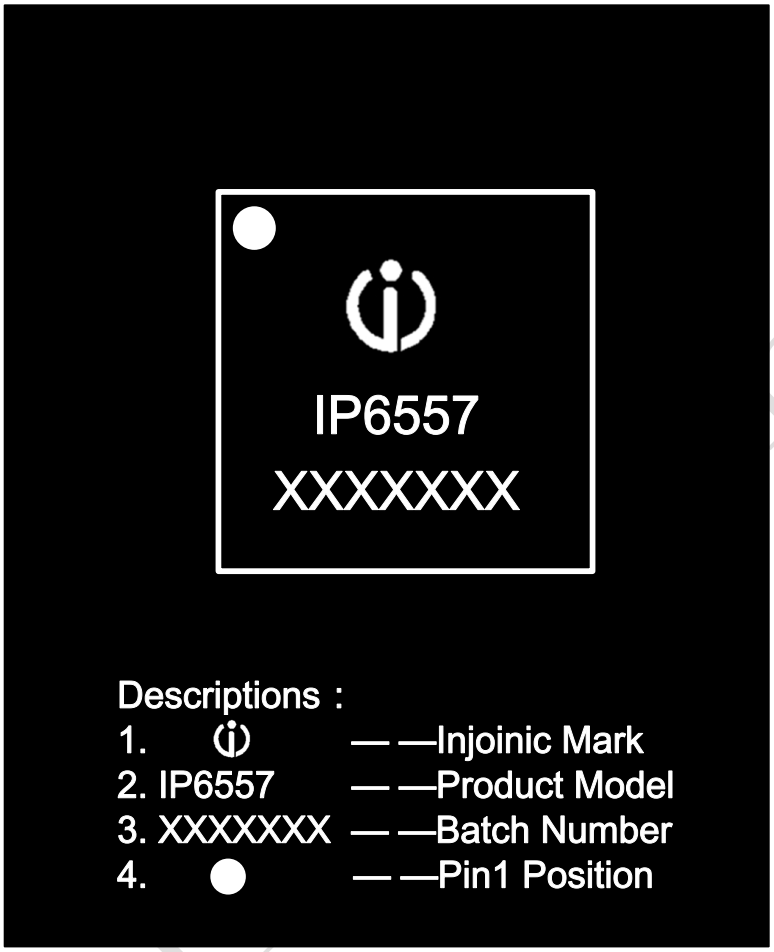


Figure 11 Silkscreen diagram

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