Output 36W Power Buck SOC with Multiple Fast Charge Protocols

1 Features

- **AEC-Q100 Qualified for Automotive Applications**
  - ✧ Grade 2： -40℃ ~ +105℃
- **Synchronized Switching Buck Converter**
  - ✧ Built-in Power MOSFETs
  - ✧ Input voltage range: 7.3V to 29.5V
  - ✧ Output voltage range: 3V to 12V
  - ✧ Output voltage line complement function
  - ✧ Output power support CV/CC mode
  - ✧ VIN=16V, VOUT=5V, peak conversion efficiency up to 93.27%
- **Support Type-C Output and USB PD Protocol**
  - ✧ Support 5V, 9V, 12V output
  - ✧ Support PD2.0/PD3.1/PPS output protocol
  - ✧ PPS support 3V to 11V adjustable voltage with 20mV/step output
- **Fast Charge Output**
  - ✧ Support Type-C PD output
  - ✧ Support BC1.2 and Apple
  - ✧ Support QC2.0, QC3.0 and QC3+
  - ✧ Support Samsung fast charge AFC
  - ✧ Support Huawei Fast charge FCP
- **Multi-Protections and High Reliability**
  - ✧ Input over voltage, input under voltage
  - ✧ Output short circuit, output over current
  - ✧ Over temperature protection
  - ✧ DP/DM/CC over voltage protection
  - ✧ HBM ESD 2KV

2 Application

- **Automotive USB Type-C PD charging ports**

3 Introduction

IP6520_Q1 is a synchronized switch buck converter which supports multiple fast charge output protocols, providing solutions for automotive USB Type-C PD charging ports.

IP6520_Q1 has built-in power MOSFETs, input voltage range is 7.3V to 29.5V, output voltage range from 3V to 12V, and supports up to 36W output power, can automatically adjust the output voltage and current according to the identified fast charging protocol, typical output voltage and current are: 5V@3A, 9V@3A.

IP6520_Q1 output power has CV/CC characteristic. When the output current is lower than the preset value, it is in CV mode with a constant output voltage; when the output current is higher than the preset value, it enters CC mode and the output voltage decreases as the output current increases.

IP6520_Q1 supports soft start, providing resistibility on the large inrush current during circuit starts up.

IP6520_Q1 supports multiple protections on input over voltage and under voltage, output over current, over voltage, under voltage and short circuit

IP6520_Q1 adopts ESOP8L Package.

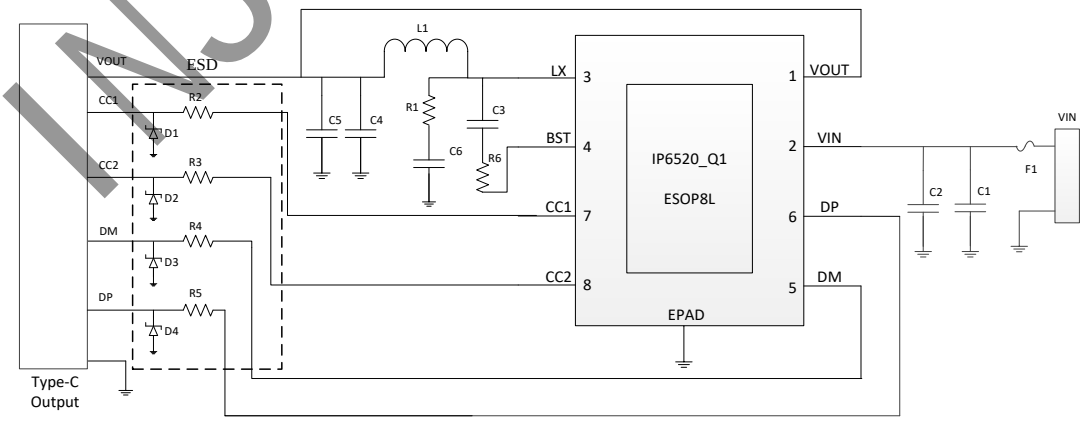


Fig.1 IP6520_Q1 Simplified Application Schematic

Content

4 Revision History

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

Initial Release V1.00（Feb 2025）

5 Typical Application Schematic Diagram

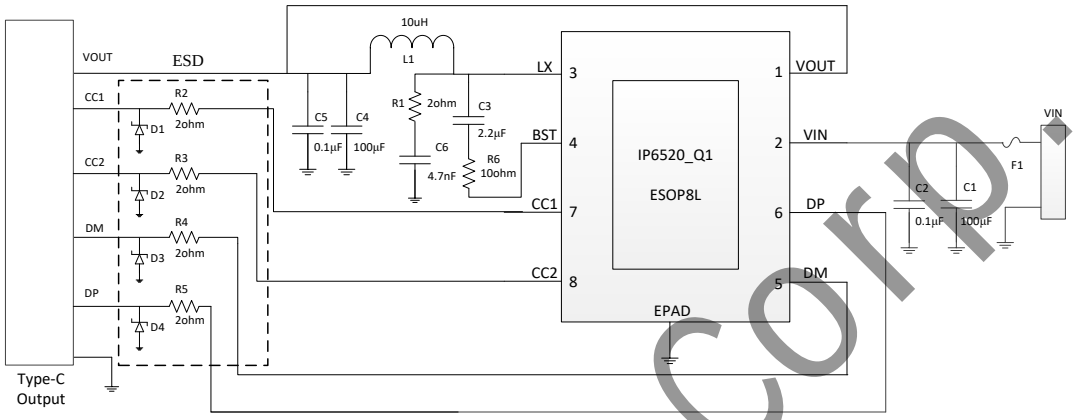


Fig. 2　IP6520_Q1 Output Application Schematic

Notes:

(1) IP6520_Q1 EPAD must have a good contact with PCB GND;

(2) C1 and C2 should be placed close to the PIN2 of IP6520_Q1; C2 requires an appropriate increase in capacitance if it is far from the 100uF capacitor or the power supply VIN;

(3) C3 should be placed close to the LX(PIN3) and BST(PIN4) of IP6520_Q1, which works as bootstrap capacitance;

(4) C5 should be placed close to the PIN1 of IP6520_Q1;

(5) R1 and C6 should be placed close to the LX (PIN3) of IP6520_Q1, and the loop composed of LX pin, R1, C6 and PGND should be minimized on the PCB board;

6 PIN Definition

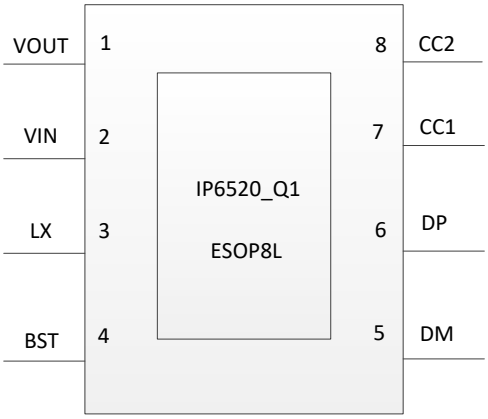


Fig. 3 IP6520_Q1 PIN Configuration

PIN List：

Pins		Description
Pin NO.	Pin Name	
1	VOUT	VOUT voltage feedback pin
2	VIN	Input voltage node, ceramic filter capacitor should be placed close to IC
3	LX	Power switch node, connected to external inductor
4	BST	Bootstrap capacitor pin, bootstrap capacitor should be placed close to the BST pin and the LX pin of IP6520_Q1, which provides voltage to the grid drive of the High-side MOS.
5	DM	USB C port fast charge communication pin DM
6	DP	USB C port fast charge communication pin DP。
7	CC1	USB C port detection and fast charge communication pin CC1
8	CC2	USB C port detection and fast charge communication pin CC2
9(EPAD)	PGND	Power ground

7 IP Series Model Selection Table

7.1 Automotive USB Type-C PD Charging Model Selection Table

Product	SPEC.
IP6529_Q1	Output 45W power buck SOC with multiple fast charge protocols
IP6591_Q1	Synchronous Buck-Boost Controller with IIC/FB
IP2727_Q1	Fast charging protocol IC for Automotive USB Type-C PD output

7.2 IP6520_Q1 Model Selection Table

Product	SPEC.				
IP6520_Q1	USB Type-C	PDO	5V/3A	9V/3A	-
		QC	5V/3A	9V/2A	-

Notes:

1. IP6520_Q1 supports a maximum power output of 36W (12V/3A).

8 Internal Block Diagram

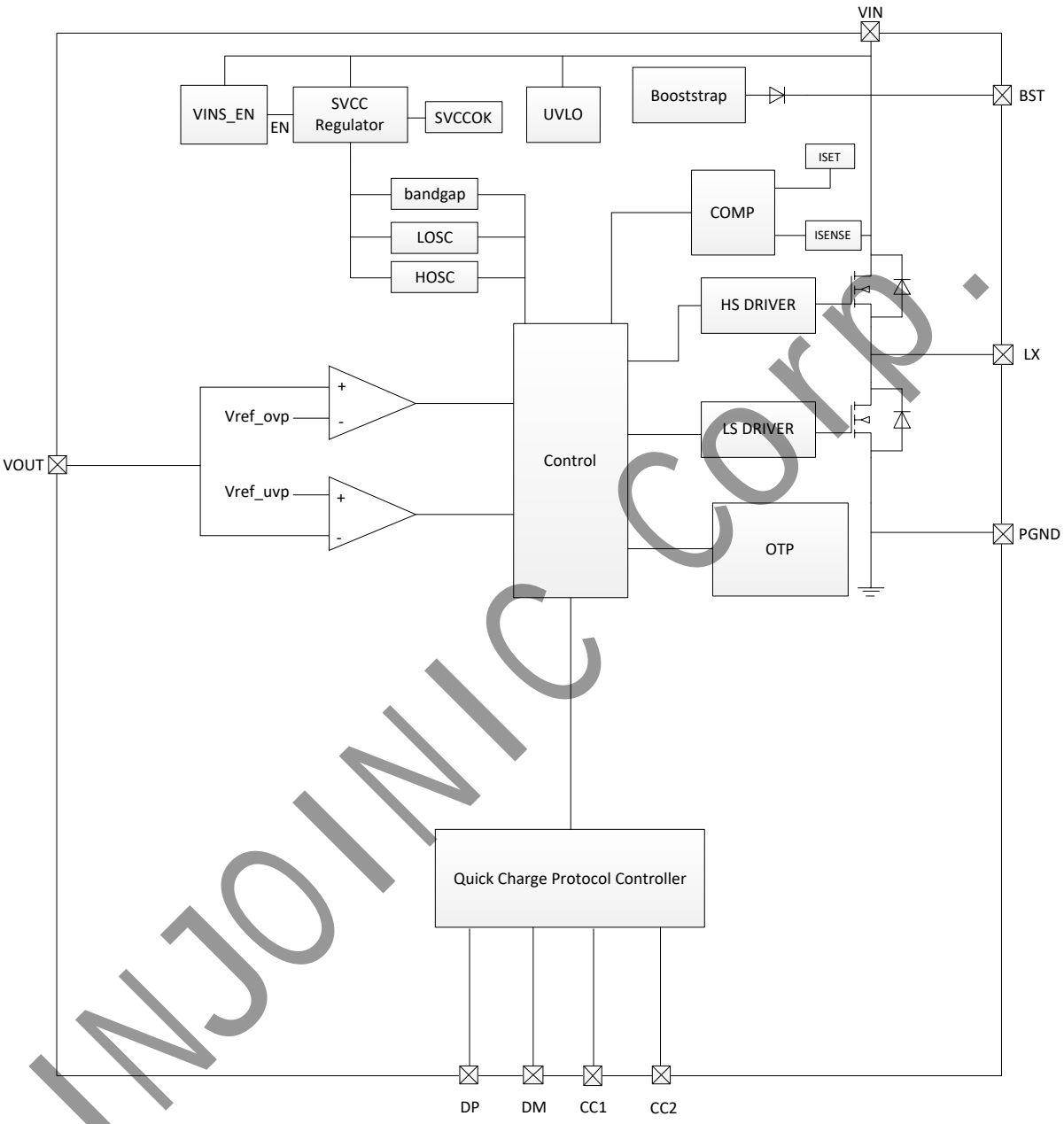


Fig. 4 IP6520_Q1 Internal Block Diagram

9 Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Input voltage range	V_{IN}	-0.3 ~ 36	V
LX voltage range	V_{LX}	-0.3 ~ VIN+0.3	V
VOUT voltage range	V_{VOUT}	-0.3 ~ 20	V
DP/DM voltage range	$V_{DM/DP}$	-0.3 ~ 6	V
CC voltage range	$V_{CC1/CC2}$	-0.3 ~ 15	V
Junction Temp range	T_J	-40 ~ 150	℃
Storage Temp range	Tstg	-60 ~ 150	℃
Operating ambient temperature range	T_A	-40 ~ 105	℃
Thermal resistance (junction to ambient）	θ_{JA}	50	℃/W
ESD（HBM）	ESD	2	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

10 Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Input voltage	V_{IN}	7.3	16	29.5	V

*Devices performance cannot be guaranteed when working beyond those Recommended Operating Conditions.

11 Electrical Charateristics

Unless otherwise specified, TA=-40~+105℃, L=10uH, VIN=16V, VOUT=5V, tested on the IP6520_Q1 demo.

Parameters	Symbol	Test Condition	Min.	Typ.	Max.	Unit.
Input system						
Input voltage	V_{IN}		7.3	16	29.5	V
Input under voltage	V_{IN-UV}	Rising voltage	7.2	7.3	7.4	V
	$V_{IN-UV-TH}$	Hysteresis voltage	-	0.4	-	V
Input over voltage	V_{IN-OV}	Rising voltage	29	29.5	30	V
	$V_{IN-OV-TH}$	Hysteresis voltage	-	0.2	-	V
Input quiescent current	I_Q	VIN = 16V	-	1.5	-	mA
Power switching system						
High-side MOS Ron resistance	$R_{DS(ON)-HIGH}$		-	30	-	mΩ
Low-side MOS Ron resistance	$R_{DS(ON)-LOW}$		-	20	-	mΩ
Switching frequency	F_{SW}		315	350	385	KHz
Output system						
Output voltage	V_{OUT}		3	5	12	V
Output voltage ripple	ΔV_{OUT}	VIN = 16V, VOUT = 5V@3A	75	85	100	mV
		VIN = 16V, VOUT = 9V@3A	85	90	100	mV
		Note: Typical values tested under the demo board reference design				
Soft start time	T_{SS}	VIN = 16V, VOUT = 5V	-	4	-	ms
Output line compensate voltage	V_{COMP}	VIN = 16V, VOUT = 5V, IOUT = 3A	-	180	-	mV
Max output current in CC mode (IP6520_Q1)	I_{OUT}	VIN = 16V, VOUT = 5V	-15%	3	+15%	A
		VIN = 16V, VOUT = 9V	-15%	3	+15%	A
Output hiccup restart voltage	V_{OUT}	Hiccup restart voltage when output enter CC mode(VOUT preset voltage >= 5V)	-	4.1	-	V
		Hiccup restart voltage when output enter CC mode (VOUT) preset voltage < 5V)	-	3	-	V

Output hiccup restart time	T_{HIC}	VIN = 16V, VOUT short circuit	-	2	-	s
DPDM over voltage protection voltage	V_{OVP_DPDM}	VIN = 16V, VOUT=5V	-	4.5	-	V
CC over voltage protection voltage	V_{OVP_CC}	VIN = 16V,VOUT=5V	-	6.0	-	V
Thermal shutdown temperature	T_{OTP}	Rising temperature	-	150	-	℃
Thermal shutdown temperature hysteresis	ΔT_{OTP}		-	40	-	℃

12 Function Description

12.1 Synchronized Switching Buck Converter

IP6520_Q1 integrates a high efficiency synchronous switching buck converter, which supports a wide input voltage range of 7.3V to 29.5V, and an output voltage range of 3V to 12V.

IP6520_Q1 integrates power switch MOSFETs with 350kHz working frequency.

The peak conversion efficiency of IP6520_Q1 is up to 93.27% at VIN=16V, VOUT=5V.

IP6520_Q1 automatically adjusts the output voltage and current based on the recognized fast charging protocol.

IP6520_Q1 has a soft-start function to prevent malfunction caused by excessive inrush current at startup. Soft-start time is 4ms for VIN=16V and 5V no-load output.

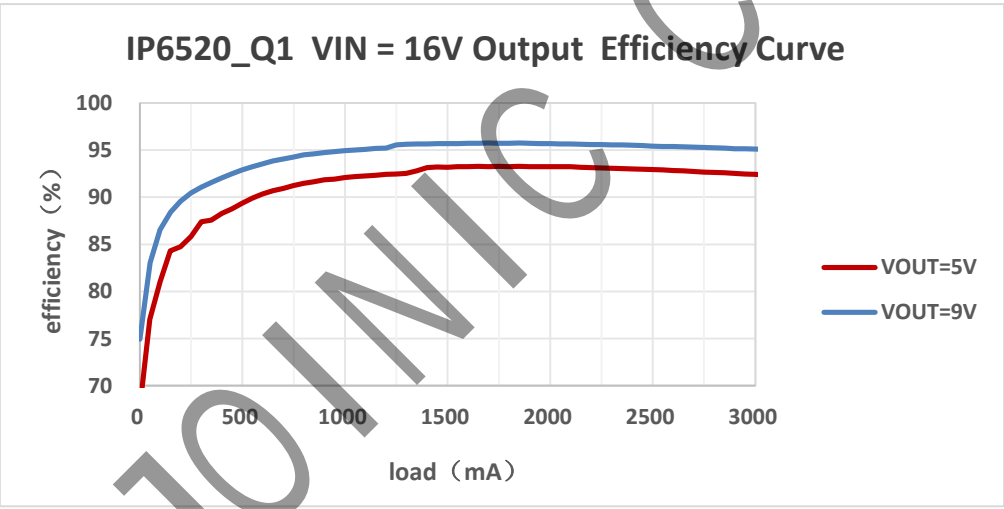


Fig. 5 IP6520_Q1 Output Efficiency Curve

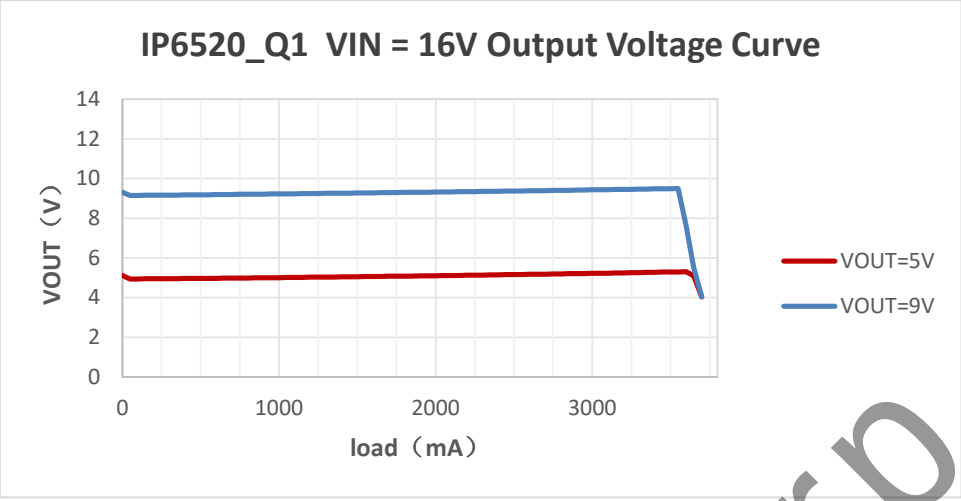


Fig 6 IP6520_Q1 Output Voltage Curve

12.2 Output Voltage Line Complement Function

IP6520_Q1 supports output line compensate, output voltage will increase about 60mV as output current increases 1A

12.3 Output CC/CV Characteristic

IP6520_Q1 output power has CV/CC characteristic, when the output current is lower than the preset value, it is in CV mode with a constant output voltage; when the output current is higher than the preset value, it enters CC mode, and as the output current increases, the output voltage will decrease rapidly until the output voltage under voltage protection is triggered;

When VOUT preset voltage is higher or equal to 5V, if the output current continues to increase and output voltage is lower than 4.1V, the output will be shut down and hiccup restart after 2sec. When VOUT preset voltage is lower than 5V, if the output current continues to increase and output voltage is lower than 3V, the output will be shut down and hiccup restart after 2sec.

12.4 Protections

IP6520_Q1 supports input under voltage protection: when the VIN voltage is lower than 6.9V, IP6520_Q1 detects the input under voltage and turns off the output

IP6520_Q1 supports input over voltage protection: when the VIN voltage is higher than 29.5V, IP6520_Q1 detects the input over voltage and turns off the output, and IP6520_Q1 will consider the VIN normal and turn on the output until the VIN drops under 29.3V.

IP6520_Q1 supports output under voltage protection: when VOUT preset voltage is higher or equal to 5V and if the VOUT voltage is lower than 4.1V, IP6520_Q1 determines the output is under voltage and will turn off the output and hiccup restart after 2sec. When VOUT preset voltage is lower than 5V and if the output voltage is lower than 3V, IP6520_Q1 determines the output is under voltage and will turn off the output and hiccup restart after 2sec.

IP6520_Q1 supports short circuit protection: 8ms after the circuit is started, if VOUT voltage is under 4.1V, IP6520_Q1 determines the output is short circuit and will turn off the output and hiccup restart after 2sec.

IP6520_Q1 supports DP/DM/CC over voltage protection, when DP/DM voltage is higher than 4.5V, or CC1/CC2 voltage is higher than 6.0V, IP6520_Q1 determines relevant signal PIN is over voltage and will turn off the output and hiccup restart after 2sec.

IP6520_Q1 supports over temperature protection: when the IP6520_Q1 detects the temperature of IC is higher than 150℃,IP6520_Q1 will turn off the output When the temperature decreases below 110℃, IP6520_Q1 determines the temperature has recovered and will restart the output.

12.5 Fast Charge Protocols

IP6520_Q1 supports multiple fast charge protocols：

- Support DCP (BC1.2 and Apple)
- Support Qualcomm quick charge QC2.0, QC3.0 and QC3+
- Support Huawei FCP
- Support Samsung AFC
- Supports Type-C output and USB PD2.0/PD3.1/PPS protocol

12.6 Type-C Port and USB PD Protocol

IP6520_Q1 supports Type-C output and USB PD2.0/PD3.1/PPS protocol.

IP6520_Q1 supports USB PD protocol output 27W, Package broadcast: 5V/3A, 9V/3A.

IP6520_Q1 supports the standard Type-C specification and will not turn on the output until the CC connection is successful

IP6520_Q1 Type-C port detects the fast charge requirement automatically through DP/DM and CC1/CC2 pins and adjusts the output voltage and current accordingly.

13 Application Notes

13.1 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.

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 of the input capacitor is calculated as follows:

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

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

13.2 Inductance Selection

The inductor with 10uH is recommended for most applications.

The DCR of inductor has a great influence on the conversion efficiency of the system, and low DCR inductors are recommended. For applications 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 to avoid inductor saturation, causing inductance drop and system instability.

The calculation formula of the PEAK current (IL(PEAK)) is as follows:

$$I_{L(PEAK)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

I_{LOAD} is the LOAD current, ΔI_L is the peak-to-peak value of the inductor current, The calculation formula of ΔI_L is as follows:

$$\Delta I_L = \frac{V_{OUT} * (V_{IN} - V_{OUT})}{V_{IN} * L * F_S}$$

V_{IN} is the input voltage, V_{OUT} is the output voltage, L is the inductance, F_S is the switching frequency.

13.3 Output Capacitance Selection

Output capacitance is used to keep the output stable. The value of ESR and capacitance has an impact on the output ripple. The output ripple voltage $V_{out-ripple}$ can be calculated as follows:

$$V_{out-ripple} = \Delta I_L * (R_{ESR} + \frac{1}{8 * F_S * C_{OUT}})$$

ΔI_L is the peak-to-peak value of the inductor current, 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.

14 Typical Application Schematic

Just with inductor, capacitors, and resistor peripherals, can IP6520_Q1 realize a total solution of automotive USB charging ports.

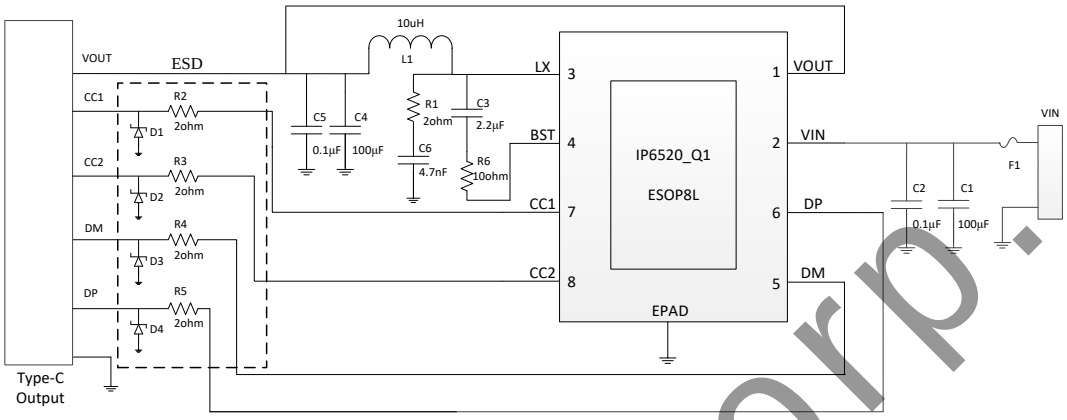


Fig. 7 IP6520_Q1 Type-C Output Application Schematic

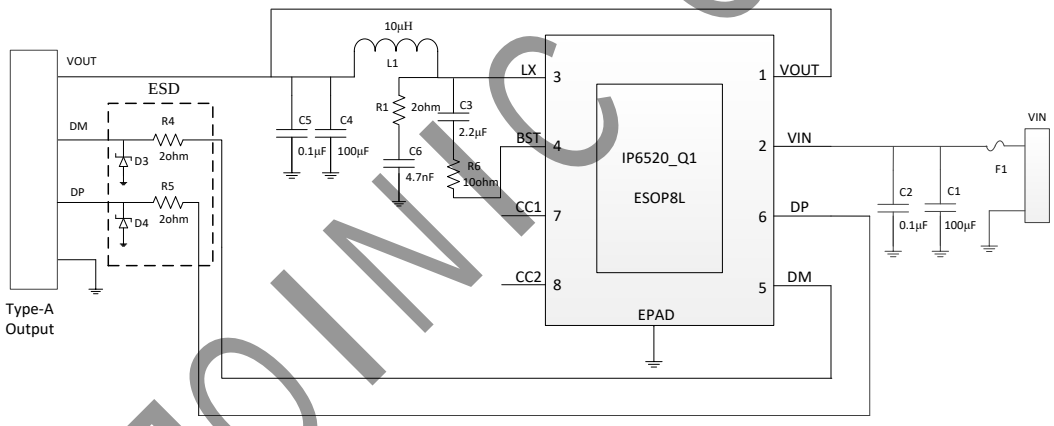


Fig.8 IP6520_Q1 Type-A Output Application Schematic

NOTES:

(1) EPAD of IP6520_Q1 must have good contact with PCB GND;

(2) C1 and C2 must be connected to PIN 2; C2 requires an appropriate increase in capacitance if it is far from the 100uF capacitor or the power supply VIN;

(3) C5 must be connected to PIN1;

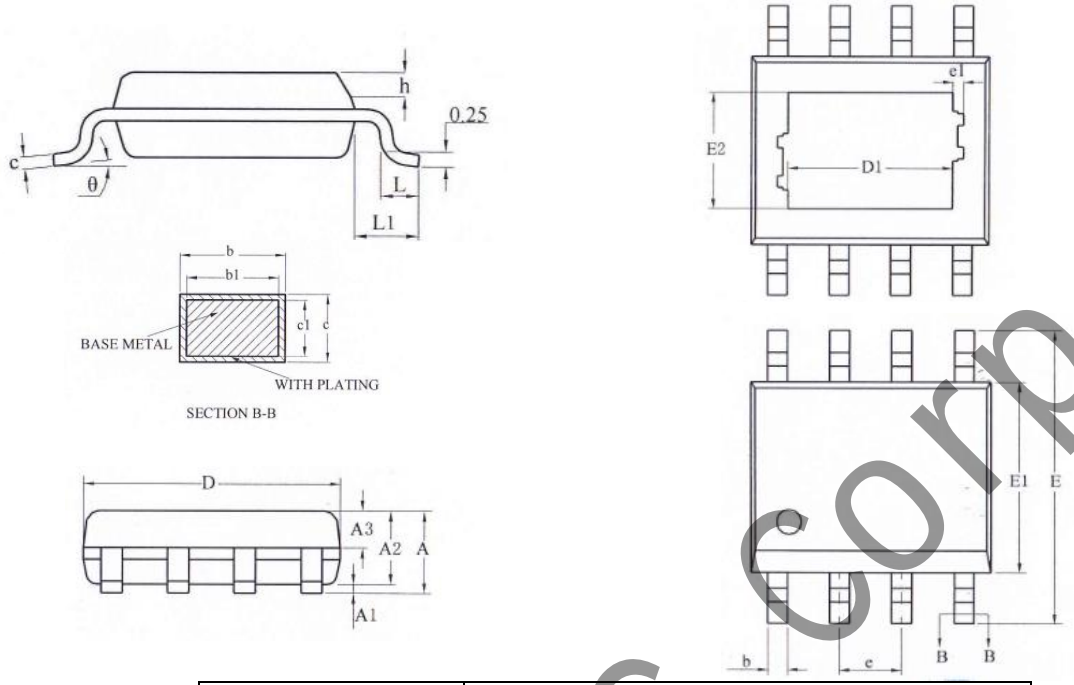
(4) R1 and C6 should be placed close to the PIN3 of IP6520_Q1, the loop composed of LX(PIN3), R1, C6 and PGND should be minimized on the PCB board;

15 BOM List

The IP6520_Q1 DEMO shown in Fig 7 above is used as an example to tidy up the BOM table as follows:

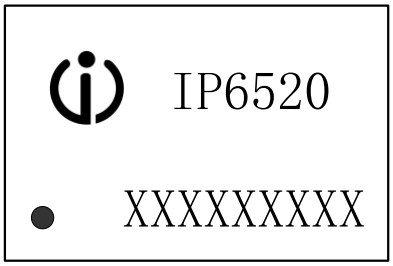
No.	Part Name	Type	Unit	Num.	Location	Note
1	IC	IP6520_Q1	PCS	1	U1	
2	electrolytic capacitor	100μF/35V	PCS	1	C1	Withstand voltage higher than 35V. Using solid-state capacitors can increase efficiency.
3	electrolytic capacitor	100μF/16V	PCS	1	C4	Withstand voltage higher than 16V
4	Power inductance	22μH+/-20%，current 4.5A DCR<12mohm	PCS	1	L1	3L Electronic
5	SMT capacitor	0603 2.2μF 10%	PCS	1	C3	Withstand voltage higher than 16V
6	SMT capacitor	0603 100nF 10%	PCS	1	C2	Withstand voltage higher than 35V, place near IC pin in layout
7	SMT capacitor	0603 100nF 10%	PCS	1	C5	Withstand voltage higher than 16V
8	SMT capacitor	0603 4.7nF 10%	PCS	1	C6	
9	SMD resistor	0603 2ohm 5%	PCS	1	R1	
10	SMD resistor	0402 2ohm 5%	PCS	4	R2, R3, R4, R5	
11	SMD resistor	0402 10ohm 5%	PCS	1	R6	
12	TVS	0402	PCS	4	D1, D2, D3, D4	
13	Fuse	F1	PCS	1	F1	current 4A

16 Package



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	--	--	1.65
A1	0.05	--	0.15
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	--	0.47
b1	0.38	0.41	0.44
c	0.20	--	0.24
c1	0.19	0.20	0.21
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	--	0.50
L	0.50	0.60	0.80
L1	1.05REF		
θ	0	--	8°
D1	--	3.10REF	--
E2	--	2.21REF	--
e1	--	0.10REF	--

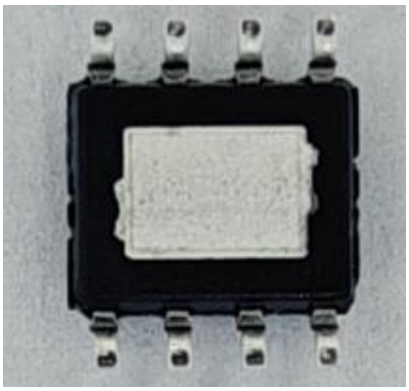
17 Silk Screen Information



NOTE:
1、 --INJOINIC LOGO
2、IP6520 --Product model
3、XXXXXXXXX -Product lot number
4、 --PIN1 location identification

IP6520_Q1 Silk Screen Information

18 Photos of Physical Objects



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