IP6535L

Output 36W Power Buck SOC with Multiple Fast Charge Protocols

1 Features

- **Synchronous Step-Down Converter**
  - Built-in Power MOSFETs
  - Input Voltage Range, 5.4V to 30V
  - Output voltage range: 3V~12V
  - Output power support CV/CC mode
  - VIN=24V, VOUT=5V@3A, Conversion efficiency up to 93.61%.
  - Soft-Start
  - Output Voltage Line Loss Compensation, 80mV@1A
- **Fast Charge Output**
  - Supports DCP (BC1.2, Apple, Samsung)
  - Supports Qualcomm Quick Charge Protocol QC2.0 and QC3.0
  - Supports Samsung Fast Charge Protocol AFC
  - Supports Huawei Fast Charge: FCP and HSCP
- **Multi-Protection and High Reliability**
  - Input overvoltage, input under voltage
  - Output short circuit, output overcurrent protection
  - Over temperature protection
  - Input Voltage Withstand up to 30V
  - HBM ESD 4KV
- **Package: SOP8L**

2 Application

- **Car Charger**
- **Fast Charge Adapter**
- **Intelligent Power Hub**

3 Introduction

IP6535L is a synchronous switch buck regulator which supports multiple fast charge protocols, providing total solution to car charger, fast charge adapter and intelligent power hub applications.

IP6535L has built-in power MOSFET, input voltage range is 5.4V to 30V, output voltage ranges from 3V to 12V, and supply up to 36W output power. The output voltage is automatically adjusted based on the corresponding protocol identified by IP6535L. Typical output portfolio is 5V@3A, 9V@3A and 12V@3A.

IP6535L supports multiple fast charge protocols. The protocol is identified by the signal on DP/DM, and IP6535L adjusts output voltage according to the corresponding protocols. IP6535L supports DCP (BC1.2, Apple, Samsung), Qualcomm Quick Charge QC2.0 and QC3.0, Samsung AFC, Huawei FCP and HSCP

IP6535L incorporates multiple safety protect -tions, such as input OV/UV, output OV/UV/OC and SC protection.
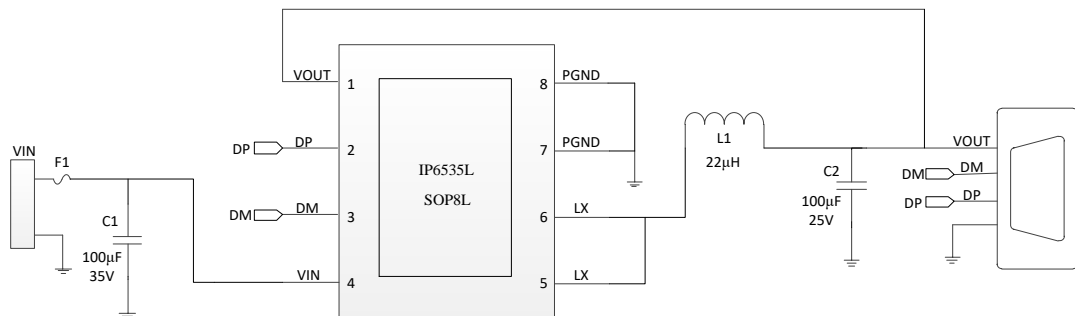

Fig.1　IP6535L Simplified Application Schematic

Content

4 Revision History

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

Initial Release V 1.00 (Apr 2024)

5 Typical Application Schematic Diagram

IP6535L Peripheral only need a few inductors, capacitors, resistors, you can achieve a full function of the car charging scheme.
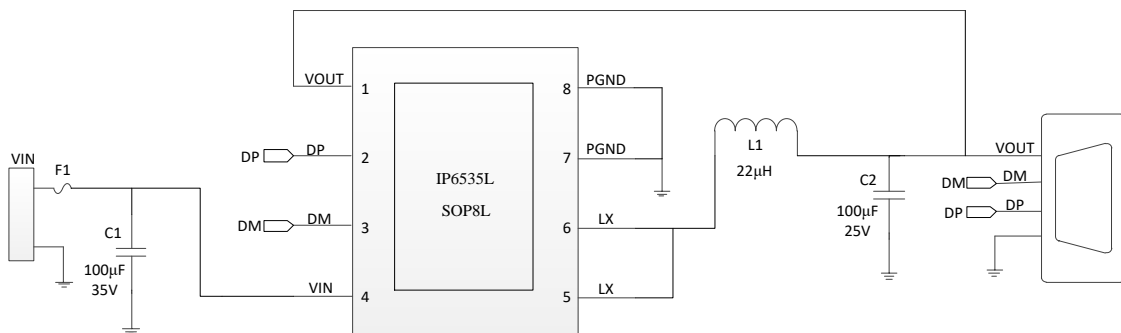
Fig. 2   IP6535L Application Schematic

Notes:

(1) PIN3 is a Low-voltage PIN. it is recommended to add white oil between PIN3 and PIN4 to prevent contact and damage to the PIN.

(2) The GND of the input and output capacitors should be connected with the PGND of a large area.

(3) If the scheme needs to consider EMI debugging, the RC absorption circuit at LX can be reserved. The RC circuit should be placed near PIN5 and 6, and the loop composed of RC circuit, IC LX and PGND should have the smallest area on the PCB.

6 PIN Definition
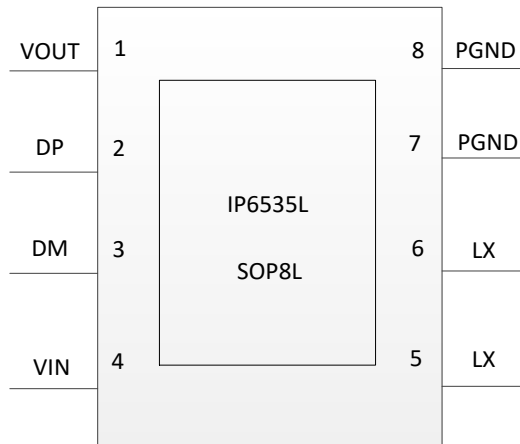
Fig. 3　IP6535L PIN Configuration

Pins		Description
Pin NO.	**Pin Name**	
1	VOUT	VOUT voltage feedback pin
2	DP	USB A port fast charge communication pin DP
3	DM	USB A port fast charge communication pin DM
4	VIN	Input voltage node
5	LX	Power switch node, connected to external inductor
6	LX	Power switch node, connected to external inductor
7	PGND	Power ground
8	PGND	Power ground

7 IP Series Model Selection Table

7.1 IC Selection Table

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	PIN2PIN
IP6525TQ	18W	-	√	√	√	√	-	√	-	-	-	-	ESOP8	
IP6535	36W		√	√	√	√	√-	√					SOP8	PIN2PIN
IP6535L	36W		√	√	√	√	√-	√					SOP8	PIN2PIN
IP6525T_NU	18W	-	√	√	√	√	-	√	-	-	-	-	ESOP8	PIN2PIN
IP6525S	18W	-	√	√	√	√	√	√	√	√	-	-	ESOP8	PIN2PIN
IP6525S_OC	18W	-	√	√	√	√	√	√	-	√	-	-	ESOP8	
IP6520	18W	-	√	√	√	√	√	√	√	-	√	-	ESOP8	PIN2PIN
IP6520T	20W	-	√	√	√	√	-	√	-	-	√	-	ESOP8	PIN2PIN
IP6520T_PPS	20W	-	√	√	√	√	-	√	-	-	√	√	ESOP8	
IP6537_C	18W	-	√	√	√	√	√	√	√	√	√	√	QFN24	PIN2PIN
IP6537_C_30W20V	30W	-	√	√	√	√	√	√	√	√	√	√	QFN24	PIN2PIN
IP6529_C	27W	-	√	√	√	√	-	√	-	-	√	√	QFN24	
IP6538U_AA	24W	√	√	√	√	√	√	√	√	-	-	-	QFN32	PIN2PIN
IP6538U_AC	27W	√	√	√	√	√	√	√	√	-	√	√	QFN32	PIN2PIN
IP6551	4.8A	√	√	-	-	-	-	-	-	--	-	-	QFN32	
IP6527U_A	24W	-	√	√	√	√	√	√	√	-	-	-	QFN32	PIN2PIN
IP6527U_C	27W	-	√	√	√	√	-	√	√	-	√	√	QFN32	PIN2PIN
IP6559_C	100W	-	√	√	√	√	√	√	-	-	√	√	QFN64	PIN2PIN
IP6559_AC	100W	√	√	√	√	√	√	√	-	-	√	√	QFN64	PIN2PIN
IP6557_C	140W	-	√	√	√	√	√	√	√	√	√	√	QFN40	

7.2 IP6535L Series Product Selection

Product	Notes
IP6535L	Standard Product

8 Internal Block Diagram
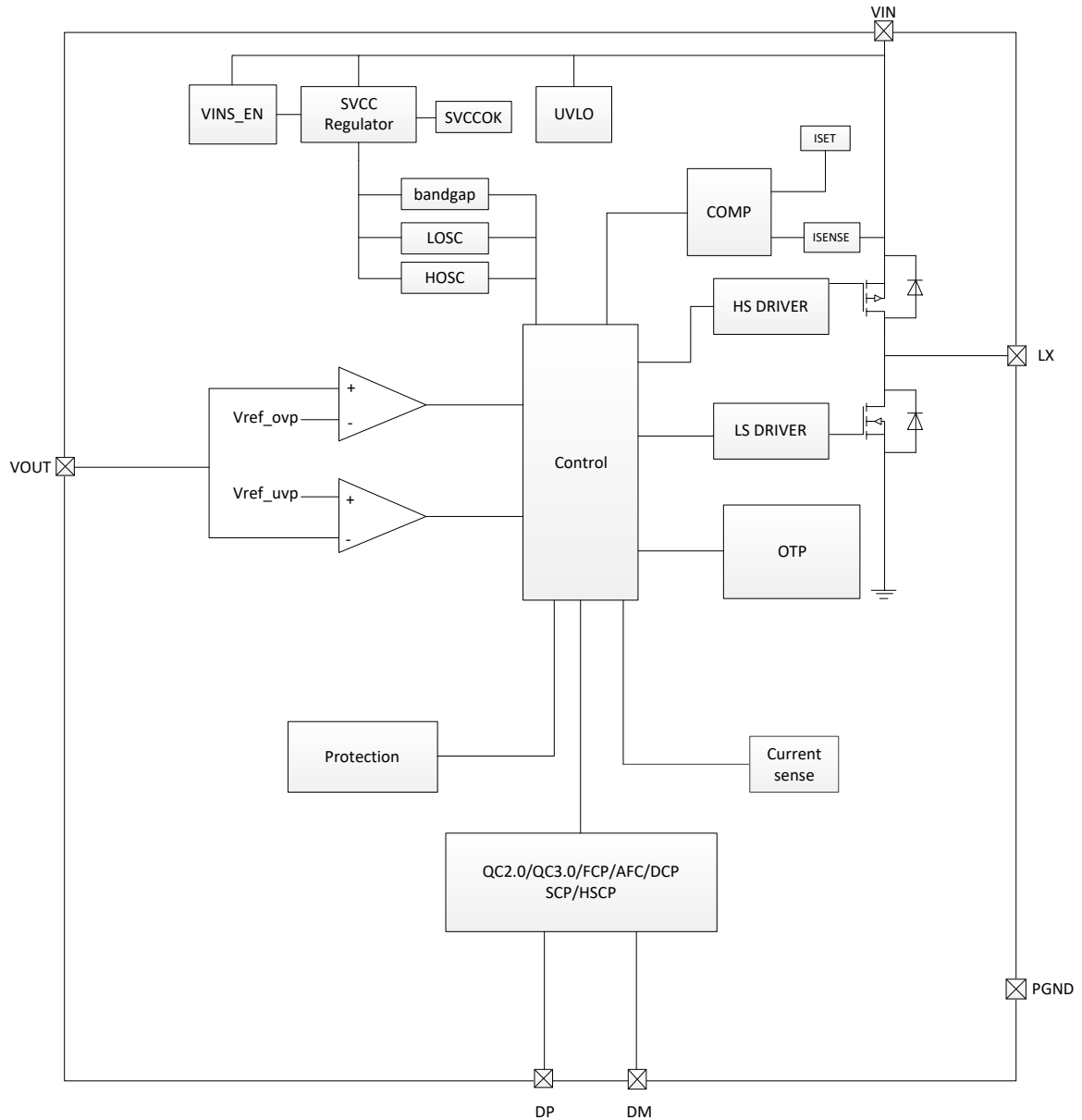
Fig. 4   IP6535L Internal Block Diagram

9 Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Input voltage range	V_{IN}	-0.3 ~ 32	**V**
LX voltage range	V_{LX}	-0.3 ~ 32	**V**
VOUT voltage range	V_{VOUT}	-0.3 ~ 30	**V**
DP/DM voltage range	$V_{DP/DM}$	-0.3 ~ 10	**V**
Junction Temp range	T_J	-40 ~ 150	**℃**
Storage Temp range	Tstg	-60 ~ 150	**℃**
Thermal resistance (junction to ambient)	θ_{JA}	80	**℃/W**
ESD（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.

10 Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Input voltage	V_{IN}	5.4	12/24	30	V

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

11 Electrical Charateristics

Unless otherwise specified, TA=25℃, L=22uH, C_{OUT}=100uF Solid-state capacitance (About 30mΩ ESR).VIN=12V, VOUT=5V, tested on the IP6535L demo.

Parameters	Symbol	Test Condition	Min.	Typ.	Max	Unit
Input system						
Input voltage	V_{IN}		5.4	12	30	V
Input under voltage	V_{IN-UV}	Rising voltage	5.3	5.4	5.5	V
	$V_{IN-UV-TH}$	Falling voltage	-	0.3	-	V
Input over voltage	V_{IN-OV}	Rising voltage	29.8	30	31	V
	$V_{IN-OV-TH}$	Falling voltage	-	0.2	-	V
Input quiescent current	I_Q	VIN=12V,VOUT=5V@0A	-	5	-	mA
Power switching system						
High-side MOS Ron resistance	$R_{DS(ON)}$		-	48	-	mΩ
Low-side MOS Ron resistance	$R_{DS(ON)}$		-	25	-	mΩ
Switching frequency	F_{LX}		95	115	130	KHz
Output system						
Output voltage	V_{OUT}		3	5	12	V
Output voltage ripple	ΔV_{OUT}	VIN=12V,VOUT=5V@3A		90		mV
		VIN=12V,VOUT=9V@2A		70		mV
		VIN=24V,VOUT=12V@1.5A		90		
		Note: Typical values tested under the demo board reference design				
Soft start time	T_{SS}	VIN = 24V,VOUT = 5V	-	1.3	-	ms
Output line compensate voltage	V_{COMP}	VIN = 12V,VOUT = 5V,IOUT = 3A	-	240	-	mV
Max output current in CC mode	I_{OUT}	VIN = 12V,VOUT <= 5V	-	3	-	A
		VIN = 12V,5V < VOUT <= 9V	-	3	-	A
		VIN = 24V,VOUT <= 12V	-	3	-	A
Output hiccup restart voltage	V_{OUT}	Hiccup restart voltage when output enter CC mode	-	3.0	-	V
Thermal shutdown Temp	T_{OTP}	Rising temperature	-	150	-	℃

Thermal shutdown Temp hysteresis	ΔT_{OTP}		-	40	-	°C

12 Function Description

12.1 Synchronous Step-Down Converter

IP6535L integrate a high efficiency synchronous switching buck converter, which supports a wide input voltage range of 5.4V to 30V,and an output voltage range of 3.0 to 12V.

IP6535L integrate power switch MOSFET with 115kHz working frequency.

The conversion efficiency is up to 93.61 % at VIN=24V, VOUT=5V@3A. The efficiency under different input voltage and load current is shown in Fig. 5.And Fig. 6 shows the output voltage characteristics under different load current.

IP6535L automatically adjusts the output voltage and current based on the recognized fast charging protocol.

IP6535L has a soft-start function to prevent malfunction caused by excessive inrush current at startup. Soft-start time is 1.3ms for VIN=24V and 5V no-load output.
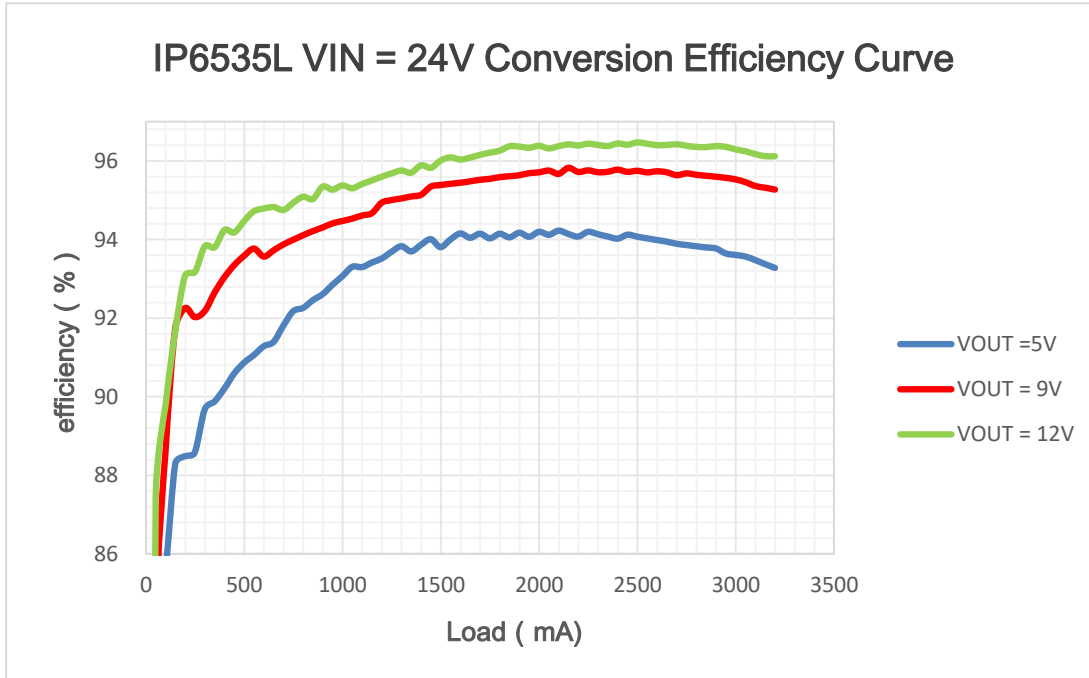

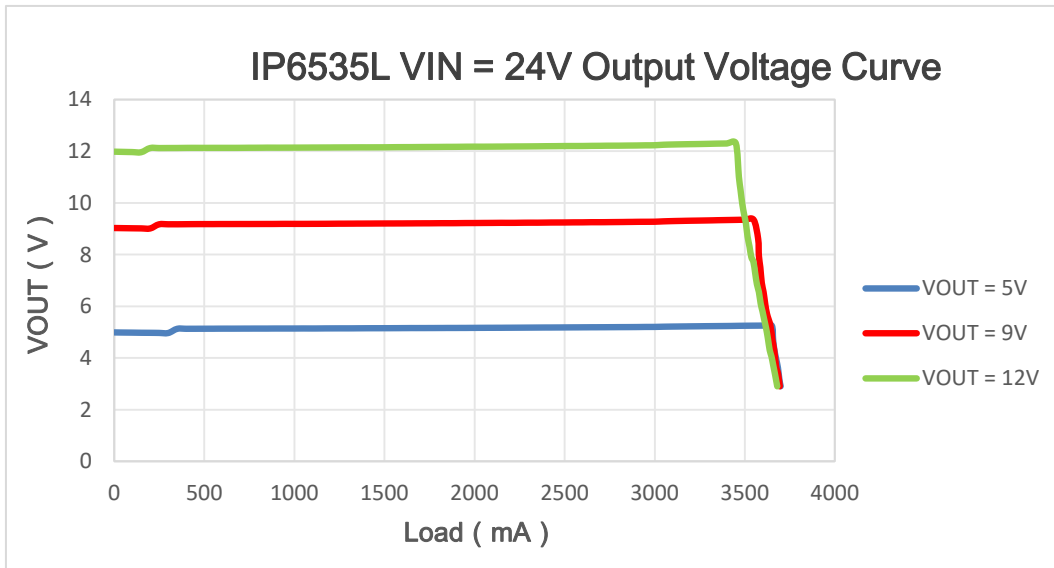Fig. 5　IP6535L Conversion Efficiency Curve when VIN=24V Output

Fig. 6   IP6535L Vout-Iout Curve when VIN=24V Output

12.2 Output Voltage Line Complement Function

IP6535L supports output line compensate, output voltage will increase about 80mV as output current increase 1A.

12.3 Output CC/CV Characteristic

IP6535L 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.

12.4 Protections

IP6535L supports input undervoltage protection: When the VIN voltage is lower than 5.1V, IP6535L detects the input undervoltage and turns off the output.

IP6535L supports input over voltage protection: When the VIN voltage is higher than 30V, IP6535L will turns off the output. When the VIN drops under 29.8V, IP6535L will consider the VIN normal and turn on the output.

IP6535L supports output under voltage protection: When the VOUT output is reduced to 3.0V, the IP6535L detects the output undervoltage, turns off the output, and restarts after 2sec.

IP6535L supports short circuit protection: 8ms after the circuit is started, if VOUT voltage is under 3V, IP6535L determines the output is short circuit and will turn off the output and hiccup restart after 2sec.

IP6535L supports over temperature protection: when the temperature detected is higher than 150℃,the output will be turned off. When the temperature decreases below 110℃, IP6535L determines the temperature has recovered and will restart the output.

12.5 Fast Charge Protocols

IP6535L supports multiple fast charge protocols:

➢ Support DCP (BC1.2 Samsung and Apple)
➢ Support Qualcomm quick charge QC2.0, QC3.0
➢ Support Huawei FCP and HSCP
➢ Support Samsung AFC

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 22uH 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 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 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

The 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

IP6535L Peripheral only need a few inductors, capacitors, resistors, you can achieve a full function of the car charging scheme.
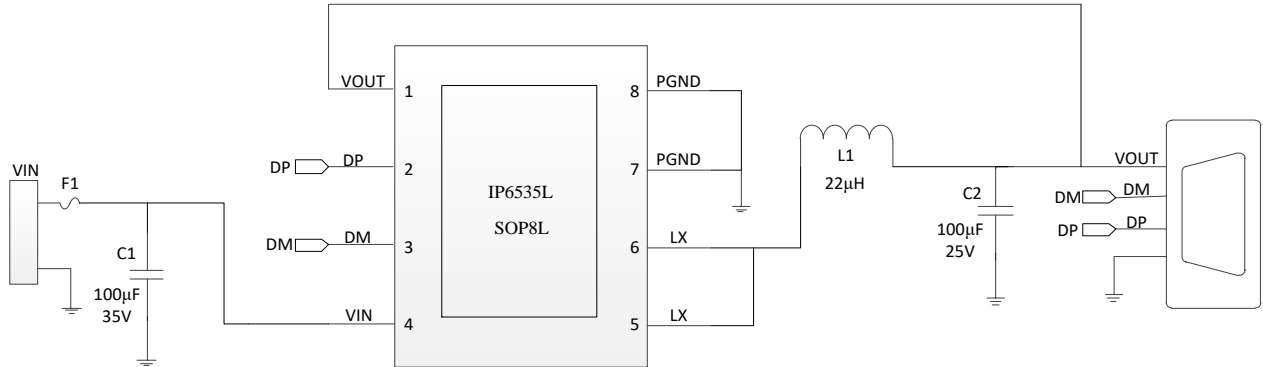

Fig. 7 IP6535L Output application schematic diagram.

Notes:

(1) PIN3 is a Low-voltage PIN, it is recommended to add white oil between PIN3 and PIN4 to prevent contact and damage to the PIN.

(2) The GND of the input and output capacitors should be connected to the PGND of a large area.

(3) If the scheme needs to consider EMI debugging, the RC absorption circuit at LX can be reserved. The RC circuit should be placed near PIN5 and 6, and the loop composed of RC circuit, IC LX and PGND should have the smallest area on the PCB.

15 BOM

NO.	Device	Spec.	Unit	Counts	Designator	Note
1	IC	IP6535L	PCS	1	U1	
2	magnetic ring inductor	22uH+/-20%,Nominal current 6A DCR<12mohm	PCS	1	L1	
3	capacitor	100uF/35V	PCS	1	C1	Rated voltage>35V.
4	capacitor	100uF/25V	PCS	1	C2	Rated voltage>25V
5	Fuse	F1	PCS	1	F1	Current value 4A

16 Considerations for PCB Layout

IP6535L integrated buck converter, PCB layout is important for system stability, EMI, and other performance indicators, the IP6535L PCB layout suggestions are as follows:

1. The output feedback line to the VOUT PIN of chip needs to be far away from the LX line, and ground isolation should be used between the two lines.

2. The GND of the input and output capacitors should be connected to the PGND of a large area;

3. If the scheme needs to consider EMI debugging, the RC absorption circuit at LX can be reserved. The RC circuit should be placed near PIN5 and 6, and the loop composed of RC circuit, IC LX and PGND should have the smallest area on the PCB.

4. The following paths with high currents flowing through them should be thickened:

● The VIN of the input positive IC shall be copper-lined;

● the LX of the IC to the inductor L1 shall be copper-lined as short as possible;

● The output VOUT network shall be copper-lined;

17 Package
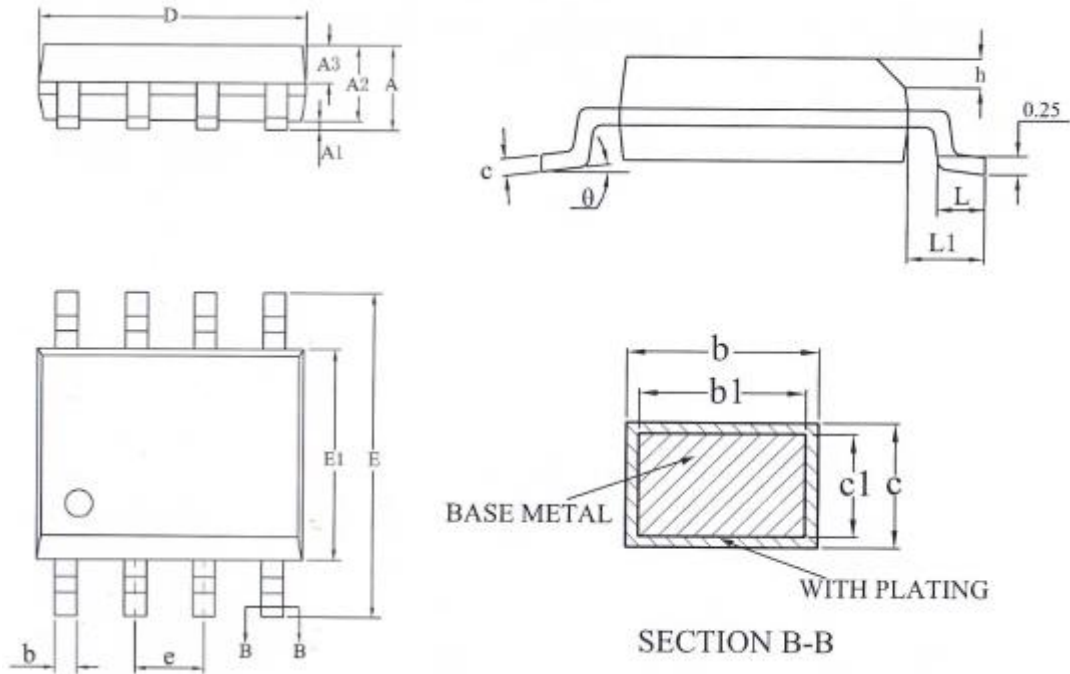
| SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.10	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.47
b1	0.38	0.41	0.44
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05REF		
θ	0	—	8°

18 Silk Screen Information

说明：
1、 (J)　--INJOINIC logo
2、IP6535L　--Product model
3、XXXXXXXX　--Production lot number
4、●　--PIN1

IP6535L Silk screen instructions

19 Photos of Physical Objects
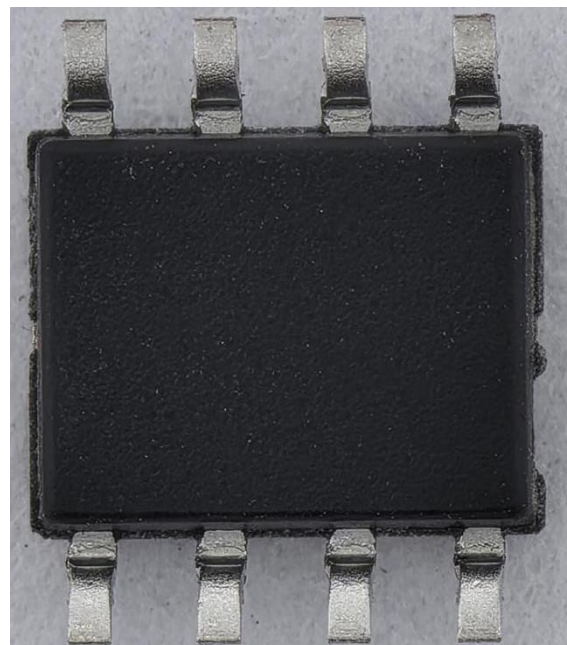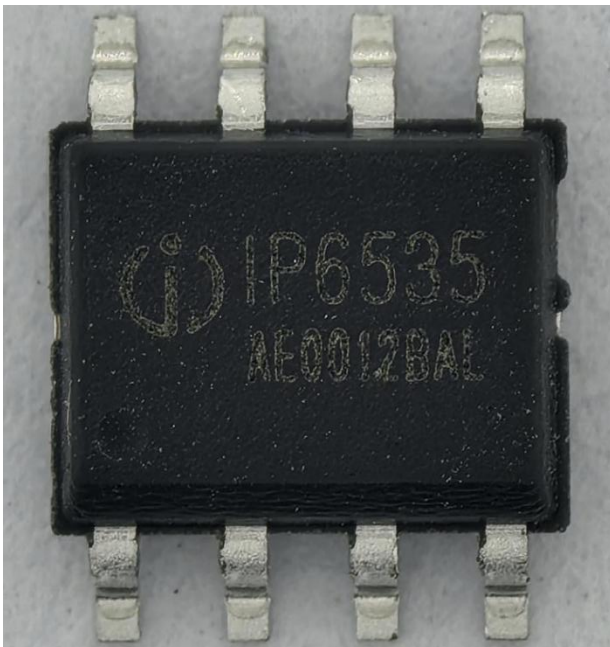
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