Output 45W Power Buck SOC with Multiple Fast Charge Protocols

1 Features

- **AEC-Q100 Qualified for Automotive Applications**
  - Temperature grade 2: -40℃~+105℃
- **Synchronous Step-Down Converter**
  - Built-in Power MOSFETs
  - Input voltage range: 7.3V to 29.5V
  - Output voltage range: 3.0V to 21V
  - Output voltage line complement function
  - Output power support CV/CC mode
  - VIN=16V, VOUT=5V@3A, Conversion efficiency up to 93.7%
- **Support Type-C Output and PD Protocol**
  - Support 5V, 9V, 12V,15V,20V output
  - Support PD2.0/PD3.1 output protocol
  - PPS support 3.3V to 21V 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 Huawei Fast charge FCP
  - Support Samsung fast charge AFC
  - Support Universal fast charging UFCS
- **Multi-Protection and High Reliability**
  - Input overvoltage, input under voltage
  - Output short circuit, output overcurrent protection
  - Over temperature protection
  - DP/DM/CC over voltage protection
  - CC withstand voltage of 25V
  - HBM ESD 2KV
- **Package: 4*4mm QFN24**

2 Application

- **Automotive USB charging ports**

3 Introduction

IP6529_Q1 is a synchronized switch buck regulator which supports multiple fast charge output protocols, providing solutions for car charger and charge adaptor.

IP6529_Q1 has built-in power MOSFET, input voltage range is 7.3V to 29.5V, output voltage ranges from 3V to 21V, and supply up to 45W 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.

IP6529_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.

IP6529_Q1 has built-in 12-bit ADC, which can accurately measure input voltage, output voltage and current, and chip temperature, and can read output voltage and output current information through the IIC.

IP6529_Q1 supports soft start, providing resistibility on the large inrush current during circuit start up.

IP6529_Q1 supports multiple protection on input overvoltage and under voltage, output overcurrent, overvoltage, under voltage and short circuit.

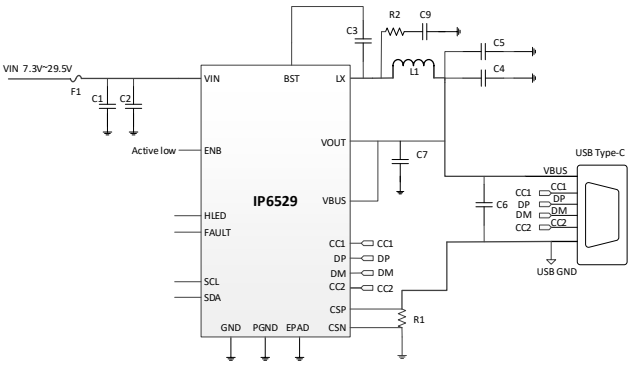


Fig.1 IP6529_Q1 Simplified Application Schematic

Content

4 Revision History

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

Initial Release V 1.00 (Apr 2023)

Changes from Revision V1.00 (Apr 2023) to Revision V1.10(Oct 2023)

1、Change the schematic diagram and BOM

2、Change the description of HLED and FAULT function.

Changes from Revision V1.10（Oct 2023）to Revision V1.15（Sep 2024）

1、Increase switching frequency gear: 330kHz (support customization)

5 Typical Application Schematic Diagram

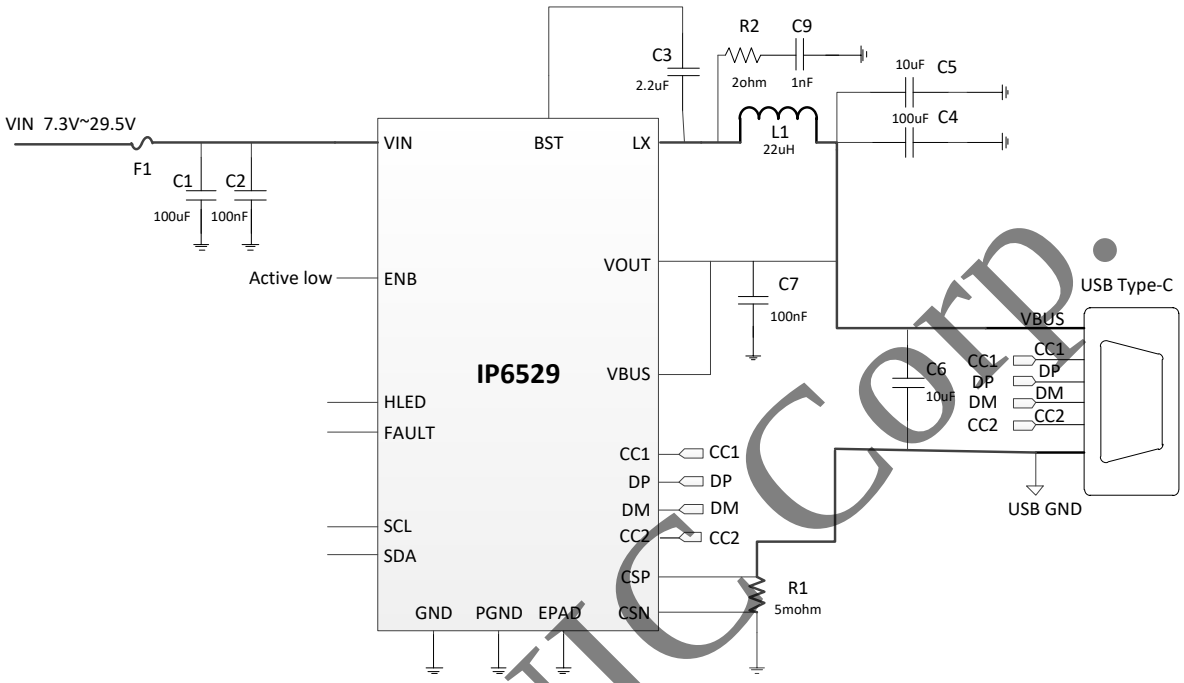


Fig. 2 IP6529_Q1 Application Schematic of PD Fast Charging Output With External Sensing Resistor

Notes:

(1) IP6529_Q1 EPAD must have a good contact with PCB GND;

(2) ENB cannot be suspended and needs to be given a definite level; the chip turns on when ENB is low and turns off when ENB is pulled up to 2V or more;

(3) C1 and C2 should be placed close to the PIN2/PIN3 of IP6529_Q1; C2 requires an appropriate increase in capacitance if it is far from the 100uF capacitor or the power supply VIN;

(4) C7 and C8 should be placed close to the PIN18/PIN19 of IP6529_Q1;

(5) R2 and C9 should be placed close to the LX (PIN22/PIN23/PIN24) of IP6529_Q1, and the loop composed of LX pin, R2, C9 and PGND should be minimized on the PCB board;

(6) When the USB port on the program does not use DP and DM pin, the DP and DM interface should be reserved on the PCB to facilitate subsequent upgrades of the device.

6 PIN Definition

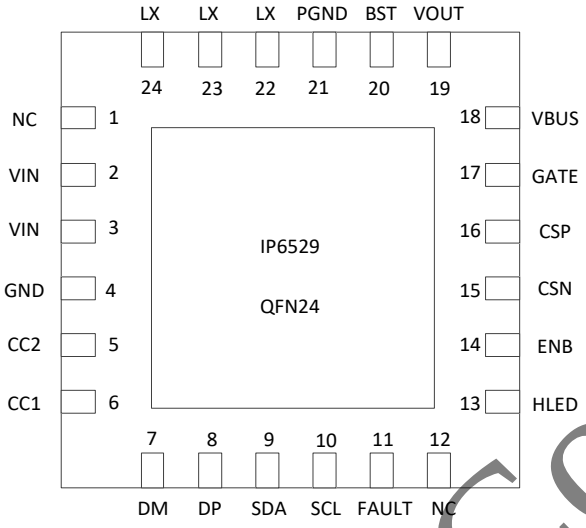


Fig. 3 IP6529_Q1 PIN Configuration

Pins		Description
Pin NO.	Pin Name	
1/12	NC	NC pin
2/3	VIN	Input voltage node
4	GND	System ground
5	CC2	USB C port detection and fast charge communication pin CC2
6	CC1	USB C port detection and fast charge communication pin CC1
7	DM	USB C port fast charge communication pin DM
8	DP	USB C port fast charge communication pin DP
9	SDA	IIC serial interface data input/output pin
10	SCL	IIC serial interface clock input pin
11	FAULT	Abnormal status indication pin
13	HLED	Fast charge output indication pin
14	ENB	Chip enable pin, cannot be suspended. Chip enable when ENB is pulled low externally.
15	CSN	Output Current sampling negative terminal
16	CSP	Output Current sampling positive terminal
17	GATE	Output path MOS driver pin
18	VBUS	VBUS voltage detection pin
19	VOUT	VOUT voltage feedback pin
20	BST	Bootstrap capacitor pins
21	PGND	Power ground
22/23/24	LX	Power switch node, connected to external inductor
25	EPAD	Power ground

7 IP6529_Q1 Model Selection Table

Product	USB	Output Power			
IP6529_Q1	USB Type-C	PDO	5V/3A	9V/3A	-
		QC	5V/3A	9V/2A	-

Notes:

1. IP6529_Q1 supports a maximum power output of 45W (20V/2.25A).
2. The FAULT and HLED Pins of the IP6529_Q1 can be multiplexed for other functions as required.
3. The switching frequency of IP6529_Q1 can be customized to 115KHz/330kHz according to requirements.

8 Internal Block Diagram

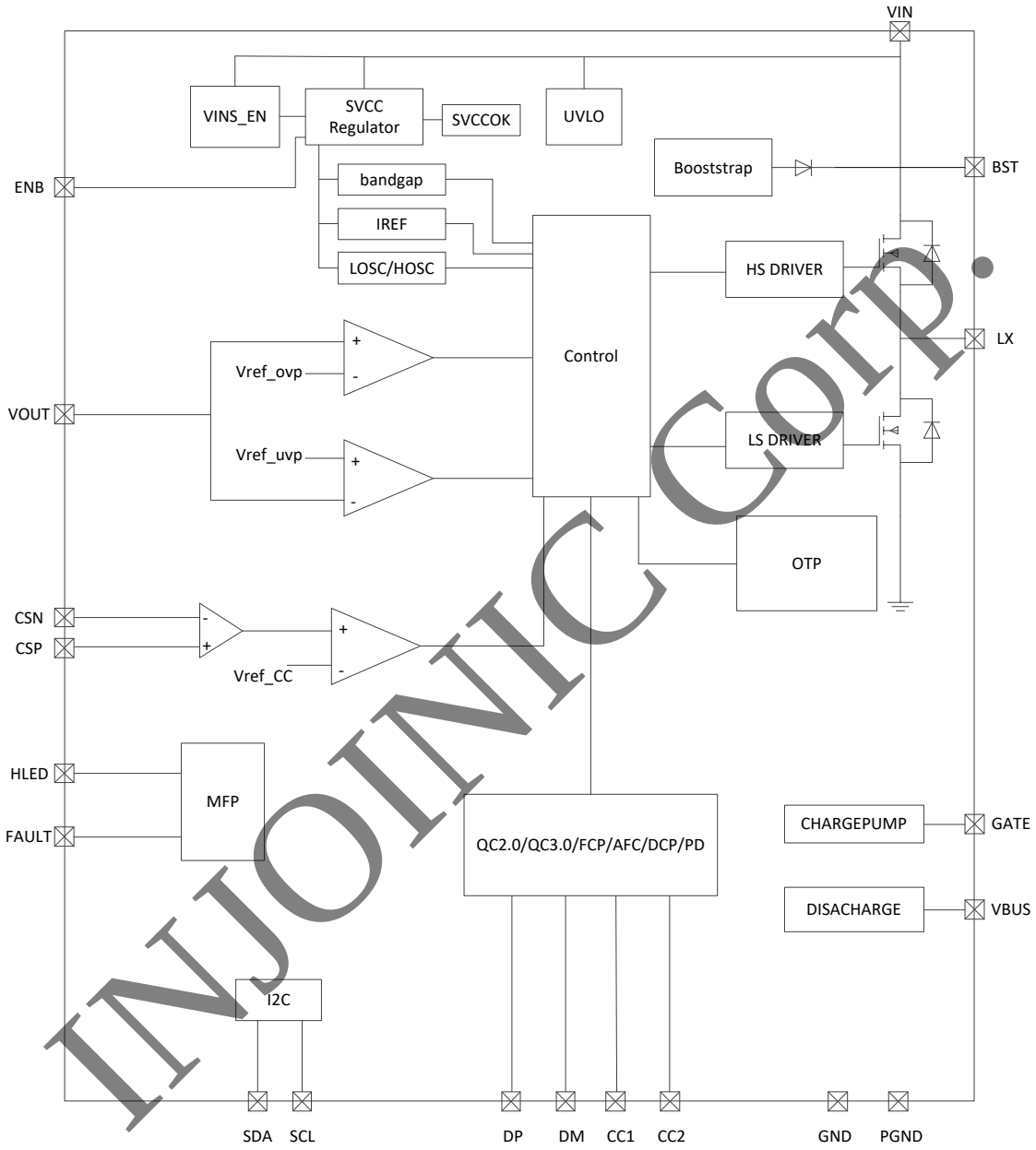


Fig. 4 IP6529_Q1 Internal Block Diagram

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 ~ 25	V
DP/DM/CC voltage range	$V_{DP/DM/CC1/CC2}$	-0.3 ~ 22	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=22uH, VIN=16V, VOUT=5V, tested on the IP6529_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	7.1	7.2	7.3	V
	$V_{IN-UV-TH}$	Falling voltage	-	0.3	-	V
Input over voltage	V_{IN-OV}	Rising voltage	29.3	29.5	29.8	V
	$V_{IN-OV-TH}$	Falling voltage	-	0.2	-	V
Input quiescent current	I_Q	VIN=16V, Standby status	-	0.55	-	mA
Shutdown current	I_{SD}	Input current at ENB=3.3V, VIN=16V	-	15	-	uA
Power switching system						
High-side MOS Ron resistance	$R_{DS(ON)\_L}$		-	30	-	mΩ
Low-side MOS Ron resistance	$R_{DS(ON)\_H}$		-	20	-	mΩ
Maximum Duty Cycle	D_{MAX}	VIN = 9V，VOUT = 9V/3A	-	95	-	%
Switching frequency	F_S		100	115	130	KHz
Switching frequency(optional)	F_{S_1}		310	330	350	KHz
Output system						
Output voltage	V_{OUT}		3	5	21	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	-	8	-	ms
Output line compensate voltage	V_{COMP}	VIN = 16V，VOUT = 5V，IOUT = 3A	-	150	-	mV
Max output current in CC mode (IP6529_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	-	4.1	-	V

		voltage >= 5V)				
Output hiccup restart voltage	V_{OUT}	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	-	165	-	℃
Thermal shutdown temperature hysteresis	ΔT_{OTP}		-	10	-	℃
ENB PIN						
ENB Input shutdown voltage	$V_{ENB-OFF}$	Input voltage of ENB rises to turn the device off	2	-	-	V
ENB Input turn-on voltage	V_{ENB-ON}	Input voltage of ENB drops to turn the device on	-	-	0.5	V
ENB Input turn-on delay time	T_{ENB-ON}	Delay time form ENB input is low to DCDC on	-	170	-	ms
ENB Input shutdown delay time	$T_{ENB-OFF}$	Delay time form ENB input is high to DCDC off	-	50	-	μs

12 Function Description

12.1 Synchronized Switch Buck Regulator

IP6529_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 3.0V to 21V.

IP6529_Q1 integrate power switch MOSFET with 115kHz working frequency.

The conversion efficiency is up to 93.7% at VIN=16V, 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.

IP6529_Q1 automatically adjusts the output voltage and current based on the recognized fast charging protocol.

IP6529_Q1 has a soft-start function to prevent malfunction caused by excessive inrush current at startup. Soft-start time is 8ms for VIN=16V and 5V no-load output.

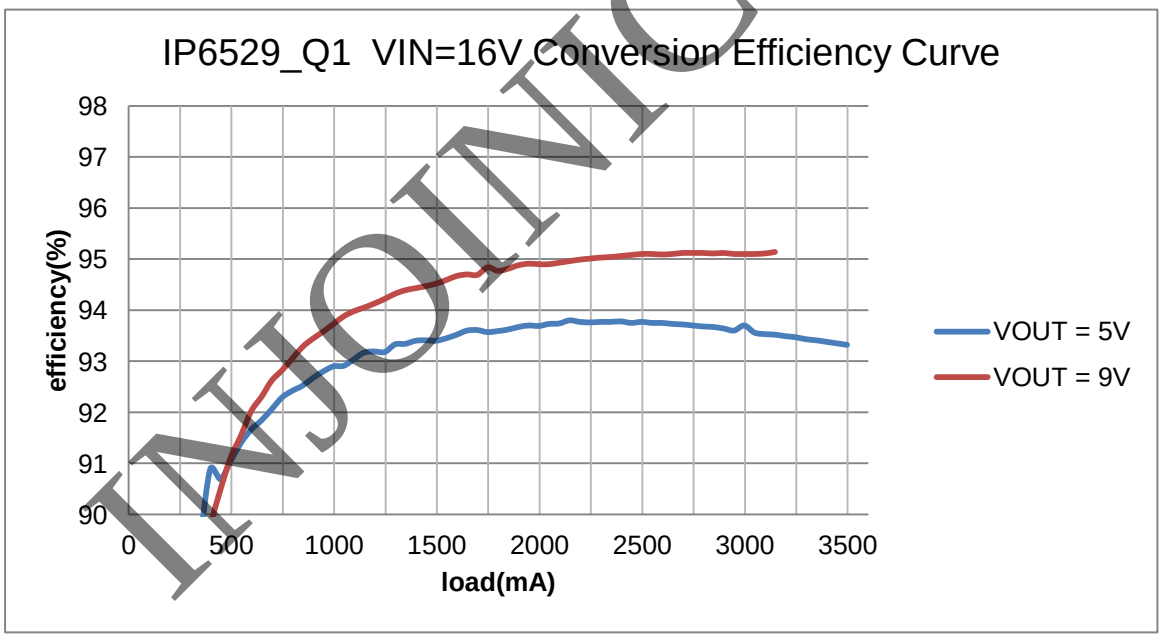


Fig. 5 IP6529_Q1 Conversion Efficiency Curve

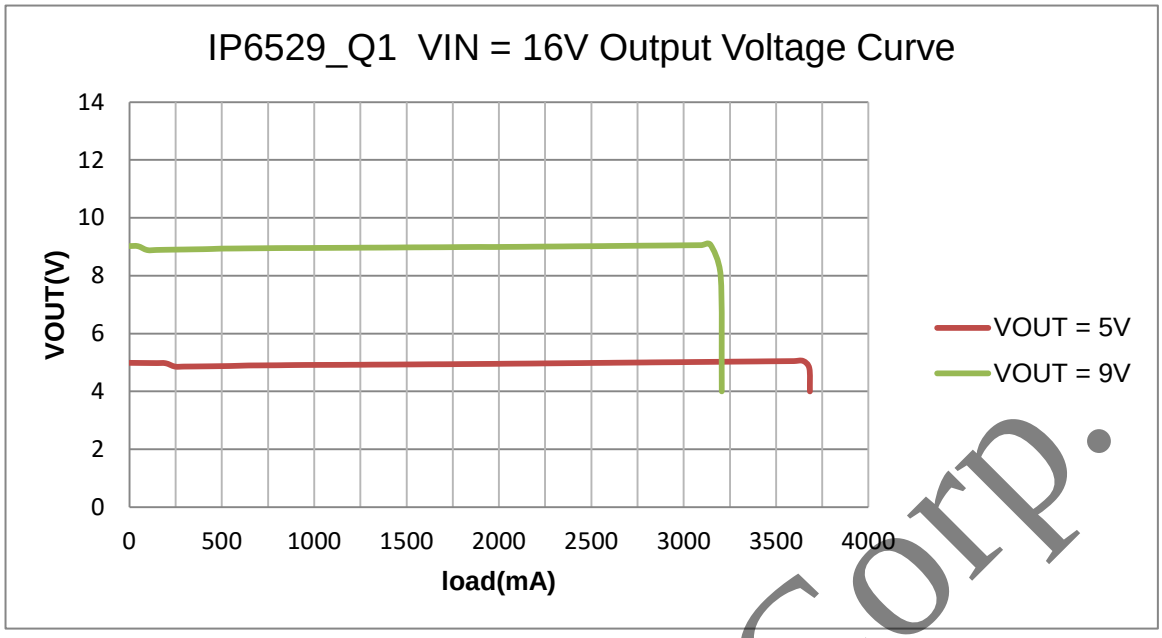


Fig. 6 IP6529_Q1 Vout-Iout Curve when VIN=16V Output

12.2 Output Voltage Line Complement Function

IP6529_Q1 supports output line compensate, output voltage will increase about 50mV as output current increases 1A.

12.3 Output CC/CV Characteristic

IP6529_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 undervoltage protection is triggered;.

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

12.4 Output CC Current Set

IP6529_Q1 output current limit can be adjusted by regulating the 5mohm sensing resistor between CSP and CSN. The voltage drops between CSP and CSN is detected to determine if the current load current is up to the preset current level.

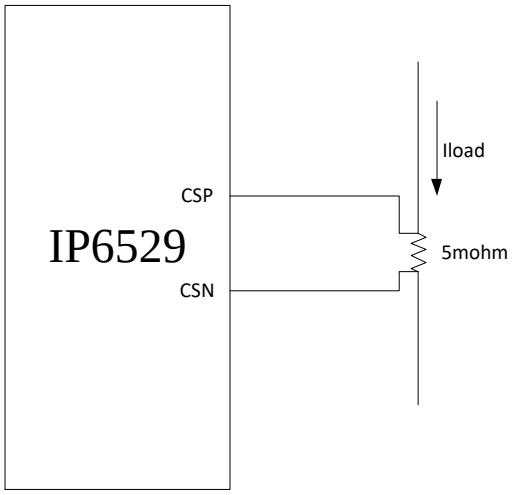


Fig. 7 IP6529_Q1 Output Current Limiting Circuit

In PCB layout, pay attention to the trace routing of CSP and CSN, the trace should go out directly from the two sides 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%. When the value of 5mohm current detect resistor is changed, the IP6529_Q1 output current limit will be changed accordingly.

12.5 Protections

IP6529_Q1 supports input undervoltage protection: When the VIN voltage is lower than 6.9V, IP6529_Q1 detects the input undervoltage and turns off the output.

IP6529_Q1 supports input over voltage protection: When the VIN voltage is higher than 29.5V, IP6529_Q1 will turns off the output. When the VIN drops under 29.3V, IP6529_Q1 will consider the VIN normal and turn on the output.

IP6529_Q1 supports output under voltage protection: When VOUT preset voltage is higher or equal to 5V, if the VOUT voltage is lower than 4.1V, IP6529_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, if the output voltage is lower than 3V, the output will be turned off and hiccup restart after 2sec.

IP6529_Q1 supports short circuit protection: 8ms after the circuit is started, if VOUT voltage is under 4.1V, IP6529_Q1 determines the output is short circuit and will turn off the output and hiccup restart after 2sec.

IP6529_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, IP6529_Q1 determines relevant signal PIN is over voltage and will turn off the output and hiccup restart after 2sec.

IP6529_Q1 supports over temperature protection: when the temperature detected is higher than 165℃, the output will be turned off. When the temperature decreases below 155℃, IP6529_Q1 determines the temperature has recovered and will restart the output.

12.6 Fast Charge Protocols

IP6529_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 (MAX 12V)
- Support Universal fast charging UFCS
- Supports Type-C output and USB PD2.0/PD3.0 (PPS) protocol

12.7 Type-C Port and USB PD Protocol

IP6529_Q1 supports Type-C output and USB PD2.0/PD3.0 (PPS) protocol.

IP6529_Q1 supports USB PD protocol output 27W; Package broadcast: 5V/3A, 9V/3A.

IP6529_Q1 supports the standard Type-C specification and will not turn on the output until the CC connection is successful.

IP6529_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.

12.8 ENB PIN Function

ENB is an external enable pin, which cannot be suspended and needs to be given a definite level; The chip turns on when ENB is low and turns off when ENB is pulled up to 2V or more;

ENB is 3.3V, the shutdown current at 16V input is 15uA.

ENB can not be connected to a high-voltage of 6V or more, otherwise it will cause this PIN overvoltage breakdown.

12.9 HLED PIN Function

HLED PIN of IP6529_Q1 can be multiplexed as fast charging output indication function, as the following function description:

Used as fast charging output indication function, connects external light-emitting diode, Which will light up when QC and other high-voltage fast charging request voltage is not 5.0V, that is, the application voltage above or below 5.0V will light up; can be suspended when this function is not needed.

HLED PIN can not be connected to a high-voltage of 6V or more, otherwise it will cause this PIN over-voltage breakdown.

12.10 FAULT PIN Function

FAULT PIN supports open-drain output, which supports the indication of abnormal status such as input over-undervoltage, over-temperature, DP/DM over-voltage, CC over-voltage, DM is shorted to GND, etc.

FAULT PIN can not be connected to a high-voltage of 6V or more, otherwise it will cause this PIN to over-voltage breakdown.

12.11 IIC Control and ADC

IP6529_Q1 supports IIC control, as salve, external device can use IIC to control IP6529_Q1 as needed.

IP6529_Q1 built-in 12-bit ADC, can accurately measure the input voltage, output voltage, output current, and the ADC information can be read through IIC.

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

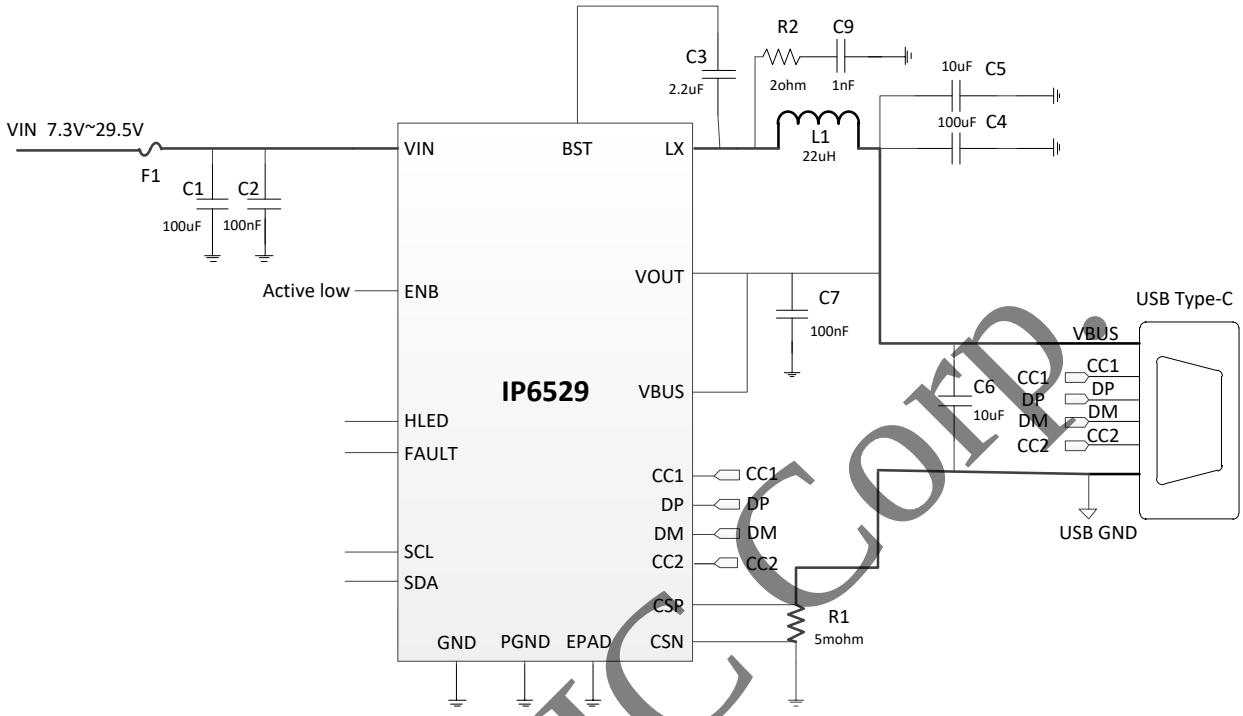


Fig. 8 IP6529_Q1 Application Schematic of PD Fast Charging Output With External Sensing Resistor

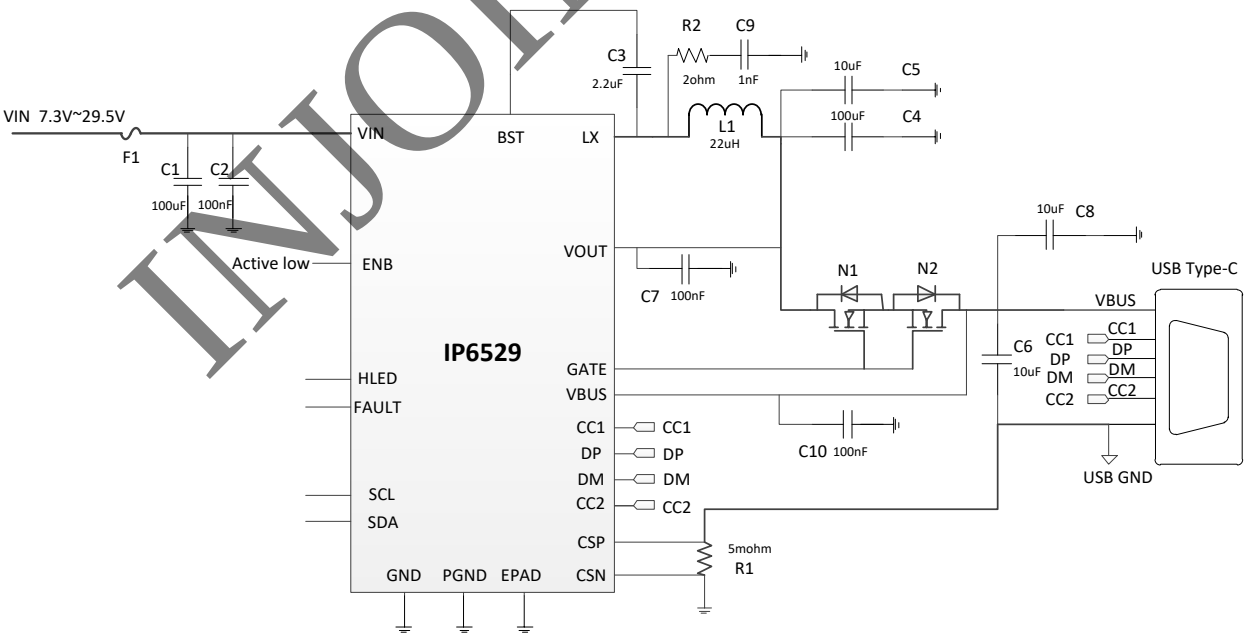


Fig. 9 IP6529_Q1 Application Schematic with External Sensing Resistor and Path MOS

15 BOM

Taking IP6529_Q1 DEMO as an example (Figure 9), the collated BOM list is as follows:

NO	Device	Spec.	Unit	Counts	Designator	备注
1	IC	IP6529_Q1	PCS	1		
2	magnetic ring inductor	22uH+/-20%，Nominal current 5A DCR<12mohm	PCS	1	L1	
3	electrolytic capacitor	100uF/35V	PCS	1	C1	Rated voltage>35V.
4	electrolytic capacitor	100uF/25V	PCS	1	C4	Rated voltage>25V
5	SMD capacitor	0603 100nF 10%	PCS	3	C2, C7, C10	Rated voltage>35V
6	SMD capacitor	0603 2.2uF 10%	PCS	1	C3	Rated voltage>35V
7	SMD capacitor	0603 1nF 10%	PCS	1	C9	Rated voltage>35V
8	SMD capacitor	0603 10uF 10%	PCS	3	C5, C6, C8	Rated voltage>25V
9	SMD resistor	0603 2R 5%	PCS	1	R2	
10	SMD resistor	1206 5mohm 1% precision, temperature coefficient less than 100ppm	PCS	1	R1	Current sense resistor
11	MOSFET	MOSFET	PCS	2	N1, N2	
12	Fuse		PCS	1	F1	

16 Considerations for PCB Layout

IP6529_Q1 integrates buck converter, PCB layout is important for system stability, EMI, and other performance indicators, the IP6529_Q1 PCB layout suggestions are as follows:

1.The capacitor C2 on VIN should be close to the VIN pin of the IC, so that the loop area can be minimized at these points from VIN to PGND via the capacitor;

2. Capacitor C3 shall be placed close to the LX and BST of the IC;

3. The EPAD of IC pad needs to be windowed and punches plentiful enough overholes to ensure good contact between the EPAD with tin and the PGND of system during production;

4. 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.

5. The current sampling line for 5mohm resistance shall be directly drawn from both ends of the resistance. The line should be parallel, as short as possible and avoid LX and other nodes;

6. The loop composed of RC circuit of LX, LX pin and PGND of IC shall be as small as possible on the PCB board;

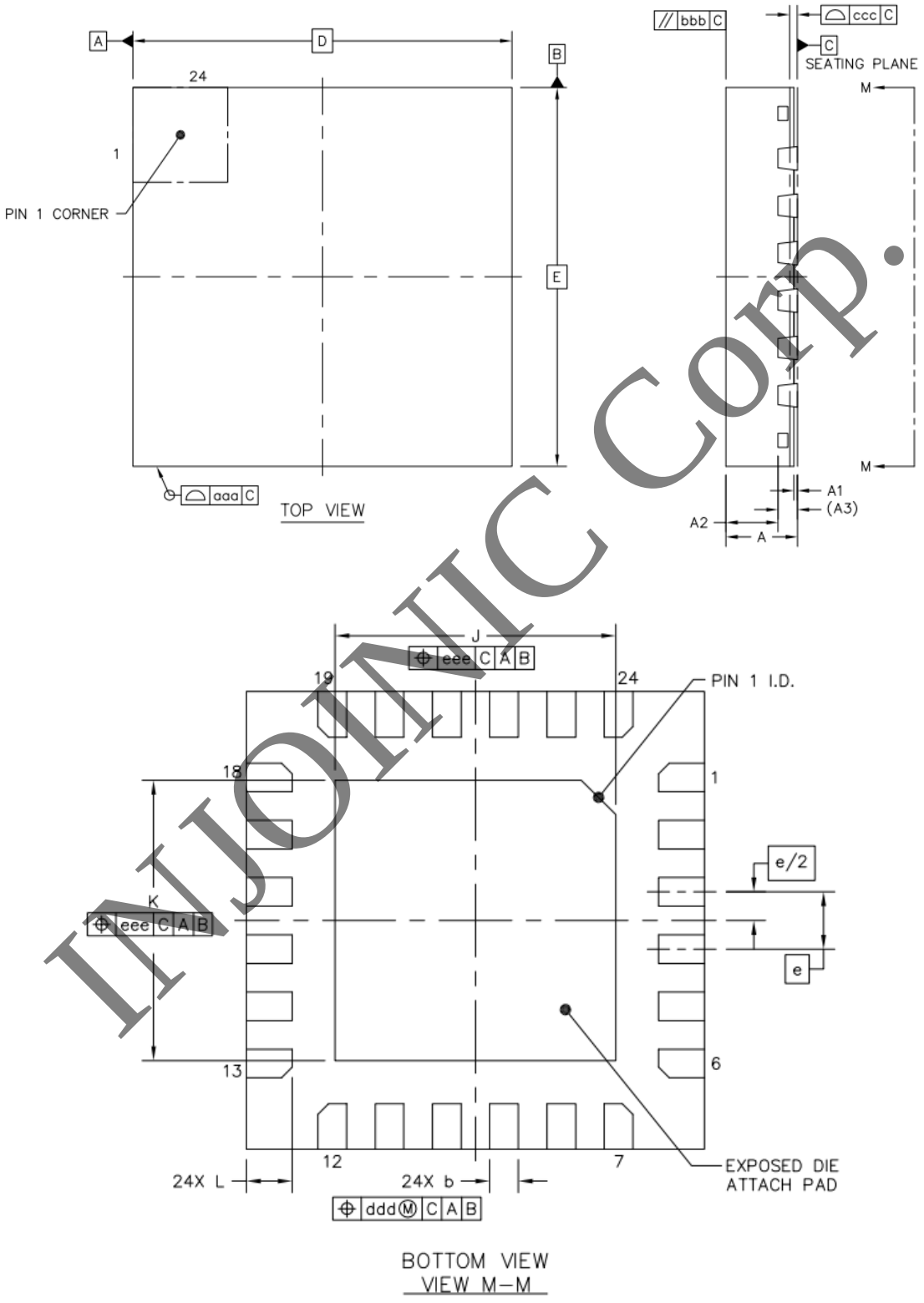
7. The GND of the input and output capacitors must be connected to the PGND of a large area;

8. When the program on the USB holder without DP/DM pins, the PCB shall reserve DP/ DM interface, to facilitate the device for subsequent upgrades.

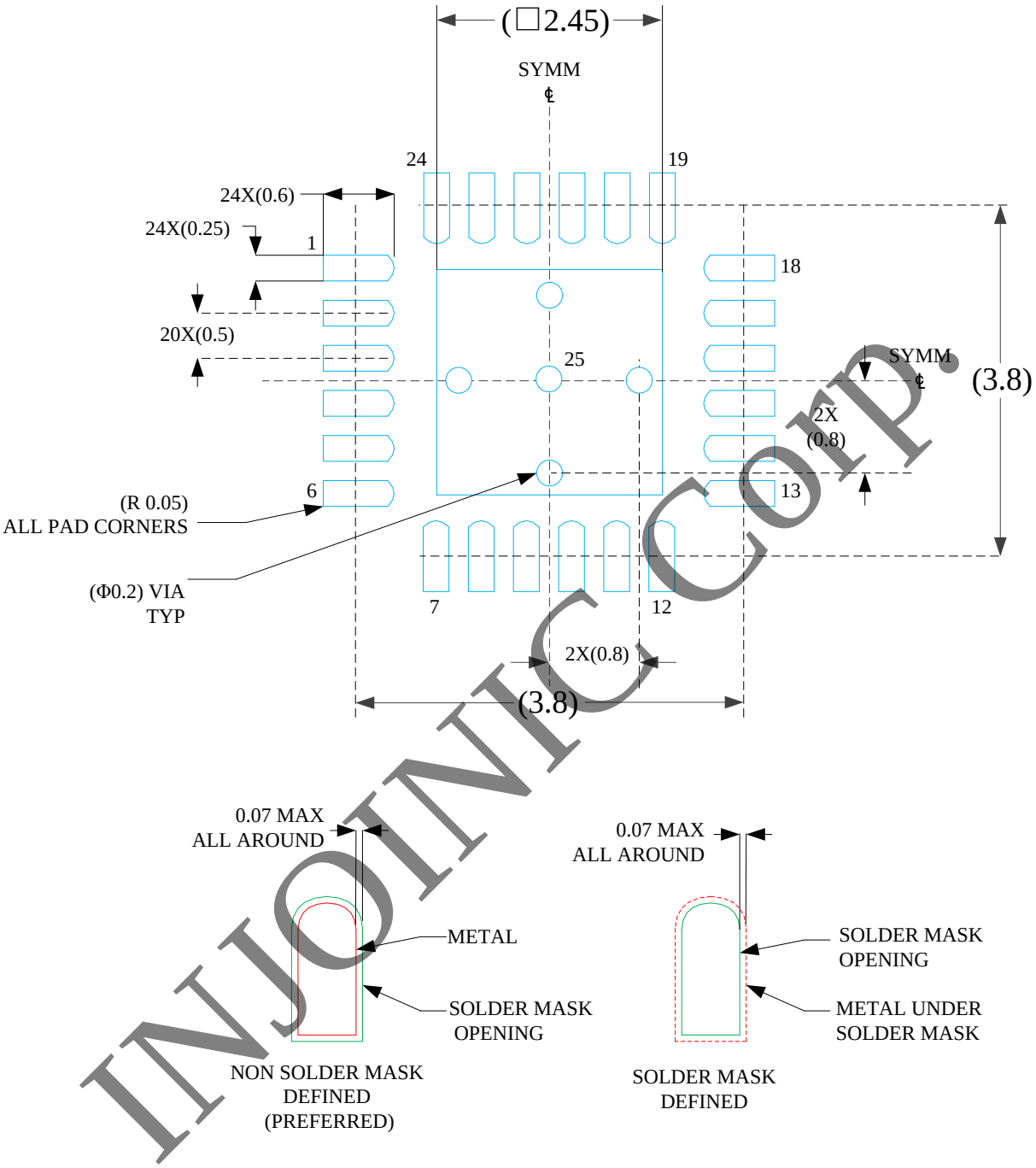
9. The following paths with high currents flowing through them should be thickened:

- 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;

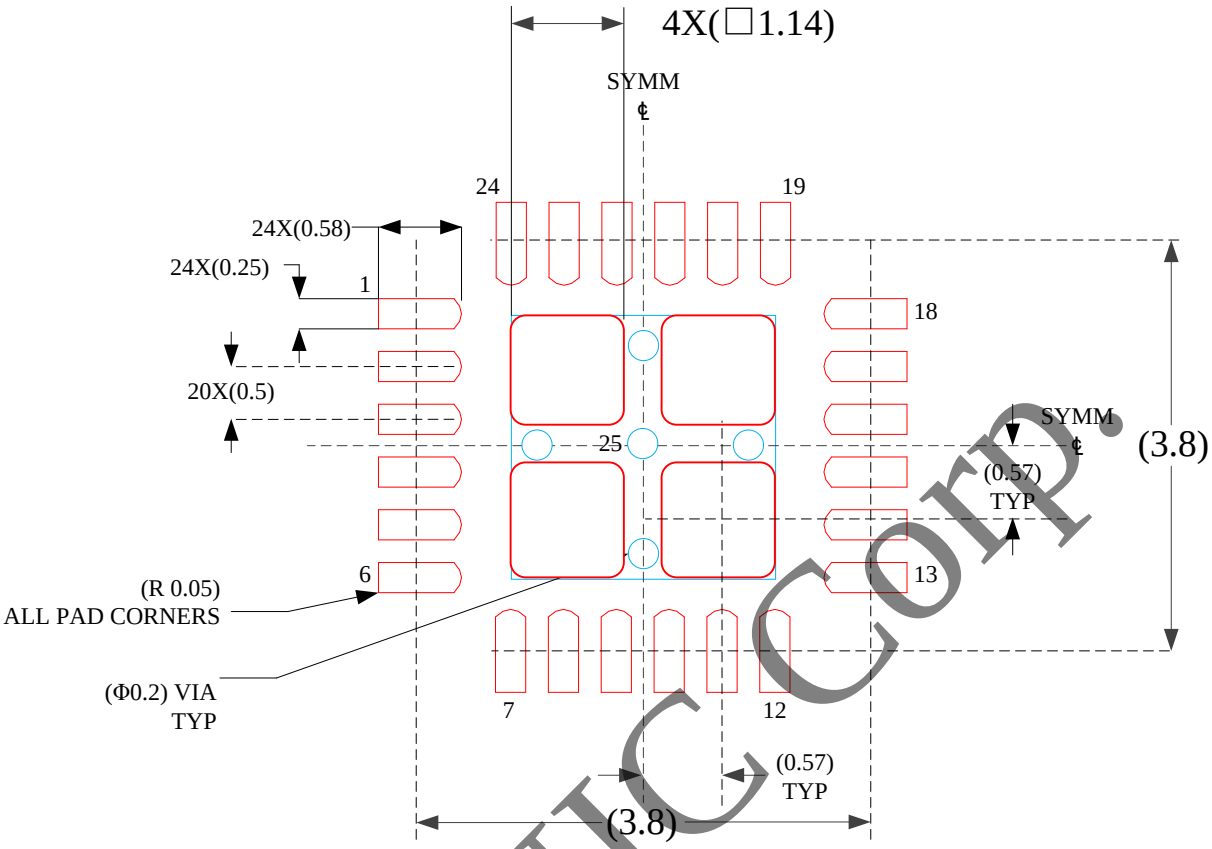
17 Package



	SYMBOL	MIN	NOM	MAX
Total THICKNESS	A	0.7	0.75	0.8
STAND OFF	A1	0	0.035	0.05
MOLD THICKNESS	A2	--	0.55	--
L/F THICKNESS	A3		0.203 REF	
LEAD WIDTH	b	0.2	0.25	0.3
BODY SIZE (X)	D		4 BSC	
BODY SIZE (Y)	E		4 BSC	
LEAD PITCH	e		0.5 BSC	
EP SIZE (X)	J	2.35	2.45	2.55
EP SIZE (Y)	K	2.35	2.45	2.55
LEAD LENGTH	L	0.35	0.4	0.45
PACKAGE EDGE TOLERANCE	aaa		0.1	
MOLD FLATNESS	bbb		0.1	
COPLANARITY	ccc		0.08	
LEAD OFFSET	ddd		0.1	
EXPOSED PAD OFFSET	eee		0.1	



SOLDER MASK DETAILS

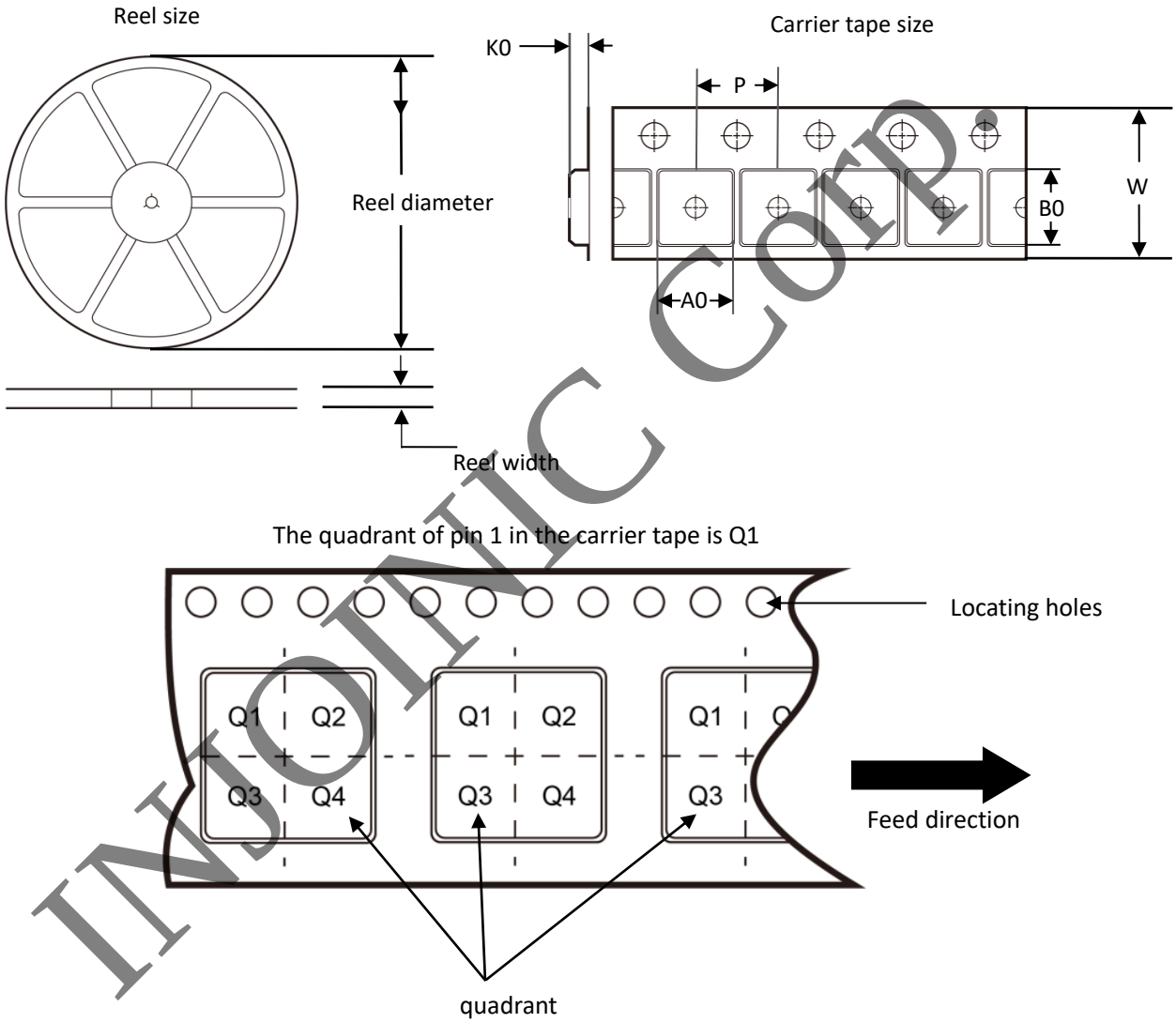


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
80% PRINTED SOLDER COVERAGE BY AREA
SCALE: 20X

18 Tape and Packaging Information

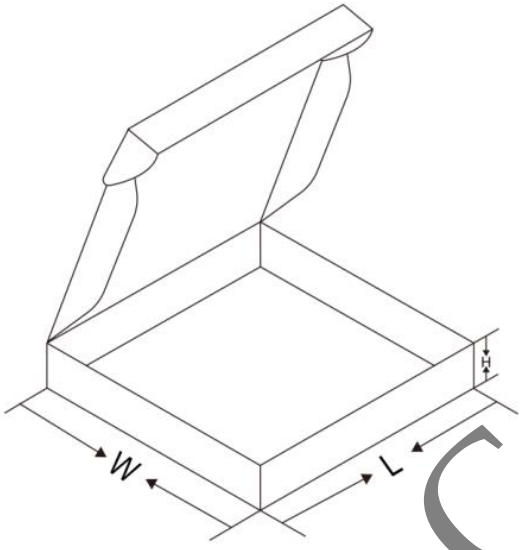
18.1 Tape Information



*All sizes are standard

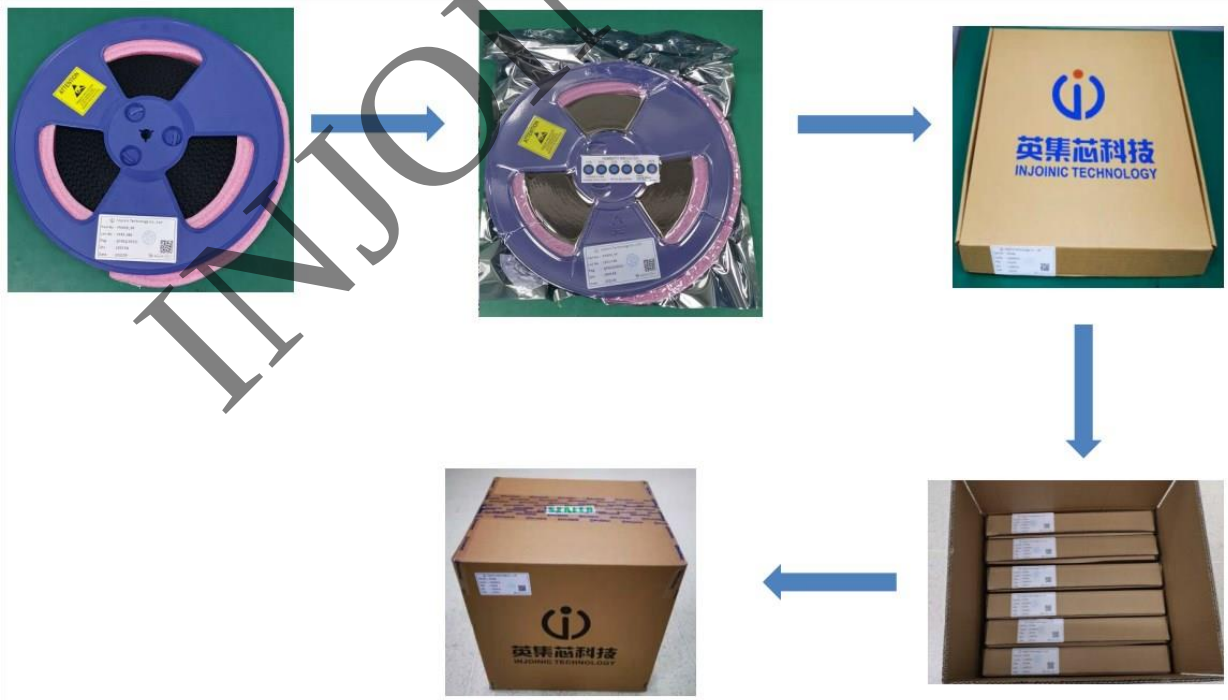
IC model	Pkg	Pin num	standard quantity	Reels diameter (mm)	Reels Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P (mm)	W (mm)	Pin1 quadrant
IP6529_Q1	QFN24	24	5000	330	12.5	4.45 ±0.10	4.50 ±0.10	1.2 ±0.10	8.0 ±0.1	12 ±0.3	Q1

18.2 Reel Packaging Carton Specifications



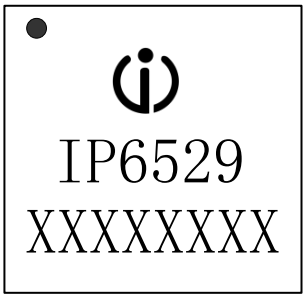
*All sizes are standard

Package form	Packaging method	Only/disc	Disc/inner box	Only/box	Inner box/carton	Only/carton	Inner box length（mm）	Inner box width（mm）	Inner box height（mm）
QFN24	Taping	5000	2	10000	6	60000	360	360	50



Carton size:385*345*380mm **Inner box size:360*360*50mm**

19 Silk Screen Information

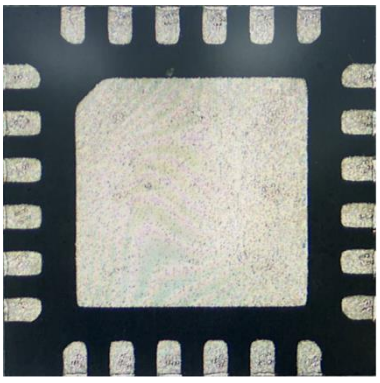


Illustrate:

1、 --INJOINIC LOGO
2、IP6529 --Product model
3、XXXXXXXX--Production lot number
4、● --PIN1 location identification

IP6529_Q1 Silk screen instructions

20 Photos of Physical Objects



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