

A Power Bank SOC With Integrated Buck-Boost Driver Supporting Bi-directional Fast Charging Protocol Such As SCP, PD3.0, Supporting 2~4 Series Batteries and Supporting Maximum Power 45W

1 Feature

- **Supporting Multiple USB Ports Simultaneously**
 - ✧ 2 USB A output ports
 - ✧ 1 USB C input/output port
 - ✧ 1 Lightning input port
- **Fast Charging**
 - ✧ Every port supports fast charging
 - ✧ Support QC2.0/QC3.0/QC3+ output
 - ✧ Support FCP input/output
 - ✧ Support AFC input/output
 - ✧ Support SCP input/output
 - ✧ Support DRP try.SRC, PD3.0 input/output
 - ✧ Support BC1.2, Apple
- **Integrated USB PD2.0/PD3.0 Protocol**
 - ✧ Support PD2.0 input/output protocol
 - ✧ Support PD3.0 input/output and PPS output protocol
 - ✧ Support 5V/9V/12V/15V/20V input
 - ✧ Support 5V/9V/12V/15V/20V output
 - ✧ Support adjustable voltage in 20mV increments in PPS Mode
 - ✧ Integrate hardware Bi-phase mark codec (BMC) protocol
 - ✧ Integrate Physical Layer protocol
 - ✧ Integrate hardware CRC
 - ✧ Support Hard Reset
- **Power Control**
 - ✧ Integrated bidirectional Buck-Boost NMOS driver
 - ✧ Integrated charge-pump to control external NMOS
- **Charge**
 - ✧ Adaptive charging current adjustment
 - ✧ Support 4.15V/4.20V/4.30V/4.35V/4.40V battery
 - ✧ Support charging Lithium Iron Phosphate Battery (3.65V)
 - ✧ Support 2/3/4 batteries in series
- **Boost**
 - ✧ Maximum output power 45W

- ✧ Up to 94%@5V/2A efficiency with synchronous switching
- ✧ Support line compensation
- **Battery Level Display**
 - ✧ Integrated 14-bit ADC and coulombmeter
 - ✧ Support 4/2/1 LEDs to indicate battery level
 - ✧ Support 188 nixie tube
 - ✧ Self-learning coulombmeter, more uniform power display
 - ✧ Support configuring initial battery capacity by external pin
- **Other Functions**
 - ✧ Automatic detection of mobile phone plugging and unplugging
 - ✧ Fast charging status indication
 - ✧ Battery temperature detection
 - ✧ Enter standby mode automatically in light load
 - ✧ Integrated lighting driver
- **Multiple Protections, High Reliability**
 - ✧ Input overvoltage and undervoltage protection
 - ✧ Output overcurrent, overvoltage, short circuit protection
 - ✧ Battery overcharge, overdischarge, overcurrent protection
 - ✧ Overtemperature protection
 - ✧ NTC protection for charging and discharging battery
 - ✧ ESD 4kV, input (including CC/DP/DM PINS) withstand voltage 30V
- **Low BOM Cost**
 - ✧ Integrated switch power MOSFET driver
 - ✧ Single inductor for charging and discharging
- **Package Size: 7mm × 7mm 0.5pitch QFN48**

2 Application Product

- Power bank, Portable Energy Storage Power Supply
- Portable devices such as mobile phones and tablets

3 Description

IP5386 is a power management SOC that integrates QC2.0 / QC3.0 / QC3+ output fast charging protocol, AFC/FCP/SCP input and output fast charging protocol, TYPE-C PD2.0/PD3.0 input and output fast charging protocol and PPS output protocol, BC1.2/iPhone protocol, synchronous bi-directional buck-boost converter, lithium battery charging management and battery power indicator, providing a complete power solution for fast charging mobile power supplies. It can support four USB ports such as two USB A ports, one USB C port and one lightning port at the same time and fast charging when any USB port is connected alone. When two or more output ports are used at the same time, every port's output voltage is 5V.

Due to the high integration of IP5386, only one inductor is needed to realize the bidirectional buck-boost function. Only a few peripheral components are needed in the application, which effectively reduces the size of the overall solution and reduces the BOM cost.

IP5386 supports 2/3/4 series batteries and the synchronous switch buck-boost system can provide a maximum output capacity of 45W. When there is no load, it automatically enters the dormant state.

IP5386 synchronous switch charging system provides up to 8.0A charging current. The built-in IC temperature, battery temperature and input voltage control loop intelligently adjust the charging current.

IP5386 built-in 14-bit ADC can accurately measure battery voltage and current. Built-in power calculation method can accurately obtain battery power information. The battery power curve can be customized to accurately display the battery power.

IP5386 supports 4/2/1 LED power display, supports 188 and other nixie tube power display; supports battery temperature detection.

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4 Reversion History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Updated from Revision V1.00 to Revision V1.01	Page
• Change Formatting.....	1
Updated from Revision V1.01 to Revision V1.02	Page
• Updated the Standby current at the battery terminal	12

5 Typical Application

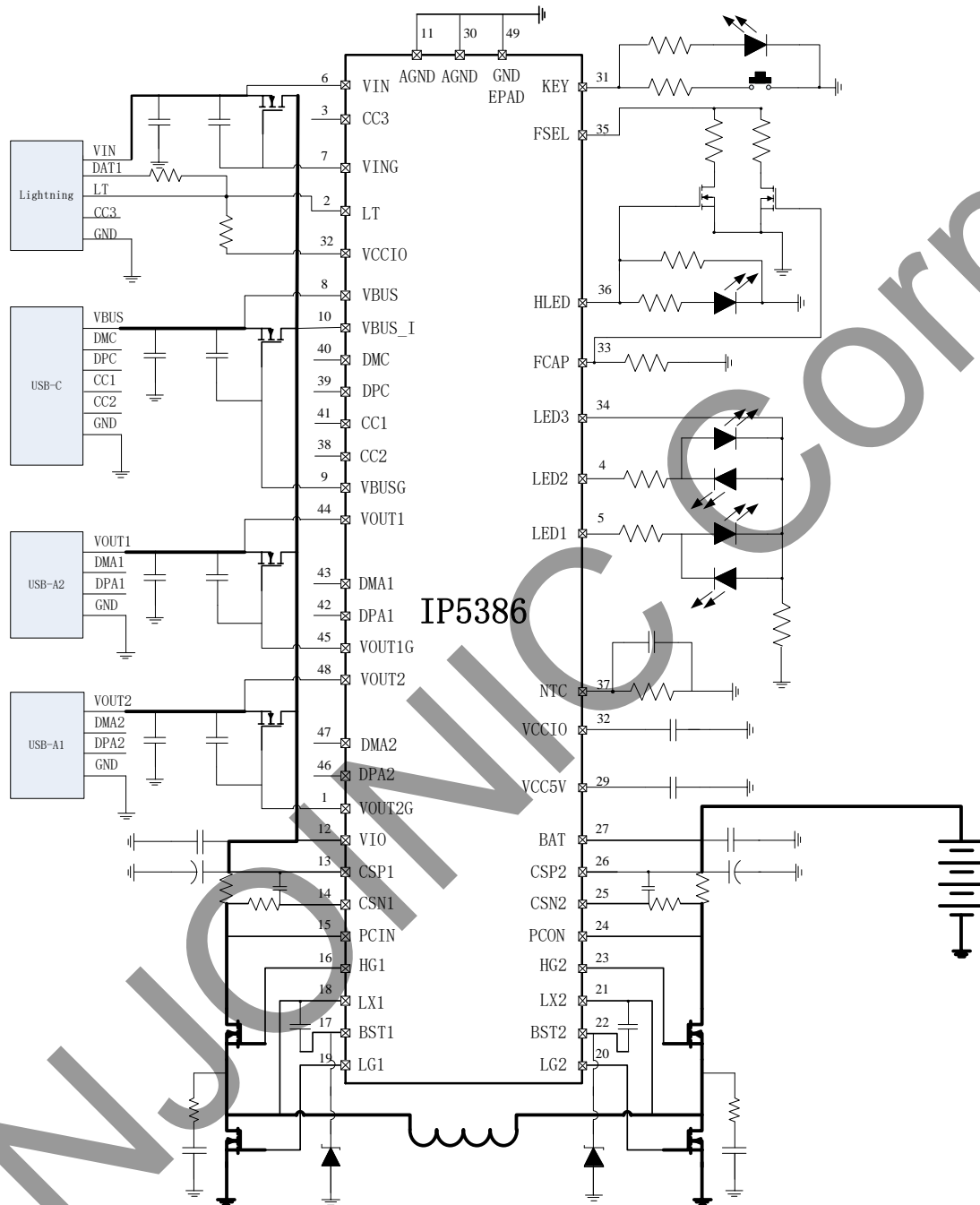


Figure 1 Simplified Application Schematic

6 IP Series Products List

6.1 Power Bank IC

IC Part No.	boost/charge		Main features								Package	
	boost	charge	LED number	light	key	I2C	DCP	USB C	QC Certificate	PD3.0 /PPS	Package	Compa-tibility
IP5303T	1.0A	1.2A	1,2	✓	✓	-	-	-	-	-	ESOP8	◆ PIN2PIN
IP5305T	1.0A	1.2A	1,2,3,4	✓	✓	-	-	-	-	-	ESOP8	
IP5306	2.4A	2.1A	1,2,3,4	✓	✓	✓	-	-	-	-	ESOP8	
IP5306H	2.4A	2.1A	1,2,3,4	✓	✓	✓	-	-	-	-	ESOP8	
IP5407	2.4A	2.1A	1,2,4	✓	✓	-	-	-	-	-	ESOP8	
IP5209	2.4A	2.1A	3,4,5	✓	✓	✓	✓	-	-	-	QFN24	PIN2 PIN
IP5209U	2.4A	2.1A	3,4,5	✓	✓	✓	✓	-	-	-	QFN24	
IP5189T	2.1A	2.1A	1,2,3,4	✓	✓	✓	✓	-	-	-	QFN24	PIN2 PIN
IP5189TH	2.1A	2.1A	1,2,3,4	✓	✓	✓	✓	-	-	-	QFN24	
IP5310	3.1A	3.0A	1,2,3,4	✓	✓	✓	✓	✓	-	-	QFN32	
IP5506	2.4A	2.1A	NixieTube	✓	✓	-	-	-	-	-	ESOP16	
IP5508	2.4A	2.1A	NixieTube	✓	✓	-	✓	-	-	-	QFN32	
IP5320	3.1A	3.0A	NixieTube	✓	✓	✓	✓	✓	-	-	QFN28	
IP5566	3.1A	3.0A	1,2,3,4	✓	✓	-	✓	✓	-	-	QFN40	
IP5322P	18W	4.0A	1,2,3,4	✓	✓	✓	✓	-	✓	-	QFN32	
IP5332	18W	4.0A	1,2,3,4	✓	✓	✓	✓	✓	✓	✓	QFN32	
IP5328P	18W	4.0A	1,2,3,4	✓	✓	✓	✓	✓	✓	✓	QFN40	
IP5356	22.5W	5.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN40	
IP5353	22.5W	5.0A	4	✓	✓	-	✓	✓	✓	✓	QFN32	
IP5358	22.5W	5.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN48	
IP5568	22.5W	5.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN64	
IP5388	30W	5.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN64	
IP5389	100W	8.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN64	
IP5386	45W	8.0A	NixieTube	✓	✓	-	✓	✓	✓	✓	QFN48	

6.2 IP5386 Common Custom Product Description

Part No.	function description
IP5386_LED_BZ	Support 2-4 batteries, maximum power 45W, support 4/2/1 LEDs
IP5386_188_BZ_30W2S	Support 2 batteries, power 30W, support AACC interface, support 188 nixie tube

7 Pin Description

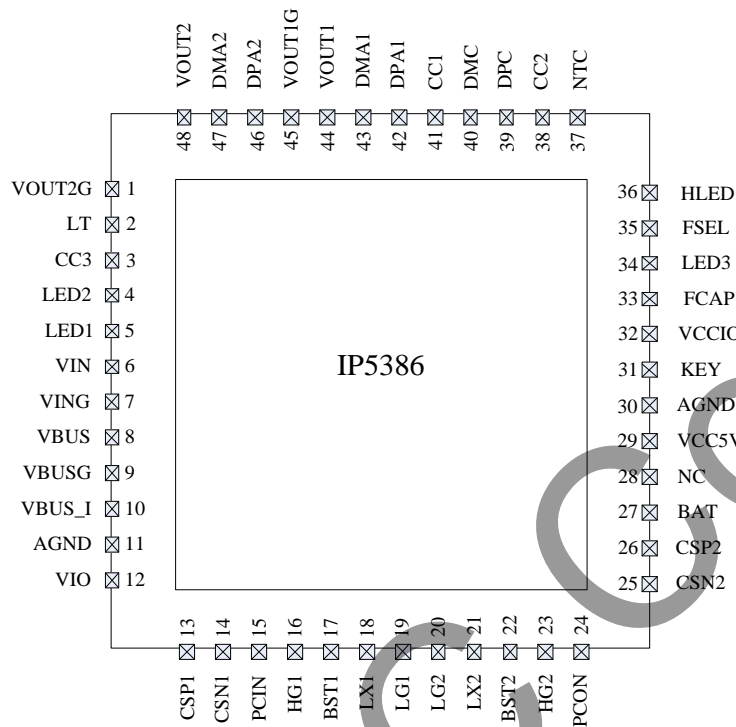


Figure 2 IP5386 Pin Diagram

7.1 IP5386 Pin Description

PIN Num	PIN Name	PIN description
1	VOUT2G	Used to control NMOS in USB-A2 port output path
2	LT	Lightning decoding pin
3	CC3	Lightning port detection and fast charging communication pin CC3
4	LED2	Used to drive power indicator LED2
5	LED1	Used to drive power indicator LED1
6	VIN	VIN input charging power pin of Lightning port
7	VING	Used to control input path NMOS of Lightning port
8	VBUS	VBUS input/output power supply pin of USB-C port
9	VBUSG	Used to control input/output path NMOS of USB-C port
10	VBUS_I	Used to detect current of USB-C port path
11	AGND	Analog ground
12	VIO	Mobile power input/output pin
13	CSP1	Current sampling positive terminal of mobile power input/output terminal
14	CSN1	Current sampling negative terminal of mobile power input/output terminal
15	PCIN	Mobile power input/output peak current sampling pin

16	HG1	Input/output terminal upper tube control pin of H-bridge power tube
17	BST1	Input/output terminal bootstrap voltage pin of H-bridge power tube
18	LX1	Inductor connection pin of mobile power input/output terminal
19	LG1	Input/output terminal lower tube control pin of H-bridge power tube
20	LG2	Battery terminal lower tube control pin of H-bridge power tube
21	LX2	Inductance connection pin of mobile power battery terminal
22	BST2	Battery terminal bootstrap voltage pin of H-bridge power tube
23	HG2	Battery terminal upper tube control pin of H-bridge power tube
24	PCON	Battery peak current sampling pin
25	CSN2	Current sampling negative terminal of battery terminal
26	CSP2	Current sampling positive terminal of battery terminal
27	BAT	Battery terminal pin
28	NC	Not connected
29	VCC5V	System 5V power supply, to supply power to the internal analog circuit of the IC
30	AGND	Analog ground
31	KEY	Key and light pin
32	VCCIO	System 3.3V power supply, to supply power to the internal digital circuit of the IC
33	FCAP	Used for battery capacity selection. You can choose different battery capacities by connecting different resistors.
34	LED3	Used to drive power indicator LED3, reused as VSET
35	FSEL	Used for system NTC function and input and output maximum power selection.
36	HLED	Fast charge mode indicator, reused as battery number selection
37	NTC	Used for NTC resistance detection.
38	CC2	Used for USB-C port detection and fast charging communication
39	DPC	Used for USB-C port fast charging intelligent recognition
40	DMC	Used for USB-C port fast charging intelligent recognition
41	CC1	Used for USB-C port detection and fast charging communication
42	DPA1	Used for USB-A1 port fast charging intelligent recognition
43	DMA1	Used for USB-A1 port fast charging intelligent recognition
44	VOUT1	USB-A1 port power output from this pin
45	VOUT1G	Used to control NMOS in USB-A1 port output path
46	DPA2	Used for USB-A2 port fast charging intelligent recognition
47	DMA2	Used for USB-A2 port fast charging intelligent recognition
48	VOUT2	USB-A2 port power output from this pin

8 Internal Block Diagram of the Chip

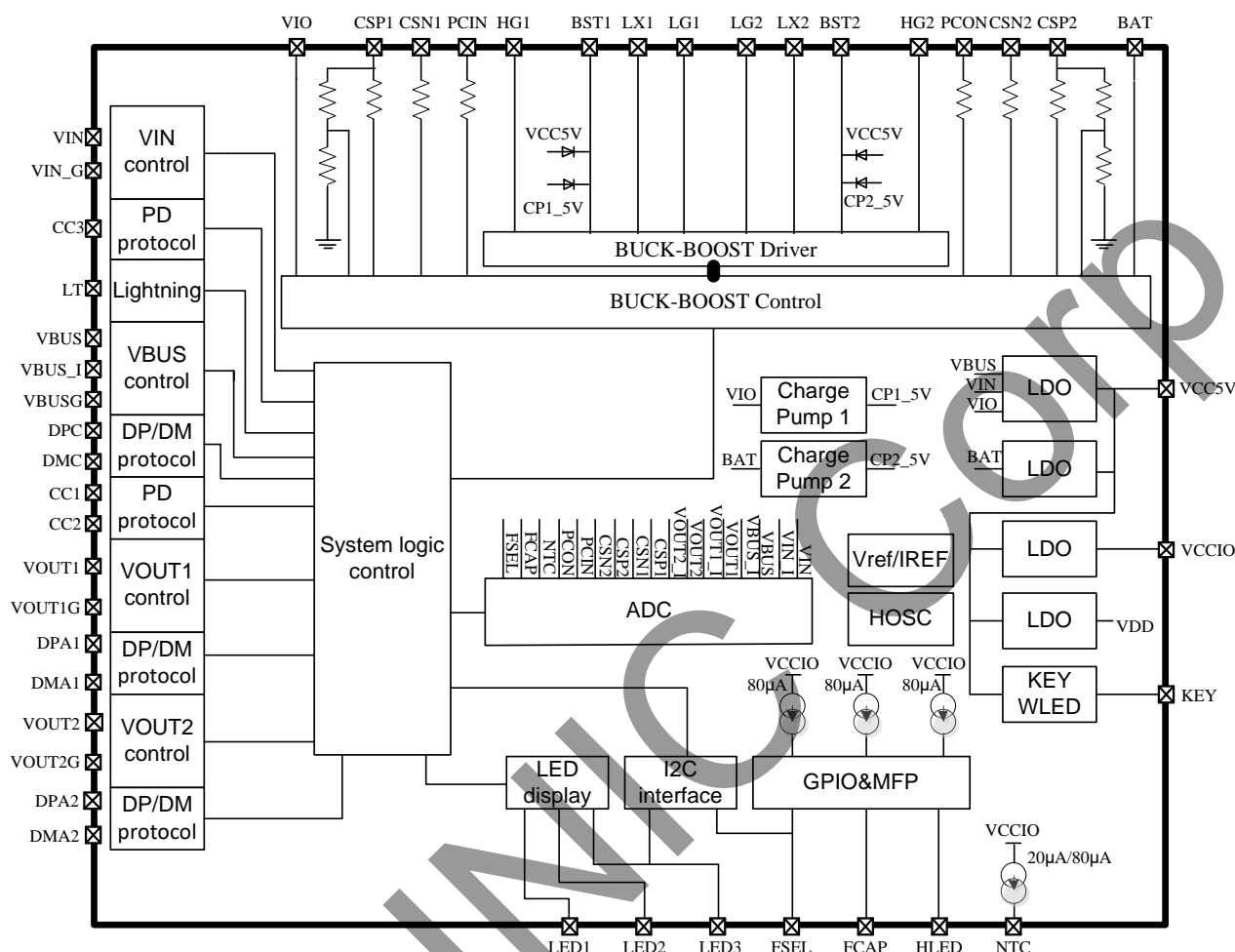


Figure 3 Internal Block Diagram Of The Chip

9 Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Input Voltage Range	VBAT/VIN/VBUS	-0.3 ~ 35	V
Protocol Port Voltage Range	DP/DM/CC	-0.3 ~ 30	V
Digital GPIO voltage range	LED/FCAP	-0.3 ~ 8	V
Junction Temperature Range	T _J	-40 ~ 125	°C
Storage Temperature Range	T _{stg}	-60 ~ 150	°C
Thermal Resistance (Junction to Ambient)	θ _{JA}	26	°C/W
Human Body Model (HBM)	ESD	4	kV

*Stresses higher than the values listed in the Absolute Maximum Ratings section may cause permanent damage to the device. Excessive exposure under any absolute maximum rating conditions may affect the reliability and service life of the device.

10 Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Battery Voltage	VBAT	5.6		18	V
Input Voltage	VIN/VBUS	4.5		24	V
Working temperature	T _A	-40		85	°C

* Beyond these operating conditions, device operating characteristics cannot be guaranteed.

11 Electrical Characteristics

Unless otherwise specified, T_A=25°C, L=4.7μH

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit	
Charging System							
Input voltage	V _{IN} /V _{BUS}		4.5	5/9/12/15/20	25	V	
Input overvoltage	V _{IN}			13	14	V	
	V _{BUS}			22	24	V	
Charging constant voltage	V _{TRGT}	The number of battery is N, R _{VSET} = 27kΩ	N*4.16	N*4.20	N*4.24	V	
		The number of battery is N, R _{VSET} = 18kΩ	N*4.26	N*4.30	N*4.34	V	
		The number of battery is N, R _{VSET} = 13kΩ	N*4.31	N*4.35	N*4.39	V	
		The number of battery is N, R _{VSET} = 9.1kΩ	N*4.36	N*4.40	N*4.44	V	
		The number of battery is N, R _{VSET} = 6.2kΩ	N*4.11	N*4.15	N*4.19	V	
		The number of battery is N, R _{VSET} = 3.6kΩ	N*3.6	N*3.65	N*3.7	V	
Charging Current	I _{CHRG}	VIN=5V, input current		1.8	2.0	2.3	A
		VIN=9V, input current		1.8	2.0	2.2	A
		VIN=12V, input current		1.35	1.5	1.7	A
		VBUS=5V, input current		2.7	3.0	3.3	A
		VBUS=9V, input current	Not PD	1.8	2.0	2.3	A
			PD	2.7	3.0	3.3	A
		VBUS=12V, input current	Not PD	1.35	1.5	1.7	A
			PD	2.7	3.0	3.3	A
		VBUS = 15V, input current	Power is 30W	1.8	2.0	2.3	A
Power is 45W	2.7		3.0	3.3	A		

		VBUS = 20V, input current	Power is 30W	1.35	1.5	1.7	A
			Power is 45W	2	2.2	2.4	A
Trickle Charging Current	I _{TRKL}	VIN=5V, VBAT<2.5V			50	100	mA
		VIN=5V, 2.5V<=VBAT<N*3.0V		150	0.025*FCAP	1000	mA
Trickle voltage cut-off	V _{TRKL}	The number of battery is N, V _{TRGT} is not 3.65V.		N*2.9	N*3	N*3.1	V
	V _{TRKL}	The number of battery is N, V _{TRGT} is 3.65V.		N*2.7	N*2.75	N*2.85	V
Charging stop current	I _{STOP}			100	0.025*FCAP		mA
Recharging Voltage Threshold	V _{RCH}	The number of battery is N.			V _{TRGT} - N*0.1		V
Charging cut-off time	T _{END}			45	48	51	Hour
Boost System							
Battery operation voltage	V _{BAT}	The number of battery is N.		N*2.75		N*4.5	V
DC output voltage	QC2.0 V _{OUT}	V _{OUT} =5V@1A		4.75	5.00	5.25	V
		V _{OUT} =9V@1A		8.70	9.00	9.30	V
		V _{OUT} =12V@1A		11.60	12.00	12.40	V
	QC3.0/ QC3+ V _{OUT}	@1A		3.6		12	V
	QC3.0 Step				200		mV
	QC3+ Step				20		mV
Output voltage ripple	ΔV _{OUT}	VBAT=4*3.7V, VOUT=5.0V, fs=250kHz, Iout=1A			40		mV
		VBAT=4*3.7V, VOUT=9.0V , fs=250kHz, Iout=1A			40		mV
		VBAT=4*3.7V, VOUT=12V , fs=250kHz, Iout=1A			40		mV
Maximum output power of discharge system	P _{max}	Under the PD protocol, different P _{MAX} resistance values correspond to		20		45	W

		different Pmax.				
Boost efficiency	η_{out}	$V_{BAT}=8V, V_{OUT}=5V, I_{OUT}=3A$		94		%
		$V_{BAT}=8V, V_{OUT}=9V, I_{OUT}=3A$		93		%
		$V_{BAT}=8V, V_{OUT}=12V, I_{OUT}=3A$		94		%
		$V_{BAT}=15V, V_{OUT}=5V, I_{OUT}=3A$		90		%
		$V_{BAT}=15V, V_{OUT}=9V, I_{OUT}=3A$		90		%
		$V_{BAT}=15V, V_{OUT}=12V, I_{OUT}=3A$		94		%
Boost system shutdown current	I_{shut}	$V_{BAT}=N \times 3.7V$, multiple ports output 5V	4.3	4.6	5.0	A
		$V_{BAT}=N \times 3.7V$, single port outputs 5V	3.2	3.6	4.0	A
		$V_{BAT}=N \times 3.7V$, single port outputs 9V, not under PD protocol condition	2.22	2.4	2.7	A
		$V_{BAT}=N \times 3.7V$, single port outputs 12V, not under PD protocol condition	1.67	1.8	2	A
		$V_{BAT}=N \times 3.7V$, single port outputs , under PD protocol condition		PDO * 1.15		A
Shutdown power threshold under light load condition	P_{out}	$V_{BAT}=3.7V$		350		mW
Detection time for overcurrent load	T_{UVD}	The output voltage is continuously lower than 2.4V.		30		ms
Detection time for short-circuit load	T_{OCD}	The output voltage is continuously lower than 2.2V.		40		μs
Control System						
Switch frequency	f_s	Discharging switch frequency		400		kHz
		Charging switch frequency		400		kHz
VCCIO output voltage	V_{CCIO}		3.15	3.3	3.45	V
Standby current at	I_{STB}	$V_{BAT}=14.8V$. The average		200	400	μA

the battery terminal		current after the key is turned off.				
LDO output current	I_{LDO}		25	30	35	mA
The current that drives LED lighting	I_{WLED}		10	15	20	mA
The current that drives LED display	I_{L1} I_{L2} I_{L3}	Voltage decreases 10%.		3	9	mA
Detection time for automatic shutdown when total load is light	T_{1load}	The load power is continuously less than 350mW.	30	32	34	s
Detection time for automatic shutdown of output port under light load	T_{2load}		14	16	18	s
Detection time of short press on key for waking	$T_{OnDebounce}$		60		500	ms
The time of opening WLED	$T_{Keylight}$		1.2	2	3	s
Temperature which leads to power off	T_{OTP}	heating	110	125	140	°C
Temperature hysteresis after power off	ΔT_{OTP}			40		°C

12 Description of Function

12.1 Lock State and Activation

When the IP5386 is connected to the battery for the first time, no matter what the battery voltage is, the chip is in a lock state, and the lowest digit of the battery indicator will flash 4 times, or the nixie tube 0% will flash 4 times to indicate. When not in the charging state, if the battery voltage is too low, the shutdown will be triggered, and IP5386 will go into lock state at this time.

In the low battery state, in order to reduce static power consumption, IP5386 can't detect the insertion of the load and it can't be activated by pressing the key. At this time, pressing the key can't activate the buck-boost output, but the lowest battery indicator will flash 4 times to prompt.

In the lock state, the chip can be activated only after entering the charging state.

12.2 Charging

IP5386 integrates the trickle current, constant current and constant voltage lithium battery charging management system with synchronous switch structure, and supports automatic matching of different charging voltage specifications:

When the battery voltage is less than V_{TRKL} , it will apply trickle charging;

When the battery voltage is greater than V_{TRKL} , it will apply constant current charging, and the maximum charging current of the battery terminal is 8.0A;

When the battery voltage is close to the setting value, it will apply constant voltage charging; when the battery terminal charging current is less than the stop charging current I_{STOP} and the battery voltage is close to the constant voltage, the charging is stopped. After the charging is completed, if the battery voltage is lower than $(V_{TRGT}-N*0.1)V$, it will restart the battery charging.

IP5386 has switch charging technology with a switching frequency of 400kHz. When charging with ordinary 5V input, the input power is 10W; when charging with fast charging input, the maximum input power is 45W. The charging efficiency can reach 96%, which can shorten the charging time by 3/4.

IP5386 supports simultaneous charging and discharging. When charging and discharging simultaneously, both input and output are 5V.

12.3 Boost

IP5386 integrates a synchronous switching converter system that supports high-voltage output and supports a wide voltage range of 3.0V~21V. The synchronous switching buck-boost system can provide a maximum output capacity of 45W. The built-in soft-start function prevents malfunctions caused by excessive inrush current during start-up. It also has output overcurrent, short circuit, overvoltage, overtemperature and other protective functions to ensure the stable and reliable operation of the system.

The current of the discharging system can be automatically adjusted with the temperature to ensure that the IC temperature is below the set temperature.

$V_{BAT} = 8V$, $V_{OUT} = 5V/9V/12V/15V/20V$, the boost efficiency curve is as follows:

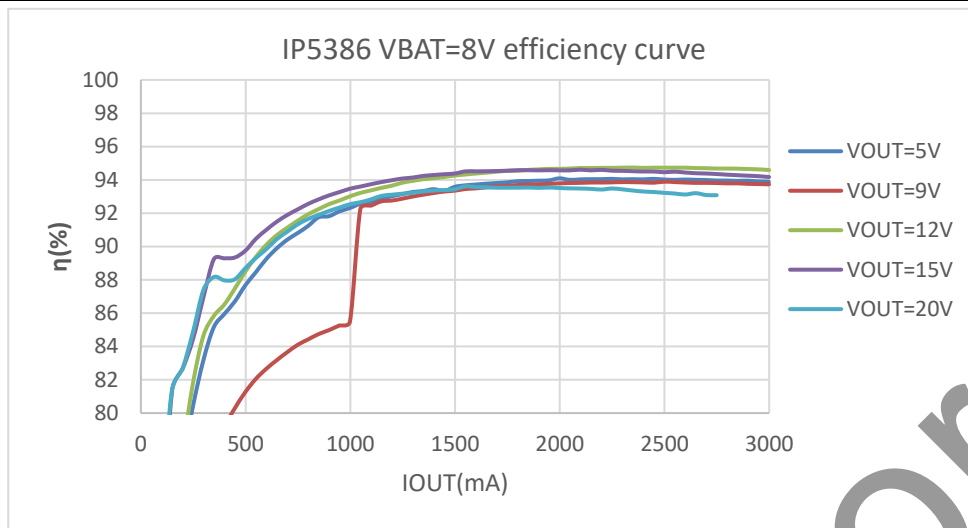


Figure 4 Boost Efficiency Curve Under The Condition Of VBAT=8V

VBAT=15.2V, VOUT=5V/9V/12V/15V/20V, the boost efficiency curve is as follows:

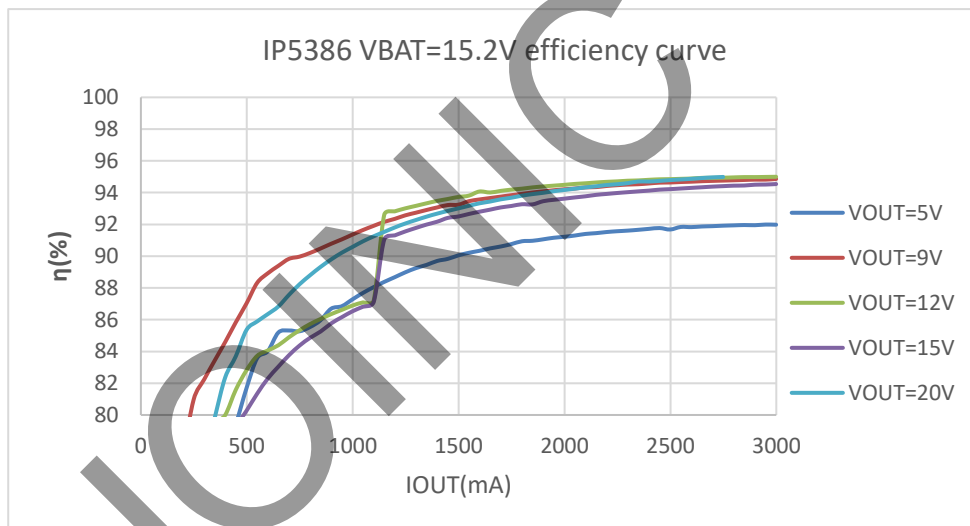


Figure 5 Boost Efficiency Curve Under The Condition Of VBAT=15V

12.3.1 USB C

IP5386 integrates USB C input and output recognition interfaces, automatically switches the built-in pull-up and pull-down resistors, and automatically recognizes charging and discharging properties of the inserted device. With Try.SRC function, when the attached device is also DRP device, IP5386 will supply power for the opposite device.

When it works as a DFP, it will output 3A current capability information through CC pin; when it works as a UFP, it can identify the output current capability of the opposite device.

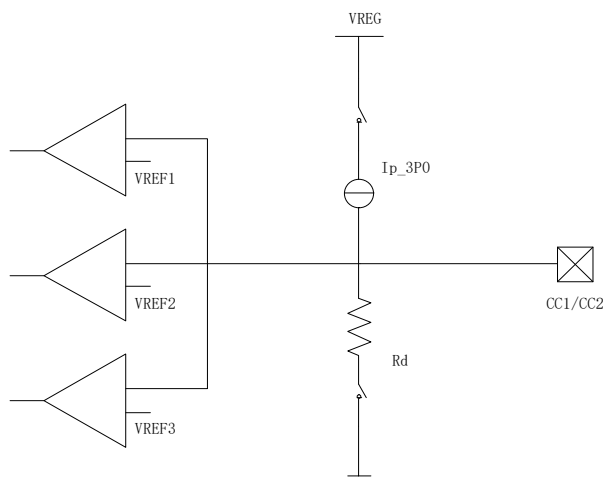


Figure 6 CC Internal Circuit

Table 1 Pull-up And Pull-Down Ability

Name	Value
Ip_3P0	330μA
Rd	5.1k

Table 2 Comparator Threshold Of Pull-Up Ip

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (vRa)	0.00V	0.75V	0.80V
vRd-Connect	0.85V	2.45V	2.60V
No connect(vOPEN)	2.75V		

Table 3 Comparator Threshold Of Pull-Down Resistor Rd

Detection	Min voltage	Max voltage	Threshold
vRa	-0.25V	0.15V	0.20V
vRd-Connect	0.25V	2.04V	
vRd-USB	0.25V	0.61V	0.66V
vRd-1.5	0.70V	1.16V	1.23V
vRd-3.0	1.31V	2.04V	

Figure 4-36 DRP Timing

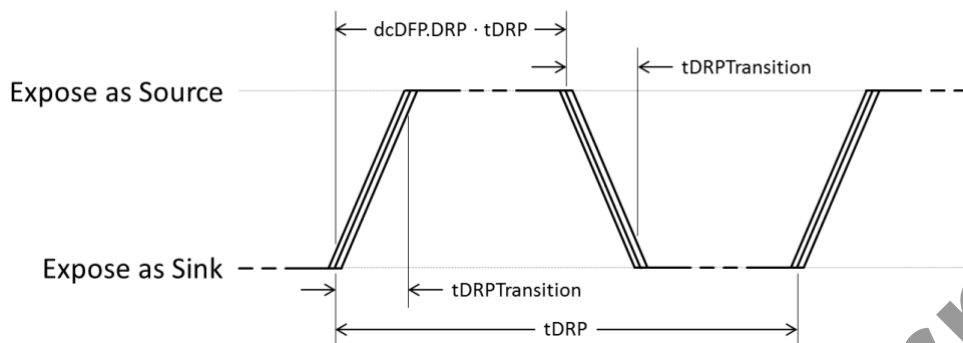


Figure 7 USB C Detection Cycle

Table 4 USB C Detection State Transition

	Minimum	Maximum	Description
tDRP	50ms	100ms	The period a DRP shall complete a Source to Sink and back advertisement
dcSRC.DRP	30%	70%	The percent of time that a DRP shall advertise Source during tDRP
tDRPTransition	0ms	1ms	The time a DRP shall complete transitions between Source and Sink roles during role resolution
tDRPTry	75ms	150ms	Wait time associated with the Try.SRC state
tDRPTryWait	400ms	800ms	Wait time associated with the Try.SNK state

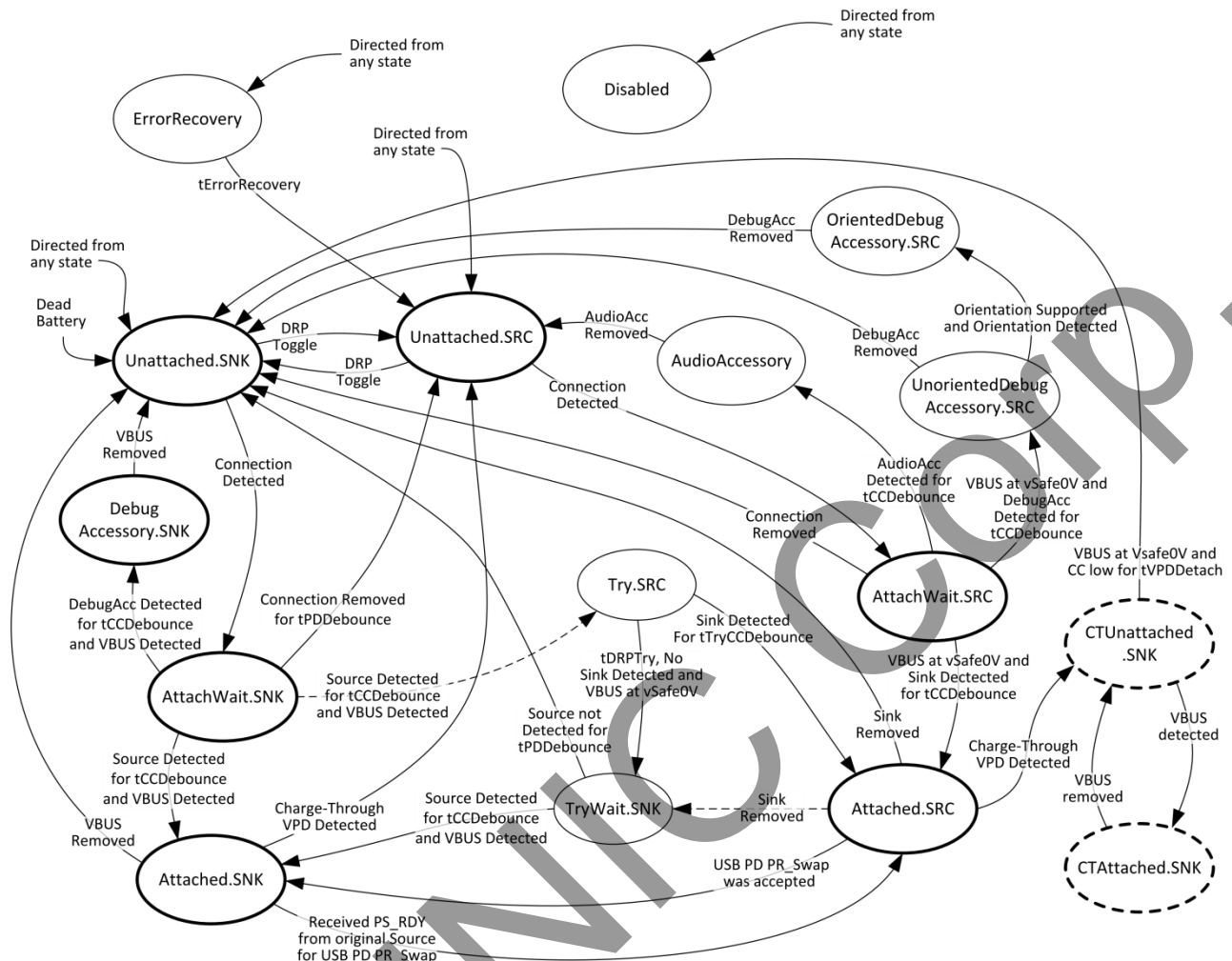


Figure 8 USB-C Detects State Transitions

12.3.2 USB C PD

IP5386 integrates USB C Power Delivery PD2.0/PD3.0/PPS (Programmable Power Supply) protocol, physical (PHY) layer for data transmitting/receiving across the CC wire and hardware biphasic mark coding (BMC) module.

IP5386 supports PD2.0/PD3.0 bidirectional input/output protocol and PPS output protocol. The maximum output power is 45W. Input voltage gears includes 5V, 9V, 12V, 15V, 20V. Output voltage gears includes 5V, 9V, 12V, 15V, 20V.

For example: when the output power is configured as 30W, the output broadcast capability is 5V@3A, 9V@3A, 12V@2.5A, 15V@2A, 20V@1.5A, PPS 3.3V~16V@2A.

12.3.3 Fast Charging Protocol

IP5386 supports multiple fast charging protocols: QC2.0/QC3.0/QC3+, FCP, AFC, SCP, Apple.

Input QC2.0/QC3.0/QC3+ protocol is not supported for charging the power bank. External fast charging protocol IC is not supported.

When the mobile power bank charges the mobile phone, it will automatically detect the fast charging sequence on the DP and DM PINs after entering the discharge mode, and intelligently identify the type of

mobile phone, which support QC2.0/QC3.0/QC3+, FCP, AFC, SCP protocol, Apple 2.4A mode, BC1.2 ordinary 1A mode.

For Apple 2.4A mode: DP=DM=2.7V.

For BC1.2 mode: DP short to DM.

In the BC1.2 mode, when the DP voltage is detected to be greater than 0.325V and less than 2V for 1.25s, the initial judgment is that there is a fast charging request. At this time, the short circuit between DP and DM will be disconnected, and DM will be pulled down to ground by a 20kΩ resistor. If it is satisfied that the DP voltage is greater than 0.325V and less than 2V, and the DM voltage is less than 0.325V for 2ms, the fast charging connection is considered successful. After that, the requested voltage can be output according to the requirements of QC2.0, QC3.0, QC3+. As long as the DP voltage is less than 0.325V, the fast charge mode is forced to exit, and the output voltage immediately returns to the default 5V.

Table 5 QC2.0, QC3.0 Rules For Requesting Output Voltage

DP	DM	Result
0.6V	GND	5V
3.3V	0.6V	9V
0.6V	0.6V	12V
0.6V	3.3V	Continuous Mode
3.3V	3.3V	hold

Continuous Mode is the unique working mode of QC3.0, QC3+. In this mode, the output voltage can be adjusted in a 200mV step according to the QC3.0 protocol requirements, or it can be adjusted in a 20mV step after the QC3+ handshake is successful.

Table 6 The Fast Charging Protocol Supported By Each Port Of IP5386

Protocols	VOUT1 Output	VOUT2 Output	Lightning Input	TYPEC Output	TYPEC Input
QC2.0	√	√	-	√	-
QC3.0	√	√	-	√	-
QC3+	√	√	-	√	-
AFC	√	√	-	√	√
FCP	√	√	-	√	√
SCP	√	√	-	√	√
PD2.0	-	-	√	√	√
PD3.0	-	-	-	√	-
PPS	√	√	-	√	-

supported: √

not supported: -

12.4 Charging and Discharging Path Management

12.4.1 Standby:

If Lightning or USB-C is connected to a power supply, charging can be started directly.

If a USB-C UFP device is inserted into USB-C or an electrical device is inserted into USB-A, the discharging function can be automatically turned on.

IP5386 will turn on when the key is pressed or there is a load on USB-A1, USB-A2, or USB-C, otherwise it will keep standby state.

12.4.2 Discharging:

When the key is not pressed, only the path of the output port that is connected to electrical device will be opened, and the path of the output port that is not connected to electrical device will be closed.

Any port of USB-A1, USB-A2, USB-C can support output fast charging protocol, because of a single inductor solution, it can only support one voltage output. In other words, It only supports fast charging output when only one output port is turned on. When two or three output ports are used at the same time, the fast charging function will be automatically turned off.

According to the connection shown in the "Simplified application schematic", when any output port has entered fast charging output mode, if another output port is plugged in with an electrical device, it will first close all the output ports, turn off the high-voltage fast charge function, and then turn on the output port where the device exists. At this time, all the output ports only support Apple and BC1.2 charging. When in the multi-port output mode, if the output current of any output port is less than about 80mA (MOS $R_{ds_ON}@10m\Omega$), the port will be automatically closed after 16s. When it is detected that the number of electrical device is reduced from multiple to one, after about 16s, all output ports will be closed first, then the high-voltage fast charging function will be turned on, and the output port connected to the electrical device will be turned on. In this way, the device can be reactivated to request a fast charging. When only one output port is turned on, and total output power is less than about 350mW for about 32s, IP5386 will close the output port, stop discharging and enter standby state.

12.4.3 Charging:

Any one of Lightning and USB-C can be plugged into a power source to charge the battery. If they are all connected to the power source, the first plugged-in power source will be used first for charging.

In the case of charging only, it will automatically recognize the fast charging mode of the power supply and automatically match the appropriate charging voltage and charging current.

12.4.4 Charge while discharging

When the charging power supply and the electrical device are plugged in at the same time, the chip will automatically enter the charging and discharging mode. In this mode, it will automatically close the internal fast charging input request. When the VIO voltage is only 5V, the discharging path is opened to supply power to the electrical device; if the VIO voltage is greater than 5.6V, for safety reasons, the discharging path will not be opened. In order to charge the electrical device normally, IP5386 will increase the charging undervoltage loop to above 4.9V to ensure that the electrical device is given priority to supply power.

During the charging and discharging process, if the charging power is unplugged, IP5386 will turn off

the charging and restart discharging to supply power to the electrical device. For safety reasons, and to reactivate the mobile phone to request fast charging, the voltage will drop to 0V for a period of time during the conversion process.

During the charging and discharging process, if the electrical device is unplugged, or the electrical device is fully charged and stops drawing power, the corresponding discharging path will be automatically closed after about 16s. When the discharging paths are closed and the state returns to the charging only mode, the charging undervoltage loop will be lowered and the fast charging will be automatically reactivated, then the charging of the mobile power supply will be accelerated.

12.5 Automatic Detection for Mobile Phone

12.5.1 Automatic detection for mobile phone insertion

If an inserted phone has been automatically detected by IP5386, IP5386 will wake up from standby state immediately and turn on the boost to charge the phone. This design can save the step of turning on the key and support the mold scheme without key.

12.5.2 Automatic detection for fully charged mobile phone

IP5386 samples the output current of each port through the on-chip ADC. When the output current of a single port is less than about 80mA ($MOS\ R_{ds_ON}@10m\Omega$) and lasts for about 16s, the output port will be closed. When the total output power is less than about 350mW and lasts for about 32s, it is considered that the mobile phones of all output ports are fully charged or unplugged, and the buck-boost output will be automatically turned off.

12.6 Key Function

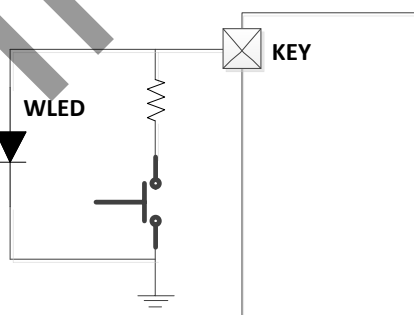


Figure 9 Key Circuit

Key circuit is illustrated in Figure 9, which can recognize short press or long press operation.

- Pressing the key for longer than 100ms but less than 2s is a short press action. Short press will turn on the battery indicator and boost output.
- Pressing the key for longer than 2s is a long press action. Press and hold to turn the light on or off.
- There will be no response when the key is pressed for less than 30ms.
- Short press the button for two consecutive times within 1s, the boost output, power display and lighting will be turned off.
- Long press for 10s to reset the entire system.

12.7 Fast Charging Status Indicator

HLED is used to indicate the current fast charging mode. Regardless of charging or discharging, the indicator will automatically light up when entering the fast charging mode and the output is not 5V.

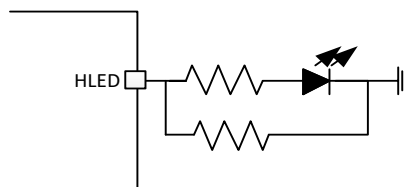


Figure 10 Fast Charging State Indication

12.8 Coulombmeter and Battery Level Display

IP5386 has a built-in coulombmeter, which can realize accurate battery power calculation.

IP5386 supports 4-LED, 2-LED, 1LED mode.


IP5386 supports 188 nixie tube to display power.

12.8.1 Coulombmeter

IP5386 supports externally setting the initial capacity of the battery, and uses the integral of the current and time of the battery terminal to manage the remaining capacity of the battery. When a 5 mΩ detection resistor is used between the battery current detection pins CSP2 and CSN2, the current battery capacity can be accurately displayed. When the battery current detection pins CSP2 and CSN2 are shorted, the battery current can be estimated to display the estimated current battery capacity; IP5386 supports the automatic calibration of the total capacity of the current battery in a complete charging process from 0% to 100%, and more reasonable management of the actual capacity of the battery.

The formula for setting the initial capacity of the battery through the IP5386 external PIN: battery capacity = $R21 \times 1.0$ (mAH). The minimum value is 2000mAH, and the maximum value is 30000mAH.

When the voltage on the FCAP pin is less than 100mV or greater than 2700mV, it will be recognized as a short-circuit or open-circuit abnormality in the R21 resistor.



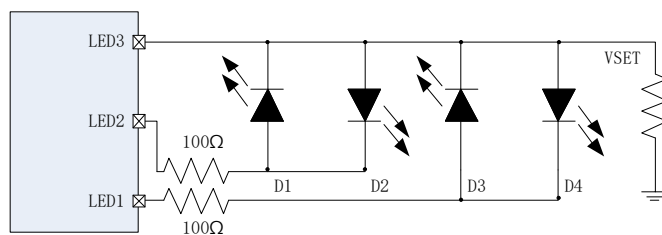
R21	capacity
5kΩ	5000mAH
10kΩ	10000mAH
15kΩ	15000mAH
20kΩ	20000mAH
25kΩ	25000mAH
30kΩ	30000mAH

Note: The capacity in the table refers to the capacity of a single battery

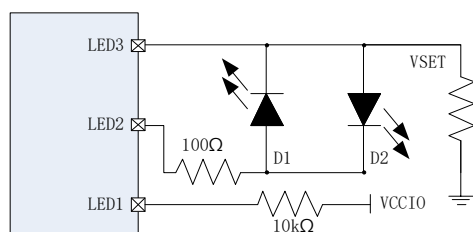
Figure 11 Battery Capacity Configuration Circuit

12.8.2 LED Power Display Mode

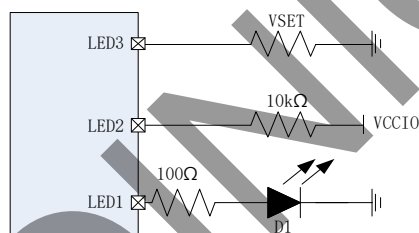
IP5386 4-LED,2-LED,1-LED mode to display the capacity of the battery is as follows:



4LED mode



2LED mode



1LED mode

Figure 12 4-LED Connection

4-LED display mode:
charging:

Table 7 Charging Lamp Display

Battery capacity C(%)	D1	D2	D3	D4
Fully charged	ON	ON	ON	ON
$75\% \leq C$	ON	ON	ON	0.5Hz Flash
$50\% \leq C < 75\%$	ON	ON	0.5Hz Flash	OFF
$25\% \leq C < 50\%$	ON	0.5Hz Flash	OFF	OFF
$C < 25\%$	0.5Hz Flash	OFF	OFF	OFF

discharging:

Table 8 Discharging Lamp Display

Battery capacity C(%)	D1	D2	D3	D4
$C \geq 75\%$	ON	ON	ON	ON
$50\% \leq C < 75\%$	ON	ON	ON	OFF
$25\% \leq C < 50\%$	ON	ON	OFF	OFF
$3\% \leq C < 25\%$	ON	OFF	OFF	OFF
$0\% < C < 3\%$	1.0Hz Flash	OFF	OFF	OFF
$C = 0\%$	OFF	OFF	OFF	OFF

2-LED display mode:

charging: The D1 flashes in a 2s cycle (1s on and 1s off), and is always on when fully charged.

discharging: The D2 is always on, and when the power is lower than 5%, it flashes at 1Hz (0.5s on and 0.5s off).

1-LED display mode:

charging: The D1 flashes in a 2s cycle (1s on and 1s off), and is always on when fully charged.

discharging: The D1 is always on, and when the power is lower than 5%, it flashes at 1Hz (0.5s on and 0.5s off).

12.8.3 188 Nixie Tube Display Mode

The nixie tube supported by IP5386 is as follows:

Table 9 Nixie Tube Display Mode

Nixie Tube	During charging		During discharging	
	Not fully charged	Fully charged	Battery capacity <5%	Battery capacity >5%
188 (YF2252SR-5)	0-99% ones place Flash 0.5Hz	100% always on	0-5% ones place 1Hz Flash	5%-100% always on

5-pin 188 nixie tube is as follows:

(未注尺寸公差 Unspecified Tolerances is: ± 0.2

发光颜色: 白色、翠绿

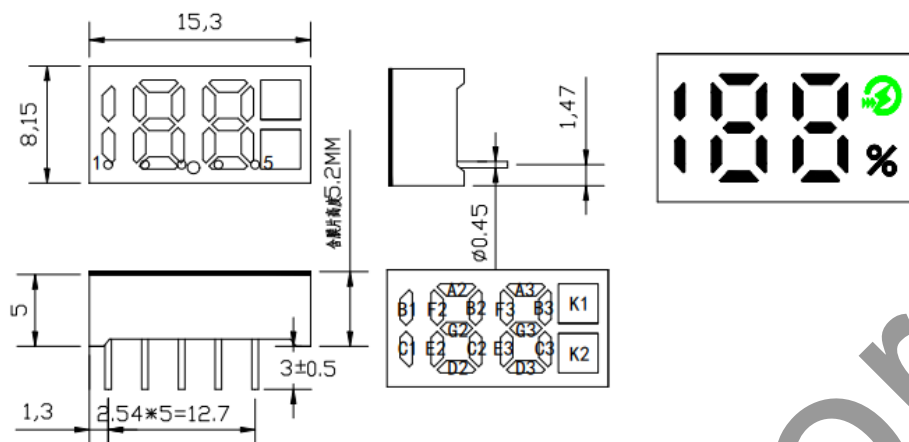


Figure 13 Nixie Tube

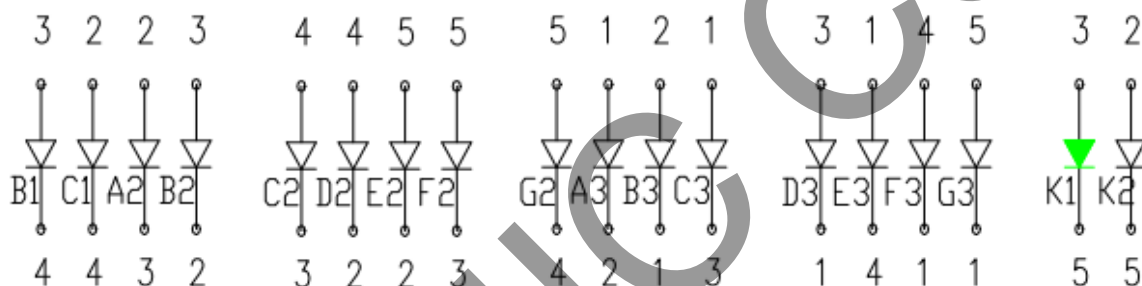


Figure 14 5-pin 188 Nixie Tube Circuit

12.9 Setting the System Input/Output Maximum Power

IP5386 sets the maximum input and output power of the system by judging the resistance value connected to the FSEL PIN.

Input and output maximum power configuration table:

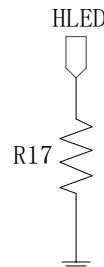
FSEL	R16	Max input power	Max output power
	18k Ω	20W	20W
	13k Ω	20W	30W
HLED	9.1k Ω	30W	30W
	6.2k Ω	30W	45W
	3.6k Ω	45W	45W

Figure 15 Power Configuration And Connection Method

12.10 Setting the Number of Batteries in Series

IP5386 sets the number of system batteries in series by judging the resistance value of the R17 resistor connected to the HLED pin, and configures the corresponding battery parameters.

Configuration table of the number of batteries in series:



R17	Number of batteries connected in series
9.1kΩ	2
6.2kΩ	3
3.6kΩ	4

Figure 16 Setting the Number Of Batteries In Series

12.11 VSET(Battery Type Setting)

IP5386 sets the battery type by outputting 80μA current to the resistor connected to GND on the VSET(LED3) PIN and judging the voltage on the VSET, thereby changing the battery display threshold, the constant voltage for charging the battery, and the protection voltage. The different resistances to GND connected to VSET and the corresponding different battery types are shown in the following table. When the voltage of VSET exceeds all judgment ranges, the chip will recognize the circuit as a short circuit or an abnormal open circuit.

Table 10 Battery Type Setting

Resistance from VSET to GND	VSET (Theoretical Voltage)	VSET Voltage Judgment Range	Corresponding Battery Type
27 kΩ	2160 mV	1750 mV ~2550 mV	4.2V
18 kΩ	1440 mV	1220 mV ~1750 mV	4.3V
13 kΩ	1040 mV	860 mV ~1220 mV	4.35V
9.1 kΩ	728 mV	600 mV ~860 mV	4.4V
6.2 kΩ	496 mV	384 mV ~600 mV	4.15V
3.6 kΩ	288 mV	216 mV ~384 mV	3.65V

Note:

1. 3.65V refers to lithium iron phosphate battery and corresponding turn-off voltage is 2.75V.
2. Note that the accuracy of the external resistance should be 1% and the voltage of VSET should be in the middle of the judgment range.

12.12 NTC Function and Threshold Selection

IP5386 integrates NTC function, which can detect battery temperature. When the IP5386 is working, a constant current source is generated at the NTC pin, and an external NTC resistor is used to generate a voltage. The IC internally detects the voltage of the NTC pin to determine the current battery temperature.

*Connect a 100nF capacitor in parallel with the NTC PIN to GND, the capacitor needs to be placed close to the chip PIN.

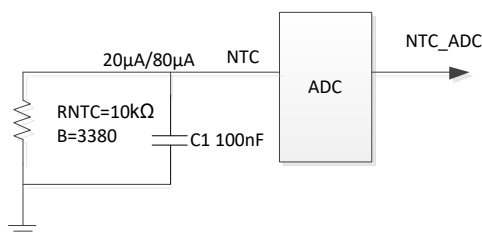


Figure 17 NTC Circuit

IP5386 discharges 80µA current on the FSEL PIN. If this PIN is connected with different resistors, different voltages can be obtained. The IC will detect the FSEL voltage and select different NTC functions according to the FSEL voltage. When the voltage of FSEL exceeds all judgment ranges, the chip will recognize the circuit as a short circuit or an abnormal open circuit.

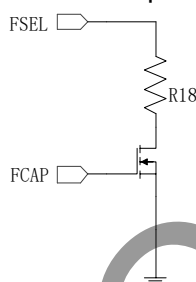


Figure 18 NTC Threshold Selection

Table 11 NTC Threshold Selection

FSEL External Resistance	FSEL Theoretical Voltage	FSEL Voltage Judgment Range	NTC Function
27 kΩ	2160 mV	1750 mV~2550 mV	NTC first gear
18 kΩ	1440 mV	1220 mV~1750 mV	NTC second gear
13 kΩ	1040 mV	860 mV~1220 mV	NTC third gear
9.1 kΩ	728 mV	600 mV~860 mV	NTC fourth gear
6.2 kΩ	496 mV	380 mV~600 mV	NTC fifth gear
3.6 kΩ	288 mV	216 mV~380 mV	NTC sixth gear

Note that the accuracy of the external resistance should be 1% and the voltage of FSEL should be in the middle of the judgment range.

IP5386 has six built-in NTC functions. By changing the resistance between FSEL PIN and GND, the corresponding NTC function can be set. The functions are as follows:

NTC first gear:

In the charging state, charging stops when the NTC temperature is lower than 0°C (0.55V), normal charging between 0 and 45°C, and charging stops when the NTC temperature is higher than 45°C (0.39V).

In the discharge state, discharge is stopped when the NTC temperature is lower than -20°C (1.39V), normal discharge is between -20°C and 60°C, and the discharge is stopped when the NTC temperature is higher than 60°C (0.24V).

NTC second gear:

In the charging state, charging stops when the NTC temperature is lower than 2°C (0.50V), normal charging between 2°C and 43°C, and charging stops when the NTC temperature is higher than 43°C

(0.42V).

In the discharge state, discharge is stopped when the NTC temperature is lower than -10°C (0.86V), normal discharge is between -10°C and 55°C , and the discharge is stopped when the NTC temperature is higher than 55°C (0.28V).

NTC third gear:

In the charging state, charging stops when the NTC temperature is lower than 0°C (0.55V), normal charging between 0 and 45°C , and charging stops when the NTC temperature is higher than 45°C (0.39V).

In the discharge state, discharge is stopped when the NTC temperature is lower than -10°C (0.86V), normal discharge is between -10°C and 55°C , and the discharge is stopped when the NTC temperature is higher than 55°C (0.28V).

NTC fourth gear:

In the charging state, when the NTC temperature is lower than -10°C (0.86V), the charging stops, the current limit of the BAT terminal is $0.2C$ between -10°C ~ 0°C , and C is equal to the battery capacity set by FCAP, and the normal charging is between 0°C and 45°C (0.39V). Between 45°C and 55°C , the constant voltage charging voltage is reduced by $0.1V \cdot N$ to charge the battery with normal current, and the NTC temperature is higher than 55°C (0.28V) to stop charging.

In the discharge state, discharge is stopped when the NTC temperature is lower than -20°C (1.39V), normal discharge is between -20°C and 55°C , and the discharge is stopped when the NTC temperature is higher than 55°C (0.28V).

NTC fifth gear:

In the charging state, when the NTC temperature is lower than 2°C (0.50V), the charging stops, the current limit of the BAT terminal is $0.1C$ between 2°C and 17°C , and C is equal to the battery capacity set by FCAP, and the normal charging is between 17 and 43°C (0.42V). and the NTC temperature is higher than 43°C to stop charging.

In the discharge state, discharge is stopped when the NTC temperature is lower than -20°C (1.39V), normal discharge is between -20°C and 60°C , and the discharge is stopped when the NTC temperature is higher than 60°C (0.24V).

NTC sixth gear:

In the charging state, When the NTC temperature is lower than -10°C (0.86V), the charging stops, the current limit of the BAT terminal is $0.2C$ between -10°C and 0°C (0.55V), and the charging is normal between 0°C and 45°C . the BAT terminal current is limited to $0.2C$ for charging between 45°C ~ 55°C (0.28V), C is equal to the battery capacity set by FCAP, and the NTC temperature is higher than 55°C (0.28V) to stop charging.

In the discharge state, discharge is stopped when the NTC temperature is lower than -20°C (1.39V), normal discharge is between -20°C and 55°C , and the discharge is stopped when the NTC temperature is higher than 55°C (0.28V).

*Note:

After detecting the abnormal temperature of the NTC, it resumes normal operation when the temperature is ± 5 degrees Celsius of the protection temperature. In the brackets after the above temperature, the NTC PIN voltage corresponding to the temperature is written. The calculation method is: the current discharged by the NTC PIN * the NTC resistance value at the temperature.

The NTC resistance parameter referenced in the above temperature range is $10k\Omega @ 25^{\circ}\text{C}$ $B=3380$. Other models are different and need to be adjusted.

If the scheme does not require NTC, the NTC pin should be connected to the ground with a 10kΩ resistor, and cannot be left floating or grounded directly.

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13 Layout considerations

13.1 VIO and BAT Terminal Sampling Lines

In the schematic diagram, BAT and CSP2 belong to the same network, but they must go to the 5mΩ sampling resistor end respectively when routing. Similarly, CSN2 and PCON also need to go to the 5mΩ sampling resistor end respectively.

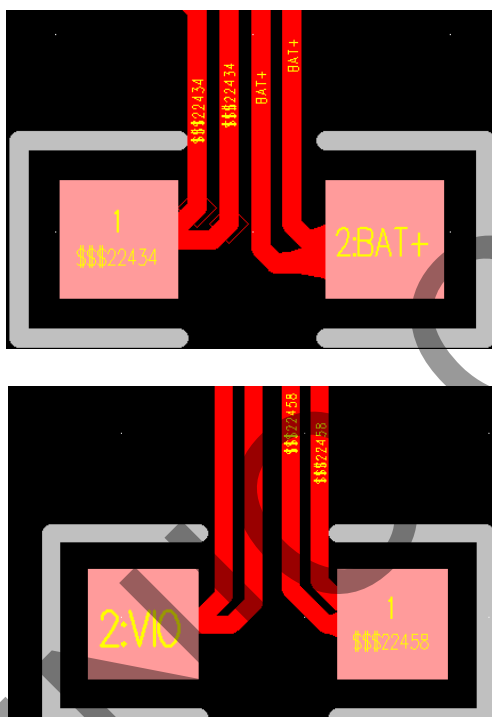


Figure 19 5mΩ Resistance Sampling Line

13.2 VIO and BAT Capacitors

The VIO and BAT terminal capacitors need to be close to the sampling resistor, and the ground of the capacitor needs to be close to the ground of the lower tube of the H-bridge, and as many vias as possible should be made. For example: BAT terminal capacitor location.

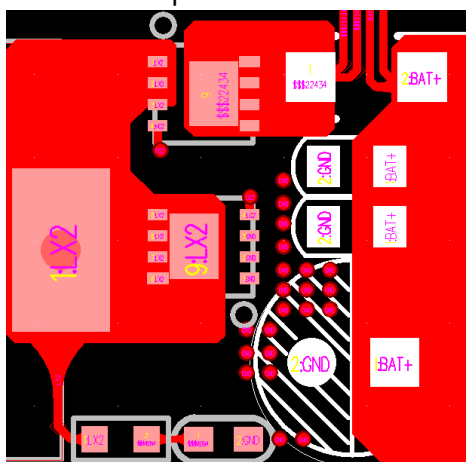


Figure 20 BAT Capacitors

13.3 The Wiring from VIO to output USB-A1, USB-A2 MOS Tube

The wiring from VIO to USB-A1 and USB-A2 output MOS needs to be routed separately at the VIO of the VBUS_I resistor, otherwise it may affect the automatic recovery fast charging function when multi-port to single-port.

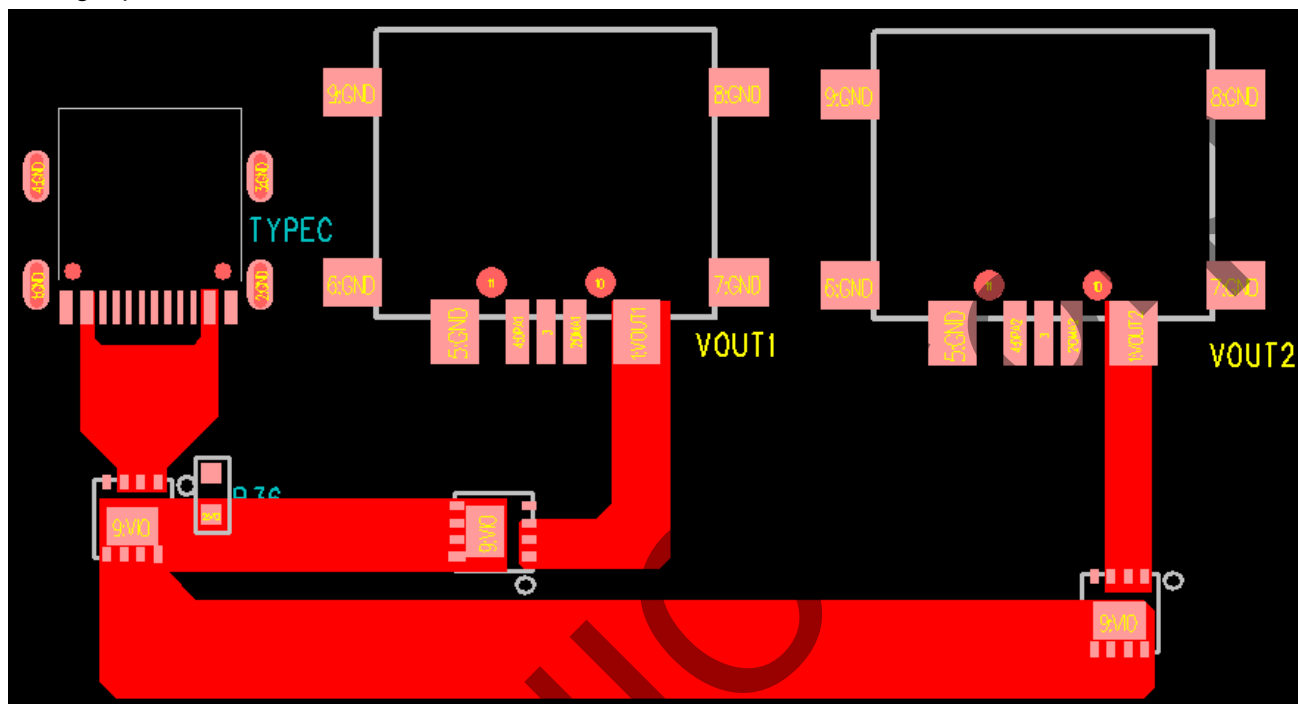


Figure 21 Route The VIO To Each Output Port

14 Application Schematic

14.1 Application Schematic Diagram of LED Lamp Scheme

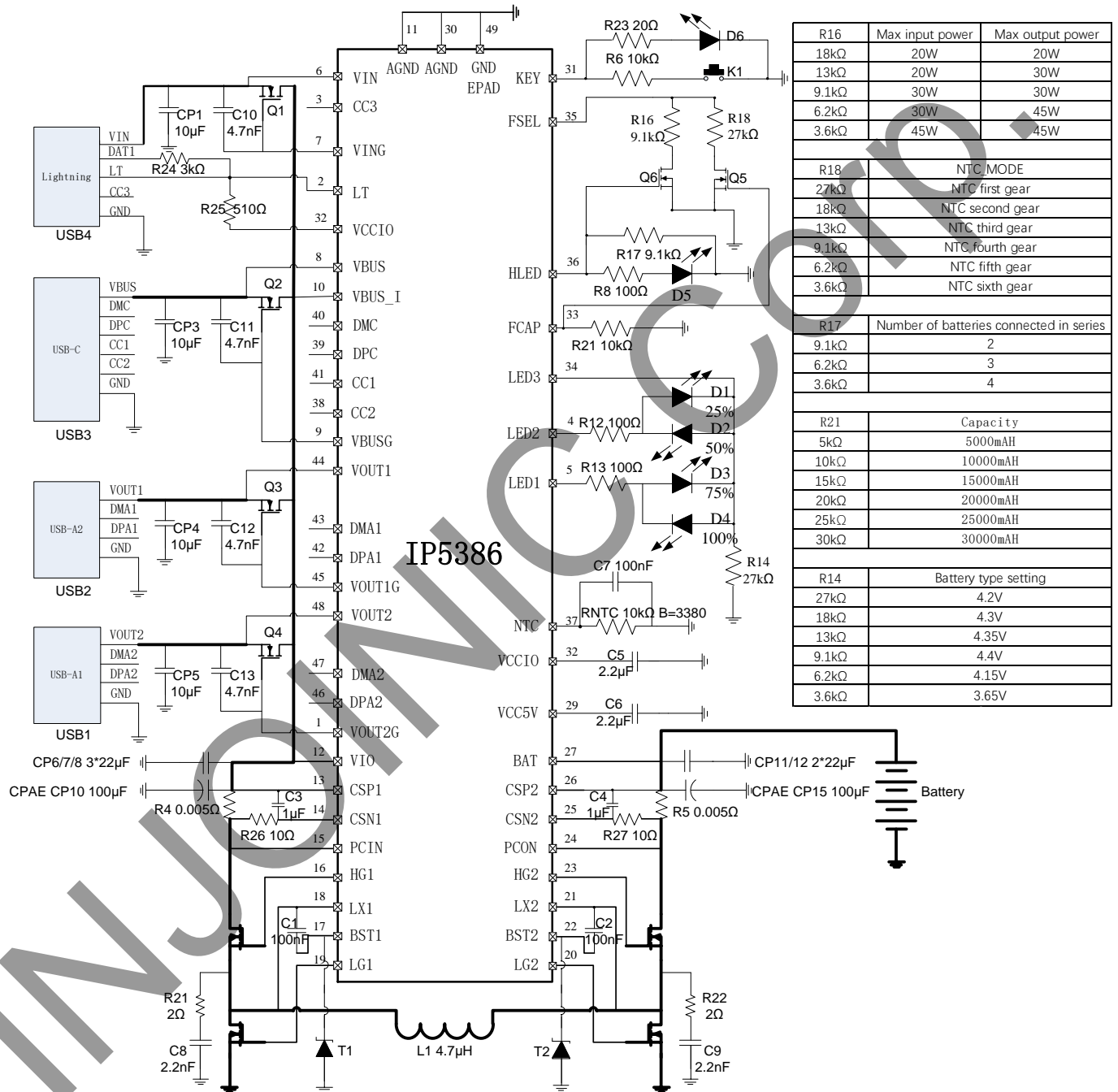


Figure 22 IP5386 LED Lamp Scheme Application Schematic Diagram

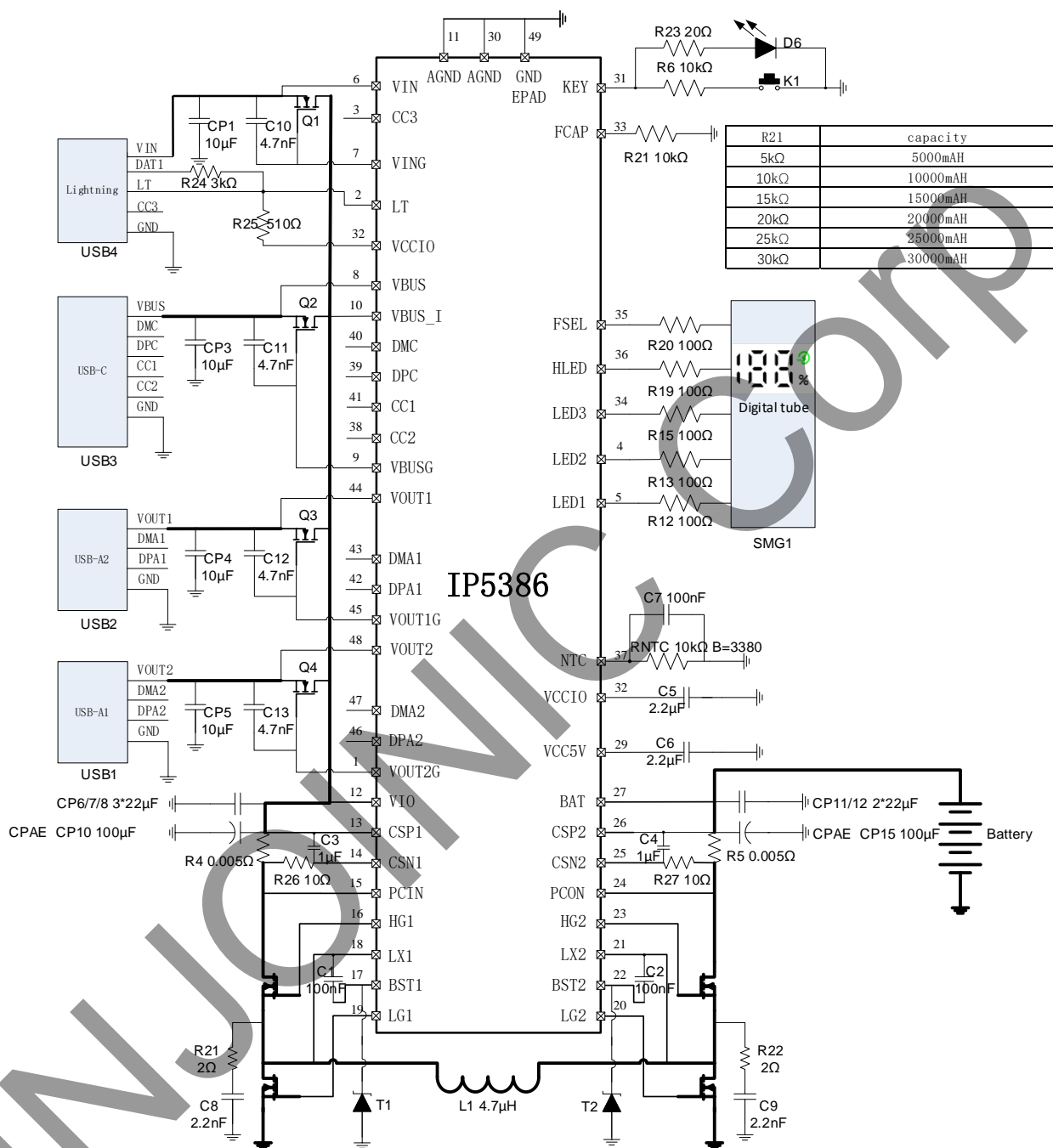


Figure 23 Digital Tube Solution Application Schematic Diagram

BOM

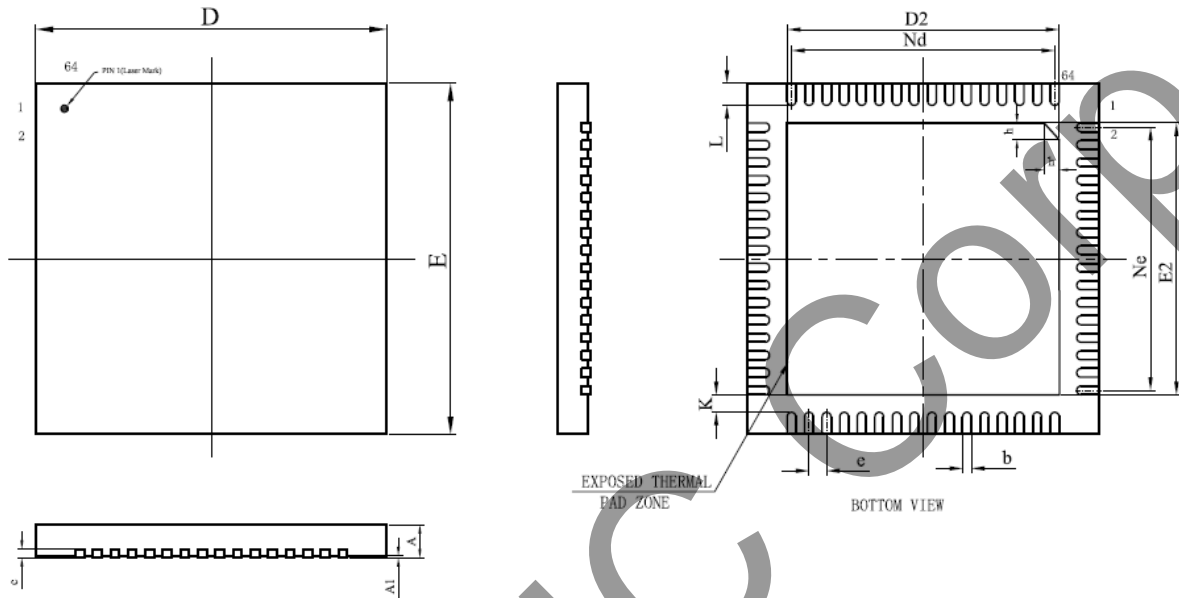
Serial number	Part name	Type	Location	Number	Remarks
1	SMT IC	QFN48 IP5386	U1	1	
2	SMT capacitor	0603 100nF 10% 50V	C1 C2	2	
3	SMT capacitor	0603 1μF 10% 16V	C3 C4	2	
4	SMT capacitor	0603 2.2μF 10% 16V	C5 C6	2	
5	SMT capacitor	0805 10μF 10% 25V	CP1 CP3 CP4 CP5	4	
6	SMT capacitor	0805 22μF 10% 25V	CP6 CP7 CP8 CP11 CP12	5	
7	SMT capacitor	0603 2.2nF 10% 50V	C8 C9	2	
8	CPAE capacitor	100μF 35V 10%	CP10 CP15	2	
9	Inductor	4.7μH SPA1265-4R7	L1	1	
10	SMT NMOS	CWT3081AP	H-bridge NMOS	4	
11	TVS	30V TVS	T1 T2	2	
12	SMT resistor	0603 10Ω 1%	R26 R27	2	
13	SMT resistor	0603 2Ω 1%	R21 R22	2	
14	SMT resistor	1206 0.005Ω 1%	R4 R5	2	
15	SMT resistor	0603 10kΩ 1%	R21	1	
16	SMT resistor	0603 9.1kΩ 1%	R16	1	
17	SMT resistor	0603 27kΩ 1%	R18	1	
18	SMT NMOS	2N7002	Q5 Q6	2	
19	SMT resistor	0603 9.1kΩ 1%	R17	1	
20	SMT capacitor	0603 100nF 10% 50V	C7	1	
21	NTC thermal resistor	10kΩ@25℃ B=3380	RNTC	1	
22	SMT resistor	0603 100Ω 1%	R12 R13	4	
23	SMT LED	0603 blue	D1 D2 D3 D4	4	
24	SMT LED	0603 red	D5	1	
25	SMT resistor	0603 100Ω 1%	R8	1	
26	SMT resistor	0603 27kΩ 1%	R14	1	
27	Digital tube	YFTD1508SWPG-5D	SMG1	1	
28	SMT resistor	0603 100Ω 1%	R12 R13 R15 R19 R20	5	
29	LED	5MM LED	D6	1	
30	SMT resistor	0603 20Ω 1%	R23	1	
31	SMT resistor	0603 10kΩ 1%	R6	1	
32	KEY	SMT 3*6	K1	1	
33	SMT NMOS	AET3121BP	Q1 Q2 Q3 Q4	4	
34	SMT capacitor	0603 4.7nF 10% 50V	C10 C11 C12 C13	4	
35	Output USB	AF10 8 pins USB	USB1 USB2	2	
36	USB C	USB C connector	USB3	1	

	connector				
37	Lightning connector	Apple lightning connector	USB4	1	

INJOINIC Corp.

15 Package

15.1 Package of the Chip



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	-	0.02	0.05
b	0.15	0.20	0.25
c	0.18	0.20	0.25
D	7.90	8.0	8.10
D2	6.10	6.20	6.30
e	0.4 BSC		
Nd	6.00BSC		
E	7.90	8.0	8.10
E2	6.10	6.20	6.30
Ne	6.00BSC		
L	0.45	0.50	0.55
K	0.20	-	-
h	0.30	0.35	0.40

15.2 Marking Description



Note:


- 1、 --Injoinic Logo
- 2、IP5386 --Part Number
- 3、XXXXXXXX --Manufacture number
- 4、○ --PIN1 Location

Figure 24 Silk Screen Printing

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