
Dual ports Type-C Buck Converter with Fast Charge Protocols of PD3.0/PPS/PD2.0, QC3.0/QC2.0, FCP, AFC, MTK PE+2.0/PE+1.1

1 Features

- **Synchronous-rectified buck converter**
 - ◇ Built-in power MOSFET
 - ◇ Input voltage range: 8.2V~32V
 - ◇ Output voltage range: 3V~20V, adjustable according to the fast charge protocol
 - ◇ Output voltage has line compensate function of 50mV/A
 - ◇ Support CV/CC output mode: CV mode (output current < preset value); CC mode (output current > preset value)
 - ◇ conversion efficiency up to 96.5% with VIN=12V, VOUT=5V/3A
- **Dual ports fast charge output**
 - ◇ Support dual ports USB Type-C output
 - ◇ Support USB Type-C and USB A output
 - ◇ Support dual ports USB A output
 - ◇ Support any port fast charge output
 - ◇ Dual ports auto plug-in and plug-out detection
- **Type-C USB PD protocol output**
 - ◇ Support 5V, 9V, 12V,15V,20V voltage output
 - ◇ Support PD2.0/PD3.0(PPS) output protocol
 - ◇ PPS support 3.3~21V adjustable voltage with 20mV/step output
- **Fast charge output of dual Type-C and dual USB A ports**
 - ◇ Support 2 ports of Type-C PD output
 - ◇ Support 2 ports of BC1.2, Apple, Samsung
 - ◇ Support 2 ports of QC3.0 and QC2.0
 - ◇ Support 2 ports of MTK PE+2.0 and PE+ 1.1
 - ◇ Support 2 ports of FCP and SCP
 - ◇ Support 2 ports of Samsung fast charge: AFC
 - ◇ Support 2 ports of OPPO fast charge: VOOC
- **Multi protection and high reliability**
 - ◇ Support input over voltage and under voltage protection, support output short circuit, over current and over temperature protection
 - ◇ DP/DM/CC over voltage protection
 - ◇ DP/DM/CC withstand voltage of 30V
 - ◇ ESD 4KV, DC withstand voltage of 40V
- **Package: 5*5mm QFN32**

2 Application

- Car charger
- Fast charge adaptor
- Smart power strip

3 Description

IP6538 is a Synchronous-Rectified Buck Converter which supports multiple fast charge output standards with dual Type-C output ports and dual USB A output ports. It provides solutions for car charger, fast charge adaptor and smart power strip.

IP6538 supports dual Type-C output ports or dual USB A output ports or a Type-C output port plus a USB A port output port. Includes dual ports auto plug detection function, fast charge is supported on any single port, the two ports will output 5V when two ports have attached devices at which the overall output power is 5V/4.8A.

IP6538 has built-in power MOSFET, input voltage range is 4.5V to 32V, output voltage ranges from 3V to 20V with up to 45W power supply. The output voltage and current is auto adjusted dynamically based on the fast charge requirement. IP6538 has a conversion efficiency of up to 96.5% when output 5V/3A.

IP6538 output has CV/CC mode, when the output current is lower than preset value, the output voltage will be constant in CV output mode; when the output current is higher than preset value, the output voltage will decrease in CC output mode.

IP6538 supports output line compensation, when output current increases, the output voltage will increase accordingly that makes up the resistive voltage drop introduced by connection, wire, and PCB traces.

IP6538 supports soft start function that protects the input power source from inrush current at start up.

5 Pin Functions

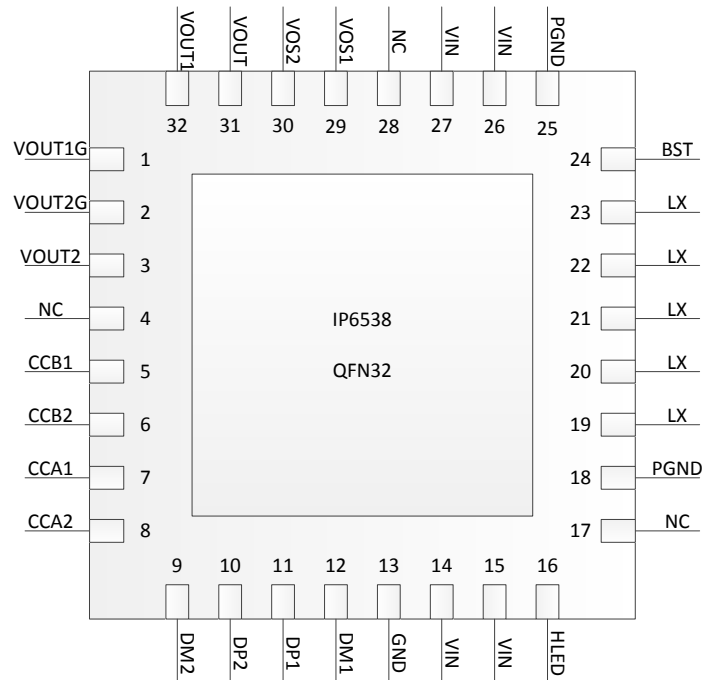


Figure 2. Pin Functions

| Pins | | Description |
|----------------|----------|---|
| Pin No. | Pin Name | |
| 1 | VOUT1G | Control external NMOS of VOUT1 output |
| 2 | VOUT2G | Control external NMOS of VOUT2 output |
| 3 | VOUT2 | VOUT2 output plug in detection pin |
| 4/17/28 | NC | Floating PIN, do not connect |
| 5 | CCB1 | Group B CC1 (For Type-C 2) |
| 6 | CCB2 | Group B CC2 (For Type-C 2) |
| 7 | CCA1 | Group A CC1 (For Type-C 1) |
| 8 | CCA2 | Group A CC2 (For Type-C 1) |
| 9 | DM2 | VOUT2 DM |
| 10 | DP2 | VOUT2 DP |
| 11 | DP1 | VOUT1 DP |
| 12 | DM1 | VOUT1 DM |
| 13 | GND | Ground |
| 14/15/26/27 | VIN | Power input |
| 16 | HLED | Fast charge state indicator LED drive |
| 18/25 | PGND | Power ground |
| 19/20/21/22/23 | LX | DCDC switch point, connect to inductor |
| 24 | BST | Connect to bootstrap capacitor |
| 29 | VOS1 | VOUT1 output current negative sense pin |
| 30 | VOS2 | VOUT2 output current negative sense pin |
| 31 | VOUT | VOUT1/VOUT2 output current positive sense pin |

| | | |
|----|-------|---------------------------------|
| 32 | VOUT1 | VOUT1 output plug in detect pin |
| 33 | EPAD | Ground |

6 Absolute Maximum Ratings

| Parameters | Symbol | Value | Unit |
|----------------------------|-----------------|---------------------|------|
| Input Voltage Range | V_{IN} | -0.3 ~ 40 | V |
| LX Voltage Range | V_{LX} | -0.3 ~ $V_{IN}+0.3$ | V |
| DM/DP/CC Voltage Range | $V_{DM/DP/CCA}$ | -0.3 ~ 30 | V |
| Junction Temperature Range | T_J | -40 ~ 150 | °C |
| Storage Temperature Range | T_{stg} | -60 ~ 150 | °C |
| Package Thermal Resistance | θ_{JA} | 40 | °C/W |
| Human Body Model (HBM) | ESD | 4 | KV |

*Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.

Exposure to Absolute Maximum Rated conditions for extended periods may affect device reliability.

*Voltages are referenced to GND unless otherwise noted.

7 Recommended Operating Conditions

| Parameters | Symbol | Min. | Typ. | Max | Unit |
|---------------|----------|------|-------|-----|------|
| Input Voltage | V_{IN} | 8.2 | 12/24 | 32 | V |

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

8 Electrical Characteristics

Unless otherwise specified, $T_A = 25^\circ\text{C}$, $L=22\mu\text{H}$, $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=5\text{V}$

| Parameters | Symbol | Test Condition | Min. | Typ. | Max | Unit |
|---|-------------------------|---|------|------|------|------------|
| Input system | | | | | | |
| Input voltage | V_{IN} | | 8.2 | 12 | 32 | V |
| Input under voltage | $V_{\text{IN-UV}}$ | Rising voltage | 8.1 | 8.2 | 8.3 | V |
| | | Falling voltage | 7.8 | 7.9 | 8 | V |
| Input over voltage | $V_{\text{IN-OV}}$ | Rising voltage | 32.7 | 32.8 | 33 | V |
| | | Falling voltage | 32.3 | 32.5 | 32.6 | V |
| Input quiescent current | I_{Q} | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=5\text{V}/0\text{A}$ | -- | 3 | -- | mA |
| Power system | | | | | | |
| High-side MOS Ron resistance | $R_{\text{DS(ON)}}$ | | -- | 9 | -- | m Ω |
| Low-side MOS Ron resistance | $R_{\text{DS(ON)}}$ | | -- | 8 | -- | m Ω |
| Switching frequency | F_{S} | | -- | 150 | -- | KHz |
| Maximum duty cycle | D_{MAX} | $V_{\text{IN}}=12\text{V}$ | -- | 97 | -- | % |
| Output system | | | | | | |
| Output voltage | V_{OUT} | | 3 | 5 | 20 | V |
| Output voltage ripple | ΔV_{OUT} | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=5\text{V}/3\text{A}$ $C_{\text{OUT}}: 220\mu\text{F}+22\mu\text{F}$ | 80 | 85 | 90 | mV |
| | | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=9\text{V}/3\text{A}$ $C_{\text{OUT}}: 220\mu\text{F}+22\mu\text{F}$ | 65 | 70 | 80 | mV |
| | | $V_{\text{IN}}=24\text{V}$, $V_{\text{OUT}}=12\text{V}/2.25\text{A}$ $C_{\text{OUT}}: 220\mu\text{F}+22\mu\text{F}$ | 115 | 125 | 150 | mV |
| Soft start time | T_{SS} | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=5\text{V}$ | -- | 4 | -- | ms |
| Output line compensate voltage | V_{COMP} | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}=5\text{V}$, $I_{\text{OUT}}=1\text{A}$ | -- | 50 | -- | mV |
| Single port max output current in CC mode | I_{OUT} | $V_{\text{IN}}=12\text{V}$, $V_{\text{OUT}}\leq 4\text{V}$ | -- | 3.6 | -- | A |
| | | $V_{\text{IN}}=12\text{V}$, $4\text{V}<V_{\text{OUT}}\leq 5\text{V}$ | -- | 3.6 | -- | A |
| | | $V_{\text{IN}}=12\text{V}$, $7\text{V}<V_{\text{OUT}}\leq 9\text{V}$ | -- | 3 | -- | A |
| | | $V_{\text{IN}}=24\text{V}$, $9\text{V}<V_{\text{OUT}}\leq 12\text{V}$ | -- | 2.25 | -- | A |
| Output hiccup restart voltage | V_{OUT} | Hiccup restart voltage when output enter CC mode (V_{OUT} preset voltage \geq | -- | 3.2 | -- | V |

| | | | | | | |
|---|---------------------------|---|----|-----|----|----|
| | | 5V) | | | | |
| | | Hiccup restart voltage when output enter CC mode (VOUT preset voltage < 5V) | -- | 2.7 | -- | V |
| No-load output voltage | V _{out1} | VIN=12V, IP6538_AC no device connected | -- | 5 | -- | V |
| | V _{out2} | | -- | 0 | -- | V |
| DPDM over voltage protection voltage | V _{OVP_DPD} M | VIN=12V, VOUT=5V | -- | 4.8 | -- | V |
| CC over voltage protection voltage | V _{OVP_CC} | VIN=12V, VOUT=5V | -- | 6.5 | -- | V |
| Thermal shutdown temperature | T _{OTP} | Rising temperature | -- | 150 | -- | °C |
| Thermal shutdown temperature hysteresis | ΔT _{OTP} | | -- | 35 | -- | °C |

9 Function Description

Synchronous-Rectified Buck Converter

IP6538 integrate a Synchronous-Rectified Buck Converter, input voltage range is 8.2V~32V, output voltage range is 3V~20V, maximum dual port output current is 4.8A.

IP6538 integrate power switch MOSFET with 150kHz working frequency.

The conversion efficiency is 96.5% at $V_{IN}=24V$, $V_{OUT}=5V/3A$. The conversion efficiency is 95.3% at $V_{IN}=12V$, $V_{OUT}=5V/4.8A$. The conversion efficiency is 94.1% at $V_{IN}=24V$, $V_{OUT}=5V/4.8A$.

IP6538 auto adjust output voltage and current according to the fast charge requirement.

IP6538 has soft start function, preventing the huge inrush current cause damage to the IC.

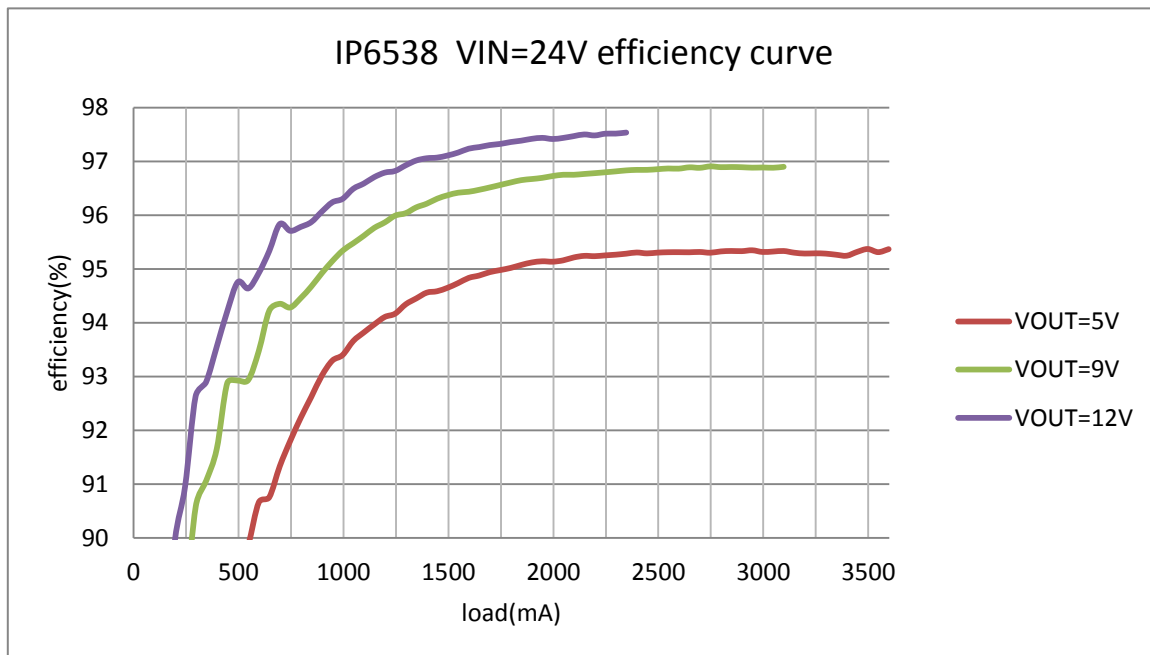


Figure 3. IP6538 output efficiency curve when $V_{IN} = 24V$

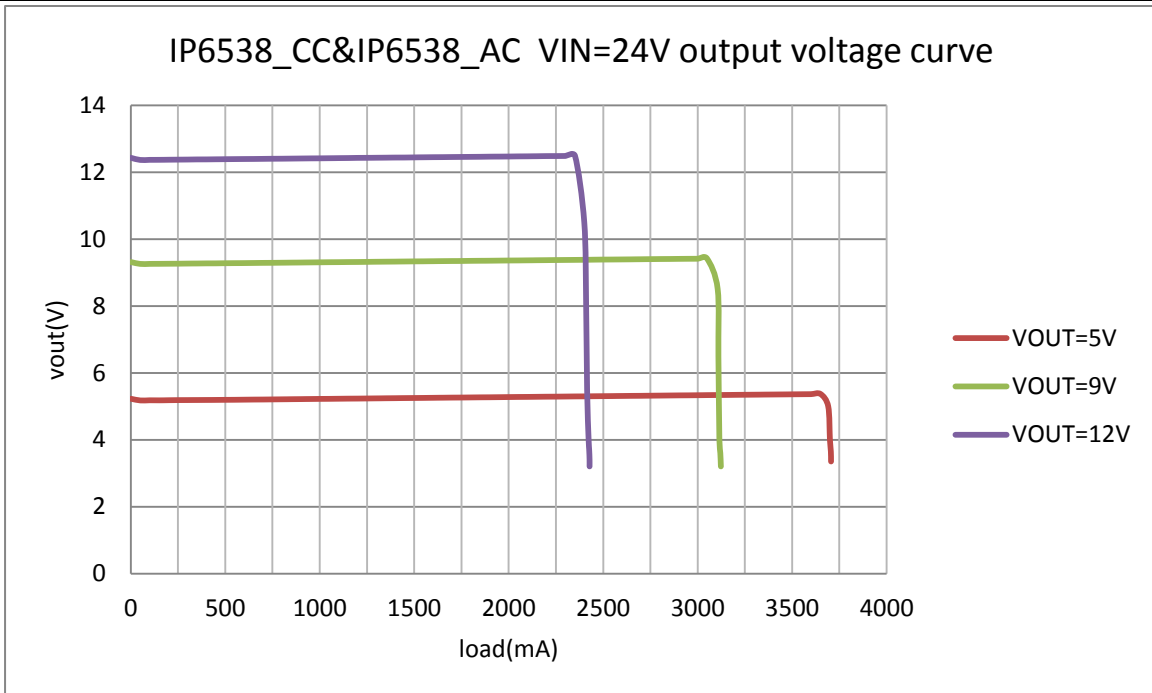


Figure 4. IP6538_CC and IP6538_AC Vout-lout curve when VIN=24V

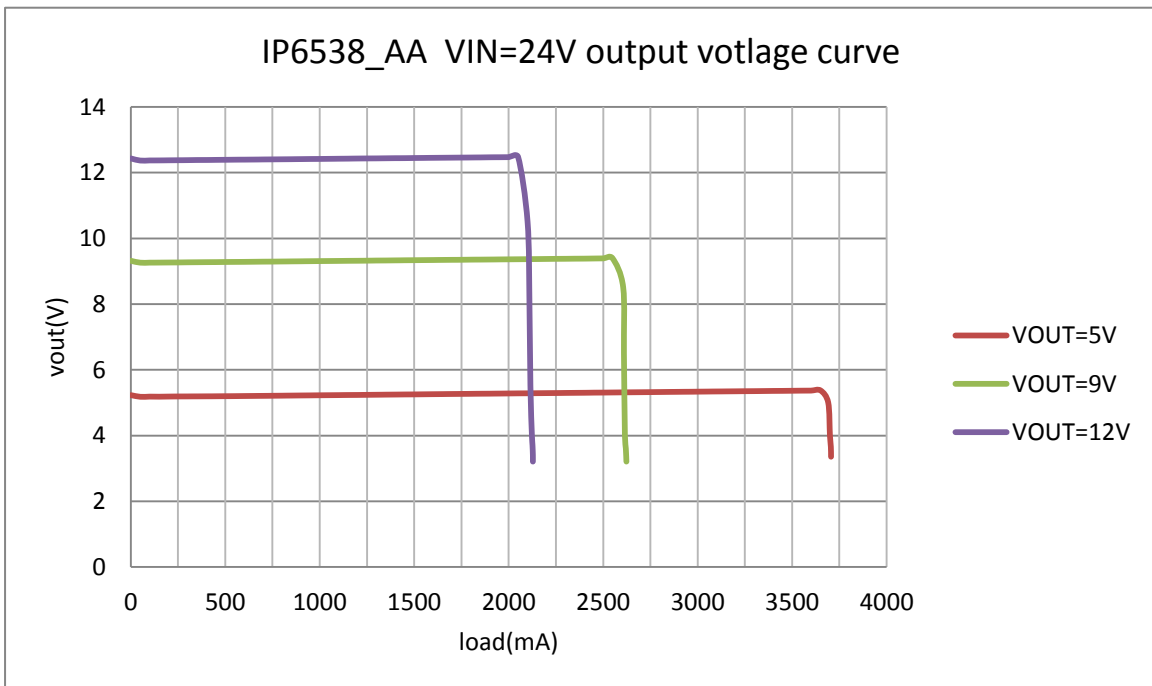


Figure 5. IP6538_AA Vout-lout curve when VIN=24V

Output Voltage Line Compensation Function

IP6538 output support line compensation function: the output voltage will increase 50mV as output current increase 1A.

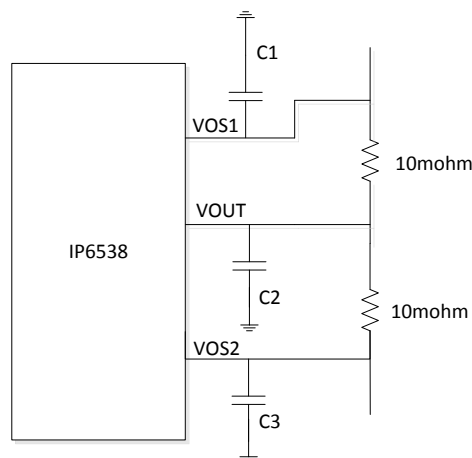
Output CC/CV Character

IP6538 output has CV/CC mode: when the output current is lower than preset value, the output is in CV mode with constant voltage; when the output current is higher than preset value, the output is in CC mode with decreasing output voltage.

When VOUT preset voltage is higher or equal to 5V, if the output voltage is lower than 3.2V, the output will be shut down and hiccup restart after 2sec; When VOUT preset voltage is lower than 5V, if the output voltage is lower than 2.7V, the output will be shut down and hiccup restart after 2sec.

Output CC Current Set

IP6538 VOUT1 output current limit can be adjusted by regulate the 10mOhm sensing resistor between VOUT and VOS1. VOUT2 output current limit can be adjusted by regulate the 10mOhm sensing resistor between VOUT and VOS2. The load current is measured by detect the voltage drop between VOUT and VOS.



For IP6538_CC and IP6538_AC, different voltage is mapped to different current limit value shown below:

| | | | |
|------------------------|------|------|--------|
| Vout (V) voltage | 5V | 9V | 12V |
| Iout1(A) current limit | 3.6A | 3A | 2.25A |
| VOUT-VOS1 | 36mV | 30mV | 22.5mV |

When the value of 10mOhm current detect resistor is changed, the current limit of VOUT1 and VOUT2 will change accordingly.

In PCB layout, pay attention to the trace routing of VOS1/VOS2 and VOUT, the trace should go out directly from the two side of 10mOhm resistor, avoiding introduce current limit deviation because of additional PCB trace resistor. Other than that, the 10mOhm resistor should use alloy resistor with good temperature coefficient (100ppm) and high precision of 1%.

Protection Function

IP6538 will detect the VIN voltage, if VIN voltage is lower than 7.9V, IP6538 will enter standby mode and shut down the output.

IP6538 support input over voltage protection: when the VIN voltage is higher than 32.8, IP6538 determines the VIN is over voltage and shutdown the output; when VIN decrease under 32.5V, IP6538 determines the input voltage recovers and opens the output.

IP6538 support output under voltage protection: when VOUT voltage is lower or equals 5V, if the VOUT voltage is lower than 3.2V, IP6538 determines the output is under voltage and will shut down the output and hiccup restart after 2sec.

IP6538 support short circuit protect, 4ms after the circuit is started, if VOUT voltage is under 3.2V, IP6538 determines the output is short circuit and will shut down the output and hiccup restart after 2sec.

IP6538 support DP/DM/CC over voltage protection, when the DP1/DM1/DP2/DM2 voltage is higher than 4.8V, or when the CCA1/CCA2/CCB1/CCB2 voltage is higher than 6.5V, IP6538 determines the signals are over voltage and will shut down the output and hiccup restart after 2sec.

IP6538 support over temperature protection: when the temperature detected is higher than 150°C, the output will be shut down. When the temperature decreases below 115°C, IP6538 determines the temperature has recovered and will restart the output.

When the junction temperature is high, the output voltage and current will be adjusted automatically by IP6538 to keep the constant temperature of the junction temperature.

Dual Fast Charge Output Ports

IP6538 support two USB output ports: dual USB Type-C ports or dual USB A ports or USB A port plus USB Type-C port. Any port support fast charge output when working along, when the two ports are working at the same time, both ports output 5V.

IP6538_AC and IP6538_CC single port output power 5V/3.6A, 9V/3A, and 12V/2.25A.

IP6538_AA single port output power 5V/3.6A, 9V/2.5A, and 12V/2A.

Dual ports both in working, IP6538 output 5V/3.6A for single port and 5V/4.8A for two ports together, current limit is based on single port.

IP6538 integrate dual port auto plug detection function, any ports plug in or plug out can be detected and the USB ports will be open or shut down based on the detect result.

Output Fast Charge Protocol

IP6538 support fast charge protocol:

- ✧ Support BC1.2, Apple, Samsung
- ✧ Support Qualcomm QC2.0, QC3.0
- ✧ Support MTK PE+1.1 and MTK PE+2.0
- ✧ Support Huawei Fast charge: FCP and SCP
- ✧ Support Samsung fast charge : AFC
- ✧ Support OPPO fast charge : VOOC

Type-C Port and USB PD Protocol

IP6538_CC support dual ports Type-C output and USB PD2.0/PD3.0 (PPS) protocol, USB PD protocol output 27W; Package broadcast: 5V/3A, 9V/3A, 12V/2.25A and PPS 3.3V-5.9V/3A, 3.3V-11V/3A.

IP6538_AC support single port Type-C output and USB PD2.0/PD3.0 (PPS) , USB PD protocol output 27W; Package broadcast: 5V/3A, 9V/3A, 12V/2.25A and PPS 3.3V-5.9V/3A, 3.3V-11V/3A.

IP6538_AA do not support Type-C output or PD2.0/PD3.0 (PPS) protocol.

IP6538 Type-C port detects the fast charge requirement automatically through DP/DM and CC1/CC2 pins and adjusts the output voltage and current accordingly.

10 Typical Application Schematic Diagram

IP6538 car charging solution only needs MOSFET, inductor, capacitor and resistor.

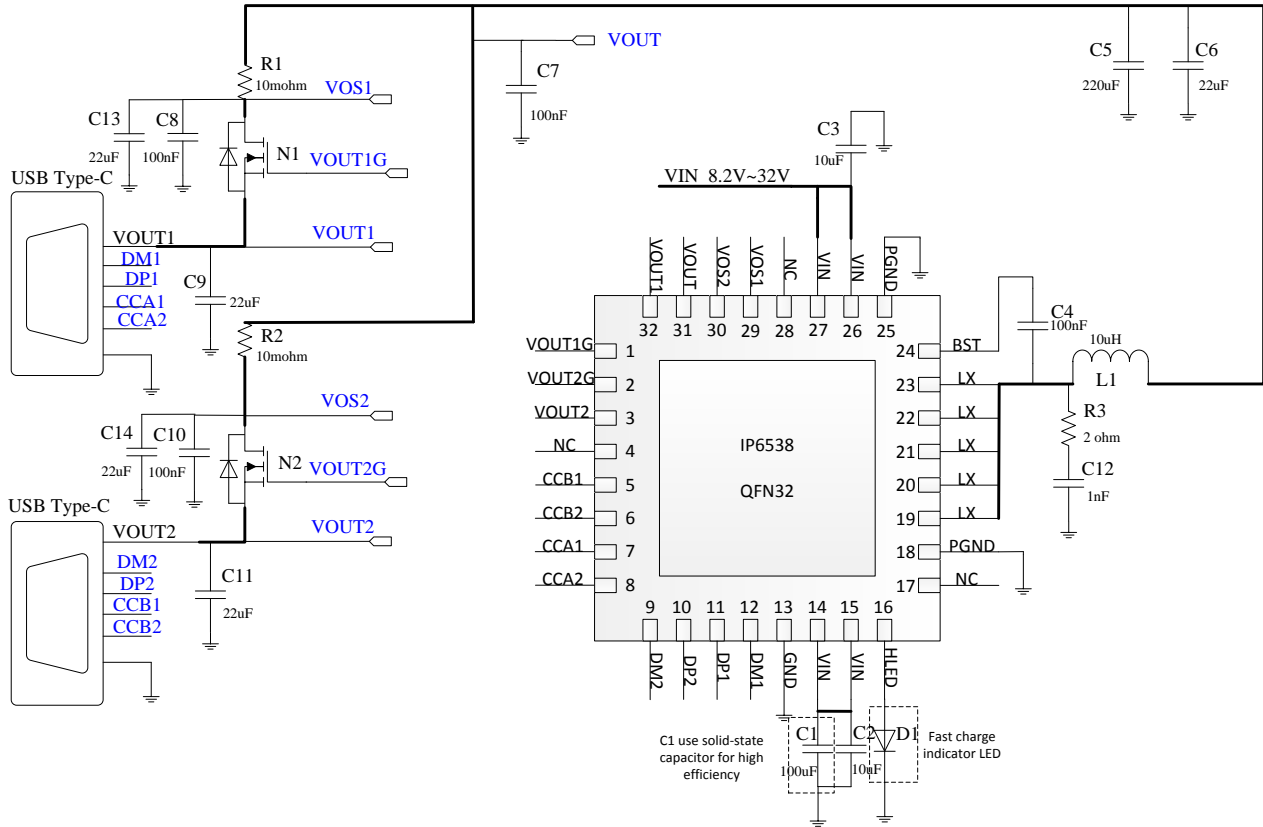


Figure 6. IP6538_CC dual USB Type-C output ports fast charge application schematic diagram

NOTES:

1. PIN7/8/11/12 must be connected to USB Type-C 1;
2. PIN5/6/9/10 must be connected to USB Type-C 1;
3. USB Type-C 1 VBUS must be connected to PIN 32;
4. USB Type-C 2 VBUS must be connected to PIN 3;
5. C2 and C3 should be placed close to the PIN;
6. C7, C8, and C10 should be placed close to the PIN;

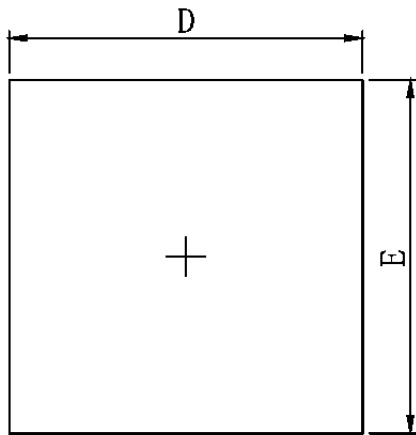
11 BOM List

| No. | Part Name | Type | Unit | Qty | Location | Notes |
|-----|------------------------|--|------|-----|-------------------|---|
| 1 | IC | IP6538 | PCS | 1 | | |
| 2 | TC-220M-4.5A-CS137125 | 10uH+/-20%, current 5A DCR<12mohm | PCS | 1 | L1 | 3L Electronic |
| 3 | SMD capacitor | 0603 0.1uF 10% | PCS | 3 | C7, C8, C10 | Withstand voltage higher than 25V |
| 4 | SMD capacitor | 0603 0.1uF 10% | PCS | 1 | C4 | Withstand voltage higher than 10V |
| 5 | SMD capacitor | 0805 22uF 10% | PCS | 5 | C6,C9,C11,C13,C14 | Withstand voltage higher than 25V |
| 6 | SMD LED | 0603 | PCS | 1 | D1 | |
| 7 | Electrolytic capacitor | 100uF/35V | PCS | 1 | C1 | Withstand voltage higher than 35V Use solid-state capacitor will increase efficiency |
| 8 | Electrolytic capacitor | 220uF/25V | PCS | 1 | C5 | Withstand voltage higher than 25V |
| 9 | SMD capacitor | 0603 10uF 10% | PCS | 3 | C2, C3 | Withstand voltage higher than 35V |
| 10 | SMD resistor | 0603 2R 5% | PCS | 1 | R3 | |
| 11 | SMD capacitor | 0603 1nF, 50V 10% | PCS | 1 | C12 | |
| 12 | SMD resistor | 1206 10mohm 1% precision, temperature coefficient less than 100ppm | PCS | 2 | R1, R2 | Current sense resistor |
| 13 | NMOS | Rds(on)<20m ohm I>=5A | PCS | 2 | N1, N2 | |

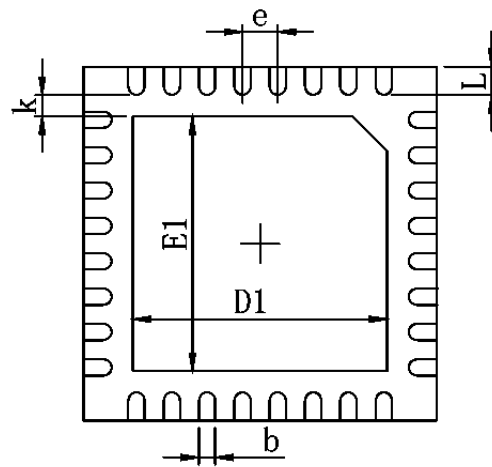
12 IP series IC Products List

| IC Part | Charge/ Discharge | Dual ports | Protocols | | | | | | | | | | Package | |
|-------------|----------------------|---------------|-----------|-----------|-----------|-----|-----|-----|-----------|------|-----------|----------------|---------|---------|
| | | | DCP | QC 2.0 | QC 3.0 | FCP | SCP | AFC | MTK PE | SFCP | PD 2.0 | PD3.0 (PPS) | Pkg | P2P |
| IP6502 | 2.4A | - | √ | - | - | - | - | - | - | - | - | - | SOP8 | PIN2PIN |
| IP6503 | 3.1A | - | √ | - | - | - | - | - | - | - | - | - | ESOP8 | |
| IP6503_2A4 | 2.4A | - | √ | - | - | - | - | - | - | - | - | - | ESOP8 | |
| IP6503S | 3.1A | - | √ | - | - | - | - | - | - | - | - | - | ESOP8 | PIN2PIN |
| IP6503S_2A4 | 2.4A | - | √ | - | - | - | - | - | - | - | - | - | ESOP8 | |
| IP6523S_N | 3.4A | - | √ | - | - | - | - | - | - | - | - | - | ESOP8 | |
| IP6505 | 24W | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | - | ESOP8 | |
| IP6505T | 24W | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | - | ESOP8 | PIN2PIN |
| IP6525T_N | 18W | - | √ | √ | √ | √ | - | √ | - | - | - | - | ESOP8 | |
| IP6510 | 18W | - | √ | √ | √ | √ | - | √ | - | - | √ | - | ESOP8 | |
| IP6518C | 36W | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | - | QFN24 | PIN2PIN |
| IP6518 | 45W | - | √ | √ | √ | √ | √ | √ | √ | √ | √ | - | QFN24 | |
| IP6515 | 4.8A | √ | √ | - | - | - | - | - | - | - | - | - | QFN32 | |
| IP6538_CC | 27W | √ | √ | √ | √ | √ | - | √ | √ | - | √ | √ | QFN32 | PIN2PIN |
| IP6538_AC | 27W | √ | √ | √ | √ | √ | - | √ | √ | - | √ | √ | QFN32 | |
| IP6538_AA | 24W | √ | √ | √ | √ | √ | - | √ | √ | - | - | - | QFN32 | |
| IP6527_A | 24W | - | √ | √ | √ | √ | √ | √ | √ | - | - | - | QFN32 | PIN2PIN |
| IP6527_C | 27W | - | √ | √ | √ | √ | - | √ | √ | - | √ | - | QFN32 | |

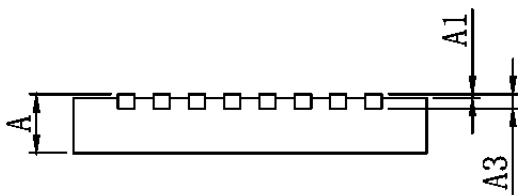
13 Package



TOP VIEW



BOTTOM VIEW



SIDE VIEW

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|--------|---------------------------|-------|----------------------|-------|
| | Min. | Max. | Min. | Max. |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A3 | 0.203REF. | | 0.008REF. | |
| D | 4.924 | 5.076 | 0.194 | 0.200 |
| E | 4.924 | 5.076 | 0.194 | 0.200 |
| D1 | 3.300 | 3.500 | 0.130 | 0.138 |
| E1 | 3.300 | 3.500 | 0.130 | 0.138 |
| k | 0.200MIN. | | 0.008MIN. | |
| b | 0.200 | 0.300 | 0.008 | 0.012 |
| e | 0.500TYP. | | 0.020TYP. | |
| L | 0.324 | 0.476 | 0.013 | 0.019 |

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