

Flash Forward

2020 OPPO Flash Charging Global

Launch

Technology Introduction

Overview

OPPO has been leading the development of flash charging technology. As early as 2014, OPPO made a breakthrough launch with its VOOC flash charging technology which adopted a low-voltage high-current direct charging solution that was first applied to the device Find 7. Four years later, VOOC flash charging was upgraded to 50W SuperVOOC, first applied to the OPPO Find X Super Flash Edition and the OPPO Find X Automobili Lamborghini Edition. The technology enables both phones to be fully charged in 35 minutes. In October 2019, OPPO Reno Ace adopted the latest 65W SuperVOOC2.0 flash charging technology. This marked the first time in which a commercial smartphone with a 4000mAh battery could be fully charged in 30 minutes. In April 2020, OPPO Reno Ace2 was the first device to carry the 40W AirVOOC wireless flash charging technology, which can fully charge a 4000mAh battery in 56 minutes, allowing wireless charging to provide similar speed as wired charging. By end of March 2020, there were over 157 million VOOC flash charge users worldwide.

In July 2020, as we are entering the era of intelligent connectivity, OPPO continues to improve and upgrade the VOOC flash charge technology, and work on the development of high-power, wireless and miniaturized flash charge technologies in order to provide users with a safe, efficient and convenient flash charging experience.

- **125W flash charge:** Using only 5 minutes, the 125W flash charge is able to charge a 4,000mAh battery up to 41%, and it is able to fully charge it in just 20 minutes at the fastest rate. Simultaneously, stricter temperature control helps to make the flash charge process even safer.

- **65W AirVOOC wireless flash charge:** With the 65W AirVOOC wireless flash charge, users are able to charge a 4000mAh battery in 30 minutes to 100% at the fastest rate. This is faster than most wired fast charging technologies in the market and solves the issue of low efficiency in wireless charging, thereby making this technology popular. Its conceptual wireless charger has adopted a convenient vertical design; a fan and an e-sports level semiconductor refrigerator operate together to dissipate heat more efficiently. Through innovative critical-state self-forming technology and moldless rapid prototyping, the charger features the first technological application of its type in a consumer electronics product.
- **50W mini SuperVOOC charger:** The OPPO 50W mini SuperVOOC charger became the first charger to integrate an ultra-thin shape similar to a business card case size. The technology behind the OPPO 50W mini SuperVOOC charger has successfully reduced the components size which take up the most space in the device. OPPO achieves this by using a new topology design in order to achieve a highly efficient power conversion which removes the conventional electrolytic capacitor and introduces pulse charging – the first in the industry, aviation-grade high power clamping diodes as well as high frequency switching power supply technology.
- **110W mini flash charger:** The OPPO 110W mini flash charger is designed without an electrolytic capacitor and uses high frequency switching power supply technology. It contains a high efficiency power conversion and temperature control system as a result of a pioneering dual-level architecture. A stacking structure makes the charger smaller, with a volume similar to a conventional 18W adapter.

Contents

Chapter 1: 125W flash charge, a game-changing flash charge technology for mobile phones.....	5
1. OPPO' s 125W flash charge sets a new mobile phone charging speed record in the 5G era	5
2. The architecture is fully upgraded	5
3. 10 newly added temperature sensors and 128-bit high-strength encryption algorithm make the charger safer.....	11
4. Compatible with charging protocols for next-generation mobile phones and laptops	13
Chapter 2: 65W AirVOOC wireless flash charge: Charging for the future	14
1. Continuously upgrading wireless flash charge to stay ahead of the curve	14
2. The most cutting-edge wireless charge technology for mobile phones	16
3. Dual-coil design taking the lead and multiple schemes being applied at the same time	19
Chapter 3: 50W mini SuperVOOC charger and 110W mini flash charger, the latest breakthrough in OPPO flash charge technology	29
1. Small and convenient device to enable flash charge anytime, anywhere.....	29
2. New design and pulse charging make the world's smallest and thinnest 50W charger.....	30
3. 110W mini flash charger, the ultimate exploration in high-power, miniaturization	38
Chapter 4: OPPO VOOC flash charge is starting its sixth year, high-power, wireless and miniaturized chargers, opening a new era of flash charge across the market	44
1. VOOC flash charge enlightens the industry and benefits 157 million users.....	44
2. Continuously expand the VOOC flash charge ecosystem and benefit more users.....	47

Chapter 1: 125W flash charge, a game-changing flash charge technology for mobile phones

1. OPPO' s 125W flash charge sets a new mobile phone charging speed record in the 5G era

5G' s advanced connectivity heralds the dawn of a new connected era where devices are always in ubiquitous application scenarios, bringing along with it higher energy consumption requirements. This poses new challenges for battery life and charging technology, making more efficient and safer charging technology an urgently needed solution in the 5G era.

On July 15, 2020, OPPO released its cutting-edge 125W flash charge technology, which sets a new charging speed record for mobile phones. In only 5 minutes, the 125W flash charge can charge a mobile phone' s 4,000mAh battery up to 41%, and to 100% in just 20 minutes at the fastest rate. Leading the industry-wide charging technology revolution, the 125W flash charge fully conforms to OPPO's stringent security and safety standards, delivering an enhanced charging experience.

2. The architecture is fully upgraded

- **Evolved from OPPO' s industry-leading SuperVOOC architecture, the 125W flash charge delivers greatly upgraded overall design**
 - ✓ The 125W flash charge deploys a series bi-cell design that ensures optimum charging efficiency. The design allows charge pumps to be used to halve the voltage of the double cells during discharging. It is

also compatible with mobile phone chipsets to make the most of charge pump technology.

- ✓ Loop management of charging protocols: OPPO' s custom chips manage the charging process. These include the: VCU intelligent control chip, AC/DC control chip, MCU charge management chipset, BMS battery management chip, and custom protocol handshake chipset. The charger, charging cable, and handset form a complete loop of charging protocols.
- ✓ The customized MCU chip integrates the previous peripheral monomer components. Compared with 65W SuperVOOC2.0, the integration is greatly improved, which helps to save internal space. The chip will be widely utilized in flash charging in the future.

OPPO 125W
flash charge



- **Upgraded charger, charging cable and handset take the flash charge to a whole new level:**

The charger of 125W flash charge is designed with mature and proven 20V/6.25A technology and Type-C interface. It boasts three parallel charge pumps that output energy directly to the battery for effective heat dispersal and optimal charging efficiency. The power supplied to handsets is converted through a charge pump to 10V/12.5A, which conforms to existing device specifications and has been tested in terms of heat dissipation, guaranteeing optimal efficiency and enhanced safety. Furthermore, the battery's discharge rating of 6C is double that of the preceding technology's 3C rating, allowing the hardware to support maximum 125W.

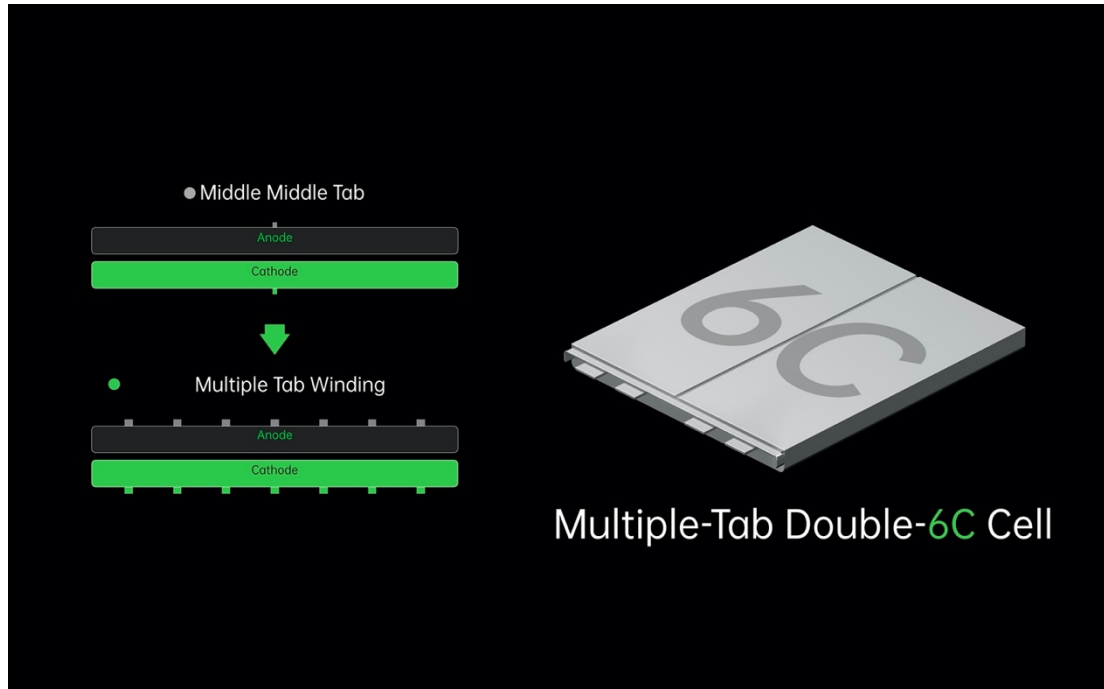
✓ **Charger:**

- Supports 20V, 6.25A and 125W (peak value), with significantly improved power density. In OPPO's laboratory, in the working mode of constant voltage and constant current output, the maximum output voltage can reach 21V and the peak current can reach 5.95A.
- The compact size delivers portability with the size being only slightly larger than that of the 65W SuperVOOC 2.0. Its length, height and width are 64mm, 61.5mm and 30mm respectively; the volume is about 118cm³ and the weight is 153.8g.
- Its Type-C interface is compatible with PD and PPS protocols, giving users the option to charge mobile phones, laptops or other devices in the future.

✓ **Handset:**

- The 125W flash charge features four charge pumps, including one in the discharging circuit, which halves the voltage of the double cells during discharging, thereby reducing power consumption and improving performance. Each of the other three, contained in the charging circuit, carries 42W of energy, which improves efficiency by sharing the load current of each charge pump and dissipates heat, resulting in an extremely safe solution. The three charge pumps convert the 20V 6.25A delivered by the charger into 10V 12.5A and then charge the battery. Conversion efficiency is up to 98%, which results in super-fast charging speed.
 - Double BTB interfaces: While in previous solutions both BTBs have had positive and negative poles, 125W flash charge's approach is unique: one BTB has a positive pole and the other a negative pole. This format cuts thermal loss and boosts charging efficiency as the charging and discharging circuits are separated, thereby shortening the charging path and reducing internal resistance.
 - Overvoltage fuse protection results in incredibly reliable functionality.
- ✓ Battery:
- Because of its bi-cell design, the battery discharge rating is 6C, double the preceding technology's 3C rating.
 - Battery's life expectancy is maintained at 80% after 800 charging-discharging cycles. Compliant with rigorous measurement standards, the battery is designed with secure charging and discharging in mind to protect its life.
 - Upgraded battery structure: The battery's novel parallel multiple-

tab structure is an important innovation on single-tab batteries, reducing internal resistance and effectively lowering heat production during charging.



Schematic diagram of the multiple tab structure

✓ Charging cable:

- 125W flash charge' s Type-C to Type-C charging cable provides users with a wider range of flash charge protocols than the 65W SuperVOOC' s Type-A to Type-C format, including those for mobile phones, tablets and laptops.
- The encrypted E-mark cable can transmit a 5A current, and up to 6.5A if OPPO's encrypted information is recognized.
- The low-impedance and highly reliable Type-C interface delivers safe and fast charging from charger to charging cable to handset.

✓ Algorithm:

- Optimized VFC trickle-charge algorithm: Charging efficiency

between 90% to 100% is improved, enabling trickle-charge speed to go up by 200%.

- VCVT intelligent tuning algorithm: Previous solutions relied on mobile phones' software and hardware to manage charging. However, this approach doesn't meet OPPO's high standards as it results in too many crashes or stalls. The answer is OPPO's new algorithm, which enables smart current adjustment at 100mA and 10mV, thereby improving charging efficiency and mitigating heat transfer. OPPO deploys a dedicated customized intelligent chip (IC) in mobile phones to manage two-way communication between the handset and charger.



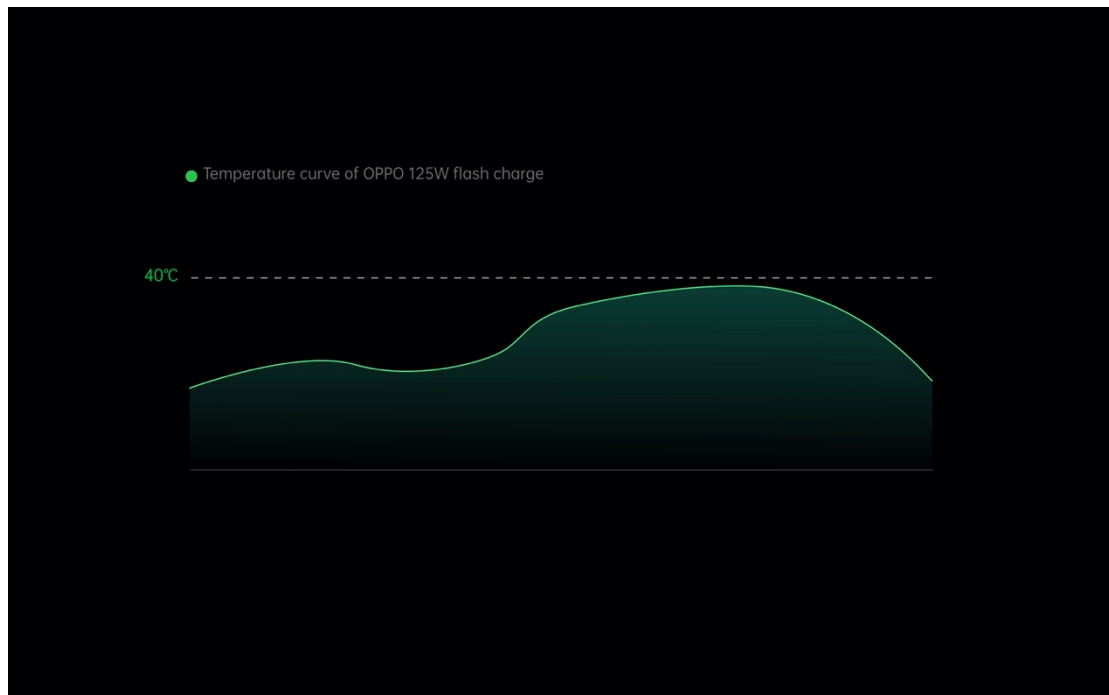
3. 10 newly added temperature sensors and 128-bit high-strength encryption algorithm make the charger safer

The 125W flash charge delivers a safe and seamless charging experience while also pushing the boundaries of charging speed. By taking a holistic approach to the safety of the chargers, wires and the handsets, OPPO minimizes potential safety hazards and risks, providing an efficient and secure charging experience.

- **Greater safety:**

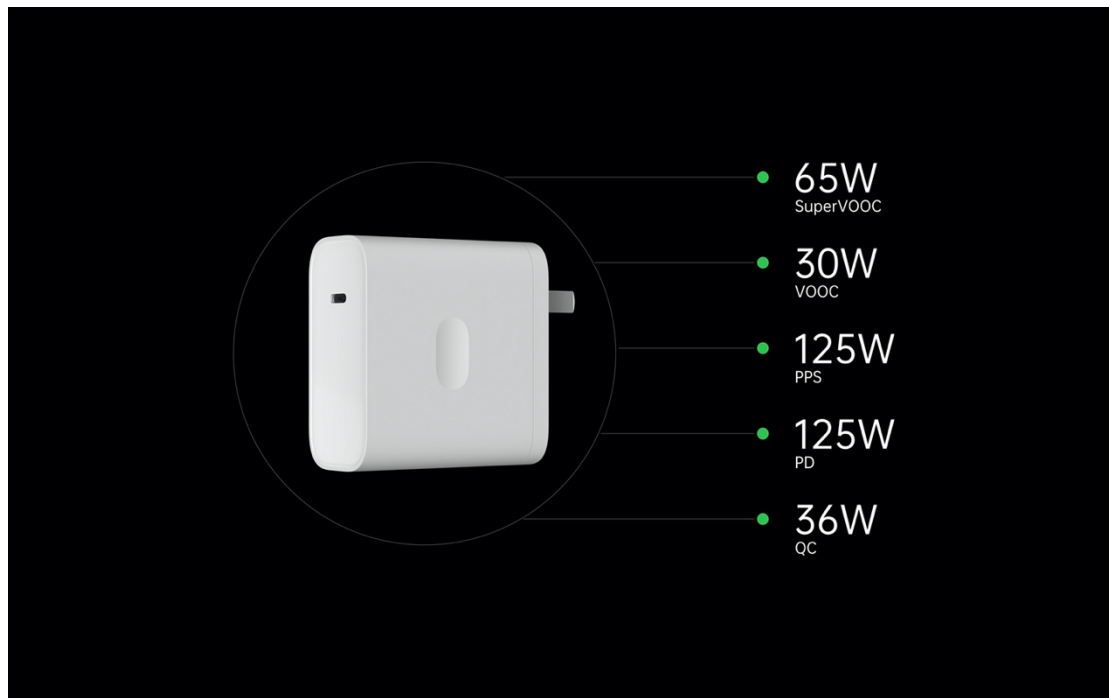
- ✓ The 125W flash charge adopts five-fold safety protection measures in the charger, wires and handset, as well as a specially customized intelligent control chip that controls voltage, current and temperature to deliver a safe charging experience.
- ✓ OPPO customized a battery safety monitoring chip to monitor in real-time whether the battery in the mobile phone is damaged by external forces when in use.
- ✓ Temperature protection has been enhanced via the 10 newly-added temperature sensors, which are in addition to the existing four sensors (three on the phone and one on the charger). These sensors are installed in the battery tabs, BTB, and power supply motherboard junctions to monitor charging status in real-time. This offers an enhanced temperature monitoring that ensures the maximum temperature of the mobile phone body never exceeds 40°C during the charging process with 125W high power and the screen turned off (under constant 25°C environment). OPPO's smart charging strategy can swiftly adjust the charging power in real-time even if the user is

playing video games, reducing heat and avoiding abnormalities.



*Thermal imaging diagram of the 125W flash charge at its highest temperature
when charged in room temperature of approximately 25 °C*

- ✓ A more complex and secure 128-bit encryption owned by OPPO has been added while also following TBS protocols of the USB IF public version to prevent security risks caused by hackers attempting to tamper with firmware.



4. Compatible with charging protocols for next-generation mobile phones and laptops

As a leader in flash charge technology, OPPO attaches great importance to the building of a robust ecosystem that supports flash charge protocols widely used in the industry to deliver the benefits of its flash charge solutions to more users.

OPPO' s 125W flash charge is not only compatible with OPPO' s VOOC protocols, but also supports other flash charge protocols in the industry such as PPS, PD and QC, meaning that it can also quickly charge mobile phones, tablets, laptops and other devices. This allows users to charge battery rapidly when it is running low, relieving them of the "low battery anxiety" that they often suffer.

Charger of the 125W flash charge supports the below flash charge protocols / devices power:

Protocols/Device model	Maximum power
SuperVOOC	65W
VOOC	30W
PPS	125W
PD	65W (constant output)
QC	36W
Huawei P40 Pro	18W
Xiaomi 10 Pro	30W
vivo X50 Pro	18W
iPhone 11 Pro	22.5W
iPad Pro	45W
MacBook Pro	65W

Chapter 2: 65W AirVOOC wireless flash charge: Charging for the future

1. Continuously upgrading wireless flash charge to stay ahead of the curve

In 2019, OPPO took the lead in rolling out 30W wireless flash charge technology, and later putting an upgraded 40W AirVOOC into mass production for the OPPO Ace2. In doing so, OPPO solved the problem of low efficiency in wireless charging, thereby making the technology widely available and more popular. Building on its strengths in the flash charge field, OPPO released 65W AirVOOC wireless flash charge on July 15, 2020 while also showcasing its conceptual wireless charger. With

the new technology, users can charge a 4000mAh battery to 100% in 30 minutes at the fastest rate, which is faster than most wired flash charge technologies in the market.



The 65W AirVOOC conceptual wireless charger has adopted groundbreaking vertical design that blends aesthetics and practicality. The front uses an integrally formed hot bending glass, with its length, width and height being 13.7cm, 8.27cm, and 11.69cm respectively. Through critical state self-forming technology, it realizes moldless rapid prototyping, which features the first application of this technology in a consumer electronics product. OPPO uses the beautifully-sculpted glass to cover the complex wireless flash charge components, thus disguising the cutting-edge technology in a simple and aesthetically-pleasing way.

- **Simpler and more accurate alignment:** High-power wireless charging requires strict alignment, requiring the mobile phone to be aligned with centers of the X-axis and Y-axis of the wireless charger within an error range

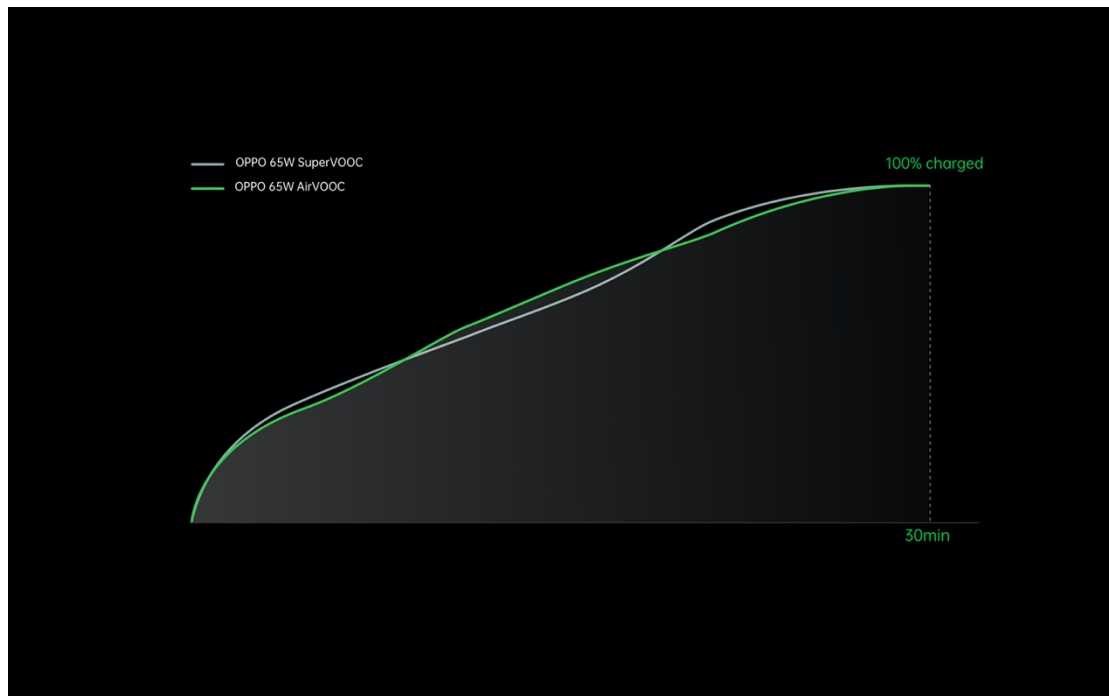
of 2mm. The vertical design makes mobile phone charging easier to align, thus realizing the capacity for high-power charging.

- **Better heat dissipation:** The round design increases the area of the glass panel to aid heat dissipation. At the same time, a fan and an e-sports level semiconductor refrigerator work in conjunction to dissipate heat more efficiently.
- **More practical:** The vertical design allows users to operate the mobile phone while charging. Users can enjoy content and check notifications without interrupting the charging process, which is more convenient and practical.

2. The most cutting-edge wireless charge technology for mobile phones

65W AirVOOC wireless flash charge, the result of OPPO' s further exploration of high-power wireless flash charge based on the 40W AirVOOC, is the latest upgrade to wireless flash charge, providing increased efficiency and flexibility.

- **On par with the SuperVOOC 2.0 in terms of speed and allowing streaming while charging:** With its dual parallel power channels (output at 20V 2A and 20V 1.25A respectively), the 65W AirVOOC wireless flash charge can flash-charge mobile phones, placed either horizontally or vertically, even when other tasks, such as browsing or video streaming, are being conducted. When a phone is placed vertically on the conceptual charger, the 65W AirVOOC wireless flash charge can charge a 4,000mAh battery to 100% in 30 minutes at the fastest rate. When a phone is placed horizontally, the technology can charge the device wirelessly at 25W power.

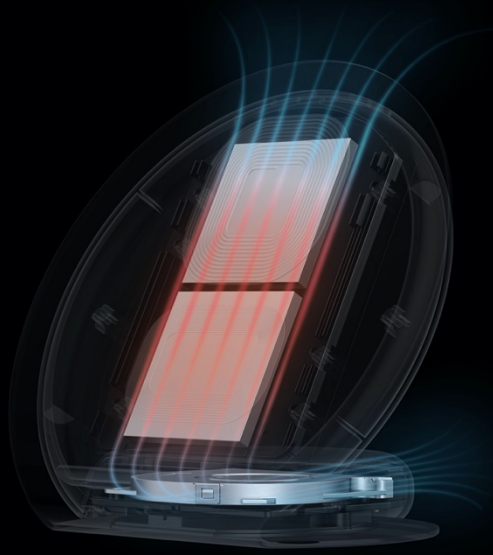


- **Excellent temperature control:** The 65W AirVOOC wireless flash charge performs the same as the 65W SuperVOOC 2.0 in terms of temperature control, keeping the highest charging temperature under 40°C (under constant 25°C environment, with screen off, standby mode on). This temperature is critical as any rise above it would be noticeably felt by users. Mobile phones charged with the 65W AirVOOC wireless flash charge will not be uncomfortably hot, nor will performance be compromised.

E-sports level
semiconductor
heat cooling

$\leq 40^{\circ}\text{C}$

Phone temperature



- **Compatible with the Qi standard devices:** The 65W AirVOOC wireless flash charge not only supports OPPO' s own AirVOOC portocals, but is also compatible with the wireless charging Qi standard introduced by the Wireless Power Consortium. It supports current mainstream wireless charging devices as well as Qi-BPP5W and Qi-EPP10W.
- **Foreign object detection:** 65W AirVOOC wireless flash charge has a foreign object detection function for the real-time monitoring of foreign metal objects between the charging board and the mobile phone that may drain power and pose safety hazards. Once a foreign metal object is detected, charging will immediately be halted to prevent any potential hazards, which, coupled with temperature monitoring, adds to safety redundancy.

- **Sharing mature technology of VOOC flash charge platform:** The mature VOOC flash charge technology brings with it five-fold safety protection, and VFC trickle charging optimization algorithm to ultimately increase the charging speed.

3. Dual-coil design taking the lead and multiple schemes being applied at the same time

As leader in flash charge technology for mobile phones, OPPO has promoted the improvement of charging efficiency and the transformation of charging methods. OPPO continues to innovate charging technology with the aim of achieving new breakthroughs in advanced wireless flash charge technology. OPPO is exploring single-coil and multi-coil charging solutions, and through optimization and innovation, the company aims to provide users with more efficient, convenient and safe wireless charge technologies.

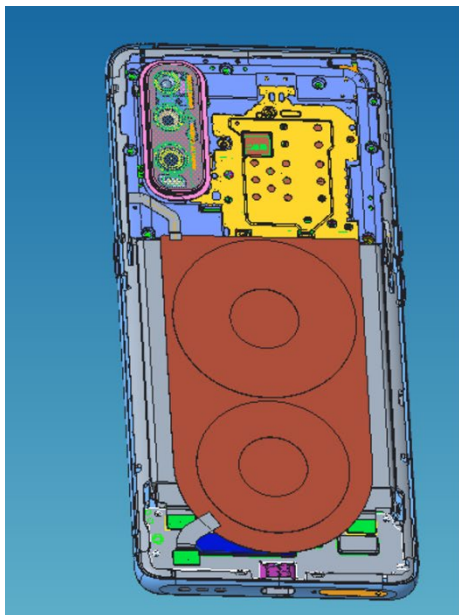
- **Dual-coil, dual-power channels:** The 65W AirVOOC wireless flash charge adds a set of power channels on top of its predecessor and has two sets of power channels connected in parallel.

➤ *Background reading – 65W AirVOOC wireless flash charge vs. its predecessor*

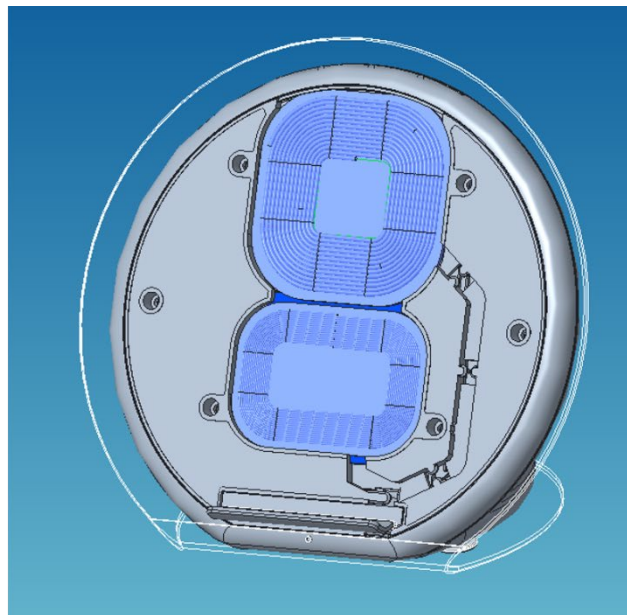
Previous generation of VOOC wireless charge technology: 40W AirVOOC technology has only one ACDC prior to output from the charger, which transfers power to the wireless charger. The transmitting (TX) control module controls the inverter circuit's conversion of the direct current output by the charger into alternating current, then transfers it to the receiving coil of a mobile phone in the form of

magnetic energy via the transmission coil. The phone's receiving (RX) control module controls the rectifier circuit to convert the received alternating current into direct current, and outputs it to the half-voltage module of the charge pump. This output from the charge pump is connected to the double cells.

The 65W AirVOOC wireless flash charge adds new charging path, realizing dual-coil charging: From the transmission circuit to the receiving circuit, the technology features two sets of circuits (40W coil and 25W coil) for parallel charging. This technology includes two sets of charging modules: double transmitting (TX) control modules, double transmitting (TX) coils, double receiving (RX) control modules, double receiving (RX) coils, double isolated charge pumps and double batteries. This type of dual wireless charging engine, coupled with the dual sets of circuits for parallel charging, massively boosts wireless charge power, thereby making the charging process faster and more efficient.



Left: 65W AirVOOC mobile phone dual coils



Right: 65W AirVOOC conceptual wireless charger dual coils

- **Isolated charge pump technology for enhanced safety**

- ✓ Wireless charge technology typically adopts a high voltage and low current solution to mitigate impedance in the power receiver (RX) coil of mobile phones. To further reduce the energy loss caused by voltage conversion, OPPO's 65W AirVOOC wireless flash charge technology adopts VOOC isolated charge pump technology, which, combined with a series bi-cell structures, enables the battery to absorb as much electric energy from the receiver coil as possible. The technology is able to efficiently match the receiving end of wireless charge, improve efficiency, reducing heat and ensuring safety.
- ✓ DC isolation scheme: The technology can effectively block the potential direct current path. Even if the fragile semiconductor device is performing abnormally, a dangerous voltage and current cannot directly reach the battery, guaranteeing safety. It is noteworthy that security protections in the VOOC technology platform is never completely reliant on any semiconductor device. A multi-layer ceramic capacitor (MLCC) is also used in the DC isolation scheme of the VOOC isolated charge pump. In addition, the VOOC platform uses fuse overvoltage protection on the battery protection board, rather than on the semiconductor protection device.

- ***Background reading 1 -- Why does conventional charge pump technology fail to meet OPPO's efficiency and safety standards?***

Traditional charge pump technology has been commercialized for more than 20 years. Due to improvements in semiconductor

technology, the charge pump is more powerful and efficient and can be used in mainstream products. But the traditional charge pump adopts hard switching, which restricts efficiency and fails to support high power, maintain high-frequency or achieve circuit miniaturization. These limitations do not meet OPPO's quality standards for flash charge.

In addition, the traditional design of charge pump technology is a structure in which 4 MOSFETs are connected in series, which determines that the battery, a safety-related load, is directly attached to the charge pump. This structure contradicts the VOOC concept of safety. The failure rate index of semiconductor components, ESD static breakdown, and locking due to interference will be transferred to the MOSFET, resulting in more than twice the voltage being directly applied to the battery, which could be disastrous in extreme conditions.

➤ ***Background reading 2 -- How does OPPO define the safety risk of charging?***

There are only two indicators to assess risk: the probability of occurrence and the intensity of occurrence. OPPO believes that although traditional charge pump technology shows low probability of risk, its intensity of risk is too great. For this reason, since years ago, OPPO had submitted a patent for isolated charge pump technology, reliability of which is no longer restricted to the technical assurance of semiconductor technology or the characteristics of semiconductor

devices. With low tolerance and a soft terminal, MLCC can ensure the reliability of the application of the circuit and the resonance of soft switching, thereby obtaining high efficiency. MLCC can also manage high voltage, while traditional semiconductor devices increase voltage to the detriment of efficiency.

- **Blocking the power interference in high power wireless charging**

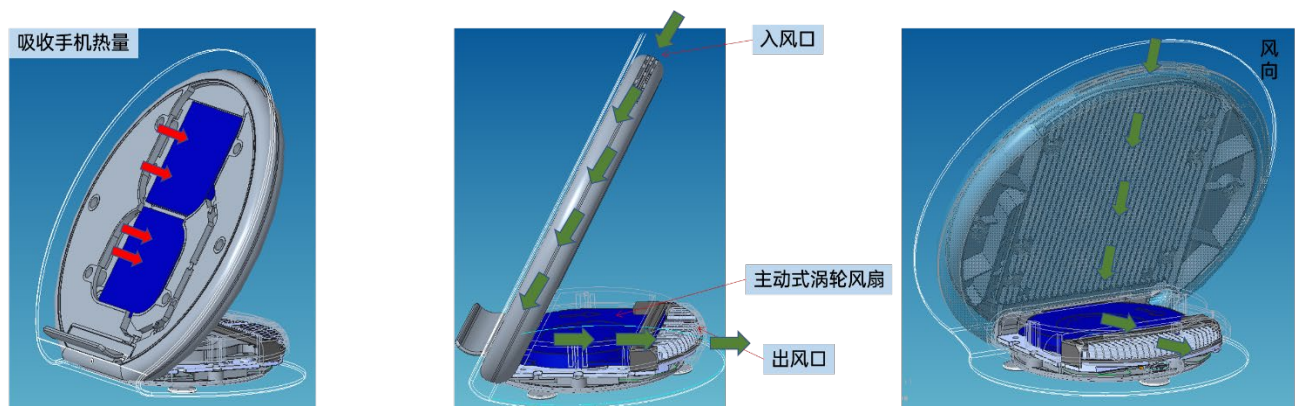
There are two types of power interference. The first is 100Hz interference on the communication signal resulting from 220V mains electricity. This interference frequency is low compared to a normal communication signal of 2kHz. As a result, it can be filtered by changing the circuit of the signal. The second type of interference originates from the discrepancy in operating frequencies of the dual coils, even though they are set to operate at the same frequency. This type generates interference during communication. To address this problem, engineers at OPPO have undertaken a number of efforts, 1) stretching the operating frequency of the dual coils, filtering out differential parts of the high frequencies, 2) adding independent crystal oscillators, improving the consistency and reducing the difference frequency of the dual coils, thus reducing the discrepancies in frequency.

- **Multiple cooling methods for charging**

- ✓ Conceptual wireless charger: vertical design that enables quick heat dissipation.
- ✓ Dual-cell series architecture: it adopts OPPO' s proprietary dual-cell series architecture, which requires one level of power conversion less

than traditional single-cell architecture while maintaining excellent heat dissipation.

- ✓ Semiconductor cooler: the 65W AirVOOC wireless flash charge features an advanced and efficient semiconductor cooler under the transmitter coil and closer to the heat source, enhancing heat control efficiency. It can quickly absorb and transfer the heat generated from the coil. In the case, the temperature of the back of the phone is kept below 40 °C, which is over 2 °C lower than that of only using the fan to dissipate heat.



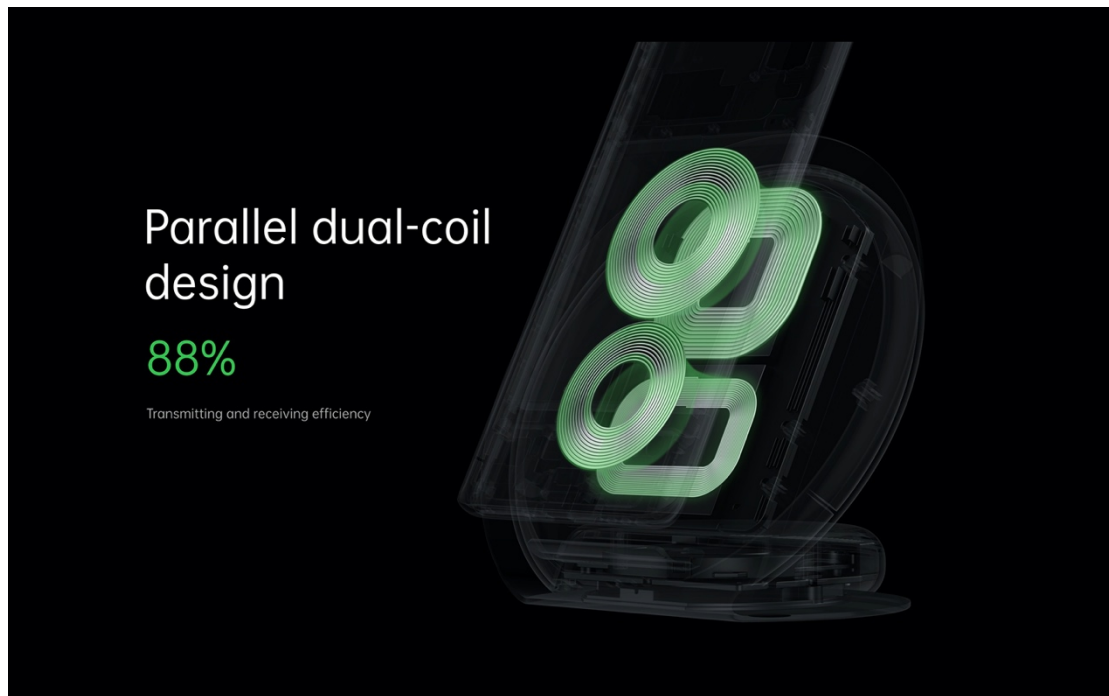
Heat direction in 65W AirVOOC conceptual wireless charger during heat dissipation

➤ ***Background reading -- Semiconductor cooler and the enhancement of past cooling methods for wireless charge***

There are two main ways to dissipate the heat generated during wireless charging: One is to transfer the heat to the charger through thermal conduction. For a better cooling effect, this solution requires the phone's back to fit snugly on the wireless charger. The second way is forced air cooling, which blows cool air onto the phone using a fan.

However, in the case of dual-coil and high power consumption charging when the air passes over the phone's back cover, it has to go through an extended air duct which creates more resistance, greatly hampering the cooling effect.

The 65W AirVOOC wireless flash charge uses a semi-conductor cooler made of materials that take advantage of the Peltier effect, meaning that as the DC flows through the galvanic junction made of two types of semiconductor materials, it absorbs the heat at one end and releases it at the other. Thus, the cooler side can help reduce the temperature of the phone. The semiconductor cooler innovatively divides the heat from the phone during the charging process into two parts: heat from the coil and heat from the management circuit. The heat from the coil is transferred through multiple layers to be absorbed by the semiconductor cooler. The fan then cools down the management circuit through air induction. By making full use of the air entering and exiting through the fan, it solves the heat dissipation problem at two key locations.



- **Built on the essence of VOOC direct charge architecture**

OPPO' s VOOC wireless flash charge platform aims to provide real-time communication adjustment and matching of the wireless charging board for CVCC (CVCC, constant-voltage and constant-current) direct charging. In this way, it is similar to the VOOC wired flash charge, which completes voltage and current adjustments at the charger end. OPPO has spent two years independently developing the entire charging system, and owns proprietary algorithms and logic at the receiving (mobile phone), transmitting (charging board), charging (charger) and battery ends.

- ✓ Real-time communication regulation: The wireless charger and the mobile phone' s wireless charging coil forms a closed loop in which the wireless charger adjusts its transmitting voltage and power. This directly changes the voltage of the mobile phone' s wireless charging coil and indirectly adapts the output current of

mobile phone wireless charging coil to the battery. This allows the system to control and regulate the entire charging process.

- ✓ Constant-voltage and constant-current direct charging: The energy received from the wireless charging coil of the mobile phone does not need to be adjusted by CVCCU (Constant-Voltage and Constant-Current Unit). Instead, it is directly charged into the battery after proportional voltage transformation by the safe and high-efficiency VOOC isolated charge pump. In this way, the wireless charger more effectively shares the task of the Constant-Voltage and Constant-Current Unit. This design was pioneered by the wired VOOC and has become mainstream in the industry.
- ✓ Double-loop control: Same as the 40W AirVOOC wireless flash charge, through software and hardware customization that includes a wireless charge control loop and a charging chip control loop, the 65W AirVOOC wireless flash charge mitigates the heating problems associated with transmitters, coils and mobile phones, therefore helping to improve the efficiency of wireless charge.

➤ ***Background reading 1 - How does traditional wireless charge design work?***

The transmitter (wireless charger) is responsible for transmitting energy, while the receiver (mobile phone wireless charging coil) is responsible for receiving energy. The biggest challenges for the wireless charge of mobile phones are how to deal with energy after receiving it and how to continuously charge the battery. The transmission and reception of energy between the charger and the

mobile phone coil is a mature technology and not the challenging part. The real challenge is how to directly charge high voltage energy of the wireless charging coil into a mobile phone battery. The voltage of 20V is unbearable for mobile phone batteries. Therefore, traditional high-voltage wireless charge design requires the support of a mobile phone's internal charging circuit to maintain a constant voltage and a constant current. This can lead to high voltage difference, loss and heat all occurring inside the mobile phone. These not only affect the charging efficiency and speed, but also the user experience due to the heat produced. Such design will face the same heating and safety problems as a wired flash charge design adopting the high voltage and low current approach.

➤ ***Background reading 2 - Why does wireless flash charge require high voltage combined with a low current?***

The ways to increasing charging power are to either raise the current or raise the voltage. The only way to increasing power in wireless charge is to raise the voltage and reduce the current.

Because of the limitations brought about by the shape and size of mobile phones, the wireless receiving coil needs to be as small and thin as possible. In this case, the greater the current, the greater the rate of temperature rise in the wireless charging coil. Therefore, the only way to increasing power in wireless charge is to raise the voltage.

Chapter 3: 50W mini SuperVOOC charger and 110W mini flash charger, the latest breakthrough in OPPO flash charge technology

1. Small and convenient device to enable flash charge anytime, anywhere.

With the emergence of heavy app use in the 5G era including video editing and sharing and massively multiplayer online games, consumers need new ways to charge their devices and quickly restore power when they are running out. Designed to be highly portable and maintain a powerful flash charge performance, OPPO' s new 50W mini SuperVOOC charger and 110W mini flash charger provide consumers with high-speed flash charge on-the-go so their devices remain full of power anytime, anywhere.



2. New design and pulse charging make the world's smallest and thinnest 50W charger

OPPO officially launched the world's smallest and thinnest 50W mini SuperVOOC charger. Easily stashed in jeans and jacket pockets, this on-the-go charger meets the flash charge mobile needs of the 5G era. The OPPO 50W mini SuperVOOC charger has achieved the ultimate balance of size, performance, aesthetics, and safety for high-power charger products. The charger has reached production quality and will go to the market at certain time.



- **Ultra-thin appearance, cutting-edge charger design**

OPPO designed the unique appearance of OPPO 50W mini SuperVOOC charger using industry standards for smartphone design. For travel, this little charger is far superior to the "large and bulky" chargers of the past. The OPPO 50W mini SuperVOOC charger uses multi-radian curve processing technology, becoming the first charger to adopt an ultra-thin track shape. The charger's prongs can be folded into its body, and it feels round and smooth like a pebble. Beneath its stunning

around 60g. This is far smaller than the smallest 50W adapter currently on the market and is even much smaller than lower power adapters. OPPO 50W mini SuperVOOC charger can easily fit in shirt pockets, coat pockets, and handbags, making it convenient for commuting or traveling.

Charger Volume Comparison			
Product	Item	Data	Unit
50W mini SuperVOOC charger	Length	8.22	cm
	Width	3.9	cm
	Thickness	1.05	cm
	Volume	33.66	cm ³
50W SuperVOOC charger (Find X charger)	Length	5.19	cm
	Width	5.19	cm
	Thickness	3.0	cm
	Volume	80.8	cm ³
A 45W small charger	Length	6.8	cm
	Width	3.0	cm
	Thickness	3.0	cm
	Volume	61.2	cm ³
A 30W small charger	Length	3.8	cm
	Width	3.5	cm

	Thickness	4.1	cm
	Volume	54.53	cm ³

- ✓ **One device for everything:** OPPO' s 50W mini SuperVOOC charger supports 100-240V 50/60Hz input voltage as well as universal power standards worldwide. It is compatible with PD charging protocols, supports up to 27W (9V3A) PD, supports up to 50W (11V4.5A) PPS fast charge, and can charge a variety of devices including mobile phones, tablets and laptops. OPPO 50W mini SuperVOOC charger is also completely compatible with VOOC devices; the charger can charge VOOC, VOOC 3.0, and VOOC 4.0 mobile phone devices at the highest power.


50W mini SuperVOOC charger supports the below flash charge protocols/device power:

Protocols/Device model	Maximum power
SuperVOOC	50W
VOOC	30W
PPS	50W
PD	27W
QC	18W
Huawei P40 Pro	18W
Xiaomi 10 Pro	30W

vivo X50 Pro	18W
iPhone 11 Pro	22.5W
iPad Pro	27W
MacBook Pro	27W

- ✓ **Super flash charging speed:** OPPO' s 50W mini SuperVOOC charger can fully charge a 4000mAh cell phone battery in just 42 minutes at the fastest rate, providing users with an easy, efficient, on-the-go flash charge experience.

OPPO 50W mini SuperVOOC charger



Mini and portable
60g burdenless feel
10.5mm extremely slim

Non-electrolytic capacitor design
PCB volume reduced by 52%
Clamping diodes, aircraft-grade
Pulse charging, first in the industry

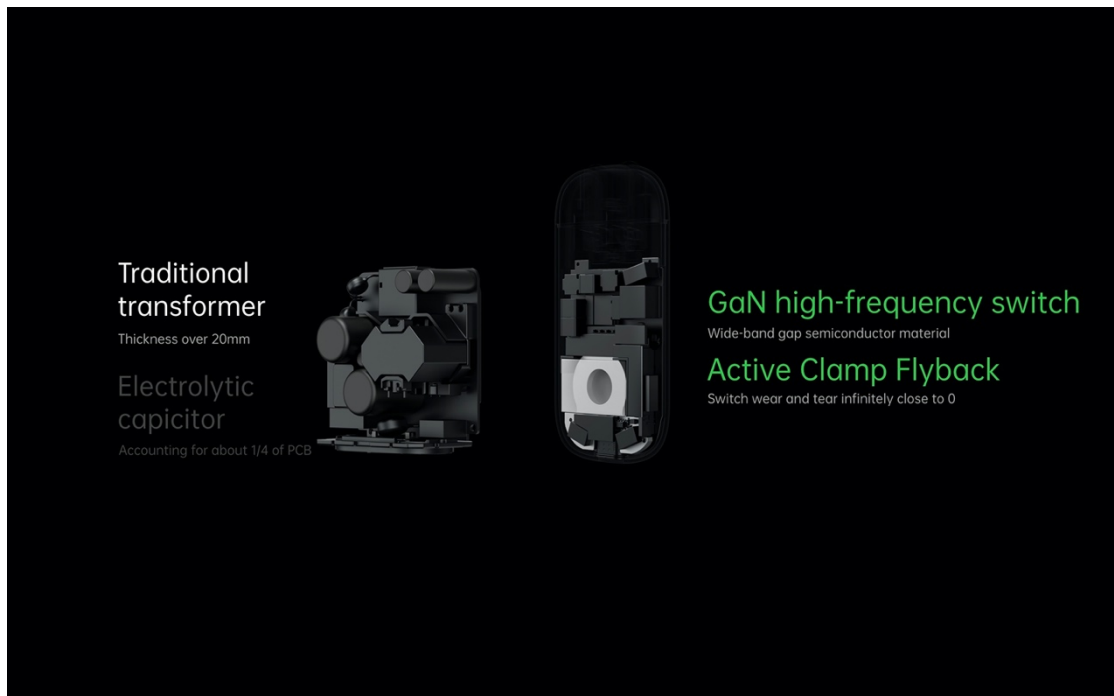
High-frequency Planar transformer
Thickness reduced by 60%
GaN high-frequency switch
Active Clamp Flyback architecture

- **Five major designs ensure the charger' s safety and reliability**

OPPO 50W mini SuperVOOC charger reduces the size of the components that take

up the most space. OPPO does this by using a new topology design to achieve highly efficient power conversion, by removing the conventional electrolytic capacitor, and by introducing pulse charging – the first in the industry, aviation-grade high power clamping diodes and high frequency switching power supply technology. Built for both safety and reliability, the 50W high-power charger still achieves a super small size.

- ✓ **Designed without an electrolytic capacitor:** Designing an charger without an electrolytic capacitor can reduce the charger greatly. The electrolytic capacitor is one of the most important parts in a traditional charger because it is responsible for crucial functions like energy storage, filtering, lightning strike signal absorption, and preventing the destruction of the back-end current. Its high temperature resistance and electrolytic capacitor longevity, however, have always been difficult problems to solve and are the biggest obstacles to miniaturizing high-power chargers, as the electrolytic capacitor takes up half size of the whole charger. Designing OPPO 50W mini SuperVOOC charger without an electrolytic capacitor helps eliminate problems related to the electrolytic capacitor, silicon bridges, and varistors. This improves high temperature resistance, increases the service life, and optimizes the structure of the charger, making a high-density, miniaturized design possible.



Capacitor of traditional 50W charger

- ✓ **The first pulse charging in the industry:** The input current of OPPO 50W mini SuperVOOC charger is naturally 100Hz pulse power because OPPO leveraged innovative topology and eliminated the electrolytic capacitor at the input end. In contrast with conventional charging methods, pulse charging uses a larger current to charge, while battery concentration polarization and ohmic polarization are eliminated when charging is stopped. This means the next round of charging will be smoother and faster, and less temperature change occurs so the battery life is less affected. In February 2016, OPPO proposed the concept of "low-voltage pulse" during its SuperVOOC Technology Prototype Exhibition at MWC in Barcelona. With the removal of the electrolytic capacitor and the introduction of a low-voltage pulse system, the OPPO 50W mini SuperVOOC charger provides high-power charging. Additionally, this innovative charger prevents the temperature from rising too high to ensure

efficiency and safe charging.



- ✓ **Leading-edge gallium nitride (GaN) power devices:** In order to appropriately dissipate heat in small-sized high-power chargers, the chargers must reach requirements of at least 94% efficiency. OPPO customized a new AC-DC control pane, using ZVS (Zero Voltage Switching) and ZCS (Zero Current Switching) technologies to achieve high-efficiency switching rates. OPPO also uses the industry's latest gallium nitride (GaN) power devices to reduce the power conversion device size, thereby reducing the volume of the charger.
- ✓ **High frequency planar transformer:** OPPO 50W mini SuperVOOC charger uses a high frequency planar transformer instead of a traditional magnetic core transformer. This greatly reduces charger volume and offers additional beneficial features like smaller leakage inductance, more flexible operating frequency, greater heat dissipation capacity, and stronger reliability.

✓ **Aviation-grade high-power clamping diodes, anti-lightning strike:**

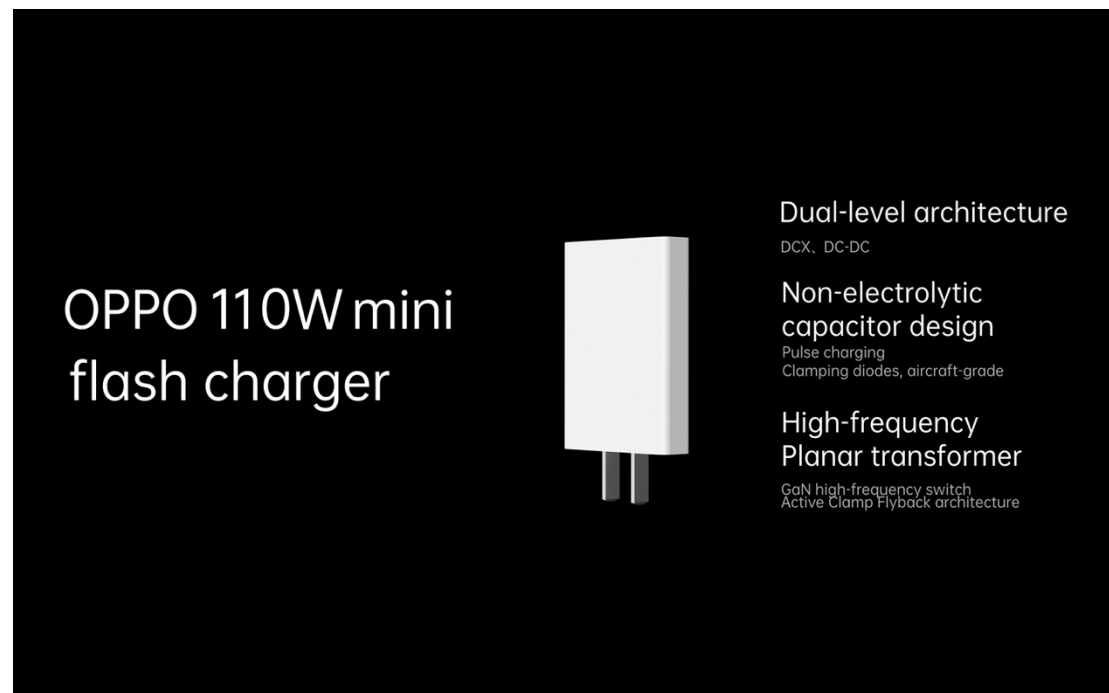
Removal of the electrolytic capacitor helps to reduce the stress on the silicon bridge and the varistors. The specifications and device volume are also reduced. This saves valuable PCB area to solve the problems of lightning strikes and electromagnetic interference (operating electronic devices will cause magnetic interference with other nearby electronic devices). OPPO 50W mini SuperVOOC charger also uses aviation-grade high-power clamping diodes to prevent lightning strike problems; this is the first use of these diodes in consumer electronics. The use of new filtering architecture, custom integrated inductors, optimized control algorithms, and layout and wiring strategies in the charger reduce electromagnetic interference and meet strict reliability index requirements.

3. 110W mini flash charger, the ultimate exploration in high-power, miniaturization

▪ **Innovative dual-level architecture technology, exploring the future of high-power charger miniaturization**

OPPO 110W mini flash charger is designed without an electrolytic capacitor and uses high frequency switching power supply technology to reduce the number and volume of components in the charger. It achieves high efficiency power conversion and temperature control through a pioneering dual-level architecture. An extreme stacking structure allows the final charger volume to achieve a volume of only 35.76cm^3 (65.5mm x 45.5mm x 12mm, not including the prong), with maximum voltage at 110W (20V 5.5A), power density at $3.08\text{W}/\text{cm}^3$ - three times the density of similar chargers available in the market. This is the first time a high-power

miniaturized charger has reached over 100W, making its volume and efficiency far superior to other high-power chargers. It can fully charge a 4000mAh battery in 20 minutes at the fastest rate.



- ✓ **New dual-level architecture:** 110W mini flash charger uses OPPO's own patented new dual-level architecture with a high frequency planar transformer. Using the 50W mini SuperVOOC charger as a foundation, ZVS (zero voltage switching) and ZCS (zero current switching) are made even more extreme on the 110W mini flash charger. The dual-level architecture reduces heat generation, improves output power levels, and ensures 96% conversion efficiency through two voltage drops. It also makes the structure stacking much easier and helps keep the volume much smaller by the combination of two ultra-high efficiency component parts.
- ✓ **High-frequency switching design:** The operating efficiency of high

efficiency power chargers on the market is actually quite low at only about 100KHz. This results in devices like inductors and capacitors only being available in large sizes. The 110W mini flash charger uses gallium nitride and high-frequency switching technology to increase the operating frequency while creating optimized space to miniaturize high-power chargers.

- ✓ **Designed without an electrolytic capacitor:** The 110W mini flash charger uses OPPO's exclusive electrolytic capacitor-free technology, which greatly reduces the size of the charger. The charger is also designed using aviation-grade components and electromagnetic interference (EMI) solutions. High-power clamping diodes and new filter architecture are used to solve lightning strikes and electromagnetic interference (EMI) problems. This product also meets the strict reliability and safety requirements of OPPO's VOOC flash charge platform.

- **Highly compatible and super fast charging enables users to enjoy flash charge in the 5G era**

- ✓ **Compatible with mainstream flash charge protocols:** OPPO 110W mini flash charger adopts a USB-C interface and supports mainstream charging protocols like VOOC, PD, PPS, and QC. It can support up to 65W PD, 110W PPS, and 36W QC, and can charge most electronic devices on the market, mobile phones that support PD/QC standards, and office laptops that support the PD standard.
- ✓ 110W mini flash charger supports the below flash charge protocols / device power:

Protocols/Device model	Maximum power
SuperVOOC	65W
VOOC	30W
PPS	110W
PD	65W (constant output)
QC	36W
Huawei P40 Pro	18W
Xiaomi 10 Pro	30W
vivo X50 Pro	18W
iPhone 11 Pro	22.5W
iPad Pro	45W
MacBook Pro	65W

- ✓ **Charging speed beyond imagination:** OPPO 110W mini flash charger provide consumers with “on-the-go charging” . It allows users in the 5G era to completely end their dependence on battery pack chargers, improve overnight charging habits, and make flash charge available on-the-go - anytime, anywhere.
- ✓ **Five-fold safety charging protection:** OPPO 110W mini flash charger is equipped with proprietary chip protection. Like the VOOC flash charge technology platform, it enjoys a five-fold safety protection. The 110W mini

flash charger also pioneered the use of dual-level architecture, which can achieve up to 96% conversion efficiency, effectively control the temperature, reduce the probability of device failure, and further improve battery life.

- **Humanized design creates a lightweight, portable, and simple appearance**

OPPO 110W mini flash charger is much smaller than the mainstream 65W chargers on the market and is similar in size to a conventional 18W charger. Users can easily carry this small charger while traveling. The charger's high compatibility provides a one-stop solution for all of the user's electronic charging needs and offers freedom from having to match corresponding chargers for electronic device. The 110W mini flash charger design adheres to OPPO's design aesthetics; the simple white shell has rounded corners for users to easily and comfortably hold.

- **Flash charger, the next step for flash charging**

OPPO's flash charger represents the top level of miniaturization technology for high-power chargers. With the 5G era increase in demand for mobile flash charging, there is a trend to develop more mini high-power chargers.

- ✓ **High-frequency switching design:** OPPO innovatively adopts a high-frequency switch design for mini chargers. This is one of the industry's key technologies for the future of charger miniaturization. The maturity of high frequency switching technology will also contribute to the miniaturization of peripheral components on the main board of devices. This will provide support for more flexible internal designs of mobile phones/IoT devices, which can lead to lighter and thinner devices with the

possibility for more imaginative and even completely new designs.

- ✓ **Exclusive dual-level architecture:** In order to ensure safety while further increasing the charging power, OPPO uses an exclusive patented dual-level power supply change architecture in the 110W mini flash charger to achieve a secondary voltage reduction with an ultra-small volume. Achieving up to 96% efficiency conversion reduces heat generation and increases output power levels.
- ✓ **Designed without an electrolytic capacitor:** Innovative topology design without an electrolytic capacitor helps eliminate problems related to the electrolytic capacitor, silicon bridges, and varistors. This improves high temperature resistance, increases the service life, and optimizes the structure of the charger making a high-density, miniaturized design possible.



Chapter 4: OPPO VOOC flash charge is starting its sixth year, high-power, wireless and miniaturized chargers, opening a new era of flash charge across the market

1. VOOC flash charge enlightens the industry and benefits 157 million users

OPPO VOOC flash charge was independently developed by OPPO and first released in 2014. OPPO has continuously led the development of fast charging technology in the industry. To date, there are over 157 million VOOC flash charge users worldwide. With the popularization of apps like games and videos that consume huge amounts of power and large-scale commercial 5G use, there are new requirements for mobile phone battery life and charging experiences. Based on this observation, OPPO is continuously improving its VOOC flash charge technology so users can improve charging efficiency when charging on-the-go.

- **VOOC flash charge' s unique concept:**
 - ✓ Efficiency and safety are two of the most important core considerations for OPPO' s flash charge. Efficiency is the goal and safety is the prerequisite. If we had to choose between safety and efficiency, OPPO would always choose safety. OPPO puts safety first.
 - ✓ OPPO has always upheld the concept of direct charging and the VOOC platform is a whole system that includes the "charging receiver, transmitter, charging terminal and battery terminal," that forms a closed loop VOOC charging protocol through customized hardware and algorithms.
- **VOOC flash charge has applied for many patents and passed authoritative standards sertification:**

- ✓ VOOC flash charge technology is a fast charging technology independently developed by OPPO. OPPO has applied for over 2,800 patents with it worldwide and nearly 1,250 patents have been authorized;
- ✓ VOOC flash charge technology has also received a Five-Star Certification from the China Telecommunications Technology Lab (CTTL), under China's Ministry of Industry and Information Technology; this was the first fast charging technology to receive five-star certification from the CTTL.
- **The VOOC flash charge technology platform has two complete technologies: VOOC wired flash charge and AirVOOC wireless flash charge, and keeps iteratively updates:**
 - (1) VOOC flash charge is continuously evolving:
 - In 2014, OPPO took the lead in launching the OPPO developed VOOC flash charge technology, innovatively adopting the low-voltage high-current direct charging solution, and taking the lead on Find 7;
 - Also in 2014, OPPO reduced the VOOC mini charger volumes on N3 and R5, and separated the charger and wire in the design;
 - In 2016, OPPO first proposed the SuperVOOC super flash charging concept at MWC, and demoed the product prototype;
 - In 2018, OPPO equipped the OPPO Find X Super Flash Charge and OPPO Find X Lamborghini versions with SuperVOOC. This technology's charging power is close to 50W, which can fully charge a 3400mAh battery phone in 35 minutes. In 2018, OPPO additionally launched the OPPO R17 Pro also equipped with this technology.
 - In October 2019, OPPO officially equipped the OPPO Reno Ace with 65W SuperVOOC 2.0 super flash charging technology. This was the first time a

commercial model mobile phone with battery energy equivalent to 4000mAh fully charged up in 30 minutes.

- In July 2020, OPPO released 125W flash charge, resetting the mobile phone record for flash charge.

(2) OPPO launches AirVOOC wireless flash charge to supplement and improve the flash charge experience for all market segments:

- Since 2012, OPPO's focus on wireless charging has become a substantial business. A wireless charging kit that included a charging base and a protective cover was released with the OPPO Finder launched that year. The kit uses TI's wireless charging chip and follows the WPC wireless charging standards.
- In 2019, the 30W AirVOOC wireless flash charge technology was officially launched, presenting "wireless" VOOC flash charge for the first time.
- In 2020, OPPO Reno Ace2 was launched with the 40W AirVOOC wireless flash charge, which can fully charge 4000mAh in 56 minutes.
- In July 2020, OPPO launched 65W AirVOOC wireless flash charge with charging speeds comparable to the industry's mainstream "wired" flash charge technology.

(3) The launch of the high-power ultra-small charger opens up new directions for chargers with its record-light and thin features and its convenience.

- In July 2020, in order to fulfil users' needs of mobile flash charge in the 5G era, OPPO launches the world's smallest and thinnest 50W mini SuperVOOC charger and 110W mini flash charger, which are compatible with flash charge protocols such as PD, PPS and QC. They are able to charge most laptops, tablets and mobile phones available in the market.

2. Continuously expand the VOOC flash charge ecosystem and benefit more users

- Currently OPPO VOOC flash charge series has supported 30+ OPPO models
- Based on VOOC flash charge technology, OPPO has launched a variety of peripheral accessories including flash charge portable power banks, and flash charge car chargers, and reached cross-border cooperations with Gundam, Pokémon, EVA Evangelion and others to become a leader in the industry.
- Additionally, the OPPO VOOC flash charge technology platform has helped over 23 manufacturers develop flash charge patent licenses, covering charger chips, power banks, car chargers, charging stations and other smart applications and devices. OPPO is constantly expanding their plans for the flash technology ecosystem, including plans for vehicle application and office scenarios, so that more users can enjoy the convenience brought by VOOC flash charge technology across many market segments.
- The value of VOOC patents continues to increase, and the flash charge patent ecosystem including barrier patents, industry standards, and technology certifications is taking shape. VOOC flash charge has become a typical sample of OPPO patents, enabling OPPO to cooperate with more partners within the flash charge ecosystem.