Individual Project Report: iPhone 14/14Pro New Features and Technologies

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1. Introduction

1.1. Product Evolution

On 29th June 2007, the original iPhone was released following Steve Jobs announcing it at the Macworld convention earlier that year (9th Jan 2007), receiving substantial media attention, the iPhone's journey had just begun. Afterward, Apple released the new iPhone series every year. The figure below depicts the evolution of each iPhone series.

Fig. 1. iPhone Evolution

The naming rule of iPhone is usually follows by a number, only in 2017 and 2018, they name the product as iPhone X, XR. Next, they return the original naming rule. From the evolution of iPhone product, we can find several characteristics, including a larger size, more camera sensor, and a higher screen ratio. iPhone series have proposed many innovation in the overall evolution, e.g., touch ID, face ID etc.

In 16th Sep 2022, Apple released the brand new iPhone series: iPhone 14/14 Pro series. It can categorize into four products, including iPhone 14, iPhone 14 Plus, iPhone 14 Pro, and iPhone 14 Pro Max, the price of iPhone 14 start at NT$ 27,900, iPhone 14 Plus start at NT$ 31,900, iPhone 14 Pro start at NT$ 34,900, and the iPhone 14 Pro Max start at NT$ 38,900. The price of the iPhone 14 series is a bit expensive than the previous iPhone 13 series. The following figure shows the new iPhone series:

Fig. 2. iPhone 14/14 Pro series

1.2. New Features/Technologies

In iPhone 14/14 Pro series, there are many new features and technologies, As shown in fig. 3, the new features is not only about hardware but also the software.

Fig. 3. New features/technologies

The new features of hardware are including the new camera sensors, the new A16 Bionic chip, and a whole new screen with a better display, etc. About the software, the new technologies including the car crash detection, emergency SOS via satellite, and the new Dynamic Island, etc. The new features/technologies will be introduced in detail in Sec. 4.

2. Spec

In this section, we summarize and compare the spec of the iPhone 14/14 Pro series. Table 1 shows the different spec between the different products:

Table 1. Specification

	iPhone 14	**iPhone 14 Plus**	**iPhone 14 Pro**	**iPhone 14 Pro Max**
Screen size	6.1-inches	6.7-inches	6.1-inches	6.7-inches
Refresh rate	60 Hz	60 Hz	1-120 Hz	1-120 Hz
CPU	Apple A15 Bionic	Apple A15 Bionic	Apple A16 Bionic	Apple A16 Bionic
Storage	128, 256, 512GB	128, 256, 512GB	128, 256, 512GB	128, 256, 512GB
RAM	6GB	6GB	6GB	6GB
Cameras	Dual 12MP (wide, ultrawide)	Dual 12MP (wide, ultrawide)	48MP main, 12MP ultrawide, 12MP telephoto with 3x optical zoom	48MP main, 12MP ultrawide, 12MP telephoto with 3x optical zoom

We can divide the products into two category, the iPhone 14 (iPhone 14/14 Plus) and iPhone 14 Pro (iPhone 14 Pro/14 Pro Max). The iPhone 14 Pro series have the newest features and technologies whereas the iPhone 14 series is almost the same as the iPhone 13 series. Therefore, we introduce the new features and technologies based on the iPhone 14 Pro series in the rest of the report.

For the spec of cellular and wireless communications, iPhone 14 series have support the latest protocol, including 5G (sub-6 GHz and mmWave) with 4x4 MIMO, gigabit LTE, Wi-Fi 6, Bluetooth 5.3, Ultra Wideband chip for spatial awareness, and support VoLTE. It also provides a high precision dual-frequency GPS, support the commonly satellite, including GLONASS, Galileo,

QZSS, and BeiDou.

iPhone 14 series also have multiple sensors for different application. There is a LiDAR scanner on iPhone 14 Pro and Pro Max, which provides a better accuracy for the portrait mode and the extension application for augmented reality (AR). Other sensors including high dynamic range gyro, high-g accelerometer, dual ambient light sensors, and barometer are also in iPhone 14 series. A proximity sensor is also in iPhone 14 series to enable the face ID function.

3. iPhone 14 Series Teardown

In this section, we introduce the teardown of iPhone 14 Pro Max. The teardown figures show the internal architecture, we focus on the part of CPU, 5G modem and other crucial components in this section.

As shown in the figure below, we introduce the yellow part of the figure in the right hand side. The figure on the left hand side is the zoom in of the yellow part, we can find that there is the heart of iPhone 14 Pro Max: A16 bionic chip. Other component such as PMIC is also in this part. The Broadcom BCM59365EA1IUBG is the wireless charging receiver.

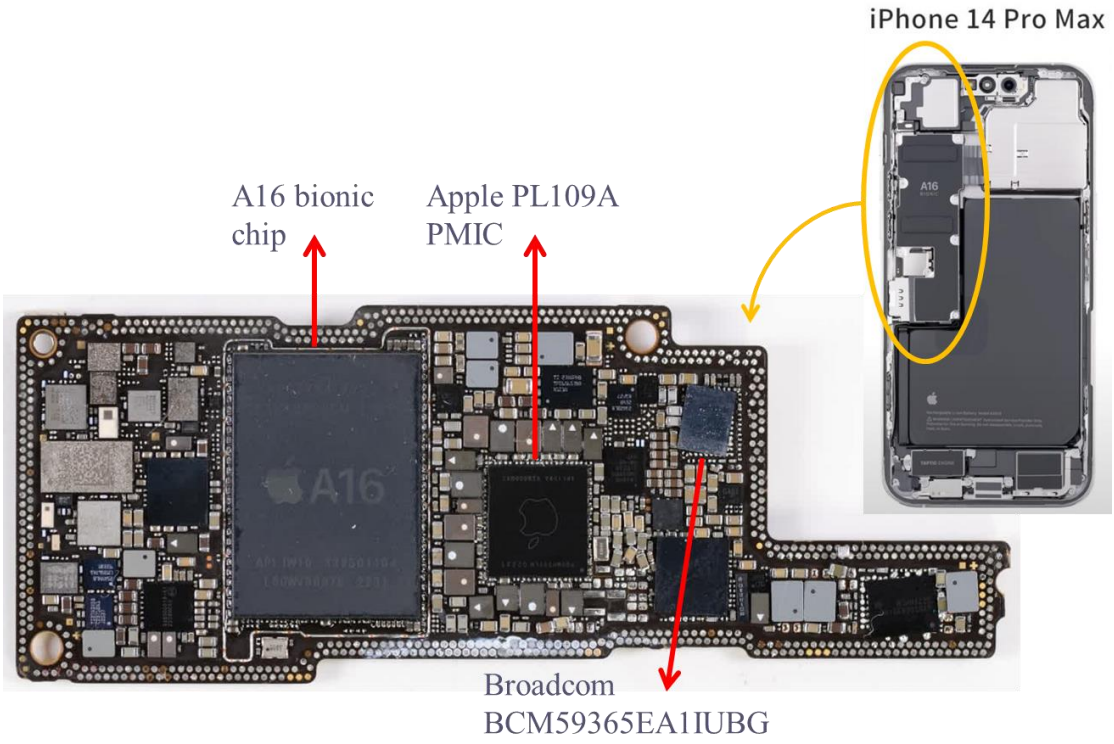


Fig. 4. iPhone 14 Pro Max teardown-1

Fig. 5 and 6 is the opposite side of the fig. 4, most of the component in fig. 5 is about the communication module, the biggest update is the Qualcomm 5G solution which is based on the Qualcomm C65 5G modem. Other relative component is the RF transceiver, RF front end module, envelope tracker, mmWave intermediate frequency IC, and the mmWave antenna.

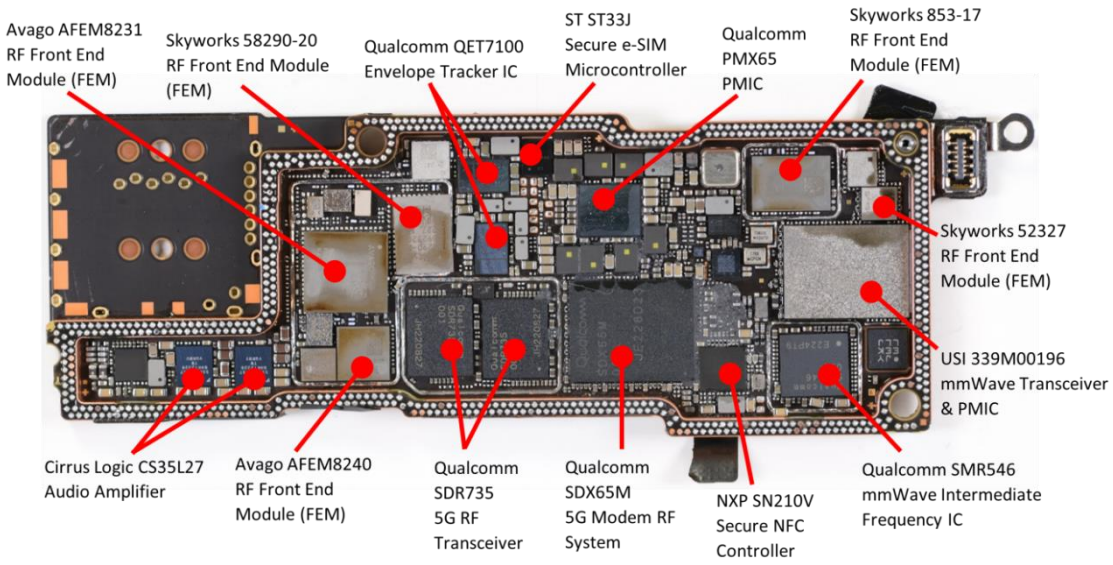


Fig. 5. iPhone 14 Pro Max teardown-2

In fig. 6, the important component is the Wi-Fi/Bluetooth combo chip, the NAND flash memory, and the brand new antenna for satellite communication.

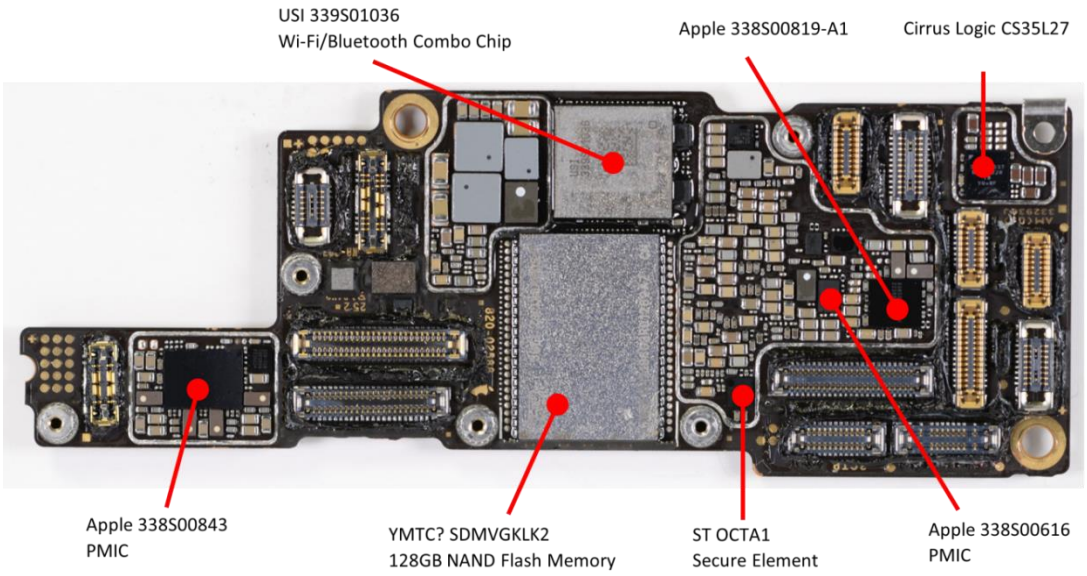


Fig. 6. iPhone 14 Pro Max teardown-3

4. Technology Analysis and Applications

In this section, we introduce the new technologies and its application in iPhone 14 series.

4.1. A16 Bionic Chip

The A16 Bionic chip is one of the new upgrade in iPhone 14 series, it consists of 16 billion transistors which is more than the A15 Bionic chip. The CPU is constructed by 2 firetorm and 4 icestorm cores. The codename of the 2 high-performance cores are Everest which frequency is up to 3.46 GHz, the codename of the 4 power-efficiency cores are Sawtooth which frequency is up to 2.02 GHz. The GPU part is constructed by 5 GPU cores, it couple with 50% memory bandwidth due to the LPDDR5 memory which provides a higher bandwidth. The A16 chip also has a neural engine which used to deal with the computation of machine learning. The neural engine contains 16 cores with the capability of 17 trillion operation per second (TOPS). Another component are the ISP and display engine, the ISP is designed to handle the higher resolution image sensor, it is capable of performing up to 4 trillion operations per photo. Display engine is first on Apple A-series chip, it handles task like the 1 Hz refresh rate, and enables a better functioning “Always on Display”.

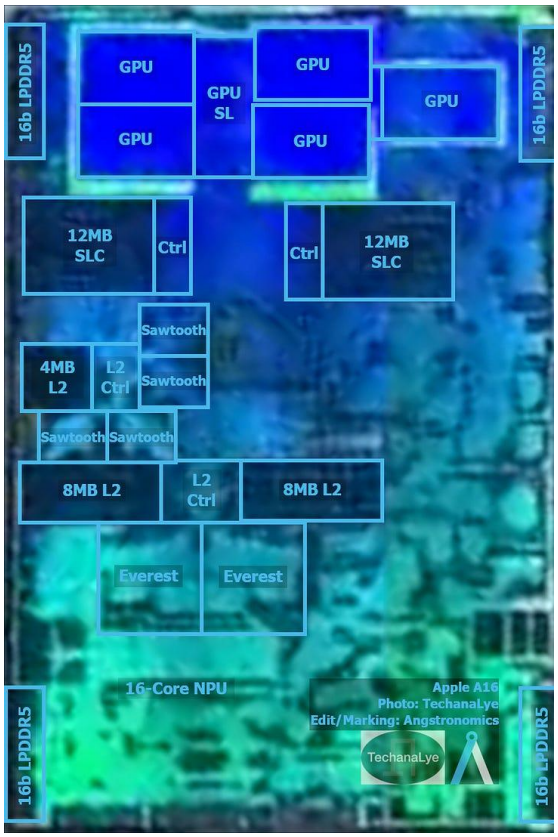


Fig. 7. Die photo

Table 2. CPU spec

CPU	
Architecture	2x 3.46 GHz – Everest 4x 2.02 GHz – Sawtooth
Instruction set	ARMv9-A
L1 cache	256 KB
L2 cache	16 MB (performance core)
	4 MB (efficient cores)
	24 MB (system cache)
Technology	TSMC 4 nm

Memory	
Type	LPDDR5-6400
Max. Memory	6 GB
Bandwidth	51.2 GB/s

Fig. 7 is the die photo of A16 chip, the top part of the photo is the 5 core GPU, the middle part is the CPU, and the bottom part is the 16-core neural engine, ISP, and the display engine. Table 2 is the detail specification of the A16 chip, we can find that it use the latest ARM instruction set: ARMv9-A, and the chip is manufacture by TSMC with its 4nm process. As mentioned before, the A16 chip adopts the latest LPDDR5 memory, and its size is 6GB with a 51.2GM/s bandwidth.

We compare the CPU and GPU performance with its biggest competitor – Qualcomm. Fig. 8 is the comparison of CPU, the CPU of Galaxy Z Fold 4 and S22 Ultra is Qualcomm Snapdragon 8Gen1, and S21 Ultra has a Qualcomm Snapdragon S888. From the result, we can observe that the A16 Bionic take the lead with a huge gap in not only single core but also multi core. The Snapdragon 8Gen1 has a better performance than the S888. Moreover, the A15 bionic chip also has a higher performance than Snapdragon 8Gen1, which tells us that the A-series chip lead their competitor more than a generation. Fig. 9 depicts the GPU comparison, we can find that the A16 bionic chip also has a better performance than its competitor.

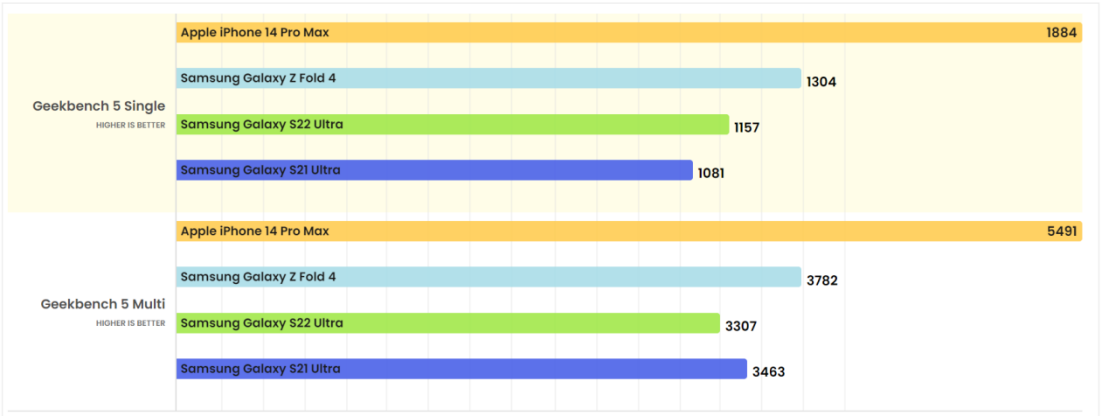


Fig. 8. CPU performance comparison

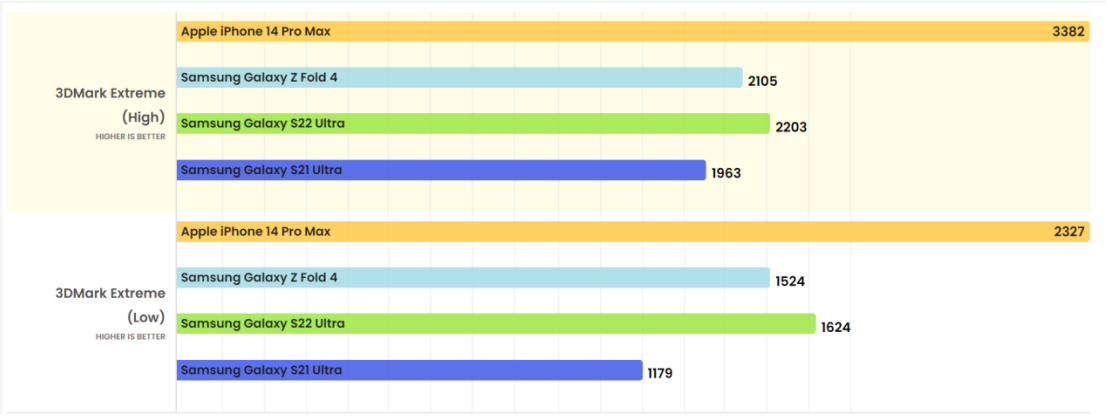


Fig. 9. GPU performance comparison

4.2. Camera System

In the camera system, we will mainly focus on the main camera since it has a huge upgrade compare with other cameras. The new photonic engine in iPhone improves the cameras, producing more detail in low-light performance. The main upgrade is the 48MP main camera sensor. Fig. 10 depicts the specification of the new main camera. For the image processing algorithm, Apple bins pixels together in group of 4, which result in a 12MP photos with improving lighting since it can capture more detail. Moreover, it also enables the user to capture the full 48MP image by ProRAW mode. Another upgrade is the new zoom step between wide 1x and telephoto 3x, unlike the previous iPhone product using the telephoto camera to zoom in 2x, the iPhone 14 series use the 48MP main camera to achieve the 2x zoom in by cropping the image for a 2x zoom, i.e. cropping the middle 12MP pixels from the 48MP pixels image. Since the main camera has a better performance than the telephoto camera. Therefore, it improves the image quality of 2x zoom in compare with the previous iPhone series.

Fig. 10. iPhone 14 Pro Max main camera

Another new feature is Apple improves the Masked PDAF (phase different autofocus) thanks to the new 48MP main camera. Lets' talk about the Masked PDAF technique, it uses the phase different between different focusing points to find out where to focus, the focusing points is among the pixels. Fig. 11 depicts the die photo and the optical photo between iPhone 13 Pro Max and iPhone 14 Pro Max. From the die photo, we can observe that the iPhone 14 Pro Max has a bigger die size due to the 48MP camera sensor. The optical photo

depicts the focusing pattern, the white points in the optical photo denote the focusing point. From the optical photo, we can observe that iPhone 14 Pro Max has a different Masked PDAF pattern compared to the iPhone 13 Pro Max, including a new double metal pattern for each 2x2 pixel group, which improves the focusing speed and performance.

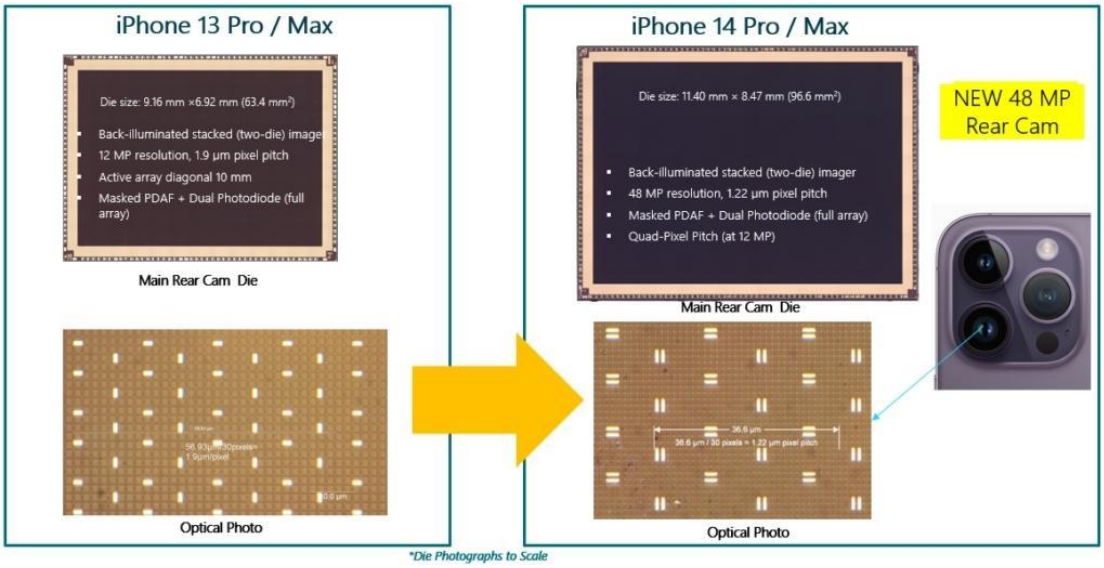


Fig. 11. Main camera die photo

Fig. 12 depicts the ultrawide rear camera, it reuse the iPhone 12 pro wide-angle main camera and features Masked PDAF plus full array dual photodiode (DP), i.e. each pixel consist of either focusing diode or diode use to capture image, which improve the focusing speed. The die photo shows that the die size of iPhone 14 Pro Max has a larger size than the iPhone 13 Pro Max.

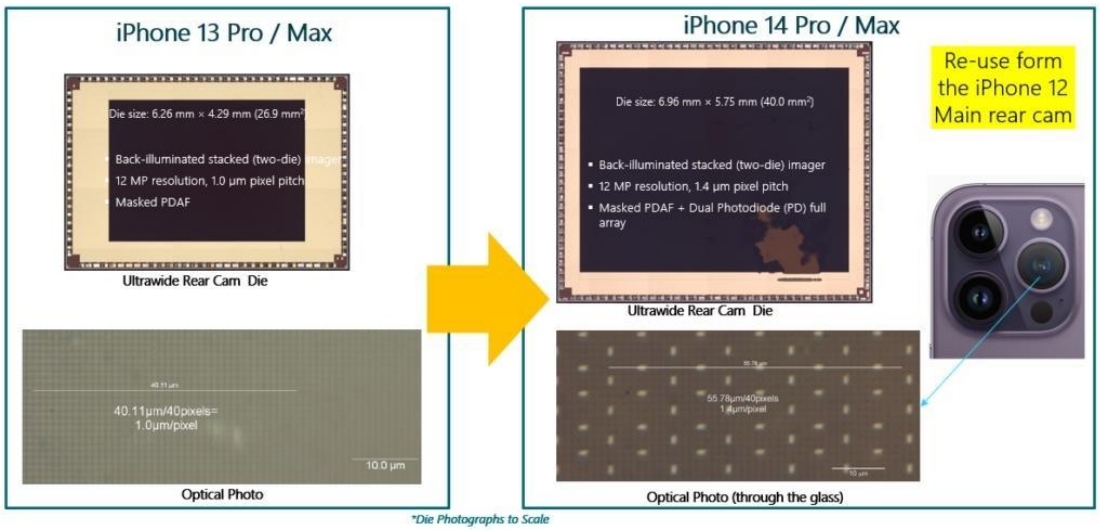


Fig. 12. Ultrawide camera die photo

The telephoto rear camera is exact the same as the iPhone 13 series. iPhone 14 Pro/Pro Max also has a Lidar camera in order to improve the low light autofocus speed and improve the quality of portrait mode. For the front camera, it upgrade with a PDAF function, which has a better focusing performance. Moreover, with the upgrade camera sensor and the A16 chip, it also improve the video recording performance, including the cinematic mode can now shoot in 4K up to 30fps, and a new action mode which applies extreme video stabilization.

4.3. Emergency via SOS Satellite

Another new feature is iPhone 14 Pro is the satellite communication, which is first seen in a smartphone. Before introduce the satellite communication technologies, we need to introduce the Qualcomm X65 modem, which is adopt by iPhone 14 series. It is the world's first 10 Gigabit 5G and first support the 3GPP release 16. Its 5G download speed zoom up to 130% faster than iPhone 13 Pro which adopt the Qualcomm X60 modem. It support several new bands, including the new n259 (41GHz), n70, and n53 (2.4 GHz) bands. Moreover, Qualcomm adopt its new advanced power-saving technique to obtain a better power efficiency.

Thanks to the X65 modem, iPhone 14 Pro series is enabled satellite communication since it support the n53 bands. Apple cooperates with the company Globalstar which has bands license and satellite in America. iPhone user can use this emergency service when cellular and Wi-Fi coverage is not available. It appears a short questionnaire to help the user answer vital question with a few simple taps. The emergency SOS via satellite sends multiple information to the emergency center, including medical ID, emergency contacts, and location. The left hand part of Fig. 13 depicts the overall procedure, while you cannot connect to a cellular of Wi-Fi, you can enable the emergency service, and your iPhone will start to find a satellite to connect. After connect to a satellite, you can answer the question, including what emergency you are suffer and what do you need, etc. Next, it will send emergency information to the center, you can also text to the emergency center in this part. Another function is you can share your location to your contacts by function "find my location" without an emergency service when you get lost. The right hand part of Fig. 13 depicts the scenario and the UI of the application, this app can also navigate when you lost the cellular signals.

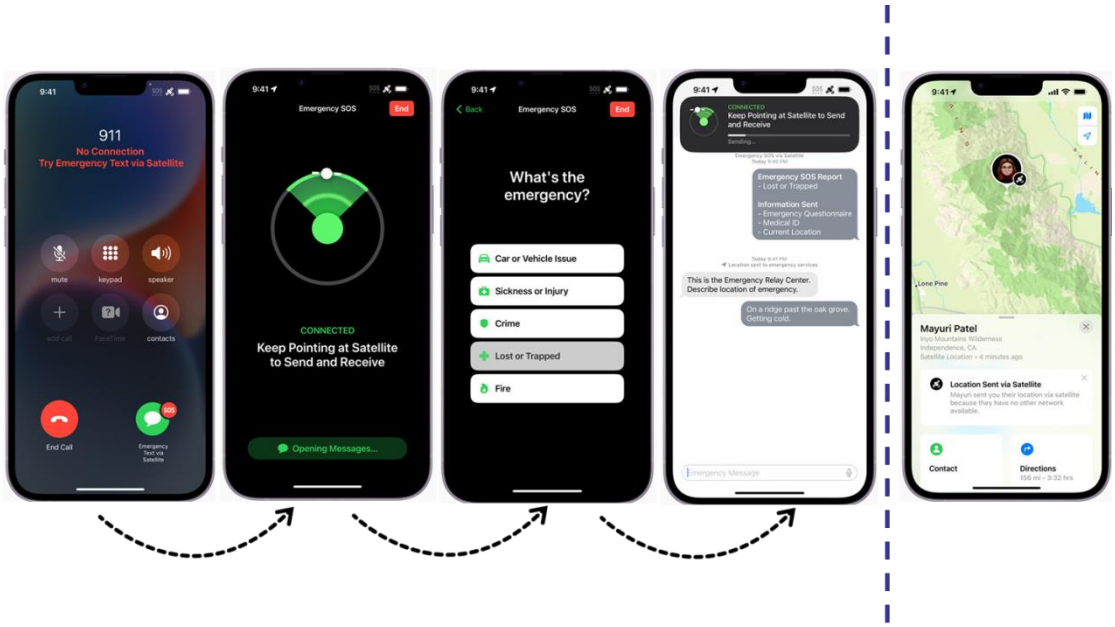


Fig. 13. Emergency via SOS satellite

4.4. Dynamic Island

Another new feature of iPhone 14 Pro series is the Dynamic Island. First we talk about the hardware. Face ID is composed by three components, including IR projector, IR camera, and proximity sensor, iPhone 13 Pro series put the proximity sensor within the face ID notch. Compare with the iPhone 13 Pro Max series, Apple move the proximity sensor under the screen, which makes the required cutout size smaller. Therefore, it provides a smaller notch. Fig. 14 depicts the different.

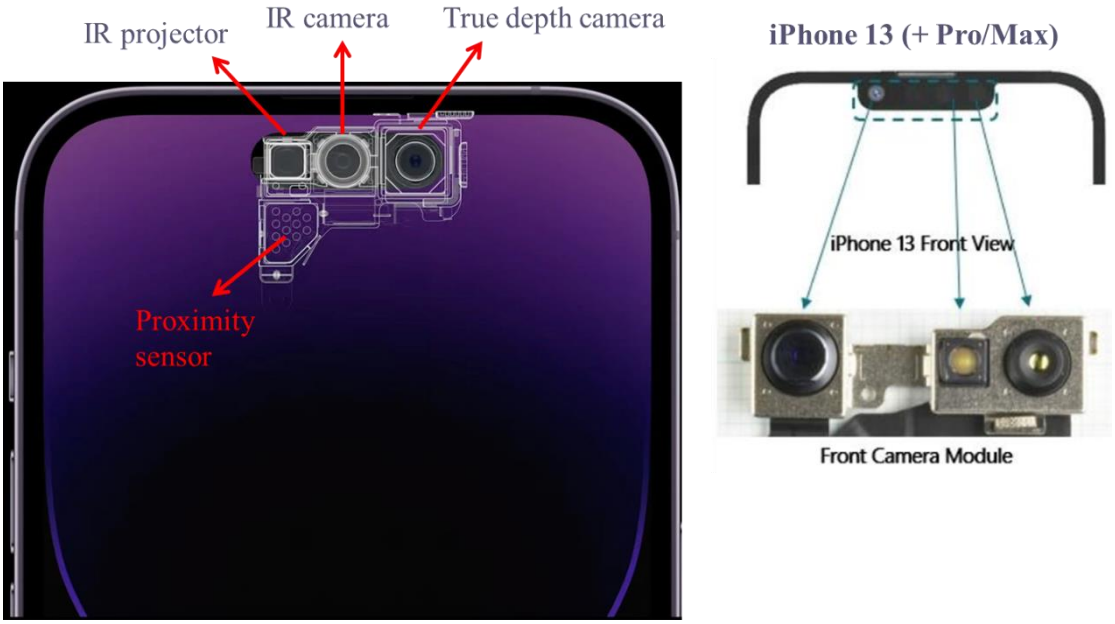


Fig. 14. Face ID component between iPhone 13 Pro Max and iPhone 14 Pro Max

Now we can introduce the Dynamic Island, the Dynamic Island is an interactive notch that surrounds the iPhone's front camera and face ID sensor, it provides a new interaction for users. It's possible to interact with certain types of content displayed in the Dynamic Island, it also support live activities, third party apps. Fig. 15 depicts the example of third party apps, there is a pet on the top of the screen which you can interact with.

Fig. 15. Dynamic Island third party apps

Fig. 16 depicts the live activities application. For example, it can update the flight information you are going to take. If you are watching a baseball game, it can update the information of the game.

Fig. 16. Dynamic Island live activities

Fig. 17 shows another example that it can operate in split mode, i.e., it can operate two apps in the same time.

Fig. 17. Dynamic Island split island

4.5. Car Crash Detection

iPhone 14 Pro series can detect if you are in a severe car crash, it uses a set of inputs to detect vehicle crash detection. The inputs consist of gyroscope, G-force accelerometer, GPS information, microphone, and barometer. Note that barometer is used to detect whether your car airbag is activate or not.

By machine learning method, it fuses the multi-modal input to classify the car crashes. Since the different modality may have different characteristics, an efficient fusion algorithm is necessary to let the feature have a best representation which contains the crucial information. Apple claimed the model was developed using more than 1 billion hours of real world driving and crash data.

There are four types of car crashes can be detected: Front-impact, Side-impact, Rear-end collision, and Rollovers. Fig. 18 depicts the four types car crashes can be detected. Fig. 19 depicts the application UI when iPhone detect a car crash, it will call the emergency center automatically if you didn't response to your phone.

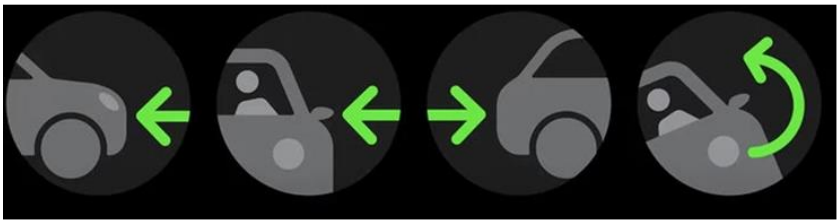


Fig. 18. Four types car crashes

Fig. 19. Car crash detection

4.6. Always on Display

The iPhone 14 Pro and Pro Max feature a more advanced OLED panel with a more variable refresh rate. The previous-generation iPhone 13 Pro has a variable refresh rate between 10 Hz and 120 Hz. In iPhone 14 Pro series, it's upgraded which the refresh rate can go as low as 1Hz to enable a new Low Power mode. Fig. 20 depicts the new features of the panel of iPhone 14 Pro series, it has a better brightness and a higher contrast ratio compare to the iPhone 13 Pro series.

Thanks to the upgrade of the panel and the new display engine mentioned previously, the iPhone can operate the Always on Display function in a low refresh rate. Fig. 21 depicts the Always on Display function, when you turn off the screen, it will turn to Always on Display mode. Compare to its competitor, Android phone, iPhone just dim the brightness and still show the background wallpaper rather than switch the background wallpaper to all black.

Fig. 20. Features of iPhone 14 Pro panel

Fig. 21. iPhone 14 Pro Always on Display

5. Industry Analysis

In this section, we analysis the industry of iPhone 14, and make a SWOT analysis to observe its pros and cons.

5.1. Supply Chain

Below is the list of iPhone 14 supply chain:

- NAND flash – Sandisk
- LPDDR5 SDRAM – Samsung
- OLED panel – Samsung Display
- Taptic engine driver – Analog Devices
- UWB module – Universal Scientific Industrial (環旭電子)
- RF front-end module – Broadcom, Skyworks
- Envelope Tracker – Qualcomm, Qorvo
- NFC control component – NXP
- A16 Bionic chip – TSMC
- CMOS image sensor (CIS) – Sony

Fig. 22 depicts the other part of the supply chain, we can observe that there are many Taiwanese companies, which also demonstrate that the product quality of Taiwanese companies is well and have a price advantages compare to other countries. Several companies have been cooperative with Apple many years, most of the company in supply change is as same as the previous iPhone Products.

Fig. 22. iPhone 14 Pro supply chain

5.2. SWOT Analysis

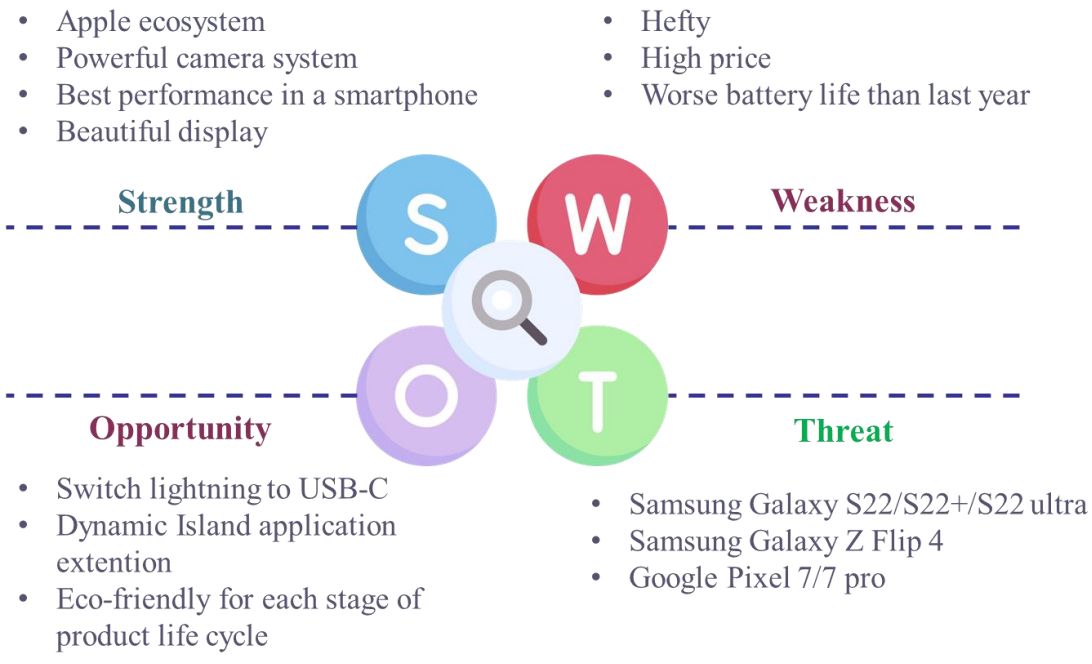
We make a SWOT analysis in this part, which contains four aspects, including strength, weakness, opportunity, and threat.

First is the Strength of iPhone 14, it has a powerful camera system and still getting improve in each generation. The Apple ecosystem provides the user a best experience among different Apple products. iPhone 14 Pro also has the best performance in a smartphone and lead its competitor with a huge gap. It also has a beautiful display.

Next we analyze its weakness. Compare to its competitor, it is heavier and got a higher price. It also has a worse battery life than the iPhone 13 series.

Next is the opportunity of iPhone 14. It got a chance to switch its i/o port from lightning to USB-C since USB-C has a higher transmission speed, with more and more media use iPhone to record or filming, it is necessary to use a higher transmission speed i/o port to transmit data. The new Dynamic Island on iPhone 14 Pro series provides a potential market on application developer since it support the third part apps. Another opportunity is that Apple claims its manufacture of their product is eco-friendly and can still improvement in the next product generation.

For iPhone 14's threat, its biggest competitor is the products of Samsung and Google, including the Samsung Galaxy S22/S22+/S22 ultra, Samsung Galaxy Z Flip 4, and the Google Pixel 7/7Pro.



6. Conclusion

iPhone 14 series provides several new features/technologies. The Dynamic Island brings a new interface to interaction which support third-party apps can bring a potential to the market of apps developer. The new 48MP main camera provides better color fidelity and low-light performance and the improved autofocusing technique provide a higher autofocus speed. The Always on Display feature on iPhone 14 Pro series is more useful than other Android competitor since it can display more information. The iPhone 14 Pro feel potentially more useful in unforeseen circumstances, including the car-crash detection, emergency SOS via satellite communication.

However, most of the new features/technologies mentioned above only on iPhone 14 Pro series where the iPhone 14 series is almost the same as the iPhone 13 series. The target audience of iPhone 14 series is a bit confused. Fig. 23 shows the selling number compare with iPhone 13 series. We can observe that the selling number of iPhone 14 is decrease, most of the consumer bought iPhone 14 Pro series and iPhone 14 Plus rather than iPhone 14. This is the problem Apple need to think about it for the next generation. Overall, iPhone 14/14 Pro series is still a powerful product on the market, and its biggest competitor is itself.

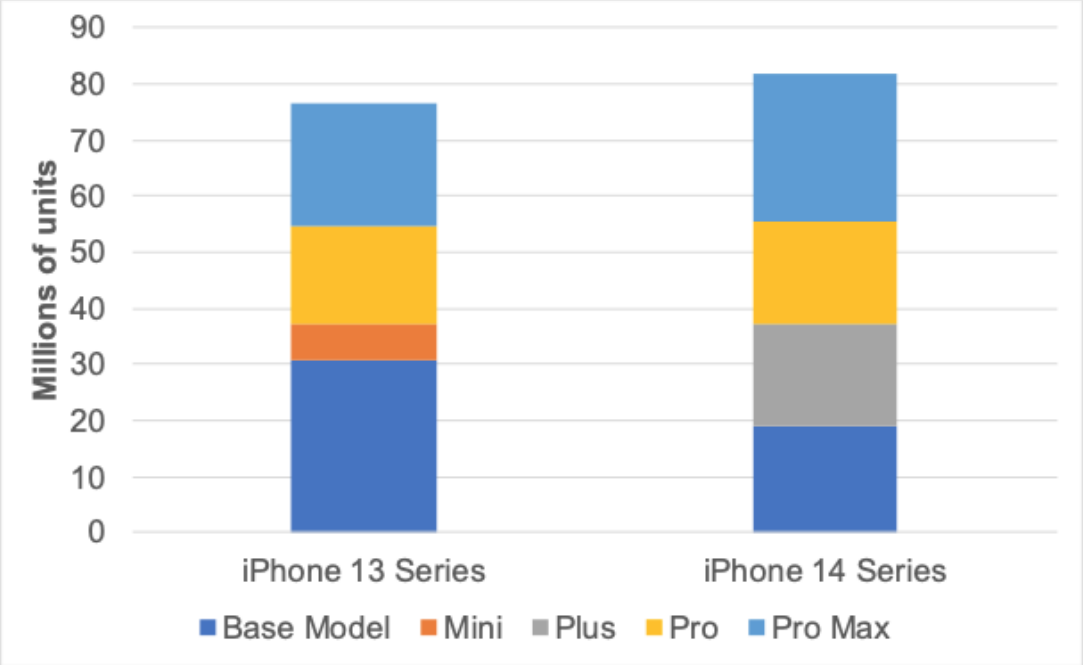


Fig. 23. Selling number of iPhone 13 series and iPhone 14 series

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