Developing the Industrial Internet of Things
Course 2

Product Teardown

Iphone X

by

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December 25, 2021

Introduction and Problem Solved by the Device

Iphone X is pronounced as “Iphone ten” and is developed by Apple Inc. It was released on November 3, 2017. It was the first phone to use an OLED screen. It has a face ID which scans the user’s face to unlock the device. Its price tag on the release was US$999 and made it the most expensive that time. It is also known for its unique design. The advantages of the IPHONE X (TEN) screen is the use of an OLED Super Retina Display type with a bigger screen at 5.8 inches size. Apple solved the problem by delivering users a big screen for multimedia, entertainment or doing anything on their smartphone.

Device Market and Application Area

Market share of Apple iPhone smartphone sales worldwide since 2007 to date. Apple claimed commercial success with a 15.2 percent share of the market in the third quarter of 2021, a drop from the previous quarter. In 2018 Singapore was the biggest market followed by the United Arab Emirates. You can download applications in the apple store and run it as needed.

Block Diagram

Looking at the diagram see Figure 1 in Appendix. You will see 16 blocks connected to the Iphone Processor. A few of these blocks contain two components in the same chip such as the accelerometer and 6-axis gyroscope. The 16 blocks are the the display or touchscreen module, rf chipset, power management IC, memory, RF/PA section, user interface IC content, battery pack, camera, major mechanical, barometric pressure, color sensor, proximity sensor, electronics compass, wlan/bluetooth module, true depth sensing suite, and accelerometer/gyroscope 6-axis. Most of the modules are connected to the processor via digital io and IP communication interface as shown. I divided the Iphone X into two major components: the electro-mechanical elements and the IC element. The electro-mechanical elements are composed of the display/touchscreen module and major mechanical parts such as the rear enclosure. The IC content is composed of the sensors, wireless communication element, the camera and user interface IC content which is connected to the microphone and speaker, battery pack and memory. Notice how the power supply is connected by a yellow line to a battery pack and the battery pack sourcing the power of the apple processor. In actuality the battery pack and power in the processor will be sourcing all the IC components but for simplicity it is not shown. Here I want the reader to focus on the arrows which represent the flow of data and the interface that is used. Notice also that the line has three types: the double arrow which represents two way flow of data, single arrow or one way data, and a line which means simply connected.

Technical Details

The display/touchscreen module is a 5.8” diagonal, 2436x1125 AMOLED, with force touch beneath polarizer, and with touch sensor covered with glass and is manufactured

by Samsung Display. AMOLED is a display technology and stands for Active Matrix Organic Light Emitting Diodes. It is a type of OLED display and is used in smartphones.[1]

The touch sensor is provided by Nisha CO.

The major mechanical/electro-mechanical elements are composed of the enclosure, main, bottom, machined aluminum frame, rear cover glass and stainless steel plate and the other mechanical or electro-mechanical parts.

The camera is composed of two elements. The first one is the primary camera module which is dual, wide-angle f/1.8 telephoto, f/2.4 12 megapixel, BSI CMOS with OIS. This is an upgrade of camera lens from 5P f/2.8 in iPhone 8+ to 6P f/2.4 and dual camera with OIS. F/1.2 means that the aperture is wide. So basically the smaller the value next to F/ the wider the aperture the better. OIS is a hardware solution that uses a micro-electromechanical system (MEMS) gyroscope to detect movement and adjust the camera system.[2] BSI, or Back Side Illuminated sensors are also known as 'Back Illuminated' sensors. They are a revision of traditional sensor designs which increase the light gathering efficiency of the sensor to deliver higher sensitivity, less noise and better all round image quality.[3] The secondary camera is a 7 megapixel, BSI CMOS, fixed lens.

The Apple Processor is the Apple A11 Bionic, 64-bit 6 core CPU, 3-Core GPU both implemented in 10 nm technology.

The rf chipset is manufactured by Qualcomm and includes the following: the baseband RFIC, the rf transceiver and the power management integrated circuit. The baseband IC which is a multimode baseband processor, CAT-16 and in 14nm technology. CAT-16 means a category 16 Gigabit LTE which is 256QAM, 3x20 MHz CA, and 4x4 MIMO. The actual rated downlink speed achieved through this combination of technologies is not quite 1 Gbps, but 979 Mbps. It's also worth mentioning Cat 16. LTE's secondary configuration, which doesn't require more complex 4x4 MIMO antenna arrays. Using 2x2 MIMO, 256 QAM and 4x20 MHz CA, speeds of up to 800 Mbps are possible.[4] The rf transceiver is a multi-mode and multiband. There are a total of three power management integrated circuit or PMIC chipset two of which are manufactured by Dialog Semiconductor GMBH and one from STMicroelectronics all of which are used for Apps Processor and power management. The last part of PMIC is the Wireless Charging Controller manufactured by Broadcom LTD.

The memory is composed of 64 GB TLC flash and SDRAM, LPDDR4, 3GB PoP. Triple-level cell (TLC) NAND stores 3 bits per cell. By adding more bits per cell, this

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[1] "What is AMOLED? - The Official Samsung Galaxy Site." https://www.samsung.com/global/galaxy/what-is/amoled/. Accessed 25 Dec. 2021.

[2] "What is image stabilization? OIS, EIS, and HIS explained - Android ...." 14 Nov. 2021, https://www.androidauthority.com/image-stabilization-1087083/. Accessed 24 Dec. 2021.

[3] "What is a BSI sensor? Back-side illuminated sensors explained." 2 Jul. 2021, https://www.digitalcameraworld.com/uk/features/what-is-a-bsi-sensor-and-are-they-actually-important-bsi-sensors-explained. Accessed 25 Dec. 2021.

[4] "Explainer: What is Gigabit LTE? | TechSpot." 9 Feb. 2017, https://www.techspot.com/guides/1328-gigabit-lte-explained/. Accessed 24 Dec. 2021.

reduces the cost and increases the capacity.[5] Synchronous dynamic random-access memory (synchronous dynamic RAM or SDRAM) is any DRAM where the operation of its external pin interface is coordinated by an externally supplied clock signal. DRAM stores each bit of data in a memory cell. Low-Power Double Data Rate (LPDDR), also known as LPDDR SDRAM. Low-Power means smaller bit bus, but is more power efficient unlike RAM used in desktops. The LPDDR4 specification aims to double data rates (up to 3200 Mb/s) over last generation RAM and to save on energy consumption for mobile devices. Package-on-Package (POP), as its name implies, is a semiconductor packaging innovation that involves the stacking of two or more packages on top of one another. Signals are routed between the packages through standard package interfaces.[6]

The RF/PA section is composed of three FEM (front end module)/DRX, one filter, one PAM and two Transmit Modules. The filter is manufactured by Broadcom and is implemented in quadplexer. A quadplexer is a 5-port filtering device that splits one input into four different outputs, each with a different frequency.[7]. The next three FEM/DRX are manufactured by Skyworks Solutions Inc. FEM is a part of the rf system between the antenna and the digital baseband section of a wireless system. In this case the antenna and the RFIC chipset. Discontinuous reception (DRX) standardized by the third generation partnership project (3GPP) is an efficient power saving protocol used in mobile devices.[8] The Pulse Amplitude Modulation (PAM) is manufactured by Skyworks Solution Inc. The transmit module that is manufactured by Broadcom LTD is multi-mode, multi-band. It contains 3 Sony Rf Switches and 4 analog ICs with a duplexer and filters. A duplexer is an electronic device that allows bi-directional communication over a single path. The transmit module that is manufactured by Skyworks Solution Inc. is also multi-mode, and multi-band. It contains 2 Skyworks Rf Switches and Skyworks analog ICs with duplexers. The user interface IC content is composed of Audio Codec and Audio Power Amplifier which is manufactured by Circus Logic Inc and NFC controller which is manufactured by NXP Semiconductors. An NFC controller chip combines both an NFC reader and an NFC tag for an integrated solution. It is often embedded in NFC-enabled devices such as: Smartphones. Mobile Point of Sales (POS) E-wallet applications (banking cards, bus tickets, health cards, loyalty card, etc.).[9]

As for the sensors the Accelerometer/Gyroscope 6-axis is manufactured by Bosch Sensortec GMBH, Electronic Compass is by ALPS Electric Co Ltd, Barometric Pressure Sensor is by Bosch Sensortec GMBH, Color Sensor is by AMS AG, and Proximity time-of-flight is by STMicroelectronics. The True Depth Sensing Suite is composed of an

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[5] "Difference between SLC, MLC, TLC and 3D NAND in USB flash ...." https://www.kingston.com/unitedkingdom/en/solutions/pc-performance/difference-between-slc-mlc-tlc-3d-nand. Accessed 25 Dec. 2021.

[6] "Package-on-Package (POP) - EESemi.com." https://www.eesemi.com/pop.htm. Accessed 25 Dec. 2021.

[7] "What is a Quadplexer? - everything RF." 3 Jul. 2019, https://www.everythingrf.com/community/what-is-a-quadplexer. Accessed 25 Dec. 2021.

[8] "An overview of the discontinuous reception (DRX) mechanism in ...." https://www.researchgate.net/figure/An-overview-of-the-discontinuous-reception-DRX-mechanism-in-LTE-A_fig1_330819401. Accessed 25 Dec. 2021.

[9] "What is an NFC Chip? - STMicroelectronics." https://www.st.com/content/st_com/en/support/learning/st25-education/nfc-chip.html. Accessed 25 Dec. 2021.

IR camera, Flood Illuminator and Dot Projector, all of which are manufactured by STMicroelectronics/Texas Instrument.

The Wireless LAN/Bluetooth Module is manufactured by Murata Manufacturing Co Ltd. The WLAN is IEEE802.11ac compliant and the Bluetooth is Bluetooth 5.0 compliant. Key features of 802.11ac standard:Frequency band of 5GHz. The 802.11n operates in both 2.5GHz and 5GHz RF bands Whereas 802.11ac operates only in 5GHz RF bands to restrict usage in this band is mainly driven by the wider channel bandwidth requirements for 802.11ac. Modulation 802.11ac uses Orthogonal Frequency-Division Multiplexing (OFDM) to modulate bits for transmission. While the modulation method is the same as that used in 802.11n, 802.11ac optionally allows the use of 256 QAM. This increases the number of bits per subcarrier from 6 to 8, resulting in up to a 33% increase in PHY data rate. Backwards Compatibility - 802.11ac provides backwards compatibility with 802.11a and 802.11n devices operating in the 5 GHz band. This means that 802.11ac interworks with devices supporting 802.11a and 802.11n technologies & 802.11ac frame structures can accommodate transmission with 802.11a and 802.11n devices . More MIMO spatial streams - Support for up to eight spatial streams (four in 802.11n). Speed: The Minimum speed of 802.11ac 1300 Mbps and the Maximum speed of 802.11ac standard is like 6.93 Gbps. The maximum speed is increased compared to 802.11n IEEE standard.[10] Known as Wi-Fi 5. The specification has multi-station throughput of at least 1.1 gigabit per second (1.1 Gbit/s) and single-link throughput of at least 500 megabits per second (0.5 Gbit/s). This is accomplished by extending the air-interface concepts embraced by 802.11n: wider RF bandwidth (up to 160 MHz), more MIMO spatial streams (up to eight), downlink multi-user MIMO (up to four clients), and high-density modulation (up to 256-QAM).[11] With Bluetooth 5.0, devices can use data transfer speeds of up to 2 Mbps, which is double what Bluetooth 4.2 supports. Devices can also communicate over distances of up to 800 feet (or 240 meters), which is four times the 200 feet (or 60 meters) allowed by Bluetooth 4.2.[12]

The battery packs are manufactured by Sunwoda Electronics Co Ltd. It is a Li-polymer battery, 2 cells combined in unusual layout to fit form factor, 3.8 V and 2716 mAh. The power supply charger of 5V, 1A is enough for the power requirement of this device and is an AC to USB Type A.

Security Concerns/Risks

Apple Confirms 22 Security Reasons To Update Your iPhone. None of the security issues fixed in iOS 15.1 or iOS 14.8. 1 are known to have been exploited in the wild. However, some of them are serious—especially the Kernel vulnerabilities which could give an attacker access to your iPhone.[13]

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[10] "802.11ac wireless LAN standard and Its Advantages and ...." https://www.anandsoft.com/networking/802.11ac.html. Accessed 25 Dec. 2021.

[11] "IEEE 802.11 - Wikipedia." https://en.wikipedia.org/wiki/IEEE_802.11. Accessed 25 Dec. 2021.

[12] "Bluetooth 5.0: What's Different, and Why it Matters - How-To Geek." 31 Aug. 2018, https://www.howtogeek.com/343718/whats-different-in-bluetooth-5.0/. Accessed 25 Dec. 2021.

[13] "iOS 15: Apple Issues 22 Important iPhone Security Updates - Forbes." 21 Sept. 2021, https://www.forbes.com/sites/kateoflahertyuk/2021/09/21/ios-15-apple-gives-iphone-users-22-security-reasons-to-update-now/. Accessed 25 Dec. 2021.

Concluding Comments

Examining Iphone X is a perfect way to understand how technologies fit together and what are the current trends of technology. Writing a technical paper for Iphone X teardown is like implementing a project and doing a project planning in reverse direction. Which helps solidify the first part of this course concept. This investigation of Iphone X helps me see how different technologies come together to tackle modern needs and problems. Makes me see the bigger picture and what could lie ahead. Finding the technical information on the product is hard but rewarding. I have to look up on multiple sites to check whether the information is true and accurate. After taking this course I have a clearer picture of what and how products like apple are made, technology like VLSI and FPGA are made and how software and firmware engineering fit in the picture. Which is something I can leverage on other electronic products.

Appendix

Figure 1: Iphone X Block Diagram

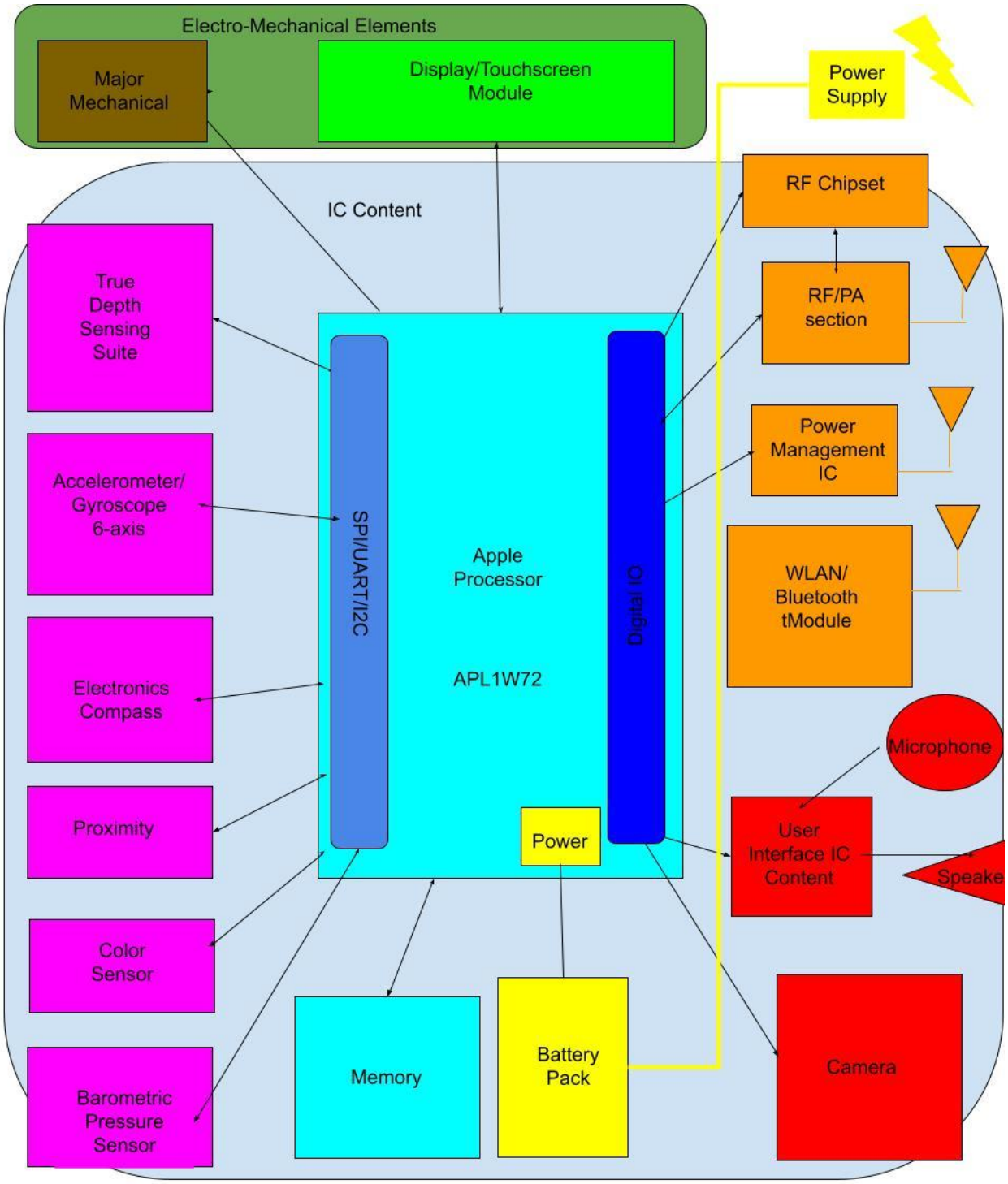
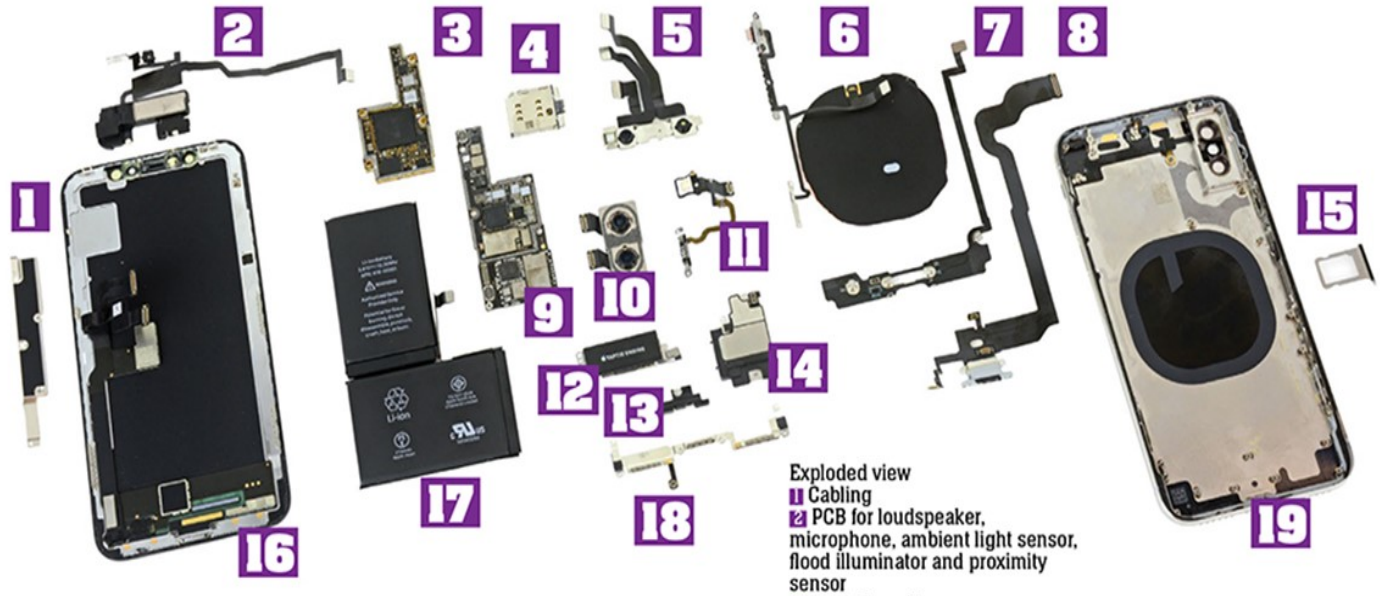
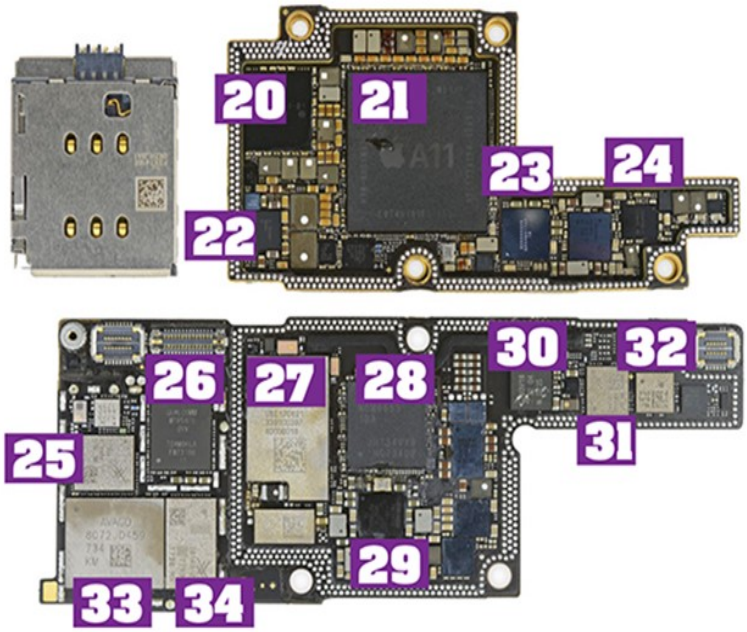


Figure 2: Product breakdown



Exploded view
1 Cabling
2 PCB for loudspeaker, microphone, ambient light sensor, flood illuminator and proximity sensor
3 Logic board 1
4 Logic board 2
5 Front/Face ID camera array
6 Wireless charging coil
7 Cabling
8 Lightning port cable
9 Logic board 3
10 Rear 12MP camera
11 Flash
12 Taptic engine
13 Barometric vent
14 Lower speaker
15 SIM tray
16 Front/display
17 Battery
18 Cabling
19 Rear enclosure



Logic board (1)
20 Power management, Apple
21 Apps processor, Apple
22 Battery charger, Texas Instruments
23 Audio codec, Apple
24 Power management, Apple

Logic board (2)
25 Power amplifier, Skyworks
26 Gigabit LTE transceiver, Qualcomm
27 Wi-Fi/Bluetooth module, Apple/Murata
28 LTE Modem, Qualcomm
29 Power management, Qualcomm
30 NFC controller, NXP Semiconductors
31 Power amplifier, Skyworks
32 Power amplifier, Skyworks
33 MMMB power amplifer, Broadcom/ Avago
34 Power amplifier, Skyworks

Face ID array
35 IR camera
36 Front-facing camera
37 IR dot projector

Reference Designator	Manufacturer's Part Number	Part Name	Manufacturer	Description	Quantity	Unit of Measure	Unit Cost	Cost
1	AMB585NE01	Display / Touchscreen Module	SAMSUNG DISPLAY	5.8" Diagonal, 2436x1125 AMOLED, W/ Force Touch Sensor Beneath Polarizer, and with touch sensor and cover glass	1	Each	$110.00	$110.00
2		Major Mechanical / Electro-Mechanical		ElementsRear EnclosureEnclosure, Main, Bottom, Machined Aluminum Frame, Rear Cover Glass, & Stainless Steel PlateAll other mechanical / electro-mechanical	1	Each	$61.00	$61.00
3		Primary Camera Module and Secondary Camera Module		Dual, Wide-Angle F1.8/ Camera lens upgrade from 5P Telephoto F2.4 12MP, BSI CMOS/7MP, BSI CMOS, Fixed Lens	1	Each	$35.00	$35.00
4	MDM9655RF/WTR5975/ PMD9655	RF Chipset (Baseband IC,RF Transceiver,Power Management)	QUALCOMM	Baseband, RFIC, & PMIC Chipset/Baseband Processor, Multi-Mode, 14nm - CAT16 Modem	1	Each	$18.00	$18.00
5	338800341-B1/338800306-A1/STB600BO/BCM59355A2IUB3G	Power Management IC (Apps Processor/Other PM/WRC)	DIALOG SEMICONDUCTOR GMBH/ DIALOG SEMICONDUCTOR GMBH/ ST MICROELECTRONICS/ BROADCOM LTD	PMIC, Wireless Charging Controller, WPC Qi Compliant All other Power Management Wireless Charging	1	Each	$14.25	$14.25
6	TSBL2271C3747/ HOHKNNNDBMAUUR-NEH	Memory(NAND (EMMC, MLC, ...) /DRAM	TOSHIBA SEMICONDUCTOR/ SK HYNIX INC	Flash, NAND, 64GB, TLC SDRAM, LPDDR4, 3GB, POP	1	Each	$33.45	$33.45
7	KF1732/ SKY13762/ SKY13760/ SKY13770/ AFEM-8072/ SKY78140-22/ SKY77366	RF/PA Section(FEM / Filters/ PAMs / Transmit Modules)	BROADCOM LTD /SKYWORKS SOLUTIONS INC	Duplexer / FEM /DRX / Transmit Module, Multi-Mode, Multi-Band, Contains 3 Sony RF Switches & 4 Analog ICs, wl Duplexers & SAW Filters Transmit Module, Multi-Mode, Multi-Band, Contains 2 Skyworks RF Switches & 2 Skyworks Analog ICs, w/ Duplexers PAM All other RF	1	Each	$16.60	$16.60
8	338800248/ CS35L26/ PN80V	User Interface IC Content(Audio Codec/NFC Controller)	CIRRUS LOGIC INC/ NXP SEMICONDUCTOR	Audio Codec Audio Power Amplifier NFC Controller All other User Interface	1	Each	$10.05	$10.05
9	BMP28x	Sensors (Accelerometer / Gyroscope, 6-Axis Electronic Compass Barometric Pressure Sensor Color Sensor Proximity - time-of-flight)	BOSCH SENSORTEC GMBH/ ALPS ELECTRIC CO LTD/ AMS AG/ ST MICROELECTRONICS	Accelerometer / Gyroscope, 6-Axis Electronic Compass Barometric Pressure Sensor Light Sensor Proximity - time-of-fligh	1	Each	$2.35	$2.35
10		True Depth Sensing Suite (IR Camera Flood Illuminator)	ST MICROELECTRONICS / TEXAS INSTRUMENTS	IR Camera/ Flood Illuminator/ Dot Projector	1	Each	$16.70	$16.70
11	339800397	WLAN/BT Module	MURATA MANUFACTURING CO LTD	IEEE802.11ac, Bluetooth 5.0	1	Each	$7.35	$7.35
12		Battery Pack(s)	SUNWODA ELECTRONICS CO LTD	Battery, Li-Polymer, 2-Cell, 3.8V, 2716mAh2 Cell combined in unusual layout to fit form factor	1	Each	$6.00	$6.00
13		Box Contents / OtherPower supply charger) Headset Headphone Jack Adapter USB to Apple Lightning CableOther		Charger, 5V, 1A, AC to USB Type A Stereo w/ Apple Lightning Plug Headphone Jack Adapter USB to Apple Lightning Cable Box, literature, packaging	1	Each	$12.00	$12.00
							Total Cost	$370.25
Note: Reference designator is used in assembly drawings to "call out" parts and show where on a PCB they are to be mounted								
Note: An assembly drawing shows how to construct the product from the list of items in the BOM								