iPhone 13 with USB-C and selective slow-charging — Project Proposal

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Team 61

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Introduction

Problem

iPhones (and some other mobile Apple devices) have had the Lightning connector for almost a decade. While it has been the dream of many to have an iPhone with a USB-C connector, Apple will very likely not release iPhones with USB-C. This has multiple implications – it hinder the one-charge-for-all plan proposed by the EU to reduce e-waste, and it undermines the adoption of USB-C as a universal interface. The data transfer rate of USB-C can be significantly faster than lightning, and the power delivery of USB-C is also much more capable and universal.

Moreover, phone manufacturers have been competing for faster and faster charging speeds. Indeed, the fast-charging can lead to an improvent in user experience. However, fast-charging comes at an inevitable and significant cost to battery longevity. The faster we charge our phone batteries, the quicker its lithium cells wear out. To prevent premature battery failure from frequent fast-charging, some phone manufacturers have added an option to charge batteries at an intentionally slow rate (when reasonable, such as when charging your phone overnight). iPhones don’t have this feature, but a USB-C iPhone can achieve selective slow-charging.

Solution

The solution we provide is to modify an iPhone 13-series smartphone. The modification entails removing the lightning cable port inside the iPhone, and adding a lightning-to-USB-C converter with microcontroller which provides slow-charging functionality. And finally modify the iPhone chassis to accommodate all the electronics and to anchor a new USB-C receptacle inside the iPhone.

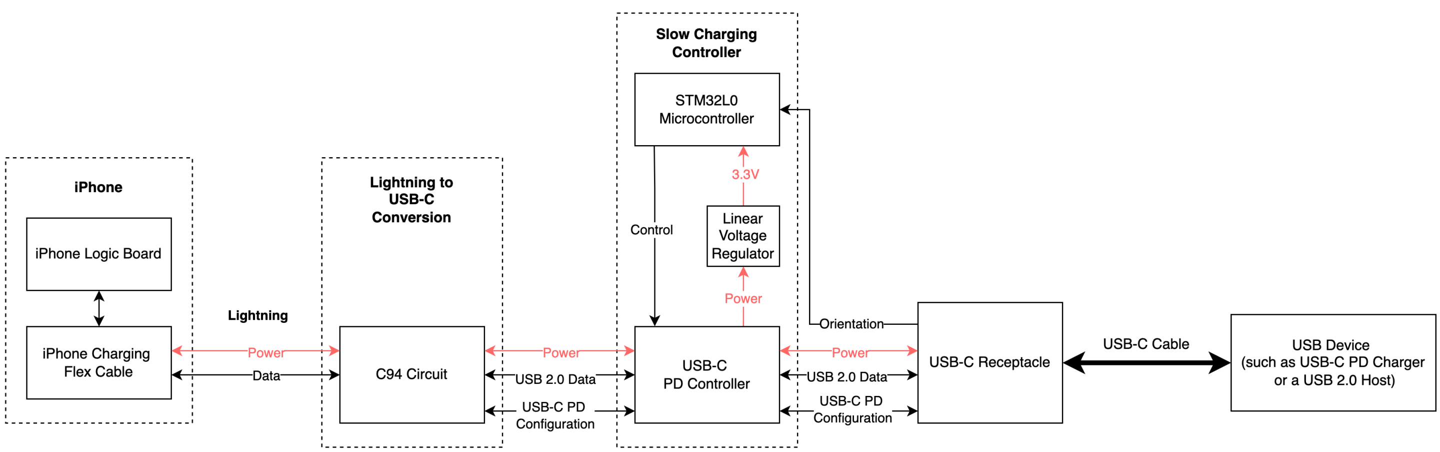
For lightning to USB-C conversion logic, we will extract and use the components from the “C94” circuit on a certified Lighting to USB-C cable, and then, we will replace the lightning port inside iPhone with USB-C receptacle. For the USB-C slow-charging functionality, we are planning to design a USB-C orientation detection logic feature as the trigger of two different charging modes. And with the slow-charging mode, we will use the USB-C Power Delivery 3.0 controller to negotiate a maximum of 5V input from the charger. All these electronics will be housed on a flexible PCB in order to make use of the limited internal space in the iPhone, right below the battery.

High-Level Requirements

- The modified iPhone must function as intended, similar to a brand-new iPhone (except for the lack of lightning connection).
- The iPhone must be able to charge at full speed (at least 18W when discharged) and send USB 2.0 data over the USB-C connection.
- The iPhone must negotiate different charging voltages when the USB-C plug's orientation changes.

Design

Block Diagram



> Note: the connections labelled as "Power" without a voltage specification may carry anywhere between 5V and 12V, depending on the negotiated `VBus` voltage as per the USB-C Power Delivery specification.

Subsystem(s)

Lightning to USB-C Conversion

Subsystem Overview

This subsystem deals with converting all lightning logic to USB-C. This subsystem uses the C94 circuit from an Apple-certified Lightning to USB-C cable, which we have to add as a black-box.

Subsystem Requirements

- The C94 logic is able to perform a successful USB-C PD negotiation via the `CC1` output.
- The C94 logic is able to perform USB 2.0 data transfer over the `D+` and `D-` output.

Slow Charging Controller

Subsystem Overview

This subsystem contains all the required circuitry to detect the orientation of the USB-C plug, and to perform a USB-C PD negotiation if necessary. Upon successful power negotiation, the incoming power is provided to the C94 logic for charging the iPhone. We have chosen the microcontroller to be a STM32L0 for its ultra-low power, small footprint and ease of use.

Subsystem Requirements

- The orientation detection logic is able to detect the difference in orientation of a standard USB-C to USB-C cable with USB-C PD support, regardless of cable's USB data specification.
- The subsystem can negotiate 5V charging with a USB-C PD charger as per the USB-C PD 3.0 specification in one of the USB-C plug orientations.
- The subsystem can negotiate 9V and 12V charging with a compatible USB-C PD charger as per the USB-C PD 3.0 specification in the other USB-C plug orientation.
- The components of this subsystem maintain a temperature under 60°C with only passive heat dissipation in a closed chassis.

- ## Tolerance Analysis

Our biggest concern is with the slow charging controller subsystem, and especially with the design of the USB-C Power Delivery controller. Depending on what voltage the C94 circuit expects on the `VBus` line prior to negotiation, we might need an additional USB-C PD controller (or an additional channel on the existing controller) to relay the information about the negotiated voltage to the C94 circuit.

Ethics and Safety

There can potentially be some electrical and heat hazards with our project since we're going to modify the charging logic inside the phone by adding our own designs. Our team will strive to ensure that we follow the IEEE Code of Ethics[1] throughout our project, and make sure the safety, health, and welfare of the device's user are held paramount. This, it is important for us to frequently inspect and test our device, to always be prepared to accept honest criticism of our work, and to acknowledge and correct errors, as stated in #5 of the IEEE Code of Ethics[1].
Since there already exists an open source project that has demonstrated the Lightning to USB-C conversion logic on an iPhone X, we will be using it as a reference when doing similar parts in our project. We shall make sure to cite the source properly to not violate #5 of IEEE Code of Ethics[1] — "... to properly credit the contributions of others."
Another source of concern could be about personal privacy, since we will be modifying the USB 2.0 data channel on the iPhone. However, we can ensure that our design would not bring any new risk of privacy breaches because we will use the components from the C94 circuit on a certified Lighting to USB-C cable. Thus #1 of the IEEE Code of Ethics[1] is upheld.

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1. Ieee.org. 2021. *IEEE Code of Ethics*. [online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 10 February 2022]. ↩ ↩ ↩ ↩