Type-C PPS (Programmable Power Supply) with Parallel Battery Management Evaluation Board

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Project Summary — The overall goal of our senior design project is to design and create a printed circuit board capable of showcasing the parallel battery management functionality of the MAX17330 chip: a proprietary fuel gauge with integrated charging and protection. As a part of our project, our group will be responsible for interconnecting the hardware and software required for our final product. Our board will take in power via a type C programmable power supply (PPS), go through a type-C detection chip for safety(MAX 77958), followed by a switched capacitor (MAX77932) or DC-DC buck converter (MAX77976) as a form of voltage division. Then, the system will divide between two MAX17330 chips, each powering their own battery. The overall unit will be controlled by a microcontroller which will communicate with an LCD, which will be responsible for displaying the power flow from type-C port and batteries to system load.

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1 Need for this Project

Overall the goal of our project–as with most in the engineering field–is to satisfy our client: Analog Devices. As described in the project summary, our board will handle parallel battery management while taking in a type C PPS. The circuit board we create will ultimately be utilized by ADI in trade shows and customer technology demonstrations. With our board, ADI will be able to showcase the MAX17330 chip and all of its capabilities in an isolated setting. Many times in trade shows, companies like ADI have boards that populate dozens of components on them. In these cases, it is harder for consumers to see the true performance of single desired chips. Our board will solve this problem. After our project is complete, ADI will have the ability to exhibit the MAX17330 chip in separated segments. For a complex chip like the MAX17330, a board, like the one we will create, is necessary to demonstrate its complete functionality. One by one, ADI can demonstrate the chip's main functions: charging, protection, and updating the fuel gauge. Furthermore, the following battery charging features can be portrayed to potential clients: AccuCharge, battery charger, charge timer, input current limit, and thermal regulation of the charging unit will fully be on display.

2 Problem Statement and Deliverables

For this project, our client — Analog Devices, Inc. — tasked us to design a printed circuit board (PCB) with Type-C PPS input and software to showcase the parallel battery management functionality of the MAX17330 (charger, fuel gauge, and protector for lithium ion batteries) for their technology demonstrations and trade shows.

For this project we have various deliverables, ranging from hardware to software requirements. Firstly, we have to create a PCB that can take a type-C input for charging. This input should be able to power all hardware components on the board and, ultimately, charge two batteries simultaneously. Moreover, this board should be able to hold batteries and properly connect them to the battery chargers. Next, there also must be an LCD that can display various information. Overall, the board should be able to charge the batteries, allow them to discharge, and display the required information.

For the software part of the project, we need to be able to know which battery (or batteries) are being charged/discharged, meaning we need to know the direction of current. One of the deliverables will be the ability to display this in real time on the LCD. On the same LCD we should be able to display the percentage battery capacity that has been filled on each battery so far. Designing a proper user interface will be a challenge because of the large amount of information that needs to be displayed, making it another deliverable in and of itself. Finally, the device should be able to direct all current to a non-full battery if the other battery is full, leading to a faster charging time of that last battery.

In sum, the device we will deliver will have myriad features, both hardware and software. The hardware features can be summarized by stating that the device will include a PCB that will be able to take a type-C input and charge two batteries at the same time, all the while utilizing ADI's featured chip as well as other components shown in the visualization. The software deliverables can be condensed into the following: we will display charging progress with real time updates on an LCD, as well as make sure that once a battery is full, the other battery will charge quicker.

3 Visualization

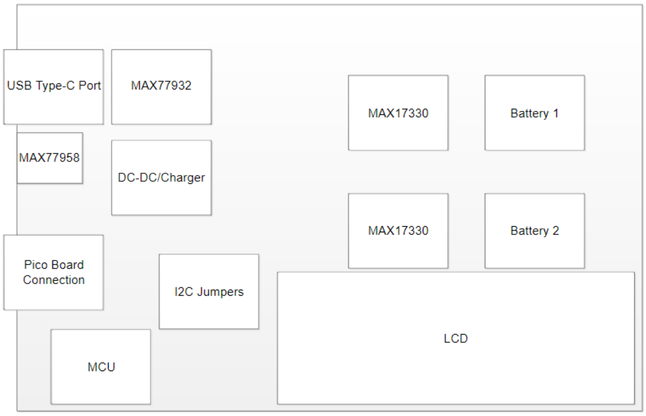

Fig 1. The above visualization of the project identifies a zoomed-out PCB layout that we will implement

We anticipate the overall board being about the size of an 8.5 by 11 inch area. However, note that the graphic is not drawn to scale. In terms of components, we anticipate an external type-C connection port to be on the top right of our board. The MAX77958 chip will then have a close proximity to the type-C port for convenience due to the physical connections that may be required between these two components. Then, directly to the right of the type C port, our group will choose to either employ the MAX77932 chip or a DC-DC charger for voltage division. As the diagram traces, to the right of the component we end up choosing, we will have the two separate systems, each with a MAX17330 chip and a battery. Finally towards the bottom of the board, we will have a liquid crystal display sized at approximately 3 by 5 inches, and a Pico board connection, I2C jumpers, and an MCU directly to the left of the LCD.

4 Competing Technologies

Although there are no direct competitors for the MAX17330 and the PCB we are developing, the concept of parallel battery charging has been researched by companies. With technology becoming smaller and more portable, battery management has become an especially relevant topic in the discussions of advancing commercial devices. Each company aims to achieve a method of efficiently charging/discharging parallel batteries of a sustainable and rechargeable system. Some prominent examples of battery technologies that are similar to the ones in our senior design project are Texas Instruments' BQ25960 board and Infineon's CYPD3177 board.

Texas Instruments BQ25960 Switched Cap Parallel Battery Charger Evaluation Board

TI's BQ25960 bears many similarities with the MAX17330 chip that we aim to use in our PCB. The BQ25690 is a parallel battery charger that uses a switch capacitor in its architecture to charge a single-cell Li-ion battery. The chip has protective features to prevent overvoltage and overcurrent from the input and output. It also has the temperature sensing capabilities that allows it to accurately measure how much heat is being emitted from the battery and input cable. This chip efficiently enables to charge parallel batteries with up to 8A, but requires a smart wall adapter with USB Power Delivery Programmable Power Supply (PPS) specifications in order to achieve any real world application.

Infineon CYPD3177 USB Type-C™ Power Management Evaluation Board

The CYPD3177 USB Type-C Power Management Evaluation Board is a PCB from Infineon that is used in order to recharge any consumer rechargeable electronics with a USB type-C power adapter. This board is used to provide a method of charging that enables its users to successfully connect any device that is powered by a barrel connector. The firmware within the chips of the board are able to convert the power drawn by the USB type-C to an acceptable level that can be stored. A few external components are necessary for any engineering application, but no firmware development is required from the user.

5 Engineering Requirements

The requirements specified for the engineering of the type-C PPS parallel battery management board for ADI include functions, objectives, and specifications as follows:

Functions

1. Parallel Battery Management
   a. Manage initialization of gauge and alerts for parallel battery charging
   b. Manage when to request increase or decrease voltage from switch cap (at a frequency of at least 1hz, updates every one second)
   c. Report state of each battery to display
   d. Each battery charged is a single-cell lithium battery and has a nominal voltage of 3.7V and a capacity between 2000 and 3500 mAh
2. Display
   a. Receive data such as power levels, current, and voltage from battery and power systems
   b. Display power flow from type-C port, batteries and to system load
3. PPS Negotiation
   a. Interface with MAX77958 to detect available power on type-C port and set adapter voltage to appropriate levels
   b. Compliant with USB type-C Version 1.3 and PD 3.0. PD 3.0 max voltage is 20V with max current 5A, (100W max)
   c. Respond to voltage adjustments from battery charger

Objectives

1. Report clear, accurate current and voltage readings gained from chips to LCD (+- 7.5mV reading for ADC, 78.125uV ADC res, and +-1% of current measurement gain error, charge voltage accuracy +7.5mV at room temperature 25 degrees Celsius, and 58.80mm W x 35.28mm H LCD screen with 20 Hz refresh rate)
2. Cableless design (except for USB type-C input)
3. Use ADI chips for DC-DC converter/charger, (1 cell lithium battery nominal 3.7V, be able to convert voltage above 3.7V to 3.7V), USB type-C power delivery controller, and switch-capacitor converter
4. Software automatically controls components from onboard MCU
5. Portable (weighs less than 5 pounds without batteries connected and is a single unit)

Constraints

1. Time
   a. Fabrication and assembly of PCB takes ~5 weeks
   b. Shipping of EV kits and parts take up to a week
2. USB type-C PPS protocols (has to be compliant with USB type-C Version 1.3 and PD 3.0. PD 3.0 max voltage is 20V with max current 5A, (100W max)
3. Must use either a buck converter or a switched cap which will be the MAX77932 or MAX77976, respectively (these are also ADI chips)
   a. MAX77932 dual phased switched capacitor converter gives 8A of output current, but divides voltage by 2. Both of these values are not amenable
   b. MAX77976 input and output is much more flexible, but at expense of space, and lower efficiency compared to the switch capacitor
4. Limited MCU memory (around 32kB)
5. Cableless design
6. Unable to use I2C libraries own by ADI that facilitate communication between MCU and ICs
7. Size of PCB is limited to 8.5 x 11 inches

ACKNOWLEDGMENT

The authors wish to thank Professor Alan Pisano, Professor Osama Alshaykh, and Research Professor Michael Hirsch for their unconditional support towards the completion of this project.

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