Final Testing Report

To: Professor Pisano, Professor Osama, Professor Hirsch

From: Sunwoo Park, Antonio Alonso, Eric Cho, Harry Katsaros, David Liu

Team: Team 1 - Analog Devices

Date: 04/25/23

Subject: Final Testing Report

1.0   Equipment

- 1x USB-C power output (wall outlet)
- 2x PKCELL LP785060 3.7 V 2500mAh lithium-ion battery
- 2x Uxcell 4 Ohm 25 Watt Resistor
- 2x Battery Management IC, MAX17330
- 1x Type-C Power Delivery Controller, MAX77958
- 1x Switched-Capacitor Converter, MAX77932
- 1x Adafruit Raspberry Pi Pico
- 1x FocusLCDs 40x2 (182x33.5) LCD, C402ALBSBSW6WN33XAA
- 2x WS2812 NeoPixel Addressable LEDs
- 1x PPS-compatible wall outlet to USB-C adapter
- 1x TACKLife DM07 Handheld Smart Digital Multimeter
- 2x USB-A to micro-USB connector for data/communication
- Connection cables
    - 1x USB-C to USB-C connector
    - 7x Hook-to-hook jumper wires
    - 12x male-to-female wires
    - 2x male-to-male wires
- Analog Devices MAX77958_2s3 EV Kit GUI

2.0   Setup

1. First, before attaching any components to a power source, it is necessary to make the proper connections among the three Maxim evaluation boards in our prototype: the Type C power delivery controller, the battery management IC and the switch capacitor. For this the hook to hook cables will be needed.
2. On the MAX77958 evaluation board, connect a cable to the pin labeled "vbus" and connect the other end to the pin labeled "in" on the MAX77932.
3. Connect a cable from the "in" on the MAX77932 to the enable pin labeled "en" on the same board. This will provide the necessary operational voltage needed to trigger the functionality of the switch capacitor.

4. Continuing on the MAX77932, make a connection from the "out" pin to the "VUSB" pin on the MAX17330. Make the same connection between the MAX77932 and the second MAX17330 evaluation board in use.
5. Next, it is necessary to make the proper ground connections. Using another cable, connect the pin "GND2" on the MAX77958 to "PGND" on the MAX77932.
6. Additionally, a connection between "PGND1" on the Max77932 and "DGND" on the MAX17330 will be necessary. Make the same connection between the MAX77932 and the second MAX17330 evaluation board in use.
7. It will also be helpful to solder male pins onto the "SYSP", "SYSN", "BATTP", and "BATTN" points of both MAX17330 boards. This will make connections during testing easier.
8. On each MAX17330 board, connect a cable from the "BATTP" terminal to the positive end of the battery and the "BATTN" terminal to the negative end of the battery in use. For clarification, there should be a separate battery connected to each MAX17330 board.
9. Use a USB-C to USB-C cable to connect the input USB-C port of the MAX7758 to an external power source.
10. Using a micro USB-A to USB mini cable, connect the USB mini to the USB mini port on the IC's and connect the USB-A to an external USB port.
11. Connect "SYSP" and "SYSN" of the MAX17330 board to the positive and ground outputs respectively of the voltage source. The charging voltage upper bound is 3.6-4.8V. Do this for both MAX17330 boards.
12. Using the male-to-female wires connect LCD connections to Raspberry Pi Pico connections as follow:
    ```
    a. RS              →    GPIO 16
    b. E               →    GPIO 17
    c. D4-D7           →    GPIO 18-21
    d. VCC, LED+       →    VBUS
    e. R/W, VSS, LED-  →    GND
    ```

13. With male-to-male wires connect potentiometer pins to the Raspberry Pi as follows:
    ```
    a. VIN             →    VBUS
    b. GND             →    GND
    ```

14. With male-to-female wires connect the potentiometer to the LCD as follows:
    ```
    a. VOUT            →    VEE
    ```

Charging Setup
1. The first step needed for battery charging is to power the MAX77958. This can be done using a PPS-compatible USB-C adapter power block that is plugged into a wall outlet.
2. Next we will have to provide 2 separate connections from the VBUS and GND2 pins of the MAX77958 chip to the VIN and PGND pins of the MAX77932 respectively.
3. It is then necessary to make the proper connections to the MAX17330 chips(charger, fuel gauge, and battery protector). Two connections should be made from the OUT and PGRD1 pins of the MAX77932 to the SYSP and SYSN pins of the MAX17330 respectively.

      a. For a dual battery setup, there should be two MAX17330 chips used and connections should be made from the OUT and PGRD1 pins of the MAX77932 to the SYSP and SYSN pins of each MAX17330 chip respectively.

4. A connection should then be made from the BATTP and BATTN pins of the MAX17330 chip to the positive and negative terminals of the battery.
      a. For a dual battery setup, two sets of these connections should be made connecting each MAX17330 chip to its respective battery.

Discharging Setup

1. For discharging, connections should be made from the positive and negative terminals of the battery to the SYSP and SYSN terminals of the MAX17330
      a. For a dual battery setup, a second set of these connections should be made so that each battery is effectively connected to its respective MAX17330 chip.

2. Next a connection will have to be made from the BATTP and BATTN of the MAX17330 to each end of a 4 ohm 25 Watt resistor.
   a. For the dual battery setup, this connection should be made for the second MAX17330 board as well.

ADI Evaluation (EV) Kit GUI Setup for MAX77958

1. Launch the MAX77958_2s3 and plug in the MAX77958 via another micro-USB to USB-A cable.
2. Go to the "Device" dropdown and select "Connect." Once the window pops up with the two I2C devices for the MAX77958, press "OK."
3. Now, click on the "Command" tab and select "Set PPS Mode (0x3C)" from the dropdown. Enter the values as shown in the screenshot below:
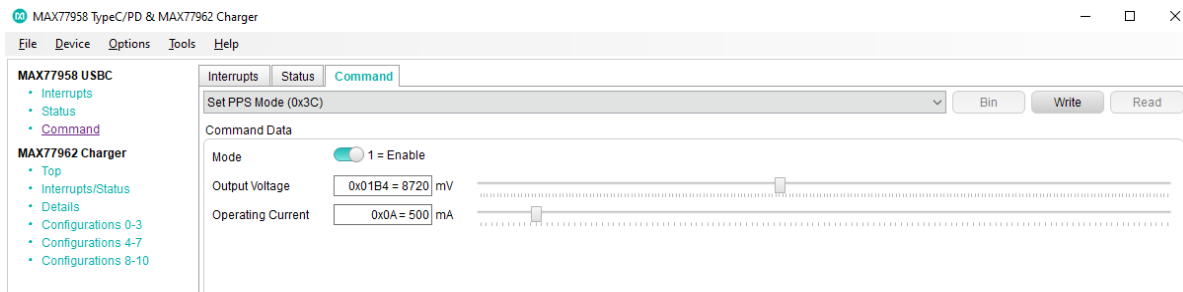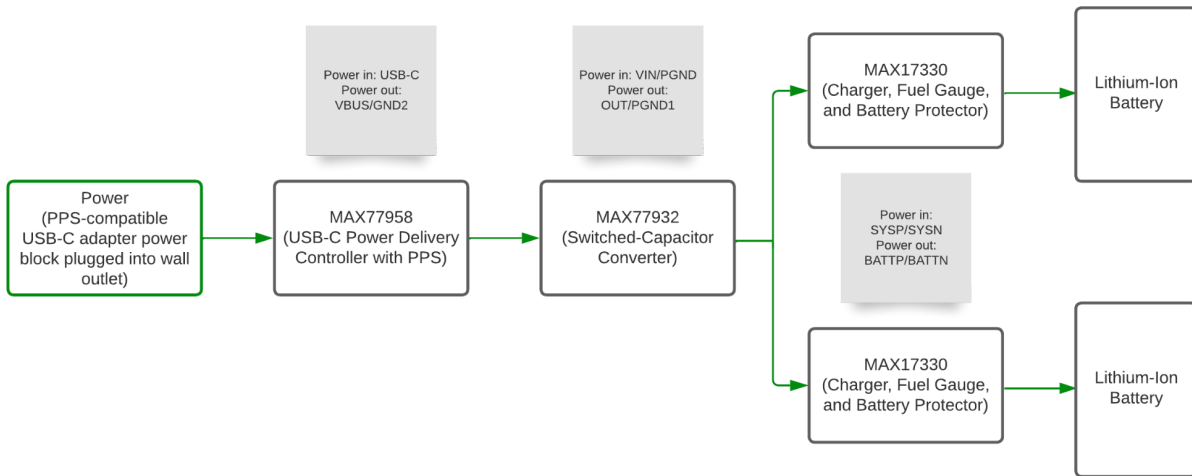

   In this step, you are setting the Programmable Power Supply (PPS) output voltage to be 8720 mV and the output current to be 500 mA. These are the values that will be outputted by the MAX77958 and inputted to the MAX77932.
4. Then, select "SrcCap APDO Request (0x3A)" from the same dropdown. Enter the values as shown in the screenshot below:
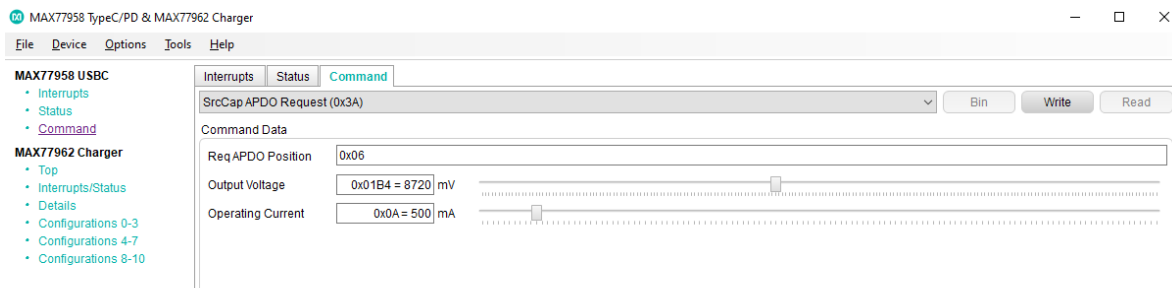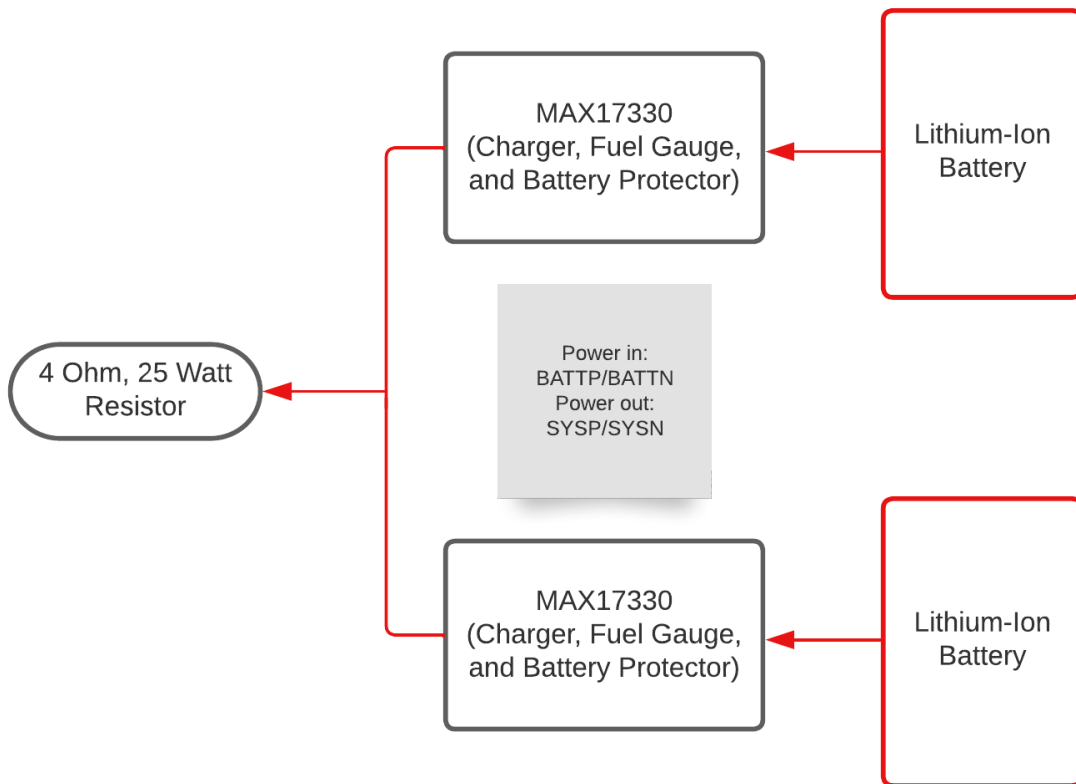

   In this step, you are setting the Augmented Power Delivery Output (APDO) to the PPS-compatible output position, which is position 0x06 for our power block. Then, you are setting the output voltage and operating current to match that of the PPS voltage from the previous step.
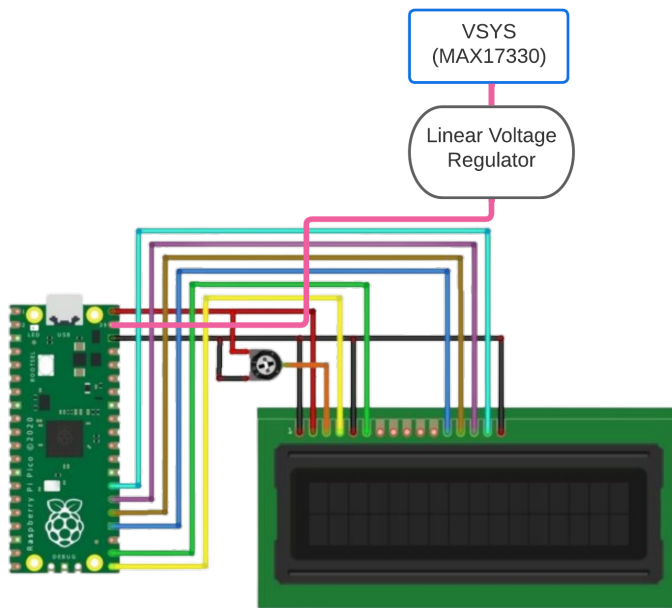5. Finally, check that the voltage output is 8720 mV by probing the "VBUS" and "GND" pins of the MAX77958 with a multimeter.

Charging Power Flow Setup

Power in: USB-C
Power out:
VBUS/GND2

Power in: VIN/PGND
Power out:
OUT/PGND1

Power
(PPS-compatible USB-C adapter power block plugged into wall outlet)

MAX77958
(USB-C Power Delivery Controller with PPS)

MAX77932
(Switched-Capacitor Converter)

MAX17330
(Charger, Fuel Gauge, and Battery Protector)

Lithium-Ion Battery

Power in:
SYSP/SYSN
Power out:
BATTP/BATTN

MAX17330
(Charger, Fuel Gauge, and Battery Protector)

Lithium-Ion Battery

Discharging Power Flow Setup

MAX17330
(Charger, Fuel Gauge, and Battery Protector)

Lithium-Ion Battery

Power in:
BATTP/BATTN
Power out:
SYSP/SYSN

4 Ohm, 25 Watt Resistor

MAX17330
(Charger, Fuel Gauge, and Battery Protector)

Lithium-Ion Battery

Raspberry Pi Pico Pin	LCD Pin	Potentiometer Pin
GPIO 16	RS	-
GPIO 17	E	-
GPIO 18-21	D4-D7	-
VBUS (5V)	VCC, LED+	VIN
GND	R/W, VSS, LED-	GND
-	VEE	VOUT

Raspberry Pi Pico and LCD Connections

3.0   Testing Steps

Charging Test

1. With only one MAX17330 connected to the MAX77932, check with the multimeter that the MAX77932 outputs around 4.3-4.4 V.
2. As soon as the connection is made between the two boards, the MAX17330 should immediately start charging its battery. Check that the LED lights under the board turn green and that the LCD displays a positive charging current through the MAX17330.
   a. Repeat this step with both MAX17330s connected to the circuit.
3. Also, check that the LCD is updating with an appropriate battery percentage and current through the MAX17330s.
4. Once verification of charging is complete, disconnect the MAX17330s from the MAX77932. When no connection is made to the MAX17330s, check that the LED lights under both boards turn white and the LCD displays approximately 0 mA of current through both boards.

Discharging Test

1. Connect one of the MAX17330s' SYSP/N pins in parallel with the 4 Ohm resistor.
2. As soon as the connection is made between the board and the resistor, the MAX17330 should immediately start discharging its battery. Check that the LED lights under the board turn red and that the LCD displays a negative discharging current through the MAX17330.
   a. Repeat steps 1 and 2 with the other MAX17330.
3. Also, check that the LCD is updating with an appropriate battery percentage and current through the MAX17330s.

5. Once verification of discharging is complete, disconnect the resistors from the MAX17330s. When no connection is made to the MAX17330s, check that the LED lights under both boards turn white and the LCD displays approximately 0 mA of current through both boards.

4.0   Measurable Criteria
- FOR CHARGING, we expect the VSYS voltage on the MAX17330 to be around 4 volts
- FOR CHARGING, we expect the charging current through the MAX17330 to be around .5 Amps
- FOR DISCHARGING, we expect the VSYS voltage on the MAX17330 to be around 3.7 volts
- FOR DISCHARGING, we expect the discharging current through the MAX17330 to be less than -0.5 Amps
- FOR PARALLEL CHARGING, we expect the VSYS voltage on the MAX17330 to be around 4 volts
- FOR PARALLEL CHARGING, we expect the charging current through the MAX17330 to be around .5 Amps
- FOR PARALLEL DISCHARGING, we expect the VSYS voltage on the MAX17330 to be around 3.7 volts
- FOR PARALLEL DISCHARGING, we expect the discharge current through the MAX17330 to be less than or equal to -.5 Amps
- We expect the LED lights to change to GREEN during charging, RED during discharging, and white when neither are occurring for the respective MAX17330s

5.0   Results

| Operation	Expected VSYS Voltage on MAX17330	Measured VSYS Voltage on MAX17330	Expected CHG/DIS Current through MAX17330	Measured CHG/DIS Current through MAX17330
Charging (8 V via MAX77958)	~4 V	4 V	~200-800 mA	792 mA
Discharging (4 Ohms via resistor)	~3.7 V	3.7 V	<-500 mA	-831 mA
Parallel Charging (8 V via MAX77958)	~4 V	4 V	~200-800 mA	748 mA, 566 mA
Parallel Discharging (4 Ohms via resistor)	~3.7 V	3.7 V	<-500 mA	-820 mA, -840 mA

| Condition to be Checked	Correct? (Y/N)
Charging (8 V via MAX77958)	Y
Discharging (4 Ohms via resistor)	Y
Parallel Charging (8 V via MAX77958)	Y
Parallel Discharging (4 Ohms via resistor)	Y
Raspberry Pi Pico Powered by Circuit	Y
LCD Powered by Raspberry Pi Pico	Y
LCD Displaying Battery SOC	Y
LCD Displaying Current through MAX17330s	Y
LED Lights Correspond to State	Y

6.0 Conclusion

- The MAX77958, MAX77932, and the MAX17330 all work as intended individually
- The MAX77958, MAX77932 work as intended when connected in series
- The two MAX17330 connected in parallel to each other in series with the MAX77932 work as intended
- There are miniscule to zero voltage drops between the evaluation kit connections meaning connections are correct and barely any static power is lost between connections
- The MAX17330 does indeed charge the lithium ion batteries because the voltage outputted from the MAX77932 and into the MAX17330 is greater than the voltage of the batteries and we verified that the charging current is positive
- Parallel charging works (positive charging current through both MAX17330s):
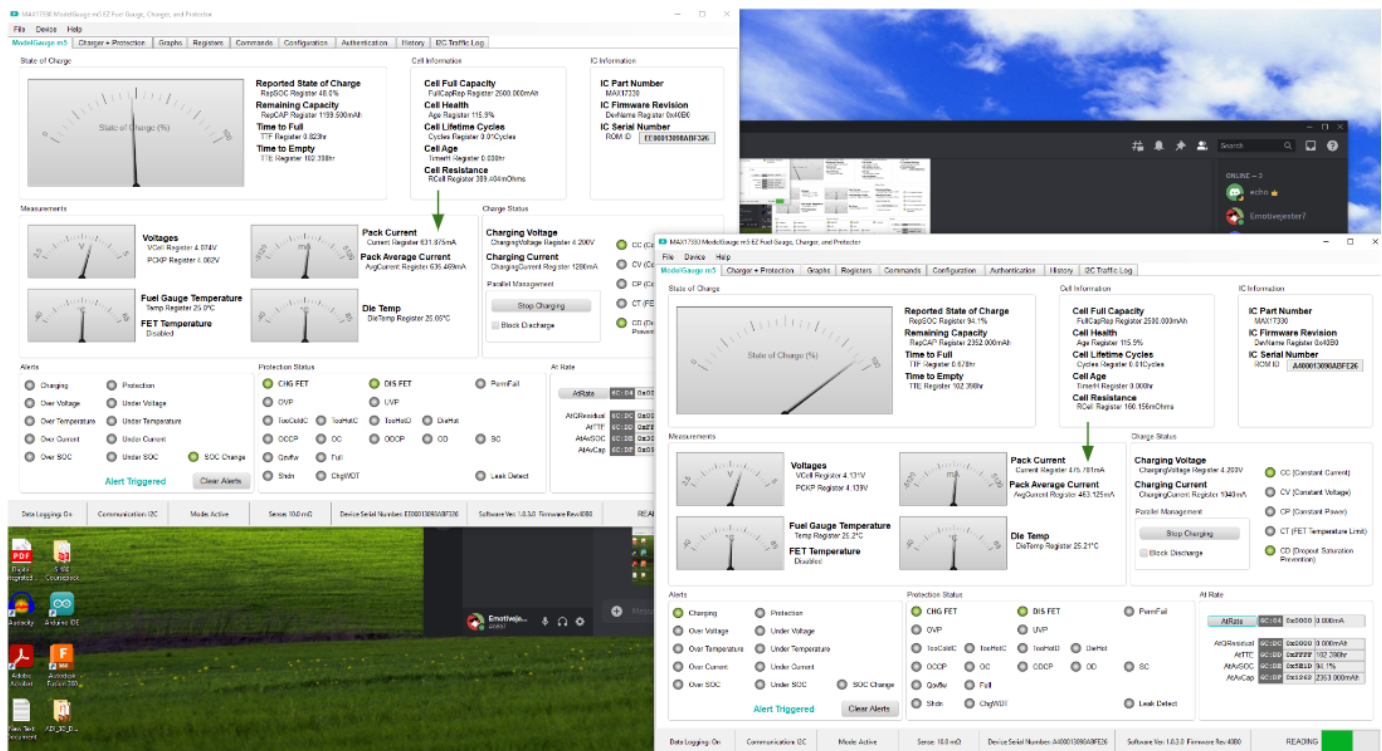
- Parallel discharging works (negative charging current through both MAX17330s):
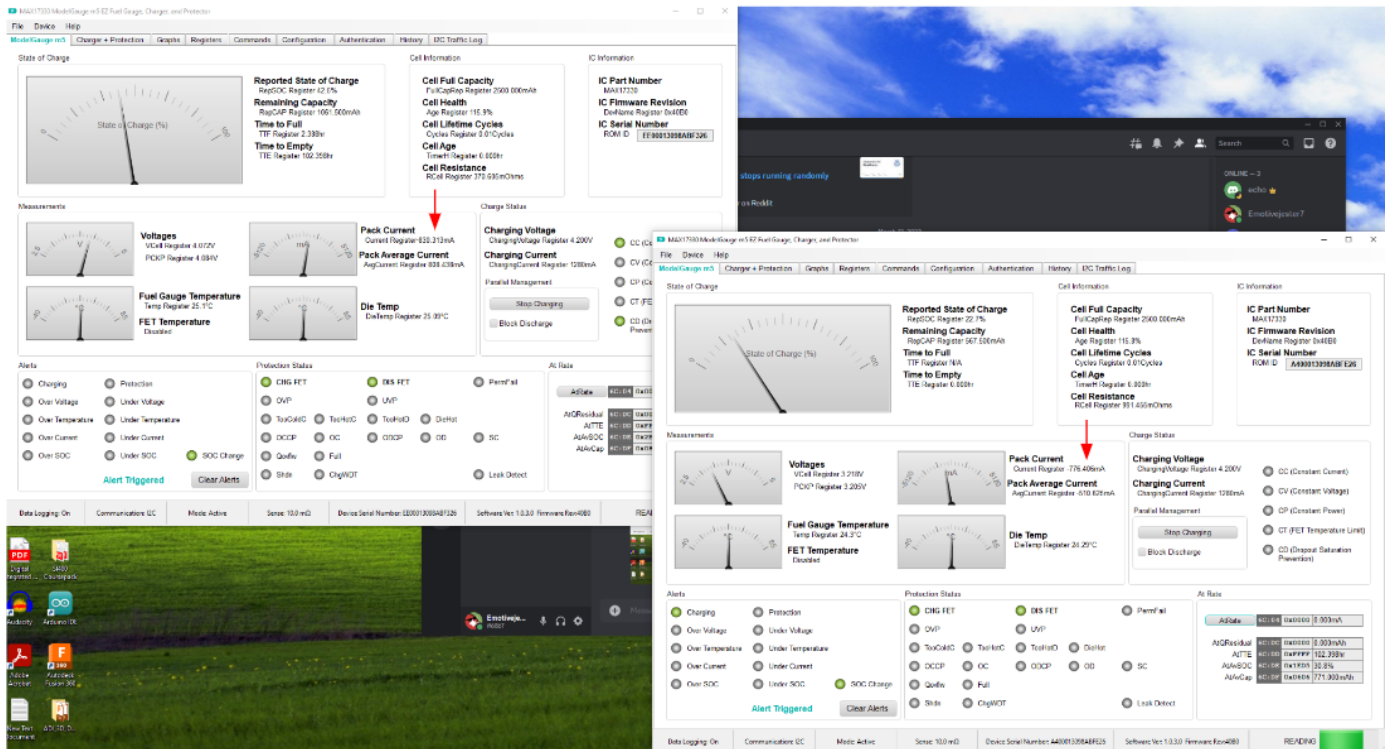
- One MAX17330 can charge (positive current) while the other can discharge (negative current) simultaneously:
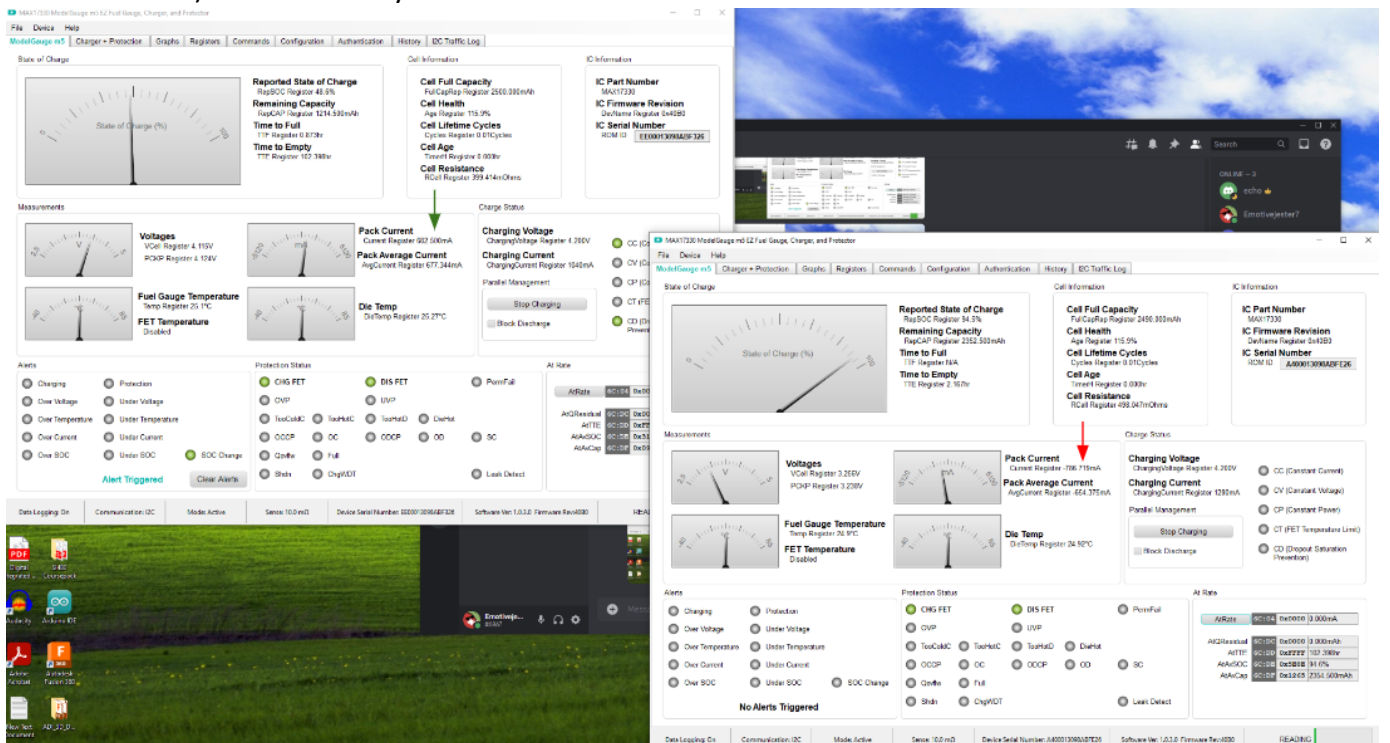
- The Raspberry Pi Pico is successfully powered by the circuit since it is able to read from the MAX17330 registers
- The LCD is successfully powered by the Raspberry Pi Pico and communicates with the Pico. Here is a video of the battery levels of one MAX17330's battery (Battery A) being updated in real time:
  - https://drive.google.com/file/d/1IRpCBSkbonDPv0UxHvafsH8YlruG9_kz/view?usp=share_link
- The LCD is successfully powered by the Raspberry Pi Pico and communicates with the Pico. Here is a video of the current through both MAX17330s being updated in real time:
  - https://drive.google.com/file/d/1Xp2rvthy9kto-PtnufVS5MQoUzmatspI/view?usp=share_link
- The LED lights under both MAX17330s change colors based on the state of the ICs. They turn green when charging, red when discharging, and white if in a neutral state (neither charging nor discharging).