2025 TEEP Progress Report Week-17

1. Description

Coming from last week's progress on stabilizing voltage measurement and protection logic, Week 16 focused on refining the core charging circuitry and improving the performance of the 3S Li-ion charger module. With the earlier research on balancing methods, charging profiles, and protection IC behavior completed, this week's goal was to move from theory and troubleshooting toward real-world integration and feature enhancement.

The work concentrated on smoothing charging current fluctuations, improving precision in the CC/CV charging stages, redesigning the hardware to ensure consistent balancing performance, and beginning the initial planning for integrating real-time charger status visualization.

Overall, this week served as a transition from low-level testing to building a more complete, reliable, and user-friendly 3S charger module.

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2. Work Done

2.1 Charging Algorithm & Firmware Optimization

- Implemented improved CC-mode current smoothing to avoid spikes during cell imbalance.
- Adjusted the transition threshold between CC (Constant Current) and CV (Constant Voltage) phases for more reliable cutoff behavior.
- Tuned PWM-based charge current control for the MOSFET driver (smoother ramp-up and ramp-down).
- Added early-stage safety checks for reverse polarity, over-voltage, and temperature faults.

2.2 Hardware Improvements

- Redesigned the resistor network used for voltage feedback into the charging controller to improve measurement precision for each cell.
- Added decoupling capacitors near the balancing IC and charging MOSFETs to stabilize current flow.
- Improved thermal dissipation layout around the MOSFET/driver area to reduce overheating during fast charging.
- Replaced weak jumper wires with thicker ones to reduce voltage drop during high-current operation.

2.3 System Integration Work

- Successfully tested synchronized charging + balancing operation for all three cells.
- Began defining the data packet structure to report:
    - Cell voltages
    - Pack voltage
    - Charging current
    - Balancing status
- Started planning communication flow for microcontroller → Flask dashboard → web interface.

2.4 Testing and Validation

- Performed long-duration charging tests (25–40 minutes) to observe current stability.
- Compared charging curves before and after algorithm adjustments.
- Verified that balancing kicks in only when cell voltage deviation exceeds defined threshold.
- Logged charge current, voltage trends, and CV-mode settling for later analysis.

3. Observations and Findings

- Current smoothing significantly reduced oscillations during the CC charging stage.
- Thermal improvements around the MOSFET area helped maintain stable current delivery.
- Balancing IC activation became more predictable after correcting feedback resistors.
- The charger module now behaves more consistently, making it suitable for dashboard visualization and logging.

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4. Challenges Faced

- Difficult to balance strong filtering with fast response — too much smoothing delayed CV-mode transition timing.
- MOSFET heating still noticeable during fast-charge mode at higher current levels.
- Small resistor-tolerance differences created variations in charge cutoff voltage.
- Timing conflicts occurred when charge monitoring and balancing updates were triggered too close together.

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5. Next Steps

5.1 Dashboard Integration

- Start building the Flask dashboard for:
    - Individual cell voltage display
    - Pack voltage
    - Charge/discharge current
    - Charging-phase indicators (CC/CV/Balancing)
- Implement real-time streaming of charger status over Serial/WiFi.

5.2 Advanced Control & Calibration

- Integrate temperature-based charging slowdown (thermal throttling).
- Add fine calibration constants for each cell feedback line.
- Store calibration and safety thresholds inside EEPROM for persistence.

5.3 Hardware Enhancements

- Move toward PCB design optimized for heat dissipation and noise reduction.
- Add precision metal-film resistors for accurate voltage sensing.
- Upgrade balancing resistor array to improve long-term reliability.
- Verify MOSFET headroom for higher-current charging profiles.

5.4 System Documentation

- Prepare block diagrams of 3S charging architecture.
- Document the CC/CV algorithm flow, protection logic, and balancing mechanism.
- Begin drafting the final experimental demonstration plan.

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6. Resources Used

- Datasheets: BMS IC, balancing IC, MOSFET driver, and charger controller
- Application notes for CC/CV charging techniques
- Tutorials on thermal management and current-control loops
- Flask backend and Chart.js dashboard references

7. Reflection

This week represented a major shift from testing individual components toward forming a complete 3S charger module. Improvements in both hardware design and firmware control logic significantly enhanced charging stability and accuracy. I also gained deeper insight into how different stages of the charging process interact and how even small hardware or algorithmic changes can affect overall charging behavior.

With strong progress on stability and control, the next focus is user interface development and final safety validation. As the charger module becomes more refined, I am now closer to delivering a fully reliable and user-friendly 3S Li-ion charging system.