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Battery cycler to generate open li-ion cell aging data and models

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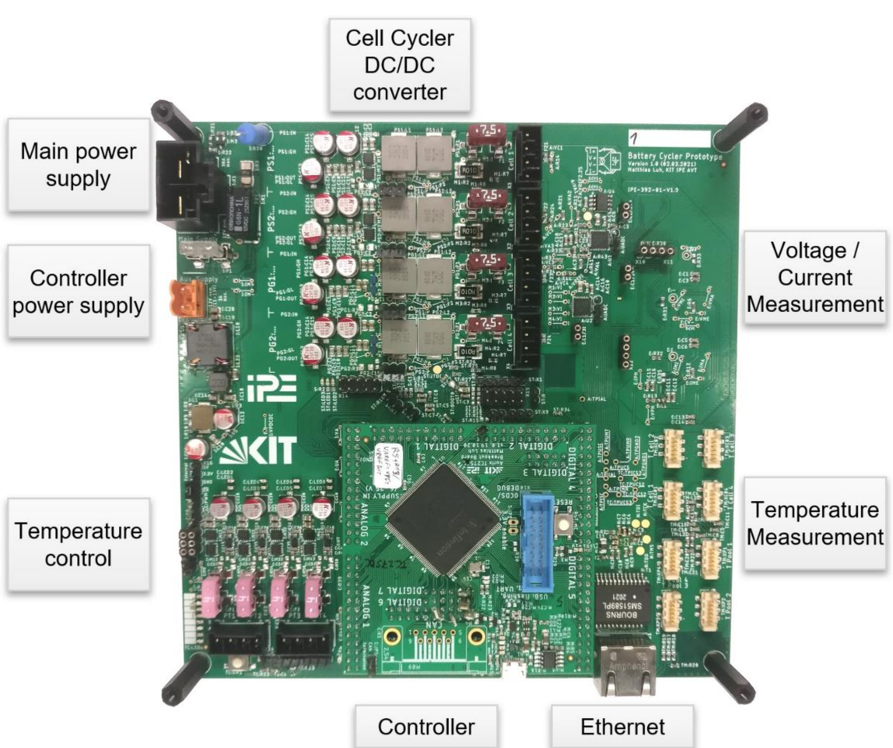
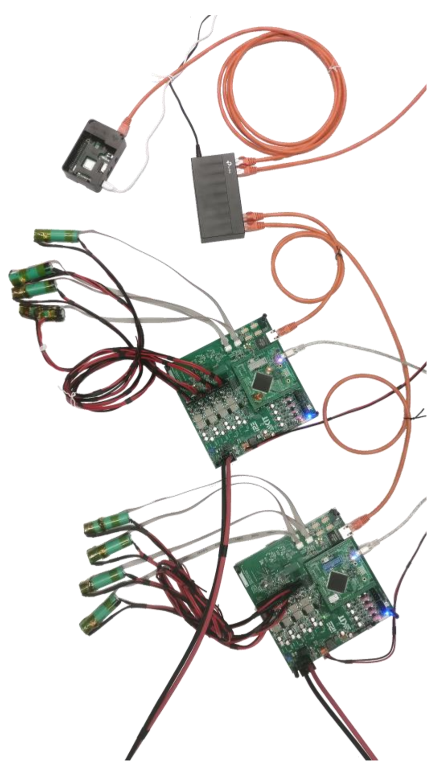
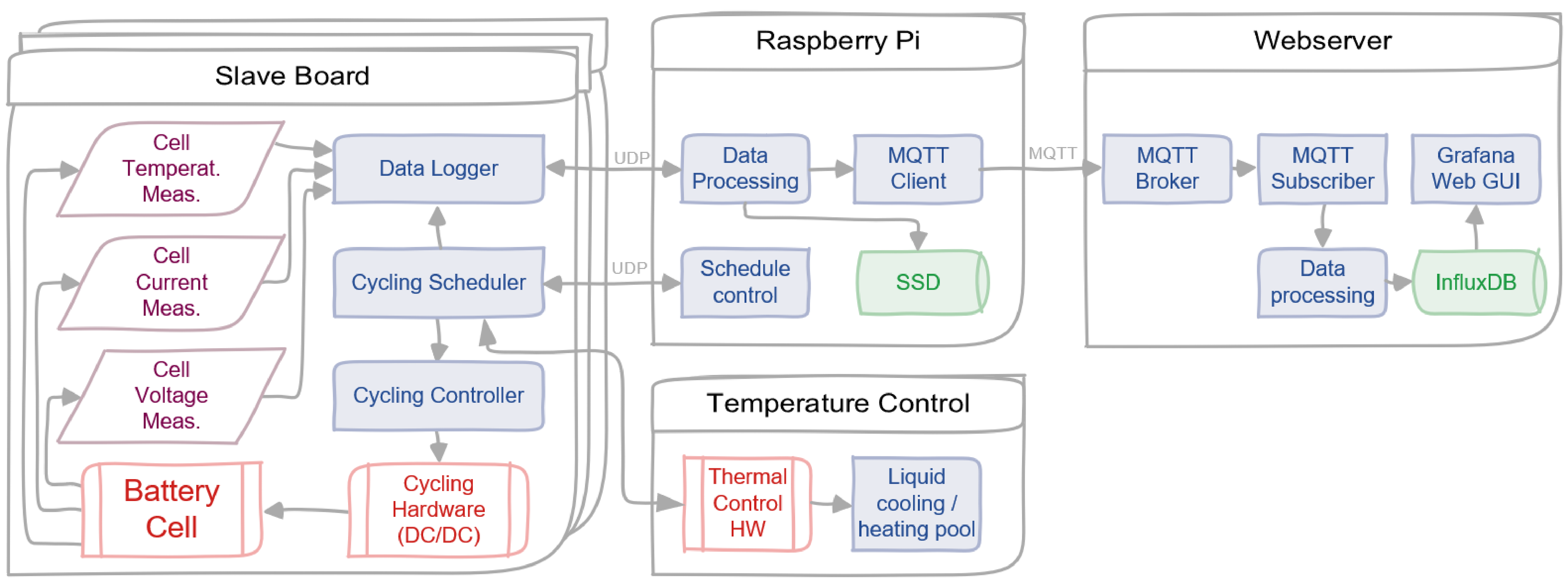
Keywords: Batteries, Lifetime, Power cycling, Battery impedance measurement, Gallium Nitride (GaN)

Motivation:

- **Batteries:** Key role in the decarbonization of the electricity and mobility sectors (EV / BESS)
- **Battery aging:** Influences lifetime, cost, environmental impact, carbon footprint of product / application
  - Aging of li-ion cells dependent on many aspects, primarily [1], [2]:
    - Cyclic aging (cell in use): temperature (T), charge/discharge limit (SoC/V), charge/discharge rate (I)
    - Calendar aging (anytime): temperature (T), State of Charge (SoC/V)
  - Modeling of battery degradation:
    - Electrochemical effects [3], [4]: complex, many unknown factors for product engineers / designers
    - Heuristic models or AI: need to perform expensive & time-consuming aging experiments
  - Issues:
    - significant challenges ➔ possible for large manufacturers, but not small businesses / research groups
    - Many cells needed for meaningful model (commercial cycler for 200+ channels: very expensive!)
    - Only few publications of comprehensive aging data (no raw data, hard to derive models) [6] - [11]
- **Our goal:** Generate comprehensive, reusable cell aging dataset & model accessible to the public
  ➔ Develop own cycler to perform the aging experiments at a fraction of the cost

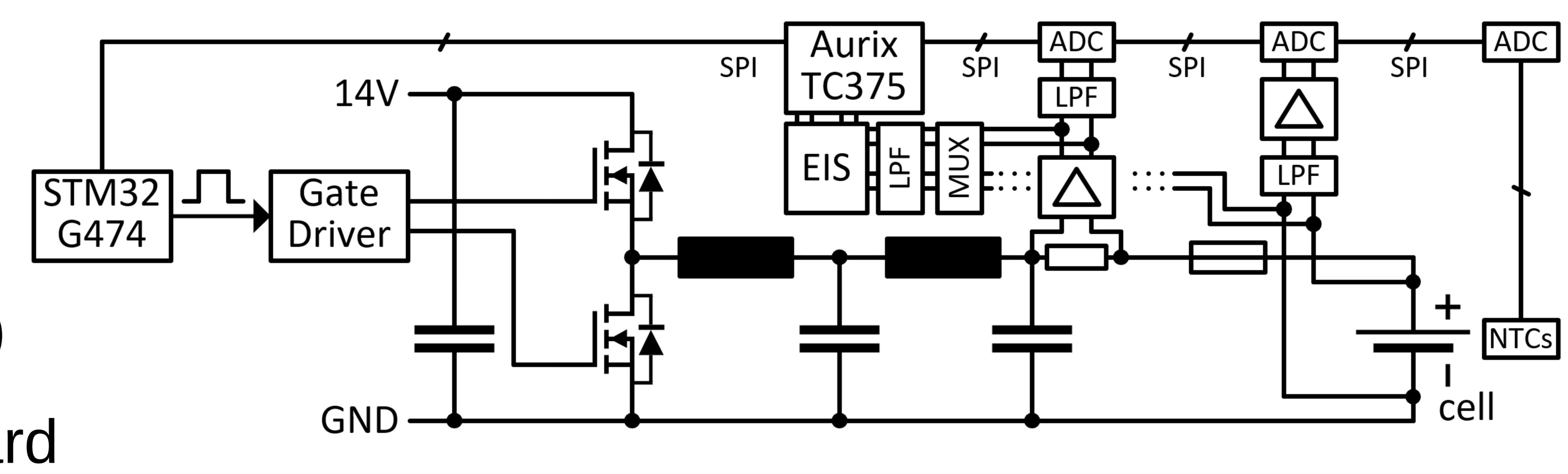






Experimental setup using the Battery Cycler Prototype Board:

- Charge / discharge 4 cells per slave with up to 4.5 V / ±7.5 A, temperature control of cells (liquid cooling / heating fluid)
- Measurement of cell voltage, current, temperature, DoD, estimated SoC (data storage: SD card, SSD, web server)
- Controller: Infineon Aurix TriCore TC375 (scheduling, control, data processing / com.), STM32G474 (HRTIM PWM)
- Final slave board: 12 cells, separate temperature control board



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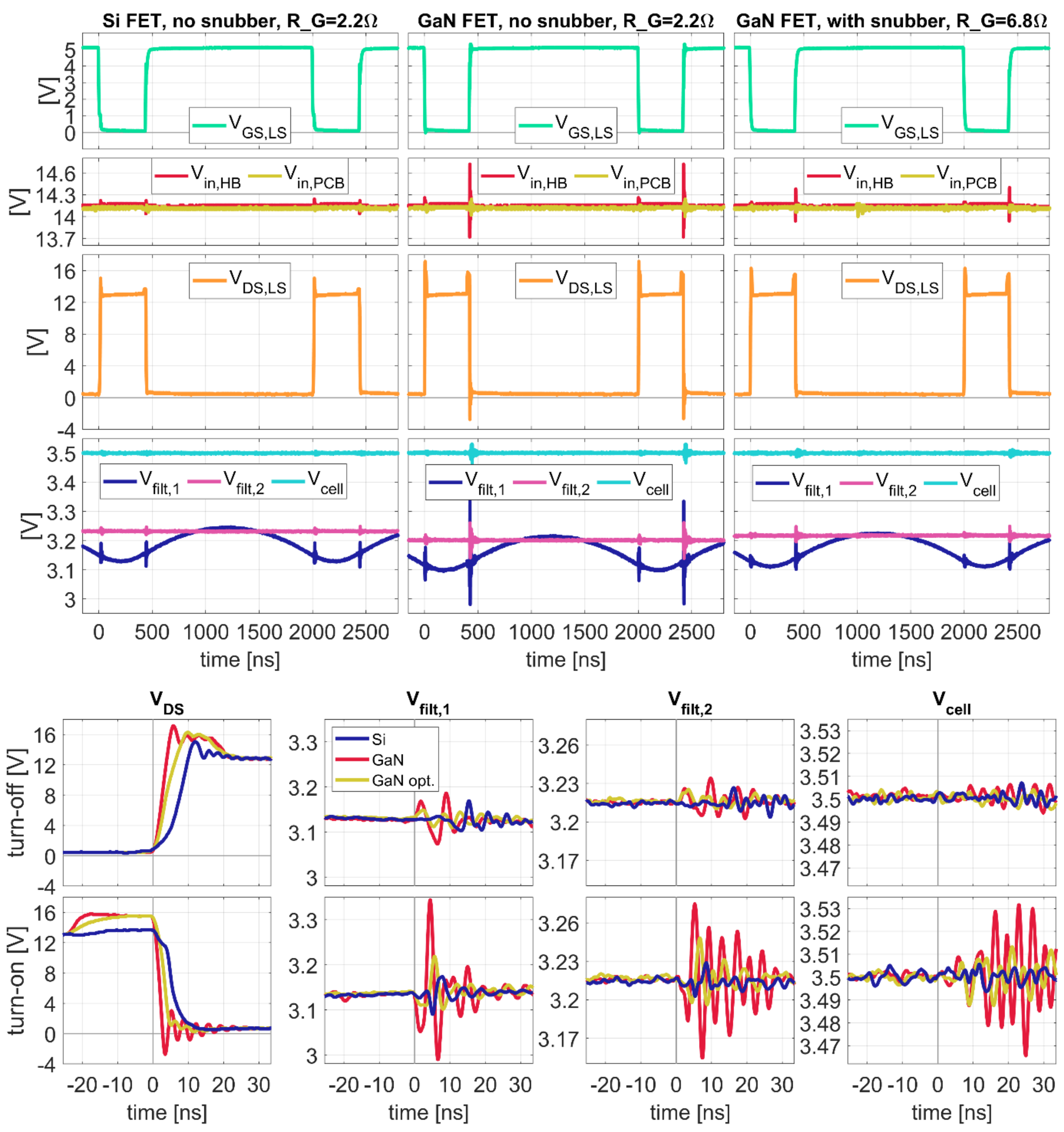
Results & Discussion:

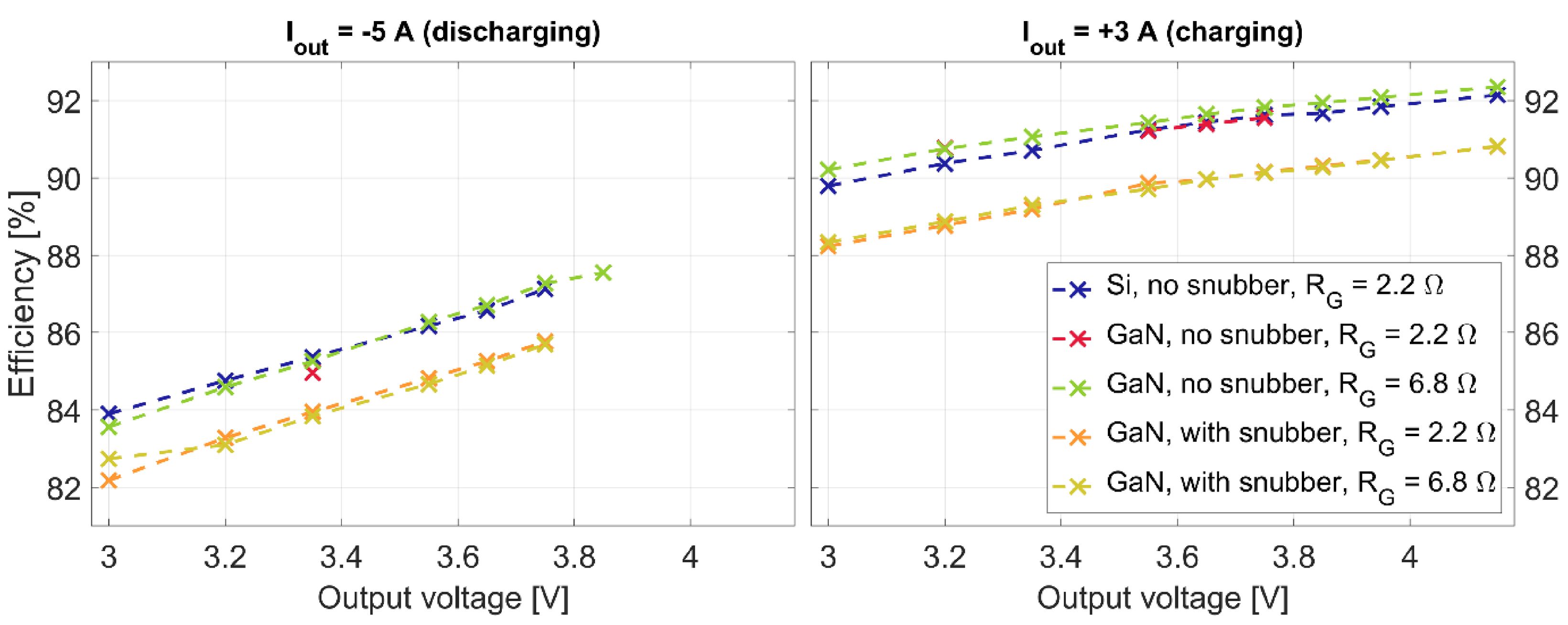
Switching behavior:

- Comparison of Si (Rohm RQ3E100BN) and GaN MOSFET (EPC Co. EPC2045) with / without snubber
- GaN: faster switching, but higher diode voltage drop, overshoot & noise (disturbs cell voltage measurement)



Efficiency:

- Comparable efficiency of Si/GaN if no snubber is used
- GaN FET needs snubber, Si does not (higher efficiency)

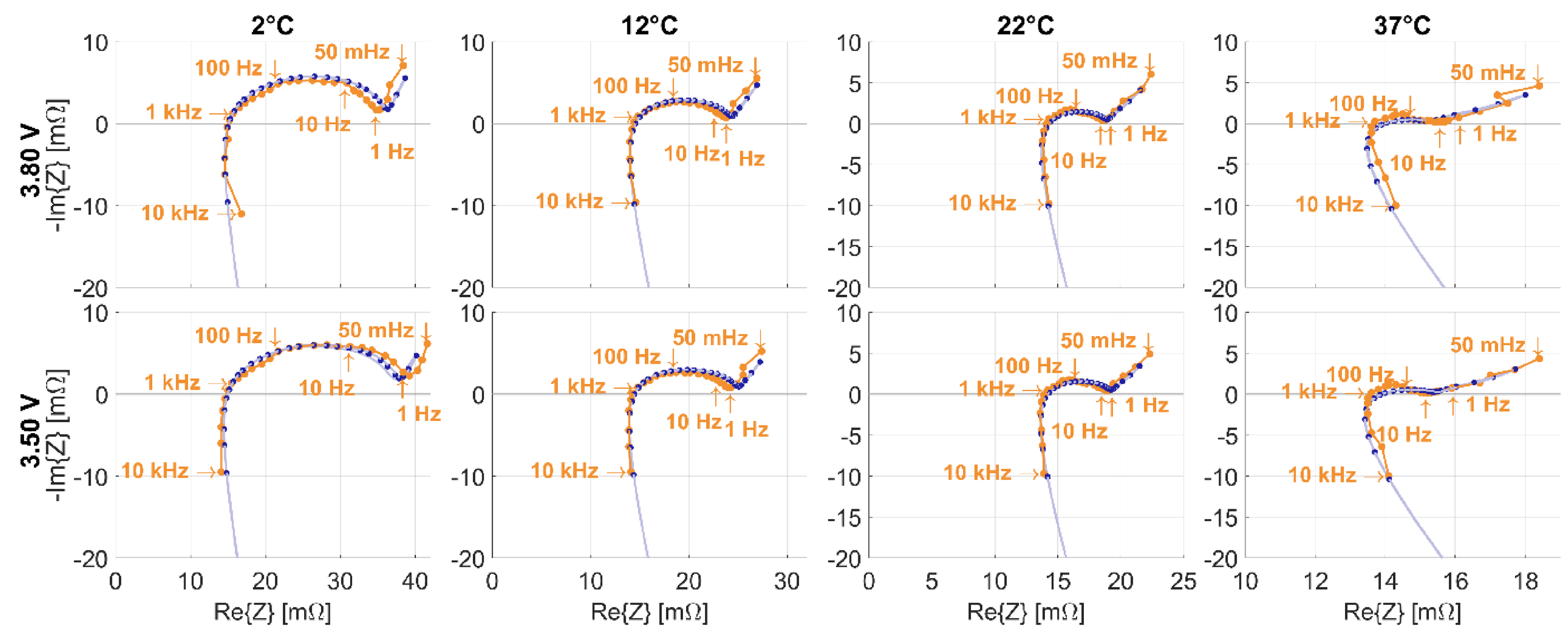


Controller performance & accuracy:

- Seamless, high-dynamic CV/CC control (steady after 4-20 ms)
- Accuracy: ca. 1.5 mV (0.044 %), 4.8 mA (0.096%)

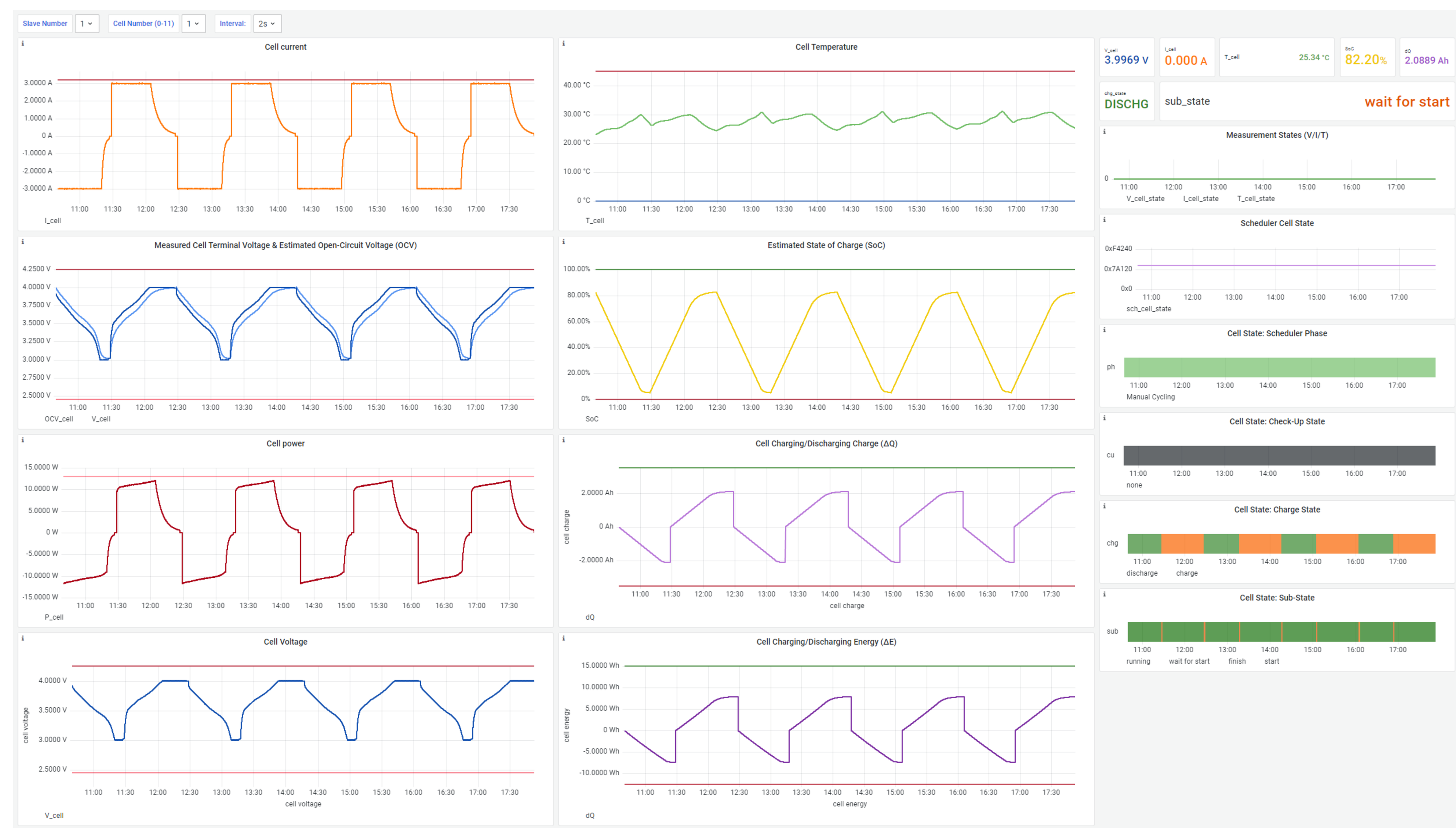
Electrochemical Impedance Spectroscopy (EIS):

- Cell is excited with sinusoidal current (typ. 200 mA - 1 A) generated by the DC/DC converter
- Amplitude measured with peak detection circuit + ADC, Phase measured with comparator & timer
- Prototype board (orange) vs. BioLogic VSP (blue) for 50 mHz - 10 kHz (avg. amp. err.: 1.54 %, ph. err.: 1.03°)
- No superior precision, but well usable (esp. for 0.2 Hz - 5 kHz)



Data Acquisition and visualization:

- Online visualization in open-source tool Grafana
- Live data analysis possible (available after 1-2 seconds)



Conclusion & Outlook:

- Battery aging is a critical aspect of lifetime, cost, and life cycle analysis of products / applications using batteries
- Lack of freely available, easily reusable li-ion cell aging data & models (which is what we want to generate)
- We presented a battery cycler prototype & are currently finalizing the setup we use in the aging experiment

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