Interference Scenarios during Single Cell Impedance Measurements in Automotive Battery Packs

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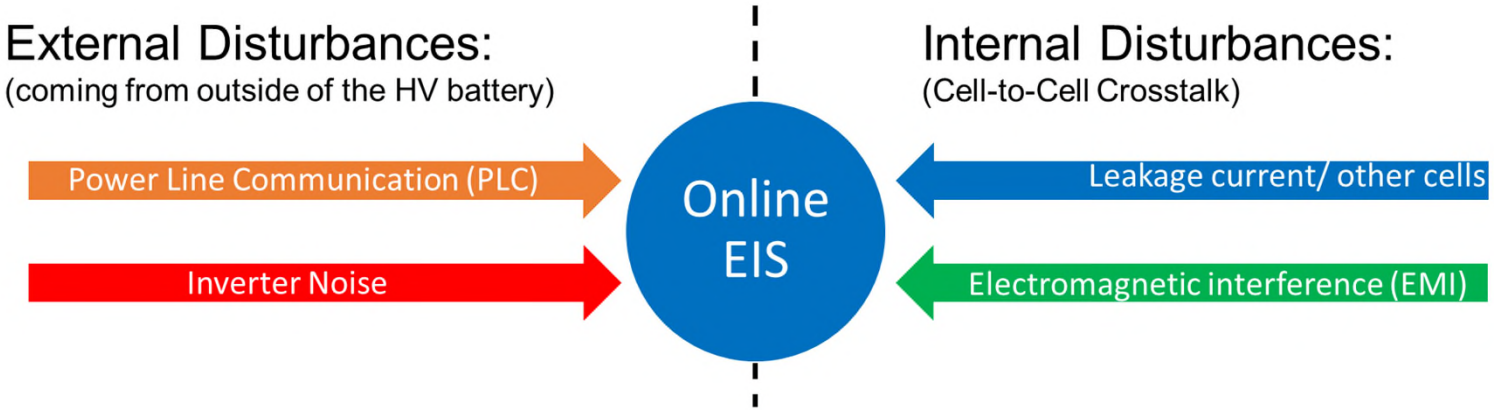
Motivation

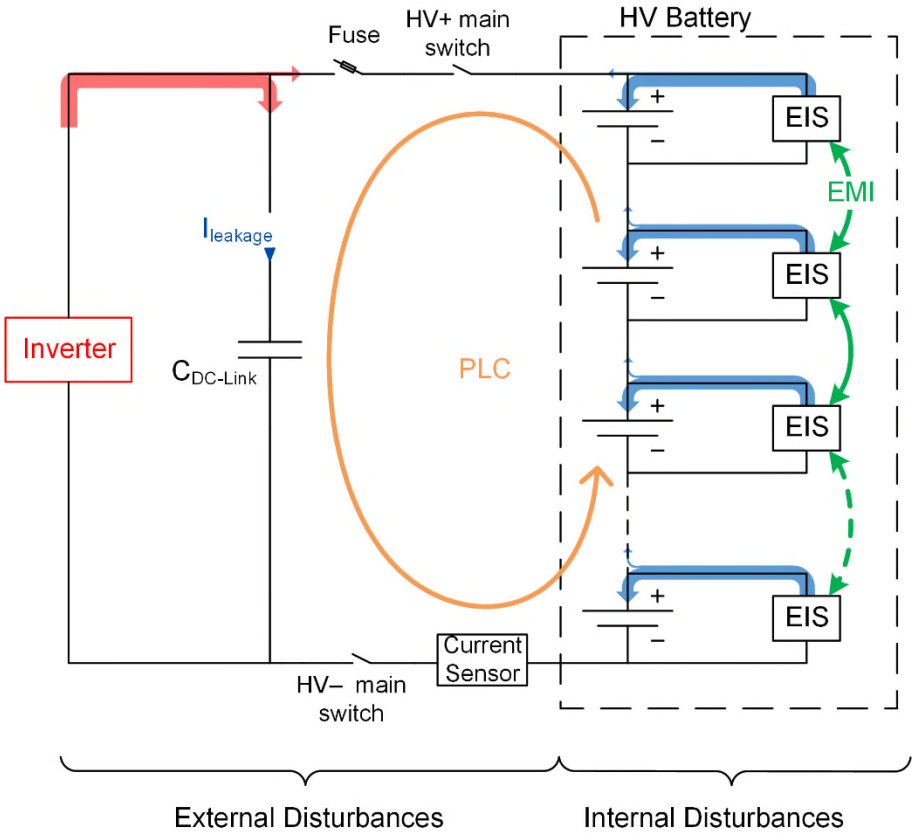
- Online Electrochemical Impedance Spectroscopy (EIS) measurements of Li-ion battery cells can be used for state estimation like inner-cell temperature, state of charge (SoC) and state of health (SoH) in electric vehicles (EVs)
- Online EIS measurements are sensitive to many disturbances:



- The impact of the disturbances (illustrated in same colors on next slide) is investigated to estimate the necessary robustness of online EIS

Overview: EIS disturbances in the electric power train

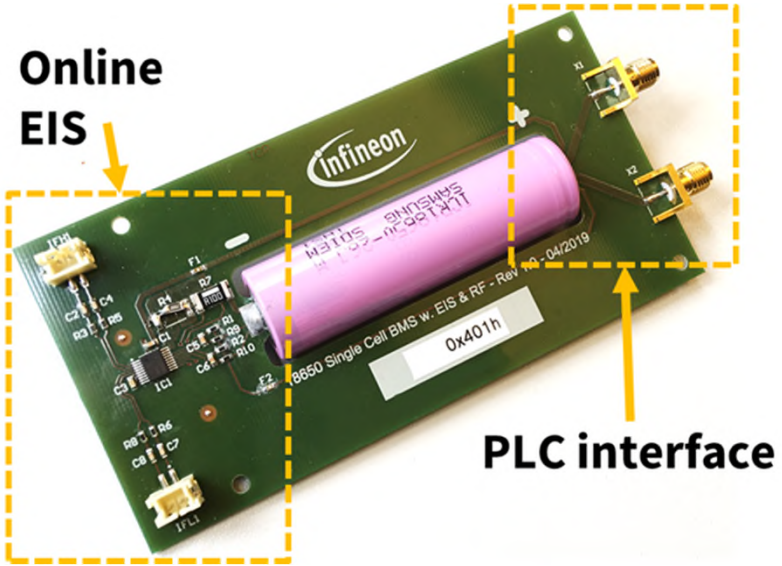
- **Internal disturbances**, occurring between cells inside of the battery pack:
  - EIS leakage current via DC-link capacitor
  - Electromagnetic interference (EMI) between cell monitoring circuits (CMCs)
- **External disturbances**, coming from outside of the battery pack:
  - Impulsive noise of load current
  - Power line communications (PLC)



Experiment 1: External Disturbances

- Evaluation Board with
  - 18650 Lithium-ion cell
  - Online EIS prototype IC by Infineon Technologies AG
  - High frequency interface for PLC and noise signals
- Feed in via high frequency interface
  - Random noise signals (**1a**)
  - PLC signals (**1b**)

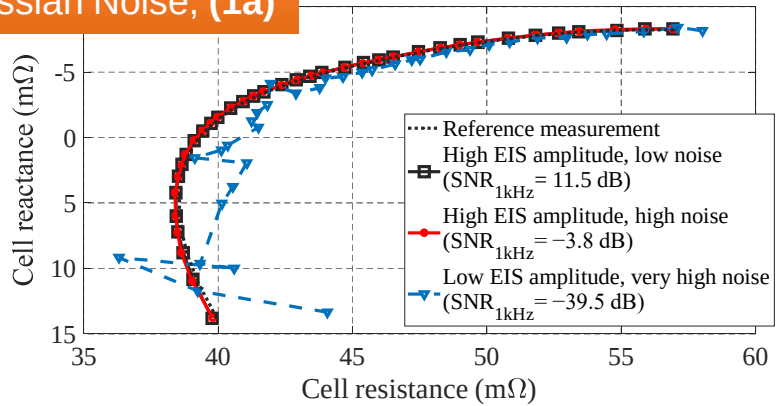
  and evaluate interference with EIS measurement

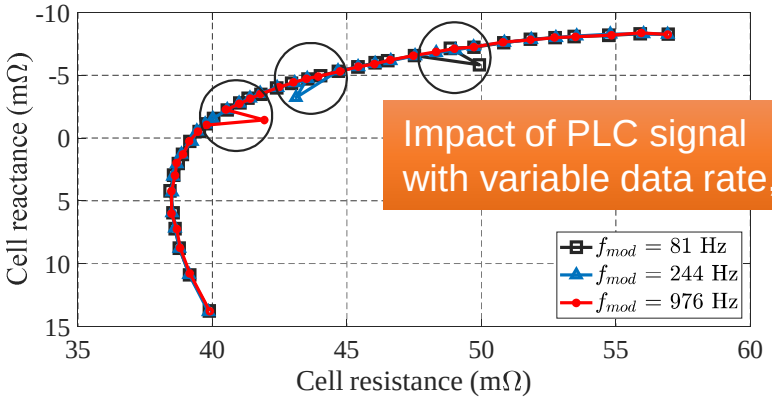


Results Experiment 1

- Noise leads to distortion of impedance result only in worst case scenario of unrealistic signal-to-noise ratio (SNR)
- Noise power can enter the cell better at higher frequencies

Impact of White Gaussian Noise, (1a)



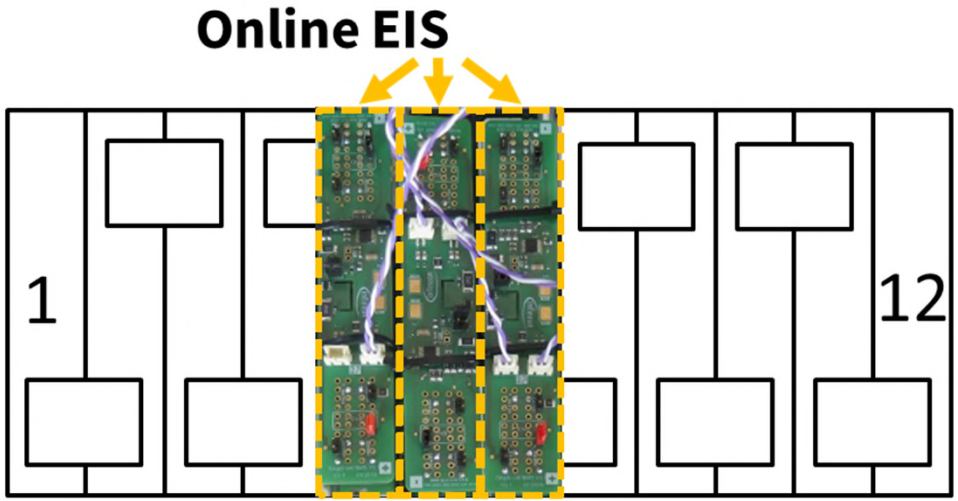


Impact of PLC signal with variable data rate, (1b)

- If the PLC data or packet rate equals an EIS frequency, narrowband distortion occurs (tested with 2-ASK)
- The EIS measurement filter bandwidth is narrow (some Hz)

Experiment 2: Internal Disturbances (Crosstalk)

- Battery module with
  - 12 prismatic Lithium-ion automotive cells
  - Three online EIS prototype ICs by Infineon Technologies AG placed onto 3 neighbor cells
- Evaluation of disturbance of
  - Radiated EMI crosstalk from neighbor cells (**2a**)
  - Leakage of EIS excitation current through DC-link capacitor current path (**2b**)

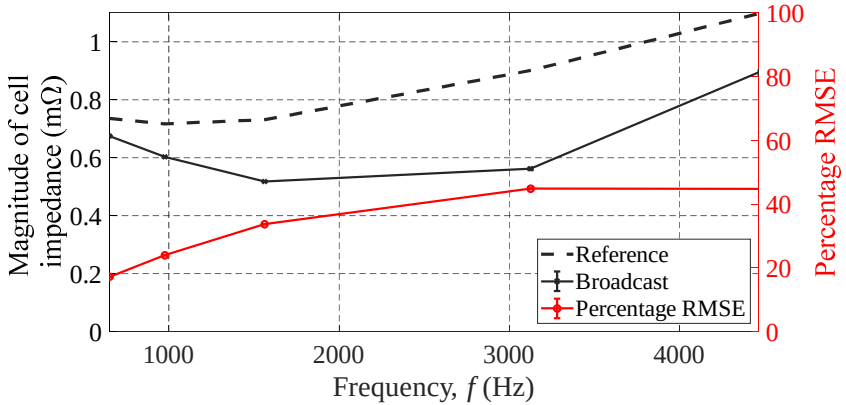


Results Experiment 2

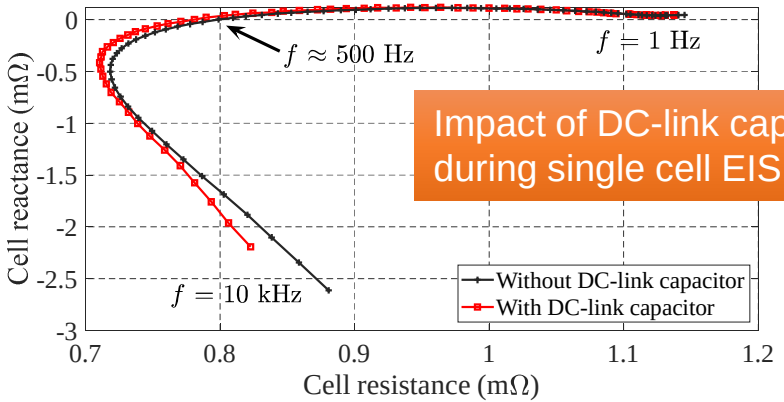
Distance between EIS-ICs	Mean value (μΩ) at 1.1 kHz	90% Confidence Level μΩ) at 1.1 kHz	Percentage RMSE at 1.1 kHz
0 (adjacent)	539.06	0.44	24.55 %
1 cell	764.94	0.38	9.09 %
2 cells	691.25	0.23	2.65 %

- Root-mean-square error (RSME) and thus crosstalk increases for higher frequencies and closer distances

Cell-to-cell EMI (crosstalk) over frequency (**2a**)

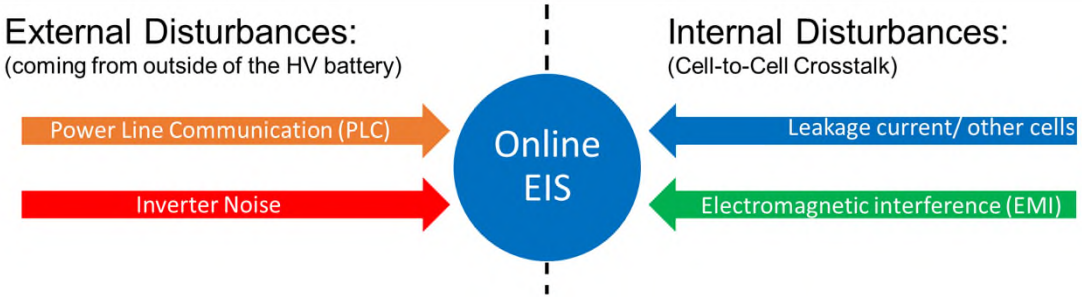


Impact of DC-link capacitor during single cell EIS (**2b**)



- Visible error in real and imaginary part of impedance for higher frequencies (> 500 Hz)
- DC-link capacitor draws non-negligible current during EIS excitation

Conclusions



(1a) Noise signals in the EIS frequency band can lead to disturbance, especially at higher frequencies (> 1 kHz).

(1b) PLC on the battery can interfere with the EIS measurement, if the data or packet rate equals an EIS measurement frequency; For lower excitation currents, the interference becomes more problematic.

(2a) The measured cell impedance is affected by EMI coming from neighbor EIS-ICs measuring at the same time. The higher the frequency and the closer the cell distance, the higher the crosstalk.

(2b) If a battery module is connected to a DC-link capacitor, a small portion (approx. 0.2 % at 1 kHz, 2% at 10 kHz) of the EIS current will not flow into the cell but rather across the DC-link, leading to distortions.

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