

# MEASURING AUXILIARY BATTERY SOH USING EIS

EVALUATION AT ROOM TEMP VS 0C

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# EIS AND SOF

## Inspiration

### Background

Main approach for determining battery SoH is capacity checks which is accurate, but invasive and damaging to the health of the battery.

### Our Position

It is possible to establish a better approach of determining the battery's state of health.

### Proposal

We can use EIS to gain additional insight on the battery's condition.



### Why this battery and what are its applications?

- 12V AGM used as an auxiliary battery in electric vehicles
- Field testing suggests minimal deep discharge cycles, operating in a shallower SoC
- Undercharge may result in sulfation and SoC, SoH, or SoF fading



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# DCS12-18AH TEST PROTOCOL

## 20% DoD Based on Customer Requirements

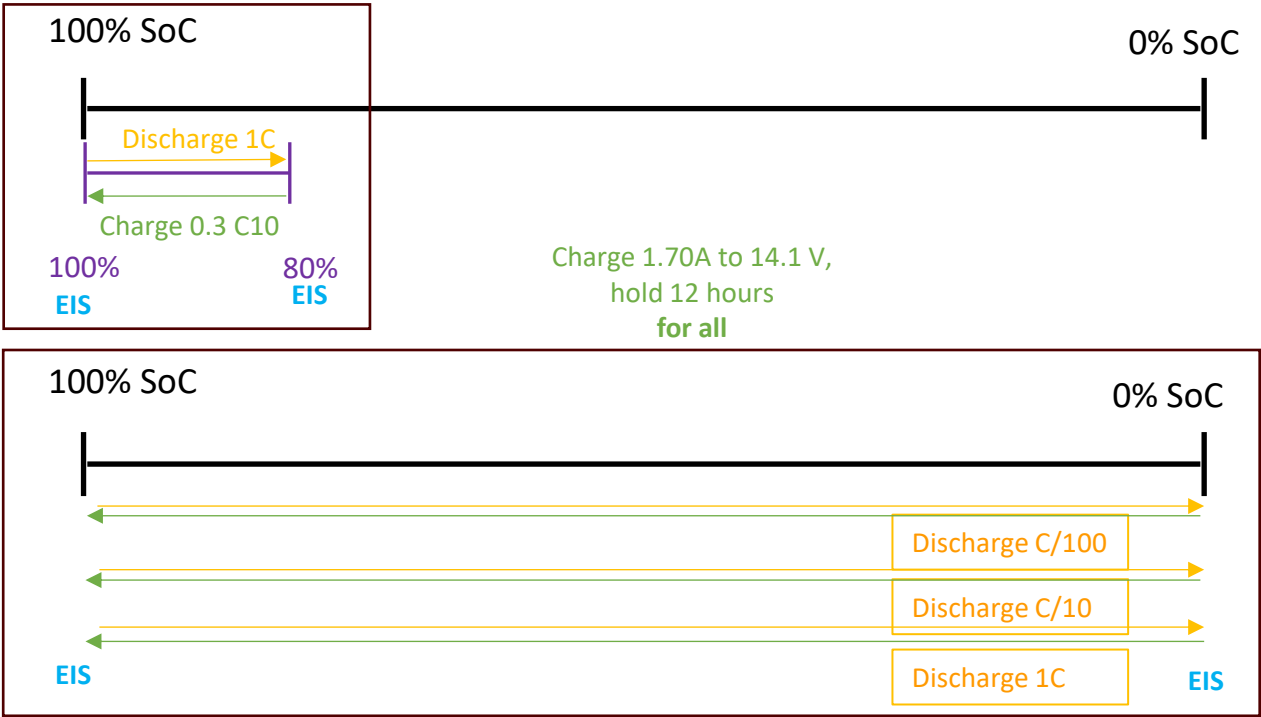


| Step | Description       | Details                                                     |
|------|-------------------|-------------------------------------------------------------|
| 1    | Boost             | CC-CV, (1.580 A) to 14.1V, hold for 16 hours                |
| 2    | Rest              | 2 hours                                                     |
| 3    | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 4    | Discharge         | CC, 1.710A for 2 hours                                      |
| 5    | Rest              | 10 minutes                                                  |
| 6    | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 7    | Charge            | I = 5.130A to 14.20, 101% chargeback                        |
| 8    | Rest              | 2 hours                                                     |
| 9    | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 10   | Loop              | Go to discharge (step 4) 99 times                           |
| 11   | Equalizing charge | CC, 0.3A, 5 hours or 15.9V                                  |
| 12   | Rest              | 2 hours                                                     |
| 13   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 14   | Loop              | Go to discharge (step 4) 1 Time                             |
| 15   | Discharge         | CC, C/100 (0.210A) to 1.75 VPC (10.5V)                      |
| 16   | Rest              | 10 minutes                                                  |
| 17   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 18   | Charge            | CC-CV, 1.70A to 14.1V, hold for 18 hours or 110% chargeback |
| 19   | Rest              | 2 hours                                                     |
| 20   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 20   | Discharge         | CC, C/10 (1.730A) to 1.75 VPC (10.5V)                       |
| 21   | Rest              | 10 minutes                                                  |
| 22   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 23   | Charge            | CC-CV, 1.70A to 14.1V, hold for 18 hours or 110% chargeback |
| 24   | Rest              | 2 hours                                                     |
| 25   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 26   | Discharge         | CC, 1C (14.340A) to 1.70 VPC (10.2V)                        |
| 27   | Rest              | 10 minutes                                                  |
| 28   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 29   | Charge            | CC-CV, 1.70A to 14.1V, hold for 18 hours or 110% chargeback |
| 30   | Rest              | 2 hours                                                     |
| 31   | EIS               | 10kHz - 50 mHz, 10 mV                                       |
| 31   | Loop              | Back to 4 24 times                                          |

### Notes:

1. Initial capacity check is performed
2. Test was performed at room temp & 0C

### 200 Times



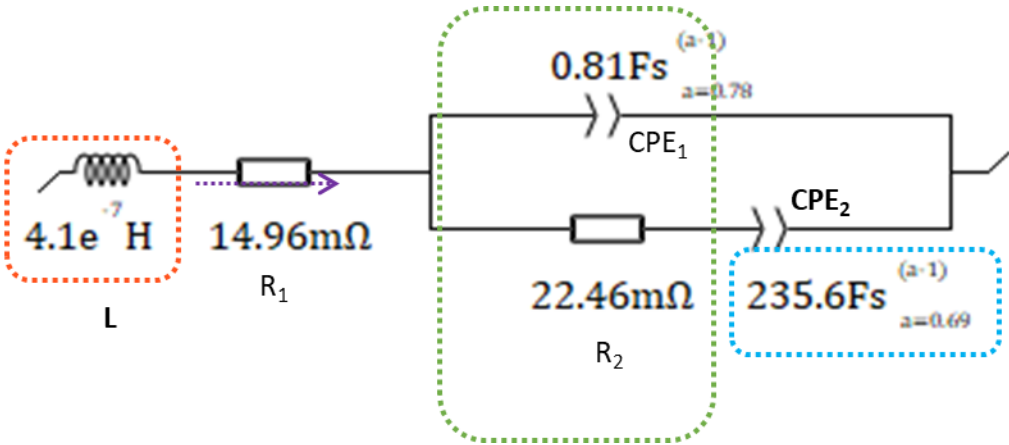
# EQUIVALENT CIRCUIT MODELING

Deep Cycle Series 18 Ah (DCS-12)



Equivalent Circuit:

$$L1 + R1 + Q1/(R2 + Q2)$$

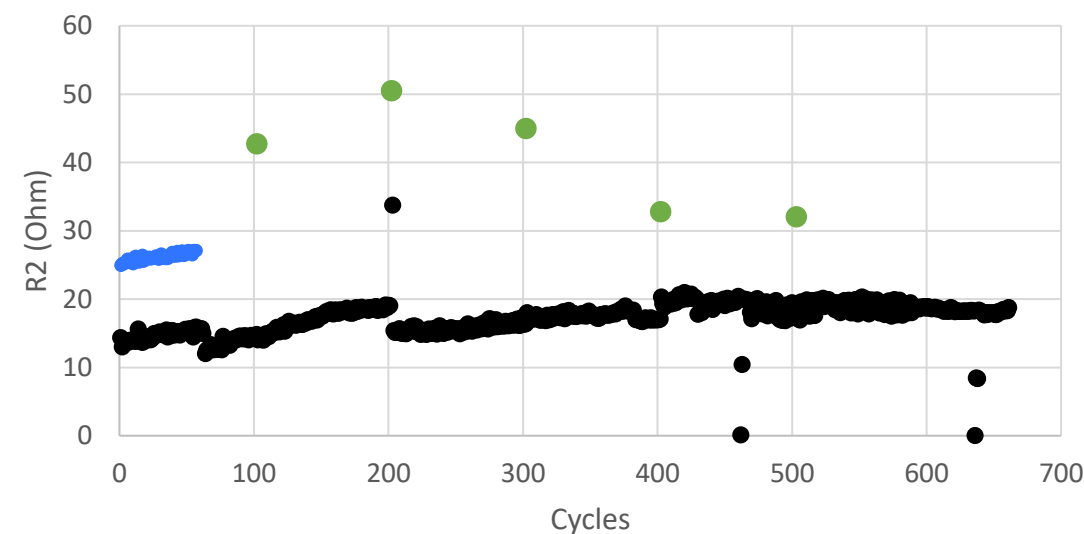
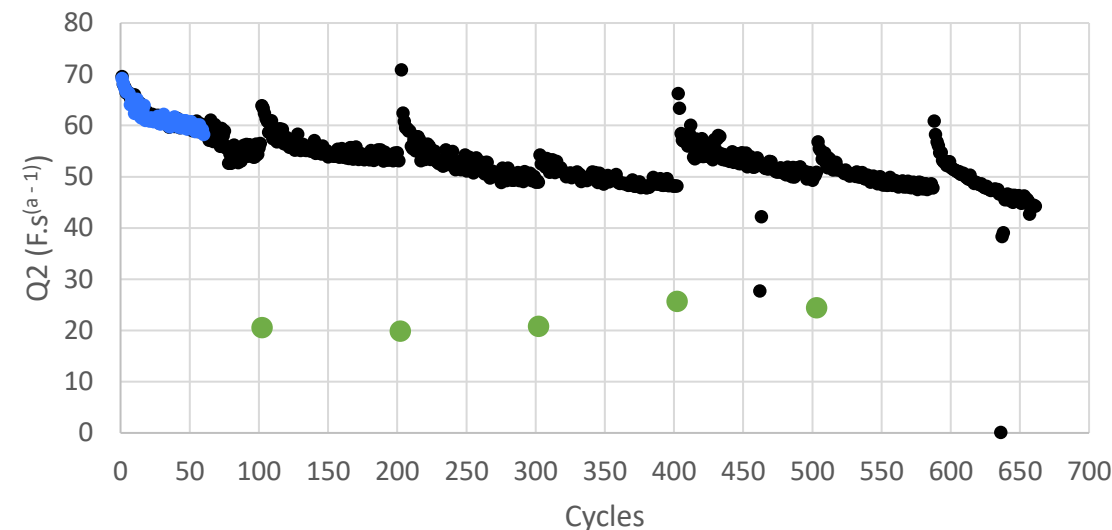
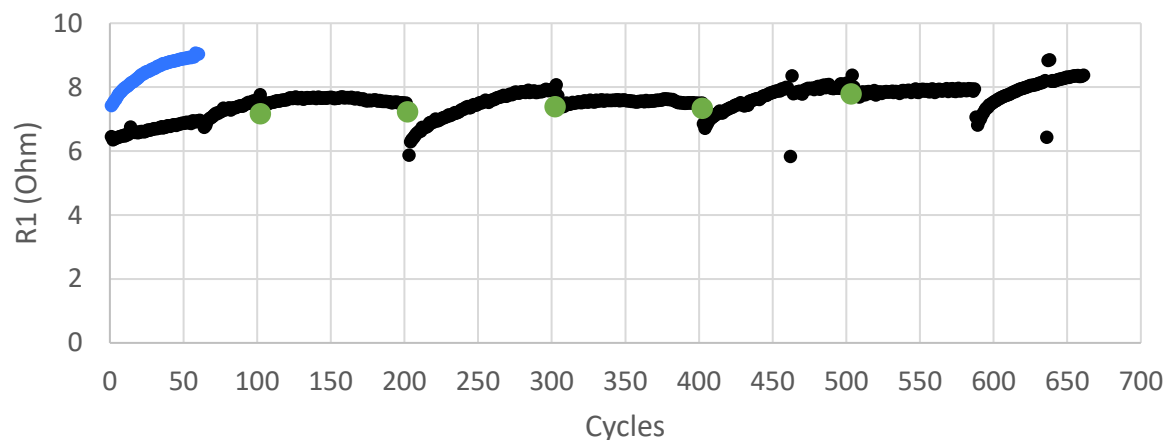
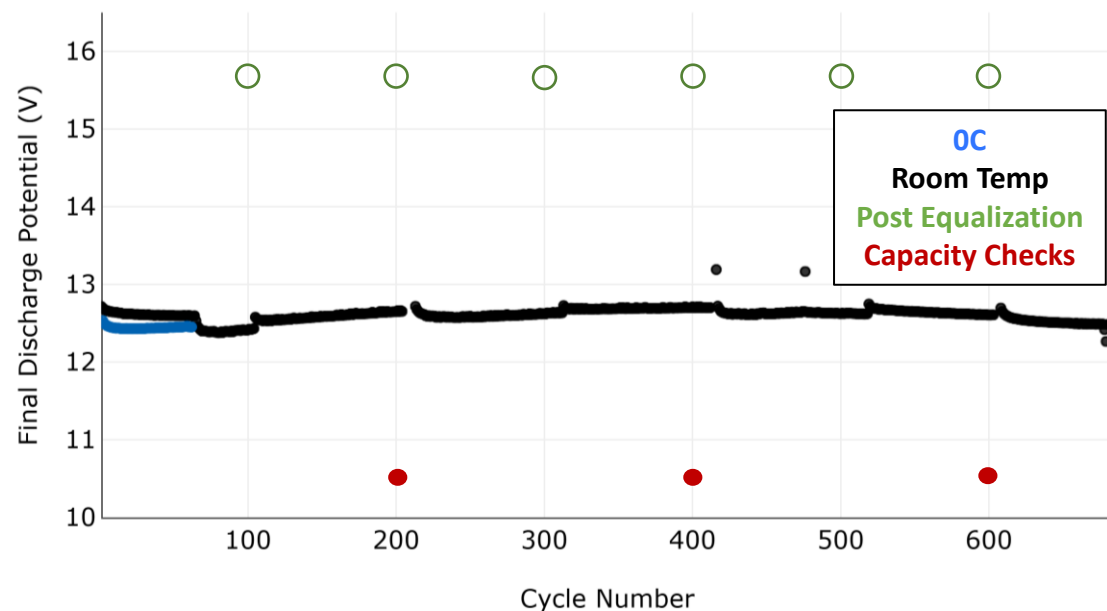


Options for EIS: **PEIS** or **GEIS**

| Parameter | Description                                                             |
|-----------|-------------------------------------------------------------------------|
| $L_1$     | Inductive artifact (wiring, leads)                                      |
| $R_1$     | High-freq. ohmic resistance (electrolyte, system, internal connections) |
| $Q_1$     | High-freq. CPE (redox reaction)                                         |
| $R_2$     | Charge-transfer resistance                                              |
| $Q_2$     | Low-freq. CPE associated with porous electrode/ double layer            |

# RELATIONSHIPS TO CYCLING DATA – 80% SOC

## Qualitative Analysis

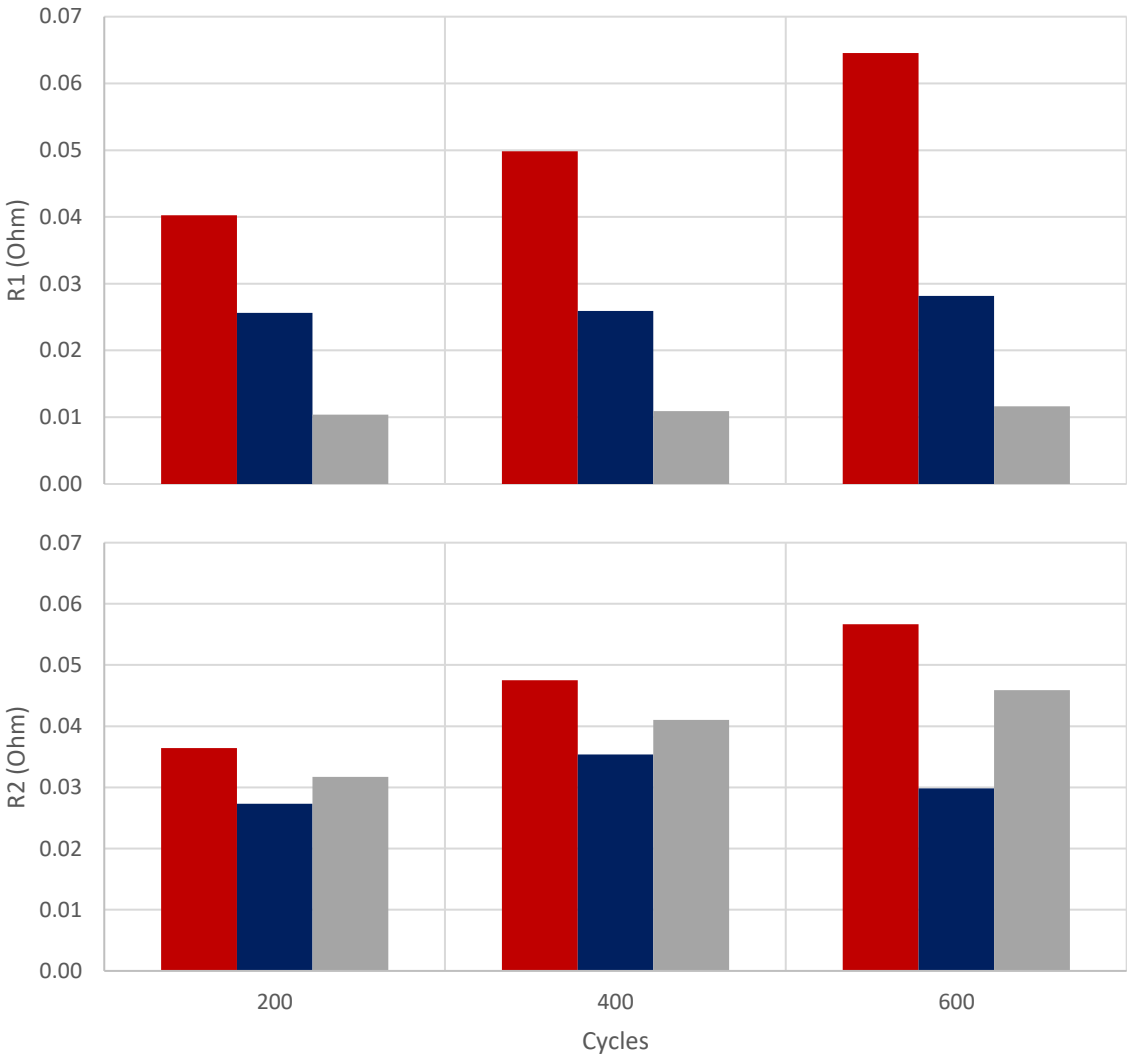
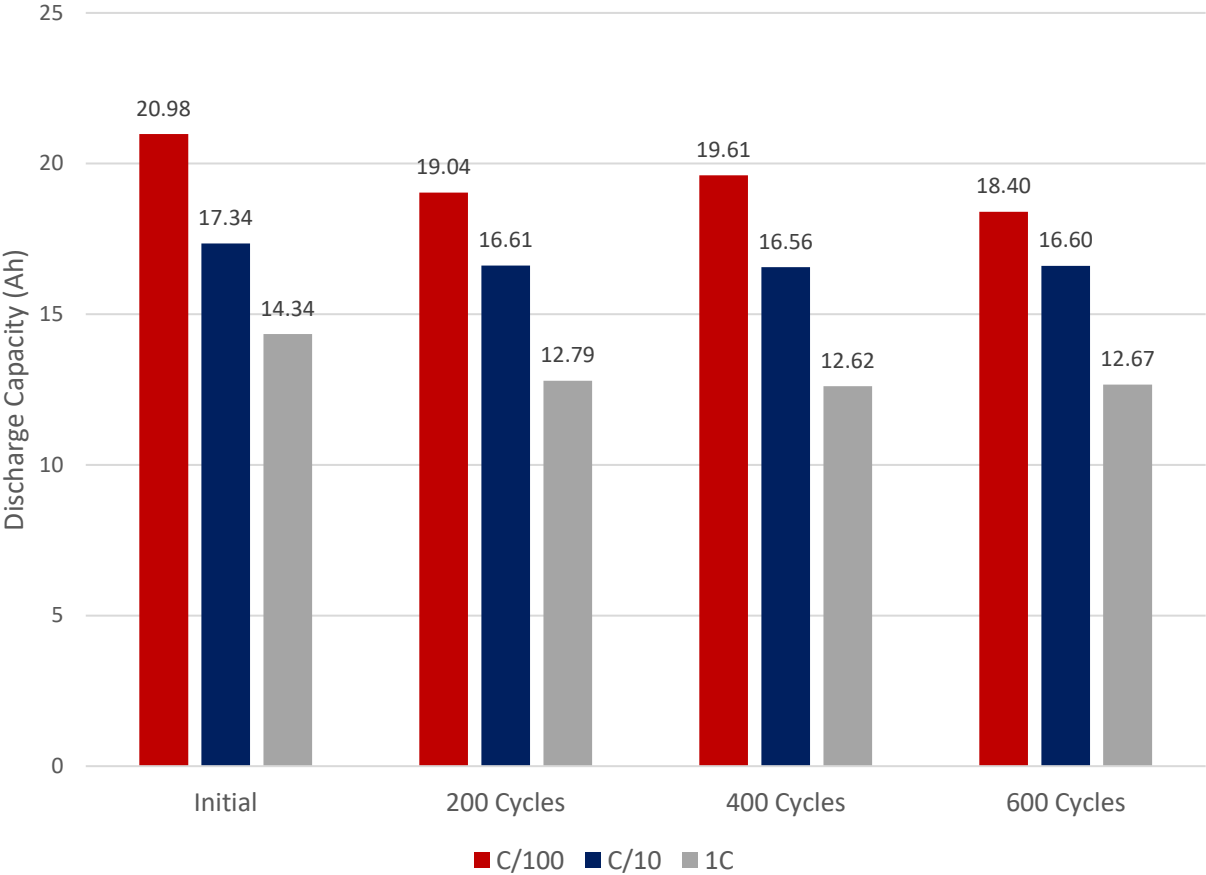


# DISCHARGE CAPACITY

C/100, C/10, and 1C Discharges

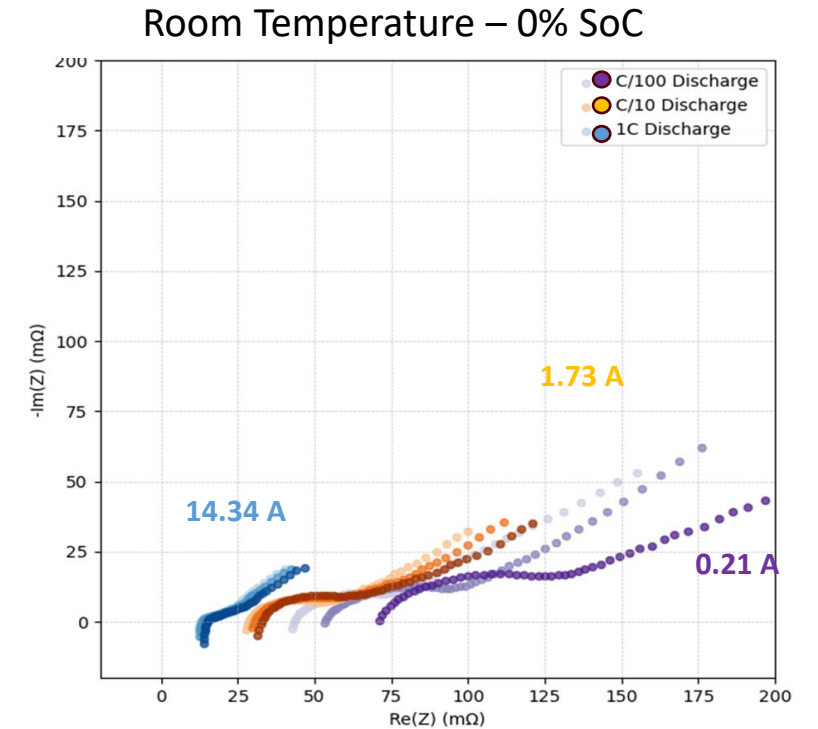
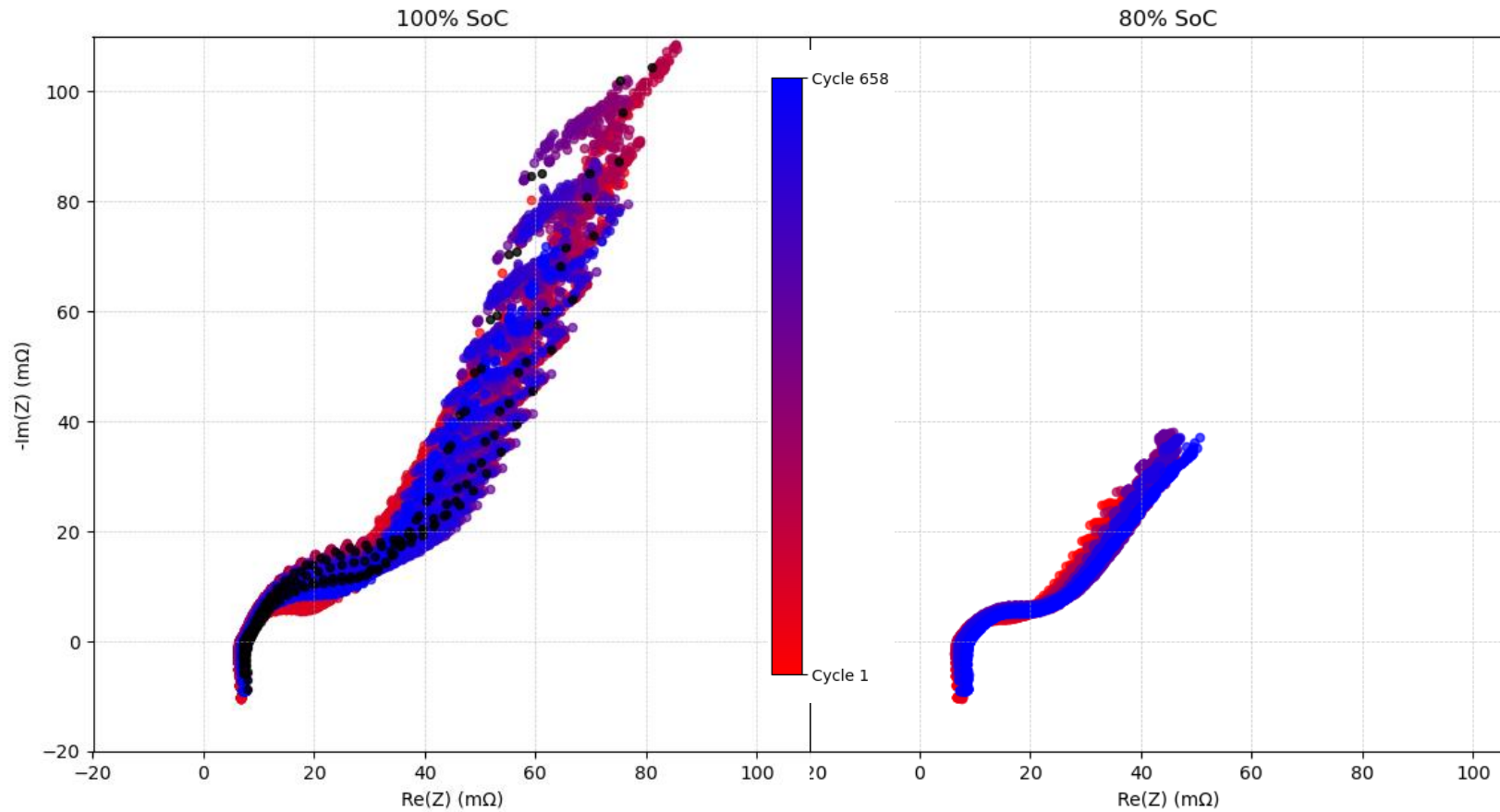


Room Temperature



# DISCHARGE CAPACITY

C/100, C/10, and 1C Discharges



# ALBA

## Response

### Do More with Less

Rather than performing a capacity check for battery SoH, we can preserve health of the battery and perform quicker, non-invasive EIS measurement.

### Dependable solutions:

Goal is to detect premature failures and improve long-term reliability of battery system.

### Competitive Edge

Lithium utilizes a battery management system to increase performance. If EIS can be utilized in conjunction with other tools to develop a BMS, it follows that there will be a noticeable battery improvement.

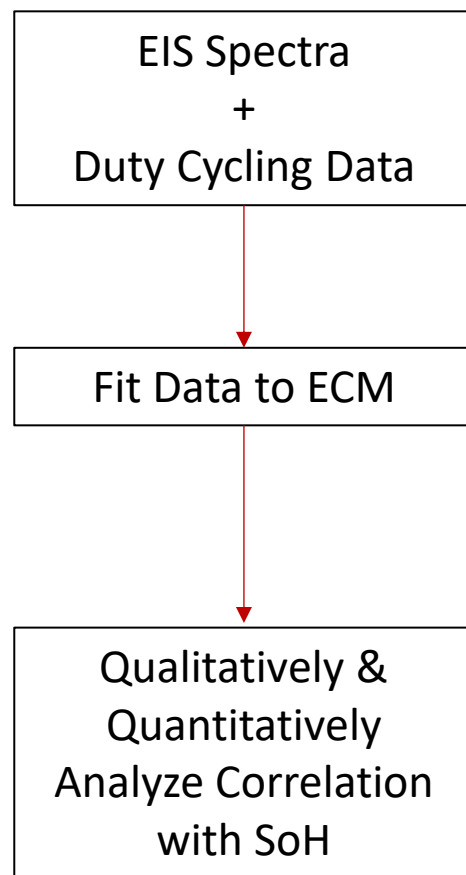


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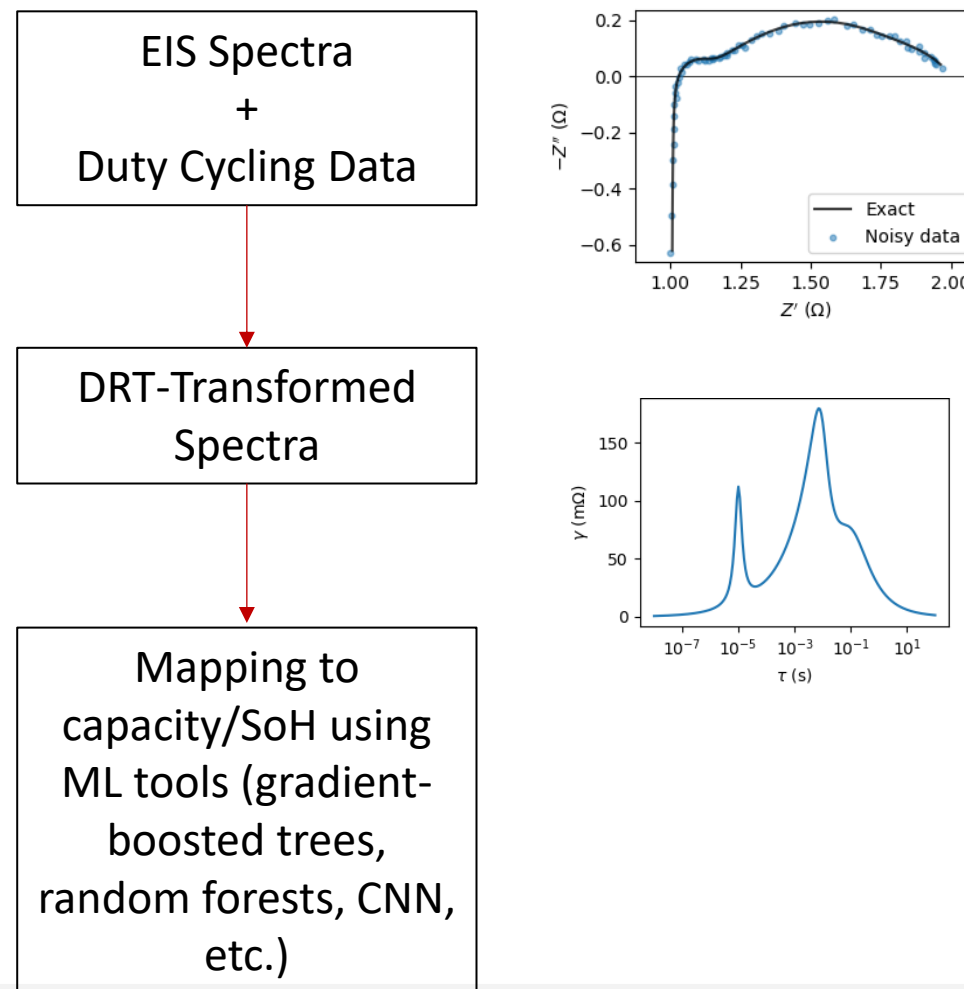
# FUTURE WORK

## Non-Parametric Approaches and Complete Abstraction

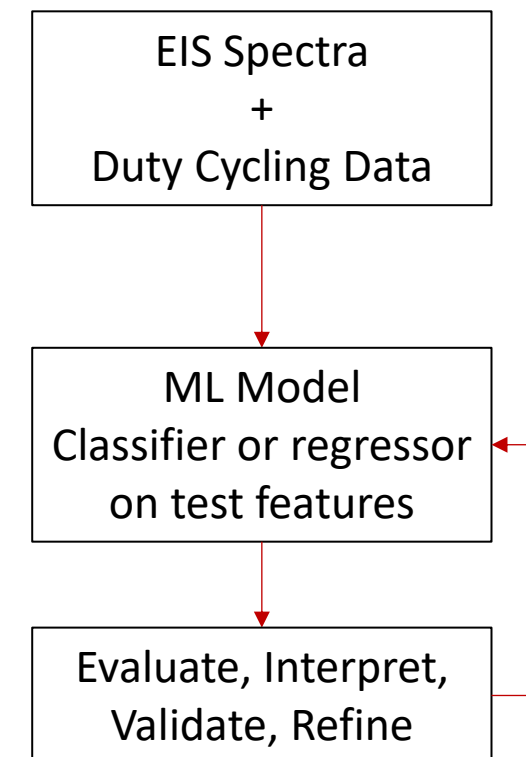
### Parametric Approach



### Non-Parametric Approach



### Complete Abstraction



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