DRIVING TO $1/KG H2

SILICON + AI ENHANCED ELECTROLYZERS

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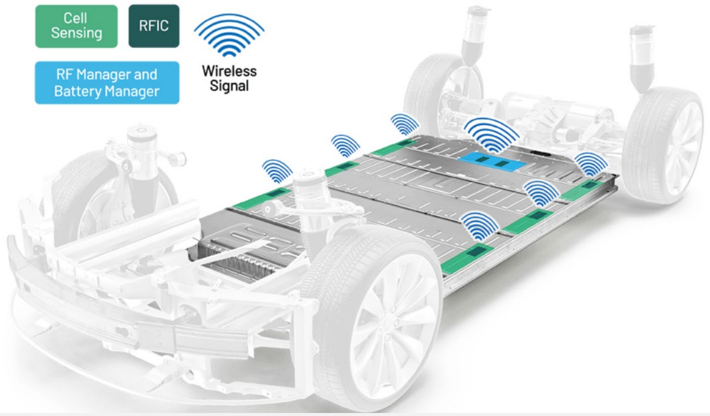
ANALOG DEVICES

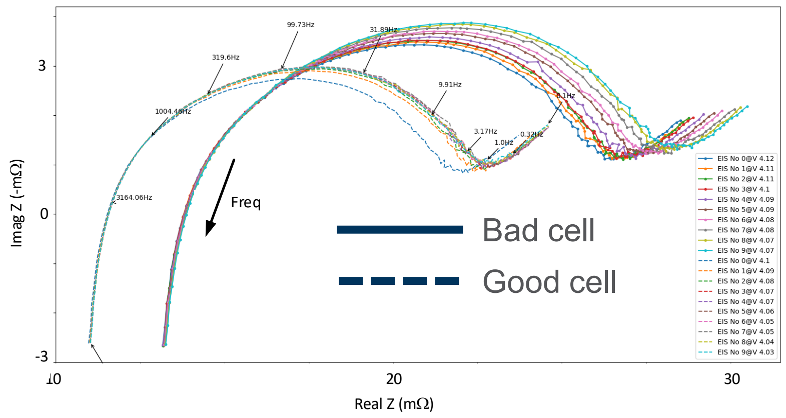
AHEAD OF WHAT'S POSSIBLE™

About Analog Devices

$9.6B semiconductor company at the interface of the physical and the digital

- Autonomous Transportation & Machines
- Automotive Electrification
- 5G & Next-Gen Connectivity
- Digital Health
- Industry 4.0 & Smart Energy
- Immersive Consumer Experiences





General Motors' Future Electric Vehicles to Debut Industry's First Wireless Battery Management System

Technology developed in collaboration with Analog Devices, Inc.

2020-09-09

Electrochemical Impedance Spectroscopy to identify failing cells

Electrolyzer Reliability & Impact of ML-aided Bypass

	Single Cell	1MW Stack $N = 140$ cells	1MW Stack with bypass
Failure probability	$p_f = 0.7\%$ *in* T_f = *7 years*	$1 - (1 - p_f)^N = 63\%$ *in* T_f = *7 years*	Indicated by EIS measurements & bypassed
Time between replacements	$T_r = \frac{T_f}{\log\left(\frac{1}{1-p_f}\right)} = 1000$ years	$\frac{T_r}{N} = 7$ years [1, 2]	No replacements needed

At least 10x reduction in H_2 cost adder due to stack replacement

Ability to dynamically scale stack size to load balance

Scheduled vs unscheduled downtime: reduced O&M cost

Flexibility to redesign MEA for improved efficiency and cost: reduced reliability bottleneck

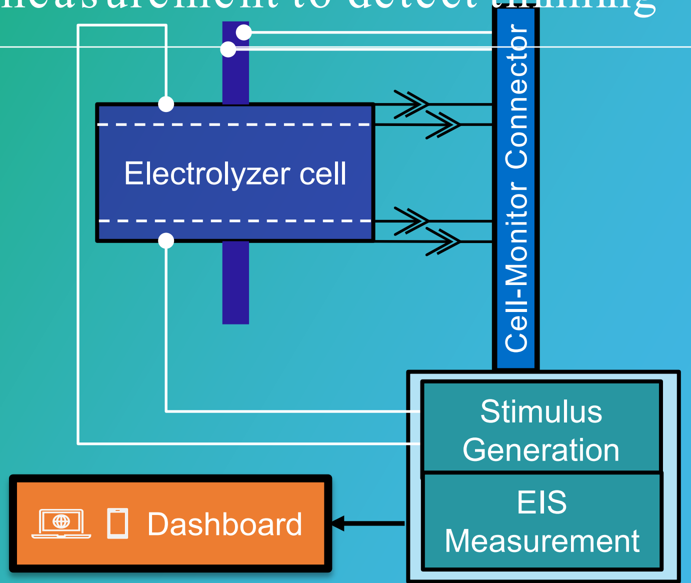
[1] Derived from properties of independent Poisson failure processes
[2] Numbers from Peterson, D. et al., *Hydrogen Production Cost From PEM Electrolysis 2019*; DOE Hydrogen and Fuel Cells Program Record, February 3, 2020

ADI EIS Monitoring Solution

Monitoring solution that measures wideband impedance for every cell

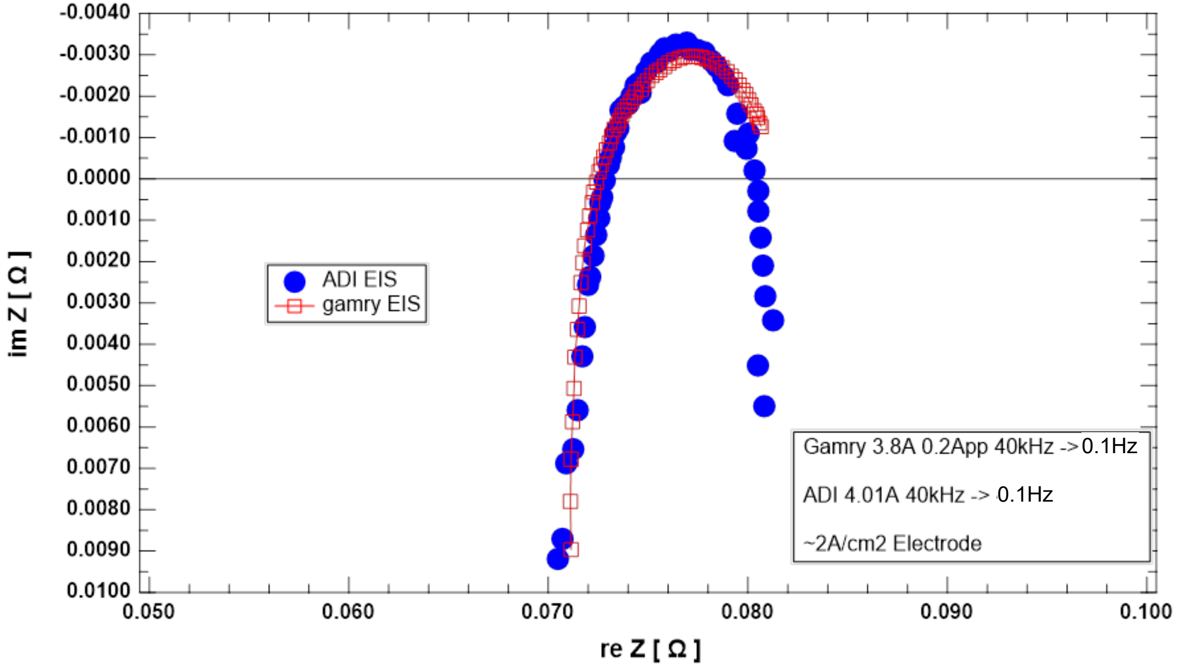
Provides insights on deteriorating cells and identifies causes for failure

Challenge: high dynamic range measurement to detect thinning

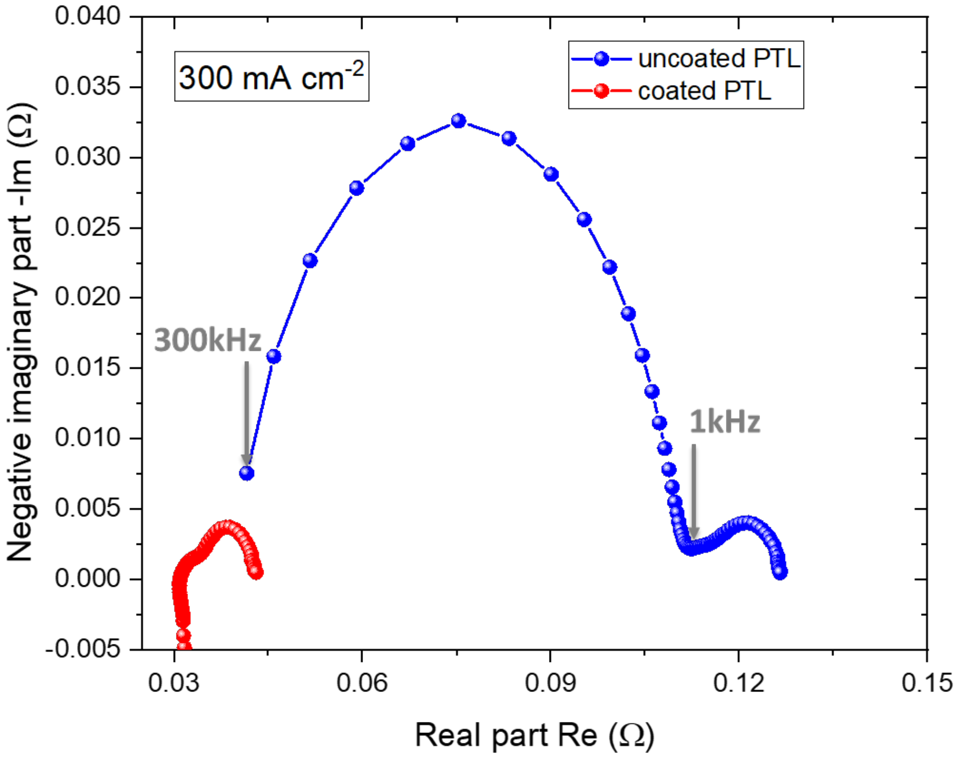


- Pinholes and Membrane Contamination
- Membrane Thinning
- Deterioration of Porous Transfer Layer Coating
- Catalyst-Layer Loading Loss and Surface Area Loss
- Foreign Materials in the Membrane

Early Returns with Small Stacks



Comparison Against Reference Measurement



Fault Detection

Predictive analytics & self-healing

Bypass switching to turn hard failures to soft

Extending lifetime and allowing larger stacks reduces cost

Enabling flexible MEA design

Challenges

- Switch design for 3000+ A
- Bipolar plate material (electrical conductivity + chemical stability)