DRIVING TO $1/KG H2

SILICON + AI ENHANCED ELECTROLYZERS

Sasha Dass

Director, Engineering Program Management, Analog Devices

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

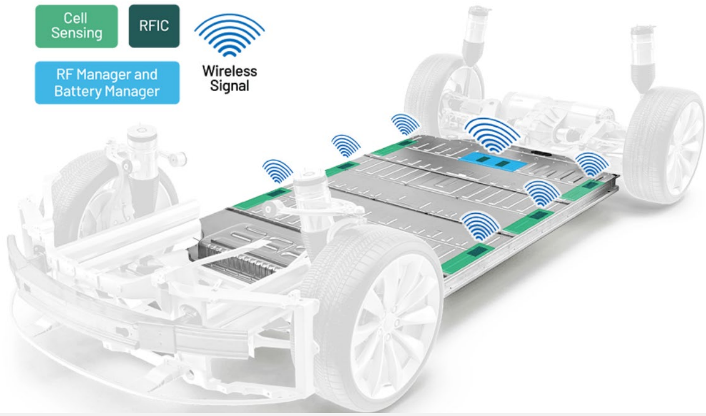
Automotive Electrification

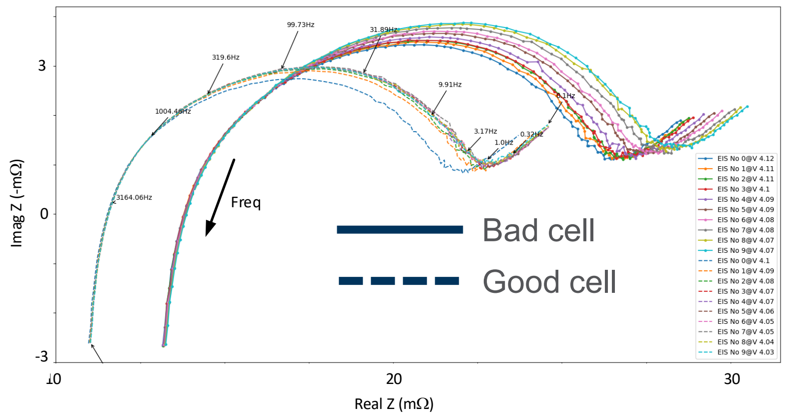
5G & Next-Gen Connectivity

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

More flexible MEA design: single cell failures less significant

[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

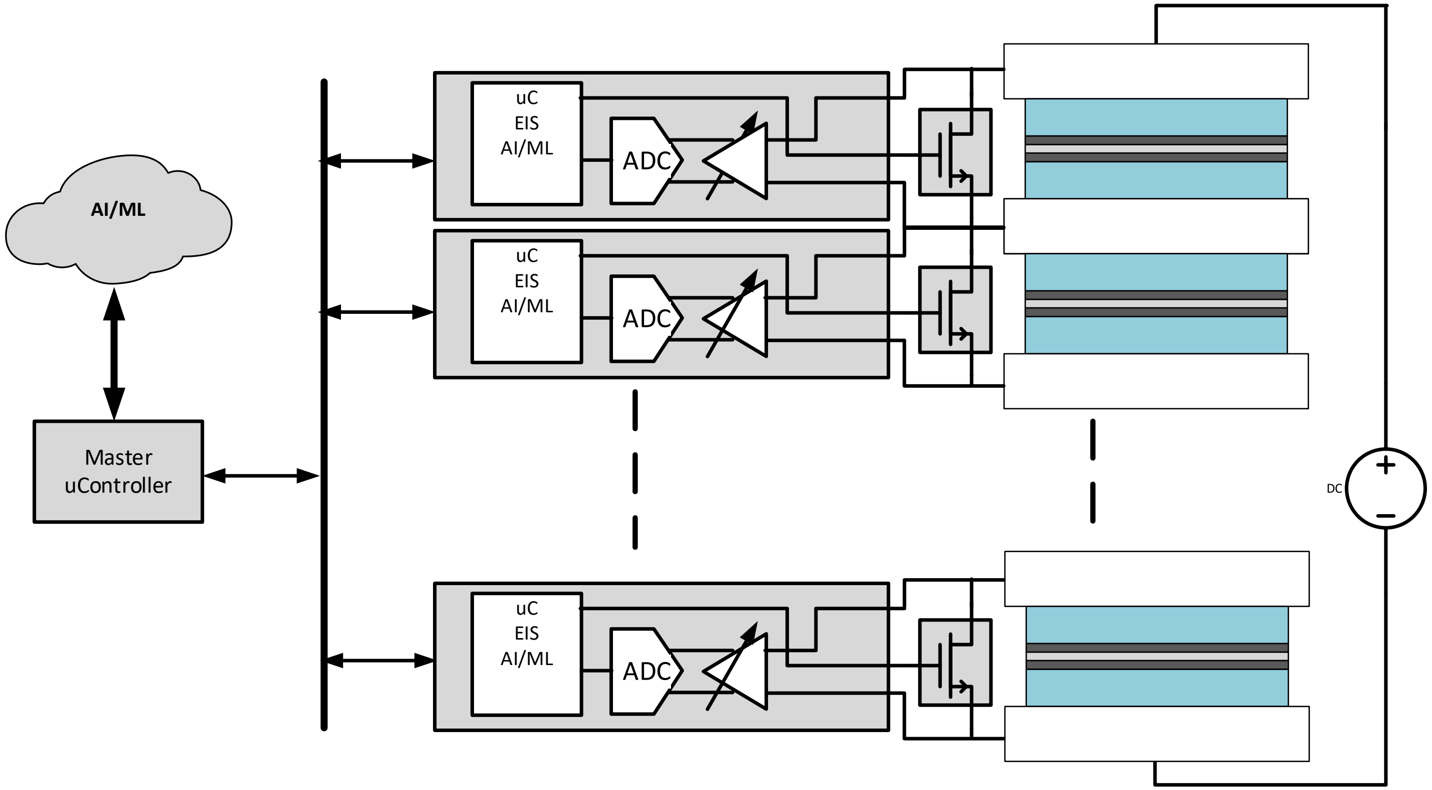
Predictive analytics & self-healing

Electrochemical Impedance Spectroscopy + AI/ML to predict failures

Bypass switching to turn hard failures to soft

Extending lifetime reduces cost

Sponsoring projects with NREL and MIT



Hydrogen Energy Earthshot Summit: Electrolysis Track

Balance of Plant Supply Chain Industrial Panel

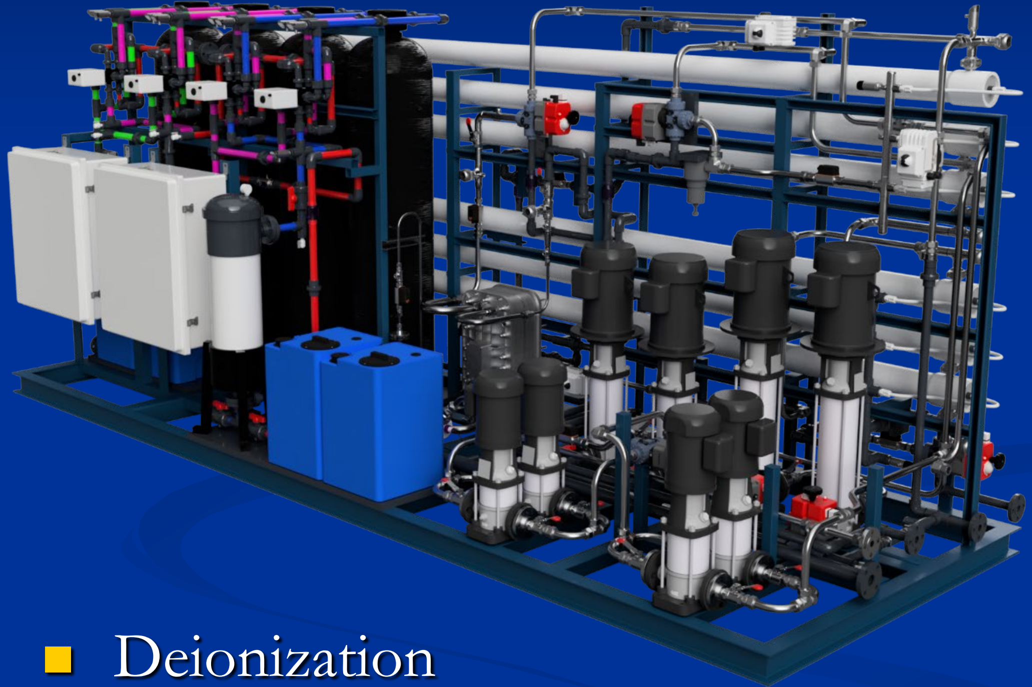
Water Purification

Stan Lueck

RODI Systems Corp., Aztec, New Mexico, USA

Water Purification Needs and Objectives

- Primary Ultrapure Water Makeup
- Storage Recirculation
- Electrolyzer Loop Polishing



- Deionization
- Degassing
- TOC Removal

Water Purification Challenges

Lowering Cost

- Capex Reduction
  - System Design
  - Materials of Construction
  - Manufacturing Methods
- Opex Reduction
  - Automation and Reduced Labor Cost
  - Reduced Chemical Consumption
  - Reduced Power Consumption
- Identifying Indirect Cost Savings

Other Challenges

- Elevated Water Temperature
- Non-Typical Feed Water Sources
- Identifying Actual Quality Requirements

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89 YEARS OF EXPERIENCE

Adsorption Technology Experts

DOE Hydrogen Shots Sep 1,2021

Hydrogen Drying Experience

- Adsorption Technology Experts since 1932
- 1935 hydrogen dryers for hydrogen-cooled generators
- Manufacturing hydrogen dryers for *electrolysers* since 1963

Hydrogen Drying Considerations

APPLICATION VARIABLES: water content, pressure, temperature, outlet dewpoint required, oxygen content

COST DRIVERS: regeneration type, oxygen removal, instrumentation, specifications, certifications

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Electrolyzer Application: Hydrogen Dryer Characteristics

Hydrogen Drying Experience

Flow	300 scfh (8.5 ncmh) to 40,000 scfh (1130 ncmh)
Pressure	2 psig (0.14 barg) to 2850 psig (194 barg)
Temperature (Inlet)	+40°F (+5°C) to +158°F (+70°C)
Dewpoint Required (Outlet)	-40°F (-40°C) to -100°F (-73.3°C)
Oxygen Removal	From 30 ppmv to <5ppmv

Questions?

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