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Battery Management Innovation

Advancements In Battery Charging, conditioning & Testing

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Presentation Outline

- Introduction to Midtronics
- Introduction to Conductance technology
- onGUARD & inGEN platforms
- Future needs and opportunities

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Introduction

- 18 years in battery testing, charging and monitoring
- Global company based in Willowbrook, IL, plus operations in North Bay, Ontario and IJsselstein, The Netherlands
- Quality reputation including ISO9000 and QS9000
- Sales offices world wide

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Introduction

- Serve multiple industries - Automotive, HD Trucks Telecom, Power Utility, Cable and Wireless Communications, UPS, Military and Railroad
- Product development focus:
  - Vehicle Service Equipment
  - Industrial Applications
  - OE Integrated Solutions

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Technology and Engineering

- Engineering focus - innovative solutions
  - Conductance Testing Technology
  - Conductance Controlled Charging Technology
- Growing patent portfolio: 69 issued and 20+ pending
- Exclusive concentration on battery testing, charging and engineering applications

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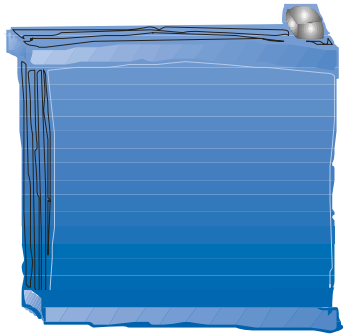
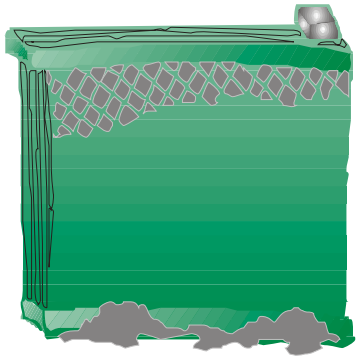
Conductance Primer

- Conductance relates to the battery's ability to produce power
- Conductance has a linear correlation with the Cold Cranking Amps
- High conductance is an indication of a healthy battery
- Conductance declines as the battery ages and plates degrade and fail





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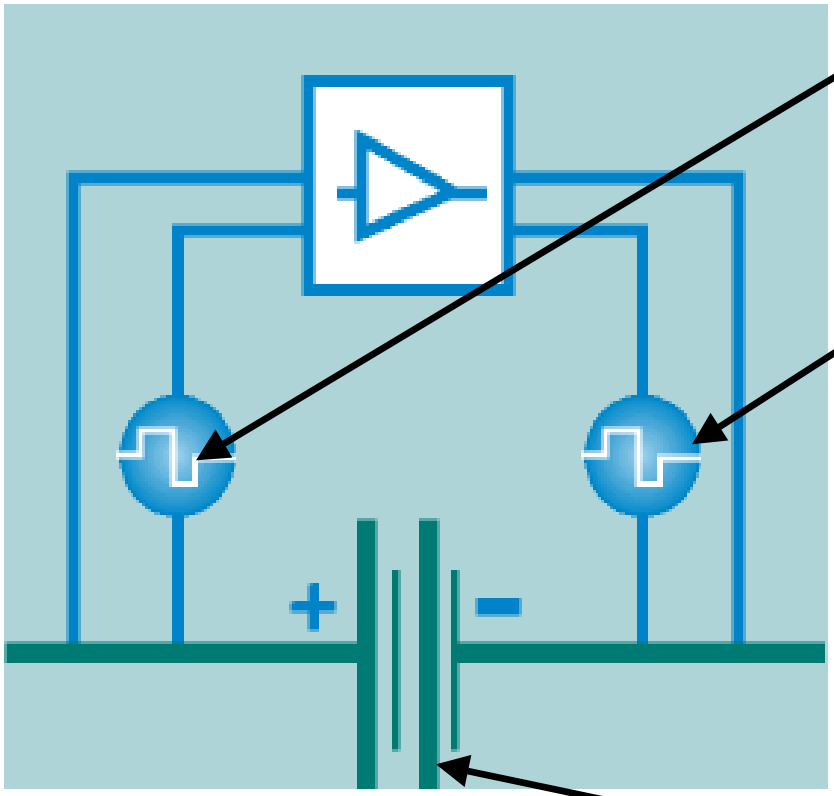
How is Conductance Measured ?

Conductance Measurement



- A low voltage A/C Signal is Impressed across the battery terminals (V_{AC})
- The A/C Current (I_{AC}) Response is measured
- Conductance (G) is calculated using Ohm's Law: $G = I_{AC}/V_{AC}$

Plate Surface Area

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Conductance Primer

Conductance Benefits:

- Passive test is repeatable & non-invasive
- No battery discharge, enhanced safety
- SOH independent of battery SOC
- Batteries measured on-line, all the time
- SOC, SOH and other diagnostics

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Emerging Conductance Technologies

onGUARD

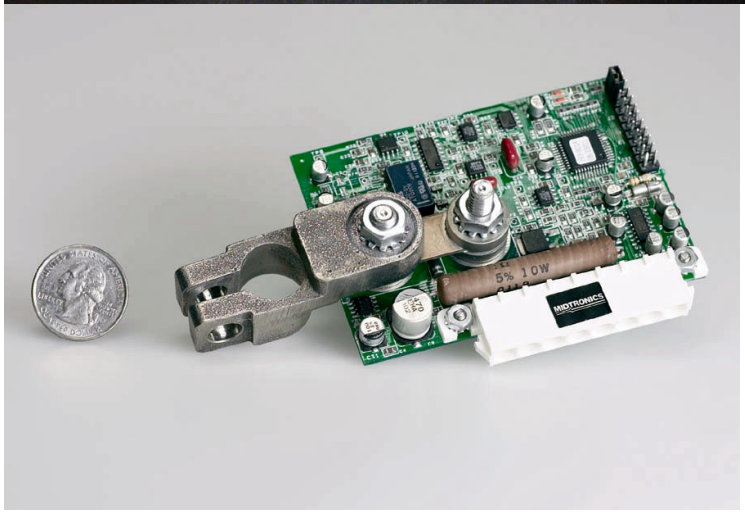
Battery-integrated Conductance Testing

- The “Smart Battery” solution

inGEN

Vehicle-integrated Conductance Power Management

- Continuous, real-time battery system monitoring



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onGUARD

Circuit measurement inputs:

- Voltage: 7.0V – 20.0V
- Temperature: -40C - +85C
- Conductance: 300 – 1500 CCA

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❖***Push to test design with simple indication of Good, Replace, or Needs Charge***

❖***Measures battery conductance, voltage and temperature***

State of Health LED

State of Charge LED

LED lights when charge energy is needed

Calibration Done on Battery at Installation

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Development Status

onGUARD

- Integrated battery unit launched in Japan in first quarter of 2003 for automotive aftermarket
- High volume, low-cost voltage sensor ready for production for European battery manufacturer
- Wireless data transfer and communication projects underway
- ASIC development underway
- Licensing available for hardware/circuit design, or SOC/SOH algorithms only

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iBMS Solutions and Future Integration

Midtronics focus is on vehicle-integrated and/or on-board technology solutions for SOC and SOH data using inGEN

- Are there other Options? -

Battery Modeling – ***BUT errors over time and results vary per the battery, application and environment***

Fuzzy logic – ***BUT battery variables and applications may NOT be consistent (see graph on next slide)***

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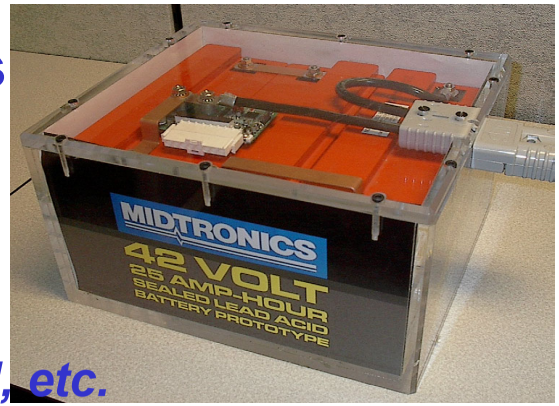
Why the need for inGEN?

An increased burden for battery Systems:

- **Increasing electrical power demands**
  - Comfort and convenience systems
  - Safety systems
  - Fuel Economy
    - ✓ *Idle stop/start function*
    - ✓ *Electric air conditioning, valve control, etc.*
    - ✓ *X-by-wire replacing mechanical systems*



- **Automotive OEMs are evolving 42V systems**
  - 36V batteries used for essential operating systems
  - Hybrid (HEV) advances

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Need for Improved Fuel Economy - Lower Emissions

New demands for the battery:

Assuming lead-acid for cost and availability requirements

- Nominal operation is in >90% SOC range
- 42V/HEV operating in 40-50% SOC range
  - = Current designs lose 90% of their cycle life.
- Varying discharge rates
  - Not just starting - - 2-3KW loads, Must now look at varying electrical system demands, some vary according to each user operating needs
- Regenerative or Rapid charging of battery

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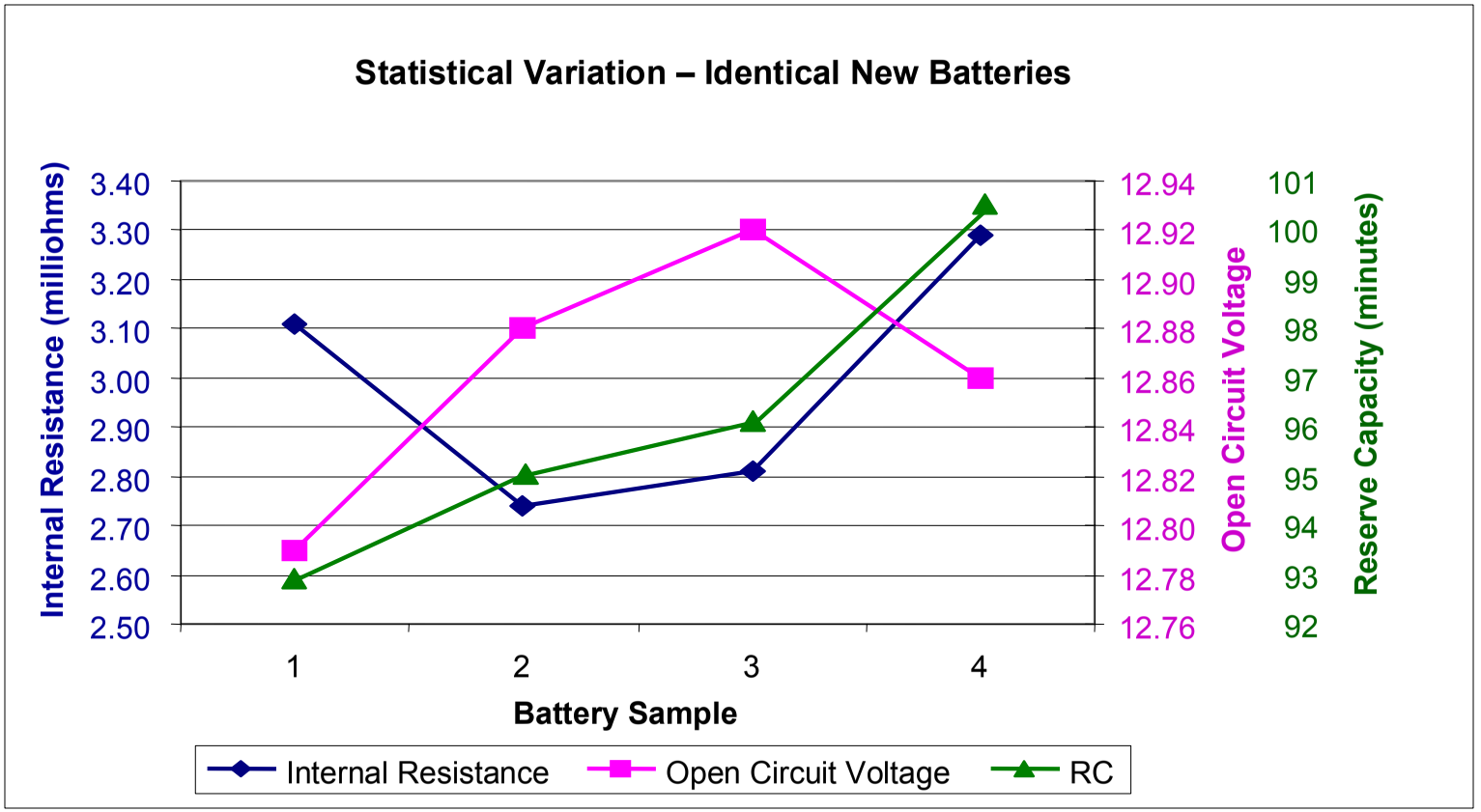
Past Battery Monitoring Techniques and Issues

Modeling/Mapping Issues:



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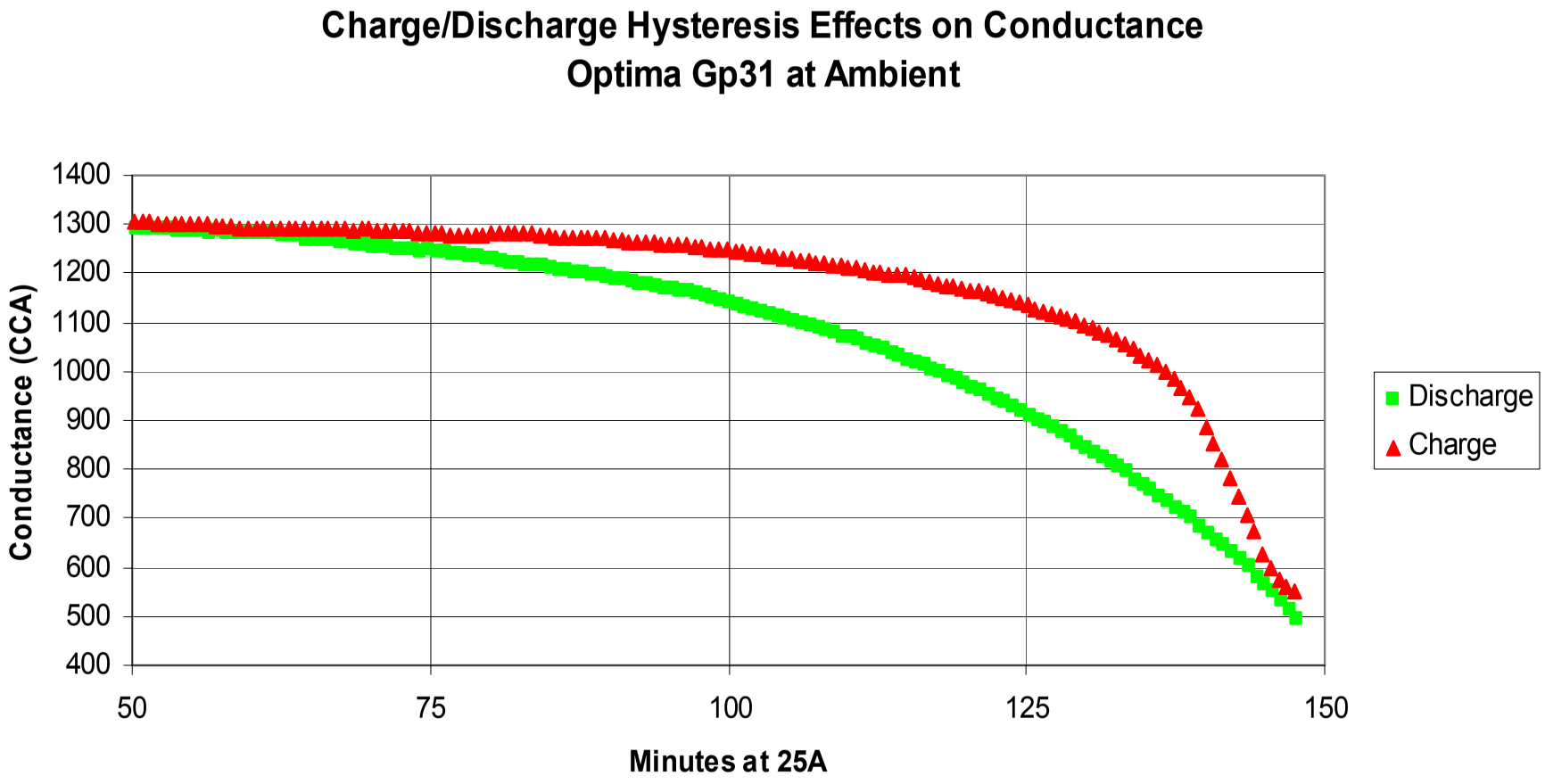
Hysteresis Effects



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inGEN Integrated Battery Monitoring System (iBMS)

What's needed? - A battery fuel gauge!

- iBMS approach will provide the answers
- **Simplicity** – eliminates variable measurements, provides distinct diagnostics and prognostics
- **SOC and SOH:** variations of these can produce prognostics required for OEM proposed terms like - *Deliverable Energy, Discharge Capability, Charge Acceptance, even Battery State of Life*
- **Accuracy** – Must know beforehand if the battery cannot deliver energy required for the application

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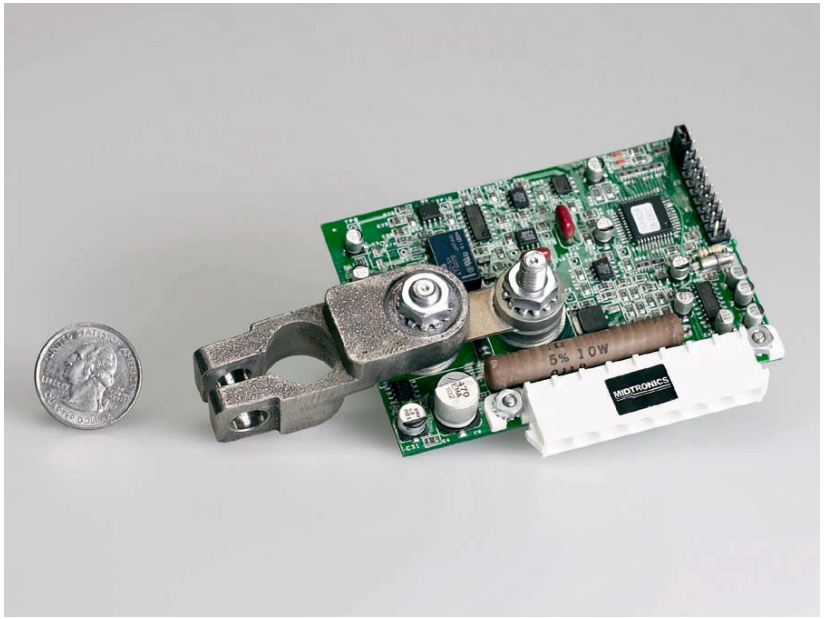
Essential Parameters the iBMS will Monitor

Continuous, accurate measurement of battery system:

- Voltage (AC/DC)
- Current
- Temperature
- Time
- *Conductance*
  - multiple measurements at varying loads



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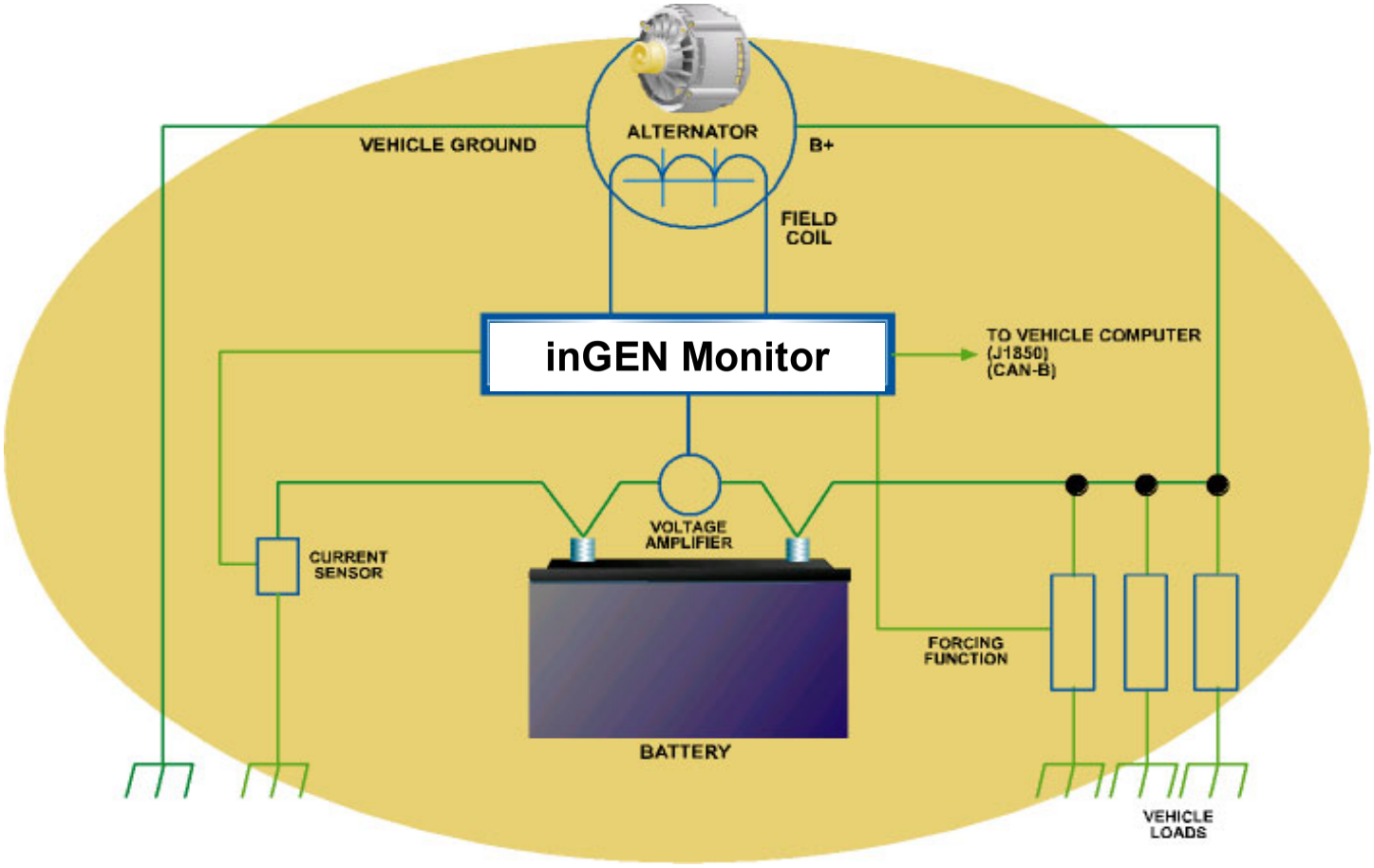
inGEN System Block Diagram



Standard configuration; other OE integrations are in development

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Why is inGEN New?

Revolutionary advancements in battery monitoring…

- Continuous, real-time battery system monitoring during engine operation
- Noise immunity
- No effect of alternator, regulator or other charging systems
- Algorithm provides diagnostics/ prognostics, and it is NOT based on specific battery design and data tables

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What the Diagnostics Mean

- **State of Charge (SOC)**
  - the % of stored energy which is influenced by the actual battery state of health
- **Cranking State of Health (CSOH)**
  - ensures that the battery has the cranking power needed to start the vehicle (high rate)
- **Reserve State of Health (RSOH)**
  - ensures that the battery has reserve capacity needed to supply all consumers (low rate)

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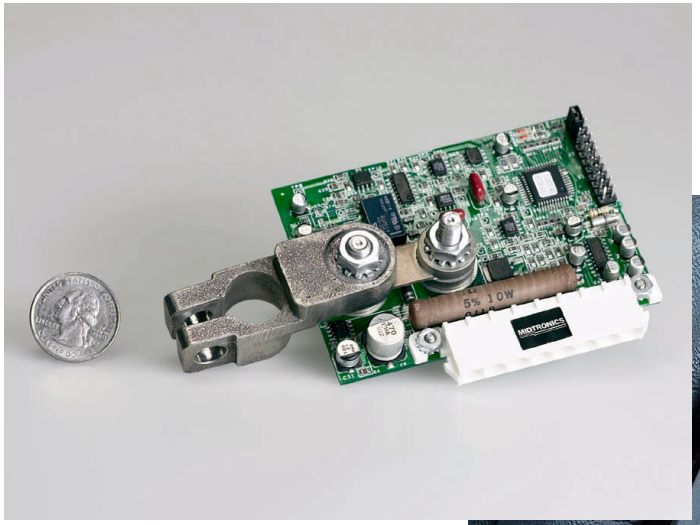
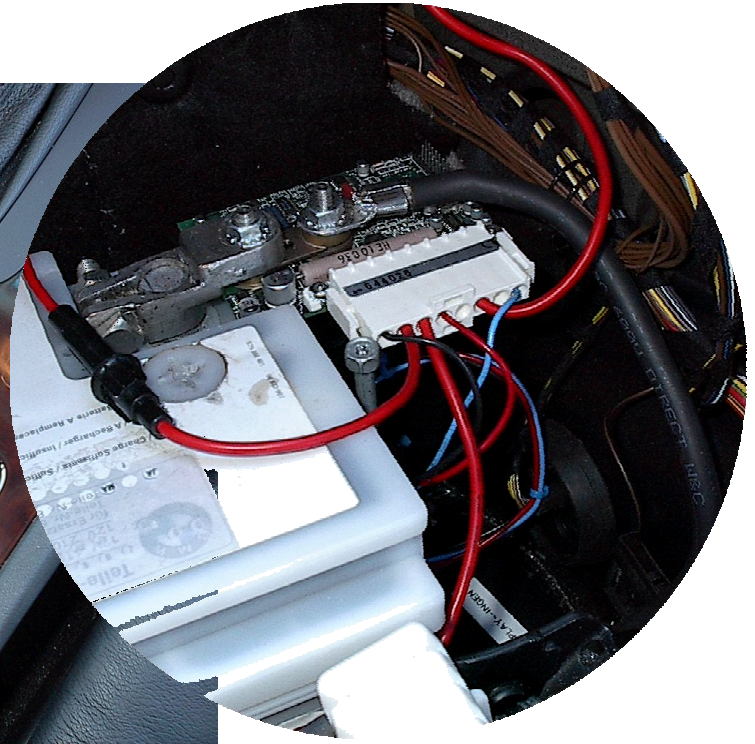
inGEN Installation





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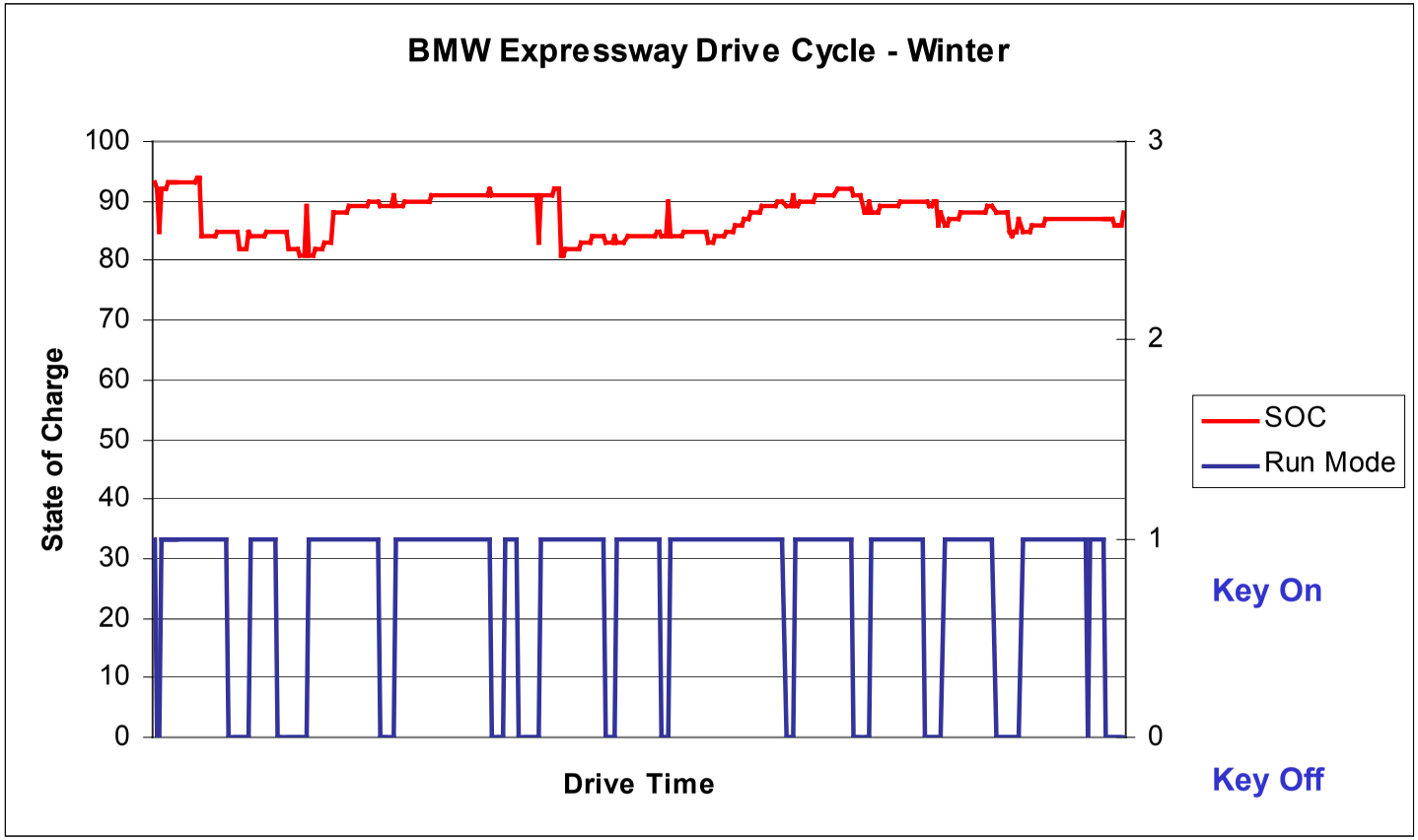
Expressway Drive Cycle 1999 BMW - SOC



"Y" axis represents 14 days (Key On Scale / Key Off Scale = 7.5)

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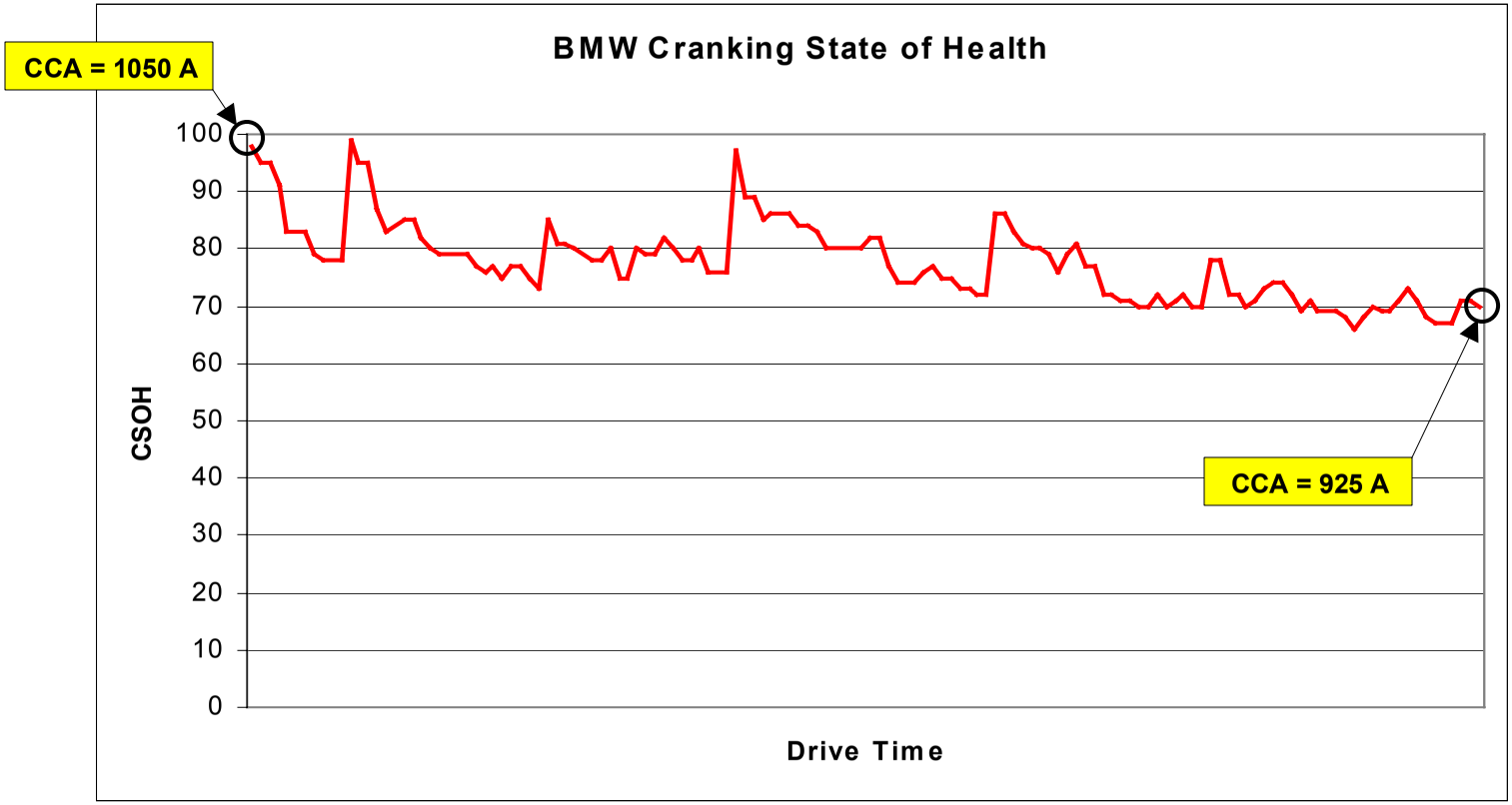
Expressway Drive Cycle '99 BMW - CSOH



"X" axis represents 6 months; For "Y" axis, 0% or CCA MIN approximately

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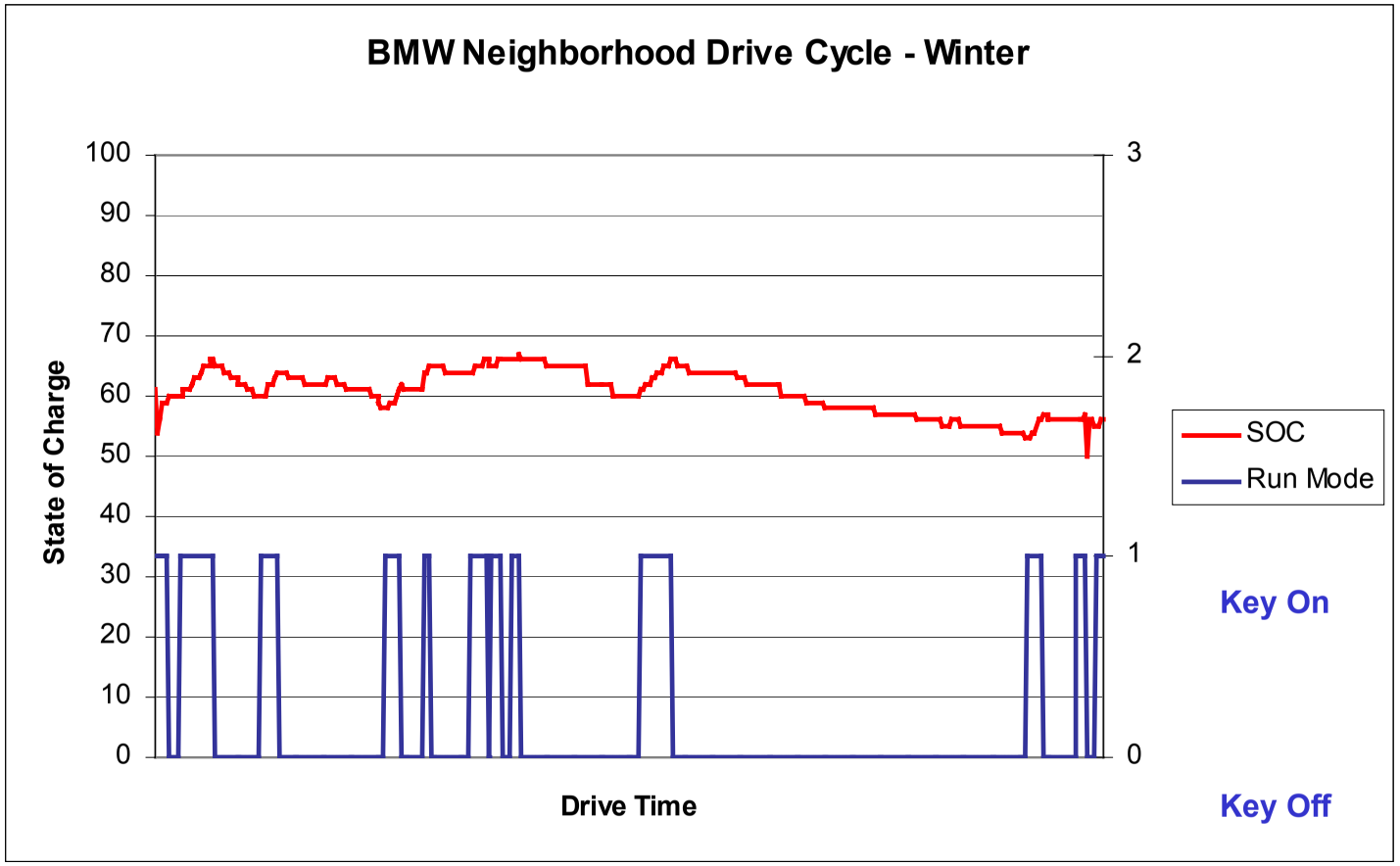
Neighborhood Drive Cycle
2001 BMW - SOC



"X" axis represents 14 days (Key On Scale / Key Off Scale = 7.5)

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1999 Dodge Grand Caravan

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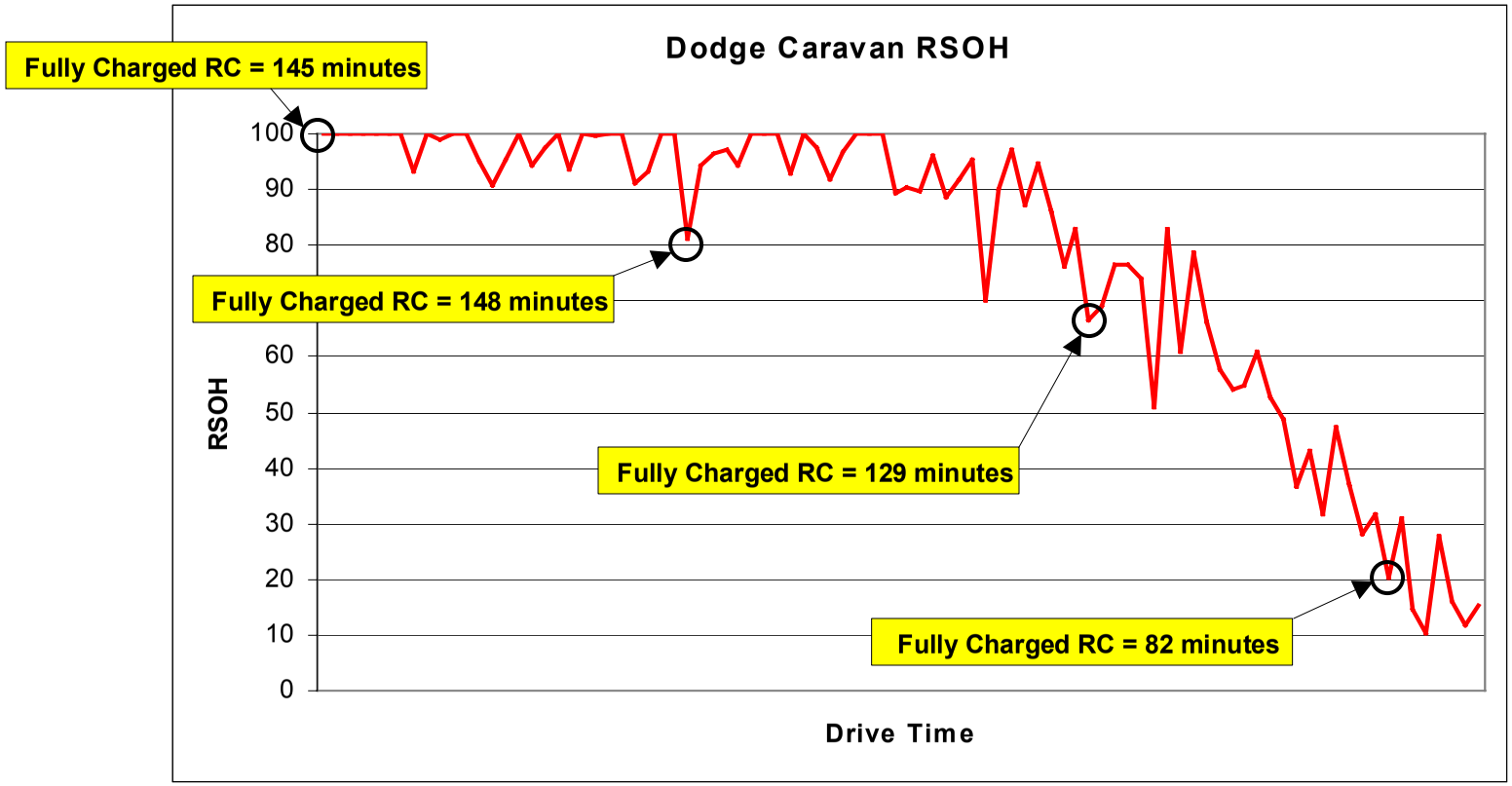
Engine Compartment Battery
99 Dodge Caravan - *RSOH*



"X" axis represents 11 months

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Jeep Wrangler

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Idle-stop and Variable alternator system

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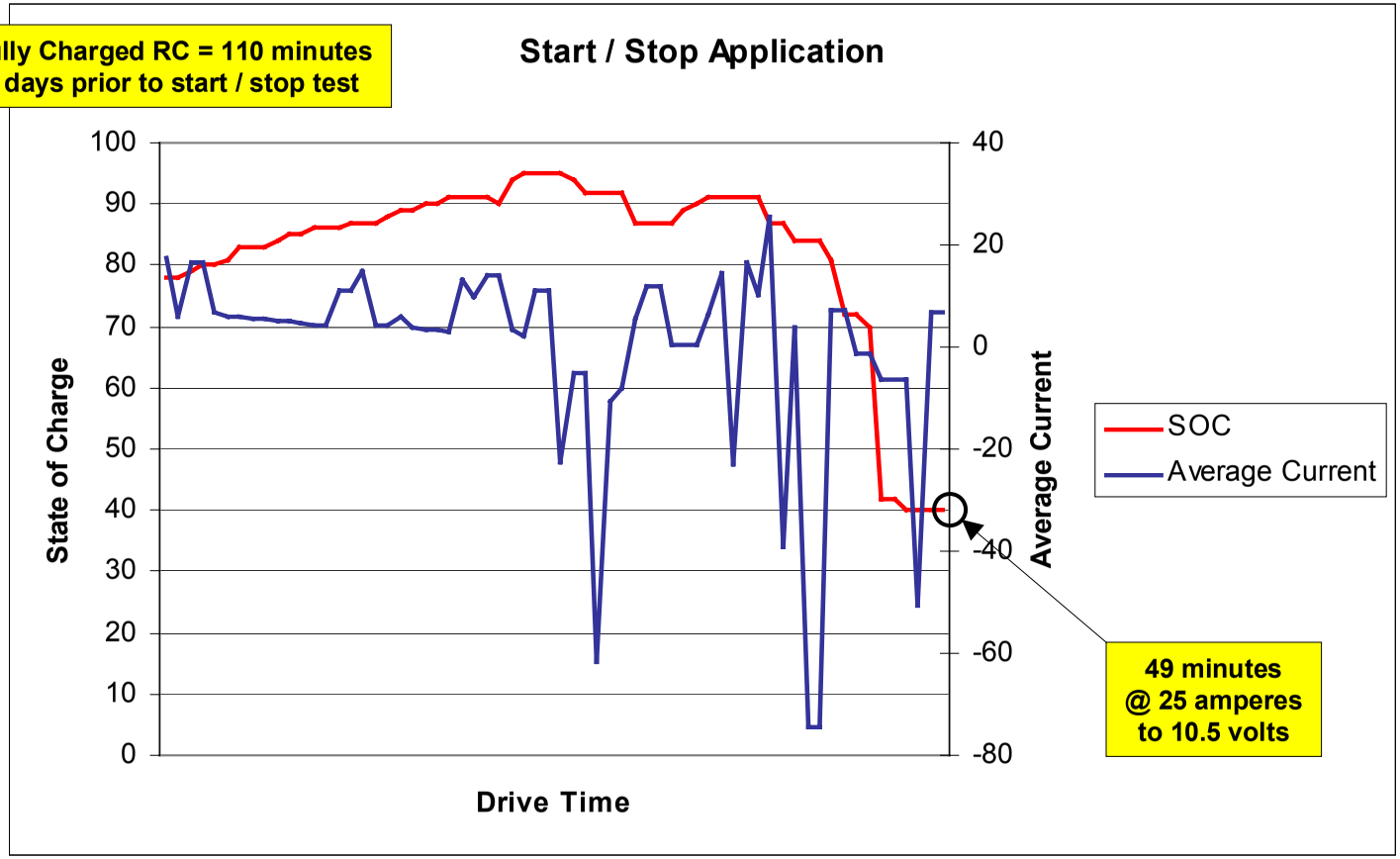
"Idle Stop" SOC Data Collection



"X" axis represents 1 hour normal mode, 1 hour start / stop mode

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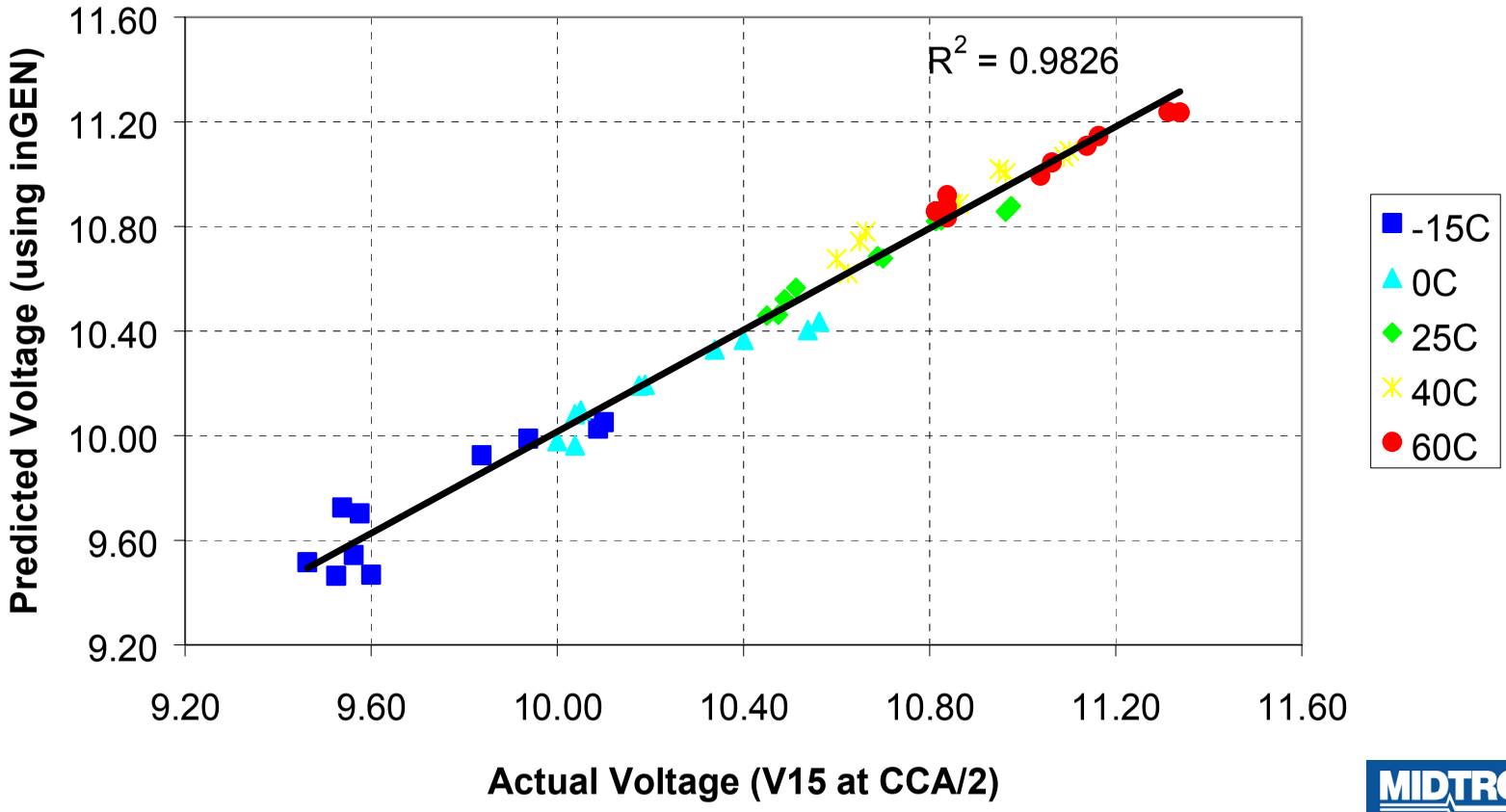
Starting/Cranking Prediction

Voltage Prediction Using inGEN
Furukawa Batteries at Various Temperatures



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New Diagnostic Possibilities

- **Voltage prediction** - can identify if a battery can deliver the power required to start a vehicle with a known starter draw profile

- **Current prediction** - at a given voltage - determines if a battery can deliver the required starting current at or above a minimum battery voltage

- Voltage or current predictions can be compared to actual vehicle specifications set at virtually any temperature

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New Diagnostic Possibilities

- Midtronics has demonstrated inGEN data correlation to ***high rate*** (cranking) loads and ***low rate discharges*** (hotel and consumer loads) over a wide temperature range
- Work is ongoing to enhance the inGEN data output to match specific customer needs
- inGEN has already demonstrated capabilities in measuring vehicle battery packs with multiple batteries in parallel

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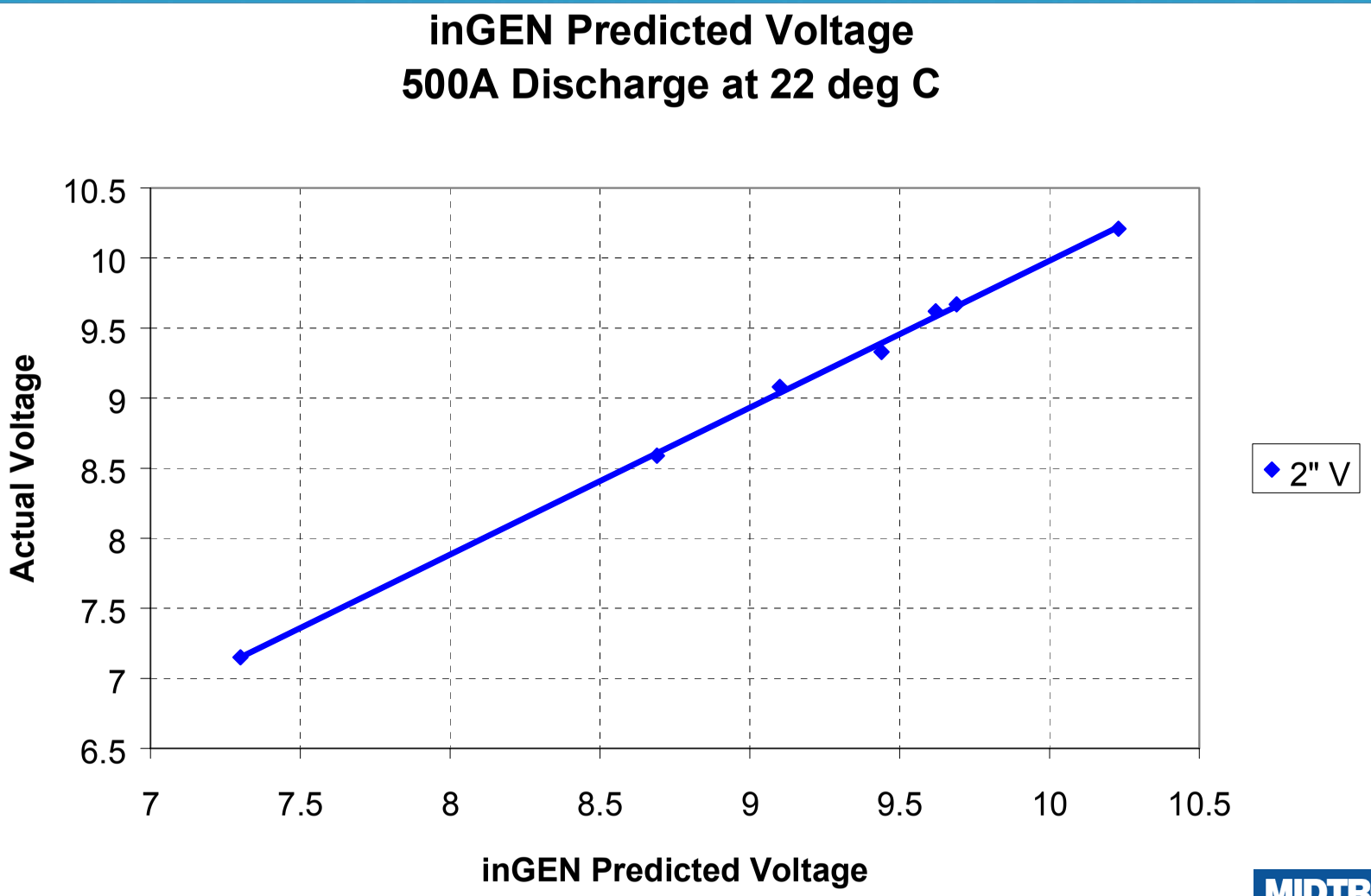
Starting/Cranking Prediction



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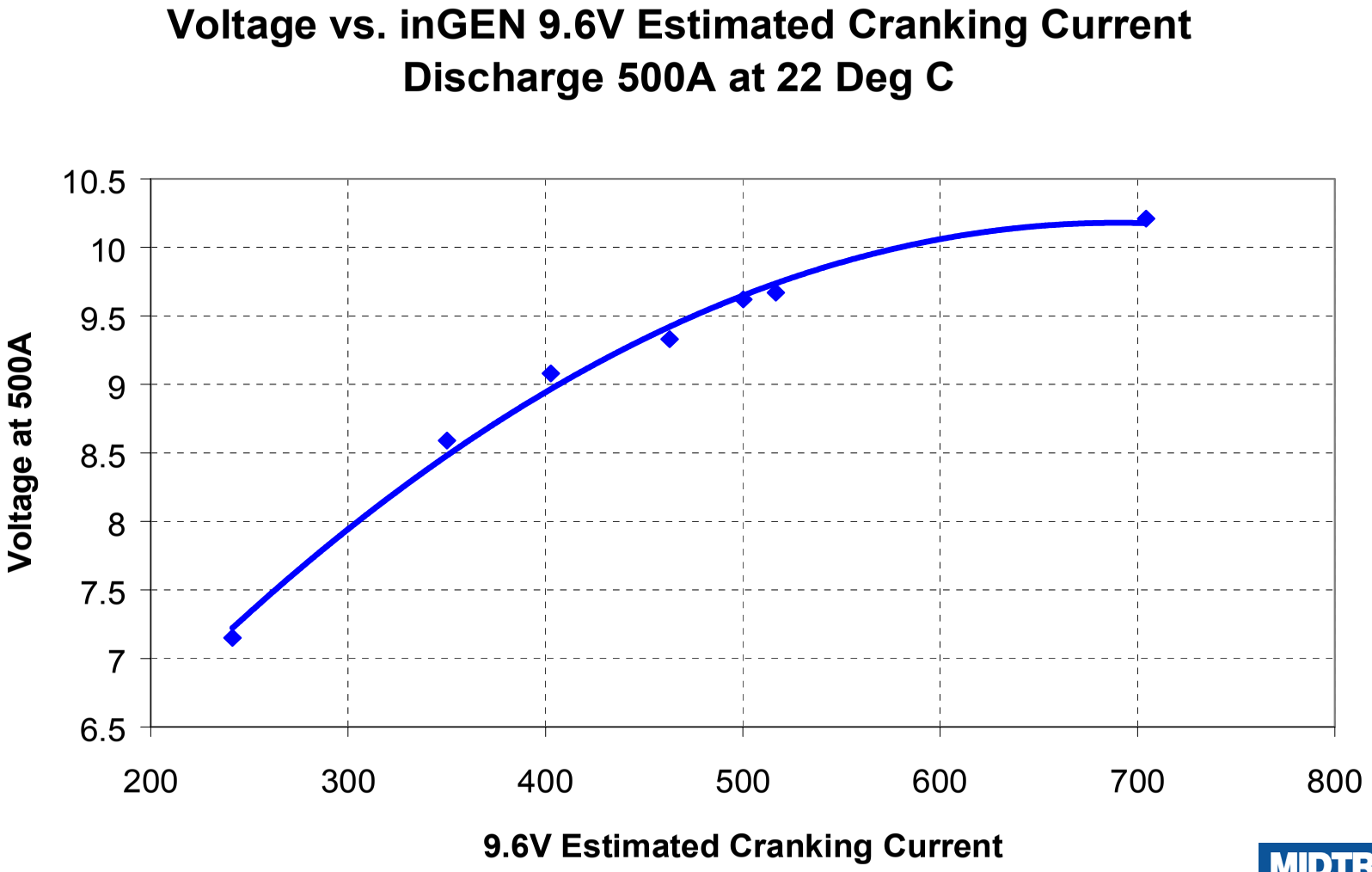
Starting/Cranking Prediction



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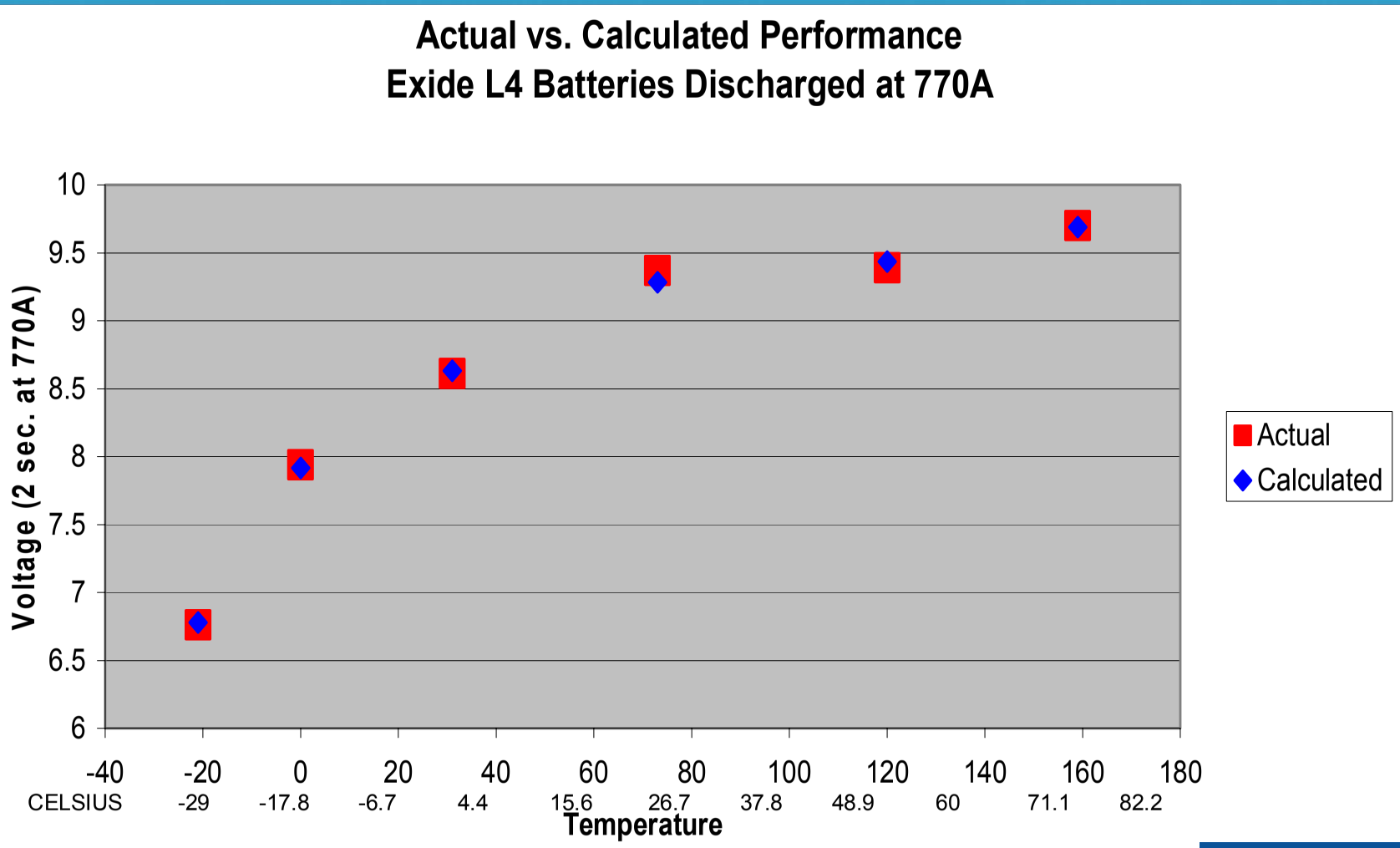
Starting/Cranking Prediction



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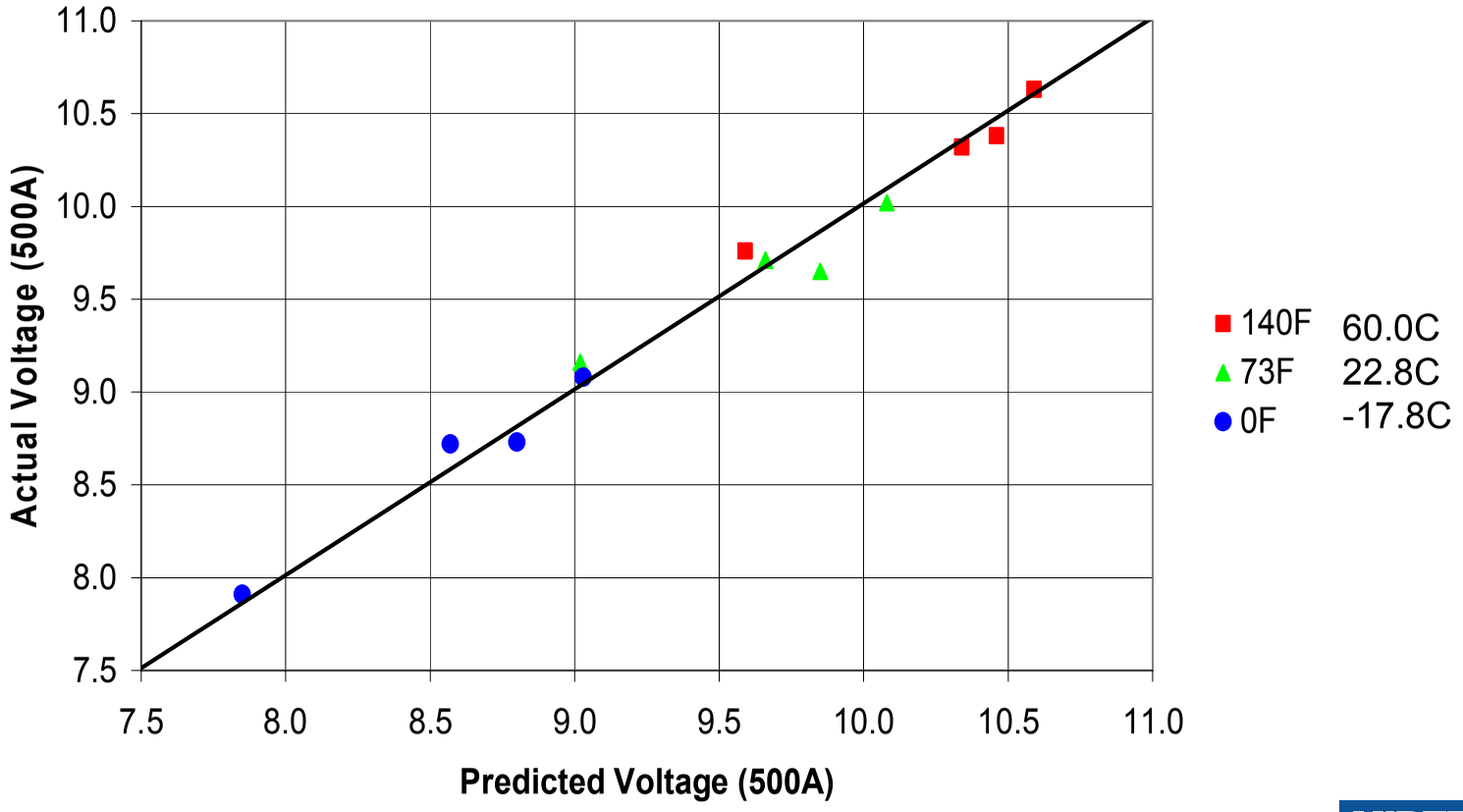
Starting/Cranking Prediction

Actual vs. Predicted Starting Voltage
L4 Batteries at Various Temperatures and SOC



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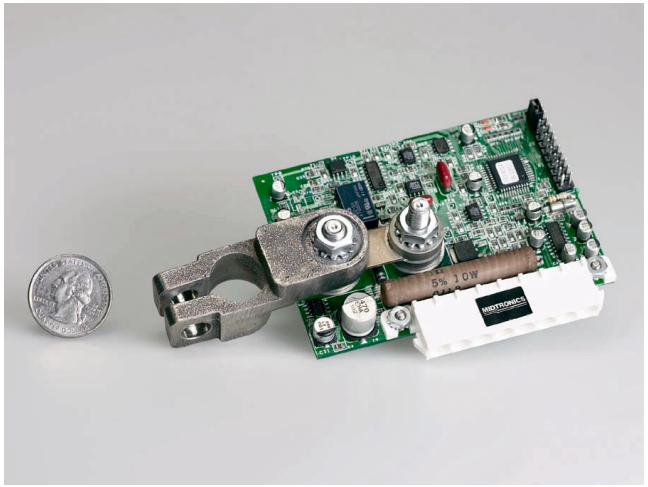
inGEN integration

inGEN data can form the backbone of information used to control and optimize the charging system

- Eliminate Overcharging
- Eliminate Undercharging
- Increase Battery Life
- Electrical system analysis
- Detect starter/alternator wear-out
- Enable load-shedding or disconnects



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Outputs and interface

Key Elements

Time/ Date	Volts	Current (Amps)	Temp (°F)	Conductance (CCA)	SOC (%)	CSOH (%)	RSOH (%)
7:36:00	12.33	23.71	72	773	91	71	100
7:38:02	13.85	04.64	73	760	92	71	100

Minimal amount of elements represented; inGEN technology can also supply other measurement variables as required by the charging system or application

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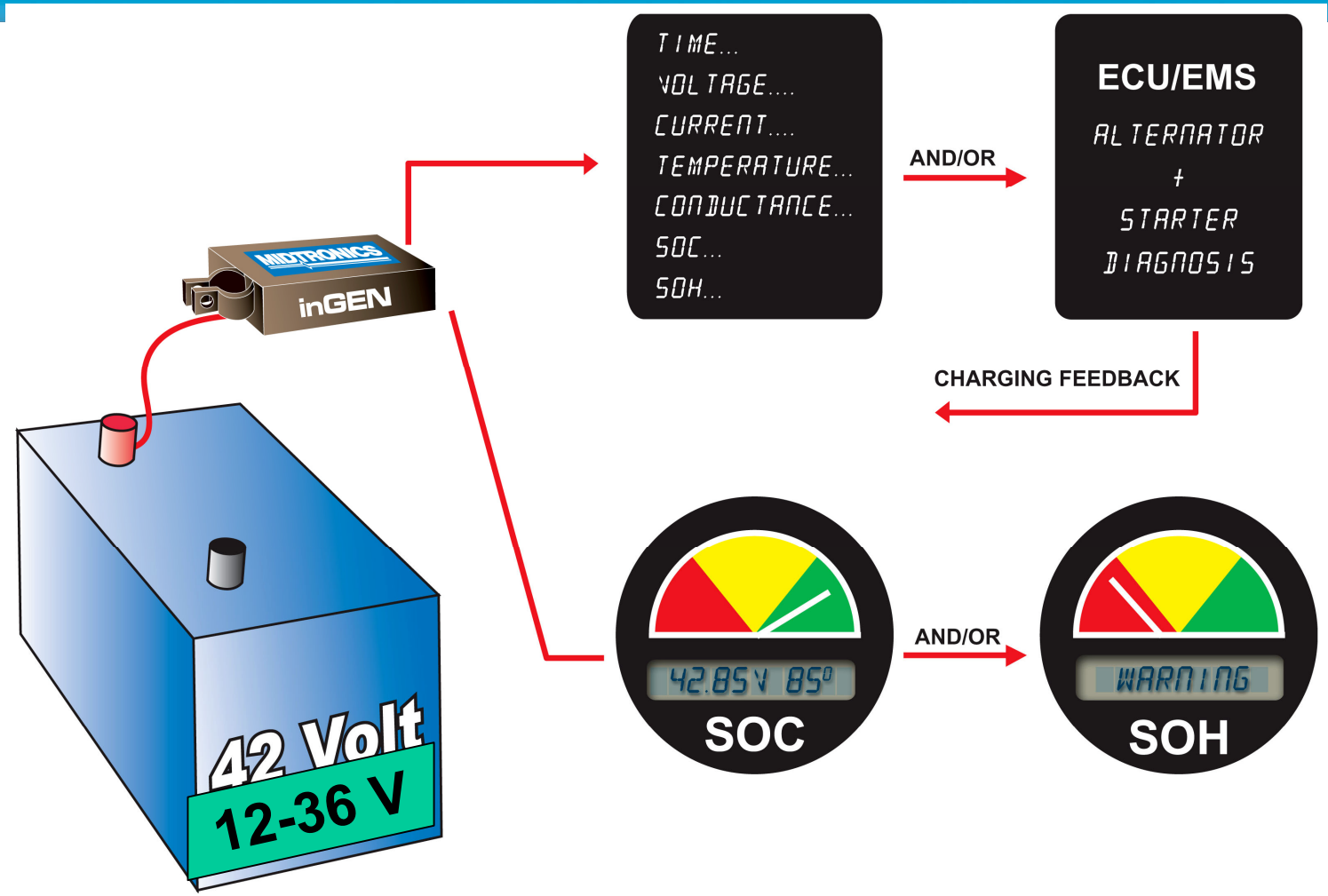
inGEN integration



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iBMS Solutions and Future Integration

Focusing on vehicle-integrated or on board technology for SOC and SOH

What's needed?: Battery Voltage, Current, Temperature - AND - Conductance

- **Integrated for accurate SOC measurement**
- **Provides SOH measurement**
- **Can provide cranking prediction**
- **Global OEM standard for battery service**

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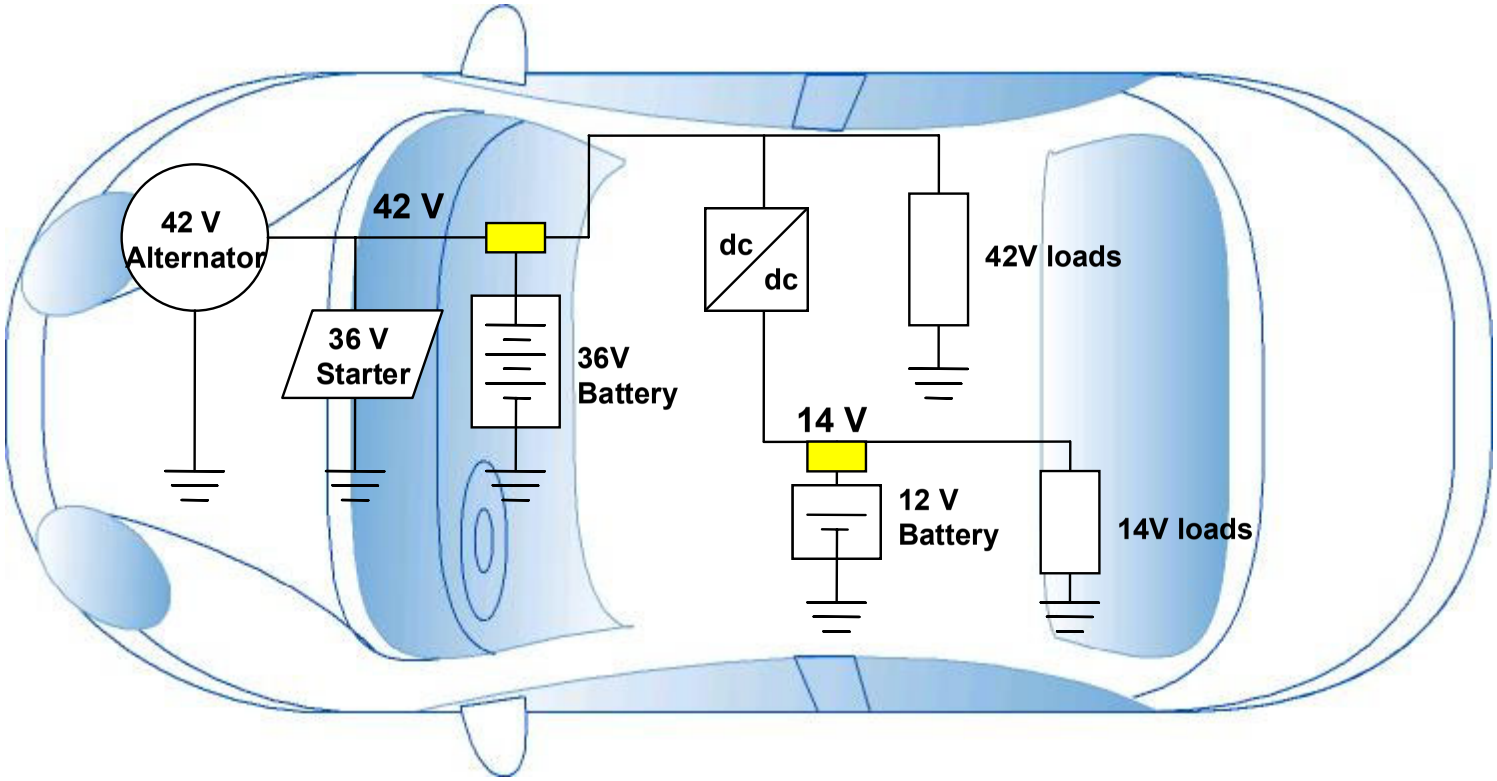
42 Volt inGEN System Block Diagram



42V system – Dual Voltage Architecture

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Benefits of inGEN: Summary

Improvements in:

- Battery Intelligence
  - Real-time Data
  - Diagnostics
- Battery Performance
- System Performance
- Weight Performance
- Cost Performance

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Development Status

inGEN

- Hardware has been tested in-vehicles for over 3 years . ~24 vehicle fleet worldwide.
- Prototypes deployed through OEM and Tier 1s around the world
- Product is licensed for production in a MY2005 European passenger vehicle
- Complete vehicle sensor being produced for military and heavy-duty truck applications
- Licensing available for hardware/circuit design, or SOC/SOH algorithms only
- ASIC and shunt options for 2003

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Midtronics Brings…

- Technology and innovation
- Battery knowledge
- Long term relationships with battery manufacturers
- Entrepreneurial spirit and vision
- Acceptance and support by almost all OEM's – they include …….

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Market Acceptance

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THANK YOU!

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