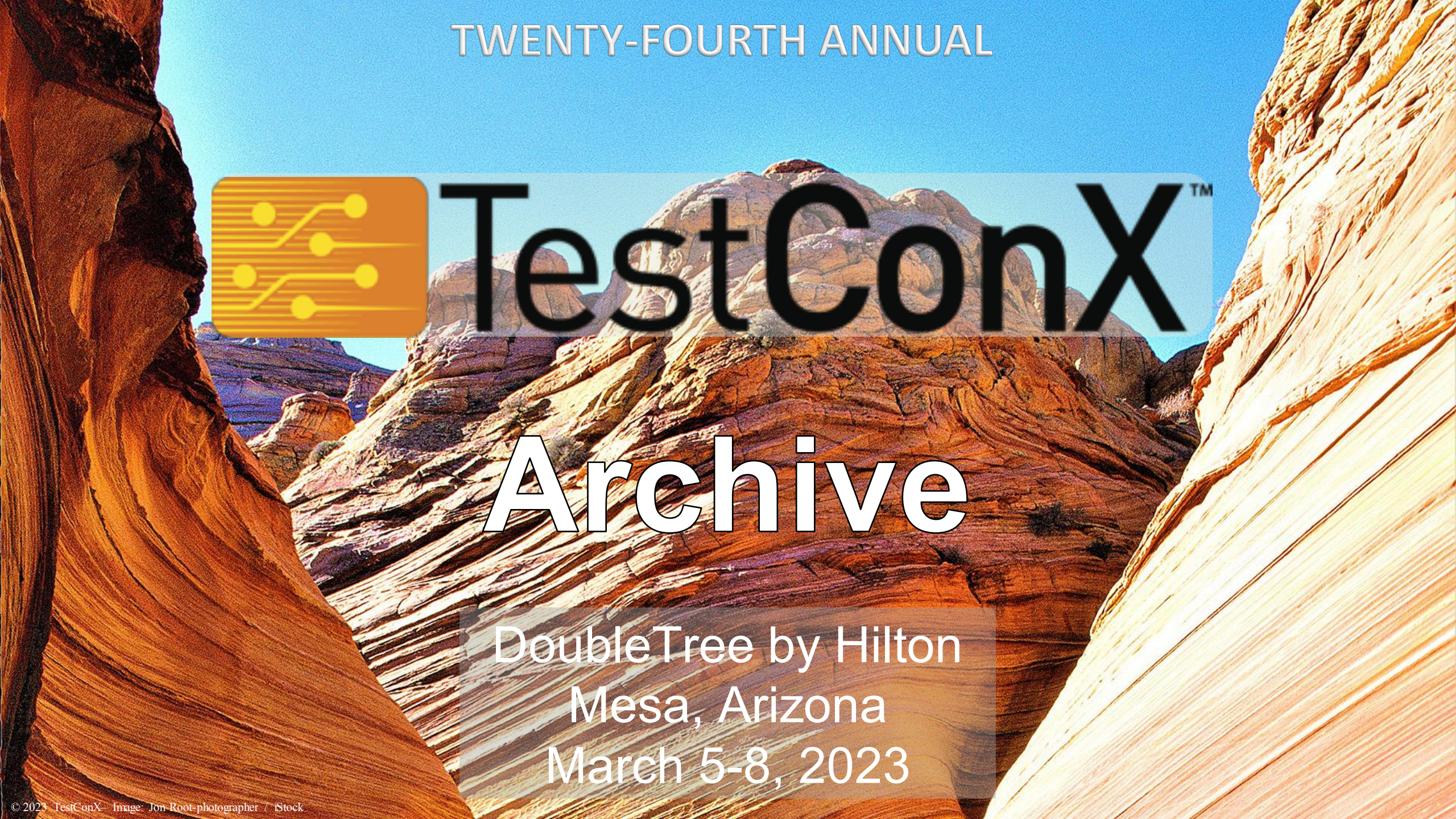

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Battery Management System (BMS) Device Testing and Trends for Automotive

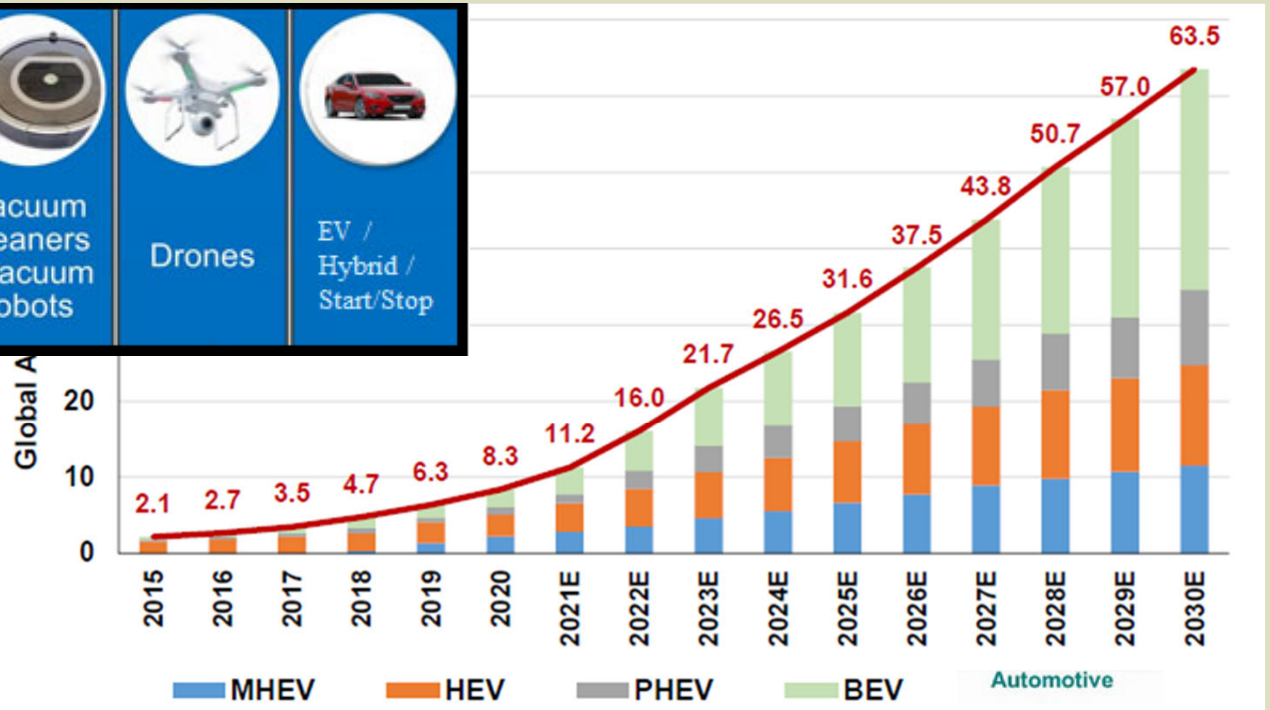
Brent Rousseau
Teradyne Inc.

Mesa, Arizona • March 5–8, 2023

TERADYNE

Driving Battery Management to the Next Level

Battery Management Systems (BMS) control charging and balancing of the charge on individual cells within a battery pack, as well as monitoring the **State of Charge** (SoC), temperature and health of the battery pack.



Source: Credit Suisse estimates (Global Auto Research team)

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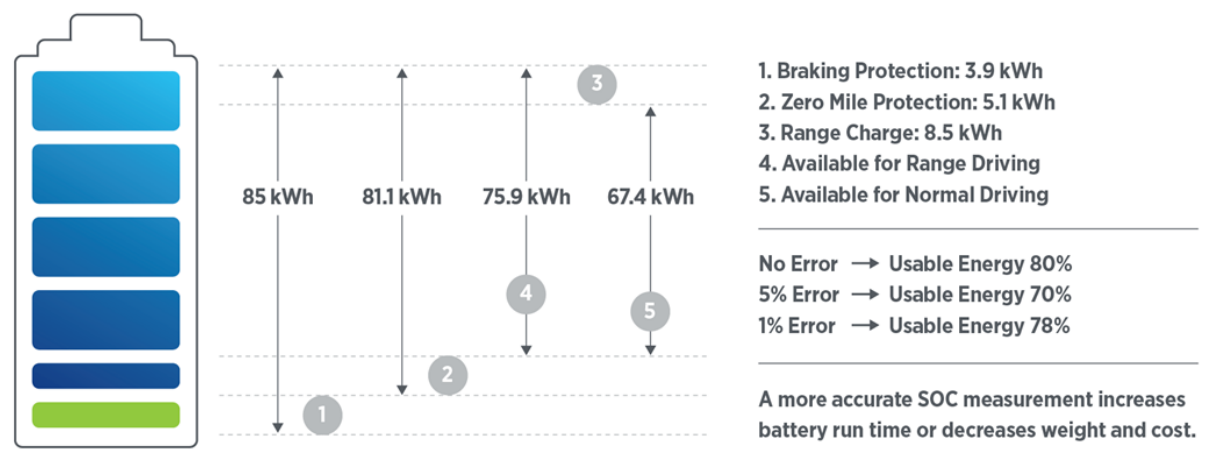
Battery Management System (BMS) Device Testing and Trends for Automotive 2 2023

2

BMS Accuracy is Critical for Electric Vehicle Adoption

- **Driving Range**
  - Range can be increased with the same battery and a more accurate BMS
- **Safety & Reliability**
- **More precise SoC**
  - Enables greater battery Utilization
  - Maintains battery safety
  - Improves driver confidence
- **Vehicle Cost**
  - Greater battery utilization/efficiency allows smaller, lower weight battery packs

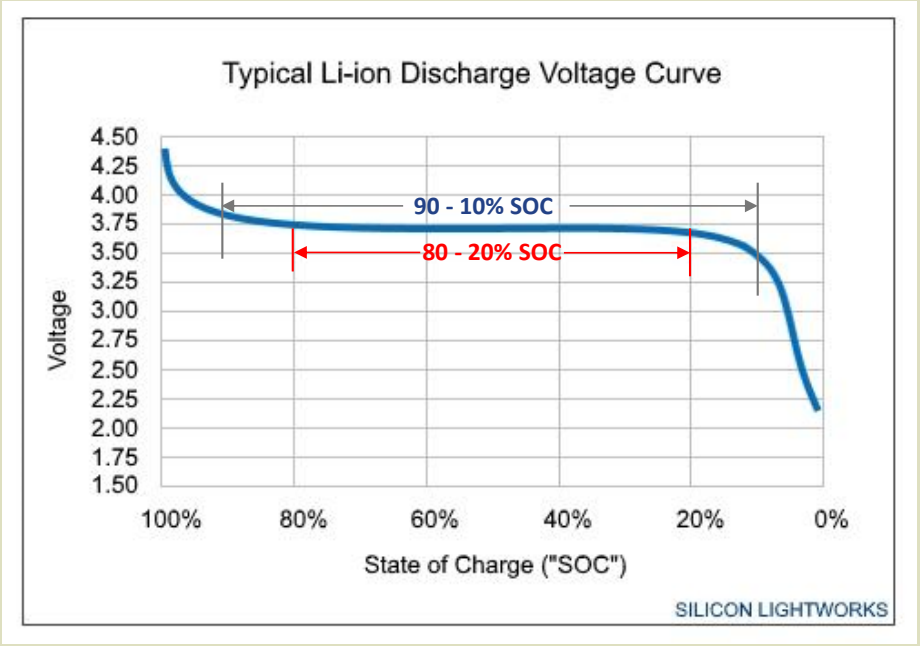


Source: Teradyne, Inc.

- Cells are kept between 10 & 90% of limits
- Must be kept between 15 & 85% if 5% accuracy
- Can be between 11% & 89% if 1% accuracy

Accuracy Challenge for BMS Devices

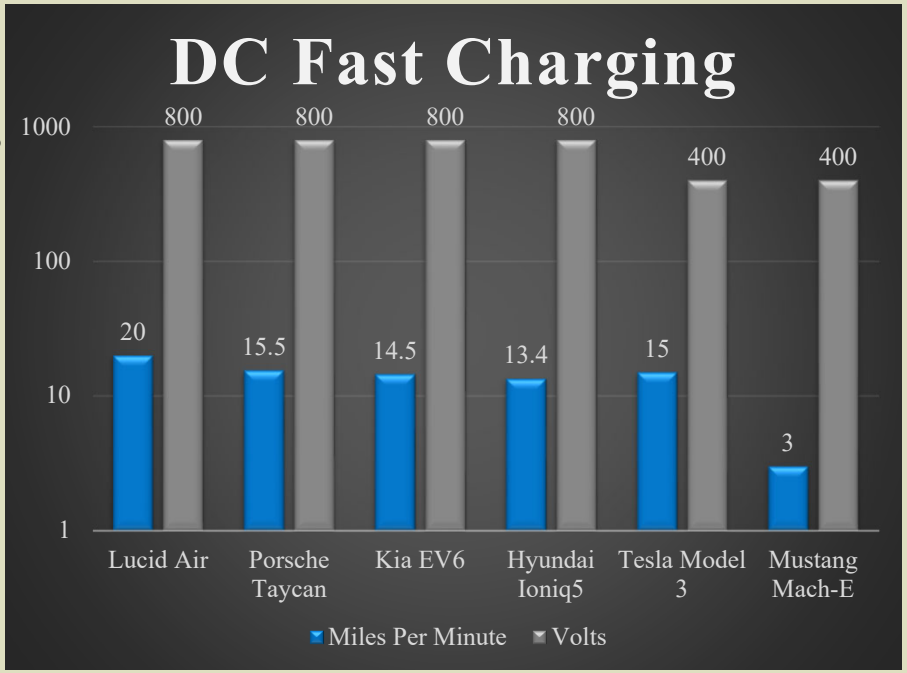
- Full Li-ion SoC 100-0% range is from ~4.3V (fully charged) down to 2.2V (discharged).
- Looking at Li-ion full range, it would appear to be an easy task (~2.1V voltage range or 21mV / 1% SoC change).
- A typical Li-ion discharge usage ranges from 80-20% or 90-10% of the full battery range.
- In 80-20% region the SoC voltage is quite flat at 3.75-3.65V (~100mV total or 1.7mV / 1% SoC change).
- Since measurement system should be 10X better than reading, BMS suppliers are requesting **100uV or 50uV of measurement accuracy** in the 5V range.



Source: Silicon Lightworks, LLC

BMS Trends are Impacting Device Testing

- Better Accuracy!
  - ~100uV accuracy requirements for ATE
  - Competitive advantage for semiconductor suppliers
- Higher Voltages (requires more cells)
  - Mainstream: 400-800V(100-250kW)
  - Leading edge: 800-900V (250-350kW)
  - 2025+: 1000V (enables “charging=re-fueling”)
- Cell to Pack architecture
  - High cell count stack → higher channel count BMS device
  - Allows more capacity in same space



Achieving 100 µV Accuracy for BMS

- **Auto Calibrate the 3458A:** Every 24 hours or when it's internal temperature drifts by >±1°C
  - Eliminates temperature drift error
- **Focused Calibration of ATE differential meter** : Use the 3458A to spot cal the QMS every 24 hours or if ambient temperature has drifted more the 4°C from last Spot Cal.
  - Quad Measurement System (QMS): precision differential meter on ETS-800
  - Focus Calibration is application specific calibration routine to improve relative measurement accuracy
  - Calibrates out both offset and gain in one measurement using precision references on Device Interface Board (DIB)
- **Thermal EMF starts to come into play at these low level voltages**
  - EMF = Electromagnetic Field, can picture this as Thermocouples
  - This can be due to material differences on resistors and mechanical relays

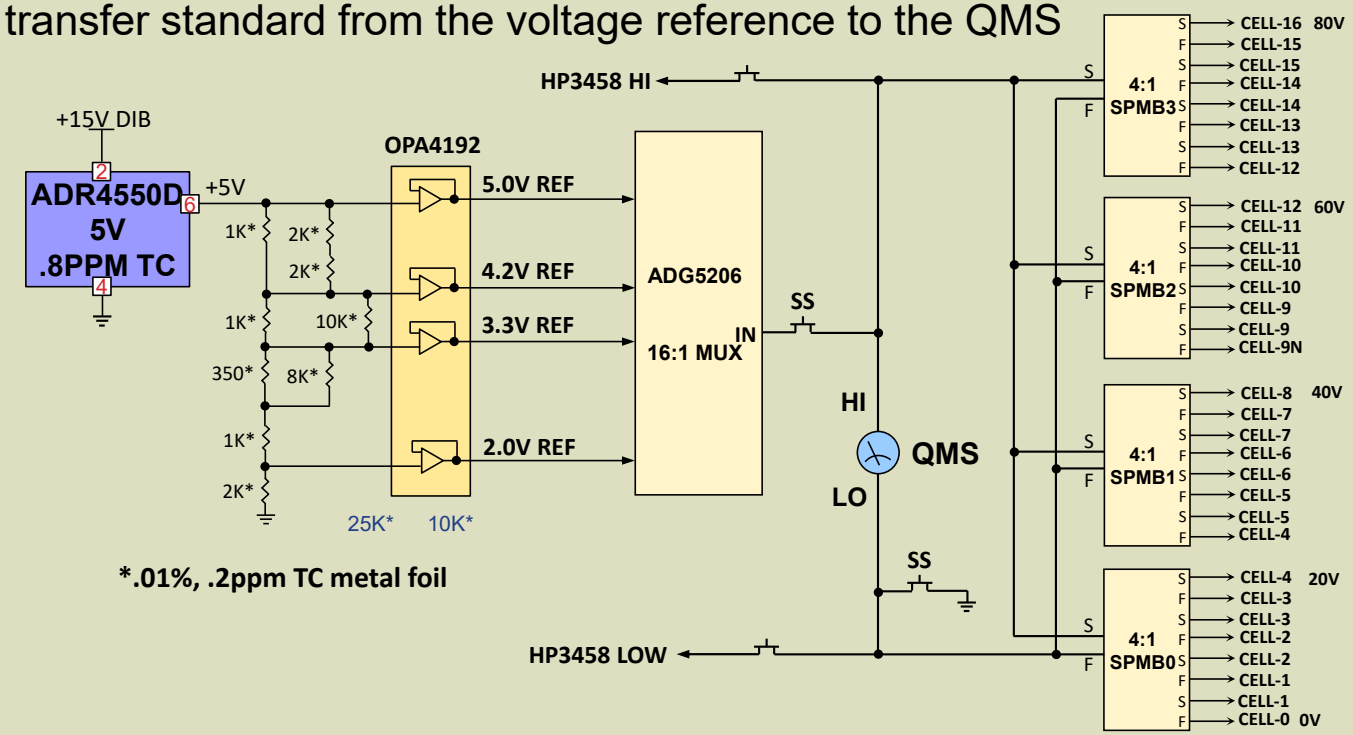
Example Focus Calibration Circuit

Use High Accuracy Voltage References:

- Use a high precision, low temperature compensation voltage reference to compare the 3458A to the QMS.
- The 3458A is used as a voltage transfer standard from the voltage reference to the QMS

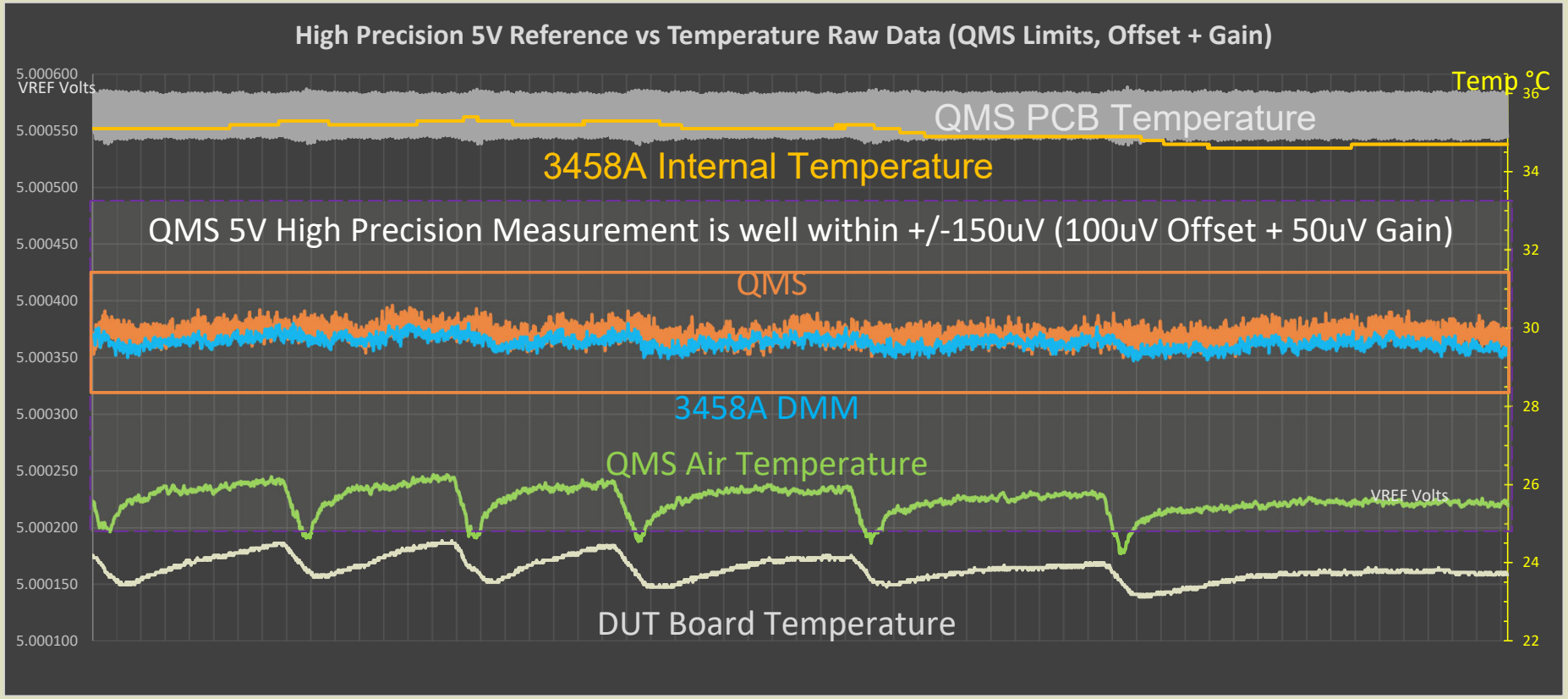
Reduce Thermal EMF:
Elimination of thermal EMF effects caused by relay heating.

- Relays are powered on and left on until the test program is unloaded.
- Use solid state or low thermal EMF relays in DIB design when possible.



*.01%, .2ppm TC metal foil

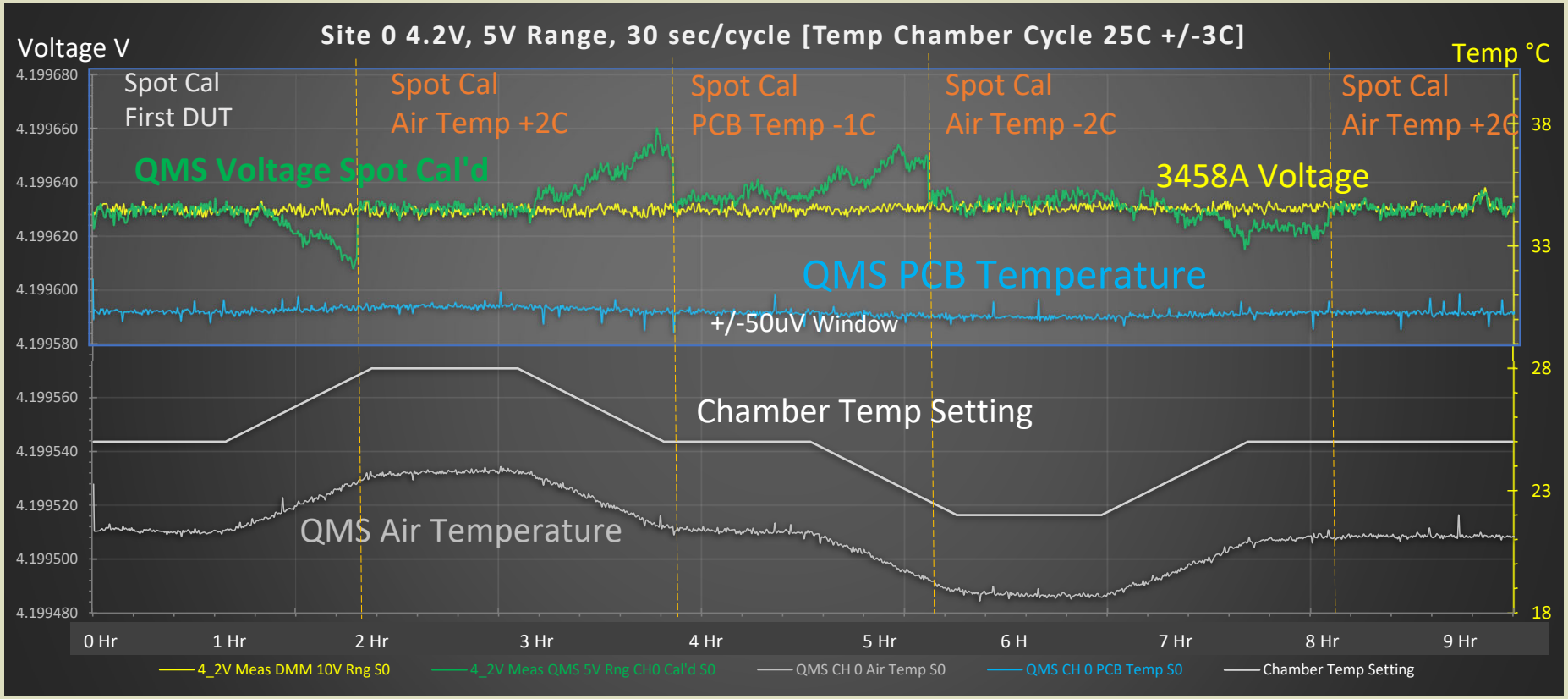
Temperature Stability Key to Deploying Focused Calibration



Source: Teradyne, Inc.

Study on QMS Temperature Stability

QMS (5V Range) using Spot Cal (QMS Air +/-2V)

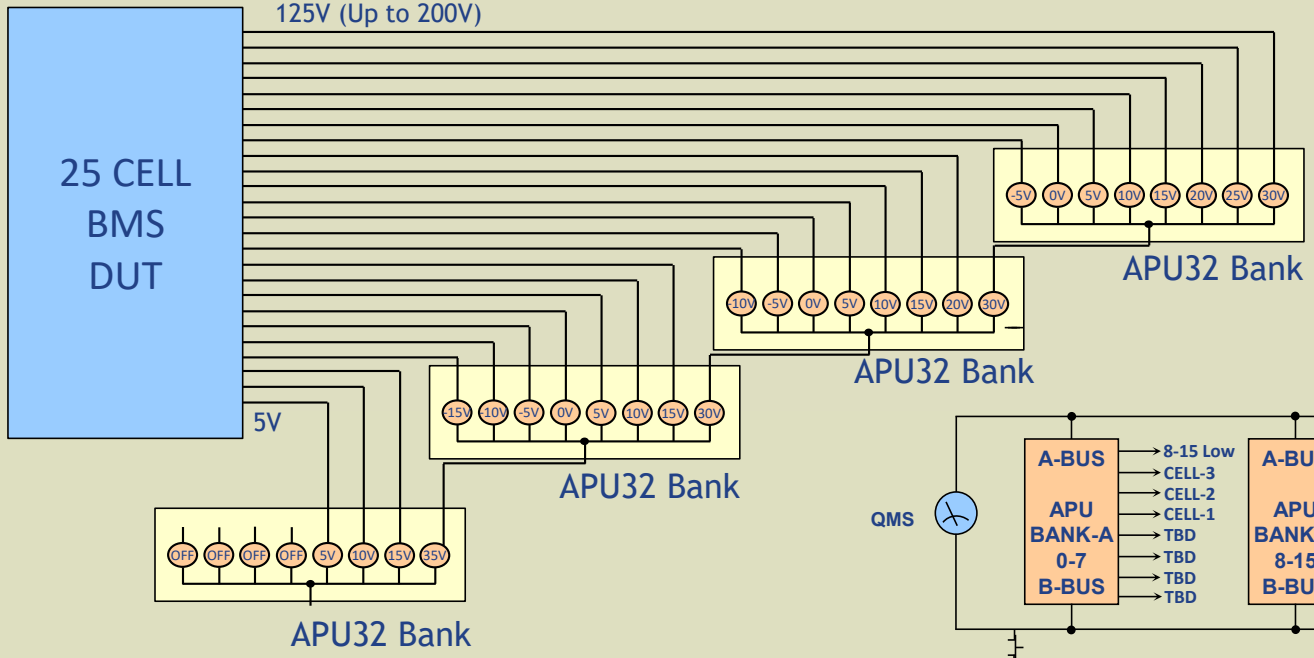


Source: Teradyne, Inc.

Scaling to High Voltage and High Site Count for BMS

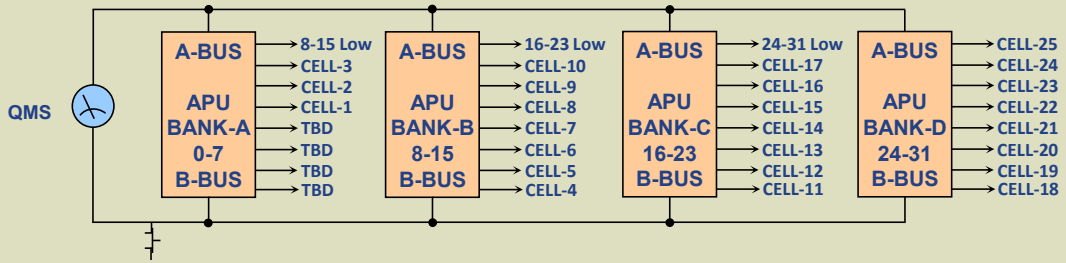
Use QMS through external BUS inputs (no channels sacrificed)

- Uses standard tester instruments
- Extra DIB relays not needed for QMS to scan Cell Voltage Stack



Enablers for Economical Test (x8 to x16 sites):

1. Dense floating low power VI
2. Integrated matrices & muxes to minimize DIB circuitry
3. Large applications space



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Addressing Key Test Challenges for BMS

- **Very accurate/stable Vsource and Vmeasure is required**
  - +/-0.1mV accuracy at 5V (floating at >100V common mode)
- **Increasing volumes and cost pressure requires increase in site count**
  - x2/4 sites →x4/8 sites →x8/16 sites
- **Key tester requirements**
  - High density floating low power V/I
  - Achieve 100uV accuracy (focused calibration required/acceptable)
  - Large applications space & muxing to enable focused calibration and filtering circuitry
  - Digital supporting period & timeset switching on the fly for automotive communication protocols

Acknowledgements

- Contributions / Acknowledgements
  - Brian Foley – QMS data
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  - Dennis Keogh