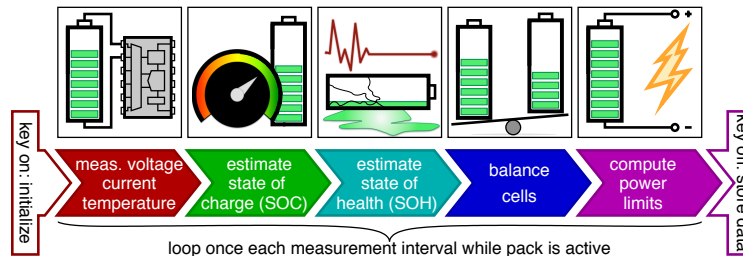## States versus parameters

- A BMS must be able to estimate two fundamentally
  different types of nonmeasurable battery-pack quantity
  - □ <u>States</u> change quickly (*e.g.*, state-of-charge, diffusion voltage, hysteresis voltage)
  - □ <u>Parameters</u> change slowly (*e.g.*, cell capacities, resistances, aging effects)
- SOC estimate for all cells is important input to balancing, energy, power calculations

key on: initialize | meas. voltage current temperature | estimate state of charge (SOC) | estimate state of health (SOH) | balance cells | compute power limits | key off: store data

loop once each measurement interval while pack is active

Simple versus better

- While we might be interested in estimating entire
  battery-model state, we first focus on estimating SOC only
  - □ You will learn some simple methods that lack robustness
  - □ Then, you will learn methods that estimate entire
    battery-model state, enabling more advanced applications
- Recall, SOC is something like a dashboard fuel gauge that
  reports a value from "Empty" (0 %) to "Full" (100 %)
- But, while there exist sensors to measure a gasoline level in
  a tank accurately, there is (presently) no sensor available to
  measure SOC
- And, accurate SOC estimates produce additional benefits...
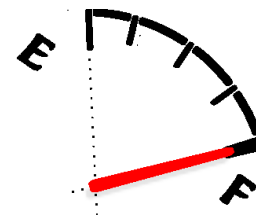
Additional benefits (1)

Longevity: If a gas tank is over-filled or emptied, tank is fine

- However, over-charging or over-discharging a battery cell
  may cause permanent damage and result in reduced lifetime
- An accurate SOC estimate may be used to avoid harming cells by not permitting
  current to be passed that would cause damage

Performance: Without good SOC estimator, one must be overly conservative when
using battery pack to avoid over/undercharge due to trusting poor estimate

- With a good estimate, especially one with known error bounds, one can
  aggressively use the entire pack capacity

Additional benefits (2)

Reliability: Poor estimators behave differently for different
usage profiles (e.g., different vehicle drive cycles)

- A good SOC estimator is consistent and dependable for any driving profile, enhancing overall power-system reliability

Density: Accurate battery state estimates allow battery pack to be used aggressively within design limits, so pack doesn't need to be over-engineered

- This allows smaller, lighter battery packs

Economy: Smaller battery systems cost less. Warranty service on reliable systems costs less

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Summary

- BMS must estimate battery-cell states and parameters
  - □ This course focuses on estimating battery-cell states
- There are simple state estimators and better state estimators
  - □ You will learn how to implement some of each category
- "Better" state estimators can improve battery-system longevity, performance, reliability, density, and economy
  - □ It is often worth investing some effort to implement a "better" estimator

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Credits

Credits for photos in this lesson

- Gauge on slide 2: Pixabay license (`https://pixabay.com/en/service/license/`), `https://pixabay.com/en/fuel-gauge-gasoline-measure-meter-40193/`