What is a ROM and Why Use It?

• What is ROM?
  – A mathematical simplification of a high fidelity model
  – Model reduced to essential inputs and outputs

• Why ROM?
  – Full physics solvers are very accurate general analysis tools, but can be computationally expensive
  – For thermal electronics simulations:
    • Time dependent power cycles?
    • Fully transient vs. steady state solutions and time-averaging techniques

• Benefits of ROM
  – Reduced simulation time (think 10x-100x)
  – Embed ROM into larger system simulations
Linear Thermal Modeling

**Linear time-invariant (LTI) systems**: any dynamic model that matches the measured impulse or step response, will provide identical output results for any arbitrary input.
Case Study: Video Card Model

- Cooling enclosure and heating locations (B1-4, T1-8):
- Temperature at heating locations, plus 7 locations on PCB

- Linear Time Invariant assumption
- State space representation
- Model is “trained” by full-physics simulation of step responses
- Curve fitting to compute proper state space matrices

Air Flow In 3 m/s

Power Input Signals

Temperature Output Signals

LTI State-Space ROM

Physics-Based Simulation Model

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<th>Power Input Signals</th>
<th>Temperature Output Signals</th>
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Case Study: Video Card Model Results

- State Space Model (Solid) (~1s)
- Full CFD Simulation (Dots) (~20min)
- Error < 1%

Validating step responses, CFD vs. ROM

Validating arbitrary power cycle CFD vs. ROM
One More ROM Example

Volkswagen Motorsport used LTI ROM techniques to model the thermal behavior of an electric vehicle battery pack for the 2018 Pikes Peak International Hill Climb race

*Story featured in 2019 Issue 1 of ANSYS Advantage Magazine*

**Challenge:** Develop a fast thermal model to simulate the full drive cycle

**Solution:** Develop a thermal LTI ROM

**Results:** Won the race and beat the record by full 15 seconds on June 24
Electronics Thermal Simulation is not Limited to PCB-Package-Chip...

Example: RF/Antenna Systems of 5G Wireless

- Mobile antenna performance degradation due to temperature
- mm-wave base station array gain reduction due to temperature
- mm-wave antennas, massive MIMO, complex phased array beamforming

Mm-wave link margin degradation vs. distance due to thermal performance drift
Some Key Takeaways...

- Electronics thermal simulations can be applied to a **variety of physical scales**
- Democratization of simulation: a **wide spectrum of complexity possible**
- Multiphysics/coupled simulations can inspire **cross-disciplinary design efforts**
Thank You