System Level Power Electronics

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LYRA ELECTRONICS

Agenda

- Lyra overview
- Power Electronics
- Integration opportunities
- Challenges

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Who are Lyra Electronics?

- Lyra Electronics was founded in 2011 to support the global adoption of electrification across many industries by investing in significant research and development of Power Electronics
- Currently 38 employees
- Organic growth and IP generation
- Turnkey design
  - Requirements capture
  - Simulation
  - Prototype design
- All engineering in house
  - Electronics
  - Mechanical
  - Software
  - Test and validation
  - Functional safety

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Power Electronics

- What do power electronics do?
  - convert AC to DC or DC to AC, increase or decrease the voltage, control energy flow

- Power electronics is the combination of embedded software and hardware which, in combination, represent the single point of control and ‘intelligence’ in electrification
  - Batteries – while chemically complex – are entirely passive
  - motors are complex interactions of magnetics, electricity and mechanics but, again, are entirely passive

- the hardware aspect of power electronics uses complex, rapidly developing materials science to manage the flow of electrical energy at very high power levels

- the software aspect of power electronics controls the hardware with extremely high accuracy to deliver power management to the entire electrical architecture

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Power Electronics

- More specifically, in all case power electronics act between
  - source, e.g. batteries, grid, PV, Fuel Cell
  - and load, e.g. batteries, motor, the grid, heater)

- There is a strong synergy between electronics, software and mechanical engineering
  - considerable advantage is gained from understanding all aspects

- In a conventional powertrain sense, power electronics are analogous to
  - the induction system, valve train and ECU

- The challenges – and therefore the opportunities for development - are legion
  - maximum efficiencies are realised when very small switching tolerances are enabled by the hardware and managed by software

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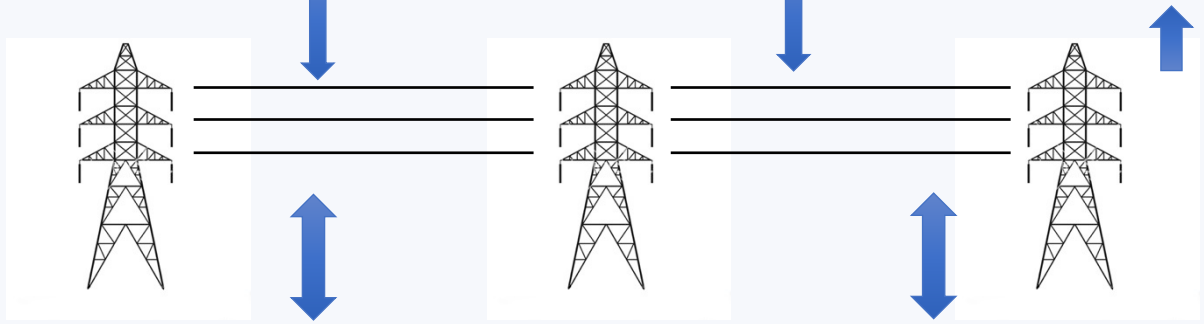
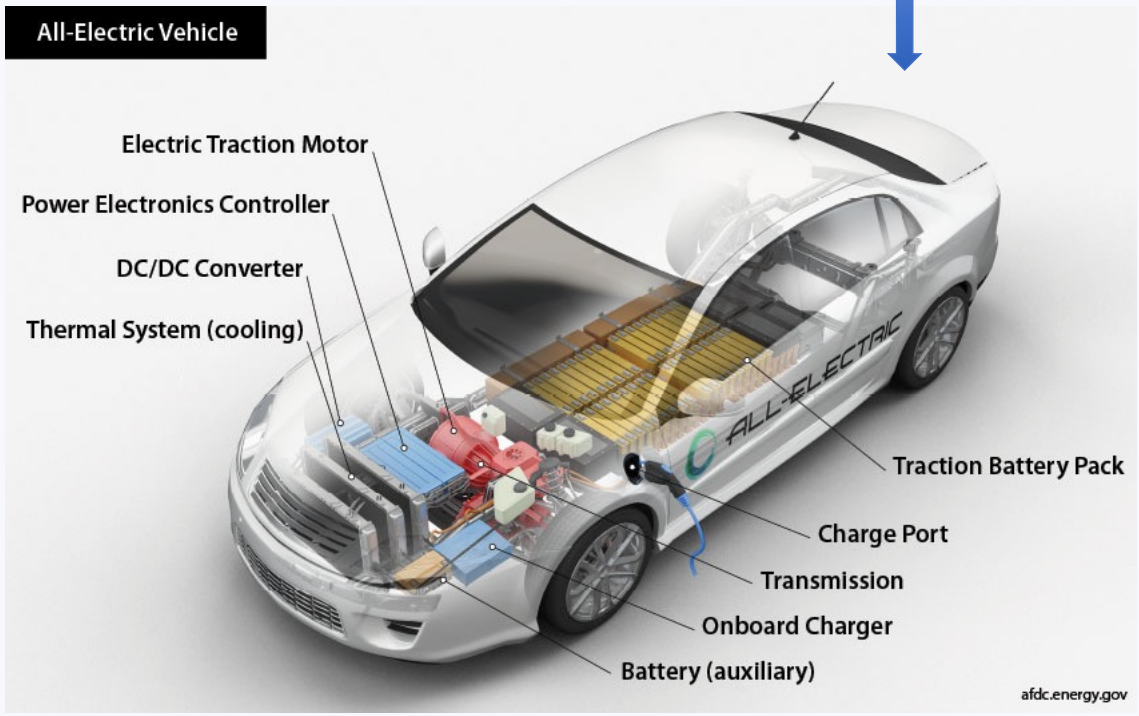
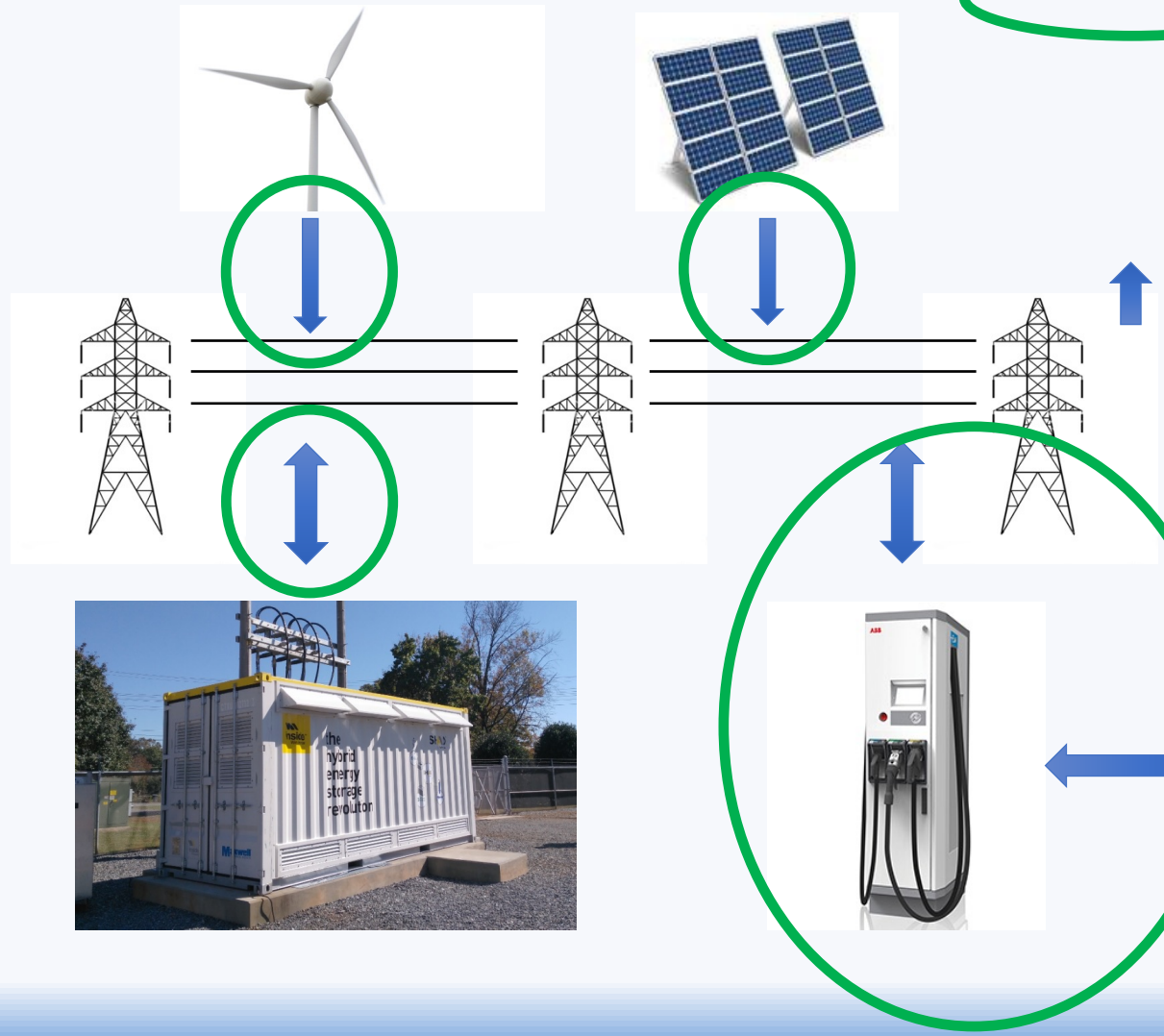
Power Electronics

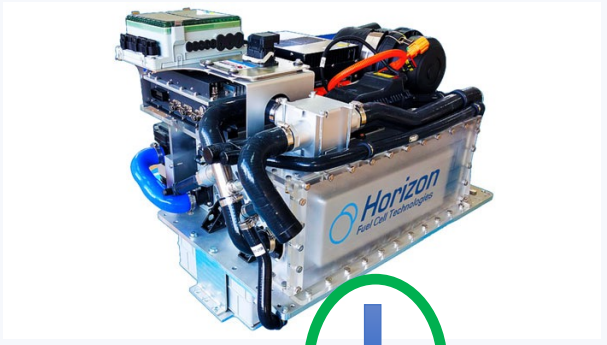


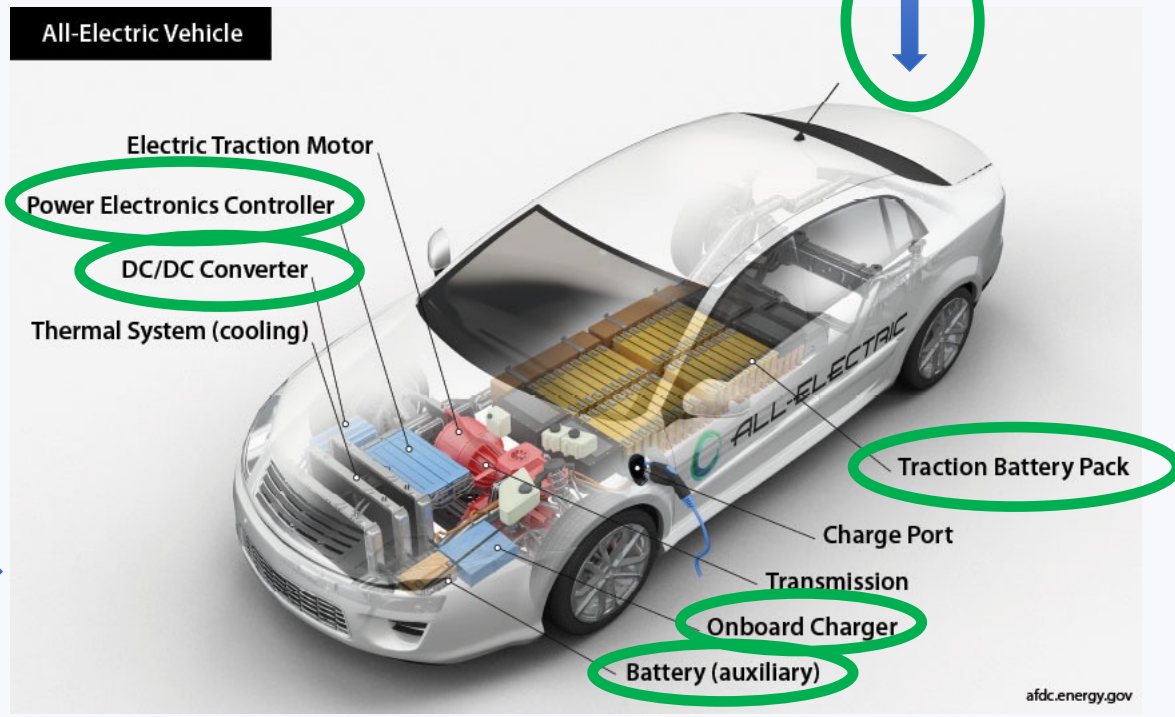


Power Electronics

Lyra's technology







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Power Electronics

- as with many technologies it's easy to imagine that where we are now is the pinnacle
  - this is rarely the case

- Lyra believes power electronics today are as evolved as the Apple II was in 1979
  - in 1979 industry saw the status of computing as incredible
  - some companies saw the technology as only just beginning

- Evolution of Power Electronics
  - Transistor, Thyristor, MOSFET, IGBT, SiC, GaN
  - Synergy with Macintosh Computer to modern MacBook Pro

- industry is embracing electrification and yet power electronics is in its infancy

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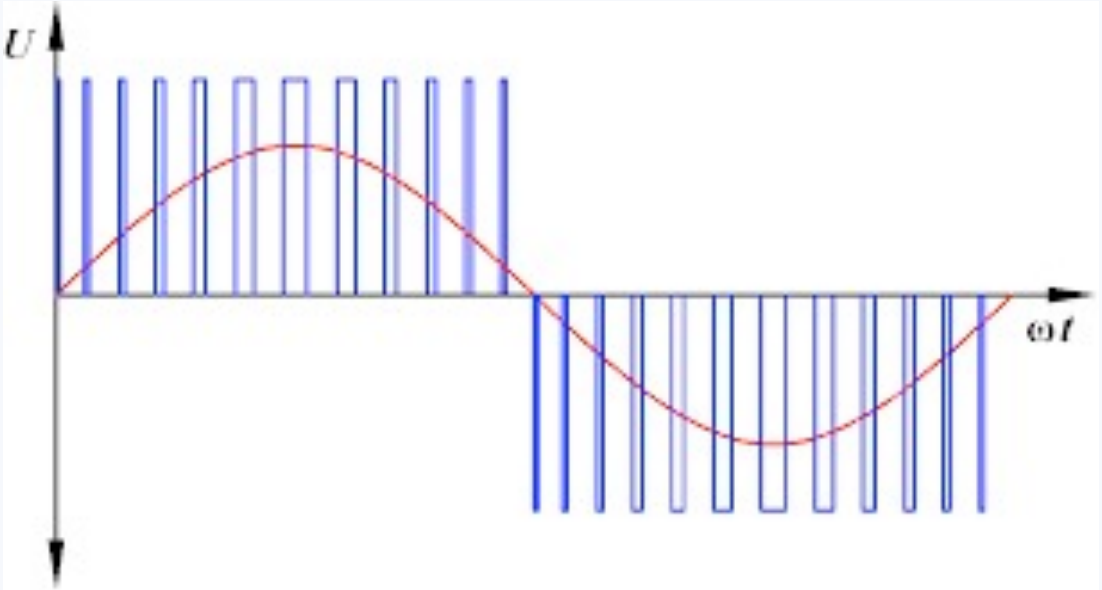
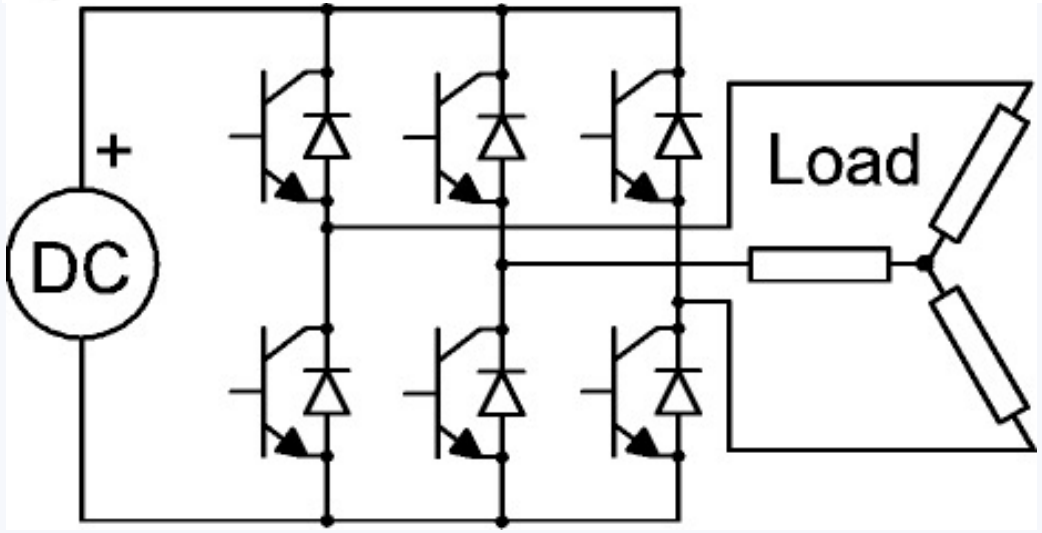
Power Electronics - Examples

- Motor drive inverter
  - Converts DC to AC
  - Controls current in the stator windings
  - Torque and speed

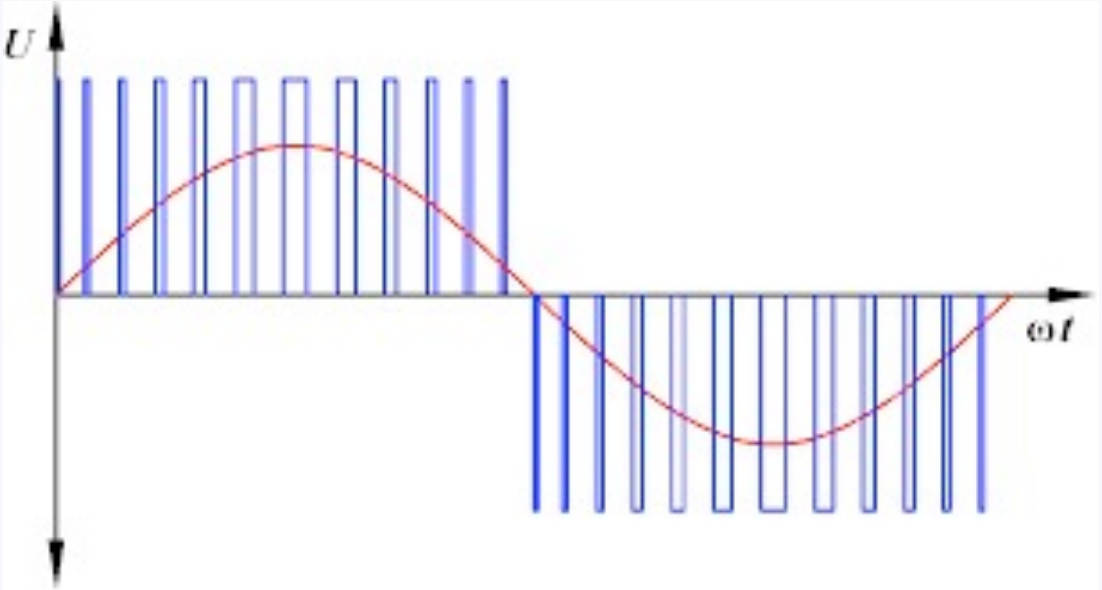
- Power electronics
  - Transistors switch in patterns
  - PWM to create sine wave current
  - Si MOSFETs high on resistance, fast switching
  - Si IGBTs fixed voltage drop, slow switching
  - Si Super Junction MOSFETs low on resistance, fast switching, limited voltage range
  - Si, limited temperature





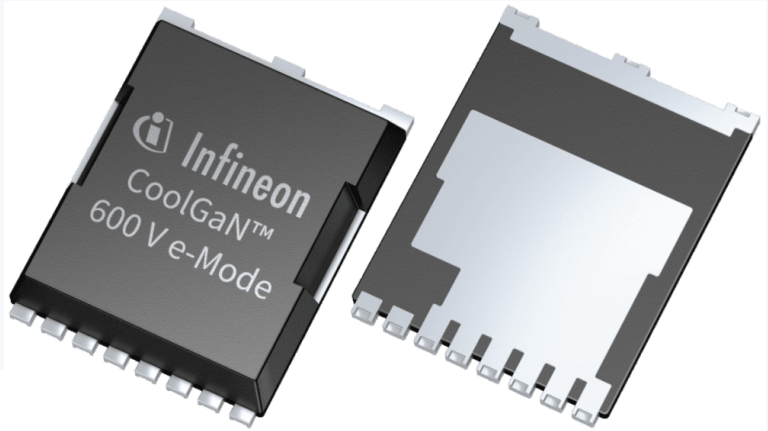
Power Electronics - Examples

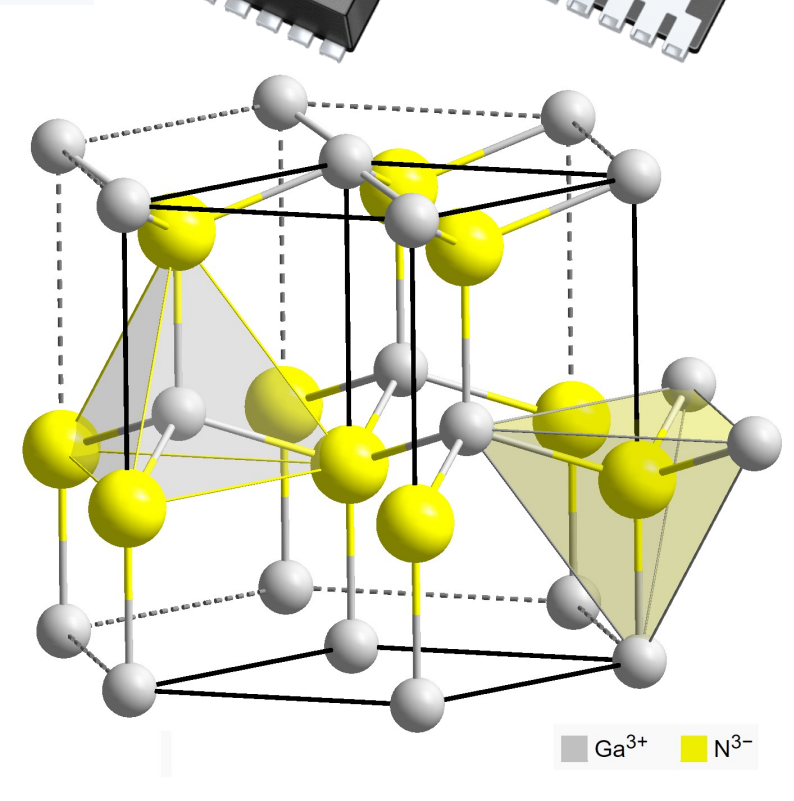
- Silicon Carbide (SiC) MOSFETs
  - Limited availability
  - High voltage
  - High switching speed
  - Low resistance (99%
  - Higher temperature
  - High cost of manufacture
  - Package limitations
  - EMC and Partial Discharge issues



Power Electronics – Next Steps

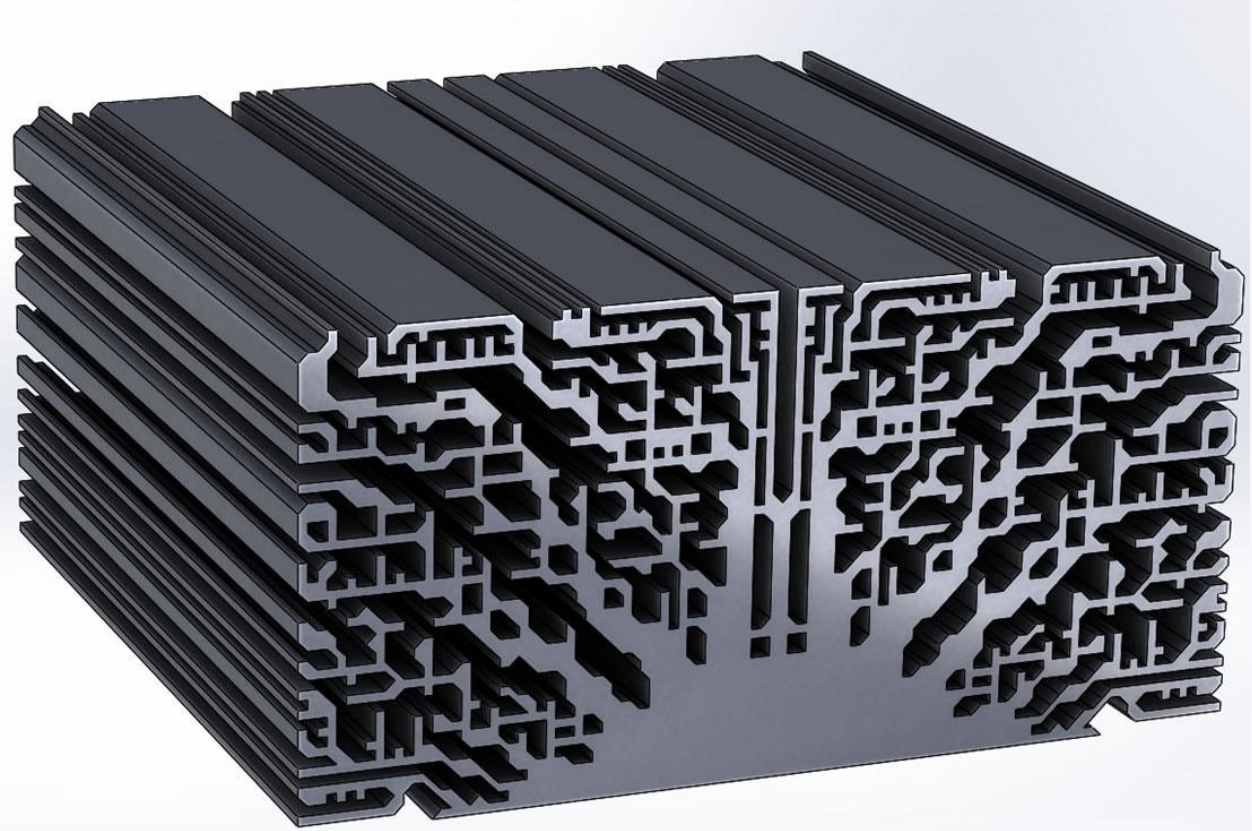
- Gallium Nitride (GaN) MOSFETs
  - Limited voltage
  - Very high switching speed
  - Low resistance (99.3% predicted efficiency)
  - Need vertical device (epitaxial growth difficult)
  - Poor robustness
  - EMC and Partial Discharge issues





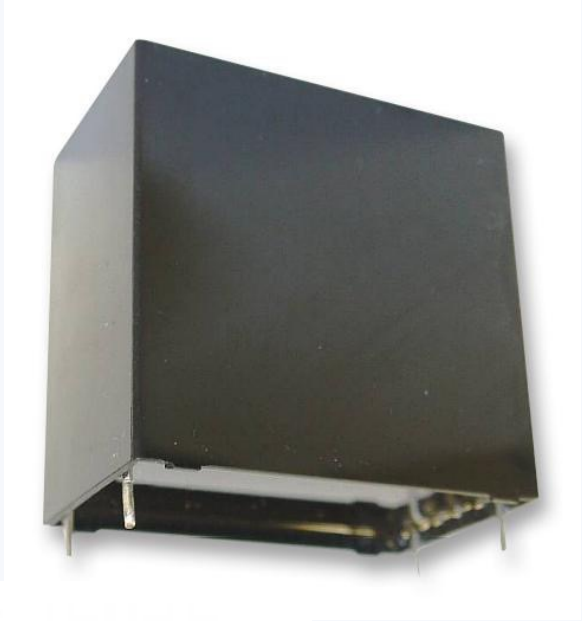
Power Electronics – Next Steps

- Silicone on Sapphire
  - Standard manufacturing process
  - High temperature operation
- Diamond
  - Ultra low resistance
  - Ultra high switching
  - Ultra high temperature operation
- Additive manufacturing
  - Complex shapes
  - Very high power density



Power Electronics – Next Steps

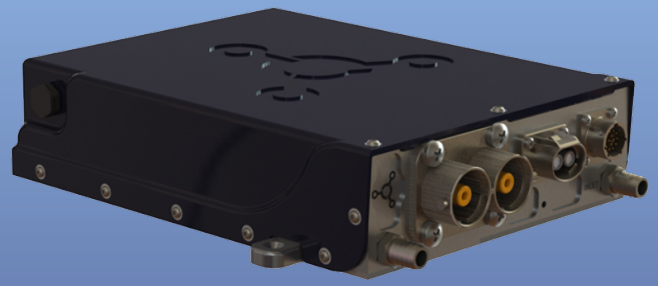
- Passive components need to catch up
  - Capacitors
    - Low Inductance
    - Smaller
    - Longer life
  - Inductors/Transformers
    - Smaller
    - Better magnetics
    - Better insulation

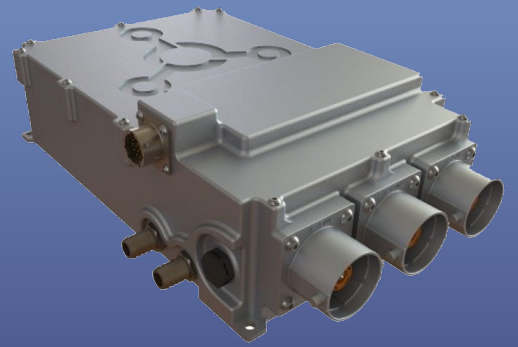


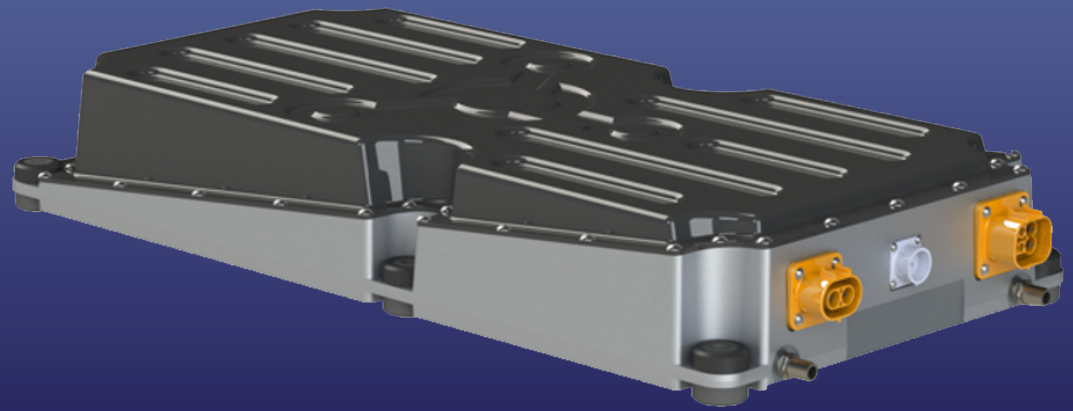
Integration

- power electronics devices require
  - enclosure, cooling, mounting, connections
- integration with Motor (EDU)
  - currently the most undertaken route
  - leaves other essential components isolated despite similar technology

- integration is often driven by legacy ‘departments’ in the OEMs rather than the most appropriate point for system benefits
  - thermal management
  - copper mass
  - component count
  - packaging
  - operating efficiency







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Challenges

- Many opportunities exist in the growth of power electronics
  - component improvement
  - increased technology in switching and control methodologies
  - system based integration and design
  - production and assembly methods

- Many challenges exist
  - relatively new technology means wisdom is rare – skilled resource is hard to find
  - component availability
    - long term – new technologies come with risk
    - short term – global component shortage

- Lyra employs a design strategy which allows the core power electronics to be managed with variant controller architecture

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Thank you

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