AZD
AZURE DYNAMICS
part of the solution

AZD Power Electronics for Hybrid Vehicles

June 13, 2011

Agenda

- Azure Dynamics Background
- P/HEV and EV Products
  - P/HEV Balance
  - Transit Connect Electric
  - LEEP Lift
- Power Electronics
- V2G considerations

Who is Azure Dynamics?

- **Azure Dynamics is an industry leader in hybrid electric and electric powertrain solutions in the commercial vehicle segment**
- **~ 20 years in this industry**
- **Locations in Detroit, Boston, Vancouver & UK (total employees ~ 160)**



Broad Range of Applications

PHEV Balance Hybrid

- 14 kWh Li-Ion battery (nominal = 346 V)
- Electric drive motor cont. power ~ 50 kW
- >20 mile electric range (blended)
- Acceleration rates within ~ 10% of stock veh.
- Level 1 & 2 Smart charging capability
- Charge time (240V) ~ 4 hours

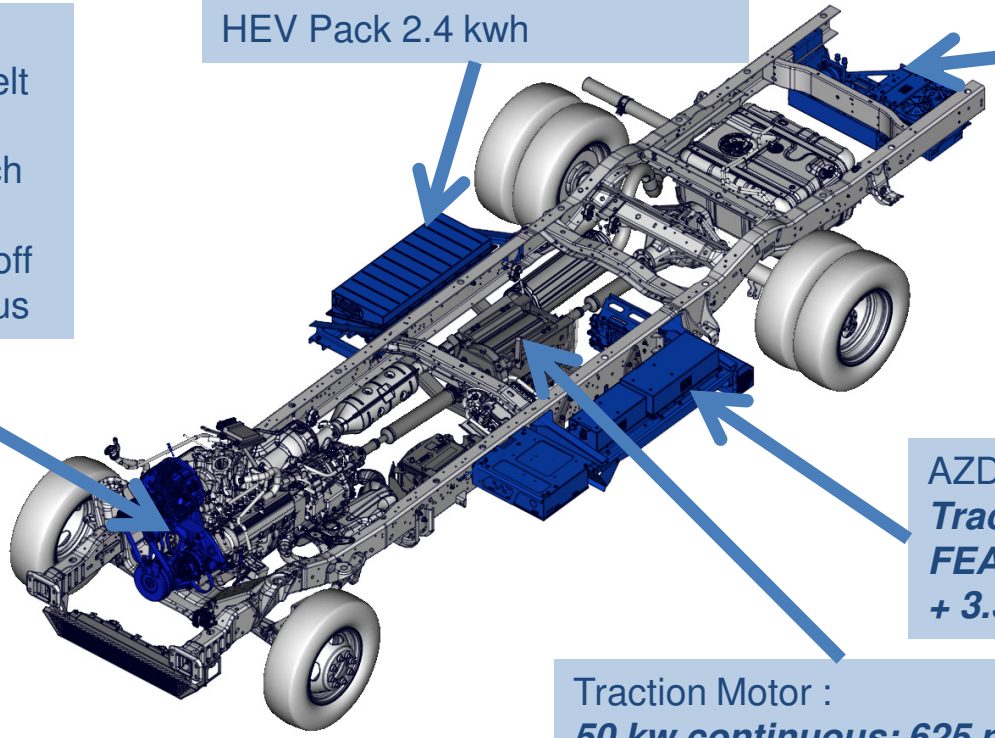
- **Azure's PHEV product offer the following features:**
  - Engine Idle Off
  - Urban Electric drive Performance
  - Electric launch assist (PHEV and HEV mode)
  - Regenerative braking
  - Electric A/C – chassis cab and body
  - Automatic conventional mode redundancy
  - Electric power steering and brake assist

2011 MY Balance Hybrid Technology

JCS Li Ion PHEV battery Pack
14 kwh
HEV Pack 2.4 kwh

65,000 BTU Electric A/C compressor – AZD Force Drive inverter controlled (for Shuttle bus)

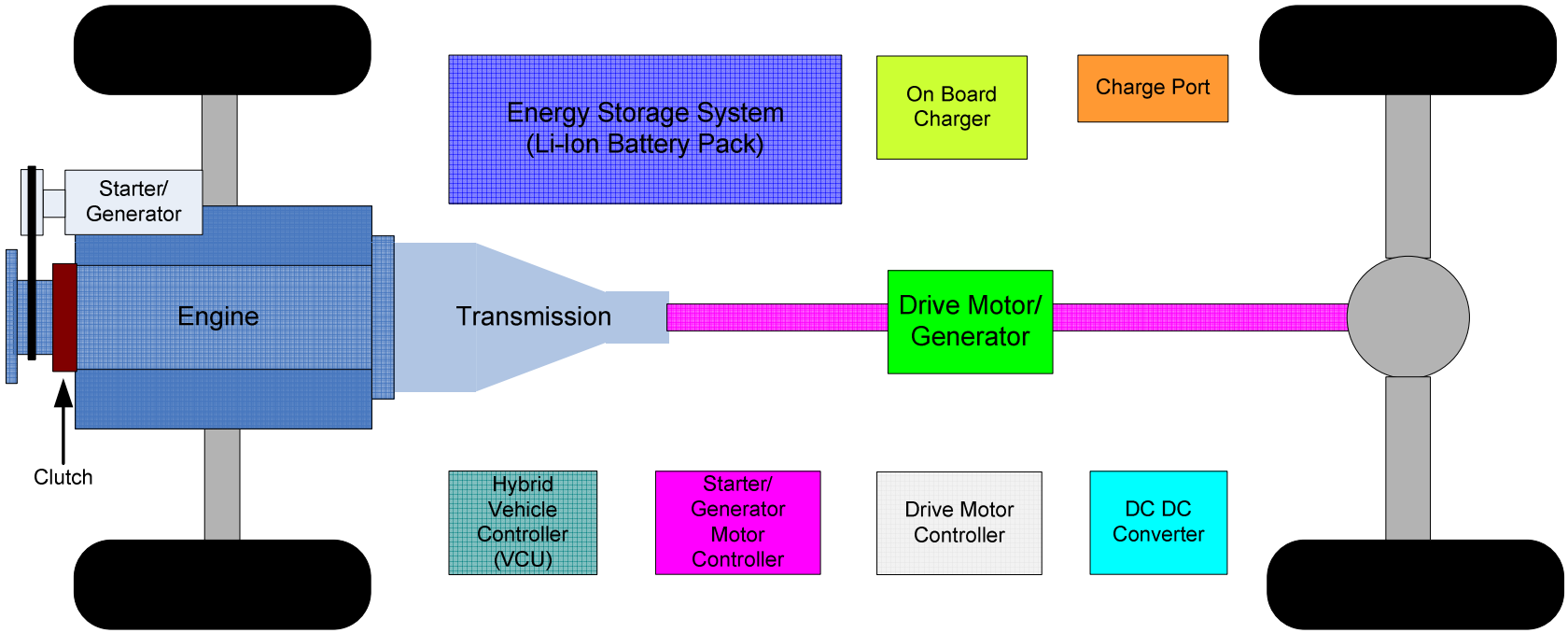
Advancements to AZD Industry Leading V8 Belt Starter Generator - integrated electric Clutch – motor can spin auxiliaries with Engine off - Approx 6 kw continuous



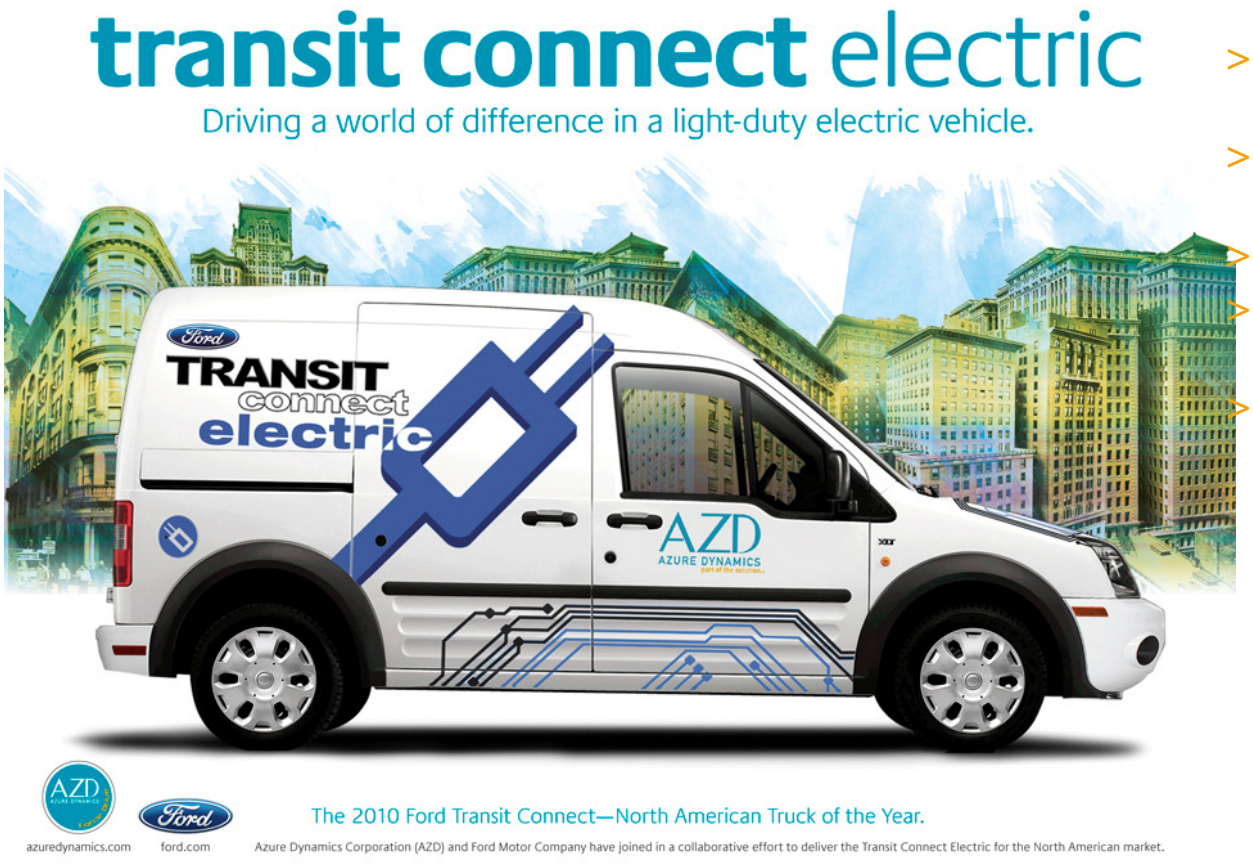
AZD Force Drive inverters:
Traction – (600 amp)
FEAD – (400 amp)
+ 3.3 kw charger

Traction Motor :
50 kw continuous; 625 nm peak torque

PHEV Balance

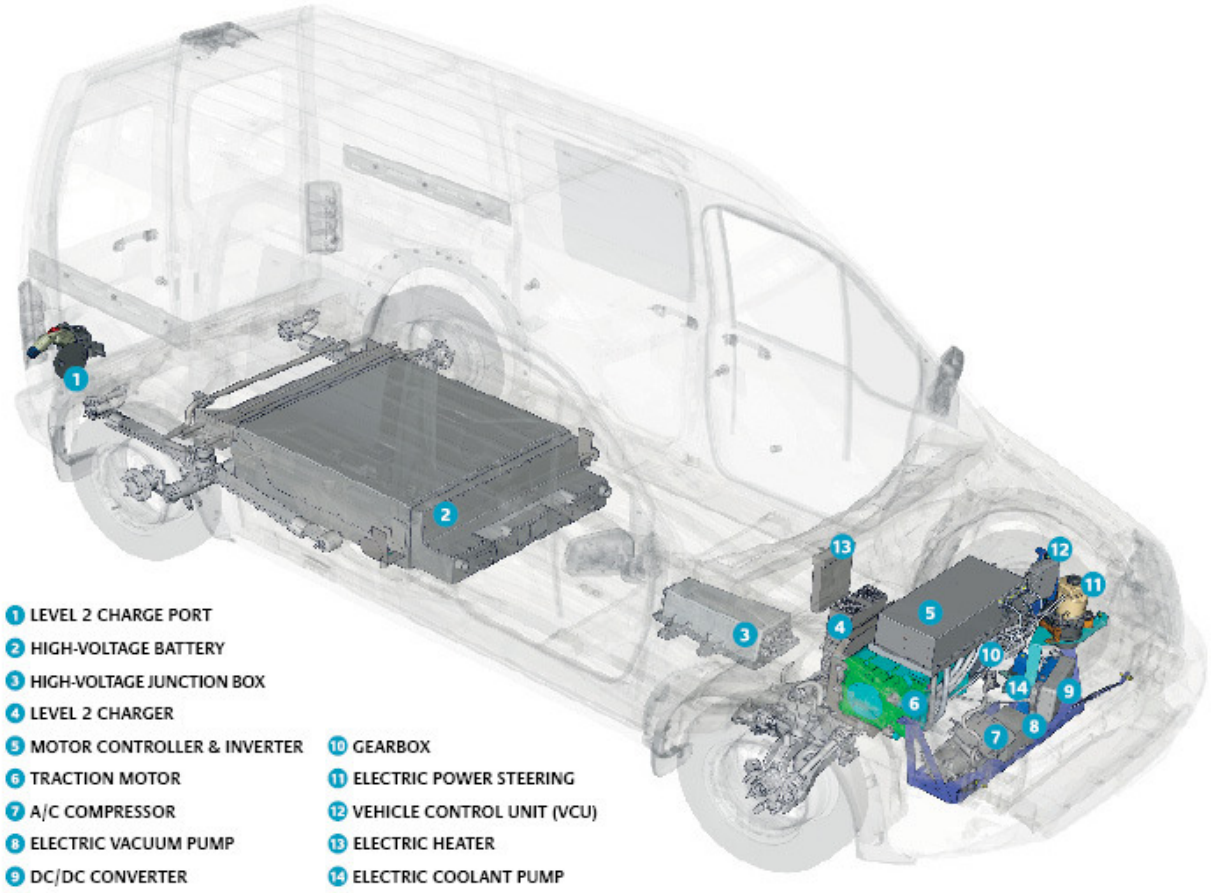


Transit Connect Electric

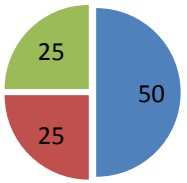


- **28 kWh Li-Ion battery (nominal = 346 V)**
- **Electric drive motor cont. power ~ 57 kW**
- **80 mile electric range UDDS**
- **Level 1 & 2 Smart charging capability**
- **Charge time (240V/30A) ~ 8 hours**

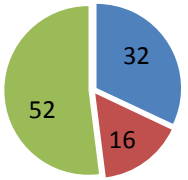
Lessons Learned – Ideal Platform for an EV



UDDS Energy Distribution



US06 Energy Distribution



LEEP Lift

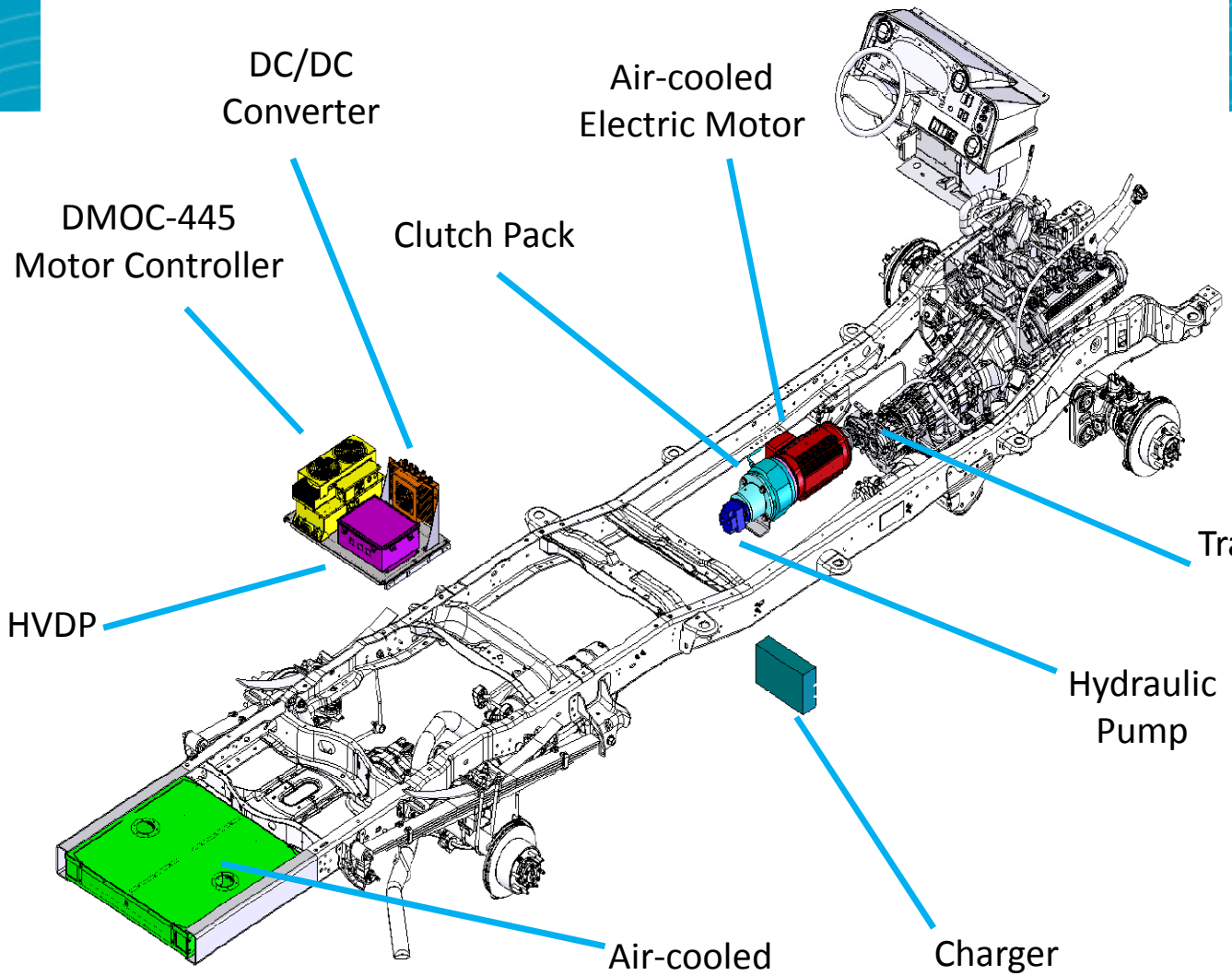
System Benefits are:

- Significant fuel and emissions savings
- Anti-idle compliance
- Engine-off boom operation
- Engine-off 12V DC Supply
- Reduced overall engine maintenance
- Excellent fault tolerance
- No-little impact to normal packaging space
- Modest impact on payload

Options

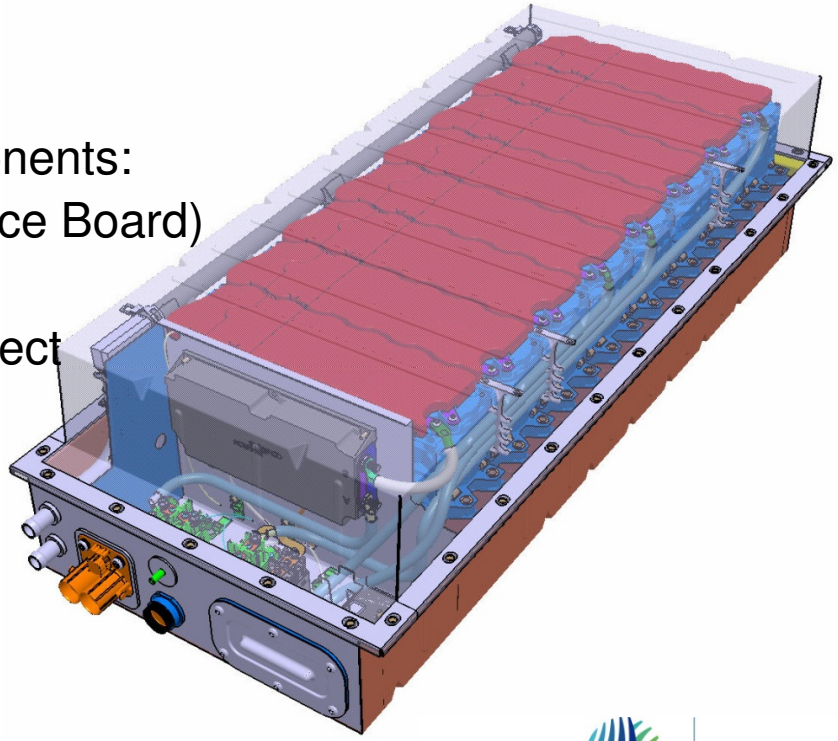
- Plug-in recharging capable
- 2 kVA 115 VAC export Power
- 750 Watt 12V Blocks of power

LEEP Lift System Implementation



PHEV Balance Hybrid Pack

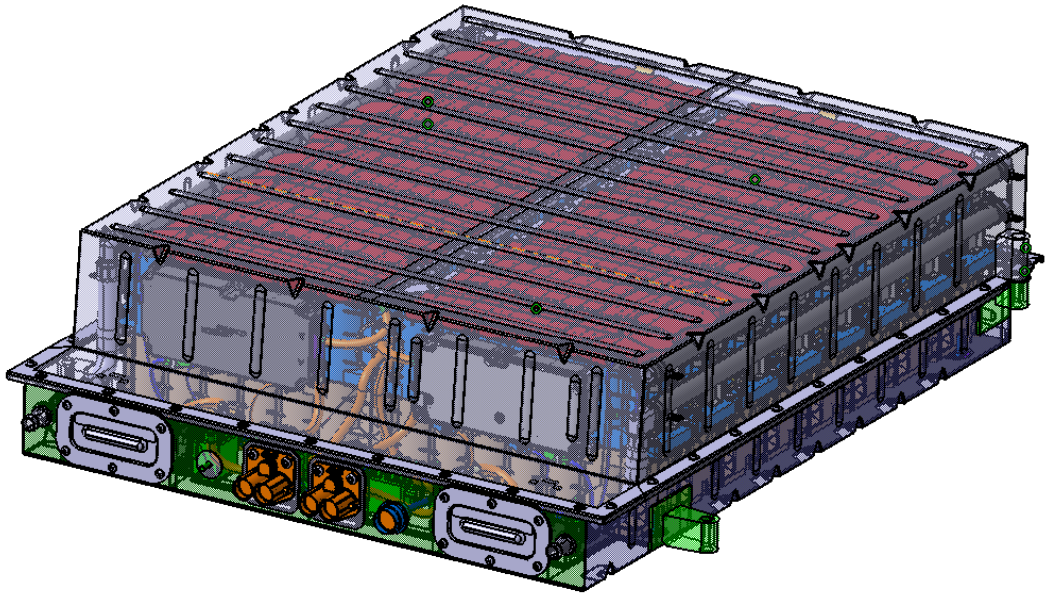
- Liquid Cooled,14 kWh system
- 346 V nominal
- 96 x VL41M cells
- Unique housing utilizing carry-over components:
  - Core Electronics (BMU, CSC and Trace Board)
  - EM12B Module; Coolant Manifolds
  - HV / LV Connectors; Service Disconnect
  - Contactors; Pre-charge Resistor



Johnson Controls | saft

Transit Connect Electric Pack

- Liquid Cooled, 28 kWh system
- 192 x VL41M cells
- 2 parallel strings of 96 cells
- 346 V nominal
- Unique housing utilizing carry-over components:
  - Core Electronics (BMU, CSC and Trace Board)
  - EM12B Module; Coolant Manifolds
  - HV / LV Connectors; Service Disconnect
  - Contactors; Pre-charge Resistor
- **DESIGN LIFE – 10 Years; 120,000 Miles**



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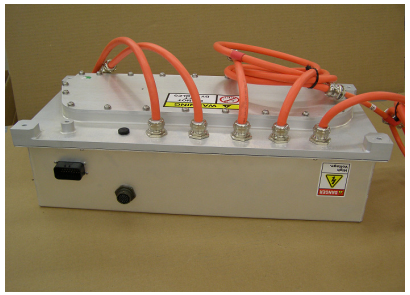
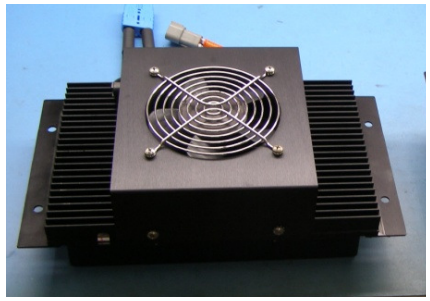
Flagship Components

Our components are based on over 15 years of development and field experience

- Digital Motor Controllers (DMOC)
  - Ground-up design
  - Three power levels (120 kVA, 80 kVA, 20 kVA)
  - All digital field oriented control
  - Space-vector PWM
  - Thermal management (air and liquid cooled)
  - Over and under-voltage protection
  - Three level over-current protection

- DC-DC Converters
  - Voltage source and battery charging
  - Isolated power transfer

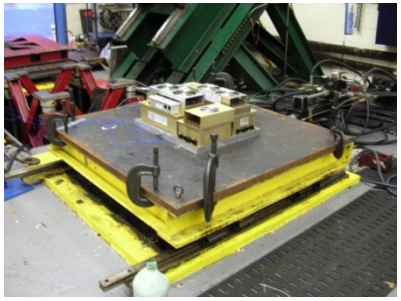


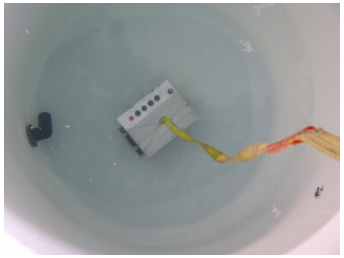


Power Electronics

Our latest generation components are designed to meet the stringent requirements of commercial fleets.

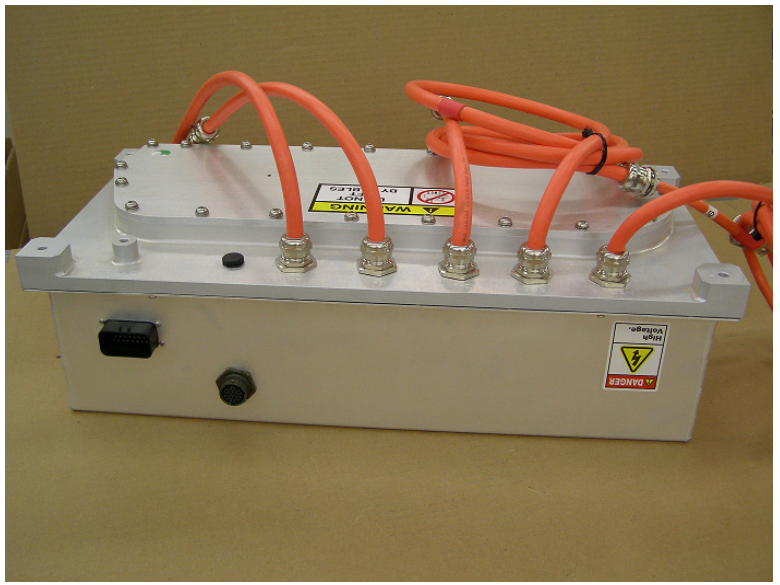
- Life: 20,000 hours
- EMC:
  - EU specifications 2004/104/EC
  - Ford ES-XW7T-1A278-AC
  - GM3097
- IP65/IP67
- Chemical: SAE J1455
- Vibration: ISO 16750-3





Gen-II Characteristics

- Max AC current: 420 Arms
- Max DC voltage: 400 VDC
- Coolant: 55C @ 10l/min
- Weight: 21 kg
- Volume: 25 L
- AC Motor Control Algorithms
- Derivability Algorithms
- CAN Interface
- UDS for Diagnostics



DMOC645-LC

Gen-III Drive Characteristics

- Nominal peak power: 150 kW
- Max voltage (non-operating): 550 V – up from 450V
- Max operating voltage: 450V – up from 400 V
- Max output current: 420 Arms - unchanged
- Rated current: 200 Arms, at 10l, 65C coolant – up from 55C
- Weight: 15 kg – down from 21 kg (DOE: 12 kW/kg)
- Volume: 10 L – down from 25 L (DOE: 12 kW/L)
- Cost: 40% reduction
- ISO 26262 compliant (Functional Safety)
- Complete Ford EMC compliance

V2G Considerations

- V2G components must be robust to meet on vehicle environmental; EMC; Safety; performance requirements
- P/HEV and EV's are already cost challenged – V2G must provide economic return
- What is the best way to integrate – standalone or with drive inverter & motor? Some level of integration is preferred for lower cost, weight and robustness
- What is the new design life requirements for all affected components – already a 20,000 hr requirement without considering V2G?
- Vehicle availability for EV's – when to charge/discharge?
- Standardized communications and smart grid readiness
- How will battery life be affected?

Lessons Learned – Opportunities to Support Wider EV Adoption

EV range and infrastructure continue to limit widespread adoption

- There is no single answer => focus on all of the following areas will improve EV adoption:
  - Battery advancements
  - Vehicle and electric drive efficiency gains
  - Fast charging infrastructure -> mitigate need of on-board energy
  - V2G and Smart charging -> improve Cost of ownership
  - Range extender and PHEV options

Q & A