2014 DOE VEHICLE TECHNOLOGIES ANNUAL MERIT REVIEW

Next Generation Inverter

Project ID # **APE040**

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General Motors
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GENERAL MOTORS

OVERVIEW

Timeline

- Start - October 2011
- Finish – January 2016
- 62.9% Complete

Barriers

- Cost
- Efficiency
- Performance and Lifetime
- Mass and Volume

Budget

- Total project funding
  - DOE - $6.0M
  - GM - $10.6M
- Funding received
  - FY12 - $0.8M
  - FY13 - $1.7M
  - FY14 - $1.2M

Partners

- Lead – General Motors
- Tier 1, 2, & 3 Suppliers - Hitachi, Delphi, Infineon, HRL, Panasonic, AVX, Kemet, and VePoint
- Collaborations - National Renewable Energy Laboratory, and Oak Ridge National Laboratory

RELEVANCE

Research Focus Area: High Power Traction Inverters

➔Modularity/Scalability

➔Components – power module, gate drive, capacitor, current sensor and control card

➔Supplier development

Objective

- Program, develop the technologies and the engineering product design for a low cost highly efficient next generation power inverter capable of 55kW peak/30kW continuous power.
- Current (3/13 through 3/14), detailed design, build, and initiate test of early units

Addresses Targets

- The Inverter is to improve the cost of the power electronics to $3.30/kW produced in quantities of 100,000 units, and the power density to 13.4kW/l, and a specific power of 14.1kW/kg, with an efficiency >94% (10%-100% speed at 20% rated torque) to meet the DOE 2020 goals

Uniqueness and Impacts

- Technology Co-development with the Tier 1, 2, and 3 suppliers
- Detailed knowledge of vehicle application and ability to understand and assess vehicle impacts to make necessary materials and technology trades.

MILESTONE

Month /Year	Milestone or Go/No-Go Decision	Status
June 2012	Power Inverters Based on Conventional, Transfer Molded, and Encapsulated Power Module Technology Delivered for Evaluation	Complete
Jan 2013	Initial Technology and Production Cost Assessment Complete with Report	Complete
Jan 2014	Concept Design Review – DOE “Go/No-Go” Decision	Complete
June 2014	Critical Design Review	

APPROACH

- Engage with Tier 1, 2, and 3 suppliers along with National Labs to co-develop technology that reduces cost and increase efficiency, without increasing volume or mass
- Ensure modularity and scalability of inverter to meet all vehicle applications
  - Packaging will fit in all vehicle applications
  - Consistent electrical parameters and mechanical structure
  - Has to adhere to global manufacturing processes
  - Has to provide adequate cooling for the capacitor
  - Has to have low inductance
- Demonstrate technology to verify feasibility and cost

STRATEGY

- Inverter requirements need to be refined to better describe real vehicle use
  - Inputs necessary for actual results are as follows: vehicle, powertrain, and electric traction system
- Select technologies that are aligned with vehicle application to make common inverters
  - Power module, gate drive, capacitor, and control card
- Cost reduction versus performance trade-offs
- Ensure compatibility with future switches

ACCOMPLISHMENTS – DESIGN SELECTION

Top level rational of selection

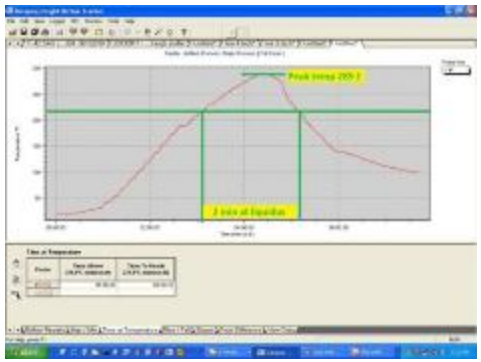
- Three types conventional, transfer molded , and encapsulate
- Cost, scalability, modularity

Result, modified conventional

- Benefits
  - Adheres to common manufacturing processes globally
  - Flexibility to meet all vehicle applications while maintaining commonality
  - Simplified unit assembly
- Disadvantages
  - Complexity of design at lower level components
  - Intimate knowledge/understanding of all components and processes to produce required at OEM

ACCOMPLISHMENTS – ATTACHMENT PROCESS

- Substrate to heatsink and die to substrate attachment
- Solder and sinter pastes, and plating identified
- Temperature profile development



ACCOMPLISHMENTS - COMPLIANT PIN PROCESS

- All process parameters identified and specified

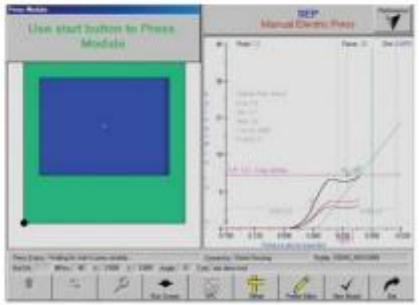
TYCO 6-Ton Machine MEP-6T

Optional Pin Penetration Sensing Tooling (PPS)

Option pin penetration sensing (PPS) tooling provides and additional quality check for products applied on a CSP. PPS tools are specifically designed for the product applied to verify that every pin properly penetrates the PCB by a predetermined distance. Coupled with force monitoring, PPS tools give assurance of the proper location, penetration and application of every compliant pin on every product applied. The PPS check is performed in real-time without the need for an additional or destructive quality test.

Run Time Press Monitoring

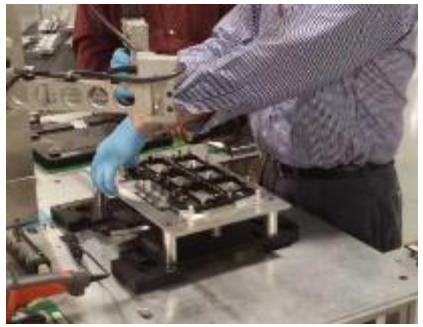
The run time screen provides complete operator interface and feedback. Each press cycle is monitored for Force vs Distance and data is clearly displayed. Press stroke status is shown to acknowledge proper application or error information. A picture of the end product can also be used to guide the operator through the pressing sequence to reduce operator error.

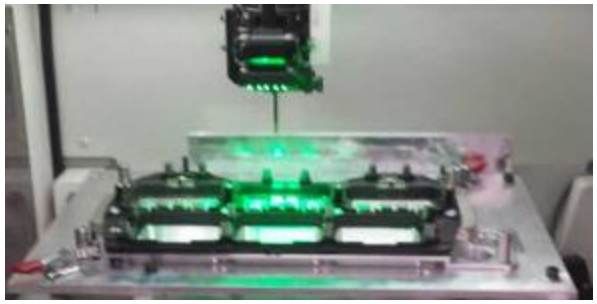


ACCOMPLISHMENTS – INVERTER BUILD

Early build completed to test and verify design concept and develop manufacturing process

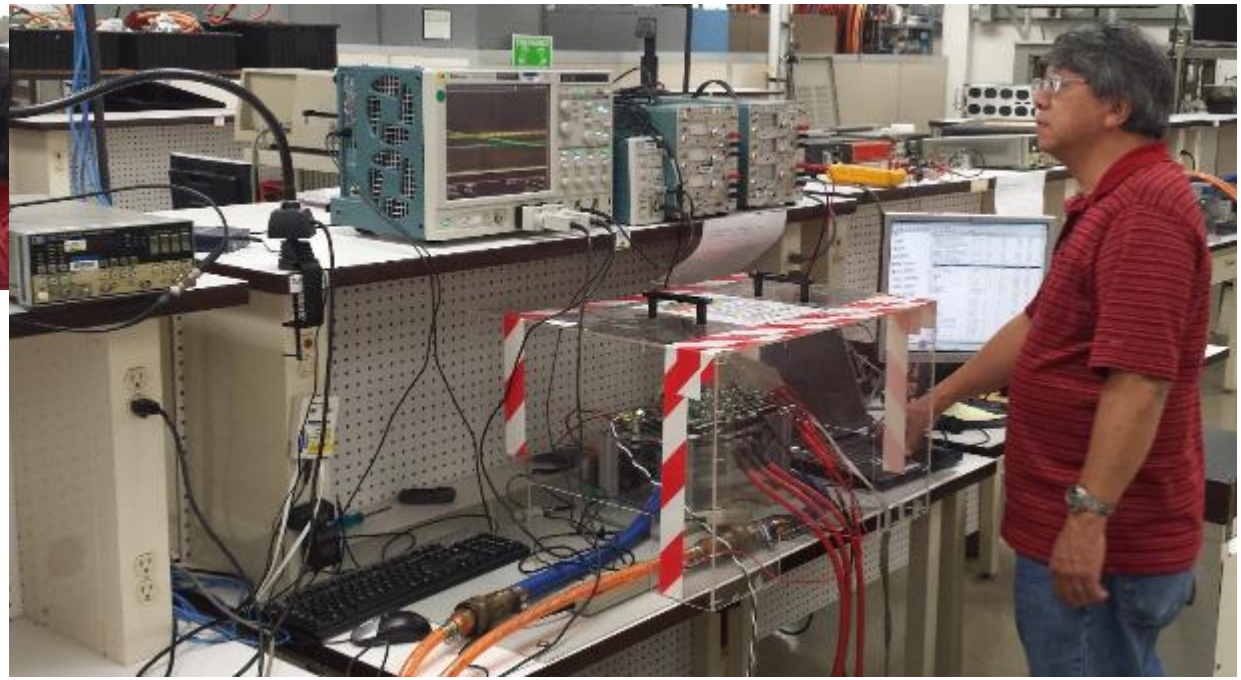
- Five units built
- Demonstrated integrated inverter design
- Well documented build provided meaningful learnings
- Key suppliers involved during build and provided feedback on part design



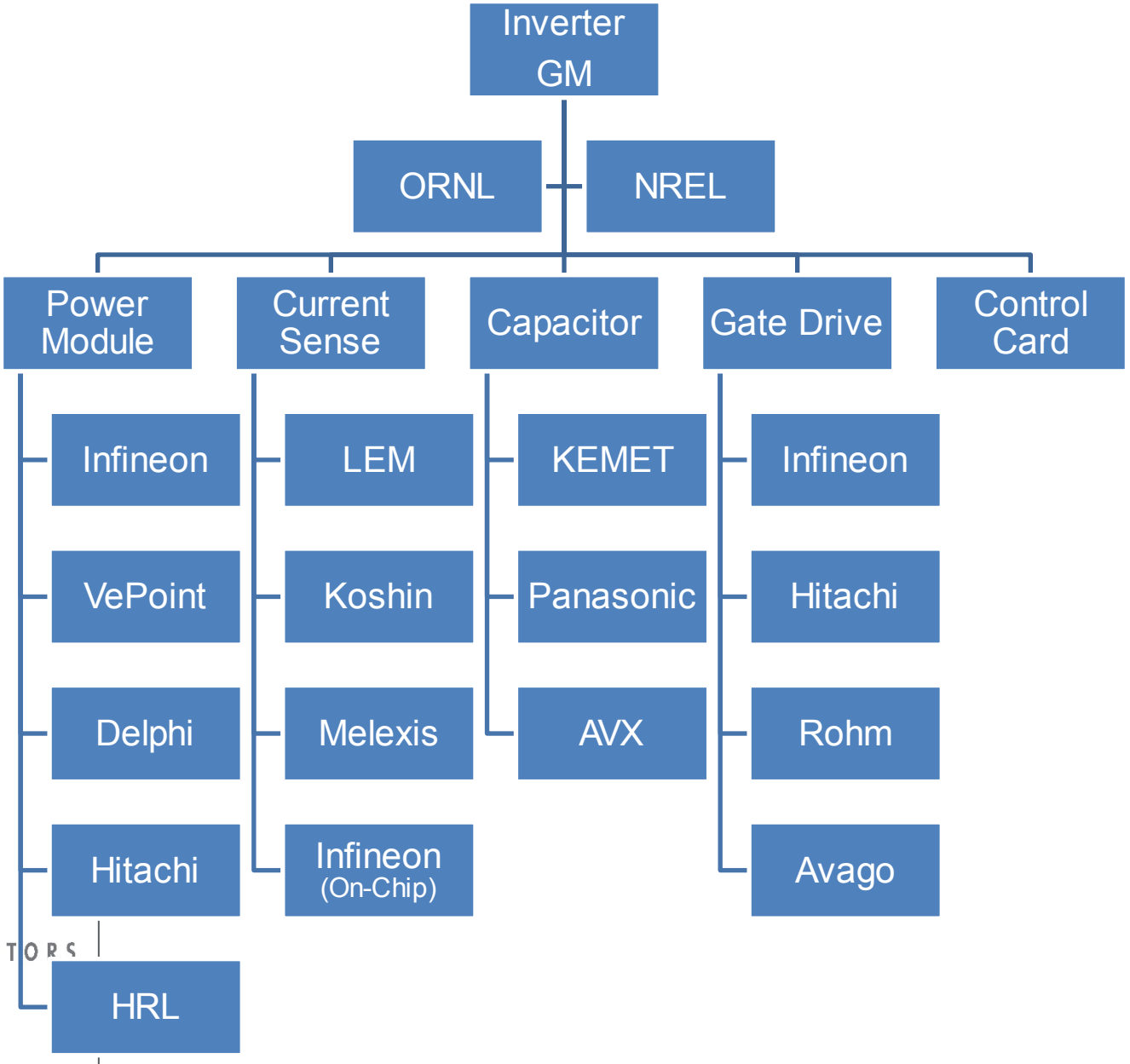


ACCOMPLISHMENTS – ELECTRICAL TEST

- Control and Gate Circuitry test complete
- Inductive load
  - Coolant ambient
  - Max current and voltage
- No design issues found



COLLABORATIONS AND COORDINATION



FUTURE WORK

FY14

- Critical Design Review
- Early Build & Test
- Final Technology and Production Cost Assessment Report

FY15

- Delivery of 3 Next Gen Inverter Units for Confirmatory Testing

SUMMARY

- Design selection to modified conventional based on criteria of cost, scalability, and modularity
- Process development for proto builds complete
  - Attachment die, substrate, and heatsink
  - Compliant pin
- Early unit build complete for electrical tests and learnings are being incorporated into design
- Unit testing has initiated

DOE IMPACT ON GM

General Motors has not made prototype power electronics in a production facility since 1999. Through DoE's funding of the Next Gen Inverter Project, GM has successfully made prototype inverters in a GM electronics production facility. These inverters meet tough cost and power density goals. This work has put GM on the path to seriously considering bringing Power Electronic production back in-house, a possibility that would not exist without DoE funding.

Questions