Development of High Pressure Common Rail Systems incorporating Advanced Electronic Control Strategies for future Heavy Duty Vehicles

Stephen Crossley
Engineering Manager, F2P System – Delphi Diesel Systems, Heavy Duty Business

Commercial Vehicle Megatrends
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Delphi Advantages

*Helping the industry increase fuel economy, enhance performance and reduce emissions. Cost effectively!*

◆ A global leader in diesel and gasoline engine management systems
◆ Multi-billion dollar organization with locations on five continents:
  – 23 Engineering Centers
  – 31 Manufacturing Sites and Joint Ventures
◆ Full line powertrain management systems product portfolio
◆ Complete engine management systems for passenger vehicles, commercial and off-highway vehicles, and non-automotive applications
◆ Flexible engineering approach that encourages collaboration and innovation
◆ Systems expertise that contributes to superior product design and high value
◆ Timely technologies that meet the needs of the marketplace
Diesel Engine Management Systems

- Industry’s best value conventional Light Duty diesel common rail systems:
  - Precise injection performance for the life of the vehicle
  - Extremely fast and reliable, balanced-value servo-solenoid Delphi Multec® Diesel Injectors

- Revolutionary direct acting Piezo Light Duty diesel common rail system for premium applications:
  - Significantly reduces CO2 emissions and delivers better fuel economy, power and torque

- Long history of Medium Duty diesel fuel injection:
  - Found on millions of engines around the world

- New unit pump common rail system for small engine programs:
  - Ideal for emerging markets and entry level vehicles

- A world leader in Heavy Duty diesel injection:
  - State-of-the-art conventional injection
  - New ultra-high pressure common rail system

  » The focus of this presentation.
Delphi Diesel Systems EURO VI Heavy Duty Common Rail Systems Overview

- Development of these intricate systems posed challenges
  - 1.6 million km B10 life
  - Ultra high pressure, up to 3000 bar
  - Flexible and controllable multiple injection
  - Consistent, robust and reliable performance
  - Common system concepts and components
  - Cost effectiveness

- Successful development through cross-function project teams
FIE Product Technology Evolution for EURO VI

- Unit injector systems evolve to Distributed Pump, High Pressure, Common Rail System (CRS).
  - Fully enclosed in rocker cover.

- Unit Pump/Smart injector systems evolve to Distributed Pump, High Pressure, CRS.
  - Direct swap for existing systems

- New remote pump CRS
  - Self contained pumping system

- Electronic Control Unit, upgraded for EURO VI / EPA13 and CRS control
Heavy Duty Common Rail – Value Proposition

- Flexible and modular system configurations provide solutions for the full range of Heavy Duty EURO VI engine architectures

- Complete FIE + ECU + S/W system for FIE / Engine / Vehicle management

- 3000 bar combined with flexible multiple injection

- Reduced NVH and high system efficiency

- Demonstrated EURO VI confidence and reliability

- Designs allow for upgrades and evolution
Product Technology – Pump

- Ultra high pressure pumping options with common concepts and application specific embodiments

- Distributed pump elements utilise integrated individual digital latching Outlet Metering Valve control

- Distributed pump systems provide flexible pumping capacity and option of live selectable displacement

- Remote pump incorporating integrated Inlet Metering Valve and fuel lift pump, 2 or 3 pumping elements for 4 & 6 cylinder engines
Product Technology – Injector

- Common concepts and components in application embodiments with specific high pressure fuel and electronic connections
- Excellent fuelling accuracy, multiple injection consistency and robustness up to 3000 bar
- 3-way balanced Nozzle Control Valve
- Tuneable orifice controlled hydraulic system, selectable opening rate independent of closing rate
- High volume nozzle capsule to minimise pressure wave effects
- Critical interfaces feature a combination of optimized geometry with advanced DLC type coatings to maintain performance over life
- Minimised total leakage reducing parasitic losses and improving thermal management
Product Technology – ECU

- An evolution of the mature ETC3 ECU provides integrated FIE, engine & vehicle control functions for Euro VI systems
- Applied across global emissions levels and supports all DDS HD FIE technologies
- Configurable input and output connections (216 pins), packaged in functional groups
- 12v and 24v applications, with operating capability at voltage extremes (9-32v)
- Adaptive 50v FIE drive waveform ensures consistent operation
- Environmental rating of 105°C without additional cooling
Software Control and Calibration

- A comprehensive EURO VI software package has been developed that integrates FIE control, OBD, application and calibration elements.
- Combines unique DDS HD strategies, enhanced Delphi generic modules and customer defined functions.
- Closed loop Rail Pressure based control of minimum fuel quantities over life.
- Multiple injection control, with Pressure Wave Compensation (PWC).
- Robust HD Injector Birth Trim ensuring consistent performance across all injector operating modes.
- On Board Diagnostics that exceed the EPA2013 legislative requirements and innovative fault manager.
- All advanced system strategies and diagnostics are fully calibrated on the engine application.
Engine Performance Benefits

- Common rail allows flexible and optimized injection timing

- Multiple injection capability provides improvements to combustion characteristics reduced NVH and engine out emissions

- Efficient high pressure injection with minimised parasitic losses

- Minimised part-to-part variability and small quantity control allowing post injection optimisation

- The improvement from current FIE to EURO VI FIE realises 3-5% BSFC reductions at constant EURO VI smoke and NOx levels

Fuel Consumption Reductions (EGR Swings)

Current System

EURO VI System

2g/kWhr NOx
(~6mg/kWhr PM)
Future Developments

- Targeting 3000bar+ pressures through design innovation on the key system elements also focusing on further reductions in parasitic losses
- Optimized pumping element arrangements for new engine architectures
- World fuel robustness, combined with enhanced thermal management
- Hybrid, Stop/Start capabilities
- Real time closed loop combustion control, through FIE modulation
- ECU electrical efficiency and processing power improvements
- Technology development systems currently on test are already demonstrating the predicted benefits

No limitations to innovation!!!
Summary

- Three innovative high pressure flexible common rail systems have been successfully developed.
- The systems include electronic hardware and software for FIE, engine and vehicle control complying with EURO VI and US13 legislation.
- Design innovation has achieved commonality of robust concepts combined with maximum installation flexibility.
- The systems provide cost effective solutions suitable for all engine architectures being utilised to meet EURO VI emissions and efficiency targets.
Thank you for your attention
System Validation

- Demonstrate durability and consistency of performance, B10 life 1.6 million km, over multiple applications
- Utilizes a combination of system and component testing on rig, engine and vehicle
- Complete representative systems, FIE and engine, set up on multiple rigs, run at accelerated and application specific conditions for reliability and confidence demonstration
- Extensive FEA analysis and rig testing to 4500 bar for infinite structural life
- Targeted tests demonstrate robustness at extreme operating conditions
- High load and performance/emissions engine tests
- Vehicle field tests of most common and extreme applications for final road release