ECU Design Challenges for Low Cylinder Count Engines

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Pi SHURLOK™

The ECU Dilemma

- A low cylinder count ECU must manage these needs
  - Applications: motorcycle, UAV, stationary power generation, landscaping, boating
  - Environmental: commercial vs. military
  - Multiple fuels – gasoline, diesel, natural gas
  - Low production volumes
  - Variety of emissions standards
  - Short time to market
  - Safety critical features – electronic throttle control
  - Integration with other systems – traction control
  - Passenger car ECU unacceptable solution due to size, weight, sealing requirements, and sometimes connector choice
  - Technology growth – variable valve timing, variable intake runner length, rider selectable power maps

Evolution of low cylinder count ECU

- Three data points to consider
  - Emerging market, Euro 2 emissions
    - Compare to early-90s ECU
    - Similar I/O & processor (16bit)
  - Small commuter motorbike (1 or 2 cyls)
    - Similar I/O & processor to above
    - Size/weight packaging constraints
  - Large motorbike, with all the "toys"
    - Compare to early-2000s ECU
    - Increased I/O & processor
- Processor evolution from 16-bit, fixed-point with 250k code space
  - Now 32-bit, floating point, 2M code space
- I/O has evolved from ~ 50 pin controller to 100pins
- Evolution to include electronic throttle, has safety & engineering process implications

Evolution (contd)

- The small engine evolution now can be compared to the pass-car and heavy duty changes from mid-90s to mid-2000s.
- The same trajectory, but without the same volumes that were driving the previous evolution.
- This time the applications are much more niche, with potentially different application interfaces.

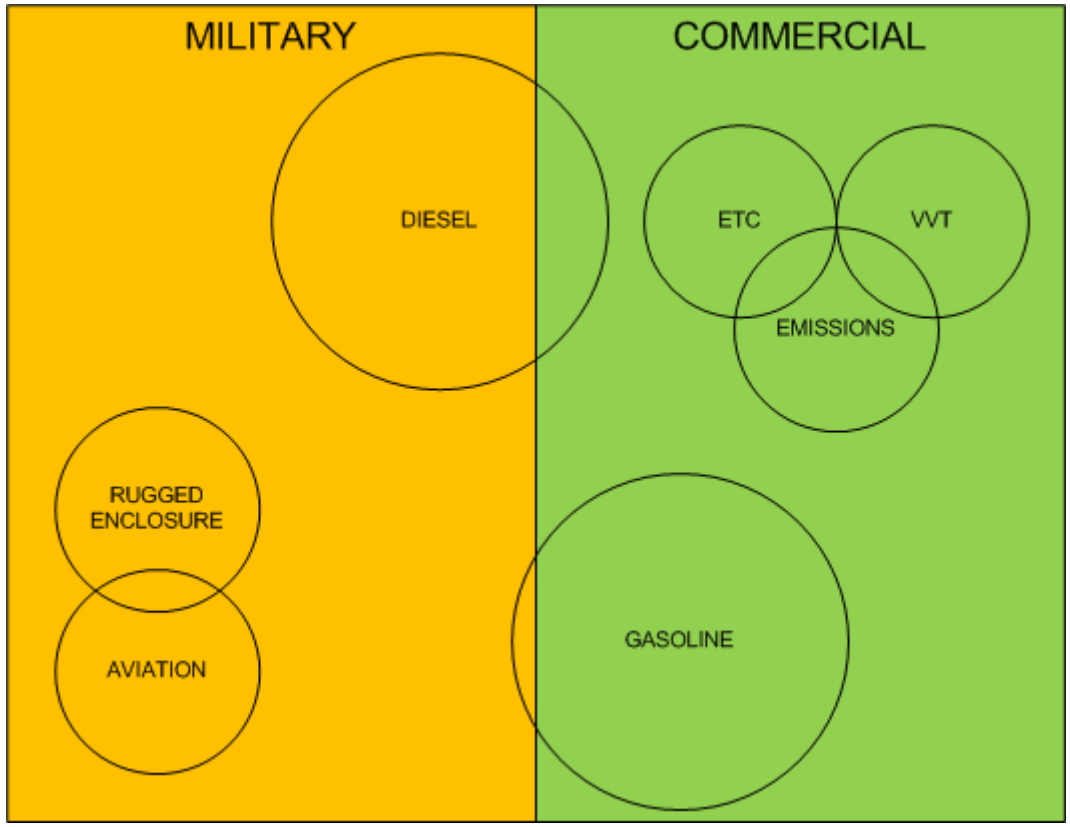
Past

Present

Future

Small Engine Market

- Lack of Venn intersection across industry is expected.
- Remove high-cost BOM items from core design.
  - Rugged enclosure
  - Diesel injection drives
- Core validated design, with two enclosure variants.
- Second ECU for diesel injector drive

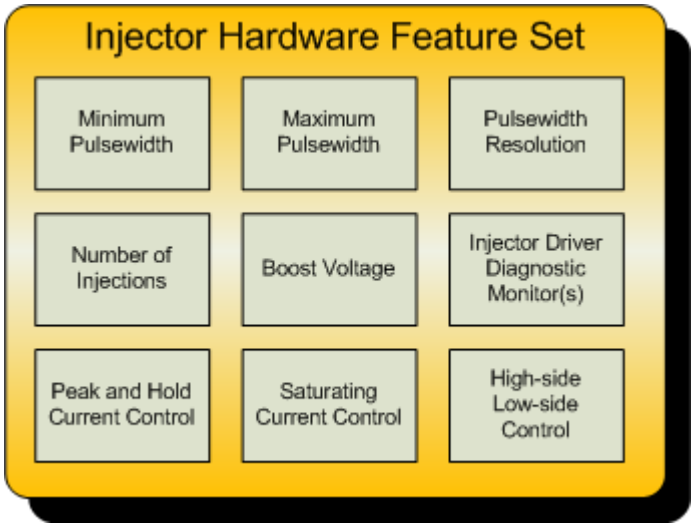


Solutions – HW Design

- Full feature small cylinder count engine ECU is hard to separate from a full feature passenger car engine ECU.
  - High feature to Low feature reduces I/O by over 50%
  - Dual VVT, dual ETC, multiple HEGO, fuel rail pressure control, boost control, injectors per cyl > one
- Focus HW design on core features and functionality
  - Initial NRE and re-design NRE is >> BOM cost for low volume applications
  - Purposely overdesign hardware for features, functionality, and flexibility
  - One hardware design fits multiple applications
  - ASIC Examples:
    - Infineon: FLEX series MultiChannel Low Side Switches, Constant Current Control IC for Transmission, Integrated Switch Mode Power Supply with buffered sensor supplies.
    - ST Microelectronics integrated ignition coil driver
    - Freescale multifunction drivers (MC33812, MC33810, MC33800), switch detection and interface (MC33972)

Example

- Injector hardware and software driver design flexibility
  - Address variety of fuels and applications.
  - Requires hardware and TPU software to have a rich feature set
  - Software and/or hardware configuration of features
- Library based approach for designs

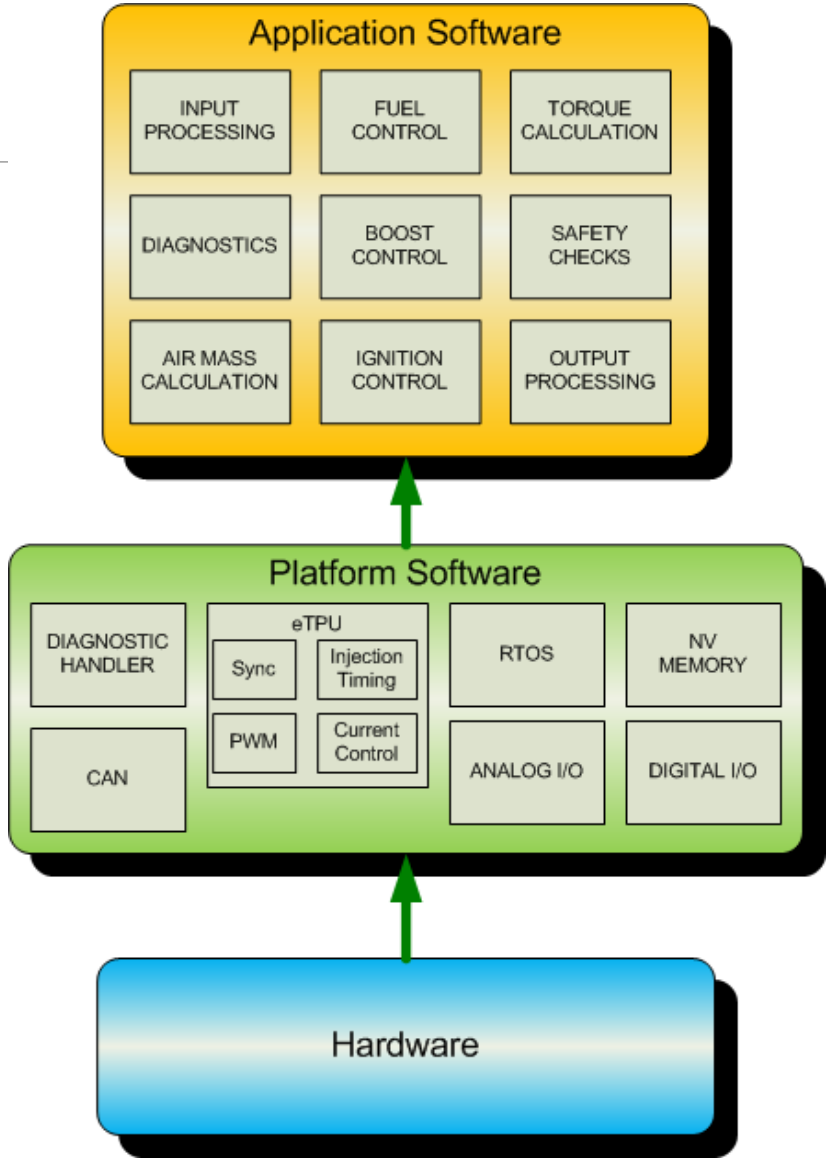


Solutions – HW Design

- Minimize enclosure variations
  - Core board design able to support multiple enclosures and multiple connectors
  - Each new enclosure/connector system has a HIGH fixed cost to implement, validate and bring to volume production.
  - Carefully choose connector family which offers pin count variation across the range expected.
  - Connector family should also allow for both sealed and un-sealed enclosures.

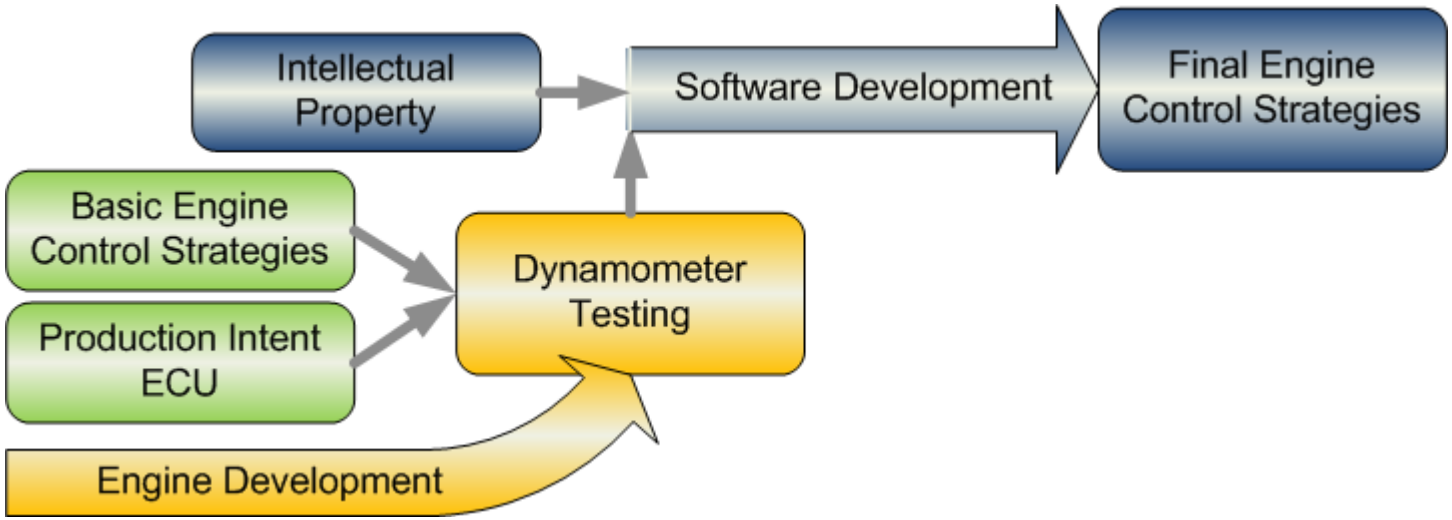
Solutions – Software Design

- One software strategy to handle all applications is unreasonable
- Need abstraction layer between application software and hardware (aka Platform Software)
  - Specific to HW design
  - Software must provide lowest common denominator interface
  - Keeps application software agnostic of HW design and more portable.



Solutions – Software Design

- Application SW
  - Core strategies (base algorithms) in model-based form
  - Auto code generation (fast to prototype)
  - Modeling vs. sensing to reduce BOM cost of system. "Software is free"



Solutions – Software Design

- Cost savings through sensor reduction
  - Software development and testing can be expensive
  - Limited applicability
  - Weight savings and reduced mechanical complexity. Increased software complexity.
  - Undesirable failure mode effects
  - Payback at high volume
- Examples
  - Ethanol fuel composition estimation
  - Engine speed and sync determination through intake pressure
  - Air charge temperature estimation via ambient temperature and coolant temperature
- Best used for rationality checks, not for control.

Summary

- Success in banding low-volume customers together to minimize per unit cost.
  - Requirements capture very difficult and timely
  - High degree of upfront planning. ROI is long term.
- Basic engine control strategies for early engine dynamometer development is a key enabler
- Integrated low-level API and robust autocoding environment
  - From model to s-record without manual code manipulation
  - Supports customers doing IP development, lowers bar for SW development skills required
- Sensorless system benefits to be analyzed carefully

Thank you for your attention

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Vehicle electronics from concept to manufacture