Powertrain Control Software
A Modular (or à la carte) Approach
Vocis

- Specialists in:
  - Transmission and Driveline Control System Engineering; software, hydraulic & electrical actuation systems
  - Vehicle integration
  - Production controller design, prototyping controllers and dataloggers
  - Rapid turnaround prototype gearbox design, assembly and testing
  - Software application and calibration

- Widely experienced in delivering challenging & high value automotive programmes

- Currently working on numerous production programmes, with Graziano, and independently

- Already working with many of the worlds most highly respected companies

- Actively engaged in R & D, Hybrids, EV’s and University collaborations

- Software supplier for McLaren MP4-12C and Lamborghini 7-speed AMT

- ISO9001 & TickIT accredited in April 2009.
Powertrain Software Structure
High Level Algorithms

- *Siena II* software platform developed in-house for transmission control

- Architecture allows ease of application to multiple transmission types on different ECU architectures

- Successfully used on variety of transmission types and projects
  - Production
  - Demonstrators
  - Rig Test

- Recent developments include
  - Condition monitoring
  - Improved adaptation and maintenance routines

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High Level Modules

- Driver Strategy
- Shift Sequencing
- Clutch Control
- Gear Actuation
- Engine Interface
- Pressure Control
- OBDII
Powertrain Software Structure
Low Level Algorithms

- The structure for the low level software is the same as Vocis normal software structure, but only having one actuator and reduced set of inputs allows for greater choice of low cost electronic hardware

- Vocis TMS-20 controller used during development
  - Rapid prototyping controller
Conventional DCT and AMT Applications With Vocis Modular Software

DCT

AMT

Powertrain Control Software, A Modular Approach
Marco Fracchia, Vocis Ltd
Power-on Upshift: DCT
Schematic of shift Event

Torques:
- ICE Torque
- Clutch 1 Torque
- Clutch 2 Torque

Speeds:
- Engine Speed
- Input 1 Speed
- Input 2 Speed

Positions:
- Gear Posn. 1-5
- Gear Posn. 2-4
Power-on Upshift: DCT Module Sequencing for Preselect

- Torques
  - DST
  - SEQ
  - GAC

- Speeds
  - Engine Speed
  - Input 1 Speed
  - Input 2 Speed

- Positions
  - Gear Posn. 1-5
  - Gear Posn. 2-4

- Clutches
  - Clutch 1 Torque
  - Clutch 2 Torque

- ICE Torque
Power-on Upshift: DCT Module Sequencing for Torque Phase

- **Torques**:
  - DST
  - SEQ
  - DWC

- **Speeds**:
  - Engine Speed
  - Input 1 Speed
  - Input 2 Speed

- **Positions**:
  - Gear Posn. 1-5
  - Gear Posn. 2-4

- **Torque Phases**:
  - ICE Torque
  - Clutch 1 Torque
  - Clutch 2 Torque
Power-on Upshift: DCT Module Sequencing for Inertia Phase

- Torques
  - DST
  - SEQ
  - ENG
- Speeds
  - Engine Speed
  - Input 1 Speed
  - Input 2 Speed
- Positions
  - Gear Posn. 1-5
  - Gear Posn. 2-4
- ICE Torque
  - Clutch 1 Torque
  - Clutch 2 Torque

Module Sequencing for Inertia Phase:

- Upshift: DCT
Power-on Upshift: DCT
Resultant Output Torque

Torques

Output Torque
ICE Torque
Clutch 1 Torque
Clutch 2 Torque

Speeds

Engine Speed
Input 1 Speed
Input 2 Speed

Positions

Gear Posn. 1-5
Gear Posn. 2-4
Power-on Upshift: AMT
Schematic of shift Event

Torques

ICE Torque
Clutch Torque

Speeds

Engine Speed
Input Speed

Positions

Gear Posn. 1-5
Gear Posn. 2-4
Power-on Upshift: AMT Module Sequencing for Torque Roll-off Phase

- DST
- SEQ
- ENG
- SDC

Torques

- ICE Torque
- Clutch Torque

Speeds

- Engine Speed
- Input Speed

Positions

- Gear Posn. 1-5
- Gear Posn. 2-4
Power-on Upshift: AMT
Module Sequencing for Gear Change Phase

Torques
- DST

Speeds
- SEQ

Positions
- GAC

ICE Torque
- Clutch Torque

Engine Speed
- Input Speed

Gear Posn. 1-5
- Gear Posn. 2-4
Power-on Upshift: AMT Module Sequencing for Torque Roll-on Phase

- Torques
  - DST
  - SEQ
  - ENG
  - SDC
- Speeds
  - ICE Torque
  - Clutch Torque
  - Engine Speed
  - Input Speed
- Positions
  - Gear Posn. 1-5
  - Gear Posn. 2-4
Power-on Upshift: AMT
Resultant Output Torque

Torques

Engine Speed
Input Speed

Positions

Gear Posn. 1-5
Gear Posn. 2-4

ICE Torque
Clutch Torque

Output Torque

Torques

Speeds

Engine Speed
Input Speed

Positions

Gear Posn. 1-5
Gear Posn. 2-4

ICE Torque
Clutch Torque

Output Torque
Electric Vehicle
2SED – 2 Speed Electric Drive

- A patented 2-speed powershifting transmission
- Design is for maximum efficiency
- Single electromechanical actuator, on-demand
- Optimised cost and part count
- Park lock functionality with no extra components
- Compact overall dimension
- Weight approx. 45kg
- Fully functional design proven in demonstrator vehicle
- Improved acceleration and terminal velocity
- Now in 3rd generation of design, having undergone loaded rig testing and imminently in-vehicle testing

EM: 250Nm, 210kW, 15,000rpm
2SED: Powerflows

1st Gear
Power Flow through one-way clutch

2nd Gear
Power Flow through friction clutch

Friction Clutch

Locking Ring

Sprag Clutch

Powertrain Control Software, A Modular Approach
Marco Fracchia, Vocis Ltd
Multi-Speed EV Transmissions: Philosophy for Design: **Software**

- Need to consider the additional implications of transmission control software
  - Siena core software exists, and modules created for 2SED

![Diagram showing the software architecture for Multi-Speed EV Transmissions](image)
Power-on Upshift: 2SED
Schematic of shift Event
Power-on Upshift: 2SED
Module Sequencing for Locking Ring

Torques
- DST

Speeds
- SEQ

Positions
- GAC

Motor Torque
- Clutch Torque

Motor Speed

Locking Ring Posn.
Power-on Upshift: 2SED
Module Sequencing for Torque Phase

- Motor Torque
- Clutch Torque
- Motor Speed
- Locking Ring Posn.
Power-on Upshift: 2SED
Module Sequencing for Inertia Phase
Power-on Upshift: 2SED
Resultant Output Torque

Torques
- Output Torque
- Motor Torque
- Clutch Torque

Speeds
- Motor Speed

Positions
- Locking Ring Posn.
Electric Vehicle
4SED – 4 Speed Electric Drive

- A patented 4-speed powershifting transmission for vehicles with 2 traction motors
- Predicted 15% reduction in energy consumption over NEDC
  - Motors used close to their peak operating efficiency
  - Gearbox with only 2 stage helical mesh and splash lubrication
- Single electromechanical actuator, on-demand
- Very simple gearbox - mechanically more simple than a manual
  - Clutch-less and Synchroniser-less
- Weight approx. 24kg
- Fully functional design proven and running in demonstrator vehicle
- Different driving strategies for economy and performance
  - 1-motor driving OR 2-motor driving
  - 7 gear combinations
- Improved acceleration and terminal velocity

EM(x2): 75Nm, 35kW, 15,000rpm

Powertrain Control Software, A Modular Approach
Marco Fracchia, Vocis Ltd
Control Software Strategy: Shift Types

Engagements:
- to/from 1-Gear or 2-Gears

All other shifts (power on/off & up/down)
- 1-Gear to 1-Gear Shift
- 1-Gear to 2-Gear Shift
- 2-Gear to 1-Gear Shift
- 2-Gear to 2-Gear Shift

Example of Driving in: 1\textsuperscript{st} Gear & 2\textsuperscript{nd} Gear
Control Software Strategy: High Level Algorithms

- The elegance of the transmission concept allows for a reduced set of the Vocis software algorithm modules to be used.

Powertrain Control Software, A Modular Approach
Marco Fracchia, Vocis Ltd
Power-on Upshift: 4SED
Schematic of shift Event

Torques

Speeds

Positions

Motor 1 Torque
Motor 2 Torque

Motor 1 Speed
Motor 2 Speed

Barrel Position
Power-on Upshift: 4SED Module Sequencing for Torque (Roll-off) Phase
Power-on Upshift: 4SED
Module Sequencing for Barrel Selection

- DST
- SEQ
- GAC

Torques
- Motor 1 Torque
- Motor 2 Torque

Speeds
- Motor 1 Speed
- Motor 2 Speed

Positions
- Barrel Position
Power-on Upshift: 4SED
Module Sequencing for Inertia Phase

Torques

- DST

Speeds

- SEQ
- MOT

Positions

- Barrel Position

Motor 1 Torque
Motor 2 Torque
Motor 1 Speed
Motor 2 Speed
Power-on Upshift: 4SED Module Sequencing for Barrel Selection

- Torques
  - DST
  - Motor 1 Torque
  - Motor 2 Torque

- Speeds
  - SEQ
  - Motor 1 Speed
  - Motor 2 Speed

- Positions
  - GAC
  - Barrel Position

Module Sequencing for Barrel Selection
Power-on Upshift: 4SED
Module Sequencing for Torque (Roll-on) Phase

- **DST**: Barrel Position
- **SEQ**: Motor 2 Speed
- **MOT**: Motor 1 Torque
- **Motor 1 Torque**
- **Motor 2 Torque**
- **Motor 1 Speed**
- **Motor 2 Speed**
- **Barrel Position**
Power-on Upshift: 4SED
Resultant Output Torque

Torques

Speeds

Positions

Motor 1 Torque
Motor 2 Torque

Motor 1 Speed
Motor 2 Speed

Output Torque

Barrel Position

Resultant Output Torque

Motor 1 Speed
Motor 2 Speed

Torques

Speeds

Positions

Motor 1 Torque
Motor 2 Torque

Output Torque

Barrel Position
Hybrid ogeco – Hybrid Powershifting AMT

- **ogeco** is a patented hybrid powertrain concept that has minimised on-cost, reduced complexity and better package in comparison to a Hybrid DCT.

- Mechanical efficiency is improved over Hybrid DCT with a more efficient dry clutch (vs. wet clutch) and two-shaft main transmission layout.
  - Rolling road tests have shown 6% reduction in CO₂ with respect to a conventional DCT (before taking into account hybridisation as a means of reducing fuel consumption).

- **Split personality** gear shifting, gives DCT comfort for city driving and best-in-class shifting for track driving.

**ICE:** 650Nm, 430kW, 8,000rpm  
**EM:** 200Nm, 120kW, 14,000rpm
ogeco Controls Overview

AMT 6-speed gearbox control

- DST
- SEQ
- SDC
- GAC
- ENG

2-speed hybrid drive control

- DSTh
- SEQh
- MOT
- GAC

Support Functions

- Pressure Control
- OBDII
The Hybrid Control and the Electric Motor torque arbitration for the demonstrator vehicle are also handled in the transmission controller.

For production, it would be expected that:
- the Hybrid control would be a module in the engine controller or the function of a Supervisor controller.
- the electric motor torque arbitration could be integrated into the Inverter control module.
Power-on Upshift: AMT with Torque Infill
Schematic of shift Event

Torques:
- ICE Torque
- Motor Torque
- Clutch Torque
- Output Torque

Speeds:
- Engine Speed
- Input Speed
- Motor Speed

Positions:
- Hybrid Coupling
- Gear Posn. 1-5
- Gear Posn. 2-4

Output Torque as an AMT
Powertrain Control Software

Summary

- There are many new challenges in powertrain control
  - Accelerated by Dual Clutch Transmission
  - And now a multitude of hybrid solutions that can need new software, but with modular approach can be integrated into the same core software
  - The key enabler is well defined boundaries and communication between modules

- All software written as production intent
- ISO26262 best practice for functional safety
  - Including Level 2 and Level 3 software suitable for multi-core processors
- Brand values can be tuned within sub modules
- Vocis are well placed to provide turnkey solutions or individual software modules that can be integrated into proprietary software and hardware
Thank you!

www.vocis.co.uk

www.oerlikon.com/graziano

Pioneers in the development of innovative automotive transmissions and their control systems