BorgWarner at a Glance

Products:
Engine, Transmission and AWD systems

Operations:
56 Locations
19 Countries

Employees:
19,700

Market Drivers:
better fuel economy
reduced emissions
great performance

2013 Sales:
$7.437 Billion
# A Portfolio of Leading Powertrain Solutions

## Engine 67% / SALES

### Turbo Systems
- Wastegate
- Variable Turbine Geometry (VTG)
- Regulated 2-stage (R2S™)

### Thermal Systems
- Thermal Management
- Components and Systems
- Visctronic® Systems
- Fans/Fan Drives

### Morse TEC
- Engine Valve Timing Systems
  - Timing Chain
- Variable Cam Timing
  - Oil Pressure Actuated
  - Torsional Assist
  - Cam Torque Actuated
- HY-VO® Transmission Chain
  - Transmission/Transfer case chain

## Drivetrain 33% / SALES

### Emissions Systems
- Exhaust Gas Recirculation (EGR) Valves
- EGR Coolers & EGR tubes
- Integrated EGR Modules
- Secondary Air Systems
- Actuators
- Glow Plugs
- Instant Start System
- Pressure Sensor Glow Plugs
- Gasoline Ignition Technology
- Sensor Technology
- PTC Cabin Heaters
- Thermostats
- Coolant and Control Valves

### Transmission Systems
- DualTronic® Systems for Dual Clutch Transmissions
- ECO-Launch™ Stop/Start Accumulator Solenoid Valves
- One-way Clutches and Modules
- Friction and Steel Plates

### TorqTransfer Systems
- AWD Couplings
- Transfer Cases
- eGearDrive® Electric Drive Transmissions
- eAWD Torque Vectoring
- AWD Electronic Controls and Systems Integration
Background and drivers
Why All Wheel Drive?

FWD  AWD
Why Through-the-Road HEV (eAWD) ?

BorgWarner modular and flexible concept for:

- Hybridization
- AWD
- Torque Vectoring
- Differential Brake
- Acceleration boost

- 20 % fuel economy improvement
- Traction improvement
- Superior stability and handling
- Traction improvement
- Downsized ICE

Parallel hybrid with electrical rear axle a.k.a
Through-The-Road Hybrid
Why Torque Vectoring?

Accelerator

Braking

Left Turn

Right Turn

TV

AWD
Improved stability by yaw damping

Improved driveability and fun to drive factor

Use of torque vectoring function to compensate vehicle dynamics when moving from FWD to RWD in a hybrid installation (patent pending)
How to do electrical torque vetoring?

Two motor concept vs. Diff motor concept

\[ P = T \cdot \Delta \omega \]
eAWD Transmission Basics
Phase 1 eAWD Demonstrator

- System installed in a Saab 9³ Aero in 2009
- System specification
  - 12 kW nominal power, 12 kW peak
  - Maximum wheel torque 950 Nm
  - Torque vectoring torque 500Nm
  - Battery voltage 250 V
  - Torque vectoring for stability and fun to drive
Phase 2 eAWD Demonstrator

- System installed in a Volvo XC70
- System specification
  - 50 kW nominal power, 80 kW peak
  - Maximum wheel torque 2500 Nm
  - Torque vectoring torque 1000 Nm
  - Pure electrical drive up to 130 kph
  - EM Disconnect
Phase 3 OEM Vehicle Demonstrators

- Delivery of 4+1 units to 2x OEM’s in January 2012
- System specification
  - 40 kW nominal power, 65 kW peak
  - Maximum wheel torque 2000 Nm
  - Torque vectoring torque 1200 Nm
  - Pure electrical drive up to 150 kph
  - EM Disconnect
BorgWarner eAWD Technology
System Overview – Main Components

- TV PE
- Coolant OUT
- Vehicle signal connector
- Coolant IN
- Traction Phase leads
System Overview – Main Components

- Accumulator
- Valves
- Oil Pump
- Oil filter
Cooling & Hydraulics - Water

Cooling of TV ECU and heat exchanger

Water Inlet
- 50% Ethylene glycol
- 50% Water

Water Outlet

Heat Exchanger
Cooling & Hydraulics - Oil

Hydraulic system for cooling of stators, lubrication of bearings and gear shift actuation

- Oil channels over TV motor
- Oil channels over traction motor
- Accumulator
- Valves
- Oil Filter
- Oil Pump
- Oil reservoir
- Heat Exchanger Oil/Water

Patented
Power Electronics - Interfaces

Vehicle
- LV DC Supply
- CAN/Flexray
- Traction PE

Pump Valves

TV Resolver
TV Temp

TV Motor phase leads

Traction Resolver
Gear Shift Sensor
Traction Temp

HV DC Supply

Water Out
Power Electronics

- Integrated ECU for TV motor control, AWD and TV vehicle dynamics, gear shift, cooling and lubrication control.
- ASIL-D Compliant
- Modular/Optional ECU for non-TV variants.

- Non-TV ECU for hydraulic oil system and gear shift actuation

TV ECU

Low voltage
- Logics
- Pump control
- Valve control
- Gear shift control

High voltage
- Custom SRM Module
Electrical Machines

TV Motor
- SR
- 24,000 rpm
- 6,5 kW
- 39 Nm

Why an SRM?

Traction Motor
- PMSM
- 12,000 rpm
- 60 kW
- 180 Nm
TV EM Operation – Overview

Dynamic Driving Load Spectra
TV EM Operation – Range

Normal Operation
[0-Tmax at 0~1,7krpm]

Dynamic Driving Load Spectra

Low μ Yaw Dampening
[Pmax at 8krpm]

ESP Intrusion
[0Nm at 24krpm]
Specific TV EM Requirements

- **Base Speed (BS)** ~1700rpm
- **Constant Power Range (CPR)** 0-8000rpm (~1:5)
- **0Nm at maximum operating speed (Nmax)** 24000rpm (>14x BS)
- **Burst Speed (Nburst)** 30000rpm (>17x BS)
TV EM Type Selection

- **PMSM**
  - Good torque quality
  - Design challenge to meet $N_{burst}$ requirement
  - Optimization for normal operating conditions (below BS) not possible due to trade off to $N_{max}$ controllability $\rightarrow$ Higher current requirement
  - ASIL-target $\rightarrow$ Complex 0Nm Safe State and high sensitivity to position errors at $N_{max}$

- **SRM**
  - Inherent wide CPR and robust high speed rotor
  - Optimization for normal operating conditions (below BS) is possible, no trade off to $N_{max} \rightarrow$ Lower current requirement
  - ASIL-target $\rightarrow$ Simple (switched off) 0Nm Safe State and no sensitivity to position errors at $N_{max}$
  - Torque quality is sensitive to position errors
Thank You For Your Attention

Our Vision
- A Clean, Energy-Efficient World

Our Mission
- Deliver Innovative Powertrain Solutions that Improve Fuel Economy, Emissions & Performance