Shifting Up for Heavy Duty

Transmission and hybrid systems development
Transmission and hybrid system development from concept to start of production

The automotive transmission has gained much significance in recent years and is a key component in the modern powertrain. Modern commercial vehicle transmissions satisfy exacting demands on driving dynamics as well as ride comfort, and they reduce fuel consumption and emissions. Hybridizing the powertrain provides the capability of utilizing further potential.

IAV specialists make an important contribution to achieving these ambitious goals with unique synthesis programs for new, optimized transmission structures, a perfected development process, efficient methods, the systematic use of simulation tools, an automated calibration process and a broad range of measuring and testing equipment.

At IAV, more than 300 experienced engineers – all with excellent qualifications – design, develop, test, integrate and calibrate transmissions and their complex control systems on all continents – from the initial idea to the perfected and efficient volume product.

More than twenty-five years of worldwide development projects with prominent manufacturers and component suppliers, along with innovations, and expertise in mass production development are testimony to our expertise. IAV’s know-how covers all transmission types on the market from manual, automated manual and hybrid transmissions to transfer cases in all-wheel-drive applications.

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To develop future transmission systems, IAV uses unique, computer-based synthesis programs that generate all conventional and hybrid transmission structures. Independently from the target application, may it be an On-Road or Off-Road Commercial Vehicle or a Passenger Car, the flexibility of the tools enables IAV to find the best solutions. That’s why this systematic process is requested by OEM’s and TIER1 suppliers all around the world. We provide our clients with new, optimized transmission structures for extremely compact, low-loaded transmissions with high ratio spread, very good gear stepping, simple shift logic for flexible shift strategies and maximum levels of efficiency. Generated using clearly defined methods, the transmissions we give our customers guarantee the basis for innovative and competitive volume products.

Flexible use for different transmission technologies:
- Manual transmissions (MT) with spur gears
- Automated manual transmissions (AMT) with spur gears
- Dual-clutch transmissions (DCT) with spur gears
- Automatic transmissions (AT) with planetary gears
- Continuously variable transmissions with conventional (CVT), hydrostatic (hCVT) or electric variator (eCVT)

Generating all possible combinations of transmission variants
+ Analyzing and evaluating conventional and hybrid transmission properties
+ Selecting the best transmission for our customer

Sequence of transmission synthesis for versatile transmission technologies
Future power trains for commercial vehicles will be facing tough challenges with sometimes contrary requirements. The various transmission systems harbor different potentials to optimize the whole power train - may it be a highly efficient DCT with its similarity to MT’s and AMT’s, an AT with its high power density or a CVT with its freedom to set the ratio for any desired speed of the vehicle. Hybridization makes the assessment of the optimal power train configuration even more complex. That’s why IAV’s experts use unique tools to generate and evaluate new transmissions. IAV’s transmission concepts are characterized by a higher functionality than the state of the art with at the same time a low number of components. Low loads on the mechanical elements are essential for a compact design. High efficiency of the gear set and the actuation system contribute to reducing the life cycle costs.

**Automatic transmission for Commercial Vehicles: 9-AT3000**
- Simple layout with 4 planetary gear sets and 6 shift elements
- 3,000 Nm / 2,000 rpm input torque / speed
- Size comparable to current AT’s for commercial vehicles
- Flexible series of ratios with starting ratios between 5.3 and 8.6 for different transmission variants
- Low loaded shift elements for low actuation energy and low drag losses

**IAV concepts with an innovative edge**
- 9-AT3000: 9-speed AT with 3000 Nm input torque for inline application
- 8H+-eCVT: 8 ICE speeds with electric CVT functionality
- 9-DCT: 9-speed DCT with dry dual clutch for inline application
Physically Based Universal Clutch Characteristic

Real-time estimation for short and long-term adaptation

Modern dual-clutch transmissions satisfy the most exacting of consumer demands in terms of shift time and comfort. Most concepts for controlling power transmission make it necessary to know the clutch characteristic (i.e., ratio of controlled variable to transferred torque) inside out. Identifying both permanent and temporary changes in the clutch characteristic is one of the challenges a transmission control system needs to master.

IAV employs a progressive and innovative process for correcting friction clutch error during operation. Following a purely physical approach, the process centers around an algorithm that estimates the characteristic curve. For the first time, this new model is being used as part of a system for controlling a dual clutch.

The newly developed equation can be used for describing both wet and dry dual clutch systems. The parameters can be interpreted and tolerated in a way that makes physical sense, providing the capability of deriving and diagnosing limits and starting values of control parameters entirely from knowing the clutch system under observation.

Offering various options, the algorithm can be controlled in a flexible manner. This, for example, not only makes it suitable for rapid, short-term correction within a drive-off cycle but also for long-term adaptation. Algorithm control also permits partial estimates, reducing computing effort and speeding up the estimation process. Preferred learning situations can also be defined.

Unlike conventional adaptation processes, using the algorithm involves no intervention in the clutch control system. It is a purely observational process that can be used in any slip situation and ensures a high level of tolerance toward dynamic, noisy and imperfectly synchronized signals. Performing approximately 200 computing operations per adaptation step, the algorithm can be used in a production-level automotive control unit.
We have many years of experience in constructing demonstrator vehicles in the transmission segment. Examples include the conversion and sport-tuning of a production vehicle with IAV’s prototype transmission control system.

The entire software is implemented on a model basis in Matlab/Simulink. Everything is computed in floating point arithmetic in line with prototyping level. The strategy levels are based on torque matched to transmission input, producing simple, generic gearshift handling. Actuator control employs physical plant parameters which significantly reduces calibration work.

IAV has designed the transmission control software to manage any AT transmission and perform all gear shifts to give optimum ride comfort. This covers all the main functionalities required by modern transmission software.

Gear speed is selected on the upper layer of the driving strategy, either automatically in line with the chosen gearshift concept (comfort/sport) or manually after tapping the gear lever. Fast-off and dynamic shift point adaptation functionality is supported. The individual shift phases are coordinated by the shifting strategy, with shift aborts and shift modifications also being handled. The clutch strategy controls the actual shifting phases, e.g. speed synchronization and torque processing. Another software layer provides the basis for controlling the actuators as well as basic signal and power-train CAN handling. A diagnostics module monitors and checks fundamental control constraints.

Expertise:
- Construction of transmission demonstrators for in-vehicle use
- Rapid prototyping for all-encompassing transmission software
- Model based transmission control algorithm development
Automated Transmission Calibration

Optimization process: Optishift and Evalshift

The increasingly complex and involved process of calibrating transmissions means it must undergo further systemization and automation to meet the challenges that lie ahead. Optishift provides an environment for calibrating the transmission all automatically. It initially uses sensitivity analyses for identifying the parameters with the most influence on transmission control as a way of helping the calibration engineer select the parameters for calibration.

Optishift provides interfaces to the commonly used INCA, CANape or ControlDesk calibration tools, making it possible to monitor the measurement process and adjust parameters fully automatically. The results of measurement data analysis – in the form of an objective assessment of the results to be calibrated – can then be used for multi-criteria parameter optimization. Optishift is suitable for use in the vehicle as well as in simulation environments and on the test bench.

Compared with calibrating the shifting process manually, it produces similar or better results for standard shifting operations. The outcome remains virtually unaffected by the engineer’s personal font of experience, and parameter sets can be defined for any shift time to provide the best possible level of ride comfort.

The Velodyn simulation environment can be used for generating initial calibrations as well as for validating parameter sets. Various detailed model approaches are available that give the engineer optimum...
support at all stages of the calibration process. For instance, models of the rest of the vehicle are used on the test bench for lacking components, allowing a variety of calibration activities to be performed before prototype vehicles even exist.

Objective evaluation of the events being optimized is an important part of automated calibration. Unlike subjective assessment, it provides the basis for guaranteeing judgment reproducibility and granularity of the type required for automating the calibration process. Evalshift then evaluates drivability using the laws of physics for aspects such as the shift process. Relevant criteria are extracted from the signal curves and passed on to the optimizing engineer. By visualizing time characteristics and criteria, Evalshift permits direct comparison of results at manual calibration level. The vehicle data base tool Benchalyzer provides an easy to use interface to compare different vehicles by driveability or even performance criteria. The calibration testing tool Caltet supports the subjective evaluation process in the vehicle by guiding the user and storing data automatically. Based on these tools a documentation can be created to monitor the project status, the calibration progress. These documents can be used for releasing data sets. IAV’s Calguide® tool can be applied for managing calibration data and parameter sets. Developing vehicle versions with automatic transmissions to manufacturing readiness level involves balancing the vehicle’s specific driving and shifting strategies at a faster pace. The IAV-Autoshift calibration tool from IAV GmbH offers a wide range of capabilities in relation to defining the initial configuration of all shift programs and optimizing them for a modern transmission control system: Rapid generation of basic calibration, a plausibility check, graphic shift-line adaptation as well as fast integration into the calibration hardware.

Benefits
• Shift strategy requirements & conditions
• Shift curves can easily be modified, visualized and checked
• Export to customer-specific formats
• Support for INCA PC and CANape
→ Shorter development time
Multi-Criteria Optimization of Electric Machine

With powertrain electrification on the increase, new electric machines are needed that provide greater efficiency at lower cost. For this reason, IAV experts have developed an innovative method that provides the capability of optimizing various types of electric machines, e.g., induction machines, permanent-magnet machines and switched reluctance machines, in relation to a wide range of different criteria. Computation uses finite element analysis of magnetic field density with subsequent calculation of relevant losses. Modern computation clusters make it possible to analyze and evaluate extensive parameter variations in a very short time.

Optimization parameters
- Machine type
- Slot and tooth layout of the metal sheet
- Integration and size of air chamber
- Arrangement and geometry of magnets
- Diameter and length of air gap
- Winding design
- Material of iron sheet and magnet

Optimization targets
- High efficiency and torque capacity at typical operating points
- Engine speed strength
- Good performance in field-weakening range
- Low cyclic irregularity
- Ease of control
- Low material and production costs

Efficiency map of a synchronous machine – Potential from optimization

Finite element calculation of the magnetic flux density for different machine types
The InDrive-Simulator is an innovative development tool for simulating and designing complex vehicle and powertrain systems under real driving conditions. It combines the advantages of offline simulation with the experience of driving a real prototype. As such, the InDrive-Simulator bridges the gap between simulating the first concept draft and testing the real-life prototype. The system consists of several main components. These are the basic vehicle with its interfaces, the real-time simulation computer with models and acceleration controller together with a dataset and visualization system.

At the heart of it is IAV's tried and proven Velodyn simulation tool with the real-time system for computing vehicle dynamics. Based on current vehicle speed, position of the accelerator, brake pedal, gear, current slope and cornering radius, the system uses mathematical models of the powertrain components to calculate the virtual prototype's expected acceleration. Depending on the level of model detailing used, it also computes other target variables like energy demand, SOC of the battery or component temperatures.

An acceleration controller in the vehicle operates the test mule in a way that accurately reproduces the virtual prototype's setpoint acceleration computed on the real-time system. To do this, the controller sends its output signal to the engine and transmission control unit. In addition, the onboard ACC system actively controls any required deceleration by the brake system.

The InDrive-Simulator

• Helps developers to design new hybrid or electric concepts and assess their market relevance
• Provides ongoing support in the development process from the early design phase
• Can be used for developing and studying any powertrain topology
• Makes it possible to compare and optimize components and target vehicle
• Gives clients the possibility of trying out concepts within their own operating conditions
• Can be used in the early development phase to feel what a design is like to drive before setting up hardware prototypes

The InDrive-Simulator is a development tool that covers all relevant influencing variables:

• Driver-specific responses
• Vehicle application and mode of operation
• Driving cycle / route including its topography
• Environmental and traffic conditions

Benefits of the InDrive-Simulator for the combustion engine:

• Low-cost integration
• Wide range of appropriate base vehicles available
• Hardly any constraints from simulating the longitudinal dynamics of conventional powertrains
Analysis and Simulation

Obtaining valuable information

Analysis and simulation provide the benefit of obtaining valuable information on static strength, lifespan, noise and vibration at a very early stage — long before the initial hardware is available. Our simulation specialists do this using numeric computation and simulation processes, such as the finite-element method (FEM) and multi-body simulation (MBS).

**Finite Element Analysis (FEA)**
- Static and dynamic strength analysis
- Topology optimization

**Software**
- ABAQUS, MSC.Nastran, FEMFAT, OptiStruct

**Multi-Body System Simulation (MBS)**
- Modal driveline analysis
- Gear whine and rattle simulation
- Optimizing decoupling behavior (DMF, pendulum, …)
- Load reversal response

**Software**
- SimulationX, SIMPACK, SimDrive

**NVH Analysis:**
- Vibration amplitudes at mountings
- Acoustic analysis (sound pressure)
- Structure-borne noise evaluation
- Psychoacoustics

**Software:**
- MSC.Nastran, IAV_SBNOISE
IAV Virtual Drive Simulation

Fast modeling and assessment of powertrain concepts

Virtual Drive Simulation is a software tool for simulating the longitudinal dynamics of vehicles. It can be used in the concept phase as well as for analysis of a more detailed nature. The software comes with an easy-to-configure powertrain model and also provides predefined powertrain topologies. Comprehensive analyses provide the basis for rapid benchmarking and deriving trends. Keeping computing times short, it can be used for evaluating a large number of variants and for multi-criteria optimization.

Example: energy-saving potential

Analysis tasks
- Consumption, CO₂ emissions in cycle or at constant velocity
- Spurt and elasticity
- Climbing and acceleration ability
- Drivability and basic key figures
- Potential for start-stop and recuperation

IAV Velodyn

An innovative tool for simulating longitudinal powertrain dynamics

Using Velodyn for ComApps to simulate overall systems provides an effective methodology in developing conventional and hybrid powertrain structures for commercial vehicles and mobile working and farming equipment. Velodyn for ComApps is a Matlab/Simulink®-based simulation environment developed by IAV. Growing all the time, a comprehensive model library is available for selectively modeling different applications. Simulation is quickly set up in modular form. The basis for this is provided by a bus structure that was developed by IAV and manages all input and output signals of the different model blocks.

At co-simulation level, IAV Velodyn can also be linked up with relevant domain simulation tools, such as Dymola, SimulationX, GTPower etc. to adjust the complexity of the overall vehicle model’s individual component in line with needs.

Applications:
- Analyzing concepts in relation to longitudinal dynamics, work performance, emissions and consumption
- Analyzing the effects of varying individual drive and vehicle components
- Developing and testing software components
- Calibrating machine, transmission, engine and hybrid functions
- MIL, SIL and HIL tests
- Test automation

Model structure for a long-distance truck
Market observation – methods, processes, tools

Market observation is a focal aspect in IAV’s development activities and provides the basis for analyzing the potential of customer vehicles. Conducting benchmark analyses both for itself and on behalf of its customers, IAV generates detailed strengths-weaknesses profiles. The vehicle measurements this involves can be extremely diverse. From a simple consumption and performance analysis to function and strategy analyses as well as detailed design and BOM analysis. These measurements are conducted on roller dynamometers with the entire vehicle, or at detailed level on powertrain, component and special stripped-down test benches.

Using dedicated IAV tools, the data obtained are then evaluated, turned into graphic form and compared with the IAV Knowledge Database. IAV Knowledge Database is a data management and analysis tool for compiling vehicle and powertrain specifications. The system offers a platform for global benchmarking. Modular in form, it can be adapted to any specific application area. The IAV Knowledge Database is available for our development partners and customers to purchase and use.

Fields of knowledge come from trade journals, conferences, online/websites, trade and consumer publications from Europe, Asia and North America. It is also possible to store a customer’s internal data and compare them with the external data provided. The IAV Knowledge Database includes information on vehicles propelled by conventional and alternative drives.

Data security is guaranteed by means of the authorization concept. Using authority groups, it is possible to control data access and protect confidential data.

Methods of analysis can be set up to suit any specific inquiry task. Selected vehicles, engines, transmission etc. are displayed in a table. Technical parameters are presented in graphic form as point charts (e.g. scatter bands), bar charts or spider charts. Characteristic curves and maps can be overlaid to evaluate and visualize the differences.

Data communication is available for importing and exporting data from and to Microsoft Excel spreadsheets making it easy to continue processing all search and inquiry results. External data sources can be imported (e.g. EPA).

Benchmarking

Levels in IAV benchmark process

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<td>4</td>
<td>Technical part analysis</td>
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<td>3</td>
<td>Teardown and BOM documentation</td>
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<tr>
<td>2</td>
<td>Vehicle and testbench measurements of performance, consumption and driveability</td>
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<tr>
<td>1</td>
<td>Competition analysis/market study</td>
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We meet the increasingly complex demands on the functionality and efficiency of powertrains using an effective, perfected and start-to-finish design process for developing transmissions and hybrid systems. Our attention is focused on designing all types of new and derivative transmissions to the point of mass production. We use our particular strengths in optimizing transmission design: Close cooperation with all of the development and production departments involved as well as our vast experience in product-range and vendor management.

With our many years of experience, expertise and process-related knowledge in developing components, function assemblies, complete transmission and hybrid systems to the point at mass production, we are the right address for your transmission development projects. Our experts in designing transmission mechanics, hydraulics and electro-mechanics employ state-of-the-art design and simulation tools – some developed in-house – as well as a wide range of CAD and PDM systems.

**Selection of design activities:**
- Definition of requirements and product specifications
- Systematic dimensioning of mechanical elements based on load spectrum
- Layout, design (3D) and derivation of production drawings (2D)
- 1D, 2D, 3D tolerance simulation (statistical, cross-assembly)
- Product data management and competence in CAD methodology
- D-FMEA
- Vendor and product range management

**Mechanical transmission systems**
Today, the need to reduce the time and cost factor in designing and developing transmissions makes it essential to adapt durability simulation.

IAV uses computation software and processes to predict the life of the entire transmission system on the basis of load spectra that can be generated by simulation or measurement. This permits comparison of several concepts at an early stage of the design process with a view to optimizing the preferred solution. The influence of derivative applications can also be analyzed, e.g., for hybridizing a conventional powertrain. In addition, dimensioning the mechanical elements with greater precision helps to speed up and cut the costs involved in testing.

**Hydraulic components and control units**
Hydraulic systems are used when forces and movements need to be transferred with a high level of precision, speed and efficiency. In automotive hydraulics, other demands include functional intelligence coupled with maximum efficiency and minimum package.

Our hydraulic systems – used in controlling transmissions for example – meet all of these requirements. Whether it is electro-hydraulic pressure supply systems with multi-stage pumps, solenoid valves or integrating all components into a single transmission control module, we will find the best possible solution for your specific application in terms of performance, comfort and durability – and all at an attractive price.

We are equally at home with other hydraulic actuation systems, such as parking-lock systems or torque vectoring modules. Our portfolio covers all aspects from concept definition, simulation, prototyping to testing all disciplines. With our state-of-the-art in-house testing, analysis and laboratory equipment, we are also your expert partner in the field of competitor benchmarks, durability tests, failure analysis and optimization.
System Integration

More than the sum of its parts

The growing number of autonomous sub-functions in commercial vehicles along with increasing pressure from policymakers and industry for safe, efficient and low-emission vehicle is ultimately leading to a huge rise in the complexity of control systems, particularly in the powertrain.

With many years of experience in driveline integration, IAV’s system engineers work in line with the SIMILAR* process.

Stating the problem is the most important system engineering task (identifying/understanding customer needs; establishing the need for change, discovering requirements; defining system functions).

Investigate alternatives and evaluate them based on performance, cost and risk.

Model the system, running model clarifies requirements, reveals bottlenecks and fragmented activities, reduces cost and exposes duplication of efforts.

Integrate the systems by designing interfaces and bringing system elements together so that they work as a whole. This requires extensive communication and coordination.

Launch the system, making the system do what it was intended to do.

Assess performance by using evaluation criteria, technical performance measures and metric. measurement is the key. No measure, no control. No control, no improvement.

Re-evaluation should be a continual and iterative process with many loops.

As a competent development partner, IAV meets these requirements and is at your disposal every step of the way through the product generation process.

Integrating sub-systems

The complexity of modern powertrain components is growing all the time and hybridization is bringing new distributed functions. IAV tests new functions for sub-systems using rapid prototyping as early as the offline simulation stage with IAV VeloDyn closed loop before integration takes place. State-of-the-art measurement technology and testing facilities are available for conducting error response tests on the individual component as well as for testing components in an integrated way. The basis for functional validation is provided by ISO 61508 or ISO 26262. Interface checks, function analyses as well as cyclic conformity and software testing ensure smooth integration. Automating and re-using subsystems, interfaces and tests is the aim wherever it makes sense.

Integrating the overall system

Integrating new component types into new or existing systems is a challenge on its own. With a view to system architecture, competent engineers define and develop the interfaces and analyze the interaction of distributed systems. Particularly in the light of green technology (hybrid), innovative integration strategies / approaches are needed for integrating new and existing components. Coordinating the project partners, the hardware and the software as well as the mechanical system is just as much at the focus as validating the overall system and verifying the distributed systems (integration test). Starting up the vehicle complements the portfolio.

IAV’s system engineering goal is to satisfy our costumers’ needs, to increase the probability of system success, to reduce the risks and total life-cycle cost. We have proved this in many projects – do it in the SIMILAR way!

Software and Algorithm Development

Many years of experience in professional software development for various transmissions

We are your expert provider for developing complex control systems for transmission, hybrid and electric drive applications. Our expertise centers on developing production-ready as well as prototype open and closed-loop control strategies for all contemporary automatic transmissions, such as dual-clutch transmissions (wet and dry), automated manual and planetary automatic transmissions with converter.

Automatic transmissions are employed in conventional and hybrid powertrains. It is in this context that our efforts focus on aspects, such as controlling the gearshift process in dual-clutch transmissions and planetary automatic transmissions, on developing diagnostic and safety strategies as well as on additional functions such as start/stop, coasting and activating additional torque in hybrid powertrains. The customer alone decides whether the development process follows a model-based or conventional approach.

Our development activities are always integrated in clearly defined processes from the aspect of requirements, testing and quality management.

Assisting the process of algorithm development, we utilize the benefits of early closed-loop simulation at model-in-the-loop or software-in-the-loop level.

IAV uses standard as well as customized tools and development environments for developing prototype software in the shortest time possible.

No rapid prototyping without prototype control unit: We use our own control unit to avoid any compromises in controlling prototypes. In addition to the computer core, of course, it integrates all requisite input and output stages that bring new hybrid or transmission concepts to life. Its robust configuration, also for accommodation in the engine compartment, automotive-type plug connectors, calibration access via XCP-over-Ethernet, flexibility of the numerous output drivers and the full tool chain for automatically generating code from TargetLink, including integration with existing or newly developed C Code, enable us to commission prototype transmissions in next to no time.

Competencies in control system Development

• Production-ready development of entire transmission control systems for AMTs and DCTs
• Development of entire transmission control systems for planetary automatic transmissions with converter
• Clutch control for wet and dry systems
• Hydraulic and electromechanical actuators
• Safety-relevant systems and diagnostics
• Powertrain management
• Requirements management
• Model-based software development
• Tool chain for autocoding
• Software development for production software to SPICE
• Software quality management
• Closed-loop simulation (MiL, SiL)
• HIL systems and software validation
• Configuring and integrating embedded software
The vehicle of tomorrow is defined by complex and diverse powertrain concepts. From the conventional drive to hybrid concepts and the electric vehicle. System diversity and complexity go hand in hand with ever more effort involved in coordinating torque. And the demands on functional safety are increasing in the same proportion as well.

The aim of functional safety is to identify and evaluate hazards inherent in the system and then counteract them systematically by applying appropriate measures to reduce them to an acceptable level. This is the basis on which our experts specify, realize, test and validate safety concepts that reflect the state of the art.

IAV has been developing vehicle powertrains to the level of manufacturing readiness on behalf of many different customers for over 25 years – also providing support in creating relevant safety concepts, such as the tried and proven three-level EGAS concept for engine control units and its adaptation to innovative transmission and e-mobility concepts.

All this puts us in a position to develop effective and also efficient technical solutions for our customers.

What we do
• Manage and provide assistance with the safety process
• Analyze and realize safety concepts relating to all aspects of the powertrain
• Provide consulting in relation to applying ISO 61508 or ISO 26262
• Provide independent reviews and assessments

Diagnostics / OBD

Satisfying the specific demands of diagnostics in electronic transmission control systems – is an elementary key aspect of what we do

Diagnostics are gaining more and more significance in the context of all-round consumer satisfaction. Our current focus is on electronic transmission management. In general, this is divided into functional diagnostics and diagnostics required by law (OBD). Our experts have over a decade of experience in all relevant subject areas.

Functional diagnostics
• Analysis and creation of functional diagnostic concepts at system level
• Defining specifications for and implementing diagnostic functions at (sub-)system level

Defining specifications for and implementing fault management (fault handler)
 Verification and testing / validation on HIL systems and in the vehicle
 Calibration and adjustment to different vehicle versions / platforms
 Support in customer service at the OEM

On-board diagnosis (OBD)
• Evaluation and definition of the OBD relevance of parts and components of the electronic transmission control system
• Planning and configuration of OBD-specific functions and software modules, such as the fault manager or in-use monitoring performance ratio

Planning, performance and evaluation of OBD approval and acceptance tests required by law
 Advice on generating as well as producing the approval documentation required
 Definition and coordination of interfaces with the control units involved
 Definition and selection of fault codes required by law
 Definition, generation and implementation of test automation in the field of OBD
In addition to the all-encompassing process of software and algorithm development, IAV provides support in testing for assessing changed and/or new sources just in time. This involves several efficient, fast and lean test stages.

White-box tests have the purpose of formally verifying software quality. We not only examine software metrics, MISRA rules and observance of project-related guidelines but also perform the classic code coverage tests for locating numerically problematical calibrations and operations. The latter are conducted both in the form of reviews as well as semi-automatically.

We take care of formal and functional verification for model-driven software development where model testing, model-in-loop and back-to-back tests are our everyday work tools. Automatically generated (structure-based) test vectors provide the necessary code coverage whereas functional testing of the modeled functions verifies implementation in line with requirements.

HiL simulators are used for automatically examining the resultant software for its anticipated behavior on the target hardware. Beside the obligatory diagnostic tests, we also analyze and evaluate all aspects of transmission functions.

Moving extensive test scenarios from the vehicle onto the HiL (test automation) produces huge time savings in testing and also improves the reproducibility of results. Automated evaluation provides further benefits. For example, the data measured during testing can be scanned automatically for defined criteria, resulting in additional test coverage.

Competencies:
- Test management for production-level projects
- Verification of production-level software
- White-box testing
- Black-box testing
- Test automation
- Carrying out TPI (Test Process Improvement)
Drivability – a term that covers both subjective as well as objective factors. Jerky clutch engagement, for example, is evaluated subjectively whereas objective measurements record acceleration, vibration or acoustics. Modeling and simulation methods are used for examining physical processes to improve the calibration process. Modern powertrain concepts with automated gear selection need to meet ever tighter legislation while also taking account of the consumer’s personal driving style and providing contemporary ride comfort. This trade-off can only be resolved by taking an integrated approach to the powertrain. This is why modern powertrain concepts only use transmission control systems that work on an interconnected basis.

Our engineers develop calibration solutions in accordance with generally acknowledged criteria or criteria agreed with the client and ensure constant high quality for volume production. Everything is then balanced and validated in test drives under all climatic and country-specific conditions.

For many years, IAV has been a strategic partner to customers across the globe in the field of transmission calibration. In the course of key or vehicle derivative projects this involves all-embracing development activities to manufacturing readiness level. The range of services we provide in this domain is extremely broad and covers the following aspects:

**Shift Quality (SQ)**
- Configuration and optimization of clutch actuation and the gearshift process
- Gear engagement / start / drive-off cycle
- Limit sample calibration (tolerances / wear)
- Optimization of comfort and acoustics
- Calibration under all climatic conditions
- Calibration of WSC (wet starting clutch) / TCLC (torque converter lockup clutch) control and strategy
- Neutral idle control
- Clutch adaptation
Driving strategy
- Calibration of basic gearshift programs
  - ECO / Manual / Off-Road / Low Range / Hybrid ...
- Configuration and optimization with all basic functions:
  - Uphill and downhill detection
  - Upshifts on rapidly releasing accelerator pedal (fast-off)
  - Driver type detection
  - Gearshift adjustment to catalyst heating, altitude
  - Control unit requests for keeping gear
  - Downshifts on deceleration
- Producing software modification requests and new functions

Activities in calibrating diagnostics / OBD:
- Diagnostic software
  - Calibration of hardware diagnoses
  - Calibration of processing layer / abstraction layer (substitute values, ...)

Activities in calibrating diagnostics / OBD:
- Calibration of functional diagnostics (e.g. gear engagement failure)
  - Fault handler
  - Calibration of fault handling (recognition and debounce)
  - Calibration of fault indicator (service fault codes etc.)
  - Calibration of fault response (e.g. limp-home operation as well as alternative responses, such as gear suppression etc.)
- On-board diagnosis
  - Calibration of OBD fault manager in relation to debouncing the OBD state machine according to statutory guidelines as well as calibration of fault codes required by law (e.g. P / U codes to SAE specifications)
- Diagnostic communication
  - Calibration of communication side (CAN, K-Line, ...)

Calibration Process
IAV works on your projects in line with a strictly defined process. This ensures that quality, costs and deadlines are properly balanced in every development phase. This process is documented down to every last detail and provides the work basis for our projects.
Testing

We validate all transmission components and the overall system

Our test specialists measure transmission characteristics from initial load collective measurement to the start of production on the basis of specification requirements and customer-specific test criteria. These include function and endurance tests on components, transmission systems and entire powertrains, validating resistance to misuse and evaluating acoustics.

Proceeding from objective criteria, we examine and optimize the shift comfort of manual transmissions and selection comfort of automatic transmissions using the selector shift pedal measurement system (SSPM) developed by IAV.

We conduct testing on our own test benches that are equipped with
state-of-the-art measurement systems. Validation drives carried out under extreme conditions (summer, winter, altitude) complement the test series. Our clients can build on our engineers’ many years of experience with all transmission types – particularly in analyzing roller bearings, gearings and synchronizers.
Whenever you need, we shall be pleased to assist you with state-of-the-art test bench equipment, highly qualified staff and over 30 years of experience. Our test benches are configured for transmissions, e-drives and hybrid systems of every conceivable type.

**Powertrain test bench**
- Function and endurance tests on transmission systems and entire powertrains
- Drive: internal combustion engine
- Power output: 535 kW / 2 x 3,600 Nm / 3,000 rpm
- Hybrid development (150 kW battery simulator)
- Dynamics, vibration and rotational-irregularity tests
- Controlled resonance (endurance) tests
- Simulation of driving dynamics on the test bench
- Front or rear-wheel drive

**Transmission test bench**
- Function and endurance tests on transmissions systems and entire drivetrains
- Drive: 370 kW / 650 Nm / 10,000 rpm (upgradable to 20,000 rpm)
- Output power: 2 x 290 kW / 2 x 4,200 Nm / 3,000 rpm
- Combustion engine simulation
- Hybrid development (250 kW battery simulator)
- All-electric drive systems
- Dynamics, vibration and rotational-irregularity tests
- Controlled resonance (endurance) tests
- Simulation of driving dynamics on the test bench
- Front or rear-wheel drive

**Hydraulic test bench**
- Function and endurance test on mechatronic and hydraulic components
- Measurement of oil flow, pressure and driving power / efficiency analysis
- Benchmark analysis
- Investigations on cold start, leakage, switching time
- Highly dynamic tests / vibration
- Temperature range of ambient and fluids -30 to 150°C
- Fully automated test cycles or manual tests

**Power loss test bench**
- Power loss analysis on full engines and engine components
- Power loss optimization of assemblies
- Benchmark investigations
- High accuracy and reproducibility from hydrostatic mounting
- 160 Nm / 75 kW / 8,000 rpm (10,000 rpm without flywheel mass)
- Asynchronous pendulum dynamometer / measurement accuracy ± 0.3 Nm

**Test center for e-traction systems**
- Battery system test bench
- Battery cell test bench
- Electric motor test bench
- Transmission system test bench
- Battery simulator
Hybrid and E-Testing
Test center for e-traction systems

Systematic testing
Getting power and energy from the individual cell through the module and system and into the overall powertrain demands state-of-the-art testing equipment. The new Electromobility Test Center is the answer to the new challenges encountered in developing electric and hybrid vehicles.

Battery system / cell test bench
• Battery system test bench
• Battery cell test bench
• Electric motor test bench
• Transmission system test bench
• Battery simulator

Special Test Tools
Selector Shift Pedal Measurement System (SSPM)

Objective analysis of shift comfort on manual transmissions and selection comfort on automatic transmissions
In most cases, shift or selection comfort is evaluated on the basis of purely subjective impressions. Recording forces and travel on engaging the clutch and changing gear, IAV’s SSPM (Selector Shift Pedal Measurement) system provides the capability of comparing these impressions with the results obtained from measurements. Developed in-house by IAV, the hardware and software can be matched to any specific need.

Particular benefits
• Objective investigation into shift comfort of manual transmissions, automatic and dual-clutch transmissions
• Recording pedal characteristics
• Verification of subjective anomalies
• Examination of specific requirements
• Easy installation and removal for fast start-up
• Benchmark examination
Storage area
Cell tester
Transmission test bench
Control room
E-motor test bench
HV system integration testing
Battery test bench

SSPM being used in the vehicle
Prototyping

Flexible and fast, production-ready solution always at the focus

Prototyping not only demands craftsmanship and the right tools but above all an understanding how the solution will interact with the overall system. It involves a continual process of change and adaptation during the design phase. This is only possible by optimizing the link between product realization (both software and hardware) and engineering development.

IAV’s staff benefit from broad-ranging expertise in the entire vehicle and team building flexibility (in terms of the technical disciplines involved) for the specific prototype solution. This is the only way of ensuring the ideal flow of information beyond system boundaries. It is also why IAV can build prototypes extremely quickly while never losing sight of delivering a feasible, production-ready solution for the overall vehicle.

IAV delivers prototype parts from:
- Individual component to overall vehicle
- Valve to transmission
- Bowden cable to mechatronics
- Hardware to software

IAV provides the following service portfolio
- Component construction & vehicle assembly
- Start-up, function validation & acceptance inspections
- Integration of measurement & testing facilities
- Support in relation to test, validation & development mules
- Supervision and setting up low-volume production

IAV security standards cover:

Confidentiality of information
- Information confidentiality in accordance with client’s framework agreement
- Separate project teams
- Sensitization of staff
- Partner companies sworn to secrecy

Prototype protection
- Defined processes for prototype protection
- Secure prototype workshops
- IAV’s own prototype transporter

Data protection, data security
- EDC and network security defined in “IT Security Policy”
- Documented internal access authorizations
- Encryption and data security concepts
Prototype Manufacturing

Service Portfolio

Machining of prototype and in-house manufacturing of components, assemblies and test parts is an important prerequisite for effective project handling.

Machining
- Milling / drilling
- Turning
- Grinding
- CAM

Quality assurance
- Measuring of:
  - accuracy
  - length
  - surface roughness
  - contour and topographies
  - hardness
- Certification

Metalworking / plumbing
- Sheet-metal working
- Bending
- Welding
- Pressing
- Cutting
- Heat treatment

Universal Machining Centre for 5-axis machining

Coordinate Measuring System
Our project managers follow an interdisciplinary approach in developing complex technical systems. All-embracing system integration is achieved by viewing the subsystems or components under development within the overall big picture. We take care of coordination as a way of making sure our project results are seamlessly integrated into the products our clients develop.

Assisting in a coordinating capacity, IAV’s Project Management Office (PMO) provides assistance as coordinator in developing a technology. The PMO is the central contact for matters relating to project management and large-scale projects at IAV. IAV has developed project management methods that conform to international standards and the standards of the Project Management Institute (PMI®) and automotive SPICE®. Continuous alignment with best practice and lessons learned ensures that project management undergoes an ongoing process of improvement.

Project management at IAV:
- Project management to PMI
- Definition and application of a project management process
- Project management as a separate discipline
- Training and qualification programs
- Qualified project managers for interdisciplinary projects

Benefits to the Customer

| Understanding customers’ requirements | • Adopt the customer’s view
| • Identify the demands on the product (market) |
| Shared target focus | • Target-focused planning
| • Identify unresolved issues
| • Fill "gaps" and minimize risk |
| Working together in the project team | • Cover all interfaces
| • Ease strain on customer resources
| • Report and inform in full |
| Ensuring the target is reached | • Meet customer demands
| • Keep to customer demands (Q standards etc.) |
| Reaching the target | • Reliably deliver
| • Deliver at set price |

Our transmission and hybrid developers constantly face the challenge of developing innovative and complex products for our clients in the shortest of times. This is why systematic and standardized project management provides the basis for organizing all customer projects even more effectively and efficiently while also taking them to completion.

The project managers are involved in talks with our customers as early as the project inception phase to ensure the project starts smoothly and is successfully carried through. The project manager best qualified for the project focus in terms of technical competence and subject matter is selected as the customer’s contact for the duration of the project.
Development Process

Everything under control

We meet the increasingly complex demands on the functionality and efficiency of powertrains using an effective, perfected and start-to-finish process for developing transmissions and hybrid systems. Our attention is also focused on developing new and derivative transmissions to the point of mass production. To do this, our experienced experts in developing transmission mechanics, hydraulics and software and hardware for electronic control units employ state-of-the-art design, simulation and development tools – some developed in-house – as well as a wide range of CAD and PDM systems. We use our particular strengths in optimizing product design and algorithm development: close cooperation with all of the development and production departments involved as well as our vast experience in product range and supplier management.

- Powertrain development from the advance-engineering stage to start of mass production
- Efficient project handling by experienced specialists, proven process tool chain and methods, extensive infrastructure and competent project management
- Personal responsibility for engineering, schedule and quality at component and system level with IAV System Responsible Persons (SRP) and IAV Component Responsible Persons (CRP)
- High level of flexibility in the type and size of work packages using the option with the best possible prospects of success in terms of development objective, budget and time schedule
- Interdisciplinary product development with a high level of direct responsibility
- Hardware solutions and algorithm development on a one-stop shop basis
- Our development activities are in line with process models such as Automotive Spice and CMMI
- Test process with high-level and low-level testing embedded in the development process, including test management

Development Process

Target management
- Design / parts list
- Simulation
- Change management
- Support in testing and approval
- Software / diagnostics / algorithms

Supplier management
- Support in manufacturing
- Release
- Purchasing
- Provision and revision of information
- Control unit hardware

Integration and calibration
- Mechanics + hydraulics
- E-machine + power electronics
- Software and algorithm development

In-development testing (hardware and software)
- Prototype manufacturing
- Procurement and quality assurance
- Powertrain and vehicle assembly

General overview of development process

Tasks and Interaction of IAV System Responsible Person (SRP)
Costs are an increasingly important aspect in developing transmissions and e-drive systems. Our cost-engineering experts work out the costs of producing hybrid and transmission system components at an early project stage.

Cost analysis in development
- Bottom-up costing for different technological and production options
- Decision-making support in selecting suppliers
- Concept comparison
- Establishing modification costs

Benchmarking
- Dismantling engines or assemblies
- Technical assessment
- Cost evaluation
- Best-practice recommendation and assessment of potential

Product cost optimization
- Cost driver analysis
- Expert workshops, value analysis in interdisciplinary teams with designers and cost engineers
- Design revision or re-designing and assessment of cost-reducing potential
- Action prioritization and monitoring
- Support in production-ready development activities

Cost Engineering
The way to technically and cost-optimized solutions

Example cost breakdown

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