High Performance ECU Calibration
Using Realtime ECU Interface

New application methods for dynamic ECU calibration like those of AVL are tailored for the complex requirements of modern powertrains. Especially the dynamic character and behavior of powertrains at the lowest emission levels are a challenge for development engineers. To use these methods successfully it is necessary to improve quality, reproducibility, stability and safety for data acquisition in the development process. A precondition for this is a fast and powerful ECU connection which creates additional possibilities for new applications and methodology.

1 Introduction

As a lot of processes run in real time and systems engineering development is heading more and more towards dynamic measuring methods to obtain faster and more precise measuring results, modern calibration systems are required for support. In the future, the question will no longer be whether to place a realtime system on the test bed, but how to establish a high performance connection between the systems. Sooner or later, each system in the test field will have to provide a realtime environment to keep up with the increasing requirements.

The following article will show the advantages and possibilities of new application methods using a real time ECU interface (iLinkRT) which is discussed on the basis of real world examples.

An important topic here is the safe test operation. A great benefit can be gained when testing with incompletely calibrated ECUs by the heavy use of bypass applications. Furthermore testing time can be reduced through the use of a scalable and fast interface. This can ensure also the highest requirements on the safe operation of the units under test. Therefore the system architecture with the multi master functionality is also explained.

2 Powerful Interface to the ECU

A major prerequisite for powerful and automated ECU calibration is a fast real-time access to the ECU. The solution setup in the following approach consists of the fast ECU interface ETK [1] and the device ES910 which handles both (realtime) data processing and the communication with the connected systems. The ES910 is a compact high-performance simulation and communication system. It is designed for automotive use cases on test benches and in-vehicle. The ES910 includes the complete set of interfaces which are relevant for the execution of the calibration job, **Figure 1**:

- Interfaces to the ECU: ETK, XETK, CAN, FlexRay, LIN
- Interface for fast measurement - ES400 Interface
- Host interface (INCA, iLinkRT)-Gbit-Ethernet.

Due to its high performance and multi functionality, the ES910 is able to handle all test bench relevant applications in parallel:

- Execution of realtime models, e.g. controllers, which were created in SIMULINK, ASCET or as C-Code (e.g. for function bypass applications)
- Functional restbus simulation of ECUs
- Gateway between different communication interfaces (e.g. FlexRay/CAN)
- Measurement and calibration interface for INCA
- Fast calibration via iLinkRT.

The ES910 provides for adjacent systems via iLinkRT a fast, physical value based, multi-master access to the internal variables and data of the ECU. Current performance tests with fast calibration pro-

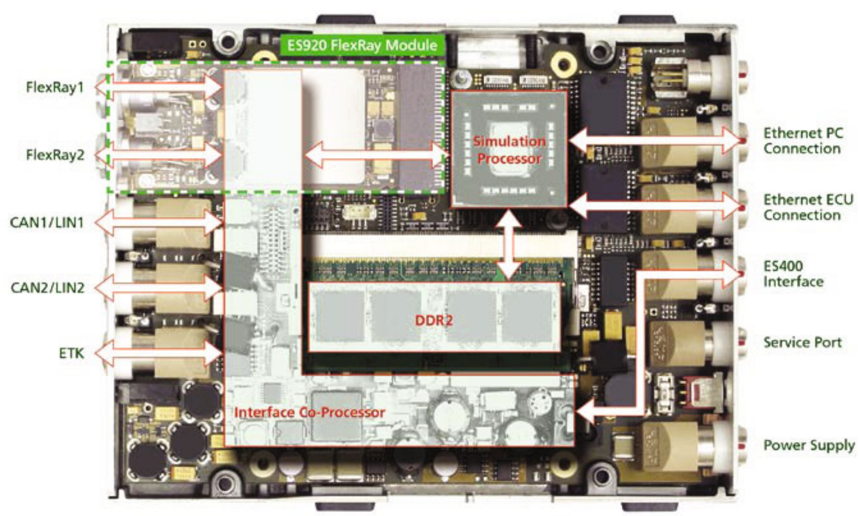

Figure 1: Simplified block diagramm

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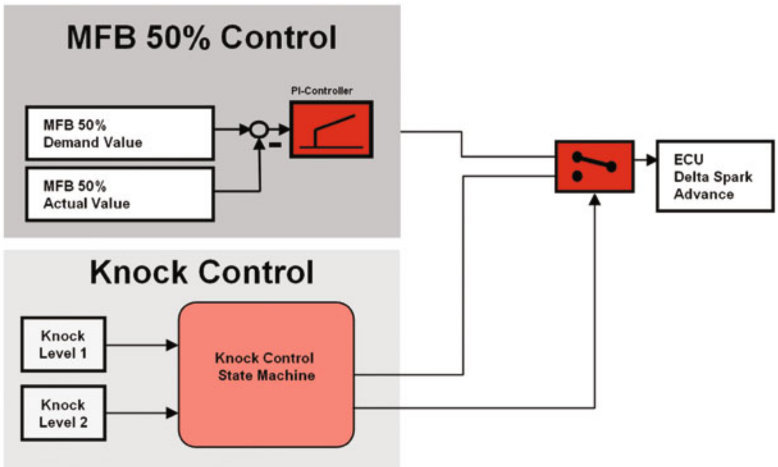

Figure 2: Real time control example: Combustion controller

cedures have shown the following results for the cycle times:

- One parameter (2 Byte) – 0,3 ms
- Five parameters (5 x 2 Byte) – 0,7 ms
- One map 16x16 (256 Byte) – 0,7 ms
- Five maps 16x16 (5 x 256 Byte) – 2,6 ms.

This performance enables the execution of fast real time controllers outside of the ECU in the real-time kernel of the automation system and creates thereby the prerequisite for the execution of the new calibration methods.

3 Application Examples

Below some application examples are presented that can benefit from the new ECU interface iLinkRT.

3.1 Realtime Controller Applications

An essential component is the Cameo RT system where realtime capability can be realized either with the standard interface CAN or the new iLinkRT interface. This enables the combination of all necessary methods for application tasks in one package and the reduction of the interfaces to the remaining systems to a minimum.

Combustion controllers have been used extensively with gasoline engines to ensure safe operation of prototype engines or optimal adjustment of certain parameters.

In order to present the capability of the complete interconnection with iLinkRT a full load measurement of a supercharged gasoline engine was performed. Thereby real time controllers such as component protection control and combustion control were active, **Figure 2**.

The component protection control corrects the amount of fuel until a predetermined lambda value is reached (normally $\lambda = 1$). If a critical temperature is reached, e.g. as here a maximum exhaust gas temperature of 950 °C, the air fuel mixture is enriched to produce cooling.

The combustion control adjusts the combustion via the ignition timing to the predetermined value (MFB50 = 8 °CA) until the knock limit is reached. After this has happened the knock control is activated to take back the ignition timing as long as knocking combustion is detected.

Figure 3 presents two repetitions of this full load measurement: The combustion control adjusts the ignition point so that no more knock can be detected; the component protection control activates the enrichment of the air fuel mixture above 2500 rpm.

The tests proved that the controllers run significantly more stable with iLinkRT, due to improved reaction time, compared to ASAP3. In addition the results are a lot better reproducible.

This new interface to the ECU provides a lot of benefits especially for the parallel operation of bypass application in real time. Therefore test runs can be performed in a full automated way even at critical operating points that up to now had to be measured manually.

Additionally it should be mentioned that particularly in these critical operating conditions, the achievable data quality is considerably better than it would have been in manual operation.

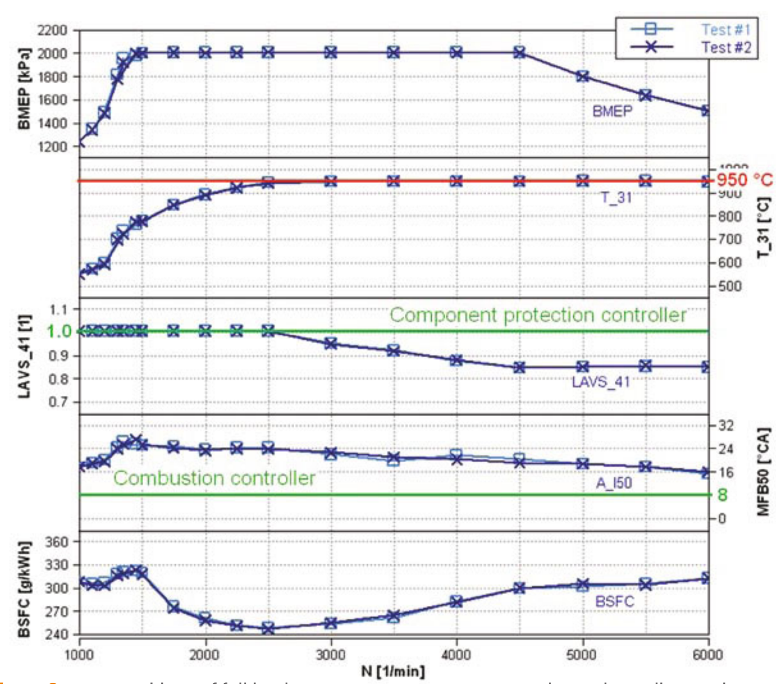

Figure 3: two repetitions of full load measurements on one supercharged gasoline engine using real time controllers

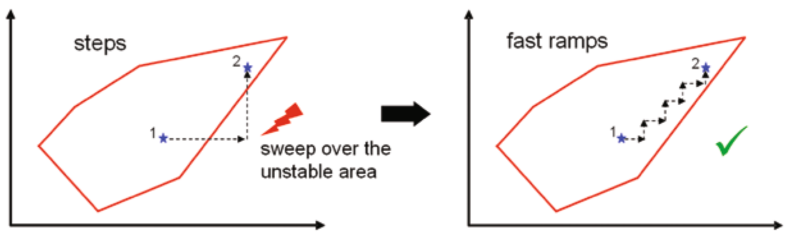

Figure 4: Benefits of fast ramps regarding stable operating range

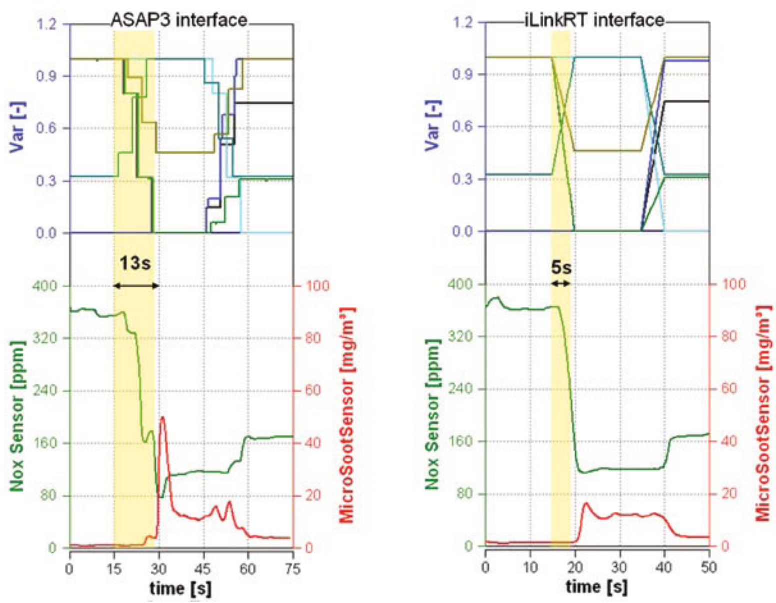

Figure 5: ECU parameter ramps with ASAP3 in comparison with iLinkRT interface

3.2 DoE Applications for Engine Calibration

Meanwhile, many tasks in combustion development use complex maps with up to 9 degrees of freedom. Emissions optimization of diesel engines in particular employs a DoE workflow: "test planning – measurements – modeling – optimization".

In order to guarantee automated and stable measurements it is important to adjust the various variables as fast as possible to avoid possible limit violations: Due to the sequential adjustment of the engine maps a step variation can lead to instable operation (fig.4a). Furthermore, if the time span between the individual adjustments is relatively long it can cause high emission peaks. In order to avoid instable operation outside the design space, ramp generators were developed that approach the following variation in small sub-steps, **Figure 4**.

However, also with these fast ramps it is important that each step is as small, and the sequentially setting of parameters, are as fast as possible so that a smooth process of the test sequence is guaranteed.

Especially here the benefits of the presented high-performance interface to the ECU – iLinkRT- are effective.

When examining e.g. a test run where after 15 seconds stabilization time the next variation point is approached, one can see that at 7 to be classified engine maps in 13 seconds 3 intermediate steps are possible if the standard interface "ASAP3" is used (fig 5a). In contrast, by means of the iLinkRT interface these 7 engine maps can be overwritten in 10Hz steps so that a nearly continuous interpolation is possible (fig.5b). Next to the benefit of a reduction of the measuring time of about 30% the achievable improvement of data quality is an essential characteristic: Especially when examining soot traces in **Figure 5**, continuously measured with the AVL Microsoot sensor, one can see that the dynamic excitation is significantly lower, due to the smaller steps during the adjustment. Therefore overshooting in the response variables (especially soot) does not appear. Experience proves that next to improved data quality also an extension of maintenance time of these sensitive measuring devices as well as improvement of reproducibility can be achieved.

To sum up it can be seen that the new iLinkRT interface shows advantages in the following practical application of measurement strategies: fast map adjustments; real time limit reactions; improved data quality through continuous variation of parameters; multidimensional step excitements in the system; test run stability; etc.

Examples for new methods which are using the strategies mentioned above and which have been described in various publications are given:

- Slow Dynamic Slopes (SDS): Continuous variation of ECU parameters under quasi-stationary conditions followed by the evaluation of the recorded data. Application examples: mapping; charge determination; torque mapping
- Continuous Limit Approach (CLA): Continuous variation of ECU parameters with real time limit reaction and stationary measurement in the stable region of the design space. Application examples: design space evaluation and DoE applications for stratified gasoline engines; full load optimization
- Amplitude modulated Fast Steps (AFS): Dynamic DoE sequence for fast measurement of emissions with dynamic modeling and calculated final steady state values. Application examples: emission optimization; tolerance evaluation
- Amplitude modulated Pseudo Random Binary Signal (APRBS): Dynamic excitement for optimization of ECU controllers. Application examples: air mass controller; air charge controller.

4 Summary

The solutions described in this article have been created with the help of the AVL Powertrain Calibration environ-

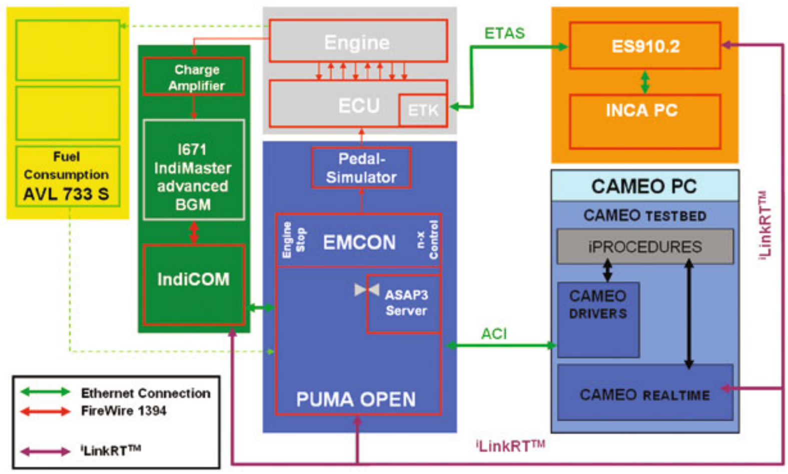

Figure 6: Future test bed set up with iLinkRT

ment CAMEO V3 and address mainly the fast setting of ECU data. The solution with iLinkRTTM is the precondition for running smooth ramps with simultaneously changing of ECU values or maps. The described example of the optimization of a turbo charged engine via SDS method showed how it was possible to achieve faster and safer test results. It has to be stated here that a step by step integration of iLinkRTTM is possible also for existing systems. The concept of this interface enables in future the connection of all systems which are necessary within the calibration process, **Figure 6**.

For future dynamic calibration procedures further potential was identified and it was shown that these methods have to go hand in and with a further development of the measurement instrumentation. All these requirements can be realized in a consequent usage of the AVL iProcedureTM - concept.

5 Outlook

To go for increased efficiency in the calibration process needs a permanent development of the used methods with respect to the possibilities of practical use in our daily work. The examples described in this paper showed which system solutions are necessary to use the potential of dynamic procedures. Therefore it has to be assured that for a specific application task a complete and continuous workflow is designed.

These preconditions come from the requirement that test definition, online test strategies with intelligent limit reactions, real-time controllers as well as modeling and evaluation must interlock seamlessly to each other. The complete system described in this paper combines a simple parameterization on the one hand and robustness and performance of the new interface iLinkRT on the other hand. A significant increase of efficiency within the calibration process was proven already in many applications. ■