Integrated Solution for Internal Combustion Engine Test Bench Control, Data Acquisition and Engine Control Unit Calibration

by

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Products Used:

LabVIEW 2009

NI ECU Measurement and Calibration Toolkit

NI PXI-8186

NI PXI-5401

NI PXI-4070

NI PXI-6229

NI PXI-6123

NI PXI-6602

NI PXI-8461

NI BNC-2110

NI TB-2715

Category:

Industrial Control Systems and Embedded Design Applications

The Challenge:

Developing and building internal combustion engine test bench sub-modules for test bench control, digital data acquisition and on-line calibration of look-up tables downloaded on the engine control unit (ECU).

The Solution:

Using National Instruments off-the-shelf software and hardware, such as LabVIEW programming environment and PXI with appropriate modular cards, to rapidly solve numerous challenging data acquisition and control problems on the Internal Combustion (IC) Engine test bench.

Introduction

Internal Combustion Engines Department, at the Faculty of Mechanical Engineering, University of Belgrade is the largest and oldest institution devoted to IC Engine research in Serbia (and region of former Yugoslavia as well). Dealing with one of the most dynamical object in mechanical engineering, our research would be unimaginable without intensive lab work and usage of cutting-edge acquisition systems. With roots from early 80's with in–house developed data acquisition and measurement systems for our engine test labs, we started to use NI solutions almost a decade ago.

Background

Observing the development of IC engines reveals two major trends: the requirement for increasing engine performance and that for reducing emissions of harmful pollutants. State-of-the art experiences show that fulfilling both requirements is only possible with implementation of complex engine control algorithms with a series of input parameters. IC engines are very complex dynamic systems whose work process is affected by large number of control parameters (beside: environment conditions, geometric characteristics, etc.) such as: air/fuel ratio, throttle position, spark advance, intake and exhaust valve timing, EGR valve position and others. It is necessary to perform optimization process in order to obtain optimum performance in terms of actual engine torque, fuel consumption, emissions of pollutants and other parameters as variable of engine speed and load. It is impossible to obtain optimal ECU look-up tables without carrying out extensive engine testing, no matter how precise and advanced present IC engine simulations software packages are.

ECU hardware & software testing

During previous years, students have shown great interest in engine management problems, becoming devoted involvement in developing an open ECU to be used in our IC Engine test labs. All components – from engine wiring harness, to power driver modules for injection and ignition system as well as signal conditioning modules were built solely by students. The system modularity, based on Freescale MPC565 microcontroller enables ease of modification and great usability in lab and testing conditions.

Within the process of projecting of ECU it is preferably to perform HIL testing in order to verify the developed ECU software prior using it on the real engine. We have found NI hardware and LabVIEW are very suitable for realizing this task. We have used NI PXI-6123 and PXI-6229 multifunction data acquisition boards for simultaneous engine sensor signal simulation, on the one hand, and simulated verification on the other. Features provided by PXI-5401 32-bit DDS-based function generator and NI PXI-4070 Digital Multimeter (DMM) cards were very helpful in ECU validating process. More comfortable and easier way to accomplish engine signal generation is possible by implementing NI FPGA hardware, which certainly will be the next step in upgrading our HIL system.

ECU parameter calibration & data measurement

The CAN (Controller Area Network) is widespreadly used in the automotive industry for in-vehicle data transmission and communication. One of the special CAN communication protocol devoted to ECU calibration is CAN Calibration Protocol (CCP). Using NI PXI-8461/2, High-Speed PXI-CAN Interface card and VI provided by NI ECU Measurement and Calibration Toolkit, two-way communication between NI PXI and MPC565 microcontroller was easily established (Fig. 1).

CCP was used for data acquisition from ECU's software and for calibration of tunable parameters, defined in the ECU development stage. Numerous engine sensors (engine speed, intake collector pressure and temperature, throttle position, air mass flow, intake air temperature, wide band lambda sensor, etc.) were also read among the vast number of variables available through the CCP. Through parameter tuning we were able to modify air/fuel ratio or influence ignition timing in the real time while the engine was running. In this way, we had complete insight in the developed ECU's software functioning and basic environment for its optimization.

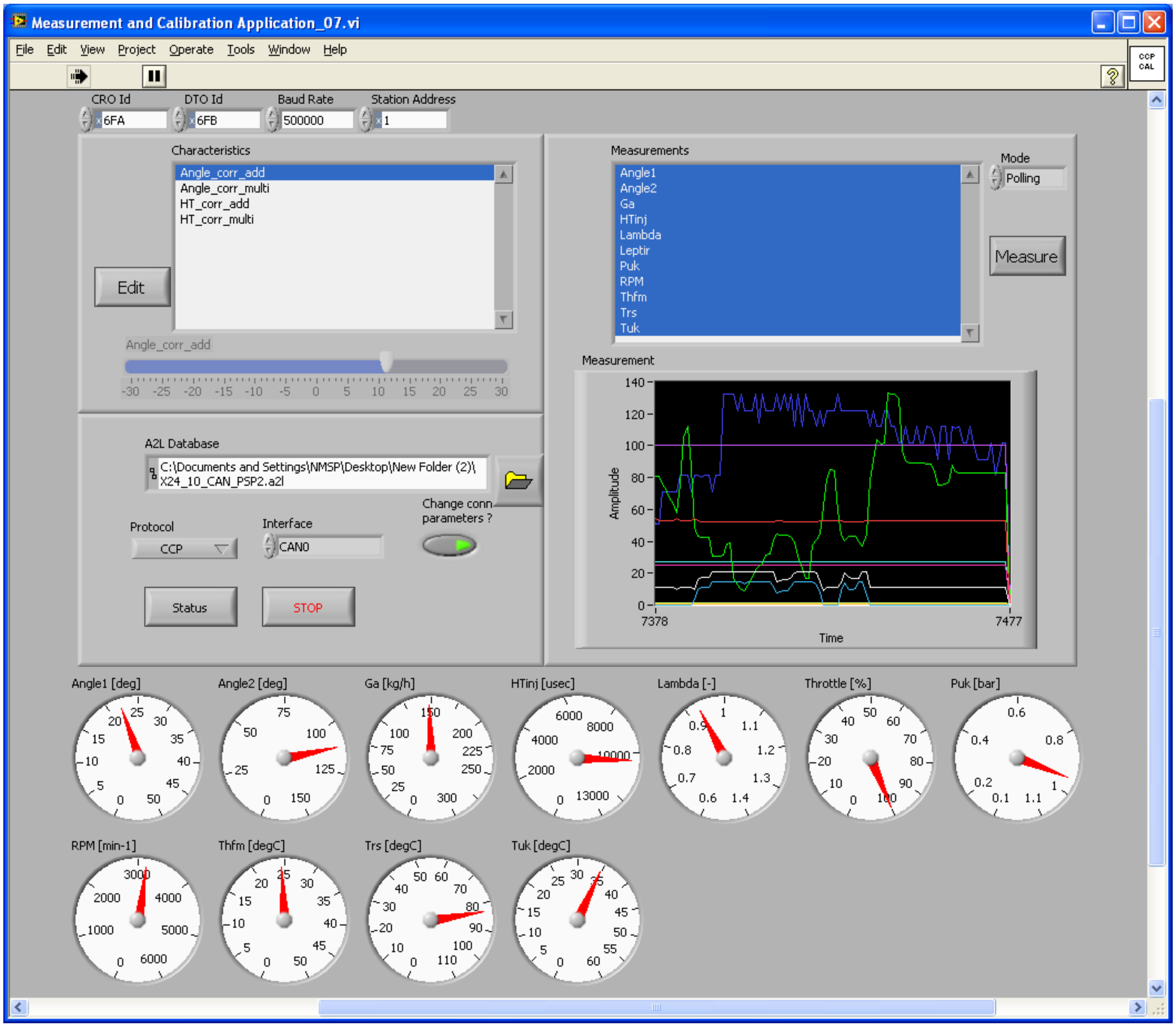

Figure 1: Measurement and Calibration application.

Engine test bench control and data monitoring

Testing an IC engine involves data acquisition from various engine-mounted sensors as well as test bench system and IC engine control. The whole system for monitoring and control of engine test bench was developed in LabVIEW, relying on PXI's hardware resources and its multifunctional and counter cards. That enabled comfortable control of engine load, cooling and fuel supply system. Through this application, information from various sensors were available and clearly visualized (brake torque, engine speed, engine power, exhaust gases temperature, intake air, coolant and oil pressure and temperature, fuel mass flow and A/F ratio, etc.). Since all these readings came from sensors mounted in parallel with engine's original automotive sensors accessed by the ECU, this application allowed testing of ECU's signal conditioning capabilities and software functionality.

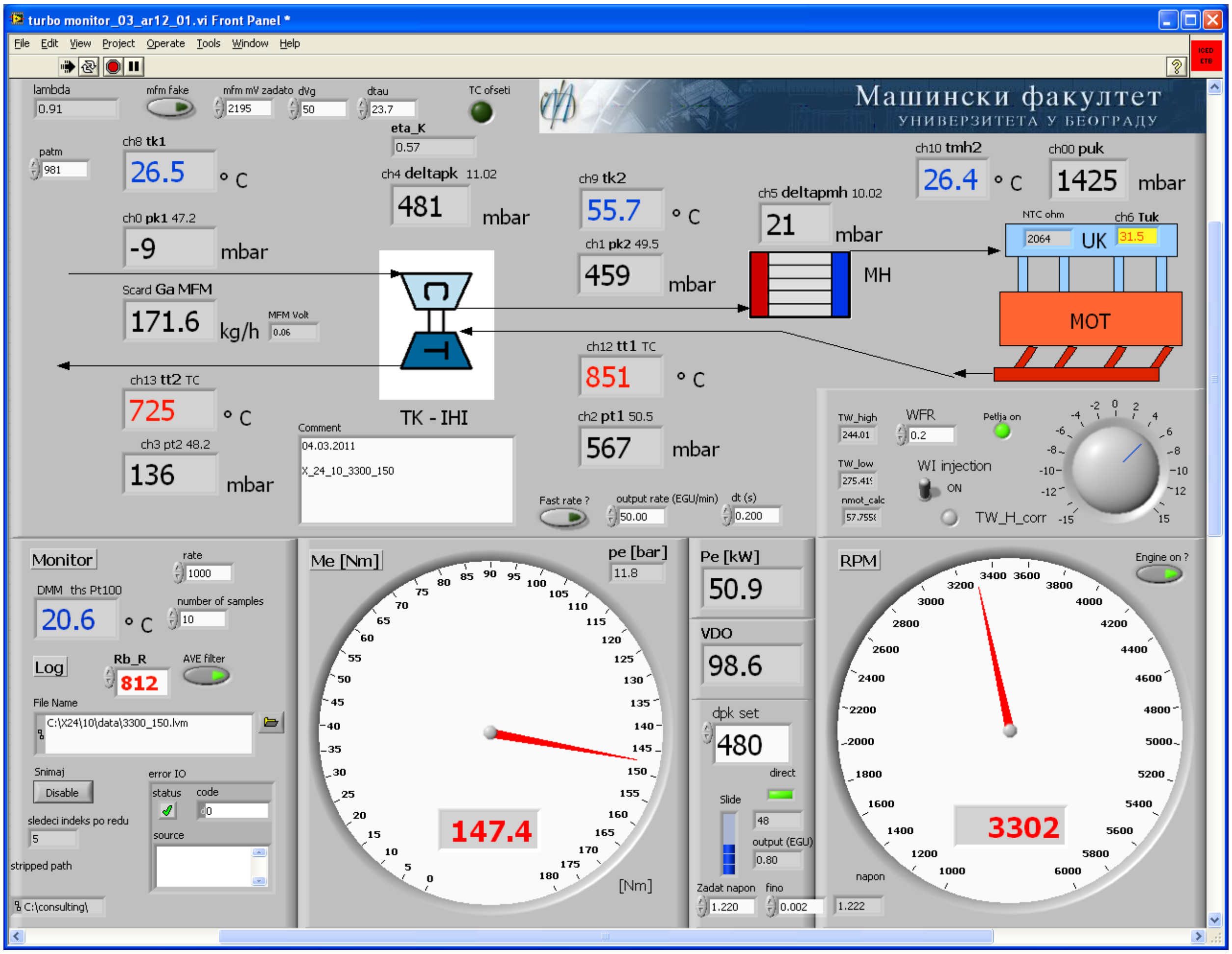

Figure 2: Monitor application.

In-depth work cycle monitoring & analysis

Optimization of some parameters requires a detailed engine work cycle analysis based on angle-resolved in-cylinder pressure measurement (engine indicating). We have realized this task by using an encoder-triggered NI PXI-6123. In order to reduce PXI's CPU load, we have implemented Network-Published Shared Variables to transfer acquired data to another PC on which a specially developed LabVIEW application, devoted to indicated parameters analysis, was executing. This analysis application is relying on in-house developed MATLAB code implemented by means of MATLAB script nodes. Thanks to them, we obtained a huge programming-saving effort while achieving very fast analysis time. One of the results of this analysis is the angle position of the 50 % combustion energy conversion process. Since this position is strongly related to the engine's efficiency and is mostly influenced by ignition timing parameters – this result was immediately used for ECU's calibration.

Conclusion

Thanks to National Instruments hardware and software solutions we were able to take control over the engine and engine test bench and to calibrate ECU's control parameters within one programming environment which successfully integrates data acquisition, control and CAN and LAN communication. Besides its versatility LabVIEW enabled emphasizing of valuable IC engine work process data with its graphical capabilities. This concept has proven to be invaluable, especially in the education process of engineers building their skills in the areas of IC engine testing and development.