



# Software and Hardware Challenges of Engine Test Bed Automation – Example of FME ICED Lab

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**Abstract:** State of the art engine test bed system is a highly complex and demanding testing environment. Built as a tool for providing a versatile test environment for modern IC engines, this system requires automation system capable to establish real-time data and commands exchange between test bed various components. The establishing of engine test bed automation system is particularly challenging in combining software and hardware components from different manufacturers. This paper presents methods and solutions used in establishing such automation system in the ICED Lab at the FME, University of Belgrade by integrating control system of AC asynchronous machine, digital acquisition and measurement system and AVL Cameo software within the NI Labview environment.

**Keywords:** AVL Cameo, Engine test bed automation, Engine testing and measurements, Engine modelling and mapping, NI LabView.

## 1. Introduction

With the need of having automated engine test bed system, which would allow development and execution of standard and non-standard engine test plans, the Internal Combustion Engines Department (ICED) Lab at the Faculty of Mechanical Engineering (FME), University of Belgrade has obtained engine test bed that allows stationary and dynamic engine testing. In order to round-up the automated system, AVL CAMEO [1] software is used, as a top of the line product in Design of Experiment for engine calibration and test and measurement procedures. Additionally, the acquisition of relevant data from the sensors installed on the engine was done using the NI LabVIEW [2] and NI PXI [3] platforms. The main challenge was how to integrate these sub-systems in one coherent whole, so the system could be reliable as it must be during engine testing.

## 2. System Overview

The engine test bed deployed in the ICED Lab consists of AC asynchronous machine SCHORCH LN8280M-A [4] coupled with ROTRONICS PGB 301 [5] digital test stand controller and ROTRONICS CEA 301 [6] throttle position controller. The ROTRONICS PGB 301 is, in fact, a digital dual-loop control rack for engine test bed which allows simultaneous control of the dynamometer and throttle actuator. The communication between the engine test bed components is made via MODBUS [7] TCP/IP protocol.

Via the control rack, the dynamometer and the throttle actuation can be operated in two modes: “Local“ and “Remote“. “Local“ operation mode is a method of choosing the control modes and setting the setpoints of parameters that is relevant for that particular control mode by the operator via the user interface installed on the control rack’s front panel. “Remote“ operational mode is a method of choosing the control modes and setting the setpoints of parameters remotely from a supervisor (*i.e.* AVL CAMEO) via TCP/IP communication protocol, which allows more rapid execution of engine test plans, especially when dynamic engine test procedures are conducted.

The ROTRONICS PGB 301 and AVL CAMEO have been developed to be natively paired with ROTRONICS KRONOS [8] and AVL PUMA Open [9] software, respectively. The difficulty was that neither of those software were not designed to be paired with non-ROTRONICS and non-AVL equipment, respectively, hence there was a necessity to design and develop a bridge communication application between

them. As there was a powerful NI PXI platform already deployed at ICED Lab and in charge of digital data acquisition, it was convenient to use NI LabVIEW programming environment installed to develop such bridge communication application that would run on NI PXI.

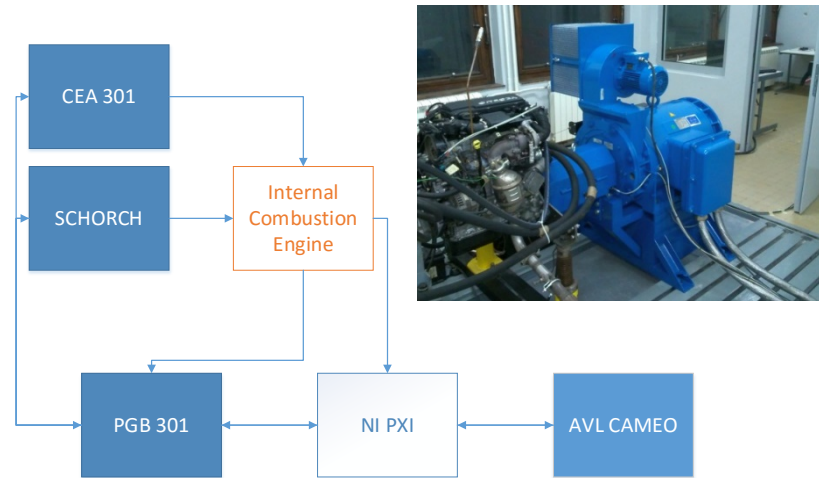


Figure 1. Automated engine test bed system at ICED Lab overview

### 3. Communication Application

As mentioned, the test bed control rack deployed at ICED Lab internally communicates with its peripherals via MODBUS TCP/IP protocol, where MODBUS stands for an application layer messaging protocol for client/server communication between devices connected on different types of buses or networks. MODBUS registers (messages) available via ROTRONICS PGB 301 (the client) control rack differ in type, size, format and in access mode as in Table 1:

Table 1. MODBUS registers available via ROTRONICS PGB 301 control rack

Register type	Size [bit]	Format	Access mode
Coil	1	Bit	Read/write
Discrete Inputs	1	Bit	Read-only
Input Register	16/32	Float/Uint16/Uint32	Read-only
Holding Register	16/32	Float/Uint16/Uint32	Read/write

The first step in bridge communication application development in NI LabVIEW programming environment was to develop universal subroutines for rapid and low resource requirement for read/write procedures to every register type. Low resource requirement was an ultimate goal of application development due to the exchange of a vast number of digital signals between the test bed control rack and AVL CAMEO software through NI PXI. Once the communication between NI PXI and the test bed control rack was fully defined and debugged, the focus was turned towards the successful resolving of the communication between NI PXI and AVL CAMEO, which have proved to be rather more difficult.

AVL CAMEO (the server) communicates with automated test systems through a TCP/IP based get/set communication interface. Once communication has been established, AVL CAMEO sends a series of requests to the client to which responses have to be issued immediately. The requests differ in form, the arguments used, replies needed, etc. Typically, the first set of requests refer to a forwarding of channel number, name and type (read-only or read/write), available control modes for dynamometer and engine, as well as available routines for use (remote engine start, stop, idle, etc.) to the server. After the first set of commands, AVL CAMEO disconnects in order to allow the operator to define test plans to be executed with available control modes and channels. The second set of commands that AVL CAMEO forwards to the client is characterized by a high frequency of digital data exchange through all of the system components, and corresponds to an engine test plan procedure running. During engine test plans running, it is an imperative to manage the potential communication congestion, and to assure that no message is left unanswered. After the test completion, server, usually sends to the control rack command to put the test bed in predefined steady

state operating point (typically idle), saves the acquired logs, and disconnects.

The bridge communication application in NI LabVIEW has been designed to manage requests from the server, to decode them, to simultaneously pass server requests to the control rack either for read or write, to generate adequate response to server, to be intolerant to the number of requests from server, *etc.* At the same time, the application is needed to have built-in error handling and test stop procedures in case of anomalies, as well as to have subroutines for handling requests from the server to control rack for which the rack does not have built-in routines. A typical example of such request handling routine is the management of reaching demanded operating point. AVL CAMEO forwards the request for operating point change via so-called „Rampsetpoints“. „Rampsetpoints“ are given in such a manner that AVL CAMEO simultaneously forward requests for increase/decrease in given set of control parameters (i.e. machine shaft rotational speed and demanded engine torque if operating in ROTRONICS PGB 301 Constant Speed / Constant Torque control mode) in predefined amount of time for each of control parameters change.

The presented dynamic test-bed control solution is thoroughly tested. Fig. 2 presents the engine torque and speed during realization of a dynamic test cycle conducted during control system trials. Set values of the engine speed and torque are obtained through a high-fidelity simulation of the particular vehicle driven on a NEDC cycle (AVL CRUISE simulation software). Simulation results, containing engine torque and speed demand values, are then transferred to the AVL CAMEO for building a test plan which is then executed on the test bench through the described LabVIEW application. Presented results are demonstrating the capability of the test system to conduct highly dynamical IC engine testing with the open possibility for further responsiveness and accuracy improvement by PI torque controller tuning.

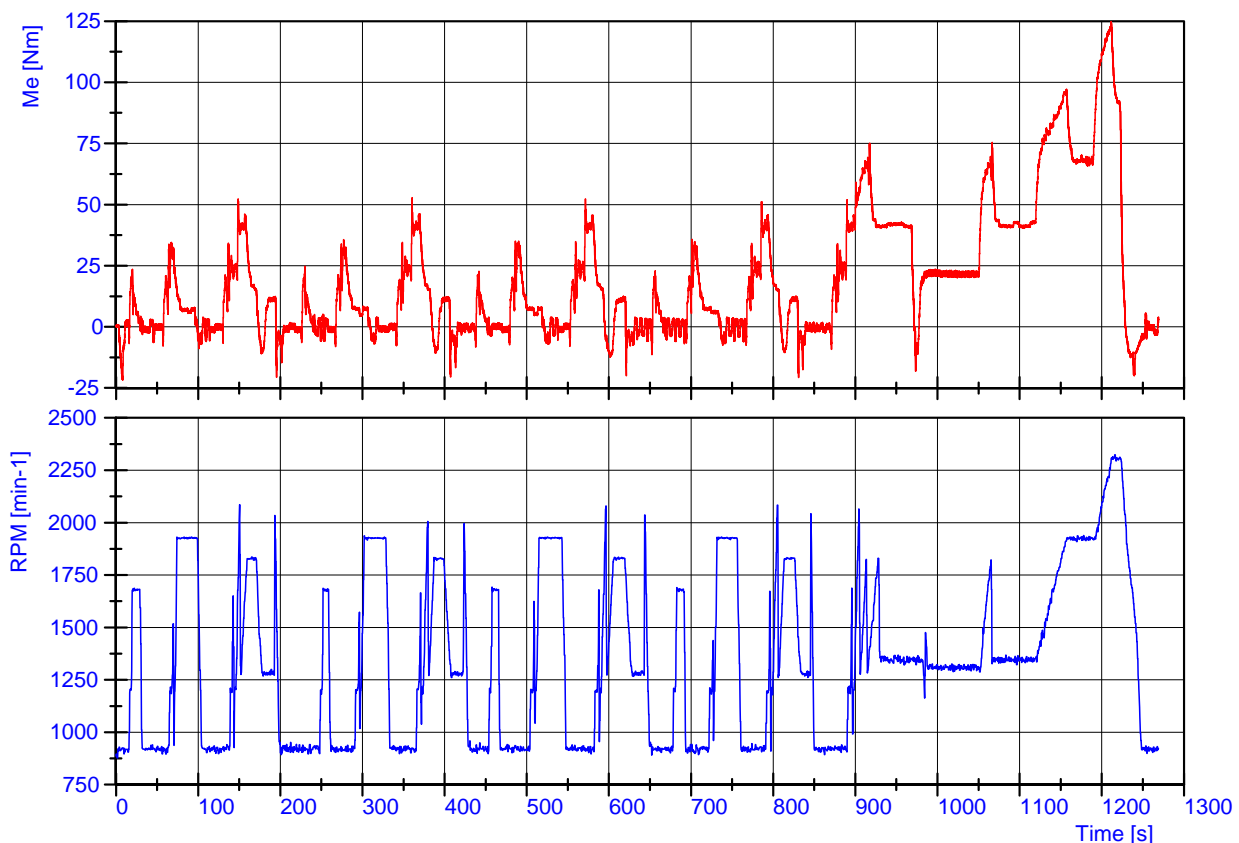


Figure 2. An example of realized dynamic testing of the PSA DV4TD engine on the ICED engine test-bed. (Virtual testing of the Citroen C1 1.4 hdi vehicle through the NEDC driving cycle )

## 4. Conclusion

The establishment of communication between three different software platforms (ROTRONICS PGB 301 - MODBUS, NI LabVIEW and AVL CAMEO), has proven to be a challenging, but feasible task. Particular attention was given to debugging and synchronization of the communication between engine test bed subsystems, which was eased by the method of modular programming, used throughout the work on this project.

With the communication between given platforms operational, a wide spectrum of complex engine test plans can be conducted at the ICED Lab at the FME, University of Belgrade, in addition to existing engine test procedures.

## Acknowledgements

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