borghi & saveri S.r.l.

dal 1935
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Bench automation system

1. Description

The Bench automation System adapts to the available test system layout: besides the control of engine speed and torque it can be used to manage air, oil, coolant and fuel conditioning systems, directly implementing the actuators real-time control, or simply dispatching demand targets to external controllers. Every component of the test cell (e.g., the ventilating, fuel supply, fire extinguishing systems, etc.) can be directly controlled or remoted, and any type of test cell transducer can virtually be managed.

2. Acquisition and bench control software

The automation system consists of the dynamic bench control and the signals acquisition module. The signals are used both for the management of the bench (alarms, procedures, etc.) and for recording and monitoring. A National Instruments real-time controller manage the system and it guarantees the execution of calculations in a deterministic manner. It is based on a modular architecture to allow to add other hardware on request. The system specifications are:

Channel	Range	Quantity	Sample frequency
Analog Input	± 10V	16	100 kHz
Analog Input	± 20mA	8	100 kHz
PT100-1000	see pag. 2	16	25 Hz
TC-K-J-S-R-B-E-T-N	see pag. 2	16	25 Hz
Digital Out (Relè)	-	8	-
Analog Out	± 10V	16	25kHz
Digital Out (PWM)	0-5V	8	100 kHz
CAN	Up to 1000 Mbit/s	4	-
Ethernet	-	1	-
Video	-	4	-

Included in the supply:

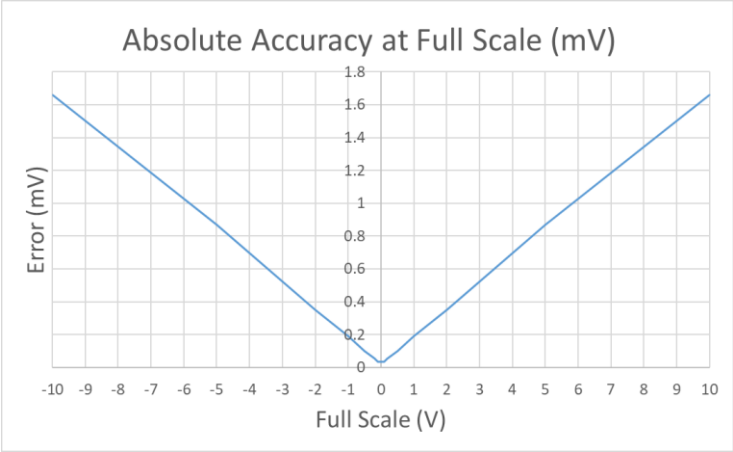
- A host PC with Windows 10 operating system, two monitors, mouse and keyboard.
- A bench control console for the manual management of the cell (two rotary encoders, push-button panel for quick commands, emergency button and visual alarm indicators)

The automation system has a calculation loop that works at the maximum frequency of 500 Hz:

- for each channel acquired it is possible to set the type and frequency of filtering via software without any modification to the system components. For example, it is possible to record an analog input sampled at 100 kHz, at a cut-off frequency of 10, 25, 50, 100, 500 Hz.
- Perform simulated cycles or preconfigured manoeuvres with a timestep up to 2ms (500 Hz).
- The maximum diagnosis delay of an alarm, for example vibrations on the electric machine or values indicating out of range, is 2ms.

The characteristics of the acquisition system are:

- Analog input in voltage: resolution 16bit maximum error 1.6mV at 10V, typical accuracy sees the following table:



- Thermocouple K:
  - Resolution 16bit minimum measurement step 0.02 ° C
  - Linearity ± 0.2% f.s. maximum error less than ± 3.1 ° C
  - Measurement range: -200 ° C + 1370 ° C

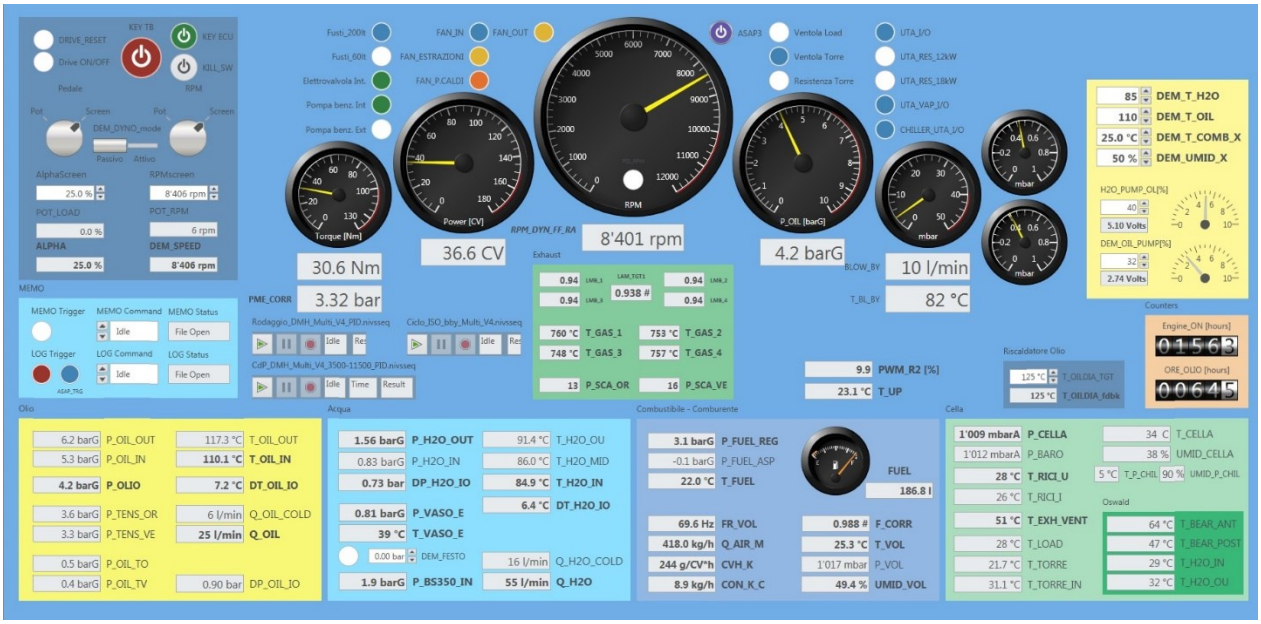
Type	Min	Max
J	-200°C	1200°C
K	-200°C	1370°C
S	-50°C	1760°C
R	-50°C	1760°C
B	400°C	1820°C
E	-200°C	1000°C
T	-200°C	400°C
N	-200°C	1300°C

- Thermo-resistance PT1000 with 2 or 3 wiring harness:
  - Resolution: 16bit minimum measurement step 0.006 ° C
  - Linearity ± 0.1% f.s. maximum error less than ± 0.4 ° C
  - Measurement range: ± 200 ° C

Input type	Min	Max
PT100	-200°C	850°C
PT1000	-200°C	200°C
NI100	-60°C	180°C
NI1000	-60°C	150°C

The control software is based on Veristand by National Instruments, which takes care of its maintenance and updating. The main features of the architecture developed are:

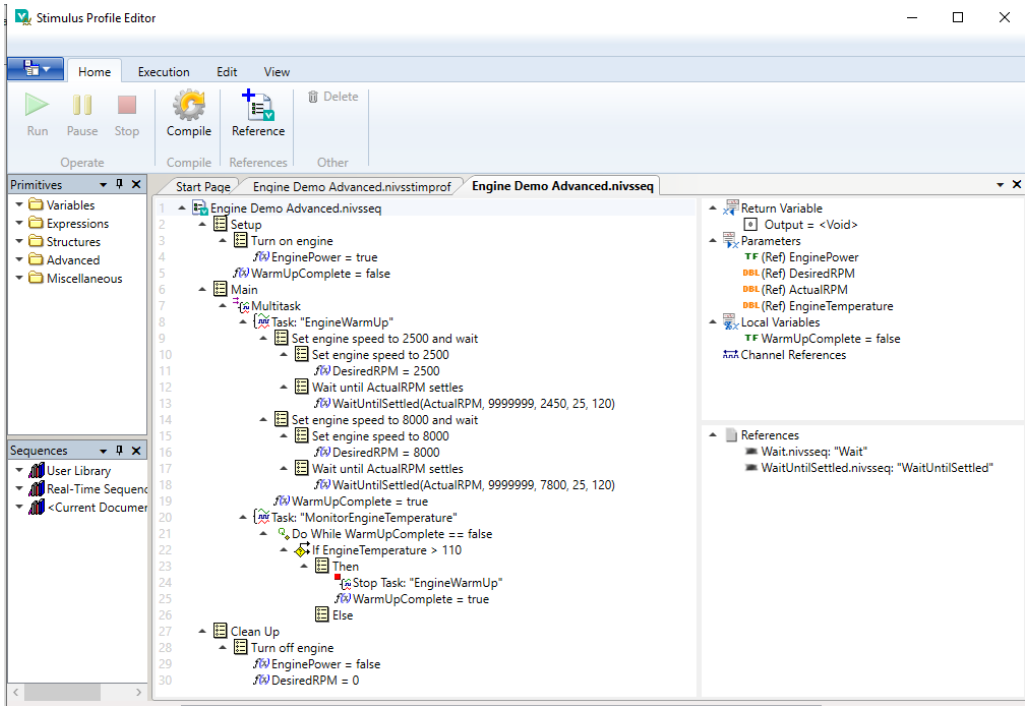
- Record the data during the test by selecting the cut-off frequencies of the individual channels as desired. The maximum acquisition frequency is the command loop one (500Hz). The others frequency can be a fraction and they can be configured by the customer. The analog inputs at 10 kHz and 100 kHz are processed to be available within the command loop (500 Hz). In this way the input can be filtered, recorded, used for calculated channels, etc. They can also be recorded in a dedicated high frequency at 5 and 50 kHz respectively.
- Record the averaged parameters (MEMO)
- Add, configure, and customize the control PIDs of the actuators.
- Create a customized user interface in terms of indicators and controls to be displayed on the screen. It is possible to create multiple pages with controls and indicators, multi-variable graphs, and custom alarm indicators. A zoom is available, the various interfaces can be saved and then loaded during the test start phase. An example of interface is shown in the following image:



Configurable user interface

- Create calculated channels using mathematical formulas recorded at the same frequency as the command loop.
- Monitor and alarm the cell control signals and react in the event of an emergency by stopping the test, securing the device under test and generating a file with a settable buffer before the alarm occurrence.
- Create customized alarm reaction procedures to be linked to specific alarms.
- Send, via CAN or ethernet, measurements, calculated channels and recording triggers to third-party systems such as, the indicating combustion analysis system. Among these, the torque values acquired by the torque meter, the motor rotation speed, any pressures or temperatures, etc.
- Perform standard tests in manual mode by the operator by acting on the console commands. Perform automatic and semi-automatic cycles based on csv or txt files. In this mode the system can starts the test autonomously and operate unattended.

- The automatic cycle can be programmed autonomously by the customer using a dedicated interface that involves the use of preconfigured blocks (ramps, if and while conditions, parallel executions, the possibility of uploading data via .csv, etc.). In this way it is possible to manage the engine warm up and any additional retro-activated circuits on bench measurements such as oil heating or air handling units.
- Interface the automation system with the ETAS INCA ECU management system, using the ASAP communication protocol via ethernet and read and write calibrations and measurements.



Automatic cycle configuration interface

The System provides an interface for third-party systems such as, for example, the combustion analysis system, the fuel consumption or blow by measurement system. The communication can be managed via analogue, digital signals, or communication protocols such as serial, can, ethernet, etc.

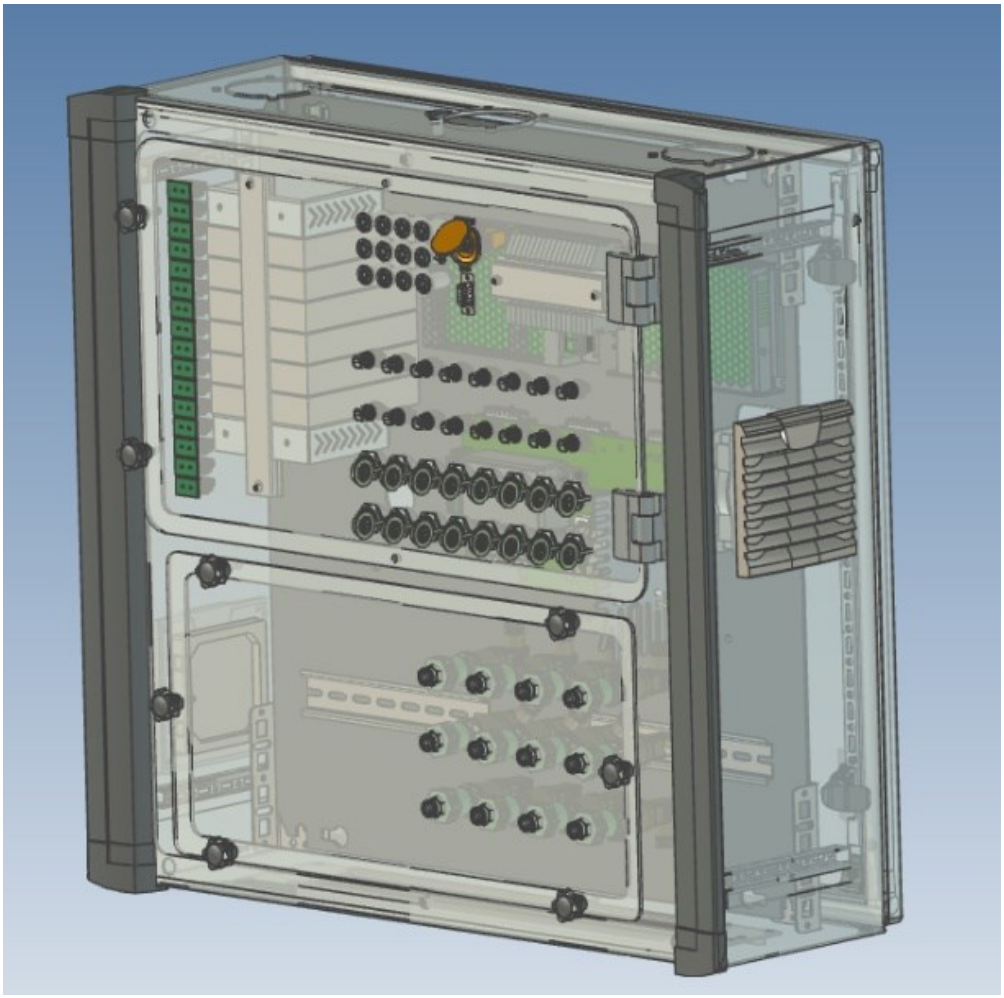
3. Acquisition box and swivel arm

The acquisition box, supplied by Rittal, contains all the connections between the automation system and the test bench. The dimensions are:

- width: 600mm
- height: 600mm
- depth: 210mm

The box is equipped with a customized front panel where the input and output sockets are available, and it is suspended by an adjustable arm made by Rittal.

The swivel arm has two joints of about 180° each and a swivel connection on the box to ensure correct positioning, it has a load capacity of 70 kg.



Acquisition box

Swivel arm

4. Command console

The control console can be realized on customer request in terms of controls, indicators, colours and shape. The standard proposal is equipped with the following interfaces (see figure "Control console"):

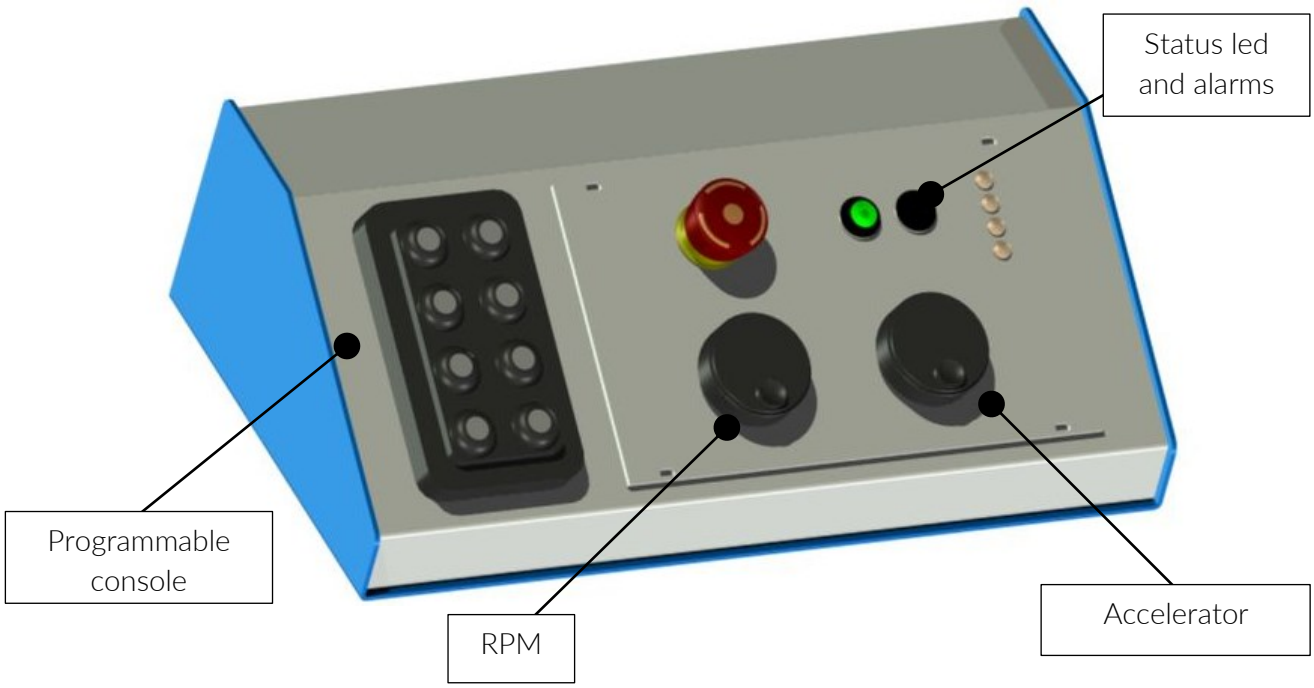
- Black mushroom pushbutton for hard stop cell
- Red mushroom pushbutton for cell soft stop
- Quadrature encoder for rpm control
- Quadrature encoder for load control or other physical or virtual actuator
- Programmable keypad for customized functions
- Status LED

The Console is delivered in configuration with a knob for adjusting the device under test rotational speed and one for adjusting a second actuator (for example, accelerator position actuator not subject to offer) or a virtual actuator (simulated accelerator 0 - 10V). For applications, it is possible to select other control modes associated with manual controls such as:

- N/T
- T/N
- N/x
- T/x

The control modes can be associated with the keys on the programmable keypad.
The knob is made by using a quadrature encoder to detect the rotation speed of the knob itself and thus change the setpoint dynamically depending on the rotation speed set by the operator.

Any changes or additions to the proposed button layout can be agreed in the design phase with the customer.



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