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VIRTUAL INSTRUMENT FOR SENSORS AND ACTUATORS FUNCTIONING MONITORING IMPROVING

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Abstract: *In the paper there is presented a method to improve some mechatronic systems performances testing, by developing and implementation of a flexible software interface, as virtual instrument for monitoring the testing results. This software proved to be very useful and user friendly, being designed to test ten types of sensors and actuators. Until present were tested five from the list of ten systems, getting conclusive and pertinent information on the tested systems performances. Based on these it was possible to establish very efficiently and proper which kind of sensors does correspond, must to be calibrated or should to be replaced. The big challenge in our research is to acquire and develop also necessary hardware interfaces, to improve the assisted systems performances monitoring, by auto data transferring from sensors/actuators to the computing systems. It will be considered also the software interface extension in order to enlarge the list of tested mechatronic systems.*
Keywords: *software, programming, sensors, actuators, auto-vehicle*

1. CONCEPT OF MECHATRONIC VEHICLE

Nowadays, the modern car means, first of all a complex mechatronic system, ensuring the engine functioning safety, meaning, first of all its functioning in closed loop. Other aspects regarding the car behavior improving in traffic means the pollution reduction, ensuring a high yield, active and passive safety, improving the navigation and diagnostic systems and not least the comfort in the passenger compartment [1], [2], [3], [4]. Related to this aspect, the most modern cars are also equipped with detection systems or video cameras to find if the driver is tired, or, for instance, if his eyes can no more to follow the state of the road very closely at the same time [5].
For this reason, to improve all aspects regarding the car functioning, the mechatronic systems play a crucial role, invoking several sub-systems. The first one is represented by the execution elements (mechanic or pneumatic actuators) adjusting for instance, the functioning parameters referred to the engine or ABS system. Other sub-systems refer to different sensors that measure the functioning parameters, very useful for a modern vehicle. Some example in this reason are the following: for monitoring of: oil or coolant temperature, air-carburant flow, air-carburant pressure, oil quality, wheels speed, throttle valve position etc. [6], [7] The sensors can function different principles, depending on their applications (e.g. magnetic principle, for rotation speed sensors, ultrasonic or optic (e.g. LASER principle [8]) for carburant or oil level measuring and monitoring. The most important component is the central unit, having as a key element one or more microcontrollers, who centralizes all signals providing from sensors, and also sends different signals and commands to the execution elements for closed loop adjustment of the functioning parameters regarding all automotive systems.
Referring to the sensors or actuators, they play a special role in the good functioning of all mechatronic systems, meaning that these must always function at their maximum capacity, in the best possible conditions. For this reason, a complete and proper evaluation of their functioning is indispensible. Due to the evaluation results, some important decisions can be made, for instance to continue their using, if the test was passed, the necessity of their re-calibration or re-adjusting or even their replacing if necessary [4], [6], [7].

2. EXPERIMENTAL EQUIPMENT

The research started from a didactic existing kit, containing 10 sensors and actuators, used in the modern vehicles. The list of them is presented in the table 1. The existing kit is associated to a laboratory didactic gauge, in order to show and explain the functioning and using mode for the sensors and actuators (figure 1). Actually it is used for the students in the 4th year of study, in Mechatronics specialization.

Table 1: List of sensors and actuators for modern auto-vehicles, contained in the existing didactic kit

System name	System type	Application
1. Manifold Pressure	Sensor	Air – carburant pressure
2. Zirconium Dioxide Lambda Probe	Sensor	Oxygen content of the exhaust gases
3. Titanium Dioxide Lambda Probe	Sensor	Oxygen content of the exhaust gases
4. Air flow Meter	Sensor	Air – carburant flow
5. DC Motor	Execution element	Automatic closing of devices (doors, windows, throttle)
6. Air Temperature	Sensor	Cooling agent or oil temperature
7. Idle Speed	Actuator	Crankshaft speed monitoring for idle mode
8. Oil Quality	Sensor	Quality evaluation for engine's lubrication oil
9. Coolant Temperature	Sensor	Cooling agent temperature measuring
10. Throttle Valve Potentiometer	Actuator	Throttle position monitoring

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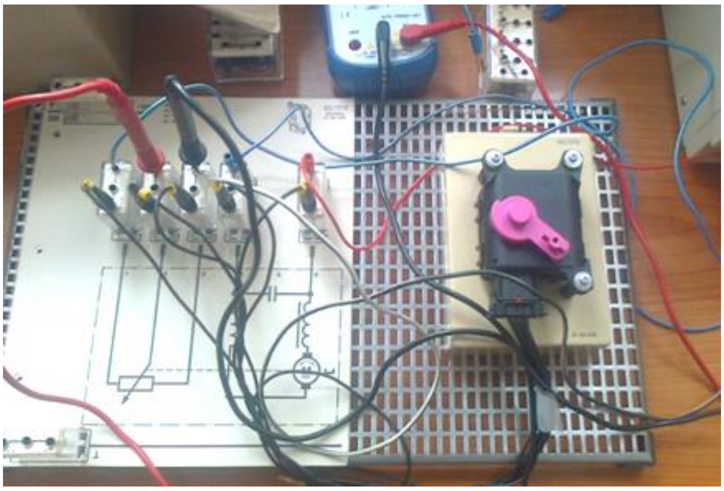

Figure 1: Assembly scheme for DC motor testing [7]

3. DEVELOPPED SOFTWARE INTERFACE SENSORS AND ACTUATORS FUNCTIONNING TESTING

3.1 The role of the software interface

Due to the major importance of this kind of elements in the modern car as mechatronic system, in the research it was proposed a solution to test the functioning characteristics of the sensors and actuators, starting to the main information on their using manual guide [7]. It was proposed a method to make use of a software interface (A.S.A.M.vi - Auto Sensors and Actuators Monitoring.vi), flexible one for testing all sensors and actuators contained in the didactic existing kit, with which, the use to be able to evaluate the performances in terms of functioning. Especially, it is about the output signal evolution, reported to an input signal, having as reference an output etalon signal, according to the manual guide [7].

The reason for which it was preferred Lab VIEW as programming environment was that this allows to create graphic interfaces, simulating the functioning of different kind of virtual instruments for verifying and testing. Besides, in Lab VIEW, it is possible to ensure the connection with a large range of gadgets and devices for an efficient evaluation in real time [9].

As a result, it was established that the main role of the software interface is to verify, selectively, the functioning parameters of the sensors and actuators, according to the etalon parameters of the systems functioning.

3.2 Software interface describing

The interface with the user does contain several input text boxes and test dialog (in red), through the user can establish the testing conditions and also can select from a list the sensor or actuator submitted to be evaluated. In the following there are described the role of these: The first one refer to the system choosing for testing (figure

3), being associated several text boxes to bring to the user the most important information about the selected system from the list. For this, when programming, several strings were defined, containing text according to each kind of system. A switch-case structure was used to relate each case of system selection to the text-dialog selector, accessed by the user.

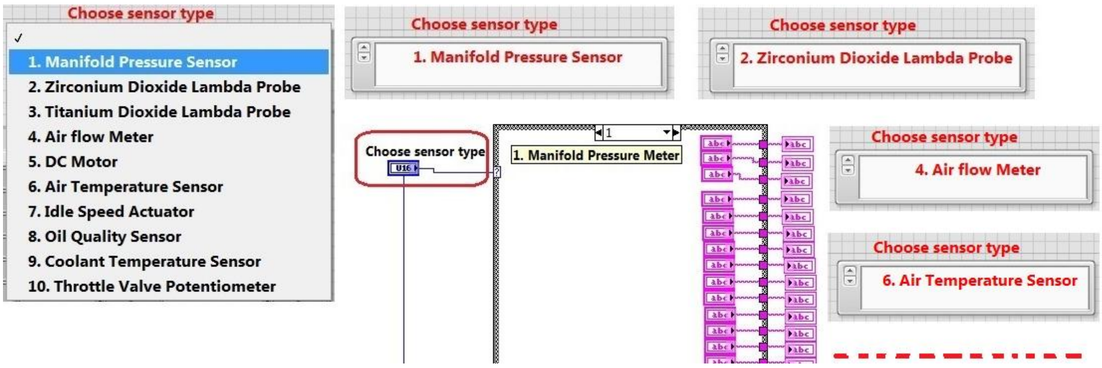

Figure 2: Selection from the list of the system to be evaluated

The other input dialog are referring to the dialog boxes for input data variables, that the user has to complete during evaluation, and software running (figure 3).

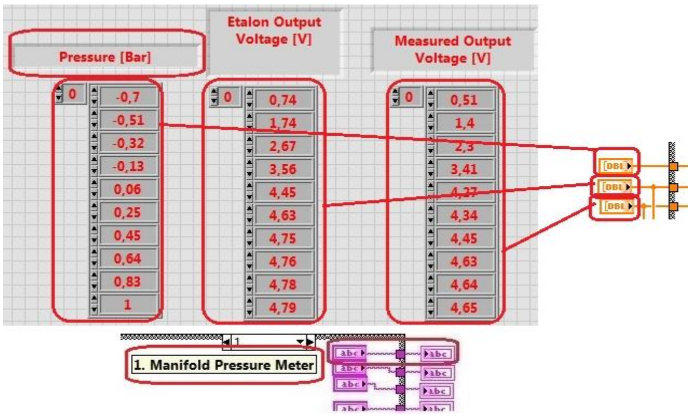

Figure 3: Dialog boxes for input data introducing

Associated to the three 1D defined arrays, three strings were defined for displaying the text boxes containing the information specific to the input data corresponding to each evaluated sensor or actuator. Besides, a switch-case structure, containing al necessary strings was used. The three 1D arrays refer to the input and output variables defining the sensor or actuator functioning behavior. For instance, in case of pressure sensor (figure 3), the input variables refer to the pressure values to which the sensor is tested and the output variables are refer to the output voltage signal as sensor response; one refer to the etalon output signal and the other refer to the measured output signal.

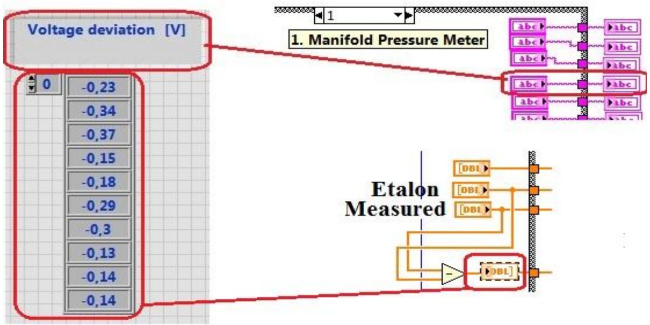

Figure 4: Output text box for results on sensor measuring displaying

Based on the input data related to the evaluated sensor, the output text dialog items are represented in blue, displaying the results on sensor measuring accuracy (figure 4). Inside the case-switch structure it was programmed the calculus algorithm for the values of deviation of the measured output signals reported to the etalon output signals. As in the case of input text dialog boxes, for the output text boxes there are several items to display the information on the results (type of signal, measuring unit etc.). This is possible due to other several strings defining. Besides, other output text boxes have the role to inform the user on the averaged and maximum values of the output signal deviation. The averaged and maximum values are expressed both in measuring units (volts, amperage etc.) and in percentage (figure 5). Similarly it was programmed the calculus algorithm for to determine this kind of values of deviation.

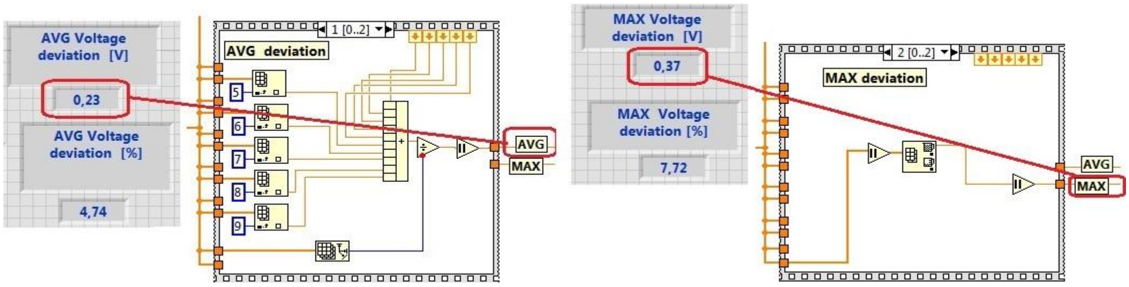

Figure 5: Output text-boxes for averaged and maximum values of the measuring deviations in case of each tested sensor or actuator

A sequence structure was used for calculus algorithm programming, having two sequences. The first one contains the sub-routine for average deviation determination and in the second sequence it was programmed the sub-routine for maximum value of deviation calculus.

The most conclusive clues for user informing about the results on system testing are refer to three LEDs of state, each one corresponding to one case (figure 6).

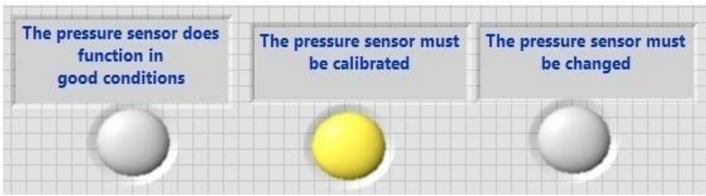

Figure 6: The three LEDs of states indicating the test results

The first case is where the system does not correspond and it must be changed. In this case the LED in red turns on (figure 7). The second case corresponds to the situation in which the system must be re-calibrated or more carefully verified, when the yellow LED turns on (figure 8). The last case is that when the tested sensor or actuator corresponds and the green LED turns on (figure 9). Obviously, the states of the three LEDs are strictly related to the results on signal deviation (as it was presented in the figures 4 and 5), this being concretized in programming a Boolean algorithm for addressing the three status LEDs (figures 7, 8 and 9). The algorithms refer to the following conditions: if the averaged and maximum output signal deviations are both less than a certain percentage (ensuring a good functioning for the sensor/actuator), then it corresponds and the green LED turns on. If the averaged deviation is greater than the percentage but the maximum value is under double of the imposed percentage, than the system must be recalibrated and the yellow LED will turn on. And, finally, if both the averaged and maximum output signal deviations are greater than double of the imposed percent, than the sensor/ actuator must be changed. In this case the red LED will turn on. In terms of programming for the described algorithms a Boolean Case structure was used, containing other two Boolean case sub-structures. Each one of them addresses each of the three state LEDs (true-false), through a Boolean condition (figures 7, 8 and 9).

The texts displaying referring to the verdict about the tested sensor are generated via several strings, associated to a switch – case programming structure, corresponding to each sensor/actuator.

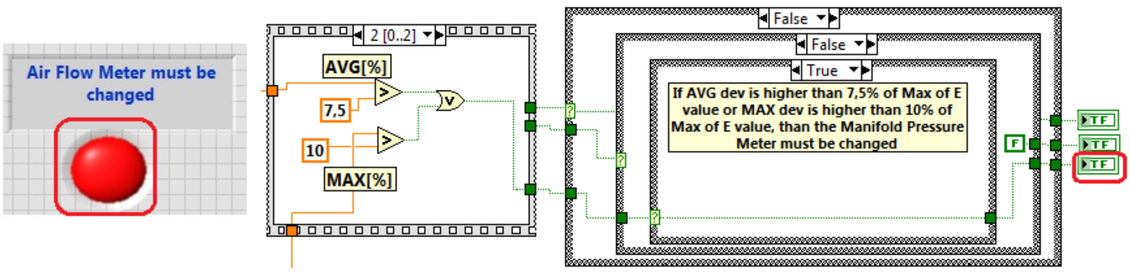

Figure 7: Programming sub-routine and red LED turning on in case of the tested sensor/actuator does not correspond

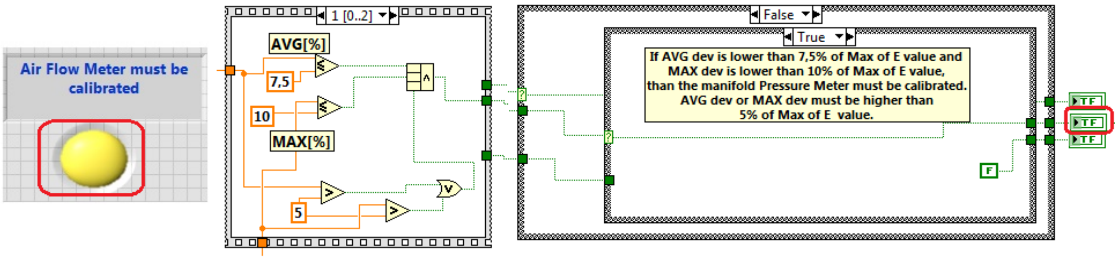

Figure 8: Programming sub-routine and yellow LED turning on in case of the tested sensor/actuator must be calibrated

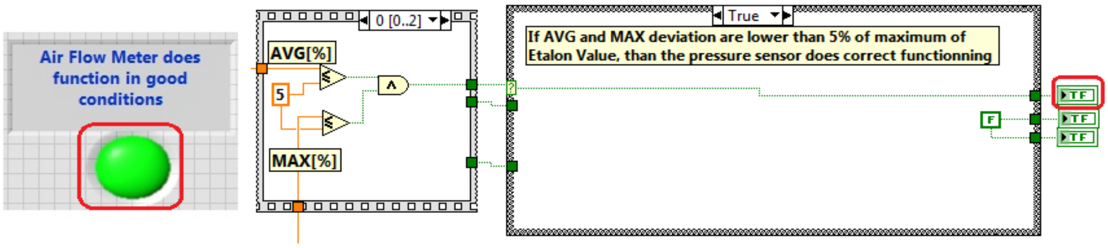

Figure 9: Programming sub-routine and green LED turning on in case of the tested sensor/actuator does correct function

Another indication referring to the results on the tested sensor/actuator refer to a graphical chart distribution of the output signal deviation, during the testing duration. It can be easily observed if the deviation distribution exceeds the yellow limits (meaning that the system must be calibrated) or even the red limits (meaning that the system must be replaced) (figure 10).

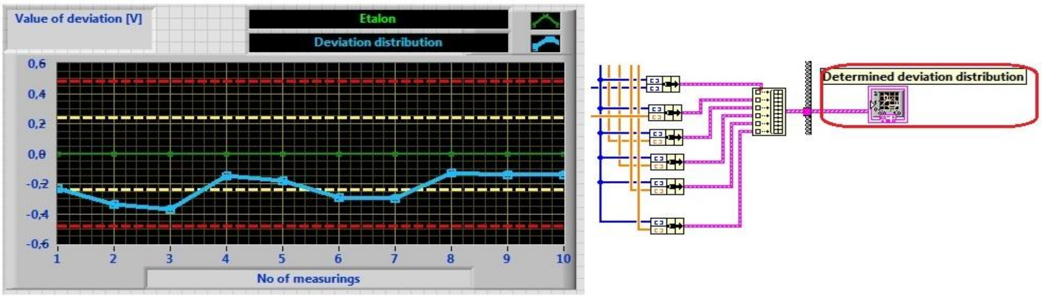

Figure 10: Example of graphical chart of output signal deviation distribution, invoking that the tested sensor must be re-calibrated

Another graphical chart present the distribution diagram of the measured output signal reported to the etalon output signal (figure 11).

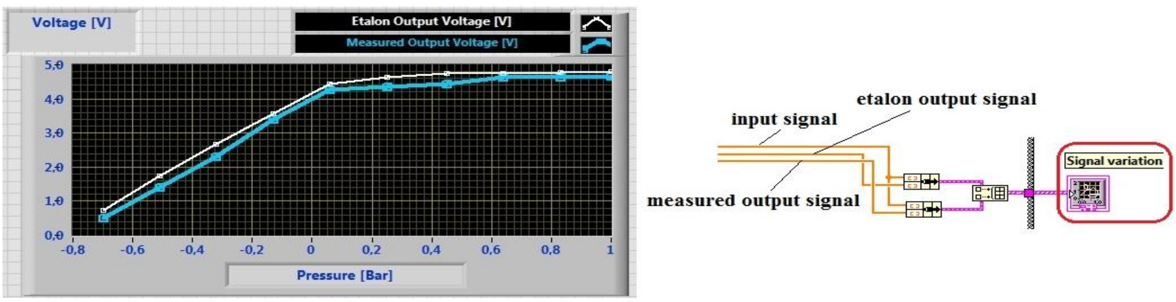

Figure 11: Example of graphical distribution diagram meaning the output measured signal reported to the etalon output signal in case of testing the pressure sensor

3.3 Software interface using

Assisted sensors and actuators using the software interface invoke the following steps that the user has to do, as is mentioned in table 2.

Table 2: Necessary steps when running software interface

Step specification	Significance
1. Choosing sensor / actuator type	- selection from the predefined list of the system submitted to be tested; - auto-displaying all information about the system to be evaluated (type of input and output signals, measuring units)
2. Filling the data in the first 1D array	- manually introducing of the data referring to the input signal values, according to the manual guide
3. Filling the data in the second 1D array	- manually introducing of the data referring to the etalon output signal values, according to the manual guide
4. Filling the data in the third 1D array	- manually introducing of the data referring to the measured output signal values, during or after measuring process
5. Software running	- auto-generation of all output results: - output signal deviations values; - averaged and maximum output signal deviations; - graphical displaying of the output signal deviations distribution diagram, reported to the imposed limits; - turning on of one of the three LEDs of state, indicating the verdict about the tested sensor.

4. RESULTS AND CONCLUSION

The assisted evaluation method for sensors and actuators functional parameters is in the process, until present being evaluated 5 of the 10 systems. The 5 tested sensors and actuators are the following: Manifold Pressure sensor, Zirconium dioxide Lambda probe, Titanium dioxide Lambda probe, Air Flow Meter and DC Motor. Due to the software interface, as virtual instrument for evaluation it was proved that two of the tested systems are corresponding (the Manifold Pressure sensor and the Air Flow meter), other two systems need adjusting and re-calibrations (Zirconium dioxide Lambda probe and DC motor), while a system does not correspond and it should be changed (Titanium dioxide Lambda probe). In the future it be considered to test the other sensors and actuators, using the virtual instrument, A.S.A.M.vi.
Actually, the created software can be used only in manual mode, meaning that the user must manually to introduce the measured output signal values, in the present there is no communication interface with a gadget or with a computing system (such of communication system did not exist in the sensors and actuators kit. For this reason, in our further researches we will consider to improve the assisted monitoring solution, through creating or acquiring one or two hardware interfaces, making possible the automated measuring and systems testing. Thus could be possible due to the possibility to transfer the data to the computing systems (desktops, laptops) or to the modern gadgets (smart phones, I phones, tablets etc.), directly from the monitored sensors or actuators.

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