Using Virtual Instruments to Design an Automotive Air Conditioning Simulation System for Fiat

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The Challenge: Providing Turin Centro Ricerche Fiat with a thermodynamic test bench to simulate an automotive air conditioner system in various climatic conditions and under different motor spin regimes.

The Solution: Developing an electronic control system using a hardware platform with AT-MIO and National Instruments SCXI for regulation and for data acquisition applications, as well as LabWindows/CVI software for logical control, measurement, and analysis tasks.

Multiple Engineering Features
At REM automazioni, we designed an automotive air conditioning simulation system for Fiat with features including:

- Independent control of nine PID loops such as dragging motors, pump and fan flow rates, heaters, and cooling valves
- Maximum flexibility in test-parameter setup
- Advanced data analysis with custom algorithms and a reference table to help engineer activities

Hardware with Three Functional Blocks
To reproduce real “on car” operating conditions for air conditioner systems, we developed hardware consisting of three functional blocks:

- Water condenser – a variable-flow, cold-water circuit simulates the car radiator
- Evaporator – an SSR-controlled boiler reproduces a thermal load into the car cockpit
- Refrigerator circuit – A 30 KW AC-3 servo motor with a frequency inverter drags an automotive compressor with a magnetic clutch

The compressor ranges from 0 to 6,000 rpm with high acceleration dynamics. A stepper motor driven valve regulates the freon flow rate. We achieve thermal exchange between different stages using brazed plates heat exchanger water-glicole solution rather than R134a freon gas.

We provide any circuit components through electrical transduced probes to obtain full control of any parameter needed to regulate loops and system mathematical characterization.

We based our hardware control system on an AT-MIO board with a SCXI-1000 chassis equipped to manage 32 analog inputs, including temperature, magnetic and Coriolis flow meters, pressure transmitters, torque meters, and angular speed of compressor dragging motors.

We use multiloop regulation tasks based on SCXI-1124 boards with six analog outputs to control an SSR power modulation of water heaters, a three-way motorised cooling valve, motor inverters for compressor-dragging, and condenser and refrigerator circuit pumps.

Using LabWindows/CVI, we can reuse C code and drastically reduce software development time so the Centro Ricerche Fiat programming staff can concentrate on bench-control features.

We completely submit test bench digital controls, including manual commands, actuators, and lamps, to the SCXI system using the SCXI-1162 and SCXI-1163 optically isolated digital input modules. We implement safety controls using electromechanical circuits and dynamic oversight of software and hardware systems that includes a watchdog tool with automatic power-off command in case of fault. Using National Instruments products in this system design, we eliminated the need for PLCs.

Centro Ricerche Fiat engineers rely on accurate temperature measurements to deliver quality test results, which in turn depend heavily on complex calculations closely related to acquired signals. Therefore, we selected National Instruments SCXI as our high-performance signal conditioning platform because each analog input channel has its own instrumentation amplifier, a 2 Hz lowpass filter, and a precision cold-junction compensation sensor.

A Variety of Software
We designed the system software to execute a preliminary stabilizing step of thermal circuits followed by simulated motor speed cycle during the car run phase. During the test phase, the software plots all data on trend and XY graphs and saves it to external database files.

The first step uses closed-loop selection for any stage and relevant set-point setting. On the whole, the system uses nine control strategies, returning to five simultaneously operating PID loops. Because of the system complexity, we concentrated on software development to ensure Centro Ricerche Fiat engineers would have freedom in bench setup and use. We can achieve this goal much easier with the powerful help of a standard C environment and CVI-specific tools included in the PID Toolkit.
Customer Solutions

We based the simulation phase on a compressor motor speed variation during an adjustable time cycle. During the cycle, the system maintains constant operating conditions for the circuits. The exact reproduction of the motor speed profile compels high-precision control of program execution time. We can do this using a multithreaded structure with different scan times for elaboration charge and task priority.

In the next step for this application, we convert PC/SCXI-based hardware architecture using a PXI 1011 chassis. With this upgrade, we can maintain SCXI signal conditioning modules using a PXI 8176-RT real-time embedded controller as an automotive CAN bus interface module.

User Interface with Supervisor Controls

We developed the user interface main panel with supervisor controls, including analog measurement, PID loop state, and compressor motor speed. A text message panel shows any system event and signals alarms and anomalies by underlining the text in red.

The bench engineer can use three independent strip chart panels to switch on or off any analog measurement curves. This function proved a very useful tool for analyzing physical transient phenomena during testing.

We designed the comments recorder for Centro Ricerche Fiat engineers to use as a specific text input panel to write free messages or observations into a test report file. Our comments recorder makes it easy to locate specific events during offline data analysis.

We completed the user interface with a series of service panels such as I/O configuration panels, advanced hardware diagnostic panels, and alarms and log file management panels.

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