MIRACLE²

Micro Rapid Controller & Logging Environment

Alma Automotive

MIRACLE² is an extremely compact and fully featured programmable platform suitable for Rapid Control Prototyping and smart data acquisition. Designed to fulfil the tasks that are usually required in automotive and motorsport applications, with a form factor ideal for on-board installation, MIRACLE² is the best solution for Real-Time acquisition, processing and control prototyping.

Distinctive features at a glance

- Powered by National Instruments SOM (Xilinx Zynq™, with Dual Core ARM® processor, Artix-7 FPGA on top and 512 MB RAM)
- Programmable with the typical **NI LabVIEW toolchain**
- Scalable software, easy to use (focus on applications) and **open to other software toolchains**
- **Sample source code provided**, showing the use of all peripherals
- **Compatible with MATLAB®, Simulink®, Stateflow®** model execution, allowing the re-use of already available software not implemented in LabVIEW, for model based applications
- High-level interface, low-level actions
- Standard communication protocols implemented (CAN, Ethernet, RS232, CCP, XCP)

One size fits all

MIRACLE^2 represents Alma Automotive's answer to daily customers' needs, who want to get their application up and running in a short time scale. MIRACLE^2 is a fully featured prototyping system, powerful and compact, easy-to-program, flexible and **customizable on demand**. Essentially, MIRACLE^2's flexibility reflects the made-to-measure service offered by Alma Automotive. Thanks to the insightful experience we have matured over the years, we can help clients to develop and implement their applications.

Ready-to-use products

- OBI-M2 (combustion analysis system)
- microHIL
- Basic data logger

Potential applications

- ECU by-pass via CAN
- Smart Data Logger
- Multi-accelerometer platform (up to 8 triaxial accelerometers, signal processing and merging with IMU and GPS information)
- WiFi telemetry
- Process automation controller
- Smart video acquisition and processing via USB

Customer-tailored systems

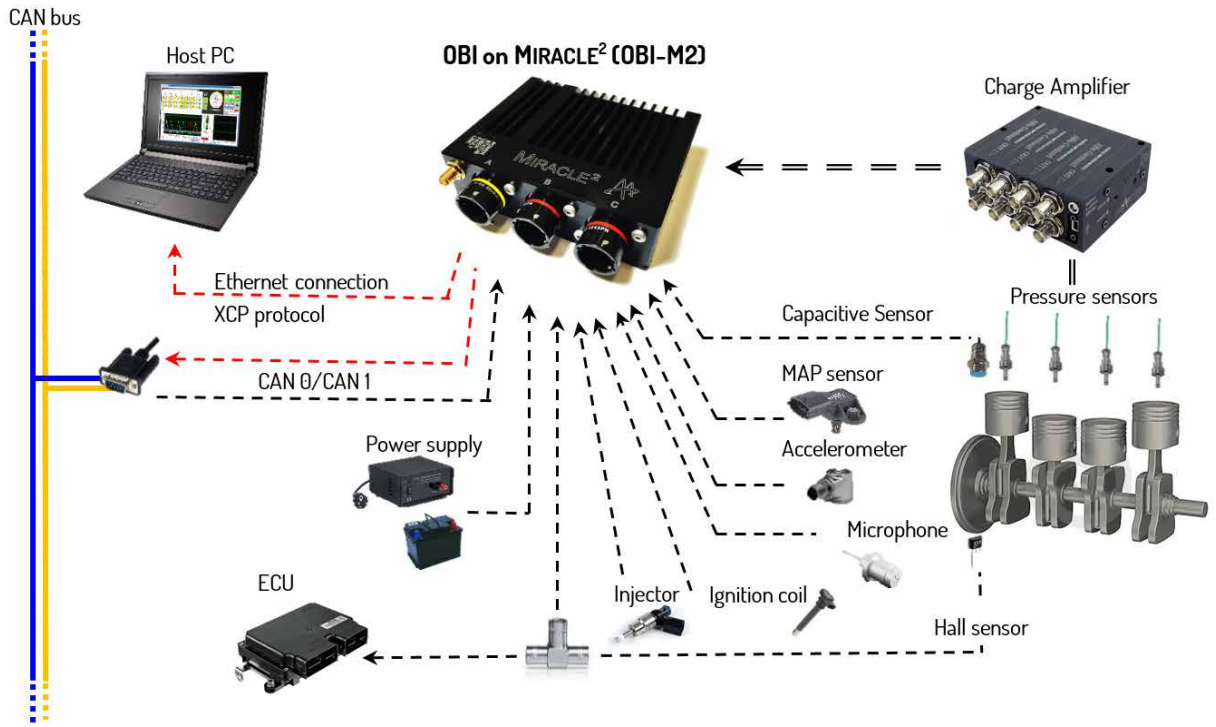
RCP systems already developed for various engine development applications

OBI-M2 is Alma Automotive's combustion analysis system implemented on MIRACLE². Thanks to its rugged and compact package OBI-M2 is the best solution for combustion analysis in vehicles and motorbikes, ideal for on-board engine calibration and control from passenger cars to racing applications.

System components

Overview of the complete combustion analysis system:

1. Cylinder pressure sensors
2. Miniature charge amplifier **Alfa Centauri** (by Alma Automotive)
3. Engine position sensor connector
4. Power supply 6-26 VDC
5. Host PC for run time visualization and data acquisition (standalone operation without PC is also possible)



Layout of the system components with connection to the application engineer's PC

Why National Instruments and LabVIEW?

NI reconfigurable I/O (RIO) technology gives you the ability to define your own custom measurement hardware circuitry using reconfigurable FPGA chips and LabVIEW graphical development tools. The RIO core includes an FPGA chip and surrounding circuitry that enable LabVIEW to perform hardware synthesis.

The combination of NI LabVIEW FPGA module and NI LabVIEW Real-Time module is a complete solution for creating reliable, stand-alone embedded systems with a graphical programming approach.

Top 10 reasons to use NI LabVIEW for Designing Embedded Systems

What is an FPGA?

FPGA (Field-programmable gate array) is a reprogrammable silicon chip that has the same flexibility as software running on a processor-based system, with the difference of not being limited by the number of processing cores available.

Unlike processors, FPGAs are truly parallel in nature, so each independent processing task is assigned to a dedicated section of the chip, and can function autonomously without any influence from other logic blocks.

FPGA gives you the enormous flexibility of designing custom functionalities, by implementing the application logic in hardware circuits rather than executing on top of an OS, drivers and application software.

In order to configure your FPGA you don't need to know any hardware description language (HDL), because LabVIEW translates your easy-to-write graphical code into the complex VHDL code.

The LabVIEW programming environment is distinctly suited for FPGA programming because it clearly represents parallelism and data flow, so even if you are inexperienced in traditional FPGA design processes, you can leverage FPGA technology.

In addition, you can use LabVIEW to integrate existing VHDL into your LabVIEW FPGA designs.

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POWERED BY NATIONAL INSTRUMENTS LabVIEW™

Technical data	
Dimensions	105x85x30mm
Weight	400 g
Temperature range	-40°C +85°C
Power supply	6-26 VDC
Power consumption	6 W typ.
Vibration	20-2500Hz 10g sine sweep - 20-2500Hz 6g random profile

Hardware	
Real time processor	667 MHz Dual-Core ARM Cortex A9
FPGA	Artix-7
Storage	512 MB Onboard + 32 GB Flash
RAM	512 MB

I/O Capabilities	
Analog Input	24 channels (2 high voltage channels ±40V), 16bit, ±10V differential input range, up to 400ksps, simultaneous sampling, with antialiasing filter (100kHz) ±0.1% accuracy
Analog Output	16 channels, 16bit, ±10V output range, up to 100ksps, calibrated to ±0.1% accuracy
Digital Input (accept up to 25 V)	8 @ 5V, 500 kHz
Digital Input (protected up to 12 V)	8 @ 5V, 10MHz
Digital Output (protected up to 25 V)	16 @ 5V, 10MHz

Connectivity
Gigabit Ethernet, WiFi 150N, 2 x Can (1 Mbit/s), RS232, USB, Optional GPS, Motorsport High Density Connectors

Auxiliary sensors
Accelerometer, Magnetometer, Gyroscope (9 axis total)

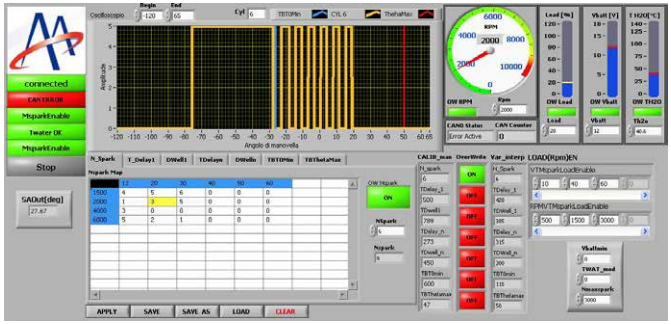
Software

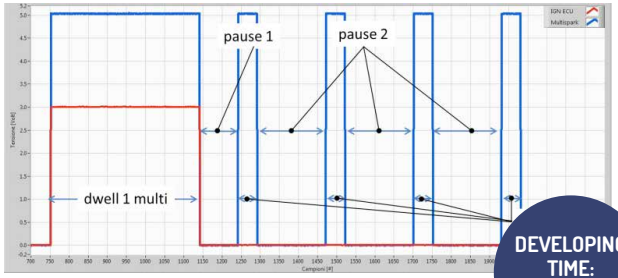
A simple “Demo project” showing the use of all peripherals is provided as a royalty free fully open LabVIEW project. In the next pages, a few examples of applications developed for our clients are shown in the form of case studies.

For pricing, demo versions and further information, please contact us.

CASE STUDY

Multi-Spark ignition system for fuel consumption and exhaust emissions reduction in a high performance GDI engine





DEVELOPING TIME: 3 WEEKS

THE CHALLENGE

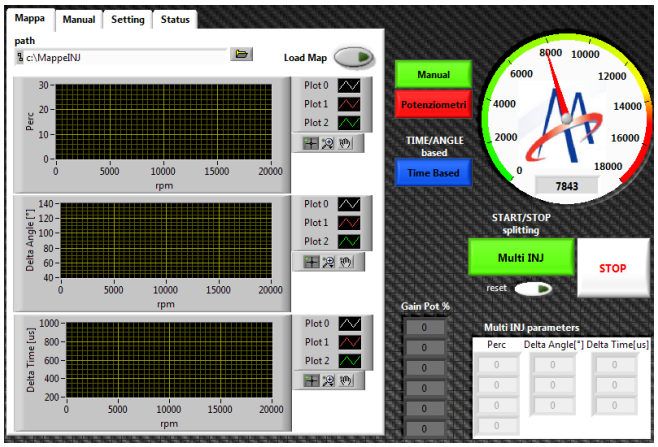
Developing a combustion control system based on optimal management of multiple spark discharge events, in order to increase combustion stability, reduce pollutant emissions and fuel consumption, and avoid partial or missing combustion cycles.
Our client's request was a cost-effective solution to several combustion-related issues that affect Gasoline Direct Injection (GDI) engines during cold start and part load operation. The problem of optimizing combustion efficiency and improving its stability during such operating modes is even more critical for high performance engines, which are designed to maximize charge efficiency especially at medium-high engine speeds.

THE SOLUTION

Using the original ECU to control all the actuation parameters including spark advance, and MIRACLE to realize the multicharge/discharge coil current pattern. The Rapid Control Prototyping system has been designed to guarantee flexibility, accuracy and easy access: it has been equipped with an easy-to-use interface, enabling the user to change crucial control parameters in real-time, such as the number of subsequent charge-discharge pulses, the dwell time of each coil charging event, and the intervals between consecutive sparks.

CASE STUDY

Splitting of standard ECU single-injection into a multi-injection pattern with the same total injection time



DEVELOPING TIME: 2 WEEKS

THE CHALLENGE

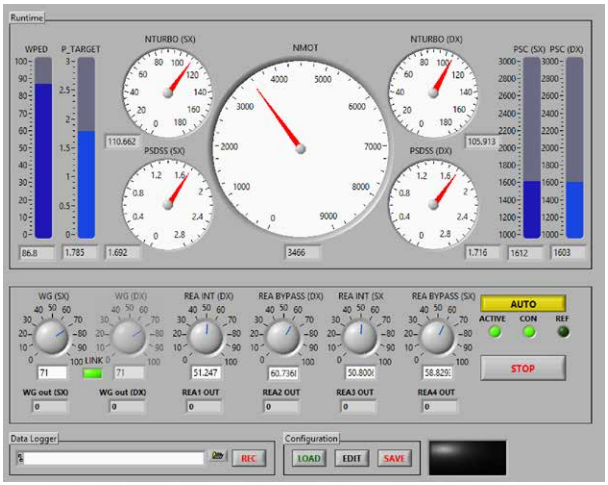
Developing a Rapid Control Prototyping system able to turn a single-injection logic command into a multi-injection pattern, while maintaining the same total injection time. In particular, the task was to generate up to four injections, with the possibility of adjusting duration and dwell times, by means of engine look-up tables spanned by engine speed or by manually changing the values through a set of potentiometers.

THE SOLUTION

Using MIRACLE to develop a system that acquires the standard ECU single-injection command and generates the multi-injection in the very same engine cycle, according to the multi-injection pattern defined by the user or automatically calculated from the engine map. In order to enable the manual control to be performed, the system acquires six analog inputs from the potentiometers and processes them to change the multi-injection parameters.

CASE STUDY

Multi turbo/electric turbo management



DEVELOPING TIME: 4 WEEKS

THE CHALLENGE

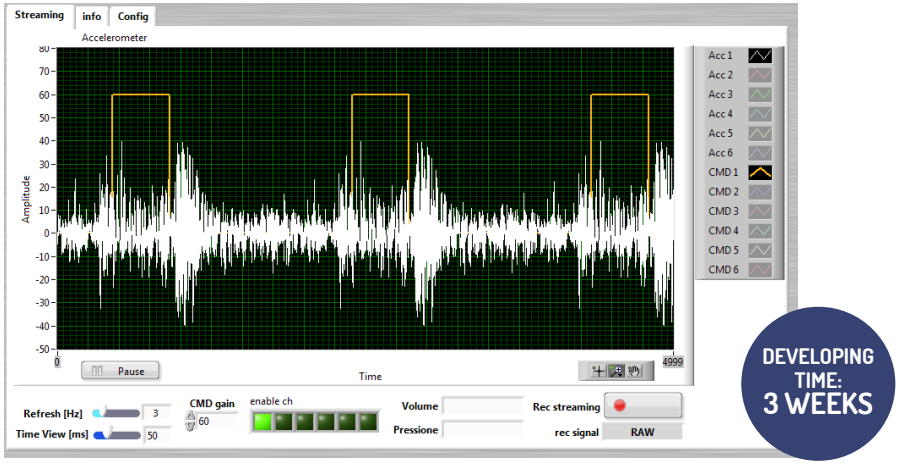
Evaluating of potential transient and static performance improvement for turbo engines in the lower rpm range of the power envelope, by using an electric compressor. Essentially the objective is to interface with the existing ECU in order to obtain certain information, such as the target boost value, and to drive the electric compressor and the bypass valves accordingly to the driver torque demand. In order to set this up and test it at the bench in the quickest way, the system has to be able to easily adapt the control laws to accommodate different electric compressors and turbocompressors, while evaluating different engine layouts.

THE SOLUTION

We chose to implement the controller on our MIRACLE platform, which allowed an easy interface with all sensors and devices required thanks to its extensive I/O. We used the CAN bus to communicate with the ECU and the electric compressor, whereas the fast digital I/O to control the bypass valves in closed loop. The user interface, which runs on a standard PC or Laptop, is easy to use and allows for monitoring and configuring of the real-time model running on MIRACLE. The connection to the RT controller is made via a fast Ethernet connection.

CASE STUDY

Accelerometer-based monitoring and diagnosis of Injector status



THE CHALLENGE

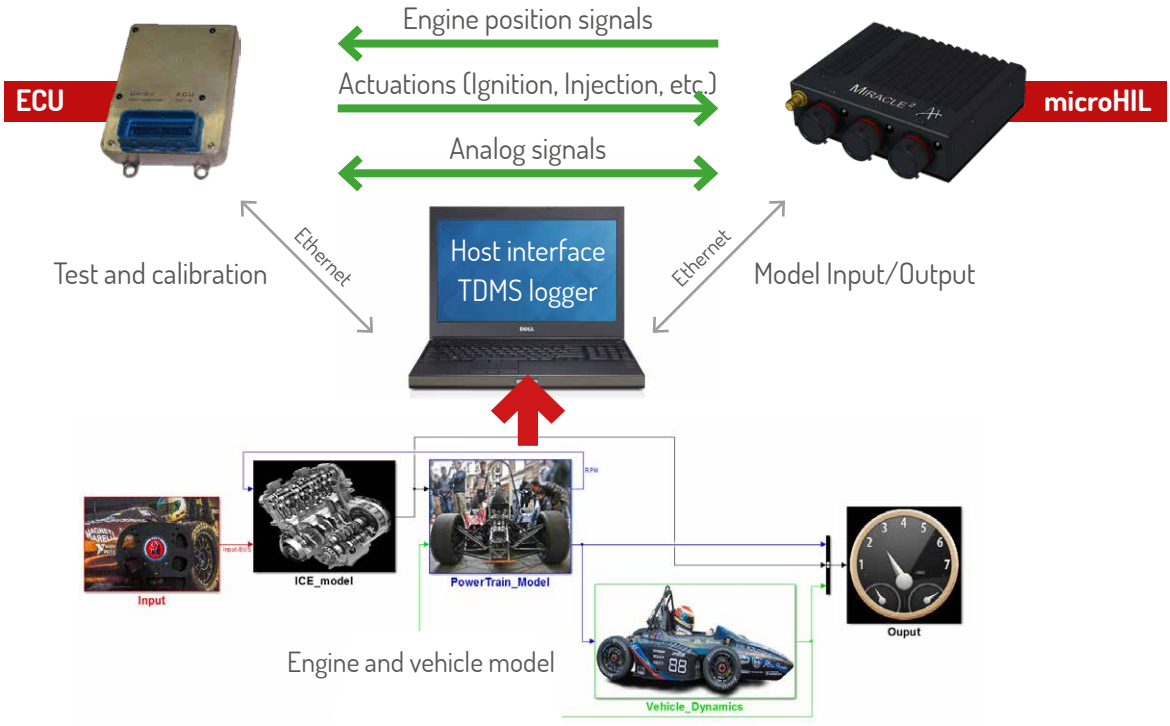
Developing a Rapid Control Prototyping system that acquires the signal coming from an accelerometer installed on the injector, relates the signal to the injection command and evaluates whether the signal is compliant with the proper functioning of the injector, publishing analysis results via CAN.

THE SOLUTION

Developing a system that identifies the injection command and relates it to the cycle-by-cycle acquisition of the accelerometer signal, which is also digitally filtered. Thanks to the fast analog and digital inputs, the CAN communication and the FPGA embedded in MIRACLE, it has been possible to meet the requirements. The system monitors if the injector is working properly, and publishes results on CAN every single engine cycle. The user can monitor and record the signals acquired through a web interface.

CASE STUDY

MicroHIL for development and testing of ECUs



THE CHALLENGE

Developing a small and flexible hardware-in-the-loop (HIL) test system, for real-time engine and vehicle simulation to reduce the amount of physical testing required during the ECU development and validation process.

THE SOLUTION

Thanks to the extensive connectivity, the FPGA for low-level and high-speed signal processing and generation, and the Real-Time processor for high-level control algorithms, MIRACLE has been chosen as the perfect hardware to meet the challenge. Moreover, the system communicates via Ethernet with the host machine, where the engine and vehicle models run on Simulink®.

Originally established as a spin-off of University of Bologna, Alma Automotive represents the synergy between knowledge acquired in academic research activities and years of experience in developing applied solutions. The company has now evolved to offer both ready-to-use products and engineering services supported by bespoke hardware and software solutions.
Highly oriented towards new challenges, Alma Automotive's mission is to provide innovative solutions and tools to help customers in the development of ever more efficient engines and powertrains.
Our partnership with National Instruments and the strong relationship we have with top-tier automotive companies is testimonial to the high level of skill and quality of services offered to our clients.

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