Whitepaper

LabVIEW Embedded Applications in Action!

The possible applications of LabVIEW on embedded hardware are just as diverse as the general application flexibility of LabVIEW itself. They range from stationary applications to mobile handheld measuring devices. From condition monitoring and predictive maintenance to energy generation and transmission to mobility and transportation. The following features characterize these products in comparison to LabVIEW laboratory use:

1. The applications require a well thought-out software architecture
2. They are real-time capable and the measured data acquisition is scaled up to MHz
3. They must function reliably in 24/7 continuous operation
4. Some applications run on battery power

In this league, requirements and software engineering, efficient hardware abstraction and a scalable software architectures are just as important as in traditional embedded systems. There are many advantages to thinking in resource-saving "C" during graphical coding in LabVIEW. This means avoiding dynamic memory, fat data types, paying attention to memory leaks and consistently recognizing and correcting failures.

This whitepaper tells the story of exceptional LabVIEW Embedded applications from Schmid Elektro-nik's practical experience. In its first large scale LabVIEW project, Schmid digitized traditional rail-way technology with state-of-the-art laser measuring devices, laying the foundation for condition monitoring and predictive maintenance. The result: a modular and field-tested embedded hardware and software toolbox. Years later, this turned out to be the key to a major project for an energy giant in the Norwegian deep sea, which resulted in the birth of LabVIEW Embedded and the Zbrain-Platform. This innovative technology mix, together with IoT know-how gained in the railway sector, finally opened the door to a major project for the same company again: a telemetry system for the eco-race track and data strategies as a tangible step towards a sustainable energy and mobility future.

For some sensitive areas, the use of LabVIEW in series products is too complicated or even out of bounds, as there are no standards and guidelines for graphical languages and the software code cannot be certified. Here, LabVIEW is mostly used in research, proof-of-concepts, MVPs, prototyping or measurement and test systems.

Contents

1 Condition Monitoring

1.1. Extreme situation requires pipeline monitoring 1000m below sea level

It’s the year 2006. The Norwegian technology company entrusted with a pipeline monitoring project in der Ormen Lange, Naxys, is facing massive challenges: Developing a measuring network 1,000 meters below sea level, acoustically synchronizing six measuring nodes in milliseconds and six months of continuous operation – to be developed in just seven months!

The choice thus falls on the still young technology "LabVIEW Embedded" and Naxys contacts Schmid Elektronik. Firstly because Schmid owns a modular hardware toolbox, field-tested in rail measuring devices for the harsh railway sector. Secondly, Schmid has just proven the concept of LabVIEW Embedded for this railway sector and is planning to implement it. Schmid and Naxys are working together on the pipeline measurement network. A video and a white paper offer interested readers a deep dive into the project implementation. In any case, the monitoring system is delivered on time and the project is successfully completed.

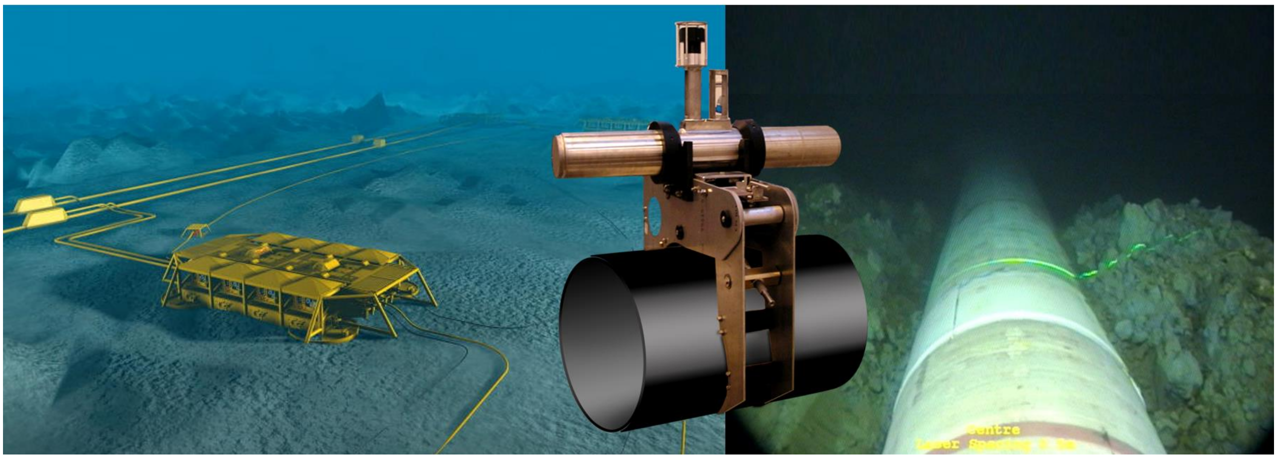

Fig. 1 | Graphically programmed, time-synchronised vibration measurement:
half a year on the battery and in continuous operation - at a depth of 1000m!

The success in the Norwegian deep sea attracts media attention and the joint paper from Naxys and Schmid receives the Best Paper Award at the VIPDays 2007 in Fürstenfeldbruck, Germany. It also rewards Schmid Elektronik with the NI partnership (now part of EMERSON) and connects them with NI's R&D team in Austin, Texas/USA. Concerns about the reliability of graphical programming with LabVIEW on embedded hardware are put to rest with this project and sparks a product idea: the Zbrain platform! This is still used today by numerous Schmid customers as a design and development accelerator. LabVIEW Embedded as the enabler of the platform later scaled from the C generator to Linux, multicore microcontrollers and FPGA.

What we didn't realize at the time was that 10 years later, it would be precisely this very Zbrain platform to open the door to another major project for the same corporate: a racing IoT system for Shell Eco-marathon... It will be a similar "Mission Impossible", which will be successfully completed thanks to the Zbrain platform. This again will lead to another reward: Schmid Elektronik to join the ranks of Shell Eco-marathon partners. But that's a different story.

1.2. Condition monitoring in power plants

An innovative Swiss pioneer demonstrated how "LabVIEW Embedded" can unleash creativity and productivity, act as a development accelerator and provide a global competitive edge for a small and medium sized business. In only two years, a product family with several stationary and portable, production-ready transient recorders for partial discharges in power plants was developed.

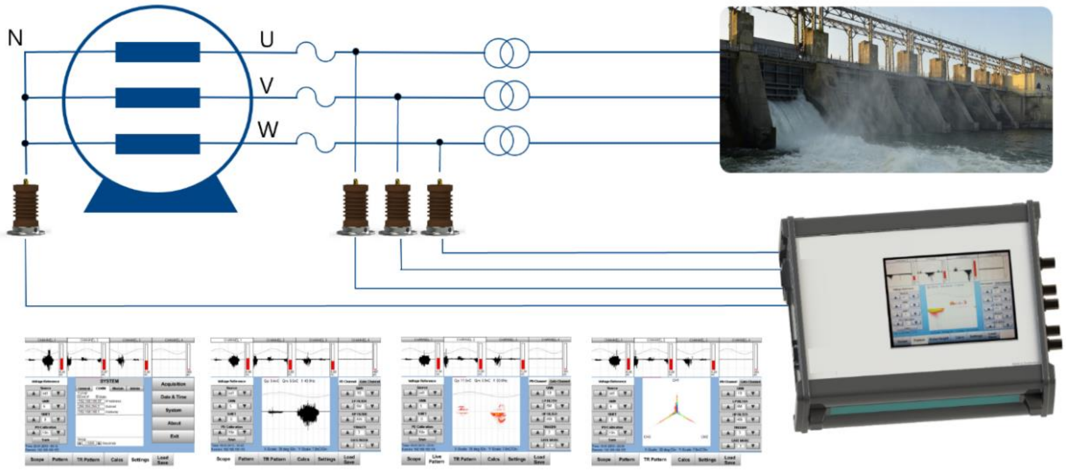

Fig. 2 | Meaningful status information of a power plant thanks to high availability in robust 27/7 operation.

Simultaneous measured value acquisition with 6x 64kHz, continuous transient analysis of 384,000 values per second, simultaneous TCP/IP communication and a comprehensive GUI on a 5.7" multi-touch display showed that graphically programmable microcontrollers can produce mature applications for condition monitoring.

1.3. Monitoring critical building infrastructure

Vibrations generated on Singapore's construction sites can have damaging effects on surrounding buildings, structures and vibration-sensitive equipment. These include hospitals, medical laboratories and semiconductor manufacturing facilities that house sensitive equipment such as electron microscopes, MRI scanners, surgical microscopes and laser profilometers.

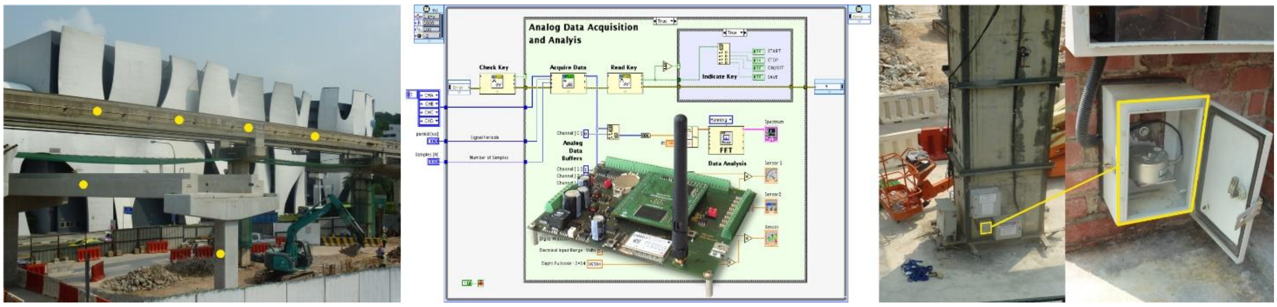

Fig. 3 | Detecting and analysing sensitive micro vibrations and reporting damage via SMS. One week on the battery.

The requirement: detecting and analyzing vibrations with extremely low amplitude well below an intensity that can be felt by humans. The micro-vibration monitoring system developed for this purpose prevents potential damage caused by the vibrations, such as equipment malfunctions and image errors. The monitoring system offers systematic data recording as well as an alarm for immediate and corrective damage limitation. In an emergency, a warning message is sent via SMS to the operator.

2 Safe, Comfortable and Punctual Rail Travel

This large scale project is about digital quality assurance in public rail transportation and how LabVIEW on embedded hardware contributed to the three key metrics: punctuality, comfort and safety. The underlying contact between wheel and rail is a tough steel-to-steel connection. As soon as a new track is installed and the first train has passed over it, rails, turnouts and wheels are subject to continuous wear. We experience this at first hand in everyday life, for example when a train pulls into the station with a loud squeal and the wheels and rails wear down audibly. At some point, they are worn down to the permissible limits and have to be replaced. This replacement is expensive, disrupts rail traffic and is therefore delayed as long as possible. To ensure the safety of passengers at all times, the infrastructure is regularly monitored and maintained.

Fig. 4 | Safety, punctuality and comfort in trams, metros, mainline railways and freight transport require condition monitoring and predictive maintenance.

A mathematical theory and physical models for the evaluation and maintenance of turnouts exists since 1970. The resulting general and specific standards describe recipes and gauges on how this wearing infrastructure must be measured and maintained with welding and grinding. This ensures that train passengers get from A to B safely, punctually and comfortably at all times. Country-specific standards are based on

- geometric target profiles for rails, turnouts and wheels.
- described failure mechanisms and tolerance limits, such as the maximum permissible horizontal wear 14 mm below the top edge of a rail head.

For a long time, such values were measured using error-prone mechanical gauges. These were placed on the rail, simulating a wheel to rail contact and providing the key figures via engraved notches. Profiles were measured with mechanical probes that move over the rail.

The millennium change was to change this old tradition and usher in a new digital age...Around this time, a Swiss pioneer from the traditional inspection and maintenance sector of tram networks, subway railways and local railways has a vision:

to create the digital twin of rail profiles using contactless high precision lasers, calculate the degree of wear from the data and use this to gain knowledge for maintenance. This pioneer is looking for a technology partner to turn his vision into field-ready devices: Schmid Elektronik. The next two sections show what has become of this vision and the role LabVIEW and the Zbrain platform played in it. This story on ni.com takes a closer look at the technical details.

2.1. Digital condition monitoring of railway tracks and turnouts

Soon after the start of the project, it becomes apparent that several mobile and stationary devices will be created in the years to come and that different I/O will be required. Schmid Elektronik is therefore planning a modular embedded hardware and software toolbox in parallel to the rail measuring devices; from analog precision inputs for the laser modules to servo drives in linear axes. These functional modules are continuously tested in the harsh environment of rail maintenance and the findings are fed back to the development team. The heart and brain of this hardware is a digital signal processor from Analog Devices, which is initially programmed object-oriented in C++. A few years later, this text-based language will be replaced by LabVIEW Embedded as part of a deep-sea project and, together with the field-tested I/O modules, the Zbrain platform will emerge.

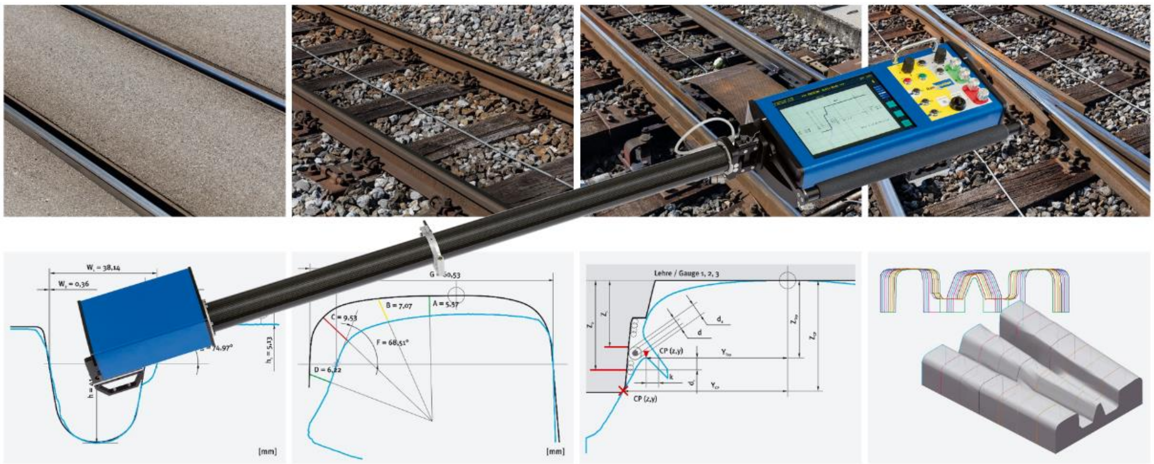

Fig. 5 | The laser-based, graphically programmed rail measuring device is light and easy to handle, offers a battery life of 8 hours, works reliably in rough field use throughout the night shift and thus becomes the digital "partner" of the inspection staff.

Back to the rail track. LabVIEW plays a decisive role in data evaluation here. The trick: Schmid learns from the traditional and widely used rail inspection and maintenance standards, transforms them from analog to digital processes and develops close to the real world. I still remember the night-time operations on Zurich's tram network between 1:00-4:00 am. This is the time window for inspection and maintenance. It's hard to believe what goes on next to the tracks... Thanks to this approach, the new method has been adopted by track layers and grinders and the higher productivity is greatly appreciated. All evaluation algorithms, such as the centering of target and actual profiles and the calculation of radial wear, are programmed in LabVIEW, giving these users an enormous competitive advantage over those using mechanical gauges and paper notepads.

Over time, the radius of action of Schmid's digital inspection solution expands. The device is soon used throughout Europe and later finds its way to the USA, Australia, New Zealand, Singapore and China. One of the milestones is the approval by Deutsche Bahn (DB) for its high-speed network. It is the first laser-based hand-held measuring device to be certified for rail profile cross-sections for train networks operated above 280 km/h. This requires a laser accuracy of 50µm.

A second key stone is the inspection of turnouts as the most critical railway infrastructure. LabVIEW becomes an enabler to reactivate and digitize old and forgotten turnout know-how from the 1970s and to make this monitoring process fast, transparent and precise for new projects in China. As a result, the turnouts can remain in operation until they are worn to their permissible limits without compromising ride comfort or safety. The benefits speak for themselves: an expected 25% longer service life and 25% savings on maintenance!

Fig. 6 | Laser-based, automated condition monitoring of railway track infrastructure: two laser scanners (black) are connected to the main computer (red) and are controlled by LabVIEW Embedded. The measurement data is stored in a structured manner according to a network plan, processed and made accessible to everyone at the appropriate level.

3.1. Predictive maintenance thanks to intelligent grinding of rail tracks

Once the state of wear of the rails and turnouts is known through inspection, maintenance plans are drawn up by transport companies and external maintenance service providers are commissioned. These service providers are deployed at night and grind or mill the infrastructure back to new condition during operational breaks. It has been proven that smart machines equipped with cutting edge measurement and control technology offer a competitive benefit.

That's why the measurement technology previously used for inspection is finding its way into the grinding vehicles. First, the current condition of the track is downloaded from the cloud and the grinding passes are planned based on the profile deviations. Finally, the grinding process is monitored with laser scanners until the rail profile matches the target geometry again.

This enables targeted grinding and thus reduces the number of work passes. The control variables obtained from the measurement results are transmitted to the grinding head control system via CAN or Ethernet.

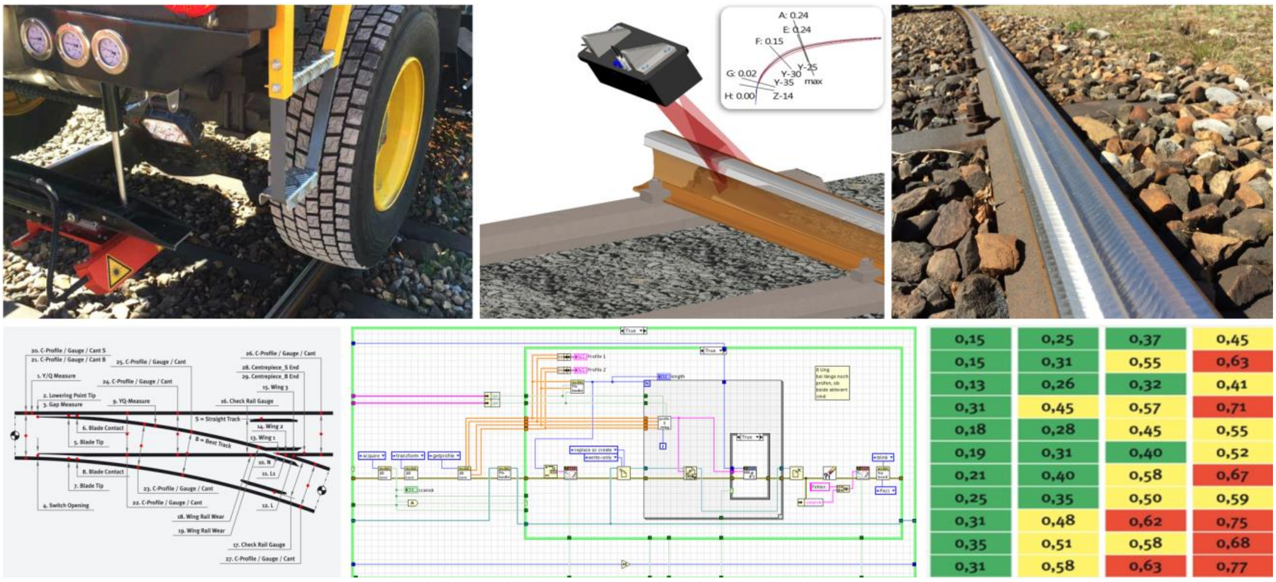

Fig. 7 | Tough outdoor requirements for a rail measuring device in the aggressive environment of grinding trains: a temperature range of -20° to 80°C, vibrations and shocks, grinding dust, sparks and humidity - robustness and reliability are required.

The measuring system in the intelligent grinding vehicle essentially consists of five components:

1. Two laser curtains simultaneously scanning both rail profiles at 20 Hz and deliver point clouds of 1,500 measurements with an accuracy of 0.25 mm.
2. A robust main controller including a measuring computer with the NI System on Module (SOM), SSD hard drive and GPS module.
3. Ethernet and WiFi to the higher-level master computer or display.
4. 4G module for IoT connection.
5. All housed in a milled IP65 aluminum housing.

The communication expertise gained from component 3 and 4 is one of the reasons why Schmid Elektronik will later take on the racetrack IoT project.

3 Energy Generation, Transmission and Efficiency

The clean, efficient and therefore sustainable use of energy is a recurring theme throughout the history of Schmid Elektronik. Today, Schmid supports the industry in three niche areas: generating energy sustainably, converting it efficiently and using it mindfully:

4.1. Generating energy with 80% efficiency from solar energy

Concentrated sunlight can be used not only to generate electricity, but also hot water. The latter can in turn be used for cooling or for cleaning drinking water. The "Sunflower" small-scale solar power plant developed in Switzerland uses a parabolic dish to concentrate sunlight at its focal point to a factor of 2000. Anyone who has ever experimented with a magnifying glass and the sun knows the burning effect. Thanks to the combination of highly efficient solar cells and an active water cooling system, the efficiency increased up to 80%. A tracking system guided the dish around two axes, always directly following the sun, hence its name.

Fig. 8 | A vision for the highly efficient solar energy of tomorrow with a complex mix of technologies: from the rough concrete structure to the micromechanical silicon cooling system, with a graphically programmable embedded system with safety and emergency functions, IoT-Link and local measuring network with over 100 controlled sensors and actuators on the CAN bus.

The brain of the system was tailored LabVIEW hardware based on the SOM. On a sunny day, the 10 meter high and 18-ton heavy sunflower delivered 32kW: 12kW electrical and 20kW thermal. Enough to supply several average households. A larger system with several sunflowers could thus supply enough energy and clean water for a village. At its core, the sunflower consisted of the following three system components: the optics, the receiver and the tracker. From an engineer's point of view, the innovative and interdisciplinary character, the cost-effectiveness and the mix of technologies are particularly fascinating: construction, mechanical, optical, electronic and software engineers work agile and hand in hand towards a common goal and think in terms of the system.

4.2. Testing high-voltage direct current transmission (HVDC)

This test application involves high-speed communication via optical fibers as the last mile to converter modules. These are used in energy transmission, for example to connect offshore wind farms. Similar technologies are also used in heavy industry, railway and electromobility. A customized optical adapter module enables the customers team to serve a complex niche market with a high quality product and first-class service. High-speed signals can be decoded and analyzed in real time for test purposes.

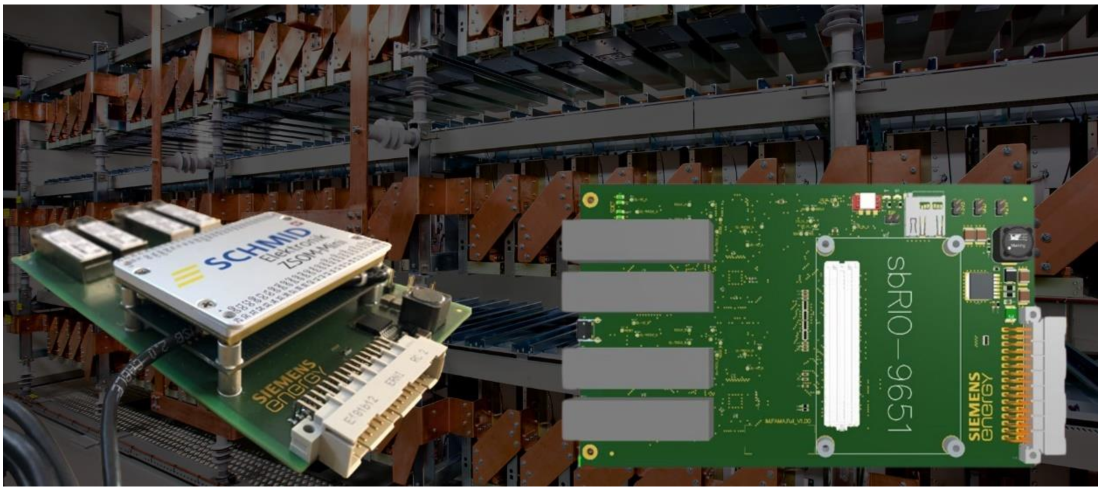

Fig. 9 | The system provides an optically isolated analogue signal path in the inverter test system. The signal is converted from analog to digital (14-bit/100MSPS), transmitted optically in series at 2GBps and converted back to analog again.

"We value the mutual trust and professional cooperation with our partner Schmid Elektronik, which offers absolutely reliable quality in production and testing as well as in the development of hardware and software. The agile and open-minded way of working enables flexible, lean processes, especially for our prototypes and small series. Schmid Elektronik is one of our mainstays in adapting the NI platform to our special needs in the field of HVDC converter testing (high-voltage direct current transmission)." (Julian Lange, Siemens Energy)

4.3. Increasing energy efficiency thanks to telemetry and race data

There was this phone call out of the blue. The same energy giant as in the deep sea story 10 years earlier contacted us. Could we deliver the Minimum Viable Product (MVP) of an onboard computer that connects racing cars to the IoT? In just eight weeks!

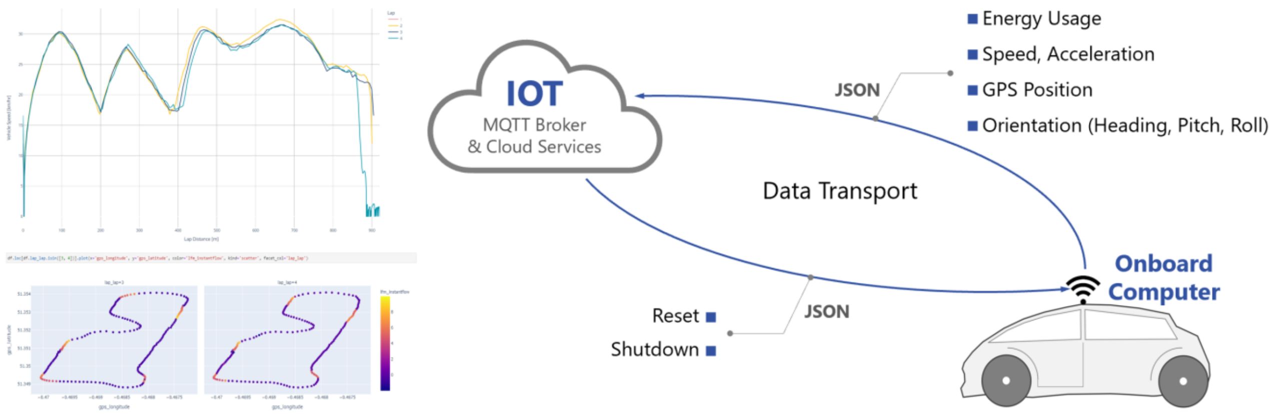

Fig. 10 | The MVP for a racetrack IoT system is designed to connect sensor data from vehicles with IoT services. The goal is to collect race data from the start to the finish line.

The project idea sounded plausible: add an exciting Formula 1 style show format to a previously somewhat monotonous marathon: a "grand finale" with a live data view of the race and how it unfolds. The strategy: the MVP provides the data transport between the vehicle and the Internet. The hypothesis: the emotions of participants and spectators will run high during dramatic head-to-head races, sweep them off their seats and create nail-biting moments. This will make the races more attractive and better known.

The energy efficiency achieved in this STEM community (STEM: science, technology, engineering and mathematics) is unique. The record holder can, in comparison, cover the distance from London to Rome and back with just a single liter of fuel or 10 kWh of electrical energy!

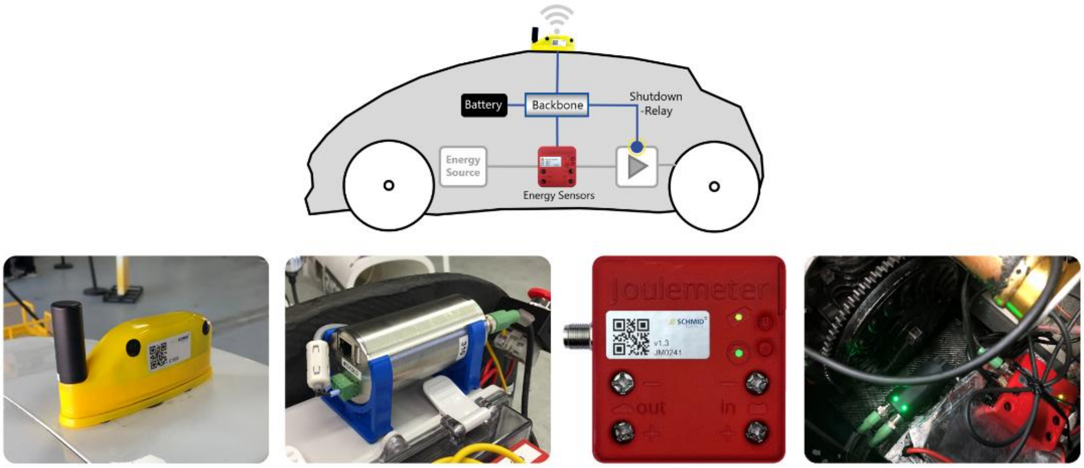

Fig. 11 | from left to right: the second-generation onboard computer consists of the outer, yellow fin and the inner backbone. It is powered by a battery and connects to various energy sensors such as the joulemeter (red) or liquid flowmeter (black).

We used LabVIEW in all project phases when developing this onboard computer: From the proof-of-concept (PoC) and MVP to the prototype, series production and testing. Thanks to a new kind of project organization and the Zbrain platform, the task was mastered at the end of the day. The technical and organizational challenges of the project were tough:

1. The onboard computer to send various sensor data such as energy consumption and GPS position to an IoT server every second.
2. This required a technology mix with 4G, WIFI and GPS as well as the MQTT protocol and JSON exchange format, which are popular in the IoT sector. Although this is not rocket science, a GPS disaster that we experienced showed us that the devil is often in the detail.
3. The massive time pressure in all phases had a significant impact on the project. The central question was, how can several developers beat the clock by working on the very same embedded software in parallel on the same platform?
4. Multiple miniaturization until the form factor fits.
5. Heat, humidity, vibrations and electromagnetic fields - the embedded system must deliver reliable data in the extreme environment of an engine compartment.

The stories 100km on just five teaspoons of fuel, IoT MVP in just 8 weeks and Race data in action: from theory to practice tell how this turned out.

4 Mobility & Transportation

Schmid Elektronik's Zbrain system was never used as a product in real cars. However, there were many projects in the transportation industry where this platform has been successfully applied. Here are four examples around driving dynamics and energy efficiency.

5.1. Decentralized measurement technology in the wheel hub and telemetry connection

Car manufacturers regularly launch their latest models in spring, after the major trade fairs. At the same time, stylish tires are launched on the market - but they have to be put through their paces first. This was the task of a mobile measuring device. It was to examine the driving dynamics by means of precise speed recording in all four wheels.

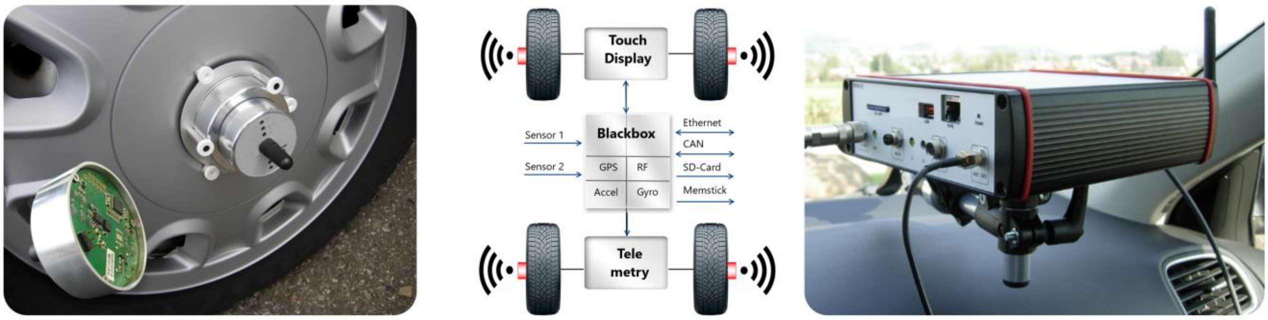

Fig. 12 | Rotation sensors mounted in the wheel hubs send the speed signals to a 'black box' with touch display, data memory, telemetry interface and access to the vehicle's internal CAN bus.

The time frame for the development project was set at four months. The task was to connect application-specific sensor signals such as wheel speeds, two configurable sensor inputs, 3D accelerations, 3D rotation rates and the vehicle speed with GPS and time stamps, show them live on a display and store them synchronized on mobile storage media.

At the same time, the data was to be communicated to the tower in real time via an analog telemetry system. For a later phase, it was planned to send it wirelessly to a tablet and connect it to the vehicle's CAN bus.

Various models for the quality of driving dynamics could be created using the sensor data and the measured variables derived from it. Measurements to characterize the fuel efficiency, wet grip and external rolling noise of tires are important in connection with the tire label, which has been mandatory since November 2012.

Applications such as measuring the performance of engines in mining trucks, speed tests of 600 horse power police vehicles, measuring extreme acceleration in corners in motorsport and wheel lock during braking are also planned.

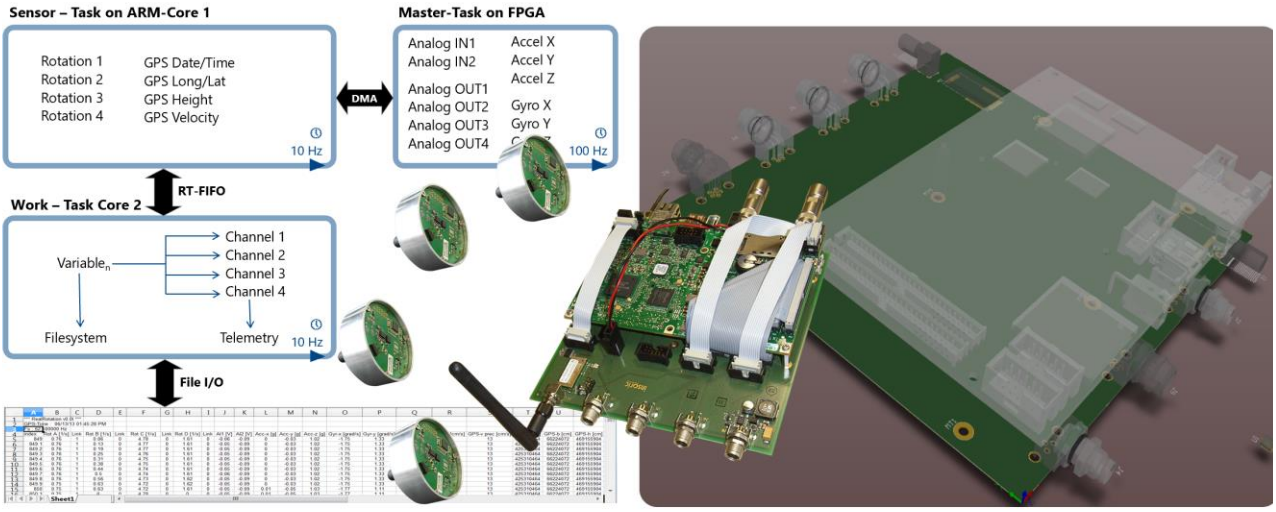

Fig. 13 | An application-specific baseboard is the link between the graphically programmable hardware, the housing and the connectors for the external sensors and communication. Three synchronised tasks are responsible for recording, processing, visualising, storing and communicating the sensor signals and the derived measured variables.

5.2. Dashboard MVP for racing drivers in motorsport

The first step of the telemetry system in the Shell Eco-marathon was to offer spectators a digital experience with screens showing live how the race unfolds: 100km on just five teaspoons of fuel.

The second step followed on the heels of the first: providing the teams with the data after the races so that they can gain knowledge from it and further increase energy efficiency, e.g. with data-driven race strategies: Race data in action: From theory to practice. One day, the idea came up of providing the driver with live information directly into the cockpit to support him or her while driving. Another MVP was needed to test this idea!

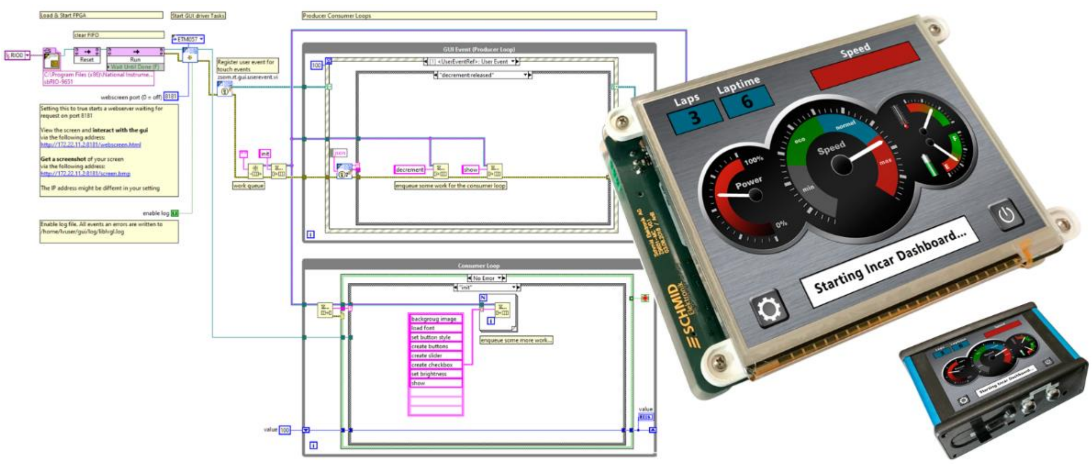

Fig. 14 | The MVP of a dashboard for racing drivers prevented a good idea from being implemented incorrectly.

The strategy consisted of a robust dashboard for the cockpit, connected to the existing onboard computer via Ethernet or CAN. The hypothesis that the drivers would embrace it turned out to be totally wrong. They actually wanted direct access to the live data. But please via smartphone and presented to the driver via their own app. Thanks to MVP, we have probably saved thousands of swiss francs in unnecessary development time!

5.3. Automating racing processes thanks to intelligent vehicles

As part of its global decarbonization program, the race organizer of Shell Eco-marathon plans to reduce the size of the on site technical team to ultimately reduce flights. Automation was to compensate for the missing technicians and again MVPs were asked to iteratively learn and test the following idea: to equip the onboard computers in the racing vehicles with intelligence so that they can take over some repetitive tasks. This idea was to be validated using two different strategies:

1. Artificial "eyes" (color sensor) and "ears" (beacons) enable the onboard computers to recognize patterns on the road and eavesdrop on contextually relevant content based on local geodata.

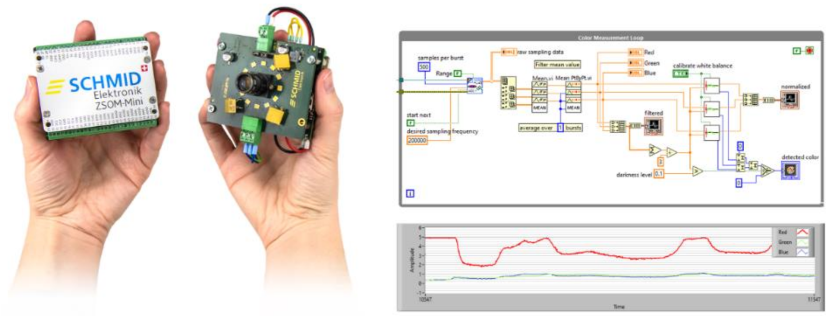

Fig. 15 | MVP for an intelligent color sensor,
realised with the Zbrain standard platform ZSOM-Mini

2. A "seventh sense" by adding GPS-RTK (Real-Time-Kinematic) enables the onboard computers to determine its position with centimeter accuracy, allowing vehicles to easily find their way around a digitally stored location model.

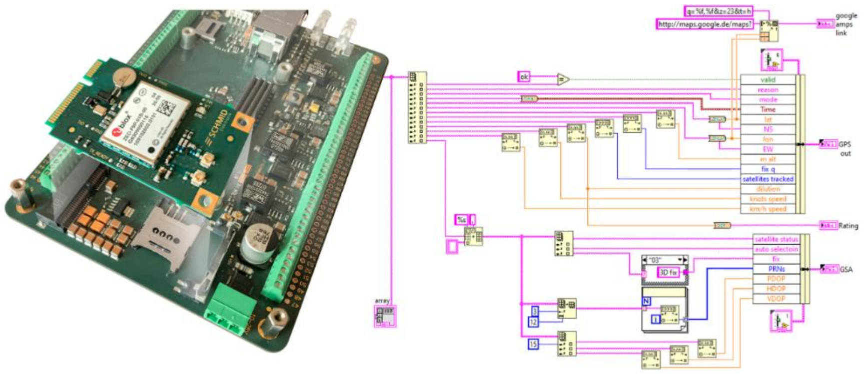

Fig. 16 | MVP for high-precision GPS data (RTK), realised with the Zbrain standard platform ZSOM-Control.

Tests have shown that the strategy using precise GPS-RTK data leads to the target more reliably and quickly than the solution using artificial eyes and ears. Here too, the idea had to be subjected to a reality check before the time-consuming hardware and software development could begin.

5.4. Only with the power of the sun through the Australian outback

The "World Solar Challenge" in Australia is one of the toughest races for solar vehicles in the world. It is held every two years on the public Stuart Highway. The catch: only the sun is allowed as an energy source, demonstrating the benefits of renewable energy. After all, the solar-powered vehicles cross the Australian continent using only around two thirds of the power of a standard vacuum cleaner.

Similar to Formula 1, the pilot controls the solar car on the multifunctional steering wheel using buttons and joysticks: the "Eco/Cruise" mode for average speeds between 60-80 km/h is used for most of the race. It limits the motor current to 10 A, reduces energy losses by smoothing out peaks and thus requires an average of around 16 Wh/km. During overtaking maneuvers, the pilot switches to "Power" mode. Here, 35 A and thus top speeds of 100 km/h are available. However, such "escapades" consume 20 Wh/km and more. Braking takes place at two stages: The motor brake is applied on the first millimeters of the brake pedal. Further deflection activates the hydraulic brake.

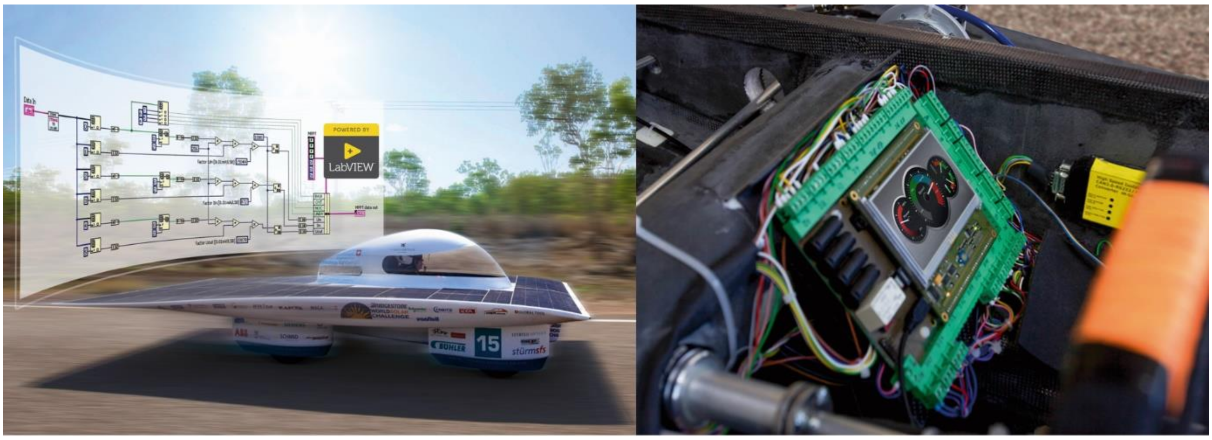

Fig. 17 | Economical and powered only by the sun through the Australian outback. All components of the solar car, from the chassis and body to the running gear, embedded hardware and software, transfer the solar energy generated to the road with maximum efficiency to the road.

The pilot in the cockpit has only limited possibilities to analyze the data live and draw conclusions for the race strategy of the 3000 km long road race. A reliable telemetry system between the solar car and the support vehicle therefore plays a crucial role. While the pilot concentrates on the road, the support team evaluates the operating data and combines it with meteorological information and the remaining distance to the next control stop. In particular, the performance of the photovoltaic system and the health of the battery are closely monitored. As a result, the pilot receives a new driving tactic or speed adjustment by radio. The goal of the entire race strategy is to achieve an optimum energy balance, which is influenced by the vehicle speed.

5 Mobile Battery-Operated Handhelds and Portables

The measurement network in the Norwegian deep sea ran on a battery for six months. This resulted in the commercially available Zbrain platform and thus opened a new solution: running LabVIEW on mobile, battery-operated portables or handheld measuring devices!
The following four examples represent many other applications with similar challenges.

6.1. Taking the elevator experience to a new level

Imagine getting into an elevator full of people and expecting a smooth, safe and comfortable ride. This is exactly what a new, mobile measuring device ensures and it is even driving digital change in this previously rather traditional industry. It is simply placed on the elevator cabine for the elevator test, connects to the outside world via WIFI and records measured values during the ride.

Fig. 18 | A battery-operated measuring handheld for the lift contains a high-precision acceleration sensor and communicates the data to the tablet via WIFI.

TÜV SÜD opted for a graphical programming approach with LabVIEW Embedded on an off-the-shelf-module from NI partner Schmid Elektronik for the development of this handheld measuring device. The requirements included acceleration measurement, smart battery management, a simple operating concept and a WIFI connection.

Using high-precision sensors and customized hardware, it measures the acceleration and deceleration of the elevator. No unpleasant jerking, no sudden stops or dynamics that make you feel uneasy. Just a smooth and comfortable ride that everyone can appreciate and the reassurance that the safety systems are working.

The measuring device is a joint project between TÜV SÜD, TÜV Hessen and Schmid Elektronik. Its core consists of a high-precision acceleration sensor and a robust battery management system for single-cell lithium-ion batteries, including a charging circuit via USB-C and a charging indicator. The device charges in 3 hours and has an average battery life of up to 8 hours. A sophisticated energy concept ensures high efficiency. The programmable switch-on sequence enables reliable start-up. Numerous hardware and software functions guarantee a stable 24/7 operation. The user operates the device via a smart button and LED displays, which are elegantly and ergonomically guided to the top of the housing via light pipes.

The hardware functions are integrated on a customized baseboard with a ZSOM-Mini that can be graphically programmed with LabVIEW. This hardware is packaged together with the battery in a compact, robust and high-quality standard housing and is suitable for harsh field use.

6.2. Mobile LIDAR-Measurement Device for an Outdoor Application

Schmid Elektronik developed a customised baseboard with its own software development kit (SDK) and an application framework for a LIDAR application. The latter served the customer as a quick introduction to LabVIEW embedded technology. The application is confidential, which is why we are reporting here on the framework and what a customer can expect from such a framework. It contains software modules for the analog and digital I/O, the communication interfaces and the temperature measurement. This is important for thermal management because the hardware is integrated into a fanless housing.

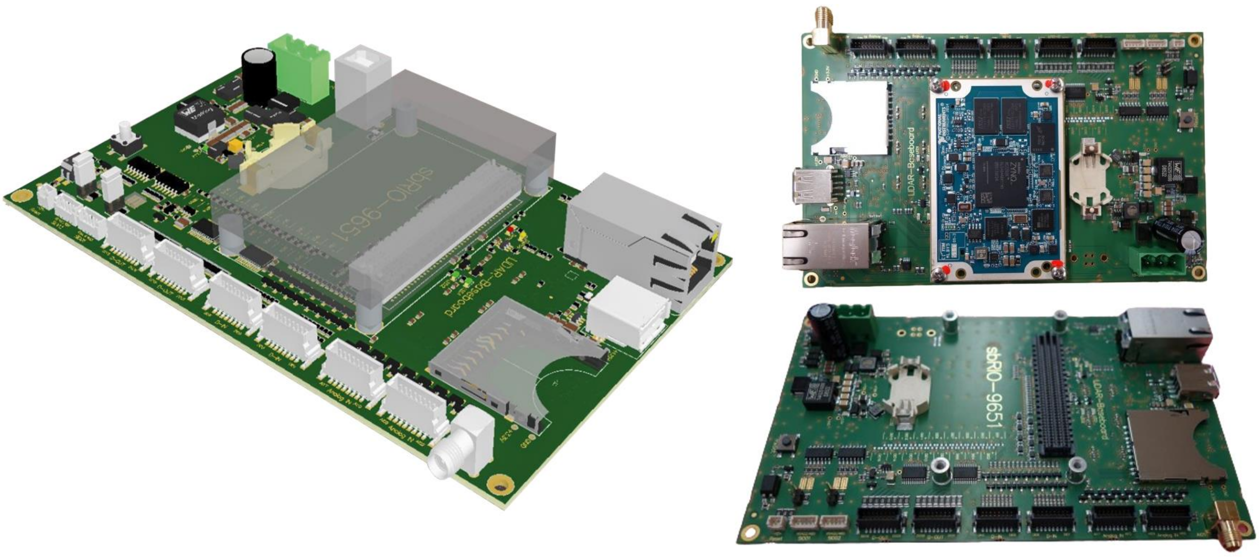

Fig. 19 | In addition to the 100MHz ADC, the LIDAR board contains 16 digital inputs and outputs, a file system (SD card), RS422 and RS485 and SSH access.

The heart of this application is the fast analog acquisition with 100MHz. The FPGA code for this consists of several hierarchically operating loops that run at different frequencies:

1. The measurement **data acquisition loop** runs at 200 MHz, generates the clock and reads out the sampled values on each falling edge of the clock signal. The values are pushed into a FIFO for the next loop:
2. The **calculation and buffer loop** runs at 100 MHz, i.e. once per sample. It processes the sampled values and pushes the results back into FIFOs/memory so that slower loops can process them. Everything that needs to be calculated for each sample is placed in this loop without a single one being lost. The feedback nodes are used to distribute the workload of the timed single-cycle loop. The more feedback nodes, the higher the latency of the calculation and the more calculations are possible within the timed single cycle loop.
3. The **transmit burst loop** sends blocks of sampled values to the RT host at a rate specified by the host. These values are lossless within the blocks, but not between the blocks.
4. The **transmit FFT loop** sends the FFT results to the RT host. This prevents the FPGA from reading and writing the same memory cell at the same time (this would generate incorrect values). The send loop tells the calculation & buffer loop which half of the memory it can use to write values.

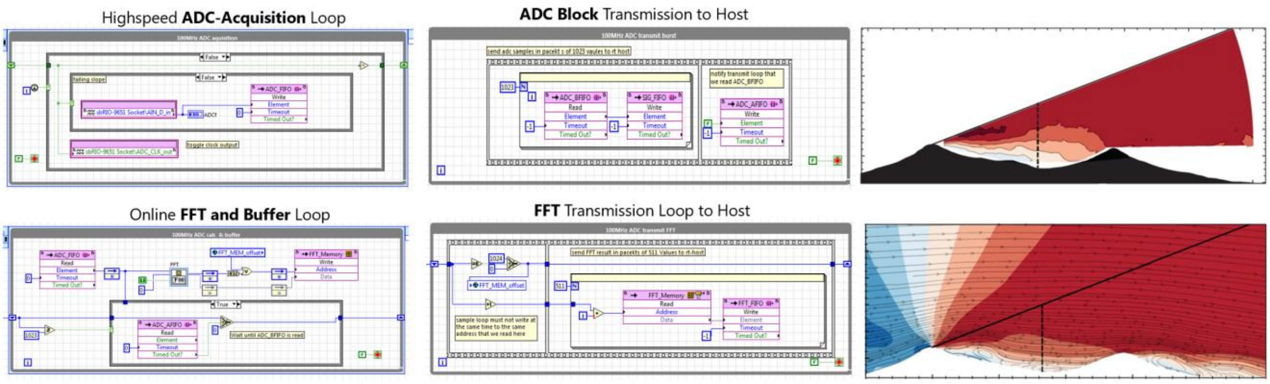

Fig. 20 | The framework for 100MHz measurement data acquisition essentially contains loops for the acquisition, FFT calculation and transmission of the time and frequency signals to the host

The main program reads and writes all digital and analogue inputs and outputs. It also operates the USB interface, the serial RS422/485 channels and the SD card memory. Finally, it reads the various temperatures from the System-on-Module.

The temperature of the SOM depends on its workload, the ambient temperature and the cooling strategy. The software framework heats the SOM to a temperature of 50K above the ambient temperature when it is open horizontally on the desk. While the SOM consumes about 6.4 W, the thermal resistance is therefore about 8 K/W (Kelvin per Watt). If the module is rotated by 90° so that it is upright, the cooling is about 15% better. Further improvements can be achieved with heat sinks and active cooling.

6.3. A smart Laser Module that Meets the Eye

Optical coherence tomography (OCT) is a non-invasive and high-resolution imaging technique and diagnostic tool that has found its way into many areas in recent years. In medicine, for example, it is used to measure the inside of living human tissue over a small measuring range of a few millimetres in real time. For this purpose, the swiss company EXALOS developed a flexibly configurable, broadband laser source that includes a micro-optical workbench, operated by mixed-signal electronics developed by Schmid Elektronik. The goal was to provide users with an intelligent and autonomously operating system as a "black box" in which the laser light source can be configured and operated via defined electrical interfaces and a USB interface.

Control electronics was required in which a microcontroller is responsible for external communication, i.e. to the customer's system, as well as for controlling and monitoring the laser light source internally. The clock generated and controlled by DDS (Direct Digital Synthesis) is amplified via a high-voltage stage for the micromechanical mirror. In parallel, the clock is precisely aligned in phase with optical "wobbling" of the laser light source, i.e. by tuning the wavelength, and made available to the customer via an interface. A control loop generates an extremely low-noise electrical drive current for the optical amplifier so that the light in the laser cavity can be generated and amplified in a stable and low-noise manner. Another control loop stabilises the temperature of the laser source. The microcontroller generates and records various optical and electrical signals via specific I/O connections with slow or fast ADCs and DACs in parallel, electrically isolated domains.

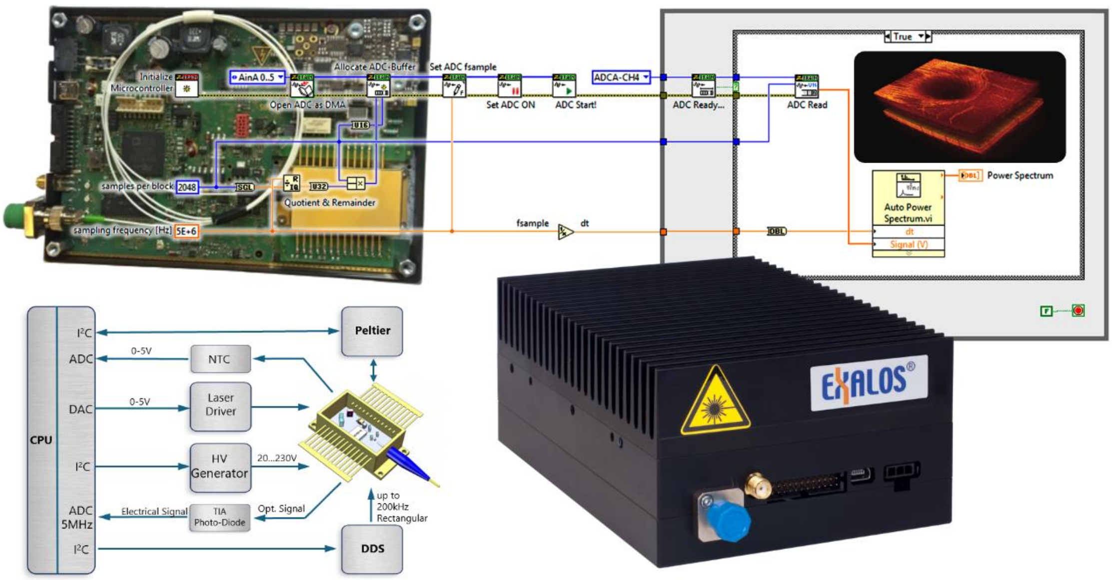

Fig. 21 | The compact laser module hardware in an aluminium housing adapts and configures tunable laser sources and thus covers various tasks and customer requirements.
Fast analog signal sampling with 5MHz and subsequent Fourier transformation were graphically programmed in record time with LabVIEW Embedded.

With this method and the resulting smart platform, added value was achieved on three levels:

- Firstly, complex microcontroller, analog and digital technology was conveniently abstracted for the manufacturer of the laser module. This allowed the developer to concentrate fully on developing the laser light source and the embedded LabVIEW application, giving the module "intelligence" and thus gaining a market advantage.
- Secondly, the manufacturer of OCT instruments is offered an easy-to-integrate, turnkey solution that can be configured via USB. The triggered optical depth scans can be fed to a higher-level measurement computer with FPGA, where they are analysed and displayed live. As a result, the application engineers do not get lost in the details, but can concentrate on the main task of system integration.
- Thirdly, the attending physician has a precise instrument at his disposal that delivers fast and customised results.

6.4. Sleep monitoring "on humans" in the medical field

A small group of medical domain experts required a mobile measuring device for monitoring respiratory disorders. This was not about life-support systems, but about targeted measurement campaigns. Devices of this type require a minimum of quality assurance measures to acquire a certificate. Respiratory flow determination is a method used for the long-term detection of sleep disorders. In everyday clinical practice, thermistors are used for this purpose, which register the temperature differences between the inhaled and exhaled air. This method is subject to errors and only allows imprecise statements to be made about the respiratory flow.

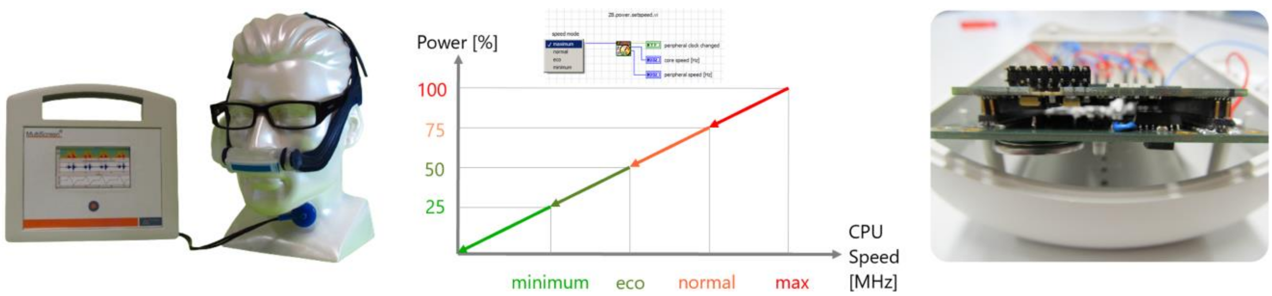

Fig. 22 | Low power consumption was the be-all and end-all for this mobile measuring device. This was achieved by switching off unused components or scaling the processor clock.

With this in mind, a portable, battery-operated device was developed that precisely detects and immediately assesses the respiratory flow. Adhere to standardised processes in the software life cycle for standards-compliant software development so that the device could be approved in accordance with the MPG. This included software risk management, software configuration management and problem resolution management.

6 Research Projects

The following two applications were created within three years after the pipeline project. The spider robot in particular was great fun and amazed many people. At its first appearance, it impressed everyone with a pure limbo! It received the "Editors Choice" award at NIWeek in Austin.

7.1. Autonomous spider robots for disaster relief operations

Emergency! It's a good thing that there is enough life-saving equipment available in many parts of the world today. It is vital to avoid additional loss of life. At the same time, it is important to avert additional accidents as quickly as possible during rescue operations after disasters, for example in buildings at risk of collapse. With this in mind, Nanyang Polytechnic University in Singapore has developed a new solution based on the autonomy of individual mobile robots and the interaction of them that leads to team work.

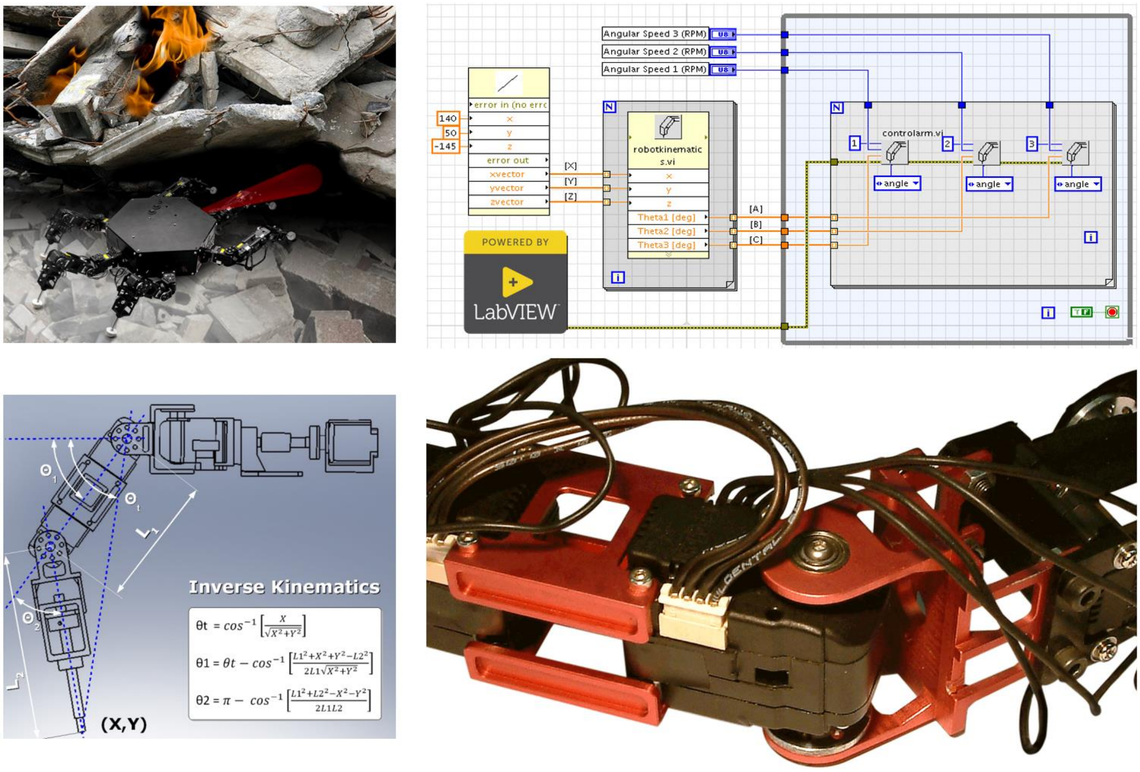

Fig. 23 | Inspired by nature: a six-legged robot spider with a flexible walking pattern moves effortlessly through disaster areas. Four intelligent motors with built-in, programmable PID controllers are connected via a serial RS-485 network and seamlessly integrated into the limbs. Smooth movements are achieved through inverse kinematics based on trigonometric functions and matrix operations.

The six-legged robot spider is small, mobile and can avoid various obstacles in order to search for trapped victims in hard-to-reach places. Detecting and destroying landmines is another area of application in which this robot could replace humans. It meets these requirements with an extremely mobile walking pattern with six independent legs. This allows it to move in all directions on surfaces where the use of robots is normally no longer possible or too risky.

7.2. Research acceleration for two-liter satellite

The "Purdue Sat", classified as a nanosatellite, was developed by the University of Aeronautics and Astronautics in Purdue, USA. Its special feature was its ability to realign itself in space autonomously and without conventional thrusters.

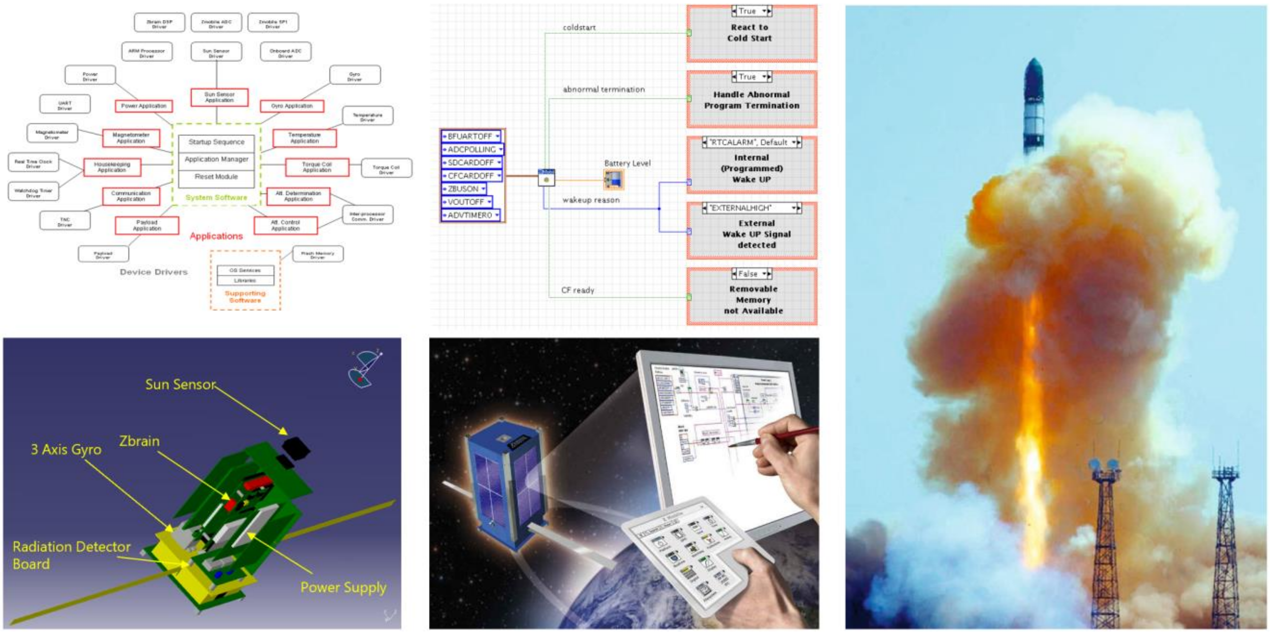

Fig. 24 | The flight control system of the two-litre satellite consists of 6 subsystems: Attitude Determination System, Attitude Control System, Scientific Payload, Communication System, Power Subsystem and Flight Calculation System.

The solution is unique in that it is based solely on the interaction between the magnetic moment generated by the satellite and the Earth's magnetic field. This requires highly complex mathematical modelling and a huge amount of numerical data processing at runtime. This problem was solved with LabVIEW Embedded on a low-power target. Schmid Elektronik collaborated with Purdue on the development and implementation of the flight calculation system software. As part of the joint project, a reliable real-time concept was developed that is suitable for long-term applications in space. This mainly involves an intelligent energy scheme and safe error detection and correction. Schmid contributed knowledge gained from a successfully installed deep-sea monitoring system, which was also based on LabVIEW Embedded.

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