Battery-Powered, Scalable DSP/Microprocessor Targets for LabVIEW Embedded

A practical demonstration with an Industrial Handheld Device

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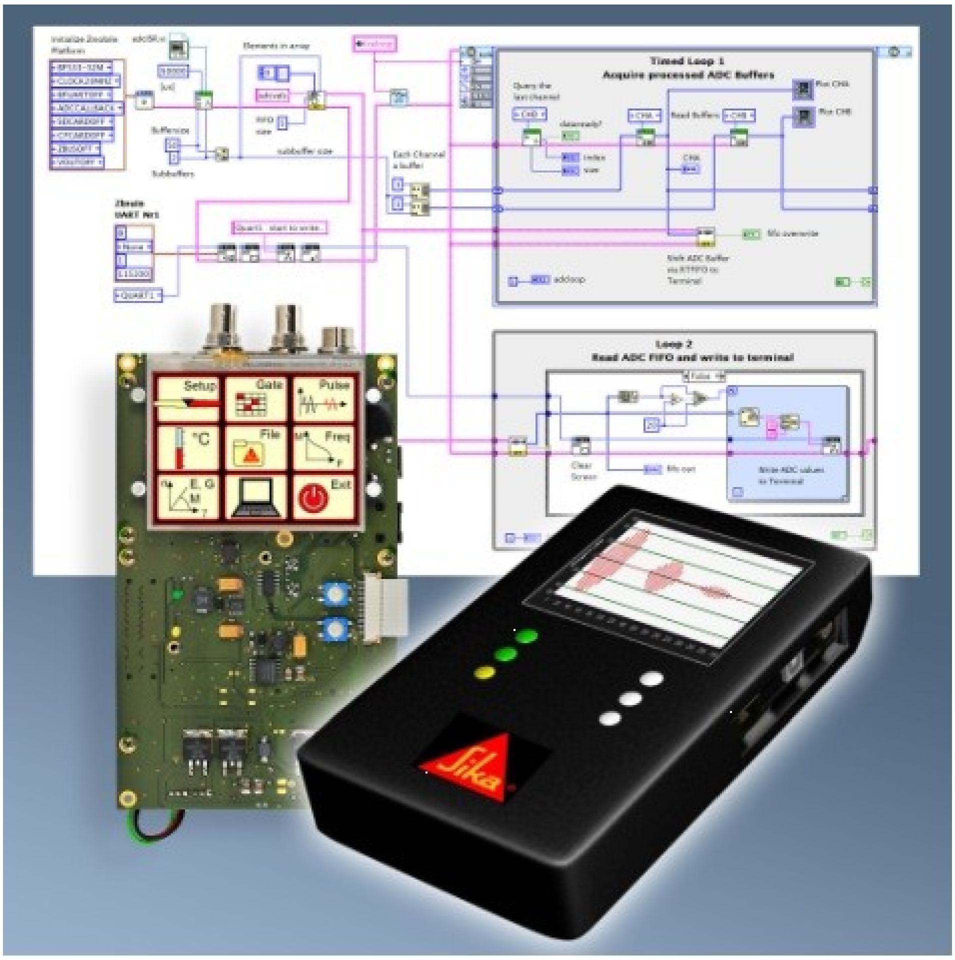

In this paper we show how we realized a highly functional series device with a graphical system design added with both a powerful Blackfin processor and the system solution ZBrain. From the idea to the product, we demonstrated how to overcome the boundaries with the example of the construction of an ultrasonic handheld apparatus.

Abstract

Today's designs are constantly challenged with better performance and flexibility for all development cycles. This paper describes, how a successful deployment of a complete system has been accomplished using a ready-to-run hardware and software development framework. This new and unique approach was ventured by SIKA to develop a mobile ultrasonic handheld device **(see Figure 1)** using Microprocessor OEM modules coupled with the LabVIEW Embedded module as a high-level programming environment. This combination offered both efficiency and convenience to be able to manage the complex tasks and to overcome issues and problems that always appear during embedded system design.
The requirements needed for the handheld apparatus included (i) a 25MHz signal generation, (ii) a 50MHz data acquisition (iii) with a 24 hours mobility (iv) an ergonomic user interface made with a touch screen (v) a data storage on removable media (CF-card) as well as (vi) remote control via USB (Figure 2). This paper highlights some of the issues for both hardware and software, generally needed for the development of handheld devices. We also show the development of a new, unique and rapid GUI development method which can be used for any mobile and stationary embedded design.

Highest Demands on Hardware, Software and Mechanics

The realized apparatus represented in **Figure 1** has to follow a series of specifications settled by Sika. Ultrasonic measurements need the (i) signal generation from 10kHz until 25MHz, (ii) with a signal acquisition of 50MHz coupled with (iii) a rapid correlation and analysis of the acquired data. As the final product was designed for mobility use, it necessitated also to be (i) compact and ergonomic, (ii) to have long battery runtime, (iii) to be directly controlled with a touch screen and to be able to transfer the data either to a computer or to a memory card.

Figure 1. Ergonomic customer design for high operating comfort

Early benchmark results concluded in the deployment of the complex measuring tasks into two independent CPU's in order to match the timing requirements. The processor shown on the left of **figure 2** runs the main application with the user interface and host communication. It is connected to the underlying data acquisition co-processor through a high-speed serial link, as represented on the right of **figure 2**. This DAQ processor is responsible for signal generation, signal measuring and reading of physical instrumentation. Pre-processed raw data and results are then transferred back to the main processor. All tasks are fully synchronized.

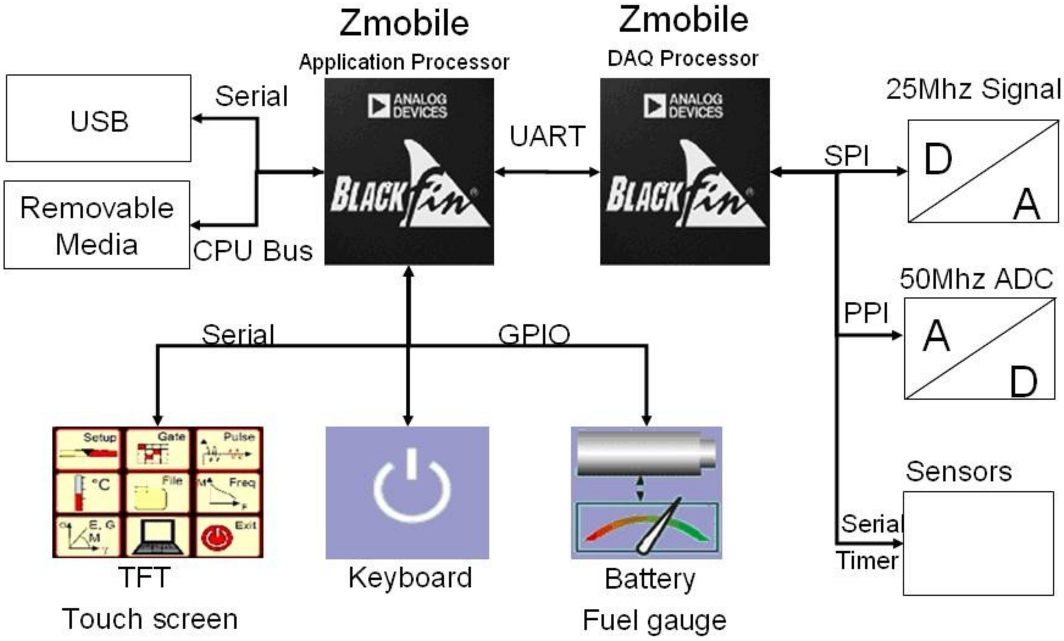

Figure 2. Block diagram with application processor (left) and separate co-processor for data acquisition and signal analysis (right).

The Ultrasound Measurement Principle

The principle of the ultrasonic measurement follows the echolocation of the bat: an oscillation packet is emitted and the elapsed time until the echo returns is measured as represented in **Figure 3 (left)**. As is the case here, this method can be used in test engineering to analyze material resistance. The method can return pivotal information on the quality of material. Unlike acoustic methods, the frequencies here lie in the MHz range.

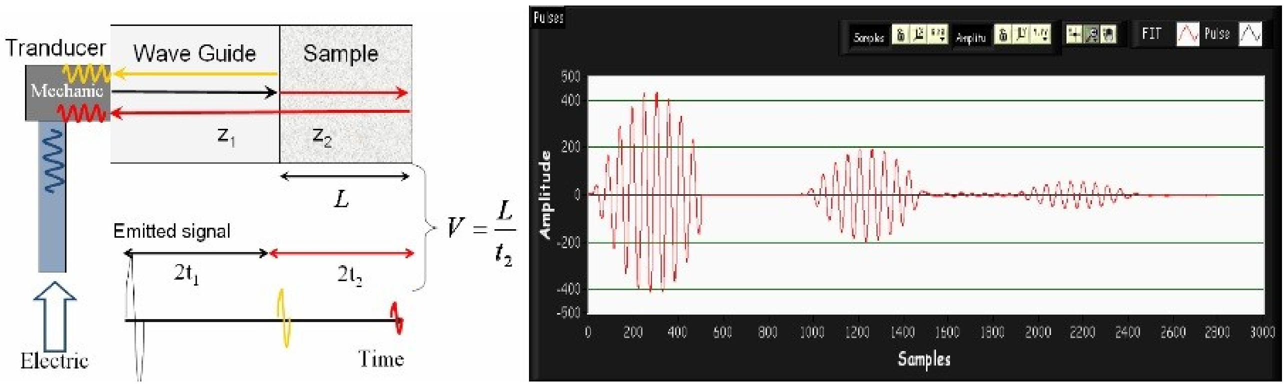

Figure 3. Left: an electric signal is converted to a mechanical signal with a transducer. The generated ultrasonic wave propagates through the material where it is submitted to a reflection at the interface between the wave guide and the sample. Right: the time of fly is acquired with the embedded oscilloscope.

An algorithm developed by SIKA Technology derives the exact response time and amplitude from the echo signal, from which the material under test can be characterized.

Mobility as the Key Factor

A mobile battery-powered device must be both small and handy, but should also consume as little energy as possible to ensure a long operating time. This is the reason why an embedded PC can't be used in most of the cases. The points listed in the following table can usually be applied for any mobile device:

Low energy consumption	Ideally, the energy consumption adapts to the workload of the device, which means that the device switches to a more powerful mode with higher energy consumption for complex calculations and returns afterwards to the energy-saving mode. This can be realized, for example, with a dynamically changed processor clock or with a variation of the core voltage. It should be ensured that the electronic display and the measurement equipment can be switched separately.
Battery switching and battery charge	While the device is mains-operated, the battery charges. If the device is disconnected from the mains supply, the device should switch smoothly to the battery-operated mode.
Display of the battery charge condition	When using mobile devices, the user must be informed of the battery charge condition. Many battery packs are already equipped with battery charge condition circuitry.
Automatic power Off	If the device does not receive a user entry in a specified period of time, the device should switch to standby mode.
Automatic power On	For many logging applications it makes sense if the device can automatically switch back on after a specified period of time.
User Interface	The apparatus is provided with an ergonomic interface. A touch screen is usually the first choice. LEDs and buttons are normally sufficient for applications which don't require a lot of user interaction.
Process IO	The task requires that analog values are measured and output and that digital ports are set.
Data Storage	In data logging systems, large amounts of data are primarily stored on portable data carriers such as CF cards.
Data Transfer to a PC	For the user, transfer via USB is very convenient.

The completion of all these points confronts the system-developer with complex and detailed tasks. This demands a lot of valuable developing time which then is sorely missed for the actual work on the core issue.

Figure 4. Graphical embedded system programming "Out-of-the-Box" with standardized function blocks /VIs.

For this reason, the flexible standard platform "ZMobile" was chosen as device base for the construction of the handheld apparatus. Each of the above mentioned functions is already available as a tried and tested hardware and software component **(Figure 4)** and can be easily dragged and dropped from a palette into the program as shown in **Figure 5**.

The ultrasonic device comprises several battery states in order to preserve the battery and thus to enable battery operation of up to 24 hours **(Figure 5 left)**. The display is disabled completely for long-term measurements and is reactivated with a press button. When the display is disabled, a blinking LED shows the status of the device.

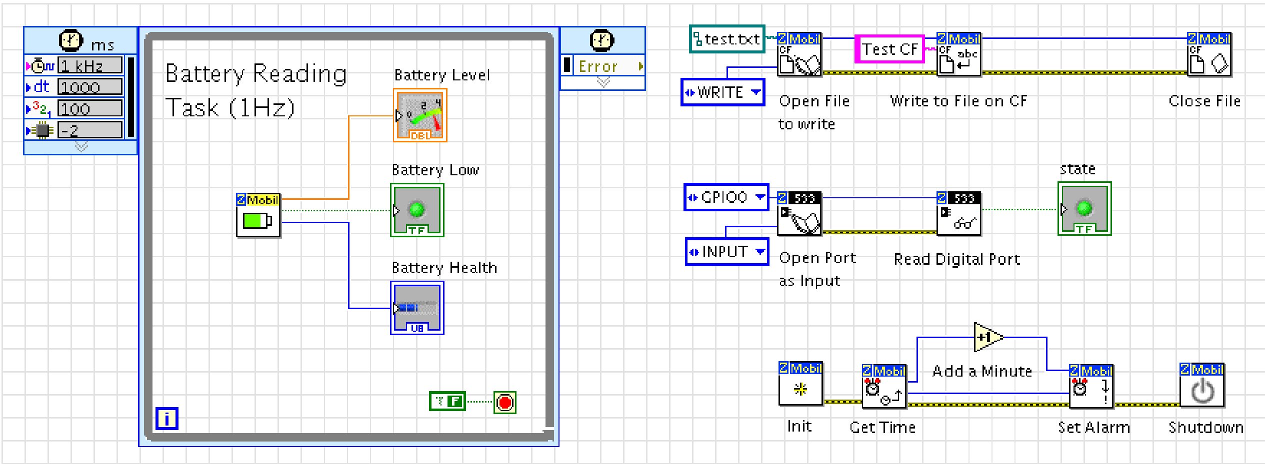

Figure 5. Programming model of the ZMobile embedded platform: battery monitoring (left), alarm and shutdown (right bottom), digital IO (right middle) and reading/writing to removable memory such as a CF card (right top)

Designing and Optimizing GUIs with Drag & Drop

In the realizing process of the GUI (Graphical User Interface), a great emphasis was placed on the ergonomic and abstraction as represented in **Figure 6**. The complex technology should not appear to the user who is only willing to see the end result.

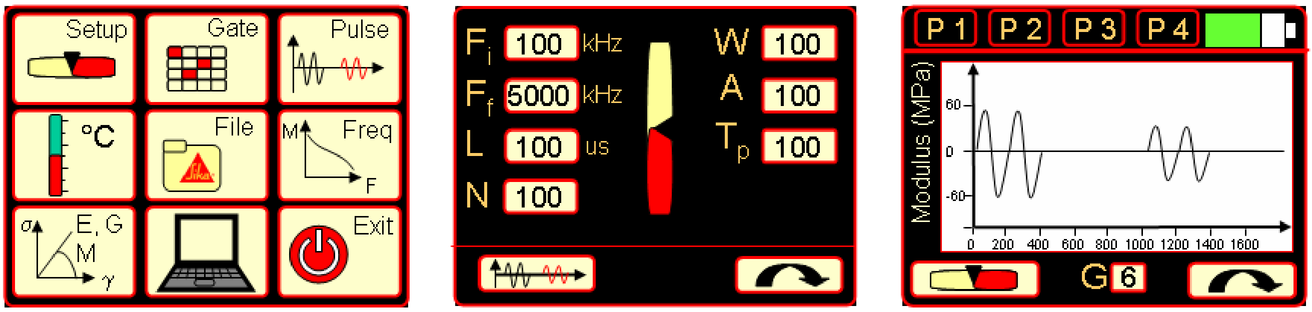

Figure 6. The clearly designed user interface with a main menu (left), parameter settings (middle) and signal graphics (right) conceals the complexity of the system

With Schmid Engineering's "Fast Debug Mode" (FDM, similar to HIL = Hardware-In-The-Loop) the otherwise intricate design and programming of a GUI proved to be very efficient. It is no longer necessary to design the GUI at the computer in a simulation mode. Now, the GUI can be directly on-line implemented, designed and edited on-target.

The convenient graphical debugging (FDM) made the time-consuming C-code generation obsolete for a great part of the application development and thereby accelerated the GUI development considerably. This enabled Sika to design a practical and ergonomic GUI.

LabVIEW Embedded Makes Signal Analysis Easy

LabVIEW is already recognized as a classic tool for solving numerous tasks concerning measurement, testing, and automation technology. Usually, computer controlled hardware is employed. For mobile devices, however, which are limited by their weight, size, and energy consumption, the developer is usually forced to delve into the depths of low-level programming and to use a text based programming language.

Todays possibility of programming the microprocessor directly with LabVIEW can be regarded as a real innovation. This revolutionary approach enables, for the first time, a comprehensive graphical programming of an embedded system. Thus, the LabVIEW user can now develop mobile applications in his familiar environment. The high degree of abstraction obtained with the graphical programming lends itself to simple systems as well as highly complex systems. A Fourier Transform calculation suddenly becomes as easy as accessing a digital port.

Which Processors Are Supported?

Principally every 32 bit processor can be operated by the LabVIEW Embedded SDK. However, a certain amount of effort is required to integrate the respective standard processor tool chain into the LabVIEW environment. This problem has already been solved for Analog Devices Blackfin Processors and ARM/CORTEX based microcontrollers. National Instruments "Embedded Modules" offer platform specific C-Code generators that are linked with processor specific RTOS' and libraries for accessing the CPU.

Other third-party manufacturers extend this solution by adding process-I/Os, real-time services, and other tools. In addition to these prefabricated hardware and software components including the low-level drivers, design-in or systems integration services are offered. Embedded software and hardware developing services for individual LabVIEW target platforms with customized form factors and process-I/O are also an alternative.

What Is the Difference to Programming on a Computer?

The programmer can use the familiar LabVIEW environment completed with palettes, block diagram, and front panel. In the first tool versions, the main purpose of the latter has been only for debugging. For example, parameters have been modified and read at runtime. After the release of the embedded GUI feature in LabVIEW 8.6, engineers now design a graphical user interfaces on the LabVIEW frontpanel, test it directly on the embedded TFT and finally deploy it to the target platform.

Most LabVIEW VIs, including the mathematics and signal processing blocks are available without any restrictions. Board-specific functions that the respective hardware offers can be dragged and dropped from the VI palette into the application **(Figure 4)**. Additional features provide target specific tasks such as creating and executing real-time code or loading a standalone application into the targets flash memory. However, an embedded system retains limited storage and processor resources which can lead to bottlenecks in the system's performance. Benchmarks, duly set, can prevent nasty surprises.

How Can I Join?

Evaluation kits and industrial grade reference designs for application specific domains present a simple and cost-effective method for evaluating the LabVIEW Embedded Modules. Alliance members or collaborative partners offer complete development and test environments that meet industrial requirements. This allows the creation of fully functional systems out-of-the-box, e.g sound & vibration monitoring devices.

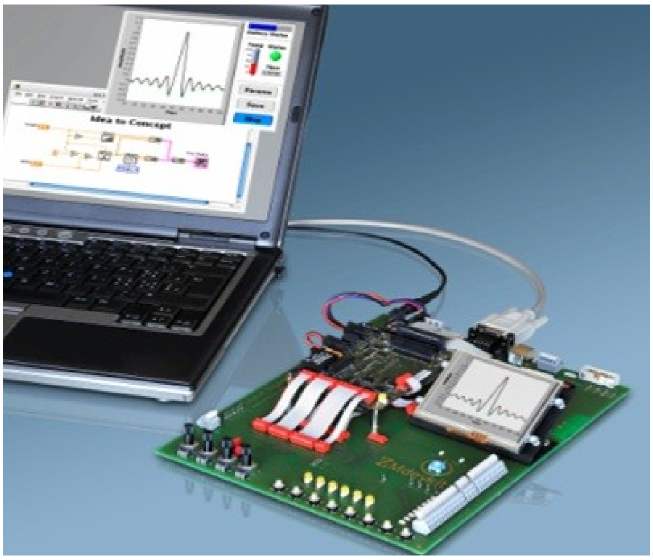

Figure 7. The ZMobile Development Kit (Schmid Engineering) offers an easy introduction to program with LabVIEW Embedded

The ZBrain System used for this handheld and represented in **Figure 7** comprises all necessary functions for mobile and stationary applications. It is suitable for the professional programmer as well as for the process specialist having little or no experience with embedded software development.

Each system function can employ a powerful VI: analog and digital inputs, analog and digital outputs, PWM and counters, keyboard inputs, real-time clocks (RTC), parameter memory, mass storage, TFT, and configurable high-speed UARTS.

Digital and analog I/O as well as operations can be simulated with integrated potentiometers, switches, LEDs, RS232, RS485, USB, buzzers, battery terminals, RTC support battery, CF card, and touch screens.

The developed programs and strategies can thus be tested before the hardware and software is used in the operational system.

Consistent Programming Language

Apart from the perks of graphical programming, LabVIEW offers with the embedded module a consistent and transparent programming language which can be used for feasibility studies, prototyping, and series production alike.

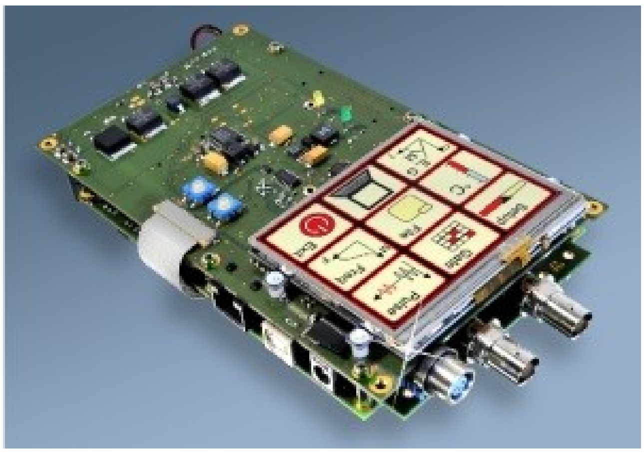

Figure 8. Measurement handheld under the hood: Stacked construction in combination with standard OEM modules and application specific boards.

The customized end platform, suitable for series production **(Figure 8),** can be programmed in LabVIEW just like the proto-type. The developed algorithms are reused 1:1 as VIs.

This procedure was employed for the construction of the device. Due to computer measurement technology and long-term LabVIEW know-how, SIKA was able to acquire test data and develop the evaluation algorithm long before the start of the hardware development cycle. This preliminary work was followed by the decision to employ Schmid Engineering as external development partner and solution provider to integrate step by step the algorithm into the series custom device.

Conclusion

In this paper, a complete development scenario of a low power measurement system has been addressed. The combination of a rapid prototyping, field proven embedded software and hardware allowed a new product to be completed in a short term.
LabVIEW Embedded facilitated an efficient, flexible, and clear graphical programming model for the construction of an ultrasonic handheld apparatus. In many companies, LabVIEW is a widely-used and appreciated tool, as is the case at Sika. This offers the potential for including know-how and existing solutions in the form of mathematical algorithms directly into a series product. And to bring with scientists, system engineers and domain experts additional manpower to the project team. As a common language between customer, manager, and development team, LabVIEW Embedded promotes new transparency, dynamics and increased interdisciplinary cooperation for projects. Due to OEM hardware and software and also the real-time expertise of board manufacturers, efficient programming of mobile and stationary devices moves digital embedded system design to the next level.

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