Demonstrator for Resolution Increase and Auto-correction in Embedded Measurement Systems

Frühauf, U.; Kranz, E.-G.; Leuterer, H.; Dresden University of Technology, Department of Electrical Engineering and Information Technology, Laboratory of Circuits and Systems, Chair Electronic Measurement; Mommsenstrasse 13, D-01062 Dresden, fruehauf@iee.et.tu-dresden.de, kranz@iee.et.tu-dresden.de, leuterer@iee.et.tu-dresden.de

Summary:

For investigation and training of students in the field of high resolution measurement technology was built an embedded measurement system with 16 bit resolution and additional modules for self-diagnostics and auto-correction, including a monitoring measurement system for evaluation.

Keywords:

Embedded measurement system; auto-correction; evaluation system

1. Introduction

The exact knowledge of the uncertainty and also the current state of calibration situation is for an embedded measurement system very crucially, particularly for higher resolution systems of 14 or 16 bits. The reliability of a measurement subsystem is important for the quality of any measurement results [1]. High resolution does not guarantee automatically high precision for the user (or for a higher ordered controlling system), but it seems first in such a way. There is for teaching a wide field of special tasks:

1. Explaining the problems of high resolution measurement systems and possibilities to solve them.
2. Discussing methods for high stability of system parameters and for noise reduction with special algorithms, circuits, elements, technologies and necessary design steps.
3. Showing methods for testing and calibrating of ADCs and analogue circuits in the measurement channel and for the hole measurement chain.
4. Examining algorithm and different realizations for calibration, (self-)diagnostics and auto-correction [1], [2].

For this field of tasks was built an embedded measurement system with 16 bit resolution and additional modules for self-diagnostics and auto-correction. The necessity of access to internal nodes and elements for testing forced a design with jumpers and test points. That gives the possibility, to vary the used structure of the measurement channel or parameters of relevant elements and to study the results. The problems and their solution have been derived from an industrial research project.

2. The Demonstrator

The realized measurement system consists of a 16bit microcomputer C167 (from Phytec / Infineon), which is coupled over the interface RS232 (or CAN) to a PC. The C167 is programmed to control the ADC and the self-correction. It also takes over the control of the sampling ADC, the noise reduction for selectable time-windows, simple diagnostic functions and the data preparation and communication. For that embedded virtual device a set of instructions was defined. Every command forces an answer to the PC. Queries and commands for measuring force the transfer of the result after end of measuring. Only after that the microprocessor can receive the next command. So we have defined time conditions for the sampling process without special sampling hardware. The sampling rate is driven by an internal timer of the microprocessor. Therefore it was necessary, that the interfaces of ADC and microprocessor are adequate for a direct coupling (Fig. 1).

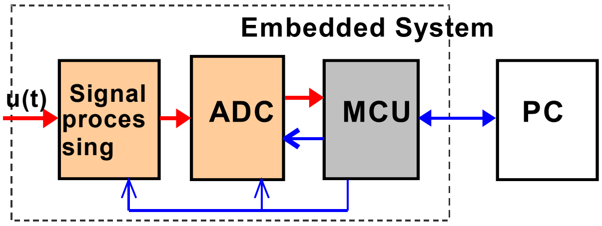


Fig. 1: The embedded system demonstrator

The analogue path includes a 16 bit-DAC with a high stable reference and switches for an active offset compensation in the input circuit, that can also be used for measuring the gain over the voltage range (Fig. 2). That gives the possibility to correct the measurement value through controlling MCU.

First step is to determine ADC-values for fixed values of reference voltage by the reference DAC. The MCU stores the results and calculates the offset error and the gain error. With these measured reference and correction values the MCU corrects the ADC values of the measured signal $u_e(t)$. Because the characteristic of the realized analogue channel is very good linear, it is used a linear correction function. The stored offset error serves for an active offset compensation.

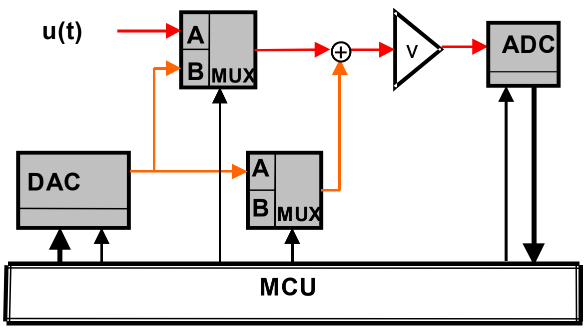


Fig. 2: Principle of self-calibrating circuit

For examining of the embedded measurement system there is an additional PC-controlled measurement system, based on IEEE488 devices (voltage reference source and voltmeter) and controlling program, based on LabView (Fig. 3). The microprocessor is coupled about the RS232 interface. With the defined instructions the PC-user can control the work of the embedded system with a special LabView-Library. After measuring the microprocessor sends the collected data to the PC. The LabView-program realizes the Visualisation of the transfer curve.

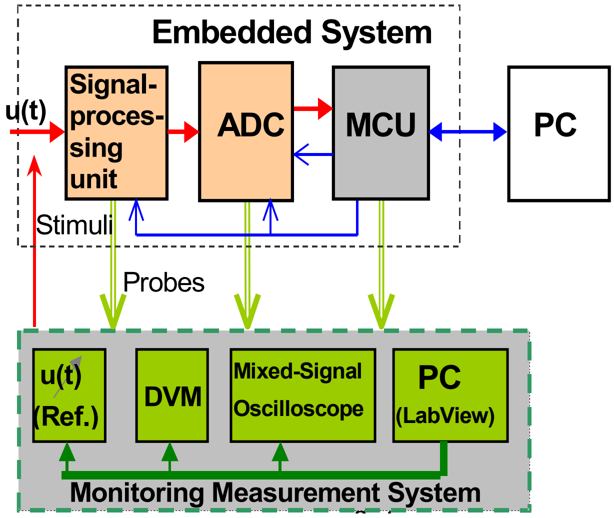


Fig. 3: Measurement system for evaluation

In the first step, with this system it is possible, to estimate the transfer function of the system and to calculate qualifying parameters, like absolute and relative deviation related to the reference source input. In the second step, the user can calculate parameters of the software-based correction for the host-based data evaluation in the next cycle (LabView / PC). In the third step it is possible to compensate the offset of the analogue path active and directly and to correct the measured values in the microprocessor. The PC gets the corrected measured values.

Another possibility is to show the effectiveness of averaging for higher resolution. The noise caused from surroundings (unshielded system), power source (DC/DC-converter) and from ADC itself is very important, not negligible, and costs approximate 4 or more bits of the maximal ADC resolution. In this case helps a measuring instruction for forming averaged values for exact defined conditions (time windows with a selectable numbers of samples).

Parts of the analogue signal processing unit are an offset-adjustable preamplifier (Fig. 2) and modules for special analogue signal handling, like

(a) selectable filters (Fig. 4) with different characteristics,

(b) calibrating multiplexer circuit for self-calibrating systems,

(c) multiplexer with analogue boundary-scan-ability for systems with good on-board testability, corresponding to fig. 2.

So it is possible for students to study the problems of real analogue systems. Simultaneous they have to solve the problems of precision measurement technology in practice.

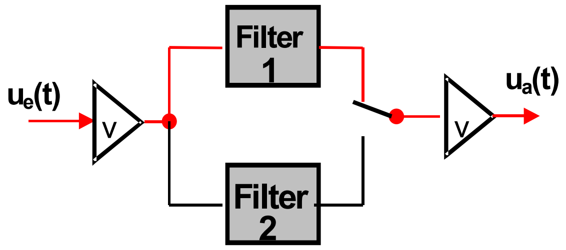


Fig. 4: Module of analogue signal processing

With module corresponding to (a) (selectable filter) we can demonstrate

- the meaning of bandwith of the input circuit in a measurment channel for the available signal frequency range, respectivly
- the effect of using such a filter for noise reduction or
- the meaning of time constant of filters and other circuits (settling time).

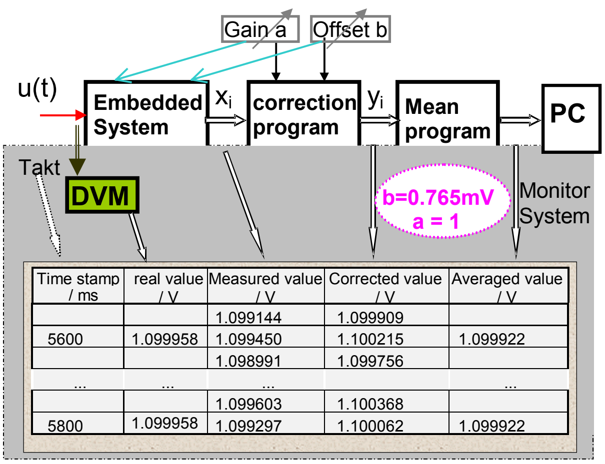
Therefore we have realized a module with selectable filter circuits, a simple low-pass filter and a non-linear filter circuit with reduced settling time [3].

The module corresponding to (b) demonstrates the use of a special multiplexer with additional internal switches to some reference sources (like MAX4539, [4]) for self-calibration.

The module corresponding to (c) opens additionally the possibility of design-for-testability in analogue systems by the standard methods of analogue boundary-scan. Here we applied one of the first useable analog test access device with the "normal" function of an analogue multiplexer. In this case no additional circuit for the test access was necessary, because the test access structure is included in the multiplexer circuitry [5].

For training students it is neccesary to demonstrate the problems of allowed and not-allowed tolerances of measurment devices very impressive. That means, we have to explain possible consequences, because they often ignore those very small tolerances without any valuations. For this task the monitoring measurement system is neccessary.

With this monitoring measurement system the students can realize the exact analysis of relevant variations of any system parameter and they can see the effects of any parameter variation. So we hope, that they can better understand the effectivness of special design rules and methods and the methods of calibrating, too. Therefore it is especially to show the resulting differences in the real and in the binary number range, including the given limits of tolerances. These tasks are realizeable with a system of LabView-libraries. One library controls the embedded system with the implemented commands and transfoms the received answer in a file or an internal variable. This library can be embedded in a higher program library, which controls also the monitoring measurement system, including the calculation of correction values and displaying the results.



Time stamp / ms	real value / V	Measured value / V	Corrected value / V	Averaged value / V
		1.099144	1.099909	
5600	1.099958	1.099450	1.100215	1.099922
		1.098991	1.099756	
...	...	...		...
		1.099603	1.100368	
5800	1.099958	1.099297	1.100062	1.099922

Fig. 5: Evaluation protocol

Next step is to demonstrate the stability of the working point over a longer time. Then we can show the shift of these correcting values over the time. This point is only for documentation of interest, if surrounding conditions are also measured. Therefore we have planed to use the MCU-internal ADC for measuring the temperature on the board additionally.

3. Conclusion

It could be shown, that it is possible to design a measurement system of high resolution on a relative simple technological level by using noise reduction methods and embedded correction features. One has to take in account the analogue design and layout rules by including an additional precision reference element and switches. These components has to be programmable in relation to the diagnosed internal states. Of course, the last point can only be realized with respect to the requests of the concrete surroundings.

Some problems in the realization phase were forced through the non-availability of qualified elements - in contrast to the offers of the distributors and the producers. But now, the most producers offer new ADCs with integrated self-calibration facilities. The using of those possibilities must be trained. The presented evaluation system can help for understanding this technology.

References

[1] Frühauf, U.; Liu, J.-G.: "Fault-tolerant measurements of electrical quantities based on self-calibration", XV IMEKO-World Congress, Osaka (Japan) June 13-18, 1999, Proceedings Vol. IV, pp 135-142

[2] Liu, Ji-Gou: "Eigenkalibrierende Messverfahren und deren Anwendungen bei den Messungen elektrischer Größen", Fortschritt-Berichte VDI Reihe 8 Mess-, Steuerungs- und Regelungstechnik, Nr. 830 VDI-Verlag, Düsseldorf 2000, ISBN 3-18-383008-6

[3] Burt, Rod; Stitt, R. Mark: "Fast Settling Low-pass Filter", Application Bulletin AB-022, Burr-Brown Corporation, 1991

[4] -: "MAX4539/4540 - Low-Voltage, Single 8-to-1 and Dual 4-to-1 Cal-Multiplexers", Maxim Integrated Products, 19-4780, Rev 1, 6/99

[5] -: "IEEE 1149.4 Analog Test Access Device", National Semiconductor Corporation, DS200041, 2000