HIGH TEMPERATURE DENSITY MEASUREMENT CELL WITH A PCMCIA-INTERFACE

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Abstract: One of the most precise and reliable measurement methods for density measurement of liquids and gases depends on the principles of a mechanical oscillator. With this method the density is determined by measuring the natural frequency of the oscillator. Measurement devices using this method can be categorized in two groups. The first type incorporates the mechanical oscillator in the housing of the device and is mainly used in laboratories. The second type of measurement devices could be defined as evaluation units, because the sensor e.g. mechanical oscillator is external and only connected by means of electrical connections. These types are used in the field of process data control or data acquisition. The reason for separating the sensor from the evaluation unit lies in the fact that such external cells are used on remote locations in the process or the sensor is exposed to extreme physical conditions (e.g. high pressure, high temperatures). The first part of this article gives an overview about the functionality of such a high temperature measurement cell. The second part of this paper is intended to introduce a sophisticated PCMCIA interface which acts as an interface between the external density measurement cell and several hosts like PCs, PDAs or modern density measurement devices.

1 INTRODUCTION

The sensor principle used in this application converts the density of a liquid into the period of an oscillating mechanical resonator. A U-shaped tube, whose open ends are mechanically mounted on a solid base plate, is filled with the liquid. For exciting this mechanical fork oscillator a periodic excitation force is applied, which is in opposite phase to the speed of movement of the tubes, thus compensating the mechanical damping force. The electrical excitation system consists of a speed sensor, a limiting amplifier and an actuator for mechanical feedback. (see Figure 1)

Both the mass M of the tube and the mass $\rho.V$ of the liquid inside as well as the spring constant c of the tube determine the resonant frequency f and its inverse, the period T, according to equation 1. Re-arranging this relationship results in equation 2, which is the basis for the subsequent numerical calculations.

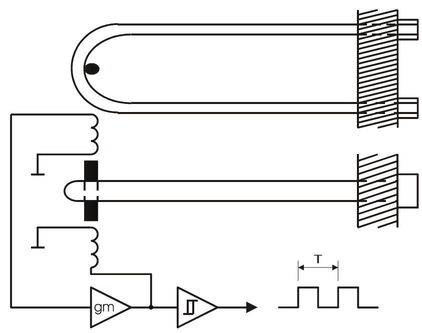

Figure 1: Mechanical fork oscillator (Leopold, Eichberger, 1993)

$$T = 2\pi\sqrt{\frac{M + \rho.V}{c}} \qquad \rho = \frac{T^2}{4.\pi^2.V} - \frac{M}{c}$$

Equation 1: Period of the fork, Equation 2: Density

The frequency of the mechanical oscillator, which is output as a binary voltage or current signal, is measured using a high resolution counter and a

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precise and stable reference oscillator. As standard PCs or PDAs do not have the capability to handle such a signal directly, considerations about how to incorporate such an interface have to be taken (see chapter 3).

2 THE HIGH TEMPERATURE MEASUREMENT CELL

Density measurement at temperatures up to 400 °C significantly increases the useful range of applications, for example in the fields of material research or the petroleum industry. Normally, the mechanical resonator is mounted inside the housing of the instrument, together with its electrical interfaces and a microprocessor control unit.

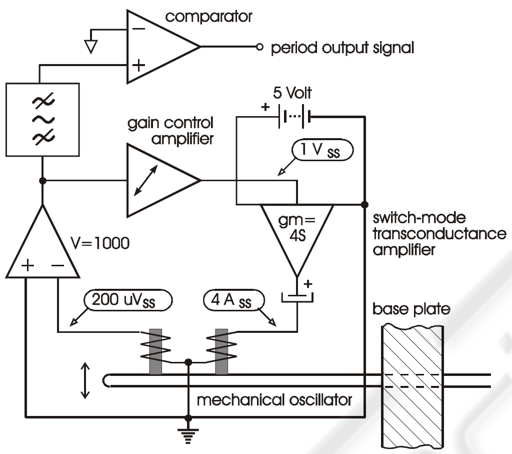

Figure 2: Excitation amplifier (Leopold, Eichberger, 1993)

Due to the demanding ambient conditions an external measurement cell design was implemented. The system can operate as a stand-alone unit or be placed in a temperature-controlled oven. It consists of a mechanical fork oscillator, PT100 temperature sensors and an optional set of electrical heaters. The electrodynamic excitation uses two AlNiCo magnets, mounted on the moving end of the fork resonator, which dip into pick-up and drive coils. These coils are made of five turns of steel wire and attached to a ceramic insulator. An interface box, located nearby and operating at normal ambient temperatures, performs the basic hardware interface functions. The period of the mechanical resonator, temperature data and the power control of the heaters are transmitted or received in a digitally encoded format. Figure 3 gives a functional overview of the excitation system. Four amps of drive current deliver only 200 micro volts from the feedback coil, causing stringent requirements on the analogue signal processing circuitry. The amplitude of the mechanical resonator is regulated by a gain controlled amplifier. A band-pass filter and a comparator provide a precise period output signal.

3 EXTERNAL CELL INTERFACE

External cells most often use a frequency output voltage or current loop (0-18mA) to enable evaluation units to determine the density. In contrast to Lab-Density-Meters, were the frequency signal from the internal cell is directly evaluated by a microcontroller, external cells require an electronic interface to convert the analogue signal in digital values. Such an interface consists of a power supply, an additional microcontroller, a separate housing and communication lines for transmitting a standardized protocol. Figure 4 shows the high temperature cell in its housing. The shielded tubes contain the electrical connections for the excitation system, two PT100 temperature sensors and AC-powered heaters.

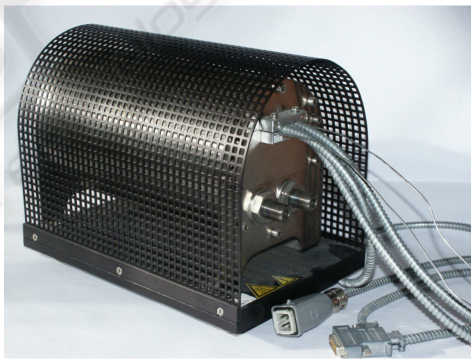

Figure 3: External high temperature density measurement cell (Anton Paar GmbH, 2005)

In order to achieve an economical solution, efforts were made to reduce the complexity of the system and to lower the components count. Finally, the best compromise was achieved by using a PCMCIA interface.

3.1 PCMCIA Interface

PC Cards (PCMCIA, 1998), were the first generation of credit card sized cards, introduced in the late 1980s. The cards provide 68 pins for electrical connections. In general, PC-Cards are either available as memory cards in several technologies (ROM, RAM, FLASH), or as I/O cards (ATA disk-drives, network/modem-, or interface-cards). Depending on the card's thickness, PC-Cards are available in 3 different mechanical types (Type: I, II, II) in the range from 3.3, 5 to 10.5 mm. Independent from the card's technology, the characteristics of the card are described in a special memory area on the card, called CIS (card information structure).

Figure 4: PCMCIA I/O card (Kontron,2005)

Typically, cards only contain Flash devices and a rudimentary control circuit. As the card is powered by the host, no separate power supply is needed. The card kits (housing) are available from different vendors with the necessary plugs and shielded cables. Card kits provide a low cost, high quality housing for electronic circuits. Because of the long availability on the market, most of the laptops and PDA (personal digital assistant) are equipped with a PC-Card slot. Even modern laboratory density meters provide the user with such slots.

3.2 Cards Control Circuit

The main task of the card's control circuit is the precise determination of the oscillator frequency of the mechanical fork resonator. Therefore the signal has to be converted into a binary logic signal which is compared with a precise high frequency crystal time base The digital output of this circuit (gated timer without termination error) has to be stored in data registers which are accessible from the host with the standardized PCMCIA interface.
The realisation of the digital circuitry using a CPLD-technology (complex programmable logic devices) offers a lot of advantages. CPLDs offer the user the flexibility of programming them in the field (ISP) by means of a JTAG-interface. Low power consumption, less PCB (printed circuit board) area, high integration and high level programming support (VHDL, ABEL) are good arguments for the use of these devices.

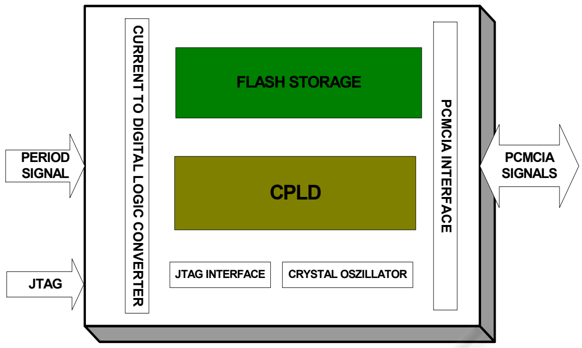

Figure 5: Block diagram of the PC-Card interface

3.3 PLD Logic

The control logic (Röhrer,1989) implemented in the CPLD fulfils the following requirements:

- Counting of the period signal based on a stable and high precision reference crystal oscillator
- Storing of counter results after a selectable gate time (1, 2, 4, 8 sec.) with an additional identifier
- Consecutive measurements, no termination error
- Implementation of data register for the intermediate results, accessible from the host via the PCMCIA interface
- Implementation of a command register (average time register)
- Generation of the chip select signals for additional Flash storage memory on the card.

For the implementation of these requirements, HDL-Tools (hardware description language) capable for many languages (VHDL, ABEL, VERILOG) are available from different vendors. Typically, the required tools are provided by the vendor of the CPLD.

3.4 PC-Card Structure

The logic circuits in the CPLD and the additional Flash Storage memory on the PC-Card are implemented according to the following memory map:

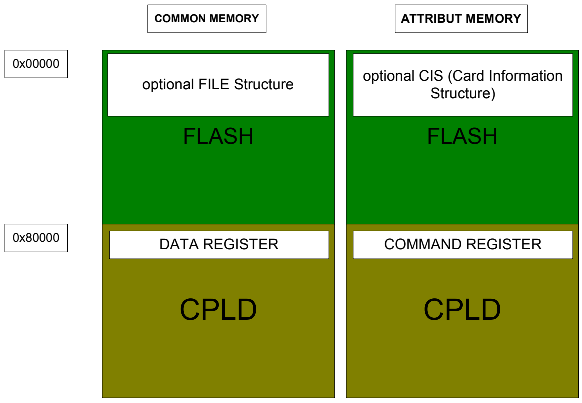

Figure 6: Memory mapped I/O card

As shown in Figure 6, the PC-Card is designed as a memory card with an address range of 64 kByte In the lower part of this range, the built-in flash memory is selected and provides two types of information. The first, called Attribute Memory, enables the PC-Card to be used in combination with an operation system. A special data structure (CIS, Card Information Structure]) located at the address: 0x0000 describes the card's characteristics in a standardized way (PCMCIA, 1989). One of the characteristics of this PC-Card is the command register at the location: 0x80000, which is used to set the gate time of the period measurement. The second kind of information is placed in the common memory address area. An optional file system located at the address which is defined in the attribute memory can be used to store additional information (see chapter 4.5). Above the address: 0x80000, an eight-byte data structure stores the measurement results. Details of the structure are shown in Figure 7.

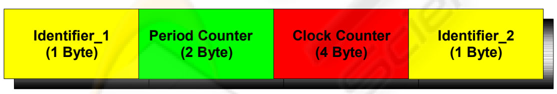

Figure 7: Data structure of the period measurement

Every time a measurement cycle is completed, the identifier is automatically incremented. The result of the measurement is calculated by dividing the period counter by the clock counter. Synchronization of the reading and the measurement logic is done by evaluation of both identifiers. Only if these identifiers are equal, the data structure is accepted to be consistent.

3.5 Software Interface

A PC-Memory-Card type was developed for this application. Such cards do not require specialized software drivers, because they are detected correctly by modern operating systems. Access to the memory mapped data registers is implemented using a file-mapped-I/O method. A special file image is placed in the Flash-Storage with a total length of 0x80000 Bytes. In this image the last file in the directory structure is not a real, but a virtual data file. Within the FAT (File Allocation Table) the content of this virtual file is linked to the data registers in the CPLD outside the Flash-Storage area. The software running at the host computer can now easily access the measurement data by issuing a read command to this file. Calibration data and parameters as well as customer specific algorithms are stored at the host. The application program uses this additional information to calculate the density from the measurement data.

The remaining files on this image are real data files. They hold the necessary information concerning the PC-Card (documentation, evaluation program etc.).

4 CONCLUSION

The application of the described PC-Card-Interface shows excellent results in the field and offers for the evaluation of external density cells a convenient solution which is capable to interact with PCs, PDAs, modern laboratory density meters and evaluation units (Anton Paar GmbH, 2005). The PC-Cards CIS informs the host about the file system and is therefore mapped as an exchangeable volume without the need of special drivers. Due to the file-mapped I/O structure, only simple file access is required to get the measurement data.

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