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VIRTUAL ELECTRONIC SCALES

D. Kovacevic [1]***, S. Skundric*** [1] ***and B. Dimitrijevic*** [2]
[1] Electrical Engineering Institute "Nikola Tesla",Inc., Belgrade, Yugoslavia
[2] Department of Measurement, Faculty of Electronic Engineering, Nis, Yugoslavia

Abstract: The paper presents a new concept of virtual electronic scales (VES) conceived as a PC peripheral. The traditional approach, "specific scales for specific application", has dominated the development and production of both mechanical and state-of-the-art electronic scales. The main aim of this paper is to promote a PC-based approach – electronic weight scales as a virtual instruments. The paper offers a detailed presentation of originally developed hardware and software structures of VES called Soft Scales, based on strain-gauge load cells, of 2¸200 kg measurement range, accuracy class III*, up to 10,000 scale intervals. Finally, a list of specific applications and realisation of both trade scales and body mass index measurement sistem as a virtual instruments, together with a brief measurement-technical comparison between the classical and PC-based approach are presented.*

Keywords: computer-based measurement, virtual instrumentation, electronic weigh scales, sensors, transducers

1 INTRODUCTION

In the domain of electric measurement the end of the century is characterised by a very close linking of metrological and information subsystems. Developing from analog, through digital to intelligent instrumentation, contemporary instrumentation today is passing through a phase designated as "virtual instrumentation". Although the precise meaning of the phrase has not quite been agreed upon, it refers to complex measurement systems based on PCs with software resources as the key elements of the system [1].

Weighing by means of scales, as a branch of measurement technique, has relied for centuries on the achievements of precision mechanics and mechanical engineering. The construction and manufacture technology of mechanical scales have been developed and improved. When it seemed that scales had reached the peak of perfection, electrotechnics provided fresh impetus to their development by introducing elements of electronics such as transistors, integrated circuits and microprocessors, thereby making possible transmission and processing of measurement results. Finally, computer technology has entered the sphere of weighing. Software designs have made possible a higher degree of quality and opened up new possibilities of application of scales. Weighing has thus become a complex interdisciplinary activity integrating the achievements of metrology, mechanical engineering, electrotechnics, electronics and informatics. Fig. 1.a. shows the structure of electronic scales made up of sensor, electronic and information subsystems.

The paper presents a new concept of virtual electronic scales (VES) conceived as a PC peripheral. This concept is based on several years of research into and development of strain-gauge-based load cells (SGLC) [2] [3], electronic scales [4] [5], as well as computer-supported measurement systems [6], [7], [8], at the Electrical Engineering Institute "Nikola Tesla", Belgrade, Yugoslavia.

The traditional approach to the development and manufacture of scales, both mechanical and state-of-the-art electronic scales, has been "specific scales for specific application", as in the case of trade, post office or baby scales, etc. The main aim of this paper is to promote the concept of VES as a PC-based virtual instrument. This concept is characterised by the fact that the choice of application determines the functioning of the measurement instrument. SoftScale is realy multiple instruments in one. Buy the hardware only once and add the functionality you need – as you need it. Based on the general structure of contemporary electronic scales shown in Fig. 1.a and the basic idea of realising as many applications as possible with the least hardware and software changes possible, specific requirements for the realisation of each of the three subsystems were laid down. These include as wide a measurement range as possible, a high level of accuracy (automatic calibration, system calibration, software compensation and measurement error compensation), flexibility in the choice of resolution and speed of measurement, the possibility of changing and expanding the functions and characteristics.

Fig. 1.b. shows a simplified block diagram of VES of 2-200 kg measurement range, accuracy class III, up to 10,000 scales intervals, connected to a standard-type PC hardware and software. It consists of a sensor part (SP), an electronic part (EP), and a PC. The SP has two SGLCs linked mechanically in series inside one scales, thereby increasing the dynamic range of the scales 10 times, and a temperature sensor (TS) for monitored temperature compensation. The EP has four inputs (two for SGLCs, one for TS and one for reference voltage) and, as the central part, a bridge transducer (BT) based on the delta-sigma modulation technique.

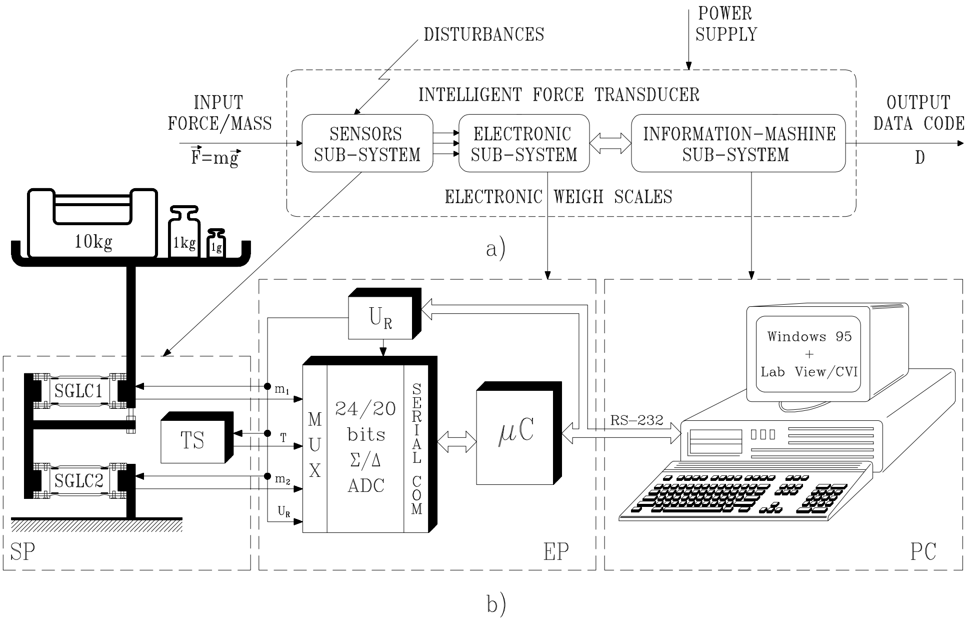

Figure 1. Intelligent force transducer or electronic weigh scales as a system: a) Principle block sheme; b) Simplified block diagram of multifunctional electronic scales consisting of: sensor part (SP), electronic part (EP) and computer (PC).

The system thus conceived makes possible the realisation of a great number of applications while using the same hardware and introducing the required changes in the software applied. The list of applications presented in this paper includes trade, post office and medical scales, unit-counting scales, scales determining humidity level, and is open to further development as far as the potential of the hardware applied allows. This concept is basically open to all PC applicatios, thus all forms of electronic communications are possible via Ethernet, Internet or other protocols. The concept is capable to cover such a wide spectrum of applications through networked data procesing to in-process meintenance and service or software updating.

2 THE HARDWARE STRUCTURE

The hardware structure is conceived so as to make possible the realisation of as many applications as possible without changing the hardware and with minimal changes to the software.

SGLC1 and SGLC2 are force transducers of the platform type, most often used for the construction of low-capacity electromechanical scales (2-500 kg). The actual construction used is the one designated in literature as a coupled-double-beam load cell, together with certain original modifications presented in some detail in the relevant literature [2]. The basic modification with these SGLCs is the possibility of subsequent creep error compensation by means of the elastic console coupling method, that is, two semi-bridges forming a full unbalanced Wheatstone bridge. SGLC1 and SGLC2 are designed for accuracy class C, 3,000 scale intervals and the nominal load of 2kg and 20kg respectively. Linked mechanically in series, with a common load receiver, as shown in Fig. 1.b., they make possible a considerable increase of the measurement range, that is, the measurement of both small (of the g order of magnitude) and large (of the kg order of magnitude) masses with approximately the same measurement error. For loads of up to 2 kg, both cells are loaded, but only the signal coming from SGLC1 is relevant for the measurement. When masses of more than 2 kg are measured, SGLC1 is mechanically protected from overload, and the signal coming from SGLC2 is used for the purpose of measurement. In this way, a more accurate measurement range increase is achieved than in the case of the usual method of using a single load cell with multiple measurement ranges.

The temperature compensation for SGLC1 and SGLC2 is effected by means of classical compensation methods. The compensation for zero temperature change is effected by using temperature-adjustable resistors in the corresponding branch of the bridge, whereas the compensation for temperature sensitivity change is effected by means of temperature-adjustable resistors in the power supply branch. The possibilities of this sort of compensation are limited, however, and are applicable up to accuracy class C 5000. Further progress is possible only if temperature is measured by means of TS, as shown in Fig. 1.b., and correction by means of corresponding software algorithms.

The requirements concerning the accuracy of temperature measurement and complexity of compensation algorithms are directly proportionate to the magnitude of initial temperature errors. If, in terms of temperature characteristics, SGLC1 and SGLC2 fulfil the requirements of class C, with 2,000 or 3,000 scale intervals in the 0^0C–40^0C temperature range, it is possible, by means of software methods, to increase the accuracy class to at least 10,000 scale intervals by measuring temperature using some of the classical TSs (thermoresistant or p-n junction) which guarantee a repeatability of at least $\pm 0.5^0$ C.

The BT is a complete analog front end for both DC-excited and AC-excited bridge applications, as weight-scales or pressure measurement. BT receives signals directly from transducers and outputs a serial digital word [9],[10]. The PC is of standard configuration, making possible the use of the Windows platforms. The connection between VES and PC is effected by means of the standard serial interface RS-232C.

3 THE SOFTWARE STRUCTURE

The appearance and constant development of PC have made it possible to combine various types of scales into a single universal scales without any decrease in the characteristics of each particular application. PCs, with their considerable hardware and software resources, particularly in the sphere of static and slow-changing measurement, have a significant advantage over microcontrollers because writing programs in a high-level language is rather more efficient than writing programs in the assembler. The testing, correction and change of programs are also much simpler. In the realisation of VES the criterion of efficient programming was adopted, so that only the most basic and essential program routines on the level of BT were written in the assembler, namely, the configuration of hardware, input and output, and calibration of offset and sensitivity, whereas all of the remaining software was written in the LabWindows/CVI for Windows 95 program packages [11]. The package is designed for the realisation and programming of virtual instruments. It combines all the characteristics of object and graphic programming, which simplifies and makes faster the task of writing particular applications.

Through the serial interface RS-232C the PC is linked to the microcontroller in the electronic part of the scales, as shown in Fig. 1.b. It is through this link that the PC sends commands to the controller and receives the measurement data. The PC monitor is used as a universal display which, depending on the type of scales, changes its appearance easily. Fig. 2 shows the appearance of the PC monitor screen, together with the main menu, submenu of applications, and the realisation of VES as trade scales. The software structure is menu-driven: from the main menu, the subprograms for configuration, compensation, calibration and applications may be called up.

3.1 Configuration block

The configuration is effected both on the level of BT and on the level of PC, and all the configuration registers on BT are accessible to PC through the serial link. The number of input channels may be adjusted, as well as the serial communication parameters and digital filter parameters; control, status, test, etc. parameters may also be set up.

3.2 Compensation block

The overall performance of specific-type scales greatly depends on the manner and efficiency of the compensation techniques performed. On the level of BT, the system supports a number of calibration options, the most important ones among them being the internal and system calibration. The calibration sequences are of decisive importance for the short-term and long-term stability of VES. The compensation block on the level of PC contains important algorithms for the purpose of compensation for particular types of errors, including noise histogram analysis, linearity and hysteresis analysis, creep error correction, software temperature compensation.

Statistical techniques can be used to acquire performance measurements, assess the effects of noise and compensate for noise. The noise histogram analysis assumes that noise is random, with a Gaussian distribution. The actual mean differs from the sample mean by the range of peak-to-peak noise divided by the square root of the number of samples *n*. Thus averaging multiple samples reduces the error by $(n)^{-1/2}$. Averaging sacrifices throughput for improved resolution and reduced uncertainty.

The non-linearity error correction in transducers and instruments has been dealt with in a number of studies, from the earliest analog passive or active circuits, through digital hardware, to digital software linearisation techniques. The software techniques have developed from the look-up tables methods to the application of very complex algorithms of numerical analysis. This paper adheres to the criterion of achieving the required level of accuracy by applying as simple as possible an algorithm. There exist three possible linearisation methods in VES: 1. multiinterval linear interpolation with a maximum of 11 calibration points; 2. linearisation and calibration in 3 points; 3. linearisation by means of polynomials with a maximum of 11 calibration points. A detailed comparison of the possibilities of the algorithms proposed in the linearisation of SGLC would be beyond the scope of this paper.

A new and very attractive sphere of research of particular importance that has emerged in connection with virtual instruments, including “virtual scales”, is the possibility of hysteresis and creep error correction by means of software methods. A more detailed analysis of one proposed methodology is presented in the literature [3].

In the section dealing with the hardware structure, in connection with the software compensation to counteract the influence of temperature, certain suggestions were made concerning the required level of accuracy when measuring temperature, since temperature is the basic disruptive factor. The simplest software algorithm for temperature compensation is linear interpolation throughout the work range of temperature. If there exist greater requirements, either concerning the level of accuracy or for an exceptionally wide work range of temperature, or in case that non-linear effects of temperature-induced errors are manifested, the application of multiinterval linear or polynomial interpolation is advisable, wherein the interpolation error monotonously converges towards zero with the increase of the number of intervals, that is, calibration points.

3.3 Calibration block

Finally, with the compensation parameters adjusted, the full calibration procedure is carried out for the purpose of determining the overall measurement uncertainty or determining the allowed error margin for a given application.

3.4 Application block

The concept proposed and the hardware and software structures presented are task-oriented operating and application system which is strong enough to support the realisation of VES with a great number of applications.

4 APPLICATIONS

Fig. 2. shows one of the layouts form the applications of multifunctional scales where the advantages of the graphic environment are fully manifested. The option chosen is Applications-Trade. In addition to the main menu and the submenu of applications, the screen contains three virtual displays for:

a) mass (kg),
b) unit price (DM/kg),
c) total (DM).

On the right-hand side of the trade scales panel are buttons with some products whose unit prices are memorised. By pushing the appropriate button, the unit price of the product in question is automatically entered and the total is calculated. Naturally, the unit price may be entered manually, from the numerical part of the PC keyboard. Any change of parameters, such as the numbers pertaining to mass, unit price or total, or a change of numbers, modes and arrangement of the buttons with memorised unit prices in the concept of the virtual instrument is very simple. Such changes, which may be dictated by market requirements, would have required months of work and cost a great deal in the case of the classical concept.

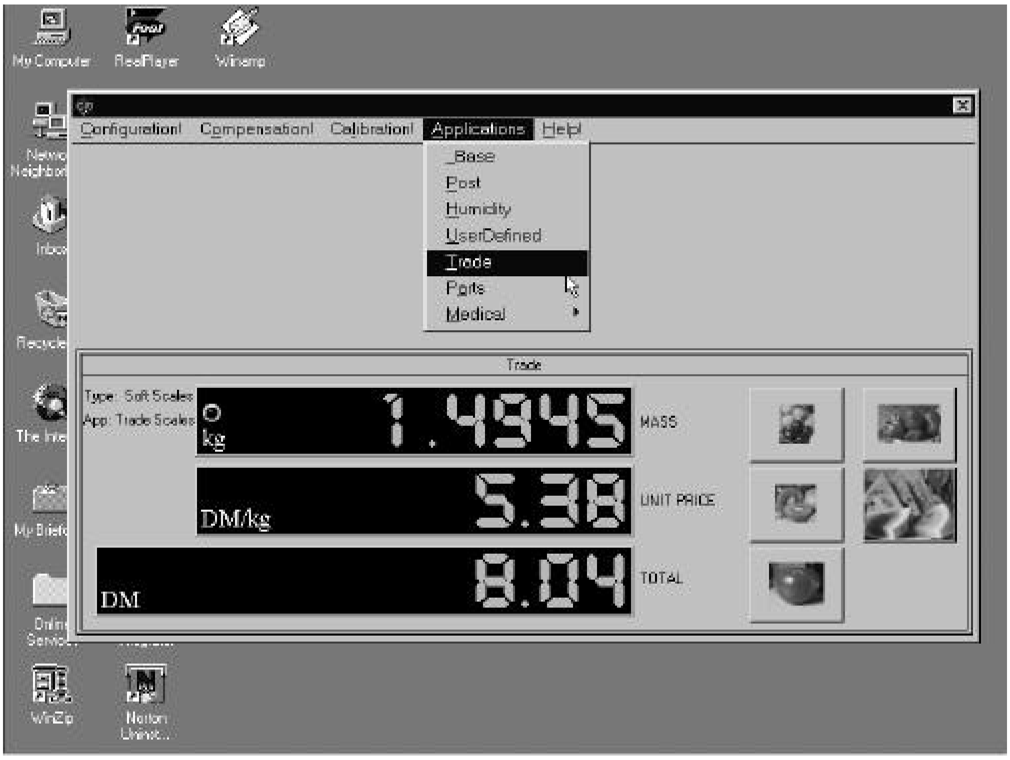

Figure 2. The outlook of PC monitor screen with the main menu and realization of the SoftScale virtual electronic scale as trade scales.

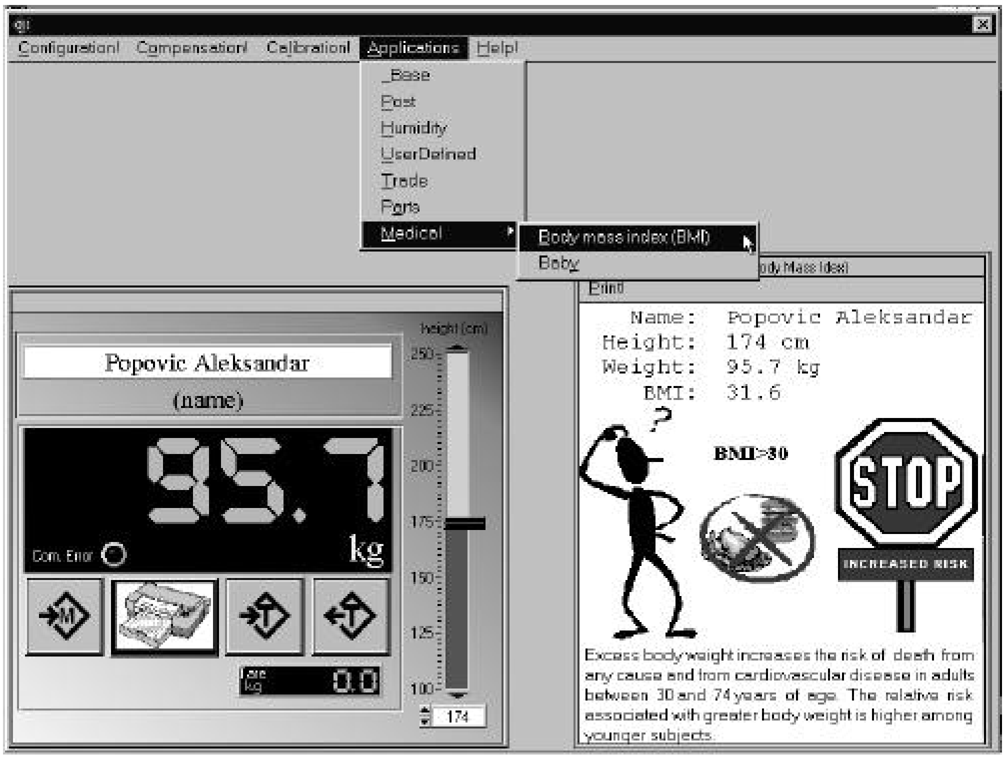

Figure 3. The outlook of PC monitor screen with the main menu and realization of the SoftScale virtual electronic scale as BMI measurement system.

Body mass index (BMI) has been the medical standard for obesity evaluation since the early 1980s. Gaverments researchers developed it to take heigh into accaunt in weight measurement. BMI–the weight in kilograms divided by the square of the height in meters–is known to be associated with healt state of the person. BMI measurement system, besides mass measurement, must have some kind of distance measurement. Fig. 3 shows the outlook of PC monitor screen with the main menu and realization of the SoftScale virtual electronic scale as medical application – BMI measurement system.

The applications realised, as well as those that may be defined by the user, may easily be reconfigured, reprogrammed or recalibrated with altered requirements, which makes the concept of VES exceptionally flexible and open to further development.

5 CONCLUSION

The development of instrumentation in the last decade of the twentieth century has culminated in the emergence of the virtual instrument technique. The application of the virtual instrument technique in the domain of electronic scales makes possible the introduction of a new philosophy of development and manufacture of scales. Strong, flexible and unified hardware combined with powerful, flexible and easily changeable software resources for the production of virtual instruments make possible the manufacture of multifunctional scales which are easily adjusted to some specific purpose, resulting, compared to the classical concept, in improved performance, reduced cost and time of development.

The paper describes an original VES realised as a PC peripheral, of 2-200 kg measurement range, accuracy class III, 10.000 scale intervals. The specific features of the hardware and software solutions realised were pointed out. In addition to the classical theory of software compensation of SGLC errors, the possibility of software correction of hysteresis and creep errors of SGLC, which was rather more difficult within the framework of the classical concept, was pointed out. Some of the concrete applications of VES were briefly described, together with a detailed description of the realisations of both trade scales and BMI measurement system. This concept is basically open to all PC applicatios, thus all forms of electronic communications are possible via Ethernet, Internet or other protocols.

In the future, we may expect with certainty further integration of digital instrumentation and information technologies. It is, therefore, all the more important to pay greater attention to the concept of virtual instruments, from terminological definitions and clarification to the sphere of legal metrology.

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AUTHORS: Dr. Dragan KOVACEVIC, Institute "Nikola tesla", 11000 Belgrade, Koste Glavinica 8a, Yugoslavia, Phone: +381 11 3690-674, Fax: +381 11 3690-823, E-Mail: dkovac@ieent.org ,
Prof. Dr. Bozidar DIMITRIJEVIC, Faculty of Electronic Engineering, 18000 Nis, Beogradska 14, Yugoslavia, Phone: +381 18 46-466, Fax: +381 18 46-180, E-Mail: dimitrijevic@elfak.ni.ac.yu