High Speed Monitoring System for Electrical Equipments

M. Brojboiu[1], V. Ivanov[1] and S. Ivanov[2]

[1] Department of Electrical Apparatus and Technologies
Faculty for Electrical Engineering, University of Craiova
107, Decebal Blv, Craiova, 200440 Craiova (Romania)
Phone: +40 251 435724, Fax:+40 251 436447, e-mail: mbrojboiu@elth.ucv.ro, vivanov@elth.ucv.ro

[2] Department of Electrical Drives, Faculty for Electromechanical Engineering, University of Craiova
107, Decebal Blv, Craiova, 200440 Craiova (Romania)
Phone: +40 251 435724, Fax:+40 251 435255, e-mail: sivanov@em.ucv.ro

Abstract. The modern electric equipments include performant monitoring systems based on microcontrollers. The hardware architecture and software structure depend on the application.

The paper deals with an experimental monitoring system developed based on a versatile microcontroller and suited transducers, as well as with the user interface that allows the on-line configuration of the hardware system.

In order to obtain an optimised code, the assembling programming was chosen, by using the well developed interruption system of the microcontroller. The user interface was developed by the way of Graphic User Interface of Matlab.

Key words

monitoring, microcontroller, assembler, user interface.

1. Introduction

The on-line monitoring and diagnosis of the equipments is an actual concern due to the necessity of higher reliability in all the domains of the industry. The electrical equipments, being characterised by small time constants and high risk, impose major efforts in order to develop competitive monitoring systems. On the other hand, the costs involved by such systems need to be as low as possible, without cutting the imposed performances.

As such monitoring systems implies two main parts: hardware (sensors, transducers, A/DC, serial transmission) and software (field module programming, transmission protocols, user interface), the two subsystems must interact without conflicts, achieving the expected performances.

The paper deals with such simple, experimental monitoring system, developed by the authors, by using a commercial microcontroller within the 8051 family. The architecture of the microcontroller programming will be mostly be detailed.

2. The hardware architecture

A. Microprocessor

The hardware part of the monitoring system is centred on the Dallas microcontroller DS87C550. This type of microcontroller is code fully compatible with the 8051 family microcontrollers, being equipped with many integrated peripherals [1] that make it suitable for embedded applications. More than that, being equipped with the high speed core specific to the Dallas microcontrollers (four clock periods per machine cycle, in opposition with 12 clocks for the "classical" 8051 family), the performances achieved by the hardware subsystem based on this module make it very suitable for the on-line monitoring of the high speed electrical equipments.

Along the specific performances and facilities of the DS87C550 Dallas microcontroller, it can be highlighted: the existence on-chip of an eight channels, 10 bits analogue to digital converter, with internal or external reference; four 8 bits PWM channels; 55 digital I/O lines; two full-duplex serial ports; 16 interruption sources, 6 of them being external.

Additionally, the hardware facilities of the microcontroller, simplify its integration in distributed multi-processor systems, that communicate on a common bus.

The Figure 1 depicts the bloc diagram of the acquiring and transfer module. It consists of the blocs: *Sources*, *Controller*, *Local console*, *Inputs*, *Outputs* and *Serial communication line*. The *Sources* bloc is supplied by a double voltage ±9V. By the way of three precise voltage regulators, it supplies the regulated voltages to the micro system. The *Controller* bloc is the core of the module and consists of the controller itself, the full duplex RS485 serial interface, connector to the 7 digits display, digital open collector output, that can be used for commanding a power element (relay), non-volatile serial EEPROM with 32 bytes, for saving adjusting parameters or essential events, 8 micro switches for possible changes of the system's functionality, LED for signalling the state of the system.

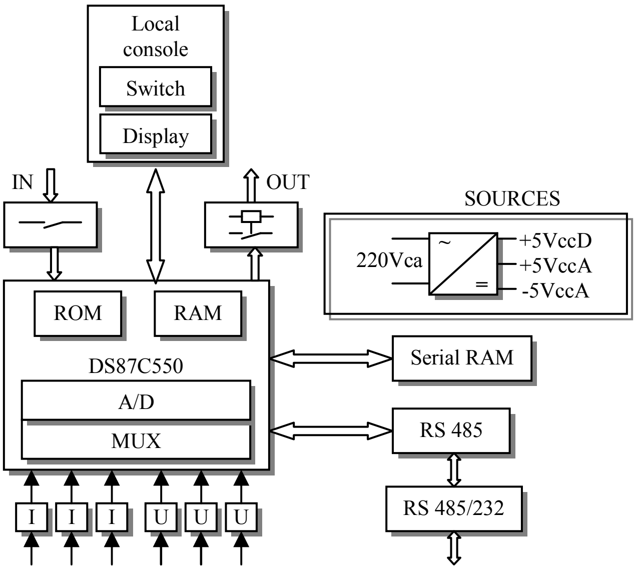

Fig. 1. Main structure of the hardware subsystem.

As protocol for the serial communications was chosen RS485, due to its advantages comparing with the wide spread RS232 or RS422.

B. Measurements

In order to integrate the mentioned component in the hardware subsystem of the monitoring structure, specific to the electrical equipments, special transducers must be used (Fig. 2).

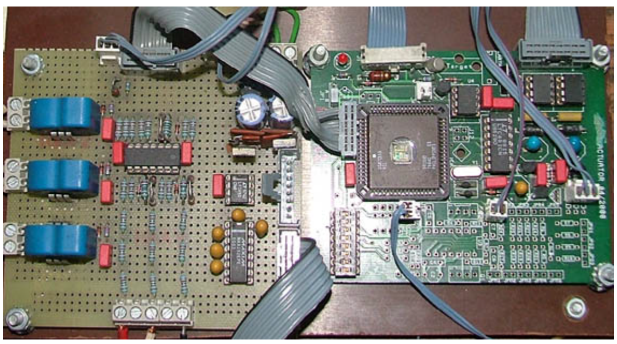

Fig. 2. The hardware subsystem.

The system was designed to acquire all the three phase currents and voltages. As current sensors, LEM transducers LTS15-NP are used, special adapted to the microcontroller based systems (single ended supply) [2].

Concerning these transducers there are two important aspects that must be pointed out, regarding the use in digital systems:

– supplying voltage is 5 V;
– the output is single polarity, with a 2.5 V offset and ±0.625 V trip, special adapted to the usual 8 bits analog to digital converters.

The voltages are measured by using three precise voltage dividers, built with 1% resistors. These dividers were designed in such manner to obtain, at the rated voltage, a trip by ±0.5 V. The 1% tolerance is quite enough, but more important is the thermal stability. For this reason, for building these dividers were used resistors with identical thermal factor.

The compensation of the possible offset both of the current transducers and of the resistive dividers is performed a single time, at the system setting, by using the calibration routine. This task is achieved only in local-mode control, by proper configuring the micro switches. The obtained values are stored in the non volatile serial EEPROM RAM. At each start of the system, the offsets' values are read from the serial non volatile RAM and further used for the correction of the acquired samples.

The same non volatile serial EEPROM RAM is used to store the number of the commutations performed by the installation, available at the user's demand. Due to the importance of stored values, at start, a short routine verifies that the data are not corrupted.

The domain of the possible input signals reaches 830V for the voltages, 8.2A for the current respectively. We mention that in what concern the current domain, it corresponds to the 5A connection of the transducers and can be easily extended to 12.3A or 24.6A with different connections. In order to extend the measure domains, it is also possible to have external voltage and/or current transformers.

C. Control

The whole hardware subsystem is fully controlled by a fast serial interface based on the RS 485 protocol.

The sample frequency is fixed, but programmable by the user interface by the way of the serial link, depending on the number of channels to be acquired, in the range 175 μs – 1 ms. Being programmed using the assembly language, the whole advancement of the acquisition task is based on using the interruption system of the microcontroller.

3. Programming architecture

For the fastest and efficient behaviour to the user's demanded functions, the acquiring and transfer module was programmed in *assembler*, by using the complex *interrupting system* of the controller.

The tasks performed by the main program are depicted in Fig. 3.

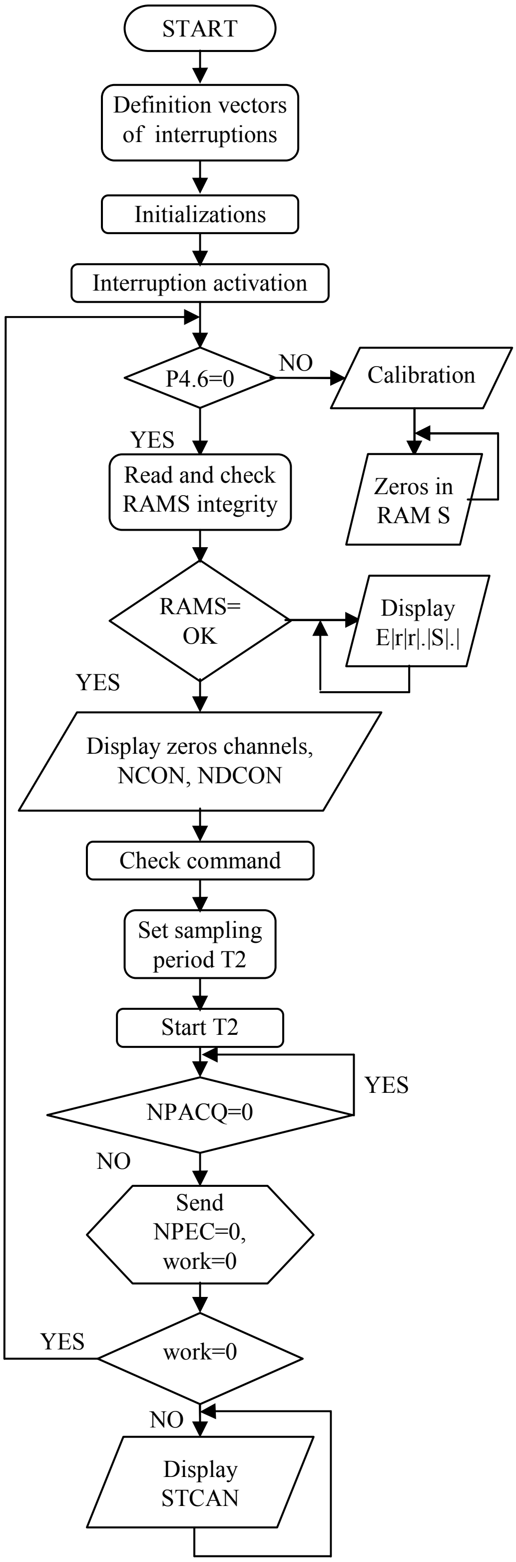

Fig. 3. The flowchart of the main program.

At the first operation, a calibration procedure is called, that determines and stores in a non-volatile serial RAM, the channels' offsets, used further for the samples correction.

By using the interruption system of the microcontroller, the code, written in assembly, is quite compact and efficient. The whole acquisition process is started by the serial port interruption that receives a command generated by the user interface (on-line). Depending on the structure of the channels to be acquired, the sampling period is programmed within a Timer, in order to have equidistant samples. At each Timer interruption, all the programmed channels are sampled consecutively, based on the EOC interrupt.

Due to the limitations of the internal RAM memory of the microcontroller, the acquisition strategy was fixed to get all the time *120 samples* within *20 ms*. Depending on the option of the user, the following types of acquisitions can be performed: one channel (phase voltage or current) with 175 μs sampling period; two channels (phase current and voltage of the same phase) with 350 μs sampling period; three channels (phases currents or voltages of the three phases) with 500 μs sampling period; six channels (all phases currents and voltages of the three phases) with 1 ms sampling period. The equidistance between the acquired data packages is achieved by a proper programming of one Timer of the controller, which will generate an interruption at specified intervals. Immediately after the acquisition of the first sample, the transmission routine is started and consequently, the acquisition and the transmission work in parallel, on the same bank of data.

The software structure of the acquiring and transfer module is organized as the main program (*init1*) and the more routines: *i_rec* – the routine that treats the receiving and transmission interruptions of the serial communication port; *acq* – the routine that starts the acquisition of the samples, formats and stores the current sample, at each EOC interruption; *send* – the routine that sends on serial port the 120 samples; *iext* – the routine activated by the external interrupts that increments the number of switches-on or switches-off, stored then in the non volatile serial RAM; *calibr* – the routine that performs, at the very first start up, the measurement of the zeros of all the six channels, then stores them in the non volatile serial RAM and resets the number of commutations of the equipment; *rw_rams* – the routine that reads and writes a byte in the non volatile serial RAM, at the generic address updated at call; *delay* – the routine that generates the different delays used in the programs.

4. Experimental results

The described hardware subsystem and user interface were used to monitor different loads. The results confirm the good accuracy of the system (Fig. 4).

As an example for the synthetic values displaying, Fig. 5 presents the results for the high inductive load, when the phase B was selected as monitoring channels.

The results obtained with the experimental microsystem are compared with the information found with an industrial measurement equipment, the Fluke 196 power scope.

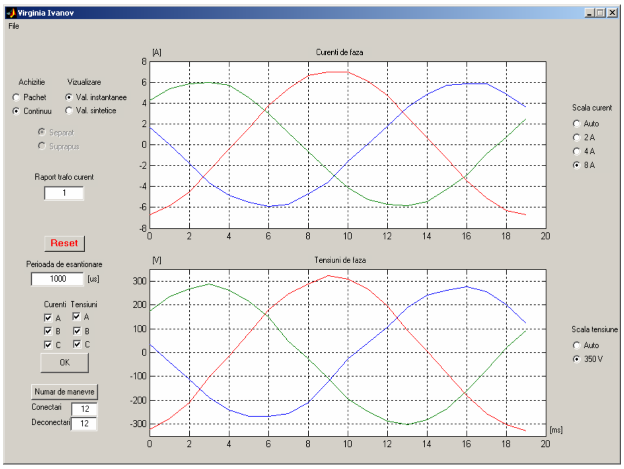

Fig. 4. Experimental results with resistive load.

Fig. 5. Synthetic values for the phase B of an inductive load.

Figure 6 depicts the instantaneous (a) and synthetic (b) values obtained with the microsystem. Figure 7 contains the plots of the screen of the scope.

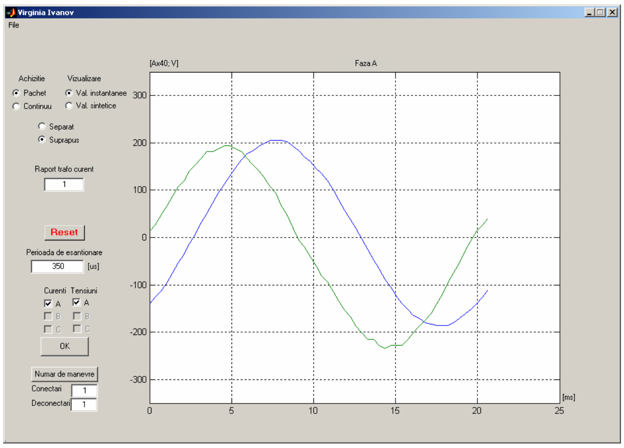

Fig. 6.a. Instantaneous values for the phase A of an inductive load.

The assembly of the experimental results prove the fidelity of the displayed monitored signals and the accuracy of the synthetic values computes based on the samples obtained with the built micro system.

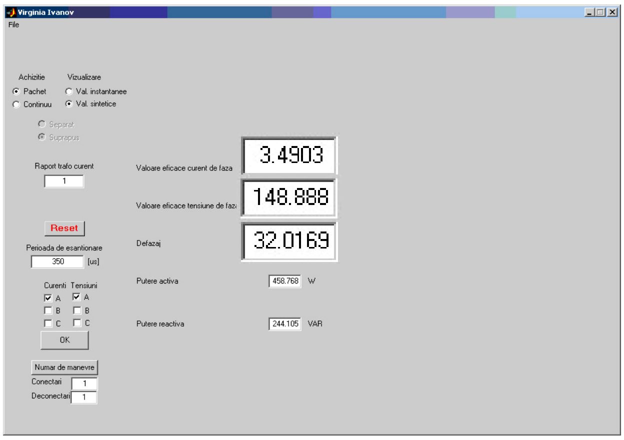

Fig. 6.b. Synthetic values for the phase A of an inductive load.

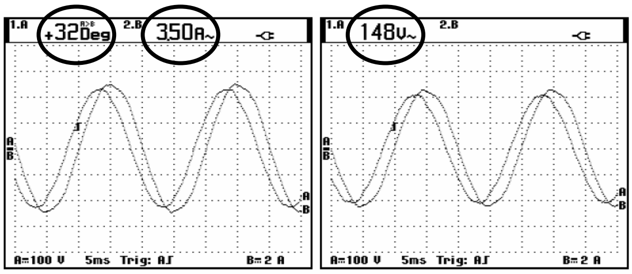

Fig. 7. Fluke 196 plots.

5. Conclusions

A simple, experimental model of a monitoring system of the electric equipments was presented. The experimental results, compared with the indications of classical measurement devices confirm the correctness, both of the microcontroller programming and of the algorithms specific to the user interface.

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