Moving Toward Full Automation of High Accuracy Multifunction Instruments Calibration Systems

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Abstract: The main purpose of this paper is to present a simple and straightforward proposal for electronic AC-DC transfer standard (Fluke 792A) automation. It was included in one of our multifunction calibration systems, reducing the calibration time, still keeping the same high accuracy results. Details regarding calibration system as well as AC-DC transfer standard automation sub-system and experimental results are shown.

Keywords: automation, calibration, AC-DC transfer, standard, automated switch.

1. INTRODUCTION

The voltage and current laboratory (Latce) of Inmetro (Brazilian National Metrology Institute) is responsible for carring out the realization, representation, maintenance and dissemination of the volt and ampère in Brazil, as well as for keeping and carring out the conservation and traceability of the national standards of voltage and electrical current quantities.

Although there is a wide calibration lab network in Brazil, which provides calibration services for industries, another labs etc., their instruments and standards need to be calibrated at Inmetro, to ensure their traceability to SI units. Every year, Latce calibrates more than 150 high accuracy multifunction instruments in DC voltage, AC voltage, DC current and AC current. This number would be impossible to achieve based on manual calibrations. That is why, in the 90's, Latce started the automation of its calibration systems.

A big step was taken at the end of the 90's, when Latce developed a new automated system. This new system was composed of one commercial potentiometer and its extender (MIL 8000A and 8001A), capable of measuring DC voltage, ranging from 10 mV to 1 kV, achieving an accuracy level of approximately ±1 μV/V [1]. This system brought a big advance to Latce at that time, allowing it to attend satisfactorily the increasing calibration services requests.

From then on, other automated systems have been developed at Latce, in order to measure also DC current, AC voltage and AC current. However, some measurements still needed operator's interference. When a source or other instrument was calibrated in AC voltage with an electronic AC-DC transfer standard (Fluke 792A), calibration software warned the operator when its range had been fully calibrated, so the knob of the transfer might be moved to the next range.

A rising demand of multifunction instruments calibration led the laboratory to develop a complete Fluke 792A AC-DC transfer standard automation. In this sub-system, the AC-DC transfer knob can be moved using a low-cost automated range switch stepping motor-based. Hence, AC voltage calibrations can be performed fully automated. This is a new step toward a full automation of a high accuracy multifunction instruments calibration system. This sub-system saves a not negligible time, providing short-term calibrations.

Filipski and Rinfret got a complete 792A automation including a stepping motor in their AC-DC transfer calibration system [2]. Although this paper brings no details regarding the mechanical switch used in their system, one can see it on the figures. The switches communication with computers are serial-based.

2. SEMI-AUTOMATED CALIBRATION SYSTEM

Latce's semi-automated calibration system revealed itself slow since it depends on operator's interference. The system remains in stand-by without the operator's presence. This fact reflects in the total term a calibration takes, due to the big amount of required points; also compromises a fixed schedule in cases the measurand did not provide the best results at first, so part of the calibration should be performed again.

The figure 1 shows an operator changing the Fluke 792A knob position to the requested range informed by the calibration software (PC not shown) in an AC voltage calibration.

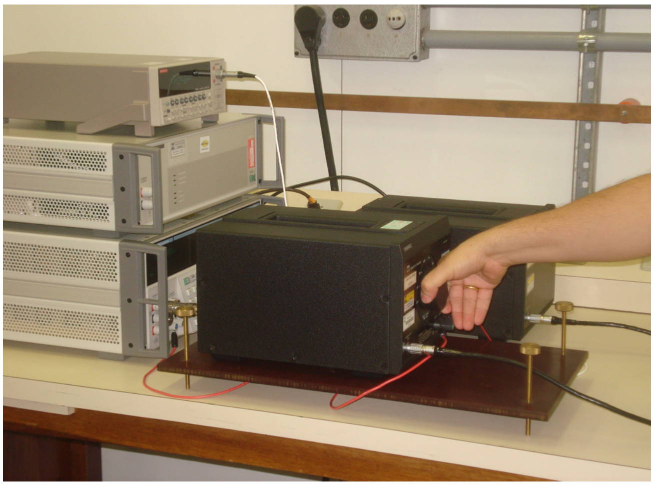

Fig. 1. A semi-automated system showing a multifunction instrument calibration using the Fluke 792A

3. FLUKE 792A AC-DC TRANSFER STANDARD AUTOMATION SUB-SYSTEM

The automation aim is to perform calibrations faster and to allow the operator to keep other activities simultaneously.

The sub-system proposed in this paper consists in a low cost automated range switch for a Fluke AC-DC transfer standard, model 792A, integrated to the preexistent calibration software.

It is, basically, composed by a PC running the 792A switch control software, a low cost digital acquisition (DAQ) sub-system and a stepping motor (see diagram below):

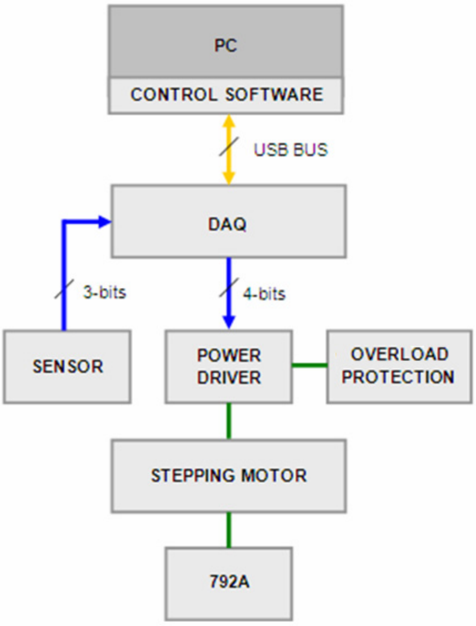

Fig. 2. 792A automation sub-system block diagram

The digital acquisition system used (NI USB-6008) is a 12-Bit, 10 kS/s low-cost multifunction DAQ and it has two parallel digital I/O ports [3]. It executes write and read functions in one of these two ports when requested by 792A switch control software.

The sub-system uses a 8-bits parallel I/O port, although only 7-bits are needed. 4-bits are used for the stepping motor control and 3-bits are used to read the 792A knob position.

The “SENSOR” box stands for 792A position sensors, which are copper contacts on a printed circuit board. Their configuration is shown below (Table 1):

Table 1. Position sensor configuration

Knob Position	792A Range	Binary Code of Contacts		
1	22 mV	0	0	0
2	220 mV	0	0	1
3	700 mV	0	1	0
4	2,2 V	0	1	1
5	7 V	1	0	0
6	22 V	1	0	1
7	70 V	1	1	0
8	220 V	1	1	1

0 – Ground
1 – (+ 5 V)

The PC controls the stepping motor through the “POWER DRIVER”. It is composed by a transformer, a filtered rectifier circuit and a manual adjustable voltage level, which is responsible for adjusting the torque applied to the 792A knob. It needs a torque of approximately 1 N.m to change the range. This value changes a little bit from one unit to another one. Hence, this adjustment allows the technician to adjust the torque for each 792A used. The power driver is protected by the “OVERLOAD PROTECTION” circuit.

The communication between digital acquisition system and PC is USB standard, which provides more versatility to the 792A automation. Besides, serial RS-232 and parallel IEEE 1284 standard communication ports are getting more difficult to find in new PC’s.

The Latce’s calibration software was developed in Labwindows. To avoid major changes in the calibration software, which could bring unexpected side effects, the switch control software is composed of eight executable files (one for each position) which are called by the calibration software when needed. The executable files were developed in LabVIEW.

The 792A switch control software is executed according to the following diagram (Fig. 3):

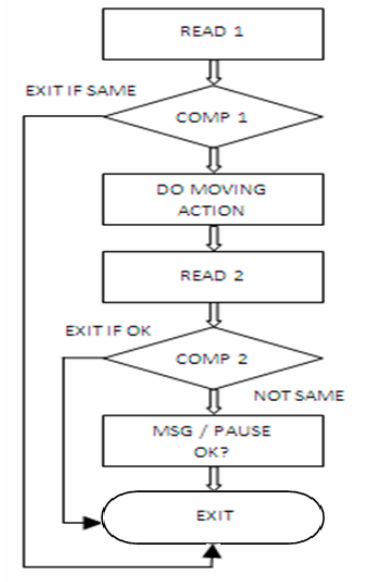

Fig. 3. Switch control software diagram

When the calibration software calls an executable file that corresponds to the destination position of 792A, the switch control software reads the current position (READ 1) on a DAQ port and compares (COMP 1) this position with the destination one; if the current and the destination positions are the same, the software ends (EXIT). If they are not the same, it selects an appropriate action (DO MOVING ACTION) to move the knob to the requested range.

After the switch control does a moving action, its software reads the new current position (READ 2) and compares it (COMP 2) with the destination one. If the current and the destination positions are the same (EXIT IF it is OK), the switch control software ends. If the current and the destination positions are not the same, a message pops up to the operator indicating a fault. The calibration system remains in pause until the operator presses the OK button to stop the calibration. This is a simple and straightforward security level.

This control is based on PC platform, but the 792A switch control software can be simply inserted in a microcontroller with a USB chip to reduce the cost of the system.

The figure 4 shows the complete system using the automated range switch with Fluke AC-DC transfer standard (PC not shown):

Fig. 4. Complete system using the automated range switch.

3.1. 792A automation sub-system potential drawbacks

Some 792A automation sub-system potential drawbacks can be pointed as follows:

- **Noise added to the calibration system:** when the 792A knob is at the correct position, the stepping motor is not supposed to move and the power supply does not drive it anymore. The power consumption of the 792A automation sub-system is low and the noise added to the calibration system by the power supply is negligible.
- **Calibration interference due to mechanical movements:** the 792A automation sub-system only moves the knob before the stabilization time begins. Only after this stabilization time, the measurement cycle is performed. So, mechanical moving action applied to the knob does not cause interference in the calibration.
- **Wrong knob position:** the stepping motor is connected to proper gears in order to provide 0.15 degrees rotation for each step. Since there are about 30 degrees between two adjacent range positions, there is enough resolution to reach the desired knob position.
- **Uncertainty increase:** since there is neither mechanical nor electrical interference during calibrations, due to the 792A automation sub-system, one can say it does not increase the calibration system uncertainty.
- **Wrong stepping motor torque:** 792A knob needs a torque of approximately 1 N.m to change the range. This value changes a little bit from one unit to another one, due to constructive differences. Hence, the stepping motor torque needs to be adjusted accordingly. This is done by manually adjusting the stepping motor power supply. This adjustment can be done in a few minutes. Although a better solution could be an automated feedback loop control, the cost/benefit ratio should be analized.

4. RESULTS

In order to test the 792A automation sub-system within the automated system, we performed an AC voltage source calibration on 6 ranges, 5 points per range in 4 frequencies with both kinds of systems: a preexistent semi-automated and the automated one (which has the automated range switch). The 22 mV range at 40 Hz, 60 Hz, 400 Hz and 1 kHz was chosen, in order to illustrate a commom request by customers and also because it is the most sensitive range.

No significant difference in the calibration measurements was detected comparing the two systems results, except for the calibration time spent. The measurement errors (μV/V) for each calibration point are close enough and well within the expanded uncertainties (k=2) for each situation (see figure 5).

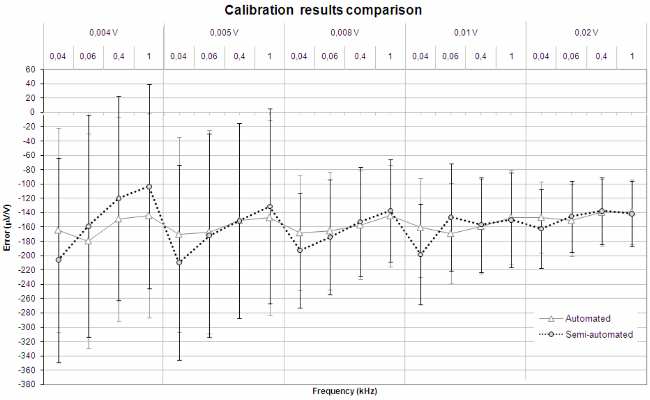

Fig. 5. Automated x semi-automated calibrations

The figure 6 ilustrates the comparison between the time required for a typical AC voltage source calibration (120 measurement points, defined by the amplitude and frequency) in both ways of calibration. A semi-automated one was performed in 4 working days wich lasts 7 hours each. So, the system remains out of operation for the next 17 hours left. On the other hand, in an automated calibration, the remaining 17 hours of each day are used to continue the calibration. One can see the total calibration time needed by the automated system takes about 30% of the total semi-automated one (since it not only avoids operator interference but also can be done through the night shift and weekends). An extra battery pack can be recharged meanwhile, so the system can be used in the next working day, by exchanging the battery packs.

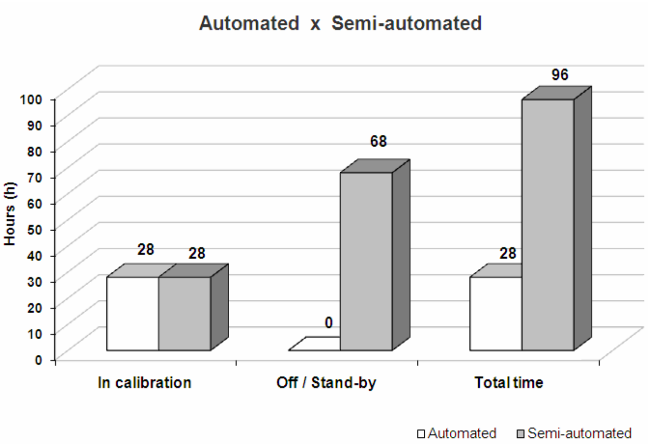

Fig. 6. Time spent by both systems

5. CONCLUSION

The proposed 792A AC-DC transfer standard automation sub-system reduces considerably the overall calibration time without neither compromising the measurement results nor producing an uncertainty increment.

The automated range switch can be used in further applications by adjusting the knob adapter according to the width and height of other equipment. The current version of this automated range switch costs about US$ 500.00 (only hardware). Since the prototype is approved and operational, the NI USB-6008 can be replaced by a microcontroller, reducing the automated range switch final cost and still using USB-based communication. If there is a parallel port available (or using a USB-parallel converter), it can be used instead of the NI-USB-6008. A 792A automated switch can be commercially found by US$ 32,000.00 approximately (final price but tax).

It also can be used in AC-DC transfer calibrations using 792A transfer standards, where two automated range switches control both the standard and the measurand AC-DC transfer. Alternatively, this sub-system can be improved in order to have a motor control central unit and several unit motors.

In order to protect the 792A transfer standard against damages, two more security levels can be implemented: firstly by changing either the 792A switch control software or the calibration software to verify the full range of the input by the output (output voltage is close to 2,2 V for full range signals); secondly by increasing the 792A switch control hardware to detect the overload led indicator of the 792A.

AC voltage, DC voltage, AC current and DC current meter calibrations as well as AC and DC voltage source calibrations are currently performed automatically at Latce. However, AC and DC current source calibrations are still performed semi-automatically (due to standard resistors changes, which are done manually). We're still evaluating AC and DC current source calibrations automation, considering the needed equipments (scanners, wires proper to work in a broad frequency and current ranges and consequent increase in final uncertainties), cost/benefit ratio etc.

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