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Automatic Method of Assessment and Grading of Students in a Measurement Laboratory

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***Abstract* – High activity levels in measurement laboratories can often exceed the time allocated for individual laboratory sessions. These laboratories involve a wide range of measurement tasks—from simple to complex—while students operate under strict time constraints. Consequently, the manual evaluation of student performance by instructors becomes labor-intensive and time-consuming. The digitization of the assessment process offers an effective solution. This paper presents a method that integrates LabVIEW with an SQL database to automatically record, verify, and grade student performance in laboratory sessions. The proposed method includes automated data saving for each student, validation of measurement accuracy, and objective grading mechanisms. Various tools are employed for real-time data acquisition, verification, and automatic evaluation of student activities.**

I. INTRODUCTION

Technical universities distinguish themselves through specialized laboratory sessions for experimentally proving the theoretical knowledge. The diversity and complexity of laboratory exercises are crucial in academic programs, but they also increase the difficulty of the assessment process for instructors. As technology evolves, so does the complexity of laboratory tasks—especially in measurement laboratories—requiring educators to:

a) verify the measurement data collected by students;

b) check the correctness of parameters calculated by students;

c) assess the conclusions formulated at the end of each measurement task.

Digital tools for learning assessment support the structured documentation of student performance. This organization enhances the instructor's ability to analyze stored data for planning future teaching activities and improving student outcomes. As outlined by Pellegrino & Quellmalz (2010) [1], the key contributions of digital technologies to learning assessment include: immediate feedback, enhancement of student-centered learning, support for collaborative learning, broader measurement capabilities, improved response flexibility, increased efficiency, reduced instructor workload, and better student performance. Moreover, they facilitate the integration of formative and summative assessment strategies [2].

Several platforms have already been developed to assist educators with grading. For instance, the "BetterExaminations" platform optimizes traditional exam workflows with diverse question types and advanced management features, enabling students to take exams remotely [3]. Crowdmark provides a grading toolkit that allows educators to deliver rich feedback and has demonstrated up to a 75% productivity gain in independent studies [4]. Additionally, automated tools for both formative and summative assessment in introductory programming courses are detailed in [5], while other approaches offer automation without compromising evaluation quality [6].

II. DESCRIPTION OF THE METHOD

In measurement laboratories that employ both interfaced and non-interfaced instruments, verifying the correctness of measurement processes is inherently challenging. This paper proposes a solution involving the acquisition, verification, and grading of measurement data using digital tools.

After completing the laboratory worksheet with the results obtained from measurements, the student inputs the data into a virtual instrument developed in LabVIEW. This tool allows for immediate verification of the measured values by comparing them to expected ranges. Regardless of correctness, all data are saved in a .txt file, enabling subsequent instructor review. To demonstrate the method, a virtual instrument was created for a specific laboratory task titled "Study and Verification of a Data Acquisition Board." In this experiment, students use a National Instruments USB-6008 data acquisition (DAQ) board, which integrates the ADS7870 system. The block diagram of the system is shown in Figure 1.

This system includes voltage reference, input multiplexer, precision programmable amplifier, 12-bit analog-to-digital converter, internal oscillator with programmable frequency divider, configuration registers for multiplexer, amplifier, and ADC and an SPI interface.

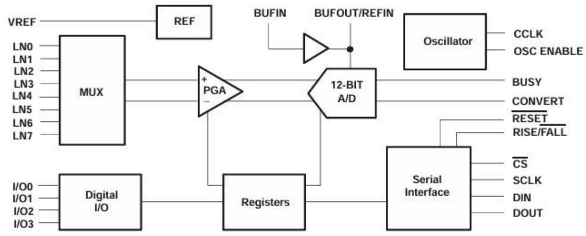


Figure 1. ADS7870 data acquisition system

To evaluate the accuracy of this board, students perform two setups: one for DC voltage measurement and another for AC voltage RMS value measurement.

Figure 2 shows the first setup.

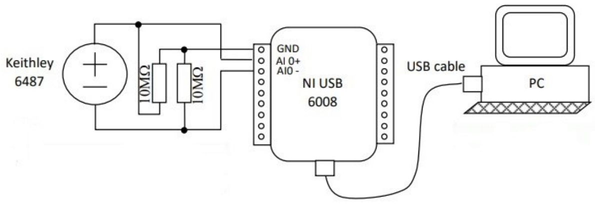


Figure 2. Measurement circuit for USB6008 accuracy checking in DC

A Keithley 6487 voltage source, configured as a standard voltage generator, is connected to the differential analog input (AI0+, AI0−) of the USB-6008 board. The board is interfaced with a PC running the LabVIEW virtual instrument. The student applies voltages from −10 V to +10 V with 2 V increments and records the corresponding readings from the USB-6008. These values are entered into the virtual instrument for validation. The student also calculates the following parameters: the absolute error, the relative error and the allowable error of the USB-6008 and the allowable error of the Keithley 6487. All these values are entered into the virtual instrument tables for verification.

Figure 3 shows the second setup.

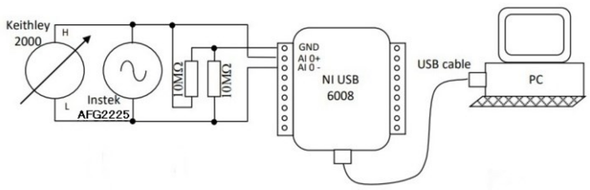


Figure 3. Measurement circuit for USB6008 accuracy checking in AC

An Instek AFG2225 signal generator is connected to the USB-6008's differential input (AI0+, AI0−), providing a 50 Hz sinusoidal signal with variable amplitude. A Keithley 2000 digital multimeter is also connected to measure the RMS voltage. The signal amplitude varies from 1 V to 7 V (1 V steps), which corresponds to RMS values up to 7.07 V, within the board's ±10 V input range.

The student must apply voltages from 1 V to 7 V RMS, in 1 V steps and read these fixed values from the USB6008 card. He will add the values indicated by the Keithley 2000 digital multimeter in the virtual instrument that checks their correctness. After completing the measurement process, the student must calculate the other parameters such as: the absolute error and the relative error of USB6008 and the allowable error of the reference instrument. These parameters will be input in the tables (Figure 4) available in the virtual instrument for verification.

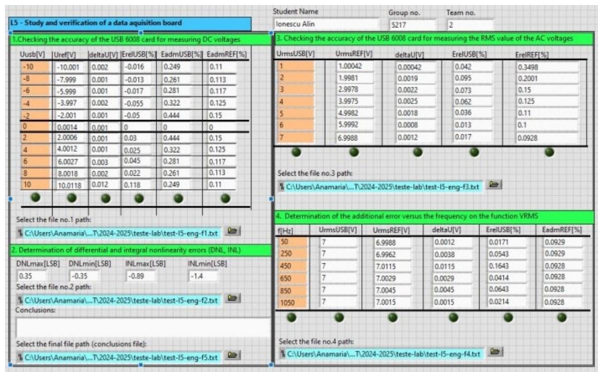
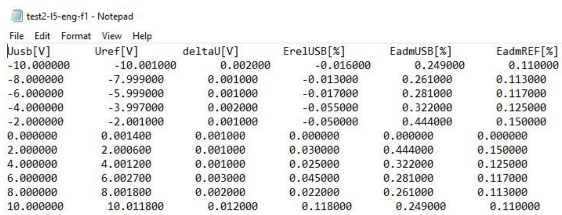


Figure 4. LabVIEW instrument front panel

The instrument includes four main sections corresponding to the four subsections of the student's lab worksheet: two for DC analysis, two for AC analysis. A dedicated section for student conclusions is also included. The fixed reference values are displayed in orange, while students enter their measured/calculated data in white fields. Blue fields indicate file paths for saving the .txt outputs. Figures 5 and 6 show examples of the .txt generated files.


test2-l5-eng-f1 - Notepad

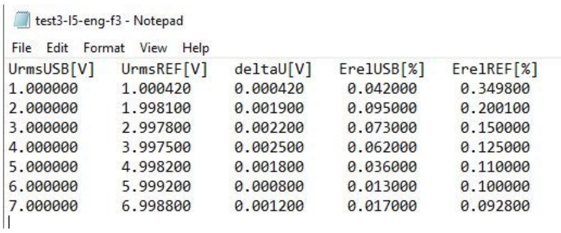
File Edit Format View Help

Uusb[V]	Uref[V]	deltaU[V]	ErelUSB[%]	EadmUSB[%]	EadmREF[%]
-10.000000	-10.001000	0.002000	-0.016000	0.249000	0.110000
-8.000000	-7.999000	0.001000	-0.013000	0.261000	0.113000
-6.000000	-5.999000	0.001000	-0.017000	0.281000	0.117000
-4.000000	-3.997000	0.002000	-0.055000	0.322000	0.125000
-2.000000	-2.001000	0.001000	-0.050000	0.444000	0.150000
0.000000	0.001400	0.001000	0.000000	0.000000	0.000000
2.000000	2.000600	0.001000	0.030000	0.444000	0.150000
4.000000	4.001200	0.001000	0.025000	0.322000	0.125000
6.000000	6.002700	0.003000	0.045000	0.281000	0.117000
8.000000	8.001800	0.002000	0.022000	0.261000	0.113000
10.000000	10.011800	0.012000	0.118000	0.249000	0.110000

Figure 5. Sample Output File: DC Measurement Section

To interface LabVIEW with a SQL database, the following steps were required: SQL installation, ODBC server setup, and installation of the LabVIEW SQL Toolkit.

The most complex task was the ODBC configuration and the database structure, shown in Figure 7.


test3-l5-eng-f3 - Notepad

UrmsUSB[V]	UrmsREF[V]	deltaU[V]	ErelUSB[%]	ErelREF[%]
1.000000	1.000420	0.000420	0.042000	0.349800
2.000000	1.998100	0.001900	0.095000	0.200100
3.000000	2.997800	0.002200	0.073000	0.150000
4.000000	3.997500	0.002500	0.062000	0.125000
5.000000	4.998200	0.001800	0.036000	0.110000
6.000000	5.999200	0.000800	0.013000	0.100000
7.000000	6.998800	0.001200	0.017000	0.092800

Figure 6. Sample Output File: AC Measurement Section

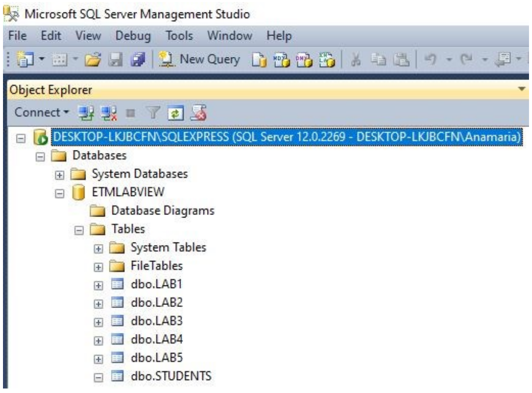


Figure 7. Database structure

LabVIEW transfers the acquired data into an SQL database named ETMLABVIEW, which includes a table with STUDENTS and five additional tables corresponding to different lab assignments. This paper focuses on Lab Assignment 5, for which the data flow was described above.

After the SQL Toolkit is installed, the blocks for database read/write operations become available in LabVIEW. The LabView application is created using a sequence type structure that includes 7 frames. The operating diagram from Figure 8 presents the 7 frames.

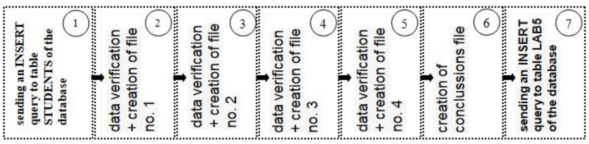


Figure 8. Virtual instrument frames in LabVIEW

The 7 frames perform the following functions:

1. The automatic input of the student's identification data into the database.
2. The verification of the measurement data and caomputed parameters and the creation of the first txt file.
3. The verification of the measurement data and calculated parameters and creation of the second txt file.
4. The verification of the measurement data and calculated parameters and the creation of the third txt file.
5. The verification of the measurement data and calculated parameters and creation of the fourth txt file.
6. The creation of the file that contains the conclusions of the 4 measurement processes.
7. The automatic input of all five files into the database.

The block diagram, shown in Figure 9, handles the insertion of measurement data and calculations from Lab Assignment 5, by importing the .txt files generated by each student. This action is carried out in the last frame of the virtual instrument.

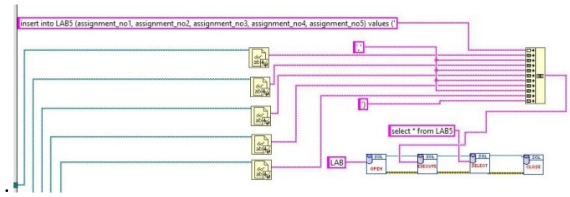


Figure 9. LabVIEW Block diagram for inserting text files into the database

These files populate the LAB5 table, making the data accessible for grading and analysis.

III. RESULTS AND DISCUSSIONS

To verify the correct integration between the .txt files generated in LabVIEW and the SQL database, data from three students, each belonging to a different lab team, were introduced into the virtual instrument. The first stage of verification consists of analyzing the recorded measurement data. If discrepancies are detected between the results of different students in the same team, these inconsistencies are noted in the database, as illustrated in Figure 10.

As seen in Figure 10, for the first laboratory assignment, three different files were uploaded. The first six columns of each entry list the names of the measured and calculated parameters. The subsequent six columns contain the actual numerical values. Notable differences are observed among the three students in parameters such as the voltage measured by the reference source, and in the computed absolute and relative errors.

After data validation, the calculated parameters are compared against the acceptable ranges predefined by the instructor. Based on this comparison, a final grade is determined and saved in the database for each laboratory sheet submitted by students.

student_id	assignment_no1
1	Uusb[V] Uref[V] deltaU[V] ErelUSB[%] EadmUSB[%] EadmREF[%] -10.000000 -10.001600 0.002000 -0.016000 0.249000 0.110000 -8.000000
2	Uusb[V] Uref[V] deltaU[V] ErelUSB[%] EadmUSB[%] EadmREF[%] -10.000000 -10.001800 0.002000 -0.018000 0.249000 0.110000 -8.000000
3	Uusb[V] Uref[V] deltaU[V] ErelUSB[%] EadmUSB[%] EadmREF[%] -10.000000 -9.992900 0.007000 -0.071000 0.249000 0.110000 -8.000000

Figure 10. Example Result of a Database Selection Query

For example, 3 students were entered the data as they appear in the database, in figure 10, by running the virtual tool. We analyzed the first file sent by the students, which was loaded in the column assignment_no.1. It is observed that the information of interest is separated by spaces and thus the data analysis will be performed following those spaces.

The actual data analysis begins after the sixth row of the column, as the initial entries contain either the names of the measured or calculated parameters or predefined values. The first verification step involves the reference voltage corresponding to the initial reading from the data acquisition card (−10.000 V), which must fall within the acceptable range of [−10.009 V to −9.900 V]. Subsequently, the absolute error is evaluated and must lie within [−0.09 V to 0.09 V], while the relative error must fall within [−0.09% to 0.09%].

The next phase consists of validating the permissible error limits for the two devices involved in the measurement process—namely, the data acquisition card and the direct current (DC) source. For the acquisition card, the accepted error margin is between 0.2% and 0.3%, whereas for the reference DC source, the error must be within the interval of 0.09% to 0.19%.

If all recorded values in the database conform to the specified stability intervals, the student is awarded the maximum score for that section of the laboratory sheet. Finally, the mean value of the scores obtained across the five evaluation sections on the lab sheet is computed, which constitutes the final grade for the laboratory assignment.

IV. CONCLUSIONS

Assessing students' understanding of laboratory material is a crucial component of engineering education. Traditionally, this evaluation is performed through a final test administered at the end of the laboratory cycle. However, continuous laboratory assessment, where students receive regular evaluations throughout the term, is increasingly being adopted by university instructors. This method is especially beneficial in online or distance learning environments. Continuous assessment aligns well with the objectives of measurement education, as it mirrors real-world engineering contexts in which professionals must routinely meet short deadlines. It encourages students to consistently engage with course material and provides ongoing feedback on their understanding. Furthermore, this approach contributes to the development of students' metacognitive skills, which are essential for lifelong learning and adaptability in modern engineering practice [7].

In the present work, the proposed assessment method was tested on a single laboratory exercise. However, the framework can be extended to include all laboratory assignments in a course dedicated to electrical measurements. The grading process focused primarily on the measurement and calculation sections, but the laboratory activity also includes a conclusions section, which allows students to reflect on their experience and outcomes.

In future developments, we aim to apply artificial intelligence techniques to automatically analyze and evaluate student conclusions. This would facilitate an objective assessment of the qualitative aspects of lab work, further supporting fair and comprehensive grading.

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