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WRITING LABORATORY REPORTS OF EXPERIMENTAL WORK DIRECTLY ON THE COMPUTER, A FEASIBILITY STUDY

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Abstract - In this paper we present the results of a feasibility study on writing an electronic laboratory report while performing experiments. This way of reporting may lead to better documented experiments, to improved information exchange between members of a project group and facilitate writing a final report for the outside world. Results from a pilot study with student groups indicate that these improvements are obtained indeed. The reports look more professional, are better structured and well readable. Also the information exchange between group members showed improvement. The management of data and reports however needs attention, as students tend to neglect this aspect.

Keywords: education in measurement, laboratory report, computer support

1. INTRODUCTION

Traditionally, during practical work the (measurement) engineer will keep a lab-report in which all relevant details of the work are written down on paper. These details will include the underlying theory, a description of the set-up, simulated and experimental data, an analysis of the results and finally conclusions. Nowadays, almost any practical work is supported heavily by the computer: The design of equipment is carried out on the computer and measurement data are stored and processed on the computer. A consequence of this development is an increased amount of (experimental) data, making a full account of all results rather impractical when written down in a paper report. Therefore, a tendency towards poorly or insufficiently documented experimental work is noticed. Also, a final report will be created using a computer with text-editing facilities so that the information from the paper lab-report has to be transferred again to the computer. For these reasons making lab-reports on the computer may be advantageous.

In this paper, a project is described to investigate the possibility to use the computer for making lab-reports about experimental work. To this, a number of software packages have been brought together. These software packages are integrated with software for data acquisition and data processing so that the report and the data can be kept together easily.

The remainder of this paper contains a description of the project. In section 2 the set-up of the project is discussed. In section 3, the results of two pilots are described and discussed shortly and then in section 4, conclusions are drawn.

2. SET-UP OF THE PROJECT

2.1 Motivation

The use of the computer for making lab-reports can be advocated from more than one viewpoint. Regarding the report itself, we maintain that:

- Using the computer, working neatly and in a structured way is stimulated.
- Results from computerised experiments (tables, graphs, etc.) can be presented directly in the lab-report.
- Data from computerised experiments can be kept together with the lab-report in one environment, stimulating good bookkeeping of the data and the report. This is even more important in the case of a larger project, carried out by a team of workers.
- Additional information from outside (especially from the internet) can be included easily in the report

Also a number of advantages from the communication point of view can be mentioned:

- The lab-report(s) can be used more easily to write a final report for the outside world.
- Information exchange about laboratory work between team members and between students and a teacher can happen smoothly.
- In an educational environment, communication between teacher and student is simplified, using electronic facilities. At the University of Twente, the TeleTOP communication system [2] is used for this.

2.2 Requirements to a software environment

Available software - Developments in software go very fast these days, which will make homemade software outdated very soon. Therefore we only want to use commercial software as much as possible.

User friendliness - In the first place, users (among them students) should be stimulated to document their practical work well. Using the computer for this should cost the user no more time than a hand written report would have taken. If possible it should save time to the user. This requirement is by no means an easy one, as a lab report will contain elements like equations, graphs, tables etc. and software packages for making these, often work clumsily with many mouse actions.

Organisation and communication - An experimental set-up nowadays may contain many parts, all connected to a computer system:

- Dedicated hardware and software for measurement and control purposes
- Software for simulation and data processing
- Word-processing software

It is therefore easy to loose the overview over the set-up and the experimental data. Thus, it is important to keep an effective bookkeeping of them:

- The original measurement data should be kept in store explicitly and well separated from processed data. They must be documented: The date of measurement and relevant system parameters should be stored with the data.
- The validity of the data should be checked. It should be checked automatically if the measured data have changed since last data processing, which produced the processed and presented data (graphs).
- It is not allowed to change the results of an "official" experiment. So it may be necessary to fix experimental data at a certain point of time and to provide them with some sort of "stamp". This is certainly important if the results are used afterwards to prove certain facts formally (like before the court), to prove originality and to protect intellectual property.

During the first part of the project described in this paper the main emphasis was on the user friendliness of the available software. Therefore the question to be answered was if it is feasible to make the lab-report of experimental work directly on the computer. In the case of an affirmative answer, the next step will be to create an environment for effective data management. A sketch of such an environment is given in [1].

2.3 Plan of the project

Practical work at the University of Twente is carried out in laboratory courses, to learn the basics, and in student projects to apply and integrate capabilities from different practical and theoretical courses. During lab-courses, standard experiments are carried out in one day. Also the lab-report is written during this day without any delay. No additional final report is written. The lab report is handed to the assistant at the end of the day. This puts severe requirements to the user friendliness of the software, if the lab-report is going to be written on the computer. Student projects last longer, at least a week, and the assistant only looks at the lab-reports marginally. Instead, assessment is based on a group report assembled from the lab-reports. Students have more freedom to manage their time during a project. Therefore, time limitations are less severe in such a project.

The standard laboratory set-up available to the students is sketched in figure 1. The hardware consists of an oscilloscope, digital multi-meter and function generator, all connected (HPIB-bus) to a PC running Windows 2000. During the feasibility study a graphics tablet has been made available for making free-hand drawings.

To investigate the feasibility of our approach, it was decided to carry out two pilots, the first one during a student project of three weeks [3] and the second one during a lab-course, (a number of one day exercises).

2.4 Description of the pilots

After an inventory of available software [3] (part 1), two packages were composed, consisting of a word processor, a graphical program, and programs for data-acquisition, data processing and hardware programming. Two word-processors were used: Microsoft Word, and MathCad, which is a sheet-like program from MathSoft Inc., containing facilities for editing and manipulating equations. MS-Word is a natural choice being the most widely used word-processor. MathCad organises the information in separated blocks, which can be placed freely on the page. Making a lab-report, this may be an attractive feature, which made us decide to offer it as an alternative. The packages are given in table 1.

TABLE 1 Software packages, available to the students

	Package 1	*Package 2*
Texteditors	MS-Word 2000	Mathcad 2001
Spreadsheet	MS-Excel 2000	
Math	Matlab, Maple	
Electrical schemes	P-Spice	
Drawing	Painter Classic, MS-Paint	
Simulations	P-spice, Matlab	
Graphs	Matlab, Excel	
Measurements	Labview	

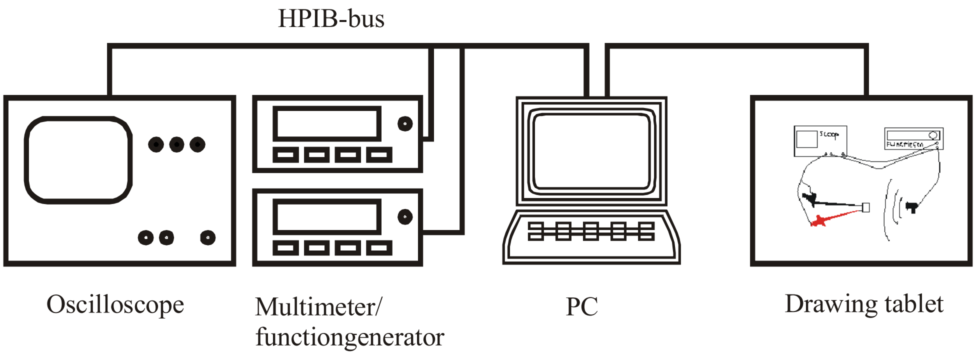


Figure 1 Standard hardware set-up for practical work at the University of Twente

The first pilot during a student project has been carried out in June 2002, the second one during the lab-course in December 2002. The results are discussed in section 3.

2.5 Investigation method

Student project - Totally, eight students were involved with the pilot, divided over two groups, each carrying out a project [3] (part 2). The number of groups was kept limited for practical reasons (hardware, supervision), but this limits the statistical significance of the results. Partially this could be compensated for by an extensive questionnaire, completed by the students, followed by interviews.

The questionnaire was set up systematically. Questions were posed about the following items:

- The text-editor: its ease of use and user friendliness
- All additional programs: their ease of use and user friendliness and the ease of incorporating the results into the text-document
- The use of the graphics tablet
- Time spending: Did working with the software cost time or save time, compared with the lab report on paper?
- Some additional questions about advantages and drawbacks of making computer assisted journals.

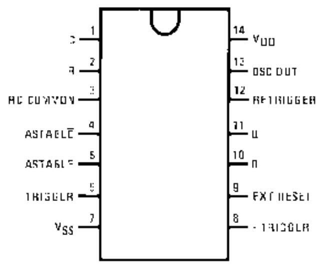
Lab-course - Even with the experience from the student project, the strict time constraints during the lab-course could cause problems. Therefore the number of groups was again kept limited during this pilot. According to the practice of the lab-course there were four groups of two students. All groups performed two experiments of one day each. Again the students were interviewed afterwards, using an extensive questionnaire.

3. RESULTS

3.1 Example parts of the reports

Examples of reports during the project are shown in figures 2, 3 and 4. The students show that the possibilities of the computer to produce valuable lab-reports are quite extensive. Figure 2 gives an example of included product information, obtained from the Internet. In figure 3, measurement results are stored in an Excel-table and then presented in a graph. Figure 3 shows a description of a measurement set-up including a hand-made sketch using the drawing tablet.

Pin Assignments for SOIC and DIP

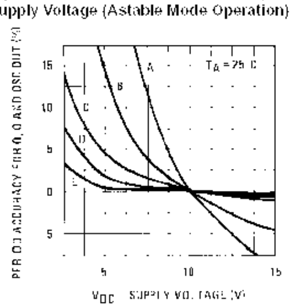


Top View

Fig. 2 Pinaansluiting van de 4047.

De multivibrator kan met een gekozen weerstand en condensatorwaarde een bepaalde frequentie blokgolf genereren. In fig.3 staat een tabel met frequentiewaarden bij verschillende condensator- en weerstandswaarde

Typical Q, $\overline{Q}$, Osc Out Period Accuracy vs Supply Voltage (Astable Mode Operation)



	f_Q, $\overline{Q}$	R	C
A	1000 kHz	22k	10 pF
B	100 kHz	22k	100 pF
C	10 kHz	220k	100 pF
D	1 kHz	220k	1000 pF
E	100 Hz	2.2M	1000 pF

Fig.3 Grafiek met periodieke nauwkeurigheid vs. Voedingsspanning met daaronder een tabel met frequentiewaarden als resultaat van R en C.

Figure 2 Example of a lab report made during the project, containing hardware product information

De meetresultaten (tabel 1 + fig 5):

R (kΩ)	frequentie (kHz)
55,8	73,8
80,9	51,7
90,8	45,8
95,1	43,3
98,8	42,7
101,8	40,8
104,2	39,5
108,7	38,3
154,6	27,3

tabel 1. verandering van de frequentie bij verschillende weerstandswaarden. C=110 pF, V=+9V

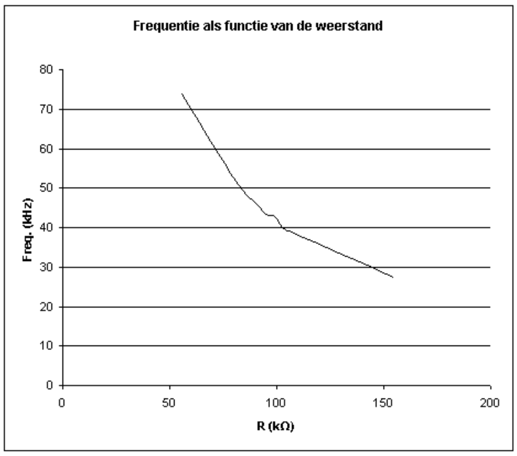


fig 5. tabel 1 in grafiekvorm.

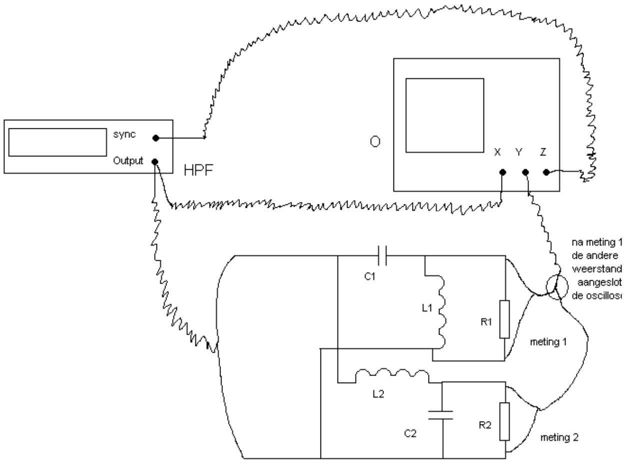
Met een weerstandswaarde van ongeveer 102 kΩ krijgen we de gewenste frequentie.
Uit fig 3 bleek al dat we een weerstandswaarde ongeveer tussen de 50 en 150 kΩ moest liggen (bij C constant is de grafiek van de vorm 1/x). Op basis van de resultaten van die 2 metingen zijn de andere meetpunten voor de andere metingen gebaseerd.
De voedingsspanning bleek ook een beetje van invloed op de frequentie (ongeveer 0,5 kHz per volt), vandaar dat deze op een vaste waarde moest worden afgesteld.

Figure 3 Example page from of the same report containing own measurement results

De gebruikte apparatuur van beide metingen staat in tabel 2.

Symbool	Apparaat	Model	Locatie
O	Oscilloscoop	Hewlett-Packard 54603B	Tafel 10A2
HPF	Functiegenerator	Hewlett-Packard 33120A	Tafel 10A2
M	Meetbrug	Philips PM6303	Tafel 5A

Tabel 2: gebruikte meetapparatuur



Figuur 2: meetopstelling voor de meting van de overdracht

Figure 4 Example of a report from the lab-course with a sketch of the measurement set-up

3.2 Evaluation of the questionnaires: student project

Structure and neatness of the report – All students indicate that a well-defined structure of the report is important and that the use of the computer (with document templates) helps to improve the structure. Also the neatness of the report improves, although this was not a priority of the students

The text-editor – The students were positive about working with MathCad as a tool for making lab-reports. The way MathCad organises the document in blocks was appreciated. The students were somewhat less positive about MS-Word. Working with MS-Word, some students had difficulties keeping included objects on the right place. Only one of the eight students preferred a report on paper. With MathCad, the students appeared to use less scribbling paper.

Equations – MS Equation Editor can be learned easily, but works slowly because of the many mouse actions, required. Writing down equations in MathCad requires some exercise, but is easier afterwards.

Including objects from other programs – This option is one of the big advantages of the computer while making lab-reports. Most easy is the use of Object Linking and Embedding (OLE). However, the students could also handle situations where a program does not support OLE. Then screen dumps were used.

Drawing tablet - Although the students exercised in using the drawing tablet, they did not consider the tool to be useful. The main complaint was that they had problems with the hand-eye coordination and it was indicated that using the mouse was as easy as using the tablet.

Data-management – Without announcement the students were asked to show their data. Four of them had organised the data neatly in folders. The other four students had their data spread all over the hard disk.

Exchange of information – The students appreciated the possibility of reading each other's reports during the project. This enables to get information from someone else without disturbing him/her. Using the TeleTOP WEB-site, the information was sent to the tutor (the first author) who was kept informed better about the project.

Riffling through the report – Two students announced that they lost the overview over the report and that they had difficulties, comparing information from different pages. The other students did not mention this problem.

Time spending – Making the report on the computer appeared to save some time. The students attributed this to the timesavings during the preparation of the end-report.

Wireless flexibility – One laptop with a wireless network connection was made available for each group of four students. The students only used them at the workplace. Thus, the fact that they could work somewhere else was not used.

3.3 Evaluation of the questionnaires: lab-course

Although the students had roughly the same view on making digital reports, there were some striking differences.

The text-editor - All students were quite positive about MS-Word, but only two out of eight students liked working with MathCad. Two of the students even stopped working with MathCad and continued writing on paper.

Equations - With MS-Word as text-editor, a majority of the students worked with MS-equation editor although three of them also used MAPLE and one used the drawing-tablet. Two of the students were negative, the others were positive. With MathCad as a text-editor, it would be obvious to use the built in equation editor. However also MAPLE, MS-equation editor and the drawing tablet were used. Although most students were positive about creating equations in general, many negative remarks were made about the MathCad editor.

Data management - No student cared about data management. It was almost impossible to find back anything of the reports on the computer. (At the end of the day, prints of the lab-reports were handed to the assistant.)

Exchange of information - As the experiments lasted only one day, exchange of information among the students was not an important issue. Also no timesavings were indicated, because no final report had to be made.

Despite a number of problems and drawbacks, the students were in general content with the MS-Word environment, but the comments about the MathCad were mixed positive and negative.

3.4 Discussion

Students appreciated the idea of making a laboratory journal directly on the computer, for group projects as well as for individual laboratory training courses. Compared to hand-written reports, no extra time-loss has been observed when using the computer. Using electronic lab-reports showed additional advantages when applied to group projects: a better exchange of information between group members and the option of using elements from the laboratory logs to compose the final project report. The MathCad program requires more practice than MS-Word before it can be used comfortably. This may explain the differences in appreciation of the students between the group project and the laboratory training. Moreover, students have different preferences with respect to the choice of packages, even when there is sufficient time for training.

Points of attention - Two important aspects for further investigation are the equation editor and the possibility to include freehand drawings into the documents. Data management during execution of experimental work is another important issue. A next step will be to create a framework to facilitate file and data management.

4. CONCLUSIONS

Making laboratory reports directly on the computer appears to be a realistic option, both for laboratory training courses and during group projects. The latter profit most of electronic lab-reports. The reports showed better readability and are more structured when compared to the hand-written logs. An aspect that still needs particular attention is file and data management.

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