Computerised measurement laboratory for engineering students

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ABSTRACT: Computerised measurements have become an indispensable part of engineering practice in all its disciplines. In the first year of the Electrical and Energy Systems course at the University of South Australia (UniSA), a laboratory component has been developed to introduce engineering students to computerised measurement to understand and use sensors, signal conditioning, data acquisition and computer virtual programming environment. The students also develop practical skills in soldering and testing electronic devices and systems, to be used later in computerised measurements. The computer measurement practicals include the National Instruments (NI) LabVIEW data acquisition and result processing setups to produce practical reports with meaningful discussions of the results obtained. The five sensors used in the laboratory relate to real life applications. The article details implementation of the computerised measurement laboratory in the context of the overall course (Electrical and Energy Systems) delivery and assessment.

INTRODUCTION

Fundamental Electrical Engineering courses at UniSA went through re-development and re-implementation phases on average every 4-5 years between 1993 and 2013. Circuits and Devices 1 (1993), was followed by Electricity and Electronics (1997), then, Introduction to Electrical Engineering (2001), Electrical and Energy Systems (2006) and culminating again in revised Electricity and Electronics (2013) that have been offered with an amended and improved content, in the context of changing degree programmes [1].

The laboratory component of the fundament electrical engineering courses was significantly amended in 2012 with the introduction of the two distinctive, but complementary components: the instrumentation practical and the computerised measurements practical [2]. Prior to that, the laboratory component was project based and differentiated for different student populations (electrical, civil and mechanical engineering) [3].

It was successfully implemented for several years, but it was felt by the teaching staff that the preparedness of the first year students for open ended project tasks was simply not there and the required support for the students became unsustainable. Thus, more structured laboratory practicals were designed and implemented in 2012.

In the last offering of Electrical and Energy Systems in 2012, the assessments tasks were split between 10 tutorial quizzes (20%), instrumentation practical report (15%) based on 3x2 hour sessions in the laboratory, computer measurement practical report (25%) based on 5x2 hour laboratory sessions and the final examination (40%). The examination component was still sizeable due to plagiarism issues in the coursework based assessment.

The material required for the computerised measurement practical was covered in the lectures and also in tutorials by including in the programme: computer-based instrumentation systems, measurands and sensors, signal conditioning, data acquisition, multiplexers, noise, shielding, grounding, analogue-to-digital (A/D) conversion, sampling rate, sampling rules, sample and hold circuit, aliasing, quantisation and errors in a measurement system.

On the software side, there were introductions to Multisim, LabVIEW and MATLAB, as well as simulation of electrical/electronic circuits and processing of measurement results.

In this article, the authors discuss in some detail the content and the implementation of the computer measurement laboratory in the first year of engineering degrees at UniSA, with resulting conclusions to follow. They illustrate the laboratory concept on the example of the first computer measurement exercise that is the temperature measurement.

COMPUTERISED MEASUREMENT LABORATORY

Nowadays computers are ubiquitously present in engineering laboratories. They give a different dimension to experimental work and students' learning. Also, the objectives of engineering instructional laboratories, which have been well summarised shift the focus towards data acquisition and emphasise development of skills in *data analysis* [4]. Once data are recorded by digital instruments they are imported into MATLAB for processing.

This gives students unlimited opportunities to learn and implement data analysis skills. Advanced students are encouraged to use this opportunity to develop their research skills by searching methods and algorithms for data/signal processing MATLAB as a tool very much supports these endeavours.

Many universities have consequently developed computerised measurement laboratories in all engineering disciplines. Very widespread ones are in mechanical and electrical engineering [5][6]. Computer based laboratories offer important advantages like flexibility in their use including remote access leading to widespread expansion in development of virtual and remote laboratories [7-10].

The computer measurement practical is project-based intentionally designed to be very much hands-on and less open-ended than the project laboratory before [3]. Students usually work in teams of two. Students solder a data acquisition/signal conditioning printed circuit board (PCB) preceded by a soldering practice and, then, use the board to acquire, process and visualise signals, in six different exercises. Soldering was included on purpose, to give the students practical skills in this area, to be used in further educational and household/hobby applications.

Five sensors are used in the UniSA computerised measurement laboratory. The first sensor is an analogue temperature sensor LM34 from National Semiconductors, with which students learn data acquisition, analogue/digital conversion and logging with NI USB-6009 data acquisition (DAQ) board. Similar sensors are used in domestic and industrial temperature measurement applications.

Heart pulse rate monitoring with piezoelectric film vibration LTDO sensor from Parallax is conducted in the second experiment on the neck - the carotid pulse on the soft place of the Adam's apple. The signal conditioning is conducted by a charge amplifier, piezoelectric film sensors have broad applications in switches, impact sensors (printers, sports, musical instruments, traffic sensors), vibration sensors, accelerometers, ultrasound (medical imaging, acoustics, fluid level sensing) and in audio applications.

Four dimensional tilt sensors explaining position detection of smart phones, tablets and games is the next. Its popular application is the change of the orientation of the screen image (vertical or horizontal). It can be also used as an inexpensive replacement for accelerometers in applications, such as robotics, tilt sensing and car alarms.

The third sensor is charge, transfer, infrared QTI reflective sensor from Parallax for reflectivity of surface measurements. In this application it was used in digital mode to detect black and white stripes: the barcodes on everyday products. It can be also used in analogue mode for detecting different shades of grey.

Light measurement with a phototransistor VT935G-B from Parallax is used to determine the colour temperature is the next exercise. The photoresistor is a semiconductor with its resistance changing depending on the intensity of light falling on it. When dark, the sensor's resistance is at least 1MΩ and less than 20kΩ under strong light. Practical applications of the sensor are light dependent: street lights, headlights in cars switching, photographic exposure meters, smoke detectors and alarms, etc.

The sampling rate and aliasing exercise was designed to determine the proper data acquisition with NI DAQ to select the minimum sampling rate for a given A/D conversion. Many signals include noise and other parasite signals of high frequencies. That is why when sampling *the Anti-aliasing* - low pas filters needed to be used before DAQ. It was one of the more complex technical areas to be approached by more advanced students.

Seemingly, the sensor applications are relevant to all engineering disciplines as are the data acquisition and result processing using LabVIEW and MATLAB, and circuit simulation using NI Multisim.

As the laboratory programme is relatively demanding, 30% of its assessment was made non-compulsory, and it was for ambitious students only to obtain the bonus marks.

ELECTRONIC COMPONENTS IDENTIFICATION AND SOLDERING TECHNIQUES

In the initial phase of the project, the students identify electronic components and solder them on a printed circuit board. Before they start soldering of the project printed circuit board (PCB - Figure 1), they practice on a soldering board, which was prepared for them. They also have a chance to use some copper braid to try de-soldering components. Detailed instructions on soldering the board and testing its quality and integrity were provided to the students. The soldered project PCB is shown in Figure 2.
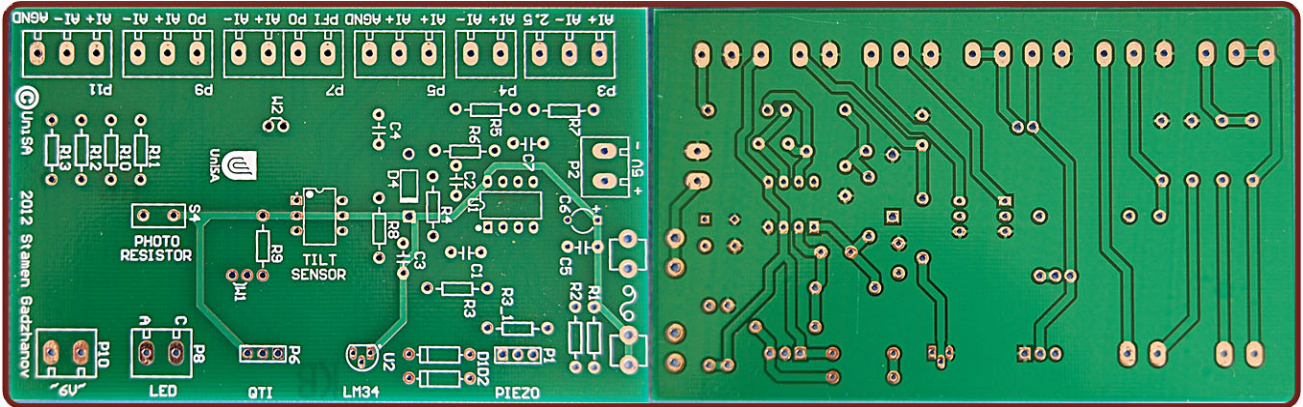
Figure 1: Project PCB - top and bottom layers.

Students are required to observe the following procedures: connect the pre-soldered printed circuit board to the provided USB DAQ device, ask the supervisor to check the connections before continuing, connect the DAQ device to the USB port of the computer. It should be recognised by Windows and the corresponding drivers installed. Start the NI LabVIEW 2011 program. Observe the provided *emp_Measurement_LM34.VI,* virtual instrument with the front panel shown in Figure 3.
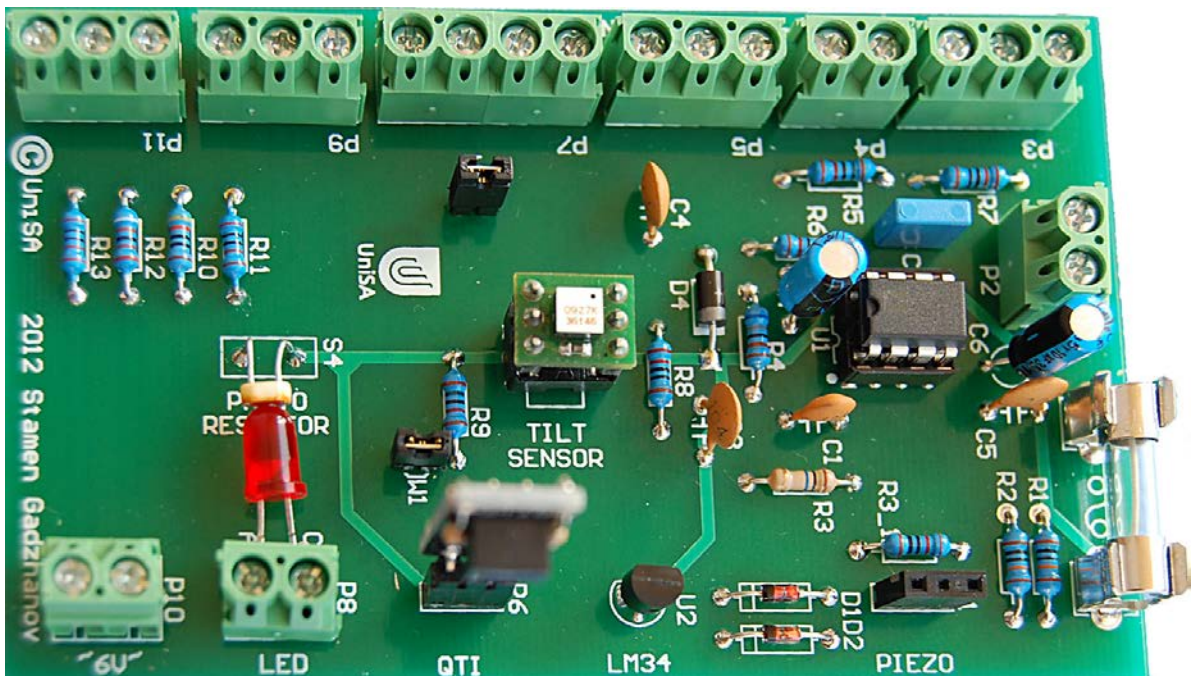

Figure 2: Project PCB - final appearance with soldered components.

DATA ACQUISITION, CONVERSION AND LOGGING WITH TEMPERATURE SENSOR

In this exercise, the students learn how to acquire analogue data with an NI DAQ, do basic data manipulations in NI LabVIEW programming environment, log the data from the measurement and save it into a measurement file, present the collected data in the form of indicators, charts and MATLAB plots.

The required equipment includes: pre-soldered printed circuit board (PCB), containing the temperature sensor LM34 and all other needed circuits and connectors. These included National Instruments data acquisition board NI USB-6009/6341, National Instruments LabVIEW 2011 programming environment, temperature measurement virtual instrument interface (Figure 3), *Temp_Measurement_LM34.VI* virtual instrument (Figure 4) and Mathworks MATLAB programming environment. Students changed the sensor sensing temperature by touching the sensor. The temperature is displayed both in Celsius and Fahrenheit degrees. The latter being the standard in the USA is not showing the sign of diminishing!

Instructions to the students include studying the block diagram (Figure 4) and the adjustment of settings of the DAQ assistant and *Write to Measurement file.VI* virtual instrument. The students need to set-up the device and the analogue input in the DAQ assistant. Then, describe what they have done and the meaning of the parameters: sampling rate, number of samples, minimum and maximum voltage, differential input.
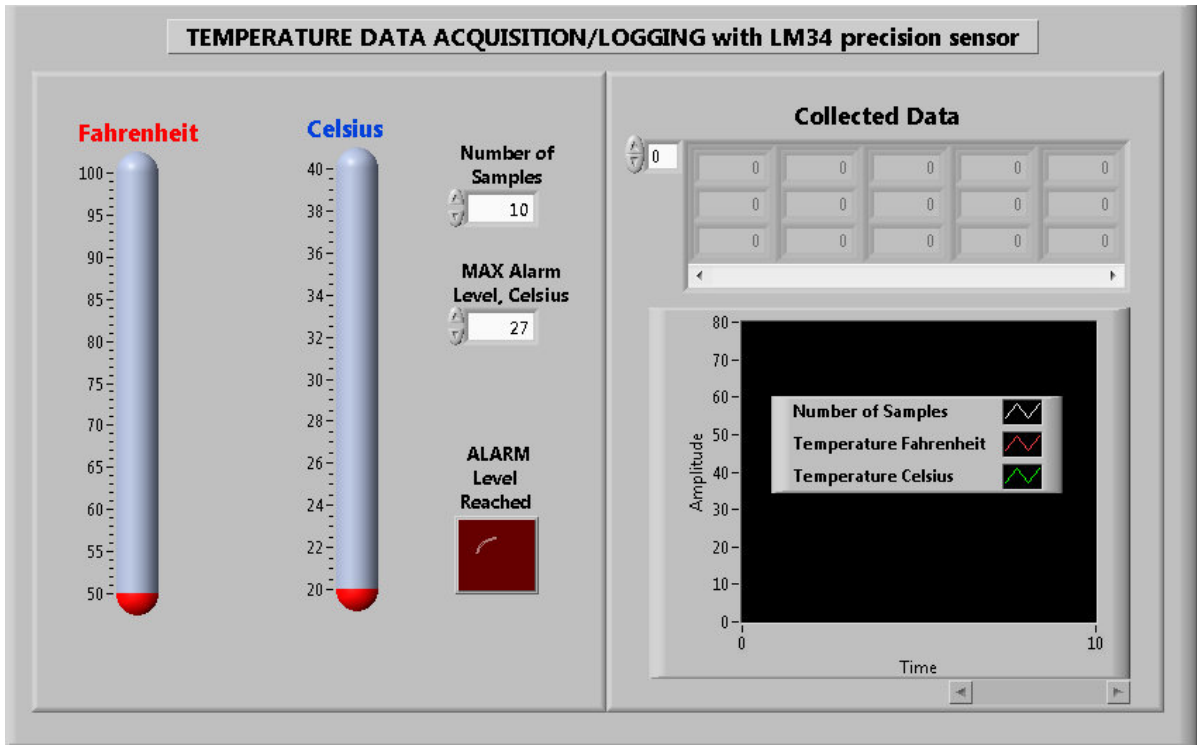
Figure 3: LabVIEW front panel interface for temperature data acquisition and logging.
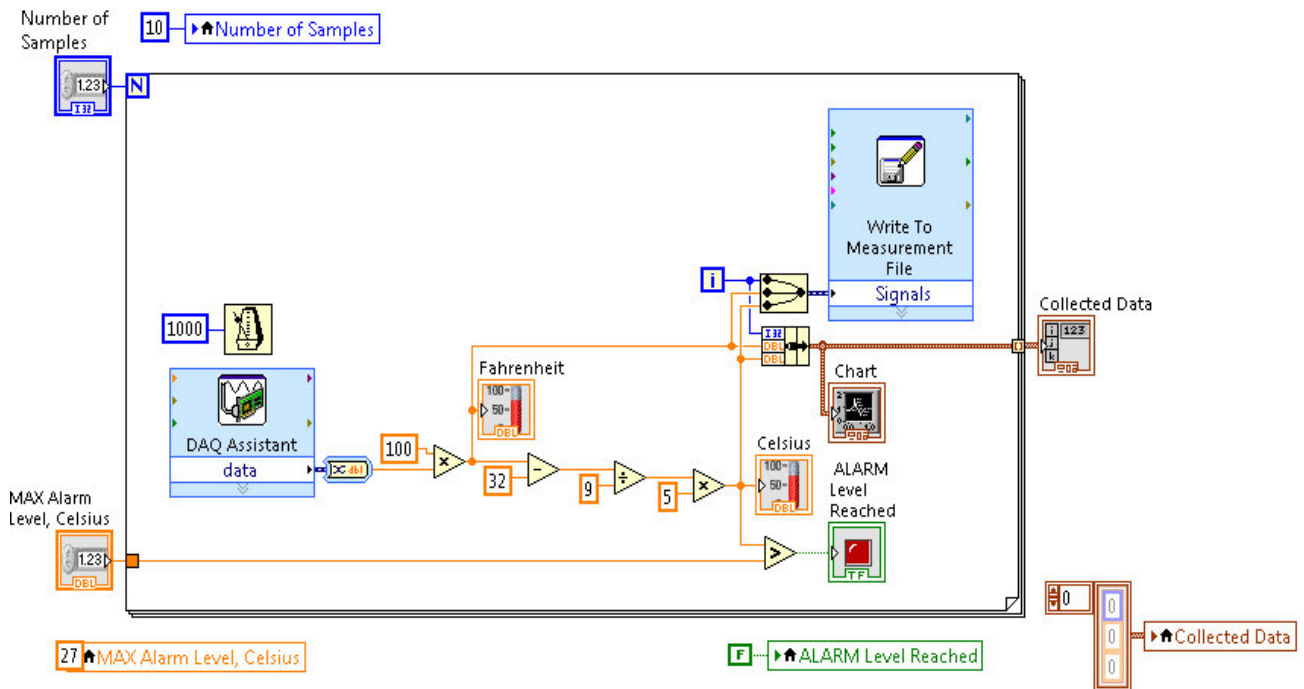

Figure 4: LabVIEW block diagram for temperature data acquisition and logging.

As the device was already powered-up from the USB port the VI can be run several times to collect data. Touching the LM34 sensor with fingers increases the temperature. When a student gains enough experience of how to use it, he/she will adjust the temperature alarm level to a degree where it will be triggered when they touch the sensor.

The students repeat the measurement and save the logged data (measurement file) for their report. They also take and save appropriate screenshots of the VI front panel. They can scroll through the measured/collected data in the array indicator and through the graph using the vertical and horizontal scrollbars.

The students, then, open the saved data file in MATLAB and are required to create a script to plot the data. One possible solution of the programme is presented in Figure 5. Students include screenshots in their reports; an example is shown in Figure 6.

```
Command Window                                              →  □  ↗  ×

      This is a Classroom License for instructional use only.
      Research and commercial use is prohibited.
>> load Data_Log_Measurement_Temp_60009_opit.txt;
>> time = Data_Log_Measurement_Temp_60009_opit (:,1);
>> temp_F = Data_Log_Measurement_Temp_60009_opit (:,2);
>> temp_C = Data_Log_Measurement_Temp_60009_opit (:,3);
>> plot(time,temp_F,'b',time,temp_C,'r');
>> legend('Fahrenheit', 'Celsius');
>> title('Temperature F/C change vs. time');
>> xlabel('Time [s]'); ylabel('Temperature [degrees]');
fx >> |
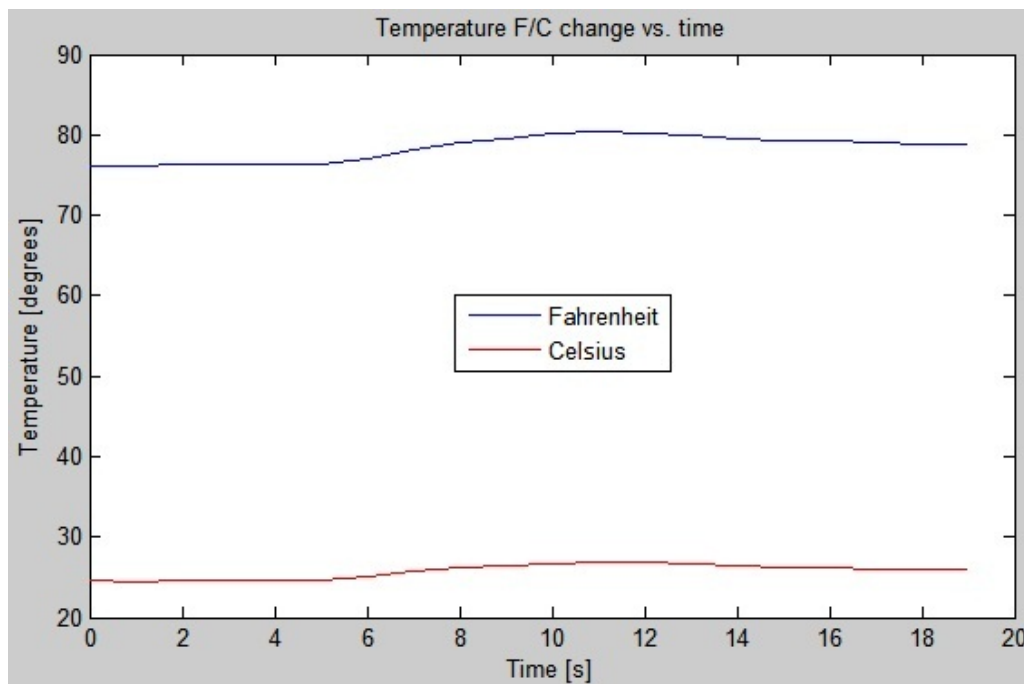```

Figure 5: MATLAB plotting script.



Figure 6: MATLAB plot of the collected temperature data.

CONCLUSIONS

The experiments developed have demystified to the students the process of measurement using sensors, measurement data acquisition, processing and visualisation, as well as related hardware and software, items contained in devices used every day in household and industry applications.

The practicals have contributed to the increased awareness and hands-on ability of engineering students in using computerised measurement techniques. They developed skills that are important for their future studies and their careers in modern industrial environments.

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