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Measurement and observation inside a PC

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ABSTRACT: At Edith Cowan University, a Computer Installation and Maintenance (CIM) unit was developed in response to employers' expectations of computer science graduates and the students' need to develop skills in this area. Previous studies have shown that these students typically lack sufficient physics and maths to properly support their learning in the CIM unit. As such, various practical workshop activities began to be trialed that were designed to improve the students' physics and maths skills within a CIM context. These activities range from simple measurements of power plug DC voltages, to observing and measuring the period of clock pulses on an ISA bus and then calculating the frequency and bandwidth. Observations and measurements of the monitor synchronisation pulses also led to calculations. This approach is in line with the general philosophy of the CIM unit where both practical and theoretical exercises help to promote mutual reinforcement. Students are required to use a Cathode Ray Oscilloscope (CRO) to make these observations and measurements. Although almost all students had never used a CRO, they were able to obtain meaningful results after some brief orientation tasks.

INTRODUCTION

The last decade has seen a rapidly increasing demand for trained computer professionals with the widespread adoption of PCs by business and community organisations. However, some of the skills required by employers are not provided by university computing degrees [1]. In particular, many employers demand practical skills in installing software and hardware, as well as fault finding and the maintaining of PCs.

A single semester Computer Installation and Maintenance (CIM) unit was developed at Edith Cowan University (ECU), Perth, Australia, to meet this demand [2]. It is regularly oversubscribed and enjoys high student approval ratings. The unit has no prerequisites (apart from normal university entry) and adopts a practical top-down and problem-orientated approach where the PC is considered as a collection of inter-related modules. Each module is looked at in detail appropriate to a first year unit and first line maintenance objectives. *First line maintenance* may be taken to mean on-site, in-situ problem identification and correction – the faulty module is identified and replaced. The CIM unit consists of one two-hour lecture and one two-hour *hands-on* workshop each week.

The workshops require students to take the cover off a PC to install and test a range of components (eg a CD-ROM drive). In particular, they provide a supportive environment where students can gain practical skills, experience, knowledge and confidence.

The results of surveys undertaken by staff on the CIM unit indicate that CIM students perceive the workshops as a very important part of this unit. The most recent such anonymous survey discovered that 51% of students found the workshops very useful, 45% found them to be useful, 4% were neutral, whilst 1% noted that they were not useful and none found the workshops useless. Moreover most students wanted more practical and also thought that the practicals helped them to understand the theory aspects of the unit.

PHYSICS CONCEPTS

Physics concepts underpin a range of topics covered in CIM lectures and workshops, including occupational health and safety. Following concerns that many CIM students were not demonstrating a rudimentary knowledge of school physics, a questionnaire was administered to ascertain their background in physics and test their understanding of simple electric circuits. A slim majority of students indicated that they had no physics above lower secondary school science. Although the questionnaire tested concepts and skills normally taught at this level, most students (including some with upper secondary school physics) recorded a poor result [3]. Unfortunately, this was in keeping with research that suggests that students often have difficulties with these basic concepts and some misconceptions are widespread [4-8].

In keeping with this, it was noticed by staff on the CIM unit that some students did not appear to have an appreciation of representations of the waveforms and of signals described in the literature and unit material. For example, students drawing signals sloping backwards confirmed such suspicions as this indicated that part of the signal was undergoing a time reversal. When questioned further on this matter it transpired that it was not due to poor artistic skills on the part of the students but rather a misunderstanding of the representation being used. Methods were sought to give students an understanding of the meaning of waveform representation. Hence there was a need to address the physics needs of CIM students within the CIM unit. The development of teaching strategies and materials is an ongoing collaborative project between physics and computer science staff at ECU.

POWER SUPPLY AND ISA BUS MEASUREMENTS

The ISA bus, in common with many computer buses, carries a combination of data, control and power supply lines [9]. The oscilloscope was used by students to investigate the waveform of the DC supplies provided, hopefully a straight flat line, and to note the different voltages +5 V, +12 V, 0 V, -5 V and -12 V. The students could also observe that these are the same as those provided by the PC's internal power supply plugs for the floppy and hard disk drive electrical power requirements.

Many students had problems in converting between time periods and frequencies or imagining how such information might be used. Calculations involving frequency and time periods were used in bandwidth calculations undertaken by students to indicate performance bottlenecks due to computer hardware limitations.

The following example illustrates the type of calculations that students are required to undertake. It should be noted that the concept of bandwidth used here is bits or bytes per second and not Hertz or Megahertz from telecommunications theory. Bandwidth can be regarded as given by the following formula:

> *Bandwidth = Clock x Data Path Width x Efficiency. The early Intel 8088/86 required a memory cycle time of 4 clocks cycles (Efficiency = ¼) however, for the Intel 80x86 series, including the Pentium, the memory cycle time consists of only 2 clocks (Efficiency = ½) for external DRAM* [10]. *A 100 Mhz Pentium, with a data path of 8 bytes has therefore a bandwidth of 400 Mbytes/s* [11].

It was decided to allow students to observe the waveforms of the ISA bus clock line using the oscilloscope. The clock line was chosen because it would trigger the oscilloscope with an almost constant frequency to give a visible constant trace on the screen. The oscilloscopes could measure frequencies up to 20MHz and the ISA bus clock bus frequency is 8.33 MHz [12]. Hence this frequency was within the capabilities of the 20 MHz oscilloscopes used for measuring the frequency, although not for accurately determining waveform shape. A rule of thumb measure indicates that at least 10x the frequency limit for sine waves is required for accurate square wave observation. The lack of suitable square wave generators of appropriate frequency further limited the testing of the ability of the Cathode Ray Oscilloscope (CRO) to accurately display 8 MHz square waves in this respect

Old decommissioned machines were utilised to avoid damage to the more modern PCs. This ensured that even if the oscilloscope probes short-circuited any power carrying pins, then it would not matter even if these machines were destroyed. The only spare PCs fulfilling these criteria were not of the same type. However, nearly all PCs possess an ISA bus and this provided a common platform from which to obtain readings.

The use of the oscilloscope in this workshop was as a learning tool and not as part of their future likely employment in the CIM field as this unit covers only first line maintenance and modular replacement is used. The use of such CROs to detect component malfunctioning is therefore unnecessary. This workshop provided the opportunity for students in computing science to observe for them-selves that what their text books and unit staff had informed them was correct by noting readings and making measurements. Such experiences are common in other science subjects.

With respect to the ISA bus, Messmer notes that… *The bus frequency is generated by dividing the CPU clock, thus the ISA bus largely runs synchronous to the CPU* [13]. As the ISA bus regularly resets its frequency, students experienced problems in obtaining a stable trace. However, with a little perseverance and minor adjustments of the oscilloscope fine time base controls, the resulting waveforms could be viewed with not too much difficulty.

It was important that staff members are available to obtain a trace in case of any difficulty encountered. When students first start to become familiar with the CRO, it is possible for them to be unable to find the trace and having a staff member on hand to show them how to locate it can assist students to gain confidence.

STUDENT WORKSHOP ACTIVITIES WITH THE CATHODE RAY OSCILLOSCOPE

Activities using a CRO were incorporated into two successive CIM workshops. About half an hour of each two-hour workshop was allocated for each CRO session and students normally worked in groups of three. In each CRO session, students were given a detailed work sheet to guide them through the various activities. The demonstrator was on-hand to help students through these activities.

During the first workshop, students undertook activities to familiarise themselves with the basic functions of a CRO. These were to measure both DC and AC voltages and to measure the period and see the shape of various periodic signals. In the first part, students adjusted both the voltage and time scales in measuring the voltage of a household battery (1.5 V DC).

In the second part, a frequency generator was used to produce various periodic signals for students to see and measure both voltages and time periods. In particular, students gained practice in calculating frequencies from the measured time periods. For many students this was a difficult task as it involved the use of prefixes and scientific notation. This problem has been identified and is currently being addressed. Students were also able to pick up and measure the period of noise in the wire from the 50 Hz AC mains electricity in the room.

In a second workshop, students connected a fine voltage probe to the CRO and measured signals inside a computer where they measured some DC voltages. First, they identified the colour of wires coming out of the power supply and then measured the DC voltage of each corresponding power plug. Attention was then turned to the ISA Bus and its DC voltages were then measured.

Students were asked to observe the ISA bus clock signal and measure the period, calculate the frequency and finally calculate the ISA bus bandwidth. The period of the ISA bus clock signal should be 0.12 µs giving a frequency of 8.33 MHz. Measurements for the period between 0.1 µs and 0.2 µs were common, although many students did measure the anticipated value of 0.12 µs. Students then calculated the bandwidth for the

16 Bit ISA Bus (using an efficiency of 0.25). During the remainder of this workshop, students looked at both ISA and the PCI bus architecture.

EVALUATION OF WORKSHOP ACTIVITIES

At the conclusion of the CRO activities, nearly all students completed an anonymous questionnaire on their experiences. They were asked to agree (or strongly agree) or disagree (or strongly disagree) with a number of statements and were then invited to make comments on any benefits and difficulties encountered with the activities.

Forty students completed the questionnaire and they were overwhelmingly positive about their experiences with the CRO in the CIM workshops. Over three quarters of the respondents noted that time spent using the CRO was worthwhile; that the CRO activities should be incorporated in future CIM workshops and that their understanding of period and frequency had improved. Furthermore, 90% of students agreed or strongly agreed that they were able to use a CRO to measure voltages and periods inside a computer. This was in agreement with the researchers' observations of these students at work.

The CRO is an instrument that students' do not have a hands-on encounter until tertiary level physics and only 13% of students had any physics at tertiary level. Indeed, 42% of the students surveyed had no physics at school past compulsory general science at year 10. It was a major challenge to design a set of activities that would enable students from non-physics backgrounds to be able to use a fairly complicated instrument in a meaningful way in a relatively short amount of time.

Responses to the open-ended questions that asked for the most beneficial and most difficult aspects of the activities covered a wide range of replies that probably reflected the diversity of educational backgrounds involved. However, seeing was the most common benefit followed by measuring with responses like *to see the actual signals (instead of assuming them)*, *being able to measure frequencies and periods* and *being able to see the voltages of different pins*. The most common difficulties experienced by the students were in reading or adjusting the CRO, the mathematics involved, or even in attempting to keep *steady hands* when taking measurements using the CRO probes.

The results of the survey were consistent with observations made during the workshops. Students were challenged by these activities in many ways, but with the assistance of their peers or the demonstrator, they were able to work their way through to the desired outcomes.

CONSOLIDATION AND EXTENSION

Buoyed with the success of the CRO activities, these were consolidated into one workshop session and extended to include a new activity on monitors in the following semester. In this new set of activities, students probed the monitor outlet socket of a PC to view signals from the vertical and then the horizontal synchronisation pins in a VGA monitor socket. The pins were probed with partially opened up paper clips of the required thickness (using Sellotape as insulation) and attached to crocodile clips that fed the signal into the CRO.

The students measured the vertical and horizontal time periods, so that they could calculate the vertical and horizontal synchronisation frequencies and then the number of frames per second and lines per frame (although the latter can be obtained directly from the time periods). The vertical synchronisation frequency is the number of frames per second, and the number of lines per frame (which depends on the software display mode chosen) is given by dividing the horizontal synchronisation frequency by the vertical synchronisation frequency.

Students who rapidly completed the tasks were given the option to change the screen display resolution and observe the corresponding change in line and frame rates from a second measurement of the vertical and horizontal time periods.

At the conclusion of the workshop, nearly all students completed an anonymous questionnaire on their experiences, which included the relevant questions from the previous semester for comparison, plus two questions on the new monitor activity. The results for this semester were more positive than those previously obtained. In particular, students were stronger in their beliefs that time spent using the CRO was worthwhile and should be incorporated into future CIM workshops. After completing the monitor activity, over three quarters of the students agreed or strongly agreed that their understanding of how monitors produce pictures had improved.

CONCLUSIONS

Students require some knowledge of physics to be competent in installation and maintenance of computers. Cooperation between computer science involved in the CIM unit and the physics staff has enabled students in the CIM unit access to class sets of expensive equipment. Collaboration between these staff has allowed for the development of strategies to address students' physics needs in the context of the CIM class. The use of the CRO to measure voltages and time periods on an ISA bus is an example of how such collaboration can improve the experiences of students.

It should be noted that this collaboration has worked in both directions and physics students have also undertaken a similar tasks in the CIM workshop to help improve their skills and appreciation of the practical importance of basic physics understanding to modern technological devices such as the PC. These tasks were modified to take into account the physics students' greater knowledge and experience of the CRO and probable lesser experience of the internal workings of a typical PC.

Although taking measurements and making observations is common for students in science units, this is not often the case in computer science units. However, it must be stressed that the CRO is used in the CIM unit primarily as a teaching aid and is not intended for diagnostic use. CIM students found the CRO activities worthwhile and were able to use the CRO to measure voltages and time periods.

For work on higher frequency buses, such as the PCI bus and effectively observing square waves on the ISA, bus higher frequency CROs will be required to enable this work to be extended to higher frequency buses and to provide reliable images of the waveforms under investigation.

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