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Portable Embedded Sensing System using 32 Bit Single Board Computer

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1. Introduction

Data acquisition is the process of bringing a real-world signal, such as a voltage, into the computer, for processing, analysis, storage or other data manipulation (Rongen, n.d.). Generally, Data Acquisition Systems (DAS) are used to electronically monitor or gather data from the external physical environment (Ng, 1994). DAS normally consists of three elements: acquisition hardware, input and storage/display unit. The acquisition hardware plays a vital role in influencing the performance of DAS. Most of the previous research has used Personal Computer (PC) as the acquisition hardware. The trend was then changed from standard PC to high speed PC to provide better performance in terms of data processing and data transferring. The embedded processor board has become a new alternative platform for DAS application. Several embedded processor board used as acquisition hardware are microcontroller, Field Programmable Gate Array (FPGA), Digital Signal Processor (DSP) and Single Board Computer (SBC). The microcontroller is the most popular platform for small and simple application because of its low cost. Some developments use FPGA as Data Acquisition Unit (DAU). FPGA allows modification of internal logic circuitry without touching hardware component. The DSP board is mostly used in applications that handle real-time computation process. The other current trend on embedded technology application is the Single Board Computer (SBC). One major advantage of using an SBC is that it can handle multitasking processes since it run with a modular Operating System (OS). The development can be done using high level language such as C, Java and Perl which are widely used, flexible and have a lot of support from the open source community. However, the key to select a suitable processor board depends on the purpose of its application so that the optimum functionality can be used according to its specifications.

2. Embedded-based DAS

In the early days of DAS, the Personal Computer (PC) is a main choice to operate as acquisition hardware (Omata, 1992; Rangnekar, 1995). Data is collected from the input using serial communication. This medium needs both input and data logger connected to serial or parallel port. Martin, S. (1990) stated that a major limitation of desktop computers in data acquisition and control application is the fact that it were designed for in office automation. He also mentioned that the desktop computer often does not meet the real-time requirement of high performance data acquisition and control. The use of the PC in DAS has several restrictions. It is normally installed in the laboratory or at a fixed place. Hence, it is not portable to handle different situation such as real-time outdoor testing. A sample may change due to varying time and conditions and this will influence the measured result if the measurement is not done in real-time. The embedded-based DAS is therefore a promising solution towards a portable DAS within a small scale hardware system.

The advancement in electronic and Integrated Circuit (IC) technology development has spawned a new platform in DAS. The DAS is changing from PC-based to embedded system application based. The embedded system is normally designed so as to minimize size, power consumption and cooling requirements (James, 2000). In these systems, hard disks are frequently replaced by ROM-based device which provide storage for all software including the operating system. An embedded controller is a mixture of control hardware and software to perform specific task. The embedded controller can handle many tasks depending to the software embedded within it. The processor board is an important component in industrial application. It handles most of the system processes such as retrieving data and controlling the systems. The advancement of recent electronic and fabrication technology has led to widespread utilization of tiny processors to manage complicated and complex tasks. Microcontroller, Digital Signal Processor (DSP) and Field Programmable Gate Array (FPGA) are examples of popular embedded based acquisition hardware currently in use. Microcontrollers use serial communication, while DSP, FPGA and SBC might include faster communication method such as Universal Serial Bus (USB) and Ethernet.

Microcontroller is one of the early embedded-based acquisition hardware used in DAS. The DAS microcontroller based is very popular previously and is still being used because of its low cost (Hansen, 2004; Riley, 2006; Misal, 2007). Many applications are using microcontrollers as control units for simple system and small applications. The trend in embedded based DAS is changing towards a more advanced and powerful processor board. The Field Programmable Gate Array (FPGA) is a semiconductor device that can be configured by the customer or designer after manufacture. It has an internal logic blocks or digital electronic gates to perform complex combination functions. FPGA has become a popular DAU since it allows modification and simulation of logic circuitry without hardware modification (Laymon, 2003). The Digital Signal Processer (DSP) is a specialized microprocessor designed for digital signal processing generally in real-time computing. DSP board are widely used in applications such as audio signal processing, video compression, speech recognition and image manipulation. According to Eyre and Bier (2000), the latest DSP processor board functions with a faster clock cycle, has more instruction set and have wider data buses to enable more data to be processed. The DSP board is also chosen as a processor board to handle real-time computation with mean acquisition rate around micro second (μs) (Alderighi et al., 2002).

3. Single board computer

The early microcomputer uses backplane that is attached with several circuit modules such as Central Processor Unit (CPU), memory, serial port and peripherals. The idea of SBC is to combine all those parts in a single board without backplane. Robert A. Burckle (n.d.) from WinSystems in his article 'The Evolution of Single Board Computers' states that the first SBCs were proprietary designs needed to satisfy a specific application. That statement is precisely true and fulfills the standard of embedded systems definition. Table 2.1 outlines several SBCs from various manufacturers with CPU architecture, form factor and its features. Only a few examples are taken from original sources (Baxter, 2001), and with different table view.

Manufacturer/ SBC (model)	CPU Architecture/ Form Factor	Features
Motorola/ MVME5100	PowerPC/ VMEbus	750/7400 Altivec, dual-PCI mezzanine card sites, up to 1GB ECC SDRAM, dual Ethernet ports, two serial ports, up to 16MB Flash
Zynx/ ZX4500	PowerPC/ CompactPCI	24 10/100 Ethernet ports, two Gigabit Ethernet ports, PMC/PPMC slot for additional I/O and an expansion processor, fully hot-swap compliant
Ampro/ Little Board/P5x	x86/ EBX	PC/104-plus expandable PCI/ISA bus, P5x supports up to 256MB DRAM with bootable Compact Flash socket and 10/100Base-T Ethernet, USB, IrDA, KB, floppy, IDE, serial and parallel I/O, also supports C&T 69000-series PCI LCD/CRT controller with PanelLink, LVDS and NTSC options
WinSystems	x86/ PC/104	133MHz 586DX with up to 72MB Flash disk, CRT/LCD display video controller, Ethernet, IDE and floppy disk controllers, serial, parallel and keyboard
Bright Star/ mediaEngine	StrongARM/ 5.2"x5.3"	8-64MB SDRAM at 100MHz, 1-20MB Flash, Type II Compact Flash socket, Type I/II/II PCMCIA socket, 10Base-T Ethernet, three serial ports, V.90 modem, LCD panel controller, USB slave interface
Intel/ Assabet	StrongARM/ 2.5"x5"	64-256MB of TSOP SDRAM, 64-128MB onboard socketed Flash, integrated LCD support, Bluetooth, GSM digital radio, audio in and out, built-in TV encoder supporting S-video, NTSC, PAL and RGB formats, IrDA port, soft-modem support

Table 1. Embedded Linux SBCs (Baxter, 2001)

Generally the SBC is a complete computer built on a single Printed Circuit Board (PCB). It has all important elements similar to the standard computer including processor, memory and Input Output (I/O). Certain peripheral are also available within SBC including serial port, parallel port and USB port. The Ethernet port, wireless network socket, audio line in and VGA port may customize as well that are sometimes custom-built to perform specific tasks. Otherwise it does not come with default display unit and input hardware. The most

important feature of the SBC is it can run modular OS. The Z80-based "Big Board" (1980) was probably the first such SBC that was capable of running a commercial disk operating system (LinuxDevices, n.d.).
Most SBC boards use commercial off-the-shelf (COTS) processor. This helps reducing development time and dependencies on technical staff to develop dedicated processor board from scratch. The SBC processor board is suitable for use in critical and complex applications to develop a systems model or handle an analysis before running the real system such as in a flight simulator (Peters, 2007). SBCs are often integrated into dedicated equipment which is used, for example, in industrial or medical monitoring applications (James, 2000). The use of embedded systems is reasonably low cost and small physical size promising the most effective solution. It is not only suitable for portable system but also significantly improving the capabilities of the instrument (Perera, 2001). Zabolotny et al. (2003) has replaced the VME (Versa Module Eurocard bus) controller with embedded PC for TESLA cavity controller and simulator DAS. The replacement was made to enhance functionality in terms of bits and register manipulation, data processing operation and to increase efficiency of data acquisition and control and enhancing data transfer.

4. System overview

Hardware design gives an overview of the physical interaction among the devices of the system. Hardware components of the DAS are shown in Fig. 1 below. SBC acts as an acquisition hardware that acquires data from sensors. A signal conditioning circuit is used for high output impedance sensor, to match the built-in ADC on the SBC board. The developed DAS based on SBC is named Portable Embedded Sensing System (PESS). PESS is developed with an integration of SBC, matrix keypad, LCD panel and sensors. The matrix keypad functions as an input device and information data is displayed using LCD panel. Fig. 2 outlines the PESS system architecture which consists of hardware and software.

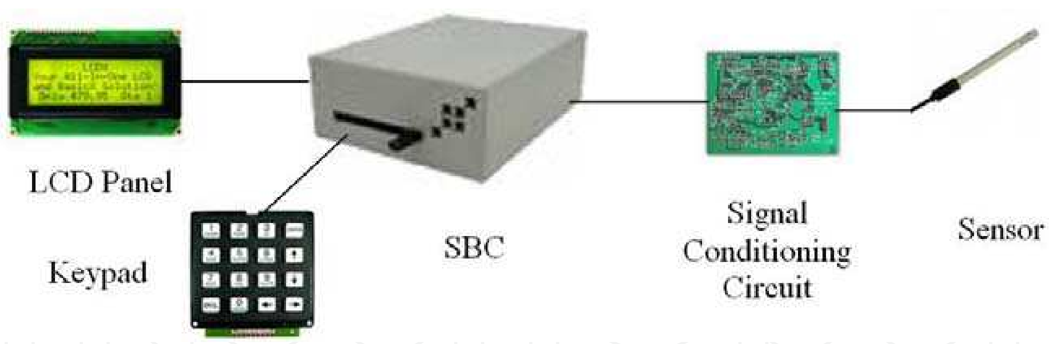


Fig. 1. PESS hardware design

The PESS system has several limitations in terms of storage capacity and data view space. Compact Flash (CF) is used as storage devices which functions as a hard disk for the SBC. The data that can be stored on the CF is up to 4GB. Due to the limitation of CF storage device, PESS is not suitable for applications that require large storage capacity.

4.1 Embedded acquisition hardware: TS-5500 SBC

Technologic System offers semi-custom and off-the-shelf Single Board Computers (SBC). The product from Technologic Systems available in two different architectures which are ARM and X86.

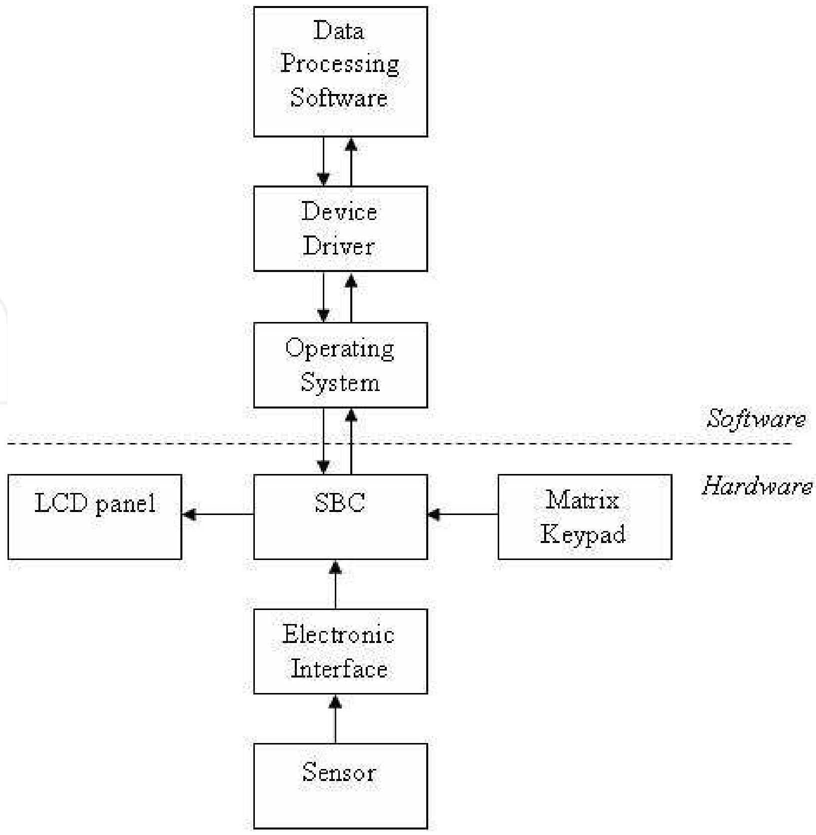


Fig. 2. PESS system's architecture

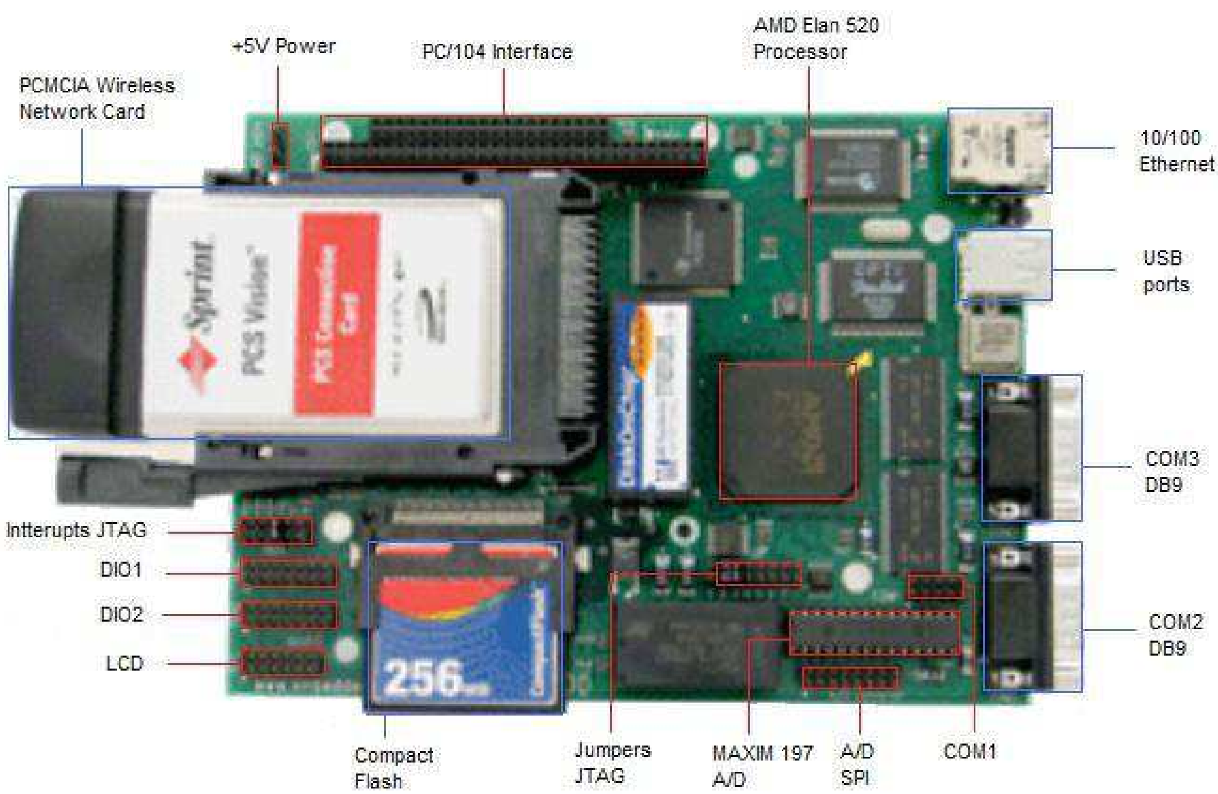


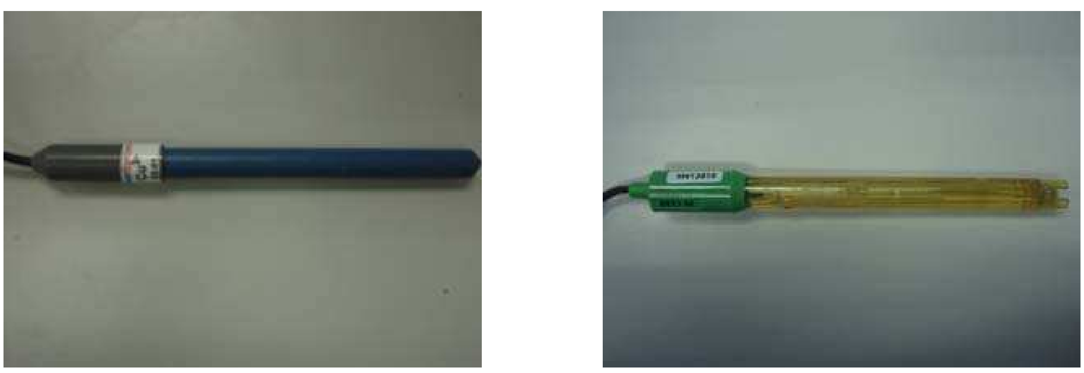
Fig. 3. TS-5500 Single Board Computer

For ARM SBCs, they can be identified with TS-7000 number series. There are four series for ARM SBCs which are TS-7200 series, TS-7300 series, TS-7400 series and TS-7800 series. The X86 SBCs is available in two series which are TS-3000 and TS-5000. The X86 SBCs have slower CPU compared to ARM SBCs. The TS-3000 series run Intel 386 CPU with 33 MHz and has small memory which is 8 MB. The TS-5000 series run 133 MHz AMD Elan 520 CPU and has 32 MB of memory. The TS-5000 series is manufactured with wireless network interface. Fig. 3 show the TS-5500 SBC main board.

TS-5500 SBC from Technologic Systems has been used by many developers in various fields including robotic, web server application and data acquisition and control system. In 2003, Hoopes, David, Norman and Helps presented the development of autonomous mobile robot based on TS-5500 SBC. The other example of robotic design and development based on TS-5500 SBC was built by Al-Beik, Meryash and Orsan.

4.2 Sensor interfacing

Two types of analog sensors are used which are temperature sensor and ion selective electrode. LM35DZ temperature sensor from National Semiconductor is a simple analog sensor used in this research where it's measurement is not using a signal conditioning circuit. Copper (Cu^{2+}) ion selective electrode from Sensor Systems are used with a reference electrode for high impedance output sensor type. Fig. 4(a) and 4(b) show the Copper ion selective electrode and reference electrode respectively.



(a) (b)

Fig. 4. a) Copper ion-selective electrode b) Ion-selective reference electrode

The most frequently processes performed in signal conditioning are amplification, buffering, signal conversion, linearization and filtering (Ismail, 1998). ADC normally can read analog inputs that have low output impedance. If the input impedance of the sensor is high, the ADC reading is unstable and not reliable. Typically the glasses electrodes such as pH probes or gas concentration probes are of this type (Microlink, n.d.). Therefore a signal conditioning circuit has to be integrated with a high output impedance sensor (*Application notes 270*, 2000). This can be done by attaching to a voltage follower as a buffer element to match the impedance. In this research, the signal conditioning circuit built has two stages circuit. The first stage functions as a buffer unit which will decrease the input impedance from analog input. The second stage is a filter that removes the noise signal. The OPA2111 (*OPA2111*, 1993) operational amplifier is used within the signal conditioning circuit. The OPA2111 has high internal resistance of 10^{13} Ω for differential mode and 10^{14} Ω for common-mode. The signal conditioning circuit used is shown in Fig. 5.

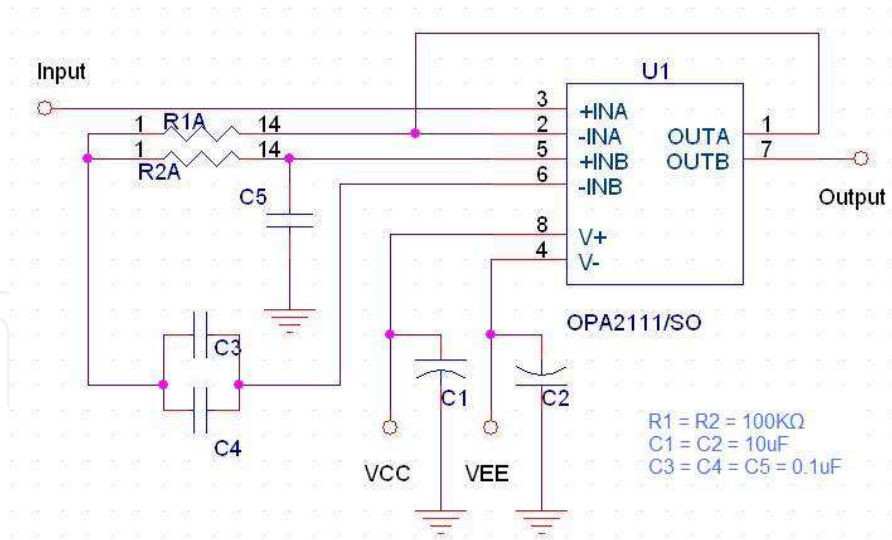
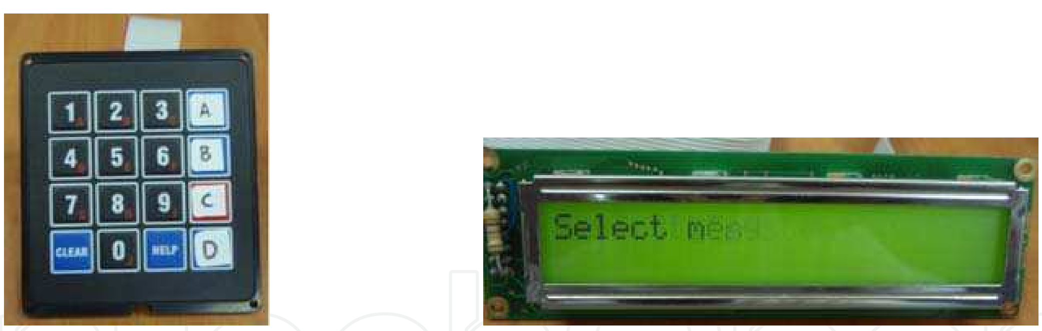


Fig. 5. Signal conditioning circuit

4.3 Input/Output of PESS system

The 4x4 16 button matrix keypad is used as input device for the system developed. The keypad is manufactured by ACT Components, Inc with physical size 4.7"W x 1.7"H x 0.4"T. A nine (9) pin input is used to connect between matrix keypad with device or processor board using serial cable. The 24x2 alphanumeric LCD panel is use as display for this system. The LCD is manufactured by Lumex Inc with physical size of 118mm x 36mm x 12.7mm. It connected to processor board using 9 inputs serial cable.



(a) (b)

Fig. 6. a) 4x4 matrix keypad b) 24x2 alphanumeric LCD panel

4.4 Embedded OS: TSLinux

Technologic Systems provides two free OSes which are developed by their research team: Linux and DOS. These OSes are developed to be used with their product only. However, many other OSes can also be used with TS products such as uC/OS-II, eRTOS, microCommander modular Human-Machine Interface (HMI), MicroDigital SMX modular and QNX Embedded Real Time OS. TSLinux is chose to run on SBC in this research. TSLinux is a PC compatible embedded Linux distribution built from open source. There is a tailored Linux kernel for each TS SBC, along with completed driver support for the hardware. The kernel source is also provided to end users to enable custom changes and development.

Several TSLinux features as follows:

- Glibc version 2.2.5
- Kernel version 2.4.18 and 2.4.23
- Apache web server with PHP
- Telnet server and client
- FTP server and client
- BASH, ASH, minicom, vi, busybox, tinylogin

5. Software development

Two software modules developed in the PESS system which are the Analog Input Preprocessing and Data Presentation. The Analog Input Preprocessing module involves data acquiring from sensor, converting analog input to digital output and calculating converted output to human readable value. A C code named *sensor* to cope all those processes is developed. Data Presentation module in PESS system is handled by a program named *Interactive System*. An *Interactive System* provides current sensor' readings and the information of the system such as disk (CF) usage and memory capacity status. Fig. 7 show the interaction between both software modules which running concurrently. *Sensor* program processing the analog inputs and store converted data into shared memory, meanwhile those current data available on shared memory can be accessed via *Interactive System* program.

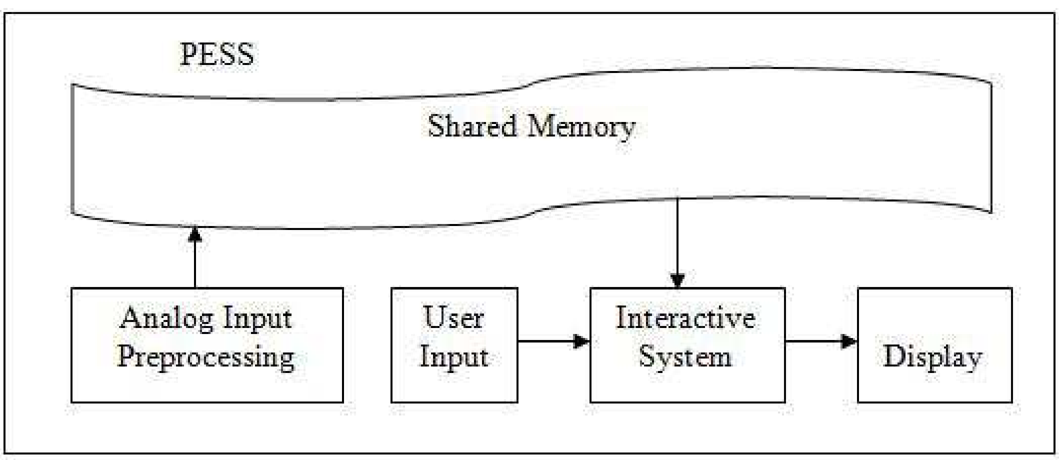


Fig. 7. Software architecture of PESS system

5.1 Analog input preprocessing

Signals from analog sensors must be converted to digital signals before electronic device can read them. The conversion from analog input to digital output is done using the ADC. The digital outputs which are in binary format is then calculated into human readable value in decimal value and presented in Volt parameter. The TS-5500 supports an eight-channel, 12-bit ADC capable of 60000 samples per second. Each channel is independently software programmable for a variety of analog input ranges: -10V to +10V, -5V to +5V, 0V to +10V and 0V to +5V. The ADC control register, the Hex 196 setting is outlined by Fig. 8 below. The IO address is read from right to left starting with 0. The settings are based on a bipolar mode with 5V output range for all channels.

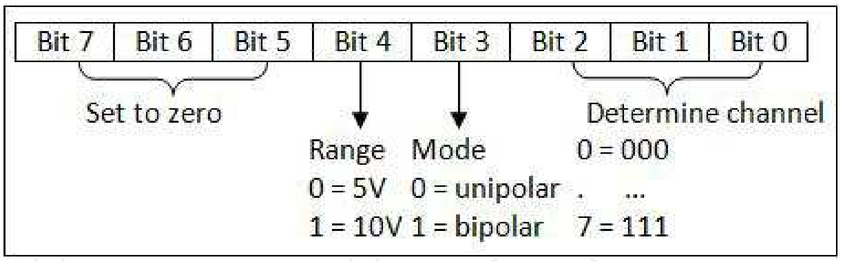


Fig. 8. ADC control register

The processes of Analog Input Preprocessing can be divided into four stages: initialization, bit checking, reading and storing. At the initialization stage, the permission to access ADC IO register must be set. Three registers are involved in accessing the ADC I/O address which are, Hex 195, Hex 196 and Hex 197. The digital output of an analog input is available after the ADC has completely converted the input within 11µs. The End of Conversion (EOC) status can be checked at bit 0 of register Hex 195. The conversion is completed if the bit 0 of Hex 195 indicates '0'. The digital output of the converted analog input is available at Hex 196 and Hex 197. 8 bits of them is available at Hex 196 which called as the lower 8 bits or LSB. The other 4 bits is available at Hex 197 which called as the upper 4 bits or MSB.

Analog Input Preprocessing algorithm

Step 1 : Initialize the IO permission of ADC
Step 2 : Create and attach shared memory file descriptor
Step 3 : Set up ADC control registers
Step 4 : Check End Of Conversion (EOC) signal
4.1 If EOC signal HIGH (1)
Go to Step 4 until EOC signal LOW (0)
Step 5 : Determine input mode
: Check sign bit
Step 4 : Read all (12) digital output (LSB and MSB)
Step 5 : If input mode negative
5.1 Perform two's compliment
Step 6: Convert binary value (digital output) to decimal value
Step 7: Store converted reading into shared memory
Step 8: End

Fig. 9. Analog Input Preprocessing algorithm

5.2 Data presentation

The *Interactive System* provides important information about the PESS system. The main goal of the *Interactive System* is to display current sensors' readings upon requested by the user. It also provides other information of the system (PESS) such as disk usage and memory status which viewed at the LCD panel. Another feature included in *Interactive System* is a control process. This process is to enable user to restart or shutdown the PESS for maintenance purposes. The matrix keypad functions as an input device that handles menu selection in the *Interactive System*. Fig. 10 outlines the main flow chart of the *Interactive System*.

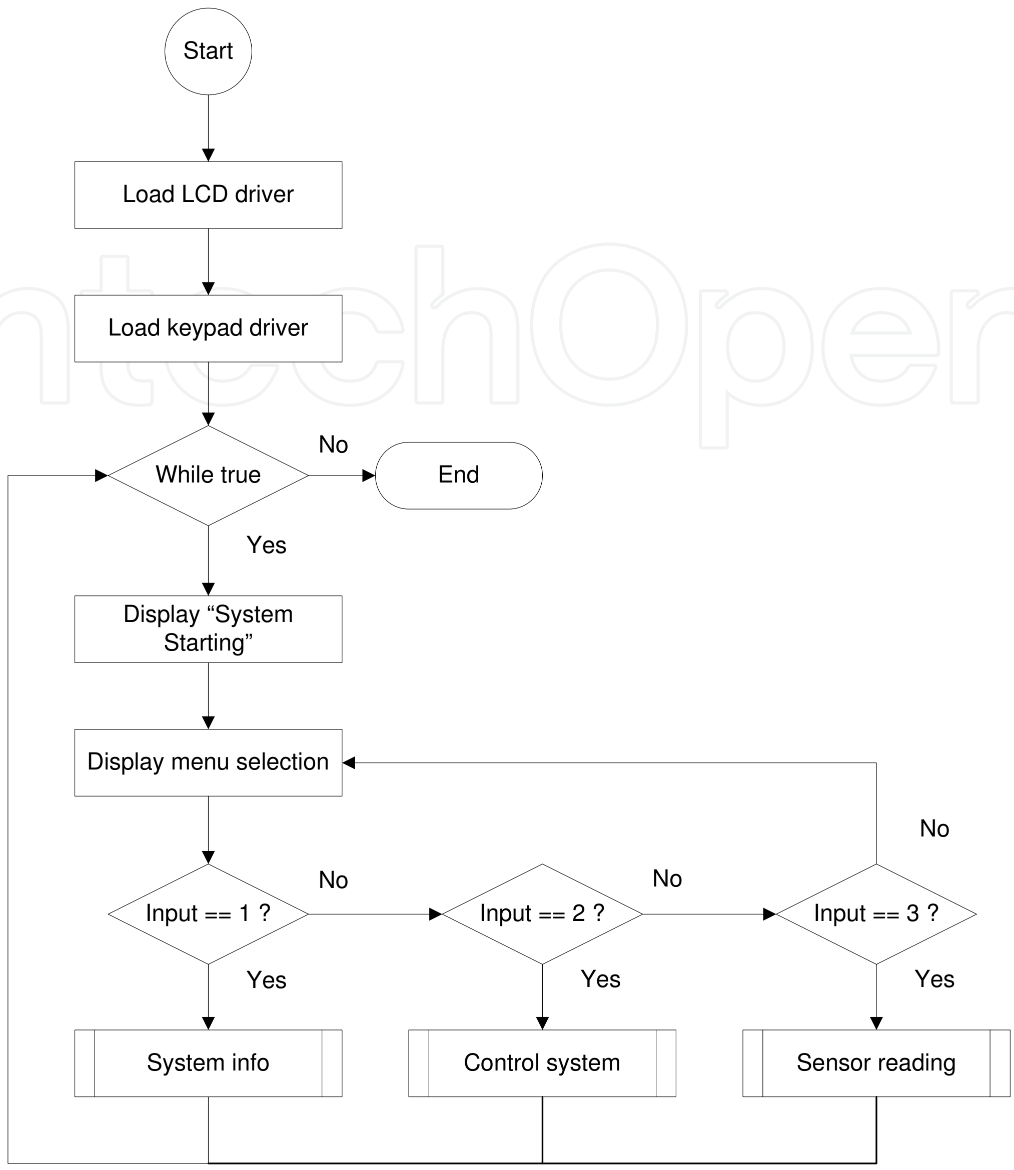


Fig. 10. *Interactive System* flowchart

Three options are provided: to check current sensors' readings, to check systems' information or to control the system. Three subroutines are created to handle those processes which are *system info*, *control system* and *sensor reading* as outlined by Fig. 10 above. Actually the processes of these three subroutines are carried out by combining the binary C code and shell scripts. Shell scripts retrieve current sensors' readings which are processed by the *sensor* program, and manipulate Linux commands to retrieve system information and control the system. The binary C code grabs the data given by the shell script codes and displays them.

6. PESS implementation

Standard method to gain the result of environment parameters such as water and air quality is using laboratory experiment. The laboratory experiment is not suitable for long period testing work such as in monitoring process. The alternatives method can resolve that

limitation. The US Environment Protection Agency (EPA) define alternatives method as any method but has been demonstrated in specific cases to produce results adequate for compliance monitoring (Quevauviller, 2006).
The alternatives method leads to real-time data sampling which can produce instant output result for *in situ* deployment. It also provides easier usage with advance electronic devices in a compact size but can perform multitasks excellently. The handheld instrument usage is one of the alternatives methods such as using Data Acquisition (DAQ) device. The DAQ device such as SBC offers variety of peripherals to make it function as a standalone system. Meanwhile the ion specific electrodes is also been used in many application with handheld instrument. For example, non-invasive chemical sensor arrays provide a suitable technique for *in situ* monitoring (Bourgeois, 2003). Many researches use specific ion selective electrode or sensor array for detection of target environmental substance or gases (Carotta, 2000; Becker, 2000; Wilson, 2001; Lee, 2001).
The measurement of the LM35DZ temperature sensor is done without connecting the signal conditioning circuit. The LM35DZ sensors are only given a power supply and grounding. The sensor' outputs are connected directly to ADC port of SBC during measurement. Fig. 11 shows the experimental setup to acquire ion selective electrode's reading. Three parts involve here are: (1) SBC, (2) Sensors (electrodes) and (3) Signal conditioning circuit. While the red arrows marks from point A and B are the input and output from signal conditioning circuit respectively. Sensor reading' results are presented in next section.

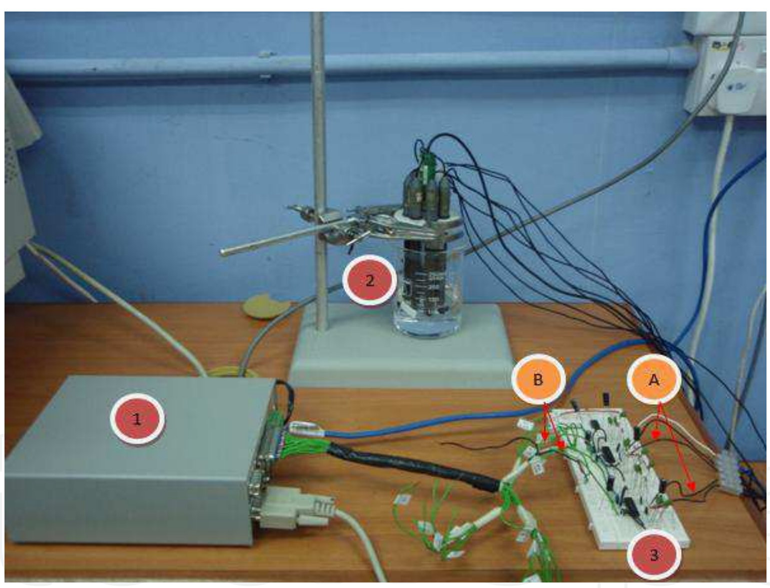


Fig. 11. Experimental setup of ion-selective electrodes

The programs called *sensor* and *Interactive System* are developed to handle all processes involved in Analog Input Preprocessing and Data Presentation modules respectively. Both modules are running separately but have a relationship in terms of data sharing. Fig. 12 outlines the state diagram for PESS system and the running processes listing. The current running process on PESS system including *sensor* and *Interactive System* as underlined in figure below. Analog Input Preprocessing module acquires data from sensors and storing converted data in a shared memory at PESS. These processes are repeated again with new inputs after certain time interval. While the *Interactive System* retrieve those converted data from shared memory and view it at LCD panel.

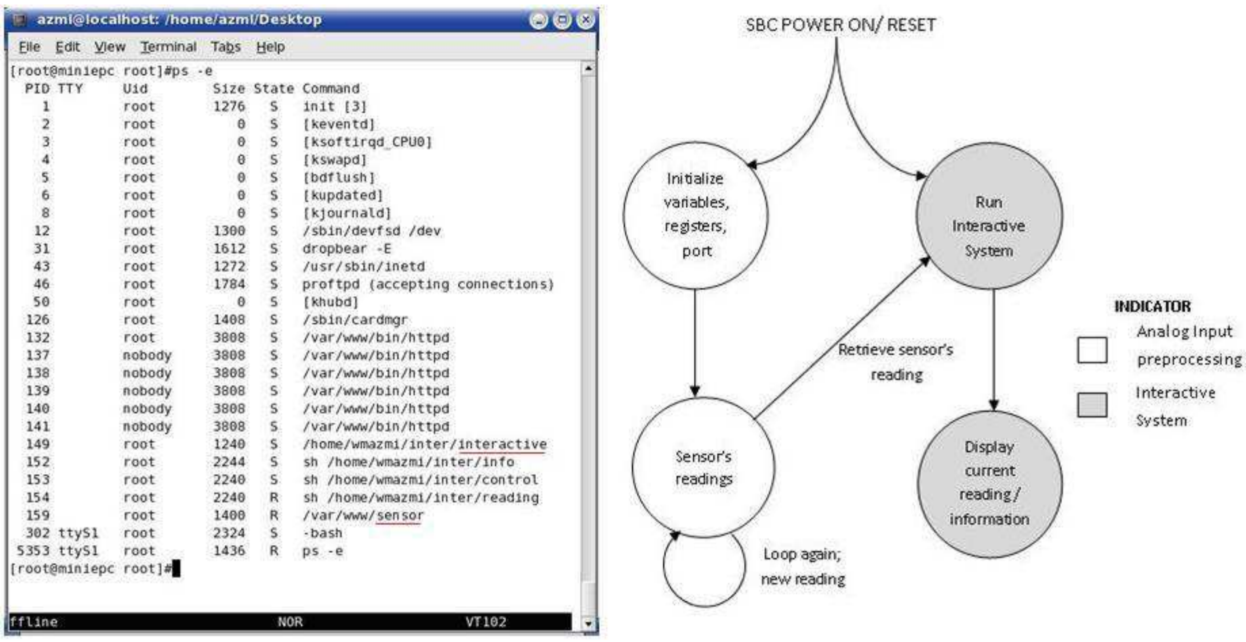


Fig. 12. PESS state diagram and running process listing

Four processes (programs) are set up to automatically start during the boot up program. The processes are: inserting the matrix keypad driver module; running *sensor* process; running the scripts (*info.sh*, *reading.sh* and *control.sh*) of *Interactive System*; and running the *Interactive System* program itself. These processes are underlined in Fig. 13. This procedure can be done by configuring how process will start up at */etc/init.d* directory.

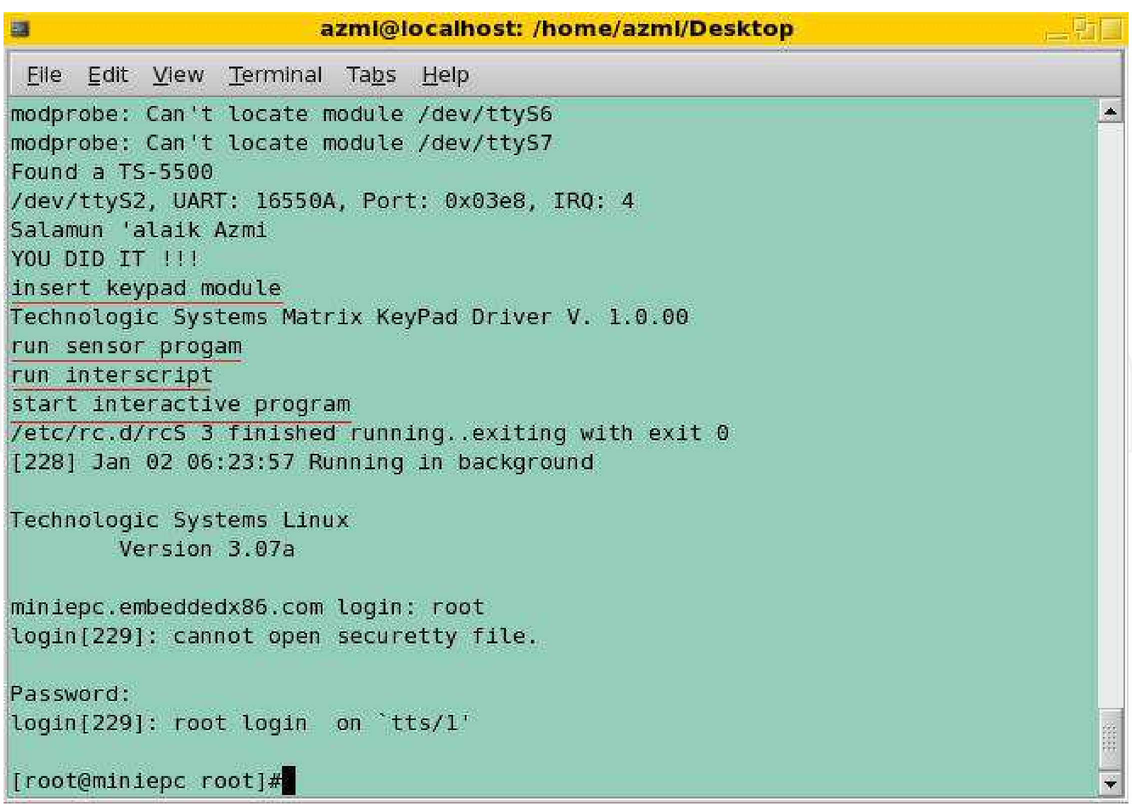


Fig. 13. Start processes automatically during system boot up

The integration between the SBC, the matrix keypad and the alphanumeric LCD display is to create an *Interactive System* for a standalone system. Fig. 14(a) shows the components that are connected to allocated ports. A serial ribbon cable is used to connect the matrix keypad and LCD panel to pin ports on SBC. Fig. 14(b) and Fig. 14(c) show the menu selection of *Interactive System* and current sensor' readings respectively.

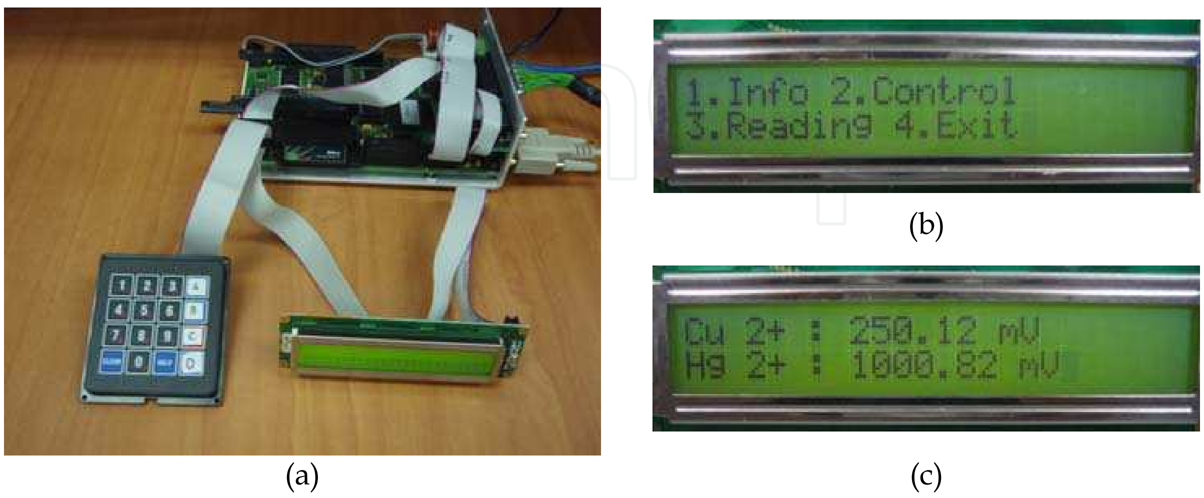


Fig. 14. a) Hardware used in *Interactive System* b) *Interactive System* menu selection c) Example of current sensor' readings

7. Result and discussion

Bit error is the value of an encoded bit that has been changed due to a transmission problem such as noise in the line and which is then interpreted incorrectly. Commonly notated as bit error ratio (BER), the ratio of the number of failed bits to the total number of bits calculated. The number of bits in the ADC determines the resolution of the data acquisition system. The resolution of an ADC is defined as follow (*Principle of Data Acquisition and Conversion*, 1994);

$$\text{Resolution} = \text{One LSB} = \frac{V_{FSR}}{2^n} \tag{1}$$

Where V_{FSR} is a full scale input voltage range and n is the number of bits.
The ADC is set up to read all eight analog channels using bipolar mode within 5V range. Therefore the total output range is 10V which are from -5V to +5V. The step resolution of digital output is calculated as below;

n = 12

V_{FSR} = 10V (-5 V to +5 V)

$$\text{Resolution} = \frac{10\text{ V}}{2^{12}} = 2.44\ mV$$

Analog input reading verification is the important part in PESS development as it will ensure that the sensor' readings is correct and reliable. Verification testing of analog input reading is carried out by checking the output of each ADC channels. DC power supply is used as input to ADC and tapped manually to every channel. In a single reading, only one channel is given 1.0 V input while the rest is given 0 V using ground signal of SBC. The first

1.0 V input is given to channel 7, then to channel 6 until the last channel, channel 0. Fig. 15 shows the input from DC power supply while Fig. 16 show the result of analog input reading verification testing. From Fig. 15, the input from DC power supply is 1.002V as displayed by digital multimeter.

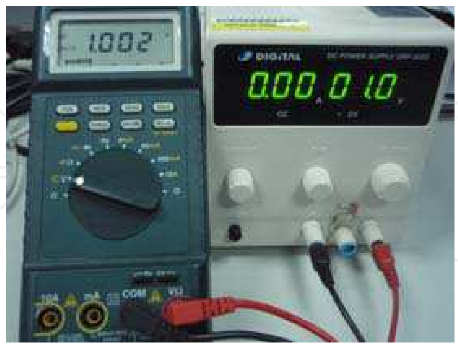


Fig. 15. Input from DC power supply

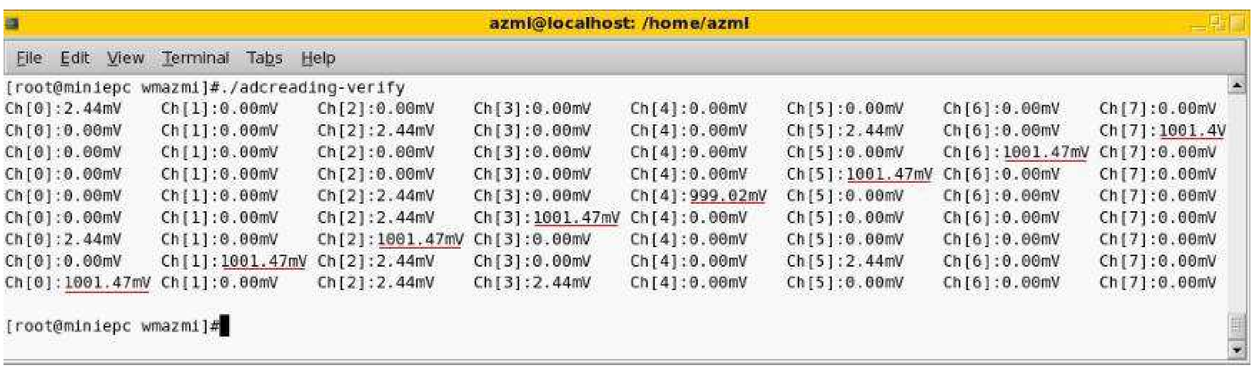


Fig. 16. Analog input reading verification output

Every channel is given 0 V input for first reading as shown in first line in Fig. 16. The error recorded in first line reading is 2.44 mV which is given by channel 1 which equals to 1 step resolution. Then 1.0 V input is given to channel 7 as shown by the second reading and for other channels the input given is 0V. The reading is presented in 2 floating point. From Fig. 16, the readings recorded are 1001.47 mV and 999.02 mV for channels that was given 1.0 V input. The reading variants are 0.53 mV and 2.98 mV respectively. From the results above, the analog input reading has small error which are 1 and 2 step resolutions so that the readings is considered reliable.

The readings of temperature sensor at room temperature is around 1110 mV and 1120 mV as shown by line 1 until line 5 in Fig. 17 below. Heat was forced to the temperature sensor using a lighter (fire) for a few seconds. The readings are increased at the moment the heating process as shown by line 6 until line 10 in Fig. 17.

A measurement of ion-selective electrodes is carried out to observe their output reading reliability. The reading of ion-selective electrodes are considered reliable if their readings are stable and do not fluctuate. The Copper electrode is tested with Copper standard solution which has been produced by mixing sterile water and Copper liquid. In this research, five different standard solution densities are used: 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm. Firstly, the Copper sensor is tested using 10 ppm standard solution. The Copper ion-selective electrode together with the reference electrode are immersed in 10 ppm Copper standard solution. Measurement is started five minutes after those electrodes immersed. The measurement is repeated for 20 ppm of Copper standard solution. These steps are repeated until the standard solution reaches 50 ppm. Fig. 18 shows the reading of Copper ion-selective electrode. From the graphs, the readings are decrease with higher standard solution density for each case.

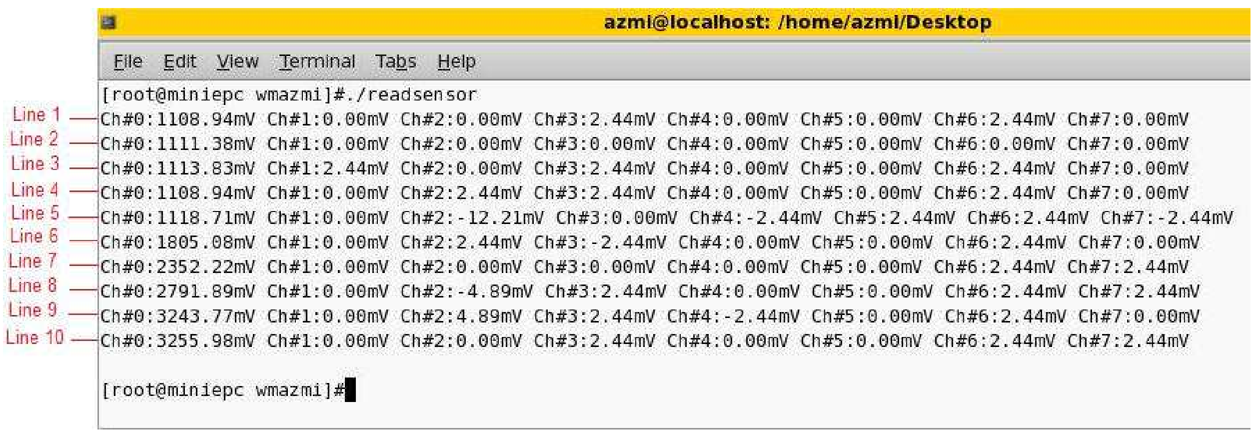


Fig. 17. LM35DZ temperature sensor readings

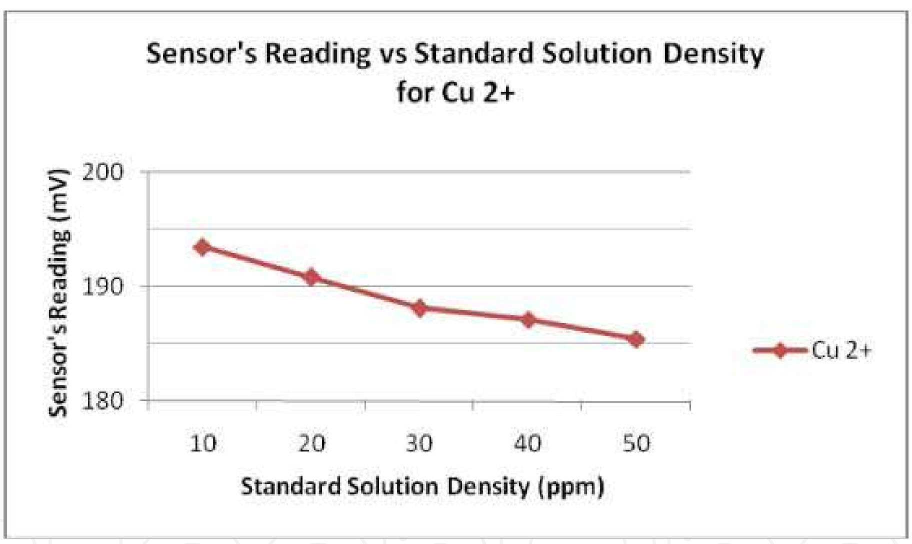


Fig. 18. Copper sensor's reading versus standard solution density

8. Conclusion

Data Acquisition System (DAS) is one of common system currently applied in industrial application such as automation control, alert system and monitoring system. The advancement of electronic technology has led to tremendous applications using embedded systems. Embedded based application has led to portable and small form factor system with medium or high speed processor. In this research, a DAS has been developed using a 32bit Single Board Computer (SBC). The developed DAS is an integration of SBC, matrix keypad and LCD display and named as Portable Embedded Sensing System (PESS). PESS can be used as a data logger for a short term data collection which can provide immediate results for portable works either for indoor or outdoor experiment.

Two software modules developed in PESS systems which are Analog Input Preprocessing and Data Presentation. The processes involved in Analog Input Preprocessing are acquiring analog sensor's input, converting analog signal to digital signal and calculating digital output to human readable values. These processes are done by a program named *sensor*. An *Interactive System* handles input given by user via matrix keypad and output to the LCD display for Data Presentation modules.

PESS has limited data storage capacity since it used a Compact Flash (CF) to store temporary data. This system also has limitation in term of visualization where data are viewed via LCD panel. These limitation can be enhanced by extending the PESS system into a network based DAS. PESS system can be used as Sensor Node (SN) that collecting data from fields and sending the collected data to the server that able in providing larger storage capacity. The user interface can be developed to provide interactive data presentation which can be access remotely via internet. The network based DAS is normally applied in monitoring system especially for long period and scheduled activities.

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The book is intended to be a collection of contributions providing a birdâ€™s eye view of some relevant multidisciplinary applications of data acquisition. While assuming that the reader is familiar with the basics of sampling theory and analog-to-digital conversion, the attention is focused on applied research and industrial applications of data acquisition. Even in the few cases when theoretical issues are investigated, the goal is making the theory comprehensible to a wide, application- oriented, audience.

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