Development of DAS for prototype of brinell-macro-hardness tester using triplex of force-resistive-sensors manipulated by raspberry pi 3 model B

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Abstract. The resulting of advanced technology, the size of Personal Computer (PC) was reduced into the same size as cigarette box. Thus, the Brinell-macro-hardness tester used Raspberry Pi 3 (RPi3) Model B to acted as the Data Acquisition System (DAS) or the mini-PC which used for measuring of Active-Weight-Loading (AWL) parameters. This DAS used the triplex of force-resistive sensors equipped using IC-MCP3008 and interfaced with RPi3. This IC was used to converse the analogue signal of AWL to 10 bits of the digital signal, and then, the digitalized-data were transferred through the Serial Peripheral Interface (SPI) of RPi3, respectively. In the acquisition procedure, the real-time of measuring-data were revealed using the Graphical User Interface (GUI) which developed using the python language version 2.7. Consequently, it was perceived that this DAS can be fabricated using simple and low-cost design. Therefore, this contrivance can be regularly used for AWL measurement which is the one part of Brinell hardness measurement. Finally, the fabrication of electronic parts and software interfacing which manipulated using RPi3 were presented in the discussion section.

1. Introduction
In the area of material characterizations, the hardness is related to other mechanical properties. Brinell hardness measurement is the classical method that used the spherical shape of indenter to imprint onto the surface of testing sample. The basic principle uses two necessary parameters for the hardness evaluation including: the applied loading and the indentation diameter, and then, the Brinell hardness number (BHN) can be calculated using these two parameters [1,2].

Recently, the DAS acted as the mini-PC that was widely used for home automation [3], for real-time vehicle detection [4], and etc. Outside of the hospital area, the heart defect and aberrant symptom can be diagnosed using Electro-Cardio-Gram (ECG) associated with Internet of Things [5]. Meanwhile, there are many groups of developer that presented several kinds of these boards to use for development such as Arduino Uno Rev.3, Arduino MEGA2560 Rev.3, Nano Pi M1, Orange Pi 3, RPi 3, and etc. All these modules are very well-known in the area of electronics engineering and physics which used for the developing of the new prototype with low-cost fabricating consideration. Not only these revealed the advantages as the low-cost but also these items can be used in the same applications as the using of advanced instruments.
Although the using of RPi3 as the DAS or the simple data logger revealed the performance of acquisition are closely to the using of Arduino Uno Rev.3 or Arduino MEGA2560 Rev.3, the advantages of using of RPi3 are focused on the Graphics Processing Unit (GPU) that was included in this RPi 3 board. Not only the RPi3 present the high performance of graphics computing rather than Arduino boards but also the data can be transferred with sampling rate in ranging of 75 to 200 kilo-Sample-Per-Second (kSPS) when using with the SPI of IC-MCP3008 [6]. Therefore, the RPi 3 was used for measuring the value of AWL, and then, these measured results were used for the BHN analysis in the next routine.

Regularly, the classical PC was used for interfacing with the Brinell-macro-hardness apparatus [2] but now the size of PC was reduced into the smaller one due to the advanced technology, thus, the electronic components and the software interfaces that were developed and manipulated for this DAS using RPi3 Model B is the point of view for this representation. This description of DAS was focused on the value of AWL that designed for measuring of soft materials, for examples, papers, softwood, soft-metal, and etc. Therefore, this presentation would like to reveal that the fabrication of all electronic elements for hardware developing and working process for software developing, both of these were used for the conversion between the electronic signal to the value of AWL. Ultimately, all these parts of software progression were developed using the python v2.7.

2. Theoretical background

This DAS was fabricated using the basic principle of electronics. The majority of knowledge was focused on the amplifying and the converting mechanisms of measured signals. These caused by the using of IC-LM324 and IC-MCP3008. This DAS used for measuring of the value of AWL using the prototype of Brinell-macro-hardness tester [2] which displayed in figure 1 (a,b). In this report, IC-LM324 was used as the current amplifier which used the same basic of voltage follower or voltage buffer in principle of electronics. The important characteristic of this IC is that the electronic power of output can be amplified about 10^6 times respect to the electronic power of input, whereas, the input and output of voltage will be the same value [7]. Following that, the analogue voltage (Vin), sometimes called as continuous signal, can be converted to the digital signal or the discrete signal using IC-MCP3008 associated with using of 5 VDC from IDE of RPi 3 as VREF which were examined in equation 1 [6], respectively.

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\text{Discrete Signal} = \frac{1024 \times V_{in}}{V_{REF}}
\]  

3. Calibration methods

In this process, the electronic signals of FSR1, FSR2, and FSR3, were transferred and amplified using IC-LM324, and then, passed through the input of continuous voltage of IC-MCP3008 including: CH0, CH2, CH4, respectively. By this way, this continuous voltage can be measured using any voltage measuring instrument, thus, these three points will be used for the voltage calibration.

Following that, the 7.5-Digit Graphical Sampling Multimeter (Model: Keithley DMM7510) was used as the instrumental reference [8]. This equipment was used for two voltage measurement including: first, the 5 VDC of RPi3 Model B was used as the voltage source that supplied for all components in this circuits. This 5 VDC is the same voltage as VEE in IC-LM324 and VDD and VREF in IC-MCP3008, and this VDD can be probed between point A and E. Second, the sensing voltage of FSR1, FSR,2, and FSR3, were probed at the point including: B, C, and D with respected to point E, respectively. These voltage signals were measured by Keithley DMM7510 was used to compare with the input voltage that calculated from the codes of output voltage. These points used for the voltage measuring were presented in figure 1(a), while, these triplex-FSR were represented the top-view alignment in figure 1(b), respectively. These codes were converted using IC-MCP3008, after that, the weight loadings were varying for AWL generating of the calibration data. Then, this process was modified to use with other FSR, after that, these calibrations were used to convert the FSR signal to the value of AWL. These procedures revealed as the flow chart in figure 1(c) as following:
Figure 1. The illustration presented (a) the DAS that used for the Brinell-macro-hardness tester [2], and (b) the top-view alignment of triplex-FSR that were declared as: FSR1, FSR2, and FSR3, and (c) the flow chart that was used for the calibrating and the measuring all values of AWL, respectively.

Figure 2. The illustration of experimental data with GUI when presented using (a) the triplex-FSR signals, (b) the FSR1 signal, (c) the FSR2 signal, and (d) the FSR3 signal, respectively.
4. Experimental results and discussion

From figure 2, all continuous-electronic signals will be converted to discrete-electronic signals and displayed the value of AWL using GUI passed through the display monitor that equipped using RPi 3. The real-time results exhibited all triplex-FSR signals in figure 2(a) and then the individual of FSR signal including: FSR1, FSR2, and FSR3, were revealed in figure 2(b,c,d), respectively. Because of the using the weight loading as an observation parameter, thus, this presentation used the maximum value of the weight loading at 322.7 N as an activated condition. After that, the weight loading was reduced with stepping of 10.0 N and down to the minimized value at 22.6 N, respectively.

From figure 2(a) and figure 2(d), the AWL of FSR3 signal presented more noises in both of activated and deactivated condition for measuring of AWL. This can be indicated that these two points have an influence on the diameter indenter, thus, this process should be more awareness during the measurement. Moreover, all AWL that were measured using the signals of FSR1, FSR2, and FSR3 and expressed the value in ranging: 7.0 N to 60.0 N presented that the effect of noises was reduced. Finally, these resultants confirmed that this Brinell-macro-hardness measuring apparatus [2] can be used associated with this fabricated DAS for measuring of BHN.

5. Conclusion

In conclusion, this presentation demonstrated that this DAS can be used for the in-house measuring of Brinell hardness measurement when the calibration mechanisms of the triplex-FSR were accomplished. Furthermore, it was perceived that this DAS can be occurred using the simple and the low-cost designing. Therefore, this contrivance can be regularly used for AWL measurement and displayed the interpreted results using GUI that equipped with RPi3. Although the GUI illustrated the AWL with noises, this effect can be reduced using the simple electronics like filter circuits, the discretized algorithm, and/or using both of them. Furthermore, these resultants confirmed that this apparatus [2] can be used associated with this contrived DAS for qualifying of BHN. And this apparatus is appropriated to measure the value of AWL in the ranging: 7.0 N to 60.0 N when the noise-optimized processes were applied. Finally, the image-digitized algorithm used for measuring of the diameter of indenter is going on the developing process.

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