International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
OPEN ACCESS
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST52310592

Development of Electrometer for Dose Area Product (DAP) Measurement to Monitor Patient Dose in Radiography Examinations

Hidayat Hidayat, Choirul Anam*, Eko Hidayanto, Ulil A. Taufiq

Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Jl. Prof. Soedarto SH, Tembalang, Semarang 50275, Central Java, Indonesia

*Corresponding author: anam@fisika.fsm.undip.ac.id

ARTICLEINFO

Article History:

Accepted: 15 Sep 2023

Published: 08 Oct 2023

Publication Issue

Volume 10, Issue 5

September-October-2023

Page Number

568-573

ABSTRACT

This study aimed to develop an electrometer for dose area product (DAP) measurement to monitor patient doses on X-ray radiography examinations. The electrometer was developed based on the Atmega8535 microcontroller as the processing unit. This electrometer was operated at 12 volts of direct current (DC) and controlled by buttons for navigation. The system (i.e. in-house electrometer and DAP meter) was carefully designed so that it can easily perform calibration and dose measurements. The system was evaluated at variations of tube voltage, tube current, and exposure time. The developed system results in high accuracy and precision as indicated by low percent error (PE) and relative standard deviation (RSD) compared to standard system. The highest PE and RSD are 1.69% and 1.42% for tube voltage variation, 3.85% and 3.58% for tube current variations, and 12.10% and 0.92% for exposure time variations. In conclusion, the developed system is feasible to be used as a patient dose measurement tool to meet the needs of radiation protection to achieve the principle of "as low as reasonably achievable (ALARA)".

Keywords: DAP, Electrometer, Radiography and Patient Dose

I. INTRODUCTION

X-ray radiography is widely used to enforce diagnostics and screening purposes [1-3]. In examinations using ionizing radiation such as X-rays, the dose received by the patient needs to be considered. The radiation dose received by patients in radiographic examinations can vary depending on the modality, techniques, and exposure factors. Exposure parameters can be optimized through the exposure index (EI) information from computed radiography (CR) or digital radiography (DR) systems to maintain the lowest possible dose while achieving good image quality [4–8].

The EI has been reported having a strong relationship with patient dose, which is often measured by the dose area product (DAP) meter [9]. However, EI cannot replace the DAP as a patient dose indicator, because EI does not directly represent patient dose [9–12]. Direct patient dose measured using a DAP system is usually integrated inside the collimator [13, 14].

Some radiography machines, especially those distributed in Indonesia, do not always have a DAP system for monitoring the patient dose. Meanwhile, the patient dose must be controlled, especially if there is repeated exposure. This can have consequence of a long-term effect on the patient. The effects that occur can be various kinds of diseases, such as skin and other organ cancers. [15]. Thus, monitoring patient doses using a DAP system is very important. Therefore, if X-ray radiography machine does not have a built-in DAP system, then it is necessary to employ an additional DAP meter for monitoring patient doses in order to monitor patients from excessive radiation and fulfill the "as low as reasonably achievable (ALARA)" principle. However, DAP meter available on the market are often not accompanied by an electrometer to process and display the results. In this study, therefore, we developed an in-house electrometer for DAP measurement to monitor patient dose in radiography examinations.

II. METHODS AND MATERIAL

The electrometer was developed using the Atmega8535 microcontroller. Resistors, capacitors, transistors, diodes, and prototype circuit boards (PCBs) were also used to develop an electrometer. A 16×2 liquid crystal display (LCD) was used as a display. The electrometer received and processed data from an Accurate DAP Series ACCUDAP-D147. The developed electrometer connected to DAP sensor was then tested on portable X-rays as a radiation source. A standard electrometer of Raysafe X2 Solo was used as reference.

A. Hardware Development

Figure 1 shows a design of the electrometer. The electrometer consisted of a conditioning circuit, microcontroller, 16×2 LCD, buttons (Select, Reset, Up, and Down), and power supply. The Atmega8535 microcontroller, signal conditioning circuit, LCD, and buttons were mounted on a Printed Circuit Board (PCB) according to the design. The DAP sensor and power supply were connected to the PCB using plug connectors.

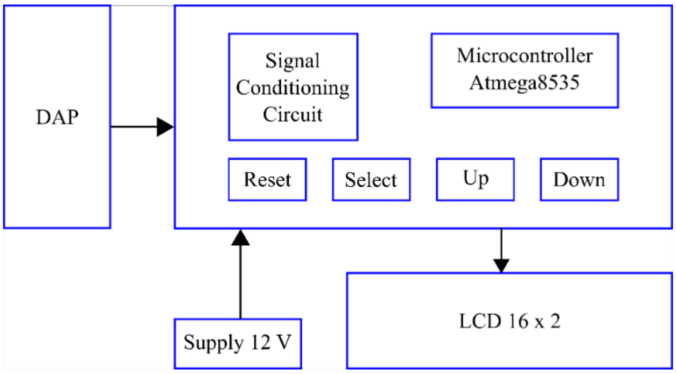

Figure 1. Electrometer block diagram.

The signal conditioning circuit controlled the input signal from the DAP sensor and then amplified it. A microcontroller Atmega8535 was used to control electronic circuits, calculate, and convert input readings from DAP sensors according to the program algorithm. The Atmega8535 consisted of a central processing unit (CPU), memory, certain inputs and outputs (I/O), and support units such as an integrated analog-to-digital converter (ADC).

Up and Down buttons were used to increase and decrease the voltage (kV) and current (mA) according to the settings listed on the device. Select's button was used to activate the settings that have been selected using the Up or Down button. Reset button was used to restore the device's state to its original. It will eliminate all memory and data stored in storage or data that has been taken from several exposures. The 16×2 LCD display and power supply were used to provide a DC power supply to the microcontroller system. The power supply used was 12 volts DC.

B. Software Development

Figure 2 shows a flowchart of the software for the electrometer. If the device was turned on, the program was initialized by checking all components, such as the LCD, microcontroller, and DAP sensor. If the reset button was pressed for three seconds, then the LCD display changed to calibration mode. Otherwise, it entered idle mode. Idle mode was condition where the device was ready to take measurements. If there was an input signal (analog) from the DAP sensor to the microcontroller, then the input signal was converted into a digital signal. The digital signal was processed to produce a DAP value and displayed on the LCD.

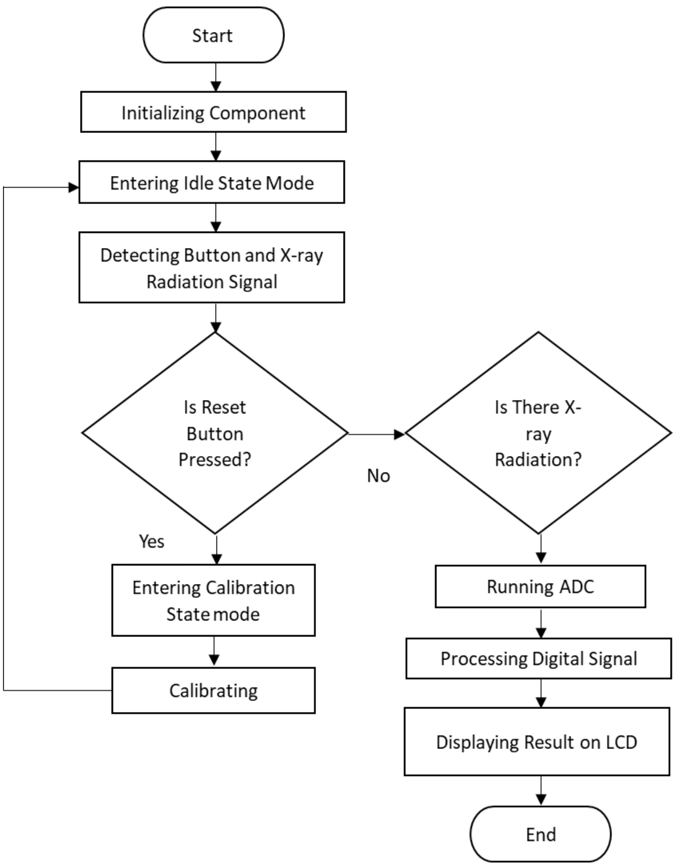

Figure 2. Flowchart for the electrometer for measuring the DAP.

C. Device Evaluation

The electrometer was calibrated using a standard electrometer of Raysafe. The accuracy and precision of the developed electrometer were evaluated. The evaluation was carried out by varying parameters of tube voltage, tube current, and exposure time. The tube voltage variation was 50, 55, 60, 65 and 70 kV. The tube current variation was 40, 50, 63, 71 and 80 mA. The exposure time variation was 0.1, 0.2, 0.32, 0.4 and 0.5 s. Each variation was repeated three times.

The accuracy and precision of the electrometer are analyzed using percent error (PE) and relative standard deviation (RSD) [16, 17]. The PE is the ratio of the absolute difference between the doses obtained from the developed (measurement) and those from the Raysafe (reference). The RSD is the ratio of the standard deviation to the average value of repetitions of the measurement. PE and RSD are formulated in equations 1 and 2.

$$PE = \frac{|Measurement - Reference|}{Reference} \times 100\% \quad (1)$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(D_i - \bar{D})^2}$$

$$RSD = \frac{\sigma}{\bar{D}} \times 100\ \% \quad (2)$$

III. RESULTS AND DISCUSSION

An electrometer from Atmega8535 microcontroller is successfully developed and is shown in Figure 3. Noticeable parts from the developed electrometer were display 16 × 2 (a), reset button (b), select button (c), up button (d), down button (e), power supply plug (f) and DAP sensor plug (g). The developed electrometer can measure dose from the Accurate DAP ACCUDAP-D147 series. The measured dose has been compared with Raysafe as a reference.

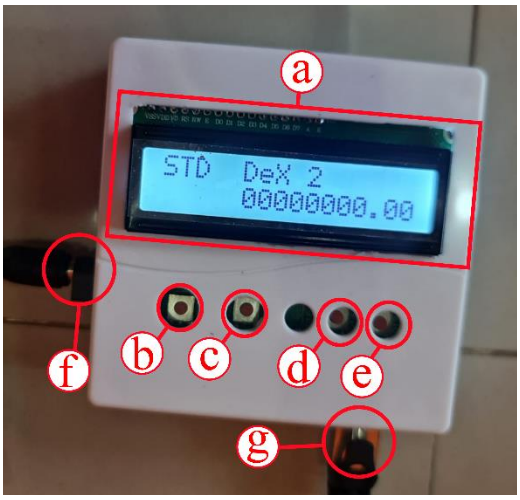

Figure 3. Photograph of the developed electrometer. (a) LCD 16 × 2, (b) Reset Button, (c) Select Button, (d) Up Button, (e) Down Button, (f) Power Supply Plug, and (g) DAP Sensor Plug.

Table 1 shows the doses measured from the developed electrometer dose and their comparison to those from the Raysafe dose at tube voltage variation. The doses measured using the developed electrometer in tube voltage variation are accurate with the highest PE value of 1.69% compared to those from the Raysafe. Measurements using developed electrometer have high precision, with the highest RSD value of 1.42%.

Table 2 shows the doses measured from the developed electrometer dose and their comparison to those from the Raysafe dose at tube current variation. The doses measured using the developed electrometer at the tube current variation has high accuracy and precision, with a slightly higher PE compared to the measurements in Table 1. The highest PE is 3.85%. and the highest RSD is 3.58%.

Table 1. Comparison of measured doses from the developed electrometer and Raysafe at the tube voltage variation.

Tube voltage (kV)	Tube current (mA)	Exposure time (s)	Developed electrometer		Raysafe		PE (%)
			Average Dose (µGy)	RSD (%)	Average Dose (µGy)	RSD (%)	
50			73.18	0.41	73.94	0.17	1.02
55			96.80	1.42	98.47	0.89	1.69
60	80	0.4	120.16	0.45	121.17	0.69	0.83
65			141.95	0.43	142.73	0.30	0.55
70			165.16	0.99	166.90	0.98	1.04

Table 2. Comparison of measured doses from the developed electrometer and Raysafe dose at the tube current variation.

Tube voltage (kV)	Tube current (mA)	Exposure time (s)	Developed electrometer		Raysafe		PE (%)
			Average Dose (µGy)	RSD (%)	Average Dose (µGy)	RSD (%)	
	40		39.04	3.58	40.61	1.56	3.85
	50		48.88	0.59	50.01	1.21	2.27
50	63	0.4	59.64	0.43	60.61	0.73	1.61
	71		66.64	0.91	68.43	1.73	2.62
	80		72.62	0.11	73.94	0.17	1.79

Table 3. Comparison measured doses from the developed electrometer and Raysafe dose at the exposure time variation.

Tube voltage (kV)	Tube current (mA)	Exposure time (s)	Developed electrometer		Raysafe		PE (%)
			Average Dose (μGy)	RSD (%)	Average Dose (μGy)	RSD (%)	
50	40	0.1	10.97	0.42	12.48	1.64	12.10
		0.2	20.52	0.74	21.77	0.84	5.76
		0.3	31.57	0.40	32.61	1.29	3.20
		0.4	39.81	0.55	41.43	1.38	3.91
		0.5	49.61	0.92	51.32	0.53	3.33

Table 3 shows the doses measured from the developed electrometer dose and their comparison to those from the Raysafe dose at exposure time variation. The doses measured using the developed electrometer at the exposure time variation has high accuracy and precision. The PE value of this time variation shows a higher percentage value than those at the tube voltage and tube current variations, with the highest PE value is 12.10%.

IV. CONCLUSION

The electrometer for DAP meter was successfully developed. Accuracy and precision of the developed electrometer are represented in the PE and RSD. The highest PE and RSD for dose measurements of tube voltage variation are 1.69% and 1.42%; for tube current variation are 3.85% and 3.58%; and for exposure time are 12.10% and 0.92%. The developed electrometer is feasible for clinical applications because the measurements result is accurate.

V. ACKNOWLEDGEMENTS

This work was funded by the Riset Publikasi Internasional Bereputasi Tinggi (RPIBT), Diponegoro University, No. 569-187/UN7.D2/PP/IV/2023.

VI. REFERENCES

[1] Halldin, C. N., Blackley, D. J., Petsonk, E. L., & Laney, A. S. (2017). Pneumoconioses radiographs in a large population of US coal workers: variability in a reader and B reader classifications by using the International labour office classification. Radiology, 284(3), 870-876.

[2] Heinzerling, A., Cummings, K. J., Flattery, J., Weinberg, J. L., Materna, B., & Harrison, R. (2021). Radiographic screening reveals high burden of silicosis among workers at an engineered stone countertop fabrication facility in California. American Journal of Respiratory and Critical Care Medicine, 203(6), 764-766.

[3] Eslami, M., Tabarestani, S., Albarqouni, S., Adeli, E., Navab, N., & Adjouadi, M. (2020). Image-to-images translation for multi-task organ segmentation and bone suppression in chest x-ray radiography. IEEE transactions on medical imaging, 39(7), 2553-2565.

[4] Mothiram, U., Brennan, P. C., Lewis, S. J., Moran, B., & Robinson, J. (2014). Digital radiography exposure indices: A review. Journal of medical radiation sciences, 61(2), 112-118.

[5] Rochmayanti, D., Wibowo, G. M., & Setiawan, A. N. (2019). Implementation of exposure index for optimize image quality and patient dose estimation with computed radiography (a clinical study of adult posteroanterior chest and

anteroposterior abdomen radiography). In Journal of Physics: Conference Series, 153(1), 012032.
[6] Khong, P. L., Ringertz, H., Donoghue, V., Frush, D., Rehani, M., Appelgate, K., & Sanchez, R. (2013). ICRP publication 121: radiological protection in paediatric diagnostic and interventional radiology. Annals of the ICRP, 42(2), 1-63.
[7] Seeram, E., Davidson, R., Bushong, S., & Swan, H. (2013). Radiation dose optimization research: Exposure technique approaches in CR imaging–A literature review. Radiography, 19(4), 331-338.
[8] Park, H., Yoon, Y., Kim, E., Jeong, H., & Kim, J. (2022). Monitoring clinical exposure index and deviation index for dose optimization based on national diagnostic reference level: Focusing on general radiography of extremities. Journal of X-Ray Science and Technology, 30(3), 419-432.
[9] Erenstein, H. G., Browne, D., Curtin, S., Dwyer, R. S., Higgins, R. N., Hommel, S. F., & England, A. (2020). The validity and reliability of the exposure index as a metric for estimating the radiation dose to the patient. Radiography, 26, S94-S99.
[10] Mothiram, U., Brennan, P. C., Robinson, J., Lewis, S. J., & Moran, B. (2013). Retrospective evaluation of exposure index (EI) values from plain radiographs reveals important considerations for quality improvement. Journal of medical radiation sciences, 60(4), 115-122.
[11] Esien-Umo, E. O., Erim, A. E., Chiaghanam, N. O., Ogbu, T., Ijever, A. W., Archibong, B. E., ... & Ekpo, E. U. (2023). Exposure index in digital radiography: initial results of awareness and knowledge from Nigerian digital radiography practices. Journal of Medical Imaging and Radiation Sciences, 54(1), 58-65.
[12] Seeram, E. (2014). The new exposure indicator for digital radiography. Journal of Medical Imaging and Radiation Sciences, 45(2), 144-158.
[13] Mohd Fahmi, M. Y., Aisyahton, A., & Ahmad Zaky, H. (2013). A comparison of two indirect methods for skin dose in chest radiography. Health, 4(2), 103-114.
[14] Heo, Y. C., Cho, J. H., & Han, D. K. (2017). Dose-Decreasing Effect of the First Reversed Laser Beam Collimator for C-Arm Type Angiographic Equipment. Journal of Korean Medical Science, 32(7), 1083-1090.
[15] Ahmed, A. I., Babiker, A. A., Abbas, S. M., Alsulayyim, N., Dous, G. B., Alanazi, G., & Almawash, A. (2022). Reject analysis in digital radiography prospective study. Scholars J Appl Med Sci, 6(896), e9.
[16] Luangchana, P., Pornprasertsuk-Damrongsri, S., Kiattavorncharoen, S., & Jirajariyavej, B. (2015). Accuracy of linear measurements using cone beam computed tomography and panoramic radiography in dental implant treatment planning. International Journal of Oral & Maxillofacial Implants, 30(6).
[17] Uwano, I., Kudo, K., Yamashita, F., Goodwin, J., Higuchi, S., Ito, K., ... & Sasaki, M. (2014). Intensity inhomogeneity correction for magnetic resonance imaging of human brain at 7T. Medical Physics, 41(2), 022302.

Cite this article as :

Hidayat Hidayat, Choirul Anam, Eko Hidayanto, Ulil A. Taufiq, "Development of Electrometer for Dose Area Product (DAP) Measurement to Monitor Patient Dose in Radiography Examinations", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 5, pp. 568-573, September-October 2023. Available at doi : https://doi.org/10.32628/IJSRST52310592
Journal URL : https://ijsrst.com/IJSRST52310592