Synchronization of a camera and x-ray tube in digital radiography system in UNNES medical physical laboratory

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Abstract. Much development of medical devices has been made in the field of radiology. An example is the development of analog radiology into digital radiology. The result of a digital radiographic x-ray is a digital radiograph that can be processed further with image processing techniques. After that it can be printed (printed image) or sent by a teleradiology method. To increase the digital image results, a delay was needed between the opening of the camera lens and the x-ray exposure. Then a delay circuit optimization is needed between the DSLR (digital single lens reflex) cameras, and x-ray exposure on Arduino Uno-based analog radiographs which are used as a unit delay and relay. In the unit delay, a push button triggered a millisecond, so that the Arduino IDE program was needed to set a delay. The relay functioned as a separator between the DC (Direct Current) on the camera and the AC (Alternating Current) on the x-ray tube. The results obtained were that the longer the x-ray exposure, the more intensity. Variation in delay time was regulated in the Arduino IDE program to get the best image quality with the least intensity of light to reduce radiation side effects in patients.

1. Introduction

Physics can be applied in various fields. One of them is the field of health or medicine. After the development of classical physics into quantum physics using the principle of waves, X-rays fields that can penetrate objects were used in the medical field to show organs in the human body.

The development of medical devices is progressing very rapidly to meet the demand of the times which is required for instrument to work efficiently. One of these developments has been in the field of radiology. Radiology tools were originally developed into digital radiology tools. Conventional analog radiography still uses x-ray films. X-ray films from conventional radiography are viewed using a light box. This visual-based diagnostic result is very dependent on the doctor's subjectivity and subject to technical weaknesses when printing the X-ray films. After the switch to digital radiography, x-ray results were obtained in the form of digital images. The advantage is that results of digital radiographs can be further processed, by processes like image processing techniques (image processing, pattern recognition and image archiving). The results of the digital radiograph can be printed (printed image) or sent via the Local Area Network (LAN) or social networking to the radiologist's personal computer for diagnosis.
Not all hospitals have digital radiology tools because the prices are expensive [14]. Susilo et al. made a modification to conventional radiography with the addition of a DSLR camera that can produce digital images at the UNNES (Universitas Negeri Semarang) Medical Physics department. The results obtained are less than optimal because the x-ray irradiation time together with the opening time of the camera lens is too extensive. To increase the digital image results, a delay is needed between the opening of the camera lens and x-ray irradiation.

So, a design was proposed to build a series of time delay exposures between DSLR cameras and conventional Arduino Uno based radiographs using the push button and SPDT relay.

1.1. Digital Radiography
The x-ray generator is the principle of x-ray radiography. Modification of conventional radiographic systems into digital radiograph uses additional impermeable light tubes behind an intensifying screen so that the shadow of the object can be captured by a DSLR camera and then forwarded to the VC image capture unit (video capture) [14]. The scheme of digital radiology system design can be seen in Figure 1.

![Figure 1. Designing digital radiology systems based on digital cameras.](image)

DSLR cameras are the development of SLR cameras (single lens reflexes) originally used in the 1980s-1990s in Japan. Along with its current development, the camera system has become very flexible allowing the selection of focal lengths, openings, and maximum openings (lens speed) [7]. DSLR is an electronic device that uses DC current from the battery while digital radiography uses AC current from PLN electricity. The difference between the characteristics between AC and DC when directly connected will result in current errors [9]. An SPDT (single pole double throw) relay is needed to control the flow of current so there is no error [15].

Digital results from digital radiography are forwarded to the PC using image processing software [14]. Image processing is done to improve the original image and to improve performance in analysis, it is also used to help improve performance in several applications such as image analysis, computer vision and object detection [2].

1.2. Proteus
Proteus is an electrical system simulator [13] that works through software and hardware [12] components such as Microcontroller [11], DSP [5], FPGA, embedded boards such as Arduino, sensors, and actuators. With Proteus, the system can be simulated using hardware components and can debug the hardware by detecting maximum errors without having to have a physical prototype [10].

1.3. Arduino Uno
Arduino Uno is an open platform responsible for hardware data acquisition in the toolbox. Various types of connection ports, including digital input / output [8], PWM output, UART TTL (5V) serial communication, and analog inputs, make Arduino Uno boards a strong and cost-effective hardware for data collection purposes [1]. The Arduino Uno board has an Atmel ATmega328 microcontroller that can be programmed in C / C ++ [3] through integrated development (IDE). The regulated 5 V and 3.3 V output can be obtained from the Arduino board to provide voltage supply for certain sensors. Arduino Uno supports six analog input pins [16] that read data in the range 0-5 V with 10 bit resolution [4].

2. Methods
The design was carried out at the Medical Physics Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, UNNES. A laptop was prepared as a medium for simulation and programming was installed on Arduino Uno. The software used was Proteus and Arduino IDE. Simulation was used to reduce errors during experiments and to see the output signal as a result of the program delay on the Arduino IDE using Proteus as shown in Figure 2.

The program on the Arduino IDE, after being successfully simulated, is then installed on the Arduino Uno which has been connected to a delay circuit that uses a push button as a trigger, a relay as a safety, and two LED as indicators of the opening of the DSLR camera lens and x-ray exposure.

![Figure 2. Simulation of delay circuits on proteus software.](image)

![Figure 3. Design of delay circuit based on Arduino Uno](image)

Installation of components on Arduino is adjusted to the output and input of each component used. The installation of these components can be seen in Figure 3 and the pins are adjusted as shown in table 1.
Table 1. Pair of components and Arduino pins

| Arduino Component | Information |
|-------------------|-------------|
| Pin A2 Button pin | As analog output |
| Pin 4 LED (camera) | As digital output |
| Pin 13 Relay | As a digital input |
| Pin GND Protoboard | As ground |
| Pin 5V Protoboard | As a voltage source Vcc is worth 5V. |

Arduino programs were made using Arduino IDE software, and the script used was adjusted to the series discussed earlier. The script is written like Figure 4 below:

![Arduino IDE sketch](image)

Figure 4. Sketch the delay circuit program on the Arduino IDE software.

Void setup () functions to initialize variables and pin modes. The setting function will only run once each time the Arduino board is turned on or restarted. Void loop () is useful for executing program commands that have been made. This function will automatically control the Arduino board either reading the input or changing the output done repeatedly according to the specified delay.
3. Results and Discussion

3.1. Results
Six variations were carried out with 200, 400, 600, 800, 1000, and 1200 millisecond delay times. After variation, the signal results obtained in the Proteus simulation are as shown in Figure 5 (a), 5 (b), 5 (c), 5 (d), 5 (e) and 5 (f).

Figure 5(a). Graphic display variation of 200 ms delay time.

Figure 5(b). Graphic display variation of 400 ms delay time.

Figure 5(c). Graphic display variation of 600 ms delay time.

Figure 5(d). Graphic display variation of 800 ms delay time.

Figure 5(e). Graphic display variation of 1000 ms delay time.

Figure 5(f). Graphic display variation of 1200 ms delay time.
3.2 Discussion
In the graphical display on the oscilloscope, time variations show that the longer the delay time, the farther the distance between the first channel (yellow) and the second channel (blue). The first channel represents the output of the opening of a temporary DSLR camera lens, and the second channel is the exposure to the length of the x-ray tube radiation.

The length of time the DSLR camera lens is opened and the x-ray is exposed is indicated by the width of the pulse on the oscilloscope. The longer the time needed, the wider the pulse. The length of the opening of the camera lens depends on the type of camera used, while the exposure of the x-ray is determined by the amount of current per second. Determination of the current value depends on the thickness of the patient’s body size [6].

Credit on DSLR cameras will appear when there is a trigger from the push button. After there is a gap according to the variation, the pulse on the x-ray will be visible. The electric current between the DSLR cameras and the x-ray tubes is connected to the relay so there is no error in the current flow. This relay is needed so that the delay circuit that has been created can be used to synchronize the opening of DSLR camera lenses and x-ray exposure safely and as needed.

4. Conclusion
Through the simulation and delay circuit experiment, the Arduino Uno-based delay circuit can be used to synchronize DSLR cameras and x-ray exposure on the digital radiographic system at the UNNES Physics Medical Laboratory to improve the image quality of digital radiography.

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