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X-Ray machine control with wireless based on mA parameters

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Abstract. An x-ray machine is a medical device that is used as a diagnostic tool for patients. The conventional x-ray machine consists of a control system, high voltage and tube x-ray machine. The control system on conventional x-ray machines uses too many cables so it looks less efficient. Control of the x-ray machine must be carried out in the same room as the equipment so that it can endanger the radiographer when it will be operated, because the radiographer will be continuously exposed to radiation. Therefore, an x-ray machine control system is designed that is safe for radiographers when operated and efficient in the use of cables. This research method uses the Arduino application to change the conventional control system to wireless, with the aim of providing the radiographer's safety because he operates the device from a separate room and does not face the x-ray machine directly. Current selection uses several contactors at each different current. The contactor is controlled by a microcontroller connected by a series of drivers. The process of selecting voltage, current and time is carried out on a Personal Computer (PC) connected to the controller via Bluetooth. The test is done by measuring the output voltage of the filament transformer using an AVO meter, then comparing it with the voltage calculation results obtained from the x-ray machine tube specifications. Based on the tests that have been done, it is found that the correction value is small and does not deviate much, which is 0.01 V when selecting mA 50 and 0.09 V when selecting mA 60. The x-ray machine can be controlled wirelessly using a PC with a distance 6 meters in conditions blocked by a 9 cm thick wall.

1. Introduction

A medical device that is usually used as a diagnostic tool for the condition of body parts in patients. The x-ray machine uses a vacuum tube as a source of electrons. The electrons will be accelerated and hit the anode metal. This process produces x-rays. X-rays emitted from the tube will penetrate the target object in the form of the patient's organs. The imaging results will be captured by positive film and will produce an image file of the object. This image file will be used as material for diagnosing abnormalities in the patient's body parts[1]. The x-ray machine consists of a control system, high voltage and an x-ray tube[2].

X-ray operations need to be adjusted to the selected parameters, including high voltage (kV), current (mA) and exposure time[3]. Control system for these three parameters must have high accuracy, so that the x-rays produced meet medical standards and do not exceed the tolerable limits allowed[4][5]. In conventional x-ray machines, the control system used is an analog model, which is still using a rotary switch as a selector, where in this analog system requires a special space that is used for laying supporting devices, namely cables. The x-ray machine has a high amount of radiation. The radiation dose can affect humans, animals, plants and all types of living things[6]. Optimization of radiation dose is very important for the quality and quantity of x-ray equipment. The widespread use of x-rays in patient diagnosis and management has led to increased radiation exposure[3]. An effective dose is a dose that is designed to represent the overall detrimental biological effect of radiation exposure[7][8].

The dose is calculated based on the weight of the energy concentration stored in each organ from radiation exposure using parameters that reflect the type of radiation and the potential for radiation-related mutagenic changes in each organ in the reference subject[9][10]. An x-ray radiation dose that is too high will expose the patient to unnecessary radiation which can cause ionization of soft tissue[11], organs and fluids in the human body which can lead to cell damage and lead to cancer[12]. The resulting image will be darker, especially on conventional x-ray machines[13], this of course can endanger radiographers, because they will be continuously exposed to radiation every time they operate the x-ray machine[14]. This can be minimized by using a special lead-coated apron when operating the x-ray machine[15], however the use of the apron is deemed less efficient, because the lead-coated apron has a heavy weight[16].

Research conducted by Ferry Suyatno et al with the title "Microcontroller-Based Diagnostic X-ray Machine Prototype Engineering", x-ray machines have used a microcontroller as a data processor[17][18]. The setting of high voltage (kV), current (mA) and time (s) has been controlled by a microcontroller[19], but the device between the x-ray and the controller operated by the radiographer is very close, because the distance is too short, which does not allow the use of cables too length, given the space requirements, it can be dangerous for the radiographer because it will be exposed to radiation directly[20][21].

Based on these problems, security is needed for everyone in the radiology room, namely by developing innovations in control of conventional x-ray machines by changing the control system, from analog to digital and control is carried out wirelessly through a Personal Computer (PC). Engineering digital control systems are used to improve the way parameters are set on the x-ray machine to make it more accurate and more efficient in using cables. One strategy to minimize the dose received by the radiographer is to change the technical or analog control system to a digital control system[22]. Meanwhile, wireless control aims to reduce the radiation hazard received by the radiographer.

2. Methodology

The method used in this research is experimental by using Arduino as a programming processing and followed by analysis of the test results based on data obtained from changes in the tool controller.

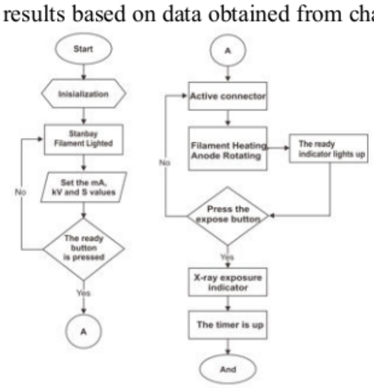

Figure 1. Tool Flow Chart

2.1 Software Design

The development of a wireless x-ray machine controller requires a good system shown in Figure 1. This flow diagram describes all the processes that occur when the tool is operated, from the initial process when the tool is turned on to the final process when the tool is turned off process when the tool is turned on to the final process when the tool is turned off. When the x-ray machine is operated, the microcontroller circuit will initialize, the first step taken is to see the input voltage that enters the machine, it can be seen on the LVC (Line Voltage Compensator) Display if the input voltage has not reached 220V then the LVC will adjust the input voltage until to 220V, when using the tool for X-rays, the first thing to do is adjust the kV, mA and S after it is set, then continue by pressing the ready button when ready is reached then the green indicator light will light up, after the ready indicator lights up, you can continue by pressing the exposure button, if the ready indicator is not yet on, the exposure process will not be able to run, when the device is exposed, the tool will produce an x-ray, the red indicator will light up when the exposure process is complete.

2.2. Hardware Design
At the hardware design stage, a circuit block is made, which consists of a minimum series of Arduino system, a series of drivers and a circuit for current controllers.

2.2.1 Minimum Arduino System
The minimum system is a hardware plan that will be used to create a simple command application needed to fill the microcontroller IC, so that the IC can be used to run the program as desired. To make the minimum system circuit, several main components are needed, such as: an oscillator or crystal and also a capacitor. Below is a picture of the minimum system circuit of a microcontroller using Arduino:

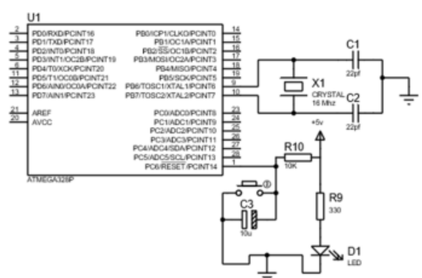

Figure 2. Minimum System Series

The circuit above uses a 5V power supply as a voltage source to the microcontroller IC. In the circuit above, a 16 MHz crystal is used which functions as an oscillator or external frequency generator. At PIN C 6 it is connected to a series that has a push button switch in it, this switch is used when you want to load or download programs in the minimum system circuit.

2.2.2 Driver Circuit
The driver circuit is a circuit that connects the microcontroller with other circuits. In this circuit there are several main components, namely relays and transistors. The relay driver schematic is shown in the Figure below:

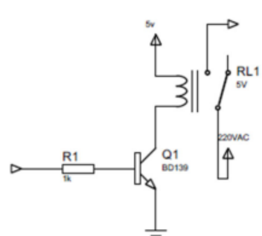

Figure 3. Driver Series

When the base foot is energized, the collector and emitter feet will be connected so that the coil on the relay will be connected to ground and the relay will be active, when the relay is active, the 220 VAC voltage at common will be supplied to the load through the Normally Open (NO) contact. This relay driver circuit will be active when there is a command on the microcontroller, when it gets a command, the microcontroller circuit will drain the voltage to the transistor.

2.2.3 Current Control Circuit

This current control circuit (mA) functions to provide a choice of current to be used in the exposure process and also the current used when the appliance is in standby. The current that is regulated in this circuit is the current contained in the X-ray tube. In this circuit there are several main components, including contactors and autotransformers. Below is a picture of 4 current control circuit:

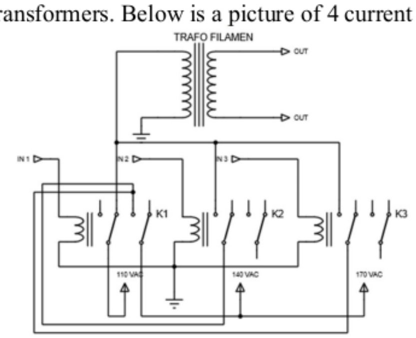

Figure 4. Flow Control Circuit

2.3. Data Retrieval Technique

The test data provided is the measurement results of the input voltage and output voltage of the filament transformer and the distance of the Bluetooth connection on this module. Voltage measurements were carried out 20 times for each mA choice using the Avometer gauge. Distance measurements are carried out in 3 stages with different conditions at each stage.

3. Result and Discussion

Medical equipment, especially radiology equipment, is a very important diagnostic tool and is needed by doctors for health services. The radiation dose received by the patient depends on the magnitude of the x-ray intensity and the length of exposure. Bones will absorb more radiation because they contain more calcium. The dose absorbed into the skin is directly proportional to tube current, length of exposure and the square of peak kV. X-rays are ionizing radiation and can have an adverse effect (stochastic effect) on the human body. All exposure to ionizing radiation needs to be justified and optimized in terms of benefits and risks. The immunosuppressive effects of ionizing radiation are well known and are generally ascribed to the killing of radiosensitive lymphocytes.

3.1. Filament Transformer Output Voltage Measurement

This measurement was carried out 20 times for each choice of mA. Measurements are made using the avometer measuring instrument.

Table 1. Voltage Measurement

Option mA	Average	Correction
50	5,01	0,01
60	6,09	0,09

Table 1 shows the average results of the measurement of the output voltage on the filament transformer in each mA option. In the choice of mA 50, an average value of 5.01 V is obtained with a correction value of 0.01 V. In the choice of mA 60, an average value of 6.09 is obtained with a correction value of 0.9 V.

3.2. Connection Distance Measurement
Measurement of control distance with this tool is carried out by two methods, namely without barrier and using a barrier. The barrier used was a concrete wall with a thickness of 9 cm. Measurements are made using a ruler measuring instrument. This measurement aims to determine how far this tool can be controlled wirelessly.

3.2.1 Distance Without Barriers
Measurement of the distance without a barrier was carried out 3 times with a distance of 3 meters, 6 meters and 10 meters respectively. The measurement results are shown in Table 2 below:

Table 2. Measurement of Distance Without Barriers

Experiment to	Distance (m)	Connection	
		Yes	No
1	3	•	
2	6	•	
3	10	•	

At a distance of 3 meters the tool can still be connected to the controls and can be controlled normally, as well as at a distance of 6 meters and 10 meters. This is in accordance with the HC-05 Bluetooth module specification which can work at a distance of 10 meters without obstructions.

3.2.2 Distance with Barriers
Measurement of the distance with the barrier was carried out 3 times with a distance of 3 meters, 6 meters and 10 meters respectively. The measurement results are shown in Table 3 below:

Table 3. Measurement of Distance Without Barriers

Experiment to	Distance (m)	Connection	
		Yes	No
1	3	•	
2	6	•	
3	10		•

At a distance of 3 meters the tool can still be connected to the controls and can be controlled normally, as well as at a distance of 6 meters. At a distance of 10 meters the tool cannot be connected to the device, when connecting there is an error in the program. This is because the HC-05 Bluetooth module can only work with a distance of ± 5 meters if there are obstacles.

3.3 Display Tools When in Use
In this tool there are 3 indicator lights that will turn on alternately when the tool is in use. The indicator lights are green, orange and red respectively. The green light is the indicator for the device in the standby position, the orange light is the indicator for the device in the ready position and the red light is the indicator for the device in the exposure position.

Figure 5. Condition of Standby Equipment

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Figure 5 Above is the position of the tool in standby, which is indicated by the filament is dimly lit and the green indicator on the appliance is on.

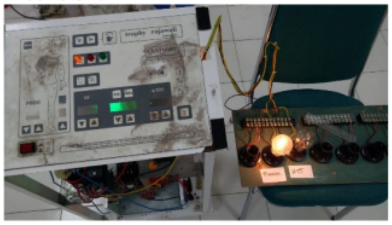

Figure 6. Condition of Ready Tool

Figure 6 Above is the position of the tool in the ready state, which is indicated by the brightly lit filament and the orange indicator light on the tool.

Figure 7. Condition of the Exposure Tool

Figure 7 Above is the position of the tool in the exposed state, which is indicated by a brightly lit filament and the red indicator light on the tool is on.

4. Conclusion

Based on the research that has been done, it can be concluded that the resulting stress measurement using the AVO meter and compared with the calculation results, obtained a correction value that does not deviate much at each mA, namely 0.1 V at a current of 50 mA and 0.9 V at a current of 60 mA. While the maximum distance measurement results, the tool can still be connected to the control system as far as 6 meters, this distance is obtained when the tool with the control system is blocked by a wall with a thickness of ± 9 cm. When conditions are not obstructed, the appliance can still be connected within 10 meters. Based on the results of distance measurements, this tool will be safer when used by the radiographer because it can be controlled from a separate room from the radiographer. Arduino-based wireless x-ray machine control system has functioned well after measurement and testing, this can be seen from the small value of the voltage correction obtained and the distance between the tool and the module connection, all parameters can work according to their function.

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