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Controlling System for Sample Preparation of Gamma Camera

MOHAMMED ABDELKAREEM OSMAN
University of Medical Sciences & Technology, Khartoum Sudan
HEISUM MUHAMAD EWAD
University of Medical Sciences & Technology, Khartoum, Sudan

Abstract:

The science and clinical practice of nuclear medicine involves the administration of trace amounts of compounds labeled with radioactivity (radionuclide) that are used to provide diagnostic information in wide range of disease states. Although radio nuclides have some therapeutic uses, similar underlying physics principles. Nuclear medicine study involves injecting a compound, which is labeled with a gamma ray emitting into the body. The radio-labeled compound is called radiopharmaceutical or more commonly tracer or radiotracer. Radionuclide is one of most important applications of radioactivity in nuclear medicine and radionuclide imaging to obtain a picture of the distribution of radioactively substance with the body after it has been administered.

The radiotracer shielded safely in container called generator until used in different applications, and most important generator for radioactive material is Molybdenum99-Technetium99 (99Mo - 99Tc) system, because low dose gamma ray per emit with reasonable half life time six hours.

In most development countries the oncology hospitals, they are preparing the radioactive material by physicians and technicians, while preparing the radioactive material they are expose himself to high radiation dose because all preparation procedures are done manually, also technician working close the patient for injecting and monitoring the radioactive material also he expose himself to radiation, so must be found some way to protect all field workers from *radiation hazard in gamma camera hot lab by design robot from local electronic material available in Sudan market.*

Key words: radio nuclides, gamma camera, Sudan market.

1. INTRODUCTION

The Nuclear Regulatory Commission's mandate to protect public health and safety and the environment includes regulation of the medical use of radioactive (byproduct) material in the fields of nuclear medicine, radiation therapy, and research.

Radionuclide is one of most important applications of radioactivity in nuclear medicine and radionuclide imaging laboratories found almost every hospital, performing hundreds and even thousands of images procedures per month in large institutions. [1]

The preferred emission for this application is gamma radiation in the appropriate energy rang 80 to 500 keV. Gamma rays of these energies are sufficiently to penetrating in the body tissues to be detected from deep-layer organs, can stop sufficiently by dense scintillation layer and shielded with reasonable thickness layer of lead. [1]

The wide variety of radiopharmaceuticals and procedures used lungs, liver, kidneys, and bones. It also helps physicians detect and identify lesions, such as cysts, tumors, hematomas, and infracted tissue, as well as areas of altered ontogenesis and abnormalities of the cortex and white matter. In addition, the gamma camera can work in tandem with a computer to evaluate cardiac function and perfusion. [2]

Technetium99 it’s very favorable because low dose gamma ray per emit with reasonable half life time six hours. Also iodine ion (I-) is useful to studying thyroid and metastatic of thyroid cancer or for delivering a concentrated radiation dose to thyroid tissues for therapeutic purpose. [3]

Most of the times you are asked to lie very still on your back and the camera is rotated around you. Each image takes from three minutes to one hour. The length of time for the entire procedure varies significantly. Your doctor's office will discuss with you the amount of time needed for your particular exam or you may call our department [4].

Other medical robots patrol hospitals as nurses and staff members. At a medical center in Maryland, a robot named Mr. Gower navigate the hallways, riding elevators, opening doors, and delivery patients medications to the nurses' station all on its own. [5]

Michael A. Thompson measured the Patient who has been dosed with therapeutic activities of 131I for thyroid carcinoma poses a unique set of problems for nuclear medicine technologists in their efforts to reduce personnel exposure and control contamination spread. The study intended to (a) review practical radiation safety concerns associated with hospitalized 131I therapy patients; (b) propose preventative measures that can be taken to minimize potential exposure and contamination problems; and (c) review pertinent federal regulation that apply to patients containing therapeutic level of radio nuclides.[6]

The annual dose calculated for the patients and co-patients at rooms around the nuclear medicine department, the results show that doses are fairly high. Measure should take to improve the waste management in the department for better protection of workers, patients and co-patient. [7]

The authors aimed to provide an introduction to radiation safety and monitoring so that health care providers and support personnel who may have contact with patients, equipment, and facilities that use radioactive material may be more aware of the policies and precautions that in place to ensure their safety. [8]

A framework for the preparation of a risk assessment for the control of contamination in a nuclear medicine department is presented. This includes assessment of the procedures performed, occupancies and workflows for the department and a review of control measures. A risk assessment should also include a contamination monitoring programmed and a practicable approach is presented. [9]

Image Formation in Nuclear Medicine:

The radioactivity is generally administered to the patient in the form of a radiopharmaceutical - the term radiotracer is also used. This follows some physiological pathway to accumulate for a short period of time in some part of the body. A good example is 99mTc-tin colloid which following intravenous injection accumulates mainly in the patient's liver. The substance emits gamma rays while it is in the patient's liver and we can produce an image of its distribution using a nuclear medicine imaging system. This image can tell us whether the function of the liver is normal or abnormal or if sections of it are damaged from some form of disease.

Table 1 shows different radiopharmaceuticals are used to produce images from almost every region of the body**:**

Table 1: Example Radiotracer Part of the Body

99mTc -HMPAO	Brain
Na99mTc O4	Thyroid
99mTc-Tin Colloid	Liver
99mTc-Damaged Red Blood Cells	Spleen
75Se-Selenomethionine	Pancreas
99mTc -DMSA	Kidneys

The form of information obtained using this imaging method is mainly related to the physiological functioning of an organ as opposed to the mainly anatomical information which is obtained using X-ray imaging systems.

Nuclear medicine therefore provides a different perspective on a disease condition and generates additional information to that obtained from X-ray images. Our purpose here is to concentrate on the imaging systems used to produce the images. Early forms of imaging system used in this field consisted of a radiation detector (a scintillation detector for example) which was scanned slowly over a region of the patient in order to measure the radiation intensity emitted from individual points within the region. One such device was called the Rectilinear Scanner. Such imaging systems have been replaced since the 1970s by more sophisticated devices which produce images much more rapidly.

The most common of these modern devices is called the gamma camera and we will consider its construction and mode of operation below [10].

2. GAMMA CAMERA

The large piece of equipment is called a Gamma Camera but it's a bit different from the cameras that you're probably familiar with! In order to image a specific organ the radioisotope is mixed with a special pharmaceutical which is injected into a vein and then travels round the body to be absorbed by the target organ. The Gamma Camera is the piece of equipment used to detect the gamma rays from the radiopharmaceutical and to build them up into an image or series of images. The head of the gamma camera is the part that detects the gamma rays. Cameras may have one, two or three heads – the one in the picture has two heads that can be moved into different positions.

Each head has a collimator - roughly analogous to a lens followed by a crystal that converts the gamma rays to pulses of light. These pulses are amplified by photo-multiplier tubes and passed to a computer that works out where the original gamma ray came from. More computing then rejects pulses caused by scatter and builds up the image. A single image may be taken or the camera may rotate around the patient to produce a series of slices in a similar manner to CT and MRI [11]

2.1 Method of ambient dose measurement

The licensee is required to perform surveys with a radiation detection survey instrument at various intervals but at least once a month. Surveys must be done weekly in areas of radionuclide use or storage and waste storage. A daily survey must be done of all area where by-product material requiring a written directive was prepared or administered. A daily survey is not required if the patient is confined to a hospital room. Records must include the instrument used, the name of the individual making the survey, and the date [2].

3 MATERIALS AND COMPONENT

All the experimental materials, equipments, measuring devices, procedures employed to perform measurements and their methods which were used in this study will be presented in this chapter in details. Experimental procedures for obtaining signals and Imaging are achieved using single head gamma camera as follows:

3.1Mo/Tc generators

SYRTEC generator is a system containing an alumina chromatographic column, loaded with fission 99MO (T1/2 = 66 h), which produce sterile pyrogen free and isotonic eluate 99mTC (T1/2= 6 h) as sodium pertenate for injection, in these study a number of generators had been used with a different serial numbers.

3.2 Gamma camera system

The gamma camera, which is encased in metal, is capable of detecting radiation and taking pictures from different angles. A gamma camera does not emit any radiation. It may be suspended over the examination table or it may be beneath the table. Often, gamma cameras are dual-headed with one camera next to the other at a 90 degree angle. In some imaging centers, the gamma camera is located beneath the exam table and out of view. The camera may be located within a large, doughnut-shaped scanner similar in appearance to a computed tomography (CT) scanner. Figure 3.2 present a photo of gamma camera scanner. Single photon emission computed tomography (SPECT) uses a gamma camera that rotates around the body to produce more detailed, three dimensional images. A photon emission tomography (PET) scanner is a large machine with a round, doughnut shaped hole in the middle, similar to a CT or MRI unit. Within this machine are multiple rings of detectors that record the emission of energy from the radiotracer in body. A computer aids in creating the images from the data obtained by the camera or scanner. A probe is a small hand held device resembling a microphone that can detect and measure the amount of the radiotracer in a small area of the body. There is no specialized equipment used during radioactive iodine therapy, but the technologist or other personnel administering the treatment may cover your clothing and use lead containers to shield the technician from radioactive material will be receiving.

3.3 Dose administration

The 99mTc is eluted for Mo/Tc generator in an evacuated sterile vile with known volume 5 or 9 ml are available in Al-Neelain diagnostic center, MDP pharmaceutical is mixed with the eluted 99mTc after measuring the dose using multi-dose calibrator, 5 mCi is the standard dose for patient undergoing whole body bone scan procedures in Al-Neelain diagnostic center.99mTc-MDPradiopharmaceuticals are subject to oxidation. Care is well taken to avoid introducing air into the multi-dose vial. Quality control performed before administration of the radiopharmaceutical and doses are carefully calculated.

3.4Requirements and components

In order to establish project goals the following components were selected. Current Amplifier IC ULN2804, Arduino, Colored Resistor, Capacitor, Light-emitting diode and Relay.

3.5 Programming Environment

Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself kits.

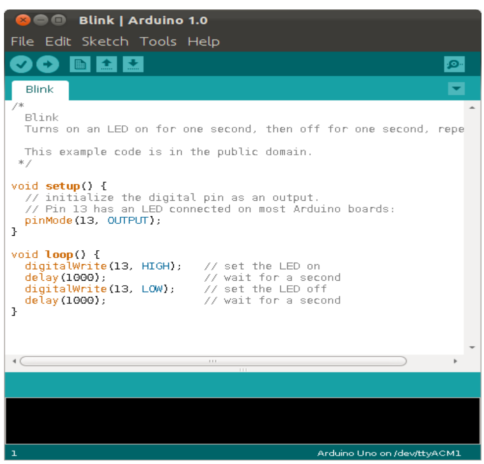

Figure 1. Arduino IDE Sketch

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project. The Arduino project started in 2003 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats, and motion detectors. The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014. [11]

4. DESIGN AND SIMULATION

4.1 Block Diagram

The block diagram below has been shown the connections and interfaces between the Arduino mega and the devices. The keypad its push button keypad for data entry, CPU is central processing unit for order and decision making for system when the technician select the appropriate amount of solutions, and interface circuit its interfacing between CPU and motor to translate signals and make valves opening (high)/closing (low) for flow control of liquid, and vibration motor is mixing solution and make it ready for injection.

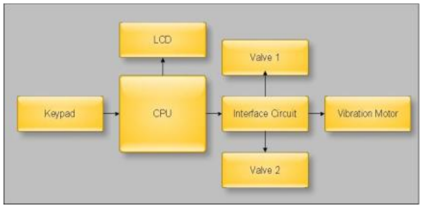

Figure 2. Basic System Block Diagram

4.2 Interconnection Block Diagram

The interconnection between different system components using pins of this components for input/output, such as connection between LCD module 16X2 and Arduino using pins (2, 3, 4, 5, 6, 7) and using pins (8, 9, 10, 11) for pumps as outputs.

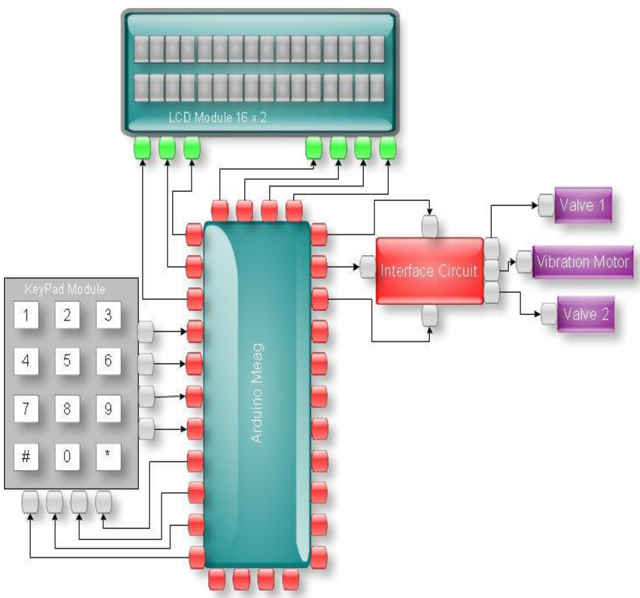

Figure 3. Interconnection System Block Diagram

4.3 Testing Circuit

A testing circuit was designed using frizzing software in order to view all of the connections and interfaces between the Arduino mega and the devices.

The circuit includes liquid crystal display, motors that illustrates the valves, potentiometer to adjust the LCD contrast, 4 by 4 keypad module and a current amplifier IC (ULN2803)

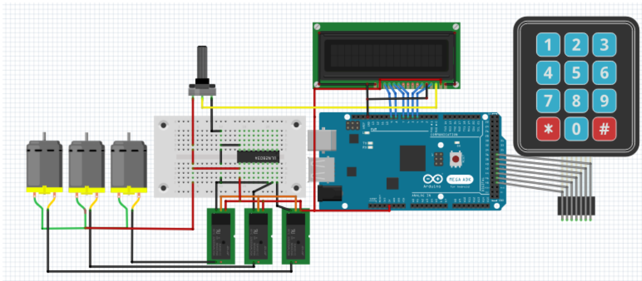

Figure 4. Testing Circuit Scheme

A shaking motor was used to insure of the well mixed of the hazard materials, the time of shaking is from 15 to 60 seconds and it can be readjusted.

The liquid crystal display was used to provide the system user with a vision to the entered dose values and the status of the system and all its functionalities, moreover the LCD displays the process that the central processing unit (Arduino Mega) is working on.

4.4 Computer Model

The following computer models illustrate the flow of the program inside the Arduino mega and provide a good view to the non-programmers to view the main functions and conditions used in the programming code.

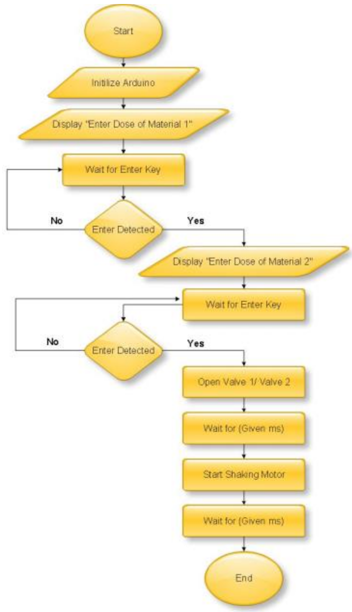

Figure 5. System Flowcharts

4.5 Circuit Diagram

A circuit diagram was designed in order to view all of the connections and interfaces between the Arduino mega and the devices.

The circuit includes liquid crystal display, a motor that illustrates the valves, potentiometer to adjust the LCD contrast, 4 by 4 keypad module and a current amplifier IC (ULN2803) and switching relays.

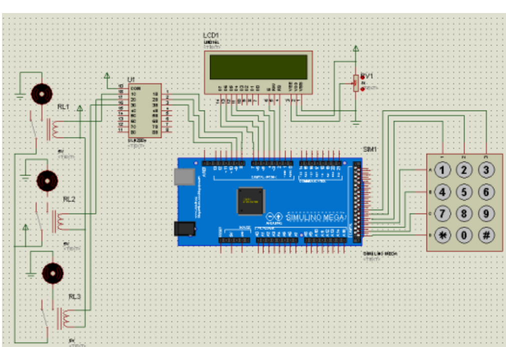

Figure 6. Simulated Circuit Diagram

5. RESULTS AND DISCUSSION

In this chapter the results and discussion was included, the results shows the exact system performance among a certain tests, these tests allow the device to be well calibrated to increase its efficiency and accuracy.

5.1 Testing and Results

5.2 Calibrating Dose in Milliliters

Arduino board offers a good and well calibrated time and sequence which provides an accurate dose based on the time sequence in milliseconds, the following table represent the dose in milliliters verses the time in milliseconds.

Table 2. Calibrating Dose in Milliliters

Test number	Time in milliseconds	Dose in Milliliters
1	10	0.5
2	20	1
3	40	2
4	60	3
5	80	4
6	100	5
7	600	30

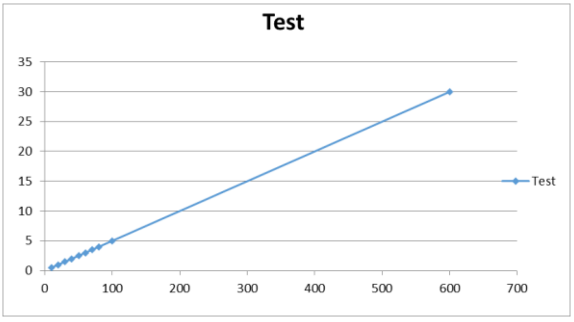

Figure 7. shown linear relationships between preparing Time and dose

5.3 Calibrating two different materials in different containers

Table 3. Calibrating two different materials in different containers

Test number	Required Dose ml	Material A ml	Material B ml	Time in ms (A)	Time in ms (B)
1	5	3	2	60	40
2	3	1.5	1.5	30	30
3	1.5	1	0.5	20	10
4	6	2	4	40	80
5	10	7	3	140	60
6	7	3	4	60	80
7	2	1	1	20	20

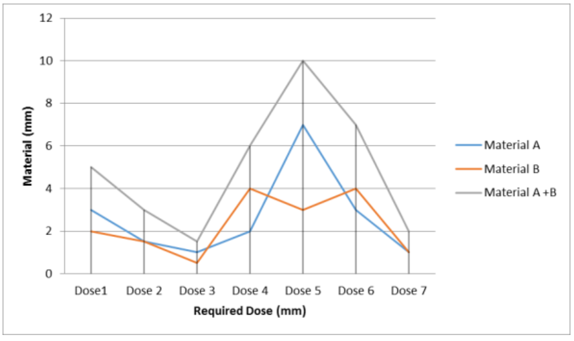

Figure 8. The relationship between required dose and amount of materials

6. TEST AND EXPERIMENTS

6.1 Radiation Materials Optimal Distance

While examining the optimal distance of Radiation Materials from the Filling Device it was found that the Radiation Materials must be near to less than 1 cm.

6.2 Optimal shielded and technician Distance

The optimal distance **shielded** and **technician** is 5 meter.

6.3 Power Consumption for the control circuit

The supply of the control circuit is less than 1.5 Ampere, so a 9 volt battery was used to power up the control circuit.

6.4 Power consumption of the device circuit

The supply of the device is less than 1.5 Ampere, so a 9 volt battery was used to power up the devices.

6.5 Accuracy of system

The most important factor in this system its accuracy, so to determine accuracy we can calibrate system with ideal output and material pumped, and measured by volumetric cylinder, it's figured in below table 4.

Calibration No.	Ideal output (ml)	Pumped output (ml)	Accuracy
1	100	130	+30
2	200	227	+27
3	300	320	+20
4	400	450	+50
5	500	540	+40

Table 4. calibration of ideal and pumped output of system for material (A)

Calibration No.	Ideal output (ml)	Pumped output (ml)	Accuracy
1	100	125	+25
2	200	238	+38
3	300	330	+30
4	400	440	+40
5	500	530	+30

Table 5. Calibration of ideal and pumped output of system for material (B)

So calculated average accuracy of material (A) pump is 33.4 ml and average accuracy of material (B) pump is 32.6 ml. Total accuracy average is 33 ml.

Figure 9. Volumetric cylinder

6.6 System speed

From above table 5. the system speed is figured by equation:

$$Required\ Dose\ time =$$
$$(time\ of\ material\ (A)ms + time\ of\ material\ (B)ms) + vibrator\ mixing\ time$$

Equation 5.1

Vibrator mixing time = 2000 ms

Delay time = 200 ms

Total time required for dose preparation equal:

Time of material A + time of material B + vibrator mixing time + delay time

Equation 5.2

7. CONCLUSION

In this project, an Automatic Dose Mixing Device for radioactive Elements was designed and successfully work passing through all of the challenges that face the design reaching a successful implementation and calibration stage.

Moreover the device contains the ability of entering dose through keypad letting the microprocessor unit take a decision of how much its required time to pass a view millimeters dose outside the container.

Limitations was found in this method that is based on timing, which occurs due to the minimum time required to open and close the valve since the valve is electromechanical and it is effected by the time required to fully open and full closed.

The system accuracy is above the expected results that reach about 88% accuracy.

A certain suggestions are written in the recommendation to solve the problem and increase the accuracy.

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