Radiation Survey Meter

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Abstract- *After Chernobyl and more recently, Fukushima nuclear accident, people are concerned about their safety and health. Radioactivity cannot be noticed by our five senses. To know how much radioactivity is there in a place we need a specific device, like our RADIATION SURVEY METER. It has been designed as economical, easy to use,accurate for the non-technical public to keep at home or work place and monitor the radioactivity level in the area. Our objective is to sense the gamma radiation, display its intensity and save the data in memory so that it can be further analyzed. The system consists of a gas filled radiation detector (GM tube) which will sense the radioactivity. The high DC voltages necessary to polarize GM tube (500 - 900 V) can be obtained from batteries with few and less expensive electronic components. The system has been designed using digital display technique using microcontroller, LCD and keys. The system is also facilitated with USB interface.*

Keywords- Nuclear accidents, radioactivity, radiation survey meter, GM tube

I. INTRODUCTION

Radiation Survey meter is a portable radiation detection and measurement instrument used to detect, presence of radiation in the surrounding. This radiation may be due to alpha particles, beta particles, gamma rays or x-rays. It also gives us the measure of intensity of radiation. Our Radiation survey meter is a micro controller based, portable, light weight, battery operated instrument for measurement of environmental dose rate gamma ray and x-ray radiation.

Recent Radioactive Incident In India

The recent news about the death of a scrap yard worker in New Delhi due to radiation poisoning is an eye opener for radioactive safety and awareness.In early April 2010, a machine from Delhi University containing cobalt-60, a radioactive metal used for radiotherapy in hospitals, ended up in a scrap yard in the city. The origin of radioactive Coblat-60 was traced to Delhi University's Chemistry department which auctioned a Gamma Irradiator to a scrap dealer. The dealer dismantled it and gave it to others, leading to the radiation exposure.

Recent Radioactive Incident In Japan

The Fukushima I nuclear accidents are a series of ongoing equipment failures and releases of radioactive materials at the Fukushima I Nuclear Power Plant, following the 9.0magnitude earthquake and tsunami on 11 March 2011.

Measurements taken by the Japanese science ministry and education ministry in areas ofnorthern Japan 30–50 km from the plant showed radioactive caesium levels high enough to cause concern. Food grown in the area was banned from sale. It was suggested that worldwide measurements of iodine-131 and caesium-137 indicate that the releases from Fukushima are of the same order of magnitude as the releases of those isotopes from the Chernobyl disaster in 1986. Tokyo officials temporarily recommended that tap water should not be used to prepare food for infants. Plutonium contamination has been detected in the soil at two sites in the plant.

Our instrument is very much handy to radiation experts during such incidents.

Basics of Radiation

Radiation is the energy emitted in the form of microscopic particles or photons. Radiations interact with matter through fundamental interactions of our nature, predominantly through the electromagnetic (for charged particles and photons) and strong interactions (for hadrons).
Radiations are classified as:
1) Alpha particles
2) Beta particles
3) Gamma rays
As our field of interest is restricted to gamma rays and X-rays, we will discuss about them only.

GAMMA RAYS

Gamma rays are electromagnetic waves rather like X-rays and radio waves. Thus gamma rays have no mass and no charge. Gamma rays have a high penetrating power - it takes a thicksheet of metal such as lead or concrete to reduce them significantly. We don't find pure gamma sources - gamma rays are emitted alongside alpha or beta particles. After a nucleus has emitted an α-particle or a β-particle, it may still have too muchenergy: we say it is in an "excited state". It can get rid of this energy by emitting a pulse of very high frequency electromagnetic radiation, called a gamma ray.

Units of Radioactivity Roentgen(R)

The roentgen is a unit used to measure a quantity called exposure. The roentgen measures the energy produced by gamma radiation in a cubic centimeter of air. This can only be used to describe an amount of gamma and X-rays, and only in air. One roentgen is equal to depositing in dry air enough energy to cause 2.58E-4 coulombs per kg. It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x-rays.

Roentgen (R) = energy which will produce 1 billion ion pairs/mL air.

Rad (Radiation Absorbed Dose)

The rad is a unit used to measure a quantity called absorbed dose. This translates to theamount of energy actually absorbed in some material, and is used for any type of radiation andany material. One rad is defined as the absorption of 100 ergs per gram of material. One roentgen of gamma radiation exposure results in about one rad of absorbed dose. The unit rad can be used for any type of radiation.

Rem (Roentgen Equivalent Man)

The Rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. To determine equivalent dose (Rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation. For gamma rays and beta particles, 1 rad of exposure results in 1 Rem of dose.

Need of Radiation Survey Meter

It is useful for Health Physics applications in Nuclear Power plants, Nuclear Medical Centers and Radio Isotopes laboratories.There are two types of monitoring devices Radiation survey meter and Pocket Dosimeter. Radiation Survey Meter calculates the dose rate per hour and Pocket Dosimeter measures the dose actually absorbed by operator. However both instruments work on the same principle. ‘Quality NDT services’ has sponsored our project. The company works on Non-Destructive Testing. NDT allows parts and material to be inspected and measured without damaging them so that it doesn’t interfere with a product's final use. For Non-Destructive Testing they use Gamma rays as well x-rays. Forgeneration of gamma rays the radiation sources used are Cobalt-60 and Caesium-137. When the testing is carried out, the area around testing instrument should berestricted where the radiation intensity could be hazardous for human being. Safetyof the operators is most important as operators have to face the radiation continuously. Therefore, an operator should carry personal radiation monitoring device. So depending on the reading proper shielding (lead block or concrete block) can be used.

1. Detector (sensor) – The detectors available for sensing radiation are gas filled tubes and scintillation detector. Scintillation detectors use a crystal that fluoresces when a particle travels through it. This crystal is mounted on top of a sensitive photomultiplier, which will detect any generation of a light pulse in the crystal. Scintillation tubes however are expensive and require a complicated power supply and amplifier, making them unsuitable for home construction. The gas filled tubes on the other hand, are simple to construct and inexpensive.

2. Low Power Consumption – Design a Radiation Survey Meter such that it uses minimal power for its operation. So that it can work on low voltage battery (5 to 9 volt). For this purpose we have selected PIC16F2550 controller with Nano Watt technology.

3. Information Storage – This feature is important because it accumulates radiation counts over a period of time instead of the standard button setting that only displays the radiation levels at that particular moment. This feature is helpful in determining longer term exposure.

4. Compact Size **-** Radiation Survey Meter do not have to be big and bulky. It should be compact, light and easy to carry.

5. Durability – Radiation detector should be able to withstand extreme temperatures and the housing should not crack, peel, split or shatter.

6. Low Level Sensitivity **-** Portable radiation detector should measure from below ambient radiation levels. But this will further increase the cost of product as more sensitive detectors costs high. The GM tube used in our project can detect radiation intensity in mR/hr.

7. Detection Measurement – The operating range of a radiation detection device is important for Radiation Survey Meter. A typical maximum operating range would be to 1 R/hr. The range depends on the sensor used in instrument.

SPECIFCATIONS

Detector Geiger Müller Tube Halogen quenched type (gamma rays & x-rays detector)
Measurement units 1) CPS (Counts per second)2) mR/hr (mille Rontgen per hour)
Maximum measuring Range Dose rate: 5 R/hr Count rate: 90000CPS

Sensitivity 18 CPS/mR/hr (Co60)	
Powered by four AA Alkaline batteries (1.5V)	

Characteristics of Our Instrument

1) The 500V DC G-M tube biasing voltage is generated by a PIC microcontroller in boost power supply configuration.
2) The display is menu driven with 4 line LCD digital readout.
3) Microcontroller ‘sleep’ mode is used to reduce power consumption
4) Radiation measurements are date/time stamped by an internal real time clock.
5) Internal memory can store 375 radiation measurements using PIC18F2550.
6) Built-in USB interface for data upload to a personal computer.
7) PIC firmware is written in freely available C language.
8) Personal computer software is written in latest version of Visual Basic.Net

Working of Gm Tube

Most GM tubes look like metal covered glass cylinders with just two connections, see pictures above (fig. 2.2a and 2.2b). Inside they are filled with a noble gas (Neon is usual, but Helium or Argon can also be used) plus a small amount of a halogen.

Electrically, a GM tube is a cylindrical capacitor with the gas as the dielectric. A wire placed along the axis acts as one electrode and the cylindrical metal shield as the other. A large DC voltage (between 500 and 1200 V) is set up between the electrodes with no current normally flowing through the gas. If any ionizing radiation enters the tube and breaks some gas atoms into ions (that is, if it has enough energy) the ions are accelerated by the electrical field and collide with other atoms thus multiplying hugely the number of ions inside the tube. This is known as' avalanche effect'. The flowing through the gas and the electrical circuit the tube is connected to.

DEVICE CONCEPTS AND OPERATION

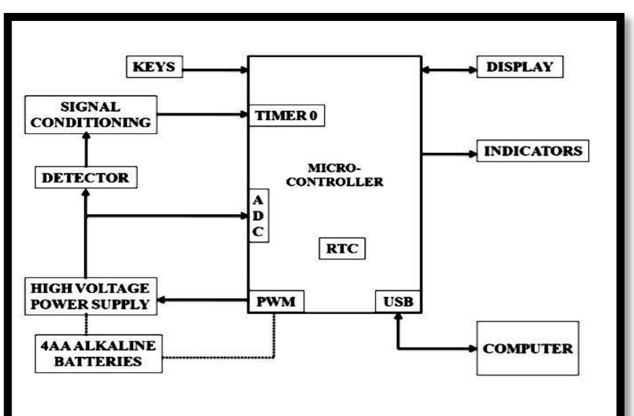


Fig -1: Block diagram of the radiation survey process

Fig - 2: GM tube STS-5(SBM-20)

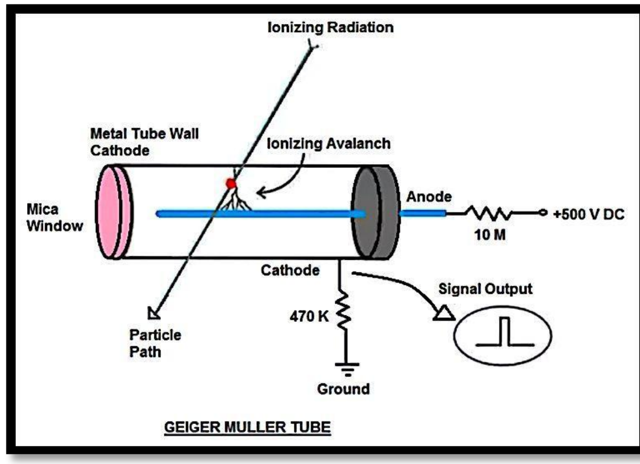


Fig -3: Traditional Geiger Muller counter utilize a thin end window tube and a high voltage supply applied through a resistor

Detector Circuit

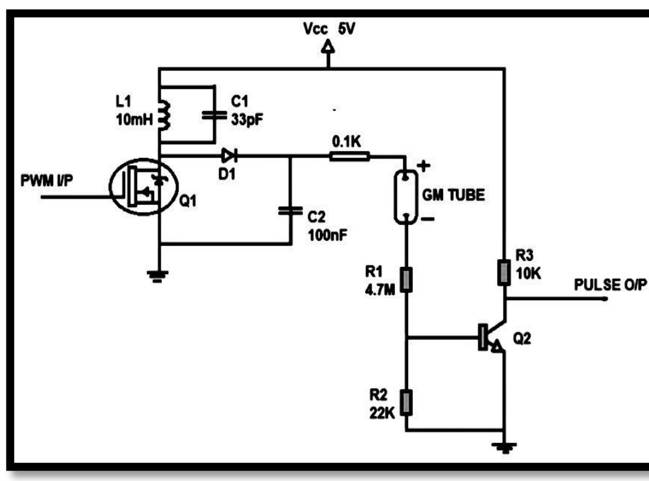


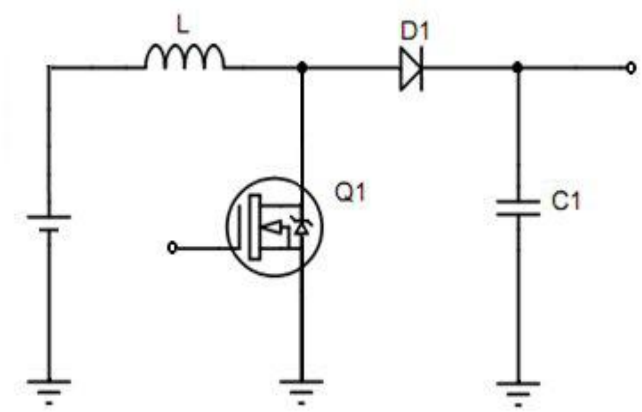
Fig - 4: Detector circuit diagram

Detector circuit consists of the radiation detector (GM tube), a boost converter (to provide necessary voltage required by the GM tube), and a pulse counting circuit (to count and transmit the pulses generated by GM tube.

Power Supply

Geiger Müller tube requires high DC voltage (400V -1500V) for its operation. For the tube recommended voltage by manufacturing company is 500V. By using transformer voltage can be step up to desired level, but the circuit may become bulky. So we are using step up chopper to get high DC voltage.

General circuit diagram for step up chopper is shown below



Controller

We have selected **PIC16F2550** for its following features:

- Low power consumption (**nanoWatt technology**).
- Available in **28 pin PDIP**
- 32K of flash program memory.
- Built-in full speed USB capability.
- Multiple built-in 10-bit analogue to digital conversion.
- Speeds up to 48MHz (12MIPS).
- Self programmability.
- Four separate timers.
- Low cost.

Display Module

We have used 20x4 LCD (JHD204A) in the 'Radiation Survey Meter'. The software we have designed is a menu driven, so we require wider display to make it more user friendly and simple and it is available with this LCD.

It is used in 4-bit mode. Connections are as shown in the table below.

LCD PIN	CONTROLLER PIN	
D7	RB7	DATA PINS
D6	RB6	
D5	RB5	
D4	RB4	
EN	RA5	CONTROL PINS
RS	RA3	
RW	RA2	

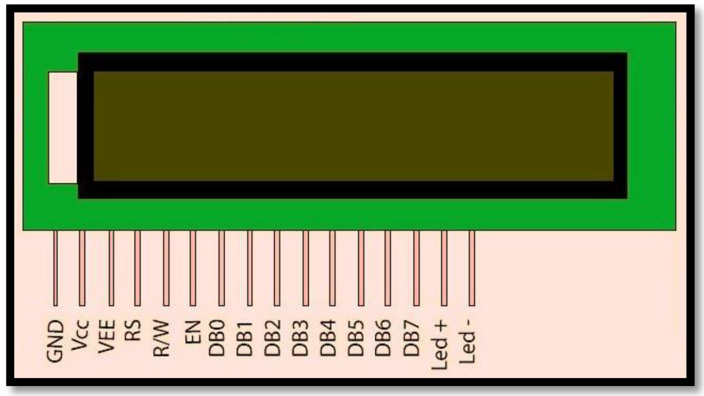


Fig -5: LCD 16X2 display

WORKING MECHANISM

Radiation will cause the insulating property of gas in the GM tube to momentarily break down, which will cause a voltage spike on the tube output. This voltage spike is sent to a 2N3904 NPN transistor. The positive pulse causes the transistor to switch and its collector is brought to ground. Each negative transition on pin6 of micro-controller causes the TIMER0 value to increase by one, up to a maximum count of 65535.

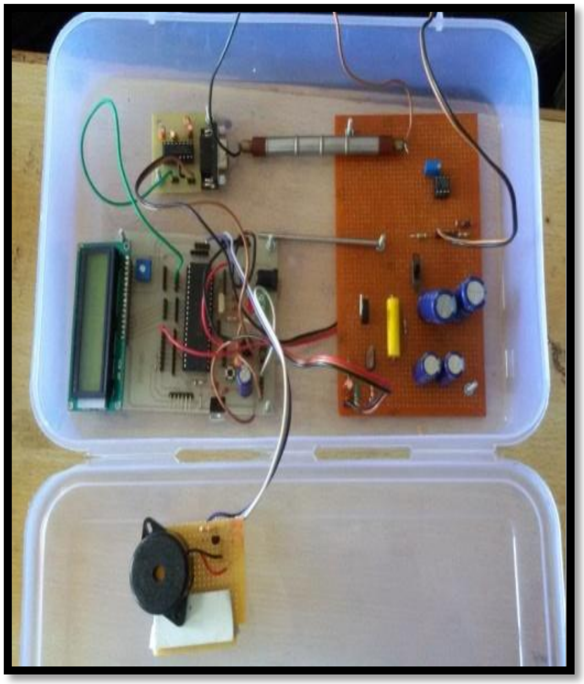
One of the challenges was in getting the 'RADIATION SURVEY METER' (RSM) to keep track of time. Microchip suggests implementing a simple low power real time clock on the PIC18F2550 by adding an external 32.768 KHz crystal and two 22pF capacitors on Timer1 inputs.

In order to keep accurate time, micro-controller needs to be powered at all times. This eliminates the need for a manual power switch. The micro-controller uses an interrupt scheme and 'sleep' operating mode to keep battery drain to a minimum. When the micro-controller is put to sleep, the main 20MHz oscillator stops and it executes no instructions. In sleep mode, the 32.768 KHz crystal connected to TIMER1 will continue to oscillate and TIMER1 will continue to increment. When TIMER1 overflows (once per second), an interrupt will occur and the micro-controller will wake up, increment the time and go back to sleep. In sleep mode with the 'RADIATION SURVEY METER' (RSM) will use about 5.5mA of timekeeping current. In normal operating mode, the RSM uses about 42.5mA of current. When the high voltage is being generated the total current used is 58mA. When micro-controller wakes up, once each second, it will also check to see if the EXECUTE menu button has been pressed. It will also check to see if the RSM has been plugged into a computer USB port.

If either of these conditions has occurred, the micro-controller will remain awake and the user can interact with the RSM through the menu system. If the RSM is unplugged from the

USB port or the user selects the 'RADIATION SURVEY METER OFF' menu option, the RSA will turn off the LCD and go back to sleep.

DEVICE CHARACTERISTICS



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4. Radiation measurements are date/time stamped by an internal real time clock.
5. Internal memory can store 375 radiation measurements using PIC16F877A.
6. Built-in USB interface for data upload to a personal computer.
7. PIC firmware is written in freely available C language.

4. OBSERVATIONS We have observed and noted down the readings obtained using the radiation source Thorium of Symbol**Th** and atomic number 90. It is a radioactive actinide metal. The half life of thorium-232 is about 14 billion years.

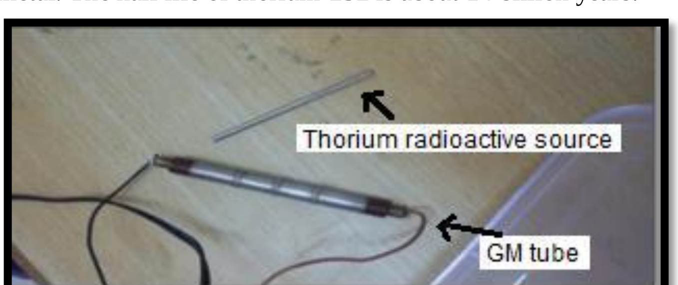

Fig -6: Thorium rods-radioactive source

The readings on GM tube are obtained under three situations:
1. When there is no radioactive source around -In this case the GM tube must show background noise reading (which is predefined as ≤10 pulses per 10 seconds)
2.When the Radioactive source is kept around the GM tube (distance up to 15 cm). In this case the reading must be ≥10 pulses per 10 seconds and the buzzer must start sounding.
3. When the radioactive source is kept on the GM tube (by placing paper between tube and source to avoid direct contact between them) - In this case the reading must be higher and the buzzer must sound

Observation Table:

Following readings are taken for counts per10 seconds.

Sr. no.	Distance between source and GM tube	Radiation intensity in counts per 10 seconds
1.	No nearby source	3 counts/10 sec
2.	≤15 cm	13 counts/10 sec
3.	≤0.5cm	21 counts/10 sec

RESULTS

Sensitivity of STS -5/SBM-20 GM tube for Cobalt- 17 cps/mR/hr 1 cps= 0.06 mrem/hr

Conversion formula:

Sensitivity= counts per second/(mrem/hr)

RESULTS CALCULATED

Sr No.	Distances between source and GM tube	Radiation intensity in Counts per 10 seconds	Radiation level in standard unit; mrem/ hr
1.	No source nearby	3 counts per 10 sec	0.0235
2.	≤15cm	13 counts per 10 sec	0.0823
3.	≤0.5cm	21 counts per 10 sec	0.1176

CONCLUSION

Radiation detectors are widely used in industrial applications (nuclear power plants and military applications) as well as in research surveys for detecting emission of radioactive radiations. This project discusses the implementation where a large sized, complicated detector is replaced by compact GM tube radiation detector, in order to prepare a small sized, mobile and inexpensive radiation detection device based on low cost PIC microcontroller. These controllers help in detecting the radiations emitted by radioactive material with minimum external hardware requirement by retaining the efficiency of detector and hence reducing the cost of detection device making it more affordable

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