Title	Design and Implementation of KIT Uno32-Based GM Counter
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Design and Implementation of chipKIT Uno32-Based GM Counter

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Abstract

The portable GM counter is designed and implemented using chipKIT Uno32 microcontroller board and the Velleman's K2645 Geiger Muller (GM) counter module. The GM counter module consists of the GM tube and DC high voltage circuit. The radiation coming into the GM tube produces a small current due to the flow of electrons and positive ions. The electrons are then accelerated using high voltage to produce a small current pulse at the anode of the GM tube. The voltage pulse is obtained by placing appropriate resistor at the output. The output voltage pulse is used to drive the buzzer. The buzzer makes the sound every time the radiation enters the GM tube.   The output voltage pulse has a peak of about 9 V. The voltage pulse is then divided using series resistors to obtain one third of the original value. The pulse is then fed to the input of the chipKIT Uno32 board to count the radiation. The radiation doses in μR/h are displayed on the LCD module.

Key words: chipKIT Uno32 microcontroller board, Velleman's K2645 Geiger Muller (GM) counter module, buzzer, voltage pulse, radiation doses, LCD module

Introduction

The nuclear radiation is everywhere due to natural and artificial sources. The radiation can be hazardous to living organisms because of its ionizing power in matter. Nuclear radiation and radioactive isotopes are used in health, agriculture, education of nuclear techniques and environmental protection sectors as well as energy production sectors. Therefore the nuclear radiation monitoring systems play a key role in monitoring environmental contamination due to hazardous nuclear radiation and assessing the safety of food for both local consumption and export. The amounts of radiation falls on materials are monitored using ionizing radiation dose-rate meters or simply survey meters. The Vellemen's K2645 Geiger-Muller counter kit has been used with various kinds of microcontrollers and microcontroller boards such as BASIC Stamp I microcontroller board, ATMega 8 microcontroller, PIC16F877A microcontroller. In this research work, the Vellemen's K2645 Geiger-Muller counter together with the chipKIT Uno32 microcontroller board is used to monitor the nuclear radiation.

The functional block diagram of the chipKIT Uno32-based GM counter is shown in Figure 1. It consists of K2645 GM counter, voltage divider circuit, chipKIT Uno32 microcontroller board, LCD module and power supply.
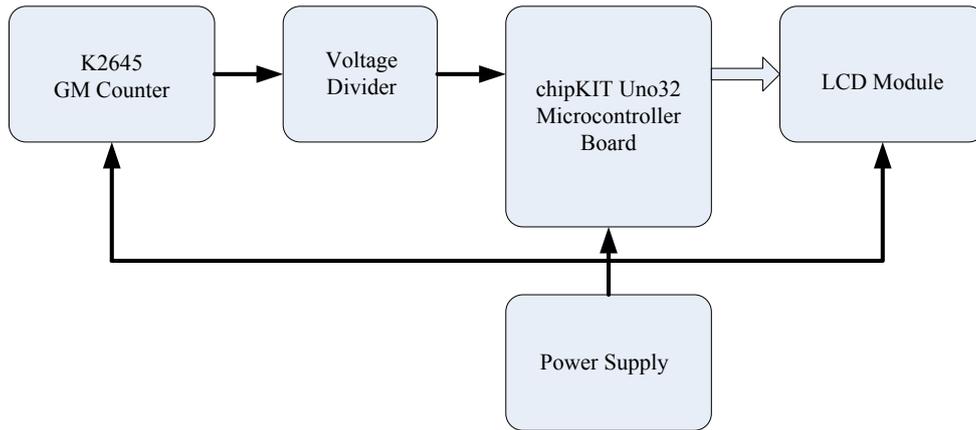
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Figure (1) The functional block diagram of the chipKIT Uno32- based GM counter

Design and Construction

The design, construction and operation of the chipKIT Uno32-based GM counter will be explained in this section. Design and operation of the K2645 GM counter, voltage divider circuit, chipKIT Uno32 microcontroller board and LCD display circuit will be described in some detail. The operation of the GM counter will also be explained. Finally, the software implementation required for the GM counter will be discussed.

The Velleman's K2645 GM Counter

The K2645 Geiger-Muller counter used for this research work is a smart kit for nuclear radiation detection. It produces sound when the radiation is detected by the device. The more dangerous radiation makes the more noise in the detector. The kit comes as a portable set with very low power consumption (200 μA). Under a normal radiation conditions a 9V battery can keep it working continuously for at least 2 months. The beeping speed of the buzzer increases when more radiations are captured. The photo of the K2645 GM counter is shown in Figure 2.

Figure (2) The photo shows the K2645 GM counter.

GM Counter Circuit

The GM counter circuit is shown in upper left side of Figure 5. N1 and N2 are the heart of a slow running oscillator. Every 10 seconds the output of N2 goes positive for a few hundreds of milliseconds. Only then the oscillator with N7 and N3 starts running. This signal goes via N8 and N9 to transistors T1 and T2. These are alternatively switching the transformer coils, producing an AC-voltage at the secondary winding of the transformer. Finally a voltage multiplier (D5-D13, C5-C12) converts it to a very high DC voltage (600 V).

Radioactive particles that reach the tube cause current peaks on R11 that trigger the mono-stable oscillator N6/N10, producing a 100 ms beep. The output of N5 is connected to the voltage divider circuit, R13 and R14. The voltage at the middle of two resistors is then reduced to half of input voltage. The voltage of HIGH output state at N5 output is about 9 V. Therefore, the output voltage at divider is about 4.5 V for HIGH state. The divider output is then put to the counter input pin (38) of the chipKIT Uno32 microcontroller board. This input pin is programmed to count the number of counts obtain from the GM counter circuit.

The formula for converting counts to microrems/h ($\mu R/h$) was derived from the response graph (Figure 3) included with the Geiger counter. This formula is:

$$\mu R/h = \text{counts per minute} * 100/15$$

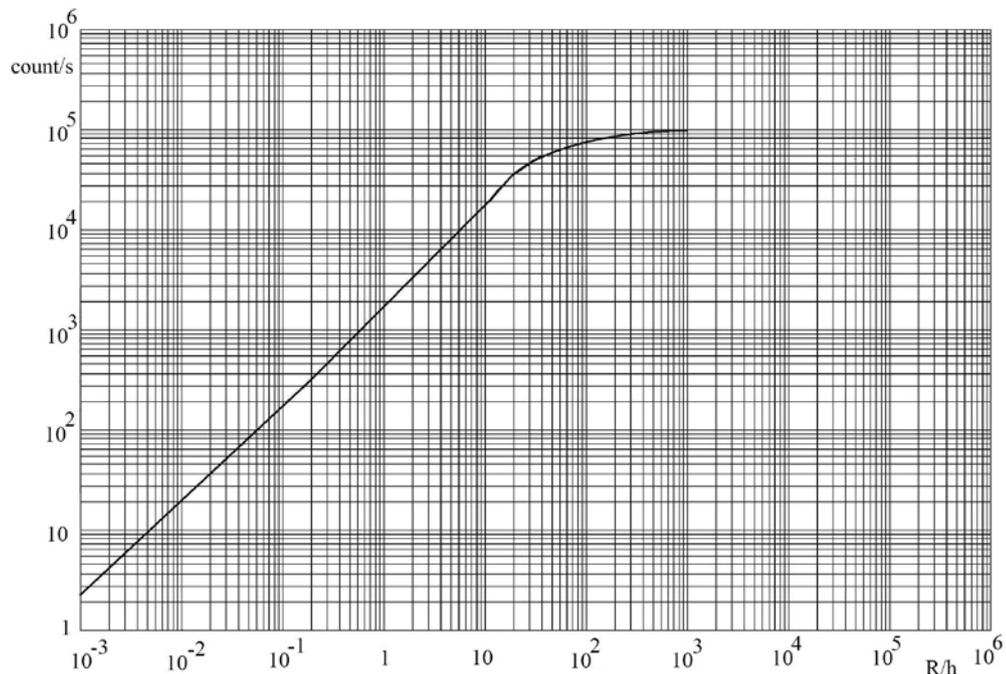The resulting counts/minute and $\mu R/h$ values are then displayed on LCD display screen.

Figure (3) The response graph showing typical count rate as a function of dose rate (^{60}Co)

chipKIT Uno32 Microcontroller board

The chipKIT Uno32 development board is based on the powerful PIC32MX320F128 microcontroller, which features a 32-bit MIPS processor core running at 80MHz, 128K of flash program memory, and 16K of SRAM data memory. The board can be powered via USB or an external power supply. The on-board USB-UART interface provides a communication path between the board and the MPIDE tool running on the PC. MPIDE stands for Multi-Platform Integrated Development Environment and is a complete tool for developing and downloading embedded applications into the chipKIT Uno32 board. The chipKIT Uno32 microcontroller board is shown in Figure 4.

Figure (4) The chipKIT Uno32 microcontroller board

The Uno32 board uses a standard Mini-B USB connector for connection to a USB port on the PC. The FTDI FT232RQ chip next to the USB connector provides an USB-UART interface for a two-way serial communication between the PC and the board. The same serial port is used by the MPIDE to communicate with the serial bootloader running on the Uno32 board while downloading user applications. The Uno32 can be powered either via USB or from an external power supply. The automatic switch-over circuit on-board causes the external supply to be used if both supplies are present.

The chipKIT and Arduino systems both use logical pin numbers to identify digital I/O pins. The valid logical pin numbers for the Uno32 board are 0-43. The chipKIT Uno32 board provides altogether 42 I/O pins that are accessible through connectors J5, J6, and J7. Each I/O pin can source or sink a maximum of 18mA. However, to keep the output voltage within the specified voltage range (V_{OL} = 0.4V, V_{OH} = 2.4V), the pin current must be restricted to source and sink at most 7mA and 12mA, respectively. The maximum current that can be sourced or sunk across all I/O pins simultaneously is 200mA.

LCD Display Circuit

The LCD module used in this research work is 16×2 lines LCD module. The LCD display circuit is shown in the complete circuit diagram. As can be seen in the circuit, the LCD module is designed to receive data bits in 4-bit mode. The upper 4-bits (DB4-DB7) are used to receive data from the chipKIT Uno32 microcontroller board. The lower 4-bits are not used and tied together with ground. The R/W pin is also grounded because the LCD module is used to write data from the microcontroller. There is no read operation from the LCD module back to microcontroller. The preset resistor is used to adjust the light level of the LCD module.

The upper line of the LCD module displays the message "GM Counter". The lower line is used to show measured radiation doses in μR/h .

Operation of the GM Counter

The radiation coming into the GM tube produces small current due to the flow of electrons and positive ions. The electrons are then accelerated using high voltage to produce a small current pulse at the anode of the   GM tube. The voltage pulse is obtained by placing appropriate resistor R11 of 220 kΩ at the output. The output voltage pulse is used to drive the buzzer. The buzzer makes the sound every time the radiation enters the GM tube.   The output voltage pulse has a peak of about 9 V. The voltage pulse is then divided using series resistors (R13 and R14) to obtain one third of the original value. The pulse is then fed to the input of the chipKIT Uno32 board to count the radiation. The radiation doses in μR/h are displayed on the LCD module. The complete circuit diagram of the constructed GM counter is shown in Figure 5.
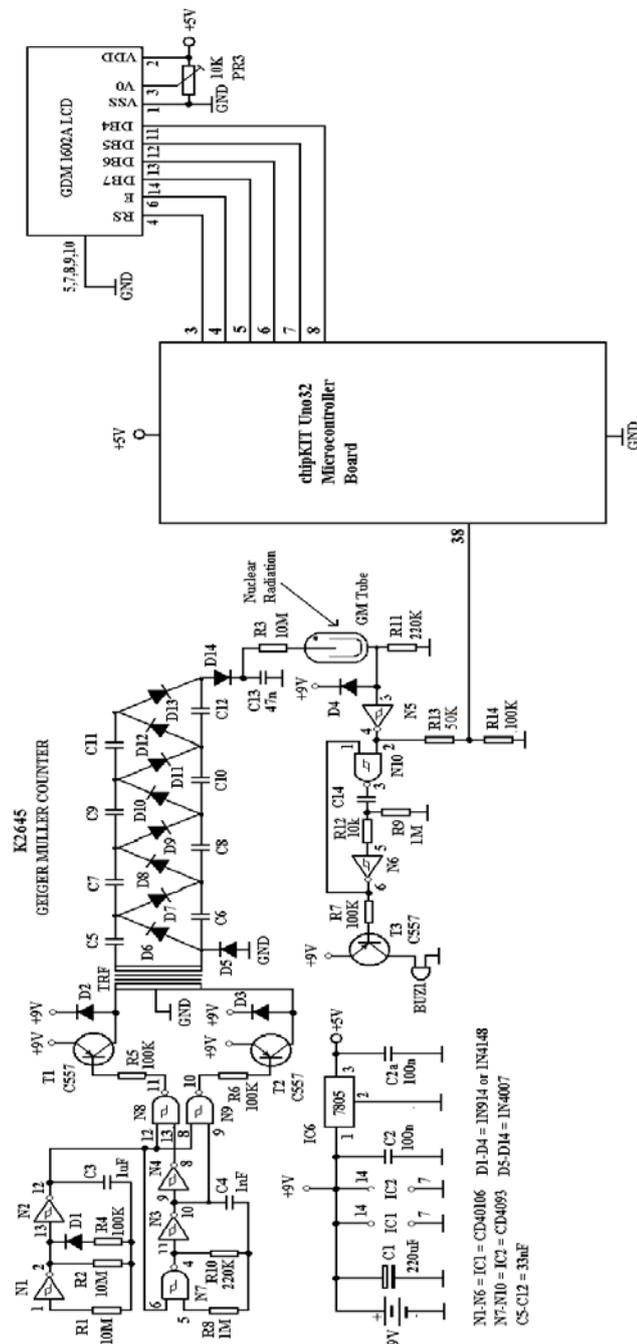

Figure (5)   The complete circuit diagram of the chipKIT Uno32-based GM counter

Implementation of Program Software

The flow chart diagram of the chipKIT Uno32 microcontroller board-based GM counter is shown in Figure 6. At the start of the program, the port directions of the microcontroller board are set. Then the microcontroller pins, used to send control and data signals to the LCD module, are defined. In this research work, 4-bit mode is used to display data and message on the LCD module. The upper line of the 16×2 lines LCD module displays the message "GM Counter". Then the program counts number of pulses coming from the chipKIT pin 38. The program is then processes to get the value of radiation doses using the relation "μR/h = counts per minute * 100/15". Then the measured radiation dose is displayed on the lower line as "- - - - - μR/h ". The program waits about 1s and then loop back to the start of the range selection statement. The program is repeated as long as the power is turned ON.

```
                    ┌─────────────┐
                    │    START    │
                    └─────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │   Set Port Direction   │
              └────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │   Set LCD Pin and Mode │
              └────────────────────────┘
                           │
                           ▼
         ┌──────────────────────────────────┐
         │ Set chipKIT Uno32 pin 38 as       │
         │ Counter Input                     │
         └──────────────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │ Initialized Counter to │
              │         Zero           │
              └────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │  Measured Pulses       │
              │  (Counts) from GM      │
              │  Counter about 10 sec  │
              └────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │  Converts counts into  │
              │  Counts per minute(CPM)│
              └────────────────────────┘
                           │
                           ▼
         ┌──────────────────────────────────┐
         │ Converts Counts per minute into  │
         │ corresponding radiation dose μR/h │
         │ "μR/h = counts per minute *100/15"│
         └──────────────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │ Display the message    │
              │ "GM Counter" on LCD    │
              └────────────────────────┘
                           │
                           ▼
              ┌────────────────────────┐
              │ Display the radiation  │
              │ dose in μR/h on LCD    │
              └────────────────────────┘
                           │
                           └──────► (loop back)
```
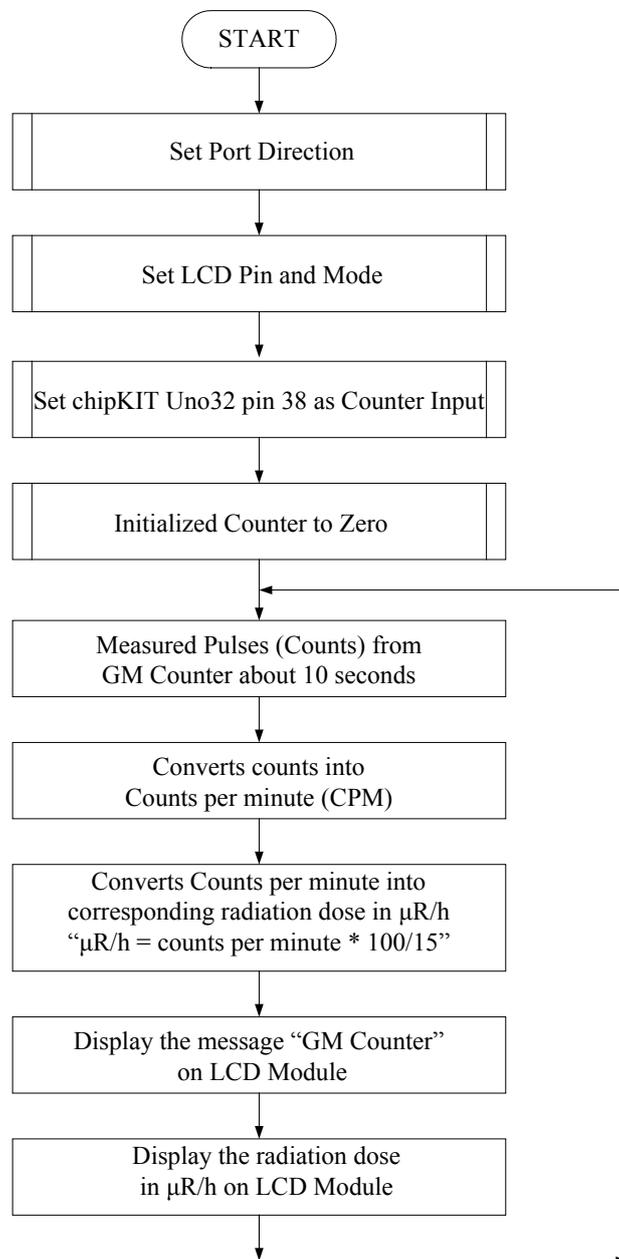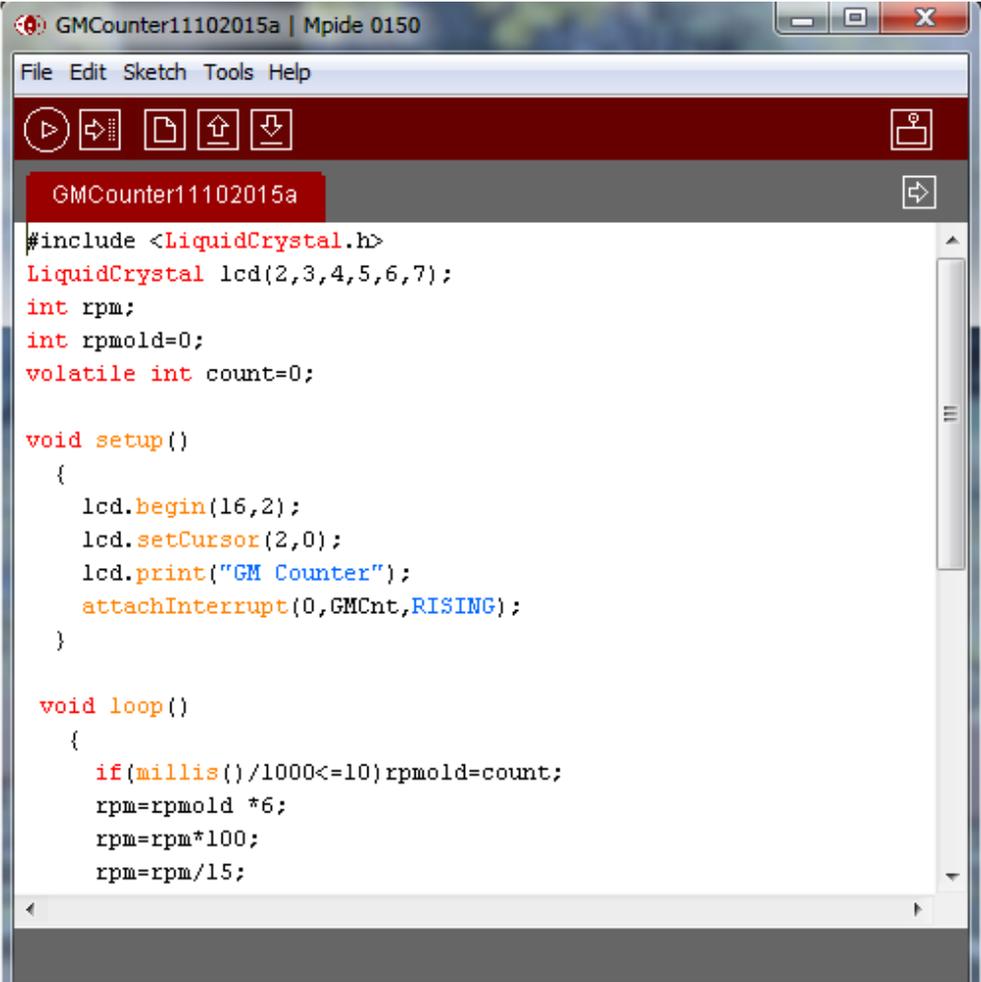
Figure (6) The flow chart diagram for the operation of GM counter

The source code for chipKIT Uno32 microcontroller board is written in C language (also called a sketch). The screen capture of the source code (sketch) for the constructed GM counter is shown in Figure 7. The Digilent Multi-Platform Integrated Development Environment (MPIDE) is used for the project. The MPIDE is a modified version of the popular Arduino IDE. MPIDE is compatible with both native Arduino hardware and software and with Digilent's chipKIT PIC-32–based family of microcontrollers. The IDE is based on a simplified set of C/C++ language and libraries, with the aim of providing a microcontroller software development environment with less technically minded people.


```c
#include <LiquidCrystal.h>
LiquidCrystal lcd(2,3,4,5,6,7);
int rpm;
int rpmold=0;
volatile int count=0;

void setup()
  {
    lcd.begin(16,2);
    lcd.setCursor(2,0);
    lcd.print("GM Counter");
    attachInterrupt(0,GMCnt,RISING);
  }

 void loop()
   {
     if(millis()/1000<=10)rpmold=count;
     rpm=rpmold *6;
     rpm=rpm*100;
     rpm=rpm/15;
```

Figure 7 The screen capture of the source code (sketch)

Results and Discussion

The chipKIT Uno32 microcontroller board-based GM counter is designed and constructed. The photograph of the constructed GM counter is shown in Figure 8. The photograph of the LCD display showing the radiation dose is shown in Figure 9. The measured radiation dose is shown in LCD display. The radiation dose taken by the constructed counter is calibrated by using the relation given by the manufacturer. The constructed GM counter can be assembled as portable unit.
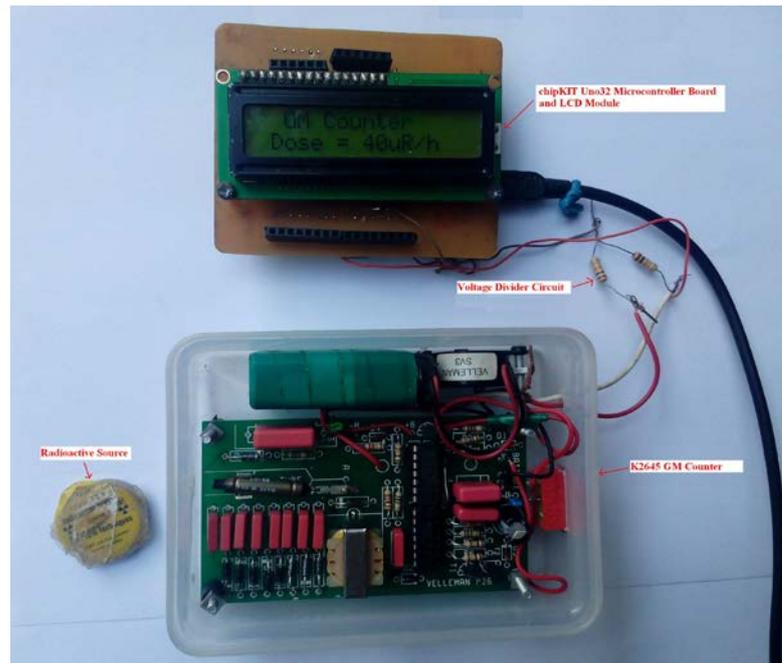
Figure (8) The photograph of the constructed GM counter

Figure (9) The photograph of the LCD module showing radiation dose

Conclusion

The range of the radiation dose that can be measured by the constructed counter is from 1 μR/h to several hundreds μR/h range. The application of the constructed counter can be extended to log data by adding some memory module. The counter can also be modified to interface with PC (or laptop computer) for real time monitoring and data processing purposes. The portability of the counter makes application in the field service.

Acknowledgements

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