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Section A

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An intelligent electret radiation dosimetry system based on a 80535 microcontroller

Paulo Estevão Cruvinel *, Sergio Mascarenhas

EMBRAPA-CNPDIA, P.O.Box 741, 13560-970 São Carlos-SP, Brazil

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Abstract

This work presents an intelligent system based on a 80535 microcontroller for determining X and γ-rays dose with a cylindrical electret ionization chamber. The versatility obtained with the use of intelligent instrumentation presents advantages in applications hazardous to operators. Results show the reliability of the system for radiation dosimetry as well as its suitability for a wide range of applications. © 1999 Elsevier Science B.V. All rights reserved.

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Keywords: Radiation dosimetry; Electrets; X- and γ-ray instruments; Microcontroller

1. Introduction

The electret state of dielectrics is usually determined by measurement of surface potential decay [1,2], allowing estimation of decay time constant and prediction of its further behavior. Concerning electrets, several applications have been suggested and implemented since the first electret device, a microphone, was described in 1927. Broad range applications in the late 1980s included electret microphones, electret filters, electret dosimeters, piezopolymer transducers, and pyroelectric sensors. The field of eletret applications remains challenging, however; new devices based on electret technology are found in the areas of solar energy conversion, radon dosimetry, acoustic and pyroelectric silicon technologies, and underwater detection [3–6]. Radiation effects in eletrets and dosimetry can be found in Multhaupt [7] and Kirsh and Chen [8]. Electret dosimeters, first described about 41 years ago, were initially designed to measure γ-radiation [9] and, in the past six years, due to public concern about health hazards from α-radiation, the use of electret-based radon dosimeters has greatly expanded on a commercial basis for indoor and environmental measurements. Moreover, electret neutron dosimeters are currently being studied intensively [10]. An electret dosimeter with cylindrical active volume was introduced by Mascarenhas et al. [11] for possible use in personnel and area monitoring. With dimensions similar to those of the common pen dosimeter, the

* Corresponding author. Tel.: +55 016 274 2477; fax: +55 016 272 5958; e-mail: cruvinel@cnpdia.embrapa.br.

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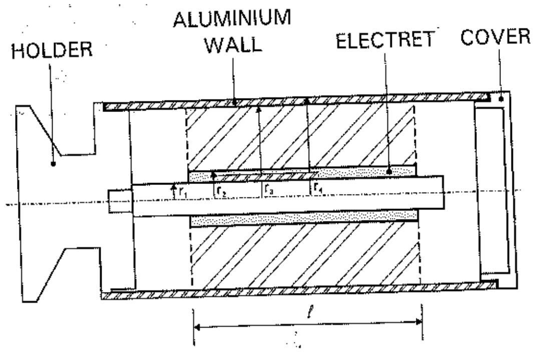

Fig. 1. The electret dosimeter with cylindrical active volume and its dimensions (after Mascarenhas and Zimmermann, 1979).

electret has both a total surface charge of order of 10^{-9} C and a readout sensitivity of 10^{-5} Gy with a useful range of 5×10^{-2} Gy. Fig. 1 shows the electret dosimeter with cylindrical active volume and its dimensions. The full-energy response curve as well as the degree of reproducibility and accuracy of the dosimeter was reported by Guerrini [12].

The use of electrets for dosimetry has been reviewed by Gross [13]. Contributions in which electric fields for an ionization chamber are produced by an electret have been reported by Bauser and Runge [14]. In this work, cylindrical electret ionization chambers were used as reported by Cameron and Mascarenhas [15] and Cruvinel et al. [16]. In these, the electret also serves to detect remaining uncompensated charge after exposure to ionizing radiation.

This paper presents an intelligent system based on a 80535 microcontroller (SMRD) for radiation dosimetry using electrets. Experimental results are presented to illustrate system performance.

2. Experimental procedure and discussion

The electrometer and microcontroller circuitry based on a 80535 chip is shown in Fig. 2.

This arrangement allows measurement of dosimeter performance and characteristics such as decay leakage. The equivalent surface charge on the electret of the dosimeter may be either read directly into a $3\frac{1}{2}$ LCD display or stored in the system's random access memory. The integration preamplifier used for the electrometer consists of the commercially available operational amplifier (opamp) No. CA3140A with a capacitor of 1 nF in the feedback loop. The CA3140A BiMOS operational amplifiers feature gate-protected MOS/FET (PMOS) transistors in the input circuit to provide very high input impedance, very low input current, and high-speed performance.

The microcontroller AMD 80535 is a stand-alone, high-performance single-chip computer based on 8051 architecture. It incorporates several enhancements which significantly increase design flexibility and overall system performance. It also has on board both an 8 bit A/D converter and a 16 bit timer. Other features include a 256×8 RAM (Random Access Memory), six 8 bit ports and 48 I/O lines. Communication with a PC -compatible or a PDP 11/44 computer may be established by using a serial RS232-C protocol. Various software has also been elaborated to perform tasks necessary for controller and data acquisition. Most instructions used are executable in 1 μs. A 32 K EPROMS (27256) is available for programming.

In this experiment the electrets were charged negatively and typically induced an electric field > 1000 V/m in the air gap enclosed in the ionization chamber. The surface of the Teflon FEP® electret film was charged by the Corona discharge method. Fig. 3 shows schematically the electrical model for measurements of the total electret surface charge, i.e., the corresponding dose.

The magnitude of the equivalent surface charge $|Q_-|$ on the electret can be given by

$$|Q_-| = |(Q_{1+}) + (Q_{2+})|, \tag{1}$$

where (Q_{1+}) and (Q_{2+}) are, respectively, the induced charge on the central electrode and the internal wall of the dosimeter. The total surface charge on the electret is (Q_-). In addition, the electric fields $E(r)$ can be given by

$$E(r) = \frac{(Q_-)}{2\pi\varepsilon_0 rl}\left\{\frac{[(l/k)(\ln r_2/r_1)]}{(l/k)(\ln(r_2/r_1) + \ln(r_3/r_2))}\right\}, \tag{2}$$

where ε_0 is the dielectric permitivity, $r_1 = 1.20$ mm, $r_2 = 1.45$ mm, $r_3 = 7.60$ mm, $r_4 = 8.00$ mm, and

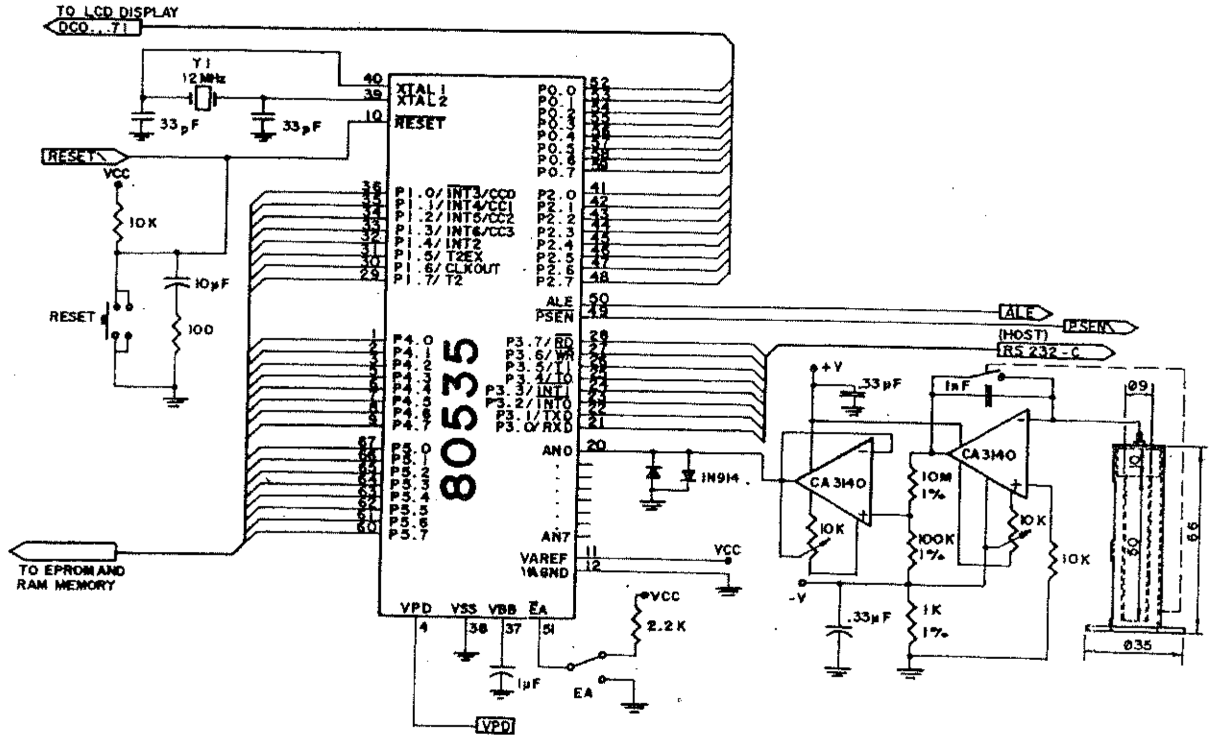

Fig. 2. Electronic circuit of the electrometer with 80535 microcontroller. The electrometer is shown connected to the AN0 input.

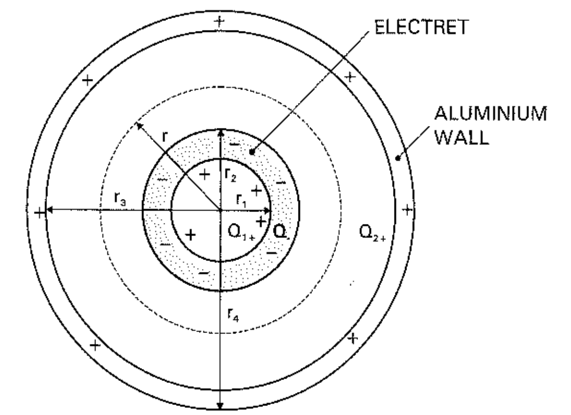

Fig. 3. The electrical model for measurements of the equivalent surface charge on the electret, i.e., the corresponded dose.

$l = 30.00$ mm are the dimensions of the electret dosimeter; r is given by the dimensions of the charge collecting device connected to the electrometer input, which is 7.55 mm ($r_2 < r < r_3$);

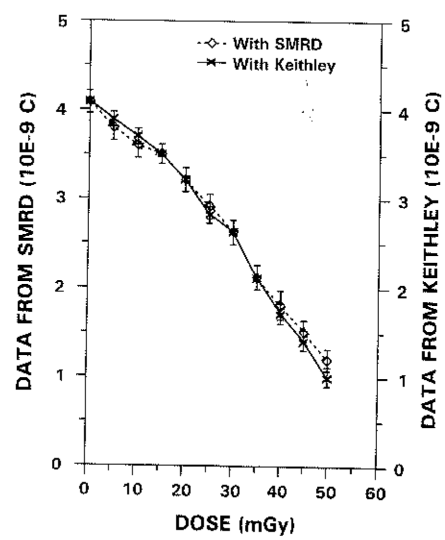

Fig. 4. Correlation of the results obtained with the SMRD and a Keithley electrometer.

Table 1
The basic algorithm for the A/D converter and readout electrometer task

```
;   A/D converter and readout
electrometer task routine.
;   System for radiation dosimetry
using electrets.
;   Continuously reads all analog
inputs and sends to host to be
; displayed on screen.
;  The analog-to-digital converter is
set up as a background
; (interrupt-driven) task.
;
==========================
==
; VOID connections
; Electrometers EL0-EL7 to inputs
AN0-AN7
;
==========================
==
;    m a i n   p r o g r a m
; ---------------------------------
----; internal memory use
; bytes:
  analog0 equ 0c0h     ;  0-th adc
input
  analog1 equ 0c1h     ;  1-th adc
input
  analog2 equ 0c2h     ;  2-th adc
input
  analog3 equ 0c3h     ;  3-th adc
input
  analog4 equ 0c4h     ;  4-th adc
input
  analog5 equ 0c5h     ;  5-th adc
input
  analog6 equ 0c6h     ;  6-th adc
input
  analog7 equ 0c7h     ;  7-th adc
input
  channel equ 0d3h     ;  a/d conv.
pointer
  clock equ  0f0h  ; software clock
; bits
  dir_left equ 10h ; rotate direction
; ---------------------------------
----
; system calls          registers used
; ---------------------------------
----
 ascbin   equ  0100h  ; a, r2, error
flag
 autoexec equ 0103h
 beep     equ 0106h ; none
 binasc   equ 0109h ; a
 break     equ  010ch  ; a, (reads
accumulator)
 chkbrk    equ  010fh  ; a, (reads
serial port)
 cret    equ 0112h ; a
 crlf    equ 0115h ; a
 delay   equ 0118h ; a
 display  equ 011bh ; a
 getbyt  equ 011eh ; a, b
 getchr  equ 0121h ; a
 getchrx  equ 0124h ; a
 init    equ 0127h
 inkey   equ 012ah ; a
 mdelay   equ 012dh ; a
os_return equ 0130h
 percent  equ 0133h ; a
print   equ 0136h ; a, dptr
 prsphx   equ 0139h ; a, r2
 prtstr   equ 013ch ; a
 prthex   equ 013fh ; a, r2
sdelay   equ 0142h ; a
 setintvec equ 0145h ; a, dptr
 sndchr   equ 0148h ; a
; ---------------------------------
----
   org 8000h
   lcall print
   db "press any key to begin...", 0
   lcall crlf
   lcall getchr
   mov  ip0, #0
   mov  ip1, #0
   lcall initadc       ; initialize adc
   lcall print
   db "initialization done", 0
   lcall crlf
   setb  eal
loop:
    lcall shwadc
    mov  a, #10h
    lcall delay
    lcall inkey
    cjne  a, #3, loop
    clr  eal
    ljmp  os_return
;
==========================
==
; subroutine shwadc
; ---------------------------------
----
shwadc:
   push  acc
   push 1
   mov  r1, #0c0h ; analog 0
shw1:
   mov  a, @r1
   lcall prsphx
   inc  r1
   cjne  r1, #0c8h, shw1
   lcall crlf
   pop  1
   pop  acc
   ret
;
==========================
==
; subroutine initadc - initialize adc
; input   : none
; output  : initializes adc interrupt
;                   to continuously read
analog values
; destroys : a, dptr
; ---------------------------------
----
initadc:
      clr   eadc           ; disable adc
interrupts
      clr   iadc            ; reset adc
interrupt flag
      mov  a, #6      ; sixth interrupt
source
      mov dptr, #adcisr ; setup
interrupt vector
      lcall setintvec
setb  eadc        ; adc interrupt mask
bit
mov   a, adcon    ; read adc control
register
    anl    a, #0d0h        ;  select
channel 0, single shot
     mov  adcon, a
     mov     dapr,  #0        ;  start
conversion
     ret;
==========================
==
; subroutine adcisr
; input   : adc interrupt
; output  : continuously obtains and
stores analogue
;             values in [c0-c7] of internal
Ram.
;            internal Ram d3 stores the
analog channel
;           being converted
; destroys : nothing - uses a, r0, and
r1
; ---------------------------------
----
adcisr:
   push  psw
   mov   psw, 0         ; select register
bank 0
   push  acc
   push  0
   push  1
;   mov   a, #'+'
;   lcall sndchr
   mov  r0, #channel
   mov  a,  @r0     ; recall channel
   add    a,   #analog0  ; compute
channel store address
   mov  r0, a
   mov   a,   addat     ; read analog
value
   mov   @r0, a         ; store analog
value
   mov  r1, #channel
   mov  a,  @r1     ; recall channel
   inc  a
   anl  a,  #7      ; next channel
   mov  @r1, a
   mov   a, adcon        ; adc control
register
   anl  a, #0d0h
   orl  a, @r1
   mov   adcon, a        ; select next
channel
   clr   iadc              ; reset adc
interrupt flag
   mov   dapr, #0         ; start next
conversion
   pop  1
   pop  0
   pop  acc
   pop  psw
   reti;
==========================
==
; end of program
```

and k is the dielectric constant of the electret. Thus, taking into account Eqs. (1) and (2), it is possible to calculate the theoretical equivalent surface charge to be induced on the charge collecting device, given by

$$Q = q_{el} + \frac{2\pi\varepsilon_0 l}{\ln(r_3/r)} + \frac{1}{\ln(r_2/r)}\left\{kq_{el}\ln\left(\frac{r_2}{r}\right) + \frac{kq_{el}2\pi\varepsilon_0 l}{C_{el}}\left[1 + \frac{\ln(r/r_2)}{\ln(r_3/r)}\right]\right\}, \quad (3)$$

where q_{el} and C_{el} are, respectively, the measured value of the charge on the electrometer and the value of the capacitance on the electrometer circuit's feedback loop.

A total surface charge of 10^{-9} C and a readout sensitivity of 10^{-5} Gy with a useful range up to 5×10^{-2} Gy were reached. The readout method involves removing a cap attached to the electrometer circuit from the ionization cylindrical readout electrode. The charge or voltage there induced was proportional to the uncompensated charge on the electret.

Fig. 4 compares measurements obtained by using the SMRD system and a Keithley 616 digital electrometer. For this experiment an electret dosimeter was exposed to a ^{241}Am γ-ray source. Considering the errors given in Fig. 4, the equivalent charge of the electret dosimeter obtained by the SMRD seems to correlate well with that obtained by the Keithley 616 digital electrometer, i.e., $y = 0.22 + 0.93x$ with a coefficient of linear correlation $r^2 = 0.98$. Table 1 shows a basic A/D converter and readout electrometer task routine. This intelligent system stands out by allowing connections of up to eight electrometers or more if an analog multiplexed circuit is added to the architecture.

3. Conclusions

The versatility obtained with the use of intelligent instrumentation has shown several advantages in applications for instrumentation and automatic control, as well as in applications hazardous to operators. Therefore, in intelligent process control communication is much more powerful than that offered by unidirectional transfer of analog data to a remote host computer. Furthermore, results show the reliability of the system with simple hardware implementation for radiation dosimetry. Moreover, the concept uses only one single-chip low-cost microcontroller and has a wide field of applications, e.g., in hospitals, research laboratories, and nuclear centers for dosimetry.

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