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A MICROPROCESSOR CONTROLLED, PERSONNEL THERMOLUMINESCENCE DOSIMETRY READER

Gerald F. Hunt

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A MICROPROCESSOR CONTROLLED, PERSONNEL THERMOLUMINESCENCE DOSIMETRY READER*

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Abstract

Using a DEC LSI-11^{**} microprocessor, we have developed a thermoluminescence dosimetry reader for personnel dosimetry. This microprocessor provides system control, accumulates data for temporary storage on a cassette, and later outputs the data to a large computer. The

microprocessor also provides a human/system interface through a computer terminal. A programmable high-voltage supply and a light-emitting diode are used in the reader system to automatically control photomultiplier tube gain.

Introduction

The thermoluminescence dosimetry (TLD) reader removes the TLD from an individual's TLD packet, heats the crystal, records the amount of light it gives off, and then reads and records the individual's identification (ID) number, which is encoded in the packet. It also records the type of TLD used, the date, and the time that has elapsed since the individual's TLD was last read. If a reading is over a preset limit, a "glow curve" that has been temporarily stored in a waveform recorder will be plotted on a strip-chart recorder.

This glow curve is a plot of the crystal's light output versus time as the crystal is heated, and is of interest in proving the validity of the read. At fixed intervals, a light source in the reading chamber is turned on; then system calibration is checked and adjusted if necessary.

Figure 1 is a block diagram of the TLD reader system, and Fig. 2 is a photograph of the actual system. The TLD packet is shown in Fig. 3.

Fig. 1. Block diagram of TLD reader system.

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[†] Lawrence Livermore Laboratory, University of California, P. O. Box 5505, Livermore, California 94550.

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Fig. 2. TLD reader system.

The sequence of events during a normal read is as follows:

1. A tube loads the packet onto a rotating table. If the packet is not loaded, the system enters a calibration cycle while the operator changes the tube.
2. The table rotates to the first station, where a mylar cap is pulled off the packet, exposing the TLD crystal.
3. At the second station, the crystal is cleaned to reduce the amount of dust or mylar silvers, which flash when heated.
4. The third station is the reading station. Here a

Fig. 3. TLD packet encoded with ID number, showing the TLD crystal and the crystal cap.

needle picks up the crystal with a vacuum. Then it is pulled up into a stream of heated nitrogen, and a photomultiplier (PM) tube observes the crystal as it luminesces. Two shutters associated with the PM tube are synchronized to prevent ambient light from reaching the PM tube.

5. At the next station, the encoded ID number is read. A light source illuminates the packet, which is positioned over phototransistors, to detect the presence of a hole. If the system is not able to read the ID number, the packet is rotated to an inspection station where an operator repairs the problem (cleans the holes in the packet). Then the operator types in the ID number or the system attempts to reread it.

6. After the system has read the ID number, the packet is offloaded into the discharge tube, and the cycle is restarted.

TLD Reading Electronics

The total light the crystal gives off during heating is measured to determine how much radiation the crystal has been exposed to since annealing. This light is measured by positioning the TLD crystal at one of two focal points in an elliptical chamber and by positioning the face of the PM tube at the other focal point. The crystal is then heated to 240°C, and the PM tube yields a current output that is proportional to the light given off by the crystal.

Current from the PM tube is monitored by a low-level current-to-frequency converter¹ (Figs. 4 and 5). This converter is a recycling integrator that detects low-level currents from 10^{-12} to 6×10^{-5} A without changing range. A hybrid design (linear and digital circuitry), the converter uses a high-speed, low-input-current FET operational amplifier with a 51-pF feedback capacitor for integration. When current output reaches 200 mV, a comparator triggers the reset circuitry, and the integration capacitor discharges. The entire reset circuit is small and is mounted on the socket of the PM tube to take advantage of the constant temperature and short lead lengths. If a reading is high enough to exceed the range of the current-to-frequency converter, then one of two or both neutral-density filters may be moved into place. These filters attenuate the light received by the PM tube by 10:1, 100:1, or 1000:1.

The PM tube used in the system has a nominal diameter of 50 mm, a bialkali (SbKCs) photocathode, and 13 venetian-blind dynodes. Its spectral response of 285 to 650 nm covers the thermoluminescence spectrum of the TLD crystal used (LiF, TLD 100 and 700) emission spectrum of 350-600 nm. The PM tube is cooled to 30±1°C by a thermoelectric refrigerated chamber. This chamber also shields the PM tube from rf interference, reducing dark current to a low, stable value that can be "bucked out" in the current-to-frequency converter. The effects of exterior magnetic fields are reduced by shielding,

Fig. 4. Block diagram of current-to-frequency converter.

and PM tube fatigue is minimized by limiting the normal maximum anode current to less than 1 μA and the normal anode-to-cathode voltage to less than 1100 V. Long-term gain stability of less than 1% has been achieved.

The pulse train from the current-to-frequency converter drives a timer scaler and a rate meter. The timer scaler is used both as a scaler and a visual display.

The microprocessor gates the scaler on for a 13-s interval, during which time the waveform recorder records the analog output of the rate meter. At the end of the reading period, the scaler data are transferred to the microprocessor where they are tested to see if they indicate LO, GO, or HI condition. A LO condition causes the system to pause while the operator checks to see if the crystal was picked up. The GO condition

Fig. 5. Circuit diagram of current-to-frequency converter.

indicates normal operation and that the data will be recorded. A HI condition indicates a higher than background dose of radiation, and the glow curve stored in the waveform recorder is plotted on a strip-chart recorder for further analysis.

After the read is completed, the microprocessor outputs the data to a terminal for printing and storage on a

cassette. At some time later, the microprocessor will read the cassette, and the data will be transferred to the Laboratory's central computer system (Octopus) to calculate exposure and update the records.

Calibration and Control

Calibration is maintained by reading TLD crystals with known exposures monthly and by using the data for reference during each month's readings. System gain is held constant by automatically entering a calibration mode every time the packet-supply tube is emptied, which occurs every 65 readings. A light-emitting diode (LED) driven by a constant-current source (Fig. 6) is illuminated. Because it is temperature-sensitive, the LED is mounted next to the PM tube to take advantage of the constant temperature and is directed away from the PM tube to measure the chamber's reflectivity. The microprocessor gates the scaler on for a fixed interval of time and checks the number of counts accumulated. If the results indicate the system gain has shifted, the microprocessor adjusts the gain by varying the high voltage of the PM tube. This is accomplished by a digital-to-analog converter that drives a programmable high-voltage power supply. The high-voltage control circuit is shown in Fig. 7.

The control panel has an Automatic/Manual switch, a Finger Ring switch, and three switches that control the shutters and the crystal pick-up needle. It also has indicators for calibration cycle, reading limit, nitrogen temperature limit, shutter status, and employee number readout. The reading-limit and nitrogen-temperature indicators have an accompanying audio alarm. An oscilloscope above the scaler monitors the output of the current-to-frequency converter. By observing its signal, one can detect some system malfunctions. The control panel, scaler, and oscilloscope appear in Fig. 8.

Most system control is provided for through software. The program is written in Assembly Language, is 4000 words in length, and is divided into two major routines. One routine controls the system in Automatic mode; the other provides control in Manual mode. When in Automatic mode, the system follows the sequence outlined in the "Introduction" of this paper. Automatic mode will not be terminated until the current operation is complete.

There are 13 subroutines available in Manual mode. Some are designed to allow the operator to change parameters used in the reading operation, while others are diagnostic routines for checking system performance or for exercising the system for maintenance. One subroutine communicates with the Octopus computer system to output collected data.

When the system is switched back to Automatic mode, the operator may either return the table to the station it occupied when the system was switched to Manual mode or restart the program, in which case the table will be automatically rotated to its starting position.

During operation, several checks are made to ensure that the system is functioning properly. If a malfunction is detected, a message describing the malfunction is printed, and the system waits for operator action before continuing. Malfunctions may include the system's failure to rotate to the first

Fig. 6. Constant-current source for calibration LED.

The following information was obtained from the above mentioned source:

1. The equipment is a radio receiver and transmitter.

2. It is capable of receiving and transmitting signals in the VHF and UHF bands.

3. The equipment is used for communication between the ground and the aircraft.

4. It is a portable unit and can be used in a variety of environments.

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