IMPROVED VERSION OF THE DUAL-CHANNEL SYSTEM TO MEASURE BONE MINERAL CONTENT

By

R. M. Witt, C. E. Vought and R. B. Mazess
Department of Radiology
University of Wisconsin Medical Center
Madison, Wisconsin

1102

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Certain modifications and improvements have been made on the breadboard two-channel system described in last year's report (1). The charge amplifier has been redesigned and various other changes have been made to decrease the deadtime of the complete system. The entire breadboard has been made compatible with existing equipment. A 60-Hz timer was constructed with a preset count mode so that the system could function as nuclear pulse counting device in our laboratory. The dual-channel system is now composed of the following components: an amplifier; two single-channel analyzers; two five-decade scalars; two six-decade data buffers; two address control boards; two five-decade visual numeric displays; a one decade preset 60-Hz timer; and associated control switches, potentiometers, and connectors.

Charge Amplifier

A new charge amplifier which is composed of discrete components was constructed with an FET input to handle the capacitive load of the detector cable. The output pulse has a 200 nsec risetime and a 20 μ sec decay time constant.

Pulse Shaping Network

The input circuit to the pulse shaping stage was changed to provide a "zero" to cancel the 20 μ sec "pole" response of the charge loop. The capacitor coupling the pulse shaping stage and the linear amplifier stage was decreased providing a second differentiation of the CR-RC shaped pulse. The second differentiation creates a bipolar pulse and eliminates the baseline shift which occurred at high count rates ($>10^4$). The bipolar pulse has a total length of 6 μ s and a crossover point at about 1.5 μ s.

Single Channel Analyzer-Comparator Logic Dead Time

The comparator logic sequence remains the same, but the time constants of the monostable vibrators in the comparator logic circuit have been decreased to more rapidly process the shorter amplifier pulse. The new processing time of the system is 3.8 μ s. The measured processing time of the entire detector-to-analyzer system is 5 μ s. The comparator logic circuit is a paralyzable type so that the dead time can be corrected with an analytic function at excessive count rates. With a processing time of 5 μ s the system can count at 10 kHz with 5% count loss.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

phd

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Scaler Displays

Two five-decade numeric digital displays which are TTL logic compatible were added to the scaler outputs. These displays consist of a decoder/driver IC and a 4 x 7 dot array of light emitting diodes (LED) (Hewlett-Packard Series 5082-7300).

Compatibility of Scaler Control and Buffered Output

Our present digital acquisition system is composed entirely of commercial components all built to nuclear instrument module, NIM, standards (2). The data collection and output components consist of a digital magnetic tape interface (NE-25)*, and two addressable, buffered scalers (NS-30A)*. Both the data buffers and the addressing controls are contained on separate printed circuits, P.C., boards. To make the scaler control logic and the scaler outputs compatible with the existing data acquisition system two address control boards and two buffer boards were purchased and connected to the two scalers of the dual-channel system.

Data Buffer Boards

The data buffer boards are compatible with the TTL logic of 7400 series scalers used in the dual-channel system and contain 24 bits of storage which is enough for six decades of BCD data.

Address Control Board

The address control board contains an address coder programmable from 0 to 99, the run flip-flop (Q and $\bar{Q}$) to start and stop the scalers, and various control gates to operate the data buffers and reset the scalers. The control signals (START, STOP, and RESET) to operate the address control can be generated either locally by push buttons on the dual-channel system or by remotely by the interface device. To control all the scalers simultaneously an ADDRESS OVERRIDE, AO, signal must also be generated and sent to each address control board.

Magnetic Tape Interface Device

The magnetic tape interface device provides the necessary control signals to the address control boards to simultaneously control all scalers, and the necessary control circuitry to write the contents of the scaler buffers serially onto digital magnetic tape. The interface only writes data from components which respond to the proper addressing codes.

Both the address control board and the interface require a PRESET STOP signal which indicates the termination of a fixed time interval or the accumulation of a fixed number of counts. Upon receiving a PRESET STOP signal, the address control board stops the scalers and allows their contents to transfer to the data buffers and the interface device records all scaler buffers which respond to the addressing commands.

* Harshaw Chemical Company, Inc.

MASTER

Timer

A 60-Hz timer was designed and built to provide an elapsed time counter and a PRESET STOP signal for the Address Control board and interface. Two versions of the timer were designed, Figures 4a and 4b. For the version used in the dual-channel system the timer flip-flop is controlled by the Address Control board run flip-flop and the PRESET STOP signal is sent out via the local control signal output connector. In the second version the timer flip-flop is directly controlled by push buttons and the PRESET STOP signal is directly returned to the flip-flop to automatically clear all dividers and counters at the end of each time period.

For both versions the time base is supplied by a regenerative switch which converts the 60-Hz power-line sine waveform directly into a fast fall-time clock pulse followed by a $\div 6$ counter to give a time base of 100 millisecond pulses. The 10 pps signal is then divided by 10 and 100. The Timer Mode Switch can select which divider output pulse is sent to the decade counter. Thus the time base can be scaled by 1, 10 or 100.

The counter is a one decade BCD counter whose output is compared with the output of a one decade BCD thumbwheel switch. When the counter is the same as the thumbwheel switch setting, a PRESET STOP signal is sent out. When the timer is controlled by the Address Control board, it has the feature that it can be stopped and put into "Hold" and then restarted without affecting the elapsed time.

All dividers and counters are set to zero by the RESET signal from the timer flip-flop. However, since the start signal is not synchronized with the 60-Hz time base, each Start-Stop cycle has an error of one clock cycle or 16 millisecond with the 60-Hz timer.

Packaging of the Breadboard

Since the dual-channel system has been designed to be compatible with other devices which are built to Nuclear Instrument Module (NIM) standards, the breadboard unit was also mounted in a standard NIM module. All components composing the improved dual-channel system fit into a standard three-width NIM module, Figures 1, 2. All important controls and connectors, and scaler displays are located on the front panel, Figure 3. The dimensions of the unit are 102.9 mm wide x 207.7 mm high, and 248.8 mm deep. The complete unit weighs 2.27 kg.

Control Configurations

The dual-channel system has been designed to provide flexible control and all connectors are compatible with our existing NIM digital acquisition system. The unit has three front panel push buttons: Start, Stop, and Reset. Each push button provides a +5 volt pulse along with a +5 volt ADDRESS OVERRIDE signal. These local control

signals along with the PRESET STOP signal from the internal timer are available at an output connector on the rear of the module. Another rear connector serves as an input for these same control signals. A third 50-pin connector provides parallel connections between the different NIM modules for the data, address and control signals. Depending on the interconnections, the unit can be controlled locally or remotely.

Local Control

If a cable is connected between the local control signal output and input connectors, the dual-channel system can be controlled by its front panel push buttons and its internal 60-Hz preset timer. If the unit is connected to a compatible scaler via the 50-pin connectors, it can provide parallel control of these devices with the front panel push buttons and the internal timer.

Remote Control Mode

If the dual-channel system is connected to a compatible interface device via the 50-pin connector, the unit can be remotely controlled by the interface in both its automatic and manual modes. When controlled by the interface, the contents of the buffered scalers can be written onto digital magnetic tape. In the above configuration the push buttons on the dual-channel system and the interface are connected in parallel. To avoid erroneous control signals all operations should be initiated by the interface controls. If a compatible remote timer with a preset stop signal is connected to the dual-channel system via the local signal input connector, the system can be controlled by the interface, but with the external timer providing the timer base to the scalers.

Conclusion

In addition to serving as a prototype for the inflight electronics package for bone mineral determinations, the dual-channel system in its present configuration can be used with our present digital acquisition system. The dual-channel system is suitable for both the single photon and the two photon techniques of determining bone mineral content, BMC (3,4). Since the unit is more compact than our present system, it would be more suitable as a portable field unit for making preflight, postflight, and other ground base measurements of BMC where a digital system is required.

References

1. Sitzman, J.C., Vought, C.E. and Mazess, R.B., Preliminary Report on a Dual Photon Bone Mineral Measuring Instrument, USAEC Report C00-1422-98 (1971).
2. Judy, P.F., Ort, M.G., Kianian, K. and Mazess, R.B., Developments in the Dichromatic Attenuation Technique for the Determination of Bone Mineral Content In Vivo, USAEC Report C00-1422-97 (1971).
3. Judy, P.F. and Cameron, J.R., A Dichromatic Method for the Measurement of Bone Mineral Content, USAEC Report C00-1422-60 (1969).
4. Cameron, J.R. and Sorenson, J.A., Measurement of Bone Mineral In Vivo; An Improved Method, Science 142: 230-232 (1963).

Figure 3. Front panel of dual channel system describing the various controls. The system which is mounted in a three width Nuclear Instrumentation Module contains a 60 Hz timer, two single channel analyzers, two buffered scalers, and two addressable control boards. The scaler buffers and addressed control boards are compatible with a commercial digital magnetic tape interface device.¹

¹ Harshaw Model NE-25.

Figure 1. Front view of the dual channel system illustrating the positions of the controls necessary to operate the unit after the breadboards were mounted in a three width Nuclear Instrumentation Module.

Figure 2. Side view of the dual channel system illustrating the placement of the breadboards into a three width Nuclear Instrumentation Module.

60 ~ TIMER, REMOTE CONTROL

Figure 4a. Schematic of 60-Hz timer with Start-Stop flip-flop controlled by remote signals from the Address Control Board.

60~TIMER, INTERNAL CONTROL

Figure 4b. Schematic of 60-Hz timer with Start-Stop flip-flop controlled by push buttons.

COMPARISON OF COMPACT SCINTILLATION DETECTORS
FOR BONE MINERAL CONTENT MEASUREMENTS

by

R. M. Witt and R. B. Mazess
Department of Radiology - Cosmic Medicine Laboratory
University of Wisconsin Medical Center
Madison, Wisconsin 53706

It appears that the best detector for counting the transmitted photons in the absorptiometric determination of bone mineral content (BMC) remains a thallium-activated sodium iodide, NaI(Tl), scintillation crystal optically coupled to a photomultiplier tube (PMT). A PMT suitable for the detector to be used with the bone scanner for space flight should be compact to minimize its volume and mass, and it should be a ruggedized type meeting the necessary shock, vibration and acceleration specifications. To serve as part of a low energy (30 keV to 60 keV) scintillation photon detector, the tube should have high current gain ($\times 10^6$) and a low anode dark current ($\sim 10^{-10}$ amperes) at the specified operating voltage and temperature.

In addition the tube should have only a small "hysteresis" instability in the anode current and a small change in the anode sensitivity after the light and the high voltage are applied. The gain should be stable ($< 1\%$ change) with time and for order of magnitude changes in the count rate. The photocathode material should have a high quantum efficiency and the spectral response should be matched to the emission spectrum of NaI(Tl) scintillator which peaks at about 410 nanometers.

The specifications for two small PMT's suitable of space flight were compared to determine if they were suitable for the new compact inflight bone mineral scanner, Table 1. Both PMT's are developmental models. Of the two tubes compared in this report, tube B appears to have the best current gain and dark current specifications while still retaining the need to be small and compact. The prototype scanner, described in another report¹, was designed to use this tube as the scintillation detector.

Reference

1. R. B. Mazess and Y. Towliati, A Compact Scanner for Measurement of Bone Mineral, USAEC Report, COO-1422-120, (1972)

TABLE 1. COMPARISON OF TWO DEVELOPMENTAL PHOTOMULTIPLIER TUBES SUITABLE FOR SPACE FLIGHT

	TUBE A C31016B			TUBE B 11J412			
	<u>MIN</u>	<u>TYPICAL</u>	<u>MAX</u>	<u>MIN</u>	<u>TYPICAL</u>	<u>MAX</u>	<u>UNITS</u>
ELECTRICAL SPECIFICATIONS:							
Cathode Sensitivity							
Luminous	47x10 ⁻⁶	67x10 ⁻⁶			70x10 ⁻⁶		A/lm
Radiant		.079 ¹		.058 ²	.070 ²		A/W
Quantum Efficiency		24 ¹		17.5 ²	21 ²		%
Current Amplification		1.9x10 ⁵			10 ⁵ at 1700V		
					10 ⁶ at 2400V		
Anode Dark Current		5x10 ⁻¹⁰	1x10 ⁻⁹		2.5x10 ⁻¹¹	1.0x10 ⁻¹⁰	A
Operating Voltage, anode to cathode			1500			3500	V
Operating Current			20			100	μA
MECHANICAL SPECIFICATIONS:							
Maximum Length		4.7			9.3 Potted		cm
Maximum Diameter		2.67			3.18 Potted		cm
Maximum Cathode Diameter		1.90			2.48		cm
Cathode Type		CsKSb			CsKSb		
Window Material		Corning #7056			Corning #7056		
Number of Dynodes		10			12		
ENVIRONMENTAL STRESS:							
Temperature		-100 to +85			-80 to +150		°C
Shock		75± 7g's, 11 ± 1msec			150g, 6msec		
Vibration		20.7g(rms) 50 to 2000Hz			30g, 20 to 2000Hz		

Notes: 1. at 400 nm
2. at 410nm