A Test System for a Miniature Neutron Detector

Jerry D. Balls and John L. Bowers
The Bendix Corporation
Kansas City Division

Summary. A flexible automated test system for calibrating and testing a miniature neutron detector, used in telemetry systems, is described. The test system is cost effective, easily calibrated and maintained, and was available for use 6 months after design initiation.

Introduction. Small neutron detectors are used in telemetry systems to determine neutron pulse characteristics and to supply this information in a form that can be telemetered.

Previous test methods involved manual integration of oscilloscope photographs and laborious mathematical calculations to calibrate these miniature neutron detectors. Several techniques are outlined that have been used in the past as well as the most recent method which is implemented by the subject test system.

The function of the miniature neutron detector is shown in sufficient detail to provide understanding of the test system design and operation. The hardware is organized to utilize the CAMAC (IEEE) 583 interface standard. The CAMAC system was chosen because of the high speed digitizing capability not commercially available in other systems and the significant long term savings that can be realized as a result of standard hardware package design and standard interface specifications.

Neutron Detector. The miniature neutron detector has been designed to verify the correct operation of a pulsed 14-MeV neutron generator.[1] The detector (Figure 1) is assembled from the following components:

- A plastic scintillator (fluor) converts neutron energy to light.
- An optical detector collects the light and converts it into an amplified electrical analog signal.
- A power supply and electronic signal-conditioning circuitry produce an output when a neutron level exceeds a prescribed value.

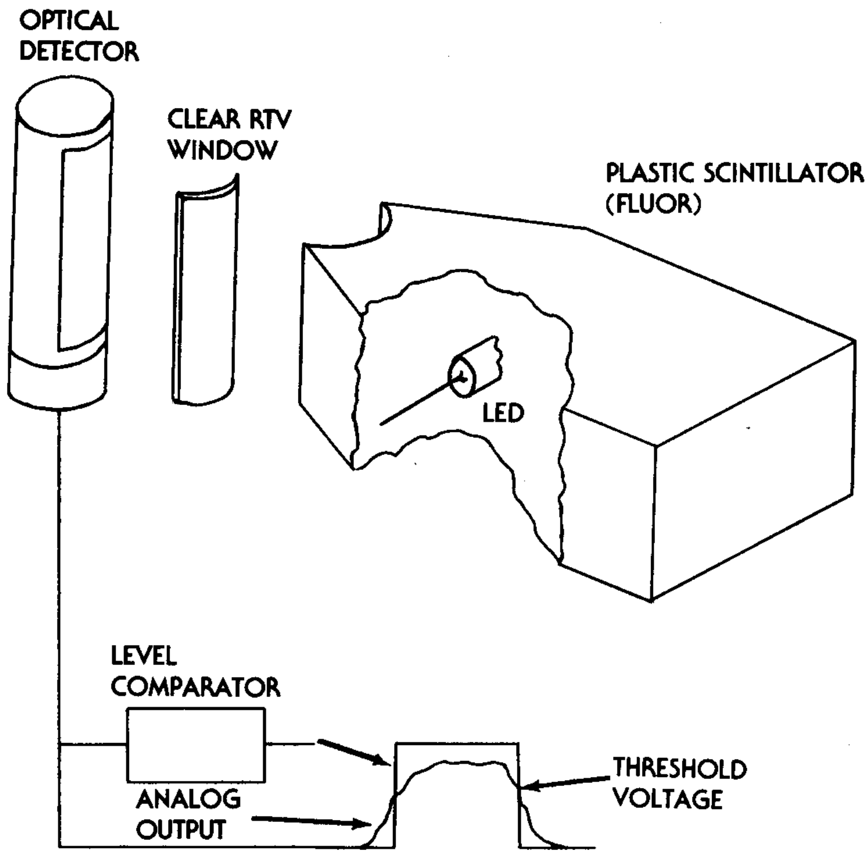

Figure 1. Miniature Neutron Detector

- A light-emitting diode, mounted in the scintillator, provides a means of simulating the light generated by a neutron burst and allows the detector to be independently tested (self checked) for correct operation.

The analog output (Figure 2) is generated by a neutron flux striking the fluor and generating light detected by the photomultiplier tube. The gain of the photomultiplier tube and the threshold voltage of the comparator can then be adjusted to produce a digital output when a predetermined neutron flux is present. Calibration techniques involve comparing the response of the neutron detector to the response of a larger (16 times fluor volume) standard neutron detector (lead probe) and adjusting the neutron detector for the desired output. The three techniques (Figure 3) used to determine the correct output of the neutron detector are neutron detector analog and lead probe analog pulse peak comparison; neutron detector analog and lead probe analog pulse integral comparison; and neutron detector digital pulse and lead probe analog pulse comparison.

Test System. The size and complexity of the system hardware was limited to two instrument bays (Figure 4) to keep the test system flexible with respect to the configuration and mission. In addition, the test system could not be complex or involve equipment that was designed and fabricated from scratch in order to meet the operational date.

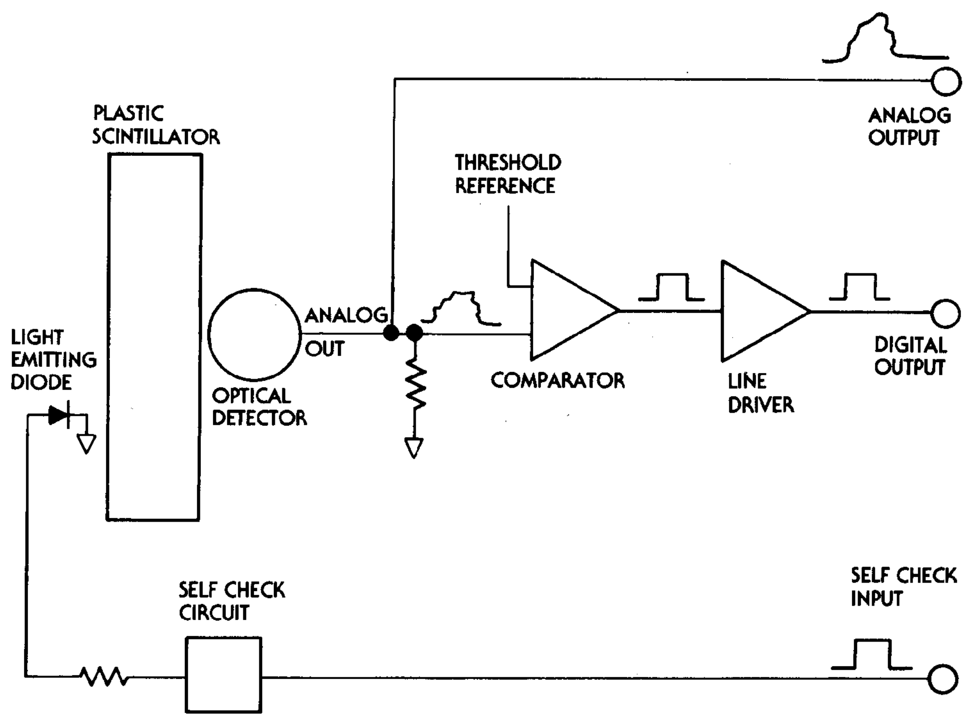

Figure 2. Diagram of Neutron Detector

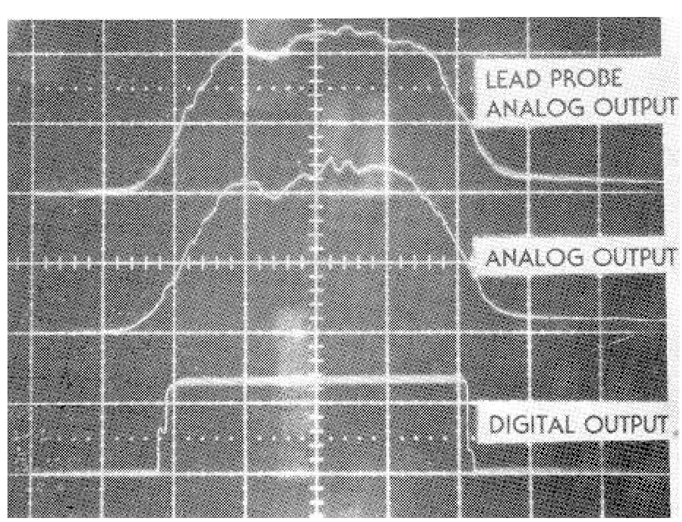

Figure 3. Oscilloscope Display of Output From Neutron Detectors

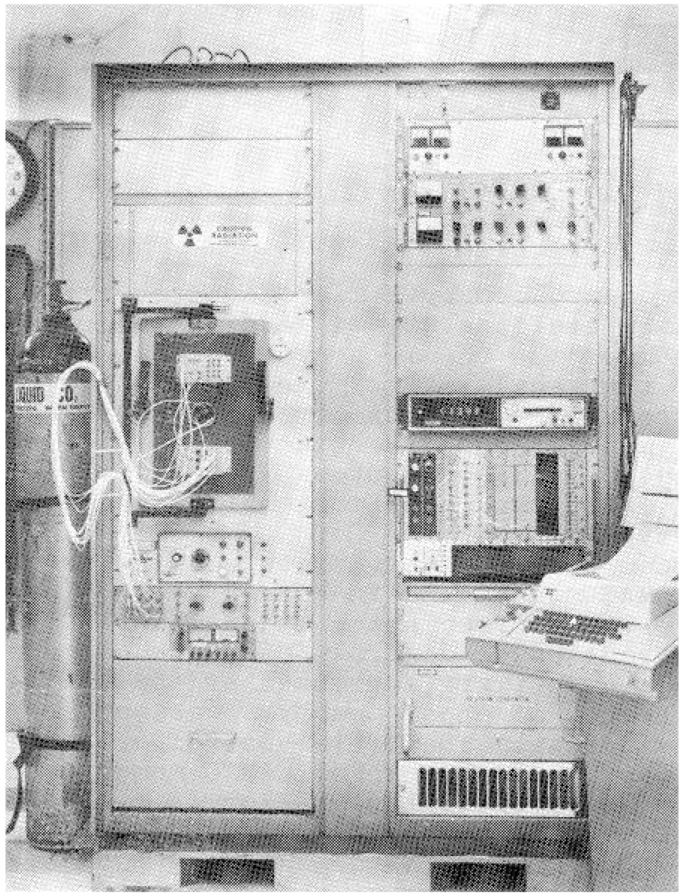

Figure 4. Instrument Bays

The test system was made more efficient by controlling it with an Intel 8080 microprocessor used in a Computer Automated Measurement and Control (CAMAC), IEEE 583, standard crate. The CAMAC crate is controlled by a microcomputer crate control module located in stations 23, 24, and 25 (Figure 5). The crate also accommodates the lead probe counts system (amplifier, discriminator, time/scalers) and the transient digitizers used for waveform storage. The microcomputer controller accesses the instrument modules contained in the crate (timer/scalers and digitizers) and performs automatic data retrieval and analysis. The output and operator control is performed through an ASR 33 teletype.

The microcomputer-operated crate controller is a three-station-wide CAMAC module and is connected to a one-station-wide memory module. The microcomputer is an Intel 8080 with teletype interface and front panel control interface contained in the module. Crate stations are addressed by the use of an “F” code register and the use of upper memory locations for the station number and sub-address. The crate controller contains an 8K memory and is expandable by use of CAMAC memory modules.

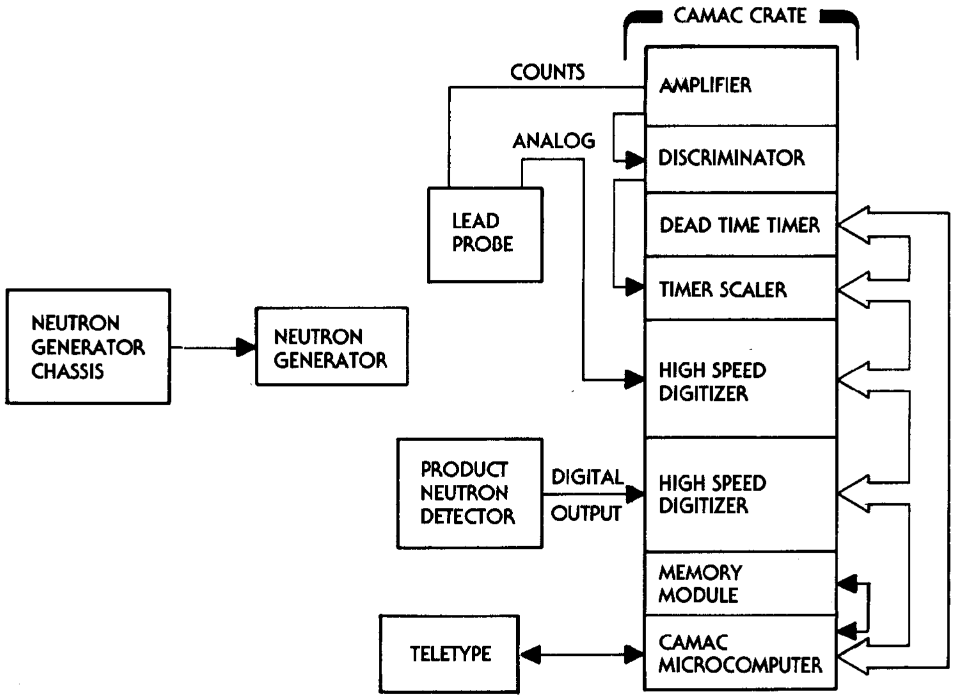

Figure 5. Block Diagram of Test System

The high speed transient digitizer is a three-station-wide CAMAC module that accepts a 0 to 2.5 volt input signal into 50 ohms. The input voltage is digitized into a six bit word and sampled every 25 nanoseconds. The result is stored in the digitizer's 1K word memory. Digitizing action is initiated by the application of a start pulse on the front panel after an enabled digitizing command is applied through the dataway. The contents of the digitizer are read by applying an initialized memory command, then a read command through the dataway. On each successive read command, the digitizer memory is incremented. More than one digitizer may be connected in either series or parallel recording modes.

A prototype module is used in this system to generate and synchronize pulses required to start the timer/scaler and digitizer and to fire the neutron generator. The prototype module is a "breadboard" CAMAC module that can be wired to serve a specific task. It is comprised of IC sockets with wire wrap capability and interconnects to the dataway for addressing.

The timer/scaler is a one-station-wide CAMAC module that may function as either a timer, counter, or both. The timer is programmed to a preset time interval through the dataway and is started by either application of a start pulse to the front panel or by a dataway command. During the timing interval, the scaler performs its counting function and the counts value is read through the dataway.

<u>Test System Operation</u>. Calibration of the lead probe (Figure 5) is established using a barium 133 transfer standard and is checked using the counts section (amplifier, discriminator, and timer scalers), of the lead probe, and the calibration software for the microcomputer. The test system operates by starting one of the timer-scalers and counting pulses from the lead probe for 2.376 seconds. This is done 20 times to allow for fluctuations in background radiation readings. The average is used for the background count. The barium is installed in the lead probe and the same procedure is followed taking 20 readings and averaging them. Then, the adjusted barium count is calculated by subtracting the background count from the barium count.

The gain of the photomultiplier tube in the lead probe is varied until the counts (adjusted for background radiation) from the lead probe are equal to the calculated output of the barium 133 for that date (based on the radioactive half-life and decay of barium 133). After calibration of the lead probe, all test results involving neutrons are based on the counts from the lead probe which are proportional to the total neutrons in a pulse. The self check is then run by using one digitizer to record an input pulse to the unit and the other digitizer to record the output pulse from the neutron detector. The input and output pulse widths are then calculated as well as the propagation delay in 25 nanosecond increments. By using the digitizers in the parallel recording mode, they are synchronized so that readings correspond in time between the two digitizers.

Following self check tests, one of the digitizers is disconnected from the self check input pulse and connected to the prompt pulse from the lead probe. The functional tests are accomplished by starting one of the timer/scalers, the two digitizers, and simultaneously pulsing the neutron generator from the prototype module. The microcomputer then looks at the timer/scaler to determine when it has timed out (24 milliseconds). After the first timer/scale has timed out, the microcomputer then turns on the second timer/scaler for 2.376 seconds to count pulses from the lead probe. Upon completion of a shot, there are the counts from the lead probe, the digitized wave-from of the prompt pulse from the lead probe, and the digitized output pulse from the neutron detector to be used for calculating the unit sensitivity. By using the counts, the sensitivity factors of the lead probe, and the integral of the prompt pulse, a neutron flux rate can be determined at any point in time by the corresponding value of the prompt pulse. Therefore, by calculating the value for the neutron flux rate when the digital pulse from the product changed state, the sensitivity of the product can be determined. This is repeated 30 times in order to reduce the error encountered by using a small area fluor. The average, variance, and standard deviation are then calculated. Other items such as pulse widths, peak values, and running average are also calculated for each of the 30 tests.

Test System Software. The software for the Intel 8080 based crate controller was generated by the use of an Intel PLM compiler. The PLM compiler generates the hexadecimal machine code for the Intel 8080 and outputs via a paper tape. The paper tape is then loaded through the teletype into the RAM memory in the CAMAC memory module. Then, the program is burned into PROM in the memory module utilizing a program supplied with the crate controller. The program presently in use occupies approximately 4K words of PROM and uses about 100 words of RAM for variable storage.

The program written in PLM language is segregated into procedures (subroutines) and these procedures are called in sequence to test the neutron detector. As an example, a module is addressed by an N, A, F sequence where N is the station number the module is occupying, and A and F are the sub-address and function code for the desired execution of that particular module. The function code is handled by an F code register (port 8 of the microcomputer). The N and A utilize the upper 512 words in memory that is defined as the 4 least significant bits being sub-address A, the next 5 bits are the station number N, and the 7 most significant bits are 1's. Addressing this location in memory decodes the N and A value on the dataway. To read a counts output of a timer/scaler in station 12, the sub-address and function code defined in the timer/scaler manual are A (1), F (0). To accomplish this, a 0 is output to port 8 and location 1111, 1110, 1100, 0001 is addressed in memory. The following PLM language procedure, called NAF, was created:

```
NAF; PROCEDURE (N, A, F);

DECLARE (N, A, F) BYTE;

DECLARE POINT ADDRESS;

DECLARE A1 BASED POINT BYTE;

DECLARE VAR BYTE;

OUTPUT (8) = F;

POINT = 64024+A+(N*16);

VAR = A1;

RETURN;

END NAF;.
```

When this procedure is called, the values of N, A, and F are passed in the procedure. As in the preceding example, the value of N, A, and F are 12, 1, and 0 respectively. To read the scaler, an instruction CALL NAF (12, 1, 0) allows the counts value to appear on data ports 0 and 1.

The entire program is made up of 25 such procedures of which some call on other procedures themselves. Revision and additions to the program are simplified by the use of procedures, and can be handled by either changing the contents of a procedure or changing the sequence by which the procedures are executed. Additional testing capability can be obtained by adding another sequence of procedure executions and the same software could then be used to test more than one type of product depending on where the program is initialized.

Conclusions. This work has demonstrated the feasibility of a recent technique to be used for neutron detector calibration. It is superior to past methods and techniques which took 20 times longer because of the use of microcomputer control and data analysis. The procedure eliminated operator subjectivity inherent in manual interpretation of oscilloscope photographs. In a production atmosphere, the ability of an automated test system to handle larger workloads with more consistent data reduction and analysis will improve the quality of the neutron detector production.

Reference.

1. W. R. Long, Miniature Detector Report SCL-DC-68-27, Sandia Corporation, Livermore, California. November 1968.

APPENDIX

CAMAC. The non-proprietary CAMAC (Computer Automated Measurement and Control) system standard (IEEE 583) defines modular units and the dataway which interconnects them. Dimensions are specified for the crates (module containers) and the plug-in modules which supply the various logic functions contained within the system. Also detailed are the interconnection arrangement, including sockets, and the interconnecting data highway (IEEE 595 and IEEE 596).

These standards permit mechanical and electrical compatibility between equipment supplied by different sources. The CAMAC standard was developed as a computer-controlled second generation of the nuclear instrumentation module (NIM) family. By utilizing the CAMAC standard in the design and construction of an instrumentation system, much of the unnecessary and routine detail of equipment redesign and modification can be alleviated by allowing the utilization of the equipment mainframe concept.

CAMAC was created to provide flexible instrumentation that can be reconfigured easily and not be dedicated to a specific task. The concept manifests itself by the fact that CAMAC systems can be easily adapted to different computers and controllers. This allows a CAMAC system to be updated to a new computer, if required, without the expense of massive and uneconomical interface redesign and construction. This flexibility is a requirement at all the major nuclear laboratories which utilize many different types of computers.

CAMAC is an international standard originated at the major European nuclear laboratories. The United States Atomic Energy Commission (now Energy Research and Development Administration) has reviewed and endorsed its use.

Many U.S. vendors are producing CAMAC instruments and hardware. These vendors manufacture everything from blank sheet metal (enclosures, components, and crates for modules) to complete instruments (programmable power supplies, pulse generators, attenuators, counters, and delay generators) meeting the CAMAC specification.

As a result of the incorporation of the CAMAC standard, an instrumentation system will remain flexible and adaptable for years with the capability of being modified and reconfigured with minimum cost to the user. This feature will allow a system to remain current and eliminate the usual plight of obsolescence associated with dedicated test equipment.

The use of CAMAC has been proposed to NASA by the Bendix Aerospace Systems Division for use on the space shuttle. Other companies are considering the use of CAMAC instrumentation in related process control and instrumentation applications.