TITLE: A MULTIPLE MICROPROCESSOR BASED NUCLEAR REACTOR POWER MONITOR

MASTER

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REACTOR POWER MONITOR

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by

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ABSTRACT

The reactor power monitor is a portable multiple-microprocessor controlled data acquisition device being built for the International Atomic Energy Association. Its function is to measure and record the hourly integrated operating thermal power level of a nuclear reactor for the purpose of detecting unannounced plutonium production. The monitor consists of a ^3He proportional neutron detector, a write-only cassette tape drive and control electronics based on two INTEL 8748 microprocessors. The reactor power monitor operates from house power supplied by the plant operator, but has eight hours of battery backup to cover power interruptions. Both the hourly power levels and any line power interruptions are recorded on tape and in memory. Intermediate dumps from the memory to a data terminal or strip chart recorder can be performed without interrupting data collection.

INTRODUCTION

The reactor power (RPM) is a portable low power data collection instrument being built for the International Atomic Energy Agency (IAEA). It will be used to measure and record the hourly integrated operating thermal power level of a nuclear reactor in order to detect unannounced plutonium production.

The monitor consists of a ^3He proportional neutron detector (1-in. diameter x 17-in. length, 4 atmospheres), control electronics based on two microprocessors (INTEL 8748) and a write-only cassette tape drive. The detector is shielded by cadmium and 1-1/4 inches of polyethylene to provide sensitivity only in the direction of the reactor. The instrument is packaged in a Zero aluminum suitcase that will be bolted to the biological shield so that nothing can be placed between it and the reactor.

The unit is powered from 120 Vac, 60 Hz line current provided by the plant operator. It also contains about eight hours of battery backup to cover power interruptions. All of the control electronics, with the exception of the two processors, are implemented in CMOS in order to obtain low power consumption. There is a possibility that a CMOS version of the 8748 will soon be available, reducing power consumption even more.

The hourly data are recorded as percent of rated reactor power in the range of 1% to 128% with a 1% resolution. Each power level is derived by counting the pulses from the neutron detector for an hour and dividing by a calibration constant (CALCNT)

$$\text{PERCENT POWER LEVEL} = \frac{\text{HOUR COUNT}}{\text{CALCNT}}$$

The calibration constant is calculated during the initial setup by counting for a set period of time (1/8 hour) and dividing by the current operating level of the reactor. (A parameter set in by the IAEA inspector.)

$$\text{CALCNT} = \frac{1/8 \text{ HOUR COUNT} \times 8}{\text{CURRENT POWER LEVEL}}$$

These data, along with a record of line power interruptions, are stored on cassette tape and in memory. The tape serves as the final nonvolatile output and is written onto at a rate of two lines per day. (Twelve hourly levels per line.) Storage in memory allows intermediate dumps of the accumulated data to a terminal or strip chart recorder without disturbing the data collection. Memory capacity is 128 days (3072 bytes).

OPERATION

A major goal in the design of this instrument was simplicity of installation and operation. A 10-s neutron counter and display is included to aid in initial placement. Using this, the IAEA inspector chooses an area along the biological shield and then bolts the case in place. After connecting power, he inserts a blank cassette and sets in the date, time, and operating level. The case is then locked and requires no further attention. After three months the inspector returns to retrieve the cassette. At this point he has the option of performing a terminal or strip chart dump, resetting the time, recalibrating the instrument, or just replacing the tape without disturbing the operation.

HARDWARE

A block diagram of the RPM hardware is shown in Fig. 1. It is based on two INTEL 8748 microprocessors. The main processor handles the majority of the instrument's functions and the tape processor acts as an intelligent tape controller. The two processors interface via an 8-bit data link and two control lines. The data lines are used to transmit bytes from the main processor to the tape processor, while the interrupt and acknowledge lines implement a handshaking protocol to control these transfers.

The main processor uses memory mapped I/O to communicate with its various peripherals over an 8-bit data bus. Attached to this bus is the front panel interface, a 3K memory, UART, D/A converter and an 8-bit counter. The front panel interface allows the processor to read front panel switches for time set, calibration, and function. Memory is used to store collected data for intermediate output via the UART and D/A converter. The counter is the lower 8 bits of the 24-bit neutron counter (the upper 16 bits are implemented in software).

The main processor is also interfaced to the 10-s counter/display, line power indicator, and the tape processor. The line power indicator allows it to determine the state of the ac power (present or absent). Updating of the 10-s counter and display is done by the main processor, allowing visual confirmation that the processor is operating. The interface to the tape processor allows the main processor to send data to the cassette tape asynchronously.

The tape processor controls a MEMODYNE write-only cassette tape drive. This drive consists of a stepper motor, drive mechanism, and tape head. The motor is driven by the processor as data are supplied to the head. A 256-byte memory is used to store the formatted ASCII data as a line is being written to the tape.

SOFTWARE

Figure 2 shows a basic a basic flow chart of the main processor software. On a reset it initializes itself and then runs into a background loop that monitors the user function switch and performs the indicated operation. These operations include setting of the real time clock, output of data to a terminal, and setup of calibration and strip chart output. The default function is monitoring the line power. When the power goes down or comes up, the information is sent, along with the date and time, to the tape processor to be written onto the cassette.

The second segment of software is the interrupt service routine. This runs every one-half second in response to a hardware generated 2-Hz interrupt. Real time is kept track of via a software clock update of one second every other interrupt. On this interrupt, data are sent to the D/A during a strip chart output, and calibration calculations are performed at the end of a calibration period.

At the end of each hour this routine reads the neutron counter, scales the data, and stores it in memory. On the end of the day it sends the day's data (24 levels) to the tape processor to be written onto the cassette.

The software for the tape processor is sketched out in Fig. 3. It contains three main segments. First is the external interrupt service routine that is run in response to an interrupt generated by the main processor. This tells the tape processor that there is data to be put onto the cassette. The data are read in and the type determined (a day's power levels or a line power change). This segment then indicates the type and presence of the data to the background segment.

The background segment is accessed via a reset. It initializes the processor and then runs into a loop, waiting for new data to be captured by the external interrupt segment. When new data becomes available, it is formatted into an ASCII output line and stored in the line memory. The timer is then enabled to start output to the cassette.

The final segment is run in response to a timer interrupt. This interrupt has the highest priority and can interrupt the other segments. It sends the output line, one bit at a time, to the recorder head while simultaneously stepping the motor. After sending a bit, the timer is reset for the next interrupt (unless the output is over). The value set into the timer determines the delay between timer interrupts and thereby regulates the output rate of the data to the cassette recorder.

SUMMARY

The reactor power monitor being developed for the IAEA is a portable, multiple microprocessor-based system designed to measure and record the hourly integrated operating power level of a nuclear reactor in order to detect unannounced plutonium production. Its main components are a ^3He neutron detector, write-only cassette tape drive, and control electronics based on two INTEL 8748 microprocessors. The instrument is bolted to the reactor biological shield by an IAEA inspector and will function independently for up to three months. The percent power level at which the reactor operates is calculated and recorded hourly and then dumped on cassette tape at the end of the day. The cassette tape is the final output. Intermediate outputs from memory to a strip chart recorder or data terminal are also available. The system is specifically designed for portability, ease of operation, and low power consumption. It is powered by ac line current supplied at the site but has a battery backup to allow continued operation during periods of power failure.

Fig. 1 Hardware Block Diagram.