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February 3, 2000

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U.S. Nuclear Regulatory Commission
Washington D.C. 20555

RE: Report of the Period Safety System Malfunction at The Ohio State University Research Reactor (OSURR), License R-75, Docket 50-150

This written report is being submitted as required by the OSURR Technical Specification (TS) 6.6.2(2)(c). The required telephone communications per TS 6.6.2(1)(c) were made on 1-25-2000. These reports are in response to the apparent malfunction of the period safety system that could have rendered it incapable of performing its intended function. This apparent malfunction was discovered while the reactor was shut down on 1-24-2000. Its cause, corrective actions, and measures to preclude recurrence are attached for your review. They have also been forwarded to Don W. Miller, Director of the OSURR and the Reactor Operations Committee for review and approval as required by TS 6.5.2.

Sincerely,

David B. Ashley
Dean, College of Engineering and
The John C. Geupel Chair in
Civil Engineering

c. Don W. Miller, Director OSURR
Richard D. Myser, Associate Director OSURR
Theodore S. Michaels, USNRC Senior Project Manager
USNRC Region III

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Report of Period Safety System Malfunction at the OSU Research Reactor

Introduction

While testing the outputs of the Log N Period Amplifier module (Keithley 25012A) on 1/24/2000, an unexpected output of this module was measured. The signal from this output serves as an input to the Period Safety Amplifier (PSA) module. The expected signal is a voltage that is linear with the base-10 logarithm of the current from a compensated ion chamber (CIC) (e.g., the signal increases by 10 volts for every 10x increase in detector current). Instead, the module output deceased slightly with increasing detector current.

The PSA module provides a backup trip for a reactor transient period of less than 1 second if the primary trip mechanism fails to function when a 5-second period is reached.

Problem diagnosis

To diagnose the problem, we started by following the manufacturer's procedures for zeroing and calibrating the Log N Period Amplifier module. After doing this, we were still not getting a proper output to the PSA module.

We verified that the front panel log N meter on the Log N Period Amplifier was providing proper indication for test signals. Figure 1 shows a simple schematic diagram of the module. Correct front panel meter readings indicated that the problem lay between point A and the output labeled 'LOG N OUTPUT' on the diagram.

We determined that the signal was being propagated correctly up to point B on Figure 1. However, the high-voltage, 10x amplifying stage was not giving the correct output. We measured the voltages on the power supply leads to the Burr-Brown op-amp that powers this 10x amplification stage and found that the high-voltage power supply was providing insufficient voltage to the Burr-Brown op-amp.

The power leads to the high-voltage were disconnected to determine if the high voltage was being pulled down by a failed op-amp. The power supply voltages were still not providing sufficient voltage (they were about +6 V_{DC} and –11 V_{DC} instead of $\pm$90 V_{DC}). The power supply was therefore inoperative. This only affects the 10x amplification stage, as all of the other electronics in the Log N Period Amplifier module are powered from a separate $\pm$15 VDC supply. Therefore the functionality of the rest of the module was unaffected by this power-supply failure.

Corrective Action Taken

It was determined that the two amplification stages between point A and the LOG N OUTPUT could be bypassed. A schematic of this is shown in Figure 2. To understand why two op-amp stages can be eliminated, some background is necessary. The Log N Period Amplifier module was designed to send a high-voltage signal to a vacuum-tube-based precursor to the PSA module. Some time after the Log N Period Amplifier module had been installed, the PSA module replaced the former period scram module. The current PSA module uses solid-state devices instead of vacuum tubes, so the 0-80 volt input signal needed to be reduced by a factor of 10 to a level that the PSA module components could use. Because of the chronological order in which these modules were replaced, the signal passed from the Log N Period Amplifier to the PSA was being needlessly multiplied by a factor of 10 and then divided by a factor of 10.

Rather than trying to find outdated components to replace the high-voltage 10x-amplification stage, we decided that eliminating unnecessary complexity was a preferable solution. This could be accomplished by bypassing the two inverting amp stages in the Log N Period Amplifier module and eliminating the voltage divider in the PSA module.

However, in addition to making changes that ensured a proper detector-based signal was processed by the PSA, we had to ensure that test signals were properly processed. Test signals fed to the PSA to verify its functionality were passed through two voltage dividers to give a proper input. One of these was a divider through which only test signals passed, and the other was a divider through which detector-based signals also passed. Since the latter of these dividers needed to be removed for proper detector-based signal propagation, the former was also removed and the action of both replaced with a single new voltage divider. Consequently, the test signals undergo the same division as before and the detector-based signals bypass the unnecessary gain and division stages.

Finally, the question of input isolation had to be considered. Because the two inverting amp stages provided a level of isolation between the two modules by preventing the PSA from loading the Log N Period Amplifier module output voltage, we needed to verify that no signal loading would now occur. Detector-based signals no longer go through a voltage divider, so the input impedance of the PSA is that of a buffer stage to which the input is connected. This has a very high impedance, so loading does not occur.

Testing

To test that the new system was working properly, we performed four stages of testing. These included a test of the functionality of the Log N Period Amplifier, two tests of the functionality of the PSA, and a final test of the complete system.

First, current levels spanning the range of those from the CIC were introduced into the Log N Period Amplifier module and the output voltages were observed and compared to expected values. The input ranges from 10^{-12} A to 10^{-4} A, and the corresponding output voltages range from 0-8 V (1 V / decade). This test gave satisfactory results.

Next, the PSA module was tested with an HP waveform generator as its input. For a stable reactor period, the output of the Log N Period Amplifier to the PSA is a ramp whose slope is inversely proportional to the period. Therefore, to test the PSA, we used a sawtooth waveform with a cycle-time of 10 seconds whose slope corresponded inversely to the desired period. We determined this slope using the equation:

$$\text{signal voltage} = \log_{10}(P/P_0) = \log_{10}(e^{t/\tau})$$

where
P = reactor power (W)
P_0 = starting reactor power (W)
t = time (s)
τ = reactor period (s)

For example, if we wanted to test a 30-second period, we introduced a signal that spanned 0 to 0.145 V (= $\log_{10}[e^{10/30}]$) in 10 seconds. We first tested for reactor period settings of 30 seconds, 10 seconds, 3 seconds, and 1 second. The PSA only gave a trip signal for the 1-seond period. This was an appropriate response, because the PSA module is supposed to provide a trip signal for reactor periods of less than 1 second. In addition to monitoring the trip function, a voltage internal to the PSA that is proportional to the period (referred to hereafter as 'PSA period signal') was recorded for each period input for comparison with later results.

Next, the slope of the input was adjusted until the trip threshold was found. This threshold was determined to be a period of 1.84 seconds. This allows for a conservative trip function by being greater than 1 second, but is not so great (> 5 seconds) that it precludes the primary reactor period trip function provided by the period recorder.

Following this, we switched the PSA to test mode and introduced test signals from the Period Generator that is used for normal reactor pre-start checkouts. The test signals used were for the same reactor periods simulated with the waveform generator. The 1-second test input resulted in a trip. The PSA period signal was measured for each input, and the measured values were reasonably close to those measured in the previous test.

Finally, when we were confident that the corrective action was effective, we tested the two modules together with an actual signal from the CIC with the reactor operating normally. First we tested with the reactor on a nominal 30-second period (~29 s), and then we tested with a nominal 10-second period (~11 s). Neither input tripped the reactor, and both gave PSA period signals that were consistent with the previous tests. Given that all test results were consistent with each other and that the trip setpoint was conservative, it was concluded that the system was working properly.

Measures Taken to Reduce the Probability of Recurrence

To reduce the probability of this malfunction being repeated, we are adding measurements to verify log N signal availability to the PSA and to verify that the whole measurement channel is functioning properly. To verify log N signal availability to the PSA, we need to check the log N output of the Log N Period Amplifier module. Because two amplification stages are now being bypassed as a result of the corrective action, this measurement is accomplished by steps outlined in OSU-NRL procedure IM-12 Section V.E.2. Therefore, no procedural changes are needed. To verify that the whole measurement channel is functioning properly, we are revising OSU-NRL procedure IM-12 Section V.H to include measurement of the PSA module period while the reactor is on a 10-second period. These steps should help ensure that the probability of a recurrence is minimized.

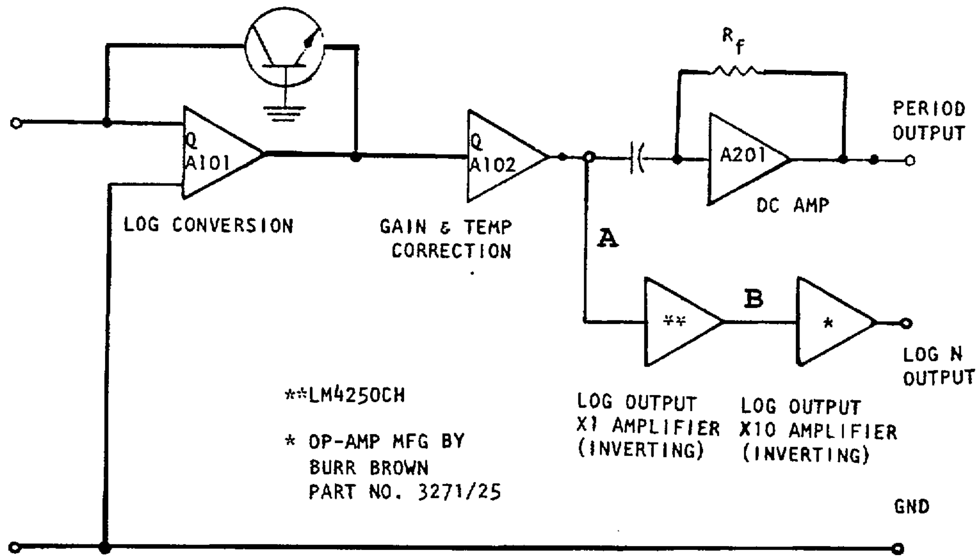

Figure 1: Log N Period Amplifier Schematic Prior to Change

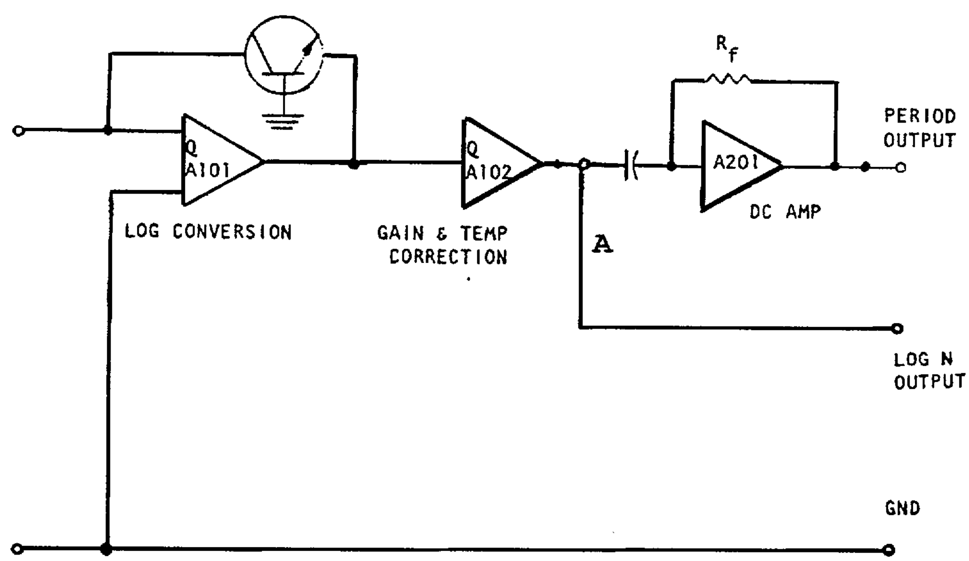

Figure 2: Log N Period Amplifier Schematic after Change