A Digitized Wide Range Channel for New Instrumentation and Control System of PUSPATI TRIGA Reactor (RTP)

Zareen Khan Abdul Jalil Khan ,Mohd Idris Taib, Izhar Abu Hussin, Nurfarhana Ayuni Bt Joha, Roslan Md Dan

Electronic, Instrumentation and Control section
Nuclear Power Division
Malaysia Nuclear Agency

Abstract

Wide Range Channel is one of very important part of Reactor Instrumentation and Control system. Current system is using all analog system. The main functions of the new system are to provide Wide-log power and Multi-range linear power. The other functions are to provide Percent power and Power rate of change. The linear power level range is up to 125% and the log power system to cover from below source level to 150%. The main function of digital signal processor is for pulse shaping, pulse counting and root mean square signal processing. The system employs automatic on-line self diagnostics and calibration verification.

Key words – Wide Range Channel, wide log power, Multi –range linear power, percent power

1.0 INTRODUCTION

The main system of the new instrumentation is a wide range channel which operates at low power in the pulse mode and at higher power in the Campbell mode. From this channel important parameters are extracted and displayed on a color graphic screen, such as: linear power, log power, period, count rate, percent power. In this channel a microprocessor is involved using a special developed software which practically cannot be verified. As a redundant safety channel, GA offered one percent power channel which creates a hard-wired shut down signal at nominal power plus 10%. This means that only one hard-wired safety channel was available in the proposed system. This design is unacceptable according to European standards and had to be modified. Besides the neutron monitoring channel which is considered only as an operational channel without safety relevance, two identical hard-wired linear channels (NMP-1, NMP-2) have been installed. Both channels are constantly compared and any discrepancy exceeding 10% trigger an alarm. Further, both channels are switched together by a range switch, resulting in a reactor scram signal in each range at 10% overpower. In addition, two strip chart recorders for linear power and for fuel temperature recording during pulse operation are provided.

The reactor is controlled by four nuclear channels, their signals are displayed both at a colour graphic-monitor and at bar graph indicators. The auto-ranging wide-range channel controls the reactor power from the source level (around 5 mW) up to nominal power of 250 kW. It uses a Campbell fission chamber, the signal is controlled by a microprocessor.

Neutron monitoring system is designed to replace the source range, intermediate range, and power range channels with a single neutron detector assembly and amplifier/processor unit. The system consists of a unique neutron detector ,high speed, low- noise counting circuits combined with root mean square (rms) signal conditioning circuits, diagnostic / microprocessor circuits, and

4 to 20m A isolated output buffers. The complete channel provides a wide range logarithmic output covering the entire neutron flux range from 2 X 10^{-8} to 120 % of full power, a multirange linear output covering 2 X 10^{-8} to 120% of full power, a percent power channel covering the flux range from 1% to 120% of full power and a wide range period channel covering the full ten decades.

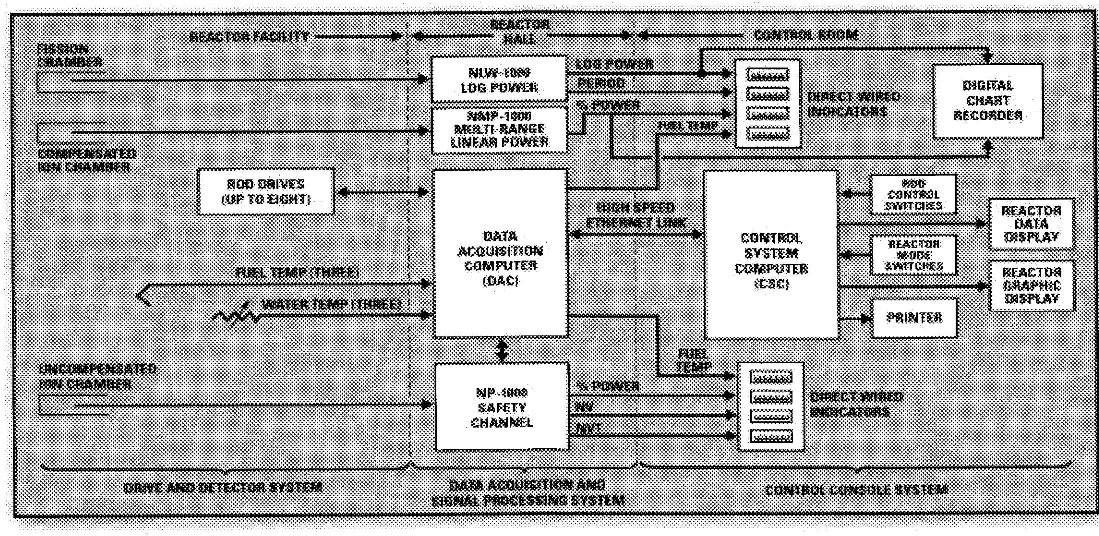


Figure1: Simplified research reactor control system block diagram (General Atomic, 2008)

1.1 Basic Knowledge Of Digital Signal Processing (DSP)

The Texas Instruments TMS320C6701 is the latest and highest performance floating point DSP processors available from TI. DSP processors are similar to general-purpose microprocessors except that they are more optimized to perform multiplication and addition operations. Thus they are widely used in the applications that require real time analysis

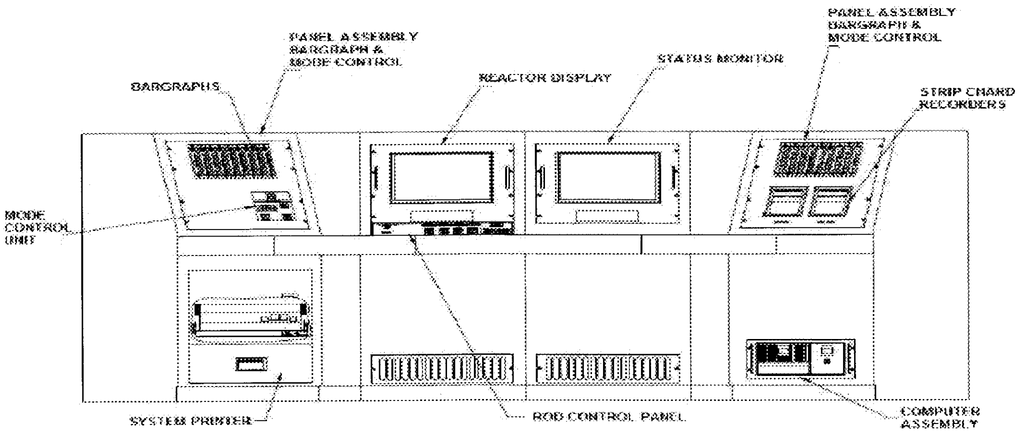
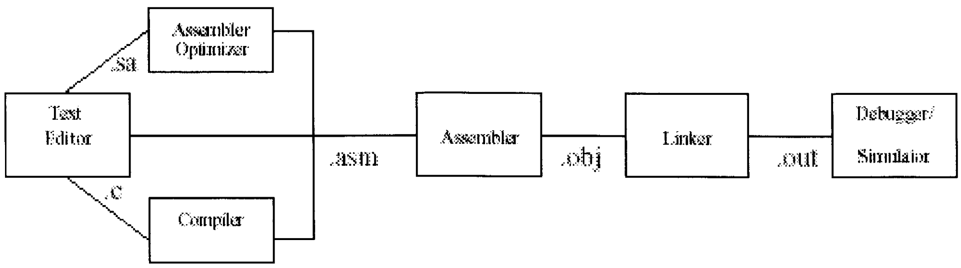


Figure 2: Digital TRIGA control system console designed by General Atomic, 2008

2.0 PROPOSED APPROACH AND METHODOLOGY

2.1 Software Development Tools

For C6701, the software tools for converting a C or assembly file into a DSP executable file include the compiler, assembler, linker, and debugger/simulator. illustrates the steps involved for going from a source file to an executable.



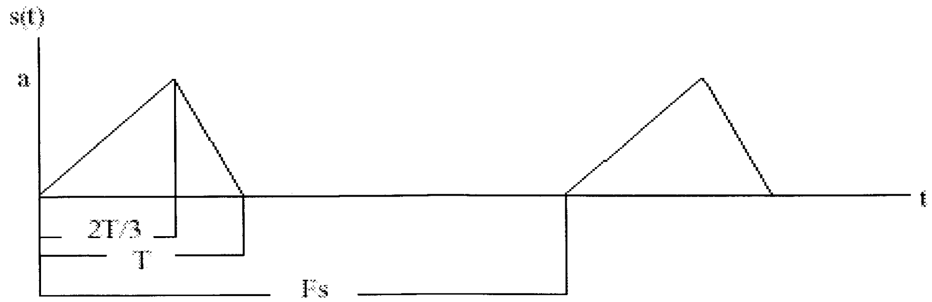
software tool called Code Composer Studio (CCS), which provides an easy way to use graphical user environment for interfacing and debugging purposes with real-time capabilities. All the program in this thesis is written in C language, which is more readable but less efficient.

2.2 Signal Processing Algorithm

In signal processing part, which involves signal generation, noise adding, filtering, sampling, threshold detecting and error probability calculating. Signal generation is to generate triangle waveforms which are almost based on the measurement data of the communication theory laboratory. Noise adding is to let signals go through a white Gaussian noise- like channel, which implemented as random values originated from matlab. Filtering is to let received signals go through a filter, which is matched to the signals that are transmitted. Sampling is to sample the signals at every integral values time a basic sampling time Ts plus T. Threshold detecting and error probability is to reconstruct the transmitting signals after sampling based on the value of threshold and using the reconstructed values to calculate the error probability.

2.3 Signal Generation

The triangles are generated through a function generation. The waveform for it is plotted below:



To implement these on DSP board, I can only use points to represent these triangles. It is easy to get the three sides' mathematic line equations of a triangle based on the data from measurement.

L1: y = 3a/2T * t

L2: y = 3a/T*(T-t)

L3: y = 0

Then, according to different ts, the triangles can be represented using C language easily.

2.4 Noise Adding

It is very difficult to simulate white Gaussian noise channel as the noise generator does. What I did is to use random values to represent the noise and define noise variance which is multiplied to these random values and then add them directly to the signals after signal mode changing. But of course it is different from white noise channel and thus generating some errors to the whole system.

2.5 Filtering

From the communication theory, match filter is a filter that is matched to the transmitting signals. The reason why we use match filter is that the signal after filtering can achieve the maximum value which is the best time for sampling and then we can reconstruct the original signals.

2.6 Sampling, Threshold Detecting and Error Calculating

Sampling is used at the receiver side to get the values of signals after finishing processing. And these values we get are used for reconstruction the transmitting signals. After match filter, the signals are maximized at every T + k/Fs without noise. Thus every T + k/Fs is the right time for sampling. According to threshold set, the signals are reconstructed. In this project, the threshold is set to 0 since we use signal mode 3 (signal mode will be described in the following chapter) in the lab. The reconstructed signals are used to compare to the transmitting signals, thus we can find the errors and also calculate the error probability. This is the simulation result for error probability, and the theoretical error probability is expressed as below

Data Mode 1 $$P_e = Q(\sqrt{\frac{E_s}{2N_0}})$$

Data Mode 3 $$P_e = Q(\sqrt{\frac{2E_s}{N_0}})$$

2.6 Full Digital Control Evaluation System

The implementation of the new equipment described above and an efficient data acquisition system increases considerably the reliability of the reactor instrumentation, even maintaining the current analog control logic. However, the total change of analog control for a digital one would place the in the state-of-the-art instrumentation and control system. Bellow is presented, as an example, some specifications of a control system designed by General Atomics Electronic Systems Inc. (2008).since 1980 provides digital control console to its reactor and from other reactor manufacturers, the software developed by the General Atomics manages 13 research reactors around the world. The GA reactor instrumentation and control system shall be designed and manufactured to comply with the guidance given in American Nuclear Society (ANS), ANSI Guide ANSI/ANS 15.15-1978, "Criteria for the Reactor Safety Systems of Research Reactors" and the IAEA Safety Series 35-S1. The GA control system includes:

- most of manual data logging can be eliminated;
- provides automatic or manual reactor operation modes;
- provides complete real-time operator display;
- replays historical operating data on monitor or printer;
- eliminates spare parts replacement problems;
- meets all applicable NRC and IEEE specifications.

Instrumentation and control systems for all new TRIGA reactors have now evolved into compact, microprocessor-driven systems. As with previous generations of the I&C systems, they are designed to enable inexperienced students and nontechnical personnel to operate the reactor with a minimum of training, with simplicity afforded as a result of the inherently safe characteristics derived from the physical properties of the UZrH fuel. Four operating modes are typically available: manual, automatic, pulsing, and "square wave," the latter being a one-button startup sequence for bringing the reactor up quickly (a few seconds) to its operating steady-state power level. TRIGA reactors have also been licensed to operate in unattended mode, again as a result of the protection afforded by the safety characteristics of the U-ZrH fuel (Fouquet et al., 2003)

3.0 RESULTS AND DISCUSSION

3.1 Amplifier Assembly

Neutron monitor preamplifier assembly is wall-mounted, it may be located up to 100 ft from the neutron detector. The amplifier assembly is qualified to the requirement of IEEE 323-1974. The modular plug-in subassemblies contained in the amplifier assembly are the pulse preamplifier electronics, the bandpass filter and rms electronic, the signal conditioning circuits, the low voltage power supply and the digital diagnostic and communication electronics.

3.2 Signal Process Assembly

Processor assembly is designed to be installed outside containment and up to 3000 ft from the amplifier assembly. The processor assembly is qualifies to the same seismic and environment standards as the amplifier assembly, and also has a design life of 40 years. The amplifier assembly communicates with the processor assembly via two twisted-pair shielded cables. The amplifier circuit design employs the latest concepts in automatic on-line self-diagnostics and calibration verification. Detection of unacceptable circuit performance is automatically alarmed on the local control/display panel and at the remote display location.
The neutron monitoring system consists of the following items, a specially shielded, low –noise fission chamber in a water proof housing, an amplifier / signal conditioning assembly (preamplifier) and a single processor/output assembly(DSP microprocessor)

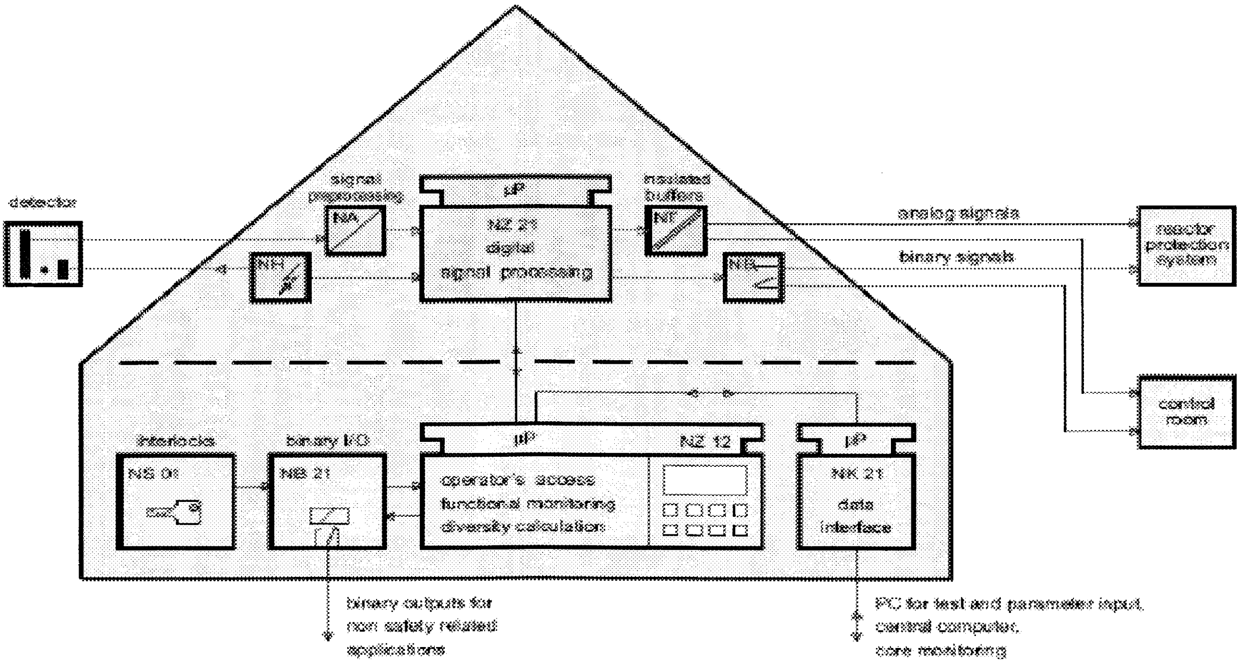


Figure3: Architecture signal processing channels for wide range channel

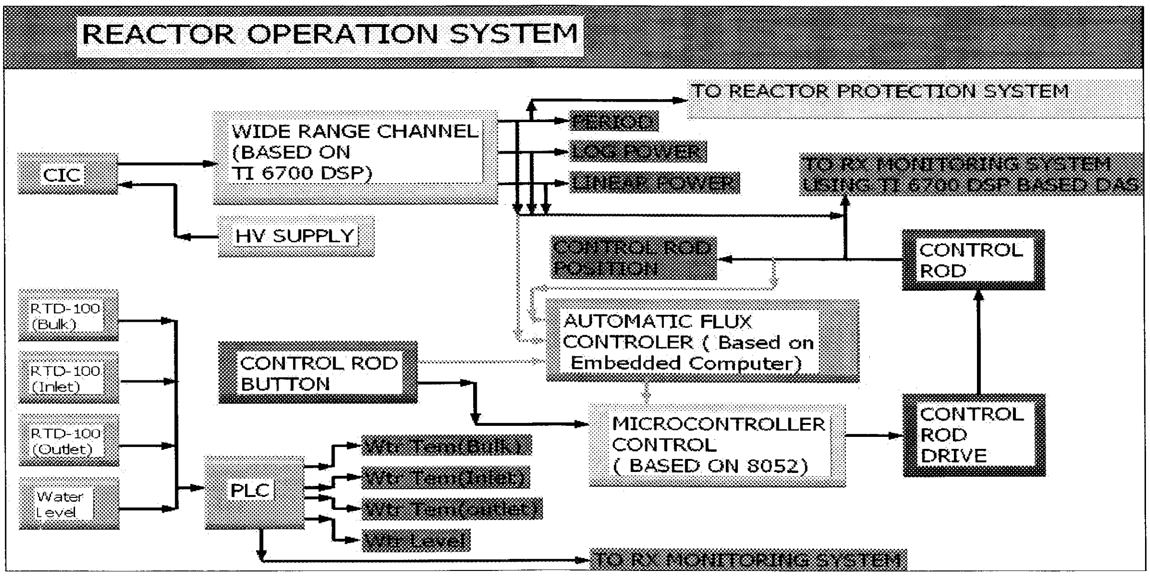


Figure4: Block diagram of Reactor Operation System

4.0 CONCLUSION

The new system would be based on DSP microprocessor, and would utilize displays that are typical of state-of-the-art control rooms. The new reactors consoles were designed to provide the operation with safe and reliable in different modes as: manual, automatic, square wave, and pulse. All control functions can be implemented with computer technology. One of the design specifications was to use state-of-the-art digital equipment to improve reliability, increase the flexibility of upgrading, and reduce lifecycle costs. In addition, it provides a human-machine interface that the students would see in industry. The new control and safety system allows the TRIGA to remain an active research center to educate students

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