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Special Purpose Computer Provides Programmable Digital Filter for Sampled-Data Control Systems

This versatile, generalized digital filter in the form of a special-purpose computer, should be of interest to designers, users of feedback control systems, and design engineers involved in EDP technology. The design concepts for a digital filter used in feedback control systems represent a useful invention since complex-function integrated circuits have become available, thus permitting the digital filter to be implemented at low cost.

Today's digital computers can be used as both an analytical device and a system's component. As an analytical device, the digital computer renders many trial-and-error and optimization procedures practical. As a system's component, the digital computer can perform the control function necessary for proper system operation. Operating in this manner, the digital computer may be called a digital filter (or controller).

The term "digital filter" is a process or algorithm which accepts an input sequence of numbers and transforms it into an output number sequence; this algorithm may be described by linear difference equations with constant coefficients.

The design process for digital filters consists of two phases: first, the specification of the filter coefficients; and second, the realization of the specified filter. Sampled-data control techniques, frequency domain techniques and random noise rejection techniques represent methods for determining the coefficients of a digital filter. Once a digital filter has been specified, a realization procedure compatible with the intended application of the filter must be selected.

One frequent application for digital filters is the compensation of sampled-data control systems. The digital filter used in this manner must meet rigid size, reliability, and speed requirements. Many of the normal procedures to realize a digital filter fail to meet some of these requirements. A general purpose computer can realize a digital filter, but it is inherently large and expensive. A hybrid implementation has been tested but it does not always meet reliability standards.

Continuous improvements in Large Scale Integration (LSI) technology suggest the feasibility of employing a small, fast, special purpose computer to realize digital filters. This approach can also meet the reliability requirements by means of redundancy afforded only by the application of LSI. Consequently, this approach is chosen as the subject of this study.

The study of the special purpose realization for digital filters is conducted in three parts: the organization of the computer, the logical design and synthesis; and experimentation with the computer in two sampled-data control systems. The logical synthesis and design of the computer's functional blocks are discussed and the design substantiated by analytical techniques verifying the proposed quantization and round-off schemes.

For experimentation purposes, the special purpose computer is connected into the Pendulous Integrating Gyroscopic Accelerometer (PIGA) control loop and into an analog computer simulation of the Saturn V thrust vector control (t.v.c.) system. Techniques for improving the experimental performance of the computer as a digital filter (or controller) of sampled-data control systems are also described.

Notes:

1. Computation round-off, input quantizing, and coefficient quantizing in the digital filter have been analyzed. The sample-data system output error is

(continued overleaf)

determined to be more sensitive to coefficient quantizing than to input quantizing and round-off errors; thus coefficient quantizing should be avoided.

2. Improving the performance of the digital filter by increasing the order, coefficient resolution and input resolution has been proposed. After comparing results, the conclusion is that cascading second order digital filters and time-sharing one Arithmetic Unit represents the most practical approach proposed.
3. The following documentation may be obtained from:

   Clearinghouse for Federal Scientific and Technical Information
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.65).

   Reference: NASA TMX53766(X69-70947), Design of a Real-Time Programmable Digital Filter

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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