THE SIMULATION OF TRANSPORT DELAY WITH THE HYDAC* COMPUTING SYSTEM

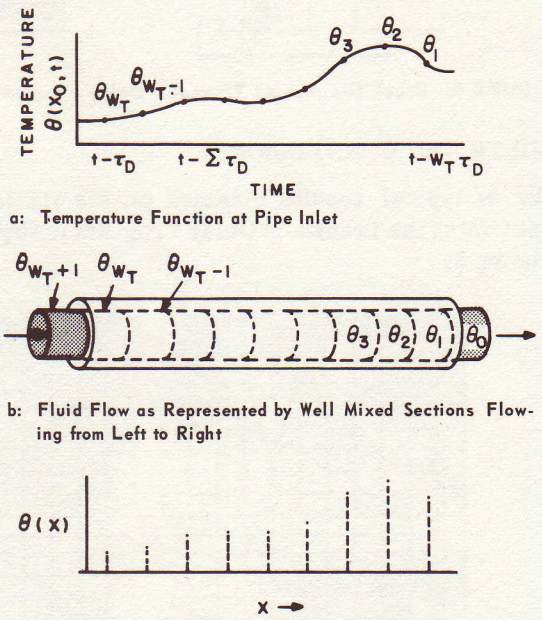
INTRODUCTION

These notes describe the simulation of transport delay with the EAI HYDAC Computing System, utilizing a combination of analog and digital components to provide a high speed, multichannel, variable delay capability.

The need to simulate a transport delay arises frequently in analog computation, occurring as the solution of flow and wave partial differential equations. That is, the realistic simulation of systems involving the flow of liquids and gases in pipes or the propagation of electric or acoustic waves requires the representation of the transport delay phenomena.

The standard analog computer approach -- a linear computer circuit with delay transfer functions approximated by Padé polynomials -- suffers from two basic limitations: 1) the large phase errors at high frequencies prevent realistic representation of rapidly changing and discontinuous functions, and 2) the large number of multipliers required for variable time delay make this approach uneconomical.

An alternative approach employs sampling of the analog signal, storage of the discrete samples in memory cells, and reconstruction of a stair-step approximation to the function by reading out each stored value after a delay of τ_D seconds. The HYDAC program used in the study described employs this method for simulating transport delay. It utilizes analog-to-digital conversion, digital function storage, and appropriate logic components to provide a pure delay of sampled functions from the analog computer. The analogy shown in Figure 1 will help to clarify this discrete simulation approach.



a: Temperature Function at Pipe Inlet

b: Fluid Flow as Represented by Well Mixed Sections Flowing from Left to Right

c: Discretized Temperature Profile as a Function of Pipe Length

FIGURE 1. Pictorial Representation of Discrete Sampling Method of Simulating Fluid Flow Transport Delay

BENEFITS

Several benefits are provided through this simulation technique. In particular, in terms of capacity and versatility, the program

- provides up to ten independent channels of delay
- makes available storage capacities of 16, 64 or 256 words per channel
- permits a wide range of delay times since each channel can accept a different velocity variable, can use memory units of different capacity, and
- has the capability to simulate very long delays through the use of digital storage.

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COMPUTER PROGRAM

The basic operations performed by the HYDAC Transport Delay Program are shown in the block diagram of Figure 2.

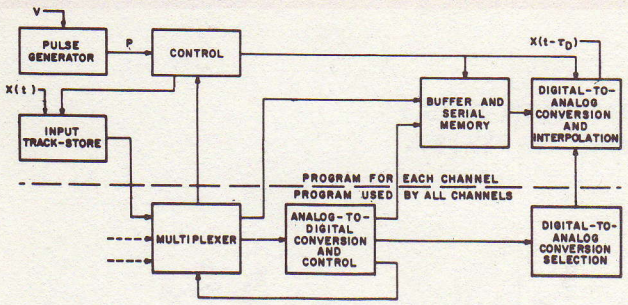

FIGURE 2. Block Diagram of Transport Delay Program

RESULTS AND CONCLUSIONS

A plot of typical results obtained on the HYDAC System using the Transport Delay Program is shown in Figure 3.

To illustrate the effect of variable delay, the velocity of both channels was reduced by a factor of two at the point indicated in the figure. This step change caused an immediate reduction in the frequency at the output of the pipe, which is sustained until the input appears at the output with the new velocity. As shown, channel one had not yet reached the new steady state at the end of the recording shown. Although such a pure step change may not be realizable in physical systems, this simulated condition can be considered a worst case test.

This hybrid transport delay simulation program is but one of a series of standard general purpose programs which are available as "software" for the HYDAC system. For complete details on the program described, please write for Hybrid Computing Techniques: 1.3.7h, Bulletin No. ALHC 63011.

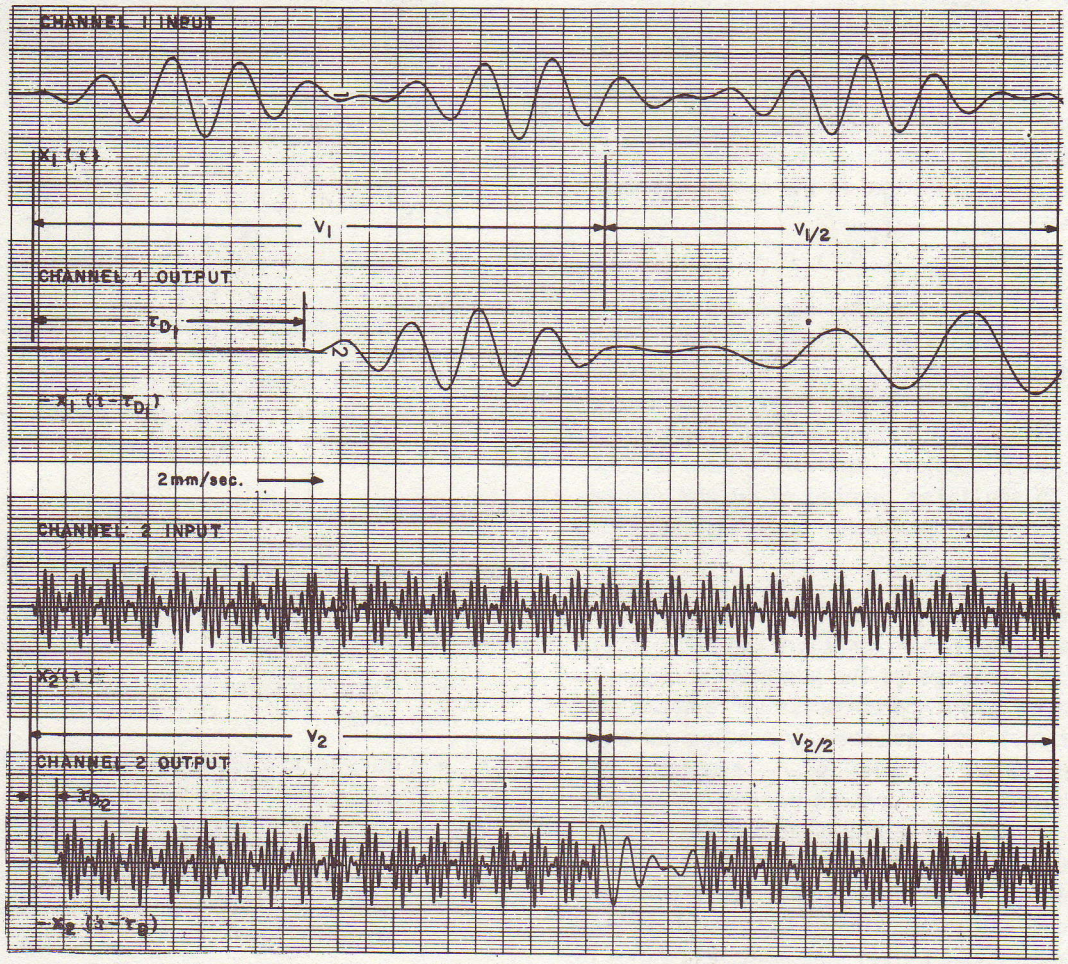

FIGURE 3. Sample Results for Two Channel Transport Delay Including Effect of Velocity Change

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