NASA-AMES HYBRID COMPUTER FACILITIES AND THEIR APPLICATION TO PROBLEMS IN AERONAUTICS

INTRODUCTION

These notes describe, in general, the unique and versatile hybrid computing system at the NASA-Ames Research Center and discuss briefly four problems which emphasize the wide range of application of this computing facility. Designed and developed by EAI in cooperation with NASA-Ames engineering personnel, the system consists of the Ames digital logic simulator (DLS) . . . a prototype of the EAI Digital Operations System (DOS 350) . . . and the Ames Linkage System . . . a sophisticated analog/digital communication channel that interfaces an EAI 231-R analog computer to an IBM 7090 digital computer. This hybrid computing system makes possible the computation of space-flight equations on a real-time basis. In addition, the linkage system provides extensive communication facilities between the digital computer and a space vehicle simulator cockpit.

This combined computational facility, intended initially for use only in solving problems associated with the aero-space field and designed within the stringent physical requirements existing at the Ames Moffet Field location, has proven particularly gratifying in its application to a much wider variety of problem areas than originally foreseen. Indeed, the promise for future applications seems unlimited, especially in the new problems available to analog simulation computers since being interconnected with the DLS. These new problems include:

1. Data Applications
   a. data reduction
   b. data readout
2. Simulation Applications
   a. simulation of logical control systems
   b. simulation of transport delays
   c. simulation of display generation
3. Computer Control Applications
   a. analog computer control
   b. linkage system control

THE DIGITAL LOGIC SIMULATOR

Programming Elements

The Ames digital logic simulator was designed as an accessory to existing analog simulation computers and was equipped to connect easily into the function with these standard real-time computers. Figures 1 and 2 show the logical and digital components of the DLS divided, for purposes of illustration, into the two general categories of logical operation and digital word components. These all are available for interconnection through a removable problem prepatch panel by the familiar analog patching method.

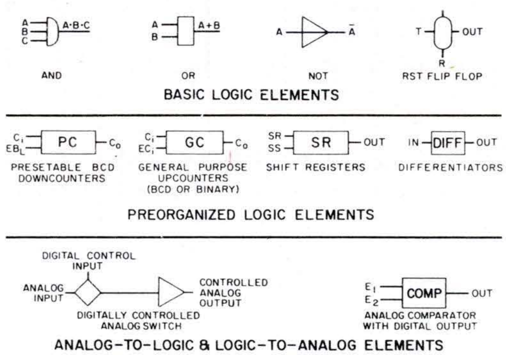

Figure 1. Logical operation components of the DLS

Applications

One of the first applications of the DLS was in ***computing the average heart rate from electrocardiograph (EKG) signals*** that had been recorded on magnetic tape. The tapes contained continuous EKG data from two human subjects enclosed in a small capsule for seven days, and involved level selection and the accumulation of resultant counts. Figure 3 shows the basic method used.

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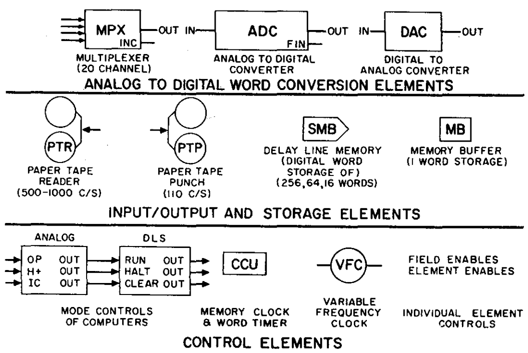
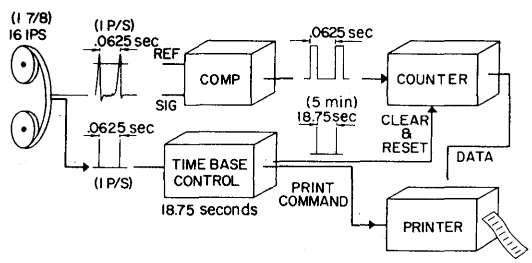


Figure 2. Digital word components of the DLS



	TAPE SPEED IPS	ECG RATE	AVERAGING INTERVAL	TOTAL RUNNING	READOUT = HEART BEATS / 5min: 350, 360, 355, 358
RECORD TIMING	1 7/8	~1 P/S	5 min	7 DAYS	
PLAYBACK TIMING	16	.0625	18.75 sec	10.5 hr	

Figure 3. Basic method of computing average heart rate from EKG records.

A somewhat allied technique of data processing is described in EAI Application Study: 2.4.2h (Bulletin No. ALHC 64053) entitled Hybrid Computer Techniques For Determining Probability Distributions (1).

An example of the versatility of the DLS in flight simulation problems was its application as a ***tracking task simulator*** in which the tracking errors of pilots were studied. Figure 4 shows the degree of participation of the DLS in this simulation.

Of particular interest here was the utilization of high-speed paper-tape-punch readout, a technique which represented a major saving in technical manpower and made analog-computed results instantly available to powerful digital computer analysis.

One of the principal reasons for including digital word units in the DLS was to provide the capability of ***simulating transport delays***. The basic scheme for generation of time delay using digital elements is illustrated in Figure 5.

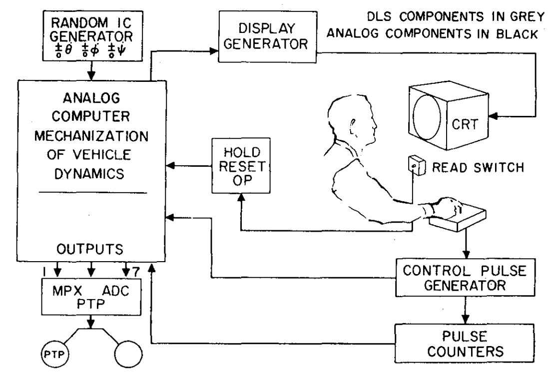


Figure 4. Block diagram of tracking task simulator showing digital logic simulator functions.

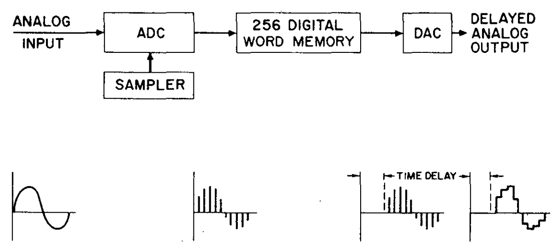
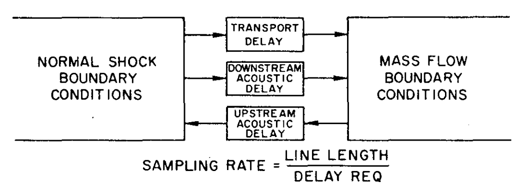


Figure 5. Basic digital logic simulator system for time delay simulation.

The particular problem investigated involved the simulation of a jet engine control system for a supersonic airplane. The transport delays between the engine inlet and exit of the aerodynamic shock of the disturbances were mechanized using the DLS components shown in Figures 1 and 2.



DELAY CHANNEL	DELAY, sec	DELAY LINE	SAMPLE RATE, S/sec	SAMPLE INTERVAL, msec	DELAY LINE ACCESS TIME, msec
1	2.5	256	102.4	9.76	1.953
2	1.67	256	153.6	6.51	.488
3	.714	64	89.6	11.16	.122

Figure 6. Simplified block diagram of supersonic engine simulation using digital logic simulator delay program.

THE AMES LINKAGE SYSTEM

Design Features and Application

Several successful linkage systems are designed in the literature (3,4), and many characteristics of these systems are shared by the Ames linkage. Therefore, only those features which make the Ames system unique and which present unusual design and/or application problems will be discussed.

Three major factors shaped the design of the Ames Linkage System:

1. The physical separation of the analog and digital facilities (a distance of one-half mile) presented the initial crucial problem as to which of the available transmission media (mircowave radio, telemetry, etc.) would provide the most satisfactory digital wave shapes over this distance. Parallel digital transmission by wire cable was the design selected; Figure 5 shows the results of a test run to check system performance. Operational experience also has been very satisfactory, with millions of words having been transmitted error-free in both directions.

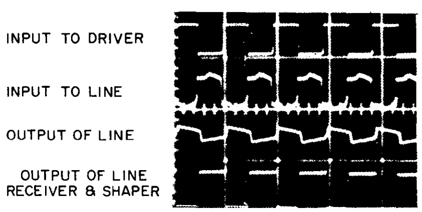


Figure 7. Oscillograph of 2500-foot transmission system performance.

2. The requirement for authentic reproduction of data display, data input, and pilot controls in an application involving the simulation of space flight and atmospheric reentry made necessary a degree of communication between the simulator cockpit and the digital computer for in excess of that required by just the linkage of the analog and digital computers. Figure 6 shows a simplified block diagram of the signal paths required for optimum communication.

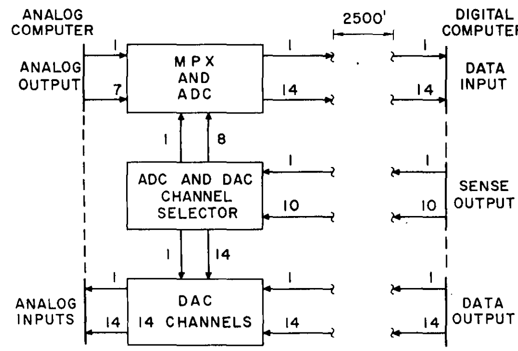


Figure 8. Signal linkage between computers.

3. The conservation of digital computer time in the simulation for economic reasons, so that there would be only a minimum interruption of normal digital production demands was another very important factor. A digital computer program called a data acceptance routine (DAR) was devised and implemented which virtually eliminates idle time in the digital computer for changes between production and simulation computations. When a simulation computation is required, the digital computer is halted and the DAR is entered. After the hybrid computation is completed, the digital computer returns to the production problem. Changeover time using the DAR is approximately 10 seconds.

Please send for Application Study: 3.4.8h, Bulletin No. ALHC 64029 for complete details on this hybrid computer facility.