SYSTEM RESPONSE ANALYSIS WITH THE ANALOG MEMORY AND LOGIC SYSTEM

INTRODUCTION: These notes describe the application of a general-purpose analog computer equipped with the Analog Memory and Logic System to an analysis of system response characteristics. The system chosen for illustrative purposes is a servo loop, as shown in Figure 1, which receives an input signal via a band-pass filter. It is desired to consider the response of this system to both fixed and random inputs.

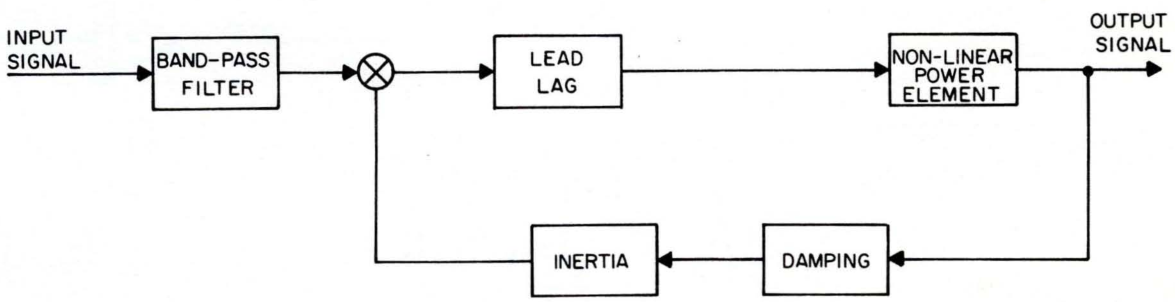

Figure 1.

THE ANALOG MEMORY AND LOGIC SYSTEM

In order to accomplish a complete analysis, it is necessary that the analog computer used will provide flexible control and timing of individual integrator modes and time constants. This facility is included in the Analog Memory and Logic System, which terminates mode control logic and timing signals on a separate patch panel from that of the main program. Oscillators and adjustable counters generate the necessary mode control wave forms. These timing signals can be distributed to individual components or to groups of components. Integrator time constants also can be selected individually or in groups. Logic gates and high-speed voltage comparators permit sophisticated programming of integrator and analog memory unit operating modes.

SYSTEM SIMULATION

A model of the system to be investigated is programmed on the analog computer. By means of the mode control and time scale selection provisions of the Analog Memory and Logic System, three modes of operation are possible without re-programming:

(1) real-time simulation. . .permits solution to take place at a relatively slow speed for recording system response to a step input with maximum accuracy on an electro-mechanical x-y plotting board.

(2) high-speed repetitive operation. . .permits repetitive solution of the problem with a faster time-scale, for observing the change in system response on a cathode-ray tube display unit for different step inputs. A permanent record of system response or of changes in response characteristics may be plotted on an x-y plotting board by means of the Stroboscopic Plotting technique described below.

(3) compressed time-scale operation. . .permits continuous solution with a very fast time-scale, for obtaining more significant averages for random inputs over a given time-span. The probability distribution curve for system variables may be plotted on an x-y plotting board by means of the Probability Distribution Analysis technique described below.

STROBOSCOPIC PLOTTING

In High-Speed Repetitive Operation, the step response of system variables can be observed on the screen of the display unit. For some applications, it is necessary to obtain permanent records of system response or of changes in response while the computer is operating repetitively. Since electro-mechanical recording devices such as x-y plotters or strip-chart recorders are too slow to follow the high-speed solutions, it is necessary to employ a stroboscopic recording technique. This technique makes use of Analog Memory units which sample the value of a variable or variables at time t during each solution. The parameter t is slowly varied or "swept" across the entire solution as the samples are filtered and plotted against it. The computer block diagram for accomplishing this is shown in Figure 2. The output of a repetitive operation time-base integrator (a) is compared in a high-speed comparator (b) to the output of a time-base integrator (c) in real-time operation. This provides a means of referencing the high-speed repetitive time-base of the computer to the time-base of the plotter. An Analog Memory unit (d), controlled by the comparator and the repetitive operation drive, samples the variable and holds it until the beginning of the next repetitive solution (OPERATE period), at which time it transfers the sampled value to another memory unit (e). The first memory unit then begins to track the variable again, while the output of second unit drives one axis of the plotter through a low-pass filter. The output of the real-time integrator drives the other axis of the plotter.

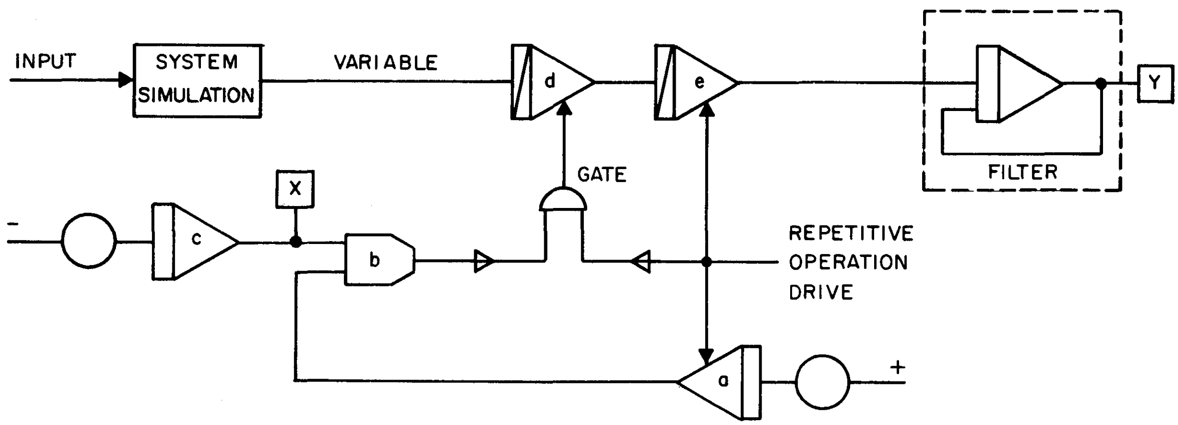

Figure 2

PROBABILITY DISTRIBUTION ANALYSIS

It is frequently necessary to plot the cumulative probability distribution curve for system variables. The curve represents the probability (or fraction of time) for the variable to exceed a certain value, plotted against that value. Figure 3 shows the computer block diagram for accomplishing this. The computer simulation of the system is submitted to a stationary Gaussian noise input from a noise generator, and the problem is then solved with a very fast time-scale, in order to obtain more significant averages over a given time-span. The output of a slowly varying real-time integrator (a) with a constant input is compared to the system variable in a comparator-limiter circuit (b). The circuit generates a fixed voltage when the variable exceeds the output of the real-time integrator, and has no output voltage when the variable is less than the integrator output. This rectangular (on-off) output is integrated for a short time interval by a repetitive integrator (c) driven by the master timer. The output of this integrator is sampled by an Analog Memory unit (d) at the end of its OPERATE period, and is transferred to a second memory unit (e) at the beginning of the next OPERATE period. The output of the second memory unit represents at all times the last value obtained for the integral, proportional to the probability of the system variable's exceeding the present output level of the real-time integrator. The output of the second memory unit drives one axis of the plotter through a low-pass filter, and the output of the real-time integrator drives the other axis.

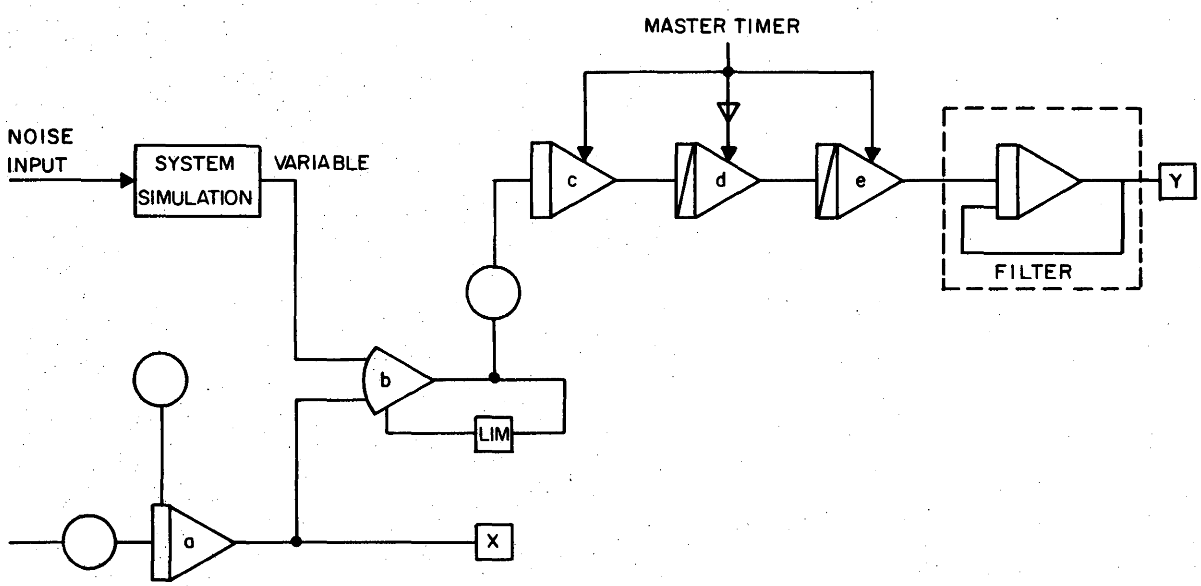
MASTER TIMER
NOISE
INPUT
SYSTEM
SIMULATION
VARIABLE
c
d
e
FILTER
Y
b
LIM
a
X

Figure 3