

XXIX. SIGNAL PROCESSING*

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RESEARCH OBJECTIVES

This research encompasses a variety of studies pertaining to the recording, processing and reproduction of acoustic and visual signals. Examples include nonlinear and time-variant filters, signal-to-noise ratio improvement in tape recording, input and output transducers, and the effects of signal variations on perceptual responses. Included in these research activities are several projects that are stimulated by the ideas and work of Dr. Manuel V. Cerrillo, and several that were formerly reported under the heading of "Statistical Communication Theory."

1. Signals and Perception

For many years, Dr. M. V. Cerrillo has conducted numerous existential experiments with acoustic and visual signals. In each case, he was able to show that small changes in physical signals can produce relatively large changes in perceptual response. He also showed that certain types of distortion or the addition of certain kinds of noise in either the acoustic or visual case can yield a subjectively more pleasing result than high-fidelity linear transmission or reproduction. He also initiated work on the relation of symmetries to the recognition process and to the esthetic aspects of the perceptual response.

The insights gained by Dr. Cerrillo in his experiments on perceptual responses to various signal processes have stimulated an interest in related studies, many of which would have been difficult to perform a decade or more ago. For example, recent improvements in circuit technology in the form of high-performance, low-cost, integrated circuits ease the design, construction, and operation of the audio signal-processing systems needed for more detailed study of perceptual responses. For visual signals, modern computer display techniques offer opportunities for rapid variation of parameters compared with the laborious and time-consuming methods used by Dr. Cerrillo. Preliminary work with a multichannel sound system is under way, and experiments with a computer display system are being initiated.

2. Noise in Switching Circuits

Mechanisms contributing to switching-time jitter in regenerative bistable devices and circuits have been the subject of intensive study for several years. Models relating time jitter to more basic $1/f$, shot, and thermal noise processes in the circuit components have been found for the tunnel diode switch¹ and for a class of bipolar transistor circuits.²

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(XXIX. SIGNAL PROCESSING)

We plan to continue this work. There are classes of nonlinear differential equations that relate dynamic variables in a given regenerative circuit to noise present at the switch input or generated within components of the circuit. We shall investigate these equations. The solutions of these equations are related, in some regions of operation, to first-passage time problems. Consequently, we are also trying to solve some basic first-passage time problems for low-order Markov processes by using a combination of Fokker-Planck equation and Monte Carlo simulation methods.

A. G. Bose, J. D. Bruce, D. E. Nelsen, A. V. Oppenheim,
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References

1. D. E. Nelsen, "Statistics of Switching-Time Jitter for a Tunnel Diode Threshold-Crossing Detector," Technical Report 456, Research Laboratory of Electronics, M. I. T., Cambridge, Mass., August 31, 1967.
2. B. W. Stuck, "Switching-Time Jitter Statistics for Bipolar Transistor Threshold-Crossing Detectors," S. M. Thesis, Department of Electrical Engineering, M. I. T., June 1969.

A. WORK COMPLETED

1. FIRST-PASSAGE TIME STATISTICS OF
A RAMP PLUS NOISE

A Master's thesis with this title was presented to the Department of Electrical Engineering, M. I. T., by Marvin R. Sambur, in August 1969.

D. E. Nelsen

B. TIME-DOMAIN SYNTHESIS

In 1956, M. V. Cerrillo reported on a method of time-domain linear synthesis wherein he considered systems whose impulse responses were of the type shown in Fig. XXIX-1a. By approximating them with a string of m pulses (as in Fig. XXIX-1b) he was able to show that any of the following operations could be realized: pure transmission, delayed transmission, advanced transmission, any derivative up to order $(m-1)$, any linear combination of these.

Two such systems have been built for $m_{\max} = 4$, one of which is reported here. The heart of this realization is an analog shift register (see Fig. XXIX-2). This is essentially a string of sample-and-hold circuits, clocked by a digital timing network in such a way as to operate like a shift register with analog sampled levels in place of ones and zeros. The contents of each sample-hold are tapped and multiplied by some a_k , then summed together so that

$$\begin{aligned} y(t) &= a_1 x(t-\delta) + a_2 x(t-2\delta) + a_3 x(t-3\delta) + a_4 x(t-4\delta) \\ &= x(t)^* [a_1 u_0(t-\delta) + a_2 u_0(t-2\delta) + a_3 u_0(t-3\delta) + a_4 u_0(t-4\delta)]. \end{aligned}$$

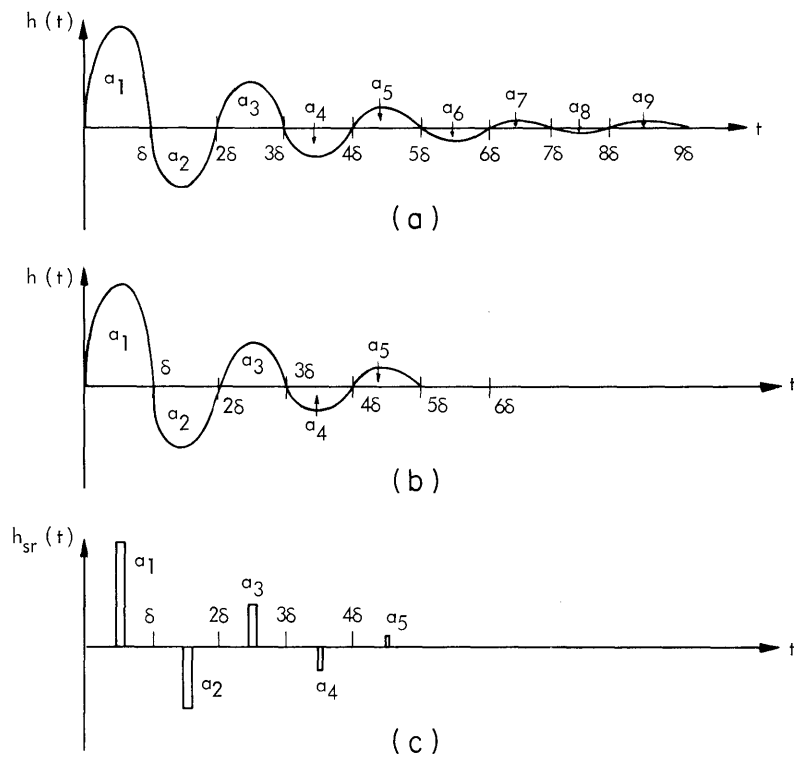


Fig. XXIX-1. (a) Type of impulse response under consideration.
 (b) Pulse approximation of $h(t)$. $\hat{h}(t)$
 (c) Shift-register realization of $h(t)$.

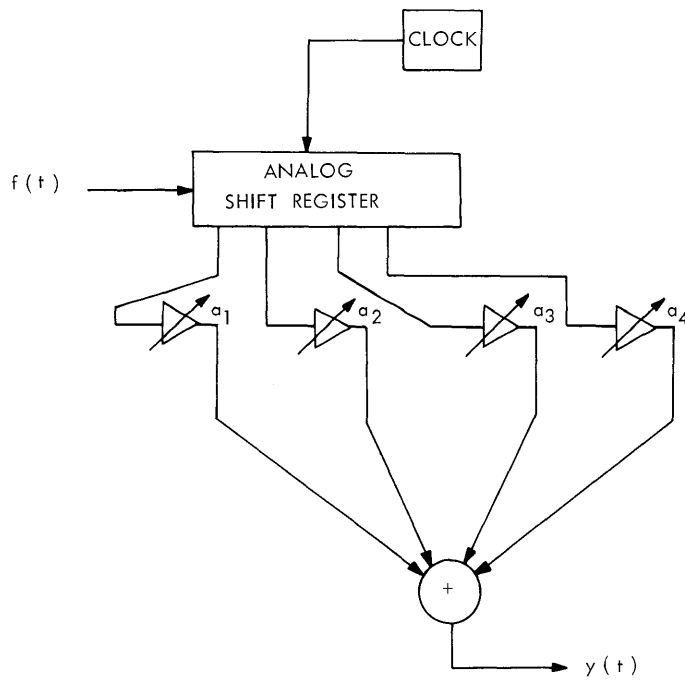


Fig. XXIX-2. Diagram of the system for synthesizing $\hat{h}(t)$.

(XXIX. SIGNAL PROCESSING)

If all of the frequencies of interest in $x(t)$ are sufficiently below $1/\delta$, it makes little difference if impulses or pulses are used as long as correct areas and spacings are maintained. Thus we have a valid approximation of the type of response under consideration.

By setting the coefficients properly and in the manner that Dr. Cerrillo had stated, quite good results were obtained. Within the bandwidth restrictions set out above, the system was able to produce all of the predicted operators very satisfactorily. Further research into the behavior of such systems in the frequency domain is being carried out by R. Kent Stockwell.

M. Bruce-Lockhart