HYBRID COMPUTER TECHNIQUES FOR DETERMINING PROBABILITY DISTRIBUTIONS

INTRODUCTION

These notes describe, in general, the unique circuits for computing instantaneous (IAPD) and peak (PAPD) amplitude probability distributions, using an EAI 231 R General Purpose Analog Computer combined with the Ames digital logic simulator (DLS) . . . a prototype of the EAI Digital Operations System (DOS 350). There is also described briefly an application of this automated method involving dynamic-stability studies of space vehicles.

A large number of engineering and scientific problems involve the concepts of probability and statistics. In a strictly academic problem, it is relatively easy to determine probability distributions. In practical problems, however, it is a long, tedious and costly task to obtain such distributions when the information from recorded random signals must be analyzed graphically by hand.

DEFINITIONS AND ASSUMPTIONS

The following terms, as used in these notes, are defined for clarity in interpreting the discussion:

IAPD: This is understood here as the percentage of time a random signal is above some arbitrary amplitude level, where there are n arbitrary levels to provide the distribution comparison.

PAPD: This is identical with IAPD except that comparison is made for the total number of peaks above the arbitrary level.

Root-Mean-Square (RMS) The normal meaning is used here; that is

$$E_{RMS} = \sqrt{\frac{1}{T} \int_{t=o}^{t=T} \left[f(t)\right]^2 \, dt}$$

where T is the signal period.

Absolute Value This term is synonymous with rectification as used here. That is, all negative portions of the signal are inverted after any d-c components have been removed. This can be expressed as:

$$\left| f(t) \right| = \left| f_1(t) - \frac{1}{T} \int_o^T f_1(t)\, dt \right|$$

where f_1 (t) is the signal recorded on the tape. Figure 1 shows the rectification (the absolute value) of a typical signal.

Counter: A counter is a circuit constructed of flip-flops and gates that is capable of counting either a number of events or a time duration. When properly enabled, a counter can count either up or down and in either binary or decimal.

Analog Comparator: A comparator is a device capable of accepting two analog inputs and producing either a high or low output logic level depending on the sign of the sum of the inputs.

Digital Differentiator: In this application, one-way differentiators were used. These produce a blip one clock pulse wide when the logical input changes from a low level to a high level.

The basic assumptions made in designing the circuits were: (1) signal samples are statistically independent, and (2) the frequencies of interest are between 10 cps and 150 cps.

SIGNAL PREPARATION

The signal, recorded on magnetic tape, must be processed before it is analyzed in the DLS. This processing must include the following: (1) signal

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amplification, (2) drift compensation (trend removal), (3) rectification, (4) level selection, (5) sampling rate selection, and (6) RMS calculation.

Figure 2 shows the analog computer circuit devised to accomplish items 1, 2, and 3.

Figure 3 shows the circuit devised to generate the RMS (item 6) of the information signal continuously.

A typical information signal and its rectified signal are shown in Figure 4. In this case, the majority frequency content is about 20 cps.

Level Selection (item 4): The signal was quantized into eight discrete levels, counting the zero volt level. Levels were selected by setting potentiometers manually between 0 and 16 volts.

Sampling Rate (item 5): Sampling rate was varied by adjusting the variable clock frequency (using counters), and can be adjusted easily for analyzing data with higher or lower frequency components.

SYSTEM APPLICATION

Pressure cell and strain gage measurements were made of turbulent air flow and structural oscillations of a space-vehicle and launch-vehicle combination during ascent through the atmosphere. The purpose was to determine the suitability of different combinations of space vehicles, boosters, and escape tower shapes on the dynamic stability of a space launch system. The signals were recorded on magnetic tape using FM and the information then fed to the computer to determine the probability distribution curves.

Using the circuits and signal processing procedure described above, and special digital circuits for up- and down-counting, the IAPD and PAPD curves for this study were obtained and agreed favorably with the normal distribution curve (IAPD) and the Rayleigh distribution curve (PAPD).

The method is very economical compared with other methods. The same data, for example, that it takes 5 to 7 man-days to reduce by hand can be reduced in 30 seconds by this combined hybrid system.

Please send for Application Study: 2.4.2h, Bulletin No. ALHC64053 for complete details on this hybrid application.

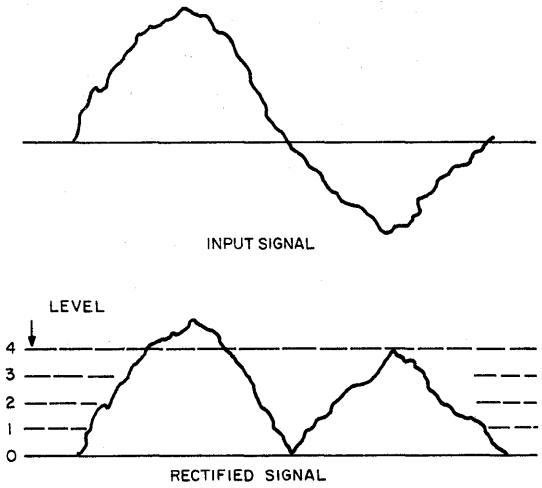

Figure 1. One Cycle of a Typical Information Signal

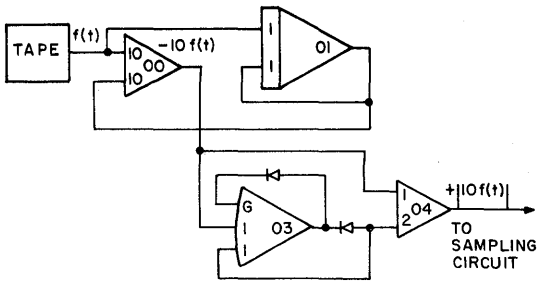

Figure 2. Analog Computer Circuit

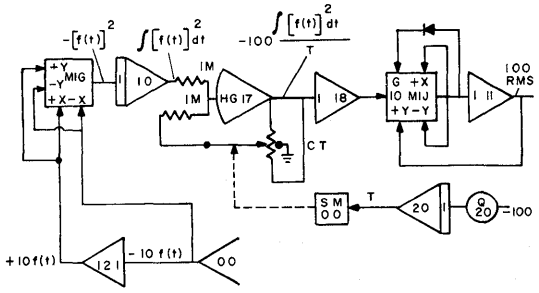

Figure 3. RMS Circuit

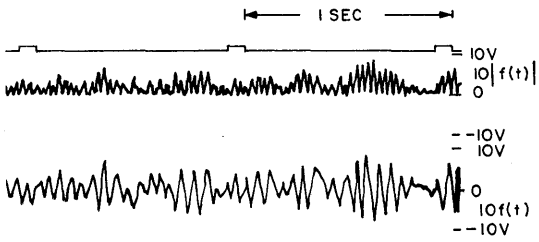

Figure 4. Typical Information Signal