A CENTRAL PROBABILITY-GENERATING STATION¹

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Instead of choosing fixed values of independent variables, some experimenters prefer to specify only the expected mean value, and to allow the value to vary probabilistically. Several devices are available for arranging the random variation of a variable in the laboratory. Descriptions are given by Clark and Hull (1965), Millenson (1963), Schoenfeld, Cumming, Hearst, Snapper, and Haas (1960), Schoenfeld, Cumming, Snapper and Haas (1960), and Thomas and Curran (1964). Probability gating devices are also commercially available. The commonly used devices have the same inadequacy—*i.e.*, at any setting, they generate a fixed probability. (The device described by Thomas and Curran avoids this limitation, but has only one input.) An expensive piece of equipment can thus be used in only one experiment at a time. Figure 1 shows a probability generator which can be used to obtain different probabilities at the same time. One part represents the digital logic, the other the actual circuitry, as explained below.

The principle of operation is simple. A clock sends pulses to a series of flip-flops. The output of a flip-flop (FF) is sent to one leg of an AND gate (A1, A2, A3, A4 in Fig. 1). The "last" leg of the AND gate receives the input to be operated on. The input is shaped by a one-shot (OS) into a square wave of very short duration with respect to the period of the clock. (The OS was set at 100 μ sec and the clock at 100 cps, but operation was satisfactory with frequencies up to 1000 cps.) The output of the AND gate controls a power-handling device, such as a relay-driver (RD). Consider A1. It has two legs (inputs), one con-

nected to FF1, the other to the input. An output thus requires that there be an input and that FF1 is in one of its two possible states (state 1). Therefore, on the average, nearly half the inputs will result in outputs, provided the inputs are not synchronized with the clock. The distribution of outputs will be that of a series of Bernoulli trials. A2 has three legs. One is connected to FF1, one to FF2, and one to the input. In this case, one quarter of the inputs will result in outputs. The probability of an output can be made as low as required simply by adding an FF, an AND gate, and the associated circuitry. The latter may have to include amplifiers of the output (state 1) of FF1, FF2, *etc.*

So far, each of the output stations represents a different transfer function with respect to the same input. The inputs from different experiments are distinguished by putting each input with the probability output through another AND gate (AX in Fig. 1). Then, the condition for a particular output is that the probability generator has given an output, and that a particular input has occurred. The logic of this method is portrayed in the case of inputs 3a and 3b in Fig. 1.

Digi-bits were used to build the system. The total cost was \$620 including power supply. It requires only a few hours to assemble, even for someone not familiar with digi-bits. Four FF's were used, giving a minimum probability of .0625. The system was to be used with conventional relay equipment. Therefore, AX was made with relays on a panel to be fixed on the relay rack. The design of AX is shown below the broken line in Fig. 1. An input closes relay 1, which in turn sends an input to the probability generator. If, and only if, the probability generator produces an output, relay 2 closes for the duration of that output (50 msec). Relay 1 is also kept closed for the same time to render further inputs ineffective.

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Fig. 1. Representation of the device described in the text. Clock: Digi-bits MV106; Control: Digi-bits CX105; FF1, FF2, FF3, FF4: Digi-bits FF101; OS (input): Digi-bits OS102; OS (output): Digi-bits OS102 with .33 μ F ext. cap; A1, A2, A3, A4: Digi-bits AG103; RD: Digi-bits RY104; R1, R2: Potter and Brumfield KR6069; R: 330 ohms; C: 25 μ F.

Thus, the arrangement shown for input 4 represents a particular realization of the logic shown in the case of inputs 3a and 3b.

The control package (CX105—marked “control” in Fig. 1) may be replaced by an FF, which is less expensive. The circuit is represented in the inset. The contacts shown there are those of R1. In the resting state, the FF is set and maintained in state 0 by the application of 12 v through the contacts of R1. The FF is maintained in State 1 so long as R1 operates. The output (State 1) of the FF drives the input OS. Standardizing pulse width by CX105 is superfluous since the input OS also standardizes the pulse width. Moreover, in this application no precaution is required against the possibility of contact bounce in R1, because multiple closures of the NO input contacts of R1 will have exactly the same effect as a single closure—i.e., changing the state of the

FF from 0 to 1. The input control represented in the inset is therefore the more elegant one from a logical point of view.²

Five inputs and outputs were provided for each probability value, but any number could be added. The generator serves a whole laboratory, with several different experiments running simultaneously.

Expected and obtained values have been compared over several months. Results show that actual mean frequencies of outputs were slightly smaller than the expected values.

The outputs at each probability station are not independent. If the same state of the FF's is connected to all the AND gates, then all outputs at a given AND gate will coincide with “potential” outputs at all the AND gates

²I am grateful to F. Hegge for suggesting the use of an FF as an input controller.

representing a lower probability. Therefore, it is not, for example, possible to obtain a probability of .75 by paralleling the inputs and outputs of the first two stations ($p = .5$ and $p = .25$), unless the inputs are desynchronized. This can be done on the rack by using, for R1, relays which have different closure times. Otherwise, the probabilities available are restricted to the negative powers of 2.

Digital logic devices are unpopular because of their sensitivity to noise (transients). The device described here has a valuable fail-safe feature: no output is registered on the rack unless relay 1 has operated, and the relay is virtually noise-proof. The fact that obtained output frequencies were actually lower than expected values indicates that noise in the system is not a practical problem.

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