INSTRUMENTATION & TECHNIQUES

An inexpensive quasirandom interpulse interval generator

NAOYUKI OSAKA

Otemon-Gakuin University, Ibaraki, Osaka, Japan 567

Using modulo-2 (exclusive-OR) feedback logic, quasirandom interpulse intervals can easily be generated at very low cost. These intervals can be used as quasirandom foreperiods for reaction latency measurements during vigilance tasks.

Figure 1 illustrates a block diagram of the logic implementation. Clock generator (NE555) supplies shift pulses to each of the 15-stage presettable shift registers (SN7496 X 3), in which the preset data are shifted from the 1st (A) to the 15th (O) register. The logic circuit is distinguished by the use of modulo-2 feedback (SN7486) for the maximum length linear shift register generator counters (MLS) (Morris & Miller, 1971, p. 299). The length of the cycles generated is dependent on the points from which the feedback is generated (for details of the feedback connections, see Watson, 1962, p. 369). For example, a 15-stage MLS

counter, with feedback taken from 14th (N) and 15th (O) stages, has a maximum cycle length of $2^{15} - 1$ (32,767), where 15 is the number of shift register stages: Maximum length is defined as $2^N - 1$, where N is the number of stages. The function fed back can be any modulo-2 term, and is generally expressed in Boolean function as: $F = aA \oplus bB \oplus \dots \oplus nN \oplus oO$, where a, b, ..., n, o are coefficients that have a value of either zero or one. The operator $\oplus$ indicates exclusive-OR function. In this case, one sets $F = 000 \dots 011$. At the time after the nth (ϕ_n) shift pulse, one gets n+1th (ϕ_{n+1}) state bit pattern, which can be related

Figure 1. Low-cost circuit for a quasirandom interpulse interval generator.

Figure 2. Frequency histogram of the output.

to ϕ_n by a transition matrix as:

$$\begin{bmatrix} F \\ O \\ N \\ \vdots \\ C \\ B \end{bmatrix} = \begin{bmatrix} 000 \dots\dots\dots 11 \\ 1 & & & & 0 \\ & 1 & & & 0 \\ & & \ddots & & \vdots \\ & & & \ddots & \vdots \\ & & & & 100 \\ & & & & 10 \end{bmatrix} \begin{bmatrix} O \\ N \\ M \\ \vdots \\ B \\ A \end{bmatrix}$$

$$[\phi_{n+1}] = [T] [\phi_n],$$

where $[T]$ is the transition matrix, and A, B, ..., N, O correspond to 1st, 2nd, ..., 15th register, respectively. For example, if $\phi_n = [000 \dots 010]$, then $\phi_{n+1} = [100 \dots 001]$, $\phi_{n+2} = [110 \dots 000]$, and $\phi_{n+3} = [011 \dots 000]$ are obtained.

Overall behavior of the circuit can be observed at Point X in Figure 1 (output of the last register), where a series of pulses such as 0100... can be obtained as an original pulse train. Within Periods 0 and 1, $2^{N-1} - 1$ and 2^{N-1} , respectively, can be obtained.

Figure 3. Autocorrelation $\phi(\tau)$ as a function of τ . An output analysis.

Table 1
List of Components for Quasirandom Interpulse Interval Generator

IC 1	Signetics NE555 linear integrated timer.
IC 2, 3, 4	Texas SN7496 5-bit shift registers.
IC 5	Texas SN7486 quadruple two-input exclusive-OR gates.
IC 6, 7	Texas SN74121 monostable multivibrators.
IC 8	Texas SN7404 hex inverters.
C1	100 μ F 25-V electrolytic capacitor.
C 2, 3	10 μ F 25-V electrolytic capacitors.
R 1	1 M Ω preset register.
R 2, 9, 10	50 k Ω preset registers.
R 3, 4	3.3 k Ω 5% resistors.
R 5, 6, 7, 8	270 Ω 5% resistors.
D 1, 2, 3, 4	Toshiba TLR-102 light-emitting diodes.
SW 1, 2	Omron SSL1L microswitches.

Note—Refer to Signetics (Note 1) and Texas Instruments (Note 2) publications.

Each register can be parallel loaded by using the clear switch in conjunction with the preset inputs. After clearing all stages to zero levels, data to be loaded are applied to the individual preset inputs (A, B, . . . , N, O), and a one-loaded pulse is applied to the preset switch. Presetting, like clearing, is independent of the level of the clock pulse. The clear switch must be one, and the preset switch or preset inputs must be zero when clocking occurs.

While the shift register can be preset to almost any value, zero in all bits is not allowed. An occasional advantage is that any "random" sequence can be duplicated exactly by presetting the shift register to almost any value used to initiate the initial sequence.

In Figure 1 uniformly distributed one and zero can be observed at light-emitting diode (LED) output D1, whereas positive (D2) and negative (D4) edge-triggered pulse, of the original pulse, are generated using a one-shot function (SN74121 X 2) at a variable-time constant (by R9 and R10) up to approximately 280 msec. Quasirandom interpulse intervals can be observed at output D3 where both edge-triggered pulses are exclusive-OR gated. Count trigger output of each one-shot can be used as a reaction latency measurement. High-voltage ac control can also be implemented by using the Triac in connection with a photocoupler instead of LED output.

Figure 2 is a frequency histogram of interpulse intervals for 269 sample pulses. The clock frequency was adjusted at approximately .5 Hz using R1 and R2: The frequency of oscillation is given by $1.46/C1(R1 + 2R2)$. The histogram is skewed as expected from mathematical

properties of the MLS. The frequency for each run's length (interval) is 2^{N-r} , where r is the run's length ($N > r$). To test the serial randomness of the output, an autocorrelation analysis was performed using the following formula:

$$\phi(\tau) = N^{-1} \sum_{t=1}^N X(t+\tau)X(t), \quad (\tau = 0, 1\Delta, 2\Delta, \dots, m),$$

where τ , N , t , and Δ indicate time lag (maximum lag $m = 58$), length of the data sample ($N = 269$), time point, and half clock cycle, respectively. The results (shown in Figure 3) indicate that the MLS counter generates generally good quasirandom interpulse intervals for reaction latency study.

Components are listed in Table 1. Total cost of the components is approximately \$5.

REFERENCE NOTES

1. Signetics Corporation. *Signetics linear data book* (Vol. 1), 1972.
2. Texas Instruments, Inc. *The TTL data book for design engineers* (1st ed.), 1973.

REFERENCES

- MORRIS, R. L., & MILLER, J. R. (Eds.). *Designing with TTL integrated circuits*. New York: McGraw-Hill, 1971.
- WATSON, E. J. Primitive polynomials (Mod 2). *Mathematical Computation*, 1962, 16, 368-369.

(Received for publication September 22, 1976;
revision accepted August 12, 1977.)