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Two-channel random pulse generator

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The amplification of random thermal noise is utilized to generate two channels of pulses whose frequencies are random with time. The phase relationship between the two channels is also random with time. The pulses can be used to randomize presentation of stimuli for experimentation or training.

Random or pseudorandom quantities are often generated digitally with counters, switches, and monostables. The circuit of Figure 1 utilizes a random analog quantity (the voltage fluctuations due to atomic thermal vibration) to generate a random digital output. Thermal noise is statistically random, but it is often difficult to prevent pickup from periodic voltage sources such as 60-Hz line signals from contaminating an electronically generated thermal noise signal. This contamination cannot be prevented by the relatively low common-mode rejection (CMR), 70-90 dB, of most amplifiers.

In the circuit of Figure 1, thermal noise is amplified by an integrated-circuit instrumentation amplifier, A1 (AD521J). This circuit has a CMR of 110 dB at a voltage gain of 1,000, which effectively eliminates 60-Hz influence at the output of A1.[1] This output, thermal noise voltage of approximately 1-mV peak-to-peak amplitude, is ac coupled to a second gain stage, Amplifier A2. The value of capacitance is chosen to attenuate less than 1-Hz 1/f low-frequency noise to give a more uniform noise-frequency spectrum. Amplifier A2 does not require high CMR, since the effect of unwanted signals in a system is basically determined by the first-stage contribution. The amplified thermal noise voltage at the output of A2 has a peak-to-peak amplitude of approximately 210 mV maximum. The amplitude is random with time. However, this is wide-band noise, composed of a wide range of frequency components, and is not too useful. Amplifier A3 forms a narrow band-pass filter (Pease, Note 1) which is set to transmit only a narrow range of the frequency components of the wide-band noise. This small frequency band controls the occurrence of signals which have large enough amplitude to trigger the comparator, Amplifier A4. The amplitude vs. frequency characteristic of the filter is shown in Figure 2. In this circuit, the 25-kΩ potentiometer setting controls the center frequency, f_o, without changing other characteristics of the filter such as 3-dB bandwidth and gain at f_o.[2] (Changing the center frequency does, however, change the Q of the circuit.)

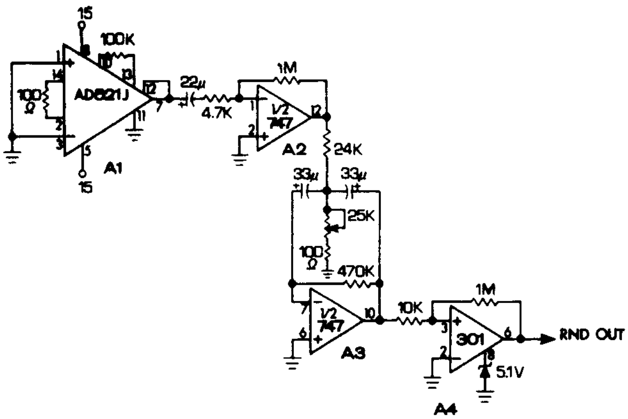

Figure 1. Circuit for generating a random digital frequency.

The comparator used here is a 301A operational amplifier constrained to make TTL-compatible transitions at its output by using a 5.1-V Zener diode at Compensation Pin 8. A small amount of positive feedback from the 1-MΩ resistor creates a slight hysteresis (5 mV) in the comparator trigger voltages. This addition avoids oscillation in the comparator due to a slowly changing voltage at the input.

The filter gain-frequency characteristic determines the probability distribution of the frequency of occur-

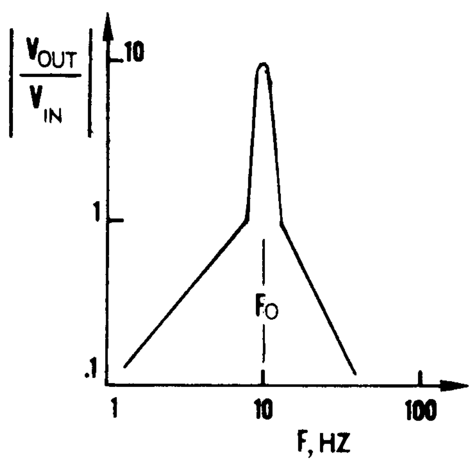

Figure 2. Gain-frequency characteristic of the band-pass filter section.

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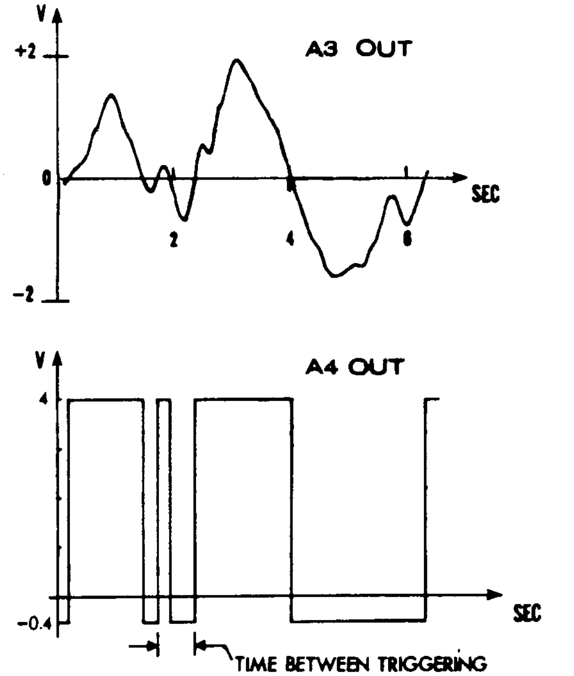

Figure 3. Example of filter and comparator output voltages for f_o = .5 Hz.

rences. The mean time between triggerings is determined by the center frequency, f_o, of the filter. The probability distribution of the random time between triggerings will have a shape similar to Figure 2, with a mean at $1/f_o$ sec and a σ related to the bandwidth and Q of the filter.

As an example, if the center frequency is set to .5 Hz, only the voltage summation of a narrow band of noise frequencies about .5 Hz is transmitted through to the comparator. This voltage will trigger the comparator a random number of times per second as the voltage randomly crosses the comparator threshold voltage, again an average of once every 2 sec, as illustrated in Figure 3. The standard deviation of this value is related to the Q of the filter. A histogram representation of the distribution is shown in Figure 4.[3]

For independent control of both f_o and σ, a different filter scheme is required, since this filter changes both quantities simultaneously. Logically, different combinations of low-pass, band-pass, and high-pass filters can introduce control of kurtosis or skew, as well.

Possibly the most straightforward control of f_o and σ can be obtained by using two variable filters, one low-pass and one high-pass. The location of the corner frequency of each can be used to control the shape of the distribution.

Two of these random pulsers are used in the two-channel stimulator. The two channels of random logic pulses are used to trigger Monostables OS1 and OS2 in Figure 5. The two channels are randomly different in phase. When triggered, a monostable output changes state for a time, τ_o. This time is the stimulus presentation time and can be controlled by varying R. For the 74123,

$$\tau_o = .28\ RC.$$

Simultaneous activation of both channels is prevented by feeding the monostable output of one channel into the CLEAR input of the other. When one channel is activated (i.e., its output goes LO), the application of a LO to the CLEAR input of the other channel prevents all output transitions on that channel until the stimulus time is over.

The outputs are also fed into transistor drivers to light a LED lamp for each channel as a visual aid for the duration of the stimulus presentation. Total component costs for the two-channel random stimulus generator are less than \$50, including resistors and potentiometers, or less than \$25 for one channel. Truth tables for the 7474 and 74123 can be found in any manufacturer's TTL data book.

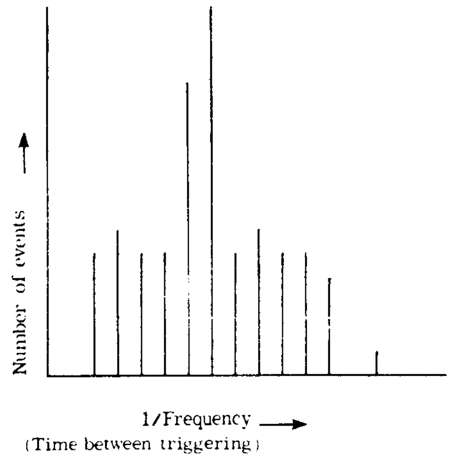

Figure 4. Representative probability distribution of the time between comparator triggerings for f_o = .5 Hz.

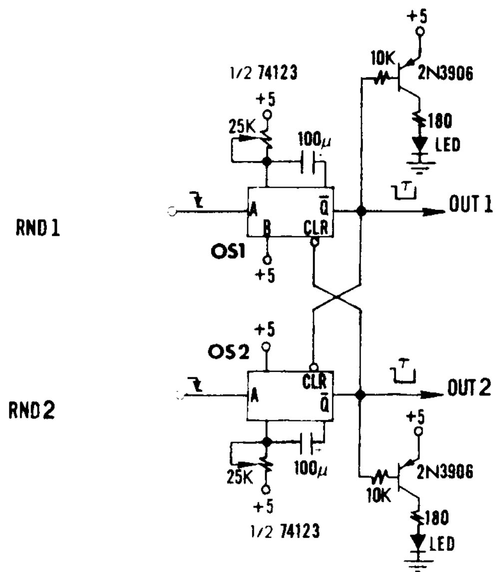

Figure 5. Two-channel stimulator circuit.

COMPONENT LIST

AD521J: Instrumentation amplifier, Analog Devices, Inc.
747: Dual op amp package, any mfr.
301A: General-purpose op amp, any mfr.
7474: TTL medium-speed D-type flip-flop, any mfr.
74123: Dual TTL monostable, any mfr.
2N3906: General-purpose PNP transistor, any mfr.

REFERENCE NOTE

1. Pease, R. A. *Band-pass active filter with easy trim for center frequency.* Teledyne Philbrick Application Bulletin, No. 4, 1972.

NOTES

1. If the differential input voltage is zero, the effect at the output of a common-mode voltage is, in a closed loop: $V_o = AV_C/(CMR)$, where V_o = output voltage, A = closed-loop gain, V_C = common-mode voltage, (CMR) = common-mode rejection.
2. For the component values shown in Figure 1, $.06\ \text{Hz} \leq f_o \leq .6\ \text{Hz}$.
3. By using a computer to count and measure times between triggerings, we obtained histogram distributions of the time between triggerings. These were not possible to hard copy, so a typical histogram is shown.

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