A PULSE GENERATOR FOR TESTING SHIFT-REGISTER
COINCIDENCE ELECTRONICS

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A Pulse Generator for Testing Shift-Register Coincidence Electronics

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Abstract

A multi-function electronic pulser has been implemented as a nuclear instrument module for the checkout and debugging of neutron coincidence counter shift-register electronics. The pulser has five different outputs: random, correlated, periodic, burst, and a long-delay circuit check. The frequency for the random and periodic is selectable from frequency of 5 kHz and consists of pulse pairs produced randomly at a rate of 2.5 kHz. The second pulse of a pair follows the first with a probability proportional to \( \exp(-t/\tau) \). The correlated pulser produces an exponential die-away after 0.5 \( \mu \)s following the first pulse of the pair. The burst pulser produces a fixed burst of 16 at a rate of 16 MHz; the burst rate is 100 Hz. The long delay is used to check the long delay of a shift-register. The long delay consists of pulse pairs separated by 4096.5 \( \mu \)s produced at a rate of 100 Hz.

Introduction

A prototype pulse generator has been developed for testing shift-register coincidence electronics without the use of neutron sources and detectors. This project is part of a program to produce random and correlated pulse streams under computer control for automated testing of coincidence electronics and for simulation of neutron coincidence assay systems for measurement control, detector development, and training activities. The present prototype pulse generator tests all of the digital circuits used for collecting data from neutron pulse streams in coincidence electronics packages. This prototype (Fig. 1) is packaged in a single-wide Nuclear Instrumentation Module (NIM) and is manually operated. Six of these modules have been built.

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Description

The pulser produces five types of pulse streams as described below. All of the output pulses have transistor-transistor logic (TTL) voltage levels (roughly +5 V during a pulse and roughly zero between pulses) and have 32-ns pulse widths. The pulser uses an internal 16-MHz clock as a reference for all of the output pulse streams. This clock has a specified accuracy of 0.01% within its operating range; in practice, it is observed to be accurate to 0.001% at room temperature.

Periodic

The periodic output produces uniformly-spaced pulses at frequencies from 8 MHz to 15.2588 Hz in steps of a factor of 2. The frequency is chosen with push-button switches; the frequency is $2^n \times 16$ MHz, where $n$ is the push-button setting ($1 \leq n \leq 20$).

Random

The “random” pulses are produced by a pseudo-random pulse generator following the design of Swansen and Ensslin. The logic was implemented in a field-programmable logic array (FPLA) and fits into a single FPLA chip. The output pulses are synchronized with the 16-MHz clock; the start of consecutive pulses is never closer together than 62.5 ns. A three-position toggle switch below
the push-button switches on the front panel of the pulser selects whether the output is periodic, random, or correlated. The frequency of the random output is selected just as for the periodic output and has the same range of choices.

**Correlated**

The correlated output has a fixed frequency of 5 kHz and consists of pulse pairs produced at random at a rate of 2.5 kHz. The second pulse of a pair follows the first with a probability proportional to \( \exp(-t/\tau) \), where \( t \) is time after the first pulse and \( \tau \) is the pulse die-away time. The pulse die-away time represents the neutron die-away time in a thermal neutron detector and is fixed at 100 µs in the pulser. The correlated pulser produces an exponential die-away after 0.5 µs following the first pulse of the pair. The correlated pulser can therefore be used to test the predelay and gate settings in the shift-register electronics, provided that the predelay is set to \( \geq 0.5 \) µs.

**Long delay**

The long-delay pulser output is used to check the long delay in the shift register. It consists of pulse pairs produced periodically at a rate of 100 Hz. The second pulse always follows the first after a 4096.5 µs delay. Because the long delay in the shift-register coincidence circuit is 4096 µs, the long-delay pulser should produce coincidence counts in the accidental gate when the predelay is < 0.5 µs, but not when the predelay is > 0.5 µs.

**Burst**

The burst pulser is used to test the input derandomizer of the shift-register coincidence circuit. The burst pulser produces bursts of 16 pulses periodically at a rate of 100 Hz. The pulses in the burst are spaced 62.5 ns apart, so all 16 are produced in 1 µs. Because the shift register in the coincidence circuit operates at 4 MHz (250 ns per shift), the input pulses during a burst arrive too quickly to be stored directly in the shift register. They are saved in the derandomizer until space is available in the shift register. If the derandomizer is working correctly, no pulses from the burst pulser will be lost.

**Test procedure**

To use the pulser to test a shift-register coincidence circuit, connect the pulser output to the shift-register input and use the neutron coincidence counting (NCC) code to operate the shift-register circuit. The attached spreadsheet shows an example worksheet to test the Los Alamos MSR4, the Canberra 2150, and the Aquila PSR circuits. The full test consists of all 12 measurements and 16 rate comparisons; it takes about 45 minutes to complete. A partial test, which can be done in about 20 minutes, consists of measurements 2, 3, 4, 11, and 12; if these tests pass, the others are very
likely to pass also. The last column in the worksheet shows “Pass/fail” for the checksum test; if this test fails for any run in a measurement, an error message appears in the NCC code at the end of the line showing the count rates for that run.

<table>
<thead>
<tr>
<th>Mean</th>
<th>Pulser</th>
<th>Bit</th>
<th>Switch</th>
<th>Checksum</th>
<th>Mean</th>
<th>Probability</th>
<th>Gate</th>
<th>Tested</th>
<th>Expected</th>
<th>Measured</th>
<th>Lower</th>
<th>Upper</th>
<th>Pass/fail</th>
<th>Pass/fail</th>
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<td>input</td>
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<td>test</td>
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<td>rate (1%)</td>
<td>rate (1%)</td>
<td>(1%)</td>
<td>(1%)</td>
<td>(1%)</td>
<td>(1%)</td>
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<td>3,999,800</td>
<td>4,000,400</td>
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<td>****</td>
<td></td>
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<td>16</td>
<td>singles</td>
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<td>3,787,000</td>
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<td>signal</td>
<td>****</td>
<td>on</td>
<td>30 x 10</td>
<td>3</td>
<td>64</td>
<td>singles</td>
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<td>****</td>
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<td>on</td>
<td>30 x 10</td>
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<td>64</td>
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<td>burst</td>
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<td>4,001,000</td>
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<tr>
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<td>scaler</td>
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<td>3,999,000</td>
<td>4,001,000</td>
<td>****</td>
<td>****</td>
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</table>

Setup parameters in NCC code:

- Background: all background rates = 0 (under "Edit | Background")
- Normalization constant = 1 (under "Edit | Normalization")
- Shift-register type: MSR4 (2150) or PSR (under "Edit | Detector parameters")
- Deadtime: all deadtime parameters = 0 (under "Edit | Detector parameters")
- Detector die-away time = 100 (under "Edit | Detector parameters")
- Standard deviation calculation: theoretical (under "Edit | Error calculation method")
- Quality-control tests: off (under "Acquire | Rates only")
- Checksum test: depends on measurement; see table (under "Edit | Test parameters")
- Acquire all data under "Acquire | Rates only".

Note:
- For measurements 7, 8, 9, and 10, exact agreement is required, but not every line each test is done.
- The pulser and shunt register clock are not synchronized: if a measurement happens to start during a
- burst (short test) or between a pair of pulses (long delay test), the test can fail.

Comment

The next goal in the pulser development is to produce a prototype pulser that will generate arbitrary singles, doubles, and triples rates under computer control at total count rates up to 500 kHz. This will permit automated testing of coincidence circuits and realistic simulations of neutron detector outputs.

Reference