



# Red Hat

## **OpenSSL CPU Time Jitter RNG Entropy Source version 2.2.0**

### **SP 800-90B Non-Proprietary Public Use Document**

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# Table of Contents

1 Description.....	. 2
2 Security Boundary.....	. 2
3 Operating Conditions.....	. 3
4 Configuration Settings.....	. 4
5 Physical Security Mechanisms.....	. 4
6 Conceptual Interfaces.....	. 4
7 Min-Entropy Rate.....	. 4
8 Health Tests.....	. 5
9 Maintenance.....	. 6
10 Required Testing.....	. 6

# 1 Description

The OpenSSL CPU Time Jitter RNG version 2.2.0 is a non-physical entropy source, part of the kernel binary and OpenSSL FIPS provider, that feeds the secondary DRBGs in the OpenSSL. The noise generation of this entropy source is based on the tiny variations in the execution time of the same piece of code. The execution time of this piece of code is made unpredictable by the complexity of the different hardware components that comprise modern CPUs and the different internal states that the operating system can have at a certain point in time.

The entropy source was tested on the operational environments listed in Table 1 using both possible timers. The noise source was tested under the assumption that its output is non-IID.

*Table 1: Operational environment and version.*

<b>Manufacturer</b>	<b>Model</b>	<b>Operational Environment and Version</b>	<b>Processor</b>
Dell	PowerEdge R440	Red Hat Enterprise Linux 9	Intel(R) Xeon(R) Silver 4216
IBM	z16 3931-A01	Red Hat Enterprise Linux 9	IBM z16
IBM	IBM 9080-HEX	Red Hat Enterprise Linux 9 on PowerVM FW1040.00 with VIOS 3.1.3.00	IBM POWER10

# 2 Security Boundary

The boundary for this non-physical, software-based entropy source is the executable code compiled from the C code that implements it. The noise source, LFSR, and HMAC-SHA-512 conditioning component are implemented as part of the kernel executable. The AES-256 CTR DRBG conditioning component is implemented in the OpenSSL FIPS provider.

Figure 1 depicts the overall design of the entropy source and its core operations.

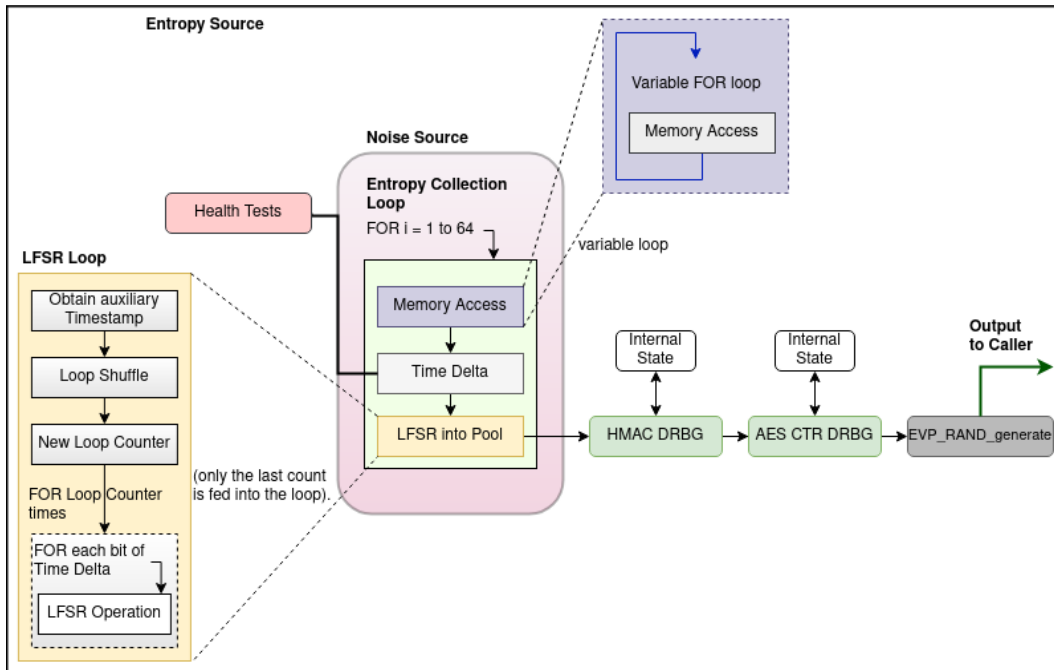


Figure 1: CPU Jitter 2.2.0 Design

The noise source is implemented by collecting and accumulating variances of the execution time of a defined set of instructions. The accumulation is done with the assistance of a Linear-Feedback Shift Register (LFSR) function that works as the first conditioning component of the entropy source, as well as an entropy pool that is used to accumulate the acquired entropy, then the NIST SP 800-90Ar1-compliant HMAC-SHA-512 DRBG (the second conditioning component), and finally the AES-256 CTR DRBG (the third conditioning component), implemented in OpenSSL. The time jitter of the execution time is measured over the processing logic of the LFSR and functions that support the implementation.

If the Repetition Count Test (RCT) or the Adaptive Proportional Test (APT) health tests fail, the noise data is discarded, the entropy source halts without outputting any data, and a failure code is returned to the caller. If the health test failure is permanent, the kernel which contains this entropy source will panic.

### 3 Operating Conditions

The noise source is non-physical, and thus the operating conditions are inherited from the operational environment in which the entropy source is installed, as shown in Table 2 below.

Table 2: Operating Conditions for each Operational Environment

Manufacturer / Model	Temperature	Voltage	Humidity	Clock Speed	Cache Sizes
Dell PowerEdge R440	10C° - 35C°	+5V	10 to 80 %	2.1 GHz	L1d: 16x32 KB L1i: 16x32 KB L2: 16x1 MB L3: 22 MB

Manufacturer / Model	Temperature	Voltage	Humidity	Clock Speed	Cache Sizes
IBM z16 3931-A01	10C° - 35C°	+5V	10 to 80 %	5.2 GHz	L1d: 8x128 KB L1i: 8x128 KB L2: 16x32 MB L3: 256 MB
IBM 9080-HEX	5.0C° - 40.0C°	200 - 208 / 220 - 240 Vac	8 to 85%	3.4 GHz	L1d: 2x64 KB L1i: 2x96 KB L2: 2x2 MB L3: 2x8 MB

## 4 Configuration Settings

The following lists “#defines” in the kernel source code jitterentropy.c:

```
#define JENT_MEMORY_BLOCKS 64
#define JENT_MEMORY BLOCKSIZE 32
#define JENT_MEMORY_ACCESSLOOPS 128
```

In addition, OpenSSL allows configuration of the following primary DRBG values:

- **random**
- **cipher**
- **digest**
- **properties**
- **seed**
- **seed\_properties**

None of these values should be altered. If any changes are made, this would invalidate the ESV entropy certificate.

## 5 Physical Security Mechanisms

The noise source is non-physical. The physical security mechanisms only apply to the hardware component of the operational environment in which the entropy source is installed, and thus the entropy source inherits those mechanisms.

## 6 Conceptual Interfaces

The entropy source provides the following interfaces:

- `EVP_RAND_generate()`: Obtains conditioned entropy for the caller. This is the main function of the entropy source, the one that shall be used to request entropy data. This interface corresponds to the `GetEntropy()` conceptual interface from SP 800-90B.
- `jent_lfsr_time()`: Obtains raw noise data for testing purposes. This interface corresponds to the `GetNoise()` conceptual interface from SP 800-90B.

## 7 Min-Entropy Rate

The noise source provides an entropy rate for each time delta of  $H_{submitter} = 1$  bit/bit.

The entropy source collects 64 time deltas of 64 bits each (4096 bits) as input to the LFSR conditioning component. This corresponds to 64 bits of entropy. The output entropy rate of the LFSR is assessed to be 0.931587 bits/bit.

Then, four 64-bit output blocks of the LFSR are used to seed the HMAC-SHA-512 DRBG conditioning component, which corresponds to 238 bits of entropy. This DRBG conditioning component outputs a 256 bit block, which is assessed to contain 225 bits of entropy.

Finally, 256 bits from the HMAC-SHA-512 DRBG is used to reseed the AES-256 CTR DRBG conditioning component, which corresponds to 225 bits of entropy. This DRBG conditioning component also outputs a 256 bit block, which is also assessed to contain 224 bits of entropy.

As a result, the entropy source provides 0.875000 bits/bit of entropy rate at its output.

## 8 Health Tests

The entropy source implements the following continuous health tests:

- Repetition Count Test conforming to SP 800-90B section 4.4.1.
  - o  $H=1$  bit of entropy per 64-bit sample.
  - o Intermittent failure alpha value  $\alpha_i=2^{-30}$ .
  - o Permanent failure alpha value  $\alpha_p=2^{-60}$ .
  - o Intermittent failure cutoff value  $C_i=31$
  - o Permanent failure cutoff value  $C_p=61$
- Adaptive Proportion test conforming to SP 800-90B section 4.4.2.
  - o  $W=512$
  - o  $H=1$  bit of entropy per 64-bit sample
  - o Intermittent failure alpha value  $\alpha_i=2^{-30}$
  - o Permanent failure alpha value  $\alpha_p=2^{-60}$
  - o Intermittent failure cutoff value  $C_i=325$
  - o Permanent failure cutoff value  $C_p=355$
- Stuck (Non-Permanent) Test: The stuck test computes the first, second and third discrete derivatives of the time value that will be processed by the LFSR. If any of these derivatives are zero, then the received time delta is considered stuck. In this case the LFSR is still updated, but the entropy value is not counted and the output of the LFSR is not used for insertion into the entropy pool. The stuck test then triggers the RCT for further processing. The second derivative is in fact the RCT itself.

As allowed by Section 4.3 of SP 800-90B, the entropy source defines two types of health test failures for the RCT and the APT: intermittent failures and permanent failures.

An intermittent failure is characterized by a false positive probability  $\alpha_i=2^{-30}$ , which lies within the recommended range of  $2^{-20} \leq \alpha \leq 2^{-40}$ . When an intermittent failure is detected, the CPU Jitter RNG is automatically reset (which includes clearing the entropy pool and resetting the DRBG conditioning component), and the caller is notified of this failure. The

only exception to this rule is during the startup tests, where intermittent failures will be treated as permanent.

Permanent failures are characterized by a false positive probability of  $\alpha_p = 2^{-60}$ . When a permanent failure is detected, the CPU Jitter RNG is also reset, but the Linux kernel that contains this entropy source immediately enters the error state. In practice, this results in a kernel panic.

The continuous-health tests are applied to each new sample obtained from the noise source.

The stuck test is considered non-permanent, as positive stuck tests will be registered but will not immediately halt the entropy source.

Startup tests conduct the same set and parameters of the continuous health tests on 1024 samples of noise data. The data is discarded after the startup tests have completed successfully. Any health test failure during the startup tests will always be treated as a permanent failure, which results in the permanent shutdown of the entropy source.

On-demand health tests of the noise source may be performed by rebooting the operational environment, which results in the immediate execution of the start-up tests. Typically, this entropy source designed for OpenSSL cannot be reloaded without restarting the executable. Similarly, the data used for the on-demand health tests are discarded after successful completion.

## 9 Maintenance

There are no maintenance requirements as this is a software-based entropy source.

## 10 Required Testing

To test the entropy source, raw data samples must be collected using a test harness that is capable of accessing the `jent_lfsr_time()` noise interface from the entropy source. The test harness and accessory kernel tools must be supplied by the vendor.

Raw noise data samples consisting of at least 1,000,000 bytes must be collected from the operational environment at its normal operating conditions and processed by the SP 800-90B entropy tool that is provided by NIST. The expected min-entropy rate must approach the one in Section 7.

Restart data must be collected at normal operating conditions through the `jent_lfsr_time()` interface following the restart procedure specified in SP 800-90B (i.e., 1,000 samples from 1,000 restarts each) and processed by the NIST SP 800-90B entropy tool. The minimum of the row-wise and column-wise entropy rate must be more than half that of the raw noise entropy rate.

If conditioned entropy data is to be tested, then the `EVP RAND generate()` interface shall be accessed instead of `jent_lfsr_time()` interface.