Non-Physical Entropy Sources

RBG Workshop
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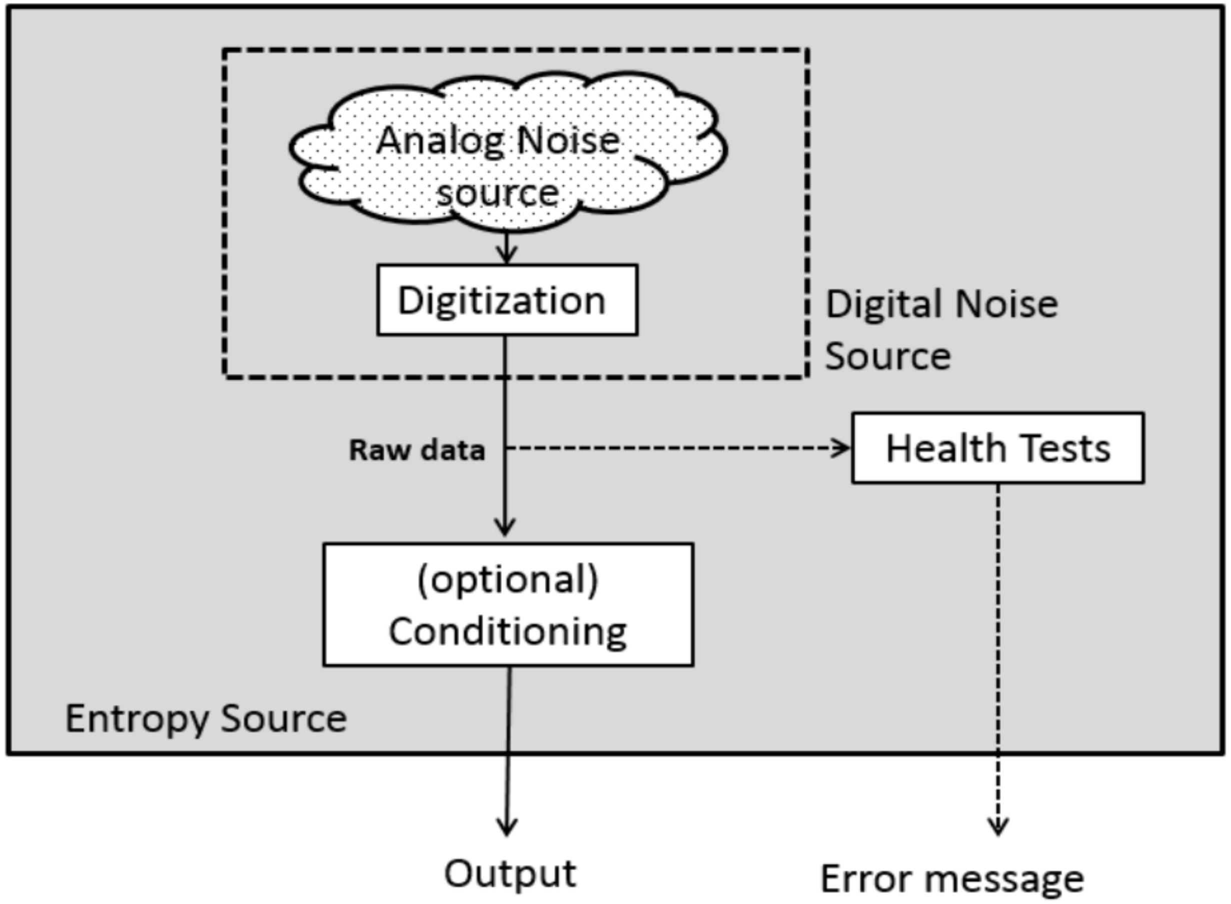
Outline

- Physical vs. Non-Physical
- Entropy Justification
- Health Tests
- Conditioning Components



Physical versus Non-Physical

Physical

- Depend on some natural phenomena, like thermal noise, quantum shot noise, ...
- 25 Entropy Validations
- Ring oscillators, meta-stable latches, …

Non-Physical

- Depend on timings available within a complex system
- 20 Entropy Validations
- 19 are CPU Jitter sources

Non-Physical Noise Sources

- Time it takes to process an interrupt request
  - E15, Apple CoreCrypto v11.1
- Time it takes to perform a complex operation
  - E1, NetApp CPU Jitter v3.4.0
- Race conditions between multiple threads
- The sample size may be arbitrary in relation to the noise source

Clocks

- When using a clock to “capture” entropy, often this is done with time deltas rather than raw time stamps

- A delta may only contain 16 bits of information, easy to see any entropy is likely in the low order bits
    - But not always! Some lower precision system clocks may fix the least significant bits!

- Very dependent on the underlying hardware and operating system

```
clock[i] = current_time

complex operation

clock[i+1] = current_time

delta = clock[i+1] - clock[i]
```

Configuration Settings

- Software settings affect the entropy source…
  - Compilers
  - Configuration flags
  - Optimizations
  - Other processes handled by the OS

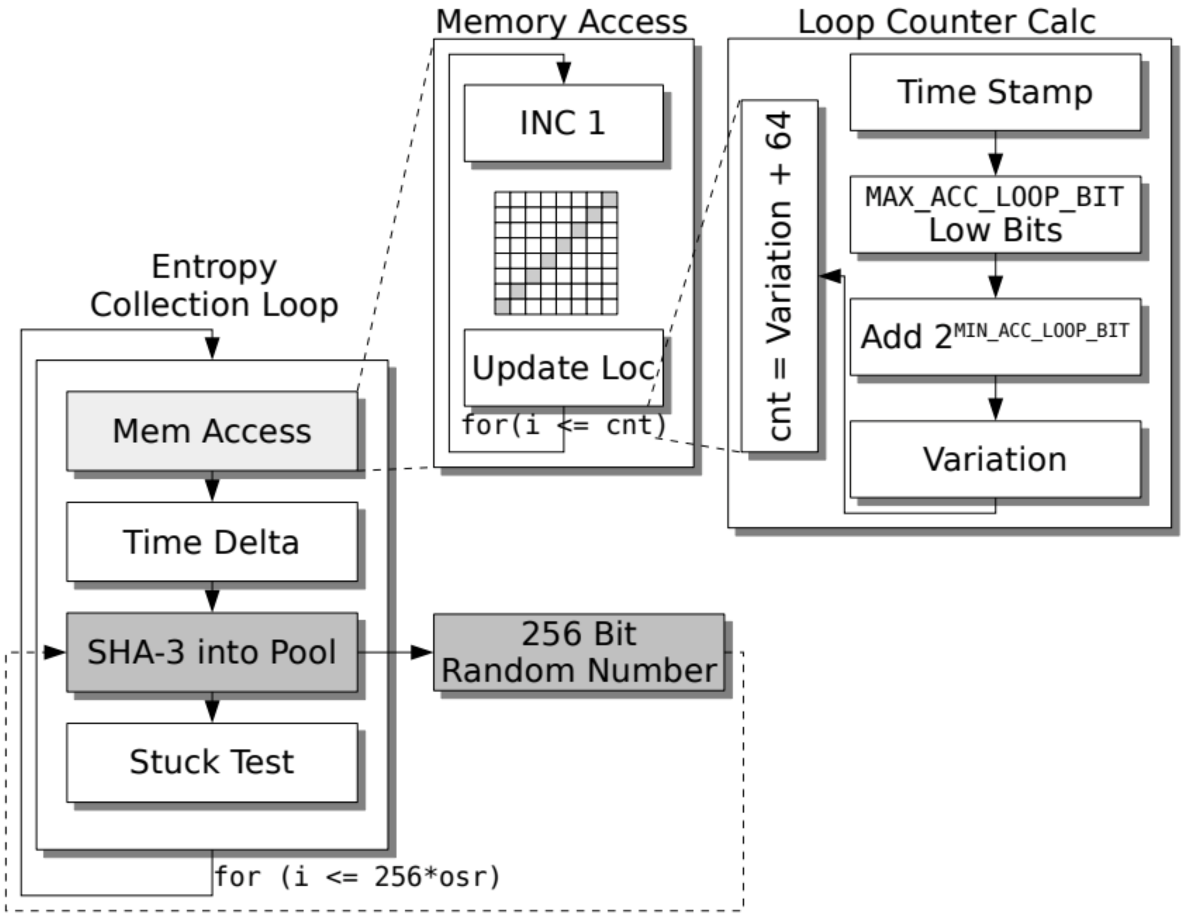
- Hardware settings affect the entropy source…
  - Clock speed
  - Cache sizes

- A validated non-physical entropy source must use specific configurations!

CPU Jitter

- Relies on memory access timings and unknown wait states of the memory buffer

- Uses cache misses by overflowing L1 cache, as L2 cache readings have more variance



https://www.chronox.de/jent/doc/CPU-Jitter-NPTRNG.pdf

Entropy Justification

- Difficult to claim large amounts of entropy per sample
- Typical estimates range from 0.33 bits to 1 bit per 64-bit sample
  - Remember a 64-bit sample may not contain 64 varying bits per sample
- Heuristics tend to make a claim that *any* entropy exists
- Joshua Hill – “What To Expect When You’re Expecting (to Evaluate JEnt Against SP 800-90B)”
  - https://www.untruth.org/~josh/sp80090b/What%20To%20Expect%20When%20You're%20Expecting%20(to%20Evaluate%20JEnt%20Against%20SP%20800-90B)%2020210904-1.pdf
  - For a presentation of a similar talk: CMUF Entropy Working Group-20221018 1702-1

Entropy Justification

- Base assumption for CPU Jitter is 1 bit of entropy per sample
  - https://www.chronox.de/jent/doc/CPU-Jitter-NPTRNG.pdf

- Reliance then becomes justifying that the hardware and software configurations allow the entropy source to make that claim

- Provide clock speed, cache sizes, amount of memory used in accesses, compiler flags, JEnt configuration parameters…

Health Tests – Failure Modes

- Failure modes are difficult for non-physical sources
- A similar operation is being run millions of times to gather entropy…
  - Periodicity?
  - Loss of entropy over time?
- Does the source behave well on idle or busy systems?
- Is this for a virtual environment where specific hardware isn’t a guarantee?

Health Tests

- Because sources are software-based, there is a lot of freedom to add developer-defined health tests to mitigate concerns

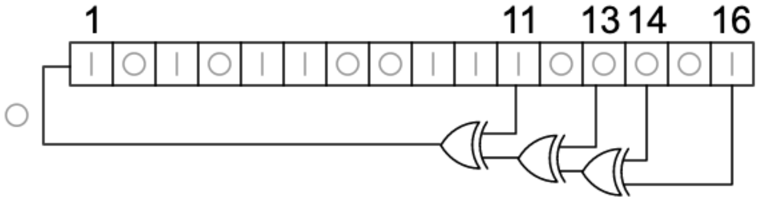
- RCT and APT do not deal with periodicity
  - Repetition Count Test and Adaptive Proportion Test are defined in SP 800-90B

- CPU Jitter v3.4.0 adds a Lag Predictor Test that uses the 90B estimator to address potential periodicity

Conditioning Components

- CPU Jitter times the full operation of the noise source and conditioner

- CPU Jitter v2 – LFSR on a primitive polynomial
  - 64-bit sample processed one at a time, 64 times
  - Non-bijective, despite the primitive polynomial being injective and surjective
  - Nin = 4096, NOut = 64



- CPU Jitter v3 – SHA-3-256
  - Much easier claim on full-entropy
  - 64-bit sample processed one at a time, 256+ times
  - Still considered vetted with a loop around SHA-3

Conditioning Components

- In Linux systems, an entropy source might be shared between kernel space and user space

- If CPU Jitter is used in kernel space with a DRBG, the entropy source for user space will chain the DRBG

- Considered two separate entropy sources for certification due to the differences in the conditioning component chain

Questions?