

# Engineering Cryptographic Software 2021

November 10, 2021

**Submission Deadline:** January 21, 2022, 23:59 (Amsterdam time)  
Submission via Brightspace only!  
Submission in **groups of two!**

## Assignment

Download C reference implementations of

- ChaCha20 (<http://cr.yp.to/papers.html#chacha>),
- Poly1303 (<http://cr.yp.to/papers.html#poly1305>), and
- ECDH key exchange on Curve25519 in Edwards form

from <https://cryptojedi.org/peter/teaching/ce2021/ce2021-sw-assignment.tar.bz2> and optimize all three primitives for the ARM Cortex-M4 microcontroller.

## Code requirements

In order to get a passing grade (i.e.,  $\geq 6$ ) for Part I of the Cryptographic Engineering course, the code you submit must fulfill **all the following minimal requirements**:

1. It must not have any secret-dependent branches or access to memory at secret-dependent locations.
2. The submitted software must offer the same functionality as the C reference implementations, i.e., regression tests must pass.
3. All three primitives must be substantially faster than the C reference implementations, i.e., take at most
  - 30 000 cycles for ChaCha20,
  - 80 000 cycles for Poly1305, and
  - 35 000 000 cycles for ECDH `scalarmult_base` and 32 000 000 cycles for ECDH `scalarmult`.
4. The `crypto_core_chacha20` function must be rewritten in assembly.

## Submission requirements

Each submission must consist of two parts:

1. A `tar.bz2` archive containing your code. This should be simply the original code package with additional files and modified Makefiles as required for your optimized versions.

2. A pdf document briefly describing the optimization techniques you applied for each of the three primitives.

Additionally, please keep the following in mind when submitting:

- Only one student of each group of two should submit; make sure to mention both names and both S-numbers in the submission documents.
- Do not modify the files called `test.c` and `speed.c` from the original code package.

## Hints for optimizing the three primitives

### Optimizing ChaCha20

The natural way to reimplement the core of ChaCha20 in assembly are the following steps:

- Write `quarterround` function in assembly.
- Merge 4 `quarterround` functions into a full round.
- Implement loop over 20 rounds in assembly.

For further optimization you might want to also write the loop over the message length in assembly.

### Optimizing Poly1305

The reference implementation is using a very small radix of  $2^8$  for arithmetic in  $\mathbb{F}_p$  with  $p = 2^{130} - 5$ . An obvious strategy for optimizing is to rewrite the field arithmetic using a larger radix, for example  $2^{26}$ .

### Optimizing ECDH

Before optimizing the ECDH software, it makes sense to investigate for possible timing leaks (secret-dependent branches and/or memory addresses) and eliminate those.

There are many ways how the ECDH software can be sped up, for example:

- more efficient scalar multiplication,
- specialized base-point scalar multiplication,
- optimized group arithmetic, and
- optimized field arithmetic (using larger radix).