P3140

std::int_least128_t

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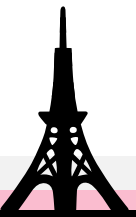
1. Introduction

Proposed types for `<cmath>`

`std::int_least128_t` `std::int_fast128_t`
`std::uint_least128_t` `std::uint_fast128_t`

Desired semantics

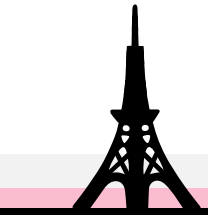
- Width of ≥ 128 bits (minimum-width types)
  - `std::int128_t` and `std::uint128_t` by proxy (exact-width types)
- Types are mandatory
- Types are extended integer types
- Strong standard library support
  - Some library changes required



2. Motivation

128-bit integers are useful

- Code search `/int128|int_128/ language:c++` ⟶ 145K files
  - For reference, `/std::byte/ language:c++` ⟶ 45.6K files
  - For reference, `/long double/ language:c++` ⟶ 582K files
- Used in *many* domains:
  - Cryptography and random number generation
  - Widening, multi-precision, fixed-point arithmetic
  - Implementing, parsing, printing (decimal) floating-point
  - Huge numbers (high-precision time, financial systems, etc.)
  - UUID, IPv6
  - Bitsets, bit-manipulation
  - …



2. Motivation

The push for 128-bit integers

Language	Support/Evolution
C++	`__int128`, `_Signed128`, `_BitInt(128)`
C	`_BitInt(128)`
CUDA	`__int128`
C#	`Int128`
Rust	`i128` (RFC-1504)
Swift	SE-0425
Go	golang/go/issues/9455

Many languages also support 128-bit through multi-precision integers in the standard library.

2. Motivation

128-bit integers have hardware support

Operation	x86_64	ARM	RISC-V
64 → 128-bit unsigned multiply	`mul`	`umulh, mul`	`mulhu, mul`
64 → 128-bit signed multiply	`imul`	`smulh, mul`	`mulsu, mul`
128 → 64-bit unsigned divide	`div`	N/A	`divu` (RV128I)
128 → 64-bit signed divide	`idiv`	N/A	`divs` (RV128I)
64 → 128-bit carry-less multiply	`pclmulqdq`	`pmull, pmull2`	`clmul, clmulh`

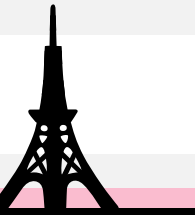
2. Motivation

Motivating example

Using 128-bit integers, `isinf(float128_t)` can be implemented as follows:

```
constexpr float128_t abs(float128_t x) {
    return bit_cast<float128_t>(
        bit_cast<uint128_t>(x) & (uint128_t(-1) >> 1));
}

constexpr bool isinf(float128_t x) {
    return bit_cast<uint128_t>(abs(x))
        == 0x7fff'0000'0000'0000'0000'0000'0000'0000;
}
```



3. Impact on the standard

C Compatibility

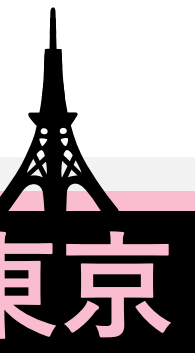
- ABI issues related to `intmax_t` have been resolved in C23.
- `std::int_least128_t` does not imply existence of `int_least128_t` in C.
- `std::printf` support for 128-bit must be optional.

Core language impact

None. (extended integer semantics are just fine)

Standard library impact

- Menial changes (adding macros, aliases, etc.)
- Enhancing support for extended integers (`std::to_string`, `std::bitset`, etc.)
- Preventing 128-bit integers from breaking ABI (`std::ranges::iota_view`)



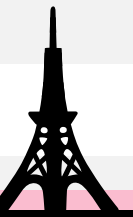
3. Impact on the standard

Enhancing support for extended integers

- Some overload sets (`std::abs`, `std::to_string`, `std::bitset` constructor) are restricted to standard integer types.
- Adding overloads for `std::int_least128_t` would not comply.

```
// current overload set
constexpr int           abs(int j);
constexpr long int      abs(long int j);
constexpr long long int abs(long long int j);

// proposed overload set
constexpr signed-integer-least-int abs(signed-integer-least-int j);
```



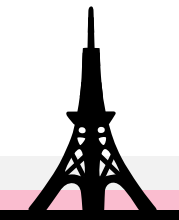
4. Impact on implementations

Implementing `std::int_least128_t`

- GCC and clang provide `_BitInt(128)` and `__int128` (with some restrictions).
- No built-in type for MSVC, only `std::_Signed128`, `std::_Unsigned128` classes.

Implementing standard library (non-)changes

- Many menial changes (defining macros, aliases, relaxing constraints, …)
- Numerics and bit manipulation (`std::gcd`, `std::popcount`, …)
- New overloads (`std::abs`, `std::to_string`, `std::bitset`)
- 256-bit arithmetic for `std::linear_congruential_engine<std::uint128_t>`
- Overwhelming majority of standard library unchanged.
- As mentioned before, 128-bit `std::printf` support is optional.



5. Design

Questions

- *"Why no standard integer?"*
  - `long long long` is too long; also, this would break ABI.
- *"Why no `std::int_least256_t`?"*
  - Too little motivation, unclear ABI, long literals.
- *"Why not solve this more generally (e.g. `_BitInt(N)`)?"*
  - *Huge* effort, better done through `std::big_int<N>`.
- *"Why make it mandatory?"*
  - If it's optional, library authors do twice the work.
  - Implementation effort is reasonable, software emulation acceptable.
  - It's already here: `_BitInt(128)`, `__int128`, `std::_Signed128`.
- *"Why rely on extended integer semantics?"*
  - No core wording changes; semantics are desirable.

References

Jan Schultke; **P3140:** `std::int_least_128_t` (latest revision)
https://eisenwave.github.io/cpp-proposals/int-least128.html