

Singleton

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Introduction

Singleton belongs to the *creational patterns*.

It's quite notorious one - I would dare to say: almost as the goto statement (although, the old enough readers probably remember the Basic - procedural language - where the only way to control the program flow was via goto statements).

The simple idea behind is - the User-Defined Type (UDT) can be instantiated only once.

Essentially, it's similar to using the global static variable which is strongly discouraged, for various reasons.

It's actually initializing the static variable within local - block scope once, in a thread-safe way, and

use it "everywhere" - across the entire program.

But - these are implementation details.

So, Singleton is not about having the single instance of the class in a program - but rather being prohibited by design to produce multiple instances of the same type.

For example, Inversion Control Containers (ICC) - is the way to hold either a single instances of the dependency modules, or to provide the API for obtaining the new instances from container on each and every request.

Holding the singletons wouldn't be able to satisfy such requirement.

<More on that>: https://github.com/damirlj/modern_cpp_tutorials/tree/main?tab=readme-ov-file#tut5

@note This is not chosen by accident - If you rethink - this is a valid alternative for Singleton design pattern

Where to use singletons?

Whenever there is a need for a single - centralized component for managing certain resources: for performing a particular job (SRP - Single Responsibility Principle) and be accessible across the entire code - as static storage class which lifetime is bounded to the lifetime of the program.

Implementation

The Singleton design pattern relies on two premises:

- Having a **private constructor**: to control the fabrication of the type
- Providing the **single instance** - with static storage duration

This becomes quite obvious in Java(Kotlin) implementation

```
private enum Singleton implements Supplier<T> {  
    INSTANCE;  
  
    private final T instance;  
  
    Singleton() {  
        instance = new T();  
    }  
  
    @Override  
    public T get() {  
        return instance;  
    }  
}  
  
private T() {}  
public static T get() {return Singleton.INSTANCE.get();}
```

where T is enclosing type - that will be turned into singleton.

Enum class in Java/Kotlin is a perfect choice since:

- Each enumeration constant is static instantiation of the enum class which is **thread-safe** (INSTANCE == static Singleton)
- The enum constructor is by design private

This way, calling `T.get()` will retrieve the single instance of T, by instantiate at the very first call - in a thread-safe manner, the static instance of enum class Singleton (INSTANCE) - calling the private constructor `Singleton()` - which will internally

call the private constructor of the enclosing class T - for which we want to behave as actual singleton.

C++ implementation

The very same effect we can achieve in C++ using classical Scott Meyers' singleton implementation

```
// Singleton by design
class Singleton
{
public:
    [[nodiscard]] static Singleton& get()
    {
        static Singleton instance{}; // static variable within local scope: thread-safe instantiation
        return instance;
    }

    // Copy operations forbidden
    Singleton(Singleton& ) = delete;
    Singleton& operator=(Singleton& ) = delete;

    // Move operations allowed: for storing the singleton instance within
    // movable placeholder (std::unique_ptr)
    Singleton(Singleton&& ) = default;
    Singleton& operator=(Singleton&& ) = default;

    ~Singleton() = default;

private:
    Singleton() = default;
};
```

But what if we want to be more deterministic on the singleton lifetime management, when there is a need for a proper resource release - where the order of destruction plays the role?

This is not the issue in Java/Kotlin - since there is a GC involved: there is no destructor and RAII concept

We need to extend the interface with additional API - to fulfill this requirement.

Possible implementation can be

```
// Using factory method - to create a singleton on the stack and return
// the (shared) pointer on it.
// This expensive approach would be justifiable only in case that we want to have a control
// over the singleton lifetime management - in case of custom-specific destruction,
// when acquired resources has to be released, or destruction has to be done in a specific order
friend auto factory::createOnStackPtr<Singleton>(); // since constructor is private
[[nodiscard]] static std::shared_ptr<Singleton> getPtr()
{
    static std::shared_ptr<Singleton> instance = factory::createOnStack<Singleton>();
    return instance;
}
```

Where one possible implementation of stack allocation could be

```
namespace factory
{
    /**
     * Factory method
     *
     * Creating object as instance of a T on the stack.
     * It relies on the static instantiation that is thread-safe.
     * It will use pre-allocated memory on the stack (std::array),
     * using placement new for allocation
     */
    template <typename T, typename...Args>
    auto createOnStackPtr(Args&&...args)
    {
        using stack_memory = std::array<std::byte, sizeof(T)>;
        static stack_memory stack{};
        #if __cplusplus >= 201703L
            static std::pmr::monotonic_buffer_resource buf {stack.data(), stack.size()};
            return new(&buf)T {std::forward<Args>(args)...};
        #else
            return new(stack.data())T {std::forward<Args>(args)...};
        #endif
    }
}
```

```

template <typename T>
void deleteOnStackPtr(T*& ptr)
{
    if(ptr) [[likely]]
    {
        ptr->~T();
        ptr = nullptr;
    }
}

// Control the life-time of the on the stack allocated pointer
template <typename T, typename...Args>
auto createOnStack(Args&&...args)
{
    static auto* ptr = createOnStackPtr<T>(std::forward<Args>(args)...);

    auto deleter = [](T* p) { deleteOnStackPtr(p); }; // deleter embedded into type
    return std::unique_ptr<T, decltype(deleter)> {ptr, deleter};
}

```

For more generic implementation of the stack allocator - check it

https://github.com/damirij/modern_cpp_tutorials/blob/main/docs/desing%20patterns/Factory%20method.pdf

Singleton helper

We can isolate the second premise - having single static instance of the parameterized type, into separate helper utility class - this time using the `std::call_once` (no advantage in compare with Scott Meyers' singleton - took as demonstration only)

```

// For turning any class into "singleton" - ensuring it's called once

template <typename T>
requires std::is_default_constructible_v<T>
class SingletonHelper
{
    static inline std::once_flag once {};
    static inline T* instance = nullptr;
public:
    static T& get()
    {
        std::call_once(once, []{ instance = factory::createOnStackPtr<T>(); });
        return *instance;
    }
};

```

Well, this will work with to limitations:

- T must have public constructor
- T must be default-constructible

We can overcome the second limitation by separating the initialization from getter method, which result in introducing another mutex, so that getter method is once again thread-safe.

For client code - this imposes the order in which methods can be invoked (`init()` call must precede the `get()` call)

```

template <typename T>
class SingletonHelper
{
    static inline std::once_flag once_ {};
    static inline T* instance_ = nullptr;
    static inline std::mutex lock_ {};

public:
    static T& get()
    {
        std::lock_guard lock {lock_};
        if (instance_ == nullptr) throw std::logic_error("<SingletonHelper> T is not instantiated");
        return *instance_;
    }

    // Separating the creation - instantiation from retrieving the instance (getter)
    // violates the thread-safeness
    // For that - we need to introduce additional mutex
    template<typename...Args>
    static void init(Args&&...args)

```

```

    {
        std::call_once(once_,
            [&]
            {
                instance_ = factory::createOnStackPtr<T>(std::forward<Args>(args)...);
            });
    }
};

```

To overcome the first limitation, turning the parameterized type constructor into *private* - we need additionally to couple the factory method we used to produce a single instance on the stack- in SingletonHelper class - with parameterized type declaration

```

template <typename T>
requires std::is_arithmetic_v<T>
class A
{
    private:
        friend A* factory::createOnStackPtr<A>(value_type&&);
        explicit A(value_type val) noexcept: value_(val) {}
        ...
    private:
        value_type value_;
};

```

Turning A into singleton becomes now quite easy

```

using int_type = A<int>;
using singleton_type = SingletonHelper<int_type>;

```

<Entire code>: <https://godbolt.org/z/c9nnrYz5M>