O.1 — Bit flags and bit manipulation via std::bitset

BY ALEX ON AUGUST 17TH, 2019 | LAST MODIFIED BY NASCARDRIVER ON JANUARY 19TH, 2020

On modern computer architectures, the smallest addressable unit of memory is a byte. Since all objects need to have unique memory addresses, this means objects must be at least one byte in size. For most variable types, this is fine. However, for Boolean values, this is a bit wasteful. Boolean types only have two states: true (1), or false (0). This set of states only requires one bit to store. However, if a variable must be at least a byte, and a byte is 8 bits, that means a Boolean is using 1 bit and leaving the other 7 unused.

In the majority of cases, this is fine -- we're usually not so hard-up for memory that we need to care about 7 wasted bits (we're better off optimizing for understandability and maintainability). However, in some storage-intensive cases, it can be useful to "pack" 8 individual Boolean values into a single byte for storage efficiency purposes.

Doing these things requires that we can manipulate objects at the bit level. Fortunately, C++ gives us tools to do precisely this. Modifying individual bits within an object is called **bit manipulation**.

Bit manipulation is also useful in encryption and compression algorithms.

Author's note

This entire chapter is optional reading. Feel free to skip it and come back later.

Bit flags

Up to this point, we've used variables to hold single values:

```
int foo { 5 }; // assign foo the value 5 (probably uses 32 bits of storage)
std::cout << foo; // print the value 5
```

However, instead of viewing objects as holding a single value, we can instead view them as a collection of individual bits. When individual bits of an object are used as Boolean values, the bits are called **bit flags**.

As an aside...

In computing, a flag is a value that acts as a signal for some function or process. Analogously, in real life, a mailbox flag is used to signal that there is something inside the mailbox, so the mailbox doesn't have to be opened to check.

To define a set of bit flags, we'll typically use an unsigned integer of the appropriate size (8 bits, 16 bits, 32 bits, etc... depending on how many flags we have), or std::bitset.

```
#include <bitset> // for std::bitset

std::bitset<8> mybitset {}; // 8 bits in size means room for 8 flags
```

Best practice

Bit manipulation is one of the few times when you should unambiguously use unsigned integers (or std::bitset).

In this lesson, we'll show how to do bit manipulation the easy way, via std::bitset. In the next set of lessons, we'll explore how to do it the more difficult but versatile way.

Bit numbering and bit positions

Given a sequence of bits, we typically number the bits from right to left, starting with 0 (not 1). Each number denotes a **bit position**.

```
76543210  Bit position
00000101  Bit sequence
```

Given the bit sequence 0000 0101, the bits that in position 0 and 2 have value 1, and the other bits have value 0.

Manipulating bits via std::bitset

In lesson **4.12 -- Literals** we already showed how to use a std::bitset to print values in binary. However, this isn't the only useful thing std::bitset can do.

std::bitset provides 4 key functions that are useful for doing bit manipulation:

- test() allows us to query whether a bit is a 0 or 1
- set() allows us to turn a bit on (this will do nothing if the bit is already on)
- reset() allows us to turn a bit off (this will do nothing if the bit is already off)
- flip() allows us to flip a bit value from a 0 to a 1 or vice versa

Each of these functions takes a bit-position argument indicating which bit position we want operated on.

Here's an example:

```
#include <bitset>
#include <iostream>

int main()
{
    std::bitset<8> bits{ 0b0000'0101 }; // we need 8 bits, start with bit pattern 0000 0101
    bits.set(3); // set bit position 3 to 1 (now we have 0000 1101)
    bits.flip(4); // flip bit 4 (now we have 0001 1101)
    bits.reset(4); // set bit 4 back to 0 (now we have 0000 1101)

    std::cout << "All the bits: " << bits << '\n';
    std::cout << "Bit 3 has value: " << bits.test(3) << '\n';
    std::cout << "Bit 4 has value: " << bits.test(4) << '\n';

    return 0;
}
```

This prints:

```
All the bits: 00001101
Bit 3 has value: 1
Bit 4 has value: 0
```

What if we want to get or set multiple bits at once

std::bitset doesn't make this easy. In order to do this, or if we want to use unsigned integer bit flags instead of std::bitset, we need to turn to more traditional methods. We'll cover these in the next couple of lessons.

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10 comments to O.1 — Bit flags and bit manipulation via std::bitset

HolzstockG
February 4, 2020 at 5:44 am · Reply

As I understand when we set as above written "std::bitset<4> test", then for this variable is allocated an entire byte, but we are using only 4 bits of it right?

nascardriver
February 4, 2020 at 8:42 am · Reply

Yep. No type in C++ can be smaller than 1 byte.

Wolfma
January 19, 2020 at 3:49 am · Reply

In the code example in the section "Manipulating bits via std::bitset" list initialization should be used to be in line with the rest of this great tutorial. Keep up the great work!

```
std::bitset<8> bits(0b0000'0101); // we need 8 bits, start with bit pattern 0000 0101
```

to

```
std::bitset<8> bits{ 0b0000'0101 }; // we need 8 bits, start with bit pattern 0000 0101
```

nascardriver
January 19, 2020 at 4:49 am · Reply

Done, thanks!

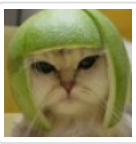
koe
December 20, 2019 at 8:46 am · Reply

"a variable must be at least a byte"

I have wondered about this. Surely a Boolean occupies more than one byte in memory, because there is type and ID information also. Doesn't consolidating 8 Booleans into one std::bitset<8> reduce more than 7 bytes?

nascardriver
December 21, 2019 at 2:46 am · Reply

> because there is type and ID information also
No, types and identifiers only exist in your code, but not at run-time.



Alex
January 1, 2020 at 7:02 pm · Reply

For classes, this isn't quite true if RTTI is enabled. See https://en.wikipedia.org/wiki/Run-time_type_information

Parsa
October 22, 2019 at 3:43 pm · Reply

What if we wanted to flip all of the bits? Loop?

nascardriver
October 23, 2019 at 3:02 am · Reply

You can use `operator~`.

```
std::bitset<4> b{ 0b0101 };

std::cout << ~b << '\n'; // 1010
```

fordreaming
December 10, 2019 at 12:16 am · Reply

great,Thanks