

# CS33 Homework Assignment 4 Solutions

Fall 2023

1. C currently does not support a 128-bit integer data type. In this problem, you're going to do some of the work to implement such a type. We'll stick with unsigned integers for now.
  - a. We need an appropriate *typedef*. Define a type, *ulong128\_t*, that allows us to easily access the low-order 64 bits and the high-order 64 bits. Keep in mind that x86-64 is a little-endian architecture.

Answer:

```
typedef struct {
    unsigned long low;
    unsigned long high;
} ulong128_t;
```

- b. If we're going to make use of this type, we need, among many other things, an implementation of multiplication. Produce an implementation, in x86-64 assembler, of Mult128:

```
void Mult128(ulong128_t *op1, ulong128_t *op2, ulong128_t *res);
```

On return, *res* should point to a *ulong128\_t* containing the product of *\*op1* and *\*op2*. You should expect your answer to use around 12 instructions, including the *ret* at the end. Some hints:

- i. You might first write an approximate version of Mult128 in C, compile it with the *-S* (which tells gcc to produce assembler code) and *-O1* flags, and work with the gcc-produced assembler code (which will be in a *.s* file)
    - ii. The product of  $(a + b)$  and  $(c + d)$  is  $ac + ad + bc + bd$ . (You probably knew this!)
    - iii. The portion of the result that's greater than or equal to  $2^{128}$  can be ignored, since we're concerned only with the low-order 128 bits of the product.
    - iv. The unsigned multiply instruction, *mulq*, produces a 128-bit result from two 64-bit operands. The multiplicand is in *%rax* (and thus isn't mentioned explicitly as an operand). The multiplier is given as the only operand to the instruction. The high-order 64 bits of the result will be put in *%rdx* (caution, this register also holds the third argument to the function!); the low-order 64 bits of the result will be put in *%rax*.

Answer:

```
Mult128:
    movq    %rdx, %r10        # save address of third param, since rdx is needed for
                                # 128-bit mult
    movq    (%rdi), %rax       # get low-order 64 bits of op1
```

```

mulq  (%rsi)           # multiply times low order 64 bits of op2
movq  %rax, (%r10)      # save low-order 64 bits of result
movq  %rdx, 8(%r10)     # save high-order 64 bits of result
movq  8(%rdi), %rax     # get high-order 64 bits of op1
mulq  (%rsi)           # multiply times low-order 64 bits of op2
addq  %rax, 8(%r10)     # add low-order 64 bits of result to high-order 64 bits
                                # of prev result
movq  (%rdi), %rax     # get low-order 64 bits of op1
mulq  8(%rsi)          # multiply times high-order 64 bits of op2
addq  %rax, 8(%r10)     # add low-order 64 bits of result to high-order 64 bits
                                # of prev result
ret                                # return to caller

```