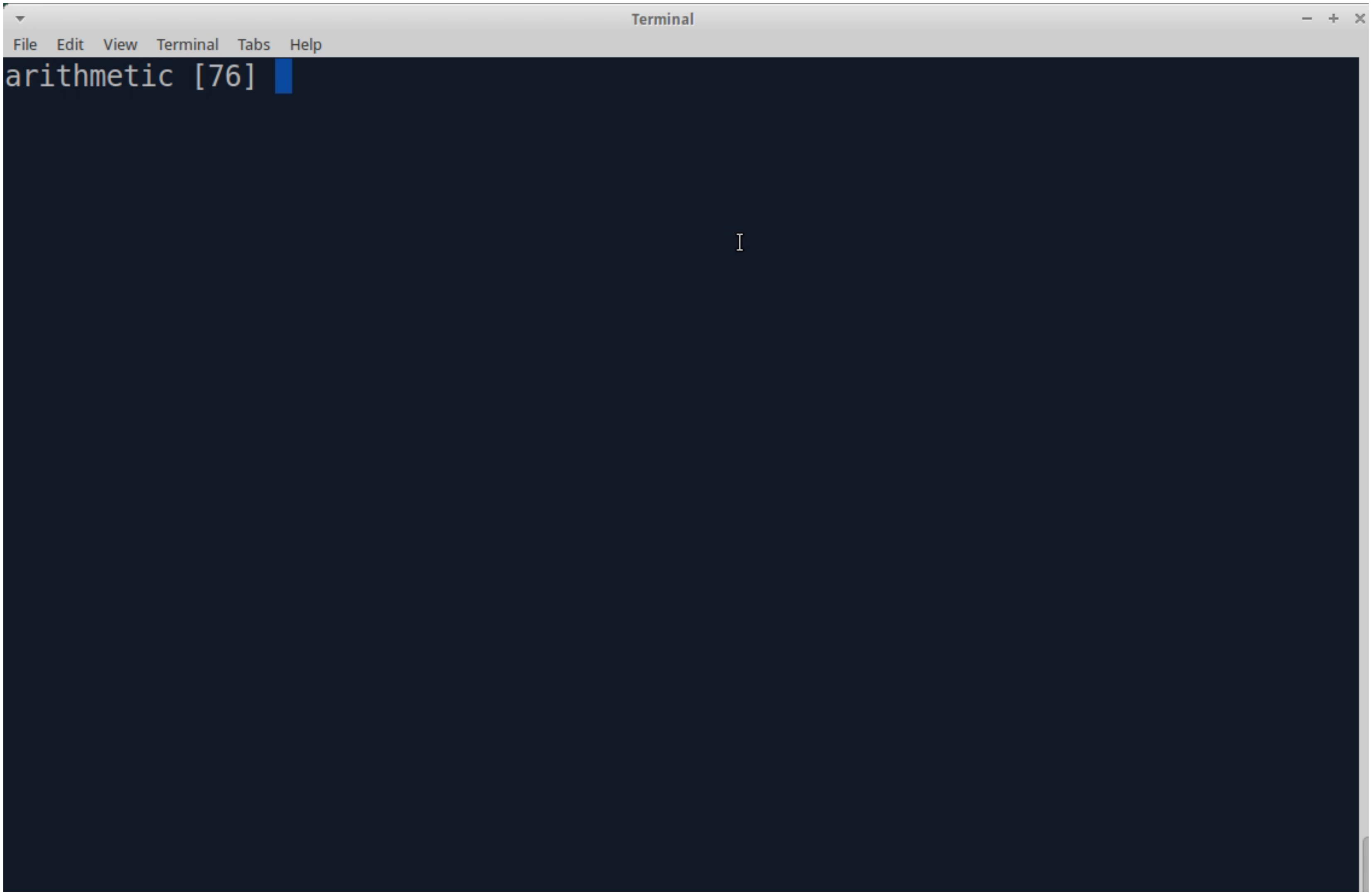
Arithmetic

- Learning Objectives
  - Explain how to encode both positive and negative numbers in binary
  - Add and subtract binary numbers
  - Explain why 2's complement is a good representation


Terminal
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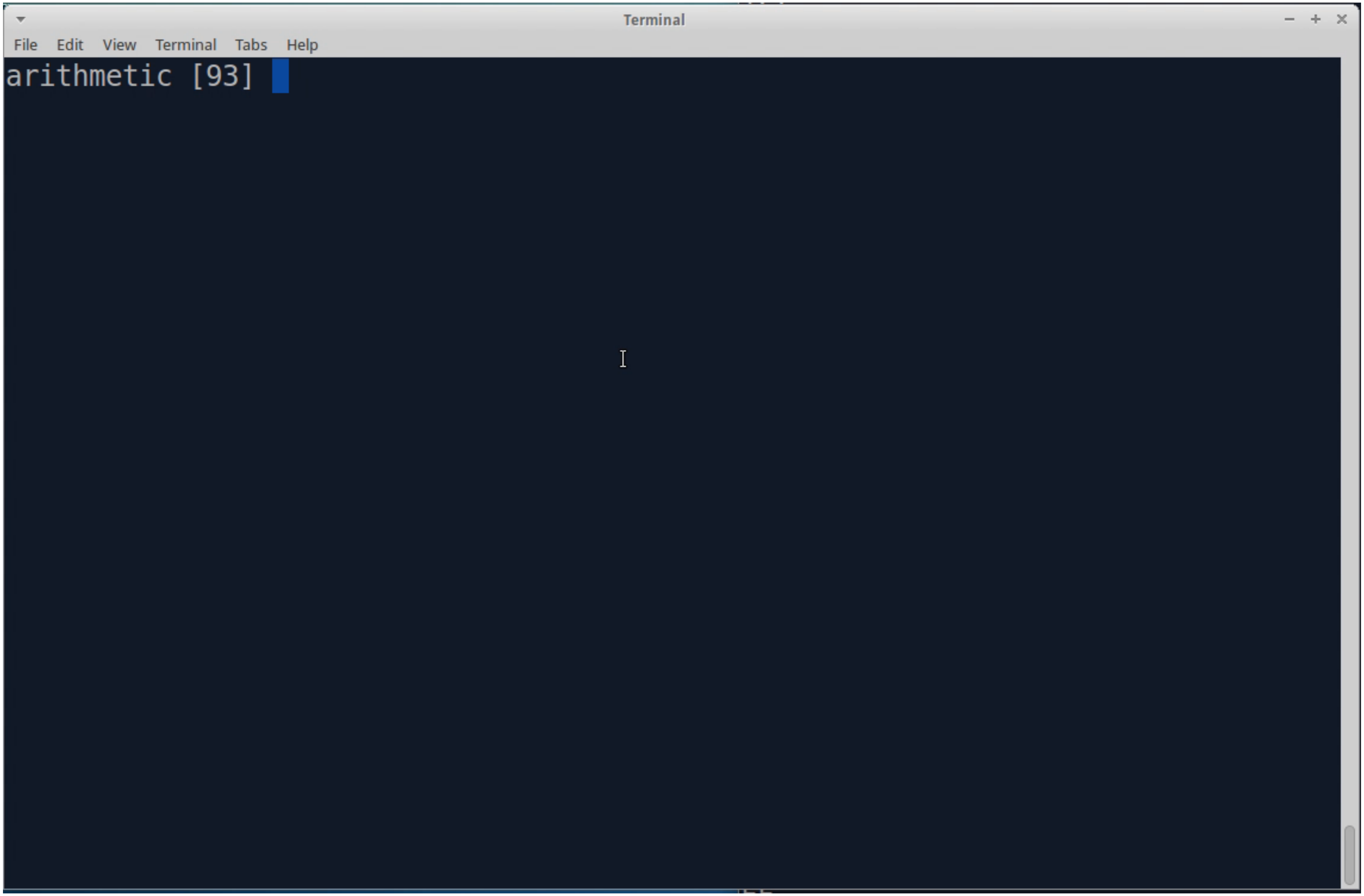
arithmetic [76]

```
 Command 'ls' from package 'coreutils' (main)
 Command 'lsh' from package 'lsh-client' (universe)
ls]: command not found
arithmetic [81] pwd
/home/ubuntu/cs61/cs61-videos/arithmetic
arithmetic [82] ls
Makefile   hexdump.h  signs    signs.o   signs2.c  signs3    signs3.o  signs4.c
hexdump.c  hexdump.o  signs.c  signs2    signs2.o  signs3.c  signs4    signs4.o
arithmetic [83] more signs2.c
#include <stdio.h>
#include "hexdump.h"

int
main(int argc, char ** argv)
{
        /* Suppress compiler warnings. */
        (void)argc;
        (void)argv;

        int negs[4] = {-1, -2, -3, -4};

        hexdump(negs, sizeof(negs));
}
arithmetic [84] 
```

Negative Numbers

- What do we know so far?
  - Negative (small) numbers appear very large (they start with 0xff).
  - Counting in negative numbers does seem to follow a regular counting pattern.
- You might hypothesize that negative numbers are positive numbers with the bits flipped.
- How might you test that?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2's Complement Arithmetic

- We can formalize what we observed, simply by examining values in memory:
- We represent –`n` by taking the inverse of `n` (`~n`) and adding 1 to it:
  - `-n = (~n) + 1`
- Example (in 8 bits):
  - `N = 5; 5 = 00000101`
  - `~N = 11111010`
  - `~N + 1 = 11111011 = 0xfb`

Why 2's Complement

- "It makes arithmetic operations just work."
- How do we add binary numbers?
  - 0 + 0 = 0
  - 0 + 1 = 1
  - 1 + 1 = 0 (carry the 1)
- Example (again in 8 bits)
  - 35 + 5

```
  00100011     0x23
  00000101     0x05
 ----------   ------
  00101000     0x28
  0x28
```

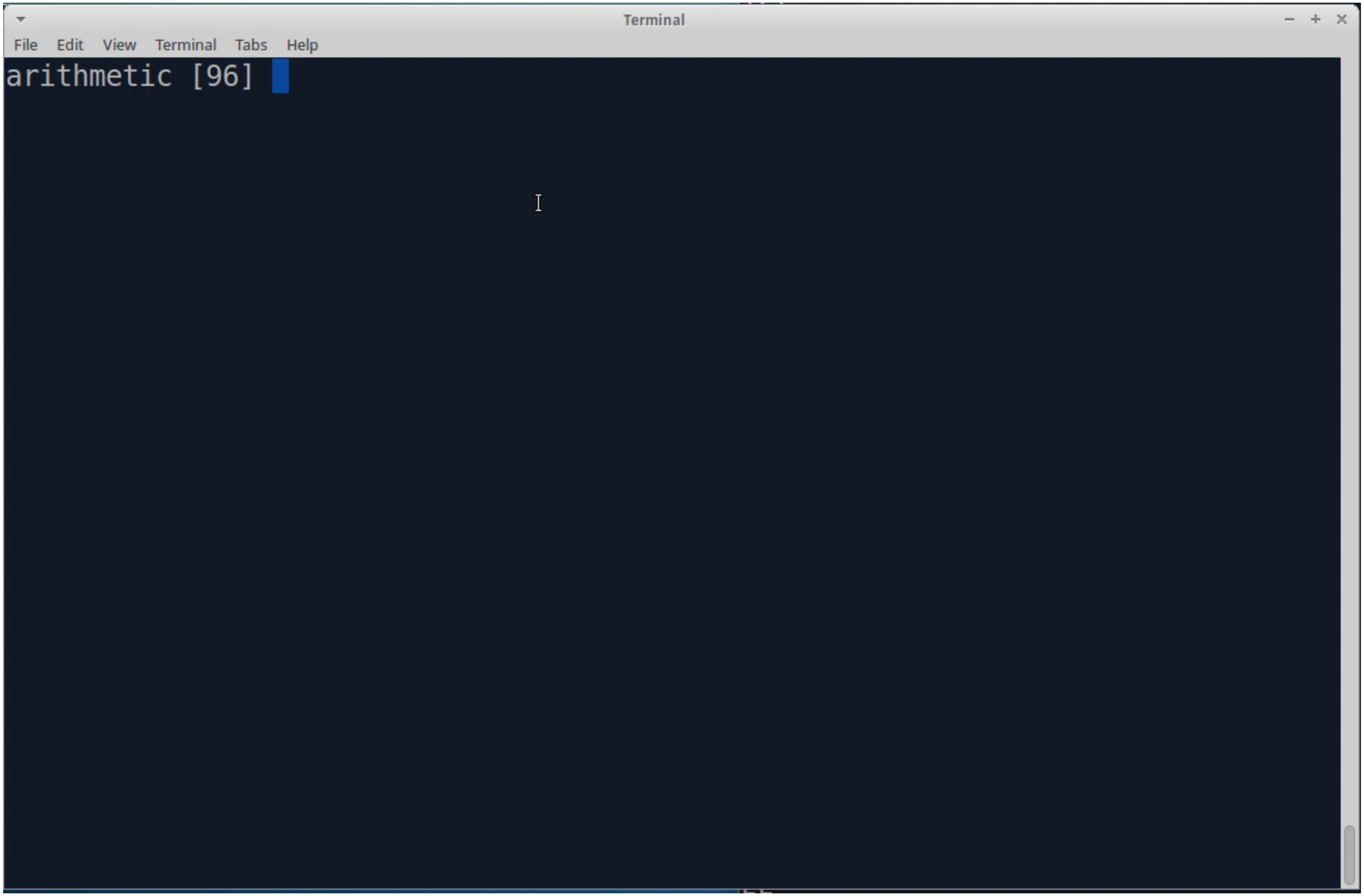
Addition with Negative Numbers

- Let's see what happens when we try to add two negative numbers.
- Example: -3 + -10

  11111101
  11110110

- Final check: -1 + 1 ought to equal 0!

  11111111
  00000001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