ECE 220: Computer Systems & Programming

Lecture 14: File I/O in C

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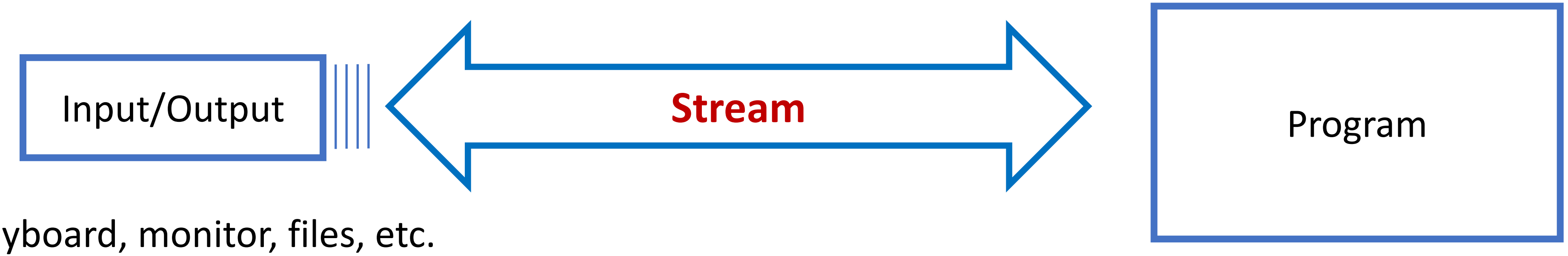
I/O Stream

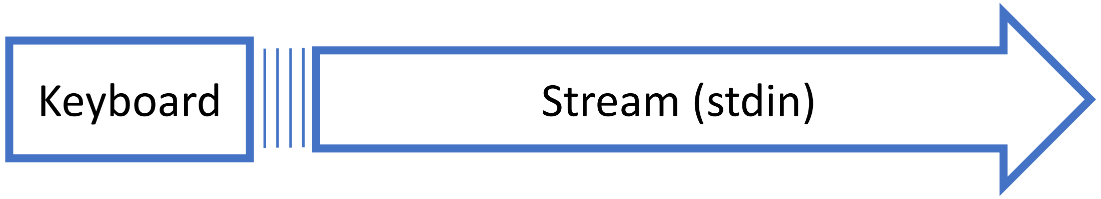


i.e. keyboard, monitor, files, etc.

Stream

- Interfacing with I/O and program
- a sequence of data (text or binary) to which the actual input/output is mapped

For example,



```
scanf("%d", &x)
```

Stream Abstraction for I/O

- A text stream is a sequence of ASCII characters, such as
  - *the sequence of ASCII characters* printed to the monitor by a single program
  - *the sequence of ASCII characters* entered by the user during a single program
  - *the sequence of ASCII characters* in a single file
- Characters are processed in the order in which they were added to the stream
  - e.g., a program sees input characters in the same order as the user typed them.
- C has three default “Standard streams”
  - Input (keyboard): `stdin`
  - Output (monitor): `stdout`
  - Error (monitor): `stderr`

(sidenote) When do you use `stderr`?

- It’s a good practice to redirect all error messages to `stderr`, while directing all regular outputs to `stdout`.
- Example:

```
fprintf(stdout , "Normal output1\n");
fprintf(stdout , "Normal output2\n");
fprintf(stderr, "Error1 \n");
fprintf(stdout , "Normal output3\n");
fprintf(stderr, "Warning1\n");
```

```
./a.out
```

[monitor]

```
Normal output1
Normal output2
Error1
Normal output3
Warning1
```

```
./a.out >a.log 2>err.log
```

[a.log]

```
Normal output1
Normal output2
Normal output3
```

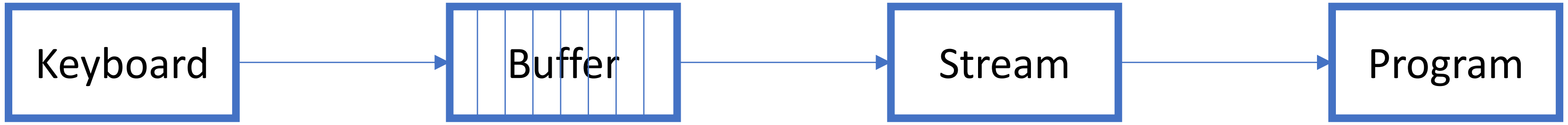
[err.log]

```
Error1
Warning1
```

Buffering

- Every value that goes into the stream is captured by the low-level OS software and kept in a **buffer** (a small array)

Input Buffering



Keyboard

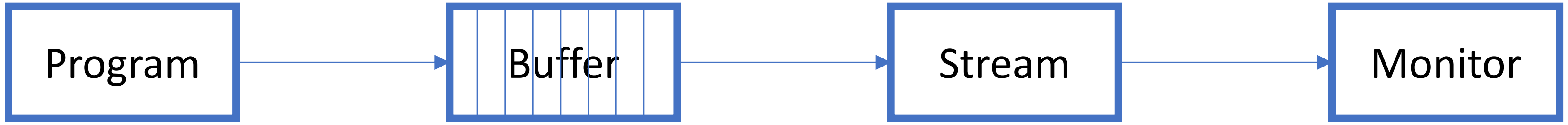
Buffer

Stream

Program

The buffer is released when the user presses Enter key.

Output Buffering



Program

Buffer

Stream

Monitor

The buffer is released when the program submits a newline character (‘\n’)

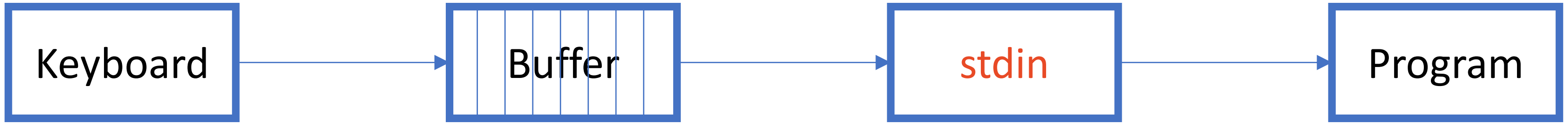
- Buffer allows to decouple the producer from the consumer.

Input Buffer

getchar

- Reads one ASCII character from stdin (keyboard)
- LC-3 GETC or IN TRAP

Input Buffering



```
    char in1, in2, in3;

    in1 = getchar();
    in2 = getchar();
    in3 = getchar();

    printf(”result:\n");
    printf("%c", in1);
    printf("%c", in2);
    printf("%c", in3);
```

You type

ABCD↵

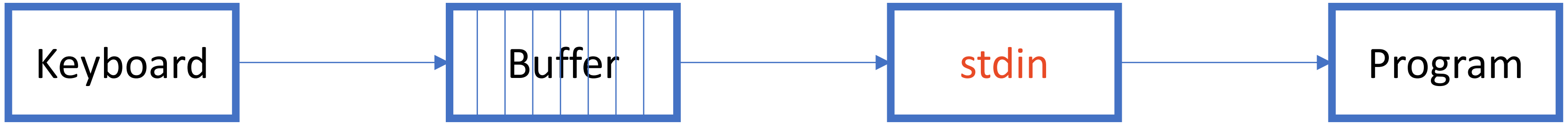
1. Before type enter(↵), the buffer is not released to the stream
2. Only ‘A’, ‘B’, ‘C’ will be read by getchar()

Input Buffer

getchar

- Reads one ASCII character from stdin (keyboard)
- LC-3 IN TRAP

Input Buffering



```
    char in1, in2, in3;

    in1 = getchar();
    in2 = getchar();
    in3 = getchar();

    printf(”result:\n");
    printf("%c", in1);
    printf("%c", in2);
    printf("%c", in3);
```

You type

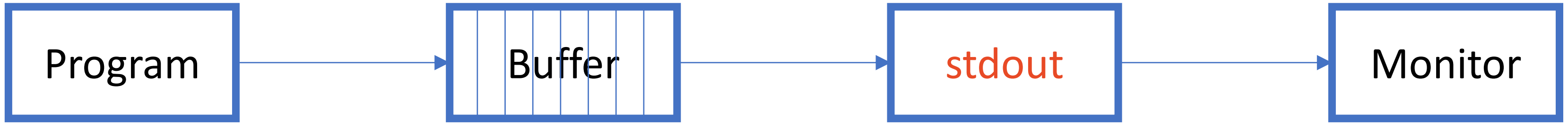
A↵

Output Buffer

`putchar`

- Displays one ASCII character to stdout (monitor)
- LC-3 OUT TRAP

Output Buffering



```
int main(){
    putchar('a’);

    sleep(5);
    putchar('b');
    putchar('\n’);
}
```

What do you see?

1. ‘a’, then 5 seconds, then ‘b’
2. ‘ab’, then 5 seconds
3. 5 seconds, then ‘ab’.

Output Buffer

putchar

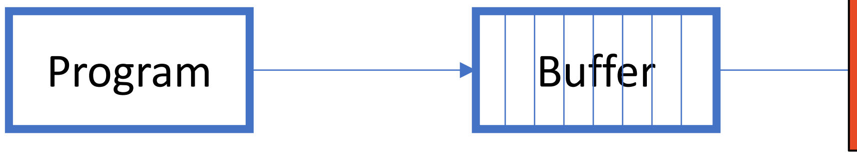
- Displays o
- LC-3 OUT

**side note*

putchar, fprintf or fputs flushes the buffer at

1. **new line**
2. **program reads from input buffer**
3. **after program exists**

Output Buffering



```
int main(){
    putchar('a’);

    sleep(5);
    putchar('b');
~~    putchar('\n’);~~
}
```

What do you see?

1. 5 seconds, then ‘ab’.
2. Nothing
3. Segment fault

Basic I/O Functions

- Creating I/O streams
    - `fopen`: open/create a file for I/O
    - `fclose`: close a file for I/O
- I/O one character at a time
    - `fgetc`: Reads an ASCII character from stream
    - `fputc`: Writes an ASCII character to stream
    - `getchar`: Reads an ASCII character from the keyboard
    - `putchar`: Writes an ASCII character to the monitor
- I/O one line at a time
    - `fgets`: Reads a string (line) from stream
    - `fputs`: Writes a string (line) to stream
- Formatted I/O
    - `fprintf`: Writes a formatted string to stream
    - `fscanf`: Reads a formatted string to stream
    - `printf`: Writes a formatted string to the monitor
    - `scanf`: Reads a formatted string to the keyboard

File I/O

- A file is a sequence of ASCII characters (or binary) stored in some storage device.
- Each file is associated with a stream.
  - It can be input stream or output stream or both.
- To read or write a file, we declare a file pointer (The `FILE` type is defined in `<stdio.h>`)

```
        FILE *infile;
```

- Read/write a file requires 3 step:
  1. Open the file
  2. Do reading or writing
  3. Close the file

Creating I/O stream

`FILE* fopen(char* filename, char* mode)`

Open a file to read or write

- **Parameters**
  - filename
  - mode: how the file will be used
    - “r” – read from the file
    - “w” – write, starting from the beginning of the file
    - “a” – write, starting at the end of the file (append)
- **Return value**
  - success: returns a pointer to FILE
  - failure: returns NULL

Creating I/O stream

`int fclose(FILE* stream)`

Close a file

- **Parameters**
  - stream: Pointer to a file

- **Return value**
  - success: returns 0
  - failure: returns EOF

    (Note: EOF is a macro, commonly -1)

```c
    FILE *myfile;
    myfile = fopen("test.txt", "w");
    if(myfile == NULL){
        printf("Cannot open file for write.\n");
        return -1;
    }
     .
     .
     .
    fclose(myfile);
    return 0;
```

I/O one character at a time

`int fgetc(FILE* stream)`

Read a single character from a file, then advanced to the next character.

- **Parameters**
  - stream: Input stream

- **Return value**
  - success: returns the current character
  - failure: returns EOF

I/O one character at a time

```
int fputc(int character, FILE* stream)
```

Write a single character to a file

- **Parameters**
  - character: character to be written
  - stream: Output stream

- **Return value**
  - success: write the character to file and returns the character written
  - failure: returns EOF

Example

```
    char c;
    FILE *fp1, *fp2;

    if((fp1=fopen("original.txt", "r")) == NULL){
        printf("Unable to open a file.\n");
        return -1;
    }
    if((fp2=fopen("modified.txt", "w")) == NULL){
        printf("Unable to open a file.\n");
        return -1;
    }

    do{
        c = fgetc(fp1);
        if(c>='0' && c<='9')
            fputc(c,fp2);
    }while(c!= EOF);
    fclose(fp1);
    fclose(fp2);
```

I/O one line at a time

`char* fgets(char* string, int num, FILE* stream)`

Read a line from a file

- **Parameters**
  - string: Pointer to a destination array
  - num: Max # of char to be copied into *string*
  - stream: Input stream

- **Return value**
  - success: returns a pointer to string
  - failure: returns NULL

- fgets vs scanf

```c
char buf[SIZE_BUF];

//store into buf until SIZE_BUF-1 characters
//or a newline or the end-of-file
fgets(buf, SIZE_BUF, stdin);

//store into buf until whitespace
scanf("%s", buf);
```

I/O one line at a time

`int fputs(const char* string, FILE* stream)`

Write a string to a file

- **Parameters**
  - string: Pointer to a source array
  - stream: Output stream

- **Return value**
  - success: returns a non-negative value
  - failure: returns EOF

```c
    FILE *fp;
    char buffer[SIZE];

    if((fp= fopen("append.txt", "a"))== NULL){
        printf("cannot open the file\n");
        return -1;
    }
    printf("Enter a string to append: ");
    fgets(buffer, SIZE, stdin);

    fputs(buffer, fp);
    fclose(fp);
```

Formatted I/O

int fprintf(FILE* stream, const char* format, …)

Write formatted output to a stream

- **Parameters**
  - stream: Output stream
  - format: String that contains the text to be written
    - format specifier: %d, %lf, %s, etc
  - (additional arguments): Replace a format specifier

- **Return value**
  - success: returns the number of characters written
  - failure: returns a negative number

Formatted I/O

int fscanf(FILE* stream, consta char* format, …)

Read formatted input from a stream

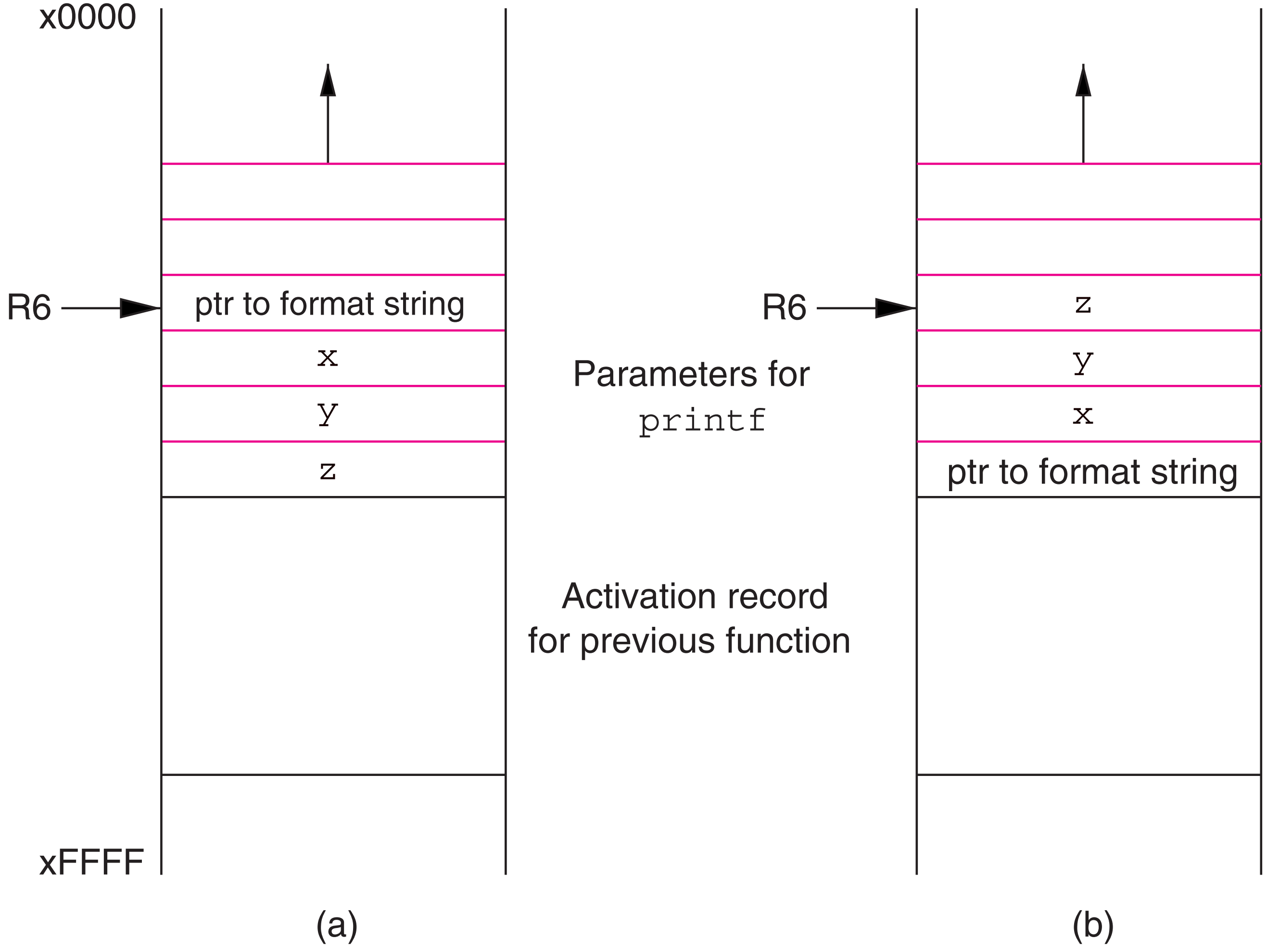
- **Parameters**
  - stream: Input stream
  - format: String that specifies how to read the input
    - format specifier: %d, %lf, %s, etc
  - (additional arguments): A pointer to store read data

- **Return value**
  - success: returns the number of items read
  - failure: returns EOF

Variable Argument Lists

- The number of arguments in a `printf` or `scanf` depends on the number of data items being read or written.
- We have two options for pushing the arguments:
  1. *right-to-left*
  2. *left-to-right*
- Which one is easier to figure out the number of arguments for the callee-function?

`printf("%d %d %d\n", x, y, z);`



(a) is easier because "ptr to format string" is always on the top before the function call occurs.
Once printf takes over, it can access the first parameter and analyze the format string to determine the other parameters.

Example

data.txt

```
4311 Alice 3.42
1133 Bob 4.0
```

→

swapped.txt

```
Alice 4311 3.42
Bob 1133 4.0
```

```
    int uid;
    char name[20];
    double gpa;
```

Example

```
data.txt

4311 Alice 3.42
1133 Bob 4.0
```

→

```
swapped.txt

Alice 4311 3.42
Bob 1133 4.0
```

```c
int uid;
char name[20];
double gpa;

FILE *fp_in = fopen("data.txt", "r");
FILE *fp_out = fopen("swapped.txt", "w") ;

while( fscanf(fp_in, "%d %s %lf", &uid, name, &gpa) != EOF)
    fprintf(fp_out, "%s %d %lf\n", name, uid, gpa);

fclose(fp_in);
fclose(fp_out);
```