Computing Laboratory

Review of C – Operators, Expressions, Control Flow, Basic Input/output

Malay Bhattacharyya

Assistant Professor

Machine Intelligence Unit
Indian Statistical Institute, Kolkata

October, 2021

The C compiler

Source code → **(C compiler)** → **Object code**

Object code → **(C linker)** → **Executable**

Standard conformance of C

Significant Features	**C89**	**C99**	**C11**
Implicit function declaration	Yes	No	No
IEEE 754 floating point support	No	Yes	Yes
Inline functions	No	Yes	Yes
long long int	No	Yes	Yes
complex type, complex.h	No	Yes	Yes
variadic macros	No	Yes	Yes
gets	Yes	Yes	No
Alignment specification	No	No	Yes
No return specification, stdnoreturn.h	No	No	Yes
Type generic expressions	No	No	Yes
Multi-threading, thread.h	No	No	Yes
Bounds checking	No	No	Yes

Note: C99 and C11 are formally known as ISO/IEC 9899:1999 and ISO/IEC 9899:2011, respectively.

The first C program

<u>Source</u>: Welcome2C.c

The first C program

Source: Welcome2C.c

```
#include<stdio.h>
int main(){
    printf("Welcome 2 C");
    return 0;
}
```

The first C program

Source: **Welcome2C.c**

```
#include<stdio.h>
int main(){
    printf("Welcome 2 C");
    return 0;
}
```

Compilation: **gcc Welcome2C.c**

The first C program

Source: Welcome2C.c

```
#include<stdio.h>
int main(){
    printf("Welcome 2 C");
    return 0;
}
```

Compilation: gcc Welcome2C.c

“Welcome2C.c” is compiled and the executable “a.out” is created.

The first C program

Source: Welcome2C.c

```
#include<stdio.h>
int main(){
    printf("Welcome 2 C");
    return 0;
}
```

Compilation: gcc Welcome2C.c

"Welcome2C.c" is compiled and the executable "a.out" is created.

Execution: ./a.out

The first C program

Source: Welcome2C.c

```
#include<stdio.h>
int main(){
    printf("Welcome 2 C");
    return 0;
}
```

Compilation: gcc Welcome2C.c

“Welcome2C.c” is compiled and the executable “a.out” is created.

Execution: ./a.out

Welcome 2 C**(cursor here!!!)**

Dissecting the code

```
#include<stdio.h>
int main(){
    statement;
    function1(argument);
    statement;
    return 0;
}
int function1(int arg){
    function2();
    statement;
}
void function2(){
    statement;
}
```

Dissecting the code

```
#include<stdio.h>
int main(){
    statement;
    function1(argument);
    statement;
    return 0;
}
int function1(int arg){
    function2();
    statement;
}
void function2(){
    statement;
}
```

Note: The program name can be anything.

Basic characteristics

- A C program should have at least the main() function.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.
- Every statement in C must end with a semicolon.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.
- Every statement in C must end with a semicolon.
- C is case sensitive.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.
- Every statement in C must end with a semicolon.
- C is case sensitive.
- C is a free-form language.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.
- Every statement in C must end with a semicolon.
- C is case sensitive.
- C is a free-form language.
- C is a loosely typed language.

Basic characteristics

- A C program should have at least the main() function.
- There can be at most a single main() function in the program.
- Every statement in C must end with a semicolon.
- C is case sensitive.
- C is a free-form language.
- C is a loosely typed language.
- C is a middle level language.

Free-form language

A C statement can be broken into multiple lines.

Free-form language

A C statement can be broken into multiple lines. E.g., the statements

```
printf("Welcome 2 C");
```

and

```
printf
("Welcome 2 C");
```

are both same producing the same output.

Loosely typed language

```
char c;
int i;
float f;
```

Loosely typed language

```
char c;
int i;
float f;
```

Here, the data types of c, i, f become flexible. They can be used interchangeably.

Loosely typed language

```
char c;
int i;
float f;
```

Here, the data types of c, i, f become flexible. They can be used interchangeably. E.g., assigning “c = 70” is same as assigning “c = ‘F’”.

Loosely typed language

```
char c;
int i;
float f;
```

Here, the data types of c, i, f become flexible. They can be used interchangeably. E.g., assigning "c = 70" is same as assigning "c = 'F'".

Note: Type casting is still there for converting the data types.

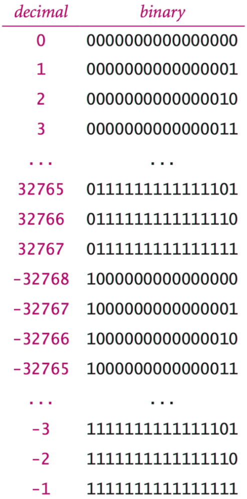
In-built types

Integer data types

Type	Size*	Minimum	Maximum
char	8 bits	-2^{7}	$2^{7}-1$
short int	16 bits	-2^{15}	$2^{15}-1$
int	32 bits	-2^{31}	$2^{31}-1$
long int	32 bits	-2^{31}	$2^{31}-1$
long long int	64 bits	-2^{63}	$2^{63}-1$
unsigned char	8 bits	0	$2^{8}-1$
unsigned short int	16 bits	0	$2^{16}-1$
unsigned int	32 bits	0	$2^{32}-1$
unsigned long int	32 bits	0	$2^{32}-1$
unsigned long long int	64 bits	0	$2^{64}-1$

* Dependent on machine configuration.

In-built types



decimal	*binary*
0	0000000000000000
1	0000000000000001
2	0000000000000010
3	0000000000000011
...	...
32765	0111111111111101
32766	0111111111111110
32767	0111111111111111
-32768	1000000000000000
-32767	1000000000000001
-32766	1000000000000010
-32765	1000000000000011
...	...
-3	1111111111111101
-2	1111111111111110
-1	1111111111111111

16-bit integers
(two's complement)

In-built types

“Real” (floating point) numbers

Type	Size
float	32
double	64
long double	128

Examples:

```
1.23456    3.45e67
1.         +3.45e67
.1         -3.45e-67
-0.12345   .00345e-32
+.4560     1e-15
```

In-built types

“Real” (floating point) numbers

Type	Size
float	32
double	64
long double	128

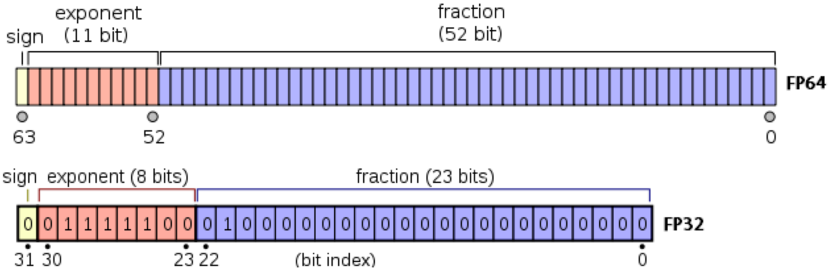
Examples:

```
1.23456
1.
.1
-0.12345
+.4560
3.45e67
+3.45e67
-3.45e-67
.00345e-32
1e-15
```

- Do not use commas as thousand-separators.
- At times behavior may be counter-intuitive (more about this later).

IEEE 754 floating point support

IEEE standard for floating point arithmetic (IEEE 754) is a technical standard for floating point representation on digital computers.



Boolean values

Any non-zero value is treated as **TRUE** and zero is treated as **FALSE**.

Examples:

0	False	0e10	False
1	True	'A'	True
6 - 2 * 3	False	'\0'	False
(6 - 2) * 3	True	x = 0	False
0.0075	True	x = 1	True

Type casting

```
int a = 5, b = 2;
float d;
d = a/b;
printf("Division result = %f",d);
```

Type casting

```
int a = 5, b = 2;
float d;
d = a/b;
printf("Division result = %f",d);
```

```
Division result = 2.000000
```

Type casting

```
int a = 5, b = 2;
float d;
d = (float)a/b;
printf("Division result = %f",d);
```

Type casting

```
int a = 5, b = 2;
float d;
d = (float)a/b;
printf("Division result = %f",d);
```

```
Division result = 2.500000
```

Escape sequences

How can we print the following using print statements?
', ", \

Escape sequences

How can we print the following using print statements?
', ", \

What will be the output of following?

```
char *title = "Bhattacharyya";
printf("This is Malay \r%s",title);
```

Escape sequences

How can we print the following using print statements?
', ", \

What will be the output of following?

```
char *title = "Bhattacharyya";
printf("This is Malay \r%s",title);
```

Bhattacharyya

Arithmetic operators

Summation $(+)$

Subtraction $(-)$

Multiplication $(*)$

Division $(/)$

Modulo division $(\%)$

Arithmetic operators

Summation $(+)$

Subtraction $(-)$

Multiplication $(*)$

Division $(/)$

Modulo division $(\%)$

Note: Modulo division operator works on the integers (negative too!!!) only and returns the sign of the numerator.

Relational operators

Less than $(<)$

Less than equals to $(<=)$

Greater than $(>)$

Greater than equals to $(>=)$

Equals to $(==)$

Not equals to $(!=)$

Logical operators

Logical and (&&)

Logical or (||)

Logical not (!)

Assignment operators

Assignment $(=)$

Increment and decrement operators

Increment $(++)$

Decrement $(--)$

Increment and decrement operators

```
int i = 5;
i++;
printf("%d", i);
printf("\n%d", i++); // Post-increment operation
printf("\n%d", ++i); // Pre-increment operation
```

Increment and decrement operators

```
int i = 5;
i++;
printf("%d", i);
printf("\n%d", i++); // Post-increment operation
printf("\n%d", ++i); // Pre-increment operation
```

```
6
6
8
```

Conditional operators

Ternary (? :)

```
int i = 0;
int j = 1;
int result = (i > j)? i : j;
```

Bitwise operators

Bitwise and (&)

Bitwise or (|)

Bitwise not ($\sim$)

Bitwise xor ($\wedge$)

Left shift ($<<$)

Right shift ($>>$)

Bitwise operators

```
int i = 11;
printf("%d", i>>1); // 1 place right shift (i unchanged)
printf("\n%d", i<<2); // 2 places left shift (i unchanged)
```

Bitwise operators

```
int i = 11;
printf("%d", i>>1); // 1 place right shift (i unchanged)
printf("\n%d", i<<2); // 2 places left shift (i unchanged)
```

```
5
44
```

Bitwise operators

```
int i = 11;
printf("%d", i>>1); // 1 place right shift (i unchanged)
printf("\n%d", i<<2); // 2 places left shift (i unchanged)
```

```
5
44
```

Decimal	**Binary**							
11	0	0	0	0	1	0	1	1
5	0	0	0	0	0	1	0	1
44	0	0	1	0	1	1	0	0

Operator precedence

What will be the output of the following program?

```
#include<stdio.h>
int main(){
    int n = 10;
    n = 20, 30, 40;
    printf("First n = %d\n",n);
    n = (50, 60, 70);
    printf("Second n = %d\n",n);
    return 0;
}
```

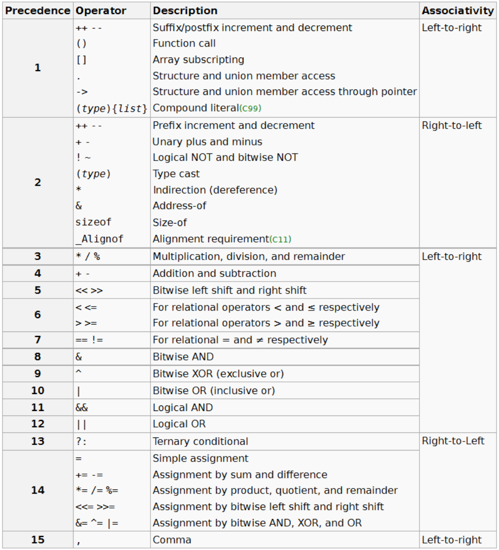
Operator precedence

What will be the output of the following program?

```
#include<stdio.h>
int main(){
    int n = 10;
    n = 20, 30, 40;
    printf("First n = %d\n",n);
    n = (50, 60, 70);
    printf("Second n = %d\n",n);
    return 0;
}
```

```
First n = 20
Second n = 70
```

Operator precedence



Precedence	Operator	Description	Associativity

1	`++ --`
	`()`
	`[]`
	`.`
	`->`
	`(`*`type`*`){`*`list`*`}`
		Suffix/postfix increment and decrement
		Function call
		Array subscripting
		Structure and union member access
		Structure and union member access through pointer
		Compound literal(C99)
			Left-to-right

2	`++ --`
	`+ -`
	`! ~`
	`(`*`type`*`)`
	`*`
	`&`
	`sizeof`
	`_Alignof`
		Prefix increment and decrement
		Unary plus and minus
		Logical NOT and bitwise NOT
		Type cast
		Indirection (dereference)
		Address-of
		Size-of
		Alignment requirement(C11)
			Right-to-left

3	`* / %`	Multiplication, division, and remainder	Left-to-right
4	`+ -`	Addition and subtraction	
5	`<< >>`	Bitwise left shift and right shift	

6	`< <=`
	`> >=`
		For relational operators < and ≤ respectively
		For relational operators > and ≥ respectively	

7	`== !=`	For relational = and ≠ respectively	
8	`&`	Bitwise AND	
9	`^`	Bitwise XOR (exclusive or)	
10	`|`	Bitwise OR (inclusive or)	
11	`&&`	Logical AND	
12	`||`	Logical OR	
13	`?:`	Ternary conditional	Right-to-Left

14	`=`
	`+= -=`
	`*= /= %=`
	`<<= >>=`
	`&= ^= |=`
		Simple assignment
		Assignment by sum and difference
		Assignment by product, quotient, and remainder
		Assignment by bitwise left shift and right shift
		Assignment by bitwise AND, XOR, and OR	

15	`,`	Comma	Left-to-right

Conditional – if-else

```
if(Condition){
    statement 1;
    statement 2;
}
else{
    statement 3; // Execute if Condition fails
}
```

Conditional – if-else

```
if(Condition){
    statement 1;
    statement 2;
}
else{
    statement 3; // Execute if Condition fails
}
```

Note: A single statement can be included (within if/else) by default without using any brackets.

Conditional – if-else

What will be the output of the following program?

```
if(!printf("Hi!"))
    printf("Hi!");
else
    printf("Bye!");
```

Conditional – if-else

What will be the output of the following program?

```
if(!printf("Hi!"))
    printf("Hi!");
else
    printf("Bye!");
```

Hi!Bye!

Conditional – switch-case

```
switch (E) {
    case value1 :
       statement;
       break;
    case value2 :
       statement;
       break;
    ...
    case valuen :
       statement;
       break;
    default:
       statement;
 }
```

Iterative – for loop

```
for(Initialization;Condition;Increment/Decrement){
    statement 1;
    statement 2;
}
```

Iterative – for loop

```
for(Initialization;Condition;Increment/Decrement){
    statement 1;
    statement 2;
}
```

Alternatively, we can write

```
for(Initialization;Condition;Increment/Decrement)
    statement 3;
```

Iterative – for loop

```
for(Initialization;Condition;Increment/Decrement){
    statement 1;
    statement 2;
}
```

Alternatively, we can write

```
for(Initialization;Condition;Increment/Decrement)
    statement 3;
```

Note: The ‘Initialization’, ‘Condition’, and ‘Increment/Decrement’ are all optional.

Iterative – for loop

What will be the output of the following program?

```
unsigned char i = 0;
for(;i>=0;i++);
    printf("%d\n",i);
```

Iterative – for loop

What will be the output of the following program?

```
unsigned char i = 0;
for(;i>=0;i++);
    printf("%d\n",i);
```

The program iterates infinitely!!!

Iterative – for loop

What will be the output of the following program?

```
unsigned char i = 0;
for(;i>=0;i++);
    printf("%d\n",i);
```

The program iterates infinitely!!!

Unsigned characters can never be negative and so $i >= 0$ never yields FALSE.

Iterative – while loop

```
while(Condition){
    statement 1;
    statement 2;
}
```

Iterative – while loop

```
while(Condition){
    statement 1;
    statement 2;
}
```

Alternatively, we can write

```
while(Condition)
    statement 3;
```

Iterative – while loop

```
while(Condition){
    statement 1;
    statement 2;
}
```

Alternatively, we can write

```
while(Condition)
    statement 3;
```

Note: A non-zero value is treated as a TRUE ‘Condition’, otherwise FALSE.

Iterative – do-while loop

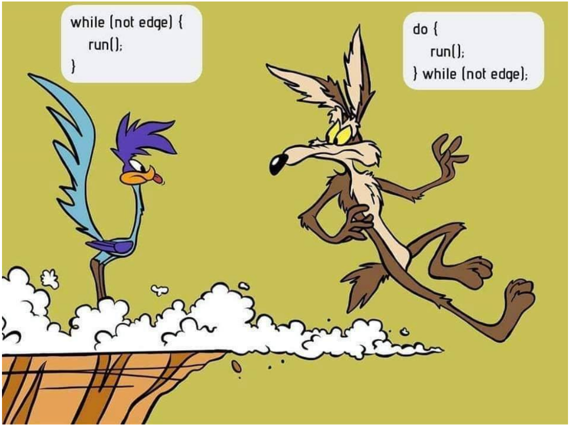
```
do{
    statement 1;
    statement 2;
}while(Condition);
```

Iterative – do-while loop

```
do{
    statement 1;
    statement 2;
}while(Condition);
```

Note: The statements inside the block are executed (by default) at least once irrespective of the 'Condition'.

Iterative – Comparing while and do-while



break and continue

- **break:** immediately jump to the next operation after the loop
- **continue:** do the update operation if applicable, and continue with the next iteration of the loop

break and continue

- **break:** immediately jump to the next operation after the loop
- **continue:** do the update operation if applicable, and continue with the next iteration of the loop

```
for(i=1; i<=100; ++i){
     printf("%4d",i);
     if (i%10 != 0)
        break;
     printf("\n");
}
```

break and continue

- **break:** immediately jump to the next operation after the loop
- **continue:** do the update operation if applicable, and continue with the next iteration of the loop

```
for(i=1; i<=100; ++i){
     printf("%4d",i);
     if (i%10 != 0)
        break;
     printf("\n");
}
```

```
i = 0;
while(i < 100){
    ++i;
    printf("%4d",i);
    if (i%10 != 0)
        continue;
    printf("\n");
}
```

Input/Output

I/O from the terminal

- `printf`, `scanf`
- `getchar`, `putchar`

Input/Output

I/O from the terminal

- printf, scanf
- getchar, putchar

I/O from files

- File pointers: FILE *
- fopen, fclose
- fprintf, fscanf
- fgetc, fputc
- fgets, fputs

Input/Output

I/O from the terminal

- `printf`, `scanf`
- `getchar`, `putchar`

I/O from files

- File pointers: `FILE *`
- `fopen`, `fclose`
- `fprintf`, `fscanf`
- `fgetc`, `fputc`
- `fgets`, `fputs`

- Practice reading man pages.
  e.g. `$ man fopen`
- **Do not use** `gets()`**!**

Format specifiers

Specifying the format of a variable in the formatted Input/Output (`printf()` / `scanf()`) statement.

Format specifier	Purpose
%c	character I/O
%s	string/series of characters I/O
%d	signed integer I/O (assumes base 10)
%i	signed integer I/O (auto detects base)
%u	unsigned integer I/O
%o	unsigned octal integer I/O
%x/%X	unsigned hexadecimal integer I/O
%e/%E/%f/%g	double/floating point I/O
%lf	long double I/O

More on scanf()

We can take input strings with delimeters (e.g., spaces or commas) in between as follows.

```
char str[20];
scanf("%[^\t\n]s", str);
```

Command line arguments

The `main()` function can receive arguments directly from the command line as follows.

```
#include<stdio.h>
int main(int argument_count, char *argument_value[]){
    int i;
    for(i=0; i<argument_count; i++){
        printf("%s\n",argument_value[i]);
    }
    return 0;
}
```

Note: `argument_count` keeps the number of arguments passed from the command line and `argument_value[]` stores the arguments as array of strings. Both these variable names are user-defined.

Command line arguments

Execution:

```
./a.out DFS is fun
```

Output:

```
./a.out
DFS
is
fun
```

Problems – Day 2

1. The `abundancy` of a natural number n is defined as the rational number $\frac{\sigma(n)}{n}$, the ratio between the sum of divisors of the number and the number itself. A number n is defined as `friendly` if it shares `abundancy` with one or more other numbers. This means there might exist a pair of numbers i and j such that $i \neq j$ but $\frac{\sigma(i)}{i} = \frac{\sigma(j)}{j}$. For example, 6 and 28 are `friendly` with each other because $\frac{\sigma(6)}{6} = \frac{\sigma(28)}{28} = 2$. Write a program to verify whether a pair of integers given as user input are `friendly` or not.
2. Given a positive integer n as user input, find out the number of trailing zeros in $n!$.
   Note: This can be done with $\log_5 n$ number of divisions.

Problems – Day 2

3. Suppose m and n are (signed) integers and x and y are floating variables. Write logical conditions that evaluate to `TRUE` if and only if:
    - $x + y$ is an integer.
    - m lies strictly between x and y.
    - m equals the integer part of x.
    - x is positive with integer part at least 3 and with fractional part less than 0.3.
    - m and n have the same parity (i.e., are both odd or both even).
    - m is a perfect square.
4. Write a program to print the following pattern using generic controls over print. Let the line number be user input.

```
   *
  * *
 *   *
*     *
```

Problems – Day 2

5. Consider an n-digit number. Square it and add the right n digits to the left n or $n-1$ digits. If the resultant sum is same as the original number, then it is called a `Kaprekar` number. E.g., 45 is a `Kaprekar` number. Write a program to verify whether a given number is `Kaprekar` or not.
6. Let m and n be 32-bit unsigned integers. Use bitwise operations to assign to m the following functions of n:
   - 1 if n is odd, 0 if n is even.
   - 1 if n is divisible by 8, 0 otherwise.
   - 2^n (Assume that $n <= 31$).
   - n rotated by k positions to the left for some integer $k >= 0$.
   - n rotated by k positions to the right for some integer $k >= 0$.