

Courses

**Write an
Article**

G-Fact 1 |
(Sizeof is an
operator)

G-Fact 2

G-Fact 3

G-Fact 4

G-Fact 5

G-Fact 6

G-Fact 7

G-Fact 8

How are
variables
scoped in C
– Static or
Dynamic?

Scope rules
in C

How Linkers
Resolve
Global
Symbols
Defined at
Multiple
Places?

Complicated
declarations
in C

Redeclaration
of global
variable in C

Data Types
in C

Use of bool
in C

Integer
Promotions
in C

Comparison
of a float
with a value
in C

Storage
Classes in C

Static
Variables in
C

How to
deallocate
memory
without
using free()
in C?

calloc()
versus
malloc()

How does

free() know
the size of
memory to
be
deallocated?

Use of
realloc()

int (1 sign bit
+ 31 data
bits)
keyword in C

Program
error signals

Why array
index starts
from zero ?

TCP Server-
Client
implementation
in C

How to
return
multiple
values from
a function in
C or C++?

Dynamic
Memory
Allocation in
C using
malloc(),
calloc(),
free() and
realloc()

Commonly

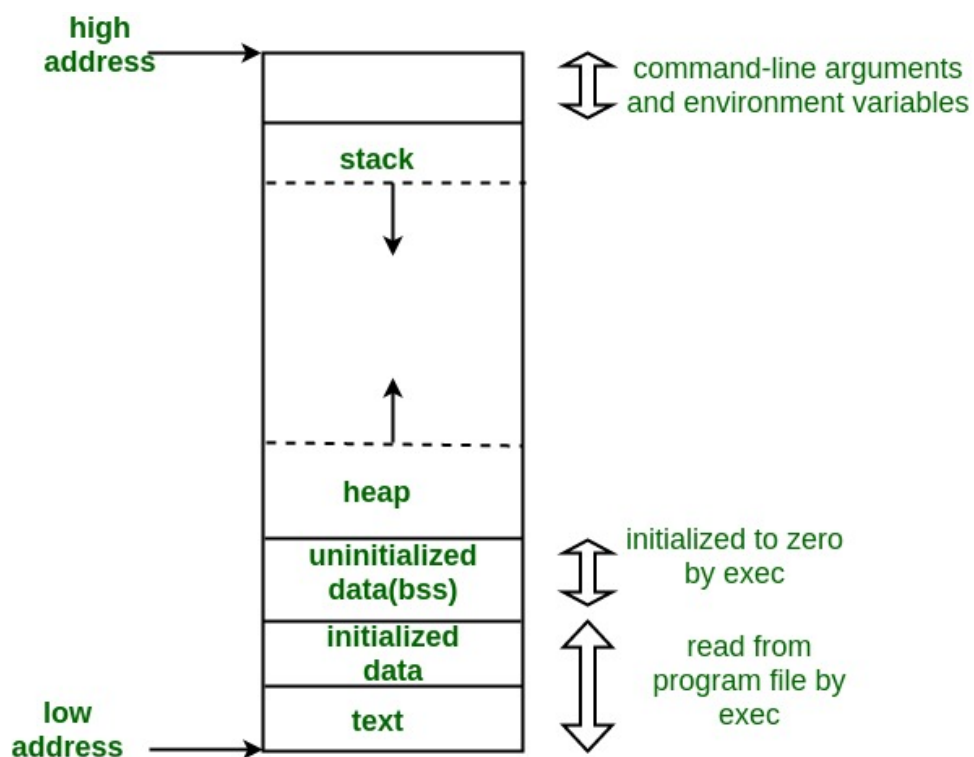
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Programming
Interview
Questions |
Set 3



Memory Layout of C Programs

A typical memory representation of C program consists of following sections.

1. Text segment
2. Initialized data segment
3. Uninitialized data segment
4. Stack
5. Heap



A typical memory layout of a running process

1. Text Segment:

A text segment, also known as a code segment or simply as text, is one of the sections of a program in an object file or in memory, which contains executable instructions.

As a memory region, a text segment may be placed below the heap or stack in order to prevent heaps and stack overflows from overwriting it.

Usually, the text segment is sharable so that only a single copy needs to be in memory for frequently executed programs, such as text editors, the C compiler, the shells, and so on. Also, the text segment is often read-only, to prevent a program from accidentally modifying its instructions.

2. Initialized Data Segment:

Initialized data segment, usually called simply the Data Segment. A data segment is a portion of virtual address space of a program, which contains the global variables and static variables that are initialized by the programmer.

Note that, data segment is not read-only, since the values of the variables can be altered at run time.

This segment can be further classified into initialized read-only area and initialized read-write area.

For instance the global string defined by `char s[] = "hello world"` in C and a C statement like `int debug=1` outside the main (i.e. global) would be stored in initialized read-write area. And a global C statement like `const char* string = "hello world"` makes the string literal "hello world" to be stored in initialized read-only area and the character pointer variable `string` in initialized read-write area.

Ex: `static int i = 10` will be stored in data segment and `global int i = 10` will also be stored in data segment

3. Uninitialized Data Segment:

Uninitialized data segment, often called the "bss" segment, named after an ancient assembler operator that stood for "block started by symbol." Data in this segment is initialized by the kernel to arithmetic 0 before the program starts executing

uninitialized data starts at the end of the data segment and contains all global variables and static variables that are initialized to zero or do not have explicit initialization in source code.

For instance a variable declared `static int i;` would be contained in the BSS segment.
For instance a global variable declared `int j;` would be contained in the BSS segment.

4. Stack:

The stack area traditionally adjoined the heap area and grew the opposite direction; when the stack pointer met the heap pointer, free memory was exhausted. (With modern large address spaces and virtual memory techniques they may be placed almost anywhere, but they still typically grow opposite directions.)

The stack area contains the program stack, a LIFO structure, typically located in the higher parts of memory. On the standard PC x86 computer architecture it grows toward address zero; on some other architectures it grows the opposite direction. A “stack pointer” register tracks the top of the stack; it is adjusted each time a value is “pushed” onto the stack. The set of values pushed for one function call is termed a “stack frame”; A stack frame consists at minimum of a return address.

Stack, where automatic variables are stored, along with information that is saved each time a function is called. Each time a function is called, the address of where to return to and certain information about the caller’s environment, such as some of the machine registers, are saved on the stack. The newly called function then allocates room on the stack for its automatic and temporary variables. This is how recursive functions in C can work. Each time a recursive function calls itself, a new stack frame is used, so one set of variables doesn’t interfere with the variables from another instance of the function.

5. Heap:

Heap is the segment where dynamic memory allocation usually takes place.





The heap area begins at the end of the BSS segment and grows to larger addresses from there. The Heap area is managed by `malloc`, `realloc`, and `free`, which may use the `brk` and `sbrk` system calls to adjust its size (note that the use of `brk/sbrk` and a single “heap area” is not required to fulfill the contract of `malloc/realloc/free`; they may also be implemented using `mmap` to reserve potentially non-contiguous regions of virtual memory into the process’ virtual address space). The Heap area is shared by all shared libraries and dynamically loaded modules in a process.

Examples.

The `size(1)` command reports the sizes (in bytes) of the text, data, and bss segments. (for more details please refer man page of `size(1)`)

1. Check the following simple C program

```

 #include <stdio.h>
 int main(void)
{
     return 0;
 }

```





```

[narendra@CentOS]$ gcc memory-layout.c -o memory-layout
[narendra@CentOS]$ size memory-layout
text      data      bss      dec      hex      filename
960       248       8        1216     4c0      memory-layout

```

2. Let us add one global variable in program, now check the size of bss (highlighted in red color).

```

 #include <stdio.h>
 int global; /* Uninitialized variable stored in bss*/
 int main(void)
{
     return 0;
}

```





```

[narendra@CentOS]$ gcc memory-layout.c -o memory-layout
[narendra@CentOS]$ size memory-layout
text      data      bss      dec      hex      filename
960       248       12       1220     4c4      memory-layout

```

3. Let us add one static variable which is also stored in bss.

```

 #include <stdio.h>
 int global; /* Uninitialized variable stored in bss*/
 int main(void)
{
     static int i; /* Uninitialized static variable stored in bss */
    return 0;
}

```





```

[narendra@CentOS]$ gcc memory-layout.c -o memory-layout

```





```
[narendra@CentOS]$ size memory-layout
text      data      bss      dec      hex      filename
960       248       16       1224     4c8      memory-layout
```

4. Let us initialize the static variable which will then be stored in Data Segment (DS)

```
 #include <stdio.h>
 int global; /* Uninitialized variable stored in bss*/
 int main(void)
{
     static int i = 100; /* Initialized static variable stored in DS */
    return 0;
}
```

```
[narendra@CentOS]$ gcc memory-layout.c -o memory-layout
[narendra@CentOS]$ size memory-layout
text      data      bss      dec      hex      filename
960       252       12       1224     4c8      memory-layout
```

5. Let us initialize the global variable which will then be stored in Data Segment (DS)

```
 #include <stdio.h>
 int global = 10; /* initialized global variable stored in DS*/
 int main(void)
{
     static int i = 100; /* Initialized static variable stored in DS */
    return 0;
}
```

```
[narendra@CentOS]$ gcc memory-layout.c -o memory-layout
[narendra@CentOS]$ size memory-layout
text      data      bss      dec      hex      filename
960       256       8        1224     4c8      memory-layout
```

This article is compiled by **Narendra Kangralkar**. Please write comments if you find anything incorrect, or you want to share more information about the topic discussed above.

Source:

http://en.wikipedia.org/wiki/Data_segment

http://en.wikipedia.org/wiki/Code_segment

<http://en.wikipedia.org/wiki/.bss>

<http://www.amazon.com/Advanced-Programming-UNIX-Environment-2nd/dp/0201433079>

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[C | Dynamic Memory Allocation | Question 2](#)

[C | Dynamic Memory Allocation | Question 3](#)

[C | Dynamic Memory Allocation | Question 8](#)

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19

2.6

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