

Part 1

Steps in Compilation of a C program.

Hello World Program in C:

```
hello.c  X
C hello.c > ...
1  #include <stdio.h>
2  int main(){
3      printf("Hello World!\n");
4      return 0;
5  }
6
```

Step 1: Preprocessing:

```
ashu@Ashu-PC: ~/COE
ashu@Ashu-PC:~/COE$ cpp hello.c > hello.i
ashu@Ashu-PC:~/COE$
#include <stdio.h>
int main(){
    printf("Hello world!\n");
}
```

Preprocessing Output

```
C++ hello.i  X
C++ hello.i
1  # 1 "hello.c"
2  # 1 "<built-in>"
3  # 1 "<command-line>"
4  # 31 "<command-line>"
5  # 1 "/usr/include/stdc-predef.h" 1 3 4
6  # 32 "<command-line>" 2
7  # 1 "hello.c"
8  # 1 "/usr/include/stdio.h" 1 3 4
9  # 27 "/usr/include/stdio.h" 3 4
10 # 1 "/usr/include/x86_64-linux-gnu/bits/libc-header-start.h" 1 3 4
11 # 33 "/usr/include/x86_64-linux-gnu/bits/libc-header-start.h" 3 4
12 # 1 "/usr/include/features.h" 1 3 4
13 # 424 "/usr/include/features.h" 3 4
14 # 1 "/usr/include/x86_64-linux-gnu/sys/cdefs.h" 1 3 4
15 # 427 "/usr/include/x86_64-linux-gnu/sys/cdefs.h" 3 4
16 # 1 "/usr/include/x86_64-linux-gnu/bits/wordsize.h" 1 3 4
17 # 428 "/usr/include/x86_64-linux-gnu/sys/cdefs.h" 2 3 4
18 # 1 "/usr/include/x86_64-linux-gnu/bits/long-double.h" 1 3 4
19 # 429 "/usr/include/x86_64-linux-gnu/sys/cdefs.h" 2 3 4
20 # 425 "/usr/include/features.h" 2 3 4
21 # 448 "/usr/include/features.h" 3 4
22 # 1 "/usr/include/x86_64-linux-gnu/gnu/stubs.h" 1 3 4
23 # 10 "/usr/include/x86_64-linux-gnu/gnu/stubs.h" 3 4
24 # 1 "/usr/include/x86_64-linux-gnu/gnu/stubs-64.h" 1 3 4
25 # 11 "/usr/include/x86_64-linux-gnu/gnu/stubs.h" 2 3 4
26 # 449 "/usr/include/features.h" 2 3 4
27 # 34 "/usr/include/x86_64-linux-gnu/bits/libc-header-start.h" 2 3 4
28 # 28 "/usr/include/stdio.h" 2 3 4
29
30
31
32
33
34 # 1 "/usr/lib/gcc/x86_64-linux-gnu/7/include/stddef.h" 1 3 4
35 # 216 "/usr/lib/gcc/x86_64-linux-gnu/7/include/stddef.h" 3 4
36
37 # 216 "/usr/lib/gcc/x86_64-linux-gnu/7/include/stddef.h" 3 4
```

```
C++ hello.i  X
C++ hello.i
772
773
774 extern int pclose (FILE *__stream);
775
776
777
778
779
780 extern char *ctermid (char *__s) __attribute__((__nothrow__ , __leaf__));
781 # 840 "/usr/include/stdio.h" 3 4
782 extern void flockfile (FILE *__stream) __attribute__((__nothrow__ , __leaf__));
783
784
785
786 extern int ftrylockfile (FILE *__stream) __attribute__((__nothrow__ , __leaf__));
787
788
789 extern void funlockfile (FILE *__stream) __attribute__((__nothrow__ , __leaf__));
790 # 868 "/usr/include/stdio.h" 3 4
791
792 # 2 "hello.c" 2
793
794 # 2 "hello.c"
795 int main(){
796     printf("Hello World!\n");
797     return 0;
798 }
799
```

Step 2: Generating Assembly Code (Compiling):

```
ashu@Ashu-PC: ~/COE
ashu@Ashu-PC:~/COE$ cpp hello.c > hello.i
ashu@Ashu-PC:~/COE$ gcc -S hello.i -o hello.s
ashu@Ashu-PC:~/COE$
```

```
hello.s  X
hello.s
1      .file    "hello.c"
2      .text
3      .section .rodata
4      .LC0:
5          .string "Hello World!"
6      .text
7      .globl  main
8      .type   main, @function
9      main:
10     .LFB0:
11         .cfi_startproc
12         pushq   %rbp
13         .cfi_def_cfa_offset 16
14         .cfi_offset 6, -16
15         movq    %rsp, %rbp
16         .cfi_def_cfa_register 6
17         leaq    .LC0(%rip), %rdi
18         call    puts@PLT
19         movl    $0, %eax
20         popq    %rbp
21         .cfi_def_cfa 7, 8
22         ret
23     .cfi_endproc
24     .LFE0:
25     .size  main, .-main
26     .ident  "GCC: (Ubuntu 7.4.0-1ubuntu1~18.04.1) 7.4.0"
27     .section .note.GNU-stack,"",@progbits
```

Step 3: Assembling (Generating Object Code):

```
ashu@Ashu-PC: ~/COE
ashu@Ashu-PC:~/COE$ cpp hello.c > hello.i
ashu@Ashu-PC:~/COE$ gcc -S hello.i -o hello.s
ashu@Ashu-PC:~/COE$ as hello.s -o hello.o
ashu@Ashu-PC:~/COE$
```

```
hello.o.hexdump x
1 | Offset: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
2 | 00000000: 7F 45 4C 46 02 01 01 00 00 00 00 00 00 00 00 00 .ELF.....
3 | 00000010: 01 00 3E 00 01 00 00 00 00 00 00 00 00 00 00 00 ..>.....
4 | 00000020: 00 00 00 00 00 00 00 00 C8 02 00 00 00 00 00 00 .....H.....
5 | 00000030: 00 00 00 00 40 00 00 00 00 00 40 00 0D 00 0C 00 ....@.....@....
6 | 00000040: 55 48 89 E5 48 8D 3D 00 00 00 00 E8 00 00 00 00 UH.eH.=...h....
7 | 00000050: B8 00 00 00 00 5D C3 48 65 6C 6C 6F 20 57 6F 72 8....]CHello.Wor
8 | 00000060: 6C 64 21 00 00 47 43 43 3A 20 28 55 62 75 6E 74 ld!..GCC:.(Ubunt
9 | 00000070: 75 20 37 2E 34 2E 30 2D 31 75 62 75 6E 74 75 31 u.7.4.0-1ubuntu1
10 | 00000080: 7E 31 38 2E 30 34 2E 31 29 20 37 2E 34 2E 30 00 ~18.04.1).7.4.0.
11 | 00000090: 14 00 00 00 00 00 00 00 01 7A 52 00 01 78 10 01 .....zR..X..
12 | 000000a0: 1B 0C 07 08 90 01 00 00 1C 00 00 00 1C 00 00 00 .....
13 | 000000b0: 00 00 00 00 17 00 00 00 00 41 0E 10 86 02 43 0D .....A....C.
14 | 000000c0: 06 52 0C 07 08 00 00 00 00 00 00 00 00 00 00 00 .R.....
15 | 000000d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
16 | 000000e0: 01 00 00 00 04 00 F1 FF 00 00 00 00 00 00 00 00 .....q.....
17 | 000000f0: 00 00 00 00 00 00 00 00 00 00 00 00 03 00 01 00 .....
18 | 00000100: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
19 | 00000110: 00 00 00 00 03 00 03 00 00 00 00 00 00 00 00 00 .....
20 | 00000120: 00 00 00 00 00 00 00 00 00 00 00 00 03 00 04 00 .....
21 | 00000130: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
22 | 00000140: 00 00 00 00 03 00 05 00 00 00 00 00 00 00 00 00 .....
23 | 00000150: 00 00 00 00 00 00 00 00 00 00 00 00 03 00 07 00 .....
24 | 00000160: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
25 | 00000170: 00 00 00 00 03 00 08 00 00 00 00 00 00 00 00 00 .....
26 | 00000180: 00 00 00 00 00 00 00 00 00 00 00 00 03 00 06 00 .....
27 | 00000190: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
28 | 000001a0: 09 00 00 00 12 00 01 00 00 00 00 00 00 00 00 00 .....
29 | 000001b0: 17 00 00 00 00 00 00 00 0E 00 00 00 10 00 00 00 .....
30 | 000001c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
31 | 000001d0: 24 00 00 00 10 00 00 00 00 00 00 00 00 00 00 00 $.
32 | 000001e0: 00 00 00 00 00 00 00 00 00 68 65 6C 6C 6F 2E 63 .....hello.c
33 | 000001f0: 00 6D 61 69 6E 00 5F 47 4C 4F 42 41 4C 5F 4F 46 .main._GLOBAL_OF
34 | 00000200: 46 53 45 54 5F 54 41 42 4C 45 5F 00 70 75 74 73 FSET_TABLE_.puts
35 | 00000210: 00 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00 .....
36 | 00000220: 02 00 00 00 05 00 00 00 FC FF FF FF FF FF FF FF .....|.....
37 | 00000230: 0C 00 00 00 00 00 00 00 04 00 00 00 0B 00 00 00 .....
```

Step 4: Linking Generating Executable File:

```
ashu@Ashu-PC: ~/COE
ashu@Ashu-PC:~/COE$ ld -static -o hello -L`gcc -print-file-name= /usr/lib/x86_64-l
linux-gnu/crti.o /usr/lib/x86_64-linux-gnu/crti.o hello.o /usr/lib/x86_64-linux-gnu/c
rtn.o --start-group -lc -lgcc -lgcc_eh --end-group
ashu@Ashu-PC:~/COE$
```

```

hello.exe.hexdump x
1  Offset: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
2  00000000: 7F 45 4C 46 02 01 01 00 00 00 00 00 00 00 00 00  .ELF.....
3  00000010: 03 00 3E 00 01 00 00 00 30 05 00 00 00 00 00 00  ..>....0....
4  00000020: 40 00 00 00 00 00 00 00 58 19 00 00 00 00 00 00  @.....X.....
5  00000030: 00 00 00 00 40 00 38 00 09 00 40 00 1D 00 1C 00  ....@.8...@....
6  00000040: 06 00 00 00 04 00 00 00 40 00 00 00 00 00 00 00  .....@.....
7  00000050: 40 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00  @.....@.....
8  00000060: F8 01 00 00 00 00 00 00 F8 01 00 00 00 00 00 00  x.....X.....
9  00000070: 08 00 00 00 00 00 00 00 03 00 00 00 04 00 00 00  .....
10 00000080: 38 02 00 00 00 00 00 00 38 02 00 00 00 00 00 00  8.....8.....
11 00000090: 38 02 00 00 00 00 00 00 1C 00 00 00 00 00 00 00  8.....
12 000000a0: 1C 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00  .....
13 000000b0: 01 00 00 00 05 00 00 00 00 00 00 00 00 00 00 00  .....
14 000000c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
15 000000d0: 78 08 00 00 00 00 00 00 78 08 00 00 00 00 00 00  x.....X.....
16 000000e0: 00 00 20 00 00 00 00 00 01 00 00 00 06 00 00 00  .....
17 000000f0: B8 0D 00 00 00 00 00 00 B8 0D 20 00 00 00 00 00  8.....8.....
18 00000100: B8 0D 20 00 00 00 00 00 58 02 00 00 00 00 00 00  8.....X.....
19 00000110: 60 02 00 00 00 00 00 00 00 00 20 00 00 00 00 00  ^.....
20 00000120: 02 00 00 00 06 00 00 00 C8 0D 00 00 00 00 00 00  .....H.....
21 00000130: C8 0D 20 00 00 00 00 00 C8 0D 20 00 00 00 00 00  H.....H.....
22 00000140: F0 01 00 00 00 00 00 00 F0 01 00 00 00 00 00 00  p.....p.....
23 00000150: 08 00 00 00 00 00 00 00 04 00 00 00 04 00 00 00  .....
24 00000160: 54 02 00 00 00 00 00 00 54 02 00 00 00 00 00 00  T.....T.....
25 00000170: 54 02 00 00 00 00 00 00 44 00 00 00 00 00 00 00  T.....D.....
26 00000180: 44 00 00 00 00 00 00 00 04 00 00 00 00 00 00 00  D.....
27 00000190: 50 E5 74 64 04 00 00 00 0C 07 00 00 00 00 00 00  Petd.....
28 000001a0: 0C 07 00 00 00 00 00 00 0C 07 00 00 00 00 00 00  .....
29 000001b0: 44 00 00 00 00 00 00 00 44 00 00 00 00 00 00 00  D.....D.....
30 000001c0: 04 00 00 00 00 00 00 00 51 E5 74 64 06 00 00 00  .....Qetd....
31 000001d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
32 000001e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  .....
33 000001f0: 00 00 00 00 00 00 00 00 10 00 00 00 00 00 00 00  .....
34 00000200: 52 E5 74 64 04 00 00 00 B8 0D 00 00 00 00 00 00  Retd....8.....
35 00000210: B8 0D 20 00 00 00 00 00 B8 0D 20 00 00 00 00 00  8.....8.....
36 00000220: 48 02 00 00 00 00 00 00 48 02 00 00 00 00 00 00  H.....H.....
37 00000230: 01 00 00 00 00 00 00 00 2F 6C 69 62 36 34 2F 6C  ...../lib64/l
38 00000240: 64 2D 6C 69 6E 75 78 2D 78 38 36 2D 36 34 2E 73  d-linux-x86-64.s

```

Running Executable File:

```

ashu@Ashu-PC: ~/COE
ashu@Ashu-PC:~/COE$ ld -static -o hello -L`gcc -print-file-name= /usr/lib/x86_64-l
linux-gnu/crt1.o /usr/lib/x86_64-linux-gnu/crti.o hello.o /usr/lib/x86_64-linux-gnu/c
rtn.o --start-group -lc -lgcc -lgcc_eh --end-group
ashu@Ashu-PC:~/COE$ ./hello
Hello world!
ashu@Ashu-PC:~/COE$

```