

Introduction to 8086 Assembly

Lecture 13

Inline Assembly

Inline Assembly

- Compiler-dependent
- *GCC* → *GAS* (the GNU assembler)



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University of Technology

Intel Syntax => AT&T Syntax



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- Registers: `eax` => `%eax`
- Immediates: `123` => `$123`
- Memory:
 - `lbl1` => `$lbl1` (address of `lbl1`)
 - `[lbl1]` => `lbl1` (content of `lbl1`)

Intel Syntax => AT&T Syntax



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- Operand order reversed:
 - `mov dest, src` => `mov src, dest`
- Operand size in command (`movb`, `movw`, `movl`, `addb`, `addw`, `addl`, etc):
 - `mov eax, ebx` => `movl %ebx, %eax`
 - `add dl, ch` => `addb %ch, %dl`
- Indirect addressing
 - `mov eax, [ebx]` => `movl (%ebx), %eax`
 - `add ax, [ebx+4]` => `addw 4(%ebx), %ax`
 - `mov dword [ebx], 1` => `movl $1, (%ebx)`

Compile C to AT&T Assembly



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- `gcc -S myprogram.c`
- `gcc -S -masm=att myprogram.c`

More on Intel vs. AT&T Syntax



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- https://en.wikipedia.org/wiki/X86_assembly_language#Syntax
- https://en.wikibooks.org/wiki/X86_Assembly/GAS_Syntax
- <https://imada.sdu.dk/Courses/DM18/Litteratur/IntelInATT.htm>

Basic inline assembly



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inline1.c

```
int main() {  
  
    asm ("movl $1, %eax");  
  
    return 0;  
}
```

inline2.c

```
int main() {  
  
    __asm__ ("movl %eax, %ebx");  
  
    return 0;  
}
```

Basic inline assembly



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```
int main() {  
    int a;  
  
    asm("movl $10, %eax; xchgb %al, %ah");  
  
    asm("movl $10, %eax;"  
        "xchgb %al, %ah");  
  
    return 0;  
}
```

inline3.c

Basic inline assembly



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```
int main() {  
    int a;
```

inline3.c

```
    asm("movl $10, %eax; xchg %al, %ah");
```

```
    asm("movl $10, %eax;"  
        "xchg %al, %ah");
```

```
    return 0;  
}
```

Isn't semicolon used
for comments?

Basic inline assembly



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```
int main() {  
    int a;  
  
    asm("movl $10, %eax; xchg %al, %ah");  
  
    asm("movl $10, %eax;"  
        "xchg %al, %ah");  
  
    return 0;  
}
```

inline3.c

→ This is GAS not NASM!

Global symbols (functions, global variables)



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inline4.c

```
#include <stdio.h>

int g = 0;

void print_sum(int a, int b) {
    printf("sum=%d\n", a+b);
}

int main() {

    asm ("movl $110, g");    // NASM: mov dword [g], 110

    printf("g=%d\n", g);

    asm ("pushl $10;"        // NASM: push 10
        "pushl $13;"        // NASM: push 13
        "call print_sum;"    // NASM: call print_sum
        "addl $8, %esp;");   // NASM: add esp, 8

    return 0;
}
```

Global symbols (functions, global variables)



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inline4.c

```
#include <stdio.h>

int g = 0;

void print_sum(int a, int b) {
    printf("sum=%d\n", a+b);
}

int main() {

    asm ("movl $110, g");    // NASM: mov dword [g], 110

    printf("g=%d\n", g);

    asm ("pushl $10;"        // NASM: push 10
        "pushl $13;"        // NASM: push 13
        "call print_sum;"    // NASM: call print_sum
        "addl $8, %esp;");   // NASM: add esp, 8

    return 0;
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline4.c && ./a.out
g=110
sum=23
```

Global symbols (functions, global variables)



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inline4.c

```
#include <stdio.h>
```

```
int g = 0;
```

```
void print_sum(int a, int b) {  
    printf("sum=%d\n", a+b);  
}
```

**Do not use this technique!
It might not always work!**

```
printf("g=%d\n", g);
```

```
asm ("pushl $10;"          // NASM: push 10  
     "pushl $13;"          // NASM: push 13  
     "call print_sum;"     // NASM: call print_sum  
     "addl $8, %esp;");    // NASM: add esp, 8
```

```
return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline4.c && ./a.out  
g=110  
sum=23
```

Global symbols (functions, global variables)



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inline4.c

```
#include <stdio.h>
```

```
int g = 0;
```

```
void print_sum(int a, int b) {  
    printf("sum=%d\n", a+b);  
}
```

```
int main
```

```
asm (
```

```
printf("g=%d\n", g);
```

```
asm ("pushl $10;"          // NASM: push 10  
     "pushl $13;"          // NASM: push 13  
     "call print_sum;"     // NASM: call print_sum  
     "addl $8, %esp;");    // NASM: add esp, 8
```

```
return 0;
```

```
}
```

what about local variables?

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline4.c && ./a.out  
g=110  
sum=23
```

How GCC handles inline assembly?



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```
#include <stdio.h>
```

```
inline5.c
```

```
int main() {
```

```
    int a,b,c,d;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("charand_command %ebx, %eax");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

How GCC handles inline assembly?



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```
#include <stdio.h>

int main() {
    int a,b,c,d;

    scanf("%d %d", &a, &b);

    c = a+b;

    asm ("charand_command %ebx, %eax");

    printf("a=%d b=%d, a+b=%d\n", a, b, c);

    return 0;
}
```

inline5.c

No Error Compiling to Assembly!

```
b.nasihatkon@kntu:lecture13$ gcc -S inline5.c -o inline5.asm
b.nasihatkon@kntu:lecture13$
```


How GCC handles inline assembly?



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```
#include <stdio.h>
```

inline5.c

```
int main() {
```

```
    int a,b,c,d;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("charand_command %ebx, %eax");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
:
```

inline5.asm

```
movl -16(%rbp), %eax
```

```
addl %edx, %eax
```

```
movl %eax, -12(%rbp)
```

```
charand_command %ebx, %eax
```

```
movl -16(%rbp), %edx
```

```
movl -20(%rbp), %eax
```

```
movl -12(%rbp), %ecx
```

```
movl %eax, %esi
```

```
movl $.LC1, %edi
```

```
movl $0, %eax
```

```
:
```

```
b.nasihatkon@kntu:lecture13$ gcc -S inline5.c -o inline5.asm
b.nasihatkon@kntu:lecture13$
```

How GCC handles inline assembly?



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```
#include <stdio.h>
```

inline5.c

```
int main() {
```

```
    int a,b,c,d;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("charand_command %ebx, %eax");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
:
```

inline5.asm

```
movl -16(%rbp), %eax
```

```
addl %edx, %eax
```

```
movl %eax, -12(%rbp)
```

```
charand_command %ebx, %eax
```

```
movl -16(%rbp), %edx
```

```
movl -20(%rbp), %eax
```

```
movl -12(%rbp), %ecx
```

```
movl %eax, %esi
```

```
movl $.LC1, %edi
```

```
movl $0, %eax
```

```
:
```

just inserting
inline assembly

```
b.nasihatkon@kntu:lecture13$ gcc -S inline5.c -o inline5.asm
b.nasihatkon@kntu:lecture13$
```

How GCC handles inline assembly?



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```
#include <stdio.h>
```

inline5.c

```
int main() {
```

```
    int a,b,c,d;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("charand_command %ebx, %eax");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

GCC just inserts inline assembly!

Assembler Error!

```
b.nasihatkon@kntu:lecture13$ gcc inline5.c
```

```
inline5.c: Assembler messages:
```

```
inline5.c:10: Error: no such instruction: `charand_command %ebx,%eax'
```

How GCC handles inline assembly?



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```
#include <stdio.h>

int main() {
    int a,b,c,d;

    scanf("%d %d", &a, &b);

    c = a+b;

    asm ("charand_command %ebx, %eax");

    printf("a=%d b=%d, a+b=%d\n", a, b, c);

    return 0;
}
```

inline5.c

GCC just inserts inline assembly!
It has no idea what the inline code is doing!

Assembler Error!

```
b.nasihatkon@kntu:lecture13$ gcc inline5.c
inline5.c: Assembler messages:
inline5.c:10: Error: no such instruction: `charand_command %ebx,%eax'
```

How GCC handles inline assembly?



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```
#include <stdio.h>

int main() {
    int a,b,c,d;

    scanf("%d %d", &a, &b);

    c = a+b;

    asm ("charand_command %ebx, %eax");

    printf("a=%d b=%d, a+b=%d\n", a, b, c);

    return 0;
}
```

inline5.c

***GCC just inserts inline
assembly!
It has no idea what the
inline code is doing!
=> side effects!***

Assembler Error!

```
b.nasihatkon@kntu:lecture13$ gcc inline5.c
inline5.c: Assembler messages:
inline5.c:10: Error: no such instruction: `charand_command %ebx,%eax'
```

What can go wrong?



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```
#include <stdio.h>
```

```
inline6.c
```

```
int main() {
```

```
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"
```

```
        "movl $1, %ecx;"
```

```
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

What can go wrong?



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```
#include <stdio.h>
```

```
inline6.c
```

```
int main() {  
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"  
        "movl $1, %ecx;"  
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

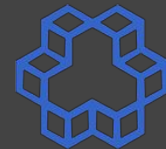
```
    return 0;
```

```
}
```

might or might not work as registers unexpectedly change. (worked in this case).

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline6.c && ./a.out  
2 3  
a=2 b=3, a+b=5
```

What can go wrong? Case 1:



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```
#include <stdio.h>
```

```
inline7.c
```

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"
```

```
        "movl $1, %ecx;"
```

```
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```


What can go wrong? Case 1:



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```
#include <stdio.h>
```

inline7.c

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

gcc tries to use
a register to
store c

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"
```

```
        "movl $1, %ebx;"
```

```
        "movl $1, %ecx;"
```

```
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

What can go wrong? Case 1:



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```
#include <stdio.h>
```

inline7.c

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"
```

```
        "movl $1, %ebx;"
```

```
        "movl $1, %ecx;"
```

```
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline7.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=1
```

What can go wrong? Case 1:



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```
#include <stdio.h>
```

inline7.c

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"
```

```
        "movl $1, %ebx;"
```

```
        "movl $1, %ecx;"
```

```
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline7.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=1
```

What can go wrong? Case 2:



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```
#include <stdio.h>
```

```
inline6.c
```

```
int main() {  
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"  
        "movl $1, %ebx;"  
        "movl $1, %ecx;"  
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;  
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline6.c && ./a.out  
2 3
```

```
a=2 b=3, a+b=5
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -O1 inline6.c && ./a.out  
2 3
```

```
a=1 b=1, a+b=2
```

turn on optimization

Solution 1: use volatile keyword



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```
#include <stdio.h>
```

```
inline8.c
```

```
int main() {
```

```
    volatile int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"  
        "movl $1, %ebx;"  
        "movl $1, %ecx;"  
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline8.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=5
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -O1 inline8.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=5
```

turn on optimization

Solution 1: use volatile keyword



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```
#include <stdio.h>
```

```
inline8.c
```

```
int main() {
```

```
    volatile int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %eax;"  
        "movl $1, %ebx;"  
        "movl $1, %ecx;"  
        "movl $1, %edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

renders optimization useless!

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline8.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=5
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -O1 inline8.c && ./a.out
```

```
2 3
```

```
a=2 b=3, a+b=5
```

turn on optimization

Learn more about **volatile** keyword



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- <https://barrgroup.com/Embedded-Systems/How-To/C-Volatile-Keyword>
- <https://www.geeksforgeeks.org/understanding-volatile-qualifier-in-c/>
- [https://en.wikipedia.org/wiki/Volatile_\(computer_programming\)](https://en.wikipedia.org/wiki/Volatile_(computer_programming))
-

Solution 2: tell compiler what registers are affected



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```
#include <stdio.h>

int main() {
    volatile int a,b,c;

    scanf("%d %d", &a, &b);

    c = a+b;

    asm ("movl $1, %eax;"
        "movl $1, %ebx;"
        "movl $1, %ecx;"
        "movl $1, %edx");

    printf("a=%d b=%d, a+b=%d\n", a, b, c);

    return 0;
}
```


Extended Inline Assembly



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```
asm ( "assembly code" : output registers : input registers : clobbered registers );
```

Solution 2: tell compiler what registers are affected



```
#include <stdio.h>
```

```
inline9.c
```

```
int main() {
```

```
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"
```

```
        "movl $1, %%ebx;"
```

```
        "movl $1, %%ecx;"
```

```
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

Solution 2: tell compiler what registers are affected



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```
#include <stdio.h>
```

inline9.c

```
int main() {  
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"  
        "movl $1, %%ebx;"  
        "movl $1, %%ecx;"  
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

use double %
for registers

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;  
}
```

Solution 2: tell compiler what registers are affected



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```
#include <stdio.h>
```

```
inline9.c
```

```
int main() {  
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"  
        "movl $1, %%ebx;"  
        "movl $1, %%ecx;"  
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

clobbered registers

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;  
}
```

Solution 2: tell compiler what registers are affected



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```
#include <stdio.h>
```

```
int main() {  
    int a,b,c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"  
        "movl $1, %%ebx;"  
        "movl $1, %%ecx;"  
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;  
}
```

inline9.c

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline9.c && ./a.out  
2 3
```

```
a=2 b=3, a+b=5
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -O1 inline9.c && ./a.out  
2 3
```

```
a=2 b=3, a+b=5
```

turn on optimization

Solution 2: tell compiler what registers are affected



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```
#include <stdio.h>
```

```
inline10.c
```

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"
```

```
        "movl $1, %%ebx;"
```

```
        "movl $1, %%ecx;"
```

```
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

Solution 2: tell compiler what registers are affected



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University of Technology

```
#include <stdio.h>
```

inline10.c

```
int main() {
```

```
    int a,b;
```

```
    register int c;
```

```
    scanf("%d %d", &a, &b);
```

```
    c = a+b;
```

```
    asm ("movl $1, %%eax;"
```

```
        "movl $1, %%ebx;"
```

```
        "movl $1, %%ecx;"
```

```
        "movl $1, %%edx;" : : : "eax", "ebx", "ecx", "edx");
```

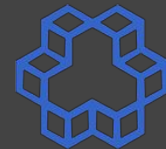
```
    printf("a=%d b=%d, a+b=%d\n", a, b, c);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline10.c && ./a.out
2 3
a=2 b=3, a+b=5
```

Give input to inline assembly



K. N. Toosi

```
#include <stdio.h>
#include <string.h>
```

inline11.c

```
int main() {
    char msg[] = "Salaaaam Kako!\n";
    int length = strlen(msg);

    asm ("movl    $4, %%eax;" // system call 4: sys_write
        "movl    $1, %%ebx;" // file handle 1: stdout
        "int     $0x80;"     // syscall
        : // no outputs
        : "c" (msg), "d" (length) : "eax", "ebx");

    return 0;
}
```

no outputs

inputs
(input constraints)

clobbered
registers

```
# sys_write
movl    $4, %eax # syscall no.
movl    $1, %ebx # file handle
movl    $msg, %ecx # message
movl    $13, %edx # length
int     $0x80
```


Give input to inline assembly



K. N. Toosi

```
#include <stdio.h>
#include <string.h>
```

inline11.c

```
int main() {
    char msg[] = "Salaaaam Kako!\n";
    int length = strlen(msg);

    asm ("movl    $4, %%eax;" // system call 4: sys_write
        "movl    $1, %%ebx;" // file handle 1: stdout
        "int     $0x80;"     // syscall
        :      : "c" (msg), "d" (length) : "eax", "ebx");

    return 0;
}
```

ecx **edx**

```
# sys_write=4
movl    $4, %eax # syscall no.
movl    $1, %ebx # file handle
movl    $msg, %ecx # message
movl    $13, %edx # length
int     $0x80
```

Give input to inline assembly



K. N. Toosi

```
#include <stdio.h>
#include <string.h>

int main() {
    char msg[] = "Salaaaam Kako!\n";
    int length = strlen(msg);

    asm ("movl    $4, %%eax;" // system call 4: sys_write
        "movl    $1, %%ebx;" // file handle 1: stdout
        "int     $0x80;"     // syscall
        :      : "c" (msg), "d" (length) : "eax", "ebx");

    return 0;
}
```

inline11.c

```
# sys_write=4
movl    $4, %eax # syscall no.
movl    $1, %ebx # file handle
movl    $msg, %ecx # message
movl    $13, %edx # length
int     $0x80
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline11.c && ./a.out
Salaaaam Kako!
```

Registers



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a	eax, ax, al
b	ebx, bx, bl
c	ecx, cx, cl
d	edx, dx, dl
S	esi, si
D	edi, di
r	register
f	a floating point register

Get output



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```
#include <stdio.h>
```

inline12.c

```
int main() {
```

```
    int x = 12, y=13;
```

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

```
    asm ("xchgl %%eax, %%ebx"
```

```
        : "=a" (x), "=b" (y)
```

```
        : "a" (x), "b" (y)
```

```
        : );
```

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

```
    return 0;
```

```
}
```

Get output



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```
#include <stdio.h>
```

inline12.c

```
int main() {
```

```
    int x = 12, y=13;
```

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

```
    asm ("xchgl %%eax, %%ebx"
```

```
        : "=a" (x), "=b" (y) → outputs
```

```
        : "a" (x), "b" (y) → inputs
```

```
        : );
```

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

```
    return 0;
```

```
}
```

Get output



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```
#include <stdio.h>
```

inline12.c

```
int main() {
```

```
    int x = 12, y=13;
```

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

```
    asm ("xchgl %%eax, %%ebx"
```

```
        : "=a" (x), "=b" (y) → outputs
```

```
        : "a" (x), "b" (y) → inputs
```

```
        : );
```

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

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline12.c && ./a.out
```

```
x=12, y=13
```

```
x=13, y=12
```

Get output



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```
#include <stdio.h>
```

inline13.c

```
int main() {
```

```
    int x = 12, y=13;
```

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

```
    asm ("xchgl %0, %1"
```

```
        : "=r" (x), "=r" (y) → outputs
```

```
        : "0" (x), "1" (y) → inputs
```

```
        : );
```

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

```
    return 0;
```

```
}
```

Get output



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```
#include <stdio.h>
```

inline13.c

```
int main() {
```

```
    int x = 12, y=13;
```

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

```
    asm ("xchgl %0, %1"
```

```
        : "=r" (x), "=r" (y) → outputs
```

```
        : "0" (x), "1" (y) → inputs
```

```
        : );
```

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

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 inline13.c && ./a.out
```

```
x=12, y=13
```

```
x=13, y=12
```


Use Intel Syntax with GCC



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- Modern versions of *GAS* support Intel Syntax
- The *GAS* GNU Syntax is a bit different from NASM Syntax
 - the `.intel_syntax` and `.att_syntax` directives

Use Intel Syntax with GCC



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- Bad Solution:
 - Put your code between the `.intel_syntax` (better `.intel_syntax noprefix`) and `.att_syntax` directives
- Good solution:
 - Compile with `-masm=intel` gcc option.

Use Intel Syntax with GCC



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```
#include <stdio.h>
#include <string.h>

int main() {
    char msg[] = "Salaaaam Kako!\n";
    int length = strlen(msg);

    asm ("mov    eax, 4;" // system call 4: sys_write
        "mov    ebx, 1;" // file handle 1: stdout
        "int    0x80;"   // syscall
        :      : "c" (msg), "d" (length) : "eax", "ebx");

    return 0;
}
```

inline14.c

Use Intel Syntax with GCC



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```
#include <stdio.h>
#include <string.h>

int main() {
    char msg[] = "Salaaaam Kako!\n";
    int length = strlen(msg);

    asm ("mov    eax, 4;" // system call 4: sys_write
        "mov    ebx, 1;" // file handle 1: stdout
        "int    0x80;"   // syscall
        :      : "c" (msg), "d" (length) : "eax", "ebx");

    return 0;
}
```

inline14.c

```
b.nasihatkun@kntu:lecture13$ gcc -m32 -masm=intel inline14.c && ./a.out
Salaaaam Kako!
b.nasihatkun@kntu:lecture13$
```

Be careful with compiler optimization!



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```
#include <stdio.h>
```

inline15.c

```
int main() {
```

```
    int count = 0;
```

```
    asm ("mov eax, 0" : : : "eax");
```

```
    for (int i = 0; i < 10; i++) {
```

```
        asm ("inc eax;" : "=a" (count) : : );
```

```
    }
```

```
    printf("count=%d\n", count);
```

```
    return 0;
```

```
}
```

Be careful with compiler optimization!



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```
#include <stdio.h>
```

inline15.c

```
int main() {
```

```
    int count = 0;
```

```
    asm ("mov eax, 0" : : : "eax");
```

```
    for (int i = 0; i < 10; i++) {
```

```
        asm ("inc eax;" : "=a" (count) : : );
```

```
    }
```

```
    printf("count=%d\n", count);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -masm=intel inline15.c && ./a.out
```

```
count=10
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -masm=intel -O1 inline15.c && ./a.out
```

```
count=1
```

volatile keyword for inline assembly



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```
#include <stdio.h>
```

inline16.c

```
int main() {
```

```
    int count = 0;
```

```
    asm volatile ("mov eax, 0" : : : "eax");
```

```
    for (int i = 0; i < 10; i++) {
```

```
        asm volatile ("inc eax;" : "=a" (count) : : );
```

```
    }
```

```
    printf("count=%d\n", count);
```

```
    return 0;
```

```
}
```

volatile keyword for inline assembly



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```
#include <stdio.h>
```

inline16.c

```
int main() {
```

```
    int count = 0;
```

```
    asm volatile ("mov eax, 0" : : : "eax");
```

```
    for (int i = 0; i < 10; i++) {
```

```
        asm volatile ("inc eax;" : "=a" (count) : : );
```

```
    }
```

```
    printf("count=%d\n", count);
```

```
    return 0;
```

```
}
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -masm=intel inline16.c && ./a.out
```

```
count=10
```

```
b.nasihatkon@kntu:lecture13$ gcc -m32 -masm=intel -O1 inline16.c && ./a.out
```

```
count=10
```


Inline assembly is compiler-dependent



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```
__asm {  
    mov al, 2  
    mov dx, 0xD007  
    out dx, al  
}
```

```
__asm mov al, 2  
__asm mov dx, 0xD007  
__asm out dx, al
```



Microsoft Visual C

<https://msdn.microsoft.com/en-us/library/45yd4tzz.aspx>

References & further reading



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University of Technology

- <https://gcc.gnu.org/onlinedocs/gcc/Constraints.html>
- <https://www.codeproject.com/Articles/15971/Using-Inline-Assembly-in-C-C>
- <https://www.ibiblio.org/gferg/ldp/GCC-Inline-Assembly-HOWTO.html>
- <https://www.cs.virginia.edu/~clc5q/gcc-inline-asm.pdf>