

Brennan's Guide to Inline Assembly

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Ok. This is meant to be an introduction to inline assembly under DJGPP. DJGPP is based on GCC, so it uses the AT&T/UNIX syntax and has a somewhat unique method of inline assembly. I spent many hours figuring some of this stuff out and told **Info** that I hate it, many times.

Hopefully if you already know Intel syntax, the examples will be helpful to you. I've put variable names, register names and other literals in **bold type**.

The Syntax

So, DJGPP uses the AT&T assembly syntax. What does that mean to you?

- **Register naming:**

Register names are prefixed with "%". To reference **eax**:

```
AT&T:  %eax  
Intel:  eax
```

- **Source/Destination Ordering:**

In AT&T syntax (which is the UNIX standard, BTW) the source is *a/ways* on the **left**, and the destination is *a/ways* on the **right**.

So let's load **ebx** with the value in **eax**:

```
AT&T:  movl %eax, %ebx  
Intel:  mov ebx, eax
```

- **Constant value/immediate value format:**

You must prefix all constant/immediate values with "\$".

Let's load **eax** with the address of the "C" variable **booga**, which is static.

```
AT&T:  movl $_booga, %eax
Intel:  mov eax, _booga
```

Now let's load **ebx** with **0xd00d**:

```
AT&T:  movl $0xd00d, %ebx
Intel:  mov ebx, d00dh
```

- **Operator size specification:**

You must suffix the instruction with one of **b**, **w**, or **l** to specify the width of the destination register as a **byte**, **word** or **longword**. If you omit this, GAS (GNU assembler) will attempt to guess. *You don't want GAS to guess, and guess wrong!* Don't forget it.

```
AT&T:  movw %ax, %bx
Intel:  mov bx, ax
```

The equivalent forms for Intel is **byte ptr**, **word ptr**, and **dword ptr**, but that is for when you are...

- **Referencing memory:**

DJGPP uses 386-protected mode, so you can forget all that real-mode addressing junk, including the restrictions on which register has what default segment, which registers can be base or index pointers. Now, we just get 6 general purpose registers. (7 if you use **ebp**, but be sure to restore it yourself or compile with **-fomit-frame-pointer**.)

Here is the canonical format for 32-bit addressing:

```
AT&T:  immed32(basepointer,indexpointer,indexscale)
Intel:  [basepointer + indexpointer*indexscale + immed32]
```

You could think of the formula to calculate the address as:

$$\text{immed32} + \text{basepointer} + \text{indexpointer} * \text{indexscale}$$

You don't have to use all those fields, but you *do* have to have at least 1 of immed32, basepointer and you *MUST* add the size suffix to the operator!

Let's see some simple forms of memory addressing:

- Addressing a particular C variable:

```
AT&T:  _booga
Intel:  [_booga]
```

Note: the underscore ("_") is how you get at static (global) C variables from assembler. *This only works with global variables.* Otherwise, you can use extended asm to have variables preloaded into registers for you. I address that farther down.

- Addressing what a register points to:

AT&T: (%eax)
Intel: [eax]

- Addressing a variable offset by a value in a register:

AT&T: _variable(%eax)
Intel: [eax + _variable]

- Addressing a value in an array of integers (scaling up by 4):

AT&T: _array(,%eax,4)
Intel: [eax*4 + array]

- You can also do offsets with the immediate value:

C code: *(p+1) where p is a char *
AT&T: 1(%eax) where eax has the value of p
Intel: [eax + 1]

- You can do some simple math on the immediate value:

AT&T: _struct_pointer+8

I assume you can do that with Intel format as well.

- Addressing a particular char in an array of 8-character records:

eax holds the number of the record desired. **ebx** has the wanted char's offset within the record.

AT&T: _array(%ebx,%eax,8)
Intel: [ebx + eax*8 + _array]

Whew. Hopefully that covers all the addressing you'll need to do. As a note, you can put **esp** into the address, but only as the base register.

Basic inline assembly

The format for basic inline assembly is very simple, and much like Borland's method.

```
asm ("statements");
```

Pretty simple, no? So

```
asm ("nop");
```

will do nothing of course, and

```
asm ("cli");
```

will stop interrupts, with

```
asm ("sti");
```

of course enabling them. You can use `__asm__` instead of `asm` if the keyword `asm` conflicts with something in your program.

When it comes to simple stuff like this, basic inline assembly is fine. You can even push your registers onto the stack, use them, and put them back.

```
asm ("pushl %eax\n\t"  
    "movl $0, %eax\n\t"  
    "popl %eax");
```

(The `\n`'s and `\t`'s are there so the `.s` file that GCC generates and hands to GAS comes out right when you've got multiple statements per `asm`.)

It's really meant for issuing instructions for which there is no equivalent in C and don't touch the registers.

But if you *do* touch the registers, and don't fix things at the end of your `asm` statement, like so:

```
asm ("movl %eax, %ebx");  
asm ("xorl %ebx, %edx");  
asm ("movl $0, _booga");
```

then your program will probably blow things to hell. This is because GCC hasn't been told that your `asm` statement clobbered `ebx` and `edx` and `booga`, which it might have been keeping in a register, and might plan on using later. For that, you need:

Extended inline assembly

The basic format of the inline assembly stays much the same, but now gets Watcom–like extensions to allow input arguments and output arguments.

Here is the basic format:

```
asm ( "statements" : output_registers : input_registers : clobbered_registers);
```

Let's just jump straight to a nifty example, which I'll then explain:

```
asm ( "cld\n\t"
      "rep\n\t"
      "stosl"
      : /* no output registers */
      : "c" (count), "a" (fill_value), "D" (dest)
      : "%ecx", "%edi" );
```

The above stores the value in **fill_value** **count** times to the pointer **dest**.

Let's look at this bit by bit.

```
asm ( "cld\n\t"
```

We are clearing the direction bit of the **flags** register. You never know what this is going to be left at, and it costs you all of 1 or 2 cycles.

```
      "rep\n\t"
      "stosl"
```

Notice that GAS requires the **rep** prefix to occupy a line of it's own. Notice also that **stos** has the **l** suffix to make it move **longwords**.

```
      : /* no output registers */
```

Well, there aren't any in this function.

```
      : "c" (count), "a" (fill_value), "D" (dest)
```

Here we load **ecx** with **count**, **eax** with **fill_value**, and **edi** with **dest**. Why make GCC do it instead of doing it ourselves? Because GCC, in its register allocating, might be able to arrange for, say, **fill_value** to already be in **eax**. If this is in a loop, it might be able to preserve **eax** thru the loop, and save a **movl** once per loop.

```
      : "%ecx", "%edi" );
```

And here's where we specify to GCC, "you can no longer count on the values you loaded into **ecx** or **edi** to be valid." This doesn't mean they will be reloaded for certain. This is the clobberlist.

Seem funky? Well, it really helps when optimizing, when GCC can know exactly what you're doing with the registers before and after. It folds your assembly code into the code it's generates (whose rules for generation look *remarkably* like the above) and then optimizes. It's even smart enough to know that if you tell it to put (x+1) in a register, then if you don't clobber it, and later C code refers to (x+1), and it was able to keep that register free, it will reuse the computation. Whew.

Here's the list of register loading codes that you'll be likely to use:

```
a      eax
b      ebx
c      ecx
d      edx
S      esi
D      edi
I      constant value (0 to 31)
q,r    dynamically allocated register (see below)
g      eax, ebx, ecx, edx or variable in memory
A      eax and edx combined into a 64-bit integer (use long longs)
```

Note that you can't directly refer to the byte registers (**ah**, **al**, etc.) or the word registers (**ax**, **bx**, etc.) when you're loading this way. Once you've got it in there, though, you can specify **ax** or whatever all you like.

The codes *have* to be in quotes, and the expressions to load in *have* to be in parentheses.

When you do the clobber list, you specify the registers as above *with* the **%**. If you write to a variable, you *must* include "**memory**" as one of The Clobbered. This is in case you wrote to a variable that GCC thought it had in a register. This is the same as clobbering all registers. While I've never run into a problem with it, you might also want to add "**cc**" as a clobber if you change the condition codes (the bits in the **flags** register the **jnz**, **je**, etc. operators look at.)

Now, that's all fine and good for loading specific registers. But what if you specify, say, **ebx**, and **ecx**, and GCC can't arrange for the values to be in those registers without having to stash the previous values. It's possible to let GCC pick the register(s). You do this:

```
asm ("leal (%1,%1,4), %0"
    : "=r" (x)
    : "0" (x) );
```

The above example multiplies `x` by 5 really quickly (1 cycle on the Pentium). Now, we could have specified, say `eax`. But unless we really need a specific register (like when using `rep movsl` or `rep stosl`, which are hardcoded to use `ecx`, `edi`, and `esi`), why not let GCC pick an available one? So when GCC generates the output code for GAS, `%0` will be replaced by the register it picked.

And where did `"q"` and `"r"` come from? Well, `"q"` causes GCC to allocate from `eax`, `ebx`, `ecx`, and `edx`. `"r"` lets GCC also consider `esi` and `edi`. So make sure, if you use `"r"` that it would be possible to use `esi` or `edi` in that instruction. If not, use `"q"`.

Now, you might wonder, how to determine how the `%n` tokens get allocated to the arguments. It's a straightforward first-come-first-served, left-to-right thing, mapping to the `"q"`'s and `"r"`'s. But if you want to reuse a register allocated with a `"q"` or `"r"`, you use `"0"`, `"1"`, `"2"`... etc.

You don't need to put a GCC-allocated register on the clobberlist as GCC knows that you're messing with it.

Now for output registers.

```
asm ("leal (%1,%1,4), %0"
    : "=r" (x_times_5)
    : "r" (x) );
```

Note the use of `=` to specify an output register. You just have to do it that way. If you want 1 variable to stay in 1 register for both in and out, you have to respecify the register allocated to it on the way in with the `"0"` type codes as mentioned above.

```
asm ("leal (%0,%0,4), %0"
    : "=r" (x)
    : "0" (x) );
```

This also works, by the way:

```
asm ("leal (%ebx,%ebx,4), %ebx"
    : "=b" (x)
    : "b" (x) );
```

2 things here:

- Note that we don't have to put `ebx` on the clobberlist, GCC knows it goes into `x`. Therefore, since it can know the value of `ebx`, it isn't considered clobbered.
- Notice that in extended asm, you must prefix registers with `%%` instead of just `%`. Why, you ask? Because as GCC parses along for `%0`'s and `%1`'s and so on, it would interpret `%edx` as a `%e` parameter, see that that's non-existent, and ignore it. Then it would bitch about finding a symbol named `dx`, which isn't valid because it's not prefixed with `%` and it's not the one you meant anyway.

Important note: If your assembly statement *must* execute where you put it, (i.e. must not be moved out of a loop as an optimization), put the keyword **volatile** after **asm** and before the ()'s. To be ultra-careful, use

```
__asm__ __volatile__ (...whatever...);
```

However, I would like to point out that if your assembly's only purpose is to calculate the output registers, with no other side effects, you should leave off the **volatile** keyword so your statement will be processed into GCC's common subexpression elimination optimization.

Some useful examples

```
#define disable() __asm__ __volatile__ ("cli");
```

```
#define enable() __asm__ __volatile__ ("sti");
```

Of course, **libc** has these defined too.

```
#define times3(arg1, arg2) \
__asm__ ( \
    "leal (%0,%0,2),%0" \
    : "=r" (arg2) \
    : "0" (arg1) );
```

```
#define times5(arg1, arg2) \
__asm__ ( \
    "leal (%0,%0,4),%0" \
    : "=r" (arg2) \
    : "0" (arg1) );
```

```
#define times9(arg1, arg2) \
__asm__ ( \
    "leal (%0,%0,8),%0" \
    : "=r" (arg2) \
    : "0" (arg1) );
```

These multiply arg1 by 3, 5, or 9 and put them in arg2. You should be ok to do:

```
times5(x,x);
```

as well.

```
#define rep_movsl(src, dest, numwords) \
__asm__ __volatile__ ( \
    "cld\n\t" \
```



```
"rep\n\t" \
"movsl" \
: : "S" (src), "D" (dest), "c" (numwords) \
: "%ecx", "%esi", "%edi" )
```

Helpful Hint: If you say **memcpy()** with a constant length parameter, GCC will inline it to a **rep movsl** like above. But if you need a variable length version that inlines and you're always moving dwords, there ya go.

```
#define rep_stosl(value, dest, numwords) \
__asm__ __volatile__ ( \
"cld\n\t" \
"rep\n\t" \
"stosl" \
: : "a" (value), "D" (dest), "c" (numwords) \
: "%ecx", "%edi" )
```

Same as above but for **memset()**, which doesn't get inlined no matter what (for now.)

```
#define RDTSC(llptr) ({ \
__asm__ __volatile__ ( \
".byte 0x0f; .byte 0x31" \
: "=A" (llptr) \
: : "eax", "edx"); })
```

Reads the TimeStampCounter on the Pentium and puts the 64 bit result into llptr.

The End

"The End"?! Yah, I guess so.

If you're wondering, I personally am a big fan of AT&T/UNIX syntax now. (It might have helped that I cut my teeth on SPARC assembly. Of course, that machine actually had a decent number of general registers.) It might seem weird to you at first, but it's really more logical than Intel format, and has no ambiguities.

If I still haven't answered a question of yours, look in the **Info** pages for more information, particularly on the input/output registers. You can do some funky stuff like use **"A"** to allocate two registers at once for 64-bit math or **"m"** for static memory locations, and a bunch more that aren't really used as much as **"q"** and **"r"**.

Alternately, [mail me](mailto:brennan@delorie.com), and I'll see what I can do. (If you find any errors in the above, *please*, e-mail me and tell me about it! It's frustrating enough to learn without buggy docs!) Or heck, mail me to say "boogabooga."

It's the least you can do.

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Thanks to Eric J. Korpela <korpela@ssl.Berkeley.EDU> for some corrections.

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