Introduction to Intel x86-64 Assembly, Architecture, Applications, & Alliteration

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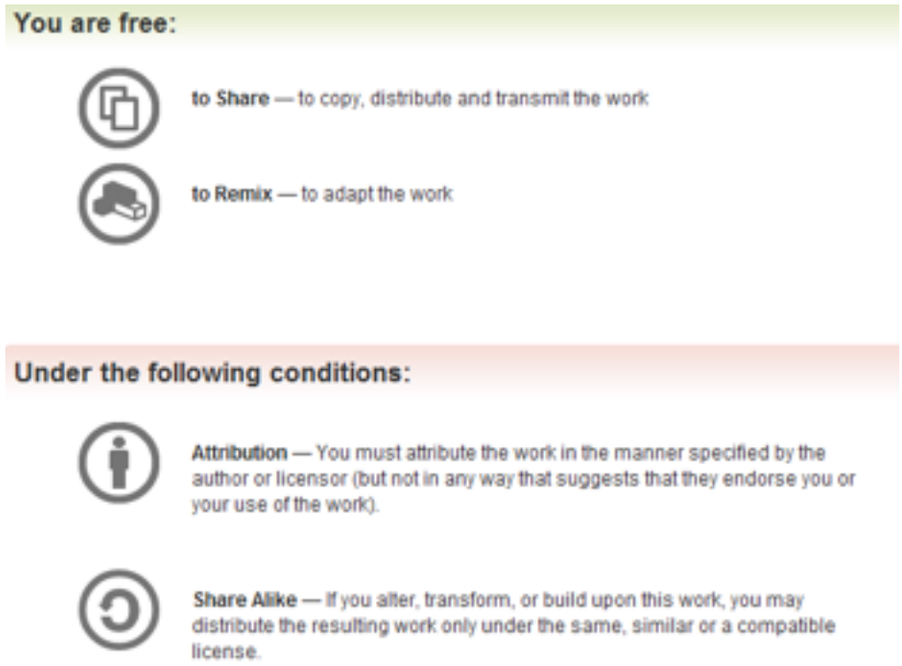

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ShiftExample1.c

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

int main(int argc, char **argv)
{
        unsigned int a, b, c;
        a = atoi(argv[0]);
        b = a * 8;
        c = b / 16;
        return c;
}
```

Note: Compiled with “Maximize Speed”, to clear away a bit of cruft

```
main:
0000000140001010  sub      rsp,28h
0000000140001014  mov      rcx,qword ptr [rdx]
0000000140001017  call     qword ptr [40008368h]
000000014000101D  shl      eax,3
0000000140001020  shr      eax,4
0000000140001023  add      rsp,28h
0000000140001027  ret
```

Whither the multiply and divide instructions?!

SHL - Shift Logical Left

- Can be explicitly used with the C “<<” operator
- First operand (source and destination) operand is an r/mX
- Second operand is either cl (lowest byte of ecx), or a 1 byte immediate. The 2nd operand is the number of places to shift.
- It **multiplies** the register by 2 for each place the value is shifted. More efficient than a multiply instruction.
- Bits shifted off the left hand side are “shifted into” (set) the carry flag (CF)
- For purposes of determining if the CF is set at the end, think of it as n independent 1 bit shifts.

shl bl, 2

	00110011b (bl - 0x33)
result	11001100b (bl - 0xCC) CF = 0

shl bl, 3

	00110011b (bl - 0x33)
result	10011000b (bl - 0x98) CF = 1

SHR - Shift Logical Right

- Can be explicitly used with the C “>>” operator
- First operand (source and destination) operand is an r/mX
- Second operand is either cl (lowest byte of ecx), or a 1 byte immediate. The 2nd operand is the number of places to shift.
- It **divides** the register by 2 for each place the value is shifted. More efficient than a multiply instruction.
- Bits shifted off the right hand side are “shifted into” (set) the carry flag (CF)
- For purposes of determining if the CF is set at the end, think of it as n independent 1 bit shifts.

shr bl, 2

	00110011b (bl - 0x33)
result	00001100b (bl - 0x0C) CF = 1

shr bl, 3

	00110011b (bl - 0x33)
result	00000110b (bl - 0x06) CF = 0

ShiftExample1.c takeaways

- When a multiply or divide is by a power of 2, compilers prefer shift instructions as a more efficient way to perform the computation

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

int main(int argc, char **argv)
{
        unsigned int a, b, c;
        a = atoi(argv[0]);
        b = a * 8;
        c = b / 16;
        return c;
}
```

```
main:
0000000140001010  sub      rsp,28h
0000000140001014  mov      rcx,qword ptr [rdx]
0000000140001017  call     qword ptr [40008368h]
000000014000101D  shl      eax,3
0000000140001020  shr      eax,4
0000000140001023  add      rsp,28h
0000000140001027  ret
```

Huey Lewis and the News

That's the power of ~~love~~ sign!

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

int main(int argc, char **argv)
{
        unsigned int a, b, c;
        a = atoi(argv[0]);
        b = a * 8;
        c = b / 16;
        return c;
}
```

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

int main(int argc, char **argv)
{
        int a, b, c;
        a = atoi(argv[0]);
        b = a * 8;
        c = b / 16;
        return c;
}
```

http://4.bp.blogspot.com/-FAaWCtna3mw/Tc69R-mPbFI/AAAAAAAABxA/Nriylz_dc20/s1600/hlhlfr.jpeg

ShiftExample2.c

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

int main(int argc, char **argv)
{
        int a, b, c;
        a = atoi(argv[0]);
        b = a * 8;
        c = b / 16;
        return c;
}
```

```
main:
0000000140001010  sub      rsp,28h
0000000140001014  mov      rcx,qword ptr [rdx]
0000000140001017  call     qword ptr [40008368h]
000000014000101D  shl      eax,3
0000000140001020  cdq
0000000140001021  and      edx,0Fh
0000000140001024  add      eax,edx
0000000140001026  sar      eax,4
0000000140001029  add      rsp,28h
000000014000102D  ret
```

```
main:
0000000140001010  sub       rsp,28h
0000000140001014  mov       rcx,qword ptr [rdx]
0000000140001017  call      qword ptr [40008368h]
000000014000101D  shl       eax,3
0000000140001020  shr       eax,4
0000000140001023  add       rsp,28h
0000000140001027  ret
```

Vs

```
main:
0000000140001010  sub       rsp,28h
0000000140001014  mov       rcx,qword ptr [rdx]
0000000140001017  call      qword ptr [40008368h]
000000014000101D  shl       eax,3
0000000140001020  cdq
0000000140001021  and       edx,0Fh
0000000140001024  add       eax,edx
0000000140001026  sar       eax,4
0000000140001029  add       rsp,28h
000000014000102D  ret
```

Changed

CD* is added as an VS-ism. It's necessary for the math to work out, but I feel like I've only run into it *once ever* in the wild. So I don't consider it that important for beginners to know and I'm skipping it. But you can feel free to come back and read this code once we've gone through the RTFM section.

SAR - Shift Arithmetic Right

- Can be explicitly used with the C “>>” operator, if operands are signed
- First operand (source and destination) operand is an r/mX
- Second operand is either cl (lowest byte of ecx), or a 1 byte immediate. The 2nd operand is the number of places to shift.
- It divides the register by 2 for each place the value is shifted. More efficient than a multiply instruction.
- Each bit shifted off the right side is placed in CF.

sar bl, 2

	10110011b (bl - 0xB3)
result	**11**101100b (bl - 0xEC)

!=

shr bl, 2

	10110011b (bl - 0xB3)
result	**00**101100b (bl - 0x2C)

mov cl, 2; sal bl, cl

	00110011b (bl - 0x33)
result	**00**001100b (bl - 0x0C)

==

mov cl, 2; sal bl, cl

	00110011b (bl - 0x33)
result	**00**001100b (bl - 0x0C)

SAL - Shift Arithmetic Left

- Actually behaves exactly the same as SHL!
- First operand (source and destination) operand is an r/mX
- Second operand is either cl (lowest byte of rcx), or a 1 byte immediate. The 2nd operand is the number of places to shift.
- It divides the register by 2 for each place the value is shifted. More efficient than a multiply instruction.
- Each bit shifted off the left side is placed in CF.

sal bl, 2

	10110011b (bl - 0xB3)
result	11001100b (bl - 0xCC)

==

shl bl, 2

	10110011b (bl - 0xB3)
result	11001100b (bl - 0xCC)

mov cl, 2; sal bl, cl

	00110011b (bl - 0x33)
result	11001100b (bl - 0xCC)

==

mov cl, 2; sal bl, cl

	00110011b (bl - 0x33)
result	11001100b (bl - 0xCC)

ShiftExample2.c takeaways

- Compilers still prefer shifts for mul/div over powers of 2
- But when the operands are *signed* rather than unsigned, it must use different instructions, and potentially do more work (than the unsigned case) to deal with a multiply
- CDQ isn't important for beginners to know, left as an exercise for the reader for later ;)

```
int main(){
        int a, b, c;
        a = 0x40;
        b = a * 8;
        c = b / 16;
        return c;
}
```

```
main:
0000000140001010  sub      rsp,28h
0000000140001014  mov      rcx,qword ptr [rdx]
0000000140001017  call     qword ptr [40008368h]
000000014000101D  shl      eax,3
0000000140001020  cdq
0000000140001021  and      edx,0Fh
0000000140001024  add      eax,edx
0000000140001026  sar      eax,4
0000000140001029  add      rsp,28h
000000014000102D  ret
```

Instructions we now know (26)

- NOP
- PUSH/POP
- CALL/RET
- MOV
- ADD/SUB
- IMUL
- MOVZX/MOVSX
- LEA
- JMP/Jcc (family)
- CMP/TEST
- AND/OR/XOR/NOT
- INC/DEC
- SHR/SHL/SAR/SAL