Computer Architecture Assignment 1

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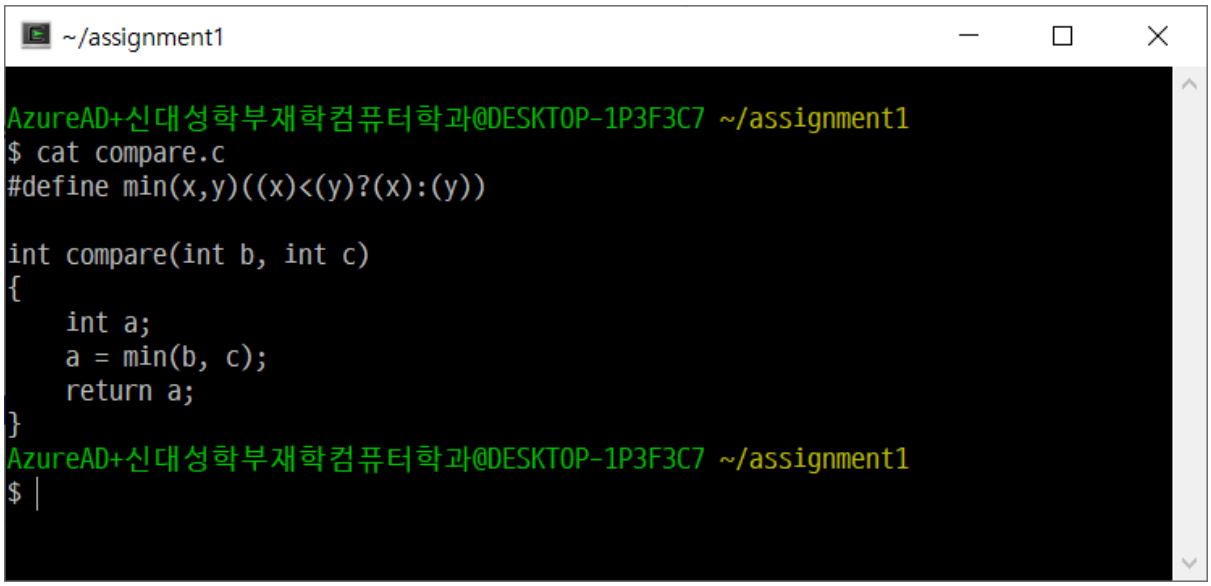
Explanation of the role of Makefile in Eclipse project

Makefile is setting file for 'make' which is program in linux. To make simple, it's just set of commands in linux. When we execute 'make' program with 'Makefile' in linux, it compiles with commands in that setting file.

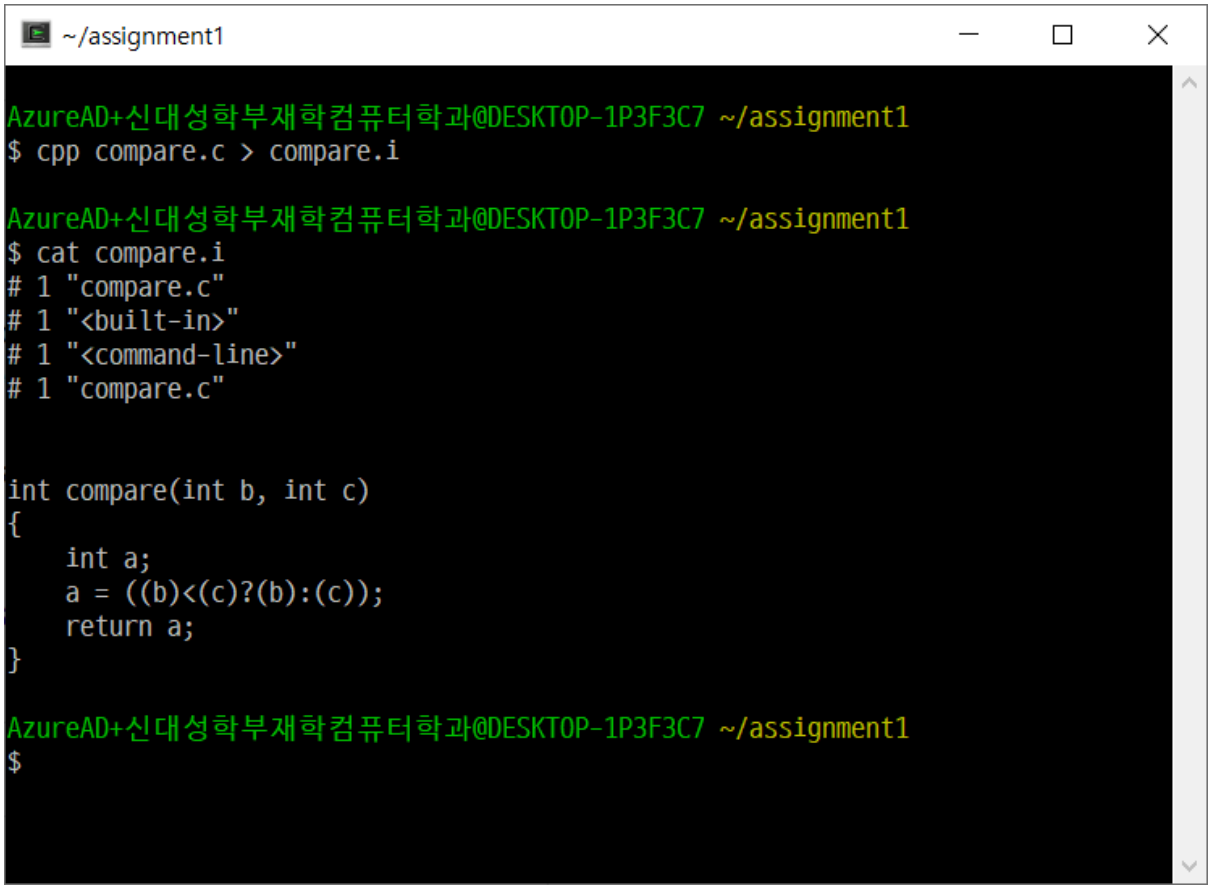
In Eclipse project, Makefile has similar role but has a little difference. We use build button to use 'Makefile' setting, not using 'make' command.

Outputs of each compilation step in the native compilation

0. Example code(compare.c)



1. Preprocessing(compare.i)



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2. Compilation(compare.s)

```
$gcc -S compare.i
```

```
 .file  "compare.c"
 .text
 .globl _compare
 .def   _compare;       .scl    2;      .type   32;     .endef
_compare:
LFB0:
 .cfi_startproc
 pushl  %ebp
 .cfi_def_cfa_offset 8
 .cfi_offset 5, -8
 movl   %esp, %ebp
 .cfi_def_cfa_register 5
 subl   $16, %esp
```

```
 movl   8(%ebp), %eax
 cmpl   %eax, 12(%ebp)
 cmovle 12(%ebp), %eax
 movl   %eax, -4(%ebp)
 movl   -4(%ebp), %eax
 leave
 .cfi_restore 5
 .cfi_def_cfa 4, 4
 ret
 .cfi_endproc
LFE0:
 .ident "GCC: (GNU) 7.4.0"
```

---

3. Assembler(compare.o > compare.dump)

```
$as compare.s -o compare.o
$objdump -SD compare.o
```

```
compare.o:     file format pe-i386


Disassembly of section .text:

00000000 <_compare>:
   0:   55                              push   %ebp
   1:   89 e5                           mov    %esp,%ebp
   3:   83 ec 10                        sub    $0x10,%esp
   6:   8b 45 08                    mov    0x8(%ebp),%eax
   9:   39 45 0c                    cmp    %eax,0xc(%ebp)
   c:   0f 4e 45 0c                 cmovle 0xc(%ebp),%eax
  10:   89 45 fc                    mov    %eax,-0x4(%ebp)
  13:   8b 45 fc                    mov    -0x4(%ebp),%eax
  16:   c9                              leave
  17:   c3                              ret

Disassembly of section .rdata$zzz:

00000000 <.rdata$zzz>:
   0:   47                              inc    %edi
   1:   43                              inc    %ebx
   2:   43                              inc    %ebx
```

```
   3:   3a 20                      cmp    (%eax),%ah
   5:   28 47 4e                 sub    %al,0x4e(%edi)
   8:   55                           push   %ebp
   9:   29 20                     sub    %esp,(%eax)
   b:   37                             aaa
   c:   2e 34 2e                  cs xor $0x2e,%al
   f:   30 00                     xor    %al,(%eax)
  11:   00 00                     add    %al,(%eax)
 ...

Disassembly of section .eh_frame:

00000000 <.eh_frame>:
   0:   14 00                      adc    $0x0,%al
   2:   00 00                     add    %al,(%eax)
   4:   00 00                     add    %al,(%eax)
   6:   00 00                     add    %al,(%eax)
   8:   01 7a 52                 add    %edi,0x52(%edx)
   b:   00 01                     add    %al,(%ecx)
   d:   7c 08                    jl     17 <.eh_frame+0x17>
   f:   01 1b                     add    %ebx,(%ebx)
  11:   0c 04                      or     $0x4,%al
  13:   04 88                      add    $0x88,%al
  15:   01 00                     add    %eax,(%eax)
  17:   00 1c 00                 add    %bl,(%eax,%eax,1)
  1a:   00 00                     add    %al,(%eax)
  1c:   1c 00                      sbb    $0x0,%al
  1e:   00 00                     add    %al,(%eax)
  20:   04 00                      add    $0x0,%al
  22:   00 00                     add    %al,(%eax)
  24:   18 00                     sbb    %al,(%eax)
  26:   00 00                     add    %al,(%eax)
  28:   00 41 0e                 add    %al,0xe(%ecx)
  2b:   08 85 02 42 0d 05       or     %al,0x50d4202(%ebp)
  31:   54                           push   %esp
  32:   c5 0c 04                 lds    (%esp,%eax,1),%ecx
  35:   04 00                      add    $0x0,%al
        ...
```

Outputs of each compilation step in the cross-compilation for MIPS

0. Example Code(compare.c) and Makefile

```
#define min(x, y) ((x) < (y) ? (x) : (y))

int compare(int b, int c)
{
    int a;
    a = min(b, c);
    return a;
} // end of compare.c
```

```
...
all: testvec

testvec: testvec.o compare.o
	$(LD) $(LDFLAGS)  testvec.o compare.o -o testvec
	$(OBJDUMP) -xS  testvec > testvec.dump
	$(OBJCOPY) -O  binary testvec testvec.bin
	./bin2hex.perl > testvec.hex
	./hex2mif.perl
#	./mipsel-readelf -a testvec > testvec.r
#	./mipsel-nm testvec > testvec.n

testvec.o: testvec.s
	$(AS) $(ASFLAGS) testvec.s -o testvec.o

compare.o:    compare.c
	$(CPP) compare.c > compare.i
	$(CC) -Wall -S compare.i
	$(AS) $(ASFLAGS) compare.s -o compare.o
#	$(OBJDUMP) -xS compare.o > compare.dump (this part is executed on
Cygwin not eclipse)
#	$(CC) $(CCFLAGS) compare.c
...
```

---

1. Preprocessing(compare.i)

```
# 1 "compare.c"
# 1 "<built-in>"
# 1 "<command line>"
# 1 "compare.c"


int compare(int b, int c)
{
    int a;
    a = ((b) < (c) ? (b) : (c));
    return a;
}
```

---

2. Compilation(compare.s)

```
    .file   1 "compare.c"
    .section .mdebug.abi32
    .previous
    .text
    .align  2
    .globl  compare
    .ent    compare
compare:
    .frame  $fp,24,$31          # vars= 16, regs= 1/0, args= 0, gp= 0
    .mask   0x40000000,-8
    .fmask  0x00000000,0
    .set    noreorder
    .set    nomacro

    addiu   $sp,$sp,-24
    sw      $fp,16($sp)
    move    $fp,$sp
    sw      $4,24($fp)
    sw      $5,28($fp)
    lw      $2,24($fp)
    nop
    sw      $2,12($fp)
    lw      $3,28($fp)
    nop
    sw      $3,8($fp)
    lw      $4,8($fp)
    lw      $3,12($fp)
    nop
    slt     $2,$3,$4
    beq     $2,$0,$L2
    nop

    lw      $4,12($fp)
    nop
    sw      $4,8($fp)
$L2:
    lw      $2,8($fp)
    nop
    sw      $2,0($fp)
    lw      $2,0($fp)
    move    $sp,$fp
    lw      $fp,16($sp)
    addiu   $sp,$sp,24
    j       $31
    nop

    .set    macro
    .set    reorder
    .end    compare
    .size   compare, .-compare
    .ident  "GCC: (GNU) 4.1.1"
```

3. Assembler(compare.o > compare.dump)

```
../../assignment1/compare.o:     file format elf32-bigmips
../../assignment1/compare.o
architecture: mips:3000, flags 0x00000011:
HAS_RELOC, HAS_SYMS
start address 0x00000000
private flags = 1: [no abi set] [mips1] [not 32bitmode] [noreorder]

Sections:
Idx Name          Size      VMA       LMA       File off  Algn
  0 .text         00000074  00000000  00000000  00000034  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, CODE
  1 .data         00000000  00000000  00000000  000000a8  2**0
                  CONTENTS, ALLOC, LOAD, DATA
  2 .bss          00000000  00000000  00000000  000000a8  2**0
                  ALLOC
  3 .reginfo      00000018  00000000  00000000  000000a8  2**2
                  CONTENTS, READONLY, LINK_ONCE_SAME_SIZE
  4 .pdr          00000020  00000000  00000000  000000c0  2**2
                  CONTENTS, RELOC, READONLY
  5 .mdebug.abi32 00000000  00000000  00000000  000000e0  2**0
                  CONTENTS, READONLY
  6 .comment      00000012  00000000  00000000  000000e0  2**0
                  CONTENTS, READONLY
SYMBOL TABLE:
00000000 l    d  .text      00000000 .text
00000000 l    d  .data      00000000 .data
00000000 l    d  .bss       00000000 .bss
00000000 l    d  .mdebug.abi32    00000000 .mdebug.abi32
00000000 l    d  .reginfo   00000000 .reginfo
00000000 l    d  .pdr       00000000 .pdr
00000000 l    d  .comment   00000000 .comment
00000000 l    df *ABS*      00000000 compare.c
00000000 g     F .text      00000074 compare


Disassembly of section .text:

00000000 <compare>:
   0:  27bdffe8      addiu  sp,sp,-24
   4:  afbe0010      sw     s8,16(sp)
   8:  03a0f021      move   s8,sp
   c:  afc40018      sw     a0,24(s8)
  10:  afc5001c      sw     a1,28(s8)
  14:  8fc20018      lw     v0,24(s8)
  18:  00000000      nop
  1c:  afc2000c      sw     v0,12(s8)
  20:  8fc3001c      lw     v1,28(s8)
  24:  00000000      nop
  28:  afc30008      sw     v1,8(s8)
  2c:  8fc40008      lw     a0,8(s8)
  30:  8fc3000c      lw     v1,12(s8)
  34:  00000000      nop
  38:  0064102a      slt    v0,v1,a0
  3c:  10400004      beqz   v0,50 <compare+0x50>
```

```
  40:  00000000      nop
  44:  8fc4000c      lw     a0,12(s8)
  48:  00000000      nop
  4c:  afc40008      sw     a0,8(s8)
  50:  8fc20008      lw     v0,8(s8)
  54:  00000000      nop
  58:  afc20000      sw     v0,0(s8)
  5c:  8fc20000      lw     v0,0(s8)
  60:  03c0e821      move   sp,s8
  64:  8fbe0010      lw     s8,16(sp)
  68:  27bd0018      addiu  sp,sp,24
  6c:  03e00008      jr     ra
  70:  00000000      nop
```

---

4. Linker(testvec > testvec.dump)

```
testvec:     file format elf32-bigmips
testvec
architecture: mips:3000, flags 0x00000012:
EXEC_P, HAS_SYMS
start address 0x00000000

Program Header:
    LOAD off    0x00000060 vaddr 0x00000000 paddr 0x00000000 align 2**4
         filesz 0x00000084 memsz 0x00000084 flags rwx
private flags = 1: [no abi set] [mips1] [not 32bitmode] [noreorder]

Sections:
Idx Name          Size      VMA       LMA       File off  Algn
  0 .text         00000084  00000000  00000000  00000060  2**4
                  CONTENTS, ALLOC, LOAD, CODE
  1 .reginfo      00000018  00000000  00000000  000000e4  2**2
                  CONTENTS, READONLY, LINK_ONCE_SAME_SIZE
  2 .pdr          00000020  00000000  00000000  000000fc  2**2
                  CONTENTS, READONLY
  3 .comment      00000012  00000000  00000000  0000011c  2**0
                  CONTENTS, READONLY
SYMBOL TABLE:
00000000 l    d  .text      00000000 .text
00000000 l    d  .reginfo   00000000 .reginfo
00000000 l    d  .pdr       00000000 .pdr
00000000 l    d  .comment   00000000 .comment
00000000 l    df *ABS*      00000000 compare.c
00000010 g     F .text      00000074 compare



Disassembly of section .text:

00000000 <compare-0x10>:
   0:  0c000004      jal    10 <compare>
   4:  00000000      nop
   8:  ac020054      sw     v0,84(zero)
   c:  00000000      nop

00000010 <compare>:
```

```
10:  27bdffe8     addiu  sp,sp,-24
14:  afbe0010     sw     s8,16(sp)
18:  03a0f021     move   s8,sp
1c:  afc40018     sw     a0,24(s8)
20:  afc5001c     sw     a1,28(s8)
24:  8fc20018     lw     v0,24(s8)
28:  00000000     nop
2c:  afc2000c     sw     v0,12(s8)
30:  8fc3001c     lw     v1,28(s8)
34:  00000000     nop
38:  afc30008     sw     v1,8(s8)
3c:  8fc40008     lw     a0,8(s8)
40:  8fc3000c     lw     v1,12(s8)
44:  00000000     nop
48:  0064102a     slt    v0,v1,a0
4c:  10400004     beqz   v0,60 <compare+0x50>
50:  00000000     nop
54:  8fc4000c     lw     a0,12(s8)
58:  00000000     nop
5c:  afc40008     sw     a0,8(s8)
60:  8fc20008     lw     v0,8(s8)
64:  00000000     nop
68:  afc20000     sw     v0,0(s8)
6c:  8fc20000     lw     v0,0(s8)
70:  03c0e821     move   sp,s8
74:  8fbe0010     lw     s8,16(sp)
78:  27bd0018     addiu  sp,sp,24
7c:  03e00008     jr     ra
80:  00000000     nop
```