

COMP 3050 Computer Architecture

Homework #4 Due Thursday, March 19

February 19, 2026

- This assignment is due on **Thursday, March 19**
- All of your submissions must include a minimum of **four** separate files:
 - **File 1:** A short **write-up** that **first** specifies what you think your **degree of success** with a project is (**from 0% to 100%**), followed by a brief discussion of your approach to the project along with a **detailed description** of any problems that you were **not** able to resolve for this project. **Failure to specifically provide this information will result in a 0 grade** on your assignment. If you do **not disclose** problems in your write-up and problems are detected when your program is tested, you will receive a grade of 0. **Make sure that you include your email address in your write-up so that the corrector can email you your grade.**
 - **File(s) 2(a, b, c, ...):** For this assignment you must submit 3 files which will include:
 - your **complete new commented microcode source code**, in the form of an **.mc** file, as discussed in class.
 - your **complete new commented flex source file**, in the form of an **.ll** file, as discussed in class
 - your **complete new commented masm C source file**, in the form of an **.c** file, as discussed in class
 - **File 3:** A **make file** to build your assignment. This file must be named **Makefile**. (The makefile in this case will need to direct the build of the masm assembler after modifications.)
 - **File 4:** A file that includes your **resulting output** run(s) from your project. This is a simple text file that shows your output, but make sure that you **annotate it** so that it is self descriptive and that all detailed output is well identified. Use the **script** command from the shell as discussed in class to capture all screen output to a file. This file must show:
 - Your building of the new masm tool
 - Your assembly into object files of each of the 3 test files that you must build and run, found on mercury at:
 - ~bill/ a4_div_test.asm
 - ~bill/ a4_mult_test.asm
 - ~bill/ a4_rshift_test.asm (files are also on the class web site)
 - Your mic1 execution using the new microcode and the resulting debug dump of each of the 3 test files
 - Make sure each of these files is appropriately annotated for readability
- The files described above should be the only files placed in one of your subdirectories, and this subdirectory should be the target of your submit command (see the on-line file **Assignment_Submit_Details.pdf** for specific directions).

- You will provide a new version of the MIC-1 microcode which will support the implementation of **three new MACRO machine instructions**:

RSHIFT <argument is value 0 – 15>

Right shift the current accumulator by the argument number of bits. This is a zero-fill operation and the argument must be a value between **0 and 15** (a four bit magnitude only value, located in the least significant 4 bits)

MULT <argument is value 0 – 63>

multiply the value at the **top of the stack** by the **six bit immediate value** in the instruction (remember, we're using 10 bit opcodes here). The **result of the multiplication should replace the value at the top of the stack**, provided that no overflow occurred. If the multiplication **would overflow a 16 bit result**, the top of the stack **must not be changed**. After the operation, the **accumulator** must be set to **0 if the multiplication succeeded, and -1 if an overflow occurred**.

DIV <no arguments>

divide the 16 bit 2s complement number at the top stack location **SP** (the dividend) by the 16 bit 2s complement number at the location just under the top location **SP+1** (the divisor), and push on **two new locations with SP-1 having the (unsigned) remainder** of the division and **SP-2 (new top of stack) having the 16 bit 2s complement quotient**. If the absolute value of the divisor is greater than the absolute value of the dividend, **the quotient should be set to 0 and the (unsigned) remainder set to the absolute value of the dividend**, and if the divisor is **equal to 0 (this is an illegal case)** the **remainder** should be set to **-1** and the **quotient** should be set to **0**. After the operation, the **accumulator** must be set to **0 if the division was legal, and -1 if an attempt to divide by 0**.

- The approach we'll use here is to extend the op-code field from 7 bits (as used in the INSP and DESP instructions for example) to a total of 10 bits, using the eighth bit as a gateway (i.e., bit-on means to break out to a 10 bit op-code, while bit-off means a 7 bit op-code)
- Since bit 8 is used as a gateway, the 10 bit op-code will provide us with 4 new combinations, and we'll use them as follows:
 - 1111111 1 00 mmmmmm for **MULT** (6 bit multiplier field mmmmmm as operand)
 - 1111111 1 01 xxssss for **RSHIFT** (4 bit shift field ssss as operand)
 - 1111111 1 10 xxxxxx for **DIV** (no operand)
 - 1111111 1 11 xxxxxx for **HALT** (no operand)
- A collection of test masm programs are included with this assignment, and you must show that you can assemble, run and provide correct output for each of these tests. The source code for each test will be placed on the class web site

- The attached examples shown below should serve as a template for the work flow of this assignment
 - Re-write the mic1 microcode and build a new promfile source that includes support for the required new instructions. You must comment this microcode to show your additions
 - Translate your new microcode source into a 32 bit microcode .dat file using the **mcc** program found in ~bill/cs305:
`$ ~bill/cs305/mcc my_new_microcode.mc > prom_new.dat`
 - Re-write the masm assembler to include support for your new macro instructions, providing comments in the code and the flex specification file to highlight your new code
 - Build your new **masm** program using something like the Makefile at:
`~bill/cs305/NandRshiftExample/Makefile_nand_rshift`
 This will build a new **masm** program from your flex specification changes and your changes to the mic1symasm.c files. This new masm should now be able to recognize and generate mic1 machine code for the newly implemented instructions (MULT, DIV, RSHIFT and HALT).
 - Use your new **masm** assembler to assemble the supplied assembly test programs into object files that can be run with the mic1 emulator. Test code available on-line at:
http://www.cs.uml.edu/~bill/cs305/Assignment_4_help_dir/
 or directly on mercury at:
`~bill/cs305`
 - Run the test object files in the mic1 emulator using your new microcode and using the embedded de-bugger to display your results for each test
- Your submitted directory should contain:
 - Your write-up first (make sure you discuss all the steps you took to get this assignment completed)
 - Your commented microcode source
 - Your commented masm sources (.c and .ll)
 - Your masm Makefile
 - The output of mic1 runs for each test program

Original Microcode (~bill/cs305/promfile.txt)

```
70:a := ac; { 1111101 = SWAP }
71:ac := sp;
72:sp := a; goto 0;
73:alu := tir; if n then goto 76;
74:a := band(ir, smask); { 1111110 = INSP }
75:sp := sp + a; goto 0;
76:tir := tir + tir; if n then goto 80;
77:a := band(ir, smask); { 11111110 = DESP }
78:a := inv(a);
79:a := a + 1; goto 75;
80:rd; wr; { 11111111 = HALT }
```

Extended Microcode

```
70:a := ac; { 1111101 = SWAP }
71:ac := sp;
72:sp := a; goto 0;
73:alu := tir; if n then goto 76;
74:a := band(ir, smask); { 1111110 = INSP }
75:sp := sp + a; goto 0;
76:tir := tir + tir; if n then goto 80;
77:a := band(ir, smask); { 11111110 = DESP }
78:a := inv(a);
79:a := a + 1; goto 75;
##### NEW MICROCODE #####
80:tir := tir + tir; if n then goto 97; { 1111 1111 1x = HALT }
81:alu := tir + tir; if n then goto 89; { 1111 1111 01 = RSHIFT }
82:mar := sp; a := sp + 1; rd; { 1111 1111 00 = NAND }
83:rd;
84:mar := a; b := mbr; rd;
85:rd;
86:c := mbr;
87:a := band(b, c);
88:ac := inv(a); goto 0;
89:a := lshift(1); { 1111 1111 01 = RSHIFT }
90:a := lshift(a + 1);
91:a := lshift(a + 1);
92:a := a + 1;
93:b := band(ir, a);
94:b := b + (-1); if n then goto 96;
95:ac := rshift(ac); goto 94;
96:goto 0;
97:rd; wr; { 1111 1111 1x = HALT }
```

Original Flex Scanner (~bill/cs305/MasmSrc/mic1symasm.ll)

```
#define      LODD      1
#define      STOD      2
#define      ADDD      3
#define      SUBD      4
#define      JPOS      5
#define      JZER      6
#define      JUMP      7
#define      LOCO      8
#define      LODL      9
#define      STOL     10
#define      ADDL     11
#define      SUBL     12
#define      JNEG     13
#define      JNZE     14
#define      CALL     15
#define      PSHI     16
#define      POPI     17
#define      PUSH     18
#define      POP      19
#define      RETN     20
#define      SWAP     21
#define      INSP     22
#define      DESP     23
#define      HALT     24
#define      INTEG     25
#define      JUNK     26
#define      LABEL     27
#define      LOC      28
#define      STR      29

%%
[Ll] [Oo] [Dd] [Dd]          return (LODD) ;

[Ss] [Tt] [Oo] [Dd]          return (STOD) ;

[Aa] [Dd] [Dd] [Dd]          return (ADDD) ;

[Ii] [Nn] [Ss] [Pp]          return (INSP) ;

[Dd] [Ee] [Ss] [Pp]          return (DESP) ;

[Hh] [Aa] [Ll] [Tt]          return (HALT) ;
                                :
                                :

\".+\"                          return (STR) ;

-?[0-9] [0-9]*                return (INTEG) ;

[A-Za-z] [0-9A-Za-z]*:        return (LABEL) ;

\\.LOC                          return (LOC) ;

;.*\\n      ;

" "      |
"\\t"    |
"\\r"    |
"\\n"    ;

[^ \\t\\r\\n]*                return (JUNK) ;
```

Original MASM Assembler (~bill/cs305/MasmSrc/mic1symasm.c)

```
p1 = fopen("/tmp/passone", "w+");
unlink("/tmp/passone");
while(tok=yylex()){
switch(tok){
case LODD: switch(tok=yylex()){
case INTEG:
str_12(yytext);
fprintf(p1,"%d 0000%s\n", pc, cstr_12); // opcode LODD
break;
case LABEL:
fprintf(p1,"%d U0000000000000000 %s\n", pc, yytext);
break;
default:
fprintf(stderr,"Bad operand after LODD is %s on line %d\n",
yytext, pc);
exit(1);
}
break;
case STOD: switch(tok=yylex()){
case INTEG:
str_12(yytext);
fprintf(p1,"%d 0001%s\n", pc, cstr_12); // opcode STOD
break;
case LABEL:
fprintf(p1,"%d U0001000000000000 %s\n", pc, yytext);
break;
default:
fprintf(stderr,"Bad operand after STOD is %s on line %d\n",
yytext, pc);
exit(1);
}
break;
```

```

case DESP: if((tok=yylex()) != INTEG){ /* DESP */
    fprintf(stderr,"Bad operand after DESP is %s\n",yytext);
    exit(1);
}
str_8(yytext);
fprintf(p1,"%d 1111110%s\n", pc, cstr_8);
break;

case HALT: fprintf(p1,"%d 1111111000000000\n",pc); /* HALT */
break;

case INTEG: str_16(yytext); /* INTEG */
    fprintf(p1,"%d %s\n", pc, cstr_16);
    break;

case LABEL: if (label_pc == pc){ /* LABEL */
    fprintf(p1,"%d U0000000000000000 %s\n", pc, yytext);
    break;
}
search_sym_table(yytext);
update_sym_table(yytext);
label_pc = pc;
pc--;
break;

case LOC: if((tok=yylex()) != INTEG){ /* LOC */
    fprintf(stderr,"Bad operand after .LOC is %s\n",yytext);
    exit(1);
}
if((temp = ((unsigned short)atoi(yytext) )) < pc){
    fprintf(stderr,"Bad operand after .LOC is %s, TOO SMALL
!n",yytext);
    exit(1);
}
pc = temp - 1;
break;

case STR: i=1; /* STR */
do{
    if(*(yytext+i) == '\\'){
        bstr_16(0);
        fprintf(p1,"%d %s\n", pc, binstr_16);
        break;
    }
    temp = (unsigned short)*(yytext+i++);
    if(*(yytext+i) != '\\'){
        temp = (temp | ((unsigned short)*(yytext+i) << 8));
    }
    bstr_16(temp);
    fprintf(p1,"%d %s\n", pc, binstr_16);
}while(*(yytext+i++) != '\\') && ++pc);
break;

/* JUNK */
case JUNK: fprintf(stderr,"Unrecognized token is %s\n",yytext);
    exit(26);

/* default */
default: fprintf(stderr,"Default case, unrecoverable error\n");
    exit(26);
}

```

Extended Flex Scanner

```

#define      LODD      1
#define      STOD      2
#define      ADDD      3
#define      SUBD      4
#define      JPOS      5
#define      JZER      6
#define      JUMP      7
#define      LOCO      8
#define      LODL      9
#define      STOL      10
#define      ADDL      11
#define      SUBL      12
#define      JNEG      13
#define      JNZE      14
#define      CALL      15
#define      PSHI      16
#define      POPI      17
#define      PUSH      18
#define      POP        19
#define      RETN      20
#define      SWAP      21
#define      INSP      22
#define      DESP      23
#define      HALT      24
#define      INTEG      25
#define      JUNK      26
#define      LABEL      27
#define      LOC        28
#define      STR        29
#define      MULT      30
#define      RSHIFT     31
#define      DIV        32

%%

[Ll] [Oo] [Dd] [Dd]      return (LODD) ;
[Ss] [Tt] [Oo] [Dd]      return (STOD) ;
[Aa] [Dd] [Dd] [Dd]      return (ADDD) ;
                           :
                           :

[Hh] [Aa] [Ll] [Tt]      return (HALT) ;
[Mm] [Uu] [Ll] [Tt]      return (MULT) ;
[Rr] [Ss] [Hh] [Ii] [Ff] [Tt] return (RSHIFT) ;
[Dd] [Ii] [Vv]           return (DIV) ;

\".+\"                   return (STR) ;

-?[0-9][0-9]*            return (INTEG) ;

[A-Za-z][0-9A-Za-z]*:    return (LABEL) ;

\\.LOC                   return (LOC) ;

;.*\\n      ;

" "      |
"\\t"    |
"\\r"    |
"\\n"    ;

[^ \\t\\r\\n]*          return (JUNK) ;

```


Extended MASM Assembler

```
case DESP: if((tok=yylex()) != INTEG){
    fprintf(stderr,"Bad operand after DESP is %s\n",yytext);
    exit(1);
}
str_8(yytext);
fprintf(p1,"%d 11111110%s\n", pc, cstr_8);
break;

case HALT: fprintf(p1,"%d 111111111000000\n",pc);
break;

case MULT: if((tok=yylex()) != INTEG){
    fprintf(stderr,"Bad operand after MULT is %s\n",yytext);
    exit(1);
}
str_6(yytext);
fprintf(p1,"%d 111111100%s\n", pc, cstr_6);
break;

case RSHIFT: if((tok=yylex()) != INTEG){
    fprintf(stderr,"Bad operand after RSHIFT is %s\n",yytext);
    exit(1);
}
str_6(yytext);
fprintf(p1,"%d 111111101%s\n", pc, cstr_6);
break;

case DIV: fprintf(p1,"%d 111111110000000\n",pc);
break;

case INTEG: str_16(yytext);
    fprintf(p1,"%d %s\n", pc, cstr_16);
    break;

case LABEL: if (label_pc == pc){ /* for < lbx: lby: > */
    fprintf(p1,"%d U0000000000000000 %s\n", pc, yytext);
    break;
}
search_sym_table(yytext);
update_sym_table(yytext);
label_pc = pc;
pc--;
break;
```