The MAC-1 Instruction Repertoire has been extended with the addition of four new instructions and this new Instruction Set Architecture is called the MAC-2. The MAC-2’s Instruction Repertoire is attached, as is the corresponding microprogram that fetches, decodes and executes these MAC-2 instructions. This microprogram’s 32-bit binary words reside in the file \texttt{mpc1}, and the corresponding MAL source code resides in the file \texttt{mpc1.pascal}. These two ascii text files reside in the course webpage, URL: \texttt{http://www.ece.umd.edu/class/enee350-1.F2006/Homework/}.

A program to test the new MAC-2 instructions also resides there called \texttt{tst}, and the new opcodes table used by the assembler (\texttt{assem}) is in the file \texttt{tst.opcodes.new} also on this webpage. Use an internet browser and go to the course webpage and save these files. You should first copy these four files into the working directory that you will use to accomplish this programming assignment. That way \texttt{assem} and \texttt{sim} can look for them there.

For each subroutine (function) which uses the new MAC-2 opcodes that you wish to assemble using \texttt{assem}, (e.g., in files \texttt{prg3sub1} and \texttt{prg3sub2}) first copy \texttt{tst.opcodes.new} into \texttt{prg3sub1.opcodes.new} and into \texttt{prg3sub2.opcodes.new}, respectively. Recall that \texttt{assem} looks for the new opcodes table under the same file name as the program being assembled but with the “.opcodes.new” file name extension appended to the name.

1. Write & test a procedure (i.e., a function subroutine) \texttt{inv(x)} to compute the bit-wise logical complement (i.e., the 1’s complement) of the argument (passed on the stack by reference) and returned by value in the ac register. (Recall DRC(x) = RC(x) - 1, and x is a 16-bit word.)

2. Making use of the new MAC-2 instructions and the \texttt{inv(x)} function, write and test a procedure (i.e., a function subroutine) \texttt{xor(x,y)} that computes the bit-wise logical exclusive-OR of the n-tuples x and y. Again, the arguments are passed by reference, with address y pushed on the stack first followed by address x pushed on the stack followed by a call to function xor, which returns the value computed in the ac register (return by value). Recall \( x \oplus y = x' \cdot y + x \cdot y' = [(x' \cdot y') + (x \cdot y')]' \). (Assume that ac and f are volatile registers; i.e., only the calling program needs to save and restore them if they contain values to be preserved, so the called routines can use them as scratch registers. Also, n=16, so that x and y are 16-bit words.)

3. Making use of the new MAC-2 instructions and the \texttt{xor(x,y)} function, write and test a procedure (i.e., function subroutine) \texttt{hd(x,y)} that computes the Hamming Distance between the two binary n-tuples x and y. Again, the arguments are passed by reference, with address y pushed on the stack first followed by address x pushed on the stack followed by a call to function hd, which returns the value computed in the ac register (return by value). (Recall that Hamming Distance can be computed by counting the number of one’s in the n-tuple z, where the difference n-tuple z = xor(x,y); again assume that n=16 for 16-bit words x and y.)

4. Test your functions with the following main program (called “\texttt{prg3main}”) and its data. This program is located on the next page and the source code can be copied from the course webpage for your convenience. Turn in printouts of the separate assemblies, linkage, and the snapshots of memory before and after execution with simulator \texttt{sim}. Assuming that the absolute program after linking is \texttt{prg3main.abs}, then you must call \texttt{sim} with the following statement: \texttt{"sim prg3main.abs mpc1 mpc1.pascal"}. Highlight and explain the final contents of the locations containing the test results. Be sure to comment cogently your code.

\texttt{see next page for prg3main}
/prg3main
EXTERN inv
EXTERN xor
EXTERN hd
ans1 RES 1
ans2 RES 1
ans3 RES 1
ans4 RES 1
ans5 RES 1
ans6 RES 1
ans7 RES 1
x1 0x6A34
x2 0x3CD1
begin loco 4020
swap
loco x2
push
call inv
stod x2
loco x1
push
call inv
stod x1
call xor
stod ans1
call hd
stod ans2
loco x3
stol 1
call xor
stod ans3
call hd
stod ans4
loco x2
stol 0
call xor
stod ans5
call hd
stod ans6
loco x2
stol 1
call xor
stod ans7
insp 2
halt
x3 0x7E0B
END begin

2