ECE 212 Lab - Introduction to Microprocessors
Department of Electrical and Computer Engineering
University of Alberta

Lab 1: Introduction to Assembly Language.

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1 Introduction

TODO This text is filler text from an ece 210 lab report The purpose of this experiment was to explore the process behind designing and implementing real life design problems using the Xilinx software. A multiplexer (MUX) and demultiplexer (DEMUX) circuit were designed with the goal of sending data to three different 'radio astronomers'. Xilinx was used to create schematics for the circuit, which was then programmed to the Xilinx FPGA development board. The second part of the experiment involved the design and implementation of a lab access control circuit, again using Xilinx and the development board.

A multiplexer is a device that selects a single input from multiple signals, and only transmits one signal. It effectively receives multiple inputs, and only has a single output. The selection occurs based on the values of the 'selection signals'. For a 2x1 (two input signals) multiplexer, only one select signal is needed, but for a 4x1 multiplexer, two select signals are needed.

Multiplexers are often coupled with demultiplexers. DEMUXs receive a single input, and then send this input on to different possible outputs or 'locations', based again on the select signals inputted. The combination of a multiplexer and a demultiplexer allow the transfer of multiple signals over a shared medium or transmission line, in a process known as multiplexing. The signals are combined at the transmitter by the MUX and then split up at the receiving end by the DEMUX.

In the lab, the Xilinx software was utilized to design a three input/one output MUX, and a one input/three output DEMUX using only AND gates, OR gates, and inverters. Initially, Boolean expressions representing the MUX and DEMUX were simplified using a K-Map. From these simplified expressions, two separate designs were created using schematic capture tools, and then were utilized to implement data transmission to engineers. The output of the MUX was wired to the input of the DEMUX. The three outputs from the DEMUX are then sent to the office of radio astronomers. Three additional outputs are used, (designated as 'engineering indicators') to confirm the radio astronomers are receiving data. Only one of these engineering indicators should be turned on, considering the DEMUX selects only one output.

In the second part of the experiment, a circuit was designed and then implemented to control access to two labs: Lab0 and Lab1. Two input signals are accepted (a 2-bit card code and a 3-bit key), with three output signals (Lab0_unlock, Lab1_unlock, and Alarm). A valid card read and correct key entered unlocks the appropriate lab, and invalid input signals will sound the alarm.

2 Design

2.1 Part A

For the first part of the lab, the address register a1 was chosen to initially point to memory location 0x2300000, which is the starting point of where the input data was stored. We used this address register to keep track of the memory location of the next long word of data to be read as an input to our program. Even though one memory location is capable of storing one ASCII character, in this lab, 4 memory locations were used to store one ASCII character, as specified in the lab manual. Next, a2 was selected to initially point at the memory location 0x231000, which is the starting location of where our output for the converted values was. This register was used to keep track of the memory location of where the next long word of our converted data would go. The data register d2 was chosen to temporarily store data so we could do comparisons and process the input data.

The *Setzeros.s* and the *DataSrorage.s* files, which were provided, were used to initialize memory contents.

We started with a loop branch that served as our main looping function. This loop first starts by moving data from a memory location pointed to by a1, to the data register d2 so that we could start comparing the input data to known ASCII values. In the first comparison, the input character is compared to '0x0D', which is the ASCII code for the 'Enter' key. This code is meant to signal the end of the program, so if the input was the ASCII code for 'Enter', we branched to a label that would end our program. The next step was to determine if the input character was valid. For Part A, an input character was valid if it was an ASCII character from 0-9, A-F, or a-f. In other words, the data was accepted if it was in the following ranges: 0x30-0x39, 0x41-0x46, or 0x61-0x66. If the input character was invalid, we brached to a label named 'err', which would put the error code 'FFFFFFFF' in the memory location pointed to by a2, which keeps track of where our output data goes.

If the input character was valid, we had three branches to take care of each of the accepted ranges of input. For example, in the branch that took care of the input range A-F, the ASCII value of 'A' was subtracted from the input value, and the difference was added to the hex value 0xA. The converted value is then moved to the memory location pointed to by a2, which keeps track of where our output data goes. Similar steps were done to convert input characters in the other accepted ranges. After converting the input character and moving the output to the location pointed by a2, we branched to a label 'endloop', which increments the addresses stored in a1 and a2 by 4, and then branches to the loop, where the process is repeated. The flowchart diagram can be found in the Appendix.

2.1.1 Part A Sample Calculations of Conversion

input = '9' = 0x39
0x39 - 0x30 = 0x9

input = 'E' = 0x45
0x45 - 0x41 = 0x4
0x4 + 0xA = 0xE

input = 'd' = 0x64
0x64 - 0x61 = 0x3
0x3 + 0xA = 0xD

2.2 Part B

The design for Part B was very similar to Part A. The address register a1 still initially points to 0x2300000, but this time, a2 now points to 0x2320000, which is where the converted data is stored.The same data register d2 was used to temporarily store the input and process the data. Just like in Part A, the *Setzeros.s* and the *DataSrorage.s* files were used to initialize memory contents as well.

Once again, we had a loop branch that initially loads input data from the location pointed to by a1 into data register d2, and the ASCII 'Enter' code still terminates the program, as before. In Part B, valid inputs are the ASCII characters A-Z and a-z. (0x41-0x5A and 0x61-0x7A) Error

handling was also similar to Part A, where the value 0xFFFFFFFF was stored at the memory location pointed to by a2. We had two branches to handle the two ranges of accepted characters.

For example, if an input character was in the range a-z, a difference was taken relative to the ASCII character 'a', and added to the ASCII character 'A'. The converted value is then stored at the memory location pointed to by a2, and the addresses stored in a1 and a2 are incremented by 4 before the loop starts over. The flowchart diagram can be found in the Appendix.

2.2.1 Part B Sample Calculations of Conversion

input = 'M' = 0x4D
0x4D + 0x20 = 0x6D
0x6D = 'm'

input = 'd' = 0x64
0x64 - 0x20 = 0x44
0x44 = 'D'

3 Testing

3.1 Part A

Initially, we visually tested our code by using the debugger in Eclipse IDE. While stepping through the code, we would check the values at relevant memory locations, and the data and address registers. When the bugs were ironed out, we went on to the next phase of testing. Our code was tested using the provided *Lab1Test.s* file. More specifically, this program was moved into the project folder, downloaded to the ColdFire microcontroller, and the MTTTY serial monitor was loaded to monitor the expected output. Our code was further tested by replacing the 'DataStorage.s' file with the other variants provided named: *DataStorage1.s*, *DataStorage2.s*, and *DataStorage3.s*. Finally, our program, which produced the correct output, was verified by a lab TA.

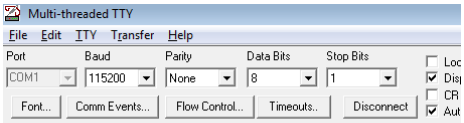
3.2 Part B

The procedure for testing our code for part B was very similar to the process described above in Part A. We visually inspected our code in the Eclipse IDE, used the Eclipse debugger to step through our code, and monitor relevant memory addresses and registers. When we were confident that we had a working solution, we used the provided files *Lab1Test.s*, and the *DataStorage*.s* files to verify our solution by downloading the program to the ColdFire microcontroller, and monitoring the output in MTTTY. Finally, our solution was verified by a lab TA.

4 Questions

4.1 Question 1

"What happens when there is no exit code 0x0D provided in the initialization process? Would it cause a problem? Why or why not?"




```
Waiting 2sec to start 'A' to abort
Configured IP = 10.0.0.120
Configured Mask = 255.255.255.0
MAC Address= 00:03:f4:03:af:f9
Application started
Welcome to lab1 test program, please select
Press 1 to test part a
Press 2 to test part b
1
The conversion is starting at 0x2300000:
Ascii Character = 0 Decimal value = 0
Ascii Character = 1 Decimal value = 1
Ascii Character = 2 Decimal value = 2
Ascii Character = 3 Decimal value = 3
Ascii Character = 4 Decimal value = 4
Ascii Character = 5 Decimal value = 5
Ascii Character = 6 Decimal value = 6
Ascii Character = 7 Decimal value = 7
Ascii Character = 8 Decimal value = 8
Ascii Character = 9 Decimal value = 9
Ascii Character = A Decimal value = 10
Ascii Character = B Decimal value = 11
Ascii Character = C Decimal value = 12
Ascii Character = D Decimal value = 13
Ascii Character = E Decimal value = 14
Ascii Character = F Decimal value = 15
Ascii Character = a Decimal value = 10
Ascii Character = b Decimal value = 11
Ascii Character = c Decimal value = 12
Ascii Character = d Decimal value = 13
Ascii Character = e Decimal value = 14
Ascii Character = f Decimal value = 15
Welcome to lab1 test program, please select
Press 1 to test part a
Press 2 to test part b
```

Figure 1: MTTTY output when testing our Part A solution

A: Yes. This would cause a problem, because there would be no way to exit the program, so the program would keep reading data and moving the converted values to memory locations, until the program attempts to read or write to a memory location that is restricted or non-existant. This would then cause the program to crash.

4.2 Question 2

"How can our code be modified to provide a variable address range? For example, what if I only wanted to convert the first 10 data entires? "

A: TODO You could, like, use a counter in some other data register like d3 and the main loop would go, and at the end, we can do a sub.l #1, %d3, then you do a cmp.l, and then if blt, continue the loop, but if bge, then go to end label

5 Conclusion

TODO Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetuer a, feugiat vitae, porttitor eu, libero. Suspendisse

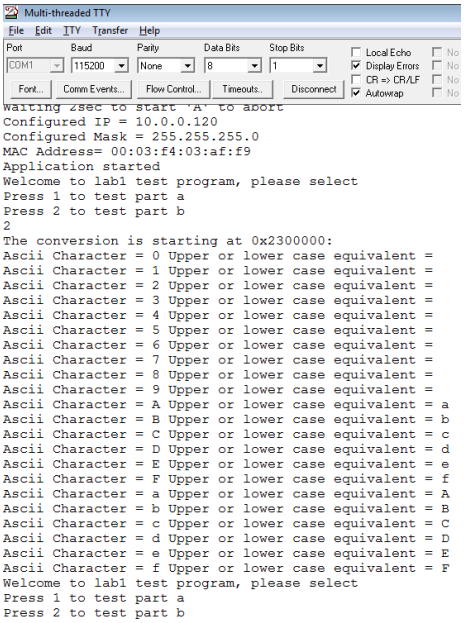


Figure 2: MTTTY output when testing our Part B solution

sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetuer. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

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6 Appendix

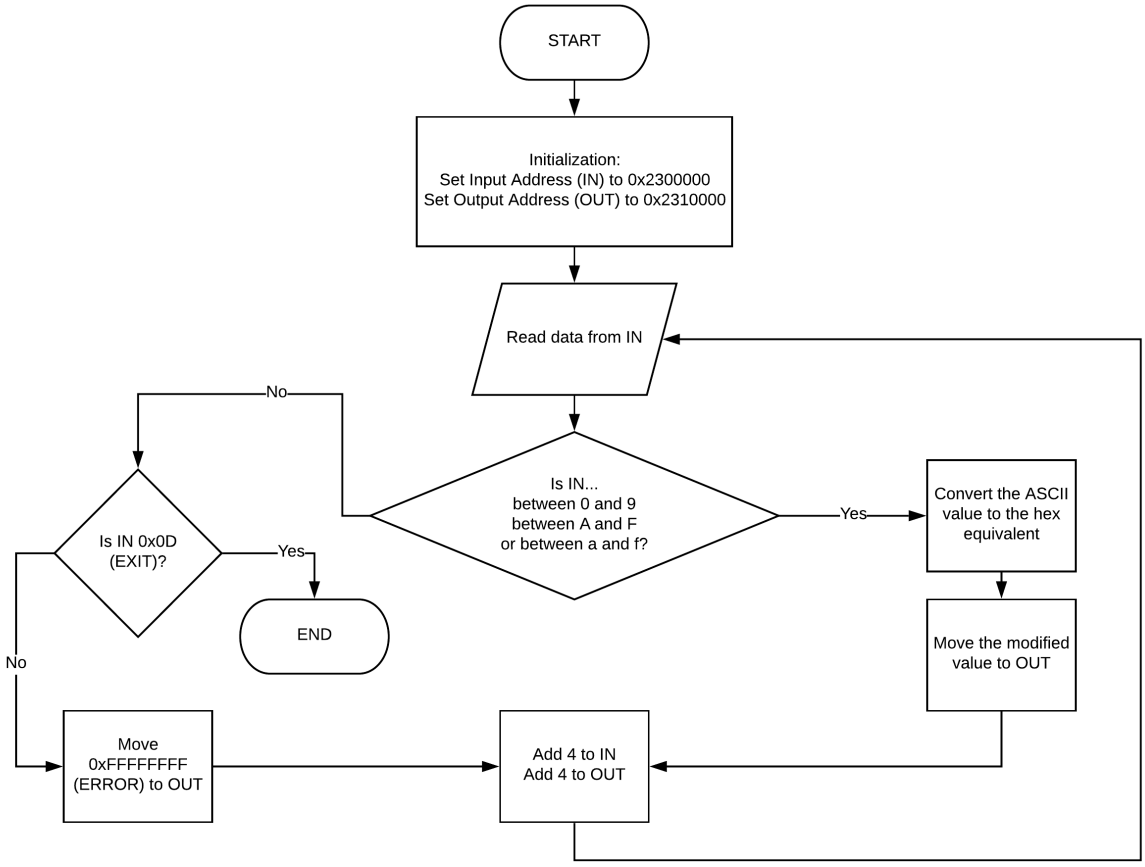
6.1 Part A Assembler Code

```
/* DO NOT MODIFY THIS ------------------------------------------------------*/
.text

.global AssemblyProgram

AssemblyProgram:
lea       -40(%a7),%a7 /*Backing up data and address registers */
movem.l %d2-%d7/%a2-%a5,(%a7)
/*------------------------------------------------------------------------*/

/************************************************************/
/* General Information ******************************************/
/* File Name: Lab1a.s ***************************************/
/* Names of Students: Arun Woosaree and Navras Kamal          **/
/* Date: 1/29/2018                                            **/
/* General Description:                                       **/
/* Converts ASCII letters 0-9, a-f, A-F to hex value 0x0-0xF  **/
/************************************************************/

/*Write your program here*************************************/

movea.l #0x2300000, %a1              /* save input  address to a1*/
movea.l #0x2310000, %a2              /* save output address to a2*/

/* let a value in quotation marks be the ASCII value of the character
   enclosed by the quotation marks*/

loop:               /* the looping function                     */
 move.l (%a1), %d2  /* move the value at address a1 to d2,      */
                    /* call this 'inval' from henceforth        */

 cmp.l #0x0D, %d2   /* Check if the inval is the enter code     */
 beq end            /* if it is, go to the end of the program   */
                    /* (breaking the loop)                      */

 cmp.l #0x2F, %d2   /* compare inval to the hex value of "0"    */
 blt err            /* if inval is less than ASCII zero         */
                    /* it is not valid, throw an error          */

 cmp.l #0x3A, %d2   /* compare the inval to the hex value of ":", */
                    /* which is one ASCII value higher than "9"   */
 blt zeronine       /* if it is less than the value of ":"        */
```

```
                    /* then it must be a value between "0" and "9"*/
                    /* thus go to the proper part of the code to  */
                    /* handle this value                          */

 cmp.l #0x41, %d2   /* compare the inval to "A"                    */
 blt err            /* if it is less than the "A" than it is      */
                    /* invalid, throw an error                    */

 cmp.l #0x47, %d2   /* compare the inval to "G"                    */
 blt bigathruf      /* if it is less than the value of "G" then   */
                    /* it must be in the range "A" through "F"    */
                    /* thus go to the part of the code to handle  */
                    /* these values                               */

 cmp.l #0x61, %d2   /* compare the inval to "a"                    */
 blt err            /* if it is in this range it is invalid,      */
                    /* thus throw an error                        */

 cmp.l #0x67, %d2   /* compare the inval to "g"                    */
 blt littleathruf   /* if it is less than "g" then it must be in  */
                    /* the range "a" through "F"                  */
                    /* thus go to the part of the code to handle  */
                    /* these values                               */

/*    if inval is above "f" then the code will continue here      */

err:
 move.l #0xFFFFFFFF, (%a2)   /* throw the error code to the output*/
                             /* address location                  */
 bra endloop                 /* go to the end of the loop before  */
                             /* restarting the loop               */

zeronine:           /* inval is between "0" and "9"               */
 sub.l #0x30, %d2   /* subtract the hex value of "0" from inval,  */
                    /* which will leave a value from 0x0 to 0x9,  */
                    /* for "0" to "9" respectively                */
 move.l %d2, (%a2)  /* move this calculted hex value to the output*/
                    /* address location                           */
 bra endloop        /* go to the end of the loop before restarting*/
                    /* the loop                                   */

bigathruf:          /* inval is between "A" and "F"               */
 sub.l #0x41, %d2   /* subtracts the hex value of "A" d2. This is */
                    /* the difference between d2 and the character*/
                    /* and "A"                                    */
```

```
 add.l #0xA, %d2     /* adds the value of "A" to d2, which will    */
                     /* make it into the hex representation of the */
                     /* original ASCII value                       */
 move.l %d2, (%a2)   /* move this value to the output address      */
                     /* location                                   */
 bra endloop         /* go to the end of the loop before restarting*/
                     /* the loop                                   */

littleathruf:        /* inval is between "a" and "f"               */
 sub.l #0x61, %d2    /* subtracts the hex value of "a" d2.         */
                     /* This is the difference between d2          */
                     /* and the character and "a"                  */
 add.l #0xA, %d2     /* adds the value of "a" to d2, which will    */
                     /* make it into the hex representation of     */
                     /* the original ASCII value                   */
 move.l %d2, (%a2)   /* move this value to the output address      */
                     /* location                                   */
 bra endloop         /* go to the end of the loop before restarting*/
                     /* the loop                                   */

endloop:             /* handles code to be executed before the     */
                     /* start of a new loop                        */
 add.l #0x4, %a1     /* increment the input address by 4           */
 add.l #0x4, %a2     /* increment the output address by 4          */
 bra loop            /* restart the loop                           */

end:                 /* end the custom part of the program         */

/*End of program ************************************************/

/* DO NOT MODIFY THIS ------------------------------------------------*/
movem.l (%a7),%d2-%d7/%a2-%a5 /*Restore data and address registers */
lea      40(%a7),%a7
rts
/*------------------------------------------------------------------*/
```

6.2 Part A Flowchart Diagram



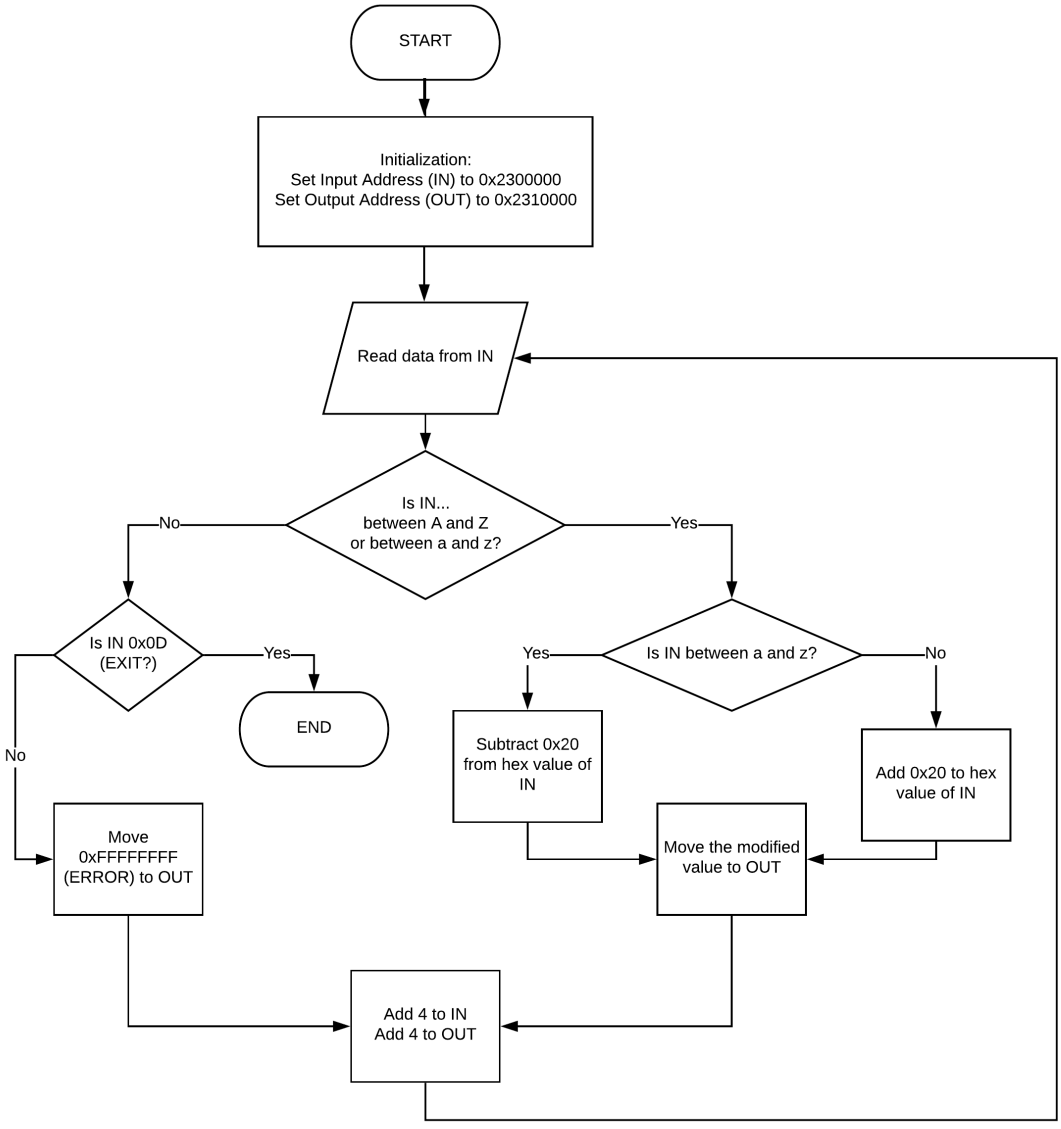
6.3 Part B Assembler Code

```
/* DO NOT MODIFY THIS ------------------------------------------------------*/
.text

.global AssemblyProgram

AssemblyProgram:
lea       -40(%a7),%a7 /*Backing up data and address registers */
movem.l %d2-%d7/%a2-%a5,(%a7)
/*------------------------------------------------------------------------*/

/************************************************************/
/* General Information ******************************************/
/* File Name: Lab1b.s *******************************************/
/* Names of Students: Arun Woosaree and Navras Kamal          **/
/* Date: 1/29/2018                                            **/
/* General Description:                                       **/
/*                                                            **/
/************************************************************/

/*Write your program here*************************************/

movea.l #0x2300000, %a1      /* save input address to a1          */
movea.l #0x2320000, %a2      /* save output address to a2         */

/* let a value in quotation marks be the ASCII value of the      */
/* character enclosed by the quotation marks                     */

loop:                        /* the looping function              */
 move.l (%a1), %d2           /* move the value at address a1 to d2 */
                             /* Call this 'inval' from henceforth  */

 cmp.l #0x0D, %d2            /* Check if the inval is enter code   */
 beq end                     /* if it is, go to the end of the     */
                             /* program (breaking the loop)        */

 cmp.l #0x41, %d2            /* compare the inval to "A"           */
 blt err                     /* if it is less than the "A" than it */
                             /* is invalid, throw an error         */

 cmp.l #0x5B, %d2            /* compare the inval to "["           */
 blt bigathruz               /* if it is less than the value of    */
                             /* "[" then it must be in the range   */
                             /* "A" through "Z"                    */
                             /* thus go to the part of the code to */
```

```
                        /* handle these values                */

 cmp.l #0x61, %d2       /* compare the inval to "a"           */
 blt err                /* if it is in this range it is       */
                        /* invalid, thus throw an error       */

 cmp.l #0x7B, %d2       /* compare the inval to "{"           */
 blt littleathruz       /* if it is less than "{" then it is  */
                        /* in the range "a" through "z"       */
                        /* thus go to the part of the code to */
                        /* handle these values                */

bigathruz:              /* inval is between "A" and "Z"       */
 add.l #0x20, %d2       /* adds the hex difference between    */
                        /* "A" and "a", making it into the    */
                        /* lowercase equivalent               */
 move.l %d2, (%a2)      /* move this value to the output      */
                        /* address location                   */
 bra endloop            /* go to the end of the loop before   */
                        /* restarting the loop                */

littleathruz:           /* inval is between "a" and "z"       */
 sub.l #0x20, %d2       /* subtracts the hex difference       */
                        /* between "a" and "A", changing it   */
                        /* into the uppercase equivalent      */
 move.l %d2, (%a2)      /* move this value to the output      */
                        /* address location                   */
 bra endloop            /* go to the end of the loop before   */
                        /* restarting the loop                */

 /* if inval isn't a valid character then code will continue here */
err:
 move.l #0xFFFFFFFF, (%a2)  /* throw the error code to the output */
                        /* address location                   */
 bra endloop            /* go to the end of the loop before   */
                        /* restarting the loop                */

endloop:                /* handles code to be executed before */
                        /* the start of a new loop            */
 add.l #0x4, %a1        /* increment the input address by 4   */
 add.l #0x4, %a2        /* increment the output address by 4  */
 bra loop               /* restart the loop                   */

end:                    /* end of custom program section      */
```

```
/*End of program ************************************************/

/* DO NOT MODIFY THIS ------------------------------------------------------*/
movem.l (%a7),%d2-%d7/%a2-%a5 /*Restore data and address registers */
lea     40(%a7),%a7
rts
/*------------------------------------------------------------------------*/
```

6.4 Part B Flowchart Diagram



7 Marking Sheet