Illinois Institute of Technology

ECE 441 Monitor Project

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Acknowledgment

I acknowledge all of the work including figures and code belongs to me and/or persons who are referenced.

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Abstract

This project involved designing and implementing a Monitor program using the MC68000 assembly language. The program implements twelve basic debugger functions as well as two author defined functions. It is designed to handle exceptions, and is meant to be an educational piece of software for students taking ECE 441 at the Illinois Institute of Technology.

1 Introduction

The Sanper-1 ELU is a Motorola MC68000 based microcomputer designed by Dr. Jafar Saniie and Mr. Stephen Perich for use in college level computer engineering courses[2]. For user interaction, it utilizes a monitor program called TUTOR that enables users to actively interact with the microcomputer. The design objective of this project is to re-implement the functionality of TUTOR into a student written monitor program titled MONITOR441. The program should be able to perform basic debugger functions such as memory display, memory sort, memory change, etc., and must have the ability to handle exceptions. The design constraints are:

- Code must be smaller that 3K starting from address $1000
- Stack size must be 1K starting at memory location $3000
- Macros may not be used
- Erroneous inputs should not kill the program

Twelve debugger functions must be implemented, along with two user defined debugger commands.

2 Monitor Program

The monitor program operates in a command driven environment. It acts as a typical shell, providing a user interface to access the microcomputer's services. The main program being run is a command line interpreter. Based on the input that the user enters, the interpreter determines if the input entered is valid and subsequently executes the specified command. It was developed using the Easy68K Simulator, thus the TRAP #15 handler is used instead of the MC68000's TRAP #14 handler. The structure of how this program operates is shown in Figure 1.

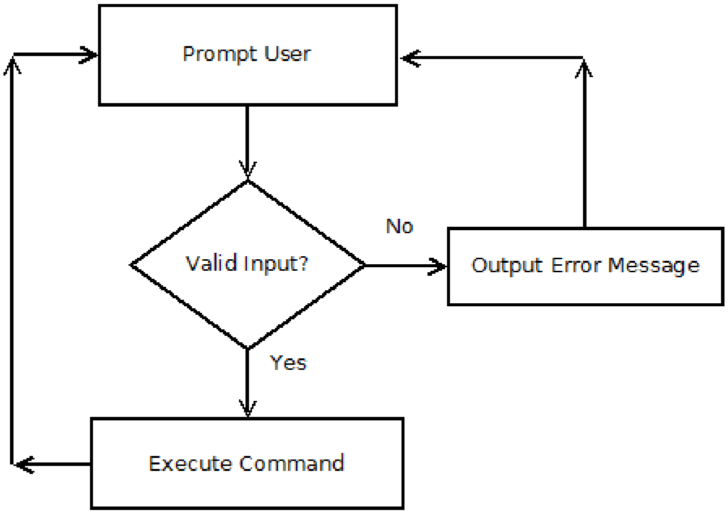


Figure 1: Structure of Monitor Program

2.1 Command Interpreter

2.1.1 Algorithm and Flowchart

The algorithm for the command interpreter uses simple string matching to determine if input is correct. The algorithm begins by outputting the message `MONITOR441>` and accepting input from the user. It then checks for the ASCII value $48 which corresponds to the letter H. This is to check for either the `HELP` command or `HXDC` command. If an H was not entered, it then checks for the ASCII value $4D which corresponds to a memory command. If this fails, then it checks for ASCII value $47, corresponding to the `GO` command. If this fails, the ASCII value $44 is tested, corresponding to the `DF` command. If this fails, it checks for $42, which signifies a `BLCK` command. If this fails, $53 is tested for the `SORTW` command. If this fails, $45 is tested for the `ECHO` command. If this fails $2E is checked for the modify register command. If all of these checks fail, the user has entered incorrect input and an error message is displayed. If any of these checks succeed, the command line interpreter jumps to the respective command's helper interpreter function.

These subroutines check for each character of the user input in order to verify the command the user entered was correct. These helper functions also serve to differentiate commands that start with the same character. The flowchart for this process is shown in Figure 2.

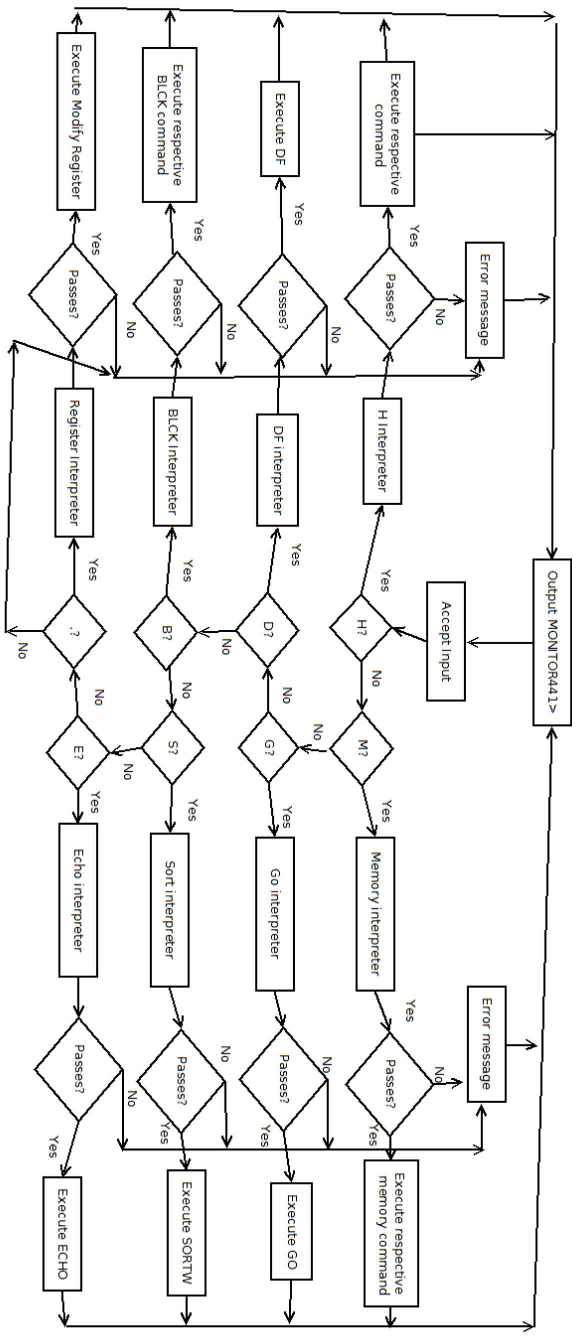


Figure 2: Flowchart for Command Line Interpreter

2.1.2 Assembly Code

```
SHELL:
            PEA      *              ;save PC on Stack for DF
            ADD.L    #4,SP          ;get original value of stack pointer
            MOVE.L   SP,-8(SP)      ;save it
            ADD.L    #-8,SP         ;update Stack position
            MOVE     SR,-(SP)       ;save Status register for use with DF
            MOVE.L   A6,-(SP)       ;temp save

            MOVE     USP,A6         ;for use with DF command
            MOVE.L   A6,-(SP)       ;store USP to STACK
            ADD.L    #4,SP
            MOVE.L   (SP),A6      ;restore original value
            MOVE.L   -(SP),4(SP)    ;move correct value to correct stack position
            ADD.L    #4,SP          ;point stack to CORRECT PLACE


            MOVEM.L D0-D7/A0-A6,-(SP)   ;save initial values of registers
            MOVEM.L D0-D7/A0-A6,-(SP)   ;unorthodox implementation to save registers when using DF command


            LEA   PROMPT,A1         ;Load message
            MOVE.W   #11,D1         ;load n bytes
            MOVE.B   #1,D0          ;set up trap call
            TRAP     #15
            LEA      BUFFER,A1      ;set up storage for command
            MOVE.B   #2,D0          ;load input trap call
            TRAP     #15
            CMP.B    #$48,(A1)      ;check for help/hxdc
            BEQ      HELPORHXDC
            CMP.B    #$4D,(A1)      ;check for memory command
            BEQ      MEMTEST
            CMP.B    #$47,(A1)      ;check for go
            BEQ      GOTST
            CMP.B    #$44,(A1)      ;check for df
            BEQ      DFTST
            CMP.B    #$42,(A1)      ;check for blck command
            BEQ      BLCKTEST
            CMP.B    #$53,(A1)      ;check for sort command
```

```
                BEQ     SORTTEST
                CMP.B   #$45,(A1)     ;check for echo command
                BEQ     ECHOTEST
                CMP.B   #$2E,(A1)     ;check for modify register command
                BEQ     MODIFYREGTEST
                BRA     UNKNOWNCMD
RESTORE:        MOVEM.L (SP)+,D0-D7/A0-A6
                MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
                ADD.L   #4,SP         ;account for USP, it'll fix itself (it shouldn't be used)
                                      ;EASY68k simulator starts in supervisor mode
                MOVE    (SP)+,SR
                MOVE.L  (SP)+,D0      ;save stack cuz it'll get destroyed
                ADD.L   #4,SP         ;get rid of PC, itll fix itself
                MOVE.L  D0,SP
                CLR.L   D0            ;no longer needed

                BRA     SHELL
*-------------------------------------------------------------------------------------------

ECHOTEST:       ADD.L   #1,A1
                CMP.B   #$43,(A1)+     ;C?
                BNE     UNKNOWNCMD
                CMP.B   #$48,(A1)+     ;H?
                BNE     UNKNOWNCMD
                CMP.B   #$4F,(A1)+     ;O?
                BNE     UNKNOWNCMD
                CMP.B   #$20,(A1)+     ;SPACE?
                BEQ     ECHO
                BRA     ERRORSR
*-------------------------------------------------------------------------------------------


*-------------------------------------------------------------------------------------------

```

```
BLCKTEST:     ADD.L    #1,A1
              CMP.B    #$46,(A1)     ;BF?
              BEQ      BFTEST
              CMP.B    #$4D,(A1)     ;BMOV?
              BEQ      BMOVTEST
              CMP.B    #$54,(A1)     ;BTST?
              BEQ      BTSTTEST
              CMP.B    #$53,(A1)     ;BSCH?
              BEQ      BSCHTEST
              BRA      UNKNOWNCMD
*   ____________________________________________________________________________

BSCHTEST:     ADD.L    #1,A1
              CMP.B    #$43,(A1)
              BNE      UNKNOWNCMD
              ADD.L    #1,A1
              CMP.B    #$48,(A1)
              BNE      UNKNOWNCMD
              ADD.L    #1,A1
              CMP.B    #$20,(A1)
              BNE      ERRORSR
              BRA      BSCH

*   ____________________________________________________________________________

BTSTTEST:
              ADD.L    #1,A1
              CMP.B    #$53,(A1)
              BNE      UNKNOWNCMD
              ADD.L    #1,A1
              CMP.B    #$54,(A1)
              BNE      UNKNOWNCMD
              ADD.L    #1,A1
              CMP.B    #$20,(A1)
              BNE      ERRORSR
              BRA      BTST

*   ____________________________________________________________________________

```

```
BMOVTEST:      ADD.L     #1,A1
               CMP.B     #$4F,(A1)
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
               CMP.B     #$56,(A1)
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
               CMP.B     #$20,(A1)
               BNE       ERRORSR
               BRA       BMOV
*
  ----------------------------------------------------------------------------------
BFTEST:        ADD.L     #1,A1
               CMP.B     #$20,(A1)
               BNE       ERRORSR
               BRA       BF
*
  ----------------------------------------------------------------------------------

DFTST:         ADD.L     #1,A1
               CMP.B     #$46,(A1)
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
               CMP.B     #$00,(A1)
               BNE       ERRORSR
               BRA       DF
*
  ----------------------------------------------------------------------------------

SORTTEST:       ADD.L     #1,A1
               CMP.B     #$4F,(A1)      ;O?
               BNE       UNKNOWNCMD
                ADD.L     #1,A1
               CMP.B     #$52,(A1)      ;R?
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
               CMP.B     #$54,(A1)      ;T?
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
               CMP.B     #$57,(A1)      ;W?
               BNE       UNKNOWNCMD
               ADD.L     #1,A1
```

```
                CMP.B   #$20,(A1)
                BNE     ERRORSR

                BRA     SORTW
*
    ________________________________________________________________________

GOTST:          ADD.L   #1,A1
                CMP.B   #$4F,(A1)
                BNE     UNKNOWNCMD
                ADD.L   #1,A1
                CMP.B   #$20,(A1)+
                BNE     ERRORSR
                BRA     GO
*
    ________________________________________________________________________

HELPORHXDC:     ADD.L   #1,A1
                CMP.B   #$45,(A1)    ;is it help?
                BEQ     HELPTST
                CMP.B   #$58,(A1)    ;or is it hxdc
                BEQ     HXDCTEST
                BRA     UNKNOWNCMD
*
    ________________________________________________________________________

HELPTST:
               ADD.L   #1,A1    ; check next char
               CMP.B    #$4C,(A1) ;check for L
               BNE      UNKNOWNCMD
               ADD.L   #1,A1
               CMP.B    #$50,(A1)    ;check for P
               BNE      UNKNOWNCMD
               ADD.L   #1,A1    ;check for anything else
               CMP.B    #$00,(A1)
               BNE      ERRORSR
               BRA      HELP



*
    ________________________________________________________________________
```

```

MEMTEST:        ADD.L    #1,A1
                CMP.B    #$53,(A1)
                BEQ      MSSPCTEST
                CMP.B    #$44,(A1)
                BEQ      MDSPCTEST
                CMP.B    #$4D,(A1)
                BEQ      MMSPCTEST
                BRA      UNKNOWNCMD

MSSPCTEST       ADD.L    #1,A1
                CMP.B    #$20,(A1)
                BEQ      MEMSET
                BRA      ERRORSR

MDSPCTEST:
                ADD.L    #1,A1
                CMP.B    #$53,(A1)
                BNE      ERRORSR
                ADD.L    #1,A1
                CMP.B    #$50,(A1)
                BNE      UNKNOWNCMD
                ADD.L    #1,A1
                CMP.B    #$20,(A1)
                BEQ      MEMDISP
                BRA      ERRORSR

MMSPCTEST:      ADD.L    #1,A1
                CMP.B    #$20,(A1)
                BEQ      MM
                BRA      ERRORSR
*
HXDCTEST:
                ADD.L    #1,A1
                CMP.B    #$44,(A1)
                BNE     UNKNOWNCMD
                ADD.L    #1,A1
                CMP.B    #$45,(A1)
                BNE      UNKNOWNCMD
                ADD.L    #1,A1
                CMP.B    #$43,(A1)
                BNE      UNKNOWNCMD
                ADD.L    #1,A1
                CMP.B    #$20,(A1)
                BNE      ERRORSR
                BRA      HXDC
*
   ------------------------------------------------------------------------------------------------
MODIFYREGTEST:
                ADD.L    #1,A1
                CMP.B    #$44,(A1)
                BEQ      MRD
                CMP.B    #$41,(A1)
                BEQ      MRA
                BRA      UNKNOWNCMD

*------------------------------USER DEFINED COMMANDS
   ------------------------------------*
*
   ------------------------------------------------------------------------------------------------
ECHO: *What terminal DOESN'T have echo?*

           MOVE.L   A1,A2    ;setup to find end of string
EEND:      CMP.B    #$00,(A2)+
           BEQ      EFOUND
           BRA      EEND
EFOUND:
           SUB.L    #1,A2    ;off by one
           SUB.L    A1,A2    ;find out how many bytes
           MOVE.L   A2,D1    ;place it for trap function
           MOVE.L   #0,D0
           TRAP     #15

           BRA RESTORE
```

2.2 Debugger Commands

2.2.1 Help

2.2.1.1 Algorithm and Flowchart

Help is a simple command that prints out a series of strings that display the available commands, their syntax, and a short description of each command. The syntax to invoke this command is `HELP`. The flowchart for this command is shown in Figure 3.

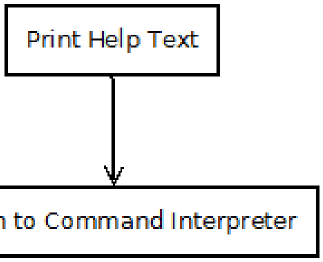


Figure 3: Flowchart for Help

2.2.1.2 Assembly Code

```
HELP:           LEA     HTXT,A1         ;list of commands test
                MOVE.W  #17,D1
                MOVE.B  #0,D0
                TRAP    #15
                MOVE.W  #0,D1           ;newline
                TRAP    #15

                LEA     HTXT1,A1        ;mem display command
                MOVE.W  #75,D1
                MOVE.B  #0,D0
                TRAP    #15
                LEA     HTXT1A,A1       ;mem display
                MOVE.W  #61,D1
                MOVE.B  #0,D0
                TRAP    #15
                LEA     HTXT1B,A1       ;mem display
                MOVE.W  #20,D1
                MOVE.B  #0,D0
                TRAP    #15
                MOVE.W  #0,D1           ;newline
                TRAP    #15

                LEA     HTXT2,A1        ;hxdec command text
                MOVE.W  #75,D1
                MOVE.B  #0,D0
                TRAP    #15
                MOVE.B  #0,D1           ;newline
                TRAP    #15

                LEA     HTXT3,A1        ;sort command text
                MOVE.W  #69,D1
```

```
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT3A,A1       ;sort command text continued
        MOVE.W  #57,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT3B,A1       ;sort command text continued
        MOVE.W  #20,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT3C,A1       ;sort command text continued
        MOVE.W  #21,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT3D,A1       ;sort command text continued
        MOVE.W  #29,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT3E,A1       ;sort command text continued
        MOVE.W  #51,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1          ;newline
        TRAP    #15

        LEA     HTXT4,A1       ;memory modify command text
        MOVE.W  #71,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT4A,A1       ;mem modify command text continued
        MOVE.W  #69,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT4B,A1       ;mem modify command text continued
        MOVE.W  #27,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT4C,A1       ;mem modify command text continued
        MOVE.W  #30,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT4D,A1     ;mem modify command text continued
        MOVE.W  #31,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT4E,A1     ;mem modify command text continued
        MOVE.W  #36,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1
        TRAP    #15          ;newline

        LEA     HTXT5,A1     ;memory set command text
        MOVE.W  #70,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT5A,A1     ;memory set command text continued
        MOVE.W  #28,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1        ;newline
        TRAP    #15

        LEA     HTXT6,A1     ;block fill command text
        MOVE.W  #70,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT6A,A1     ;block fill command text
        MOVE.W  #72,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT6B,A1     ;block fill command text
        MOVE.W  #38,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1
        TRAP    #15          ;newline


        LEA     HTXT7,A1     ;block move command text
        MOVE.W  #68,D1
        MOVE.B  #0,D0
        TRAP    #15
```

```
            LEA      HTXT7A,A1      ;block move command text
            MOVE.W   #72,D1
            MOVE.B   #0,D0
            TRAP     #15
            LEA      HTXT7B,A1      ;block move command text
            MOVE.W   #24,D1
            MOVE.B   #0,D0
            TRAP     #15
            MOVE.B   #0,D1         ;newline
            TRAP     #15

            LEA      HTXT8,A1      ;block test command text
            MOVE.W   #71,D1
            MOVE.B   #0,D0
            TRAP     #15
            LEA      HTXT8A,A1      ;block test command text
            MOVE.W   #59,D1
            MOVE.B   #0,D0
            TRAP     #15
            MOVE.B   #0,D1         ;newline
            TRAP     #15

            LEA      HTXT9,A1      ;block search command text
            MOVE.W   #70,D1
            MOVE.B   #0,D0
            TRAP     #15
            LEA      HTXT9A,A1      ;block search command text
            MOVE.W   #45,D1
            MOVE.B   #0,D0
            TRAP     #15
            MOVE.B   #0,D1         ;newline
            TRAP     #15

            LEA      HTXT10,A1      ;go command text
            MOVE.W   #61,D1
            MOVE.B   #0,D0
            TRAP     #15
            MOVE.B   #0,D1        ;newline
            TRAP     #15

            LEA      HTXT11,A1     ;df command text
            MOVE.W   #56,D1
            MOVE.B   #0,D0
            TRAP     #15
            MOVE.B   #0,D1
```

```
        TRAP    #15

        LEA     HTXT12,A1      ;help command text
        MOVE.W  #66,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1          ;newline
        TRAP    #15

        LEA     HTXT13,A1      ;echo command text
        MOVE.W  #52,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1          ;newline
        TRAP    #15

        LEA     HTXT14,A1      ;modify register command text
        MOVE.W  #71,D1
        MOVE.B  #0,D0
        TRAP    #15
        LEA     HTXT15,A1      ;modify register command text
        MOVE.W  #63,D1
        MOVE.B  #0,D0
        TRAP    #15
        MOVE.B  #0,D1          ;newline
        TRAP    #15

        BRA     RESTORE
```

2.2.2 Memory Display

2.2.2.1 Algorithm and Flowchart

Memory display is an extremely useful tool to look at blocks of memory. The syntax to call this function is `MDSP <address1> <address2`, where `<address1>` is the starting address and `<address2>` is the ending address of the memory contents to be shown. This command also displays the block of memory from `<address1>` to `<address2 +16bytes>`. The flowchart for this command is shown in Figure 4.

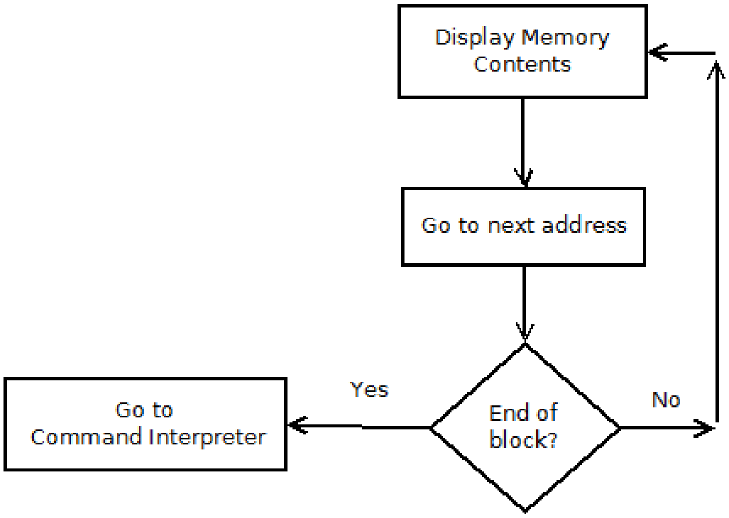


Figure 4: Flowchart for Memory Display

2.2.2.2 Assembly Code

```
MEMDISP:     LEA      BUFFER,A2
             MOVE.L   #1,D6          ;counter for how many times to loop
             ADD.L    #5,A2          ;get first address
             MOVE.L   A2,A3
FINDEND1:    CMP.B    #$20,(A3)+
             BEQ      FINDNEXT
             BRA      FINDEND1
FINDNEXT:    MOVE.L   A3,A4
             MOVE.L   A3,A5
             SUB.L    #1,A3     ;get rid of off by one error
FINDEND2:    CMP.B    #$00,(A5)+
             BEQ      MEMNEXT
             BRA      FINDEND2
MEMNEXT:     SUB.L    #1,A5     ;off by one error
             JSR      ASCII_ADDRESS
             MOVE.L   D5,A6     ;put 1st address in A6
             MOVE.L   A4,A2
             MOVE.L   A5,A3
             JSR  ASCII_ADDRESS
             MOVE.L   D5,A5     ;second address in A5
             MOVE.L   A6,A0     ;for second run through
             MOVE.L   A5,A1     ;see above comment
```

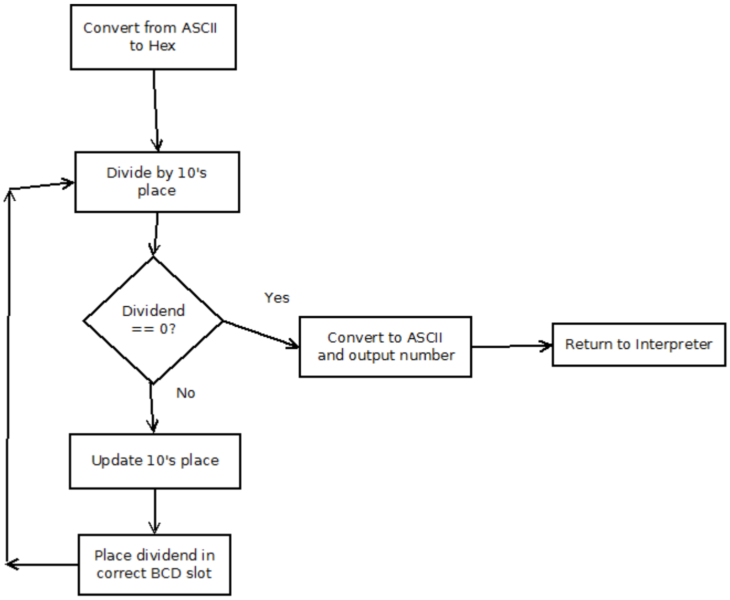
```
                ADD.L    #16,A1 ;16 byte offset
                MOVEM.L  A1,-(SP)
DISPLOOP:       CMP.L    A6,A5
                BLT      SECONDLOOP
                MOVE.L   A6,D3
                JSR      HEXTOASCII
                SUB.L    A2,A3
                MOVE.L   A3,D1    ;number of ascii values to display
                MOVE.L   A2,A1
                MOVE.L   #1,D0
                TRAP     #15
                LEA      SPACE,A1
                MOVE.L  #1,D1
                TRAP     #15
                CLR.L    D3
                MOVE.B   (A6),D3
                JSR      HEXTOASCII
                SUB.L    A2,A3
                MOVE.L   A3,D1
                MOVE.L   A2,A1
                MOVE.L   #0,D0
                TRAP     #15
                ADD.L    #1,A6
                BRA      DISPLOOP

SECONDLOOP:
                MOVE.B   #0,D0
                MOVE.B   #0,D1
                TRAP     #15
                MOVEM.L  (SP)+,A1
                MOVE.L   A0,A6    ;reinit
                MOVE.L   A1,A5
                SUBI.L   #1,D6
                CMP.L    #$0,D6
                BEQ      DISPLOOP
                SUB.L    #4,SP    ;off by long error on stack
                BRA      RESTORE
```

2.2.3 HXDEC

2.2.3.1 Algorithm and Flowchart

This command allows the user to enter a hexadecimal value (up to FFFF), and the program will return the equivalent value in decimal format. The syntax to call this function is `HXDEC <data>`. It works by extracting the

ASCII values byte by byte and determining the 16's place of each byte. The value extracted is then multiplied by its respective 16's place and added to a register that stores the total. This total must then be converted into BCD for output and then into ASCII to display it on the terminal. The flowchart for this command is shown in Figure 5.



Convert from ASCII to Hex
Divide by 10's place
Dividend == 0?
Yes
Convert to ASCII and output number
Return to Interpreter
No
Update 10's place
Place dividend in correct BCD slot

Figure 5: Flowchart for HXDEC

2.2.3.2 Assembly Code

```
HXDC:       LEA  BUFFER, A2     ;load buffer
            ADD.L     #6,A2     ; start of number
            MOVE.L    A2,A3     ;set up end pointer
            MOVE.L    #1,D1     ;set up 16's place
            CLR.L     D2        ;clear total
            CLR.L     D3        ;temp holder for number
            CLR.L     D6        ;Final Value in BCD
            MOVE.L    #10000,D4       ;maximum 10's place of converted
    number
            MOVE.L    #16,D5         ;Max number of rotates needed
            LEA  $3A00,A5
            LEA  $3A00,A4     ;set up start pointer
FINDLASTNUM:
        CMP.B #$00,(A3)+
        BEQ     CONVERTMINUS1
        BRA     FINDLASTNUM
CONVERTMINUS1:
                SUB.L   #1,A3 ; cure off by 1 error
CONVERT:
                SUB.L   #1,A3
                CMP     A3,A2
                BGT     ENDCONVERT
                CMP.B   #$40,(A3)
                BGT     HIGHHEX
                SUBI.B  #$30,(A3)   ;get hex value
                BRA     COMPUTATION
HIGHHEX:        SUBI.B  #$37,(A3)   ;get hex value
COMPUTATION:
                MOVE.B  (A3),D3
                MULU    D1,D3   ;get 16's place
               ; DIVU    #16,D3  ;get rid of off by 1 exponent error
                MULU    #16,D1  ;inc 16's place counter
                MOVE.B  D3,(A4)
                SUB.L   #1,A4
                ADD.L   D3,D2   ;store it in total for debugging
                CLR.L   D3      ;get rid of any numbers in there
                BRA     CONVERT
ENDCONVERT:                     ;must convert back to ascii for display
                CLR.L   D3      ;Cleared for workability
                DIVU    D4,D2   ;get 10's place digit
                MOVE.W  D2,D3   ;extract 10's place digit to D3
                ROL.L   D5,D3   ;put it in its place
                CLR.W   D2      ;get rid of whole number
                SWAP    D2      ;keep remainder
                SUBI.L  #4,D5   ;dec rotate counter
                ADD.L   D3,D6   ;put it into it's place
                DIVU    #10,D4  ;go down a 10's place
                CMP.W   #0,D4   ;are we done
                BEQ     OUTPUTNUM
                BRA     ENDCONVERT

OUTPUTNUM:
               MOVE.L   D6,D3   ;put into register for conversion to ASCII
               JSR      HEXTOASCII
               MOVEA.L  A2,A1   ;get start of number
               SUBA     A2,A3   ;get how many bytes to output
               MOVE.L    A3,D1     ;for Trap call
               MOVE.L    #0,D0
               TRAP      #15

               BRA RESTORE
```

2.2.4 SORTW

2.2.4.1 Algorithm and Flowchart

This command implements the most common sort algorithm for a set of data, the bubble sort. Because the user has the choice to choose between sorting the data in ascending or descending order, it also implements a "rock" sort. It works by first determining which option, ascending or descending, the user has selected. Once determined, the first data in the set is analyzed to the next immediate adjacent value in memory. If the current data is larger than the next data (assuming ascending order for example), the two words of data are swapped. This value is continuously checked against its immediate adjacent memory until it "fits" in the current state of the list. This process is repeated for n elements in a list of n words. The runtime is $\mathcal{O}(n^2)$, and the syntax for this command is `SORTW <option> <address1> <address2>`, where both `<address1>` and `<address2>` are even addresses. The flowchart is shown in Figure 6.

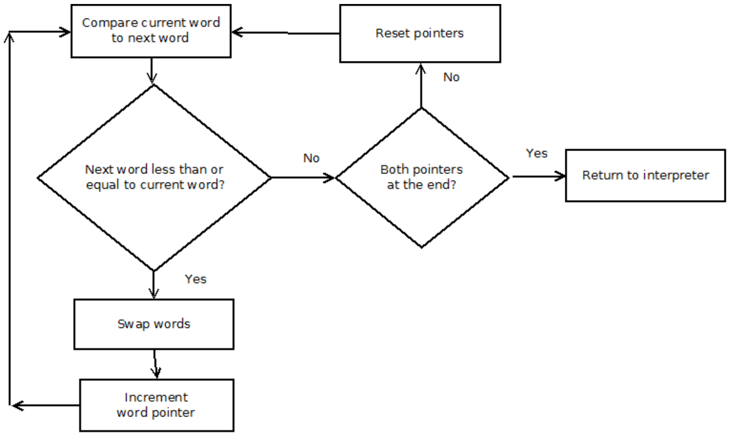

Compare current word to next word
Reset pointers
No
Next word less than or equal to current word?
No
Both pointers at the end?
Yes
Return to interpreter
Yes
Swap words
Increment word pointer

Figure 6: Flowchart for SORTW

2.2.4.2 Assembly Code

```
SORTW:   ADD.L    #1,A1         ;increment to check for semicolon/dash
         CMP.B    #$2D,(A1)     ;check for default
         BEQ      DEFAULTTEST
         CMP.B    #$3B,(A1)+
         BNE      ERRORSR
         CMP.B    #$41,(A1)     ;is it ascending?
         BEQ      ASCEND
         CMP.B    #$44,(A1)     ;or descending?
         BNE      ERRORSR
         BRA      DESCEND

DEFAULTTEST:
                  ADD.L   #1,A1     ;check for paren
         CMP.B    #$28,(A1)+    ;(
         BNE      ERRORSR
         CMP.B    #$64,(A1)+    ;d
         BNE      ERRORSR
         CMP.B    #$65,(A1)+    ;e
         BNE      ERRORSR
         CMP.B    #$66,(A1)+    ;f
         BNE      ERRORSR
         CMP.B    #$61,(A1)+    ;a
         BNE      ERRORSR
         CMP.B    #$75,(A1)+    ;u
         BNE      ERRORSR
         CMP.B    #$6C,(A1)+    ;l
         BNE      ERRORSR
         CMP.B    #$74,(A1)+    ;t
         BNE      ERRORSR
         CMP.B    #$29,(A1)    ;)
         BNE      ERRORSR
         BRA      DESCEND


ASCEND:
        ADD.L     #1,A1     ;inc
        CMP.B     #$20,(A1)     ;check space
        BNE       ERRORSR
        ADD.L     #1,A1     ;start of 1st address
        MOVE.L    A1,A2
        MOVE.L    A2,A3
AGETFIRSTADDRESS:
        CMP.B    #$00,(A3)
        BEQ      ERRORSR      ;incorrect syntax
        CMP.B    #$20,(A3)+   ;trying to find the end
        BEQ      AFADDCONV
        BRA      AGETFIRSTADDRESS
AFADDCONV:
        SUB.L    #1,A3    ;off by one error
        JSR  ASCII_ADDRESS    ;D5 now has that address
        MOVE.L  D5,A4
        ADD.L    #1,A3    ;start of second address
        MOVE.L   A3,A2    ;setup for second address
AGETSECADDRESS:
        CMP.B    #$00,(A3)+   ;trying to find the end
        BEQ      ASADDCONV
        BRA      AGETSECADDRESS
ASADDCONV:
         SUB.L   #1,A3    ;off by one
         JSR     ASCII_ADDRESS
         MOVE.L  D5,A5
         MOVEA.L  A4,A6   ;CLR A6

ARESETLOOP: MOVE.L  A6,A4     ;reset to top of loop
ACMP:       CMP.W   (A4)+,(A4)+  ;check adjacent mem
            BLS.S   ASWAP
            SUBQ.L  #2,A4
            CMP.L   A4,A5    ;done?
            BNE     ACMP      ;nope
            BRA     DONEASCEND  ;yep
ASWAP:       MOVE.L  -(A4),D0     ;start bubbling
            SWAP.W  D0
            MOVE.L  D0,(A4)
            BRA     ARESETLOOP


DESCEND:
        ADD.L    #1,A1    ;inc
        CMP.B    #$20,(A1)    ;check space
        BNE      ERRORSR
        ADD.L    #1,A1    ;start of 1st address
        MOVE.L   A1,A2
        MOVE.L   A2,A3
DGETFIRSTADDRESS:
        CMP.B    #$00,(A3)
        BEQ      ERRORSR      ;incorrect syntax
        CMP.B    #$20,(A3)+   ;trying to find the end
        BEQ     DFADDCONV
        BRA     DGETFIRSTADDRESS
DFADDCONV:
        SUB.L    #1,A3    ;off by one error
        JSR  ASCII_ADDRESS     ;D5 now has that address
        MOVE.L  D5,A4
        ADD.L    #1,A3    ;start of second address
        MOVE.L   A3,A2    ;setup for second address
DGETSECADDRESS:
        CMP.B    #$00,(A3)+   ;trying to find the end
        BEQ     DSADDCONV
        BRA     DGETSECADDRESS
DSADDCONV:
         SUB.L    #1,A3    ;off by one
         JSR      ASCII_ADDRESS
         MOVE.L   D5,A5
         MOVEA.L   A4,A6   ;CLR A6

DRESETLOOP: MOVE.L   A6,A4     ;reset to top of loop
DCMP:       CMP.W    (A4)+,(A4)+   ;check adjacent mem
            BHI.S    DSWAP
            SUBQ.L   #2,A4
            CMP.L    A4,A5    ;done?
            BNE      DCMP       ;nope
            BRA      DONEDESCEND   ;yep
DSWAP:       MOVE.L   -(A4),D0     ;start bubbling
            SWAP.W   D0
            MOVE.L   D0,(A4)
            BRA      DRESETLOOP

DONEASCEND:
DONEDESCEND:
            BRA RESTORE
```

2.2.5 Memory Modify

2.2.5.1 Algorithm and Flowchart

This command first determines which option the user has selected. Depending on this option, it reads the address entered by the user and displays the specified amount of data currently stored in memory. The user is then prompted to enter data to store into memory. The command increments the memory location and asks for input until the user enters the '.' character. The syntax for this command is `MM <option> <address>`. The flowchart is shown in Figure 7.

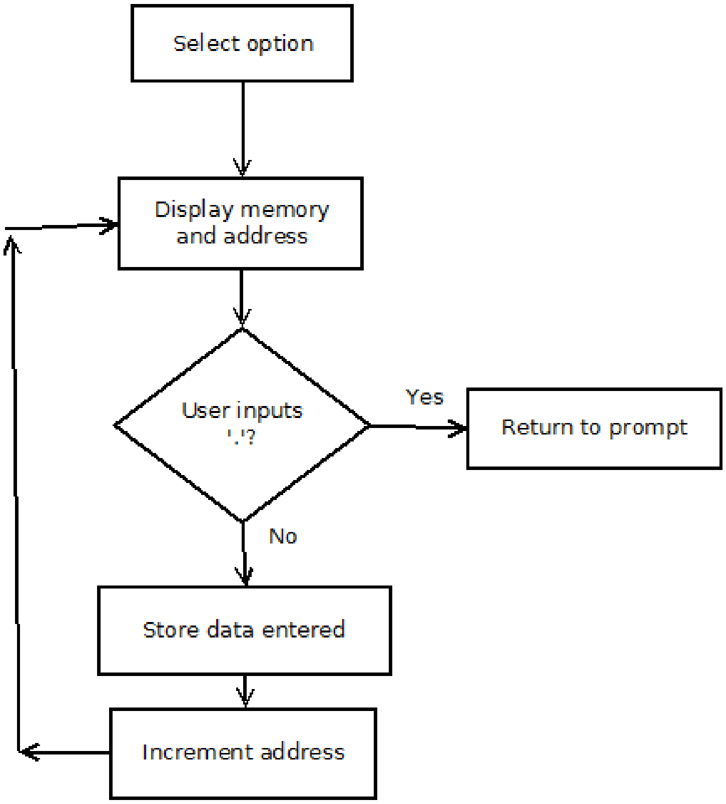


Figure 7: Flowchart for Memory Modify

2.2.5.2 Assembly Code

```
MM:      CLR.L    D2        ;used for storing values
         CLR.L    D6
SIZECHECK:
          MOVE.L  A1,A3     ;set up to find end ptr
ENDPTRMM:
          CMP.B   #$00,(A3)+
          BNE     ENDPTRMM
          SUB.L   #1,A3     ;off by one error
          ADD.L   #1,A1     ;inc pointer to start of specifier
          CMP.B   #$2D,(A1)     ;check for default
          BEQ     DEFAULT
          CMP.B   #$3B,(A1)
```

```
        BNE     ERRORSR
        ADD.L   #1,A1   ;find out which size
        CMP.B   #$57,(A1) ; word
        BEQ     WORD
        CMP.B   #$4C,(A1)   ;long
        BEQ     LONG
        BRA     ERRORSR

*************************************************

DEFAULT:
        ADD.L  #1,A1   ;check for paren
        CMP.B   #$28,(A1)+  ;(
        BNE     ERRORSR
        CMP.B   #$64,(A1)+  ;d
        BNE     ERRORSR
        CMP.B   #$65,(A1)+  ;e
        BNE     ERRORSR
        CMP.B   #$66,(A1)+  ;f
        BNE     ERRORSR
        CMP.B   #$61,(A1)+  ;a
        BNE     ERRORSR
        CMP.B   #$75,(A1)+  ;u
        BNE     ERRORSR
        CMP.B   #$6C,(A1)+  ;l
        BNE     ERRORSR
        CMP.B   #$74,(A1)+  ;t
        BNE     ERRORSR
        CMP.B   #$29,(A1)+  ;)
        BNE     ERRORSR


        ADD.L   #1,A1       ;set up for subroutine
        MOVE    A1,A2       ;set up for subroutine
        MOVEM.L D1/D6/A1-A3,-(SP)
        JSR     ASCII_ADDRESS
        MOVEM.L (SP)+,D1/D6/A1-A3
        MOVE.L  D5,A4       ;set up address to modify

MODIFYLOOP:
        *---------Display Memory First------*
        MOVE.L  A4,D3       ;set up for subroutine
        JSR     HEXTOASCII  ;convert new address to ascii for output
        SUBA    A2,A3       ;get num of bytes to produce
        MOVE.L  #1,D0
        MOVE.L  A3,D1
        MOVE.L  A2,A1
        TRAP    #15

        *add colon to denote containing data*
        MOVE.B  #$3A,(A1)
        MOVE.L  #1,D1    ;display only the colon
        MOVE.L  #1,D0
        TRAP    #15

        MOVE.B  (A4),D3
        JSR     HEXTOASCII
        MOVE.L  #2,D1
        SUB.L   A2,A3
        CMP     #2,A3
        BEQ     FORMATGOOD
        SUB.L   #1,A2
FORMATGOOD:
        MOVE.L  A2,A1
        MOVE.B  #1,D0
        TRAP    #15

        MOVE.B  #$20,(A1)
        MOVE.L  #1,D1    ;space between held data and input
        MOVE.L  #1,D0
        TRAP    #15


        *-----Enter Input--------*
        CLR.L   D3
        MOVE.L  #4,D6
        LEA     BUFFER,A1    ;set up storage for command
        MOVE.B  #2,D0        ;load input trap call
        TRAP    #15
        CMP.B   #$2E,(A1)
        BEQ     ENDLP
        CMP.B   #$00,(A1)
        BEQ     ENTER

PARSELOOP:
        CMP.B   #$00,(A1)
        BEQ     ENDPARSE
        CMP.B   #$40,(A1)
        BGT     HIGHHEXMM
```

```
          SUBI.B  #$30,(A1)    ;get hex value
          BRA     NEXTMMSTEP
HIGHHEXMM: SUBI.B  #$37,(A1)   ;get hex value
NEXTMMSTEP:
          MOVE.B  (A1),D2
          ROL.L   D6,D2
          SUBI.L  #4,D6
          ADD.L   #1,A1
          ADD.B   D2,D3    ;total byte stored in D3
          BRA     PARSELOOP
ENDPARSE:
          MOVE.B  D3,(A4)    ;commit memory change
ENTER:    ADD.L   #1,A4    ;increment address
          BRA     MODIFYLOOP

**************************************************

WORD:

          ADD.L   #2,A1        ;set up for subroutine
          MOVE    A1,A2        ;set up for subroutine
          MOVEM.L D1/D6/A1-A3,-(SP)
          JSR     ASCII_ADDRESS
          MOVEM.L (SP)+,D1/D6/A1-A3
          MOVE.L  D5,A4        ;set up address to modify

MODIFYLOOPW:
          *--------Display Memory First-----*
         ; MOVE.L  A4,D0
         ; DIVU    #2,D0
         ; SWAP    D0      ;check if it's an odd address
         ; CMP.W   #$00,D0
         ; BNE     ERRORSR
          MOVE.L  A4,D3        ;set up for subroutine
          MOVE.L  A4,A5        ;next byte of memory may not be needed
          ADD.L   #1,A5
          JSR     HEXTOASCII  ;convert new address to ascii for output
          SUBA    A2,A3        ;get num of bytes to produce
          MOVE.L  #1,D0
          MOVE.L  A3,D1
          MOVE.L  A2,A1
          TRAP    #15

```

```
        *add colon to denote containing data*
        MOVE.B  #$3A,(A1)
        MOVE.L  #1,D1     ;display only the colon
        MOVE.L  #1,D0
        TRAP    #15

        MOVE.B  (A4),D3
        JSR     HEXTOASCII
        MOVE.L  #2,D1
        SUB.L   A2,A3
        CMP     #2,A3
        BEQ     FORMATGOOD1
        SUB.L   #1,A2
FORMATGOOD1:

        MOVE.L  A2,A1
        MOVE.B  #1,D0
        TRAP    #15

        MOVE.B  (A5),D3
        JSR     HEXTOASCII
        MOVE.L  #2,D1
        SUB.L   A2,A3
        CMP     #2,A3
        BEQ     FORMATGOOD2
        SUB.L   #1,A2
FORMATGOOD2:

        MOVE.L  A2,A1
        MOVE.B  #1,D0
        TRAP    #15


        MOVE.B  #$20,(A1)
        MOVE.L  #1,D1     ;space between held data and input
        MOVE.L  #1,D0
        TRAP    #15


        *------Enter Input--------*
        CLR.L   D3
        MOVE.L  #12,D6
        LEA     BUFFER,A1     ;set up storage for command
        MOVE.B  #2,D0         ;load input trap call
        TRAP    #15
        CMP.B   #$2E,(A1)
        BEQ     ENDLP
        CMP.B   #$00,(A1)
        BEQ     ENTERW

PARSELOOPW:
        CMP.B   #$00,(A1)
        BEQ     ENDPARSEW
        CMP.B   #$40,(A1)
        BGT     HIGHHEXMMW
        SUBI.B  #$30,(A1)    ;get hex value
        BRA     NEXTMMSTEPW
HIGHHEXMMW: SUBI.B  #$37,(A1)   ;get hex value
NEXTMMSTEPW:
        MOVE.B  (A1),D2
        ROL.L   D6,D2
        SUBI.L  #4,D6
        ADD.L   #1,A1
        ADD.L   D2,D3    ;total byte stored in D3
        CLR.L   D2       ;clear for next rotate
        BRA     PARSELOOPW
ENDPARSEW:

        MOVE.W  D3,(A4)    ;commit memory change
ENTERW:  ADD.L   #2,A4    ;increment address
        BRA     MODIFYLOOPW

*************************************************

LONG:
        ADD.L   #2,A1        ;set up for subroutine
        MOVE    A1,A2        ;set up for subroutine
        MOVEM.L D1/D6/A1-A3,-(SP)
        JSR     ASCII_ADDRESS
        MOVE.L  D5,A4        ;set up address to modify
        MOVEM.L (SP)+,D1/D6/A1-A3


MODIFYLOOPL:
        *---------Display Memory First------*
       ; MOVE.L  A4,D0
       ; DIVU    #2,D0
       ; SWAP    D0       ;check if it's an odd address
       ; CMP.W   #$00,D0
       ; BNE     ERRORSR
```

```
        MOVE.L  A4,D3           ;set up for subroutine
        MOVE.L  A4,A5           ;next byte of memory may not be needed
        ADD.L   #1,A5
        JSR     HEXTOASCII      ;convert new address to ascii for output
        SUBA    A2,A3           ;get num of bytes to produce
        MOVE.L  #1,D0
        MOVE.L  A3,D1
        MOVE.L  A2,A1
        TRAP    #15

        *add colon to denote containing data*
        MOVE.B  #$3A,(A1)
        MOVE.L  #1,D1       ;display only the colon
        MOVE.L  #1,D0
        TRAP    #15

        MOVE.B  (A4),D3
        JSR     HEXTOASCII
        MOVE.L  #2,D1
        SUB.L   A2,A3
        CMP     #2,A3
        BEQ     FORMATGOOD3
        SUB.L   #1,A2
FORMATGOOD3:

        MOVE.L  A2,A1
        MOVE.B  #1,D0
        TRAP    #15

        MOVE.B  (A5)+,D3
        JSR     HEXTOASCII
        MOVE.L  #2,D1
        SUB.L   A2,A3
        CMP     #2,A3
        BEQ     FORMATGOOD4
        SUB.L   #1,A2
FORMATGOOD4:

        MOVE.L  A2,A1
        MOVE.B  #1,D0
        TRAP    #15

        MOVE.B  (A5)+,D3
```

```
            JSR       HEXTOASCII
            MOVE.L    #2,D1
            SUB.L     A2,A3
            CMP       #2,A3
            BEQ       FORMATGOOD5
            SUB.L     #1,A2
FORMATGOOD5:

            MOVE.L    A2,A1
            MOVE.B    #1,D0
            TRAP      #15
            MOVE.B    (A5)+,D3
            JSR       HEXTOASCII
            MOVE.L    #2,D1
            SUB.L     A2,A3
            CMP       #2,A3
            BEQ       FORMATGOOD6
            SUB.L     #1,A2
FORMATGOOD6:

            MOVE.L    A2,A1
            MOVE.B    #1,D0
            TRAP      #15

            MOVE.B    #$20,(A1)
            MOVE.L    #1,D1     ;space between held data and input
            MOVE.L    #1,D0
            TRAP      #15


            *------Enter Input--------*
            CLR.L     D3
            MOVE.L    #28,D6
            LEA       BUFFER,A1     ;set up storage for command
            MOVE.B    #2,D0         ;load input trap call
            TRAP      #15
            CMP.B     #$2E,(A1)
            BEQ       ENDLP
            CMP.B     #$00,(A1)
            BEQ       ENTERL

PARSELOOPL:
            CMP.B     #$00,(A1)
            BEQ       ENDPARSEL
            CMP.B     #$40,(A1)
            BGT      HIGHHEXMML
            SUBI.B   #$30,(A1)     ;get hex value
            BRA      NEXTMMSTEPL
HIGHHEXMML: SUBI.B   #$37,(A1)     ;get hex value
NEXTMMSTEPL:
            MOVE.B   (A1),D2
            ROL.L    D6,D2
            SUBI.L   #4,D6
            ADD.L    #1,A1
            ADD.L    D2,D3       ;total byte stored in D3
            CLR.L    D2          ;clear for next rotate
            BRA      PARSELOOPL
ENDPARSEL:
            MOVE.L   D3,(A4)     ;commit memory change
ENTERL:     ADD.L    #4,A4       ;increment address
            BRA      MODIFYLOOPL


ENDLP:      BRA RESTORE
```

2.2.6 Memory Set

2.2.6.1 Algorithm and Flowchart

This command is a simpler version of Memory Modify. It parses the data the user entered and stores it at one specified address. It has the syntax `MS <data> <address>`. The data entered must be byte sized. The flowchart is shown is Figure 8.

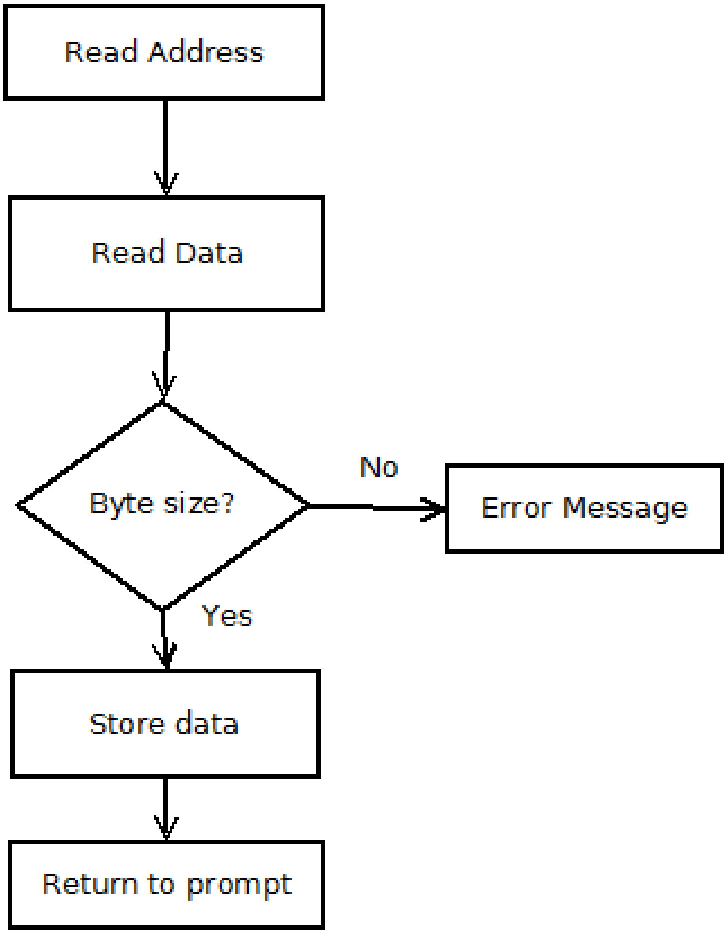


Figure 8: Flowchart for Memory Set

2.2.6.2 Assembly Code

```
MEMSET:      LEA      BUFFER, A2
             ADD.L    #3,A2
             MOVE.L   A2, A3    ;set up to find end
FINDEND:     CMP.B    #$20, (A3)+
             BEQ      MEMCONT
             BRA      FINDEND
MEMCONT:     SUB.L   #1,A3     ;get rid of off by one erro
             MOVE.L   A3, A4    ;used for data length calculator

             JSR  ASCII_ADDRESS
```

```
                MOVE.L  D5,D7       ;store value to be put in mem into D7
                ADD.L   #1,A3       ;increment to address to store it
                MOVE.L  A3,A2
MSFINDADDRESS:
                CMP.B   #$00,(A3)+
                BEQ     MOVEDATA
                BRA     MSFINDADDRESS

MOVEDATA:
                SUB.L   #1,A3       ;off by one error
                JSR     ASCII_ADDRESS
                MOVE.L  D5,A3       ;setup for storage
                MOVE.B  D7,(A3)     ;store data
                BRA     RESTORE
```

2.2.7 Block Fill

2.2.7.1 Algorithm and Flowchart

This command requires two even addresses to be entered. It then parses the word sized data entered by the user and fills the block of memory from the first address to the second address. The syntax for this command is `BF <data> <address1> <address2>`. The flowchart is shown in Figure 9.

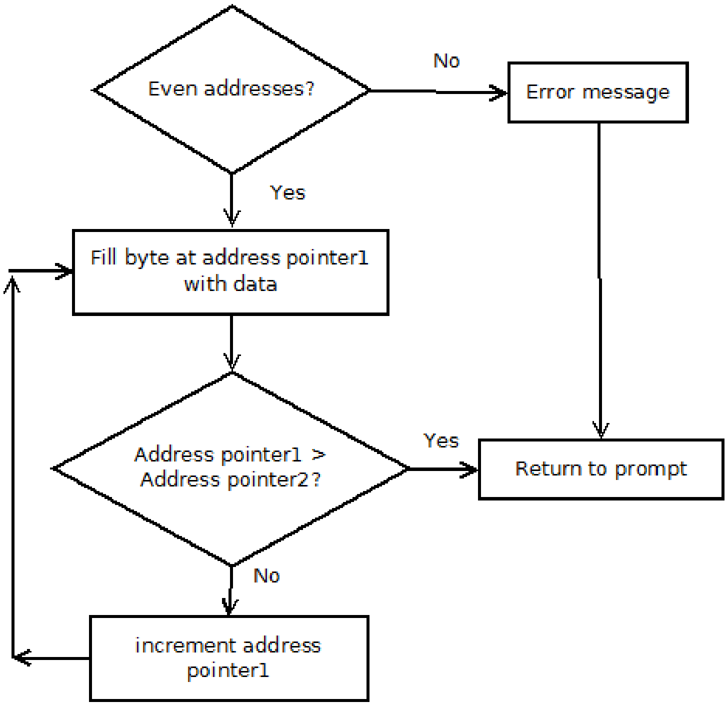

Even addresses?
No
Error message
Yes
Fill byte at address pointer1 with data
Address pointer1 > Address pointer2?
Yes
Return to prompt
No
increment address pointer1

Figure 9: Flowchart for Block Fill

2.2.7.2 Assembly Code

```
BF:
        ADD.L    #1,A1     ;first byte of data
        MOVE.L   A1,A3     ;for end ptr
BFGETENDDATA:
        CMP.B    #$20,(A3)+
        BEQ      BFNEXTADDR
        BRA      BFGETENDDATA
BFNEXTADDR:
        MOVE.L   A1,A2     ;for subroutine
        SUB.L    #1,A3     ;off by one error
        JSR      ASCII_ADDRESS
        MOVE.L   D5,-(SP)         ;save data on the stack

        ADD.L    #1,A3     ;inc end ptr to first byte of address
        MOVE.L   A3,A2     ;set start ptr
BFGETENDADDRONE:
        CMP.B    #$20,(A3)+
        BEQ     BFNEXTADDRTWO
        BRA     BFGETENDADDRONE

BFNEXTADDRTWO:
        SUB.L   #1,A3   ;off by one error
        JSR     ASCII_ADDRESS   ;convert address to hex
        MOVE.L  D5,A5       ;store address 1 in A5
        DIVU    #2,D5
        SWAP    D5
        CMP.W   #$00,D5
        BNE     ERRORSR

        ADD.L   #1,A3   ;inc end ptr to first byte of address
        MOVE.L  A3,A2   ;set start ptr
BFGETLASTEND:
        CMP.B   #$00,(A3)+
        BEQ     STOREDATA
        BRA     BFGETLASTEND

STOREDATA:
        SUB.L   #1,A3   ;off by one error
        JSR     ASCII_ADDRESS
        MOVE.L  D5,A6   ;end address in A6
        DIVU    #2,D5
        SWAP    D5
        CMP.W   #$00,D5
        BNE     ERRORSR
        MOVE.L  (SP)+,D5

DATALOOP:
        CMP.L   A5,A6
        BLT     ENDBF
        MOVE.W  D5,(A5)+
        BRA     DATALOOP

ENDBF:      BRA RESTORE
```

2.2.8 Block Move

2.2.8.1 Algorithm and Flowchart

This command move a block of memory from one section to another. Both block sizes must be equal. Starting from the first address of the first block and the first address of the second block, it moves data byte by byte to the respective memory locations until all data has been copied. Its syntax is

BMOV <address1> <address2> <address3> <address4>. The flowchart is shown in Figure 10.

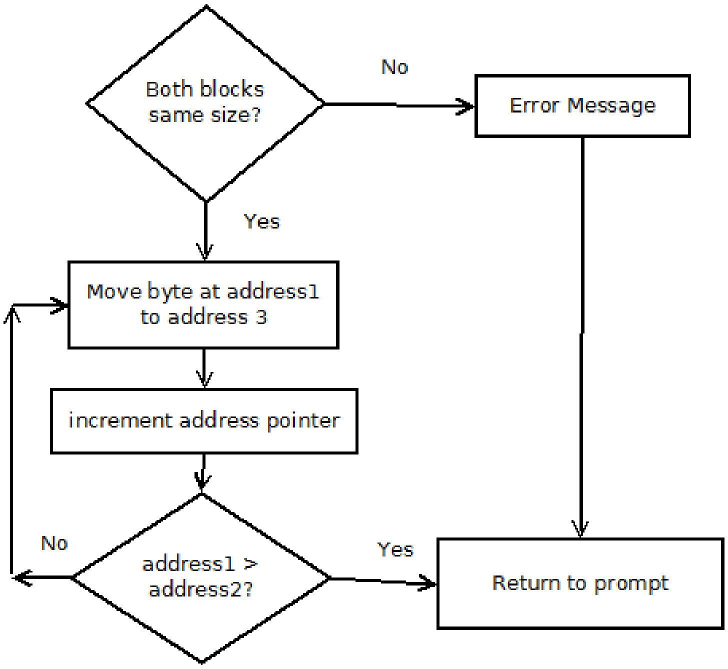


Figure 10: Flowchart for Block Move

2.2.8.2 Assembly Code

```
BMOV:   ADD.L   #1,A1    ;get to start of first address
        MOVE.L  A1,A2    ;set up start ptr
        MOVE.L  A2,A3    ;set up end ptr

FIRSTADDRESS:
        CMP.B #$20,(A3)+
        BEQ     COMPUTEFIRSTADD
        BRA     FIRSTADDRESS

COMPUTEFIRSTADD:
        SUB.L   #1,A3    ;off by one error
        JSR     ASCII_ADDRESS
        MOVE.L  D5,A0    ; save 1st address

        ADD.L   #1,A3
```

```
          MOVE.L  A3,A2
SECONDADDRESS:
          CMP.B   #$20,(A3)+
          BEQ     COMPUTESECONDADDRESS
          BRA     SECONDADDRESS

COMPUTESECONDADDRESS:
          SUB.L   #1,A3     ;off by one error
          JSR     ASCII_ADDRESS
          MOVE.L  D5,A4     ;save 2nd address

          ADD.L   #1,A3
          MOVE.L  A3,A2
THIRDADDRESS:
          CMP.B   #$20,(A3)+
          BEQ     COMPUTETHIRDADDRESS
          BRA     THIRDADDRESS

COMPUTETHIRDADDRESS:
          SUB.L   #1,A3
          JSR     ASCII_ADDRESS
          MOVE.L  D5,A5     ;save 3rd address

          ADD.L   #1,A3
          MOVE.L  A3,A2
FOURTHADDRESS:
          CMP.B   #$00,(A3)+
          BEQ     COMPUTEFOURTHADDRESS
          BRA     FOURTHADDRESS

COMPUTEFOURTHADDRESS:
          SUB.L   #1,A3
          JSR     ASCII_ADDRESS
          MOVE.L  D5,A6     ;save 3rd address



          *Check for matching dimensions*
          MOVE.L  A0,D0
          MOVE.L  A4,D1
          MOVE.L  A5,D5
          MOVE.L  A6,D6
          SUB.L   D0,D1
          SUB.L   D5,D6
          CMP.L   D1,D6
```

```
            BNE     ERRORSR
            CMP.L   A0,A4
            BLT     ERRORSR
            CMP.L   A5,A6
            BLT     ERRORSR
            ADD.L   #1,A4

DATATRANSFER:
            CMP.L   A0,A4
            BLT     BMOVDONE
            MOVE.B  (A0)+,(A5)+
            BRA     DATATRANSFER



BMOVDONE:
            BRA RESTORE
```

2.2.9 Block Test

2.2.9.1 Algorithm and Flowchart

This command fills a block of memory with byte sized data, then checks each byte of the block. If any byte is not equal to the data originally written, the program outputs the data read and the address where the test failed. If no error is detected, the program outputs a message declaring the test passed. The syntax for this command is `BTST <data> <address1> <address2>`. The flowchart is shown in Figure 11.

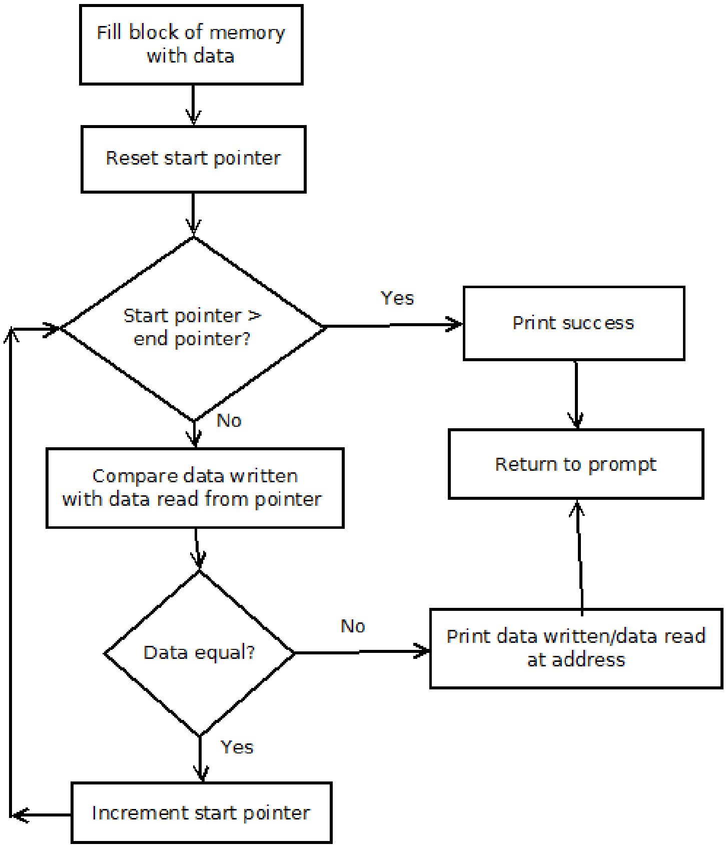

Fill block of memory with data
Reset start pointer
Start pointer > end pointer?
Yes
Print success
No
Return to prompt
Compare data written with data read from pointer
Data equal?
No
Print data written/data read at address
Yes
Increment start pointer

Figure 11: Flowchart for Block Test

2.2.9.2 Assembly Code

```
BTST:
        ADD.L     #1,A1      ;first byte of data
        MOVE.L    A1,A3      ;for end ptr
BTSTGETENDDATA:
          CMP.B   #$20,(A3)+
          BEQ     BTSTNEXTADDR
          BRA     BTSTGETENDDATA
BTSTNEXTADDR:
          MOVE.L  A1,A2      ;for subroutine
          SUB.L   #1,A3      ;off by one error
          JSR     ASCII_ADDRESS
          MOVE.L  D5,-(SP)       ;save data on the stack

          ADD.L   #1,A3   ;inc end ptr to first byte of address
          MOVE.L  A3,A2   ;set start ptr
BTSTGETENDADDRONE:
          CMP.B   #$20,(A3)+
          BEQ     BTSTNEXTADDRTWO
          BRA     BTSTGETENDADDRONE

BTSTNEXTADDRTWO:
          SUB.L   #1,A3   ;off by one error
          JSR     ASCII_ADDRESS   ;convert address to hex
          MOVE.L  D5,A5       ;store address 1 in A5
          MOVE.L  D5,A4       ;for second run through

          ADD.L   #1,A3   ;inc end ptr to first byte of address
          MOVE.L  A3,A2   ;set start ptr
BTSTGETLASTEND:
          CMP.B   #$00,(A3)+
          BEQ     STOREDATABTST
          BRA     BTSTGETLASTEND


STOREDATABTST:
          SUB.L   #1,A3   ;off by one error
          JSR     ASCII_ADDRESS
          MOVE.L  D5,A6   ;end address in A6
          MOVE.L  (SP)+,D5

BTSTDATALOOP:
          CMP.L   A5,A6
          BLT     READ
          MOVE.B  D5,(A5)+
          BRA     BTSTDATALOOP


READ:
          CMP.L   A4,A6
          BLT     COMPLETE
          CMP.B   (A4)+,D5
          BNE     FAIL
          BRA     READ

FAIL:
          LEA     BTST4,A1
          MOVE.L  #11,D1
          MOVE.L  #0,D0
          TRAP    #15

          LEA     BTST1,A1
          MOVE.L  #1,D0
          MOVE.L  #20,D1
          TRAP    #15

          MOVE.B  D5,D3       ;for subroutine
          JSR     HEXTOASCII
          MOVE.L      A2,A1
          MOVE.L  #0,D0
          SUBA.L  A2,A3       ;number of bytes
          MOVE.L  A3,D1
          TRAP    #15


          LEA     BTST2,A1
          MOVE.L  #1,D0
          MOVE.L  #17,D1
          TRAP    #15


          SUB.L   #1,A4       ;go back to address that failed
          MOVE.B  (A4),D3
          JSR     HEXTOASCII      ;convert for output
          MOVE.L      A2,A1
          MOVE.L  #0,D0
          SUBA.L  A2,A3       ;number of bytes
          MOVE.L  A3,D1
          TRAP    #15

          LEA     BTST5,A1
          MOVE.L  #27,D1
          MOVE.B  #1,D0
          TRAP    #15
          MOVE.L  A4,D3
          JSR     HEXTOASCII
          MOVE.L      A2,A1
          MOVE.L  #0,D0
          SUBA.L  A2,A3       ;number of bytes
          MOVE.L  A3,D1
          TRAP    #15
```

```
COMPLETE:

            LEA       BTST3,A1
            MOVE.L    #18,D1
            MOVE.L    #0,D0
            TRAP      #15
            BRA  RESTORE
```

2.2.10 Block Search

2.2.10.1 Algorithm and Flowchart

This command searches through a block of memory for data entered by the user. It does so by checking each value in memory byte by byte. The syntax for this command is `BSCH <data> <address1> <address2>`. The flowchart is shown in Figure 12.

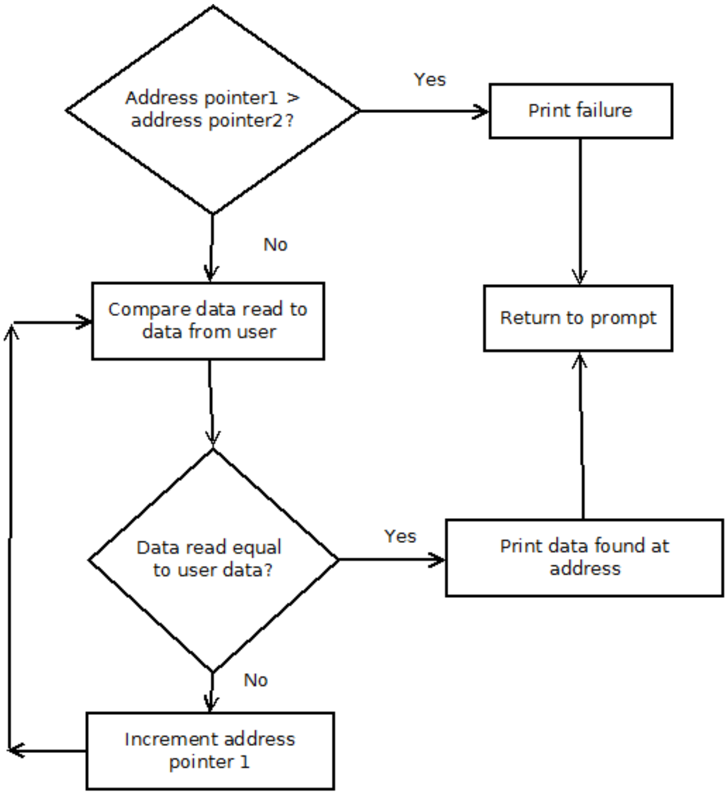

Address pointer1 > address pointer2?
Yes
Print failure
No
Return to prompt
Compare data read to data from user
Data read equal to user data?
Yes
Print data found at address
No
Increment address pointer 1

Figure 12: Flowchart for Block Search

2.2.10.2 Assembly Code

```
BSCH:
          ADD.L    #1,A1     ;start of data
          MOVE.L   A1,A2     ;set up bac ptr

BSCHENDDATA:
          CMP.B    #$20,(A2)+
          BEQ      BSCHFIRSTADD
          BRA      BSCHENDDATA


BSCHFIRSTADD:
          SUB.L    #1,A2
          MOVE.L   A2,A3
          MOVE.L   A1,A2
          JSR      ASCII_ADDRESS
          SUB.L    A1,A3     ;see how many bytes
          MOVE.L   A3,D6     ;store byte/word/long in D6
          ADD.L    #1,A2     ;set up for start of next address
          MOVE.L   A2,A3     ;set up for end ptr
          MOVE.L   D5,-(SP)      ;save data to stack


BSCHFADDEND:
          CMP.B    #$20,(A3)+
          BEQ      BSCHSECONDADD
          BRA      BSCHFADDEND


BSCHSECONDADD:
          SUB.L    #1,A3     ;off by one
          JSR      ASCII_ADDRESS
          MOVE.L   D5,A5     ;first address destination
          ADD.L    #1,A3     ;start it at next address
          MOVE.L   A3,A2     ; set up for next address


BSCHSECONDFIND:
          CMP.B    #$00,(A3)+
          BEQ      TESTOP
          BRA      BSCHSECONDFIND


TESTOP:
```

```
            SUB.L    #1,A3     ;off by one
            JSR      ASCII_ADDRESS
            MOVE.L   D5,A6     ;end address at A6
            MOVE.L   (SP)+,D5      ;restore data
            CMP.B    #2,D6
            BEQ      BYTEBSCH
            CMP.B    #4,D6
            BEQ      WORDBSCH
            CMP.B    #8,D6
            BEQ      LONGBSCH
            BRA      ERRORSR

BYTEBSCH:
            CMP.L    A5,A6
            BLT      ENDBSCH
            CMP.B    (A5)+,D5
            BEQ      FOUNDB
            BRA      BYTEBSCH

WORDBSCH:
            CMP.L    A5,A6
            BLT      ENDBSCH
            CMP.W    (A5)+,D5
            BEQ      FOUNDW
            BRA      WORDBSCH

LONGBSCH:
            CMP.L    A5,A6
            BLT      ENDBSCH
            CMP.L    (A5)+,D5
            BEQ      FOUNDL
            BRA      LONGBSCH



FOUNDB:
            SUB.L    #1,A5
            MOVE.B   (A5),D3
            BRA      SUCCESSTEXT
FOUNDW:
            SUB.L    #2,A5
            MOVE.W   (A5),D3
            BRA      SUCCESSTEXT
FOUNDL:
            SUB.L    #4,A5
```

```
        MOVE.L  (A5),D3

SUCCESSTEXT:
        LEA BSCH1,A1
        MOVE.L  #6,D1
        MOVE.L  #1,D0
        TRAP    #15

        JSR     HEXTOASCII
        MOVE.L  A2,A1
        SUB.L   A2,A3
        MOVE.L  A3,D1    ;how many bytes
        MOVE.L  #0,D0
        TRAP    #15

        LEA BSCH2,A1
        MOVE.L  #18,D1
        MOVE.L  #1,D0
        TRAP    #15

        MOVE.L  A5,D3
        JSR     HEXTOASCII
        MOVE.L  A2,A1
        SUB.L   A2,A3
        MOVE.L  A3,D1    ;how many bytes
        MOVE.L  #0,D0
        TRAP    #15


ENDBSCH:
        BRA RESTORE
```

2.2.11 Go

2.2.11.1 Algorithm and Flowchart

This command jumps to an address in memory and executes the machine code stored at that address. The syntax is `GO <address>`. The flowchart is shown in Figure 13.

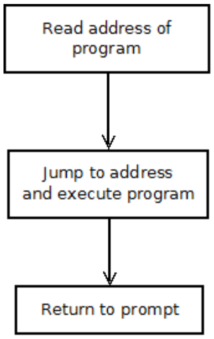


Figure 13: Flowchart for Go

2.2.11.2 Assembly Code

```
GO:
            MOVE.L   A1,A2     ;setup for hex conversion
            MOVE.L   A2,A3
GGETEND:
            CMP.B    #$00,(A3)+
            BEQ      EXECUTE
            BRA      GGETEND

EXECUTE:
            SUB.L    #1,A3     ;off by one error
            JSR      ASCII_ADDRESS
            MOVE.L   D5,A0
            JSR      (A0)      ;go to program
            **NOTE: THE PROGRAM MUST HAVE RTS OR CONTROL WILL NOT BE RETURNED BACK TO MONITOR441!!!**
            BRA RESTORE
```

2.2.12 Display Formatted Registers

2.2.12.1 Algorithm and Flowchart

This command displays the values of the registers as well as the stack pointers and program counter. It does so by first popping these values which were previously stored on stack item by item. They are then converted to ASCII for output and displayed on the terminal. The syntax is `DF`. The flowchart is shown in Figure 14.

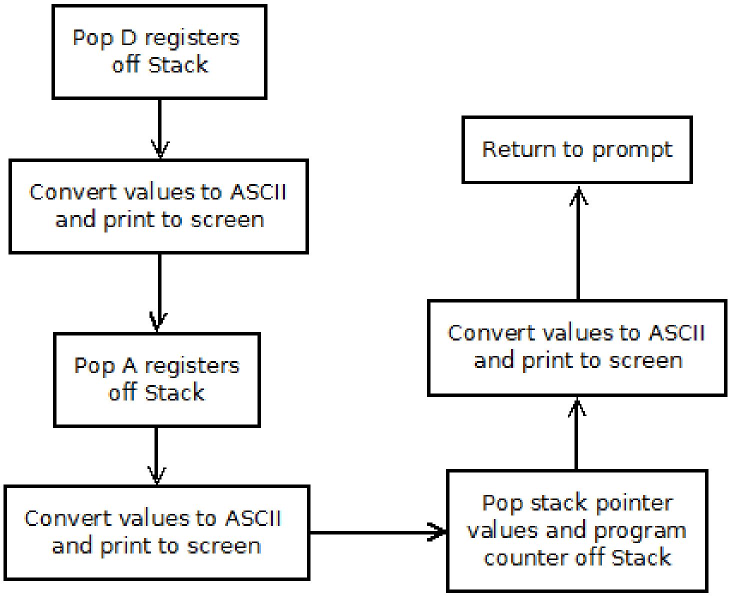

Pop D registers off Stack
Convert values to ASCII and print to screen
Pop A registers off Stack
Convert values to ASCII and print to screen
Pop stack pointer values and program counter off Stack
Convert values to ASCII and print to screen
Return to prompt

Figure 14: Flowchart for Display Formatted Registers

2.2.12.2 Assembly Code

```
DF:     *Registers have already been saved to STACK, just need to pop them off first*
        *Stack looks like this*

        *--------------*
        *|D0-D7/A0-A6|*
        *|     USP    |*
        *|     SR     |*
        *|     SSP    |*
        *|     PC     |*
        *--------------*
        *I should've used loops for efficiency but runtime is not a design constraint*
        *Maybe fix this in the future?*

          *-----------D0-----------*
        LEA         RD0,A1
        MOVE.L      #4,D1
        MOVE.L      #1,D0
        TRAP        #15
        MOVE.L      (SP)+,D3
        JSR         HEXTOASCII
        MOVE.L      A2,A1
        SUB.L       A3,A2
        MOVE.L      A2,D2
        CMP.L       #-8,D2
        BEQ         D0DONTWORRY
D0ACCOUNTFORZEROS:
         ADDI.L     #8,D2
         SUB.L      D2,A1
D0DONTWORRY:
        MOVE.L      #0,D0
        MOVE.L      #8,D1
        TRAP        #15

            *----------D1----------*
        LEA         RD1,A1
        MOVE.L      #4,D1
        MOVE.L      #1,D0
        TRAP        #15
        MOVE.L      (SP)+,D3
        JSR         HEXTOASCII
        MOVE.L      A2,A1
        SUB.L       A3,A2
        MOVE.L      A2,D2
        CMP.L       #-8,D2
        BEQ         D1DONTWORRY
D1ACCOUNTFORZEROS:
         ADDI.L     #8,D2
         SUB.L      D2,A1
D1DONTWORRY:
        MOVE.L      #0,D0
        MOVE.L      #8,D1
        TRAP        #15

            *----------D2----------*
        LEA         RD2,A1
        MOVE.L      #4,D1
        MOVE.L      #1,D0
        TRAP        #15
        MOVE.L      (SP)+,D3
        JSR         HEXTOASCII
        MOVE.L      A2,A1
        SUB.L       A3,A2
        MOVE.L      A2,D2
        CMP.L       #-8,D2
```

```
            BEQ         D2DONTWORRY
D2ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D2DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

                    *--------------D3---------------*
            LEA         RD3,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         D3DONTWORRY
D3ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D3DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

                    *--------------D4---------------*
            LEA         RD4,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         D4DONTWORRY
D4ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D4DONTWORRY:
```

```
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

            *-----------------D5-----------------*
            LEA         RD5,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         D5DONTWORRY
D5ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D5DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

              *-----------------D6-----------------*
            LEA         RD6,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         D6DONTWORRY
D6ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D6DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

                *-----------------D7-----------------*
            LEA         RD7,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         D7DONTWORRY
D7ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
D7DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

     *-----------------A0-----------------*
            LEA         RA0,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A0DONTWORRY
A0ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
A0DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

                 *-----------------A1-----------------*
            LEA         RA1,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A1DONTWORRY
A1ACCOUNTFORZEROS:
             ADDI.L     #8,D2
             SUB.L      D2,A1
A1DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

             *-------------A2--------------*
            LEA         RA2,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A2DONTWORRY
A2ACCOUNTFORZEROS:
             ADDI.L     #8,D2
             SUB.L      D2,A1
A2DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

              *-------------A3--------------*
            LEA         RA3,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A3DONTWORRY
A3ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
A3DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

              *--------------A4---------------*
            LEA         RA3,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A4DONTWORRY
A4ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
A4DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

             *--------------A5---------------*
            LEA         RA3,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A5DONTWORRY
A5ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
A5DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

            *-----------------A6-----------------*
            LEA         RA3,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         A6DONTWORRY
A6ACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
A6DONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15
          *--------HACK---*
          ADD.L   #60,SP   ;should put stack in correct place

                      *-----------------USP-----------------*
            LEA         RUS,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         USPDONTWORRY
USPACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
USPDONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15
```

```

                        *--------------SR--------------*
            LEA         RSR,A1
            MOVE.L      #4,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.W      (SP)+,D3
            MOVE.W      D3,D7     ;temp storage to restore before return
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-4,D2
            BEQ         SRDONTWORRY
SRACCOUNTFORZEROS:
              ADDI.L    #4,D2
              SUB.L     D2,A1
SRDONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #4,D1
            TRAP        #15

       *--------------SS/A7--------------*
            LEA         RSS,A1
            MOVE.L      #7,D1
            MOVE.L      #1,D0
            TRAP        #15
            MOVE.L      (SP)+,D3
            JSR         HEXTOASCII
            MOVE.L      A2,A1
            SUB.L       A3,A2
            MOVE.L      A2,D2
            CMP.L       #-8,D2
            BEQ         SSDONTWORRY
SSACCOUNTFORZEROS:
              ADDI.L    #8,D2
              SUB.L     D2,A1
SSDONTWORRY:
            MOVE.L      #0,D0
            MOVE.L      #8,D1
            TRAP        #15

       *--------------PC--------------*
            LEA         RPC,A1
            MOVE.L      #4,D1
```

```
        MOVE.L   #1,D0
        TRAP     #15
        MOVE.L   (SP)+,D3
        JSR      HEXTOASCII
        MOVE.L   A2,A1
        SUB.L    A3,A2
        MOVE.L   A2,D2
        CMP.L    #-8,D2
        BEQ      PCDONTWORRY
PCACCOUNTFORZEROS:
         ADDI.L  #8,D2
         SUB.L   D2,A1
PCDONTWORRY:
        MOVE.L   #0,D0
        MOVE.L   #8,D1
        TRAP     #15

    *---DF HACK RESTORE---*
    MOVE.W   D7,-(SP)
    ADD.L    #-72,SP
    MOVEM.L  (SP)+,D0-D7/A0-A6
    ADD.L    #12,SP    ;go back to original value
    ;MOVE.W   (SP)+,SR
    ORI.W   #$2000,SR     ;easy68k simulator is always in supervisor mode
    MOVE.L  #$01000000,SP     ;reset stack
        BRA SHELL
```

2.2.13 Modify Register

2.2.13.1 Algorithm and Flowchart

This command is used to change the value of a specific A or D register. This is done by parsing the data entered by the user, then updating the current value of the selected register. The syntax is `.<Register Type> <data>`. The flowchart is shown in Figure 15.

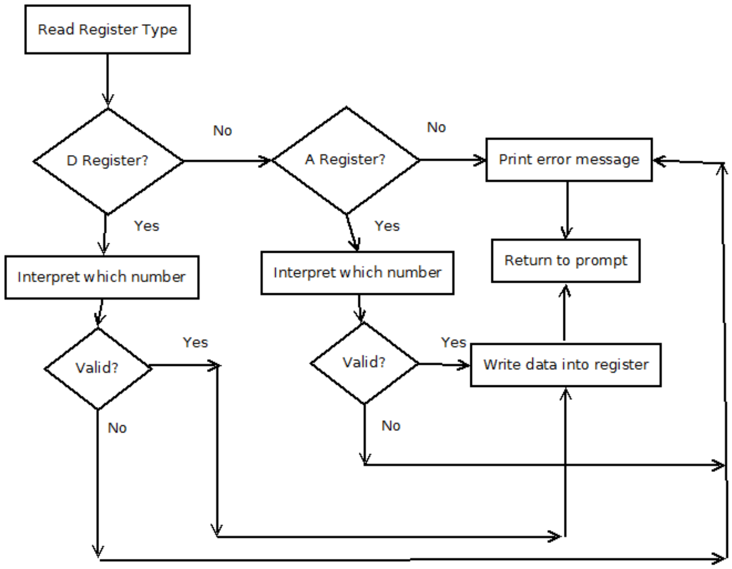


Figure 15: Flowchart for Modify Register

2.2.13.2 Assembly Code

```
MODIFYREGS:

MRD:
            ADD.L     #1,A1    ;inc
            CMP.B     #$30,(A1)
            BEQ       MRD0
            CMP.B     #$31,(A1)
            BEQ       MRD1
            CMP.B     #$32,(A1)
            BEQ       MRD2
            CMP.B     #$33,(A1)
            BEQ       MRD3
            CMP.B     #$34,(A1)
            BEQ       MRD4
            CMP.B     #$35,(A1)
            BEQ       MRD5
            CMP.B     #$36,(A1)
            BEQ       MRD6
            CMP.B     #$37,(A1)
            BEQ       MRD7
            BRA       ERRORSR
```

```

MRA:
        ADD.L   #1,A1     ;inc
        CMP.B   #$30,(A1)
        BEQ     MRA0
        CMP.B   #$31,(A1)
        BEQ     MRA1
        CMP.B   #$32,(A1)
        BEQ     MRA2
        CMP.B   #$33,(A1)
        BEQ     MRA3
        CMP.B   #$34,(A1)
        BEQ     MRA4
        CMP.B   #$35,(A1)
        BEQ     MRA5
        CMP.B   #$36,(A1)
        BEQ     MRA6
        BRA     ERRORSR





MRD0:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS    ;convert data to hex
        MOVE.L  D5,-(SP)         ;store it temporarily
        ADD.L   #4,SP        ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP        ;account for USP, it'll fix itself (it shouldn't be used)
                                 ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP        ;skip saved stack
        SUB.L   #134,SP      ;find data again
        MOVE.L  (SP),D0
        ADD.L   #138,SP         ;go back to original spot
        BRA     SHELL

MRD1:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
                                    ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP           ;skip saved stack
        SUB.L   #134,SP         ;find data again
        MOVE.L  (SP),D1
        ADD.L   #138,SP         ;go back to original spot
        BRA     SHELL

MRD2:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
```

```
                                        ;EASY68k simulator starts in supervisor mode
        MOVE     (SP)+,SR
        ADD.L    #4,SP          ;skip saved stack
        SUB.L    #134,SP        ;find data again
        MOVE.L   (SP),D2
        ADD.L    #138,SP        ;go back to original spot
        BRA      SHELL

MRD3:
        ADD.L    #1,A1
        CMP.B    #$20,(A1)+
        BNE      ERRORSR
        MOVE.L   A1,A2
        MOVE.L   A2,A3
        JSR      MRDFINDDATA
        SUB.L    #1,A3
        JSR      ASCII_ADDRESS      ;convert data to hex
        MOVE.L   D5,-(SP)           ;store it temporarily
        ADD.L    #4,SP          ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L    #4,SP          ;account for USP, it'll fix itself (it shouldn't be used)
                                        ;EASY68k simulator starts in supervisor mode
        MOVE     (SP)+,SR
        ADD.L    #4,SP          ;skip saved stack
        SUB.L    #134,SP        ;find data again
        MOVE.L   (SP),D3
        ADD.L    #138,SP        ;go back to original spot
        BRA      SHELL

MRD4:
        ADD.L    #1,A1
        CMP.B    #$20,(A1)+
        BNE      ERRORSR
        MOVE.L   A1,A2
        MOVE.L   A2,A3
        JSR      MRDFINDDATA
        SUB.L    #1,A3
        JSR      ASCII_ADDRESS      ;convert data to hex
        MOVE.L   D5,-(SP)           ;store it temporarily
        ADD.L    #4,SP          ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP         ;account for USP, it'll fix itself (it shouldn't be used)
                                  ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP         ;skip saved stack
        SUB.L   #134,SP       ;find data again
        MOVE.L  (SP),D4
        ADD.L   #138,SP       ;go back to original spot
        BRA     SHELL

MRD5:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS     ;convert data to hex
        MOVE.L  D5,-(SP)          ;store it temporarily
        ADD.L   #4,SP         ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP         ;account for USP, it'll fix itself (it shouldn't be used)
                                  ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP         ;skip saved stack
        SUB.L   #134,SP       ;find data again
        MOVE.L  (SP),D5
        ADD.L   #138,SP       ;go back to original spot
        BRA     SHELL

MRD6:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
                                    ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP           ;skip saved stack
        SUB.L   #134,SP         ;find data again
        MOVE.L  (SP),D6
        ADD.L   #138,SP         ;go back to original spot
        BRA     SHELL

MRD7:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
                                    ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
       ADD.L   #4,SP           ;skip saved stack
        SUB.L   #134,SP         ;find data again
        MOVE.L  (SP),D7
        ADD.L   #138,SP         ;go back to original spot
        BRA     SHELL

MRA0:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
                                    ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP           ;skip saved stack
        SUB.L   #134,SP         ;find data again
        MOVE.L  (SP),A0
        ADD.L   #138,SP         ;go back to original spot
        BRA     SHELL
MRA1:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS       ;convert data to hex
        MOVE.L  D5,-(SP)            ;store it temporarily
        ADD.L   #4,SP           ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP           ;account for USP, it'll fix itself (it shouldn't be used)
                                    ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
       ADD.L   #4,SP           ;skip saved stack
        SUB.L   #134,SP         ;find data again
        MOVE.L  (SP),A1
        ADD.L   #138,SP     ;go back to original spot
        BRA     SHELL

MRA2:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS   ;convert data to hex
        MOVE.L  D5,-(SP)        ;store it temporarily
        ADD.L   #4,SP       ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP       ;account for USP, it'll fix itself (it shouldn't be used)
                                ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP       ;skip saved stack
        SUB.L   #134,SP     ;find data again
        MOVE.L  (SP),A2
        ADD.L   #138,SP     ;go back to original spot
        BRA     SHELL

MRA3:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS   ;convert data to hex
        MOVE.L  D5,-(SP)        ;store it temporarily
        ADD.L   #4,SP       ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP       ;account for USP, it'll fix itself (it shouldn't be used)
```

```
                                        ;EASY68k simulator starts in supervisor mode
        MOVE     (SP)+,SR
        ADD.L    #4,SP          ;skip saved stack
        SUB.L    #134,SP        ;find data again
        MOVE.L   (SP),A3
        ADD.L    #138,SP        ;go back to original spot
        BRA      SHELL

MRA4:
        ADD.L    #1,A1
        CMP.B    #$20,(A1)+
        BNE      ERRORSR
        MOVE.L   A1,A2
        MOVE.L   A2,A3
        JSR      MRDFINDDATA
        SUB.L    #1,A3
        JSR      ASCII_ADDRESS       ;convert data to hex
        MOVE.L   D5,-(SP)            ;store it temporarily
        ADD.L    #4,SP          ;dont lose data
        MOVEM.L  (SP)+,D0-D7/A0-A6
        MOVEM.L  (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L    #4,SP          ;account for USP, it'll fix itself (it shouldn't be used)
                                        ;EASY68k simulator starts in supervisor mode
        MOVE     (SP)+,SR
        ADD.L    #4,SP          ;skip saved stack
        SUB.L    #134,SP        ;find data again
        MOVE.L   (SP),A4
        ADD.L    #138,SP        ;go back to original spot
        BRA      SHELL

MRA5:
        ADD.L    #1,A1
        CMP.B    #$20,(A1)+
        BNE      ERRORSR
        MOVE.L   A1,A2
        MOVE.L   A2,A3
        JSR      MRDFINDDATA
        SUB.L    #1,A3
        JSR      ASCII_ADDRESS       ;convert data to hex
        MOVE.L   D5,-(SP)            ;store it temporarily
        ADD.L    #4,SP          ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP       ;account for USP, it'll fix itself (it shouldn't be used)
                                ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
       ADD.L   #4,SP       ;skip saved stack
        SUB.L   #134,SP     ;find data again
        MOVE.L  (SP),A5
        ADD.L   #138,SP     ;go back to original spot
        BRA     SHELL

MRA6:
        ADD.L   #1,A1
        CMP.B   #$20,(A1)+
        BNE     ERRORSR
        MOVE.L  A1,A2
        MOVE.L  A2,A3
        JSR     MRDFINDDATA
        SUB.L   #1,A3
        JSR     ASCII_ADDRESS   ;convert data to hex
        MOVE.L  D5,-(SP)        ;store it temporarily
        ADD.L   #4,SP       ;dont lose data
        MOVEM.L (SP)+,D0-D7/A0-A6
        MOVEM.L (SP)+,D0-D7/A0-A6 ;double restore because of DF hack workaround
        ADD.L   #4,SP       ;account for USP, it'll fix itself (it shouldn't be used)
                                ;EASY68k simulator starts in supervisor mode
        MOVE    (SP)+,SR
        ADD.L   #4,SP       ;skip saved stack
        SUB.L   #134,SP     ;find data again
        MOVE.L  (SP),A6
        ADD.L   #138,SP     ;go back to original spot
        BRA     SHELL

MRDFINDDATA:
        CMP.B   #$00,(A3)+
        BEQ     GOBACK
        BRA     MRDFINDDATA
GOBACK: RTS

```

```

        BRA RESTORE
```

2.2.14 Echo

2.2.14.1 Algorithm and Flowchart

This is a simple command that outputs what the user inputs. This is done by parsing the data entered by the user and immediately setting up a trap I/O call that outputs what was just entered. The syntax is `ECHO <data>`. The flowchart is shown in Figure 16.

2.2.14.2 Assembly Code

```
ECHO: *What terminal DOESN'T have echo?*

        MOVE.L  A1,A2    ;setup to find end of string
EEND:   CMP.B   #$00,(A2)+
        BEQ     EFOUND
        BRA     EEND
EFOUND:
        SUB.L   #1,A2    ;off by one
        SUB.L   A1,A2    ;find out how many bytes
        MOVE.L  A2,D1    ;place it for trap function
        MOVE.L  #0,D0
        TRAP    #15

        BRA RESTORE
```

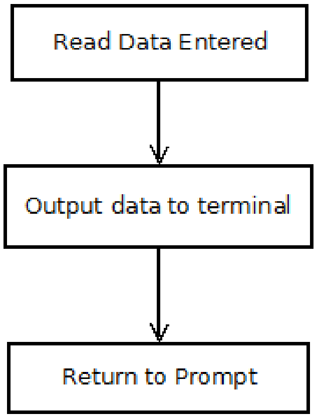


Figure 16: Flowchart for Echo

2.3 Exception Handlers

The Monitor441 program uses custom exception handlers. They are loaded using the source code:

```
 *Load custom exceptions*
LEA BERR,A1 ;init exception handlers
MOVE.L A1,$8
LEA AERR,A1
MOVE.L A1,$C
LEA IERR,A1
MOVE.L A1,$10
LEA ZERR,A1
MOVE.L A1,$14
LEA CHKERR,A1
MOVE.L  A1,$18
LEA PERR,A1
MOVE.L A1,$20
LEA ALERR,A1
MOVE.L A1,$28
LEA FLERR,A1
MOVE.L A1,$2C
MOVEM.L (SP)+,D0-D2/A1  ;restore any preset values
```

2.3.1 Bus Error Exception

2.3.1.1 Algorithm and Flowchart

This exception is called whenever a bus error exception occurs. It outputs the SSW, IR, and BA along with a custom string message. The register values are also printed to the screen. The flowchart is shown in Figure 17.

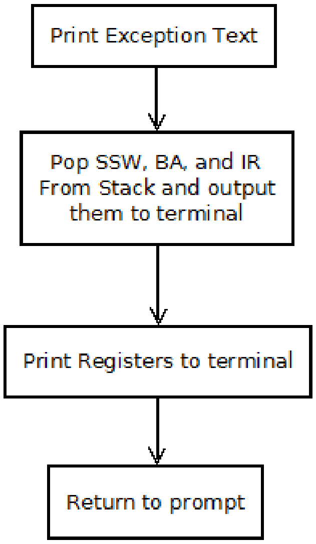

Print Exception Text
Pop SSW, BA, and IR From Stack and output them to terminal
Print Registers to terminal
Return to prompt

Figure 17: Flowchart for Bus Error Exception

2.3.1.2 Assembly Code

```
BERR:
            MOVEM.L  A1-A3/D0-D1,-(SP)
            LEA      BERR_TEXT,A1
            MOVE.L   #13,D0
            TRAP     #15
            LEA      SSW,A1
            MOVE.L   #14,D0
            TRAP     #15
            MOVE.W   (28,SP),D3
            JSR      HEXTOASCII
            SUB.L    #4,A3
            MOVEA.L  A3,A1
            MOVE.L   #4,D1
            MOVE.L   #0,D0
            TRAP     #15
            LEA      BA,A1
            MOVE.L   #14,D0
```

```
        TRAP    #15
        MOVE.L  (30,SP),D3
        JSR     HEXTOASCII
        SUB.L   #8,A3
        MOVEA.L A3,A1
        MOVE.L  #8,D1
        MOVE.L  #0,D0
        TRAP    #15
        LEA     IR,A1
        MOVE.L  #14,D0
        TRAP    #15
        MOVE.W  (34,SP),D3
        JSR     HEXTOASCII
        SUB.L   #4,A3
        MOVEA.L A3,A1
        MOVE.L  #4,D1
        MOVE.L  #0,D0
        TRAP    #15
        MOVEM.L (SP)+,A1-A3/D0-D1

        JSR     DF
        BRA     SHELL
```

2.3.2 Address Error Exception

2.3.2.1 Algorithm and Flowchart

This exception is called whenever an address error exception occurs. It outputs the SSW, IR, and BA along with a custom string message. The register values are also printed to the screen. The flowchart is shown in Figure 18.

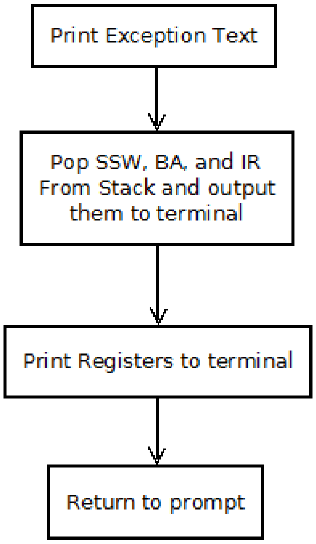

Print Exception Text
Pop SSW, BA, and IR From Stack and output them to terminal
Print Registers to terminal
Return to prompt

Figure 18: Flowchart for Address Error Exception

2.3.2.2 Assembly Code

```
AERR:
            MOVEM.L  A1-A3/D0-D1/D4-D5,-(SP)
            LEA      AERR_TEXT,A1
            MOVE.L   #13,D0
            TRAP     #15
            LEA      SSW,A1
            MOVE.L   #14,D0
            TRAP     #15
            MOVE.W   (28,SP),D3
            JSR      HEXTOASCII
            SUB.L    #4,A3
            MOVEA.L  A3,A1
            MOVE.L   #4,D1
            MOVE.L   #0,D0
            TRAP     #15
            LEA      BA,A1
            MOVE.L   #14,D0
            TRAP     #15
            MOVE.L   (30,SP),D3
            JSR      HEXTOASCII
            SUB.L    #8,A3
            MOVEA.L  A3,A1
            MOVE.L   #8,D1
            MOVE.L   #0,D0
            TRAP     #15
            LEA      IR,A1
            MOVE.L   #14,D0
            TRAP     #15
            MOVE.W   (34,SP),D3
            JSR      HEXTOASCII
            SUB.L    #4,A3
            MOVEA.L  A3,A1
            MOVE.L   #4,D1
            MOVE.L   #0,D0
            TRAP     #15
            MOVEM.L  (SP)+,A1-A3/D0-D1/D4-D5

            JSR      DF
            BRA      SHELL
```

2.3.3 Illegal Instruction Error Exception

2.3.3.1 Algorithm and Flowchart

This exception is called whenever an illegal instruction error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 19.

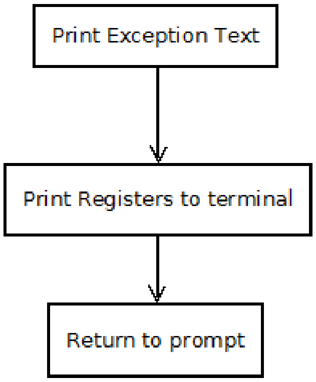


Figure 19: Flowchart for Illegal Instruction Exception

2.3.3.2 Assembly Code

```
IERR:
    MOVEM.L A1/D0,-(SP)
    LEA IERR_TEXT,A1
    MOVE.L #13,D0
    TRAP #15
    MOVEM.L (SP)+,A1/D0
    JSR DF
    BRA SHELL
```

2.3.4 Privilege Violation Error Exception

2.3.4.1 Algorithm and Flowchart

This exception is called whenever an privilege violation error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 20.

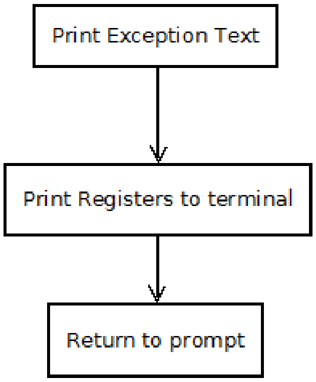


Figure 20: Flowchart for Privilege Violation Exception

2.3.4.2 Assembly Code

```
PERR:
    MOVEM.L A1/D0,-(SP)
    LEA PERR_TEXT,A1
    MOVE.L #13,D0
    TRAP #15
    MOVEM.L (SP)+,A1/D0
    JSR DF
    BRA SHELL
```

2.3.5 Divide by Zero Error Exception

2.3.5.1 Algorithm and Flowchart

This exception is called whenever a divide by zero error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 21.

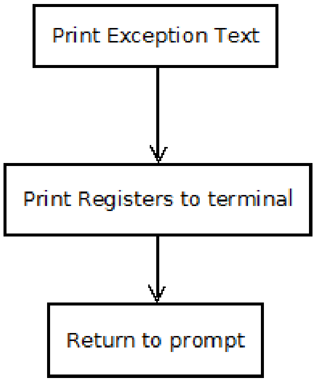


Figure 21: Flowchart for Divide by Zero Exception

2.3.5.2 Assembly Code

```
ZERR:
        MOVEM.L  A1/D0,-(SP)
        LEA  ZERR_TEXT,A1
        MOVE.L  #13,D0
        TRAP  #15
        MOVEM.L  (SP)+,A1/D0
        JSR  DF
        BRA  SHELL
```

2.3.6 A Line Emulator Error Exception

2.3.6.1 Algorithm and Flowchart

This exception is called whenever an A line emulator error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 22.

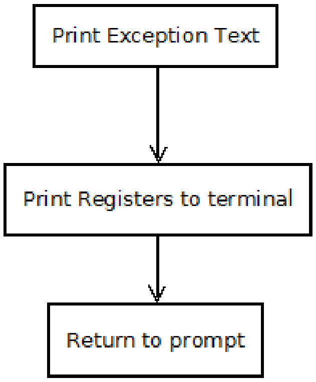


Figure 22: Flowchart for A Line Emulator Error Exception

2.3.6.2 Assembly Code

```
ALERR:
        MOVEM.L  A1/D0,-(SP)
        LEA  ALERR_TEXT,A1
        MOVE.L  #13,D0
        TRAP  #15
        MOVEM.L  (SP)+,A1/D0
        JSR  DF
        BRA  SHELL
```

2.3.7 F Line Emulator Error Exception

2.3.7.1 Algorithm and Flowchart

This exception is called whenever an F line emulator error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 23.

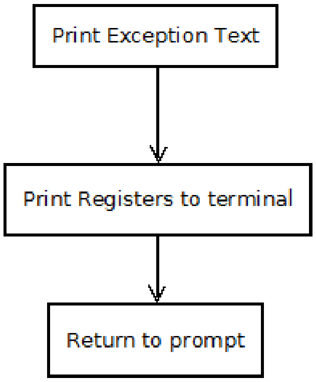


Figure 23: Flowchart for F Line Emulator Error Exception

2.3.7.2 Assembly Code

```
FLERR:
        MOVEM.L A1/D0,-(SP)
        LEA FLERR_TEXT,A1
        MOVE.L #13,D0
        TRAP #15
        MOVEM.L (SP)+,A1/D0

        JSR DF
        BRA SHELL
```

2.3.8 Check Instruction Error Exception

2.3.8.1 Algorithm and Flowchart

This exception is called whenever a check instruction error exception occurs. It outputs a custom string message, and the register values are also printed to the screen. The flowchart is shown in Figure 24.

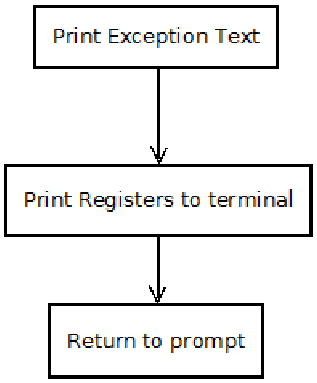


Figure 24: Flowchart for Check Instruction Error Exception

2.3.8.2 Assembly Code

```
CHKERR:
        MOVEM.L  A1/D0,-(SP)
        LEA  CHKERR_TEXT,A1
        MOVE.L  #13,D0
        TRAP  #15
        MOVEM.L  (SP)+,A1/D0

        JSR  DF
        BRA  SHELL
```

2.4 User Instruction Manual Exception Handlers

2.4.1 Syntax/Unknown Command Error

2.4.1.1 Algorithm and Flowchart

This error is meant to guide the user to input the correct syntax for a command. It first checks if the command entered is valid. If not, an unknown command message is displayed. If the command entered is valid but the syntax is incorrect, an incorrect syntax message is outputted to the terminal. The flowchart is shown in Figure 25.

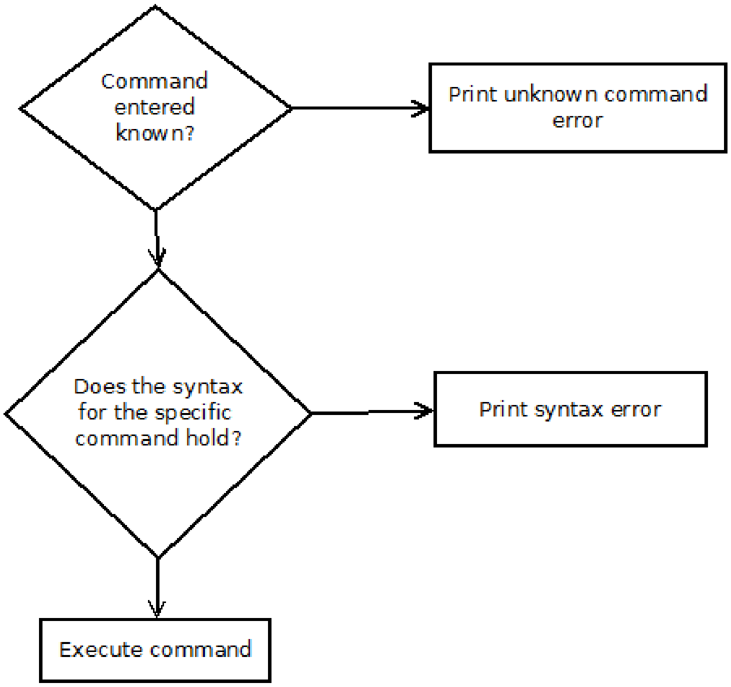

Command entered known?
Print unknown command error
Does the syntax for the specific command hold?
Print syntax error
Execute command

Figure 25: Flowchart for User Instruction Manual Exception Handler

2.4.1.2 Assembly Code

```
ERRORSR:        LEA     ERROR, A1       ;load message
                MOVE.W  #44,D1
                MOVE.L  #0,D0
                TRAP    #15
                BRA     RESTORE

UNKNOWNCMD:     LEA     ERROR1, A1      ;load message
                MOVE.W  #22,D1
                MOVE.L  #0,D0
                TRAP    #15
                BRA     RESTORE
```

3 Discussion

With a low level programming language such as assembly, the computer engineer is in full control of how each command is built. When building a monitor type program, assembly can be great because of its simplicity, but it also has its draw backs due to a lack of high level API. This increases the chances that erroneous input will kill the program or produce unpredictable results. This means that in order to have a flawless program, the amount of source code needed to be written per command could easily violate the design constraint of having under 3K code size. Because of this, major errors were checked, but it is still possible to break the program by producing minor errors. The program assumes the user knows how to accurately use the tools provided, and if wrong input is entered and an error message is not displayed, the user will have already known their input was invalid. Furthermore, there are some major limitations to the functionality of this program, for example, certain commands can only take in byte sized data or a hexadecimal to decimal conversion can only accept a maximum value of FFFF. Regardless, this program performs on par with Motorola's Tutor software and, with error checking aside, could replace Tutor entirely.

There were many engineering and design challenges encountered during the journey to construct this program. A majority of these challenges came up during the debugging of each separate command. Taking an algorithm and knowing how to code it is a simple process, but the actual implementation is the hard part. This is when things such as runtime errors must be eliminated. Overall, runtime errors accounted for 95% of the total generated errors, and the code had to be run step by step to pinpoint the exact moment of error in order to be fixed. Furthermore, deciding on how to store and manipulate data was a huge design concern. With only 7 data registers and 7 address registers, storage "containers" had to be carefully picked so that there were no memory leaks and registers needed to be untouched due to subroutines were not accessed accidentally.

4 Feature Suggestions

As discussed earlier in Section 3, complex error checking should be implemented in this program. Furthermore, more commands should be implemented to emulate not just Motorola's Tutor software, but current Operating System distributions as well. This could include commands such as , `ls` (listing files in current directory) or `cd` (change directory). If implementing an embedded system using the MC68000 processor, and the `MONITOR441` program is used as a basis, these commands could help the programmer easily analyze top layer applications such as installed files as well as low layer applications such as displaying register values.

5 Conclusion

Overall, the monitor program was created, and it has all of the requested functionality implemented. While it is not 100% error free, it provides the user a great MC6000 based piece of software for use with debugging the microprocessor. Further work could be done to improve the functionality to be on the level of Motorola's Tutor software, but this shouldn't be done as no modern day technology runs based on the MC68000 microprocessor.

References

[1] Harman, Thomas L., and Barbara Lawson. *The Motorola MC68000 Microprocessor Family: Assembly Language, Interface Design, and System Design.* Englewood Cliffs, NJ: Prentice-Hall, 1985. Print.

[2] MC68000 Microprocessor Programmer's Reference Manual

[3] SANPER-1 Lab Manuals

[4] MC68000 Educational Computer Board User's Manual