# Introduction to Microcontrollers II

brset, brclr

Indexed Addressing Example

µp Laboratory #2

BUFFALO

Assembling Code





## EECE 143 Digital Design Project

**Purpose:** To allow students to design their own digital project in order to demonstrate the utilization of digital design concepts.

**Examples:** Digital Alarm Clock, Traffic Light Simulation, Soda pop machine controller Scoreboard Display with timers

**Design Criteria:** If required, all clock sources must be designed and built by students.
You may use IC's available in the Open Lab.
You may use discrete LS or HC ICs as well as GALs.

**Grading:**

| | | |
|---|---|---|
| Design Proposal | 10 | **DUE: Monday, November 5th in class** |
| *(Preliminary design diagrams, flowcharts)* | | |
| Design Project | 30 | **Presentations & Reports: Thursday,Dec 6th** |
| *(Neatness of design, design complexity Making it work)* | | |
| Presentations | 60 | |
| *(Visual Aids, Ability to communicate design, Peer, TA and Teacher Evals)* | | |
| Final Report (Writeup) | 100 | |
| *(Purpose, Preparation, Experiment Procedure,Design Description, Schematics, Flowcharts, Code, Future Design Improvements and Considerations)* | | |
| **Total** | **200** | |

# Digital Design Projects

- Digital Alarm Clock
- Digital Temperature Buffer/Storage
- Soda Pop Machine with Password for Free Soda
- Car Turning Signal Light Controller
- Electric Door Lock Control Circuit
- Traffic Light Signal Controllers
- Digital Tic-Tac-Toe
- Digital Slot Machine
- Digital Kitchen Timer
- Sports Scoreboard with Timer
- Digital Sampler and Playback





# Design Project Presentation

- Thursday December 6
- 5-10 minutes to present your project and demonstrate
- You will be graded on
  - How well you communicate your design
  - How well you answer questions
  - Audio/visual aids (Powerpoint presentations, poster boards…)

# Design Project Written Report

- Due at time of presentation
- Typed
- Should include the following
  - Purpose
  - Design Description: A module by module description of your design.
  - Equations used in your design. Truth Tables…
  - COMPLETE schematic diagrams, block diagrams
  - Flow charts and Code ( if applicable)
  - Testing Procedures: Give a step by step account of how you test to verify your circuit works.
  - Future Design Improvements and Conclusion





# Design Project Grade Breakdown

| | |
|---|---|
| • Design Proposal | 10 |
| • Design Project | 30 |
| • Presentations | 60 |
| • Written Report | 100 |
| Total | 200 |

# A Look at Appendix A of the HC11 Reference Manual





## Load Accumulator

**LDA** LoaD Accumulator **LDA**

**Operation:** AccX ⇐ (M)

**Description:** Loads the contents of memory into the 8-bit accumulator. The condition codes are set according to the data.

**Condition Codes and Boolean Formulae:**

| S | X | H | I | N | Z | V | C |
|---|---|---|---|---|---|---|---|
| - | - | - | - | | | 0 | - |

N R7
Set if MSB of result is set; cleared otherwise

Z R7' • R6' • R5' • R4' • R3' • R2' • R1' • R0'
Set if result is $00; cleared otherwise

V 0
cleared

Source Form: LDAA (opr); LDAB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

| | LDAA (IMM) | | | LDAA (DIR) | | | LDAA (EXT) | | | LDAA (IND,X) | | | LDAA (IND,Y) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cycle | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* |
| 1 | OP | 86 | 1 | OP | 96 | 1 | OP | B6 | 1 | OP | A6 | 1 | OP | 18 | 1 |
| 2 | OP+1 | ii | 1 | OP+1 | ii | 1 | OP+1 | hh | 1 | OP+1 | ff | 1 | OP+1 | A6 | 1 |
| 3 | | | | 00dd | (00dd) | 1 | OP+2 | ll | 1 | FFFF | -- | 1 | OP+2 | ff | 1 |
| 4 | | | | | | | hhll | (hhll) | 1 | X+ff | (X+ff) | 1 | FFFF | -- | 1 |
| 5 | | | | | | | | | | | | | Y+ff | (Y+ff) | 1 |

| | LDAB (IMM) | | | LDAB (DIR) | | | LDAB (EXT) | | | LDAB (IND,X) | | | LDAB (IND,Y) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cycle | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* | Addr | Data | R/W* |
| 1 | OP | C6 | 1 | OP | D6 | 1 | OP | F6 | 1 | OP | E6 | 1 | OP | 18 | 1 |
| 2 | OP+1 | ii | 1 | OP+1 | ii | 1 | OP+1 | hh | 1 | OP+1 | ff | 1 | OP+1 | E6 | 1 |
| 3 | | | | 00dd | (00dd) | 1 | OP+2 | ll | 1 | FFFF | -- | 1 | OP+2 | ff | 1 |
| 4 | | | | | | | hhll | (hhll) | 1 | X+ff | (X+ff) | 1 | FFFF | -- | 1 |
| 5 | | | | | | | | | | | | | Y+ff | (Y+ff) | 1 |

Motorola M68HC11 Reference Manual A-17





# brset command

- Branch if Bit(s) Set:

  Performs the logical AND of location M inverted and the mask supplied with the instruction, then branches if the result is zero (only if all bits corresponding to ones in the mask byte are ones in the tested byte)

**brset $1004 %00001111 GOHERE**

*Will branch to location GOHERE if 4 LSBs of PortE are all 1's*

# brclr command

- Branch if Bit(s) Clear:

  Performs the logical AND of location M and the mask supplied with the instruction, then branches if the result is zero (only if all bits corresponding to ones in the mask byte are zeros in the tested byte)

**brset $1004 %00001111 GOHERE**

*Will branch to location GOHERE if 4 LSBs of PortE are all 0's*





```
0001                    * COUNT_BR.A11
0002                    *       Count pulses at an input.
0003                    *       Two digit BCD output.
0004                    *       Bruce Hoeppner      11/10/92
0005                    *                           06/19/94 brset, brclr
0006                    * NOTE: modifications not tested
0007                    * NOTE: bset, bclr, brset, brclr instructions
0008                    *       work for direct (page 0) or indexed mode
0009
0010                    *       Bounceless input at bit0 of PORTE
0011                    *       Output to PORTB
0012                    * Constants - Hardware dependent
0013 1000                REGBASE    equ $1000
0014 0000                _PORTA     equ $00
0015 0004                _PORTB     equ $04
0016 000a                _PORTE     equ $0a
0017 0001                BIT0  equ %00000001
0018                    ***************************************************
0019
0020
0021 c000                       org $C000          ;origin in user RAM
0022                    * Initialize
0023 c000 4f             MAIN   clra
0024 c001 ce 10 00              ldx #REGBASE
0025 c004 a7 04                 staa _PORTB,x      ;Initialize Output
0026
0027                    * Looking for a POSITIVE EDGE
0028                    * First: Loop until input = 0 (loop while bit=1)
0029 c006 1e 0a 01 fc   WAIT0   brset _PORTE,x BIT0 WAIT0
0030
0031                    * above one line replaces following three,
0032                    * and it is more clear
0033                    *WAIT0ldab $100a            ;read input
0034                    *       andb #$01          ;mask off 7 MSBs
0035                    *       bne WAIT0
0036
```

# Example: count_br.lst

This program uses the brset brclr commands which check to see if a bit or bits are set or cleared.

```
0037                    * Then: Loop until input = 1 (loop while bit=0)
0038 c00a 1f 0a 01 fc   WAIT1   brclr _PORTE,x BIT0 WAIT1
0039
0040                    * above one line replaces following three,
0041                    * and it is more clear
0042                    *WAIT1 ldab $100A       ;read input
0043                    *       andb #$01       ;mask off 7 msbs
0044                    *       beq WAIT1
0045
0046                    * Only get here if after a +edge at specified bit
0047
0048                    *Increment Count (Use adda so daa works)
0049 c00e 8b 01                 adda #$01       ;increment AccA
0050 c010 19                    daa             ;adjust for BCD
0051
0052 c011 a7 04                 staa _PORTB,x   ;write to PORTB
0053 c013 7e c0 06              jmp WAIT0
```

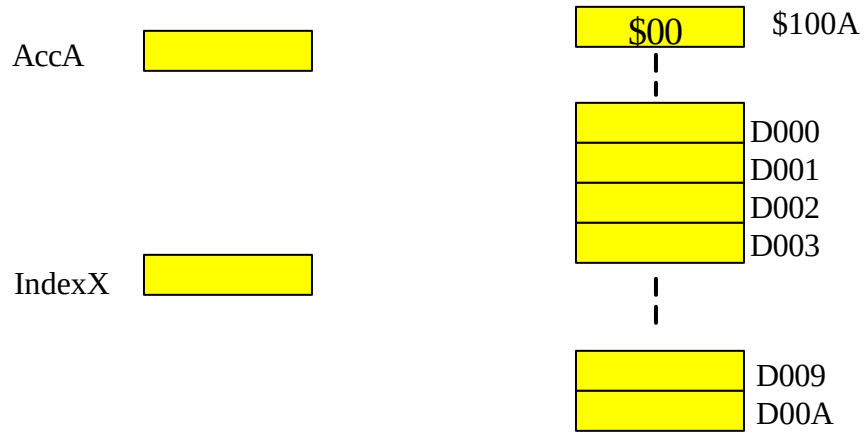
When you compare this code with that of count.a11
you will see it is a lot shorter and easier to understand





# Using Indexed Addressing in Loops

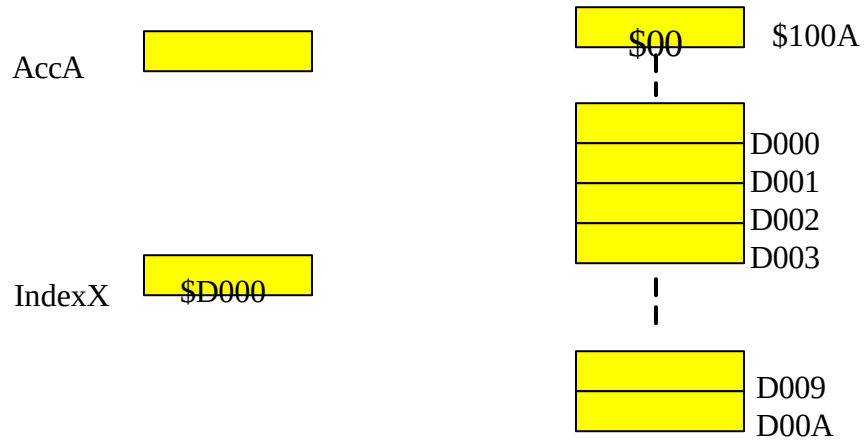
```
PORTE equ $100A     ;Set definition for PORTE
BUFFALO equ $e00a ;Set definition for BUFFALO
    org $c000       ;Store program at $c000
    ldx #$D000      ;load initial value of x register
READ ldaa PORTE     ; load value  into AccA
    staa 0,x        ; store value of AccA into memory location
    inx             ;Increment Register x
    cmpx #$D00A     ;Is x Register = $D00A?
    blt READ        ;If less than get another value
    jmp BUFFALO     ; If it is, end program
    end
```



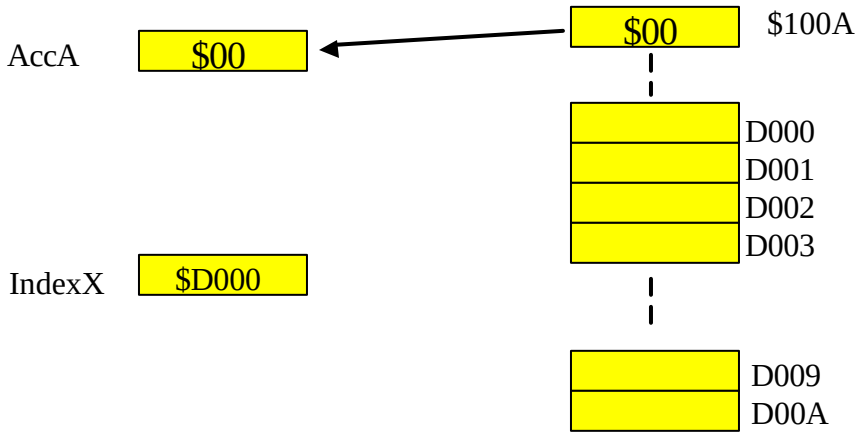





**ldx #$D000 : Loads Index Register X with $D000**
**immediate mode**



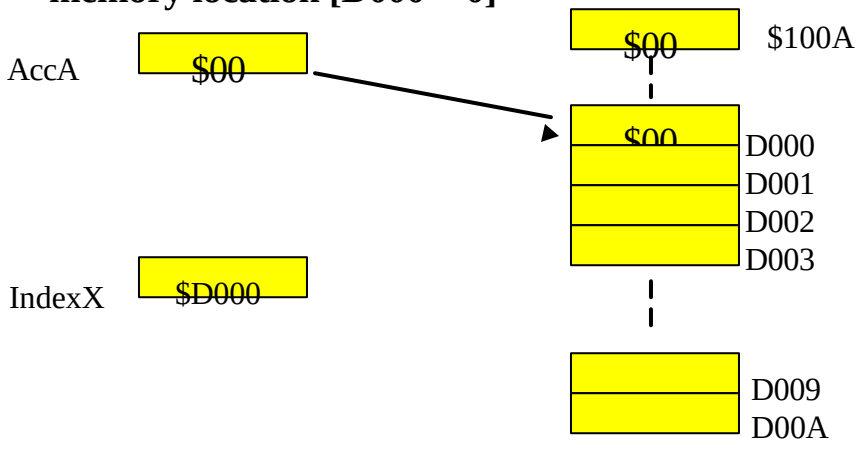
**ldaa PORTE : loads Acca with the contents of PORTE ($100A)**



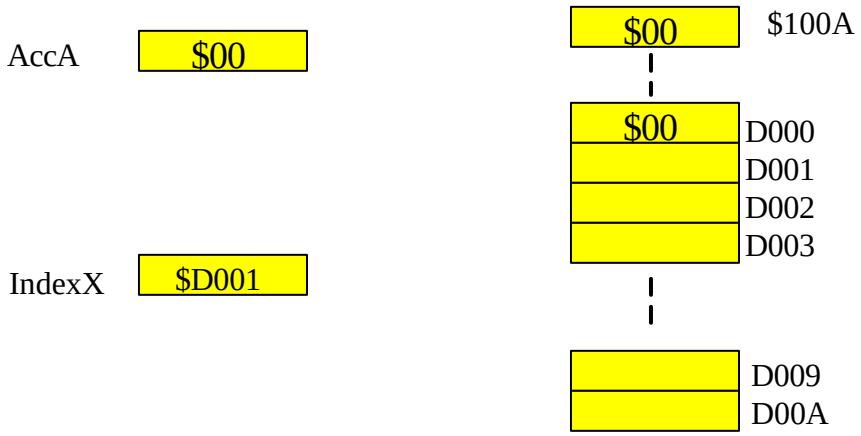





**staa 0,x ;Puts the contents of AccA into the memory location [D000 + 0]**



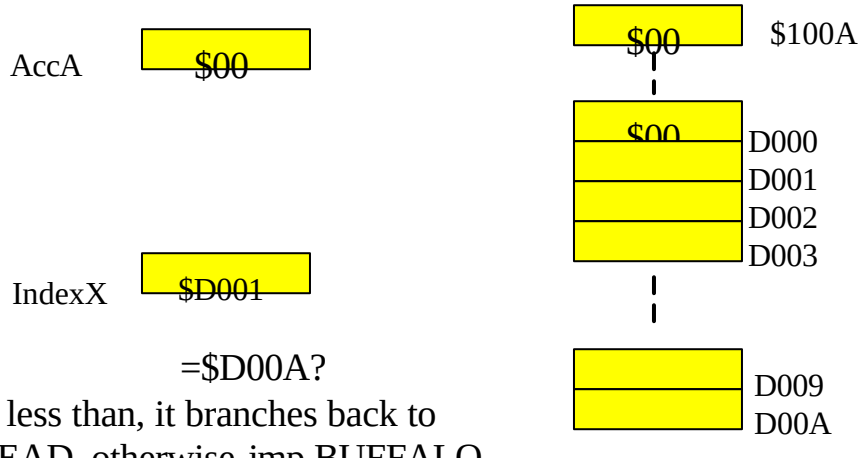
**inx : increments the Index register X**







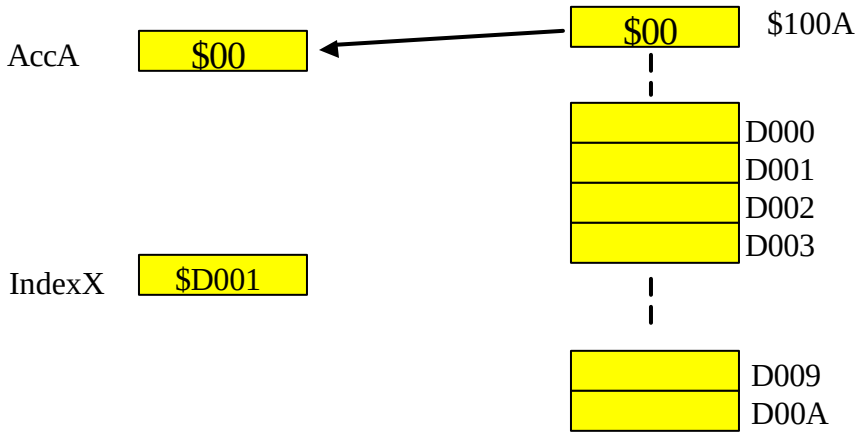

**cmpx #$D00A : compares the contents of index register X with $D00A immediate mode**




=$D00A?

If less than, it branches back to READ, otherwise jmp BUFFALO

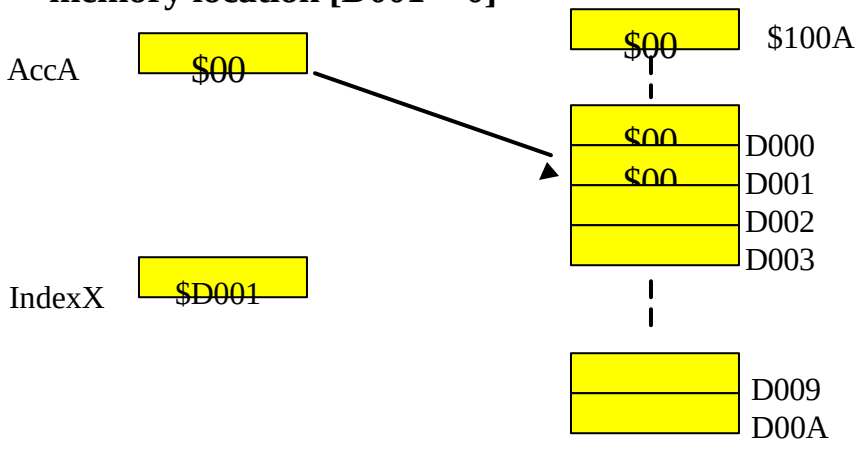
**ldaa PORTE : loads Acca with the contents of PORTE ($100A)**



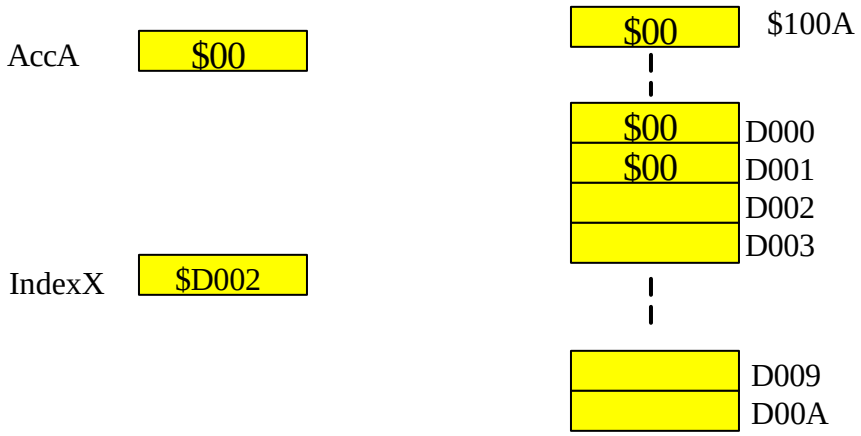





**staa 0,x ;Puts the contents of AccA into the memory location [D001 + 0]**



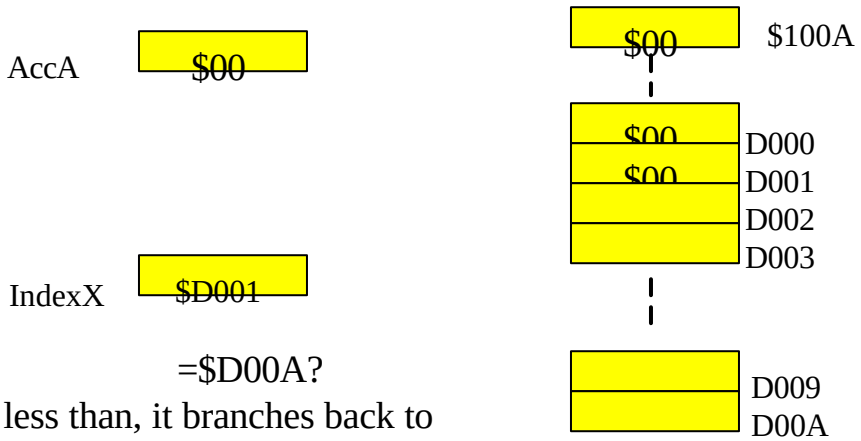
**inx : increments the Index register X**








**cmpx #$D00A : compares the contents of index register X with $D00A immediate mode**




=$D00A?

If less than, it branches back to READ, otherwise jmp BUFFALO

# Guide to A11 Files

```
PORTB equ $1004
    org $C000
MAIN clra
    staa PORTB
WAIT0 ldab $100a
    andb #$01
    bne WAIT0
WAIT1 LDAB $100a
    andb #$01
    beq WAIT1
    adda #$01
    daa
    staa $1004
    jmp WAIT0
```

**;constant declarations should be put before the org statement**

**;org <address to store program>**

**;labels and constants should start in column 1, all other statements should be tabbed to the right**

**;Default is decimal, use $ for HEX or % for binary**

**;Anything after a ";" or a * is a comment**





# AS11 Common Mistakes

see page 9-23

- Missing "#" Motorola defaults to direct or extended addressing mode.
- Using signed branches on unsigned data. AS11 has both signed and unsigned conditional branches. Unsigned (BHI BLO BHS BLS) Signed (BGT BLT BGE BLE)
- Flow charts drawn after code is written. Know what you want to do before you try to write the code.
- Missing a "$". AS11 defaults to decimal. NOTE: BUFFALO only allows HEX. No "$" is needed when using the onboard assembler ASM.
- Loading a 16-bit value into an 8-bit location or vice versa.
- Improper ending for embedded code. Use (in)finite loop or jump to BUFFALO.
- On reads: high byte first, low byte second.
- Errors when pushing and pulling from stack.
- Memory usage
- high byte AccD == AccA, low byte AccD == AccB

# Code Size and Execution Time

```
0001                * IndStor.a11
0002                * J. Chris Perez
0003                * Program uses indexed registering to loop
0004                * through a set of instructions
0005                * to increment value located
0006                * in AccA and store result in consecutive
0007                * Memory locations
0008
0009 c000                org $c000     ;Set location of program in memory
0010 c000 4f             clra                    ;Clear Accumulator A
0011 c001 ce d0 00       ldx #$d000   ; Load Index X with initial location
0012 c004 a7 00         HERE staa 0,x            ;Store contents of AccA
0013 c006 8b 01           adda #$01   ;Increment A
0014 c008 08              inx                     ;Increment Index X
0015 c009 8c d0 0a        cpx#$d00a ;Compare to $d00a
0016 c00c 2d f6           blt HERE    ; If less than, jump to store new value
0017 c00e 7e e0 0a        jmp $e00a   ;Jump to BUFFALO
 HERE      c004 *0012 0016
```





**Program is in C000-C010, therefore the program takes up 17 memory spaces.**

```
0001                * IndStor.a11
0002                * J. Chris Perez
0003                * Program uses indexed registering to loop
0004                * through a set of instructions
0005                * to increment value located
0006                * in AccA and store result in consecutive
0007                * Memory locations
0008
0009 c000                org $c000     ;Set location of program in memory
0010 c000 4f             clra                    ;Clear Accumulator A
0011 c001 ce d0 00       ldx #$d000   ; Load Index X with initial location
0012 c004 a7 00         HERE staa 0,x            ;Store contents of AccA
0013 c006 8b 01           adda #$01   ;Increment A
0014 c008 08              inx                     ;Increment Index X
0015 c009 8c d0 0a        cpx#$d00a ;Compare to $d00a
0016 c00c 2d f6           blt HERE    ; If less than, jump to store new value
0017 c00e 7e e0 0a        jmp $e00a   ;Jump to BUFFALO
 HERE      c004 *0012 0016
```

**This program is in C000-C009, therefore the program takes up 10 memory spaces.**

```
0001                * INNOT2.A11  Read word, NOT it, Write it
0002                *   Bruce Hoeppner    01 JAN 94
0003                *   Chris Perez       14 June 2000
0004                *
0005                *   Read an 8-bit word from PortE.
0006                *   Complement the word.
0007                *   Write the word to PortB.
0008                * Definitions
0009 1004             PORTB    equ  $1004
0010 e00a             BUFFALO  equ  $e00a
0011                ****************************************
0012                * Load program into 8k user RAM
0013 c000                 org  $C000
0014                * Read 8-bit word from PortE into AccA
0015 c000 b6 10 0a          ldaa $100a
0016                * Complement the word.
0017 c003 43              coma
0018                * Write the word to PortB
0019 c004 b7 10 04          staa PORTB
0020
0021                * Jump back to beginning of program
0022 c007 7e e0 0a                jmp BUFFALO beginning of program
 BUFFALO   e00a *0010 0022
PORTB     1004 *0009 0019
```





**This program takes 13 cycles ($6.5 \times 10^{-6}$ sec) to execute.**

From Appendix A:

| Instruction | addressing mode | Cycles |
|---|---|---|
| ldaa | extended | 4 |
| coma | inherent | 2 |
| staa | extended | 4 |
| jmp | extended | 3 |
| Total: | | 13 |

13 cycles/freq = 13 / 2MHz = $6.5 \times 10^{-6}$ sec

```
0001                * INNOT2.A11  Read word, NOT it, Write it
0002                *   Bruce Hoeppner    01 JAN 94
0003                *   Chris Perez       14 June 2000
0004                *
0005                *   Read an 8-bit word from PortE.
0006                *   Complement the word.
0007                *   Write the word to PortB.
0008                * Definitions
0009 1004             PORTB    equ  $1004
0010 e00a             BUFFALO  equ  $e00a
0011                ****************************************
0012                * Load program into 8k user RAM
0013 c000                 org  $C000
0014                * Read 8-bit word from PortE into AccA
0015 c000 b6 10 0a          ldaa $100a
0016                * Complement the word.
0017 c003 43              coma
0018                * Write the word to PortB
0019 c004 b7 10 04          staa PORTB
0020
0021                * Jump back to beginning of program
0022 c007 7e e0 0a                jmp BUFFALO beginning of program
 BUFFALO   e00a *0010 0022
PORTB     1004 *0009 0019
```

# Laboratory μp2: Software

**Prelab:** Create flowcharts and write code for the following:

1. Data Entry – Enter eight 4-bit numbers using a dipswitch (or BCD switch). Read the number when a button is pressed. Store the numbers in sequential memory locations, start at $D000. Display each number as it is entered.
2. Data Sort —Sort eight 4-bit numbers in memory. (Largest to smallest)
3. Data Sum – Compute the sum of eight 4-bit numbers in memory. Display result in BCD.
4. Combine Routines – Combine the functions of 1,2 and 3 into one program. Use 2 bits of PortA to specify which function to perform.00=Data Entry, 01=Data Sort,10=Data Sum, 11=Exit Program

**Design Rules:**

1. Use proper documentation when creating your source code.

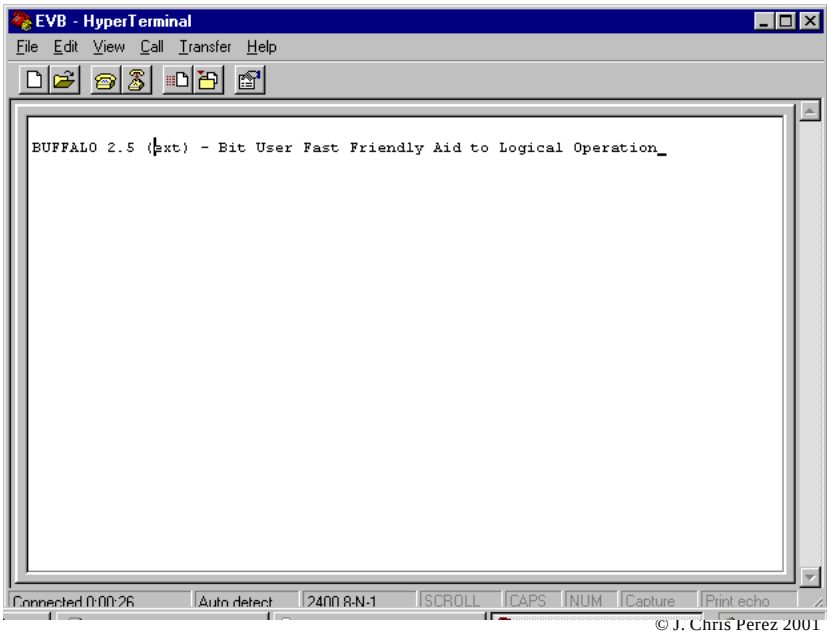
M68HC11EVB I/O limitations: PortB, PortE, PortA (excluding PA7 and PA3)

Remember for Prelab: Show schematic diagrams for all external hardware designs.





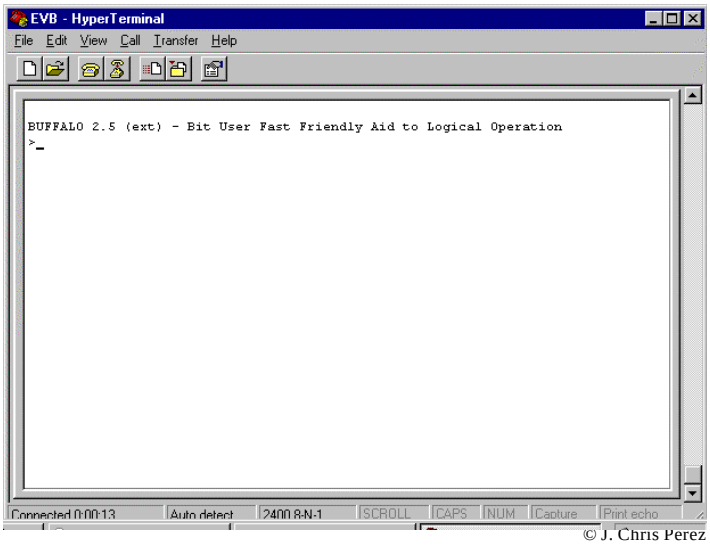
Open your hyperterminal connection to the EVB.
Power up your EVB and press the EVB RESET button.
Note the contents of the screen:
BUFFALO-stands for “Bit User Fast Friendly Aid to Logical Operations”








Press Enter. This brings up the BUFFALO prompt > You are ready to use the 68HC11EVB.



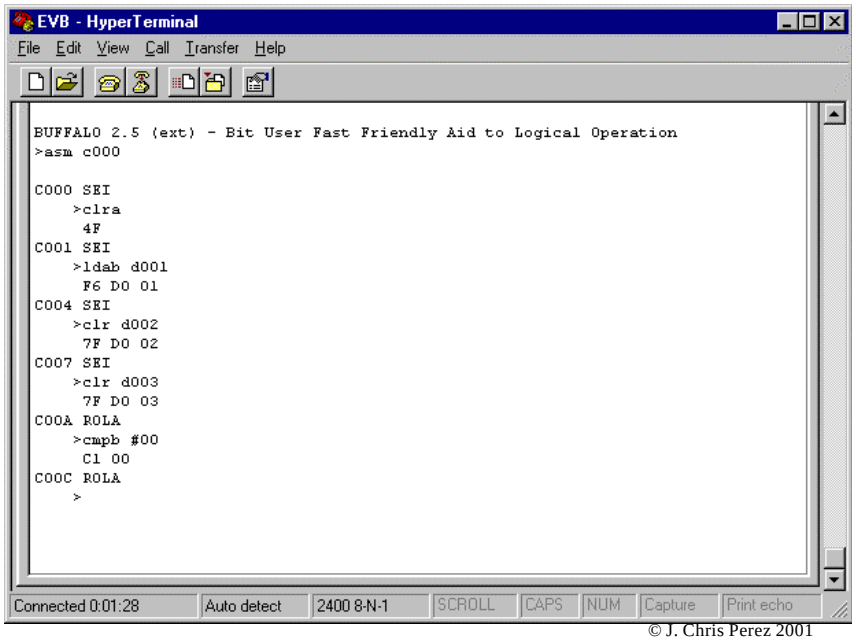
**ASM** == on-board assembler
**ASM *address***

Displays the assembly language for specified address. User may change the instruction and/or data.
Labels may not be used. Instead, use the actual memory location where the label points to. Use your .LST file for help.

Use <CR> to advance to next line of code.
Use <CTRL-C> to abort on-board assembly.





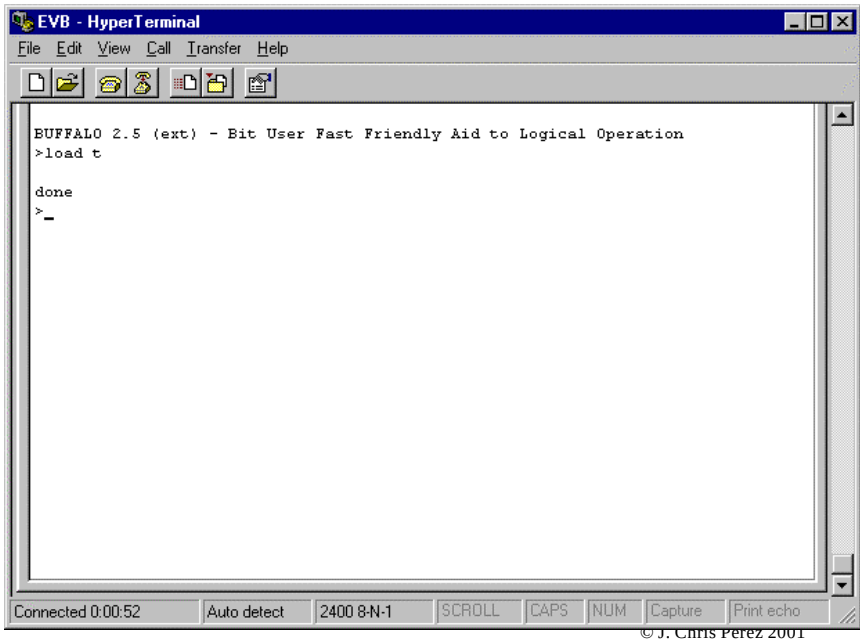


G Go / Execute command
**G *address***
Begins execution of a program at the specific address. The program must provide a jump instruction to get back to the BUFFALO prompt. (jmp $e00a)
**$E00A is the location of BUFFALO in memory.**

LOAD T
Download an assembled .S19 file from a PC
After entering the LOAD T command, go to the Transfer menu:Send Text File. Choose the .S19 file you wish to load. When the file is loaded the word done appears on the screen. You can now verify the file was loaded by using the Memory Display command (MD) and then the G command to run your program.





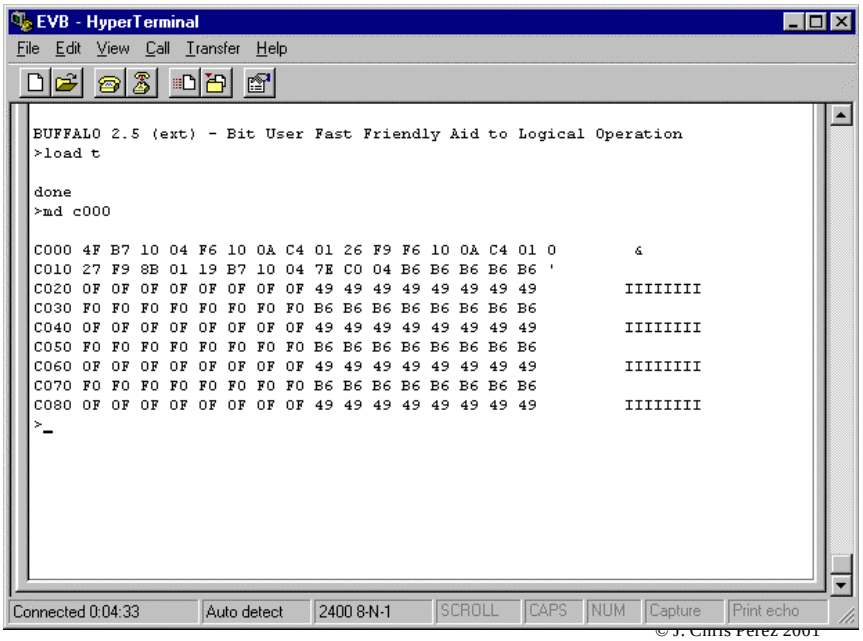


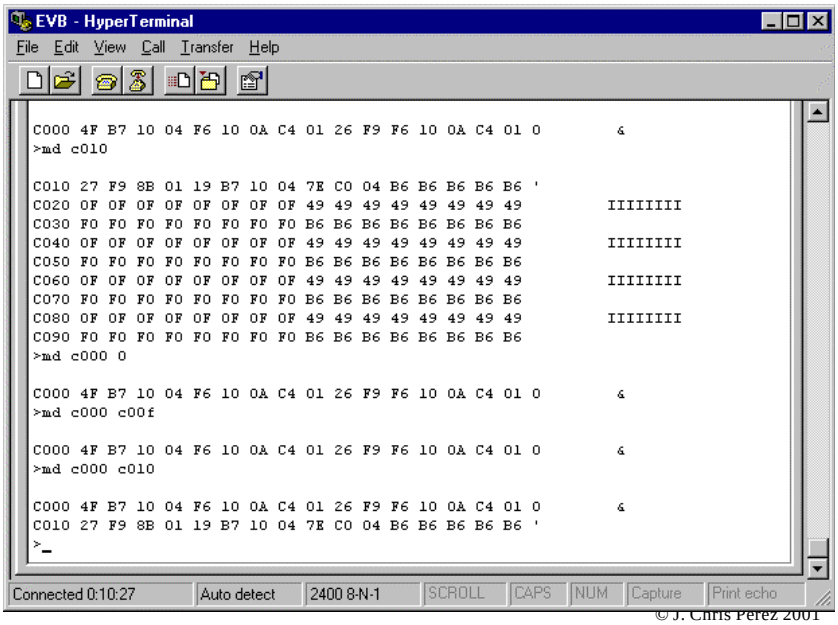
MD Memory Display: Display memory to terminal screen
***MD address_start [address_stop]***

Displays 16 bytes per line. Display will begin on an even 16 byte memory boundary. If no address_stop is given, 9 lines will be displayed. If address_stop is less than address_start, one line will be displayed.





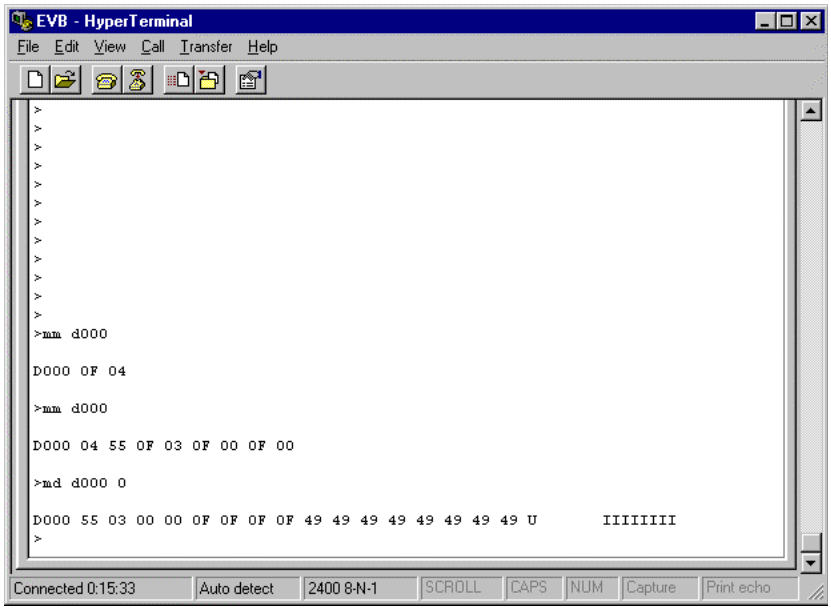







Introduction to Microcontrollers II EECE143 Lecture uP2

MM Memory modify: Display and modify memory contents.
**MM *address***
Displays memory and gives the user a chance to modify it. Use the <SPACE> key to advance to the next byte. Use CTRL-H to backup one byte. Use <CR> to return to the BUFFALO prompt.

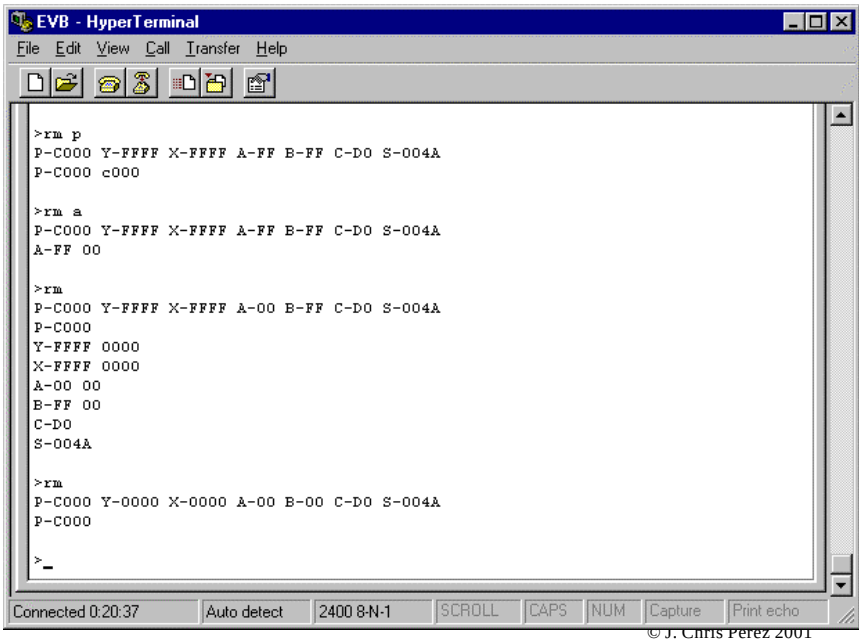







RM Register Modify: Display and modify 68HC11 registers.
**RM *[p,y,x,a,b,c,s]***
Displays the contents of the 68HC11's registers. Also gives the user the chance to modify them.
Registers include:

- P – program counter
- Y – index register Y
- X – index register X
- A – Accumulator A
- B – Accumulator B
- C – Condition code register
- S –Stack pointer






Introduction to Microcontrollers II EECE143 Lecture uP2

T Trace Instructions

T [n]

The trace instruction allows the user to execute a program n instructions at a time. The user must set the program counter to the correct starting address before using the trace command. The machine code for the instruction will be displayed along with the registers after each instructions.