Introduction to Microcontrollers

Motorola M68HC11 Specs

Assembly Programming Language

BUFFALO

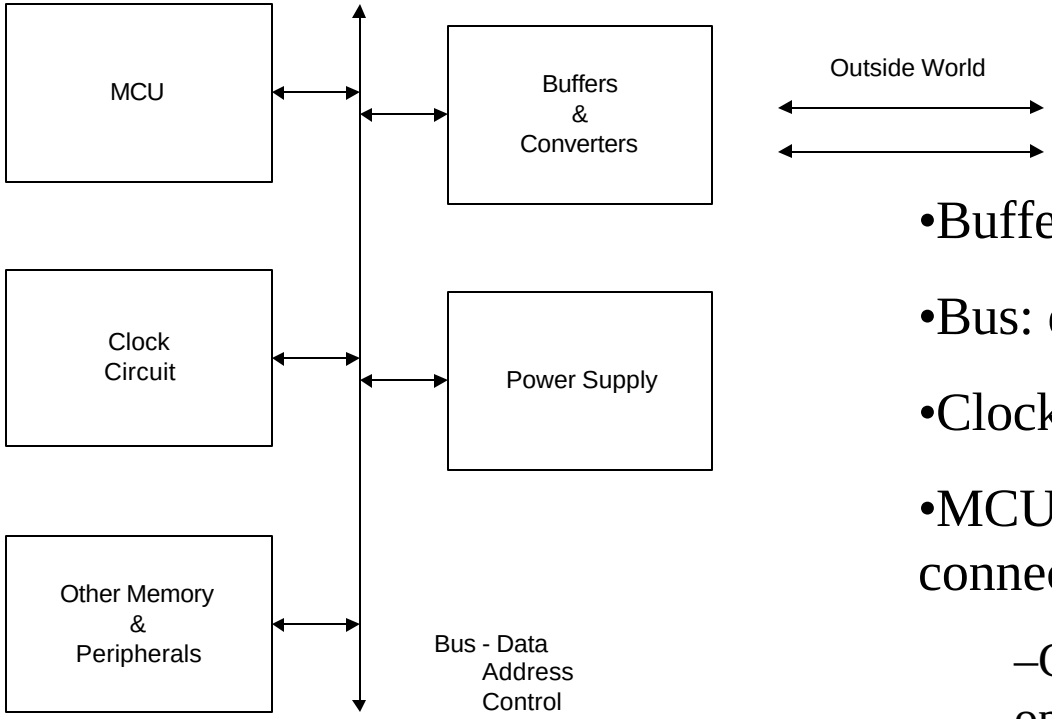
Topics of Discussion

- Microcontrollers
- M68HC11
- Package & Pinouts
- Accumulators
- Index Registers
- Special Registers
- Memory Map
- I/O Registers
- Instruction Set

What is a Microcontroller?

- Computer on a chip:
  - CPU, memory, I/O devices, timing devices
- 68HC11 most widely used
- Used in automobiles, appliances, instruments, industrial controllers
- Control applications vs data processing

Microcontroller Systems



- Buffers: condition I/O to proper levels
- Bus: data, address, control signals
- Clock: Fixed-frequency timing signal
- MCU: CPU, Memory, Registers connected by internal bus
  - –CPU: controls microcontroller operations
  - –Memory: program & data storage
    - ROM, RAM, EEPROM
  - –Registers: temporary storage for data manipulation

Motorola 68HC11 MicroController Unit

The CPU: 68HC11E9

- 8-Bit word size
- 6800 Instruction set w/extensions
- Modes of Operation:
  - Single Chip
  - Expanded
  - Special Boot
  - Test

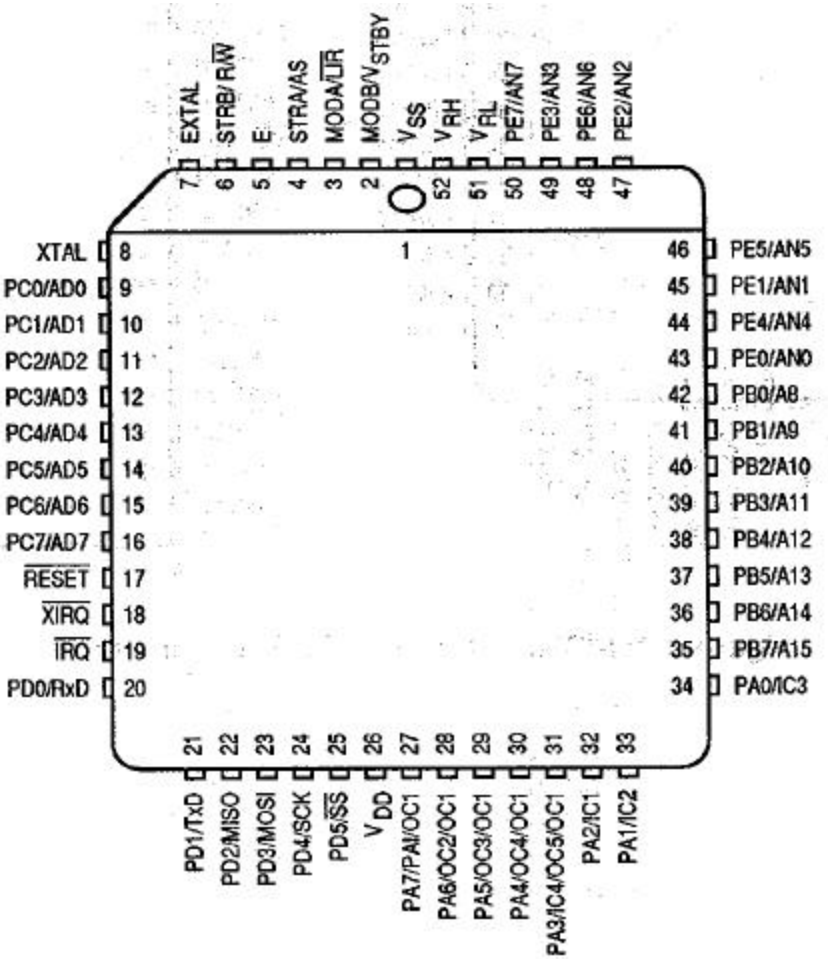
What about memory?

On Chip Memory:

(Refer to Chapter 4 in HC11 Reference Manual)

- 12k EPROM
  - User Program & Data
- 512 of EEPROM
  - Semipermanent data, calibration tables
- 256-512 RAM
  - variables & temp

68HC11E9 Pin Connections



- Ground VSS Pin 1
- E Clock Pin 5
- PORTA Pins 34-27
- PORTB Pins 42-35
- PORTE Pins 43-50

Storage Capabilities

Accumulators

- A, B 8-bit accumulators, location of math and logic functions
- D 16-bit accumulator, actually same physical device as A and B taken together

- **Index Registers**
  - X, Y 16-bit registers, used for indexed addressing (may be used as general storage registers or counters)

Special Registers

P 16-bit program counter, keeps track of address of next instruction to be executed.

S 16-bit stack pointer, used for temporary storage of the program counter (needed for subroutines)

C 8-bit condition code register. Stores several 1-bit flags (status indicators), and interrupt masks

More 68HC11 info

- Input/Output: (Memory mapped)
  - 5 parallel digital I/O ports
  - RS-232 (connect to terminals or PCs)
  - High Speed Synchronous Serial
  - Parallel Handshake (Printer)
- Timer functions
  - Generate precise digital signals
  - Measure frequency and pulse width
  - Count external events
  - Real Time Clock
- 8-channel, 8-bit Analog to Digital Converter

I/O Registers

PORTA	$1000	I-0,1,2 O-3,4,5,6 BI-7
PORTB	$1004	Output Only
PORTC	$1003	BI
DDRC	$1007	Def: 0=I, 1=O
PORTD	$1008	BI
DDRD	$1009	
PORTE	$100A	Input Only

Instruction Set Introduction

Refer to Appendix A of HC11 Reference Manual

Move Instructions

- Load Load value (or contents of memory location) TO Accumulators
- Store Store values FROM Accumulators TO Memory
- Transfer Transfer contents of Accumulators
- Stack Instructions Push and Pull
- Clear Instructions Clear Accumulators

- Arithmetic Instructions
  - Addition, Subtraction, Division
- Logic Instructions
  - AND, OR, NOT
- Shift Instructions
  - Shift Left, Shift Right, Rotate Left Rotate Right
- Control Instructions
  - Branches

Addressing Modes

Immediate Mode

Direct Addressing

(8-Bit) “Page 0 Addressing”

Extended Addressing

(16-Bit)

Indexed Addressing

Use index registers X,Y

Immediate Mode

data immediately follows instruction

Use # before number constant

Example:

LDAA #$64 loads value $64 into AccA

LDAA #100 same as above 100 = $64

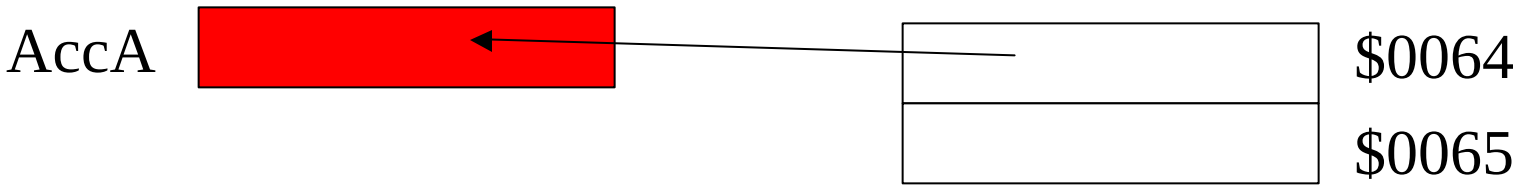
Direct Addressing (8-bit) Mode

8-bit address of data follows instruction

Also called Page 0 Addressing because assumes most significant nibble is 00

Example:

LDAA $64 loads **contents** of memory address $0064 into AccA



Extended Addressing (16-bit) Mode

16-bit address of data follows instruction

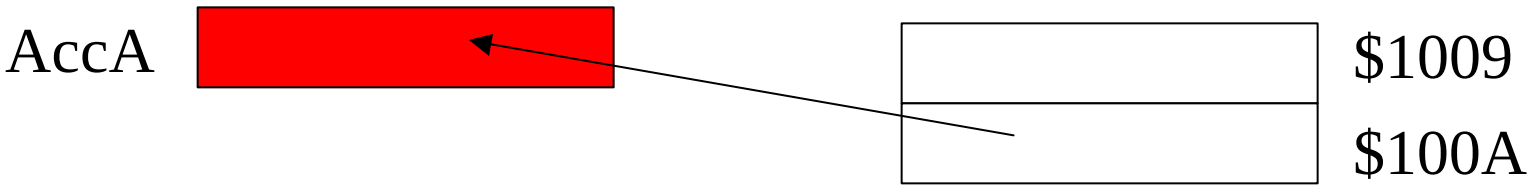
Example:

LDAA $100A loads contents of memory address $100A into AccA

Also:

PORTE EQU $100A

LDAA PORTE same as above

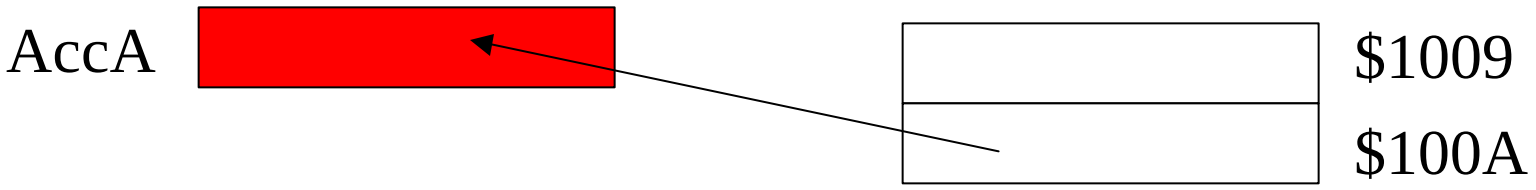


Indexed Addressing Mode

the operand's address is the content of the index register plus the ***constant*** given in the instruction

Example:

LDX #$1000	loads value $1000 into X
LDAA $A,X	loads value at memory location [[$1000] + $0A] into AccA



Programming the 68HC11

- Know your design goals & criteria
- Write code and save as text file with .A11 extension
- Either:

1. Assemble code with AS11.exe

   AS11.EXE *filename.a11* -L CRE >*filename.lst*

   Load .LST file

or

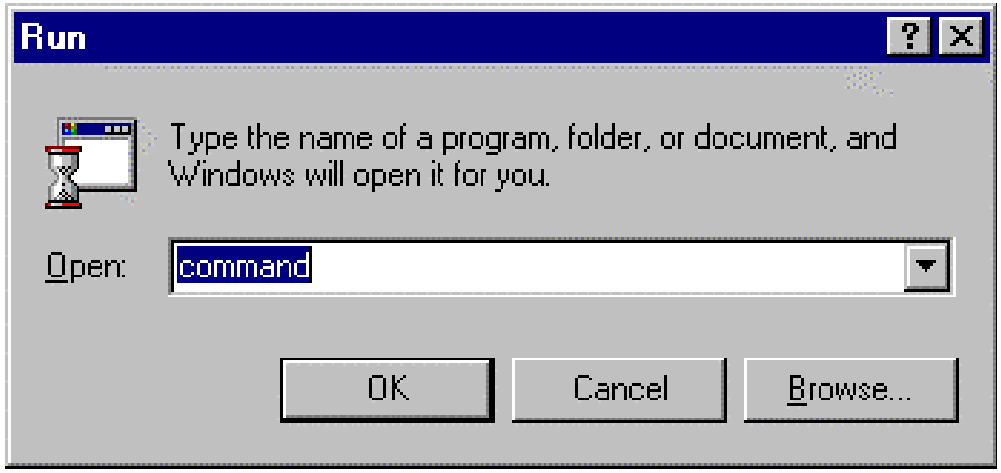
2. Use onboard assembler

Getting Started

First make sure you have a copy of AS11.EXE (from the lecture webpage- see Lecture7)

For easier use put it in the directory where you have your .A11 files (like your floppy disk)

Next run a MS-DOS Command Prompt Window by selecting Start:Run: command.exe



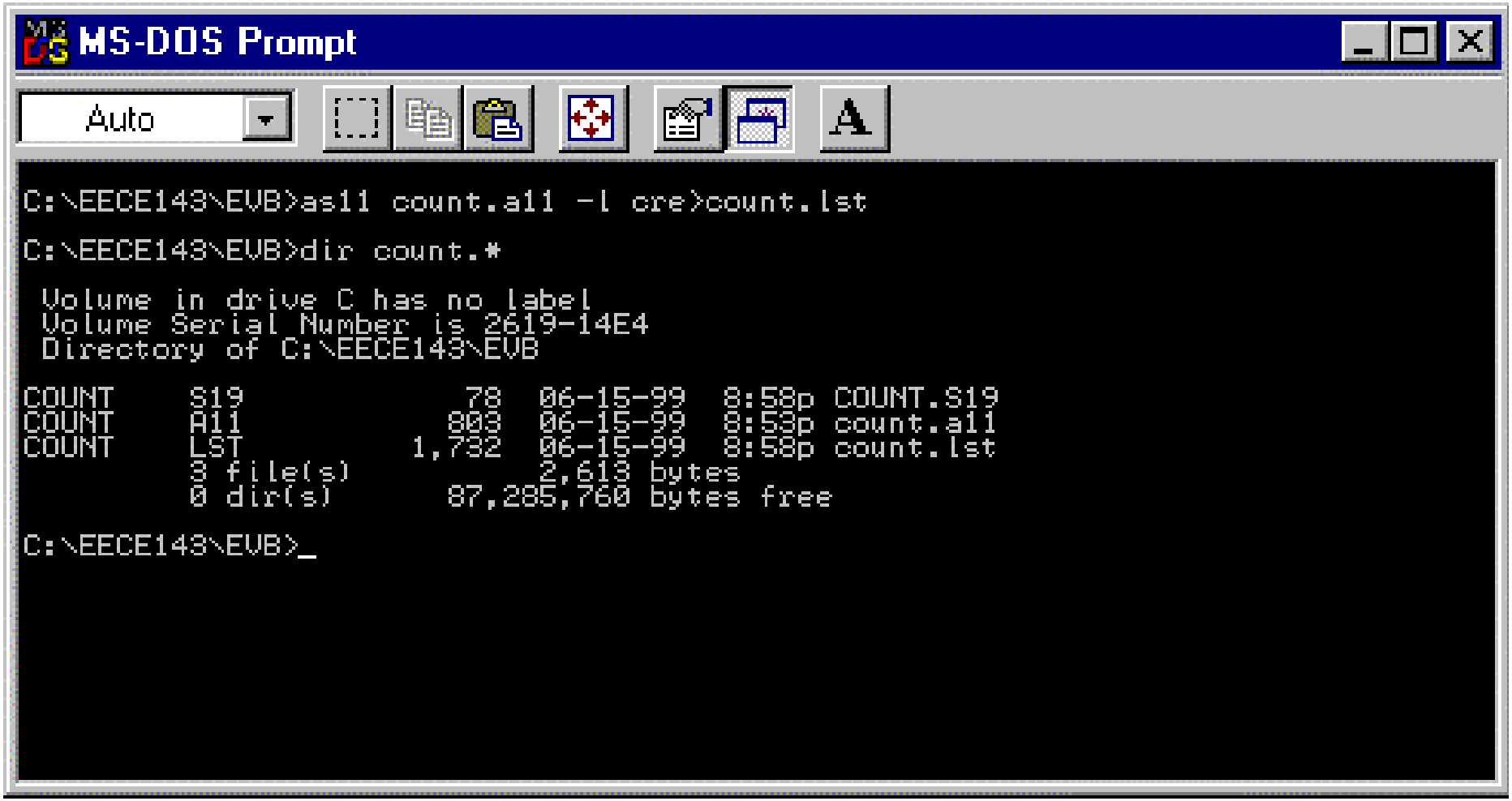
This brings up a command prompt window. Change the working directory to the location of your .A11 files.

Assemble your .A11 file using the command line:

As11.exe *filename*.a11 –L cre>*filename*.lst

This creates a .lst file which you can use for de-bugging. It also creates a .S19 file which is loaded into the HC11.

Open your .LST file in notepad and check for errors. HINT: If your .S19 file is 0 bytes, you probably had errors in your .A11 file.



```
COUNT.A11  Count pulses at an input.
*          Two digit bcd output.
*    Bruce Hoeppner     11/10/92
*    Bounceless input at bit 0 of Port E
*    Output to Port B
PORTB     equ $1004
          org  $C000     ;origin in user RAM
* Initialize
MAIN      clra
          staa PORTB
*  Loop while input = 0
WAIT0     ldab $100a     ;read input
          andb #$01      ;mask off 7 msbs
          bne WAIT0

*  Loop while input = 1
WAIT1     ldab $100a     ;read input
          andb #$01      ;mask off 7 msbs
          beq WAIT1
          adda #$01      ;increment AccA
          daa            ;adjust for bcd
          staa $1004     ;write to Port B
          jmp WAIT0
```

Sample Code A11File

Comments

* * in first column
* ; after commands

Labels in first column

Commands tabbed to right

```
 Assembling count.a11
0001                    * COUNT.A11  Count pulses at an input.
0002                    *          Two digit bcd output.
0003                    *   Bruce Hoeppner     11/10/92
0004
0005                    *   Bounceless input at bit 0 of Port E
0006                    *   Output to Port B
0007 1004                 PORTB     equ $1004
0008
0009 c000                       org  $C000    ;origin in user RAM
0010                    * Initialize
0011 c000 4f              MAIN      clra
0012 c001 b7 10 04                  staa PORTB
0013
0014                    *  Loop while input = 0
0015 c004 f6 10 0a           WAIT0     ldab $100a    ;read input
0016 c007 c4 01                    andb #$01     ;mask off 7 msbs
0017 c009 26 f9                    bne WAIT0
0018
0019                    *  Loop while input = 1
0020 c00b f6 10 0a           WAIT1     ldab $100a    ;read input
0021 c00e c4 01                    andb #$01     ;mask off 7 msbs
0022 c010 27 f9                    beq WAIT1
0023
0024 c012 8b 01                    adda #$01     ;increment AccA
0025 c014 19                       daa           ;adjust for bcd
0026
0027 c015 b7 10 04                   staa $1004    ;write to Port B
0028 c018 7e c0 04                   jmp WAIT0
```

Sample Code LST File

Created after using As11.exe
Useful for finding errors in code

INNOTOUT.A11

```
INNOTOUT.A11  Read word, NOT it, Write it
*    Bruce Hoeppner     01 JAN 94
*
*    Read an 8-bit word from PortE.
*    Complement the word.
*    Write the word to PortB.
*    Loop Continuously.
*    Essentially this turns the HC11 into an
*    Octal Inverter.
```

```
* Definitions
PORTB     equ  $1004
*****************************************
* Load program into 8k user RAM
START     org  $C000

* Read 8-bit word from PortE into AccA
          ldaa $100a
* Complement the word.
          coma
* Write the word to PortB
          staa PORTB

* Jump back to beginning of program
          jmp  START

* End of INNOTOUT.A11
```

```
0001                    * INNOTOUT.A11  Read word, NOT it, Write it
0002                    *    Bruce Hoeppner     01 JAN 94
0003                    *
0004                    *    Read an 8-bit word from PortE.
0005                    *    Complement the word.
0006                    *    Write the word to PortB.
0007                    *    Loop Continuously.
0008                    *    Essentially this turns the HC11 into an
0009                    *    Octal Inverter.
0010
0011                    * Definitions
0012 1004                  PORTB     equ  $1004
0013                    ******************************************
0014                    * Load program into 8k user RAM
0015 c000                  START     org  $C000
0016
0017                    * Read 8-bit word from PortE into AccA
0018 c000 b6 10 0a                    ldaa $100a
0019                    * Complement the word.
0020 c003 43                        coma
0021                    * Write the word to PortB
0022 c004 b7 10 04                    staa PORTB
0023
0024                    * Jump back to beginning of program
0025 c007 7e 00 00                    jmp  START
```

Mult4bit.lst

```
 Assembling mult4bit.a11
0001                 * MULT4BIT.A11  Multiply using repeated addition
0002                 *            P = M x N
0003                 *    Bruce Hoeppner     10/7/89
0004
0005 c000                      org  $C000   ;origin in user RAM
0006
0007 c000 f6 10 0a             ldab $100a   ;load M & N into AccB
0008 c003 17                   tba          ;Copy B to A
0009 c004 c4 0f                andb #$0f    ;Mask off M from N
0010 c006 44                   lsra
0011 c007 44                   lsra
0012 c008 44                   lsra
0013 c009 44                   lsra         ;Move M to 4 LSBs
0014 c00a 84 0f                anda #$0f    ;Mask off N from M
0015 c00c b7 d0 00             staa $d000   ;Store accA in temp
0016 c00f 4f                   clra         ;clear accumulator A
0017
```

Continued on next slide

Mult4bit.lst

```
0018 c010 c1 00      multiply  cmpb #00     ;check for N = 0
0019 c012 2e 03                bgt  addem   ;branch to addem when
0020                *                       ;accB > 0
0021 c014 7e e0 0a             jmp  $e00a   ;when N = 0 you are done
0022                           *                    ;go back to BUFFALO
0023
0024 c017 bb d0 00   addem     adda $d000   ;accA = accA + M
0025 c01a 5a                   decb         ;decrement accB
0026                *                       ;accB = accB - 1
0027                *                       ;N = N - 1
0028
0029 c01b b7 d0 01             staa $d001   ;store result P
0030
0031 c01e 20 f0                bra  multiply
0032
0033 c020                      end          ;end of MULT.A11
```

Bit User Fast Friendly Aid to Logical Operations

- BUFFALO Quick Reference (9-19)
- Numeric Values assumed HEX
- ASM <addr> Onboard assembler

  <CR> Next line of code

  <backspace> abort onboard assembly
- G <addr> Go, execute
- help

More BUFFALO

LOAD T download assembled file

MD <addr> memory display

MM <addr> memory modify

<space> next memory location

<CR> return to BUFFALO

RM register modify

T <n> trace (NOTE: set P before trace)

Using the On-board Assembler

```
0011                * Definitions
0012 1004           PORTB     equ  $1004
0013
0014                * Load program into 8k user RAM
0015 c000           START     org  $C000
0016
0017                * Read 8-bit word from PortE into AccA
0018 c000 b6 10 0a            ldaa $100a
0019                * Complement the word.
0020 c003 43                  coma
0021                * Write the word to PortB
0022 c004 b7 10 04            staa PORTB
0023
0024                * Jump back to beginning of program
0025 c007 7e 00 00            jmp  START
```

```
* Only recognizes HEX
    values


ASM C000 <CR>

ldaa 100a <CR>

coma <CR>

staa #1004 <CR>

jmp C000
```

More Fun and Educational Reading

- HC11 Reference Manual
- BUFFALO Monitor Quick Users Reference
- 68HC11 Instruction Set Introduction
- Sample Programs
- Search Motorola's Website for 68HC11

Experiment #7: 68HC11 Introduction

Purpose:

Learn to use microprocessors and microcontrollers, particularly the Motorola 68HC11.

Learn to program in 68HC11 assembly language.

Become familiar with programming the M68HC11.

Preparation:

Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections in the Class Notes pertaining to Microprocessors.

Prepare data for each experiment section of this lab. Indicate a specific test plan for each experiment.

Edit a text file containing the 68HC11 assembly language program: COUNT.A11.

Download AS11.EXE from the class website. Assembly the program using the AS11.EXE assembler.

```
>AS11 COUNT.A11   -L CRE  >COUNT.LST
```

Check COUNT.LST for errors. Correct any errors, and re-assemble.

Design a two digit (decimal) 7-segment display to connect to HC11-143 PortB connector.

Paste, tape or staple copies of your LST files into your notebook. Reminder: Bring to lab: a printout of COUNT.LST, a floppy disk containing your source file, COUNT.A11, and object code file, COUNT.S19.

Experiment Procedure:

1. *68HC11 Start-Up and Test*

Measure the E clock frequency and duty cycle of the M68HC11EVB

Simple Output:

Use the BUFFALO monitor's Memory Modify (MM) command to change an output port.

Simple Input:

Use the BUFFALO monitor's Memory Display (MD) and/or Memory Modify (MM) commands to change and display the binary value at an input port.

2. On-Board Assembly -- Arithmetic: Multiplication using repeated addition.

Enter program MULT4BIT.A11 into the EVB's memory using the on-board assembler (ASM C000).

Connect PortE pins to logic switches. N is 4 lsbs. M is 4 msbs.

Run the program using the Go (**G C000**) command.

Use the Memory Display (MD) command to display the product at address $D001 (P).

Repeat steps b through d for a several values of M and N.

3. Uploading Programs -- Counter program.

Uploading programs from PC to EVB. (If PC is not available enter COUNT.A11 into the EVB using the on-board assembler.)

Turn off power to the EVB.

Connect PortE, bit 0 to a push-button on the CADET. (A pull-up resistor is needed.)

Connect your two-digit display to PortB of the EVB.

Execute the Count program.