Lecture 2

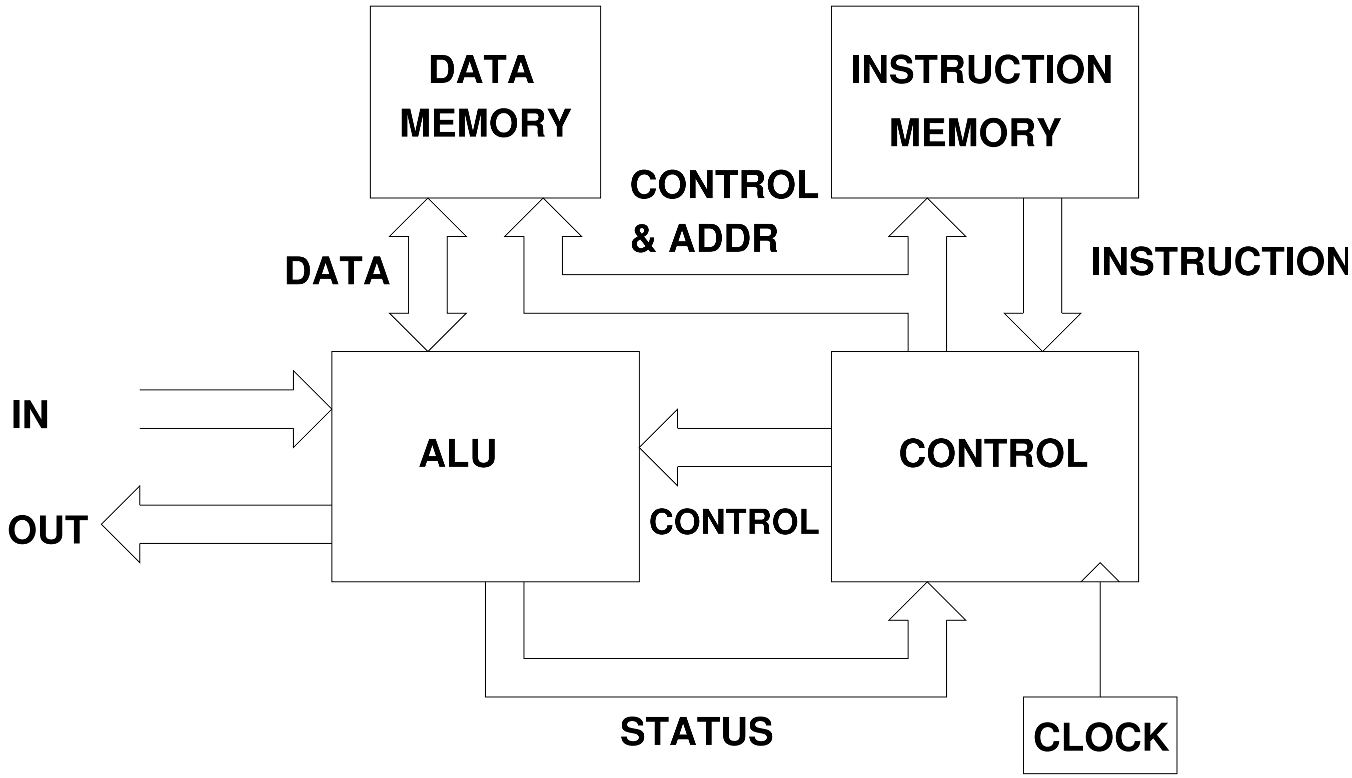
January 20, 2012

Introduction to the MC9S12 Microcontroller

- Harvard and Princeton architectures
- Memory map for a Princeton architecture microcontroller
- MC9S12 Address Space
- MC9S12 ALU
- MC9S12 Programming Model
- Some MC9S12 instructions needed for Lab 1
- A Simple Assembly Language Program
- Assembling an Assembly Language Program using Codewarrior

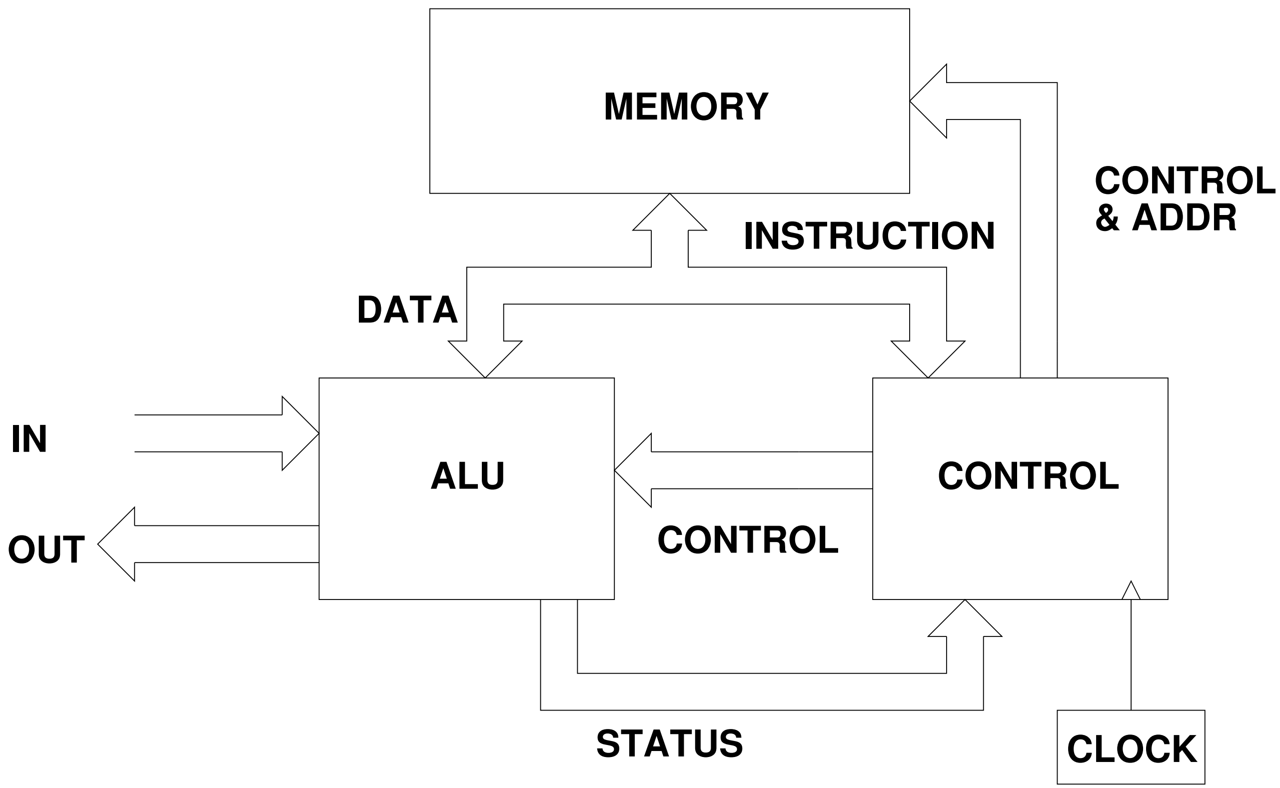
HARVARD ARCHITECTURE

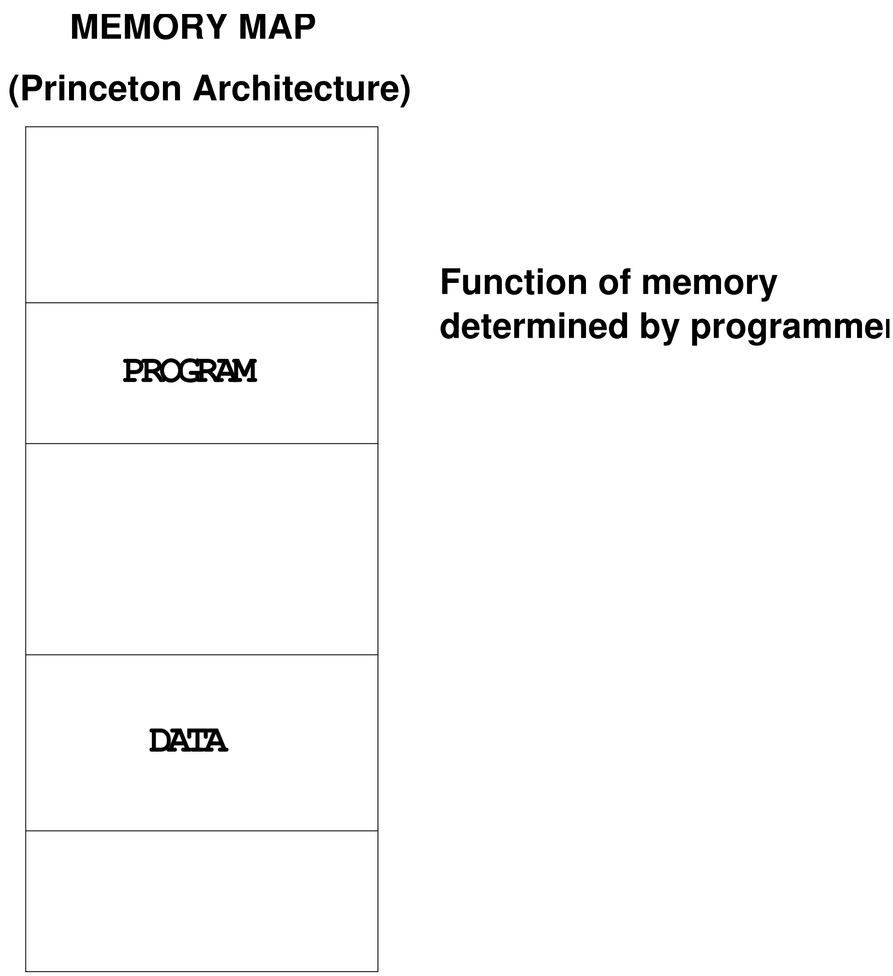
MICROPROCESSOR



PRINCETON (VON NEUMAN) ARCHITECTURE

MICROPROCESSOR

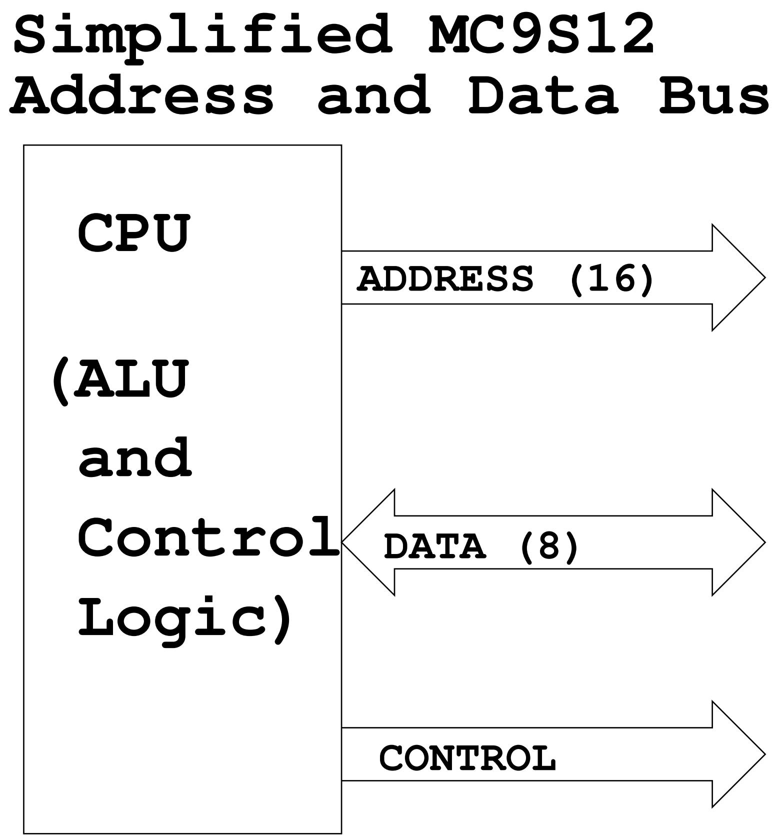




MC9S12 Address Space

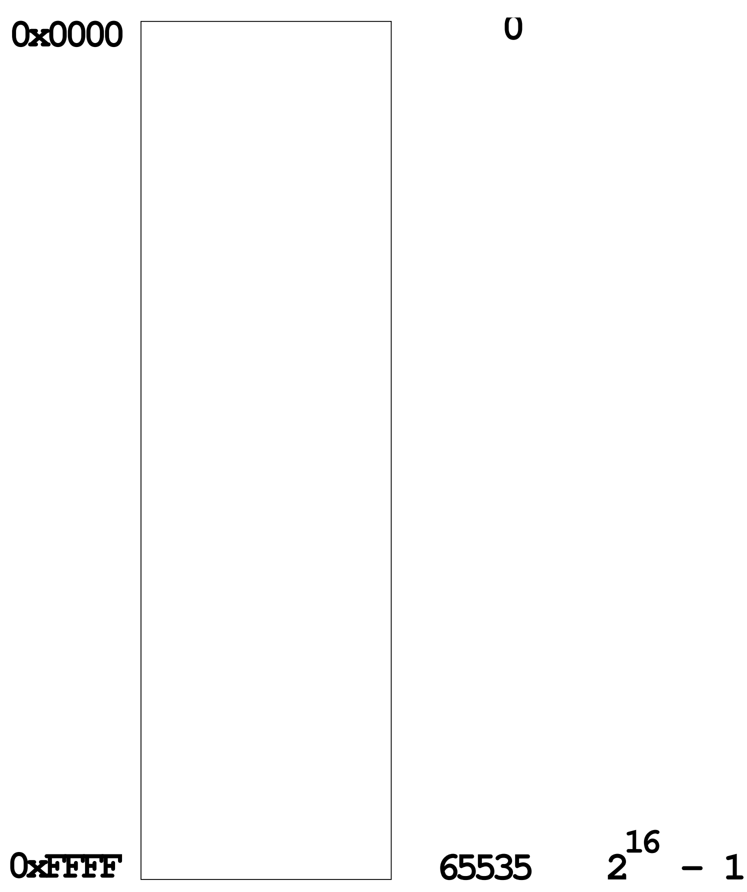
- MC9S12 has 16 address lines
- MC9S12 can address 2^{16} distinct locations
- For MC9S12, each location holds one byte (eight bits)
- MC9S12 can address 2^{16} bytes
- $2^{16} = 65536$
- $2^{16} = 2^6 \times 2^{10} = 64 \times 1024 = 64$ KB
- $(1\text{K} = 2^{10} = 1024)$

- MC9S12 can address 64 KB



MC9S12 Address Space

- Lowest address: $0000000000000000_2 = 0000_{16} = 0_{10}$
- Highest address: $1111111111111111_2 = \text{FFFF}_{16} = 65535_{10}$
- Three ways to represent hexadecimal numbers:
  - FFFF_{16}
  - `0xFFFF`
  - `$FFFF`



MEMORY TYPES

RAM:	Random Access Memory (can read and write)
ROM:	Read Only Memory (programmed at factory)
PROM:	Programmable Read Only Memory (Program once at site)
EPROM:	Erasable Programmable Read Only Memory (Program at site, can erase using UV light and reprogram)
EEPROM:	Electrically Erasable Programmable Read Only Memory (Program and erase using voltage rather than UV light)

MC9S12 has: 12 KB RAM

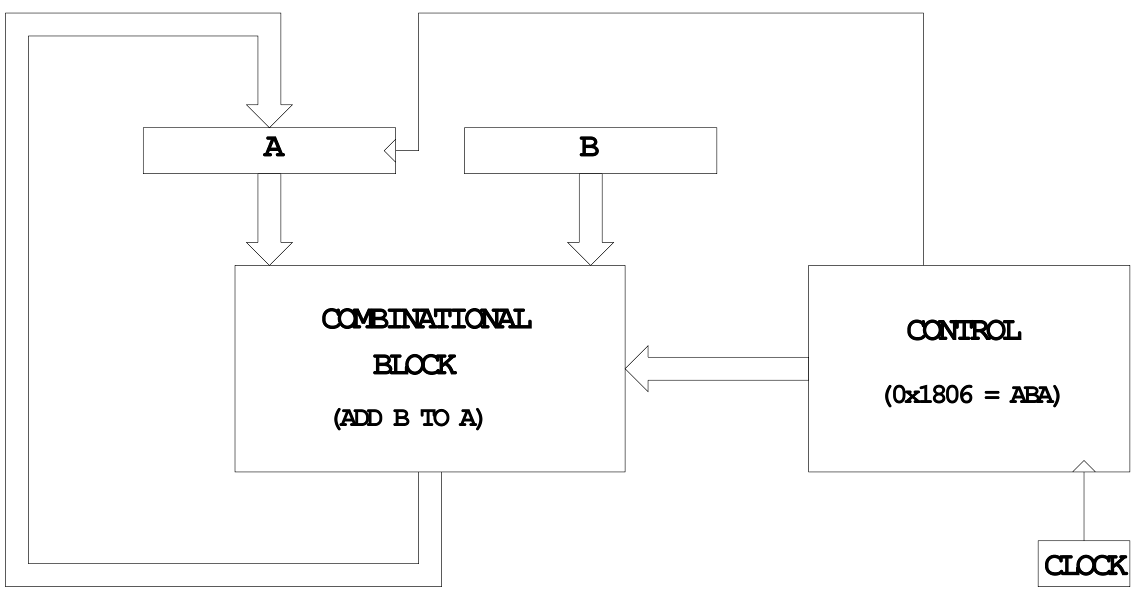
4 KB EEPROM (Normally can only access 3 KB)
256 KB Flash EEPROM (Can access 16 KB at a time)

MC9S12 Address Space

0x0000	0x03FF	Registers (Hardware)	1 K Byte (Covers 1 K Byte of EEPROM)
0x0400	0x0FFF	User EEPROM	3 K Bytes
0x1000	0x3BFF	User RAM	11 K Bytes
0x3C00	0x3FFF	D-Bug 12 RAM	1 K Bytes
0x4000	0x7FFF	Fixed Flash EEPROM	16k Bytes
0x8000	0xBFFF	Banked Flash EEPROM	16k Bytes
0xC000	0xFFFF	Fixed Flash EEPROM (D-Bug 12)	16k Bytes

MC9S12 ALU

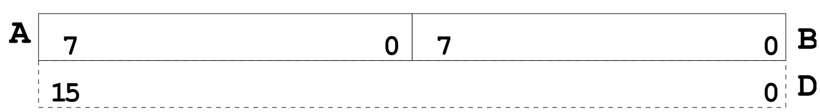
- Arithmetic Logic Unit (ALU) is where instructions are executed.
- Examples of instructions are arithmetic (add, subtract), logical (bitwise AND, bitwise OR), and comparison.
- MC9S12 has two 8-bit registers for executing instructions. These registers are called **A** and **B**.
- For example, the MC9S12 can add the 8-bit number stored in **B** to the eight-bit number stored in **A** using the instruction **ABA** (add B to A):



When the control unit sees the sixteen-bit number `0x1806`, it tells the ALU to add **B** to **A**, and store the result into **A**.

MC9S12 Programming Model

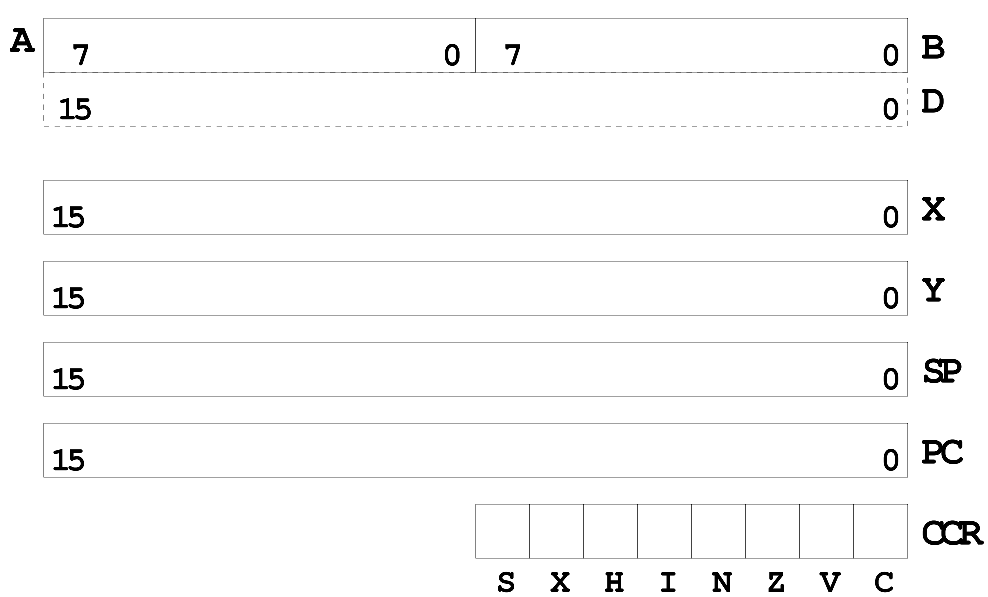
- A Programming Model details the registers in the ALU and control unit which a programmer needs to know about to program a microprocessor.
- Registers **A** and **B** are part of the programming model. Some instructions treat **A** and **B** as a sixteen-bit register called D for such things as adding two sixteen-bit numbers. Note that D is the same as **A** and **B** — if you change **A**, you change the upper eight bits of **D**.



- The MC9S12 can work with 8-bit numbers (bytes) and 16-bit numbers (words).
- The size of word the MC9S12 uses depends on the instruction. For example, the instruction LDAA (Load Accumulator A) puts a byte into **A**, and LDD (Load Double Accumulator) puts a word into **D**.

MC9S12 Programming Model

- The MC9S12 has a sixteen-bit register which tells the control unit which instruction to execute. This is called the Program Counter (**PC**). The number in **PC** is the address of the next instruction the MC9S12 will execute.
- The MC9S12 has an eight-bit register which tells the MC9S12 about the state of the ALU. This register is called the Condition Code Register (CCR). For example, one bit (C) tells the MC9S12 whether the last instruction executed generated a carry. Another bit (Z) tells the MC9S12 whether the result of the last instruction was zero. The N bit tells whether the last instruction executed generated a negative result.
- There are three other 16-bit registers – X, Y, SP – which we will discuss later.



Some MC9S12 Instructions Needed for Lab 1

`LDAA address`	Load the byte contained in memory at `address` into **A**
`STAA address`	Store the byte contained in **A** into memory at `address`
`STAB address`	Store the byte contained in **B** into memory at `address`
`ADDA address`	Add the byte contained in memory at `address` to **A**, save the result in **A**
`CLRB`	Clear **B** (0 `->` **B**)
`INCA`	Increment A Add 1 to **A** ((**A**) + 1 `->` **A**)
`DECB`	Decrement B Subtract 1 from **B** ((**B**) - 1 `->` **B**)
`LSRA`	Shift **A** right by one bit (put 0 into MSB) This divides an unsigned byte by 2
`ASRA`	Shift **A** right by one bit (keep the MSB the same) This divides a signed byte by 2
`SWI`	Software Interrupt (Used to end all our MC9S12 programs)

A Simple MC9S12 Program

- All programs and data must be placed in memory between address `0x1000` and `0x3BFF`. For our programs we will put the first instruction at `0x2000`, and the first data byte at `0x1000`
- Consider the following program:

```
ldaa $1000 ; Put contents of memory at 0x1000 into A
inca       ; Add one to A
staa $1001 ; Store the result into memory at 0x1001
swi        ; End program
```

- If the first instruction is at address `0x2000`, the following bytes in memory will tell the MC9S12 to execute the above program:

Address	Value	Instruction
0x2000	B6	ldaa $1000
0x2001	10	
0x2002	00	
0x2003	42	inca
0x2004	7A	staa $1001
0x2005	10	
0x2006	01	
0x2007	3F	swi

- If the contents of address `0x1000` were `0xA2`, the program would put an `0xA3` into address `0x1001`.

A Simple Assembly Language Program.

- It is difficult for humans to remember the numbers (op codes) for computer instructions. It is also hard for us to keep track of the addresses of numerous data values. Instead we use words called mnemonics to represent instructions, and labels to represent addresses, and let a computer programmer called an assembler to convert our program to binary numbers (machine code).
- Here is an assembly language program to implement the previous program:

```
prog     equ     $2000  ; Start program at 0x2000
data     equ     $1000  ; Data value at 0x1000

         org     prog

         ldaa    input
         inca
         staa    result
         swi

         org     data
input:   dc.b    $A2
result:  ds.b    1
```

- We would put this code into a file and give it a name, such as `main.asm`. (Assembly language programs usually have the extension `.s` or `.asm`.)
- Note that `equ`, `org`, `dc.b` and `ds.b` are not instructions for the MC9S12 but are directives to the assembler which make it possible for us to write assembly language programs. The are called assembler directives or psuedo-ops. For example the psuedo-op `org` tells the assembler that the starting address (origin) of our program should be `0x2000`.

Assembling an Assembly Language Program

- A computer program called an assembler can convert an assembly language program into machine code.
- The assembler we use in class is commercial compiler from Freescale called CodeWarrior
- How to use CodeWarrior is is discussed in Lab 1 and in Huang (Section 3.8).
- The assembler will produce a file called `main.lst`, which shows the machine code generated.

```
Freescale HC12-Assembler
(c) Copyright Freescale 1987-2009

 Abs. Rel.   Loc    Obj. code   Source line
 ---- ----   ------ ---------   -----------
    1    1
    2    2          0000 2000   prog     equ      $2000  ; Start program at 0x2000
    3    3          0000 1000   data     equ      $1000  ; Data value at 0x1000
    4    4
    5    5                               org      prog
    6    6
    7    7  a002000 B610 00              ldaa     input
    8    8  a002003 42                   inca
    9    9  a002004 7A10 01              staa     result
   10   10  a002007 3F                   swi
   11   11
   12   12                               org      data
   13   13  a001000 A2          input:   dc.b     $A2
   14   14  a001001             result:  ds.b     1
```

- This will produce a file called `Project.abs.s19` which we can load into the MC9S12.

```
S06B0000433A5C446F63756D656E747320616E642053657474696E6773
S1051000A20048
S10B2000B61000427A10013F02
S9030000FC
```

- This will produce a file called `Project.abs.s19` which we can load into the MC9S12.

```
S06B0000433A5C446F63756D656E747320616E642053657474696E6773
S1051000A20048
S10B2000B61000427A10013F02
S9030000FC
```

- The first line of the S19 file starts with a S0: the S0 indicates that it is the first line.
  - This first line is just for information; it does not contain code which is loaded into the MC9S12
  - The S0 line generated by CodeWarrior is so long that it confuses the MC9S12 Dbug-12 monitor. You will need to delete this line before loading the S19 file into the MC9S12.
- The last line of the S19 file starts with a S9: the S9 indicates that it is the last line.
- The other lines begin with a S1: the S1 indcates these lines are data to be loaded into the MC9S12 memory.
- Here is the second line (with some spaces added):

```
S1 0B 2000 B6 1000 42 7A 1001 3F 02
```

- On the second line, the `S1` is followed by a `0B`. This tells the loader that there this line has 11 (`0x0B`) bytes of data follow.
- The count `0B` is followed by `2000`. This tells the loader that the data should be put into memory starting with address `0x2000`.

- The next 16 hex numbers `B61000427A10013F` are the 8 bytes to be loaded into memory. You should be able to find these bytes in the `main.lst` file.
- The last two hex numbers, `0x02`, is a one byte checksum, which the loader can use to make sure the data was loaded correctly.

```
Freescale HC12-Assembler
(c) Copyright Freescale 1987-2009

 Abs. Rel.   Loc    Obj. code   Source line
 ---- ----   ------ ---------   -----------
    1    1
    2    2          0000 2000   prog     equu     $2000  ; Start program at 0x2000
    3    3          0000 1000   data     equ      $1000  ; Data value at 0x1000
    4    4
    5    5                               org      prog
    6    6
    7    7  a002000 B610 00              ldaa     input
    8    8  a002003 42                   inca
    9    9  a002004 7A10 01              staa     result
   10   10  a002007 3F                   swi
   11   11
   12   12                               org      data
   13   13  a001000 A2          input:   dc.b     $A2
   14   14  a001001             result:  ds.b     1
```

What will program do?

- `ldaa input` : Load contents of `0x1000` into **A**
  (`0xA2` into **A**)
- `inca` : Increment **A**
  (`0xA2 + 1 = 0xA3 -> A`)
- `staa result` : Store contents of **A** to address `0x1001`
  (`0xA3 -> adress 0x1001`)