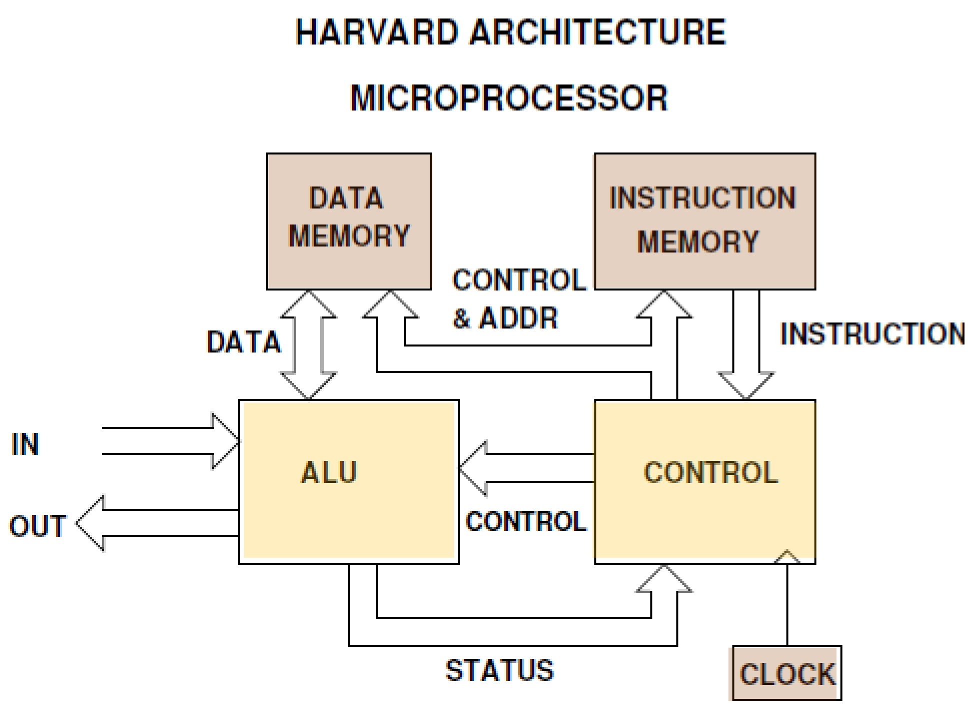
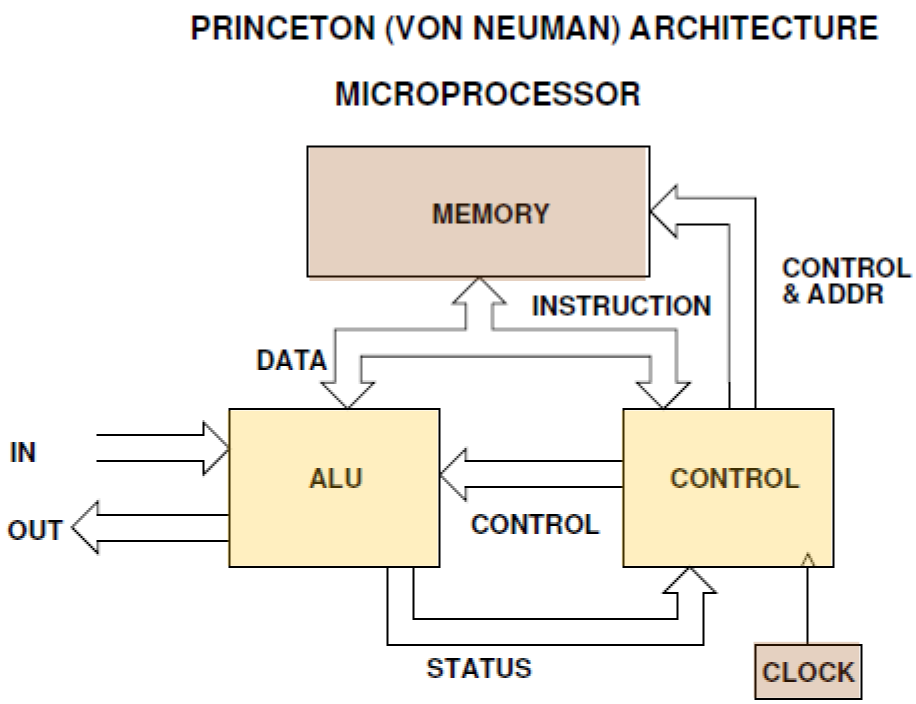
- **Introduction to the 9S12 Microcontroller**
  - Harvard architecture and Princeton architecture
  - Memory map for a Princeton architecture microprocessor
  - 68HC12 Address Space
  - 68HC12 ALU
  - 68HC12 Programming Model
  - Some 9S12 Instructions Needed for Lab 1
  - A Simple Assembly Language Program
  - Assembling an Assembly Language Program




PRINCETON (VON NEUMAN) ARCHITECTURE
MICROPROCESSOR
MEMORY
INSTRUCTION
CONTROL
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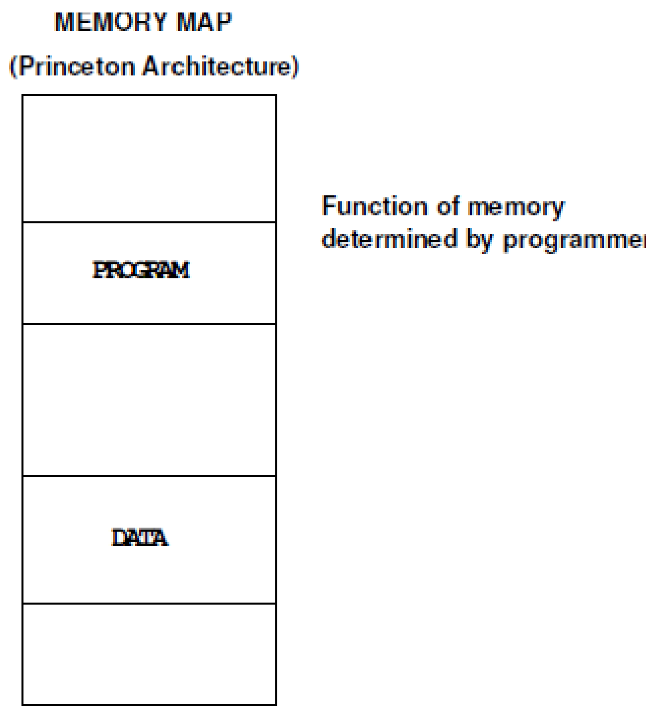
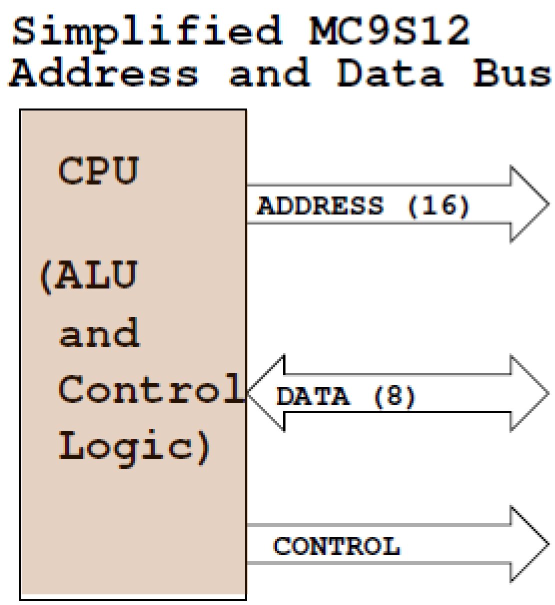


MC9S12 Address Space

- 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
- ($1K = 2^{10} = 1024$)
- MC9S12 can address 64 KB
- Lowest address: $0000000000000000_2 = 0000_{16} = 0_{10}$
- Highest address: $1111111111111111_2 = FFFF_{16} = 65535_{10}$



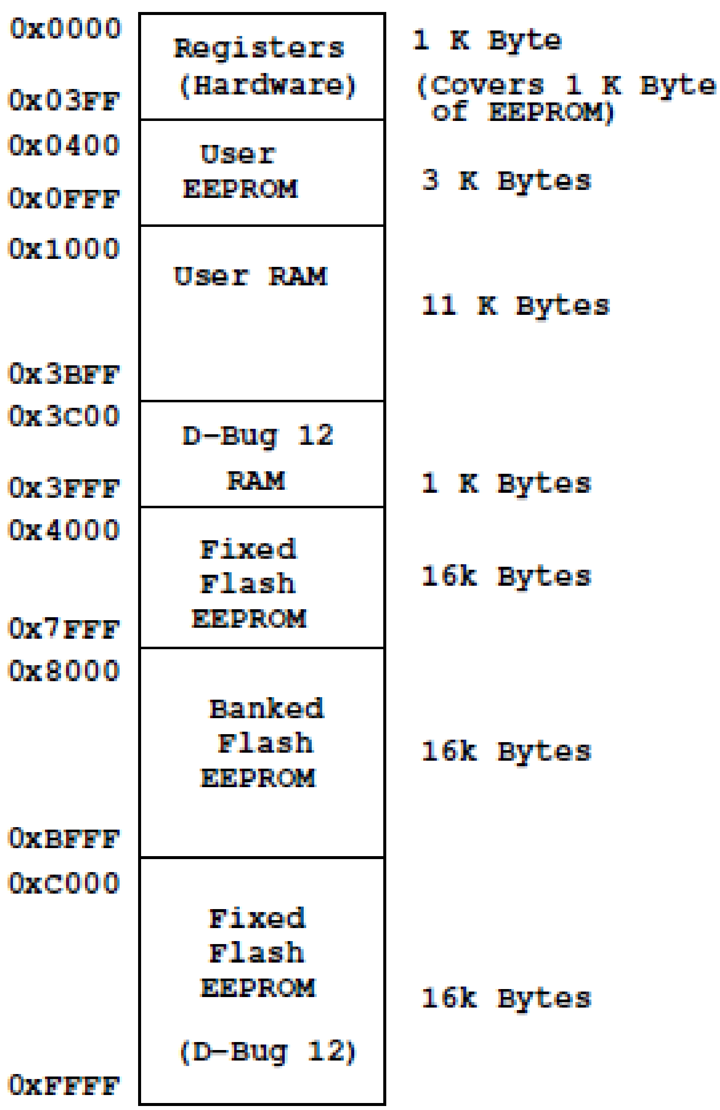
MEMORY TYPES

RAM: Random Access Memory (can read and write)
ROM: Read Only Memory (programmed at factory)
PROM: Programmable Read Only Memory
(Programmed 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



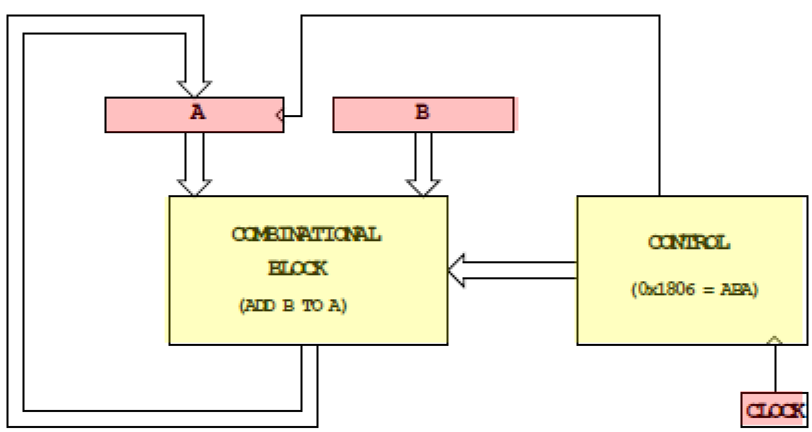
MC9S12 ALU

• 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**):

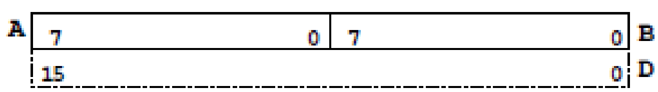


When the control unit sees the sixteen-bit number 0x1806, it tells the ALU to **add B to A**, and **store the result into A**.

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**.



• The MC9S12 can work with 8-bit numbers (bytes) and 16-bit numbers (words).

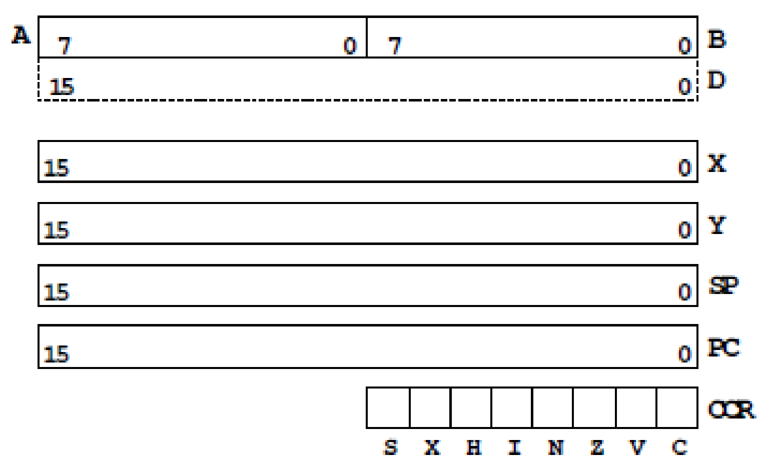
• The size of word the MC9S12 uses depends on the instruction. For example, the instruction **LDAA** (Load Accumulator A) **puts a byte into A**, and **LDD** (Load Double Accumulator) **puts a word into D**.

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 puts the byte contained in memory at **address** into **A**

STAA address puts the byte contained in **A** into memory at **address**

STAB address puts the byte contained in **B** into memory at **address**

ADDA address adds the byte in memory **address** to **A**, and save result in **A**

CLRB clears B ($0 \Rightarrow B$)

INCA adds 1 to A ($(A) + 1 \rightarrow A$)

DECB decrements B by 1 ($(B) - 1 \rightarrow B$)

LSRA shifts A right by one bit (puts 0 into MSB)
This divides an unsigned byte by 2

ASRA shifts A right by one bit (keep 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 short 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 (i.e., increment A by 1)
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 a 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       ; Start of 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**, are not instructions for the MC9S12 but are directives to the assembler which makes it possible for us to write assembly language programs. They are called ***assembler directives*** or ***pseudo-ops***. The pseudo **equ** gives a symbolic name to a numeric constant, **org** tells the assembler what the starting address (origin) of our program should be (e.g., 0x2000), **dc.b,** defines a constant byte, and **ds.b**, defines a storage byte.

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 a commercial compiler from Freescale called CodeWarrior (with Eclipse IDE) .

•How to use CodeWarrior 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.

```
S06B0000433A5C446F63756D656E747320616E642053657474696E67
73
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 it 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** indicates 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 in this line 11 (0x0B) bytes of data follow.

- The count 0B is followed by **2000**. This tells the loader that the data (program) 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.

What will this program do?

```
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
```

- 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)