Exam a week from Monday

Exam Monday February 20

You will be able to use all the Motorola manuals on the exam
No calculators will be allowed for the exam
Numbers

- -Decimal (signed and unsigned)
- -Hex to Decimal (signed and unsigned)
- -Binary to Hex
- -Hex to Binary
- -Addition and subtraction of fixed-length hex numbers
- -Overflow, Carry, Zero, Negative bits of CCR

Programming Model

- -Internal registers – A, B, (D=AB), X, Y, SP, PC, CCR

Addressing Modes and Effective Addresses

- -Inherent (INH), Immediate (IMM), Direct (DIR), Extended (EXT), Relative (REL), IDX (Not Indexed Indirect)
- -How to determine effective address

Instructions

- -What they do – Core Users Guide
- -What machine code is generated
- -How many cycles to execute
- -Effect on CCR
- -Branch instructions – which to use with signed and which with unsigned

Exam a week from Monday

Exam Monday February 20

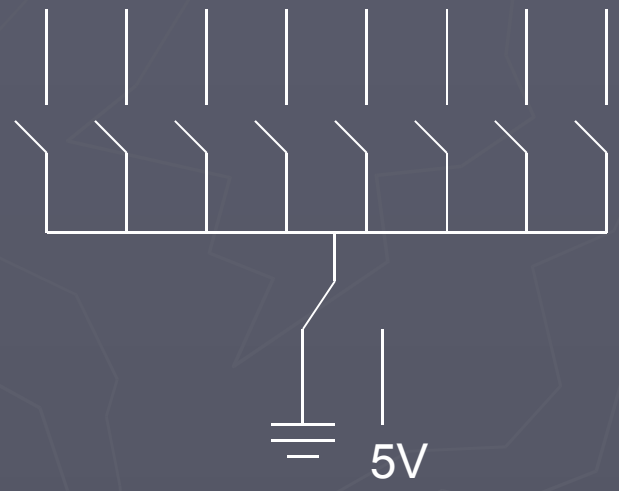
Machine Code
- -Reverse Assembly

Stack and Stack Pointer
- -What happens to stack and SP for instructions (e.g. PSHX, JSR)
- -How the SP is used in getting to and leaving subroutines

Assembly Language
- -Be able to read and write simple assembly language programs
- -Know basic assembler directives – e.g. equ, dc.b, ds.w
- -Flow charts

Using DIP switches to get data into the HC12

DIP switches make or break a connections (usually to ground)

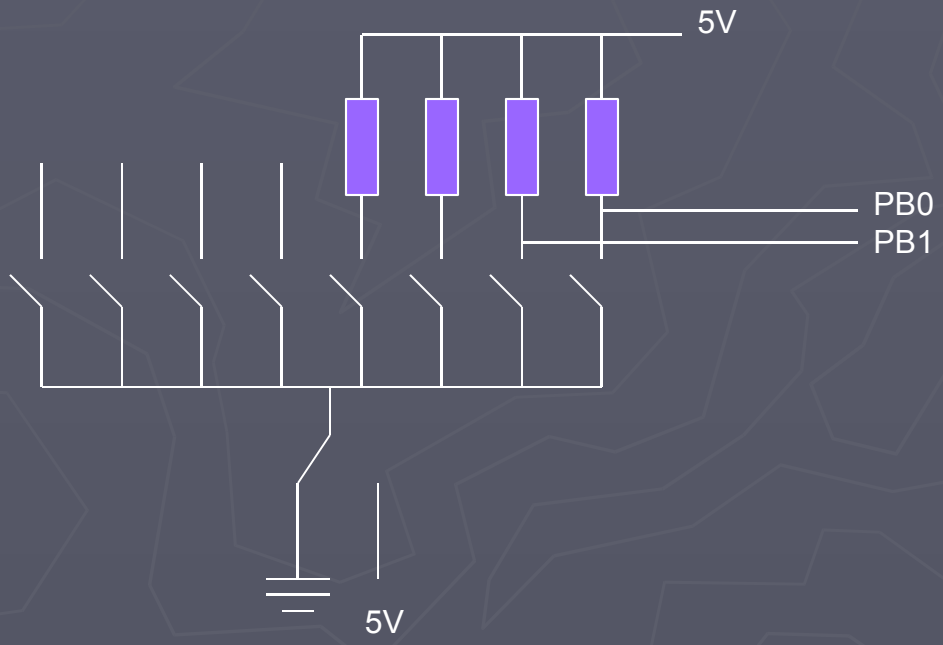


Using DIP switches to get data into the HC12

To use DIP switches, connect one end of each switch to a resistor

Connect the other end of the resistor to +5V

Connect the junction of the DIP switch and the resistor to an input port on the HC12



When the switch is open, the input port sees a logic 1 (+5V)

When the switch is closed, the input sees a logic 0 (0V)

Looking at the state of a few input pins

Want to look for a particular pattern on 4 input pins

-For example want to do something if pattern on PB3-PB0 is 0110

Don't know or care what are on the other 4 pins (PB7-PB4)

Here is the wrong way to do it:

```
ldaa    PORTB
cmpa    #b0110
beq     task
```

If PB7-PB4 are anything other than 0000, you will not execute the task.

You need to mask out the Don't Care bits before checking for the pattern on the bits you are interested in

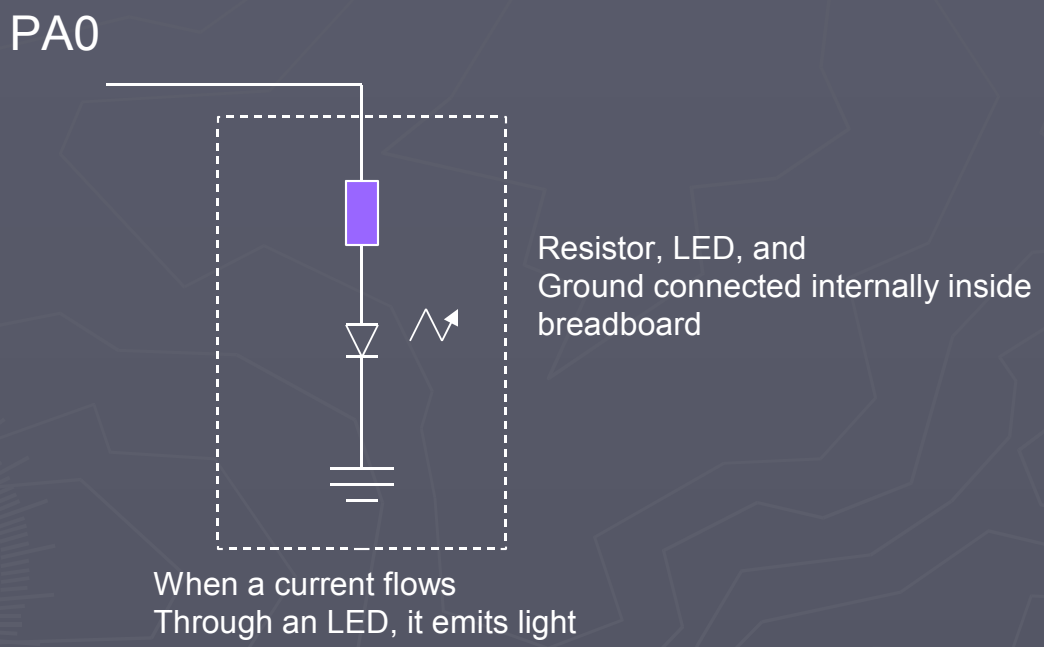
```
ldaa    PORTB
andaa   #b00001111
cmpa    #b00000110
beq     task
```

Now, whatever pattern appears on PB7-4 is ignored

Using an HC12 output port to control an LED

Connect an output port from the HC12 to an LED.

Using an output port to control an LED



Making a pattern on a 7-segement LED

Want to make a particular pattern on a 7-segmen LED.

Determine a number (hex or binary) that will generate each element of the pattern

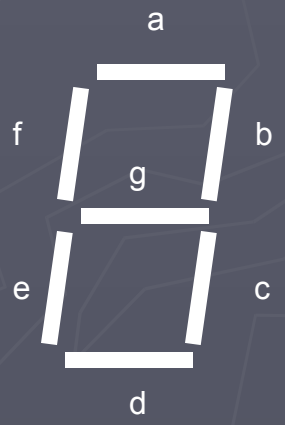
-For example, to display a 0, turn on segments a, b, c, d, e, and f, or bits 0, 1, 2, 3, 4, and 5 of PTH. The binary pattern is 00111111, or $3f

-To display 0, 2, 4, 6, 8, the hex numbers are $3f, $5b, $66, $7d, $7f.

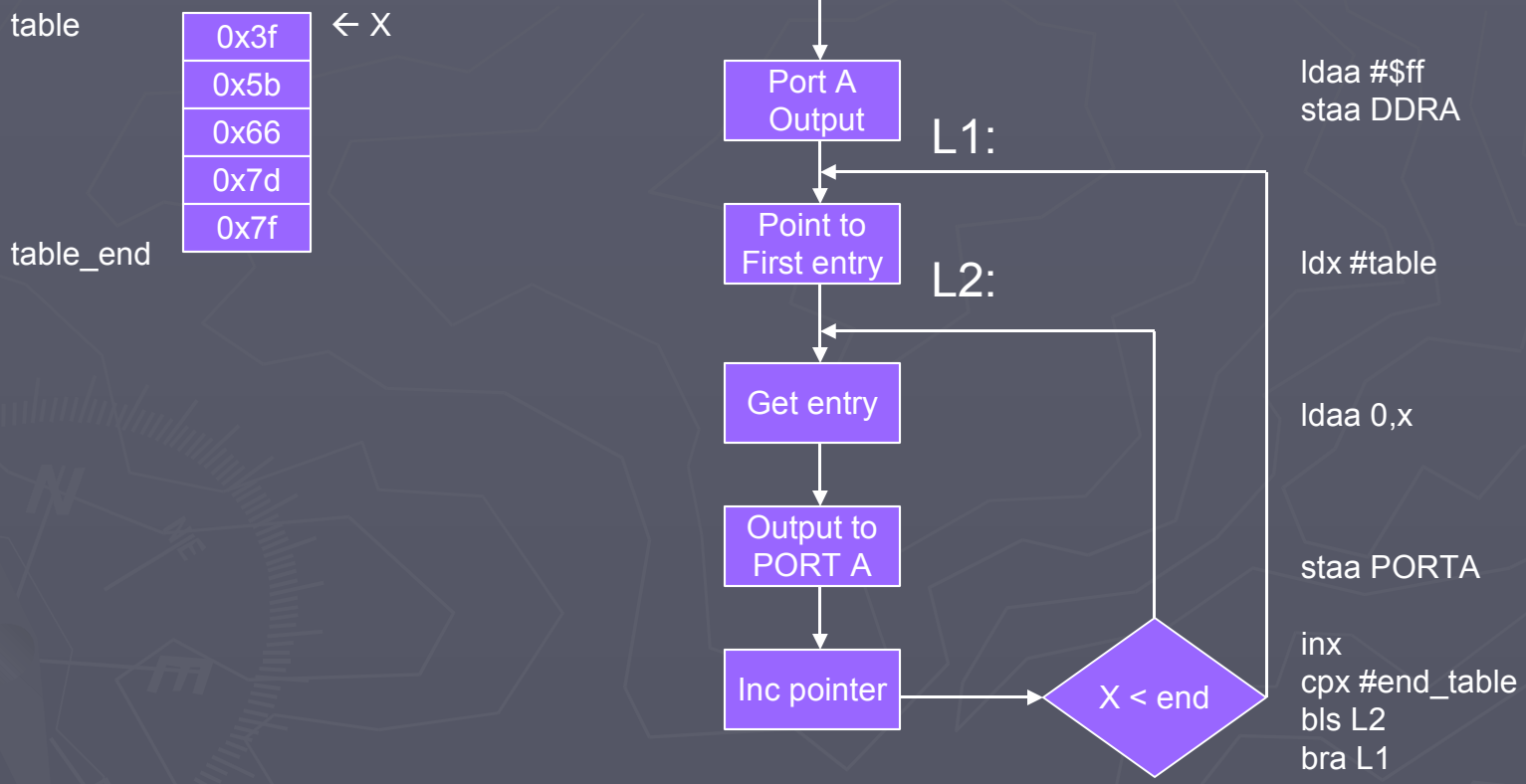
Put the numbers in a table

Go through the table one by one to display the pattern

When you get to the last element repeat the loop



Flow chart to display the patterns on LEDs



Program to display the patterns on LEDs

```
; Program to display patterns

prog:       equ     $1000
data:       equ     $2000
stack:      equ     $3C00
PORTA:      equ     $0000
DDRA:       equ     $0002
            org     prog
            lds     #stack
            ldaa    #$ff
            staa    DDRA
L1:         ldx     #table
L2:         ldaa    1,x+
            staa    PORTA
            jsr     delay
            cpx     #table_end
            bls     L2
            bra     L1

            org     data
table:      dc.b    #3f
            dc.b    $5b
            dc.b    $66
            dc.b    $7d
table_end:  dc.b    $7f
```

Subroutine "delay"

```
; Subroutine to wait for 100 ms

delay:   psha                ; 2 cycles
         pshx                ; 2 cycles
         ldaa    #250        ; 1 cycle
loop2:   ldx     #3200       ; 2 cycles
loop1:   dbne    x,loop1     ; 3 cycles   <-- I.L.
         dbne    a,loop2     ; 3 cycles
         pulx                ; 3 cycles
         pula                ; 3 cycles
         rts                 ; 5 cycles
```

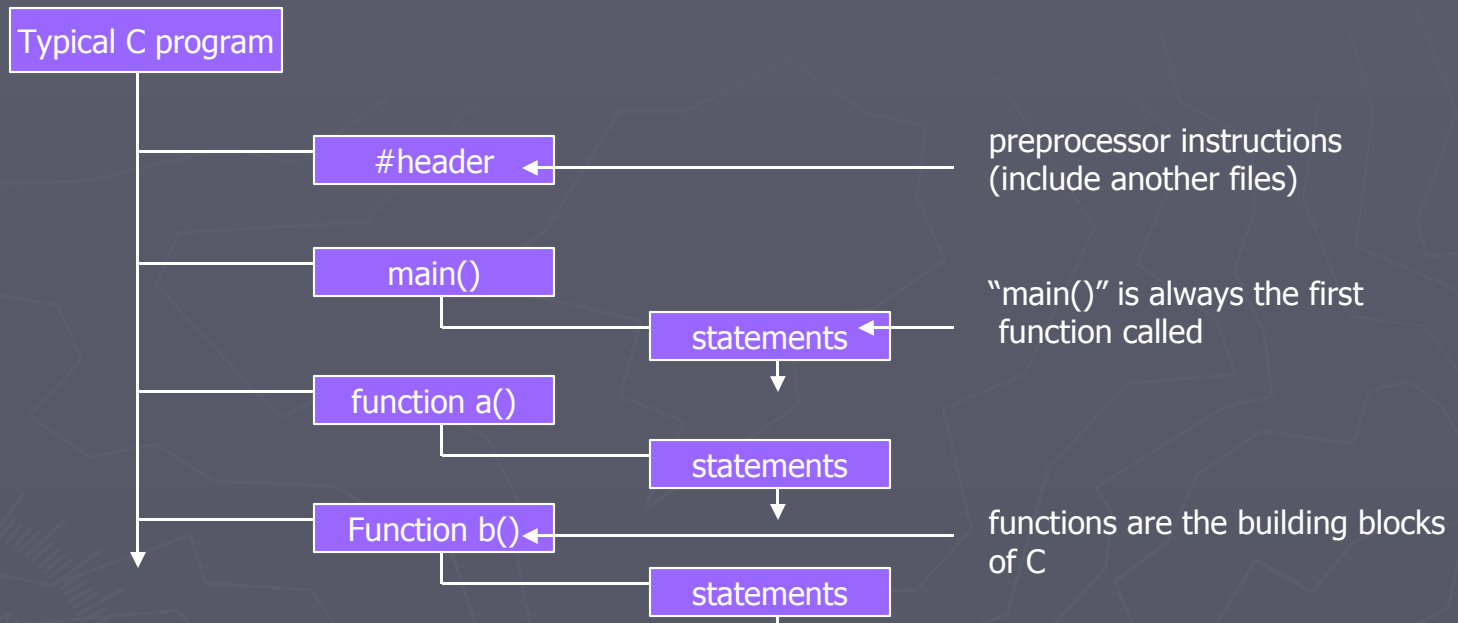
Inner loop takes 3 cycles; is executed 3200 times

Outer loop takes (2+3X+3) cycles; is executed 250 times

Total number of cycles: 2+2+1+250*(2+3*3200+3)+3+3+5 = 2,401,266 cycles

This takes 100 ms with a 24 MHz clock

Programming the HC12 in C



Advantages of C over other languages:

- Natural for the users to use top-down planning.
- Structured programming.
- Modular design.

Programming the HC12 in C

A comparison of some assembly language and C constructs

Assembly			C
; Use a name instead of a num			/* Use a name instead of a num*/
COUNT:	**EQ**	**5**	**#define COUNT 5**
; Start a program			/* To start a program */
	org	**$1000**	**main()**
	lds	**#$3c00**	**{**
			}

Note that in C, the starting location of the program is defined when you compile the program, not in the program itself.

Programming the HC12 in C

Note that C always uses the stack, so C automatically loads the stack pointer for you.

Assembly			C
; Allocate 2 bytes for a signed number			/* Allocate 2 bytes for a signed number*/
	org	**$2000**	**int i;**
i:	**ds.w**	**1**	**int j = 0x1a00;**
j:	**dc.w**	**$1a00**	
; Allocate 2 bytes for an unsigned number			/* Allocate 2 bytes for an unsigned number*/
i:	**ds.w**	**1**	**unsigned int i;**
j:	**dc.w**	**$1a00**	**unsigned int j = 0x1a00;**

Programming the HC12 in C

Assembly

```
; Allocate 1 byte for a signed number
i:      ds.b    1
j:      dc.b    $1f

; Get a value from an address and put of contents
; of address $E000 into variable i
i:      ds.b    1
        ldaa    $E000
        staa    i

*/
```

C

```
/* Allocate 1 byte for a signed number*/
signed char i;
signed char j = 0x1f;

/* Get value form an address and put*/
/* contents of address 0xe000 into i   */
unsigned char i;
i = *(unsigned char *) 0xE000;

/* Use a variable as a pointer
                unsigned char *ptr, i;
ptr = (unsigned char *) 0xE000;
i = *ptr;
*ptr = 0x55
```

In C, the construct *(num) says to treat num as an address, and to work with the contents of that address.

Programming the HC12 in C

Because C does not know how many bytes from that address you want to work with, you need to tell C how many bytes you want to work with. You also have to tell C whether you want to treat the data as signed or unsigned.

- i = *(unsigned char *) 0xE000; tells C to take one byte from address 0xE000, treat it as unsigned, and store that value in variable i.
- j = *(int *) 0xE000; tells C to take 2 bytes from address 0xE000, treat it as signed, and store that value in variable j.
- *(char *) 0xE000 = 0xaa; tells C to write the number 0xaa to a single byte at address 0xE000.
- *(int *) 0xE000 = 0xaa; tells C to write the number 0x00aa to 2 bytes starting at address 0xE000.

Programming the HC12 in C

Assembly		C
; To call a subroutine		/* To call a function */
ldaa	**i**	
jsr	**sqrt**	**sqrt(i);**
; To return from a subroutine		/* To return from a function */
ldaa	**j**	**return j;**
rts		
; Flow control		/* Flow control */
blo		**if (i < j)**
blt		**if (i < j)**
bhs		**if (i >= j)**
bge		**if (i >= j)**

Programming the HC12 in C

Assembly **C**

Here is a simple program written in C and assembly. It simply divides 16 by 2. It does the division in a function.

```
                org     $2000                   signed char i;
i:              ds.b    1
                                                signed char div (signed char j);
                org     $1000                   main()
                lds     #$3c00                  {
                ldaa    #16                             i=div(16);
                jsr     div                     }
                staa    i
                swi

div:            asra                            signed char div (signed char j)
                rts                             {
                                                        return j >> 1;
                                                }
```

A simple program in C and how to compile it

Here is a simple C program

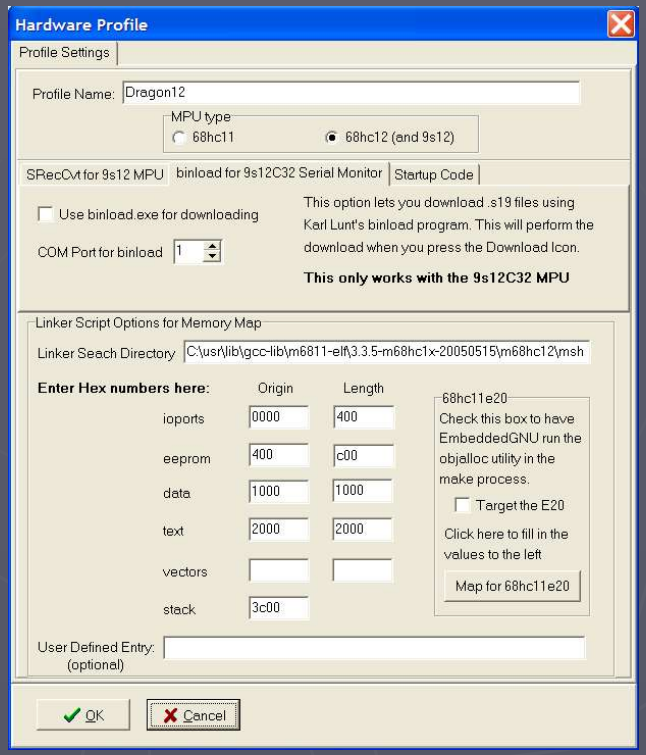
```
#define COUNT 5
unsigned int i;
main()
{
        i = COUNT;
}
```

Details of compiling of a program are discussed in detail in the text in Section 5.10. Here is an outline of the details:

1. Open the Embedded GNU (EGNU) IDE. From the **File** -> **New Source File** option. Type in your C program. Then from the **File** -> **Save unit** save your file in an appropriate directory.
3. From the **File** menu, select the **New Project** option. Give the project an appropriate name and an appropriate directory. (Note: the project base name must be different form the C file names.) When the **Project Options** popup dialog appears, click the down arrow below **Hardware Profile**, and select Dragon12. Click the **Edit Profile** button, and make sure the following are set:

    ioports from 0000, length 400
    eeprom from 400, length c00
    data from 1000, length 1000
    text from 2000, length 2000
    stack at 3c00

A simple program in C and how to compile it



Then click **OK** button

4. From the **Project** menu, select the **Add to project** option, and in the pop-up dialog box, select the C file you entered in Step 2.
5. From the **Build** menu, select the **Make** option. Under the **Compiler** window at the bottom of the screen, you will hopefully see the message No errors or warnings. If not, you will need to fix the errors.
6. If all went well, you should be able to download the compiled file into the 9S12.

A simple program in C and how to compile it

4. From the **Project** menu, select the **Add to project** option, and in the pop-up dialog box, select the C file you entered in Step 2.
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6. If all went well, you should be able to download the compiled file into the 9S12.

A simple program in C and how to compile it

If the name of the project is Project.prj, the compiler will generate a file Project.dmp. Here is some of the output from The Project1.dmp. There are a couple of things you should note about this output:

The first thing the C program does is load the stack pointer.
The main() function is the assembly language for the C program you entered.

```
00002000 <_start>:
   2000:  cf 3c 00          lds     #3c00 <_stack>
   2003:  16 20 38          jsr     2038 <__premain>

00002006 <__map_data_section>:
   2006:  ce 20 42          ldx     #2042 <__data_image>
   2009:  cd 10 00          ldy     #1000 <__data_section_start>
   200c:  cc 00 00          ldd     #0 <__data_section_size>
   200f:  27 07             beq     2018 <__init_bss_section>

00002011 <Loop>:
   2011:  18 0a 30 70       movb    1,X+, 1,Y+
   2015:  04 34 f9          dbne    D,2011 <Loop>

00002018 <__init_bss_section>:
   2018:  cc 00 02          ldd     #2 <__bss_size>
   201b:  27 08             beq     2025 <Done>
   201d:  ce 10 00          ldx     #1000 <__data_section_start>
```

A simple program in C and how to compile it

```
00002020 <Loop>:
   2020:   69 30           clr     1,X+
   2022:   04 34 fb        dbne    D,2020 <Loop>

00002025 <Done>:
   2025:   16 20 31        jsr     2031 <main>

00002028 <fatal>:
   2028:   16 20 3c        jsr     203c <_exit>
   202b:   20 fb           bra     2028 <fatal>
   202d:   20 06           bra     2035 <main+0x4>
   202f:   20 18           bra     2049 <__data_image+0x7>

00002031 <main>:
   2031:   18 03 00 05     movw    #5 <__bss_size+0x3>, 1000 <__data_section_start>
   2035:   10 00
   2037:   3d              rts
```

A simple program in C and how to compile it

```
00002038 <__premain>:
    2038:   87                  clra
    2039:   b7 02               tap
    203b:   3d                  rts

0000203c <_exit>:
    203c:   10 ef               cli
    203e:   3e                  wai
    203f:   20 fb               bra             203c <_exit>

00002041 <_etext>:
    2041:   a7                  nop
```

Pointers in C

To access a memory locations:

***address**

You need to tell compiler whether you want to access 8-bit or 16-bit number, signed or unsigned:

***(type *)address**
-To read from an eight-bit unsigned number at memory location 0x2000:
x = *(unsigned char *)0x2000;
-To write an 0xaa55 to a sixteen-bit signed number at memory locations 0x2010 and 0x2011:
***(signed int *)0x2010 = 0xaa55;**

If there is an address which is used a lot:

```
#define PORTA (* (unsigned char *) 0x0000)
x = PORTA;              /* Read from address 0x0000    */
PORTA = 0x55;           /* Write to address 0x0000     */
```

To access consecutive locations in memory, use a variable as a pointer:

```
unsigned char *ptr;
*ptr = 0xaa;            /* Put 0xaa into address       */
ptr = ptr+2;            /* Point two further into table */
x = *ptr;               /* Read form address 0x2002    */
```

Pointers in C

To set aside ten locations for a table:

unsigned char table[10];

Can access the third element in the table as:

table[2];

or as

***(table+2)**

To set up a table of constant data:

const unsigned char table[]={0x00,0x01,0x03,0x07,0x0f};

This will the tell the compiler to place the table of constants data with the program (which might be placed in EEPROM) instead of with regular data (which must be placed in RAM).

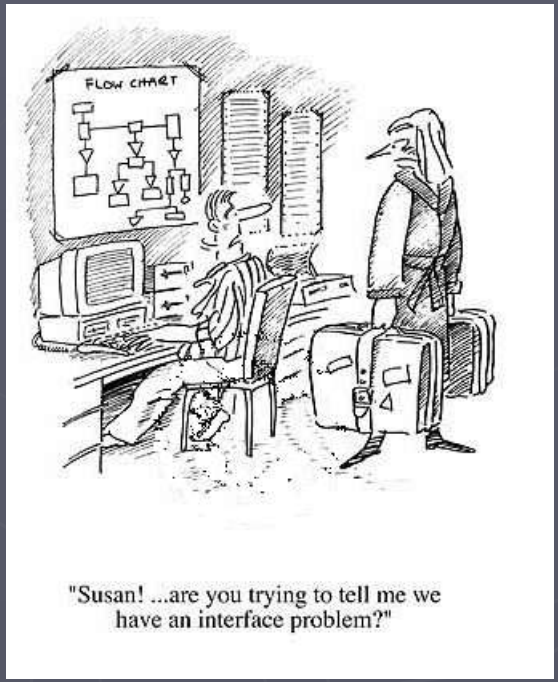
Ponters in C

There are a lot of registers (such as PORTA and DDRA) which you will use when programming in C. Rather than having. To define the registers each time you use them, you can include a header file for the HC12 which has the registers predefined. Here is the beginning of the header file iodp256.h. You can find the complete file on the EE 308 homepage. Here are a few entries from the header file:

```
/* IO DEFINITIONS FOR MCS912DP256
 * Copyright (c) 2000 by COSMIC Software */
 #ifndef _BASE
 #define _BASE 0
 #endif
 #define _IO(x) @(_BASE)+(x)
 #if _BASE == 0
 #define _PORT @dir
 #else #define _PORT
 #endif
 #define uint unsigned int

 /* MEBI Module */
 _PORT volatile char PORTA _IO(0x00); /* port A */
 _PORT volatile char PORTB _IO(0x01); /* port B */
 _PORT volatile char DDRA _IO(0x02); /* data direction port A */
 _PORT volatile char DDRB _IO(0x03); /* data direction port B */
```

“Interface problems”



"Susan! ...are you trying to tell me we have an interface problem?"