Pointers in C

- To access a memory location:

  ```
  *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 alot:

  ```
  #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 = (unsigned char *)0x2000;
  *ptr = 0xaa;          /* Put 0xaa into address 0x2000 */
  ptr = ptr+2;          /* Point two further into table */
  x = *ptr;             /* Read from address 0x2002     */
  ```

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

- 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 wihch has the registers predefined. The CD in the textbook has such a header file, called hcs12.h. You can find the complete file on the EE 308 homepage. Here are a few entries from that file:

```
#define     IOREGS_BASE  0x0000

#define     _IO8(off)    *(unsigned char  volatile *)(IOREGS_BASE + of
#define     _IO16(off)   *(unsigned short volatile *)(IOREGS_BASE + of

#define     PORTA        _IO8(0x00)     //port a = address lines a8 -
#define     PORTB        _IO8(0x01)     //port b = address lines a0 -
#define     DDRA         _IO8(0x02)     //port a direction register
#define     DDRB         _IO8(0x03)     //port b direction register
```

Here is a program which uses hcs12.h to write a 0x55 to PORTA:

```
#include "hcs12.h"

main()
{
    DDRA = 0xff;     // Make PORTA output
    PORTA = 0x55;    // write a 0x55 to PORTA
    asm(" swi");
}
```

Some C basics

- Every C program has a function main()
  - The simplest C program is:

    ```
    main()
    {
    }
    ```

  - Our compiler ends a program by executing an infinite loop – the program never returns to DBug-12. In order to return to DBug-12, include the `swi` assembly language instruction. Here is how to do that:

    ```
    main()
    {
        asm(" swi");
    }
    ```

- Every statement ends with a semicolon

  ```
  x = a+b;
  ```

- Comment starts with `/*` ends with `*/`

  ```
  /* This is a comment */
  ```

- Simple program – increment Port A

  ```
  #include "hcs12.h"

  main()
  {
      DDRA  = 0xff;  /* Make PORTA output */
      PORTA = 0;     /* Start at 0 */
      while(1)       /* Repeat forever */
      {
          PORTA = PORTA + 1;
      }
  }
  ```

- Data Types:

8-bit	16-bit
unsigned char	unsigned int
signed char	signed int

- Need to declare variable before using it:

  ```
  signed char c;
  unsigned int i;
  ```

- Can initialize variable when you define it:

  ```
  signed char c = 0xaa;
  signed int i = 1000;
  ```

  - You tell compiler it you are using signed or unsiged numbers; the compiler will figure out whether to use BGT or BHI

- Arrays:

  ```
  unsigned char table[10];  /* Set aside 10 bytes for table */
  ```

  - Can refer to elements `table[0]` through `table[9]`
  - Can initialize an array when you define it:

    ```
    unsigned char table[] = {0xaa, 0x55, 0xa5, 0x5a};
    ```

- Arithmetic operators:

  ```
  +  (add)          x = a+b;
  -  (subtract)     x = a-b;
  *  (multiply)     x = a*b;
  /  (divide)       x = a/b;
  %  (modulo)       x = a%b;  (Remainder on divide)
  ```

- Logical operators

  ```
  &  (bitwise AND)              y = x & 0xaa;
  |  (bitwise OR)               y = x | 0xaa;
  ^  (bitwise XOR)              y = x ^ 0xaa;
  << (shift left)               y = x << 1;
  >> (shift right)              y = x >> 2;
  ~  (1's complement)           y = ~x;
  -  (2's complement - negate)  y = -x;
  ```

Check for equality - use `==`

```
if (x == 5)
```

Check if two conditions true:

```
if ((x==5) && (y==10))
```

Check if either of two conditions true:

```
if ((x==5) || (y==10))
```

- Assign a name to a number

```
#define COUNT 5
```

- Include a header file (such as `hcs12.h`):

```
#include "hcs12.h"
```

- Declare a function: Tell what parameters it uses, what type of number it returns:

```
int read_port(int port);
```

- If a function doesn't return a number, declare it to be type void

```
void delay(int num);
```

Hello, World!

- Here is the standard ”hello, world” program:

```
#include <stdio.h>
main()
{
    printf("hello, world\r\n");
}
```

- To write the ”hello, world” program, you need to use the `printf()` function.
- The `printf()` function is normally a library function
- Our compiler does not have a library which includes the `printf()` function.
- DBug-12 has a built-in printf, which you can access in the following way:

```
#include "DBug12.h"
main()
{
    DB12FNP->printf("hello, world\r\n");
    asm(" swi");
}
```

- The above program is about 40 bytes long.
- Note that the DBug-12 `printf()` does not work for floating point numbers.
- You can access a few other standard C functions through DBug-12. Look at the DBug12.h include file (on the EE 308 web page) to see which ones.

Setting and Clearing Bits using Assembly and C

- To put a specific number into a memory location or register (e.g., to put 0x55 into PORTA):
  - In assembly:

    ```
    ldaa    #$55
    staa    PORTA
    ```

  - In C:

    ```
    PORTA = 0x55;
    ```

- To set a particular bit of a register (e.g., set Bit 4 of PORTA) while leaving the other bits unchanged:
  - In assembly, use the `bset` instruction with a mask which has 1's in the bits you want to set:

    ```
    bset    PORTA,#$10
    ```

  - In C, do a bitwise OR of the register with a mask which has 1's in the bits you want to set:

    ```
    PORTA = PORTA | 0x10;
    ```

- To clear a particular bit of a register (e.g., clear Bits 0 and 5 of PORTA) while leaving the other bits unchanged:
  - In assembly, use the `blcr` instruction with a mask that has 1's in the bits you want to clear:

    ```
    bclr    PORTA,#$21
    ```

  - In C, do a bitwise AND of the register with a mask that has 0's in the bits you want to clear:

    ```
    PORTA = PORTA & 0xDE;
    ```

    or

    ```
    PORTA = PORTA & ~0x21;
    ```

Waiting for a bit to be set or cleared in Assembly and C

- You often have to wait for an event to occur before taking some action.
- For example, wait for the wash cycle to finish before starting the rinse cycle.
- Usually, when an event occurs, a bit is either set or cleared.
- Here is how to wait until Bit 3 of PORTB is set:
  - In assembly:

    ```
    l1:     brclr     PORTB,#$08,l1
    ```

  - In C:

    ```
    while ((PORTB & 0x08) == 0) ;
    ```

- Here is how to wait until Bit 3 of PORTB is cleared:
  - In assembly:

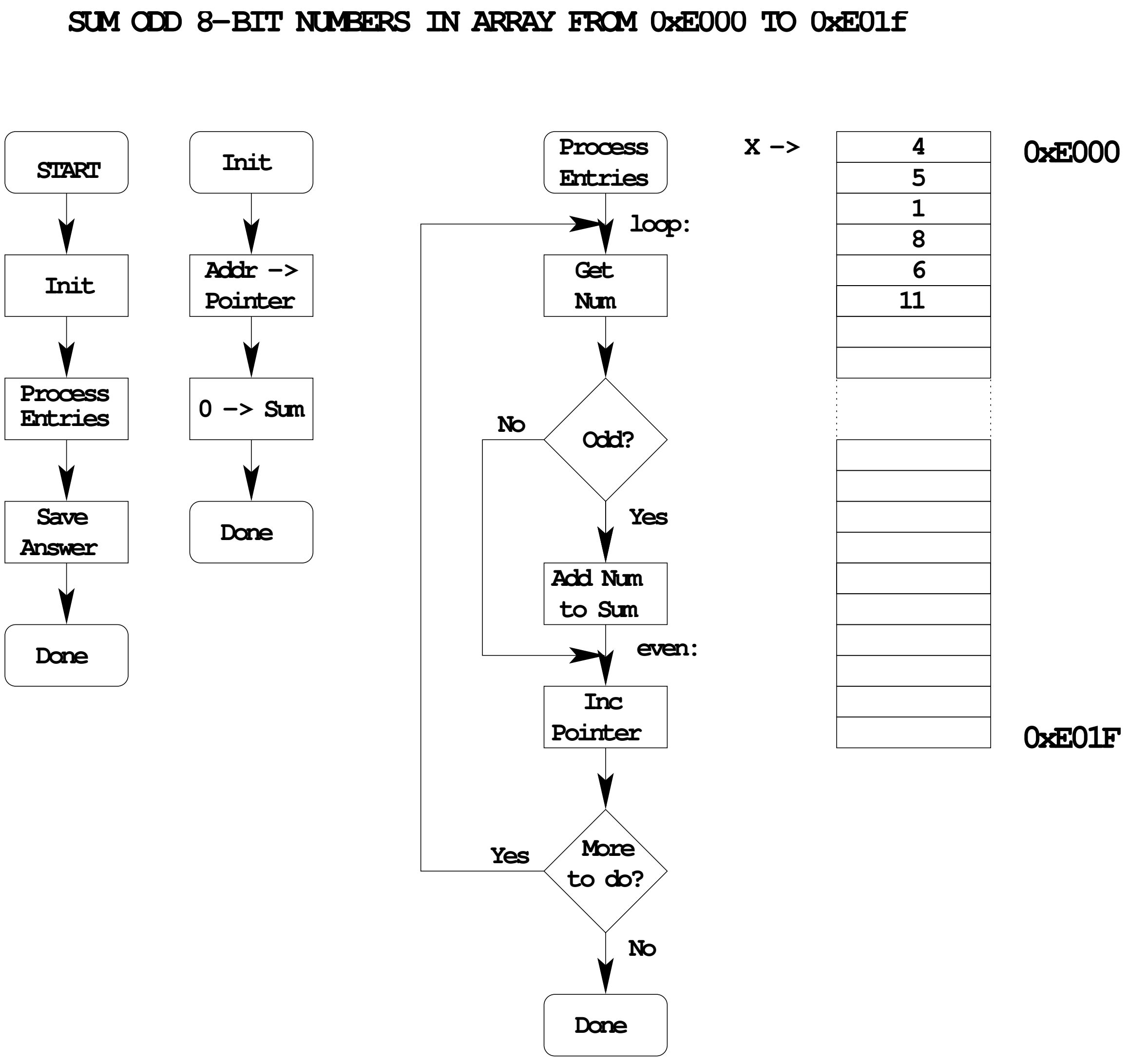
    ```
    l1:     brset     PORTB,#$08,l1
    ```

  - In C:

    ```
    while ((PORTB & 0x08) != 0) ;
    ```

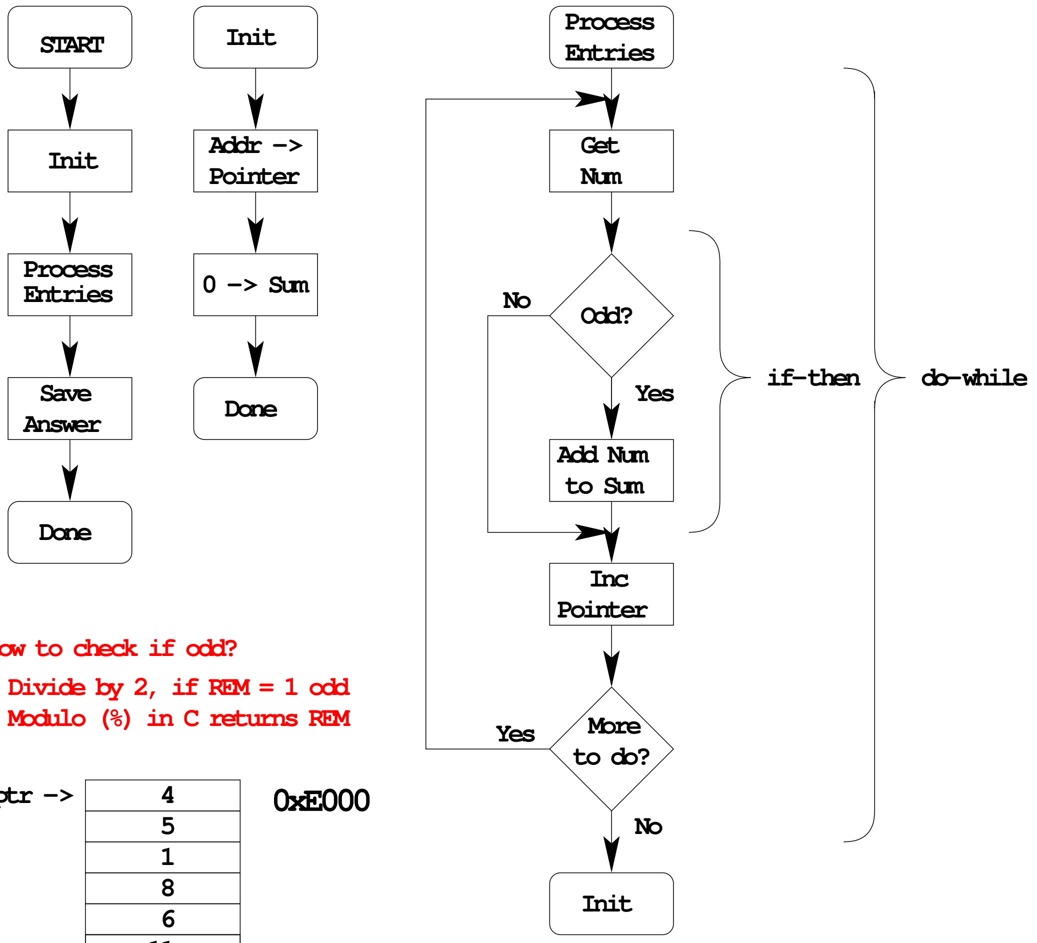
Sum the odd 8-bit numbers in an array

- Write a program to sum all the odd numbers in an array of data.
- The numbers in the array should be treated as unsigned 8-bit numbers.
- The array starts at address `0xE000` and ends at address `0xE01F`.
- This is the same program which was done in assembly language on Feb. 4, 2006.



Convert to C

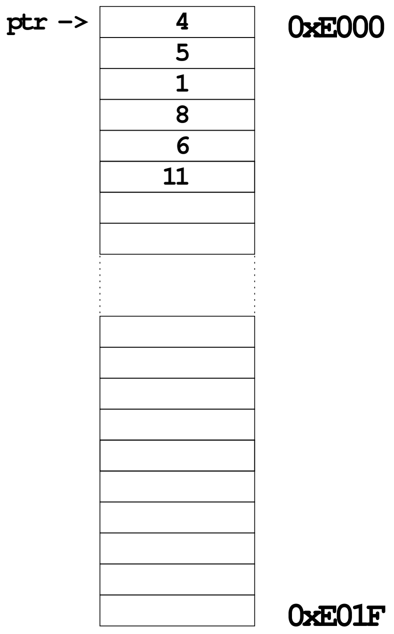
SUM ODD 8-BIT NUMBERS IN ARRAY FROM 0xE000 TO 0xE01f



How to check if odd?

Divide by 2, if REM = 1 odd

Modulo (%) in C returns REM



```
main() {
   ptr = (unsigned char *) 0xe000;
   sum = 0;
   do {
      x = *ptr;
      if ((x % 2) == 1) {
          sum = sum + x;
      }
      ptr = ptr + 1;
   }
   while (ptr <= (unsigned char *) 0xe01f);
}
```

```
/* Program to sum the odd numbers in an array
 * The numbers are unsigned characters
 * The array starts at address 0xE000 and
 * is 0x20 bytes long
 */
#include "DBug12.h"

#define START 0xE000
#define LEN   0x20
#define END   (START+LEN-1)

main()
{
    unsigned int sum;    /* Keep the running sum (need 16-bit number) */
    unsigned char *ptr;  /* Pointer to array element */
    unsigned char x;     /* Character from array */

    ptr = (unsigned char *) START;
    sum = 0;
    do
    {
        x = *ptr;              /* Get entry */
        if ((x % 2) == 1)      /* Is number odd? */
        {
            sum = sum + x;     /* Odd:  add to sum */
                               /* C automatically makes x 16-bits */
        }
        ptr = ptr + 1;         /* Advance to next */
    }
    while (ptr <= (unsigned char *) END);  /* Done? */
    DB12FNP->printf("sum = %d\r\n",sum);
    asm(" swi");
}
```

A software delay

- To enter a software delay, put in a nested loop, just like in assembly.
  - Write a function `delay(num)` which will delay for `num` milliseconds

```
void delay(unsigned int num)
{
    unsigned int i;

    while (num > 0)
    {
        i = XXXX;
                      /* ----------------------- */
        while (i > 0) /*                         */
        {             /* Want inner loop to delay */
            i = i - 1; /* for 1 ms                */
        }             /*                         */
                      /* ----------------------- */
        num = num - 1;
    }
}
```

- What should `XXXX` be to make a 1 ms delay?

- Look at assembly listing generated by compiler:

```
        0000206f <delay>:
            206f:   34              pshx
            2070:   7c 10 02        std   1002 <_.z>
            2073:   27 1e           beq   2093 <delay+0x24>
            2075:   18 00 80 03     movw  #XXX <__bss_size+0xXXX>, 0,SP
            2079:   e8
            207a:   ec 80           ldd   0,SP
            207c:   27 0a           beq   2088 <delay+0x19>
           ---------------------------------------------------
inner     | 207e:   ed 80           ldy   0,SP
loop      | 2080:   1a 5f           leax  -1,Y
takes     | 2082:   6e 80           stx   0,SP
13 cycles | 2084:   ec 80           ldd   0,SP
          | 2086:   26 f6           bne   207e <delay+0xf>
           ---------------------------------------------------
            2088:   fc 10 02        ldd   1002 <_.z>
            208b:   c3 ff ff        addd  #ffff <_stack+0xc3ff>
            208e:   7c 10 02        std   1002 <_.z>
            2091:   26 e2           bne   2075 <delay+0x6>
            2093:   30              pulx
            2094:   3d              rts
```

- Inner loop takes 13 cyles.
- One millisecond takes 24,000 cycles
  (24,000,000 cycles/sec $\times$ 1 millisecond = 24,000 cycles)
- Need to execute inner loop 24,000/13 = 1,846 times to delay for 1 millisecond

```
void delay(unsigned int num)
{
    unsigned int i;

    while (num > 0)
    {
        i = 1846;
                       /* ------------------------  */
        while (i > 0)  /*                           */
        {              /* Inner loop takes 13 cycles */
            i = i - 1; /* Execute 1836 times to     */
        }              /* delay for 1 ms            */
                       /* ------------------------  */
        num = num - 1;
    }
}
```

Program to increment LEDs connected to PORTA, and delay for 50 ms between changes

```
#include "hcs12.c"
#define D_1MS (24000/13)    // Inner loop takes 13 cycles
                            // Need 24,000 cycles for 1 ms

void delay(unsigned int num);
main()
{
    DDRA = 0xff;     /* Make PORTA output */
    PORTA = 0;       /* Start with all off */
    while(1)
    {
        PORTA = PORTA + 1;
        delay(50);
    }
}

void delay(unsigned int num)
{
    unsigned int i;

    while (num > 0)
    {
        i = D_1MS;
        while (i > 0)
        {
            i = i - 1;
        }
        num = num - 1;
    }
}
```

Program to display a particular pattern of lights on PORTA

```
#include "hcs12.c"

#define D_1MS (24000/13)    // Inner loop takes 13 cycles
                            // Need 24,000 cycles for 1 ms
#define TABLEN 8

void delay(unsigned int num);
main()
{
    const char table[] = {0x80,0x40,0x20,0x10,
                          0x08,0x04,0x02,0x01};
    int i;

    DDRA = 0xff;     /* Make PORTA output */
    PORTA = 0;       /* Start with all off */
    i = 0;
    while(1)
    {
        PORTA = table[i];
        delay(50);
        i = i + 1;
        if (i >= TABLEN) i = 0;  /* Start over when */
                                 /* end is reached  */
    }
}
```