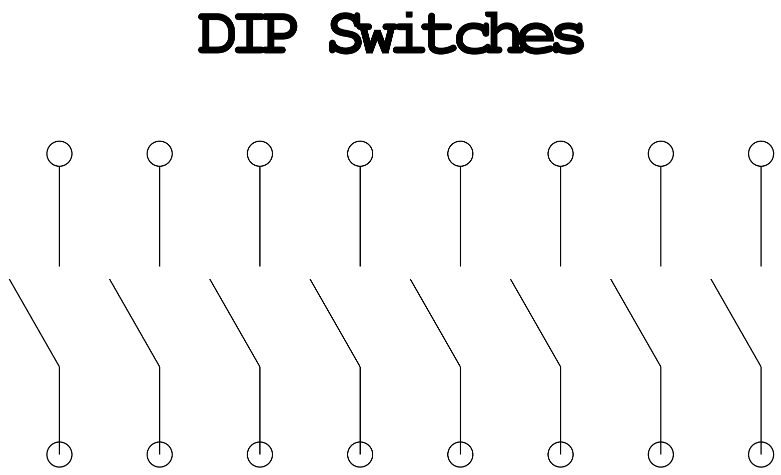
Exam 1
Monday, Feb. 20

- You will be able to use all of the Motorola data manuals on the exam.
- No calculators will be allowed for the exam.
- Numbers
  - Decimal to Hex (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
  - INH, IMM, DIR, EXT, 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
- 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 program
  - Know basic assembler directives – e.g., equ, dc.b, ds.w
  - Flow charts

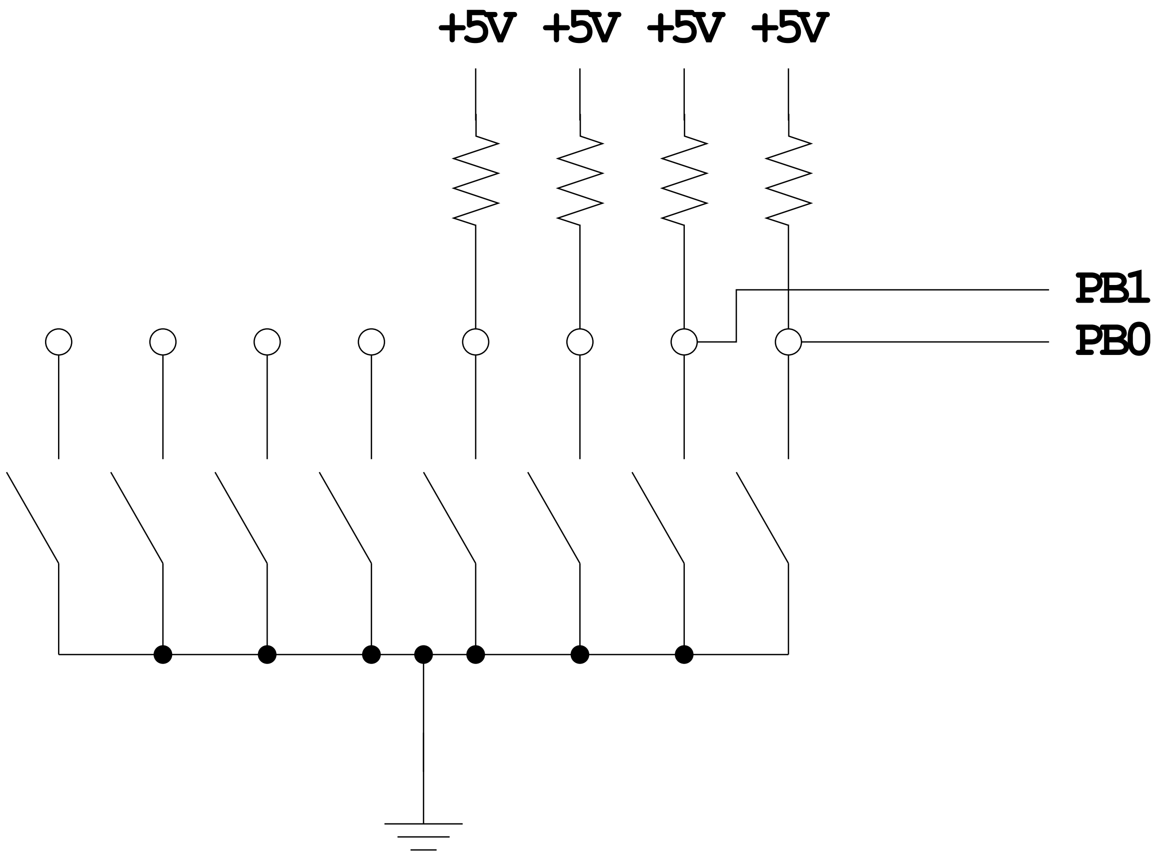
Using DIP switches to get data into the HC12

- DIP switches make or break a connection (usually to ground)



- To use DIP switches, connect one end of each switch to a resistor
- Connect the other end of the resistor to +5 V
- Connect the junction of the DIP switch and the resistor to an input port on the HC12

Using DIP Switches



- When the switch is open, the input port sees a logic 1 (+5 V)
- When the switch is closed, the input sees a logic 0 (0 V)

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

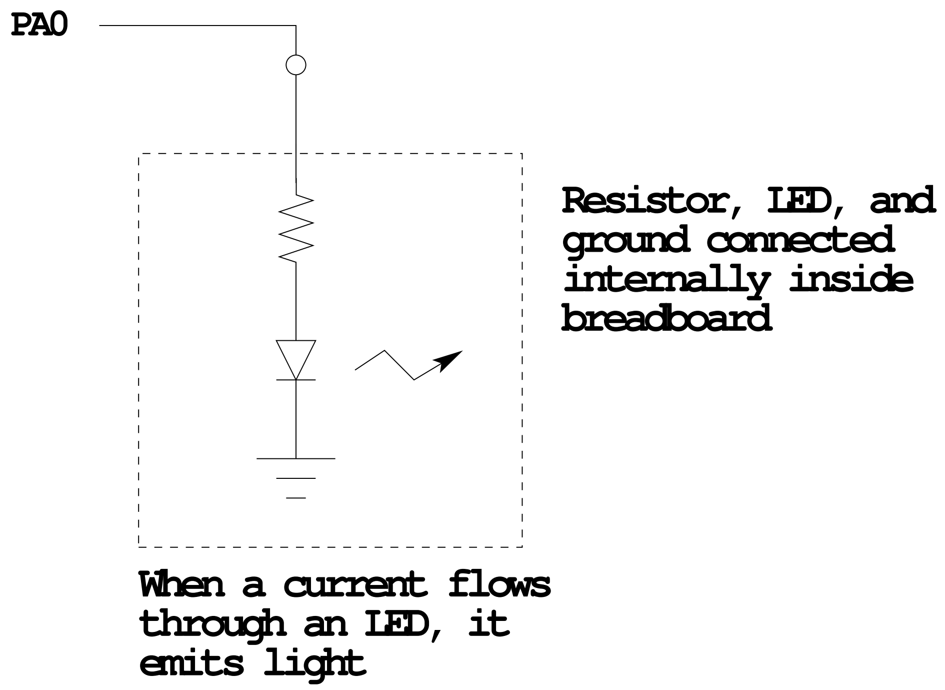
```
        ldaa    PORTB
        anda    #b00001111
        cmpa    #b00000110
beq     task
```

- Now, whatever pattern appears on PB7-4 is ignored

Using an HC12 output port to control an LED

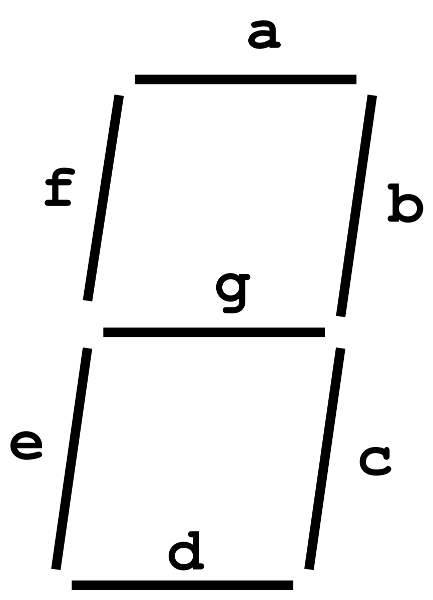
- Connect an output port from the HC12 to an LED.

Using an output port to control an LED


PA0
Resistor, LED, and ground connected internally inside breadboard
When a current flows through an LED, it emits light

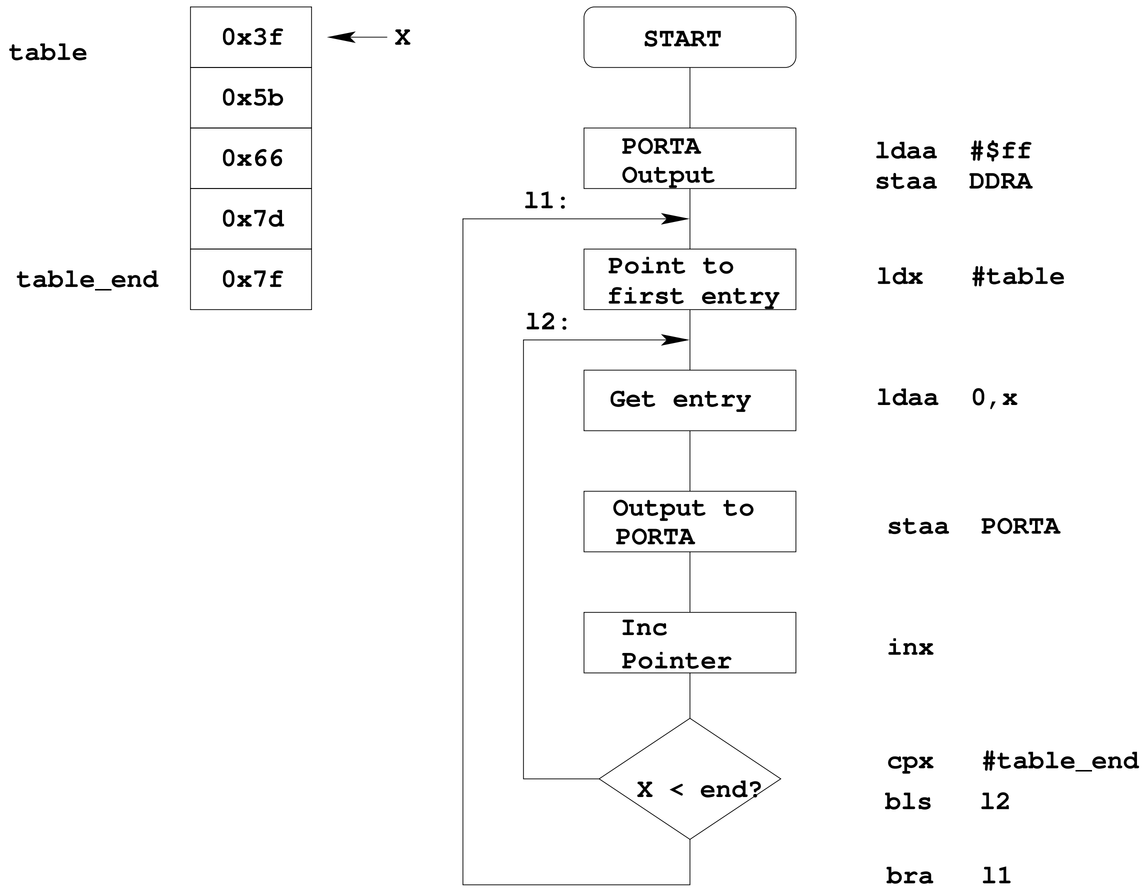
Making a pattern on a seven-segment LED

- Want to generate a particular pattern on a seven-segment LED:



- Determine a number (hex or binary) which 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

Flowchart to display a pattern of lights on a set of LEDs



```
; Program using subroutine to make a time delay

prog:       equ     $1000
data:       equ     $2000
stack:      equ     $3C00
PORTA:      equ     $0000
DDRA:       equ     $0002


            org     prog

            lds     #stack     ; initialize stack pointer
            ldaa    #$ff       ; Make PORTA output
            staa    DDRA       ;   0xFF -> DDRA
l1:         ldx     #table     ; Start pointer at table
l2:         ldaa    1,x+       ; Get value; point to next
            staa    PORTA      ; Update LEDs
            jsr     delay      ; Wait a bit
            cpx     #table_end ; More to do?
            bls     l2         ; Yes, keep going through
                               ;   table
            bra     l1         ; At end; reset pointer

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

```
; 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 inner loop |  Outer loop
            dbne    a,loop2 ; 3 cycles ------------
            pulx            ; 3 cycls
            pula            ; 3 cycls
            rts             ; 5 cycls
```

- Inner loop takes 3 cycles; is executed 3200 (X) times
- Outer loop takes (2 + 3X + 3) cycles; is executed 250 (A) times
- Total number of cycles: 2+2+1+A*(2+3X+3)+3+3+5 = 2,401,266 cycles
- This takes 100 ms with 24 MHz E-clock

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:  EQU  5                 |   #define COUNT 5
;------------------------------|   /*------------------------------*/
;start a program               |   /* To start a program */
       org   $1000             |   main()
       lds   #0x3C00           |   {
                               |   }
;------------------------------|   /*------------------------------*/
```

- Note that in C, the starting location of the program is defined when you compile the program, not in the program itself.
- Note that C always uses the stack, so C automatically loads the stack pointer for you.

```
Assembly                         |   C
-------------------------------|-----------------------------------
;allocate two bytes for        |   /* Allocate two bytes for
;a signed number               |    * a signed number */
                               |
      org     $2000            |
i:    ds.w    1                |   int i;
j:    dc.w    $1A00            |   int j = 0x1a00;
;------------------------------|   /*------------------------------*/
;allocate two bytes for        |   /* Allocate two bytes for
;an unsigned number            |    * an unsigned number */
i:    ds.w    1                |   unsigned int i;
j     dc.w    $1A00            |   unsigned int j = 0x1a00;
;------------------------------|   /*------------------------------*/
;allocate one byte for         |   /* Allocate one byte for
;an signed number              |    * an signed number */
                               |
i:    ds.b    1                |   signed char i;
j:    dc.b    $1F              |   signed char j = 0x1f;
```

```
Assembly                        |   C
;-------------------------------|   /*-----------------------------*/
;Get a value from an address    |   /* Get a value from an address */
; Put contents of address       |   /*  Put contents of address    */
; $E000 into variable i         |   /*  0xE000 into variable i     */
                                |
i:  ds.b   1                    |   unsigned char i;
                                |
    ldaa   $E000                |   i = * (unsigned char *) 0xE000;
    staa   i                    |
                                |   /*-----------------------------*/
                                |   /* Use a variable as a pointer
                                |      (address) */
                                |
                                |   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.
- 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 two 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 addess `0xE000`.
  - `* (int *) 0xE000 = 0xaa;` tells C to write the number `0x00aa` to two bytes starting at addess `0xE000`.

```
Assembly                        |   C
;-------------------------------|   /*-------------------------------*/
;To call a subroutine           |   /* To call a function */
  ldaa  i                       |   sqrt(i);
  jsr   sqrt                    |
;-------------------------------|   /*-------------------------------*/
;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)
;-------------------------------|   /*-------------------------------*/
                                |
```

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

```
ASSEMBLY                     | C
-----------------------------|---------------------
                             |
      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 C program and how to compile it

Here is a simple C program

```
#define COUNT 5

unsigned int i;

main()
{
    i = COUNT;
}
```

Details of compiling 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.
2. From the **File** menu, select the **New Source File** option. Type in your C program. Then from the **File** menu, select the **Save unit as** submenu, and save your file with an appropriate name and 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 from 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`

   Then click the **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.

If the name of your project is `Project1.prj`, the compiler will generate a file `Project1.dmp`. Here is some of the output from `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 37     jsr 2037 <__premain>

00002006 <__map_data_section>:
    2006: ce 20 40     ldx #2040 <_etext>
    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 01     ldd #1 <__bss_size>
    201b: 27 08        beq 2025 <Done>
    201d: ce 10 00     ldx #1000 <__data_section_start>

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 3b     jsr 203b <_exit>
    202b: 20 fb        bra 2028 <fatal>
    202d: 20 06        bra 2035 <main+0x4>
    202f: 20 18        bra 2049 <_etext+0x9>

00002031 <main>:
    2031: 18 0b 05 10  movb #5, 1000 <__data_section_start>
    2035: 00
    2036: 3d           rts

00002037 <__premain>:
    2037: 87           clra
    2038: b7 02        tap
    203a: 3d           rts

0000203b <_exit>:
    203b: 10 ef        cli
    203d: 3e           wai
    203e: 20 fb        bra 203b <_exit>
```

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. 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:

```
#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 */
```