Programmering av grafisk display

- Arbetsboken avsnitt 5
  - ”Drivrutrin för grafisk display”, uppg. 5.10-5.16.

- ”Datablad LCD – Grafisk” under resurser på kurshemsidan, s.14-23.

- Lab 3
  - Drivrutiner
  - Enkel grafik

- Lab 5
  - Spel

Översikt

- Egenskaper
- Implementation av drivrutiner
- Skriva till display

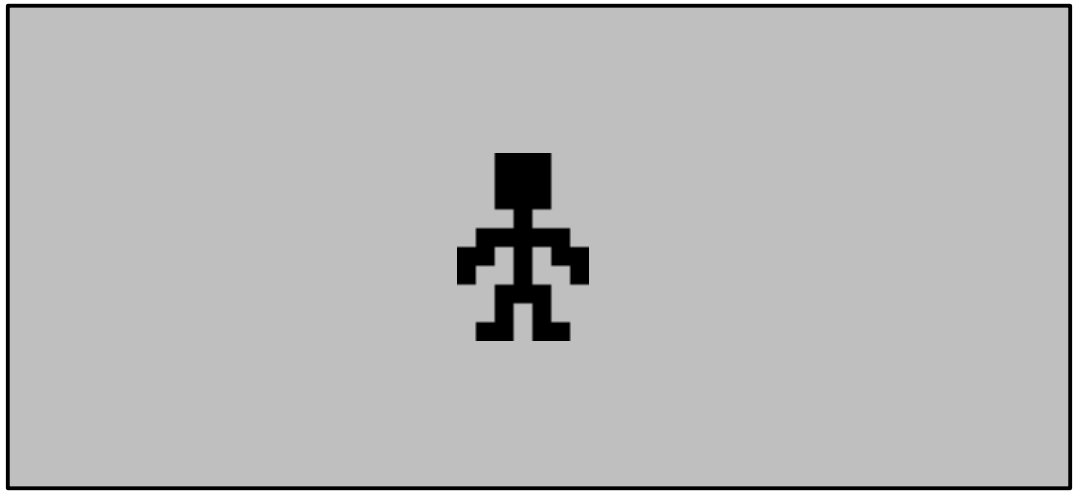
- Prestanda
- Design av grafik

Egenskaper

Upplösning på 128 x 64 pixlar.

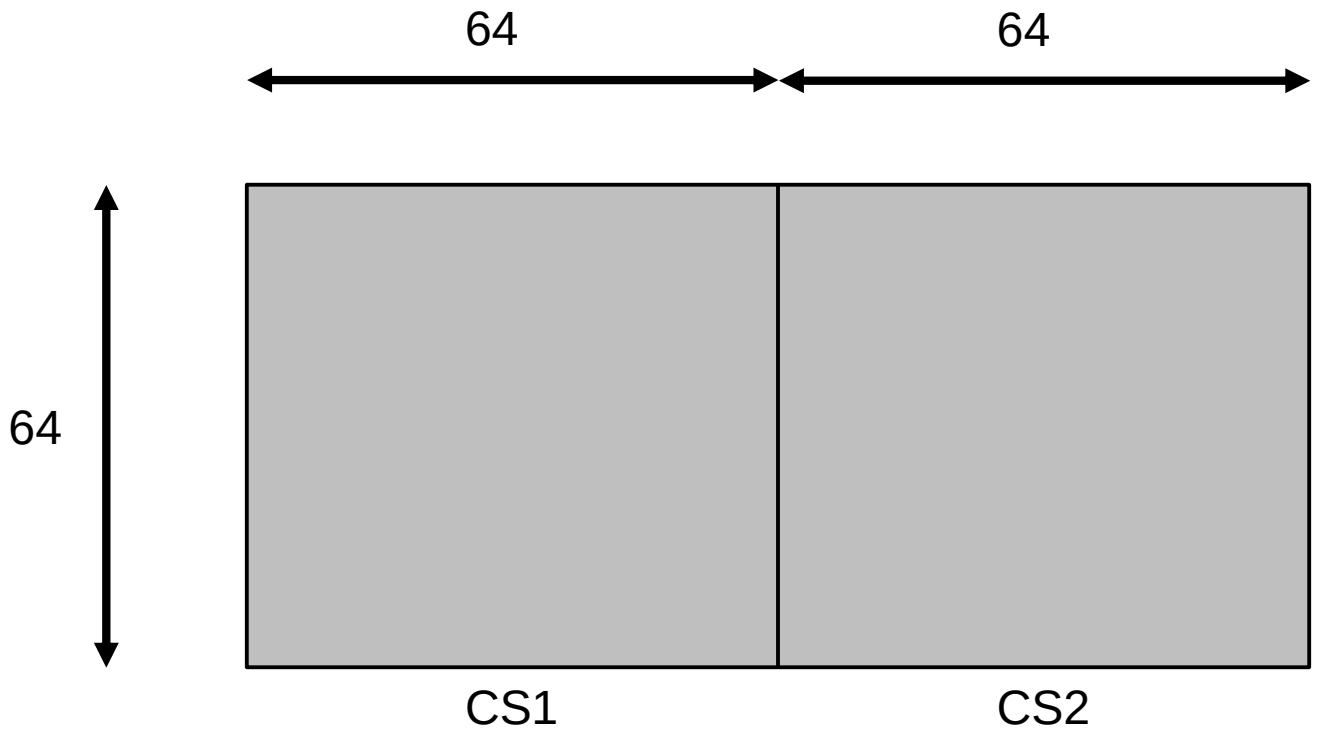
Egenskaper

- Inga färger eller ens gråskala.
- Varje pixel är antingen transparent eller fylld.
- Med andra ord: 1 bit / pixel.



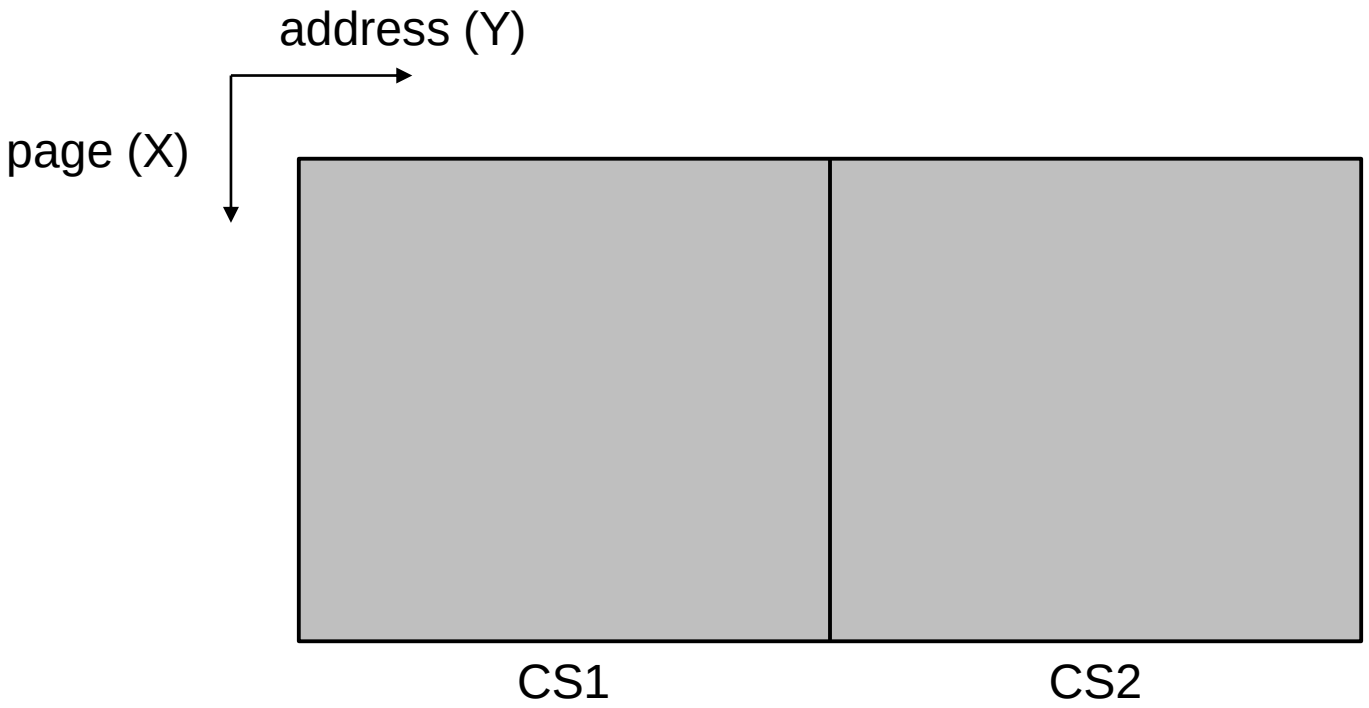
Egenskaper

- Displayen består av två separata enheter.
- CS = ”Chip Select”.



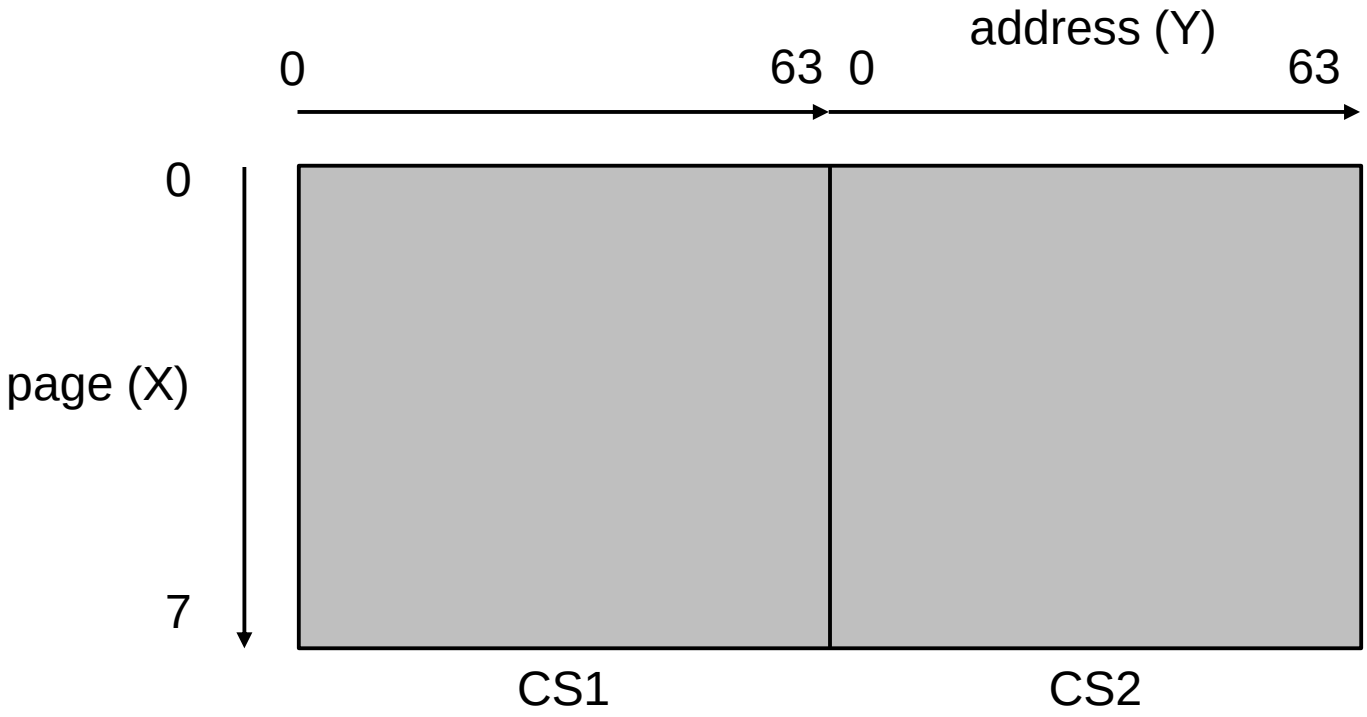
Egenskaper

- Fysiska koordinater för displayen anges i ”page” och ”address”.
- I databladet kallas page X och address Y.

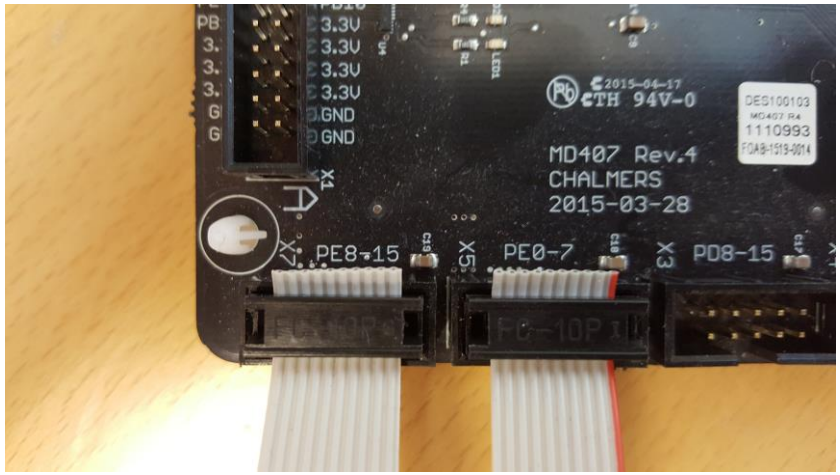


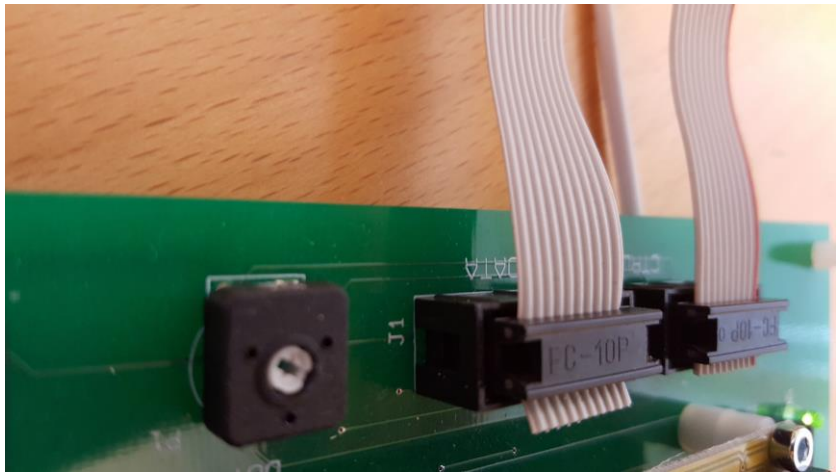
Egenskaper

- Address anger vilken pixel inom varje halva i horisontalled. Från 0-63 för varje halva.
- Page anger 0-7 i vertikalled.



Implementation av drivrutiner





Port E

Låga bitar (0-7) = styrregister
Höga bitar (8-15) = dataregister

Implementation av drivrutiner

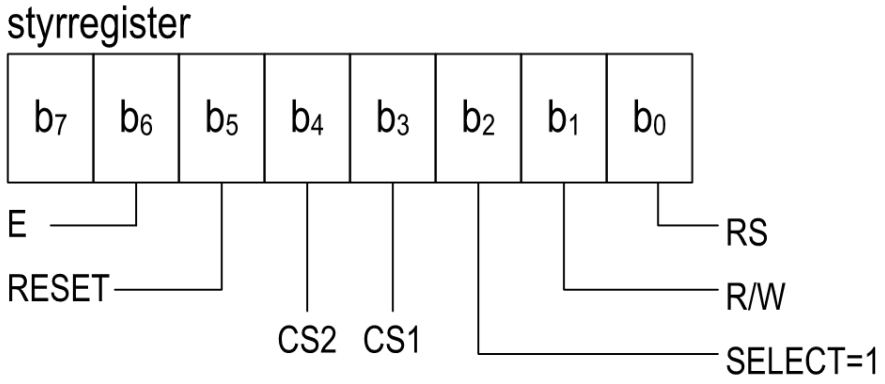
Definition av portar

```
#define PORT_DISPLAY_BASE 0x40021000 // MD407 port E

#define portModer    ((volatile unsigned int *)    (PORT_DISPLAY_BASE))
#define portOtyper   ((volatile unsigned short *) (PORT_DISPLAY_BASE+0x4))
#define portOspeedr  ((volatile unsigned int *)    (PORT_DISPLAY_BASE+0x8))
#define portPupdr    ((volatile unsigned int *)    (PORT_DISPLAY_BASE+0xC))
#define portIdr      ((volatile unsigned short *) (PORT_DISPLAY_BASE+0x10))
#define portIdrHigh  ((volatile unsigned char *)   (PORT_DISPLAY_BASE+0x11))
#define portOdrLow   ((volatile unsigned char *)   (PORT_DISPLAY_BASE+0x14))
#define portOdrHigh  ((volatile unsigned char *)   (PORT_DISPLAY_BASE+0x14+1))
```

Implementation av drivrutiner

Definition av kommandon till styrregister. Hantera synkronisering.

```
#define B_E       0x40      // Enable
#define B_RST     0x20      // Reset
#define B_CS2     0x10      // Controller Select 2
#define B_CS1     8         // Controller Select 1
#define B_SELECT  4         // 0 Graphics, 1 ASCII
#define B_RW      2         // 0 Write, 1 Read
#define B_RS      1         // 0 Command, 1 Data
```



Implementation av drivrutiner

Definition av kommandon till display, sänds via dataregister.

```
#define LCD_ON          0x3F    // Display on
#define LCD_OFF         0x3E    // Display off
#define LCD_SET_ADD     0x40    // Set horizontal coordinate
#define LCD_SET_PAGE    0xB8    // Set vertical coordinate
#define LCD_DISP_START  0xC0    // Start address
#define LCD_BUSY        0x80    // Read busy status
```

Implementation av drivrutiner

Från datablad.

Instruction	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	Function
Display on/off	L	L	L	L	H	H	H	H	H	L/H	Controls the display on or off. Internal status and display RAM data is not affected. L: OFF, H: ON
Set address (Y address)	L	L	L	H	Y address (0 - 63)						Sets the Y address in the Y address counter.
Set page (X address)	L	L	H	L	H	H	H	Page (0 - 7)			Sets the X address at the X address register.
Display start line (Z address)	L	L	H	H	Display start line (0 - 63)						Indicates the display data RAM displayed at the top of the screen.
Status read	L	H	Busy	L	On/ Off	Reset	L	L	L	L	Read status. BUSY L: Ready H: In operation ON/OFF L: Display ON H: Display OFF RESET L: Normal H: Reset
Write display data	H	L	Write data								Writes data (DB0:7) into display data RAM. After writing instruction, Y address is increased by 1 automatically.
Read display data	H	H	Read data								Reads data (DB0:7) from display data RAM to the data bus.

Implementation av drivrutiner

```
static void graphic_ctrl_bit_set(uint8_t x);

static void graphic_ctrl_bit_clear(uint8_t x);

static void select_controller(uint8_t controller);
```

Implementation av drivrutiner

```
static void select_controller(uint8_t controller){
        switch(controller){
                case 0:
                        graphic_ctrl_bit_clear(B_CS1|B_CS2);
                        break;
                case B_CS1 :
                        graphic_ctrl_bit_set(B_CS1);
                        graphic_ctrl_bit_clear(B_CS2);
                        break;
                case B_CS2 :
                        graphic_ctrl_bit_set(B_CS2);
                        graphic_ctrl_bit_clear(B_CS1);
                        break;
                case B_CS1|B_CS2 :
                        graphic_ctrl_bit_set(B_CS1|B_CS2);
                        break;
        }
}
```

Implementation av drivrutiner

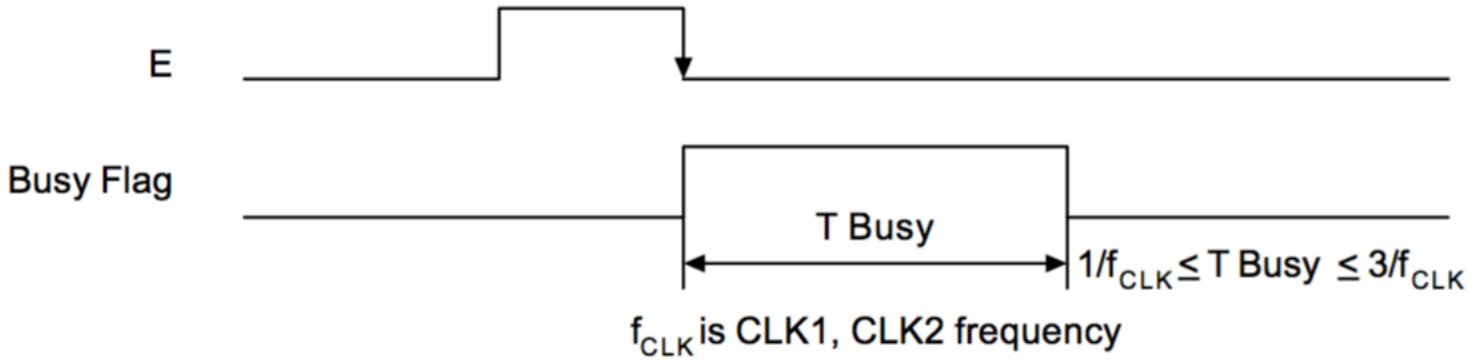
```
void graphic_initialize(void);

static void graphic_wait_ready(void);
```

Implementation av drivrutiner

```
void graphic_initialize(void) {
    graphic_ctrl_bit_set(B_E);
    delay_micro(10);

    graphic_ctrl_bit_clear(B_CS1|B_CS2|B_RST|B_E);
    delay_milli(30);
    graphic_ctrl_bit_set(B_RST);
    delay_milli(100);
    graphic_write_command(LCD_OFF,        B_CS1|B_CS2);
    graphic_write_command(LCD_ON,         B_CS1|B_CS2);
    graphic_write_command(LCD_DISP_START, B_CS1|B_CS2);
    graphic_write_command(LCD_SET_ADD,    B_CS1|B_CS2);
    graphic_write_command(LCD_SET_PAGE,   B_CS1|B_CS2);
    select_controller(0);
}
```

Implementation av drivrutiner

```
static void graphic_wait_ready(void) {
    uint8_t c;
    graphic_ctrl_bit_clear(B_E);
    *portModer = 0x00005555;        // 15-8 inputs, 7-0 outputs
    graphic_ctrl_bit_clear(B_RS);
    graphic_ctrl_bit_set(B_RW);
    delay_500ns();

    while(1) {
        graphic_ctrl_bit_set(B_E);
        delay_500ns();
        c = *portIdrHigh & LCD_BUSY;
        graphic_ctrl_bit_clear(B_E);
        delay_500ns();
        if( c == 0 ) break;
    }
    *portModer = 0x55555555;        // 15-0 outputs
}
```



Busy Check

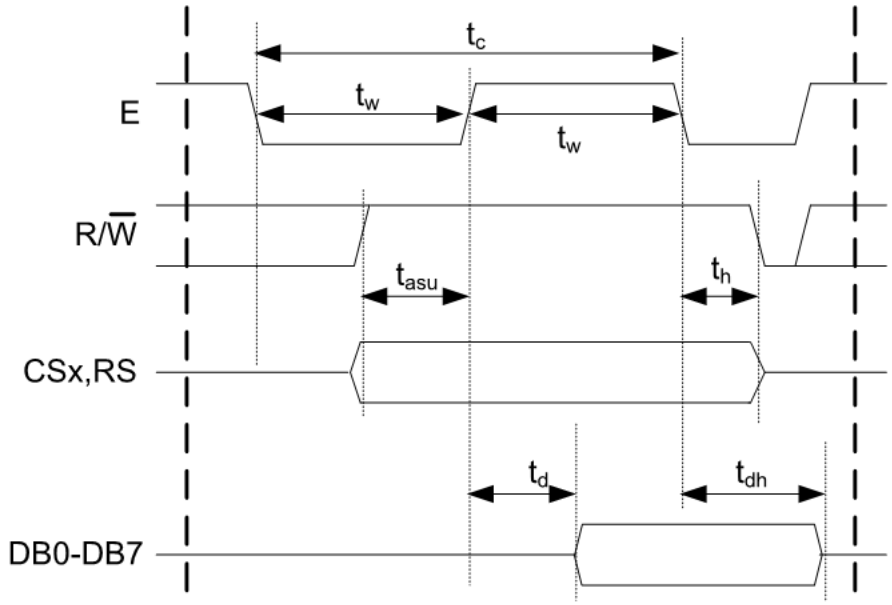
När “Busy flag” är låg så kan displayen acceptera kommandon och data. Se databladet sida 19.

Implementation av drivrutiner

```
static uint8_t graphic_read(uint8_t controller);

static uint8_t graphic_read_data(uint8_t controller);
```

Implementation av drivrutiner

```
static uint8_t graphic_read(uint8_t controller) {
     uint8_t c;
     graphic_ctrl_bit_clear(B_E);
     *portModer = 0x00005555; // 15-8 inputs, 7-0 outputs
     graphic_ctrl_bit_set(B_RS|B_RW);
     select_controller(controller);
     delay_500ns();
     graphic_ctrl_bit_set(B_E);
     delay_500ns();
     c = *portIdrHigh;
     graphic_ctrl_bit_clear(B_E);
     *portModer = 0x55555555; // 15-0 outputs

     if( controller & B_CS1 ) {
          select_controller(B_CS1);
          graphic_wait_ready();
     }
     if( controller & B_CS2 ) {
          select_controller(B_CS2);
          graphic_wait_ready();
     }
     return c;
}
```



Implementation av drivrutiner

```
static uint8_t graphic_read_data(uint8_t controller) {
    graphic_read(controller);
    return graphic_read(controller);
}
```

Enligt databladet måste vi läsa ut värdet två gånger för att det ska få effekt, se s. 19.

Implementation av drivrutiner

```
static void graphic_write(uint8_t value, uint8_t controller);

static void graphic_write_command(uint8_t command, uint8_t controller);

static void graphic_write_data(uint8_t data, uint8_t controller);

void graphic_clear_screen(void);
```

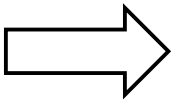
Implementation av drivrutiner

Från datablad.

Instruction	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	Function
Display on/off	L	L	L	L	H	H	H	H	H	L/H	Controls the display on or off. Internal status and display RAM data is not affected. L: OFF, H: ON
Set address (Y address)	L	L	L	H	Y address (0 - 63)						Sets the Y address in the Y address counter.
Set page (X address)	L	L	H	L	H	H	H	Page (0 - 7)			Sets the X address at the X address register.
Display start line (Z address)	L	L	H	H	Display start line (0 - 63)						Indicates the display data RAM displayed at the top of the screen.
Status read	L	H	Busy	L	On/ Off	Reset	L	L	L	L	Read status. BUSY L: Ready H: In operation ON/OFF L: Display ON H: Display OFF RESET L: Normal H: Reset
Write display data	H	L	Write data								Writes data (DB0:7) into display data RAM. After writing instruction, Y address is increased by 1 automatically.
Read display data	H	H	Read data								Reads data (DB0:7) from display data RAM to the data bus.

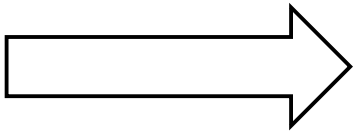
Skriva till display

```
void pixel(int x, int y, int set) {
     uint8_t mask, c, controller;
     int index;

     if((x < 1) || (y < 1) || (x > 128) || (y > 64)) return;

     index = (y-1)/8;

     switch( (y-1)%8 ) {
          case 0: mask = 1; break;
          case 1: mask = 2; break;
          case 2: mask = 4; break;
          case 3: mask = 8; break;
          case 4: mask = 0x10; break;
          case 5: mask = 0x20; break;
          case 6: mask = 0x40; break;
          case 7: mask = 0x80; break;
     }
```



```
mask = 1 << ((y-1)%8);
```

Forts.



Skriva till display

```
    if(set == 0)
       mask = ~mask;

    if(x > 64){
       controller = B_CS2;
       x = x - 65;
    } else {
       controller = B_CS1;
       x = x-1;
    }

    graphic_write_command(LCD_SET_ADD  | x, controller );
    graphic_write_command(LCD_SET_PAGE | index, controller );
    c = graphic_read_data(controller);
    graphic_write_command(LCD_SET_ADD | x, controller);

    if(set)
         mask = mask | c;
    else
         mask = mask & c;

    graphic_write_data(mask, controller);
}
```

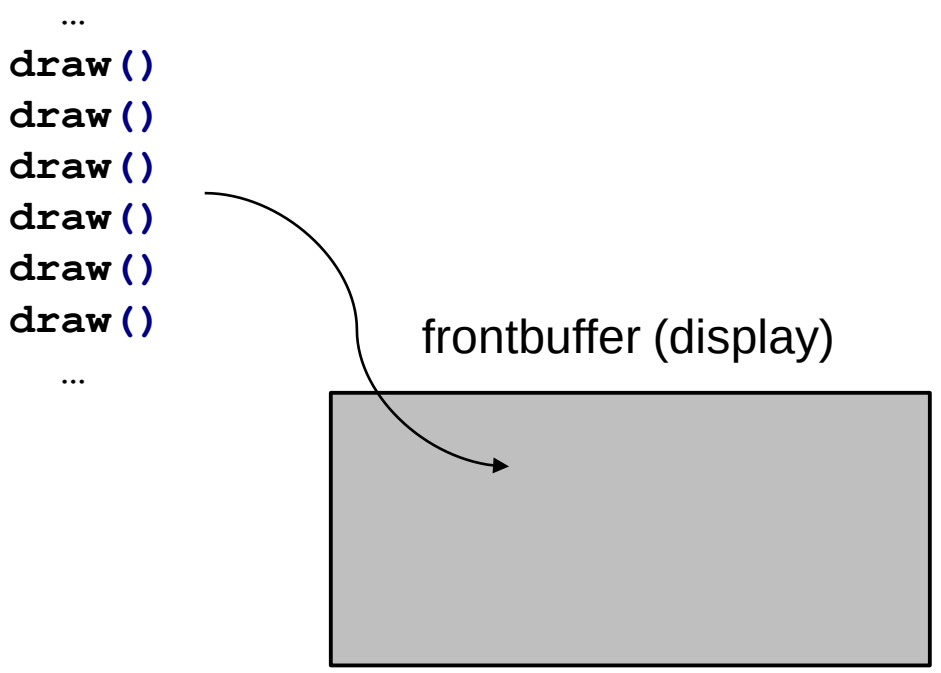
Notera: på grund av autoinkrementering av address

Prestanda

Varför flimrar det så?

På grund av att vi ritar direkt till skärmen.

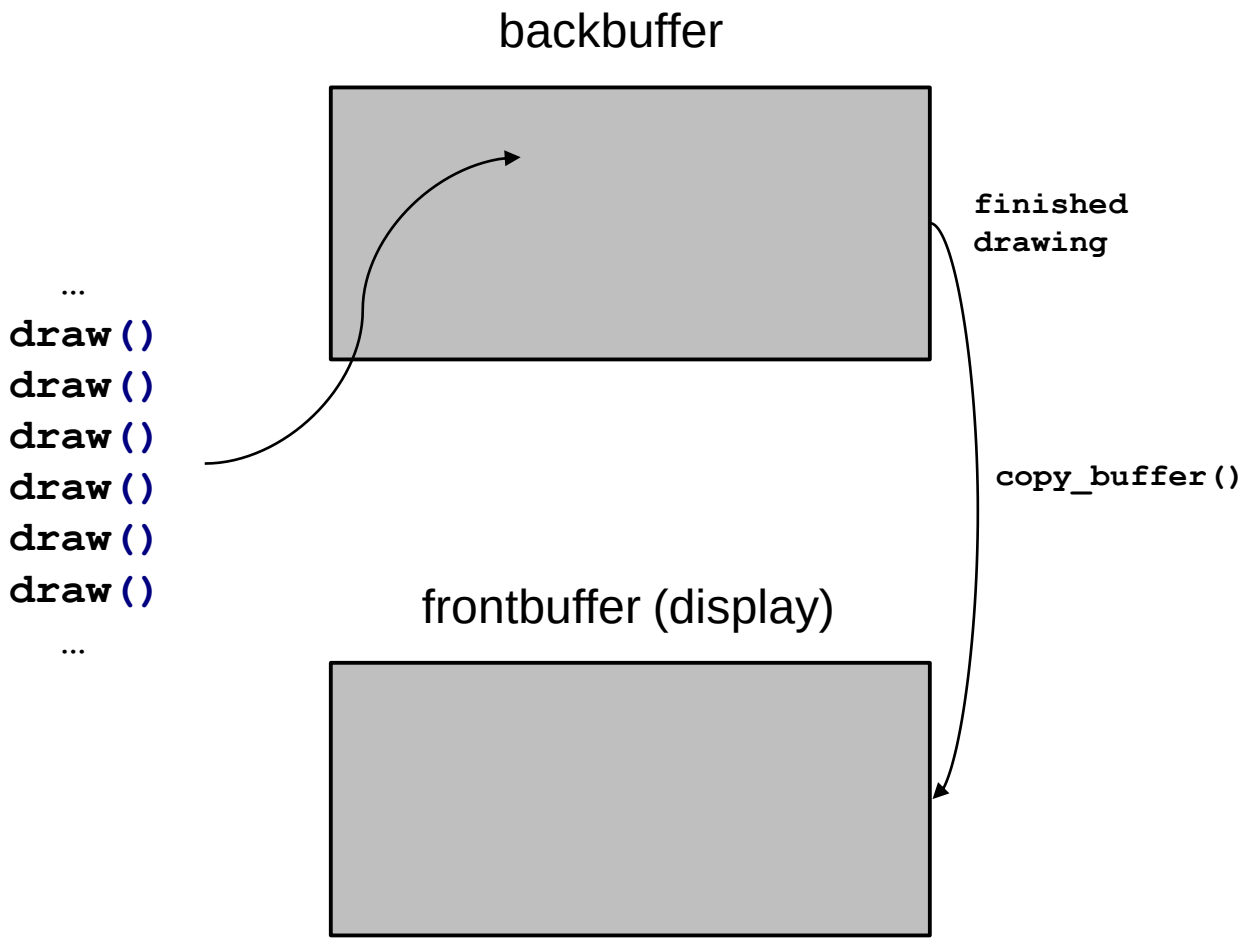
Lösning: använd dubbelbuffering.



Prestanda

Rita till en backbuffer – alltså till en buffer i RAM-minnet.

Rita sedan hela backbuffern i ett svep när vi är klara med vår nuvarande frame.



Prestanda

En enkel implementation.

```
uint8_t backBuffer[1024]; // 128 * 64 / 8

void clear_backBuffer() {
    int i;
    for (i = 0; i < 1024; i++)
        backBuffer[i] = 0;
}
```

Prestanda

Skriv till backbuffern istället för till skärmen.

```
void pixel(int x, int y) {
    uint8_t mask;
    int index = 0;
    if( (x > 128 ) || (x < 1) || (y > 64) || (y < 1) ) return;

    mask = 1 << ((y-1)%8);

    if(x > 64) {
        x -= 65;
        index = 512;
    }

    index += x + ((y-1)/8)*64;

    backBuffer[index] |= mask;
}
```

Prestanda

Kopiering av backbuffer till frontbuffer. Jämför med graphic_clear_screen().

```
void graphic_draw_screen(void) {
    uint8_t i, j, controller, c;
    unsigned int k = 0;

    for(c = 0; c < 2; c++) {
        controller = (c == 0) ? B_CS1 : B_CS2;
        for(j = 0; j < 8; j++) {
            graphic_writeCommand(LCD_SET_PAGE | j, controller);
            graphic_writeCommand(LCD_SET_ADD  | 0, controller);
            for(i = 0; i <= 63; i++, k++) {
                graphic_write_data(backBuffer[k], controller);
            }
        }
    }
}
```

Prestanda

```
int main(int argc, char **argv)
{
    POBJECT p = &ball;
    init_app();
    graphic_initialize();
    graphic_clear_screen();

    p->set_speed(p, 4, 1);
    while(1)
    {
        p->move(p);
        delay_milli(40);
    }
}
```

```
int main(int argc, char **argv)
{
    init_app();
    graphic_initialize();
    graphic_clear_screen();

    while(1)
    {
        clear_backBuffer();

        // DO STUFF.

        graphic_draw_screen();
        delay_milli(40);
    }
}
```

Design av grafik

- Arbetsbok: lista av logiska koordinater.
  - Svårt att ”rita” mer avancerad grafik.
  - Inte heller minneseffektivt: två unsigned char per pixel.

- Vill designa sprites i externt bildredigeringsprogram.
  - Problem 1: vilket format stödjer 1 bit per pixel?

- Vill ladda dessa bildfiler i vårt program.
  - Problem 2: vi har inget standardbibliotek med fil-i/o i vårt inbyggda system.

Design av grafik

- Förslag till lösning
  - Använd filformat X Bitmap (.xbm).
  - Formatet specificeras av bredd, höjd och ett antal bytes, allt direkt i c-kod!
  - Kan därför användas direkt i källkoden med `#include "image.xbm”`

person.xbm

```
1  #define person_width 7
2  #define person_height 10
3  static unsigned char person_bits[] = {
4     0x1c, 0x1c, 0x1c, 0x08, 0x3e, 0x6b, 0x49, 0x1c, 0x14, 0x36 };
5
```

Design av grafik

- Filformatet är standard och stödjs av många bildbehandlingsprogram.
- Tänkte visa två exempel som använder programmet GIMP (https://www.gimp.org/), som är gratis och finns till många plattformar.

Design av grafik

Ni vill vi designa en funktion för att rita ut sprites på X Bitmap-format.
Givet struct och hjälpfunktion nedan.

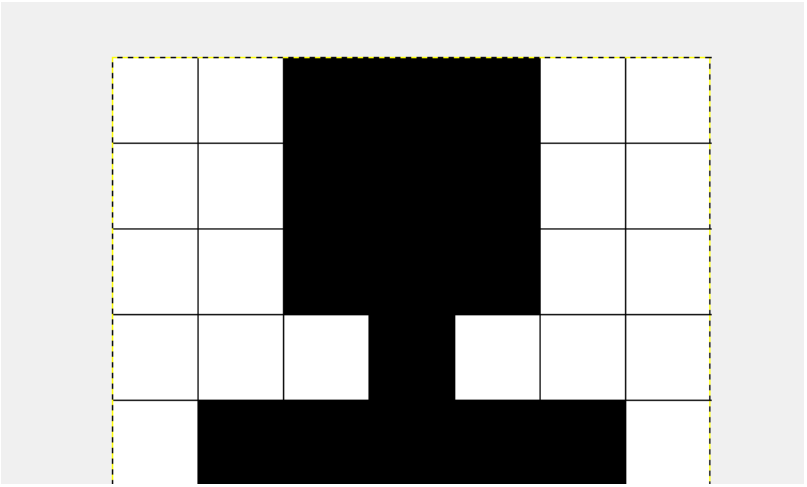
```
typedef struct
{
    unsigned char width;
    unsigned char height;
    unsigned char* data;
} sprite;


static void load_sprite(sprite* s, unsigned char* data, int width, int height)
{
    s->width = width;
    s->height = height;
    s->data = data;
}
```

Design av grafik

person.xbm

```
1   #define person_width 7
2   #define person_height 10
3   static unsigned char person_bits[] = {
4      0x1c, 0x1c, 0x1c, 0x08, 0x3e, 0x6b, 0x49, 0x1c, 0x14, 0x36 };
5
```

bit 1 2 3 4 5 6 7 8



Design av grafik

```
void draw_sprite(sprite* s, int x, int y, int set) {
    int i,j,k, width_in_bytes;

    if (s->width % 8 == 0)
        width_in_bytes = s->width / 8;
    else
        width_in_bytes = s->width / 8 + 1;

    for (i = 0; i < s->height; i++)
        for (j = 0; j < width_in_bytes; j++) {
                unsigned char byte = s->data[i * width_in_bytes + j];
                for (k =0; k < 8; k++) {
                        if (byte & (1 << k))
                                pixel(8 * j + k + x + 1, i + y + 1, set);
                }
    }
}
```