# Topic 8: The LCD Screen

CAB202. Topic 8

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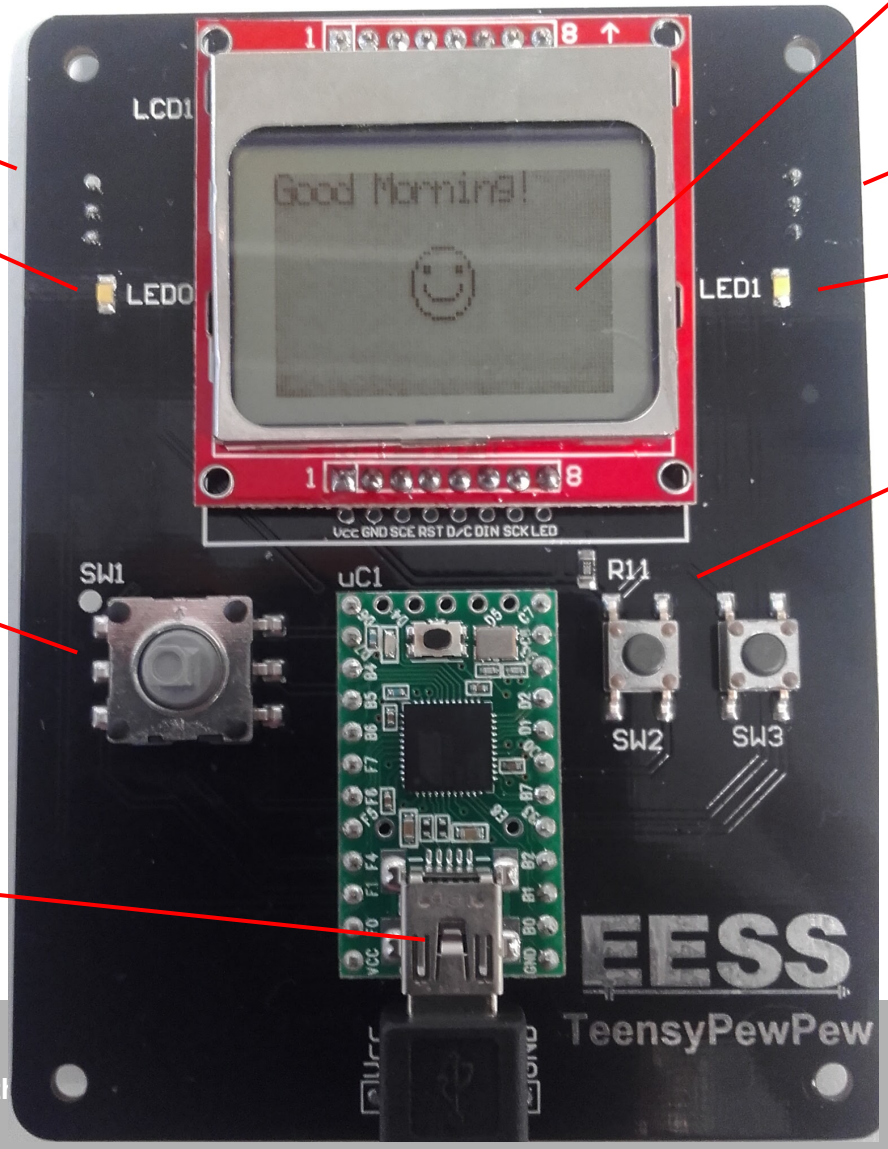
- You need your Teensy!
  - Collect from Level 9, S-Block
  - 9am-3pm with your student card

# Outline

- Revisit last week's lecture (Topic 7)
- Writing to the LCD screen in the teensy board
- Review of the cab202_teensy, our graphics library.

# Revisiting Topic 7
# QUT Teensy Board




Thumbwheel/Potentiometer

LED 1

5-Way
Push Button/Switch

USB connector

LCD

Thumbwheel/Potentiometer

LED 0

Buttons/Switches

In addition:

- Registers
- Binary operations
- Compilation cycle

# Revisiting Topic 7

- Turning an LED on/off
- Used Buttons to turn LED on/off
- LED example and bitwise shifts in more details

LED=Light Emitting Diode

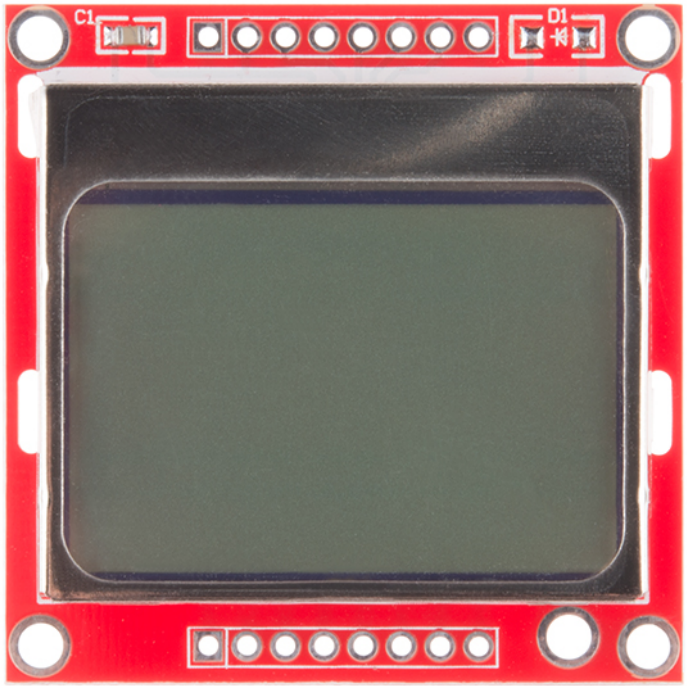
# Nokia 5110 LCD Screen (the PCD8544 LCD Controller/Driver)

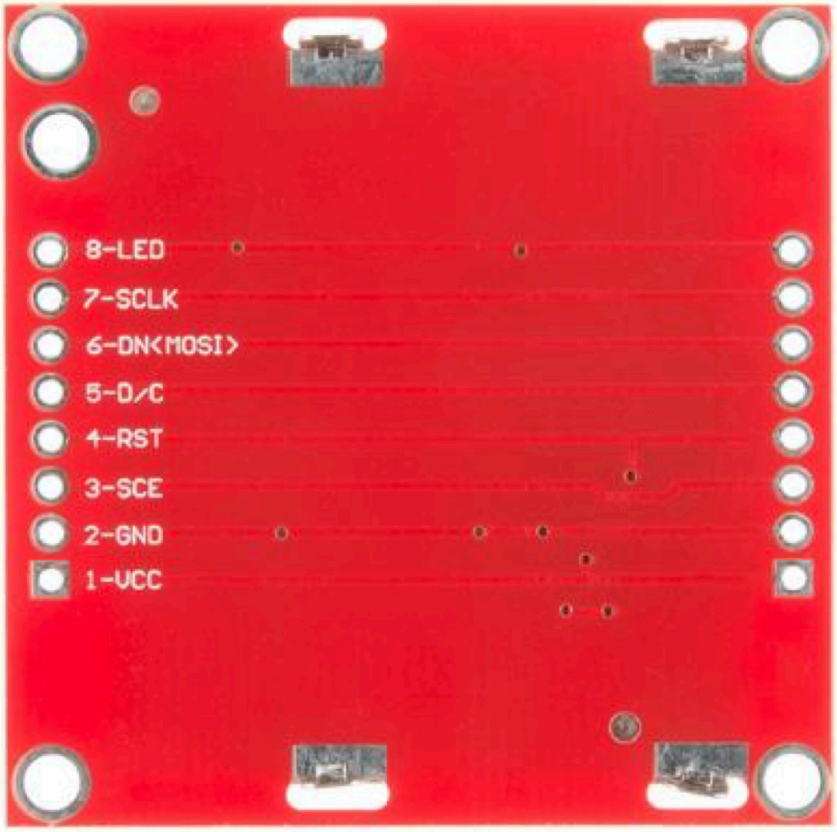
- 48x84 pixel monochrome display
- Built-in back light
- Interfaces with the microcontroller via a serial bus
- The controller has a small amount of RAM which holds the pixel data for display
- Recommended reading
  - Learning resources -> Microcontrollers-> Nokia5110-LCD Screen.pdf

# The LCD Screen

84 pixels

48 pixels

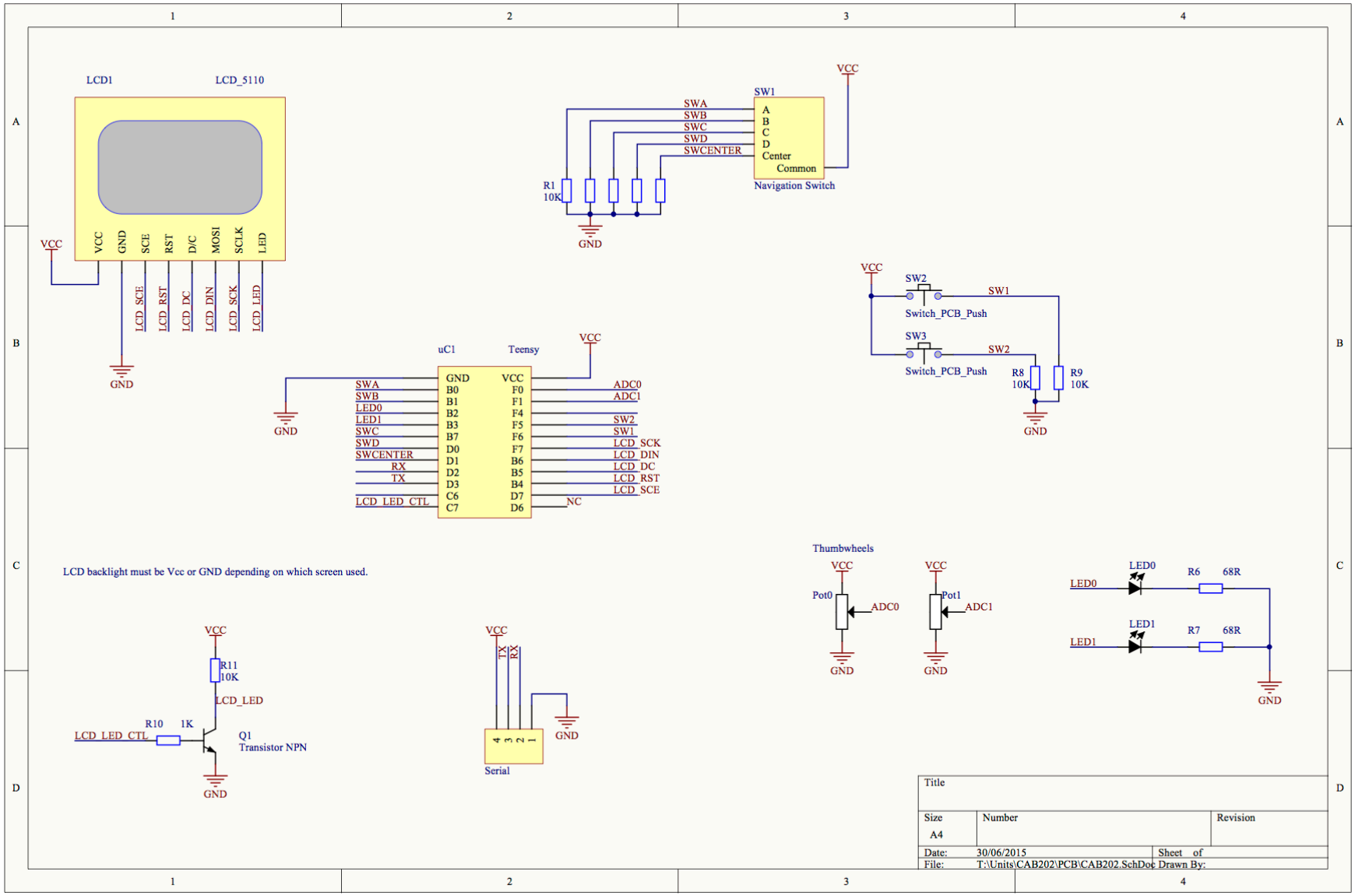


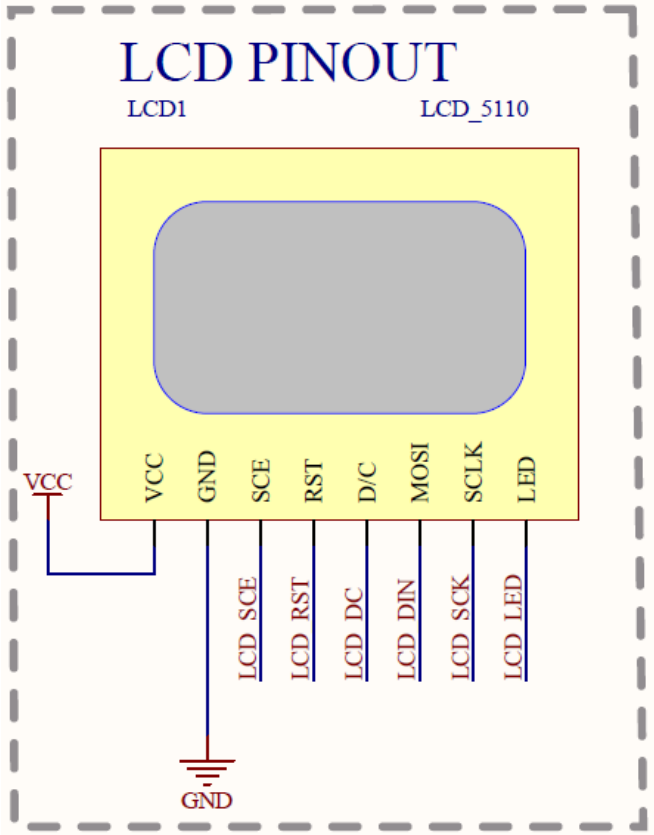

back

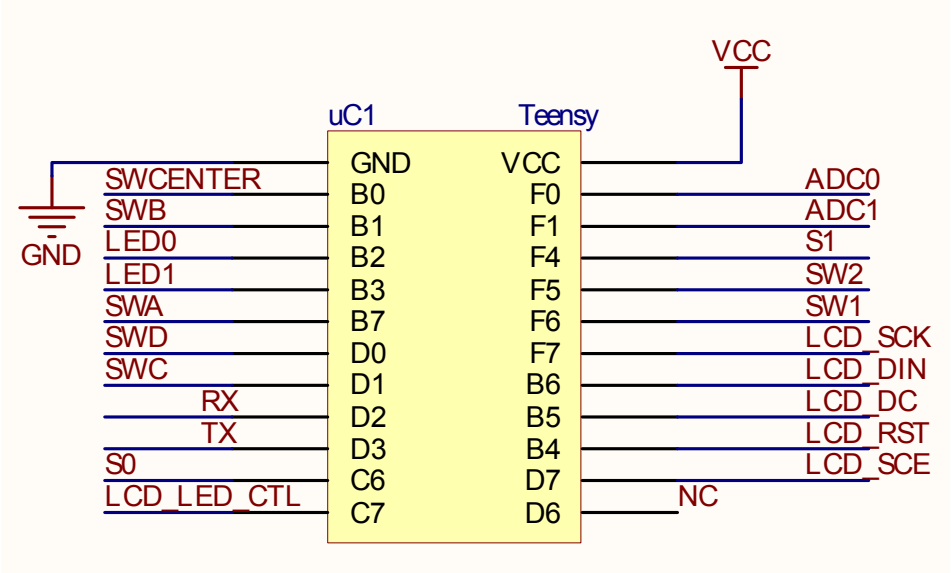
SCE = Chip Select
RST = Reset
DC = Mode select
DIN = Serial data in (MOSI)
SCLK = Serial clock
LED = backlight supply

# The LCD Screen



# The LCD Screen




Port C, pin 7 → LCD backlight.
Port F, pin 7 → LCD Serial Clock pin.
Port B, pin 6 → LCD Serial Data Input pin.
Port B, pin 5 → LCD Serial Data/Command pin.
Port B, pin 4 → LCD Reset pin.
Port D, pin 7 → LCD Chip Select pin.

http://ww1.microchip.com/downloads/en/devicedoc/Atmel-7766-8-bit-AVR-ATmega16U4-32U4_Summary.pdf

# The LCD Screen

| LCD Pin | Notes |
|---|---|
| Vcc | 3.3v volts |
| GND | GND |
| SCE | Chip select pin<br>Low: the start of data transmission<br>High: SCLK clock pulses have no effect |
| RST | Reset to default configuration |
| D/C | Data/Command pin<br>Low: incoming data must be interpreted as command<br>High: incoming data is pixel data that must be displayed |
| DIN | Serial data input pin |
| SCK | Serial clock pin |
| LED | backlight |

# The LCD Screen

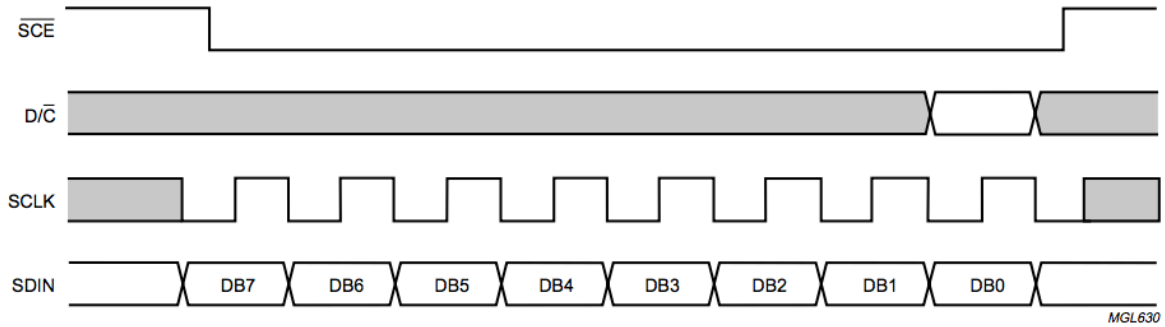



Fig.10 Serial bus protocol - transmission of one byte.

new byte

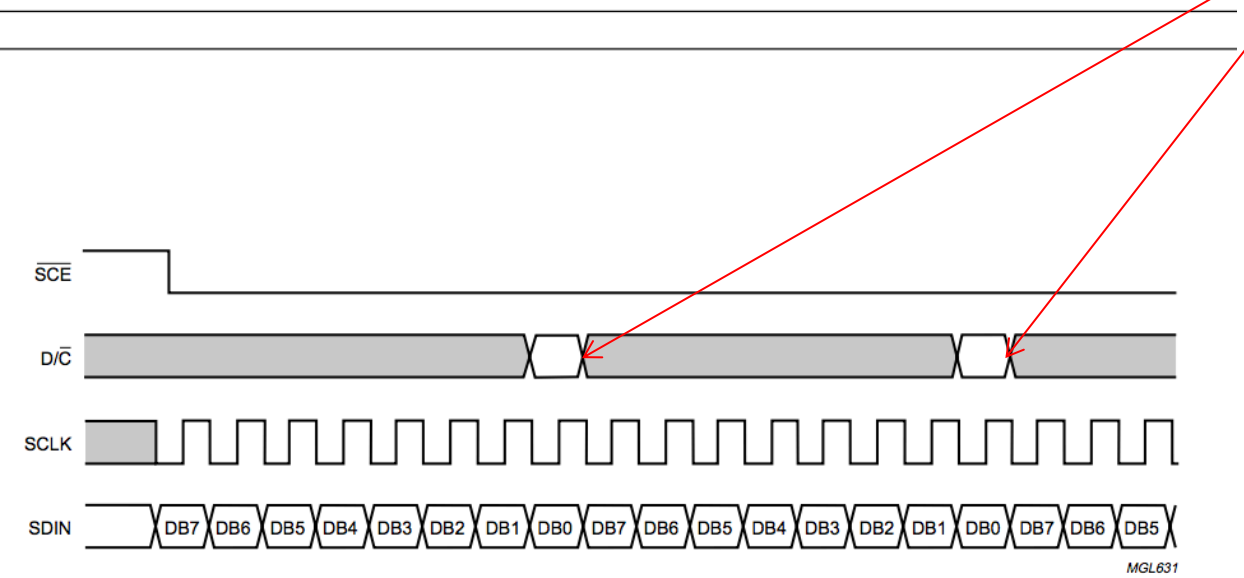



Fig.11 Serial bus protocol - transmission of several bytes.

We will use software routines (libraries) that take cake of the low level Interaction with the LCD

A library called: cab202_teensy.a

However, we will also show you how to write directly to the screen.

# What is a library?

- A library in C is a group of functions and declarations, exposed for use by other programs. The library therefore consists of an interface expressed in a .h file (named the "header") and an implementation expressed in a .c file.

- Like a .zip file, they're just a bag of object files — containing functions, of course — with a table of contents in front giving the address of each name.

- They can be static or dynamic.
  - Static are joined to the main program at compiling
  - Dynamic are referenced at compiling, but aren’t used until runtime

# Our graphics library cab202_teensy.a

- Provides a high level interface (functions) to write characters on the LCD screen.
- Similar to zdk, it will allows us to draw characters on the screen.
- How it is used?
  - Include “graphics.h” and “lcd.h” in your main.
  - Include cab202_teensy directory in your makefile (see blackboard topic 7/8)
  - Use library functions

# Our graphics library cab202_teensy.a

- Useful functions (graphics.h)
  - void show_screen(void);
    - Copy content entire screen buffer to the LCD
  - void clear_screen(void);
    - Clear/reset all the screen
  - void draw_pixel(int x, int y, colour_t colour);
    - Draw a pixel on the screen using FG or BG colours
  - void draw_line(int x1, int y1, int x2, int y2, colour_t colour);
    - Draw a line from (x1,y1) to (x2,y2) using FG or BG colours
  - void draw_char(int top_left_x, int top_left_y, char character, colour_t colour);
    - Draw a single character using FG or BG colours. Position is referenced to the top left corner of the character
  - void draw_string(int top_left_x, int top_left_y, char *text, colour_t colour) ;
    - Draw a string of character. Position is referenced to the top left corner of the character

# Our graphics library cab202_teensy.a

- Useful functions (lcd.h)
  - Void lcd_init(uint8_t contrast);
    - Initialise the screen with a value for contrast
  - void lcd_write(uint8_t dc, uint8_t data);
    - Write a byte of data to the screen
  - void lcd_clear(void);
    - Clear the screen (clear the pixels)
  - void lcd_position(uint8_t x, uint8_t y);
    - Set the address (position cursor) at the address x,y (see lecture notes **Pixel data storage** section)

# Programming the LCD

Port D, pin7 -> LCD chip select pin
Port B, pin4 -> LCD reset pin
Port F, pin7 -> LCD serial clock pin
Port B, pin6 -> LCD serial data input
Port B, pin5 -> LCD serial data/command pin

macros.h
#define SET_OUTPUT(portddr,pin)
#define SET_BIT(reg,pin)
#define CLEAR_BIT(reg,pin)

lcd.h
#define DCPIN 5 // PORTB
#define RSTPIN 4 // PORTB
#define DINPIN 6 // PORTB
#define SCKPIN 7 // PORTF
#define SCEPIN 7 // PORTD

```
void lcd_init(uint8_t contrast) {
        // Set up the pins connected to the LCD as outputs
        SET_OUTPUT(DDRD, SCEPIN);
        SET_OUTPUT(DDRB, RSTPIN);
        SET_OUTPUT(DDRB, DCPIN);
        SET_OUTPUT(DDRB, DINPIN);
        SET_OUTPUT(DDRF, SCKPIN);

        CLEAR_BIT(PORTB, RSTPIN);
        SET_BIT(PORTD, SCEPIN);
        SET_BIT(PORTB, RSTPIN);

        lcd_write(LCD_C, 0x21); // Enable LCD extended command set
        lcd_write(LCD_C, 0x80 | contrast ); // Set LCD Vop (Contrast)
        lcd_write(LCD_C, 0x04);
        lcd_write(LCD_C, 0x13); // LCD bias mode 1:48

        lcd_write(LCD_C, 0x0C); // LCD in normal mode.
        lcd_write(LCD_C, 0x20); // Enable LCD basic command set
        lcd_write(LCD_C, 0x0C);

        lcd_write(LCD_C, 0x40); // Reset row to 0
        lcd_write(LCD_C, 0x80); // Reset column to 0
}
```

See datasheet pg 14.

# Programming the LCD

Commands bytes write to the LCD

//LCD command and data

#define LCD_C 0

#define LCD_D 1

```
void lcd_init(uint8_t contrast) {
        // Set up the pins connected to the LCD as outputs
        SET_OUTPUT(DDRD, SCEPIN);
        SET_OUTPUT(DDRB, RSTPIN);
        SET_OUTPUT(DDRB, DCPIN);
        SET_OUTPUT(DDRB, DINPIN);
        SET_OUTPUT(DDRF, SCKPIN);

        CLEAR_BIT(PORTB, RSTPIN);
        SET_BIT(PORTD, SCEPIN);
        SET_BIT(PORTB, RSTPIN);

        lcd_write(LCD_C, 0x21); // Enable LCD extended command set
        lcd_write(LCD_C, 0x80 | contrast ); // Set LCD Vop (Contrast)
        lcd_write(LCD_C, 0x04);
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        lcd_write(LCD_C, 0x0C); // LCD in normal mode.
        lcd_write(LCD_C, 0x20); // Enable LCD basic command set
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        lcd_write(LCD_C, 0x40); // Reset row to 0
        lcd_write(LCD_C, 0x80); // Reset column to 0
}
```
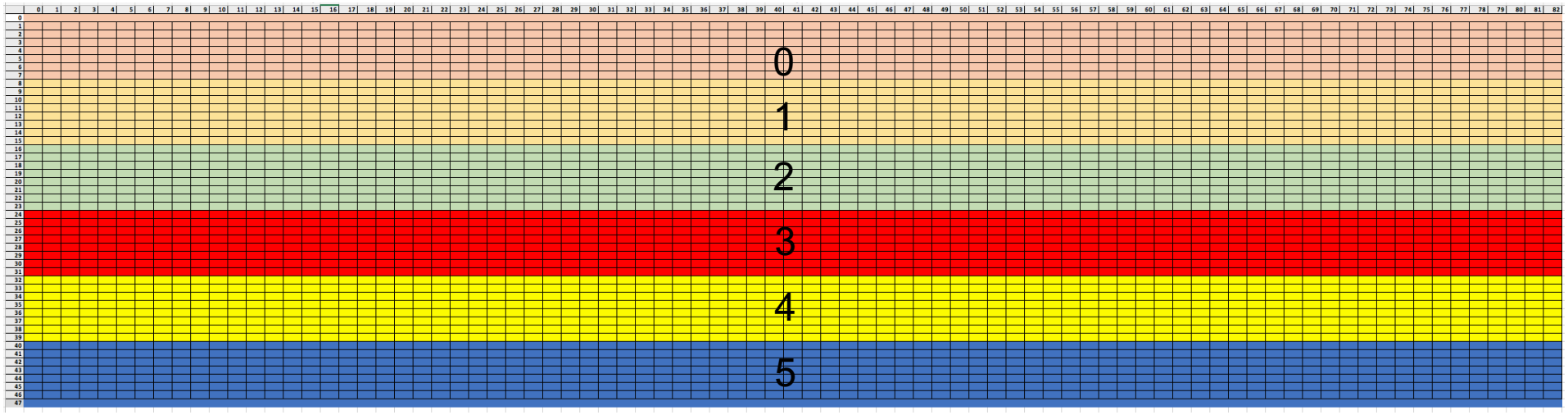
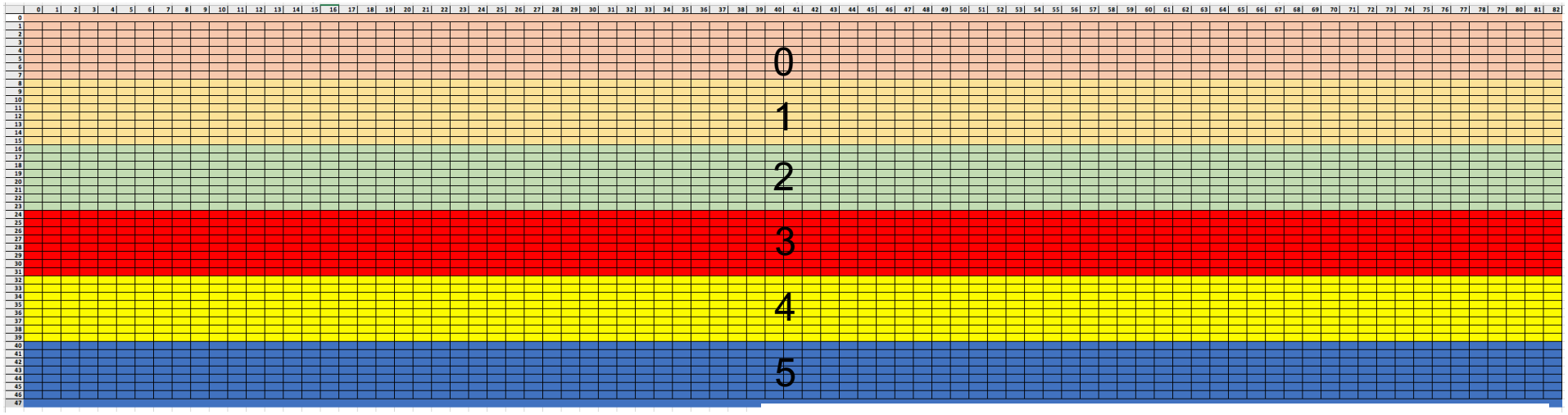

# Programming the LCD




- 6 Banks
- 84 pixels width
- 48 pixels height

# Programming the LCD



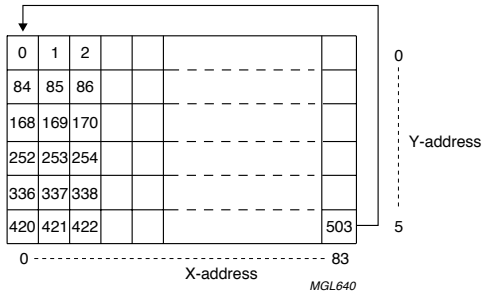




Fig.6 Sequence of writing data bytes into RAM with horizontal addressing (V = 0).

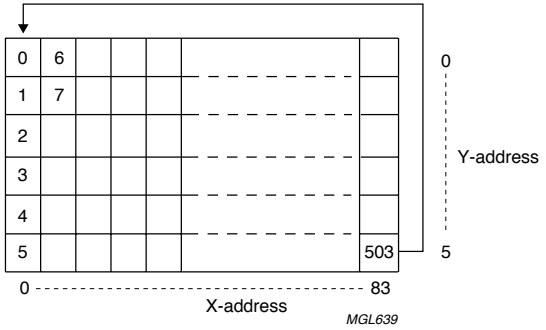
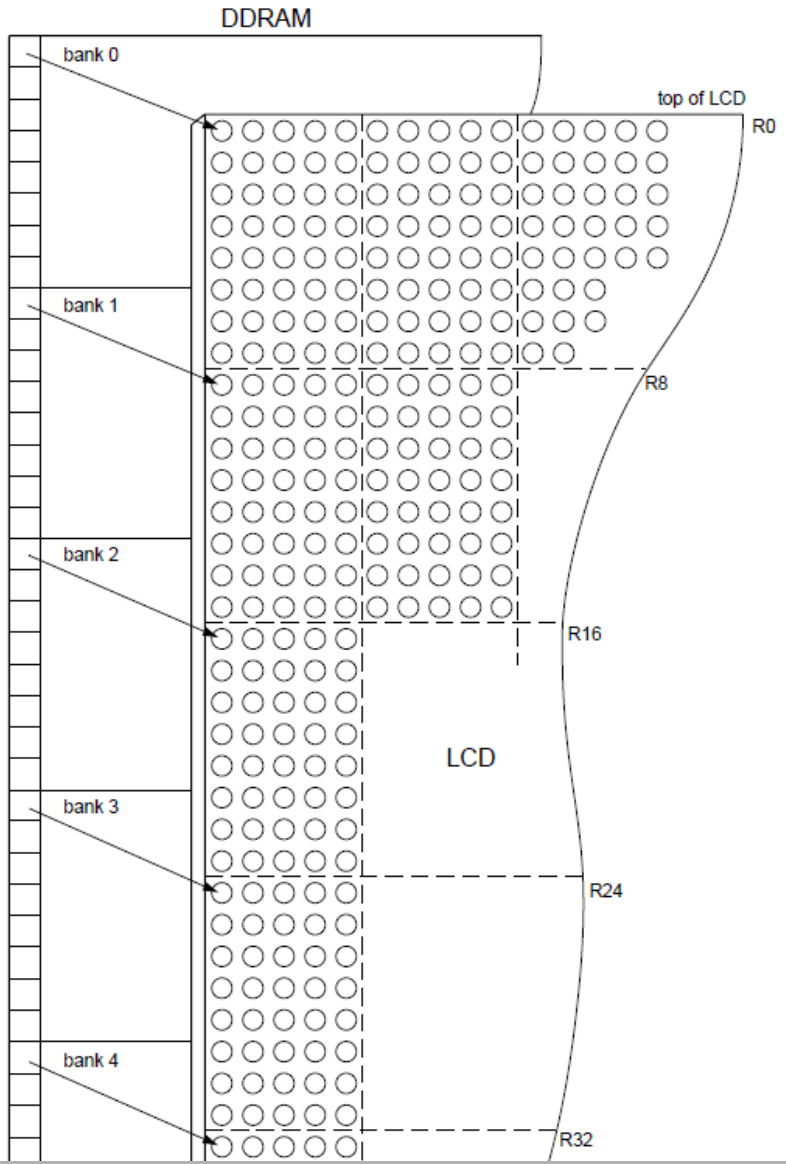



Fig.5 Sequence of writing data bytes into RAM with vertical addressing (V = 1).

# Programming the LCD




- Each bank contains a horizontal band of pixels which stretches from the left to right side of the display.
- The pixels are arranged in vertical blocks of 8, and each block of 8 pixels is packed into a byte.
- Every time we write data to the LCD display we replace a complete block of 8 pixels

# Programming the LCD

```
void lcd_write(uint8_t dc, uint8_t data) {
        // Set the DC pin based on the parameter 'dc' (Hint: use the WRITE_BIT macro)
        WRITE_BIT(PORTB,DCPIN,dc);

        // Pull the SCE/SS pin low to signal the LCD we have data
        CLEAR_BIT(PORTD,SCEPIN);

        // Write the byte of data using "bit bashing"
        for(int i = 7; i >= 0; i--) {
                CLEAR_BIT(PORTF, SCKPIN) ;
                if((data>>i) & (1 == 1)) {
                        SET_BIT(PORTB, DINPIN);
                } else {
                        CLEAR_BIT(PORTB, DINPIN);
                }
                SET_BIT(PORTF, SCKPIN);
        }

        // Pull SCE/SS high to signal the LCD we are done
        SET_BIT(PORTD, SCEPIN);
}
```

Example of using lcd_write

```
void show_screen(void) {
    // Reset our position in the LCD RAM
    lcd_position(0, 0);

    // Iterate through our buffer and write each byte to the LCD.
    for ( int i = 0; i < LCD_BUFFER_SIZE; i++ ) {
        lcd_write(LCD_D, screen_buffer[i]);
    }
}
```

# Programming the LCD

```
void lcd_clear(void) {
    // For each of the bytes on the screen, write an empty byte
    for (int i = 0; i < LCD_X * LCD_Y / 8; i++) {
        lcd_write(LCD_D, 0x00);
    }
}
```

```
void lcd_position(uint8_t x, uint8_t y) {
    lcd_write(LCD_C, (0x40 | y )); // Reset row to 0
    lcd_write(LCD_C, (0x80 | x )); // Reset column to 0
}
```

To understand lcd_position function, we need to know how pixel data is stored in RAM

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Display control | 0 | 0 | 0 | 0 | 0 | 1 | D | 0 | E | sets display configuration |
| Reserved | 0 | 0 | 0 | 0 | 1 | X | X | X | X | do not use |
| Set Y address of RAM | 0 | 0 | 1 | 0 | 0 | 0 | $Y_2$ | $Y_1$ | $Y_0$ | sets Y-address of RAM; $0 \le Y \le 5$ |
| Set X address of RAM | 0 | 1 | $X_6$ | $X_5$ | $X_4$ | $X_3$ | $X_2$ | $X_1$ | $X_0$ | sets X-address part of RAM; $0 \le X \le 83$ |
| **(H = 1)** | | | | | | | | | | |

# Programming the LCD

- To write an 8-bit block of pixel data **(pixel_block)** at screen coordinates **(px,py)**

- Get the cursor position:

```
x = px;
y = py / 8;
```

- Move LCD internal cursor:

```
LCD_CMD(lcd_set_function, lcd_instr_basic | lcd_addr_horizontal);
LCD_CMD(lcd_set_x_addr, x);
LCD_CMD(lcd_set_y_addr, y);
```

- Write the byte value:

```
LCD_DATA(pixel_block);
```

# Teensy
# Let's write some code

- Draw characters
  - TeensyBlank.c
- Draw a line
  - TeensyLines.c

  - Additional examples are provided on blackboard under Topic 8.

# Summary

- Key learning topics:
  - Basic working principle of the LCD
  - cab202_teensy library

- Example programs