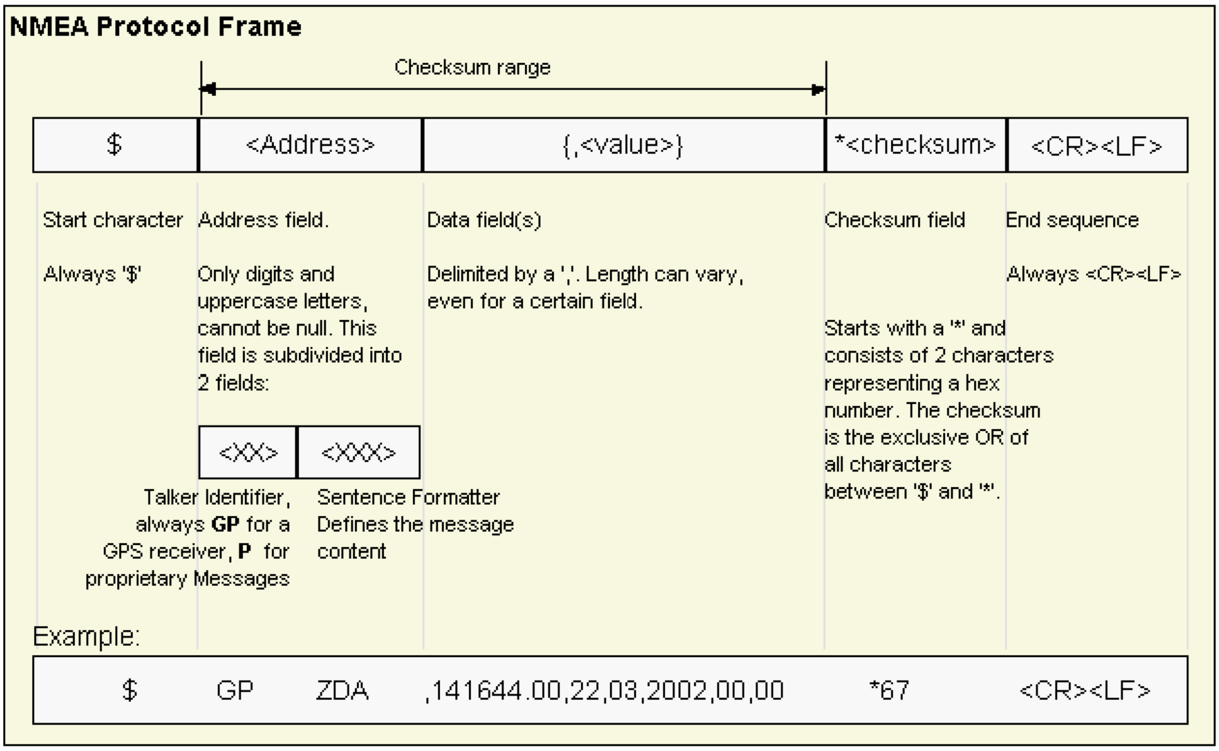
1 Design topics

- Mapping features to various modules - The functionality is separated to different modules (e.g. GPS module, Interrupt module, ...)
- Running synchronous to GPS data receiving (triggered by USART interrupt)
  - no timing/scheduling problems
  - simple integration of the basic features
  - no OS required
  - but: no complex user interaction possible (e.g. via touch screen)
- no OS is used
  - integration too time consuming
  - functions have to be reentrant
  - balancing of tasks pretty time consuming and complex (detailed design necessary)

2 The NMEA/PUBX Protocol



Start character

Always '$'

Address field.

Only digits and uppercase letters, cannot be null. This field is subdivided into 2 fields:

Talker Identifier, always **GP** for a GPS receiver, **P** for proprietary Messages

Sentence Formatter Defines the message content

Data field(s)

Delimited by a ','. Length can vary, even for a certain field.

Checksum field

Starts with a '*' and consists of 2 characters representing a hex number. The checksum is the exclusive OR of all characters between '$' and '*'.

End sequence

Always <CR><LF>

- NMEA: simple (serial) ASCII protocol (standardized)

- PUBX: proprietary NMEA extension (used for initialization)

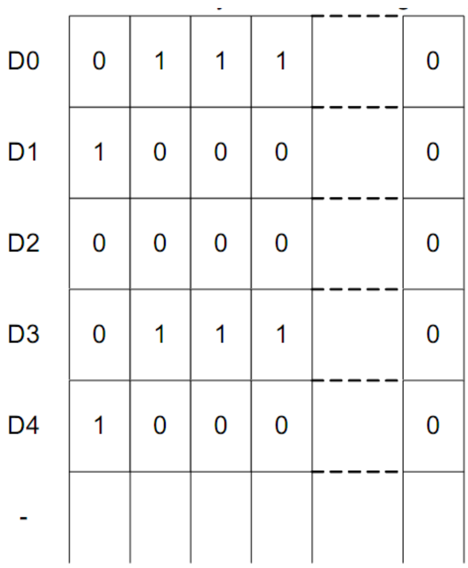
3 Components

3.1 SPI (Serial Peripheral Interface)

- simple SPI-driver
- used for communication between μC and SD chip and the display

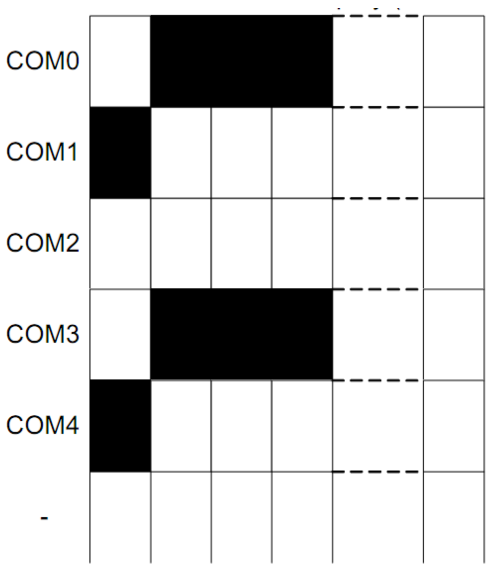
3.2 Display

3.2.1 Setting single pixels



D0	0	1	1	1		0
D1	1	0	0	0		0
D2	0	0	0	0		0
D3	0	1	1	1		0
D4	1	0	0	0		0
-						

Display data RAM



Liquid crystal display

- direct pixel access via display data RAM
- RAM is organized in pages
- total size of $(8pages * 8bit) * 132bit$ (actual only 128 bit, because of the display resolution of 128 x 64)
- internal SW buffer: sequential data structure (8 bit data type)
- positioning within the internal buffer for setting a pixel with coordinates X and Y: $INDEX = (Y * 8) + (X/8)$
- the actual bit is determined by : $BIT\_NR = Y\&0x07$ (determining the actual row within a memory page)

- Summary: the index of the data buffer represents the 'column' number within the data memory, the result of a bit-wise AND operation with Y results in the actual row of the respective memory page

Listing 1: Example: display_putpixel() function

```c
/*
 * Set/Unset a single pixel on the display
 *
 * For choosing the correct entry within the data structure (disp_ram[])
 * first the concerning page of this pixel has to be determined. This
 * is done by dividing the Y coordinate by 8 (or better: do a right shift
 * of 3 bits). For choosing the entry in the array, the X coordinate multiplied
 * by 8 (or better: left shifted by 3) has to be added to the actual page number.
 * The exact bit that shall be set/unset is determined by using the bitmask
 * (y & 0x07). This selects the exact row of the respective memory page.
 *
 * Parameters:
 *   x  X coordinate of the pixel
 *   y  Y coordinate of the pixel
 */
void display_putpixel(unsigned char x, unsigned char y, int pixel_status)
{
   if (x < DISP_WIDTH && y < DISP_HEIGHT) {
      if (pixel_status == PIXEL_ON)
         disp_ram[(y >> 3) + (x << 3)] |= (1 << (y & 0x07));
      else
         disp_ram[(y >> 3) + (x << 3)] &= ~(1 << (y & 0x07));
    }
}
```

3.2.2 Drawing BMPs/Text

- Converting BMPs into simple C-Arrays
- Text: using a 5x7 character set (organized in a simple one dimensional array)

3.3 LEDs

- simple IO access
- used as status indicator
- e.g. receiving of GPS data, recording of GPS data, ...

3.4 UART (Universal Asynchronous Receiver Transmitter)

- simple driver module
- used for communication between PC and μC

3.5 GPS

- initialization of the GPS receiver:
  - setting of the baud rate (for synchronization with the μC
  - setting refresh rate to 1 per second (receiving one data set per second)
  - selection of required data sets (RMC, GGA, VTG)
- splitting of NMEA data sets (',*' separator)
- storage into internal data structure

3.6 SDC/FAT16

- tiny open source library
- horrible code (e.g. huge amount of magic numbers, magic bit shifting with several side effects)

3.7 Touch screen