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readme.md

Lab 6

Preparation Task

LCD signal(s)	AVR pin(s)	Description
RS	PB0	Register selection signal. Selection between Instruction register (RS=0) and Data register (RS=1)
R/W	GND	LOW - WRITE to the display, HIGH READ - read from display
E	PB1	enable. This loads the data into the HD44780 on the falling edge
D[3:0]	PD3 - PD0	data pins for custom characters
D[7:4]	PD7 - PD4	Upper nibble used in 4-bit mode

What is the ASCII table? What are the values for uppercase letters `A` to `Z`, lowercase letters `a` to `z`, and numbers `0` to `9` in this table?

ASCII table is a way how to describe characters with numbers in DEC, BIN, HEX etc. Each special charracter or letter is assigned to a number. For example 'A' is represented by: DEC 65, HEX 41 and bin 100 0001.

ASCII table

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Lab results

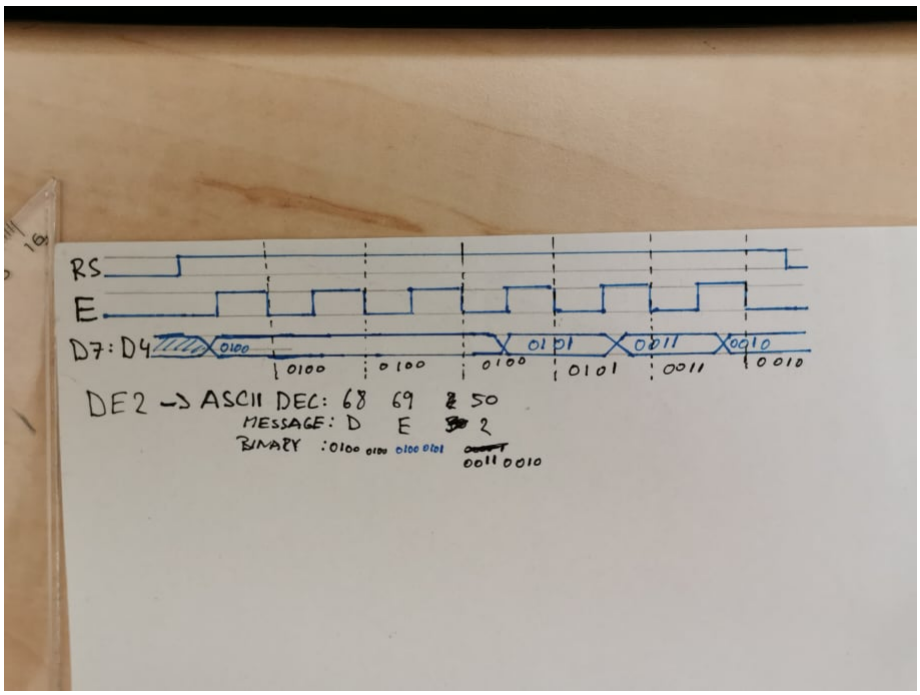
Table of functions from LCD library

Function name	Function parameters	Description	Example

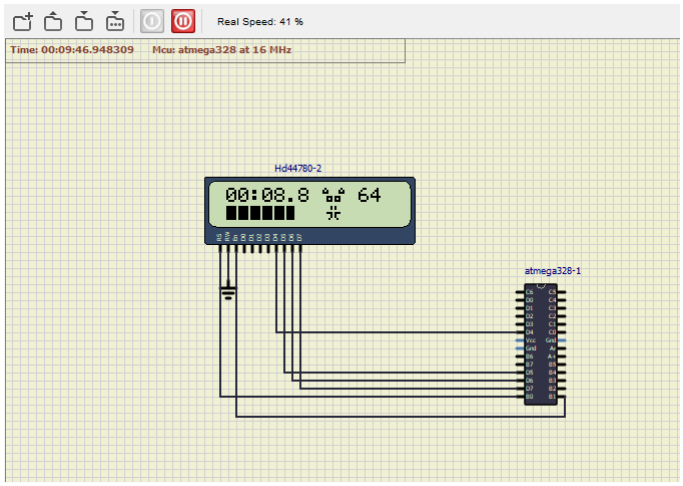
`lcd_init`	`LCD_DISP_OFF`
	`LCD_DISP_ON`
	`LCD_DISP_ON_CURSOR`
	`LCD_DISP_ON_CURSOR_BLINK`
		Display off
		Display on, cursor off
		Display on, cursor on
		Display on, cursor on, blink char
			`lcd_init(LCD_DISP_OFF);`

`lcd_clrscr`	none	Clear display and set cursor to home position.	`lcd_clrscr();`
`lcd_gotoxy`	uint8_t x, uint8_t y	set cursor's position	`lcd_gotoxy(x,y);`
`lcd_putc`	char c	Display character at current cursor position.	`lcd_putc(c);`
`lcd_puts`	string s	Display string without auto linefeed.	`lcd_puts(s);`
`lcd_command`	uint8_t cmd instruction to send to LCD controller	Send LCD controller instruction command.	`lcd_command(cmd)`
`lcd_data`	uint8_t data	Send data byte to LCD controller.	`lcd_data(data);`

HD44780 communication, message: DE2



Simulation



main.cpp

```
/* Includes ------------------------------------------------------------*/
#include <Arduino.h>
#include <avr/io.h>         // AVR device-specific IO definitions
#include <avr/interrupt.h>  // Interrupts standard C library for AVR-GCC
#include "timer.h"          // Timer library for AVR-GCC
#include "lcd.h"            // Peter Fleury's LCD library
#include <stdlib.h>         // C library. Needed for conversion function

/* Function definitions ----------------------------------------------*/
/**
 * Main function where the program execution begins. Update stopwatch
```

```
 * value on LCD display when 8-bit Timer/Counter2 overflows.
 */
//custom character
uint8_t customChar[8*8] = { //adress 0
       0b01000,0b10100,0b11100,0b00000,0b00111,0b00101,0b00111,0b10000,
//adress 1
    0b00010,0b00101,0b00111,0b00000,0b11100,0b10100,0b11100,0b00001,
//adress 2
    0b00001,0b00001,0b00000,0b00111,0b00001,0b00001,0b00010,0b00100,
// adress 3
       0b10000,0b10000,0b00000,0b11100,0b10000,0b10000,0b01000,0b00100,
// adress 4
       0b10000,0b10000,0b10000,0b10000,0b10000,0b10000,0b10000,0b10000,
// adress 5
    0b11000,0b11000,0b11000,0b11000,0b11000,0b11000,0b11000,0b11000,
// adress 6
    0b11100,0b11100,0b11100,0b11100,0b11100,0b11100,0b11100,0b11100,
// adress 7
    0b11110,0b11110,0b11110,0b11110,0b11110,0b11110,0b11110,0b11110
};

int main(void)
{
    // Initialize LCD display
    lcd_init(LCD_DISP_ON);
    lcd_gotoxy(4-1,0);
    lcd_puts(":");
    lcd_gotoxy(7-1,0);
    lcd_puts(".");
    lcd_gotoxy(10-1,0);
    lcd_puts("a");

// display custom character
 lcd_command(1 << LCD_CGRAM);
    for (uint8_t i = 0; i < 8*8; i++)
    {
        // Store all new chars to memory line by line
        lcd_data(customChar[i]);
    }
    // Set DDRAM address
    lcd_command(1 << LCD_DDRAM);

    // Display first custom character
    lcd_gotoxy(10-1,0);
    lcd_putc(0);
    lcd_gotoxy(11-1,0);
    lcd_putc(1);
    lcd_gotoxy(10-1,1);
    lcd_putc(2);
    lcd_gotoxy(11-1,1);
    lcd_putc(3);
    lcd_gotoxy(2-1,1);

    // Configure 8-bit Timer/Counter2 for Stopwatch
    // Set prescaler and enable overflow interrupt every 16 ms
    TIM2_overflow_16384us();
    TIM2_overflow_interrupt_enable();
    //timer for "progress bar"
    TIM0_overflow_1024us();
    TIM0_overflow_interrupt_enable();

    // Enables interrupts by setting the global interrupt mask
    sei();

    // Infinite loop
    while (1)
    {
    }
    // Will never reach this
    return 0;
}

/* Interrupt service routines ----------------------------------------*/
ISR(TIMER0_OVF_vect)
// progress bar
{
    static uint16_t n = 0;
    static uint8_t c = 0; //character to display
    static uint8_t pos = 0; //character to display
    n++;
    if (n >= 28) //1024 us *28 = 28.7ms --> aprox 35 times per second (display 8x5 chars per second)
    {
        c++;
        if (c > 4){ // c = 5, move cursor and reset C
            c = 0;
            pos++;
            if (pos >7-1){ // pos = 7 reset position and delete content
                pos = 0;
                lcd_gotoxy(1,1);
                lcd_puts("        "); // delete progress bar
            }
            lcd_gotoxy(pos+1,1);
            lcd_putc(c+4); // offset to correct character
        }
        else if (c == 4 ){ //this symbol was already defined
            lcd_gotoxy(pos+1,1);
            lcd_putc(0xff); // all black
        }
        else{ // c = 0,1,2
            lcd_gotoxy(pos+1,1);
            lcd_putc(c+4); // offset to correct character
        }
      n = 0;
    }

}


/**
 * ISR starts when Timer/Counter2 overflows. Update the stopwatch on
```

```
 * LCD display every sixth overflow, ie approximately every 100 ms
 * (6 x 16384us = cca 100 ms).
 */
ISR(TIMER2_OVF_vect)
{
    static uint8_t number_of_overflows = 0;
    static uint8_t tens = 0;
    static uint8_t secs = 0;
    static uint8_t secs10 = 0;
    static uint8_t min = 0;
    static uint8_t min10 = 0;
    char lcd_string[2]  = " ";
    number_of_overflows++;

    if (number_of_overflows >= 6)
    {
        // Do this every 6 x 16 ms = cca 100 ms
        number_of_overflows = 0;
        tens++;
        if (tens > 9)
        {
            secs++;
            tens = 0;
        }
        if (secs > 9){
            secs = 0;
            tens = 0;
            secs10++;
        }
        if (secs10 > 5){
            secs = 0;
            tens = 0;
            secs10 = 0;
            min++;
            lcd_gotoxy(13-1,0);
            lcd_puts("    "); //4 blank characters to reset
        }
        if (min > 9){
            secs = 0;
            tens = 0;
            secs10=0;
            min = 0;
            min10++;
        }
            if (min10 > 5){
            secs = 0;
            tens = 0;
            secs10=0;
            min = 0;
            min10 = 0;
        }

// display values
        itoa(tens,lcd_string,10);
        lcd_gotoxy(8-1,0);
        lcd_puts(lcd_string);

        itoa(secs,lcd_string,10);
        lcd_gotoxy(6-1,0);
        lcd_puts(lcd_string);

        itoa(secs10,lcd_string,10);
        lcd_gotoxy(5-1,0);
        lcd_puts(lcd_string);

        itoa(min,lcd_string,10);
        lcd_gotoxy(3-1,0);
        lcd_puts(lcd_string);

        itoa(min10,lcd_string,10);
        lcd_gotoxy(2-1,0);
        lcd_puts(lcd_string);
        //squared sec
        itoa((secs+secs10*10)*(secs+secs10*10),lcd_string,10);
        lcd_gotoxy(13-1,0);
        lcd_puts(lcd_string);
        number_of_overflows = 0;
    }
}
```