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Lab 7: Gregor Karetka

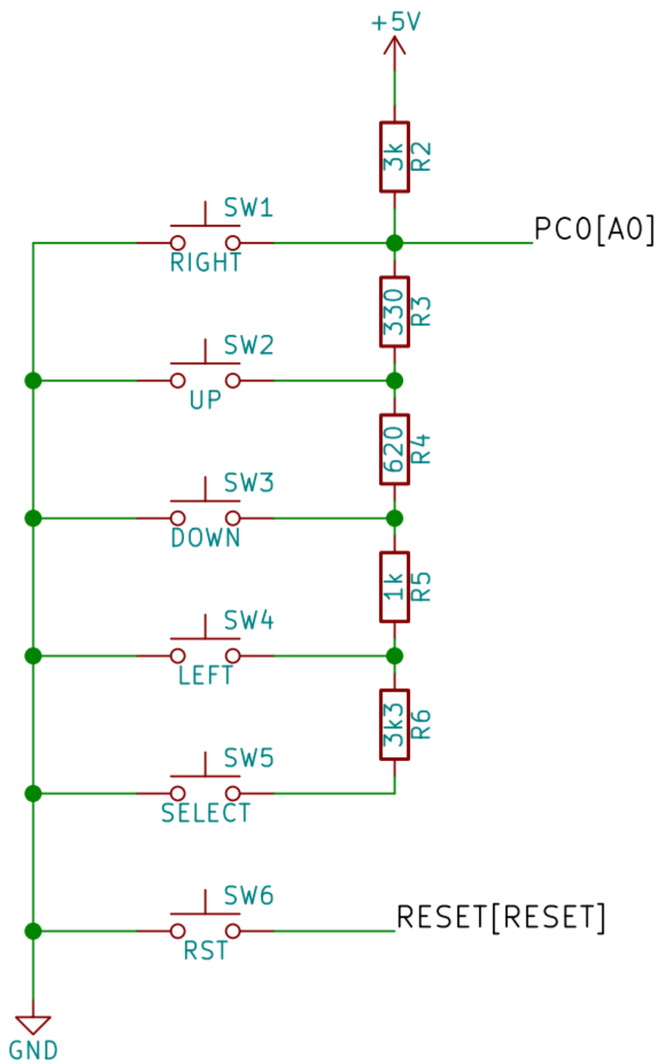
Link to your `Digital-electronics-2` GitHub repository:

https://github.com/gkaretka/Digital-electronics-2

Lab 7: ADC and UART serial communication

Preparation tasks (done before the lab at home)

1. Use schematic of the LCD keypad shield and find out the connection of five push buttons: Select, Left, Up, Down, and Right.



2. According to the connection, calculate the voltage values on pin PC0[A0] if one button is pressed at each time. In this case, the voltage on the pin is given by the voltage divider, where resistors R3, R4, R5 and R6 are applied successively.

Calculation of voltage values on pin PC0[A0] if one button is pressed at each time.

$$U_{PC0_{Right}} = U\frac{0}{R2} = 5 \cdot \frac{0\ \text{k}\Omega}{3\ \text{k}\Omega} = 0\ \text{V}$$

$$U_{PC0_{Up}} = U\frac{R3}{R2+R3} = 5 \cdot \frac{0.33\ \text{k}\Omega}{3.33\ \text{k}\Omega} = 0.495\ \text{V}$$

$$U_{PC0_{Down}} = U\frac{R3+R4}{R2+R3+R4} = 5 \cdot \frac{0.95\ \text{k}\Omega}{3.95\ \text{k}\Omega} = 1.203\ \text{V}$$

$$U_{PC0_{Left}} = U\frac{R3+R4+R5}{R2+R3+R4+R5} = 5 \cdot \frac{1.95\ \text{k}\Omega}{4.95\ \text{k}\Omega} = 1.970\ \text{V}$$

$$U_{PC0_{Select}} = U\frac{R3+R4+R5+R6}{R2+R3+R4+R5+R6} = 5 \cdot \frac{5.25\ \text{k}\Omega}{8.25\ \text{k}\Omega} = 3.182\ \text{V}$$

Calculation when no button is pressed

$$U_{PC0_{Right}} = U\frac{Inf}{R2+Inf} = 5 \cdot \frac{Inf\ \text{k}\Omega}{Inf\ \text{k}\Omega} \approx 5 \cdot \frac{1}{1} = 5\ \text{V}$$

1. Calculate the ADC values for these voltages according to the following equation if reference is Vref=5V and number of bits for analog to digital conversion is n=10.

   Calculation of ADC values for given voltage.

   $$\begin{aligned} V_{Ref} &= 5\text{V} \\ n &= 10\text{bit} \\ ADC &= \frac{U_{PC0}}{V_{Ref}} \cdot (2^n - 1) = \frac{0.495}{5} \cdot (2^{10} - 1) = 101\ [\text{-}] \end{aligned}$$

Push button	PC0[A0] voltage	ADC value (calculated)	ADC value (measured)
Right	0 V	0	todo
Up	0.495 V	101	todo
Down	1.203 V	246	todo
Left	1.970 V	403	todo
Select	3.182 V	651	todo
none	5 V	1023	todo

The operation with the AD converter is performed through ADMUX, ADCSRA, ADCL+ADCH, ADCSRB, and DIDR0 registers. See ATmega328P datasheet (**Analog-to-Digital Converter** > **Register Description**) and complete the following table.

Operation	Register(s)	Bit(s)	Description
Voltage reference	ADMUX	REFS1:0	01: AVcc voltage reference (5V), ...
Input channel	ADMUX	MUX3:0	0000: ADC0, 0001: ADC1, ...
ADC enable	ADCSRA	ADEN	1: ADC Enable, 0: ADC Disabled
Start conversion	ADCSRA	ADSC	1: Start first conversion/start conversion, 0: stop conversion
ADC interrupt enable	ADCSRA	ADIE	1: Enable interrupt, 0: Disable interrupt
ADC clock prescaler	ADCSRA	ADPS2:0	000: Division factor 2, 001: 2, 010: 4, ...
ADC 10-bit result	ADMUX	ADLAR	0: 10-bit mode(ADCH:L), 1: 8-bit mode(values stored only in ADCH)

In the lab, we are using UART library developed by Peter Fleury. Use online manual of UART library and add the input parameters and description of the functions to the following table.

Function name	Function parameter(s)	Description	Example
`uart_init`	`UART_BAUD_SELECT(9600, F_CPU)`	Initialize UART to 8N1 and set baudrate to 9600 Bd	`uart_init(UART_BAUD_SELECT(9600, F_CPU));`

Function name	Function parameter(s)	Description	Example
`uart_getc`	`void`	Get received byte from ringbuffer.	`uint8_t c = uart_getc();`
`uart_putc`	`unsigned char data`	Put byte to ringbuffer for transmitting via UART.	`uart_putc('c');`
`uart_puts`	`const char *s`	Put string to ringbuffer for transmitting via UART.	`uart_puts("msg");`

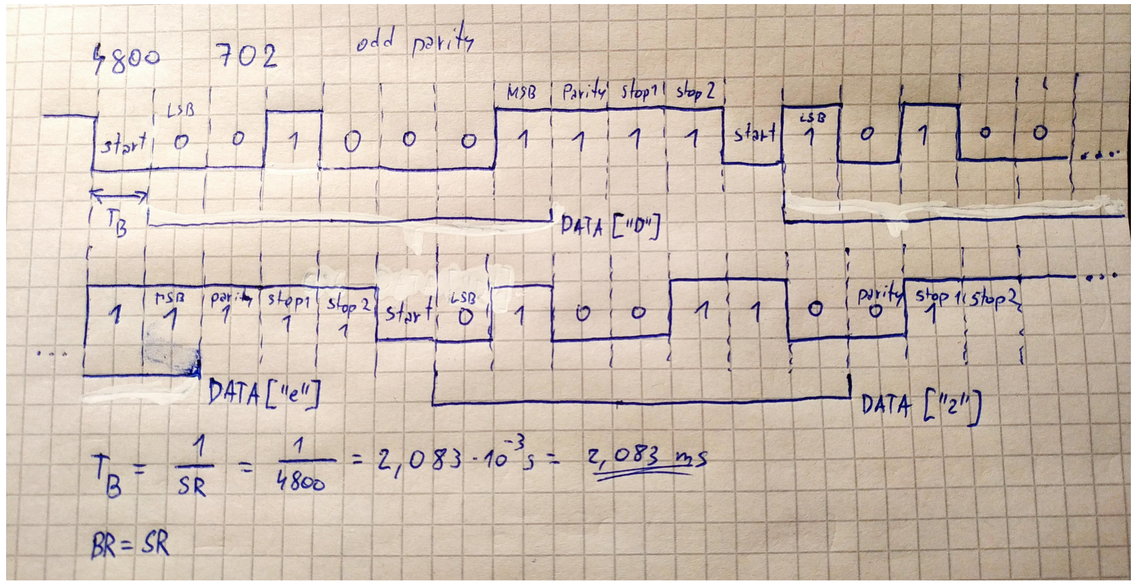
Code listing of ACD interrupt service routine for sending data to the LCD/UART and identification of the pressed button. Always use syntax highlighting and meaningful comments:

```
/*************************************************************************
 * Function: ADC complete interrupt
 * Purpose:  Display value on LCD and send it to UART.
 *************************************************************************/
ISR(ADC_vect)
{
    uint16_t value = 0;
    char lcd_string[4] = "0000";
    value = ADC;                  // Copy ADC result to 16-bit variable

    // Clear display and convert to deca (and show)
    lcd_gotoxy(8, 0);
    lcd_puts("    ");
    itoa(value, lcd_string, 10);  // Convert decimal value to string
    lcd_gotoxy(8, 0);
    lcd_puts(lcd_string);

    // UART: " value: xxxx "
    uart_puts("\033[4;32m");
    uart_puts(" value: ");
    uart_puts(lcd_string);
    uart_puts(" ");

    // Clear display and display hexa value
    lcd_gotoxy(13, 0);
    lcd_puts("    ");
    itoa(value, lcd_string, 16);  // Convert decimal value to string
    lcd_gotoxy(13, 0);
    lcd_puts(lcd_string);

    // hexa string + newline
    uart_puts(lcd_string);
    uart_puts("\r\n   key: ");

    // clear key display
    lcd_gotoxy(8, 1);
    lcd_puts("      ");

    // Display key on LCD and serial
    lcd_gotoxy(8, 1);
    if (value < 75) {
        lcd_puts("Right");
        uart_puts("Right");
    } else if (value < 150) {
        lcd_puts("Up");
        uart_puts("Up");
    } else if (value < 350) {
        lcd_puts("Down");
        uart_puts("Down");
    } else if (value < 550) {
        lcd_puts("Left");
        uart_puts("Left");
    } else if (value < 800) {
        lcd_puts("Select");
        uart_puts("Select");
    } else {
        lcd_puts("None");
        uart_puts("None");
    }

    // UART 2xnewlines
```

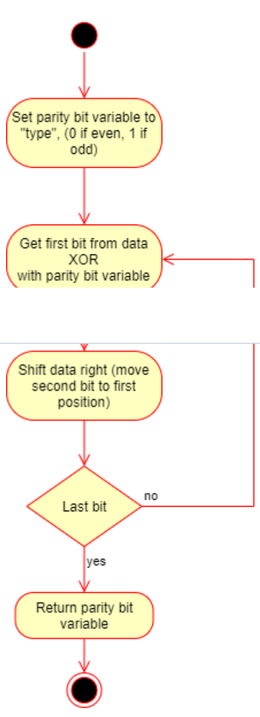
```
    uart_puts("\r\n\r\n");
}
```

UART communication

1. (Hand-drawn) picture of UART signal when transmitting three character data `De2` in 4800 7O2 mode (7 data bits, odd parity, 2 stop bits, 4800 Bd).



2. Flowchart figure for function `uint8_t get_parity(uint8_t data, uint8_t type)` which calculates a parity bit of input 8-bit `data` according to parameter `type`. The image can be drawn on a computer or by hand. Use clear descriptions of the individual steps of the algorithms.



README.md

C code for `uint8_t get_parity(uint8_t data, uint8_t type)`

```
uint8_t get_parity(uint8_t data, uint8_t type)
{
```

```
    uint8_t pbl = type;

    for (int8_t i = 0; i < 8; i++) {
        pbl = (data & 1 ) ^ pbl;
        data >>= 1;
    }

    return pbl;
}
```

Temperature meter

Consider an application for temperature measurement and display. Use temperature sensor TC1046, LCD, one LED and a push button. After pressing the button, the temperature is measured, its value is displayed on the LCD and data is sent to the UART. When the temperature is too high, the LED will start blinking.

1. Scheme of temperature meter. The image can be drawn on a computer or by hand. Always name all components and their values.