

## Tutorial 8 – I/O and Interrupts    **SOLUTIONS**

### 1. C and Assembly

Write an **assembly subroutine** "average" that can be called from the following C main program. The subroutine should calculate the average of two 8-bit values.

```
char average(char a, char b);
```

```
int main()  
{ DDRA = 0; DDRB = 0; /* input */  
  DDRD = 0xFF;      /* output */  
  
  while(1) PORTD = average(PINA, PINB);  
}
```

```
.global average ; parameters are in R24 and R22  
and: CLR R25      ; clear high byte of result R24/25  
      ADD R24, R22  
      ROR R24     ; shift right is equ. to div.-by-2  
      RET
```

**Note:** ROR has the advantage over LSR that it uses the carry-flag, in case the preceding addition has created one!

### 2. Interrupts

Write an interrupt service routine in C counting the **falling edges** on port pin E0.

```
// PIN-CHANGE INTERRUPT for Pin E0  
#include <avr/io.h>  
#include <avr/interrupt.h>  
  
char count = (char) 0;
```

```

int main (void)
{ // Init port pins
  DDRE = 0x00; // all input
  PORTE = 0xFF; // enable pullup for all pins
  DDRD = 0xFF; // all output

  PCMSK0 = 0x01; // port E0
  EIFR = 0x40;
  EIMSK = 0x40;

  sei(); // global interrupt enable
  while(1)
  { PORTD = count;
  }
}

ISR(SIG_PIN_CHANGE0)
{ if (!(PINE & 0x01)) count++;
  EIFR = 0x40; // Delete pin change interrupt
  flags
}

```

**Note:** ISR is called for **every** change (0->1 and 1->0). Reading input pin E0 and testing whether it is currently 0, makes sure to only increment the counter for the change 1->0.

### 3. Serial Transmission

Assume a serial transmission using 1 start bit, 8 data bits, 1 odd parity bit, 2 stop bits.

At a transmission speed of 9600 Baud, how long does it take to say "HI!" ?

data = 3\*(1+8+1+2) bits = 3\*12 bits = 36 bits  
time = 36 bits / 9600 bits/s = 3.75 ms

Draw the transmitted bit sequence for this message.

ASCII code for character 'u'=0x75, 'w'=0x77, 'a'=0x61

**Note** that the **lowest bit** is transmitted **first** over the serial line, so the character codes **appear** to be in **reversed order**!

