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(5) **Question 1.** C) Energy

(4) **Problem 2.** 16 bytes = 2+1 up to and including PSHA
+2 for BSR in main
+9 from interrupt PC,Y,X,A,B,CCR
+2 for BSR in handler (LowPassFilter is reentered)

(4) **Problem 3.** There is a critical section in the read-modify-write sequence in LowPassFilter.

```
$4002 F60802      LDAB  m
$400D 7B0802      STAB  m
```

(2) **Question 4.** B) Reg B

(2) **Question 5.** D) On the stack

(2) **Question 6.** D) the value is fixed and cannot be changed by the function

(2) **Question 7.** F) stored in permanent RAM

(4) **Question 8.** D) implements minimally intrusive functional debugging

(10) **Question 9.**

(3) Part a) The smallest $T_1$ is $t_{en_{max}}+tsu = 38+25 = 63\text{ns}$

(3) Part b) The smallest $T_2$ is $tw = 20\text{ns}$

(3) Part c) The smallest $T_3$ is $t_{hi}+t_{dis_{min}} = 5\text{ns}$

(5) **Question 10.**

(3) Part a) The pulse widths are 4ms, 6ms and 8ms. The greatest common divisor of these three numbers is 2ms. The width of the frame is about 18ms+a stop bit.

(2) Part b) The 10 bit frame is start+data+stop = 0 0 1 1 1 1 0 0 0 1, data bits are bit 0 to bit 7, data = 0001,1110 = $1E$

(4) **Question 11.** E) it runs slower and potentially will damage the input pin

(4) **Question 12.** If you notice a potential safety hazard, follow standard protocol and have it investigated.

(5) **Question 13.** Shannon channel capacity: $C = W \log_2 (1 + \text{SNR}) = 250 \text{ kHz} \log_2 (1 + 1000000) = 4982 \text{ kbps}$

(15) **Question 14.** Write software to measure the number rising edges on PT7.

```c
unsigned short Count;
void Ritual(void){
    asm sei             // make atomic
    Count = 0;
    DDRT_DDR7 = 0;     // input
    TSCR1 = 0x80;      // enable TCNT
    TIOS_IOS7 = 0;     // input capture 7
    TCTL3_EGR7x = 1;   // rising edge
    TIE_C7I = 1;       // arm
    asm cli            // enable
}
void interrupt 15 IC7Han(void){
    Count++;
    TFLG1 = 0x80;      // clear C7F
}
```

(10) **Question 15.** The gain is $100 = 5+200k\Omega/R_g$, $R_g = 200k\Omega/95 = 2.1 \text{ k}\Omega$. 

![Diagram](attachment://diagram.png)
(15) **Question 16.** Interface QE113 IR LED to the 9S12.

Part a) \( I_F = 100 \text{ mA}, \ V_F = 1.5 \text{V} \). The 2N2222 is selected because its \( I_{CE} > I_F \). \( V_{CE} = 0.3 \text{V} \), \( R_1 = (5-0.3-1.5)/0.1 = 32 \Omega \). \( h_f=50 \), so \( I_b = 2 \text{mA} \). We want \( V_{BE} > 0.8 \text{V} \), so \( R_2 = (5-0.8)/0.002 = 2k \), to be safe make \( R_2 = 470 \Omega \).

Part b) Show the software including the three functions and the OC6 ISR

```c
void Init(void) {
    asm sei            // make atomic
    DDRT_DDRT6 = 1;   // output
    TSCR1 = 0x80;     // enable TCNT, 8 MHz
    TIOS_IOS6 = 1;    // output compare 6
    TCTL1_OM6 = 0;
    TCTL1_OL6 = 1;    // TC6 toggle on OC
    TIE_C6I = 0;      // disarm, initially off
    asm cli           // enable
}
void interrupt 14 OC6Han(void) {
    TC6 = TC6+100;    // interrupt every 12.5us
    TFLG1 = 0x40;     // clear C6F
}
void On(void) {
    TIE_C6I = 1;      // arm, start wave
    TC6 = TCNT+20;    // soon
}
void Off(void) {
    TIE_C6I = 0;     // disarm, stop wave
}
```

Part c) The time constant of the LED (1 \( \mu \text{s} \)) is 25 times shorter than the period of the flashing software (25 \( \mu \text{s} \)); so yes, it will emit light at 40 kHz.