(4) **Question 1.** Select A,B,C,D,E,F

(4) **Question 2.** Number of stack bytes

(4) **Question 3.** Give two instructions

(4) **Question 4.** Select A,B,C,D,E,F

(3) **Question 5.** Select A,B,C,D,E,F

(3) **Question 6.** Select A,B,C,D,E,F

(3) **Question 7.** Select A,B,C,D,E,F

(4) **Question 8.** Select A,B,C,D,E,F

(4) **Question 9a.** Smallest T1

(3) **Question 9b.** Smallest T2

(3) **Question 9c.** Smallest T3

(4) **Question 10a.** Baud rate

(4) **Question 10b.** Data transferred

(4) **Question 11.** Select A,B,C,D,E,F

(5) **Question 12.** The first point of the IEEE Code of Ethics is to accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment; Give one specific example of how this might apply to embedded systems.
Wide Operating Voltage Range of 2 V to 6 V
High-Current 3-State True Outputs Can Drive Up To 15 LSSTL Loads
Eight D-Type Flip-Flops in a Single Package
Full Parallel Access for Loading

Low Power Consumption, 80-μA Max Icc
Typical tpd = 14 ns
≤6-mA Output Drive at 5 V
Low Input Current of 1 μA Max

OE does not affect the internal operations of the flip-flops. Old data can be retained or new data can be entered while the outputs are in the high-impedance state.

To ensure the high-impedance state during power up or power down, OE should be tied to VCC through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

FUNCTION TABLE
(each flip-flop)

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUT</th>
<th>(OE)</th>
<th>CLK</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>T</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>T</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>H or L</td>
<td>D</td>
<td>QO</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>X</td>
<td>Z</td>
<td></td>
</tr>
</tbody>
</table>

logic diagram (positive logic)

<table>
<thead>
<tr>
<th>(V_{CC})</th>
<th>(TA = 25{\degree}C)</th>
<th>SN54HC374</th>
<th>SN74HC374</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>MAX</td>
<td>MIN</td>
<td>MAX</td>
</tr>
<tr>
<td>(t_{clock}) Clock frequency</td>
<td>2 V</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4.5 V</td>
<td>30</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>6 V</td>
<td>35</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>(t_{W}) Pulse duration, CLK high or low</td>
<td>2 V</td>
<td>80</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>4.5 V</td>
<td>16</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>6 V</td>
<td>14</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>(t_{SU}) Setup time, data before CLK↑</td>
<td>2 V</td>
<td>100</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>4.5 V</td>
<td>20</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>6 V</td>
<td>17</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>(t_{H}) Hold time, data after CLK↑</td>
<td>2 V</td>
<td>10</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4.5 V</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6 V</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
### Parameter Table

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>FROM (INPUT)</th>
<th>TO (OUTPUT)</th>
<th>VCC</th>
<th>SN54HC374</th>
<th>SN74HC374</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>TYP</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>MAX</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNIT</td>
<td></td>
</tr>
<tr>
<td>( f_{\text{max}} )</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{pd}} )</td>
<td>CL( \overline{E} )</td>
<td>Any ( Q )</td>
<td>2 V</td>
<td>63 180 270</td>
<td>225 190</td>
</tr>
<tr>
<td>( t_{\text{en}} )</td>
<td>( \overline{E} )</td>
<td>Any ( Q )</td>
<td>4.5 V</td>
<td>17 36 54</td>
<td>45 38</td>
</tr>
<tr>
<td>( t_{\text{dis}} )</td>
<td>( \overline{E} )</td>
<td>Any ( Q )</td>
<td>4.5 V</td>
<td>14 26 38</td>
<td>32 32</td>
</tr>
<tr>
<td>( t_{\text{i}} )</td>
<td>Any ( Q )</td>
<td></td>
<td>4.5 V</td>
<td>28 60 90</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

### Voltage Waveforms

- **Pulse Durations**
- **Setup and Hold Times**
- **Input Transition Times**
- **Enable and Disable Times**

### Notes:

A. \( C_{\text{L}} \) includes probe and test fixture capacitance.
B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control.
C. Phase relationships between waveforms were chosen arbitrarily. All input pulses are supplied by generators having the following characteristics: \( f_{\text{max}} \leq 1 \text{ MHz}, Z_{\text{O}} = 50 \Omega, t_{\text{r}} = 6 \text{ ns}, t_{\text{f}} = 6 \text{ ns}. \)
D. For clock inputs, \( f_{\text{max}} \) is measured when the input duty cycle is 50%.
E. The outputs are measured one at a time with one input transition per measurement.
F. \( t_{\text{PD}} \) and \( t_{\text{PHL}} \) are the same as \( t_{\text{dis}} \).
G. \( t_{\text{PZL}} \) and \( t_{\text{PHZ}} \) are the same as \( t_{\text{en}} \).
H. \( t_{\text{PLH}} \) and \( t_{\text{PLZ}} \) are the same as \( t_{\text{pd}} \).
(4) Question 1. What fundamental electrical property is used to transfer digital data from one computer to another wirelessly.

A) Voltage  
B) Frequency  
C) Current  
D) Phase  
E) Energy  
F) Wavelength

Consider the following RTI interrupting system with its corresponding assembly code generated by a compiler (not Metrowerks). The listing includes absolute addresses. There are three permanently allocated variables: Num is at $0800, Result is at $0801 and q is at $0802. All three of these variables are initialized to 0 at start up, before main is called.

```assembly
char Num, Result;

char LowPassFilter(const char n){
    static char q=0;
    q = (n+q)/2;
    return q;
}

// called every 1.024 ms
void interrupt 7 handler(){
    Num++;
    Result = LowPassFilter(Num);
}

void main(void){
    char out;
    char p=0;
    CRGINT = 0x80; // Arm RTI
    RTICTL = 0x33; // 1.024ms
    asm cli
    for(;;) {
        out = LowPassFilter(p);
    }
}
```

```assembly
org $0800
Num rmb 1
Result rmb 1
q rmb 1
org $4000
LowPassFilter:
SEX B,Y ;n
LDAB q
SEX B,D
LEAY D,Y ;n+q
TFR Y,D
ASRA
RORB ;(n+q)/2
STAB q
RTS
handler:
LDAB #128
STAB CRGFLG
INC Num
LDAB Num
BSR LowPassFilter
STAB Result
RTI
main:
PSHA ;out
PUSH #0,1,-SP ;p
LDD #$13184
STAB CRGINT
STAA RTICTL
CLI
loop:
LDAB 0,SP ;p
BSR LowPassFilter
STAB 1,SP ;out
BRA loop
begin:
lds #$4000
clr Num
clr Result
clr m
bsr main
stop
org $FFF0
fdb handler
org $FFFE
fdb begin
```
(4) Problem 2. The `lds` instruction at `start` will clear the stack. This is all the software. Calculate the maximum number of bytes that will be pushed on the stack at any given point as this system executes.

(4) Problem 3. There is a critical section in the software system shown above. State the exact two assembly instructions between which the critical section exists.

(3) Question 4. How is the parameter `n` passed into the function? Not in general, but in this system?
   A) Reg A       B) On the stack
   C) Reg B       D) In memory location $0800
   E) Reg D       F) The compiler optimized this so much the parameter was removed

(3) Question 5. Where is the variable `out` allocated in the main program?
   A) Reg A       B) On the stack
   C) Reg B       D) In memory location $0800
   E) Reg D       F) The compiler optimized this so much the parameter was removed

(3) Question 6. What does the `const` qualifier in the function `LowPassFilter()` mean?
   A) private in scope         B) the value is fixed and can not be changed by the function
   C) stored in ROM            D) tells the compiler to fetch a new value, and do not optimize
   E) stored in global RAM     F) promoted to the next high precision

(3) Question 7. What does the `static` qualifier in the function `LowPassFilter()` mean?
   A) public in scope         B) the value is fixed and can not be changed by the function
   C) stored in ROM            D) stored in permanent RAM
   D) promoted                F) tells the compiler to fetch a new value, and do not optimize
   E) promoted

(4) Question 8. `LowPassFilter()` is called from an ISR as part of a real-time system. The SCI, and PTT are unused by the system, and all PTT pins are digital outputs. The debugging code will be placed at the end just before the return, unless otherwise stated. `SCI_OutSDec8` outputs five ASCII characters as an 8-bit signed integer at 9600 bits/sec. `Bufq` and `Bufn` are global buffers of length 100 bytes, `i` is a global variable initialized to 0. Which code would you add to perform functional debugging of this real-time system?
   A) `PTT = q;`
   B) `asm sei
     if(i<100){Bufq[i]=q; Bufn[i]=n; i++;}
     asm cli`
   C) `asm sei
     SCI_OutSDec8(q); SCI_OutSDec8(n); // busy-wait
     asm cli`
   D) `asm sei
     SCI_OutSDec8(q); SCI_OutSDec8(n); // interrupt driven
     asm cli`
   E) `PTT ^= 0x01; // at beginning
     PTT &= ~0x01; // at end`
   F) `PTT ^= 0x01; // at beginning
     PTT ^= 0x02; // at end`
(10) Question 9. The goal of this system is to allow data to be transferred from one of the flip flops FF1 FF2 FF3 to the flip flop FF4. In this particular question we will be transferring data from FF1 to FF4. In this question we will not be considering the CLK and data inputs on flip flops FF1 FF2 FF3. I.e., assume the clock inputs on the flip flops FF1 FF2 FF3 have risen and valid data loaded into the internal Q values. When O1 goes low, the data from the internal Q on FF1 is driven out on the bus. When C4 rises, that same data is clocked into FF4. Use the 74HC374 parameters with 4.5V supply.

(3) Part a) What is the smallest T1 time that can be reliably used?
(4) Part b) What is the smallest T2 time that can be reliably used?
(3) Part c) What is the smallest T3 time that can be reliably used?

(8) Question 10. The following waveform was measured on a PS0 serial input, which we think is one frame, but it might be two frames. The serial format is 1-start, 8-bit, and 1-stop bit.

(4) Part a) What is the baud rate?
(4) Part b) What data is being transferred?

(4) Question 11. A digital signal is interfaced to a microcontroller input. What happens to this digital interface when the effective capacitance to ground is increased?
   A) no change   B) the signal to noise ratio improves
   C) increase in DC current   D) the bandwidth decreases
   E) decrease in DC current   F) causes a potential back emf pulse solved by a snubber diode

end of closed book section
Open book, open notes, calculator (no laptops, phones, devices with screens larger than a TI-89 calculator, devices with wireless communication). You must put your answers on these pages. Please don’t turn in any extra sheets.

(5) Question 13. You are given a serial channel using a 100 kHz carrier frequency. The signal to noise ratio is 40 dB ($10 \cdot \log(10000) = 40$). What is the maximum possible channel capacity in bits/sec.

(15) Question 14. There is a digital signal connected to PT4. Write software to measure the number of rising edges on that signal. Show the ritual function and the input capture ISR.
(10) **Question 15.** The input, $V_{in}$, is differential, not single-ended. Design an analog circuit with a transfer function of $V_{out} = 50*V_{in} + 2.5$ powered by a single +5 V supply. You may use any of the analog chips we used in class or in lab. For example, you may use the REF03 2.50 V reference chip. The input range is $-0.05$ V to $+0.05$ V, and the output range is 0 to +5 V. Label all chips, resistors and capacitors as needed.
**Question 16.** Interface QEE113 IR LED to the 9S12. Use PT5 and output compare interrupts to create a 20 kHz modulated output, 50% duty cycle. The period of PT5 should be 50 μs. There are three public functions: `Init()` `On()` and `Off()`. The user will call `Init` once at the beginning. The IR light is initially off. If the user calls `On`, then a 20 kHz IR light will be emitted using output compare 5 interrupts. If the user calls `Off`, the OC5 interrupts are disarmed and the light is turned off. Assume the E clock is 8 MHz.

Part a) Show the hardware interface. Label all chips, resistors and capacitors as needed.

---

**Fig. 4 Normalized Intensity vs. Wavelength**

---

**ELECTRICAL / OPTICAL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Emission Wavelength</td>
<td>$I_F = 100$ mA</td>
<td>$\lambda_{PE}$</td>
<td>—</td>
<td>940</td>
<td>—</td>
<td>nm</td>
</tr>
<tr>
<td>Emission Angle</td>
<td>$I_F = 100$ mA</td>
<td>201/2</td>
<td>—</td>
<td>50</td>
<td>—</td>
<td>Deg.</td>
</tr>
<tr>
<td>Forward Voltage</td>
<td>$I_F = 100$ mA, $t_p = 20$ ms</td>
<td>$V_F$</td>
<td>—</td>
<td>—</td>
<td>1.5</td>
<td>V</td>
</tr>
<tr>
<td>Reverse Current</td>
<td>$V_R = 5$ V</td>
<td>$I_R$</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>$\mu$A</td>
</tr>
<tr>
<td>Radiant Intensity</td>
<td>$I_F = 100$ mA, $t_p = 20$ ms</td>
<td>$I_E$</td>
<td>3</td>
<td>—</td>
<td>12</td>
<td>mW/sr</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$I_F = 100$ mA</td>
<td>$t_r$</td>
<td>—</td>
<td>1000</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time</td>
<td>$I_F = 100$ mA</td>
<td>$t_f$</td>
<td>—</td>
<td>1000</td>
<td>—</td>
<td>ns</td>
</tr>
</tbody>
</table>
Part b) Show the software including the three functions and the OC5 ISR

Part c) Will the IR LED actually emit light at 20 kHz? Prove it.