Embedded Information Systems: 2nd Mid-Term Exam 08.12.2020

1. We must measure short time intervals using the dual vernier method. The period of the free-running clock is $5\,ns$, while that of the startable ones is $5.02\,ns$. From the beginning of the unknown interval till the coincidence we register 5 clock-ticks (periods), and from the end of the unknown interval till the coincidence 4 clock-ticks. Between the coincidences 3 clock-ticks (periods) of the free-running clock are registered. Please determine the length of the measured time interval (max. 4 points)!

The expression of the measured time:

$$T_x = T_0[\pm N_0 + (N_1 - N_2)(1+\delta)]$$

Here $T_0 = 5\,ns$, $N_0 = 3$, $N_1 = 5$, $N_2 = 4$, $\delta = 0.004$

$$T_x = 5[\pm 3 + (5-4) * 1.004]ns = [\pm 15 + 5.02]ns$$

Obviously only the positive value is acceptable:

$$T_x = 20.02\,ns$$

2. To provide an approximate description of a function $y(u)$ we take N measurements and we fit a model. The fitted model has the following form: $\hat{y} = \hat{y}(u) = a_0 + a_1 u + a_2 u^2$. Assuming that parameters a_0 and a_2 to be known, determine the optimum value of a_1 if the optimum is defined as the setting that minimizes $\sum_{i=0}^{N-1}(y_i - \hat{y}_i)^2$ (max. 3 points)!

$$\sum_{i=0}^{N-1}(y_i - \hat{y}_i)^2 = \sum_{i=0}^{N-1}(y_i - a_0 - a_1 u_i - a_2 u_i^2)^2$$

The optimum setting of a_1 comes from:

$$\frac{\partial \sum_{i=0}^{N-1}(y_i - \hat{y}_i)^2}{\partial a_1} = -2\sum_{i=0}^{N-1}(y_i - a_0 - a_1 u_i - a_2 u_i^2)u_i = 0$$

Where from

$$a_1 = \frac{\frac{1}{N}\sum_{i=0}^{N-1} y_i u_i - a_0 \frac{1}{N}\sum_{i=0}^{N-1} u_i - a_2 \frac{1}{N}\sum_{i=0}^{N-1} u_i^3}{\frac{1}{N}\sum_{i=0}^{N-1} u_i^2}$$

3. We apply PAR protocol within a communication channel where $d_{min} = 200\,\mu s$, $d_{max} = 1\,msec$. If the acknowledgement from the receiver does not arrive, the sender retries message-sending at maximum 4 times. Please determine the minimum of the time-out to be applied (max. 1 point)! Please determine the protocol-level value of the (a) minimum of the message forwarding time (max. 1 point), (b) its maximum value (max. 1 point), (c) its jitter (max. 1 point), (d) the value of the action delay if the knowledge of the global time is not available, and the granularity of the local clock is $10\mu s$ (max. 1 point)! Please also give the delay of the error detection (max. 1 point)!

The $timeout = 2 * d_{max} = 2\,msec$.
At protocol level $d_{minP} = 200\,\mu s$, $d_{maxP} = 4 * timeout + d_{max} = 9\,msec$, $jitter_P = 8.8\,msec$
action delay: 17.81 $msec$, delay of the error detection: $5 * timeout = 10\,msec$

4. A serial system consisting of 10 elements has equal fault rate values for each of its component. The system level MTFF is 1 year. Determine the system and the component level fault rates (max. 2 points)! If from components having this value of fault rate a parallel system consisting of 10 components is composed what will be the systems level MTFF (max. 3 points)?

For the serial system: system-level fault rate: $\lambda_s = \frac{1}{year}$, component-level fault rate $\lambda_c = \frac{0.1}{year}$.

For the parallel system: $MTFF = \frac{1}{\lambda_c}\sum_{i=1}^{10}\frac{1}{i} \approx 30\ years$.

5. To avoid the problem of hidden terminal we apply the Request To Send/Clear To Send (RTS/CTS) method. Having a bandwidth of 1 Mbit/s we must solve the transmission of 6000 bits. The time required to send RTS, CTS and ACK messages takes $0.5\,ms$ each. What is the minimum waiting time until the next message transfer of nodes not participating within the actual communication (max. 3 points)?

Transmission of 6000 bits takes $6\,ms$, thus the minimum waiting time is $(3 * 0.5 + 6)ms = 7.5ms$.

6. We apply Manchester coding for the bit sequence 1100 0110 0011 0001. Please give a graphical illustration (max. 2 points)! What is the advantage and what is the disadvantage of this coding (max. 1 point)?

For the "1"s rising edge, for the "0"s falling edge is needed, therefore it applies half bit-cell. Advantage: synchronizing code, disadvantage: "double frequency" bandwidth is required.

7. By applying parallel redundancy, we improved the availability of serial system consisting of two components with availability factor $K = 0.7$ each to a system-level availability of $K' \geq 0.8$. Please give what was the solution! Please also give the actual value of the system level availability (max. 3 points)!

Two components parallel for each:

$$K_S = [1 - (1 - 0.7)^2][1 - (1 - 0.7)^2] = 0{,}8281$$

8. The power source of a sensor-node is a battery of $3V$ having capacity of $3000mAh$. For how many days can this sensor continuously operate if the average consumption is $P = 20\,mW$ (max. 2 points)? If the intended lifetime of the sensor-node is one year, how many hours pro day can the node operate if in sleep mode the power consumption is negligible (max. 1 point)?

$$3V * 3Ah = 9Wh, \frac{9Wh}{0.02W} = 450\ hours, \frac{450}{24} = 18.75\ days, \frac{450}{365} \cong 1.23\ hours/day$$

9. Using N-version programming how many failures can be tolerated if N is an even number? What might be the advantage of such a solution (max. 2 points)? What is the condition of the applicability of recovery blocks (max. 1 point)?

$\frac{N-2}{2}$ failures can be tolerated. The advantage is the possibly higher reliability of the parallel system: If $N = 4$, then one failure is tolerated at the "price" of three correct units.

10. In a distributed system we synchronize clocks using round-trip communication. By repeating the measurements several times, we realize that the expected value of the round-trip is $10\ ms$. What can we tell about the uncertainty of this value if $d_{min} = 4.5\ ms$, and $d_{max} = 5.5\ ms$ (max. 2 points)? How large will be the uncertainty of the synchronization based on these data (max. 2 points)?

The uncertainty of the round-trip time is $\pm 1\ ms$, because it varies between 9 and 11 ms, while the uncertainty of the synchronization is $\pm 0.5ms$, because if $10ms$ is measured for the round-trip, the estimate is $5ms$, that varies between d_{min} and d_{max}.

11. The state transition matrix of a discrete-time, autonomous system is $A = diag < 0.9, -0.9 >$, its observation matrix is $C = [0.1, 0.1]$. The system is measured using an observer. Please determine the components of the corresponding observer gain matrix G to provide finite-step convergence (max. 3 points)!

$$det[\lambda I - A + GC] = 0 = det\begin{bmatrix} \lambda - 0.9 + 0.1g_0 & 0.1g_0 \\ 0.1g_1 & \lambda + 0.9 + 0.1g_1 \end{bmatrix} = \lambda^2 + 0.1\lambda(g_0 + g_1) + 0.09(g_0 - g_1) - 0.81 = \lambda^2 = 0$$

$g_0 + g_1 = 0$, $g_0 - g_1 = 9$, where from: $g_0 = 4.5$ and $g_1 = -4.5$

To pass this Mid-Term minimum 16 points are required. Good luck!