Embedded Information Systems Homework 2022

1. Comparison of Event-triggered (ET) and Time-triggered (TT) systems

We continuously measure the state variables of a complex technological process using *A*B* sensors. The signals are received and processed by communicating electronic control units (ECUs). There are *A* such units, each has *B* sensors. If the measured signal exceeds a certain limit, the computer of the operator should be informed within *B* msec. The message to be sent has a length of two bytes for each state variable, the communication overhead is 5 bytes. Between two messages 1-byte inter-message gap is required. The bandwidth of the communication channel is 1 Mbit/sec. (The parameters are given within the table below.)

1.1. By applying event-triggered operation, please investigate, about how many limit-crossings can the operator be informed in time (max *2 points*)!

1.2. By applying time-triggered operation, please investigate, to what extent the bandwidth of the communication channel can be reduced if all the state variable values are sent at the minimum frequency required (max *3 points*)!

2. Scheduling algorithms

The scheduling of the tasks to be executed on a high-performance processor is solved in run-time by a separate processor. This processor schedules the tasks periodically, at time instants given by its clock in every 2**p1* msec. The execution time of the scheduling is 0.5 msec, consequently the execution of the selected task starts afterwards. Only those tasks are considered, which at the beginning of the actual run of the scheduler are in ready-to-run state. The initial phase of the scheduler is zero, i.e., it starts running at $t = 0$.

2.1. Please show how tasks $\tau1$, $\tau2$, $\tau3$ and $\tau4$ having periods 8**p1*, 16**p1*, 32**p1* and 64**p1* msec, and computation times 2**p1*, 3**p1*, 4**p1* and 15**p1* msec, and initial phases *p3***p1*$+0.1$, *p2***p1*$+0.2$, *p1***p1*$+0.3$, and 0.4 msec, respectively, are scheduled by this scheduler using the ***Rate Monotonic*** (RM) algorithm! The initial phase means that after initialization (system start at $t = 0$) the tasks will be ready-to-run after these time delays! Please determine the processor utilization factor (max *1 point*)! Please give the schedule for that interval after which the request pattern repeats itself (max *3 points*)! Please also give the response time of the tasks (max *1 point*)!

2.2. Please give the time instants and intervals where the processor is idle (max *1 point*)! Please calculate the processor utilization factor based on these data (max *1 point*)!

2.3. Please compute the worst-case response time of task $\tau4$ for the case when the initial phases are not known! Following a proper modification, please apply the DMA analysis method to this problem (max *4 points*)! Using this method please investigate for each task separately to what extent can we increase the processing time while schedulability is guaranteed (max *4 points*)!

2.4. Please show how the ***Earliest Deadline First*** (EDF) algorithm would schedule the tasks of 2.1, if their deadlines equal to their periods, and all the further conditions remain the same (max *2 points)*!

2.5. Execution of aperiodic requests is planned to use the remaining free processor capacity. Using the RM strategy, specify a server task (max. *2 points)*!

2.6. By applying the ***Deferrable Server*** (DS) algorithm, give schedule to aperiodic requests using the server task specified in Problem 2.5! The aperiodic requests arrive at *p1***p1*$+0.1$ msec, (*p2*+10)**p1*$+0.1$ msec, and (*p3*+20)**p1*$+0.1$ msec, their computation time 3**p1* msec each (max. *3 points*).

2.7. By applying the ***Total Bandwidth Server*** (TBS) algorithm, give schedule to aperiodic requests. The aperiodic requests arrive at *p1***p1*$+0.1$ msec, (*p2*+10)**p1*$+0.1$ msec, and (*p3*+20)**p1*$+0.1$ msec, the computation time is 3**p1* msec for each (max. *3 points*).

Please give all the schedules in graphical form indicating time instants and durations exactly.

3. Dynamic Power Management

We assume that the power consumption $P(f)$ of a given CMOS processor at frequency f is:

$$P(f) = a + bf^3$$

where the unit of power is $[mW]$, and the unit of frequency is $[MHz]$. To reduce power consumption the execution frequency can be changed. The maximum available frequency is $f_{max} = 1000MHz$, while the minimum $f_{min} = 50MHz$. Changing frequency has negligible overhead and the processor can operate at any frequency between f_{max} and f_{min}. It is possible to turn the processor to the sleep mode to reduce power consumption. In this case it consumes no power. Turning the processor on to sleep mode consumes no energy. Turning the processor on to the run mode it requires additional $3 * 10^{-5}$Joule. Turning on/off the processor is performed instantly.

3.1. The energy needed to execute C cycles is $\frac{CP(f)}{f}$. There is an optimal frequency within the operation range at which the energy needed to execute any C cycles is minimum. What is the optimum frequency f_{opt} of the processor (max 2 points)?
3.2. When the processor is idle at frequency f_{min} for t seconds, then its energy consumption is $P(f_{min}) * t$. The *break-even time* is defined as the minimum interval for which it worth turning the processor off. What is the break-even time of this processor (max 2 points)?
3.3. Assuming as clock frequency f_{opt} and the processor in run state, please calculate the total energy consumption of the processor executing the tasks of Problem 2.1 for the time interval of the performed schedulability analysis/check (max 2 points)?
3.4. To reduce/minimize energy consumption, if possible, please modify the schedule without disturbing the deadlines and calculate the corresponding total energy consumption for the time interval specified in 3.3! Where it results in the reduction of energy consumption, please apply the sleeping mode! The number of cycles should be determined under the assumption that the given computation times are given for the case of clock frequency f_{opt} (max 4 points)!

Date of publishing: **September 19, 2023.**
Deadline of submission**:** **November 28, 2023.**

High quality documentation is expected: please do not submit handwritten texts if possible!
Please also indicate your name Neptun code and email!

Submission is requested to the portal: https://hf.mit.bme.hu as a single file in ***pdf*** format.

Condition of acceptance: min. **16 points** (40%). **Good luck!**

Neptun	A	B	p1	p2	p3	a	b
A8UNMW	7	40	3	6	9	10	5*10^-6
AAQ4RU	9	30	2	5	8	20	10^-5
AJ8AND	11	30	1	9	2	40	2*10^-5
ARPMPB	8	30	2	8	1	40	2.5*10^-6
BDQD5E	9	45	3	6	9	80	5*10^-6
BG6WBF	6	40	3	5	8	160	10^-5
BOI6FK	4	70	2	6	9	40	2.5*10^-6
BWTFX8	5	50	1	4	7	10	5*10^-6
BYI1SZ	6	40	2	1	4	10	5*10^-6
CBCGU0	8	40	2	8	1	20	10^-5
D6BLLW	7	40	6	8	1	40	2*10^-5
DM0BU1	8	30	3	5	8	40	2.5*10^-6
DN0EWL	12	35	1	9	2	80	5*10^-6
DOHDZF	5	50	2	1	4	160	10^-5
DXU4CS	11	30	3	1	4	20	10^-5
E7NKGO	11	30	3	4	7	40	2*10^-5
EDOXAM	9	45	1	4	7	40	2.5*10^-6
EMCKP1	8	30	3	6	9	80	5*10^-6
ERXIPV	7	40	2	1	4	10	5*10^-6

EWLQXU	5	45	2	8	1	20	10^-5
F4GLLF	8	30	6	8	1	40	2*10^-5
FCZJFD	10	40	1	9	2	40	2*10^-5
FWHEQR	4	70	2	8	1	40	2.5*10^-6
G11JWM	9	30	3	6	9	80	5*10^-6
GQ1UJJ	5	45	3	5	8	160	10^-5
GRHVN1	6	35	2	6	9	40	2.5*10^-6
H45GMC	7	40	3	5	8	10	5*10^-6
I533DB	6	35	2	1	4	10	5*10^-6
IJV1HI	12	35	2	8	1	20	10^-5
IO1PFH	5	50	6	8	1	40	2*10^-5
JQUGGW	9	45	3	5	8	40	2.5*10^-6
K1TO74	6	35	1	9	2	80	5*10^-6
K7VSWG	6	40	2	1	4	160	10^-5
L85HNB	9	35	3	1	4	20	10^-5
LUY3WR	6	35	3	4	7	40	2*10^-5
LX5RFB	11	30	3	4	7	40	2*10^-5
M5UG9O	9	45	1	4	7	40	2.5*10^-6
M7J5S8	8	30	3	6	9	80	5*10^-6
MB6J1R	7	40	3	4	7	10	5*10^-6
N514VM	5	45	3	8	1	20	10^-5
N88G93	8	30	2	6	9	40	2*10^-5
NH3KT1	10	40	1	4	3	40	2.5*10^-6
NQ66RS	4	70	5	1	4	80	5*10^-6
O2J17D	9	30	1	1	4	160	10^-5
PH8BF7	5	45	2	7	0	40	2.5*10^-6
QZFOVG	6	35	1	0	3	10	5*10^-6
RMUEW2	7	40	2	1	4	10	5*10^-6
RRBZVB	6	35	2	4	3	20	10^-5
SA8A9W	12	35	2	5	3	40	2*10^-5
SDR1AO	5	50	3	8	1	40	2.5*10^-6
US6IAV	9	45	2	7	0	80	5*10^-6
V29MNW	6	35	4	1	4	160	10^-5
V90QRZ	6	40	3	5	8	20	10^-5
VDIYN0	9	35	2	1	4	40	2*10^-5
VVUVCU	6	35	2	1	4	40	2.5*10^-6
WLVQYO	12	35	2	6	9	80	5*10^-6
WWUV17	11	30	2	6	9	10	5*10^-6
Y1G2UQ	9	35	1	6	9	20	10^-5
Y5J8ZK	10	45	3	7	3	40	2*10^-5
Y8B5KD	10	45	2	2	5	40	2.5*10^-6
YYFVWG	8	30	5	1	4	80	5*10^-6
ZVDL96	11	30	3	4	7	40	2*10^-5
ZYHB18	9	45	1	4	7	40	2.5*10^-6