jian-jia.chen [☺] tu-dortmund.de
lea.schoenberger [☺] tu-dortmund.de

Exercise for the lecture
Embedded Systems
Wintersemester 17/18

Written Exercise Sheet 3

Hints: These assignments will be discussed at E23 from 10:15 AM - 11:45 AM on 05. Dez. 2017. You are not obligated to turn in the solutions.

1 Hardware in a loop

Explain the concept "hardware in a loop". In the era of Internet of Things (IoT), for some cases, we are replacing the sensors with *human beings*. What are the potential issues when we use human beings to collect the information?

Solution: Reliability of the data may downgrade. Consistency of the data may also downgrade.

2 Internet of Things (IoT)

IoTs have become a very hot topic recently. How will you define IoT? How will IoT change the (focus of) the concept of "hardware in a loop"? If a company is very good at controlling and designing actuators, what are the challenges that the company may face if IoT become mature?

Solution: This is an open question. As the company is good at controlling and designing actuators, it may face some challenges related to the data sampling/sensor part, e.g., the reliability of the input data and the interference in the data transfer.

3 Aliasing

Do we lose information due to sampling? What is the problem due to *Aliasing*? Suppose that the incoming signal has a frequency 4000Hz, e.g., human voices. What is the minimum sampling rate we need to avoid aliasing?

Solution: Here, the incoming signal has a frequency 4000Hz. According to the Nyquist criterion, aliasing can be avoided if we restrict the frequencies of the incoming signal to less than half of the sampling rate f_s, i.e., $4000 < 0.5 f_s$. Therefore, the minimum frequency must be larger than 8000Hz.

4 Conversion

Suppose our voltage range $V_{min}..V_{max}$ is [0 V .. 4 V] and V_{ref} is 4 V. Digital values are supposed to be encoded as unsigned numbers in 4 bits. Input voltages are V_{in} = 2.3 V; 3.7 V and 1.8 V. Conversion is assumed to be done in cycles by successive approximation. Specify for each input voltage and for each step of the approximation cycles:

- the voltage used for comparison,
- the intermediate binary representation.

Solution:

Input: 2.3V		Input: 3.7V		Input: 1.8V	
inter bin	cmp volt	inter bin	cmp volt	inter bin	cmp volt
1000	2V	1000	2V	1000	2V
1100	3V	1100	3V	0100	1V
1010	2.5V	1110	3.5V	0110	1.5V
1001	2.25V	1111	3.75V	0111	1.75V

5 Pipeline analog-to-digital converter

The pipeline analog-to-digital converter is another option to digitalize analog signals.

- Describe the general functioning of a pipeline analog-to-digital converter.
- List advantages and disadvantages of a pipeline analog-to-digital converter.
- Compare the pipeline analog-to-digital converter with the well-known flash and successive approximation converters.

Hint: Browse the internet to answer this question, e.g., `https://www.maximintegrated.com/en/app-notes/index.mvp/id/1023`

Solution:

- Speed: Flash > Pipeline > Successive
- Hardware complexity: Flash > Pipeline > Successive

6 Energy and Power

Energy and power consumption are both important in embedded systems. Give concrete reasons for minimizing power consumption. Give concrete reasons for minimizing energy consumption.

Solution:

Minimizing **power consumption** is important for:

- design of the power supply and regulators
- dimensioning of interconnect and short term cooling

Minimizing **energy consumption** is important for:

- restricted availability of energy (mobile systems)
- cooling: high costs, limited space
- thermal effects
- dependability, long lifetimes

7 DVFS

Which equation describes the (dynamic) power consumption of CMOS? Let's assume that the static power consumption is 0 and the execution time is proportional to $1/f$ (not true in practice), where f is the CPU frequency. Suppose that the CPU frequency is proportional to the supply voltage. Draw the power consumption with respect to the CPU frequency. To finish the same workload by reducing the CPU frequency from 1 GHz to 0.5 GHz, how much energy can we save? If we can use $M \geq 2$ processors to finish the same workload at the same time span, draw the energy consumption with respect to M.

Solution:

- $P \propto f^3$
- 75%
- $E \propto \frac{1}{M^2}$

8 Sampling Theorem

Suppose that we sample the signals at time 0, 1, 2, 3, 4, 5, 6, 7, 8 with the following values:

t	0	1	2	3	4	5	6	7	8
values	0	1.1	1	0.3	0	-0.2	-1	-1.2	0

Explain and draw the original signal by using the *sinc()* function.

Solution: The figure is exactly the same as the figures in slides es-chen-3.4.pdf, page 13 and 14.

9 Saturating arithmetic

Suppose that the numbers in the following table are given. Please compute the result of the indicated operation using wrap-around and saturating arithmetic!

a		b		op	a op b	
(un)signed	bitvector	(un)signed	bitvector		wrap-around	saturating
signed	00011_2	signed	00110_2	+	01001_2	01001_2
signed	01110_2	signed	01111_2	+	11101_2	01111_2
signed	11110_2	signed	11100_2	+	11010_2	11010_2
signed	01010_2	signed	01011_2	*	01110_2	01111_2
unsigned	10111_2	unsigned	10110_2	+	01101_2	11111_2

10 Fixed point arithmetic

Suppose that the fixed-point numbers in the following table are given. Numbers are assumed to be signed. Please compute the result of the indicated operation!

a		b		op	a op b	
(iwl, fwl)	bitvector	(iwl, fwl)	bitvector		(iwl, fwl)	bitvector
(3,2)	00110_2	(3,2)	00110_2	+	(3,2)	01100_2
(3,2)	00110_2	(3,2)	01001_2	+	(4,2)	001111_2
(3,2)	00110_2	(4,1)	01100_2	+	(4,1)	01111_2
(3,2)	00010_2	(4,1)	00010_2	+	(2,2)	0110_2
(3,2)	00110_2	(4,1)	00110_2	*	(7,3)	0000100100_2