NTNU – Trondheim
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Department of Engineering Cybernetics

Examination in TTK4155 Industrial and Embedded Computer Systems Design

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Examination date: Wednesday 10 December 2014

Examination time (from-to): 09:00 - 13:00

Examination support material: D

Standard pocket calculator permitted.

Printed and handwritten material not permitted.

Other information:

Exam counts 60% of final grade.

Read the text carefully. Each question may have several parts.

Answers should be concise.

Language: English

Number of pages (incl. front page): 5

Number of attachments: 0

Checked by:

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Date Signature

Problem 1. (20 %)

a. Give a short definition of the concept embedded systems.

b. Why is RISC often synonymous with a so-called load/store-architecture?

c. The figure under indicates how instructions are executed in an AVR32 microcontroller. What is this mechanism called and what is the purpose?

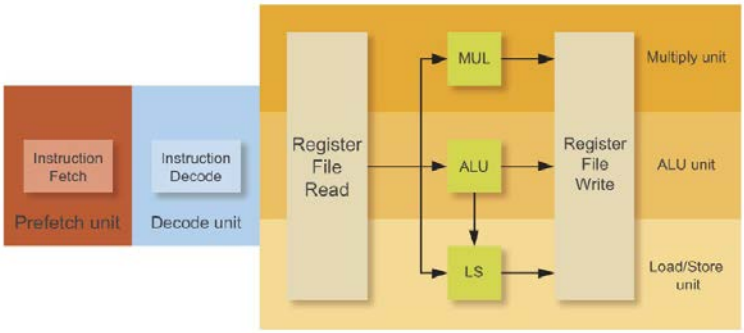

Figure 1.

d. What is an interrupt and explain briefly the purpose of this mechanism. Interrupt service routines should be programmed with short execution time. Why?

e. Some simpler microcontrollers, e.g. the Atmel AVR ATmega162, use bus multiplexing on the address/data bus. Explain why and show with a simple figure how to connect a 16 kB RAM-chip to the ATmega162's external bus interface.

Problem 2. (25 %)

a. Why should decoupling capacitors be placed as close as possible to IC supply pins?

b. Explain the basic working principle and properties of standard linear type voltage regulators. Suppose you have designed an embedded computer that draws 1 A on the 5 V and that available system voltage is 48 VDC. Make a short assessment of the consequence of using linear voltage regulator in this situation.

c. Explain what is meant by the parameters *load regulation* and *line regulation* of voltage regulators.

d. Explain the basic working principle of a SAR AD converter.

e. Mention three properties you would emphasize when selecting a microcontroller for an embedded computer that should run on an extremely low energy budget.

Problem 3. (25 %)

a. In CAN, network nodes are not addressed explicitly. CAN employs content addressing. What does this imply? Use one sentence to name an advantage of this approach.

b. How is bus arbitration handled in CAN?

c. What happens when a CAN node detects an error when receiving a message?

d. Explain with a simple figure how SPI works

e. Explain briefly the roles advertiser, scanner, broadcaster and observer in the Bluetooth LE topology.

Problem 4. (30 %)

Assume you are going to design an embedded computer for controlling the orientation of a parabolic antenna that is supposed to receive real-time high-resolution digital video from a drone (also known as UAV, Unmanned Arial Vehicle). The antenna should be controlled continuously and point as accurate as possible towards the drone in order to achieve sufficient signal quality and bandwidth for reception of the massive video stream. The drone also sends continuous information about its position, speed and heading on a separate radio link with a more moderate bandwidth. The antenna system can in this way, by knowing its own position and attitude, calculate the bearing towards the drone and in what direction the drone is heading. Orientation of the antenna is accomplished by two servo motors that controls the azimuth angle (rotation in the plane of the antenna platform, 0° - 360°) and the elevation angle from horizontal to vertical, 0° - 90°). For simplicity, it is assumed that the antenna platform is stationary, but that it can have moderate deviations in pitch and roll with respect to the earth-fixed horizontal plane (for instance by being mounted to the roof of a car, parked in sloping terrain). The motion control algorithm itself is not an issue here, but you will probably learn about it in a different course.

Further assume that:

- The system is constructed around a microcontroller of type ATmega162 (figure 2).

- ATmega162 has relatively little internal SRAM, so an external 32 kbyte SRAM is included. The external memory is needed to realize a computationally efficient regulation algorithm, for example by storing cosine tables.

- There is a dedicated sensor module for measuring the roll, pitch and yaw (compass heading) of the antenna platform. The unit does internal processing and gives the attitude of the antenna platform in the form of three analog signals in the range of 0 - 2.5 V.

- To read sensor signals, you have a 4-channel AD converter (one channel in reserve) with 16-bit resolution and a parallel bus interface. The AD converter accepts voltage signals in the range 0 – 5 V. The AD converter has an internal address space of 10

byte. The AD-converting is started when an 8-bit control word is written to the control register at address 0 in the AD converter. Address 1 is reserved for status information (status register). When the conversion has finished, the result (16-bit) will be stored in the addresses 2n+2 and 2n+3 where $n \in [0, 3]$ is the channel number. The interrupt pin of the AD converter is then pulled low. Note: The AD converter is equipped with a parallel bus interface. In other words, it must be interfaced as an I/O unit to the external address and data bus of the microcontroller as memory mapped I/O.

- The azimuth and elevation angle of the antenna is controlled by two motor controllers, one for each of the servo motors. The motor controller module takes an analog signal in the range 0 – 10 V. For the azimuth motor, the signal is adjusted to represent angles of 0° - 360°, and for the elevation motor, angles of 0° - 90°.

- To generate the motor control signals, you have a 2-channel DA converter with 10 bit resolution and parallel bus interface available. The DA converter generates voltages in the range 0 – 5 V. The DA converter has an internal address space of 6 byte, where address 0 and 1 is the control register and status register respectively. The digital value (10-bit) to be converted, is written to address 2n+2 and 2n+3 respectively, where $n \in [0, 1]$ is the channel number. The DA converter does not generate interrupts. Note: The DA converter is equipped with a parallel bus interface. In other words, it must be interfaced as an I/O unit to the external address and data bus of the microcontroller as memory mapped I/O.

- Information regarding the position of the drone, speed and direction is received by a separate system, and is then transmitted in the form of messages over a CAN-bus. This means that the antenna control system must include a CAN-controller and CAN driver. The CAN-controller that is to be used has a SPI-interface and interrupt output (open collector output).

- To determine the geographic location of the antenna, a GPS is used. The GPS module transmits positions and other information over RS-485. The UART of the micro controller together with a suitable RS-485 interface IC is used to connect these together.

- In addition, the system must be able to communicate via USB to a host computer. This is implemented using an USB interface IC, which is equipped with a SPI interface and interrupt output (open collector output).

a. Make your own further assumptions for the proper functioning of the system if necessary and describe it with a high-level block diagram (not a circuit schematic here), possibly with some simple explanations how you would design the computer. Read the specification above in detail, focus on identifying and drawing the individual function blocks that together make up the system and then sketch the interface between them using arrows.

b. Explain how you would organize the address space of the data system and develop the associated decoding logic. (Remember that in the ATmega162 the 1280 (0x0000 - 0x04FF) lowest addresses are reserved).

c. What would you do to adapt the signals between sensors/motors and AD/DA converters to optimally use the resolution?

d. Draw and explain a circuit schematic that shows how the components of the system are connected (the details can be limited to central signal lines, but the width of all buses and which ports/bit they are connected to must be shown). Specify the circuits and signals you think must be used.

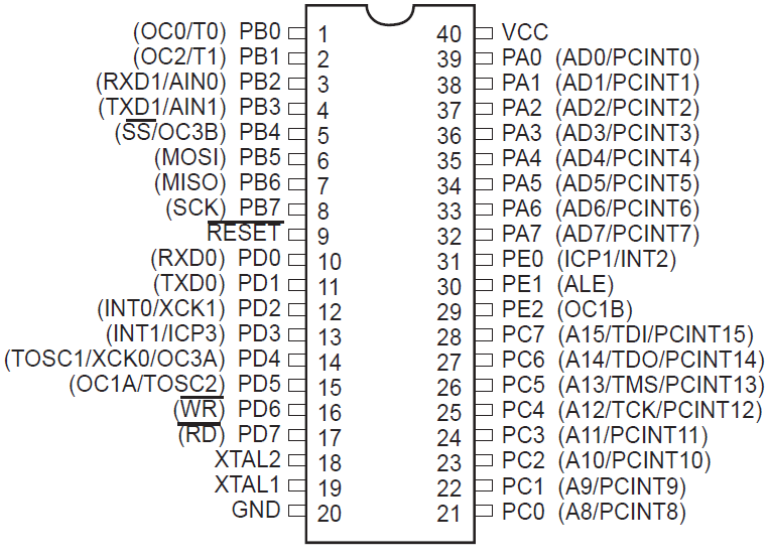

Figure 2. Atmel AVR ATmega162