[ENG07]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSc ELECTRICAL & ELECTRONICS ENGINEERING

SEMESTER 2 EXAMINATION - 2023/2024

PERVASIVE EMBEDDED SYSTEM DESIGN

MODULE NO: EEE7007

Date: Thursday 16th May 2024 **Time: 10:00 - 12:30**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

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Question 1:

a) You are tasked with developing a prototype for an embedded system using the STM32 NUCLEO-F446RE microcontroller, which is based on the ARM Cortex-M4 processor. The system requires the implementation of a digital signal processing (DSP) algorithm for real-time audio processing. Additionally, you aim to enhance the system with a basic machine learning model to classify audio signals into three categories: speech, music, and noise.

1. **DSP Algorithm Implementation**: Given the Cortex-M4's capability for efficient execution of DSP instructions, explain how you would leverage its features for optimizing the execution of a Fast Fourier Transform (FFT) algorithm used in your audio processing application. Consider the use of Single Instruction, Multiple Data (SIMD) instructions and floating-point unit (FPU) in your explanation.
2. **Machine Learning Integration**: Using STMicroelectronics' X-CUBE-AI library, describe the process of integrating a pre-trained neural network model into the STM32 NUCLEO-F446RE for classifying audio signals. Outline the steps from converting the model to integrating it with your system, and how you would utilize the library's functions for running inferences directly on the device.
3. **Debugging Features Utilization**: Discuss how you would use the advanced debugging features of STM32 NUCLEO-F446RE, specifically the real-time variable watch, to troubleshoot and optimize the performance of your DSP algorithm and machine learning model integration. Explain the advantages of being able to watch variables in real-time without halting the processor.

[15-Marks]

b) A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

[5-Marks]

Question 1 continues on the next page…

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…Question 1 continued

c) Explain the operating principle of the circuit shown in Figure 1c, which is an analog-to-digital converter (ADC) known as a Successive Approximation Register (SAR) converter. Note that DAC stands for Digital-to-Analog Converter. Describe how this SAR ADC converts an analog input signal into a digital output, mentioning the roles of the comparator, the SAR, and the DAC in the process?

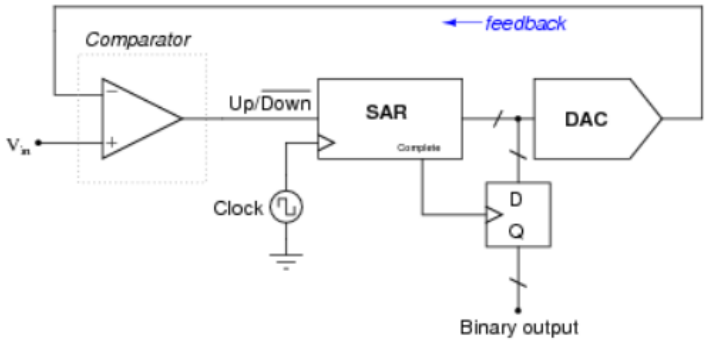

Figure 1c

[5-Marks]

Total 25 Marks

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Question 2

You are tasked with designing a low-power embedded system using the STM32 NUCLEO F446RE microcontroller for a smart agriculture project. The system requires periodic data acquisition from soil moisture and temperature sensors, and then, based on the sensor data, control a water irrigation valve and report the sensor data back to a central server via a wireless module.

a) Peripheral Configuration: Identify and briefly describe the configuration of two key peripherals in the STM32 NUCLEO F446RE that you would use for interfacing with the soil moisture and temperature sensors.

[5-Marks]

b) Power Management: Discuss one power management feature provided by the STM32 NUCLEO F446RE that could be utilized to reduce the power consumption of your embedded system during idle periods between sensor data acquisitions**.**

[5-marks]

c) Data Handling: Explain how you would manage and prepare the data from the sensors before transmission to ensure reliability and minimize power consumption.

[5-marks]

d) Wireless Communication: Choose a suitable wireless technology for transmitting the data to the central server. Justify your choice based on power consumption, range, and bandwidth requirements.

[5-marks]

e) Safety and Reliability: Propose a method to ensure that the system can recover gracefully from a power failure or unexpected reset, ensuring that irrigation control and data transmission can resume without data loss or corruption.

[5-marks]

Total 25 Marks

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Question 3

a) Explain with the help of a diagram how do the Von Neumann and Harvard computer architectures differ in terms of memory structure, execution of instructions, communication paths, and their impact on computational efficiency and design?

[16 Marks]

b) Discuss any three differences between Static Ram and Dynamic RAM

[9 Marks]

Total 25 Marks

Question 4

a) A 3-bit ADC system voltage ranges between 0 to 16 V, answer the following questions. Show your calculation clearly in each question. Indicate the unit clearly, if appropriate.

[10 marks]

b) If the ADC reading is 6, what will the range of the measured voltage be?

[5 marks]

c) Draw the graphical representation of quantization levels. Clearly indicate the voltage on the Y-axis, the voltage range, the digital level, and the numeric level.

[10 marks]

Total 25 marks

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Question 5

a) Discuss the interrupt handling mechanisms used in the ARM Cortex-M architecture. Explain how interrupts are prioritized, how they are handled, and how they are serviced by the CPU. Give an example of how interrupts could be used in an embedded system.

[15 marks]

b) Explain the role of the memory management unit (MMU) in the ARM Cortex-M architecture. Discuss the benefits of using an MMU in embedded systems and how it can be used to protect against security threats.

[10 marks]

Total 25 marks

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Question 6

a) Suppose you are working on a project that involves an embedded system utilizing a digital-to-analogue converter (DAC) to convert digital signals into analogue voltages. The DAC in question has a resolution of 12 bits and is designed to provide an output voltage range from 0 to 3.3 volts. If the digital signal is represented by the value 2048, what is the corresponding output voltage from the DAC?

[5 marks]

b) Suppose you are developing an embedded system designed to control a high-power LED array via a specific LED driver circuit. The LED driver circuit necessitates a minimum activation current of 20 mA. The microcontroller used in the embedded system can supply a maximum current of 4 mA per output pin. Given that each output pin's state (high or low) can be used to activate the LED driver circuit, what is the minimum number of output pins required from the microcontroller to adequately drive the LED driver circuit?

[5-Marks]

c) Convert the octal number 343 into a binary number by using the 3-binary digits method. Show your steps clearly.

[5 marks]

c) A 10—bit ADC has a full scale of 10.230 V, when the digital output is (11 1111 1111). The quantization Error of the ADC in mV is how much?

[10 Marks]

Total 25 marks

END OF QUESTIONS