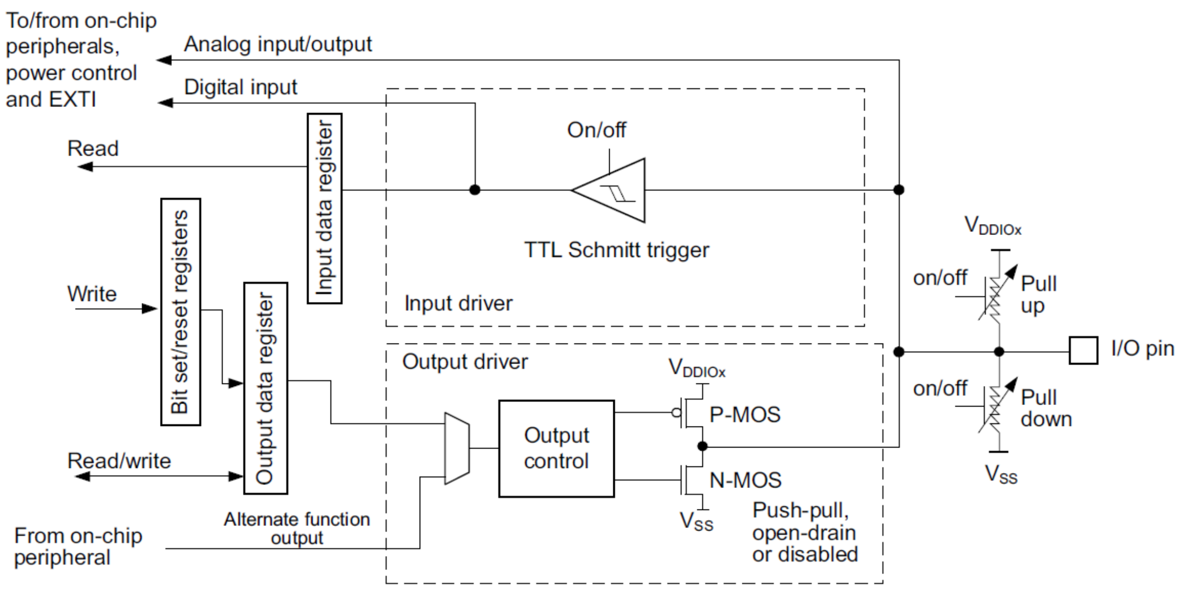
Electronics System Design – Mid Semester Exam (Feb 2025)

Please note the following:

1. Please attempt any 10 questions from the below set of questions.
2. Each question is for 4 marks. Total exam score is 40 marks
3. Maximum time for exam is 90 minutes

Q1. Draw the approximate internal diagram of a GPIO of the STM32 MCU showing clearly the Input and Output path. Add few lines of explanations

Diagram: (2 mark for diagram)



Key words: (0.5 marks for each point)

a. Push-Pull & Open-Drain output
b. Schmitt trigger at the input
c. Pull-up and Pull-down at the input
d. Direct Analog input

Input Path: (0.5 mark for each)

a. Digital: Input PU / PD and then Schmitt trigger and input register
b. Analog Input: Direct from the IO pin
c. Output: Output register to Push-Pull MOS combinations (P-MOS and N-MOS)

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Q2. What is the process of designing an Embedded system. Specify different stages of this design process with suitable examples in the explanation of all the stages.

[ANS]

1. Conceptualization & Feasibility Analysis: Making block diagram of the design showing clearly input and output interfaces. The Block diagram may include the power supply levels and interfaces
   Key words: Block diagram (0.5 mark). Power supply, Interfaces (0.5)

2. Hardware design: This includes schematics design and making them in tools like KiCad, Altium, OrCAD, PCBpro,…Once the schm is completed, the layout of the PCB is done generating gerbers and BOM, Then the PCBs are soldered and assembled.

   Key words: Schematics & Layout. (1 mark). Examples: (0.5)

3. Firmware/Software design
   Writing the software which will run on the embedded CPU. This would mean in most cases writing code in C and using Compiler, assembler and linker to generate the machine code.for example STM32Cube package using CubeMxIDE
   Key words: C or Assembly code (0.5). Examples: (0.5)

4. Integration and packaging
   Integrating all the hardware and software together to make the final proto design.

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Q3. State the differences between x86, ARM and RISC-V architectures in a table with minimum 4 points.

[ANS] 1 Mark for each row.

S.no	Feature	ARM	X86	RISC-V
1	Power Efficiency	High	Low	High
2	Performance	Moderage	High	Low/ Varies
3	Ecosystem	Mature	Mature	Emerging
4	SOC Customization	Low	Low	High
5	Applications	Embedded systems, Mobile devices	PCs and Servers	Embedded System

Q4. How would you explain the STM32 MCU toolchain and ecosystem. What benefit does it provide for the developers ? Write in bullets explaining them in minimum 3 points.

[ANS]

The MCU toolchain and ecosystem is a set of tools **including hardware and software** and **toolchains** to support them. In summary MCU ecosystem provide everything needed for embedded development using specific MCUs. The STM32 has it's own ecosystem which constitutes of the following:

The ecosystem consists of:
Boards: **Nucleo boards** (prototyping), Discovery (feature-rich), Eval kits (industrial)
Firmware examples: **STM32Cube packages**
Cloud & IoT: AWS, Azure, STM32 IoT kits.
Security: TrustZone, Secure Boot, X-CUBE-AI.
Community: ST forums, GitHub, extensive documentation.

a. IDEs: **STM32CubeIDE** (Free), Keil, IAR
b. Compilers: GCC (free), ARM Keil/IAR (optimized)
c. **Debugging/Programming**: ST-Link, J-Link, OpenOCD.
d. **STM32CubeMX**: GUI tool for peripheral configuration.
e. Middleware & Libraries: HAL/LL drivers, FreeRTOS, USB, TCP/IP, AI support.

The advantages of this toolchain and ecosystem are that it simplifies development (pre-built tools and libraries), highly scalable and versatile, strong debugging and optimization and a large community support
STM32's ecosystem makes embedded development faster, easier, and more efficient for everything from IoT to industrial automation.

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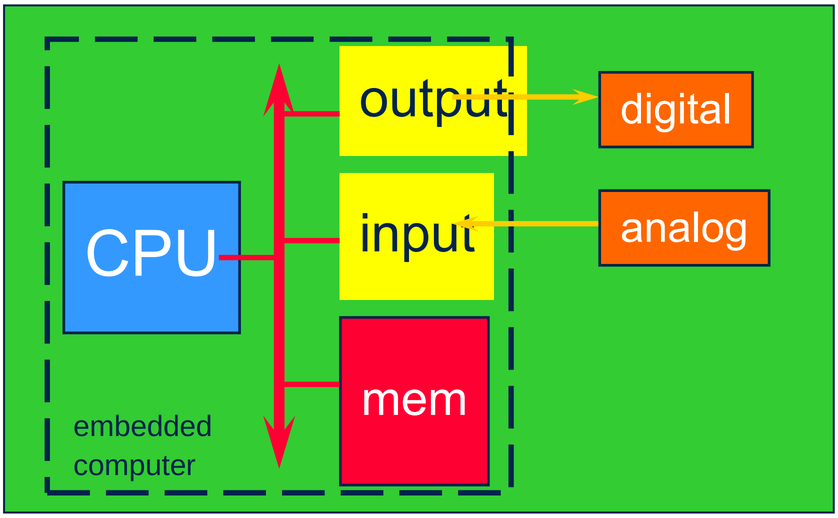
Q5. How do you define Embedded Systems ? How is it different from a Smartphone ? List minimum 4 differences.

[ANS]

A. Embedded Systems Is a combination of **hardware and software**, and perhaps additional mechanical or other parts, designed to perform a **dedicated** function. It can be said as a dedicated computation system which has been developed for some particular reason. The Embedded systems may work independently or attached to a larger system to work on a few specific functions. These embedded systems can work without human intervention or with little human intervention.



<u>Examples</u>: Digital Thermometer, BP Machine, Industrial Automation System, Antilock Braking System (ABS) in a car, Home appliances

Key words: HW + SW, Dedicated Function, Specific Purpose, **(Each point: half mark)**
Example: 1 Mark

B. Embedded systems are tailored for specific tasks with real-time efficiency, while smartphones are powerful, multi-functional devices for general use.

Any 4 differences can be taken for half mark each

Aspect	**Embedded System**	**Smartphone**
Purpose	Designed for a specific task or function	Multi-purpose device for communication, multimedia, and apps
Operating System (OS)	May run on a Real-Time Operating System (RTOS) or no OS	Uses advanced OS like Android or iOS with graphical interfaces

User Interface (UI)	Often minimal or absent (LED indicators, buttons), graphic display	Touchscreen, apps, camera, and multimedia UI
Connectivity	Limited to specific interfaces like UART, SPI, I2C, or CAN	Supports Wi-Fi, 4G/5G, Bluetooth, GPS, etc.
Power Consumption	Optimized for low power, often battery-efficient	High power consumption with frequent recharging
Real-time Performance	Designed for real-time operation with strict timing constraints	Not typically real-time, but supports multimedia and communication
Processing Power	Low to moderate processing power (e.g., ARM Cortex-M)	High processing power with multi-core CPUs and GPUs
Cost	Generally low-cost for mass production	Expensive due to advanced components and software

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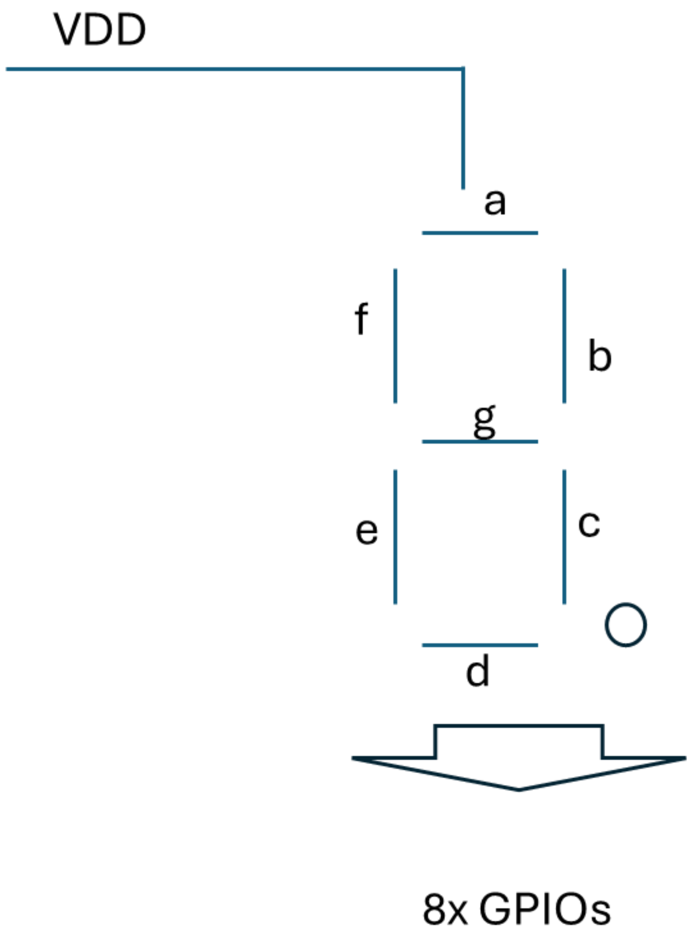
Q6. How would you interface a 7-Segment LED display with internal Common Anode configuration using GPIOs of an MCU ? How would you write numbers 3, 6 on it ?

[ANS]

Taking following inputs and expected connections

a. Common Anode configuration.
   This common Anode can be connected to VDD or MCU or via PMOS/PNP transitor (0.5 Marks)
b. 7 Segments LED cathodes connected to GPIOs. Current limiting resistances on each Cathode. (0.5 Marks)
c. 8th optional segment which is dot connected to GPIO too (0.5 Marks)

Diagram: 1 Mark



To draw:

3 : Segment a, b, c, d, f will glow. MCU shall put LOW on these segments (0.5 Marks)

Segment e,f shall be Off. MCU shall put HIGH on e,f (0.5 Marks)

6: Segment a, f, e, d, c,g will glow. MCU shall put LOW on the IOs connected to Cathode of these segments (0.5 Marks)

Segment b shall be Off. MCU shall put HIGH on it (0.5 Marks)

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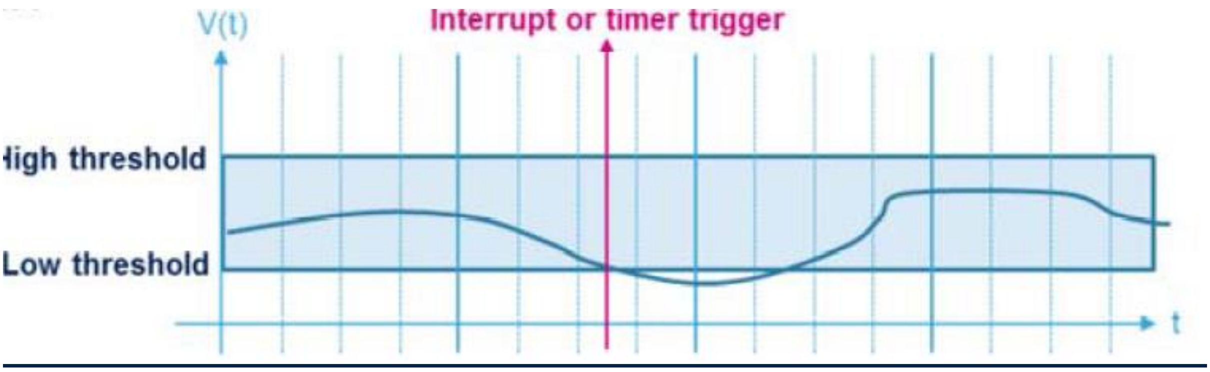
Q7. How would an Analog watchdog work for STM32 ADC ? Draw the diagram and events associated.

[ANS] The STM32 Analog Watchdog ADC Mode acts like a window comparator for the analog channels during the ADC operation It continuously monitor over and under voltage threshold conditions. If the analog input voltage goes out of the **configured** voltage window, the AWD will trigger an interrupt.

Key words: Upper Threshold, Lower Threshold Comparison, Event Generation, Configurable (0.5 marks for each key word)



Key words/actions expected: Upper threshold line, lower threshold line, ADC signal changes, Interrupt/event on upper and lower touch of the line (0.5 marks for each point covered)
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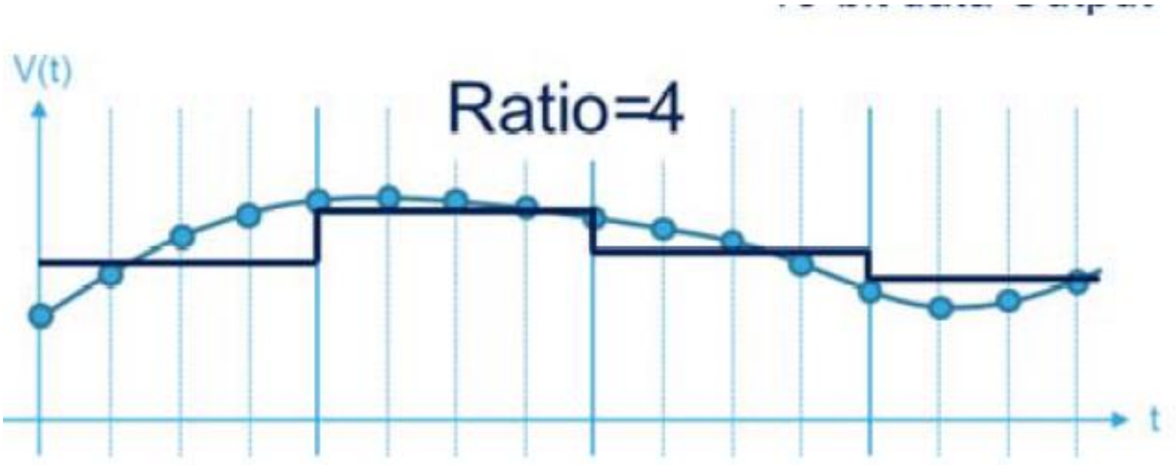
Q8. What is over sampling in ADC. What benefits does it provide for the ADC feature? With changing input signal, how would over-sampling work ?

[ANS]

Oversampling is a technique used in Analog-to-Digital Converters (ADCs) where the input signal is sampled at a rate much higher than the required Nyquist rate (twice the maximum frequency of the signal). Instead of taking a single sample, the ADC takes multiple samples over a short period and then averages them to produce a final output.

The ADC can sample by 2 to 256 times without CPU support. The converted data is accumulated in a register and the output can be processed by the data shifter and the truncater. This functionality can be used as an averaging function or for data rate reduction and signal-to-noise ratio improvement as well as for basic filtering.

Diagram:



Key words: Higher sampling, Increased resolution or better results, hardware averaging, Better Signal/Noise ratio, good for slowly changing signal, slower conversion, reduced CPU requirement (0.5 marks for each key word/feature mentioned.
Diagram: 2 marks, he multiple sampling shall be visible (0.5) and final result line (0.5) which is similar to solid blue above is expected. Changing signal shall be shows (0.5)

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Q9. What are differences between MCU and MPU. Answer in table with 5 points and add suitable examples.

Feature	MCU	MPU
1. Architecture	All-in-one: CPU, RAM, ROM, I/O, and peripherals integrated on a single chip.	Only the CPU; requires external RAM, ROM, and peripherals.
2. Processing power	Optimized for low-power and real-time tasks with lower clock speeds (MHz range).	Higher processing power (GHz range) for complex applications like OS-based systems.
3. Memory management	Fixed internal Flash & RAM, Very low options for external memory interface.	Uses external DDR RAM with MMU (Memory Management Unit) for multitasking.
4. Applications	Used in embedded systems, IoT, automotive, industrial automation.	Found in smartphones, computers, and high-end embedded systems with OS.
5.Power consumption	Low power consumption, suitable for battery-powered devices.	Higher power usage due to external memory and higher clock speeds.
Examples	STM32, ATmega328 (Arduino), ESP32	ARM Cortex-A series (Raspberry Pi), Intel Core i5, AMD Ryzen

Notes: 0.5 marks for each point, 1 mark for examples.

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Q10. You are asked to design a smart-remote controller for Air-conditioner. What would be your design considerations ? Which communication technology would you use to replace the IR interface ? Justify.

[ANS]

For designing a smart remote controller for an Air Conditioner (AC), we need to consider what hardware, communication (connectivity features), user interface, and smart features we will use.

Design considerations: (Max 2.5 marks, 0.5 marks per point)

1. Remote is battery powered
2. Need to use low power MCU
3. Buttons for the inputs
4. Possibly a small display
5. Voice interface
6. Possibly Temperature & Humidity Sensors on remote

Communication Technology for replacing IR (1.5 mark, 0.5 marks for each point)

1. Bluetooth Low Energy can be used.
    a. Need to use low-power communication due to battery operations
    b. Bluetooth Low Energy can be used.
    c. Reliable short-range control available in BLE
    d. Easy mobile app pairing can be done
    e. BLE is ideal for short-range control

Q11. You have to design a digital CCTV surveillance camera to upload the images of 640 pixel by 480 pixel per picture. Consider 2 bytes information per pixel. The frame rate asked by customer is 20 fps for remote monitoring using Smart-phone. Make a block diagram and explain the design blocks with reasoning.

[ANS]

Image resolution : 640 x 480

Image size : 640 x 480 x 2 Bytes: 614 KBytes

Fps : 20

Total data rate per second: 12.28 MBps (0.5Mark)

Block Diagram:

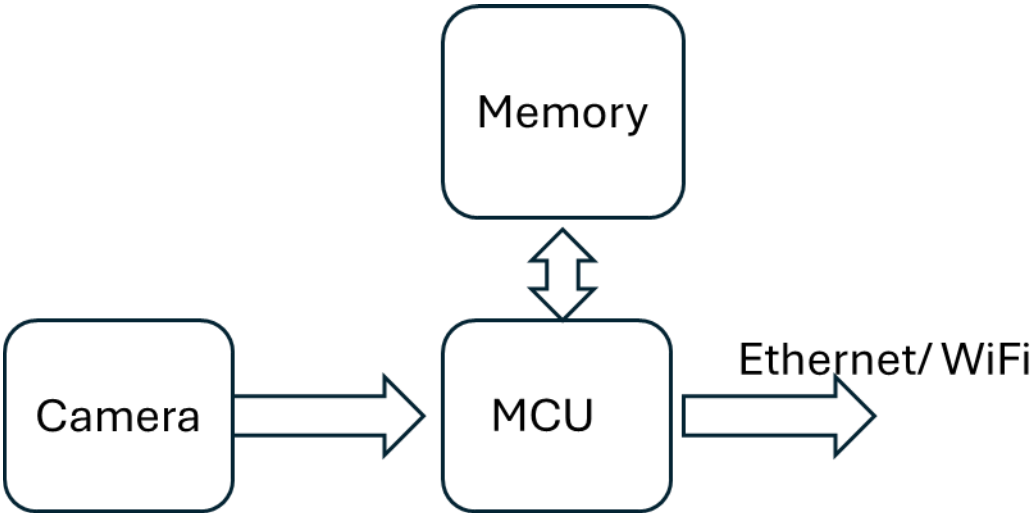
Input: Camera Sensor (0.5Marks)

MCU: High performance to handle high data rate (0.5Marks)

Interface: WiFi or Ethernet (0.5Marks).

External Memory: Additional memory may be needed for storing the images (0.5Marks).

Reason: Only Ethernett or WiFi can handle such high speed of the data handling (1 Marks)



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Q12. A General purpose MCU datasheet mentions the following specifications

	Symbol	Min	TYP	Max	Unit
Standard operating voltage	VDD	1.7		3.6	V
User external clock source frequency	F_{HSE_ext}	4	8	48	MHz
Absolute maximum external supply voltage	VDD	-0.3		4.0	V

Consider:

a. Possible 10% error in power supply connected to MCU VDD
b. Consider possible 5% tolerance in XTAL frequency

Designer decides to use this MCU in a circuit with following conditions. What would you comment on the design choices used by designer. Justify with reasons

a. Using external crystal of 44MHz, MCU is powered by 3V supply
b. MCU is powered at 1.8V, connected to external crystal of 8MHz.
c. Using external crystal of 4MHz at 3.7V
d. Using external crystal of 10MHz at 1.8V

[ANS]

a. Using external crystal of 44MHz, MCU is powered by 3V supply

[ANS] 44Mhz crystal can have minimum 44MHz-5% or 44MHz+5% [0.5 Mark]

minimum frequency can be 41.8MHz

maximum frequency can be 46.2MHz

Frequency range is **within the specification** of Specifications.

For 10% error in supply, the variation can be 3V +- 10% = 2.7V to 3.3V

So, entire supply range is within the operation range of MCU [0.5 Mark]

In this case, the design is good/OK

b. MCU is powered at 1.8V, connected to external crystal of 8MHz.

[ANS] Supply range is 1.8V +- 10% = 1.62V – 1.98V

Since lower range of the supply is out of operating range of the MCU, the design is not good and may FAIL [0.5 Mark]

The XTAL is 8MHz and can vary 8MHz +- 5% = 7.6 – 8.4MHz

The XTAL frequency is within the MCU range. [0.5 Mark]

c. Using external crystal of 4MHz at 3.7V

[ANS] The XTAL is 4MHz and can vary 4MHz +- 5% = 3.8 – 4.2MHz

The lower size of frequency is out of operating range of the MCU. The design will FAIL [0.5 Mark]

For Voltage

3.7V would vary between 3.7 +- 10% = 3.33V- 4.07V

The upper side of variation is out of operating range of the MCU. The design will FAIL [0.5 Mark]

d. Using external crystal of 10MHz at 1.8V

The XTAL is 10MHz and can vary 10MHz +- 5% = 9.5 – 10.5MHz

This range is within the operating range of MCU, So, design is OK. [1 Mark]