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Feb 22, 2024, 12:30-1:45pm. This is a closed book exam, with one 8.5 by 11-inch crib sheet (double sided). You have 75 minutes, so please allocate your time accordingly. No calculators allowed. ***Please read the entire quiz before starting***.

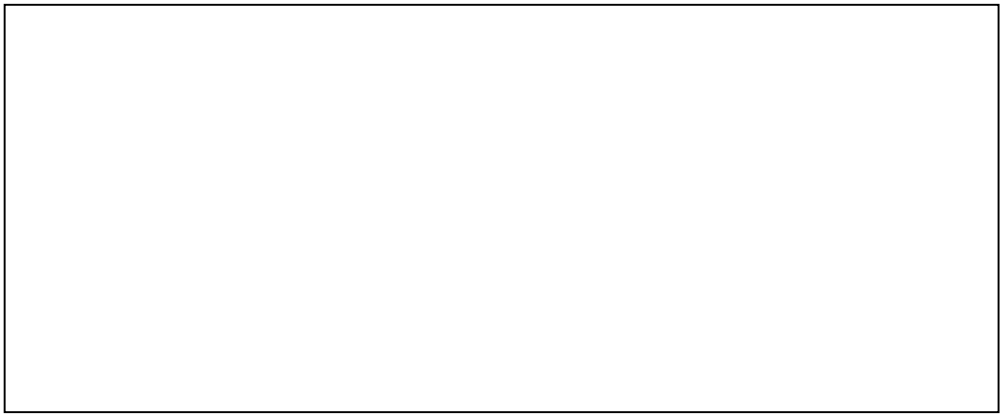
(10) Question 1. These are the parameters of the GPIO pins on ***microcontroller A***:

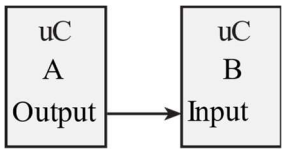
I_{OL} = 1mA, I_{OH} = 1mA, I_{IL} = 1µA, I_{IH} = 1µA,
V_{OL} = 0.3V, V_{OH} = 2.5V, V_{IL} = 0.5V, V_{IH} = 2.0 V

These are the parameters of the GPIO pins on ***microcontroller B***:

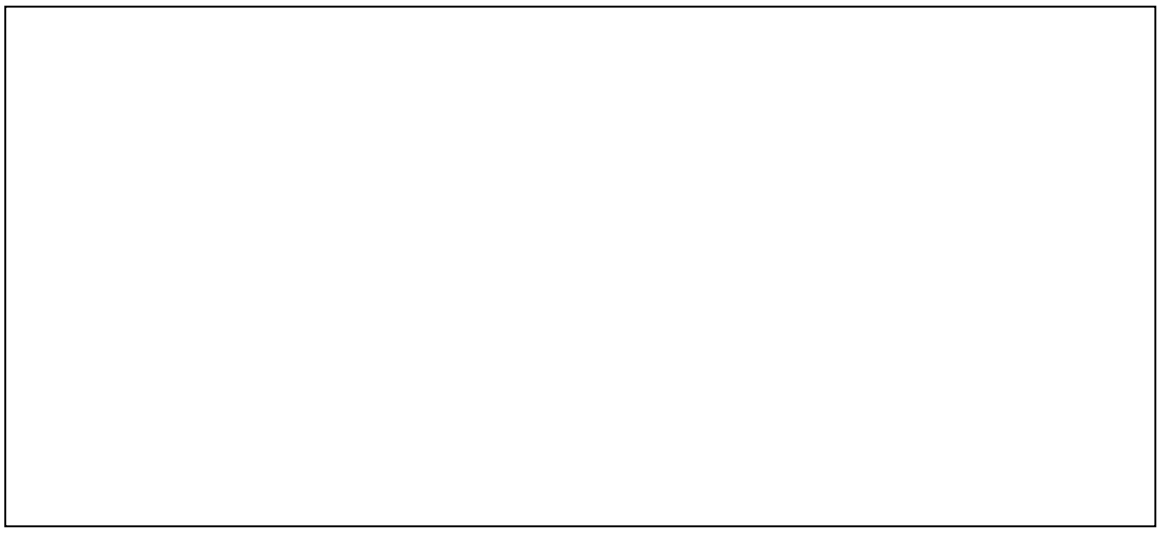
I_{OL} = 4mA, I_{OH} = 4mA, I_{IL} = 20µA, I_{IH} = 20µA,
V_{OL} = 0.7V, V_{OH} = 3.2V, V_{IL} = 1.0V, V_{IH} = 2.7 V

Can you directly connect a GPIO **Output** from microcontroller A to a GPIO **Input** on microcontroller B? If yes, prove it. If no, show at least one parameter/equation not satisfied.



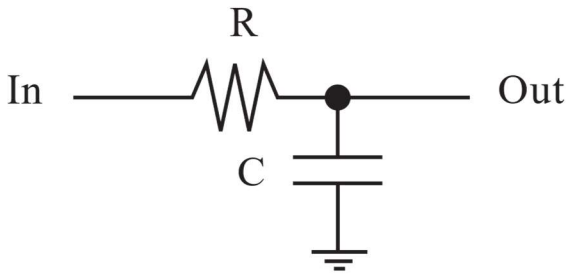


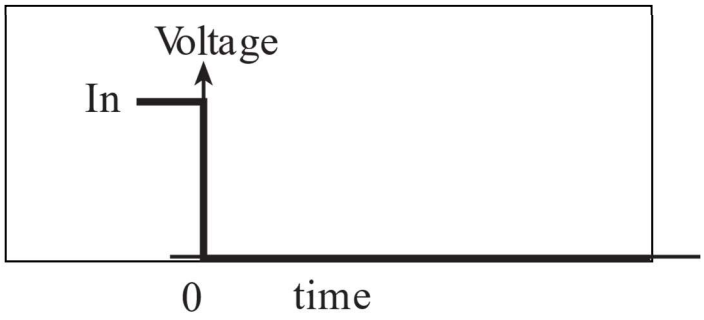
(10) Question 2. Let **x**, **y**, and **z** be three 32-bit binary fixed-point numbers. The format of **x**, **y**, and **z** are I27.Q5, I28.Q4, and I26.Q6 respectively. I27.Q5 means the 5 least significant bits of **x** are the fractional part of the fixed-point number and 27 bits are on the integer part. Write C code that adds **x** plus **y** and stores the sum in **z**. You may assume that **x**, **y**, and **z** are declared in C with **int32_t x,y,z;**



(10) Question 3. Consider the following *RC* circuit. At time 0, the input, **In**, instantaneously drops from 3.3V to 0. This in essence is what we have on every digital signal where we connect an output pin to an input pin. *R* is the output impedance of the output pin, and *C* is the input capacitance of the input pin. Recall that **τ**=**R*****C**.

Sketch the response of **Out** as a function of time. Draw it on top of the **In** versus **time** plot. I.e., place your answer inside the box. Label **τ** on the sketch.





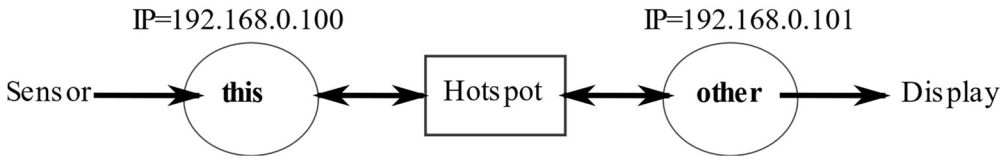
(10) Question 4. Sketch the value of each task as a function of the time from request to service.

a) hard real time

b) soft real time

c) firm real time

(20) Question 5. Consider an IoT system with two microcontrollers connected to the same wifi hotspot communication with UDP. The IP addresses of each are known as shown in the figure.



this microcontroller is streaming data to the **other** microcontroller. Consider these software tasks that could run on **this** microcontroller (not all tasks may not run):

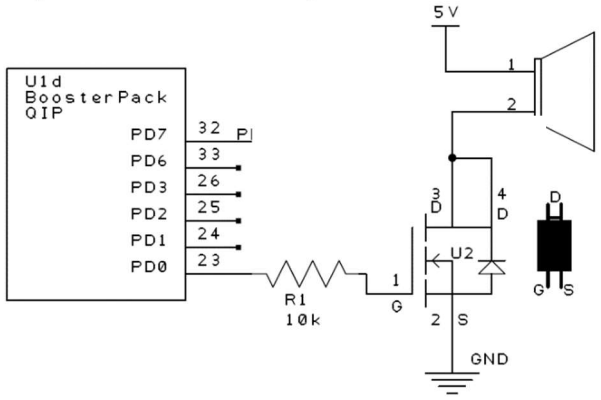
A) Create a UDP socket, allocates a data structure from the operating system, get SocketID
B) Create a TCP socket, allocates a data structure from the operating system, get SocketID
C) Connect SocketID in **this** to **other** microcontroller using IP address 192.168.0.100
D) Connect SocketID in **this** to **other** microcontroller using IP address 192.168.0.101
E) Connect to access point
F) Call ReceiveUDP function with parameter SocketID
G) Close SocketID socket, returning socket to operating system
H) Disconnect from access point
I) Call SendUDP function with parameters SocketID, data, and 192.168.0.100
J) Call SendUDP function with parameters SocketID, data, and 192.168.0.101
K) Call SendUDP function with parameters SocketID, and data

Part a) Which task(s) occur in **this** once at the start. List them in order.

Part b) Which task(s) occur every time **this** microcontroller sends data to the **other**. List them in order.

(10) Question 6. A system uses a FIFO to decouple the input ISR from the processing main program. The average arrival rate of input is 10 values per second. The average time from input in the ISR to the completion of the processing in the main program is 1 second. What is the average number of elements in the FIFO? Show your work.

(10) Question 7. Consider this speaker interface. A squarewave on PD0 will make sound.



(5) Part a) What is the purpose of the 10k resistor?

(5) Part b) What would happen if the 10k resistor were removed and replaced with 0-ohm wire?

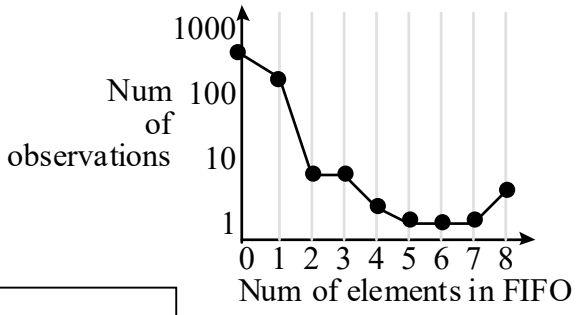
(10) Question 8. Consider the following function. **RunPt** is a global variable.

```
SwitchThread
    PUSH    {R0-R12,LR}
    LDR     R0, =RunPt ; R0=pointer to RunPt
    LDR     R1, [R0]   ; R1=value of RunPt, a pointer to a list
    STR     SP, [R1]   ; save SP in list data structure
    LDR     R1, [R1,#4]; new value for RunPt, next value in list
    STR     R1, [R0]   ; save RunPt
    LDR     SP, [R1]   ; new SP from list data structure
    POP     {R0-R12,LR}
    BX      LR
```

(5) Part a) Prove this function is not reentrant.

(5) Part b) Explain how to fix the bug

(10) Question 9. Consider an output device that uses a FIFO to pass data from main (which puts) to the ISR program (which gets). The FIFO can hold up to 8 elements. If it has 0 elements the FIFO is empty. If it has 8 elements the FIFO is full. The size of the FIFO was measured periodically resulting in the following histogram.



(5) Part a) Is this I/O bound, CPU bound, or neither (circle your answer)

I/O bound *CPU bound* *Neither*

(5) Part b) Should you increase the size of the FIFO? If yes, explain why the FIFO size should be increased. If no, explain why this FIFO size is ok.