(10) Question 1. Consider the use of a **probability mass function** to describe the noise processes involved in ADC sampling. Assume there is enough ADC noise such that repeated sampling of the same input voltage doesn’t always yield the same digital result. Draw a realistic probability mass function assuming the input is a fixed constant of 1.65 V and now hardware averaging. The sampling rate is 1000 Hz. The ADC is 12 bits and has a range of 0 to 3.3V. Label both axes including units.

(10) Question 2. Consider the following two ISRs that are running at the same priority level. You may assume there are no other accesses to Port A. Assume PA4 and PA5 are outputs connected to a scope.

```c
void ISR1(void)
{
    GPIO_PORTA_DATA_R ^= 0x10;
    // other stuff
}
```

```c
void ISR2(void)
{
    GPIO_PORTA_DATA_R ^= 0x20;
    // other stuff
}
```

Do these read-modify-write accesses to Port A create a critical section? If yes, modify the code to correct the error. If no, justify why these accesses are not critical.
(10) Question 3. These are the parameters of the GPIO pins on *microcontroller A*:

- \( I_{OL} = 1\text{mA}, \quad I_{OH} = 1\text{mA}, \quad I_{IL} = 1\mu\text{A}, \quad I_{IH} = 1\mu\text{A}, \)
- \( V_{OL} = 0.3\text{V}, \quad V_{OH} = 2.5\text{V}, \quad V_{IL} = 0.5\text{V}, \quad V_{IH} = 2.0\text{V} \)

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

- \( I_{OL} = 4\text{mA}, \quad I_{OH} = 4\text{mA}, \quad I_{IL} = 20\mu\text{A}, \quad I_{IH} = 20\mu\text{A}, \)
- \( V_{OL} = 0.7\text{V}, \quad V_{OH} = 3.2\text{V}, \quad V_{IL} = 1.0\text{V}, \quad V_{IH} = 3.0\text{V} \)

**Part a)** 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.

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

(40) Question 4. The goal is to increment *Counter* every time SW1 is pressed and decrement the same *Counter* every time SW2 is pressed. Assume the switch bounces, but the bounce time is less than 10 ms. Also assume each switch is pressed for at least 25 ms when touched, and the release time is also greater than 25 ms. The *Counter* is a shared global. Use SysTick periodic interrupts for this solution, where once the initialization is called the main program is free to run other unrelated operations. You must debounce the switches using SysTick interrupts. You cannot use any of the edge-triggered features of Port A. Assume the bus clock is 16 MHz.

```c
int32_t Counter; // difference between touches on SW1 and touches on SW2
```

**Part a)** Interface SW1 to PA7 and SW2 to PA6. Implement the hardware such that a switch touch results in a zero input. Draw the circuit including resistors and capacitors as needed. Minimize cost.
Part b) Show the ritual to initialize this system. Initialize both Port A GPIO, and SysTick interrupts. Define additional variables as needed. You need not set the priority register, but you should clear the I bit. Initialize Counter to zero. Do not include a main program.

Part c) Show the SysTick interrupt service routine. No backward jumps are allowed.

```c
void SysTick_Handler(void) {
```
(10) Question 5. Assume that PA2 is a squarewave output at 1000 Hz. Interface a 60-ohm speaker using +3.3V power so the speaker generates a loud 1000 Hz tone. Label all parts. For the necessary resistor(s) show the equations needed to determine the value(s).

(5) Question 6. What is the purpose of the DNS?

(5) Question 7. What is the difference between UDP and TCP communication? More specifically when should we use UDP and when should we use TCP?

(10) Question 8. Let $N1 \ N2 \ N3$ be the values of three binary fixed-point numbers each with a resolution of 1/16 Assume $I1, I2,$ and $I3$ are the corresponding integer parts. Write the body of the function that implements fixed-point divide, $N3 = N2/N1$. Minimize dropout, but don’t worry about overflow.

```c
uint32_t Divide(uint32_t I1, uint32_t I2){
    uint32_t I3;
    return I3;
}
```
Parameter | PN2222 ($I_C=150mA$) | 2N2222 ($I_C=500mA$) | TIP120 ($I_C=3A$)  
| PN2907 ($I_C=150mA$) | 2N2907 ($I_C=500mA$) | TIP125 ($I_C=3A$)  
| $I_e$ | 100 | 40 | 1000  
| $V_{BE_{sat}}$ | 0.6 | 2 | 2.5 V  
| $V_{CE \text{ at saturation}}$ | 0.3 | 1 | 2 V  

Parameters for the TM4C123 microcontroller (no 12mA mode will be used)  
$I_{OL} = 8mA$, $I_{OH} = 8mA$, $I_{IL} = 2\mu mA$, $I_{IH} = 2\mu mA$, $V_{OL} = 0.4V$, $V_{OH} = 2.4V$, $V_{IL} = 1.3V$, $V_{IH} = 2.0 V$
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<th>16</th>
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