IIT JODHPUR

Minor Examination: EEL3090 Embedded Systems (Feb'25)

Guidelines (Total time: 120 minutes, Maximum Marks: 25):

- Please read the question paper very carefully.
- **NO clarification is required in any question. If you ask the invigilator any question, -5 marks penalty would be awarded.** In case of any doubt, assume whatever you wish to and state that in your answer. Step-wise marks would be awarded wherever applicable.

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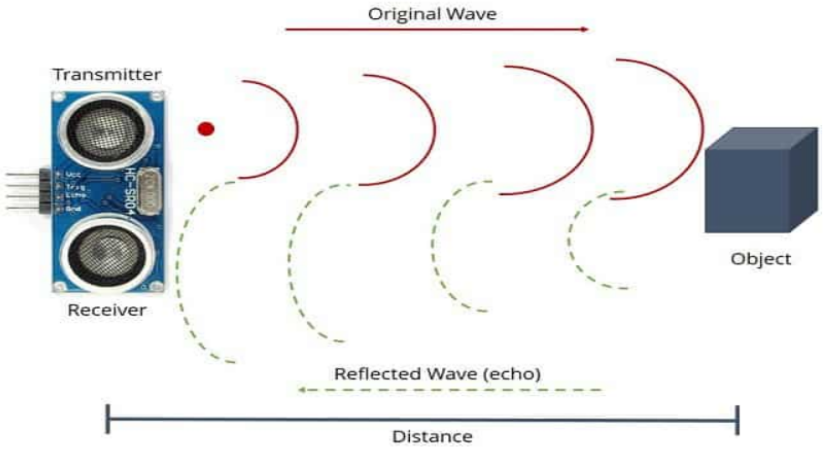
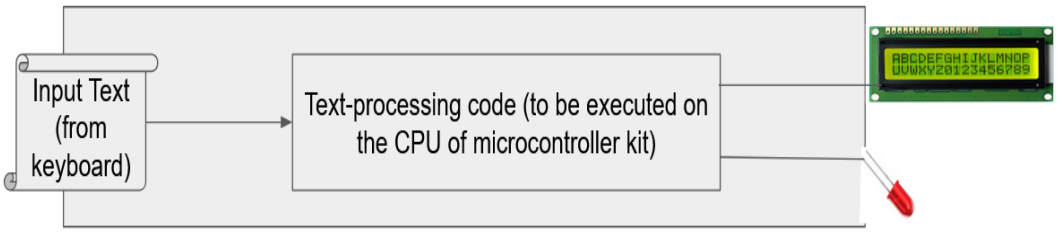
1. You are hired as an embedded systems consultant at a deep-tech startup in defense sector. The company is currently attempting to create a distance measurement setup through ultrasonic sensors that work by sending out high-frequency sound waves and measure how long it takes for them to bounce back. The specific distance from the ultrasonic sensor can be calculated based on this formula: Distance = $\frac{1}{2}$ T x S (T = Time elapsed and S = the speed of sound i.e., 343 m/s.)



You decide to use a microcontroller kit (such as STM32 discovery/nucleo board with a clock frequency of 16 MHz) for interfacing the ultrasonic sensor with the setup. Explain/describe the procedure (step-by-step) starting from the original transmitted wave (that is a single pulse of 10 μs) generation to carry out the distance measurement from a far-away object. [3]

2. You are doing an internship in a local startup named as BharatEmbeddedSystems. The goal is to produce an ultra-low power and cost-efficient text matching system as shown below:



Input (8 bits) is through a keyboard connected to a microcontroller and the output can be displayed through a LED or character display on a LCD. You are tasked with completing the LCD interfacing and the programming required to complete the setup. The goal is to display the matching characters (i.e., a string) on the LCD. You are provided with the information that LCD is a serial terminal device and can support only a maximum baud rate of 9600 bits/s. In addition, it is given to you that the microcontroller clock has an operational frequency of 15.97 MHz. Please draw the block level diagram of the internals of the above system identifying the component of the microcontroller that you need to use. Also, show all relevant calculations required to enable character display. (Hint: In your diagram, you can, for example, show CPU as one component and so on. Ignore the blocks of the microcontroller kit that are NOT needed.) [2 + 1]

3. You are doing a paid internship at a startup, MakeEmbeddedIndia that launches a payment platform named as *PayQuick*. The core of this platform is written in C/C++ but a small subroutine is written in ARM assembly for optimized performance. This portion of code is shown as below. Please write the equivalent C function and explain its utility. (Hint: CBZ instruction means that compare and branch when result is zero, SDIV instruction means signed division.) [3.5 + 1]

Assembly Program	**C Program**

AREA Program, CODE, READONLY
EXPORT __main
ENTRY
__main PROC
LDR r0, =someNumber
MOV r1, #0
MOV r2, #10
Loop CBZ r0, Stop
SDIV r0, r0, r2
ADD r1, r1, #1
B Loop
Stop B Stop
ENDP
END	

4. Suppose IITJ students form a deep-tech startup that does credit card authentication. As per this service, some operations need to be performed. One of them is the subtraction of group of 3 words (1 word = 32 bits = 4 bytes). Let's call the collection of 3 words as a 3-tuple. For efficient optimization, the software architects decide to write this subtraction function in ARM assembly. Write down this program for subtraction of 2 such 3-tuples and store result in some registers? [4]

5. Consider a scenario where we wish to connect a ARM CPU with four other peripherals either via AHB interconnection protocol/APB bridge: a multi-functionality keyboard, on-chip memory, flash memory and analog-to-digital converter (ADC).
(a) Given that the total system address space that is available to us spans from **0x00000000** to **0x60000000**. Assume that the keyboard requires a memory capacity of 0.25 GB, on-chip memory is 0.5 GB, the flash memory is 0.5 GB and the ADC is allowed to utilize the remaining memory space. Find address boundaries of each peripheral and draw all system connections properly?
(b) Given that CPU is running at a clock frequency of 1.5 GHz however, the APB bridge requires a slower clock. So, the APB bridge receives the CPU clock after division by the contents of a register named as PRESCALE. Given that the contents of PRESCALE register is 0x0E, find the time taken for one word transfer by the keyboard in the best possible scenario? [3.5 + 1]

6. Assume that students of IITJ are asked to design a microcontroller-based alarm system for fire detection. The students have access to a MCU development board that has a clock driven by 62.5 pF capacitor (C) and 1 Kohms resistor (R). This alarm system should generate an interrupt every T seconds using a specially designed SysTick timer having a VALUE register that can vary from 16 to 24 bits in length. Find the possible variation in the maximum value of T that can be obtained with this register length variation? [3]

7. Suppose that you get hired in the government-run Defense Electronics Research Laboratory (DERL) at Hyderabad, you are given the task of analyzing unknown pulses captured from radars located near the Indo-Pak borders. You utilize the concepts from EEL3090 that any hardware-based timer e.g., timer 2 (which is 32-bit timer) channel 1 in input capture mode on an STM32 microcontroller can be utilized for this purpose. Assuming a clock frequency of 80MHz in the board and a prescaler value (i.e., the division factor) of 4, please find out the maximum measurable pulse width of a square wave signal that we are receiving from an enemy radar device with a frequency of 50KHz? If the value of the capture/compare register (CCR) at the rising and falling edge of the signal are respectively known as 0x02E8 and 0x0BB8 in hex, respectively, what is the pulse width of the signal in microseconds? [2 + 1]