Jonathan W. Valvano First:_____ Last:_____

Feb 16, 2023, 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. Consider an IoT system that communicates between the TM4C123 and a web server on the cloud. For this system, you connect to the internet via Wifi, and then you will send data from the TM4C123 to the server every 1 second (1 Hz). The web server will log the data onto the cloud. Consider these software tasks that could run on the TM4C123 (not all tasks may not run):

A) Create a TCP socket (allocates a data structure from the operating system)
B) Call DNS
C) Connect to server using socket
D) Connect to access point
E) Receive TCP message
F) Close Socket (returns socket to operating system)
G) Disconnect from access point
H) Send a TCP message

Example CC3100 SimpleLink code

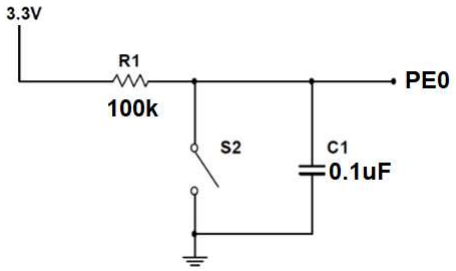
```
/* A */  SockID = sl_Socket(SL_AF_INET,SL_SOCK_STREAM, 0);
/* B */  retVal = sl_NetAppDnsGetHostByName(HostName, strlen(HostName),&DestinationIP, SL_AF_INET);
/* C */  retVal = sl_Connect(SockID, ( SlSockAddr_t *)&Addr, ASize);
/* D */  sl_WlanConnect(SSID_NAME, strlen(SSID_NAME), 0, &secParams, 0);
/* E */  sl_Recv(SockID, Recvbuff, MAX_RECV_BUFF_SIZE, 0);
/* F */  sl_Close(SockID);
/* G */  sl_WlanDisconnect();
/* H */  sl_Send(SockID, SendBuff, strlen(SendBuff), 0);
```

Part a) Which tasks occur once at the start. List them in order

Part b) Which tasks occur every second. List them in order

(10) Question 2. Consider the following interface that we could use to debounce the switch. These are some ways to combine 100kΩ (1E5 Ω) and 0.1uF (1E-7 Farads)

1E5 / 1E-7 = 1E12
1E-7 / 1E5 = 1E-12
1E5 * 1E-7 = 1E-2



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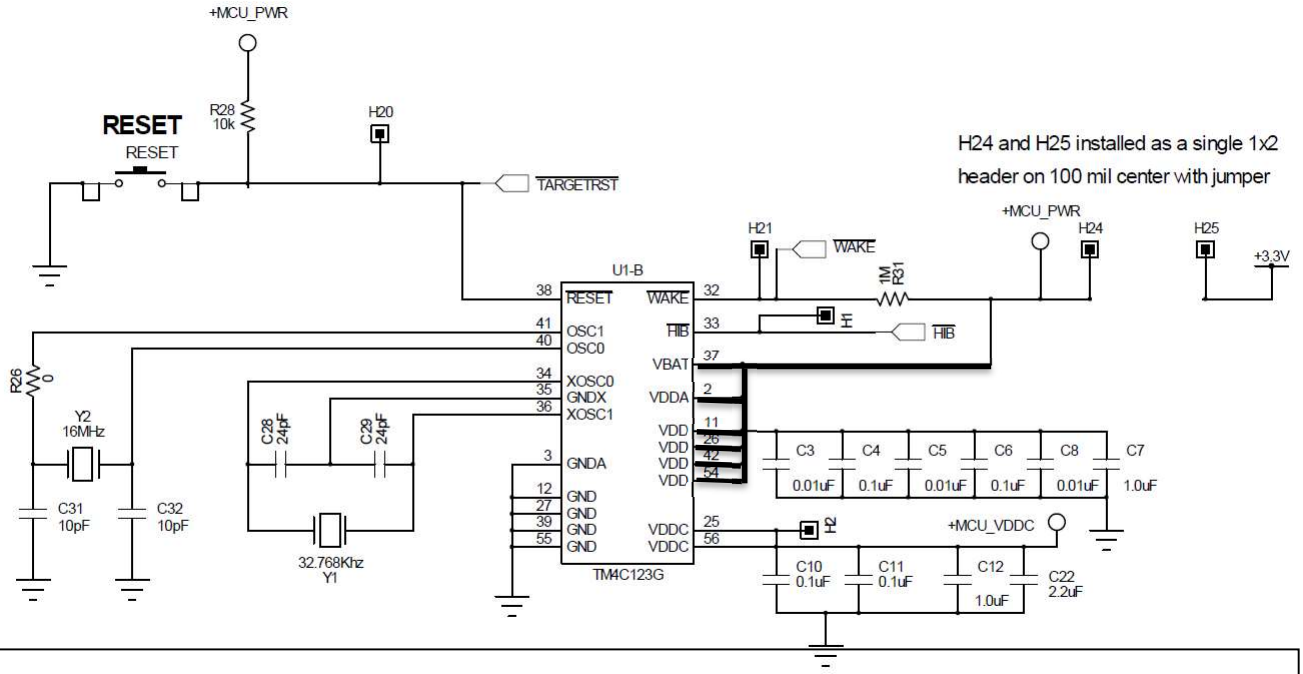
Part a) Consider the switch has not been pressed for a long time. Sketch the voltage versus time on PE0 occurring when the switch is pressed and held. Label units on the time axis as ns, us, ms, or sec.

Part b) Consider the switch has been pressed for a long time. Sketch the voltage versus time on PE0 occurring when the switch is released and remains released. Label units on the time axis as ns, us, ms, or sec.

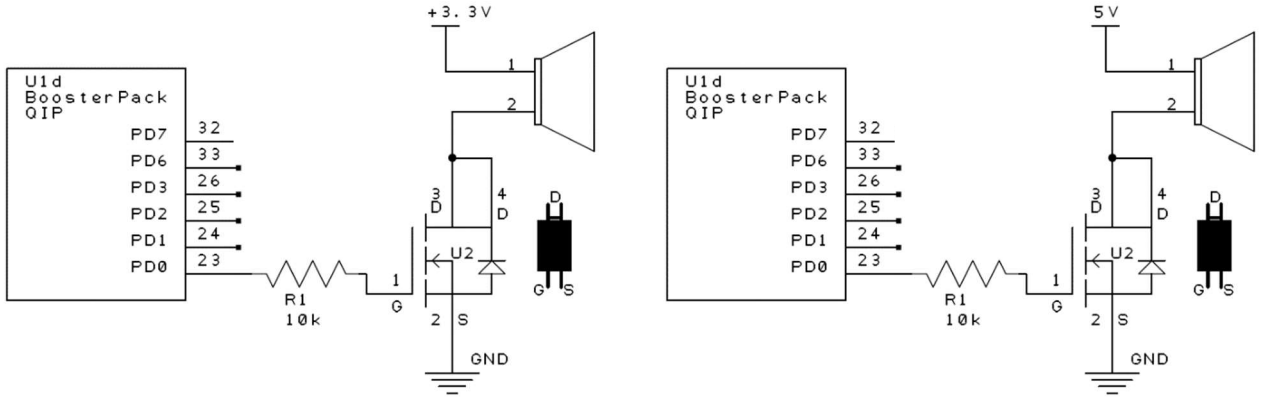
(15) Question 3. The following is the circuit on your LaunchPad. Explain in detail how to measure the total current on the 3.3V supply to the TM4C123 (VBAT VDDA and VDD). Be very specific about which tools to use and how to connect the tools.



(10) Question 4. Consider a system with one ISR for Timer0A, a second ISR for Timer1A, and a third ISR for Timer2A Briefly explain (no software needed) how to make it so the ISRs for Timer0A and Timer1A will run atomically. Running the ISR for Timer2A will not be atomic. **Atomically** means "once started, the ISR will run to completion".

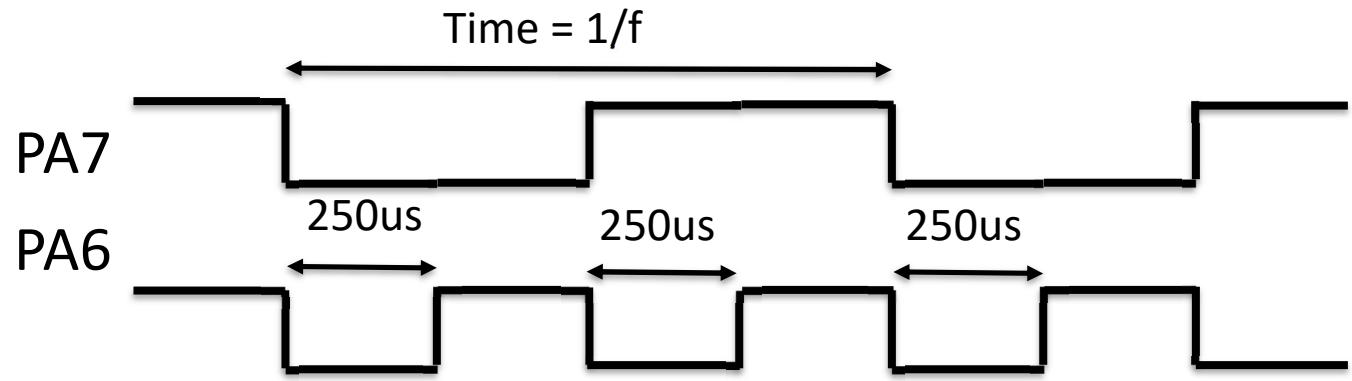
(10) Question 5. Consider a system that uses a 12-bit DAC to create an analog sine wave. The interrupt frequency is 256 kHz, the digital table has 12-bit integer values ranging the full 0 to 4095, the size of the table containing one period of the wave is 256 elements, and the resulting analog signal is 1 kHz. Estimate the SNR of the output in dB_{fs}. Give equations and show your work.

(10) Question 6. Consider these two speaker interfaces. Assume the speaker resistance, R is 8Ω, V_{GS} is 2V, and V_{DS} is 0.5V. The MOSFET could be either IRLD024 or IRLD120.



Derive equations you could use to determine how much louder the right circuit is from the left. For example, if you mean the right will be twice as loud as the left, your equation should calculate to 2. Show your work, and give your equations in terms like V_{OH}, V_{OL}, V_{CC} (3.3V), V_{BUS} (5V), R_1(10kΩ), R (8Ω), V_{GS}, and V_{DS}.

(35) Question 7. This question is very hard, so think about it. You are given an input square wave with a frequency of about 1000 Hz (990 to 1010 Hz). The input has an exact duty cycle of 50%. Let *f* be the frequency of the input wave. The input signal is connected to PA7 input. You are to create a digital output wave on PA6 with an average frequency of exactly 2**f* (frequency doubling). The output wave need not have 50% duty cycle, but it will be close. Two edges of the output wave are synchronized to the input, but the other two edges are delayed by 250µs. You must use interrupts on both PA7 (edge-triggered) and SysTick (time delay). There can be no backward jumps (no loops) in the ISRs.



Part a) Show the ritual to initialize this system. You may add global variables. Do not worry about priority. Assume a 16 MHz bus clock on the TM4C123 (every bus cycle is 62.5ns).

```
void Init(void){
  SYSCTL_RCGCGPIO_R |= 0x01;
  NVIC_ST_RELOAD_R
  NVIC_ST_CTRL_R
  NVIC_ST_CURRENT_R = 0;
  GPIO_PORTA_DIR_R &= ~0x80;
  GPIO_PORTA_DIR_R |= 0x40;
  GPIO_PORTA_DEN_R |= 0xC0;
  GPIO_PORTA_IS_R &= ~0x80;
  GPIO_PORTA_IBE_R
  GPIO_PORTA_IEV_R
  GPIO_PORTA_ICR_R = 0x80;
  GPIO_PORTA_IM_R
  NVIC_EN0_R = 1;
  EnableInterrupts();
}
```

Part b) Show the **SysTick_Handler** interrupt service routine. No **for**, **while**, or **do-while** loops are allowed.

Part c) Show the **GPIOPortA_Handler** interrupt service routine. No **for**, **while**, or **do-while** loops are allowed.

Parameters for the TM4C123 microcontroller (with 8mA mode selected)
I_{OL} = 8mA, I_{OH} = 8mA, I_{IL} = 2µA, I_{IH} = 2µA,
V_{OL} = 0.4V, V_{OH} = 2.4V, V_{IL} = 1.3V, V_{IH} = 2.0 V

7	6	5	4	3	2	1	0	Name
DATA	DATA	DATA	DATA	DATA	DATA	DATA	DATA	GPIO_PORTA_DATA_R
DIR	DIR	DIR	DIR	DIR	DIR	DIR	DIR	GPIO_PORTA_DIR_R
IS	IS	IS	IS	IS	IS	IS	IS	GPIO_PORTA_IS_R
IBE	IBE	IBE	IBE	IBE	IBE	IBE	IBE	GPIO_PORTA_IBE_R
IEV	IEV	IEV	IEV	IEV	IEV	IEV	IEV	GPIO_PORTA_IEV_R
IME	IME	IME	IME	IME	IME	IME	IME	GPIO_PORTA_IM_R
RIS	RIS	RIS	RIS	RIS	RIS	RIS	RIS	GPIO_PORTA_RIS_R
MIS	MIS	MIS	MIS	MIS	MIS	MIS	MIS	GPIO_PORTA_MIS_R
ICR	ICR	ICR	ICR	ICR	ICR	ICR	ICR	GPIO_PORTA_ICR_R
SEL	SEL	SEL	SEL	SEL	SEL	SEL	SEL	GPIO_PORTA_AFSEL_R
DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	GPIO_PORTA_DR2R_R
DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	GPIO_PORTA_DR4R_R
DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	GPIO_PORTA_DR8R_R
ODE	ODE	ODE	ODE	ODE	ODE	ODE	ODE	GPIO_PORTA_ODR_R
PUE	PUE	PUE	PUE	PUE	PUE	PUE	PUE	GPIO_PORTA_PUR_R
PDE	PDE	PDE	PDE	PDE	PDE	PDE	PDE	GPIO_PORTA_PDR_R
SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR	GPIO_PORTA_SLR_R
DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	GPIO_PORTA_DEN_R
CR	CR	CR	CR	CR	CR	CR	CR	GPIO_PORTA_CR_R
AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	GPIO_PORTA_AMSEL_R

IS=0 means edge, IS=1 means level
IBE=1 means both, IBE=0 means one
If IBE=0, IEV=1 means rising, IEV=0 means falling
Write 1 to ICR to acknowledge, writing 0's to ICR has no effect
Write 0 to IM to disarm, write 1 to arm

Address	31 – 29	23 – 21	15 – 13	7 – 5	Name
0xE000E400	GPIO Port D	GPIO Port C	GPIO Port B	GPIO Port A	NVIC_PRI0_R
0xE000E404	SSI0, Rx Tx	UART1, Rx Tx	UART0, Rx Tx	GPIO Port E	NVIC_PRI1_R
0xE000E408	PWM Gen 1	PWM Gen 0	PWM Fault	I2C0	NVIC_PRI2_R
0xE000E40C	ADC Seq 1	ADC Seq 0	Quad Encoder	PWM Gen 2	NVIC_PRI3_R
0xE000E410	Timer 0A	Watchdog	ADC Seq 3	ADC Seq 2	NVIC_PRI4_R
0xE000E414	Timer 2A	Timer 1B	Timer 1A	Timer 0B	NVIC_PRI5_R
0xE000E418	Comp 2	Comp 1	Comp 0	Timer 2B	NVIC_PRI6_R
0xE000E41C	GPIO Port G	GPIO Port F	Flash Control	System Control	NVIC_PRI7_R
0xE000ED20	SysTick	PendSV	--	Debug	NVIC_SYS_PRI3_R

Each device has a three-bit priority. Priority=0 is highest, priority=7 is lowest

Address		30		19		6	5	4	3	2	1	0	Name
0xE000E100		F		Timer0A		UART1	UART0	E	D	C	B	A	NVIC_EN0_R
0xE000E104											UART2		NVIC_EN1_R

Write 1 to EN0/EN1 to enable interrupts in NVIC, writing 0's to EN0/EN1 has no effect.

Address	31-24	23-17	16	15-3	2	1	0	Name
$E000E010	0	0	COUNT	0	CLK_SRC	INTEN	ENABLE	NVIC_ST_CTRL_R
$E000E014	0	24-bit RELOAD value						NVIC_ST_RELOAD_R
$E000E018	0	24-bit CURRENT value of SysTick counter						NVIC_ST_CURRENT_R

Write anything to CURRENT to clear COUNT and reload RELOAD into CURRENT
Write 0 to CTRL for off, write 5 to CTRL for on but disarmed, write 7 to CTRL for on and armed.
The COUNT flag is set when the CURRENT counts down from 1 to 0.