Jonathan W. Valvano First:_____ Last:_____

October 10, 2019, 3:30-4:45pm. This is a closed book exam, with one 8.5 by 11-inch crib sheet. You have 75 minutes, so please allocate your time accordingly. ***Please read the entire quiz before starting***.

(5) Question 1. Consider the IoT system from Lab 4 that communicates between the TM4C123 and the Blynk app on the phone. For this system, explain how **sockets** are used within the ESP8266.

Sockets are **data structures** that hold information allowing communication between the ESP8266 and the Blynk server. It includes address information like the IP address and port number. It includes type information like security, IPV4, and TCP protocol.

(5) Question 2. Consider the IoT system from Lab 4 that communicates between the TM4C123 and the Blynk app on the phone. For this system, explain how **virtual pins** are used.

Pins allow data to be sent from phone to TM4C123 or from TM4C123 to phone. Pins are numbered. Pins are an abstract data channel, and not associated with GPIO pins on the microcontroller

(5) Question 3. Consider an ideal capacitor, with capacitance *C*. Give the **differential equation** that relates capacitor voltage to capacitor current.

$I = C \, dV/dt$

(5) Question 4. You are asked to modify an embedded system to lower the noise on the 3.3V power line. Describe how you would **measure power line noise** to determine if your changes were successful in reducing noise. Be as explicit as possible, including both test equipment and mathematical relations.

Connect test equipment from power line to ground:
1) voltmeter in AC mode measures RMS, which is the noise measurement
2) scope in DC or AC mode, measure peak to peak or RMS of wave
3) spectrum analyzer, all components other than DC are noise

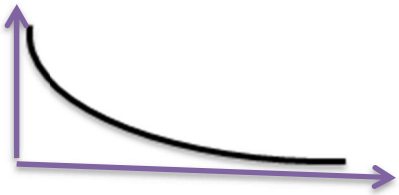
(5) Question 5. Consider a producer consumer system that uses a 16-element FIFO to pass data from the producer to the consumer. The producer is software, creating data, putting the data into the FIFO. The consumer is an interrupt-driven output device, which gets data from the FIFO and outputs it. We have added debugging instruments to the system to determine its status. After every time data is put into the FIFO, we measure the number of elements in the FIFO, and we create a probability mass function. **Draw the pmf graph** illustrating the two cases of I/O bound and CPU bound. Label the axes.

I/O bound

pmf plots counts versus FIFO size, sizes can range from 1 to 16, data shows many 16's, meaning FIFO is often full

CPU bound

pmf plots counts versus FIFO size, sizes can range from 1 to 16, data shows many 1's, meaning FIFO is often empty when PUT is called



(5) Question 6. Consider the interaction between this ISR and this main program.

```
void SysTickHander(void){
  static uint32_t counter;
   counter++;
// other stuff
}
```

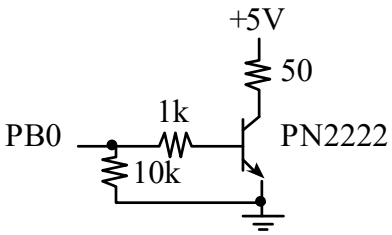
```
void main(void){
static uint32_t counter;
  Init();
  while(1){
    counter++;
// other stuff
  }
}
```

Do these read modify write accesses create a **critical section**? Answer yes or no. If no, justify your answer. If yes, describe how you would remove the bug.

No, because the two **static** variables, although permanently allocated, are separate variables. There is no sharing.

(15) Question 7. Consider this interface between the microcontroller pin PB0 and a 50-ohm speaker:
You may assume

$V_{BE(sat)}$ = 0.8 V,
$I_{C(max)}$ = 500 mA,
$V_{CE(sat)}$ = 0.5 V,
$h_{FE(max)}$ = 100



You will answer the same three questions for each of three scenarios:
Scenario 1) Assume the PB0 is uninitialized with DEN=0

In which mode is the BJT? Circle one of these four possibilities: ……

Cutoff (off),

What is the current out of the TM4C123 PB0 pin?

0 mA

What is the current across the 50 ohm speaker?

0 mA

Scenario 2) Assume the PB0 is initialized as an output with DEN=1, DIR=1, DR8R=1, but DATA=0.

In which mode is the BJT? Circle one of these four possibilities: ……

Cutoff (off),

What is the current out of the TM4C123 PB0 pin?

0 mA

What is the current across the 50 ohm speaker?

0 mA

Scenario 3) Assume the PB0 is initialized as an output with DEN=1, DIR=1, DR8R=1, and DATA=1.

In which mode is the BJT? Circle one of these four possibilities: ……

Saturated (fully on),

What is the current out of the TM4C123 PB0 pin?

Imax = 3.3V/10k + (3.3V-0.8V)/1k = 0.33mA + 2.5V/1k = 0.33mA + 2.5mA = 2.83mA
Imin = 2.4V/10k + (2.4V-0.8V)/1k = 0.24mA + 1.6V/1k = 0.24mA + 1.6mA = 1.84mA

What is the current across the 50 ohm speaker?

I = (5-0.5V)/50 = 4.5V/50 = 90 mA
(saturated because I_b=2.5mA, I_c=90mA, and I_b*h_{fe}>I_c

(20) Question 8. You are given two tasks: **`Task20()`** should be executed every 20 ms and **`Task25()`** should be executed every 25 ms. The maximum time to execute either task is 1ms.

Part a) Show the ritual to initialize this system. You will use SysTick interrupts.

```
void SysTick_Init(void){
  NVIC_ST_RELOAD_R =  399999 ;  // every 5ms
  NVIC_ST_CTRL_R =    0x07 ;
  NVIC_SYS_PRI3_R =
     (NVIC_SYS_PRI3_R& 0x00FFFFFF )| 0 ;
  EnableInterrupts();
}
```

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

```
void SysTickHandler(void){
  static uint32_t Count;
  if((Count%4)==0) Task20(); // execute every 4th interrupt
  if((Count%5)==0) Task25(); // execute every 5th interrupt
  Count = (Count+1)%20;
}
void SysTickHandler(void){
  static uint32_t Count20,Count25;
  Count20++;
  if(Count20 == 4){
    Count20 = 0;
    Task20(); // execute every 4th interrupt
  }
  Count25++;
  if(Count25 == 5){
    Count25 = 0;
    Task25(); // execute every 5th interrupt
  }
}
void SysTickHandler(void){ // this one interrupts every 2.5ms
// no jitter in either because no one ISR instance executes both
  static uint32_t Count20,Count25;
  Count20 = (Count20+1)%8; // rolls over every 20ms
  if(Count20 == 0){
    Task20(); // execute every 8th interrupt
  }
  Count25 = (Count25+1)%10; // rolls over every 25ms
  if(Count25 == 1){
    Task25(); // execute every 10th interrupt
  }
}
```

Part c) What is the worst case jitter on **`Task25`**.

If both tasks are run during the same ISR instance, then Task25 is delayed by up to 1 ms

(5) Question 9. We will store the value -8 cm with the integer -64 and store the value +8 cm with the value +64. Assuming the integer is stored as an 8-bit signed number, what are the minimum, maximum, precision and resolution of this fixed point number system? Give units for each.

Minimum = -128/8 = -16 cm	Precision = 8 bits or 256 alternatives
Maximum = +127/8 = -15.875 cm	Resolution = 0.125 cm

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

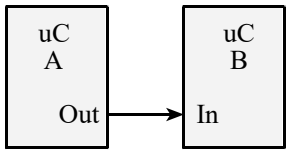
I_{OL} = 1mA, I_{OH} = 1mA, I_{IL} = 1µA, I_{IH} = 1µA,
V_{OL} = 0.3V, V_{OH} = 2.7V, V_{IL} = 0.5V, V_{IH} = 2.0 V

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} = 2.5 V

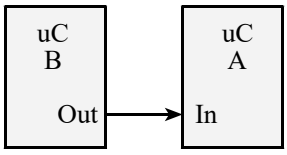
Part a) Can you directly connect a GPIO output from microcontroller A to a GPIO input on microcontroller B? If yes, prove it. If no, show at least one parameter/equation not satisfied.

The rules for "does it work?" are
I_{OH} (output) ≥ I_{IH} (input) ok
I_{OL} (output) ≥ I_{IL} (input) ok
V_{OH} (output) ≥ V_{IH} (input) ok
V_{OL} (output) ≤ V_{IL} (input) ok



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.

The rules for "does it work?" are
I_{OH} (output) ≥ I_{IH} (input) ok
I_{OL} (output) ≥ I_{IL} (input) ok
V_{OH} (output) ≥ V_{IH} (input) ok
V_{OL} (output) ≤ V_{IL} (input) no, fails, 0.7 > 0.5V



(5) Question 11. Give the definition and an example of a **firm real-time system**.

The value of an operation completed past its timing constraint is considered zero but not harmful. Examples include streaming audio, streaming video, firing spark plugs in an electronic ignition of a car engine, pulsing the heart in a pacemaker, inserting packets in a network switch, and inserting packets in a wireless router.

(15) Question 12. Make PB1 an input and PB2 an output. PB1 will be an input squarewave of unknown frequency f, and PB2 will be an output squarewave of frequency f/2. Basically, you will toggle PB2 on every rising edge of PB1.

Part a) Show the ritual to initialize this system. Fill in the boxes with a value. It need not be friendly.

```
void PortB_Init(void){ unsigned long volatile delay;
  SYSCTL_RCGCGPIO_R |= 0x02;

  delay = SYSCTL_RCGCGPIO_R;
  GPIO_PORTB_DIR_R  =  0x04  ;
  GPIO_PORTB_DEN_R  =  0x06  ;
  GPIO_PORTB_IS_R   =  0x00  ;
  GPIO_PORTB_IBE_R  =  0x00  ;
  GPIO_PORTB_IEV_R  =  0x02  ;
  GPIO_PORTB_IM_R   =  0x02  ;
  NVIC_PRI0_R = (NVIC_PRI0_R&0xFFFF00FF)|0x00008000; // priority 4
  NVIC_EN0_R =  0x02  ;

  EnableInterrupts();
}
```

Part b) Show the interrupt service routine (Port B handler). No backward jumps are allowed.

```
void GPIOPortB_Handler(void){
  GPIO_PORTB_ICR_R = 0x02;     // ack PB1
  GPIO_PORTB_DATA_R ^= 0x04;   // toggle PB2
}
```

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_PORTB_DATA_R
DIR	DIR	DIR	DIR	DIR	DIR	DIR	DIR	GPIO_PORTB_DIR_R
IS	IS	IS	IS	IS	IS	IS	IS	GPIO_PORTB_IS_R
IBE	IBE	IBE	IBE	IBE	IBE	IBE	IBE	GPIO_PORTB_IBE_R
IEV	IEV	IEV	IEV	IEV	IEV	IEV	IEV	GPIO_PORTB_IEV_R
IME	IME	IME	IME	IME	IME	IME	IME	GPIO_PORTB_IM_R
RIS	RIS	RIS	RIS	RIS	RIS	RIS	RIS	GPIO_PORTB_RIS_R
MIS	MIS	MIS	MIS	MIS	MIS	MIS	MIS	GPIO_PORTB_MIS_R
ICR	ICR	ICR	ICR	ICR	ICR	ICR	ICR	GPIO_PORTB_ICR_R
SEL	SEL	SEL	SEL	SEL	SEL	SEL	SEL	GPIO_PORTB_AFSEL_R
DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	DRV2	GPIO_PORTB_DR2R_R
DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	DRV4	GPIO_PORTB_DR4R_R
DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	DRV8	GPIO_PORTB_DR8R_R
ODE	ODE	ODE	ODE	ODE	ODE	ODE	ODE	GPIO_PORTB_ODR_R
PUE	PUE	PUE	PUE	PUE	PUE	PUE	PUE	GPIO_PORTB_PUR_R
PDE	PDE	PDE	PDE	PDE	PDE	PDE	PDE	GPIO_PORTB_PDR_R
SLR	SLR	SLR	SLR	SLR	SLR	SLR	SLR	GPIO_PORTB_SLR_R
DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	GPIO_PORTB_DEN_R
CR	CR	CR	CR	CR	CR	CR	CR	GPIO_PORTB_CR_R
AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	AMSEL	GPIO_PORTB_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

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
0xE000ED20	SysTick	PendSV	--	Debug	NVIC_SYS_PRI3_R

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

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