Jonathan W. Valvano First:_____ Last:_____

October 7, 2015, 10:00am-10:50am. This is a closed book exam, with one 8.5 by 11 inch crib sheet. You have 50 minutes, so please allocate your time accordingly. ***Please read the entire quiz before starting***.

(20) Question 1. Mark each of the following questions true or false. Put answers in the boxes

Part a) We are sampling the ADC using hardware averaging. In order to apply the **Central Limit Theorem** we assume the original data independent and identically distributed random variables.

True

Part b) Adding **`const`** in the following example causes **`Size`** to be allocated in ROM on a microcontroller.

```
void function1(const int Size){
```

False

Part c) Adding **`static`** in this example has the effect of changing the allocation of **`Count`** from the stack/registers to permanent RAM.

```
void function2(void){ static int Count=0;
```

True

Part d) In the **OpenWeatherMap.org** communication, the connection socket is used to pass data between the client and the server.

False

Part e) Adding capacitance to digital signals decreases slew rate causing slower transmission.

True

(5) Question 2. Consider the interaction between this ISR and this main program. You may assume Port B has been initialized as an 8-bit output and no other software accesses Port B. The desired behavior is to toggle four bits whenever the ISR occurs, and to toggle a different four bits each time through the loop.

```
void SysTickHander(void){
  GPIO_PORTB_DATA_R ^= 0x55;
// other stuff
}
```

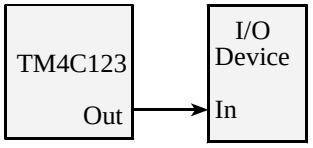
```
void main(void){
  Init();
  while(1){
    GPIO_PORTB_DATA_R ^= 0xAA;
// other stuff
  }
}
```

Do these accesses to Port B create a critical section? Answer yes or no.

Yes, critical section is the read-modify-write access in the main. Solution 1, disable interrupts and reenable around the Port B access in the main. Solution 2, use bit specific addressing

(5) Question 3. You wish to connect a device to a GPIO output of the TM4C123. These are the parameters of the I/O device:

I_{IL} = 100uA, I_{IH} = 100uA,
V_{IL} = 0.5V, V_{IH} = 2.2 V



Can you directly connect a TM4C123 output to this device? Select Yes or No:

Yes

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) (remember I_{OH} is the maximum possible current, not the actual current)
I_{OL} (output) ≥ I_{IL} (input) (remember I_{OL} is the maximum possible current, not the actual current)
V_{OH} (output) ≥ V_{IH} (input)
V_{OL} (output) ≤ V_{IL} (input)
In this case, it does not works because we have
8mA ≥ 0.1mA ok
8mA ≥ 0.1mA ok
2.4V ≥ 2.2V ok
0.4V ≤ 0.5V ok

(5) Question 4. Consider an ideal inductor, with inductance *L*. Let *V* be the voltage across the inductor, and let *I* be the current through the inductor. Give an equation that relates *L*, *I*, and *V*.

V =L dI/dt

(5) Question 5. We need to store values from 0 to +10 m, but must limit memory to 8 bits. Choose the best decimal fixed-point format assuming we are using 8-bit precision. I.e., what resolution should we use, including units?

10m/256 = about 0.04m,
Δ=0.1m, range is 0 to 25.6m

(15) Question 6) You are asked to configure all 8 bits of Port B for priority 2 rising edge interrupts. You must be friendly. Put your answers in the boxes.

```
SYSCTL_RCGCGPIO_R |= 0x02;
delay = SYSCTL_RCGCGPIO_R;
GPIO_PORTB_PCTL_R = 0x00000000;
GPIO_PORTB_DIR_R  = 0x00;
GPIO_PORTB_DEN_R  = 0xFF;
```

```
GPIO_PORTB_IS_R  = [0x00] ;
GPIO_PORTB_IBE_R = [0x00] ;
GPIO_PORTB_IEV_R = [0xFF] ;
GPIO_PORTB_IM_R  = [0xFF] ;
NVIC_PRI0_R = (NVIC_PRI0_R& [0xFFFF00FF] )| [0x00004000] ;
NVIC_EN0_R  = [0x00000002] ;
```

(5) Question 7. Consider the following user application that should create a squarewave on PB0

```
int main(void){
  Init(); // initialize Port B
  while(1){
    GPIO_PORTB_DATA_R &= ~0x01; // make it low
    GPIO_PORTB_DATA_R |= 0x01;  // make it high
  }
}
```

Describe a debugging technique you could use to determine the frequency and duty cycle of this output. Make it as noninvasive as possible.

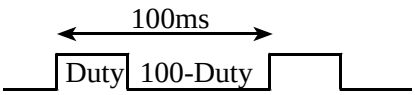
Connect a scope or logic analyzer to PB0

(30) Question 8. The goal to create a digital output wave on PB0 with a fixed period of 100ms and a variable duty cycle from 1 to 99%. The **Duty** is a shared global. E.g., if **Duty** is 25 then the wave should have a 25% duty cycle (high for 25 ms, and low for 75 ms). The main program, which you do not write, sets the global and your ISR reads it. You must use SysTick periodic interrupts for this solution, where once the initialization is called, the main program is free to run other unrelated operations. You cannot use any timer or PWM features of the TM4C123. Assume the bus clock is 16 MHz.

```
uint8_t Duty; // 1 to 99
#define PB0 (*((volatile uint32_t *)0x40005004))
```

Part a) Show the SysTick initialization function. Assume PB0 is already initialized as an output. Assume this is the only interrupt, so you can ignore priority. Do not include a main program, but do set I=0.

```
uint32_t Time;
void Init(void){
  NVIC_ST_RELOAD_R = 15999;   // reload value for 1ms
  NVIC_ST_CTRL_R = 7;         // activate and enable interrupts
  GPIO_PORTB_DATA_R |= 0x01;
  Time = 0;
  EnableInterrupts();         // I = 0
}
#define CAL 25   // cycles to service interrupt
void Init(void){
  NVIC_ST_RELOAD_R = 16000*Duty-CAL;   // reload value for high
  NVIC_ST_CTRL_R = 7;                  // activate and enable interrupts
  PB0 = 0x01;
  EnableInterrupts();         // I = 0
}
```



Party b) Show the SysTick ISR

```
void SysTick_Handler(void){
  Time++;
  if(Time==Duty){ // end of high pulse
    GPIO_PORTB_DATA_R &= ~0x01; // make it low
  }
  if(Time==100){  // end of low pulse
    Time = 0;
    GPIO_PORTB_DATA_R |= 0x01; // now high
  }
}
void SysTick_Handler(void){
  if(PB0){        // end of high pulse
    PB0 = 0x00;   // make it low
    NVIC_ST_RELOAD_R = 16000*(100-Duty)-CAL; // reload value for low
  }else{          // end of low pulse
    PB0 = 0x01;   // now high
    NVIC_ST_RELOAD_R = 16000*Duty-CAL;       // reload value for high
  }
}
```

(10) Question 9. Interface this 3-V 60-mA LED to PB0 using a PN2222A. Assume T=25C.

(2) Part a) Estimate h_{FE} for the conditions in this problem.

Any answer for h_{fe} from 150 to 200

(3) Part b) Using h_{FE} as a variable, show the equation needed for minimum I_B required as a function of h_{FE}.

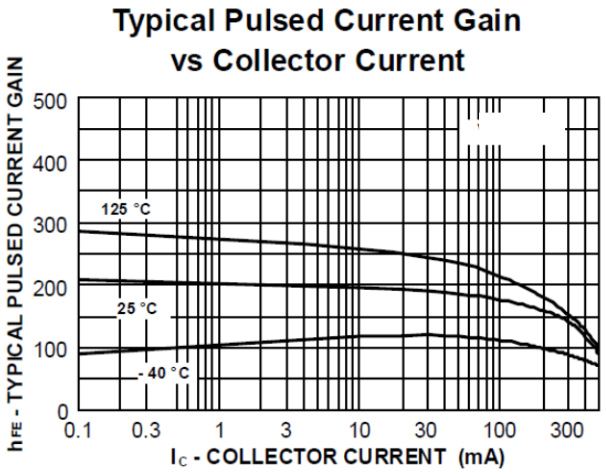
h_{fe}=180, I_B= 60mA/ h_{fe} = 60/180 = 0.33mA

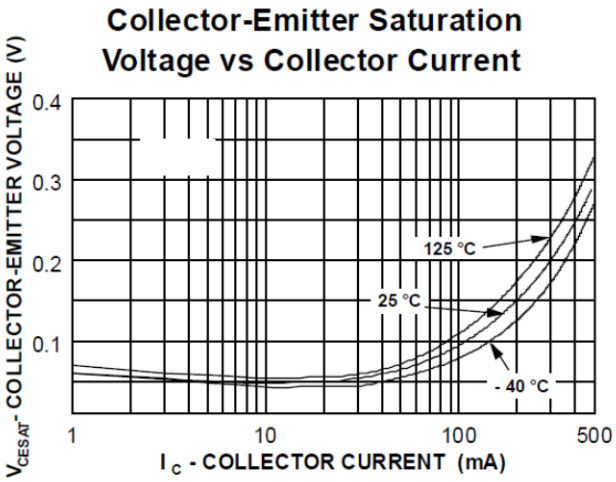
(2) Part c) What will be V_{CE} at saturation?

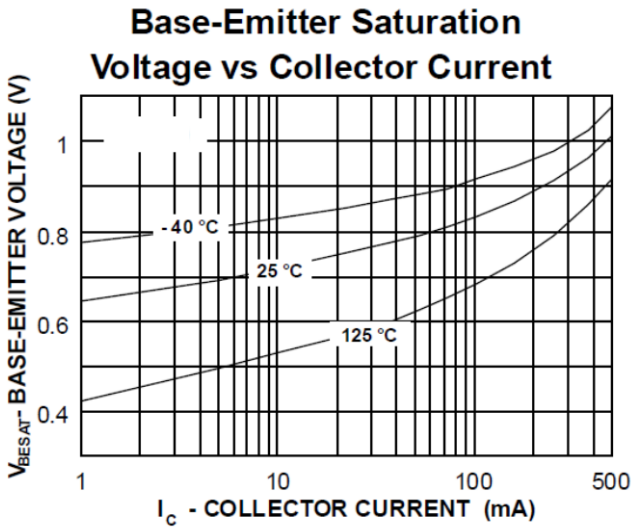
From the curve, any answer from 0.05 to 0.1V

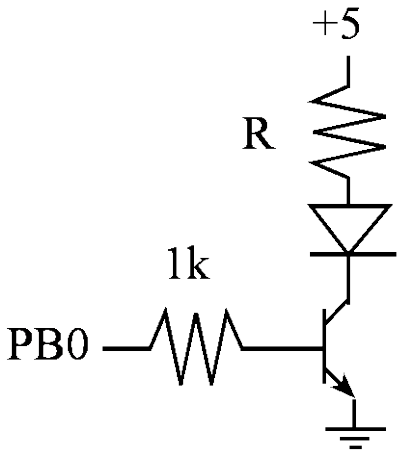
(3) Part d) Using V_{CE} as a variable, show the equation needed for R in ohms as a function of just one variable, V_{CE} in volts.

In ohms, the current is 0.06A, the voltage across R is (5-3-V_{CE})
R= (5-3-V_{CE})/0.06 = (5-3-0.08)/0.06 = (2-0.08)/0.060 = 192/6 =96/3 = 32 ohms









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

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