Jonathan W. Valvano First:_____ Last:_____

Calculator is allowed (no laptops, phones, devices with wireless communication). You must put your answers in the boxes. Do not write on the back of the page. When you are done, you turn in the closed-book part and can start the open book part.

(4) Question 1. Which digital controller type has the best accuracy? Choose one A, B, or C.

A) Proportional
B) Integral
C) Derivative

(6) Question 2. In the context of internet communication, list three items contained in a socket. *Hint*: think about the information passed to the socket when the socket is opened.

(4) Question 3. Consider the following ADC/DAC architectures: A) **successive approximation**, B) **resistor string,** C) **flash**, D) **R-2R**, or E) **sigma-delta**. Choose one of A, B, C, D, or E for each.

a) Which DAC type is most likely to be monotonic?

b) Which ADC type has the best resolution?

(6) Question 4. Choose which capacitor type to use for each application. Give one answer for each: A) **tantalum**, B) **ceramic** or C) **neither**. Choose A, B, or C for each.

a) Building an analog high pass filter

b) Removing high amplitude low frequency noise on the power line

c) Increasing the bandwidth on a high-speed digital communication.

(5) Question 5. Which inequality is incorrect, when connecting one digital output to one digital input? Choose one answer A, B, C, or D. Select E if all are correct.

A) $V_{IL} < V_{OL}$
B) $V_{IH} < V_{OH}$
C) $I_{IL} < I_{OL}$
D) $I_{IH} < I_{OH}$

(5) Question 6. Consider measurement of period performed in Lab 10 that uses input capture. What factor determines the **period measurement resolution**? I.e., what configuration would you change if you wished to change resolution?

(5) Question 7. Consider motor interface powered by 5V and a MOSFET like Lab 10. When on, the V_{DS} is 0.2V. An ohmmeter measures the motor coil resistance of 100 ohms, when the motor is not powered and disconnected from the circuit. However, a current meter inline with the powered circuit measures a current of 200 mA, where 200mA is much larger than (5V-0.2V)/100ohms = 48mA. Explain how this happened? *Hint*: draw an electrical model of a DC motor.

(4) Question 8. Consider these four architectures for power regulation: A) linear, B) boost, C) buck, D) buck-boost. For each system choose the best regulator type. Each system requires a 3.3V power supply. If there is more than one good answer, just give one of the answers.

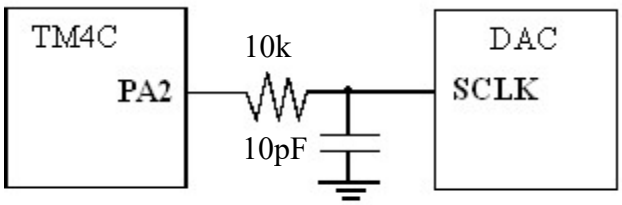
a) The system is powered with a 1.5V battery.

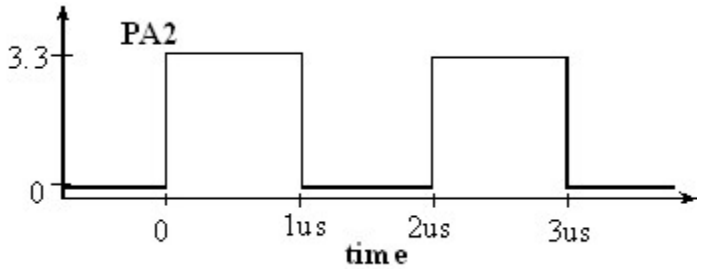
b) The system requires a power supply with low noise.

c) The system must dissipate the least amount of heat.

d) The system must run on any battery voltage from 3 to 12V.

(5) Question 9. Sketch the SCLK signal on the voltage versus time graph. Draw it on top of the PA2 versus time graph. 10k*10pF = 0.1us





Jonathan W. Valvano First:_____ Last:_____

Open book, open notes. You may use a calculator or tablet with screen lays flat on the table and no wireless communication. Basically, the screen cannot be visible to other students You must put your answers in these boxes. Please don't turn in any extra sheets or write on the back of the pages.

(10) Problem 10. Assume the following edge-triggered ISR is invoked every 1000us to 2,000,000us (this period is variable and unknown). The time to execute **`UserTask()`** ranges from 10us to 100us (this time is variable and unknown). Timer2 has been initialized so 32-bit **`TIMER2_TAR_R`** decrements every 1usec. The 32-bit **`TIMER2_TAIL_R`** is set to 0xFFFFFFFF. On each interrupt, measure the period between this interrupt and the previous interrupt. Second, measure the execution time of this running of the ISR. Add C code to this ISR that measures **`Period`** and **`Time`**. It is ok if the first interrupt calculates values incorrectly, as long as the subsequent interrupt invocations are correct. You may add local and/or static variables inside the ISR.

```
uint32_t Period; // usec time between interrupt invocations
uint32_t Time;   // usec time to complete current ISR invocation
uint32_t Percentage; // decimal fixed point, 0.01% resolution
void GPIOPortF_Handler(void){
```

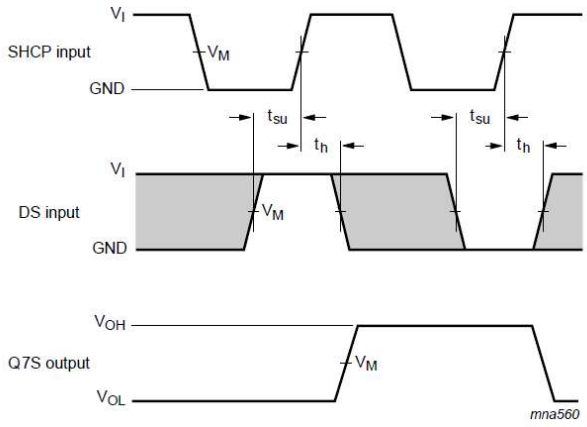
```
  GPIO_PORTF_ICR_R = 0x10; // acknowledge
  UserTask();
```

```
  Percentage = (10000*Time)/Period; // units 0.01%
}  // if Percentage = 100, UserTask is consuming 1% of CPU time
```

Bonus Question: When Valvano shouts "*World Domination!*", to what embedded system concept is he referring?

(10) Question 11. Design an analog circuit that has two inputs and one output, such that the output V_{out} is $1005*(V_1-V_2)+1.5$. The input voltages are constrained so the output will range between from 0 to 3.3V. No analog filter is required. The only available power supply voltage is 3.3V. Assume R1 and R2 are already chosen to achieve a reference of 1.5V. Full credit for a circuit with **low noise** and **excellent CMRR**. You may use any analog chip from lab, book, or lecture PowerPoints. Show design steps. Specify values for all resistors, capacitors, diodes, and inductors.

(5) Question 12. Consider this shift register. SHCP is the clock input. DS is the data input. Q7S is a digital output. Show the timing equation for the **data required interval** using symbols from this figure and syntax from the book. The voltages are $V_I = 3.3V$, $V_{OH} = 3.3V$, and $V_M = 1.65V$.



(6) Question 13. This FIFO queue implementation has shared globals **`Size`**, **`GetI`**, **`PutI`**. Consider the read modify write access to **`Size`**. This FIFO can store up to 16 elements. **`Fifo_Put`** is called by one ISR, and **`Fifo_Get`** is called by a second ISR.

```
int Fifo_Put(int32_t data){
  if(Size==16) return 0; // full
  FIFO[PutI] = data;     // save
  PutI = (PutI+1)&0x0F;  // next
  Size++;
  return 1;
}
```

```
int Fifo_Get(int32_t *datapt){
  if(Size == 0) return 0; // empty
  *datapt = FIFO[GetI];   // retrieve
  GetI = (GetI+1)&0x0F;   // next
  Size--;
  return 1;
}
```

How do I configure the two interrupts, so these two functions are not critical with respect to each other? No changes to the C code in the two ISR functions or the Put Get functions are allowed.

(10) Question 14. Interface a DC motor to the TM4C123. The motor needs to spin in only one direction. The desired DC motor voltage is 4 to 5 V, and the expected current is 0.1 to 2A. You may use any chip from lab, book, or lecture PowerPoints. Specify values for all resistors, diodes, inductors, capacitors, and chip numbers. To which TM4C123 pin would you connect the interface and why?

(15) Question 15. Complete this PID controller, which steers a 2-wheeled robot, in the background using SysTick interrupts. There are two motors, one on each wheel. There are two functions you call to set the power to each motor.

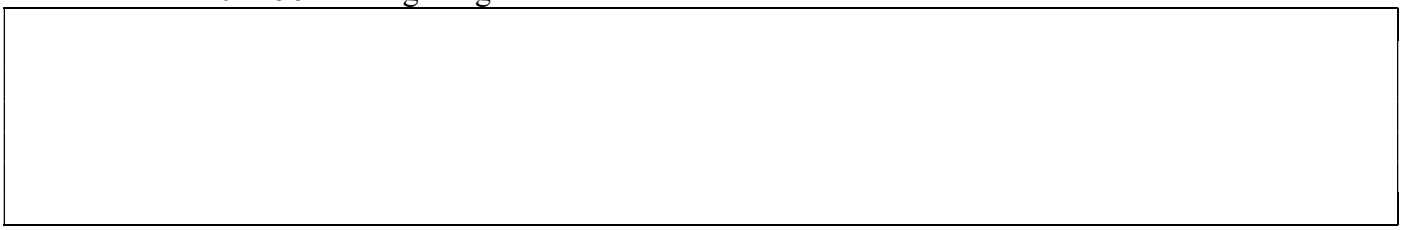
```
void Right_Duty(uint16_t UR);
void Left_Duty(uint16_t UL);
```

The above duty cycle parameters range from 100 to 9900. The desired direction is in the global variable, **SetPoint**. The measured direction is returned by the function **ReadDirection()**.

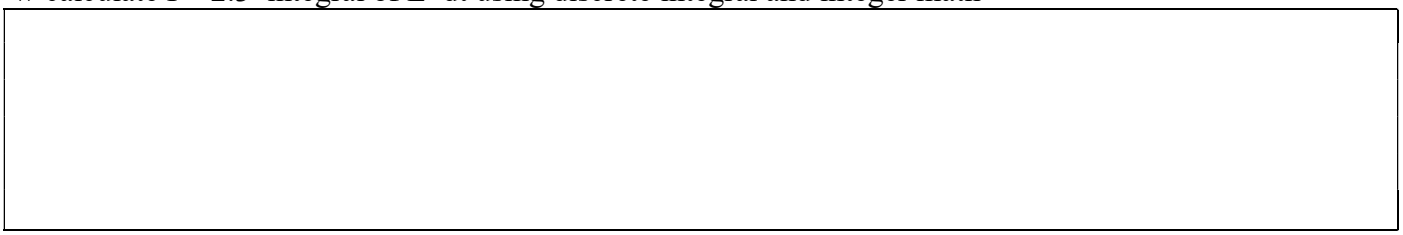
```
int32_t SetPoint;              // ranges from -1000 to +1000
int32_t ReadDirection(void); // ranges from -1000 to +1000
int32_t E,P,I,D,U;
```

Implement and run the following PID controller at 100 Hz. You do not need to write any initialization functions just the SysTick ISR. You get 0 points if you use floating point. You may add static or local variables to the ISR. **Right_Duty, Left_Duty,** and **ReadDirection** are given, you simply call them.

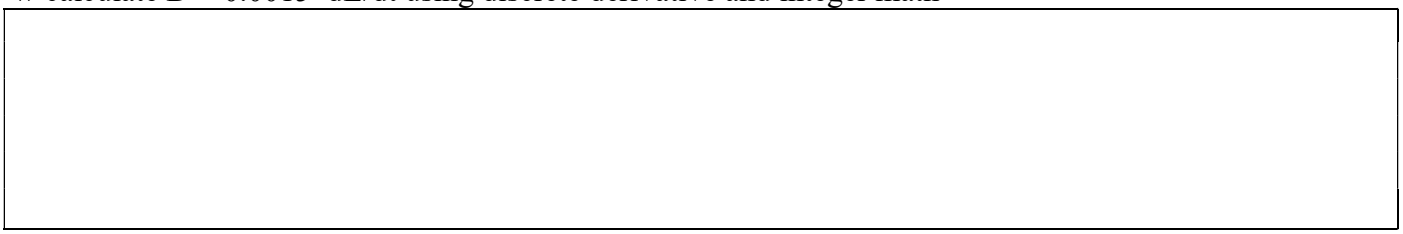
```
void SysTick_Handler(void){ // runs 100Hz, dt = 0.01sec
   E = SetPoint - ReadDirection(); // -2000 to +2000
// calculate P = 0.1256*E using integer math
```



```
   if(P < -1000) P = -1000;
   if(P > +1000) P = 1000;
// calculate I = 2.3*integral of E*dt using discrete integral and integer math
```



```
// calculate D = 0.0015*dE/dt using discrete derivative and integer math
```



```
   if(D < -100) D = -100;
   if(D > +100) D = 100;
   U = P+I+D;
   if(U < -4000) U = -4000;
   if(U > +4000) U = 4000;
   Right_Duty(5000+U);
   Left_Duty(5000-U);
}
```