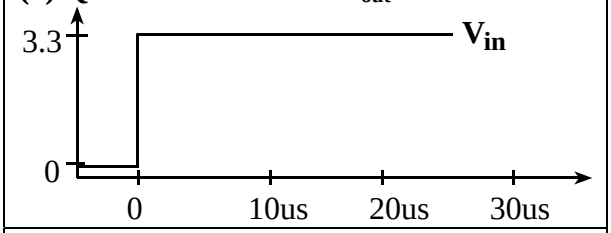
Jonathan W. Valvano First:_____ Last:_____

This is the closed book section. You must put your answers in the boxes on this answer page. When you are done, you turn in the closed-book part and can start the open book part.

(2) Question 1. Give two numbers	**(2) Question 6e.** Select A-F
(2) Question 2a. Select A, B, C	**(2) Question 6f.** Select A-F
(2) Question 2b. Select A, B, C	**(4) Question 7.** Select A-F
(2) Question 2c. Select A, B, C	**(8) Question 8.** Show equation
(2) Question 2d. Select A, B, C	
(2) Question 2e. Select A, B, C	**(4) Question 9.** Select A-F
(4) Question 3. Explain why LDO is 2.5V	**(4) Question 10.** Describe Git
(4) Question 4. Select A-F	**(6) Question 11.** Sketch $\mathbf{V_{out}}$ 
(4) Question 5. Select A-F	
(4) Question 6a. Select A-F	**(1) Question 12a.** ADC parameter
(2) Question 6b. Select A-F	**(1) Question 12b.** ADC parameter
(2) Question 6c. Select A-F	**(1) Question 12c.** ADC parameter
(2) Question 6d. Select A-F	**(1) Question 12d.** ADC parameter

(6) Question 13. Consider this function that implements a digital filter. It has an overflow bug; the sum of two 32-bit numbers is a 33-bit number. Add minimally intrusive debugging code in C to count the number of times an overflow occurs. There is a global variable, **`ErrorCnt`**, which you should increment each time an overflow occurs. As a hint to solve this problem, fill in the signed overflow flag using this table

x	**y**	**x+y**	Overflow (fill in true/false)
positive	positive	positive	
positive	positive	negative	
positive	negative	positive	
positive	negative	negative	
negative	positive	positive	
negative	positive	negative	
negative	negative	positive	
negative	negative	negative	

```
unsigned long ErrorCnt=0;

long DigitalFilter(long x){ static long y=0;









  y = (x+y)/2;









  return y;
}
```

(2) Question 1. The ten points of the IEEE Code of Ethics are summarized as
1. to **accept responsibility** consistent with the **safety, health and welfare** of the public;
2. to **avoid** real or perceived **conflicts of interest** whenever possible, and to disclose them;
3. to be **honest and realistic** in stating claims or estimates based on available data;
4. to **reject bribery** in all its forms;
5. to **improve the understanding of technology**, its application, and consequences;
6. to **maintain and improve our technical competence**;
7. to **seek, accept, and offer honest criticism** of technical work, to acknowledge and correct errors;
8. to **treat fairly all persons**;
9. to **avoid injuring others**, their property, reputation, or employment **by false or malicious action**;
10. to **assist** colleagues and to **support them in following this code of ethics**.

Which two of the ten points specifies it is important to engage in life long learning? Give two numbers.

(10) Question 2. We studied three hardware software synchronization mechanisms

A) Blind
B) Busy-wait
C) Interrupt

There is a fourth mechanism, DMA, which we will study in EE345M. There is also periodic polling, which is a mixture of busy-wait and interrupts. However, in this question answer A, B or C.

(2) Part a) Which method is least likely to cause a software crash (software stops running) when the hardware becomes faulty? Answer A, B, or C.

(2) Part b) Which method is most efficient (creates the highest overall bandwidth) for handling many I/O channels with varying bandwidth? Answer A, B, or C.

(2) Part c) Which method is most efficient (creates the highest overall bandwidth) for handling one I/O channel with varying bandwidth? Answer A, B, or C.

(2) Part d) Which method is best for implementing a situation with many I/O channels and one channel is very important? Answer A, B, or C.

(2) Part e) Which method is best for implementing a real-time system with many I/O channels? Answer A, B, or C.

(4) Question 3. The LDO pin on the Stellaris microcontroller is an internally-generated 2.5V power. It is created with a low dropout regulator. The 2.5 V is used to power a majority of the internal digital logic. Briefly explain *why* most of the microcontroller is powered with 2.5 V rather than 3.3 V.

(4) Question 4. A digital signal is interfaced to a microcontroller input. What happens to this digital interface when the effective capacitance to ground is increased?

A) no change
B) increase in DC current
C) decrease in DC current
D) the signal to noise ratio improves
E) the bandwidth decreases
F) causes a potential back emf pulse solved by a snubber diode

(4) Question 5. What is the advantage of a NRZ protocol over simple 3.3V/0V digital encoding?

A) no advantage
B) higher slew rate
C) better CMRR
D) both high and low require energy to communicate
E) lower power
F) the resistor at the end of the channel reduces reflections

(12) Problem 6. Consider the following Systick interrupting system with its corresponding assembly code generated by the uVision compiler. You may assume Systick interrupts are running and the **Foreground** function is called from the main program. The listing includes absolute addresses. ROM starts at 0x00000000, and RAM starts at 0x20000000. **Num** is at address **0x2000003C** and **Ans** is at address **0x20000040**.

```
long Num
long Ans;

long LowPassFilter(const long x){
static long y=0;
  y = (x+y)/2;
  return y;
}




void SysTick_Handler(void){
  Num++;
  Ans = LowPassFilter(1000);
}




void Foreground(void){
long out;
  Num = 0;
  for(;;) {
    out = LowPassFilter(Num);
  }
}
```

```
LowPassFilter:
0x0000042C 4601     MOV  r1,r0
0x0000042E 4A27     LDR  r2,[pc,#156]  ;@0x000004CC
0x00000430 6812     LDR  r2,[r2,#0x00] ;load y
0x00000432 1888     ADDS r0,r1,r2      ;x+y
0x00000434 EB0072D0 ADD  r2,r0,r0,LSR #31
0x00000438 1052     ASRS r2,r2,#1
0x0000043A 4B24     LDR  r3,[pc,#144]  ;@0x000004CC
0x0000043C 601A     STR  r2,[r3,#0x00] ;store y
0x0000043E 4618     MOV  r0,r3
0x00000440 6800     LDR  r0,[r0,#0x00] ;load y
0x00000442 4770     BX   lr            ;return y

SysTick_Handler:
0x00000444 B500     PUSH {lr}
0x00000446 4822     LDR  r0,[pc,#136]  ;@0x000004D0
0x00000448 6800     LDR  r0,[r0,#0x00] ;load Num
0x0000044A 1C40     ADDS r0,r0,#1      ;Num+1
0x0000044C 4920     LDR  r1,[pc,#128]  ;@0x000004D0
0x0000044E 6008     STR  r0,[r1,#0x00] ;store Num
0x00000450 F44F707A MOV  r0,#0x3E8     ;1000
0x00000454 F7FFFFEA BL.W LowPassFilter
0x00000458 491E     LDR  r1,[pc,#120]  ;@0x000004D4
0x0000045A 6008     STR  r0,[r1,#0x00] ;store Ans
0x0000045C BD00     POP  {pc}

Foreground:
0x0000045E 2000     MOVS r0,#0x00
0x00000460 491B     LDR  r1,[pc,#108]  ;@0x000004D0
0x00000462 6008     STR  r0,[r1,#0x00] ;store Num
0x00000464 BF00     NOP
loop:
0x00000466 481A     LDR  r0,[pc,#104]  ;@0x000004D0
0x00000468 6800     LDR  r0,[r0,#0x00] ;load Num
0x0000046A F7FFFFDF BL.W LowPassFilter
0x0000046E E7FA     B    loop
0x000004CC          DCD 0x2000000C  ;Points to y
0x000004D0          DCD 0x2000003C  ;Points to Num
0x000004D4          DCD 0x20000040  ;Points to Ans
```

(4) Part a) Is there a critical section in the software system shown above?

A) no critical sections
B) yes, with LR
C) yes, access to **Ans**
D) yes, access to **y** in **LowPassFilter**
E) yes, access to **Num** in **SysTick_Handler**
F) yes, access to **Num** in **Foreground**

(2) Part b) How is the parameter **x** passed into the function? Not in general, but in this system.

A) Reg R0
B) In ROM
C) Reg LR
D) On the stack
E) In RAM
F) The compiler optimized this so much the parameter was removed

(2) Part c) Where is the variable **out** allocated in the **`main`** program?

A) Reg R0
B) Reg R1
C) Reg LR
D) On the stack
E) In RAM memory
F) The compiler optimized this so much the parameter was removed

(2) Part d) What does the **`const`** qualifier for **`x`** in the function **`LowPassFilter()`** mean?

A) private in scope
B) stored in ROM
C) stored in global RAM
D) the value is fixed and cannot be changed by the function
E) tells the compiler to fetch a new value, and do not optimize
F) promoted to the next high precision

(2) Part e) What does the **`static`** qualifier for **`y`** in the function **`LowPassFilter()`** mean?

A) public in scope
B) stored in ROM
C) promoted
D) the value is fixed and cannot be changed by the function
E) tells the compiler to fetch a new value, and do not optimize
F) stored in permanent RAM

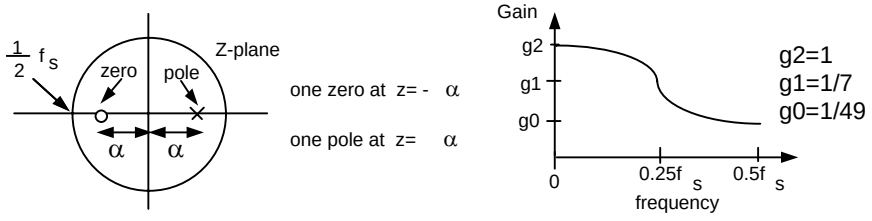
(2) Part f) How does the return from interrupt instruction **`POP {pc}`** change context?

A) gets the PC value from vector table
B) gets the PC value from RAM table
C) moves PC to LR, then pops 8 values
D) pops 0xFFFFFFF9 off stack, then pops 8 more
E) tries to move LR to PC, then pops 8 values
F) pops the return address off stack into PC

(4) Question 7. What is the fundamental justification for the Shannon Channel Capacity Theorem?
A) The information is transmitted with energy. The SCCT states that the maximum possible bandwidth can be determined from a quantitative measure of the energy per bit.
B) When defining an encoding scheme, we wish to separate the codes further apart than the noise level. The signal to noise ratio gives you the number of bits per code. The SCCT states that multiplying the signal to noise by the number by the number of codes per second yields maximum possible bandwidth.
C) The information can be modified by attenuation, distortion and noise. Basically, the SCCT is a way to estimate the maximum possible bandwidth given quantitative measures of attenuation and distortion.
D) The number of bits required to encode information can be reduced by compression. Basically, the SCCT is a way to estimate the maximum possible bandwidth given the compression ratio.
E) If a digital channel exists with no error, then a digital repeater can be added to eliminate the problem of attenuation. Basically, the SCCT is a way to state that a digital channel can achieve infinite diameter.
F) The slew rate of a digital signal defines the maximum frequency component in the wave ($f=1/\tau$). Using wave theory we can estimate the wavelength, $\lambda = v/f$. If the wavelength is less than 4 times the length of the wire, then the channel behaves like a transmission line (reflections occur at impedance changes).

(8) Question 8. There are three integers, y, x_0, and x_1. Each integer ranges from 0 to 1023. Rewrite this low pass digital filter using integer calculations (no floating point). The figure is not needed to solve.

$y = 0.1428 \bullet x_0 + 0.1071 \bullet x_1 + 0.75 \bullet y$

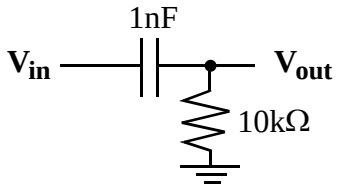


(4) Question 9. Consider the situation in which a software FIFO queue is used to buffer data between a main program and an output UART interrupt service routine. The main program calls **`Output`**, which in turn puts one byte into a software FIFO. The ISR is triggered when the UART hardware FIFO is not full. The UART ISR gets data from the software FIFO and puts it to the hardware FIFO. The UART baud rate is 100,000 bits/sec. Experimental measurements show that the average rate at which **`Output`** is called is 20,000 times/sec. What does it mean? Choose A-F.

A) The system could work, but the system is CPU bound
B) The system does not work, but could be corrected by increasing FIFO size
C) The system could work, but the system is I/O bound
D) The system does not work, but could be corrected by increasing baud rate
E) The system could work, but the FIFO is not needed and could be replaced by a global variable
F) The system could work, but interrupts are not needed in this system

(2) Question 10. Give a brief description of **Git**.

(6) Question 11. Sketch the step response of the following circuit. In particular draw the output wave as the input signal goes from 0 to 3.3 V. 1nF*10kΩ is 10 μsec.



(4) Question 12. First, think of as many ADC performance parameters as you can. Listed here are experimental procedures one might use to measure ADC performance. State the ADC parameter determined by each.

Part a) The input is slowly changed from minimum to maximum. The input voltage, V_i, that causes a change in digital output is recorded. The average of the differences $V_{i+1} - V_i$ is calculated.

Part b) The input is slowly changed from minimum to maximum. The input voltage, V_i, that causes a change in digital output is recorded. The number of V_i recordings is calculated.

Part c) The input is held constant, and the digital output is recorded multiple times. The standard deviation of these recordings is calculated.

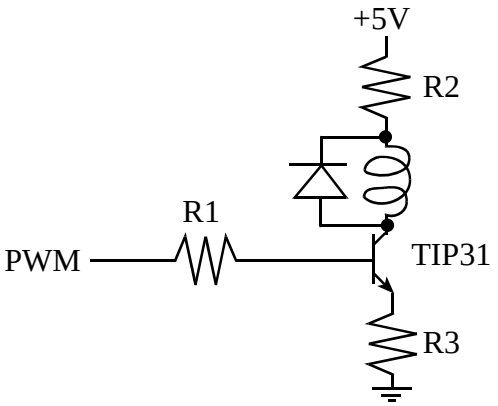
Part d) The input is slowly changed from minimum to maximum. The input voltage, V_i, that causes a change in digital output is recorded. A linear regression is performed on the input/output data set. What ADC parameter does the correlation coefficient of this regression represent?

end of closed book section

Jonathan W. Valvano First:_____ Last:_____

Open book, open notes, calculator (no laptops, phones, devices with screens larger than a TI-89 calculator, devices with wireless communication). You must put your answers on these pages. Please don't turn in any extra sheets.

(10) Question 14. The goal is to interface a motor using a TIP31 NPN transistor. The motor requires 200mA current and has a maximum 5V voltage. Model the motor as a series combination of R, L, and emf. The TIP31 parameters are: h_{fe} is 50, V_{CEsat} is 0.2V, V_{BEsat} is 0.9V. A PWM output of the microcontroller will be controlling the interface (no software required). Waste as little power as you can, so the motor spins the fastest it can.



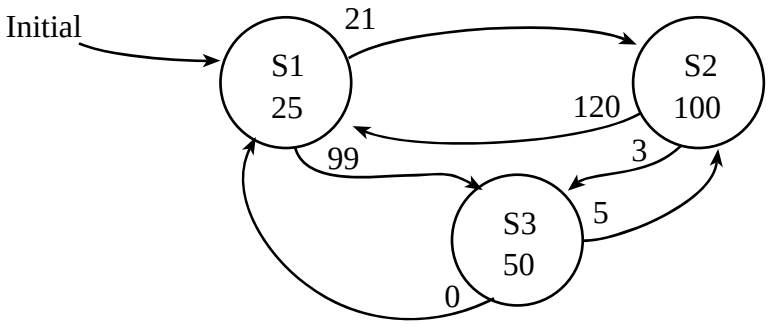
What values would you choose for the three resistors: R1, R2 and R3? Show your work, and put answers in the boxes. You are allowed to select R1, R2, and/or R3 to be zero ohms.

R1

R2

R3

(10) Question 15. The goal is to implement the following Moore FSM. Each state has exactly two defined input values. If the input does not match one of these two defined values, then the machine states does not change state. The inputs and outputs are 8-bit numbers. The machine performs an output, an input, and then changes state. The initial state is S1.



(5) Part a) Show the C code that defines this particular FSM. Include the appropriate structure and the implementation for this FSM. All solutions must have a 1-1 mapping from graph to data structure.

(5) Part b) Assume the system is initialized such that Port F is the 8-bit input and Port D is the 8-bit output. Show the C code that implements the FSM engine. There are no time delays in this system.

(10) Question 16. You will design the analog hardware for a data acquisition system to measure pressure. The range of pressure is 0 to 200 mmHg. Each resistance in the bridge is linear to pressure having a sensitivity of 0.05 Ω/mmHg. At zero pressure all four resistors are 1000 Ω. The pressure signal exists in the 0 to 100 Hz frequency range. A 1.5V reference is available if you need it.

Part a) Fill in the following design table. The bridge output (V2-V1) is a differential voltage.

Pressure (mmHg)	R1 (Ω)	R2 (Ω)	R3 (Ω)	R4 (Ω)	V2 (V)	V1 (V)	V2-V1 (V)	V3 (V)	ADC result
0	1000	1000	1000	1000					
100	995	1005	1005	995					
200	990	1010	1010	990					

Part b) A good CMRR is required. Design the analog circuit using just the single +3.3V supply mapping the bridge output (V2-V1) into the ADC input channel 0. You do not need to add an antialiasing analog low pass filter. Show chip numbers, resistor values, but not pin numbers.