The question will serve as the cover-sheet for each answer. Insert your answers, which I expect to look professional, i.e. clear and clean, after each questions. I will not grade scribbling, and will deduct points if the answer is not professional. Also, no derivation of the computations, no points. Show your work.

1. (20 pts) We want to use Hamming codes:
   (a) Give a definition of the Hamming Distance (HD) between two code words:
   (b) Give a definition of the *HD of a Code*:
   (c) What is the HD of the following code?
   01010101 00001111 11110000 10101010 00000000
   (d) In general, how many errors can be corrected when using the code above?
   (e) What would be the action if the following two words are received: 00011110 or 11111111. Justify your answer for both cases.
   (f) Now we add the code word 11111111 to the code. What is the HD of this new code?

2. (15 pts) A communication link uses 9-bit data words and Hamming error correction.

   (a) How many check bits do we need?

   (b) Derive the expressions to calculate the check bits.

   (c) The data portion of your message sent is 110010101. However, the received data portion is 100010101. Verify that your method catches this bit-error.

3. (15 pts) In order to test your "coding ability" generate a 4-bit FCS for a short message. Assume that $G(X) = X^4 + X + 1$.

   (a) Draw the shift register circuit.

   (b) Calculate the FCS for each of the following three data strings: 10, 0100, and 1100.

   (c) Next, assume that the message is 0000, but during transmission of the message and the FCS the most significant bit of the message has been flipped to 1. Show using calculation that your circuit catches this error.

4. (20 pts) Calculate the MTTF of a TMR system that contains three identical modules, each with a fail rate of λ failures per hour. You may assume that the modules obey the exponential failure law. Compare the MTTF of the TMR system with the MTTF of a single module having the same failure rate.

   Recall that a TMR is a 2-of-3 system. Derive the expression for $R(t)$, then integrate to get the MTTF.

   (a) First do the 2-of-3 system.

   (b) Next, repeat the process for a 1-of-3 system.

   (c) To get a feeling for our result, compute the MTTF assuming the failrate of a single component is 10^{-4} per hour for the following cases:

      i. 1-of-1

      ii. 1-of-3

      iii. 2-of-3

5. (20 pts) In the lecture, we discussed a triplex bus-guardian subsystem as an example of series and parallel systems. We considered two distinct failure modes: *Passive* (or silent) and *Active* (or Babbling).

   Now, consider the Dual-Tripple solution in Figure **??** to the same design problem. Assume $\lambda_{act} = \lambda_{pas} = 1 \times 10^{-5}$.

   For *EACH* of the two failure modes, do the following:

   (a) Draw the reliability block diagram (RBD).

   (b) Draw the fault-tree diagram (FT).

   (c) Using the RBD, derive an expression for the subsystem **un**reliability **by hand** and evaluate the unreliability at 1000h.

   (d) Using the FT, derive an expression for the subsystem **un**reliability **by hand** and evaluate the unreliability at 1000h.

Continued

6. (10 pts) Table 1 gives the MTTFs for components of a flight control system of a proposed airplane. The system has three independent processing units, each of them communication to the other components over a dual redundant bus. The bus is designed to exhibit benign fail behavior. Navigation is dual redundant, utilizing dissimilar components. If one one navigation system fails, the other can take over. The first navigation system the Inertia Navigation System (INS). The second navigation system is composed of a Doppler unit and two Attitude Heading and Reference System (AHRS). Only one of the AHRS units are required for this navigation system to function. Two Remote Terminals (RT) are available to communicate over the redundant busses.

Equipment	MTTF
Processing Unit	3000 h
Remote Terminal	3000 h
AHRS	1500 h
INS	1500 h
Doppler	800 h
Bus	5000 h

Table 1: MTTF Data for System Components

Furthermore, assume that:

- All faults behave in a passive (benign) manner.
- There is no redundancy *within* any box.
- You need at least one Processor operational.
- You need at least one Remote Terminal (pilot's instrument panel) operational.
- You need at least one path *each* for bus A and bus B.
- The given λ for the bus is for one bus.
- The exponential failure law applies and that the fault-coverage is perfect.

(a) (5) Draw the reliability block diagram for this system.

(b) (5) Draw the fault-tree for this system.

I am not asking you to use SHARPE on this yet, since if your diagrams are not right, there is no way for me to determine consistency between your model and the output of SHARPE. As a result, at this point in time the values in the table bare no meaning.