University of Arkansas Microelectronics-Photonics Graduate Program
PhD Candidacy Exam – March 15, 2002
Microelectronics Area of Emphasis Exam

As a senior package development engineer for one of the world's largest semiconductor manufacturers, you have been given the task of developing a "unique" packaging solution for your company's new revolutionary product. Rumors throughout the company suggest that a successful solution to this problem will result in a considerable advancement to your professional career.

The new and revolutionary product is a high-power (~ 4 kW), three-dimensional seismic source used for imaging of geological formations for petroleum exploration. In order to gain the 3-D data, the seismic source must be lowered into a pre-drilled hole to exploration depths up to thousands of feet.

This source contains a unique electronic subsystem that controls the speed of an electric actuator. The mixed-signal (i.e., analog and digital), mixed-voltage (i.e., CMOS and high voltage (i.e., < 90 V)) electronic subsystem was designed by your company's most talented circuit designer. As usual, this designer has provided you with specific constraints from which you are to formulate your solution. Some of these include:

- The ambient temperature will not exceed 200 °C.
- The power FETs, used in the implementation of this electronic controller design, must be able to operate reliably for 3 – 5 years with junction temperatures between –40 to 225 °C. A maximum of 100 hours of the operating life will be at 225 °C, a failure rate of 1000 ppm is acceptable at this point.
- All *other digital and analog components* within the electronic controller must be able to operate reliably for 3 –5 years at the operating temperatures conditions.
- All components within the electronic controller must be resistant to radiation.
- The significant power dissipation can be attributed to a number of power FETs. Assume these FETs have a total maximum power dissipation of 50 W located at the center of your substrate. The "equivalent" footprint of this heat flux can be assumed to be 2.5 mm × 2.5 mm.
- Assume the circuit designer has partitioned the circuit design into a high- and low-power section.
- Assume that a parts list is available to you. (You don't have to design the actual circuit, but should anticipate the general types of components that are required to make the circuit.)
- A hermetic package/module is required. Your package/module input is three-phase, five-wire (i.e., phase A, phase B, phase C, neutral, equipment safety ground), 208 V AC power. Your output to the actuator is three-phase, variable-frequency, variable amplitude. The package's only other interface to the outside world is a bi-directional communication link using the Control Area Network (CAN) protocol.

Part A (must be answered):

In order to prepare a preliminary packaging concept, it is necessary to choose a substrate technology. What substrate technology do you recommend? Why? What materials and metallization will be used? Sketch a cross section of the structure that indicates the material used in each layer. You must estimate the required dimensions, both vertically and laterally. State any and all assumptions that are made.

You are now responsible for developing a preliminary package design. Address the mechanical support material(s) for your substrate, and discuss package walls, pin/connector selection (i.e., for I/O), and the necessary fabrication techniques which must be used in order to implement your design.

Part B (address two of the four following items):

1. Assume you are given the controller circuit schematics for the electrical design. You are asked to provide input to your company's circuit layout guru. What layers, and in what order, must be defined as necessitated by the information given in the problem preamble to complete the circuit layout? Describe the critical layout rules, paying particular attention to the interaction between the HV and logic voltage circuits and circuit sections.
2. Develop a process flow that can be used to fabricate the complete electronic controller subsystem package. You must include, in sufficient detail, information such as: equipment type, temperatures, processing materials used, etc.
3. Construct a thermal model of the structure. Your calculations should be based on first principles. For each material used, thermal conductivity, thickness, and thermal resistance should be addressed. Propose a viable thermal management technique to maintain the integrity of all components, etc. in your design. Show, via calculations, that your technique is successful.
4. Perform a cost analysis from front end to back end - that is, from acquisition of raw materials, labor rates, costs per operation, etc. assuming quantities of 1000 parts per year. Since a parts list is available, assume that the parts are 20% of your other materials cost. You may exclude from your analysis possible additional costs in such infrastructure areas as human resources, facilities engineering, janitorial and grounds, upper level management, etc. You must include all direct manufacturing costs, both startup and continuing; and you must discuss explicitly space and personnel requirements to set up this stand-alone product line.

Part C (must be answered):

Consider the intellectual property content of your solution described in Part A. Determine if there are any existing IP public disclosures that would restrict implementation of your solution, describing in detail the potential conflicts of the three closest IP publications. List all IP sources you consulted while formulating your answer, and include the full list of examined documents as an appendix to this exam (the full list will not be counted as part of your 15 page limit).

Part D (must be answered):

The system you designed in Part A has been shipping from your factory for 24 months, and you are receiving some units back from customers due to reported data corruption in the CAN communication from the units. It is your task to perform failure analysis on the returned systems.

1. Describe the information you will seek from your customer base to help you determine the reason for the data corruption coming from your seismic unit.
2. Propose the three most likely hypotheses explaining why the systems failed in this fashion. Describe the analytical techniques, tools, and instruments you will use to investigate the cause of the data corruption, including the reasons these techniques/instruments are the most appropriate to help you clearly determine which of your three is the correct hypothesis.

Part E (must be answered): Your management team is concerned that the data corruption problem will continue in the field, and they wish to abandon the current electronic data communication approach. Evaluate the possibility of alternate data communication channels/techniques that could be used between the surface instrumentation and the in hole seismic source. Consider both current and projected technologies.

Your answer to Part E should be in the form of an upper level management white paper. It should contain sufficient detail to convince your management team of the merits of your analysis, and should be written with the objective of securing the necessary resources to support a detailed technical examination of the most favorable alternate communication scheme identified in your report.