University of Arkansas Microelectronics-Photonics Graduate Program
PhD Candidacy Exam – March 2007

Advanced Devices in Electronics at the Micro to Nanoscale
(including associated materials and processing)

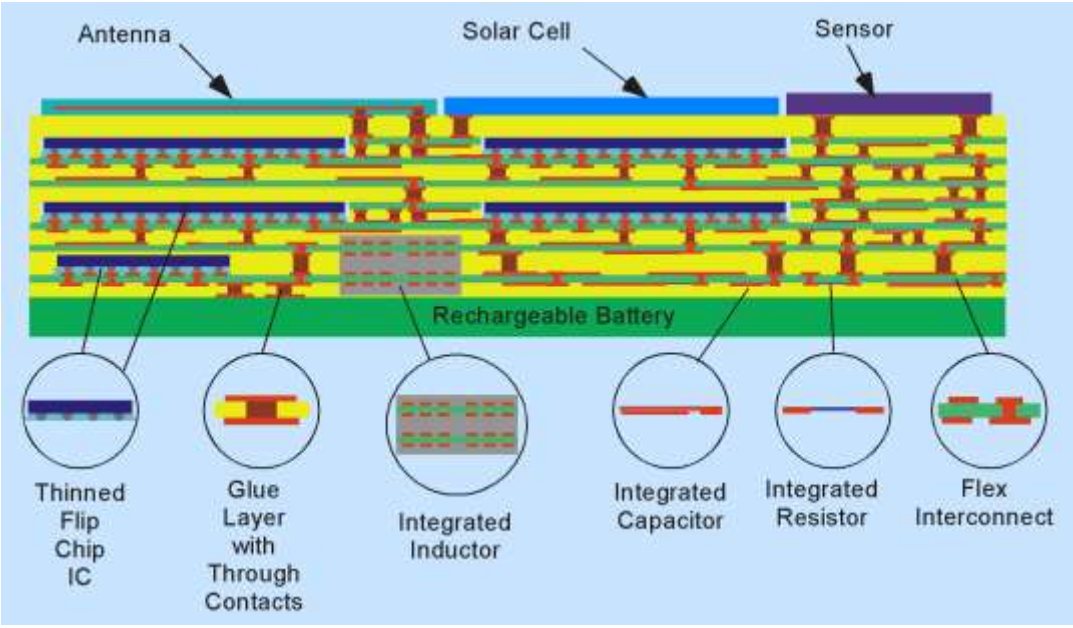
PROBLEM TO BE SOLVED

You are Vice President for Technology at the newly-formed CCE Corp. The CEO is an inventive wizard, but is clueless in bringing his inventive ideas to fruition. That's why she hired you.

CCE stands for Credit Card Electronics. But it doesn't mean electronics applied to credit cards; it means building electronic systems that are the size and shape of a credit card. There are two parts to building these systems.

1. Determining the underlying technology used to build the electronic functions.
2. Defining the function the system is to perform.

The CEO has decided that CCE's first product line is going to be a wireless, self-powered sensor network. Each credit card-sized device will perform one sensor function in a household alarm system, with that sensor function being either a) motion detection, b) fire detection, c) smoke detection, d) radon detection, or e) carbon monoxide detection. Each sensor will resemble the device shown in the figure. Each device will be marketed under the general product family name SAW (Sensor Attached Wherever).



The SAW devices are designed to be glued to the walls of the house with no connecting wires. There could be 10 – 30 of these things in a house, so production cost is a major issue. To conserve the power harvested from the solar cell, the SAW device wakes up at predetermined time intervals, senses its environmental variable, and reports in to a base station with the value or status of that variable. The base station will be built by CCE's parent corporation, BBD (Big Bad Designs), so you don't have to worry about it. The programming and alarm sounding functions will also be handled by BBD. You just need to report what the SAW sensor "sees."

The technology development is substantial. The goal is that the device be no larger than 85 X 55 X 2 mm. Initially the device will contain thinned silicon ICs for the electronic functions, but eventually the goal for the second generation system is to use printed organic electronics on several layers of flex. For both SAW generations, thin film solar cells, thin sensors, and thin rechargeable batteries are needed. Passive component functions must use integrated passive devices within the flex-based wiring layers for thinness.

Some technical specifications that affect your SAW design:

1. Environmental condition of interest must be sampled at least every 30 seconds.
2. Detection limits of any type sensor must meet national building codes.
3. Maximum distance of a SAW to base station will be less than 200 feet.
4. SAW signal as received at box must be greater than -100 dBm.
5. System must be homeowner expandable with "glue and play" capability from one SAW to thirty SAWs with no system reprogramming or homeowner intervention at the base station.
6. Each SAW must be placed in a location that receives at least four hours of comfortable levels of interior illumination or indirect sunlight each day.
7. Each SAW must send an "I am here" signal to the box at least once every 12 hours.
8. Other specs that you define that impact total system functionality.

YOUR DELIVERABLE

Your job is to evaluate available technologies and come up with an internal 15 page combined technology implementation and product realization plan that will let the first SAW devices be shipped in the spring of 2009. The second generation SAW devices must ship in 2011, so development or technology acquisition for the printed electronics must begin now. You must write a 15 page maximum length internal proposal for your fellow CCE corporate officers describing your approach to the issues introduced above. In addition, be sure you also address at least all of the following:

Current Technologies - What is already being done in this area by other researchers, companies and governmental institutions? The current state-of-the-art for both the science and the implementation should be described, making use of diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. Do not forget to describe conjecture of upcoming technologies that could affect the competitive position of your solution. Be sure to cite all references used.

Power Technology – The powering system, including the thin solar cell, the thin rechargeable battery, and the battery-charging and power conversion circuitry are a significant part of the overall system technology. Try to leverage existing development in this area. Discuss the current state of the art, and where the technology needs to be developed to meet the size and cost requirements of CCE's SAW system.Be sure to address both the scientific and engineering issues of the question, carefully explaining performance considerations and any cost-performance tradeoffs.

Sensor Technology – Discuss the available or proposed technologies for the required sensors, with strong justification for your choice of each of the five needed detector functions.

Other Issues – Address any other issues of major importance that impacts your management team's decisions on this matter.

Manufacturing Flow – Describe the manufacturing process flow and the various pieces of equipment needed to manufacture the system, including detailed flow of any new sensors you must produce for one of the five SAW functions. What equipment is available off-the-shelf, and what needs to be developed?

Testing and Qualification - Describe how the assembled SAW devices will be tested and qualified, both for inherent reliability and for operational reliability.

Cost Analysis – At least in qualitative terms, describe the factors that will enter into the manufacturing cost analysis for the CCE product, including which costs will strongly depend on volume. Use this as an introduction to then discuss your expectations of what would be the expected percentage drop in price from early full scale manufacturing to large scale manufacturing, fully explaining your assumptions.

Intellectual Property - List in rank order of importance all IP sources that were consulted while formulating the answer, including the full list of examined documents along with key important reference data as an appendix to this exam. For instance, if the IP source is a patent, include the patent number; title; inventor name; and assignee name. (The full list will not be counted as part of the 15-page limit.) The three that are the most significant threats to your solution should be discussed within the 15-page document, making comparisons of strengths and weaknesses of these approaches relative to your own.

Of course this is just a minimum list of issues you should consider. There may be many more, The point is that your report ***should contain the evidence*** needed to make an effective and compelling case to your CEO in order to insure that she makes the right decision.