Design for Electrical and Computer Engineers
Theory, Concepts, and Practice
Instructor's Solution Manual

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Preface: How to Use This Manual

This manual provides solutions to the problems found in <u>Design for Electrical and Computer Engineers: Theory, Concepts, and Practice</u>. For guidance to instructor's we identify problems as either: review, application, and project. Review-type problems usually ask the student to restate an important concept from the text, whereas application problems are those where the students are required to solve a more in-depth project that demonstrates an understanding of the concepts learned to a new scenario. Project problems are important steps in the completion of a senior capstone design project. Each particular problem is categorized in this solutions manual as to the type of problem it is by using the key [R], [A], and [P].

Furthermore, we also provide our guidance (identified in the manual as Notes), from experience teaching the material, with pointers on how we present the material and apply it to student projects. Selected project assignments are also supplied.

We also ask that instructor's keep this manual for instructor use only and do not post or otherwise distribute our solutions in any form. Unfortunately, it is becoming all too common for solutions to be copied and distributed over the Internet, thus hurting other instructors using the book.

Feedback

Feedback and suggestions concerning any aspect of this manual, that would likely benefit the overall presentation, would be much appreciated. Please send your comments via email to Ralph-Ford@psu.edu or coulston@mines.edu

Chapter 1

The Engineering Design Process

1.1   Problems

1. In your own words, describe the difference between prescriptive and descriptive design processes. Cite examples of each.

   [**R**] *Prescriptive design processes "prescribe" an exact sequence of steps and decisions for realizing a design. There are often decisions that must be made in prescriptive processes for determining whether to move from one stage to the next, or to move to the next phase. Descriptive processes describe the general steps needed to achieve a design, but do not explicitly layout the steps which should be followed to achieve the design.*

2. Describe the relationship between the Problem Identification, Research, and Requirements Specification phases of the design process.
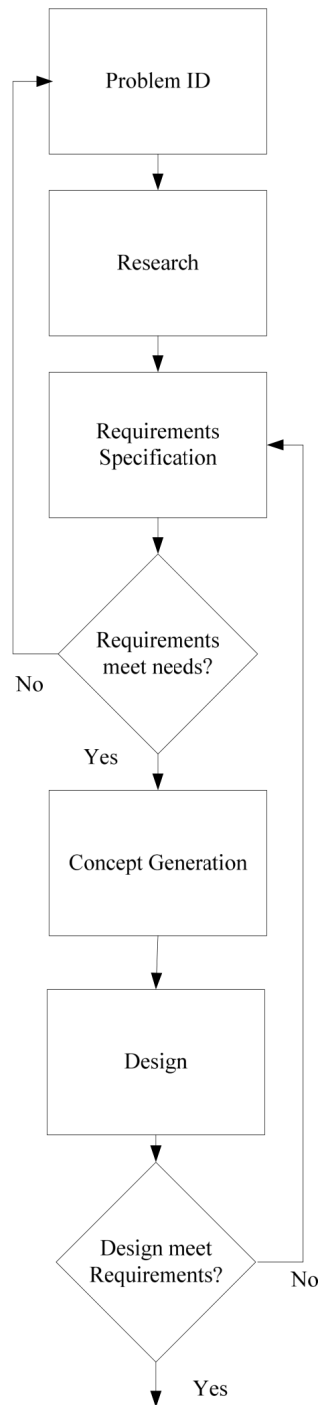
   [**R,A**] *Problem Identification, Research, and Requirements Specification are three early phases of the design process. The overall objective of these phases is to identify a problem, analyze it, and develop requirements for its solution. The Problem ID phase is where the end-user needs are determined, while further analysis occurs in the research phase. Both problem and research phases are used to develop a Requirements Specification that provides the requirements for those elements that must be satisfied in order for a successful design.*

3. Describe the relationship between the Concept Generation and Design phases of the design process.

   [**R,A**] *In Concept Generation, different technical options for solving the design are given – one is selected to pursue. In the Design Phase, the option selected from Concept Generation is further clarified and the design architecture is more clearly defined.*

4. Construct a prescriptive design process for the Problem Identification, Research, Specification, Concept, and Design phases of the design process. The result should be a flow chart that contains decision blocks and iteration as necessary.

   [**A**] *In the prescriptive design process, shown in the figure below, there are two decision points, one of which occurs after the requirements are determined. The objective in this decision is to determine whether the requirements satisfy the end-user needs. If not, the needs must be re-examined and the requirements must be updated as necessary, in order to meet the customer needs. The other decision occurs after the design is generated. Here, the objective is to determine if the design satisfies the requirements. If not, a new design*

```
                        ┌─────────────────┐
                   ──→  │   Problem ID    │
                   │    └─────────────────┘
                   │            │
                   │            ↓
                   │    ┌─────────────────┐
                   │    │    Research     │
                   │    └─────────────────┘
                   │            │
                   │            ↓
                   │    ┌─────────────────┐
                   │    │  Requirements   │  ←───────┐
                   │    │  Specification  │          │
                   │    └─────────────────┘          │
                   │            │                    │
                   │            ↓                    │
                   │         ╱     ╲                 │
                   │        ╱ Require ╲               │
                   └───────╱  ments    ╲             │
                    No     ╲ meet needs?╱            │
                            ╲          ╱             │
                             ╲        ╱              │
                              Yes │                  │
                                  ↓                  │
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                          │ Concept         │        │
                          │ Generation      │        │
                          └─────────────────┘        │
                                  │                  │
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                          ┌─────────────────┐        │
                          │     Design      │        │
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                              ╲ ments?  ╱
                               ╲      ╱
                                 Yes │
                                     ↓
```

concept must be generated.

5. Describe the main differences between the VLSI and embedded system design processes.

[**A**] *VLSI and embedded systems design share similarities and contain differences. They are both similar in that they have phases for requirements specifications, system architecture design, and technical design. The difference between them lies in the technical*

design, where the steps depend upon the technology that is being developed. In the case of VLSI, steps are used to successively refine the design to meet develop a layout level circuit; however, embedded design requires that the technical design phase consists of software and hardware co-design.

6. Using the library or Internet, conduct research on the spiral software design process.

   a) Outline the significant elements of the spiral software design process.

   b) Describe the advantages and disadvantages of this relative to the waterfall model?

   Cite all reference used.

   [**A**] *The spiral methodology reflects the relationship of tasks with rapid prototyping, increased parallelism, and concurrency in design and build activities[1] The spiral process recognizes that errors will occur in all stages of the production process and proceeds on this basis[2]. It is agreed that the development processes will have to be revisited multiple times as the design furthers completion; therefore, unlike the Waterfall model, this methodology incorporates an iteration cycle, which is continued until the design is fully complete. A Spiral Development Model diagram can be found at http://www.hyperthot.com/pm_sdm.htm as well at other sites on the Internet. Embedded in spiral design is the process of refactoring – changing software in such a way as to improve structure, but not affect the end result[3]. Overall, the spiral software design model is not as rigid, concrete, and strict as the Waterfall model; however, this method should still be planned methodically, with tasks and deliverables identified for each step within the spiral. The table below lists the advantages and disadvantages of the spiral design model in reference to the waterfall model.*

	Advantages		*Disadvantages*
1	*Increased time-to-market*	*1*	*Revisiting the same stages*
2	*Incremental & Iterative*	*2*	*Requirements are not fully identified*
3	*Promotes increase in documentation*	*3*	*Project goal is not initially established*
4	*No set structure or phase routine*		
5	*Non-idealistic*		
6	*Not as costly to revisit process steps*		
7	*Primitive to more intricate design*		
8	*Allows development to begin w/o full understanding*		

(1.) Chapman, James. "Spiral Methodology." Software Development Methodology. 2005. 20 May 2005 http://www.hyperthot.com/pm_sdm.htm

(2.) Culwin, Fintan. "The Production Process." LAW – Learn Ada On the Web. 1998. 20 May 2005 http://www.scism.sbu.ac.uk/law/Section1/chap1/s1c1p3.html

(3.) Hean, Daniel. "Design through to testing." Content & Document Management System. 2005. 20 May 2005. http://www.yedit.com/web-content-management-system/400-design-through-to-testing.html

7. **Project Application.** In preparation for project and team selection, develop a personal inventory that includes a list of five favorite technologies or engineering subjects that you are interested in pursuing. Also, list the strengths and weaknesses that you bring to a project team.

[P] *Note: We find this exercise an important step in starting students on the path of team formation and project selection and usually assign it on the first day of class. We setup an electronic bulletin board for the students and have them post this information publicly for the whole class to see. Students are then encouraged to review this and identify potential team-mates. We have also done a variation where each student is required to determine this information and then make a short oral presentation (2 minute pitch) to the class, in which they describe what types of projects they are interested in and what strengths/skills they can bring to a team.*

Chapter 2

Project Selection and Needs Identification

2.1   Problems

1. In your own words, describe the differences between creative, variant, and routine designs.

   [**R**] *Creative designs are typically new and innovative design ideas – those that did not exist before. Variant designs are variations of existing designs, with the intent of improving some aspect of the existing system. Routine designs are concerned with fairly well-known artifacts for which there is a well-developed design knowledge base.*

2. List three guidelines that should be employed when selecting a project.

   [**R**] *(1) The project must be tied to the mission and vision of the organization; (2) The project must have payback; (3) The project should be selected with criterion; (4) The project objectives should be SMART (Specific, Measurable, Assignable, Realistic, and Time- Related).*

3. Assume a customer comes to you with the following request—*Design a mechanical arm to pick apples from a tree.* What are the assumptions in this statement? Rewrite the request to eliminate the assumptions. (This problem was originally posed by Edward DeBono [Deb70]).

   [**A**] *This statement contains a solution based on the assumption that a mechanical arm (by means of picking) is the best method for removing apples off of a tree. Therefore, the design space is immediately and needlessly limited. Also, we are unsure if there is a problem with current methods of removing apples. Here is a better statement:*

   "Design a device that can improve the current method of removing apples from a tree."

   This statement is rightly ambiguous in the sense of not specifying how, or from what, to build this device. This is the type of question and approach that should be sought for establishing a needs statement.

   > **Note:** *Including the word "mechanical" may be permissible, as it clearly defines a type of device, but does not specify further details or characteristics. This situation poses a fine line between problem and solution.*

4. Assume a customer comes to you with the following request—*Design an RS-232 networked personal computer measurement system to transmit voltage measurements from a remote location to a central server.* What are the assumptions this statement? Develop a list of questions that you might ask the customer to further clarify the problem statement.

   [**A**] *This statement, much like the one confronted in problem 3, is filled with numerous assumptions and solutions. The statement proves troublesome because both the problem (transmit voltages measurements from remote location to central server) and solution (RS- 232 networked personal computer) are given to together. Furthermore, you – as the Engineer – are unsure if the prescribed solutions are the best decisions for this particular problem. In order to dissect the statement and get to the actual problem, a list of questions must be asked.*

   Sample Questions

   - *What is the purpose of this transmission system?*
   - *Why are voltage measurements currently being sent? What do they represent?*
   - *How are the measurements currently being made?*

- *What are the problems with the current system?*
- *What do you like about the current system?*
- *What type of atmosphere will this device most likely be engaged in?*
- *Do you plan to implement multiple measurement systems?*
- *Why use RS-232?*
- *What is the purpose of the central server?*
- *What are the voltage measurements of?*

> ***Note:*** *The questions given here are variations on those presented in the book to ask the client when starting into a new project. The objective in asking this question is to get practice in asking these questions. Students are often hesitant to ask questions, particularly if they are working with an industrial sponsor. It help to give them practice in do this before they meet with their customer.*

5. Describe what is meant by a marketing requirement.

   [R] *A marketing requirement is a statement that describes a need in the language of the end-user or customer. It should describe what the system should do, not necessarily how it will be accomplished.*

6. What is the purpose of an objective tree and how is it developed?

   [R/A] *The objective tree is a graphical representation of the customer/end-user needs in a hierarchical layout. It is developed by determining the customer needs (through interviews, observations, etc.) and then translating the results of that into a set of specified needs. The needs are categorized into a hierarchy which is represented in the objective tree. The categorization is based upon functionality, not importance.*

7. The needs for a garage door opener have been determined to be: safety, speed, security, reliability, and noise. Create a pairwise comparison to determine the relative weights of the needs. Apply your judgment in making the relative comparisons.

   [A]

   DEVICE: *Garage Door Opener*
   NEEDS: *Safety, Speed, Security, Reliability, and Noise*

	Safety	*Speed*	*Security*	*Reliability*	*Noise*	*Total*
Safety	*X*	*1*	*1*	*0.5*	*1*	*3.5*
Speed	*0*	*X*	*1*	*0*	*0.5*	*1.5*
Security	*0*	*0*	*X*	*0.5*	*1*	*1.5*
Reliability	*0.5*	*1*	*0.5*	*X*	*1*	*3*
Noise	*0*	*0.5*	*0*	*0*	*X*	*0.5*

Most Important	*Safety*
	Reliability
	Security
	Speed
Least Important	*Noise*

> **Note:** *There is no single solution, and the results are somewhat subjective. However, safety should always be of the highest concern in such an application. The objective of this problem is to demonstrate that students can create a matrix, make it consistent, and compute the scores.*

8. Consider the design of an everyday consumer device such as computer printer, digital camera, electric screwdriver, or electric toothbrush. Determine the customer needs for the device selected. The deliverables should be: 1) marketing requirements, 2) an objective tree, and 3) a ranking of the customer needs using pairwise comparison.

[**A**] Note: *The objective of this question is to give the individual (or preferable a small-team) practice in identifying the needs. Fairly simple and common products should be used as a first step. This can be a very good exercise for the class. Each team could select its own product and then some teams can present the results to the class. Or several or all teams could work on the same project, with a reporting session, where a team presents their findings and the others critique them.*

<u>Consumer Device Selected:</u> **Cellular Phone**

Need: *With today's high-paced world, immediate contacts are essential. Therefore, excellent cell phone design, implementation, and construction are a must.*

a) <u>**Marketing Requirements**</u> • *The system will be lightweight.*
   - *The system will withstand abusive treatment (dropping, running over, etc.).*
   - *The system will be comfortable and ergonomic.*
   - *The system will have high-quality audio encoding and decoding.*
   - *The system will not have to be frequently charged.*
   - *The system will have good signal pickup.*
   - *The system will survive from weathering (sun, rain, etc.).*
   - *The system will be easy-to-use.*
   - *The system will be able to connect to and browse the internet.*
   - *The system will contain as few buttons as possible.*
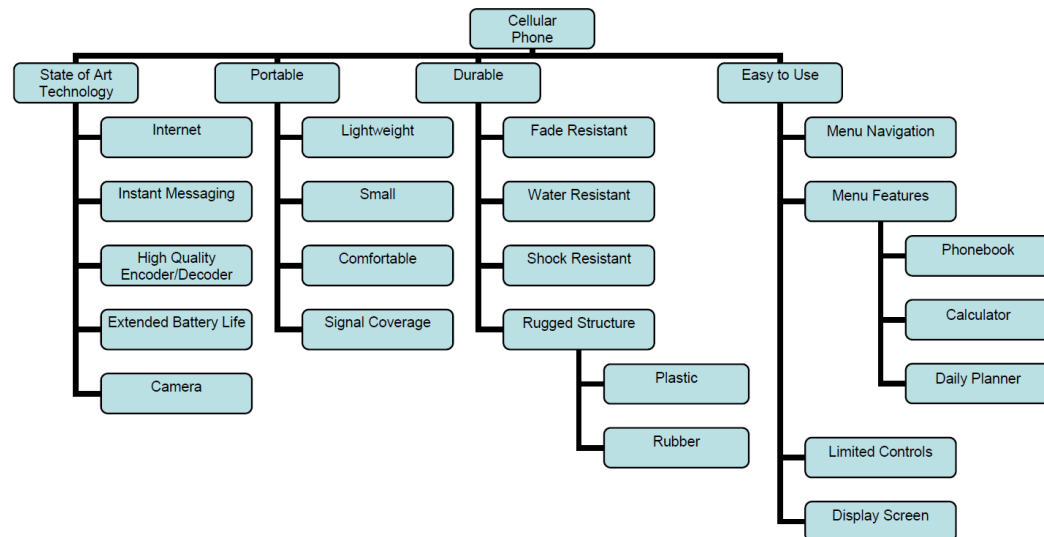
b) **Objective Tree**

Table 2.1: Cell Phone Attributes

	Technology	Portable	Durable	Easy-to-Use	Total
Technology	X	0.5	0.5	0.5	1.5
Portable	0.5	X	0.5	0.5	1.5
Durable	0.5	0.5	X	0	1
Easy-to-use	0.5	0.5	1	X	2

Table 2.2: State of the art technology

	Internet	Text	Audio	Battery	Camera	Total
Internet	X	0.5	0	0	1	1.5
Text	0.5	X	0	0	0	0.5
Audio	1	1	X	0.5	1	3.5
Battery	1	1	0.5	X	1	3.5
Camera	0	1	0	0	X	1

Table 2.3: Portable

	Lightweight	Coverage	Small	Comfortable	Total
Lightweight	X	0	0.5	0.5	1
Coverage	1	X	1	1	3
Small	0.5	0	X	0	0.5
Comfortable	0.5	0	1	X	1.5

c) **_Ranking of Customer Needs_**

d) **_Ranking_**

Most Important	Extended Battery Life and Audio Encoding/Decoding (3.5)
	Signal Coverage and Display Screen (3)
	Water Resistant (2.5)
	Easy to Use, Shock Resistant, and Phone Book Feature (2)
	State of the Art Technology, Internet, Portable, and Comfortable (1.5)
	Durable, Camera, Lightweight, Rugged, Menu Navigation, Menu Features, Limited C
	Instant Messaging, Small, Fade Resistant, Plastic, and Rubber (0.5)
Least Important	Calculator (0)

9. **Project Application.** Select criteria to be applied for selecting a project concept as shown in Example **??** then brainstorm and search to generate project concepts. Rank the top three to five concepts against the criteria as presented in Example **??**.

[**P**] Note: *If the teams are being allowed to select the project, this is a good exercise to get them to focus on criteria for project selection. Conflict often develops between team*

Table 2.4: Durable

	Fade Res.	Water Res.	Shock Res.	Rugged	Total
Fade Res.	X	0	0	0.5	0.5
Water Res.	1	X	0.5	1	2.5
Shock Res.	1	0.5	X	0.5	2
Rugged	0.5	0	0.5	X	1

Table 2.5: Easy To Use

	Navigation	Features	Lim. Ctrls.	Display	Total
Navigation	X	0.5	0.5	0	1
Features	0.5	X	0.5	0	1
Lim. Ctrl.	0.5	0.5	X	0	1
Display	1	1	1	X	3

Table 2.6: Menu Features

	Phonebook	Calculator	Planner	Total
Phonebook	X	1	1	2
Calculator	0	X	0	0
Planner	0	1	1	1

Table 2.7: Rugged Structure

	Plastic	Rubber	Total
Plastic	X	0.5	0.5
Rubber	0.5	X	0.5

members over which project to pursue, and this provides an opportunity to examine the merits of different projects. Criteria to consider are: cost, time to completion, team member skills, probability of success, interest in the project, etc.

10. **Project Application.** Determine the needs for the project selected. The result should be list of marketing requirements, an objective tree, and a ranking of the needs.

   [**P**] Note: *The objective here is the same as question 8, with difference being that it is applied to the capstone design project. A difficulty here could be that the customer may not be as easily identifiable, an example being a design competition. If the team is developing a new and creative product idea, they should be able to do this. If they are working on an industry sponsored project, they should also be able to do this. In the case of design competition or another type does not lend itself as well, the team still should be able to develop an adequate objective tree based on the project rules and their knowledge of the subject. We have had teams be very creative in finding ways to identify the customer needs from conducting web-based surveys on bulletin boards and to conduct focus groups with other students on campus.*

11. **Project Application.** Conduct a research survey for your project using the guidance presented in Section **??**. The result should be a report summarizing the results of the survey.

   [**R**] *No Answer Provided.*

12. **Project Application.** Develop a Problem Statement for your project concept as outlined in Section **??**. Apply the processes presented in the chapter as appropriate.

   [**P**] ***Note:*** *We typically have the teams complete the simple* Problem Statement *similar to those in Examples 2.1-2.3 in the text. Along with this they submit a justification for the team they have selected (*Team Proposal*) that identifies who the members are and what objectives/skills they bring to the team. Once the basic Problem Statement and Team Proposal are completed and reviewed by the instructor, it is then followed by a more*

detailed submission of the <u>*Extended Problem Statement*</u> *that is presented in the Project Application Section. This integrates all of the material from Chapter 2. In term of research, the goal here is to provoke the team to conduct research up-front and show they understand what is going on. In our experience, this is often overlooked, and teams regret it later. In our course, we typically get a 3-6 page report summarizing their findings. Our goal is to determine their level of understanding based upon that. All of this makes up part of the final design report submitted at the end of the project.*

Additional In-Class Exercise

The following exercise is one we use early on in the class to generate project ideas. The class is usually capable of generating at least one idea per minute, and we often get 40-50 ideas in a session.

As a class, the objectives are as follows:

- *Generate a minimum of 40 project ideas.*
- *Every single student in the class must offer at least on idea.*
- *If the two above criteria are met, then everyone in class gets a 10 point (100%) quiz grade. Otherwise, no grade recorded.*

<u>*Rules of Brainstorming*</u>

1. *No criticism or judgment of idea*
2. *Wild ideas are encouraged.*
3. *Quantity is stressed over quality.*
4. *Build upon and modify the ideas of others.*
5. *All ideas are recorded.*

Note: *Another option is to present a particular problem or application area and have the teams students generate ideas based upon them.*

CENBD/EE BD 480 - Engineering Design Concepts
<u>*Penn State Erie, The Behrend College*</u>

Background and Technology Survey Instructions

You should consult with your supervising faculty member when developing this section of the report. Each project is unique.

The objectives of this section are to:

- *Provide your audience (faculty, project sponsors, other students, etc) with sufficient background so that they understand the problem the team plans to solve.*
- *Demonstrate that the team has a sufficient understanding of the problem to proceed to the next stage of development.*
- *Demonstrate that the team has conducted research and understands the technology relevant to this project – namely, related solutions to the problem and their limitations.*
- *Depending on the project, you should also conduct searches on the US patent database for similar technologies.*

- *To describe what is new/unique in the proposed design.*
- *To provide additional supporting information that for the Need and Objective statements.*

Pointers:

- *If it is an industry sponsored project, you will need to provide a clear overview of the problem and any related processes. You should also indicate why it is important to the organization – what benefit it will provide.*
- *You may provide more detail on the need for the project. For example, if this has market potential, indicate what the size of the market is. If you are preventing injuries – how many injuries are there per year? Supporting statistics are always great to demonstrate the need.*
- *If there are similar systems out there, describe limitations of current designs or technology. Benchmarking or strength/weaknesses analyses of existing technologies are powerful.*
- *Describe any basic theory to be described regarding the technology. For example, say you are designing a flywheel energy storage system – you should describe the basics of how flywheel energy systems work – what are the major systems, etc.*
- *Pictures always help - be sure to provide a description of diagrams.*

On the writing itself:

- *This is expected to be well-written prose.*
- *You **must** provide a reference section. Reference all sources used – do not plagiarize. If you use a figure that is not yours, you must provide a clear reference as to where it came from – if not it is plagiarism (in which case you get a zero and reported for academic integrity hearings).*
- *Follow the same format for references as used in the class textbook. Make sure that you reference web pages properly.*
- *All figures and tables must be labeled. Follow the same format used in the book for labeling and referring to figures and tables.*
- *This should be concise 3-4 pages in length. You cannot exceed 4 pages of 11 point with 1" margins.*

Format for the report

Use 12 point Times New Roman bold for the headings of the section. 11 pt for text, 1.5 spacing between paragraphs.

Title

Team Members

1. Need
Text goes here – it should be 11 pt, Times- New Roman single spaced. Use 1.5 spacing between the paragraphs.

2. Objective

Text goes here – it should be 11 pt, Times- New Roman single spaced. Use 1.5 spacing between the paragraphs.

3. Background and Technology Survey

Text goes here – it should be 11 pt, Times- New Roman single spaced. Use 1.5 spacing between the paragraphs.

4. Marketing Requirements and Objective Tree

List the marketing requirements (numbered), Objective tree, and a summary of the ranked needs.

References

Appendix – Ranking of Needs

List the marketing requirements (numbered), Objective tree, and a summary of the ranked needs.