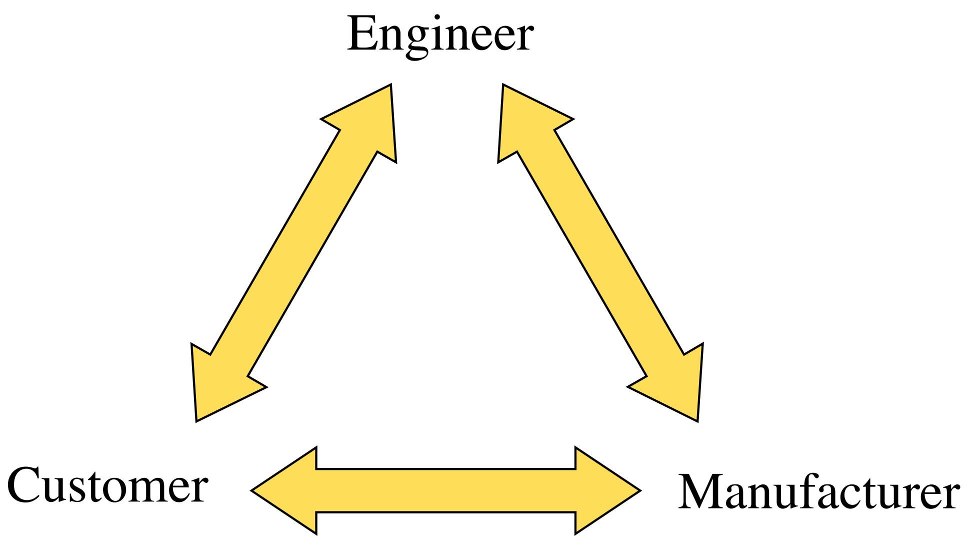
Senior Seminar

ECE 4890 Lecture Notes

Spring 2013



Mark A. Wickert

Contents

System Design

Managing the Design Process

Introduction and Course Overview

Chapter 1

Introduction

- Major themes:
  - Electrical and computer engineering design
  - Professional development
  - Preparing for ECE 4899
- Team presentations
- Instructor policies
- Course syllabus
- Engineering design introduction

Major Course Themes

Electrical and Computer Engineering Design

- The design process
- Requirements analysis
- System design
- Managing the design process
- Detail design, testing, and design management
- An integrated *case study*

Professional Development

- Beyond engineering design
- Team presentations on key ABET professional development curriculum issues
  - economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
  - professional and ethical responsibility
  - impact of engineering solutions in a global, economic, environmental, and societal context

Preparing for ECE 4899

- Choosing a project and project advisor(s)
- Prepare and deliver a pre-proposal presentation with your design team

Course Syllabus

ECE 4890
Senior Seminar
Spring Semester 2013

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mwickert@uccs.edu **Fax:** 255-3589
http://www.eas.uccs.edu/wickert/ece4890/

Office Hrs: Friday 9:15–10:00 AM, others by appointment.

Required Text J. Eric Salt and Robert Rothery, *Design for Electrical and Computer Engineers*, John Wiley, New York, 2002. ISBN 0-471-39146-8.

Grading:
1.) Topic A, B, or C, learning presentation 20%.
2.) Topics A, B, and C learning notes 20%.
3.) In-class attendance/performance/attitude 10%.
4.) Team design requirements document 25%.
5.) Pre-proposal oral presentation 25%.

Topics	Text	Weeks
1. Course Overview and Introduction	1.1–1.3	1.0
2. Project Request for Proposals (RFPs)	Web Doc	1.0
3. The Design Process	2.1–2.5	1.0
4. Requirements Analysis	3.1–3.5	2.0
5. System Design	4.1–4.7	1.5
6. Managing the Design Process	5.1–5.7	2.5
7. Detailed Design, Testing, and Design Management	6.1–6.4	1.0
8. Case Study: *Presentation from a Seasoned Electrical Engineer*; mandatory attendance	Handout A.1–A.6	1.0
9. Short Oral Presentation Topic Group A: How to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Library and internet research	Student presentations spread throughout the semester
10. Short Oral Presentation Topic Group B: Discuss what it means to have professional and ethical responsibility.	Library and internet research	Student presentation spread throughout the semester
11. Short Oral Presentation Topic Group C: Discuss the impact of engineering solutions in a global, economic, environmental, and societal context.	Library and internet research	Student presentations spread throughout the semester
12. Pre-proposal Team Presentations		1.0

Syllabus (cont)

ECE 4890/4899 Important Dates

- ECE 4899 proposal presentations Friday February 1, 8:00 – 11:00 AM, EN 101. ECE 4890 students must attend.
- ECE 4890 case study presentation by an industry engineer, Friday TBD (as early as February 15), 8:00 – 9:15 AM, EN 101. ECE 4890 students must attend. This date will be announced well in advance during a Friday class meeting, and it will also be posted on the course Web site.
- ECE 4890 ABET Topic A, B, & C presentations. ECE 4890 students must attend to either make their presentation and also to take notes on the other team presentations. There will likely be 3 total presentations spread over at most two weeks. Approximate dates are February 22 and/or March 1.
- ECE 4899 design review presentations Friday March 15, 8:00 – 11:00 AM, EN 101. ECE 4890 students must attend.
- Research librarian visit, TBD, to learn about search engines and other research related topics. Friday March 22.
- ECE 4890 design requirements documents due Friday April 12, for review by ECE faculty and project sponsors.
- ECE 4890 Pre-proposal presentations Friday May 3, 8:00 – 10:30 AM, EN 101. ECE 4890 students must participate.
- ECE 4899 final project presentations and demonstrations Friday May 10, 8:00 AM – 12:30 PM, EN 101. ECE 4890 students must attend. Note that this is the Friday before finals. Lunch is included.
- ECE 4890 Design Requirements Document Final Draft (paper copy and PDF via E-mail) due Wednesday May 15, 12:00 PM.

Alt. ECE Design Text

Ralph M. Ford and Chris Coulston, *Design for Electrical and Computer Engineers*, McGraw Hill, New York, 2008. ISBN 978-0-07-338035-3.

If you have a disability for which you are requesting an accommodation, you are encouraged to contact Disability Services within the first week of classes.

If you are a military student with the potential of being called to military service and /or training during the course of the semester, you are encouraged to contact your UCCS course instructor no later than the first week of class to discuss the class attendance policy.

Instructor Policies

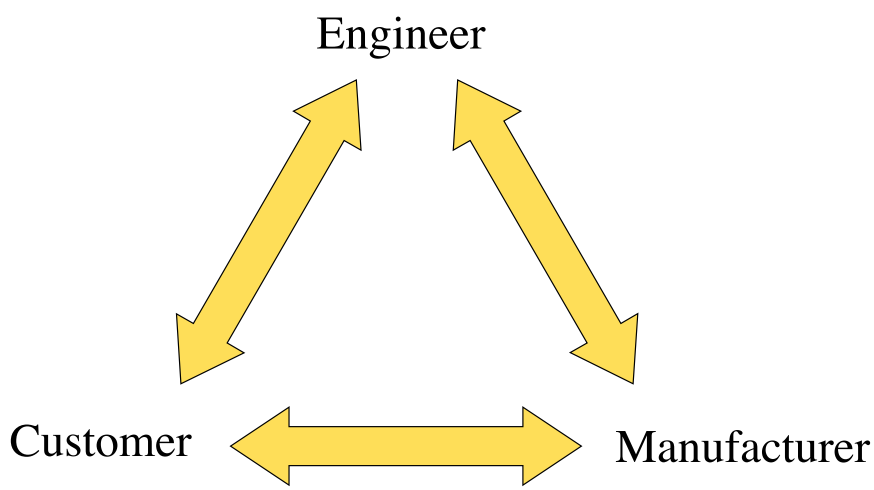
- In-class participation is a very important part of this course, and is in fact required most of the time
- If business travel or similar activities prevent you from attending class and participating in team presentations, classroom discussions, please inform me beforehand
- Grading is done on a straight 90, 80, 70,... scale with curving below these thresholds if needed

The Engineering Profession

- Consider first the definition of engineering as found in two sources
- From Webster's *New World Dictionary* –
  1.a) the science concerned with putting scientific knowledge to practical uses, divided into different branches, as civil, electrical, mechanical, or chemical engineering.
- From the *Accreditation Board for Engineers and Technologists* (ABET) –
  Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.
- Mathematical and scientific knowledge is at the core of engineering
- Engineer's solve problems, for the benefit of society, using synthesis of what is currently known about a problem's solution, and new ways of solving it
- Engineer's *design*

The Role of the Design Engineer

- In general terms, there are three *stakeholders* in any engineering design problem



- The customer is also referred to as the *client* or *end-user*
- In a larger company the customer is represented by the *marketing department*
- The engineer is a member of *research and development* (R&D)
- The manufacturing department may in fact be a separate company, that in this time of *outsourcing* and *globalization*, is in a different country

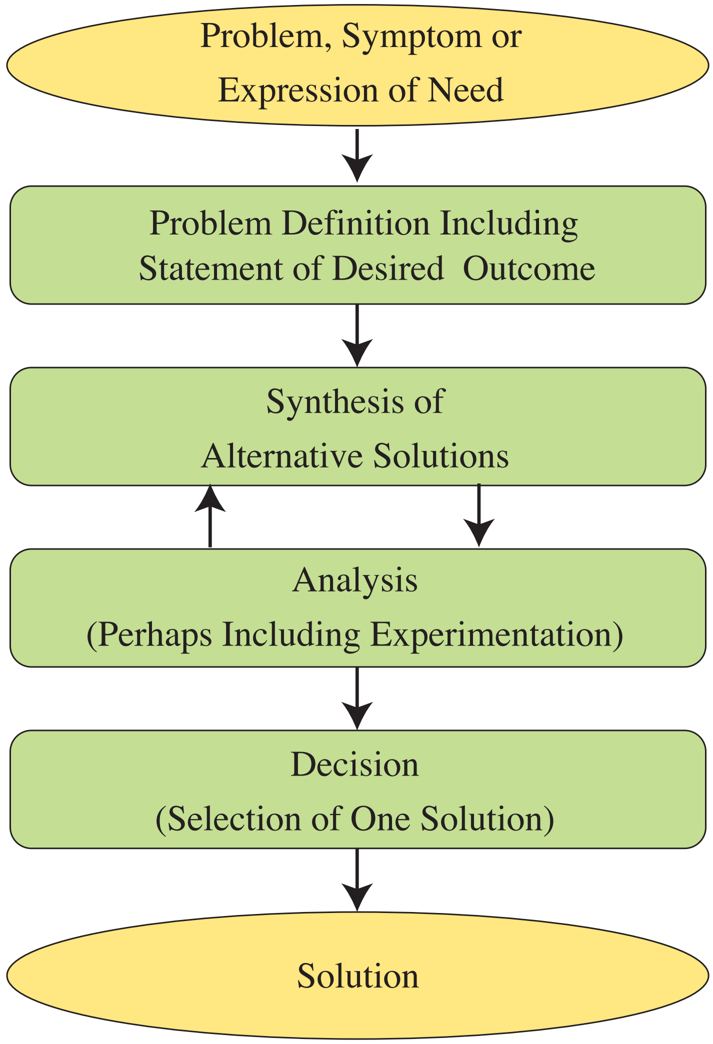
The Design Process

Chapter 2

Introduction

- Engineering and *problem solving* go together
- Scientific and mathematical knowledge are combined to form the solution

General Engineering Process

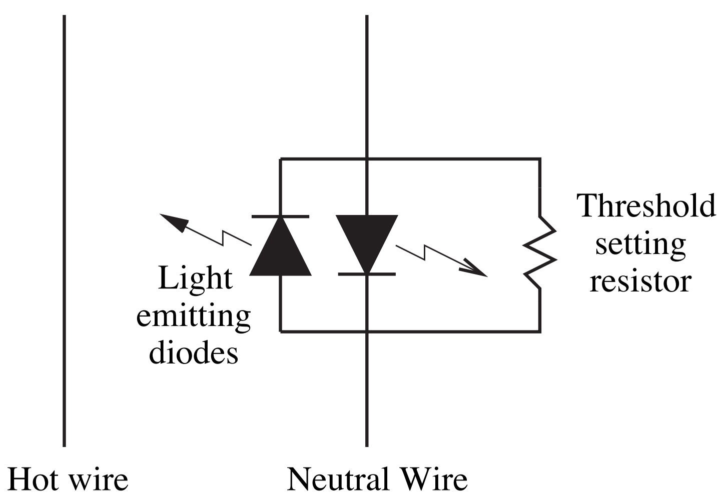


- Analysis and synthesis (Oxford American dictionary):
  - *Analysis*—detailed examination of the elements or structure of something, typically as a basis for discussion or interpretation: statistical analysis | an analysis of popular culture

    The process of separating something into its constituent elements. Often contrasted with synthesis.
  - *Synthesis*—combination or composition, in particular the combination of ideas to form a theory or system: the synthesis of intellect and emotion in his work | the ideology represented a synthesis of certain ideas. Often contrasted with analysis.
- Analysis is typically performed on an existing system, while synthesis is usually associated with a new system
- The process of analysis/synthesis may be repeated to find multiple solutions
  - Many implementations can perhaps meet the requirements, which is the best one?
  - How many solutions should be obtained?
  - The cost of generating possible solutions is expensive and drives up the non-recurring engineering (NRE) budget
  - Will the next solution attempted really be significantly better?

Applying the General Engineering Process: Engine Block Heater Extension Cord

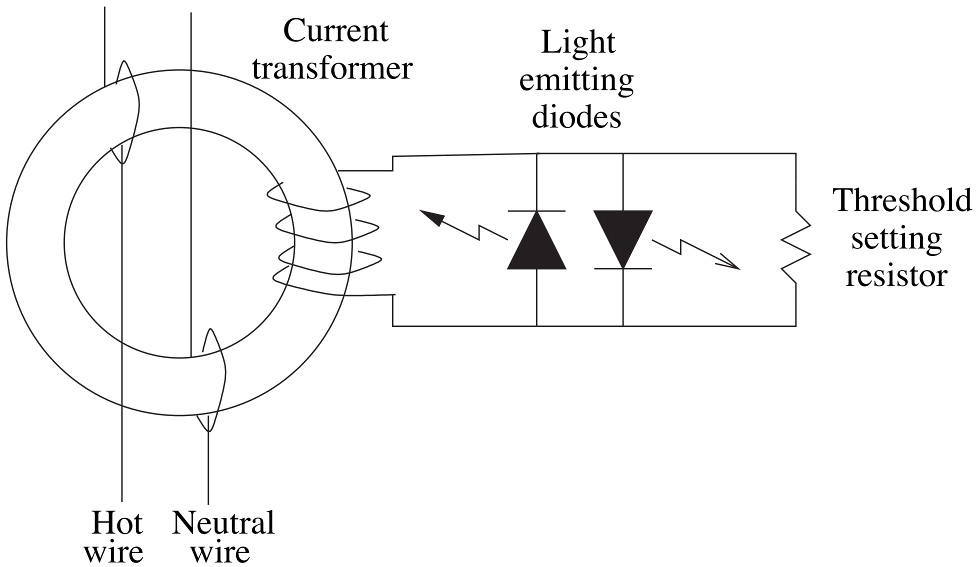
- In colder climates, northern US and Canada, engine block heaters are used to insure easy starting in the morning and when leaving work in the late afternoon
- Problem:
  - A breaker may blow and there is no indication to the employee that their heater is actually working
  - The heater may also burn out and become an open circuit
- The solution is a *smart* extension cord that gives an indication of the above two conditions at the cord end
- A marketing study says that this cord enhancement is worth a price increase of about \$7
- The new extension cord must sell for less than \$6 above the *dumb* model
- A first iteration design (synthesis):



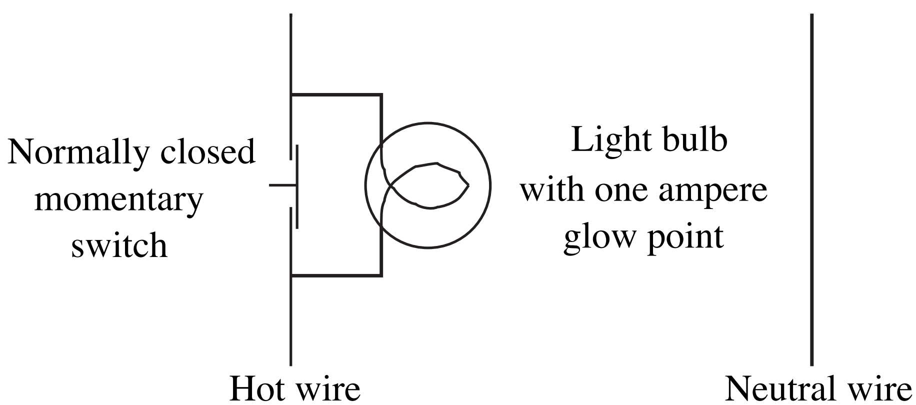
- 3–5 A when on
  0.5 A when not working

  – LEDs must carry too much forward current (4A) making the cost prohibitive

- A second iteration design (synthesis):
  – Include a current transformer



- An alternative design (synthesis):
  – Need to press a switch to see if heater is functioning properly



- Analyze the designs and choose the best:
  – LED solution $4.50, switch/build solution $4.00

- The lower cost solution is not *hands-free*, so the engineer must consult with marketing (customer) to see if this is acceptable
- What do you think?

Evaluation of Alternative Solutions

- In practice, truly optimal solutions are not possible, so we must choose from the best among the available alternatives
- Cost and performance are the main factors in an engineering solution
- Reliability and maintainability are also very important
  - Maintainability has hidden costs as highly skilled individuals my be needed to fix problems
  - Increasing reliability would reduce maintenance costs, but may drive up manufacturing cost too much
- The various criteria overlap, so sorting all of this out becomes complicated
- A design exceeding requirements is not always better, as cost objectives may then be exceeded
  - As a student the temptation is exceed the performance requirements
  - A lower performance design may be more reliable and easier to maintain
- When deadlocked over two near equal choices, *just pick!*

Design Methodologies

Factors

- Complexity of the design
- Size of the design team
- Experience
- Personal style and preferences

Bottom Line

- Best possible solution, within a set of constraints
- Obtained in the shortest possible time

Methodology A

- Consider one possible solution and complete a detailed design
- Implement it and evaluate its performance, manufacturing cost, reliability, and maintainability
- Repeat until a satisfactory solution is obtained

Methodology B

- Consider multiple solutions only to the block-level design (system design)
- The team evaluates the block-level designs using the same criteria as A

- Some solutions will be discarded early on, without the time and expense of detailed design and implementation
- Just a small number of solutions goes through detailed design, implementation, and evaluation

Methodology Pros and Cons

- Methodology B should result in better performance, reliability, and maintainability since more effort was put into obtaining the go-forward solutions (say two)
- Methodology A should be cheaper to manufacture since the lack of a block-level design likely means that circuit functions are shared and the parts count is minimal
- Methodology A is better for the design of high-volume consumer products
- Methodology B on the other hand, is better for low-volume industrial products, where high engineering costs are acceptable because reliability, maintainability, and performance are very important

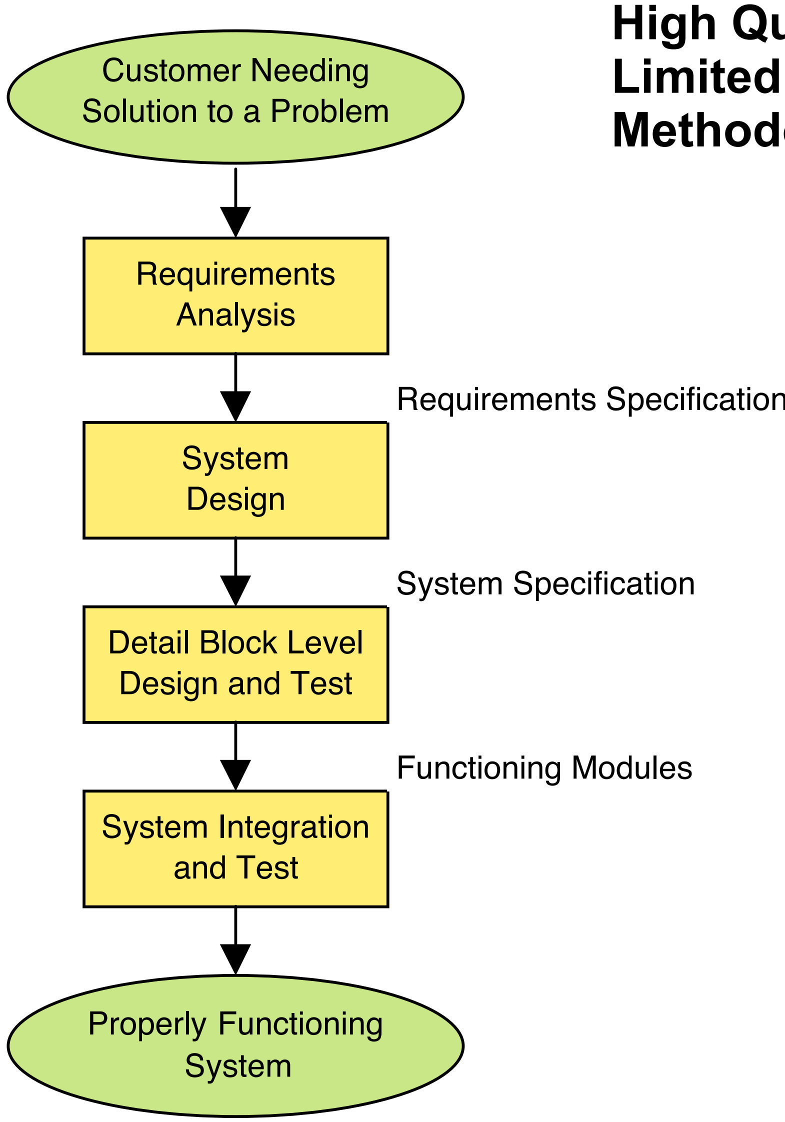
Methodology for Student Engineers/Student Design Projects

- The text has an additional design methodology it recommends for a ECE 4890/4899 type course sequence
- The goal is to produce a high quality design with limited resources (sound familiar? I frequently hear this around the campus)

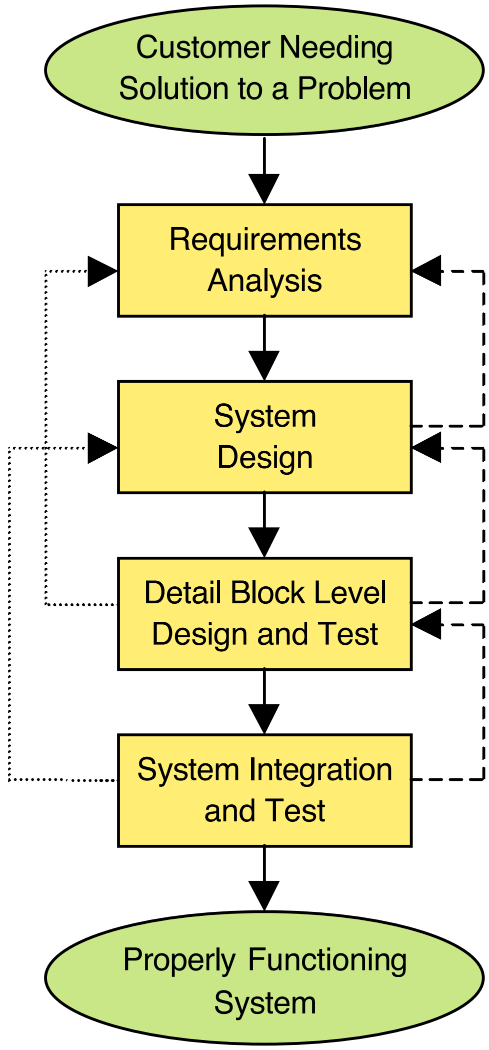
A Methodology for High Quality

- When high quality is the goal, one question might be, ... can the problem be solved?
  - The methodology must be able to ascertain this as quickly as possible to prevent time waste; why?
  - The text claims that 9 out of 10 design efforts are unsuccessful, meaning the one good design must cover the costs of the failures

High Quality with Limited Resources Methodology



- The drawback of the above is that it does not allow mistakes to be corrected as they propagate from one stage to the next
- To fix this consider the more realistic approach shown below



Jumping Back One or More Stages is Possible when an Error is Discovered

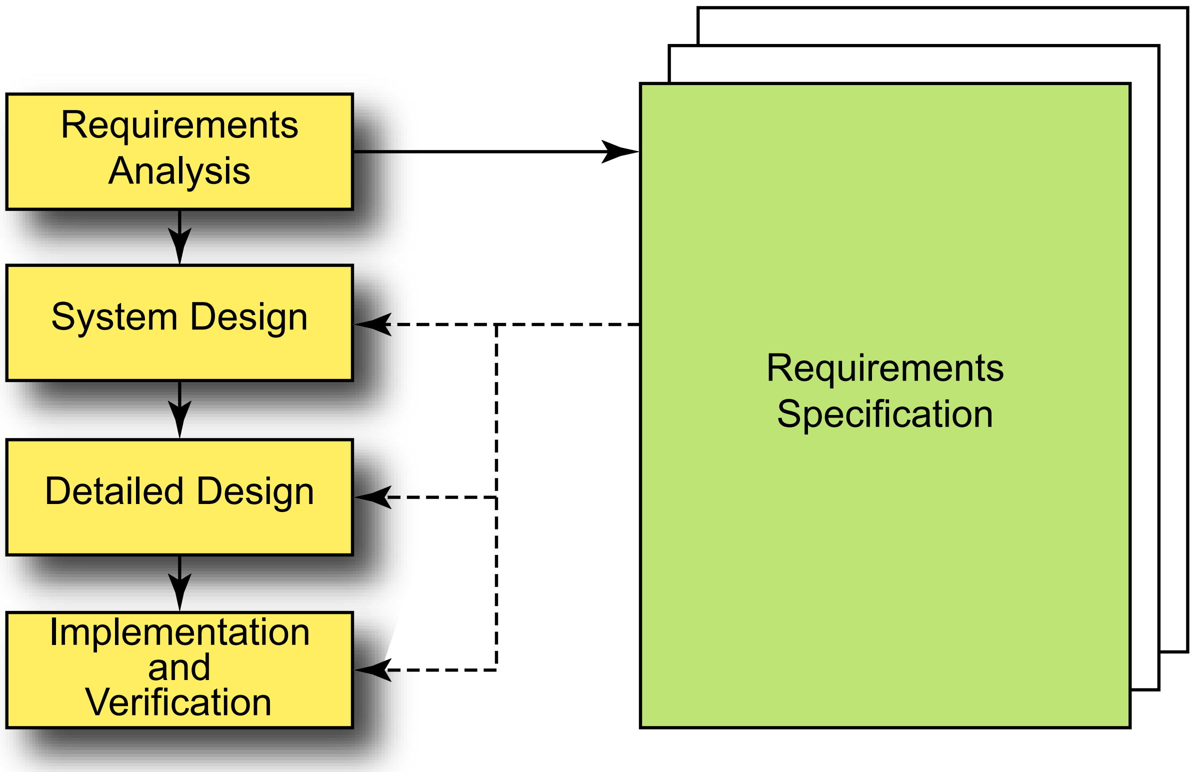
  – When errors are uncovered you can jump back one stage to rework and solve the issue(s)
  – Jumping back two stages is also possible, but it will be more costly

- The next two steps, requirements analysis and system design, Chapters 3 and 4 respectively, are the most important

Requirements Analysis

Chapter
3

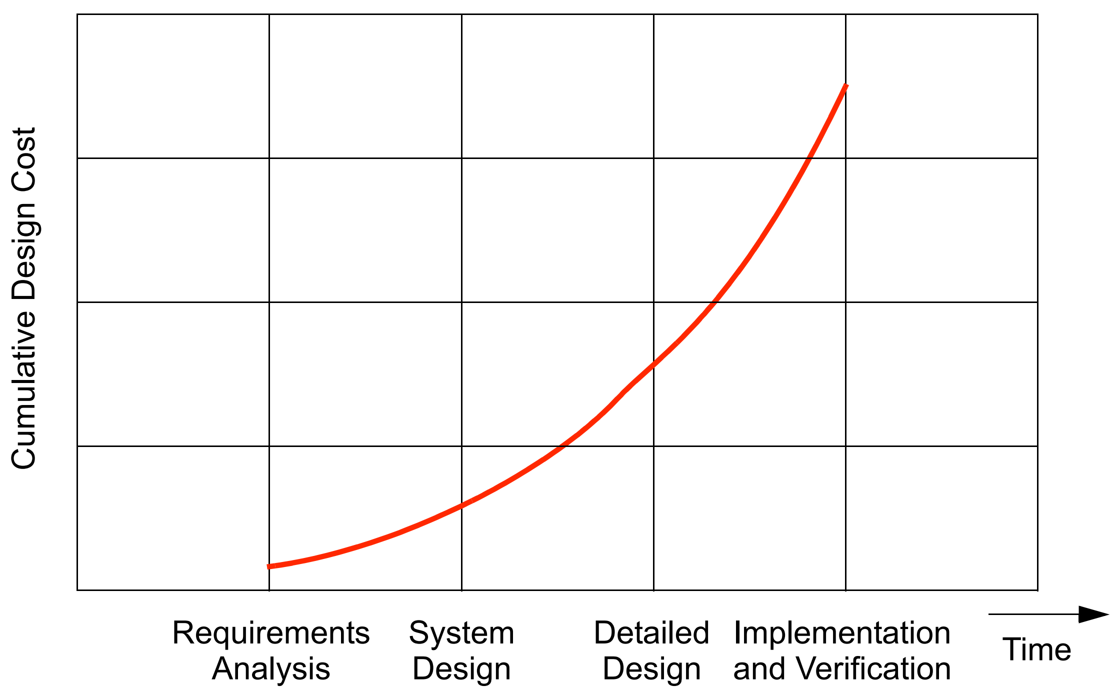
- The design methodology of Chapter 2 lists *requirements analysis* as the first step
- We will find in this chapter that producing a requirements document, along with performing a requirements analysis, forms a contract between you and the customer



  - "What exactly is the design to accomplish"
  - How will everyone with a stake in the design know when its done?"

The Importance of Requirements

- Describes tests that will be performed to verify the design
- Serves as a check point for “go, no–go” decisions
- Acts as a filter to weed out designs that are
  - Overly ambitious
  - Have conflicting objectives
  - Address intractable problems
- Not all projects are successful
  - The text authors claim that only 1 in 10 commercial design projects result in a viable product
- Costs mount exponentially as a design proceeds, so go/no–go on a project is an important decision



- Good engineering judgment is required at this phase of a design project, so experienced engineers are vital here
  - time, money, & expertise

Developing the Requirements Specification

- Focus on the customer/marketing department who needs a solution to a problem

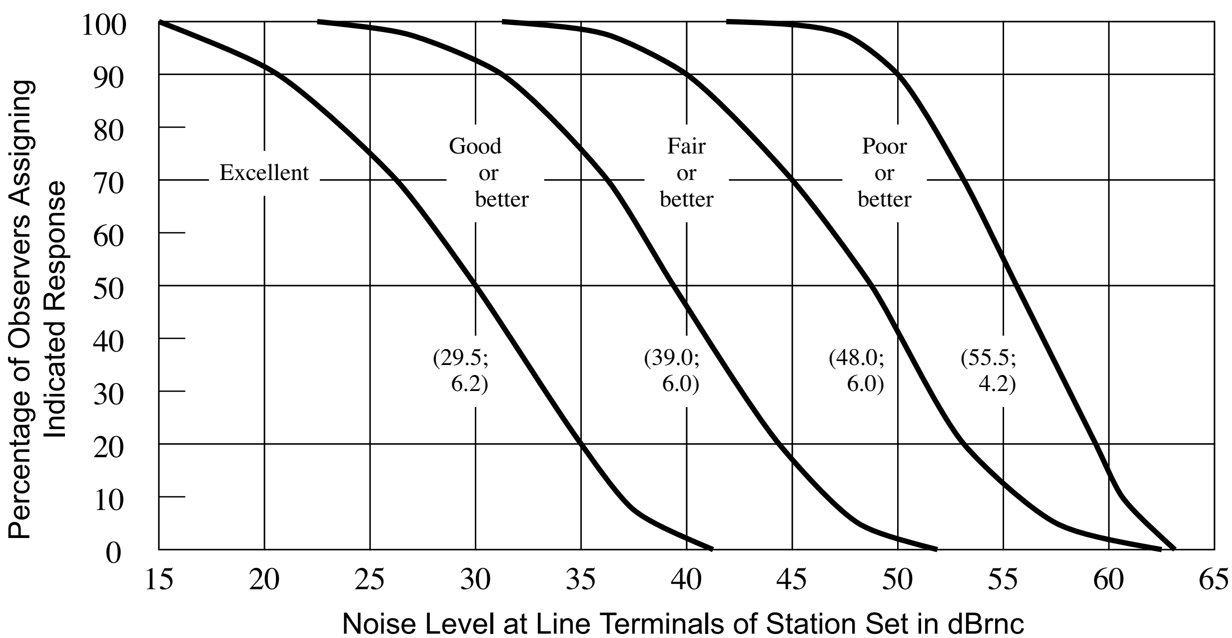
Two Scenarios

- The *informed customer*
  - Problem area is well understood
- The *frontier customer*
  - Problem lies in unexplored territory

	Informed Customer	Frontier Customer
Customer's knowledge of the problem	High— Customer knows and understand what the design should accomplish	Low—No appropriate experience or examples to draw upon
Availability of information	Readily available from: • customer • equip. vendors • competitors • similar designs • books, journals	Limited availability—No existing equipment on the market or no similar designs have been done to offer experience

	Informed Customer	Frontier Customer
Ease of doing requirements specification	Relatively easy— The task is to organize the available information	Relatively difficult—Also can be expensive. May require basic research and specialized skills
Probability of proceeding to next stage in design process	Relatively high—More up-front knowledge minimizes the risk that the design is overly ambitious	Relatively low—Unforeseen issues are likely to arise that may reveal the problem is intractable or too costly to solve

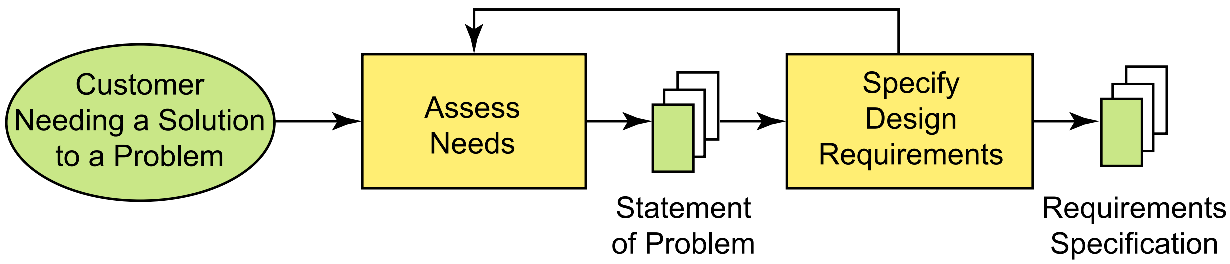
Example: Noise judgement curves used by AT&T



Notes:
1. Values in parentheses indicate average and standard deviation.
2. Received volume constant, -28 vu.

A Two-Stage Approach to Developing the Requirements Specification

- Developing the requirements specification requires different thinking than used in engineering courses
- The following figure explains the approach:

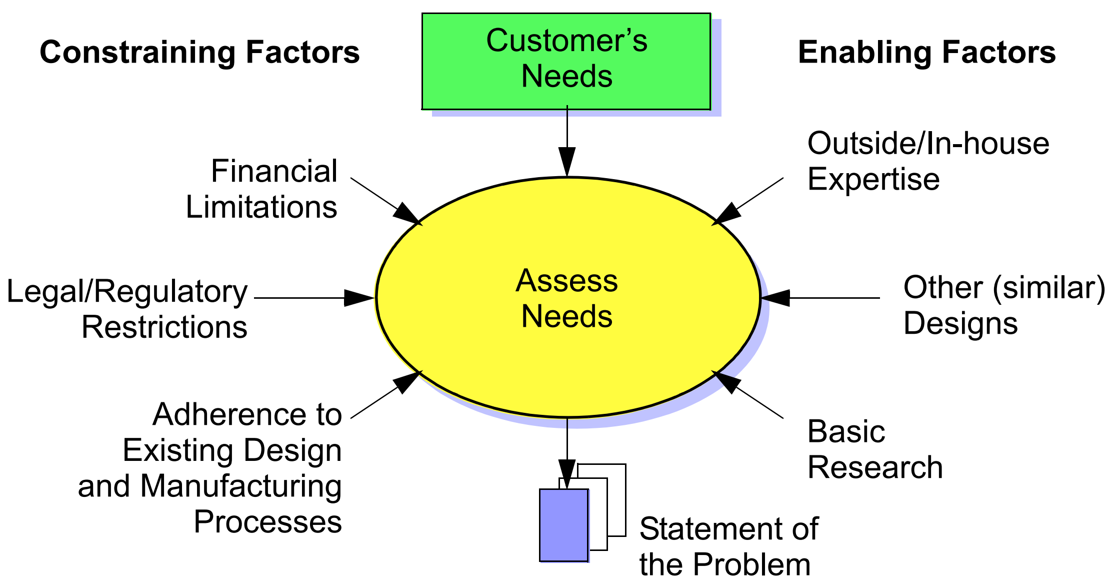


- Assess needs and organize into a problem statement
  - The language of the customer should be used, likely non-technical and nonquantifiable
- Second, turn the problem statement into a technical specification
  - At the same time establish criteria for judging the acceptability of the design
  - Note that there is a need for iteration (the feedback path)
  - The customers true needs may be called into question, and subsequently changes may be made, etc.
  - The engineer must be free to make decisions and form agreements with the customer
- The final output is the requirements specification document
- This document is a concise statement of what the design will accomplish, and the criteria used to judge the final outcome

- The document also answers the two earlier questions:
  - What exactly is the design team to do?
  - How will everyone know when the design is done?
- The document ultimately must receive approval of both the customer and the designer

Real-World Considerations

- A real-world design rarely starts with a *clean slate*
- There will be both constraining factors and enabling factors:



Needs Assessment–Stating the Problem

Nontechnical: Use the language of the customer and avoid the engineer's jargon and other technical terminology

Nonquantifiable: Avoid the use of numerical terms at this point

Complete: Cover all aspects of the design

Specifiable: It should be possible to convert a stated need into a quantitative requirement

Question the Customer: Examples

Define the Design Problem —
- What is the problem to be solved?
- Why is there a problem?
- What is my role in solving the problem
- How will I know when I am done

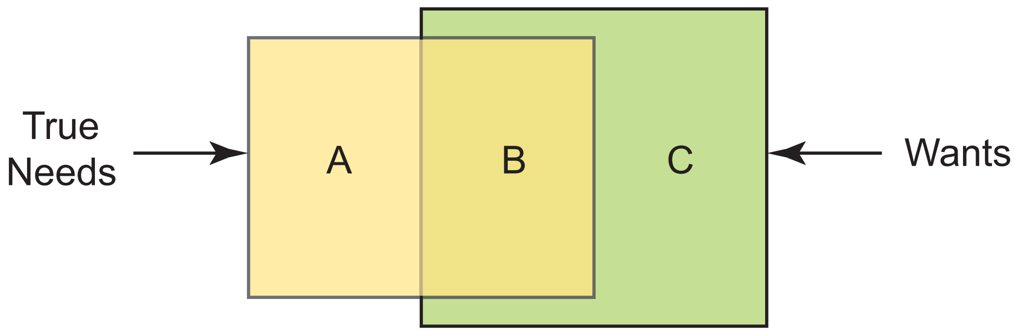
Determine Budget and Schedule Constraints —
- When is the solution needed?
- What is the upper limit of cost to do the design?
- What are your expectations of production cost in high volumes?

Reliability and Maintenance —
- What are the consequences of the system failing once in operation?
- What resources (personnel, replacement parts, budget) are available for maintenance?

Contract —
- How will it be determined when the design is complete
- How will it be determined that the design is acceptable
- How will I (firm) be paid
- Is the work that I am to do legal (ethics)

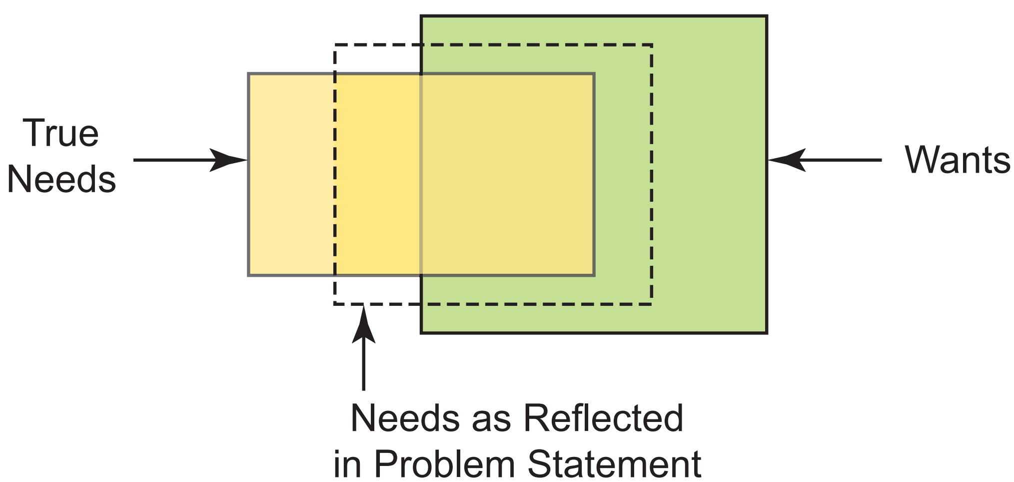
Differentiate Needs and Wants

- Determining needs is not always easy
- Wants may be confused for *real needs*



  – Wants generally exceeds the true needs

- If only wants were addressed, some of the true needs would be missed (area A), and unneeded features would be implemented (area C)
- The customer's wants must be translated into a problem statement reflecting the true needs



  – Note, the problem statement does not exactly match the true needs, but is close

Explore Project Boundaries

- Some solutions will be out of bounds
- There may be a need to fit within existing:
  - operations
  - standards
  - methods
  - procedures
  - legal boundaries

Input/Output Analysis

- View the complete design as a system having a functional block diagram with inputs and outputs

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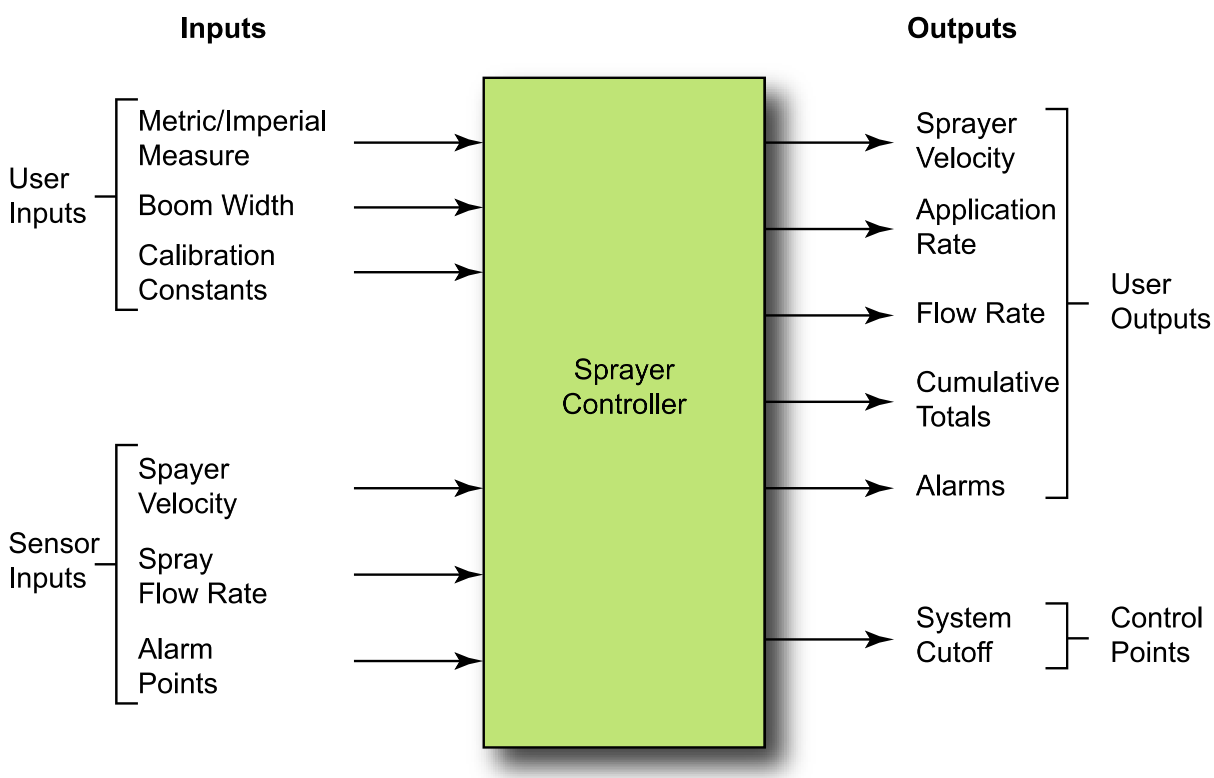
Example: An Agricultural Pressure Sprayer



- The designer and customer need to jointly develop this diagram
  - This will insure that unforeseen needs will surface

- The input/output diagram does not however indicate anything about reliability, size, and weight
- The diagram may be overkill for simple functionality designs

Preview the User Interface

- The requirements specification should include a definition of the user interface
  - This applies to both hardware and software designs
  - There may be more than one interface in some design, e.g., a remote interface via ethernet, etc.

Survey Design Attributes

- Functional
- Nonfunctional

Example: Cell Phone

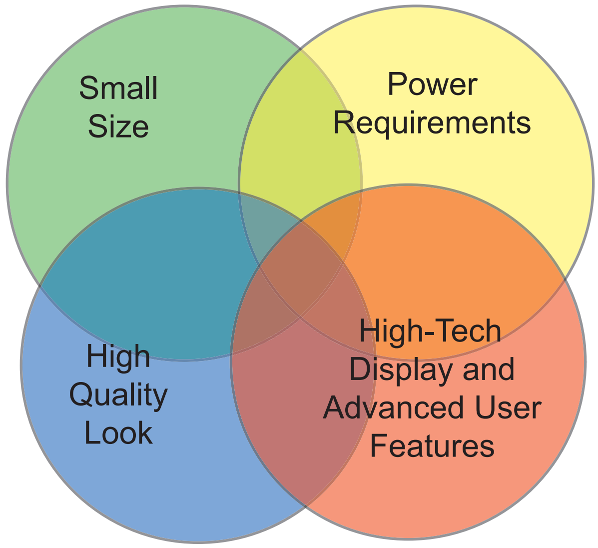
- Functional
  - Standard functions
  - Advanced functions
- Nonfunctional
  - User interface

  - Packaging
  - Battery
  - Production
  - Reliability
  - Service

Identify Conflicting Needs

- Conflicting design needs are not uncommon
  - Design trade-offs will resolve these conflicts later
  - For now we just want to anticipate them so the customer is aware of them
- Classic conflicts: cost, performance, and time
  - The customer wants high performance, but finds the associated cost and time to deliver unacceptable
  - Alert the customer if these three are out of line ASAP
- A correlation matrix can be constructed as a means to rate how overlapping design needs *correlate* in a positive or negative sense
- Conflicts should be discussed as the problem statement is developed, but resolution should not be attempted at this time
- The customer needs to know these are issues and hopefully recognize that some ‘needs’ may not be necessary

Example: Cell Phone Revisited (conflicting design needs)



Conflicting Design Needs

- Construct a correlation matrix to rate the overlapping design needs

	Size	Battery Capacity	Display/ Appearance	Range/ Performance
Size		++	++	-
Battery Capacity			+	++
Display/ Appearance				--
Range/ Performance				

++ Highly correlated positive
\+ Moderatley correlated positive
\- Moderately correlated negative
-- Highly correlated negative

Prepare a Draft Operations Manual

- When a product or system is delivered, a users manual is also delivered to provide usage instruction
- At this early stage, the draft manual will help focus both the engineer and customer on true design needs
- The draft manual can be as simple as an outline of the sections and subsections that the manual will contain

Prepare the Requirements Specification

- Now that the problem statement is complete, the requirements specification document should follow naturally
  - Recall that the problem statement is in nonquantifiable and nontechnical terms
- The requirements specification is very technical
  - It might be that some experimentation, subjective tests, and research is required

Translating Needs to Specifications

- Each design need is translated into a specification
  - All design needs are covered
  - They are independent of each other
  - Their are no contradictions

- A poor problem statement will become obvious, and may need to be reworked with the customer to remove inconsistencies
- The translation from problem statement to specifications requires the experience of the design engineer
- Outside help will likely be needed to assist with the translation:

  (1) **Search out expert sources** — ?

  (2) **Analyze similar design** — ?

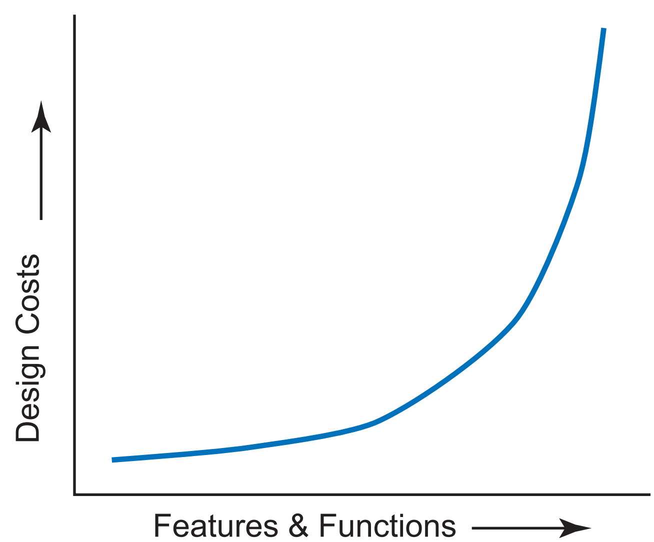
  (3) **Conduct tests or experiments** — ?

Specification of Interface Points

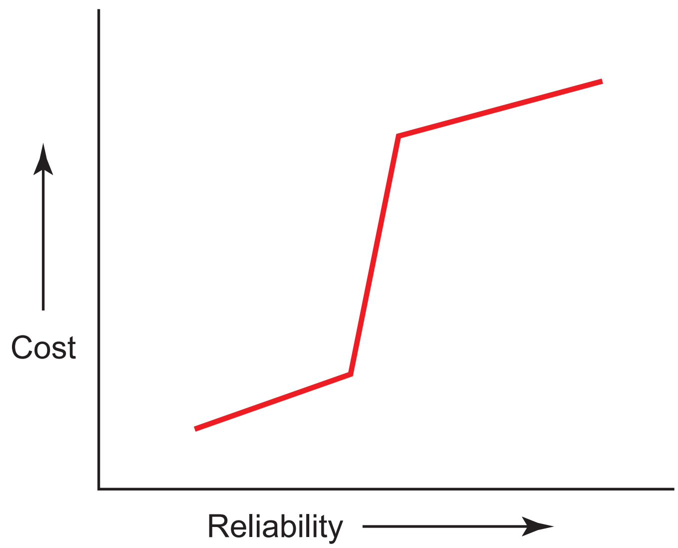
- The user interface must be completely specified
  - Conceptual drawing of the front panel; switches, key pads, displays, etc.
  - Computer screens; GUI conceptual layout
  - Electrical and mechanical interfaces such as connectors, communications standards, etc.

Excessive Requirements

- You want to meet the customer expectations, but you have to walk a fine line between being too ambitious or too lax
  - An inexperienced engineer is prone to having excessive specifications that provide needless features/functionality or make the specifications too difficult
- Added functionality to say software, may be viewed free, when in actuality time and money are needed to implement these features
  - There is also a *trickle-down* effect, in that documentation increases along with test time



- Stringent or conservative specifications can drive cost up quickly when the cost reliability threshold is reached



  - The customer needs to be made aware of this type of trade-off

Verification

- The system or acceptance test verifies whether the design fulfills the customer needs
- At the final stage of the design process, the system is subject to a final acceptance test (FAT)
- A preliminary test plan should be delivered along with the requirements specification
- *Verification Rule #1* — "If a design requirement cannot be verified, it should not be specified"
  - If need be restate the specification into a form that can be verified

Documenting the Requirements Specification

- Document the above in to a deliverable form

Example: Typical Outline for a Requirements Specification

1. Overview
2. Statement of the problem
3. Operational description (derived from the draft user's manual)
4. Requirements specification (see the case study in text Appendix A)
5. Design deliverables (all that is to be delivered to the customer)
6. Preliminary system (acceptance) test plan
7. Implementation considerations
   - Customer training, service, and maintenance
   - Manufacture
8. Attachments
   - Studies (e.g., lab reports or marketing studies)
   - Relevant codes and standards

- In the overview state why the design is being done, and what are the expectations
  - The *executive summary*
- The operational description will preview the user interface (front panel, computer GUI, etc.)

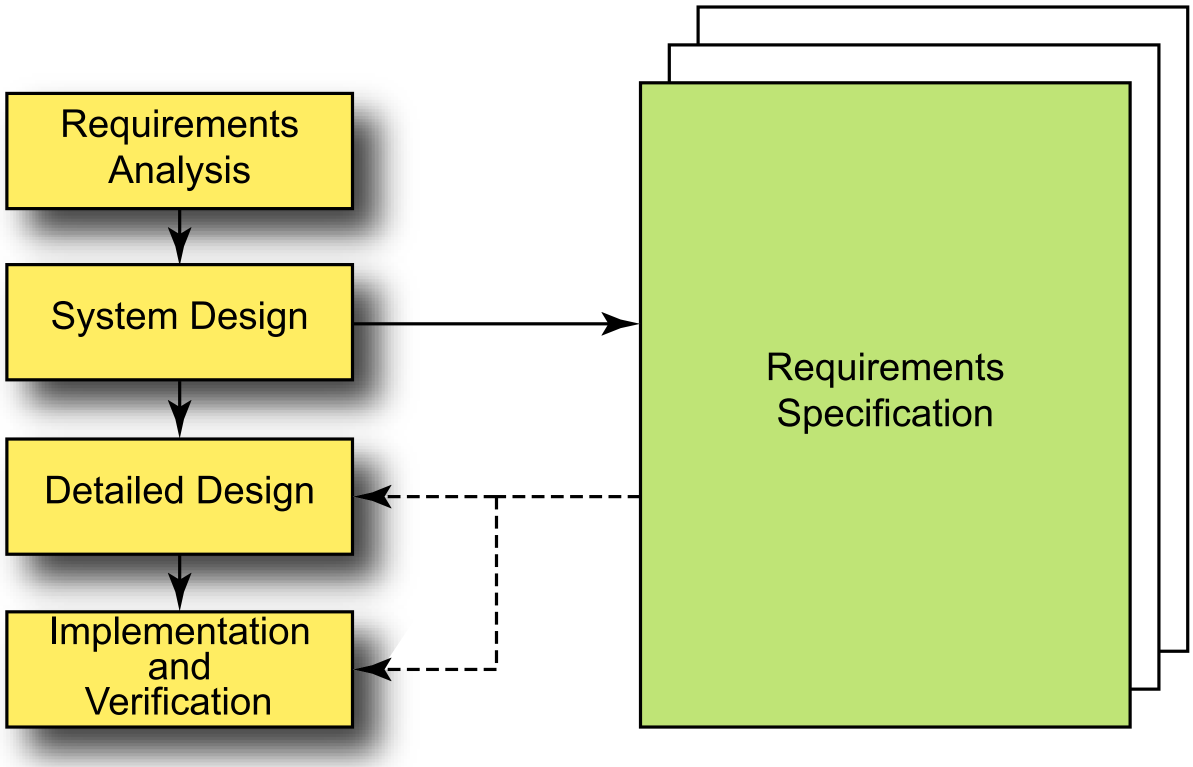
Closing Remarks

- The requirements specification will be useful to the end of the project
  - It is the agreement between the engineer and the customer as to what is to be done
  - It is a guide to remind the engineer as to what is to be accomplished as they work on the project
  - It is used to judge the final outcome
  - It is an historical record; what was the thought process as this particular design unfolded
  - A document to help the manufacturers, operators, maintainers, and future designers (re-designers) in their work

System Design

Chapter
4

- "How will the problem be solved?"



- Also known as systems engineering, this stage involves:
  - conceptualizing, analyzing, refining, and
  - selecting the ideas giving the best solution
- The output is a document that:
  - Describes the design at a functional level
  - Describes component parts that form the design
  - Shows through analysis how the design meets the intended objective

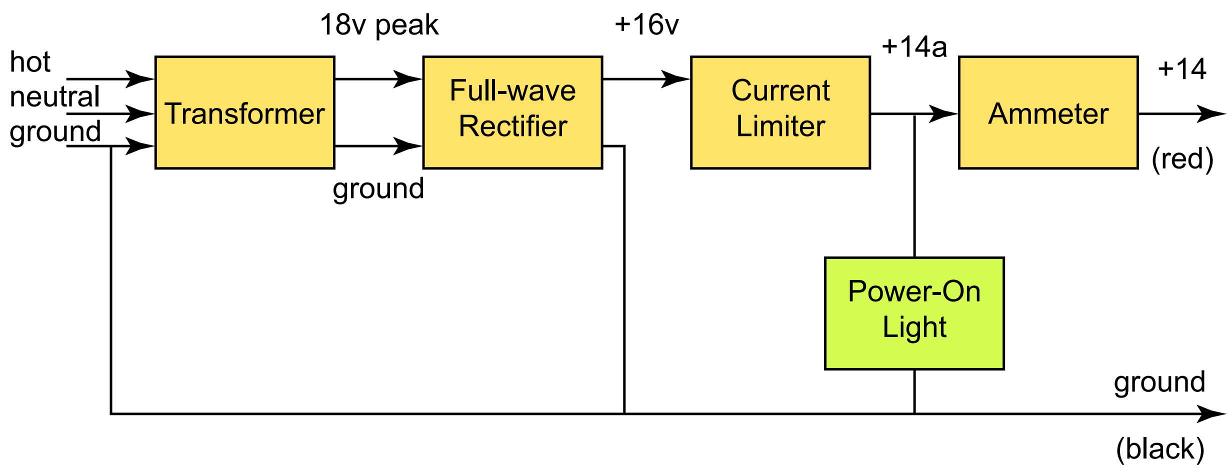
The Importance of System Design

- Innovation and novelty occurs here (patentable?)
- Create the potential for outstanding performance
- Proficiency at systems-level design is the mark of a senior engineer
- Junior level engineers typically step in after the system engineering is complete
  - Junior engineers need to look for opportunities to gain experience with this aspect
  - Start now in senior design!
- Reasons for having a solid system-level design
  - Decide if the problem is tractable
  - What are the performance limits of a design and are these limits acceptable
  - Get good estimates on cost before spending too much time on the actual design (i) cost of finishing the design, (ii) cost of manufacturing the design
  - Reduce the risk of the design not functioning properly
  - Increase the product reliability
  - Reduce the overall cost of product development
  - Provide a framework to organize and coordinate the engineers to work on the design

System Block Diagrams

- Dissect a complex problem into manageable smaller problems
  - Subdivide until the problem size is small enough to conceive a hardware/software solution
- In a design context, system means a group of interconnected elements that work together to form a function
- Each element may also be viewed as a subsystem
  - At some point the subdividing stops and we are left with a collection interconnected parts, e.g., resistors, capacitors, and diodes
- A system *block diagram* displays how the group of subsystems is interconnected to form a system
  - Each block performs a well defined function
  - The functions are usually drawn as rectangular blocks

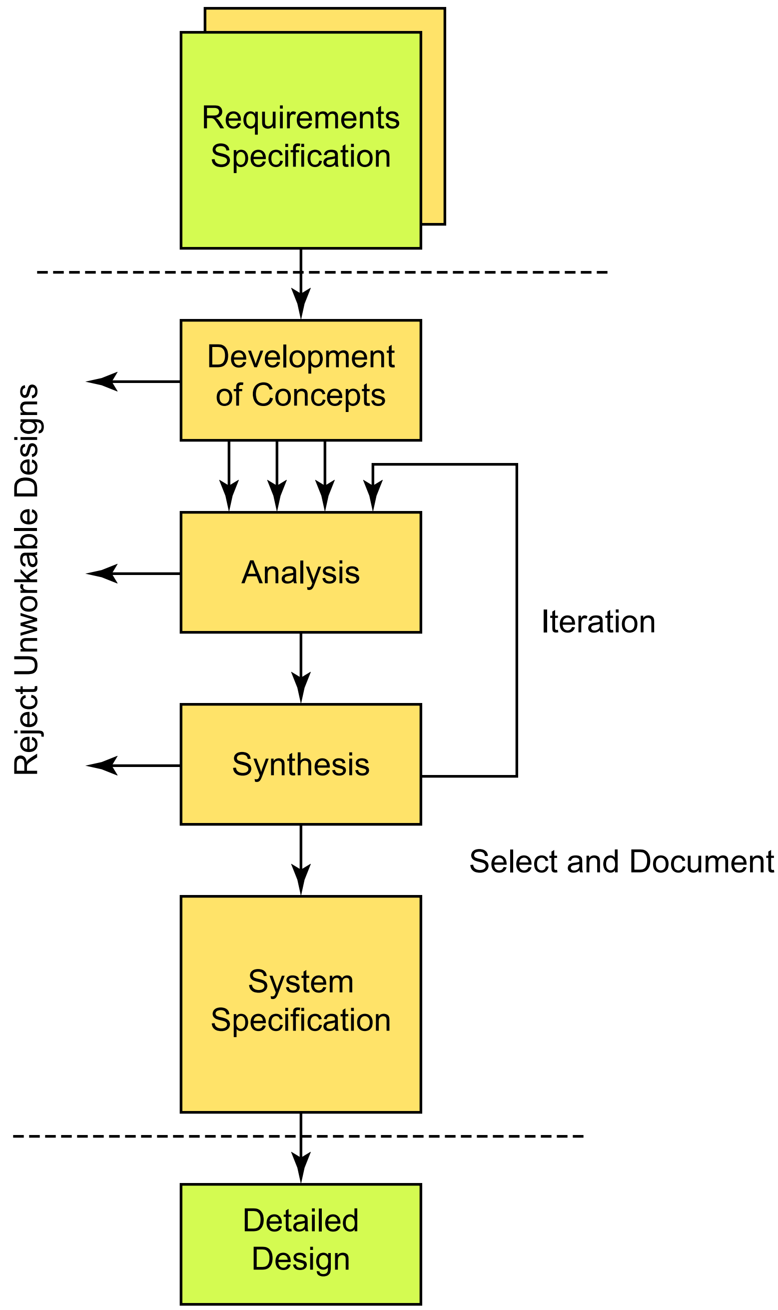
Example: A 12v Battery Charger



- Block names should be meaningful
- The functional elements here may be helpful in costing the design
- The design is composed of five blocks that can be viewed as five smaller problems
  – A sketch of the front panel may also be created at this point to better visualize how the ammeter and power-on light will be oriented to the user
- The above block diagram is likely not the first version
  – The first white-board sketch may be rather crude
  – As the design concept is refined, the block diagram is fleshed out with more detail and possibly block subdividing
- The design process and refinements to the block diagram go hand-in-hand

The System Design Process

- Synthesis, analysis, and iteration



- The system specification will contain a description of each block in the block diagram

- It will also describe how the blocks work together, and satisfy the requirements specification
- Big questions are is the design required?
  - A commercial-of-the-shelf solution (COTS) may already exist
  - Is the COTS product good enough to meet all requirements, even in the future when the product may need to satisfy additional requirements?
  - Perform a Web search and/or talk with those knowledgeable of the product area
- Leading up to the system specification requires the engineer to first conceptualize a solution, synthesis it, analyze it to see if requirements can be met, and as needed iterate the synthesis/analysis phase multiple times

Conceptualization: A Hazy Perception of the Solution

- A primitive solution lacking a detailed definite form
- Requires thinking and reasoning together with past experience and scientific knowledge
- Creative thinking skills needed, which comes from experience and practice
  - Nonlinear thinking skills generally not encountered in past engineering course work

Synthesis: Create a Well Defined Structure or Concept

- Enough detail is needed so that analysis can be performed relative to performance, risk, and cost
- A block diagram is required here to break the problem down (divide and conquer)
- Conflicting forces:
  - Complete the design quickly
  - Desire for a novel solution that offers a cost or performance advantage over the competition
- Try to adapt an existing design (*reference design*)
- Linear thinking offers the most predictable results, but a difficult problem may not yield to this process
- When a reference design does not exist, an original concept is required
  - Brainstorm with other team members to find a concept that can get you off the ground
  - If you are uncertain even after a small start, perform some preliminary analysis to gain confidence you are moving in the right direction

Analysis: Model/Analyze/Simulate/Breadboard/

- The objective is to determine if the synthesized system meets performance and cost objectives
- Risk must also be assessed

- Failure to identify via analysis and simulation that a design is lacking, must be avoided
- Preliminary design reviews (PDRs) and technical interchange meetings (TIMs) will give others the opportunity to see problems you may not see, and force a synthesis/analysis iteration

Refinement: Modify the Concept Based on Analysis Results

- Refinement is inevitable
- Minor modifications may be all that is needed
- A totally new structure may be needed if the original design is found to be at its performance limits
- Economics will also factor into the refinement
  - The easiest refinement approach may be too expensive or too risky

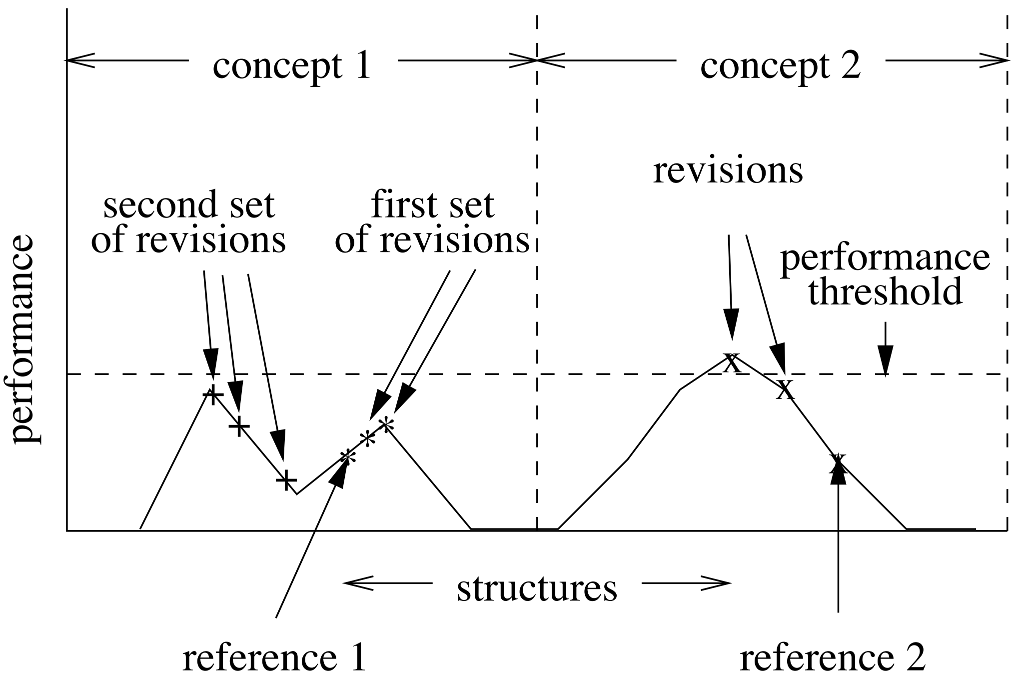
Documentation: Describes Block Function and Interconnection

- Provide details on how each function is to be implemented
- Describe interfaces to other blocks

The Synthesis/Analysis Cycle

- Not all concepts can be synthesized
- It might be that after trying a few cycles of synthesis/analysis a concept is discarded
- The engineer must start over, and again work to overcome deficiencies of earlier concepts

- For critical designs, more than one engineer may be assigned to conceptualize, synthesize, and analyze



Block-Diagram Basics

- The *fruit* of the systems-engineering design phase
- Specify blocks so that the detailed design of the block can be accomplished by a single engineer
- Suggestions for senior design
  - Each block should be implemented in a single technology, e.g., analog RF, analog baseband, digital
  - Common functions grouped into a single block
  - Create blocks to simplify the interfaces between them
  - Avoid feedback loops; try to keep feedback inside a given block

  - Specify interfaces using standards when possible (RF, analog, logic levels, etc.)
  - Timing diagrams for complex interfaces

Documentation

- The documentation will be used by everyone who has a stake in the project
  - Used to complete the detailed design and implementation of the blocks in the block diagram
  - Contains the details used in the system-level design so that future modifications resulting from bugs/errors can be dealt with efficiently
  - Used as a reference design for future/next generation products
  - Used by test engineers to design test fixtures and test procedures
  - Used by marketing to develop data sheets, manuals, and other literature for advertising and technical support

System Specification Organization

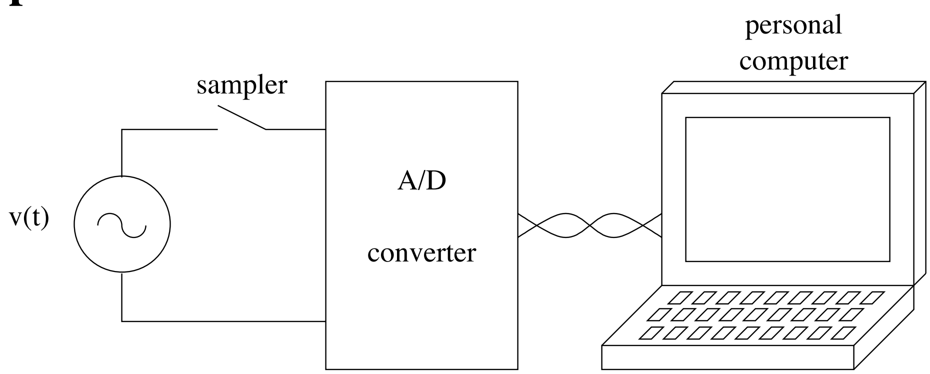
- The concept
- The block diagram
- Functional description of the blocks
- Description of the system

- System analysis

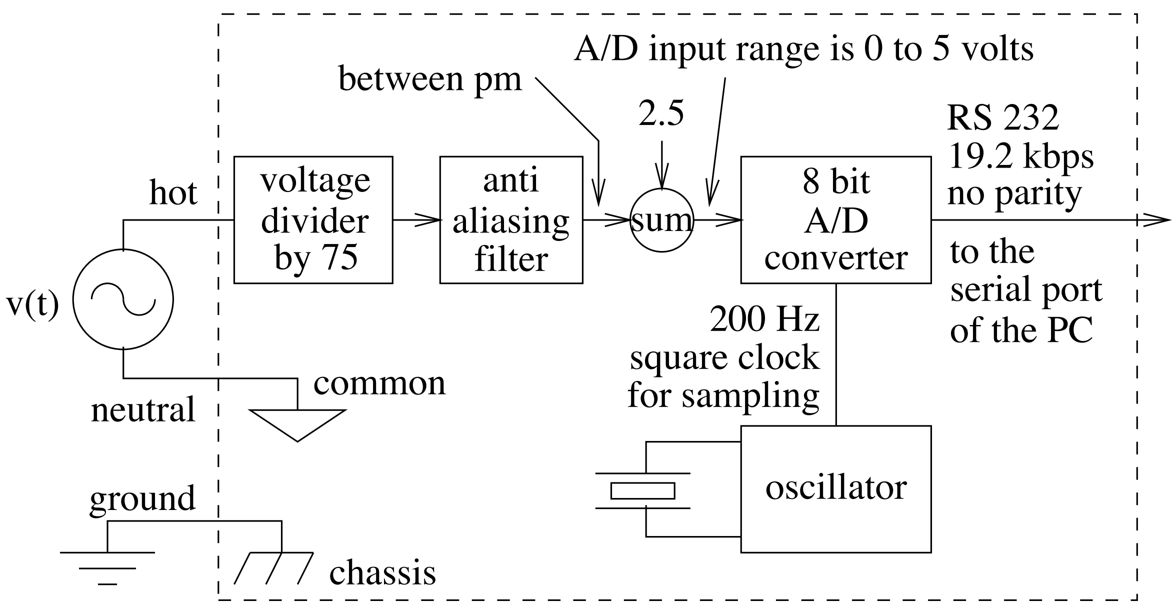
Example: 12v Battery Charger Revisited

Detailed Example: Power Line Flicker Meter

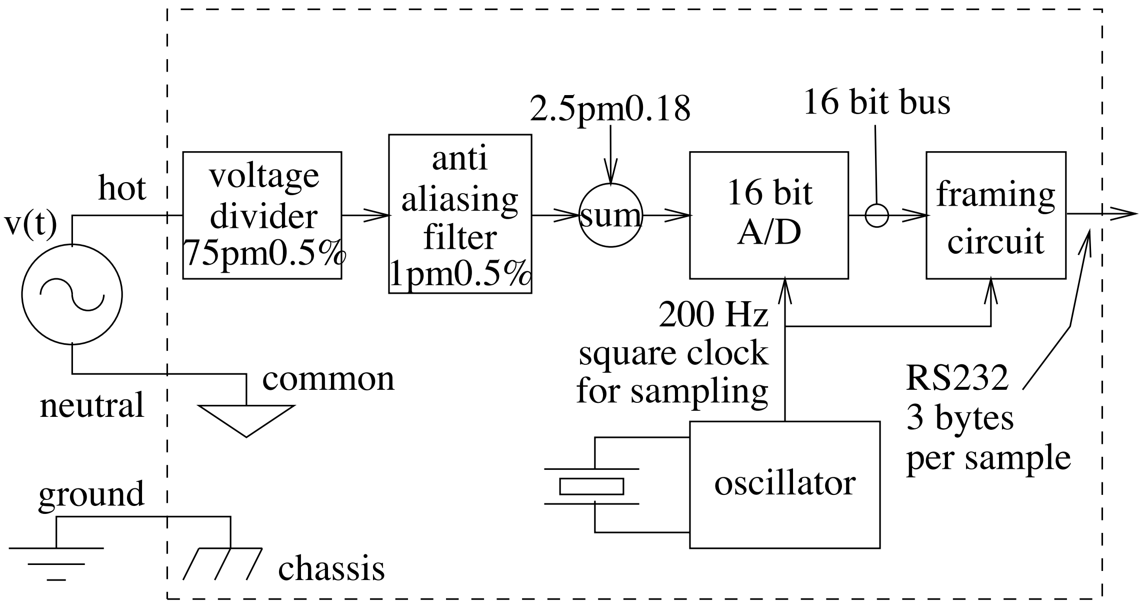
Concept



Preliminary Block Diagram



Final Block Diagram



Managing the Design Process

Chapter 5

- Relevant high level management questions include:
  - "How much is the design going to cost?"
  - "When can you deliver?"
- Secondary concerns include:
  - "How many people do you need?"
  - "What skills must they possess?"
  - "What load will you place on the lab and the machine shop?"
  - "Will you be using any special (scarce) test equipment?"
- The goal of project management is to complete on time and on budget

Text Project Definition: A quantifiable piece of work with defined start, end, and with specific deliverables.

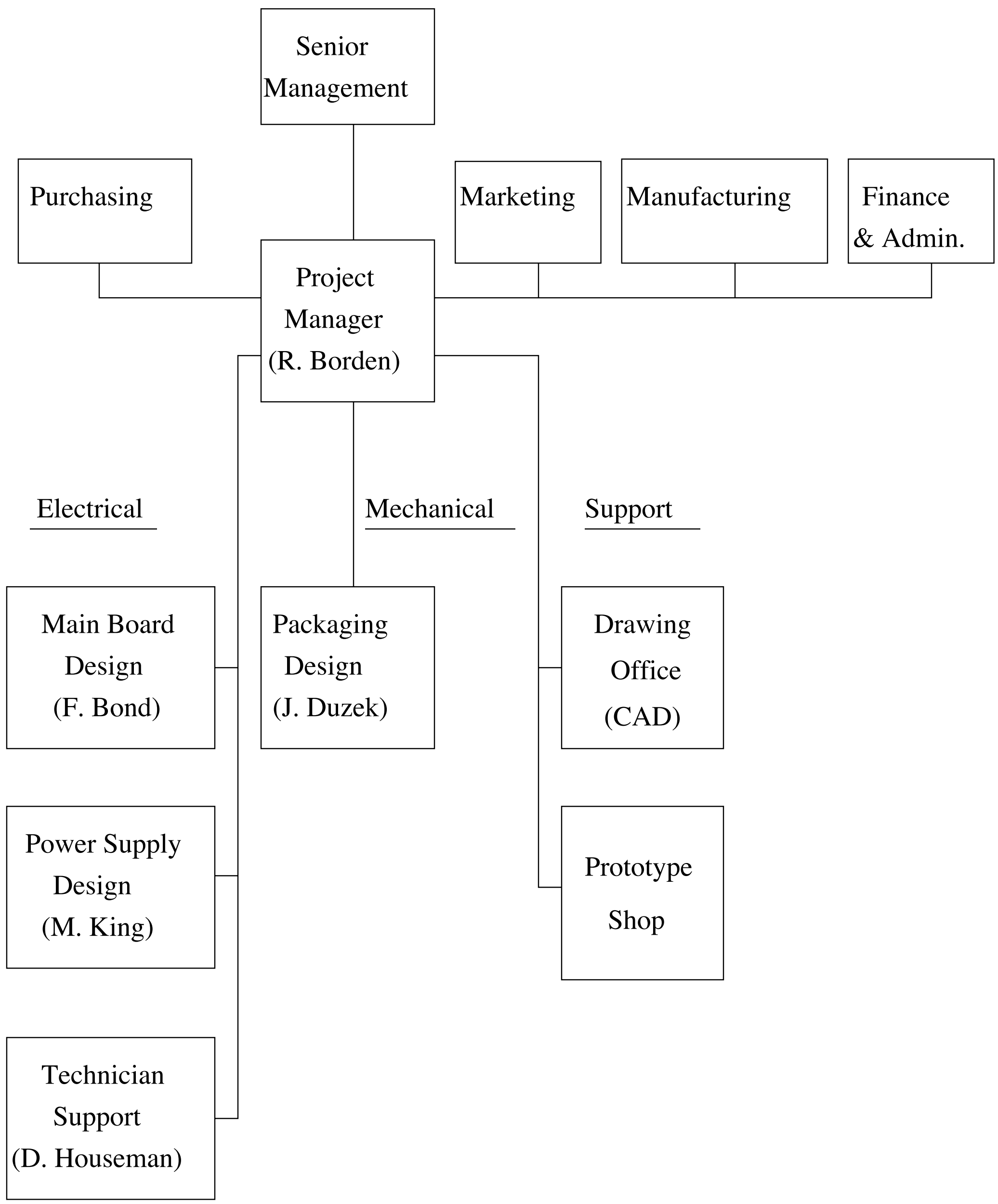
Other project attributes:

- The output is low volume, a unique product/service
- There are measurable objectives
- It uses a limited set of resources (people, materials, equipment)
- The work is often complex, uncertain, and/or urgent

The Project Management Approach

Project Organization

- Projects are always configured with some form of top-down management



- Individuals are typically assigned to more than one project

Elements of Project Management

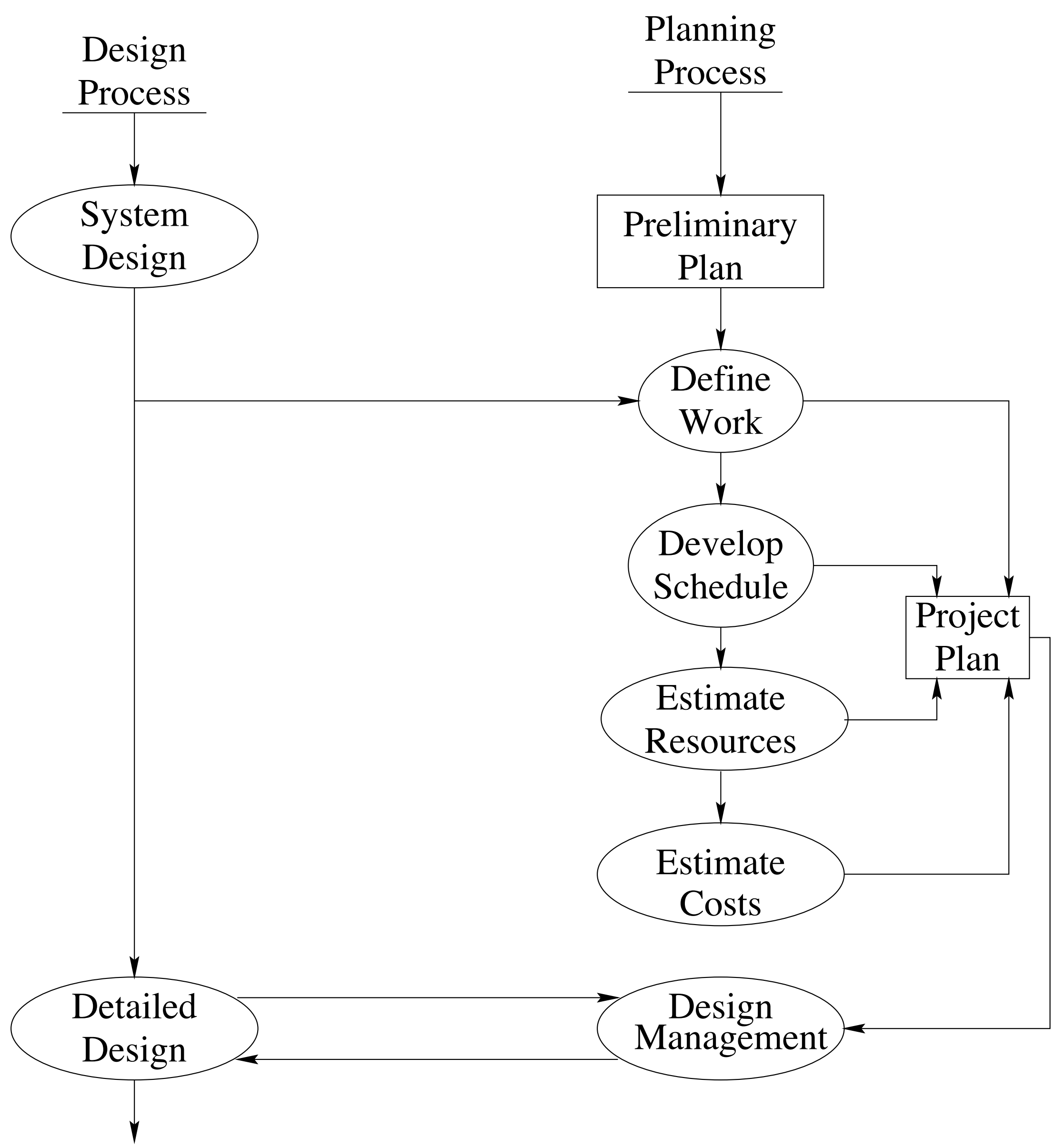
- Meeting budget and meeting schedule
- Three main elements are
  - **Planning**: A project plan defines the work to be done along with a schedule, and a budget
  - **Monitoring**: Compare actual progress with the plan and make adjustments as needed
  - **Control**: Make choices about how to optimize project performance; reallocate resources to make sure tasks complete on time and integrate smoothly
- There are many management theories
- Management theory is beyond the scope of this course, but it is safe to say that over an engineer's career, they will experience a variety approaches, some of which they may find more difficult to cope with than others

The Project Plan

- A concise statement as to how a project is to be conducted
- The project plan can take many forms, largely dependent upon the complexity and size/scope of the work
- All plans contain
  - **Definition of the Work**: A breakdown of the various tasks needed to complete the project

– **Schedule**: Dates/times for completing tasks and subtasks, demarcated by milestones
– **Resource Requirements**: Estimate each engineer's time, materials, equipment, and other support services
– **Cost Estimate** (project budget): An estimate of all costs associated with the project

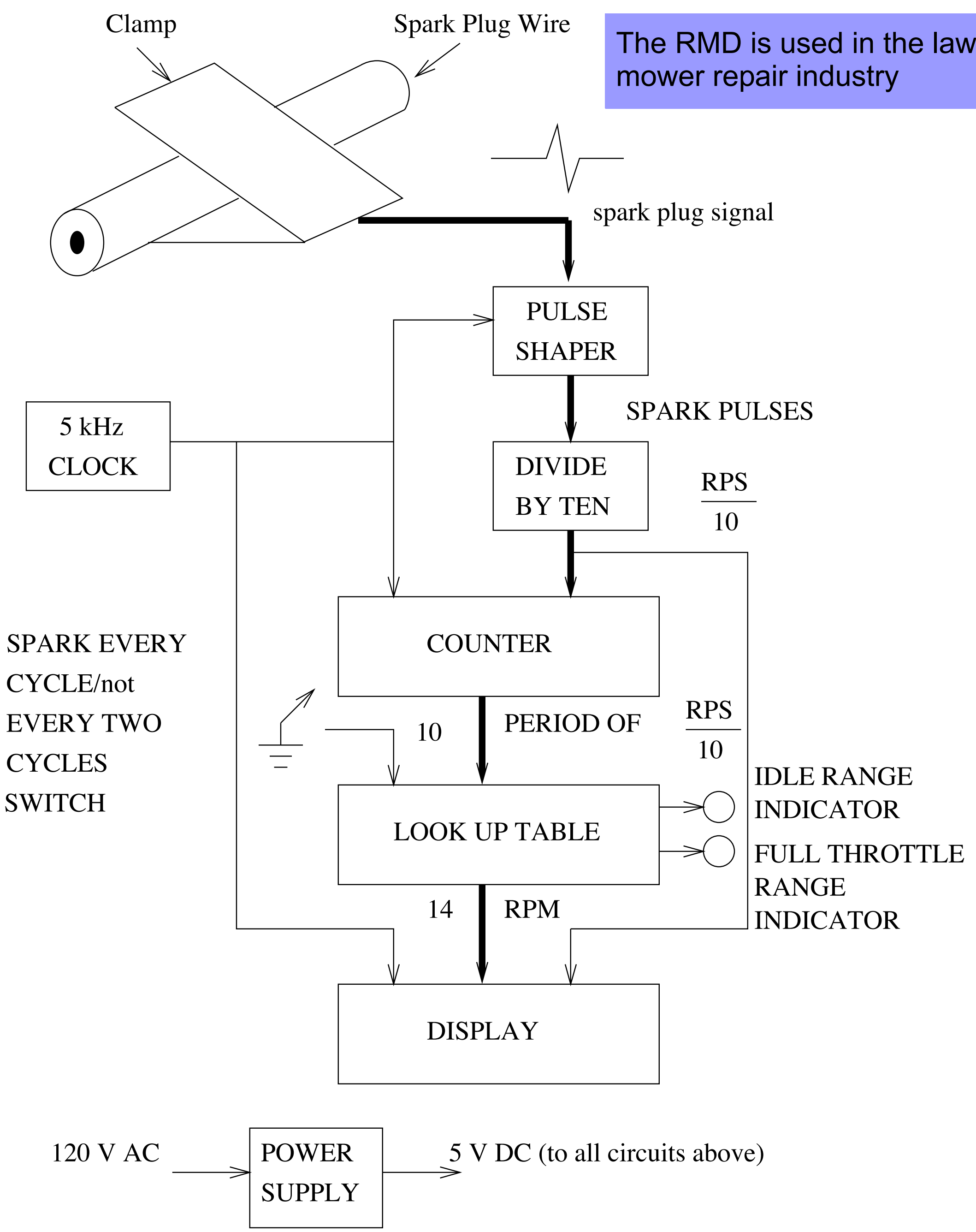
- The planning process parallels the system design stage



Defining the Work

- System Design ⇒ Block Diagram ⇒ Tasks
- The text considers the project planning associated with a *RPM measurement device* (RMD)

The RMD is used in the lawn-mower repair industry



- What makes up a task?
- Several rules apply:
  - (1) Consider a *top-down* approach starting with just a few tasks, then break them down adding detail and complexity; *bottom-up* lists all small tasks to define the project, then combine to simplify the work definition
  - (2) Each block in the block diagram should initially be a single task; if several blocks form a single module (e.g. circuit board), combine the tasks into one
  - (3) Tasks should be assignable to individual team members
  - (4) Work that leads up to a milestone should be a task, with a new task starting after the milestone (not always)
  - (5) Tasks will rely on inputs from other tasks, while a task is in process it should be independent of additional inputs
  - (6) Too many tasks increases administrative load; engineers like to design, not shuffle paper. Too few tasks oversimplifies, and increases the chance for errors in budget, schedule, and resources (newbie advice—a few too many is better than too few)

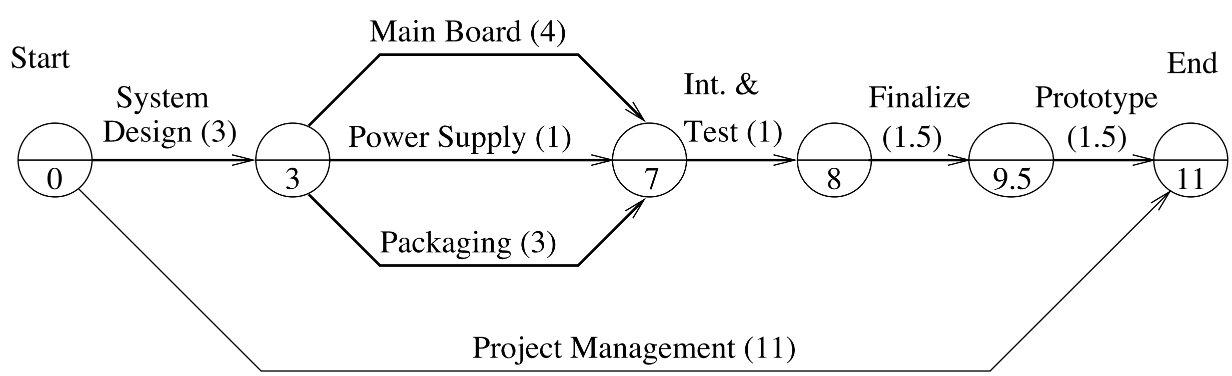
Scheduling

- The logical sequencing of tasks
- Project schedules can be kept in tools such as *Microsoft Project*, or for this course a simple bar (Gantt) chart

- Two categories are network diagrams and simple bar charts
- For the capstone design the bar chart is adequate

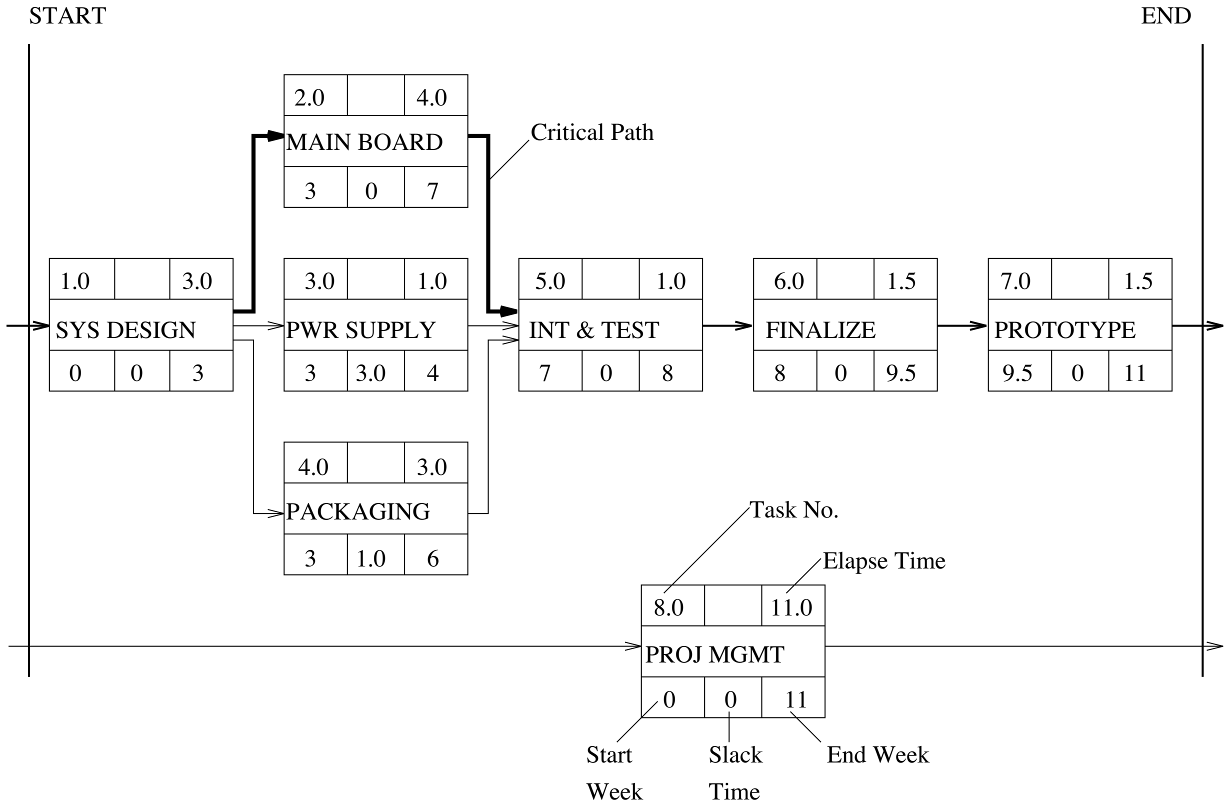
Network Diagrams

- For future reference you may encounter network diagrams knows as precedence diagrams
  - Critical path method (CPM)
  - Program evaluation and review technique (PERT)
- Graphically illustrate interdependence and precedence among tasks
- Consider the *activity on arrow* (AOA) method



  - The completion time is in the lower half of each node

- A more detailed variation is the activity-on-node (AON) method



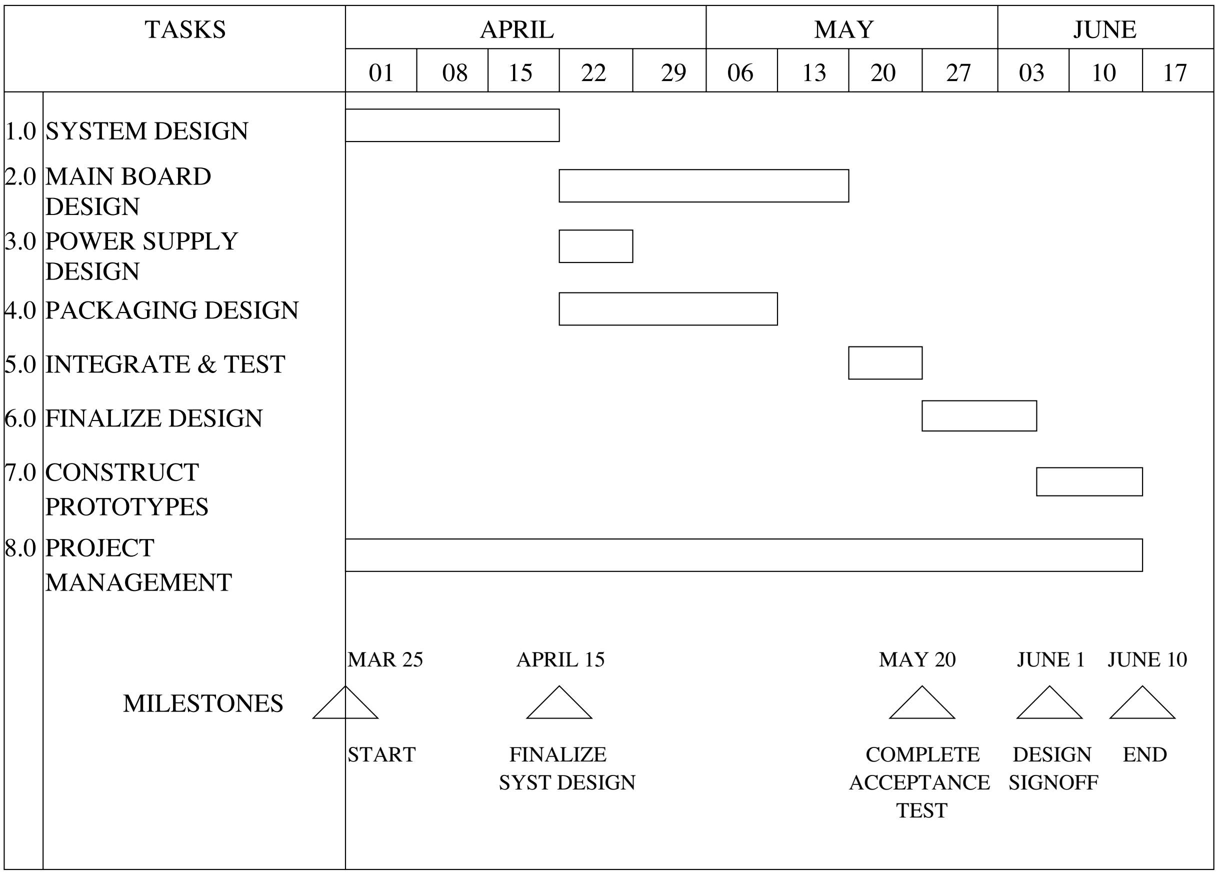
- Key aspects of all network diagrams is the ability to illustrate
  - Precedence
  - Critical paths
  - Slack time

Reviewing the Work Description

- Once a schedule is developed a means to improve the schedule might be revealed
  - Add another engineer
  - Requirements changes

Bar (Gantt) Charts

- The schedule tool of choice in the 4890/4899 sequence is the Gantt chart or *time-line diagram*



- Color or line type coding and a legend can be used to indicate individual team member responsibility
- The text contends that Gantt charts are usually developed from network diagrams
- Gantt charts are particularly useful when making customer presentations
  – Consider the network chart as the manager’s personal tool, used to develop the Gantt chart

  - The Gantt chart is used by the manager when making presentations

Comments

- Work hard on making the schedule
  - It maybe used to sell customers and company management alike on the viability of the project
- Project team members use it to see how their work relates to others, and better understand why they need to meet a deadline (no vacation or leisure time until . . .)
- Common schedule problems
  - Too many tasks make for a confusing schedule
  - Too few tasks make the project flow difficult to understand (can you really do this!?)
  - Inconsistent with some areas having a lot of detail and others too little
  - Individual team member roles are not clearly identified; don’t let this happen!

Planning Resources and Estimating Costs

- Resources and estimating costs are closely linked, so they often occur together

Costing Practices

- Personnel
- Lab, shop, and other internal facilities
- Outside services and facilities
- Supplies and materials

Estimating Personnel Requirements

- The largest category
- Availability of personnel with the right skills will have a big impact on the schedule

Budget Preparation

- Organize into a table broken down into categories that include personnel, services, and expenses

Putting the Plan Together

- The project plan document

Managing the Project

- The three functions of project management include
  - Monitoring
  - Reporting
  - Problem resolution

Performance Monitoring

- Is the design going to meet the performance as stated in the system specification?

Task Progress

- The project manager discusses progress with each team member, e.g., weekly status report delivered to manager and a visit to the manager's office
- Percent of task complete; an estimate

Schedule Status

- Pull task progress info together and provide an update of the overall schedule status

Budget Status

- Three key questions:
  - Are expenditures occurring as planned
  - Are expenditures occurring when planned
  - Is the project cost tracking the estimate

Reporting

- Project manager submits a (monthly) status report
  - Summary of work completed
  - Problem areas
  - Plans for the next period
  - Schedule and budget (updates)

Problem Resolution

- Projects can/will encounter:
  - Taking longer than expected to meet objectives
  - Taking more resources (costing more) than expected
  - It is technically infeasible to meet some objectives
- Solution approaches
  - Accept a delay but stay within budget
  - Add resources and increase the project cost
  - Change the deliverables. Perhaps adjust specifications or eliminate deliverables; (*descoping*) to maintain schedule
  - Reorganize the project to utilize resources more effectively
- The last two approaches require an amendment to the statement of work and will require the customer to sign-off

Chapter 6

Detailed Design, Testing, and Design Management

Block Design

Design Management

Communication

Documentation Control

Design Reviews

Principles of Testing

Stages of Testing

Test Practices

The System Test