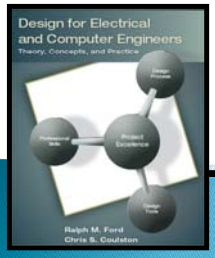
Chapter 4 – Concept Generation & Evaluation



Motivation

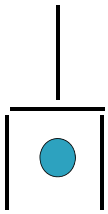
- Creativity is part of being an engineer.
- We often start with a single solution to a problem and then pursue it as the only possibility.
- Need to be creative and generate a variety possible designs.
- Need to be able to evaluate different designs.
- Systematic generation
- BE ABLE TO DEFEND YOUR DESIGN!
- Companies want to employ innovative engineers.
- Develop your engineering judgment.

Learning Objectives

By the end of this chapter, you should:

- Understand the importance of creativity, innovation, concept generation, and critical evaluation in engineering design.
- Be familiar with barriers that hinder creativity.
- Be able to apply strategies and formal methods to generate concepts.
- Be able to apply techniques for the evaluation of design concepts.

4.1 Creativity (Brainteaser)



Think of this as a shovel with a coin on the shovel. The problem is to move two of the "toothpicks" so that the coin is no longer in the shovel, but you still have a shovel.

Barriers to Creativity

- Perceptual
- Emotional
- Cultural and Environmental
- Intellectual and Expressive

Perceptual Blocks

Vertical and Lateral Thinking

"A body is discovered in a park in Chicago in the middle of summer. It has a fractured skull and many other broken bones, but the cause of death was hypothermia."

Think of the TV show ***CSI – Crime Scene Investigation***. Generate as many solutions as possible to the following scenarios. The idea is to see the problem from a variety of different viewpoints and generate plausible scenarios. You have insufficient information and should examine your assumptions.

Vertical and Lateral Thinking

Vertical thinking is?

Lateral thinking is?

Strategies for Creativity

- Have a questioning attitude
- Practice being creative
- Suspend judgment
- All incubation time
- Think like a beginner

SCAMPER

SCAMPER
- **S**ubstitute
- **C**ombine
- **A**dapt
- **M**odify
- **P**ut to other use
- **E**liminate
- **R**earrange or **R**everse

4.2 Concept Generation

Search Externally
- Literature review
- Search and review existing products
- Benchmark similar products
- Interview experts

Search Internally
- Brainstorming/brainwriting
- Nominal Group Technique
- Concept Table/Fans

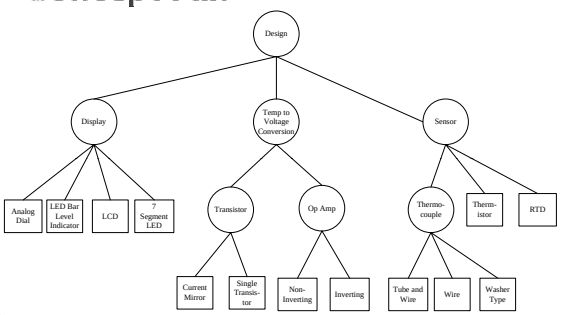
Brainstorming

Rules for group brainstorming
- No evaluation or judgment of ideas permitted.
- Encourage wild ideas.
- Focus on quantity, not quality (can always toss later!)
- Build upon, combine, or modify the ideas of others (SCAMPER).
- Record all ideas.

Morphology: Personal Computing

User Interface	Display	Connectivity & Expansion	Power	Size
Keyboard	CRT	Serial & parallel	Battery	Hand-held, Fits in pocket
Touchpad	Flat Panel	USB	AC Power	Notebook size
Handwriting Recognition	Plasma	Wireless Ethernet	Solar Power	Wearable
Video	Heads-up display	Wired Ethernet	Fuel Cell	Credit card size
Voice	LCD	PCMCIA	Thermal transfer	Flexible in shape
		Modem / Telephone		

Concept Fan



4.3 Concept Evaluation

Decision Methods (some of them)

- Strength & Weakness Analysis
- Analytical Hierarchy Process (Decision Matrix)
- Pugh Concept Selection

Strength & Weakness Analysis

- Identify and list strengths and weaknesses of each concept.
- To make more analytical, assign subjective weights to strengths and weaknesses (plus and minus factors) and sum them.

AHP (Decision Matrix)

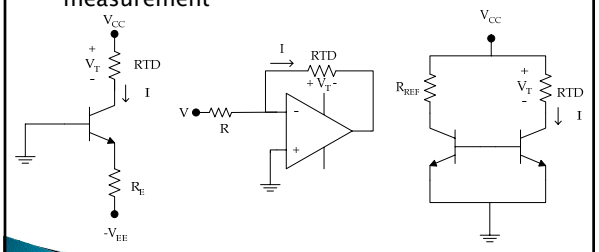
		Design Option 1	Design Option 2		Design Option n
Criteria 1		α_{11}	α_{12}		α_{1n}
Criteria 2		α_{21}	α_{22}		α_{2n}
Criteria *m*		α_{m1}	α_{m2}		α_{mn}
Score		$S_n = \sum_{i=1}^{m} \omega_i \alpha_{in}$	$S_2 = \sum_{i=1}^{m} \omega_i \alpha_{i2}$		$S_1 = \sum_{i=1}^{m} \omega_i \alpha_{i1}$

Decision Matrix: Steps

- Step 1: Determine the **selection criteria**
- Step 2: Select the **criteria weightings**
- Step 3: Identify and **rate** alternatives relative to the criteria
- Step 4: Compute the **scores**
- Step 5: Review the decision
  - *You can use all the quantitative data you can get, but you still have to distrust it and use your own intelligence and judgment.*—Alvin Toffler

Example: Quantitative Decision

- Select a current source circuit for current measurement



Step 1: Select the Criteria

In this case they are given as

- Accuracy
- Cost
- Size
- Availability

Step 2: Select the Weighting Factors

- These are computed based upon the results of the pairwise comparison – given in the problem.
- Be sure to normalize the final values.

Step 3: Compute Design Ratings

They need to be computed for the following

- Accuracy
- Cost
- Size
- Availability

Step 4: Compute the Scores

		Single BJT	Op Amp	Current Mirror
Accuracy	0.42			
Cost	0.12			
Size	0.12			
Availability	0.34			
Score				

Pugh Concept Selection

1. Select the comparison criteria
2. Determine weights for the criteria
3. Determine the concepts
4. Select baseline concept, initially believed best
5. Compare other concepts to baseline:
   - +1 better than, 0 equal to, -1 worse than.
6. Compute weighted score for concepts, not including the baseline.
7. Examine concepts: retain, update, or drop. Synthesize best elements of others where possible.
8. Update table & iterate until best concept emerges.

Pugh Concept Table

		Option 1 (Reference)	Option 2	Option 3	Option 4
Criteria 1	4	-	0	0	+1
Criteria 2	5	-	+1	-1	0
Criteria 3	2	-	-1	0	+1
Criteria 4	1	-	+1	+1	-1
Score		-	4	-4	5
Continue?		Combine	Yes	No	Combine

4.4 Project Application

- Identify different design alternatives (see also Chapters 5 and 6).
  - Search externally
  - Brainstorming sessions.
  - Nominal Group Technique
  - Morphology (Concept Tables and Fans)
  - SCAMPER
- Identify leading concept and justify
  - Strength & Weaknesses Analysis
  - Decision Matrices
  - Pugh Concept Selection

4.5 Summary

- Open your mind to creativity
  - Innovation is important
  - There are strategies to apply
- Apply Methods of Concept Generation
  - Search externally: Patents, research, experts
  - Search internally: SCAMPER, Morph Charts, Concept Fans, Brainstorming, Nominal Group Technique
- Evaluate Concepts Critically
  - Strengths/Weaknesses
  - Decision Matrices
  - Pugh Concept Selection

In-class Exercise – Step 1

- Get into teams
- Use ***brain writing 6-3-5*** to develop as many solutions as possible to the following problem.
- Each team needs to have 5-10 ideas to present to the class. Ideas need to be written down.
- "Legislation was passed to allow handguns in the cockpits of passenger airliners to prevent hijacking. Develop concepts that prevent anyone other than the pilot from using the handgun.
- **15 minutes**

Step #2

- Identify 4-6 criteria against which your solutions should be judged.
- Write down the final criteria.
- **5 minutes**

Step 3- Pugh Concept Selection

- As a team, apply Pugh concept selection to select an idea relative to the criteria you have selected.
- Turn in copies of the progressive selection matrices.
- **20 minutes**