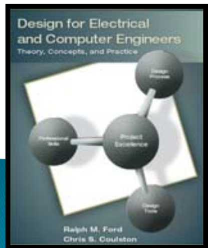
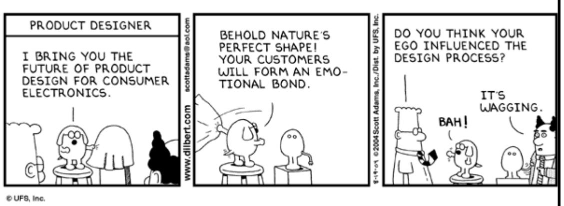
Chapter 5 – Functional Decomposition



Time for DESIGN!



Motivation – System Design

Team of engineers who build a system need:

- An abstraction of the system
- An unambiguous communication medium
- A way to describe the subsystems
  - Inputs
  - Outputs
  - Behavior
- Functional Decomposition
  - Function – transformation from inputs to outputs
  - Decomposition – reduce to constituent parts

Learning Objectives

By the end of this chapter, you should:

- Understand the differences between bottom-up and top-down design.
- Know what functional decomposition is and how to apply it.
- Be able to apply functional decomposition to different problem domains.
- Understand the concept of coupling and cohesion, and how they impact design.

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5.1 Bottom Up

- Given constituent parts
- Develop a working system
  - Build modules to accomplish specific tasks
  - Integrate modules together into working system
- For example
  - Given a supply AND, OR and NOT gates.
  - Build a computer
- Pros
  - Leads to efficient subsystem
- Cons
  - Complexity is difficult to manage
  - Little thought to designing reusable modules
  - Redesign cycles

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Top Down

- Given the specification of a system
- Develop a working system
  - Divide the problem into abstract modules
  - Reiterate until constituent parts are reached
- Pros
  - Highly predictable design cycle
  - Efficient division of labor
- Cons
  - More time spent in planning

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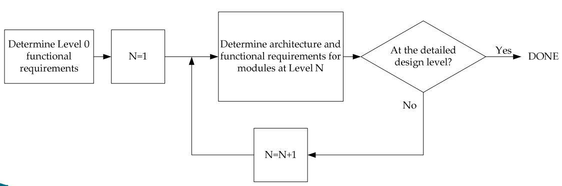
5.2 Functional Decomposition

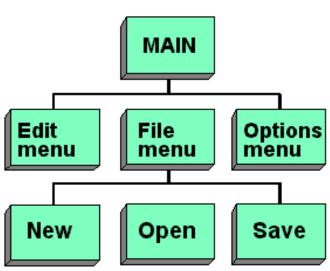
- A mathematical analogy

Functional Decomposition

- Recursively divide and conquer
  - Split a module into several submodules
  - Define the input, output, and behavior
  - Stop when you reach realizable components



Example: Program menu



5.3 Guidance

- The design process is iterative
- Upfront time saves redesign time later
- Submodules should have similar complexity
- Precise input, output, and behavior specifications
- Look for innovation
- Don't decompose *ad infinitium*
- Use suitable abstraction to describe submodules

Guidance, continued

- Look at how it has been done before
- Use existing technology
- Keep it simple
- Communicate results

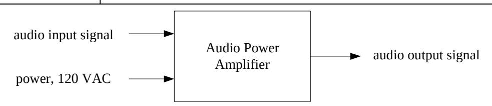
5.4 Application: Audio Power Amplifier

The system must

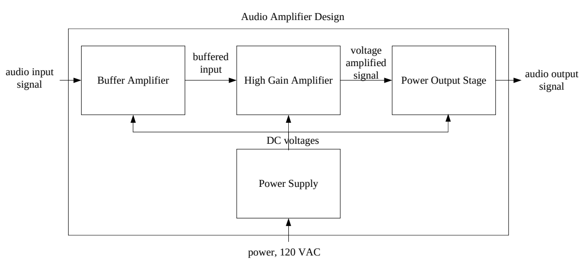
- Accept an audio input signal source with a maximum input voltage of 0.5V peak.
- Have adjustable volume control between zero volume and the maximum volume level.
- Deliver a maximum of 50W to an 8Ω speaker.
- Be powered by a standard 120V 60Hz AC outlet.

Level 0

Module	Audio Power Amplifier
Inputs	Audio input signal: 0.5V peak. Power: 120 volts AC rms, 60Hz. User volume control: variable control.
Outputs	Audio output signal: ?V peak value.
Functionality	Amplify the input signal to produce a 50W maximum output signal. The amplification should have variable user control. The output volume should be variable between no volume and a maximum volume level.



Level 1



Level 1 – Buffer amp

Module	Buffer Amplifier
Inputs	- Audio input signal: 0.5V peak. - Power: ± 25V DC.
Outputs	- Audio signal: 0.5V peak.
Functionality	Buffer the input signal and provide unity voltage gain. It should have an input resistance >1MΩ and an output resistance <100Ω.

Level 1 – High gain amp

Module	High Gain Amplifier
Inputs	- Audio input signal: 0.5V peak. - User volume control: variable control. - Power: ± 25V DC
Outputs	- Audio signal: 20V peak.
Functionality	Provide an adjustable voltage gain, between 1 and 40. It should have an input resistance >100kΩ and an output resistance <100Ω.

Application Domains

- Electronics Design
- Digital Design
- Software Design
- See the book for more in-depth examples

5.7 Example: Thermometer Design

The system must

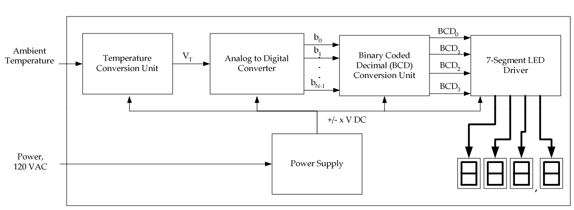
- Measure temperature between 0 and 200°C.
- Have an accuracy of 0.4% of full scale.
- Display the temperature digitally, including one digit beyond the decimal point.
- Be powered by a standard 120V 60Hz AC outlet.
- Use an RTD (thermal resistive device) that has an accuracy of 0.55°C over the range. The resistance of the RTD varies linearly with temperature from 100Ω at 0°C to 178Ω at 200°C.

Level 0

Level 0

Module	Digital Thermometer
Inputs	- Ambient temperature: 0-200°C. - Power: 120V AC power.
Outputs	- Digital temperature display: A four digit display, including one digit beyond the decimal point.
Functionality	Displays temperature on digital readout with an accuracy of 0.4% of full scale.

Level 1



Level 1

Module	Temperature Conversion Unit
Inputs	- Ambient temperature: 0-200°C. - Power: ?V DC (to power the electronics).
Outputs	- V_T: temperature proportional voltage. $V_T = \alpha T$, and ranges from ? to ?V.
Functionality	Produces an output voltage that is linearly proportional to temperature. It must achieve an accuracy of ?%.

Level 1

Module	A/D Converter
Inputs	- V_T: voltage proportional to temperature that ranges from ? to ?V. - Power: ?V DC.
Outputs	- b_{N-1} -b_0: ?-bit binary representation of V_T.
Functionality	Converts analog input to binary digital output.

Design Details

- How would you determine the unknown details in the previous 2 slides?

5.8 Coupling and Cohesion

- What is coupling?
- How much coupling is there in the modules in the Level 1 of the previous amplifier example?
- Phenomena of highly coupled systems
  - A failure in 1 module propagates
  - Difficult to redesign 1 module
- Phenomena of low coupled systems
  - Discourages reutilization of a module

Cohesion

- What is cohesion?
- Phenomena of highly cohesive systems
  - Easy to test modules independently
  - Simple (non-existent) control interface
- Phenomena of low cohesive systems
  - Less reuse of modules

5.9 Project Application: The Functional Design

- **Design Level 0**
  - Present a single module block diagram with inputs and outputs identified.
  - Present the functional requirements: inputs, outputs, and functionality.
- **Design Level 1**
  - Present the Level 1 diagram (system architecture) with all modules and interconnections shown.
  - Describe the theory of operation. This should explain how the modules work together to achieve the functional objectives.
  - Present the functional requirements for each module at this level.
- **Design Level N (for N>1)**
  - Repeat the process from design Level 1 as necessary.
- **Design Alternatives**
  - Describe the different alternatives that were considered, the tradeoffs, and the rationale for the choices made. This should be based upon concept evaluation methods in Chapter 4.

5.10 Summary

- Design approach: top-down and bottom-up
- Functional Decomposition
  - Iterative decomposition
  - Input, output, and function
  - Applicable to many problem domains
- Coupling – interconnectedness of modules
- Cohesion – focus of modules