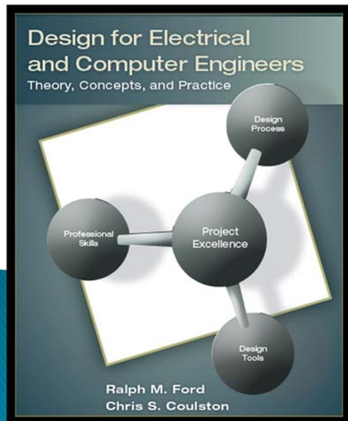
Chapter 5 – Functional Decomposition



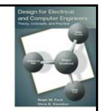
It is well-known design technique.

Translate the selected technical concept into a solution that satisfies the system requirements.

Needed because engineering design is usually complex consisting of many systems and subsystems.

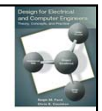
A good functional decomposition will greatly facilitate the design.

Motivation – System Design



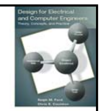
Team of engineers who build a system need:

- 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

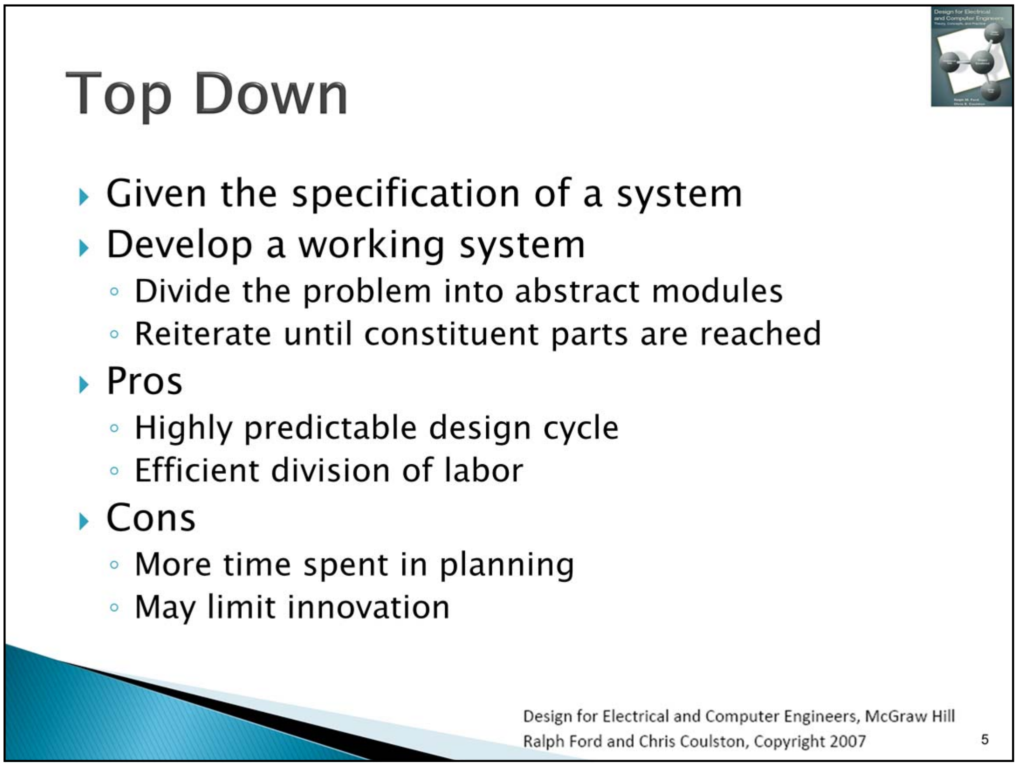
- Understand the differences between bottom-up and top-down design.
- Know what functional decomposition is and how to apply it.
- Be able to apply functional decomposition to different problem domains.
- Understand the concept of coupling and cohesion, and how they impact design.



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 power supply AND, OR and NOT gates.
  - Build a computer
- Pros
  - Leads to efficient subsystem. Lends itself to creativity.
- Cons
  - Complexity is difficult to manage
  - Little thought to designing reusable modules
  - Redesign cycles

Example: given all needed car parts, built the car

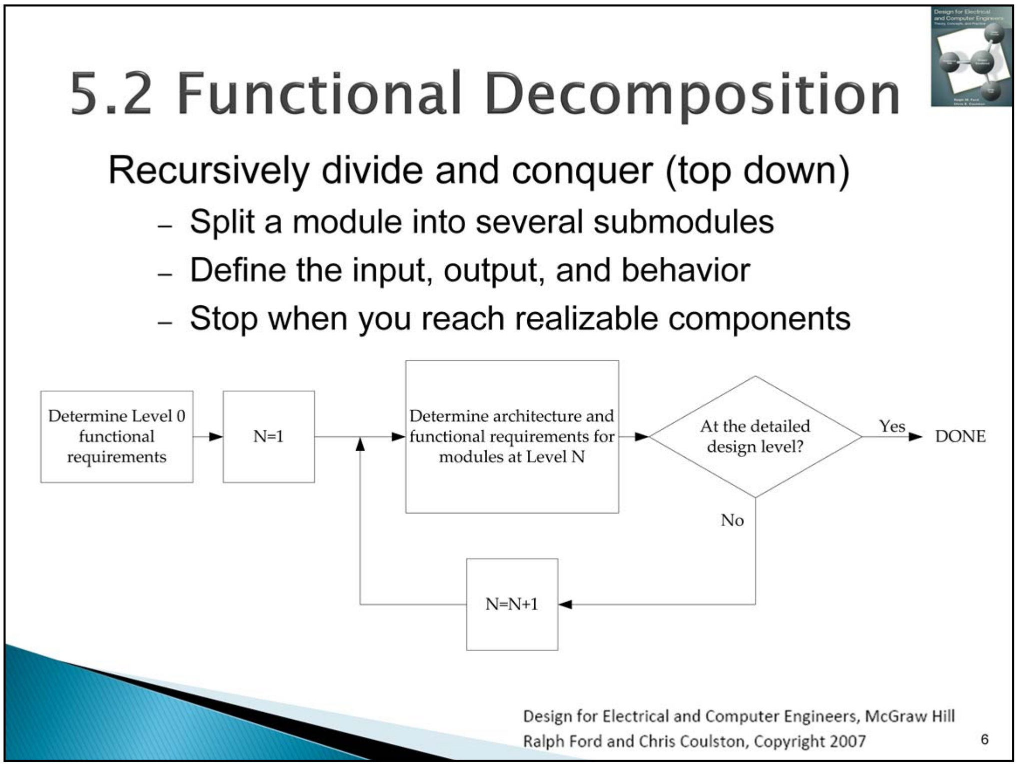


It is a divide and conquer approach. Division of labor.

Very valuable for large projects. It may limit innovation.

Most effective approach is a combination of the two:

1) Start with a Top down approach for efficient and predictable design
2) Refine it with a Bottom Up approach for improving individual modules and components and better performance.

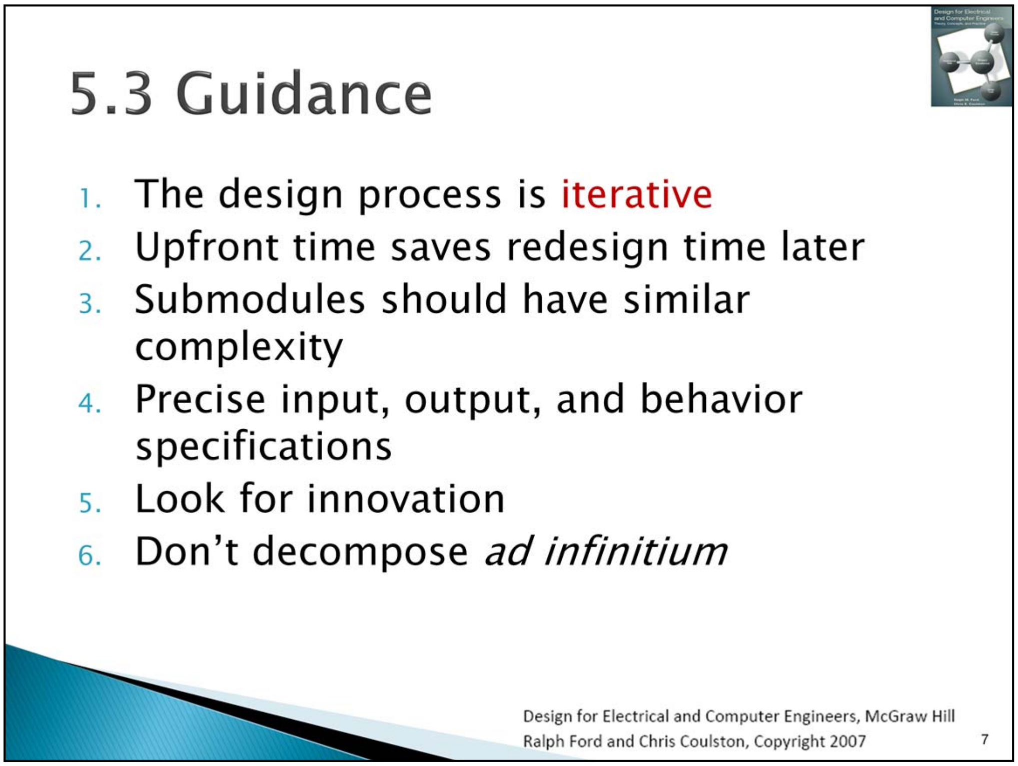


Functional specification: What does a module do?

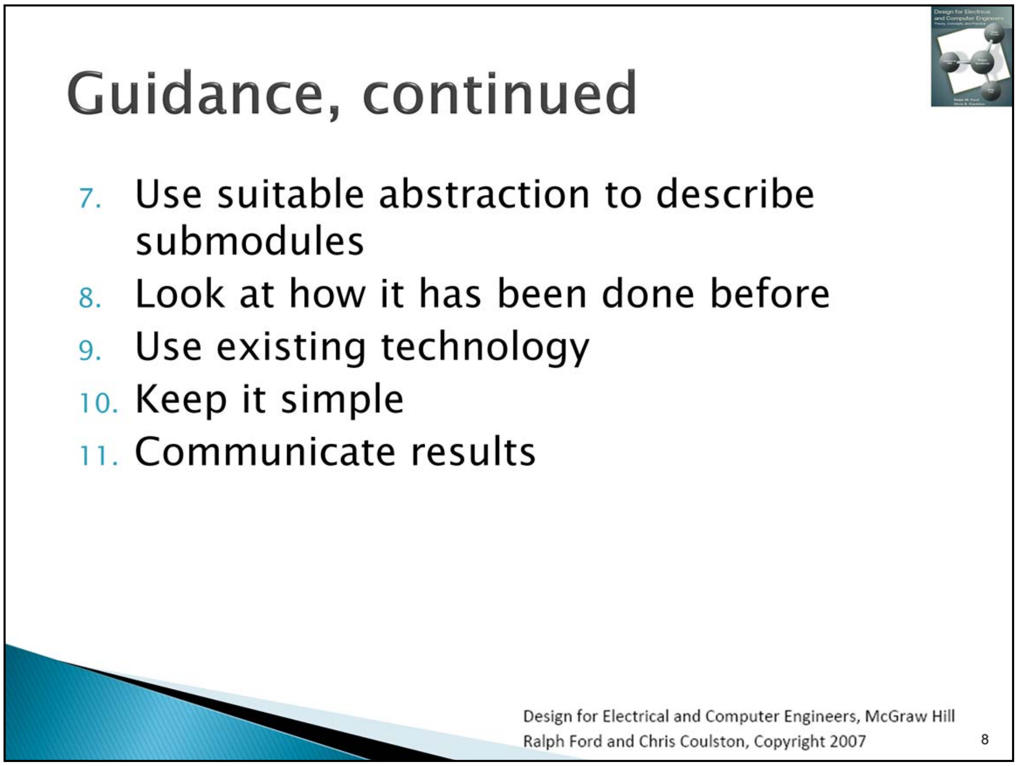
Modules (1) transform inputs (2) into outputs (3) (e.g., sensors)

Level 0 is the most abstract. It is iteratively refined after N steps to provide a detailed design. The more complex the task, the higher N.

Apply it to the complete system (module) and to each submodule



1. Start with the simplest description and continuously refine it
2. Apply knowledge meaningfully and efficiently
3. Submodules should be of comparable importance
4. Technically feasible design with clearly defined submodule parameters
5. Examine how to introduce innovation into each submodule
6. Decide on the best granularity level of your design



7. Use flowcharts, state diagrams, data flow diagrams, etc.

8. Do your literature search. Use it judge your feasibility and realism; not to limit your creativity

9. Be efficient; do not reinvent the wheel

10. Do not unnecessary complexity.

11. Clearly describe theory (why) and implementation (how) of your design. Document, document document!

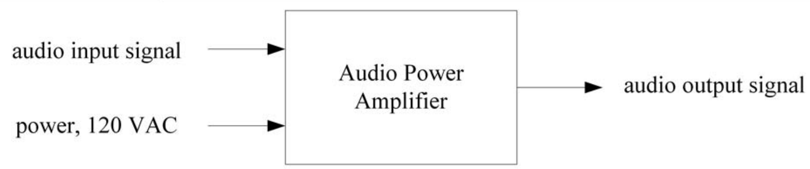
5.4 Application: Audio Power Amplifier

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.



Design for Electrical and Computer Engineers, McGraw Hill
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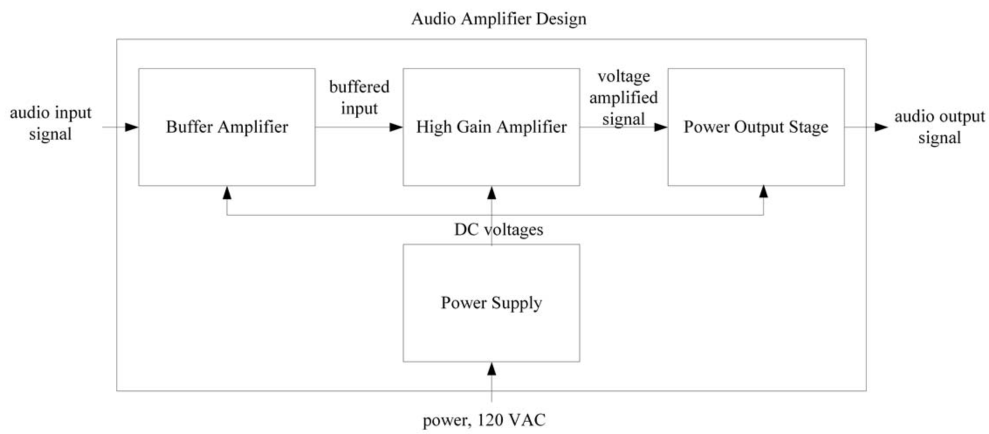
P = V^2/R

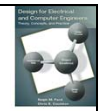
V = sqrt(P*R) = sqrt(50*8) = sqrt(400) = 20 V rms = 20*sqrt(2) peak = 28.2 V peak

Level 1



Audio Amplifier Design
audio input signal
Buffer Amplifier
buffered input
High Gain Amplifier
voltage amplified signal
Power Output Stage
audio output signal
DC voltages
Power Supply
power, 120 VAC

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.

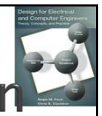
Level 1 – High gain amp

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.

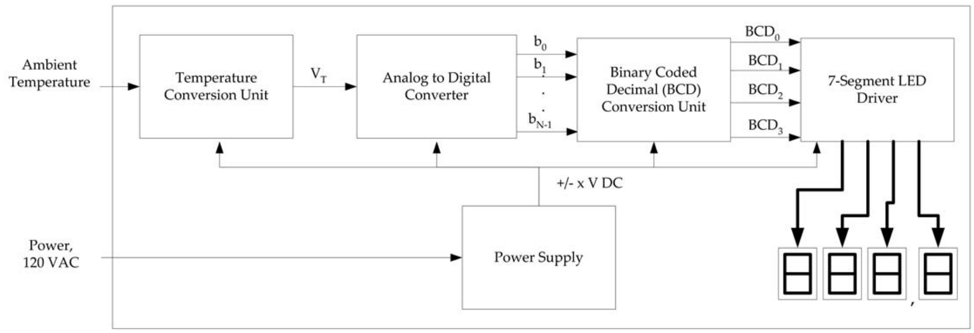
Level 0


Ambient Temperature
Power, 120 VAC
Digital Thermometer
Digital Temperature Display

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



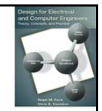
Ambient Temperature
Temperature Conversion Unit
V_T
Analog to Digital Converter
b_0
b_1
b_{N-1}
Binary Coded Decimal (BCD) Conversion Unit
BCD_0
BCD_1
BCD_2
BCD_3
7-Segment LED Driver
+/- x V DC
Power, 120 VAC
Power Supply

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 ?%.

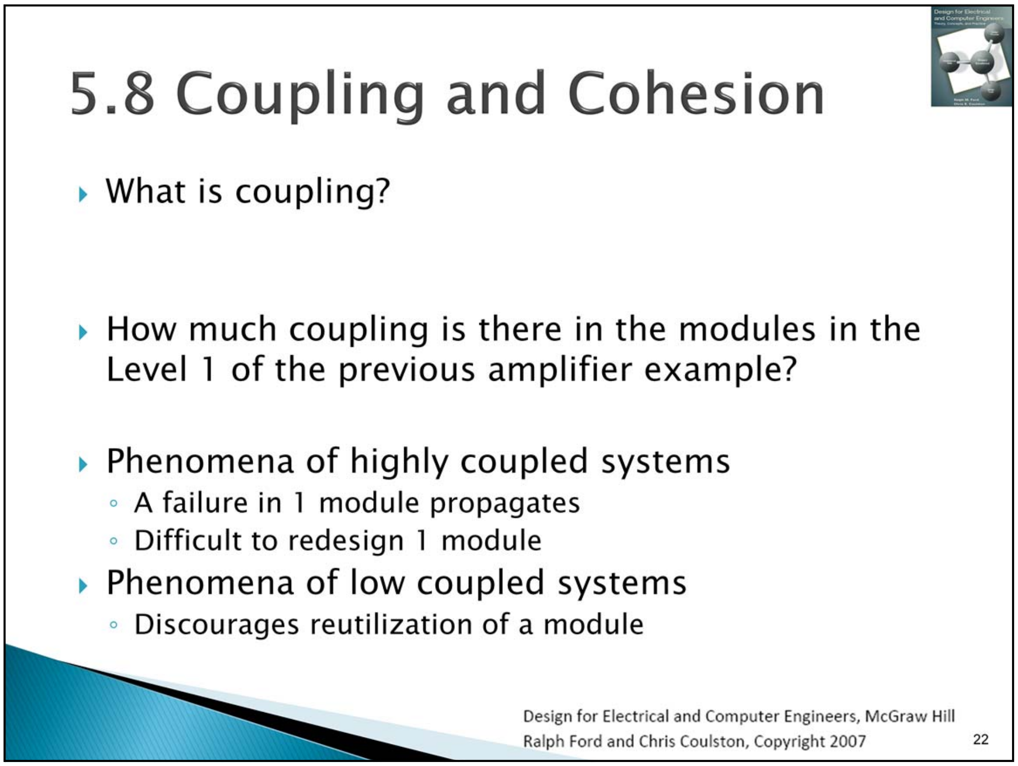
Level 1

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?



Two interconnected modules have at least one connection between them.

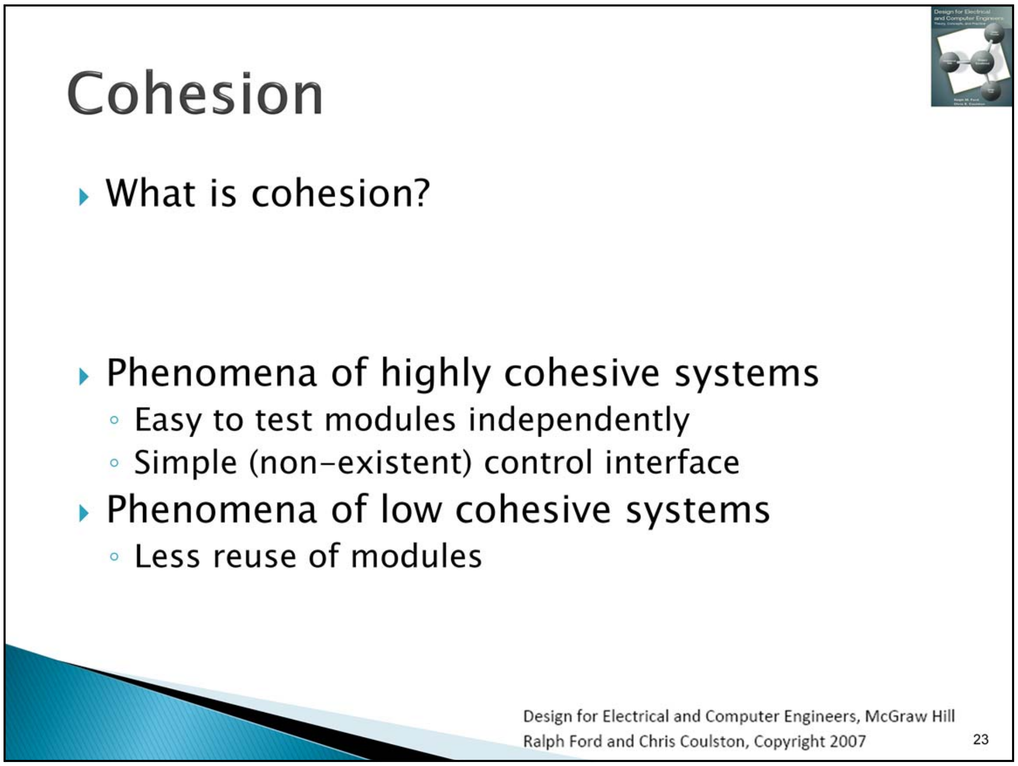
N fully interconnected modules have maximum of N(N-1)/2 connections between them.

Applies to hardware and software designs

Coupling is the extent to which system modules and submodules are connected

A lot of interconnections result in higher degree of coupling

In the amplifier design each submodule is fairly independent having one input and one output, with the exception of the power supply, which has one input and three outputs; one to each of the other modules. Therefore, this submodule is highly coupled and critical to the other three.



Cohesion: How focused is a module?

High cohesion means module does one or more things very well.

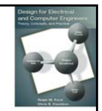
Low cohesion means the module’s operation is highly variable and dependent on its inputs

From low to high cohesion the standard categories are: Conicidental, Logical, Temporal, Communicational, Sequential and Functional.

We prefer high cohesion. That means design modules with a single well-defined functional objective.

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