Hierarchically structured product design process

Top-down specification

Bottom-up realization
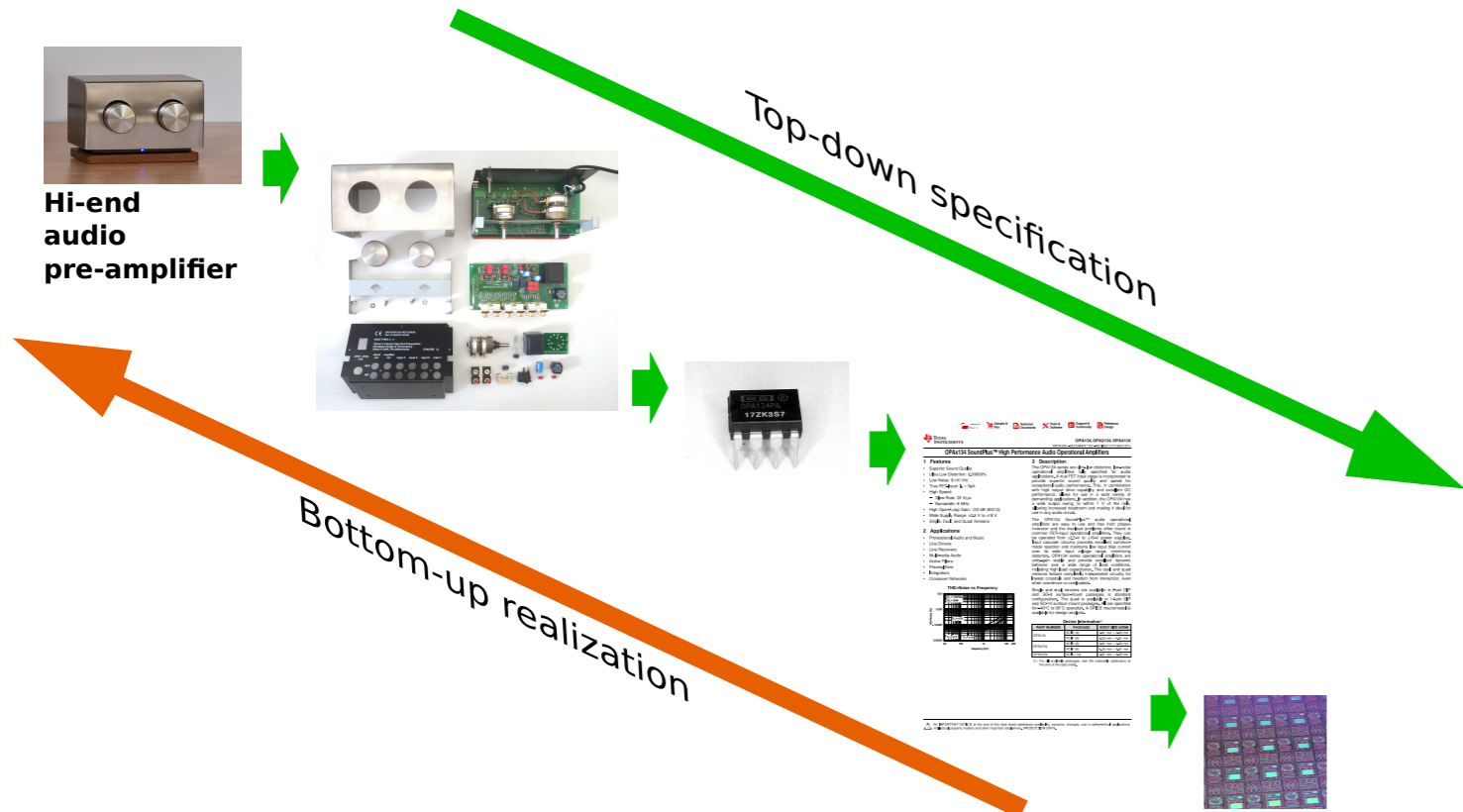
Hi-end audio pre-amplifier

- No risk propagartion during design
- Design is top-down, showstoppers appear bottom-up:
 "The devil is in the details!"

Products

Many physical products are built from sub assemblies and parts. Each of those are **objects** that need to be specified, designed, manufactured, tested, etc.

Initial requirements for an object are selected from those of the stakeholders of the relevant product life-cycle processes.

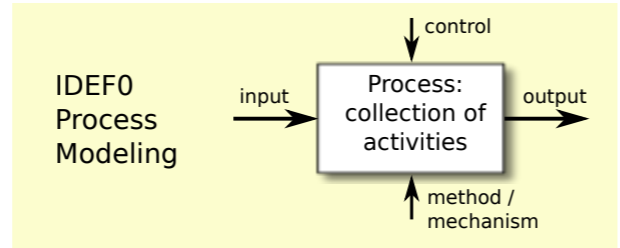During the design of the poduct, data required for all relevant life-cycle processes needs to be generated.

The review of design data and documents at project milestones, assures the quality of the design process itself.
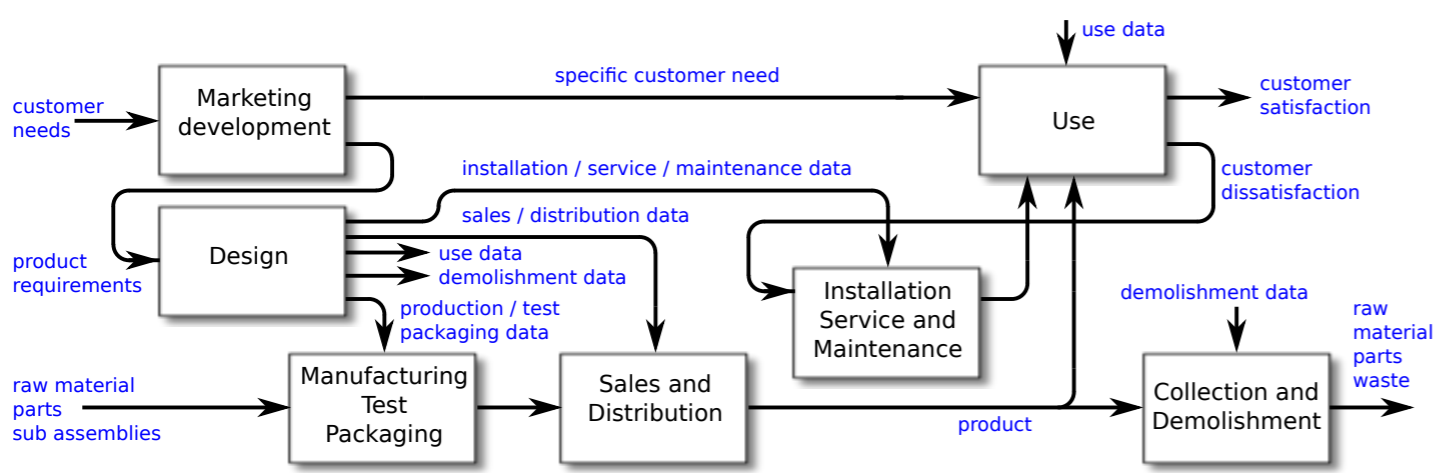
Life-cycle processes
- marketing /development
- design
- manufacturing / testing / packaging
- sales / distribution
- installation / use / service / maintenance
- collection / demolishment

IDEF0 Process Modeling

control

input → Process: collection of activities → output

method / mechanism

Product life-cycle processes

customer needs → Marketing development

specific customer need

use data

Use → customer satisfaction

installation / service / maintenance data

product requirements → Design

sales / distribution data

use data
demolishment data

production / test packaging data

customer dissatisfaction

raw material parts sub assemblies → Manufacturing Test Packaging → Sales and Distribution

Installation Service and Maintenance

demolishment data

Collection and Demolishment → raw material parts waste

product

Object Performance Specification

A document that describes the requirements for the object to be designed.
The basic design sequence has one object performance specification as input and a collection of object performance specifications for sub-objects as output.

Operational requirements
Functional requirements
The functions that should be performed by the product
Performance requirements
Engineering characteristics that describe the quality of operation
Environmental specification
Characteristics of the operational environment, such as
- temperature
- humidity
- air pressure and flow
- EMI
- shock and vibration
- illumination
- radiation
Cost factors specification
The price one is willing to pay in terms of all kinds of resources, such as
- technology
- materials
- weight
- dimensions
- power consumption
- money

$$FOM = \frac{\text{Product of performance measures}}{\text{Product of cost factors}}$$

Environment and cost factor specifications for other life-cycle process
See: - life-cycle processes
        - environmental specification
        - cost factor specification

object (initial performance specification)
Interpretation:
Define measurable characteristics for the object's performance, environment and costs

engineering characteristics
Functional decomposition:
Define the functions that have to be performed by this object

functions
Physical assignment:
Assign collection(s) of objects that can perform the defined functions

collection(s) of sub-objects
Error budgetting:
For each collection, distribute the error budget for each performance aspect over all sub-objects

collection(s) of engineering characteristics
Performance analysis:
For each collection, determine the performance-to-cost ratio

performance-to-cost ratios
Selection:
Select the collection of objects with the best performance-to-cost ratio for further engineering

sub-objects (initial performance specifications)

Object Test Specification

Test methods, conditions and pass and fail criteria for all requirements listed in the Object Performance Specification.

Object Design Specification

A document that describes the way in which the object has been designed so that it will perform in compliance with all its requirements.
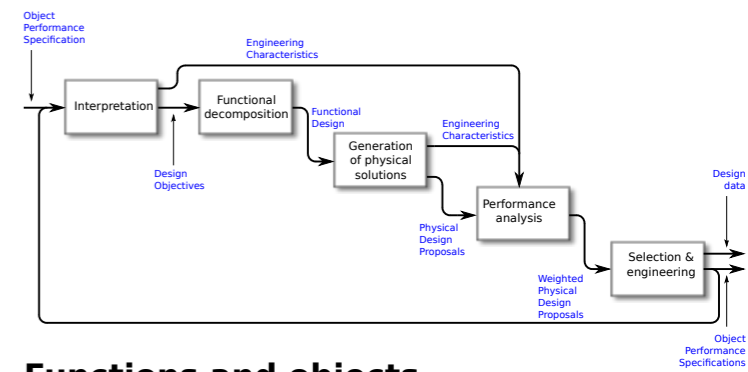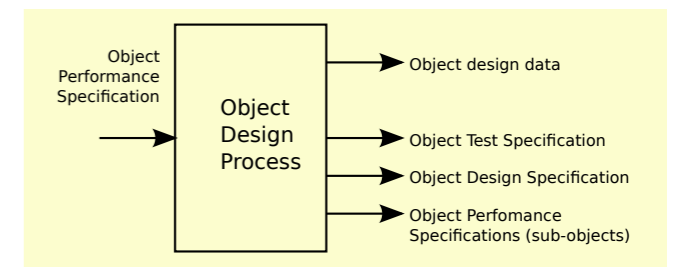- Design considerations
- Motivation of design choices
- Description of test benches
- Simulation results
- Description of experiments
- Measurement results

Object Design Data

Data, usually in digital fomat (files) required as input for the product life-cycle processes:
- IC manufacturing data: GDSII files
- PCB manufacturing data: Gerber and drill files
- part lists
- mechanical drawings
- simulation results
- prototype test results
- data for operating, maintenance and service manuals
- data for sales
- etc.

Object Design Process

Object Performance Specification → Object Design Process → Object design data
→ Object Test Specification
→ Object Design Specification
→ Object Perfomance Specifications (sub-objects)

Functions and objects

Orthogonal
Each object performs a single function

Objects

Functions

	PCA 1	PCA 2	PCA 3	Channel switch	Volume switch	Volume switch cable	Mains switch	Mains cable	Housing	Knobs	LED
Channel selection	×	×	×								×
MD pre-amplification	×										
MM pre-amplification	×										
Line pre-amplification	×										
Rumble-filter	×										
Low-pass filter	×										
Volume control		×		×	×					×	
Power supply conditioning	×				×						
User interface	×			×		×	×	×			