ME470 - Systems Design
Lab 4 Functional Analysis/Physical Decomposition
Due Date: October 8, 2009

Goals:

- Use a "Subtract and Operate" procedure to develop a function tree for a cordless electric screwdriver.
- Use the function tree to develop a Function Structure diagram for a cordless electric screwdriver.

Overview:
Functional analysis techniques in design date back to the 1920s and are most associated with engineers Pahl and Bietz whose book describes the comprehensive design methodology. The goal of a systematic approach is to help the designer produce a product that captures all of the functional goals (doesn't miss anything) and does so in an optimized manner (helps find "best" solution). Functional Analysis/Functional Decomposition has proved useful enough that it is now a standard part of engineering curriculums from Purdue to Stanford.

Functions can be determined from a customer needs list, but the technique is most easily applied to existing products (sometimes called physical decomposition). Since much of the design work of engineers is redesign of existing parts, this is the method we will use. We will be analyzing a particular cordless electric screwdriver (photographs of the disassembled screwdriver are attached).

Tasks:
Create and turn in one each

- Subtract and Operate table
- Function Tree diagram
- Function Structure diagram

Include Cover Sheet with team member names and a single campus mail box number.

Subtract and Operate Table
Use the subtract and operate procedure to generate the contents of the following table. The attached example (table 5.1 from Otto and Wood) is a good model.

Housing	Battery	Switch	Motor	Gearbox	Bit Holder

Subtract and Operate procedure (from Otto and Wood)

1. Disassemble (subtract) one component of the assembly. In our case we will do this conceptually rather that physically. The disassembly photographs may be useful.

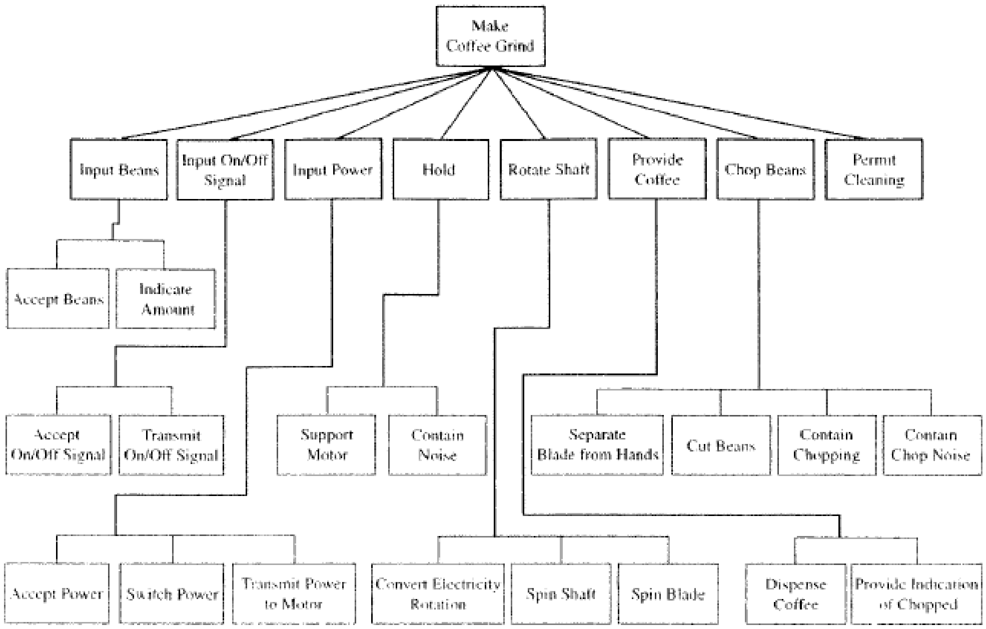
2. Operate the system through its full range. Imagine how the device will operate (or not operate) with the component missing. Imagine operation for all ranges of customer requirements for all the standard uses of the device.
3. Analyze the effect. Write down the desired functions that will not occur due to the missing component.
4. Deduce the subfunctions of the missing component. These will be functions like transport, contain, protect, etc. For a list of the suggested verbs that are used in formal functional analysis, see attached table 3 from NIST report.
5. Replace the component and repeat as many times as there are components in the assembly.
6. Translate the collection of subfunctions into a function tree.

Table 5.1 (Otto and Wood)

Chamber	Seal	Slicing Blade	Shaft	Armature
No defined way of holding content	No protection against contents splattering	Contents won't be chopped	Slicing blade won't be attached	Shaft doesn't spin
No measurable volume	No protection against spinning blade	No resistance to torque	Contents will not be chopped	Electricity is not transformed into mechanical energy
No body to measure contents	Chamber can't be closed		No resistance to torque	
No body to contain contents	Impact noise will not be enclosed			
No body to hold apparatus	Might not be able to turn on if safety feature			
Looks bad				
Difficult to clean undefined body				
Pour out contents				

Function Tree

The Subtract and Operate procedure helps us determine the critical functions and subfunctions of our device. These can be mapped to a function tree similar to figure 5.6 from Otto and Wood.



▼ ***Figure 5.6.***
Coffee mill function tree generated using the Subtract and Operate procedure.

The block at the top of the tree for an electric screwdriver is "Turn Screws" or "Loosen/Tighten Screws". The next row of blocks should be the most significant **Functions**. Since these are functions they will be stated as verbs or verb-noun combinations.

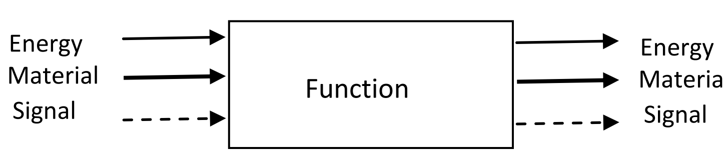
The next row of blocks would more clearly break down the specific subfunctions contained in the functions. For example a desk lamp make have a desired function of "Position Light" which may include the subfunctions of "Allow Motion" and "Maintain New Position".

<u>Suggested Technique for generating the Function Tree</u>

- Write one function or sub function on a 3x5 index card or sticky note.
- Arrange the cards in rows until group members agree that the particular functions are in the correct row and column (Is it a function or a subfunction?).
- Reproduce this arrangement electronically (Word or Powerpoint are the suggested tools).

Function Structure Diagram

The function structure diagram is a "black box" model as shown below. In the formal system all energy, material, and signal inputs and outputs are considered,



This is expanded to include the primary functions and subfunctions as in the examples that follow.

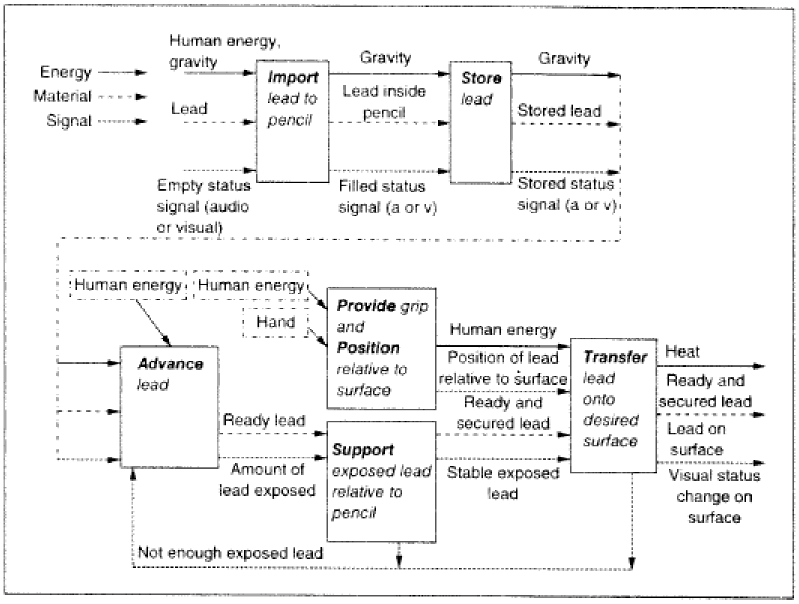


FIGURE 6.8
Function structure for a mechanical pencil.

Developed by Mr. Silas Nesson for a graduate course in design in the fall semester of 2006. Used with permission.

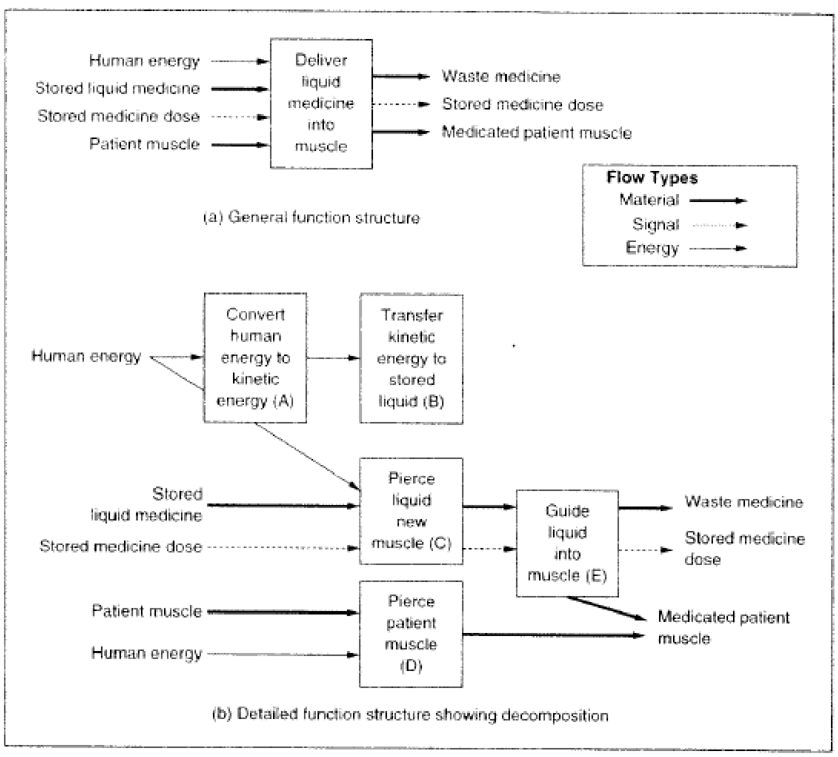
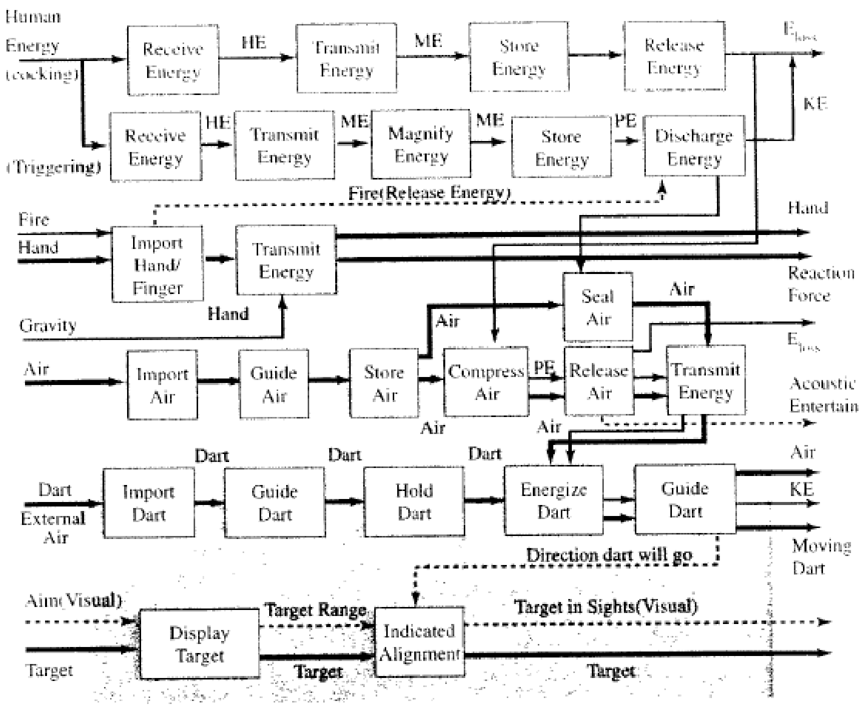


FIGURE 6.9
Function structure for a disposable syringe.



▼ ***Figure 5.23.***
Function structure of a toy dart gun. Assumes that dart enters the system.

The following steps are a simplified method for creating a function structure as outlined in **Engineering Design** by Dieter and Schmidt.

Steps in creating a function structure

1. Identify the overall function. In our case, this is the top block in the function tree.
2. Identify the basic individual functions that are required to accomplish this task. We have already done this in the first row of functions of the Function Tree.
3. Identify more precise functions from the basic functions determined in the previous step. Note that these two steps will be iterative. These more precise functions are the second level of blocks in the Function Tree.
4. Arrange the function blocks in the order that they must occur to accomplish the desired overall function. This is a flow chart of functions in which order is important. The easiest way for us to do this is to take the 3x5 cards we used to make the function tree and place them in position until the group is satisfied.
5. Add the energy, material, and signal flows between the function blocks as appropriate.
6. Double check to make sure you haven't missed a function block or flow line.
7. Reproduce the function diagram electronically.

Table 5. Functional basis reconciled function set.

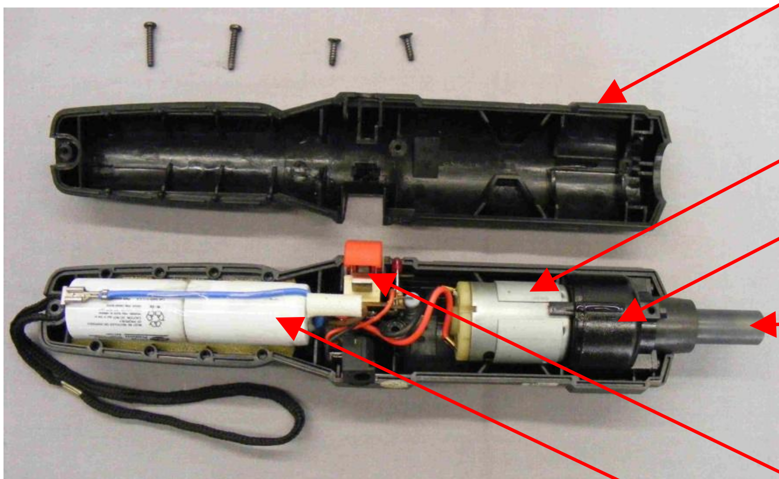
Class (Primary)	*Secondary*	*Tertiary*	*Correspondents*
Branch	Separate		Isolate, sever, disjoin
		Divide	Detach, *isolate*, release, sort, split, disconnect, subtract
		Extract	Refine, filter, purify, percolate, strain, *clear*
		Remove	Cut, drill, lathe, polish, sand
	Distribute		Diffuse, dispel, disperse, dissipate, diverge, scatter
Channel	Import		Form entrance, *allow*, input, *capture*
	Export		Dispose, eject, *emit*, empty, *remove*, destroy, eliminate
	Transfer		Carry, deliver
		Transport	Advance, lift, move
		Transmit	Conduct, convey
	Guide		Direct, shift, steer, straighten, switch
		Translate	Move, relocate
		Rotate	Spin, turn
		Allow DOF	*Constrain*, unfasten, unlock
Connect	Couple		Associate, connect
		Join	Assemble, fasten
		Link	Attach
	Mix		Add, blend, coalesce, combine, pack
Control Magnitude	Actuate		Enable, initiate, start, turn-on
	Regulate		Control, equalize, limit, maintain
		Increase	*Allow*, open
		Decrease	Close, delay, interrupt
	Change		Adjust, modulate, *clear*, demodulate, invert, normalize, rectify, reset, scale, vary, modify
		Increment	Amplify, enhance, magnify, multiply
		Decrement	Attenuate, dampen, reduce
		Shape	Compact, compress, crush, pierce, deform, form
		Condition	Prepare, adapt, treat
	Stop		End, halt, pause, interrupt, restrain
		Prevent	Disable, turn-off
		Inhibit	Shield, insulate, protect, resist
Convert	Convert		Condense, create, decode, differentiate, digitize, encode, evaporate, generate, integrate, liquefy, *process*, solidify, transform
Provision	Store		Accumulate
		Contain	*Capture*, enclose
		Collect	Absorb, consume, fill, reserve
	Supply		Provide, replenish, retrieve
Signal	Sense		Feel, determine
		Detect	Discern, perceive, recognize
		Measure	Identify, *locate*
	Indicate		Announce, show, denote, record, register
		Track	Mark, time
		Display	*Emit*, expose, select
	Process		Compare, calculate, check
Support	Stabilize		Steady
	Secure		*Constrain*, hold, place, fix
	Position		Align, *locate*, orient
Overall increasing degree of specification →			

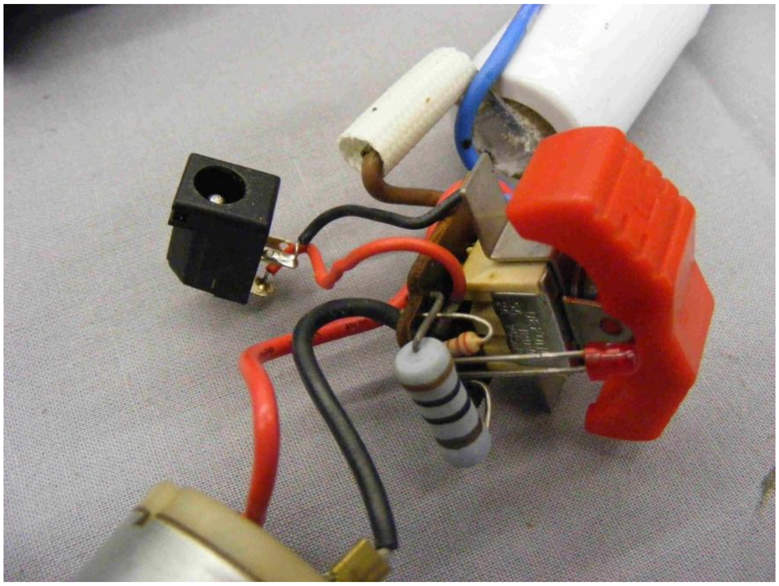
From:

NIST Technical Note 1447

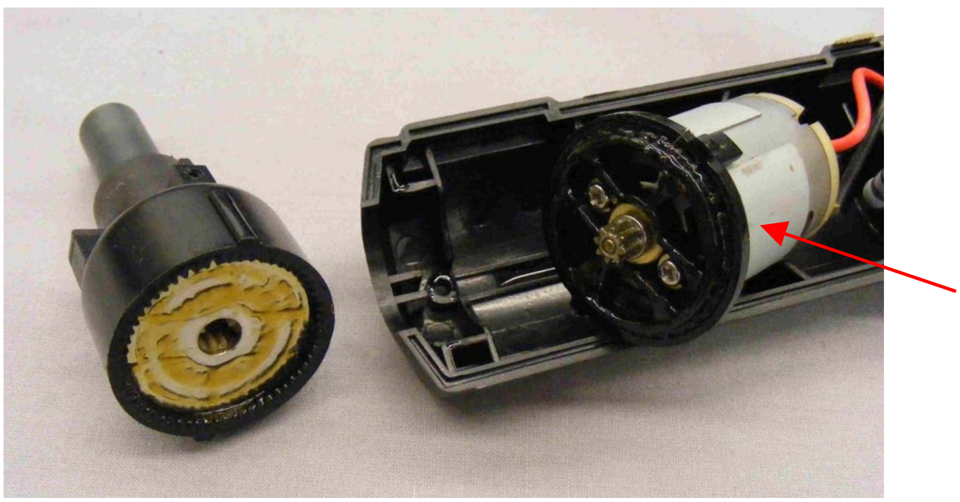
A Functional Basis for Engineering Deisgn: Reconciling and Evolving Previous Efforts

Handheld Electric Screwdriver
Physical Decomposition

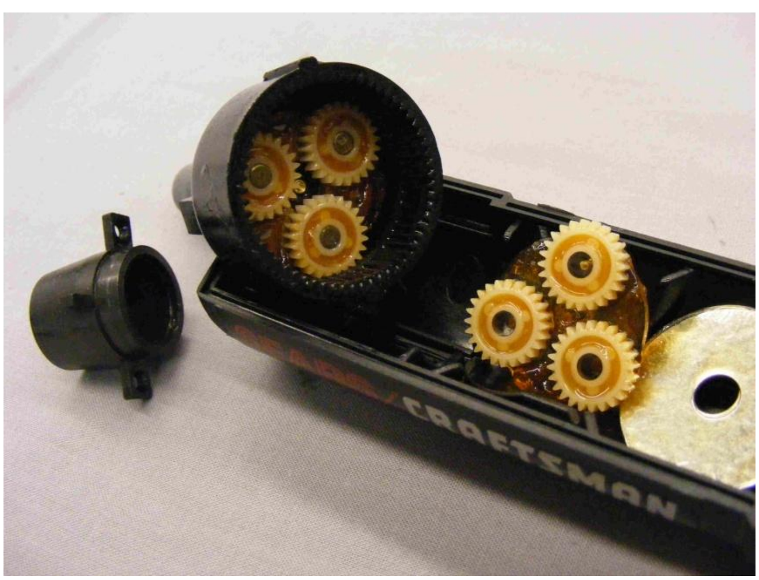




Switch



Motor with Pinion



Gear Box