Design Process

5 Major Design Stages

- Idea Generation
- **Conceptual Design**
- Detailed Design (Design Embodiment)
- Prototype/Verifications
- Refinement/Final Design/Documentation

A Project of ECE3031:

- Design of an Isolated Power Supply (Option-1):
  - 120V/60Hz ac input, 15V dc output, (2A) 30W, regulated power supply
  - Electrically isolated between input and output
  - Safe to use
  - Efficient
  - Reliable
  - Economical.....
- Design of a PV-Based Battery Charger (Option-2):
  - Charger for a 12V lead-acid battery (max. 2A charging current) from a widely-variable dc input source (10V-24V) such as a solar panel
  - (Non-isolated)
  - Safe to use
  - Efficient
  - Reliable
  - Economical.....

Brainstorming

- What features would you like to have for your product?

- What functions would you like to have for your product?

What Features Should your Product Have? (Brainstorm 2017)

- Safe
- Reliable
- Economical (affordable)
- Efficient; low power losses
- Recyclable
- Plug&Play/easy to use
- Household/commercial use
- Unidirectional plugs, accessible ports
- Display (multimeter, LED, alarm)
- Enclosure
- Portable; compact; small size
- Light weight
- Properly isolated
- Easy (simple) operation
- Aesthetic
- Grounded
- Multiple output voltages
- Standardized connectors
- Fused output
- Air-cooled, water-cooled, self-cooled
- Responsive
- Interface/feedback
- Adjustable stand
- Modular
- Waterproof
- Marking (high voltage)
- Auto shut-off (if not in use)

What Functions Should your Power Supply Have? (Brainstorm 2017)

- Isolation
- Voltage regulation
- AC-DC conversion
- Fault protection (surge, short)
- Thermal management (self-cooling, air, water)
- Voltage display (status indication)
- Manual shut down (on/off switch, circuit breaker)
- Voltage step down
- Filtering

What Functions Should your Battery Charger Have? (Brainstorm 2017)

- Display (LED)
- Charging profile for lead acid batteries:
  - current regulation
  - Voltage regulation
- DC-DC conversion (buck-boost)
- Thermal management
- MPPT

What Features Should your Product Have? (Brainstorm 2018)

- Safe to operate
- Isolated
- Reliable
- Economical (low cost)
- Efficient
- Longevity
- Compact (small size),
- Light (portable)
- User friendly
- Fault protection, (thermal)
- Power on-off
- Case (housing)
- LCD/LED display (indicator light
  - Voltage
  - Current
  - Time left to charge
  - Full charge
- Polarised plug
- USB charging
- Fast charging
- Variable voltage input

What Functions Should your Power Supply Have? (Brainstorm 2018)

- Isolation
- Voltage regulation
- AC-DC conversion
- Fault protection
- Cooling
- Voltage step down (or up, depends)
- Grounded input + cable

What Functions Should your Battery Charger Have? (Brainstorm 2018)

- Fault protection
- Display
- Charging control for lead acid batteries:
  - Current regulation
  - Voltage regulation
  - Trickle charge
  - Charge detection
- Buck-boost
- Cooling (heatsink)
- Temperature regulation

- Isolation
- MPPT (maximum power point tracking)

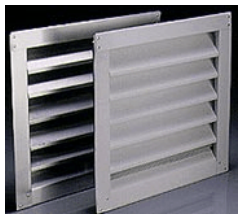
Conceptual Design - Several options without details

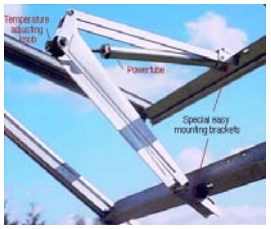
- What are the functions? (We already knew them from the functional structures)
- What are the solution alternatives?
- Can the solutions meet the technical and economic criteria?
- What are the better rough designs (how do we evaluate the options)?

Conceptual Design

- Start from the technical requirements and functions of the design
- Propose several options to implement each function (sub-function)
- Refine the options and find combination of options to implement all functions (to form design solutions)
- Evaluate the design combinations and find a combination of options to implement the product, which:
  - Best performs all functions which were determined from Idea Generation
  - Meets technical requirements
  - Provides attributes, while meeting constraints

Example: Automate opening/closing of air vents





Functional Structure of an Automatic Vent

Select Vent → Send Signal → Receive Signal → Convert Signal → Activate Vent

Ex: Automate opening/closing of air vents

- from Functions to Options (Morphological Chart)

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Select Vent	Remote switchboard	Handheld remote	1 2-way switch in room	2 1-way switches in room	Dial switch	
Send Signal	Wiring	Transmitter (rf)	Walk to room	Cable/pulley	Hoses (air/hydraulic)	
Receive Signal	Radio receiver	Electrical power device	Lever connected to pulley/cable	Hand lever	Piston (pneumatic/ hydraulic)	
Convert Signal	Air compressor	Hydraulic motor	Electric motor	Electromagnet	Combustion	Hand
Open/Close Vent	Gears	Belt	Electric field	Cable	Impact plate	

Steps to Develop Concepts from Functions

- Identify functions and construct functional structure
- Propose options for each function
  - Generate as many options for a function as possible (effective brainstorming)
- Construct morphological chart based on the functions
  - Sketches or words can be used on the chart
  - Left-hand column lists each function
  - Each row lists as many options as possible to implement the same function (5-7 options will be great)
- Identify feasible combinations (Concepts or Solutions)
  - Combine the options into several possible/feasible design concepts (i.e. various design solutions)
  - Screen the combinations of options for each function for possible solutions
  - Identify better combinations for feasible concepts (solutions)

Refine Concepts

- The morphological charts may help us to refine the concepts, by combining the options of functions or changing the functional structure.
- New ideas may be generated at this stage, which leads to innovation.
- Some degree of verifications to concepts may be done using mock-up models, small scaled tests/experiments, computer simulations etc.

Screen and Evaluate Concepts

- If a concept doesn't satisfy the specification requirements, it will be dropped.
- If the technology is not yet available to facilitate the concept, or if the concept doesn't lead to a feasible product, the concept will be dropped (based on designers' experience or engineering sense).
- Concepts are evaluated with respect to each other using measures defined by criteria (specifications and attributes) using Simple Scores.

Concept Evaluation - Simple Scores

Scoring Concepts against evaluation criteria which reflects engineering characteristics

- Criteria Weight: Criteria are rated (weighted) for their importance on a scale of 1 (very low) to 5 (very high).
- Identify feasible concepts.
- Concept Rank: Rank a concept against each criteria on a scale of 0 (does not meet the criteria) to 10 (highly meets the criteria)
- Scores = ∑Criteria Weight * Concept Rank.
- Concepts with higher scores may be better.
- Refine the evaluation in your design team.

Scores:

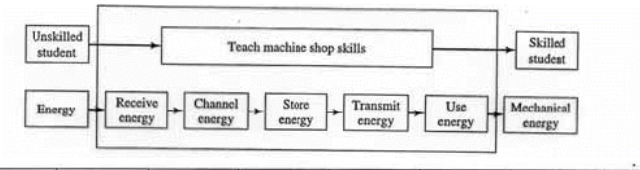
Scoring the concepts for the DC motor controller:

Analog design or Microprocessor design as solutions

The total score of a concept = sum of (concept rank of individual criteria *importance weight). The concept with the highest score wins

Criteria \ Combination	Importance Weight	Analog	Microrocessor
Under 20 grams	5	7	7
under 15 cu. cm.	3	7	5
20 amperes load	3	10	10
operating freq 3 KHz	3	8	7
< $15.00	4	8	5
voltage 5 –24	2	3	10
reprogrammable	2	1	10
safety interlock	4	0	8
Easily modified	2	0	8
		150	209

Example of Concept Evaluation: Design of a Machine Shop Kit



	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Receive	Open cylinder	Spring	Closed cylinder				
Channel	Funnel	Linkage	Shaft	Gear	Tube	Piston	
Store	Flywheel	Piston	Capacitor	Propeller	Shaft	Tube	
Transmit	Shaft	Belt	Gear	Steam wheel			
Use	Wheel & axle	Rod	Propeller	Linkage	Gear	Flywheel	Pulley

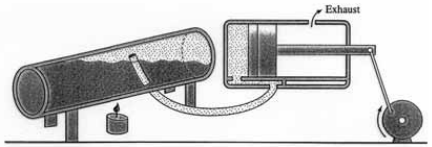


Figure 8.5 Concept I of machine shop kit: A tank full of water is heated to produce steam. The steam will travel through the tube and push the piston, which will turn the attached flywheel.

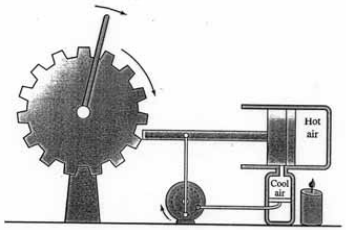


Figure 8.6 Concept II of machine shop kit: A flame is used to heat a piston, which will be pushed out to turn a gear. At the same time that the piston is pushed out, another piston is being pushed up, which will push the hot air piston back to its original position.

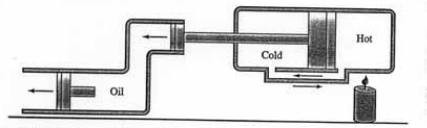


Figure 8.7 Concept III of machine shop kit: This design incorporates a system of pistons. The first piston is pushed by the pressure from heated air. It, in turn, compresses a medium of oil, which causes the final piston to be pushed.

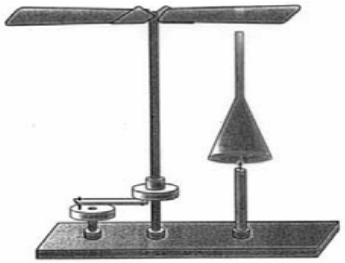


Figure 8.9 Concept V of machine shop kit: The hot air is channeled, which causes the propeller to rotate, which spins a flywheel. The flywheel is connected to a second flywheel by a connector link. Therefore, as the first flywheel turns, the second flywheel will also turn.

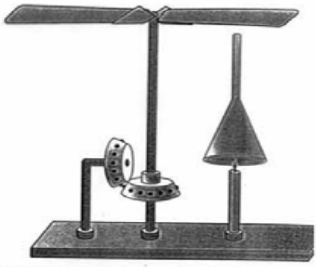


Figure 8.8 Concept IV of machine shop kit: Hot air is funneled to turn a propeller system. The propeller is connec to a central rod, which has a gear attached to it. The rotatic of blades will cause the attached gear to rotate, which turn the other gear.

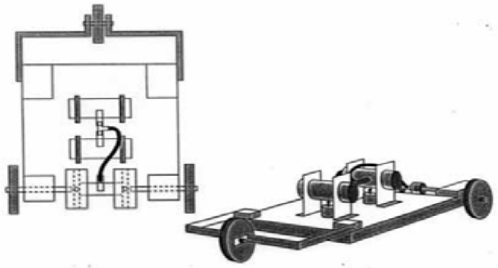


Figure 8.10 Concept VI of machine shop kit: Two metal tanks filled with water are heated with an alcohol burner. The heated water then generates steam that travels through a nylon tube to a steam tube. The steam tube is connected to two "steam wheels," which have holes drilled in them at 90 angles. The escaping steam will create rotation, which will turn the axles that turn the wheels and move the car.

Concept Evaluation: Simple Scores

Criteria	Weights	Sketch1	Sketch2	Sketch3	Sketch4	Sketch5	Sketch6
Easy to assemble	7	4	4	4	7	7	2
Easy to disassemble	7	4	4	4	7	7	2
Safe for operator	10	5	7	8	5	5	7
Low vibration	5	5	5	5	5	5	5
Portable	4	3	3	7	3	3	5
No shape edges	6	8	2	8	2	2	3
Less costly than competitors	9	7	5	8	8	8	3
Convert energy efficiently	10	5	5	5	5	5	6
No flying debris	8	5	5	5	5	5	7
Low pollution	3	3	3	3	3	3	3
Low replacement part cost	7	8	8	8	8	8	8
Low noise	4	6	7	7	5	5	5
Strong materials	6	6	7	7	4	4	4
Low energy dissipation	8	7	6	8	6	5	5
Aesthetically appealing	5	5	7	8	6	6	9
Total score (weighted)		550	528	638	546	538	570